Battery Charging Specification

(Including errata and ECNs through March 15, 2012)

Revision 1.2

March 15, 2012

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Revision History

Revision	Date	Author	Description
BC1.0	Mar 8, 2007	Terry Remple	First release
BC1.1	April 15, 2009	Terry Remple	Major updates to all sections. Added Data Contact Detect protocol, and Accessory Charger Adapter.
BC1.2	Oct 5, 2010	Terry Remple Adam Burns	Following items indicate changes from BC1.1 to BC1.2. References below to Section, Figures and Tables refer to BC1.2, unless BC1.1 is specifically indicated. 1. Allow DCPs to output more than 1.5A. Allows Portable Devices (PDs) with switch mode chargers to draw more power. Section 4.4.1. 2. Increase minimum CDP current to 1.5A. Without change, PDs had to draw less than 500mA, to avoid CDP shutdown. Table 5-2. 3. Indicate that I_{CDP} max and I_{DCP} max limits of 5A come from USB 2.0, and are safety limits. Table 5-2 note 1. 4. Allow PDs to draw up to 1.5A during HS chirp and traffic. Remove previous limits of 560mA and 900mA which was based on HS common mode ranges. Section 3.5. 5. Require CDPs to support 1.5A during HS chirp and traffic. Affects CDP common mode range. Section 3.5. 6. Reduce maximum PD current from 1.8A to 1.5A, to avoid shutdown when attached to CDP. Table 5-2. 7. Rename Docking Station to ACA-Dock, to avoid confusion with other types of Docking Stations. 8. Require ACA-Dock to differentiate itself from an ACA, by enabling V_{DM_SRC} during no activity. Section 3.2.4.4. 9. Allow CDP to leave V_{DM_SRC} enabled while peripheral not connected. Section 3.2.4.2. 10. Remove I_{CHG_SHTDWN}. This was a recommended max output current for Charging Ports with VBUS grounded. BC1.1 Section 4.1. 11. Require V_{DP_SRC} to not pull D+ below 2.2V when D+ is being pulled to V_{DP_UP} through R_{DP_UP}. Require V_{DM_SRC} to not pull D- below 2.2V when D- is being pulled high. Required for ACA-Dock support. Table 5-1 notes 1 and 2.

			12. Make DCD current source optional for PDs. Section 3.2.3. 13. Make DCD timeout required for PDs. Section 3.2.3. 14. Make Secondary Detection optional for PDs. Section 4.6.2. 15. Make Good Battery Algorithm required behavior for PDs. Section 3.2.4. 16. Remove resistive detection. BC1.1 Section 3.9. 17. Change PD Required Operating Range to include 4.5V at 500mA. Figure 4-3. 18. Allow any downstream port to act as a DCP. Section 4.1.3. 19. Require PDs to enable V_{DP_SRC} or R_{DP_PU} when charging from a DCP. Section 3.3.2. 20. Allow chargers to renegotiate current with PD by dropping and reasserting VBUS. Section 4.1.3. 21. Require PDs to discharge their own VBUS input after VBUS drops to support charger port renegotiation request. Section 4.6.3. 22. Allow PDs to disconnect and repeat Charger Detection multiple times while attached, with specified timing. Section 4.6.3. 23. Reduce DCP input impedance between D+, D- to VBUS and ground from 1MΩ to 300kΩ. Section 4.4.3. 24. Require CDPs to recover after over-current condition. Section 4.2.2. 25. Allow greater DCP undershoot for large load current steps, to enable low quiescent current chargers required by Europe. Section 4.4.2. 26. Define ACAs and ACA-Docks as types of Charging Ports. Section 1.4.5. 27. Use session valid voltage range defined in EH and OTG Supplement rev 2.0. Section 3.2.2. 28. Only devices that can operate stand-alone from internal battery power are allowed to use the Dead Battery Provision. Section 2.2. 29. Allow compound PDs to draw I_{SUSP} plus an

			additional I_{SUSP} for each downstream port. Section 2.1. 30. Remove requirement for vendors to provide typical and maximum connect time for products having a Dead or Weak Battery for compliance testing. Section 2. 31. Remove references to no battery from Dead Battery Provision. Section 2. 32. Require PD using Dead Battery Provision to enable V_{DP_SRC} from $T_{DBP\_ATT\_VDPSRC}$ after attach to $T_{DBP\_VDPSRC\_CON}$ before connect. Section 2.2. 33. Added DBP – Configured Clause, which allows PD with Dead Battery to draw I_{CFG_MAX} for $T_{DBP\_FUL\_FNCTN}$ without having to pass USBCV. Section 2.3. 34. Note constraints when trying to charge from an OTG A-device. Section 1.6. 35. Change I_{DP_SINK} and I_{DM_SINK} range from 50-150uA to 25-175uA to ease PHY design. Table 5-2 note 1. 36. Allow USB 3.0 devices to implement BC charger detection protocols, and to use USB 3.0 ranges for I_{UNIT} and I_{CFG_MAX}. Section 1.7. 37. Rename previous ACA to Micro ACA, and define the Standard ACA. Section 6. 38. Add caps to OTG and Accessory Ports on ACA to support Attach Detection Protocol (ADP). Figure 6-3. 39. Change ACA ID resistance tolerances from 5% to 1% to ease PHY design. Table 5-3. 40. Remove requirements on ACA switching time($T_{ACA\_ID\_VBUS}$) to ease ACA design. BC1.1 Section 6.5. 41. Add state diagram for PDs attached to ACA. Section 6.2.7. 42. Require PDs to limit current from ACA such that VBUS remains above V_{ACA_OPR}. Section 6.2.2. 43. Change minimum ACA operating voltage (V_{ACA_OPR}) from 3.0V to 4.1V. Table 5-1. 44. Remove requirement that ACA VBUS resistances ($R_{ACA\_CHG\_DIS}$) be greater than 10k when VBUS_CHG is greater than 6.5V. PDs are

			responsible for protecting themselves against higher voltages on VBUS. BC1.1 Section 6.7. 45. Require ACAs to continue providing power to OTG device from Charging Port, even if ground offsets or USB reset cause D- to go below V_{DAT_REF}. Section 6.2.6. 46. Change charger shutdown recovery time (T_{SHTDWN_REC}) from 2 seconds to 2 minutes. Table 5-5. 47. Indicate that ACA-Dock is required to pull D+ to V_{DP_UP} with R_{DP_UP} when VBUS is asserted. Section 3.2.4.4. 48. Remove statements regarding devices with multiple receptacles. Covered in Multiple Receptacle white paper at http://www.usb.org/developers/docs/. 49. Improve readability by adding and updating drawings, re-structuring sections, and clarifying text.
BC1.2 plus errata	Oct 12, 2011	Pat Crowe	Includes errata changes from Oct 12, 2011
BC1.2 plus further errata	Mar 15, 2012	Pat Crowe	Includes errata changes from Mar 15, 2012: 1. Corrections to Micro ACA specification.

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Acronyms

ACA	Accessory Charger Adapter
CDP	Charging Downstream Port
DBP	Dead Battery Provision
DCD	Data Contact Detect
DCP	Dedicated Charging Port
FS	Full Speed
HS	High-Speed
LS	Low-Speed
OTG	On-The-Go
PC	Personal Computer
PD	Portable Device
PHY	Physical Layer Interface for High-Speed USB
PS2	Personal System 2
SDP	Standard Downstream Port
SRP	Session Request Protocol
TPL	Targeted Peripheral List
USB	Universal Serial Bus
USBCV	USB Command Verifier
USB-IF	USB Implementers Forum
VBUS	Voltage line of the USB interface

1. Introduction

1.1 Scope

The Battery Charging Working Group is chartered with creating specifications that define limits as well as detection, control and reporting mechanisms to permit devices to draw current in excess of the USB 2.0 specification for charging and/or powering up from dedicated chargers, hosts, hubs and charging downstream ports. These mechanisms are backward compatible with USB 2.0 compliant hosts and peripherals.

1.2 Background

The USB ports on personal computers are convenient places for Portable Devices (PDs) to draw current for charging their batteries. This convenience has led to the creation of USB Chargers that simply expose a USB standard-A receptacle. This allows PDs to use the same USB cable to charge from either a PC or from a USB Charger.

If a PD is attached to a USB host or hub, then the USB 2.0 specification requires that after connecting, a PD must draw less than:

- 2.5 mA average if the bus is suspended
- 100 mA if bus is not suspended and not configured
- 500 mA if bus is not suspended and configured for 500 mA

If a PD is attached to a Charging Port, (i.e. CDP, DCP, ACA-Dock or ACA), then it is allowed to draw I_{DEV_CHG} without having to be configured or follow the rules of suspend.

In order for a PD to determine how much current it is allowed to draw from an upstream USB port, there need to be mechanisms that allow the PD to distinguish between a Standard Downstream Port and a Charging Port. This specification defines just such mechanisms.

Since PDs can be attached to USB chargers from various manufacturers, it is important that all provide an acceptable user experience. This specification defines the requirements for a compliant USB charger, which is referred to in this spec as a USB Charger.

If a PD has a Dead or Weak Battery, then the Connect Timing Engineering Change Notice (ECN) issued by the USB-IF on the USB 2.0 spec allows that device to draw up to I_{UNIT} while attached but not connected. The conditions associated with this ECN are contained in Section 2 of this specification, and are referred to as the Dead Battery Provision (DBP).

1.3 Reference Documents

The following specifications contain information relevant to the Battery Charging Specification.

- OTG and Embedded Host Supplement, Revision 2.0
- USB 2.0 Specification
- USB 3.0 Specification

1.4 Definitions of Terms

This section contains definitions for some of the terms used in this specification.

1.4.1 Accessory Charger Adaptor

An Accessory Charger Adaptor (ACA) is an adaptor which allows a single USB port to be attached to both a charger and another device at the same time.

The following terminology is used when referring to an ACA:

- ACA-A An ACA with ID resistance of R_{ID_A}
- ACA-B An ACA with ID resistance of R_{ID_B}
- ACA-C An ACA with ID resistance of R_{ID_C}

See Section 6 for details on an ACA.

1.4.2 ACA-Dock

An ACA-Dock is a docking station that has one upstream port, and zero or more downstream ports. The upstream port can be attached to a PD, and is capable of sourcing I_{CDP} to the PD. An ACA-Dock signals it is an ACA-Dock to the PD by enabling V_{DM_SRC} during USB idle, and by pulling ID to ground through a resistance of R_{ID_A}. See Section 3.2.4.4 for more details.

1.4.3 Attach versus Connect

This specification makes a distinction between the words “attach” and “connect”. A downstream device is considered to be attached to an upstream port when there is a physical cable between the two.

A downstream device is considered to be connected to an upstream port when it is attached to the upstream port, and when the downstream device has pulled either the D+ or D- data line high through a 1.5 kΩ resistor, in order to enter Low-Speed, Full-Speed or High-Speed signaling.

1.4.4 Charging Downstream Port

A Charging Downstream Port (CDP) is a downstream port on a device that complies with the USB 2.0 definition of a host or a hub, except that it shall support the Charging Downstream Port features specified herein.

A CDP shall output a voltage of V_{DM_SRC} on its D- line when it senses a voltage greater than V_{DAT_REF} but less than V_{LGC} on its D+ line when not connected to a peripheral. A CDP shall not output a voltage of V_{DM_SRC} on its D- line from the time that the peripheral is connected, to the time that the peripheral is disconnected.

1.4.5 Charging Port

A Charging Port is a DCP, CDP, ACA-Dock or ACA.

1.4.6 Dead Battery Threshold

The Dead Battery Threshold is defined as the maximum charge level of a battery such that below this threshold, a device is assured of not being able to power up successfully.

A Dead Battery is defined as one that is below the Dead Battery Threshold.

1.4.7 Dedicated Charging Port

A Dedicated Charging Port (DCP) is a downstream port on a device that outputs power through a USB connector, but is not capable of enumerating a downstream device. A DCP shall source I_{DCP} at an average voltage of V_{CHG}.

A DCP shall short the D+ line to the D- line.

1.4.8 Downstream Port

In this specification, a Downstream Port refers to either a Standard Downstream Port or a Charging Downstream Port.

1.4.9 Micro ACA

A Micro ACA is an ACA with a Micro-AB receptacle on the Accessory Port.

1.4.10 Portable Device

A PD as used in this specification is a device which is compliant with this specification and the USB 2.0 specification, and can draw charging current from USB.

1.4.11 Rated Current

The Rated Current of a Charging Port is the amount of current that a Charging Port can output and still maintain a VBUS voltage of V_{CHG}. The Rated Current of a DCP is required to be within I_{DCP}, and the rated current of a CDP or ACA-Dock is required to be within I_{CDP}.

1.4.12 Standard ACA

A Standard ACA is an ACA with a Standard-A receptacle on the Accessory Port.

1.4.13 Standard Downstream Port

In this specification, a Standard Downstream Port (SDP) refers to a downstream port on a device that complies with the USB 2.0 definition of a host or hub. An SDP expects a downstream device with a good battery to draw less than 2.5 mA average when unconnected or suspended, up to 100 mA maximum when connected and not configured and not suspended, and up to 500 mA maximum if so configured and not suspended. A downstream device can be enumerated when it is connected to an SDP.

An SDP pulls the D+ and D- lines to ground through two 15 kΩ (typical) resistors.

An SDP may have the ability to sense when a PD is driving the D+ line to V_{DP_SRC}, and then manage its power states accordingly. PDs are required to drive D+ to V_{DP_SRC} whenever they draw more than I_{SUSP} while attached but not connected, as described in the Dead Battery Provision.

1.4.14 USB Charger

A USB Charger is a device with a DCP, such as a wall adapter or car power adapter.

1.4.15 Weak Battery Threshold

The Weak Battery Threshold is defined as the minimum charge level of a battery such that above this threshold, a device is assured of being able to power up successfully.

A Weak Battery is defined as one that is above the Dead Battery Threshold and below the Weak Battery Threshold. A device with a Weak Battery may or may not be able to power up a device successfully.
A Good Battery is defined as one that is above the Weak Battery Threshold.

1.5 Parameter Values

Parameter names are used throughout this specification instead of parameter values. All parameter values are found in Section 5.

1.6 OTG Considerations

A PD with a Dead Battery cannot differentiate between a PC and an OTG A-device. Thus, a PD will treat both the same.

If an OTG A-device is connected to a PD with a dead battery, then the OTG A-device is under no obligation to provide any more current than it normally would to any device on its Targeted Peripheral List (TPL).

An OTG A-device is allowed to stop driving VBUS after a time of $T_{A\_WAIT\_BCON}$ (See OTG 2.0 Supplement for value) while waiting for the B-device to connect. Thus, a PD with a Dead Battery may not have time for significant charging when attached to an OTG A-device, if it does not connect.

1.7 Super Speed Considerations

SuperSpeed ports defined in USB 3.0 are allowed to implement the charger detection mechanisms defined in this spec. When a PD detects it is attached to a SuperSpeed port, then I_{CFG_MAX} changes to 900mA, and I_{UNIT} changes to 150mA.

2. Dead Battery Provision

2.1 Background

The USB 2.0 specification allows a downstream device to draw a suspend current of up to I_{SUSP} from a SDP when the device is not connected or when the bus is suspended. If the bus is not suspended and the device is configured, then USB 2.0 allows a device to draw up to I_{CFG_MAX}, depending on the configuration the host enables.

This limit of only I_{SUSP} when not connected can be problematic for PDs with a Dead Battery or a Weak Battery. Some PDs require more than I_{UNIT} for several seconds just to power up. Thus, PDs with Dead Batteries or Weak Batteries may not be able to power up when attached to an SDP if they can only draw I_{SUSP} when not connected.

USB 2.0 allows a PD that is a compound device to draw I_{SUSP} for each downstream port while attached but not connected or during suspend.

2.2 DBP – Unconfigured Clause

A PD with a Dead or Weak Battery is allowed to draw I_{UNIT} from a Downstream Port using the DBP while not configured, providing it behaves as follows:

- Reduces current to I_{SUSP} after timeout
    - If PD is not ready to connect and be enumerated within $T_{SVLD\_CON\_WKB}$ after attach, then it shall reduce its current to I_{SUSP}

- Enables VDP_SRC when attached but not connected
  - PD shall enable VDP_SRC within TDBP_ATT_VDPSRC of attach
  - PD shall connect within TDBP_VDPSRC_CON of disabling VDP_SRC

- Uses current to power up and enumerate, or reach Weak Battery Threshold and enumerate, as soon as possible
  - PD shall not use the DBP current to perform unrelated tasks, such as:
    - Charging beyond the Weak Battery Threshold
    - Making a phone call
    - Playing a song, video or game
    - Establishing a wireless connection
  - Only devices that can operate stand-alone from internal battery power are allowed to use the DBP.

- Passes inrush test
  - PD with Dead or Weak Battery shall pass USB-IF compliance inrush test

The unconfigured state includes the time that the PD is attached and not connected, and the time that the PD is connected and not configured. A PD enters the configured state by receiving a SET_CONFIGURATION command from the host.

2.3 DBP – Configured Clause

A PD with a Dead or Weak Battery is allowed to draw its configured current, (which can be up to ICFG_MAX), from a Standard Downstream Port using the Dead Battery Provision (DBP) while configured, and not have to pass USBCV tests, providing it behaves as follows:

- Responds to received tokens
  - PD shall respond to any tokens addressed to it, with either a NAK or any other valid USB response

- Responds to USB reset
  - Upon receipt of USB reset, a PD shall reduce its current to IUNIT. PD is allowed to disconnect upon receiving a reset. While disconnected, PD is allowed to use the DBP – Unconfigured Clause.

- Responds to USB suspend
  - Upon receipt of USB suspend, PD shall either remain connected, and reduce its current to ISUSP, or it shall disconnect. While disconnected, the PD is allowed to use the DBP – Unconfigured Clause.

- Provides full USB functionality after timeout, or disconnects
  - After a time of TDBP_FUL_FNCTN from attach, a PD shall either remain connected and be able to pass USBCV, or it shall disconnect. While disconnected, the PD is allowed to use the DBP – Unconfigured Clause.

- Uses current to reach Weak Battery Threshold and provide full USB functionality as soon as possible
  - PD shall not use the DBP current to perform unrelated tasks, such as:
    - Charging beyond the Weak Battery Threshold
    - Making a phone call
    - Playing a song, video or game
    - Establishing a wireless connection

- Provides full USB functionality upon reaching Weak Battery Threshold
  - PD shall provide full USB functionality upon reaching Weak Battery Threshold if this occurs before TDBP_FUL_FNCTN after attach.

- PD informs user within TDBP_INFORM of attach that it is charging and not available for other functions

3. Charging Port Detection

3.1 Overview

Figure 3-1 shows several examples of a PD attached to an SDP or Charging Port.

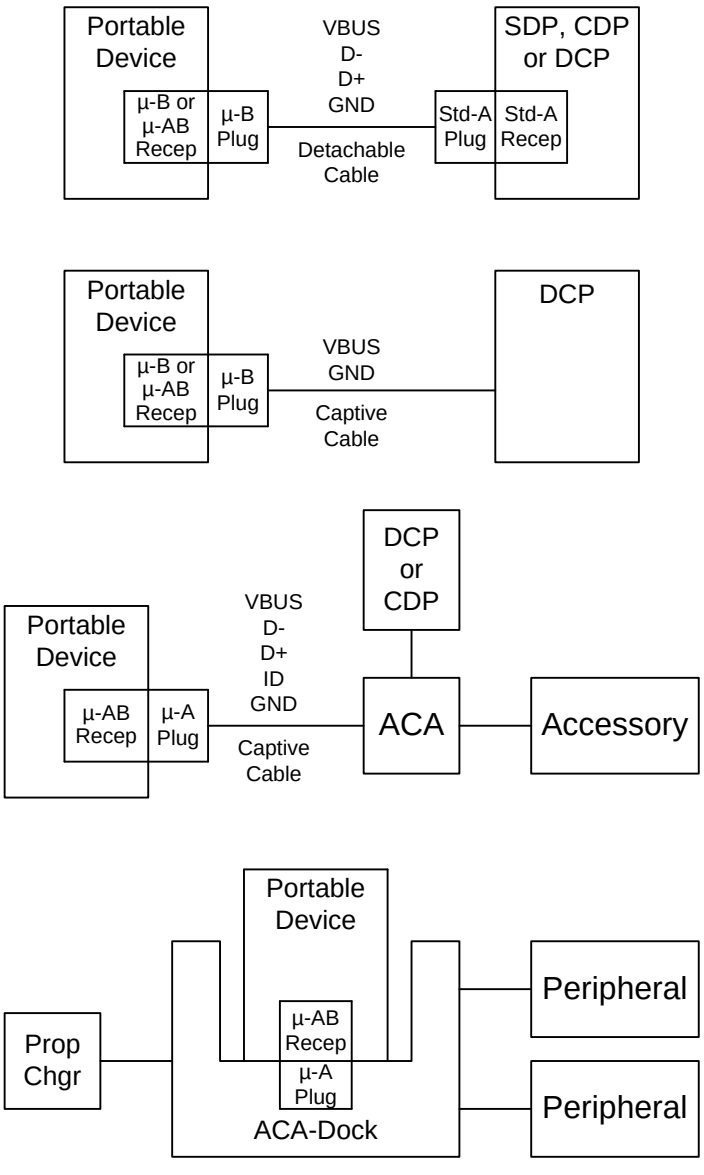

Figure 3-1 System Overview

In the first example, a Std-A to Micro-B cable is used to attach a PD to an SDP, CDP or DCP. In the second example, a DCP has a captive cable. This cable does not have wires for D+ or D-, but instead shorts the D+ and D- pins at the Micro-B plug.

In the third example, an ACA is required to have a captive cable that attaches to the Portable Device, and this cable is required to have wires for D+, D- and ID. The ACA is also required to have a port that can be attached to a DCP or CDP. The cabling for this port is described in Section 6.2.1.

In the fourth example, an ACA-Dock does not have a cable at all, but instead has a captive Micro-A plug. An ACA-Dock receives power from a Proprietary Charger, that is attached to the ACA-Dock through a proprietary cable.

3.2 Charger Detection Hardware

This section briefly describes the hardware used to do charger detection. The following sections provide more details of its operation.

3.2.1 Overview

Figure 3-2 shows the charger detection hardware for a PD.

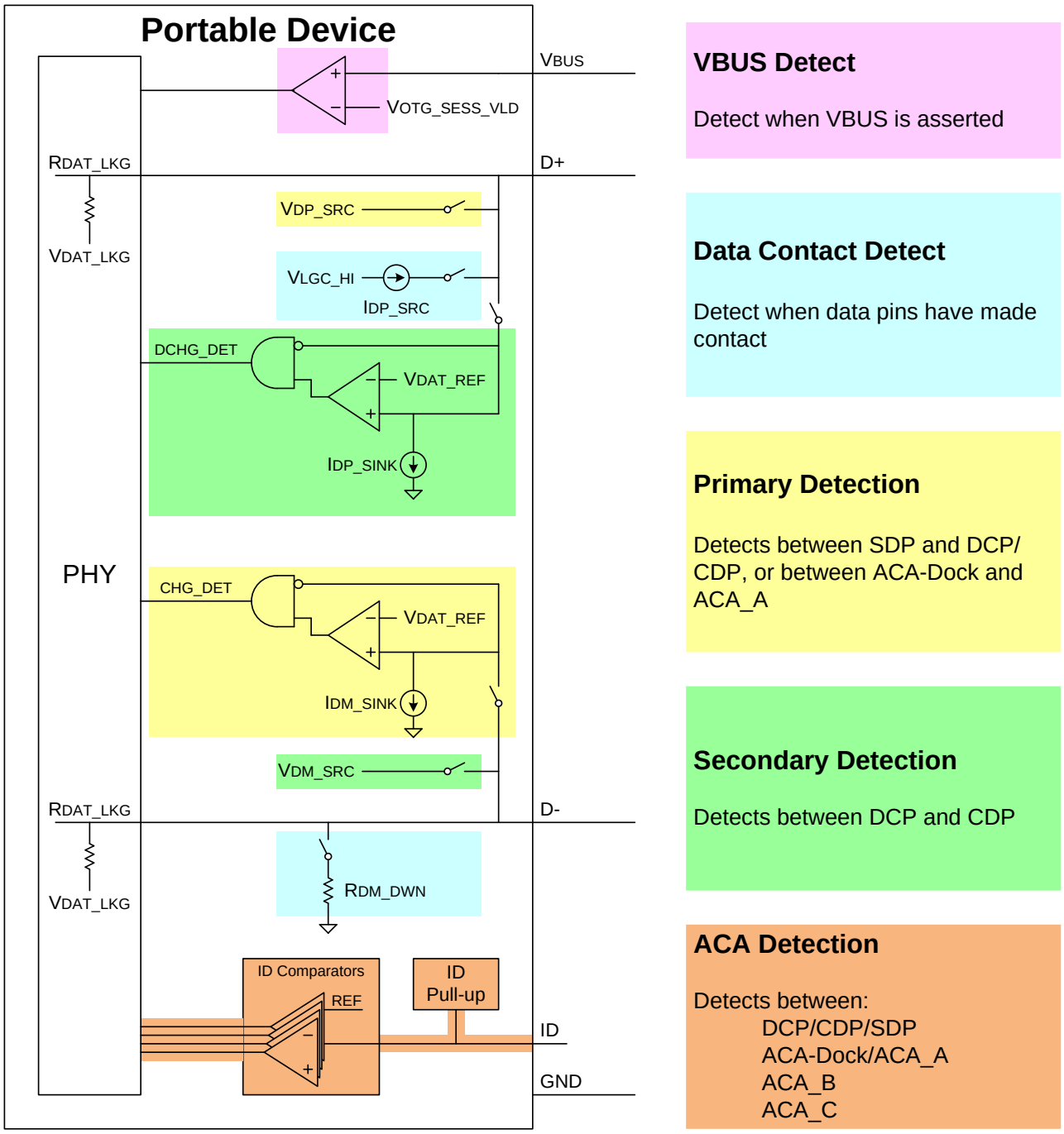

Figure 3-2 Charger Detection Hardware

3.2.2 VBUS Detect

Each PD shall have a session valid comparator that detects when VBUS is greater than its internal session valid threshold. Its internal session valid threshold shall be within VOTG_SESS_VLD.

3.2.3 Data Contact Detect

3.2.3.1 Overview

Data Contact Detect (DCD) uses a current source, I_{DP_SRC}, to detect when the data pins have made contact during an attach event. A PD is not required to implement DCD. If a PD does not implement DCD, then it shall wait a time of $T_{DCD\_TIMEOUT}$ min after the attach event before starting Primary Detection.

DCD is able to detect data pin contact whenever a PD is attached to an SDP or CDP. The primary benefit of DCD is that it allows a PD to start Primary Detection as soon as the data pins have made contact, and then connect, without having to wait for a timer to expire. As per the USB Connect Timing ECN, a powered up USB device is required to connect to a USB host within $T_{SVLD\_CON\_PWD}$ of the attach event.

DCD is also able to detect data pin contact for most cases of a PD attached to a DCP or ACA. Cases where DCD may not work include:

- DCP with too much leakage current
- ACA with charger and FS or HS B-device on Accessory Port
- ACA-Dock
- PS2 port that pulls D+ high
- Proprietary chargers that pull D+ high

Since DCD does not work in all cases, a PD is required to proceed to Primary Detection within $T_{DCD\_TIMEOUT}$ max after the attach event if pin contact has not been detected on the D+ or ID pins. See Section 3.3.2.

3.2.3.2 Problem Description

USB plugs and receptacles are designed such that when the plug is inserted into the receptacle, the power pins make contact before the data pins make contact. This is illustrated in Figure 3-3.

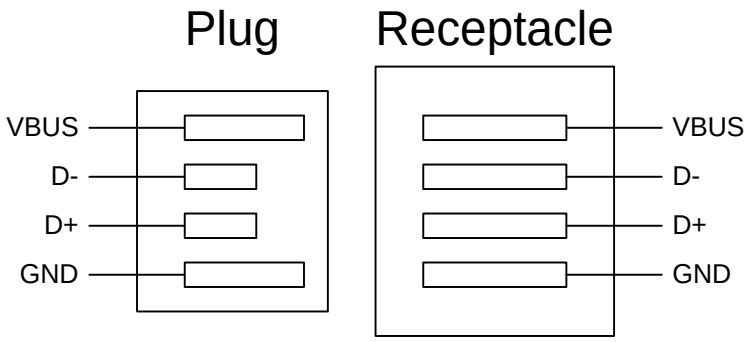

Figure 3-3 Data Pin Offset

As a result, when a PD is attached to an upstream port, the PD will detect VBUS before the data pins have made contact. The time between power pins and data pins making contact depends on how fast the plug is inserted into the receptacle. Delays of more than two hundred milliseconds have been observed.

The way that a PD distinguishes between a Charging Port and an SDP is to look at the data lines. If the PD does Primary Detection before the data pins have made contact, then the Primary Detection protocol is such that the PD will determine that it is attached to an SDP.

If a PD is attached to a DCP, and incorrectly determines that it is attached to an SDP, then the PD would draw ISUSP while waiting to be enumerated. Since a DCP will not enumerate the PD, the PD will not be able to charge.

3.2.3.3 Data Contact Detect, Not Attached

Figure 3-4 shows the case where the PD is not attached to a remote device.

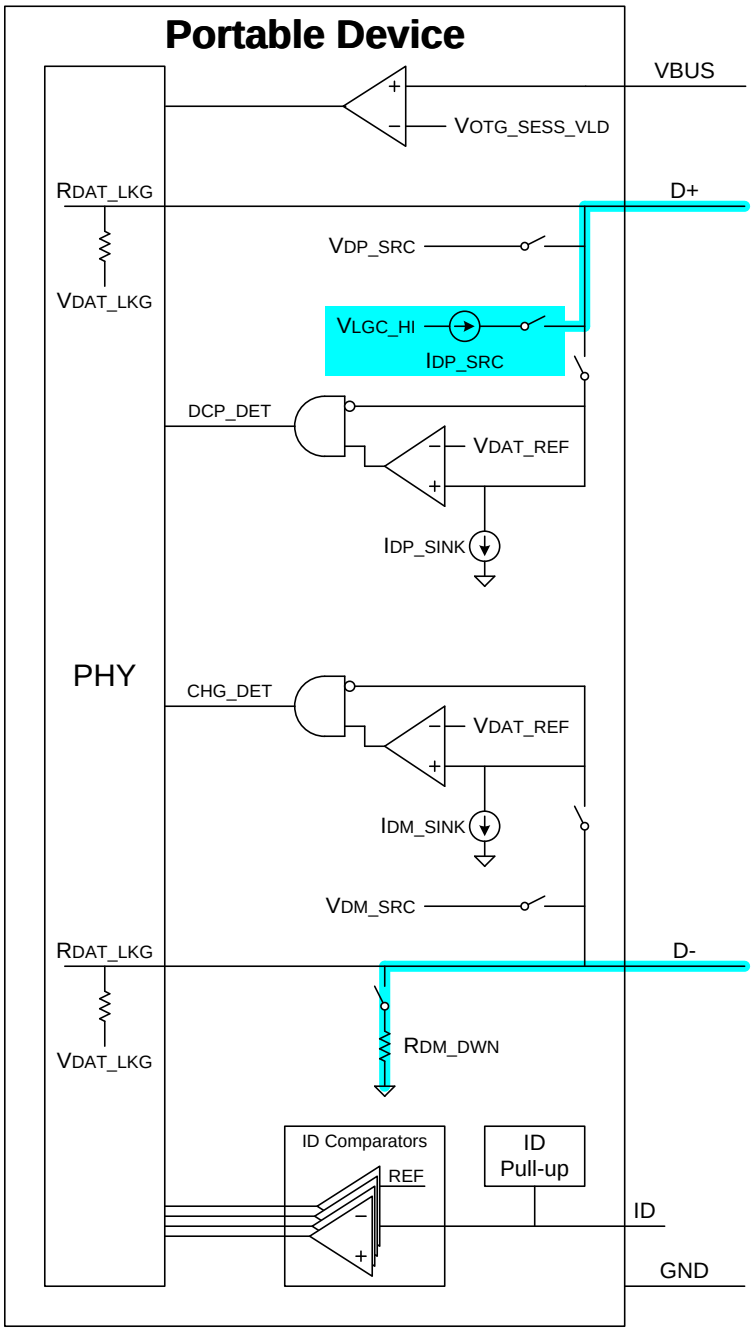

Figure 3-4 Data Contact Detect, Not Attached

The protocol for Data Contact Detect is as follows:

- PD detects VBUS asserted
- PD turns on IDP_SRC and the D- pull-down resistor
- PD waits for D+ line to be low for a time of TDCD_DBNC
- PD turns off IDP_SRC and D- pull-down resistor

When nothing is attached to the PD, the D+ line stays high. The minimum value of I_{DP_SRC} is such that it is able to hold D+ at V_{LGC_HI} for worst case leakages in the PD due to R_{DAT_LKG} and V_{DAT_LKG}.

3.2.3.4 Data Contact Detect, Standard Downstream Port

Figure 3-5 shows the case where the PD is attached to an SDP.

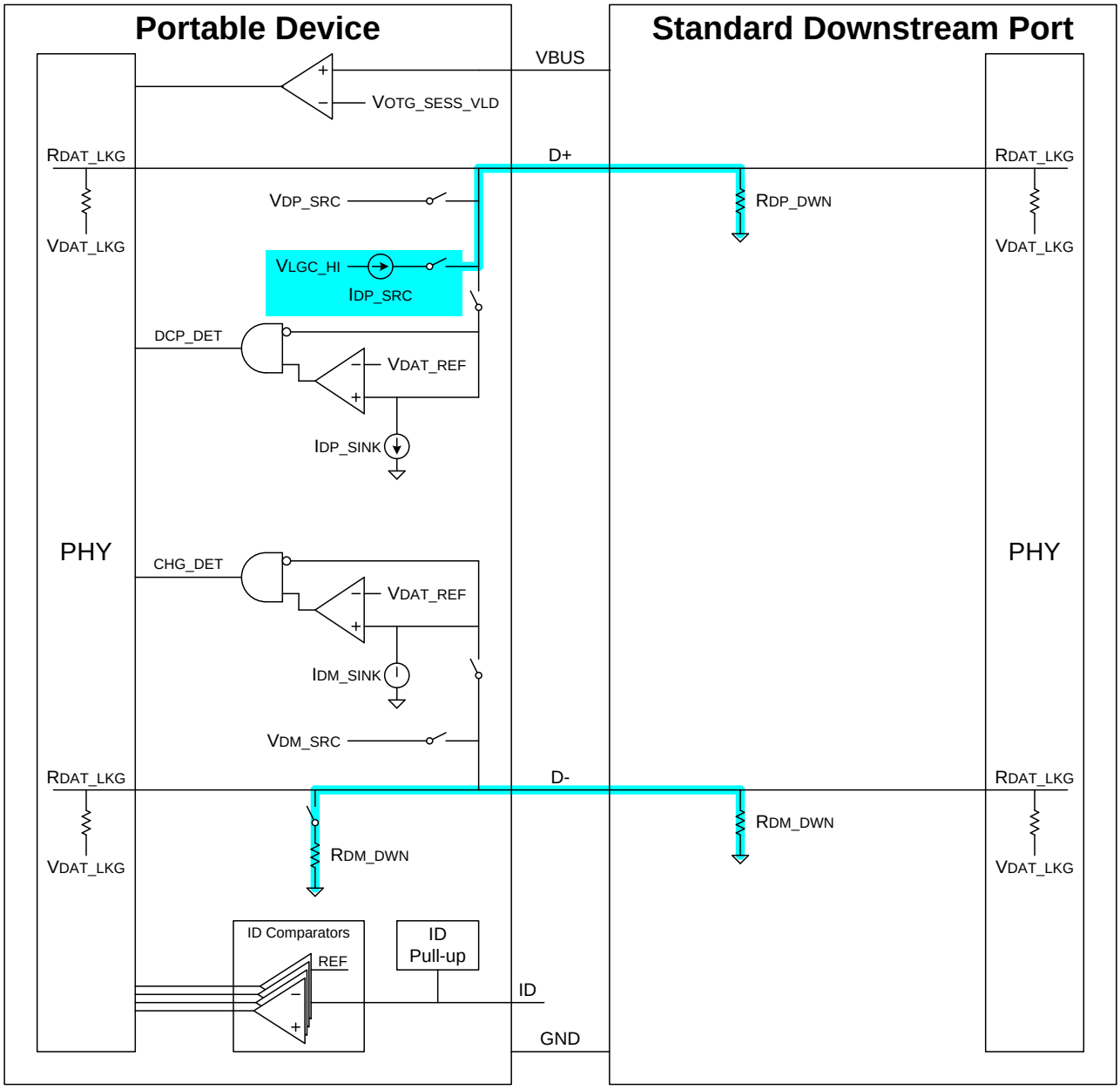

Figure 3-5 Data Contact Detect, Standard Downstream Port

When the PD is attached to an SDP, the D+ line is pulled low by R_{DP_DWN} in the SDP. The maximum value of I_{DP_SRC} is such that R_{DP_DWN} pulls D+ to V_{LGC_LOW} for worst values of R_{DAT_LKG}, V_{DAT_LKG} and R_{DP_DWN}.

3.2.4 Primary Detection

Primary Detection is used to distinguish between an SDP and different types of Charging Ports. A PD is required to implement Primary Detection.

3.2.4.1 Primary Detection, DCP

Figure 3-6 shows how Primary Detection works when a PD is attached to a DCP.

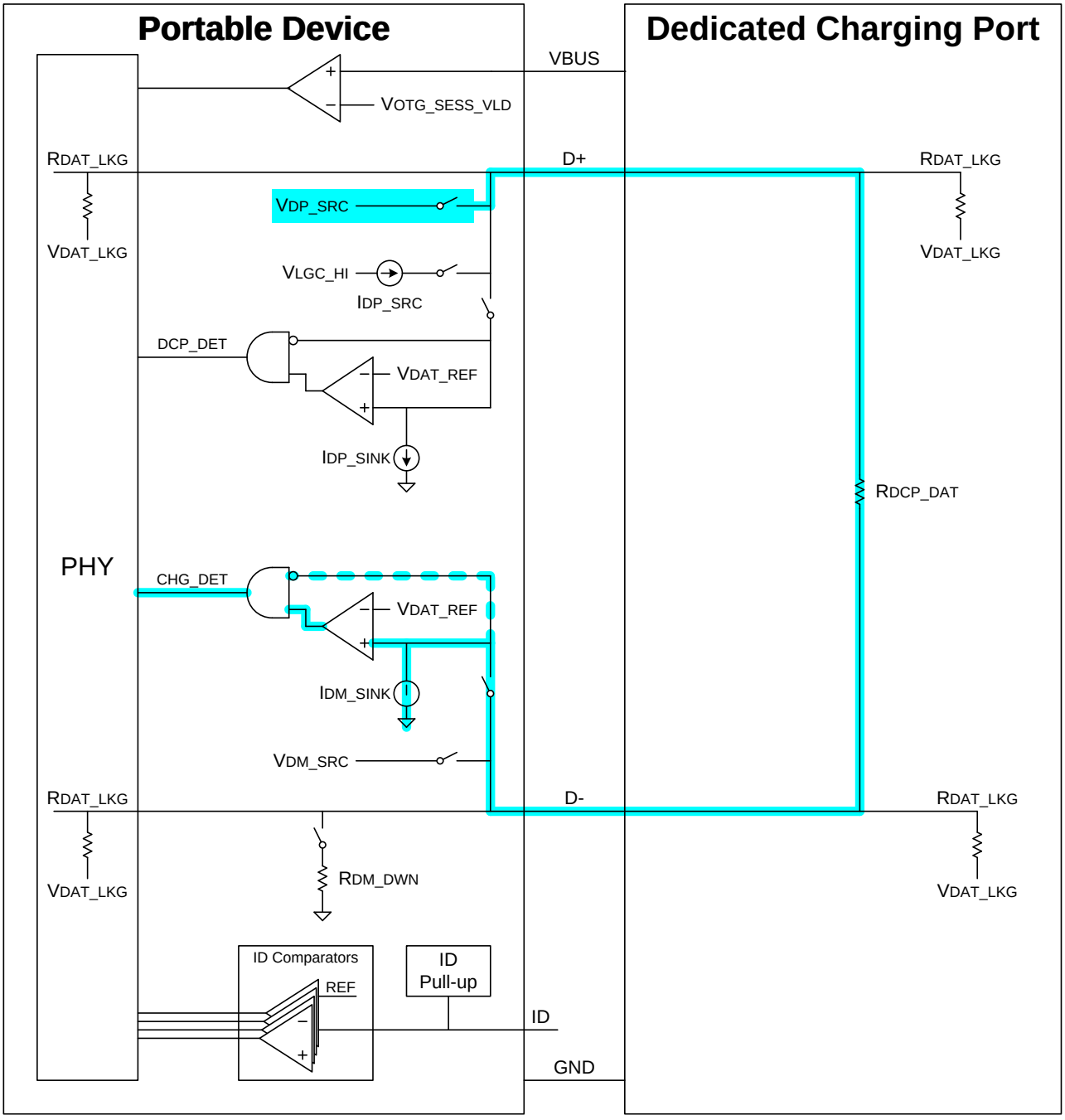

Figure 3-6 Primary Detection, DCP

During Primary Detection the PD shall turn on V_{DP_SRC} and I_{DM_SINK}. Since a DCP is required to short D+ to D- through a resistance of R_{DCP_DAT}, the PD will detect a voltage on D- that is close to V_{DP_SRC}.

A PD shall compare the voltage on D- with V_{DAT_REF}. If D- is greater than V_{DAT_REF}, then the PD is allowed to detect that it is attached to either a DCP or CDP. A PD is optionally allowed to compare D- with V_{LGC} as well, and only determine that it is attached to a DCP or CDP if D- is greater than V_{DAT_REF}, but less than V_{LGC}. The reason for this option is as follows.

PS2 ports pull D+/- high. If a PD is attached to a PS2 port, and the PD only checks for D- greater than V_{DAT_REF}, then a PD attached to a PS2 port would determine that it is attached to a DCP or CDP and proceed to draw I_{DEV_CHG}. This much current could potentially damage a PS2 port. By only determining it is attached to DCP or CDP if D- is less than V_{LGC}, the PD can avoid causing damage to a PS2 port.

On the other hand, some proprietary chargers also pull D+/- high. If a PD is attached to one of these chargers, and it determined it was not attached to a charger because D- was greater than V_{LGC}, then the PD would determine that it was attached to an SDP, and only be able to draw I_{SUSP}.

The choice of whether or not to compare D- to V_{LGC} depends on whether the PD is more likely to be attached to a PS2 port, or to a proprietary charger.

3.2.4.2 Primary Detection, CDP

Figure 3-7 shows how Primary Detection works when a PD is attached to a CDP.

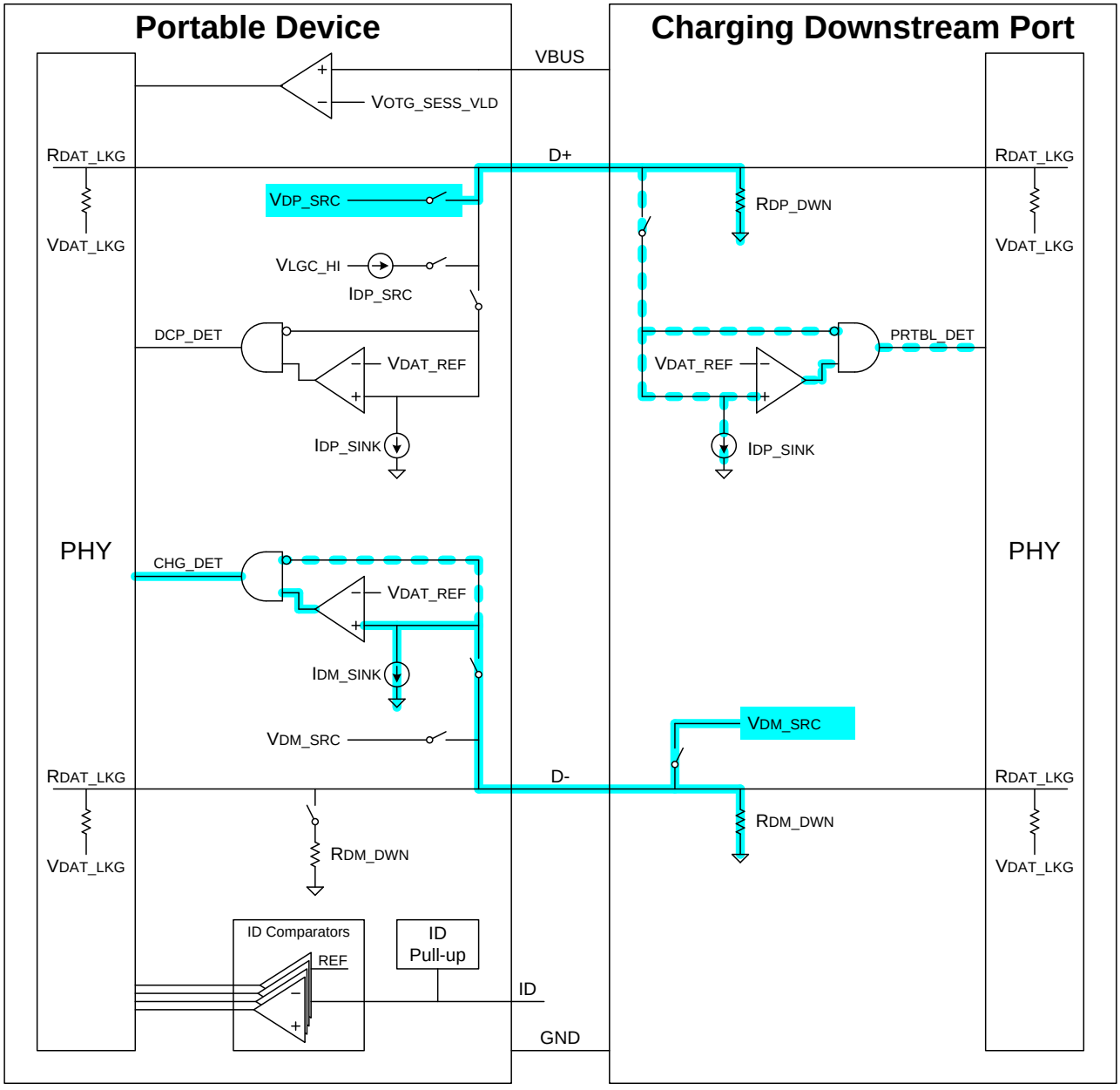

Figure 3-7 Primary Detection, CDP

A CDP is required to behave in either one of two ways when a remote device is not connected to it. The first way that a CDP is allowed to behave is to enable VDM_SRC within TCP_VDM_EN of a disconnect, and then disable VDM_SRC within TCP_VDM_DIS of a connect. When using this option, a CDP is not required to enable IDP_SINK, or to compare D+ to VDAT_REF.

The second way a CDP is allowed to behave is to compare D+ with VDAT_REF and VLGC. When D+ is greater than VDAT_REF and less than VLGC, the CDP shall enable VDM_SRC. When D+ is less than VDAT_REF

or greater than V_{LGC}, the CDP shall disable V_{DM_SRC}. Note that a CDP is required to compare D+ to V_{LGC}, in order to disable V_{DM_SRC} when the PD connects. See Section 3.4.2 for timing.

During Primary Detection the PD shall turn on V_{DP_SRC} and I_{DM_SINK}. A PD shall compare the voltage on D- with V_{DAT_REF}. If D- is greater than V_{DAT_REF}, then the PD is allowed to determine that it is attached to either a DCP or CDP. A PD is optionally allowed to compare D- with V_{LGC} as well, and only determine that it is attached to a DCP or CDP if D- is greater than V_{DAT_REF}, but less than V_{LGC}. See Section 3.2.4.1 for more details.

3.2.4.3 Primary Detection, SDP

Figure 3-8 shows how Primary Detection works when a PD is attached to an SDP.

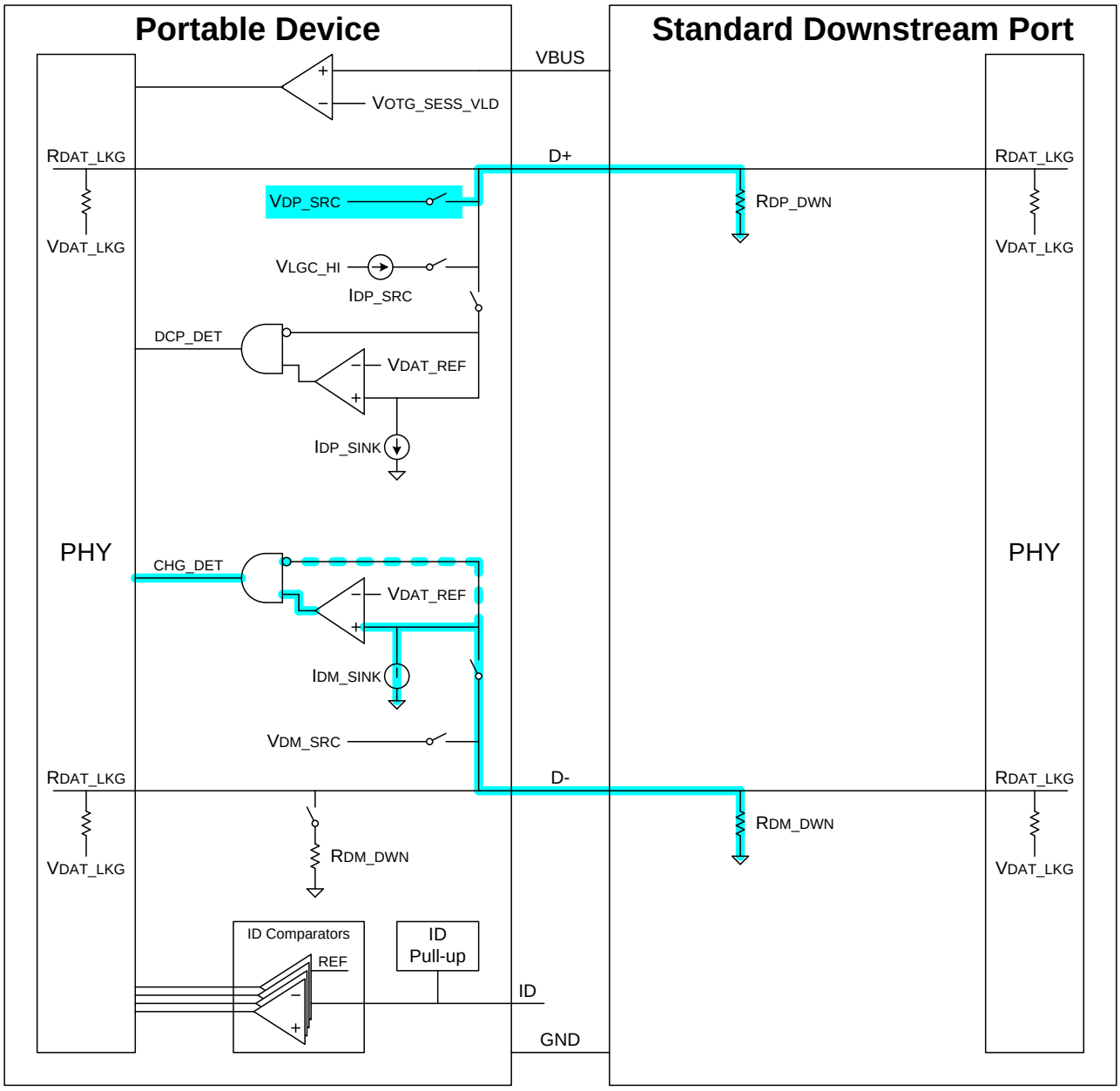

Figure 3-8 Primary Detection, SDP

During Primary Detection the PD shall turn on VDP_SRC and IDM_SINK. When a voltage of VDP_SRC is applied to D+, an SDP will continue pulling D- low through RDM_DWN.

A PD shall compare the voltage on D- with VDAT_REF. If D- is less than VDAT_REF, then the PD is allowed to determine that it is attached to an SDP. A PD is optionally allowed to compare D- with VLGC as well, and determine that it is attached to an SDP if D- is greater than VLGC. See Section 3.2.4.1 for more details.

3.2.4.4 Primary Detection, ACA-Dock

Figure 3-9 shows how Primary Detection works when a PD that supports ACA Detection is attached to an ACA-Dock.

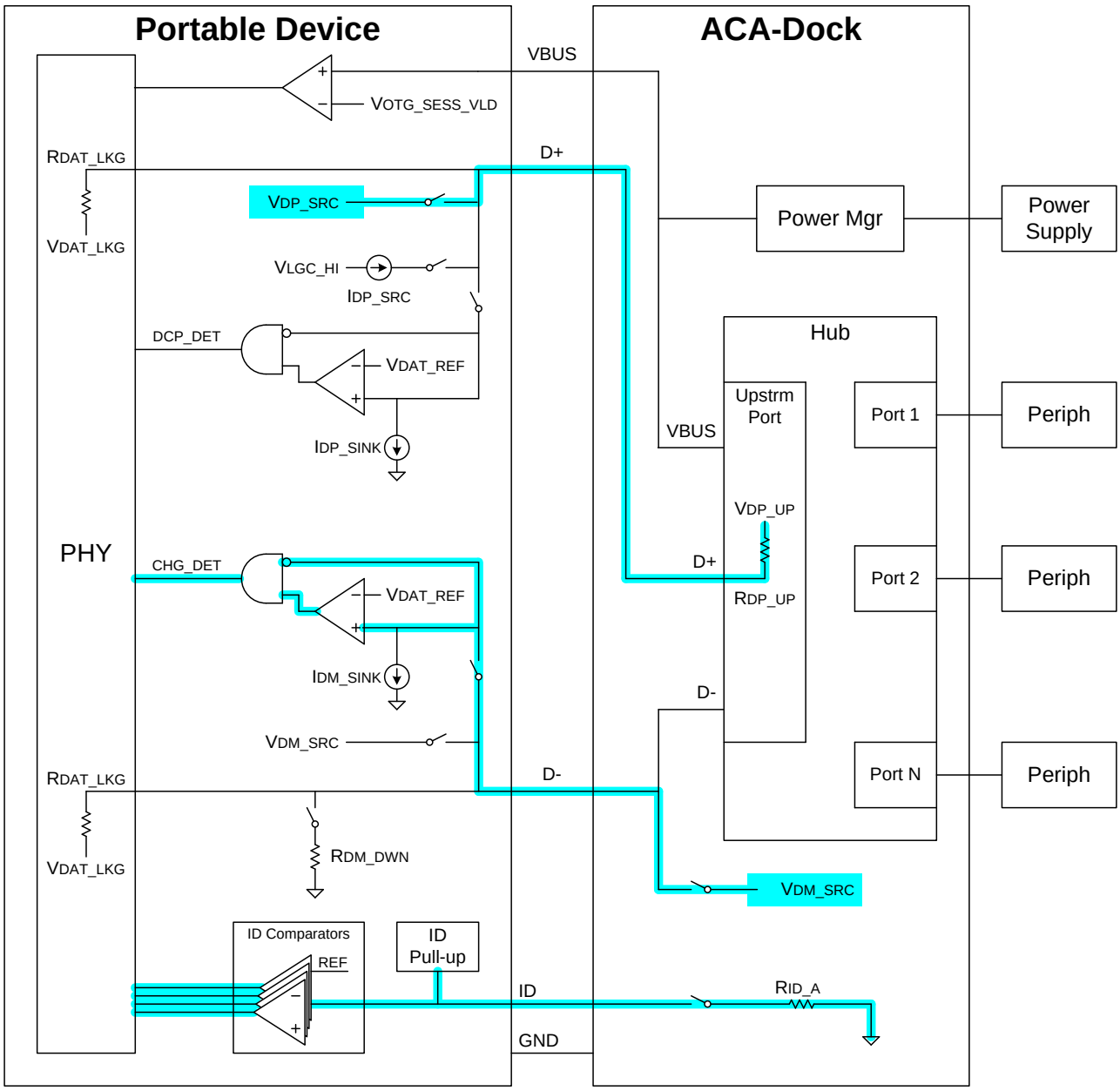

Figure 3-9 Primary Detection, ACA-Dock

An ACA-Dock is a docking station that has one upstream port, and zero or more downstream ports. The upstream port can be attached to a PD, and is capable of sourcing ICDP to the PD.

When an ACA-Dock is powered, but nothing is attached to its upstream port, it is required to bias the pins on its upstream port as follows:

- VBUS V_{CHG}
- D+ V_{DP_UP}
- D- V_{DM_SRC}
- ID R_{ID_A}
- GND GND

The VBUS pin is at V_{CHG} because the ACA-Dock is ready to provide power to a PD. The ACA-Dock is required to pull D+ to V_{DP_UP} through R_{DP_UP} because the VBUS pin is greater than $V_{OTG\_SESS\_VLD}$.

An ACA-Dock is required to enable V_{DM_SRC} whenever D+/- have been inactive (at idle J state) for a time of $T_{CP\_VDM\_EN}$. An ACA-Dock is required to disable V_{DM_SRC} within $T_{CP\_VDM\_DIS}$ of any activity on D+/-.

An ACA-Dock is required to present an impedance to ground on ID of R_{ID_A} whenever it is powered. It is required to present an impedance to ground on ID of R_{ID_FLOAT} when it is not powered.

When a PD that supports ACA detects the following conditions, it shall determine that it is attached to an ACA-Dock:

- VBUS > $V_{OTG\_SESS\_VLD}$
- D+ at V_{LGC_HI}
- V_{DAT_REF} < D- < V_{LGC}
- ID at R_{ID_A}

Note that a PD attached to an ACA-Dock is required to compare D- with V_{LGC}. If a PD were attached to an ACA that had a LS peripheral on its Accessory Port, then the ID pin of the PD would be pulled to ground through R_{ID_A}, and the D- pin would be at V_{LGC_HI} instead of V_{DM_SRC}. In order to distinguish between an ACA with a LS device and an ACA-Dock, the PD is required to detect if D- is above or below V_{LGC}.

The V_{DP_SRC} in the PD shall be such that D+ remains at a logic high while the ACA-Dock is pulling D+ to V_{DP_UP} through R_{DP_UP}. The reason for this is so that the ACA-Dock does not detect activity on D+, which could cause it to turn off its V_{DM_SRC} before the PD completes its Primary Detection.

3.2.4.5 Primary Detection, Micro ACA

Figure 3-10 shows how Primary Detection works when a PD that supports ACA Detection is attached to a Micro ACA.

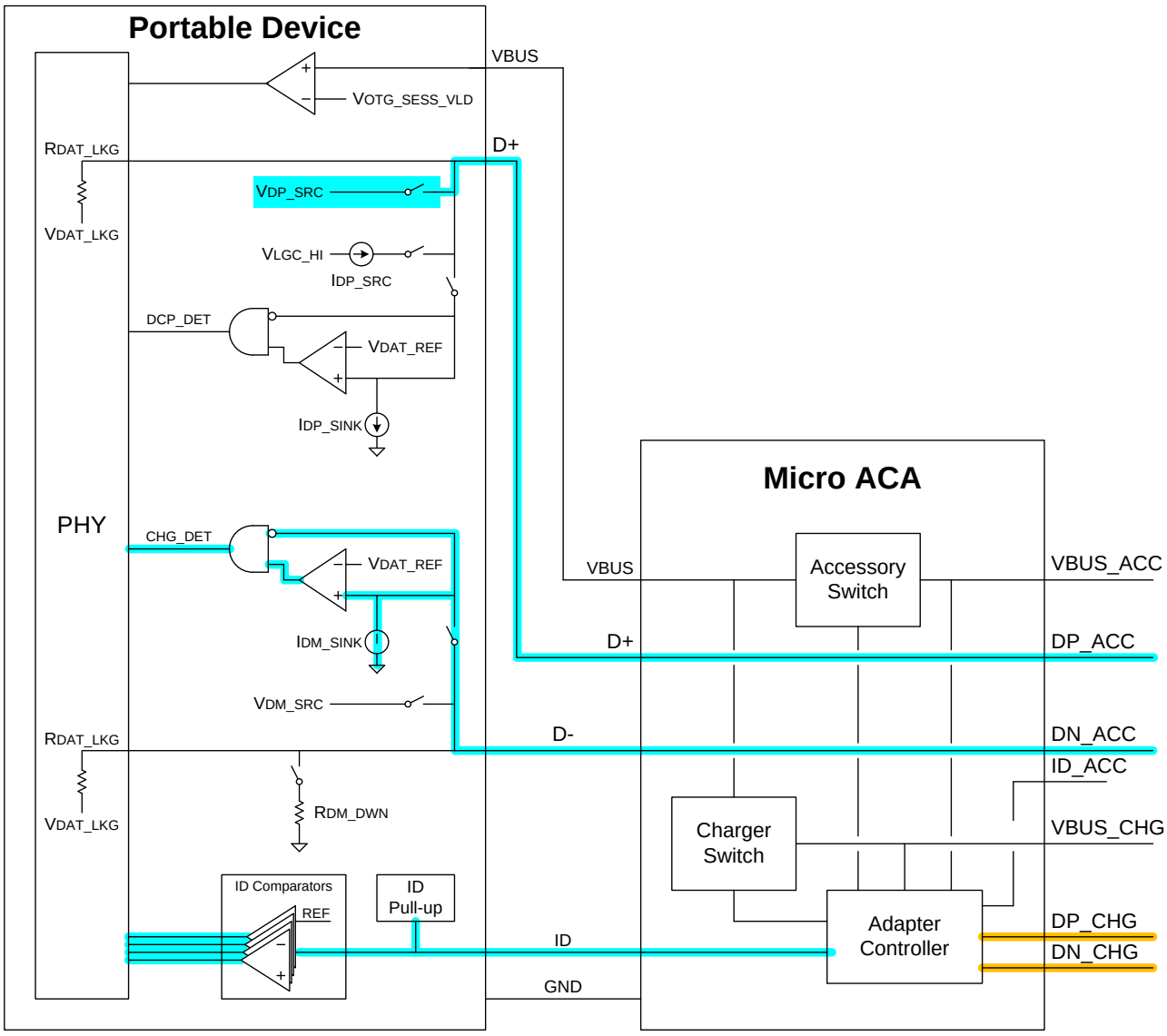

Figure 3-10 Primary Detection, ACA

A PD that supports ACA Detection is required to monitor the resistance on the ID pin whenever VBUS is greater than VOTG_SESS_VLD. If the ID resistance is RID_B or RID_C, then the PD knows that it is attached to an ACA. If the ID resistance is RID_A, then the PD could be attached to either an ACA with a B-device on its Accessory Port, or to an ACA-Dock.

In order to distinguish between an ACA with an B-device, and an ACA-Dock, the PD shall compare the voltage on D- with V_{DAT_REF} and V_{LGC} to detect what it is attached to as follows:

- D- < V_{DAT_REF} ACA with FS B-device on Accessory Port
- V_{DAT_REF} < D- < V_{LGC} ACA-Dock
- V_{LGC} < D- ACA with LS B-device on Accessory Port

The PD shall do the above detection on D- after attach, and before connect, as shown in the Good Battery Algorithm.

After doing Primary Detection, a PD that supports ACA Detection shall continue to monitor the ID line. If this resistance changes, the PD shall respond according to the state machine defined in Section 6.2.7.

An ACA is required to do a form of Primary Detection over the DP_CHG and DN_CHG lines to detect if a Charging Port is attached to the ACA Charger Port. This detection is done with the lines highlighted in yellow, and is described in Section 6.2.6.

3.2.5 Secondary Detection

Secondary Detection can be used to distinguish between a DCP and a CDP. PDs that are not ready to be enumerated within $T_{SVLD\_CON\_PWD}$ of detecting VBUS are required to implement Secondary Detection. PDs that are ready to be enumerated are allowed to bypass Secondary Detection. See Section 3.3.2 on Good Battery Algorithm.

3.2.5.1 Secondary Detection, DCP

Figure 3-11 shows how Secondary Detection works when a PD is attached to a DCP.

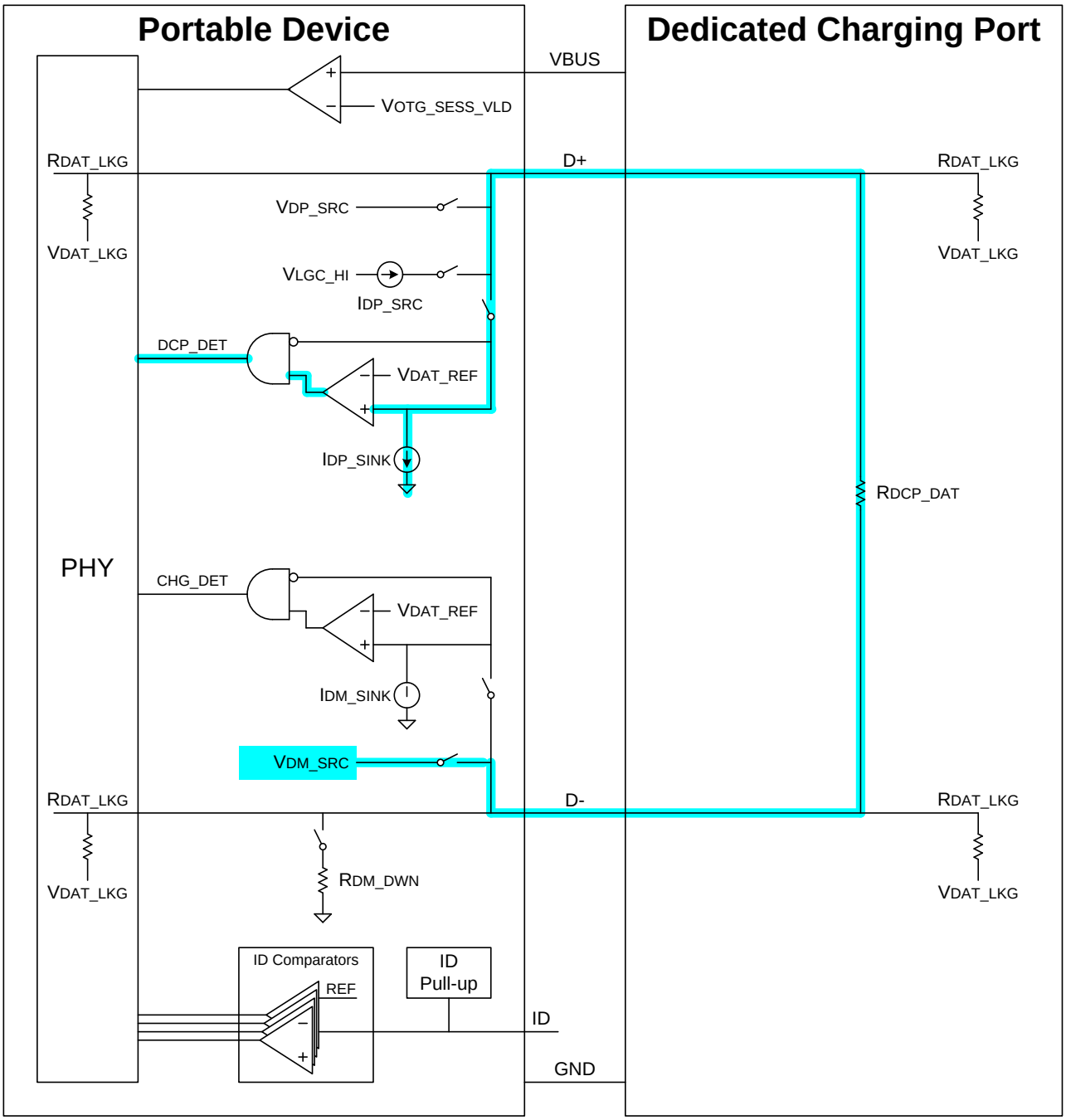

Figure 3-11 Secondary Detection, DCP

During Secondary Detection, a PD shall output VDM_SRC on D-, turn on IDP_SINK, and compare the voltage on D+ to VDAT_REF. Since a DCP is required to short D+ to D- through a resistance of RDCP_DAT, the voltage on D+ will be close to VDM_SRC, which is above VDAT_REF.

If a PD detects that D+ is greater than V_{DAT_REF}, it knows that it is attached to a DCP. It is then required to enable V_{DP_SRC} or pull D+ to V_{DP_UP} through R_{DP_UP}, as defined in the Good Battery Algorithm in Section 3.3.2.

A PD is not required to compare D+ to V_{LGC} during Secondary Detection.

3.2.5.2 Secondary Detection, CDP

Figure 3-12 shows how Secondary Detection works when a PD is attached to a CDP.

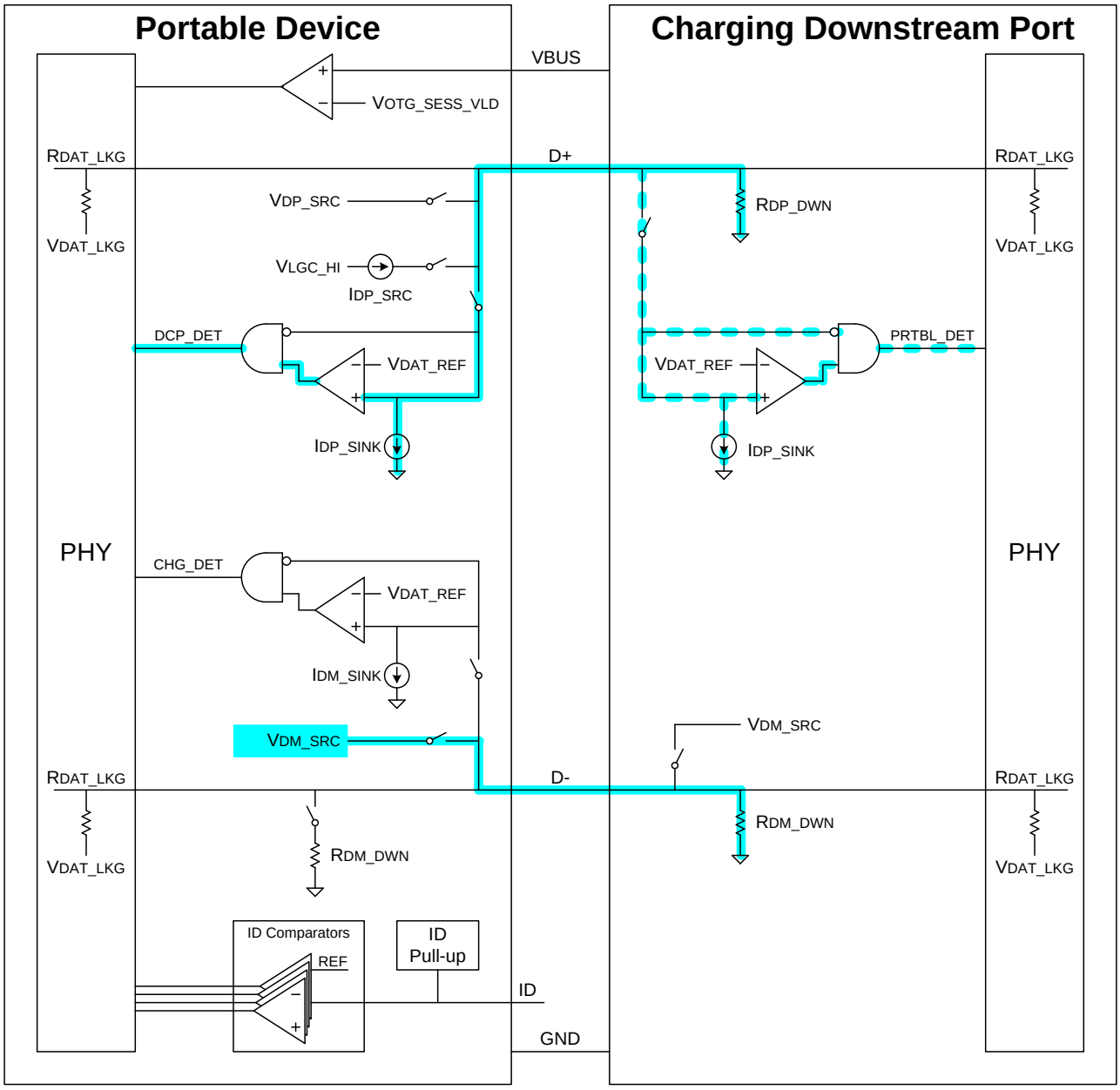

Figure 3-12 Secondary Detection, CDP

During Secondary Detection, a PD shall output V_{DM_SRC} on D-, turn on I_{DP_SINK}, and compare the voltage on D+ to V_{DAT_REF}. Since a CDP does not short D+ to D-, the voltage on D+ will be close to ground, which is below V_{DAT_REF}.

If a PD detects that D+ is less than V_{DAT_REF}, it knows that it is attached to a CDP. It is then required to turn off V_{DP_SRC} and V_{DM_SRC}, as shown in the Good Battery Algorithm in Section 3.3.2, and is allowed to draw I_{DEV_CHG}.

A PD is not required to compare D+ to V_{LGC} during Secondary Detection.

3.2.6 ACA Detection

ACA Detection allows a PD to detect when it is attached to an ACA, and to detect what type of device is attached to the ACA Accessory Port. See Section 6 for a description of the ACA.

A PD is not required to support ACA Detection. Only PDs that have a Micro-AB receptacle can support ACA Detection, since the ACA OTG Port has a captive cable terminating in a Micro-A plug.

PDs that support ACA Detection are required to implement the Good Battery Algorithm defined in Section 3.3.2.

Figure 3-13 shows how ACA Detection works when a PD is attached to a Micro ACA.

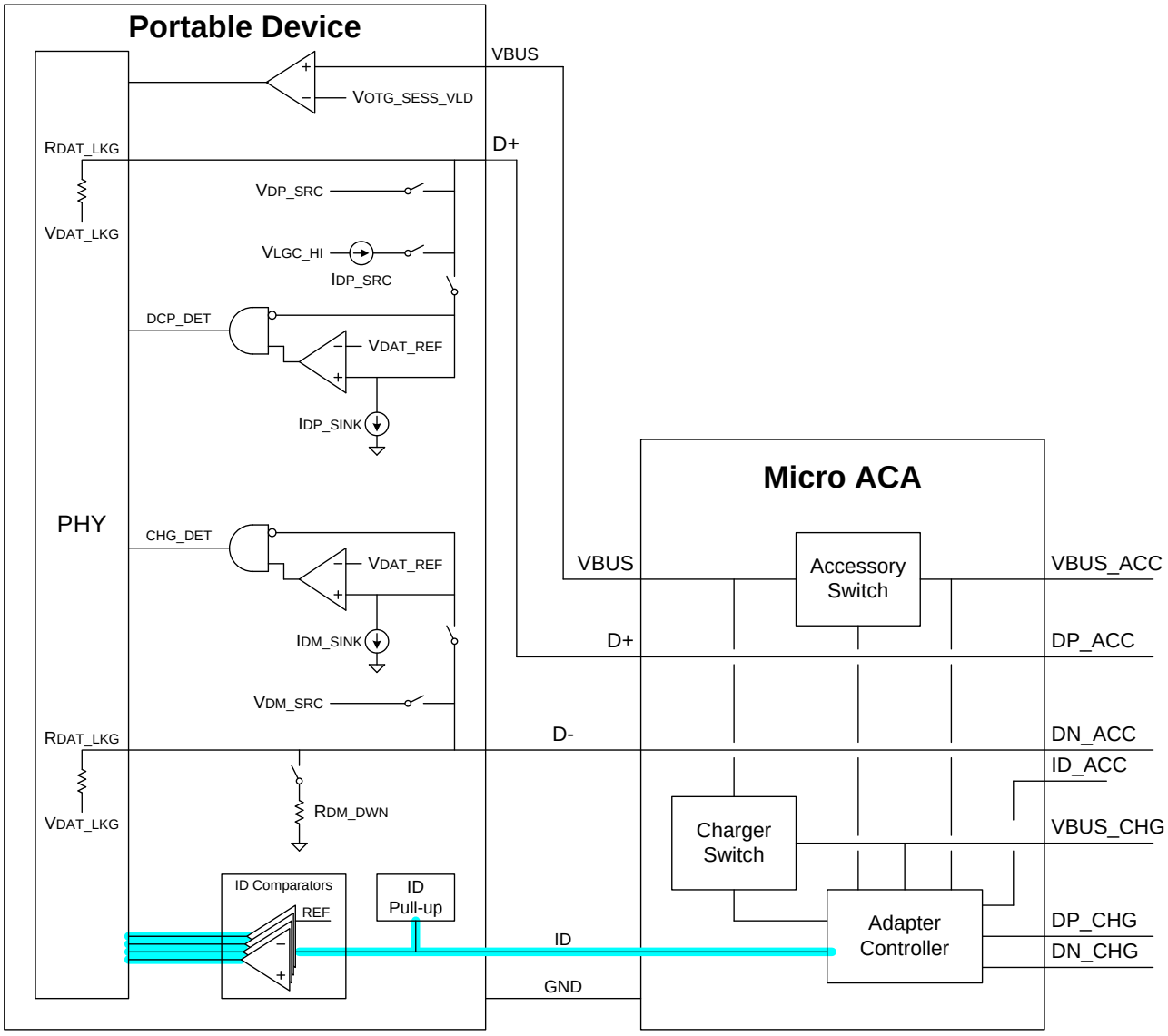

Figure 3-13 ACA Detection

A PD detects the presence of an ACA by sensing the resistance on the ID pin. There are five different resistance values that shall be detected during ACA Detection, namely: R_{ID_GND}, R_{ID_C}, R_{ID_B}, R_{ID_A} and R_{ID_FLOAT}. PDs that support ACA Detection shall monitor the ID resistance during the entire time that VBUS is asserted, and respond according to the PD State Machine in Section 6.2.7.

Note: It is important that designers take into account the following factors when designing circuitry to distinguish these ID pin resistance values:

- *The resistance has to be correctly detected in the presence of a voltage drop in the ACA cable ground resulting from I_{DEV_CHG} flowing through $R_{OTG\_ACA\_GND}$, causing the ACA ground to be lower than the OTG ground.*

- *The resistance has to be correctly detected in the presence of a voltage drop in the ACA cable ground resulting from I_{CFG_MAX} flowing through $R_{OTG\_ACA\_GND}$ causing the ACA ground to be higher than the OTG ground.*
- *Leakage currents (Table 5-3, Note 2) should be considered and their effects also taken into account.*

3.3 Charger Detection Algorithms

3.3.1 Weak Battery Algorithm

Figure 3-14 shows an example charger detection algorithm for a PD with a Weak Battery. Other algorithms are allowed, providing they comply with the DBP.

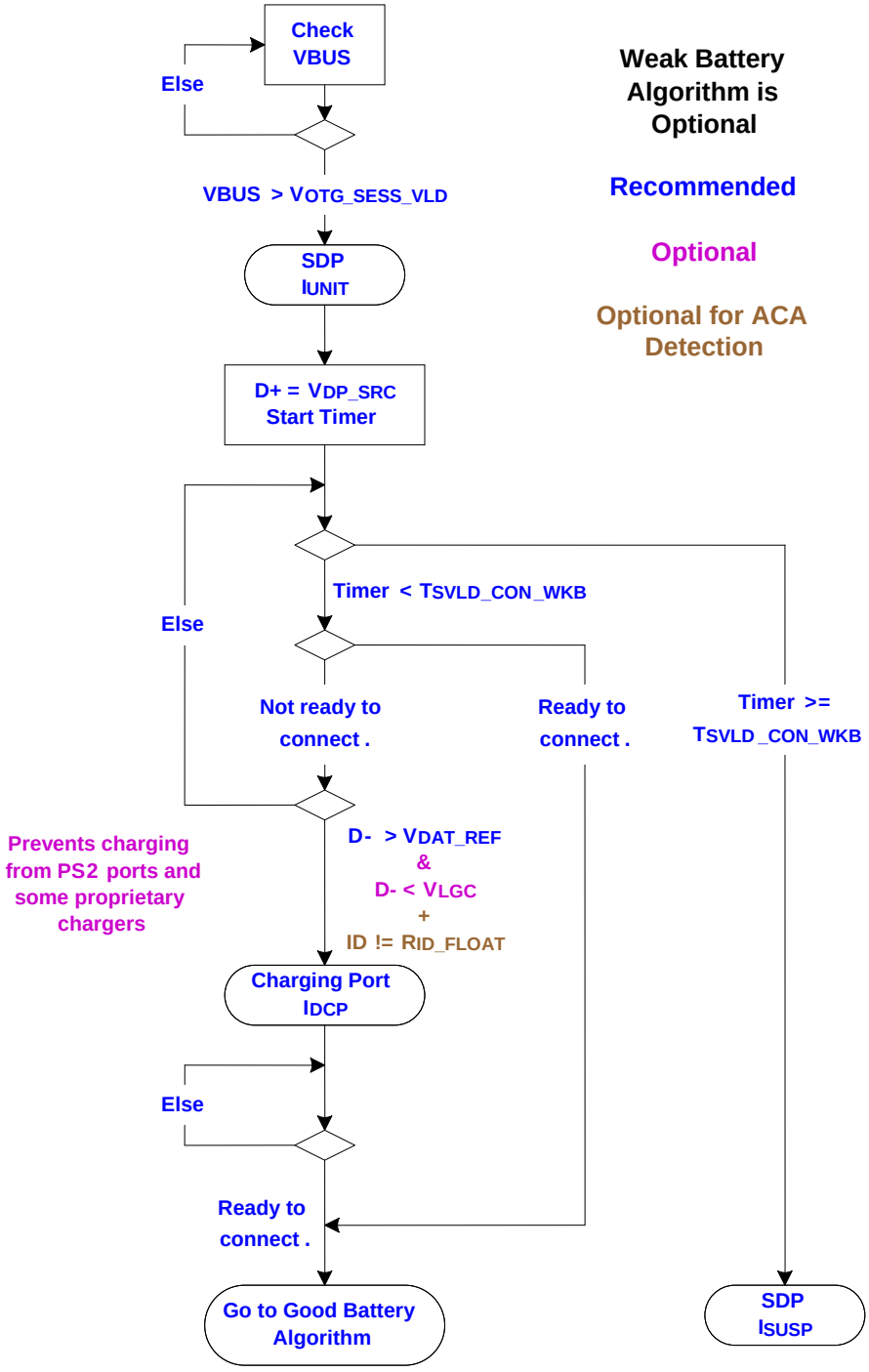

Figure 3-14 Weak Battery Algorithm

A PD is required to have internal voltage thresholds that lie within $V_{OTG\_SESS\_VLD}$, V_{DAT_REF} and V_{LGC}. In the above algorithm, a PD compares VBUS, D+ and D- with its internal thresholds. It does not compare VBUS, D+ and D- with the min or max value of $V_{OTG\_SESS\_VLD}$, V_{DAT_REF} or V_{LGC}.

In the above example, a PD with a Weak Battery detects VBUS greater than $V_{OTG\_SESS\_VLD}$, and applies a voltage of V_{DP_SRC} on the D+ pin. If the voltage on D- is greater than its V_{DAT_REF}, or if the ID pin is not floating, the PD is allowed to draw I_{DEV_CHG}. Else the PD is allowed to draw I_{UNIT}.

The V_{LGC} term shown in magenta could be added to prevent a PD from charging from PS2 ports and some proprietary chargers.

3.3.2 Good Battery Algorithm

Figure 3-15 shows the charger detection algorithm that a PD with a Good Battery is required to implement. It may also be used by a PD with a Weak Battery, subject to meeting the requirements of the Dead Battery Provision.

Thus a PD, having reached the bottom of the flow chart may in all cases, with the exception of the DCP/CDP exit, delay for up to $T_{SVLD\_CON\_WKB}$ before connecting or applying a bus reset as appropriate.

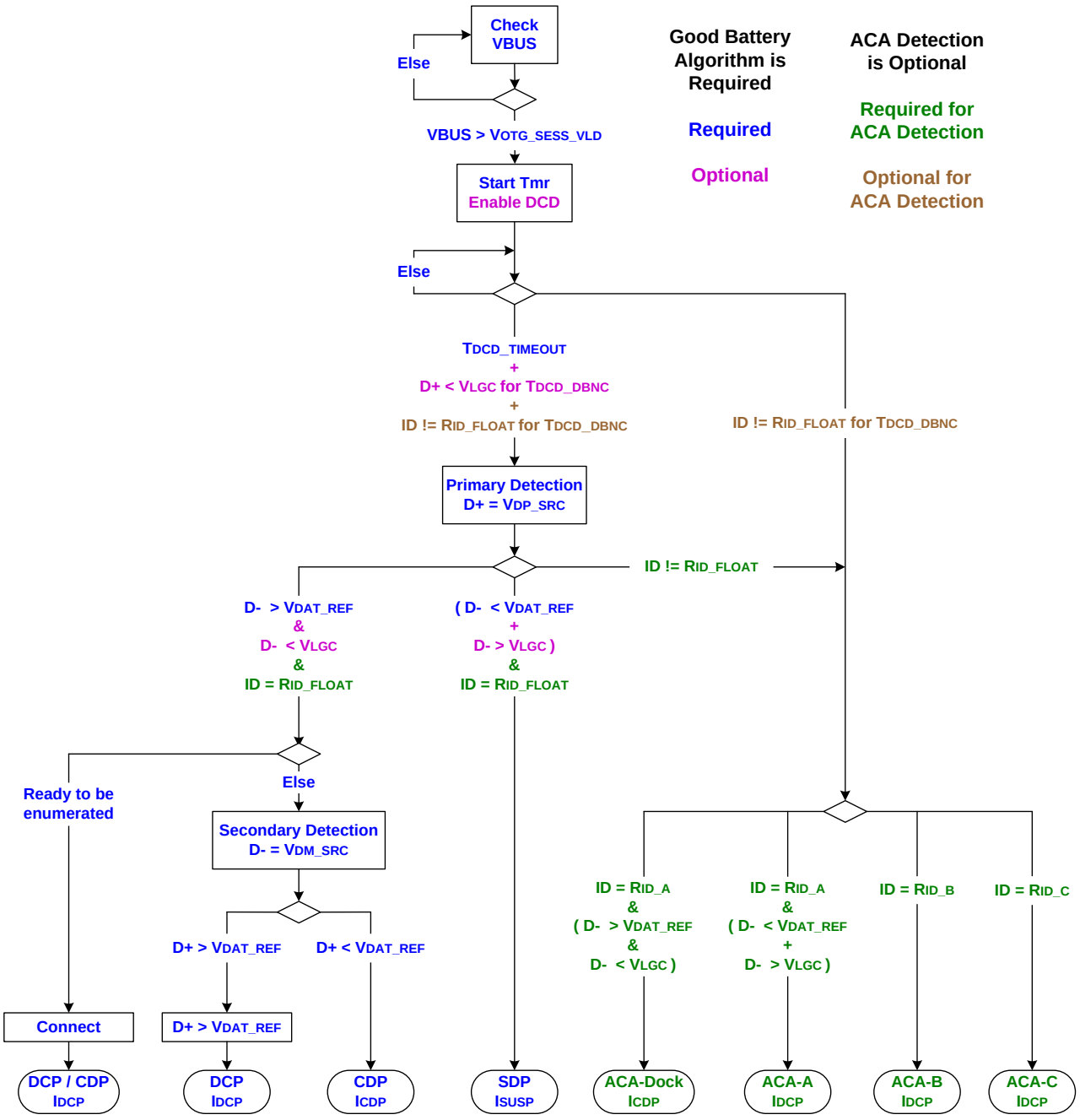

Figure 3-15 Good Battery Algorithm

A PD shall implement the Good Battery Algorithm when attached to an SDP or Charging Port. A PD is allowed to include additional branches for detecting devices or ports other than an SDP or Charging Port.

Any such branches shall not cause additional activity on D+/- and/or ID that would interfere or be confused with the next expected event when the PD is attached to an SDP or Charging Port. Branches are also allowed after any final step in detection, and these branches may include additional activity on D+/- and/or ID, except that when a PD is attached to a DCP, it shall maintain D+ greater than V_{DAT_REF} while VBUS is asserted.

Upon detecting VBUS greater than its $V_{OTG\_SESS\_VLD}$ threshold, a PD shall start a timer with a timeout value of $T_{DCD\_TIMEOUT}$. A PD that supports DCD is allowed to enable its I_{DP_SRC} and monitor for D+ being at V_{LGC_LOW} for T_{DCD_DBNC}. A PD that supports ACA Detection is allowed to monitor for ID not floating for T_{DCD_DBNC}. If the DCD timer expires before the D+ or ID conditions are detected, the PD shall proceed to Primary Detection.

If a PD detects that ID is not floating for a time of T_{DCD_DBNC}, then it is allowed to proceed directly to one of the ACA states, without having to do Primary Detection and without having to assert V_{DP_SRC}.

During Primary Detection, a PD shall enable V_{DP_SRC}, and compare D- with V_{DAT_REF}. A PD may optionally compare D- with V_{LGC} to avoid damaging a PS2 port. See Section 3.2.4.1. A PD that supports ACA Detection is required to detect the resistance on the ID line.

If a PD Detects that it is attached to either a DCP or CDP during Primary Detection, and it is ready to be enumerated, then it is allowed to take the branch where it connects. If a PD is not ready to be enumerated, then it is required to do Secondary Detection.

During Secondary Detection, the PD shall disable V_{DP_SRC}, enable V_{DM_SRC} and compare D+ with V_{DAT_REF}. If D+ is greater than V_{DAT_REF}, then the PD is attached to a DCP. The PD shall disable V_{DM_SRC}, and either enable V_{DP_SRC} or pull D+ to V_{DP_UP} through R_{DP_UP}.

If D+ is less than V_{DAT_REF}, then the PD is attached to a CDP. The PD shall disable V_{DM_SRC}, and leave both D+ and D- low until it is ready to connect and be enumerated.

A PD that is attached to a DCP shall either enable V_{DP_SRC} or pull D+ high within $T_{SVLD\_CON\_PWD}$ of attach.

A PD that supports ACA Detection is required to monitor the resistance on the ID line. If a resistance of R_{ID_A} is detected, then the PD shall compare D- with both V_{DAT_REF} and V_{LGC}, to determine if it is attached to an ACA-Dock or an ACA-A. See Section 3.2.4.4 for more details.

3.4 Charger Detection Timing

3.4.1 Data Contact Detect Timing

To initiate Data Contact Detect, the PD shall enable I_{DP_SRC} and either I_{DM_SINK} or R_{DM_DWN}. When the PD detects that the D+ line has been low for a time of T_{DCD_DBNC}, then the PD knows that the data pins have made contact.

Figure 3-16 shows the timing associated with Data Contact Detect (DCD) when pins make contact after DCD starts.

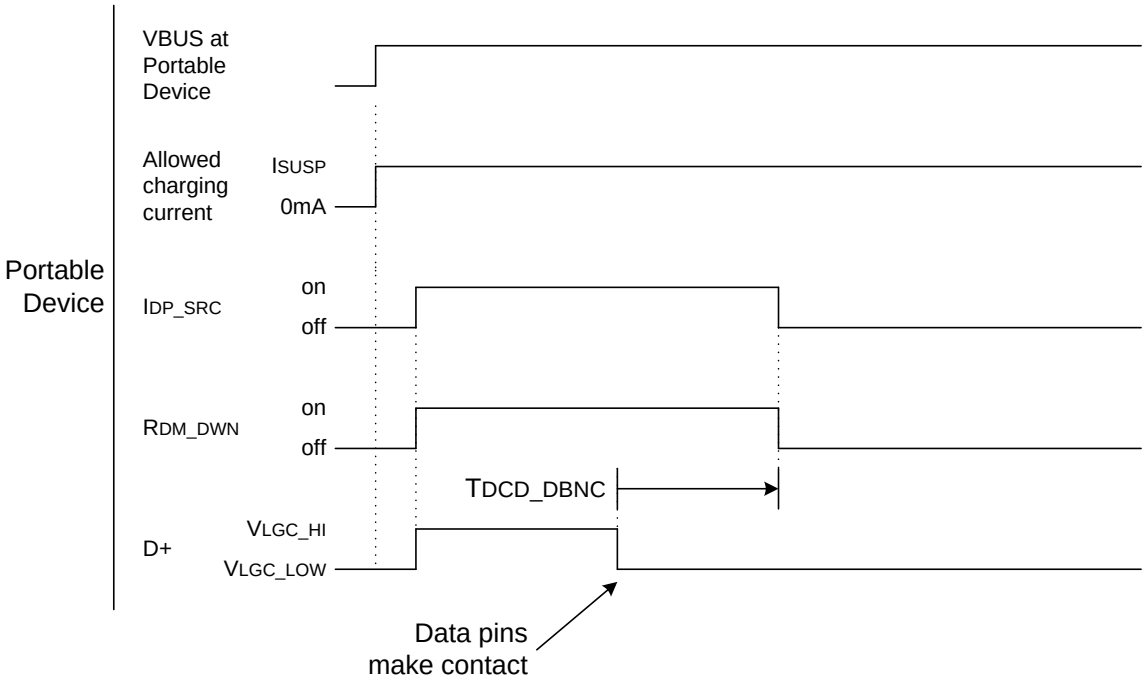

Figure 3-16 DCD Timing, Contact After Start

Figure 3-17 shows the timing associated with Data Contact Detect when pins have made contact before DCD starts.

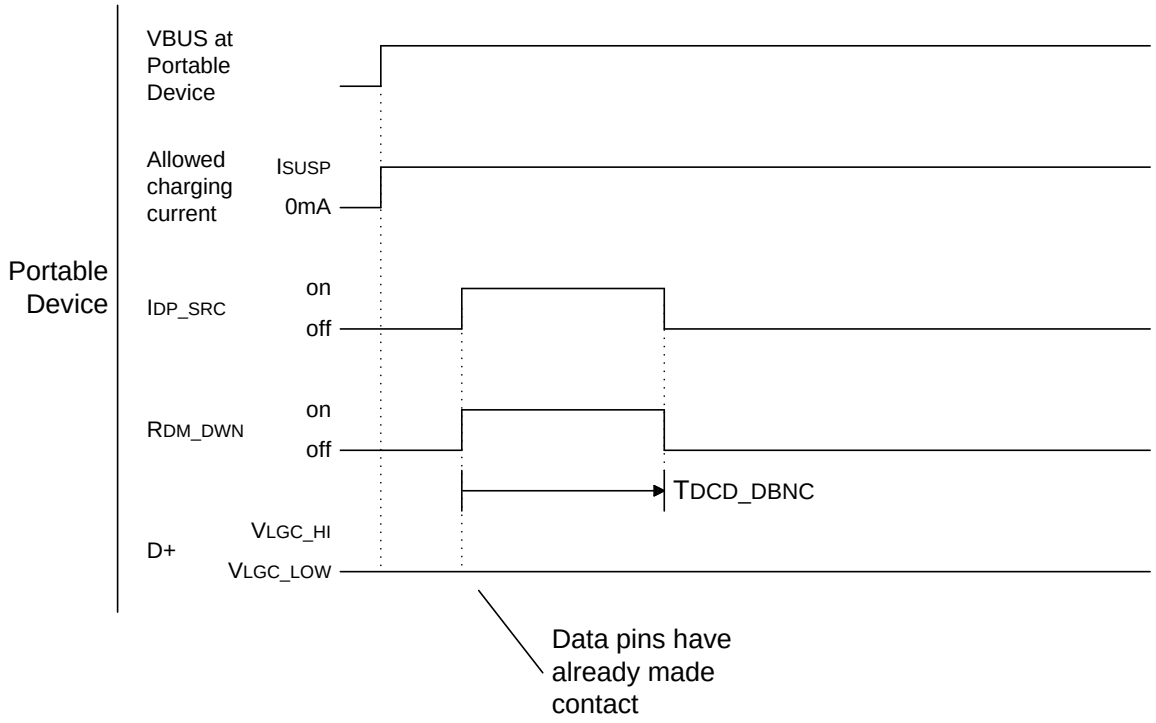

Figure 3-17 DCD Timing, Contact Before Start

Figure 3-18 shows the timing associated with Data Contact Detect when contact is not detected.

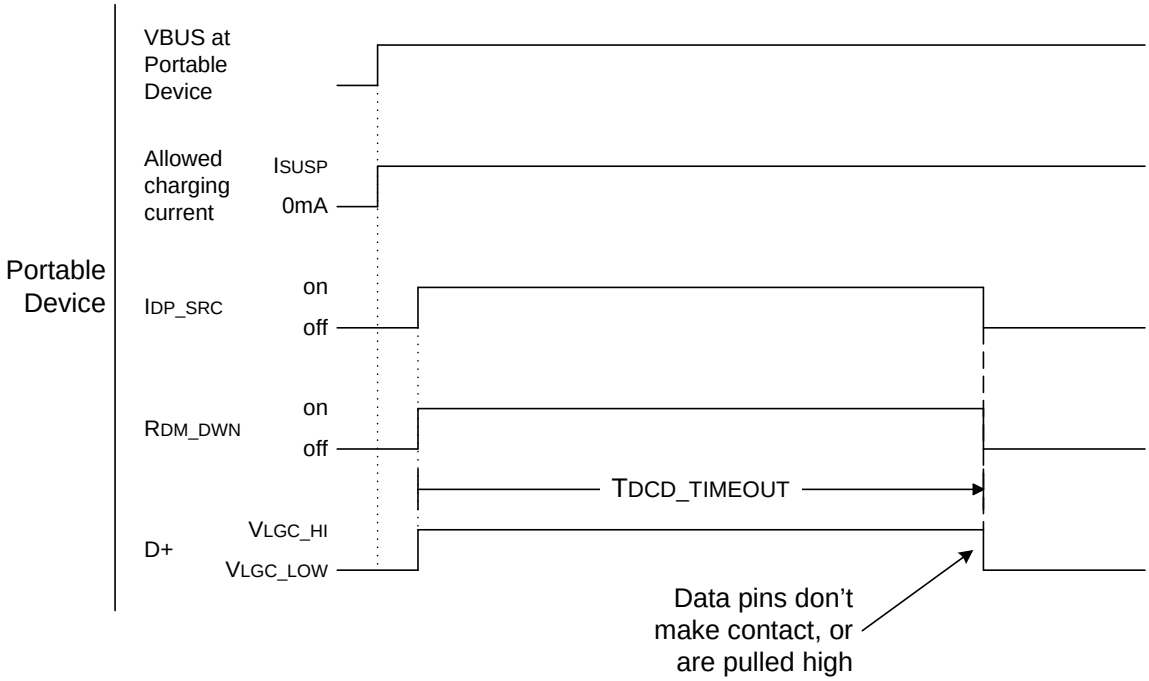

Figure 3-18 DCD Timing, No Contact

3.4.2 Detection Timing, CDP

Figure 3-19 shows the timing associated with Primary and Secondary Detection when a PD is attached to a CDP, for the case where the CDP compares D+ to V_{DAT_REF} and V_{LGC}, and enables V_{DM_SRC} accordingly. A CDP is also allowed to leave V_{DM_SRC} enabled while a remote device is not connected. See Section 3.2.4.2 for more details.

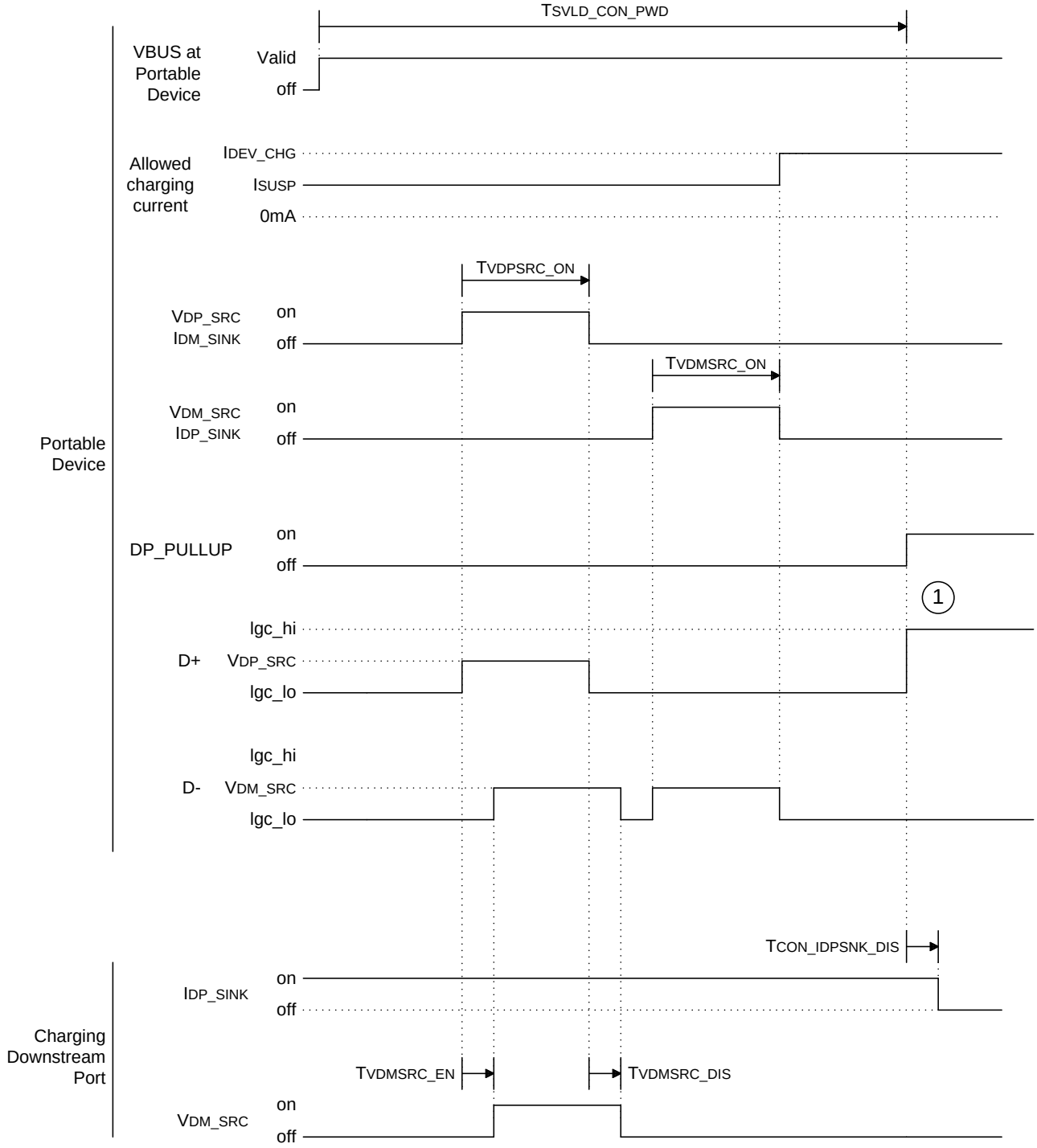

Figure 3-19 Detection Timing, CDP

Notes:

1) The timing for a LS PD is the same as shown above, except that a LS PD will pull D- high, instead of D+.

Figure 3-19 shows the Primary and Secondary Detection timing for a PD attached to a CDP. During Primary Detection, the PD turns on V_{DP_SRC} and I_{DM_SINK}. The CDP is required to have V_{DM_SRC} on D- within a time of T_{VDMSRC_EN} from when D+ is above V_{DAT_REF}. After a time of T_{VDPSRC_ON}, the PD is allowed to check the status of the D- line. If D- is above V_{DAT_REF} (and optionally below V_{LGC}, see Section 3.2.4.1) then the PD is attached to a Charging Port, and is allowed to draw I_{DEV_CHG}.

In order to do Secondary Detection, the PD is required to disable V_{DP_SRC} and I_{DM_SNK}, and enable V_{DM_SRC} and I_{DP_SINK}. After a time of T_{VDMSRC_ON}, the PD is allowed to check the status of the D+ line. Since a CDP does not source a voltage on D+, D+ is below V_{DAT_REF} and the PD is attached to a CDP.

If the PD was powered up at the time VBUS was detected, then it shall connect within a time of $T_{SVLD\_CON\_PWD}$. The CDP shall disable I_{DP_SINK} within $T_{CON\_IDPSNK\_DIS}$ of detecting the connect.

3.5 Ground Current and Noise Margins

As shown in Figure 7-47 of the USB 2.0 specification, a current of 100 mA through the ground wire of a USB cable can result in a voltage difference of 25 mV between the host ground and the device ground. This ground difference has the effect of reducing noise margins for both signaling and charger detection.

The maximum current that a PD is allowed to draw from a CDP is I_{DEV_CHG}. A PD that draws more than I_{CFG_MAX} from a CDP is required to support LS, FS, HS and chirp signaling when the local ground is V_{GND_OFFSET} max higher than the remote ground. A host port that grants the CDP handshake is required to support LS, FS, HS and chirp signaling when the local ground is V_{GND_OFFSET} max lower than the remote ground.

When the ground offset is V_{GND_OFFSET} max, the PD and CDP are required to have a greater common mode range than what is called out in USB 2.0.

4. Charging Port and Portable Device Requirements

This section describes the requirements for the following:

- Charging Downstream Port (CDP)
- ACA-Dock
- Dedicated Charging Port (DCP)
- Accessory Charger Adapter (ACA)
- Portable Device (PD)

4.1 Charging Port Requirements

The following requirements apply to all types of Charging Ports, including CDP, ACA-Dock, DCP and ACA.

4.1.1 Overshoot

The output voltage of a Charging Port shall not exceed V_{CHG_OVRSHT} for any step change in load current, nor when the Charging Port is powered on or off.

4.1.2 Maximum Current

The output current of a Charging Port shall not exceed I_{CDP} max under any condition.

4.1.3 Detection Renegotiation

A downstream port is allowed to act as an SDP, CDP or DCP, and to change between these roles. In order to force an attached PD to repeat the charging detection procedure, a downstream port is required to:

- stop driving VBUS
- allow VBUS to drop to less than V_{BUS_LKG}
- wait for a time of T_{VBUS_REAPP}
- start driving VBUS

4.1.4 Shutdown Operation

If the current drawn by a PD causes a Charging Port to go outside of its Required Operating Range, then the Charging Port is allowed to shut down. All types of shut down are allowed outside the Required Operating Range of a Charging Port, including:

- Turning off VBUS
- Constant current limiting
- Foldback current limiting

4.1.5 Failure Voltage

The output voltage of a Charging Port shall remain within V_{CHG_FAIL} for any single point failure in the Charging Port.

4.1.6 Multiple Ports

For a device with multiple Charging Ports, each Charging Port shall stay within its Required Operating Range regardless of the operation of the other Charging Ports.

4.2 Charging Downstream Port

The following requirements apply to a CDP.

4.2.1 Required Operating Range

A CDP shall output a voltage of VCHG for all currents less than ICDP min. The voltage on VBUS is averaged over a time of TVBUS_AVG. For load currents greater than ICDP min, a CDP is allowed to shut down. Once in shutdown, the requirements in Section 4.1.4 apply.

Figure 4-1 shows several example load curves for a CDP. Load curves are required to cross the line at ICDP min within a voltage range of VCHG. Load curves that cross the line at VCHG min for currents less than ICDP min are not allowed.

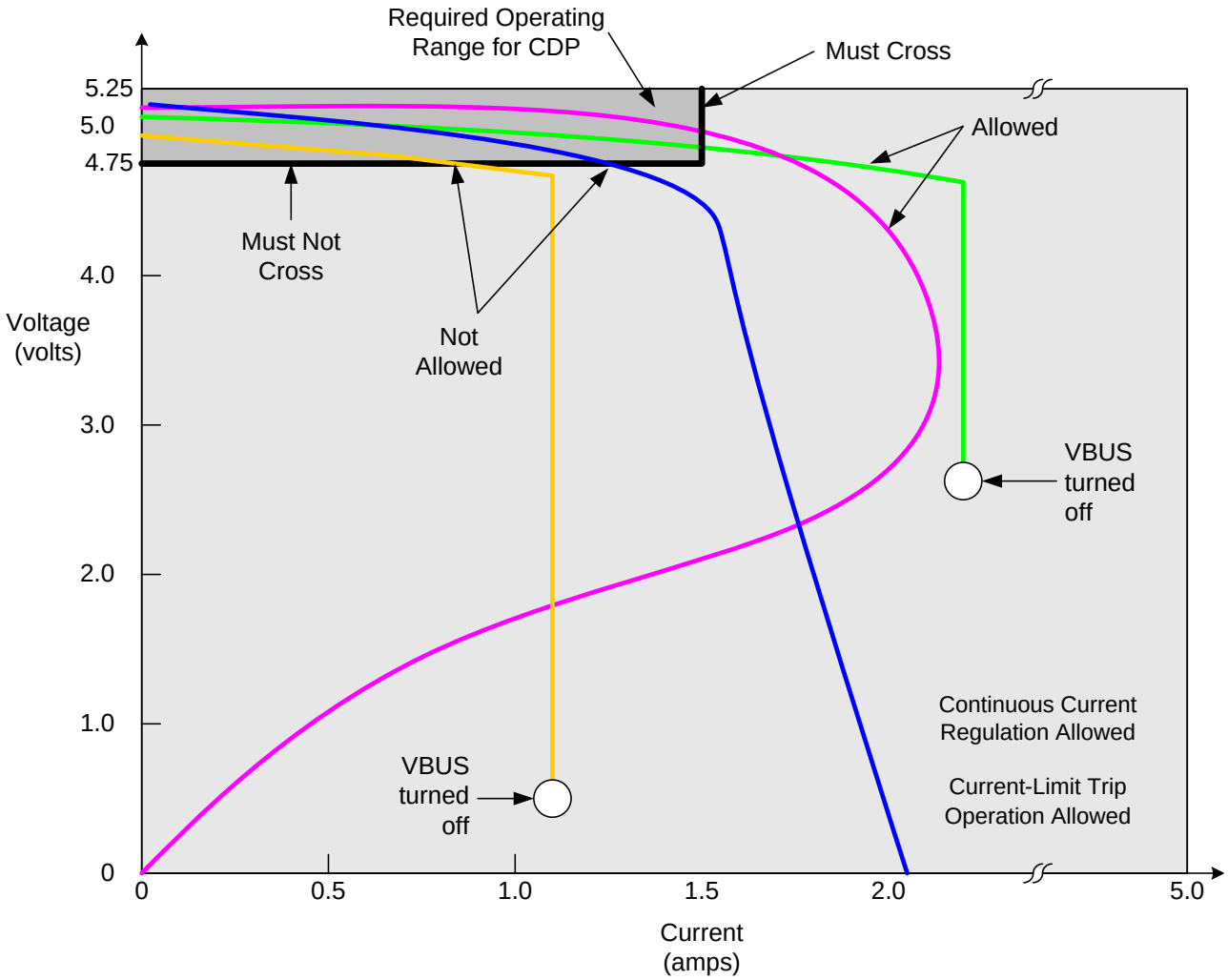

Figure 4-1 CDP Required Operating Range

4.2.2 Shutdown Operation

If a CDP goes into shutdown during a current overload condition, it shall recover and output a voltage of VCHG within a time of TSHTDWN_REC when the current overload condition has been removed.

4.2.3 Undershoot

The output voltage of a CDP shall be within V_{CHG_UNDSHT} for any step change in load currents that are less than I_{CDP} min.

4.2.4 Detection Signaling

A CDP is required to behave in either one of two ways when a remote device is not connected to it. The first way that a CDP is allowed to behave is to enable V_{DM_SRC} within $T_{CP\_VDM\_EN}$ of a disconnect, and then disable V_{DM_SRC} within $T_{CP\_VDM\_DIS}$ of a connect. When using this option, a CDP is not required to enable I_{DP_SINK}, or to compare D+ to V_{DAT_REF}.

The second way a CDP is allowed to behave is to compare D+ with V_{DAT_REF} and V_{LGC}. When D+ is greater than V_{DAT_REF} and less than V_{LGC}, the CDP shall enable V_{DM_SRC}. When D+ is less than V_{DAT_REF} or greater than V_{LGC}, the CDP shall disable V_{DM_SRC}. See Section 3.4.2 for timing.

4.2.5 Connector

A CDP shall have a Standard-A receptacle.

4.3 ACA-Dock

The following requirements apply to the upstream port of an ACA-Dock.

4.3.1 Required Operating Range

An ACA-Dock shall have the same Required Operating Range as a CDP.

4.3.2 Undershoot

An ACA-Dock shall comply with the same undershoot requirements as a CDP.

4.3.3 Detection Signaling

When a PD is attached to an ACA-Dock, the PD acts as host while drawing current from VBUS. This is similar to the case where a PD is attached to an ACA with a peripheral on the Accessory Port.

To inform the PD that it should act as host and draw current, both the ACA-Dock and the ACA are required to pull the ID pin to ground through a resistance of R_{ID_A}.

An ACA-Dock is required to provide I_{CDP} to the PD, whereas an ACA is required to provide I_{DCP}, and this must be shared between the PD and whatever is on the Accessory Port. To inform the PD that it is attached to an ACA-Dock as opposed to an ACA, the ACA-Dock shall output a voltage of V_{DM_SRC} on D- as follows:

- ACA-Dock shall start outputting V_{DM_SRC} if D+/- are at idle J for a time of $T_{CP\_VDM\_EN}$
- ACA-Dock shall stop outputting V_{DM_SRC} within $T_{CP\_VDM\_DIS}$ of any USB activity on D+/-

4.3.4 Connector

An ACA-Dock shall have a Micro-A plug that can be mated to the Micro-AB receptacle of a PD.

4.4 Dedicated Charging Port

The following requirements apply to a DCP.

4.4.1 Required Operating Range

A DCP shall output a voltage of VCHG for all currents less than IDCP min. The voltage on VBUS is averaged over a time of TVBUS_AVG.

A DCP shall not shut down if the load current is less than IDEV_CHG and the load voltage is greater than VDCP_SHTDOWN. A DCP is allowed to shut down for load currents greater than IDEV_CHG max, or for load voltages less than VDCP_SHTDWN. Once in shutdown, the requirements in Section 4.1.4 apply.

Figure 4-2 shows several example load curves. DCP load curves are required to cross the constant current line at IDEV_CHG max, or the constant voltage line at VDCP_SHTDWN. A DCP is not allowed to shut down in the Required Operating Range.

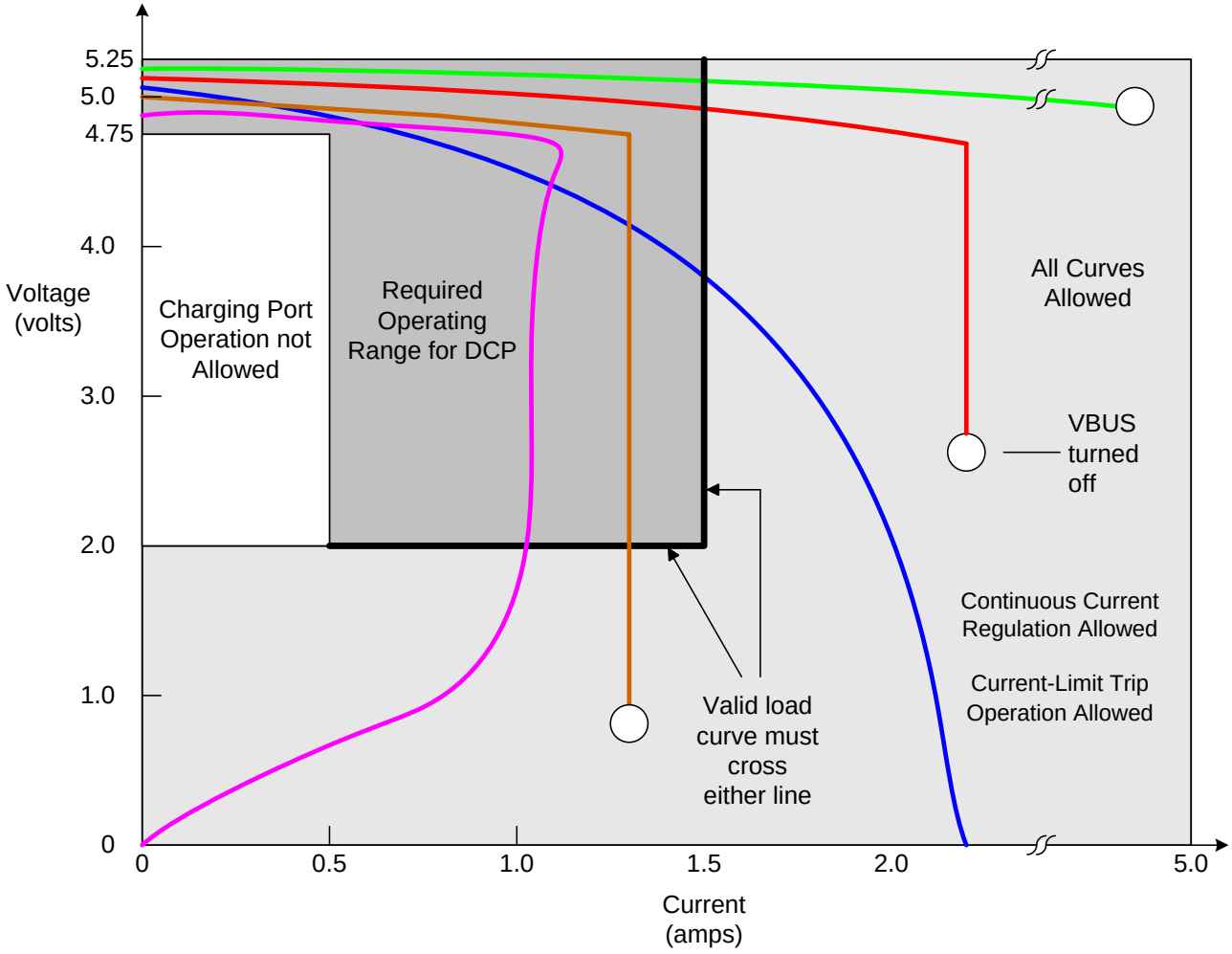

Figure 4-2 DCP Required Operating Range

4.4.2 Undershoot

For step changes in load current from IDCP_LOW to IDCP_MID, or from IDCP_MID to IDCP_HI, the undershoot voltage of a DCP shall be VCHG_UNDSHT. DCPs are required to meet this requirement for load steps from mid to hi that occur TDCP_LD_STP after the transition from low to mid. The duration of the undershoot shall be TDCP_UNDSHT.

For step changes in load current from IDCP_LOW to IDCP_HI, the output voltage of a DCP is allowed to drop to the load voltage of the attached PD for a time of TDCP_UNDSHT. After this time, the output voltage of a DCP shall be at VCHG for load currents less than IDCP min.

4.4.3 Detection Signaling

A DCP shall have an impedance between D+ and D- of RDCP_DAT.

The leakage current on the D+/- pins of a DCP shall be less than or equal to the leakage current that would occur from two resistances of RDAT_LKG tied to a voltage of VDAT_LKG. See Figure 3-6.

The capacitance between the D+/- pins and ground of a DCP shall be CDCP_PWR.

4.4.4 Connector

A DCP shall have a Standard-A receptacle, or a captive cable terminated with a Micro-B plug.

4.5 Accessory Charger Adapter

The following requirements apply to an ACA with a DCP or CDP on its Charger Port.

4.5.1 Required Operating Range

The Required Operating Range for the OTG Port of an ACA is affected by the following factors:

- Device on Charger Port (DCP or CDP)
- Current drawn from Accessory Port
- RACA_CHG_OTG
- VACA_OPR

The current available on the OTG Port is determined by how much current is supplied to the Charger Port, and how much current is being drawn from the Accessory Port. The voltage available on the OTG Port is determined by the voltage at the Charger Port, the current being drawn from the OTG and Accessory Ports, and RACA_CHG_OTG. ACA operation is only required if for Charger Port voltages in the range of VACA_OPR.

4.5.2 Undershoot

An ACA with a DCP or CDP on its Charger Port shall comply with the same undershoot requirements as a DCP.

4.5.3 Detection Signaling

An ACA shall pull the ID pin of the OTG port to ground through one of the following resistances, as specified in Section 6:

- RID_GND, RID_C, RID_B, RID_A, RID_FLOAT

An ACA shall connect the data pins of the OTG Port directly to the data pins of the Accessory Port.

4.5.4 Connector

An ACA shall have a captive cable terminated with a Micro-A plug on its OTG Port.

4.6 Portable Device

The following requirements apply to a PD.

4.6.1 Allowed Operating Range

A PD shall not draw more than I_{DEV_CHG} max from a Charging Port. A PD shall not pull the output voltage of a Charging Port below V_{DCP_SHTDWN} max. Figure 4-3 shows the Allowed Operating Range for a PD.

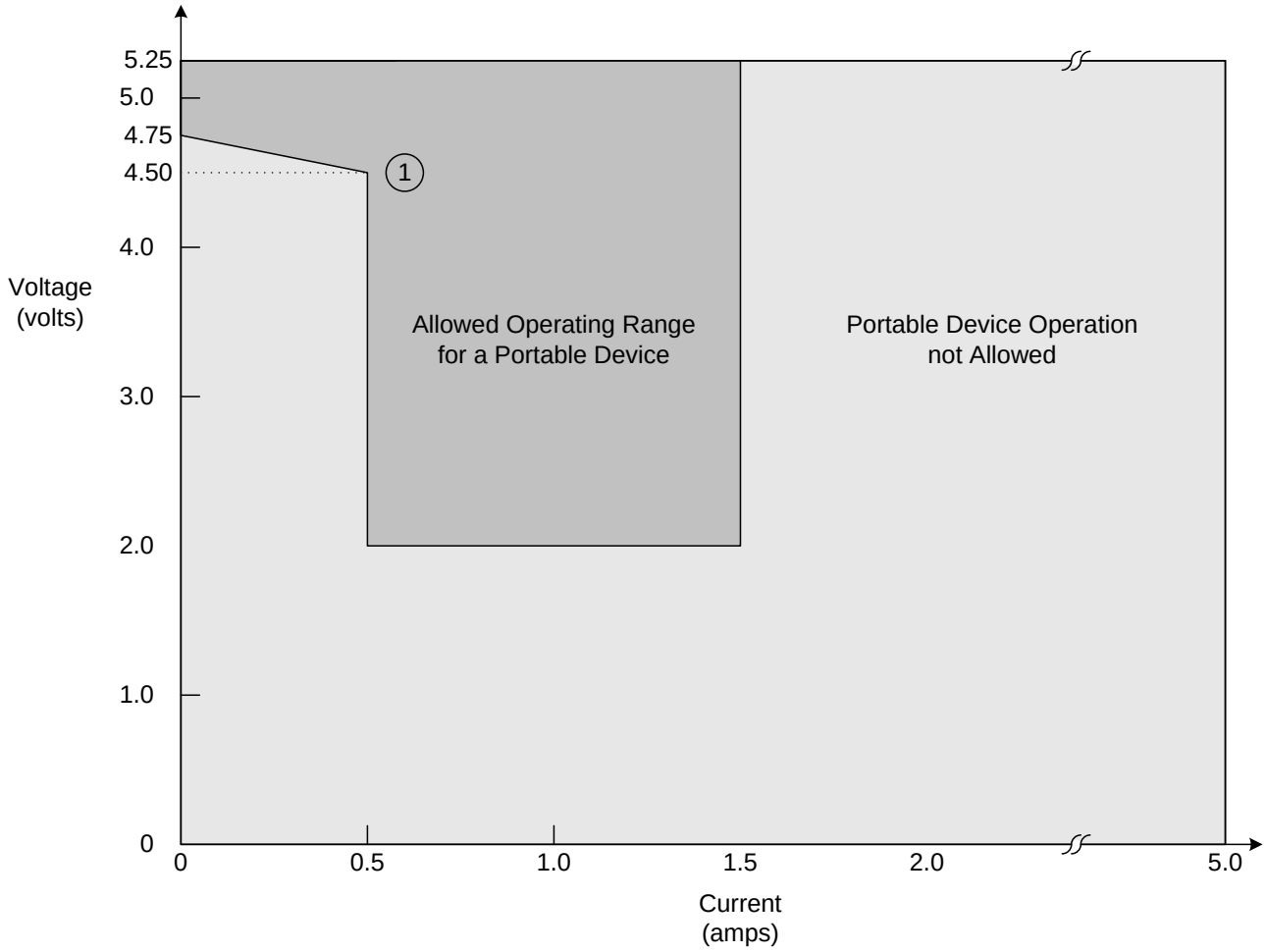

Figure 4-3 Portable Device Allowed Operating Range

Notes:

1) As per USB 2.0 section 7.2.2, the voltage on VBUS can drop from 4.75V at the upstream port down to 4.5V at the downstream port, due to resistive losses in the cable and connectors.

4.6.2 Detection Signaling

All PDs shall implement the following detection features:

- DCD timer ($T_{DCD\_TIMEOUT}$)

- Primary Detection
  - To detect between DCP, CDP and SDP
  - Compare D- to V_{DAT_REF} during Primary Detection

PDs are allowed, but not required, to implement the following detection features:

- DCD, using I_{DP_SRC}
- Compare D- to V_{LGC} during Primary Detection
- Secondary Detection
- ACA Detection

4.6.3 Detection Renegotiation

To restart the charger detection procedure, a downstream port is allowed to remove and then re-assert power on VBUS. See Section 4.1.3. In order to detect this drop in VBUS, a PD shall discharge VBUS to less than V_{BUS_LKG} within T_{VLD_VLKG} whenever VBUS is removed.

A PD is allowed to disconnect and repeat the charger detection process multiple times while attached. The PD is required to wait for a time of at least $T_{CP\_VDM\_EN}$ max between disconnecting and restarting the charger detection process.

4.6.4 Connector

A PD that mates with an ACA-Dock or ACA shall have a Micro-AB receptacle.

5. Parameter Values

This section lists the values of parameters defined in this specification.

Table 5-1 Voltages

Parameter	Symbol	Conditions	Min	Max	Units	Ref
ACA operating voltage	V_{ACA_OPR}		4.1	6.0	V	6.2.6
VBUS Leakage Voltage	V_{BUS_LKG}			0.7	V	4.1.3
Charging Port Output Voltage	V_{CHG}		4.75	5.25	V	4
Charging Port Failure Voltage	V_{CHG_FAIL}		-0.3	9.0	V	4.1.5
Charging Port Overshoot Voltage	V_{CHG_OVRSHT}			6.0	V	4.1.1
Charging Port Undershoot Voltage	V_{CHG_UNDSHT}		4.1		V	4.2.2
Data Line Leakage Voltage	V_{DAT_LKG}		0	3.6	V	3.2.3
Data Detect Voltage	V_{DAT_REF}		0.25	0.4	V	3.2
Data Sink Voltage	V_{DAT_SINK}			0.15	V	3.4.2
DCP Shut Down Voltage	V_{DCP_SHTDWN}			2.0	V	4.4.1
D- Source Voltage	V_{DM_SRC}	1)	0.5	0.7	V	3.2
D+ Source Voltage	V_{DP_SRC}	2)	0.5	0.7	V	3.2
D+ pull-up Voltage	V_{DP_UP}		3.0	3.6	V	3.2.4.4
Ground offset voltage between Host and PD	V_{GND_OFFSET}			375	mV	3.5
Logic Threshold	V_{LGC}		0.8	2.0	V	3.2.3
Logic High	V_{LGC_HI}		2.0	3.6	V	3.2.3
Logic Low	V_{LGC_LOW}		0	0.8	V	3.2.3
OTG Session Valid Voltage	$V_{OTG\_SESS\_VLD}$		0.8	4.0	V	3.1

Notes:

1) V_{DM_SRC} shall be able to source at least 250uA when D- is between 0.5V and 0.7V. V_{DM_SRC} shall not pull D- below 2.2V when D- is pulled to V_{DP_UP} through R_{DP_UP}.

2) V_{DP_SRC} shall be able to source at least 250uA when D+ is between 0.5V and 0.7V. V_{DP_SRC} shall not pull D+ below 2.2V when D+ is pulled to V_{DP_UP} through R_{DP_UP}.

Table 5-2 Currents

Parameter	Symbol	Conditions	Min	Max	Units	Ref
Charging Downstream Port Rated Current	I_{CDP}	1)	1.5	5.0	A	4.2
Maximum Configured Current when connected to a SDP	I_{CFG_MAX}	2)		500	mA	2.1
Dedicated Charging Port Rated Current	I_{DCP}	1)	0.5	5.0	A	4.4.1
DCP current, low range	I_{DCP_LOW}			30	mA	4.4.2
DCP current, middle range	I_{DCP_MID}		30	100	mA	4.4.2
DCP current, high range	I_{DCP_HI}		100		mA	4.4.2
Allowed PD Current Draw from Charging Port	I_{DEV_CHG}			1.5	A	4.6
D- Sink Current	I_{DM_SINK}	3)	25	175	µA	3.2
D+ Sink Current	I_{DP_SINK}	3)	25	175	µA	3.2
Data Contact Detect Current Source	I_{DP_SRC}		7	13	uA	3.2.3
Leakage current on ID_OTG pin from contamination	$I_{ID\_LKG\_CONT}$		-1	1	µA	6.2.6
Suspend current	I_{SUSP}	Averaged over 1sec		2.5	mA	2.1
Unit load current	I_{UNIT}	4)		100	mA	2.1

Notes

1) The maximum current is for safety reasons, as per USB 2.0 section 7.2.1.2.1.

2) If a PD is attached to a SuperSpeed port, then I_{CFG_MAX} is 900mA.

3) For source currents less than I_{DP_SINK} min, the D+ current sink is required to pull the D+ voltage to V_{DAT_SINK}. For D+ voltages less than V_{LGC} max, the D+ current sink shall not sink more than I_{DP_SINK} max. The same requirements apply to I_{DM_SINK} and D-.

4) I_{UNIT} is averaged over 250ms. If a PD is attached to a SuperSpeed port, the I_{UNIT} is 150mA.

Table 5-3 Resistances

Parameter	Symbol	Conditions	Min	Max	Units	Ref
Charger to Accessory port	$R_{ACA\_CHG\_ACC}$	1)		400	mΩ	6.2.6
OTG to Accessory port	$R_{ACA\_OTG\_ACC}$	1)		200	mΩ	6.2.6
OTG to Accessory port (ADP-pass)	$R_{ADP\_OTG\_ACC}$	5)		25	Ω	6.2.6
Charger to OTG port	$R_{ACA\_CHG\_OTG}$	1)		200	mΩ	6.2.6
Data line leakage resistance	R_{DAT_LKG}		300		kΩ	4.4.3
Dedicated Charging Port resistance across D+/-	R_{DCP_DAT}			200	Ω	4.4.3
D- Pull-down resistance	R_{DM_DWN}		14.25	24.8	kΩ	3.2
D+ Pull-down resistance	R_{DP_DWN}		14.25	24.8	kΩ	3.2
D+ Pull-up resistance	R_{DP_UP}	1), 2), 4)	900	1575	Ω	3.2.4.4
ACA ID pull-down, OTG device as A-device	R_{ID_A}	1), 2), 4)	122	126	kΩ	6.2.4
ACA ID pull-down, OTG device as B-device, can't connect	R_{ID_B}	1), 2), 4)	67	69	kΩ	6.2.4
ACA ID pull-down, OTG device as B-device, can connect	R_{ID_C}	1), 2), 4)	36	37	kΩ	6.2.4
ACA ID pull-down when ID_OTG pin is floating	R_{ID_FLOAT}	2), 3)	220		kΩ	6.2.4
ACA ID pull-down when ID_OTG pin is grounded	R_{ID_GND}	2), 3)		1	kΩ	6.2.4
OTG to ACA ground resistance	$R_{OTG\_ACA\_GND}$			100	mΩ	6.2.6

Notes

1) The ACA shall meet this parameter requirement when VBUS_CHG is at V_{ACA_OPR}.

2) The ACA shall meet this parameter requirement when its ID_OTG pin is at V_{DAT_LKG}. When detecting these resistances, an OTG device shall allow for an additional leakage current of $I_{ID\_LKG\_CONT}$ due to contamination.

3) The ACA shall meet this parameter requirement when its VBUS_CHG pin is at V_{BUS_LKG}.

4) Nominal values for these resistors are R_{ID_A} = 124k, R_{ID_B} = 68k and R_{ID_C} = 36.5k

5) The ACA shall meet this parameter requirement when VBUS_ACC and VBUS_OTG are both below V_{ACA_OPR}, and either no Charging Port is detected or VBUS_CHG is below V_{ACA_OPR}.

Table 5-4 Capacitances

Parameter	Symbol	Conditions	Min	Max	Units	Ref
Dedicated Charging Port capacitance from D+ or D- to VBUS or GND	C_{DCP_PWR}			1	nF	4.4.3
Micro ACA Capacitance from VBUS to GND	C_{MACA_VBUS}		10	100	nF	6.2.3
Standard ACA Capacitance from VBUS to GND	C_{SACA_VBUS}		10	100	nF	6.3.2

Table 5-5 Times

Parameter	Symbol	Conditions	Min	Max	Units	Ref
Connect to D+ sink disable	TCON_IDPSNK_DIS			10	ms	3.4
Time for Charging Port to remove VDM_SRC on D-	TCP_VDM_DIS			10	ms	3.2.4.2
Time for Charging Port to assert VDM_SRC on D-	TCP_VDM_EN			200	ms	3.2.4.2
Attach to VDP_SRC enable during DBP	TDBP_ATT_VDPSRC			1	sec	2.2
Attach to full USB functionality for configured PD under DBP	TDBP_FUL_FNCTN			15	min	2.3
Attach to PD informing user it is charging	TDBP_INFORM			1	min	2.3
VDP_SRC disable to connect during DBP	TDBP_VDPSRC_CON			1	sec	2.2
Data contact detect debounce	TDCD_DBNC		10		ms	3.4.1
DCD Timeout	TDCD_TIMEOUT		300	900	ms	3.2.3.1
DCP recovery time between load steps	TDCP_LD_STP		20		ms	4.4.2
DCP undershoot voltage time	TDCP_UNDSHT			10	ms	4.4.2
Charger shut down recover time	TSHTDWN_REC			2	min	4.2.2
Session valid to connect time for powered up peripheral	TSVLD_CON_PWD			1	sec	3.2.3.1
Session valid to connect for PD with Dead or Weak Battery	TSVLD_CON_WKB			45	min	2.2
VBUS voltage averaging time	TVBUS_AVG			250	ms	4.2.1
Time for VBUS to be reapplied	TVBUS_REAPP	VBUS less than VBUS_LKG	100		ms	4.1.3
D- voltage source disable time	TVDMSRC_DIS			20	ms	3.4
D- voltage source enable time	TVDMSRC_EN			20	ms	3.4
D+ voltage source on time	TVDPSRC_ON		40		ms	3.4
D- voltage source on time	TVDMSRC_ON		40		ms	3.4
Time for VBUS to decay to VBUS_LKG	TVLD_VLKG	Time from VBUS not driven		500	ms	4.6.3

6. Accessory Charger Adapter

6.1 Introduction

As PDs get smaller, it becomes more desirable for the PD to only have one external connector. If the only connector a device has is a USB connector, then a problem arises when the user wants to attach the device to a charger at the same time as it is already attached to something else.

For example, consider a user in a car with a cell phone that is attached to a headset. If the phone battery goes low, the user would like to charge the phone, and at the same time continue to talk through the headset. If the phone has only one connector, it is not possible to attach both a headset and a charger to the phone through the same connector.

Another example would be as follows. Consider a PD that has a single connector, which can also act as a handheld PC. When such a device is put into an ACA-Dock, it would act as a host to various USB peripherals, such as a hub, keyboard, mouse, printer, etc. However, while in the ACA-Dock, the device should also be able to charge at the same time.

The purpose of this section is to describe a method that allows a single USB port to be attached to both a charger and another device at the same time. This method makes use of an Accessory Charger Adapter (ACA), as shown in Figure 6-1.

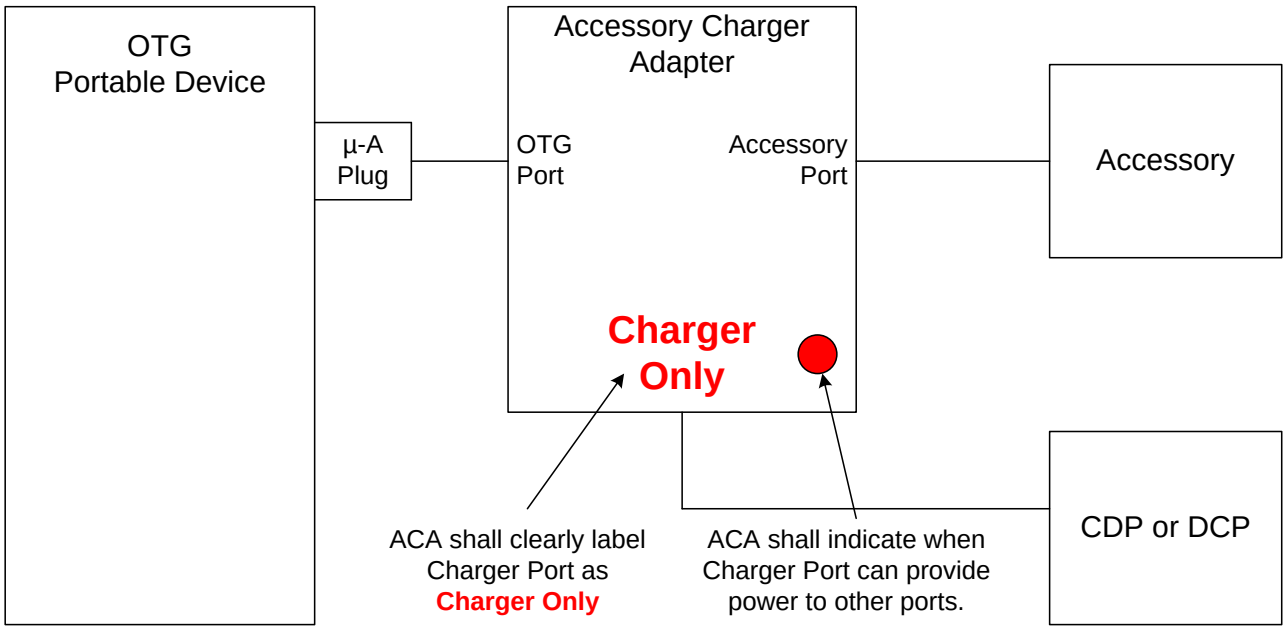

Figure 6-1 Accessory Charger Adapter

An ACA has the following three ports:

- OTG Port
- Accessory Port
- Charger Port

The OTG Port shall have a captive cable that terminates with a Micro-A plug. Only OTG devices (i.e. those with a Micro-AB receptacle) can be attached to the OTG Port.

Accessories attached to the Accessory Port can communicate with the OTG device using normal USB signaling.

The Charger Port allows the ACA to be attached to a Charging Port. Power from the Charger Port is available to both the OTG device and the accessory. An ACA is required to label the Charger Port as Charger Only. The reason for this is that the ACA does not support USB communication between the OTG Port and the Charger Port. The Charger Port is only used for power. An ACA is also required to provide an indicator that shows when the Charger Port is able to provide power to the OTG and Accessory Ports.

There are two types of ACAs:

- Micro ACA
- Standard ACA

A Micro ACA has a Micro-AB receptacle on the Accessory Port, and can be attached to either an A-device or B-device. A Standard ACA has a Standard-A receptacle on the Accessory Port, and can only be attached to a B-device.

6.2 Micro ACA

6.2.1 Micro ACA Ports

Figure 6-2 shows the ports of a Micro ACA.

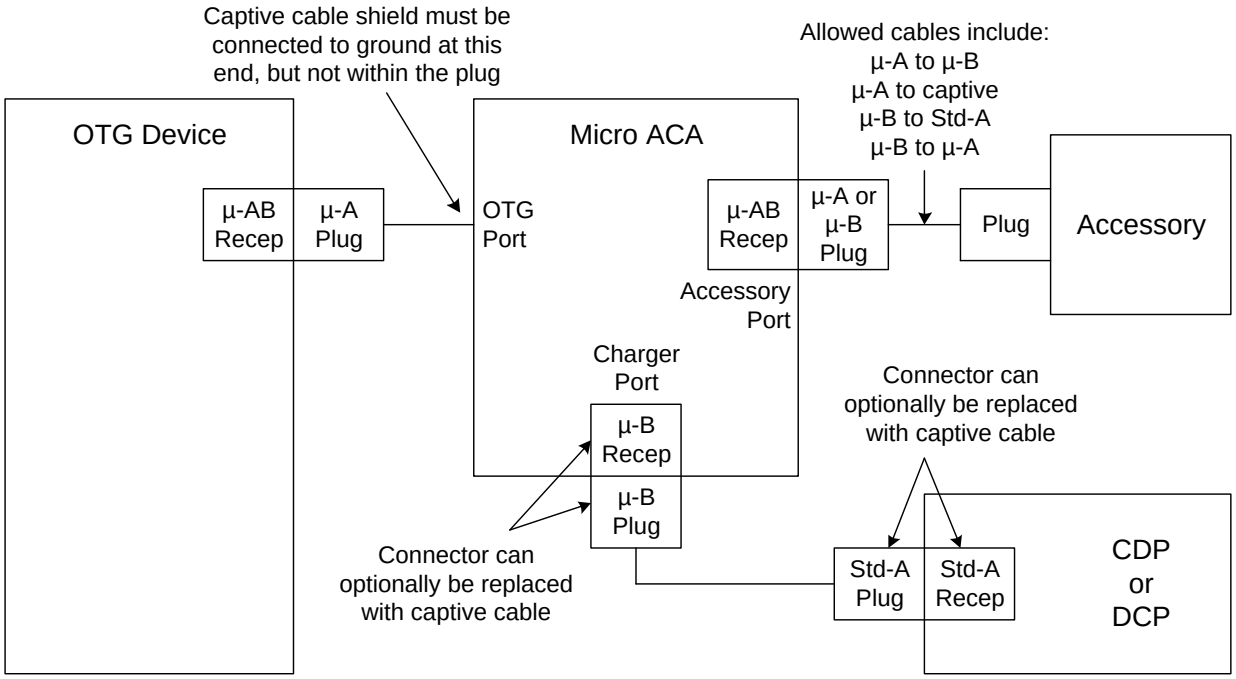

Figure 6-2 Micro ACA Ports

Various cables can be uses to attach the Accessory Port of a Micro ACA to an accessory, including:

- Micro-A to Micro-B
- Micro-A to captive
- Micro-B to Standard-A
- Micro-B to Micro-A

A Micro ACA shall have one of the following mechanical interfaces for its Charger Port:

- Micro-B receptacle
- Captive cable terminating in a Standard-A plug
- Captive cable terminating in a charger

6.2.2 Micro ACA Connectivity Options

Table 6-1 shows the different combinations of devices that can be attached to each Micro ACA port, and provides comments on their operation.

Table 6-1 Micro ACA Connectivity Options

OTG Port	Charger Port	Accessory Port	HNP Support	SRP Support	OTG Dev Charges From	Accessory Draws Current From
nothing	Charging Port	B-dev	-	-	-	Charger Port
nothing	Charging Port	A-dev	-	-	-	-
OTG dev	nothing	B-dev	yes	yes	-	OTG Port
OTG dev	nothing	A-dev	yes	yes	Accessory Port	-
OTG dev	nothing	charger	-	-	Accessory Port	-
OTG dev	PC, OTG dev	nothing	-	-	-	-
OTG dev	PC, OTG dev	B-dev	yes	yes	-	OTG Port
OTG dev	PC, OTG dev	A-dev	yes	yes	Accessory Port	-
OTG dev	PC, OTG dev	charger	-	-	Accessory Port	-
OTG dev	Charging Port	nothing	-	-	Charger Port	-
OTG dev	Charging Port	B-dev	yes	no	Charger Port	Charger Port
OTG dev	Charging Port	A-dev	yes	yes	Charger Port	-
OTG dev	Charging Port	charger	-	-	Charger Port	-

An ACA does not allow data communication through the Charger Port. The ACA only allows charging from the Charger Port when a Charging Port is attached. It does not allow charging from the Charger Port whenever an SDP or an OTG device is attached.

In the case where both an OTG device and a B-device are charging from the Charger Port, it is not necessary to support SRP, since VBUS is already asserted at both the OTG Port and Accessory Port.

The OTG device is required to limit the current it draws from the ACA such that VBUS_OTG remains above V_{ACA_OPR} min.

6.2.3 Micro ACA Architecture

Figure 6-3 shows the architecture of a Micro ACA.

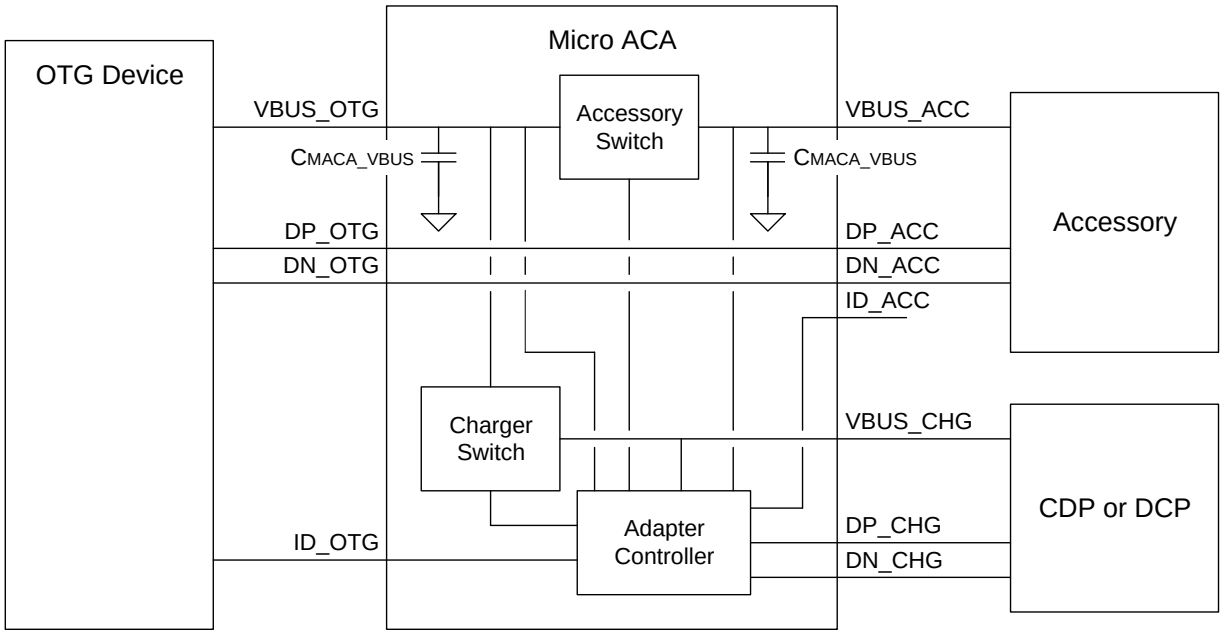

Figure 6-3 Micro ACA Architecture

The Accessory Switch allows current to flow between VBUS_OTG and VBUS_ACC. The Charger Switch allows current to flow from VBUS_CHG and VBUS_OTG. The Adapter Controller performs several functions. These functions include:

- sensing the state of the ID_ACC pin, (grounded or floating)
- outputting a state onto the ID_OTG pin, (RID_GND, RID_A, RID_B, RID_C or RID_FLOAT)
- using the DP_CHG and DN_CHG pins to detect if a Charging Port is attached to the Charger Port
- sensing the voltage on the VBUS_ACC pin
- sensing the voltage on the VBUS_OTG pin
- controlling the Charger and Accessory Switches

6.2.4 Micro ACA Modes of Operation

The operation of the Micro ACA is shown in Table 6-2, and is described below. The table assumes that an OTG device is always attached to the OTG Port.

Table 6-2 Micro ACA Modes of Operation

Row	Charger Port	Accessory Port	VBUS_ ACC	VBUS_ OTG	ID_ ACC	Charger Switch [1)]	Access Switch [1) 2)]	ID_OTG	OTG Device
1	not Chrg Port	nothing	low	low	float	open	ADP-pass	RID_FLOAT	B-dev
2a [7)]	not Chrg Port	B-device	low	low	ground	open	ADP-pass	RID_GND	A-dev
2b	not Chrg Port	B-device	driven [3)]	high	ground	open	closed	RID_GND	A-dev
3	not Chrg Port	A-dev off	low	low	float	open	ADP-pass	RID_FLOAT	B-dev
4	not Chrg Port	A-dev on	high	driven [4)]	float	open	closed	RID_FLOAT	B-dev
5	Charging Port	nothing	low	driven [5)]	float	closed	open	RID_B	B-dev
6	Charging Port	B-device	driven [6)]	driven [5)]	ground	closed	closed	RID_A	A-dev
7	Charging Port	A-dev off	low	driven [5)]	float	closed	open	RID_B	B-dev
8	Charging Port	A-dev on	high	driven [5)]	float	closed	open	RID_C	B-dev

Notes

1) Open refers to the high impedance state of the switch. Closed refers to the low impedance state of the switch.
2) ADP-pass refers to an impedance state of the switch sufficiently low to transmit ADP probes (RADP_OTG_ACC).
3) Driven via Accessory Switch from VBUS_OTG.
4) Driven via Accessory Switch from VBUS_ACC.
5) Driven via Charger Switch from VBUS_CHG.
6) Driven via Charger Switch and Accessory Switch from VBUS_CHG.
7) In row 2a, the VBUS_OTG low state can happen after TA_WAIT_BCON max of ID_OTG going low, if the OTG A-device supports sessions. (See OTG 2.0 Supplement for value.)
8) Other transitory states exist when moving between the design states shown in the rows of the table. It is the responsibility of the Micro ACA designer to take these into account.

In rows 5 and 7, a Charging Port is attached to the Micro ACA Charger Port, and either nothing is attached to the Accessory Port, or an A-device that is not asserting VBUS is attached to the Accessory Port. The ID resistance of RID_B indicates to the OTG device that it is allowed to charge, and that it is allowed to initiate SRP. The OTG device is not allowed to connect, (that is, leave DP_OTG asserted). The reason for this is that if an A-device is on the Accessory Port and is not asserting VBUS, then the USB spec requires the data lines remain at a logic low.

In row 8, a Charging Port is attached to the Micro ACA Charger Port, and an A-device that is asserting VBUS is attached to the Accessory Port. The ID resistance of RID_C indicates to the OTG device that it is allowed to charge, and that it is allowed to connect. However, it is not allowed to do SRP, since the A-device is already asserting VBUS.

In row 6, a Charging Port is attached to the Micro ACA Charger Port, and a B-device is attached to the Accessory Port. The ID resistance of RID_A indicates to the OTG device that it is allowed to charge, and that it should default to acting as host.

6.2.5 Implications of not Supporting Micro ACA Detection

The OTG supplement only defines the floating and ground states on the ID pin. The floating state is any impedance greater than 1M, and the ground state is any impedance less than 10Ω. Since the R_{ID_A}, R_{ID_B} and R_{ID_C} resistances are between the floating and ground resistance values, an OTG device that does not support ACA detection could interpret any of these values as either floating or ground.

If an OTG device interpreted the R_{ID_A} resistance as floating, then:
- it would not be aware of the opportunity to draw I_{DEV_CHG} from VBUS
- it would default to peripheral, when it should default to host

If an OTG device interpreted the R_{ID_B} resistance as grounded, then:
- it would try to drive VBUS_OTG at the same time as the ACA was driving VBUS_OTG
- it would default to host, when it should default to peripheral

If an OTG device interpreted the R_{ID_B} resistance as floating, then:
- it would not be aware of the opportunity to draw up to I_{DEV_CHG} from VBUS
- it would not be aware of the opportunity to do SRP
- it would be required to connect, and potentially violate the USB back-drive voltage spec

If an OTG device interpreted the R_{ID_C} resistance as grounded, then:
- it would try to drive VBUS_OTG at the same time as the ACA was driving VBUS_OTG
- it would default to host, when it should default to peripheral

If an OTG device interpreted the R_{ID_C} resistance as floating, then:
- it would not be aware of the opportunity to draw up to I_{DEV_CHG} from VBUS

6.2.6 Micro ACA Requirements

A Micro ACA Charger Port shall draw less than I_{SUSP} when anything other than a Charging Port is attached to it.

A Micro ACA shall draw less than I_{SUSP} when a Charging Port is attached to the ACA Charger Port and nothing is attached to the OTG Port or Accessory Port.

The resistance between the VBUS_CHG and VBUS_OTG pins of an ACA shall be $R_{ACA\_CHG\_OTG}$ when the Charger Switch is closed in rows 5-8 of Table 6-2, and the voltage on VBUS_CHG is at V_{ACA_OPR}.

The resistance between the VBUS_CHG and VBUS_ACC pins of an ACA shall be $R_{ACA\_CHG\_ACC}$ when both the Charger Switch and the Accessory Switch are closed in row 6 of Table 6-2, and the voltage on VBUS_CHG is at V_{ACA_OPR}.

The resistance between the VBUS_OTG and VBUS_ACC pins of an ACA shall be $R_{ACA\_OTG\_ACC}$ when the Charger Switch is open and the Accessory Switch is closed in rows 2b and 4 of Table 6-2 and the voltage on either VBUS_ACC or VBUS_OTG is at V_{ACA_OPR}.

The resistance between the VBUS_OTG and VBUS_ACC pins of an ACA shall be $R_{ADP\_OTG\_ACC}$ when the Accessory Switch is in condition ADP-pass in rows 1, 2a or 3 of Table 6-2.

The resistance between the internal ground of the Micro ACA and the ground pin of a Micro-AB receptacle attached to the OTG port of an ACA shall be $R_{OTG\_ACA\_GND}$. This requirement limits the difference between OTG and ACA ground under conditions of high charging current. This in turn allows the OTG device to reliably detect the ACA ID resistance under conditions of high charging current.

When a Micro ACA detects VBUS_CHG asserted, it shall output V_{DP_SRC} on DP_CHG. If the ACA detects DN_CHG greater than V_{DAT_REF}, then it is allowed to close its Charger Switch for as long as VBUS_CHG remains above $V_{OTG\_SESS\_VLD}$. Note that this could result in the ACA drawing more than I_{CFG_MAX} from a PS2 port.

If the Charger Port was attached to a CDP, then it's possible that DN_CHG may go below V_{DAT_REF} of the ACA due to charging currents causing the CDP ground to be lower than the ACA ground. It's also possible that the CDP could issue a USB reset. The ACA shall ignore either of these effects, and continue to leave its Charger Switch closed. When VBUS_CHG goes below $V_{OTG\_SESS\_VLD}$, then the ACA is required to again check for VDN_CHG being greater than V_{DAT_REF}, before opening the Charger Switch.

The Micro ACA is required to have a capacitance of C_{MACA_VBUS} on both the VBUS_OTG and VBUS_ACC pins. The reason for this is so that attached devices which support the Attach Detection Protocol (ADP) defined in OTG 2.0 can detect when they are attached to an ACA.

6.2.7 Portable Device State Diagram

Figure 6-4 shows the state diagram for a PD attached to an SDP, CDP, DCP, Micro ACA, ACA-Dock or B-device.

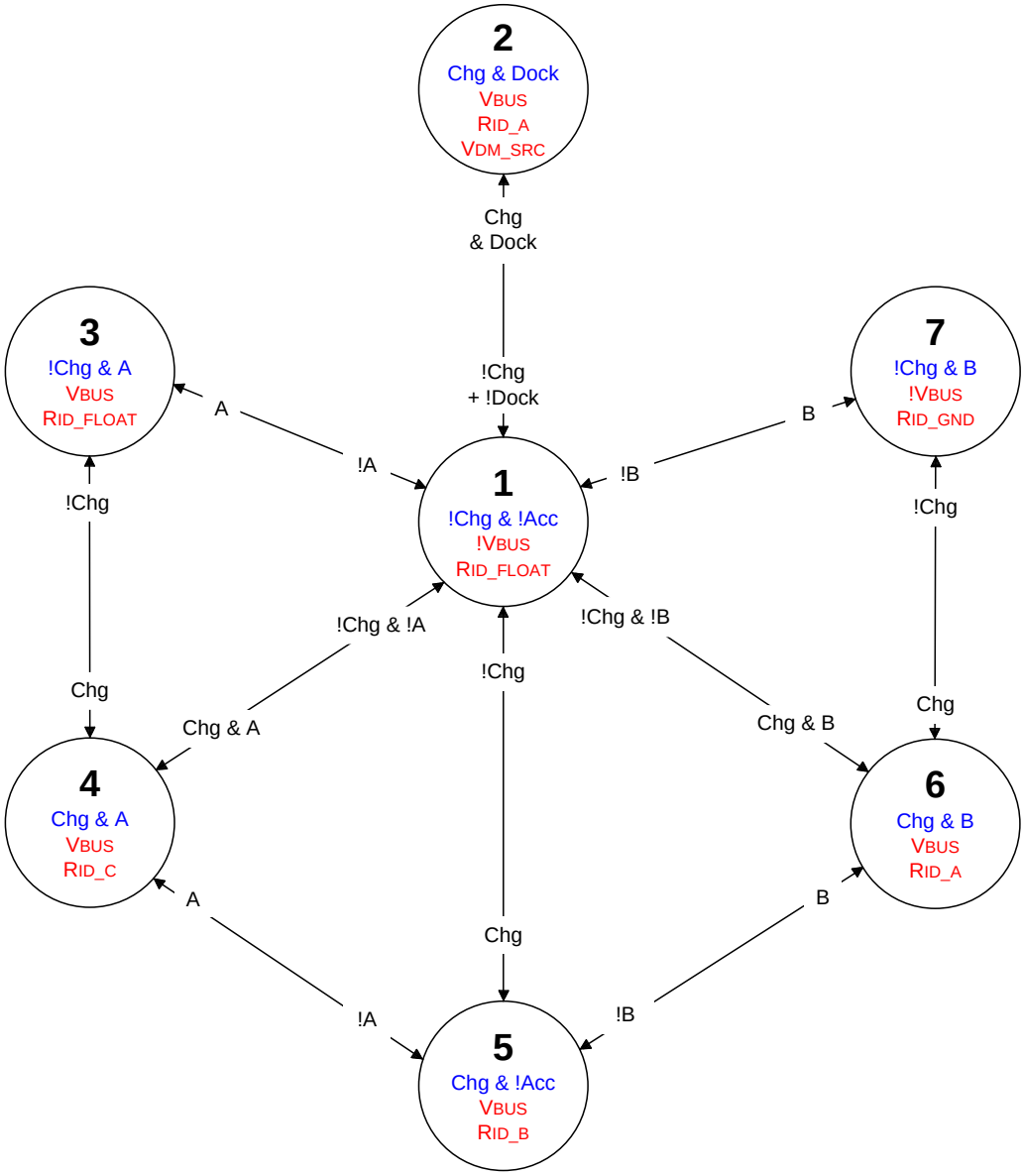

Figure 6-4 Portable Device State Diagram

Each bubble represents a state of the PD. The first row in each bubble is the state number.

The first term in the second row indicates whether the attached device is acting like a Charging Port. The second term in the second row indicates what would be attached to the Accessory Port of the ACA, if the PD is attached to an ACA. The third row indicates whether or not the attached device is driving the PD VBUS pin. The fourth row indicates what resistance the attached device is applying to the PD ID pin. In state 2, the fifth row indicates that the ACA-Dock is outputting a voltage of VDM_SRC to the D- pin of the PD.

In state 1, the PD detects that it is not attached to anything, or that it is attached to something that is not driving VBUS or pulling ID low.

In state 2, the PD is attached to an ACA-Dock that is driving VBUS. If the PD is removed from the ACA-Dock, or if the ACA-Dock stops providing VBUS, the PD transitions to state 1. An ACA-Dock is required to let its ID pin float if it is not driving VBUS. If the ACA-Dock were to ground the ID pin while it was not driving VBUS, then the PD would incorrectly transition to state 7, where it would attempt to drive VBUS into the ACA-Dock.

In state 3, the PD is attached directly to an A-device, or to an ACA that has an A-device on its Accessory Port. In either case, the PD is drawing current from the A-device, and not from the ACA Charger Port. This is why the second row has the term !Chg. If the A-device presents itself to the PD as a CDP, then the PD can draw I_{DEV_CHG} from the A-device.

In state 4, the PD is attached to an ACA that has a charger on its Charger Port, and an A-device on its Accessory Port. Detaching the PD from the ACA causes the PD to transition to state 1.

In state 5, the PD is attached to an ACA that has a charger on its Charger Port, and does not have an accessory on its Accessory Port.

In state 6, the PD is attached to an ACA that has a charger on its Charger Port, and a B-device on its Accessory Port. Detaching the PD from the ACA causes the PD to transition to state 1.

In state 7, the PD is attached to a B-device, or to an ACA that has a B-device on its Accessory Port. This is the only state in which the PD is required to output power on VBUS. In states 2 to 6, the PD is able to draw power from VBUS.

6.3 Standard ACA

6.3.1 Standard ACA Ports

Figure 6-5 shows the ports of a Standard ACA.

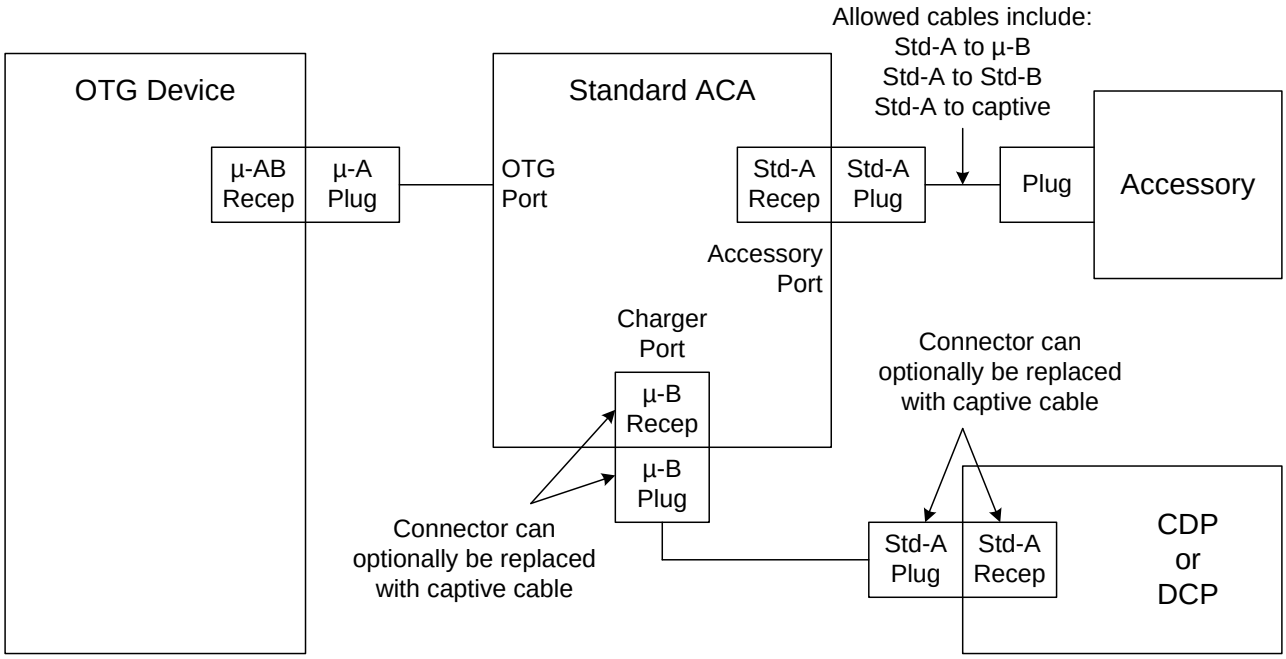

Figure 6-5 Standard ACA Ports

Various cables can be uses to attach the Accessory Port of a Standard ACA to an accessory, including:

- Standard-A to Micro-B
- Standard-A to Standard-B
- Standard-A to captive

A Standard ACA shall have one of the following mechanical interfaces for its Charger Port:

- Micro-B receptacle
- Captive cable terminating in a Standard-A plug
- Captive cable terminating in a charger

Table 6-3 Standard ACA Connectivity Options

OTG Port	Charger Port	Accessory Port	HNP Support	SRP Support	OTG Dev Charges From	Accessory Draws Current From
nothing	Charging Port	B-dev	-	-	-	Charger Port
OTG dev	nothing	B-dev	yes	yes	-	OTG Port
OTG dev	PC, OTG dev	nothing	-	-	-	-
OTG dev	PC, OTG dev	B-dev	yes	yes	-	OTG Port
OTG dev	Charging Port	nothing	-	-	Charger Port	-
OTG dev	Charging Port	B-dev	yes	no	Charger Port	Charger Port

An ACA does not allow data communication through the Charger Port. The ACA only allows charging from the Charger Port when a Charging Port is attached. It does not allow charging from the Charger Port whenever an SDP or an OTG device is attached.

In the case where both an OTG device and a B-device are charging from the Charger Port, it is not necessary to support SRP, since VBUS is already asserted at both the OTG Port and Accessory Port.

The OTG device is required to limit the current it draws from the ACA such that VBUS_OTG remains above V_{ACA_OPR} min.

6.3.2 Standard ACA Architecture

Figure 6-6 shows the architecture of a Standard ACA.

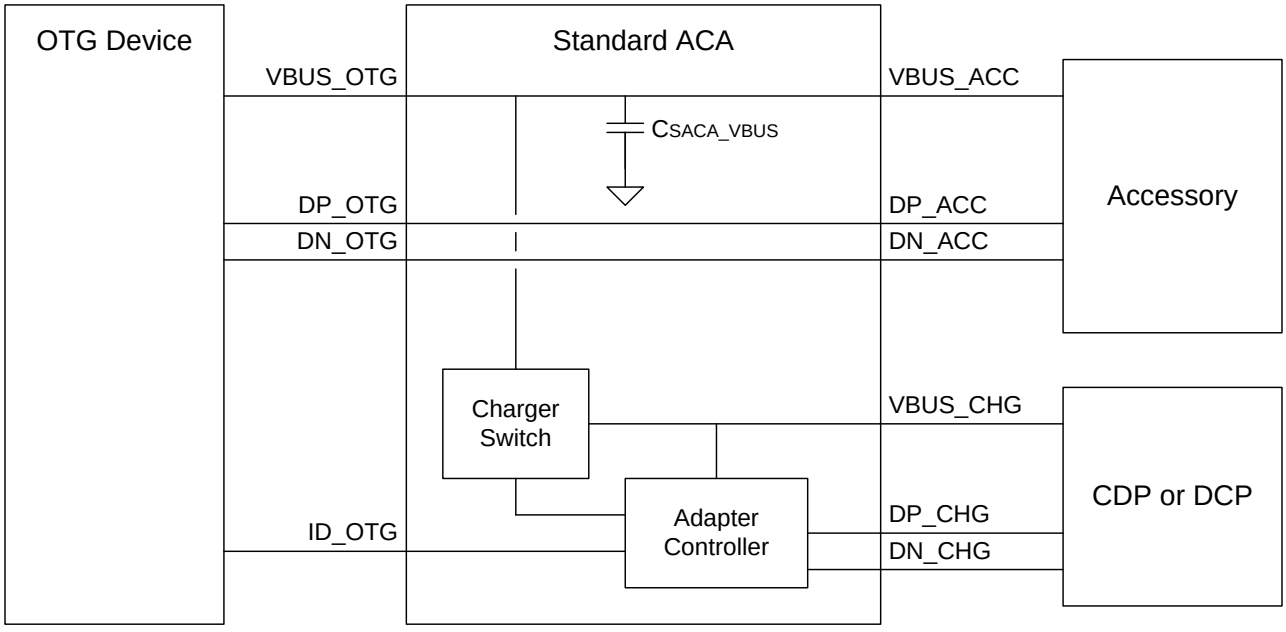

Figure 6-6 Standard ACA Architecture

The Charger Switch allows current to flow from VBUS_CHG and VBUS_OTG. Note that unlike the Micro ACA, the Standard ACA does not have an Accessory Switch.

The Standard ACA is required to have a capacitance of C_{SACA_VBUS} on the VBUS_OTG or VBUS_ACC pins. The reason for this is as follows.

The Accessory Port does not have an ID pin, since it uses a Standard-A receptacle. Thus, the Standard ACA cannot detect when a plug has been inserted into the Accessory Port, and therefore it cannot inform the OTG Device of such an attach event. If a Charging Port were attached to the ACA Charger Port, then the accessory would connect, and the OTG device could detect the connect event. If a Charging Port were not attached to the ACA Charger Port, then the OTG Device would either have to leave VBUS asserted, or it would have to do ADP. In order to allow ADP to work, the combined capacitance on the VBUS_OTG and VBUS_ACC pins needs to be C_{SACA_VBUS}.

The Adapter Controller performs several functions. These functions include:

- outputting a state onto the ID_OTG pin, (R_{ID_GND}, R_{ID_A})
- using the DP_CHG and DN_CHG pins to detect if a Charging Port is attached to the Charger Port
- controlling the Charger Switch

6.3.3 Standard ACA Modes of Operation

The operation of the Standard ACA is shown inTable 6-4, and is described below. The table assumes that an OTG device is always attached to the OTG Port.

Table 6-4 Standard ACA Modes of Operation

Row	Charger Port	Accessory Port	Charger Switch [1)]	ID_OTG	OTG Device
1	non-charger	nothing	open	R_{ID_GND}	A-dev
2	non-charger	B-device	open	R_{ID_GND}	A-dev
3	charger	nothing	closed	R_{ID_A}	A-dev
4	charger	B-device	closed	R_{ID_A}	A-dev

Notes
1) Open refers to the high impedance state of the switch. Closed refers to the low impedance state of the switch.

When a PD is attached to a Standard ACA, the ID_OTG pin is either at R_{ID_GND} or at R_{ID_A}, and the PD is always acting as an A-device.

6.3.4 Implications of not Supporting Standard ACA Detection

The OTG supplement only defines the floating and ground states on the ID pin. The floating state is any impedance greater than 1M, and the ground state is any impedance less than 10Ω. Since the R_{ID_A} is between the floating and ground resistance values, an OTG device that does not support ACA detection could intepret this value as either floating or ground.

If an OTG device interpreted the R_{ID_A} resistance as floating, then:

- it would not be aware of the opportunity to draw I_{DEV_CHG} from VBUS
- it would default to peripheral, when it should default to host

6.3.5 Standard ACA Requirements

A Standard ACA Charger Port shall draw less than I_{SUSP} when anything other than a Charging Port is attached to it.

A Standard ACA Accessory Port shall draw less than I_{SUSP} when a Charging Port is attached to the ACA Charger Port and nothing is attached to the OTG Port or Accessory Port.

The resistance between VBUS_CHG, and either VBUS_OTG or VBUS_ACC of a Standard ACA shall be $R_{ACA\_CHG\_OTG}$ when the Charger Switch is closed in Table 6-4, and the voltage on VBUS_CHG is at V_{ACA_OPR}.

The resistance between the internal ground of the Standard ACA and the ground pin of a Micro-AB receptacle attached to the OTG port of an ACA shall be $R_{OTG\_ACA\_GND}$. This requirement limits the difference between OTG and ACA ground under conditions of high charging current. This in turn allows the OTG device to reliably detect the ACA ID resistance under conditions of high charging current.

When a Standard ACA detects VBUS_CHG asserted, it shall output V_{DP_SRC} on DP_CHG. If the ACA detects DN_CHG greater than V_{DAT_REF}, then it shall close its Charger Switch for as long as VBUS_CHG remains above $V_{OTG\_SESS\_VLD}$. Note that this could result in the ACA drawing more than I_{CFG_MAX} from a PS2 port.

If the Charger Port was attached to a CDP, then it's possible that DN_CHG may go below V_{DAT_REF} of the ACA due to charging currents causing the CDP ground to be lower than the ACA ground. It's also possible that the CDP could issue a USB reset. The ACA shall ignore either of these effects, and continue to leave its Charger Switch closed. When VBUS_CHG goes below $V_{OTG\_SESS\_VLD}$, then the ACA is required to again check for VDN_CHG being greater than V_{DAT_REF}, before opening the Charger Switch.