Battery Charging Specification

Revision 1.1

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Revision History

Revision	Date	Author	Description
BC 1.0	Mar 8, 2007	Terry Remple	First release
BC 1.1	April 15, 2009	Terry Remple	Major updates to all sections. Added Data Contact Detect protocol, and Accessory Charger Adapter.

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Acronyms

ACA	Accessory Charger Adapter
DBP	Dead Battery Provision
FS	Full Speed
GPS	Global Positioning System
HS	High Speed
LS	Low Speed
PC	Personal Computer
PHY	Physical Layer Interface for High Speed USB
SOF	Start of Frame
TPL	Targetted Peripheral List
USB	Universal Serial Bus
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 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 portable devices to use the same USB cable to charge from either a PC or from a USB Charger.

If a portable device is attached to a USB host or hub, then the USB 2.0 specification requires that after connecting, a portable device 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 portable device is attached to a USB Charger, it is allowed to draw a current of I_{DEV_DCHG}. If a portable device is attached to a charging downstream port, it is allowed to draw a current of $I_{DEV\_CDP\_LFS}$ or $I_{DEV\_CDP\_HS}$, regardless of suspend.

In order for a portable device determine how much current it is allowed to draw from an upstream USB port, there needs to be mechanisms that allow the portable device to distinguish between a host or hub and a USB charger. This specification defines just such mechanisms.

Since portable devices can be attached to USB chargers from various manufacturers, it is important that all USB chargers behave the same way. This specification defines the requirements for a USB charger. USB chargers that meet these requirements and pass the associated compliance tests are eligible to be added to the USB-IF Integrators List.

If a portable device 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 100 mA for a time of $T_{SVLD\_CON\_WKB}$. The conditions associated with this ECN are contained in Section 2 of this specification, and are referred to as the Dead Battery Provision.

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

1.4 Definitions of Terms

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

1.4.1 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.

1.4.2 Downstream Port

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

1.4.3 Standard Downstream Port

In this specification, a Standard Downstream Port refers to a downstream port on a device that complies with the USB 2.0 definition of a host or hub. A Standard Downstream Port expects a downstream device to draw less than 2.5 mA average when unconnected or suspended, up to 100 mA maximum when connected 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 a Standard Downstream Port.

A Standard Downstream Port pulls the D+ and D- lines to ground through a 15 kΩ (typical) resistor. A Standard Downstream Port may have the ability to sense when a Portable Device is driving the D+ line to V_{DP_SRC}, and then react in some way. Portable Devices are required to drive D+ to V_{DP_SRC} whenever they draw more than I_{SUSP} while not connected, as described in the Dead Battery Provision.

1.4.4 Charging Downstream Port

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

When not in a USB session, a Charging Downstream Port outputs 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.

A Charging Downstream Port is capable of outputting a current of I_{CDP} from V_{BUS} at any time.

1.4.5 Dedicated Charging Port

A Dedicated Charging Port is a downstream port on a device that outputs power through a USB connector, but is not capable of enumerating a downstream device. A Dedicated Charging Port is required to output at a minimum current of I_{DCHG} at an average voltage of V_{CHG}.

A Dedicated Charging Port is required to short the D+ line to the D- line.

1.4.6 Charging Port

A Charging Port is either a Dedicated Charging Port or a Charging Downstream Port.

1.4.7 USB Charger

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

1.4.8 Portable Device

A Portable Device is considered to be any USB or OTG device that is capable of operating from its own battery, and is also capable of drawing current from USB for the purposes of operating and/or charging its battery.

1.4.9 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.

1.4.10 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 the paper, instead of parameter values. All parameter values are found in Section 5.

2. Dead Battery Provision

2.1 Background

The USB 2.0 specification allows a downstream device to draw a suspend current of up to 2.5 mA average from a Standard Downstream Port when the device is not connected or when the bus is suspended. If the bus is not suspended, then the device can draw up to 500mA, depending on the configuration the host enables.

This limit of only 2.5 mA when not connected can be problematic for Portable Devices with a Dead Battery or a Weak Battery. Some Portable Devices require more than 100mA for several seconds just to power up. Thus, some Portable Devices with Dead Batteries or Weak Batteries may not be able to power up when attached to a Standard Downstream Port if they can only draw 2.5mA when not connected.

After a Portable Device detects that it is attached to a Charging Port, it is allowed to draw up to 1.8A as described in Section 3.

2.2 Provision Conditions

Portable Devices that draw more than 2.5mA from a Downstream Port while not connected may still be certified, providing they meet the conditions specified below. These conditions are in addition to the compliance tests required for all devices.

2.2.1 Compliance Testing

When submitting Portable Devices for compliance testing that use the Dead Battery Provision, the vendor shall provide a Dead Battery for the tests, and shall declare whether or not the Portable Device should be tested with no battery.

2.2.2 No Battery Case

Portable Devices that do not have a battery installed may also use the Dead Battery Provision, provided they meet the following requirements:

- If a good battery were installed, the Portable Device would be able to run off of battery power
- The case where the battery is not installed is an exceptional use case for this Portable Device, and not likely to occur very often, if at all.

Bus-powered devices that do not normally have a battery are not eligible to use the Dead Battery Provision. Examples of such devices would include a bus-powered hub, bus-powered printer or bus-powered mouse.

2.2.3 Dead/Weak/No Battery – No Connect

Any USB device is allowed to draw a current of ISUSP for an unlimited amount of time from a Downstream Port when not connected.

In addition to this, a Portable Device with a Dead Battery, Weak Battery or no battery is allowed to draw IUNIT from a Downstream Port for up to TUNIT_ISUSP after attaching, in order to determine if it will likely be able to connect. If, after this time, the Portable Device determines that it definitely will not be able to connect, then the Portable Device shall reduce its current draw to less than ISUSP.

For example, consider a Portable Device that does not have a battery installed. If it needed the battery to get to a state where it could connect, then the Portable Device can only draw current for TUNIT_ISUSP to determine that it will never be able to connect.

2.2.4 Dead/Weak/No Battery – With Connect

A Portable Device with a Dead Battery, Weak Battery or no battery is allowed to draw IUNIT from a Downstream Port under the following conditions.

- Portable Device shall drive the D+ line to VDP_SRC from the time it starts drawing more than ISUSP, until the time that it connects
- Portable Device shall use this current to get to a state where it connects and enumerates
- Portable Device shall not draw more than ISUSP after a time of TSVLD_CON_WKB plus TCON_ISUSP from detecting a voltage on VBUS

See Section 3.4.4 for timing details.

In contrast, a self powered device or portable device with a good battery is not allowed to draw more than ISUSP after a time of TSVLD_CON_PWD plus TCON_ISUSP from detecting a voltage on VBUS.

2.2.5 Current Usage – Direct Power Up

If a Portable Device is able to power up, connect and enumerate with less than IUNIT, then such a device with a Dead Battery or Weak Battery is allowed to use the current from a Downstream Port to power up directly.

2.2.6 Current Usage – Battery Charging

If a Portable Device is not able to power up and connect with less than IUNIT, then such a device with a Dead Battery or Weak Battery is allowed to use IUNIT from the Downstream Port to first charge its battery to its Weak Battery Threshold. Upon reaching its Weak Battery Threshold, the Portable Device is required to power up, connect and enumerate.

2.2.7 Current Usage – Unrelated Modes

The Portable Device is not allowed to delay connecting and enumerating in order to go into modes that are unrelated to powering up, connecting and enumerating. Such modes might include, but are not limited to:

- Charging the battery beyond the Weak Battery Threshold
- Making a phone call
- Playing a game, song or video
- Establishing a wireless connection such as Bluetooth or WiFi or GPS

2.2.8 Inrush Tests

A Portable Device with a Dead Battery, Weak Battery or no battery shall pass inrush tests.

2.2.9 Drawing Current After Connect

After a Portable Device with a Dead Battery, Weak Battery or no battery connects, it is allowed to draw up to IUNIT for TCON_ISUSP. After TCON_ISUSP, the device is required to comply with the USB 2.0 specification rules for going into the suspended state.

2.2.10 Connect and Disconnect

A Portable Device is allowed to draw more than ISUSP under the Dead Battery Provision only when it is disconnected.

A Portable Device is allowed to connect and disconnect multiple times from when it first detects VBUS until TSVLD_CON_WKB later.

After TSVLD_CON_WKB plus TCON_ISUSP from detecting VBUS, a Portable Device must not draw more than ISUSP when it is disconnected, regardless of the state of its battery.

2.2.11 Specify Connect Times

When applying to use the Dead Battery Provision for a Portable Device, the vendor shall specify both the typical and maximum times that a device with a Dead Battery, Weak Battery or no battery will take to connect after being attached to a Downstream Port. These attach to connect times shall assume a new battery and room temperature.

2.3 OTG Considerations

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

If an OTG A-device is connected to a Portable Device 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).

If a Portable Device with a Dead Battery draws more current than the OTG A-device can provide, then the OTG A-device is allowed to end the session by dropping VBUS. If the Portable Device does not connect before the OTG A-device would normally time out the session, then the OTG A-device is allowed to end the session by dropping VBUS.

3. Charging Port Detection

3.1 Overview

Figure 3-1 is a block diagram showing a Portable Device attached to a USB port.

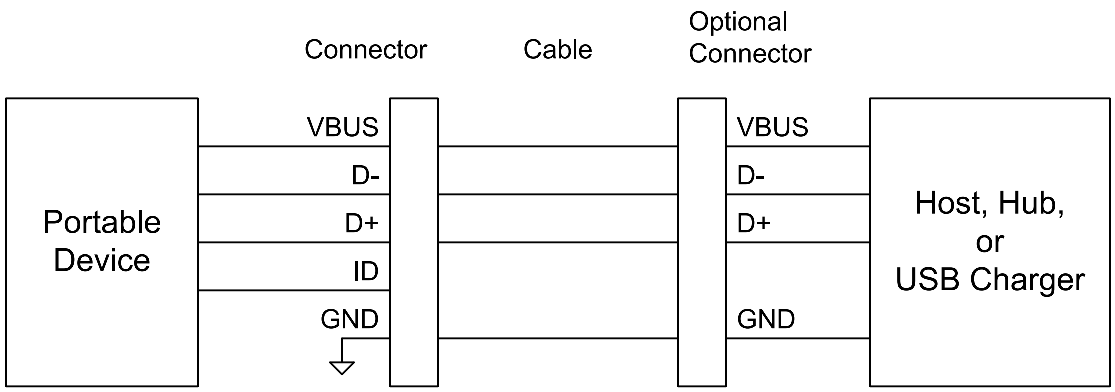

Figure 3-1 System Overview

Upon being attached to a USB port, a Portable Device detects that the voltage on VBUS is greater than its session valid voltage. For peripheral only devices, the session valid voltage can be between 0.8V to 4.0V. For OTG devices, the session valid voltage can be between 0.8V to 2.0V.

A Portable Device that does not support charger detection will assume that it is attached to a Standard Downstream Port and the Dead Battery Provision as defined in Section 2 will apply. A Portable Device that does support charger detection can check if the upstream port is a Standard Downstream Port or a Charging Port. If such a Portable Device is attached to a Charging Port, then it is allowed to draw currents as defined in Section 3.4.

The requirements specified in the following subsections for Portable Devices only apply to Portable Devices that implement the charger detection mechanism being described in that subsection.

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 Dedicated Charging Port

Figure 3-2 shows a Portable Device attached to a Dedicated Charging Port.

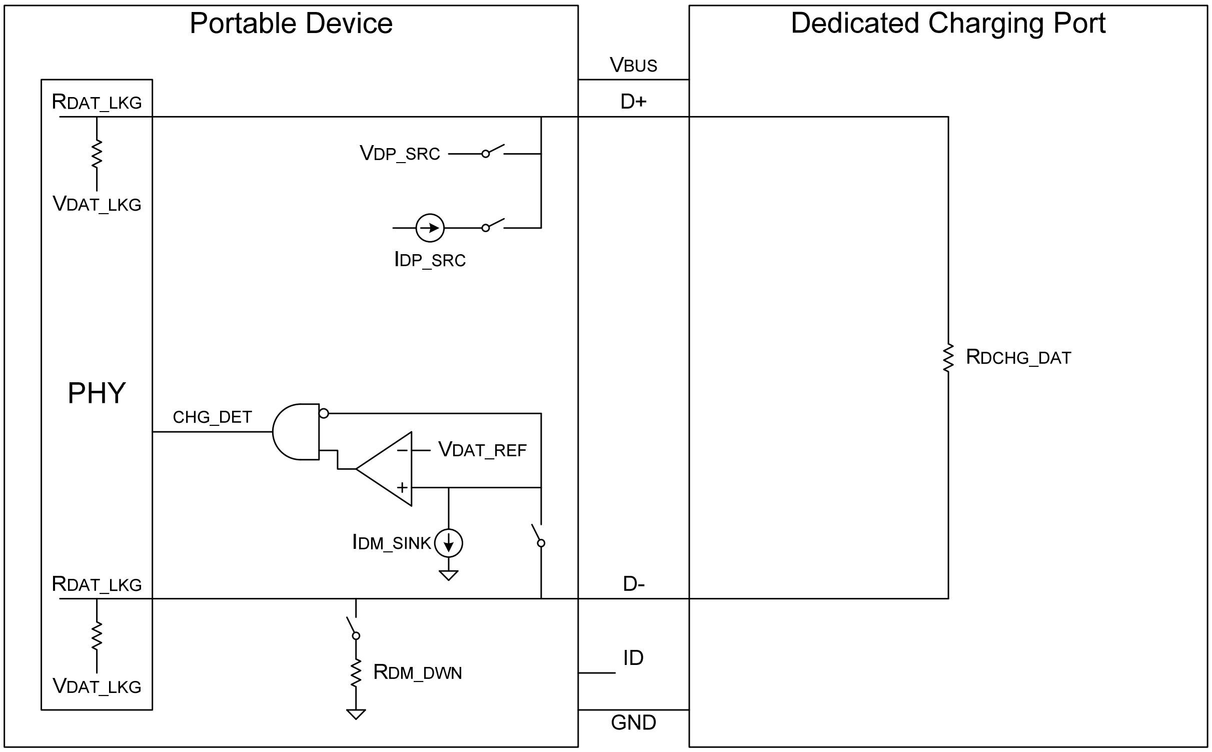

Figure 3-2 Dedicated Charging Port

The Portable Device contains a current source, IDP_SRC, and a pull-down resistor, RDM_DWN, which are used to detect when the data pins of the plug have made contact with the data pins of the receptacle. See Section 3.3 for more details.

The Portable Device also contains a voltage source, VDP_SRC, a current sink, IDM_SINK, and a comparator, VDAT_REF, for determining whether the Portable Device is attached to a Charging Port or a Standard Downstream Port.

As shown above, the Portable Device is attached to a Dedicated Charging Port. A Dedicated Charging Port is required to short the D+ and D- lines with a resistance of RDCHG_DAT. The Portable Device first checks that the connector pins have made contact by turning on IDP_SRC and RDM_DWN. If the pins have made contact, then D+ goes low.

To detect the presence of a Dedicated Charging Port, the Portable Device turns on VDP_SRC and IDM_SINK. If nothing is attached to the Portable Device, then D- gets pulled to ground by IDM_SINK. The voltage on D- is less than VDAT_REF, so the CHG_DET signal is low. If a Dedicated Charging Port is attached to the Portable Device, then the voltage on D- is VDP_SRC. This is greater than VDAT_REF and less than VLGC, so the CHG_DET signal is high.

The charger detection mechanism is defined such that it will work when the PHY has a leakage resistance of RDAT_LKG and a leakage voltage of VDAT_LKG.

3.2.2 Standard Downstream Port

Figure 3-3 shows a Portable Device attached to a Standard Downstream Port.

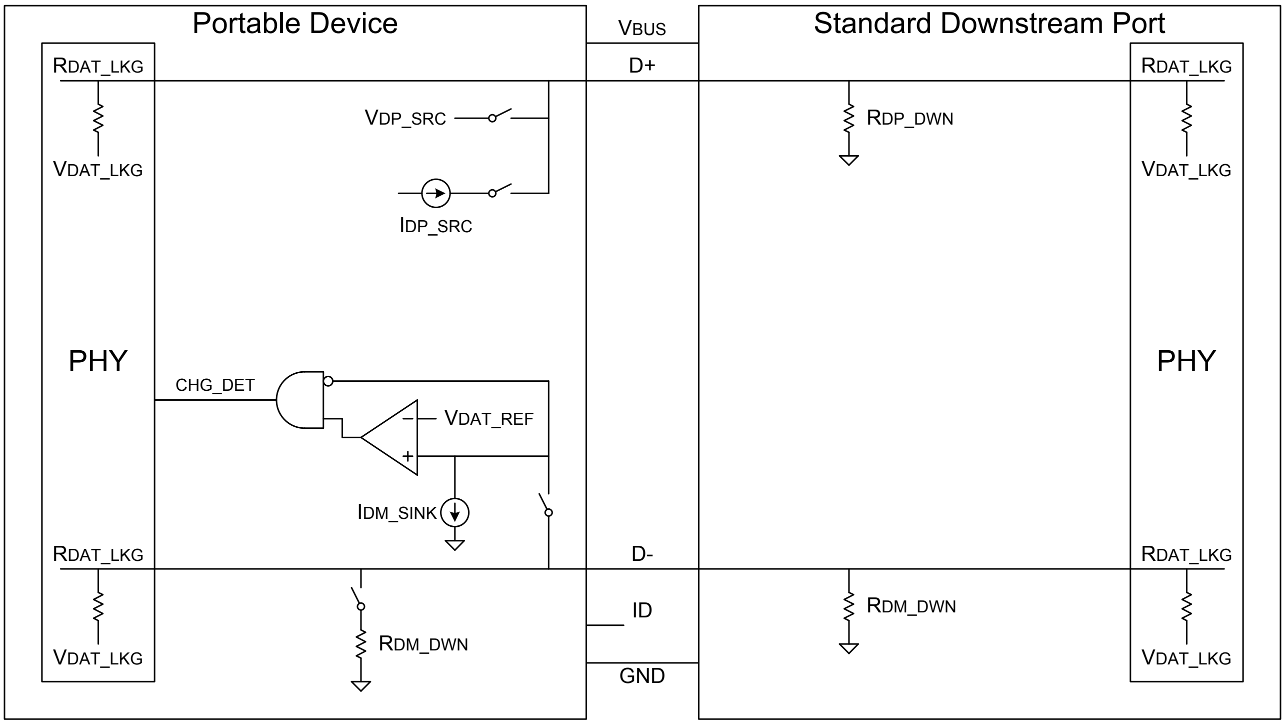

Figure 3-3 Standard Downstream Port

When the Portable Device turns on VDP_SRC and IDM_SINK, the D- line remains below VDAT_REF, and the CHG_DET signal is not asserted. The Portable Device knows that it is not attached to a Charging Port.

3.2.3 Charging Downstream Port

Figure 3-4 shows a Portable Device attached to a Charging Downstream Port.

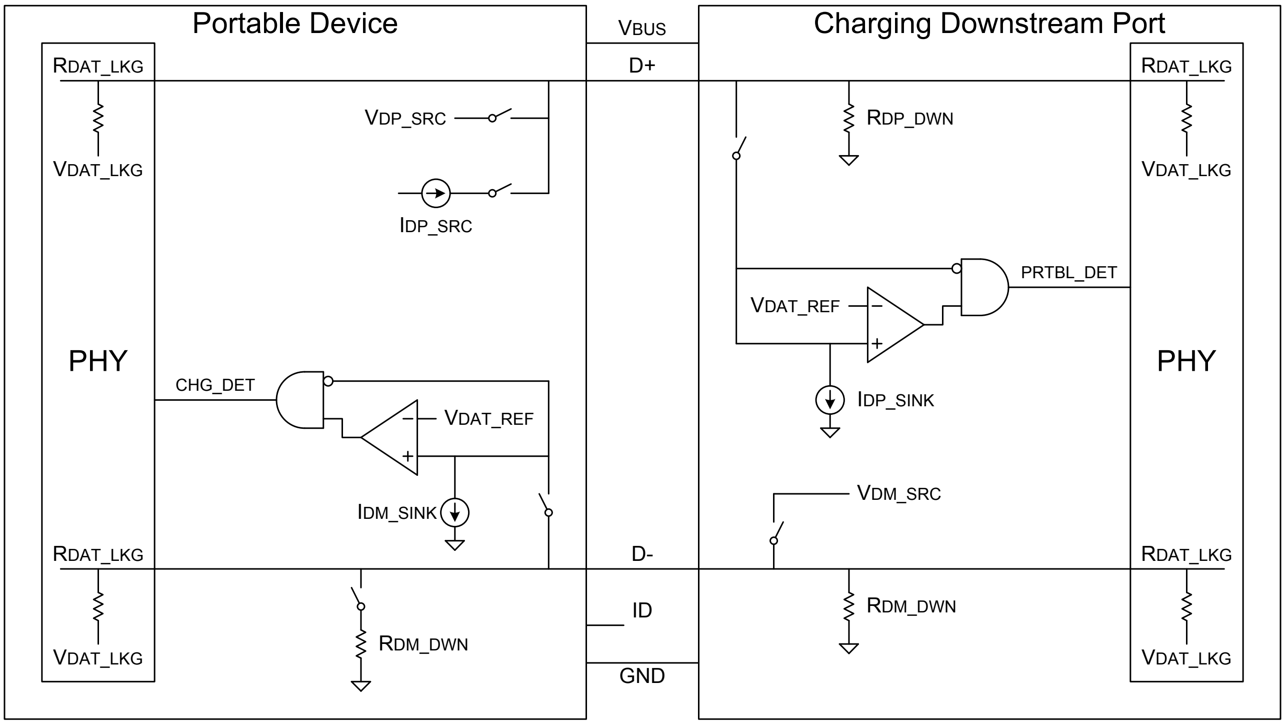

Figure 3-4 Charging Downstream Port

As before, the Portable Device turns on VDP_SRC and IDM_SINK to check if it is attached to a Charging Port. When the Charging Downstream Port detects that D+ is greater than VDAT_REF and less than VLGC, then PRTBL_DET is asserted and the Charging Downstream Port knows that a Portable Device is attached. The Charging Downstream Port responds by driving a voltage of VDM_SRC onto D-. This causes the CHG_DET signal in the Portable Device to be asserted, and the Portable Device knows that it is attached to a Charging Port.

Once the Portable Device knows that it is attached to a Charging Port, it can distinguish between a Dedicating Charging Port and a Charging Downstream Port by pulling either D+ or D- to a logic high. If the Portable Device is attached to a Dedicated Charging Port, then the other data line will go high as well. If the Portable Device is attached to a Charging Downstream Port, then the other data line will stay low.

3.3 Data Contact Detect

3.3.1 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 3-5.

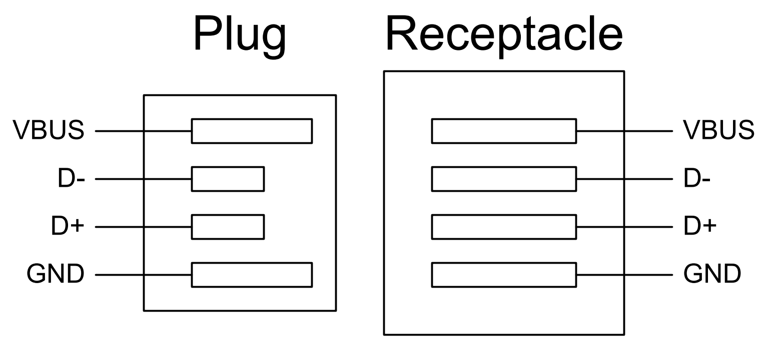

Figure 3-5 Data Pin Offset

As a result, when a Portable Device is attached to an upstream port, the Portable Device 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 several hundred milliseconds have been observed.

The way that a Portable Device distinguishes between a Charging Port and a Standard Downstream Port is to look at the data lines. If the Portable Device makes a decision before the data pins have made contact, then the Portable Device will determine that it is attached to a Standard Downstream Port.

If a Portable Device is attached to a Charging Port, and incorrectly determines that it is attached to a Standard Downstream Port, then the following would occur. The Portable Device will connect, and wait to be enumerated. While waiting to be enumerated, the Portable Device would only be allowed to draw ISUSP, even though it was attached to a Charging Port.

- To avoid this situation, the Portable Device is required to detect when the data pins have made contact.

3.3.2 Hardware Detection

In order to detect when the data pins have made contact, the Portable Device is required to pre-bias the data pins in such a way that when contact is made, at least one of the data pins changes state. Once this state change has been detected, the Portable Device is then allowed to check if it is attached to a Charging Port or a Standard Downstream Port.

This section describes a contact detect mechanism that works with worst case resistances allowed by the USB 2.0 spec, for both the Portable Device and remote device. If the Portable Device is known to have resistances that are tighter than those allowed by the USB 2.0 spec, or if the Portable Device uses a comparator instead of a the single ended receiver, then the Portable Device is allowed to use a different method for pre-biasing the data pins. However, whatever method is used is required to work for worst case resistances in the remote device.

The recommended method for Data Contact Detection is for the Portable Device to use a current source on the D+ line. When the Portable Device detects that VBUS is asserted, it turns on the current source, IDP_SRC, on D+, and turns on the pull-down resistor, RDM_DWN, on D-. If nothing is attached to the Portable

Device, the D+ line stays high. When either a Charging Port or Standard Downstream Port is attached to the Portable Device, the D+ line goes low.

Figure 3-6 shows the case where nothing is attached to the Portable Device.

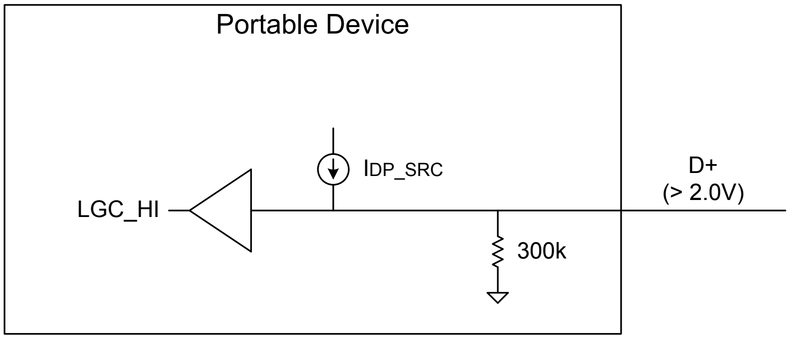

Figure 3-6 Data Contact Detect – No Remote Device

The current source, IDP_SRC, is pulling the D+ line high. As per the USB 2.0 spec, the PHY is allowed to have an input impedance of 300kΩ. If this 300kΩ were pulling D+ to ground, then the minimum current required to keep D+ at logic high is:

- IDP_SRC > V / R = 2V / 300kΩ = 7uA

Figure 3-7 shows the case where the Portable Device is attached to a Standard Downstream Port.

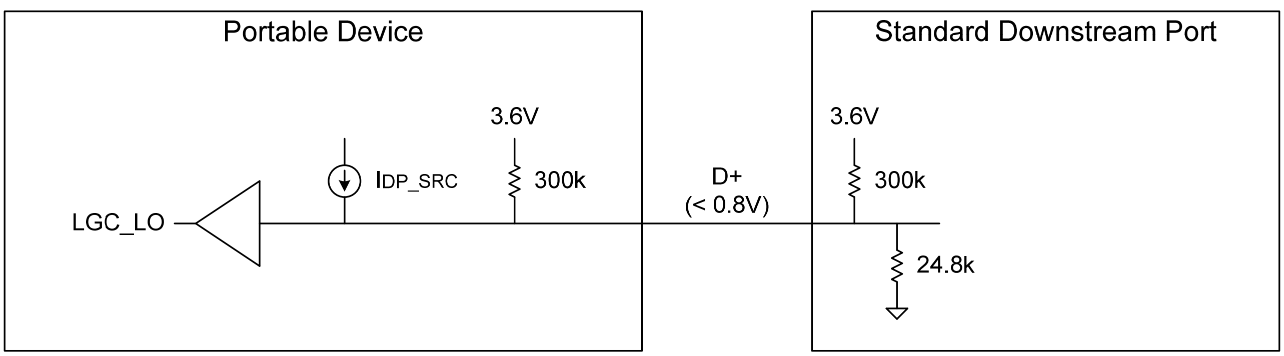

Figure 3-7 Data Contact Detect – Standard Downstream Port

In this case, the D+ line should go to a logic low when the Portable Device is attached to a Standard Downstream Port. The pull-down resistor in the Standard Downstream Port is pulling the D+ line low, and could have a value as high as 24.8kΩ. The leakage current from the Portable Device and Downstream Port could both be pulling D+ high. In order for D+ to go to logic low, the current from IDP_SRC must be less than:

- IDP_SRC < .8V / 24.8k - (3.6V - .8V) / 300k - (3.6V - .8V) / 300k = 14uA

If the Portable Device is attached to a Charging Downstream Port, then the Charging Downstream Port pulls the D+ line low with a resistance of RDP_DWN and with current sink of IDP_SNK. The D+ line at the Portable Device will again go low as soon as the D+ pins on the connector make contact.

Figure 3-8 shows the case where the Portable Device is attached to a Dedicated Charging Port. Electrically, it is the same as when the Portable Device is attached to a Downstream Port.

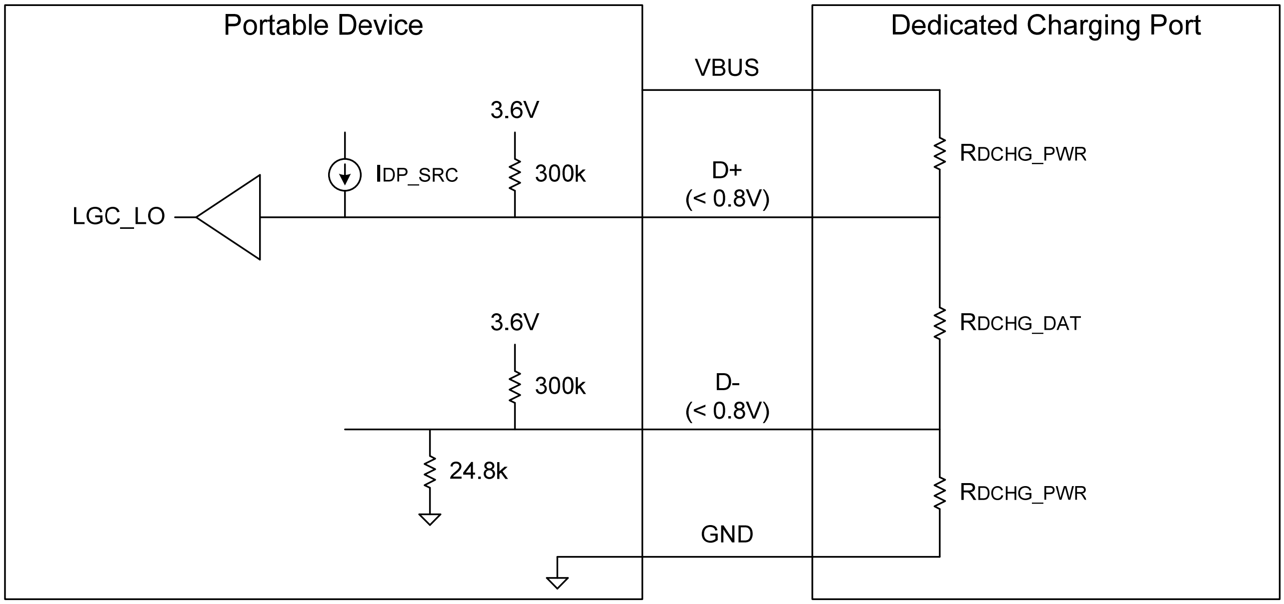

Figure 3-8 Data Contact Detect – Dedicated Charging Port

The protocol for doing Data Contact Detect is as follows:

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

The resistance between D+/- and VBUS or GND of a Dedicated Charger is required to be RDCHG_PWR.

The DCD protocol defined above does not work when a Portable Device is attached to a PS2 port, because a PS2 port pulls the D+ line high. Thus, a Portable Device that implements the above DCD protocol will not be able to charge from a PS2 port.

In general, attaching the USB port of a Portable Device to a different type of port, such as PS2, RS232 or others, through various adaptors or combinations of adaptors cannot be expected to work and could cause damage.

3.3.3 Charger Detect Delay

For legacy Portable Devices that cannot do Data Contact Detect as required in the above subsection, it is recommended that such devices use delays to minimize the chances of doing charger detection before the data pins have made contact.

At the very least, such legacy Portable Devices should wait several hundred milliseconds after VBUS has gone high, before determining that they are not attached to a Charging Port. If, after waiting several hundred milliseconds, a legacy Portable Device has not detected a Charging Port, then it should assume it is attached to a Standard Downstream Port and connect. If a legacy Portable Device does not subsequently receive a USB reset, it should disconnect and check again to see if it is attached to a Charging Port.

This approach is not recommended for new designs as it is not deterministic.

3.4 Charger Detection Timing

3.4.1 High Speed

Figure 3-9 shows the timing associated with charger detection for a HS Portable Device with a good battery.

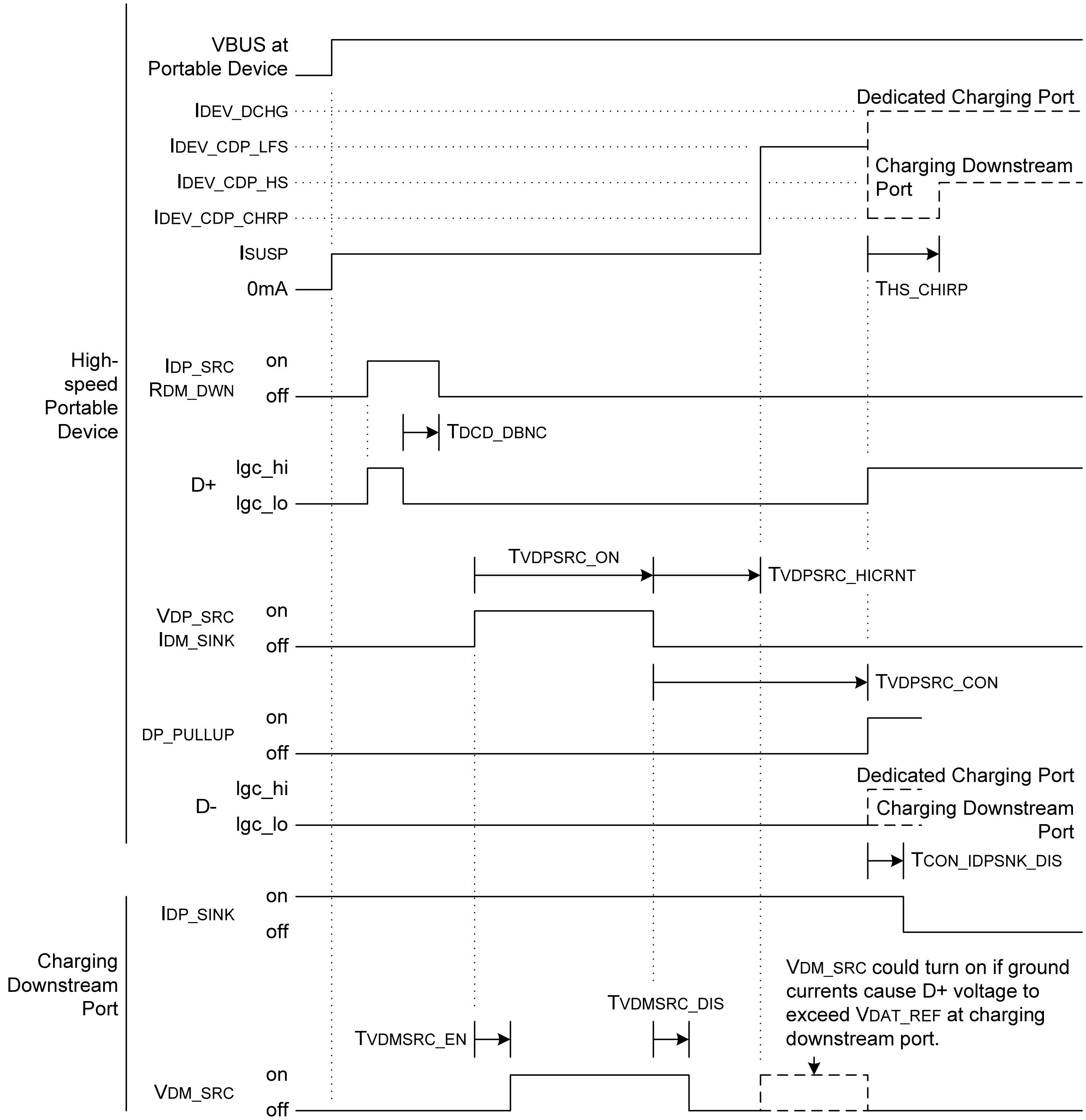

Figure 3-9 High-speed Charger Detection Timing

Notes:
1) DP_PULLUP is the waveform for a Portable Device pulling the D+ line high with a resistance of 1.5k typical.

The timing shown in Figure 3-9 is described below.

After VBUS is detected, a Portable Device with a good battery is allowed to draw ISUSP.

If the Portable Device implements Data Contact Detect as described in Section **Error! Reference source not found.**, it turns on IDP_SRC and either RDM_DWN or IDM_SINK. When the Portable Device detects that the D+ line has been low for a time of TDCD_DBNC, then the Portable Device knows that the data pins have made contact. The Portable Device then turns off IDP_SRC and RDM_DWN.

To check for a Charging Port, the Portable Device turns on VDP_SRC and IDM_SINK. After a time of TVDPSRC_ON, the Portable Device is allowed to check the status of the D- line. If D- is above VDAT_REF and below VLGC min, then the Portable Device is attached to a Charging Port. As soon as the Portable Device detects that it is attached to a Charging Port, it can turn off VDP_SRC and IDM_SINK. After a time of TVDPSRC_HICRNT , the Portable Device is allowed to draw up to IDEV_CDP_LFS from the Charging Port.

When the Portable Device is ready to be enumerated, it connects to the upstream port by asserting its D+ pull-up resistor. D+ then goes to logic high. If the Portable Device is attached to a Dedicated Charging Port, then D- line will also go to logic high, since a Dedicated Charging Port shorts D+ and D-. If D- goes to logic high, then the Portable Device is allowed to draw up to IDEV_DCHG.

If the Portable Device is attached to a Charging Downstream Port, then when D+ is pulled high, the D- line will remain at logic low. If D- stays at logic low, the Portable Device shall reduce its current draw to IDEV_CDP_CHRP during the HS chirp. After the chirp is complete, the Portable Device is then allowed to increase its current draw to IDEV_CDP_HS.

After a Portable Device determines it is attached to a Charging Port, it is required to connect by asserting D+. The reason for this is that the Charging Port could be a Charging Downstream Port. When the Charging Downstream Port detects the connect event, it will then enumerate the Portable Device.

3.4.2 Full Speed

Figure 3-10 shows the timing associated with charger detection for a FS Portable Device with a good battery.

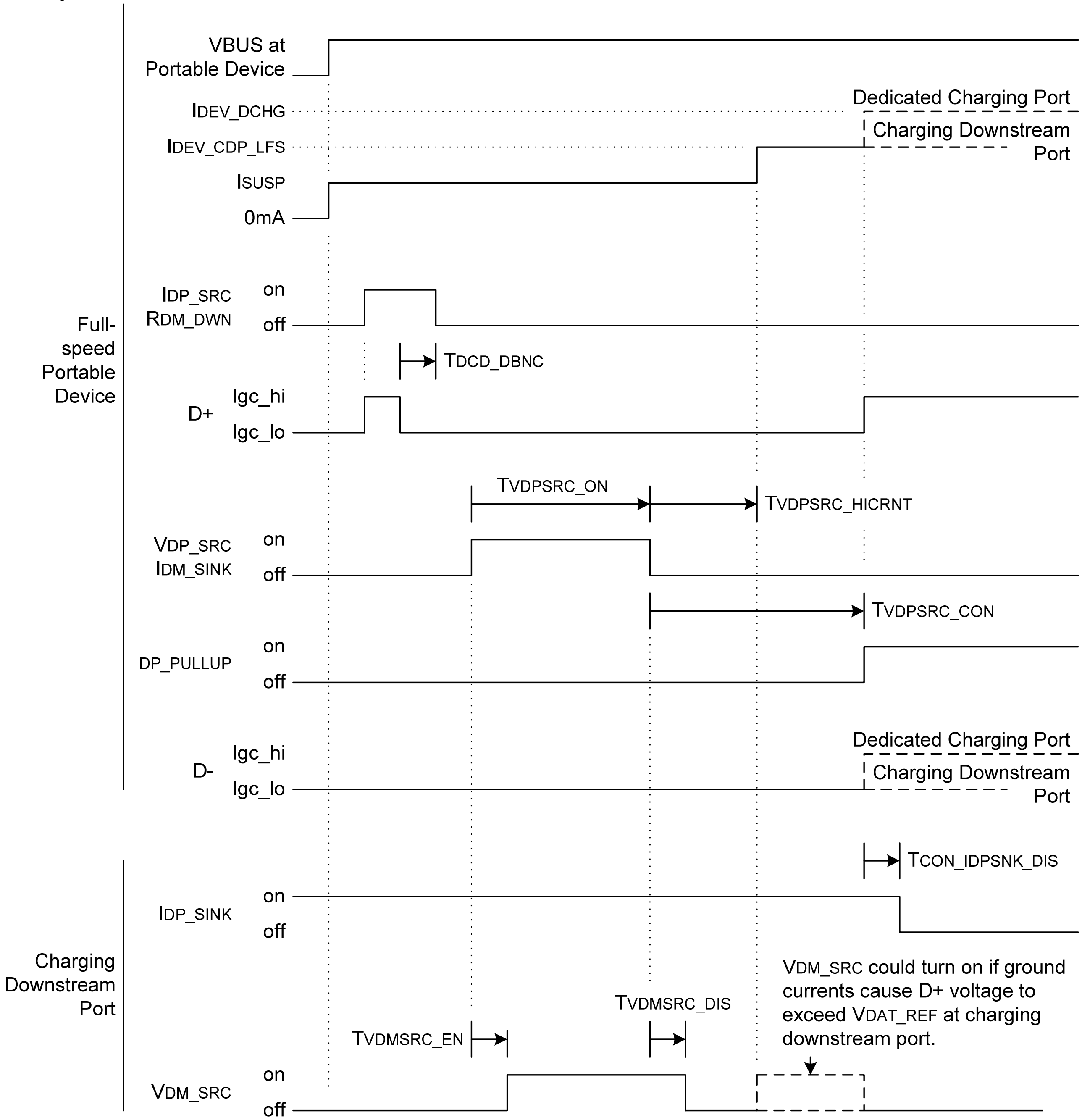

Figure 3-10 Full-Speed Charger Detection Timing

The charger detection timing for a FS Portable Device is the same as for that of a HS portable device, except that after the Portable Device connects, it can continue drawing up to IDEV_CDP_LFS from VBUS.

3.4.3 Low Speed

Figure 3-11 shows the timing associated with charger detection for a LS Portable Device with a good battery.

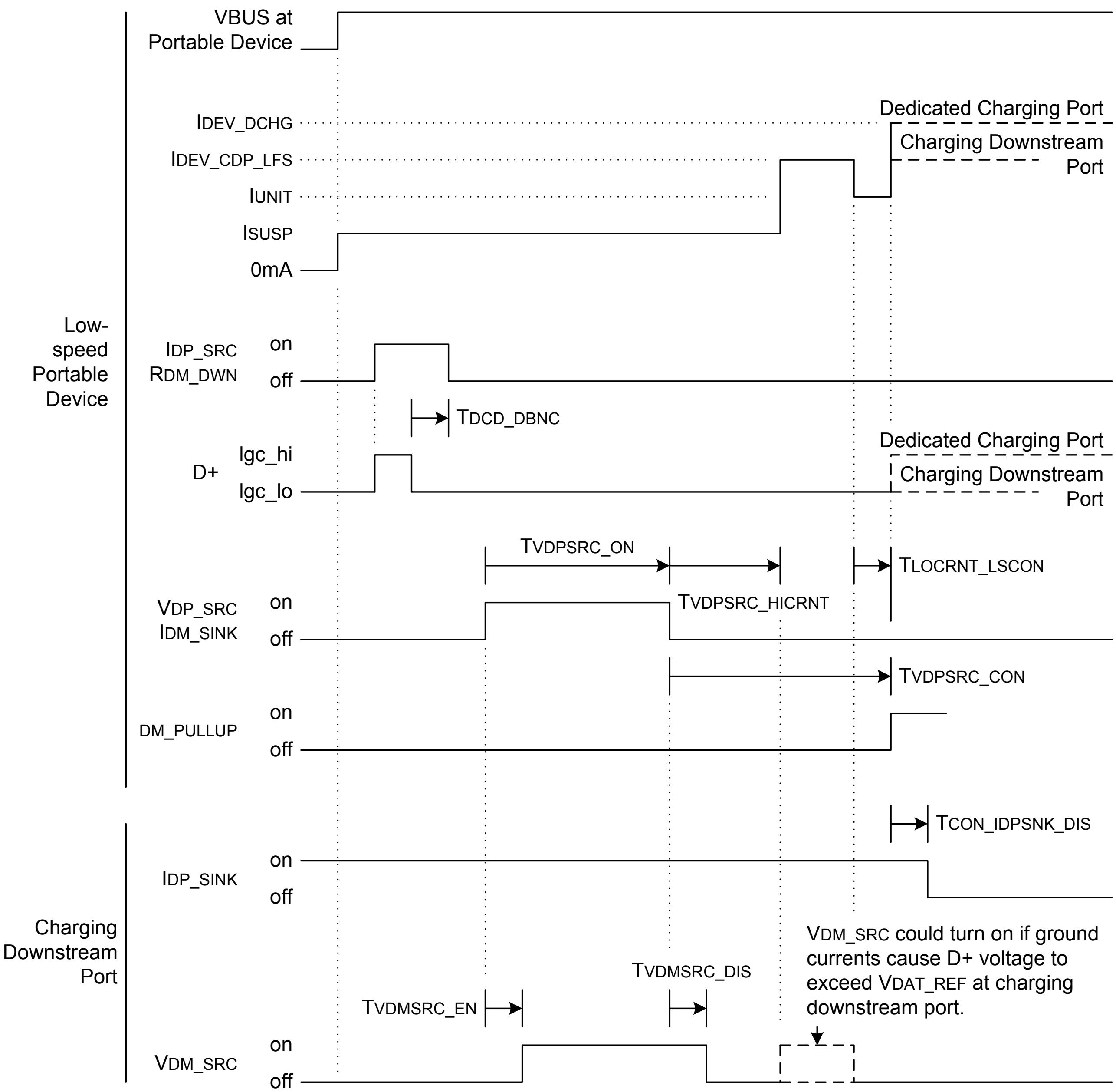

Figure 3-11 Low-Speed Charger Detection Timing

Notes:
1) DM_PULLUP is the waveform for a Portable Device pulling the D- line high with a resistance of 1.5k typical.

The charger detection timing for a LS Portable Device is the same as for that of a FS, except for a time of TLOCRNT_LSCON before the Portable Device connects. During this time before connecting, the LS Portable Device is required to reduce its current draw to less than IUNIT. The reason for this is as follows.

Before connecting, the Portable Device is outputting a logic low (<300 mV) on D+. If the Portable Device were drawing 1500 mA from the Charging Downstream Port, then the Portable Device ground could be up to 375 mV higher than that of the Charging Downstream Port. (As shown in Figure 7-47 of the USB 2.0 specification, a ground current of 100 mA can result in a voltage offset of 25 mV.)

If the Charging Downstream Port detected 675mV on its D+ line, (that is, 300mV + 375mV), it would then turn on the VDM_SRC voltage source on its D- line. If the Charging Downstream Port were driving the D- line, then the Portable Device would not be able to pull D- high to connect.

After a LS Portable Device has connected, it is then allowed to draw up to IDEV_CDP_LFS from a Charging Downstream Port.

3.4.4 Dead Battery

Figure 3-12 shows the timing associated with charger detection for a Portable Device with a dead or weak battery.

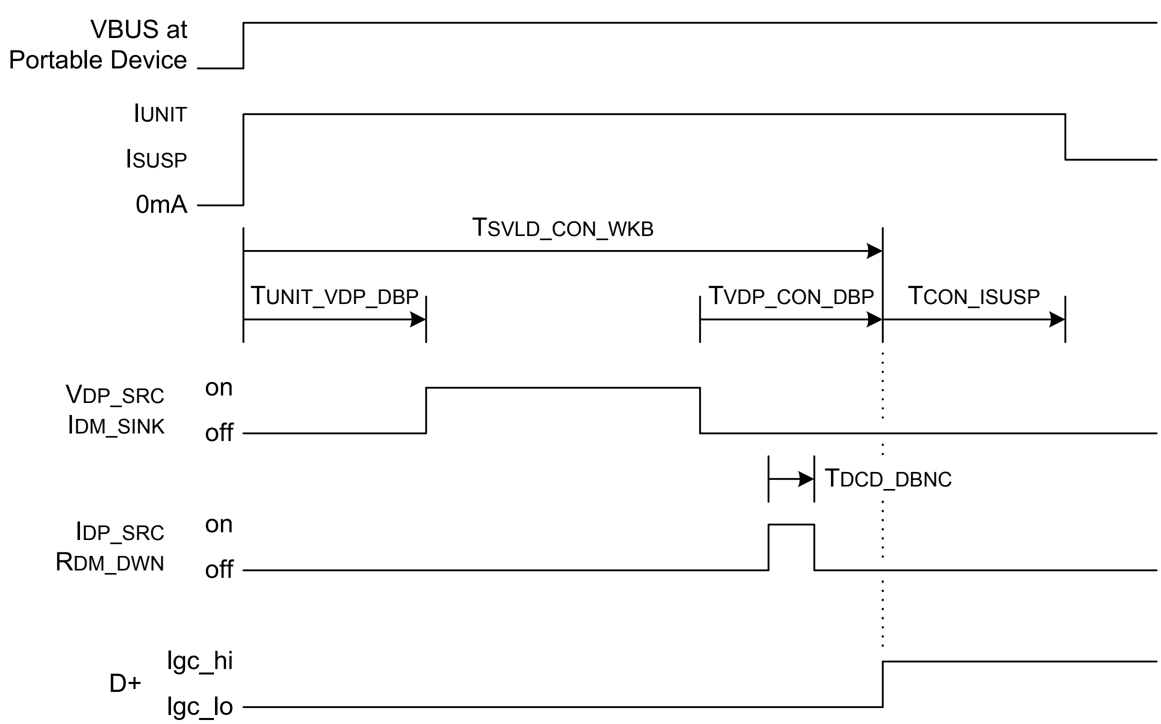

Figure 3-12 Dead Battery Charger Detection Timing

A Portable Device with a weak or dead battery is allowed to draw IUNIT from VBUS anytime after VBUS is asserted. The Portable Device is required to assert VDP_SRC within TUNIT_VDP_DBP of drawing more than ISUSP. VDP_SRC must then remain asserted while the Portable Device draws more than ISUSP.

When the Portable Device is ready to connect, it should first disable VDP_SRC, and then enable IDP_SRC for a time of TDCD_DBNC to check if the data pins have made contact. If the data pins have not made contact, then the Portable Device should inform the user that it is not attached to a valid charger or host port.

Within TVDP_CON_DBP of disabling VDP_SRC, the Portable Device is required to connect. After TCON_ISUSP of connecting, the Portable Device is required to drop down to ISUSP whenever the bus is suspended.

If the Portable Device detects that it is attached to a Charger Port during the time that V_{DP_SRC} is asserted, then it is not required to connect within $T_{SVLD\_CON\_WKB}$. When the Portable Device does connect, it shall comply with the timing defined in the previous subsections for connecting to a Charger Port as either a LS, FS or HS device.

3.5 Charging Current Limits

The standard-A connectors defined in the USB 2.0 specification are rated for 1500 mA. Charging Ports are allowed to use standard-A connectors. If a Charging Port is capable of outputting more than 1500mA, then that port shall use a version of the standard-A connector that can handle the maximum output current.

A Dedicated Charging Port is required to current limit at some current in the range of I_{DCHG}. In order for a Portable Device to force a Dedicated Charging Port into current limit mode, a Portable Device is allowed to attempt to draw a current that is greater than I_{DCHG}, and which can be as high as I_{DEV_DCHG} max. The reason why a Portable Device would force the Dedicated Charging Port to current limit is so that the charger output voltage would drop, and the Portable Device would not have to dissipate as much power.

3.6 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. As the charging current increases, this ground difference has the effect of reducing noise margins.

3.6.1 Low-speed and Full-speed Communication

The maximum current that a Portable Device is allowed to draw from a Charging Downstream Port is $I_{DEV\_CDP\_LFS}$. At this current, the Portable Device ground can be 375 mV higher than the Charging Downstream Port ground. As shown in Table 7-7 of the USB 2.0 specification, a logic output low from the Portable Device can be as high as 300 mV. When added to the 375 mV offset of the Portable Device ground, this means the Charging Downstream Port could see a voltage of 675 mV on D+/- when the Portable Device is outputting a logic low.

As shown in Table 7-7 of the USB 2.0 specification, the Downstream Port input logic threshold can be as low as 800 mV. When compared to the 675 mV coming from the Portable Device, this leaves a noise margin of 125 mV. Thus, a Portable Device is able to communicate with a Charging Downstream Port at low-speed or full-speed when drawing a current of $I_{DEV\_CDP\_LFS}$ max.

3.6.2 High-speed Communication

Table 7-7 of the USB 2.0 specification indicates that a high-speed USB PHY is recommended to work when the common mode voltage of the received signal (V_{HSCM}) is between -50mV and +500mV.

As per Table 7-7 of the USB 2.0 spec, the minimum common mode voltage that a PHY can transmit is:

- $V_{HS\_CM\_TX} = (V_{HS\_OL} + V_{HS\_OH}) / 2$
- $V_{HS\_CM\_TX}$ (minimum) = (-10 mV + 360 mV) / 2 = 175 mV

Since the common voltage of a transmitted signal is essentially DC, it does not get attenuated by the cable. Thus, the common mode voltage of the transmitted signal is the same as the common mode voltage of the receive signal. There is, of course, a small time at the start of each packet where the common mode voltage of the transmitted signal changes from ground to >175mV. During this transition period, the common mode voltage of the receive signal will lag that of the transmitted signal, but will achieve steady state before the sync word completes.

When a Portable Device is drawing current from a Charging Downstream Port, the return current through the ground line of the cable causes the ground voltage of the Portable Device to be higher than that of the Charging Downstream Port. If the ground voltage of the Portable Device is 225 mV higher than that of the Charging Downstream Port, then the minimum common mode voltage seen by the portable device is -50mV.

As shown in Figure 7-47 of the USB 2.0 specification, a ground current of 100 mA can result in a voltage offset of 25 mV. Thus, the maximum charging current that can be allowed during high-speed communication is 900mA, or $I_{DEV\_CDP\_HS}$.

During the HS chirp sequence, the Portable Device is required to output a chirp K. As per the USB 2.0 spec, (page 179, Table 7-7), the max chirp K differential level is 900mV. The maximum output low of the Portable Device is 10mV, which results in an actual swing on the D- line of 10mV to 910mV. This translates to a maximum common mode voltage of 460mV.

As per section 7.1.4.2 of the USB spec, the host is required to receive the chirp K over a maximum common mode voltage range of -50mV to 600mV. In order to keep the common mode voltage of the chirp K at the host below 600mV, the charging current should not raise the Portable Device ground by more than 140mV.

As shown in Figure 7-47 of the USB 2.0 specification, a ground current of 100mA can result in voltage offset of 25mV. Thus, the maximum charging current that can be allowed during the HS chirp is 560mA, or $I_{DEV\_CDP\_CHRP}$.

When the Portable Device is first attached to a Charging Downstream Port, the Portable Device is required to adjust its current below $I_{DEV\_CDP\_CHRP}$ before it connects. However, after the Portable Device has connected, the host is able to issue a reset at any time. In this case, the Portable Device is required to respond with a chirp K within 6ms of the start of the reset.

If the current drawn by a portable device is controlled by software, it may not be possible for the Portable Device to reduce its current from $I_{DEV\_CDP\_HS}$ to $I_{DEV\_CDP\_CHRP}$ within 6ms. In this case, it may be necessary for the portable device to limit its current to $I_{DEV\_CDP\_CHRP}$ at all times. Alternatively, the portable device could limit the max chirp K voltage to something less than 910mV, in which case it could charge at currents higher than $I_{DEV\_CDP\_CHRP}$. For each 50mV that the chirp K voltage is below 910mV, the common mode voltage goes down by 25mV, and the Portable Device is able to draw an extra 100mA.

3.7 Charger Detect Output Signal

For some implementations, the Charger Detect circuitry may be located with the PHY, while the circuitry that draws power from VBUS may be located in a Power Management Unit (PMU). In order for the PMU to know if the Portable Device was attached to a Charging Port, the PMU would need to receive a signal from the PHY.

In such cases, it is recommended that the interface between the PHY and the PMU be an active low, open drain, charger detect signal, as shown in Figure 3-13.

The PHY must be designed such that the charger detect signal (CHG_DET_N) is not clamped when the PHY is not powered. If the CHG_DET_N were clamped when the PHY was not powered, then the PMU could incorrectly determine that a charger was detected.

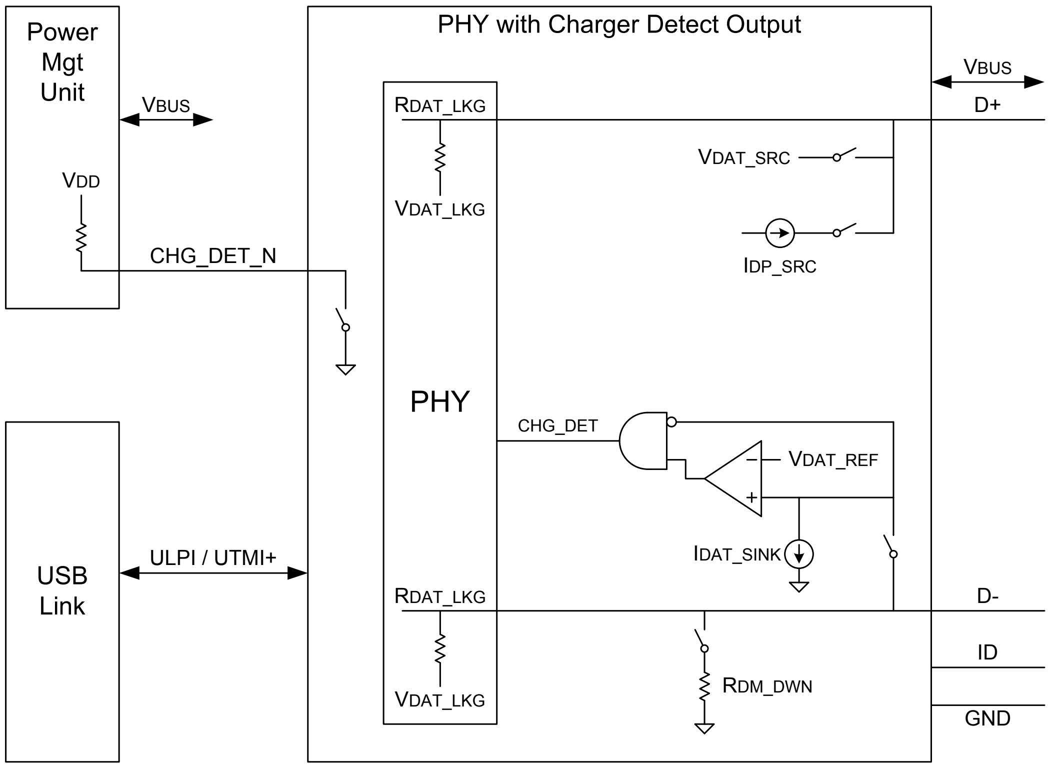

Figure 3-13 Charger Detect Output Signal

3.8 Signal Integrity

In order for a Portable Device to detect a Charging Port, the Portable Device needs to have additional circuitry as shown in Figure 3-2. When implementing this additional circuitry on a Portable Device, it must be done in such as way so that the portable device can still pass compliance testing.

For instance, Section 7.1.6.2 of the USB 2.0 specification recommends that the total capacitance to ground of either the D+ or D- line (CHSLOAD) be less than 10 pF. If the detection circuitry adds too much capacitance or stub length to either line, then eye pattern may be affected.

3.9 Resistive Detection Mechanism

For legacy Portable Devices that do not have the charger detection mechanism described in the previous sections, it is possible to use resistors to detect the presence of a Dedicated Charging Port. However, detection mechanisms using resistors are not recommended for new designs, for the following reasons:

- they cannot made to work with Standard Downstream Ports under worst case conditions of input impedance on D+/-
- they do not work with Charging Downstream Ports
- they will incorrectly identify a PS2 port as a Charging Downstream Port, and allow current to be drawn that would damage the motherboard

4. Charging Specifications

4.1 Charging Port

A Charging Port shall have an average output voltage of VCHG when it is not in current limit mode. The time over which voltage is averaged is TVBUS_AVG.

A Dedicated Charging Port shall go into current limit mode at some current within the range of IDCHG. A Charging Downstream Port is not required to go into current limit mode, but may do so at some current within the range of ICDP. In current limit mode, the output voltage of a Charging Port shall drop to a level that allows the Charging Port to continue outputting its maximum current.

If the output voltage of a Charging Port drops to VCHG_SHT_DWN, then the Charging Port is allowed to reduce its output current. This is referred to as shutdown mode. This voltage may be measured at the output of the Charging Port, and does not need to include the voltage drop across the cable. A Charging Port shall remain in voltage limit or current limit mode at voltages above VCHG_SHT_DWN.

If a Charging Port goes into shutdown mode due to a short across VBUS and ground, and the short is subsequently removed, then the Charging Port output voltage shall recover within a time of TSHT_DWN_REC. If a Charging Port does support the shutdown mode, then it is recommended that during shutdown, the Charging Port limit its output current to ICHG_SHTDWN.

A Charging Port shall output a voltage of VDM_SRC on D- when it sees voltage less than VLGC and greater than VDAT_REF on its D+ line. A Dedicated Charging Port is required to do this by shorting the D+ line to the D- line through a resistance of RDCHG_DAT.

A Dedicated Charging Port is required to have an impedance between D+ and GND of RDCHG_PWR. A Dedicated Charging Port is also required to have a capacitance between D+ and GND of CDCHG_PWR. These same two requirements also apply to D+ and VBUS, D- and GND, and D- and VBUS.

If the current drawn from a Charging Port is less than 500mA, then transient load currents shall not cause the output voltage from the charger to go below VCHG_UNDSHT. Under no circumstances shall the transient voltage of a Charging Port exceed VCHG_OVRSHT. The average voltage on VBUS during any such transients shall still be VCHG, where the averaging period is TVBUS_AVG.

A Charging Port is required to have a standard-A receptacle or a captive cable terminating in a micro-B plug.

If there is a single failure within a device with a Charging Port, then the output voltage on VBUS shall not exceed VCHG_FAIL. A Portable Device is not required to operate or survive either of these voltages on its VBUS pin. However, these voltages shall not cause a Portable Device to fail in such a way as to harm the user.

A Charging Port is required to tolerate its VBUS pin being driven by any voltage less than VCHG max at the same time as it is driving a voltage of VCHG onto the VBUS pin.

A device having a Dedicated Charging Port is required to specify on its packaging or casing, the rated current at which the output voltage of the Dedicated Charging Port is capable to supply VCHG. The actual current at which the Dedicated Charging Port voltage drops to 3.6V is required to be within +50%/-0% of the current value specified on the package or casing.

Figure 4-1 shows a graph of the Dedicated Charging Port output voltage versus output current.

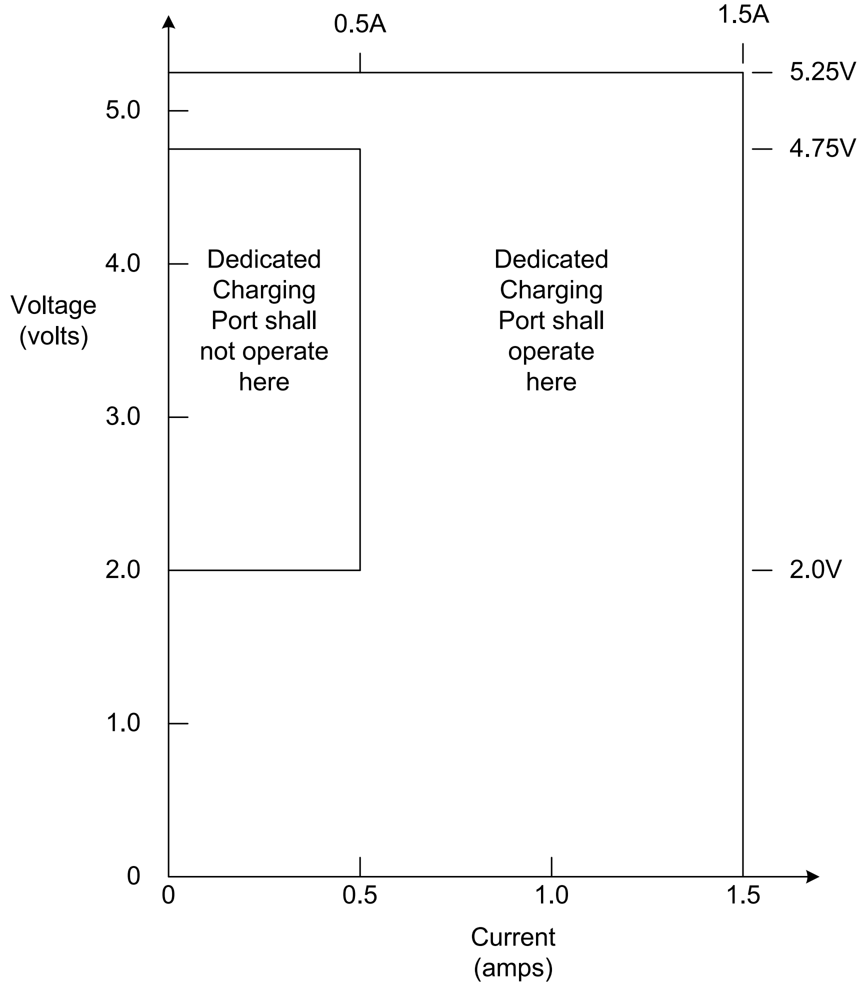

Figure 4-1 Dedicated Charging Port Voltage versus Current

4.2 Portable Devices

Portable Devices shall limit the amount of current they attempt to draw from a Dedicated Charging Port to IDEV_DCHG. Figure 4-2 shows the current a Portable Device can draw from a Dedicated Charging Port.

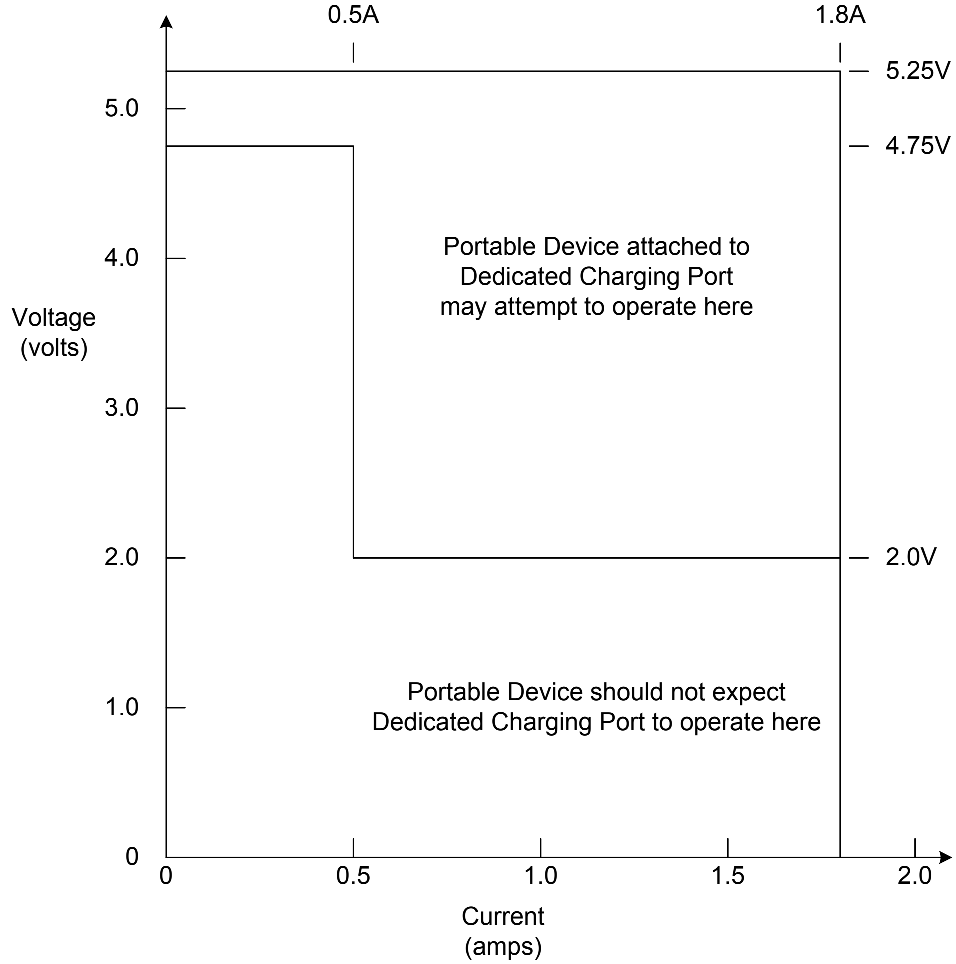

Figure 4-2 Portable Device Current from Dedicated Charging Port

Portable Devices shall limit the amount of current they draw from a Charging Downstream Port to IDEV_CDP_LFS when they are connected at LS or FS. They shall limit their current draw to IDEV_CDP_HS when they are connected at HS. Figure 4-3 shows the current a Portable Device can draw from a Charging Downstream Port.

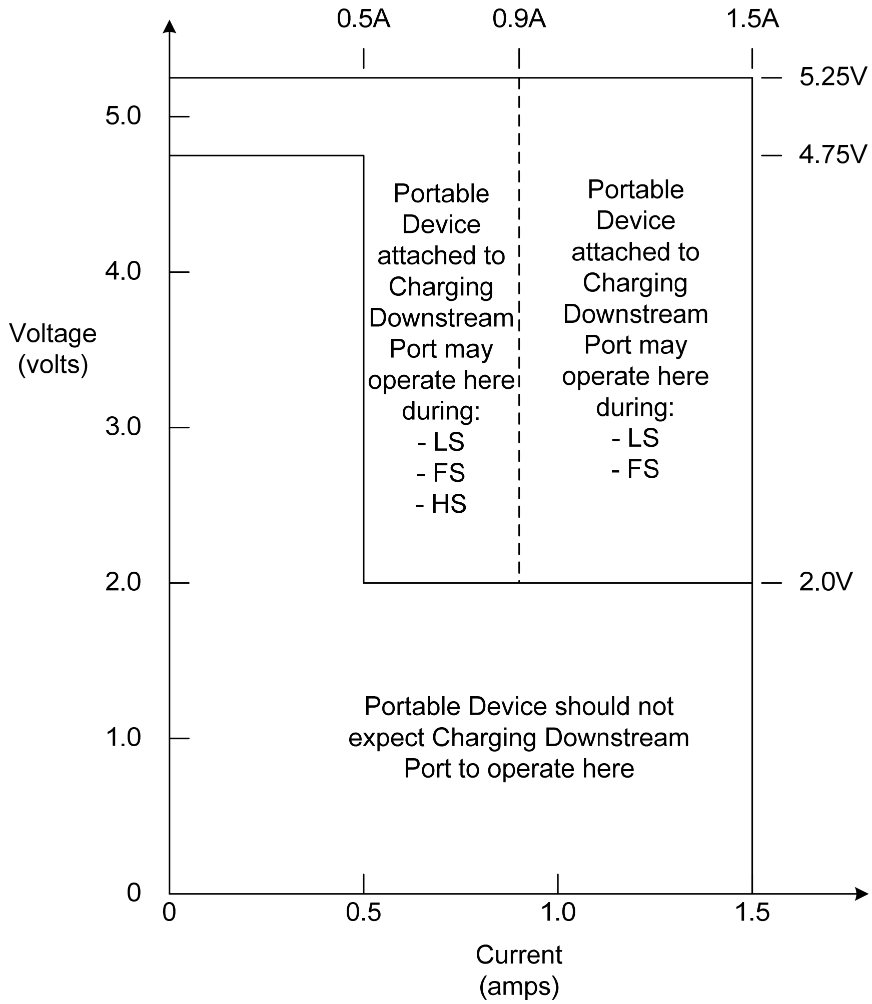

Figure 4-3 Portable Device Current from Charging Downstream Port

Portable Devices shall not cause the voltage between VBUS and GND to drop below VCHG_SHT_DWN under normal operating conditions. This voltage shall be measured at the Portable Device.

Figure 4-4 shows an example of how a Portable Device might limit the amount of current it draws from a Charging Port.

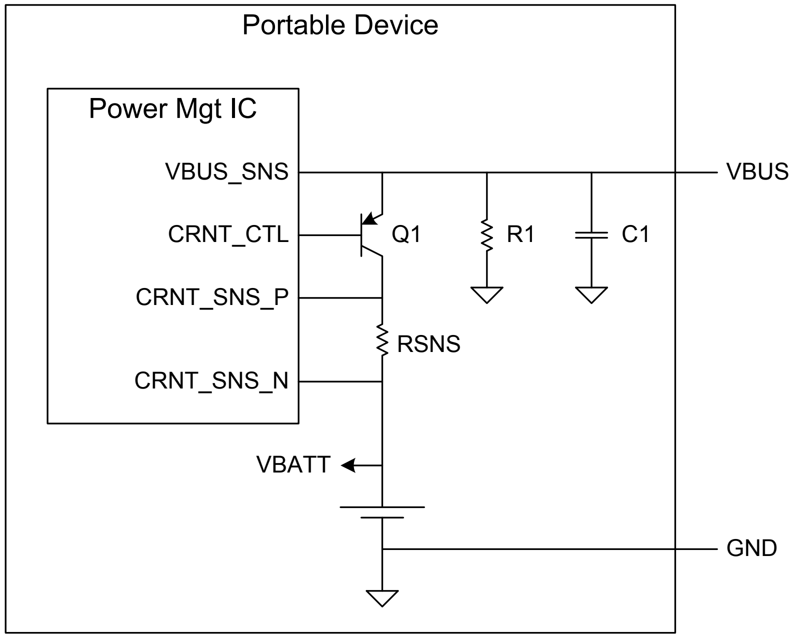

Figure 4-4 Current Limiting Example

In the example shown in Figure 4-4, the Portable Device measures how much current is being drawn from the Charging Port through RSNS. It then controls the amount of current coming into the Portable Device by adjusting the base current of Q1.

With the above implementation, the Portable Device will not cause the voltage on VBUS to go below VCHG_SHT_DWN as long as the battery voltage is greater than VCHG_SHT_DWN.

Portable Devices that cause a Charging Downstream Port to enter current limiting mode must ensure that signaling levels on D+ and D- remain within the USB 2.0 specifications.

4.3 Devices With Multiple Downstream Ports

If a device has multiple Downstream Ports, and one of these ports is a Charging Downstream Port, then the following restrictions apply.

If a Charging Downstream Port on a device goes into current limit mode, such that the VBUS voltage at that port drops below VCHG, then that event shall not cause the VBUS voltage at another Downstream Port of the same device to drop below VCHG.

If a device has at least one Charging Downstream Port and at least one Standard Downstream Port, then the marking and/or position of these ports shall be such that the user can readily distinguish the difference.

If a device has multiple Charging Downstream Ports, then all such ports shall have the same current output capability.

If a device has multiple Charging Downstream Ports, and each port is capable of outputting some level of current, it is not necessary for all of the Charging Downstream Ports to be able to output that level of current at the same time. A device is allowed to dynamically adjust the current limit of each port, as long as the current at each port remains within I_{CDP}.

A device with Downstream Ports is not allowed to also have Dedicated Charging Ports.

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 disable voltage	V_{ACA_DIS}	Note 2	6.5		V	6.7
ACA operating voltage	V_{ACA_OPR}		3.0	6.0	V	6.7
Charger Output Voltage	V_{CHG}	I_{CHG} < 500 mA	4.75	5.25	V	4.1
Charger Failure Voltage	V_{CHG_FAIL}		-.3	9.0	V	4.1
Charger Overshoot Voltage	V_{CHG_OVRSHT}			6.0	V	4.1
Charger Shut Down Voltage	$V_{CHG\_SHT\_DWN}$			2.0	V	4.1
Charger Undershoot Voltage	V_{CHG_UNDSHT}		4.1		V	4.1
Data Line Leakage Voltage	V_{DAT_LKG}		0	3.6	V	3.9
Data Detect Voltage	V_{DAT_REF}		0.25	0.4	V	3.2
D- Source Voltage	V_{DM_SRC}	Note 1	0.5	0.7	V	3.2
D+ Source Voltage	V_{DP_SRC}	Note 1	0.5	0.7	V	3.2
Logic Threshold	V_{LGC}		0.8	2.0	V	1.4.4

Notes:
1) The voltage sources, V_{DP_SRC} and V_{DM_SRC}, shall be able to source at least 250uA when the output voltage is in the specified range.

2) ACA shall be disabled for any voltage greater than V_{ACA_DIS} min.

Table 5-2 Currents

Parameter	Symbol	Conditions	Min	Max	Units	Ref
Charging Port Shutdown Current	ICHG_SHTDWN			100	mA	4.1
Dedicated Charging Port Output Current	IDCHG		0.5	1.5	A	3.5
Portable Device Current from Dedicated Charging Port	IDEV_DCHG			1.8	A	3.5
Portable Device Current from Charging Downstream Port at Low or Full Speed	IDEV_CDP_LFS			1.5	A	3.5
Portable Device Current from Charging Downstream Port at High-speed	IDEV_CDP_HS	After connecting. See Figure 3-9.		900	mA	3.5
Portable Device Current from Charging Downstream Port during chirp	IDEV_CDP_CHRP			560	mA	3.6.2
D- Sink Current	IDM_SINK		50	150	µA	3.2
D+ Sink Current	IDP_SINK	Note 1	50	150	µA	3.2
Data Contact Detect Current Source	IDP_SRC		7	13	uA	**Error! Reference source not found.**
Charging Downstream Port Output Current	ICDP		0.5		A	3.5
Leakage current on ID_OTG pin from contamination	IID_LKG_CONT		-1	1	µA	6.7
Suspend current	ISUSP	Averaged over 1sec		2.5	mA	2.2
Unit load current	IUNIT			100	mA	2.2

Notes
1) The IDP_SINK current sink must operate over a voltage range of .15V to 3.6V. As shown in Figure 3-9, IDP_SINK remains turned on till after D+ goes to a logic high.

Table 5-3 Resistances

Parameter	Symbol	Conditions	Min	Max	Units	Ref
Charger to Accessory port	RACA_CHG_ACC	VBUS_CHG @ VACA_OPR		400	mΩ	6.7
OTG to Accessory port	RACA_OTG_ACC	VBUS_OTG @ VACA_OPR		200	mΩ	6.7
Charger to OTG or Accessory ports when ACA disabled	RACA_CHG_DIS	VBUS_OTG @ VACA_DIS	10		kΩ	6.7
Charger to OTG port	RACA_CHG_OTG	VBUS_CHG @ VACA_OPR		200	mΩ	6.7
Data line leakage resistance	RDAT_LKG		300		kΩ	3.9
D- Pull-down resistance	RDM_DWN		14.25	24.8	kΩ	3.2
D+ Pull-down resistance	RDP_DWN		14.25	24.8	kΩ	3.2
Dedicated Charging Port resistance across D+/-	RDCHG_DAT			200	Ω	3.2.1
Dedicated Charging Port resistance from D+/- to VBUS / GND	RDCHG_PWR		2		MΩ	4.1
ACA ID pull-down, OTG device as A-device	RID_A	Note 1,2,3	119	132	kΩ	6.5
ACA ID pull-down, OTG device as B-device, can't connect	RID_B	Note 1,2,3	65	72	kΩ	6.5
ACA ID pull-down, OTG device as B-device, can connect	RID_C	Note 1,2,3	35	39	kΩ	6.5
ACA ID pull-down when ID_OTG pin is floating	RID_FLOAT	Note 1,2	220		kΩ	6.5
ACA ID pull-down when ID_OTG pin is grounded	RID_GND	Note 1,2		1	kΩ	6.5
OTG to ACA ground resistance	ROTG_ACA_GND			100	mΩ	6.7

Notes
1) The resistance presented on the ID_OTG pin by the ACA shall be within the specified range for all ID_OTG voltages between 0.5V and 3.6V, and shall include any leakage currents from the ACA.

2) When detecting the resistance on the ID_OTG pin of an ACA, the OTG device is required to allow for an additional leakage current of IID_LKG_CONT.

3) Nominal values for these resistors are RID_A = 124k, RID_B = 68k and RID_C = 36.5k.

Table 5-4 Capacitances

Parameter	Symbol	Conditions	Min	Max	Units	Ref
Dedicated Charging Port capacitance from D+ or D- to VBUS or GND	C_{DCHG_PWR}			1	nF	4.1

Table 5-5 Times

Parameter	Symbol	Conditions	Min	Max	Units	Ref
ID resistance to VBUS switch delay	TACA_ID_VBUS		20	40	ms	6.5
Connect to D+ sink disable	TCON_IDPSNK_DIS			20	ms	3.4
Connect to suspend current time	TCON_ISUSP			1	sec	**Error! Reference source not found.**
Data contact detect debounce	TDCD_DBNC		10		ms	**Error! Reference source not found.**
Current limit prior to LS connect	TLOCRNT_LSCON		20		ms	3.4.3
Charger shut down recover time	TSHT_DWN_REC			2	sec	4.1
Session valid to connect time for powered up peripheral	TSVLD_CON_PWD			1	sec	2.2.4
Session valid to connect for peripheral with dead or weak battery	TSVLD_CON_WKB			45	min	2.2.4
Unit current to D+ voltage under DBP	TUNIT_VDP_DBP			1	sec	3.4.4
Unit load to suspend current	TUNIT_ISUSP			1	sec	2.2.3
VBUS voltage averaging time	TVBUS_AVG			1	sec	4.1
D- voltage source enable time	TVDMSRC_EN		1	20	ms	3.4
D- voltage source disable time	TVDMSRC_DIS			20	ms	3.4
D+ voltage under DBP to connect	TVDP_CON_DBP			1	sec	3.4.4
D+ voltage source off to connect	TVDPSRC_CON		40		ms	3.4
D+ voltage source off to high current	TVDPSRC_HICRNT		40		ms	3.4
D+ voltage source on time	TVDPSRC_ON		40		ms	3.4

6. Accessory Charger Adapter

6.1 Introduction

As portable devices get smaller, it becomes more desirable for the portable device 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 portable device that has a single connector, which can also act as a handheld PC. When such a device is put into a docking station, it would act as a host to various USB peripherals, such as a hub, keyboard, mouse, printer, etc. However, while in the docking station, 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.

6.2 Adapter Ports

Figure 6-1 shows the ports of an Accessory Charger Adapter (ACA).

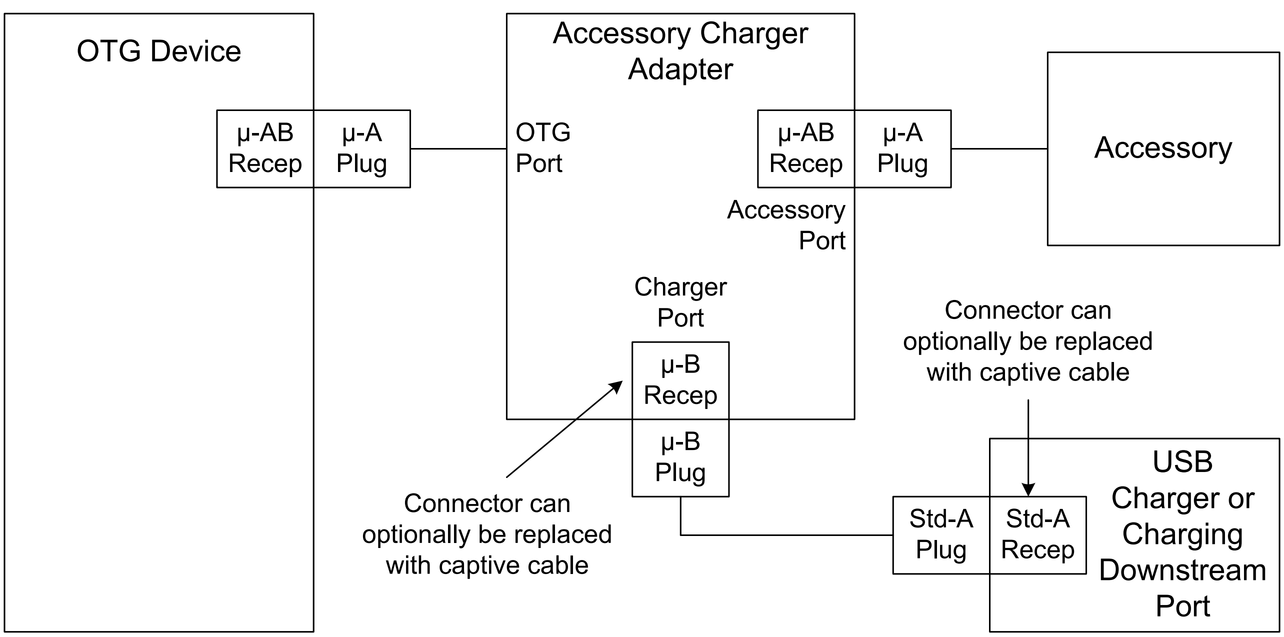

Figure 6-1 Accessory Charger Adapter Ports

An ACA has three ports. The OTG port attaches to the OTG device. The OTG Port is required to have captive cable, terminating in a micro-A plug. The micro-A plug ensures that the OTG port of the ACA can only be attached to an OTG device, since only an OTG device is allowed to have a micro-AB receptacle.

The Accessory Port attaches to an Accessory. It is required to have a micro-AB receptacle in order for it to be able to attach to a downstream B-device. Since the Accessory Port can accept either a micro-A plug or a micro-B plug, the accessory could be either an A-device or a B-device.

The Charger Port attaches to either a USB Charger or to a Charging Downstream Port. An ACA is required to have one of the following mechanical interfaces:

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

If an ACA has either a micro-B receptacle or a standard-A plug, then the ACA is required to clearly label the Charger Port as Charger Only. The reason for this is that with either a micro-B receptacle or a standard-A plug, it is physically possible to attach either a PC or an OTG device to the Charger Port. However, the Charger Port will not allow charging from either a Standard Downstream Port or an OTG device. This labeling requirement is shown in Figure 6-2.

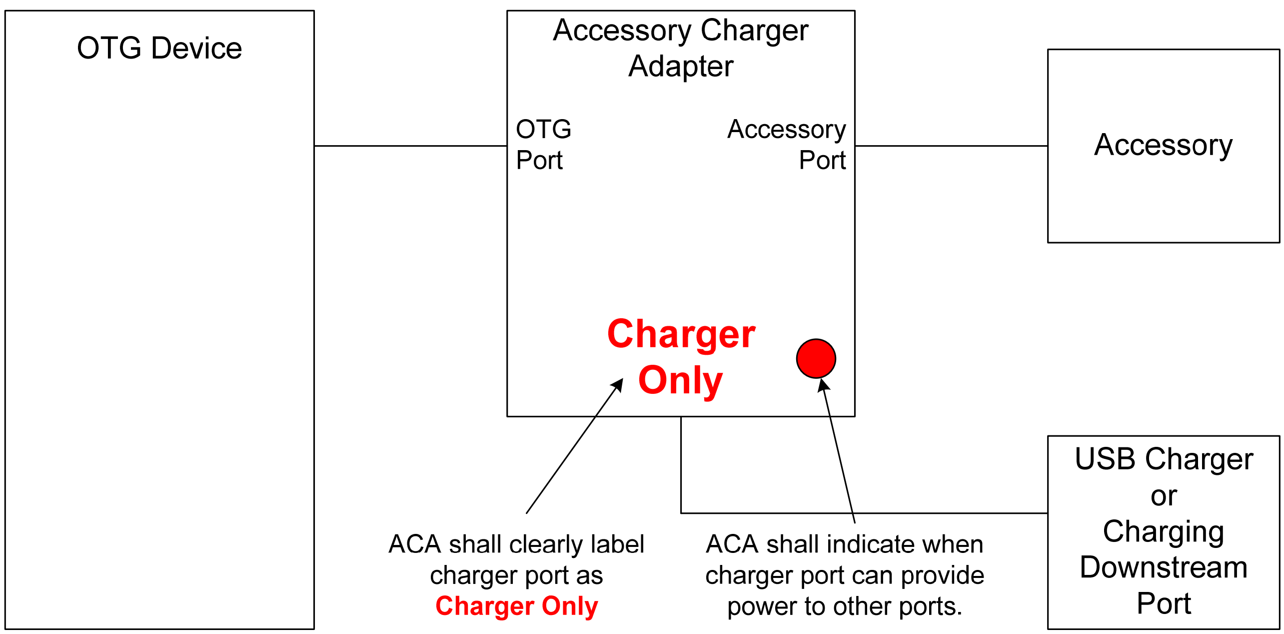

Figure 6-2 Charger Port Labeling and Indicator

The ACA shall also provide some sort of indication when the Charger Port can provide power to the OTG and Accessory Ports.

6.3 Connectivity Options

The primary application for an ACA is to allow an OTG device to attach to a charger, at the same time as it is attached to a downstream B-device. Both the OTG device and the downstream B-device can draw power from the charger, while at the same time the OTG device is communicating with the downstream B-device.

However, given the types of connectors on each of the ACA ports, it is possible to attach different types of devices to each port.

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

Table 6-1 Connectivity Options

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

The ACA does not allow data communication through the Charger Port. The ACA only allows charging from the Charger Port when a USB Charger is attached. It does not allow charging from the Charger Port whenever a Standard Downstream Port 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 possible or necessary to support SRP, since VBUS is already asserted at both the OTG Port and Accessory Port.

When both the OTG Port and Accessory Port are drawing current from the Charger Port, it is up to the OTG device to manage current from the Charger Port. A USB Charger is required to provide a minimum of I_{DCHG}. If the OTG device knows that the accessory is drawing less than I_{DCHG} min, then the OTG device can draw whatever is not being drawn by the accessory and ACA. The OTG device is also allowed to draw current from the USB Charger such that the USB Charger goes into current limit mode. However, the OTG must manage this such that the voltage on VBUS_ACC remains high enough to support operation of the accessory.

6.4 Architecture

Figure 6-3 shows the architecture of an ACA.

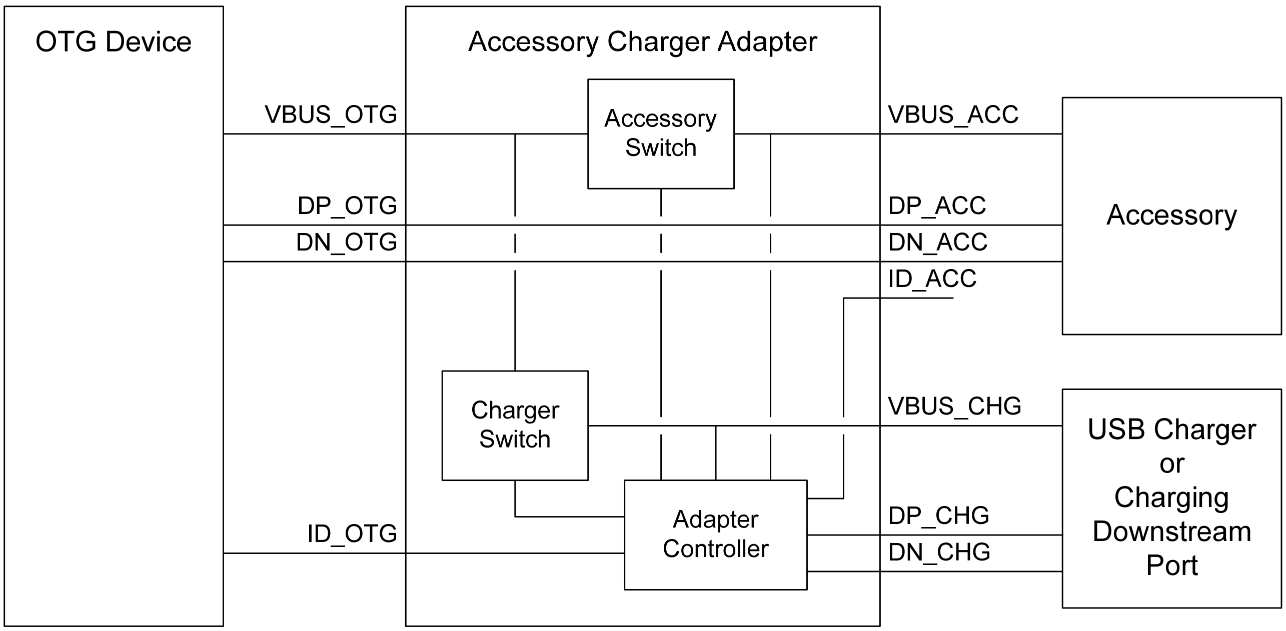

Figure 6-3 Accessory Charger Adapter Architecture

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, (grounded, RID_A, RID_B, RID_C or floating)
- using the DP_CHG and DN_CHG pins to detect if a charger is attached to the Charger Port
- sensing the voltage on the VBUS_ACC pin
- controlling the Charger and Accessory Switches

6.5 Modes of Operation

The operation of the 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 Modes of Operation

Row	Charger Port	Accessory Port	VBUS_ ACC In	ID_ACC	Charger Switch	Access Switch	ID_OTG	OTG Device
					Note 1	Note 1		
1	non-charger	nothing	low	float	open	closed	RID_FLOAT	B-dev
2	non-charger	B-device	low	ground	open	closed	RID_GND	A-dev
3	non-charger	A-dev off	low	float	open	closed	RID_FLOAT	B-dev
4	non-charger	A-dev on	high	float	open	closed	RID_FLOAT	B-dev
5	charger	nothing	low	float	closed	open	RID_B	B-dev
6	charger	B-device	low	ground	closed	closed	RID_A	A-dev
7	charger	A-dev off	low	float	closed	open	RID_B	B-dev
8	charger	A-dev on	high	float	closed	open	RID_C	B-dev

Note 1: Open refers to the high impedance state of the switch. Closed refers to the low impedance state of the switch.

In order for the ACA to detect that a USB Charger is attached to the Charger Port, it checks for VBUS, and also checks the data lines using the method described in Section 3. If a USB Charger is not detected, then the ACA leaves the Charger Switch open, and rows 1 to 4 in Table 6-2 apply. Thus, if a Standard Downstream Port were attached to the Charger Port, the Charger Switch would remain open. The resistance between the ID_OTG pin and ground of the ACA shall be RID_FLOAT or RID_GND as indicated in the table.

In rows 5 and 7, a charger is attached to the 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 charger is attached to the 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 charger is attached to the 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.

In row 2, the Accessory Switch is closed, and the OTG device is outputting power to the accessory. If a USB Charger is then attached to the Charger Port, the ACA will transition to row 6, and the Charger Switch will be closed. The OTG device will detect that the ID pin resistance has changed to RID_A, and should stop driving a voltage onto its VBUS pin. After the ACA closes the Charger Switch, and before the OTG device stops driving VBUS, there is brief time during which both the USB Charger and the OTG device are driving VBUS. This overlap prevents the accessory from losing power, and potentially needing to be powered up again. Due to this overlap, both the OTG device and the USB Charger are required to tolerate having a voltage less than VCHG max driven on VBUS at the same time as they are outputting a voltage on VBUS.

When transitioning from row 4 to row 8, the ACA is required to open the Accessory Switch and close the Charger Switch a time of TACA_ID_VBUS before changing the ID_OTG resistance. This allows for the case where a PC is attached to the Accessory Port. The OTG device should not start drawing a current of IDEV_DCHG from the ACA until after the Charger Switch has been closed

When transitioning from row 8 to row 4, the ACA is required to change ID_OTG resistance a time of TACA_ID_VBUS before closing the Accessory Switch and opening the Charger Switch. This allows for the case where a PC is attached to the Accessory Port. The OTG device should reduce its current to that allowed by the PC before the Accessory Switch closes.

6.6 Legacy Considerations

Previous versions of the OTG supplement only define the floating and ground states on the ID pin. An impedance to ground on the ID pin of greater than 100k was defined to be the floating state, whereas impedances between 10ohms and 100k could be interpreted by a legacy OTG device as either ground or floating. Thus, a legacy OTG device could incorrectly interpret resistances of RID_A, RID_B and RID_C as either grounded or floating.

If a legacy OTG device interpreted the RID_A resistance as floating, then:

- it would not be aware of the opportunity to draw IDCHG from VBUS
- it would default to peripheral, when it should default to host

If a legacy OTG device interpreted the RID_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 a legacy OTG device interpreted the RID_B resistance as floating, then:

- it would not be aware of the opportunity to draw up to IDCHG 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 a legacy OTG device interpreted the RID_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 a legacy OTG device interpreted the RID_C resistance as floating, then:

- it would not be aware of the opportunity to draw up to IDCHG from VBUS

6.7 Requirements

An ACA is required to draw less than ISUSP from its Charger Port when anything other than a USB Charger is attached to it.

An ACA is required to draw less than ISUSP from its Accessory Port when a USB Charger is attached to the Charger Port.

The resistance between the VBUS_CHG and VBUS_OTG pins of an ACA shall be RACA_CHG_OTG when the Charger Switch is closed in Table 6-2, and the voltage on VBUS_CHG is at VACA_OPR.

The resistance between the VBUS_CHG and VBUS_ACC pins of an ACA shall be RACA_CHG_ACC when the Charger Switch and Accessory Switch are closed in Table 6-2, and the voltage on VBUS_CHG is at VACA_OPR.

The resistance between the VBUS_OTG and VBUS_ACC pins of an ACA shall be RACA_OTG_ACC when the Charger Switch and Accessory Switch are closed in Table 6-2, and the voltage on VBUS_CHG is at VACA_OPR.

The resistance between the VBUS_CHG and either the VBUS_OTG or VBUS_ACA pins of an ACA shall be RACA_CHG_DIS when the voltage on the VBUS_CHG pin is VACA_DIS.

The resistance between the internal ground of the ACA and the ground pin of a micro-AB receptacle attached to the OTG port of an ACA shall be ROTG_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 charger, OTG device and accessory are all attached to an ACA, then under worst case conditions of ACA resistance, charger output voltage, OTG current and accessory current, the voltage on the VBUS_OTG and VBUS_ACC pins may not be above 4.4V. It is the responsibility of the OTG device to ensure that the accessory has enough voltage to operate, or to inform the user that this configuration is not supported.

6.8 Docking Station

The operation of the ACA defined in this section can also be used to implement a docking station, such as the example configuration shown in Figure 6-4.

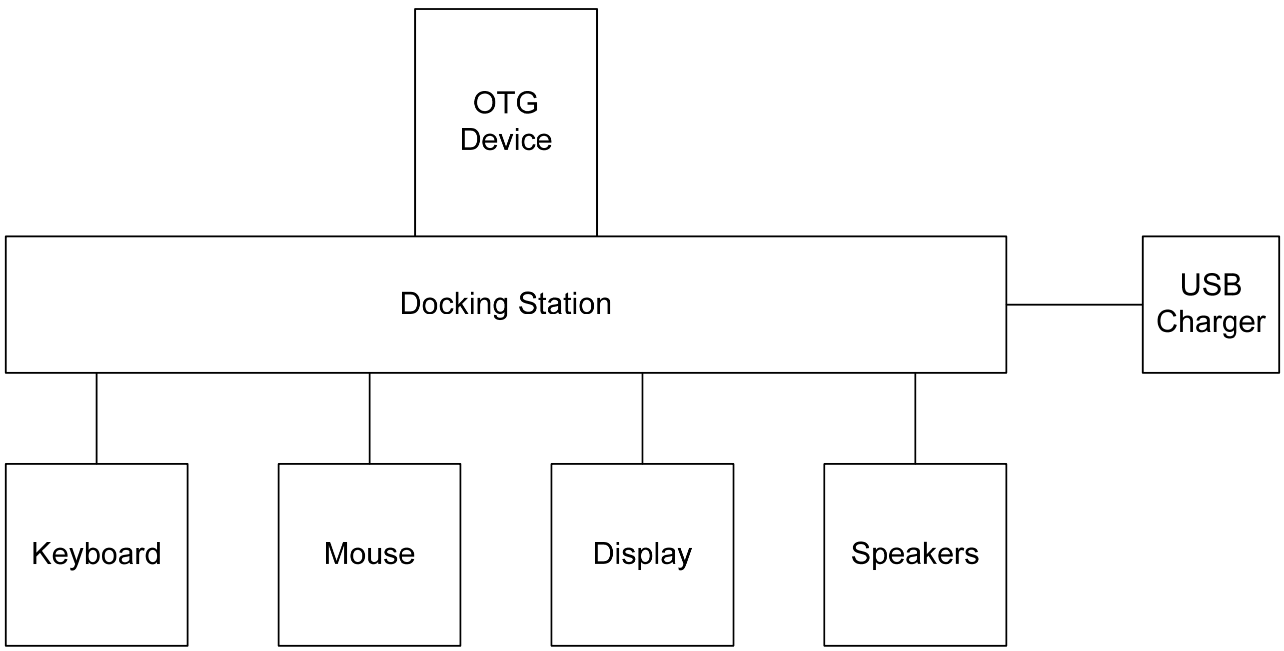

Figure 6-4 Docking Station

In this case, the docking station would contain a hub, and the OTG device would always act as host to the hub. The charger would provide power for the OTG device, as well as for the docking station and any peripherals that were attached.