On-The-Go and Embedded Host Supplement to the USB Revision 2.0 Specification

Revision 2.0 version 1.1a

July 27, 2012

Revision History

Revision	Issue Date	Comment
0.7	11/07/2000	initial draft
1.0	12/18/01	first release
1.0a	June 24, 2003	Add definition of "OTG Device", clarify short versus long debounce, Update contributor list, set copyright information, and apply minor editorial changes to all sections
1.2	April 4, 2006	Reformat all sections. Clarify sections 3.3, 5.1.1 and 6.9.1.1. Add section 5.3.12. Skip version 1.1 to eliminate ongoing confusion with rev 1.1 of the USB core specification. Replace "DRD" and "Dual Role Device" with "OTG and "On-The-Go Device". Clarify SRP and HNP usage in section 5.3.1 and 6.1, respectively. Add section 6.6.6.1 HS Electrical Test Mode Support – text from Embedded HSET document. Delete classes from TPL.
1.3	December 5, 2006	Refer to the USB 2.0 specification and the Micro-USB supplement for all connector and cable assembly information and replace mini-connector references with micro-connector references
2.0	May 8, 2009	Supplement now covers all types of Targeted Hosts (new definition) including OTG devices and Embedded Hosts. Document restructuring and consolidation of document content. Updated introduction. Clarification of operation, user experience (including symmetry principle), TPL and no silent failures requirements. Dynamic role swaps during active connections (HNP polling). New power saving protocol (ADP). Removal of VBUS pulsing. HW changes enabling support for USB battery charging requirements and general HW design simplification. Updated definitions for power supply operation. Relaxation of some protocol timing parameters. Optimization of state machine behavior. Appendix includes operational sequence diagrams and ADP calculations/examples.
2.0 plus errata and ECN	June 4, 2010	Includes errata changes from May 25,2010 and the ECN for testability April 2 2010.
2.0 plus errata and ECN	July 14, 2011	Includes errata changes from July 14, 2011.
2.0 version 1.1	April 17, 2012	Changes to allow Embedded Hosts to use the Micro-AB receptacle. Changes to enable OTG Devices which do not support role swapping. Removed footnote requiring specific accuracy for timer values. Clarify that the A-peripheral OTG descriptor usage is undefined.

Revision	Issue Date	Comment
2.0 version 1.1a	July 27, 2012	Fixed issues with hotlinks and Section numbering. Captions moved above figures. Editorial issues corrected. Clarified operation with respect to Power Delivery insertion detect. Changed VBUS decay criteria in Section 4.2.4. Removed the term “dual-role” from Section 7 and clarified usage of state diagrams depending on the level of HNP support. Added state diagram for an EH with a Micro-AB.

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1 Introduction

1.1 Overview

The Universal Serial Bus (USB), originally designed as an interface between PCs and peripherals, has become the most successful general-purpose PC interface in the history of computing.

By definition, USB communication occurs between a host and a peripheral. The original intent was to place the heavier workload on the PC (host) and to allow USB peripherals to be fairly simple. Accordingly, the USB specification requires that PCs:

- provide power to peripherals (0.5A at ~5V)
- support all defined speeds (low-speed, full-speed and high-speed)
- support all defined data flow types (control, bulk, interrupt and isochronous)

As computing resources have become less expensive, the line between PCs and other products has blurred. Today many devices that are not PCs in the classic sense have a need to connect directly to peripherals: Printers connect directly with cameras, for example, or mobile phones may need to connect to USB headsets.

These non-PCs have the computing resources to manage a USB host function, but they need to function in ways that differ from standard PC hosts. Although they will provide host capability for some devices, it's unreasonable to require them to support the full range of USB peripherals. For example, connecting a camera to a printer makes a lot of sense, but the printer manufacturers may not think it is quite as important for the printer to support a USB GPS dongle. Because this is new territory for USB, developers need a way to understand what USB functionality they need to provide and what functionality is not required.

This specification defines these non-PC hosts as Targeted Hosts. A Targeted Host is a USB host that supports a specific, targeted set of peripherals. The developer of each Targeted Host product defines the set of supported peripherals on a Targeted Peripheral List (TPL). A Targeted Host needs to provide only the power, bus speeds, data flow types, etc., that the peripherals on its TPL require.

There are two categories of Targeted Hosts:

1. **Embedded Hosts**: An Embedded Host (EH) product provides Targeted Host functionality over one or more Standard-A or Micro-AB receptacles. Embedded Host products may also offer USB peripheral capability, delivered separately via one or more Type-B receptacles.

2. **On-The-Go**: An OTG product is a portable device that uses a single Micro-AB receptacle (and no other USB receptacles) to operate at times as a USB Targeted Host and at times as a USB peripheral. OTG devices must always operate as a standard peripheral when connected to a standard USB host.

OTG devices can also be attached to each other. This specification enables the underlying driver components to optionally swap between the role of either USB host or USB peripheral, without needing to physically turn the cable around.

1.2 Related Documents

This is not a stand-alone document. It is a supplement to [USB2.0]. Any aspects of USB which are not specifically changed by this supplement are governed by [USB2.0].

The following referenced documents can be found on the USB-IF website www.usb.org:

[Micro-USB1.01]	*Universal Serial Bus Micro-USB Cables and Connectors Supplement to the USB 2.0 Specification,* revision 1.01.
[USB2.0]	*Universal Serial Bus R*evision 2.0 Specification including ECNs and errata.
[USBBattery1.2]	*USB Battery Charging Specification, revision 1.2*.
[OTG and EH Compliance1.0]	*USB OTG and EH Compliance Plan, revision 1.0*
[USBPower1.0]	*USB Power Delivery Specification, revision 1.0*

1.3 Acronyms and Terms

This section lists and defines terms and abbreviations used throughout this specification.

ACA	Accessory Charger Adapter (see [USBBattery1.2]).
A-Device	Device with a Standard-A receptacle or a device with a Micro-A plug inserted into its receptacle. The A-device supplies power to VBUS and is host at the start of a session. If the A-device is On-The-Go (equipped with a Micro-AB receptacle), it may relinquish the role of host to an On-The-Go B-device under certain conditions (see Section 3.1).
A-Host	A-device acting in host role
A-Peripheral	A-device acting in peripheral role
A-Port	USB port with an A plug inserted into its receptacle. This port acts as an A-device.
ADP	Attach Detection Protocol. A protocol which enables an OTG device or EH to detect when a remote device has been attached or detached (see Section 3.3.5).
ADP-capable	Device which is able to perform ADP probing and ADP sensing[1].
ADP probing	This enables the local A-device or B-device to probe VBUS and detect a change in attachment status.
ADP sensing	This enables the local B-device to detect ADP probing generated by an attached device. ADP sensing is not a requirement for A-devices.
Application	A generic term referring to any software that is running on a device that can control the behavior or actions of the USB port(s) on a device.
Attach	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.
B-Device	Device with: • a Standard-B receptacle or, • Mini-B receptacle, or • Micro-B receptacle, or • Micro-AB receptacle with either a Micro-B plug or no plug inserted into its receptacle, or

[1] An ADP-capable EH is not required to do ADP sensing since it is not able to operate in the B-device position.

	• a captive cable ending in a Standard-A or Micro-A plug. The B-device is a peripheral at the start of a session. If the B-device is On-The-Go (equipped with a Micro-AB receptacle), it may be granted the role of host from an On-The-Go A-device (see Section 3.1).
B-Host	B-device acting in host role
B-Peripheral	B-device acting in peripheral role
B-Port	USB port with a B plug inserted into its receptacle. This port acts as a B-device.
Connect	This specification makes a distinction between the words “attach” and “connect”. 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.
EH	Embedded Host.
Embedded Host	A product that has one or more Standard-A and/or Micro-AB receptacles supported by a USB Host Controller. Embedded Hosts have a particular set of targeted peripherals, as described in their TPL.
FS	Full Speed (as defined in [USB2.0]).
HS	High Speed (as defined in [USB2.0]).
Host	A physical entity that is attached to a USB cable and is acting in the role of the USB host as defined in [USB2.0]. This entity initiates all data transactions and provides periodic Start of Frames (SOF’s).
HNP	Host Negotiation Protocol (see Section 3.3.2).
ID	Identification. Denotes the pin on the Micro connectors that is used to differentiate a Micro-A plug (ID pin is FALSE) from a Micro-B plug (ID pin is TRUE). See [Micro-USB1.01] for details.
LPM	Link Power Management (as defined in [USB2.0]).
LS	Low Speed (as defined in [USB2.0]).
OTG	On-The-Go.
OTG device	Device that provides both host and peripheral capabilities over a single Micro-AB receptacle, as outlined in Section 2.
Peripheral	A physical entity that is attached to a USB cable and is currently operating as a “device” as defined in [USB2.0]. The peripheral responds to low level bus requests from the host.
Peripheral-only B-device	A device with a compliant B-side connector which can act only in peripheral mode.
PET	Protocol and Electrical Tester. A test unit which is capable of performing the tests specified in [OTG and EH Compliance1.0].
Pre-session Calibration	ADP probe measurement taken when a pre-session measurement is not available. In this case, a measurement is taken, and a new session is initiated (or requested) to determine whether a remote device is attached.
SE0	Single Ended Zero (as defined in [USB2.0]).
Session	The period of time that VBUS is powered (see Section 3.3.1).
SOF	Start of Frame (as defined in [USB2.0]).
SRP	Session Request Protocol (see Section 3.3.1).

SRP-capable	Device which is able to generate or respond to SRP signaling.
Targeted Host	A host that is only required to support the peripherals on its Targeted Peripheral List. OTG devices and Embedded Hosts both have Targeted Host functionality.
Targeted Peripheral List	A list of USB peripherals that a particular Targeted Host can support (see Section 3.4).
TPL	Targeted Peripheral List.
USB	Universal Serial Bus.
USB-IF	USB Implementers Forum (See www.usb.org).

2 Operational overview

2.1 Introduction

This section describes a variety of OTG and Embedded Host use cases. Each use case pairs a type of Targeted Host with a particular type of peripheral and describes how the various protocols in this document may be used in each case.

2.1.1 Powering the USB port

For the use cases described below there are a variety of ways to initiate a USB connection. However, in each case, power must first be provided to the attached device. The most basic cases involve either:

- A wall-powered Embedded Host that provides power via the downstream port at all times or
- An insertion-based A-device which provides power via its port as soon as an A-plug is attached and continues to do so in either host or peripheral role:
    - An OTG A-device or EH can detect insertion of a Micro-A plug into a Micro-AB receptacle by detection of the ID pin becoming FALSE.
    - Embedded Hosts can detect insertion of a Standard-A plug into a Standard-A receptacle by using mechanisms described in [USBPower1.0].

Since a USB A-plug is attached to the power provider in both of these cases, in the following text we will refer to this as the USB A-port. If the Embedded Host or OTG A-device does not normally provide power via its USB A-port, when not actively communicating with another device, there are several ways to restore this power supply.

1. If the only host applications that use USB are user-initiated, then power is provided via the USB A-port when the user initiates one of these functions.
2. Any OTG A-device or Embedded Host that does not provide power via its USB A-port while a cable is attached, and has an SRP-capable peripheral on its Targeted Peripheral List, should power the USB A-port in response to user input on the attached device.
3. If the device has applications that will run automatically as soon as attachment to a particular device is detected, then it is required in this particular case that these devices support the Attach Detection Protocol (ADP). The device detects device attachment changes using ADP.
    a. When a change is detected, by an A-device it will start providing power via the USB A-port. If no device is connected, power is turned off again. If the presence of a device is detected, then the A-device queries the device type, etc.
    b. When a change is detected by a B-device it will issue a request for power to be turned on (SRP). If no device is connected power will not be provided. If power is detected then the B-device will respond to queries for device type etc.

2.1.2 Once connected

In the simplest case, the Targeted Host only activates its host functionality in response to actions on the user interface. Consider a camera that acts as a USB host to a printer. When the user initiates the print command the Camera starts providing power via the USB A-port and checks for a suitable peripheral (printer). If one is not present an error is reported. If the attached device is a supported printer then it sends the print job and on completion may power off the USB A-port.

In a similar example a printer with an Embedded Host port supports mass storage devices. While the printer is continually powered with mains power and not in sleep, it constantly provides power via the USB A-port. When a USB Flash Drive is attached it immediately connects. Once the Embedded Host learns that it has a mass storage device connected, the printer presents an interface to the user to allow her to select which of the pictures stored on the mass storage device to print.

A slightly more complicated example is a mobile device that supports HID devices. Since the power on the mobile device is at a premium, it does not continually provide power via the USB A-port even when a Micro-A plug is attached. However it is still able to detect device attachment changes to the Micro-B plug using ADP. When a change is detected, it powers the A-port. If the keyboard is detected, it will start providing power via the USB A-port, and start an application that responds to keystrokes.

A parallel example with the same user experience would be a mobile device that doesn't support ADP and a keyboard with a small battery that supports SRP. The user attaches the keyboard presses a button. Since the USB A-port is not yet providing power the keyboard requests that the USB A-port should start providing power. The phone detects the request, starts providing power via the USB A-port, and starts an application that handles the keystrokes.

2.2 OTG device to standard Host or Embedded Host

In this case, one device is an OTG device, and the other is a standard Host or Embedded Host. The OTG device meets all of the requirements of a standard USB peripheral. When the OTG device is attached to the standard Host or Embedded Host, the host queries the OTG device and treats it like a peripheral.

2.3 Targeted Host to peripheral-only B-device

In this case, one device is a Targeted Host (OTG device or EH), while the other is a peripheral-only B-device. When the Targeted Host detects that a peripheral-only B-device is attached, the Targeted Host responds by querying the peripheral-only B-device. If the Targeted Host supports the peripheral-only B-device, it will make the peripheral-only B-device available to applications running on the host. When applications on the Targeted Host wish to use the peripheral-only B-device it will be taken into use.

2.4 OTG device to OTG device

In this case, both devices are OTG devices supporting symmetrical operation (see Section 3.2). For two attached OTG devices, when the user interacts with one OTG device the user is able to access or control the second OTG device using applications running on the first OTG device.

If the user launches an application on the second OTG device while the first OTG device is still using the bus, then the second OTG device prompts the user if it is okay to terminate any current operations. If the user agrees, then current operations are terminated, and the second OTG device takes control of the interface.

2.5 Unattached Targeted Host

In this case the Targeted Host is not yet attached to a peripheral. The user launches an application on the Targeted Host, where the application is capable of accessing the USB interface. The application determines that nothing is attached to the USB interface and therefore does not list any OTG devices or peripherals as being available[2].

[2] The A-device can use a variety of methods to determine that there is no device available: 1) Lack of A-plug insertion, 2) no connect in response to VBUS assertion.

3 OTG and EH key features

This section describes the key features of the OTG and EH supplement and explains how these are addressed in the following sections of the supplement.

3.1 Connectors, cable assemblies and cable adapters

3.1.1 OTG devices

An OTG device is required to have one, and only one USB connector: a Micro-AB receptacle as defined in [Micro-USB1.01]. This receptacle is capable of accepting either a Micro-A plug or a Micro-B plug attached to any of the legal cables and adapters defined in [Micro-USB1.01].

The OTG device with the A-plug inserted is called the A-device and is responsible for powering the USB interface when required and by default assumes the role of host. The OTG device with the B-plug inserted is called the B-device and by default assumes the role of peripheral. An OTG device with no plug inserted defaults to acting as a B-device. If an application on the B-device requires the role of host, then the HNP protocol is used to temporarily transfer the host role to the B-device.

OTG devices attached either to a peripheral-only B-device or a standard/embedded host will have their role fixed by the cable since in these scenarios it is only possible to attach the cable one way around.

3.1.2 SRP-capable peripheral-only B-devices

SRP-capable peripheral-only B-devices are required to have a compliant B-device side connector as for other peripheral-only B-devices, for example: a Micro-B or captive connector.

3.1.3 Embedded Hosts

An Embedded Host is required to have either one or more Standard-A receptacles as defined in [USB2.0] and/or one or more Micro-AB receptacles as defined in [Micro-USB1.01]. Optionally an Embedded Host may also contain one or more Type-B receptacles but these must be implemented such that the user is unlikely confuse the EH with a USB hub. Since the Standard-A plug does not contain an ID pin, an EH is not able to automatically power the USB bus on plug insertion unless ADP is also supported.

Where an Embedded Host employs a Micro-AB as defined in [Micro-USB 1.01], it is possible for a user to attach another USB host to the Embedded Host via a Micro-B plug. In order to avoid back-driving VBUS in such a scenario an Embedded Host which supports Micro-AB shall only enable VBUS when ID pin becomes FALSE as defined in [Micro-USB1.01]. On detection of a valid voltage, above the range defined by VOTG_SESS_VLD, on VBUS an Embedded Host should display a non-silent failure message to the end user.

3.2 Symmetry

Symmetrical operation of OTG devices should be supported. The level of symmetry exhibited depends on the type of devices attached to each other. The following describes device operations which shall be exhibited when symmetrical operation is supported by both devices.

OTG devices attached to each other should demonstrate the same behavior to the end user regardless of whether they are attached as the A-device or the B-device. When the user interacts with one OTG device, this causes a session to be started, and the user is able to access or control the second OTG device using applications running on the first OTG device. During a session, the role of host can be transferred back and forth between the A-device and the B-device any number of times, using HNP. If

the user agrees, then current operations are terminated, and the second OTG device takes control of the interface. The session ends when applications running on it have completed.

The A-device shall always enable the B-device for HNP whenever it requests to become host (see Section 3.3.3). Similarly, the B-device shall suspend whenever the A-device requests to become host. OTG devices attached to non-OTG USB hosts (standard or Targeted) or peripheral-only B-devices will not demonstrate symmetry since the host and device roles are fixed by the cable.

The symmetry principle also has implications for power management in OTG devices. When choosing from the available configurations of an attached peripheral, an OTG device acting as host shall consider the bMaxPower value in exactly the same way regardless of whether it is acting as A-Host or a B-Host. This prevents a B-Host from selecting a configuration for an A-Peripheral that it would not be able to support when it acts as an A-Host.

3.3 Protocols

3.3.1 Session Request Protocol

In order to conserve power, an A-device is allowed to leave VBUS turned off when the bus is not being used. The Session Request Protocol (SRP) allows a B-device to request the A-device to turn on the power supply to the USB interface (VBUS) and start a session. A session is defined as the period of time that VBUS is powered. The session ends when VBUS is no longer powered.

The details of this protocol are found in Section 5.1.

3.3.2 Host Negotiation Protocol

The Host Negotiation Protocol (HNP) allows the host function to be transferred between two directly connected OTG devices and eliminates the need for a user to switch the cable connections in order to allow a change in control of communications between the devices. HNP will typically be initiated in response to input from the user or an Application on the OTG B-device. HNP may only be implemented through the Micro-AB receptacle on a device. The A-device is always responsible for powering the USB interface regardless of whether it is acting in host or peripheral role[3]. HNP support is optional for OTG devices.

At the start of a session, the A-device defaults to having the role of host. During a session, the role of host can be transferred back and forth between the A-device and the B-device any number of times, using HNP.

The details of this protocol are found in Section 5.2.

3.3.3 HNP Polling

HNP polling is a mechanism which allows the OTG device currently acting as host to determine when the other attached OTG device wishes to take the host role. When an OTG host, which supports HNP, is connected to an OTG peripheral which also supports HNP it shall poll the peripheral regularly to determine whether it requires a role-swap and grant this at the earliest opportunity.

The details of this protocol are found in Section 6.3.

[3] See [USBBattery1.2] for an exception case with ACA

3.3.4 Suspend/Resume/Remote Wakeup

An Embedded Host, OTG A-host, OTG B-peripheral or peripheral-only B-device may use the [USB2.0] mechanisms of suspend, resume and remote wakeup, including LPM, for power mangement. In this case the OTG and EH supplement shall add no new requirements in addition to those in [USB2.0]. A-devices attached to other SRP-capable devices may also manage their power by ending the session.

OTG B-hosts and OTG A-peripherals should not use the [USB2.0] mechanisms of suspend, resume and remote wakeup for power management (suspend shall be used during HNP) including LPM since the resulting behavior is indeterminate.

More details are found in Section 5.3.2.

3.3.5 Attach Detection Protocol

The Attach Detection Protocol (ADP) allows an SRP-capable Targeted Host or peripheral-only B-device to detect when a remote device has been attached or detached when VBUS is not present.

More details are found in Section 5.4.

3.4 Capability Limitation

Targeted Hosts are required to be fully compliant with USB-IF specifications including this OTG and EH supplement, [USB2.0] and [USBBattery1.2] where battery charging or ACA are supported. However a given Targeted Host is not required to support the full suite of functionality defined in these specifications. The functionality supported by a Targeted Host depends on which devices are contained on the TPL and whether or not the A-device turns off power to the USB interface.

3.4.1 Targeted Peripheral List

A Targeted Host is not required to support operation with all types of USB peripherals. It is up to the manufacturer of each Targeted Host to declare which peripherals the host will support and provide a list of those peripherals. This is called the Targeted Host's "Targeted Peripheral List" (TPL). The TPL shall accurately represent the device classes supported by the Targeted Host. The list of peripherals supported by a Targeted Host can be longer than the declared TPL provided that the TPL contains peripherals corresponding to each of the device classes supported by the Targeted Host. A product which is not declared on the TPL, but which is otherwise supported by the Targeted Host (e.g. by class), shall not be reported to the user as an unsupported device.

For example: The Targeted Host has a Target Peripheral List containing a peripheral supporting device class "X" but does not contain a peripheral supporting device class "Y". The Targeted Host must generate a failure message when a peripheral supporting device class "Y" is detected but is allowed to support any peripheral of device class "X" without reporting a failure.

OTG product designers should be aware that although they are free to decide which peripherals their product will support as a host, they have no control over which hosts will support them as a peripheral. Any product using the Micro-AB receptacle must support the various OTG protocols needed for other OTG products to properly support them as a peripheral, no matter what the cable direction or bus power state.

[OTG and EH Compliance1.0] describes the Targeted Peripheral List in more detail.

3.4.2 Device Class Support

When determining whether or not a peripheral is supported Targeted Hosts will need to either examine the peripheral's Vendor ID (VID) and Product ID (PID) or the peripheral's supported device classes. If an

OTG device does not support HNP as B-device, in this case when the OTG device is an A-device it is not allowed to support any OTG device in order to maintain symmetry. This ensures symmetry regardless of the direction of cable attachment.

3.4.3 Hub Class Support

Since the hub class is defined in [USB2.0], hubs may be listed as a supported class on the TPL provided that all USB-IF certified hubs can be supported and that the Targeted Host can supply the 5 unit loads required by bus-powered hubs. If this is not the case then specific makes and models of hub must be listed on the TPL.

3.4.4 Output Power

A Targeted Host shall provide sufficient power to each peripheral on its TPL in at least one supported configuration.

3.4.5 SRP Support

Any A-device, including a PC or laptop, is allowed to respond to SRP. Any B-device, including a peripheral-only B-device, is allowed to initiate SRP. An OTG device which is able to support HNP as a B-device shall also be able to initiate SRP.

A Targeted Host is required to respond to SRP if it ever turns off VBUS while an A-plug is inserted. A Targeted Host that keeps VBUS turned on whenever an A-plug is inserted will never have a need to respond to SRP.

3.4.6 ADP Support

Any OTG device, EH or SRP-capable peripheral-only B-device is allowed to do ADP probing. An OTG B-device or peripheral-only B-device shall also support ADP sensing if they support ADP probing.

3.4.7 HNP Support

OTG devices are not required to support HNP role swapping.

OTG devices should support HNP as an A-device. OTG devices should also support HNP as a B-device if they have any OTG device listed on their TPL. OTG devices which support HNP as a B-device shall also support HNP as an A-device,

Table 3-1 shows the possible combinations of HNP support for OTG devices.

Table 3-1: Role swapping support combinations

	HNP support as A-device	HNP support as B-device
Supported	**No**	**No**
Supported	**Yes**	**No**
Supported	**Yes**	**Yes**
Not supported	**No**	**Yes**

3.4.8 Functions and Configurations

A Targeted Host shall support at least one device function provided by each peripheral on its TPL. It is strongly recommended that a Targeted Host is able to parse and evaluate multiple configuration descriptors in the following situations:

- A device function is supported by class or
- Peripherals with multiple configurations are included on its TPL

Where such a Targeted Host is battery powered, it is recommended that this host choose a configuration with sufficiently low power consumption. To maximize interoperability with such battery powered Targeted Hosts, it is strongly recommended that OTG devices acting as peripherals and SRP-capable peripheral-only B-devices offer at least one configuration requiring less than or equal to the minimum rated output current of an A-device or less (see Section 4.2.1).

3.4.9 Operating Speeds

An OTG device shall be able to support full-speed peripherals. Support for low and high speeds is optional, and is dependant on the OTG device's TPL. An OTG device shall be able to operate as a full-speed peripheral. Operation as a high-speed peripheral is optional. Operation as a low-speed peripheral is prohibited.

An Embedded Host shall support one of the following combinations of speeds based on its Targeted Peripherals List:

- High-speed, full-speed and low-speed
- High-speed and full-speed
- Full-speed only
- Full-speed and low-speed
- Low-speed only

Should a particular speed be not supported an appropriate message shall be displayed indicating the failure to the user.

3.5 No Silent Failures

A Targeted Host is required to have means for communicating messages to the user so that they are made aware of any failures which have occurred during device operation. A message could cover any appropriate mechanism for reporting to the user including textual messages, icons, LEDs or another means deemed suitable for this purpose. Targeted Hosts are required to report such failures to the end user but this supplement does not mandate the messages themselves or the user interface mechanism to be used for such messages. Insofar as is possible, the messages shall be self explanatory, and shall not require the user to reference a manual or other additional material.

When two OTG devices are attached messages shall be displayed on the device the user is currently using; typically the OTG device acting in host role.

Different messages for hubs and non-hubs shall be displayed. If the attached peripheral is an unsupported hub, the Targeted Host shall be able to display a message indicating that the attached hub is not supported; this message shall be different from the message indicating an unsupported peripheral. When a supported hub is attached a Targeted Host shall also display a message indicating when:

- more than the maximum tier of supported hubs attached to the Targeted Host are attached or
- more than the maximum number of supported peripherals are attached to hub ports or
- more than the maximum instances of a given peripheral or device class is exceeded.

Messages shall distinguish between standalone hubs and compound peripherals.
Examples of messages where devices are attached without a hub are:

- Device not supported
- Device not responding

Examples of message relating to hubs and compound devices are:

- Max hub tier exceeded
- Too many peripherals attached
- Too many peripheral instances attached

4 Electrical Characteristics

This section defines electrical specifications for USB devices that implement the protocols defined in this specification. Any parameter that is not specified in this section is unchanged from [USB2.0].

4.1 Common Characteristics

4.1.1 VBUS Leakage

If an A-device can respond to SRP, and if VBUS is not being driven, then VBUS shall decay from VOTG_SESS_VLD max to VOTG_VBUS_LKG within TSSEND_LKG. If a B-device can initiate SRP, and if VBUS is not being driven, then VBUS shall decay from VOTG_SESS_VLD max to VOTG_VBUS_LKG within TSSEND_LKG. These constraints are required so that a B-device can initiate SRP within TB_SSEND_SRP of VBUS going below VOTG_SESS_VLD.

If a device is not driving VBUS or doing ADP probing or ADP sensing, then it shall not source more than IVBUS_LKG_SRC max to VBUS when VBUS is grounded. This is required so that a local device can be detected by a remote device doing ADP probing.

An ADP-capable device shall have a VBUS resistance to ground of ROTG_VBUS (see Section 5.4.2). If a remote device were doing ADP probing, and a local device had a VBUS resistance that was too low, then the ADP probing ramp on VBUS might not cross the VADP_SNS threshold.

4.1.2 Data Line Pull-down Resistance

When an OTG device or EH is idle or acting as a host, it shall activate both the D+ and D- pull-down resistors. These resistors shall be within the range of RPD as defined in [USB2.0].

When an OTG A-device or B-device is acting as a peripheral, it shall disable the pull-down on the D+ line but shall maintain the D- pull-down.

When an OTG device changes between host and peripheral roles, the D- pull-down shall remain asserted. This prevents the D- line on the A-device from floating if the B-device is detached. An OTG device is allowed to disable both pull-down resistors during the interval of a packet transmission while acting as either a host or a peripheral.

4.2 A-device VBUS Characteristics

4.2.1 VBUS Output Voltage and Current

The rated output current of an A-device (IA_VBUS_RATED) shall be within IA_VBUS_OUT, and greater than the bMaxPower of any peripheral on its TPL (see Section 3.4.4).

After starting to drive VBUS, an A-device shall continue to drive VBUS for a time of TA_WAIT_BCON. This ensures an attached B-device has time to connect (see Section 5.1.1).

After configuring a B-device, for any steady state load current that is less than the rated current of the A-device (IA_VBUS_RATED), the average output voltage from an A-device shall be within VA_VBUS_AVG_LO (IA_VBUS_RATED ≤ 100mA) or VA_VBUS_AVG_HI (100mA < IA_VBUS_RATED). Voltage is averaged over a time of TAVG_VBUS, and includes any transient voltages due to step changes in current.

For a step change in load current with any amplitude less than or equal to the rated current of the A-device (IA_VBUS_RATED), and an edge rate of less than 100mA/usec, the transient output voltage from an A-device shall remain within VA_VBUS_TRNS_LO (IA_VBUS_RATED ≤ 100mA) or VA_VBUS_TRNS_HI (100mA < IA_VBUS_RATED).

4.2.2 VBUS Over-current Condition

After starting to drive VBUS, the output voltage from the A-device shall reach a voltage of VA_VBUS_AVG_LO min (see Section 4.2.1) within a time of TA_VBUS_RISE, providing the non-inrush load current does not exceed the rated current of the A-device (IA_VBUS_RATED). On reaching this voltage VBUS shall then behave as defined in Section 4.2.1; this is defined as being in regulation. If VBUS does not reach VA_VBUS_AVG_LO min within TA_VBUS_RISE, then the A-device shall turn off VBUS.

If an attached B-device draws less than or equal to IA_VBUS_RATED after TA_VBUS_RISE, then VBUS shall remain valid.

If an attached B-device draws more current than IA_VBUS_RATED after TA_VBUS_RISE, then VBUS may become invalid due to an overcurrent condition. If an overcurrent condition occurs then the A-device shall turn off VBUS and indicate to the user that the B-device is not supported.

4.2.3 VBUS Capacitance

An EH or OTG A-device shall have a VBUS capacitance of CA_VBUS. This ensures that it can be detected by a remote device doing ADP probing.

For an ADP-capable A-device the VBUS capacitance may be limited to CADP_VBUS by the ADP probing implementation described in Section 5.4. If other ADP probing implementations are used there must be a probe ramp that crosses VADP_SNS so detection will still work in the remote end.

An EH with multiple ports shall be designed such that attaching a peripheral to one port does not cause VBUS to go outside the range of either VA_VBUS_TRNS_LO or VA_VBUS_TRNS_HI (see Section 4.2.1) on an adjacent port.

4.2.4 ID Pin

When a Micro-A plug is attached the ID pin becomes FALSE[4] as defined in [Micro-USB1.01]. For a non-ADP-capable OTG A-device or EH implemented through a Micro-AB receptacle, whenever the application is ready to act in host or peripheral roles, VBUS is required to reach VOTG_SESS_VLD max within TA_VBUS_ATT of the ID pin becoming FALSE unless an over-current condition is reached (see Section 4.2.2). The Standard-A plug does not contain an ID pin so this requirement is not applicable to an EH implemented through a Standard-A receptacle.

To prevent backdriving VBUS shall decay to VOTG_VBUS_LKG within TSSEND_LKG of the ID pin becoming TRUE.

Section 5.4 contains requirements relating to ADP-capable devices.

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[4] See also [USBBattery1.2] for additional ID pin usages with OTG devices.

4.3 B-device VBUS Characteristics

4.3.1 VBUS Average Input Current

An unconfigured OTG or SRP-capable peripheral-only B-device shall draw an average current of less than IB_UNCFG max current from VBUS. Current is averaged over a time of TAVG_VBUS.

A configured B-device (OTG or SRP-capable peripheral-only), acting in peripheral role, shall follow the rules regarding current draw as set down in [USB2.0] including those relating to suspend current detailed in Section 7.2.3.

When a configured OTG B-device acting in peripheral role performs HNP and becomes host, it may only draw a current of IB_UNCFG max.

4.3.2 VBUS Input Voltage

A B-device (OTG or SRP-capable peripheral-only) shall be able to operate at a voltage of VB_VBUS. Standard peripherals which wish to operate correctly with Targeted Hosts should also comply with this requirement. See also [USBBattery1.2] for requirements on peripheral operating voltages with a charger or ACA.

4.3.3 VBUS Inrush and Transient Current

Upon being attached to an A-device, an SRP-capable B-device is allowed to draw an inrush charge equivalent to that stored on a capacitance of CRPB max ([USB2.0] Table 7-7) when charged to a voltage of VA_VBUS_AVG_LO max. Any transient currents generated by the B-device shall not cause the voltage on VBUS to go lower than either VA_VBUS_TRNS_LO min or VA_VBUS_TRNS_HI min.

Except for inrush current, the maximum transient current that a configured SRP-capable B-device can draw from VBUS is determined based on the following assumptions:

- the A-device output on VBUS can be modeled by:
    - a low ESR capacitor (<100 mΩ @ 100kHz) with a capacitance of CA_VBUS min.
    - a current source which can supply a current corresponding to the bMaxPower of the B-device, at the minimum average output voltage of the A-device (see Section 4.2.1).
        - a B-device with a bMaxPower ≤ 100mA shall assume an A-device average output voltage of either VA_VBUS_AVG_LO or VA_VBUS_AVG_HI.
        - a B-device with a bMaxPower > 100mA shall assume with an A-device average output voltage of VA_VBUS_AVG_HI.
- a short cable (< 0.3m) between the A-device and the B-device.

4.3.4 VBUS Capacitance

An OTG or SRP-capable peripheral-only B-device shall have a VBUS capacitance of CRPB ([USB2.0] Table 7-7). Capacitance of this capacitor, including its nominal tolerance, shall not go below the minimum value of CRPB min.

For ADP-capable B-devices the VBUS capacitance may be limited to CADP_VBUS by the ADP probing method described in Section 5.4. If other probing methods are used there must be a probe ramp that crosses VADP_SNS so detection will still work in the remote end.

4.4 Electrical Parameters

Table 4-1: Electrical Characteristics

Parameter	Symbol	Conditions	Min[5]	Max5	Units	Ref
VBUS Voltage:						
VBUS Average Voltage (low power)[6]	VA_VBUS_AVG_LO	IA_VBUS_RATED ≤ 100 mA	4.4	5.25	V	4.2.1
VBUS Average Voltage (high power)6	VA_VBUS_AVG_HI	100mA < IA_VBUS_RATED	4.75	5.25	V	4.2.1
VBUS transient voltage (low power)	VA_VBUS_TRNS_LO	IA_VBUS_RATED ≤ 100 mA	4.1	6.0	V	4.2.1, 4.3.3
VBUS transient voltage (high power)	VA_VBUS_TRNS_HI	100mA < IA_VBUS_RATED	4.4	6.0	V	4.2.1, 4.3.3
B-device operating voltage	VB_VBUS		4.0	6.0	V	4.3.2
OTG device or EH Leakage Voltage	VOTG_VBUS_LKG			0.7	V	4.1.1
ADP discharge voltage	VADP_DSCHG			0.15	V	5.4.2
VBUS noise requirement for ADP	VADP_NOISE	+ve or –ve peak voltage		10	mV	5.4.2
VBUS Current:						
A-device Output Current[7]	IA_VBUS_OUT		8[8]	5000	mA	4.2.1
B-device (OTG or SRP-capable peripheral-only) Unconfigured Average Current6	IB_UNCFG	0 V ≤ VBUS ≤ VA_VBUS_AVG_LO max or VA_VBUS_AVG_HI max		2.5	mA	4.3.1
VBUS leakage source current	IVBUS_LKG_SRC	VBUS held at ground		70	μA	4.1.1
ADP source current[9]	IADP_SRC		1.1	1.65	mA	5.4.2

[5] The parameters in this table define the limits based on the full range of operating temperatures and implementation tolerances. Manufacturers should select the tolerance and value of each parameter at room temperature necessary to pass USB-IF compliance testing. However, these parameters shall stay within the defined limits across the full range of temperatures to ensure a functional product.

[6] Averaged over TAVG_VBUS

[7] See section 7.2.1.2.1 "Over-current protection" in [USB2.0]

[8] 8mA is the minimum value sufficient to signal the presence of VBUS. Practical implementations are likely to need a select a value of IA_VBUS_RATED much higher than this minimum value. Note: at least 100mA is allowed to be drawn by an unconfigured [USB2.0] peripheral.

[9] Other implementations or ranges are possible provided the system time constants are observed.

Parameter	Symbol	Conditions	Min[5]	Max5	Units	Ref
ADP sink current[10]	IADP_SINK		1.1	2	mA	5.4.2
Terminations:						
VBUS resistance	ROTG_VBUS	VBUS < VADP_PRB max	10		kΩ	4.1.1
Thresholds:						
OTG device Session Valid	VOTG_SESS_VLD		0.8	4.0	V	5.1.5
ADP probing voltage	VADP_PRB		0.6	0.75	V	5.4.2
ADP sensing voltage	VADP_SNS		0.2	0.55	V	5.4.2
Capacitance:						
OTG A-device or EH VBUS bypass capacitance[11]	CA_VBUS		1		µF	4.2.3
VBUS bypass capacitance for ADP-capable devices	CADP_VBUS		1	6.5	µF	4.2.3, 4.3.4
ADP threshold capacitance	CADP_THR		200	900	nF	5.4.2
DC Electrical Timing:						
Period of measurement for VA_VBUS_AVG_LO and VA_VBUS_AVG_HI	TAVG_VBUS		0.9	1.1	sec	4.2.1, 4.3.1
VBUS Rise Time	TA_VBUS_RISE	CLOAD = 10 µF IVBUS = IA_VBUS_RATED, Up to VA_VBUS_AVG_LO min		100	ms	4.2.2
Session end to VOTG_VBUS_LKG	TSSEND_LKG			1	sec	4.1.1, 4.2.4
Time to detect device attachment and turn on VBUS	TA_VBUS_ATT			200	ms	4.2.4, 5.4.2

[10] IADP_SINK is specified to discharge VBUS below VADP_DSCHG within a time of TADP_DSCHG. The important parameter is that VBUS is discharged below VADP_DSCHG within a time of TADP_DSCHG. Other methods to discharge VBUS are allowed as long as they discharge to the same level in the same amount of time.

[11] Capacitance of this capacitor, including its norminal tolerance, should not go below the minimum value of 1µF.

5 Signalling

5.1 Session Request Protocol

5.1.1 Introduction

The following figures (Figure 5-1 and Figure 5-2) show the SRP signaling process from the perspective of the A-device and the B-device. The process is as follows:

- Wait for the end of a session by monitoring VBUS and data lines
- B-device signals SRP by generating data line pulsing
- A-device detects SRP signaling and responds by asserting VBUS
- B-device detects the new session as valid

Figure 5-1: A-device SRP Timing Reference

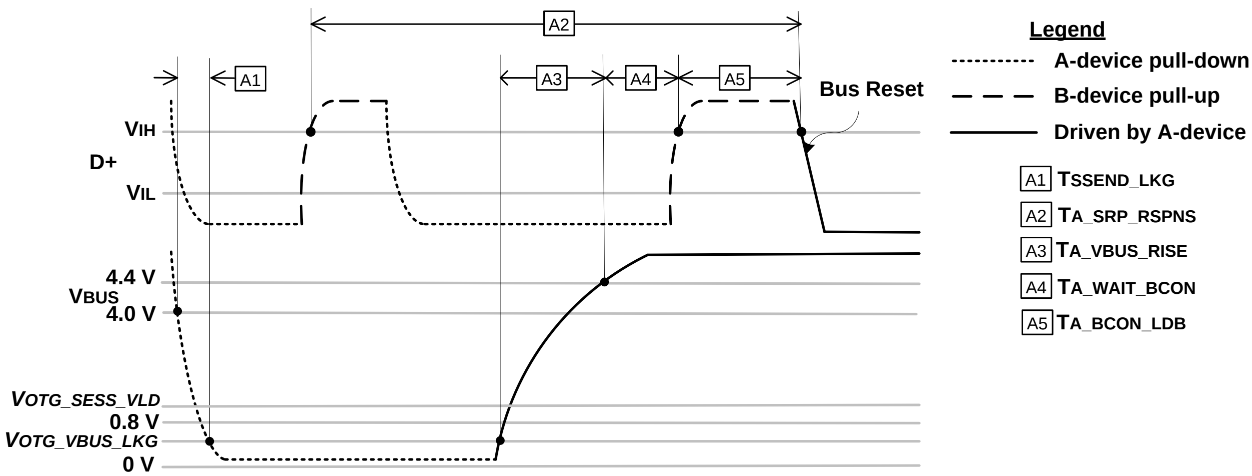
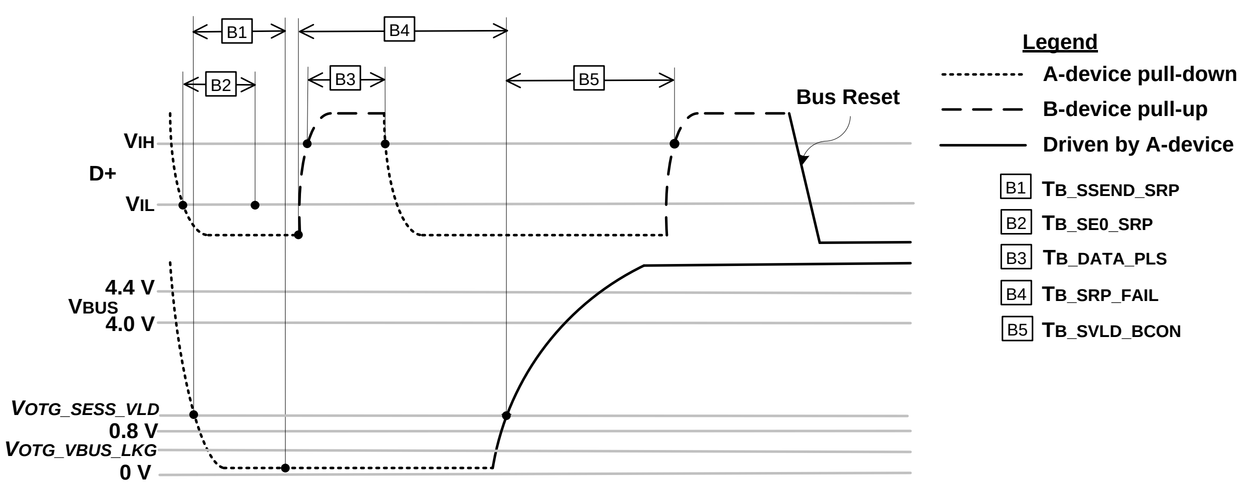


Figure 5-2: B-device SRP Timing Reference



5.1.2 Initial Conditions

The B-device may not attempt to start a new session until TB_SSEND_SRP after VBUS has gone below VOTG_SESS_VLD, and both the D+ and D- data lines have been low (SE0) for at least TB_SE0_SRP min. This ensures both the end of the previous session and that the A-device has detected a disconnect condition from the B-device.

5.1.3 Data-line Pulsing

To indicate a request for a new session using the data-line pulsing SRP, the B-device waits until the initial conditions are met as described above (in Section 5.1.2) and then turns on its D+ pull-up resistor for a period within the range specified by TB_DATA_PLS. An OTG B-device shall initiate SRP by pulling D+ high. The duration of such a data line pulse is sufficient to allow the A-device to reject spurious voltage transients on the data lines. An A-device shall detect SRP if D+ goes high. Since the D+ data-line pulse is characterized by both its rising and falling edges; both edges shall be seen before SRP is reported by the A-device.

It has been observed that some self-powered USB devices do not follow [USB2.0] Section 7.1.5.1. Devices that violate the above requirement have been observed to pull-up D+ as long as they have power applied to them, without regard to the presence of VBUS. For this reason, an A-device that responds to data-line pulsing SRP should be able to disable this capability when an offending device is attached. On detecting D+ high (while VBUS is low), for a period longer than the maximum D+ pulse width TB_DATA_PLS max, the A-device shall determine that the B device is not compliant and shall therefore disable SRP until such time as D+ drops again. When the data line returns low (indicating a disconnect), then SRP should be re-enabled.

5.1.4 VBUS Pulsing

The VBUS pulsing method of SRP defined in previous revisions of the supplement is no longer supported.

5.1.5 B-device Session Valid

When a B-device detects that the voltage on VBUS is greater than the Session Valid threshold (VOTG_SESS_VLD), then the B-device shall consider a session to be in progress. After the VBUS voltage crosses this threshold, the B-device shall assert either the D+ or D- data-line within the period bounded by TB_SVLD_BCON max. The B-device may continue to monitor VBUS during data-line pulsing.

5.1.6 Response Time or A-device

After initiating SRP, the B-device is required to wait at least TB_SRP_FAIL min for the A-device to respond. After this the B-device may inform the user that the communication attempt has failed. For this reason, it is recommended that the A-device respond to SRP in less than TA_SRP_RSPNS max. The minimum response from the A-device is to turn on VBUS and generate a bus reset.

5.1.7 Initiation of SRP

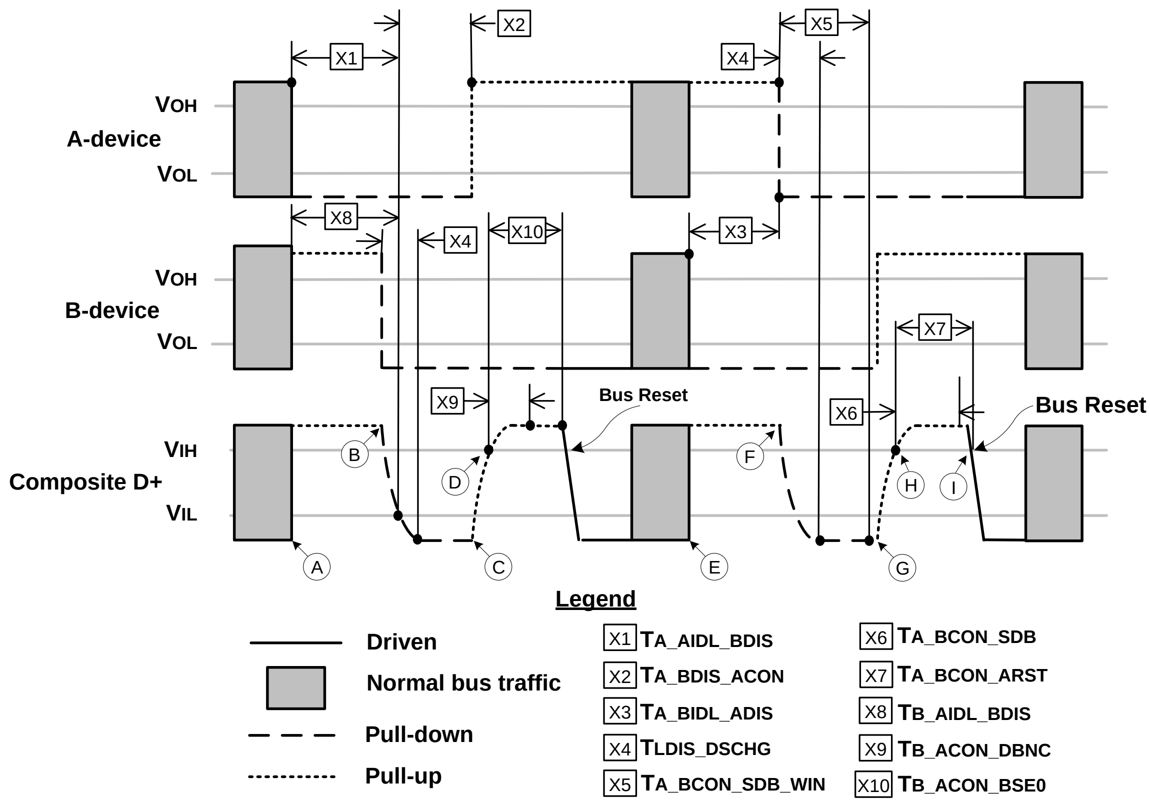
The B-device may initiate the SRP any time the initial conditions of Section 5.1.2 are met. To avoid unnecessary power drain on the A-device, a B-device should only initiate SRP in response to a particular event (typically user interaction or an ADP change). An SRP failure should not lead to the initiation of SRP. An SRP failure should not lead to the re-initiation of SRP.

5.2 Host Negotiation Protocol

5.2.1 HNP Sequence of Events

The sequence of events for HNP as observed on the USB, are illustrated in Figure 5-3.

Figure 5-3: HNP Sequence of Events (FS)



A) A-device finishes using bus and stops all bus activity, (i.e. suspends the bus).

B) B-device detects that bus is idle for more than TB_AIDL_BDIS min and begins HNP by turning off pull-up on D+[12] This allows the bus to discharge to the SE0 state.

C) The A-device detects the SE0 on the bus and recognizes this as a request from the B-device to become host. The A-device responds by turning on its D+ pull-up within TA_BDIS_ACON max of first detecting the SE0 on the bus. If the A-device does not detect a disconnect before TA_AIDL_BDIS min after suspending the bus, then the A-device is allowed to stop waiting for a disconnect and end the session.

D) After waiting TLDIS_DSCHG min to insure that the D+ line cannot be high due to the residual effect of the B-device pull-up, (see Section 5.2.2), the B-device sees that the D+ line is high[13] and D- line is

[12] If the bus was operating in HS mode, the B-device will first enter the full-speed mode (see Section 5.2.4).

[13] An OTG device is required to operate as a full-speed or high-speed peripheral. Therefore, a B-device shall only accept a connection from an A-device when D+ is pulled up. If the B-device detects a high on the D- line after disconnecting, this shall be interpreted as resume signaling from the A-device (see Section 5.3.1).

low, (i.e. J state). When the B-device has qualified the high level on the D+ line as being from the A-device., and the level has been present for at least $T_{B\_ACON\_DBNC}$ min then the A-device is connected This indicates that the A-device has recognized the HNP request from the B-device. At this point, the B-device becomes host and asserts bus reset to start using the bus. The B-device shall assert the bus reset (SE0) within $T_{B\_ACON\_BSE0}$ max of the time that the A-device turns on its pull-up.

E) When the B-device completes using the bus, it stops all bus activity. Optionally, the B-device may turn on its D+ pull-up when a FS idle condition is detected on the bus.

F) The A-device shall detect the lack of bus activity. If the bus is operating in HS mode, it shall first revert to FS suspend mode according to [USB2.0]. The A-device shall detect J-state (full-speed idle) for at least $T_{A\_BIDL\_ADIS}$ min and shall turn off its D+ pull-up. Alternatively, if the A-device has no further need to communicate with the B-device, the A-device may turn off V_{BUS} and end the session.

G) B-device turns on its pull-up. If the B-device does not connect before $T_{A\_WAIT\_BCON}$, then the A-device is allowed to stop waiting for a connection.

H) After waiting T_{LDIS_DSCHG} min to ensure that the D+ line cannot be high due to the residual effect of the A-device pull-up, (see Section 5.2.2), the A-device sees that the D+ line is high (and D- line is low) indicating that the B-device is signaling a connect and is ready to respond as a peripheral.

When the A-device has qualified the high level on the D+ line as being from the B-device, and the level has been present for the debounce interval (see Section 5.2.3) then the A-device knows that the B-device is connected as a peripheral. At this point, the A-device will either become host and assert bus reset to start using the bus within $T_{A\_BCON\_ARST}$ or end the session if it has no further actions.

5.2.2 Data Line Discharge Time

During the above steps, the amount of time that the local device shall wait for the data line to discharge, before checking to see if the remote device has connected its pull up, is determined as follows.

As per Table 7-7 of [USB2.0], the maximum capacitance for a downstream facing port is 150 pF (C_{IND} max), and the maximum capacitance for the upstream port of a device without an attached cable is 100 pF (C_{INUB} max). The differential capacitance of a worst-case USB cable is approximately 340 pF (the single-ended capacitance is lower but is not specified so assuming that the single-ended capacitance is the same as the differential capacitance will insure a worst case calculation). The pull-down resistance of each OTG device is 24.8 kΩ (R_{PD} max) or less. This results in a discharge time constant of:

- time constant = (150 pF + 100 pF + 340 pF) x (24.8 kΩ / 2) ≈ 6.7 µsec

For the data line to discharge from 3.6 V to 0.8 V requires approximately 1.55 time constants. This gives a worst case delay for the data line discharge of about 10.4 µs. In previous cases of USB specification development, time values for RC charge/discharge were used to set timing values. In most cases, these values did not have a large margin for error or to allow for simple variations in implementation to reduce costs or complexity. For this reason, the guard-band for the data-line discharge is set at about 2.5 times the calculated value. Thus, if a device uses this method to ensure the data line is at a logic low level, it shall wait for a minimum of T_{LDIS_DSCHG} min before checking the state of the data-line.

5.2.3 Debounce Interval

The debounce interval varies depending on what occurred prior to the B-device connection, and how long it has been since either D+ or D- has been pulled high. If the B-device connection is a result of SRP then the long debounce interval ($T_{A\_BCON\_LDB}$) is required. Otherwise the short debounce interval ($T_{A\_BCON\_SDB}$) is allowed.

The A-device is only allowed to apply the short debounce to B-device connection in a window of time. If the A-device waits for the B-device to connect for longer than $T_{A\_BCON\_SDB\_WIN}$ max, then the long debounce interval applies in every case.

5.2.4 Hi-speed Signalling

If the bus was operating in HS mode, the B-device will first enter the full-speed mode and turn on its D+ pull-up resistor for at least $T_{B\_FS\_BDIS}$ min before turning off its pull up to start the HNP sequence.

After B-device enters the FS mode and turns on its pull-up resistor; it waits to see if the data line goes high. If the data line does not go high within $T_{WTRSTHS}$ (from Table 7-14 in [USB2.0]), then the B-device shall start its HS chirp. Otherwise, if the D+ line does go high for at least $T_{B\_FS\_BDIS}$ min, then the B-device may start HNP.

Similarly, when the B-device has finished using the bus, the A-device will first enter the full-speed mode and turn on its D+ pull-up resistor for at least $T_{A\_BIDL\_ADIS}$ min before turning off its pull up and waiting for B-device connection.

5.2.5 Timing Summary

5.2.5.1 B-device Becoming Host

When an OTG B-device has received a SetFeature (b_hnp_enable) and requires the bus, it shall wait for the bus to enter the Suspend state before signaling a disconnect to start HNP.

After the bus enters the Suspend state, the B-device will transition from acting as a peripheral to waiting for the A-device to indicate a connect event, which would complete the transfer of control to the B-device. While waiting for the A-device to indicate a connect event, the B-device may detect a K state on the bus. This indicates that the A-device is signaling a resume condition, either because it commenced the resume before it saw the B-device lower its D+ resistor, or because it is exhibiting non-compliant behavior by retaining control of the bus after it saw the B-device disengage its D+ resistor. In this case, the B-device will return to acting as a peripheral.

If the B-device has had its D+ pull-up turned off for more than T_{LDIS_DSCHG} min and a J is detected on the bus, then this is an indication that the A-device is acknowledging the HNP request and has become the peripheral.

Once the A-device has initiated HNP (by enabling HNP and going to suspend) and detects SE0 (indicating that the B-device is requesting to become host) it shall complete the HNP process. The A-device shall not reset or resume the bus at this point in order to remain as host.If the A-device turns on its pull up before $T_{B\_ASE0\_BRST}$ min of the B-device disconnecting, then the B-device has to start bus activity by issuing a bus reset before $T_{B\_ACON\_BSE0}$ max.

5.2.5.2 A-device Becoming Peripheral

When the A-device is acting as a host and has set the OTG B-device’s HNP enable bit (b_hnp_enable = TRUE) the A-device shall place the connection to the B-device into Suspend when it is finished using the bus. If the B-device disconnects after the bus has been suspended, then this is an indication that the B-device is attempting to become host. When the A-device detects the disconnect from the B-device, it shall turn on its D+ pull-up resistor within $T_{A\_BDIS\_ACON}$ max to acknowledge the request from the B-device. The time in which the A-device shall detect the disconnect is defined in Table 7-13 of [USB2.0].

After the A-device signals a connect, it shall continue to signal a connect for at least $T_{A\_BIDL\_ADIS}$ min, while waiting for the B-device to issue a bus reset. This ensures that the B-device has at least $T_{B\_ACON\_BSE0}$ max to detect and respond to the A-device connect.

5.3 Suspend, Resume and Remote Wakeup

5.3.1 Resume Signalling

Section 7.1.7.7 of [USB2.0], states that the downstream device (in this case the B-device) interprets any non-idle signal as an indication that the upstream device (in this case the A-device) is resuming operation of the bus. If the B-device is acting as a peripheral, then this definition for resume signaling holds.

The A-device can either do a resume by putting a K state on the bus, or it can do a bus reset by outputting SE0 for longer than $T_{B\_ASE0\_BRST}$ min. The A-device is not allowed to resume unless the attached device is supported and:

- It has not been enabled for HNP (suspend/resume is being used for power saving), or
- until $T_{A\_AIDL\_BDIS}$ min time has elapsed when the attached device has been enabled for HNP.

After the B-device turns off its pull-up resistor the bus will be pulled to the SE0 state by the pull-downs on the A and B devices. This SE0 is not a resume indication. If the SE0 persists for more than $T_{B\_ASE0\_BRST}$ min, then the A-device is not responding to the HNP request from the B-device. This causes the B-device to inform the user and return to operation as a peripheral.

5.3.2 Remote Wakeup Signalling

Section 7.1.7.7 of [USB2.0] states that the upstream device (in this case the A-device) interprets any non-idle signal as an indication that the downstream device (in this case the B-device) is waking up the bus. If the B-device is not enabled for HNP, then the behavior of the A-device in response to bus activity from the B-device is as defined in the section cited above.

However, if the B-device is enabled for HNP, then only a J-to-K transition on the bus will be treated as a resume. A transition to SE0 will be treated as the start of the HNP handoff. The A-device is expected to respond by transitioning to peripheral operation and turn on its pull-up resistor on D+.

5.4 Attach Detection Protocol

5.4.1 Introduction

Attach Detection Protocol (ADP) is a protocol that allows a local device to detect when a remote device has been attached or detached. The device doing ADP probing can be either an OTG A-device, OTG B-device, EH or SRP-capable peripheral-only B-device. The remote device can be any USB device.

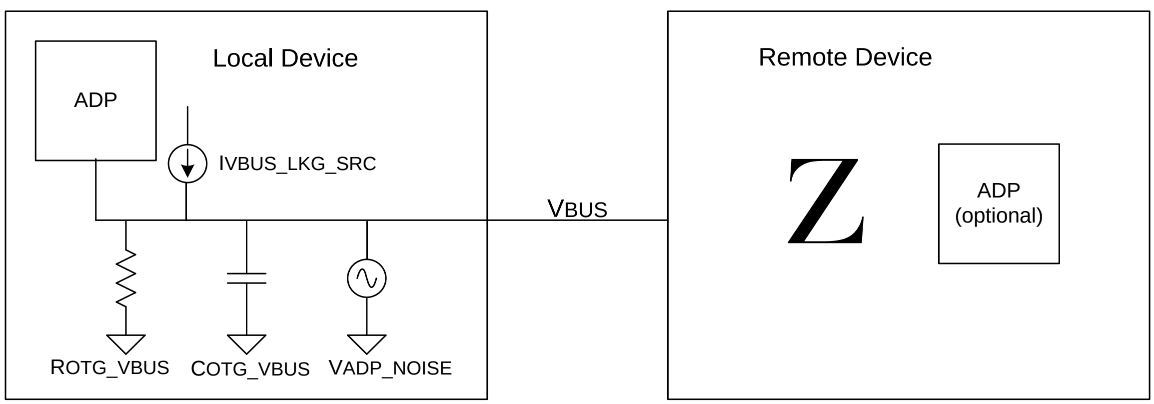
ADP operates by detecting the change in VBUS capacitance that occurs when two devices are attached or detached. The capacitance is detected by first discharging the VBUS line, and then measuring the time it takes VBUS to charge to a known voltage with a known current source. A change in capacitance is detected by looking for a change in the charge time.

If an A-device is attached to a B-device, and both are not in a session, and both support ADP, then the A-device shall perform ADP probing, while the B-device shall perform ADP sensing. During ADP sensing, the B-device looks for ADP activity on the VBUS line. If ADP activity is detected, then the B-device knows that the A-device is still attached.

5.4.2 ADP Probing

Figure 5-4 shows a local device attached to a remote device.

Figure 5-4: ADP context



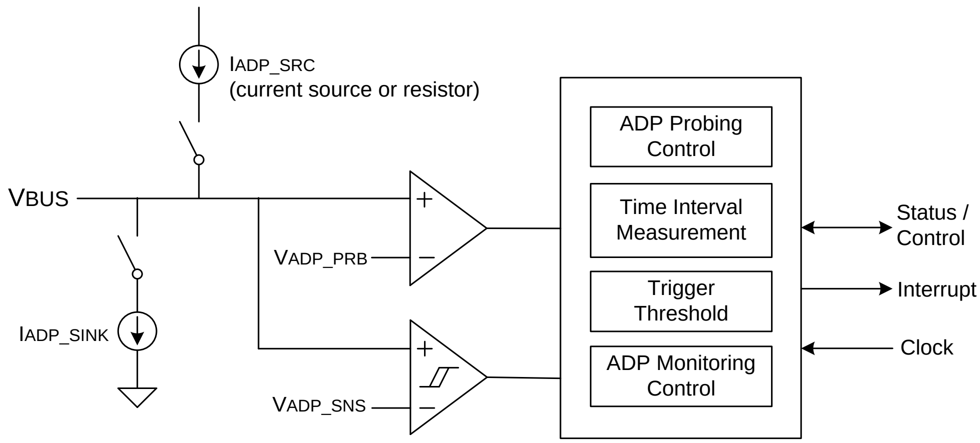
In order for the local device to reliably detect a remote device using ADP probing, the following conditions must be met:

- local device resistance of ROTG_VBUS
- local device capacitance of CADP_VBUS
- local device noise of VADP_NOISE
- local device leakage of IVBUS_LKG_SRC

The remote device is assumed to have a complex capacitance Z, and may also be doing ADP probing or sensing.

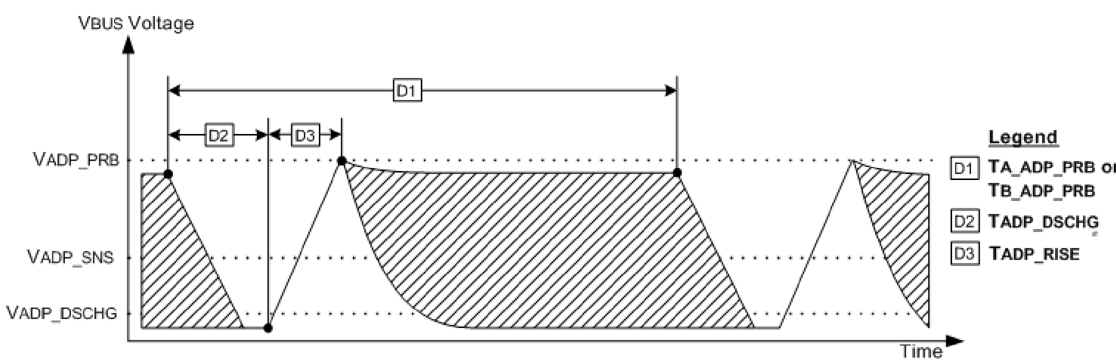
Figure 5-5 shows the architecture of the ADP block in the local device.

Figure 5-5: ADP Architecture



The ADP block has a current source (or charging resistor) IADP_SRC, a current sink IADP_SINK, two comparators, and some timing and control logic. A timing diagram for ADP is shown in Figure 5-6.

Figure 5-6: ADP Probe Timing



To measure the capacitance on the VBUS line, the local device first discharges the VBUS line below VADP_DSCHG by turning on the current sink (IADP_SINK) for a fixed amount of time. This time (TADP_DSCHG) must be long enough to ensure that VBUS goes below VADP_DSCHG for all valid combinations of remote resistance, capacitance, initial voltage (up to VOTG_SESS_VLD MAX), and leakage current. After the VBUS voltage is below VADP_DSCHG, the current sink is turned off, and the current source (IADP_SRC) is turned on. When the VBUS voltage reaches VADP_PRB, the current source is turned off. The time required for VBUS to rise to VADP_PRB (TADP_RISE) is measured.

If the time taken for VBUS to rise exceeds what would be expected for a remote device with a capacitance of CRPB max, then the local device is allowed to terminate the ramp, and simply store the maximum value as the ramp time.

After a time of either TA_ADP_PRB for an A-device or TB_ADP_PRB for a B-device, this probe cycle is repeated, and the rise time is again measured. If both devices happen to be probing on attachment the different values of probe time for A-devices and B-devices prevent repeated collisions between successive probes. If a remote device is attached or detached, then the rise time changes. The probe cycle timing for successive probe measurements on a given device must be within TADP_PRB_JTR. This allows a B-device to turn on its probe sensing in a small window around the expected probing time in order to save energy.

When a device begins probing after a session, it shall compare the first measurement taken after the session to the last measurement taken immediately before the session. For a B-device, the measurements shall also be compared before and after a session request. If the capacitance has changed by more than C_{ADP_THR}, the device shall detect that as an ADP change event. This is described in greater detail in the following paragraphs as well as in Figure 5-7 through Figure 5-9 below.

When doing ADP probing, a device is required to ignore any changes in capacitance that are less than C_{ADP_THR} min. This ensures that cable attachment is ignored when the remote end of the cable is not attached to a device. For a series of "n" probes if the capacitance changes by more than C_{ADP_THR}, between probe "n" and probe "n-2", the device shall detect that as an ADP change event. This ensures that it is possible to detect the attachment or detachment of a device presenting either C_{A_VBUS} or C_{ADP_VBUS} as its V_{BUS} bypass capacitance.

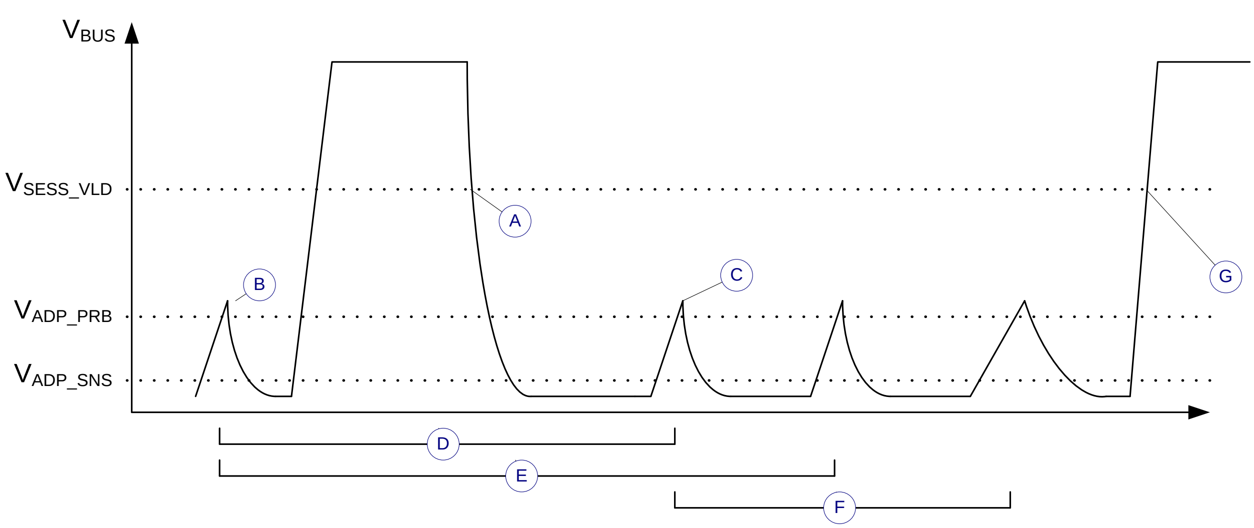
When an OTG A-device is ready to act in host or peripheral role or an EH is ready to act as host, and V_{BUS} is not present, V_{BUS} is required to reach $V_{OTG\_SESS\_VLD}$ within $T_{A\_VBUS\_ATT}$ of an ADP change event being detected by ADP unless an over-current condition is reached (see also Section 4.2.4).

If an A-device has a valid ADP probe measurement taken immediately before the session, it shall compare that measurement with the first measurement taken immediately after the session. If the two ramp times differ by more than C_{ADP_THR}, it shall initiate a session within $T_{A\_VBUS\_ATT}$ of the last ADP probe.

If a B-device starts doing ADP probing after a session (or session request) and it has a valid ADP probe measurement from immediately prior to the session (or session request), then it shall perform SRP, within $T_{B\_ADP\_PRB\_SRP}$ of the last ADP probe, if the two ramp times differ by more than C_{ADP_THR}. Otherwise, it shall continue probing and if any two ramp times, "n" and "n-2", differ by more than C_{ADP_THR}, it shall perform SRP within $T_{B\_ADP\_PRB\_SRP}$ of the last ADP probe.

If a B-device starts doing ADP probing after a session (or session request) and it does not have a valid ADP probe measurement from immediately prior to the session (or session request), then it shall perform SRP within $T_{B\_ADP\_PRB\_SRP}$ of the first ADP probe. The B-device may wait for $T_{B\_SRP\_FAIL}$, and shall then start probing again, having now acquired a pre-session measurement, as described in the paragraph above.

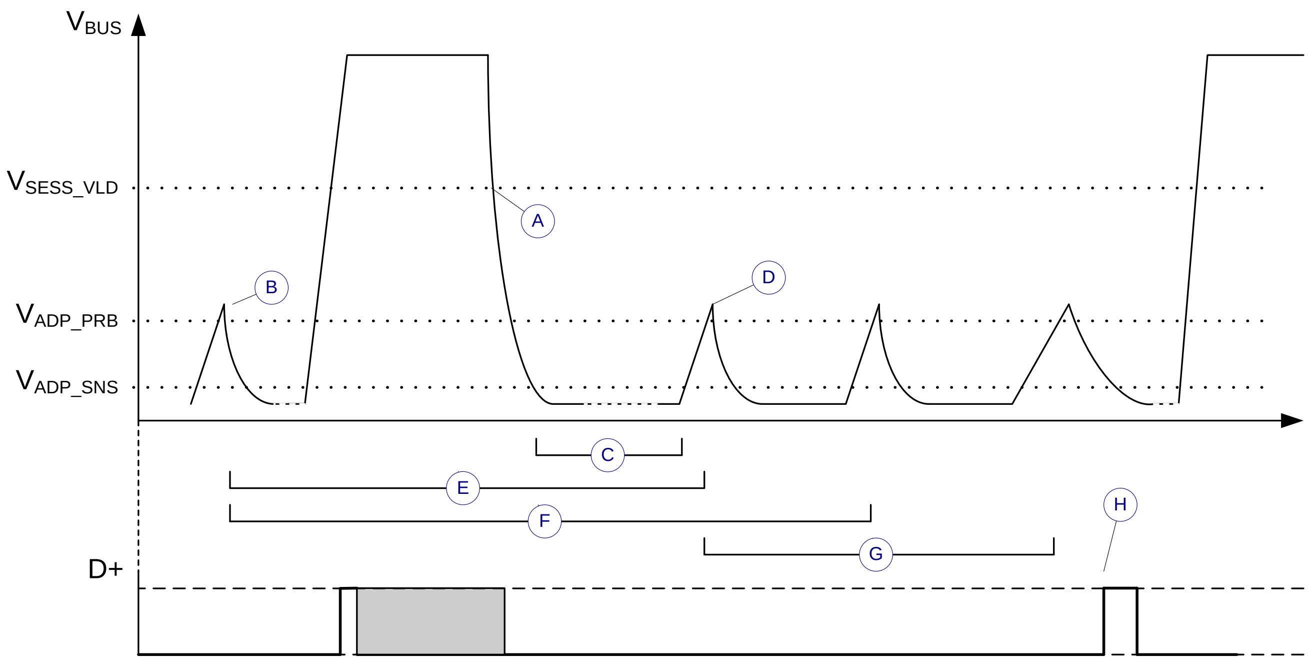
Figure 5-7: A-device ADP



Steps in Figure 5-7:

A. A-device ends session
B. A-device has pre-session calibration value.
C. A-device starts probing within TA_SSEND_PRB max of VBUS going below VOTG_SESS_VLD
D. The ADP ramp time after dropping VBUS does not differ from the ramp time before asserting VBUS.
E. A-device continues probing comparing n to n-2 ADP probes.
F. Next n to n-2 comparison (differs from C)
G. A-device again asserts VBUS after detecting ramp time differ in F

Figure 5-8: B-Device: ADP with pre-session calibration measurement

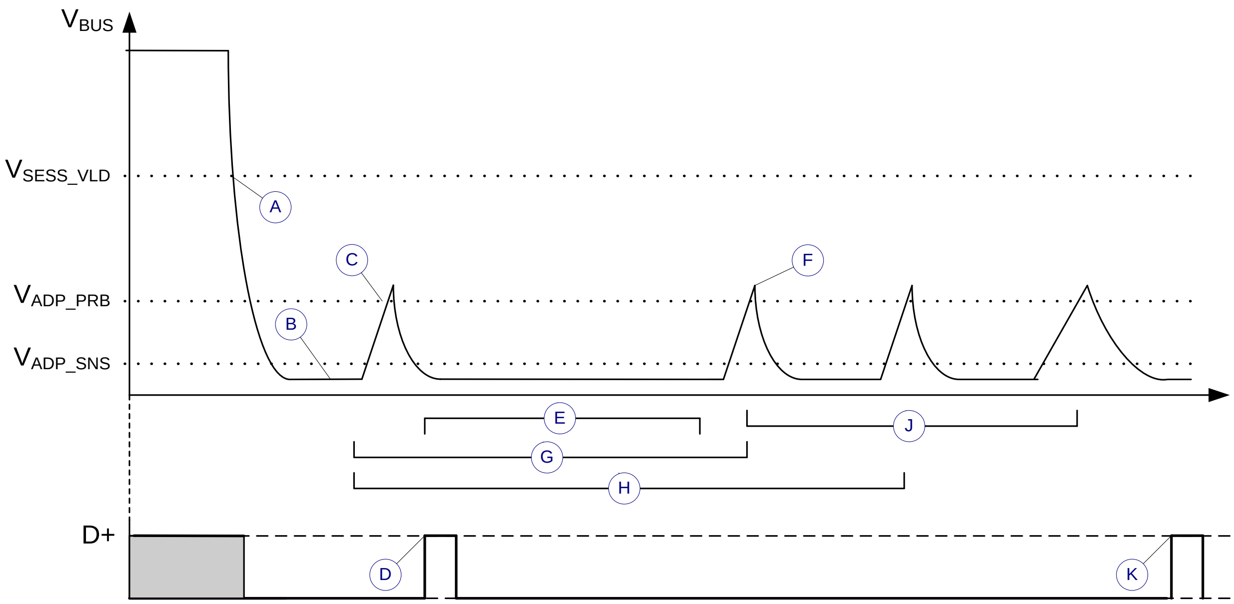


Steps in Figure 5-8:

A. B-device sees A-device end session
B. B-device had measured ramp time before session
C. B-device times out ADP sensing
D. B-device starts doing ADP probing, and it has already measured the ramp time before the session
E. B-device compares new ramp time with pre-session ramp time. Ramps not found to differ by more than CADP_THR
F. B-device continues probing and comparing n to n-2 (new ramp to pre-session ramp)
G. Probing continues until ramp times differ by more than CADP_THR.
H. As a result of ramp times differing in F comparison, B-device issues SRP pulse within TB_ADP_PRB_SRP

Note: Grey area for D+ line indicates indeterminate line state.

Figure 5-9: B-device: ADP without pre-session calibration measurement



Steps in Figure 5-9:

A. B-device sees A-device end session
B. B-device times out sensing without detecting A-device ADP probes.
C. B-device starts doing ADP probing, but it has not measured the ramp time before the session
D. B-device performs SRP within $T_{B\_ADP\_PRB\_SRP}$ of the first ADP probe at C.
E. Optionally, B-device waits for session, but no session begins within $T_{B\_SRP\_FAIL}$.
F. B-device continues probing
G. B-device verifies two ramp times (F and C) before and after the failed session request do not differ by more than C_{ADP_THR}.
H. B-device continues probing comparing n to n-2 ramp times
I. Next n to n-2 ramp time comparison, ramp times differ by more than C_{ADP_THR}
J. B-device issues SRP within $T_{B\_ADP\_PRB\_SRP}$ of the last probe if the ramp times differ

Note: Grey area for D+ line indicates indeterminate line state.

The following illustrative example procedure could be used to implement the logic described above.

The ADP-capable device maintains a set of three probe sample stores, called n, n-1 and n-2.

The first probe value obtained after powering up the device is placed into all three sample stores, so that all the recorded samples are equal. As each new probe is made, sample n-1 is copied into n-2, sample n is copied into n-1, and finally the new sample is placed in n.

If, after recording a new sample, the sample n differs from n-2 by a sufficient amount positive or negative, equivalent to C_{ADP_THR}, then this represents a 'capacitance change'. The 'capacitance change' is signalled to the device, so that it can take the appropriate OTG action, and the sample n is copied into n-1 and n-2, so that once again all samples are equal.

5.4.3 ADP Sensing

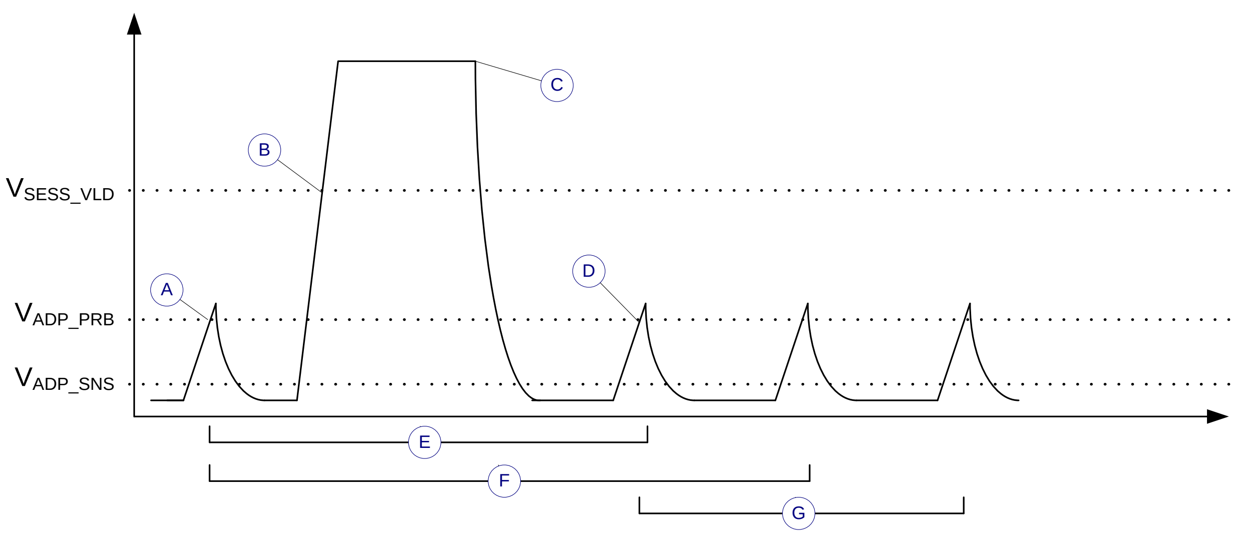
After a session has ended, an ADP-capable A-device shall issue its first ADP probe pulse within TA_SSEND_PRB of VBUS going below VOTG_SESS_VLD min. ADP-capable A-devices are recommended to define small values of TSSEND_LKG and TA_SSEND_PRB to minimize the potential for missing ADP changes at session end.

After a session has ended, an ADP-capable B-device shall perform ADP sensing until it detects that the remote device is not doing ADP probing. During ADP sensing, the B-device uses the sensing comparator to detect the ADP pulses applied to VBUS by the A-device. The B-device shall determine the A-device is not doing ADP probing after TB_ADP_DETACH of the session end or of the last sense comparator toggle. The B-device shall issue an ADP probe within TB_SNSEND_PRB of detecting the A-device is not probing, and continue probing.

5.4.4 ADP Start Up

When an ADP-capable A-device is first powered up, it shall perform at least one ADP probe cycle in order to obtain an initial value for TADP_RISE. After this probe the A-device shall then turn on VBUS within TA_VBUS_ATT to see if a B-device is attached. The delay from first power-up until VBUS is turned on shall not exceed TPWRUP_RDY. If a B-device does not connect within TA_WAIT_BCON, min then the A-device shall turn VBUS off within TA_WAIT_BCON max and shall then start ADP probing within TA_SSEND_PRB max of VBUS going below VOTG_SESS_VLD. A-device ADP startup is shown in Figure 5-10 below.

Figure 5-10: A-device ADP Startup



Steps in Figure 5-10:

A. When an ADP capable A-device is first powered up, it shall perform at least one ADP probe cycle in order to obtain an initial value of TADP_RISE.
B. After this probe, the A-device shall turn on VBUS within TA_VBUS_ATT to see if a B-device is attached.
C. A B-device does not connect within TA_WAIT_BCON min, A-device shuts off VBUS within TA_WAIT_BCON max.
D. A-device starts probing within TA_SSEND_PRB max of VBUS going below VOTG_SESS_VLD
E. The ADP ramp time after dropping VBUS does not differ from the ramp time before asserting VBUS.

F. A-device continues probing comparing n to n-2 ADP probes.
G. Next n to n-2 comparison

If the ADP ramp time after dropping VBUS differs from the ADP ramp time before asserting VBUS by a time proportional to CADP_THR or more, then the A-device shall again assert VBUS.

When an ADP-capable B-device is first powered up, and VBUS is not present, it shall perform at least one ADP probe cycle in order to obtain an initial value for TADP_RISE. The B-device shall then perform SRP to see if an A-device is attached. The delay from first power-up until this SRP pulse shall not exceed TPWRUP_RDY. If an A-device does not assert VBUS within TB_SRP_FAIL, then the B-device shall be performing ADP probing within a further TB_ADP_PRB max. A B-device need not wait for the A-device response to SRP pulse to continue probing. If the ADP rise time after SRP differs from the ADP rise time before SRP by a time proportional to CADP_THR or more, then the B-device shall issue another SRP pulse. Otherwise, it shall continue probing as described in section 5.4.2.

5.5 Signalling Timing Parameters

Table 5-1: Signalling Timing Parameters

Parameter	Symbol	Min	Max	Units	Ref
Common:					
Local Disconnect to Data Line Discharge	TLDIS_DSCHG	25		µs	5.2.1, 5.2.2
ADP cycle to cycle jitter	TADP_PRB_JTR		5	%	5.4.2
Power on until ready for USB (not mandatory see reference)	TPWRUP_RDY		30	sec	A.3.5
A-device:					
SRP Response Time	TA_SRP_RSPNS		4.9	sec	5.1.6
B-Connect Long Debounce	TA_BCON_LDB	100		ms	5.2.3
B-connect to A-reset[14]	TA_BCON_ARST		30	sec	5.2.1
Wait for B-Connect	TA_WAIT_BCON	1.1	30[15]	sec	5.2.1
A-Idle to B-Disconnect	TA_AIDL_BDIS	200		ms	5.2.1, 5.3.1
B-Disconnect to A-Connect	TA_BDIS_ACON		150	ms	5.2.1
B-Idle to A-Disconnect	TA_BIDL_ADIS	155	200	ms	5.2.1
B-Connect Short Debounce	TA_BCON_SDB	2.5		µs	5.2.3
B-Connect Short Debounce Window	TA_BCON_SDB_WIN		100	ms	5.2.3
A-device ADP probing period, (Typical = 1.75 sec)[16]	TA_ADP_PRB	1.35	1.85	sec	5.4.2
Session end to ADP probing	TA_SSEND_PRB		100	ms	5.4.3
B-device:					
Session end to SRP init	TB_SSEND_SRP	1.5		sec	5.1.2
SE0 Time Before SRP	TB_SE0_SRP	1		sec	5.1.2
Data-Line Pulse Time	TB_DATA_PLS	5	10	ms	5.1.3
SRP Fail Time[17]	TB_SRP_FAIL	5	6	sec	5.1.6

[14] It is expected that a typical implementation would be able to respond in far less time than the maximum value.

[15] This maximum value is required for testing of products which support sessions and therefore do not leave VBUS on all the time an A-plug is inserted. Manufacturers shall specify when entering compliance if they require a larger maximum value.

[16] An A-device is also allowed to use a probing period of .675 sec to .925sec.

[17] In order to improve usability an A-device should respond to SRP in much less than 5 seconds.

Parameter	Symbol	Min	Max	Units	Ref
Session Valid to B-Connect	$T_{B\_SVLD\_BCON}$		1	sec	5.1.5
A-Idle to B-Disconnect	$T_{B\_AIDL\_BDIS}$	4	150	ms	5.2.1
Time between B-device HS to FS transition during suspend, and B-device disconnect	$T_{B\_FS\_BDIS}$	1	146.875	ms	5.2.4
A-SE0 to B-Reset	$T_{B\_ASE0\_BRST}$	155		ms	5.3.1
A-Connect Debounce	$T_{B\_ACON\_DBNC}$	2.5		µs	5.2.1
A-Connect to B-SE0	$T_{B\_ACON\_BSE0}$		150	ms	5.2.1
B-device ADP probing period (Typical = 2.0 sec)[18]	$T_{B\_ADP\_PRB}$	1.9	2.6	sec	5.4.2
Time from stopping ADP probing to SRP generation	$T_{B\_ADP\_PRB\_SRP}$		5	sec	5.4.2
B-device ADP detach time, sensing mode	$T_{B\_ADP\_DETACH}$	3.0	3.4	sec	5.4.3
Sensing end to first ADP probe	$T_{B\_SNSEND\_PRB}$		100	ms	5.4.3
Testability					
Bus reset to configuring test device	T_{TST_CONFIG}		30	sec	6.4.2, 6.4.3
Maintaining configured session on test device	T_{TST_MAINT}	9.9	10.1	sec	6.4.2, 6.4.3
B-device as host, SetConfig to suspend of test device	T_{TST_SUSP}		100	ms	6.4.2.2
Session end to SRP from unit under test	T_{TST_SRP}		5	sec	6.4.3.1.1
‘otg_hnp_reqd’ flag set to Host Request Flag set	T_{TST_HNP}		5	sec	6.4.3.1.2
Reconnect after handing back control from HNP caused by ‘otg_hnp_reqd’	T_{TST_HNPEND}		5	sec	6.4.3.1.2
Time to switch off V_{BUS} after tester disconnects with ‘otg_vbus_off’ set	T_{TST_VBOFF}		5	sec	6.4.3.2.1
V_{BUS} off with no ADP after session which sets ‘otg_vbus_off’	T_{TST_NOADP}	5	6	sec	6.4.3.2.1

[18] A B-device is also allowed to use a probing period of .95sec to 1.3sec

6 Device Framework

6.1 OTG Descriptor

Any B-device compliant with this supplement shall respond to a GetDescriptor(OTG) request with its OTG descriptor as defined in Table 6-1. The B-device shall also return the OTG descriptor as part of a GetDescriptor(Configuration) request. These requests shall be treated in the same way as any other GetDescriptor command such that it may be requested in the Default, Addressed or Configured state. The OTG descriptor shall be present in all configurations. The behavior of an A-Peripheral with respect to the OTG descriptor is undefined.

The OTG descriptor consists of the following fields: *bLength*, *bDescriptorType*, *bmAttributes and bcdOTG*, with bits as defined in Table 6-1. For OTG devices the bmAttributes field only indicates support provided by a B-device acting in peripheral role.

Table 6-1: OTG Descriptor

Offset	Field	Size	Value	Description
0	*bLength*	1	Number (5)	Size of Descriptor
1	*bDescriptorType*	1	Constant	OTG type = 9
2	*bmAttributes*	1	Bitmap	Attribute Fields D7…3: Reserved (reset to zero) D2: ADP support D1: HNP support D0: SRP support
3	*bcdOTG*	2	BCD	OTG and EH supplement release number in binary-coded decimal (i.e. 2.0 is 0200H). This field identifies the release of the OTG and EH supplement with which the device and its descriptors are compliant.

6.1.1 SRP Support

This bit is set to TRUE when the B-device can initiate SRP. This bit enables the A-device to determine when the B-device can intelligently manage the removal of VBUS.

6.1.2 HNP Support

This bit is set to TRUE when a B-device is able to perform HNP. This bit enables an A-device determine when HNP polling is necessary (see Section 6.3) and when SetFeature for HNP related features is necessary (see Section 6.2.2). If the HNP support bit is TRUE, then SRP support bit shall also be TRUE.

6.1.3 ADP Support

This bit is set to TRUE if the B-device supports ADP probing and sensing. If the ADP support bit is TRUE, then SRP support bit shall also be TRUE.

6.1.4 OTG and EH Supplement Release Number

This field identifies the release of the OTG and EH supplement as defined in Table 6-1. Versions of the OTG supplement prior to v2.0 omit this field.

6.2 Standard Device Features

6.2.1 Feature Selectors

Table 6-2 shows the feature selectors required by the OTG and EH supplement. These are set with a SetFeature request from an A-device.

Table 6-2: OTG Feature Selectors

Feature Selector	Recipient	Value	Host Request	Feature supported by	Ref
b_hnp_enable	Device	3	SetFeature	B-device	6.2.2.1
a_hnp_support	Device	4	SetFeature	B-device	6.2.2.2
a_alt_hnp_support	Device	5	SetFeature	B-device	6.2.2.3

6.2.2 SetFeature Commands

An A-device shall use the SetFeature command to enable the b_hnp_enable feature in HNP capable devices (see Section 6.2.2.1). Any HNP capable device is required to accept the SetFeature commands for these features. If the device is not HNP capable, it shall return STALL if it receives a SetFeature command for any of these features

A B-device that supports this feature shall be able to accept the SetFeature command in the Default, Addressed and Configured states. [USB2.0] states that setting a feature in the Default state for other than test modes is unspecified. This supplement adds to the list of features that can be set in the Default state.

Setting this feature when it is already set is not an error. The device receiving such a command will acknowledge the command indicating successful completion.

A SetFeature command for this feature shall be executed on receipt of an uncorrupted command packet.

6.2.2.1 b_hnp_enable

Setting this feature indicates to the B-device that it has been enabled to perform HNP. A-devices without HNP support as an A-device shall not set this feature. The A-device is required to set this feature and suspend the bus within THOST_REQ_SUSP when it determines that the B-device wishes to become host (host_req_flag = TRUE). An A-device may set this feature if, and only if, the B-device is connected directly to a Micro-AB port (i.e. no intervening hub between the Host and the B-device).

This feature is only cleared on a bus reset or at the end of a session. It cannot be cleared with a ClearFeature(b_hnp_enable) command.

6.2.2.2 a_hnp_support

This feature is required in order for A-devices to maintain compatibility with legacy B-devices supporting earlier versions of the OTG and EH supplement. A-devices without HNP support as an A-device shall not set this feature. Setting this feature indicates to the B-device that it is directly attached to an A-device port that supports HNP. This feature is not required to be supported by B-devices compliant to this or subsequent versions of the OTG and EH supplement.

The A-device shall set this feature on any legacy B-device, complying with OTG supplement version 1.3 or earlier, that is attached to an A-device port that supports HNP. The A-device shall set this feature at the start of a session, before any B-device configuration is selected. HNP capable B-devices shall not return STALL in response to setting this feature.

If the A-device port that is attached to the B-device is not HNP capable, then the A-device shall not set this feature.

Before putting the legacy B-device into a configuration, the A-device has the following three options with regards to the b_hnp_enable and a_hnp_support features:

- set the b_hnp_enable feature
- set the a_hnp_support feature but not the b_hnp_enable feature
- set neither the b_hnp_enable nor a_hnp_support features

If the b_hnp_enable feature is set, the B-device is allowed to do HNP, regardless of whether or not the a_hnp_support feature is set.

If the a_hnp_support feature is set, but the b_hnp_enable feature is not set, then it is likely that b_hnp_enable will be set later when the A-device is finished using the bus.

If neither the b_hnp_enable or a_hnp_support features are set before the A-device puts the B-device in a non-default configuration, then the B-device may indicate to the user that HNP is not supported through the current connection.

The a_hnp_support feature is only cleared on a bus reset or at the end of a session. It cannot be cleared with a ClearFeature(a_hnp_support) command.

6.2.2.3 a_alt_hnp_support

This feature is now obsolete.

6.2.3 GetStatus Commands

A host is required to use the GetStatus command (**Table 6-3**), with wIndex set to the OTG status selector (**Table 6-4**) to request the Host request flag (**Table 6-5**) from the peripheral (see Section 6.3). An OTG B-device shall be able to accept the GetStatus command in the Default, Addressed and Configured states. [USB2.0] states that requesting status in the Default state is unspecified. This supplement adds to the list of statuses that can be requested in the Default state and defines a non-zero value of wIndex.

Table 6-3: GetStatus Command Format

bmRequestType	bRequest	Wvalue	wIndex	wLength	Data
10000000B	GET_STATUS	Zero	OTG status selector	1	OTG Status

Table 6-4: OTG status selector

wIndex	Status Type
F000H	OTG status selector

Table 6-5: OTG Status information

Byte	D7	D6	D5	D4	D3	D2	D1	D0
0	Reserved shall be set to zero							Host request flag

6.2.3.1 Host Request Flag

If bit D0 of the OTG status information (Table 6-5) is set to one this indicates to the host that the peripheral wishes to become host either due to some user interaction or due to an automatic application executing on the peripheral. If bit D0 is reset to zero then the peripheral doesn't wish to become host.

6.3 HNP Polling Mechanism

6.3.1 HNP Polling Process

Whenever there is an active session between two OTG devices, which support HNP, the host executes a GetStatus() with a frequency of $T_{HOST\_REQ\_POLL}$ in order to determine the state of the Host request flag as defined in the OTG status information (see Section 6.2.3). After the host has detected that the Host request flag is set to one the host shall allow the peripheral to take the host role within $T_{HOST\_REQ\_SUSP}$.

Table 6-6: HNP polling timing parameters

Parameter	Symbol	Min	Max	Units
Polling period for the event flags	$T_{HOST\_REQ\_POLL}$	1	2	sec
Time from detection of host flag until suspend	$T_{HOST\_REQ\_SUSP}$		2	sec

6.3.2 OTG A-devices

During an active session, where the bus is not suspended and the connected OTG devices are both capable of HNP, an OTG A-Host shall perform HNP polling as described in section 6.2.3[19]. An OTG A-host shall not be required to poll the Host request flag only in the case where it enables HNP, by setting b_hnp_enable within $T_{HOST\_REQ\_POLL}$ max and suspends within a further $T_{HOST\_REQ\_SUSP}$ max from the time that the OTG A-host reads the OTG descriptor.

If the OTG A-host determines that the Host request flag is set to one the OTG A-host shall allow the OTG B-peripheral to take the host role, by enabling HNP (setting b_hnp_enable) and then suspending the bus, within $T_{HOST\_REQ\_SUSP}$.

If the OTG A-host determines that the Host request flag is reset to zero when an A-device has finished its activities it may end the session immediately.

If the OTG A-device does not enable HNP by setting b_hnp_enable prior to suspend then it shall resume with a frequency of $T_{HOST\_REQ\_POLL}$, poll the status of the Host Request flag, and return to suspend. The OTG B-device can signal its intention to become host by setting the Host Request flag.

If the OTG A-device enables HNP by setting b_hnp_enable prior to suspend then it may not resume in order to poll the status of the Host Request flag. The OTG B-device can become host by initiating the HNP procedure directly. The OTG A-device shall start polling the Host Request flag whenever the USB bus resumes.

If the OTG A-device determines from the OTG descriptor that the connected OTG B-device does not support HNP (HNP support bit = FALSE) then it shall not poll the Host Request flag.

[19] When connected to legacy HNP capable OTG B-peripherals HNP polling will not be possible. In this case the OTG A-host shall give the OTG B-peripheral the opportunity to take the host role before ending the session by setting b_hnp_enable and suspending the bus for at least $T_{A\_BIDL\_ADIS}$ min (see Section 5.2.1).

If the OTG A-host detects an unsupported HNP capable OTG B-peripheral (HNP support bit = TRUE) then the OTG A-host shall either:

- maintain the session and continue HNP polling or,
- enable HNP by setting b_hnp_enable and suspend the bus for at least $T_{A\_BIDL\_ADIS}$ min before ending the session (see Section 5.2.1)

An OTG A-peripheral shall respond to GetStatus() requests by setting the Host Request bit to one when it wishes to become host and by resetting the Host Request bit to zero at other times. An OTG A-peripheral shall not STALL a GetStatus() request from an OTG B-host.

6.3.3 OTG B-devices

When an OTG B-device, which is capable of HNP in the B-device role (HNP support bit = TRUE) wishes to become host, it can signal its intention through the following mechanisms:

- If there is an active session then the OTG B-device shall set the Host Request flag in response to the GetStatus() request from the OTG A-device (see Section 6.2.3). The OTG A-device will then enable HNP by setting b_hnp_enable and suspend the bus.
- If the bus is suspended and HNP has been enabled (b_hnp_enable = TRUE) then OTG B-device shall initiate HNP.

An OTG B-device which is not capable of HNP (HNP Support bit = FALSE) shall STALL the GetStatus() request from the OTG A-device.

If an OTG B-host determines that the Host request flag is set to one the OTG B-host shall allow the OTG A-peripheral to take the host role, by suspending the bus, within $T_{HOST\_REQ\_SUSP}$.

6.3.4 Possible consequences of a role swap

A peripheral device should warn its user of the possible consequences before using HNP polling to force a role swap in situations where a badly timed role swap may cause data loss or corruption. For example, a forced role swap in the middle of a long-running low-level disk copy using the Mass Storage Class could result in a corrupted Mass Storage Device. The peripheral device may choose to warn or not to warn the user based on knowledge of the current functions it is providing to the host, as some functions may be more robust to unexpected disconnections than others.

6.4 Test Device Support

An OTG A-device, OTG B-device or EH shall recognize, and behave appropriately on encountering, a set of test devices, having VID=0x1A0A, and the PIDs defined in the following sections. An OTG A-device, OTG B-device, peripheral-only B-device or EH shall also respond correctly to the test mode feature bits defined in Section 6.4.3.

6.4.1 High-speed Electrical Test Mode Support

All USB-IF high-speed host electrical compliance tests shall be performed on high-speed hosts. These high-speed tests utilize the test modes defined in Section 7.1.20 of [USB2.0]. An OTG device or EH shall support the test device that initiates these test modes. Upon enumeration by the host, the test device presents a VID/PID pair that defines a test mode or operation to execute. Upon enumerating the test device with VID of 0x1A0A, the Targeted Host shall perform the following operations based on the PID presented. The test mode or operation shall occur on the port where the test fixture is attached.

Table 6-7: Test Modes Product ID Definitions

PID	Test Mode
0x0101	Test_SE0_NAK
0x0102	Test_J
0x0103	Test_K
0x0104	Test_Packet
0x0105	Reserved.
0x0106	HS_HOST_PORT_SUSPEND_RESUME
0x0107	SINGLE_STEP_GET_DEV_DESC
0x0108	SINGLE_STEP_ GET_DEV_DESC_DATA

6.4.1.1 Test Modes

The Test Modes described below are related to Section 7.1.20 of [USB2.0]. The host controller shall stay in the test mode until reset. A means to reset the host controller shall be provided.

Test_SE0_NAK
Upon enumerating VID 0x1A0A/PID 0x0101, the host's downstream port shall enter a high-speed receive mode as described in Section 7.1.20 [USB2.0] and drives an SE0 until the controller is reset.

Test_J
Upon enumerating VID 0x1A0A/PID 0x0102, the host's downstream port shall enter a high-speed J state as described in Section 7.1.20 of [USB2.0] until the host controller is reset.

Test_K
Upon enumerating VID 0x1A0A/PID 0x0103, the host's downstream port shall enter a high-speed K state as described in Section 7.1.20 of [USB2.0] until the host controller is reset.

Test_Packet
Upon enumerating VID 0x1A0A/PID 0x0104, the host shall begin sending test packets as described in Section 7.1.20 of [USB2.0] until the host controller is reset.

HS_HOST_PORT_SUSPEND_RESUME
Upon enumerating VID:0x1A0A/PID 0x0106, the host shall continue sending SOFs for 15 seconds, then suspend the downstream port under test per Section 7.1.7.6.1 of [USB2.0]. After 15 seconds has elapsed, the host shall issue a ResumeK state on the bus, then continue sending SOFs.

SINGLE_STEP_GET_DEVICE_DESCRIPTOR
When the host discovers a device with VID:0x1A0A/PID 0x0107, the following steps are executed by the host and the device.

1. The host enumerates the test device, reads VID:0x1A0A/PID 0x0107, then completes its enumeration procedure.
2. The host issues SOFs for 15 seconds allowing the test engineer to raise the scope trigger just above the SOF voltage level.
3. The host sends a complete GetDescriptor(Device) transfer
4. The device ACKs the request, triggering the scope. (Note: SOFs continue.)

SINGLE_STEP_GET_DEVICE_DESCRIPTOR_DATA
When the host discovers a device with VID:0x1A0A/PID 0x0108, the following steps are executed by the host and the device.

1. The host enumerates the test device and reads VID:0x1A0A/PID 0x0108, then completes its enumeration procedure
2. After enumerating the device, the host sends GetDescriptor(Device)
3. The device ACKs the request
4. The host issues SOFs for 15 seconds allowing the test engineer to raise the scope trigger just above the SOF voltage level
5. The host sends an IN packet
6. The device sends data in response to the IN packet, triggering the scope
7. The host sends an ACK in response to the data. (Note: SOFs may follow the IN transaction).

6.4.2 Protocol and OTG Electrical Test Device Support

A device with VID=0x1A0A, PID=0x0200 is defined to be a test device, required by the compliance test. An OTG A-device, OTG B-device or EH shall recognize this test device and behave accordingly as defined below. The test devices shall continue to be recognized by retail examples of the devices, to permit subsequent audit.

The test device has no endpoints, no class function, and the host shall not perform any class activity after configuration.

6.4.2.1 Behavior of OTG A-device on Enumerating Test Device

An OTG A-device shall configure the test device to configuration 1, within T_{TST_CONFIG} max of completing the bus reset.

When the OTG A-device under test enumerates the test device it shall set and/or reset its own OTG test mode feature bits as required, making use of information in the device descriptor (see Section 6.4.3). Currently only one such bit, ‘otg_vbus_off’, is defined.

6.4.2.1.1 OTG A-device supporting HNP polling.

The OTG A-device shall then maintain a session for at least T_{TST_MAINT} min during which time it shall not suspend the test device and shall allow at minimum $I_{A\_VBUS\_RATED}$ to be drawn, by the Protocol and Electrical Tester (PET), from V_{BUS}. The OTG A-device shall perform HNP polling during this period.

If, within this period of T_{TST_MAINT} such HNP polling finds that Host request flag is set, the A-device shall allow the B-device (the PET) to become host, in accordance with the HNP specification timings.

If within the period of T_{TST_MAINT} the Host Request flag is not set, a host able to recognize SRP shall, before T_{TST_MAINT} max, end the session, and be prepared to accept SRP requests.

If a role swap took place, then after the B-device (the PET) stops acting as a host, the A-device shall become host again, rather than exercising its option of ending the session. This requirement to maintain the session remains in force until the B-device detaches.

If the 'otg_vbus_off' feature bit does not get set during enumeration, and the PET disconnects before the end of the T_{TST_MAINT} min period of configured state, the OTG A-device shall maintain the session for at least $T_{A\_WAIT\_BCON}$ min and end it within $T_{A\_WAIT\_BCON}$ max..

If the 'otg_vbus_off' feature bit gets set during enumeration then, if the PET disconnects before the end of the T_{TST_MAINT} min period of configured state, the host shall turn off V_{BUS}, if it is capable of doing so, and shall not perform any ADP probes for a period defined in Section 6.4.3.2.1.

A host which is not capable of turning off V_{BUS} may, after the T_{TST_MAINT} configured period, continue to send SOFs, or may suspend the B-device.

6.4.2.1.2 OTG A-device not supporting HNP polling.

If the PET has set its OTG descriptor HNP support bit, the OTG A-device under test shall set b_hnp_enable, and shall suspend the PET within $T_{HOST\_REQ\_POLL}$ max (2 sec) plus $T_{HOST\_REQ\_SUSP}$ max (2 sec), and shall allow the B-device (the PET) to become host, in accordance with the HNP specification timings.

If the PET has not set its OTG descriptor HNP support bit, the OTG A-device shall then maintain a session for at least T_{TST_MAINT} min during which time it shall not suspend the test device and shall allow at minimum $I_{A\_VBUS\_RATED}$ to be drawn, by the Protocol and Electrical Tester (PET), from V_{BUS}. It shall then before T_{TST_MAINT} max, end the session, and be prepared to accept SRP requests.

If a role swap took place, then after the B-device (the PET) stops acting as a host, the A-device shall become host again, rather than exercising its option of ending the session. This requirement to maintain the session remains in force until the B-device detaches.

If the otg_vbus_off' feature bit does not get set during enumeration, and the PET disconnects before the end of the T_{TST_MAINT} min period of configured state, the OTG A-device shall maintain the session for at least $T_{A\_WAIT\_BCON}$ min and end it within $T_{A\_WAIT\_BCON}$ max.

If the 'otg_vbus_off' feature bit gets set during enumeration (and the PET did not set its OTG descriptor HNP support bit) then, if the PET disconnects before the end of the T_{TST_MAINT} min period of configured state, the host shall turn off V_{BUS}, if it is capable of doing so, and shall not perform any ADP probes for a period defined in Section 6.4.3.2.1.

A host which is not capable of turning off V_{BUS} may, after the T_{TST_MAINT} configured period, continue to send SOFs, or may suspend the B-device.

6.4.2.2 Behavior of OTG B-device on Enumerating Test Device

During testing, the PET may enumerate an HNP capable B-device under test, and then set the otg_hnp_reqd feature bit. The B-device shall then perform HNP and assume the host role.

The OTG B-device, once acting as a host, shall enumerate the test device within T_{TST_CONFIG} max of the bus reset, and shall Set_Configuration (0), and shall then suspend within T_{TST_SUSP} of the Set_Configuration (0), and hand back the host role to the A-device (the PET), in accordance with the HNP specification timings.

6.4.2.3 Behavior of EH on Enumerating Test Device

The EH shall configure the test device to configuration 1, within T_{TST_CONFIG} max of the bus reset.

When the EH under test enumerates the test device it shall set and/or reset its own OTG test mode feature bits as required (see below for more detail).

The EH shall then maintain a session for at least T_{TST_MAINT} min, during which time it shall allow up to $I_{A\_VBUS\_RATED}$ to be drawn from V_{BUS} by the tester.

Before T_{TST_MAINT} max, it shall end the session, and be prepared to accept SRP requests if implemented.

If the otg_vbus_off feature bit gets set during enumeration then, if the PET disconnects during the T_{TST_MAINT} min period of configured state, the host shall turn off V_{BUS}, if it is capable of doing so, and shall not perform any ADP probes for a period defined in Section 6.4.3.2.1.

6.4.3 Test Mode Feature Bits

The test mode feature bits defined in Table 6-8 shall be supported by an OTG A-device, OTG B-device, peripheral-only B-device or EH. . A USB bus reset received by a device which has any of these feature bits set, shall cause the feature bit to be cleared.

Table 6-8: Test Mode Feature Bit Definitions

Feature Bit Name	SetFeature TEST_MODE wIndex high byte value	bcdDevice Bit Number	Set/Reset	Purpose
otg_srp_reqd	0x06	-	Set by Set-Feature, cleared by device internally when SRP performed	Force an SRP to be performed. A device which does not support SRP shall STALL this request.
otg_hnp_reqd	0x07	-	Set by Set-Feature, cleared by device internally when HNP performed	Force an HNP to be performed. A device which does not support HNP shall STALL this request.
otg_vbus_off	-	0	Set by enumeration, cleared by device internally when V_{BUS} turned off.	Force V_{BUS} off after disconnect. A host not capable of controlling V_{BUS} shall ignore this feature bit.

6.4.3.1 B-device Test Mode Feature Bits

Two of these bits are defined for use on a B-device under test, and are controlled by using the standard USBrequest ‘SetFeature’ with bmRequestType = 0, wValue = TEST_MODE, wIndex low byte = 0, and wIndex high byte being a value of 0x06 or 0x07, as defined above.’

6.4.3.1.1 Feature Bit ‘otg_srp_reqd’

The feature bit relates to an SRP-capable B-device. When this flag is set by the PET (acting as an A-device and using SetFeature) it shall cause an SRP to be generated by the B-device, within T_{TST_SRP} after the A-device (the PET) turns off V_{BUS}. A B-device not capable of SRP, shall STALL the SetFeature request. Once set, the feature bit shall remain set until the SRP has been attempted, at which point it shall automatically be cleared , or until the device receives a USB bus reset.

Note: This allows the PET to check the SRP behavior after a session, without requiring user interaction, and allows testing of the requirements of Section 5.1.2 Initial Conditions, $T_{B\_SE0\_SRP}$.

6.4.3.1.2 Feature Bit ‘otg_hnp_reqd’

The feature bit relates to an HNP-capable B-device. When this flag is set by the PET (acting as an A-device and using Set Feature), the B-device shall set its Host Request Flag within T_{TST_HNP}, and after suspension, if the ‘b_hnp_enable’ feature bit of the B-device is set, shall perform its part in an HNP handoff, without the need for user intervention. It shall reset and enumerate the PET, setting configuration 0, within T_{TST_CONFIG} max of completing the bus reset. It shall then suspend and hand back control to the tester, and reconnect within T_{TST_HNPEND}.

A B-device not capable of HNP, shall STALL the Set Feature request. Once set, the feature bit shall remain set until the HNP has been occurred and control has been handed back to the PET, at which point it shall automatically be cleared, or until the device receives a USB bus reset.

6.4.3.2 A-device Test Mode Feature Bit

A-device test mode feature bits shall be set by the following method. The PET, when behaving as a B-device, shall specify the bcdDevice field in its Device Descriptor, used as a bitmapped value, each bit potentially defining a test mode feature bit. The default value of ‘bcdDevice’ is 0x0000. Undefined bits shall be set to zero by the PET. When an A-device enumerates the test device, it shall use the value in the Device Descriptor field bcdDevice to set or reset its own appropriate feature bit, according to the individual bits of ‘bcdDevice’. Note that although the name ‘bcdDevice’ implies a bcd value, it is being used in this case as a bitmapped field.

Only one A-device test mode feature bit (bit 0 - ‘otg_vbus_off ‘) is currently defined.

6.4.3.2.1 Feature Bit ‘otg_vbus_off’

This feature bit only applies to hosts capable of switching off V_{BUS}.

The feature bit is set by the A-device itself when it enumerates the test device and finds that bcdDevice, bit 0 = 1. So it will be set while the UUT is behaving as an A-device and is about to configure the B-device, and then maintain a session for T_{TST_MAINT}. If the B-device (the PET) disconnects before T_{TST_MAINT} min, the A-device shall turn off V_{BUS} within T_{TST_VBOFF}, and then maintain it off, without performing ADP, for T_{TST_NOADP}. At this point in time it shall clear the feature bit automatically, and revert to its normal behavior. If the B-device (the PET) fails to disconnect during T_{TST_MAINT} max, the feature bit shall automatically be set to zero.

Note: One purpose of this feature bit is to allow the measurement of T_{SSEND_LKG} and $I_{VBUS\_LKG\_SRC}$.

6.4.4 Unknown Device Not Supporting HNP

A device with VID=0x1A0A, PID=0x0201 is reserved as a test device, which shall not be on the TPL of any Targeted Host. It may be used by the compliance tester to represent a device which is not supported and which does not support HNP. Vendors should note that the compliance tester may use this, or any other VID/PID combination which is not on the TPL, for the purposes of tests which require compliant behavior when encountering such a device.

6.4.5 Unknown Device Supporting HNP

A device with VID=0x1A0A, PID=0x0202 is reserved as a test device, which shall not be on the TPL of any Targeted Host. It may be used by the compliance tester to represent a device which is not supported and which supports HNP. Vendors should note that the compliance PET may use this, or any other VID/PID combination which is not on the TPL, for the purposes of tests which require compliant behavior when encountering such a device.

7 State Diagrams

This section contains state diagrams provided for the reference of OTG device, EH and SRP-capable peripheral-only B-device implementers. In the case of any conflict between these diagrams and the behavior described in the rest of the document, the state machines take precedence.

- Figure 7-1 shows the state machine of an OTG A-device with HNP.
- Figure 7-2 shows the state machine of an EH with a Micro-AB connector.
- Figure 7-3 shows the state machine of an EH with a Standard-A connector.
- Figure 7-4 shows the state machine of an OTG B-device with HNP.
- Figure 7-5 shows the state machine of an ADP or SRP capable B-device (OTG B-device without HNP or a peripheral-only B-device).

The state machine for an OTG device with both A-device an B-device HNP capability is equivalent to the OTG A-device with HNP state machine combined with the OTG B-device with HNP state machine.

The state machine for an OTG device with A-device HNP capability but without B-device HNP capability is equivalent to the OTG A-device with HNP state machine combined with the B-device state machine

The state machine for an OTG device which does not support HNP is equivalent to the OTG A-device without HNP state machine combined with the B-device state machine with the role determined by the ID pin.

7.1 A-device

The OTG A-device with HNP state diagram (shown in Figure 7-1) and EH or OTG A-device without HNP state diagram (shown in Figure 7-2) consists of the states listed in Table 7-1 and uses the parameters listed in Table 7-2.There is a transition to the OTG B-device start state (b_idle) that occurs if the cable is detached. When the A-device is in any state except the a_idle state, the A-device transitions to the a_wait_vfall state before transitioning to the a_idle state and then to the b_idle state.

Figure 7-1: OTG A-device with HNP State Diagram

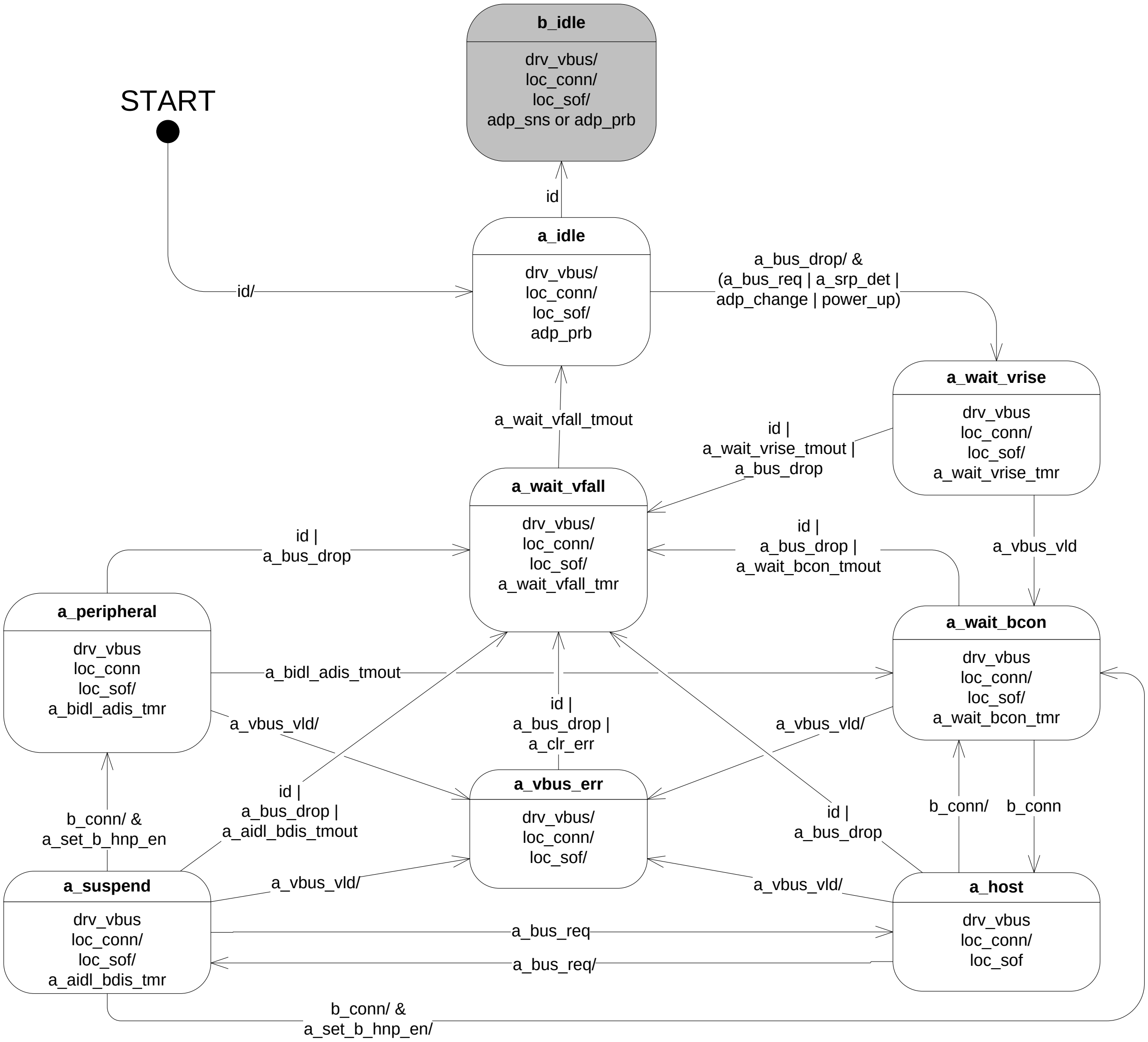


Figure 7-2: EH with a Micro-AB State Diagram

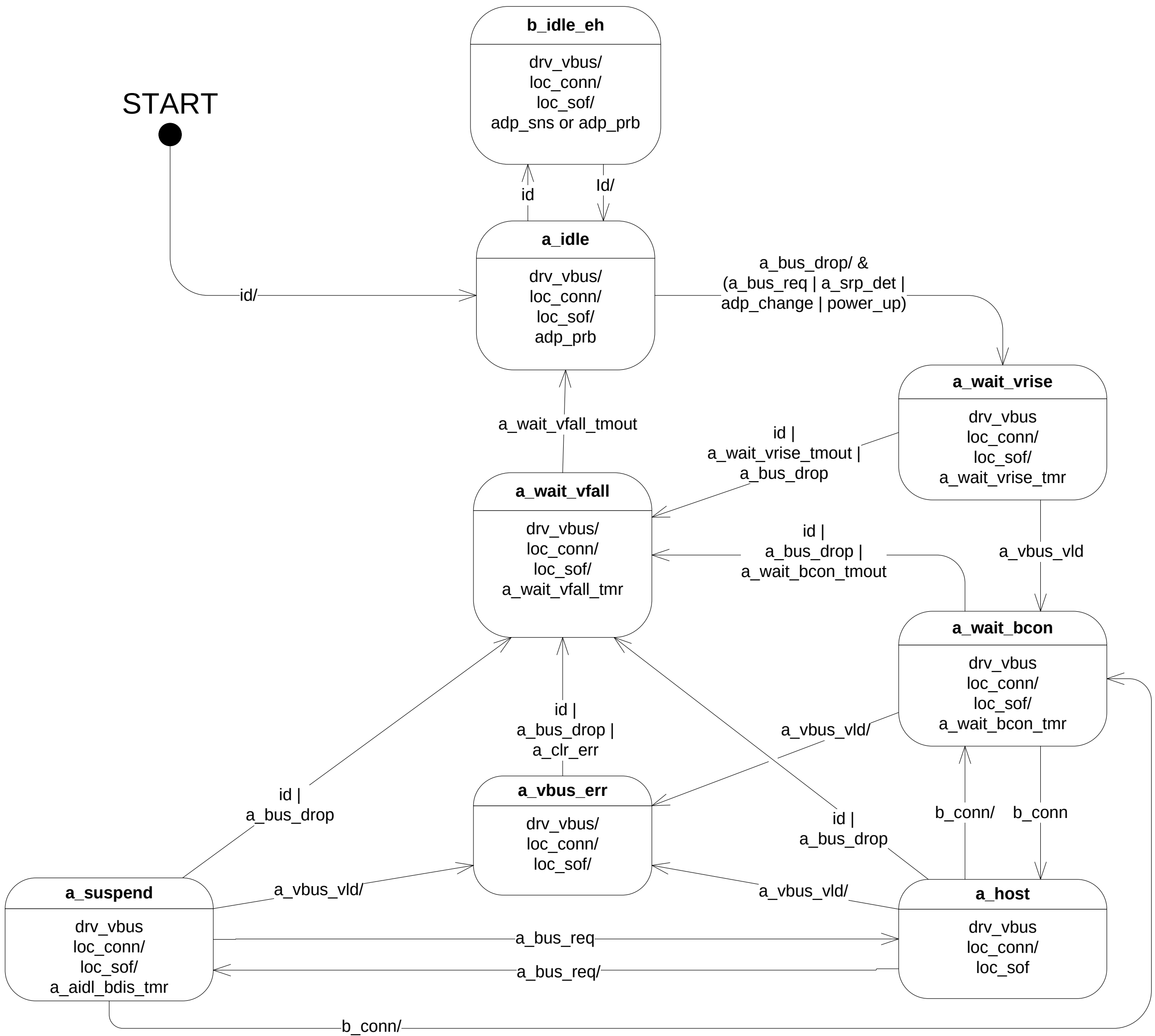


Figure 7-3: Embedded Host with a Standard-A

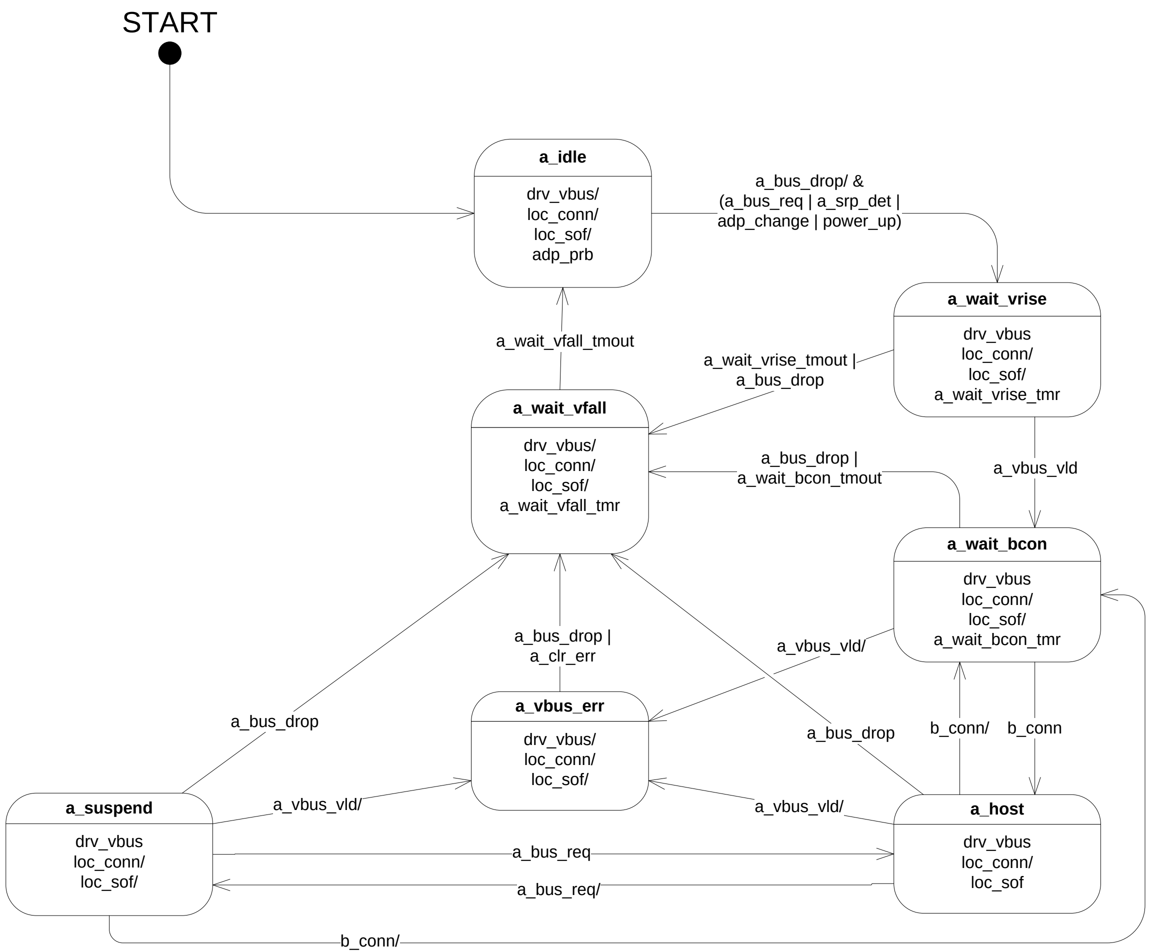


Table 7-1: A-device states

State	Description	Ref
a_idle	A-device starting state	7.1.1
a_wait_vrise	Wait for VBUS to go into regulation	7.1.2
a_wait_bcon	Wait for B-device to signal connection	7.1.3
a_host	Acting as a host	7.1.4
a_suspend	Bus suspend	7.1.5
a_peripheral	Acting as a peripheral	7.1.6
a_wait_vfall	Wait for VBUS to drop to VOTG_VBUS_LKG	7.1.7
a_vbus_err	Wait for recovery from over-current condition	7.1.8
b_idle_eh	State for an EH with a Micro-AB when id is TRUE.	7.1.9
b_idle	B-device starting state	7.2.1

Table 7-2: A-device state machine parameters

Parameter	Description	Ref
Inputs		
a_bus_drop	TRUE when the A-device application needs to power down the bus	7.4.1.5
a_bus_req	TRUE while the A-device application wants to use the bus	7.4.1.6
a_srp_det	TRUE if the A-device detects SRP	7.4.1.7
a_vbus_vld	TRUE when the VBUS voltage is in regulation	7.4.1.8
b_conn	TRUE if the B-device pulls D+ or D- high for longer than the debounce interval.	7.4.1.9
id	FALSE when a Micro-A plug is inserted in the device's Micro-AB receptacle	7.4.1.1
adp_change	TRUE when current ADP measurement (n) value, compared to the ADP measurement taken at n-2, differs by more than CADP_THR	7.4.1.2
power_up	TRUE when the A-device first powers up its USB system.	7.4.1.3
Internal variables		
a_set_b_hnp_en	TRUE when the A-device has successfully set the b_hnp_enable bit in the B-device.	7.4.3.1
Outputs		
drv_vbus	TRUE when an A-device is driving VBUS.	7.4.2.2
loc_conn	TRUE when local device has signaled that it is connected to the bus.	7.4.2.3
loc_sof	TRUE when the local device is generating activity on the bus.	7.4.2.4
adp_prb	TRUE when the local device is in the process of carrying out ADP probing.	7.4.2.5
Informative variables		
a_clr_err	Asserted to clear a_vbus_err due to an overcurrent condition and causes the A-device to transition to a_wait_vfall	7.4.3.4
Timers/Timeouts		
a_wait_vrise_tmr /a_wait_vrise_tmout	Used by an A-device to wait for the voltage on VBUS to go into regulation.	7.4.5.1
a_wait_vfall_tmr /a_wait_vfall_tmout	Used by an A-device to wait for VBUS to fall below VOTG_VBUS_LKG.	7.4.5.2
a_wait_bcon_tmr /a_wait_bcon_tmout	Used by an A-device to wait for the B-device to signal a connection.	7.4.5.3
a_aidl_bdis_tmr /a_aidl_bdis_tmout	Used by an A-device during suspend to time when it can stop waiting for a disconnect and end the session	7.4.5.4
a_bidl_adis_tmr /a_bidl_adis_tmout	Used by an A-device to determine when the B-device has finished being host	7.4.5.6

7.1.1 a_idle

This is the start state for A-devices.

The A-device transitions to the a_wait_vrise state:

- if the A-device application is not wanting to drop the bus (a_bus_drop = FALSE), and any of the following are true:
  - the A-device Application is requesting the bus (a_bus_req = TRUE), or
  - SRP is detected on the bus (a_srp_det = TRUE) or
  - an ADP change has been detected (adp_change = TRUE) or
  - the A-device has only just powered up its USB system (power_up = TRUE). Note: for an ADP-capable A-device ADP probing takes place immediately after power up in order to calibrate the measurement (see Section 5.4.4). In this case the power_up transition shall only be triggered after a reliable ADP measurement value has been obtained.

OTG devices are configured such that a change in id from TRUE to FALSE causes a_bus_req to be asserted unless the device is ADP capable (see Section 4.2.4) and that a change in id from FALSE to TRUE causes a transition to the b_idle state.

EH's with Micro-AB receptacles are configured such that a change in id from TRUE to FALSE causes a_bus_req to be asserted unless the device is ADP capable (see Section 4.2.4) and that a change in id from FALSE to TRUE causes a transition to the b_idle_eh state.

This does not apply to an EH with a Standard-A receptacle since there is no ID pin in the Standard-A plug.

7.1.2 a_wait_vrise

In this state, the A-device waits for the voltage on VBUS to go into regulation (a_vbus_vld = TRUE). Upon entering this state, the A-device starts a timer (a_wait_vrise_tmr).

The A-device transitions to the a_wait_bcon state:

- if the voltage on VBUS is in regulation (a_vbus_vld = TRUE)

The A-device transitions to the a_wait_vfall state:

- if the Micro-A plug is detached (id = TRUE, applies to OTG A-devices only), or
- if the a_wait_vrise_tmr times out (a_wait_vrise_tmout = TRUE) or
- if the A-device application wants to drop the bus (a_bus_drop = TRUE).

7.1.3 a_wait_bcon

In this state, the A-device waits for the B-device to signal a connection. Upon entering this state, the A-device starts a timer (a_wait_bcon_tmr).

The A-device transitions to the a_wait_vfall state:

- if the Micro-A plug is detached (id = TRUE, applies to OTG A-devices only), or
- if the A-device Application wants to drop the bus (a_bus_drop = TRUE), or
- if the a_wait_bcon_tmr times out (a_wait_bcon_tmout = TRUE)[20].

If the A-device detects the B-device signaling a connection (b_conn = TRUE), then the A-device shall transition to the a_host state and generate a bus reset within $T_{A\_BCON\_ARST}$ to prepare the B-device for packet traffic.

[20] An A-device may set its a_wait_bcon_tmr to an arbitrarily large value and wait an indefinitely long period of time for the B-device to connect.

If the attached device is unsupported due to an overcurrent condition (see Section 4.2.2), then the A-device transitions to the a_vbus_err state.

7.1.4 a_host

In this state the A-device performs the following actions:

- A-device enumerates B-device
- if the A-device supports the B-device (see Section 3.4.1), then the A-device sets up communication with the B-device
- else if A-device does not support the B-device then the A-device informs the user that the B-device is not supported and sets a_bus_req = FALSE

If the B-device disconnects (b_conn = FALSE) then the A-device transitions from the a_host state to the a_wait_bcon state[21].

Under the following conditions the A-device transitions from the a_host state to the a_wait_vfall state.

- if the Micro-A plug is detached (id = TRUE, applies to OTG A-devices only), or
- if the A-device wishes to stop powering VBUS (a_bus_drop = TRUE).

Under the following conditions, the A-device transitions from the a_host state to the a_suspend state:

- if the application on the A-device no longer wishes to use the bus (a_bus_req = FALSE)

If the attached device is unsupported due to an overcurrent condition (see Section 4.2.2), then the A-device transitions to the a_vbus_err state.

7.1.5 a_suspend

Upon entering the a_suspend state, if HNP has been enabled (a_set_b_hnp_en = TRUE), an OTG A-device starts the a_aidl_bdis_tmr. This timer can be set to an arbitrarily long time, but shall be longer than $T_{A\_AIDL\_BDIS}$ min.

An OTG A-device transitions to the a_wait_vfall state:

- if the Micro-A plug is detached (id = TRUE, applies to OTG A-devices only), or
- if the A-device wishes to stop powering VBUS (a_bus_drop = TRUE), or
- if the a_aidl_bdis_tmr times out (a_aidl_bdis_tmout = TRUE)

An EH will transition to the a_wait_vfall state only if it wishes to stop powering VBUS (a_bus_drop = TRUE)

For the OTG A-device state diagram in Figure 7-1 if the B-device signals a disconnect (b_conn = FALSE), and the A-device was successful in setting b_hnp_enable (a_set_b_hnp_en = TRUE), then the A-device transitions to the a_peripheral state[22].

---

[21] If the same B-device subsequently reconnects the A-device should examine its descriptors to ensure that the B-device is supporting the same device class as when it was previously connected.

[22] If b_conn became FALSE due to the removal of the B-plug (rather than a disconnect) then the a_bidl_adis_tmr will subsequently expire and the A-device will transition to a_wait_bcon. After this the a_wait_bcon_tmr will expire and the A-device will transition to a_wait_vfall.

The A-device transitions to the a_host state if a_bus_req is asserted. If a_bus_req is asserted, then the A-device can do a resume. If the A-device detects remote wakeup signaling from the B-device this may cause the A-device to set a_bus_req depending on whether it is prepared to respond to this signalling.

If the B-device signals a disconnect (b_conn = FALSE), and the A-device did not set b_hnp_enable (a_set_b_hnp_en = FALSE) or is an EH, then the A-device transitions to the a_wait_bcon state[23].

If the attached device is unsupported due to an overcurrent condition (see Section 4.2.2), then the A-device transitions to the a_vbus_err state.

7.1.6 a_peripheral

This state is not applicable to an EH. In this state, the A-device signals a connection to the B-device (loc_conn = TRUE) and responds to requests from the OTG B-device. If the A-device is capable of HS operation, then it shall begin the high-speed detection handshake whenever a bus reset is detected.

The A-device transitions from the a_peripheral state to the a_wait_vfall state:

- if the Micro-A plug is detached (id = TRUE), or
- if the A-device wants to power down VBUS (a_bus_drop = TRUE)

The A-device transitions from the a_peripheral state to the a_wait_bcon state if the a_bidl_adis_tmr times out (a_bidl_adis_tmout = TRUE). If the A-device detects more than $T_{A\_BIDL\_ADIS}$ min of continuous idle (i.e. J_state), on the bus, then the A-device may transition to the a_wait_bcon state. The A-device shall transition back to the a_wait_bcon state before $T_{A\_BIDL\_ADIS}$ max of continuous idle is detected.

If the attached device is unsupported due to an overcurrent condition (see Section 4.2.2), then the A-device transitions to the a_vbus_err state.

This is the only state in which the A-device will signal a connection to the B-device.

7.1.7 a_wait_vfall

In this state the A-devices stops driving VBUS (drv_vbus = FALSE) and waits for VBUS to fall to $V_{OTG\_VBUS\_LKG}$.

The A-device transitions from the a_wait_vfall state to the a_idle state:

- if the a_wait_vfall_tmr expires (a_wait_vfall_tmout = TRUE)

7.1.8 a_vbus_err

In this state, the A-device waits for recovery of the overcurrent condition that caused it to enter this state.

The A-device transitions to the a_wait_vfall state under the following conditions:

- if the Micro-A plug is detached (id = TRUE, applies to OTG A-devices only), or
- if the A-device is no longer capable of powering VBUS (a_bus_drop = TRUE)
- upon assertion of a_clr_err (nominally by system software)

---

[23] If b_conn became FALSE due to the removal of the B-plug rather than a disconnect the a_wait_bcon_tmr will subsequently expire and the A-device will transition to a_wait_vfall.

To preserve the integrity of the circuitry supplying power to VBUS, on entering this state it is recommended that the A-device application no longer requires a drive to VBUS (a_bus_drop = TRUE).

7.1.9 b_idle_eh

In this state the EH stops driving VBUS and should display a failure to the end user.

The EH transitions to the a_idle state when the id pin becomes TRUE.

7.2 OTG B-device with HNP

The OTG B-device with HNP state diagram shown in Figure 7-3 consists of the states listed in Table 7-3 and uses the parameters listed in Table 7-4.

Figure 7-4: OTG B-device with HNP State Diagram

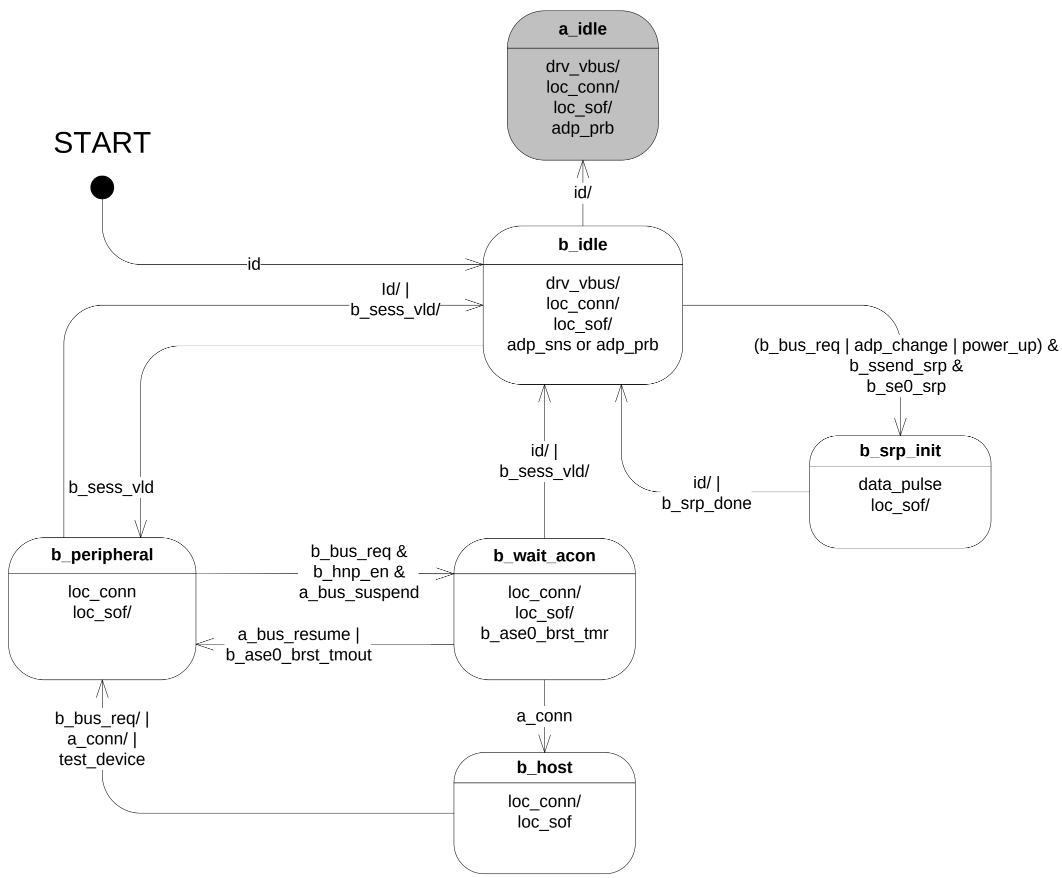


Table 7-3: OTG B-device with HNP States

State	Description	Ref
b_idle	Wait for a session to start by monitoring if VBUS rises above VOTG_SESS_VLD	7.2.1
b_srp_init	Attempt to initiate SRP	7.2.2
b_peripheral	Acting as a peripheral	7.2.3
b_wait_acon	Waiting for A-device to connect as a peripheral	7.2.4
b_host	Acting as a host	7.2.5

Table 7-4: OTG B-device with HNP state machine parameters

Parameter	Description	Ref
Inputs		
a_bus_resume	TRUE when the B-device detects that the A-device is signaling a resume (K state)	7.4.1.10
a_bus_suspend	TRUE when the B-device detects that the A-device has put the bus into suspend	7.4.1.11
a_conn	TRUE if the B-device detects a connection from the A-device	7.4.1.12
b_bus_req	TRUE during the time that the Application running on the B-device wants to use the bus	7.4.1.13
b_se0_srp	TRUE when the line has been at SE0 for more than the minimum time before generating SRP	7.4.1.14
b_ssend_srp	TRUE when the VBUS has been below VOTG_SESS_VLD for more than the minimum time before generating SRP.	7.4.1.15
b_sess_vld	TRUE when the B-device detects that the voltage on VBUS is above VOTG_SESS_VLD	7.4.1.16
id	TRUE when a Micro-A plug is not inserted in the device's Micro-AB receptacle	7.4.1.1
adp_change	TRUE when current ADP measurement (n) value, compared to the ADP measurement taken at n-2, differs by more than CADP_THR.	7.4.1.2
power_up	TRUE when the OTG device first powers up its USB system.	7.4.1.3
test_device	TRUE when the B-device is attached to an OTG test device	7.4.1.4
Internal variables		
b_srp_done	TRUE when the B-device has completed initiating SRP	7.4.3.2
b_hnp_en	TRUE when the B-device has accepted the SetFeature(b_hnp_enable)	7.4.3.3
Outputs		
data_pulse	TRUE when a B-device is performing data line pulsing	7.4.2.1
drv_vbus	TRUE when an A-device is driving VBUS.	7.4.2.2
loc_conn	TRUE when the local device has signaled that it is connected to the bus.	7.4.2.3
loc_sof	TRUE when the local device is generating activity on the bus.	7.4.2.4
adp_prb	TRUE when the local device is in the process of doing ADP probing.	7.4.2.5
adp_sns	TRUE when the B-device is in the process of carrying out ADP sensing.	7.4.2.6
Timers/Timeouts		
b_ase0_brst_tmr/ b_ase0_brst_tmout	Timer used to wait for an A-device to signal a connection.	7.4.5.5

7.2.1 b_idle

This is the starting state for OTG B-devices.

In this state, the OTG B-device waits for a session to start by monitoring if VBUS rises above the Session Valid threshold (b_sess_vld = TRUE). If VBUS rises above this threshold, the OTG B-device enters the b_peripheral state and signals a connect (loc_conn = TRUE).

The B-device transitions from the b_idle to the b_srp_init state:

- if the Application indicates that it wants to start a session (b_bus_req = TRUE), or
- an ADP change has been detected (adp_change = TRUE) or
- the B-device has only just powered up its USB system (power_up = TRUE). Note: for an ADP-capable B-device ADP probing takes place immediately after power up in order to calibrate the measurement (see Section 5.4.4). In this case the power_up transition shall only be triggered after a reliable ADP measurement value has been obtained.
- and if VBUS has been below the Session End threshold for at least TB_SSEND_SRP (b_ssend_srp = TRUE),
- and if the bus has been in the SE0 state for the minimum time before generating SRP (b_se0_srp = TRUE).

If the Micro-A plug is inserted (id = FALSE), then the OTG B-device transitions to the a_idle state and becomes an A-device.

7.2.2 b_srp_init

Upon entering this state, the OTG B-device attempts to initiate a session via SRP. Upon completion, (b_srp_done = TRUE) the OTG B-device returns to the b_idle state, to wait for the A-device to drive VBUS above the Session Valid threshold (b_sess_vld = TRUE).

If the Micro-A plug is inserted (id = FALSE), then the OTG B-device transitions to the b_idle state.

7.2.3 b_peripheral

In this state, the OTG B-device acts as the peripheral, and responds to requests from the A-device.

The OTG B-device transitions to the b_wait_acon state:

- if the Application indicates that it wants to start a session (b_bus_req = TRUE) and
- the A-device has granted the OTG B-device permission (b_hnp_en = TRUE) and
- the bus is in the Suspend state, (a_bus_suspend = TRUE)

The OTG B-device transitions to the b_idle state:

- if a Micro-A plug is inserted (id = FALSE) or
- if VBUS drops below the Session Valid threshold (b_sess_vld = FALSE)

When a high-speed capable B-device enters this state it shall enable its pull-up on D+. After the B-device enables its pull-up, it shall monitor the state of the bus to determine if a bus reset is being signaled by the A-device. If the pull-up is turned on for TWTRSTHS[24] (Table 7-14 in [USB2.0]) and the bus is in the SE0 state then a reset condition exists. If the B-device is capable of HS, it shall begin the high-speed detection handshake any time that a bus reset condition exists.

[24] The TWTRSTHS is a sample point that occurs at a device dependent time after the pull-up resistor is turned on.

7.2.4 b_wait_acon

In this state, the OTG B-device has received a SetFeature(b_hnp_enable) giving it permission to assume the role of host and it has detected that the bus has gone to the Suspend state. Upon entering this state, the OTG B-device turns off its pull-up resistor on D+, starts a timer (b_ase0_brst_tmr), and waits for the A-device to signal a connect.

The OTG B-device returns to the b_peripheral state:

- if the b_ase0_brst_tmr expires (b_ase0_brst_tmout = TRUE), or
- if the B-device detects a K_state on the bus, indicating that the A-device is signaling a resume (a_bus_resume = TRUE)

If the A-device signals a connect (a_conn = TRUE) before the b_ase0_brst_tmr expires, then the B-device transitions to the b_host state. The B-device shall be able to detect the connect from the A-device and transition to the b_host state within $T_{B\_ACON\_BSE0}$ max after D+ is detected to be high at the B-device.

The OTG B-device transitions to the b_idle state:

- if a Micro-A plug is inserted (id = FALSE) or
- V_{BUS} drops below the Session Valid threshold (b_sess_vld = FALSE)

7.2.5 b_host

Upon entering this state, the B-device issues a bus reset, and starts generating SOF's. The B-device may query the A-device for its descriptors.

While the B-device is in this state, the A-device responds to requests from the B-device. If the B-device does not support the A-device, then the B-device shall provide a message to the user informing them of this.

The B-device stops generating bus activity (loc_sof = FALSE) and transitions to the b_peripheral state:

- once the B-device has completed its usage of the A-device (b_bus_req = FALSE), or
- if the B-device detects that the A-device has signaled a disconnect (a_conn = FALSE), or
- within 30 seconds of the OTG B-device detecting that a test device, as defined in section 6.4, is attached (test_device =TRUE)

7.3 ADP-capable or SRP-capable B-device

The state diagram relevant for ADP-capable or SRP-capable B-devices is shown in Figure 7-4. It consists of three distinct states listed in Table 7-5 and uses the parameters listed in Table 7-6. Note: any parameters relating to ADP (parameters starting "adp_..") do not apply to B-devices without ADP capability.

Figure 7-5: ADP-capable or SRP-Capable B-device State Diagram

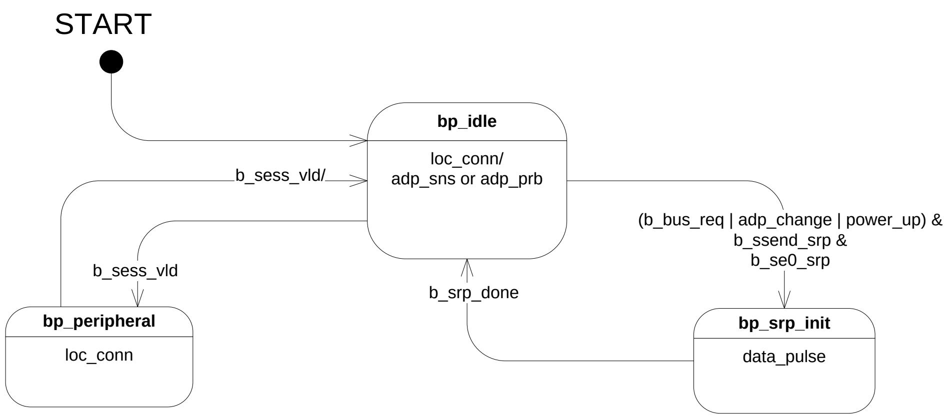


Table 7-5: ADP-capable or SRP-capable B-device states

State	Description	Ref
bp_idle	Wait for a session to start by monitoring if VBUS rises above VOTG_SESS_VLD	7.3.1
bp_srp_init	Attempt to initiate SRP	7.3.2
bp_peripheral	Acting as a peripheral	7.3.3

Table 7-6: ADP-capable or SRP-capable B-device state machine parameters

Parameter	Description	Ref
Inputs		
b_ssend_srp	TRUE when the VBUS has been below VOTG_SESS_VLD for more than the minimum time before generating SRP	7.4.1.15
b_sess_vld	TRUE when the B-device detects that the voltage on VBUS is above VOTG_SESS_VLD	7.4.1.16
b_se0_srp	TRUE when the line has been at SE0 for more than the minimum time before generating SRP	7.4.1.14
adp_change	TRUE when current ADP measurement (n) value, compared to the ADP measurement taken at n-2, differs by more than CADP_THR.	7.4.1.2
power_up	TRUE when the OTG device first powers up its USB system.	7.4.1.3

Parameter	Description	Ref
Internal variables		
b_srp_done	TRUE when the B-device has completed initiating SRP	7.4.3.2
Outputs		
data_pulse	TRUE when a B-device is performing data line pulsing	7.4.2.1
loc_conn	TRUE when the local device has signaled that it is connected to the bus.	7.4.2.3
adp_prb	TRUE when the local device is in the process of doing ADP probing.	7.4.2.5
adp_sns	TRUE when the B-device is in the process of doing ADP sensing.	7.4.2.6

7.3.1 bp_idle

This is the starting state for peripheral-only B-devices.

In this state, the peripheral-only B-device waits for a session to start by monitoring if VBUS rises above the VBUS Session Threshold (b_sess_vld = TRUE). If VBUS rises above this threshold, the peripheral-only B-device enters the bp_peripheral state.

The peripheral-only B-device transitions from the bp_idle state to the bp_srp_init state:

- if the Application indicates that it wants to start a session (b_bus_req = TRUE), or
- an ADP change has been detected (adp_change = TRUE) or
- the peripheral-only B-device has only just powered up its USB system (power_up = TRUE). Note: for an ADP-capable peripheral-only B-device ADP probing takes place immediately after power up in order to calibrate the measurement (see Section 5.4.4). In this case the power_up transition shall only be triggered after a reliable ADP measurement value has been obtained.
- and if VBUS has been below the Session End threshold for at least TB_SSEND_SRP (b_ssend_srp = TRUE),
- and if the bus has been in the SE0 state for the minimum time before generating SRP TB_SE0_SRP min(b_se0_srp = TRUE).

7.3.2 bp_srp_init

Upon entering this state, the peripheral-only B-device attempts to start a session via SRP defined. Upon completion (b_srp_done = TRUE) the B-device returns to the bp_idle state, to wait for the A-device to drive VBUS above the Session Valid threshold (b_sess_vld = TRUE).

7.3.3 bp_peripheral

In this state, the peripheral-only B-device acts as a [USB2.0] compliant device.

If VBUS drops below the Session Valid threshold (b_sess_vld = FALSE), then the peripheral-only B-device transitions to the bp_idle state.

7.4 State Machine Parameters

This section describes the inputs, internal variables, timers, and outputs associated with the state machines.

7.4.1 Inputs

7.4.1.1 id

The identification (id) input is FALSE when a Micro-A plug is inserted in the device's Micro-AB receptacle. Otherwise, this input is TRUE.

7.4.1.2 adp_change

The ADP change value (adp_change) is TRUE when an OTG device, EH or SRP-capable peripheral-only B-device is doing ADP probing (adp_prb = TRUE) and two successive ADP measurement values are different by more than CADP_THR (see section 5.4.2).

The ADP change value (adp_change) is TRUE when a B-device is doing ADP sensing of an ADP-capable A-device and then detects that the ADP probing signal is no longer present.

Both of these indicate a potential change in the attachment status of the remote device. An ADP change will cause the local device to determine whether the remote device is responsive by starting or requesting a new session.

7.4.1.3 power_up

The power up value (power_up) is TRUE when the device first powers up its USB system.

7.4.1.4 test_device

The test device value (test_device) is TRUE when the OTG device or EH is attached to a test device (see Section 6.4).

7.4.1.5 a_bus_drop

The "A-device bus drop" (a_bus_drop) input is TRUE when the Application running on the A-device wants to power down the bus, and is FALSE otherwise. When this input is TRUE, then the a_bus_req input shall be FALSE.

7.4.1.6 a_bus_req

The "A-device bus request" (a_bus_req) input is TRUE during the time that the Application running on the A-device wants to use the bus, and is FALSE when the Application no longer wants to use the bus. a_bus_req can also be set to TRUE in response to remote wakeup signaling from the B-device should the A-device decide to resume the bus.

7.4.1.7 a_srp_det

The "A-device SRP detect" (a_srp_det) input is TRUE if the A-device detects SRP as defined in Section 5.1. This bit is set when data line pulsing is detected. This variable is set to FALSE on initial power up of the A-device (power_up = TRUE) or whenever the A-device transitions to the a_wait_vfall state.

7.4.1.8 a_vbus_vld

The "A-device VBUS valid" (a_vbus_vld) input is TRUE when the VBUS voltage is in regulation.

7.4.1.9 b_conn

The "B-device connect" (b_conn) variable is used by the A-device as a condition for transitioning between the following states:

Table 7-7: b_conn state transitions

On b_conn transition	Exit State	Enter State
FALSE → TRUE	a_wait_bcon	a_host
TRUE → FALSE	a_host	a_wait_bcon
TRUE → FALSE	a_suspend	a_peripheral
TRUE → FALSE	a_suspend	a_wait_bcon

If b_conn is FALSE, it is set to TRUE if the B-device pulls D+ or D- high for longer than the debounce interval. The debounce interval varies depending on how the a_wait_bcon state was entered, and how long it has been since either D+ or D- has been pulled high. If the a_wait_bcon state was entered from the a_peripheral**,** a_host or a_suspend states, then the short debounce interval ($T_{A\_BCON\_SDB}$) is allowed. If the a_wait_bcon state was entered from the a_wait_vrise state then the long debounce interval ($T_{A\_BCON\_LDB}$) is required.

The A-device is only allowed to apply the short debounce to b_conn in a window of time. If the A-device stays in the a_wait_bcon state for longer than $T_{A\_BCON\_SDB\_WIN}$ max, then the long debounce interval applies no matter how the a_wait_bcon state was entered. If the state machine is timing the short debounce interval, changes to D- and D+ do not affect the setting of b_conn if they occur before T_{LDIS_DSCHG} min.

While the A-device is in the a_host or a_suspend state, then the A-device will set b_conn FALSE if the A-device detects that the B-device has disconnected, as described in Section 7.1.7.3 of [USB2.0]. The A-device also sets b_conn to FALSE whenever it transitions to any state other than a_host or a_suspend.

[USB2.0] insures at least 100 ms from the time the device indicates a connect until the device will be reset to start the session. This is not the case for OTG devices. They are not assured in all cases of a 100 ms interval after indicating a connect. When an OTG device signals connect, it shall be prepared to receive the bus reset that starts the session.

7.4.1.10 a_bus_resume

The "A-device bus resume" (a_bus_resume) variable is TRUE when the B-device detects that the A-device is signaling a resume (i.e. K state) on the bus.

If the B-device has transitioned to the b_wait_acon state, then a resume (i.e. K state) from the A-device will cause the B-device to return to the b_peripheral state.

7.4.1.11 a_bus_suspend

The “A-device bus suspend” (a_bus_suspend) variable is TRUE when the B-device detects that the A-device has put the bus into suspend[25].

If the B-device has been enabled to become host (b_hnp_enable feature has been set), then the B-device uses this variable to transition from the b_peripheral state to the b_wait_acon state

7.4.1.12 a_conn

The “A-device connect” (a_conn) variable is used by the B-device as a condition for entering or exiting the b_host state.

If the B-device is in the b_wait_acon state, the B-device sets a_conn TRUE if the B-device detects a connection from the A-device.

While the B-device is in the b_host state, it will set a_conn FALSE if the B-device detects that the A-device has disconnected, as described in Section 7.1.7.3 of [USB2.0]. The B-device also sets a_conn to FALSE whenever it goes to any state other than the b_host state.

7.4.1.13 b_bus_req

The “B-device bus request” (b_bus_req) input is TRUE during the time that the Application running on the B-device wants to use the bus, and is FALSE when the Application no longer wants to use the bus.

7.4.1.14 b_se0_srp

The “B-device SE0 before SRP” (b_se0_srp) variable is TRUE when the B-device is in the b_idle state, and the line has been at SE0 for more than the minimum time before generating SRP ($T_{B\_SE0\_SRP}$) (see Table 5-1)

7.4.1.15 b_ssend_srp

The “B-device session end SRP” (b_ssend_srp) input is TRUE if the B-device detects that the voltage on V_{BUS} has been below the Session Valid threshold (VOTG_SESS_VLD) for at least TB_SSEND_SRP (see Table 4-1).

7.4.1.16 b_sess_vld

The “B-device session valid” (b_sess_vld) input is TRUE when the B-device detects that the voltage on V_{BUS} is above its B-device Session Valid threshold (VOTG_SESS_VLD) (see Table 4-1).

7.4.2 Outputs

7.4.2.1 data_pulse

The “data line pulsing” (data_pulse) signal is TRUE when a B-device is performing data line pulsing (see Section 5.1.3).

[25] As per Section 7.1.7.6 of [USB2.0], the downstream device (in this case the B-device) interprets more than 3 ms of idle as an indication that the upstream device has suspended the bus.

7.4.2.2 drv_vbus

The “drive VBUS” (drv_vbus) signal is TRUE when an A-device is driving VBUS.

7.4.2.3 loc_conn

The “local connect” (loc_conn) variable is TRUE when the local device has signaled that it is connected to the bus. This variable is FALSE when the local device has signaled that it is disconnected from the bus (see Section 7.4.1.12).

7.4.2.4 loc_sof

The “local SOF” (loc_sof) bit is TRUE when the local device is generating activity on the bus. Activity begins with a bus reset followed by start of frame packets (SOF’s) or low-speed keep-alives or any other bus activity that occurs with enough frequency to prevent the peripheral device from sensing a lack of bus activity.

7.4.2.5 adp_prb

The ADP probe variable (adp_prb) is TRUE when the local device is doing ADP probing (see section 5.4.2). Implementation of the ADP feature depends on the supported use cases so for a particular implementation this variable may not be required.

An ADP-capable B-device shall first perform ADP sensing (adp_sns = TRUE). If the B-device sense comparator does not toggle for a time of TB_ADP_DETACH, the B-device shall then perform ADP probing and adp_prb will become TRUE (see Section 5.4.3).

7.4.2.6 adp_sns

The ADP sense variable (adp_sns) is TRUE when the local device is doing ADP sensing. This output is used in preference to adp_prb when the B-device detects that the A-device is doing ADP probing (see Section 5.4.3).

7.4.3 Internal Variables

7.4.3.1 a_set_b_hnp_en

The “A-device set b_hnp_enable” (a_set_b_hnp_en) bit is TRUE when the A-device has successfully set the b_hnp_enable bit in the B-device. The A-device sets this bit after it successfully sends a SetFeature (b_hnp_enable) command to the B-device. The A-device clears a_set_b_hnp_en, upon entry into the a_wait_bcon state or when the A-device asserts a bus reset.

7.4.3.2 b_srp_done

The “B-device SRP done” (b_srp_done) bit is TRUE when the B-device has completed initiating SRP.

7.4.3.3 b_hnp_en

The “B-device set b_hnp_enable” (b_hnp_en) bit is TRUE when the B-device has accepted the SetFeature(b_hnp_enable). b_hnp_en is cleared on a bus reset or when b_sess_vld is FALSE (see Section 6.2.2.1).

7.4.3.4 a_clr_err

The A-Device clear error (a_clr_err) is asserted to clear a_vbus_err due to an overcurrent condition and causes the A-device to transition to a_wait_vfall**.**

7.4.4 Informative Variables

The following variables are representations of behavior that is internal to the device.

- a_bus_req
- a_bus_drop
- a_clr_err
- b_bus_req

While the device shall demonstrate behavior related to these variables (i.e. the A-device shall turn on VBUS in response to some activity, corresponding to receiving an a_bus_req) the actual implementation and use of these variables is at the designer's discretion. The inclusion of these variables within the following state machines is not meant to convey required operation, but is an informative example only to show the behavior of the system.

7.4.5 Timers

The HNP state machines make use of the timers in Table 7-7. All timers are started on entry to and reset on exit from their associated states.

Table 7-8: OTG Device Timers

Timer	Timeout Time	Timeout Indication	Associated State
a_wait_vrise_tmr	TA_VBUS_RISE	a_wait_vrise_tmout	a_wait_vrise
a_wait_vfall_tmr	TSSEND_LKG	a_wait_vfall_tmout	a_wait_vfall
a_wait_bcon_tmr	TA_WAIT_BCON	a_wait_bcon_tmout	a_wait_bcon
a_aidl_bdis_tmr	TA_AIDL_BDIS	a_aidl_bdis_tmout	a_suspend
b_ase0_brst_tmr	TB_ASE0_BRST	b_ase0_brst_tmout	b_wait_acon
a_bidl_adis_tmr	TA_BIDL_ADIS	a_bidl_adis_tmout	a_peripheral

7.4.5.1 a_wait_vrise_tmr

This timer is used by an A-device in the a_wait_vrise state to wait for the voltage on VBUS to go into regulation (a_vbus_vld = TRUE). If VBUS is not in regulation before and after TA_VBUS_RISE (a_wait_vrise_tmout = TRUE), then this is an indication that the B-device is drawing too much current.

7.4.5.2 a_wait_vfall_tmr

This timer is used by an A-device in the a_wait_vfall state while waiting for the voltage on VBUS to fall below the VBUS leakage voltage VOTG_VBUS_LKG. When this timer expires the A-device transitions to a_idle.

7.4.5.3 a_wait_bcon_tmr

This timer is used by an A-device in the state to wait for the B-device to signal a connection, (b_conn = TRUE). If the B-device does not connect before $T_{A\_WAIT\_BCON}$, (a_wait_bcon_tmout = TRUE), then the A-device is allowed to stop waiting for a connection.

7.4.5.4 a_aidl_bdis_tmr

This timer is started by an A-device when it enters the a_suspend state if HNP has been enabled (a_set_b_hnp_en = TRUE). If the A-device does not detect a disconnect before $T_{A\_AIDL\_BDIS}$ (a_aidl_bdis_tmout = TRUE), then the A-device is allowed to stop waiting for a disconnect and end the session.

7.4.5.5 b_ase0_brst_tmr

This timer is used by a B-device in the b_wait_acon state, to wait for an A-device to signal a connection, (a_conn = TRUE). If the A-device does not connect before $T_{B\_ASE0\_BRST}$ (b_ase0_brst_tmout = TRUE), then the B-device shall return to the b_peripheral state.

7.4.5.6 a_bidl_adis_tmr

This timer is used by the A-device in the a_peripheral state. The “B-device idle timeout” (a_aidl_bdis_tmout) variable is TRUE when the A-device detects that the B-device has been idle for a sufficient amount of time to allow the B-device to have performed a reset[26]. The A-device uses this variable to transition from the a_peripheral state to the a_wait_bcon state

[26] In Section 7.1.7.6 of [USB2.0] the downstream device (in this case the A-device) interprets more than 3 ms of idle as an indication that the upstream device has suspended the bus. $T_{A\_BIDL\_ADIS}$ min is much larger than this value. This means that the B-device shall suspend the bus for more than $T_{A\_BIDL\_ADIS}$ max in order to indicate that the B-device no longer wants to act as host.

8 Embedded Host Requirements

EHs are required to follow the rules for capability limitation including support for a TPL as defined in Section 3.4 and [OTG and EH Compliance1.0]. In addition they are also allowed to support SRP and ADP as defined in Sections 5.1 and 5.4. EHs are not allowed to support HNP defined in Section 5.2.

EHs are required to follow the USB 2.0 specification except where certain features are not required for the proper functioning of the intended set of supported peripherals. EHs are at liberty to choose whether they leave VBUS always powered, or whether they support SRP or ADP. These EHs must comply with:

- the rules for connectors in Section 3.1.3
- capability limitation in Section 3.4
- "No silent failures" requirements in Section 3.5 and [OTG and EH Compliance1.0].

EHs which support SRP and/or ADP or place limitations on their functionality based on their TPL (e.g. output power) must comply with all of the electrical and protocol requirements of an OTG A-device except for those relating to HNP. This includes:

- Key features detailed in Section 3 (excluding the Micro-AB connector and HNP related features)
- Operation as detailed in Sections 2, A.3.1, and A.3.2
- Electrical characteristics for A-device host operation detailed in Sections 4.1 and 4.2.
- Support for SRP as detailed for the A-device in Section 5.1
- Support for suspend, resume, remote wakeup as defined in [USB2.0]
- Support for ADP as detailed for the A-device in Section 5.4
- Embedded Host state machine as detailed in Section 7.1

Appendix A OTG and EH Device Operation

This appendix describes how some of the use cases described in Section 2 relate to real USB OTG and EH operations and protocols. It contains details of one particular stream of OTG events for a given use case. There is no intention to cover every possible scenario but to describe the normal operational flow for a typical OTG device, EH or SRP-capable peripheral-only B-device. OTG and EH usability without ADP is poor thus ADP is strongly recommended if VBUS will not always be turned on when an A-plug is attached.

A.1 Targeted Host to peripheral-only B-device

A.1.1 Peripheral-only B-device with a hardwired captive cable

Figure A-1 and Figure A-2 show the operation when attaching and detaching a peripheral-only B-device, with a hardwired captive cable, ending in a Micro-A plug, to an OTG device/EH or Standard A plug to an EH. The Targeted Hosts are assumed to support ADP.

Figure A-1: OTG device to peripheral-only B-device with a hardwired captive cable

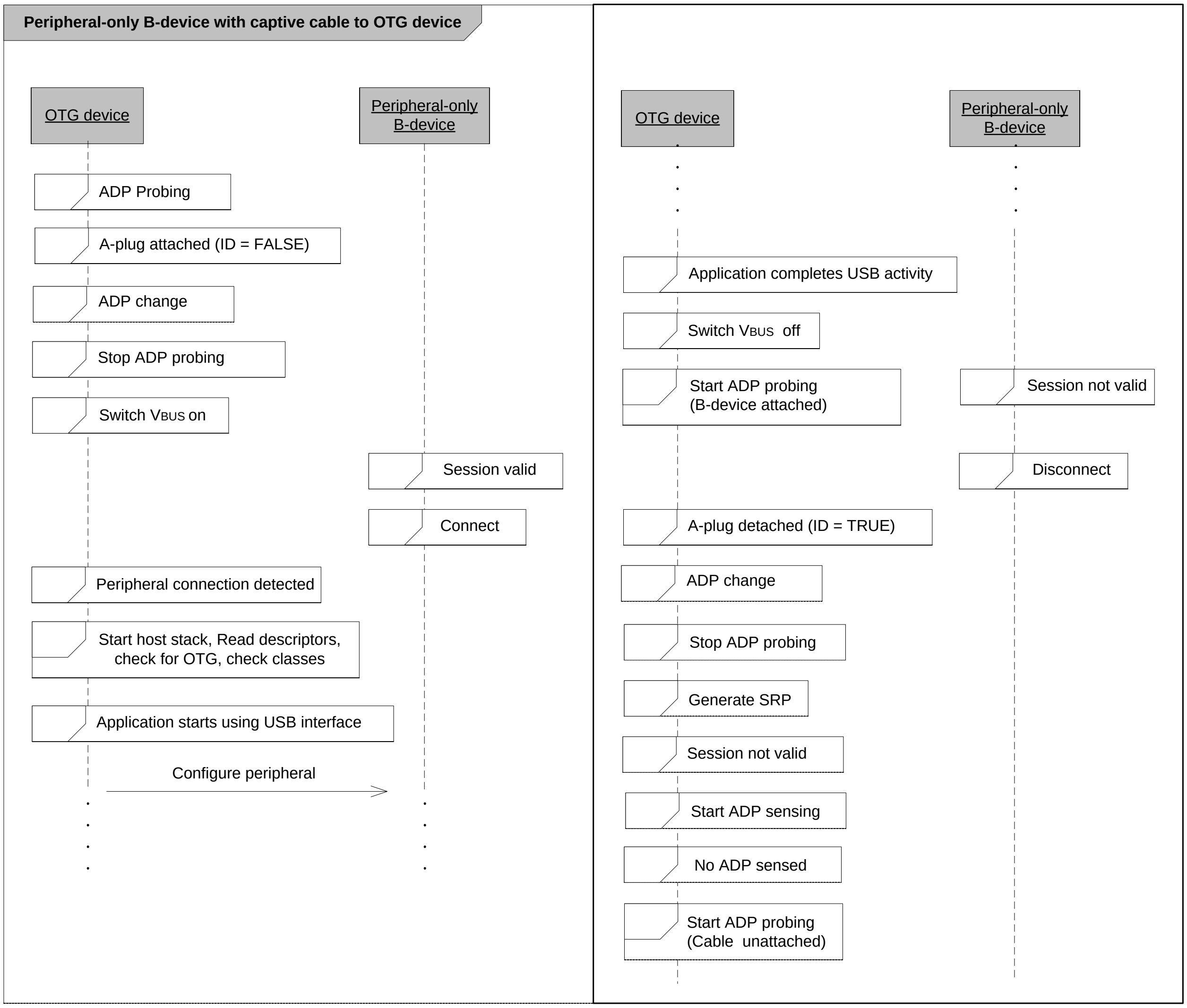
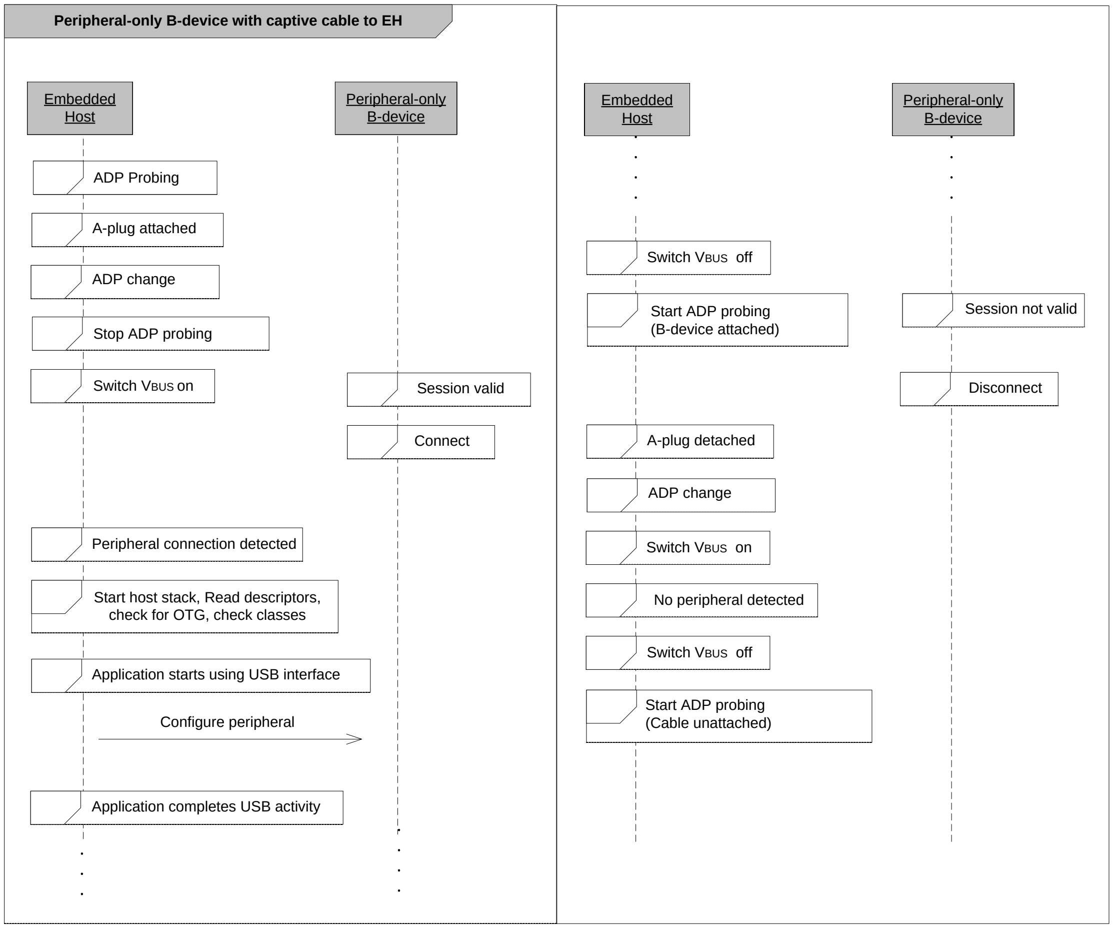


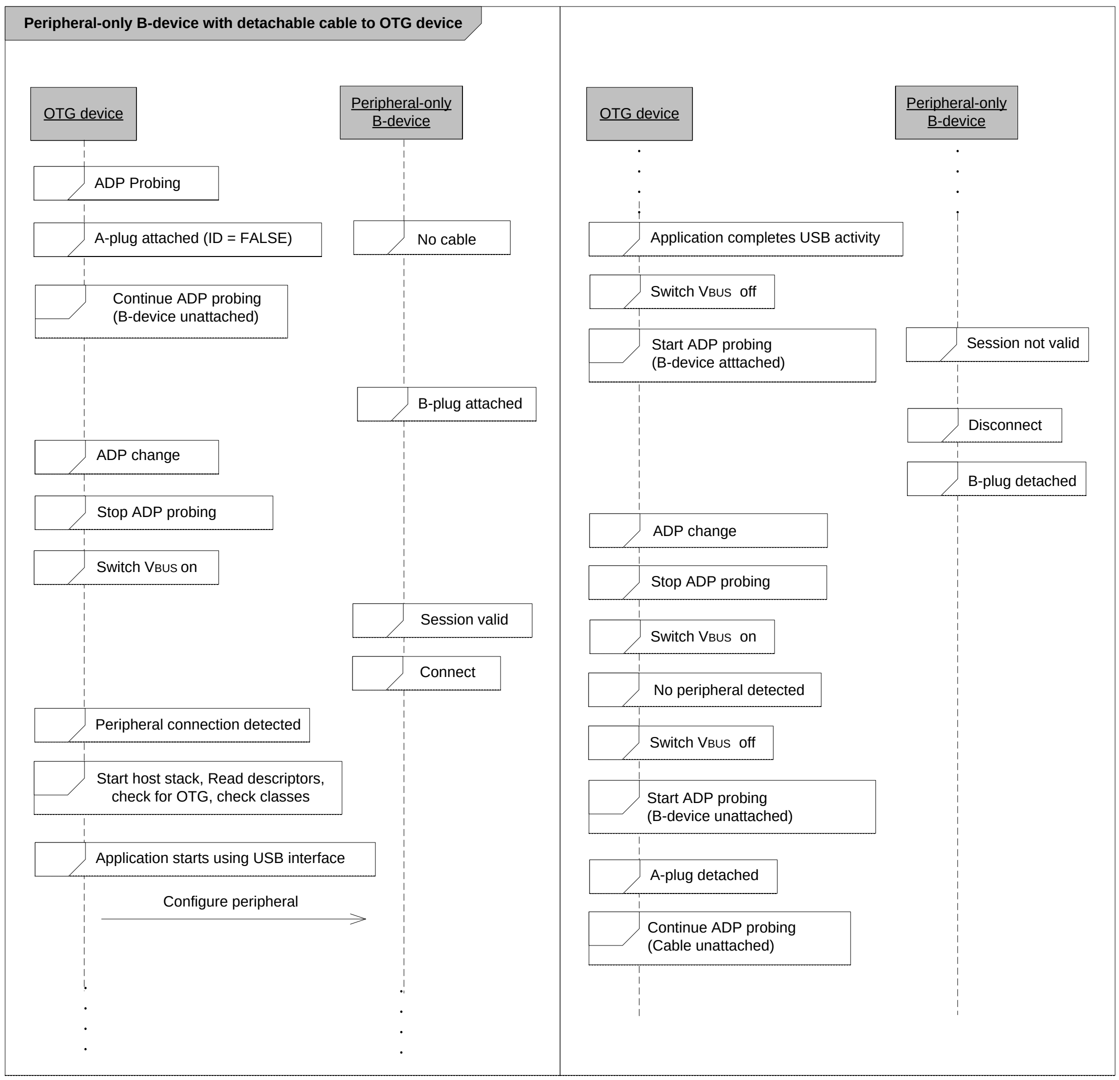
Figure A-2: Embedded Host to peripheral-only B-device with captive cable



A.1.2 Peripheral-only B-device with a detachable cable

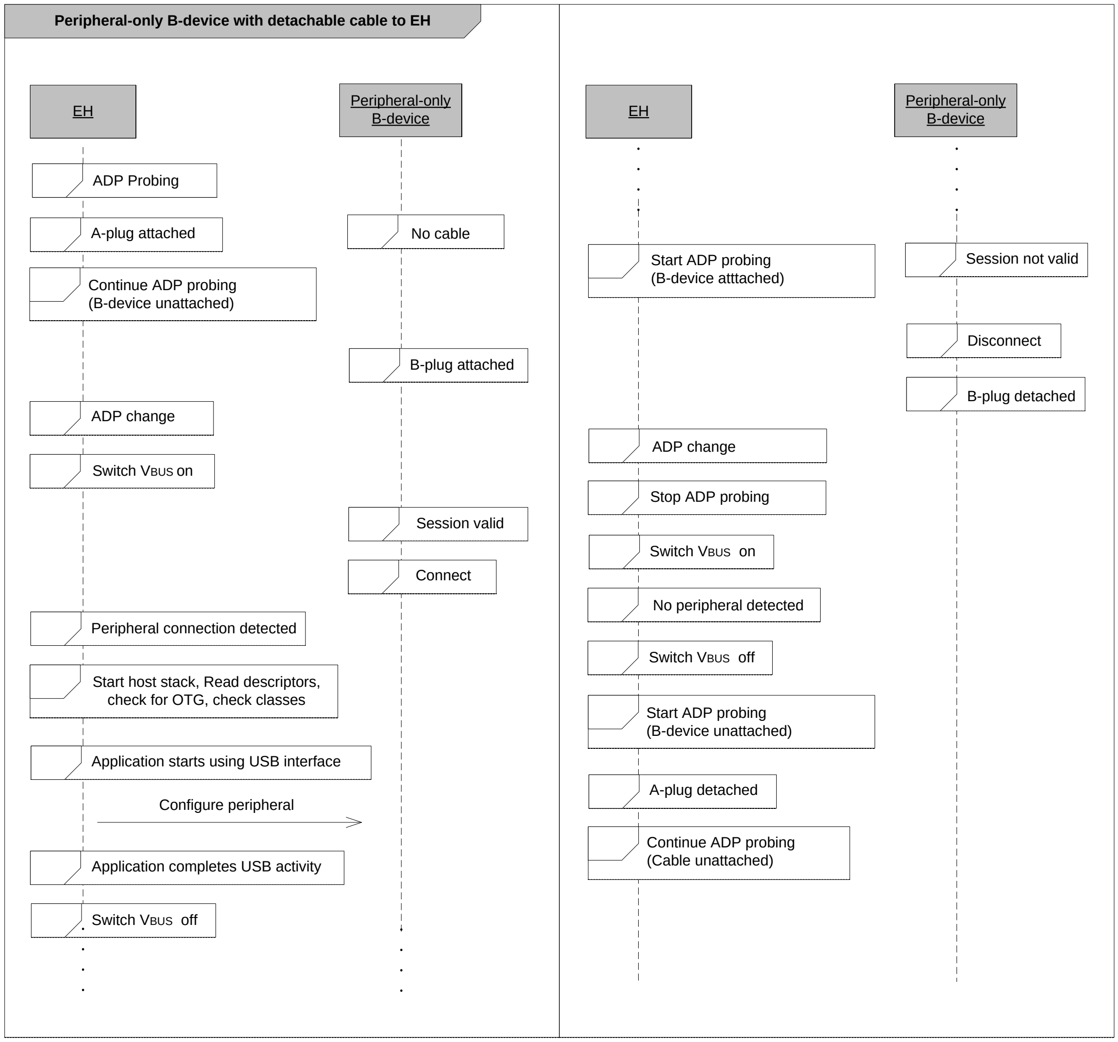
Figure A-3 and Figure A-4 show the operation when attaching and detaching a peripheral-only B-device, with a detachable cable (B-type or captive termination), ending in a Micro-A plug, to an OTG device/EH or Standard-A plug to an EH. The Targeted Host is assumed to support ADP[27].

Figure A-3: Peripheral-only B-device with a detachable cable to OTG device



[27] If the Targeted Host does not support ADP it has no way to detect the B-plug attachment. The Targeted Host can either leave VBUS turned on or raise VBUS in response to a user input (see Section 2.1.1).

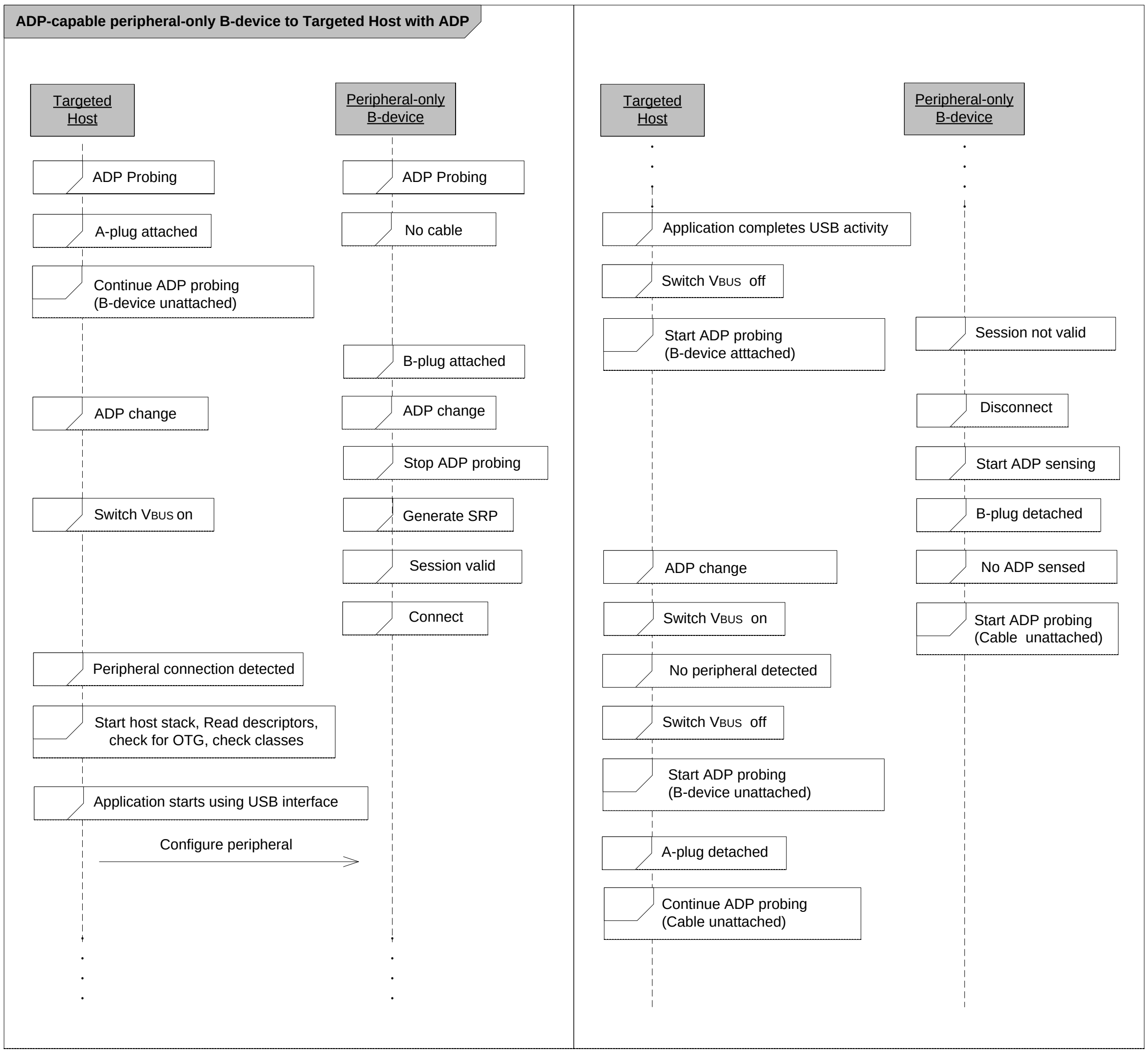
Figure A-4: Peripheral-only B-device with a detachable cable to EH



A.1.3 ADP-capable peripheral-only B-device to ADP-capable Targeted Host

Figure A-5 shows the operation when attaching and detaching an ADP-capable peripheral-only B-device, with non-captive cabling, to a Targeted Host which also supports ADP.

Figure A-5: ADP-Capable peripheral-only B-device to Targeted Host with ADP[28]



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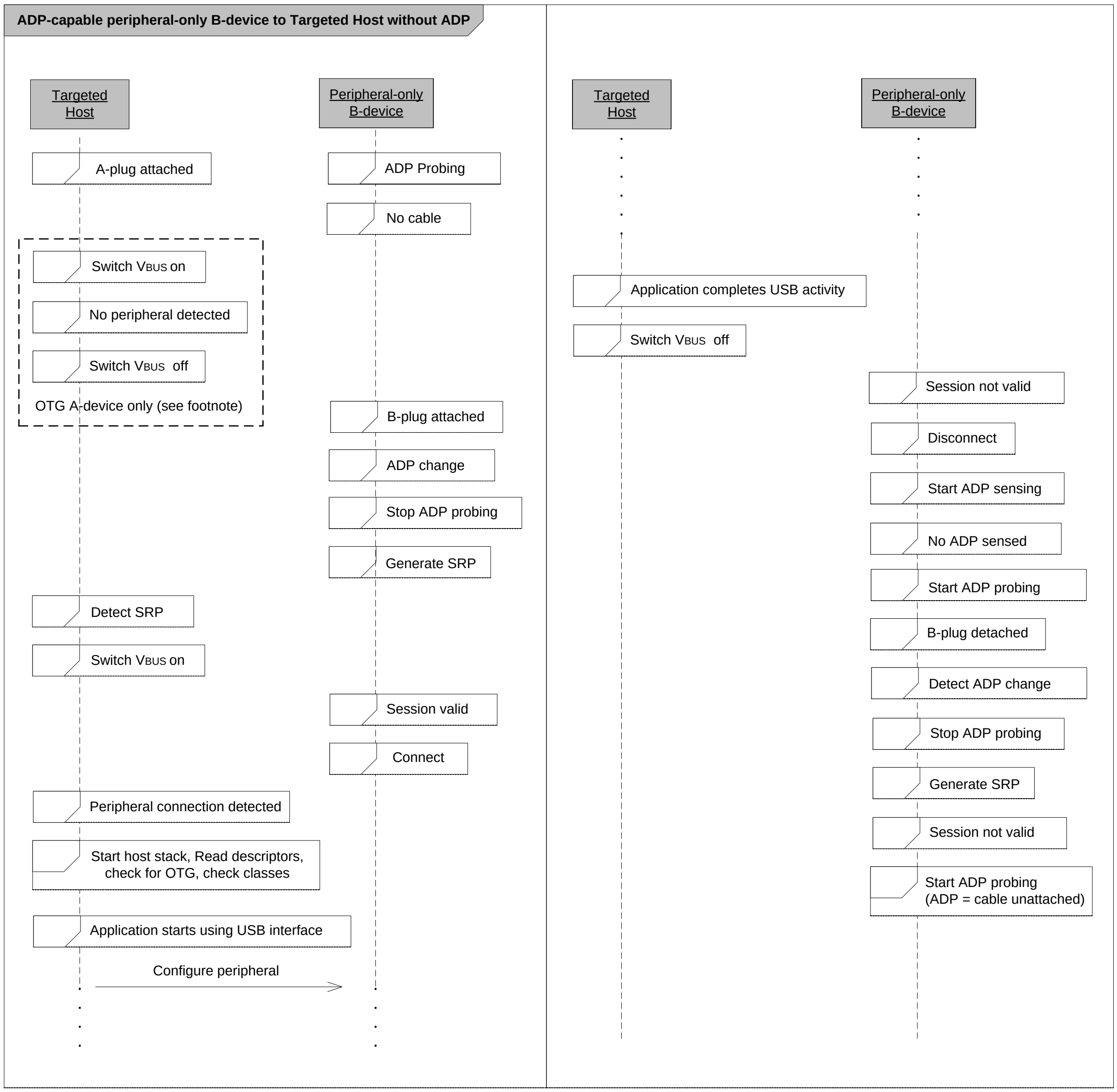
[28] An A-device without ADP capability will not be able to switch on VBUS in response to B-plug attachment.

A.1.4 ADP-Capable peripheral-only B-device to Targeted Host without ADP

Figure A-6 shows the operation when attaching and detaching an ADP-capable peripheral-only B-device, with non-captive cabling. The peripheral is attached to a Targeted Host which doesn't support ADP but has SRP support.

Figure A-6: ADP-Capable peripheral-only B-device to Targeted Host without ADP[29]

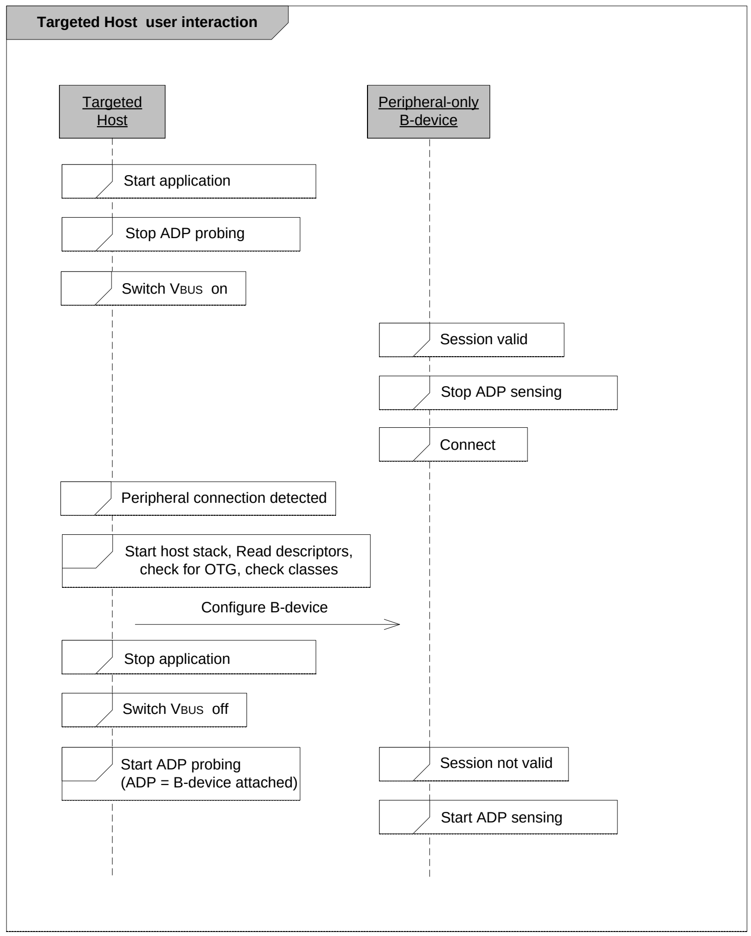


[29] An A-device without ADP capability will not be able to switch on VBUS in response to B-plug attachment.

A.1.5 User interaction with Targeted Host

Figure A-7 shows the operation when no session is active and the user interacts with an ADP-capable Targeted Host attached to a peripheral-only B-device with ADP support. The Targeted Host should check the device classes supported by the peripheral-only B-device at the start of every session since the B-device may have changed its mode of operation.

Figure A-7: User interaction with a Targeted Host when no session is active

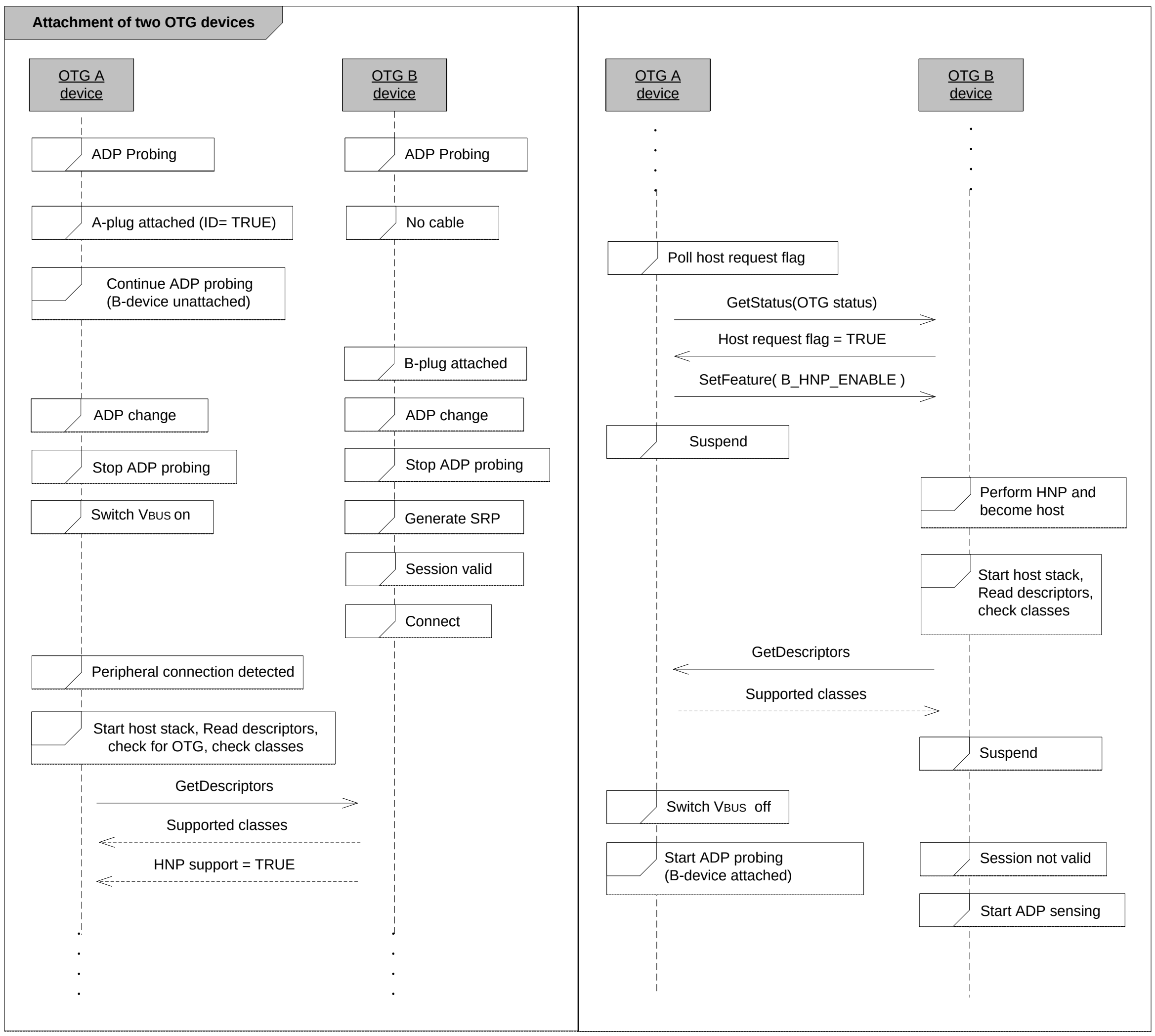


A.2 OTG device to OTG device

A.2.1 Attachment

Figure A-8 shows the operation when attaching two OTG devices, and assumes full support for HNP, SRP, and ADP (see also Section 3.4). In this case the devices are attached and then proceed to each take the host role in order to discover each other's capabilities.

Figure A-8: Attachment of OTG devices[30]

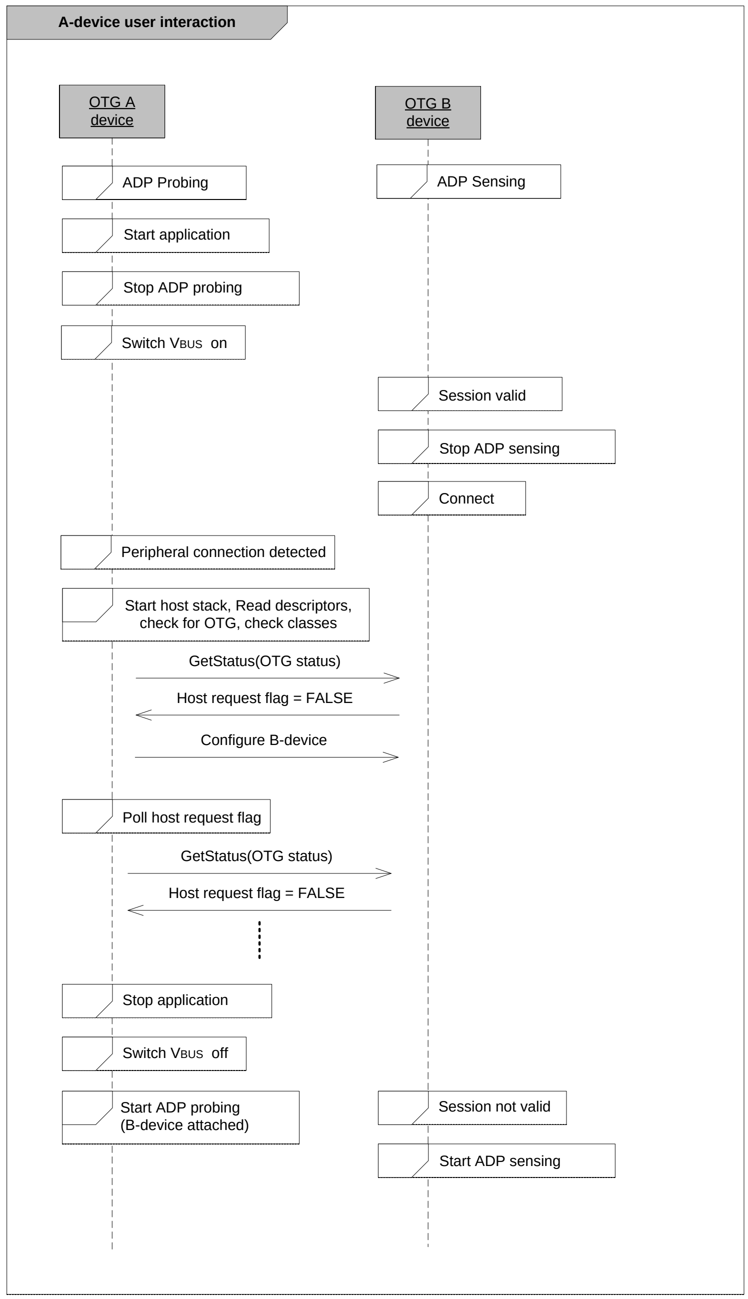


[30] It is recommended but not mandatory for the B-device to take the host role and carry out its own discovery on attachment. This helps the B-device to determine whether it makes sense for it to carry out HNP at a later stage based on the A-device's capabilities as a peripheral.

A.2.2 User Interaction with A-device When No Session Active

Figure A-9 shows the operation when no session is active and the user interacts with the A-device. These steps assume support for ADP. The OTG A-device should check the device classes supported by the peripheral-only B-device at the start of every session since the B-device may have changed its mode of operation.

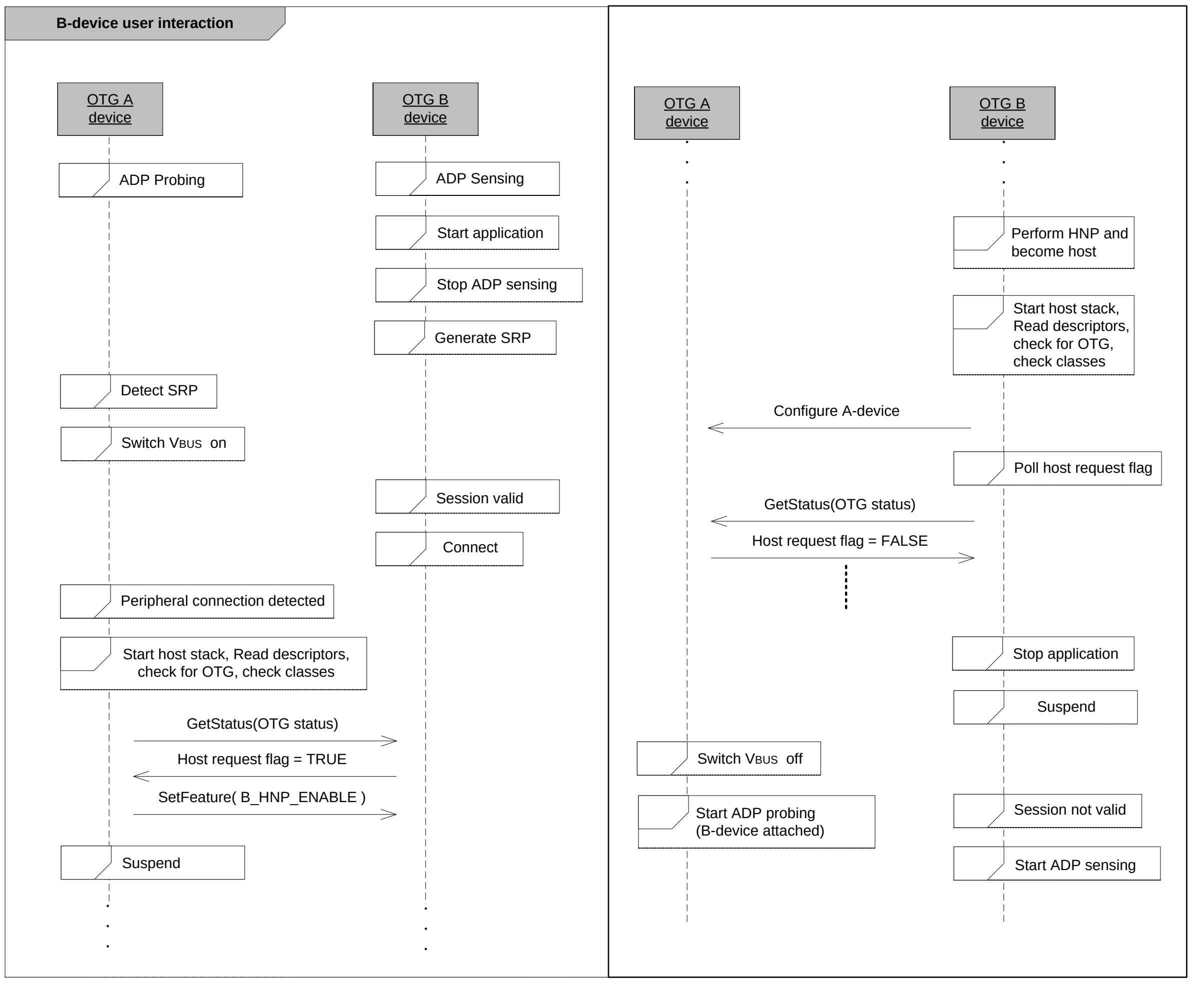
Figure A-9: Interaction with A-device when no session active



A.2.3 User Interaction with B-device When No Session Active

Figure A-10 shows the operation when no session is active and the user interacts with the B-device, and assumes full support for HNP, SRP, and ADP (see also Section 3.4). The OTG B-device should check the device classes supported by the OTG A-device at the start of every session since the OTG A-device may have changed its mode of operation.

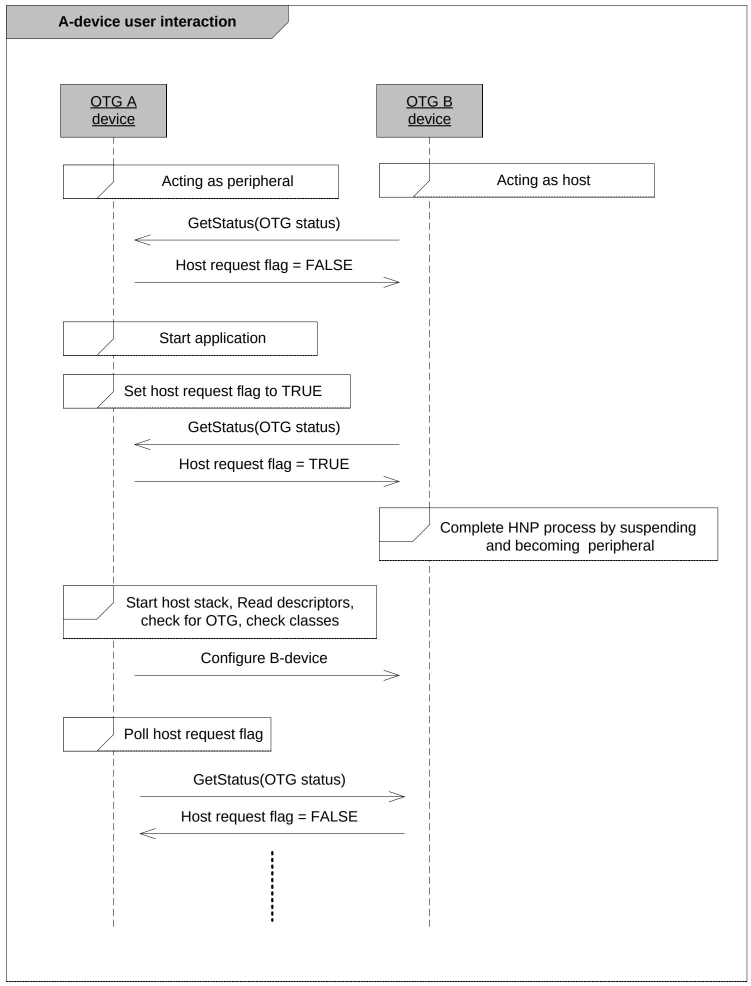
Figure A-10: Interaction with B-device when no session active



A.2.4 User Interaction with A-device When Session Active

Figure A-11 shows the operation when the B-device is active as host and the user interacts with the A-device, and assumes full support for HNP (see also Section 3.4).

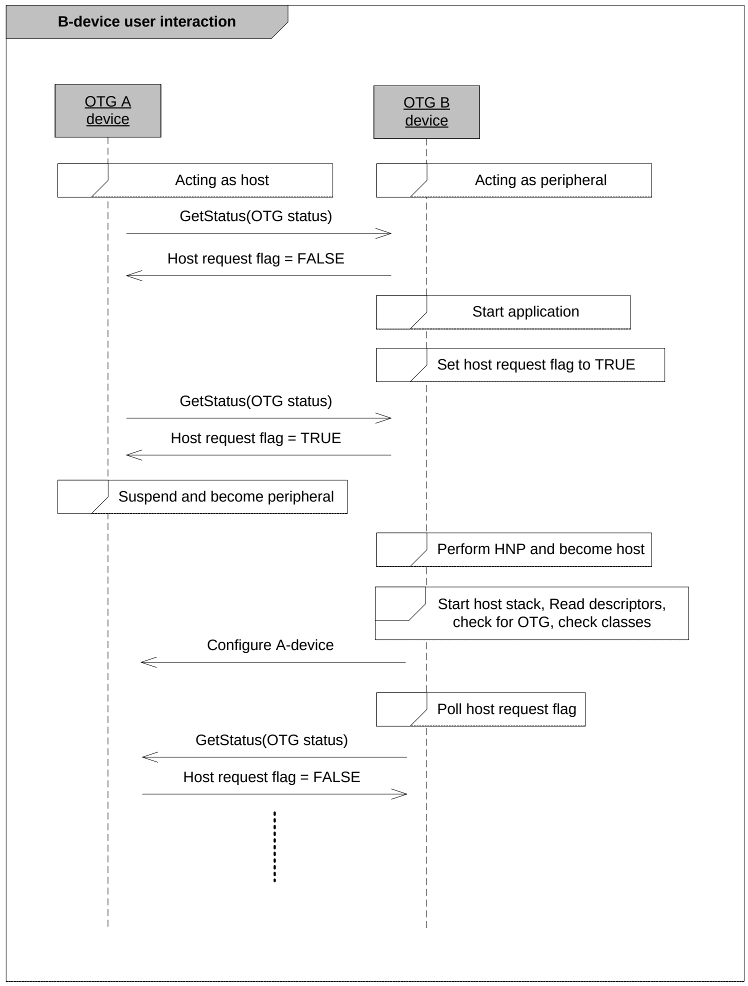
Figure A-11: Interaction with A-device during active session



A.2.5 User Interaction with B-device When Session Active

Figure A-12 shows the operation when the A-device is active as host and the user interacts with the B-device, and assumes full support for HNP (see also Section 3.4).

Figure A-12: Interaction with B-device during active session



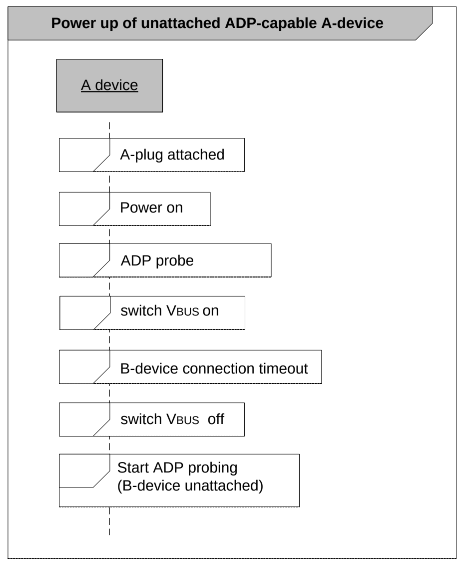
A.3 Operation on power up

The following sections describe the operation of an OTG device or EH immediately after its USB system has been powered up.

A.3.1 Power up of an unattached ADP-capable A-device

Figure A-13 shows the operation of an A-device after powering up its USB function when it is unattached, and assumes support for ADP. An EH needs ADP support in order to detect B-device attachment when VBUS is not powered.

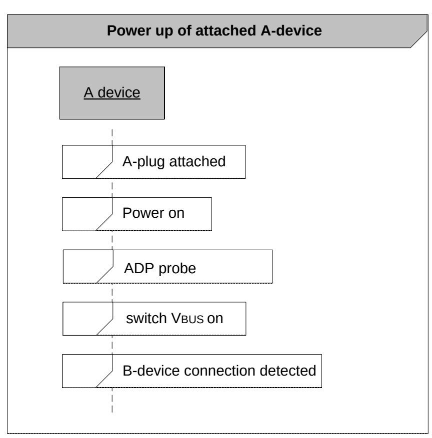
Figure A-13: Power up of an unattached ADP-capable A-device



A.3.2 Power up of attached ADP-capable A-device

Figure A-14 shows the operation of an A-device after powering up its USB function when it is attached, and assumes support for ADP. An EH needs ADP support in order to detect B-device attachment when VBUS is not powered.

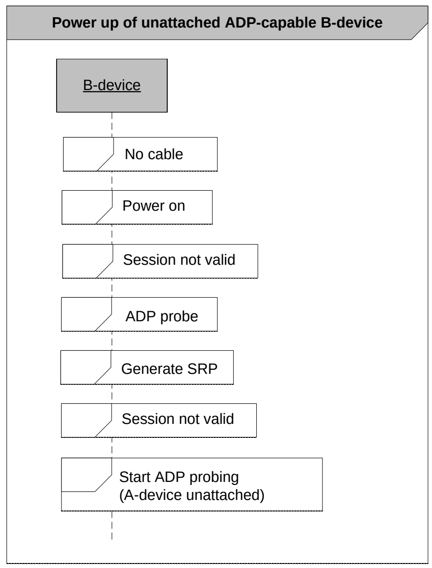
Figure A-14: Power up of an attached ADP-capable A-device



A.3.3 Power up of an unattached ADP-capable B-device

Figure A-15 shows the operation of an ADP-capable B-device after powering up its USB function when it is unattached, and assumes support for ADP.

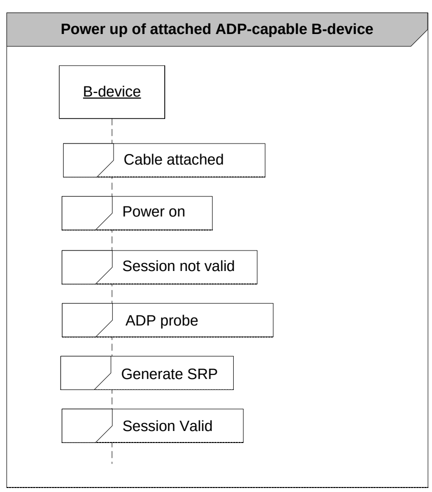
Figure A-15: Power up of an unattached ADP-capable B-device



A.3.4 Power up of an attached ADP-capable B-device

Figure A-16 shows the operation of an ADP-capable B-device after powering up its USB function when it is attached, and assumes support for ADP.

Figure A-16: Power up of an attached ADP-capable B-device



A.3.5 Timing requirements when powering up (for testability)

To allow compliance testing, an OTG device or EH shall be ready to perform USB activity at a time no longer than T_{PWRUP_RDY} from an identifiable powering on action or sequence of actions (e.g. switching on).

T_{PWRUP_RDY} is not mandatory, as a given value may not always be achievable. However the vendor shall be able to specify the maximum value of this parameter in order to allow the compliance tester to be aware of the power up delay.

The phase 'Ready to perform USB activity' shall be as defined in Table A-1.

Table A-1: Definition of "Ready to perform USB activity"

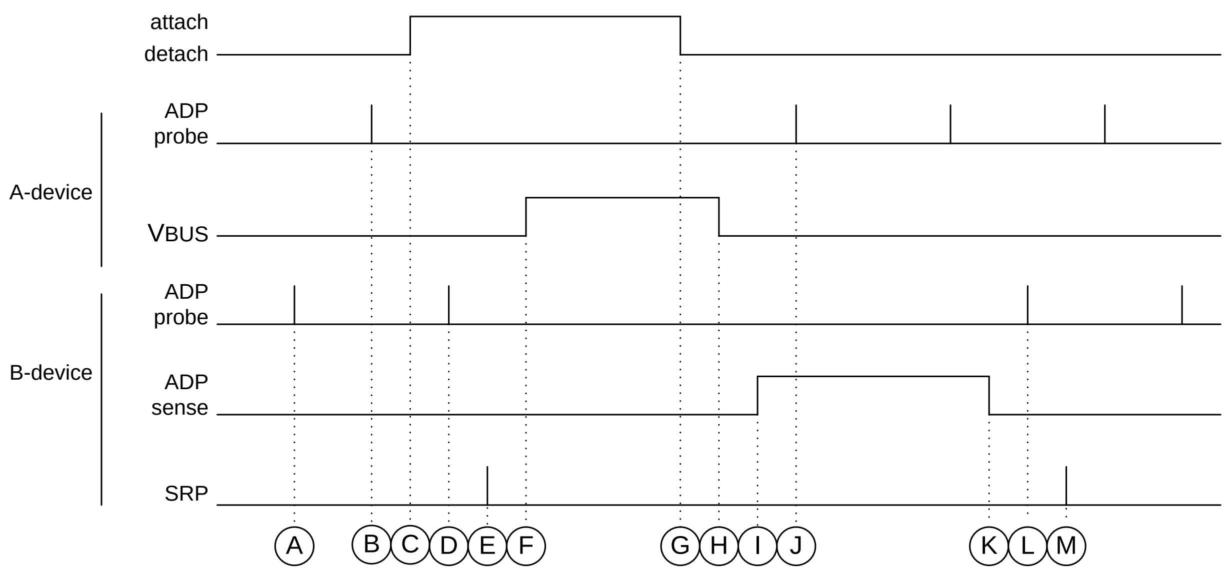
Type of unit	**Definition of 'Ready to perform USB activity'**
OTG-A or EH, ADP-capable	V_{BUS} has been turned on after initial ADP probing
OTG-A, not ADP-capable	V_{BUS} has been turned on, and OTG-A is ready to respond to a connect event.
EH supporting sessions, but not ADP-capable	V_{BUS} has been turned on, and EH is ready to respond to a connect event, or VBUS is off and EH is ready to respond to an SRP pulse
EH not supporting sessions	V_{BUS} is on, and EH is ready to respond to a connect event
OTG-B, ADP-capable	If V_{BUS} is on, OTG-B connects (data line pull-up).
OTG-B, not ADP-capable	If V_{BUS} is off, OTG-B performs SRP pulse after initial ADP probing.

Appendix B ADP examples

B.1 ADP Timing Example

Figure B-1 shows an example of ADP timing.

Figure B-1: ADP Timing Example



Two ADP-capable devices are initially detached. Both are doing ADP probing.

A. B-device issues an ADP probe pulse
B. A-device issues an ADP probe pulse
C. The two devices are attached.
D. The B-device issues an ADP probe pulse, and detects that the ramp time has changed since the previous pulse at time A.
E. The B-device issues an SRP pulse
F. The A-device responds by asserting VBUS
G. The devices are again detached.
H. The A-device responds by dropping VBUS and resumes by doing ADP probing.
I. The B-device responds by doing ADP sensing.
J. The A-device issues an ADP probe pulse.
K. The B-device has not detected an ADP probe pulse for a time of $T_{B\_ADP\_DETACH}$.
L. The B-device stops doing ADP sensing, and issues an ADP probe pulse.
M. The B-device compares the ramp time of the probe pulse at time L, with the ramp time of the previous probe pulse at time D. The times are different, since one was taken when the devices were attached, and one was taken when they were detached. Since the ramp time has changed, the B-device issues an SRP pulse. The B-device does not receive a response to the SRP pulse, since it is no longer attached to the A-device, so the B-device continues doing ADP probing.

B.2 ADP Detection Threshold

In order for a device to reliably detect an attach or detach event using ADP probing, the change in VBUS rise time for an attach/detach event must be greater than the change due to parameter variation or noise.

The conditions for the two worst cases can be seen inTable B-1.

Table B-2: ADP worst cases

Parameter	Symbol	Case 1	Case 2	Units
Local device capacitance	C_{LCL}	6.5	6.5	uF
Remote device capacitance	C_{RMT}	1.0	1.0	uF
Discharge voltage	V_{ADP_DSCHG}	0.15	0.15	V
Probe threshold	V_{ADP_PRB}	0.6	0.6	V
V_{BUS} +ve or –ve peak noise	V_{ADP_NOISE}	10	10	mV
Local current source	I_{ADP_SRC}	1.1	1.65	mA
Remote leakage current	I_{LKG_RMT}	70	70	uA

The ramp time with the remote device detached (shown in Table B-8-2) is calculated as:

- $T_{DET} = C_{LCL} * [(V_{ADP\_PRB} - V_{ADP\_DSCHG}) +/- (V_{ADP\_NOISE}) / I_{ADP\_SRC} * 32kHz$

Table B-3: ADP ramp time with remote device detached

Parameter	Case 1	Case 2	Units
ramp time, negative noise	83.2	55.5	32 kHz cycles
ramp time, positive noise	87.0	58.0	32 kHz cycles
ramp time noise delta	3.8	2.5	32 kHz cycles

The ramp time with the remote device attached (shown in Table B-8-3) is calculated as:

- $T_{ATT} = (C_{LCL} + C_{RMT}) * [(V_{ADP\_PRB} - V_{ADP\_DSCHG}) +/- (V_{ADP\_NOISE}) / (I_{ADP\_SRC} – I_{LKG\_RMT} / 2) * 32kHz$

Table B-4: ADP ramp time with remote device attached

Parameter	Case 1	Case 2	Units
ramp time, negative noise	93.0	62.7	32 kHz cycles
ramp time, positive noise	97.3	65.5	32 kHz cycles
ramp time noise delta	4.2	2.8	32 kHz cycles

The reason that only half the remote leakage current is used in the above calculation is that the remote leakage current is maximum when V_{BUS} is at ground, and it is zero when V_{BUS} is at $V_{OTG\_VBUS\_LKG}$.

The minimum time difference between attached versus detached is shown in Table B-8-4.

Table B-5: Difference between ADP attach and detach

Parameter	Case 1	Case 2	Units
attach vs detach time	6.1	4.7	32 kHz cycles

Notes on ADP parameter values:

- The threshold for detecting an attach or detach event needs to be less than the attach versus detach time, but greater than the noise delta time.
- For case one, the threshold needs to be between 3.8 cycles and 6.1 cycles when detached, and between 4.2 cycles and 6.1 cycles when attached.
- For case two, the threshold needs to be between 2.5 cycles and 4.7 cycles when detached, and between 2.8 cycles and 4.7 cycles when attached.
- It is recommended that the threshold time be set by using 5.5% of the measured ramp time, and then rounding up to the nearest half cycle of a 32kHz clock.

B.3 ADP Current Consumption

This section calculates the current consumption of an ADP circuit in a B-device with no remote device attached, assuming the parameter values in Table B-8-5.

Table B-6: ADP current consumption assumed parameter values

Parameter	Symbol	Value	Units
VBUS capacitance	CADP_VBUS	4.7	uF
ADP probing voltage	VADP_PRB	0.7	V
ADP discharge voltage	VADP_DSCHG	0.1	V
Comparator and reference current consumption	ICOMP_REF	50	uA
B-device ADP probing period	TB_ADP_PRB	2	sec
VBUS resistance	ROTG_VBUS	10	KΩ
VBUS leakage source current	IVBUS_LKG_SRC	70	uA
ADP sink current	IADP_SINK	1.25	mA
ADP source current	IADP_SRC	1.25	mA

Between ADP pulses, the leakage voltage on VBUS is:

- VVBUS_LKG = IVBUS_LKG_SRC x ROTG_VBUS = 70uA x 10k = 700mV

At the start of an ADP probe cycle, the ADP circuit must first discharge VBUS. The time required to discharge VBUS from VVBUS_LKG to VADP_DSCHG is, to a first approximation:

- TADP_DSCHG = (VVBUS_LKG - VADP_DSCHG) x CADP_VBUS / (IADP_SINK - IVBUS_LKG_SRC + .5 x VVBUS_LKG / ROTG_VBUS)
- TADP_DSCHG = (.7V - .1V) x 4.7uF / (1.25mA - 70uA + .5 x .7V / 10k) = 2.2 msec

TADP_RISE (the time required to charge VBUS from VADP_DSCHG to VADP_PRB) is the same as the discharge time, TADP_DSCHG, or 2.2msec.

The average current consumption of the charging and discharging circuitry is then:

- IADP_AVG = [ICOMP_REF x (TADP_DSCHG + TADP_RISE) + IADP_SRC x TADP_RISE] / TB_ADP_PRB
- IADP_AVG = [50uA x (2.2ms + 2.2ms) + 1.25mA x 2.2ms] / 2 sec = 1.5 uA

Additional current will also be consumed by the control and timing circuitry.