

***On-The-Go Supplement to the
USB 2.0 Specification***

Revision 1.3

December 5, 2006

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

Universal Serial Bus Specification Supplement
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1. Introduction

1.1 General

USB has become a popular interface for exchanging data between PC's and peripherals. An increasing number of portable peripherals are using the USB interface to communicate with the PC. Many of these portable devices would benefit from being able to communicate to each other over the USB interface, yet certain aspects of USB make this difficult to achieve.

Specifically, USB communication can only take place between a host and a peripheral. However, in order to qualify as a PC host, a device must have several characteristics, including:

- storage for a large number of device drivers,
- the ability to source a large current, and
- a Series "A" host connector receptacle.

It is not practical for many portable devices to have all of the above characteristics, and in many cases, these characteristics are not needed in order to interface portable devices with each other.

In order to enable these limited-requirement, portable, USB applications, this supplement to the USB 2.0 specification was developed that allows a portable device to take on the role of a limited USB host, without the burden of supporting all the above functions of a PC.

1.2 Objective of the Supplement

The objective of this supplement is to define a minimal set of changes to the USB 2.0 specification [USB2.0], such that portable USB applications are enabled.

This is not a stand-alone document. It is a supplement to the USB 2.0 specification [USB2.0]. Any aspects of USB that are not specifically changed by this supplement are governed by the USB 2.0 specification.

1.3 Intended Audience

This specification is targeted to developers of PC peripherals and portable consumer electronic devices.

1.4 Related Documents

[Micro-USB]

Universal Serial Bus Micro-USB Cables and Connectors Supplement to the USB 2.0 Specification, revision 1.0 (also referred to as the *μUSB Supplement*). This specification is available on the World Wide Web site <http://www.usb.org>.

[USB2.0]

Universal Serial Bus Specification, revision 2.0 (also referred to as the *USB Specification*). This specification is available on the World Wide Web site <http://www.usb.org>.

2. Acronyms and Terms

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

A-Device	A device with a Standard-A or 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 6).
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.
B-Device	A device with a Standard-B, Micro-B or Mini-B plug inserted into its receptacle, or a captive cable ending in a Standard-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 6).
FS	Full Speed
HS	High Speed
Host	A physical entity that is attached to a USB cable and is acting in the role of the USB host as defined in the USB Specification, Revision 2.0 [USB2.0]. This entity initiates all data transactions and provides periodic Start of Frames (SOF's).
HNP	Host Negotiation Protocol. (See Section 6.)
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-USB] for details.)
LS	Low Speed
OTG	On-The-Go
OTG device	A device with the host and peripheral capabilities outlined in section 3.2
Peripheral	A physical entity that is attached to a USB cable and is currently operating as a "device" as defined in the USB Specification, Revision 2.0 [USB2.0]. The Peripheral responds to low level bus requests from the Host.
SE0	Single Ended Zero
Session	The period of time that VBUS is above a device's session valid threshold. For an A-device, the session valid threshold is VA_SESS_VLD, while for a B-device it is VB_SESS_VLD.
SOF	Start of Frame
SRP	Session Request Protocol (See section 5.3)

Targeted Peripheral List	A list of USB peripherals that a particular On-The-Go device can support when it is acting as a host.
USB	Universal Serial Bus
USB-IF	USB Implementers Forum

3. Significant Features

This section identifies the significant features of the OTG supplement. The purpose of this section is not to present all the technical details associated with each major feature, but rather to highlight its existence. Where appropriate, this section references other parts of the document where further details can be found.

3.1 USB 2.0 Specification Compliance

Any device with OTG features is first and foremost a USB peripheral that is compliant with the USB 2.0 specification [USB2.0].

3.2 On-The-Go Device

In addition to being a fully compliant USB 2.0 peripheral, an On-The-Go device must include the following features and characteristics:

- a limited Host capability
- full-speed operation as a peripheral (high-speed optional)
- full-speed support as a host (low-speed and high-speed optional)
- Targeted Peripheral List
- Session Request Protocol
- Host Negotiation Protocol
- one, and only one connection: a Micro-AB receptacle.
- minimum IA_VBUS_OUT output on VBUS
- means for communicating messages to the user

3.3 Targeted Peripheral List

When acting as Host, an On-The-Go device is not required to support operation with all types of USB peripherals. It is up to the manufacturer of each On-The-Go device to determine what peripherals the On-The-Go device will support and provide a list of those peripherals. This is called the On-The-Go device's "Targeted Peripheral List".

In its most primitive form, the Targeted Peripheral List is simply a list of peripherals that have been successfully tested with the On-The-Go device. Each supported peripheral is identified at a minimum by the manufacturer, a model number, and a description of the type of device.

	Vendor	Model and Revision	Speed (LS, FS, HS)	Transport (Bulk, Int, Isoch)	MaxPower (mA)	VID	PID	Description
1.	Logitech	M-BJ58	LS	Int		0x046D	0xC00E	USB Wheel Mouse
2.	Yamaha	YST-MS35D	FS	Isoch		0x0499	0x3002	USB Speakers
3.	TEAC Corporation	FD-05PUB	FS	Bulk		0x0644	0x0000	USB Floppy Drive
4.	Hewlett Packard	D125XI	FS	Bulk		0x03F0	0x2311	All-In-One Printer/Scanner/Copier
5.								

The Targeted Peripheral List shall not list supported USB Classes or "similar" devices.

3.4 No Silent Failures

Whenever the cabling allows an OTG device to be connected to another OTG device or USB peripheral, and the OTG device does not support the type of communication being requested by the user, then the OTG device shall provide messages to the user that allow him or her to understand the problem, and

correct it if possible. Insofar as is possible, the messages shall be self explanatory, and shall not require the user to reference a manual or other additional material.

For example, if a B-device generates SRP, the A-device may try to give control to the B-device by trying to enable HNP. The B-device may not be HNP capable. The A-device may determine that the B-device is not HNP capable because the B-device is LS or because the B-device STALL's the command that enables HNP. When the A-device determines that the B-device is not HNP capable and that the B-device is not supported, the A-device is responsible for providing an informative message to the user that the B-device is not supported. If, however, the B-device is HNP capable it will have responsibility for informing the user if the A-device is not supported.

3.5 Supplying Current on Vbus

An On-The-Go device must be able to source a minimum current on VBUS of IA_VBUS_OUT when it is the A-device and a session is in progress.

3.6 Session Request Protocol

The Session Request Protocol (SRP) allows a B-device to request the A-device to turn on VBUS and start a session. This protocol allows the A-device, which may be battery powered, to conserve power by turning VBUS off when there is no bus activity while still providing a means for the B-device to initiate bus activity.

Any A-device, including a PC or laptop, is allowed to respond to SRP. Any B-device, including a standard USB peripheral, is allowed to initiate SRP. An On-The-Go device is required to be able to initiate and respond to SRP.

The details of this protocol are found in Section 5.3.

3.7 Host Negotiation Protocol

The Host Negotiation Protocol (HNP) allows the Host function to be transferred between two directly connected On-The-Go 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 On-The-Go B-device. HNP may only be implemented through the Micro-AB receptacle on a device.

3.8 Connectors, Cable Assemblies, and Cable Adapters

The OTG supplement uses the connectors, cable assemblies and cable adapters defined in the USB 2.0 specification [USB2.0] and the Micro-USB supplement [Micro-USB].

3.9 Hubs

On-The-Go devices may support hubs. However, the signaling methods used for the Session Request Protocol and the Host Negotiation Protocol are not handled by standard USB hubs. Therefore, when an A-device is directly connected to a standard hub, the A-device is prohibited from issuing a command that would enable the downstream device to expect or initiate HNP.

3.10 Mandated Functionality

Any device with a Micro-AB receptacle shall meet all of the requirements and provide all the functionality of an On-The-Go device.

4. Cables and Connectors

The mechanical and electrical specifications for the cables, connectors, and cable assemblies used to interconnect On-The-Go devices are provided in the USB 2.0 specification [USB2.0] and the Micro-USB supplement [Micro-USB].

5. Electrical Requirements

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 the USB 2.0 specification [USB2.0].

5.1 A-Device Electrical Requirements

5.1.1 VBUS Output Voltage and Current

When an A-device is providing power to VBUS on a port, it is required to maintain an output voltage within the specified range (VA_VBUS_OUT) on that port, under loads of 0 mA up to the rated per port output of the device's supply (IA_VBUS_OUT) as long as the rated output of the A-device is less than or equal to 100 mA.

If the current rating per port of the A-device is greater than 100 mA, then the voltage regulation is required to be between 4.75 V and 5.25 V, and the A-device is required to meet the USB 2.0 specification requirements for power providers.

If the A-device is not capable of providing at least 100 mA on a port, it must be able to detect when VBUS falls below the value necessary for proper operation of a B-device (VA_VBUS_VLD min). Any voltage below VA_VBUS_VLD min shall be detected as a low-voltage condition.

The purpose of the VA_VBUS_VLD threshold is to allow the A-device to determine whether or not it is able to output a valid voltage on VBUS. Thus, the upper limit on the VA_VBUS_VLD threshold is not specified. However, the upper limit on this threshold is generally dependent on the characteristics of the A-device power supply.

Thus, if the A-device power supply operates by driving VBUS to a reference of VA_VBUS_REF , and the output voltage does not drop below x% when the B-devices on its Targeted Peripheral List are not drawing too much current, then the VA_VBUS_VLD threshold voltage would be:

$$VA_VBUS_VLD \text{ min} < VA_VBUS_VLD \text{ THRESHOLD} \leq (x / 100) * VA_VBUS_REF$$

where x is determined by the power supply designer. This allows the VA_VBUS_VLD THRESHOLD to be some ratio of the VA_VBUS_REF supplied by the A-device power supply.

5.1.2 Vbus Input Impedance

When the A-device is powered and not providing VBUS, it shall present an input impedance on VBUS of no more than RA_BUS_IN max to GND over the range of $0 \text{ V} \leq VBUS \leq VA_VBUS_OUT$ max, as shown in Figure 5-1. If the A-device responds to the VBUS pulsing method of SRP, then the input impedance may be no lower than RA_BUS_IN min to GND. Otherwise, it may be lower.

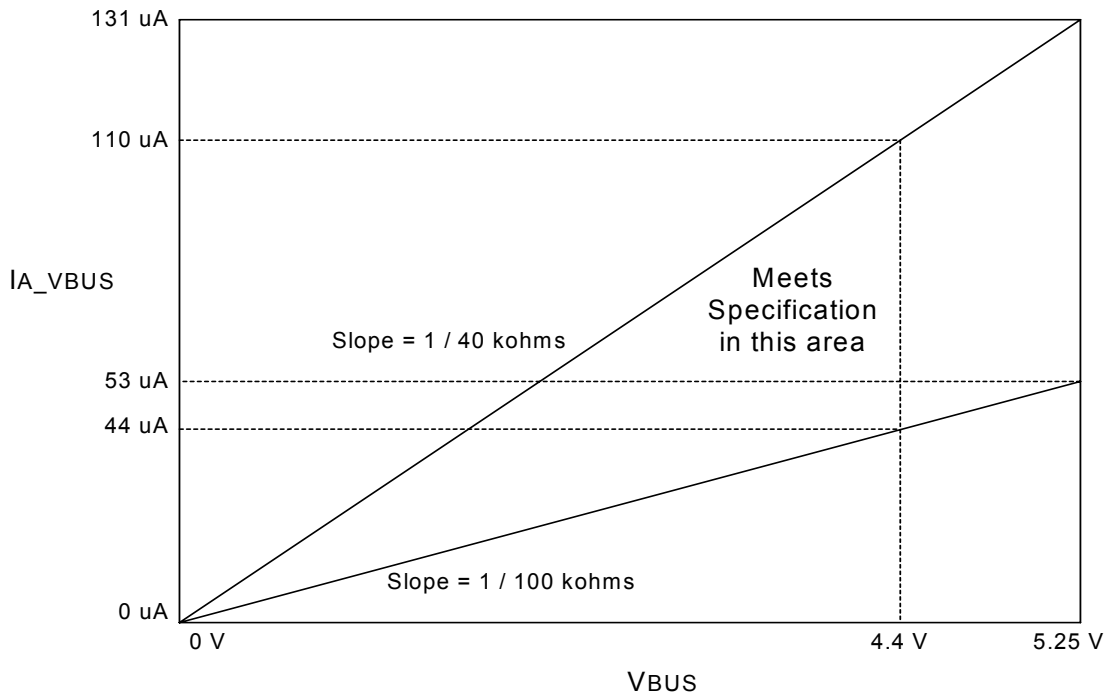


Figure 5-1 A-device Input Impedance (VBUS not driven)

5.1.3 VBUS Rise and Fall Time

When the A-device provides power, the rise time on VBUS from 0 V to VA_VBUS_VLD shall be less than TA_VBUS_RISE max when driving a constant current load equal to the rating of the device's VBUS supply and an external load capacitance of 10 μ F (this 10 μ F is in addition to any VBUS decoupling capacitance on the A-device). If VBUS does not reach this voltage within TA_VBUS_RISE max from the time that VBUS is turned on, this is an indication that the B-device is drawing more current than the A-device is capable of providing and an over-current condition exists. In such a case, the A-device shall turn off VBUS and terminate the session. The A-device shall also indicate to the user that the B-device is not supported.

Note: VBUS rise time is not specified in USB 2.0 and standard USB hosts **may** have rise times longer than TA_VBUS_RISE max. A compliant peripheral shall be able to operate with the longer VBUS rise times allowed by the USB 2.0 specification [USB2.0].

The fall time of VBUS is derived and not specified. It is only significant when the B-device initiates and the A-device responds to SRP. Before starting SRP, the B-device must insure that VBUS is below VB_SESS_VLD min. The B-device may either actively pull down VBUS through a resistance of no less than RB_SRP_DWN min (see Section 5.3.2), or it may wait for the decoupling capacitance of the A-device and B-device to discharge through the weak pull-downs that are present on VBUS.

For an A-device, the highest pull-down resistance on VBUS is RA_BUS_IN max and the decoupling capacitance is less than COTG_VBUS max. The values of the decoupling capacitor and the VBUS pull-down resistor on the B-device are known by the manufacturer of the B-device. These values are used with the worst-case values of the A-device in computing the discharge time for VBUS. If the worst-case values on the B-device are the same as for the A-device, then the longest discharge time from VA_VBUS_VLD min to VA_SESS_VLD min will be approximately 1.1 seconds.

5.1.4 VBUS Capacitance

An On-The-Go device must have a VBUS capacitance that is defined by COTG_VBUS.

The limit on the decoupling capacitance allows a B-device to differentiate between a powered down On-The-Go A-device and a powered down standard host, i.e.:

- Capacitance on A-Device COTG_VBUS
- Capacitance on Host CHPB_VBUS > 96 μ F

The USB 2.0 specification [USB2.0] requires CHPB_VBUS to have a minimum value of 120 μ F. To accommodate those implementations which have used a value for CHPB_VBUS of 120 μ F +/- 20%, the OTG Supplement assumes a worst case value for CHPB_VBUS of 96 μ F.

5.1.5 Vbus Leakage Voltage

When the A-device is not driving VBUS, the voltage on VBUS as a result of device leakage within the A-device shall not exceed VA_VBUS_LKG max. This voltage is measured with no device attached to the A-device and after VBUS has been turned off for 5 seconds.

5.1.6 Data Line Pull-down Resistance

When an On-The-Go A-device is idle or acting as a Host, it shall activate pull-down resistors on both the D+ and D- lines. These resistors shall be within the range of RPD min to RPD max.

When an On-The-Go A-device is acting as a Peripheral, it shall disable the pull-down on the D+ line but shall not disable the pull-down on the D- line. Maintaining a pull-down on the D- line prevents the A-device D- line from floating if the B-device becomes unplugged. An On-The-Go A-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.

5.1.7 Data Line Pull-up Resistance

When operating as a Peripheral, the A-device shall enable a pull-up (as defined in the USB 2.0 specification [USB2.0]) attached to the D+ line. It is allowed to disable the pull-up resistor during the interval of a packet transmission.

5.1.8 Data Line Leakage Voltage

When neither device is driving the data bus, one of the data lines will be held low by the pull-down resistor on the Host. The D- line is pulled low if the attached device is full speed and D+ line is pulled low if the attached device is low speed.

The low-level voltage on the line that is being pulled low may not be above VOTG_DATA_LKG max. As per Section 7.1.6.6 of the USB 2.0 specification [USB2.0], the attached device may have an impedance value as low as 300 k Ω (ZINP min) to 3.6 V. When the data line of the attached device is grounded, this will result in a leakage current of approximately 10 μ A. The leakage current from the Host shall be low enough such that, when combined with the approximately 10 μ A of leakage from the attached device, the voltage across the pull-down resistor shall not exceed VOTG_DATA_LKG max. This voltage is measured by pulling either D+ or D- to 3.6 V through 300 k Ω (ZINP min) when the A-device is the Host and the bus is in the idle state.

5.1.9 Data Line Discharge Time

When an A-device is in the **a_peripheral** state and detects that the bus is idle for greater than TA_BIDL_ADIS, then it is allowed to:

- disconnect its pull up
- allow time for the data line to discharge
- check if the B-device has connected its pull up

Similarly, when a B-device is in the **b_peripheral** state and detects that the bus is idle for greater than TB_AIDL_BDIS, then it is allowed to:

- disconnect its pull up
- allow time for the data line to discharge
- check if the A-device has connected its pull up

During the above steps, the amount of time that the local device must 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 the USB 2.0 specification [USB2.0], the maximum capacitance for a downstream facing port is 150 pF (CIND max), and the maximum capacitance for the upstream port of a device without an attached cable is 100 pF (CINUB 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 On-The-Go device is 24.8 kΩ (RPD max) or less. This results in a discharge time constant of:

- time constant = (150 pF + 100 pF + 340 pF) × (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 must wait for a minimum of TLDIS_DSCHG min before checking the state of the data-line.

5.1.10 VBUS Input Current Without Battery

In many cases, On-The-Go devices will be powered by a battery. When an On-The-Go device has a dead battery that is not capable of powering up the device, or if the battery has been removed, then an On-The-Go device is allowed to act as a peripheral in accordance with the USB 2.0 specification [USB2.0]. See Figure 7-29 and section 7.1.7.6 of the USB 2.0 specification for rules on current draw.

5.2 B-Device Electrical Requirements

5.2.1 VBUS Average Input Current

An unconfigured, On-The-Go B-device shall not draw more than IB_OTG_UNCFG max average current from VBUS, except for a short interval immediately before initiating SRP.

An unconfigured, SRP capable, peripheral-only B-device shall not draw more than IB_PO_UNCFG max average current from VBUS.

Average current as used above is defined as the average current over any 1 ms interval.

Before initiating SRP, either an On-The-Go or an SRP capable peripheral-only B-device is allowed to discharge VBUS for a time period of not more than 100 ms, at a current of not more than $I_{B_DSCHG_IN}$ max.

5.2.2 VBUS Peak Input Current

The peak current drawn by an SRP capable B-device shall not be so large as to cause more than a $V_{B_DELTA_PK}$ drop in VBUS from its average value. The allowable transient is computed by assuming that the A-device is a constant current source providing the average current consumed by the B-device in parallel with a C_{OTG_VBUS} min capacitor.

The 1 μ F decoupling capacitor on the A-device and the decoupling capacitor provided on the B-device will provide the only filtering of the voltage transient due to the transient current. If the transient current computed by this method is greater than 100 mA, then the transient shall be no larger than the larger of 100 mA or the value reported in *bMaxPower* in the currently selected configuration. No transient shall have a di/dt of greater than 100 mA/ μ s. (For reference, see Figure 7-48 of USB 2.0 specification [USB2.0].)

The peak current drawn by an SRP capable B-device shall not cause it to exceed the average current requirement as defined in Section 5.2.1.

5.2.3 VBUS Capacitance

The VBUS capacitance allowed for an On-The-Go B-device is the same as that allowed for an A-device, (see Section 5.1.4).

5.2.4 Data Line Pull-down Resistance

When an On-The-Go B-device is idle or acting as a Host, it shall activate pull-down resistors on both the D+ and D- lines. These resistors shall be within the range defined by RPD.

When an On-The-Go B-device is acting as a Peripheral, it shall disable the pull-down on the D+ line but shall not disable the pull-down on the D- line. Maintaining a pull-down in the D- line allows the operation of the B-device pull-down to be the same as that of the A-device. An On-The-Go B-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.

5.2.5 Data Line Pull-up Resistance

When operating as Peripheral, the B-device shall enable a pull-up (as defined in the USB 2.0 specification [USB2.0]) attached to the D+ line. It is allowed to disable the pull-up resistor during the interval of a packet transmission.

5.2.6 Data Line Leakage Voltage

For an On-The-Go B-device, the data line leakage voltage shall be as specified in Section 5.1.8 for an A-device.

5.2.7 VBUS Input Current Without Battery

In many cases, On-The-Go devices will be powered by a battery. When an On-The-Go device has a dead battery that is not capable of powering up the device, or if the battery has been removed, then an On-The-Go device is allowed to act as a peripheral in accordance with the USB 2.0 specification [USB2.0]. See Figure 7-29 and section 7.1.7.6 of the USB 2.0 specification for rules on current draw.

5.3 Session Request Protocol

5.3.1 Introduction

In order to conserve power, an A-device is allowed to leave VBUS turned off when the bus is not being used. If the B-device wants to use the bus when VBUS is turned off, then it requires some way of requesting the A-device to supply power on VBUS. For this reason, the Session Request Protocol (SRP) has been defined.

A session is defined as the period of time that VBUS is above the Session Valid threshold of a given device. This A-device threshold shall be within the range defined by VA_SESS_VLD, while the B-device threshold shall be in the range defined by VB_SESS_VLD, (see Table 5-1). 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 the Host Negotiation Protocol (HNP) defined in Section 6. The session ends when VBUS falls below the A-device Session Valid threshold.

SRP is to be used as follows: An OTG device is required to respond to SRP if it ever turns off VBUS while an A-plug is inserted. An OTG device that keeps VBUS turned on whenever an A-plug is inserted will never have a need to respond to SRP. Any A-device, including a PC or laptop, is allowed to respond to SRP.

An OTG device shall initiate SRP when an event on the OTG device requires a session to be started and it sees that it is not the A-device since an A-plug is not inserted and VBUS from the potential A-device is turned off. An OTG device whose feature set does not include initiating a conversation with an A-device (e.g., has no OTG devices on its Targeted Peripheral List) will not have cause to initiate SRP. Any B-device, including a standard USB peripheral, is allowed to initiate SRP if an event on the B-device is designed to cause a known response on some A-device(s). To avoid unnecessary power drain on the A-device, a B-device shall only initiate SRP in response to a particular event (usually user interaction), and SRP shall not be issued more than once per event.

There are two methods that shall be used by the B-device to request that the A-device begin a session. They are called “data-line pulsing” and “VBUS pulsing”. These two methods comprise the Session Request Protocol (SRP).

Two signaling methods are defined to allow maximum latitude in the design of A-devices. An A-device is only required to respond to one of the two SRP signaling methods. B-devices shall use both methods when initiating SRP to insure that an A-device responds.

5.3.2 Initial Conditions

The B-device may not attempt to start a new session until it has determined that the A-device should have detected the end of the previous session. The A-device detects the end of a session by sensing that VBUS has dropped below its session valid threshold. Since the A-device Session Valid threshold may be as low as VA_SESS_VLD min, the B-device must insure that VBUS is below this level before requesting a new session. The B-device may ensure that VBUS is below the B-device Session End threshold either by direct measurement of VBUS or by timing the discharge.

Additionally, the B-device may switch in a pull-down resistor from VBUS to ground in order to speed the discharge process as long as the pull-down resistor does not cause the B-device to draw more than 8 mA from VBUS. To ensure this, the value of the pull-down resistor must be greater than $R_{B_SRP_DWN}$, ($5.25\text{ V} / 8\text{ mA} = 656\ \Omega$).

A second initial condition for starting a new session is that the B-device must detect that both the D+ and D- data lines must have been low (SE0) for at least TB_SE0_SRP min. This ensures that the A-device has detected a disconnect condition from the device.

These initial conditions define the period after which the A-device will properly recognize SRP from the B-device.

Each B-device is required to have a Session End threshold that is within the Session End range (VB_SESS_END) defined in Table 5-1. This threshold can be implemented directly, as with a comparator, or it can be implemented indirectly, by timing a discharge of VBUS through a resistor. The reason that Table 5-1 lists a lower limit on this threshold is that leakage currents from the transceivers could prevent a non-driven VBUS from discharging below this lower voltage.

When the B-device detects that VBUS has gone below its Session End threshold and detects that both D+ and D- have been low (SE0) for at least TB_SE0_SRP min, then any previous session on the A-device is over and a new session may start.

5.3.3 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 5.3.2) and then turns on its data line pull-up resistor (either D+ or D-) for a period within the range specified by TB_DATA_PLS . An On-The-Go B-device is only allowed to initiate SRP at full-speed, and thus shall only pull up D+. 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 that is designed to detect the data-line pulsing of SRP shall generate an SRP indication if either D+ goes high or D- goes high.

Note: It has been observed that some self-powered USB devices do not follow USB Revision 1.1 Section 7.1.5 or USB Revision 2.0 Section 7.1.5.1 that state:

“The voltage source on the pull-up resistor must be derived from or controlled by the power supplied on the USB cable such that when VBUS is removed, the pull-up resistor does not supply current on the data line to which it is attached.”

Devices that violate the above requirement have been observed to pull-up D+ or D- as long as they have power applied to them, without regard to the presence of VBUS. For this reason, an On-The-Go device that responds to data-line pulsing SRP should be able to disable this capability when an offending device is attached. The process for handling this would be to start a session upon detecting D+/D- high, enumerate the device, determine that it is not supported, disable SRP, and turn off VBUS. When the data line returns low (indicating a disconnect), then SRP should be re-enabled.

5.3.4 VBUS Pulsing

To indicate a request for a new session using the VBUS pulsing method, the B-device drives VBUS anytime after the initial conditions are met as described in Section 5.3.2 and data line pulsing (Section 5.3.3) has concluded. VBUS is driven for a period that is long enough for a capacitance on VBUS that is smaller than twice the value of $COTG_VBUS$ max to be charged to VB_OTG_OUT min while a capacitance on VBUS of more than $CHPB_VBUS$ min + $COTG_VBUS$ min (~97 μ F) will not be charged above VB_HST_OUT max.

There are two scenarios that a B-device could encounter when pulsing VBUS to initiate SRP. In one scenario, the B-device is connected to an A-device that responds to the VBUS pulsing SRP. In this case, the B-device can drive VBUS above the A-device Session Valid threshold in order to wake up the A-device. (This assumes that the A-device is not already driving VBUS, in which case a session is already in progress). When driving such an A-device, the B-device shall ensure that VBUS goes above VB_OTG_OUT min, but does not exceed VB_OTG_OUT max.

In the second scenario, the B-device is attached to a standard host. In this case, the B-device shall not drive VBUS above VB_HST_OUT max. This insures that no damage is done to standard hosts that are not designed to withstand a voltage externally applied to VBUS.

In order to meet these requirements, the B-device can utilize the fact that the capacitance on a standard host will not be less than 96 μ F (CHPB_VBUS min), while the maximum capacitance allowed on an On-The-Go device is COTG_VBUS max. Based on the greater than one order-of-magnitude difference between these two capacitances, and a self-imposed current limit, the B-device designer can derive a maximum length of time the B-device is allowed to drive VBUS. By driving VBUS for this duration, the designer can guarantee that VBUS will rise above VB_OTG_OUT min if attached to an On-The-Go device, while ensuring that VBUS will not exceed VB_HST_OUT max if attached to a standard USB host.

5.3.5 B-Device VBUS Pulsing Current

The B-device VBUS pulsing circuitry must be designed such that the maximum current drawn by the B-device does not exceed IB_PO_UNCFG max. One way to ensure this restriction is met is to drive VBUS with a voltage source greater than 3.0 V and with an output impedance greater than RB_SRP_UP min. This takes into consideration the possibility that if the A-Device responds very quickly to SRP, it could drive VBUS to VA_VBUS_OUT max while the B-device is still pulsing VBUS. If this happened, then current could flow from the A-device back to the B-device. $([5.25 \text{ V} - 3.0 \text{ V}]/8 \text{ mA} \cong 281 \Omega)$

5.3.6 A-Device Session Valid

The A-device continuously monitors VBUS as long as power is available on the A-device. An A-device that is designed to detect the VBUS pulsing method will detect that VBUS has gone above the A-device Session Valid threshold (VA_SESS_VLD) and generate an indication that SRP has been detected.

5.3.7 B-Device Session Valid

When a B-device detects that the voltage on VBUS is greater than the B-Device Session Valid threshold (VB_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.

5.3.8 Duration of SRP

The maximum time allowed for the B-device to complete all of its SRP initiation activities is TB_SRP_INIT max. The SRP activities include all those activities that transpire while the B-device is not monitoring the state of VBUS. The B-device shall not monitor VBUS when doing VBUS pulsing but it may continue to monitor VBUS during the period of time when it is pulling VBUS down and during data-line pulsing. If VBUS is monitored during these periods, then the time taken for them is not counted in the TB_SRP_INIT max limit for SRP activities.

5.3.9 Order of Methods

The B-device shall first perform data-line pulsing, followed by VBUS pulsing.

5.3.10 Response Time of A-device

The A-device may be designed to respond to either of the methods of SRP. After initiating SRP, the B-device is required to wait at least TB_SRP_FAIL min for the A-device to respond, before informing 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.

5.3.11 Repetition of SRP

The B-device may initiate the SRP any time the initial conditions of Section 5.3.2 are met.

5.3.12 Operation of Bus-Powered B-Device

In order to conserve power, most OTG A-devices only start applying power to Vbus when a USB application is launched on the A-device, or when SRP is detected from the B-device. However, if a user frequently connects a bus powered peripheral (captive cable) to an OTG device, then the user may want to configure the OTG device to start supplying power to Vbus whenever a Micro-A plug peripheral is inserted.

For example, if a user frequently plugs a keyboard into a PDA, then the user may want to configure the PDA to provide power to the keyboard as soon as the keyboard is plugged in. Otherwise, the user would have to enable Vbus power by going through the PDA user interface. For the PDA to power Vbus automatically, its OTG transceiver needs to generate an interrupt whenever ID goes FALSE. Typically, the transceiver will be in low power state when this occurs.

5.4 Electrical Characteristics

Table 5-1. DC Electrical Characteristics

Parameter	Symbol	Conditions	Min	Max	Units	Ref
Vbus Voltage:						
A-Device Output Voltage	VA_VBUS_OUT	$0 \leq I_{VBUS} \leq I_{A_VBUS_OUT} < 100 \text{ mA}$	4.4	5.25	V	5.1.1
VBUS Rise Time	TA_VBUS_RISE	$C_{LOAD} = 10 \mu\text{F}$ $I_{VBUS} = \text{rated load}^1$ $0.0 \text{ V} < V_{BUS} < 4.4 \text{ V}$		100	ms	5.1.3
A-device Leakage Voltage	VA_VBUS_LKG			0.2	V	5.1.5
B-device (SRP capable) to On-The-Go Device Output Voltage	VB_OTG_OUT		2.1	5.25	V	5.3.4
B-device (SRP capable) to Host Output Voltage	VB_HST_OUT			2.0	V	5.3.4
B-device (SRP capable) Induced Transient	VB_DELTA_PK	$di/dt < 100 \text{ mA}/\mu\text{s}$		400	mV	5.2.2
Vbus Current:						
A-Device Output Current	IA_VBUS_OUT	$4.4 \text{ V} \leq V_{BUS} \leq 5.25 \text{ V}$	8		mA	5.1.1
B-Device (On-The-Go) Unconfigured Average Current	IB_OTG_UNCFG	$0 \text{ V} \leq V_{BUS} \leq 5.25 \text{ V}$ $T_{AVG} = 1 \text{ ms}$		150	μA	5.2.1
B-Device (SRP capable, Peripheral-Only) Unconfigured Average Current	IB_PO_UNCFG	$0 \text{ V} \leq V_{BUS} \leq 5.25 \text{ V}$ $T_{AVG} = 1 \text{ ms}$		8	mA	5.2.1
B-Device (SRP capable) Discharge Current	IB_DSCHG_IN	$0 \text{ V} \leq V_{BUS} \leq 5.25 \text{ V}$		8	mA	5.2.1
Data-Line Voltage:						
On-The-Go Device Leakage	VOTG_DATA_LKG			.342	V	5.1.8

¹ Each implementation must be capable of supplying a minimum of 8mA of VBUS. An implementation that is designed to provide more than 8 mA shall be able to meet the rise-time requirement for VBUS when the applied load is equal to the design limit of the supply.

Table 5-1. DC Electrical Characteristics (continued)

Parameter	Symbol	Conditions	Min	Max	Units	Ref
Terminations:						
A-device Data Line Pull-down	RPD		14.25	24.8	k Ω	5.1.6
B-device Data Line Pull-down	RPD		14.25	24.8	k Ω	5.2.4
A-Device VBUS Input Impedance to GND	RA_BUS_IN	SRP capable A-device, not driving VBUS	40	100	k Ω	5.1.2
B-device VBUS SRP pull-up	RB_SRP_UP	Pull-up voltage = 3.0 V	281		Ω	5.3.5
B-device VBUS SRP pull-down	RB_SRP_DWN		656		Ω	5.3.2
Input Levels:						
A-device VBUS Valid	VA_VBUS_VLD		4.4		V	5.1.1
A-Device Session Valid	VA_SESS_VLD		0.8	2.0	V	5.3.6
B-Device Session Valid	VB_SESS_VLD		0.8	4.0	V	5.3.7
B-Device Session End	VB_SESS_END		0.2	0.8	V	5.3.2
Decoupling Capacitance:						
On-The-Go Device VBUS Bypass Capacitance	COTG_VBUS		1	6.5	μ F	5.1.4

5.5 Device Timings

Table 5-2 lists the timing parameters of an A-device. The parameters are listed in roughly the order that they would occur during the following sequence of events.

- A-device responds to SRP and becomes Host
- A-device suspends the bus and B-device becomes Host
- B-device suspends the bus and A-device becomes Host

In case of a discrepancy between a parameter value as listed in the table below, and its value as listed in other parts of the document, the table value shall take precedence.

The states listed in the table are described in Section 6.

Table 5-2. A-device Timing

Parameter	Num	Symbol	State	Min ¹	Max ¹	Units	Ref
SRP Response Time	1	TA_SRP_RSPNS	a_idle		4.9	sec	5.3.10
Wait for VBUS Rise ²	2	TA_WAIT_VRISE	a_wait_vrise		100	ms	6.6.5.1
B-Connect Long Debounce	3	TA_BCON_LDB	a_wait_bcon	100		ms	6.6.1.12
B-connect to A-reset	3	TA_BCON_ARST	a_wait_bcon		30	sec	6.8.1.3
Wait for B-Connect	4	TA_WAIT_BCON	a_wait_bcon	1		sec	6.6.5.2
A-Idle to B-Disconnect	5	TA_AIDL_BDIS	a_suspend	200		ms	6.6.5.3
B-Disconnect to A-Connect	6	TA_BDIS_ACON	a_suspend		3	ms	6.3
B-Idle to A-Disconnect	7	TA_BIDL_ADIS	a_peripheral	3	200	ms	6.3
Local Disconnect to Data Line Discharge	8	TLDIS_DSCHG	a_wait_bcon	25		µs	5.1.9
B-Connect Short Debounce	9	TA_BCON_SDB	a_wait_bcon	2.5		µs	6.6.1.12
B-Connect Short Debounce Window	10	TA_BCON_SDB_WIN	a_wait_bcon		100	ms	6.6.1.12

¹ Time values should have precision and accuracy to within 2,500 ppm for FS capable devices and 500 ppm for HS capable devices.

² This value is vendor dependent. A compliant A-device will be capable of bringing VBUS in tolerance within no more than 100ms and waiting longer for VBUS rise is not advisable. If the vendor has designed the power supply to bring VBUS within tolerance in less than 100 ms, then it is appropriate to adjust this value downward to meet the capabilities of the implementation.

Table 5-3 lists the timing parameters of an A-device. The parameters are listed in roughly the order that they would occur during the following sequence of events.

- B-device initiates SRP and becomes Peripheral
- A-device suspends and B-device becomes Host
- B-device suspends and A-device becomes Host

In case of a discrepancy between a parameter value as listed in the table, and its value as listed in other parts of the document, the table value shall take precedence.

Table 5-3. B-device Timing

Parameter	Num	Symbol	State	Min ¹	Max ¹	Units	Ref
SE0 Time Before SRP	11	TB_SE0_SRP	b_idle	2		ms	5.3.2
Data-Line Pulse Time	12	TB_DATA_PLS	b_srp_init	5	10	ms	5.3.3
SRP Initiate Time	13	TB_SRP_INIT	b_srp_init		100	ms	5.3.8
SRP Fail Time	14	TB_SRP_FAIL	b_srp_init	5	6	sec	6.8.2.2
Session Valid to B-Connect	15	TB_SVLD_BCON	b_idle		1	sec	5.3.7
A-Idle to B-Disconnect	16	TB_AIDL_BDIS	b_peripheral	4	150	ms	6.3
Time between B-device HS to FS transition during suspend, and B-device disconnect	17	TB_FS_BDIS	b_peripheral	1	146.875	ms	6.3
Local Disconnect to Data Line Discharge	18	TLDISC_DSCHG	b_wait_acon	25		μs	5.1.9
A-SE0 to B-Reset	19	TB_ASE0_BRST	b_wait_acon	3.125	as per USB 2.0	ms	6.7.1
A-Connect Debounce	20	TB_ACON_DBNC	b_wait_acon	2.5		μs	6.6.1.5
A-Connect to B-SE0	21	TB_ACON_BSE0	b_wait_acon		1	ms	6.3

¹ Time values should have precision and accuracy to within 2,500 ppm for FS capable devices and 500 ppm for HS capable devices.

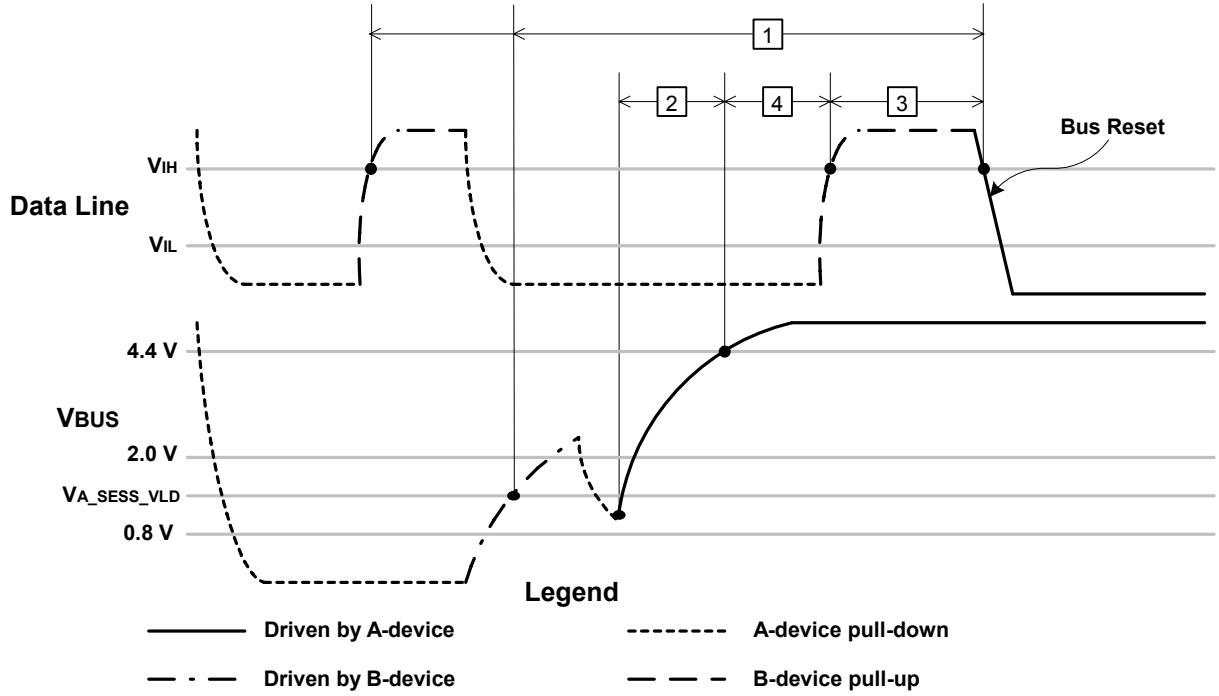


Figure 5-2 A-device SRP Timing Reference

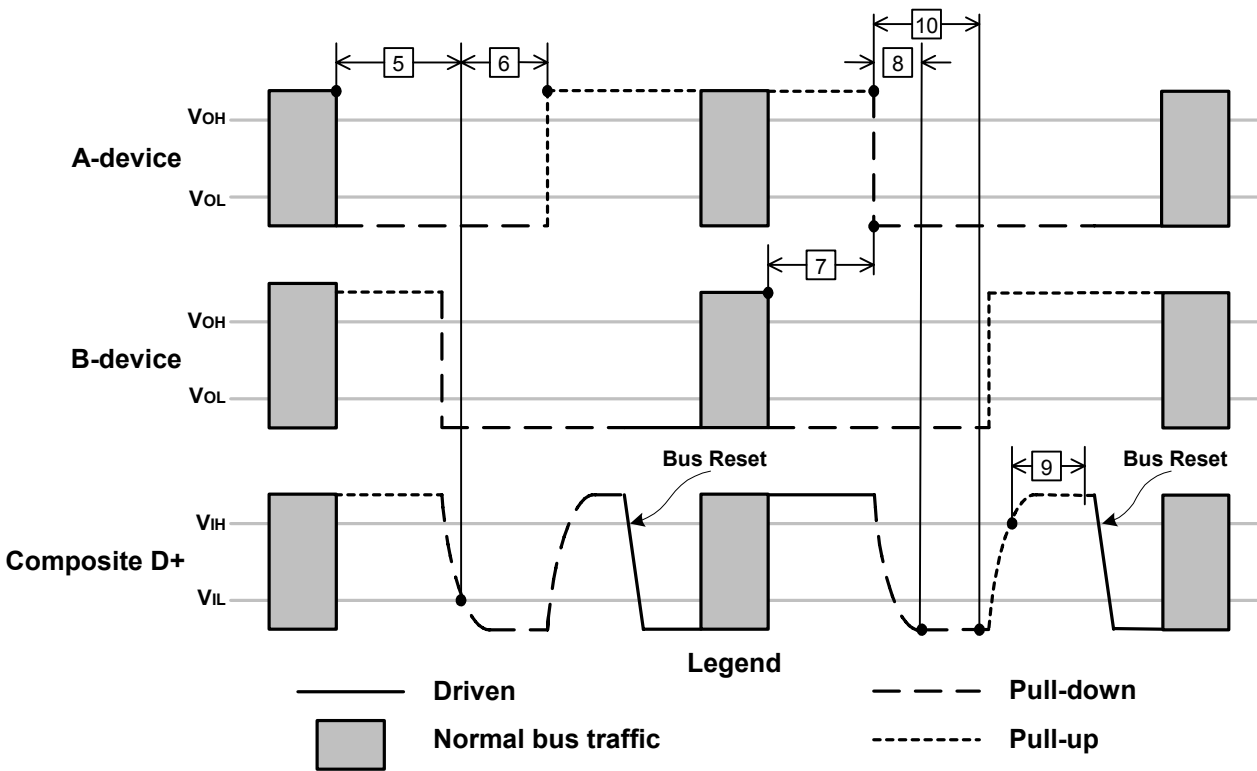


Figure 5-3 A-device HNP Timing Reference (FS)

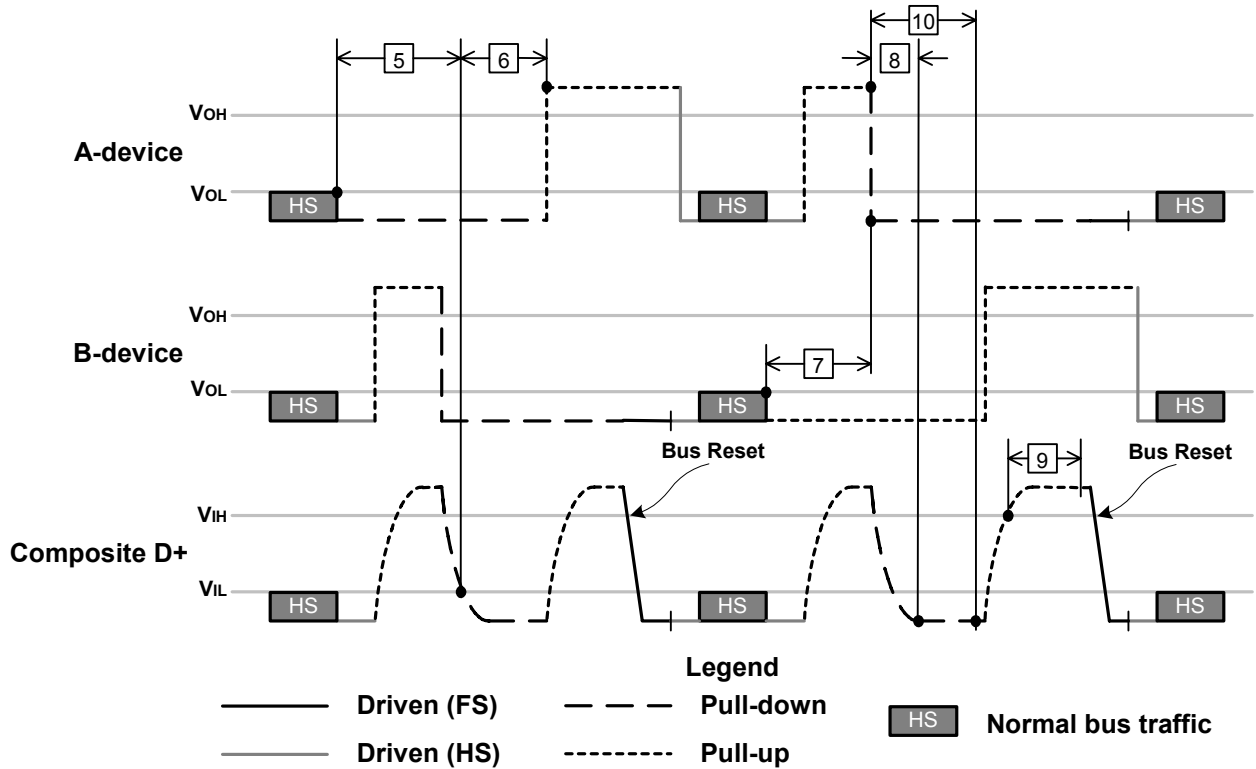


Figure 5-4 A-device HNP Timing Reference (HS)

At several points during SRP and HNP, one device is allowed a maximum length of time to respond to an event, while the other device is required to wait a minimum length of time for this response. Table 5-4 compares the maximum response time of one device to the minimum wait time of the other device.

In case of a discrepancy between Table 5-4 and the values in Table 5-2 and Table 5-3, the values in Table 5-2 and Table 5-3 take precedence.

Table 5-4. Device Timing Comparison

Device	Parameter	Symbol	State	Min ¹	Max ¹	Units
B-device	SRP Initiate Time	TB_SRP_INIT	b_srp_init		100	ms
B-device	Session Valid Voltage to Local Connect	TB_SVLD_BCON	b_idle		1	sec
A-device	Wait for B-Connect	TA_WAIT_BCON	a_wait_bcon	1		sec
A-device	SRP Response Time	TA_SRP_RSPNS	a_idle		4.9	sec
B-device	SRP Fail Time	TB_SRP_FAIL	b_idle	5	6	sec
B-device	A-Idle to B-Disconnect	TB_AIDL_BDIS	b_peripheral	4	150	ms
A-device	A-Idle to B-Disconnect	TA_AIDL_BDIS	a_suspend	200		ms
A-device	B-Disconnect to A-Connect	TA_BDIS_ACON	a_suspend		3	ms
B-device	A-SE0 to B-Reset	TB_ASE0_BRST	b_wait_acon	3.125	as per USB 2.0	ms
B-device	A-Connect to B-SE0	TB_ACON_BSE0	b_wait_acon		1	ms
A-device	B-Idle to A-Disconnect	TA_BIDL_ADIS	a_peripheral	3	200	ms

¹ Time values should have precision and accuracy to within 2,500 ppm for FS capable devices and 500 ppm for HS capable devices.

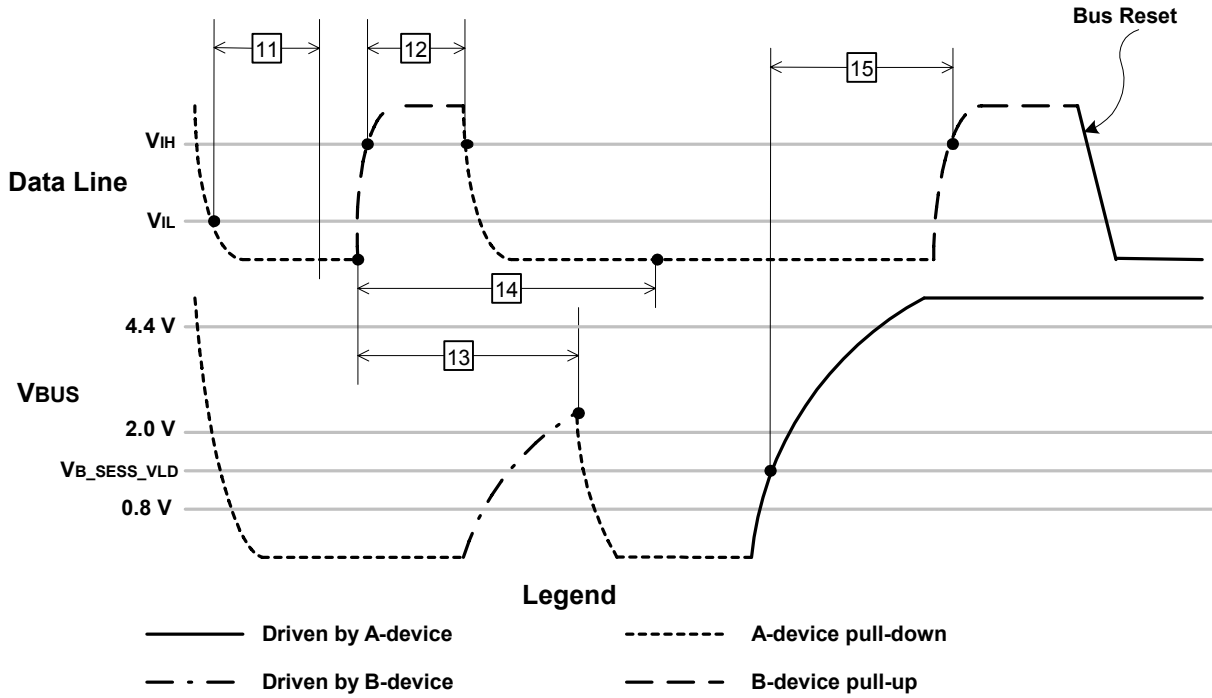


Figure 5-5 B-device SRP Timing Reference

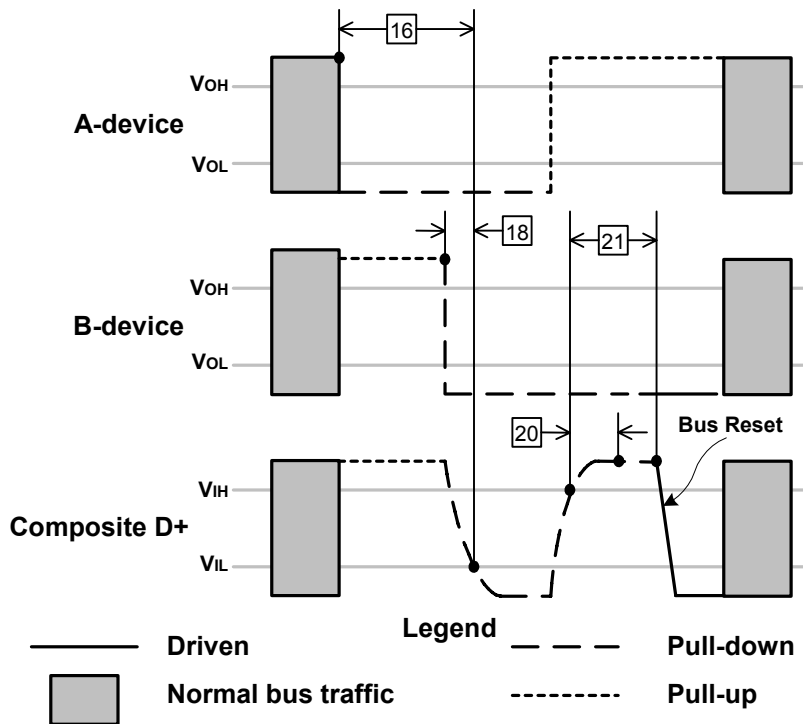


Figure 5-6 B-device HNP Timing Reference (FS)

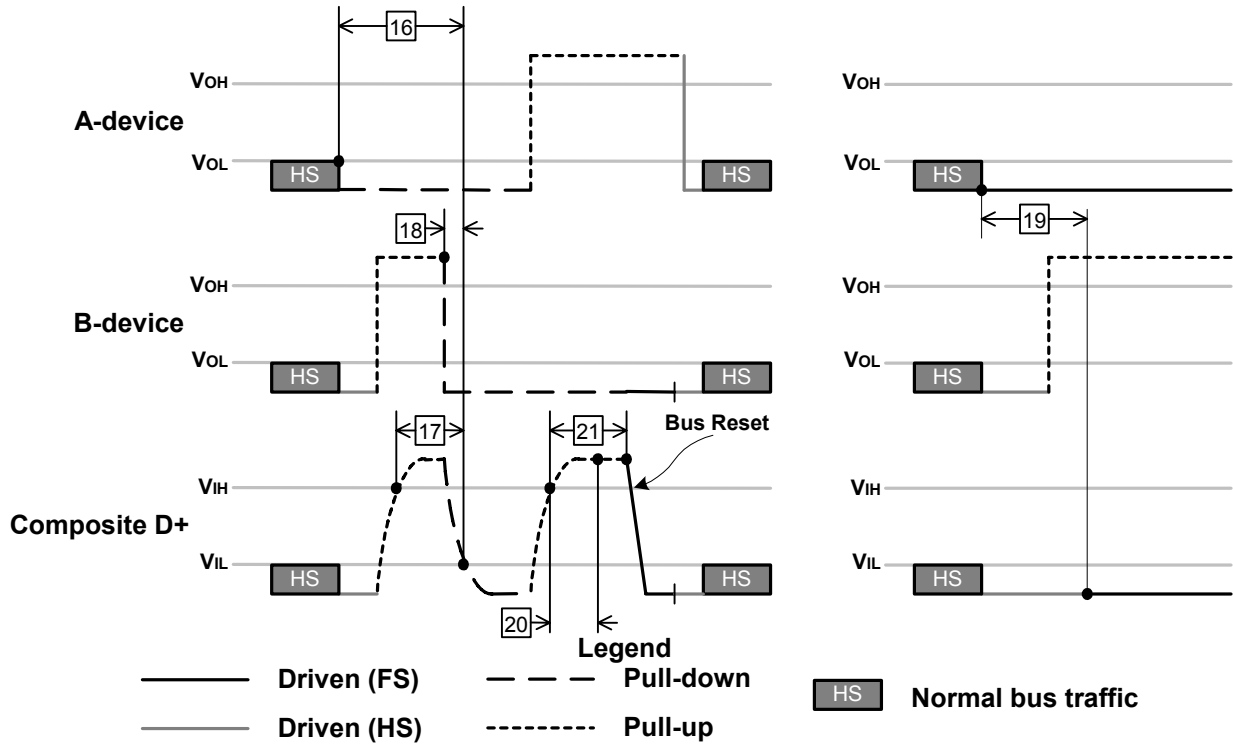


Figure 5-7 B-device HNP Timing Reference (HS)

6. Host Negotiation Protocol

6.1 Introduction

Since On-The-Go devices have a Micro-AB receptacle, an On-The-Go device can default to being either Host or Peripheral, depending upon which type of plug (Micro-A plug for Host, Micro-B plug for Peripheral) is inserted. By utilizing the Host Negotiation Protocol (HNP), an On-The-Go B-device, which is the default Peripheral, may make a request to be Host. The process for this exchange of the role of Host is described in this section. This protocol eliminates the need for the consumer to swap the cable connection in order to change the roles of the connected devices.

OTG products are required to support HNP as an A-device. OTG products must support HNP as a B-device if they can support any OTG product as a peripheral. OTG products that cannot support any OTG product as a peripheral are not required to support HNP as a B-device.

6.2 Description Priority

HNP and SRP are described in this section by each of the following methods:

- state diagrams
- text

In the case of a conflict between these two descriptions, the state diagrams shall take precedence.

It should be noted that the state diagrams are presented to show one possible implementation of the HNP and SRP protocols. The state diagram shown is non-deterministic when multiple transitions are possible out of the same state. The implementer must prioritize and choose any one of the possible transitions. An implementation that exhibits an equivalent behavior as observed at the USB connector pins would also be considered to be in compliance with this specification.

6.3 HNP Overview

HNP is used to transfer control of a connection from the default Host (A-device) to the default Peripheral (B-device). This is accomplished by having the A-device condition the B-device to be able to take control of the bus, and then having the A-device present an opportunity for the B-device to take control.

The B-device is conditioned when the A-device sends a SetFeature (b_hnp_enable) command. After sending this command, the A-device may suspend the bus to signal the B-device that it may now take control of the bus. If the B-device wants to use the bus at that time, it signals a disconnect to the A-device. If the A-device has enabled the B-device to become Host, then the A-device will interpret this disconnect during suspend as a request from the B-device to become Host. The A-device will complete the handoff by turning on its pull-up resistor on D+.

When the B-device has finished using the bus, it starts the process of returning control to the A-device simply by stopping all bus activity and turning on its D+ pull-up resistor when the bus is in FS idle. The A-device will detect this lack of activity and turn off its pull-up resistor. When the A-device detects the connection from the B-device, it will resume bus operation as Host.

The sequence of events for HNP as observed on the USB, are illustrated in Figure 6-1.

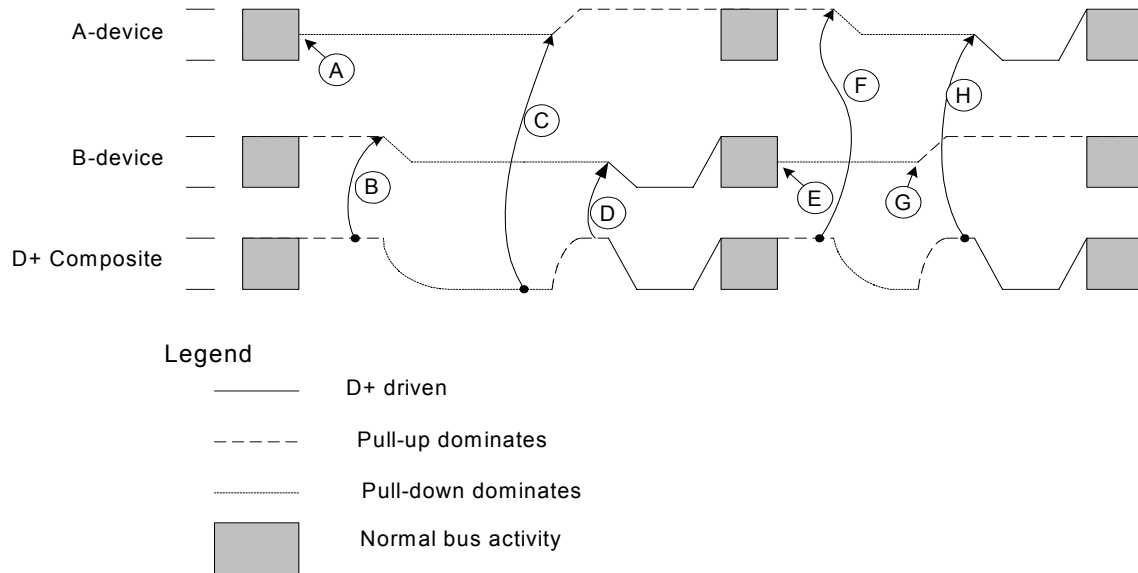


Figure 6-1 HNP Sequence of Events

- 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 $T_{A_AIDL_BDIS\ min}$ and begins HNP by turning off pull-up on D+. This allows the bus to discharge to the SE0 state. 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.

Note: 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 USB 2.0 specification [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.
- 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 $T_{A_BDIS_ACON\ max}$ of first detecting the SE0 on the bus.
- D)** After waiting long enough to insure that the D+ line cannot be high due to the residual effect of the B-device pull-up, (see Section 5.1.9), the B-device sees that the D+ line is high and D- line is low, (i.e. J state). 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 must 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)** A-device detects lack of bus activity for more than $T_{A_BIDL_ADIS\ min}$ and turns 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 VBUS and end the session.
- G)** B-device turns on its pull-up.
- H)** After waiting long enough to insure that the D+ line cannot be high due to the residual effect of the A-device pull-up, (see Section 5.1.9), 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. At this point, the A-device becomes Host and asserts bus reset to start using the bus.

6.4 OTG Descriptor

During enumeration, an On-The-Go A-device shall request the OTG configuration descriptor from the B-device. Any B-device that supports either HNP or SRP must respond by providing this descriptor in the group of descriptors returned in response to a GetDescriptor(Configuration) command. When present, the OTG descriptor shall be present in all configurations. This three-byte descriptor consists of three fields: *bLength*, *bDescriptorType*, and *bmAttributes*, with bits as defined in the following table.

Table 6-1. OTG Descriptor

Offset	Field	Size	Value	Description
0	<i>bLength</i>	1	Number (3)	Size of Descriptor
1	<i>bDescriptorType</i>	1	Constant	OTG type = 9
2	<i>bmAttributes</i>	1	Bitmap	Attribute Fields D7...2: Reserved (reset to zero) D1: HNP support D0: SRP support

6.4.1 srp_support

This bit is set to TRUE if the device supports SRP. This bit is not used by the A-device during normal operation. However, this bit is used during compliance testing to automatically detect the capabilities of the B-device.

6.4.2 hnp_support

This bit is set to TRUE if the device supports HNP. If the *hnp_support* bit is TRUE, then *srp_support* must also be TRUE.

6.5 Set Feature Commands

An A-device may use the SetFeature command to enable certain behaviors on the B-device or to indicate certain capabilities of the A-device to the B-device. 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 these features shall be able to accept the SetFeature command in the Default, Address and Configured states. (It should be noted that the USB 2.0 specification [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 one of these features 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 these features shall be executed on receipt of an uncorrupted command packet.

Table 6-2. Set Feature Command Format

bmRequestType	bRequest	Wvalue	wIndex	wLength	Data
00000000B	SET_FEATURE	Feature Selector	Zero	Zero	None

Table 6-3. On-The-Go Feature Selectors

Feature Selector	Value
b_hnp_enable	3
a_hnp_support	4
a_alt_hnp_support	5

6.5.1 b_hnp_enable

Setting this feature indicates to the B-device that it has been enabled to perform HNP. An A-device may set this feature if, and only if, the B-device is connected directly to an A-device port that supports HNP (i.e. no intervening hub between the Host and the B-device).

The b_hnp_enable feature takes precedence over either the a_hnp_support or a_alt_hnp_support features. Thus, if b_hnp_enable is set, then HNP is enabled in the B-device, regardless of whether or not the a_hnp_support or a_alt_hnp_support bits are set.

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.

6.5.2 a_hnp_support

Setting this feature indicates to the B-device that it is directly connected to an A-device port that supports HNP.

The A-device shall set this feature on any B-device that is connected 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.

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

Before putting the 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.

6.5.3 `a_alt_hnp_support`

Setting this feature indicates to the B-device that it is connected to an A-device port that is not capable of HNP, but that the A-device does have an alternate port that is capable of HNP.

The A-device is required to set this feature under the following conditions:

- the A-device has multiple receptacles
- the A-device port that connects to the B-device does not support HNP
- the A-device has another port that does support HNP

This feature is cleared at the end of a session. If this bit is set, and the user launches an Application that requires the B-device to be Host, then the B-device can provide a message to the user indicating that the user needs to connect the B-device to an alternate port on the A-device.

If both `a_alt_hnp_support` and `a_hnp_support` are set, then the meaning is the same as if only `a_alt_hnp_support` was set.

If the B-device receives a `SetFeature(b_hnp_enable)` command when this feature is set, then HNP is enabled in the B-device, as the `b_hnp_enable` bit takes precedence over the `a_alt_hnp_support` bit.

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

6.6 State Machine Parameters

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

6.6.1 Inputs

6.6.1.1 `a_bus_drop`

The “A-device bus drop” (`a_bus_drop`) input is `TRUE` when the Application running on the A-device needs to power down the bus, and is `FALSE` otherwise. When this input is `TRUE`, then the `a_bus_req` input must be `FALSE`.

6.6.1.2 `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.

6.6.1.3 `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.

Section 7.1.7.7 of the USB 2.0 specification [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 in the **b_peripheral** state, then this definition for resume signaling holds.

However, if the B-device is in the **b_wait_acon** state, then only a J-to-K transition is treated as a resume. 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 and the B-device shall treat the SE0 on the bus as a bus reset indication. This takes the B-device back to the **b_peripheral** state.

6.6.1.4 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.

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

As per Section 7.1.7.6 of the USB 2.0 specification [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.

6.6.1.5 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. In order to detect a connection from the A-device, the B-device must insure that there is no residual voltage on the D+ line from the B-device’s pull-up (See Section 5.1.9). 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 **a_conn** is set to TRUE.

Note: An On-The-Go 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.

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 the USB 2.0 specification [USB2.0]. The B-device also sets **a_conn** to FALSE whenever it goes to any state other than the **b_host** state.

6.6.1.6 a_sess_vld

The “A-device session valid” (**a_sess_vld**) input is TRUE if the A-device detects that the voltage on VBUS is above its A-device Session Valid threshold ($V_{A_SESS_VLD}$)(see Table 5-1).

6.6.1.7 a_srp_det

The “A-device SRP detect” (**a_srp_det**) input is TRUE if the A-device detects SRP as defined in Section 5.3. This bit is set when either VBUS pulsing or data line pulsing is detected. This variable is set to FALSE on initial power up of the A-device or whenever the A-device transitions to the **a_wait_vfall** state.

6.6.1.8 a_vbus_vld

The “A-device VBUS valid” (a_vbus_vld) input is TRUE when the VBUS voltage is above the A-device VBUS Valid threshold. This threshold must be at or above VA_VBUS_VLD min, specified in Table 5-1.

6.6.1.9 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.

6.6.1.10 b_bus_resume

The “B-device bus resume” (b_bus_resume) variable is TRUE when the A-device detects that the B-device is signaling a resume on the bus.

The A-device uses this variable to transition from the **a_suspend** state to the **a_host** state.

Section 7.1.7.7 of the USB 2.0 specification [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 the **a_peripheral** state and turning on its pull-up resistor on D+.

6.6.1.11 b_bus_suspend

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

The A-device uses this variable to transition from the **a_peripheral** state to the **a_wait_bcon** state

As per Section 7.1.7.6 of the USB 2.0 specification [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.

6.6.1.12 b_conn

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

<u>On b_conn transition</u>	<u>Exit State</u>	<u>Enter State</u>
FALSE → TRUE	a_wait_bcon	a_host
TRUE → FALSE	a_host	a_wait_bcon
TRUE → FALSE	a_suspend	a_peripheral

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 (TA_BCON_SDB) is allowed. If the **a_wait_bcon** state was entered from the **a_wait_vrise** state then the long debounce interval (TA_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 `TA_BCON_SDB_WIN max`, then the long debounce interval applies no matter how the `a_wait_bcon` state was entered. Note that 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 `TLDIS_DSCHG min`.

If the long debounce interval applies, then a new B-device connection is assumed and the A-device is required to allow the B-device to become host as described in 6.8.1.4.

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 the USB 2.0 specification [USB2.0]. The A-device also sets `b_conn` to FALSE whenever it transitions to any state other than `a_host` or `a_suspend`.

Note: The USB 2.0 specification [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 On-The-Go devices. They are not assured in all cases of a 100 ms interval after indicating a connect. When an On-The-Go device signals connect, it must be prepared to receive the bus reset that starts the session.

6.6.1.13 `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 (`TB_SE0_SRP`), as defined in Table 5-3.

6.6.1.14 `b_sess_end`

The “B-device session end” (`b_sess_end`) input is TRUE if the B-device detects that the voltage on VBUS is below its B-Device Session End threshold (`VB_SESS_END`) (see Table 5-1).

6.6.1.15 `b_sess_vld`

The “B-device session valid” (`b_sess_vld`) input is TRUE when the B-device detects that the voltage on VBUS is above its B-Device Session Valid threshold (`VB_SESS_VLD`) (see Table 5-1).

6.6.1.16 `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.

6.6.1.17 `a_suspend_req`

The “A-device suspend request” (`a_suspend_req`) input is TRUE during the time that the Application running on the A-device wants to suspend the bus for power savings, without ending the session. This input is FALSE when the Application does not desire the bus to be suspended.

6.6.2 Internal Variables

6.6.2.1 `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.

6.6.2.2 b_srp_done

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

6.6.2.3 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 6.5.1.

6.6.3 Outputs

6.6.3.1 chrg_vbus

The “charge VBUS” (chrg_vbus) signal is TRUE when a B-device is charging VBUS through a resistor. See Section 5.3.5.

6.6.3.2 drv_vbus

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

6.6.3.3 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 6.6.1.4.

6.6.3.4 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.

6.6.4 Informative Variables

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

- a_bus_req
- a_bus_drop
- a_clr_err
- a_suspend_req
- b_bus_req

While the device must demonstrate behavior related to these variables (i.e. the A-device must 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.

6.6.5 Timers

The HNP state machines make use of the following timers:

Table 6-4. On-The-Go Device Timers

Timer	Timeout Time	Timeout Indication	Associated State
a_wait_vrise_tmr	TA_WAIT_VRISE	a_wait_vrise_tmout	a_wait_vrise
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

All timers are started on entry to and reset on exit from their associated states.

6.6.5.1 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 rise above the A-device VBUS Valid threshold (`a_vbus_vld = TRUE`). If VBUS is not above this threshold before and after `TA_WAIT_VRISE` (`a_wait_vrise_tmout = TRUE`), then this is an indication that the B-device is drawing too much current.

6.6.5.2 a_wait_bcon_tmr

This timer is used by an A-device in the **a_wait_bcon** state to wait for the B-device to signal a connection, (`b_conn = TRUE`). If the B-device does not connect before `TA_WAIT_BCON`, (`a_wait_bcon_tmout = TRUE`), then the A-device is allowed to stop waiting for a connection.

6.6.5.3 a_aidl_bdis_tmr

This timer is started by an A-device when it enters the **a_suspend** state. If the A-device does not detect a disconnect before `TA_AIDL_BDIS` (`a_aidl_bdis_tmout = TRUE`), then the A-device is allowed to stop waiting for a disconnect and end the session.

6.6.5.4 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 `TB_ASE0_BRST` (`b_ase0_brst_tmout = TRUE`), then the B-device shall assume that the A-device is signaling a bus reset and return to the **b_peripheral** state.

6.6.6 Test Device Support

A device with VID=0x1A0A, PID=0xBADD is defined to be a test device, part of the compliance test configuration. An On-The-Go A-device or B-device shall treat a device with this identification as an unsupported device, and shall interact with the test device as defined in 6.8.1.4 and 6.8.2.5 when such a device is attached.

6.6.6.1 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 the USB 2.0 Specification [USB2.0] and associated errata. An OTG device as an **a_host** 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 embedded 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 6-5 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

Test Modes

The Test Modes described below are related to Section 7.1.20 of the USB 2.0 Specification [USB2.0] and associated errata. 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 must enter a high-speed receive mode as described in Section 7.1.20 of the USB 2.0 Specification [USB2.0] and drives an SE0 until the controller is reset.

Test_J

Upon enumerating VID 0x1A0A/PID 0x0102, the host's downstream port must enter a high-speed J state as described in Section 7.1.20 of the USB 2.0 Specification [USB2.0] until the host controller is reset.

Test_K

Upon enumerating VID 0x1A0A/PID 0x0103, the host's downstream port must enter a high-speed K state as described in Section 7.1.20 of the USB 2.0 Specification [USB2.0] until the host controller is reset.

Test_Packet

Upon enumerating VID 0x1A0A/PID 0x0104, the host must begin sending test packets as described in Section 7.1.20 of the USB 2.0 Specification [USB2.0] until the host controller is reset.

HS_HOST_PORT_SUSPEND_RESUME

Upon enumerating VID:0x1A0A/PID 0x0106, the host must continue sending SOFs for 15 seconds, then suspend the downstream port under test per Section 7.1.7.6.1 of the USB 2.0 specification [USB2.0]. After 15 seconds has elapsed, the host must 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 GetDescriptor(Device)
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).

6.7 Timing Summary

6.7.1 B-device becoming Host

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

After the bus enters the Suspend state, the B-device will transition from the **b_peripheral** to **b_wait_acon** states and wait for the A-device to indicate a connect event, which would complete the transfer of control to the B-device. While waiting in the **b_wait_acon** state, the B-device may detect a K state on the bus. This indicates that the A-device is signaling a resume condition and is retaining control of the bus. In this case, the B-device will return to the **b_peripheral** state.

If the B-device has had its D+ pull-up turned off for more than TLDIS_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.

If the B-device at any time detects more than TB_ASE0_BRST min of SE0, then this is an indication that the A-device is remaining Host and is resetting the bus, as per Section 7.1.7.5 of the USB 2.0 specification [USB2.0]. In this case the B-device shall return to the **b_peripheral** state and start to process the bus reset before TB_ASE0_BRST max.

If the A-device turns on its pull up before TB_ASE0_BRST min of the B-device disconnecting, then the B-device has until TB_ACON_BSE0 max to start bus activity by issuing a bus reset.

6.7.2 A-device becoming Peripheral

When the A-device is in the **a_host** state and has set the On-The-Go 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 must detect the disconnect is defined in Table 7-13 of the USB 2.0 specification [USB2.0].

After the A-device signals a connect, it must 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.

In some implementations of an A-device, the host controller may be on one chip, while the transceiver may be on another chip. The transceiver would typically have an integrated pull up resistor that would be controlled by the host controller through a slow serial interface. In such an implementation, it may not be possible for the A-device host controller to detect the B-device disconnect, and then turn on the A-device's pull-up resistor through the slow serial interface before $T_{A_BDIS_ACON}$ max. One method for accomplishing this with the above architecture is as follows.

After finishing data transfers between the A-device and B-device, and before suspending the bus, the A-device is sending out SOF's. The B-device receives these SOF's, and does not transmit any packets back to the A-device. During this time, the A-device host controller enables a logic block in the transceiver to look for an SE0 anytime that the A-device is not transmitting. After this logic is enabled, the A-device stops transmitting SOF's and allows the bus to go idle. If the B-device disconnects, then the bus goes to SE0, and the transceiver logic automatically turns on the A-device pull up.

Regardless of the implementation, the A-device must allow the B-device to disconnect before the A-device connects. This is so that the A-device can detect the B-device disconnect, and transition out of the **a_suspend** state.

6.8 State Diagrams

The HNP state machines are contained in this section. Figure 6-2 shows the state machine of an On-The-Go A-device. Figure 6-3 shows the state machine of an On-The-Go B-device. The HNP state machine for an On-The-Go device is equivalent to the dual role A-device state machine combined with the On-The-Go B-device state machine.

An additional state diagram for an SRP capable Peripheral-only B-device is shown in Figure 6-4.

6.8.1 On-The-Go A-Device

START

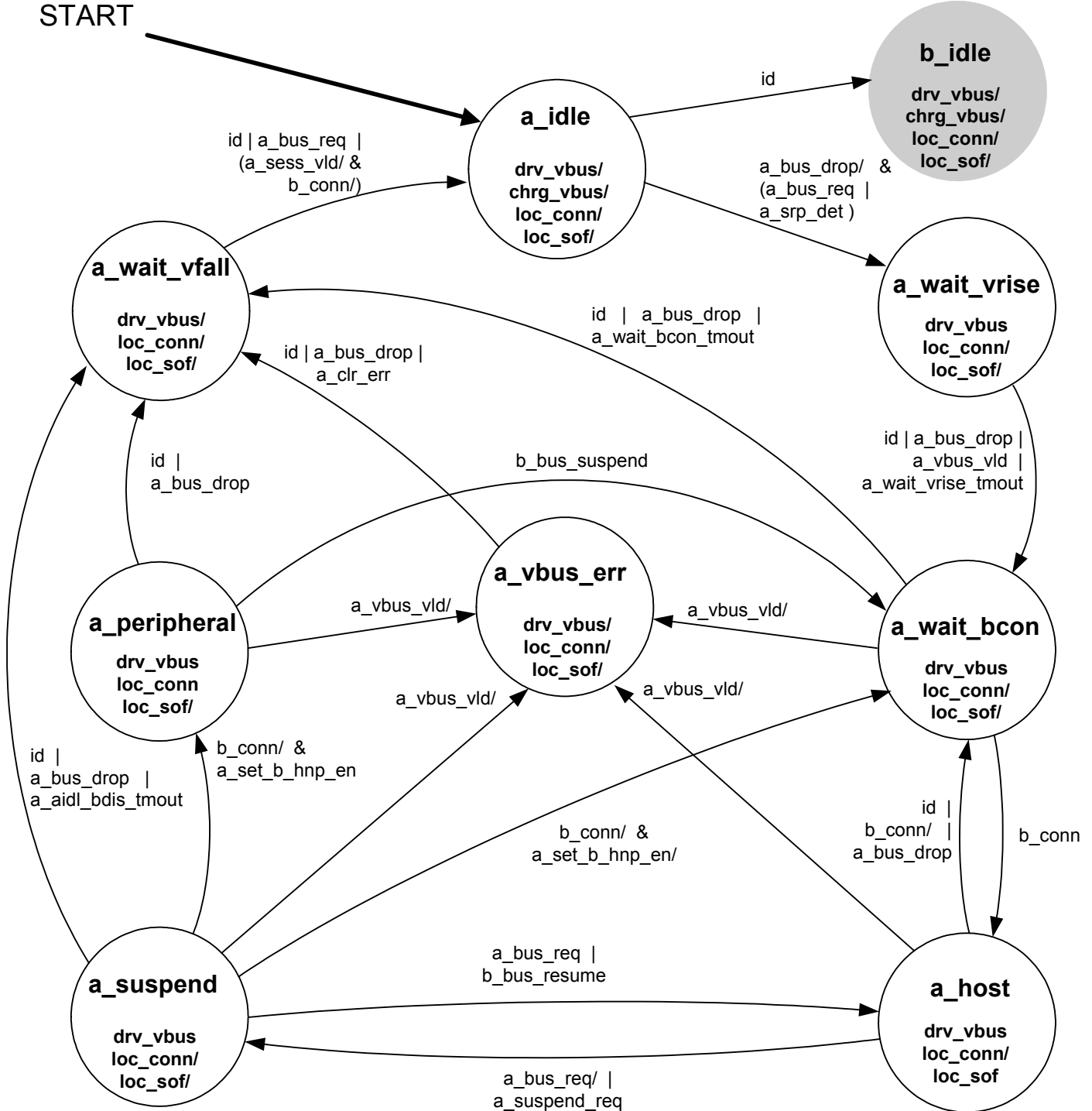


Figure 6-2 On-The-Go A-device State Diagram

The A-device state diagram shown in Figure 6-2 consists of the following eight states:

- **a_idle**
- **a_wait_vrise**
- **a_wait_bcon**
- **a_host**
- **a_suspend**
- **a_peripheral**
- **a_wait_vfall**
- **a_vbus_err**

There is a transition to the On-The-Go B-device start state (**b_idle**) that occurs if the cable is disconnected. 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.

6.8.1.1 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 either 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).

As indicated in Section 5.3.12, some OTG devices may be configured such that a change in ID from TRUE to FALSE cause **a_bus_req** to be asserted.

6.8.1.2 a_wait_vrise

In this state, the A-device waits for the voltage on VBUS to rise above the A-Device VBUS Valid threshold (**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 has risen above the A-device VBUS Valid threshold (**a_vbus_vld** = TRUE), or
- if the **a_wait_vrise_tmr** expires.

6.8.1.3 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 cable is removed (**id** = TRUE), 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).

If VBUS drops below the A-device VBUS Valid threshold (**a_vbus_vld** = FALSE), then the A-device transitions to the **a_vbus_err** state.

If the A-device detects the B-device signaling a connection (`b_conn = TRUE`), then the A-device shall end the session or transition to the **a_host** state and generate a bus reset within `TA_BCON_ARST`. See Section 6.6.1.12 for information on `b_conn`.

Note: 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.

6.8.1.4 a_host

Upon entering this state, the A-device resets the bus to prepare the B-device for packet traffic.

If `a_bus_req = TRUE`, then the A-device application wants to communicate with the B-device, and the A-device performs the following actions:

- A-device enumerates B-device
- if A-device supports B-device (i.e. B-device is on Targeted Peripheral List), then A-device sets up communication with B-device
- else if A-device does not support B-device then A-device outputs message to user indicating that B-device is not supported
- A-device sets `a_bus_req = FALSE`

Before ending the session, the A-device must allow an On-The-Go B-device the opportunity to take control of the bus. To do this, the A-device sends a `SetFeature(b_hnp_enable)` command. The A-device may send the `SetFeature(b_hnp_enable)` command to any B-device but is only required to send the command if the B-device is HNP capable (indicated in the OTG Descriptor). If the B-device responds to the `SetFeature(B_hnp_enable)` with a STALL, then the B-device is not HNP capable. "If the `SetFeature(b_hnp_enable)` command is sent and accepted during the session, then the A-device shall exit to the `a_suspend` state and wait for the B-device to start a session (See Section 6.5.2)" The A-device is allowed to transition to the **a_suspend** state without setting `b_hnp_enable`, if it does not want the B-device to become Host but wants to continue to power the bus (possibly in expectation of imminent user input). If it does suspend the bus without enabling HNP, then it must at some later time return to this state and enable HNP if the B-device is On-The-Go.

The On-The-Go A-device is required to perform HNP within `TA_SRP_RSPNS` max if it enumerates the B-device and discovers that the test device (defined in section 6.6.6) is attached. The On-The-Go A-device is not required to display an unsupported device message when attached to the test device. If the On-The-Go A-device does display an unsupported device message, the message shall not delay HNP. When connected to a test device, an A-device is not allowed to drive a resume signal longer than 30 seconds.

If an A-device has already granted the role of host to the test device once during a session, then the A-device is not required to grant the role of host to test device again during the same session.

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

- if the cable is removed (`id = TRUE`), or
- if the A-device wishes to stop powering VBUS (`a_bus_drop = TRUE`), or
- if the B-device disconnects (`b_conn = FALSE`).

If VBUS is or drops below the VBUS Valid value (`a_vbus_vld = FALSE`), then the A-device transitions to the **a_vbus_err** state.

6.8.1.5 a_suspend

Upon entering the **a_suspend** state, the A-device starts the `a_aidl_bdis_tmr`. This timer can be set to an arbitrarily long time, but must be longer than `TA_AIDL_BDIS` min.

The A-device transitions to the **a_wait_vfall** state:

- if the `a_aidl_bdis_tmr` times out (`a_aidl_bdis_tmout = TRUE`), or
- if the A-device wishes to stop powering VBUS (`a_bus_drop = TRUE`), or
- if the the cable is removed (`id = TRUE`).

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.

The A-device transitions to the **a_host** state if either `a_bus_req` is asserted, or if the B-device signals a resume by putting a K state on the bus, even if the `remote_wakeup` feature has not been enabled. If `a_bus_req` is asserted, then 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 `TB_ASE0_BRST` max. The On-The-Go A-device is not allowed to resume unless the attached device is supported, or until `TA_AIDL_BDIS` max time has elapsed.

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`), then the A-device transitions to the **a_wait_bcon** state.

If VBUS is or drops below the A-device VBUS Valid value (`a_vbus_vld = FALSE`), then the A-device transitions to the **a_vbus_err** state.

6.8.1.6 a_peripheral

In this state, the A-device signals a connection to the B-device (`loc_conn = TRUE`) and responds to requests from the On-The-Go 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 cable is removed (`id = TRUE`), or
- if the A-device is no longer capable of powering VBUS (`a_bus_drop = TRUE`).

If the A-device detects more than `TA_BIDL_ADIS` min of continuous idle (i.e. J_state for full-speed or SE0 for high-speed), on the bus, then the A-device may transition to the **a_wait_bcon** state. If no activity is detected after `TA_BIDL_ADIS` max the A-device must transition back to the **a_wait_bcon** state.

If VBUS is or drops below the A-device VBUS Valid threshold (`a_vbus_vld = FALSE`), 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.

6.8.1.7 a_wait_vfall

In this state, the A-device waits for the voltage on VBUS to drop below the A-device Session Valid threshold (`a_sess_vld = FALSE`) and for the B-device to drop D+/D- to indicate that it has detected the end of the session. Once both of these conditions are met, then the A-device transitions to the **a_idle** state. If the A-device is not On-The-Go and does not respond to the VBUS pulsing SRP, then the A-device transitions to **a_idle** when the bus enters the SE0 state and does not wait for VBUS to fall below the `VA_SESS_VLD`, threshold.

6.8.1.8 a_vbus_err

In this state, the A-device waits for recovery of the overcurrent condition that caused it to enter this state. Upon assertion of a_clr_err (nominally by system software), the A-device transitions to the **a_wait_vfall** state.

6.8.2 On-The-Go B-Device

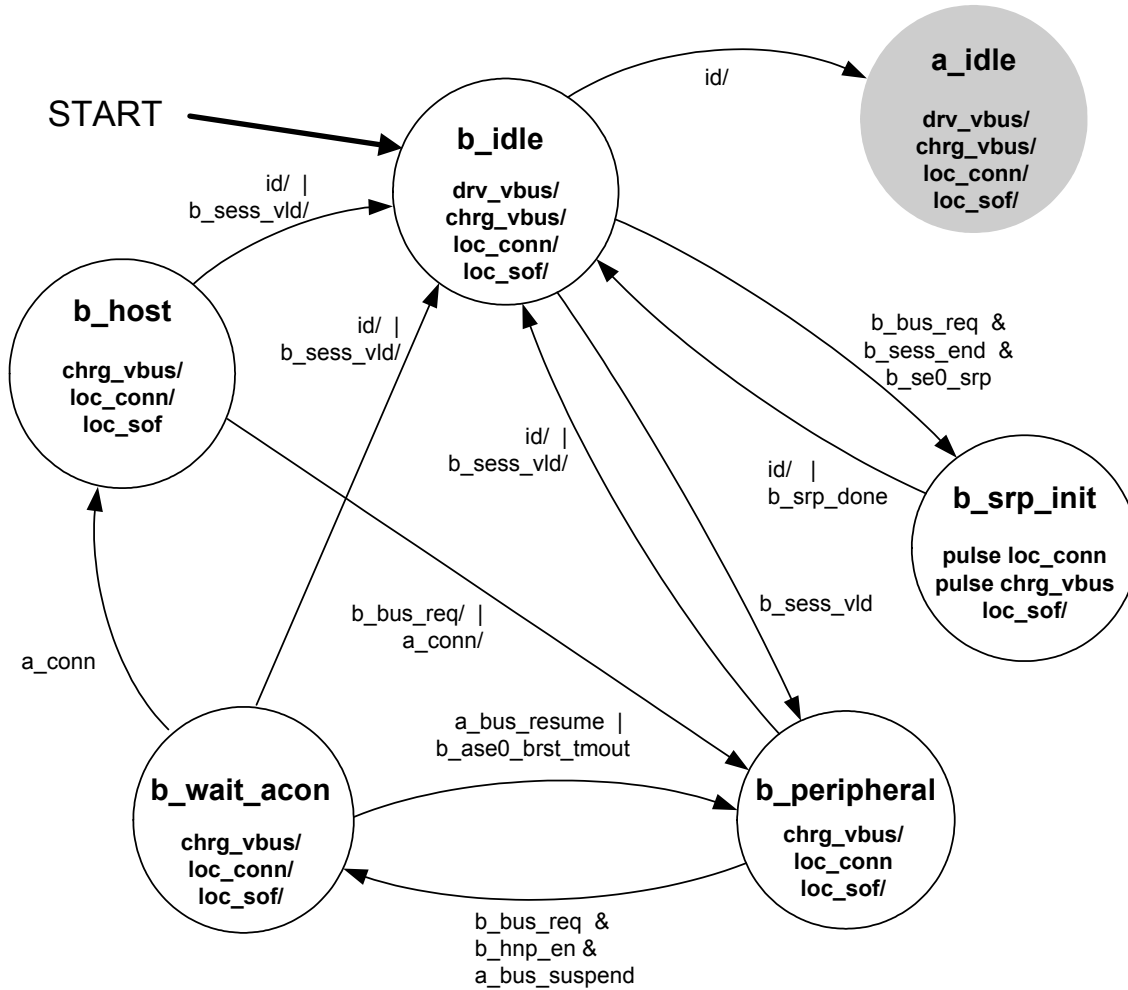


Figure 6-3 On-The-Go B-device State Diagram

The On-The-Go B-device state diagram consists of five distinct states:

- **b_idle**
- **b_srp_init**
- **b_peripheral**
- **b_wait_acon**
- **b_host**

6.8.2.1 **b_idle**

In this state, the On-The-Go B-device waits for a session to start by monitoring if VBUS rises above the B-Device Session Valid threshold ($b_sess_vld = TRUE$). If VBUS rises above this threshold, the On-The-Go 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 ($b_bus_req = TRUE$), and
- if VBUS is below the B-device Session End threshold ($b_sess_end = TRUE$), and
- if the bus has been in the SE0 state for at least TB_SE0_SRP min.

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

6.8.2.2 **b_srp_init**

Upon entering this state, the On-The-Go B-device attempts to initiate a session via SRP. Upon completion, the On-The-Go B-device returns to the **b_idle** state, nominally to wait for the A-device to drive VBUS above the B-Device Session Valid threshold ($b_sess_vld = TRUE$). Since the B-Device cannot distinguish between the A-device driving Vbus high, and any residual effect of the B-device signaling SRP on Vbus, the B-device must assume that Vbus above the B-device session threshold is due to A-device driving it high.

The B-device is required to complete its SRP activities in less than TB_SRP_INIT max. On entry to this state, the B-device shall provide an indication to the user that it is trying to establish communications with the A-device and a timer is started. This timer will continue to run until the B-device enters the **b_peripheral** state. If the timer reaches a vendor specific limit between TB_SRP_FAIL min and TB_SRP_FAIL max the B-device will indicate to the user that the A-device did not respond.

6.8.2.3 **b_peripheral**

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

If the On-The-Go B-device wishes to assume the role of Host ($b_bus_req = TRUE$) and the A-device has granted the On-The-Go B-device permission ($b_hnp_enable = TRUE$) and the bus is in the Suspend state, then the On-The-Go B-device transitions to the **b_wait_acon** state. In the event that the On-The-Go B-device started the session with an SRP request, the On-The-Go B-device shall transition to the **b_wait_acon** state within the TA_AIDL_BDIS timeout, even if b_bus_req is $FALSE$ at the time of transition.

If a Micro-A plug is inserted ($id = FALSE$) or if VBUS drops below the B-device Session Valid threshold ($b_sess_vld = FALSE$), then the On-The-Go B-device transitions to the **b_idle** state.

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 must 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 $TWTRSTHS$ (Table 7-14 in USB 2.0 specification [USB2.0]) and the bus is in the SE0 state then a reset condition exists. (Note: The $TWTRSTHS$ is a sample point that occurs at a device dependent time after the pull-up resistor is turned on.) If the B-device is capable of HS, it shall begin the high-speed detection handshake any time that a bus reset condition exists.

6.8.2.4 **b_wait_acon**

In this state, the On-The-Go 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 On-The-Go 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 On-The-Go 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 *TB_ACON_BSE0* max after D+ is detected to be high at the B-device.

If a Micro-A plug is inserted (*id* = FALSE) or VBUS drops below the session valid threshold (*b_sess_vld* = FALSE), then the On-The-Go B-device transitions to the **b_idle** state.

6.8.2.5 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.

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 On-The-Go B-device detecting that the test device (defined in section 6.6.6) is attached, then the B-device stops generating bus activity (*loc_sof* = FALSE) and transitions to the **b_peripheral** state.

If a Micro-A plug is inserted (*id* = FALSE) or VBUS drops below the B-device Session Valid threshold (*b_sess_vld* = FALSE), then the On-The-Go B-device transitions to the **b_idle** state.

6.8.3 Peripheral-Only, B-Device

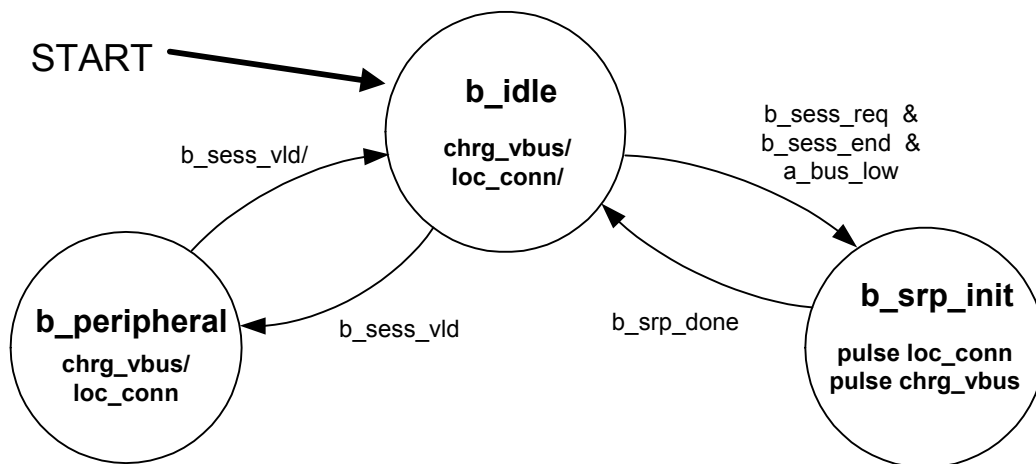


Figure 6-4 SRP Capable Peripheral-Only B-device State Diagram

The state diagram is only relevant for SRP capable Peripheral-only B-device. It consists of three distinct states:

- **b_idle**
- **b_srp_init**

- **b_peripheral**

6.8.3.1 **b_idle**

In this state, the Peripheral-only B-device waits for a session to start by monitoring if VBUS rises above the B-device VBUS Session Threshold (VB_SESS_VLD). If VBUS rises above this threshold, the Peripheral-only B-device enters the **b_peripheral** state.

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

- if the Application indicates that it wants to start a session (bus_req = TRUE), and
- if VBUS is below the B-device Session End threshold (b_sess_end = TRUE), and
- if the bus has been in the SE0 state for at least TB_SE0_SRP min.

6.8.3.2 **b_srp_init**

Upon entering this state, the device attempts to start a session using the SRP defined in Section 5.3. Upon completion, the device returns to the **b_idle** state.

6.8.3.3 **b_peripheral**

In this state, the B-device acts as a normal, USB 2.0 compliant device.

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