

USB ENGINEERING CHANGE NOTICE

Title: Pull-up/pull-down resistors
Applies to: Universal Serial Bus Specification Revision 2.0

Summary of ECN:

This ECN changes the range of the pull-up and pull-down resistors used to bias the bus. New values for the pull-down resistors are 14.25 k Ω to 24.80 k Ω . For the pull-up resistors, the values are 900 Ω to 1575 Ω when the bus is idle and 1425 Ω to 3090 Ω when the upstream device is transmitting.

Reasons for ECN:

This change allows the resistors to be moved onto the device or hub Silicon and not require laser trimming to achieve the required tolerances. This can result in a significant savings in cost, especially for a hub. It also has a significant impact on an OnTheGo, dual-role device that has to switch both the pull-up and pull-down resistors.

Impact on existing peripherals and systems:

There is no impact to current devices that are compatible with the current versions of the USB specification. The change has no impact on interoperability.

Hardware implications:

- 1) Increasing the pull-down resistor increases the discharge time of the bus after a disconnect. Worst-case discharge time increases from 15.75 μ s to 20 μ s. This increase has no operational implications.
- 2) Decreasing the pull-up resistor value increases the amount of current used for bus biasing by a small percentage (from 218 μ A max to 238 μ A or 9%). On average, the amount of current used for the biasing is reduced as the pull-down resistor value has the largest impact on the total current. If the increase in bias current is a problem for a device, it is free to use the older tolerance (i.e. if a device would be affected then it does not have to implement the change and the wider tolerance on the connected device will not have a negative impact).
- 3) The original values for the pull-down resistors assumed that the output leakage current of an off output would be about 10 μ A. With both the hub and device in the idle state, the pull-down on the low data line (D- for high and full-speed, D+ for low-speed) would be 20 μ A * 15.75 k Ω = 315 mV. To keep the idle voltage at the same level, any hub/host that uses the higher value resistance has to reduce its leakage current proportionately. If, for example, a hub has a 24.80 k Ω pull-down, then to allow for the legacy device leakage of 10 μ A, the leakage current on the hub has to be no more than 2.7 μ A. This is well within the capabilities of contemporary Si processing and testing.
- 4) The pull-up resistors change from lower resistance to higher resistance when the bus goes from idle to active. This ensures that existing hub/host Si can drive the downstream device without increasing jitter or otherwise degrading signaling margin.
- 5) Devices that use this scheme for their pull-down resistors must be aware that the pull-up resistor on a LS device may be tied to Vbus. The increase in the pull-down resistance can cause the idle voltage on the bus to rise as high as 4.1 V. If the process used does not allow this sustained voltage on the bus, then the standard values of resistance should be used.

Software implications:

None.

Compliance testing implications:

None.

Specification Changes:

No changes outside of Chapter 7.

In Chapter 7, change all occurrences in text and in drawings of:

“15 k Ω \pm 5%”

to

“14.25 k Ω to 24.80 k Ω ”

In Chapter 7, change all occurrences in text and in drawings of:

“1.5 k Ω \pm 5%”

to:

“1.5 k Ω (nominal)”

Note: No changes to test loads are proposed. All testing is to be done using the “nominal” values for pull-up (1.5K) and pull-down (15K) as currently specified.

Change sections 7.1.5.1, 7.1.5.2 as follows:

7.1.5.1 Low/Full-speed Device Speed Identification

The USB is terminated at the hub and function ends as shown in Figure 7-20 and Figure 7-21. Full-speed and low-speed devices are differentiated by the position of the pull-up resistor on the downstream end of the cable:

- Full-speed devices are terminated as shown in Figure 7-20 with the pull-up resistor on the D+ line.
- Low-speed devices are terminated as shown in Figure 7-21 with the pull-up resistor on the D- line.
- The pull-down terminators on downstream ports are resistors of ~~14.25 k Ω to 24.80 k Ω \pm 5%~~ connected to ground.

The design of the pull-up resistor must ensure that the signal levels satisfy the requirements specified in Table 7-2. In order to facilitate bus state evaluation that may be performed at the end of a reset, the design must be able to pull-up D+ or D- from 0 V to V_{IH} (min) within the minimum reset relaxation time of 2.5 μ s. A device ~~that has a detachable cable must~~ use a 1.5 k Ω \pm 5% resistor tied to a voltage source between 3.0 V and 3.6 V (V_{TERM}) to satisfy these requirements. Devices with captive cables may use alternative termination means; ~~How~~ however, the Thevenin resistance of any termination must be no less than 900 Ω and the open-circuit voltage of the pull up must not exceed V_{BUS} . These alternative means must produce an idle voltage (V_{IHZ}) on D- or D+ of between 2.7 V and 3.6 V when terminated with a pull-down resistance of 15 k Ω \pm 5% to ground.

Note: Thevenin resistance of termination does not include the ~~14.25 k Ω to 24.80 k Ω \pm 5%~~ resistor on the host/hub.

Alternative implementations for RPU are allowed on upstream facing ports on devices with detachable cables with the following restrictions:

- When the bus is in the Idle state (including Suspend) or the upstream device is asserting SE0, the pull-up resistance must be between 900 Ω and 1575 Ω . The 1575 Ω maximum value ensures that the Idle voltage is at 2.7 V or higher even when a minimum value of pull down (14.25 k Ω) is present.
- When the upstream device is transmitting data, the pull-up resistance shall switch to a value between 1425 Ω and 3090 Ω . The 1425 Ω minimum value ensures that the load presented by the switched resistance is no greater than the load presented by a 1.5 k Ω \pm 5%. The 3090 Ω maximum value is sufficient to ensure that the data line is held in a valid high state if the receiver has interpreted noise on the line as the start of a packet.
- When the upstream device is transmitting SE0, the pull-up resistance should be less than 3090 Ω but not less than 900 Ω . The resistance must be less than 3090 Ω to ensure that the data line will be pulled high within 2.5 μ s if the upstream device stops driving the SE0 without driving the bus back to an Idle state.

If a variable RPU is implemented, then the resistance switches from its low-resistance value (900 Ω to 1575 Ω) to its high-resistance value (1425 Ω to 3090 Ω) when a J-K transition is detected on the bus. This change must occur within 0.5 bit times of the transition. The resistance is switched from its high-resistance value to its low-resistance value when SE0 is detected on the bus for more than 0.5 bit times, or when the bus has been in the J state for more than 7 bit times. An implementation may implement either or both of these schemes. Figure 7-22 illustrates an implementation of a variable RPU.

The nominal value for the pull-down resistors is 15 k Ω \pm 5%. Values of up to 24.8 k Ω are allowed; however, when values exceeding 15.75 k Ω are used, allowance must be made for alternative pull-up means as described above. In particular, the pull-up resistor on the downstream device may be connected to V_{BUS} instead of to a local 3.3 V supply with a resistor value as 7.2 k Ω . If a pull-down resistance of 24.8 k Ω is used, the idle voltage (V_{IHZ}) on the D- or D+ lines can be as high as 4.1 V. Downstream ports using pull-down resistors greater than 15.75 k Ω and upstream ports of devices with captive cables using alternative termination means must be able to accommodate this idle voltage (V_{IHZ}), which is greater than the value for (V_{IHZ}) given in table 7.3.2.

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 V_{BUS} is removed, the pull-up resistor does not supply current on the data line to which it is attached.

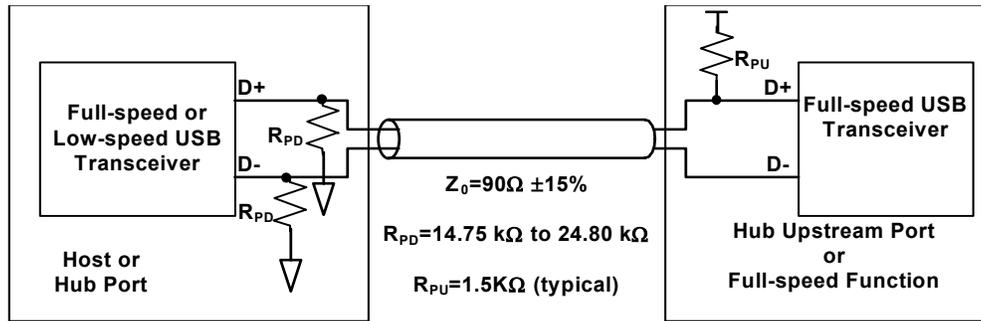


Figure 7-20. Full-speed Device Cable and Resistor Connections

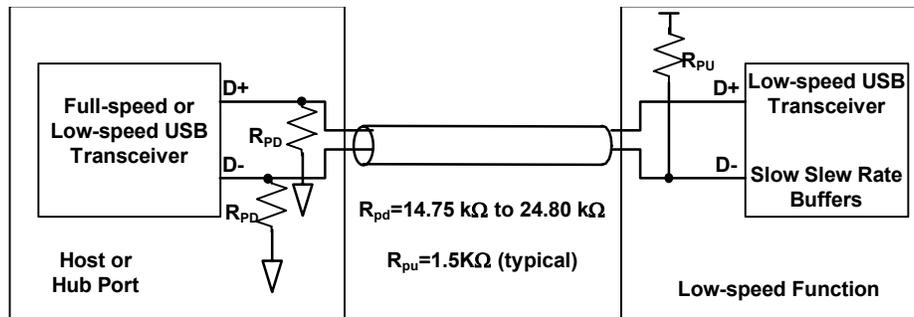


Figure 7-21. Low-speed Device Cable and Resistor Connections

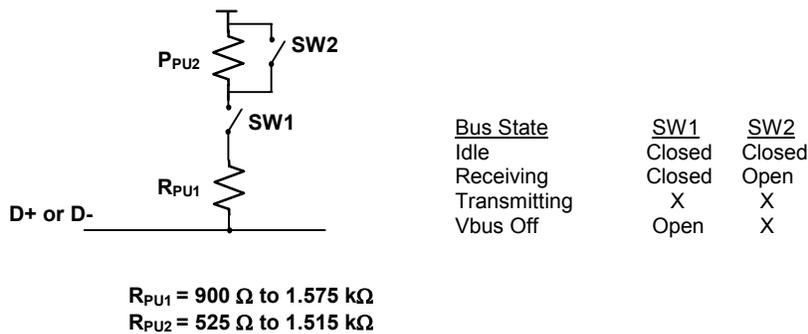


Figure 7-22. Variable Pull-up Example

7.1.5.2 High-speed Device Speed Identification

The high-speed **R**eset and **D**etection mechanisms follows the behavioral model for low-/full-speed. When reset is complete, the link must be operating in its appropriate signaling mode (low-speed, full-speed, or high-speed as governed by the preceding usage rules), and the speed indication bits in the port status register will correctly report this mode. Software need only initiate the asserting of reset and read the port status register upon notification of reset completion.

High-speed capable devices initially attach as full-speed devices. This means that for high-speed capable upstream facing ports, RPU (1.5 kΩ nominal $\pm 5\%$) must be connected from D+ to the 3.3 V supply (as ~~illustrated shown~~ in Figure 7-1 ~~or in 7-22~~) through a switch ~~which can be opened under SW control~~.

After the initial attachment, high-speed capable transceivers engage in a low level protocol during reset to establish a high-speed link and to indicate high-speed operation in the appropriate port status register. The protocol is described in Section 7.1.7.5.

In table 7-7 on page 178, change the following entry:

Parameter	Symbol	Conditions	Min.	Max.	Units
Input Levels for Low-/full-speed:					
High (floating)	VHIZ	Note 4, Section 7.1.4	2.7	3.6	V

to:

Parameter	Symbol	Conditions	Min.	Max.	Units
Input Levels for Low-/full-speed:					
High (floating)	VHIZ	Note 16, Section 7.1.4	2.7	3.6	V

Add note 16 to page 185 as follows:

Note 16: Measured at A connector with 1.5 kΩ±5% to 3.3 V ± 0.3 V connected to D+ or D- and at B connector with 15 kΩ±5% to ground connected to D+ and D-.

In table 7-7 on page 180, change the following entries:

Parameter	Symbol	Conditions	Min.	Max.	Units
Terminations:					
Bus Pull-up Resistor on Upstream Port	RPU	1.5 kΩ ±5% Section 7.1.5	1.425	1.575	kΩ
Bus Pull-down Resistor on Downstream Port	RPD	15 kΩ ±5% Section 7.1.5	14.25	15.75	kΩ

to:

Parameter	Symbol	Conditions	Min.	Max.	Units
Terminations:					
Bus Pull-up Resistor on Upstream Port (idle bus)	RPUI	Section 7.1.5.1	0.900	1.575	kΩ
Bus Pull-up Resistor on Upstream Port (upstream port receiving)	RPUA	Section 7.1.5.1	1.425	3.090	kΩ
Bus Pull-down Resistor on Downstream Port	RPD	Section 7.1.5.1	14.25	24.80	kΩ