MICROCHIP

AN1970

USB Hub Configuration Guide

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INTRODUCTION

The USB hub configuration registers provide the mechanism for developers to set a number of operating parameters. This document explains how to interpret the configuration settings and how to solve problems resulting from an improper setting.

Audience

This document is written for system developers and hardware manufacturers who are familiar with system configuration framework and structure. The goal of this application note is to describe how to correctly configure USB hubs to help facilitate product testing and development and ensure a high-quality implementation.

References

The following documents should be referenced when using this application note:

- AN 26.2 Implementation Guidelines for Microchip USB 2.0 and USB 3.0 Hub Devices
- AN 26.21 USB Device Design Checklist
- AN 26.18 SMBus Slave Interface for the USB253x / USB3x13 / USB46x4
- AN1905 USB Battery Charging with the USB57x4 Hub Controller Family

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BACKGROUND

Microchip USB Hubs provide many configuration options, providing developers tools to meet the stringent USB requirements for their application. This flexibility can create configuration challenges, even for the most experienced system designers.

USB Hub configuration selection and modes of operations are covered in the following sections:

GLOSSARY

The following are terms used throughout the document:

- **Pin Straps** - Is used to describe the use of pins as a mechanism to configure the hub

- **EEPROM** - Stands for Electronically Erasable Programmable Memory
- **SMBus** - Is an abbreviation for System Management Bus
- **OTP** - Is a form of One Time Programmable (field programmable read-only) memory

USB HUB CONFIGURATION SELECTION

Microchip provides a wide variety of versatile, cost-effective, and power-efficient USB hub solutions with an array of configuration options. The Configuration Select [CFG_SEL] pins are used to select the configuration mode. The [CFG_SEL] pins are sampled on system power on and/or the de-assertion of hardware reset via the RESET_N.

The hub configuration registers can be accessed to modify the behavior of the USB hub system in many ways:

- Pin Straps
- EEPROM
- SMBus
- OTP

TABLE 1: USB HUB CONFIGURATION SELECTION

USB HUB	PIN STRAPS	EEPROM	SMBUS	OTP
USB5734	Yes	Yes	Yes	Yes
USB5744	Yes	Yes	Yes	Yes
USB5537	Yes	Yes	Yes	Yes
USB5534	Yes	Yes	Yes	Yes
USB5533	Yes	Yes	Yes	Yes
USB5532	Yes	Yes	Yes	Yes
USB2514B	Yes	Yes	Yes	No
USB2412	Yes	No	No	No
USB2422	Yes	No	Yes	No
USB2512B	Yes	Yes	Yes	No
USB2513B	Yes	Yes	Yes	No
USB2517	Yes	Yes	Yes	No
USB2532	Yes	Yes	Yes	No
USB2533	Yes	Yes	Yes	No
USB2534	Yes	Yes	Yes	No
USB3503	Yes	Yes	Yes	No
USB3613	Yes	Yes	Yes	No

Note: Refer to the specific hub product data brief for configuration selection details.

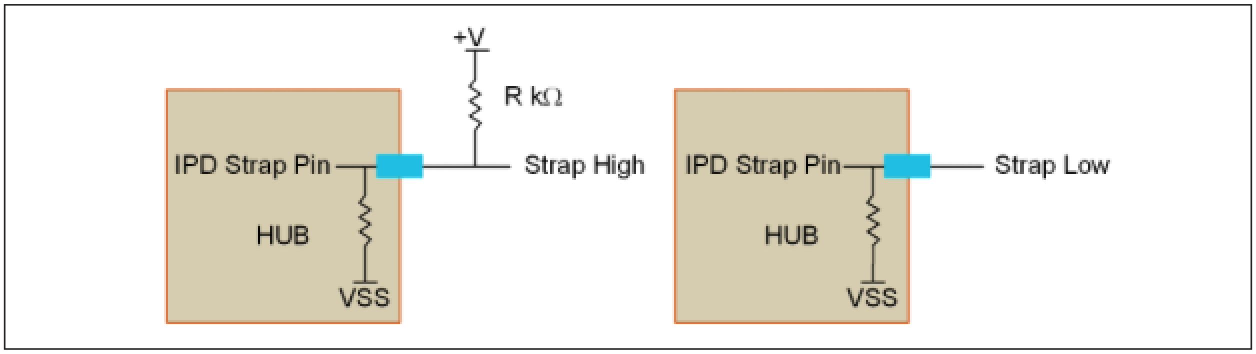
Configuration Using Pin Straps

The USB Hub Controller supports programming of many basic and more common configurable features by the use of pin strap options. The use of pin straps is simple, direct, and in many cases, all that is required to ensure correct operation.

There are two types of supported pin strap options, Internal Default Configuration with overrides and Strap Options Enabled. In either case, when Strap Options are enabled the strap option pins are sampled on power up and/or the de-assertion of hardware reset via the RESET_N pin. The USB Hub Controller datasheet will provide the details for the default configuration of the specific hub product and the selectable configuration options that are supported.

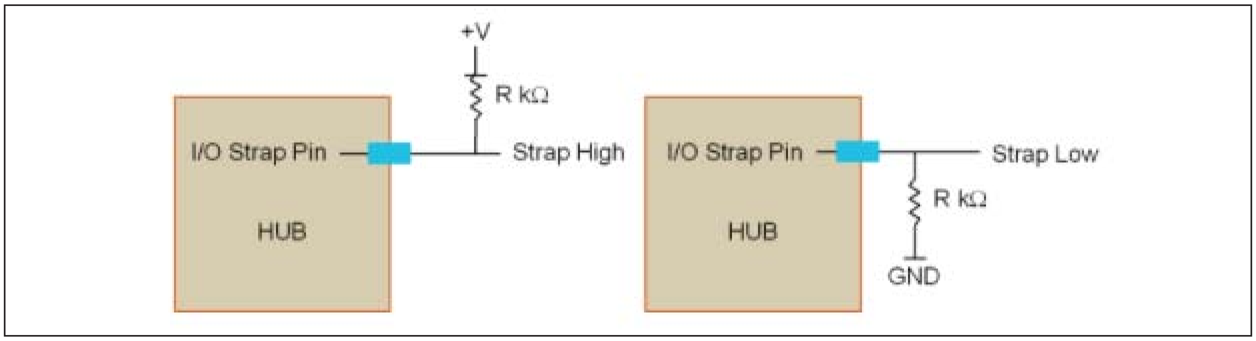
An example of a common strap option implementation using a combination of internal and/or external components is shown in Figure 1.

FIGURE 1: STRAP OPTION CONFIGURATION OVERRIDE EXAMPLE



An example of a typical strap option implementation using external components is shown in Figure 2.

FIGURE 2: STRAP OPTION CONFIGURATION EXAMPLE EXTERNAL

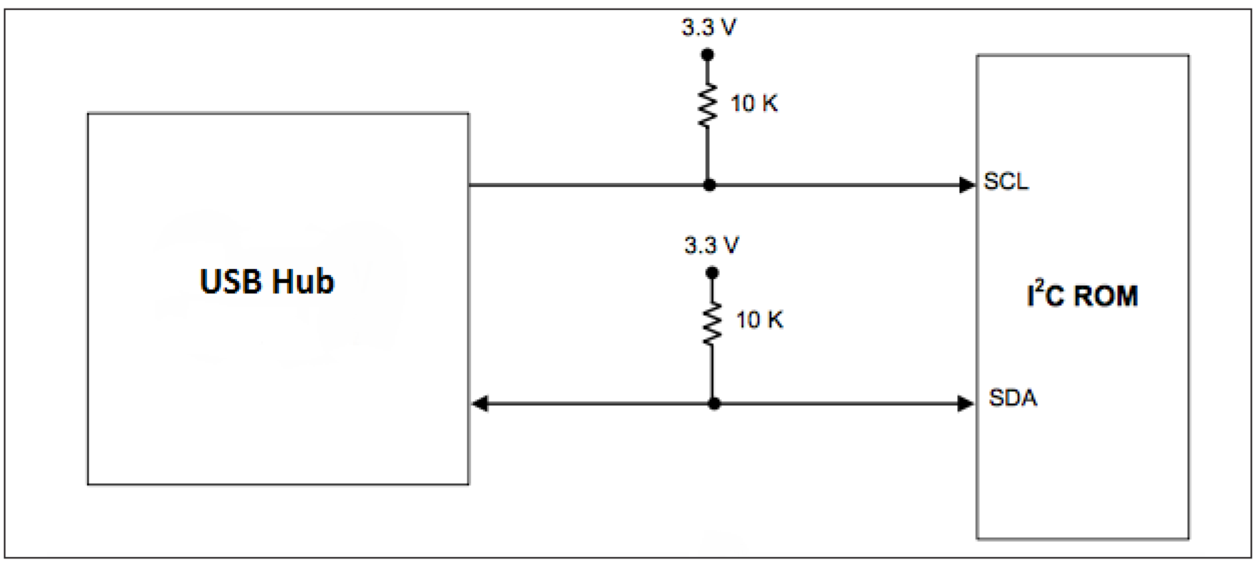


Configuration Using an EEPROM

The USB Hub Controller supports more advanced configuration options by means of a serial EEPROM interface. Certain applications will require the use of programmable devices in order to support some of the more advanced configurable features such as: Vendor and Product Specific identification. The use of an external method of programming is also required to reconfigure certain timing and/or electrical parameters.

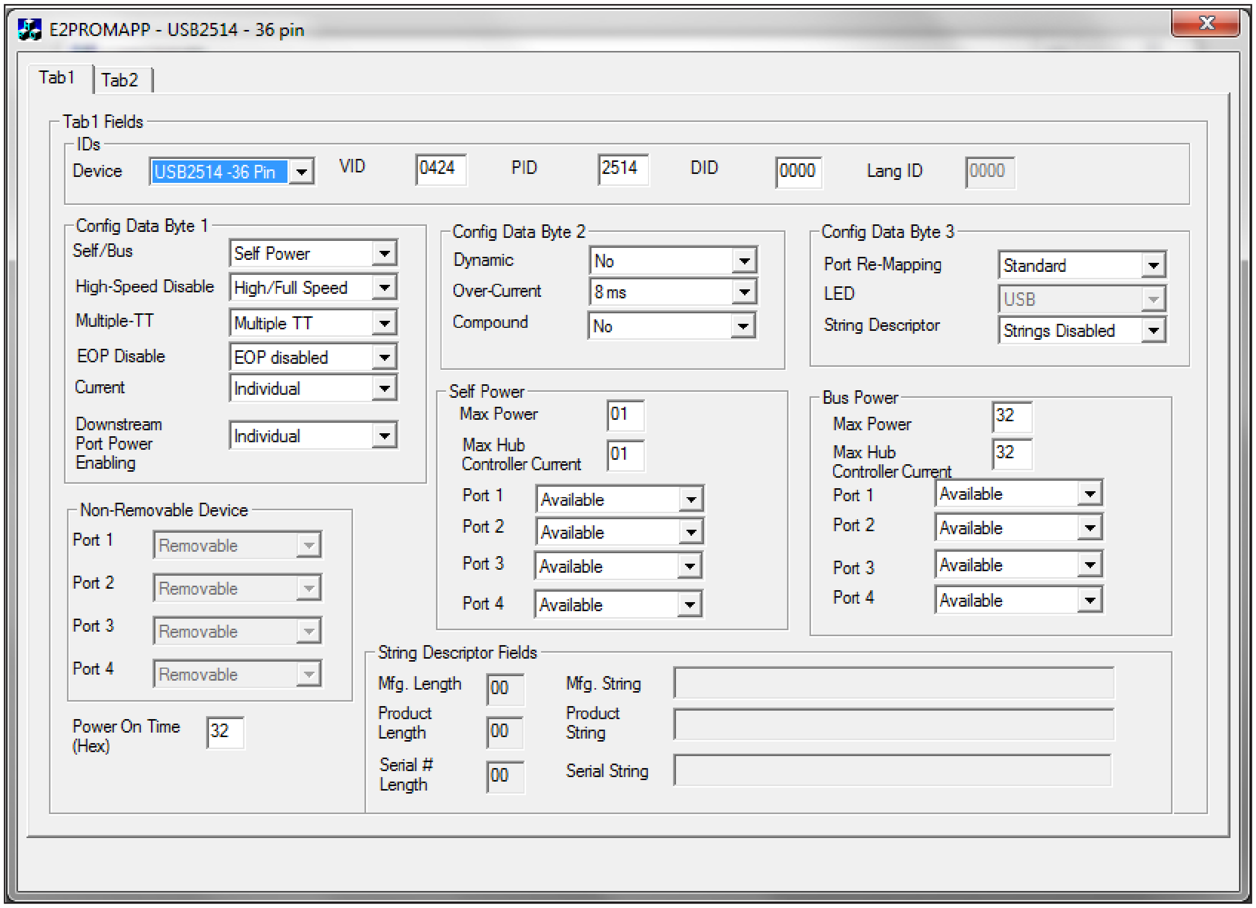
An example of a typical I2C connection is shown in Figure 3.

FIGURE 3: I2C EEPROM CONNECTION



Any Hex Editor tool may be used to generate the EEPROM binary image. The Microchip Configuration Utility for Hub EEPROM Data shown in Figure 4 is a tool that is designed to generate binary files that are used by an external EEPROM to configure the programmable parameters of the USB25xx hubs.

FIGURE 4: CONFIGURATION UTILITY FOR HUB EEPROM DATA



Once the desired configuration binary file has been generated, EEPROM devices may be manually programmed during the initial prototype phase or mass programmed for production.

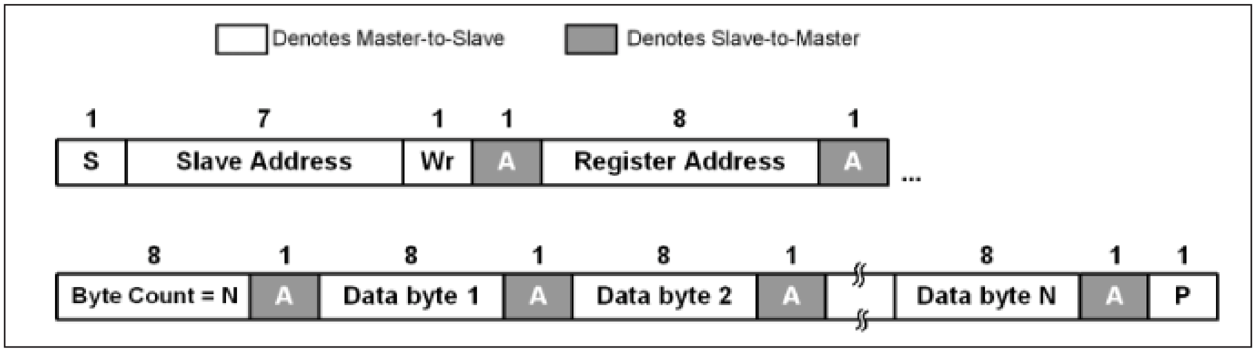
Configuration Using SMBus

Applications implementors may decide to use the SMBus interface to configure the Vendor and Product Specific IDs and modify other modes of operation. The SMBus is a 2-pin serial protocol interface commonly found in computer motherboards, laptops, docks, and similar systems. Custom profiles may be loaded via the SMBus enhancing end product versatility. Refer to the System Management Bus Specification for the timing parameters of the interface.

Example Write Sequence (for USB251x):

- Slave Address 0x58
- Register Address 0x00
- Byte count 0x03 (to write 3 bytes)
- Data Byte 1
- Data Byte 2
- Data Byte 3

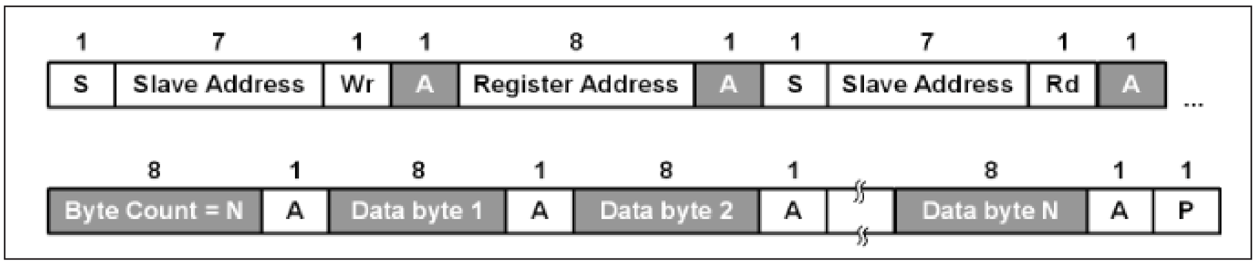
FIGURE 5: SMBUS BLOCK WRITE



Example Read Sequence (for USB251x):

- Slave Address 0x58
- Register Address 0x00
- Repeat start Slave address (will be 0x59)
- Byte Count 0x03 (to read 3 bytes)
- Data Byte 1
- Data Byte 2
- Data Byte 3

FIGURE 6: SMBUS BLOCK READ



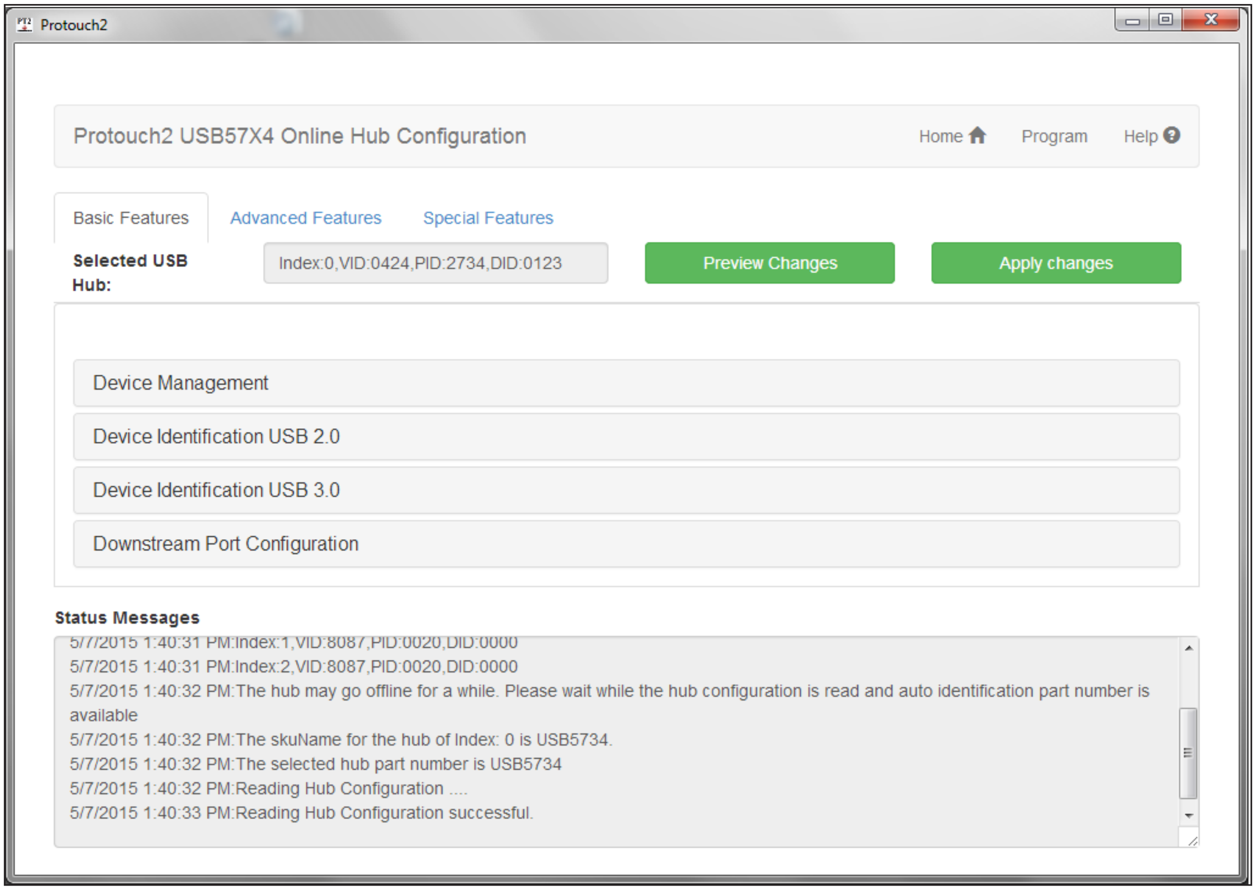
Configuration Using OTP

Many Microchip Hub Controllers support the use of an on-chip OTP ROM for custom configurations. One Time Programmable read-only memory is commonly used for large production runs, while EEPROM technology is normally used for development cycles or smaller production sizes when the program may have to be changed.

OTP is a memory space and each byte may only be programmed once. OTP programming is an additive process, and you may program/append configuration commands to the OTP space until it is completely full. OTP commands are loaded sequentially (old to new) and if the developer wishes to “undo” an OTP configuration command, a new configuration file may be used to restore the hub to its original/default settings or a new configuration file may be constructed to override the previous configuration.

ProTouch is a programming tool / configuration editor that is used for configuring and programming Microchip USB hub controllers. ProTouch is intended to be used during both the prototype phase and the final mass production stage.

FIGURE 7: PROTOUCH2 HUB CONFIGURATION TOOL



Note: The Hub must be reset or power cycled in order for the changes to take effect.

USB HUB VENDOR SPECIFIC PARAMETERS

The vendor specific registers allows the end user to set customized vendor specific parameters such as:

- Vendor ID
- Product ID
- Device ID
- String Descriptors

The USB idVendor (VID) and idProduct (PID) are 16-bit values that are used to identify USB devices by the USB host system. The USB-IF assigns specific USB vendor ID to product manufactures while the product ID is designated by the product manufacturer to individual products. The bcdDevice (DID) value is **binary coded decimal** and normally is used to identify an individual hardware or firmware revision.

The iManufacturer, iProduct, iSerialNumber found in the Device Qualifier Descriptor are USB String Descriptors which are optional and encoded in the Unicode format. USB String Descriptors provide additional product information. The LANGID field and can store strings to support multiple languages.

Note: If the USB String Descriptors are not used, the String Index fields must be set to zero indicating that there are no string descriptors available. Strings must be encoded in Unicode 3.0 format, where each character is 16 bits.

BASIC USB HUB CONFIGURATION SETTINGS

Self-Powered Hub vs. Bus Powered Hub

A self-powered hub sources and distributes power to its downstream facing ports from a local power supply. Self-powered hubs are required to provide over-current protection on the downstream facing ports. An external switch may be used for over current protection and power switching. The self-powered configuration is recommended for USB hub systems that have four or more downstream facing ports and for USB systems that include high-power USB devices that require greater than 100mA to operate.

Bus-powered hubs source and also distribute power to their downstream facing ports from the USB interface (VBUS). A USB 2.0 bus-powered hub may draw a maximum of 100mA from the USB interface and may only provide a maximum of 100mA to devices attached to its downstream facing ports. Thus, in bus-powered hub systems, all USB devices attached to the hub downstream facing ports must be low power. Therefore, a bus-powered USB hub configuration has a practical limit of no more than four downstream facing ports. If a device is plugged into a bus-powered hub that requires more current than the hub port can supply, the operating system normally reports an error to the user.

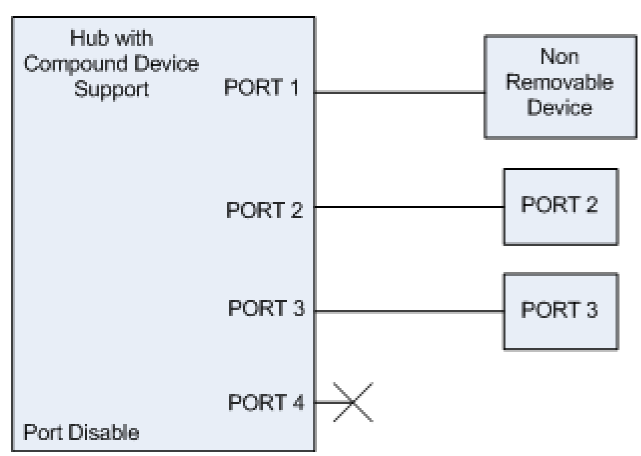
Hub Power and Max Power Reporting

The Hub Power source is reported to the host system software through the Configuration Descriptor by bit D6 of the bmAttributes field (Self Powered = 0 / Bus Powered = 1). The bMaxPower field is used to report the maximum power the hub will draw from VBUS in 2mA units. For Bus Powered hubs, the reported value must not include the power requirements for external USB devices that are attached to downstream facing ports. The external USB devices are required to report their individual power requirements.

Compound Device Support and Non-Removable Hub Ports

A Compound Device is a USB system in which the hub has one or more downstream facing ports with integrated peripheral devices permanently connected. The compound device could be an embedded device integrated into a single chip or physically non-removable external components connected to hub downstream facing ports. The Compound Device support and non-removable port values are contained in the USB Hub Descriptor wHubCharacteristics fields. A USB hub that contains user inaccessible ports must report as a part of a compound device and declare non-removable ports.

FIGURE 8: HUB WITH COMPOUND DEVICE SUPPORT AND DISABLED PORT



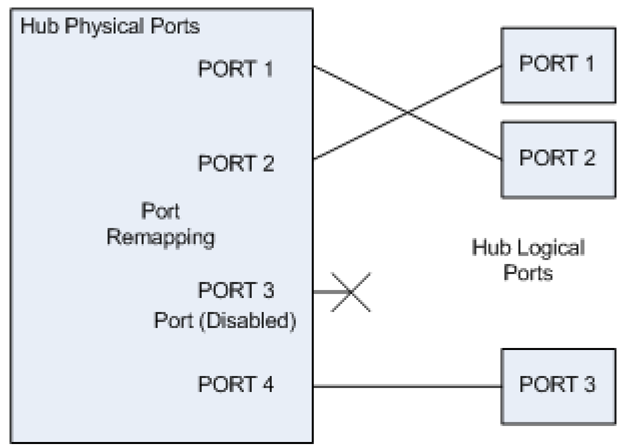
Disabling Hub Ports

Downstream facing hub port disabling may sometimes be required depending on the system application layer. Disabling unused hub ports may differ depending on the hub product selected. Consult the specified hub controller datasheet for guidance when using the hub port disable option.

Port Mapping

Downstream facing hub ports that are physically connected to connectors are known as exposed ports. Port mapping allows the system designer to logically remap the exposed ports for a more positive user experience.

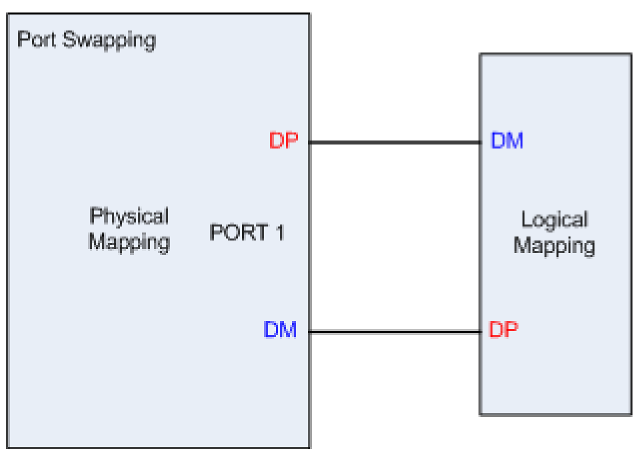
FIGURE 9: HUB CONFIGURED WITH REMAPPED PORTS AND DISABLED PORT



Port Swapping

Port Swapping reverses the USB 2.0 differential pair pin locations which helps ease the PCB design by aligning the USB signal lines directly to the connectors if necessary and is an important design consideration for maintaining a high level of signal quality or for use in multiple integrated or embedded hub systems.

FIGURE 10: HUB CONFIGURATION USING DP/DM PORT SWAPPING



USB HUB POWER SWITCHING IMPLEMENTATION OPTIONS

Individual vs. Gang Power Switching

USB hub port power switching can be implemented in Individual mode or Gang mode. When configured as Individual mode the hub port power is enabled and disabled on a port by port basis, while Gang mode enables and disables port power on all hub ports as a group.

Individual vs. Global vs. No Over Current Sensing

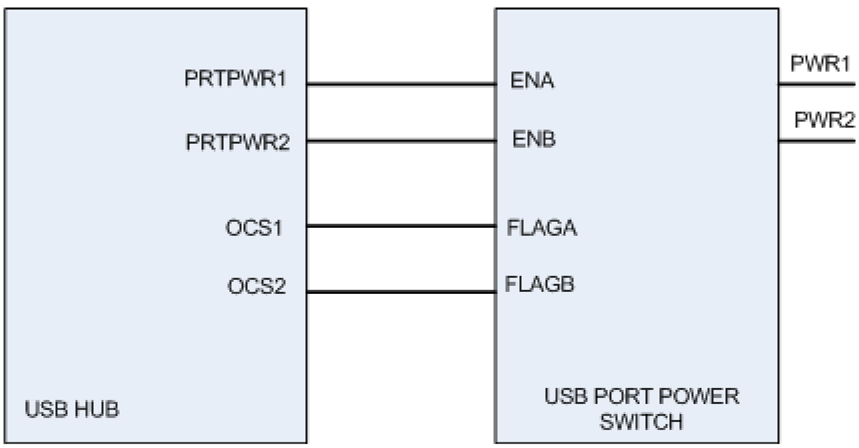
USB hubs are required to implement over-current protection circuitry otherwise known as over-current sensing (OCS). When the over-current limit is triggered, the hub shall report the OCS event to the host system software and shutdown the power on the affected port. Individual mode port power protection uses dedicated power switches for each downstream facing hub port. When a downstream facing hub port experiences a power surge, the hub turns the power off to the specific hub port.

A power surge on any hub port that is configured as Gang mode will result in the hub turning off the power to all of the downstream facing ports. A disadvantage to using Gang mode is that a power surge on one hub port will result in the loss of power to all downstream facing ports.

Bus powered hubs are not required to support Over-current sensing.

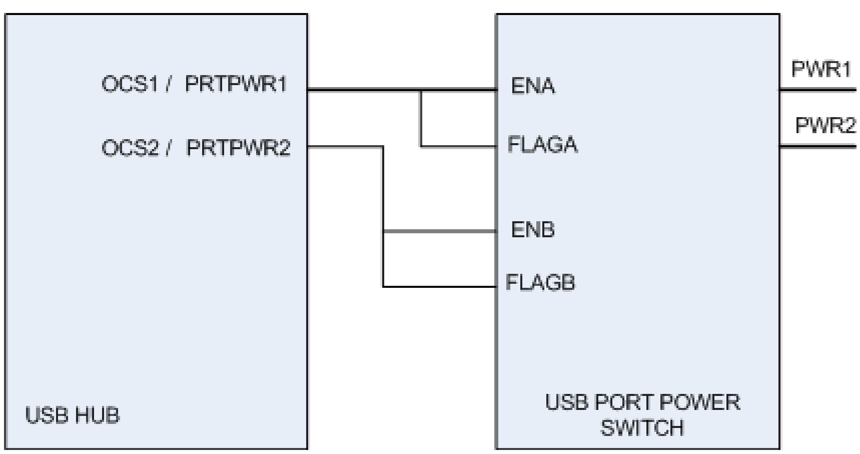
An example of individual port power control using two pin port control which has individual pins for PRTPWR and OCS is found in Figure 11.

FIGURE 11: INDIVIDUAL POWER SWITCHING AND OVER CURRENT SENSING



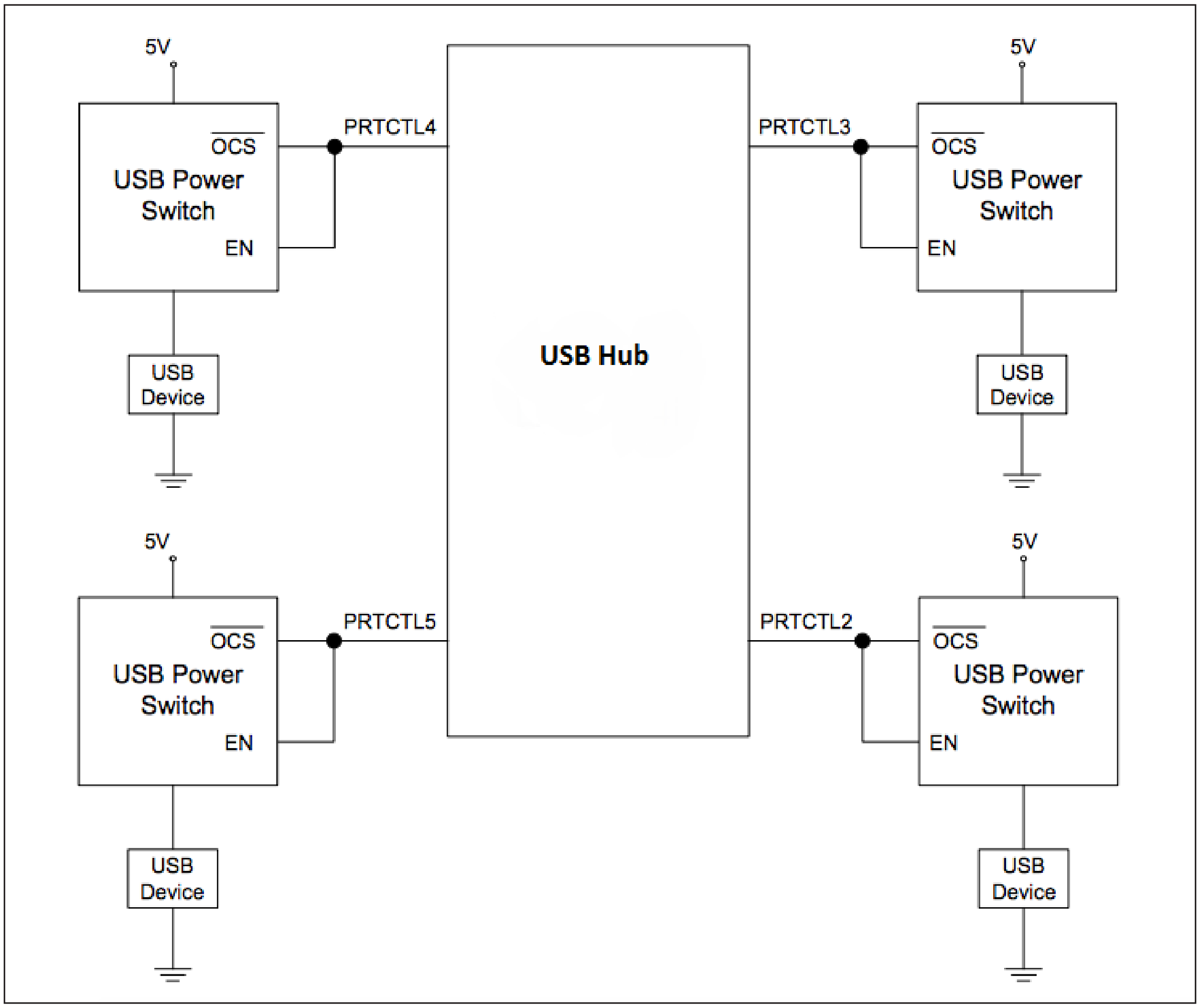
An example of individual port power control using combined port control which has shared pins for PRTPWR and OCS is found in Figure 12.

FIGURE 12: INDIVIDUAL POWER SWITCHING AND OVER CURRENT SENSING COMBINED



An example of a common Individual Mode Power Implementation using power switches is found in Figure 13.

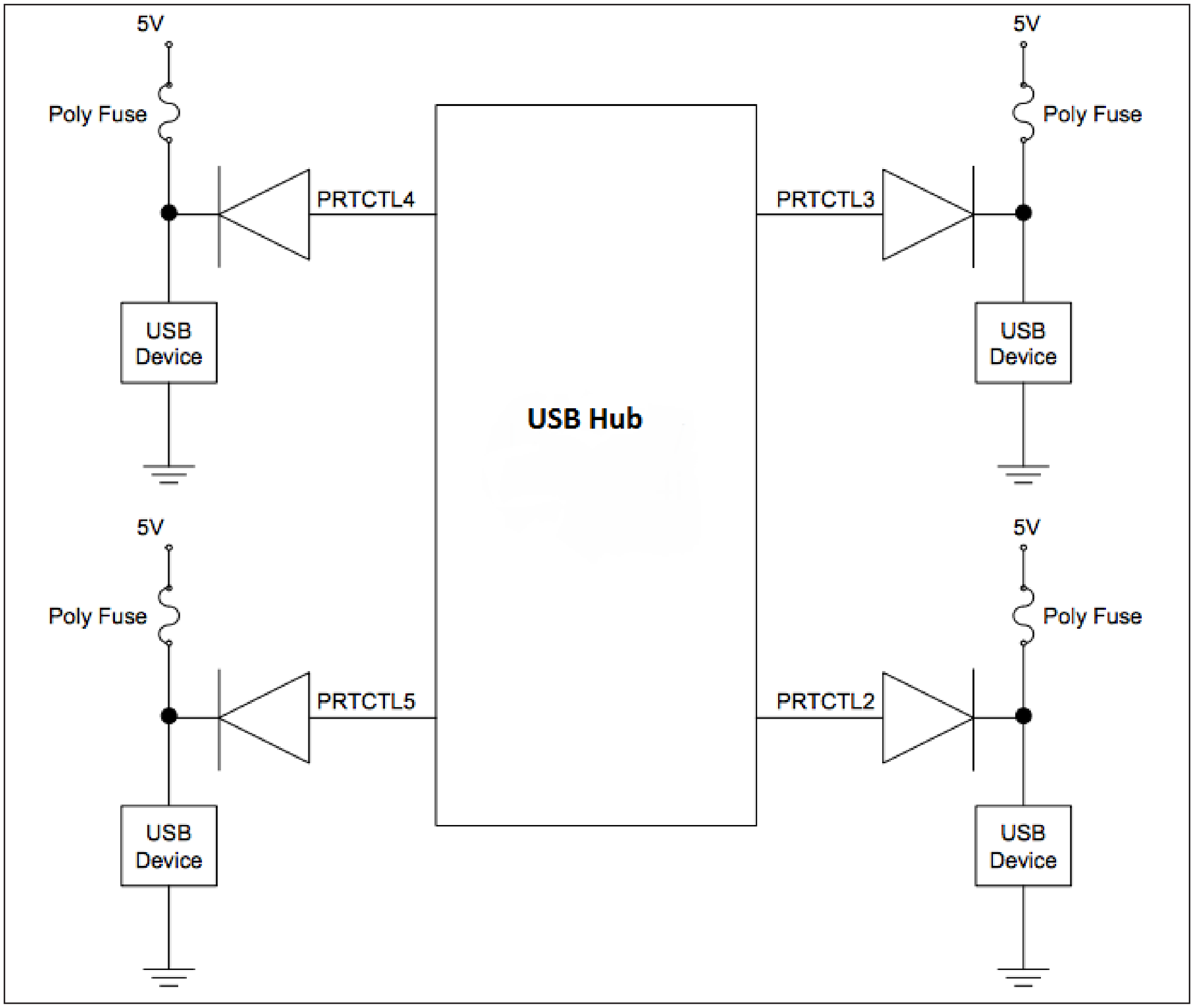
FIGURE 13: TYPICAL INDIVIDUAL MODE POWER IMPLEMENTATION EXAMPLE



Note:	Refer to the hub product specific datasheet for the correct PRTPWR and OCS connections.

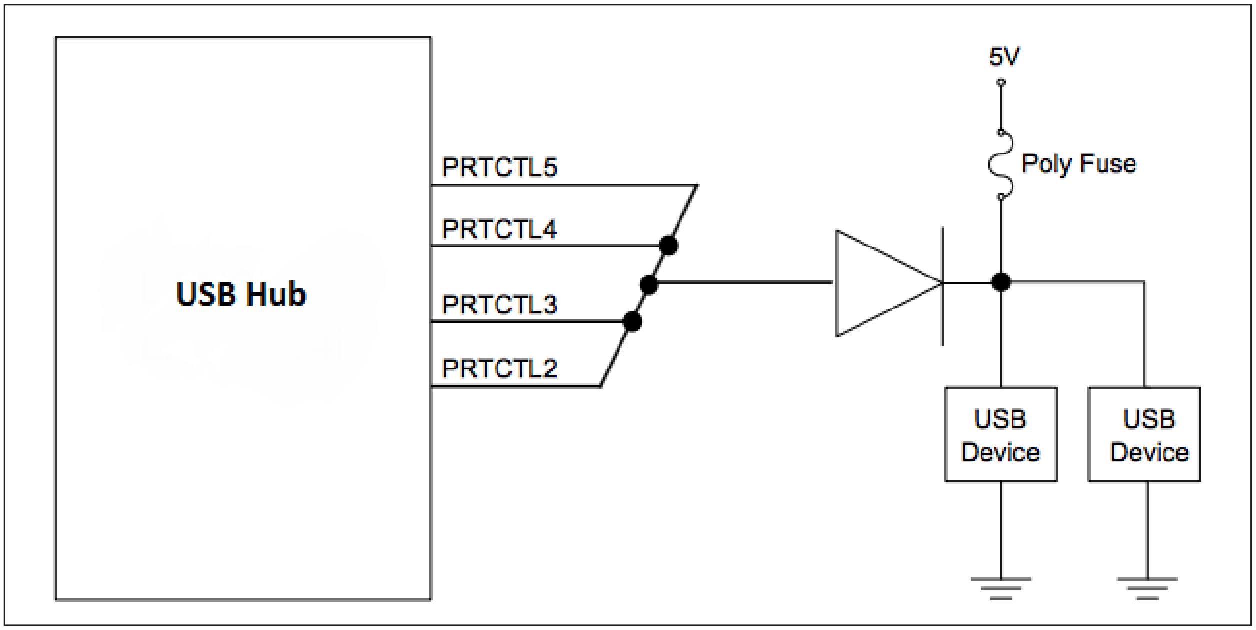
An example of a typical Ganged / Global Mode Power Implementation using multiple resettable polymeric positive temperature coefficient devices (PPTC) commonly know as a “Poly-Fuse” or “Poly-Switch” is found in Figure 14.

FIGURE 14: GANG / GLOBAL MODE USING MULTIPLE POLY-FUSE EXAMPLE



An example of a typical Ganged / Global Mode Power Implementation using a single resettable poly-fuse is found in Figure 15.

FIGURE 15: GANG / GLOBAL MODE USING SINGLE POLY-FUSE EXAMPLE



ADVANCED USB HUB CONFIGURATION SETTINGS

VariSense

VariSense technology controls the USB 2.0 receiver sensitivity with programmable levels of USB signal receive sensitivity giving the product developer the ability to lower the threshold of the squelch detector by modifying a hub configuration register allowing a lower amplitude signal to be received at the USB transceiver. This capability allows system developers to improve functional efficiency in a sub-optimal system environment.

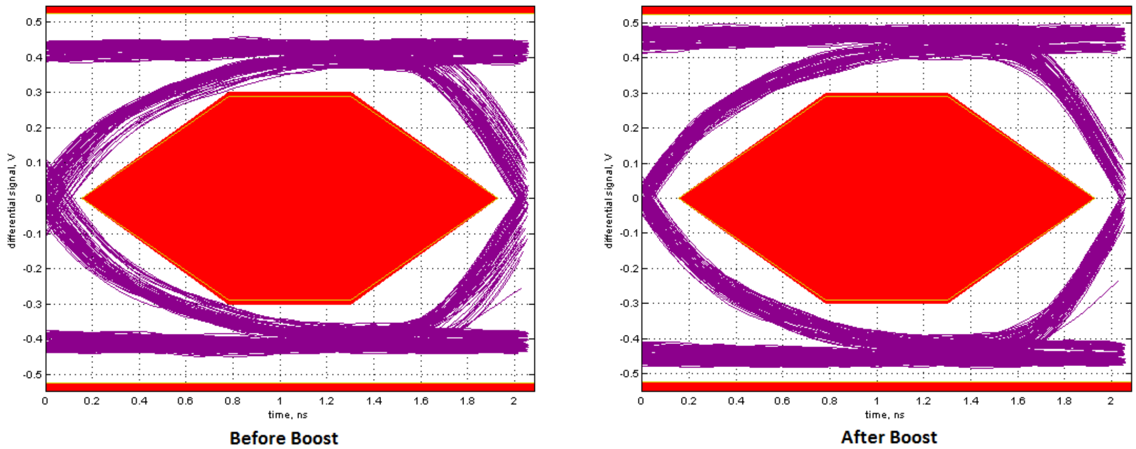
Note: Consult the selected hub controller datasheet for a detailed definition of the USB transceiver capabilities.

PHYBoost

Many Microchip Hub Controllers feature PHYBoost, a selectable (increased) current drive strength of the USB 2.0 DP/DM transmitters for improved USB 2.0 signal integrity. PHYBoost technology allows the USB transceivers to overcome attenuation and channel loss due to long trace lengths. If the PHYBoost is set too high, the application platform may be prone to fail High Speed Electrical Compliance EL_46 Eye Mask test.

Note: Advanced hub configuration options should only be changed by an experienced USB platform developer. The effects on your system should be carefully considered before programming these features.

FIGURE 16: BEFORE AND AFTER PHYBOOST SIGNAL INTEGRITY RESTORATION



Power On to Power Good Attribute

The Power on to Power Good timing attribute is often overlooked by system developers that are implementing Charging Port solutions. The bPowerOnToPowerGood USB descriptor is used by system software to determine how long to wait before accessing a hub port after the power on sequence has been initiated.

Consult the hub product specific datasheet for Charging Port details.

COMPLIANCE

USB-IF Certification

The USB-IF has instituted a certification program that requires USB devices to pass a high level of conformance to the USB Specifications. When a device has satisfactorily passed the certification program, it is given permission to display the USB Logo on the product and/or the product packaging. The USB Logo ensures that the product has been tested and has fulfilled those requirements. The USB-IF Compliance Tests range from basic functional tests to advanced electrical tests. The USB Command Verifier tool is used to determine device compliance to the USB Specification. The USB Hub test validates that the hub descriptors and hub specific characteristics match the platform layer implementation. Electrical testing evaluates the signal quality and power capability of the USB hub.

TABLE 2: USB-IF CERTIFICATION TESTS

Compliance Test	Configuration Parameters Affected
USB Device Framework	Checks VID/PID and String Descriptors Device, Configuration, and Interface Descriptors U1/U2 and LPM Functionality Functional Remote Wakeup Support Enumeration
USB Hub Test	Verifies non-removable ports and port mapping Group Global Remote Wakeup Functionality Individual Port Power On/Off Port Hot Plug Port Suspend and Port Remote Wakeup Port Attach and Detach

TABLE 2: USB-IF CERTIFICATION TESTS (CONTINUED)

Compliance Test	Configuration Parameters Affected
High Speed Electrical Test	Validates PHYBoost and Verisense High-speed Signal Quality Full-speed Signal Quality Low-speed Signal Quality Packet Parameters Receiver Sensitivity Reset, Chirp, Suspend, and Resume High-speed Disconnect High-speed (Hub) Repeater Test J, Test K, and Test SE0 Inrush Current Back Voltage
Super Speed Electrical Tests	Super Speed Transmitter Tests Super Speed Receiver Compliance Super Speed Receiver Jitter Tolerance

Microsoft® Windows® Hardware Lab Kit (HLK)

The Microsoft® Windows® Hardware Lab Kit (HLK) formerly called the “Windows HCK” or “WHQL” is a test environment that gives hardware designers and driver developers tools, guidance, and support to create products that are compatible and reliable with the Microsoft Windows Operating System. Products that pass the Microsoft Windows HLK tests are allowed to use the “Certified for Windows” logo. USB Hub Silicon must obtain full USB-IF certification in order to meet the Microsoft Windows HLK requirements. The USB hub may be at the center of a multi-function compound device that contains several features. USB hubs and hardware must be designed using the practices described herein, or the hub product will likely fail to meet the Microsoft Windows Hardware Requirements.

Compliance Summary

USB hubs commonly fail USB compliance or Microsoft HLK tests because they report that the hub may have external power when they are actually bus powered or they do not accurately report user inaccessible ports correctly. System manufacturers should be aware of these requirements when they select and configure USB hubs that are integrated into their systems as they can significantly improve the customer experience with USB hub products.

APPENDIX A: APPLICATION NOTE REVISION HISTORY

TABLE A-1: REVISION HISTORY

Revision Level & Date	Section/Figure/Entry	Correction
Note: AN1970, Revision A replaces the previous version, Revision X.X.		

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