Arasan Chip Systems Inc. White Paper

Integrated USB Hub Solution Meets Evolving USB Device Requirements

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Overview

The evolving complexity of the newer Universal Serial Bus (USB) devices has necessitated the need for integrated Hub. This paper will address the key reasons to have integrated hub in the newer generation of USB devices. Also, this paper will provide design guidelines for such integrated hub solutions, and the factors to be considered for such designs.

Introduction

USB has been the most popular peripheral interface adopted by the industry. In 2008 alone 3 billion USB devices made into the market, and a survey predicts that this could increase to 4 billion in the year 2013. This proves the embracement received for USB from peripheral vendors.

The complexity of USB devices has grown, such that a single USB functional device is not sufficient to meet the peripheral needs. For instance, a printer with a memory card reader needs two USB functionalities (a printer class and a mass storage class). The focus of this paper will address design needs of such devices, and how an integrated Hub can be used for such scenarios.

What is a Hub

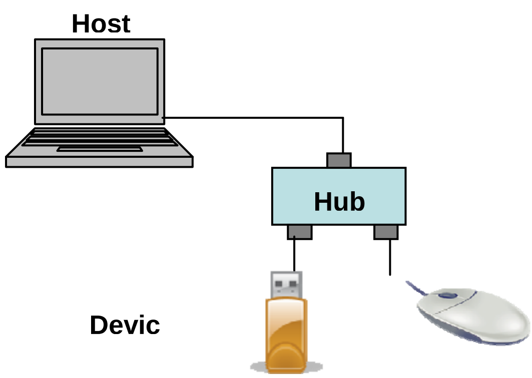

Fig1. Typical USB System

In USB systems, there are three basic entities that constitute the system: a Host controller, a Hub, and a device. The USB system is a host centric system, in which the entire topology of the USB system is governed by the token packets generated from the Host controller. The Hub is an entity which provides the mechanism to expand the number of USB ports in the system, and the device is the end peripheral in the system. Typically, a device has one or more endpoints which source or sync the data in the USB system. Fig.1 depicts a sample USB system. The Hub in this system provides multiple port connectivity to the host controller.

Device Vs Compound device

A device in USB context is a physical entity that performs a function. In other words, it is a collection of hardware components that perform a certain function. For example, the following devices with USB connectivity: a mouse, a key board, an external hard drive represent a USB device entity.

The compound device is a system in which the hub has one or more downstream ports permanently connected to a device. The hub could be a physical component connected to the device, or it could be integrated with the device functionality. Device vendors with multiple functionalities find this solution very attractive, since this facilitates design with lesser area and power. Also, this provides easier way to club multiple device functionality into single chip in a shorter time frame.

Another device category for consideration could be a composite device. A composite device has multiple interfaces in the design, which can be switched during operation. But, the complexity needed in the software and hardware has made this type of devices not popular.

Factors to be considered for a Compound device

Downstream Port

The total number of downstream port to be supported by the compound device is a major factor in the design. The downstream ports can be broadly classified into two categories: permanently attached device port, and attachable device port. The physical layer to the USB port on the permanently attached device port can be bypassed and can be replaced with wrappers communicating to the Hub's controller, which saves area consumed by the physical layer on both the upstream and downstream port of the device.

For attachable device port, the Hub should implement the physical layer of the USB connectivity, providing the ability to support external device. Another key factor to be considered on the downstream port is the port power. If the compound device is bus powered, then they are limited with the power and so is the number of downstream ports to be supported. Fig.2 below represents the architecture of a compound device with two permanently attached devices and an attachable device port.

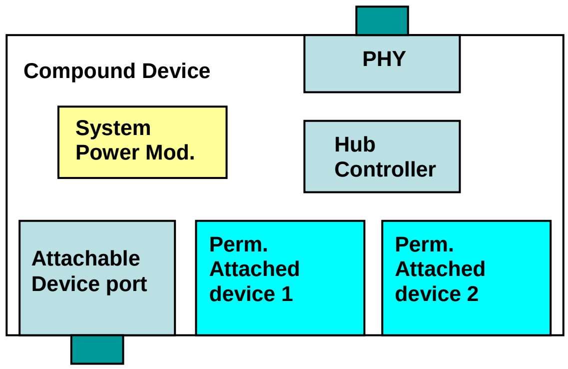

Fig2. Compound device architecture

Speed

USB 3.0 has defined support for the following speeds:

1. Low speed – 1.5 MHz
2. Full speed – 12 MHz
3. High speed – 480 MHz
4. Super speed – 5 GHz

The support for the device speed on each of the downstream port (attachable & permanent) dictates the speeds to be supported for the compound hub.

Power

Power is a key factor in this design. The compound device can be broadly classified as self powered, and bus powered device. For a bus powered device USB 2.0 specification has a maximum limit of 500 mA, and USB 3.0 has a maximum limit of 900 mA. Thus the bus powered compound device has limits on the number of devices (attachable & permanent) connected to it, and the number of devices connected is limited by the architecture.

For a self powered compound device, the number of devices to be supported is not limited by the USB maximum power on the upstream port. However, the number of devices on the downstream port is limited by the maximum power that can be drawn from the external power supply.

Transaction Translator

Transaction Translator (TT) is another key module in the Hub, which is necessary to bridge between a high speed host controller and full/low speed device attached. The TT provides a buffering mechanism between the high speed traffic and other USB 1.1 speed devices.

There are two specific implementations of the TT: per-port TT, and single-port TT. As the name specifies, the per-port TT architecture has a dedicated TT for each downstream port. In single-port TT architecture, a single TT is shared between all the downstream ports. Obviously, the per-port TT architecture has more bandwidth allocation than the single-port TT architecture.

Optionally, the TT can be omitted in the case of a compound device with dedicated high speed devices. This option is of significant consideration where the compound device supports high/full speed, and they do not have any attachable device ports. This would save buffer space and chip area in the design.

Link Layer and Repeater Buffer

In case of support for super speed (5 GHz), the compound device shall include the Link Layer (LL) on each port, which is intended to support USB 3.0 functionality; this includes the upstream facing port. It is mandatory to support the LL feature for each downstream port irrespective of the nature of the downstream port (attachable or permanently attached).

In addition, the repeater buffer shall be included in order to support attachable downstream ports. In case of permanently attached super speed devices this repeater buffer can be omitted, provided they are synchronous to the same clock source, and the buffering in the functional devices are sufficient to handle the latency requirements.

Benefits of using integrated Hub

The compound device can be implemented in two methods:

1. Discrete Hub method
2. Integrated Hub method

In first method, there are power limitations, port limitations, and functionality limitations. This is due to the fact that the Hub is a discrete solution. However, the advantage to this method is quicker time to market, since the architecture demands only demands board level changes for the compound device.

Alternatively, in second method, the integrated hub provides better power saving feature, less area size, and more options on the architecture. The disadvantage in this method is the time required to integrate the device functionality and the hub.

Conclusion

With the increasing needs for the compound devices, integrated hub is an attractive architecture for these classes of devices. The amount of power and area saved in this architecture makes it the preferable architecture for compound devices.

Here is a table that summarizes the features of the integrated hub to be considered for a compound device.

Feature	Support condition
Downstream port (attachable)	Depends on the number of external ports. This is the number of PHY needed in the downstream port
Downstream port (permanently attached)	Depends on the number of device functions attached permanently to the device
TT	Needed only if there is scenario where a High speed and full/low speed logic should be supported. For higher bandwidth user per-port TT architecture.
LL & RB	Needed only if the upstream supports super speed, and the downstream port/s has super speed support
Bus power (USB 2.0)	If the compound device consumes less than 500 mA, and it is USB 2.0 compliant. If not, self power should be opted.
Bus power (USB 3.0)	If the compound device consumes less than 900 mA, and it is USB 3.0 compliant. If not, self power should be opted.

Table 1. Summary of features of Integrated USB Hub

Arasan's USB IP Portfolio

Arasan Chip Systems, Inc has been a leading developer of USB IP dating back to its first release of USB 1.0 in 1996. Arasan's USB cores have been used in diverse applications ranging from the World's first PDA to mission critical defense applications. Arasan has a complete portfolio if USB IP including host, device, hub and embedded controllers and supports the latest USB 3.0 standard. With a sizeable group of engineers dedicated to USB IP development, Arasan is committed to being the highest quality provider of USB IP in the market.

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