White Paper

PERICOM®

by Prasad Tawade

Introduction to USB 2.0/3.0 Switches and Key Applications.

INTRODUCTION

The universal serial bus (USB) has become a dominant interface to fulfill the ever increasing needs for rapid data transfer between end devices such as PC to portable devices, infotainment systems, storage, GPS, etc because of its ability to plug and play. USB has effectively replaced a variety of earlier interfaces, such as serial and parallel ports, as well as separate power chargers for portable devices.

The original USB 1.0 specification, which was introduced in January 1996, defined data transfer rates of 1.5 Mbit/s "Low Speed" and 12 Mbit/s "Full Speed". The USB 2.0 speed specification was released in April 2000 and has become the most ubiquitous and versatile interface standard in the computing and consumer markets.

However, with ever increasing need for higher data rates, USB 2.0 had the following limitations:

- Limited bandwidth: 480Mbps
- Signaling method: Polling mechanism i.e. can either send or receive data (Half duplex)
- Power usage: Up to 500 mA

USB 3.0, also popularly known as SuperSpeed, was released in 2008 and now is increasingly becoming one of the most promising interfaces for data transfers.

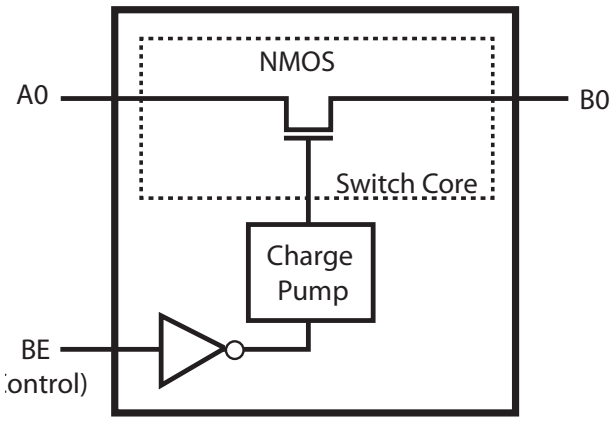
USB 3.0 helps to overcome the above limitations for USB 2.0:

- Offers ten times faster speed than USB 2.0: 5Gbps
- Offers asynchronous mechanism: Can send and receive data simultaneously
- Power usage: Up to 900mA

In several applications where USB is used as an interface standard, a USB switch is needed for connecting and routing USB signals. Designing a suitable USB switch can help designers to shorten their design cycles by enabling changes in the existing designs vs completely developing a new design, for example, applications used for debugging purposes on a field, can use USB switches, since USB switches can offer an alternate path for debugging without affecting the device operations. In this paper, we introduce the basic functionality of USB switch and the key parameters to keep in mind while selecting a USB switch. We then go on to explore the usage of USB switches in applications such as docking application, WiFi storage, KVM switches, GPS systems, etc.

What is a USB Switch?

A USB switch (Mux/De-Mux) is a bidirectional device that selects one of several input USB signals (D+/D- (USB 2.0) or Tx+,Tx-/Rx+,Rx- (USB 3.0)) and forwards the selected input into a single line or vice versa. USB switch uses the NMOS gate with charge pump which helps to increase the voltage at the gate to avoid output voltage clamp caused by the threshold.



The NMOS Switch with a charge pump on the gate

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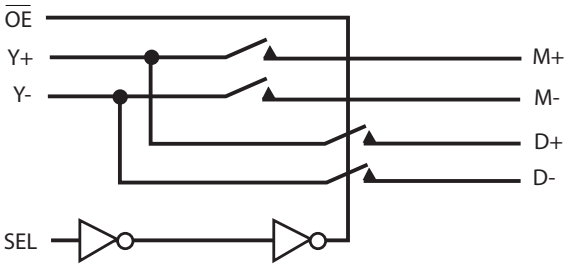


Functional Diagram 1: 2 Channel USB 2.0 Switch

Key Parameters:

Let's discuss the eight key parameters to consider when selecting a USB switch:

1. **3dB Bandwidth** is basically the max frequency signal that the device is able to route with acceptable loss. For USB 3.0 signals operating at 5Gbps ideally the operating frequency should be > 2.5GHz. However, higher the frequency better is the system performance. Pericom offers USB 3.0 switches with a 3dB bandwidth of up to 10.6GHz.

2. **On Resistance & Ron Flatness:**

On resistance (Ron) is the resistance of the closed switch path between the drain and source terminal. Ron should be as low as possible, to achieve almost no energy loss during throughput. Ron flatness is the variation in on resistance over the full signal range. Ron flatness is defined as the difference between the maximum and minimum values of on resistance as measured over the specified analog signal range.

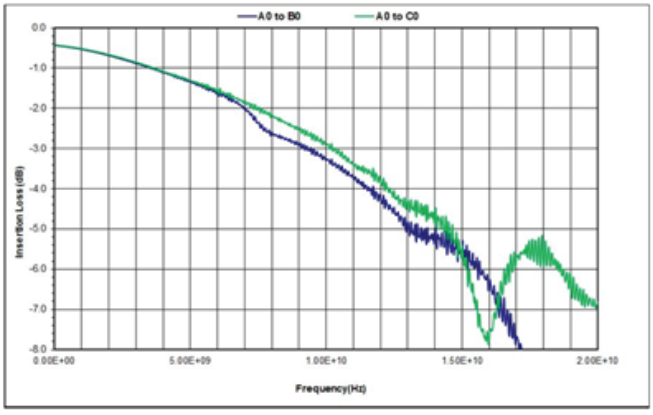
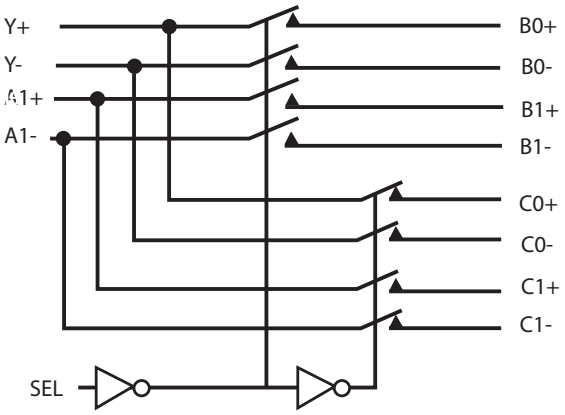


Fig.1 Differential insertion loss for PI3USB32212

It is related to distortion; thus, the lower the Ron flatness, the lower the distortion.



Functional Diagram 1: 2 Channel USB 3.0 Switch

3. **Insertion Loss** is a measure of power loss or signal attenuation at a given frequency and is measured in dB Losses greater than 1 or 2 dB will attenuate peak signal levels and increase rising and falling edge times. Pericom's USB 3.0 switch has insertion loss of -1.3db @5GHz. Fig 1. shows insertion loss plot for PI3USB32212 (2:1 combo, USB 3.1, USB 3.0 and USB 2.0 switch)

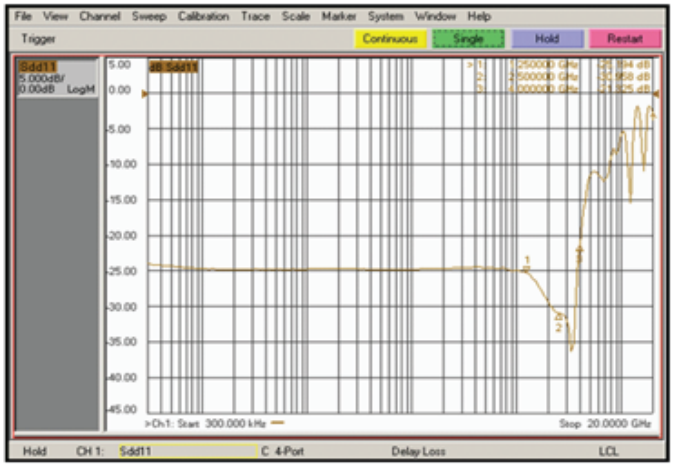


Fig.2 Return Loss

4. **Return Loss** is basically caused by impedance mismatch between circuits. Switches with excellent return loss performance ensure optimum power transfer through the switch. Fig 2. shows the return loss for Pericom 's PI3USB304 (-30dB @2.5GHz)

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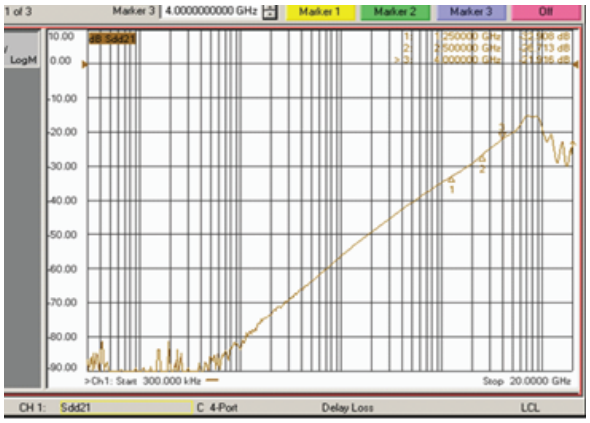

Fig.3 Off Isolation for PI3USB304

5. **Off Isolation** is the amount of noise picked in a switch in OFF state from adjacent switch in ON state. Isolation becomes more important at higher frequencies such as USB 3.0 (5Gbps or 2.5GHz), PCIe 3.0 (8Gbps or 4GHz), etc. High isolation reduces the influence of signals from other channels, sustains the integrity of the measured signal, and reduces system measurement uncertainties. Fig 3. plots the Off Isolation for Pericom's PI3USB304 (-26.7dB@2.5GHz)

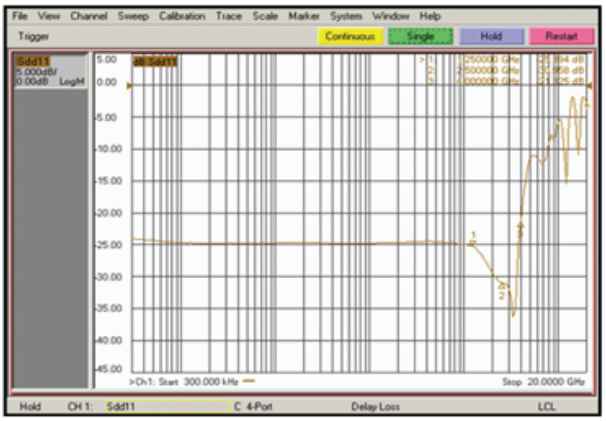

Fig 4. Crosstalk for PI2USB304

6. **Crosstalk** is defined as magnitude of signal that is coupled between the circuits. Crosstalk is usually caused by undesired capacitive, inductive, or conductive coupling from one circuit, part of a circuit, or channel, to another. Higher cross talk will cause signal degradation. Fig 4. plots the cross talk for PI3USB304 (-38dB @ 2.5GHz).

7. **ESD Protection** is an important feature for USB switches. Standard USB switches are designed to be protected up to ±2kV Human Body Model (HBM). A designer can add additional ESD protection externally, but this consumes valuable board area and adds capacitance to the input/output line. Hence, Pericom USB switches are designed to withstand ESD as high as +/-8kV HBM.

8. **Overvoltage Protection** means the switch is guaranteed to withstand specified voltages on the analog inputs which exceed the supplies. Pericom's USB switches are designed with 5V protection.

Having gone through the basic functionality of USB switches and key parameters to look for while designing a USB switch, we now survey some specific areas of application and discuss the ways in which they make use of USB switches.

USB 3.0 Switch in a Notebook Docking Application

USB 3.0 Switch is used in a Notebook Docking application to switch between the USB port on the laptop and the USB connector on the docking station.

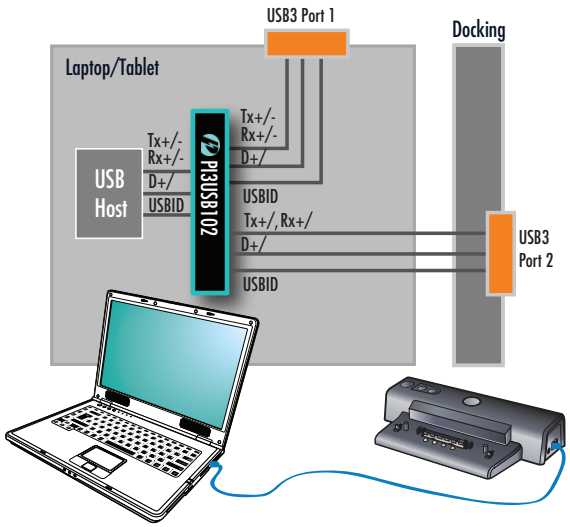

Fig 5. USB 3.0 Switch in a Notebook Docking Application

USB 3.0 Switch in a WiFi Storage

WiFi storage is simple wireless device mainly consisting of 3 main blocks:

- Integrated WiFi module
- MCU
- In-built storage (HDD)

USB 3 switch is used in a WiFi storage to either transfer data from/to HDD to the devices connected via WiFi module or device connected via USB port.

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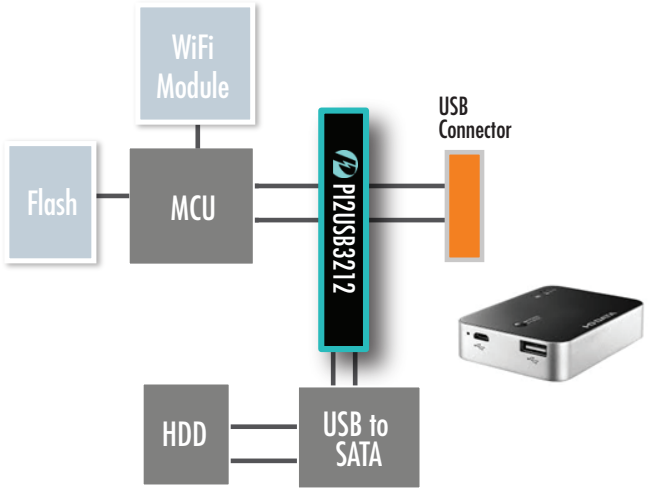

Fig 6. USB 3.0 Switch in a WiFi Application

USB 3.0 Switch in a KVM Application

A KVM switch (with KVM being an abbreviation for "keyboard, video and mouse") is a hardware device that allows a user to control multiple computers from one or more[1] keyboard, video monitor and mouse using USB interface.

As indicated in the Fig.7, a USB switch allows a USB 3.0 device (keyboard or mouse) to select between two USB host system or share a USB 3.0 host system between two USB 3.0 devices.

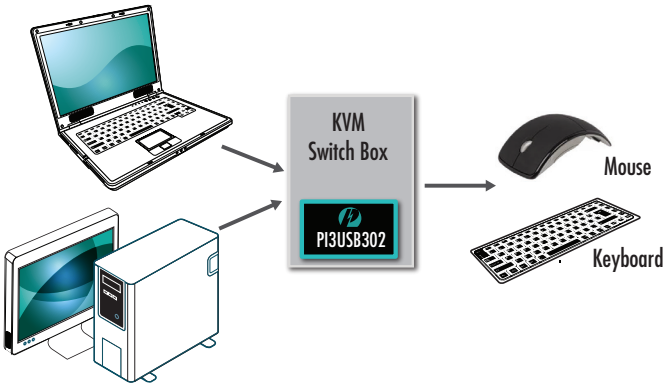

Fig 7. USB 3.0 switch in a KVM Application

USB 2.0 Switch in GPS Application

USB 2.0 switch is used to selects data path between FLASH memory for map data (consumer) or debug data from the CPU (manufacturing)

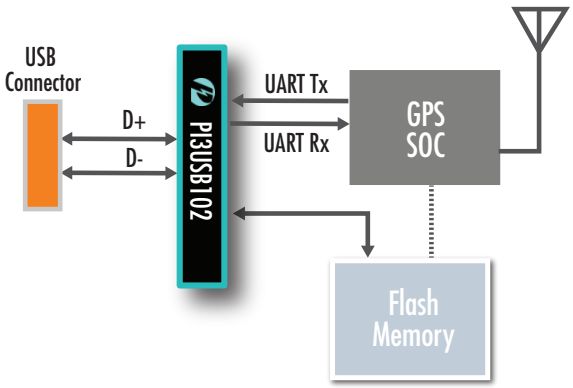

Fig 8. USB 2.0 Switch in a GPS Application

USB 2.0 Switch in Debug Application

USB switch informs the MCU when the external device mouse/ keyboard/ is

- Plugged out
- Plugged in
- Going from suspend to wake

Once the MCU understands this, it can then determine what the device is and if it is a debug dongle, the MCU can go into debug mode.

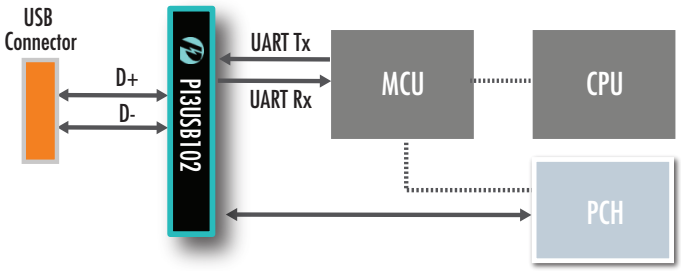

Fig 9. USB 2.0 Switch in a Debug Application

Conclusion:

As discussed in this white paper with an increased in adoption of USB as an interface standard, high speed USB switches are required in variety of applications. A careful understanding the key parameters like 3db bandwidth, return loss, insertion loss, On resistance, etc can help designer to select an appropriate USB switch.

Pericom offers a broad portfolio of USB switches specifically designed to enable a range of applications to achieve single port connectivity. The switches are designed to be compliant with USB 3.1 (Enhanced Super Speed), USB 3.0 (Super Speed), USB2.0 Full Speed (FS) and Hi-Speed (HS) with bandwidths in excess of 10.6GHz. Please visit **www.pericom.com** for more information.