

Designing USB 2.0 interface using PI3USB20 switch

By Paul Li

Introduction

USB 2.0 ports are an important feature in today's Laptop, docking station, and PC systems. To extend the USB 2.0 ports in a docking station, we can use a USB 2.0 switch, PI3USB20, as shown in Figure 1. This approach will remove the need for a hub in the docking station and reduce the cost.

Some designers are using one transceiver driver driving two USB 2.0 ports with a "T" trace without a switch. This approach will also cancel the transceiver in docking station, but there will be reflection noises from the other branch of the "T" trace and cause return loss, which will distort the eye pattern, especially for the Hi-Speed USB signals.

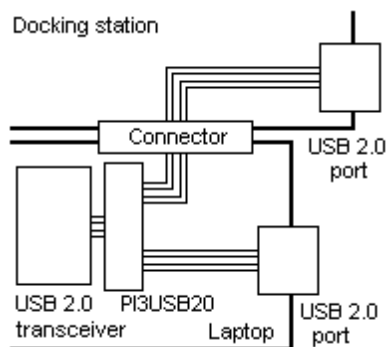


Figure 1. Using PI3USB20 switch to extend the USB 2.0 ports in notebook docking for cost reduction

In Figure 1, the PI3USB20 switch is populated in the Laptop to switch the USB signals from the transceiver to the Laptop or docking station.

When the Laptop is inserted into the docking station, the action of insertion will trigger a sensing circuit and the PI3USB20 switch then will be switched from Laptop to docking station.

There were problems found when using a normal CMOS switch for Hi-Speed USB applications, due to the fact that the high-speed differential USB signals have critical requests for the switch as follows.

- Both low R-on and low C-on of the switch are required. This request cannot be achieved easily due to lower R-on requiring larger switch die size while lower C-on requires smaller die size.
- The R-on of the switch will unbalance the balanced impedance match between the 90-Ohm impedance of the trace/cable, and the 90-Ohm termination resistor at the end of the trace/cable and will generate return-loss, which will cause the eye pattern test to be failed. The higher the R-on, the higher the return-loss therefore the worse the eye pattern becomes.

- For Hi-Speed USB signals, C-on is the major contributor to return-loss rather than R-on, verified by many tests and real application cases. Capacitance will slow down the signal edge and will shrink the signal swing range. The higher the C-on and the frequency, the higher the return-loss of the switch.
- Good R-on flatness of less than 1-Ohm, is also needed for the USB 2.0 switch to avoid signal distortion from the R-on variation.
- Low DC quiescent Icc power consumption is requested by the Laptop PC running on battery power.

The innovative USB 2.0 switch: PI3USB20

The USB 2.0 switch PI3USB20 is a single NMOS switch with gate charge pump, developed using Pericom's advanced technology to achieve low return-loss and optimized USB 2.0 eye pattern test result (Figure 2). The combination of R-on and C-on of PI3USB20 is the lowest in the market, which yield excellent eye pattern test result that are better than any competitive switch today.

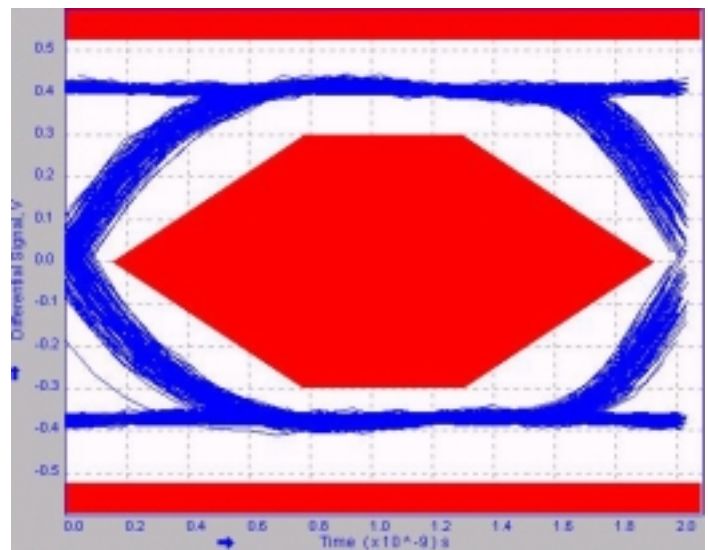


Figure 2. The eye pattern for PI3USB20 measured at the USB 2.0 port of a real Laptop motherboard using PI3USB20.

Ultra low R-on

The typical R-on of PI3USB20 is in the range of 4.2-Ohm to 4.9-Ohm, depends on the input signal level. The switch also retains good flatness of less than 1-Ohm for the input signal ranging from 0V to 3.3V.

Low C-on and C-off

Combined with ultra low R-on, the C-on and C-off of PI3USB20 are also very low (Figure 4). 8.83pF to 9.36pF (typical) for C-on, and 2.54pF to 2.93pF (typical) for C-off, with good flatness within 0.55pF. With the combination of low R-on and C-on, PI3USB20 provides excellent eye pattern test results.

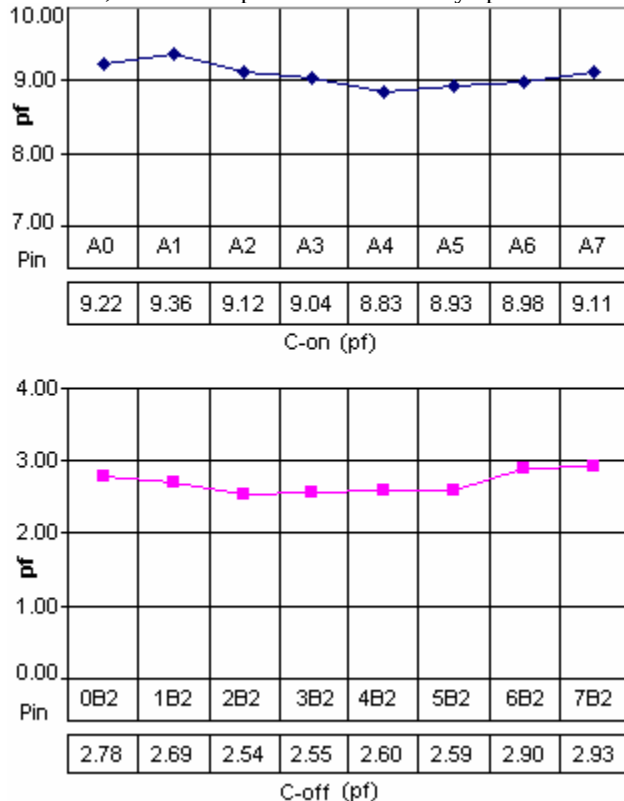


Figure 4: the typical C-on and C-off of PI3USB20

Wide low R-on range

PI3USB20 has a wide low-R-on range (Figure 5), wider than the CMOS switches and other normal NMOS switches. A CMOS switch will clamp the signal at $V_{cc} + 0.7V$ through its PMOS PN junction to V_{cc} . A normal NMOS switch with gate charge pump has higher R-on when the input signal is higher than 2.5V and will cause higher attenuation. The wide low R-on range of PI3USB20 makes it suitable for many other high speed differential applications, such as PECL, LVPECL, LVDS, CML, DDR, DDRII, etc.

NMOS switch with low quiescent I_{cc}

The switch core of PI3USB20 is a single NMOS transistor with gate charge pump. Its 0.35mA (typical) quiescent I_{cc} is quite low compared to competitive solutions at 1.0mA. Its single NMOS switch core will prevent signal transient distortion seen in CMOS switch as mentioned above.

Design guidelines and validation

When designing a Laptop with docking station using PI3USB20 switch, certain design guidelines apply as followed:

1. In order to have enough margins to tolerate the impact from the switch, the original USB 2.0 PCB circuit before using switch should have enough margin in its eye pattern test result. Otherwise, if the original PCB circuit was already failing the eye pattern test, the PI3USB20 switch will not help the PCB circuit to pass the eye pattern test.
2. In order to achieve optimized eye pattern test result, the two traces in the differential pair should be matched with length and with 90-Ohm differential trace impedance, while minimizing the length of the traces in Laptop and docking station.
3. It is strongly suggested to populate the PI3USB20 switch at the output pins of the USB 2.0 transceiver, as close to the output pins as possible. Thus, PI3USB20 becomes a portion of the transceiver's output impedance, instead of being a partial of the transmission line (the trace and cable). It is difficult to make the impedance of the switch's leads, bond wire, and die trace at 90-Ohm differential due to technology limitations. Plus the R-on and C-on, the switch will cause return-loss when inserted in the middle of the 90-Ohm differential trace. In the middle of the trace, the R-on and the C-on of the switch will cause attenuation, seen in the eye pattern test. But when the switch is located at the output pins of the USB 2.0 transceiver, the switch's R-on and C-on will be directly absorbed by the driver without trace delay. The transceiver will also absorb the impedance mismatching from the leads, bond wire, and die trace in the PI3USB20 switch. It is also suggested to populate the switch between the transceiver and the 90-Ohm termination resistors at the output of the transceiver, for optimized eye pattern test result.