USB Transceiver Design Tutorial

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Scope

- Brief overview of USB
- Focus on USB Rev. 1.1 transceiver
- Example transceiver

Agenda

- What is USB?
- Spec History
- The Transceiver
- Compliance Certification
- USB on the Go

What is USB?

- Communication system, typically among PC and peripherals
- Controlled by the host (PC)
- Intended to simplify installation of devices into a PC environment
- On the Go allows peer-to-peer communication with no separate host needed.

3 Speeds

- Slow Speed: 1.5 Mbps
- Full Speed: 12 Mbps
- High Speed: 480Mbps (USB 2.0 only)

Spec History

- 1.0, 1996
- 1.1, 1998: improvements
- 2.0, 2000: added high speed (480mbps)
- On the Go Supplement Rev 1.0 added 12/01

The Transceiver

Transceiver Components

- Low/Full Speed Transmitter
- Low/Full Speed Differential Receiver
- 2 Single-Ended Receivers
- High Speed Current Driver
- High Speed Differential Receiver
- High Speed Transmission and Disconnect Detectors
- Pullup, Pulldown Resistors

Transmission Envelop Detector

- Vdiff < 100mV → Squelch State
- Vdiff > 150mV → not Squelch
- Not Squelch during valid transitions

Transmission Envelop Detector

- Vdiff >= 625mV → Disconnect State
- Vdiff <= 525mV → not Disconnect State

Suspend Mode

- 500uA max average current within 10ms
- Typically, differential transmitter and receiver powered off
- Single-ended receivers read the bus
- 10ms to wake up after signaled by the upstream host or hub

Low/Full Speed Transmitter

- Differential Signal: D+, D-
- 28 Ohms <= Rout <= 44 Ohms
- VOL = 0.3V
- VOH = 2.8V
- 3.0V – 3.6V resistor pullup voltage
- Precisely matched rise/fall times

Signal Quality

- Signals cross between 1.3 and 2.0V
- Trise/Tfall =
  - 0.90 – 1.11 for full speed
  - 0.85 – 1.25 for slow speed
- Test assumes the specified test load—real life load is different.

Jitter

- Full-Speed:
  - 2ns consecutive
  - 1ns paired (JK to next JK, KJ to next KJ)
- Slow Speed:
  - 25ns consecutive
  - 10ns paired

Transmitter Implementation

Receiver

- Vdiff = 200mV
- 0.8V <= Vcm <= 2.5V
- Single-Ended Receivers:
  - VIL = 0.8V
  - VIH = 2.0V
- Purposes of Single-Ended Receivers:
  - Still on during Suspend Mode
  - Detect Single-Ended Zero (SE0)

Transmitter Matching Issues

- Very hard to meet +/- 10% R/F matching spec for all conditions at +/- 3 sigma
- Customer temp spec wider than official USB spec
- 10% spec not necessarily so rigid—never thoroughly hashed out by the USB core group
- Tradeoff between matching and chip area
- PFET pullup vs. NFET pulldown

External Resistors

- Series resistors
  - D+ vs. D- Rout matching effects signal matching
  - Easier to match external resistors—want low resistance on-chip and high resistance off-chip
- Integrated series or pullup resistors
- Tradeoff between cost and strict spec compliance

Subtle Spec Issues

- Output load specified for signal integrity is NOT the true output load!
- 1.5K pullup resistor

Compliance Certification

- Integrators List
- Compliance Checklist
- USB-IF Compliance Workshops or Independent Labs
  - Eye diagram
  - Inrush Current
  - Interopability

USB On the Go

- Allows 2 “peripherals” to talk without a full-scale host (PC)
- A device and B device
- Host Negotiation Protocol
- Session Request Protocol
- User-Friendly: Errors must be fully explained to the user
- Low-current. Bus can power down.

More Information

- www.usb.org has very much information, including all specs and many helpful documents.
- A USB transceiver designer should read through most of the USB spec at least once.