Hi-speed USB signal long-distance communication and test scheme design based on Ethernet communication

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Abstract. The USB universal serial bus is widely used in host computer control and data information transmission due to its plug-and-play, hot-swap support, and flexible use. However, due to cable loss and USB protocol restrictions, high-speed USB signals can only support a transmission distance of 5 meters. In this paper, there shows an engineering application design of the signal transmission scheme based on the USB signal processing chip CH317. Convert hi-speed USB signal into optical Ethernet signal to achieve long-distance transmission of high-speed USB signals. Since there is no test standard at the application layer for hi-speed USB signal, in this paper design a complete test scheme for this transmission method at the hardware layer and application layer according to the existing test standards of hi-speed USB signal and Ethernet. It has certain reference significance for the application of hi-speed USB signal long-distance transmission in engineering.

1. Introduction
The USB2.0 protocol is backward compatible with USB1.0 and USB1.1, so it can work in three modes: low-speed, full-speed and high-speed.

For long-distance transmission of USB signals, there are currently four common methods: ① The USB signal convert into RS-232 signal, and then the serial signal is forwarded through the optical module. In this way, the highest signal transmission rate is 115.2Kbps, and the longest signal transmission distance is 4 km.② Use the Embedded Chip to control the USB signal transmission chip realize simulate the USB communication process. In this way, the USB signal can be converted to the TTL level output by the Embedded Chip and then converted to the optical module for long-distance transmission. The maximum rate depends on the selection of the Embedded Chip and the optical module [1]. ③ Thought the RGMII protocol convert the USB signal into Ethernet signal for long-distance transmission, the hi-speed USB signal can be extended to 100 meters. ④ Base on the third way, after the USB signal convert to Ethernet signal by RGMII protocol, transmit the two pairs of differential signal output from the PHY chip of Ethernet to SFP optical module. This transmission method can realize the long-distance communication of the USB signal in high-speed mode, and the hi-speed USB signal can be extended by several kilometers [2]. Comprehensive transmission rate and distance we choose the fourth method. And designed measurement method for hardware testing and application layer testing for it.
2. Design of the USB signal long-distance transmission

The overall design scheme is shown in Figure 1. The hi-speed USB signal is convert to signal of RGMII protocol by the transform chip CH317, and then as the input signal to the marvell network PHY chip 88E6321 converted to the CML level signal. At last, it come to level adjustment circuit convert to the level of PECL signal which is suitable for optical transmission so that transmitted to the far end through the optical transeiver module. The remote end converts the signal into a USB signal in reverse order to communicate with the host.

In this design, CH9317 is the configuration chip of the transform chip CH317 which essence is a MCU. Because of the CH317 can only support USB 2.0 protocol we need to adapt low-speed, full-speed and high-speed USB signal with the help of HUB. At this time, according to the standard of the USB protocol, the device linked to the CH317 end belongs to the upstream equipment as the role of host, while the keyboard, mouse, and optical drive belong to the downstream equipment as the role of device. The communication between the HUB and CH317 is performed by the USB2.0 standard. The signal standard between the HUB and downstream equipment depends on the device. The interface on the host side also needs to be a USB2.0 interface. The highest communication rate of this link can reach up tp 480Mbps.

![Figure 1. The block diagram of hi-speed USB signal long-distance transmission scheme](image)

3. Hardware test scheme of hi-speed USB signal long-distance transmission

As for the test scheme of USB signal, according to the requirements of “USB 2.0 specification”[4], there are specific requirements for the Hi-Speed Signal Quality Test, Packet Parameters, Chirp Timing, Suspend/Resume/Reset Timing for Device, HUB and Host. Include the signal of rising edge, falling edge, waveform width, eye diagram, token, data packet of handshake, etc. Therefore, the purpose of hardware test is to measure whether the communication waveform meets the specification requirements. Because of USB employs NRZI data encoding to transmit USB serial data and Hi-speed USB signal rate is 480Mbps so that the hardware rate of Hi-speed USB will reach to 240MHz. According to the research of many test company, it is recommended to use the oscilloscope with the bandwidth more than 2.5 GHz and a sampling rate of more than 10 GSa/s. Depend on the different signals (USB1.0 or USB 2.0) to be measured the passive probe with 500MHz bandwidth or active differential probe with 5GHz bandwidth can be select. Base on the theory we discussed, we chose the oscilloscope type of keysight 9104A with active differential probe N2751A and passive probe N2873A.

There are two measurement ways for this scheme.

The first is manual testing and measurement using oscilloscope. Put a test fixture at the connection between the host and the USB device to input the tested signal to oscilloscope. According to the transmission rate of the measured signal (low-speed USB signal or hi-speed USB signal), select the
active differential probe or the passive probe attach to the test channel of the oscilloscope, and then adjust the storage depth, sampling rate, sampling points, resolution and trigger logic of the oscilloscope. The measurement should capture a complete communication signal between the host and the device, and then compare the parameters of the signal waveform with the requirements in “USB2.0 Specification” to determine the signal is qualified or not. For the setting of oscilloscope, you can refer to chapter 9 “Manual Testing and Measurement Using Oscilloscope” in “the Keysight D9010USBC USB 2.0 Compliance Test Application”[6].

The advantage of this method is that it only needs to add test fixture, so the implementation is simple. Not only that the selected parameter signal can be tested separately. However, the disadvantage is that each measurement needs to restart the communication between host and device, however some signals that need to be measured do not exist in each transmission.

The measurement block diagram is as follows:

![Measurement Block Diagram](image)

**Figure 2.** Manual hardware test scheme block diagram of high-speed USB signal long distance transmission

The second measurement method is automatic test. In this method we need the automatic test software “the D9010USBC USB 2.0 Compliance Test Application software” and the test fixture and the test software USBHSET from the “USB Implementers Forum”. The specific test steps refer to “Keysight D9010USBC USB 2.0 Compliance Test Application”. This scheme can only test the hardware design of USB main control chip. For the RGMII protocol signal and Ethernet output signal, test points need to be led out separately. The part of photoelectric conversion can be tested according to the test standards of “YD-T1688.2-2010”[7] and “YD-T1688.3-2011”[8]. Each of the test part in this scheme has standard operation specifications and signal index requirements, combined all the measurement standards can completely test the signal of high-speed USB signal long-distance transmission scheme.

4. Application layer test scheme of high-speed USB signal long distance transmission

After a research for this project, we found there is no test standards and test specifications for the application layer test of the high-speed USB signal. It has a very important reference value for the evaluation of equipment performance. However, the result of the application layer test to the USB signal has a cannot be ignored factor to the acceptance check of the equipment performance. At present, the standard “RFC2544” of Internet Engineering Task Force (IETF) is widely used in the performance test of network equipment. There are already more mature products abroad, such as Smart-Bits, Frame Scope and IxI A, etc. Therefore, this paper is based on the Ethernet industry test specification “Acceptance test specification for local area network (LAN) systems based on ethernet
technology” (GB/T 21671-2008)\cite{9} and “RFC2544, Benchmarking Methodology for Network Interconnect Devices”\cite{7} to verify the design meets the data transmission constraint or not. For the design we mentioned in the chapter 2, the interface of the Host and Device is USB, so it is necessary to design two tooling boards to convert USB signal into standard Ethernet RJ45 interface. The measurement block diagram is as follows:

![Block Diagram]

**Figure 3.** Performance test block diagram of hi-speed USB signal long distance transmission scheme based on Ethernet test

RFC2544 standard specifies two Ethernet testing methods. One is the dual machine mode. The sending end and receiving end are divided into two machines. Tester A sends the test flow to tester B after being forwarded by the tested equipment. Tester B carries out the test data according to the method specified in RFC2544 and output the test results. The test mode adopted in this thesis belongs to single test machine mode. That is, the test data is sent from the packet sending port of the network analyzer, and returns to the packet receiving port of the network analyzer through the network under test. The tester statistically analyzes the test data according to the method specified in the RFC2544 and output the test result of this link which is included such as throughput, delay, packet loss rate, back-to-back frames, etc. Because the transmission rate of hi-speed USB signal is 480Mbps, and the Ethernet chip involved in this scheme supports 10/100/1000BASE-T protocol, the bandwidth of data transmission in this scheme is set to 480Mbps through the test software.

5. Conclusion

In this paper, we design a kind of signal transmission scheme which transfers USB signal to Ethernet signal through photoelectric conversion. This scheme realizes the functional feasibility. And account into verify the stable transmission of hi-speed USB signal, we need to test not only the hardware but also application layer.

Therefore, in this paper designed the hardware test scheme according to the “USB2.0 Specification”, and confirm whether the design scheme meets the requirements is determined by comparing the test results with the standard indicators. As for there is no test standards and test specifications for the application layer test of the hi-speed USB signal, and we designed the application layer test base on the Optical transmission Ethernet, so the software level test of this scheme is realized base on the Ethernet test standard “RFC2544”. It is of great significance to realize the hi-speed USB signal stable long-distance transmission by perfecting the scheme design through the test results.

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