# NS1021 USB 2.0 Extender and Applications

Forward

The Universal Serial Bus (USB) is a fast, bi-directional, low-cost serial interface standard that enables peripherals to be connected to a computer or mobile phone. The USB 2.0 or Hi-Speed USB is widely used in USB cameras, mobile storage, HID control, and other peripheral devices. However, the standard USB 2.0 signals are DC-coupled, limited up to 5 meters, and susceptible to interference noise. To alleviate above problems for broader applications, a USB 2.0 extender solution based on NS1021 chipset is presented. This article describes its principle and some use cases of the NS1021 extender.

Principle

The standard USB 2.0 Host and Device share the same ground through the cable. Any voltage noise at one end causes unequal voltage potential at the other end of the cable, which may lead to the USB data transmission errors in a longer cable or a noisy environment. To break through the limitation, Norel Systems Ltd. has designed a USB 2.0 extender chipset NS1021. It enhances the USB 2.0 signaling while keeping the USB protocol layer unchanged. In physical layer, the standard USB 2.0 DC-coupled signals are converted to AC-coupled signals through data encoding and decoding. Using the AC coupling transmission reduces the common mode voltage noise from the transmission channel, improves the data transmission reliability, and significantly reduces the chance of overvoltage damage through the long-distance cable. NS1021 extender provides a high-speed and transparent channel between USB Host and Device, compatible with USB 2.0 Host, Device, and Hub. No software driver is required.

NS1021 extender guarantees the USB 2.0 Hi-speed bandwidth of 480Mbps with little transmission latency. Up to 50 meters, the transmission cable can be either a twisted pair cable such as CAT5e or a single-ended shielded cable such as coaxial cable. Since the USB protocol is not changed, NS1021 extender prevents the potential compatibility issue when working with any USB host or device. It also preserves the excellent fault tolerance mechanism made by the USB protocol itself. When connected with a USB 2.0 Hub, the USB low-speed and full-speed devices are also supported via the USB Hub. NS1021 chipset is designed to simplify the PCBA space and Bill of Materials (BOM) by integrating power regulators within a small 5mm x 5mm QFN32 package. NS1021 chipset passes 4KV HBM ESD testing on all pins in chip level ESD testing, making this NS1021 USB extender solution very robust in an ESD stressed environment.
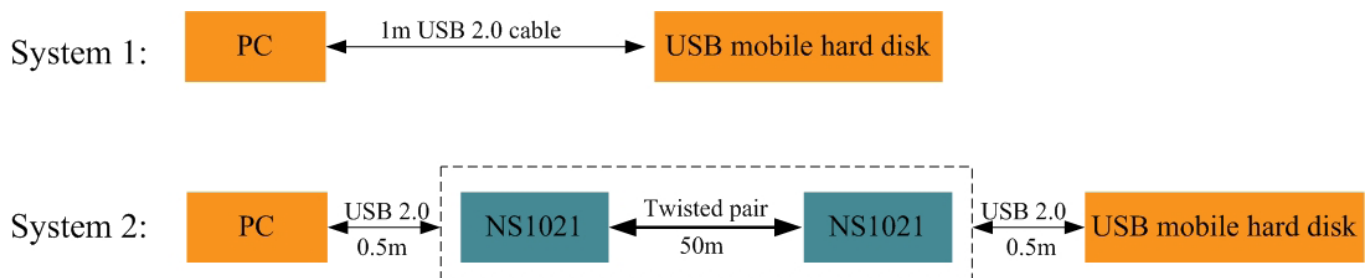
Figure 1 An example of NS1021 Extender use case

Figure 1 depicts an example of how to use NS1021 USB 2.0 extender. The System 1 is a traditional connection where a USB mobile hard disk is directly connected to the USB host on PC through a 1m USB cable. System 2 shows the remote connection of the same USB device, where a 50-meter twist pair cable and a pair of NS1021 extenders are connected between the PC and the USB hard disk. Thanks to the NS1021 USB extender, the hard disk works very well with the PC even though it is placed remotely.

To evaluate the impact of system performance and signal integrity due to the NS1021 USB extender, a CrystalDiskMark Benchmark software tool is used to compare the Read and Write speed between these two systems. USB 2.0 eye-diagram is also measured at the PC interface when forcing the USB mobile hard disk device to send the USB 2.0 test packet patten. Figure 2 and Figure 3 show the measured results of the above System1 and System2, respectively. As can be seen, NS1021 extender does not limit the USB 2.0 high-speed bandwidth, but greatly improve the transmission length with excellent signal quality.
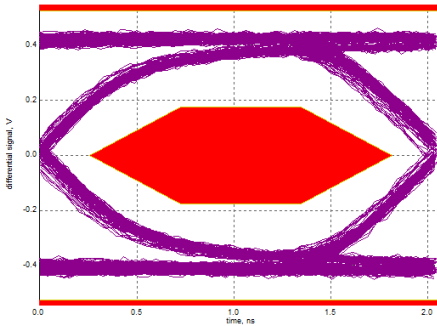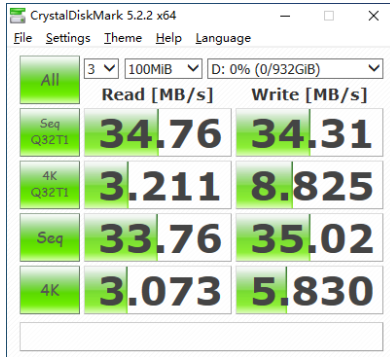

Figure 2 Measured Performance and Eye-diagram of the System 1
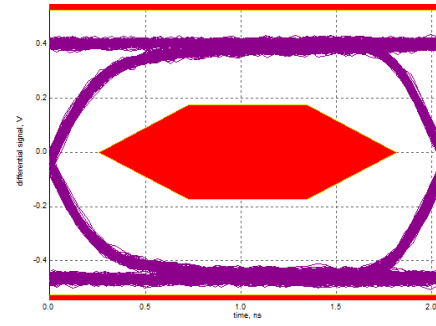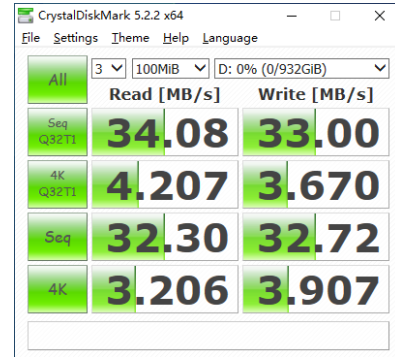

Figure 3 Measured Performance and Eye-diagram of the System 2 with NS1021 Extender

Typical Applications

NS1021 USB extender solution extends the USB 2.0 transmission distance from 5 meters to 50 meters. This Section describes some typical applications with NS1021 USB extender.

KVM Extender

KVM stands for Keyboard Video and Mouse. By physically separating the USB peripherals and the PC, KVM extender offers many benefits to Enterprise users. For example, it removes the computer noise and heat, and makes the desktop area quieter and cooler. It also moves the CPU and server to a clean and secure place.

Figure 4 shows a block diagram of a KVM extender over CAT5 cable. On the left hand, it has the NS1021 USB extender and a Video Transmitter, which can be made on a PCI extension card on the motherboard of the PC. Both USB signals and Video signals are transmitted via the Cat5 cable to the far end receiver box, shown on the right side of Figure 4. Another NS1021 USB extender and a Video Receiver receive the USB and Video signals from the cable, respectively. With an embedded USB Hub, the Keyboard, Mouse, and other USB peripherals can be connected to the receiver box. In this KVM example, NS1021 USB extender guarantees the real time and high bandwidth USB extension over Cat5 cable.
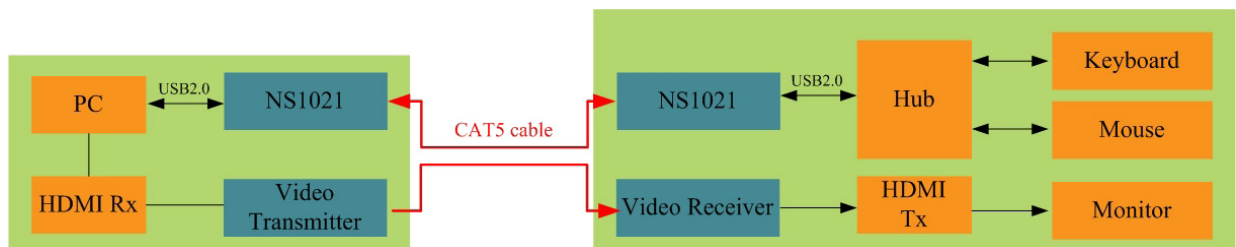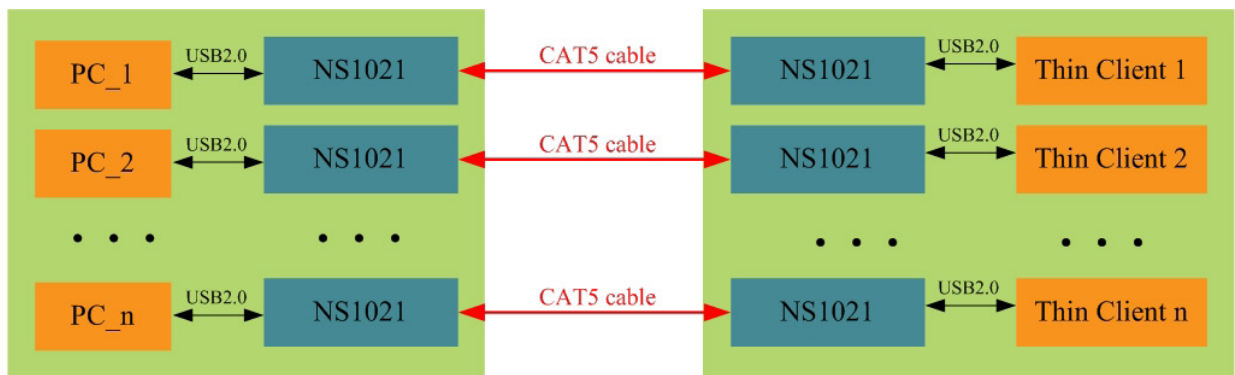

Figure 4 NS1021 Extender used in KVM application

Thin Client

Thin or Zero Clients are simple and low performance computers that are connected in a server computing environment. The remote computer or server does most of the work such as computing and storing data. Compared to the traditional PC clients, Thin Client system is more secure and manageable, less expensive and less power, and takes up less space. With the transformation of enterprise IT architecture to the "cloud era", Thin Clients have gradually gained the market acceptance as an efficient, secure, and low-cost virtualized desktop implementation.

**Figure 5 NS1021 Extenders used in Thin Client application**

Figure 5 shows a Thin Client scheme suitable for enterprise application. The system includes many identical and independent subsystems. Each subsystem consists of a Thin Client, a PC host, and a pair of NS1021 USB extender which are connected by using a Cat5 cable. The existing network cables used by the Enterprise can be possibly employed as the transmission cables for NS1021 USB extender up to 50m distance, which can meet the needs of most office spaces.

Each Client represents the terminal equipment on the employee's desktop, including keyboard, mouse, and monitor, like the KVM application. All the PC Hosts can be maintained in the central computer room. This centralized deployment method has the following advantages. First, confidential information is secured since the data on the Thin Client can only be read but not copied. Second, there is less noise and heat in the office area. This improves the working environment and employee work efficiency. In addition, the temperature, humidity, and dust prevention of the central computer room can be easily controlled, which helps to extend the computer's service life. Furthermore, it is convenient for maintenance, upgrades, inspection, and repairs once any of the PC host equipment fails.

Video Conferencing

Video conferencing plays a more and more important role in the remote work, particularly during the COVID-19 pandemic. In a typical video conferencing system, multiple audio and video streams and control streams are involved, demanding more than 5 meters transmission distance. Traditionally, the Ethernet transmission has been used in such a video conferencing system. However, it requires a complex audio/ video codec and the IP network service. The IP network does not only increase the difficulty of maintenance, but also increases the latency of the video transmission, thereby making it exceedingly difficult to deliver real-time video in live conference.
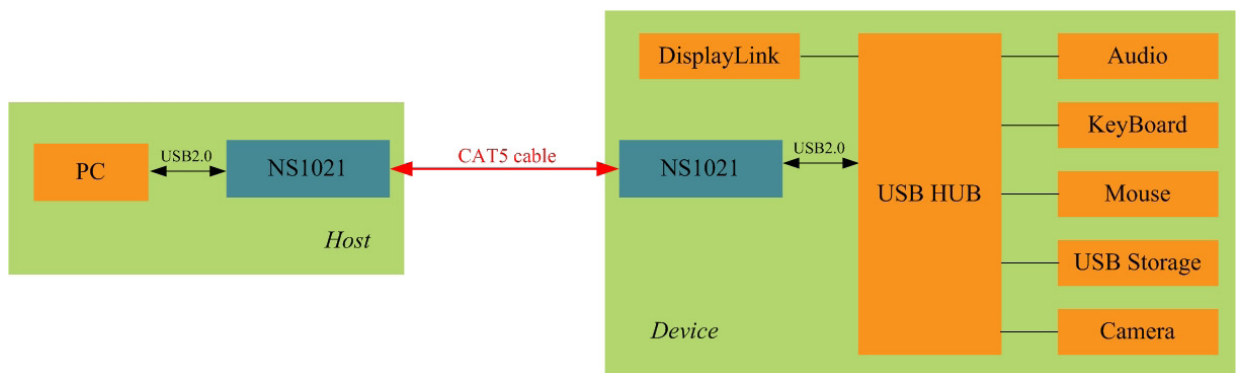
**Figure 6 NS1021 Extender used in Video Conferencing application**

NS1021 extender enables a low latency video and data transmission in a video conferencing system. Figure 6 shows a typical application. Through a USB Hub, a USB Camera and a DisplayLink Monitor can be connected to the remote PC in the video conferencing system. The USB Keyboard, mouse and external storage can also be connected in this system. Compared to the Ethernet transmission, the USB transmission in a video conferencing does not involve any additional network protocol layer and network packet operation. Therefore, the reliability and real-time performance are guaranteed. The bandwidth of USB 2.0 high-speed link through the NS1021 extender is sufficient for most video conferencing applications.

Emerging Applications

Since NS1021 extender uses AC-coupled signaling in data communication, the transmission distance is extended, and the noise immunity is significantly improved. As a result, NS1021 extender has also been found useful in some emerging applications. This Section describes some examples.

Automotive USB

The Automotive Ethernet has been extensively used in the Automotive industry. Although USB 2.0 signaling also has high data bandwidth with much less power consumption, it is not widely adopted by the Automotive industry since the USB transmission is generally believed to be difficult to meet the automotive reliability requirement. Due to the superior noise immunity of NS1021 extender, the concept of the Automotive USB is introduced.
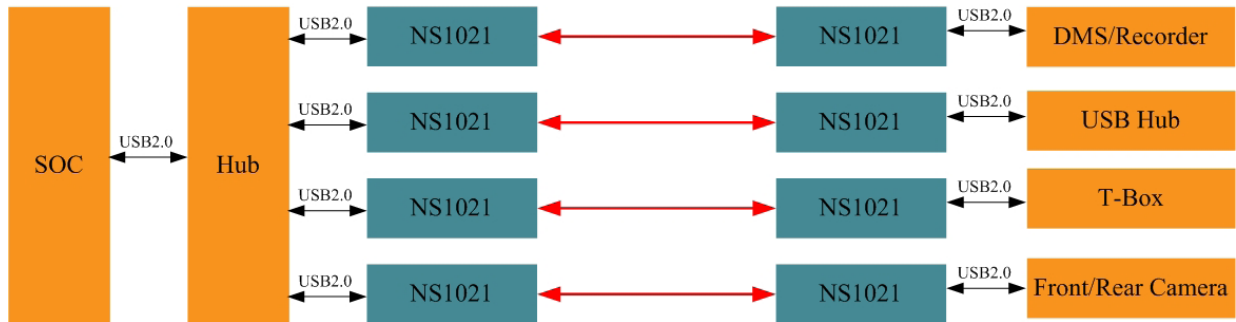

Figure 7 NS1021 Extenders used in Automotive USB application

Figure 7 shows a typical application of automotive video and data transmission based on NS1021 extenders. The central control unit SOC is connected via NS1021 extenders to some USB interface devices such as the front and rear-view cameras, Driver Monitoring System (DMS), driving recorder, T-Box, and some other USB peripherals through a USB Hub.

NS1021 extender solution enables Automotive USB connection. The bandwidth requirement of the transmission cable and the vehicle High-Speed Data (HSD) connector is less than 400MHz, and the impedance requirement of the HSD connector is differential 100 ohm +/-25%. This requirement is easy to meet, thereby greatly reducing the system cost. The wiring in the car also becomes more flexible. In contrast, the traditional HSD connector used in the car industry for high bandwidth video and data transmission is required to be above 1GHz bandwidth. The impedance variation must be within 15% range. Such connectors are much more expensive.

Hybrid AOC

Today the USB 3.1 interface has become ubiquitous on PCs, greatly increasing the speed of data communication between PCs and external devices. Thanks to the application of Active Optical Cables (AOC), high-bandwidth USB 3.1 data streams are easily passed through optical fibers to extend the transmission distance. Unfortunately, the USB 2.0 signals are DC-coupled that is different than the AC-coupled signaling of USB 3.1. Therefore, it is much more difficult to transmit USB 2.0 signals through the optical cable. As of today, it is rare to find stable and reliable optical transmission of USB 2.0.
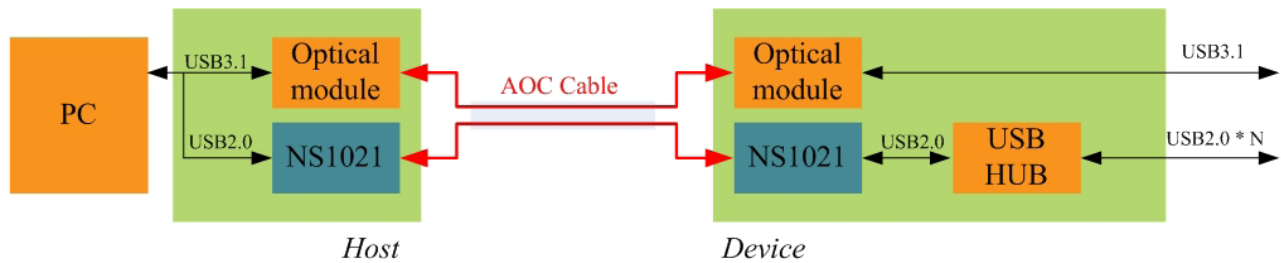
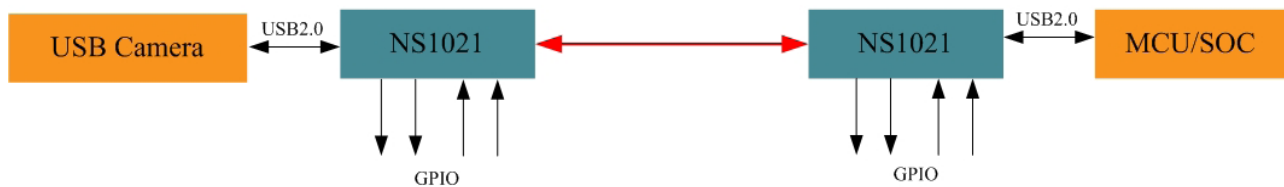**Figure 8 NS1021 Extender used in AOC application**

To solve this problem, a hybrid active optical cable has been proposed by some AOC makers. A copper wire is used to transmit the USB 2.0 signals in parallel with the optical fiber for USB 3.1 signals. An example of this hybrid AOC application is shown in Figure 8. NS1021 extender is used for USB 2.0 signal extension in addition to the optical module for USB 3.1. This hybrid optical cable is capable of transmitting both USB 2.0 and USB 3.1 signals for long distance up to 50m.

—

Machine Vision

Machine vision (MV) is the technology used to provide imaging based automatic inspection and analysis for industry applications such as automatic inspection, process control, and robot guidance. USB 2.0 cameras are cost effective, but they are not easily used in the MV applications due to the limited transmission distance and the complex electromagnetic environment in the industrial field.

To utilize the cost-effective USB 2.0 cameras in the MV applications, NS1021 extender has been adopted. The AC-coupled signaling of NS1021 extender is suited for the industry electromagnetic environment. When combined with a shielded twisted pair cable or a coaxial cable, the noise immunity can be further enhanced. This solution also supports the USB cameras that use 3D or AI technologies emerged in recent years.


Figure 9 NS1021 Extender used in Machine Vision application

Figure 9 shows an example of NS1021 extender used in the MV applications. NS1021 extender chip provides 4 GPIO pins that can be used for status light control or alarm control in these applications. In addition, NS1021 chipset has integrated power regulators within a small footprint package, making it easy to be embedded in the existing form factor of the hardware system.

USB Interface Isolation

Standard USB 2.0 is DC-coupled interface. The USB pins of the SOC are directly connected to USB connector which is exposed to external environment. To prevent the interface from damage, an isolation device may be added for protection. But the isolation device can only be connected in parallel between the USB signal line and power supply or ground. Such protection cannot completely prevent the damage caused by overvoltage on the USB interface. Therefore, it is common to find some damage on USB 2.0 interface in many industry applications. When it is difficult to repair the damaged SOC, the entire circuit board must be scrapped.
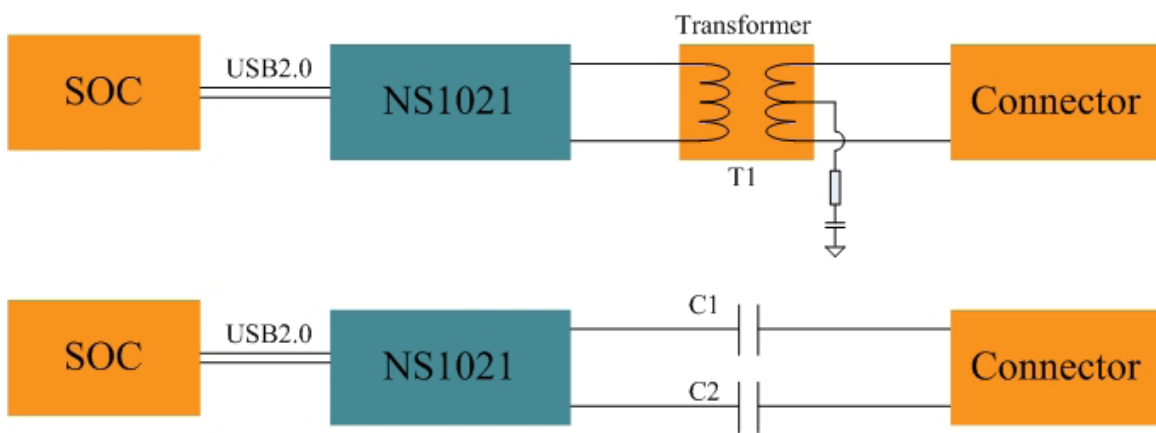
Figure 10 NS1021 Extender used in USB Interface Isolation application

NS1021 USB extender converts the USB DC-coupled signals to AC-coupled signals. This feature makes NS1021 extender ideal for USB interface isolation. As shown in Figure 10, the SOC interface is isolated by NS1021 extender with a high frequency transformer T1 or AC-coupled capacitors C1 and C2. These components effectively prevent the overvoltage from happening on the SOC interface. Therefore, the NS1021 USB extender solution provides the USB interface isolation and reduces the complexity of the maintenance.

NS1021 USB 2.0 Extender and Applications

Conclusion

NS1021 USB 2.0 Extender chipset supports USB extension over 50 meters cable, improves the noise immunity, and provides a high-speed and transparent channel between the connected USB host and devices. It is compatible with any USB 2.0 host, USB 2.0 device and USB 2.0 Hub, without the need to install a software driver. NS1021 USB extender solution has been widely adopted in many applications. We look forward to seeing more applications using NS1021 extender.