BLACK BOX®

How to extend USB and break the five-meter barrier.

Introduction

Universal Serial Bus (USB) is the most successful interface in the history of the PC, with well over ten billion USB devices in the global market and counting.

Due to its flexibility and simplicity, USB has become the de facto standard for peripheral connectivity, spanning broad markets and applications. It is designed to allow many peripherals to be connected using a single standardized interface. It provides an expandable, fast, bidirectional, low-cost, hot-pluggable, plug-and-play serial hardware interface, allowing computer users to connect different peripheral devices into a USB port and have them configure automatically, ready for use.

As versatile as USB may be, it is restricted to an operational distance limitation of five meters for USB 1.1/2.0 and approximately three meters for USB 3.0. This persistent drawback to USB functionality was resolved by the introduction of ExtremeUSB® by Icron Technologies. ExtremeUSB is a series of patented technologies designed to overcome USB's distance limitations.

This white paper describes how, through the use of extenders, USB connections are no longer limited to the desktop range of five meters (16.4 feet). It can now be extended to cover an entire campus with a range up to 10 kilometers (6.2 mi.). USB extenders are the key to bringing the benefits of extended-range USB technology to the industrial, commercial, and consumer computing marketplace.

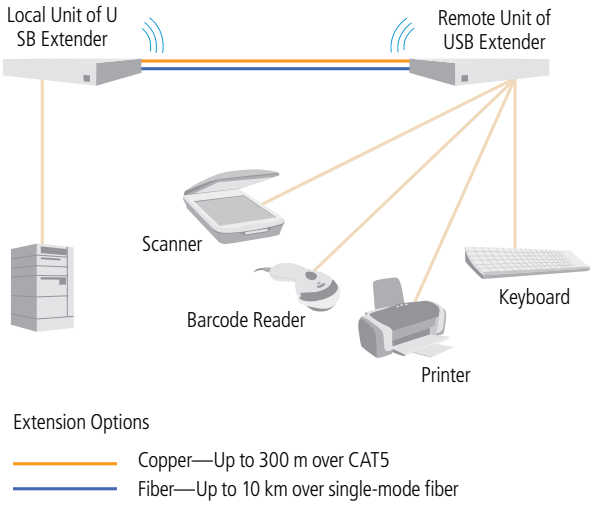

Figure 1

Specifications

USB technology is governed by specifications prepared by the USB Implementors' Forum (USB-IF). There have been three major revisions to this specification:

Revision 1.0 January 1996	This first version of USB introduced all the major components of the system.
Revision 1.1 September 1998	This version clarified some technical issues but did not introduce any new functionality.
Revision 2.0 April 2000	This version introduced high-speed (480-Mbps) operation.

Each revision of the specification is backwards compatible with previous versions. Also, because no functionality is deleted in later versions, all USB devices will continue to work with newer versions of USB.

Standard	Release Date	Throughputs	Distance Limit	Typical Applications
USB 1.1	1998 (September)	Low-Speed 1.5 Mbps Full-Speed 12 Mbps	3 m	Keyboard, mouse, game controllers, microphones, printers, Web cameras
USB 2.0	2000 (April)	High-Speed 480 Mbps	5 m	Flash drives, hard drives, Web cameras, data acquisition devices
USB 3.0	2008 (November)	SuperSpeed 5.0 Gbps	5 m	Machine vision cameras, solid state drives
USB 3.1	2013 (July)	SuperSpeed+ 10 Gbps	3 m	To be determined - Expecting first products to be available in mid/late 2014

Cable Distance Limits

Despite the numerous benefits of USB, there is a major drawback: cable distance limits. USB 1.1 and 2.0 have a cable limit of five meters and while USB 3.0 has no specified limit, a distance of approximately three meters is the effective range for reliable transmission due to its higher throughput.

There are many applications requiring computers to be located beyond five meters from the user or USB peripheral, including:

- Situations where the computer must be located away from the user in secured locations; on factory floors.
- In areas where environmental conditions (heat, cold, moisture, vibration, etc.) prevent the computers from being in the same proximity as the user.
- In machine vision/security applications where cameras are located in hidden locations.

There are options available today to extend USB; however, with varying achievable distances and solution practicality, some are more viable than others. USB extension up to 30 meters can be achieved by daisychaining up to five hubs to increase distance for USB 1.1/2.0. However, this kludged solution may require power at every second hub, limits how many devices or additional hubs can be used at the remote side and, with multiple connection points, raises concern about breakage or disconnects. Typically, this type of extension solution is not very practical or reliable.

Fortunately, another USB extension solution is available. Shortly after USB 1.1 peripherals became available to the market, a robust single cable extension technology known as ExtremeUSB was introduced. ExtremeUSB reflects a suite of patented technologies to extend USB 1.1, USB 2.0, and USB 3.0 distances well beyond the limits of USB specifications.

ExtremeUSB® Technology

ExtremeUSB is used in Black Box extender solutions to enable native USB connections to extend beyond the distance limitations imposed by the USB standard as outlined earlier. ExtremeUSB manages the strict timing requirements of the USB specification to enable USB connections over any physical transmission media, including twisted pair copper cabling (CATx), fiber optics, and wireless.

Typically, a USB extender system will have a local extender end that connects to a host such as a PC or Mac and a remote extender end that connects to a USB peripheral such as a keyboard, mouse, or camera. These two extender points are joined by the transmission media which increases the distance as shown in Figures 2 and 3.

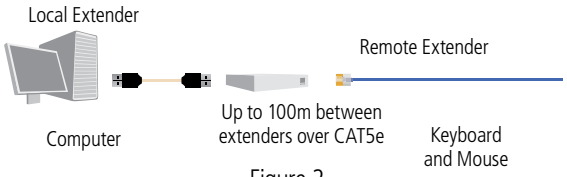

Figure 2

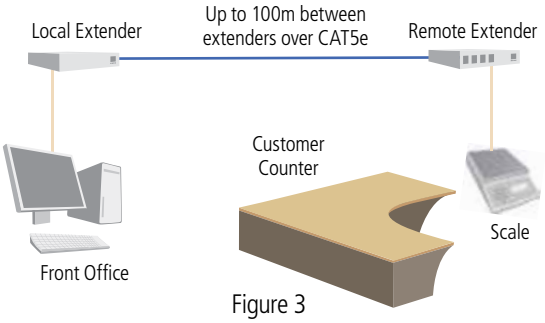

Figure 3

When extending USB, the local extender handles the expectations of the host computer, and the remote extender handles the expectations of the USB devices. If the distance is beyond spec, the extra time required to transmit packets disrupts the expected data flow, causing USB performance issues such as latency or non-recognition.

ExtremeUSB manages the turnaround time expectations in the USB protocol between the local and remote points to maintain transmit and acknowledge requirements in a transparent, driverless fashion suitable for any transmission media type. ExtremeUSB uses specialized algorithms and handling techniques to manage and overcome error situations unique to separate USB transfer types. By keeping this USB link active via proxy during the increased delays from extension, ExtremeUSB enables USB 1.1/2.0 extension up to 10 kilometers over fiber cabling and up to 500 meters over CATx.

	Dist. with ExtremeUSB
1.1	10 km
2.0	10 km
3.0	100 m

Benefits and Availability of USB Extenders

Aside from the obvious benefit of distance extension, ExtremeUSB offers other features to maintain an easy to use, consistently reliable experience with all USB compliant devices, primarily:

- ☑ Transparent USB extension
- ☑ True plug and play; no software drivers required
- ☑ Works with all major operating systems: Windows®, MacOSX®, and Linux®

USB System Components

A USB system consists of three major subsystems:

- Host controller — The brains of the system, usually mounted on a PC motherboard or PCI card. Each USB domain is managed by a single host controller.
- Hub — Provides multiple attachment points to USB.
- Device — Provides end-user functionality. Each USB domain may contain a maximum of 127 devices.

USB hubs can be daisychained to a maximum depth of five units.

Power

USB devices are also classified according to their power consumption requirements:

Low-power devices may consume up to 100 mA from the USB interface. Typical examples include joysticks and mice.
High-power devices may consume up to 500 mA from the USB interface. Typical examples include Web cams and certain keyboards with embedded hubs.
Self-powered devices may consume up to 100 mA from the USB interface. If the device needs additional power, it must be drawn from an external power supply. Typical examples include printers and scanners. For most practical purposes, self-powered devices can be considered identical to low-power devices.

USB can't measure the amount of power consumed by each device. Although the PC operating system may disallow certain device configurations because of the power budget being exceeded, this decision is based on software descriptions of device power requirements, not on a actual measured values.

USB-IF Compliance

USB extenders are fully compliant with the requirements for interoperability testing. This means that designers, manufacturers, and system integrators can integrate this technology into their own products knowing that all the plug-and-play and multi-vendor compatibility benefits of USB are retained.

USB Extension Architecture

USB extenders are composed of two units connected by a transmission line. These units are referred to as the local extender and remote extender. The local unit is connected to a downstream-facing port of a USB host controller or hub; the remote unit is connected to the upstream-facing port of a USB hub or device. Once operational, the entire USB extender system operates like a single standard USB hub.

As a standard USB hub, the USB extender system is compatible with all operating systems that support USB hubs and requires no additional software to be loaded.

Because the system appears to USB as a conventional hub (albeit a very long one), it can be connected to other hubs to the full depth permitted by USB. The system can be used as the first, last, or any intermediate hub in a chain. Multiple systems can also be used in parallel within a single domain—a common situation when opposite ends of a building need to be reached from a central computer room or telecom closet.

The only restriction placed on the configuration is that multiple USB extenders cannot be connected in series. Most USB extenders use CAT5e or above cable; if you require extra distance, consider a different extender, such as fiber.

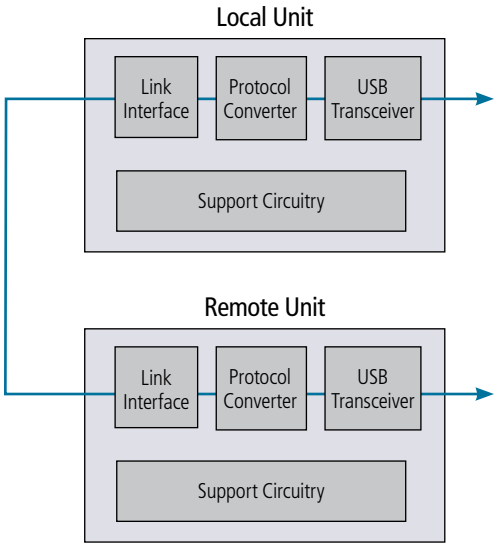

Figure 4

For USB 1.1, the extender protocol requires a point-to-point transmission system with 16-Mbps, full-duplex capacity. It can operate over any transmission media that can support these requirements, and it's ideal for extension of USB 1.1 connections up to 85 meters for keyboards, mice, game controllers, and interactive whiteboards including SMART Boards and Promethean ActivBoards.

USB Extender Components

USB Transceiver	Provides a standard upstream-facing USB port
Protocol Converter	Converts between a USB data stream and a USB extender
Link Interface	Provides a digital interface for connection to a wide range of link transceivers
USB Support Circuitry	Power regulation, power management, connectorization, line drivers, etc.

For USB 2.0, the extender protocol requires a point-to-point transmission system with 480-Mbps full-duplex capacity. It can operate over any transmission media that can support these requirements. Approximate maximum distances are as follows:

	Transmission
100-meter (328-ft.)	Over 4-pair CAT5e UTP
500-meter (1640.4-ft.)	Over 2-strand multimode fiber
10-kilometer (6.2-mi.)	Over 2-strand single-mode fiber

Operating System Support

USB is supported by the vast majority of operating systems in use today. Support for USB host controllers and USB hubs is provided "out-of-the-box" by these systems.

Because USB extender products are designed to simulate the operation of a standard USB hub, no additional software is required, so these products offer true cross-platform flexibility.

If you have an operating system not listed below, contact our free application engineering and life-time, 24x7 technical support.

USB Compatible Operating Systems

Windows	Mac	Linux	Others
Windows 2000	Mac® OS 8.6	Corel Linux® SE	Sun® Solaris™ 5.8
Windows Vista®	Mac OS 9.0	Mandriva® Linux 8.1	Silicon Graphics® Onyx®
Windows 7	Mac OS 9.2	Red Hat® Linux 7.2	
Windows 8	Mac OS X		

USB Extender Applications

Whenever the distance between the host machine and USB device is greater than five meters for USB 1.1/2.0 or three meters for USB 3.0, USB extension comes into play. This spans a variety of markets and applications including: keyboards, mice, hard drives, medical imaging equipment, gaming consoles, interactive whiteboards, boardroom conferencing systems, factory inspection and assembly, military communications, digital signage,

security cameras, mining and petroleum exploration equipment, post-production editing machines, and many more, including the following:

- Touchscreen kiosks — Using a USB extender is an easy way to place a USB-enabled touchscreen in a public space for advertising or information purposes.
- Industrial controls — USB extenders are ideal for remote control and monitoring in industrial applications.
- Surveillance cameras— Set up a surveillance camera using a USB camera linked to a PC. A USB extender enables you to place the camera exactly where you need it.

Examples of USB extension applications in classroom, hospital and factory environments, all using ExtremeUSB technology are shown in Figures 5 through 8.

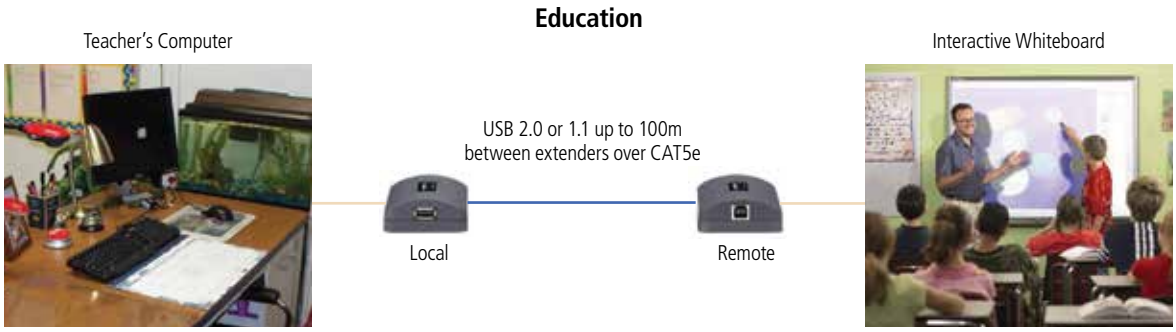

Figure 5: USB extension of an interactive whiteboard in a classroom setting.

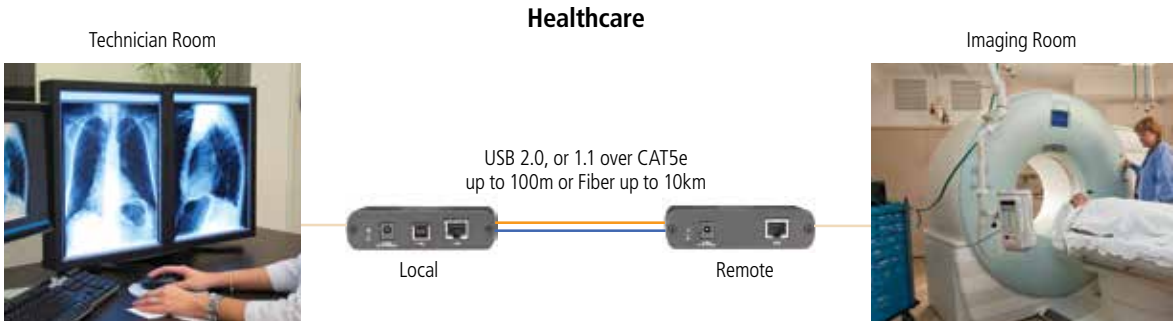

Figure 6: USB extension of MRI in a medical facility.

Figure 7: USB extension of machine vision inspection in a factory setting.

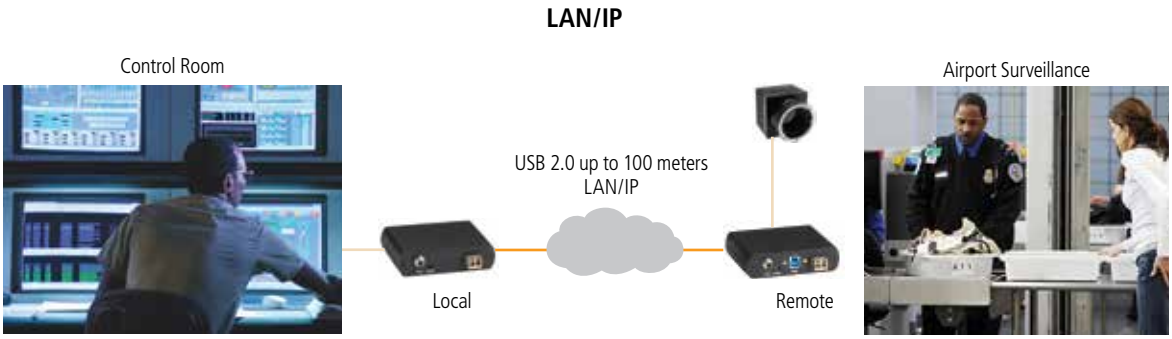

Figure 8: USB extension of surveillance at an airport.

Summary

Universal Serial Bus (USB) is the de facto standard for computer connectivity, having long replaced legacy interfaces with its numerous benefits. USB continues to be the most globally adopted computer interface by enabling next-generation peripherals through incremental bandwidth improvements. Beyond computer connectivity, USB has demonstrated its value-add versatility by having been adopted for powering mobile devices; for medical and military equipment connectivity; and for industrial floor use.

As successful as USB is supporting peripheral connectivity, it does have the persistent drawback on cable length, which is limited to five meters for USB 1.1/2.0 and three meters for USB 3.0. To address this limitation, Black Box integrated the ExtremeUSB suite of features into our extenders, eliminating USB distance restrictions by managing the turnaround timer in the USB protocol and maintaining transmit/acknowledge timing requirements while providing a USB transaction proxy over a longer reach connection. Through this technique, USB distance extension up to 10 kilometers can be achieved with no noticeable effect to the end-user experience.

In addition to the obvious benefit of distance extension, Black Box USB extenders offer other features to maintain an easy to use, consistently reliable experience with all USB compliant devices, primarily:

- Transparent USB extension
- True plug and play; no software drivers required
- Works with all major operating systems: Windows®, Mac OSX®, and Linux®

Improving the operational distance of USB enables a broader range of market applications, including medical, military, industrial automation, machine vision, education and pro AV. Without sacrificing peripheral performance or expectation, ExtremeUSB extension provides a simplified, consistent and transparent user experience.

Black Box USB Extenders

Part Number	IC101A	IC282A	IC280A	IC402A	IC400A	IC404A	IC406A	IC408A	IC502A
USB 1.1	•	•	•	•	•	•	•	•	
USB 2.0		•	•	•	•	•	•	•	
USB 3.0									•
Speeds *Low, High*	1.5, 12 Mbps	1.5, 12 Mbps	Up to 480	Up to 480	Up to 480	Up to 480	Up to 480	Up to 480	Up to 5 Gbps
Remote Hub Ports	1	2	1	2	4	4	4	4	2
Distance Supported	85 m	85 m	100 m	100 m	100 m	500 m	10 km	100 m	100 m over OM3 Multi Mode
Media Used	CATx	CATx	CATx	CATx	CATx	Fiber Multi Mode	Fiber Single-Mode	LAN or Direct Connect	Fiber Multi Mode

Frequently Asked Questions about USB Distance

Q. What are the distance limitations of USB?

A. The maximum range of USB is limited by the length of an individual USB cable and the number of cables that can be connected in series through USB hubs. The maximum length of a USB cable is three to five meters. The maximum number of USB hubs that can be daisychained (connected in series) is five. Thus, if a device is connected to a PC through five hubs, then the maximum distance from the device to the PC is 30 meters (98 ft.) (6 cables @ 5 meters [16 ft.] each).

Q. Why is the number of hubs limited to five?

A. Each hub delays the USB signal by a certain amount of time. When the host controller issues a request for data from a device, this request must pass through each hub in the chain, incurring incremental delay as it does so. A similar effect is experienced by the reply (data) from the device as it passes back through the chain of hubs to the host controller. The number of hubs is limited to five to place a limit on the round-trip delay of a signal from host controller to device and back to host controller.

Q. Why does USB impose a limit on a round-trip delay?

A. This is required to keep occupancy of the bus low. The host controller is not able to process commands for any other device while it is waiting for a reply.

Q. What would happen if the delay were too long?

A. The host controller would believe that the transaction had failed. Repeated failures might result in the device being taken out of service.

Q. How do USB extenders solve the delay problem?

A. A USB extender generates local responses that comply with the USB timing restrictions while the data is being retrieved from the remote source.

Q. Do USB extenders support all device speeds?

A. USB extenders support 1.5-Mbps and 12-Mbps speeds for USB 1.1; 480-Mbps speed for USB 2.0; and 5-Gbps for USB 3.0.

About Black Box

Black Box is a leading connectivity solutions provider, serving 175,000 clients in 141 countries with 192 offices throughout the world. Black Box offers more than 118,000 products including USB hubs and extenders. Black Box has an extensive line of USB extenders including CATx and USB. More information is available at http://www.blackbox.com/go/USBextenders

Black Box also offers extenders for many other applications, including video extenders, Ethernet extenders, and KVM extenders, as well as cabinets, racks, cables, connectors, and other video, audio, and data infrastructure products. To view Black Box's comprehensive offering, see our Web site at blackbox.com

Black Box is also known as the world's largest technical services company dedicated to designing, building, and maintaining today's complicated data and voice infrastructure systems.

We're here to help!

If you have any questions about your application, our products, or this white paper, contact our free application engineering and lifetime, 24x7 technical support at **724-746-5500** or go to **blackbox.com** and click on "Talk to Black Box." You'll be live with one of our technical experts in less than 60 seconds.