icron

Extending USB 3.0 Camera Operation in Machine Vision Applications with ExtremeUSB® Technology

» A discussion on how to overcome USB 3.0's distance limitation for machine vision applications.

EXTREME
USB®

icron.com

EXTREME
USB®

Abstract

With a 10x improved data throughput rate over USB 2.0, USB 3.0 is well poised to become a dominant machine vision camera interface, capable of supporting higher parameters of resolution (4K Ultra High Definition), frame rates and color depth. The trade off for improving bandwidth (from 480 Mbps for USB 2.0 up to 5 Gbps for USB 3.0), came at the expense of USB 3.0's operating cable distance being reduced to approximately 3 meters. In order for USB 3.0 to thrive as a viable camera interface in machine vision applications, the cable length limitation must be overcome.

This white paper examines why the USB 3.0 cable limitation is problematic and explores the different options to extend USB 3.0 considering the pros and cons of the respective extension solutions.

Machine Vision and USB 3.0

SuperSpeed USB, also known as USB 3.0, was introduced by the USB Implementers Forum (USB-IF) in 2008 and offered several advantages over USB version 2.0 including, and most notably, a 10X faster throughput rate up to 5 Gbps. This improved bandwidth, coupled with USB's plug and play ease-of-use, has fueled the growth of USB 3.0 based industrial cameras for machine vision applications. Virtually every industrial camera manufacturer now offers USB 3.0 options in their product portfolio (refer to Icron Technologies white paper *Meeting New Technological Demands in Machine Vision With SuperSpeed USB 3.0*, document # 90-01124 for details on USB 3.0 in machine vision and how it compares to other camera interfaces).

The tradeoff of improving bandwidth came at the expense of cable distance, reduced from 5 meters for USB 2.0 to approximately 3 meters for USB 3.0. This shorter reach can pose installation problems for applications where the host computer must be located some distance away from the camera. Examples include factory floors or areas where environmental conditions (heat, cold, moisture, vibration, etc.) prevent the computer from being in the same proximity, secured locations to prevent possible tampering or scientific and medical applications where hazardous biological materials could be harmful to the technician if exposed or situations of privacy concerns for patients.

Fortunately, it is possible to extend USB 3.0 camera operation using passive copper cables, hubs with passive copper cables, active copper cables or fiber optic solutions.

Passive USB 3.0 Cables

Passive USB 3.0 copper cables are a popular and relatively inexpensive option for very short range camera extension requirements of between 3 and 5 meters. The major consideration for a passive cable is its ability to maintain signal integrity over the application's required distance. Camera images are captured and transmitted in the form of an electrical signal; consequently, the signal when travelling over a cable's distance may be compromised by distortion or noise resulting in signal loss. In cases where the cable is poorly constructed or the user is trying to transmit data beyond the cable's specified distance, this signal loss can lead to unreliable performance, errors in the application or outright camera failure.

A quality passive cable should be able to reliably operate a USB 3.0 camera at 3 meters. Some passive cables specially designed to optimize signal quality and reduce electromagnetic (EMI) noise have been tested successfully with USB 3.0 cameras to extend reliably at up to 5 meters.

When choosing a passive cable, select a cable featuring the AIA USB3 Vision™ compliant locking connectors (to prevent accidental cable disconnection) and look for quality construction to ensure signal integrity. The latter may prove difficult to confirm without actually testing, however considerations are products from a recognizable brand name, published customer service number and warranty period. It is recommended to do more than just spot check when testing, especially if the application is expected to run 24/7, as errors may start to occur after a few hours of continuous operation.

Hubs + Passive USB 3.0 Cables

It is possible to connect passive cables and self-powered USB 3.0 hubs[1] together to extend the range of a USB camera; however, it is important not to exceed the recommended length between the two. Just as there is a limit on a passive USB 3.0 cable's length, there is also a limit on how many USB hubs can be connected together and still expected to function properly. The USB 3.0 specification stipulates no more than seven tiers of devices to be connected. To start, there are already two tiers of devices (the host and the camera), leaving five tiers available for use as additional hubs. Therefore, up to five USB hubs can be used for additional cable length; enabling a total maximum length of 30 meters (six sections @ 5 meters).

While 30 meters might seem like a reasonable extension distance, this approach is kludge, has inherent cable disconnection risk at each hub connection point and also requires power to be supplied to each hub, creating location issues if power sources are not readily available. As such, the multiple hub solution isn't very practical for most vision applications.

---

1   It is possible to use bus-powered USB hubs, but you will quickly run out of power as you extend your setup.

Active USB 3.0 Cables

For camera applications or systems requiring between 5 and 15 meters of extension, a quality active cable is highly recommended. Active cables are copper cables embedded with one or more semiconductor chips to boost performance. These cables are able to transmit data and power while maintaining signal integrity over longer distances compared to passive cables.

Ideally an active cable, such as Icron's USB 3.0 Spectra™ 3001-15, should be bus powered from the host computer to provide a full 5V, 900mA of power (per USB 3.0 specification) to the camera or other peripheral device to maintain proper operation. Notice in Figure 1 below that the Spectra cable has an additional USB plug to ensure full power is supplied.

Figure 1 - Icron Technologies' USB 3.0 Spectra™ 3001-15 (15m) Active Cable

Some active cables might indicate they are bus powered, however the power provided may not meet USB 3.0 specifications and only suffice for low power devices such as flash drives, not USB 3.0 cameras. In such cases the active cable needs to be connected to a USB 3.0 powered hub, which could have a negative impact on installations, if additional power sources are not available.

Proven compatibility with software and hardware is another key consideration factor. This includes operating systems (Windows®, Mac OS X®, or Linux®), host controllers (does the cable work with all or only specific USB 3.0 host controllers), and interoperability with cameras across the full range of USB 3.0 camera manufacturers.

As with the passive cable testing, thoroughness and complexity of cable testing for robust and reliable performance of active cables requires more than just a spot check test as some active cables may only be reliable for a few hours before errors start to show. Other test cases to consider are link cycling (camera recovery when either the computer or camera are disconnected and re-connected), and if using a hub, impact of brief power disruption. These are all important considerations for many applications especially when downtime may result in costly consequences.

Additional considerations include operating temperature, FCC/CE electromagnetic compliancy (Class B is more stringent than Class A), locking connectors per AIA USB3 Vision specification, warranty term, bend radius and, if necessary, the ability to pull the cable through conduit. See Figure 2 below for a factory use case example with an active USB 3.0 cable.

Figure 2 - Extending a Machine Vision Camera 15m with Icron's USB 3.0 Spectra™ 3001-15 Active Cable

USB 3.0 Fiber Optic Extenders

Fiber optic extenders are an excellent choice for extending USB 3.0 cameras over longer distances, up to 100 meters. A USB 3.0 fiber extender system typically consists of two extender units placed at each end of the application: a local extender unit connected to the host computer and a remote extender unit connected to the USB 3.0 camera(s). These two points are linked by fiber optic cable to provide the extension distance, converting electrical signals to optical signals and back again in order to facilitate the flow of data. Fiber extension solutions deliver speed, isolation and security; however, fiber cannot transmit electrical current and requires an external power source at the remote end, rendering it unsuitable for many types of industrial applications.

See Figure 3 below for an example use case with Icron's 100-meter USB 3.0 Spectra 3022 fiber extender where the local extender unit is labeled as LEX (Local Extender) and the remote as REX (Remote Extender).
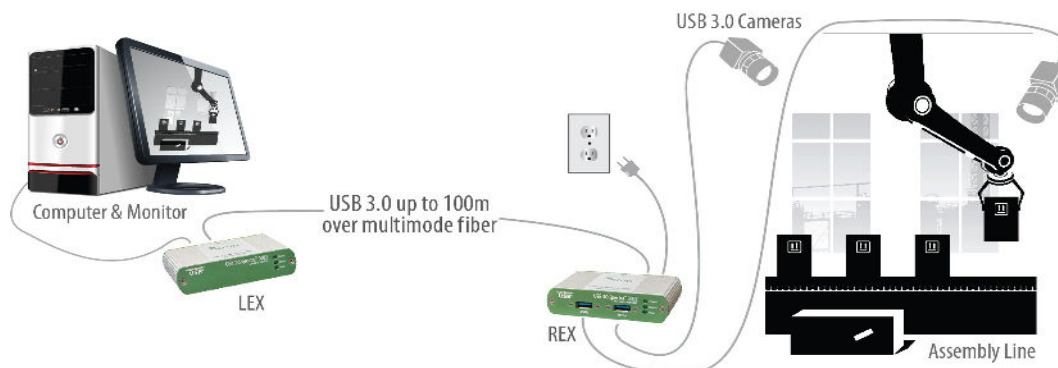

Figure 3 - Extending Machine Vision Cameras with Icron Technologies' USB 3.0 Spectra™ 3022 Fiber Extender

Alternatively, other fiber extender solutions may not include local and remote units, instead comprising of a single fiber cable integrated with electrical components. In this case however, a powered hub is required since the fiber cable will not carry sufficient power to operate a camera.

As with active copper cables, there are many different fiber based extension solutions available at different price points, so it is important to review specifications to ensure compatibility with the desired application or system at the distance required. Similar to active cables, other considerations include compatibility with operating systems and host controllers, interoperability with vision cameras, FCC/CE electromagnetic compliancy, longevity testing with link cycling and power disruption, operating temperature, locking connectors per AIA USB3 Vision specification and warranty term.

USB 3.0 Extender Comparisons

Table 1 below provides a brief overview of the four different USB 3.0 extension options discussed above for quick reference along with observed price ranges.

	Passive Cables	USB Hubs + Passive Cables	Active Cables	Fiber Optic Extenders
Max Distance	3-5m	30m	15m	100m
Bus Powered	Yes	No	Yes/No - check cable specification	No
Relative Cost Range (USD$)	$10 - $50	$30 - $160	$75 - $300	$500 - $1,000

Table 1: Comparison of USB 3.0 Extension Options

Benefits and Availability of ExtremeUSB®

Developed by Icron Technologies, ExtremeUSB® is a series of patented technologies designed to eliminate USB's distance limitations by extending USB 1.1 and 2.0 hundreds of meters over copper cabling or tens of kilometers over fiber optics and USB 3.0 up to 100 meters over fiber. ExtremeUSB is engineered to support the rigorous requirements of industrial and commercial applications. ExtremeUSB's performance is industry proven and since 1998 has been relied upon in critical use systems in medical, military & aerospace, machine vision and robotics; as well as security and boardroom automation.

Aside from the obvious benefit of distance, ExtremeUSB technology offers ease-of-use with consistent robust and reliable performance for transparent USB extension. The ExtremeUSB brand signifies proven distance extension with all USB compliant devices, does not require software drivers and works with all major operating systems, including Windows ®, Mac OS X® and Linux®.

To ensure your system or application is relying on robust, industry proven USB extension technology, look for the ExtremeUSB logo.

Figure 4: ExtremeUSB Logo

Summary

When USB 3.0 was introduced in 2008, it provided a 10x bandwidth improvement over USB 2.0, paving the way for a new generation of plug and play USB cameras capable of supporting higher parameters of resolution (4K Ultra High Definition), frame rates and color depth. As advantageous as USB 3.0 is for machine vision applications, the 3 meter constraint on cable length is a persistent drawback considering many automation applications require the host computer to be located away from the camera for a variety of reasons.

To address the short reach of USB 3.0 cable length, there are several USB 3.0 extension options available supporting different distance requirements. Passive cables are suitable for short range extension of up to 3 and 5 meters (depending on their design) and can be further extended by connecting up to five hubs. For system requirements ranging between 5 to 15 meters, active copper cables have proven superior to passive cables in maintaining signal integrity and reliable performance. If longer reach is required, fiber optic based extenders can provide extension up to and beyond 100 meters.

There are many different makes and models of USB 3.0 extension solutions at different price points so it is important to review specifications to ensure compatibility with the desired application at the distance required. The list of considerations include: compatibility with operating system and host controllers, interoperability with vision cameras, power availability, FCC/CE electromagnetic compliancy, longevity testing with link cycling and power disruption, operating temperature, locking connectors per AIA USB3 Vision specification, installation space limitations and warranty term.

ExtremeUSB is a suite of patented USB extension technologies from Icron Technologies designed for a variety of markets including machine vision and industrial automation. Aside from the obvious benefit of distance, ExtremeUSB is an industry proven technology designed to extend USB in critical use applications such as medical, military, aerospace and now machine vision. ExtremeUSB offers ease-of-use with consistent robust and reliable performance for transparent USB extension. The ExtremeUSB brand signifies distance extension with all USB compliant devices, does not require software drivers and works with all major operating systems, including Windows ®, Mac OS X® and Linux®.

By addressing the shortfall of USB 3.0's operational distance limitation, Icron's ExtremeUSB technology has eliminated a major obstacle to wide range machine vision market adoption of USB 3.0 as a cost-effective and robust industrial camera interface.

About Icron Technologies Corporation

Icron Technologies is a leading developer and manufacturer of high-performance USB and video extension solutions for commercial and industrial markets worldwide. Icron's patented extension technology extends Video and USB devices over many media types including Cat 5e, Fiber, Wireless, DisplayPort®, and over a corporate LAN. Icron's extension products are deployed in a wide range of applications including pro AV, industrial automation, machine vision, medical imaging, aerospace, interactive whiteboards, remote desktop extension, security, enterprise computing and isolated USB, or anywhere a PC needs to be remotely located from a display or peripheral device.

icron

Extending Connections™

Icron Technologies Corp.
4664 Lougheed Hwy.,
Suite 221
Burnaby, BC,
V5C 5T5, Canada

+1 604 638 3920
icron.com