

What is USB-inSync?

Synchronicity, reliability, and multi-device expandability using USB

Introduction

USB-inSync™ is a revolutionary technology which adds highly accurate timing and synchronization to the already powerful Universal Serial Bus (USB). The enhanced capability of USB-inSync™, while preserving all the features of USB, enables new applications and solutions never before possible. USB-inSync™ has transformed the fundamental properties and utility of USB. USB-inSync™ will quickly become the solution of choice for PC I/O applications where portability, expandability, performance, and cost are significant considerations.

Fiberbyte's USB-inSync™ specification defines a rugged PC-based I/O platform for test, measurement and automation systems. USB-inSync™ builds upon the USB specification that has become the preferred connectivity standard for portable, office and home computer environments. USB-inSync™ is an extension to USB that combines the widespread inter-compatibility features of the USB bus with the advanced timing and software features required for an industrial PC I/O communication platform. These advances open up a new world of possibilities in the development of synchronised systems for distributed test and measurement, data acquisition, automation and manufacturing applications.

What is USB?

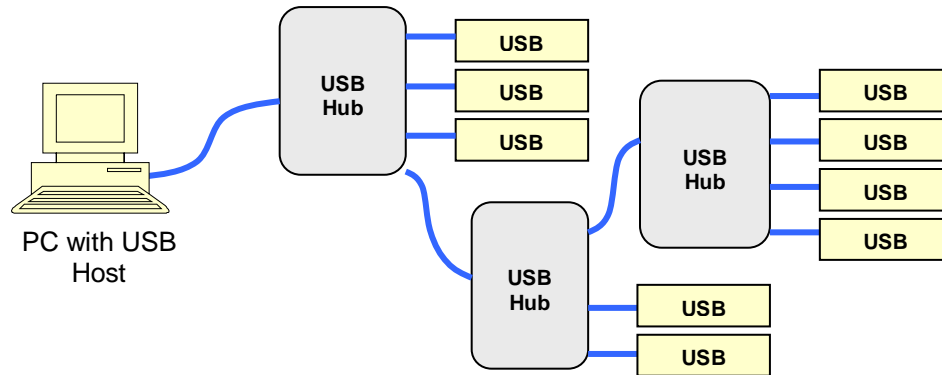
USB is by far the most popular PC interface, dominating the peripheral connectivity market with a solution to almost every application requiring external connection between computers and peripheral devices. Because of this USB has achieved 100% market penetration in the notebook and desktop PC markets with every PC currently sold offering a minimum of two ports. The well-known advantages of the standard USB specification are summarized as follows:

- External serial bus
- Frees interrupt-request lines (IRQ) for other devices
- Hi-Speed 480Mbps bandwidth
- Hot-swappable, Plug-n-play operation
- Reliability is assured through automatic error correction protocols
- Expansion via inexpensive random star topology
- Widespread PC compatibility & Low Cost

USB is a serial bus designed to operate in a point-to-point, PC-centric host – slave configuration (see Figure 1). The USB standard defines an expandable PC interface that can control up to 127 devices (including expansion hubs) from a single USB Host Controller on a PC. Each hub may have up to 7 expansion ports and can be connected to other hubs in any random topology the user desires. For a detailed and in-depth look at USB refer to Jan Axelson's excellent book, *USB Complete*, (2001) Lakeview Research.

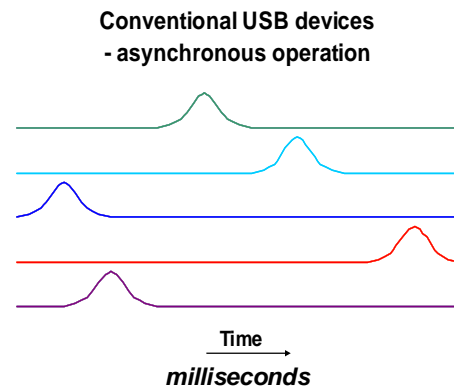
What is USB-inSync?

Figure 1: USB connection topology



Synchronization & Determinism

USB was designed to concurrently operate multiple devices that vary in nature and function. To accomplish this USB is an “asynchronous” bus which allows multiple devices to sequentially interact with the Host PC. Asynchronous control prevents devices from interacting with each other in a deterministic way. As a consequence, USB has a very limited capacity to synchronise events or processes on multiple devices. Typical USB devices can barely synchronise data streams on millisecond time scales. This is only just good enough to synchronize the left and right channels of a pair of low quality PC audio speakers (see right).



As an asynchronous bus USB has no provision for providing accurate timing information to multiple devices. Standard USB is therefore unsuitable for automation applications. The phase delay depicted in the figure above increases as the physical distance between devices increases. In fact, the phase delay is further increased with the use of standard expansion hubs. With the standard USB framework there is no ability to provide synchronous real-time control or data acquisition for applications such as test, measurement, control and automation.

Computers have become integral and critical to manufacturing control and automation, and as a consequence are found all over the manufacturing floor. USB devices make use of this existing infrastructure in a simple, reliable, and cost effective manor. Unfortunately for designers of test and automation systems the asynchronous operation of standard USB presents an obstacle that can not be overcome. The deployment of USB in real world test, measurement and automation has thus far been limited to single device data-upload applications.

What is USB-inSync?

What is USB-inSync™?

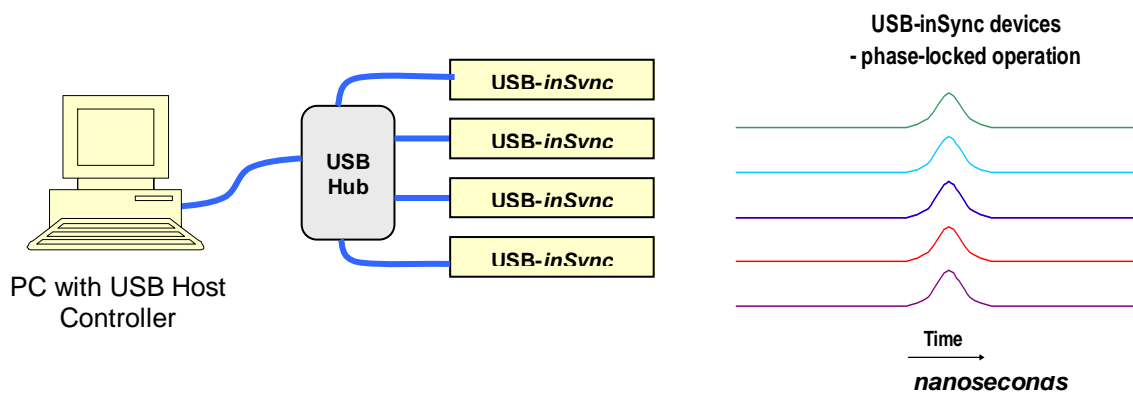
Fiberbyte has developed USB-inSync™ technology to transform the conventional asynchronous USB bus into a synchronous, deterministic and expandable control platform. Such capabilities were never envisaged by the creators of USB. USB-inSync™ devices are USB compatible and possess all the standard connectivity characteristics of USB. In addition to this, USB-inSync™ devices feature highly accurate synchronization and deterministic timing capabilities.

Each USB-inSync™ device is equipped with a local clock that is accurately phase locked to that of every other USB-inSync™ device attached to a given Host PC. A deterministic triggering system is also provided such that processes can be started and stopped in a precisely controlled manner. These two features extend USB beyond the realms of its original concept and allow new control and monitoring possibilities within a distributed PC-based environment.

Fiberbyte has therefore created a powerful extension to USB enabling a range of automation applications which require coordinated multi-device control and data acquisition.

USB-inSync™ guarantees that all local device clocks will be synchronised to within $\pm 5\text{ns}$ of each other when connected to a common expansion hub (see figure 2). This is termed **Passive USB-inSync™** because the devices automatically lock to each other without the need for any additional equipment.

Figure 2: Passive USB-inSync

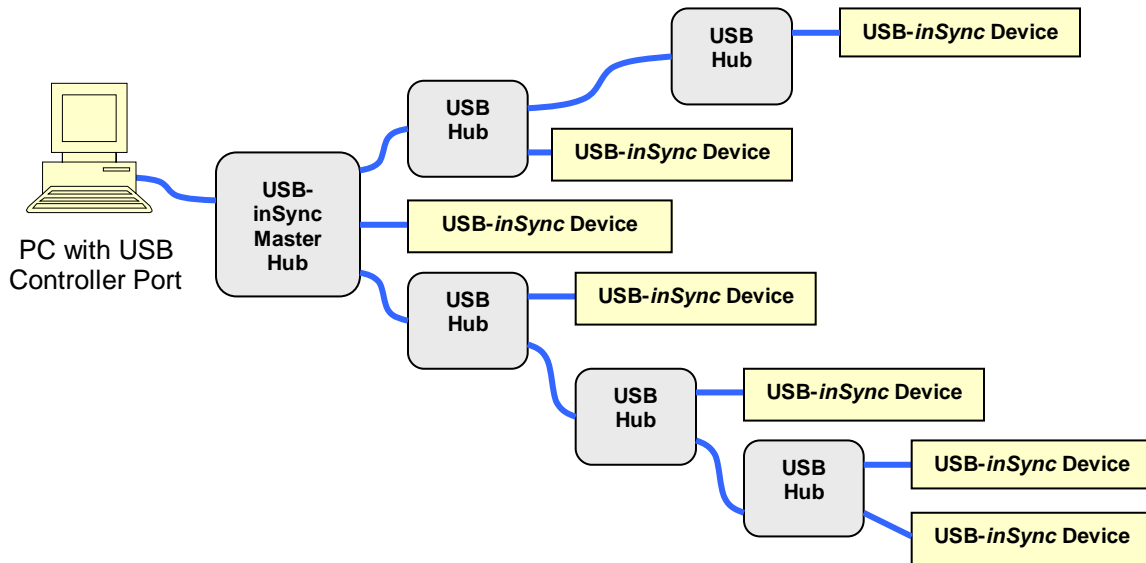


Up to six USB-inSync™ devices can be passively locked to within $\pm 5\text{ns}$ of each other by attaching to a generic USB expansion hub. USB-inSync™ devices automatically lock their clocks together in frequency, but there may be a small phase offset between clocks when the devices are located at different points along the USB connection tree. The phase offset for a typical distributed Passive USB-inSync™ configuration is of the order of 100ns. This is still four orders of magnitude better synchronization than standard USB and is perfectly adequate for the vast majority of applications.

What is USB-inSync?

However some customers will require much tighter timing control than this. USB-inSync™ also has the capability to actively compensate for these phase offsets and synchronize all clocks to within $\pm 5\text{ns}$ regardless of their connection location. Active USB-inSync, as it is called, utilizes the Fiberbyte USB-inSync™ Master Hub to measure and compensate for the clock phase offset of each device. (see figure 3).

Figure 3: Active Phase Compensation



Notice in the above figure that only one USB-inSync™ Master Hub is depicted. The master hub operates as an accurate timing controller to synchronize all device clocks, regardless of the number standard USB expansion hubs used. The Master Hub determines the phase offset and provides a correction factor to each USB-inSync™ device to ensure all devices operate in complete synchronicity. This occurs automatically during the device enumeration process and is repeated each time a new device is connected to the system, maintaining accuracy while preserving the hot-swapability of USB. As soon as Windows recognizes the device, it is available for synchronous operation. The use of a Fiberbyte USB-inSync™ Master Hub enables the tightest timing control of USB-inSync™ devices regardless of their location within your distributed PC I/O system.

USB-inSync™ Hardware Features

The USB-inSync™ hardware specification defines a system whereby each device is provided with accurate clock rate and absolute time information from the host PC. Each USB-inSync™ device has an embedded clock which is accurately phase locked to all other USB-inSync™ device clocks. The key to USB-inSync™ working over standard USB hub and ports is that the hardware platform resides solely in the USB-inSync™ device itself. When combined with the USB-inSync™ software platform full synchronization and deterministic capabilities can be implemented over standard USB hub architecture.

What is USB-inSync?

Every USB-inSync™ device connected to the same generic expansion hub will therefore operate with clocks synchronised to within a few nanoseconds, however devices connected at different levels of the USB hub tree will be subject to a small phase offset. While a minor phase offset is adequate for the vast majority of applications, USB-inSync™ provides the possibility to all but eliminate this offset. The use of Fiberbyte's Master Timing Hub ensures accurate clock phase compensation to within ± 5 ns, regardless of the device's position within the USB network. USB-inSync™ also defines a deterministic triggering system with events on different devices triggered within the same ± 5 ns tolerance.

The Fiberbyte engineering team has developed USB-inSync™ as a PC I/O platform so the possibilities for enabling every vendor's automation devices with expandable, synchronous, reliable, and cost effect control are unlimited. Most importantly, USB-inSync™ works over the standard USB bus and complies with the normal USB protocol. This means that USB-inSync™ devices will operate side by side with standard USB devices and over inexpensive standard USB hubs and cables.

USB-inSync™ Software Features

The software platform is based on our multiple device threaded digital I/O command infrastructure. A simple Graphical User Interface (GUI) is included that empowers the user to start acquiring data from Fiberbyte USB-inSync™ enabled devices within minutes of opening the box. Advanced users are provided with access to extended low-level device functionality through our COM Server. This enables interfacing through Windows based software application including MS Office, Visual Studio and National Instruments LabVIEW™. Additional LabVIEW™ device drivers are available so that USB-inSync™ devices can be quickly implemented within an existing test environment. OEM users benefit from the flexibility of multiple software interfaces to create application specific solutions.

The software platform features are summarized as:

- Fully compatible with USB1.1 driver specification
- COM Server interface for end user customization
- Drivers for industry standard interfaces such as LabVIEW™
- Links multiple USB-inSync™ modules with multiple concurrent software applications.
- Enables complete USB-inSync™ functionality
- Includes Registration manager, Message processor, Event handler
- Threaded I/O processing for synchronous sampling or deterministic control applications

Summary

Fiberbyte has transformed the consumer USB port, available on every PC and laptop, into a high bandwidth, synchronous and distributed instrumentation bus. We use the existing bus traffic to distribute highly accurate clock information to each device utilising data structures already present on the bus. The process operates with complete transparency and does not affect normal USB operation. USB-inSync™ represents the future of PC-based I/O suitable for automation, control, and measurement applications with cutting edge performance and the ubiquity of USB.

What is USB-inSync?

Fiberbyte has created in USB-inSync™, a platform that offers the synchronous and deterministic accuracy of rack-based systems such as PXI but in a distributed, PC-based format. We have succeeded in developing a new synchronous instrumentation bus capable of interfacing over 100 devices directly through the PC's USB port. This bus allows each attached device to operate with its own synchronous clock accurate to better than ± 5 nanoseconds. USB-inSync™ devices can also be operated in a deterministic manner with an event triggering temporal resolution of better than ± 5 nanoseconds, regardless of their position within the distributed system.

There are numerous test and automation applications which can benefit from the simplicity, reliability, and cost savings that Fiberbyte's USB-inSync™ technology offers. Current products and manufacturing methods require new solutions that offer increased computer integration. USB-inSync™ enables automation equipment designers to leverage existing computer infrastructure and provide distributed, synchronous and deterministic multi-device control.

USB-inSync™ Features:

- Fully compatible with USB
- Nanosecond phase-locking between USB-inSync™ devices on the same USB hub
- Nanosecond phase-compensation between expansion hubs (using Fiberbyte Master Hub)
- Real-time sampling capabilities
- COM Server interfaces with most modern software application

USB-inSync™ Requirements:

- Windows 2000 / XP Operating Systems
- Intel Pentium III PC or higher
- 128 MB RAM, 10MB hard disk space
- USB1.1 or higher Host Controller
- USB-inSync™ embedded device interface

- LabVIEW™ is a registered trademark of National Instruments

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