TECHNICAL NOTE

Overview of IRIG-B Time Code Standard

Summary

The IRIG-B time protocol is widely used by electric utilities, industrials, and others to ensure precise time synchronization of power system devices, such as breakers, relays and meters.

This document describes the protocol, gives examples of Cyber Sciences products that support IRIG-B, and describes how this legacy protocol is being replaced by PTP (Precision Time Protocol per IEEE 1588) in modern power system applications.

Introduction

The IRIG time codes were originally developed by the Inter-Range Instrumentation Group (IRIG), part of the Range Commanders Council (RCC) of the US Army. The standard was first published in 1960 and has been revised several times by the Telecommunications and Timing Group (TTG) of the RCC. The latest version is IRIG standard 200-04, "IRIG Serial Time Code Formats," updated in September, 2004.

Available Formats

Although the "IRIG-B" time code is best known, the standard actually defines a family of rate-scaled serial time codes. The six code formats use different pulse rates, or bit rates, as shown in the table below.

IRIG STANDARD 200-04

IRIG Time Code Formats

Format	Pulse Rate (or Bit Rate)	Index Count Interval
IRIG-A	1000 PPS (pulse per second)	1 ms
IRIG-B	100 PPS	10 ms
IRIG-D	1 PPM	1 minute
IRIG-E	10 PPS	100 ms
IRIG-G	10000 PPS	0.1 ms
IRIG-H	1 PPS	1 second

Time Code Attributes

All IRIG time code formats use pulse-width coding. A "binary 1" pulse has a duration of 50% of the index count interval, and a "binary 0" pulse has a duration of 20% of the index count interval. In addition "Position Identifiers" have a duration of 80% and are used as reference markers.

IRIG time code signals may be:

- **Unmodulated** (DC level shift, no carrier signal)
- **Modulated** (amplitude-modulated, sine wave carrier).
- **Modified Manchester** (amplitude-modulated, square wave carrier).

Three types of coded expressions are used in the IRIG standard:

- **Binary Coded Decimal** time-of-year (BCDTOY) and year (BCDYEAR)
- **Control Functions (CF)**, set of bits reserved for user applications
- **Straight Binary Seconds (SBS)** time-of-day (0 to 86400 seconds)

IRIG STANDARD 200-04 (cont.)

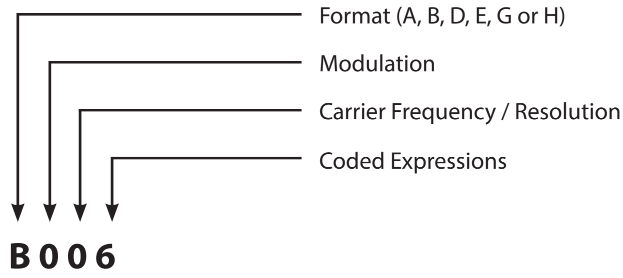
Unmodulated or Demodulated?

An IRIG-B time signal can be modulated (over a carrier signal) or unmodulated (no carrier signal), called DC Level Shift (DCLS) in the IRIG Standard.

In some manufacturers' literature, the term "demodulated" is used to describe an IRIG-B DC Level Shift (no carrier signal). In most cases, it may be assumed that this term is synonymous with unmodulated (DCLS).

IRIG Time Code Designations

In addition to the letter used to designate one of the six IRIG code formats, signal identification numbers are used to further describe specific characteristics. Thus, the complete IRIG time code designation consists of a letter and three digits, as shown below.



IRIG time codes – naming convention

IRIG Signal Identification Numbers (3 Digits)

1st Digit	Modulation
0	Unmodulated, DC Level Shift (DCLS), pulse-width coded
1	Amplitude modulated, sine wave carrier
2	Manchester modulated
2nd Digit	**Carrier Frequency / Resolution**
0	No carrier (DCLS)
1	100 Hz / 10 ms resolution
2	1 kHz / 1 ms resolution
3	10 kHz / 100 microsecond resolution
4	100 kHz / 10 microsecond resolution
3rd Digit	**Coded Expressions**
0	BCD$_{TOY}$, CF, SBS
1	BCD$_{TOY}$, CF
2	BCD$_{TOY}$
3	BCD$_{TOY}$, SBS
4	BCD$_{TOY}$, BCD$_{YEAR}$, CF, SBS
5	BCD$_{TOY}$, BCD$_{YEAR}$, CF
6	BCD$_{TOY}$, BCD$_{YEAR}$
7	BCD$_{TOY}$, BCD$_{YEAR}$, SBS

BCD: Binary Coded Decimal
CF: Control Functions
SBS: Straight Binary Seconds
TOY: Time of Year

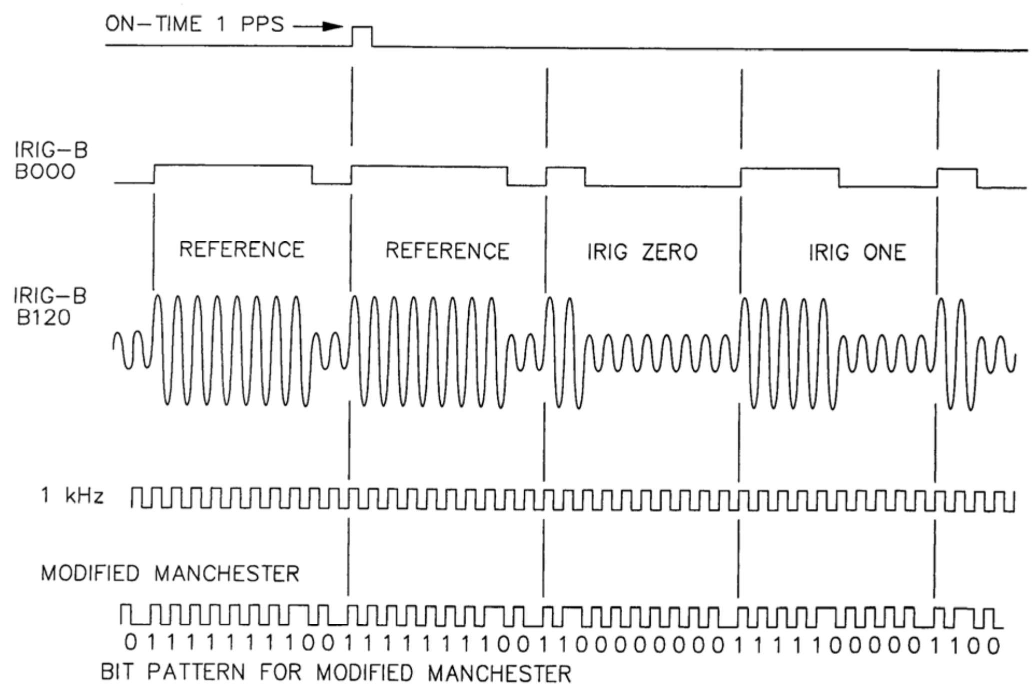
IRIG-B PROTOCOL DESCRIPTION

IRIG-B Overview

IRIG time code B (IRIG-B) is widely used in the electrical power industry. IRIG-B has a pulse rate of 100 pulses-per-second with an index count of 10 milliseconds over its one-second time frame. It contains time-of-year and year information in a BCD format, and (optionally) seconds-of-day in SBS.

IRIG-B Signals

IRIG-B is typically distributed as a DC level shift (DCLS), pulse-width coded signal ("unmodulated IRIG-B") or as an amplitude-modulated signal based on a sine wave carrier with a frequency of 1kHz ("modulated IRIG-B"). Modified Manchester modulation is also specified in the standard but is less common. A comparison of IRIG-B coding methods is shown in the figure below.



(source: IRIG Standard 200-04)

IRIG-B coding comparisons: DC level shift (unmodulated), 1kHz amplitude-modulated, and Modified Manchester

IRIG-B Reference Markers

IRIG-B uses reference markers called "Position Identifiers." The presence of two consecutive reference markers signifies the start of the time frame. The first reference marker alerts that the next rising edge will be the PPS (Pulse-per-Second) marker. ("On-Time 1 PPS" shown above.) Thus, the IRIG-B signal provides the full date and time once per second, as well as a precise start-of-interval reference for precise time synchronization if needed.

IRIG-B PROTOCOL DESCRIPTION (cont.)

IRIG-B Encoding

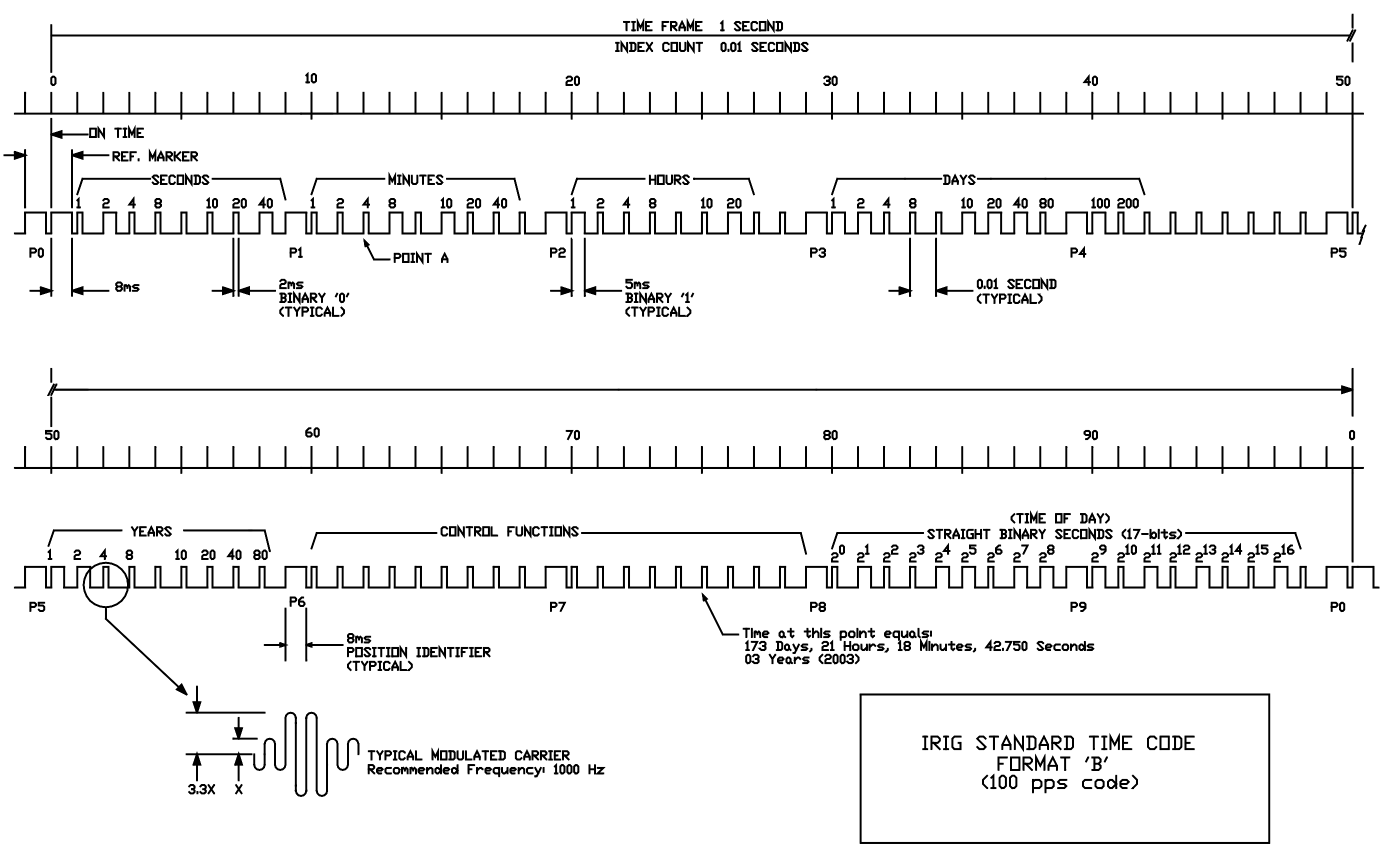
IRIG-B consists of 100 bits produced every second, 74 bits of which contain various time, date, time changes and time quality information of the time signal. Consisting of logic ones, zeros and position identifier bits, the time code provides a reliable method of transmitting time to synchronize power equipment devices. There are three functional groups of bits in the IRIG-B time code: Binary Coded Decimal (BCD), Control Functions (CF) and Straight Binary Seconds (SBS).

The BCD group contains time information including seconds, minutes, hours and days, recycling yearly. The BCD time-of-year code (BCDTOY) reads zero (0) hours, minutes, seconds, and fraction of seconds at 2400 each day and reads day 001 at 2400 of day 365, or day 366 in a leap year. The BCD year code (BCDYEAR) counts year and cycles to the next year on January 1st of each year and will count to year 2099.

The (optional) SBS time-of-day code consists of the total elapsed seconds, recycling daily. SBS reads zero (0) seconds at 2400 each day excluding leap second days when a second may be added or subtracted.

The CF group contains year, time quality, leap year, pending leap seconds and parity. Other CF bits are reserved for user-defined purposes, depending on application.

Lastly, position identifiers separate the various components of the IRIG-B time code.



(source: IRIG Standard 200-04)

IRIG-B BCD time-of-year (in days, hours, minutes, seconds) and year and straight binary seconds-of-day and control bits

IRIG-B PROTOCOL DESCRIPTION (cont.)

Note: IEEE standard 1344 was updated and replaced by IEEE C37.118-2005. Nonetheless, the term "IEEE 1344 Extensions" is still used.

IRIG-B Type with IEEE 1344 Extensions

IRIG-B TYPE	IEEE 1344	
	OFF	ON
Unmodulated, B00x	B002	B006
Modulated, B12x	B122	B126

IEEE 1344 Extensions

Year information was not specified in the IRIG standard prior to its 2004 revision. Before 2004, the IEEE adopted a standard (IEEE 1344) which included year data as part of the IRIG-B signal. This variation came to be known as "IEEE 1344 extensions."

IEEE 1344 extensions use bits of the Control Functions (CF) portion of the IRIG-B time code. Within this portion of the time code, these bits are designated for additional features, including:

- Calendar Year (now called BCDYEAR)
- Leap seconds, and leap seconds pending
- Daylight Saving Time (DST), and DST pending
- Local time offset
- Time quality
- Parity
- Position identifiers

To be able to use these extra bits of information, power system devices and other equipment receiving the time code must be able to decode them. Refer to individual product manuals to determine whether IEEE 1344 extensions are supported.

Since year information is now considered part of BCD (denoted as BCDYEAR), what was formerly considered B002 and B122 (with IEEE Extensions ON) would now be denoted as B006 and B126, respectively.

IRIG-B WIRING

Note: Because the IRIG-B signal consists of a series of pulses, a digital scope is needed for diagnostics; a standard multi-meter is not sufficient to confirm normal operation.

IRIG-B Implementation

The IRIG 200-04 standard does not define specific signal levels for IRIG-B.

Typical techniques for transmission of **unmodulated IRIG-B** (DCLS) include:

- Point to point connection of a 5V signal over coaxial cable
- Multi-point distribution of a 5V signal over shielded twisted-pair cable
- Multi-point distribution using 24 Vdc for signal and control power
- Multi-point RS-485 differential signal over shielded twisted-pair cable
- RS-232 signal over shielded cable (point to point, short distances only)
- Optical fiber

Typical techniques for transmission of **modulated IRIG-B** include:

- Coaxial cable, terminated in 50 ohms or higher, point-to-point
- Shielded twisted-pair cable, with optional termination (100 ohms)

Application considerations

When applying IRIG-B, the number and type of devices to be synchronized, the protocols supported, and the distances involved all affect system architecture; therefore, each system must be engineered individually. The first step may be to confirm that all devices support the same version of IRIG-B, for example: unmodulated IRIG-B (also known as 5V DC Level Shift, or DCLS), with or without the year (IEEE 1344 extensions), etc. The IRIG-B signal is wired to a general-purpose or dedicated digital input, configured to decode IRIG-B.

The IRIG-B source (e.g., GPS receiver/clock) may be capable of synchronizing a small number of devices in series (up to 8 or 10?) but a larger number of devices may require multiple circuits, repeaters and/or isolation means. Careful consideration is needed of clock specs, cable distances and device limitations. In some cases, it may be necessary to add appropriate termination impedance to each IRIG-B signal to eliminate signal reflections.

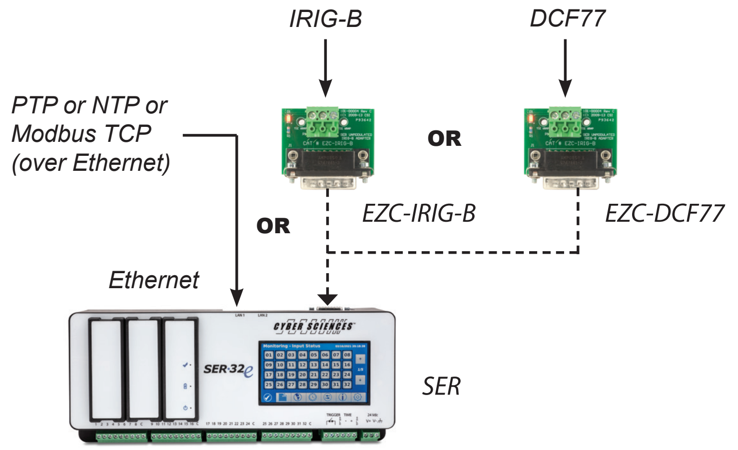
APPLICATIONS OF IRIG-B IN CYBER SCIENCES PRODUCTS

CyTime SER-32e (or SER-3200/2408-PTP)

CyTime SER-32e (or SER-3200/2408) Event Recorders accept IRIG-B as time source, then sync with each other using PTP. A PTP slave can also output IRIG-B to devices that do not support PTP. Other time-sync input and output options are also supported for flexibility and interoperability with other devices.

SER Time Source Options (Time-Sync IN)

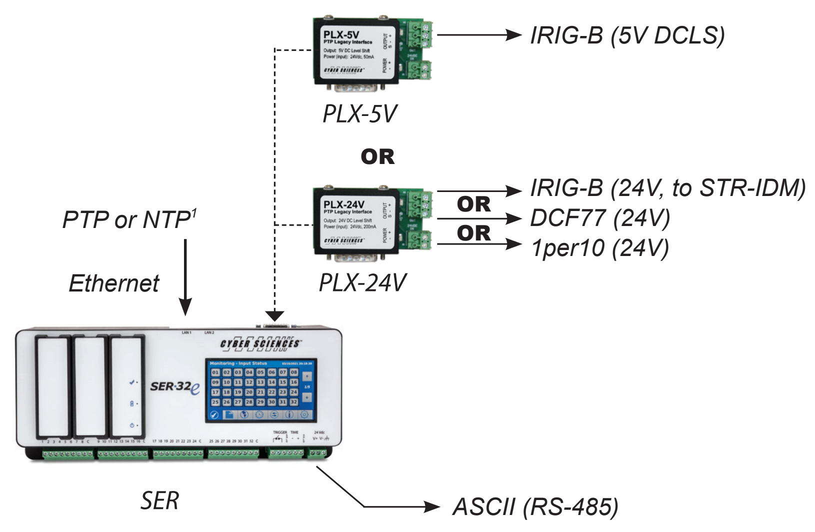
Time source options via PTP, NTP or Modbus TCP use the SER built-in Ethernet interface (RJ-45). IRIG-B or DCF77 inputs require an adapter (EZC-IRIG-B or EZC-DCF77) as shown.



SER as Time-sync Hub (Time-Sync OUT)

When PTP is selected as time source, the SER-32 also serves as a "PTP time source" for non-PTP devices, generating the time-sync protocol needed: IRIG-B, DCF77, 1per10 (via PLX adapter) or ASCII (via built-in RS-485 port), as shown below. In addition, the SER-32e can source IRIG-B, DCF77 or 1per10 when it's input is PTP or NTP.

Note: Only one protocol can be selected for output via the PLX connector (IRIG-B, DCF77 or 1per10). However, for maximum flexibility, the ASCII / RS-485 output is enabled by default any time an SER is set to use PTP for time source (IN) or time-sync (OUT).



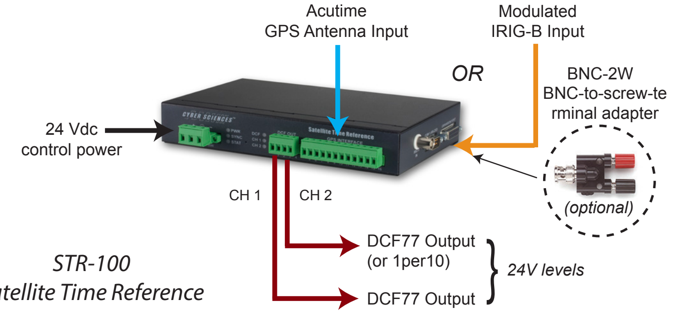
[1] NTP - SER-32e only

APPLICATIONS OF IRIG-B IN CYBER SCIENCES PRODUCTS (cont.)

If Modulated IRIG-B input is used, the STR-100 must be configured with the current year during initial setup. The full date/time (including the year) is transmitted via its DCF77 outputs.

STR-100 Satellite Time Reference

The Cyber Sciences STR-100 Satellite Time Reference accepts a GPS smart antenna input or a modulated IRIG-B signal to provide a precision time reference. The IRIG-B input supports type B122 (1kHz modulated signal with time of year).

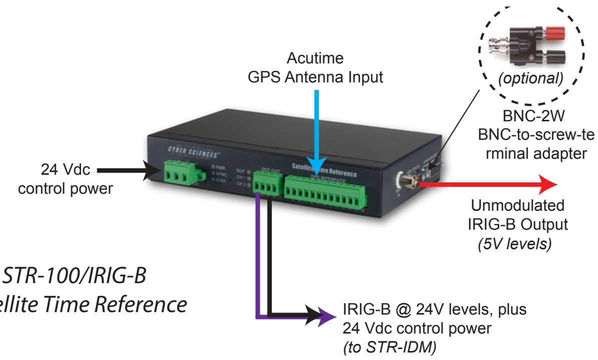


STR-100
Satellite Time Reference

STR-100/IRIG-B (IRIG-B out) Satellite Time Reference

STR-100/IRIG-B

Like the base model, the STR-100/IRIG-B accepts a GPS smart antenna input, but its output is an unmodulated IRIG-B signal, type B007 (unmodulated signal, DC level shift, BCDTOY and BCDYEAR, SBS) at 5V (side BNC) or 24V (front terminals).

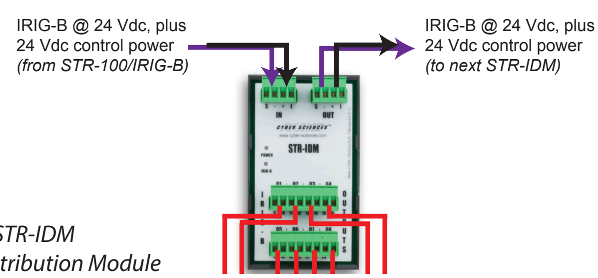


STR-100/IRIG-B
Satellite Time Reference

STR-IDM IRIG-B Distribution Module

STR-IDM

The STR-IDM IRIG-B Distribution Module enables the distribution of an unmodulated IRIG-B signal over long distances and to multiple devices. The IRIG-B signal levels between the PLX-24V (or STR-100/IRIG-B) and the first IDM (as well as to other IDMs) are 24 Vdc nominal, along with 24 Vdc control power. Each STR-IDM provides 8 additional IRIG-B outputs, type B007 (unmodulated signal, 5V DC level shift, BCDTOY BCDYEAR SBS).



STR-IDM
IRIG-B Distribution Module

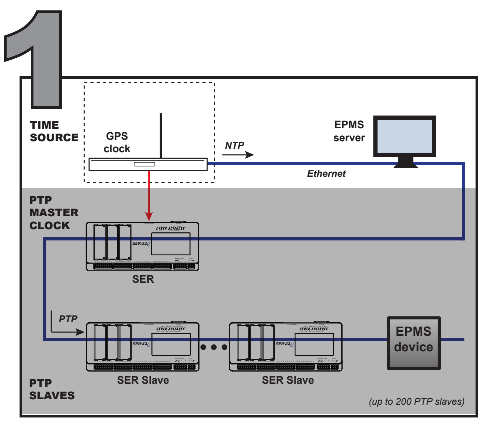
PRECISION TIME PROTOCOL (PTP) per IEEE 1588

> **For More Info on PTP:**
>
> *Tech Note: Hi-res Time Sync using PTP/1588 (TN-100)*

Time Synchronization as Easy as 1-2-3

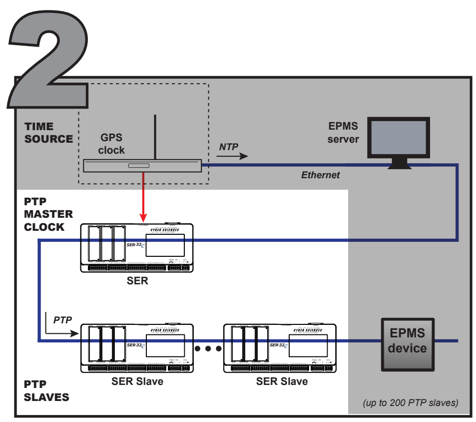
PTP (Precision Time Protocol defined in IEEE 1588) takes advantage of hardware-assisted timestamping to achieve sub-millisecond time synchronization over an Ethernet network. Cyber Sciences offers simple, scalable system architectures using PTP as the means to distribute a precise time reference to all devices that support PTP. CyTime SER Event Recorders accept a variety of time-source options, and sync with each other automatically over Ethernet, using PTP. In addition, an SER can serve as a "PTP time sync hub" for devices that do not yet support PTP.

Simple, building-block options are shown below. The first CyTime SER accepts a time reference signal (such as IRIG-B), then serves as PTP master clock for all other SERs as well as other devices which support PTP. For a device that does not support PTP, a nearby SER outputs the protocol needed (e.g., IRIG-B) effectively making this device "PTP-enabled" as well.



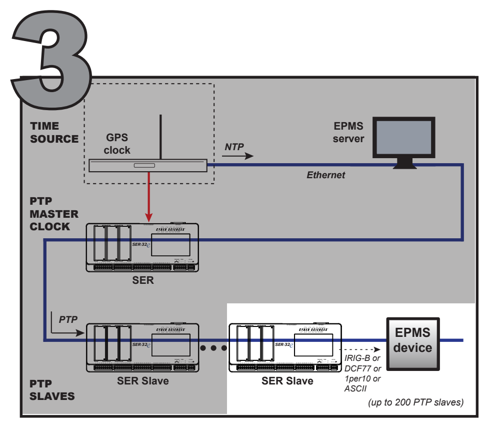
Choose a Time Source

Set the first SER's time from a web browser, EPMS software or NTP server. Optionally, add a GPS antenna/receiver to provide an external time reference traceable to UTC (Coordinated Universal Time), to compare data from other sites or organizations (e.g., electric utilities).



Sync all SERs with Each Other (PTP)

Configure the first SER to output PTP (PTP grandmaster clock); all other SERs on the same Ethernet network sync with each other automatically (within 100 µsec). No special Ethernet switches. No additional setup. Simple, affordable, scalable.



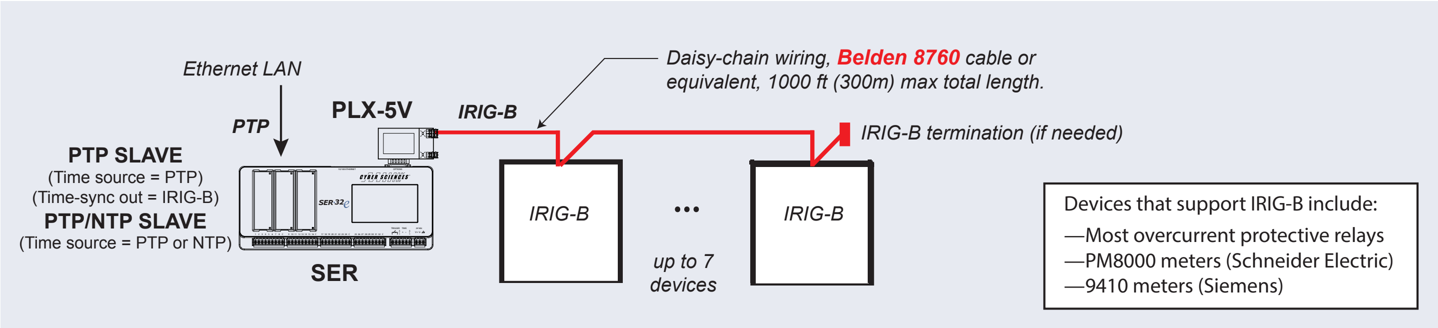
Sync Other EPMS Devices

Sync SERs with other EPMS devices using PTP over Ethernet, all within 100 µsec. No PTP? No problem! For devices that do not yet support PTP, a CyTime SER (PTP slave) can serve as a "time-source" to output the legacy protocol needed (IRIG-B, DCF77, ASCII, or 1per10).

SYNCHRONIZING NON-PTP DEVICES (via IRIG-B)

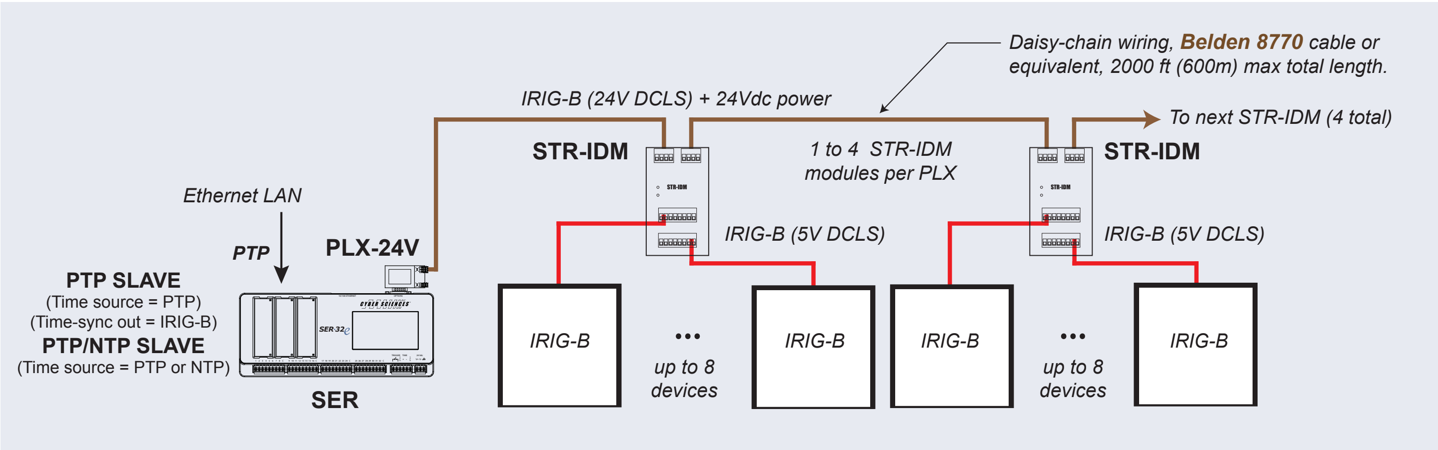
Time-sync Output: Unmodulated IRIG-B (< 8 devices)

A CyTime™ SER (with PTP enabled) can be configured to output the most common form of IRIG-B: unmodulated, or DC Level Shift (DCLS) at 5 Vdc nominal. A PTP Legacy Interface (PLX-5V) connected to the SER DB-15 port outputs the signal at 5 Vdc nominal. This IRIG-B time code supports the full date/time, including the year (IRIG code "B007"), and is compatible with most meters and relays that support IRIG-B.



Time-sync Output: Unmodulated IRIG-B (8 or more devices)

For reliable distribution over longer distances or to a greater number of devices, this same IRIG-B code can be output at 24 Vdc using a PLX-24V accessory. This signal is then distributed (with 24 Vdc control power) via a multi-point connection to "IRIG-B Distribution Modules" (IDM) which in turn convert the signal back to the expected 5 Vdc for point-to-point connection to up to eight (8) devices per STR-IDM or 32 total devices.



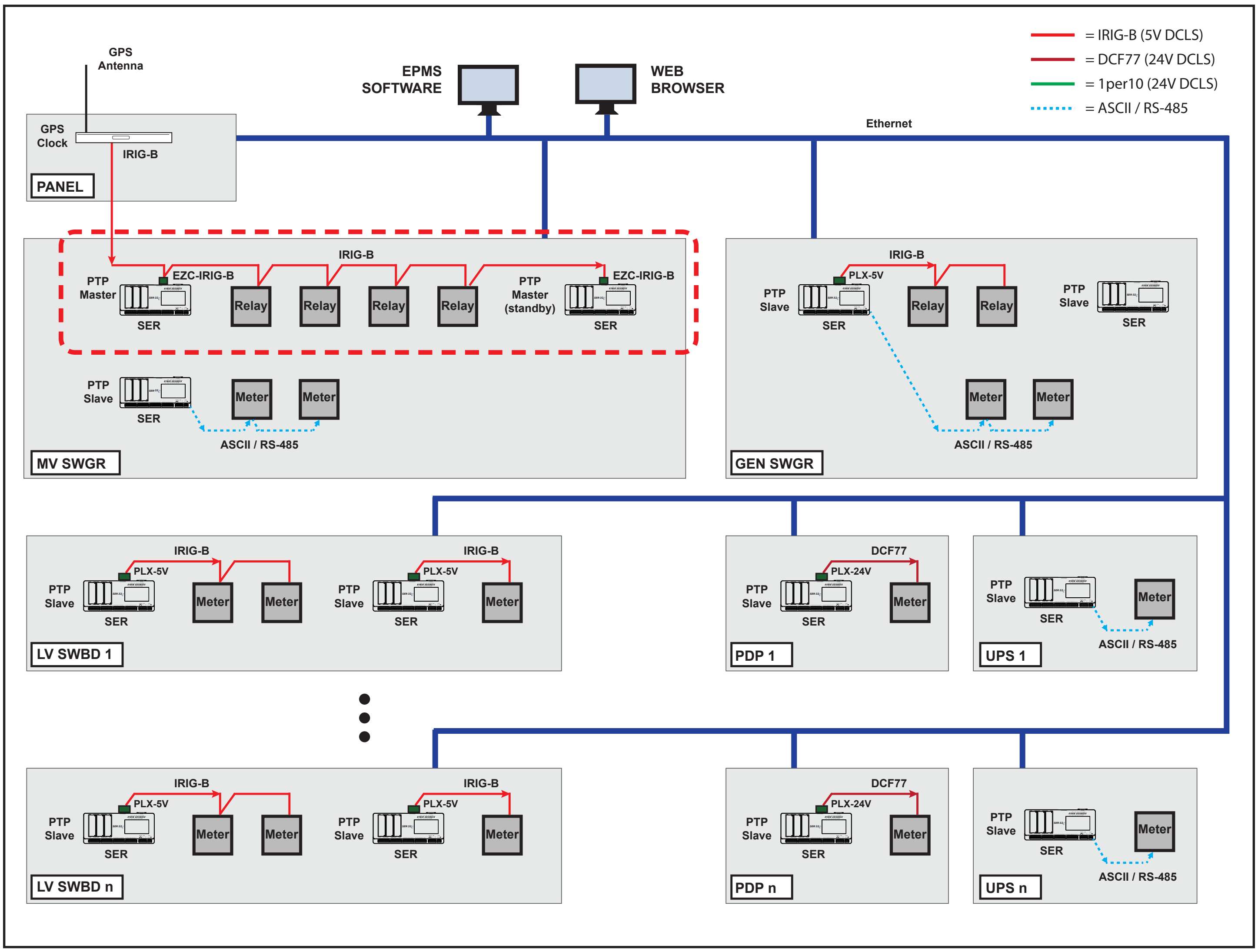
EPMS SYSTEM EXAMPLE (Sync 2 or more SERs via IRIG-B: PTP Master and PTP Standby Master)

An EPMS (Electrical Power Management System) example is shown below that uses PTP for time synchronization over Ethernet, with IRIG-B from the time source (GPS clock) and SERs as PTP time-sync hubs to output IRIG-B to devices that do not support PTP directly.

Time Source. In addition to the first SER, a second CyTime SER accepts IRIG-B as its time source from the GPS clock. In this design, both SERs are configured as a PTP master using the same PTP domain number. Using the IEEE 1588 "Best Master Clock" algorithm, one SER automatically acts as the PTP grandmaster clock, and the other waits in standby mode in case it is ever needed as a backup.

Time Distribution. The first SER (or the backup SER) serves as PTP grandmaster for all other CyTime SERs (PTP slaves), synchronized within 100 µsec of each other. If the first clock fails or goes offline, the backup PTP master becomes the grandmaster clock automatically and remains in service until the other is restored. This ensures reliable, uninterrupted time service to all devices.

Time Conversion. The devices located in other power distribution equipment enclosures are synchronized from a nearby SER, using the protocol needed (e.g., IRIG-B).



EPMS SYSTEM EXAMPLE—High-def time-sync over Ethernet using PTP; two SERs accept IRIG-B from GPS clock, one is PTP master, other is standby

REFERENCES

References

[1] IRIG Standard 200-04: "IRIG Serial Time Code Formats." September, 2004. Range Commanders Council, U.S. Army White Sands Missile Range, New Mexico 88002-5110.

[2] IEEE C37.118-2005 (replaced IEEE Standard 1344). IEEE Standard for Synchrophasors for Power Systems. Institute of Electrical and Electronics Engineers (IEEE). January 1, 2006.

[3] Kennedy, Robert A., P.E., "GPS Time Synchronization: How precision timing and sequence of events recording will make the Smart Grid even smarter," *Electrical Construction & Maintenance (EC&M)* magazine, August 19, 2011, pp. 18-20. http://ecmweb.com/computers-amp-software/gps-time-synchronization

[4] Brown, PE, Bill, and Mark Kozlowski, "Power System Event Reconstruction Technologies for Modern Data Centers," Square D Critical Power Competency Center. Aug. 2006.

[5] Dickerson, Bill, P.Eng., Arbiter Systems, Inc. "Time in the Power Industry: How and Why We Use It."

[6] Dickerson, Bill, P.Eng., Arbiter Systems, Inc. "IRIG-B Time Code Accuracy and Connection Requirements with comments on IED and system design considerations." Publication PD0037300.

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