Digital Fault Recorder

BLACKBOXDFR

Time Synchronization

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BLACKBOXDFR Synchronization Algorithm

Terms

BLACKBOXDFR – Elspec's BLACKBOX Series Digital Fault Recorder | GPS – Global Positiong Sytem | HW – Hardware | NTP – Network Time Protocol | DSP - Digital Signal Processing | IRIG-B - Inter-Range Instrumentation Group | Sync – Synchronization| PQ – Power Quality | PQZIP – Elspec Propriety PQ Compression Technology | RTC – BLACKBOXDFR's Real-Time Clock | Sync Master – Master Clock | GMT - Greenwich Mean Time | SCADA - Supervisory Control & Data Acquisition | PPS – Pulse Per Second | PPM – Pulse Per Minute| In Site – Within the Network Site

Overview

Elspec's multi-functional BLACKBOXDFR is equipped with a unique time synchronization algorithm that secures the highest level of time accuracy available on the market today. It exploits all the universal time source supports such as: NTP (Network Time source obtained by network communication), GPS (GPS time source obtained from satellites), and IRIG-B. The BLACKBOXDFR's propriety HW DSP synchronization ports is a technological breakthrough in the industry standard, ensuring precise synchronization throughout the BLACKBOXDFR network up to a singular device.

The purpose of this document is to examine all the time-synchronization configuration scenarios of the BLACKBOXDFR. It details the algorithm's innovations and deviations from the industry norm.

The Loop Hole In Today's Technology

Many DFR systems use GPS as a time reference. However, GPS receivers and supporting antennas for each measurement device are difficult to install in certain power networks. Time accuracy requires good reception for receiving satellite signals in order to achieve absolute time synchronization. Valid GPS signals usually require an external-to-building installation which in itself makes it expensive and difficult to maintain. In contrast, the BLACKBOXDFR technology provides several flexible and cost-effective alternative configuration schemes that will achieve synchronization higher than GPS level without the need for GPS.

The accuracy of the entire measurement solution and not only the accuracy of a specific GPS receiver device are of utmost importance. Comprehensive system accuracy (over multiple measurement units) is dependent on many aspects and not only on the accuracy of a specific GPS receiver. Some GPS receivers may claim less than 1 micro-second time accuracy; yet, it is not uncommon to obtain the same accuracy level within the measurement device itself. However, this may be highly dependent on the hardware, software and internal algorithm used to synchronize time with the GPS receiver itself. Therefore, many DFR systems available today has 10 milliseconds or generally "milliseconds" **time stamp** resolution the facto. In many cases the providers do not specify the exact deviation among different measurement units installed in the field.

Elspec's unique synchronization technology and configuration schemes ensure not only cost-effective installation and operation but very accurate time synchronization among all measurement units in the field. The algorithm handles all aspects of time accuracy losses resulting in **nano second resolution of time deviation**. Elspec's unique time synchronization algorithm allows accurate synchronization over Local as well as wide

Area Network without the cost and complexity of GPS. The algorithm also ensures time synchronization over five different available time sources: GPS, IRIG-B, Network, HW DSP synchronization and Internal RTC.

RTC is considered to be the 2nd level backup in instances when no other time source is available. The RTC power is backed up using an internal battery, allowing continuous incrimination, even when no power is supplied to the BLACKBOXDFR. The entire process of selecting the time source is automatic both on failure and on the recovery points.

The BLACKBOXDFR's synchronization algorithm is based on several sources with an automatic hierarchy for the preferred source availability (accuracy based hierarchy). The main time source serves as the primary/external time synchronization source whilst the alternative time sources are used as the secondary time source in case the primary source fails. All sources can be configured as either the GPS time source, IRIG-B, NTP time source, or HW DSP synchronization. Table 1 below outlines the accuracy of the BLACKBOXDFR's individual time sources.

Time Source	Accuracy
Internal Clock	±10 ppm
NTP	10µsec
GPS/IRIG B	1µsec
DSP Sync	0.05 – 0.1µsec

Table 1: BLACKBOXDFR Time Source Accuracy

BLACKBOXDFR's HW DSP Synchronization Algorithm

All standard synchronization methods GPS, IRIG-B, NTP, etc., synchronizes the time stamp of the signal. However in a power quality application in general, and especially in continuous waveform recordings, the sampling frequency between devices must be synchronized as well. Meaning that all devices should have the same sampling/cycle ratio that synchronized to the signal zero crossing. In order to obtain such a level of synchronization, the synch pulse should include both time and frequency information.

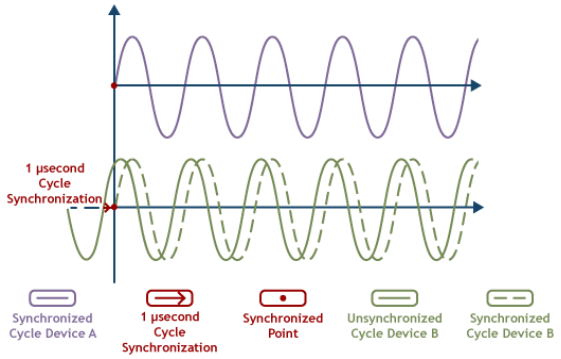

Figure 1a: *DSP Sync – PPS Signal Allignment*

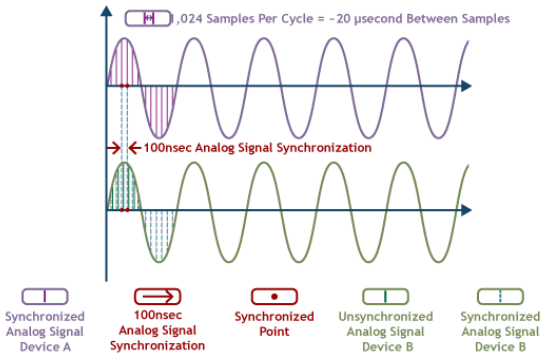

Figure 1b: *DSP Sync – Sampling Frequency Allignment*

Elspec's propriety time synchronization algorithm is a cost effective, yet high performing technology, that is able to achieve a simultaneous synchronized sampling from hundreds of channels in a decentralized redundant architecture.

Each individual BLACKBOXDFR can act as a *Sync Master* and therefore it can be used as a time reference to other units at a time accuracy of **50-100nsec.**

Time Synchronization Configuration

Elspec's BLACKBOXDFR is equipped with the company's patented PQZIP data compression technology that supports three time-synchronization configuration schemes.

Each scheme is described in relation to its functionality and network benefits.

Network-Based Time Source

In most network-based time sources the main time source is set to an external time server. Such a time server is either usually based on GPS; or NTP server equipped with a radio-reception (standard market equipment); or a NTP server computer located at network management headquarters (SCADA); or even a remote internet time server used for the wider internet users.

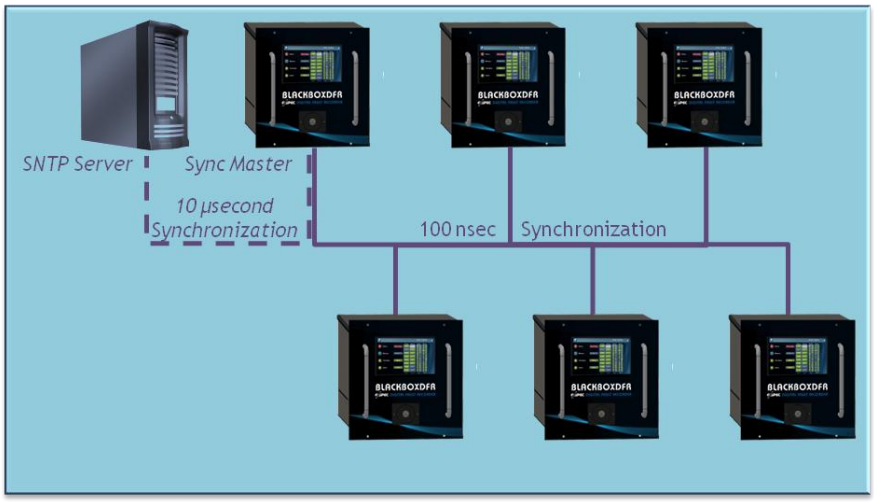

Figure 2: *BLACKBOXDFR NTP Server Synchronization*

As illustrated in Figure 2, in the BLACKBOXDFR technology the alternative time source is designated to a BLACKBOXDFR unit. Each individual unit may also act as a *Sync Master* and therefore can be used as time reference for other units. Such a designated *Sync Master* serves as the centralized site time synchronization element for the entire BLACKBOXDFR network.

The synchronization between units (time and frequency) across the site is more important than the synchronization to the external clock. Therefore, the *Sync Master* automatically holds a higher priority than the NTP server. Practically only the *Sync Master* will be synchronized to the NTP server and all other units will be synchronized in time and frequency to the *Sync Master*.

Should the external time server malfunction, the central unit which acts the *Sync Master* takes control of the time source, keeping time according to the internal RTC reference. The internal RTC is a battery backed-up real-time clock with a typical deviation of less than 10 ppm.

Subsequently, the following time accuracies are achieved:

Expected "in site" time deviation: ±100 [nsec]

GMT deviation with the availability of a NTP server: ±10 [µsec]

GMT deviation without the availability of a NTP server: ±500 [µsec]

The "in site time deviation" parameter can be expressed as the maximum deviation value among all the BLACKBOXDFR units within a site. Whilst the "GMT deviation" parameter can be expressed as the deviation of all units from the GMT (commonly used universal time). The "in site time deviation" is the most sensitive parameter for power quality analysis. Simply because the higher the value, the harder it is to correlate or analyze the effect of power events recorded from different locations.

GPS/HW DSP Sync Hybrid Time Synchronization

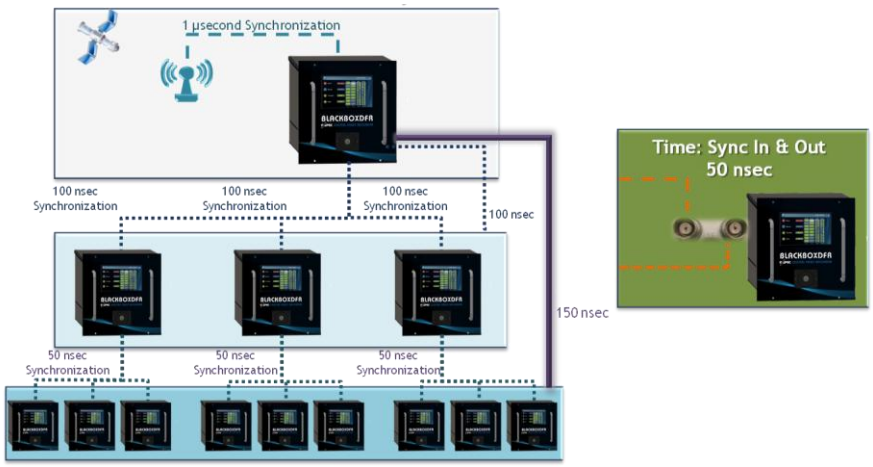

***Figure 3**: GPS/HW DSP Synchronization*

As illustrated in Figure 3, it is possible to configure a hybrid time synchronization scheme using one BLACKBOXDFR with GPS receiver extension module. The remaining BLACKBOXDFR units are configured without a GPS extension, obtaining their time from the BLACKBOXDFR unit with the GPS receiver. This configuration deviates only marginally from GMT as outlined below:

Expected "in site" time deviation: ±100 [nsec]

Expected GMT deviation at the main BLACKBOXDFR unit (with GPS): ±1 [µsec]

Obviously the time deviation for comprehensive system synchronization becomes more accurate using one main BLACKBOXDFR unit with a GPS receiver as time source.

Full GPS Time Synchronization

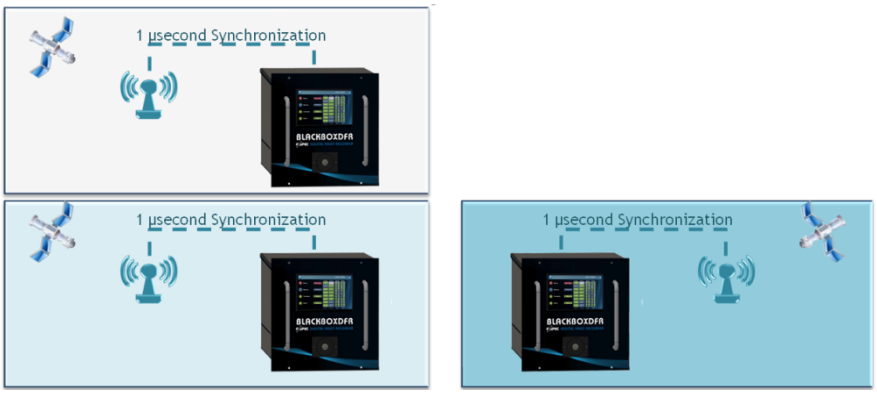

Figure 4: *GPS Time Synchronization*

With this scheme all Elspec BLACKBOXDFR units are equipped with extension GPS modules. By using GPS within all the units, ensures a high time accuracy but no frequency synchronization. Each unit will self-synchronized it sampling to the signal zero crossing. The expected accuracy will be:

Expected "in site" time deviation: ±1 [µsec]

Expected GMT deviation for all the BLACKBOXDFR units within the site: ±1 [µsec]

Whilst the accuracy of such a configuration is high, the implementation cost as well as the operational costs will prove to be more costly than the other available configurations.