

White Paper:

A Master Clock Approach to Distributing Precision Time and Frequency

Traditional time and frequency distribution is defined by splitting and amplifying a signal to as many devices as needed. The distribution amplifier became a mainstay in precision time and frequency systems. Today there is greater access to precision timing considering more clocks in space transmitting global navigation signals and more network connectivity able to maintain higher levels of timing accuracy. A new generation of master clocks is capable of leveraging these trends while offering flexibility to generate the signal types and quantities wherever needed. Distribution amplifiers can still be an important “brick” in the system to meet needs for redundancy, reliability and cost-efficiency. This white paper describes the issue of providing precise time and frequency signals of the type and quantity needed by the application using commercial-off-the-shelf devices from Spectracom.

Introduction

Synchronization is the coordination of events in unison. Like a conductor of an orchestra, synchronizing various devices is important to a well-performing system. In electronics and communications, specific requirements for synchronization can be found in digital broadcast, radio simulcast, satellite communications, telecom, test & measurement, military test ranges, and many more applications. These applications for synchronization aim to solve the problem of distributing precision time and frequency. We typically reserve the term synchronization to describe the transfer of an accurate and stable clock and timescale, based on worldwide time standards, between two time-keeping devices. But sometimes the need for time and frequency distribution does not necessarily involve synchronizing two clocks. Requirements for test and calibration in electronics manufacturing often involves splitting and amplifying a precise frequency source for multiple test stations. Typically this is done with a distribution amplifier. Today, with very flexible master clocks at our disposal, we can solve the problem of time and frequency distribution by synchronizing a clock at a main site and one at a remote site and let these clocks generate whatever signals are required at their respective site.

Trends in Time and Frequency Signals

Like cellular telephony, many communications systems such as land mobile radio, require transmissions to occur at the same time and on the same frequency. This is also true for broadcast services that are increasing bandwidth within limits of available spectrum. Transmitters in these systems need precise control over the carrier frequency and an on-time point to align data streams. So a precise frequency (typically 10 MHz) and a one-pulse-per-second signal continues to be a mainstay in synchronization. As the complexity of transmission sites increases, a well-designed network of distribution of these signals is required. That is one reason why synchronization applications more increasingly leverage an existing network to reduce complexity and decrease cost. The ubiquity of Ethernet and recent improvements in network synchronization protocols such as the emerging Precision Time Protocol standard are now considered for distributing synchronization for more than just computer clock time-keeping. Even telecom providers are solving the problem of providing synchronous services through the inherently asynchronous Ethernet because of the value of overlaying a synchronization distribution network on existing infrastructure. Finally, the use of framed frequencies in circuit-switched communications networks is waning. Similarly the old days of time-of-day synchronization via timecodes to a serial port has passed in all but maintaining legacy equipment that is too expensive to replace.

Signal	Application	Trend
1 pulse-per-second (1PPS)	An on-time point to align signals in the time domain	Depends on accuracy requirements. Used for microsecond level accuracy. Replacement by NTP or PTP if required accuracy > 10us.
Timecodes (ex: IRIG, HaveQuick, NMEA, other TOD codes)	Precision time-of-day. IRIG has strong penetration in military and industrial uses	Similar to 1pps. Replacement by NTP or PTP depending on required accuracy.
Frequency (10 MHz)	Precision waveform, T&M	Frequency distribution, particularly with low phase noise, is needed in many applications.
Framed frequency (E1/DS1)	Telecom sync	Replacement by Synchronous Ethernet and PTP in telecom networks
NTP / PTP	Network computer clock sync	NTP is very mature and robust. PTP emerging.

Time and Frequency Distribution Considerations

For the rest of this paper, we will focus on the key functions associated with time and frequency distribution. Typically it starts with identifying the master clock whose function is to generate the signals for synchronization or distribution in the type and number as required by the application. The most important parameter for time and frequency distribution is the type and number of devices requiring signals. The master clock can be known as a primary reference or, in the case of using network topology, a time server. The devices consuming the signals are known as secondary clocks, slaves or time clients. Another distinguishing feature of the distribution system is often the physical distance between the masters and slaves.

Another consideration for distribution is to maintain, as much as possible, the critical characteristics and properties of the signal. In other words, the distribution path needs to ensure integrity and accuracy of the signal and be immune to effects such as EMI that may apply noise to an unacceptable level.

As time and frequency signals tend to be at the core of the application, distribution network needs to be very reliable. For instance, a time and frequency distribution system may allow for redundancy of the master clock as it is generally a single point of failure. Manageability is another aspect of reliability. Considerations extend to how the distribution system will be continuously validated and maintained, for instance, the need to scale for later expansion.

There may be security requirements of a time and frequency system. A distribution system may cross security boundaries precluding the use of certain connections that may pose a security risk.

Time and Frequency Distribution Architecture Examples

Distribution to distant site	Synchronization performance	Redundancy considerations	Spectracom models	Figure
GPS/GNSS	20-200 nanoseconds	Redundant source via multiple satellites and other GNSS systems, master can accommodate loss of reference using a variety of schemes.	SecureSync, Epsilon Clock	A1
GPS/GNSS	20-50 nanoseconds	Redundant master clocks via an independent switch	SecureSync, Epsilon Clock, SAS-E	A2
Fiber Optics	200-3,000 nanoseconds	Dependent on master	SecureSync, DA-36	B
Network	10 milliseconds to 1 microsecond	Network protocols accommodate redundant masters	SecureSync	C

GPS/GNSS provides timing everywhere

Undoubtedly GPS has become the defacto standard for time and frequency distribution. It is highly precise and available. It offers information for traceability to national and international standards and it is being supplemented by improved receiver technology and the deployment of other global navigation satellite systems (GNSS). As shown in figure A, the role of the master clock is to use GPS as the primary reference for synchronization and to generate the exact type and quantity of signals as is required by the application. The aspect of distribution afforded by GPS is the ability to locate the same type of master clock in any location, either next door, or around the world, and be rest assured that the signals in the local distribution network are in sync.

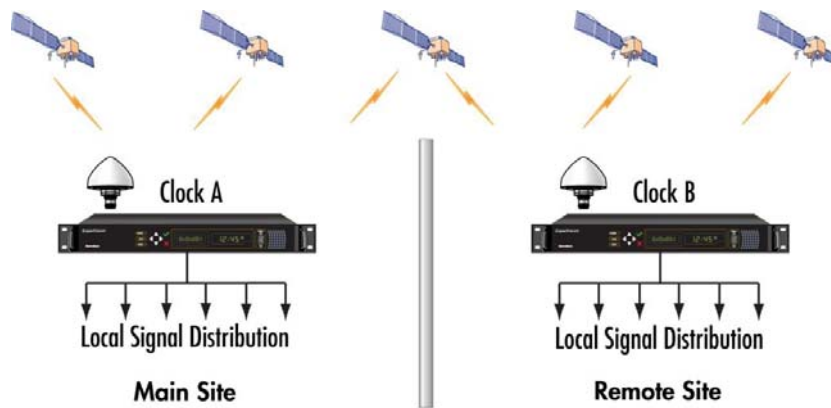


Figure A1: Using Satellites GPS/GNSS to Distribute Time & Frequency across Sites

While various redundancy strategies can account for the loss of GPS as the primary reference (other GNSS systems, other local references, or built-in high quality oscillators for accurate internal time-keeping), the master clock itself is a single-point of failure. A separate switch and amplifier device is typically the solution. It generates multiple signals from the output of one master and automatically switches to the output of another master in the case of failure of the first. See figure A2.

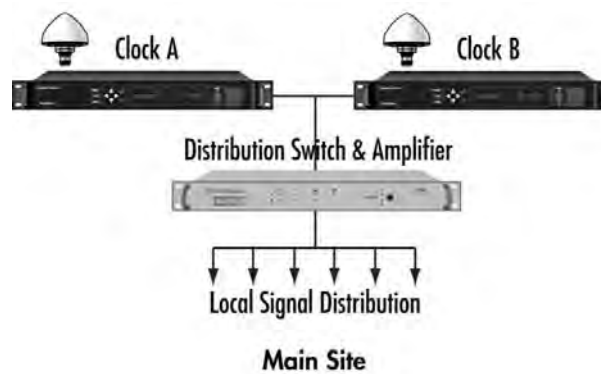


Figure A2: Local Distribution with Redundant Master Clocks

Fiber optic distribution to remote sites

When it does not make sense to deploy multiple GPS master clocks across the entire scope of the time and frequency application, we can consider various means of distributing signals from a single master clock to a remote site. Fiber optics can be used to connect sites across thousands of meters with good EMI immunity. In this case, devices are used to convert “copper” signals through optical transmitters and receivers.

There are 2 strategies for distribution over fiber optics. Figure B1 shows a more traditional distribution approach with only one master clock deployed at the main site and a distribution amplifier deployed at distant sites. The master clock generates the signal to be distributed and converts it to optical signals. The role of the distribution amp is to convert it back to electrical signals for local use and further distribute the signal by fiber (or coaxial cable).

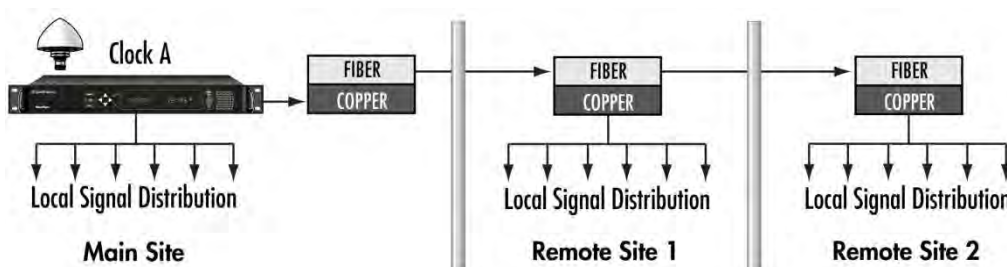


Figure B1: Fiber to Copper Distribution of One Type of Signal across Sites

An alternative is provide for a master clock at each site, synchronize them in a master and slave arrangement via fiber optics, and allow each clock to generate the signals for the local devices. The signal required at the remote site does not necessarily need to be the same as required of the local devices. See figure B2.

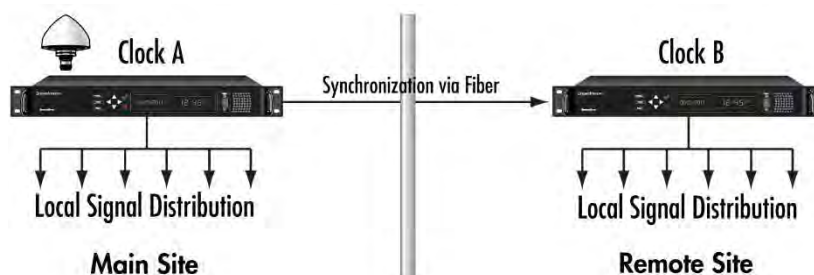


Figure B2: Local Signal Distribution via Master-Slave Clocks

Network distribution to remote sites

Using the same concept as fiber optics, we can consider synchronizing clocks at distant sites via existing network infrastructure, and reconstituting local timing within a slave clock. With the advent of Precision Time Protocol (PTP IEEE-1588) Ethernet networks can be used to transfer time and frequency across networks at sufficient precision for many applications. Previous network protocols such as NTP did not have sufficient accuracy for anymore than synchronizing computer clocks for time stamping network events. Although it requires “instrumenting” the network for careful management of asymmetric network delays, PTP can be accurate enough for slave clocks to generate a wide range of signals. See figure C. Network protocols also have the advantage of providing built-in redundancy by employing various algorithms to detect “best” masters, etc. and provides performance data for remote monitoring.

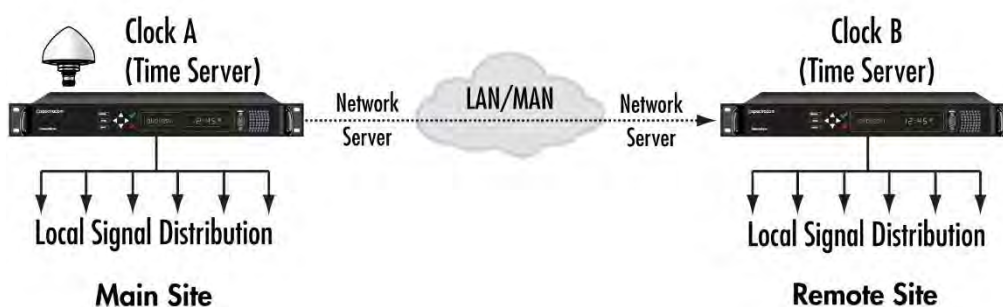


Figure C: Local Signal Distribution via Network Sync

Example of Commercial Devices

Model	Type	Signals	Features
SecureSync	Master or slave	Supports all signals	Modularity, 1RU, network server/PTP grandmaster/slave
Epsilon Clock	Master	10 MHz and 1PPS	Includes ~7 channels plus a configuration with redundant GPS clock modules and built-in switch
SAS-E	Switch and amplifier system	10 MHz and 1PPS	8 or 16 channels with switching for redundant master clocks
DA-36	Fiber 10 MHz distribution system	10 MHz	1 optical/1 coax input, 1 optical/4 coax output
TSync	Plug-in slot card and board level	Various	GPS receiver, PTP PCI express slave

SecureSync

SecureSync is a modern time and frequency synchronization instrument that employs modularity via a large selection of modules. It can be used as a master clock in any scenario described previously with a built-in GPS/GNSS receiver. It also can use a wide variety of other references as primary or back-up with optional internal oscillators for internal time-keeping. As a network appliance, it uses network



protocols for manageability and it is a high performance NTP server with several options for PTP master and/or slave. For distribution applications, SecureSync can be deployed in master-slave pairs via fiber optics or network infrastructures as shown in scenarios B and C respectively. One SecureSync is deployed as the master (with GPS receiver or similar reference). This clock generates as many signals as the local site requires. A second SecureSync is slaved to the first using a number of schemes such as IRIG timecode over fiber optic cable. Similar to its master, the slave generates as many signals as the local, secondary, site requires. This approach can support a certain degree of redundancy through its ability to prioritize and automatically switch references.

The SecureSync has one particular option module designed for redundant masters in the case of 1PPS or 10 MHz. The revertive selector option will pass an external signal from a redundant source even if the host unit fails.

Epsilon Clock

Epsilon Clock is designed for digital broadcast applications. It generates a number of 1PPS and 10 MHz signals for transmitters that can be described by scenario A. The 1RU version, EC20S, has 7 pairs (channels) of these signals. The 2RU EC22S has hot-swappable redundant GPS clock modules and a built-in switch in case of failure of the primary module. It generates 8 channels of 1PPS and 10 MHz signals. Both modules can be remotely managed via SNMP and a web browser.



SAS-E

The Switch and Amplifier System takes an input from a master clock and amplifies up to 8 (1RU) or 16 (2RU) pairs of 1PPS and frequency signals in the range of 1-16 MHz. Special configurations can include IRIG DCLS signals. The SAS-E can be managed by a web browser. It has a built-in switch for redundant master clocks as shown in scenario A2.



DA-36

This fiber distribution unit receives a 10 MHz signal from any master clock source and generates a fiber optic signal for distribution as well as 4 - 10 MHz output signals for local distribution. A series of DA-36s can be deployed as in scenario B1 where each unit can serve 4 stations that require a precision 10 MHz source.



TSync

For completeness, we mention Spectracom's line of board-level timecode reader/generators. They can accept a variety of external references including GPS to discipline an on-board precision oscillator. Software can access the board's precision time through the host computer and various time and frequency signals can be generated to external devices.



Conclusion

Precision time and frequency applications involve the transfer and distribution of various signals. Although precise, traceable and free time is available via GPS and other GNSS signals, it takes careful planning and deployment to generate synchronous signals of the type and quantity across the entire geography of the application. While many commercial-off-the-shelf hardware is available to distribute the necessary signal types and quantity, today's flexible master clocks and the trend toward improved network synchronization offer more possibilities than ever. Spectracom helps its customers build secure, reliable and cost-efficient solutions for synchronizing your application for precision time and frequency.

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