




A GUIDE TO TIME



The importance of time synchronization
in the power industry.



TEKRON
INTERNATIONAL

A close-up, artistic photograph of an hourglass. The top bulb is filled with a dark teal liquid, which is dripping through the narrow neck into the bottom bulb. The liquid in the bottom bulb is a lighter, more translucent teal. The background is a solid, light teal color. The overall composition is clean and modern.

“All GREAT
■ achievements require
time.”

Professor David J. Schwartz

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Section 1

Welcome To Tekron International

For almost a decade we've focussed on the research, design and manufacture of GPS time clocks and time synchronization systems.

Time synchronization is only a small element in complex, rugged network environments, but it is fundamentally important to their effective operation. At Tekron we are committed to providing the best devices for synchronizing time.

This guide provides an overview of why time is so critical for rugged networks - especially in the energy sector - and the solutions Tekron has developed for our customers to be certain about that fundamentally important question - what's the time?

Tekron. When you need to be certain.





Origins of time measurement

While time is an enduring and fundamental human concept, our ability to measure and use it is constantly evolving and improving.

Existing time measurement goes back more than 4000 years to the Sumerian people based in what is modern day Iraq. They developed the "sexagesimal" system we base our timekeeping systems on today, using the number 60 - 60 seconds in a minute, 60 minutes in an hour.

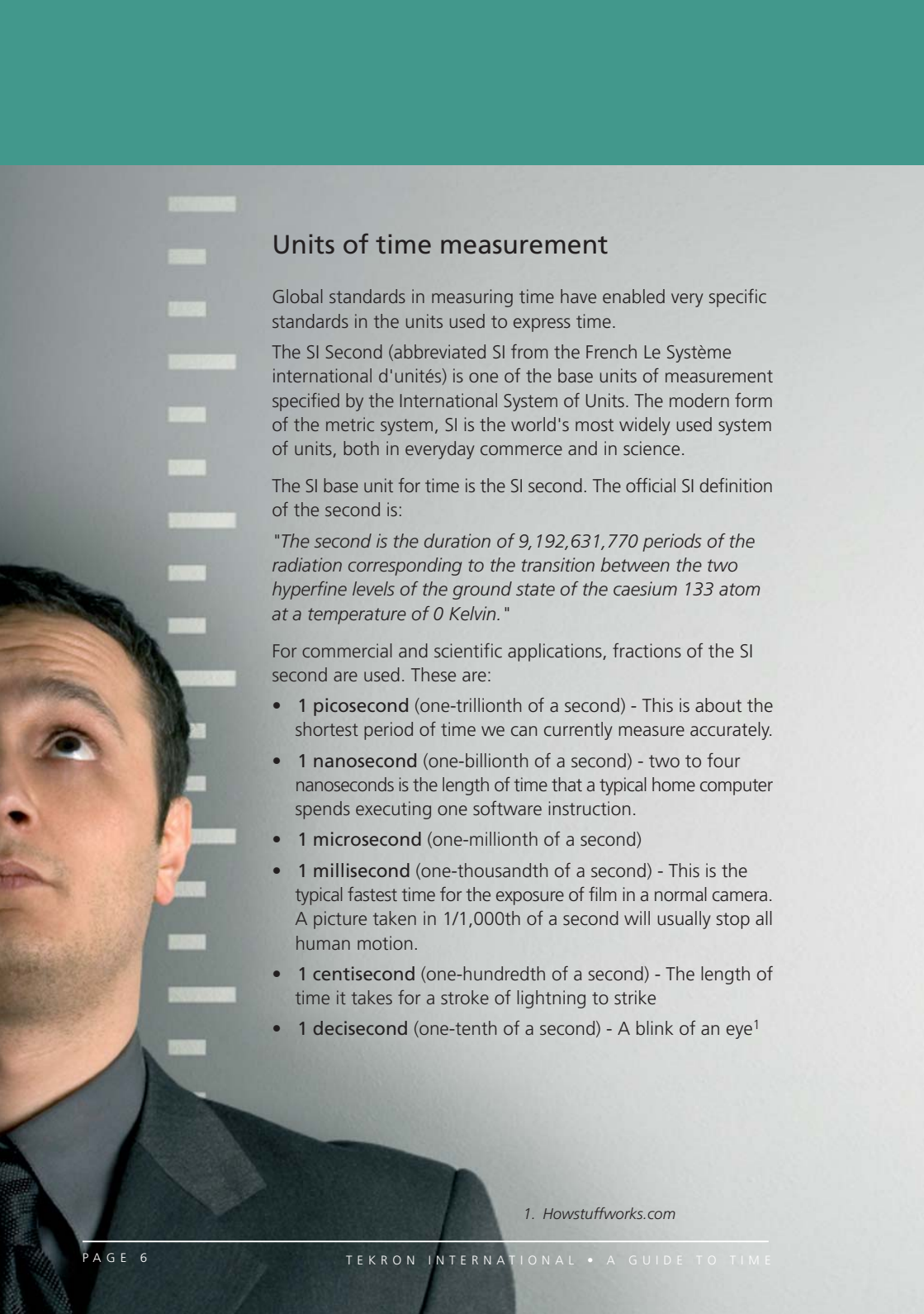
Over human history our ability to measure and record time has developed. From sundials to water clocks to sand-based hourglasses, humans have always tried to measure time to help advance its endeavors.

The English term for clock comes from one of these early methods of measuring and progress. It was derived from the Latin word for bell, as progress at sea was initially measured by tolling bells every hour.

Advance forward to today, where technological progress has transformed our measurement of time.

Atomic clocks can deliver time to an accuracy of one second in 60 million years. The development of the atomic clock led to better global standardization of time, and services as the basis of the Coordinated Universal Time (UTC) standard.

Global Positioning Systems (GPS) benefit from atomic time. Each of the 24 GPS satellites carries four atomic clocks on board. By triangulating time signals broadcast from orbit, GPS receivers on the ground can pinpoint their own location. A GPS clock uses these signals to compute exact time.



Units of time measurement

Global standards in measuring time have enabled very specific standards in the units used to express time.

The SI Second (abbreviated SI from the French Le Système international d'unités) is one of the base units of measurement specified by the International System of Units. The modern form of the metric system, SI is the world's most widely used system of units, both in everyday commerce and in science.

The SI base unit for time is the SI second. The official SI definition of the second is:

"The second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom at a temperature of 0 Kelvin."

For commercial and scientific applications, fractions of the SI second are used. These are:

- **1 picosecond** (one-trillionth of a second) - This is about the shortest period of time we can currently measure accurately.
- **1 nanosecond** (one-billionth of a second) - two to four nanoseconds is the length of time that a typical home computer spends executing one software instruction.
- **1 microsecond** (one-millionth of a second)
- **1 millisecond** (one-thousandth of a second) - This is the typical fastest time for the exposure of film in a normal camera. A picture taken in 1/1,000th of a second will usually stop all human motion.
- **1 centisecond** (one-hundredth of a second) - The length of time it takes for a stroke of lightning to strike
- **1 decisecond** (one-tenth of a second) - A blink of an eye¹

1. Howstuffworks.com

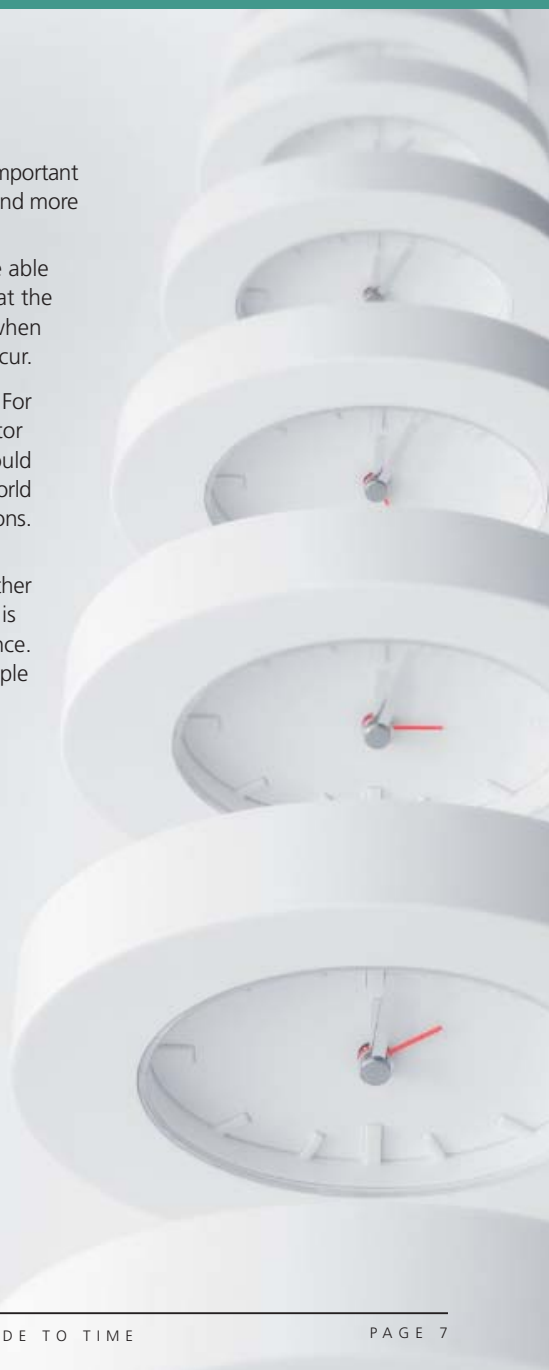
Time synchronization

Time synchronization has become more important as technology has become more global and more integrated into our daily lives.

To work effectively networks have to be able share time. This allows events to occur at the proper time and also provide proof of when particular events occurred or did not occur.

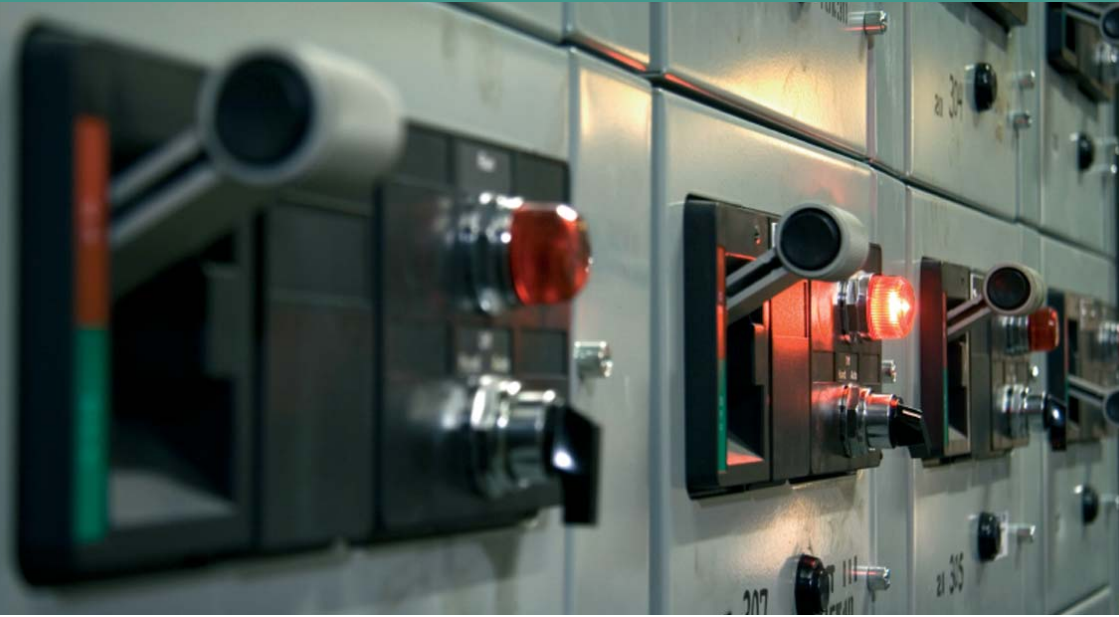
Time plays a key role in many industries. For example, the international financial sector could not operate effectively unless it could synchronize time accurately around the world to enable proper sequencing of transactions.

While certainty about time in financial transactions is measured in seconds, in other more complex industrial applications, it is parts of seconds that makes the difference. The power industry is the clearest example of this.



Section 3

Time synchronization and the power industry



The generation and distribution of energy is a sophisticated, mature industry with a huge range of proven technology. Synchronizing generators, ie. keeping them in phase at 60 cycles per second across an electricity grid, is a common and accepted part of their safe and effective management around the world. Not doing so would result in energy wastage and ultimately serious damage to the system. Consequently synchronization has been built into core power system design for many years.

Of growing importance is making time synchronization an integral part of the increasingly sophisticated control systems that are crucial to managing the modern power utility. Time synchronization plays a pivotal role in two key areas:

1. Improving the accuracy of fault diagnosis and the subsequent quality of decision making, helping to reduce down time.
2. Ensuring electricity networks are operating efficiently within system limits by helping increase the accuracy of control decisions by automatic control and protection equipment.



Crisis put focus on time

The multiple blackouts across the Northern Hemisphere in 2003 have been well traversed in the power industry. Major reviews of the way power systems were managed resulted from these near catastrophic events.

Industry and consumers were shocked when blackouts first hit in North Eastern USA and the adjacent Canadian Provinces. Similar failures subsequently occurred in London, then Birmingham, followed by Italy, France, Scandinavia and even Malaysia. Despite assurances by the CEO of National Grid in the UK that blackouts like the one in the USA could not happen "here", London suffered one of its worst ever outages.

Two common themes emerged in the analysis of the 2003 blackout events.

One, power system grids all over the world are being operated with less reserve capacity than ever before as utility owners strive to gain the best possible economic returns from their existing assets.

Two, the management and supervisory systems set up to operate and control the power systems are struggling to cope with the increasingly complex grid interconnections demanded by the deregulating energy markets.

Official reviews² of the 2003 blackouts note that in many cases, data collected from sub-station equipment was not time-stamped at all, and in other cases, the time stamps recorded were not synchronized across the network.

Recommendations were made that power utilities should take steps to ensure that power plants and substations control and supervisory data recorders are synchronized using the Global Positioning System (GPS)³. This was because there was a realization that time synchronization significantly simplifies fault analysis in the aftermath of a fault situation even between networks. In addition, it also increases the accuracy of control decisions by automatic control and protection equipment in the power network, therefore allowing optimal utilization of network assets.

2. *The NERC/US-Canada Power System Outage Task Force report on the North American blackout on August 14 2003*

3. *US-Canada Power System Outage Task Force 'Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations', Recommendation 28, p162.*

The growing importance of time synchronization

The synchronization of the AC power grid is of primary importance to grid operators. Lack of synchronization between generators can result in large amounts of energy being dissipated within the grid system with spectacular and catastrophic damage to assets and possible danger to human life. These major synchronization issues have been addressed in power system design since the earliest days of electrical energy use and techniques for synchronizing generation to the grid are generally well established and executed.

However, somewhat less attention has been paid to the need for synchronization of the protection, control and supervisory equipment that is an essential part of a modern power utility substation. Historically, primary protection equipment was designed to trip supply at a substation based on local operating conditions exceeding a set of pre-defined criteria. Protection relays were largely electromechanical devices. Automatic recording of data from such devices was simply not available - nor was it seen as particularly important, as the supply grid was a relatively simple network with minimal interconnect paths.

Growth in demand, together with privatization and increasing de-regulation have led to a vastly more complex grid structure in which power can be switched to flow over multiple different paths on a second by second basis. The factors influencing power flow paths within the grid are no longer related solely to technical issues of demand, generation, and optimized grid use, but also to external market issues such as the spot price of power generation offered from competing generating companies. Consequently, the need for closer monitoring and control of power utility network assets over a wide area arises, and continues to grow.

Current and emerging industry practice

While the basic function of a protection relay remains the same today as it has always been, modern protection relays and other IED (Intelligent Electronic Devices) installed in substations offer a host of monitoring and control functions that can generate large amounts of real time data about the operating state of the power system. In addition to the obvious parameters such as voltage, current and frequency, real-time measurement and recording of phase-angles, transients and other parameters relating to power quality is now a practical reality.

In an ideal world, such data would be captured by standardized SCADA (Supervisory Control and Data Acquisition) equipment located in each substation and transmitted

to a central control point - the Regional Control Centre for the power company - where decisions, both automatic and manual, could then be made to ensure the continued safe, secure and high quality delivery of power over the grid network in the region.

In addition, the field data would be sent on to a National Control Centre and there combined with similar data from many other Power System Operators to form an ongoing real-time picture of the instantaneous state of the National Grid.

For this ideal to be even remotely realizable, it is necessary to ensure that the incoming real-time field data be captured together with an accurate indication of the date and time of day that each data point relates to - i.e. a timestamp. The various system design approaches that are used to try and achieve this are discussed below.

Approach 1: Control Centre Reference Clock

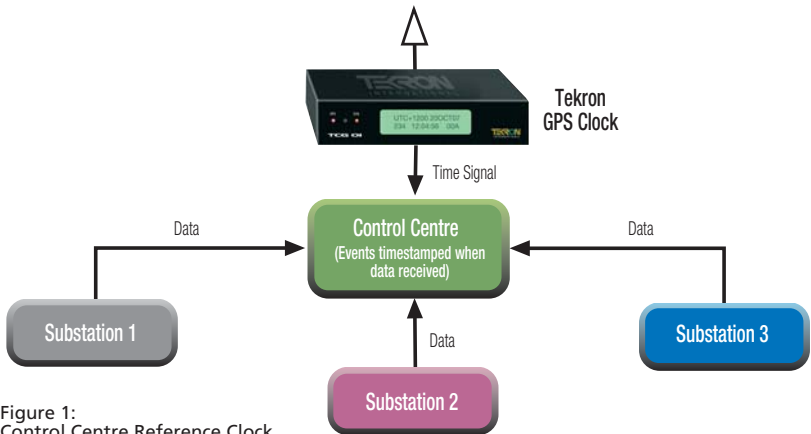


Figure 1:
Control Centre Reference Clock
Accuracy = hundreds of milliseconds
(10^{-1} secs)

The first-generation response to the issue of time-syncing substation data involves a single clock acting as a master time reference and located in the control centre. Each incoming data message from SCADA equipment located in individual substations has a timestamp added to it as it is received at the control centre.

This system has the obvious advantage of requiring investment in just one accurate clock per control centre and as control centers are usually manned, they typically provide office-like environments in which a commercial-grade GPS-controlled clock can be readily deployed.

However, the accuracy of the timestamps relative to the event that generated the data is dependent on several factors. If the communications links between each of the substations and the control centre are always predictable in terms of the delays between transmission and reception, then a fixed offset is able to be made to the timestamp to approximate the transmission delays and hence provide an approximation of the time an event actually occurred.

Unfortunately, real SCADA communication systems are not usually so predictable. Typically, within each substation, data from a number of sources (Protection Relays, IEDs) is combined in a communications data concentrator, and then transmitted to the central control location - often in response to a polled request from the control centre. This method of operating is known as "store and forward" messaging.

Depending on how many substations are being polled, how much data needed to be transmitted from each substation, how fast each transmission channel is, and what the channel error rate is like, the delays can vary by hundreds of milliseconds to seconds or even tens of seconds. In addition, the communications protocols used within the substation to gather the data from the originating equipment to the concentrator adds further timing uncertainty.

In practice, time-stamping at the control centre is not reliable and accurate enough to be of practical use in control decision-making - in fact - it is often misleading, as the very presence of a timestamp implied an accuracy that is simply not valid.

Approach 2 : System Wide Time Signal Propagation

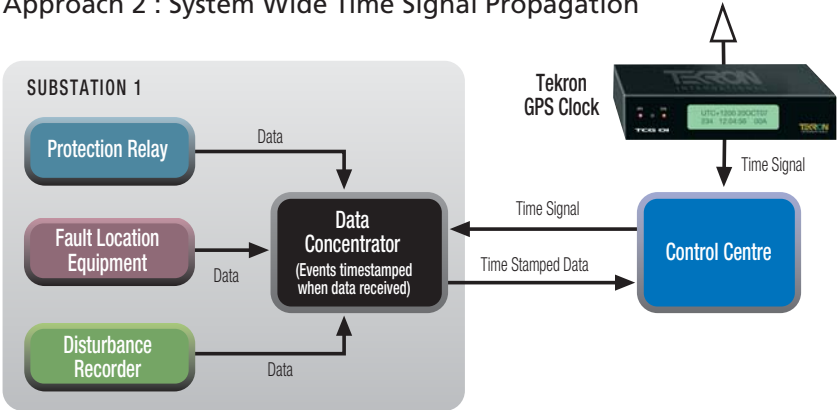


Figure 2 : System Wide Time Signal Propagation
Accuracy = tens of milliseconds (10^{-2} secs)

The second generation approach to time synchronization attempts to reduce the margin of error by applying the timestamps at a point closer in time and space to the actual event.

This is achieved by having the data concentrators in each substation maintain accurate time, and then applying the time stamps to the data as it arrives at the concentrators from the equipment in the substation.

The concentrators receive synchronization signals from the central control point periodically to assist them to maintain their internal time. Using this method, the data concentrators in different substations can be synchronized to within a few tens of milliseconds or better depending on the communications technologies used.

This approach requires a more intelligent concentrator than Approach 1. The timestamp accuracy obtained can be considered sufficient for some situations, but is usually well short of the sub-millisecond accuracy required to track modern IED state changes, and also well outside current recommendations for the industry.

Approach 3 : Individual Substation GPS Clocks - Data Concentrator Time Sync

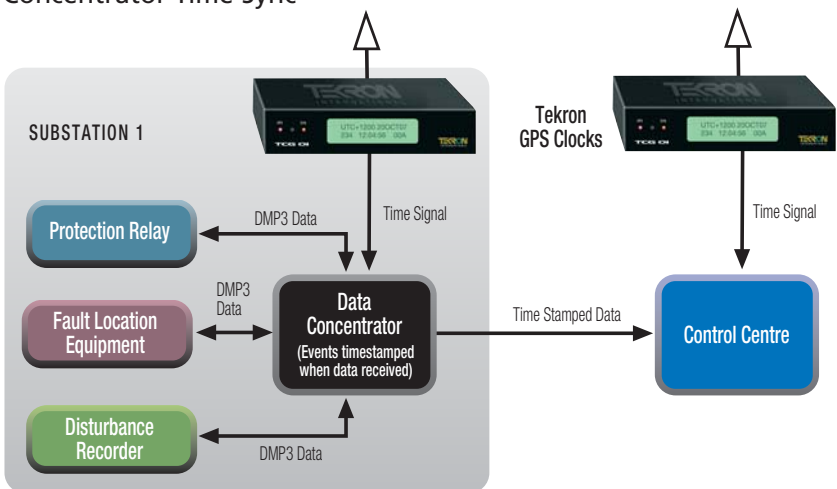


Figure 3 : Individual Substation GPS clocks - Data Concentrator Time Sync
Accuracy = milliseconds (10^{-3} secs)

The advent of relatively cheap GPS-controlled clocks means that it is now economically viable to deploy a time source that effectively offers close to atomic clock performance in each substation, thus making possible network wide, continent or even world-wide synchronization.

Many substation installations have just used the GPS clock to provide an accurate time source for the data concentrator in the sub-station, replacing the synchronization signals from the control centre.

While this configuration is an easy practical upgrade from that of Approach 2, in most cases, it fails to deliver reliable results.

The reasons for this are that this approach still relies on the substation data concentrator to either apply time stamps to incoming data, or to resend time information out to attached equipment over the substation internal communications links. In most situations, the communication paths between the concentrator and the other devices use protocols that are indeterminate. That is, data transmission delays between devices may vary depending on the volume of data that is moving across the network at any given moment. Although some link protocols in common use (such as DMP3) do allow for the propagation of time information, they do NOT guarantee a high degree of time precision on the data transmitted.

While systems configured in this way may deliver satisfactory time-stamping performance under normal conditions, it is when the internal substation communications links become heavily loaded with data originating from multiple devices simultaneously that concentrator-based time stamping becomes compromised reducing the accuracy of the timestamps applied to the incoming data to milliseconds or tens of milliseconds. Communications traffic peaks are most likely to occur when power system conditions are changing rapidly - such as in fault situations - precisely the kind of events that are important to track accurately.

In summary - the moments when reliable performance from the time synchronization system is critical are the same moments that this approach is most at risk of failing to deliver.

Approach 4: Individual Substation GPS Clocks - Dedicated Time Sync Bus

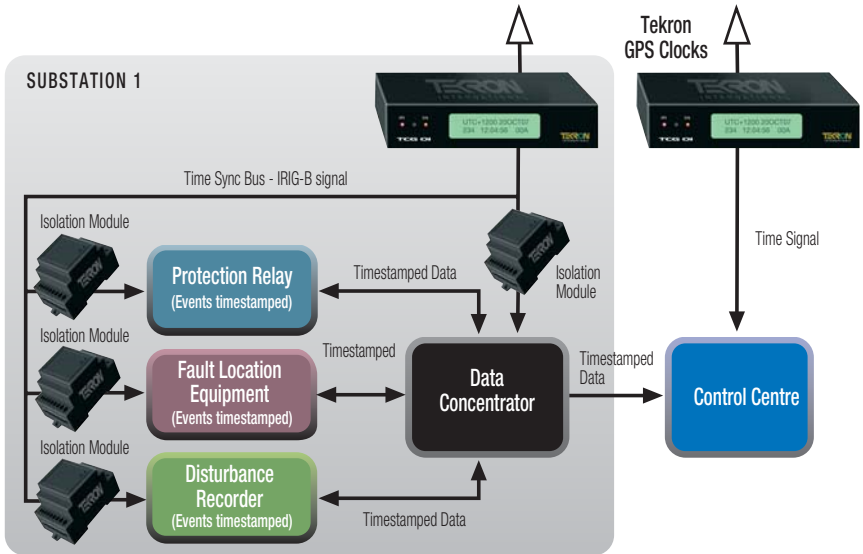


Figure 4 : Individual Substation GPS clocks - Dedicated Time Sync Bus
Accuracy = microseconds (10^{-6} secs)

The investment in an accurate GPS-controlled clock in each substation is best utilized by the installation of a dedicated time synchronization bus system delivering time signals directly to all "front-line" equipment such as protection relays and IED equipment.

With such a system in place, time stamping is done at the precise point in time and space that an event is first detected, and the timestamp becomes an integrated part of the data associated with the event.

While subsequent communication delays may still result in the data arriving at control points at some varying later time, the data already carries with it full details as to the precise time of the actual event - not an estimate.

Practical time sync bus systems can deliver microsecond accuracy, providing the precise timing required for the latest synchro-phasor measurement techniques.

It is now economic to provide a bus system of this nature combined with ethernet time server functionality in a single compact package that caters for both existing and emerging synchronization requirements in substations and elsewhere.



Time Sync Signal Bus Implementation

Most modern Protection Relays and IED can be fitted with an input port to accept a time synchronization signal - the most common being the IRIG-B time code. (See Appendix for more detail on the IRIG-B time code).

A time signal bus can be realized by using a single-pair cable carrying the time code signal from the GPS-controlled clock output to all of the equipment that requires synchronization on a "multi-drop" basis. That is, the synchronization port on each piece of equipment is connected across the two-wire line (via an isolation module) so that the line drives all of the equipment in parallel. (See Fig. 4) As the time code is a unidirectional signal (transmitting from the GPS clock) it lends itself to this simple "one to many" approach.

However, there are some key issues to be addressed in the time sync bus system design to ensure reliable results.

(a) Bus Loading

In a typical installation, there may be ten, twenty or more devices to be driven by the timing signal. Each device presents a load to the bus, and all the loads combine to present a total loading to the GPS clock source.

Different makes and models of equipment can have different input port specifications, so it is important that the total load be calculated with reference to each device's specification, and that a clock source be selected that can drive the total bus loading while maintaining full output signal level. If isolation modules are used to drive groups of equipment in each rack or bay then obviously this calculation is much simplified.

(b) Noise Immunity

Within the substation, metallic signal paths are subject to possible interference due to electromagnetic noise. Time code signals are usually low level (e.g. 0-5V), so relatively small voltage spikes induced on to the two-wire line are sufficient to render the signals unusable.

Good noise immunity can be achieved by ensuring that the two-wire bus is "balanced" with respect to station earth potential. In this case, provided that the two wires of the bus feature close electromagnetic coupling (a characteristic of twisted pair cables), any noise voltages are induced identically into both wires and are thus "invisible" to the receiving equipment.



(c) Galvanic Isolation

During earth fault conditions in a substation, large, short duration earth currents can occur. Such currents can cause the earth reference potential to vary dramatically across the station, sometimes by hundreds of volts or more. Communication and control signaling lines that signal with respect to station earth cannot operate reliably or safely under these conditions.

It is important therefore, that such signals are isolated from ground, and depending on substation layout, further isolation may be required on signal lines as they are distributed across different bays and racks. Without "between bays" isolation, it is possible that an equipment failure in one bay could be promulgated to equipment in other bays via the interconnecting control signaling cables.

Galvanic isolation also provides balanced line conditions, thus providing the bonus of good noise immunity of the signals. Fig. 4 shows an IRIG-B time signal distribution system providing synchronization signals to both control equipment and high voltage protection equipment while preserving isolation between them.

Optical fiber can also be used to convey time synchronization signals - thus overcoming both noise and isolation issues. However, optical fiber cannot be used in a "multi-drop" configuration. Systems configured with optical fiber must therefore either provide individual fiber drives to every piece of equipment - a logistical challenge if there are large numbers of devices to be synchronized, or use repeater devices at every point where a drive output is required. While optical repeaters for purely digital signals are now relatively inexpensive, if analogue (AM modulated) timing signals are required to match equipment input specifications, the expense of the optical signaling equipment usually makes their use non-economic in this application.

A major timing issue: effective isolation

It is a long established practice for protection and control equipment in substations to be required to have isolation between all inputs, outputs and earth.

Standards such as IEC60255 specify isolation levels, for different classes of exposure, up to 2 kV rms for 1 minute.

The reason for the requirement is to minimize risk of damage and equipment failure not just during fault conditions but also while normal high voltage switching operations are in progress.

Problem 1: Output Isolation

Low voltage control signals, such as TTL time sync signals, have traditionally been distributed in a substation using coax cable to ensure adequate noise immunity for the signal. By connecting the coax shield to station earth, external interference coupling into the signal circuit is minimized. The coax cable is then "multi-dropped" to feed multiple devices using BNC "Tee" connectors in an Ethernet bus-like architecture.

Under normal operating conditions, this works reasonably well, however, there is a problem. When fault currents flow through the station earth grid during a significant event, potential differences arise across the substation earth grid.

These cause high instantaneous noise current to flow in the earthed outer shield conductor of the coax, which seriously interferes with the signal. Furthermore, if the coax cable is inadvertently earthed in more than one place, currents flowing in the shield conductor are likely to damage the cable. Just when its integrity is needed the most, the now corrupted time sync signal is distributed to all connected devices throughout the sync system.

Imperfect Solutions

One potential solution is to have a clock with multiple outputs to individually feed each device, or group of devices, that need the sync signal. The drawback of this approach is the amount of cabling that would be needed.

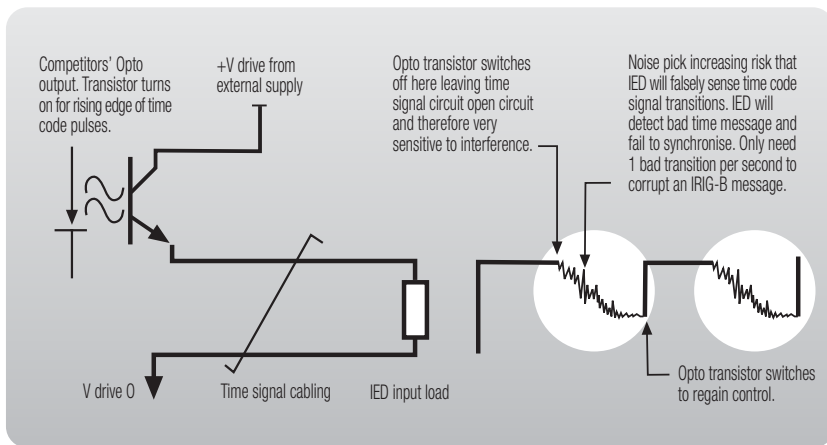
A more economical solution is a clock with an isolated output to drive balanced twisted-pair cable. The problem of potential gradients within the earth system is solved because now noise currents cannot flow to earth along the time sync distribution wiring.

In theory, this would allow a twisted-pair multi-drop distribution of sync signals, with associated savings in the amount of wiring. However, there is still a potential problem due to the way in which the isolated outputs are developed in the clock.

Most clocks use opto-isolator devices internally to provide a solid-state "contact closure" or "dry-contact" at their outputs. This is an economical way of providing isolation, but the outputs are asymmetric - that is, they can only control current to the load in one direction, either source or sink, when the output turns on. The user must provide an external power supply for the time signal circuit. When the clock output switches off the timing signal wave shape is dependant on, external noise influence, wiring impedance and load impedance. It is no longer controlled by the clock output.

In order to drive multiple devices with the sync signal at any distance from the clock without affecting signal timing and preserve noise immunity, the load must be low impedance to overcome the cable capacitance. However, when the clock output switches "on", it must source (or sink) the high current caused by the low impedance load.

Figure 1. Inferior transistor output



These conflicting design requirements result in a compromised solution; one where poor noise immunity and timing delays caused by cabling capacitance are tolerated as trade-offs against the need for high current sink capability of the opto-isolated outputs. Clock outputs that use this form of isolation circuitry can only drive a single device. With their multiple outputs and consequent wiring overhead, plus compromised noise immunity and timing accuracy, a problem still exists!

Managed Solution: Symmetrical Isolated Outputs.

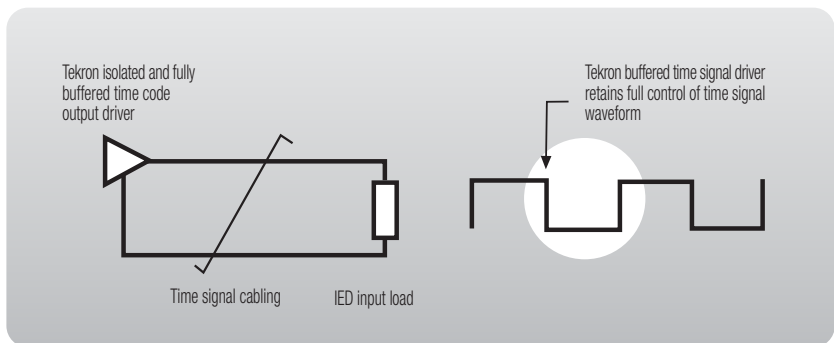
Tekron clocks solve the problem of driving long lines from isolated outputs by using balanced symmetrical outputs that can both source and sink current.

The outputs don't require an external voltage, excellent noise immunity is achieved through good line balance, there are no timing delays, and outputs are capable of driving multiple devices on a "multi-drop" line many meters from the clock.

Typically, each output on the Tekron TCG01 clock can drive 20 or more devices at varying distances from a single cable up to 50 meters or more from the clock.

Furthermore, good noise immunity and accurate timing control is maintained.

Figure 2. Tekron buffered output



With Tekron's approach, the design of a synchronizing system is greatly simplified, wiring is minimized, and reliability significantly enhanced. The balanced outputs allow easy-to-use twisted-pair cable for sync distribution around the substation, and yet still maintain good noise immunity. With these features the sync requirements of a whole substation can be catered for. It is rare that more than two clock outputs are required - although the Tekron TCG01 provides four.

For applications requiring isolation between individual devices receiving the time sync signals, Tekron's MOFRs (Multi Function Output Repeaters) can be installed to supply signal to a device or group of devices. As we have seen, the MOFR can also provide signal and protocol conversion if required by specific devices.

Problem 2: Power Supply Isolation

Substations usually have a variety of secure battery based power supplies available. A 24 volt or 48 volt supply may be available for communications equipment. Common telecommunications industry practice is for this to be grounded on the positive side. A similarly rated supply may be available for supervisory and remote control equipment. This is likely to be floating and fitted with earth fault detection. The main dc supply for control and protection is commonly approximately 125 Vdc or 250 Vdc, floating and fitted with earth fault detection. Standards vary within the industry and within companies due to the wide range of ages of assets.

Power supplies used for control purposes have cabling running to primary plant in high voltage switchyards therefore any equipment, located anywhere in the substation, that is connected to those supplies is exposed to disturbances and earth potential differences that occur in a substation during fault conditions and during normal operation of primary plant.

Unless the clock is purpose designed for a substation environment, its power supply is unlikely to have a sufficiently high isolation rating to ensure reliable operation and robustness during fault conditions. Clocks that provide no isolation are likely to ground the negative side of the supply input.

This arrangement is incompatible with the common floating battery bank and earthed positive configurations described above. Use of clocks with insufficient, or non-existent isolation in a substation requires installation of an additional power supply to provide the required level of isolation. This arrangement requires more space, makes installation more expensive and reduces overall reliability.



The Solution: Tekron's Isolated Power Supplies.

The Tekron TCG01 and TTM01 are designed for the high voltage substation environment.

They are available with a choice of 3 built in and isolated power supplies to cover supply requirements from 24 volts dc through to 250 volts dc. The high voltage version (90 - 300 Vdc) is fully isolated to in excess of 2 kV for use directly from substation primary dc supplies to maximize installation reliability and minimize total lifetime cost of ownership. Tekron clocks have been designed, right from the first prototype, to be "Fit for Purpose" in a substation environment.

Section 4

About Tekron

New Zealand has led the world in deregulation of the electricity sector, since major industry reforms were initiated in the 1980s. Electronic and software systems developed in this advanced environment have been sold into major markets around the world.

"We've standardized on them because the products work fine and we are confident in them. It is also important to our customers - they know and trust the Tekron products now."

Energy consultants,
Australia.

Tekron was formed in 1998 to meet the needs of this sector. We are all about GPS timing solutions - that's all we do and that's we are passionate about. It is this commitment to technical excellence that has made us the brand of choice in power industries around the world when operators want to be certain about time synchronization in their networks.

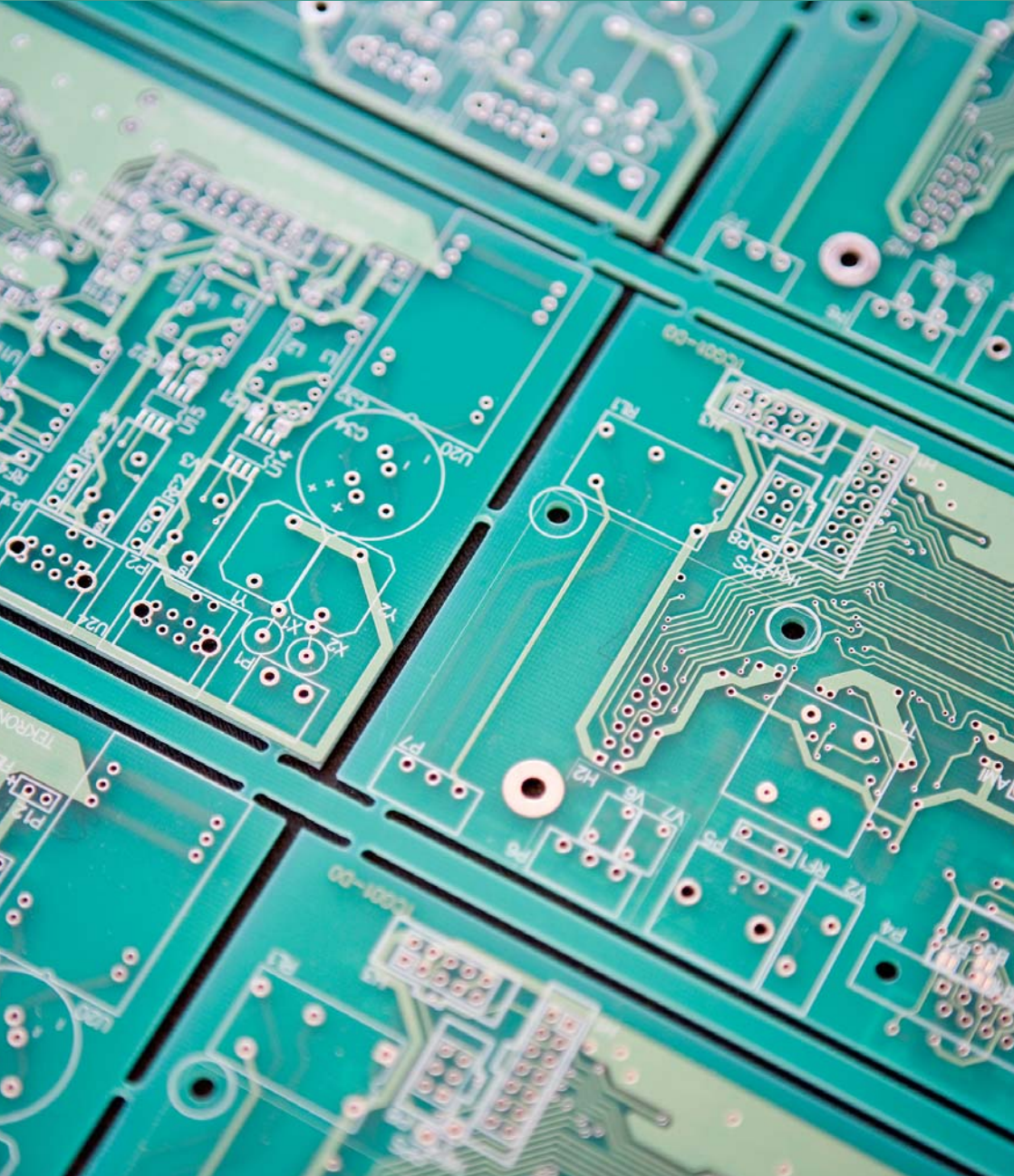
We have grown into an international company, selling our branded products directly and through leading OEM partners.

Tekron works with systems integrators such as Alstom/Areva, Foxbro Invensys and Schneider Electric; as well as relay manufacturers like General Electric, ABB and Siemens.

Our products are used across the globe, including in utilities based in Australia, South Africa, North America (Canada, USA), South America (Chile, Peru), Europe (France, Ireland, Portugal, Italy and Belarus), Scandinavia (Finland), Asia (India, Malaysia, China, Taiwan, Philippines, Japan and Indonesia), and the Middle East (Oman, Saudi Arabia).

"They are easy to configure. Other products in the past have taken sometime to configure and are a little more complicated. You basically plug in the Tekron unit and go."

Electricity utility company,
USA.



Section 5

The Tekron approach

Tekron in action



Transpower Case Study

Customer

Transpower is the owner and operator of New Zealand's national electricity grid. The nationwide grid comprises over 12,000 km of transmission line and 173 substations and switchyards.

Problem

Being able to reliably identify the order in which fault events occur at different places in the network.

The Solution: Tekron GPS Clock

Tekron designed a prototype GPS clock specifically for Transpower to evaluate in their substation environment. Time code outputs were configurable to meet all Transpower's needs and, unlike other products, Tekron's clock did not need additional hardware to meet power supply requirements and isolation for the time code outputs. This lowest cost, total solution to the problem, also uses the least panel space.

The Benefits

Transpower has found the TCG01 Time Code Generator to be a "highly cost-effective solution" which quite simply "always works and does not give any trouble".

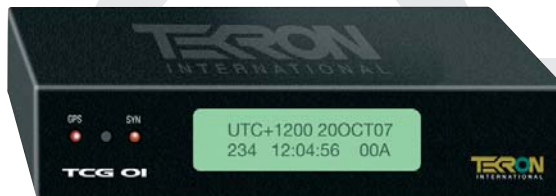
Tekron has been "very responsive" to Transpower's needs by readily providing advice and assistance during the initial trials, and by building Transpower's requirements into the design as the product evolved. The Tekron solution "meets all Transpower's requirements now and has the versatility to meet future needs."

TCG 01 GPS Clock

The Tekron TCG01 provides a time synchronization solution with superb timing accuracy (better than 100ns to UTC), designed for synchronizing multiple industrial control and SCADA devices, including protection relays and remote telemetry units.

The TCG01 has field or factory programmable customer specified output pulses, standardized time codes (e.g. IRIG-B, DCF77) and serial time strings using user friendly windows based interface.

Outputs are electrically isolated allowing direct feeds to areas with different earth potential zones without compromising the overall site earthing security.



TTM 01 GPS Clock

The TekTime TTM01 provides an economic time synchronization solution in a small form factor - DIN-rail mounted.

Like the Flagship TCG01, the TTM01 is suitable for synchronizing industrial control and SCADA equipment, but is an economical solution for use where only a small number of devices require synchronization.

Typical applications include wind farms where each tower has a TTM01 installed, or on pipelines where each control point requires a synchronized IED. The TTM01 outputs are electrically isolated and the unit shares the same user-friendly windows-based programming interface as the TCG01.



NTS 01 GPS Network Time Server

The Tekron NTS01 GPS Network Time Server provides an economic time synchronization solution for IP networks. The NTS01 provides SNTP / NTP protocol, (all versions) and supports both fixed IP and DHCP addressing.

It also supports BOOTP and ARP protocols and provides status reporting via SNMP. The NTS01 is available with either 2 or 5 ports with each port functioning as a Stratum 1 Time Server. Each port is fully independent, allowing operation on different sub-nets if required.



MOFR 01 Multi Output Function Converters

MOFRs are compact DIN-rail-mounted isolating signal repeaters / protocol converters. They convert time sync signals from copper or fiber input to copper and fiber output, providing galvanic isolation for copper signals.



On the input side, the MOFR receives a digital source signal such as un-modulated IRIG-B (typically TTL on copper) and reproduces the signal on the output side in copper with TTL, RS232 and RS422 outputs all being provided simultaneously. MOFRs can also be purchased with Fiber I/O added.

As a secondary independent function, MOFRs also provide transformer isolation for AM IRIG signals. An option is available that can convert an incoming IRIG-B signal on the digital input to an AM-IRIG-B output -thus eliminating the need to provide a separate AM-IRIG-B input signal.

Next generation products: IEEE 1588 standard

Tekron are developing a new range of precision time instruments that will support the emerging IEEE 1588 rev 2. standard to be able to provide sub-microsecond timing across Ethernet networks.

The non-determinate nature of Ethernet communications together with latency and jitter issues has historically limited timing accuracy to around 1ms at best but typically 30 or more ms. With Tekron's new IEEE 1588 range customers can enjoy sub-microsecond (a 1,000 times improvement over existing products) accuracy across their Ethernet networks.

Achieving sub microsecond precision

As an emerging standard for synchronizing devices on Ethernet networks, the IEEE 1588 precision time protocol (PTP) opens up exciting possibilities for all kinds of industrial control, telecommunications and test and measurement applications.

IEEE 1588 is designed for systems needing high accuracies beyond that achievable with existing timing protocols like IRIG-B and NTP. The standard allows for timing precision over (but not limited to) Ethernet networks to better than 100ns.

How IEEE 1588 Precision Time Protocol works

The new IEEE1588 PTP standard offers the accuracy and cost effectiveness of Network Time Protocol for existing Ethernet networks within a distributed system. Synchronized real time clocks which are local to the measurement or control device, allow data to be accurately time stamped or events to be synchronized with very high accuracy. Timing precision within the system is reliant on the synchronization of the local clocks rather than the communication links.

A PTP network will typically consist of a Grandmaster Clock which provides high precision (GPS, Atomic) reference time connected with local clocks distributed over the network. Local clocks within the system are termed masters and slaves. Within any communication path there will be a clock which is termed the master clock to which all clocks on that path will sync. Masters and slaves may swap hierarchy (and therefore class names) if a slave determines it would make a better master and if a master finds a better clock.



Tekron International's IEEE 1588 Product Range

- Achieve sub 100 nanosecond timing precision
- Flexible distributed system
- Scalable
- Easy implementation
- Retrofit to legacy networks
- Minimal footprint - bandwidth and processing load
- Cost effective - will utilize existing Ethernet networks, no dedicated wiring required

IEEE 1588 Grandmaster Clock



- GPS Time Source
- 10Base-T 100Base-TX 100Base-FX Outputs
- Accurate to within 100ns to UTC
- Industrial Temperature Range

Tekron's Grandmaster Clock provides an accurate GPS reference source for IEEE 1588 precision time protocol (PTP) networks. The clock can produce timestamps with accuracy better than 100ns to UTC over Ethernet. With a highly accurate timing reference source for use over Ethernet networks the Grandmaster clock can synchronize PTP slave clocks with a very high precision.

IEEE 1588 Transparent Switch

- 8-Port Ethernet Switch
- 10Base-T 100Base-TX 100Base-FX
- Ruggedised

The Tekron 8-port switch supports IEEE 1588 precision time protocol (PTP) transparent switch functionality. The switch can operate as an end to end or peer to peer transparent clock in accordance with version 2 of the IEEE 1588 standard.

Specialized switches are required when dealing with IEEE 1588 timing packets as standard switches do not account for the latency of packets which considerably reduces Ethernet synchronization precision. Tekron's switch will comply with IEEE 1588 transparent switching.



IEEE 1588 Standard Clock

- SNMP management
- Configurable outputs (10MHz, IRIG-B, PPS)
- Configurable via windows based software
- Firmware Upgradeable



The Tekron Standard Clock allows for highly accurate synchronization to master and grandmaster clocks in an IEEE 1588 sub domain. The ordinary clock operates as either a master or slave clock and synchronizes to a grandmaster with very high accuracy. Synchronization is achieved via the IEEE 1588 precision time protocol messages, version 1 and 2 of the protocol are supported by the clock.

Outputs of the clock include several configurable outputs and also NTP outputs. The unit is configurable via a simple to use configuration tool allowing for IEEE 1588 synchronization statistics to be gathered as well as the configuration of the output ports.



IEEE 1588 Plug-in Solutions

- **DIN Rail Mounted Line Drop-in Producing IRIG-B from IEEE1588**

This provides IRIG-B timing signals for legacy equipment that supports Ethernet communications but lacks IEEE1588 compatibility. It allows for existing relay control cards using Ethernet for data transfer and including an IRIG-B input for time synchronization to be integrated into a PTP network without having to be upgraded to full slave functionality.

The line drop-in is ideal if an existing Ethernet based relay control system requires a higher time precision. The drop-in module acts as a slave clock interacting with other PTP clocks on the network. Precise time is held by the clock which converts this message to IRIG-B. This IRIG signal can be transmitted via either a TTL over 2 pin or BNC, AM-IRIG, RS-422 or fiber.

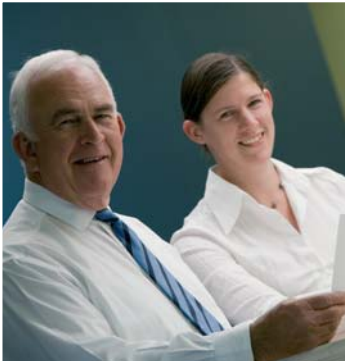
- **IEEE1588 Capable Ethernet Interface Card with IRIG-B Output**

Ideal for use within relay control devices communicating via Ethernet using IRIG-B inputs as a time source and needing a time reference upgrade to IEEE1588. The interface card acts as a slave within the PTP network. As a slave the IEEE1588 interface card will synchronize with other clocks in the network and provide a clock reference to within 100ns. The interface card can be used to provide future time triggers to the relay device and also a high precision IRIG-B output.



Section 7

Contact details



Phone: +64 4 566 7722

Fax: +64 4 569 9272

Email: information@tekroninternational.com

Corporate Office:

PO Box 31-285
409 Cuba Street
Lower Hutt
New Zealand

www.tekroninternational.com

IRIG-B Time Synchronization Code²

Although the synchronization bus can carry many forms of time signal, the IRIG-B time code is the most widely used synchronization signal within substations.

The basic form of IRIG-B consists of a pulse-width modulated digital data stream at the rate of 100 pulses per second. The leading edge of each pulse is precisely positioned in time on the incremental 10mS point within the second, while the pulse width modulation conveys time and date information repeating within each 100 pulse frame i.e. once per second.

There are a number of variations of IRIG-B time codes in common use. IRIG-B time codes are defined using a 4-character descriptor: "B x y z", and "x", "y" and "z" have meaning as follows:

B	x	y	z
[format]	[modulation type]	[frequency/resolution]	[coded expression]

"B" denotes IRIG-B

"x" designator, modulation type has three possible values:

- 0 = Unmodulated, also called DC level shift
- 1 = Amplitude Modulated (AM) sine wave
- 2 = Modified Manchester modulated

The "y" designator, frequency/resolution has values as follows:

- 0 = no carrier / index count interval (commonly used with IRIG-B)
- 1 = 100Hz carrier (not used with IRIG-B)
- 2 = 1000Hz carrier (commonly used with IRIG-B)

The "z" designator, coded expression has values as follows:

- 0 = BCD, CF, SBS
- 1 = BCD, CF
- 2 = BCD
- 3 = BCD, SBS

BCD = Binary Coded Decimal format = basic time-of-year information (does not include year information).

CF = Control Function = additional information including year information (eg IEEE1344 extensions or AFNOR extensions).

SBS = Straight Binary Seconds = seconds-of-day in binary format.

z Information is extracted from IRIG STANDARD 200-98.

The valid combinations in use for IRIG-B are: B00z, B12z and B22z.

B00z (DC level-shift IRIG-B)

B00z (DC level-shift IRIG-B) has been favored for use with new equipment in substations because, although it cannot be used for wiring runs of more than about 100 meters, it offers good timing accuracy. As long as the GPS clocks outputs are isolated and therefore balanced this effectively eliminates problems due to induced noise that can cause difficulties using this form of time code in sub-stations. This code can also be easily transmitted over fiber. Demodulation is not required, so the code can be very simply received and used by connected equipment. The B00z signals are already being used for synchro-phasor timing.

B12z (Amplitude Modulated IRIG-B)

B12z (Amplitude Modulated IRIG-B) has historically been widely used. Because this modulation is a 1Khz sine-wave, timing accuracy is inherently limited by the wave shape. This is, therefore, the least precise of all of the IRIG-B varieties, but has been in common use because, with no DC content in the signal, it lends itself to transmission over long distances. The sine-wave zero-crossing transitions have to be placed very precisely by the GPS clock (within a few microseconds of absolute UTC time), so that very good precision can still be obtained provided that the receiving equipment employs a reasonably sophisticated demodulator (e.g. PLL) to recover the timing accuracy. Sub-millisecond accuracy is achievable.

B22z (Modified Manchester IRIG-B)

B22z (Modified Manchester IRIG-B) while not yet in common use, gives the best of both worlds. It retains the razor sharp accuracy of B00z, using a 1Khz square wave, but with phase modulation rather than DC level shift. With no residual DC level, it is, therefore good for driving over long distances as well. Demodulation using PLL techniques is relatively straightforward.

Tekron Standards Compliance

Tekron products are CE certified and comply with the following international standards:

- IEC 61000-4-2:1995 Electromagnetic Compatibility (EMC) Part 4: Testing and measurement techniques Section 2: Electromagnetic discharge immunity test
- IEC 61000-4-3:2002 Electromagnetic Compatibility (EMC) Part 4: Testing and measurement techniques Section 3: Radiated, radio frequency, electromagnetic field immunity test
- IEC 61000-4-4:1995 Electromagnetic Compatibility (EMC) Part 4: Testing and measurement techniques Section 4: Electrical fast transient burst immunity test.
- IEC 61000-4-5:1995 Electromagnetic Compatibility (EMC) Part 4: Testing and measurement techniques Section 5: Surge immunity test.
- IEC 61000-4-6:2003 Electromagnetic Compatibility (EMC) Part 4: Testing and measurement techniques Section 6: Immunity to conducted disturbances, induced by radio frequency fields.
- IEC 61010-1:2001 Safety requirements for electrical equipment for measurement, control and laboratory use - Part 1 General Requirements.
- IEC 61326:2002 Electrical equipment for measurement, control and laboratory use - EMC requirements.
- CISPR 22:2003 Information technology equipment - Radio disturbance characteristics - limits and methods of measurement.

FCC 47 Part 15:2002 RF emission requirements of the Federal Communications Commission

All specifications are subject to change without notice.



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