

# Synchronizing Networks with IEEE 1588

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# Objectives

- **Introduce the IEEE 1588 Precision Timing Protocol (PTP) for synchronizing time over an Ethernet network**
- **Describe methods to develop products with IEEE 1588 PTP support**



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# How Does IEEE 1588 PTP Synchronize a Network?



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# What is IEEE 1588 Precision Time Protocol?

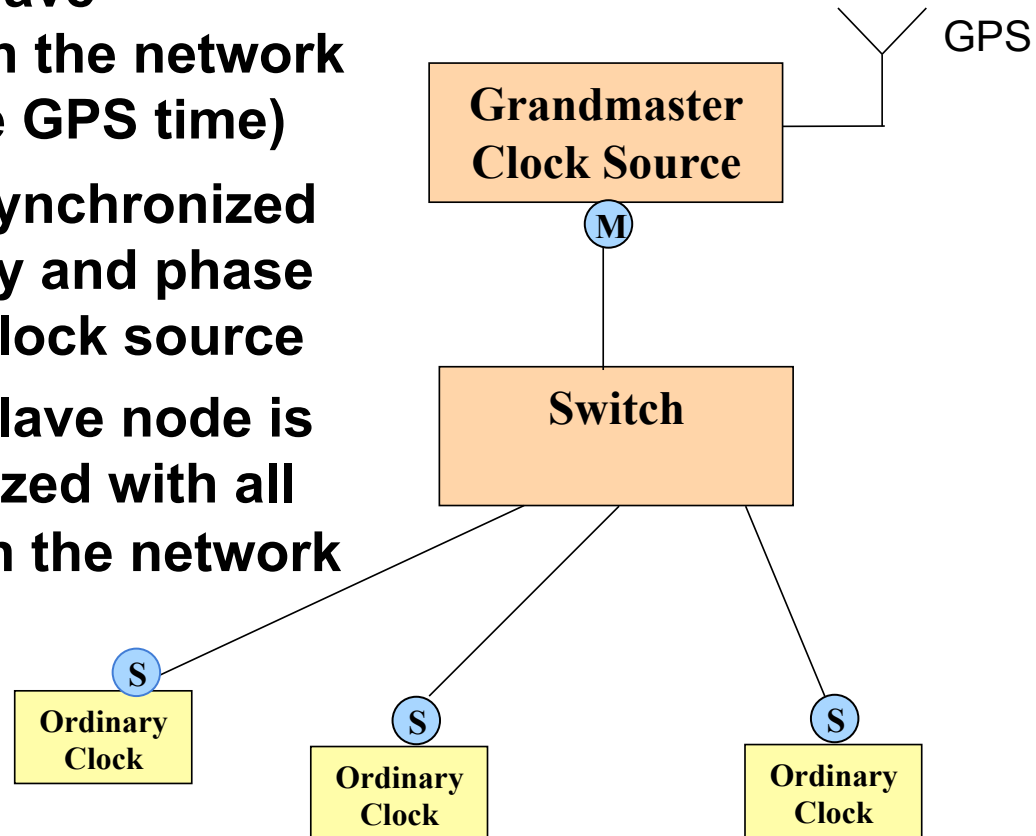
- An IEEE standard to synchronize time between nodes of an Ethernet network
- An upper layer protocol that is typically contained in a UDP/IP packet
- An algorithm to calculate the time difference between nodes and then update the time at the slave node to match the master clock

# How is IEEE 1588 PTP synchronization different from older technologies?

- **Synchronization technique**
  - Many older control and communication standards use synchronous connections that recover the frequency from the control link.
  - IEEE 1588 PTP calculates the time using the PTP algorithm, and then derives the appropriate frequency based on the PTP calculations
- **Flexibility**
  - Synchronous connections need to follow a strict hierarchy
  - IEEE 1588 PTP can adapt to the system. Hierarchy is established by the quality of the clock source, not the location of the clock in the control network

# A typical IEEE 1588 network topology

- Creates a master – slave hierarchy of clocks in the network (in this case from the GPS time)
- Each slave node is synchronized to the time, frequency and phase of the grandmaster clock source
- By extension, each slave node is effectively synchronized with all of the other nodes on the network

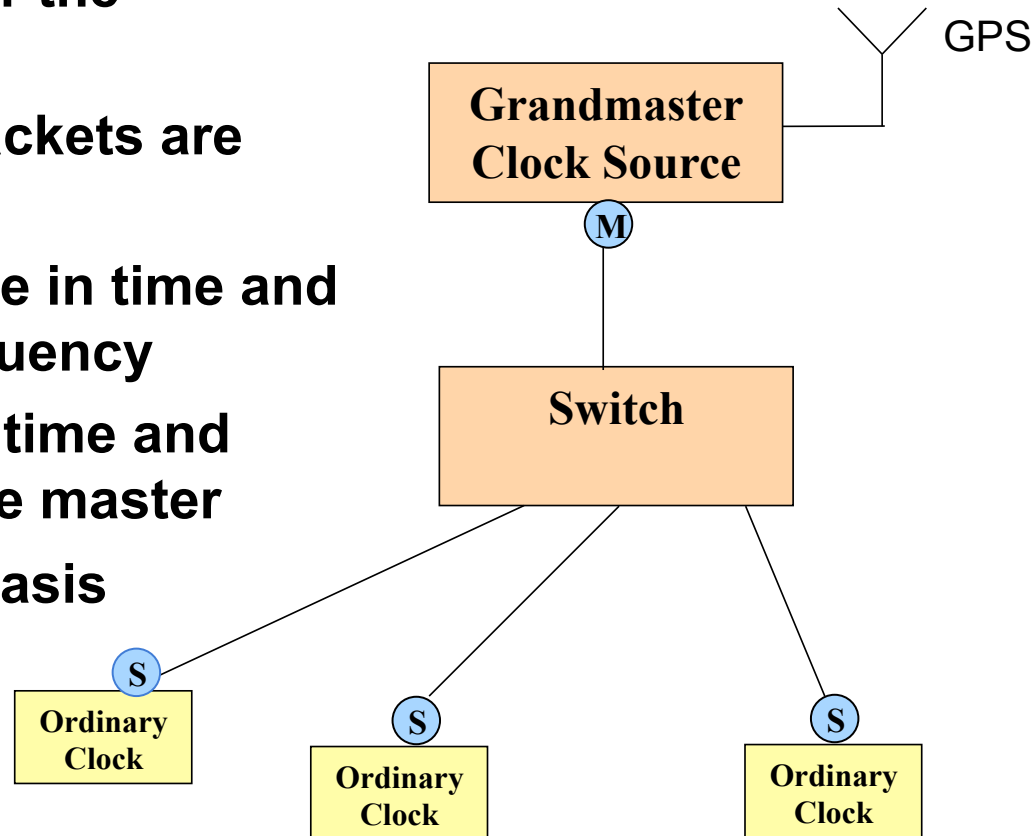


**(M)** -Time Master

**(S)** -Time Slave

# How IEEE 1588 PTP works

1. Exchange packets over the Ethernet network
2. Record the time the packets are sent and received
3. Calculate the difference in time and the differences in frequency
4. Adjust the slave clock time and frequency to match the master
5. Repeat on a periodic basis

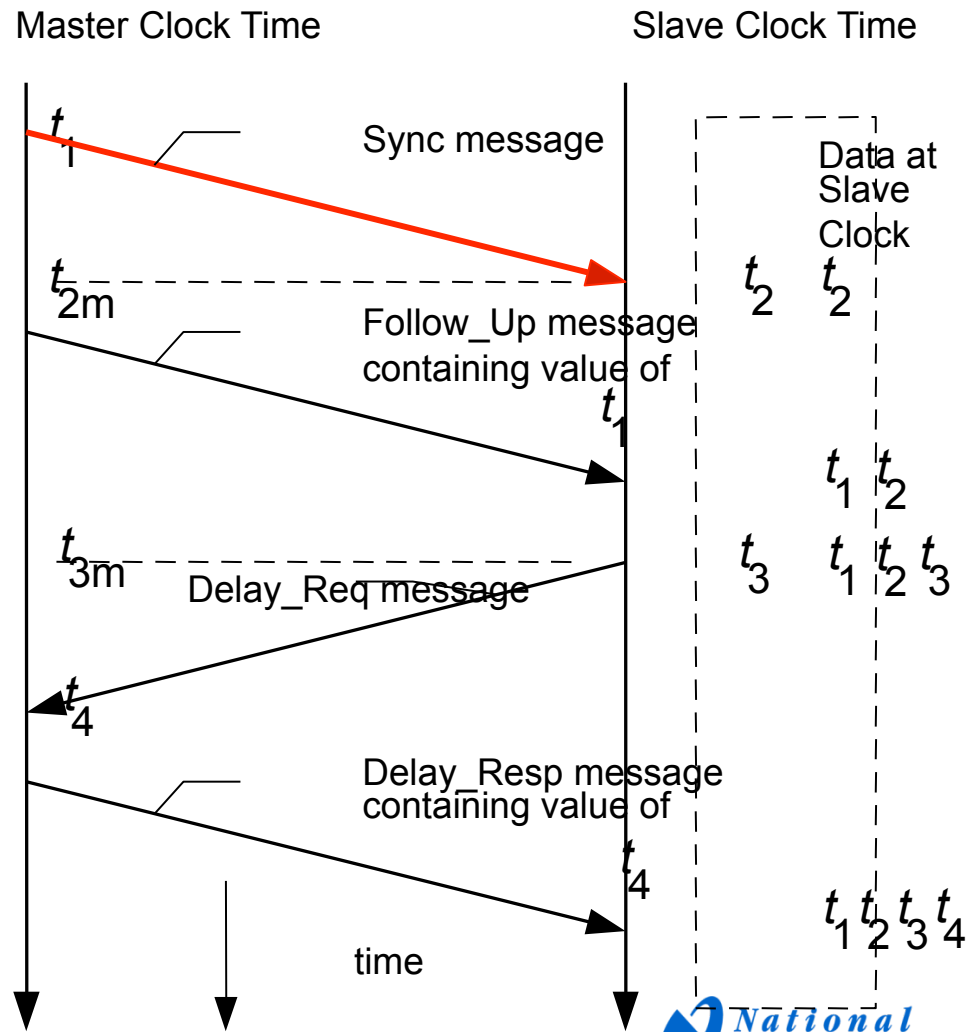


Ⓜ -Time Master

Ⓢ -Time Slave

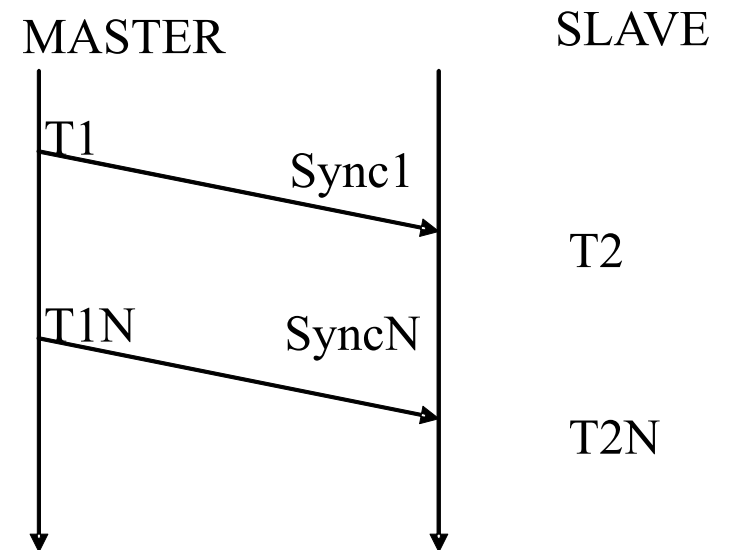
# Adjusting Time with IEEE 1588 PTP

- The time correction is calculated by:
  - meanPathDelay =  $((t_2 - t_1) + (t_4 - t_3)) / 2$
  - offsetFromMaster =  $(t_2 - t_1) - \text{meanPathDelay}$



# 1588 Rate Correction

- The rate correction is calculated by:
  - $M\_diff = T1N - T1$
  - $S\_diff = T2N - T2$
  - $rate\_ratio = S\_diff / M\_diff$
- The frequency of the slave clock may be adjusted by this factor



# General Info on the IEEE 1588 Spec

- Version 1 ratified in 2002
  - Focused on the needs of companies developing Factory Automation and Test & Measurement products
- Version 2 approved March 2008
  - Included input from Telecommunication component manufacturers and Audio / Video Bridging (AVB) development based on the IEEE 802.1AS spec



# Adding PTP Synchronization to System Design



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# Evaluating Implementation Options

- **Considerations**
  - Synchronization Precision
  - Synchronized inputs and outputs
  - Development Impact
- **Steps to implement IEEE 1588**
  - Software component
  - Hardware acceleration



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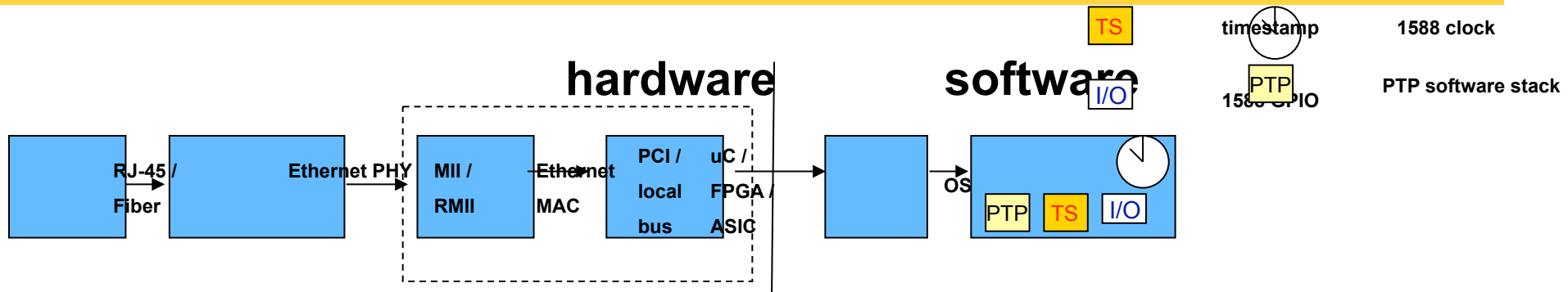


# Comparing IEEE 1588 PTP Solutions

Approach	Development Considerations	Precision Performance
Software only	Software development required	Precision too low for most applications Typical: >10 microsecond on single link
Hardware Assist in FPGA	Significant hardware change required Software and FPGA IP development required	FPGA approach timestamps at the Ethernet MAC level Typical: >30 nanosecond on single link
Hardware Assist in Microcontroller	Requires change to new microcontroller Existing software applications may need to be customized	Microcontroller approach timestamps at the Ethernet MAC level Typical: >30 nanosecond on single link
Hardware Assist in Ethernet PHY (DP83640)	Simple hardware implementation Software customization required	Tightest time synchronization commercially available Typical: <10 nanosecond on single link

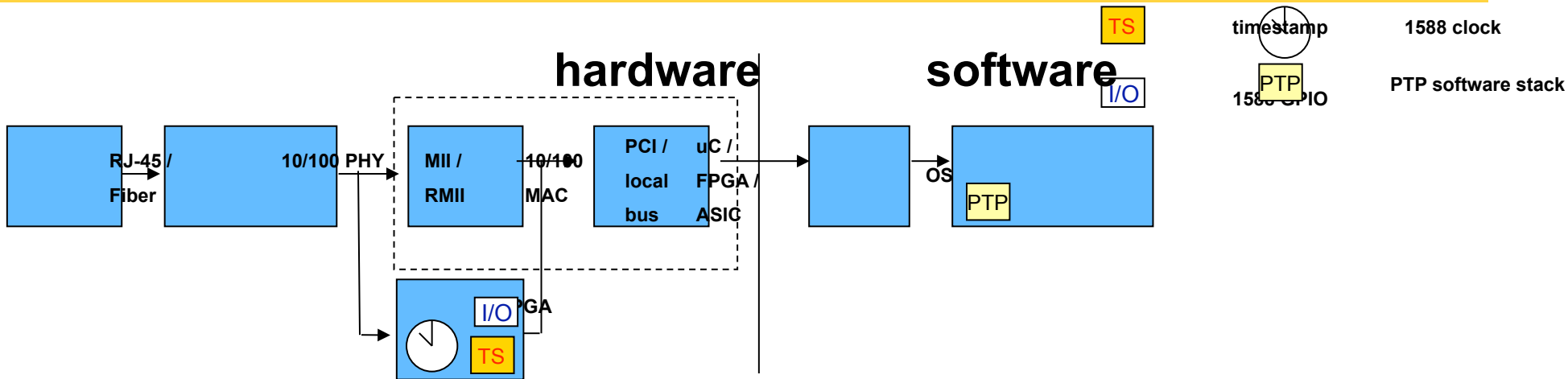


# IEEE 1588 Software Implementation



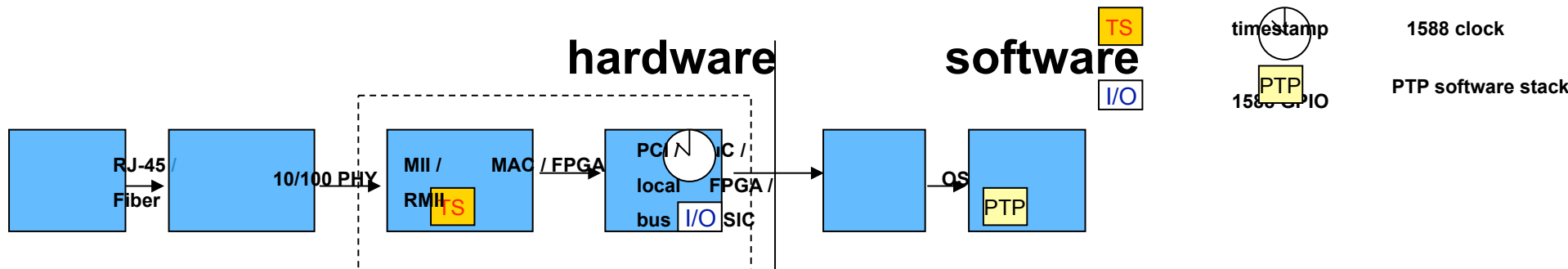
- A software only implementation handles all of the PTP functions in software
- Simplest implementation – no hardware changes
- PTP packet travels through all of the hardware from the wire and incurs delays during software processing
- Least precise synchronization not sufficient for many applications

# IEEE 1588 Implementation with Hardware Support at the MAC in an FPGA



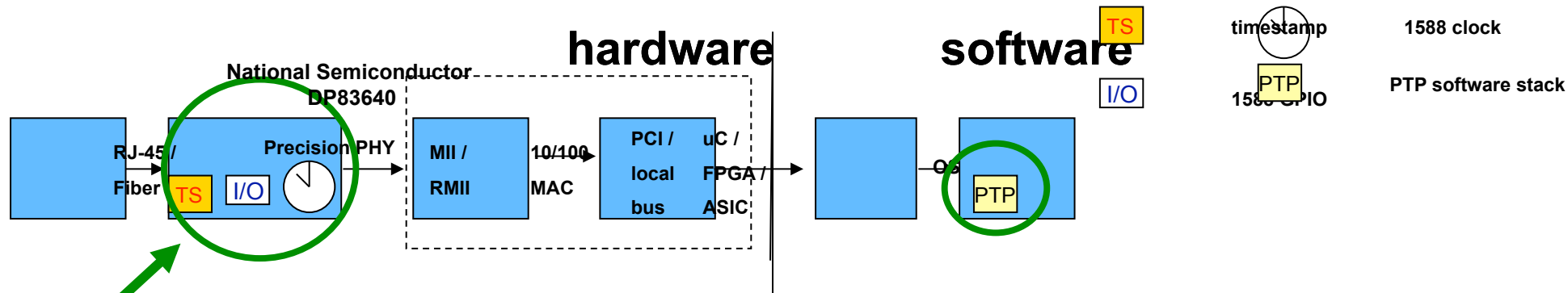
- An FPGA PTP implementation adds an FPGA that snoops on the MII bus between the PHY and the MAC to record the PTP packet times
- Requires packet processing and PTP functions to be developed in the FPGA
- Precision depends on the details of the FPGA IP and delays within the Ethernet PHY

# IEEE 1588 Implementation with Hardware Support in a Microcontroller



- A limited number of microcontrollers have PTP support built in
- Requires all software to be ported over if a different microcontroller is used
- Precision depends on the details of the microcontroller design and delays within the Ethernet PHY

# IEEE 1588 Implementation with Hardware Support at the Wire in the Ethernet PHY



- IEEE 1588 PTP added into the Ethernet PHY
- Simply replace a standard Ethernet PHY with a National Semiconductor's DP83640 Precision PHY
- Records packet times right at the wire
- Preserves existing software and hardware development
- Clock disciplining integrated into a single chip

# Summary

- **IEEE 1588 PTP is a key component to providing synchronization to Ethernet networks**
- **The IEEE 1588 PTP provides both frequency and time synchronization through an exchange of packets over an Ethernet network**
- **There are four main approaches to implement IEEE 1588 PTP: software only, development in an FPGA, as a feature built into specific microcontrollers, or as a feature in a IEEE 1588 PTP Ethernet PHY**



# Further Reading

## ***PHYTER Articles***

[“IEEE 1588 and the need for Ethernet Clock Synchronisation”](#),  
Alexander Tan, Industrial Ethernet Book, Sept 2007

[“Deploying Industrial Networks”](#),  
Bradley Kennedy, Network Systems DesignLine, May 2007

[“Avoid costly network downtime--use predictive cable diagnostics”](#),  
Andrew J McLean, Network Systems DesignLine, Dec 2006

[“Review of LAN Topologies for industrial Ethernet”](#),  
Jim Y. Wong & Tung Ngo, Network Systems DesignLine, Sept 2006

## ***1588 Links***

NIST IEEE 1588 Web site: <http://ieee1588.nist.gov/>

LXI (LAN eXtensions for Instrumentation) Standard: <http://www.lxistandard.org/home>

“Measurement, Control and Communication Using IEEE 1588”, John C. Eidson, Springer, ISBN 1846282500

The Industrial Ethernet Book: <http://ethernet.industrial-networking.com/>

[“Remote Control Synchronizes Clocks”](#), Jon Titus, ECNmag.com, March 2007

[“IEEE 1588: running Real-Time on Ethernet”](#), Dirk Mohl, Industrial Networking



## For more information

- **For more information on the National DP83640 Precision PHYTER solution check out the application notes at:**
  - <http://www.national.com/pf/DP/DP83640.html>



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