# Measuring High Accuracy Links for cnPRTC Optical Timing Connections and Other Applications

MICROCHIP

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

SMART | CONNECTED | SECURE

**Lee Cosart**

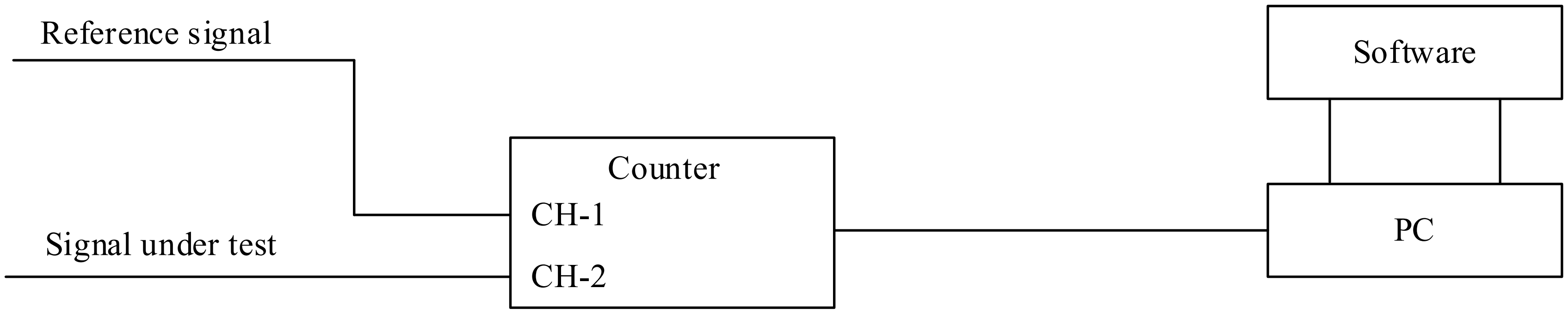
March 2023

# Introduction

- Applications increasingly demand time delivery approaching the nanosecond level or below, which in turn require measurements at the sub-nanosecond level
- Measurement technology has advanced, providing a means of making such measurements
- Several approaches are discussed here:
  - First, the approach of timestamping signals employing the latest technology can measure at the picosecond level for lower rate signals such as one pulse per second
  - Second, an alternative approach of digital dual heterodyne techniques for measuring precision phase noise can show measurement precision at the picosecond level or below for frequency signals
- These techniques are applied to measuring high-accuracy optical links needed for the cnPRTC, among other applications

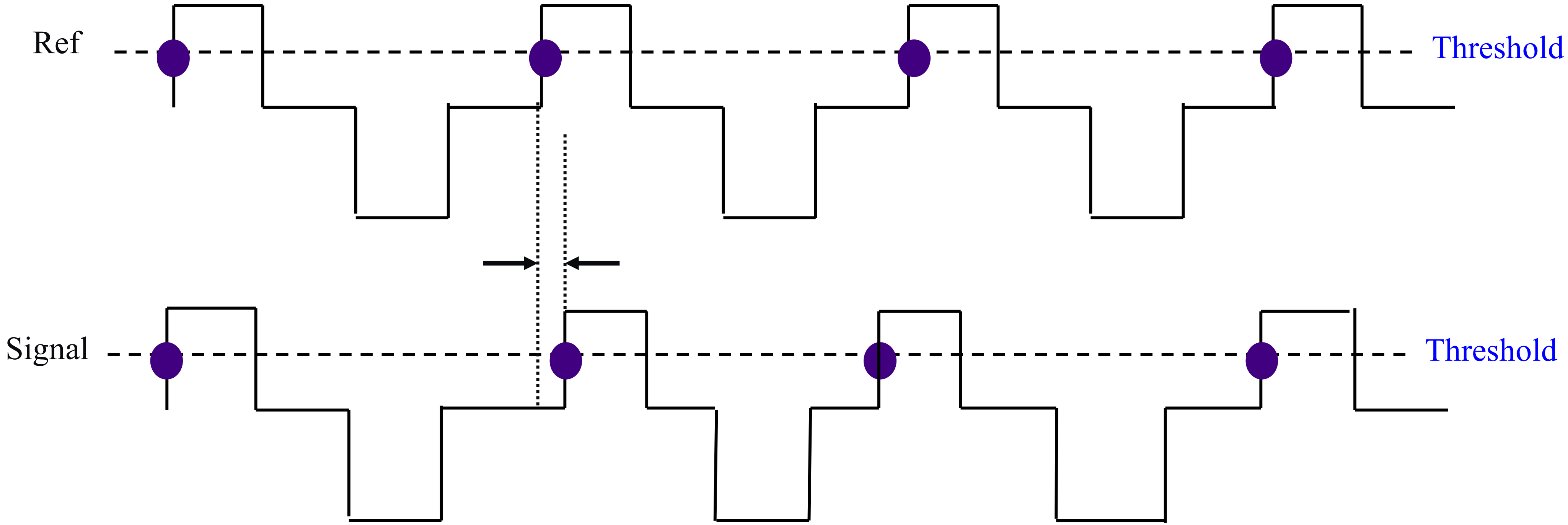
# Time Interval Counter

- Time interval counters have been used for timing measurements for decades
- Technological improvements in time interval counters illustrate the trend of improved timing measurement capabilities
- While earlier time interval counter implementations delivered timing resolution at the 500 picosecond level, newer implementations have improved that to 20 picosecond timing resolution



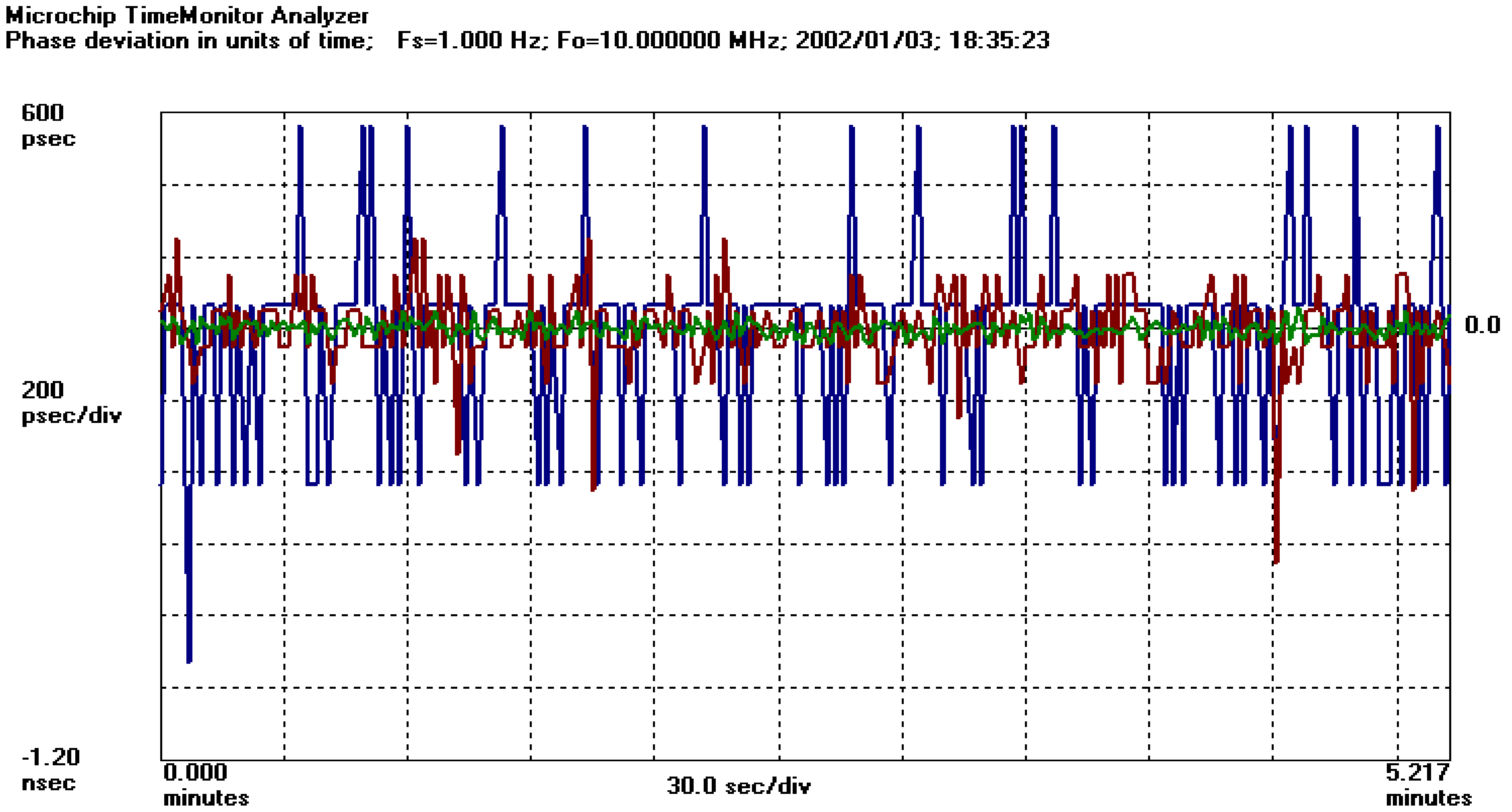
# Time Interval Counter

- A time interval counter measures the differences between the edges of the signal under test compared to the reference signal



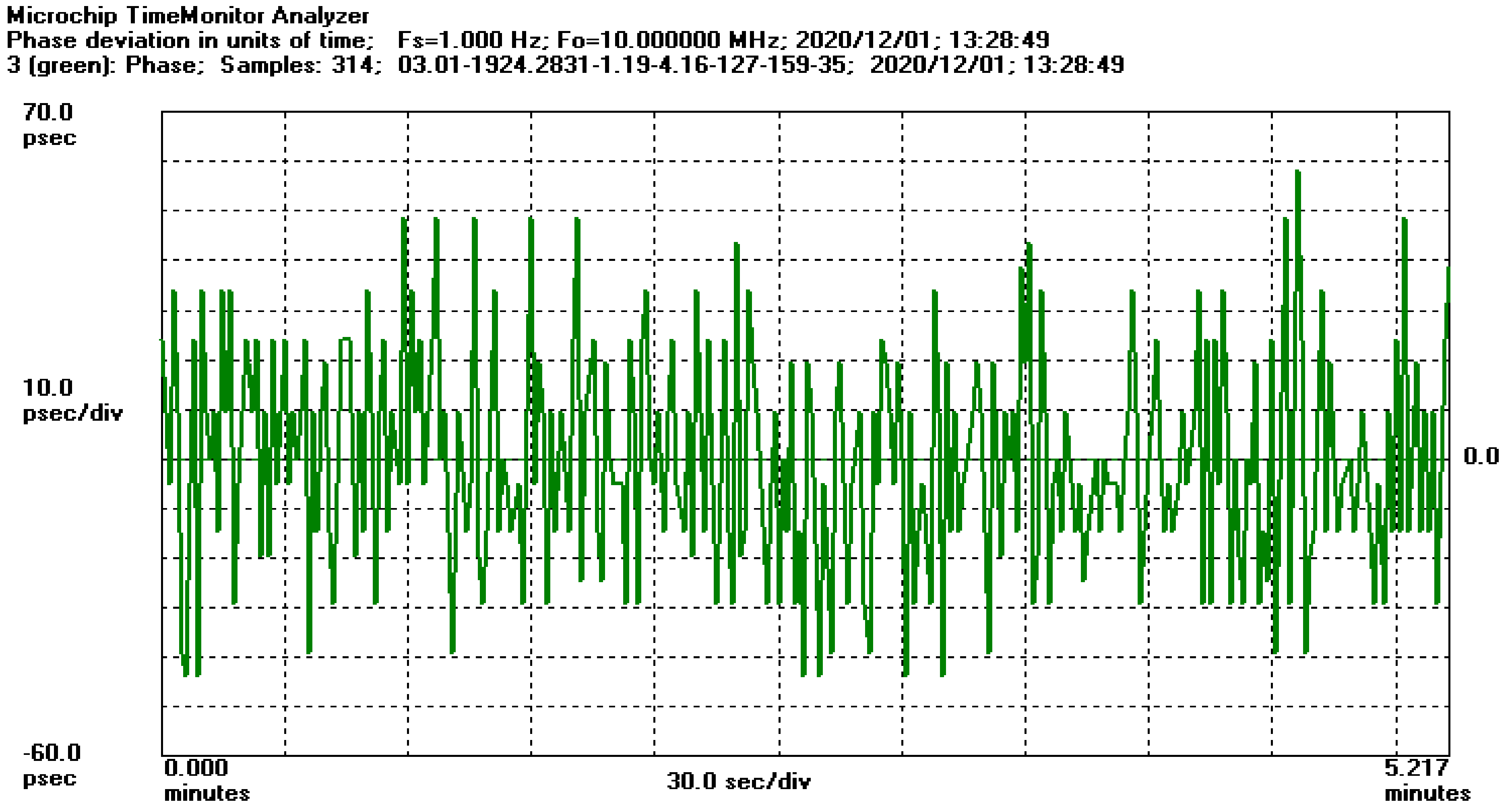
# Time Interval Counter

- A 500 ps counter (blue) compared to a 150 ps counter (red) and a 20 ps counter (green)



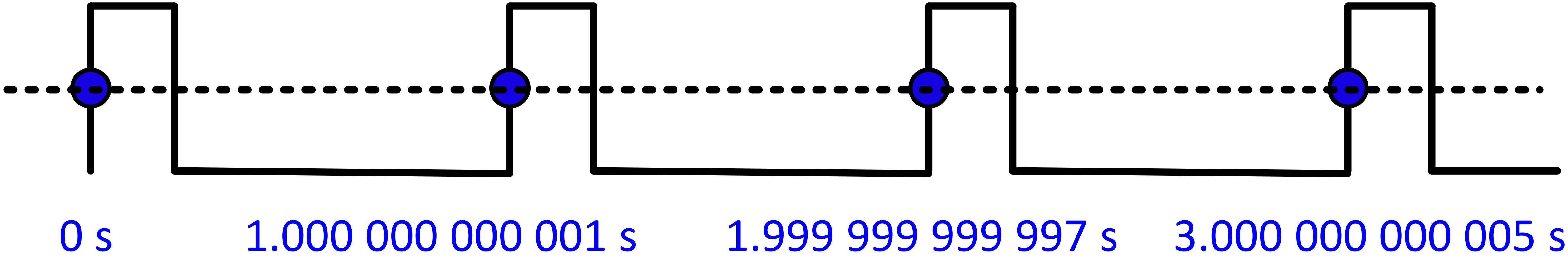
# Time Interval Counter

- The 20 ps counter (a 25x improvement over the 500 ps counter)



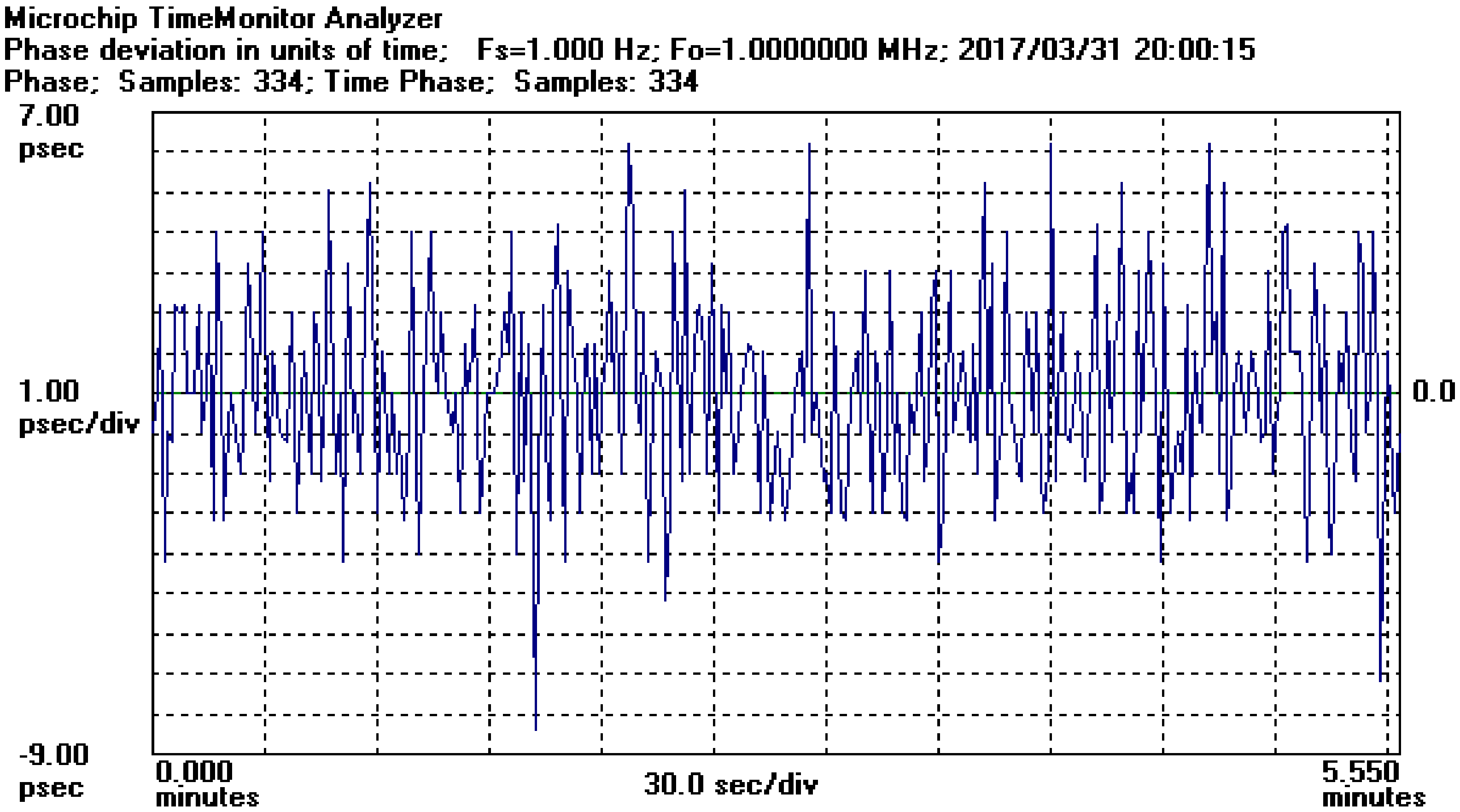
# Timestamper

- A timestamper employs an approach related to that of time interval counter, and has been referred to as a “zero dead-time counter”. It simply timestamps edges of the signal under study, and has the relationship of the edges to each other
- The timestamping approach has the advantage of accommodating a wide range of signals, including low-rate signals such as 1 PPS
- Rather than physical signal edges, the timestamps could instead represent instances of packet arrival times at a node of an optical network, for example



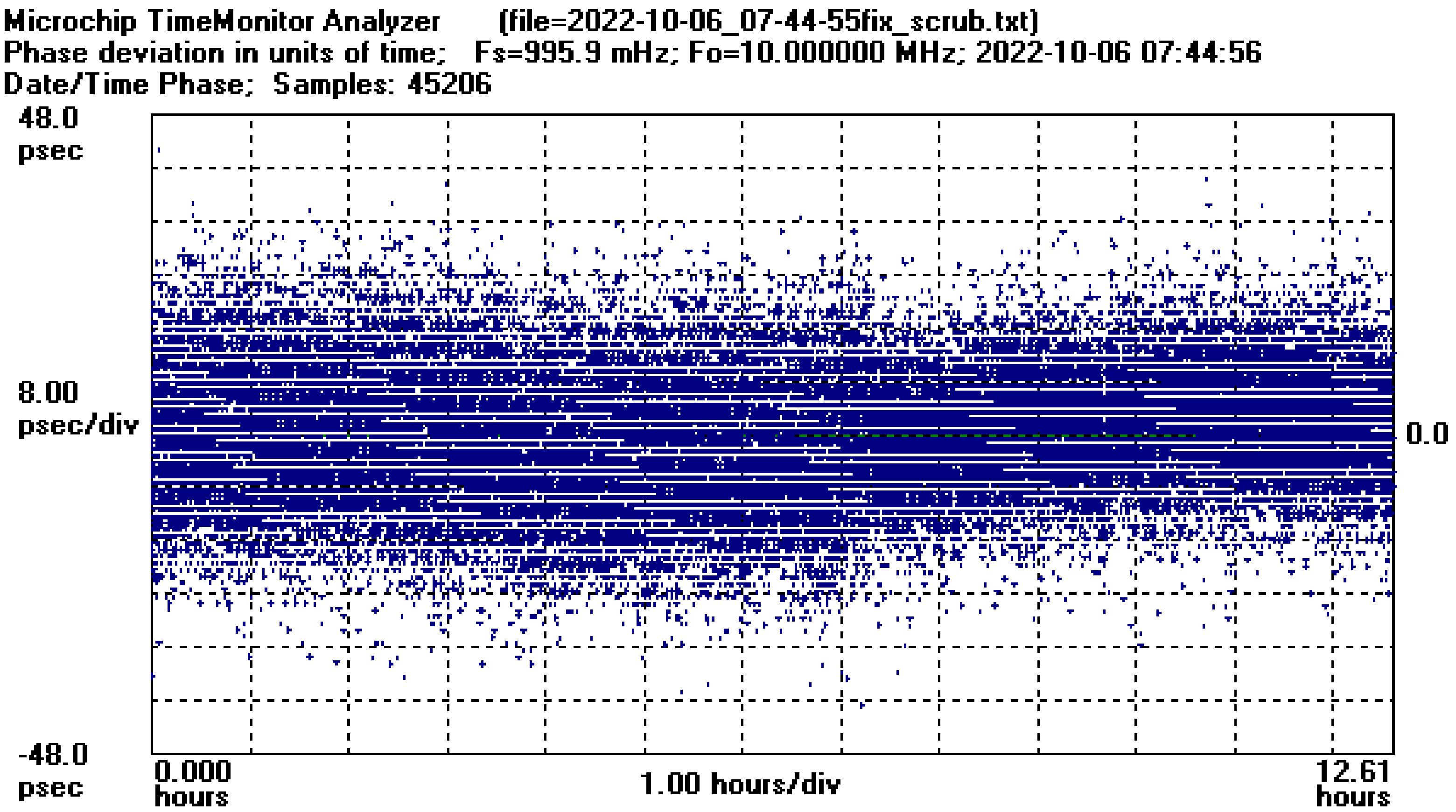
# Timestamper

- A sample measurement from a timestamper employing current technology



# Timestamper

- A sample measurement from a different timestamper employing current technology (measuring device with 10 ps standard deviation)








MICROCHIP

# Direct Digital Phase Noise

- An alternative technology allowing great measurement precision if the signal is at a sufficiently high rate is employed in recent implementations of test equipment designed to test phase noise and precision Allan Deviation
- This technology, using a direct digital phase noise approach, can measure at the sub-picosecond level
- It is a departure from the analog techniques traditionally used to measure phase noise

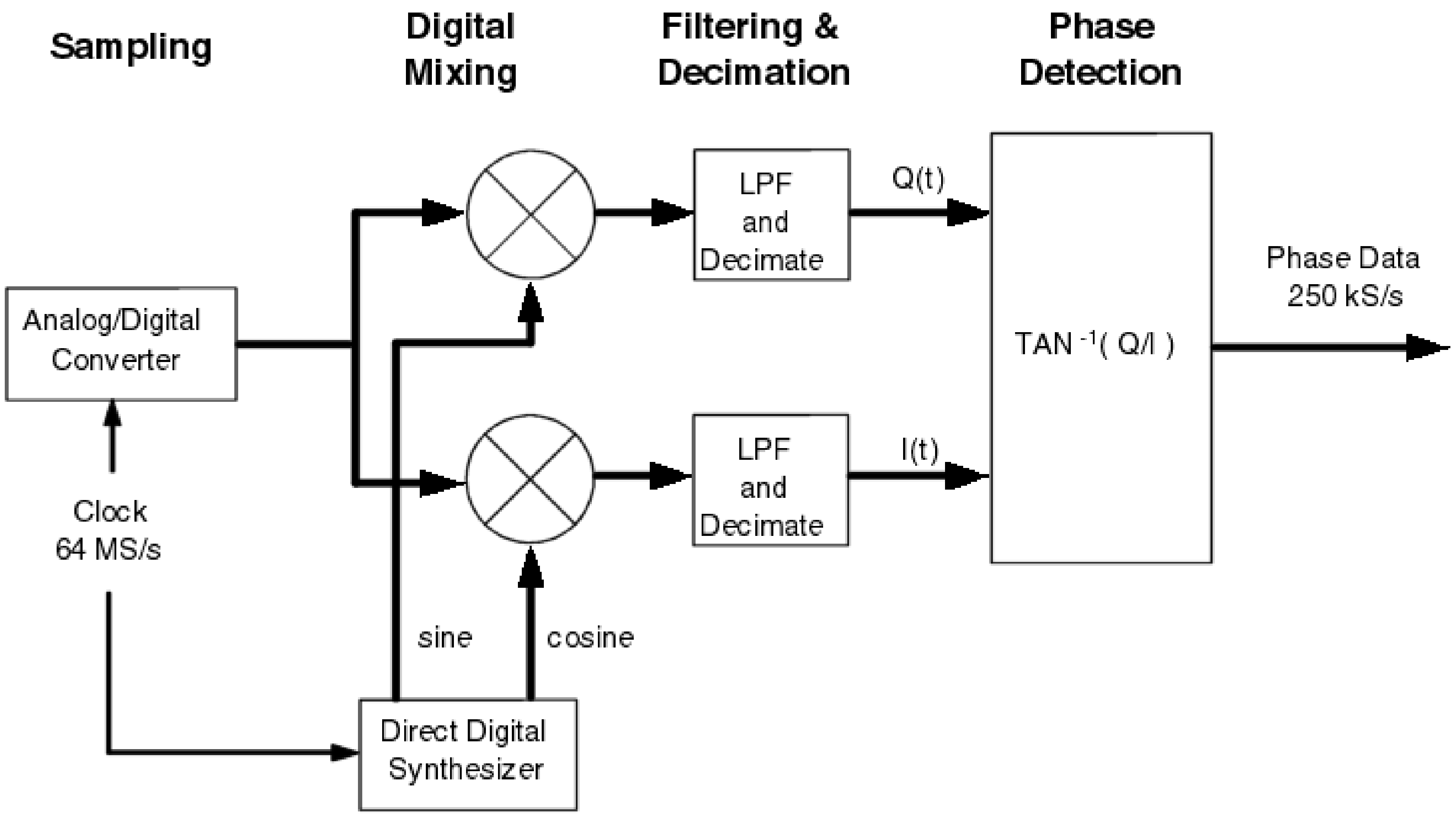
# Direct Digital Phase Noise

- Traditionally, phase noise measurements are made by analog techniques. A transducer is used to convert the phase fluctuations to a voltage that is sampled and Fourier analyzed
- The transducer is almost always a double-balanced mixer that, along with the following low noise amplifiers, must be calibrated at all Fourier frequencies of interest
- The double-balanced mixer operates as a phase detector only when the signals at the local oscillator (LO) and signal ports are approximately in phase quadrature; thus analog phase noise measurements of two sources require that the unit under test be phase locked to the reference
- Using digital techniques, it is possible to eliminate both of these restrictions making it much simpler to make high quality phase noise measurements



MICROCHIP

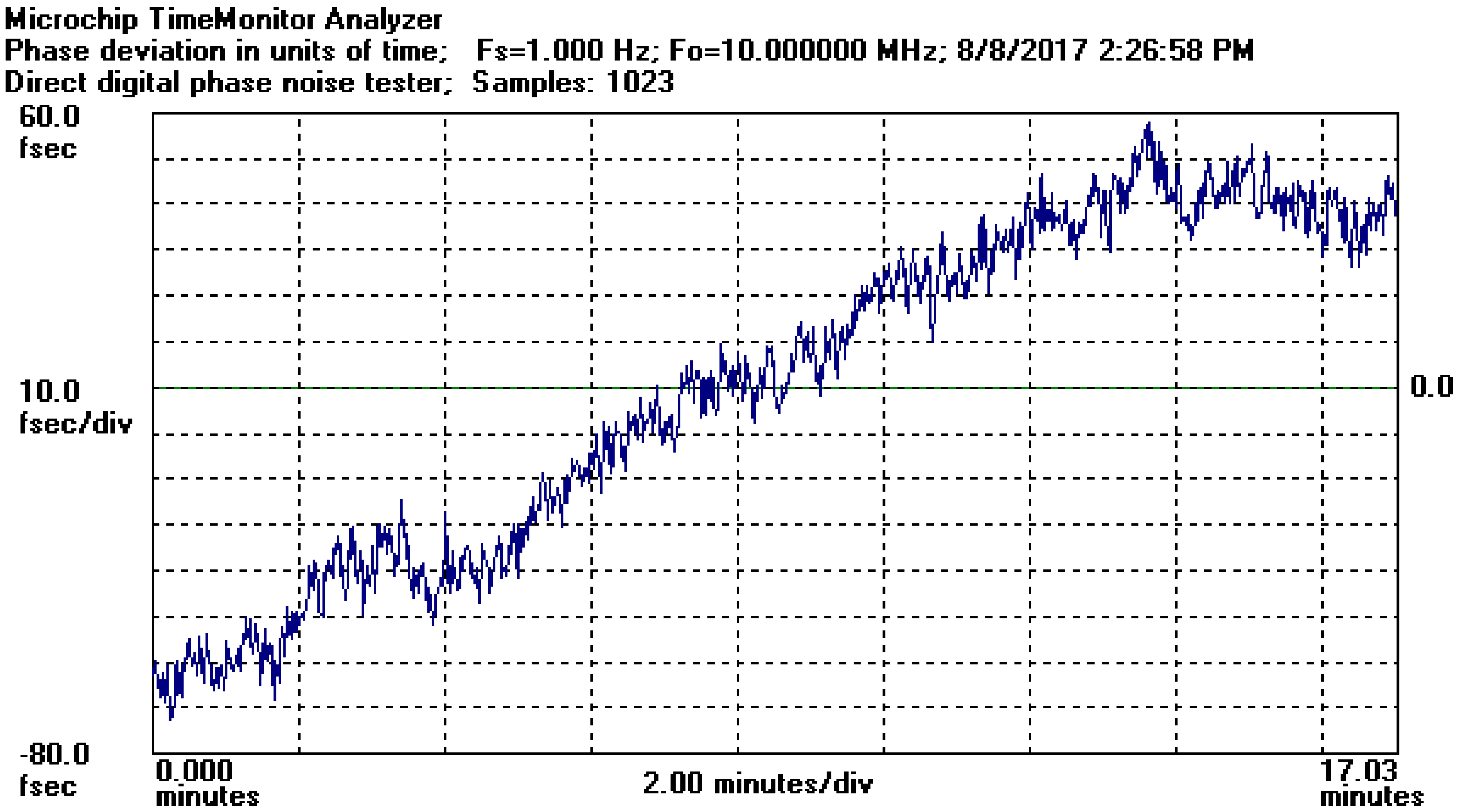
# Direct Digital Phase Noise Example System




*A local oscillator synthesized from the internal clock down-converts the input to base-band where the samples are used to compute the phase difference between the LO and the input.*

# Direct Digital Phase Noise

- This sample measurement illustrates the measurement precision achieved with this approach
- Typically, the signals are required  to be at 1 MHz of higher



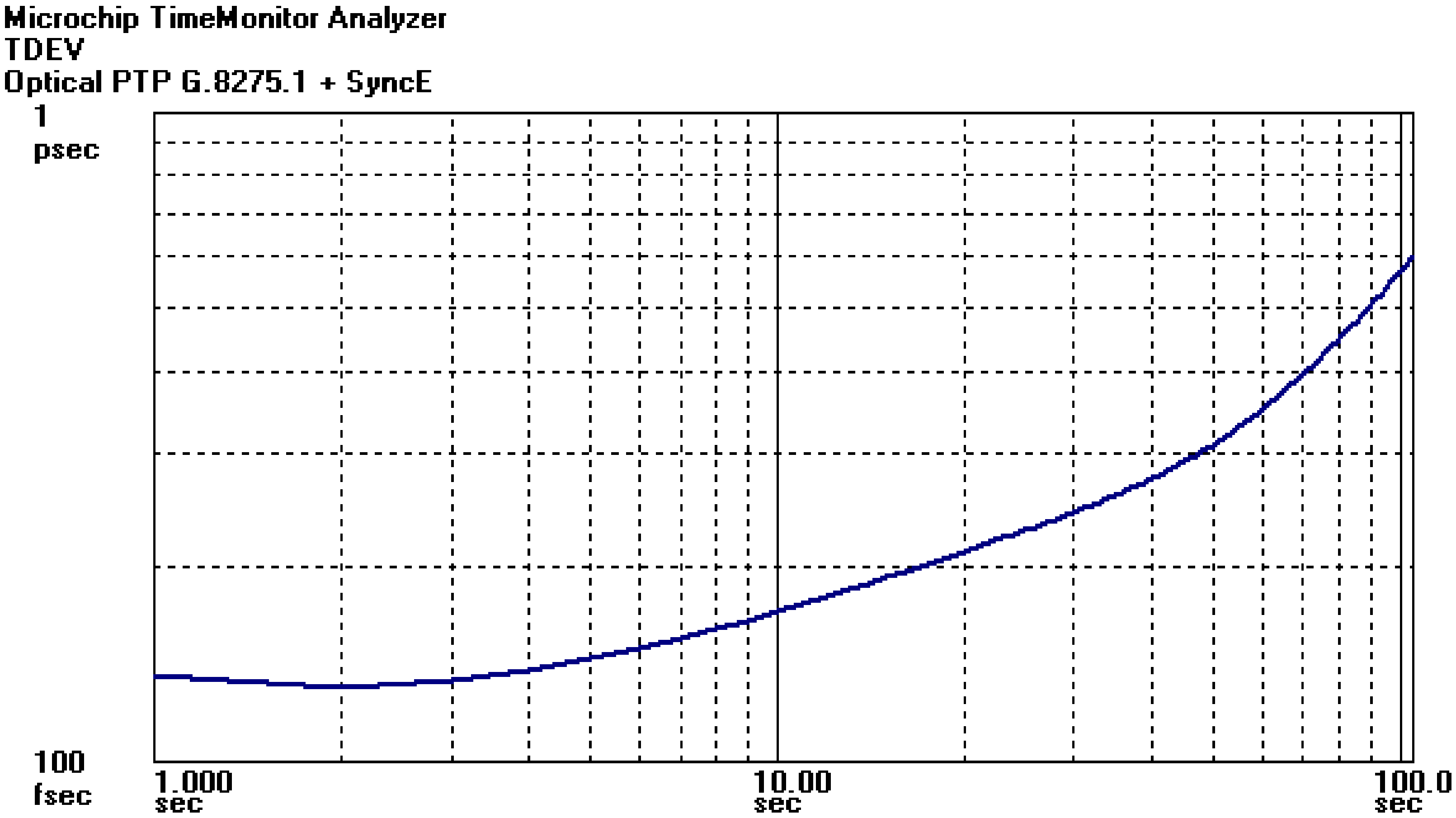





MICROCHIP

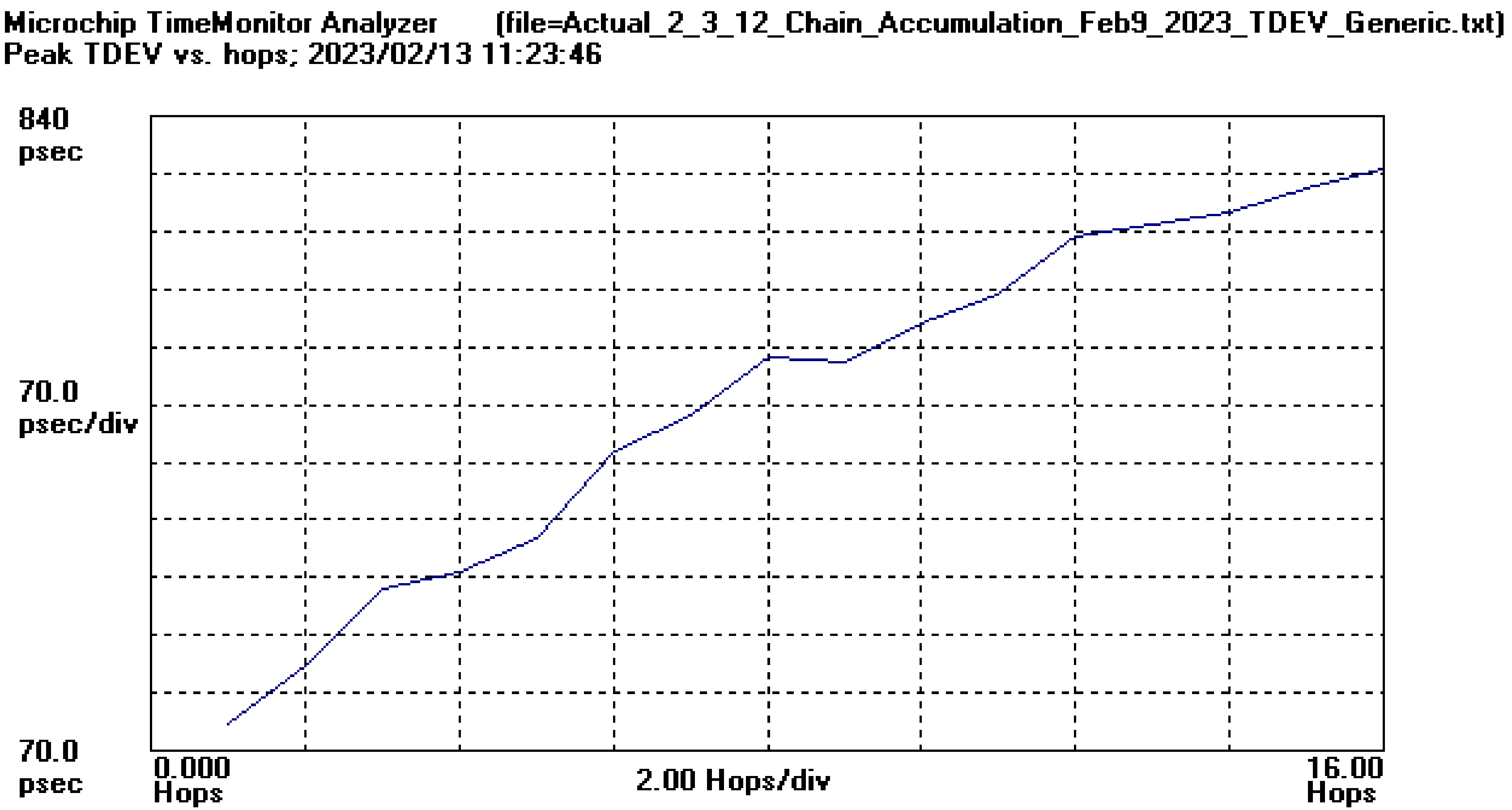
# Optical Network Measurement Example

- This example illustrates the results achievable in an optical node with packets (PTP) combined with physical layer SyncE



# High Accuracy Optical Link Measurement

- In the ITU-T sync expert group, options for delivering 1 ns or 5 ns over an optical network are being studied. Here are measurements showing accumulation of peak TDEV through 16 optical hops








MICROCHIP

# Summary

- New measurement instrumentation is capable of measuring at the picosecond level
- One approach is to take precision timestamps on the signal of interest at physical edges of packet arrival instances
- Another approach is to employ a direct digital dual heterodyne technique
- The former can accommodate low-rate signals such as "pulse per second" (1 PPS)
- The latter requires signal rates at 1 MHz or above
- Precision measurements are not confined to physical signals, but can be made by timing packet arrival instances, as in an optical network



MICROCHIP

# Thank you

**Lee Cosart**

Research Engineer

lee.cosart@microchip.com

Phone: +1-408-428-7833