TimeMonitor

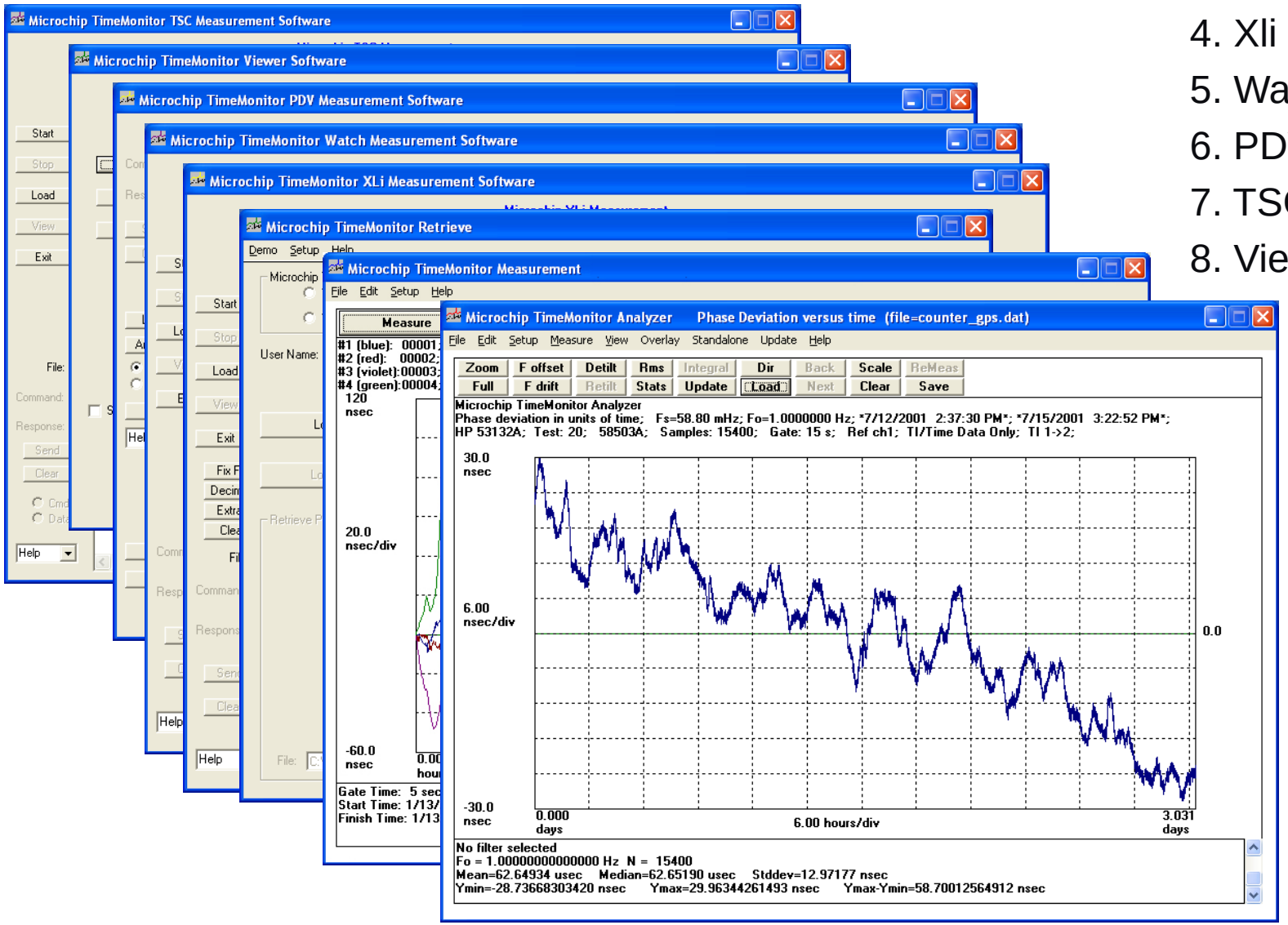
Synchronization Measurements and Analysis on Clock, Data, and Packet Network Signals

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

Part Number: 098-00926-000
Revision A – January 2021

TimeMonitor

TimeMonitor: Eight Applications



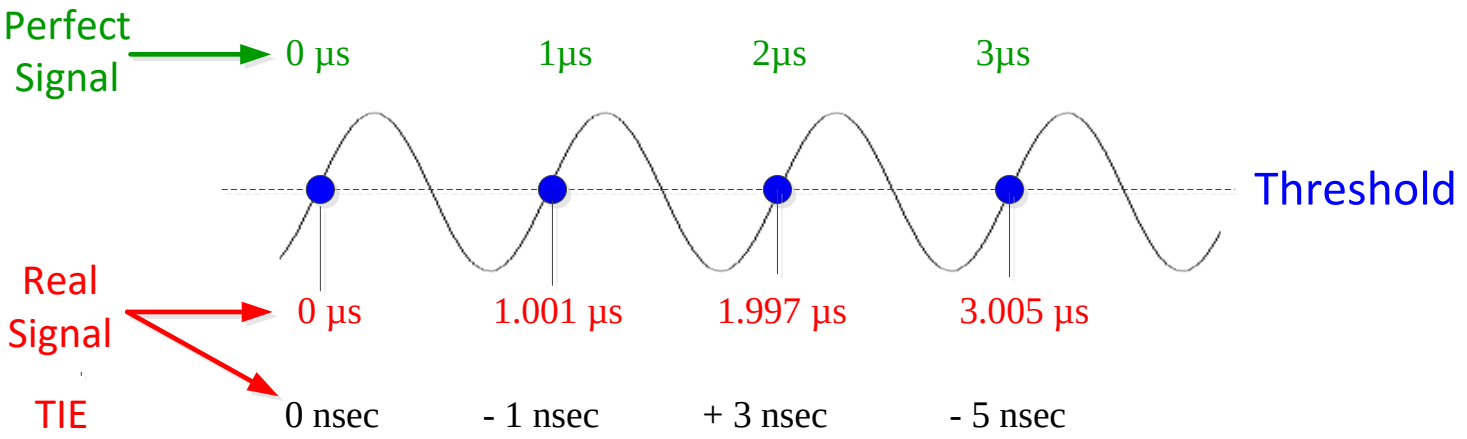
1. Analyzer
2. Measurement
3. Retrieve
4. Xli
5. Watch
6. PDV
7. TSC
8. Viewer

Presentation Outline

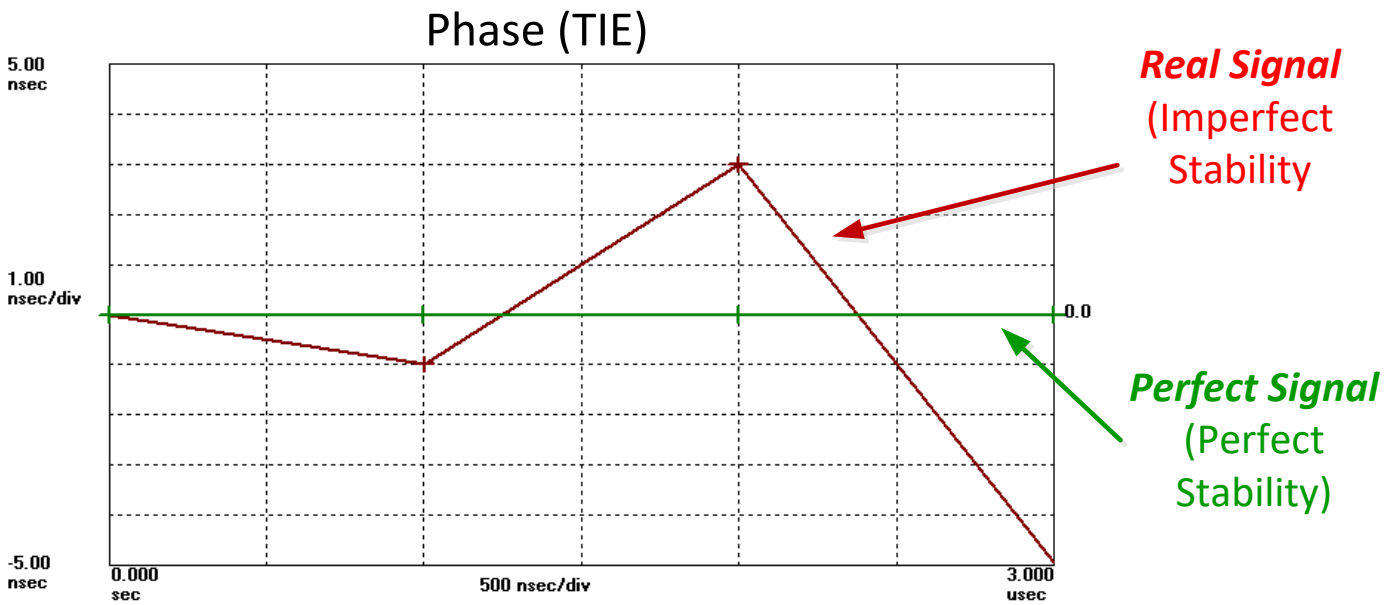
- **Sync Measurements**
  - Phase and Frequency
  - Analysis: MTIE, TDEV, ADEV, Phase Noise
  - Accuracy vs. Stability
- **Packet Measurements**
  - TIE vs. PDV
  - Equipment: Packet Probe
  - Analysis: Packet Selection, PDF, CDF
  - Two-way Analysis
- **TimeMonitor Software**
  - TimeMonitor Overview
  - TimeMonitor Analyzer
  - TimeMonitor Measurement
  - TimeMonitor PDV
  - Using TimeMonitor Analyzer for Packet Data
  - Integration/Test Automation: TimeMonitor Analyzer “Command Line”
  - Integration/Test Automation: TimeMonitor Analyzer “DLL”

Sync Measurements

Phase



Stable vs. Unstable



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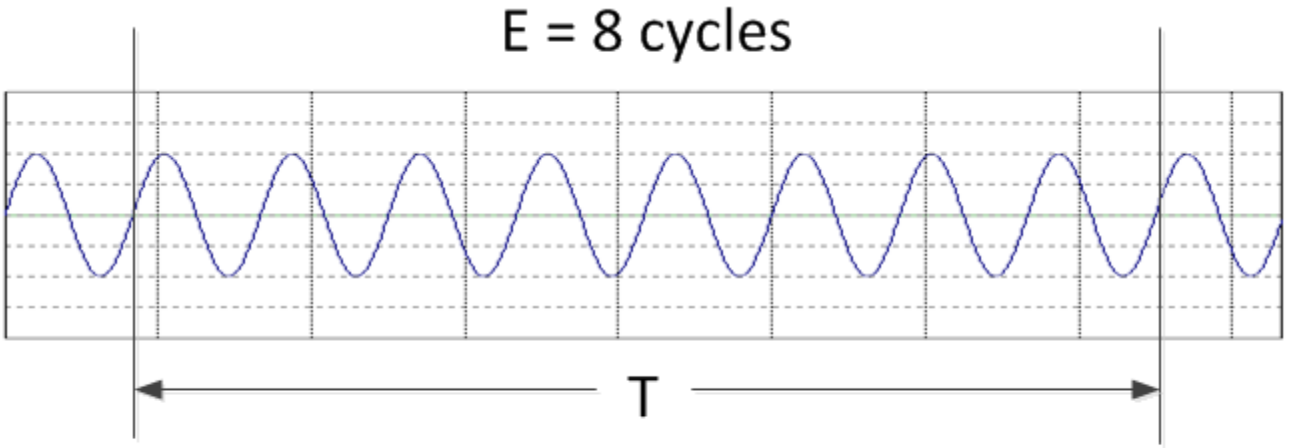
Frequency



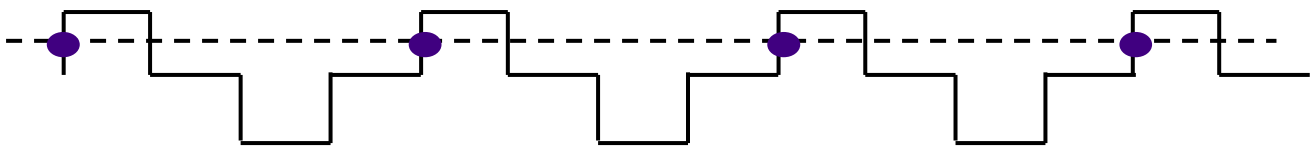
Frequency = E/T

If T = 8 µsec, F = 8cycles/8E-6sec = 1 MHz

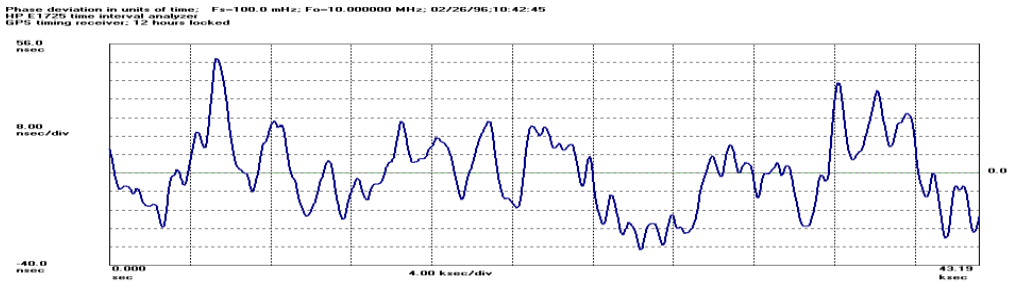
Frequency = the number of cycles per second
Ideal frequency source generates a pure sine wave

TIE Measurements

1. Timestamps

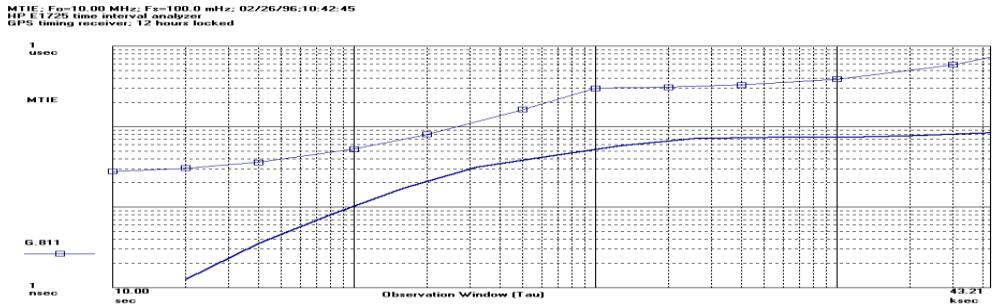


2. Phase



Phase Deviation or TIE

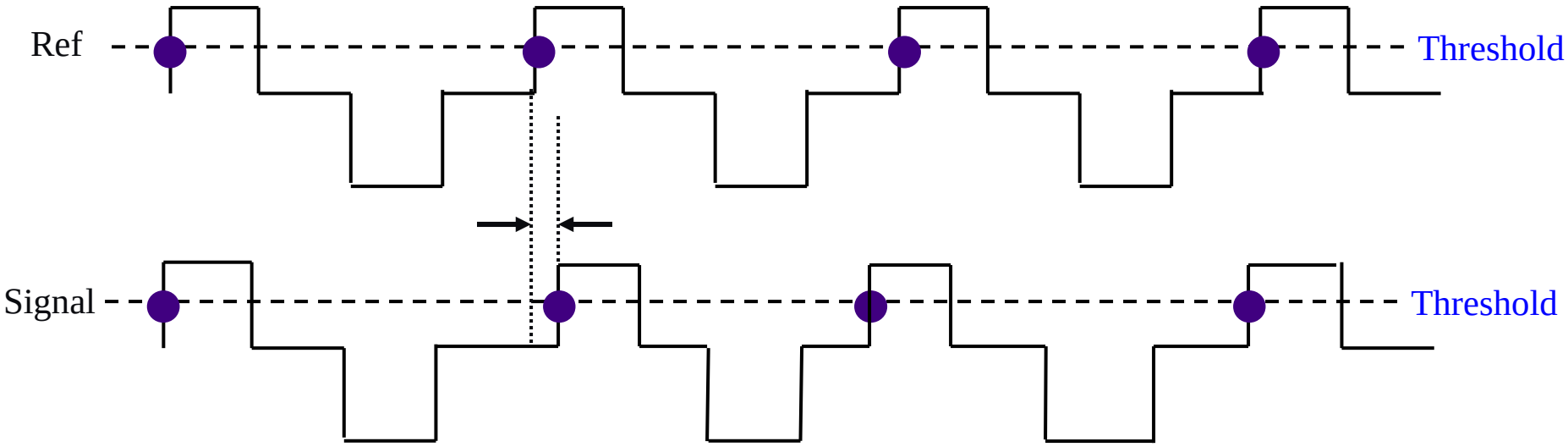
3. Analysis



MTIE, TDEV, Allan Variance, Frequency, PPSD, etc.

TIE Measurements Using a Reference Signal at the Same Frequency

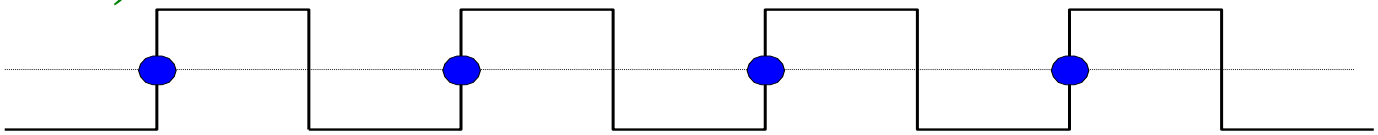
A time interval counter is used to time threshold crossings of a signal very precisely. This process is unaffected by amplitude modulation.



Timestamps: 1 MHz signal

Perfect mathematical reference (constant carrier)

0 µs 1 µs 2 µs 3 µs



Real signal measurement

0 µs 1.001 µs 1.997 µs 3.005 µs

ϕdev (time)/TIE	0 nsec	- 1 nsec	+ 3 nsec	- 5 nsec
ϕdev (degrees)	0°	- 0.36°	+ 1.08°	- 1.8°
ϕdev (UI)	0 UI	- 0.001 UI	+ 0.003 UI	- 0.005 UI

Phase Modulation Signal Model

$$v(t) = a(t) \cdot \sin\left(\phi(t)\right)$$

$$\phi(t) = \omega_o \cdot t + \theta(t)$$

$$\phi(t_i) = \omega_o \cdot t_i + \theta(t_i) = n_i \cdot 2\pi$$

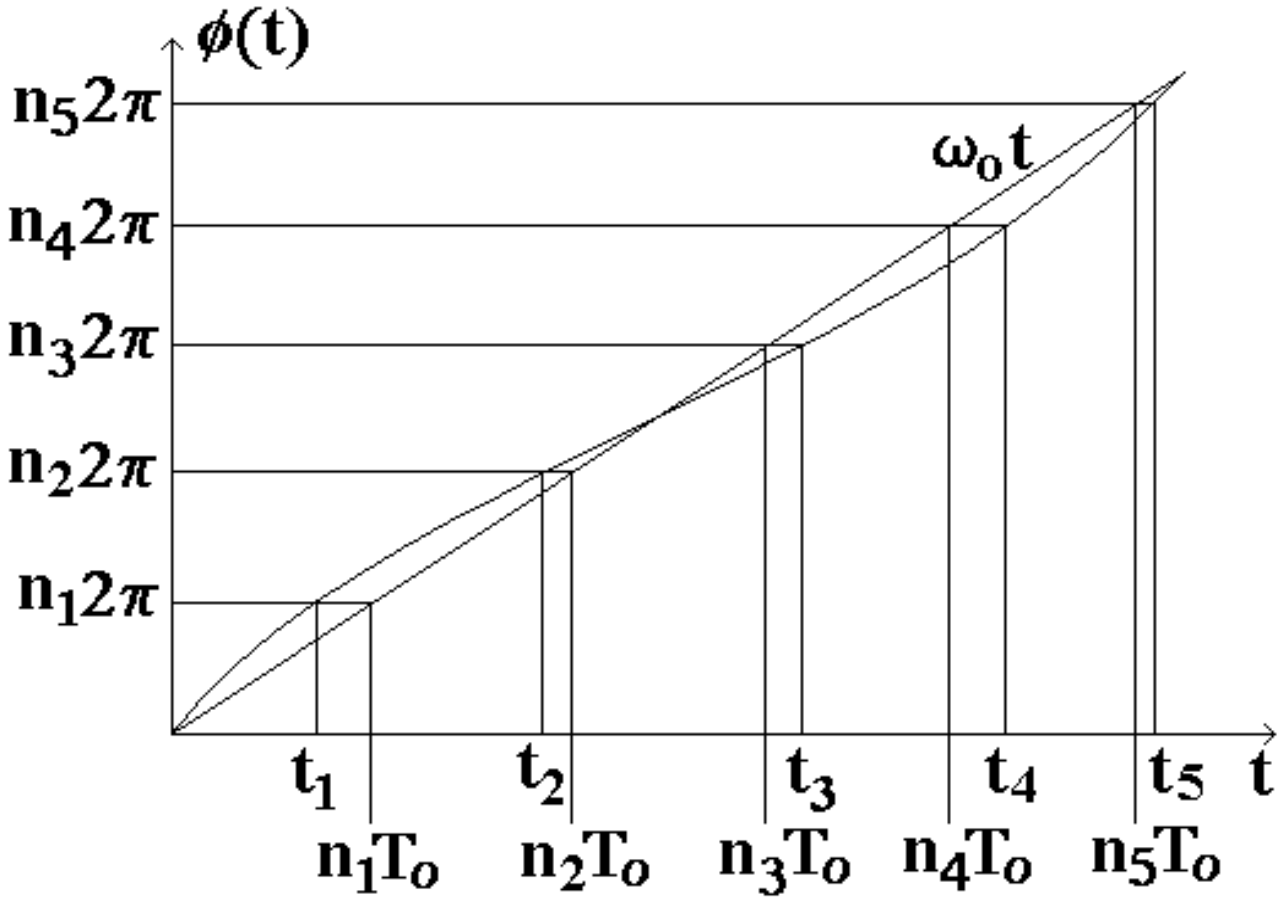
Phase deviation or TIE

$$\theta(t_i) = n_i \cdot 2\pi - \omega_o \cdot t_i = \omega_o \cdot (n_i \cdot T_o - t_i)$$

Reference frequency

Phase vs. Time

Phase deviation (TIE) is the difference between these two curves



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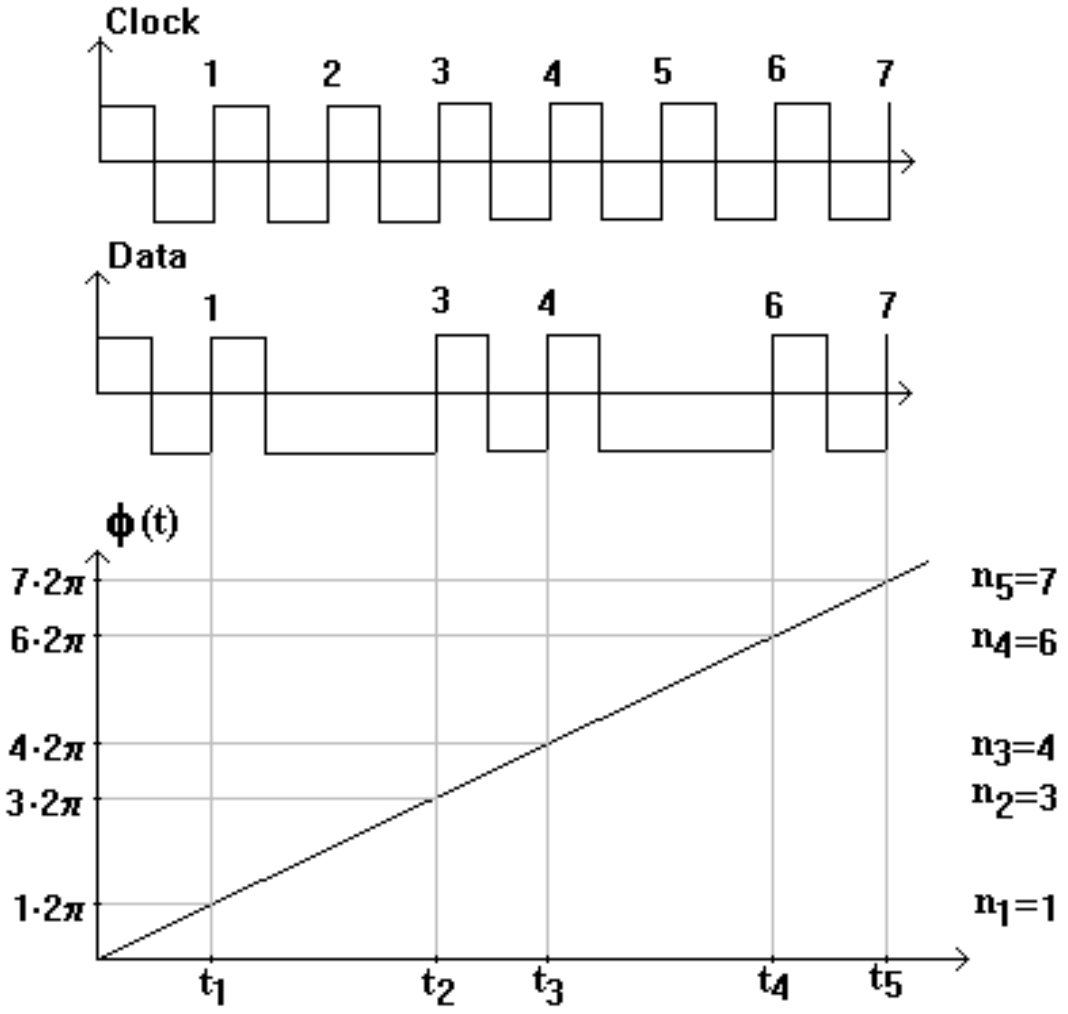
Data Signal Phase vs. Time



Sync Measurement Analysis

1. **Sync equipment measurements (lab) and**
2. **Sync interface measurements (network)**

- **For synchronization measurements, the measurement analysis used primarily is:**
  - Phase (TIE)
  - Frequency (fractional frequency offset)
  - Frequency accuracy
  - MTIE
  - TDEV
    - MTIE and TDEV analysis shows comparison to ANSI, Telcordia, ETSI, & ITU-T requirements

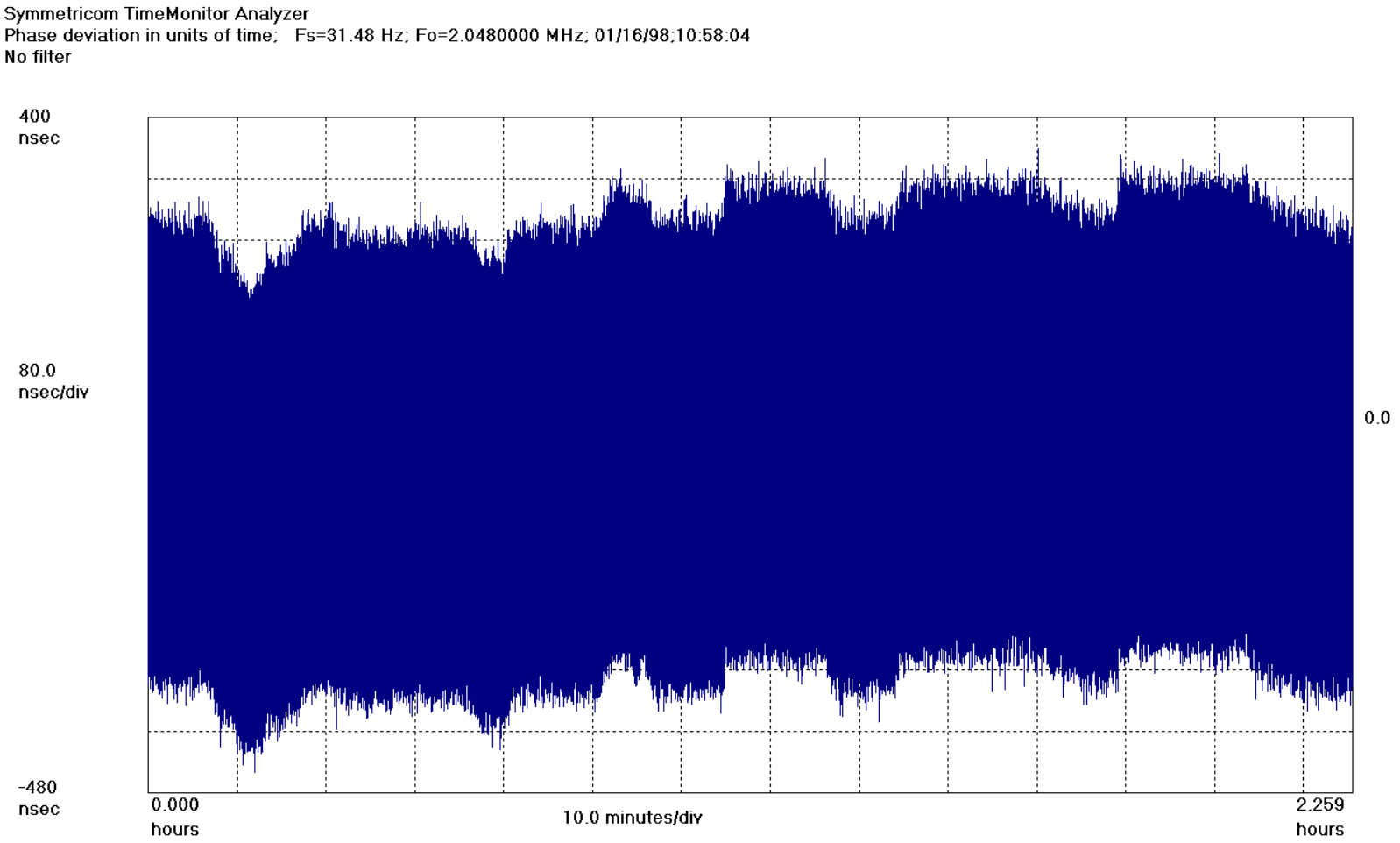
All are derived from phase

3. **Oscillator measurements**

- **For oscillators:**
  - ADEV
  - Phase noise
  - Tempco (temperature coefficient of frequency)

Analysis from Phase: Jitter & Wander

Signal with jitter and wander present



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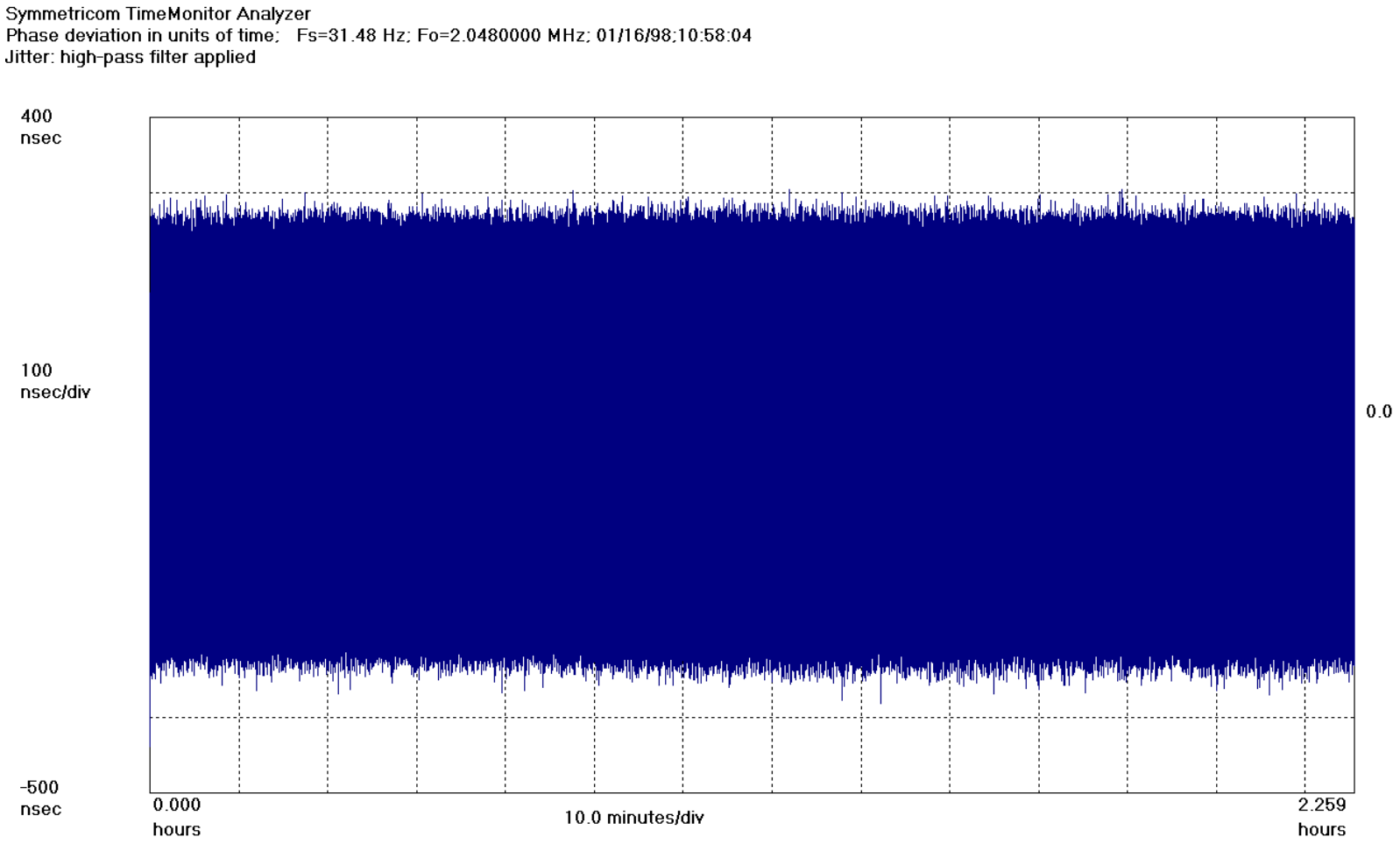
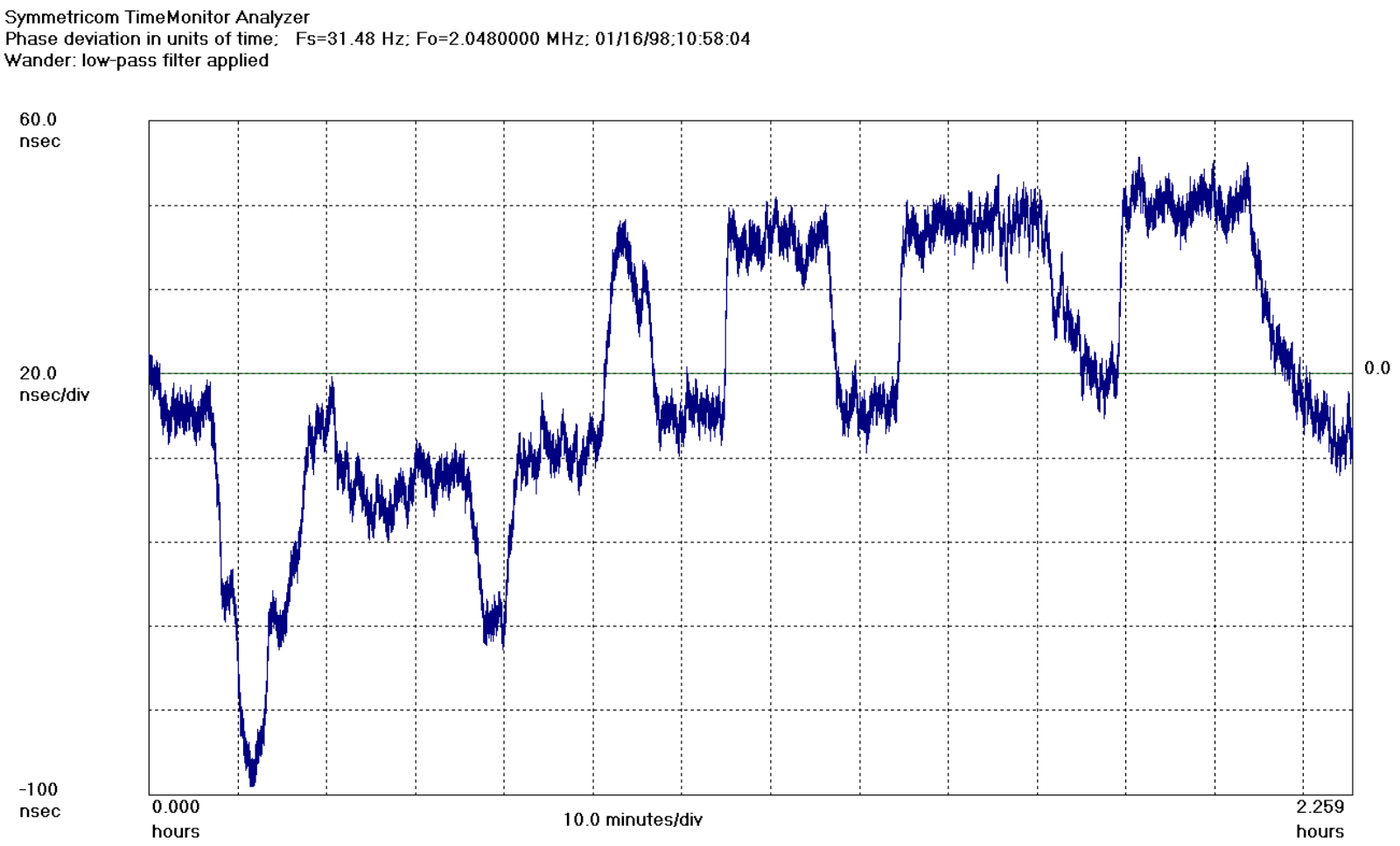
Analysis from Phase: Jitter

Jitter: Filter out low-frequency components with high-pass filter
Jitter = 740 nsec peak-to-peak = 1.52 UI peak-to-peak (E1)



Analysis from Phase: Wander

Wander: Filter out high-frequency components with low-pass filter



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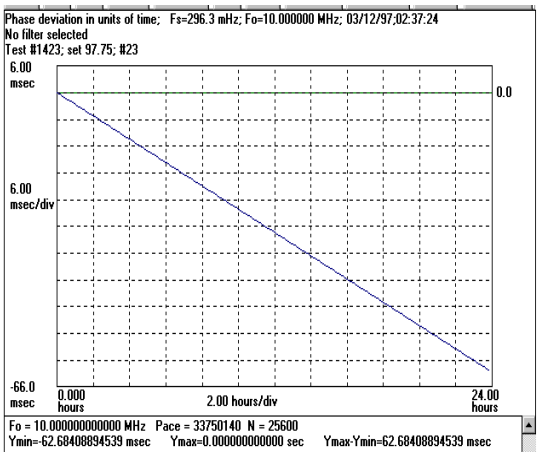
Analysis from Phase: Frequency

- **Recall the relationship between frequency and phase:**

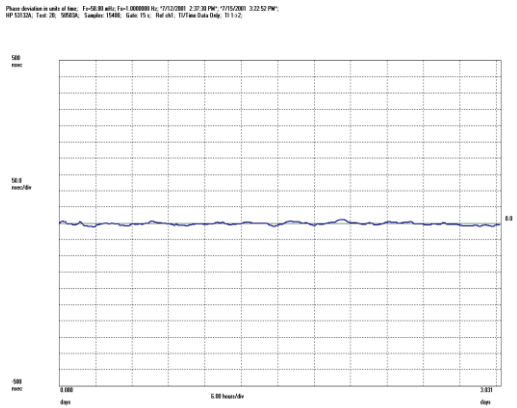
$$\omega = \frac{d\phi}{dt}$$

- **Important point: Frequency is the slope in the phase plot**



Frequency offset present

No offset: ideal phase plot (flat)



Analysis from Phase: Frequency

Timestamps(µs):	0	1.001	1.997	3.005	4.002	4.999	6.003
ϕ dev (ns):	0	-1	+3	-5	-2	+1	+3

Phase deviation slope

$$\Delta\phi dev = \Delta N \cdot T_o - \Delta t = (\Delta N - f_o \Delta t)/ f_o$$

$$fdev = f - f_o = \Delta N / \Delta t - f_o = (\Delta N - f_o \Delta t)/ \Delta t = \Delta\phi dev \cdot f_o / \Delta t$$

$$ffoff = fdev/f_o$$

For example, take the average fdev over the first 3 cycles:

Frequency Deviation = - 5nsec · 10^6Hz/3.005µsec = -1.7 kHz

Fractional Frequency Offset = -1.7 kHz/1MHz = -1.7 parts per thousand

Frequency

F Frequency: F = E/T (number of cycles/time)

F_0 Nominal frequency: F_0

FDEV Frequency deviation: FDEV = F - F_0

FFO Fractional frequency offset: FFO = FDEV/ F_0 = (F - F_0)/ F_0

Example: E = 1 000 000; T = 0.999 999 997 500 sec

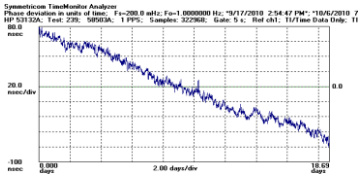
F = E/T = 1000000/0.9999999975 = 1.000 000 002 500 MHz

F_0 = 1 MHz

FDEV = F- F_0 = 2.5 mHz

FFO = FDEV/ F_0 = $2.5 \cdot 10^{-9}$ = 2.5 PPB ←

Analysis from Phase: Frequency

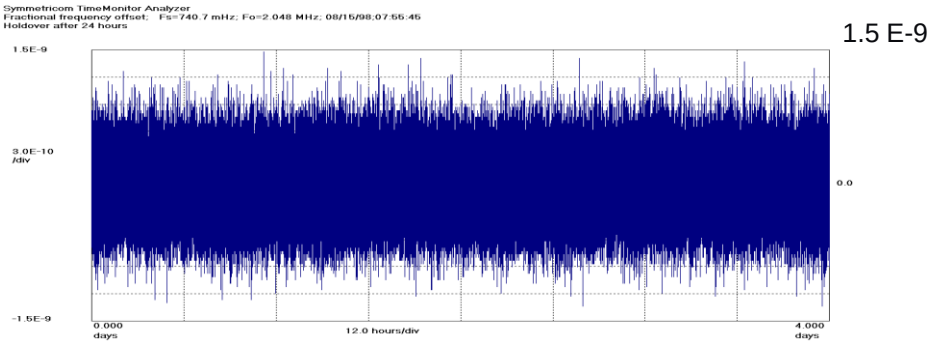


$-8.97 \cdot 10^{-14}$

Frequency Accuracy

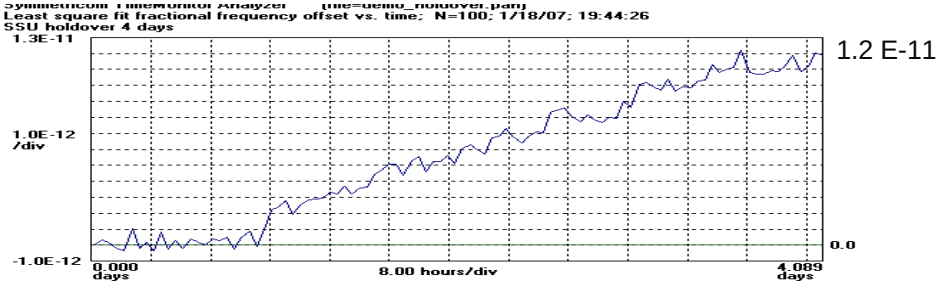
$$\omega = \frac{d\phi}{dt}$$

slope/linear: frequency offset
curvature/quadratic: frequency drift



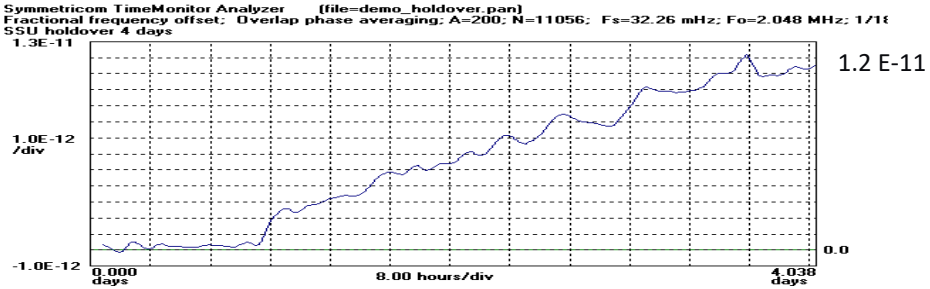
1.5 E-9

Point-by-point



1.2 E-11

Segmented LSF



1.2 E-11

Sliding Window Averaging

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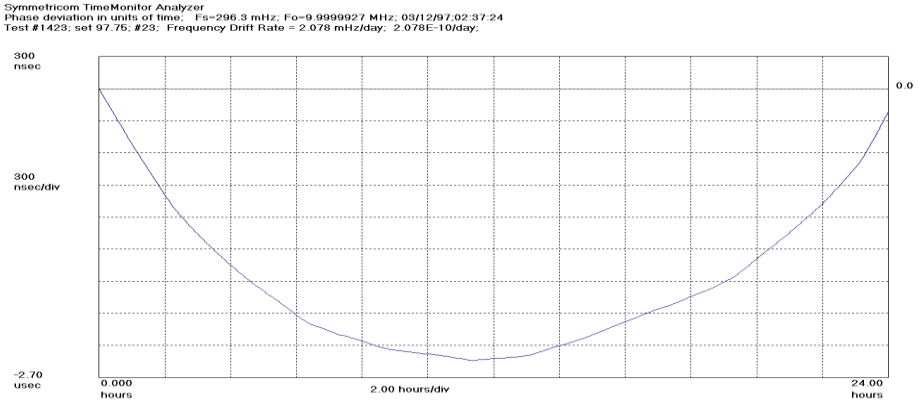
Frequency Offset and Drift

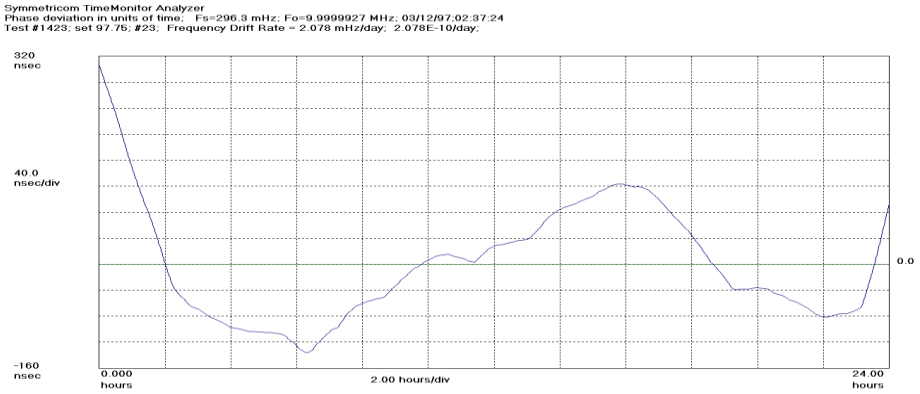
70 ms p-p

Original oscillator phase measurement (0.7ppm frequency offset)



2.5 µs p-p

Frequency offset removed (quadratic shape shows linear frequency drift of 0.2 ppb/day)



500 ns p-p

Frequency drift removed (shows residual phase movement)

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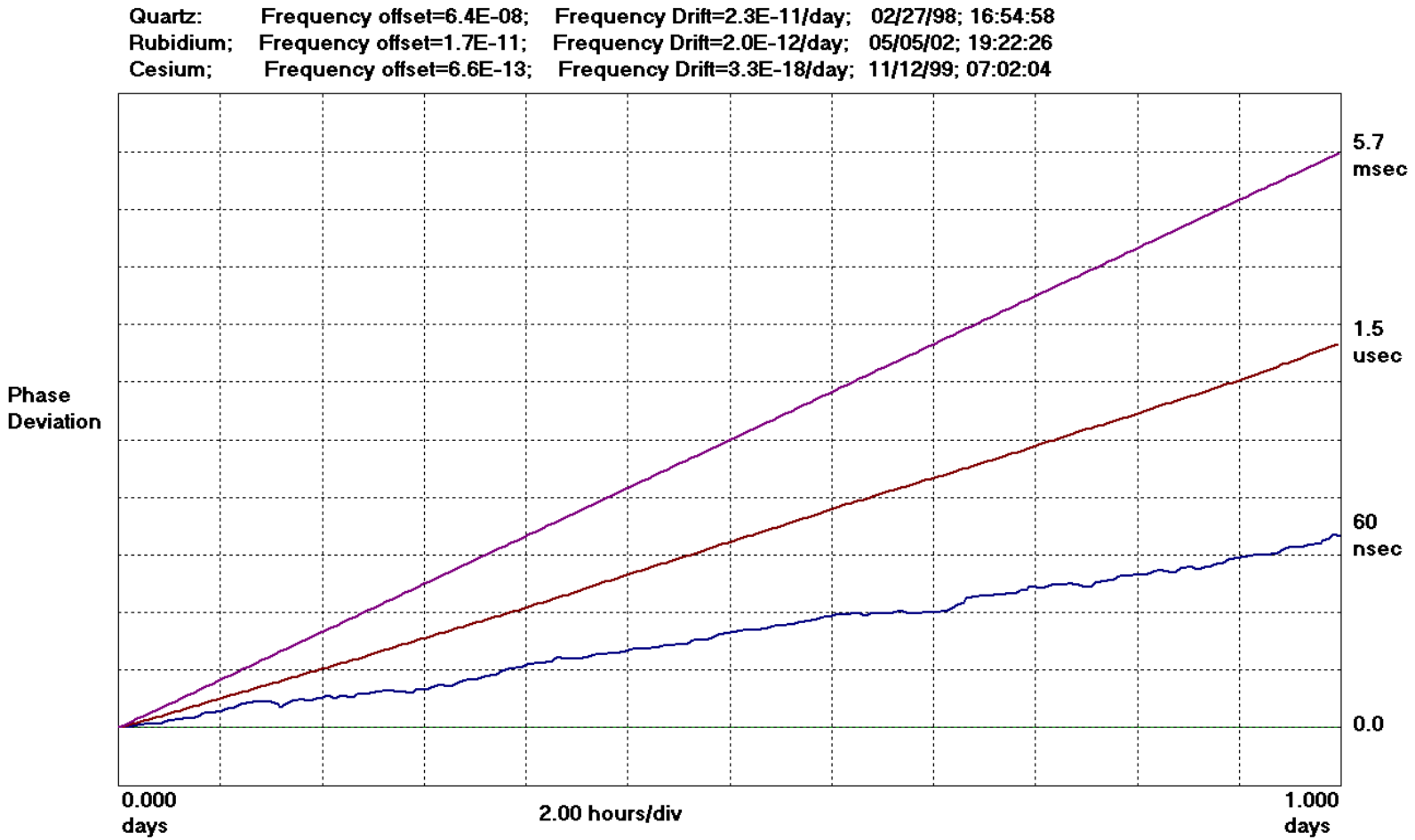
Frequency Accuracy and Stability

Quartz, Rubidium, and Cesium



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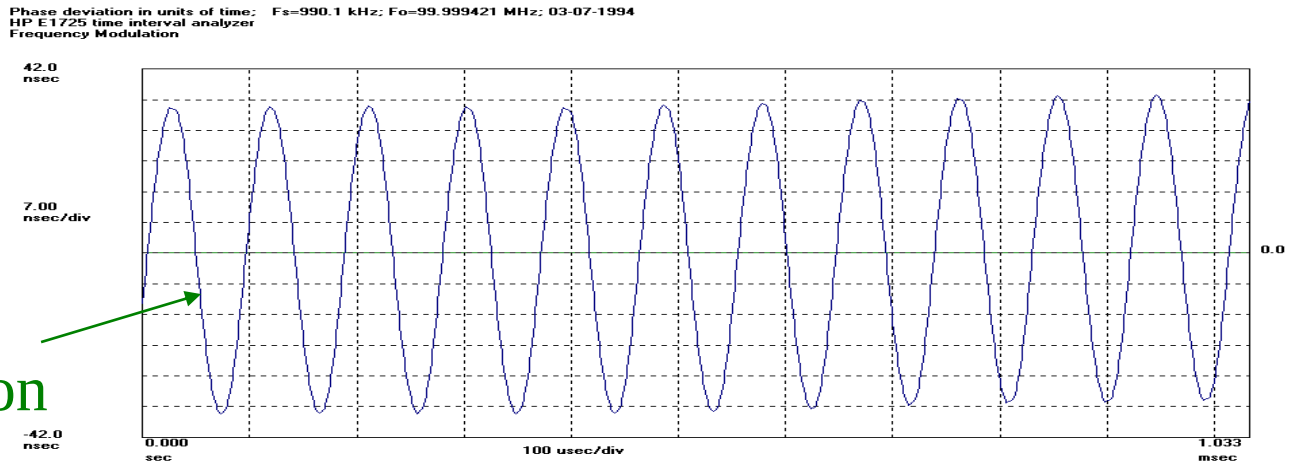
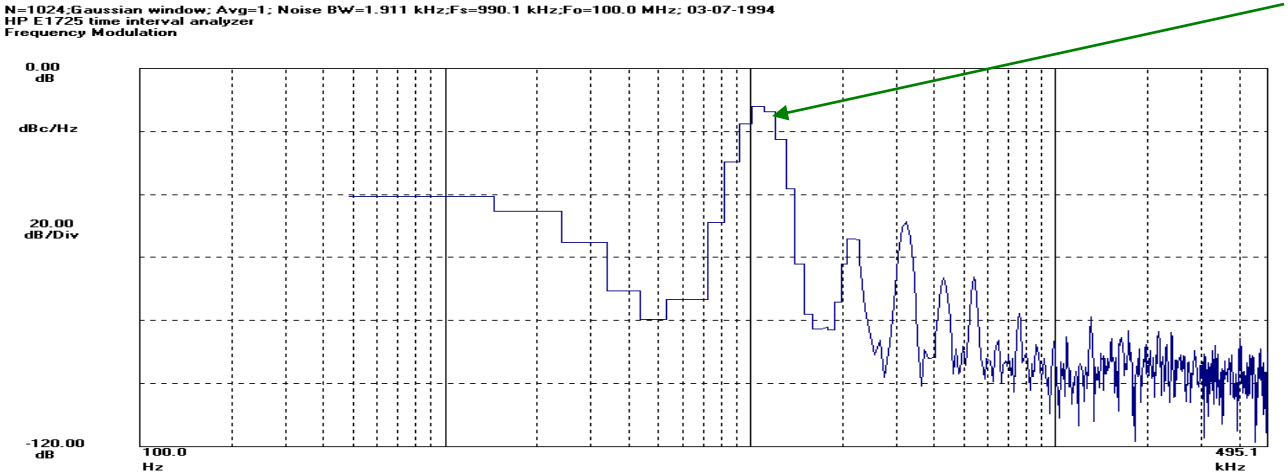
Analysis from Phase: Phase Power Spectral Density

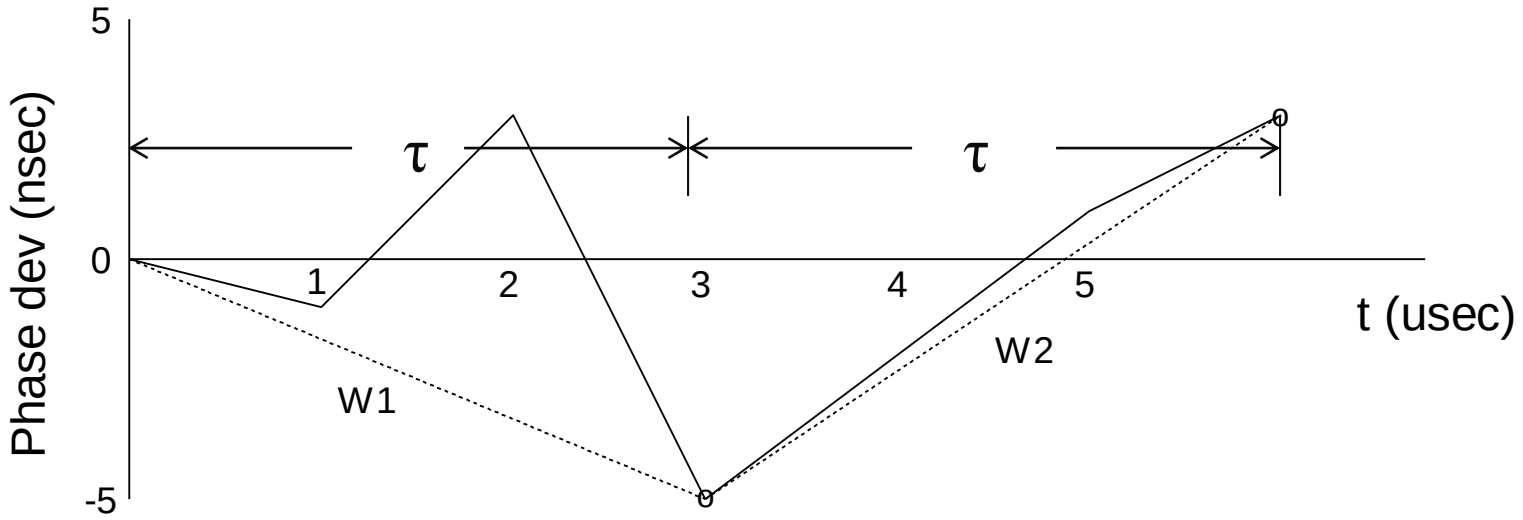


10 kHz modulation



10 kHz component

Allan Variance



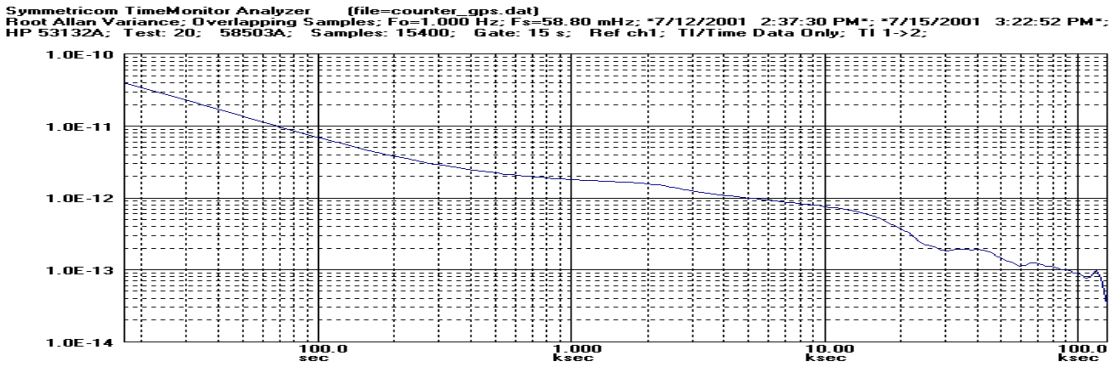
Allan Variance is a measurement of frequency stability used for characterizing oscillators.

Difference in slope = $\Delta W = W2 - W1 \Rightarrow AVAR = \frac{1}{2}\langle(\Delta W_{\tau})\rangle^2$

Change in frequency

ADEV Plot:

$(ADEV = \sqrt{AVAR})$



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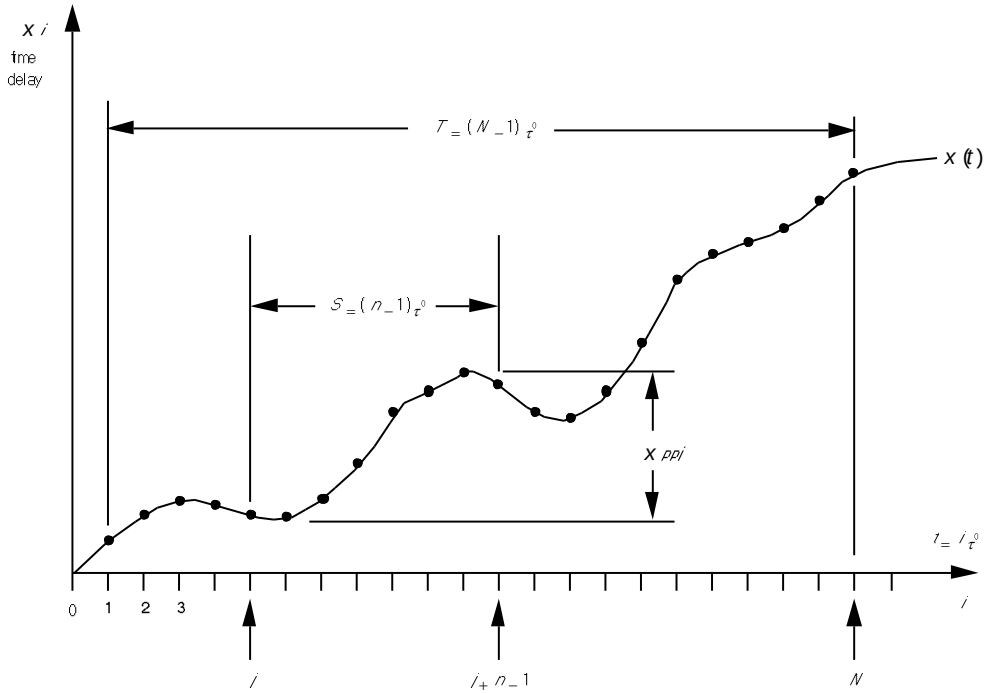
Analysis from Phase: MTIE/TDEV

$$MTIE(S) = \max_{j=1}^{N-n+1} \left[\max_{i=j}^{n+j-1}(x_i) - \min_{i=j}^{n+j-1}(x_i) \right]$$



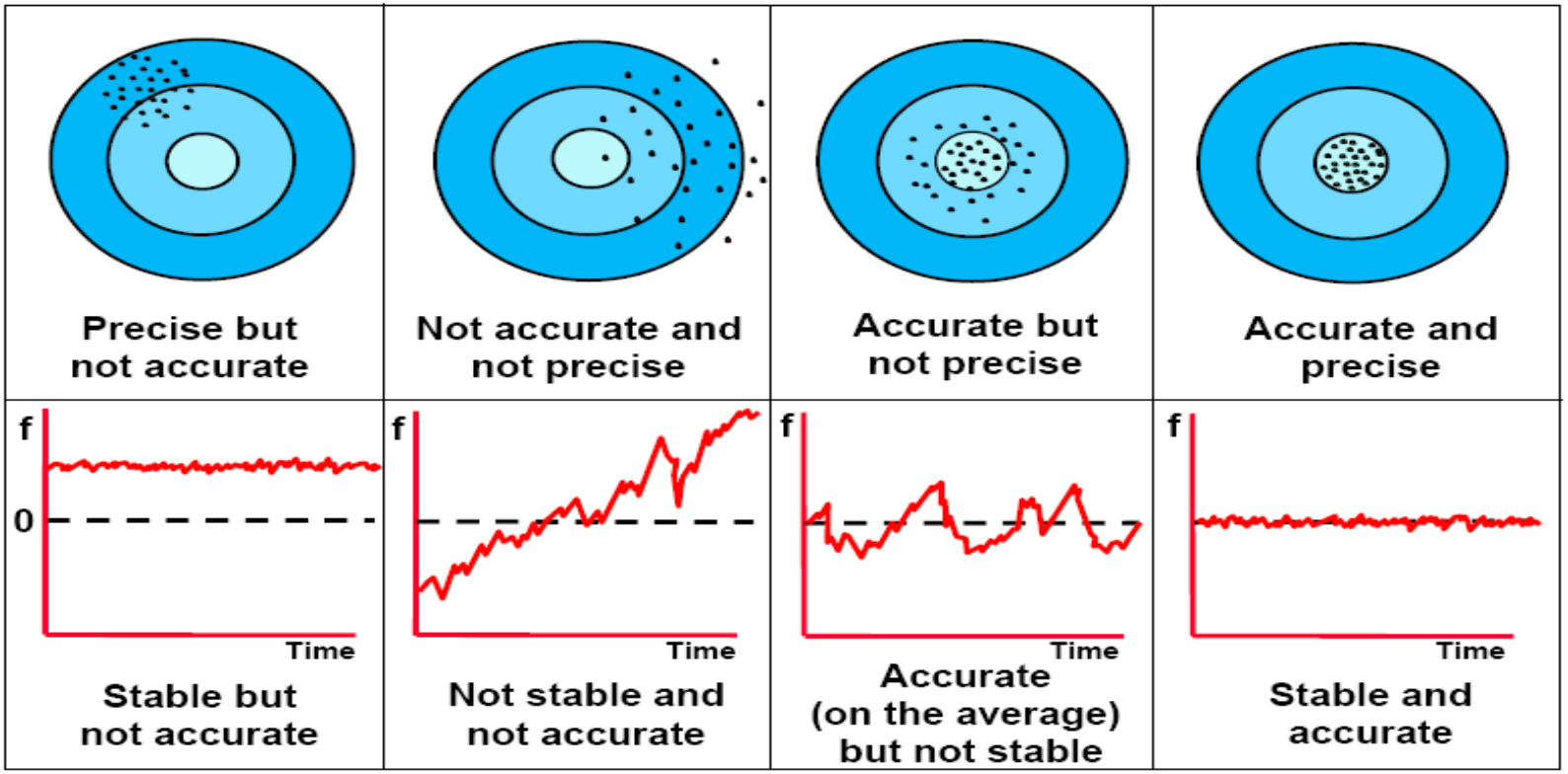
MTIE is a peak detector
MTIE detects frequency offset

$$\sigma_x(\tau) = TDEV(\tau) = \sqrt{\frac{1}{6}\left\langle \left[\frac{1}{n}\sum_{i=1}^{n} x_{i+2n} - 2\frac{1}{n}\sum_{i=1}^{n} x_{i+n} + \frac{1}{n}\sum_{i=1}^{n} x_i \right]^2 \right\rangle}$$

TDEV is a highly averaged “rms” type of calculation
TDEV shows white, flicker, random walk noise processes
TDEV does not show frequency offset

MTIE and TDEV analysis allows comparison to ATIS, Telcordia, ETSI, & ITU-T requirements

Stability and Accuracy



f is FFO

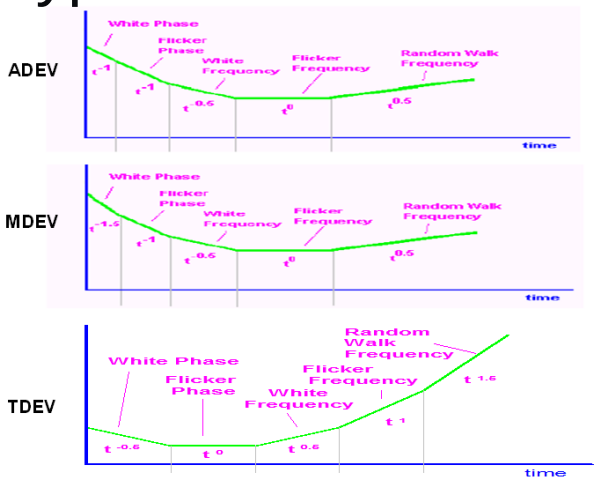
The Allan Variance family of analysis metrics is concerned with the characterization of stability

Diagram from “Time Domain Representation of Oscillator Performance”, Marc A. Weiss, Ph.D. NIST

Systematics and Stochastics

- Systematics
  - Frequency offset
  - Frequency drift
  - Environmentals (temperature, humidity, pressure, etc.)

- When systematics are removed, what remains is noise (stochastic processes). Five major noise types:
  - WPM (white phase modulation)
  - FPM (flicker phase modulation)
  - RWPM = WFM (random walk PM = white FM)
  - FFM (flicker frequency modulation)
  - RWFM (random walk frequency modulation)

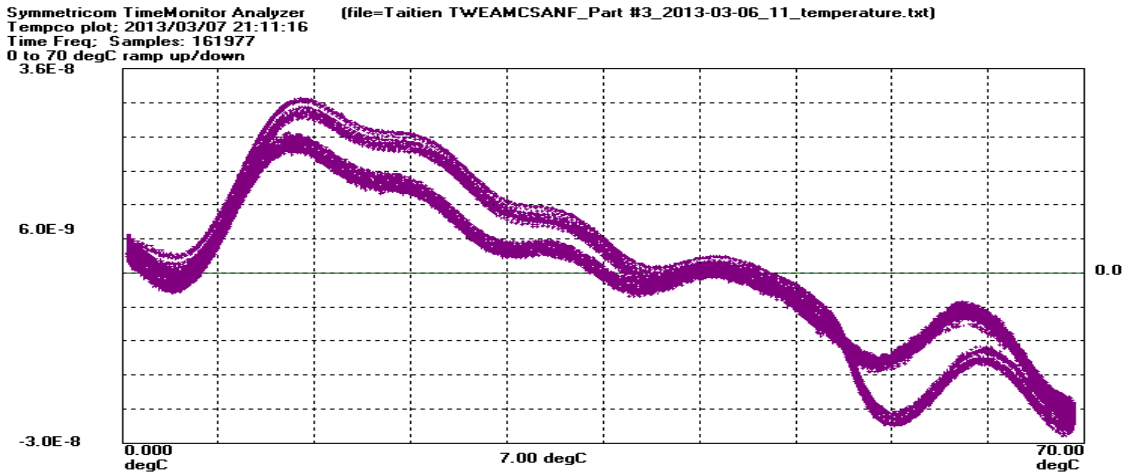


*ADEV slope: -1.0 (WPM); -1.0 (FPM); -0.5 (RWPM); 0 (FFM); 0.5 (RWFM)
*MDEV slope: -1.5 (WPM); -1.0 (FPM); -0.5 (RWPM); 0 (FFM); 0.5 (RWFM)
*TDEV slope: -0.5 (WPM); 0 (FPM); 0.5 (RWPM); 1.0 (FFM); 1.5 (RWFM)

Oscillator Testing

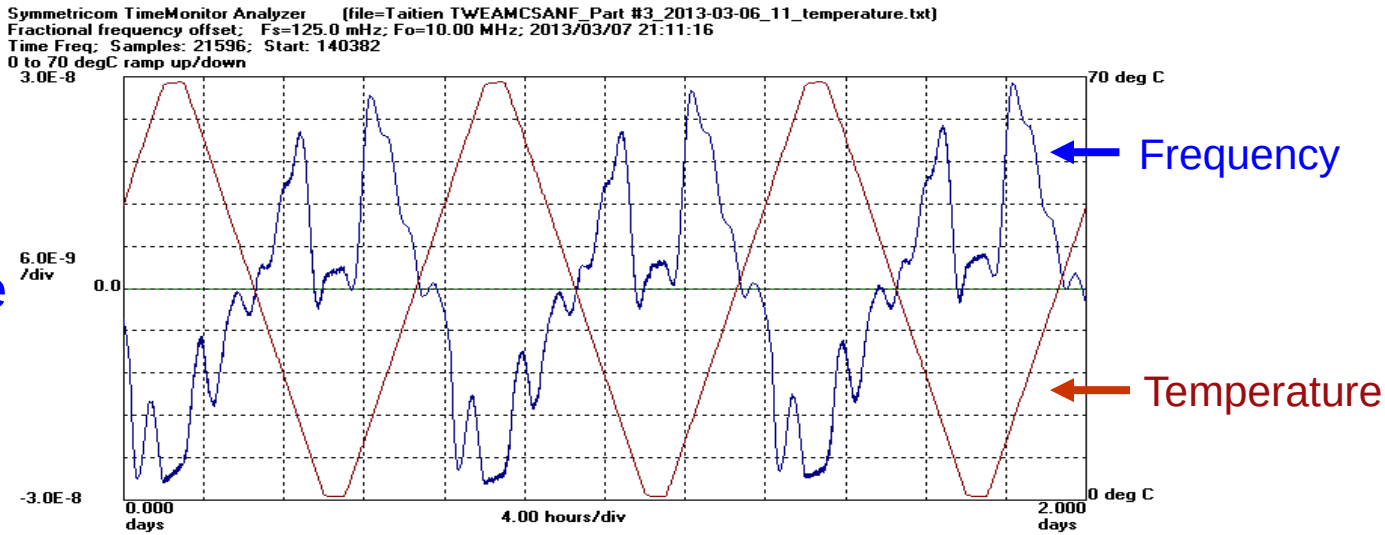
Tempco

Tempco



15 days
22 cycles
60 ppb p-p
over 70º C

F&T vs. time



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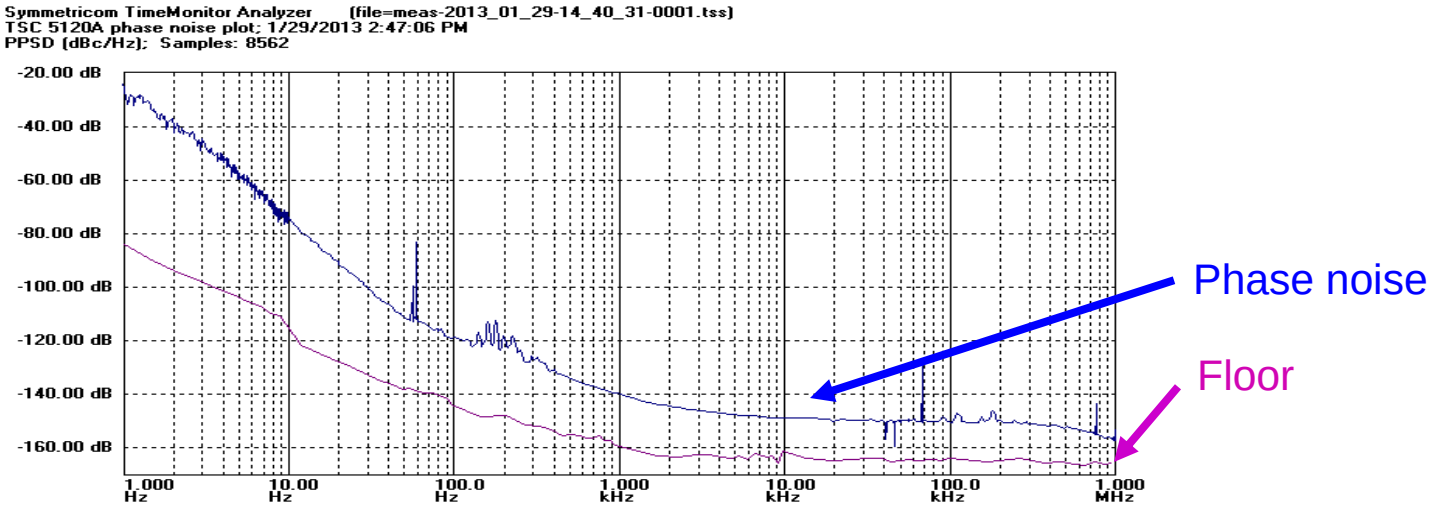
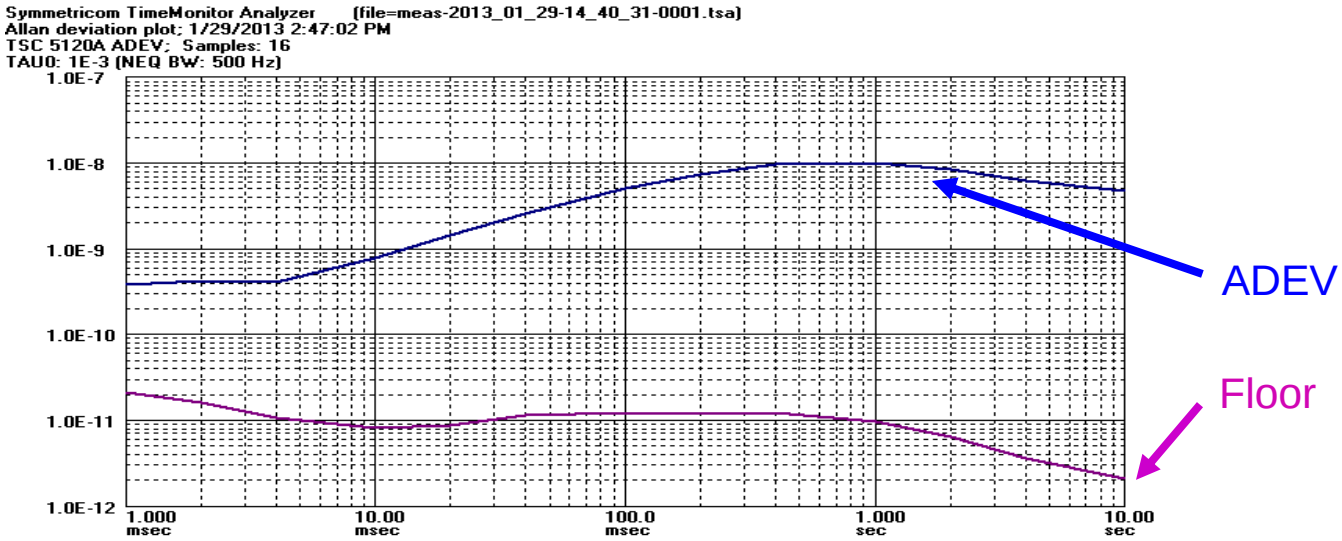
Oscillator Testing

Phase Noise & ADEV

Phase Noise



ADEV



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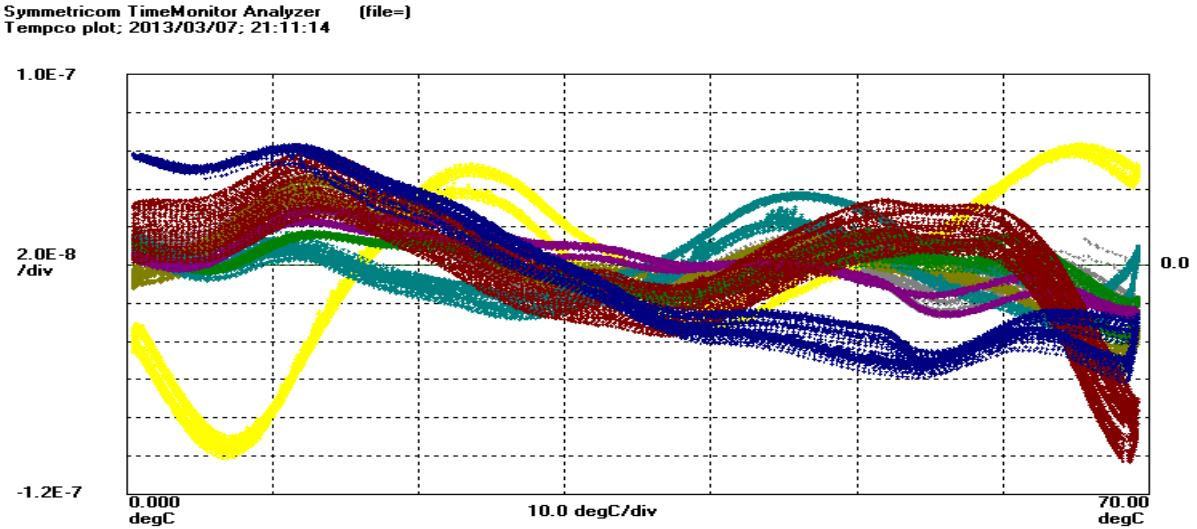
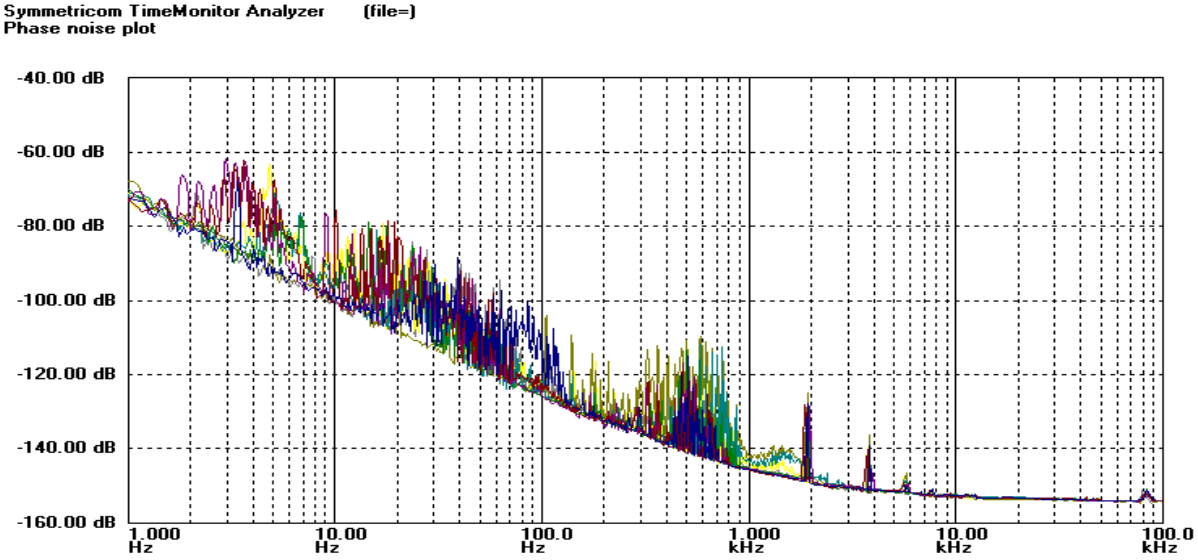
Oscillator Testing

Overlay Results

Tempco



Phase Noise



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Packet Measurements

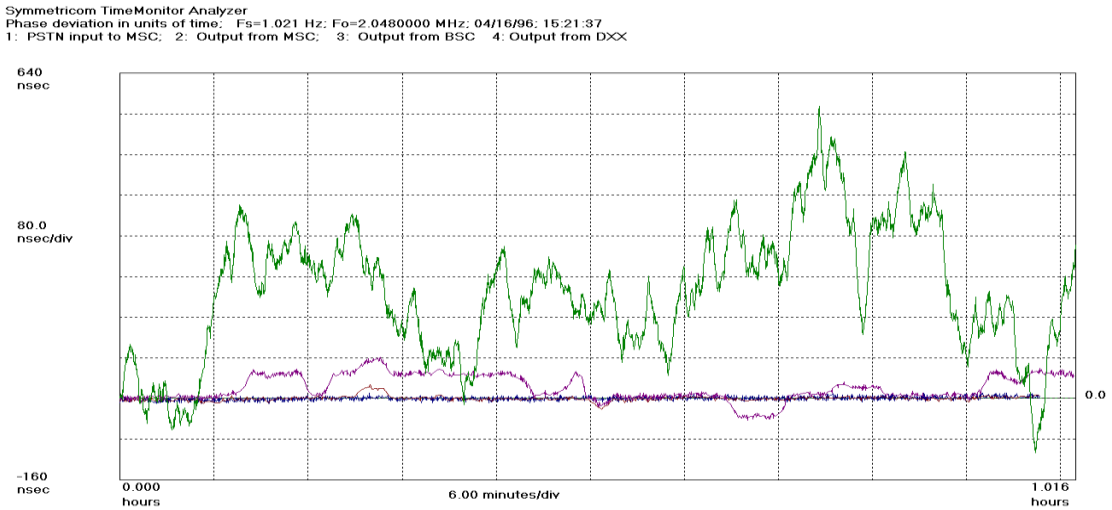
“TIE” vs. “PDV”

- **“TIE” vs “PDV”**
  - Traditional TDM synchronization measurements: signal edges are timestamped producing a sequence of samples (“circuit-switched network”)
  - Packet timing measurements: packet departure/arrival times are sampled and packet delay sequences are formed (“packet-switched network”)
  - Both require (1) PRC/GPS; (2) Precision HW timestamping; (3) PC + SW

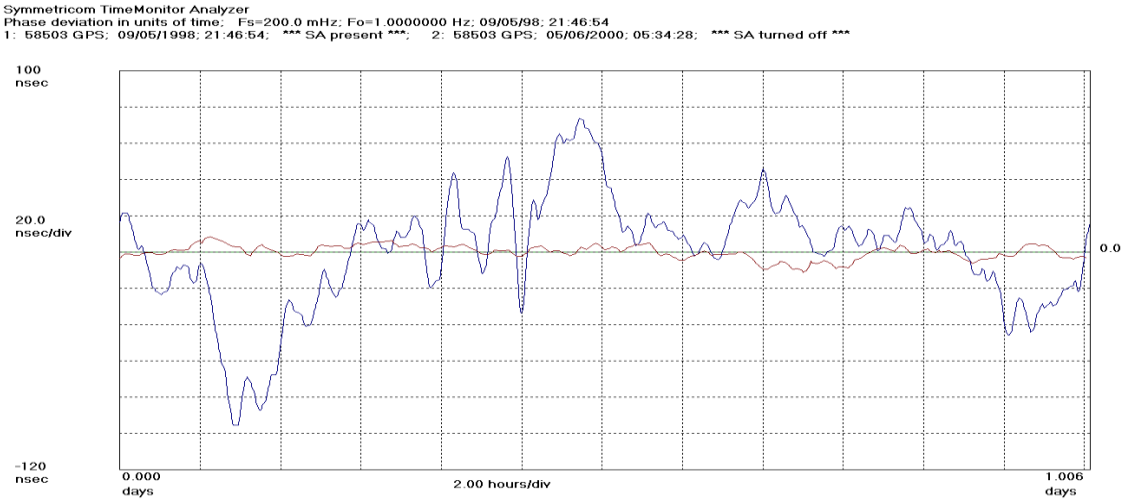
- **Measurement equipment:**
  - TIE: Counters, TIA’s, Test-sets, BITS, SSU, GPS receivers
  - PDV: IEEE 1588 probes, NTP probes, network probes

- **TIE measurements are still important in a packet world:**
  - Needed for the characterization of packet servo slaves such as IEEE 1588 slave devices
  - There are still oscillators and synchronization interfaces to characterize
  - “TIE” measurement/analysis background important to the understanding of “PDV” measurement/analysis
  - Many of the tools can be applied to either “TIE” or “PDV” data such as TDEV or spectral analysis
  - But there are new tools and new approaches to be applied to “PDV” with some of the traditional “TIE” tools less effective for “PDV” analysis

TIE Measurements: Network vs. Equipment



Network TIE



Equipment TIE

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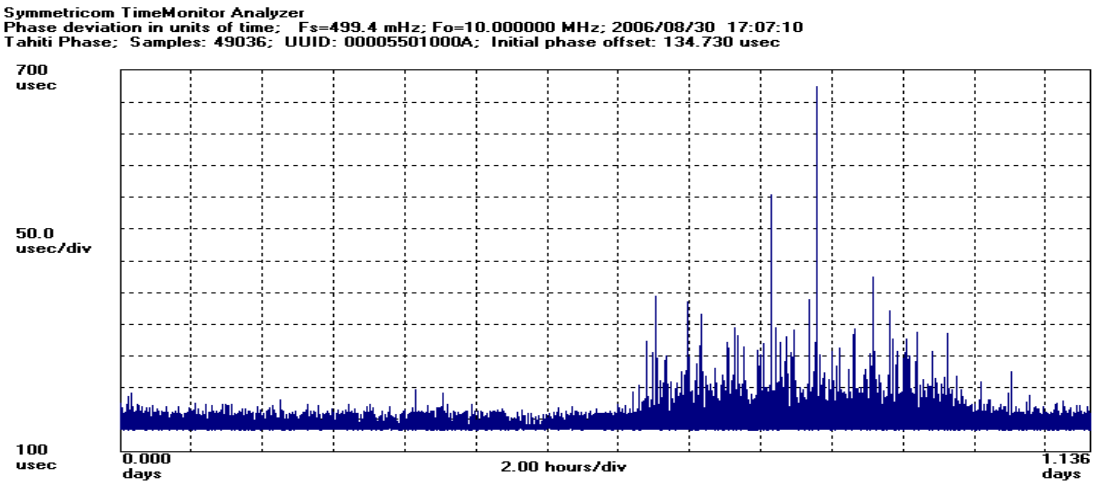
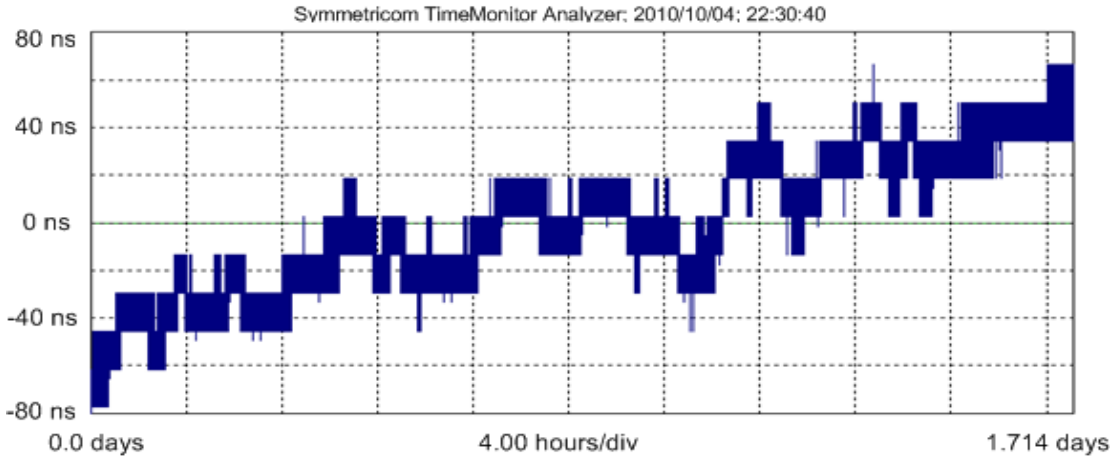
PDV Measurements: Network vs. Equipment



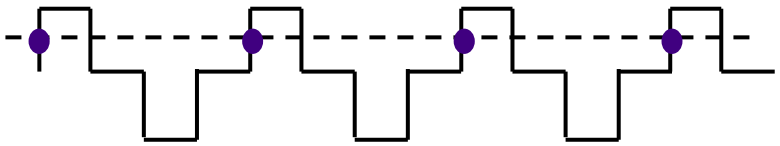
Network PDV



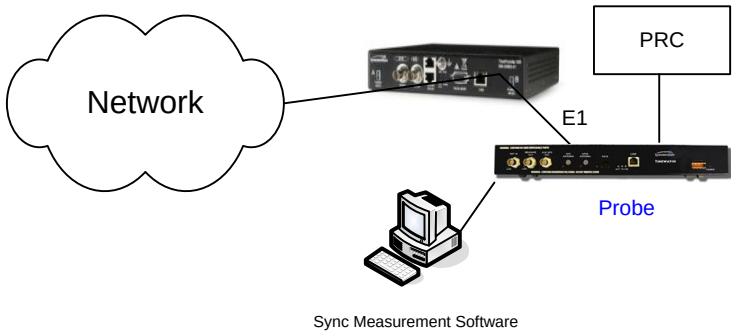
Equipment PDV

Frequency Signal “TIE” vs. “PDV”

- **“TIE” (Single Point Measurement)**
  - Measurements are made at a single point – a single piece of equipment in a single location - a phase detector with reference - is needed

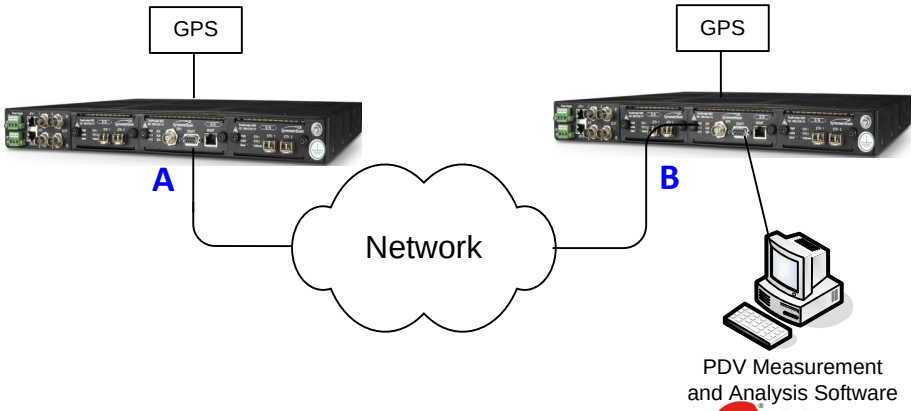


0 µs 1.001 µs 1.997 µs 3.005 µs



- **“PDV” (Dual Point Measurement)**
  - Measurements are constructed from packets time-stamped at two points – in general two pieces of equipment, each with a reference, at two different locations – are needed

	Timestamp A	Timestamp B
F	1233166476.991204496	1233166476.991389744
R	1233166476.980521740	1233166476.980352932
F	1233166477.006829496	1233166477.007014512
R	1233166476.996147084	1233166476.995977932
F	1233166477.022454496	1233166477.022639568
R	1233166477.011771820	1233166477.011602932



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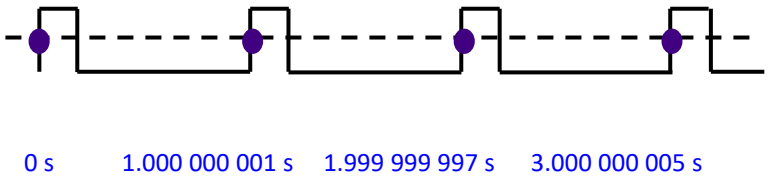
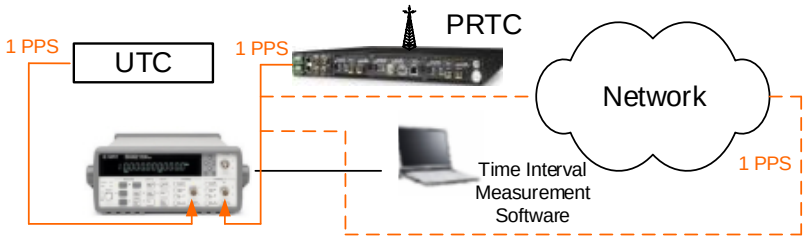
Time Signal “Physical” vs. “Packet”

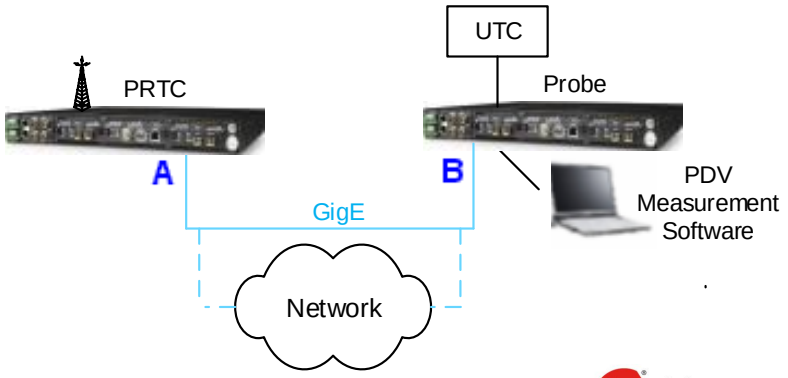
- **“1 PPS” (Single Point Measurement)**
  - Measurements are made at a single point – a single piece of equipment in a single location - a phase detector with reference - is needed





- **“Packet” (Dual Point Measurement)**
  - Measurements are constructed from packets time-stamped at two points – in general two pieces of equipment, each with a reference, at two different locations – are needed

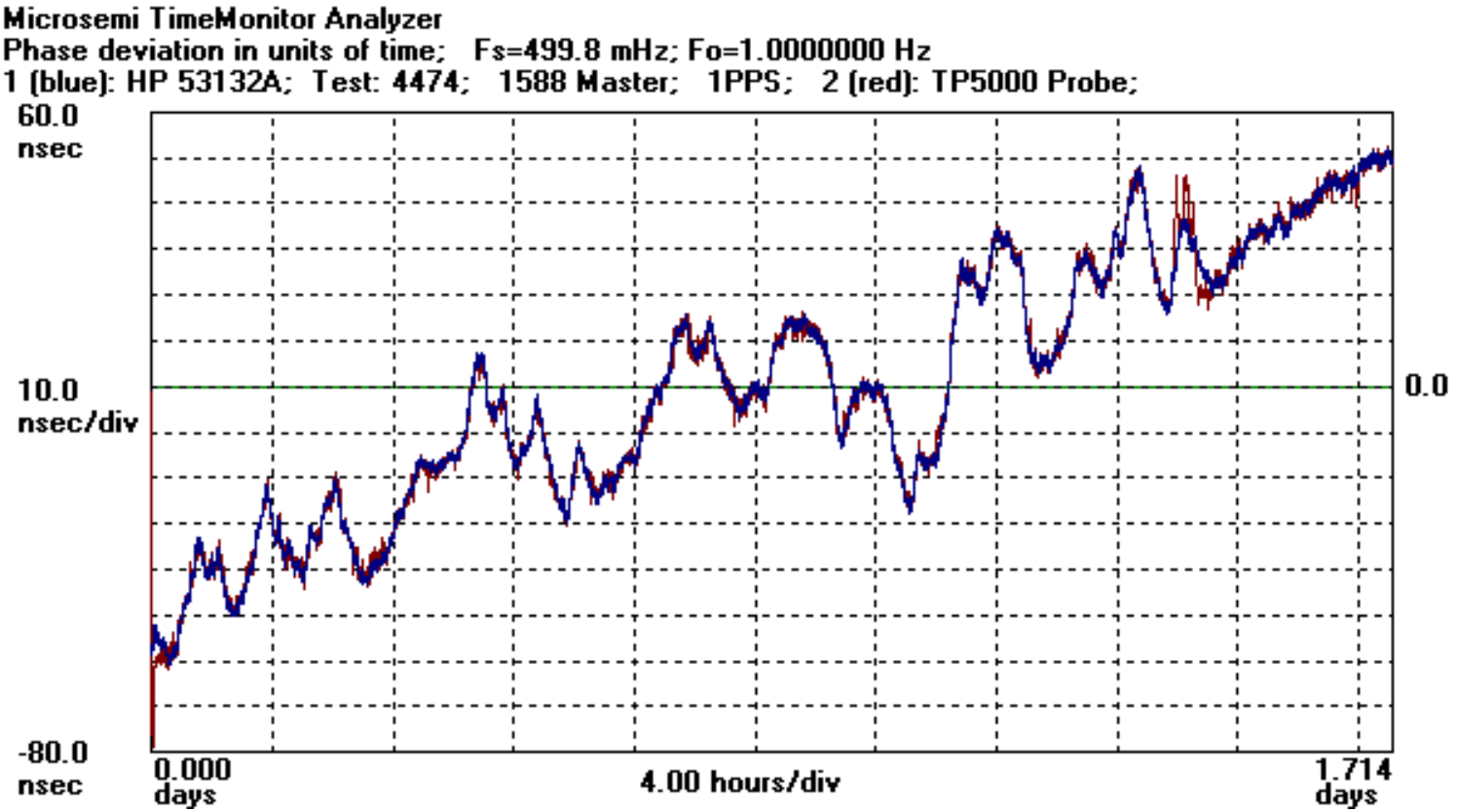
	Timestamp A	Timestamp B
F	1286231440.883338640	1286231440.883338796
R	1286231441.506929352	1286231441.506929500
F	1286231441.883338640	1286231441.883338796
R	1286231442.506929352	1286231442.506929500
F	1286231442.883338640	1286231442.883338796
R	1286231443.506929352	1286231443.506929516



MICROCHIP

Grandmaster Test PPS and Packet Probe

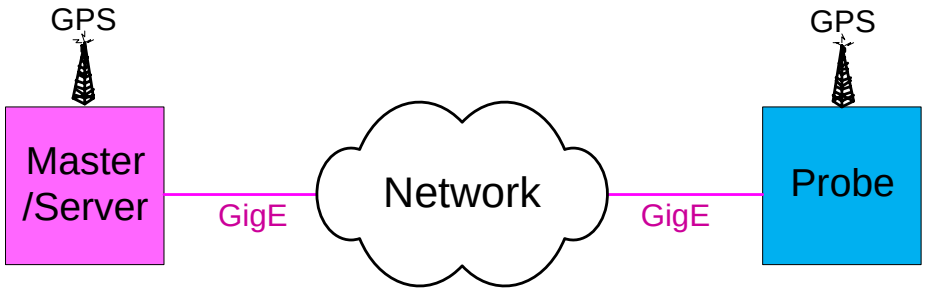
Physical 1PPS signal measurement and packet signal tested with probe match



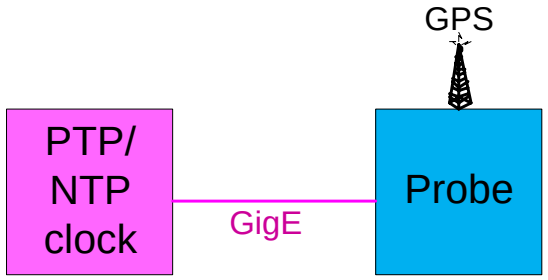
MICROCHIP

Packet Probe

Network PDV Measurement



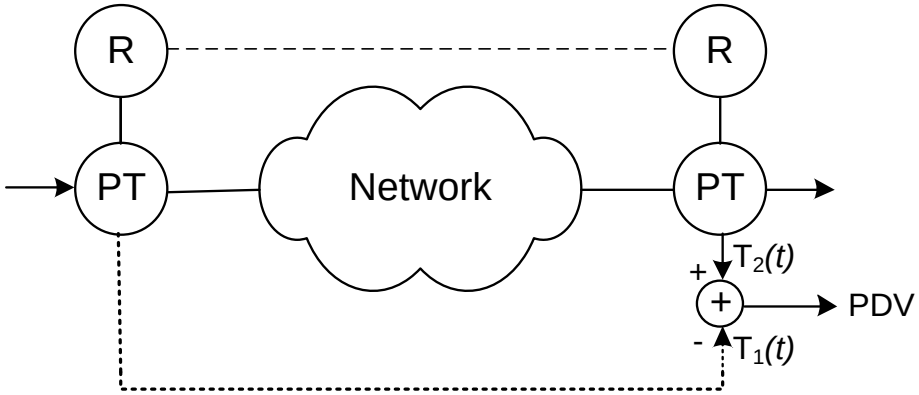
PTP/NTP Equipment Characterization



PTP GM/TC/BC
NTP server

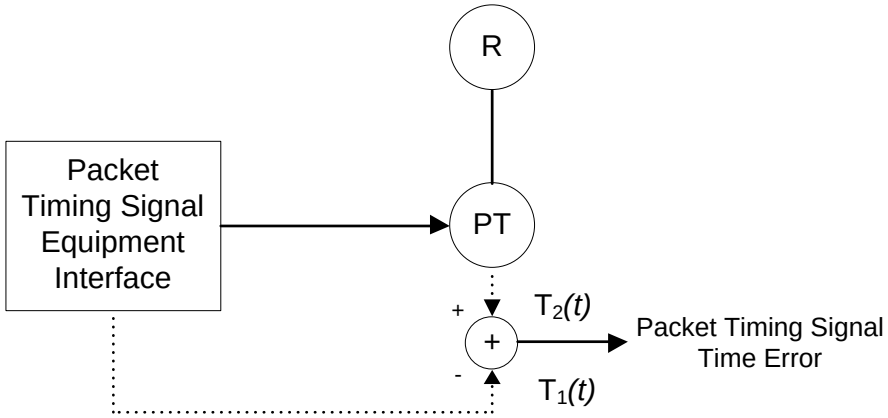
Packet Probe (G.8260 View)

Network PDV Measurement



R Time or frequency reference
PT Packet timestamper

Packet Equipment Characterization

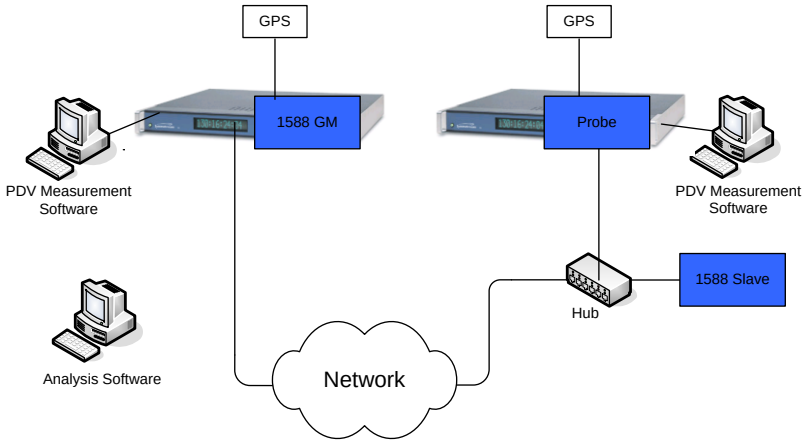


R Time or frequency reference
PT Packet timestamper

“PDV” Measurement Setup Options

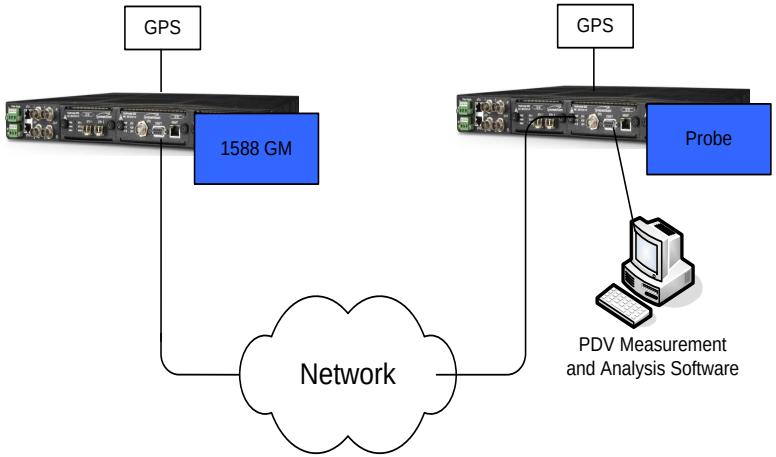
Passive Probe

(1) Hub or Ethernet Tap
(2) IEEE 1588 Slave
(3) Collection at Both Nodes



Active Probe

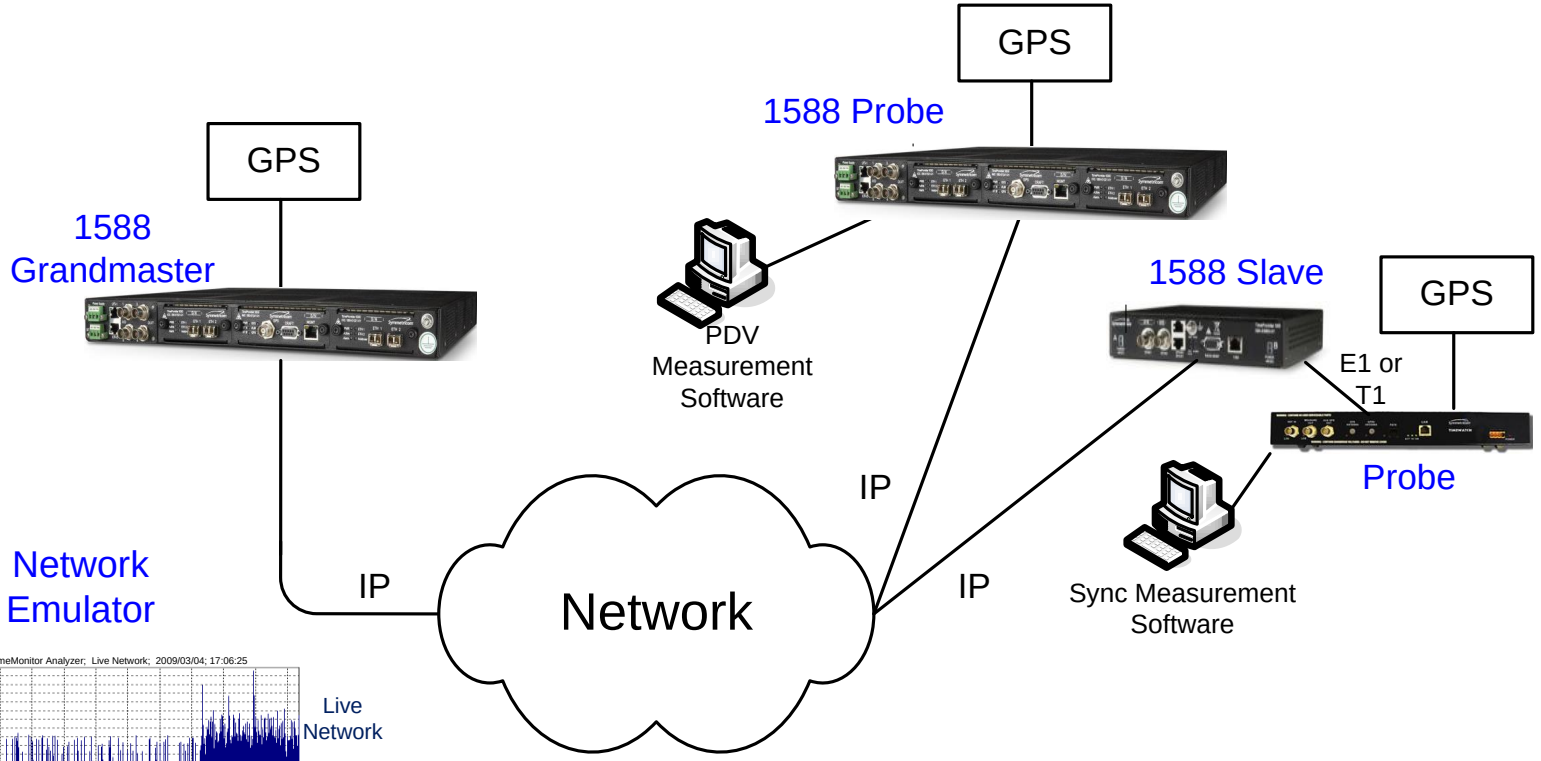
(1) No Hub or Ethernet Tap Needed
(2) No IEEE 1588 Slave Needed
(3) Collection at Probe Node Only

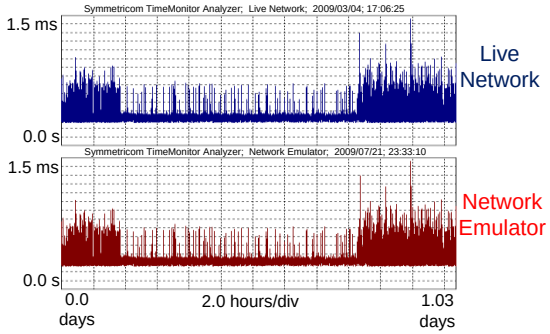


- **“PDV”**
  - Ideal setup - two packet timestampers with GPS reference so absolute latency can be measured as well as PDV over small to large areas
  - Alternative setup (lab) – frequency (or GPS) locked single shelf with two packet timestampers
  - Alternative setup (field) – frequency locked packet timestampers – PDV but not latency can be measured

“TIE” and “PDV”

In most packet network measurement setups, both “TIE” and “PDV” are measured at the same time



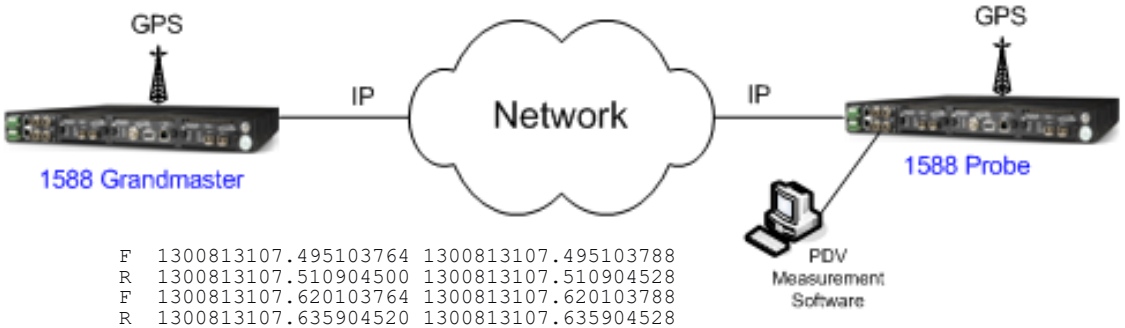


MICROCHIP

PTP and NTP Probes

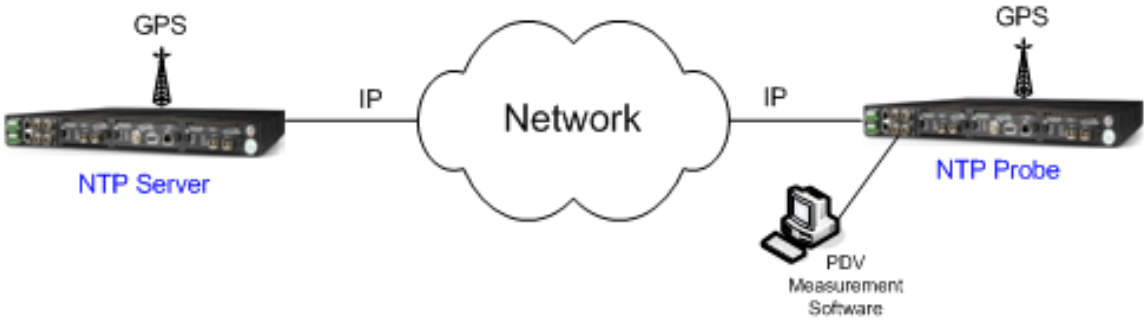
Either PTP or NTP packets can be used for probing.

- In some circumstances, one or the other might be more suitable.
- For example, NTP is useful for probing over the public internet because of NAT (network address translation) challenges.



PTP

```
F  1300813107.495103764 1300813107.495103788
R  1300813107.510904500 1300813107.510904528
F  1300813107.620103764 1300813107.620103788
R  1300813107.635904520 1300813107.635904528
F  1300813107.745103764 1300813107.745103788
```



NTP

```
N,D1335140,190A968D,D1335140,190AA710,D1335140,190AD026,D1335140,190ADBF2
N,D1335140,1D0A9EB0,D1335140,1D0AA755,D1335140,1D0AD004,D1335140,1D0ADBCF
N,D1335140,210A9EB0,D1335140,210AA710,D1335140,210AD026,D1335140,210ADBAD
N,D1335140,250A9EB0,D1335140,250AA710,D1335140,250ACFBF,D1335140,250ADB46
N,D1335140,290A9EB0,D1335140,290AA710,D1335140,290AD026,D1335140,290ADBAD
```

“TIE” Analysis vs. “PDV” Analysis

“TIE” Analysis (G.810)

- Phase (TIE)
- Frequency accuracy
- Dynamic frequency
- MTIE
- TDEV

“PDV” Analysis (G.8260)

- Phase (PDV)
- Histogram/PDF*,CDF**,statistics
- Dynamic statistics
- MATIE/MAFE
- TDEV/minTDEV/bandTDEV
- Two-way metrics: minOffset etc.

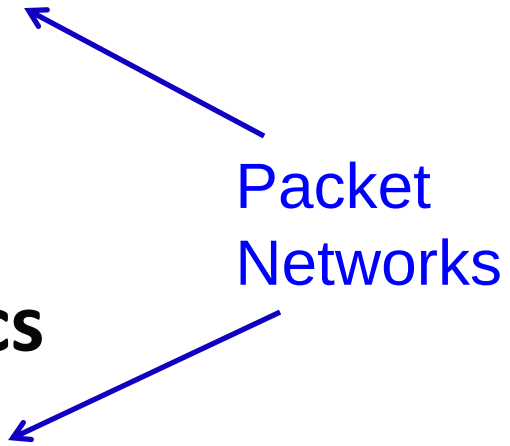
- The importance of raw TIE/PDV:
  - Basis for frequency/statistical/MTIE/TDEV analysis
  - Timeline (degraded performance during times of high traffic?)
  - Measurement verification (jumps? offsets?)

* *PDF = probability density function*

** *CDF = cumulative distribution function*

Stability Metrics

- **Traditional Clock Metrics**
  - ADEV, TDEV, MTIE
  - Traditionally applied to oscillators, synchronization interfaces
  - Also applied to lab packet equipment measurements GM, BC
- **Frequency Transport Packet Metrics**
  - minTDEV, MAFE, MATIE
  - Applied to one-way packet delay data
  - FPP/FPR/FPC (floor packet percent/rate/count)
- **Time Transport Packet Metrics**
  - minOffset or combine one-way (FPP, MAFE, etc.)
  - Applied to two-way packet delay data
  - Assesses link asymmetry



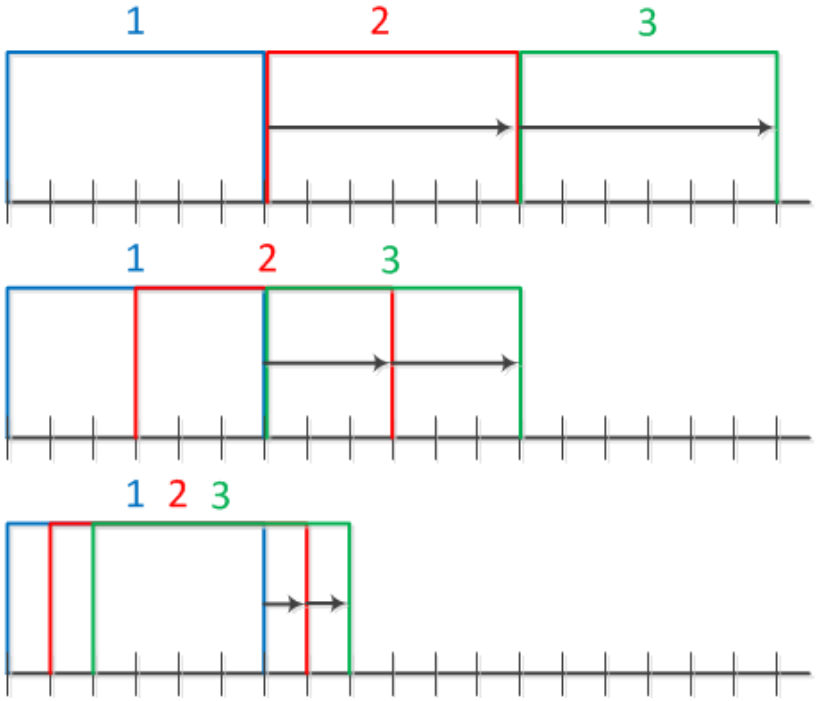
Stability metrics for PDV

- Packet Selection Processes
  1) ***Pre-processed:*** packet selection step prior to calculation
     - Example: ***TDEV***(*PDVmin*) where *PDVmin* is a new sequence based on minimum searches on the original PDV sequence
  2) ***Integrated:*** packet selection integrated into calculation
     - Example: ***minTDEV***(*PDV*)

- Packet Selection Methods
  - Minimum: $x_{\min}(i) = \min\lfloor x_j \rfloor for(i <= j <= i+n-1)$
  - Percentile: $x'_{pct\_mean}(i) = \frac{1}{m}\sum_{j=0}^{b} x'_{j+i}$
  - Band: $x'_{band\_mean}(i) = \frac{1}{m}\sum_{j=a}^{b} x'_{j+i}$
  - Cluster: $x(n\tau_0) = \frac{\sum_{i=0}^{(K-1)} w((nK+i)\tau_P)\cdot\phi(n,i)}{\sum_{i=0}^{(K-1)}\phi(n,i)}$ $\quad \phi(n,i) = \begin{cases} 1 & for \ |w(nK+i)-\alpha(n)| < \delta \\ 0 & otherwise \end{cases}$

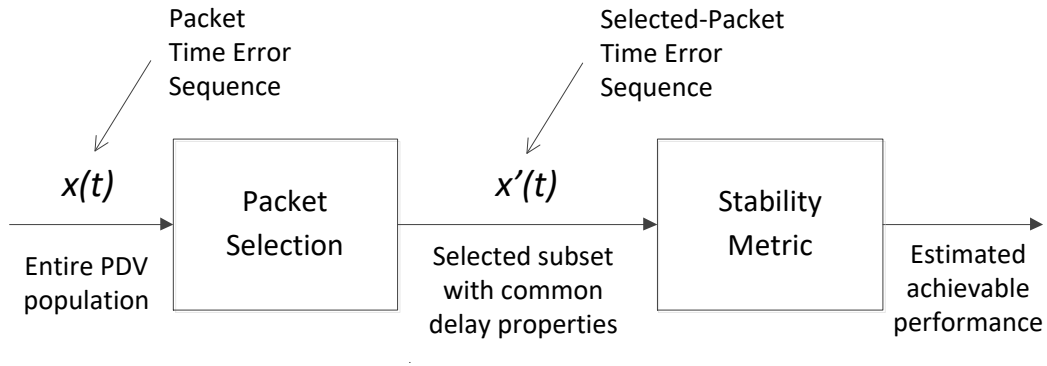
Packet Selection Windows

- Windows
  - ***Non-overlapping windows*** (next window starts at prior window stop)
  - ***Skip-overlapping windows*** (windows overlap but starting points skip over N samples)
  - ***Overlapping windows*** (windows slide sample by sample)

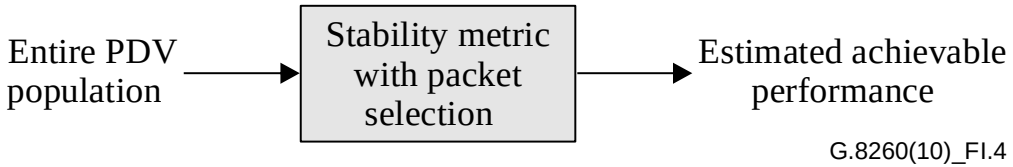


- Packet Selection Approaches (e.g. selecting fastest packets)
  - Select X% fastest packets (e.g. 2%)
  - Select N fastest packets (e.g. 10 fastest packets in a window)
  - Select all packets faster than Y (e.g. all packets faster than 150µs)

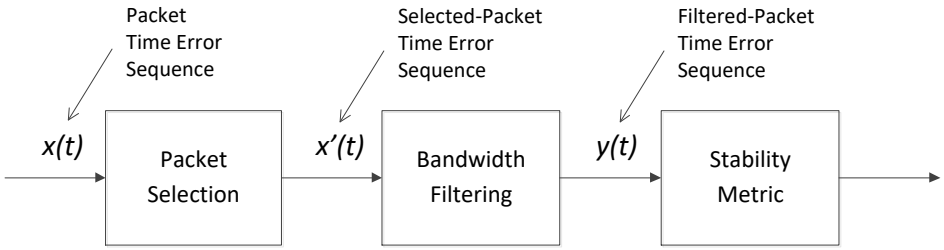
G.8260 Appendix I Metrics



Pre-processed packet selection



Integrated packet selection



Metrics including pre-filtering

FPC, FPR, FPP: Floor Packet Count/Rate/Percent

PDV metrics studying minimum floor delay packet population

Time Transport: Two-way metrics

Packet Time Transport Metrics

MeanPathDelay: $$r(n) = \left(\frac{1}{2}\right) \cdot \left[R(n) + F(n)\right]$$

TwowayTimeError: $$\eta_2(n) = \left(\frac{1}{2}\right) \cdot \left[R(n) - F(n)\right]$$

pktSelectedMeanPathDelay: $$r'(n') = \left(\frac{1}{2}\right) \cdot \left[R'(n') + F'(n')\right]$$

pktSelectedTwowayTimeError: $$\eta_2'(n') = \left(\frac{1}{2}\right) \cdot \left[R'(n') - F'(n')\right]$$

Ideal F/R: floor
("lucky" packets: fastest)

min2wayTE: $$\eta_2^{m}(n) = \left(\frac{1}{2}\right) \cdot \left[R^{m}(n) - F^{m}(n)\right]$$

pct2wayTE $$\eta_2^{p}(n) = \left(\frac{1}{2}\right) \cdot \left[R^{p}(n) - F^{p}(n)\right]$$

cluster2wayTE $$\eta_2^{c}(n) = \left(\frac{1}{2}\right) \cdot \left[R^{c}(n) - F^{c}(n)\right]$$

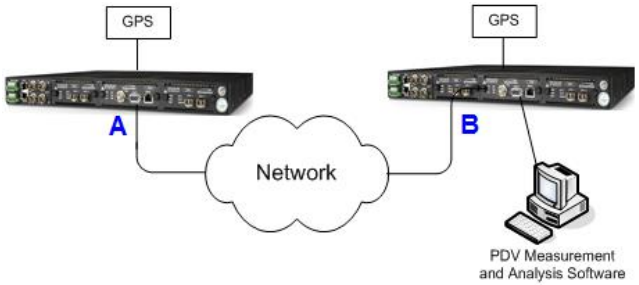
Ideal 2way TE: zero
(no asymmetry)

psTDISP (min/pct/clst time dispersion): ps2wayTE{y} plotted against psMeanPathDelay{x} as a scatter plot

ps2wayTE statistics: ps2wayTE statistic such as mean, standard deviation, median, 95 percentile plotted as a function of time window tau; min/maxATE

Weighted average: $$w(n) = \left[a \cdot F(n) + (1-a) \cdot R(n)\right]$$ where $0 \le a \le 1$

Packet Delay Sequence



Packet Delay Sequence

```
R,00162; 1223305830.478035356; 1223305830.474701511
F,00167; 1223305830.488078908; 1223305830.490552012
R,00163; 1223305830.492882604; 1223305830.489969511
F,00168; 1223305830.503473436; 1223305830.505803244
R,00164; 1223305830.508647148; 1223305830.505821031
F,00169; 1223305830.519029300; 1223305830.521302172
R,00165; 1223305830.524413852; 1223305830.521446071
F,00170; 1223305830.534542972; 1223305830.536801164
R,00166; 1223305830.540181132; 1223305830.537115991
F,00171; 1223305830.550229692; 1223305830.552551628
```

Packet Timestamps

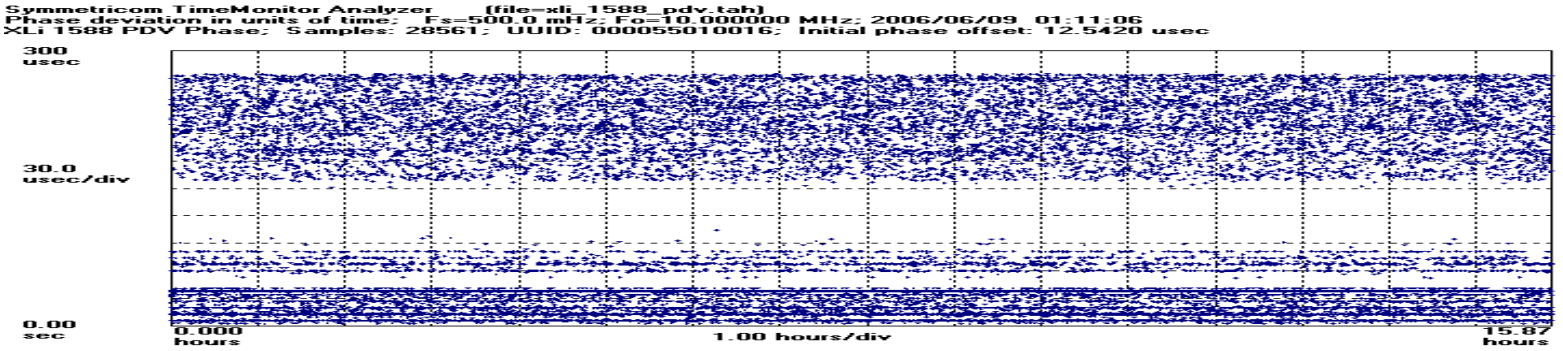
Forward

Reverse

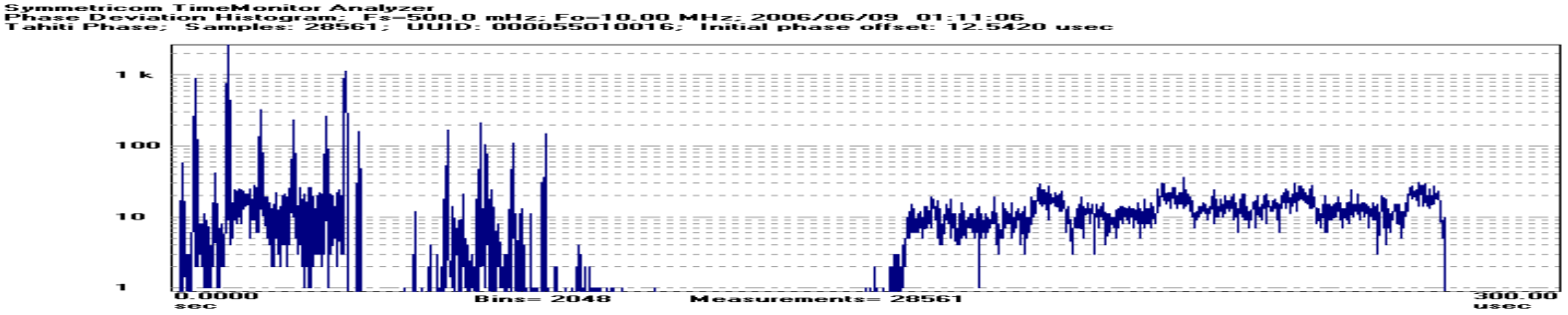
#Start: 2009/10/06 15:10:30
0.0000, 2.473E-3
0.0155, 2.330E-3
0.0312, 2.273E-3
0.0467, 2.258E-3
0.0623, 2.322E-3

#Start: 2009/10/06 15:10:30
0.0000, 3.334E-3
0.0153, 2.913E-3
0.0311, 2.826E-3
0.0467, 2.968E-3
0.0624, 3.065E-3

Packet Delay Distribution



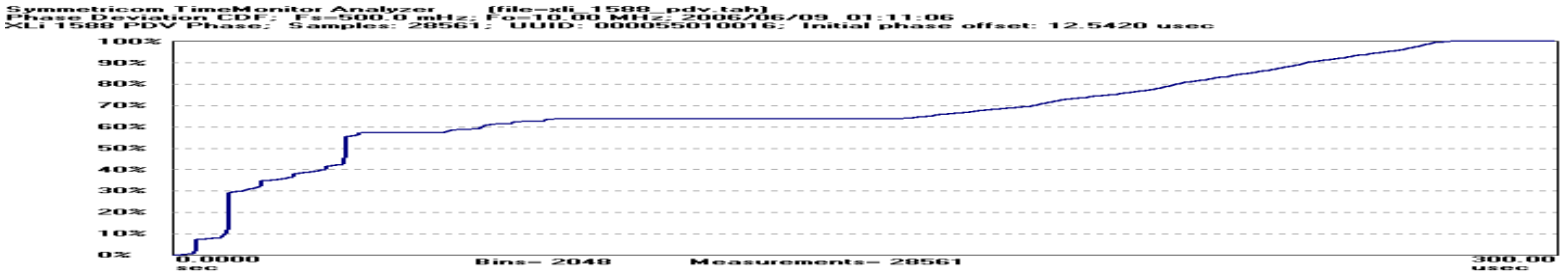
Packet Delay Sequence



PDF

Minimum: 1.904297 usec Mean: 96.71927 usec
Maximum: 275.2441 usec Standard Deviation: 97.34 usec
Peak to Peak: 273.3 usec Population: 28561 Percentage: 100.%

Statistics

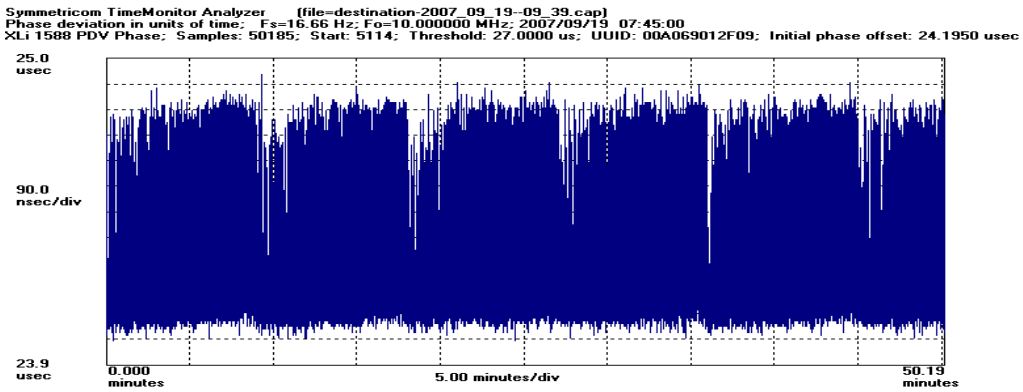


CDF

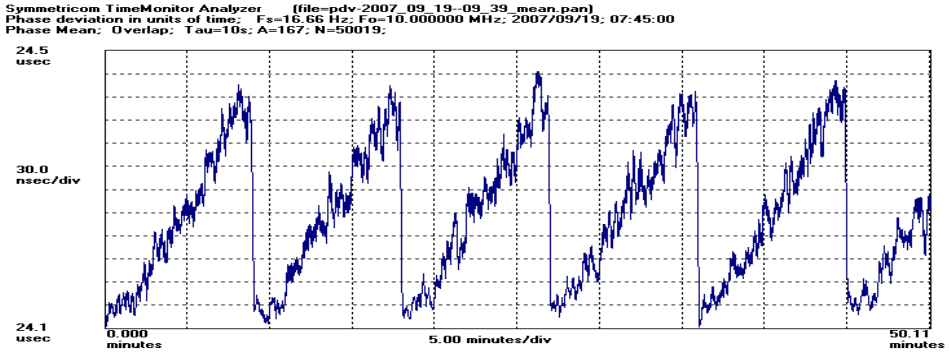
50pct: 37.65 us; 90pct: 245.5 us; 95pct: 261.9 us; 99pct: 272.3 us; 99.9pct: 274.5 us

MICROCHIP

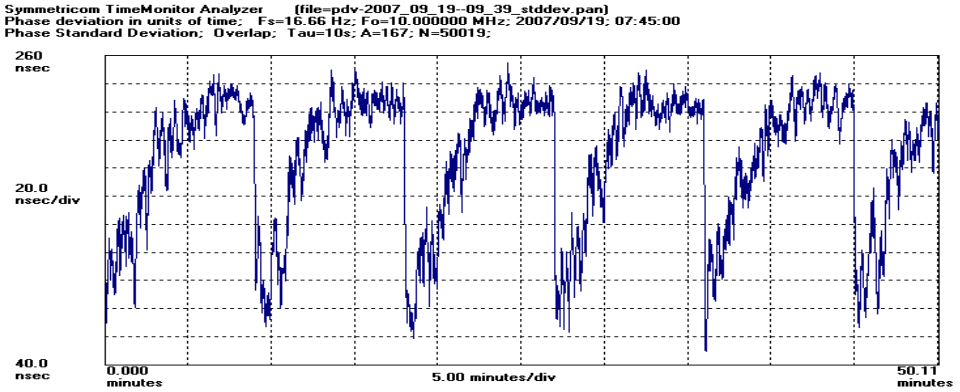
Tracked Packet Delay Statistics



Raw packet delay appears relatively static over time



Mean vs. time shows cyclical ramping more clearly



Standard deviation vs. time shows a quick ramp up to a flat peak

Packet Metrics

TDEV

$$\sigma_x(\tau) = TDEV(\tau) = \sqrt{\frac{1}{6}\left\langle\left[\frac{1}{n}\sum_{i=1}^{n} x_{i+2n} - 2\frac{1}{n}\sum_{i=1}^{n} x_{i+n} + \frac{1}{n}\sum_{i=1}^{n} x_i\right]^2\right\rangle}$$

minTDEV

$$\sigma_{x\_\min}(\tau) = \min TDEV(\tau) = \sqrt{\frac{1}{6}\left\langle\left[x_{\min}(i+2n) - 2x_{\min}(i+n) + x_{\min}(i)\right]^2\right\rangle} \quad x_{\min}(i) = \min\left\lfloor x_j \right\rfloor for(i <= j <= i+n-1)$$

bandTDEV

$$\sigma_{x\_band}(\tau) = bandTDEV(\tau) = \sqrt{\frac{1}{6}\left\langle\left[x'_{band\_mean}(i+2n) - 2x'_{band\_mean}(i+n) + x'_{band\_mean}(i)\right]^2\right\rangle} \quad x'_{band\_mean}(i) = \frac{1}{m}\sum_{j=a}^{b} x'_{j+i}$$

PDV noise type characterization w/ packet selection

1. TDEV is bandTDEV(0.0 to 1.0)
2. minTDEV is bandTDEV(0.0 to 0.0)
3. percentileTDEV is bandTDEV(0.0 to B) with B between 0.0 and 1.0

MATIE

$$MATIE(n\tau_0) \cong \max_{1\le k\le N-2n+1} \frac{1}{n}\left|\sum_{i=k}^{n+k-1}\left(x_{i+n} - x_i\right)\right| \quad , \quad n = 1, 2, \ldots, \text{integer part } (N/2)$$

MAFE

$$MAFE(n\tau_0) = \frac{MATIE(n\tau_0)}{n\tau_0}$$

minMAFE

$$\min MAFE(n\tau_0) \cong \frac{\max_{1\le k\le N-2n+1}\left|\sum_{i=k}^{n+k-1}\left(x_{\min}(i+n) - x_{\min}(i)\right)\right|}{n\tau_0}$$

where n = 1, 2, ..., integer part (N/2) and where

$$x_{\min}(i) = \min\left\lfloor x_j \right\rfloor for(i <= j <= i+n-1)$$

PDV frequency transport performance

FPP

$$FPP(n,W,\delta) = \left(\frac{\tau_P}{W}\right) \times FPC(n,W,\delta) \times 100\ \% \ \text{ for } (K-1) \le n < N$$

where

$$FPC(n,W,\delta) = \sum_{j=n-(K-1)}^{n} \phi_F(j,\delta) \ \text{ for } \ (K-1) \le n < N$$

PDV phase/frequency delivery

References: (1) ITU-T G.8260 *Definitions and terminology for synchronization in packet networks*, Appendix I, Feb. 2012
(2) ATIS-0900003.2010 Technical Report: *Metrics Characterizing Packet-Based Network Synchronization*, Oct. 2010.

Floor Packet Count/Rate/Percent

$$FPC(n,W,\delta) = \sum_{j=n-(K-1)}^{n} \phi_F(j,\delta) \quad \text{for } (K-1) \le n < N$$

$$FPR(n,W,\delta) = \frac{FPC(n,W,\delta)}{W} \quad \text{for } (K-1) \le n < N$$

$$FPP(n,W,\delta) = \left(\frac{\tau_P}{W}\right) \times FPC(n,W,\delta) \times 100\ \% \quad \text{for } (K-1) \le n < N$$

Floor Packet Calculation:

(1) Find floor
(2) Fix cluster (e.g. 150 µs) above floor
(3) Count packets within cluster in successive windows (e.g. 200s)
(4) For FPR, divide by window length
(5) For FPP, divide by window packet total and multiply by 100

Example case:

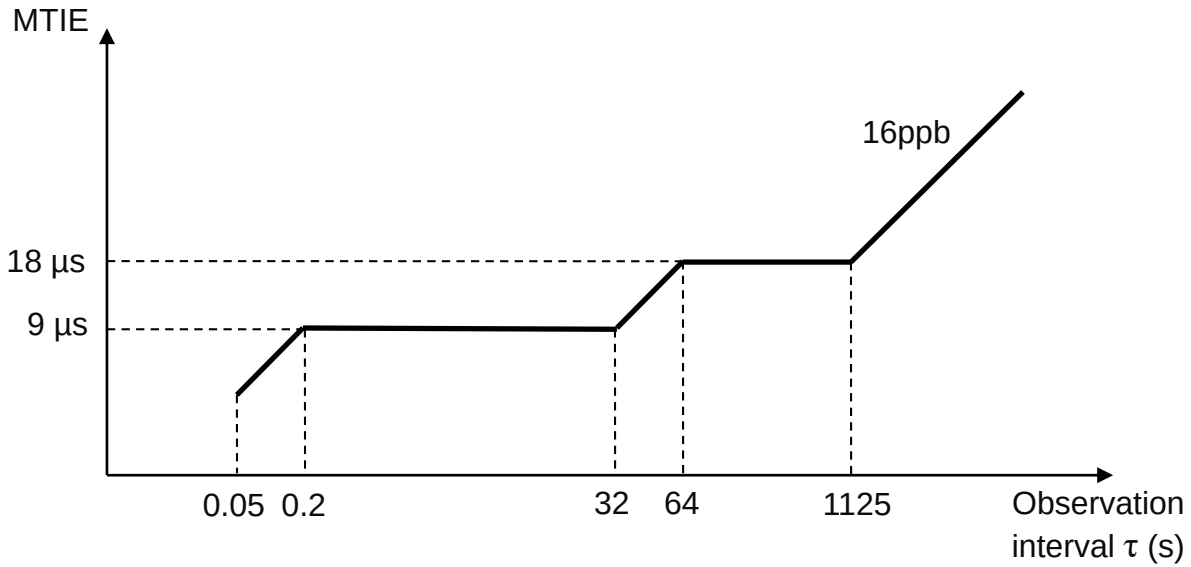
(1) 200 second window
(2) 64 pkt/s

	Min	Max
FPC	0 pkt	12800 pkt
FPR	0 pkt/s	64 pkt/s
FPP	0%	100%

Packet Frequency Transport

G.8261.1

Output Wander



$$FPP(n,W,\delta) = \left(\frac{\tau_P}{W}\right) \times FPC(n,W,\delta) \times 100\ \%\ \text{ for } (K-1) \le n < N$$

where

$$FPC(n,W,\delta) = \sum_{j=n-(K-1)}^{n} \phi_F(j,\delta) \text{ for } (K-1) \le n < N$$

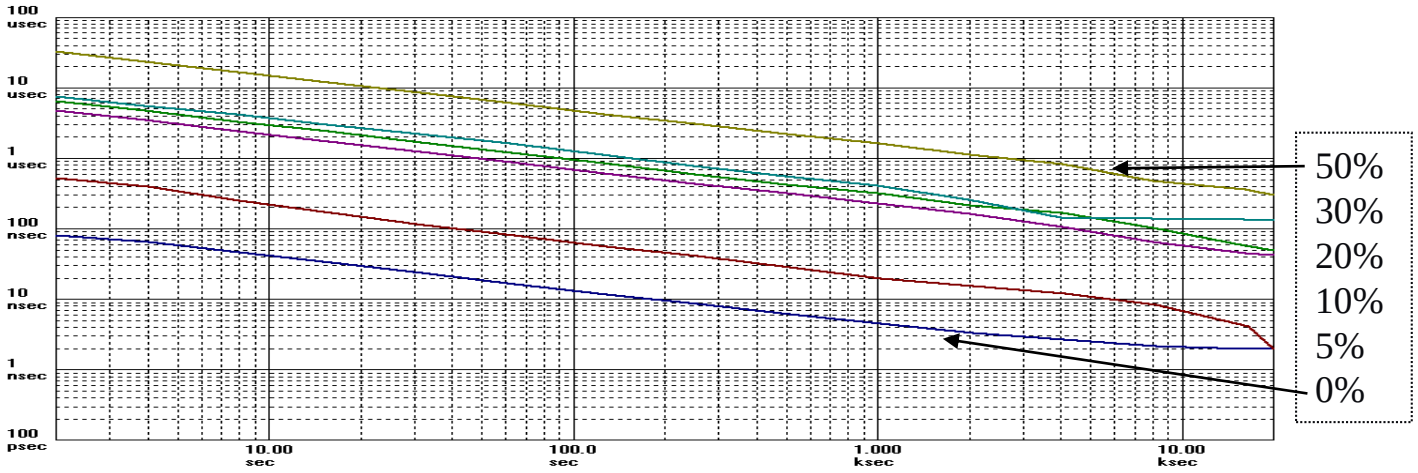
PDV

With window interval W = 200 s and fixed cluster range δ = 150 µs starting at the floor delay, the network transfer characteristic quantifying the proportion of delivered packets that meet the delay criterion should satisfy FPP (n, W, δ) ≥ 1%

That is, the floor packet percentage must exceed 1%.

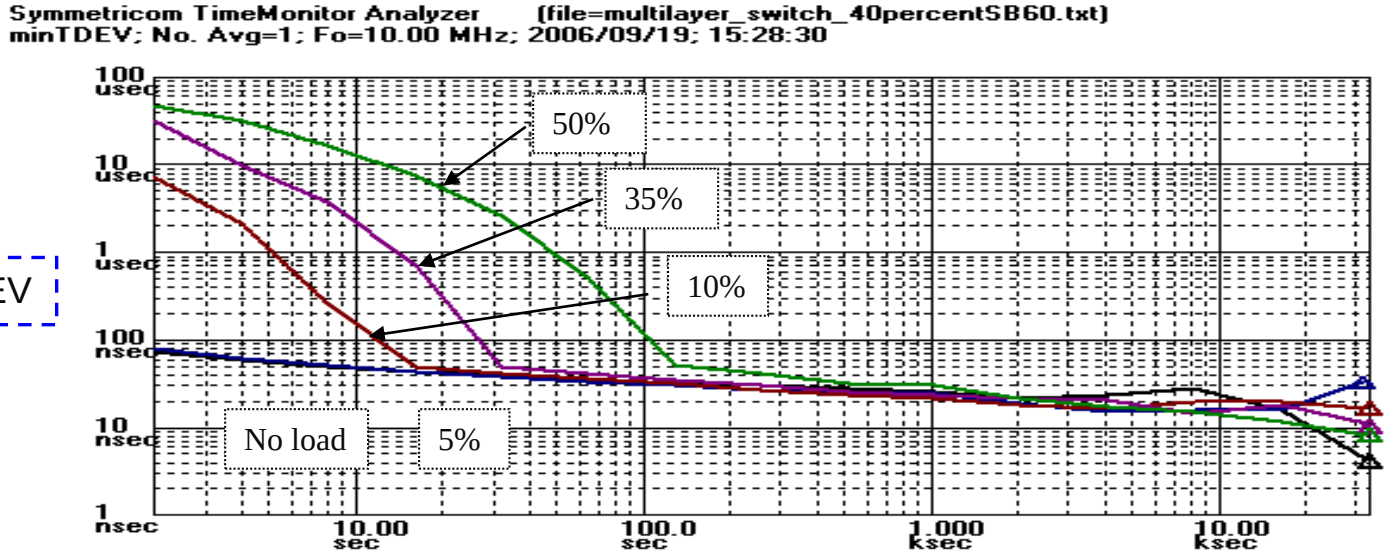
TDEV & minTDEV with Traffic

TDEV



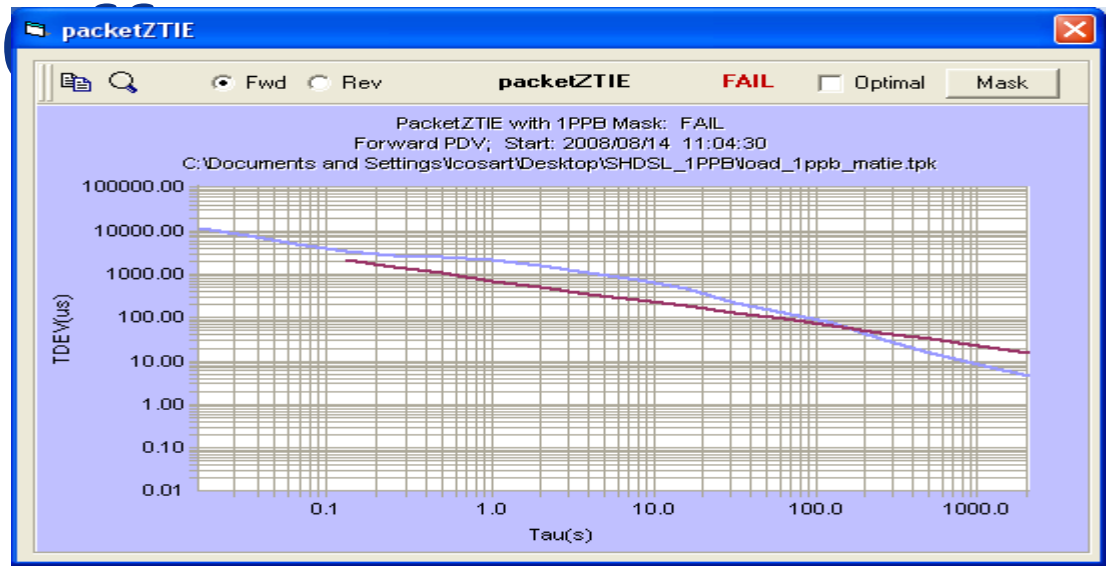
Lower levels of noise with the application of a MINIMUM selection algorithm minTDEV at various traffic levels on a switch (0% to 50%) converge

minTDEV



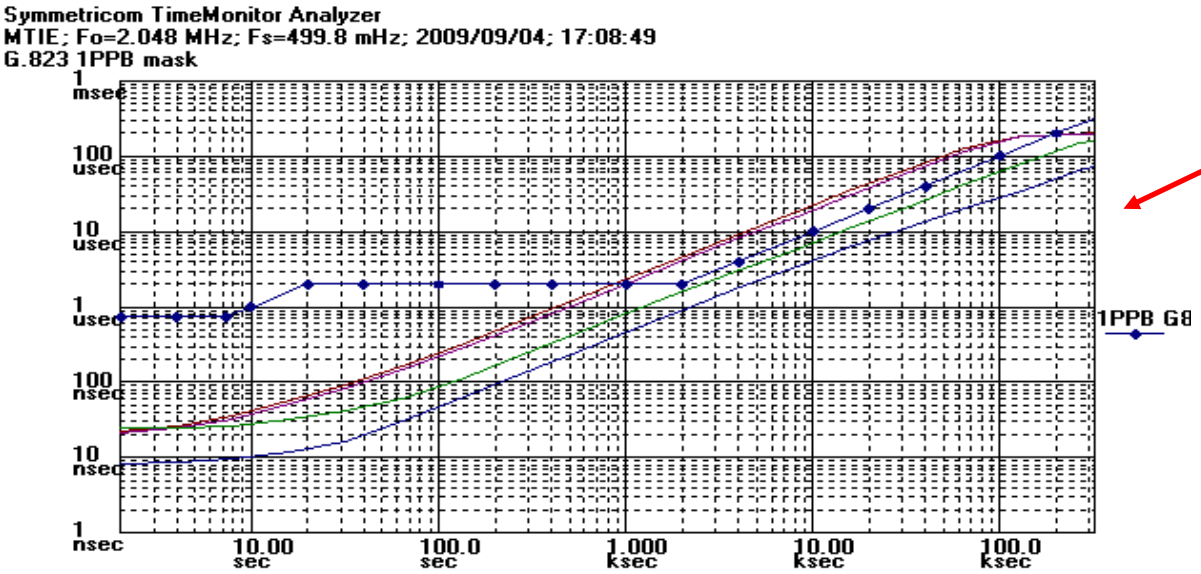
MICROCHIP

MATIE and 1588 Slave Frequency



Packet measurement

Packet data analysis:
1PPB offset predicted



Sync measurement

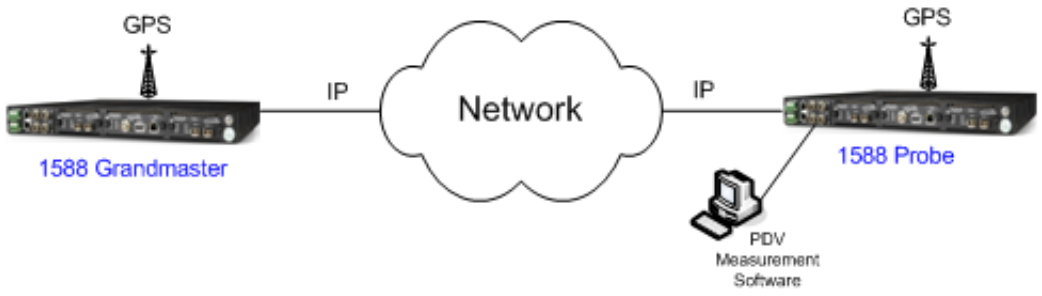
1588 slave performance:
1 PPB offset measured

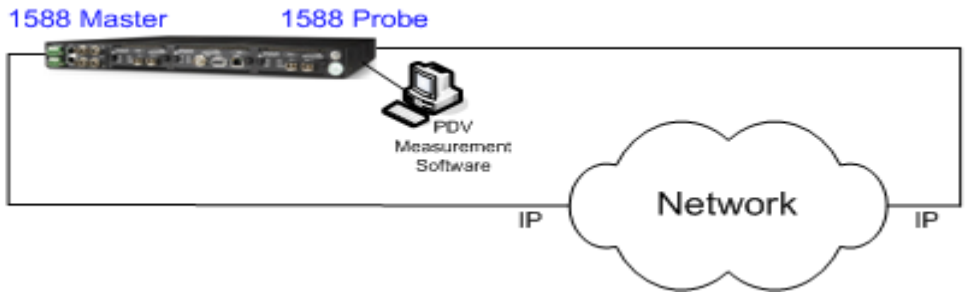
MICROCHIP

Packet Time Transport

"PDV" measurement setup for time transport

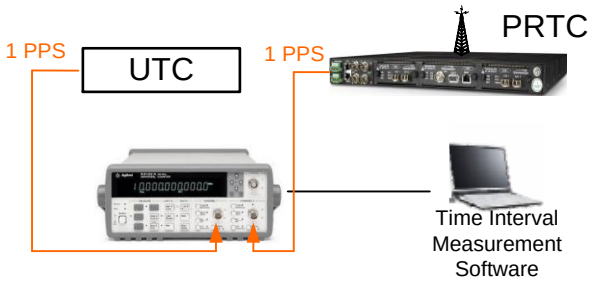
- ✓ – Ideal setup - two packet timestampers with GPS reference so absolute latency can be measured as well as PDV over small to large areas
- ✓ – Alternative setup (lab) – frequency (or GPS) locked single shelf with two packet timestampers
- ✗ – Alternative setup (field) – frequency locked packet timestampers – PDV but neither latency nor asymmetry can be measured





Time Accuracy and Stability Requirements

PRTC



G.8272

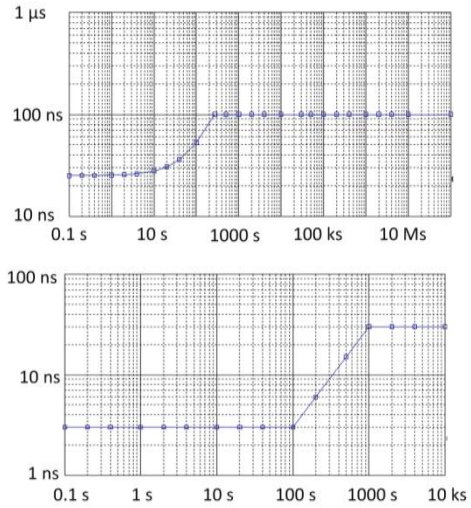
Time Accuracy

Time Error: <=100ns

Time Stability

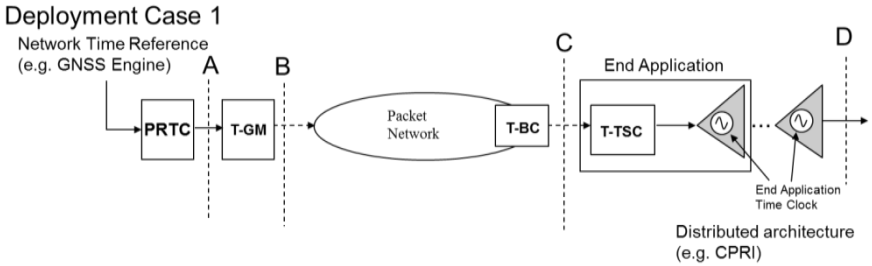
MTIE

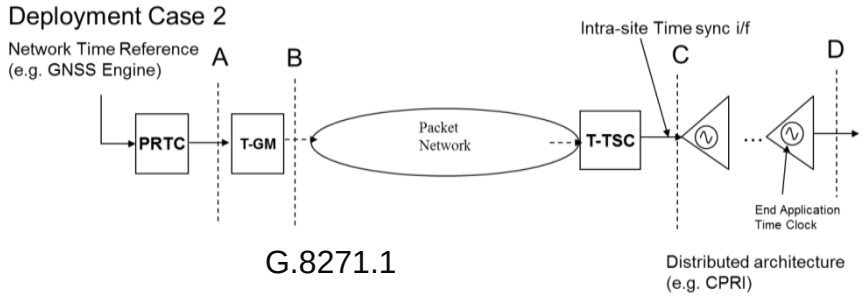
TDEV



MTIE is G.811 with 100 ns maximum
TDEV is G.811 exactly

Packet Network Limits



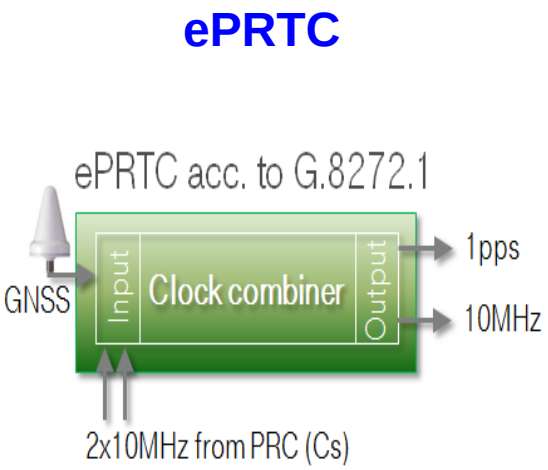


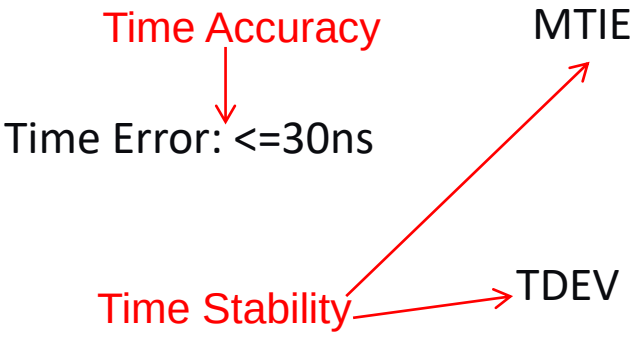
G.8271.1

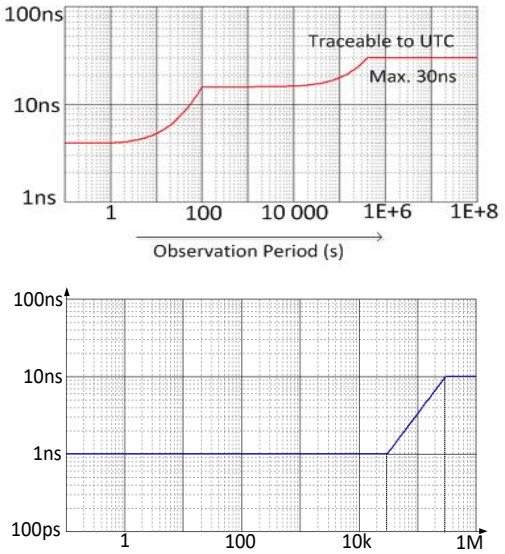
A: Time Error: <=100ns

C: Time Error: <=1.1µs

ePRTC: Enhanced PRTC G.8272.1







ePRTC Attributes

- Reliability: Immune from local jamming or outages
- Autonomy: Atomic clock sustained timescale with & without GNSS connection
- Coherency: 30ns coordination assures overall PRTC budget

Time Transport: Two-way packet delay

Forward Packet Delay Sequence

#Start: 2010/03/06 17:15:30
0.0000, 1.47E-6
0.1000, 1.54E-6
0.2000, 1.23E-6
0.3000, 1.40E-6
0.4000, 1.47E-6
0.5000, 1.51E-6

Reverse Packet Delay Sequence

#Start: 2010/03/06 17:15:30
0.0000, 1.11E-6
0.1000, 1.09E-6
0.2000, 1.12E-6
0.3000, 1.13E-6
0.4000, 1.22E-6
0.5000, 1.05E-6

#Start: 2010/03/06 17:15:30
0.0000, 1.47E-6, 1.11E-6
0.1000, 1.54E-6, 1.09E-6
0.2000, 1.23E-6, 1.12E-6
0.3000, 1.40E-6, 1.13E-6
0.4000, 1.47E-6, 1.22E-6
0.5000, 1.51E-6, 1.05E-6

Two-way Data Set

Time(s)	f(µs)	r(µs)	f'(µs)	r'(µs)
0.0	1.47	1.11		
0.1	1.54	1.09	1.23	1.09
0.2	1.23	1.12		
0.3	1.40	1.13		
0.4	1.47	1.22	1.40	1.05
0.5	1.51	1.05		

Constructing f' and r' from f and r with a 3-sample time window

Minimum Search Sequence

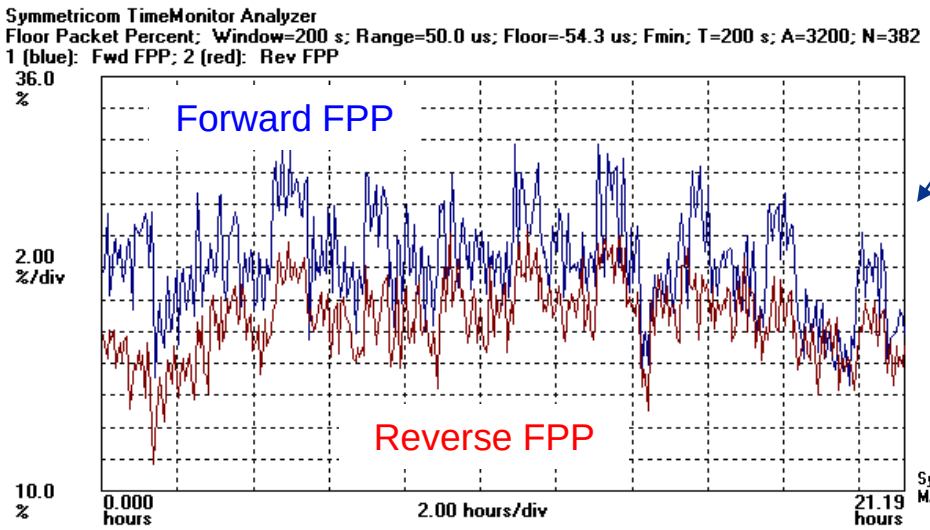
0.1	-0.07
0.4	-0.18

min2wayTE

$$\eta_2'(n') = \left(\frac{1}{2}\right) \cdot \left[R'(n') - F'(n')\right]$$

Time Transport: Two-way metrics

Forward/Reverse FPP

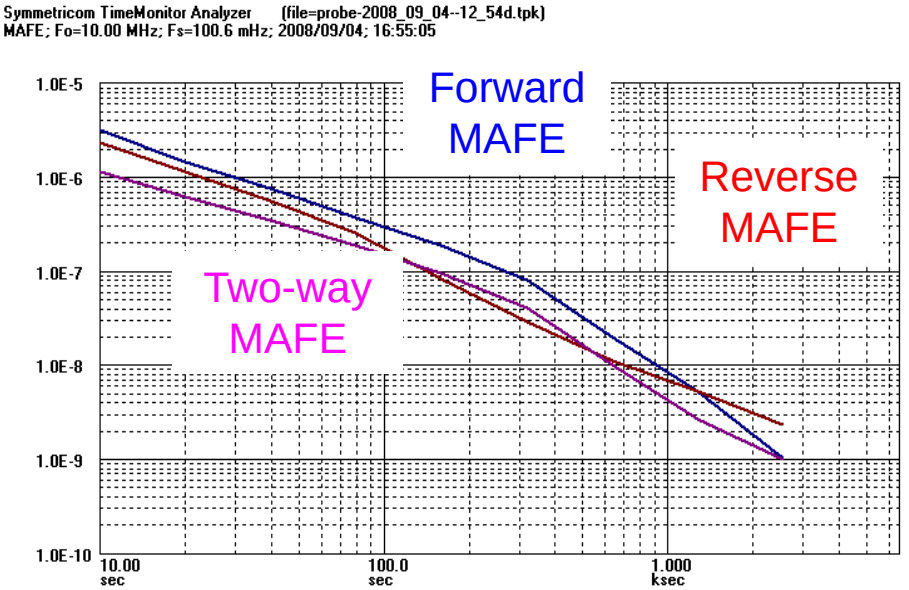


Approaches:

(1) Based on both one-way sequences

(2) Based on a single sequence constructed from both one-way sequences (e.g. offset)

Two-way MAFE (MAFE of minOffset)



Comments:

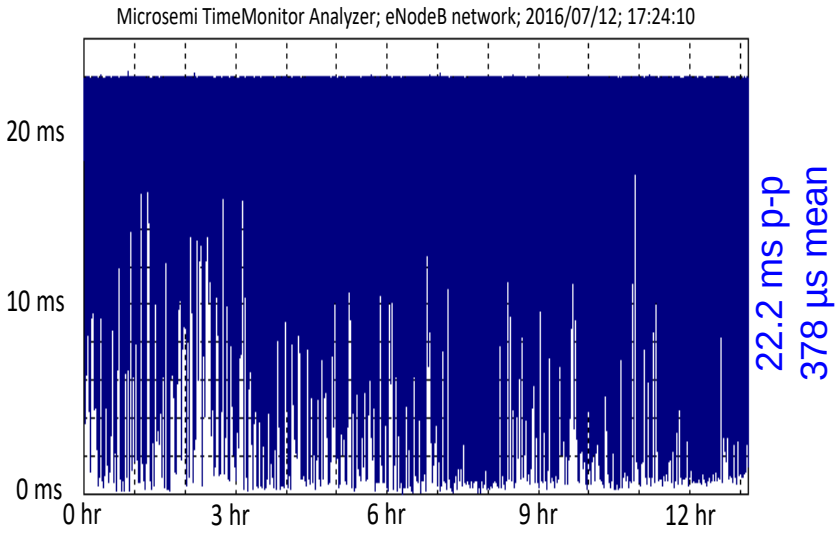
(1) Knowledge of asymmetry and latency in both directions is critical

(2) Offset is a fundamental two-way calculation

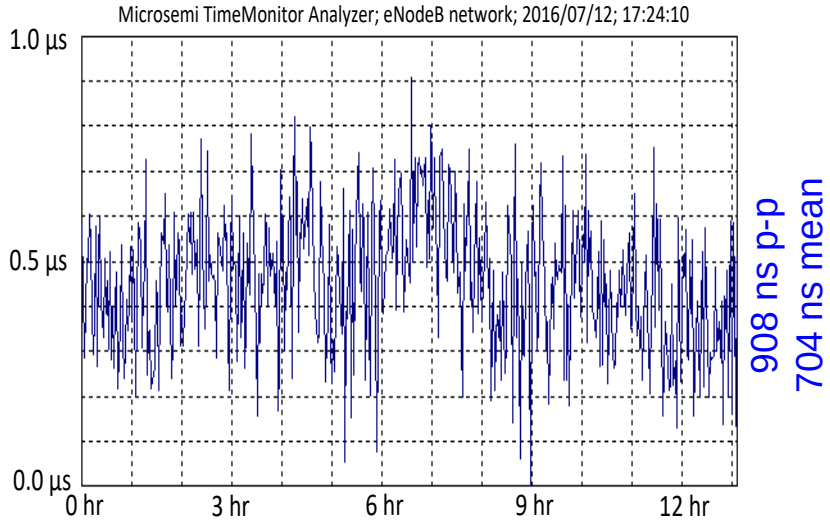
(3) Ideal fwd/rev packet: floor
Ideal offset: zero

Time Transport: Two-way metrics

2wayTE



pktSelected2wayTE

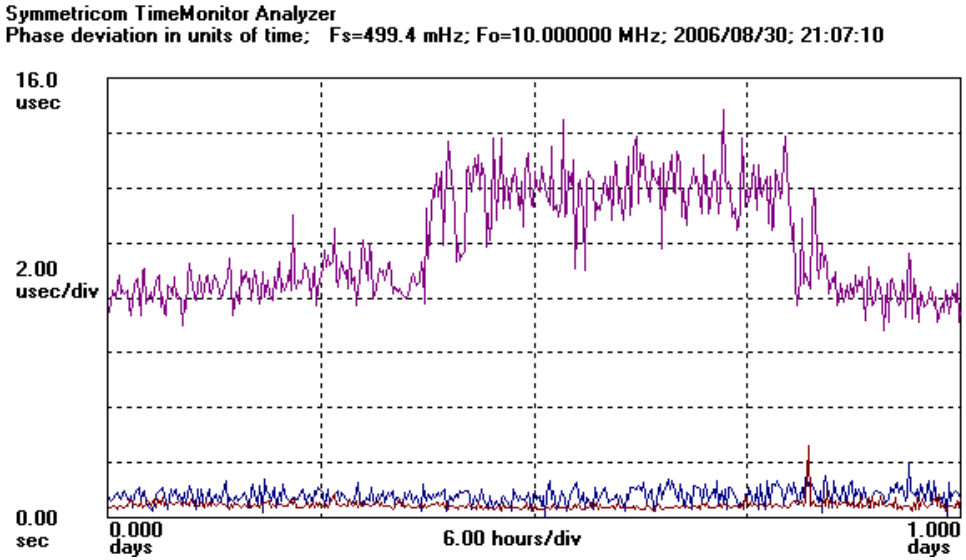


Both 2wayTE and pktSelected2wayTE plots with minimum set to 0. Mean value from unadjusted data.

Selection window = 100s
Selection percentage = 0.5%
Peak-to-peak pktSelected2wayTE = 908 ns
(G.8271.2 draft APTS limit: <1150 ns)

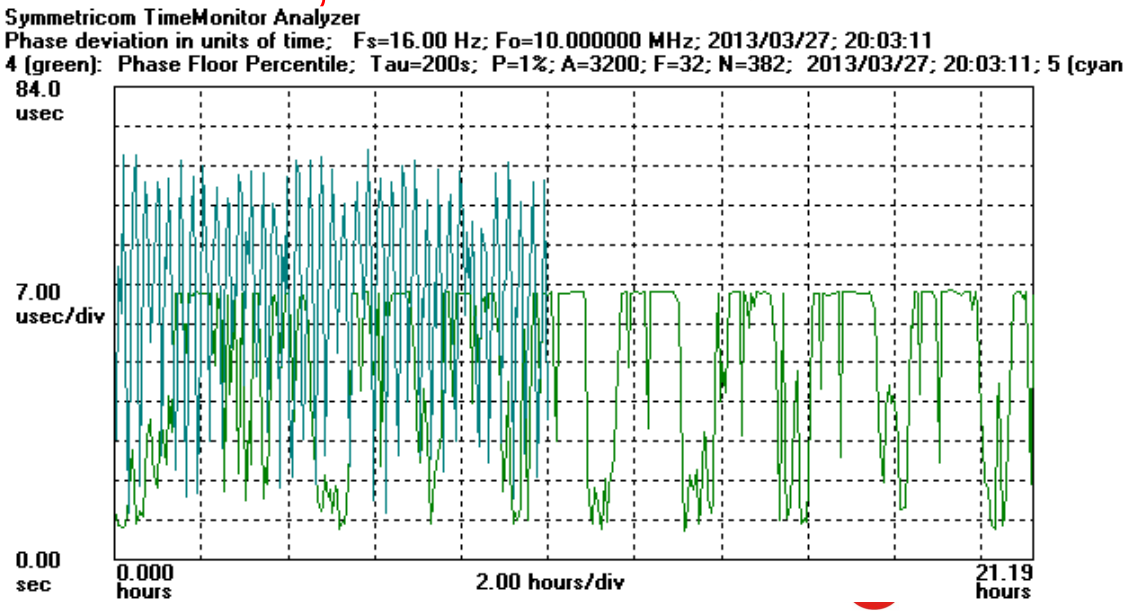
Case Studies: Five Networks

#1,#2,#3 PDV Percentile: 1%



What FPP level could be set to get at least 1% of the packets?

#4,#5 PDV Percentile: 1%

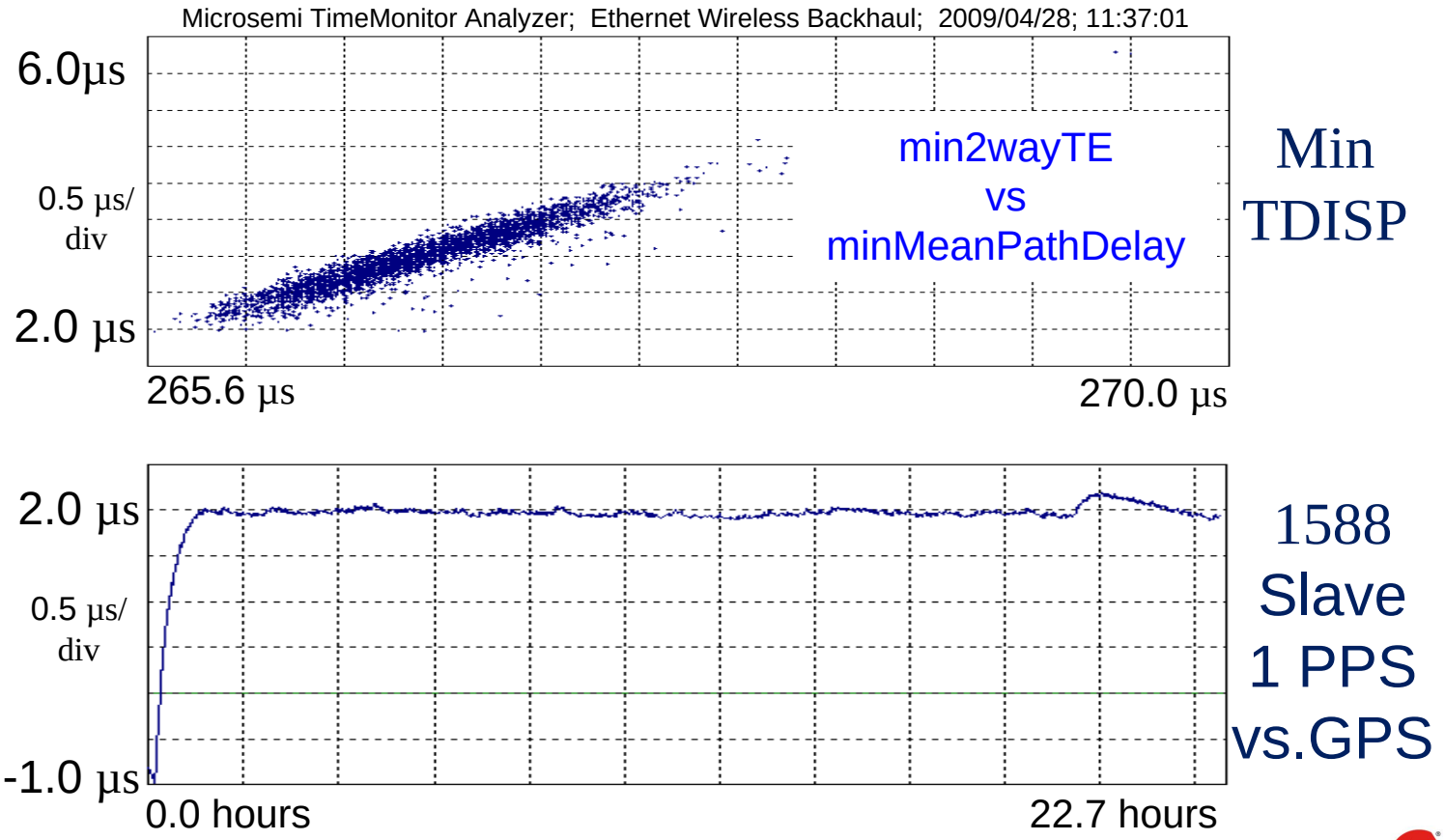


	Max 1 Percentile
U.S. Ethernet south	2.04 µsec
U.S. Ethernet north	2.60 µsec
Backhaul N America	13.8 µsec
Eth/SONET	47.8 µsec
Backhaul Europe	72.6 µsec

Two-way Time Error ⇔ Network Asymmetry

Asymmetry in Wireless Backhaul

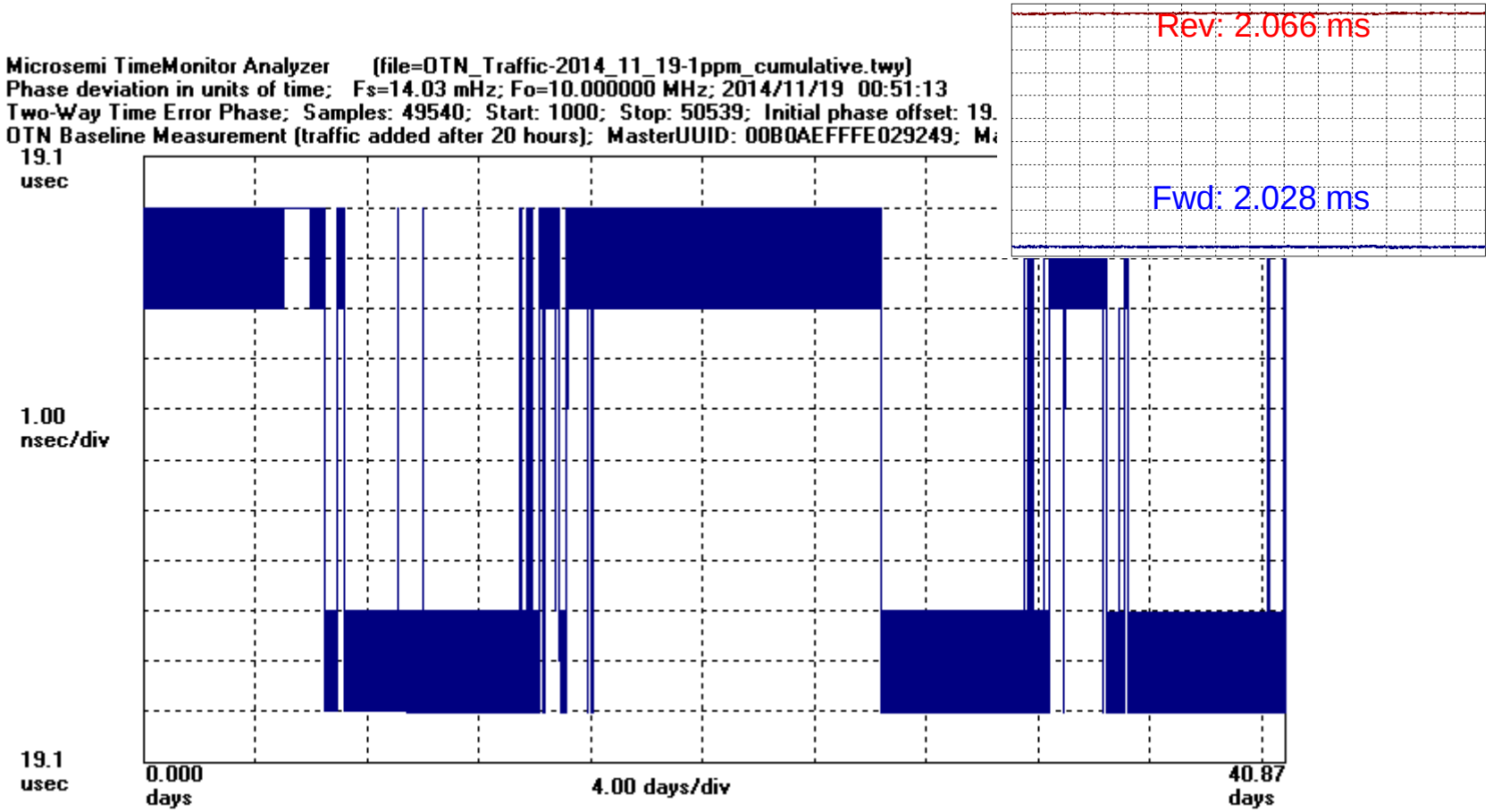
(Ethernet wireless backhaul asymmetry and IEEE 1588 slave 1PPS under these asymmetrical network conditions)



Case Studies: Network Asymmetry over Fiber

150 km fiber PTP over OTN transport

(2wayTE is 19.1 µsec which represents the 38.2 µsec difference between forward and reverse one-way latencies)



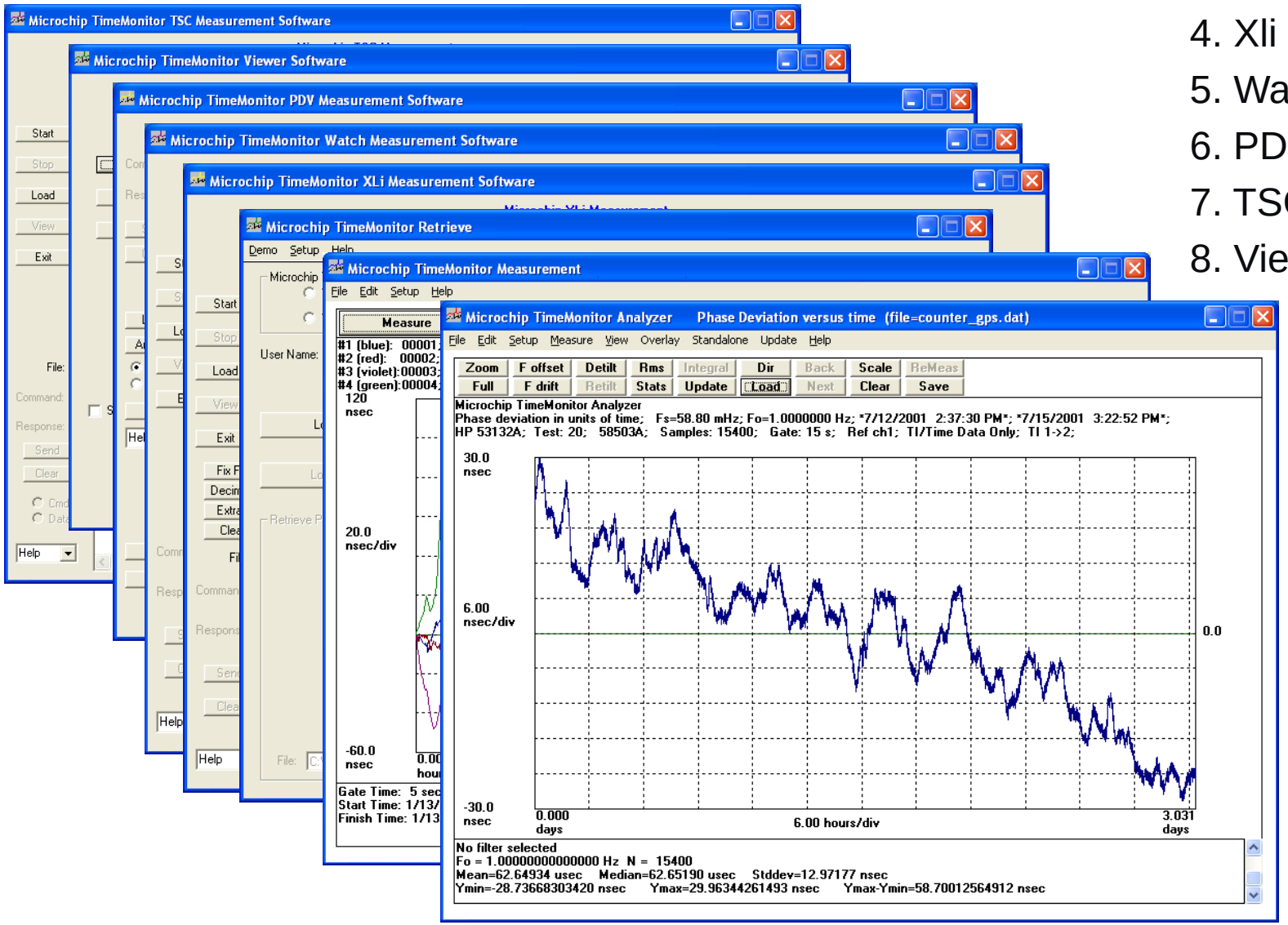
Time Transport Measurements

- Packet time transport measurements require common time scale reference at both ends of the network being studied (GNSS at both ends is a way to do this)
- Asymmetry is everywhere, asymmetry is invisible to the IEEE 1588 protocol, thus asymmetry has a direct bearing on the ability to transport time precisely
- The “offset” calculation is a direct measure of asymmetry
- There are two ways to assess time transport: (1) measuring a 1PPS reference at the node being studied and (2) measuring a packet signal at the node being studied
- Packet metrics for time transport must use both forward and reverse streams together rather than separately as is the case for frequency transport
- Packet metrics for time transport can make use of much of the methodology used for packet frequency transport metrics

TimeMonitor

TimeMonitor

TimeMonitor: Eight Applications



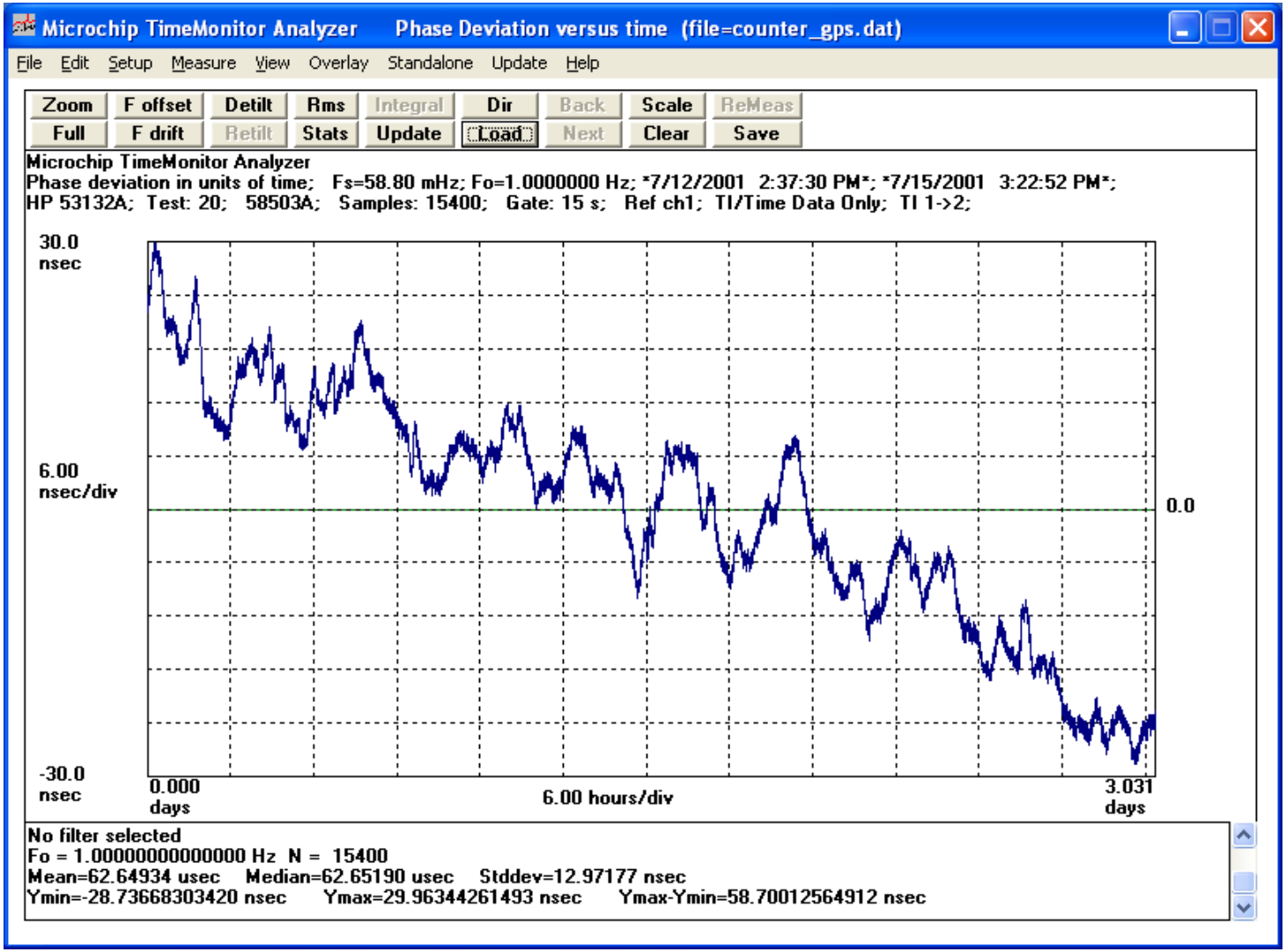
1. Analyzer
2. Measurement
3. Retrieve
4. Xli
5. Watch
6. PDV
7. TSC
8. Viewer

TimeMonitor 5.0

There are eight TimeMonitor software applications:

1. ***TimeMonitor Analyzer Software*** imports and analyzes data from more than 40 sources
   a. Test equipment from Agilent, Tektronix, Acterna, Pendulum, etc
   b. Microsemi NE (GPS, SSU, BITS) measurement data
   c. Counter data via TimeMonitor Measurement
   d. Analysis tool for TimePictra and TimeScan NMS Software
   e. Packet data: TP5k, Peerstats, Rawstats, XLi IEEE 1588 PDV, Blade PTP PDV, QoSmetrics
2. ***TimeMonitor Measurement Software*** collects data and displays phase (or frequency) using inexpensive off-the-shelf counters (can collect temperature data simultaneously also) GPIB/USB/LAN
3. ***TimeMonitor Retrieve Software*** collects performance data from Microsemi NE's: TS3000, TS2700, TimeHub, 55400, DCD, RTHC, OT21, SSU-2000, TimeProvider
4. ***TimeMonitor XLi Software*** collects phase or frequency data from the XLi shelf
5. ***TimeMonitor Watch Software*** collects phase data from the SyncWatch Probe
6. ***TimeMonitor PDV Software*** collects packet timing data from the TP5000 Probe (PTP Ethernet,Multicast,Unicast; NTP)
7. ***TimeMonitor TSC Software*** collects phase noise data from the TSC 5120A (Boulder)
8. ***TimeMonitor Viewer Software*** view TP 4100 monitor measurement files (for more extensive analysis use TimeMonitor Analyzer for importing these files)

TimeMonitor Analyzer



Using TimeMonitor Analyzer

- **FILE menu: used to load data (> 40 different data types including counter data, testset data, GPS, SSU/BITS, NTP and IEEE 1588 packet data) and for saving data, printing, and modifying data sets**
- **EDIT menu: copy graph for importing into applications such as Word, save graph to BMP file**
- **SETUP menu: VIEW and DISPLAY setups**
- **VIEW menu: perform various forms of analysis on a data set such as phase, Allan Deviation, phase power spectral density, histograms, statistics, MTIE, and TDEV**
- **HELP menu: access help file and readme file, also calculator and notepad**

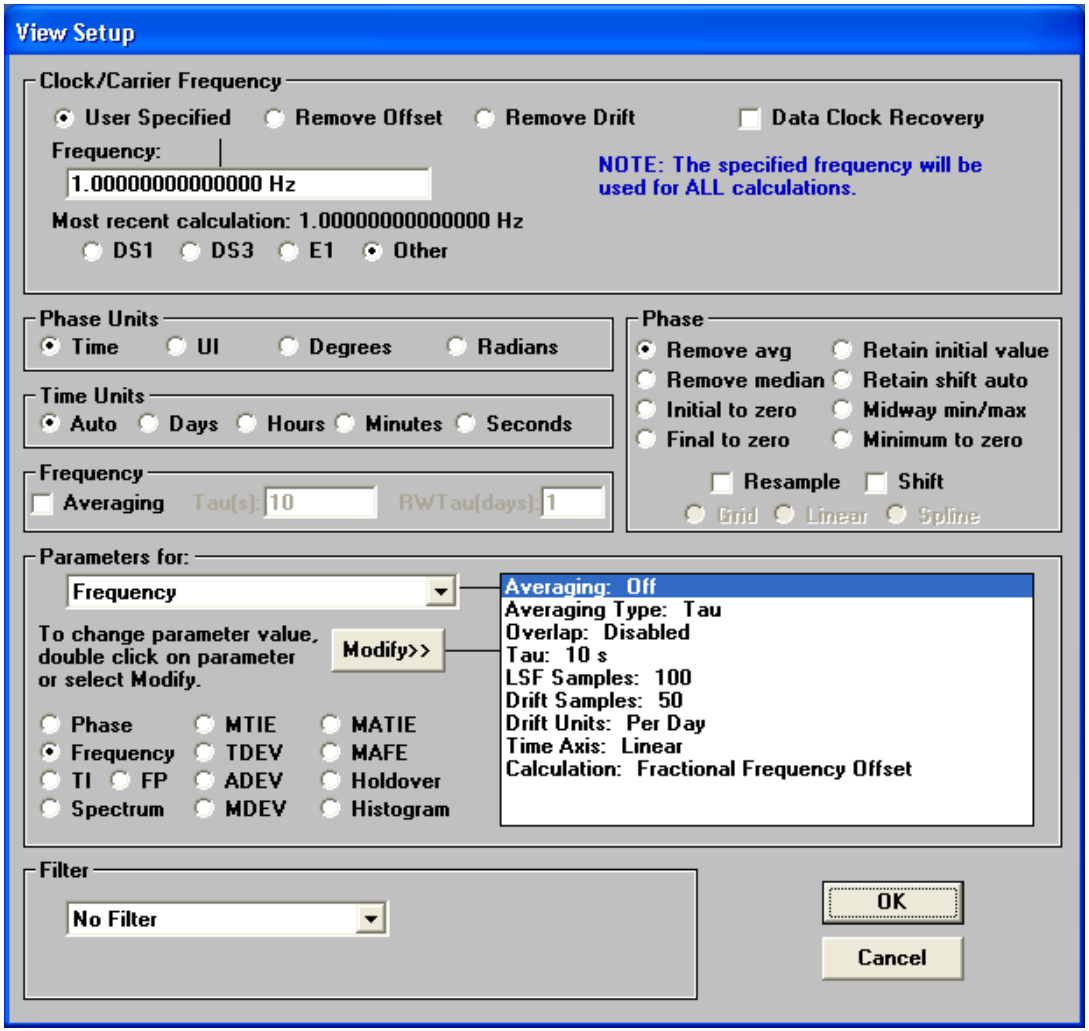
Using TimeMonitor Analyzer

- **ZOOM button:**
  - Used with mouse to zoom in on plots
  - FULL button returns to the full plot
  - MTIE Zoom and TDEV Zoom used w/phase zooms
- **F offset button:**
  - Used with two mouse clicks (on phase plot)
  - When SHIFT is held down uses the full data set
- **F drift button:**
  - Used with two mouse clicks (on phase plot)
  - When SHIFT is held down uses the full data set
- **DeTilt button:**
  - Used to remove frequency offset (on phase plot)

TimeMonitor Analyzer

View Setup

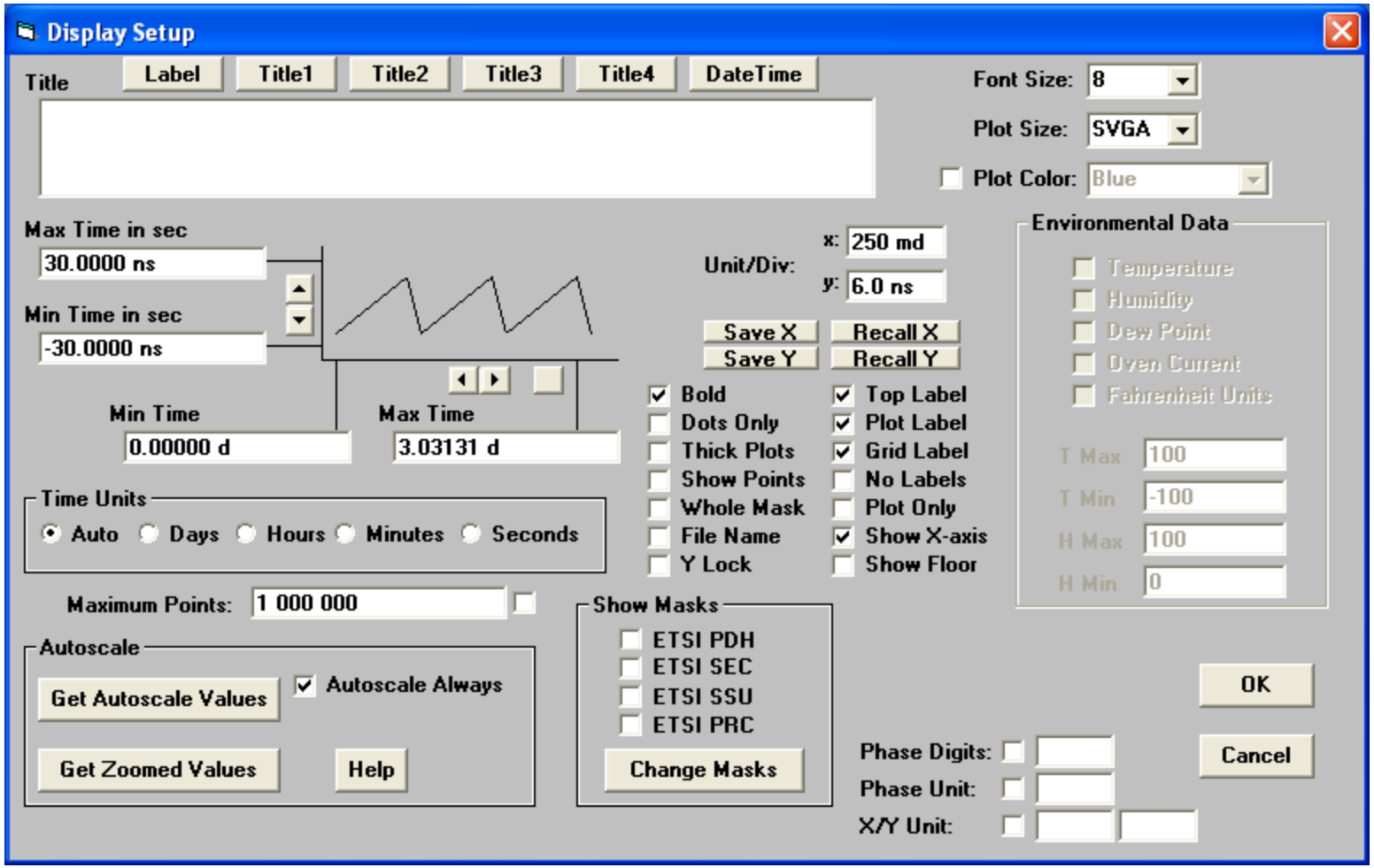
Setup for viewing data sets; removing offset, removing drift, filtering, time units, phase units, etc.



TimeMonitor Analyzer

Display Setup

Set up x/y axes, add masks, edit title, etc.

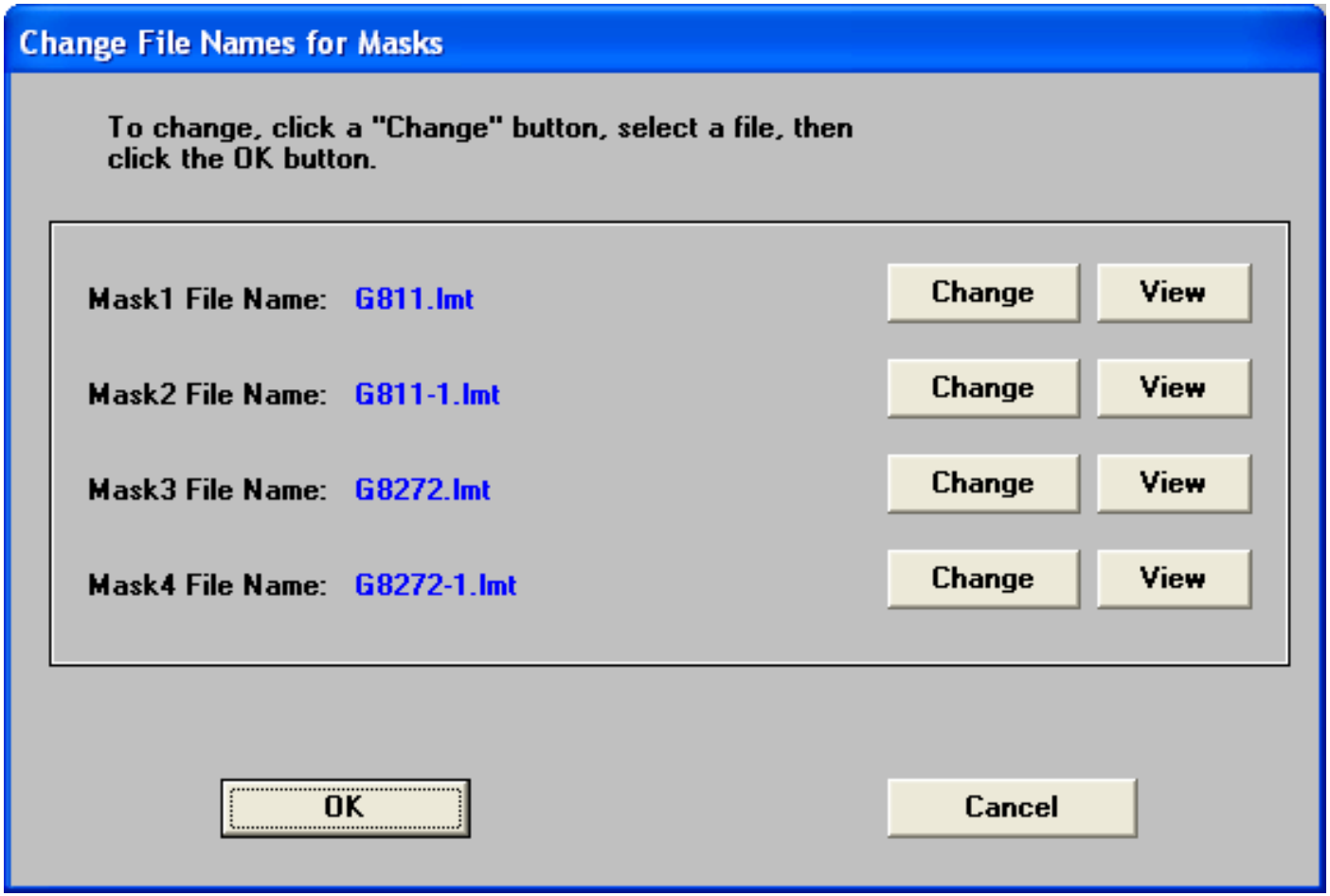


MICROCHIP

TimeMonitor Analyzer

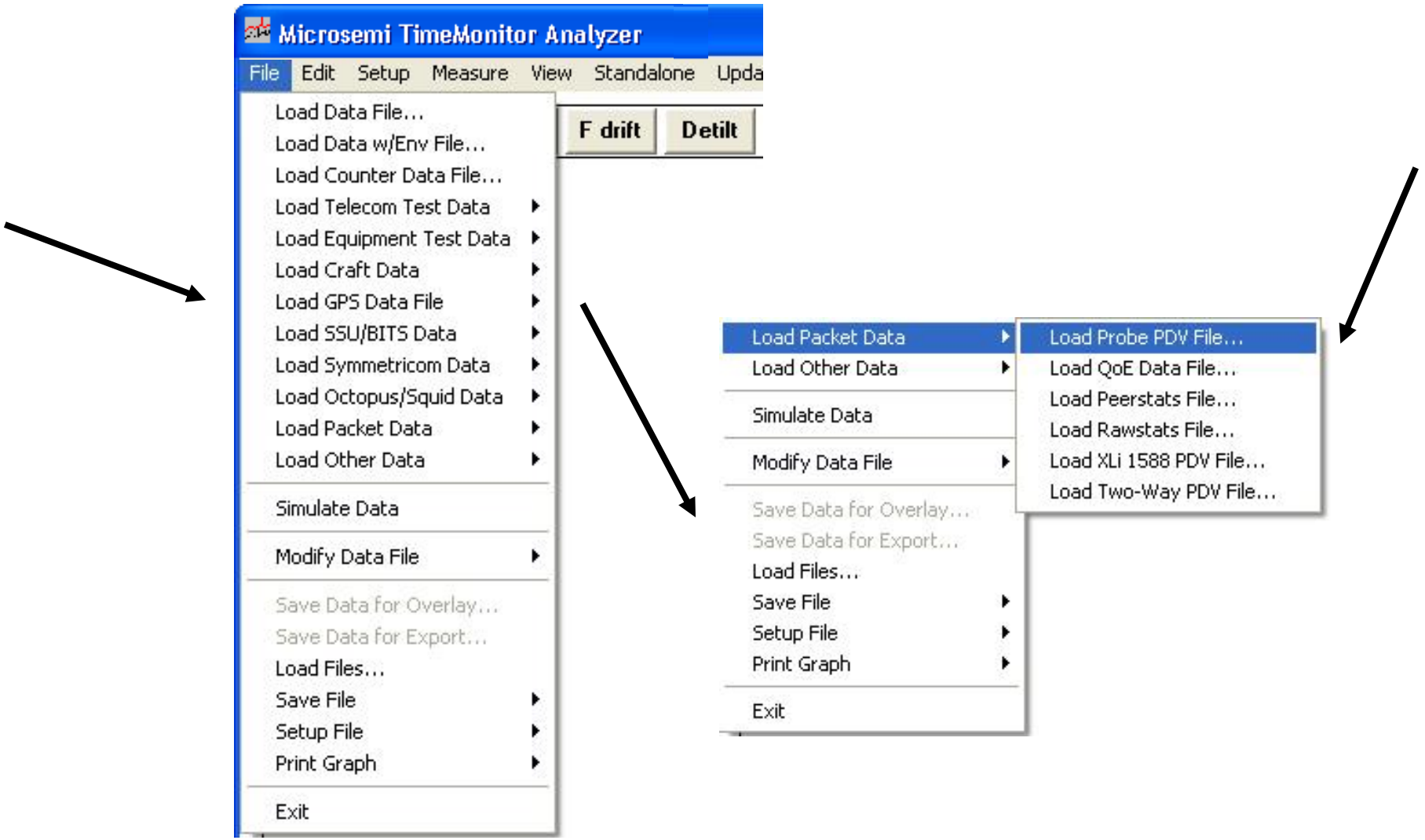
Change Masks

(Hit “Change Masks” button in Display Setup Form)



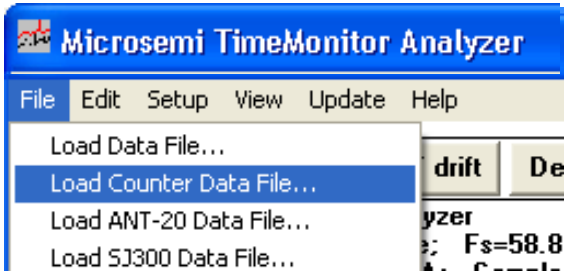
TimeMonitor Analyzer

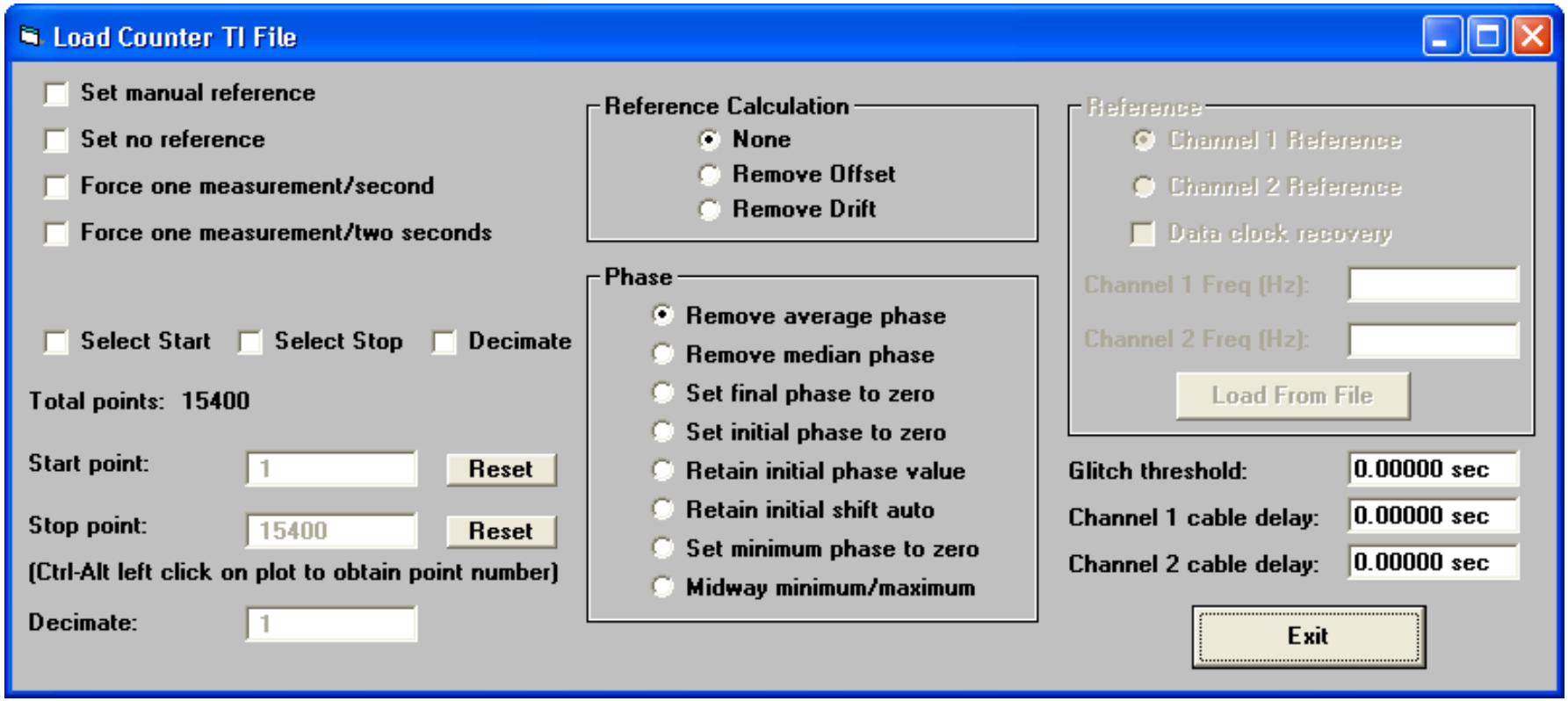
File Menu



TimeMonitor Analyzer

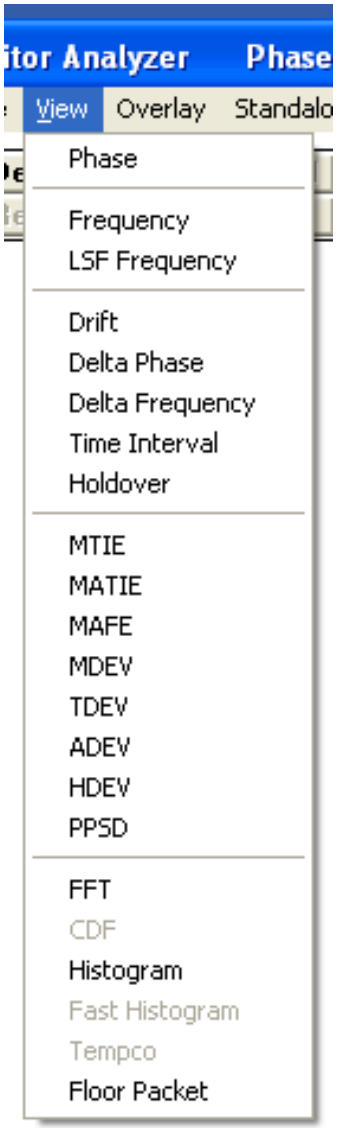
Load Counter Data





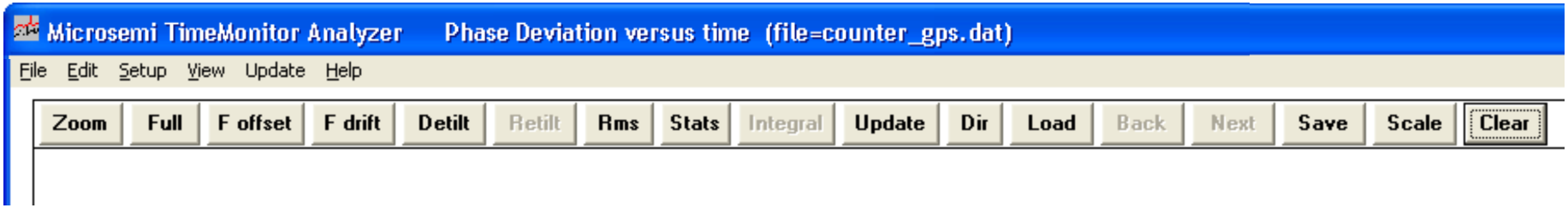
TimeMonitor Analyzer

View Menu



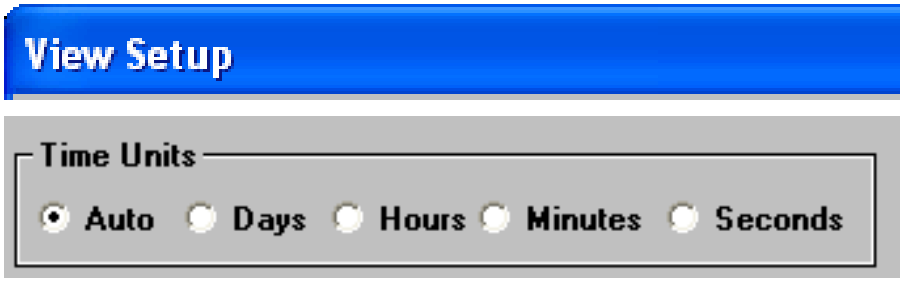
TimeMonitor Analyzer

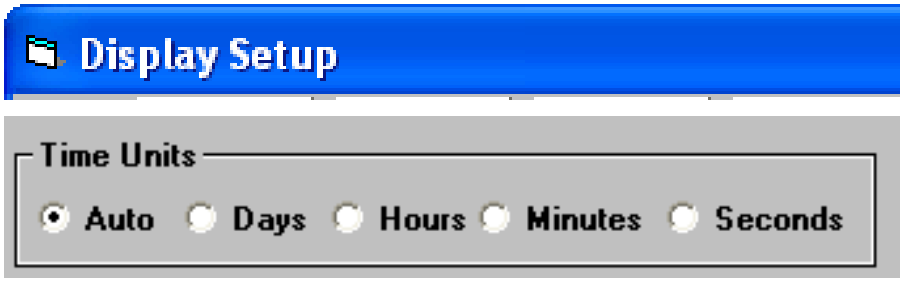
Buttons



TimeMonitor Analyzer

Time Units

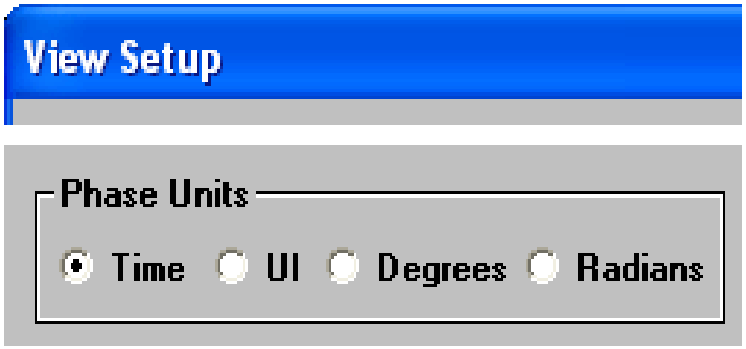




- Seconds, Minutes, Hours, and Days available
- Accessible from either View Setup or Display Setup

TimeMonitor Analyzer

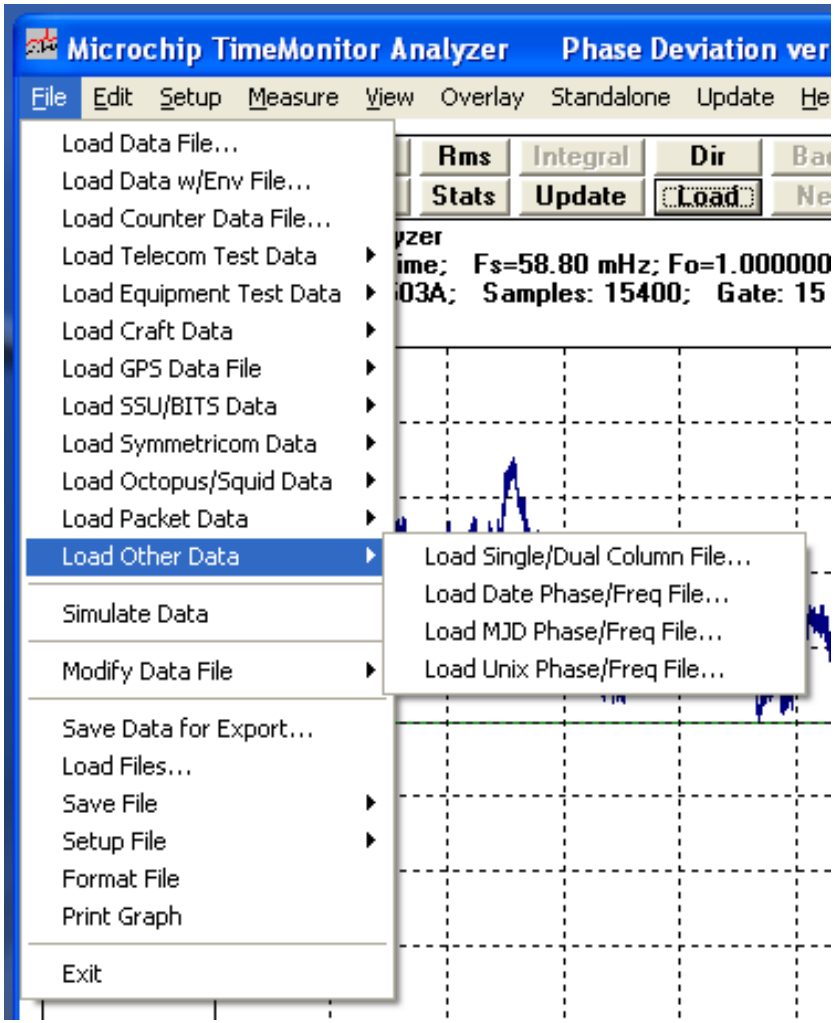
Phase Units



- Most sync phase measurements use “Unit Time” (particularly wander)
- UI (unit interval) is used for peak-to-peak jitter measurements

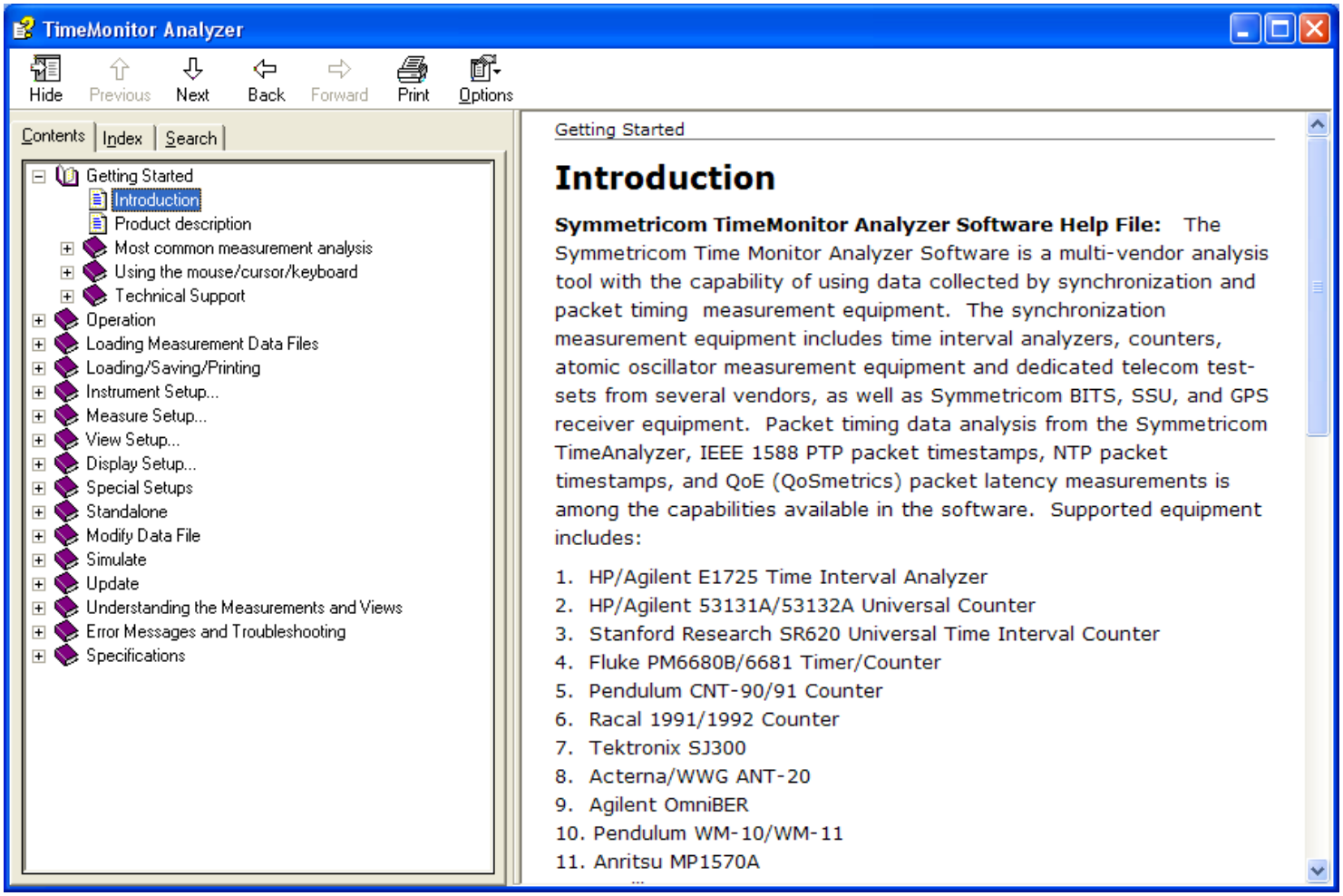
TimeMonitor Analyzer

"Load Other Data" Grouping



Using TimeMonitor Analyzer

Help File/User Guide (>500 pages!)



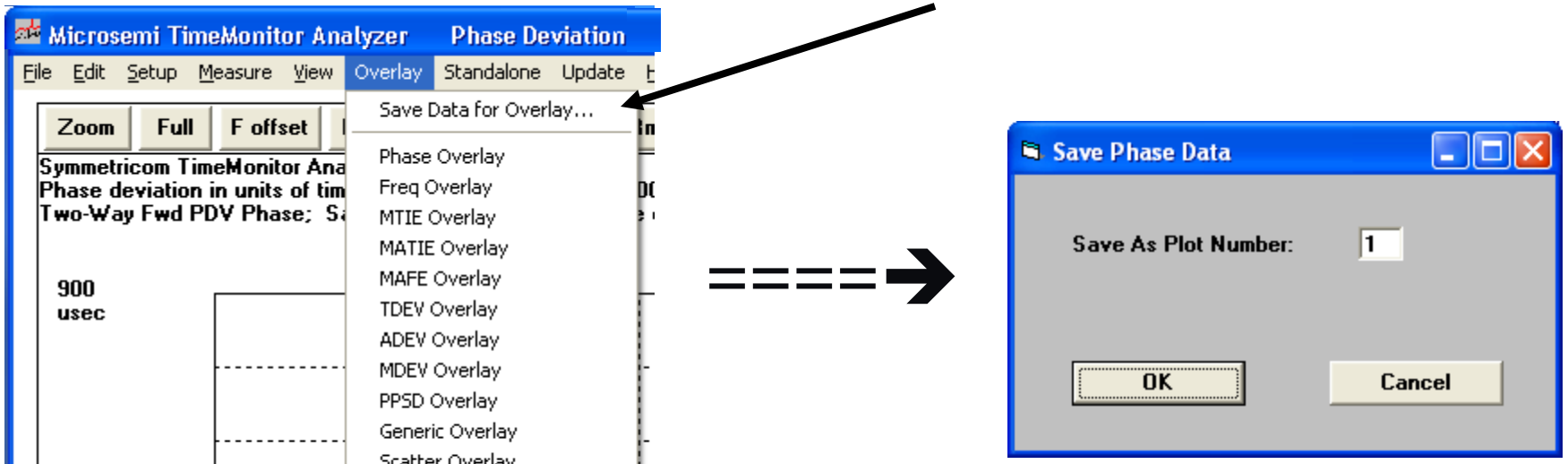
TimeMonitor Analyzer

Measurement Overlay

- **Measurements which can be overlaid:**
  - Phase Deviation
  - Fractional Frequency Offset
  - ADEV/MDEV
  - MTIE
  - TDEV
  - Scatter (eg. Tempco)
  - TimeStats
  - Histogram
  - FPP
- **Useful for comparing measurements such as:**
  - Simultaneously made measurements
  - Successive measurements made on the same signal

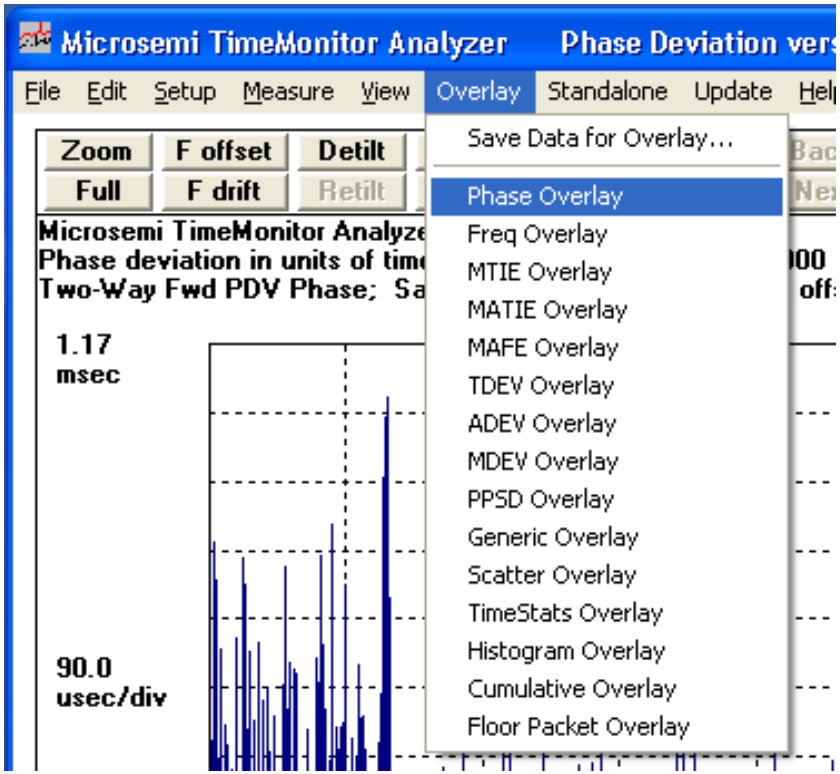
TimeMonitor Analyzer

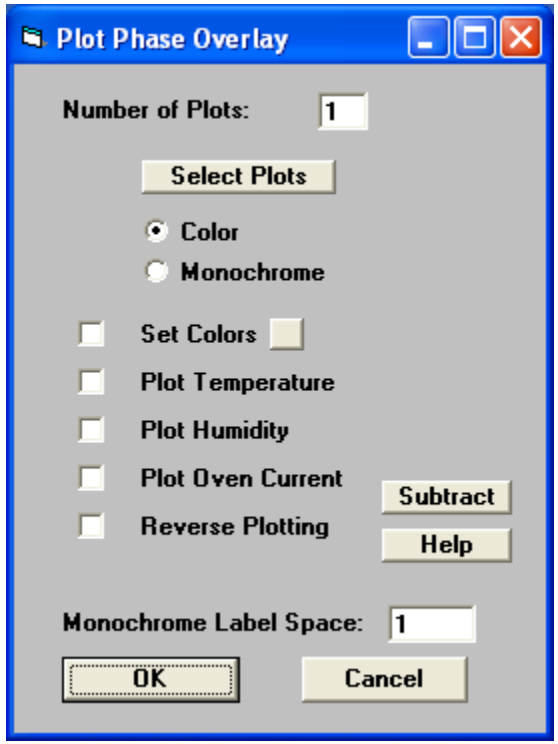
Preparing Overlay Measurements



TimeMonitor Analyzer

Viewing Overlay Measurements

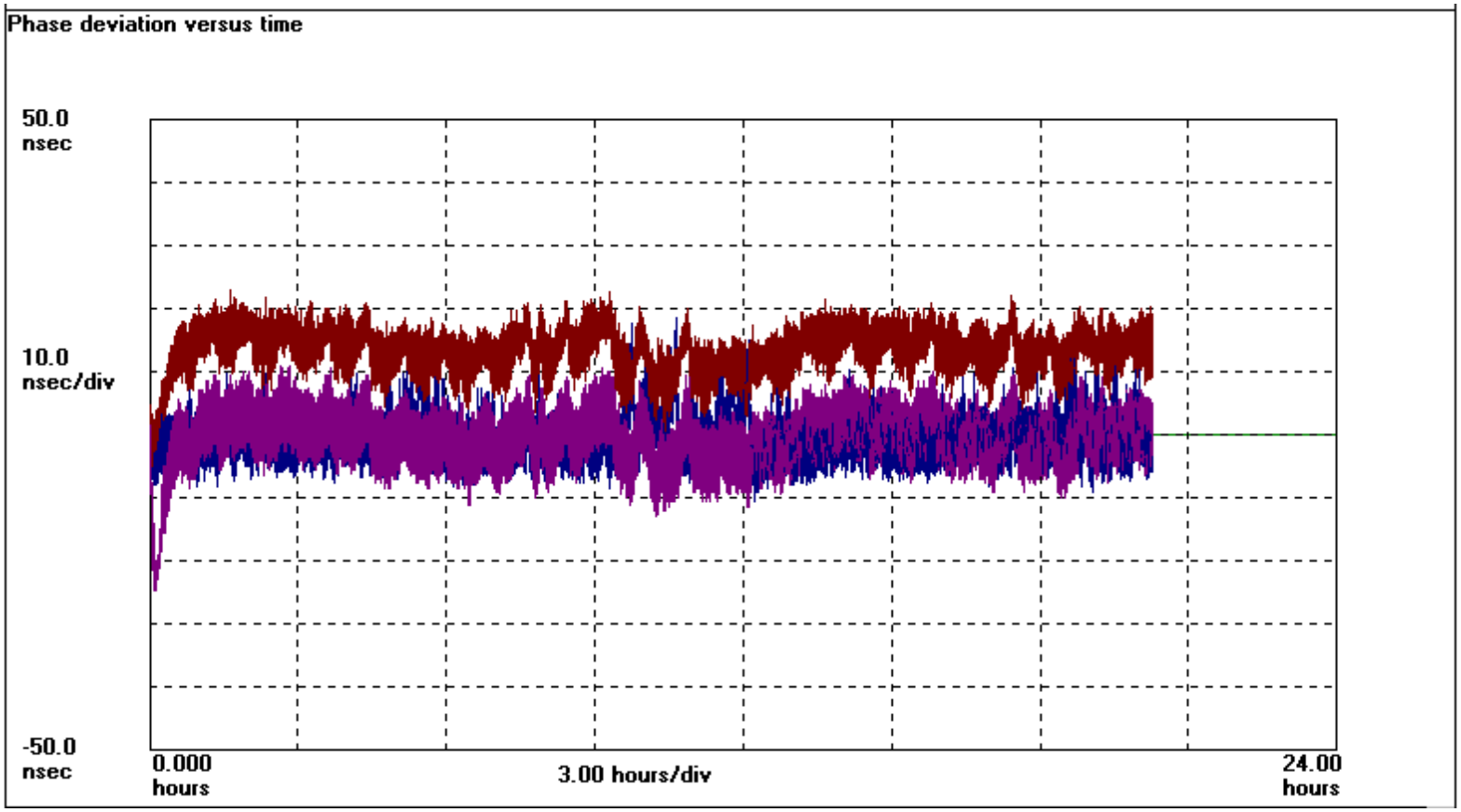




MICROCHIP

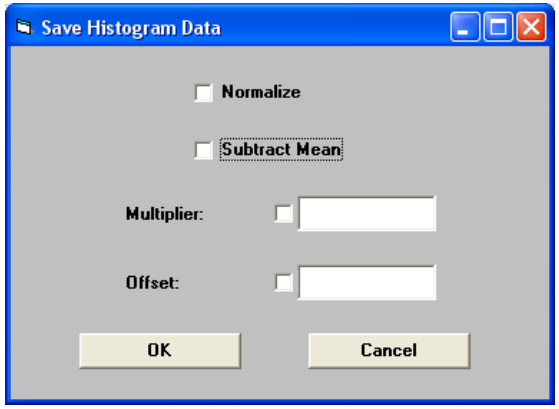
TimeMonitor Analyzer

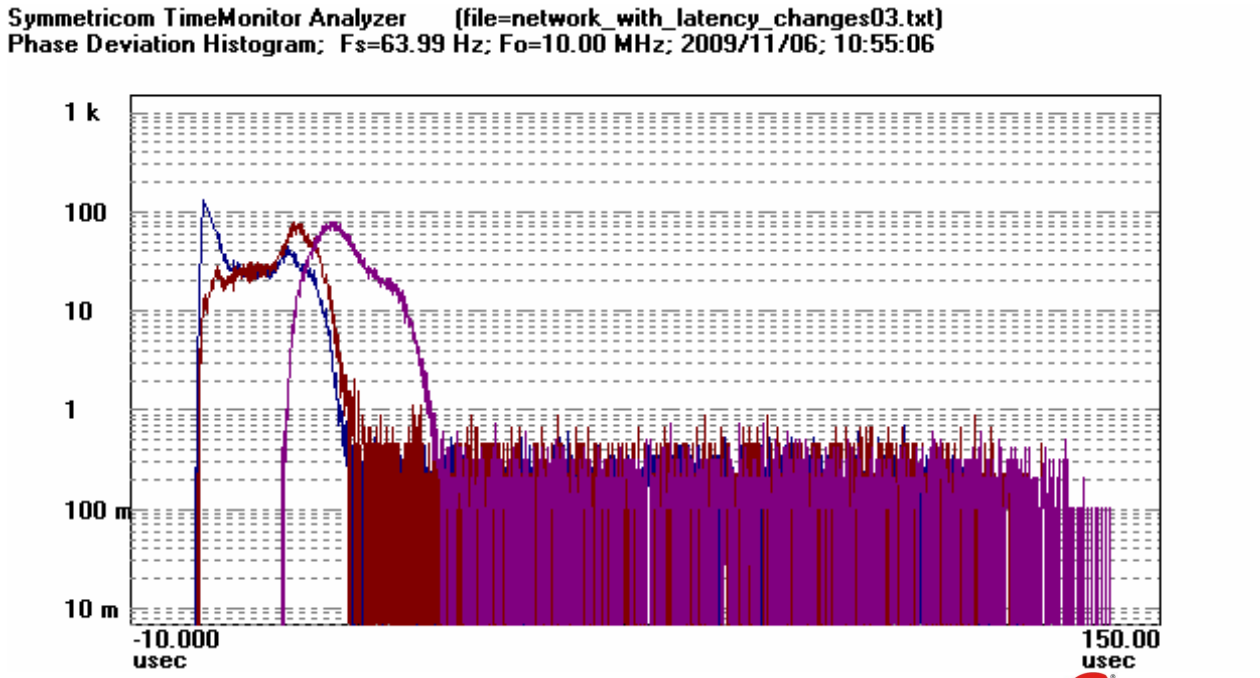
Example Overlay Measurements



TimeMonitor Analyzer

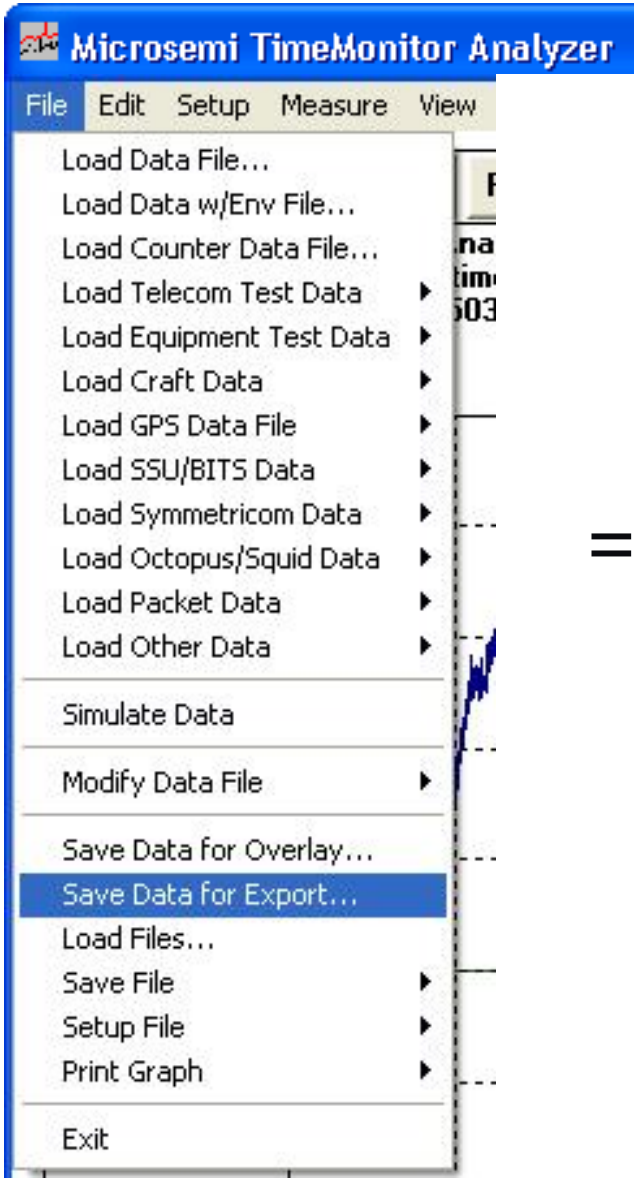
Example Histogram Overlay



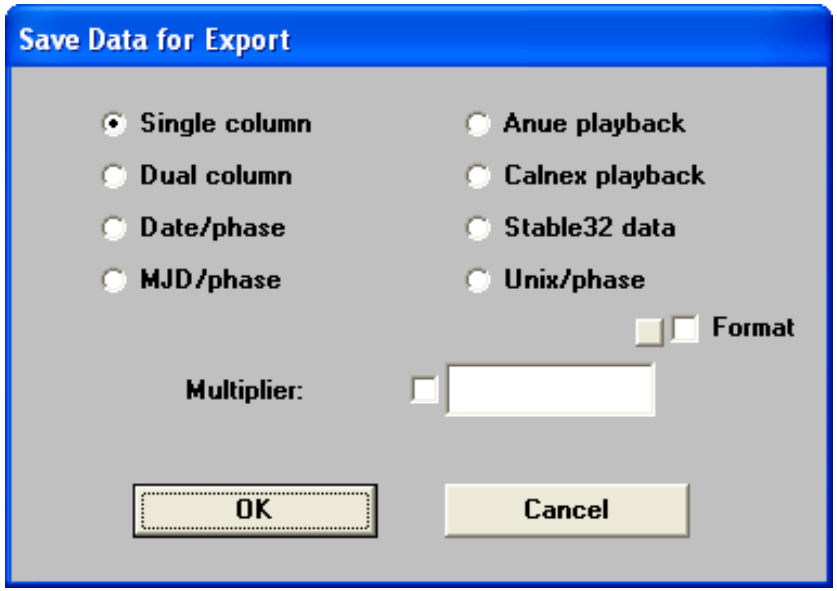


MICROCHIP

TimeMonitor Analyzer



Save Data for Export

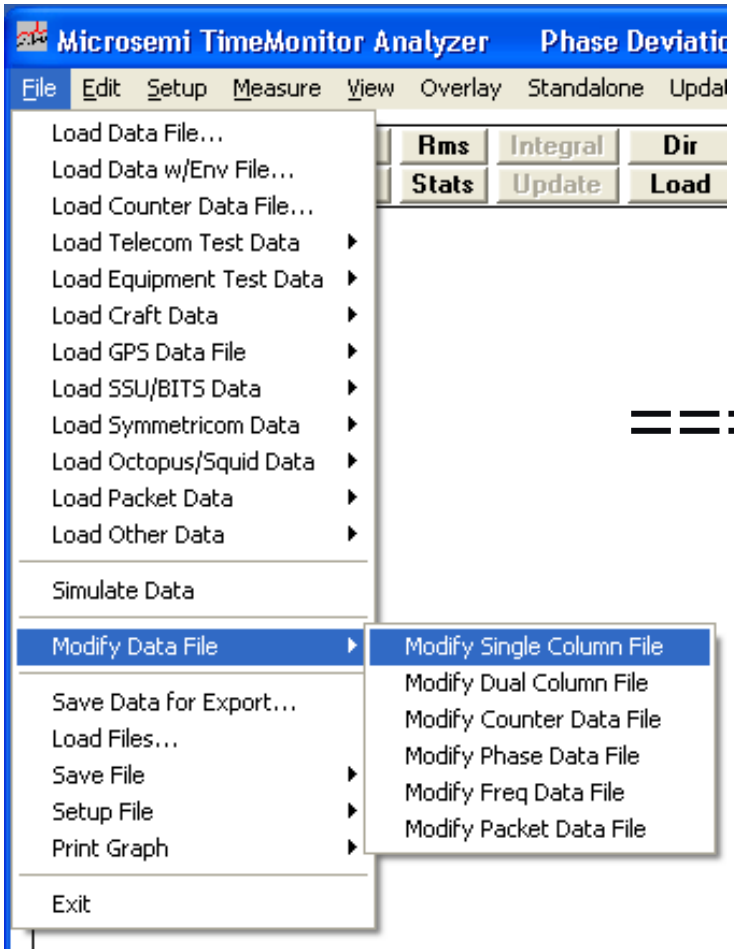


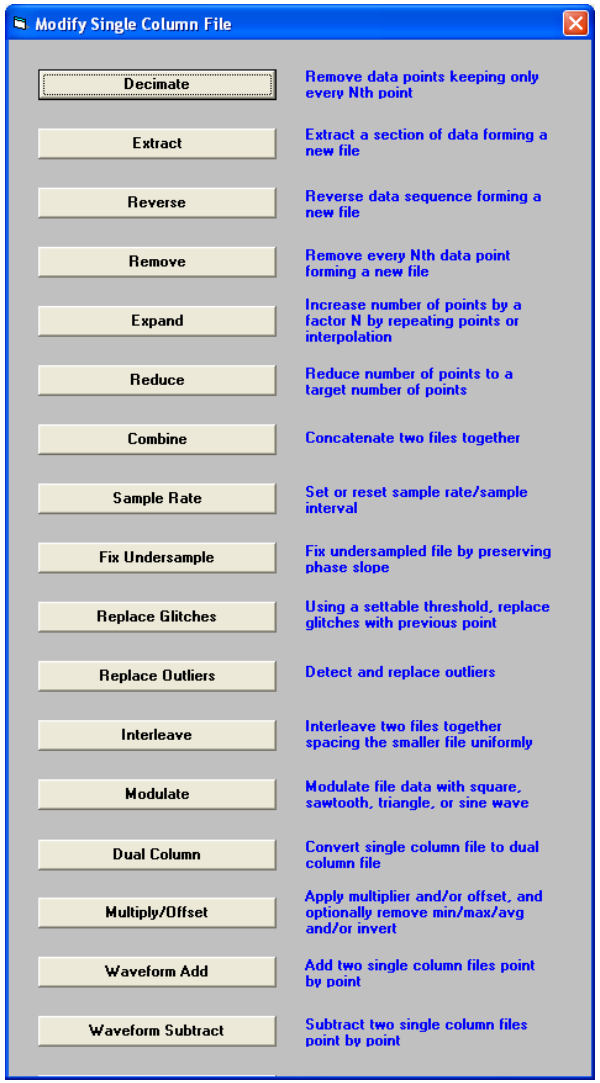
MICROCHIP

TimeMonitor Analyzer

Modify Single Column File

(Ctrl-Alt mouse click useful for finding points for “extract”)

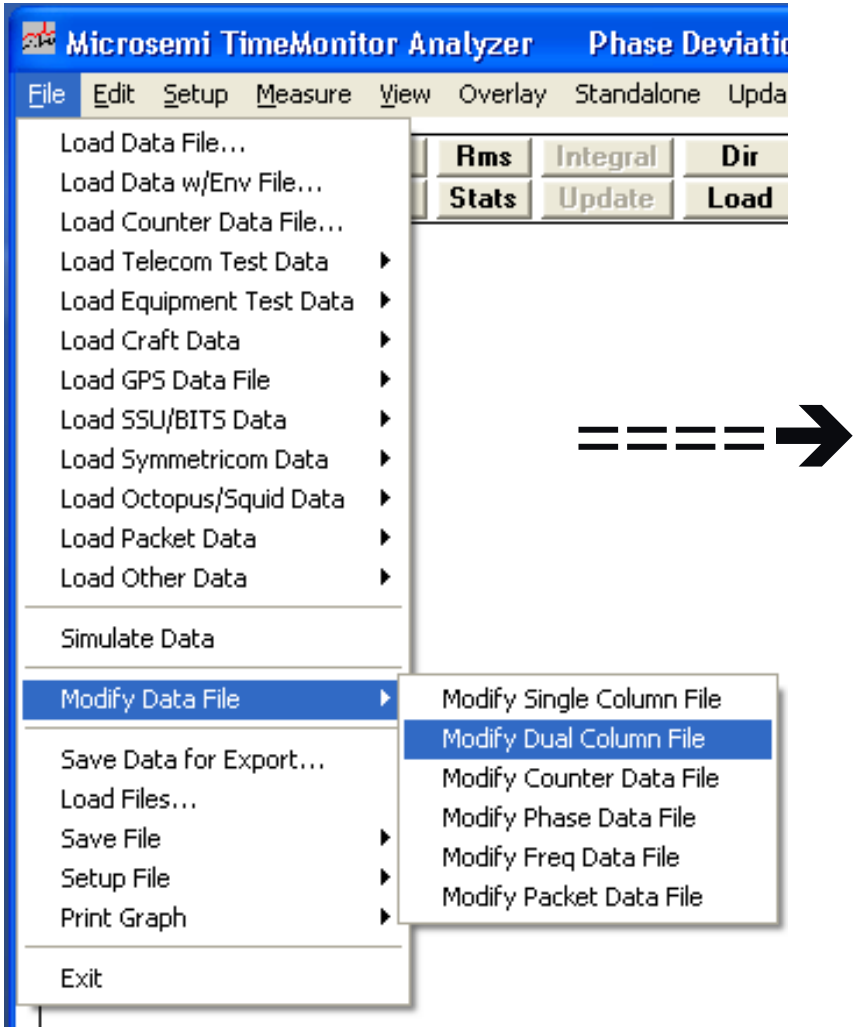




TimeMonitor Analyzer

Modify Dual Column File

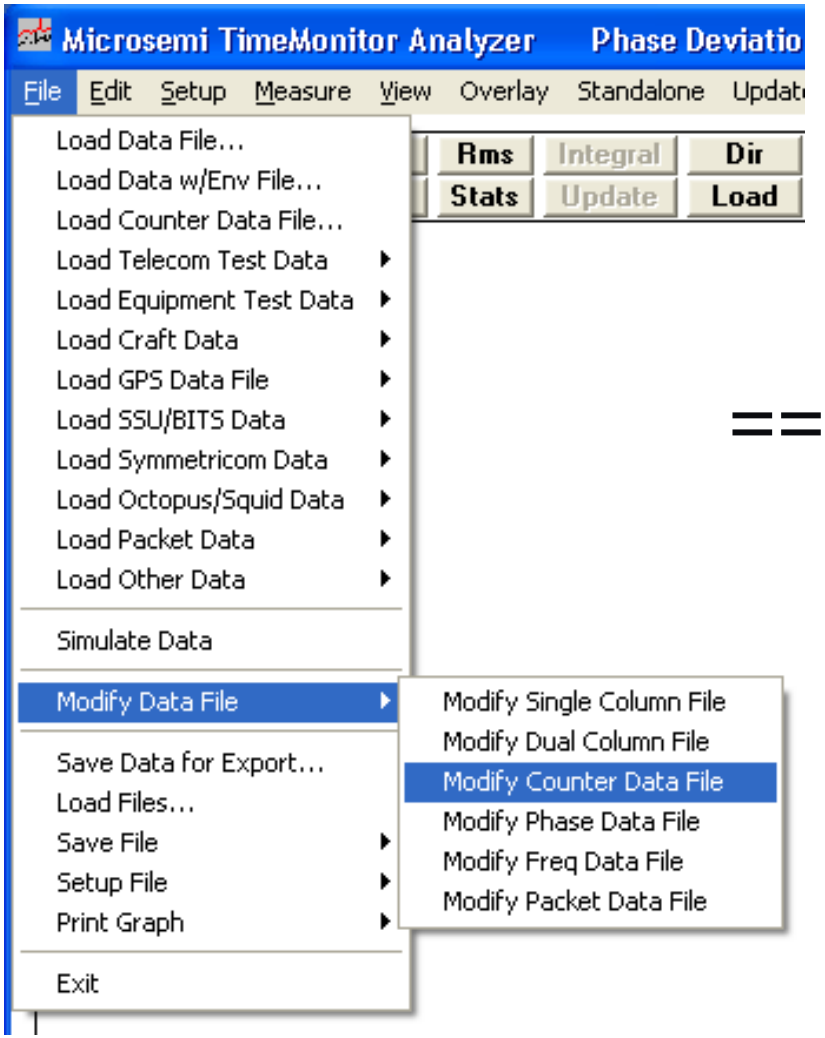
(Ctrl-Alt mouse click useful for finding points for "extract")

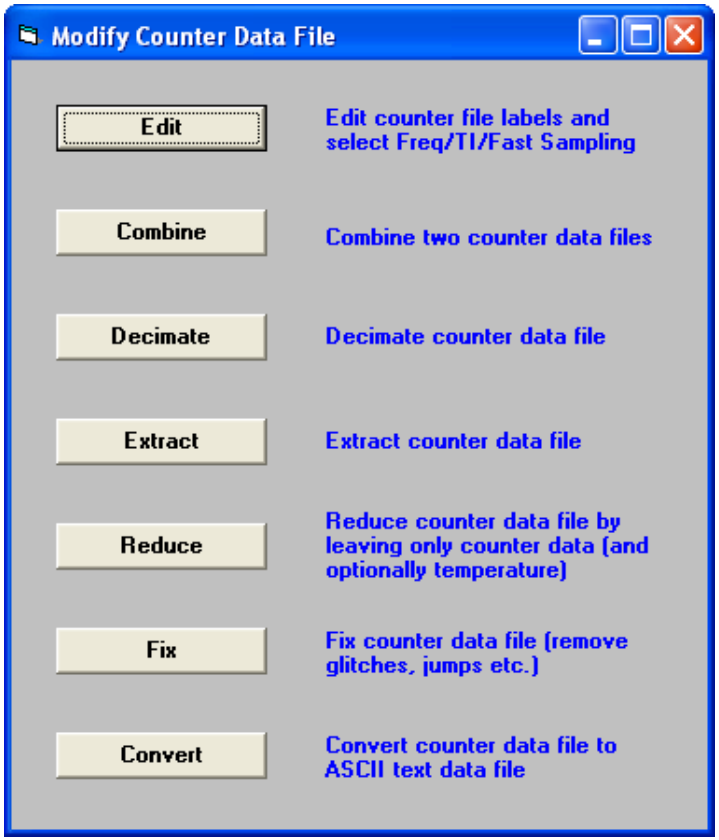


TimeMonitor Analyzer

Modify Counter Data File

(Ctrl-Alt mouse click useful for finding points for "extract")

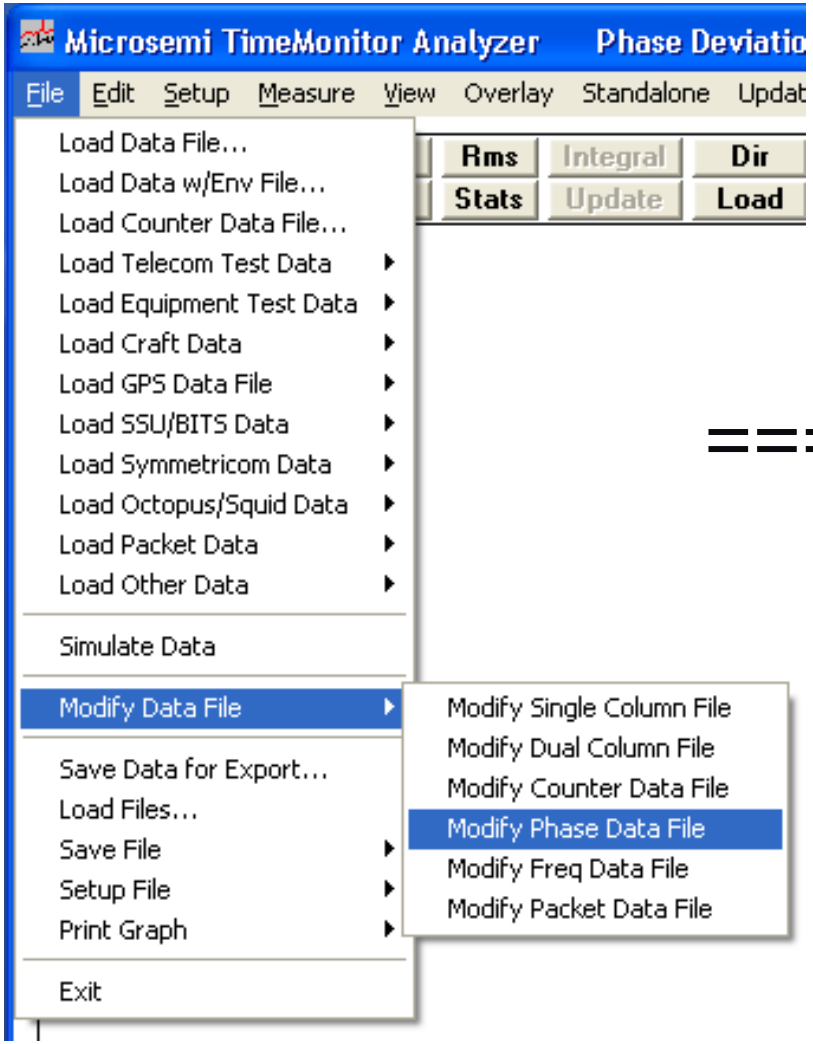


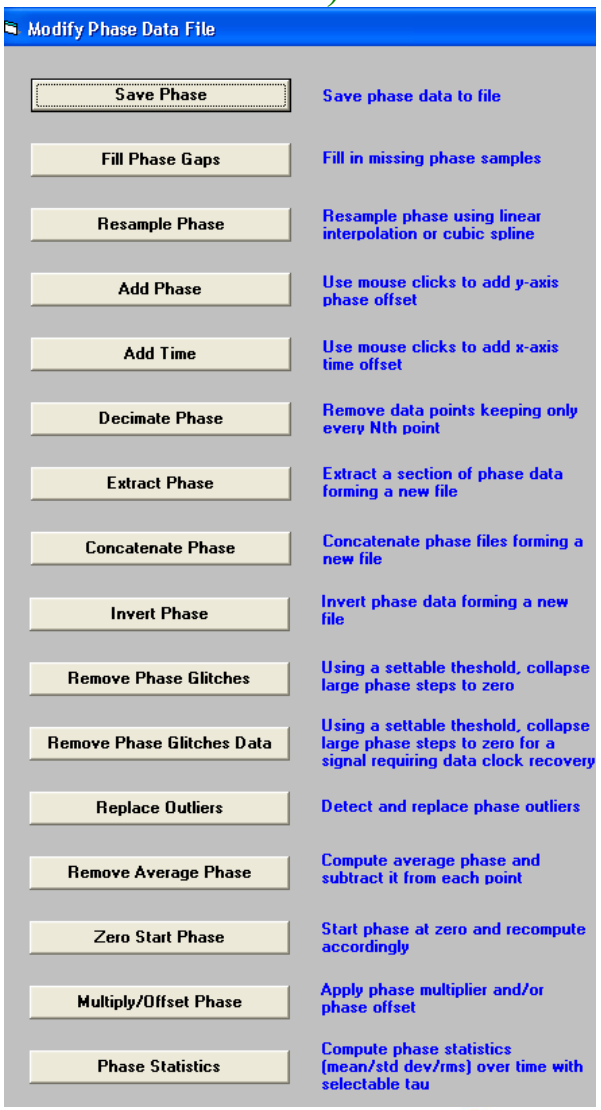


TimeMonitor Analyzer

Modify Phase Data File

(Ctrl-Alt mouse click useful for finding points for "extract")

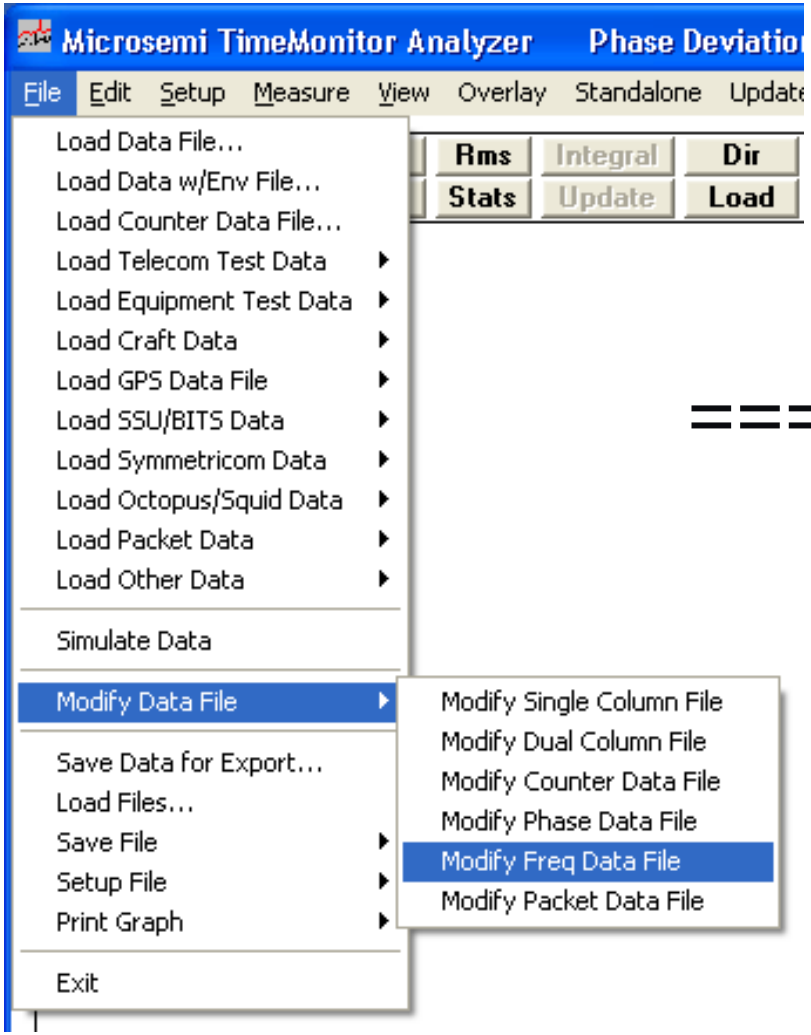


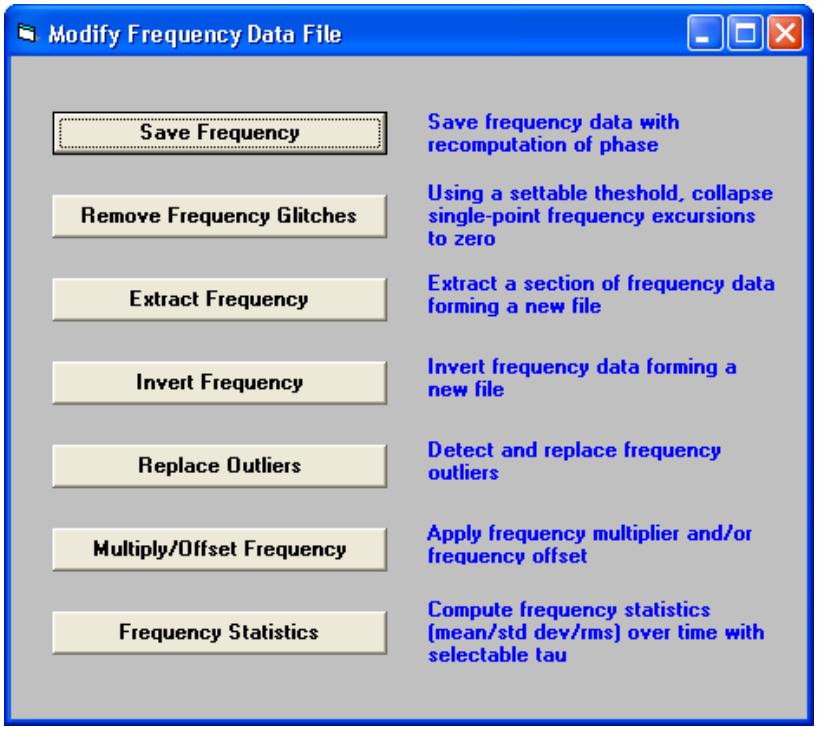


TimeMonitor Analyzer

Modify Frequency Data File

(Ctrl-Alt mouse click useful for finding points for "extract")

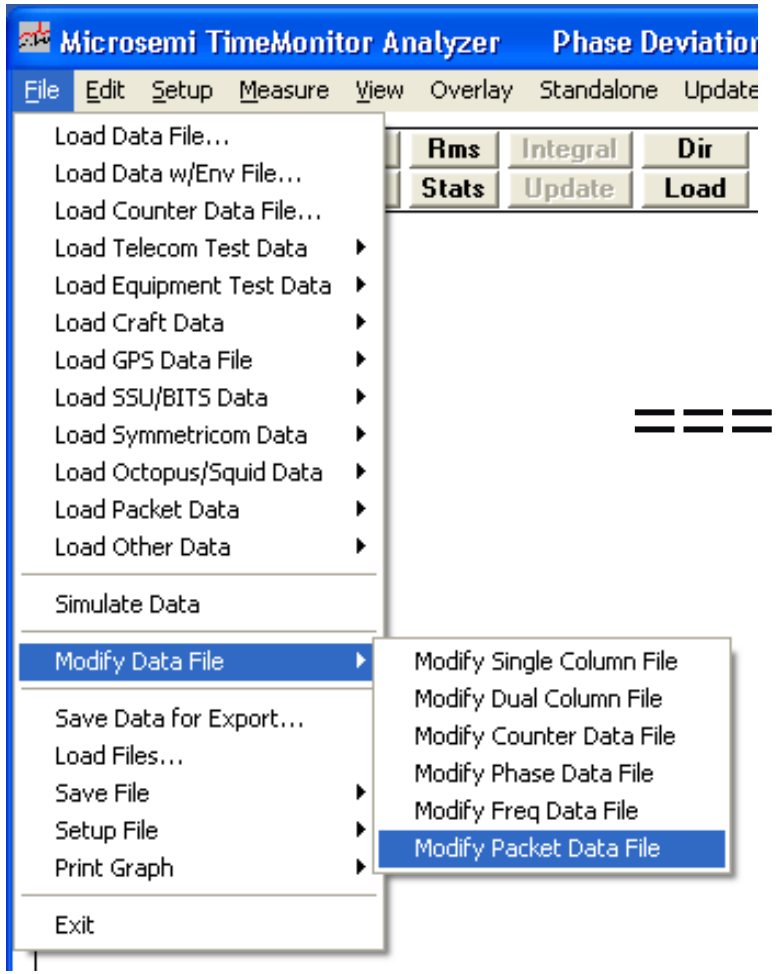


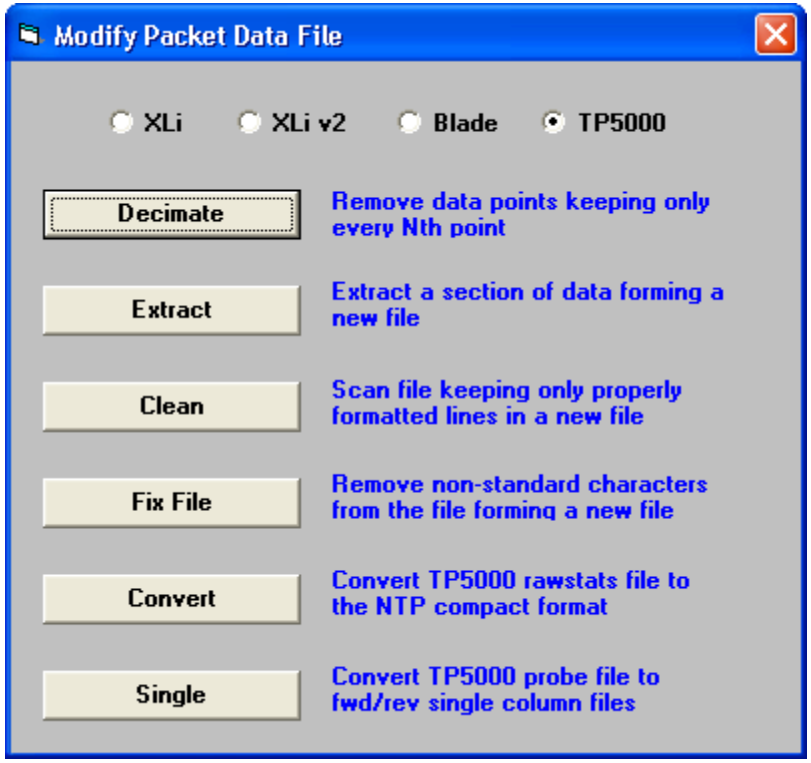


TimeMonitor Analyzer

Modify Packet Data File

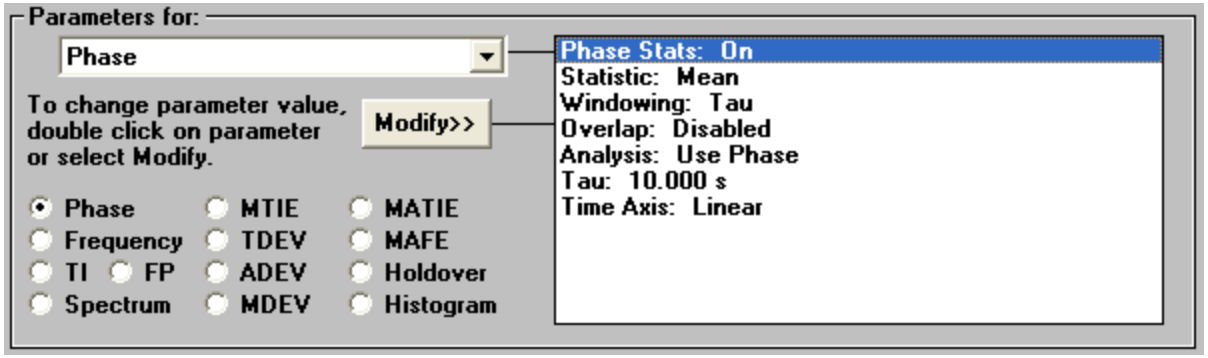
(Ctrl-Alt mouse click useful for finding points for "extract")

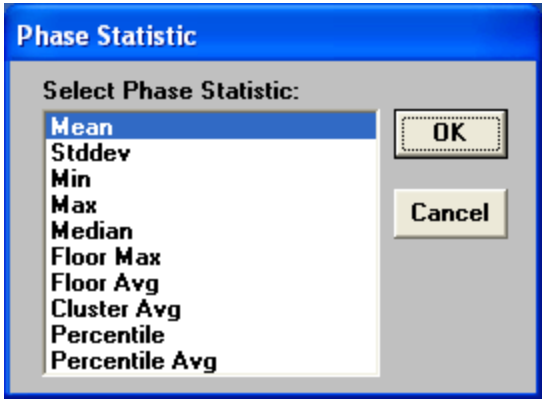




TimeMonitor Analyzer

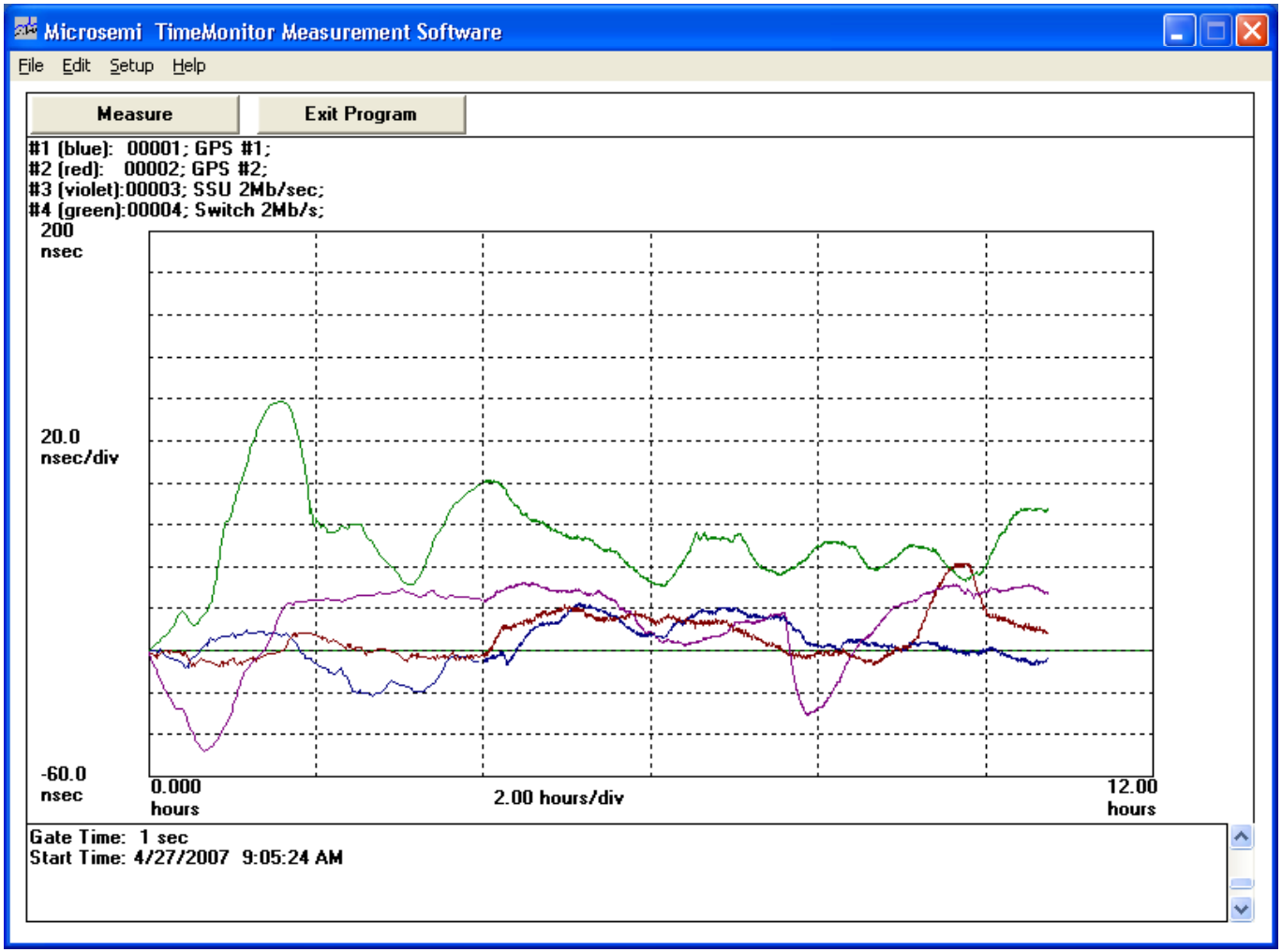
Phase Statistics





MICROCHIP

TimeMonitor Measurement



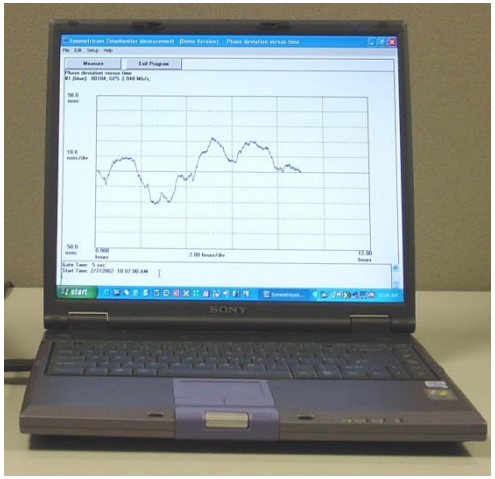
TimeMonitor Measurement

Sync Measurement Equipment List

1. Cesium clock or GPS receiver
2. Counter
3. Laptop computer with GPIB card/cable (or USB or LAN)
4. Microsemi TimeMonitor Analyzer Software
5. Microsemi TimeMonitor Measurement Software
6. Oscilloscope
7. DVM and Temperature Probe

TimeMonitor Measurement

Sync Measurement Equipment



PC

Counter

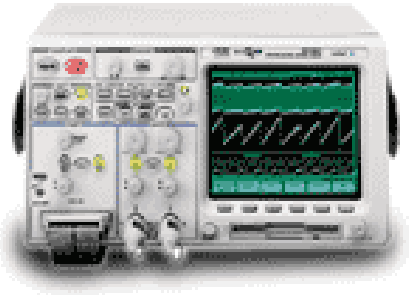
GPIB

PRC

DVM

Temperature Probe

Synthesizer



Oscilloscope

TimeMonitor Measurement

Supported Counters

Agilent 53220/30A

HP 53131/32A

Pendulum CNT 90/91

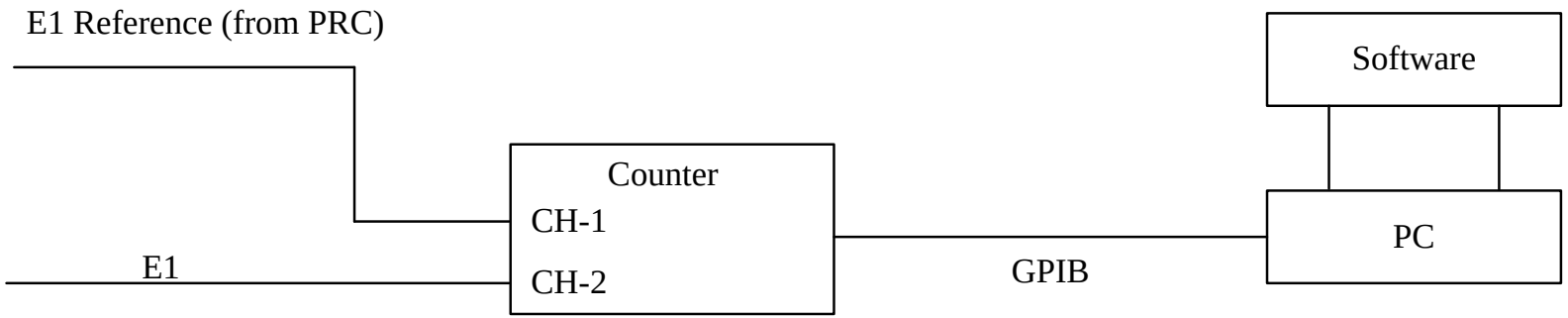
SR 620

Fluke PM6681

Racal 1991/2

TimeMonitor Measurement

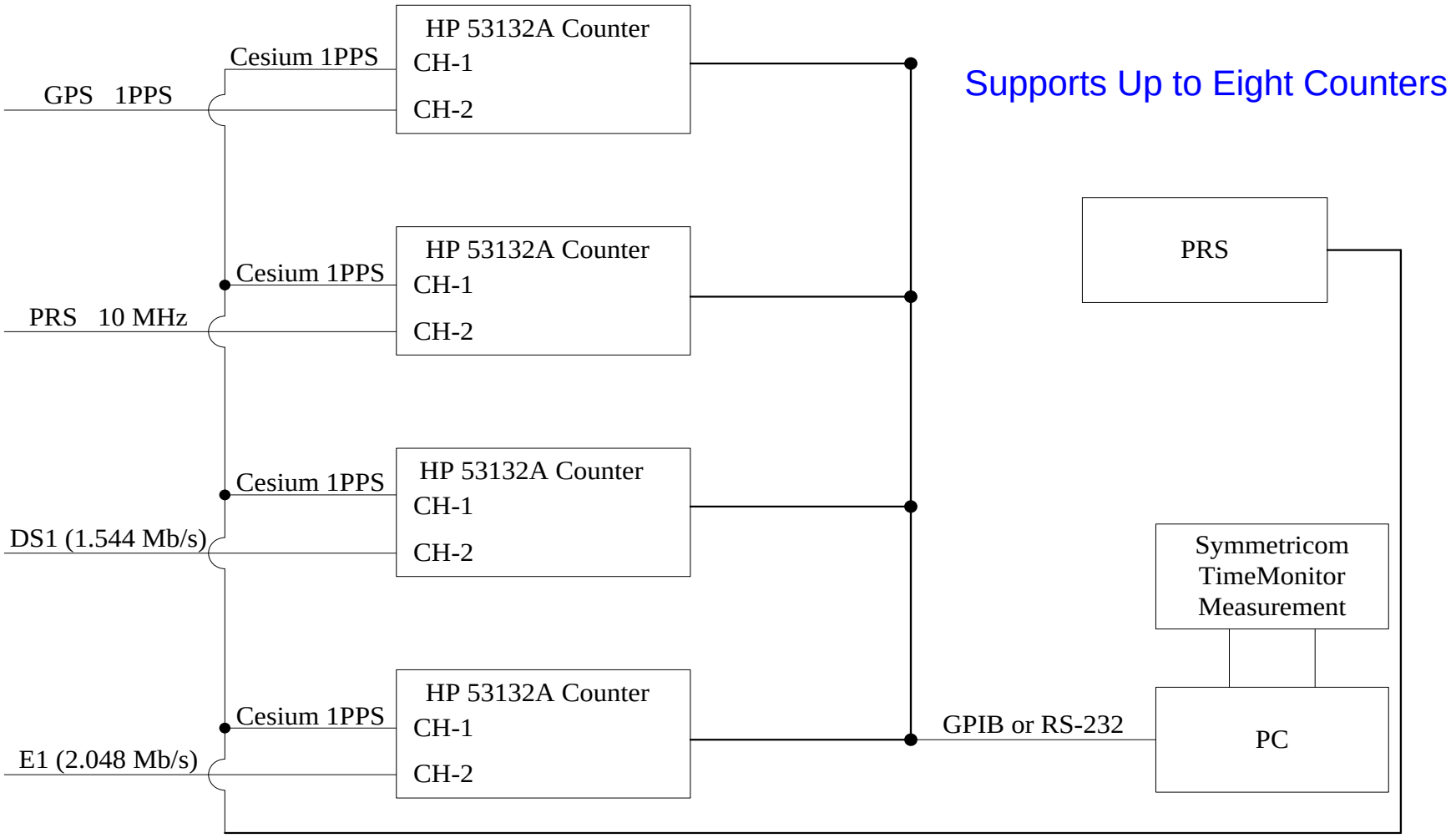
Counter Measurement Block Diagram



- Signals could be at other rates, for example
  - T1/DS1 (1.544 M)
  - E1 (2.048 M)
  - DS2 (6.312 M)
  - DS3 (44.76 M)
  - 64 kbit
  - 1 PPS
  - 10 MHz
  - STS-1/OC-1 electrical (51.84 M)
  - 140 Mb/s Tributary (139.264 M)
  - STS-3/STM-1/OC-3 electrical(155.52 M)
- Clock or data signal (software does data clock recovery)
- When working with a balanced signal, a balun and termination pad are likely required

TimeMonitor Measurement

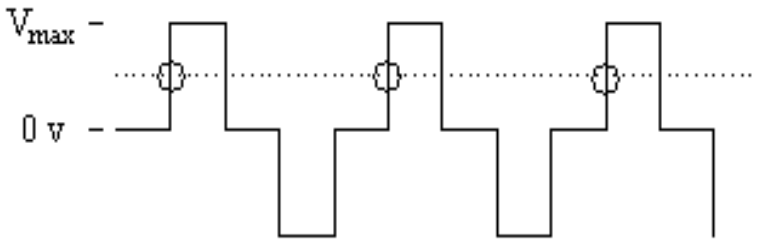
Multiple Counter Setup



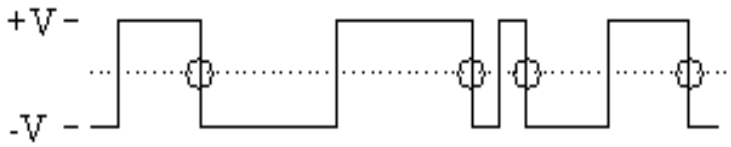
TimeMonitor Measurement

Counter Measurement Setup

- Setting thresholds – consider the signal
- Is it a bipolar signal?



0 volts is not OK

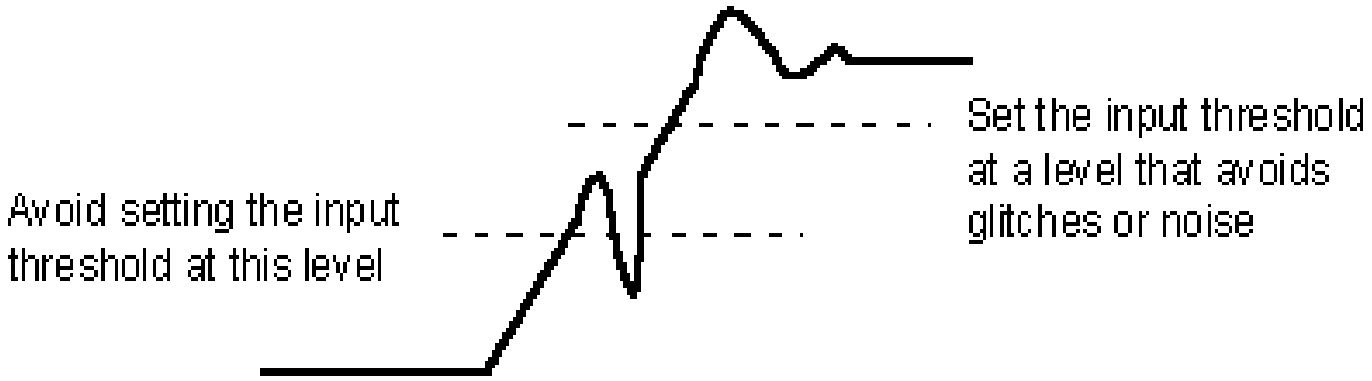


0 volts is OK

TimeMonitor Measurement

Counter Measurement Setup

- **An oscilloscope is a useful tool for working with noisy signals**



Using TimeMonitor Measurement

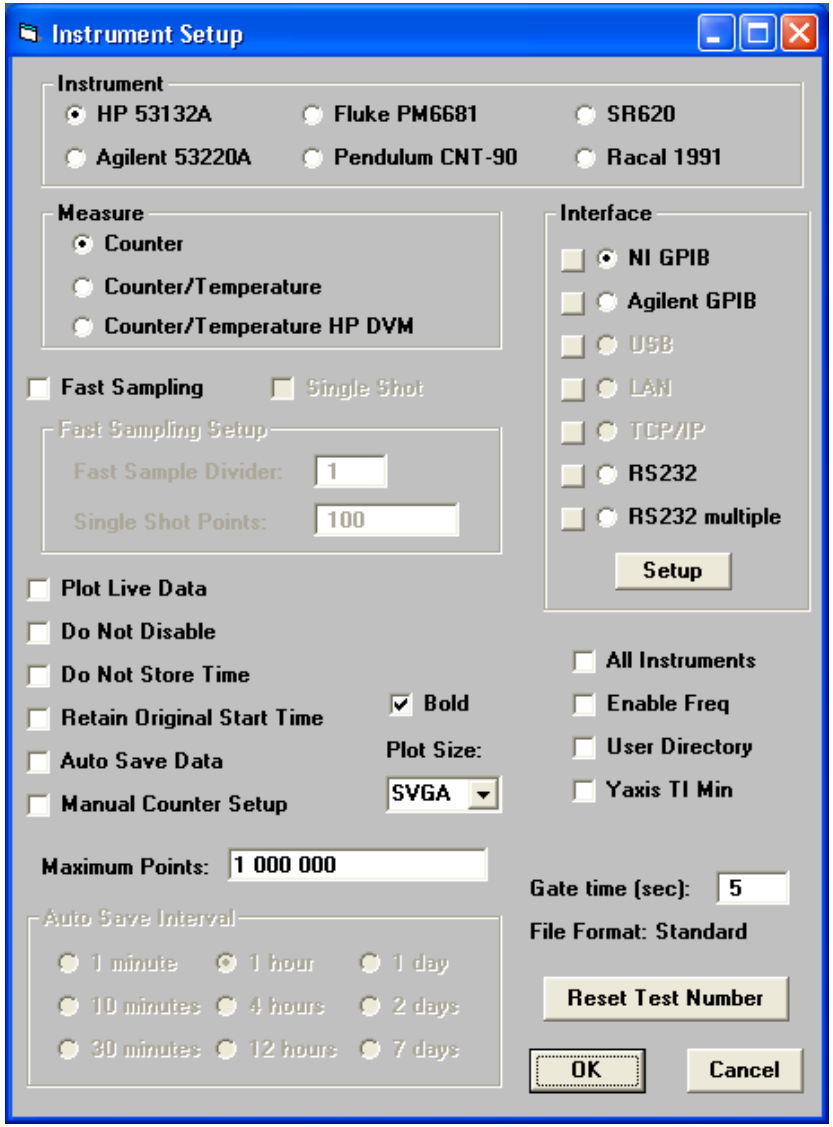
- **SETUP menu**
  - Instrument Setup: select HP/SR/Fluke/Racal/Pendulum instrument, select and setup GPIB/RS232/TCPIP interface, and other system parameters
  - Measurement Setup: setup for individual measurements (up to 8 counters can be used) including labels, counter setup, and signal parameter setting
- **HELP menu**
  - Access to help file and readme file

Using TimeMonitor Measurement

- **MEASURE button:**
  - Start measurement
- **STOP button:**
  - Stop (pause) measurement
- **COPY button:**
  - Create snapshot copy (copies) of measurement files
- **RESET PLOT button:**
  - Restart plotting with next measurement point
  - Has no effect on data stored in files (no loss of previous data)
- **PLOT button:**
  - Start plotting during live measurement
- **NO PLOT button:**
  - Stop plotting during live measurement
- **EXIT PROGRAM button:**
  - Exit program

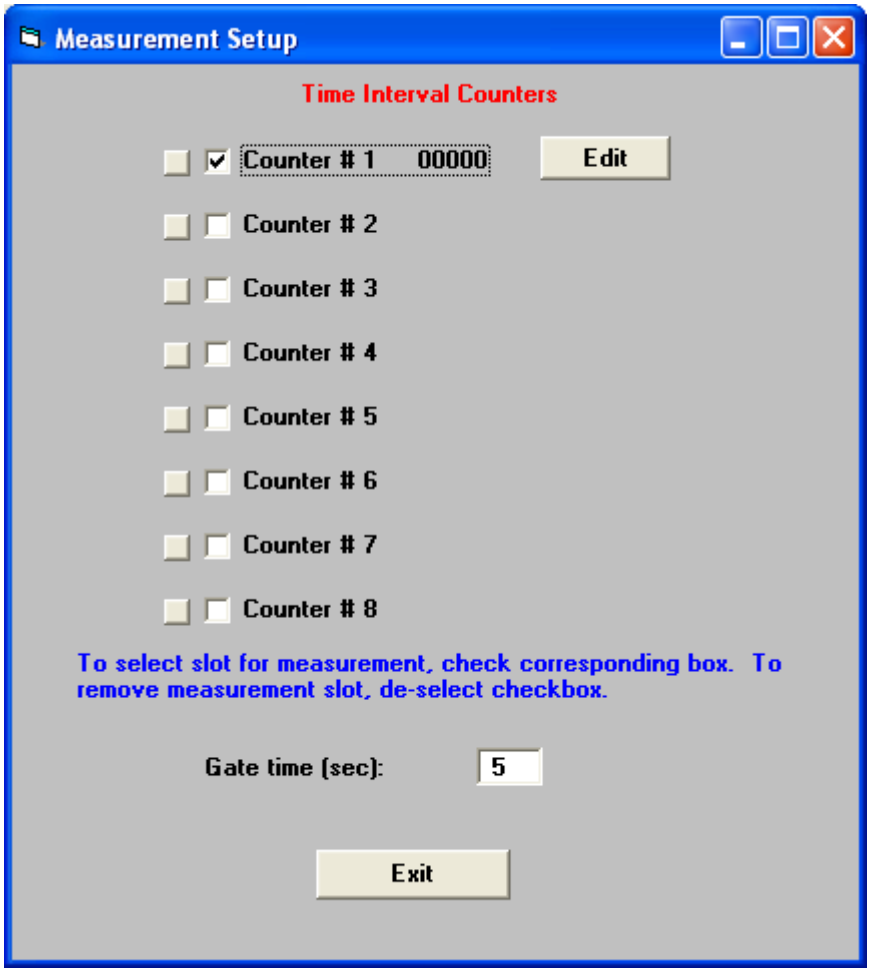
TimeMonitor Measurement

Instrument Setup



TimeMonitor Measurement

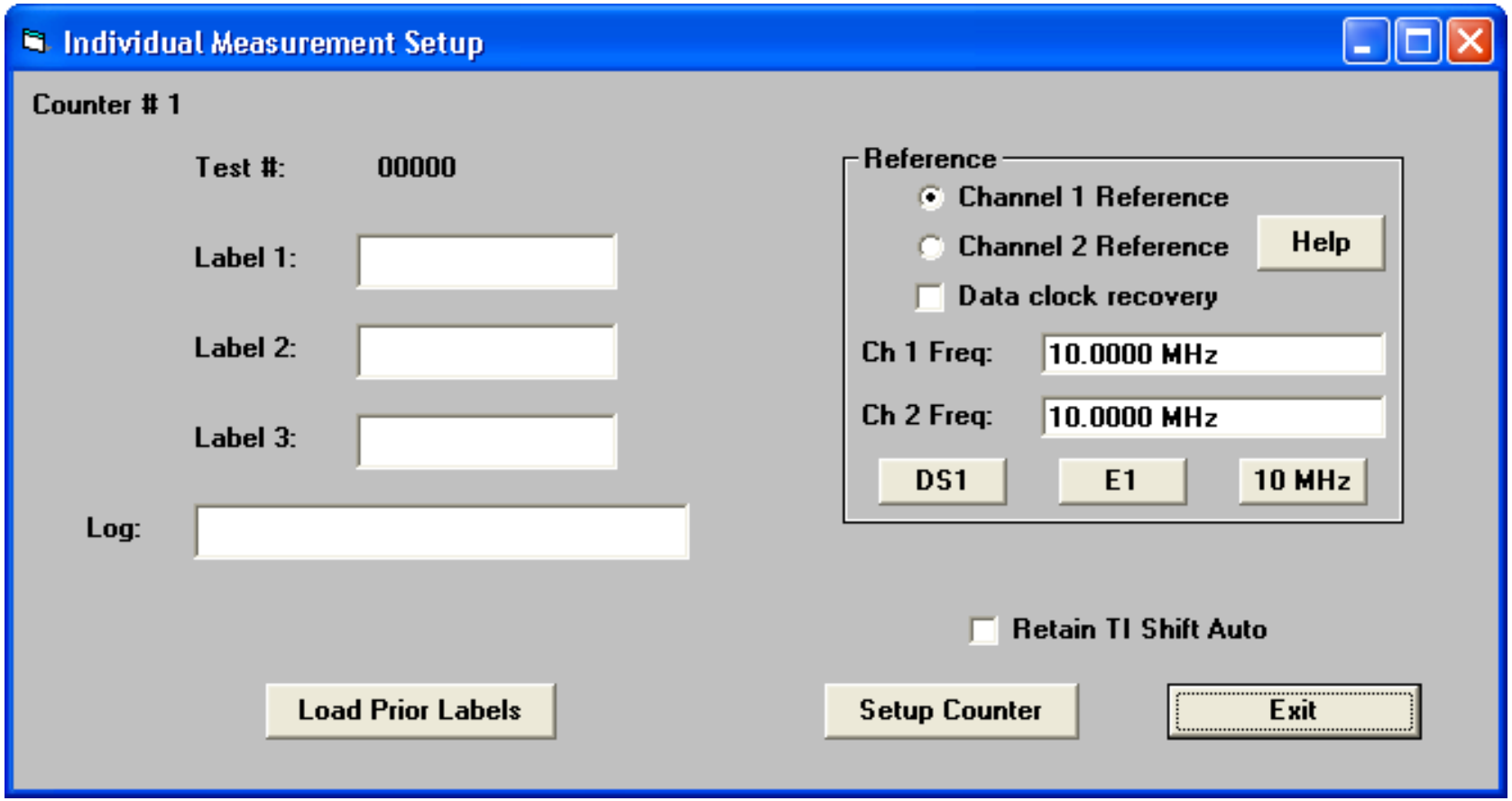
Measurement Setup



TimeMonitor Measurement

Individual Measurement Setup

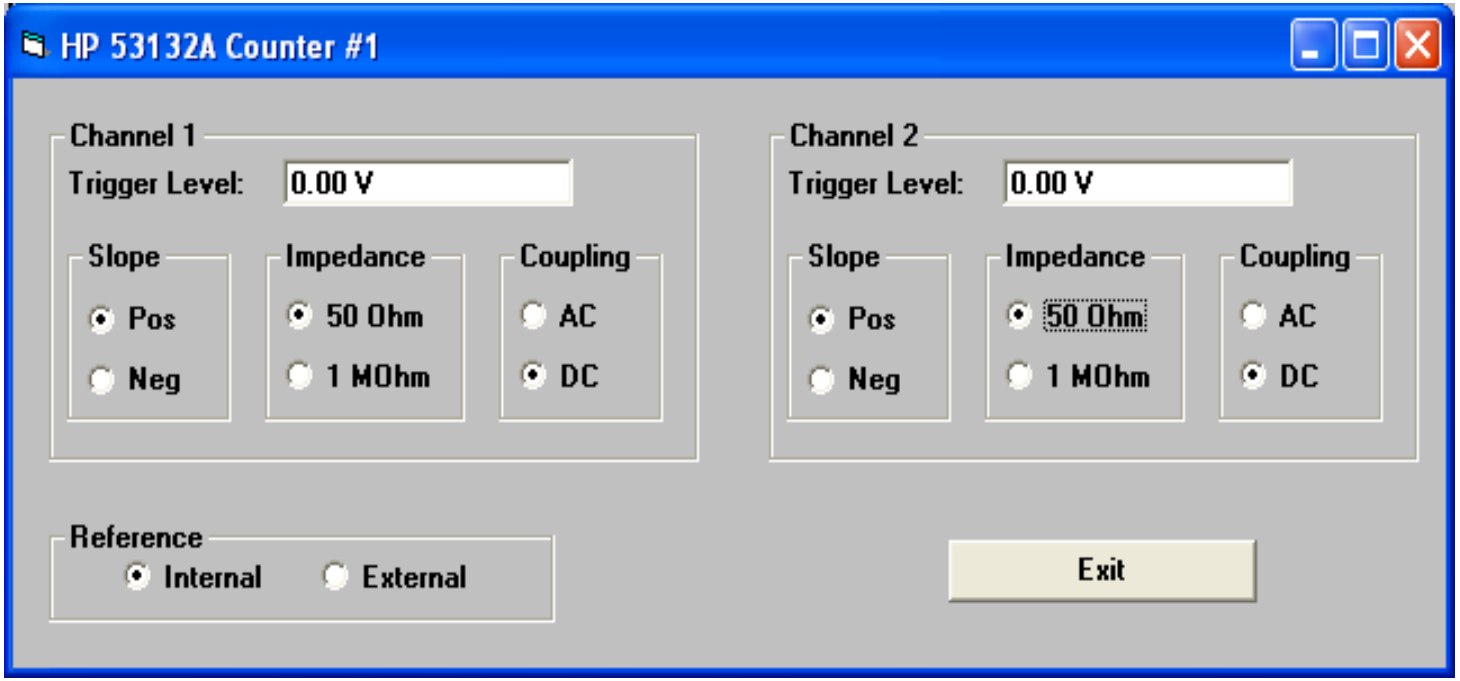
(Select Counter Checkbox or if checkbox already selected, press “Edit” button)



TimeMonitor Measurement

Counter Setup

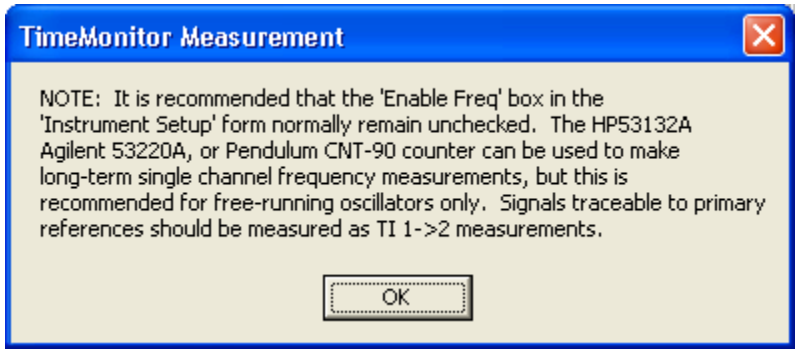
(Press “Setup Counter” button in Individual Measurement Setup screen)



TimeMonitor Measurement

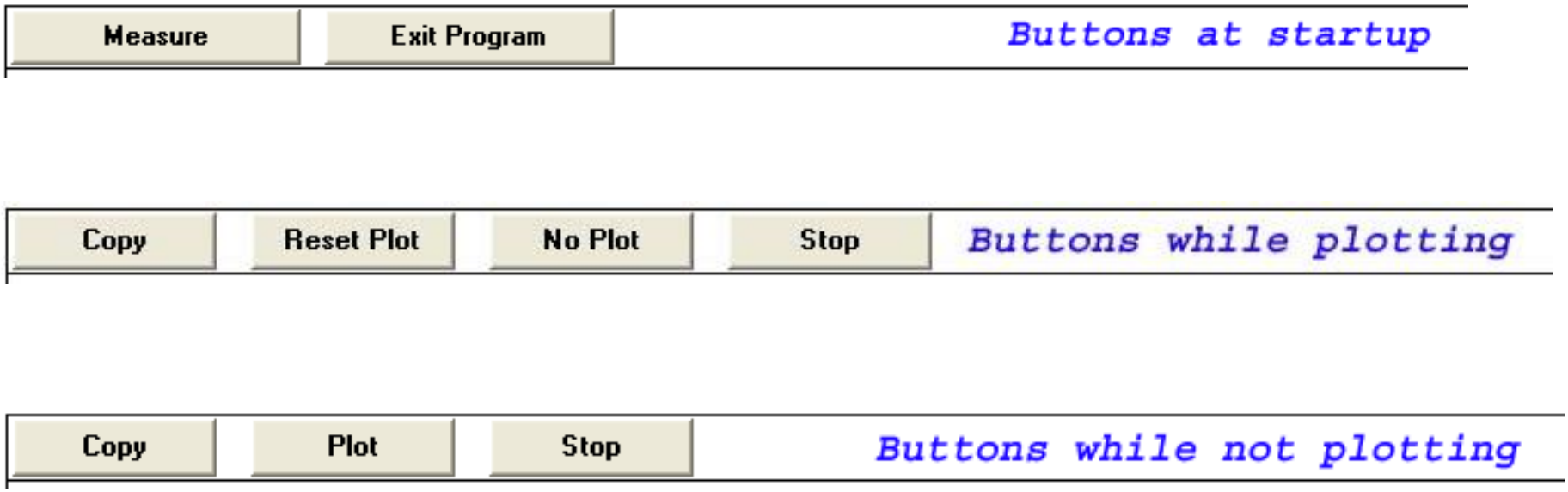
TI 1>2 vs. Frequency Measurements

- **In most cases TI 1>2 measurements are used**
- **TI 1>2 is related to phase (TIE) but is not exactly the same**
  - To compute TIE from TI 1>2, “rollovers” must be accounted for
  - Rollovers occur when the TI 1>2 passes through 0 (negative direction)
  - Rollovers occur when the TI 1>2 passes through one period (positive direction)
- **Frequency measurements**
  - Used for free-running oscillators only
  - HP 53132A, Agilent 53220/230A, or Pendulum CNT 90/91 required
  - Long gate times are required (5 seconds or more recommended)



TimeMonitor Measurement

Buttons



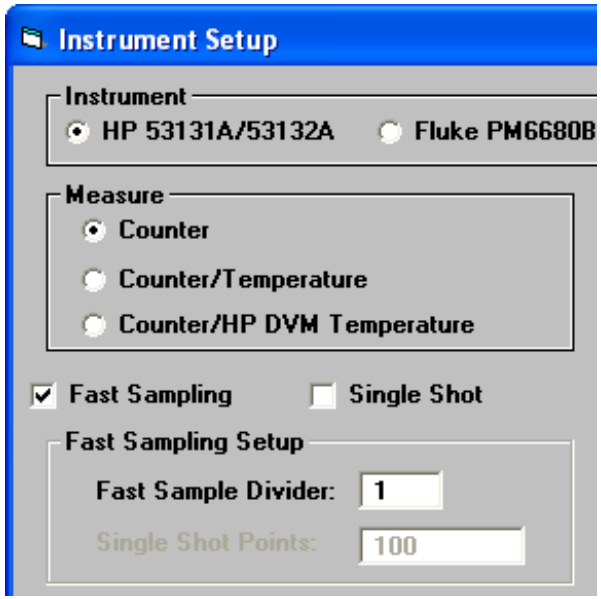
TimeMonitor Measurement

Regular Sampling

- Sampling governed by “Gate Time” which can range from 1 second to 255 seconds
- Sampling faster than 1 Hz requires selecting “Fast Sampling”

TimeMonitor Measurement

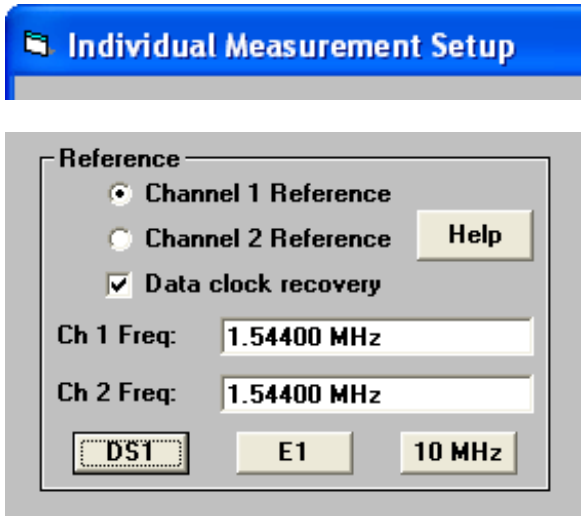
Fast Sampling



- Two types:
  - Fast Sampling
  - Fast Sampling Single Shot
- Fast Sample Divider
  - Controls sample rate
  - “1” is fastest, larger numbers slow down the sample rate increasingly
- Single Shot
  - Disables plotting, computations, and disk access during the measurement for fastest possible measurement rate
- Requires GPIB/HPIB interface
  - Regular sampling must be used for RS232 and TCP/IP

TimeMonitor Measurement

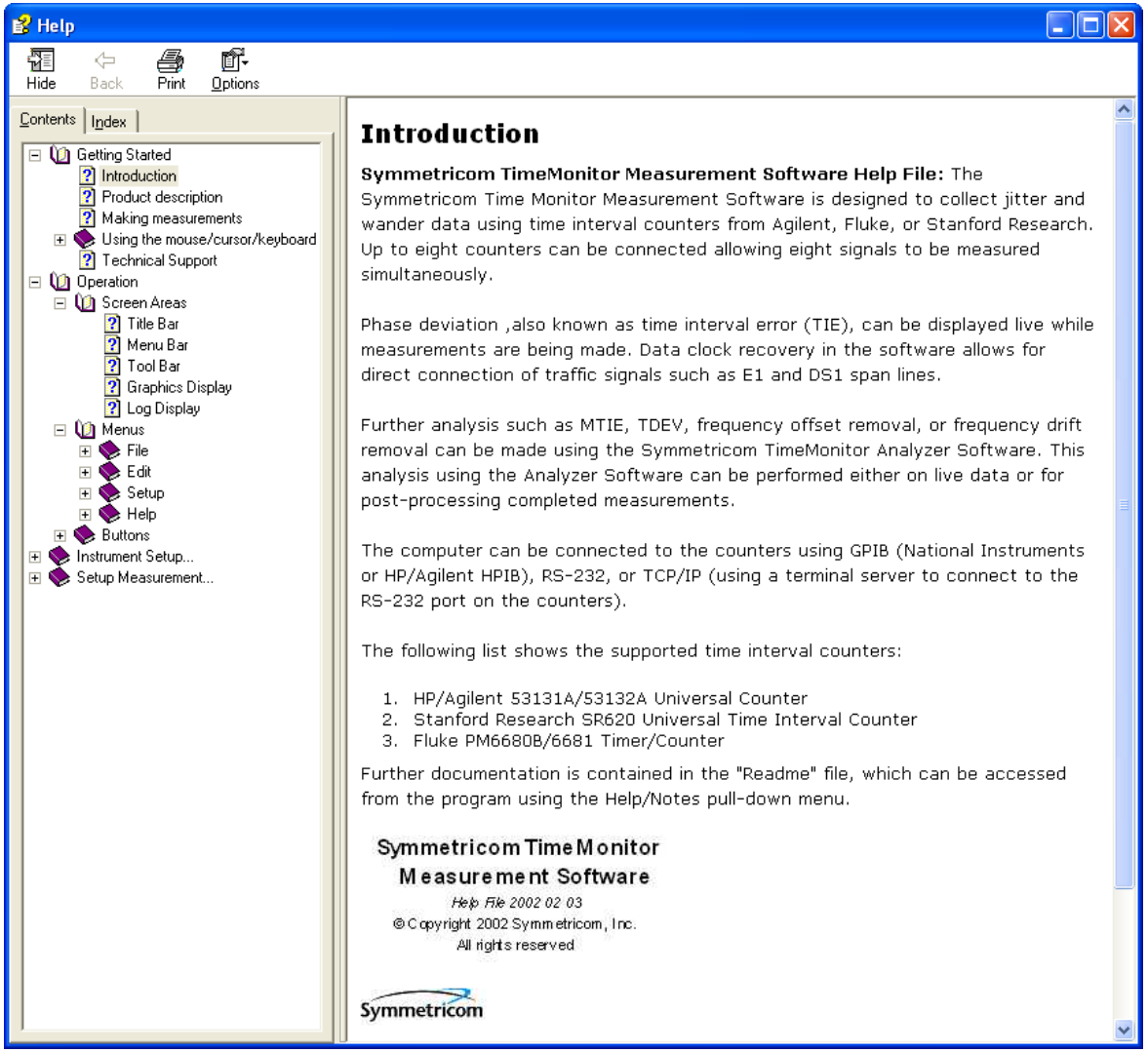
Signal Rate Setup



- Signal rates of reference and measured signals need to be specified
  - Reference signal can be Chan1 or Chan2
  - Chan1 rate is the same or submultiple of Chan2
    - Example: Chan1 = Chan2 = 1.544 MHz
    - Example: Chan1 = 1PPS, Chan2 = 1.544 MHz
    - Example: Chan1 = 5 MHz, Chan2 = 10 MHz
  - Use “data clock recovery” if either or both signals are traffic bearing (eg. DS1 or E1)

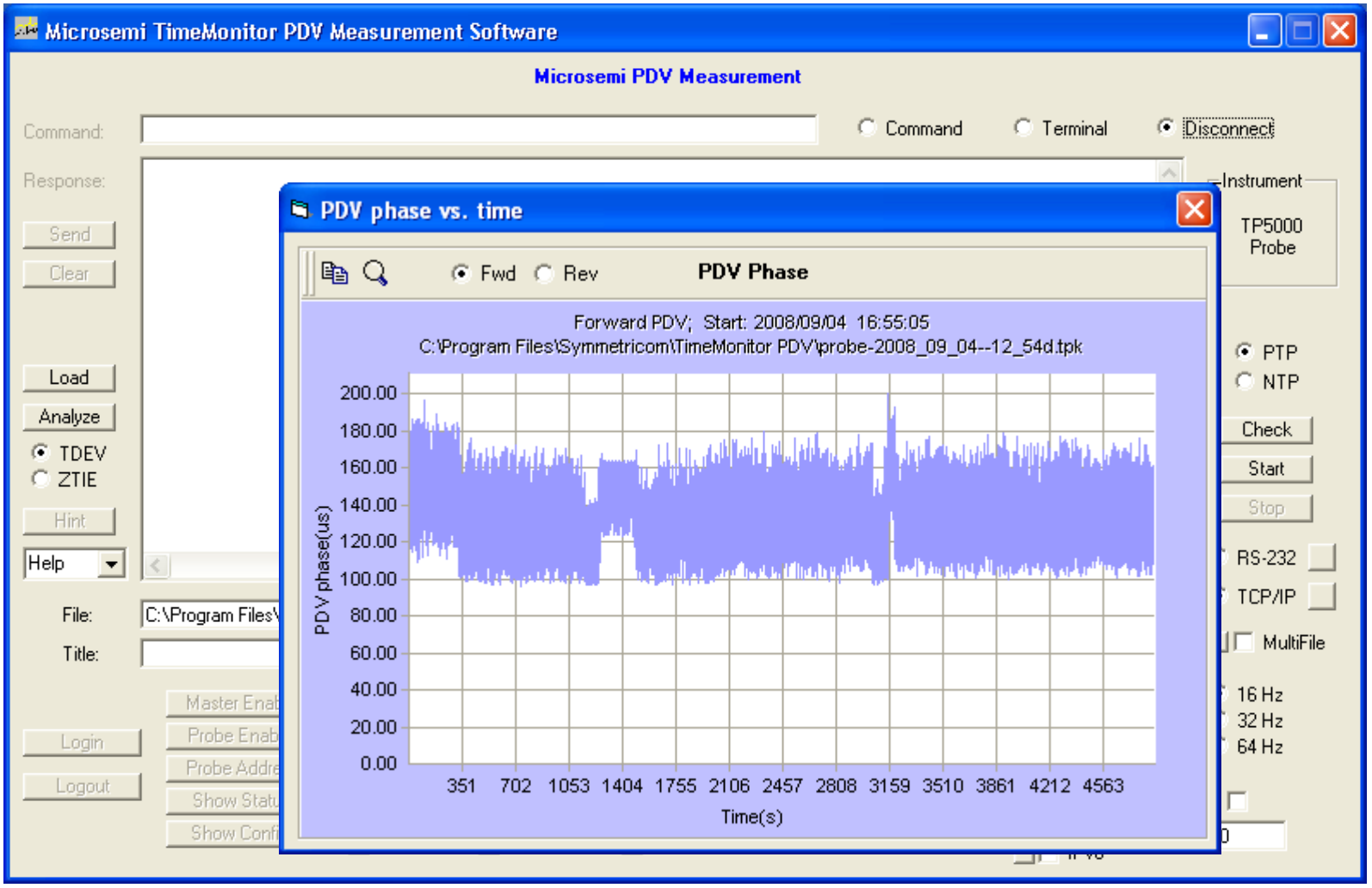
TimeMonitor Measurement

- **Help file**



TimeMonitor PDV

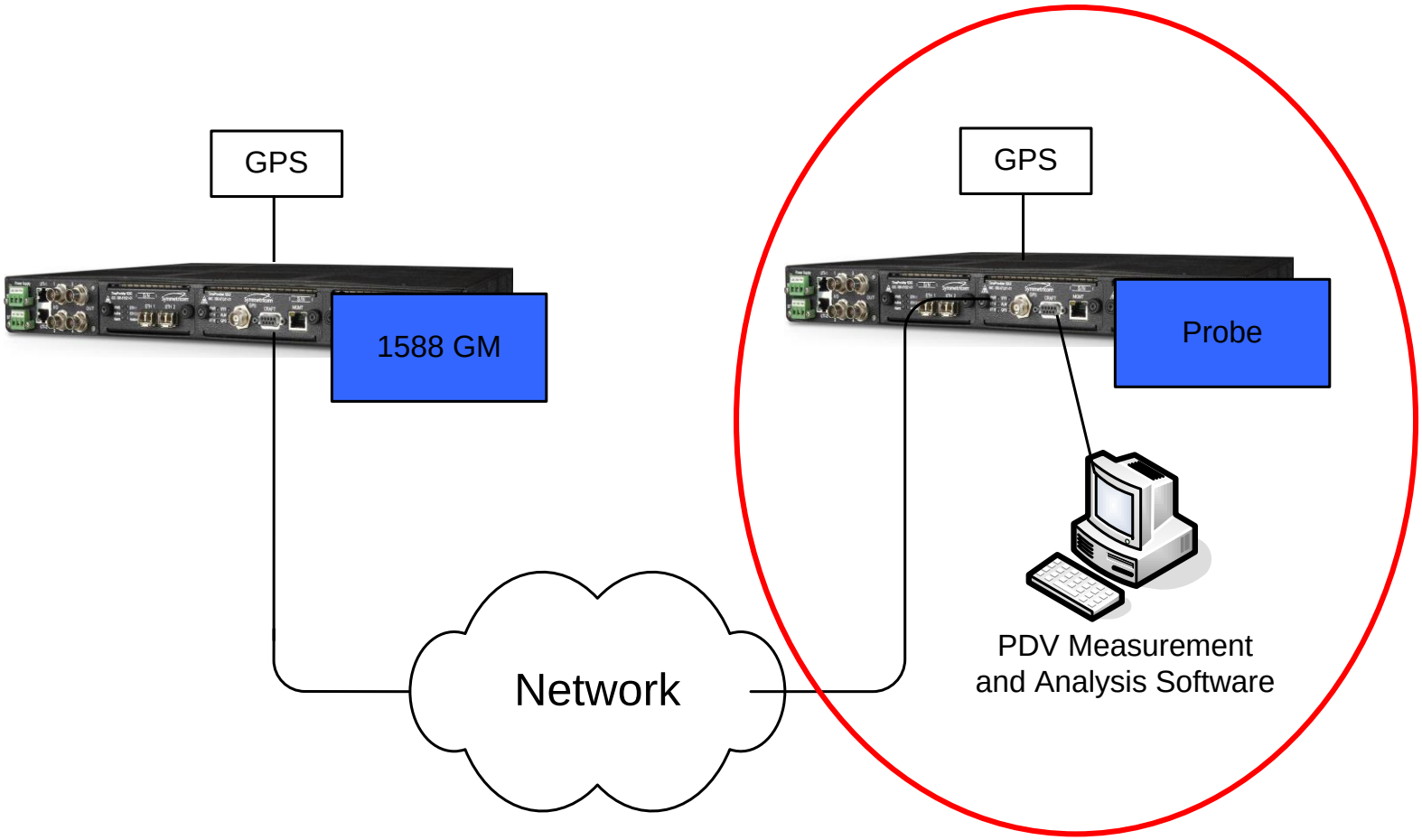
TimeMonitor PDV



TimeMonitor PDV

TP5000 Probe

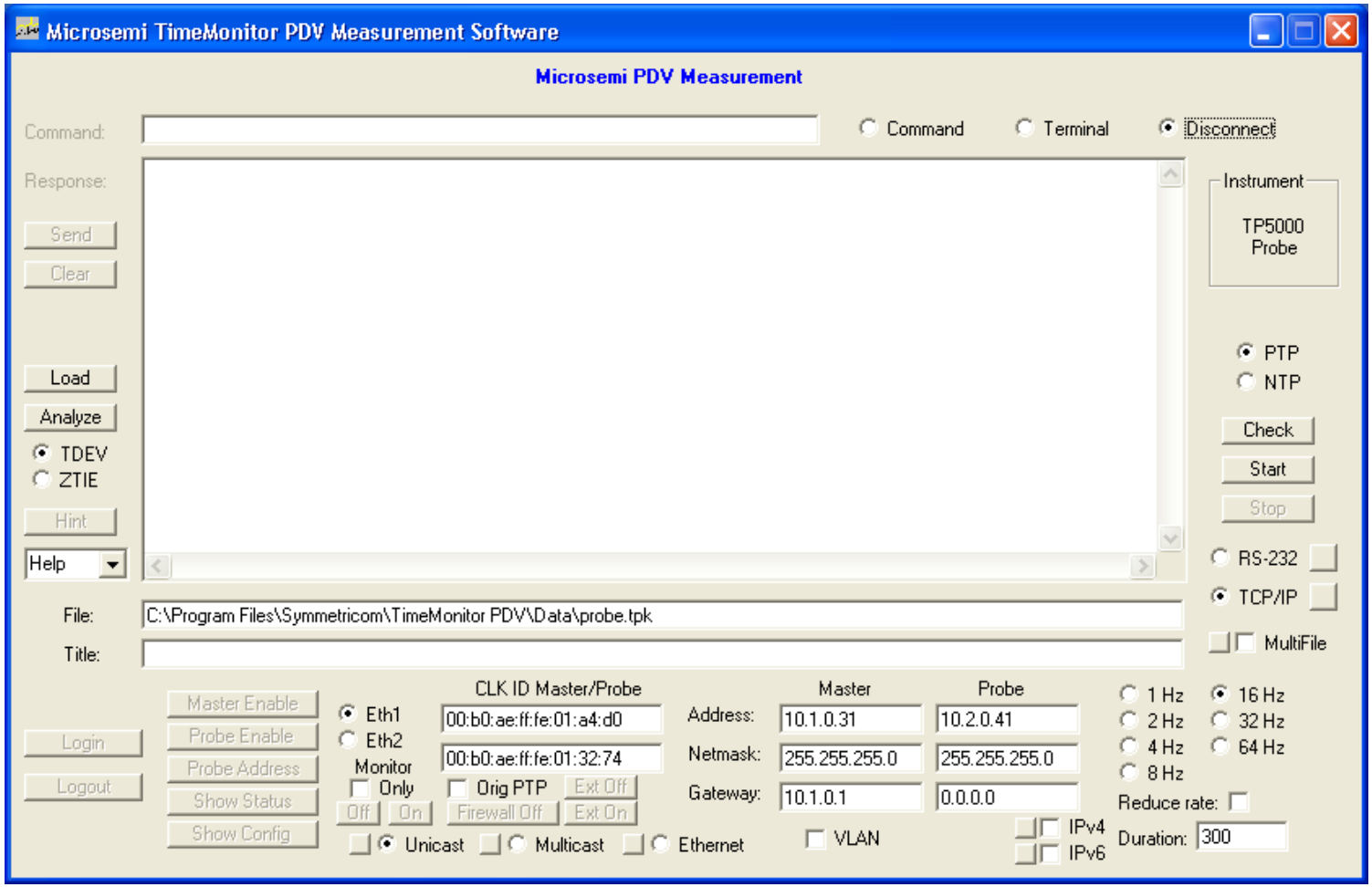
Released with TP5000 V1.1 (Mid-2009)



TimeMonitor PDV

TP5000 Probe

Data Collection with TimeMonitor PDV Software

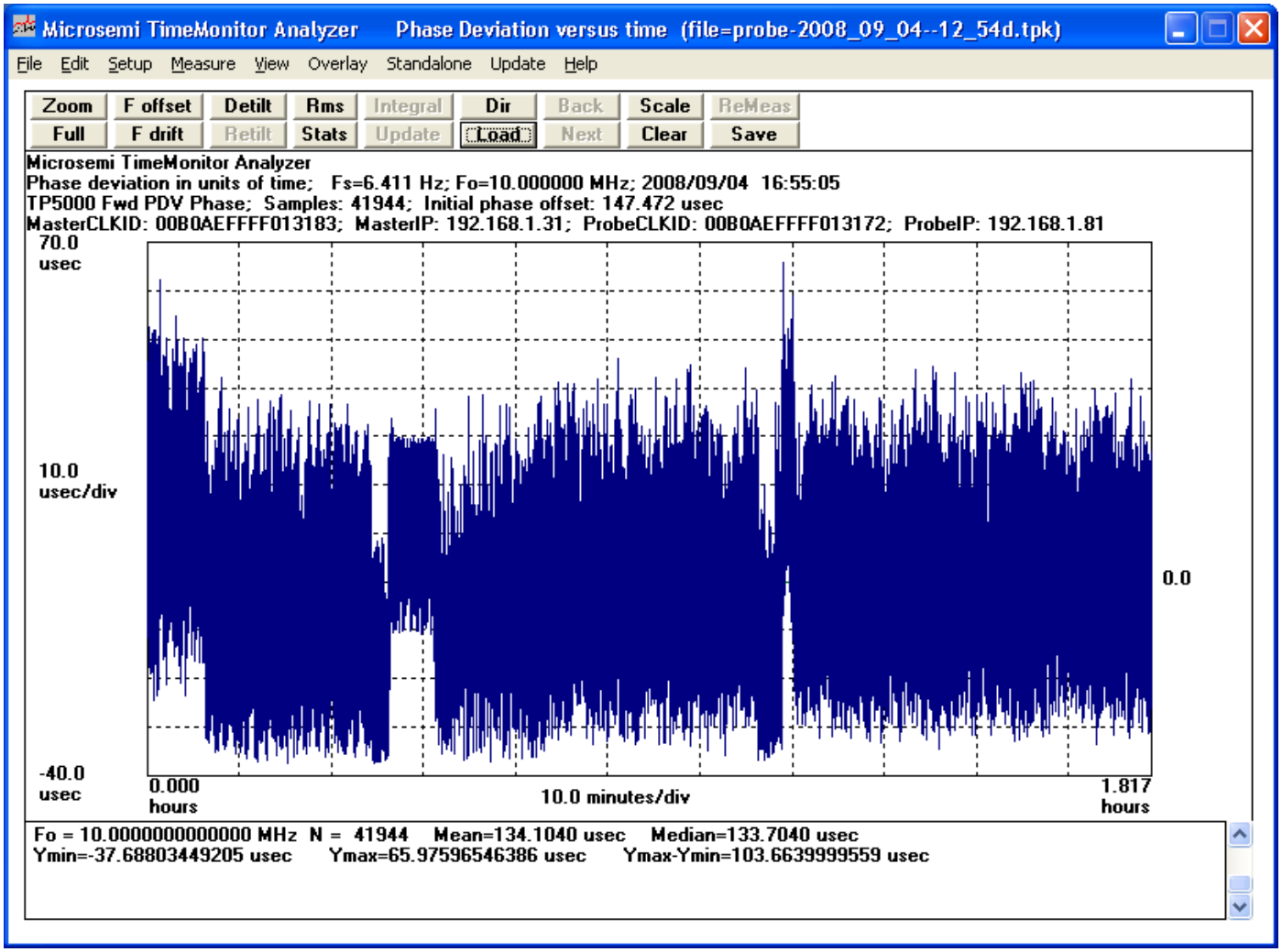


MICROCHIP

TimeMonitor PDV

TP5000 Probe

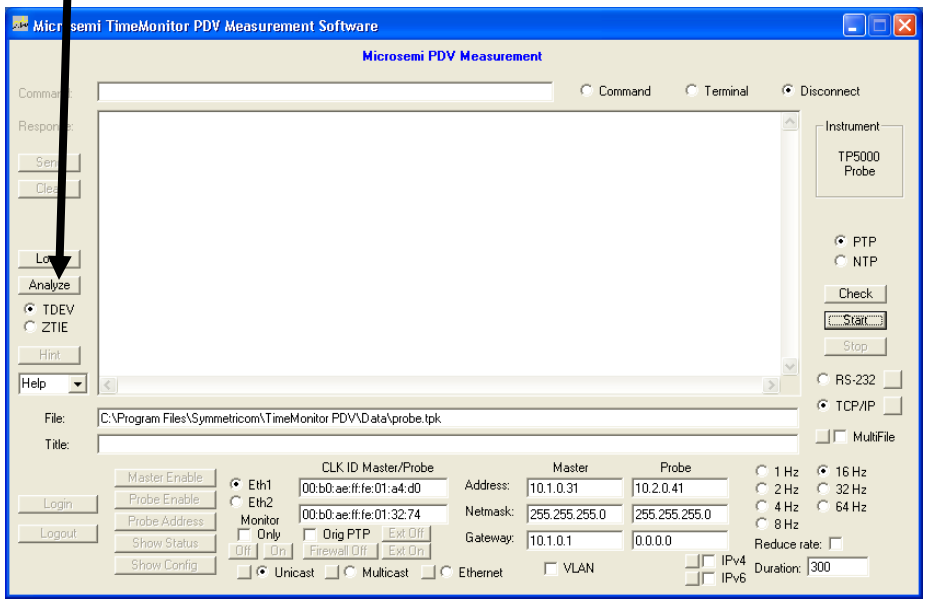
Data Viewing and Analysis with TimeMonitor Analyzer Software

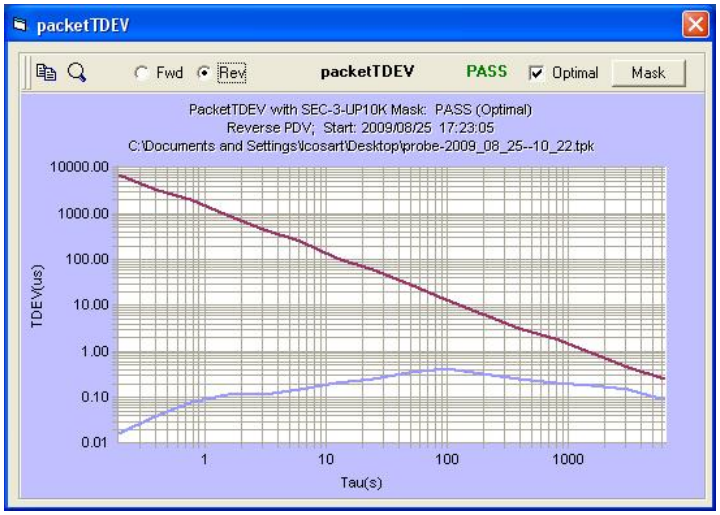


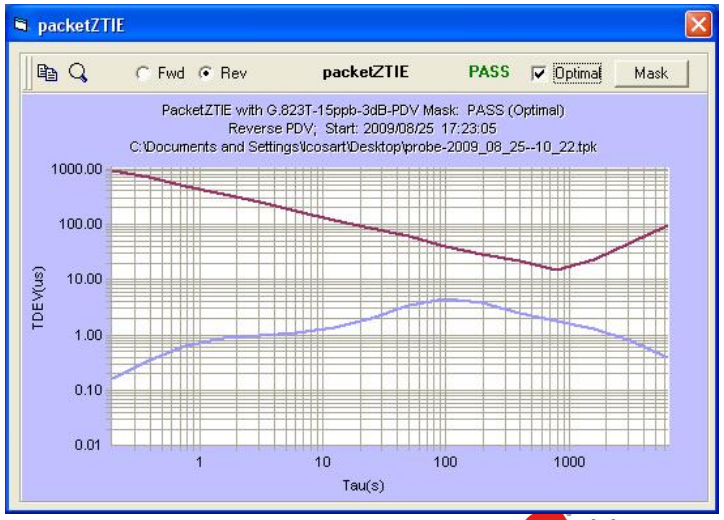
TimeMonitor PDV

Built-in Analysis

Analyze

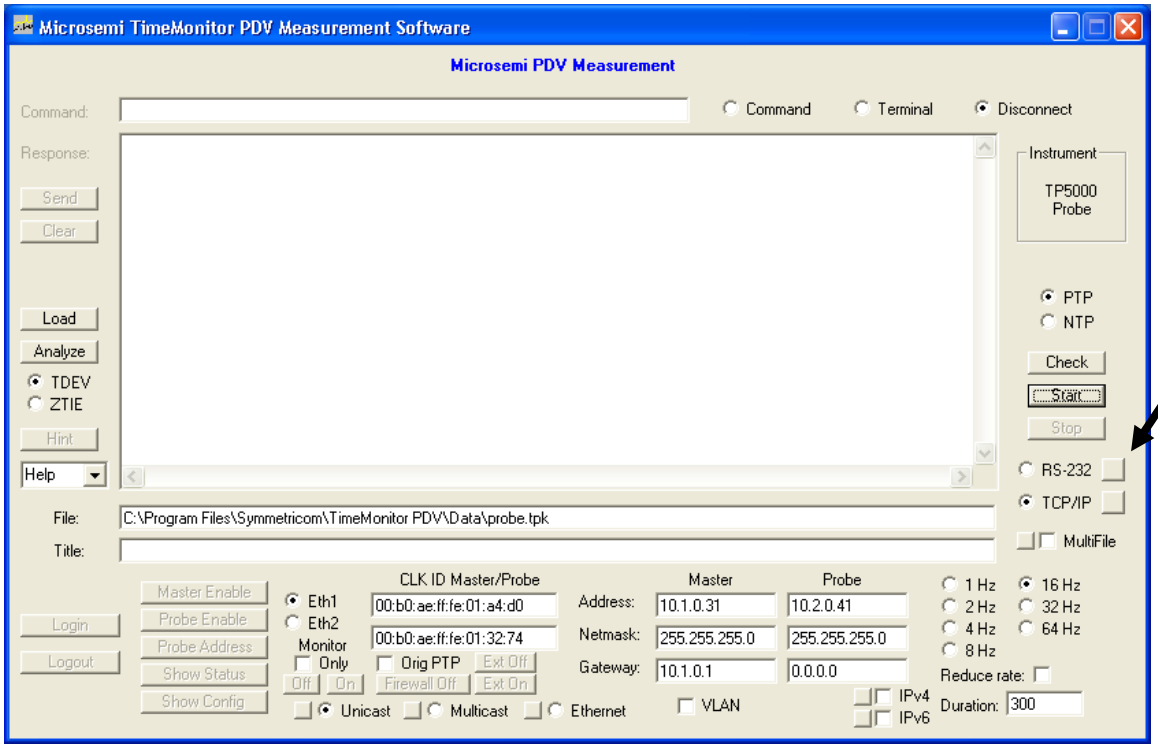






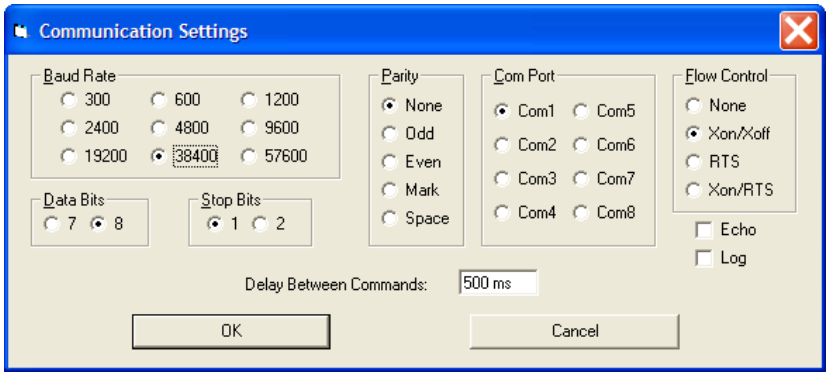
MICROCHIP

TimeMonitor PDV



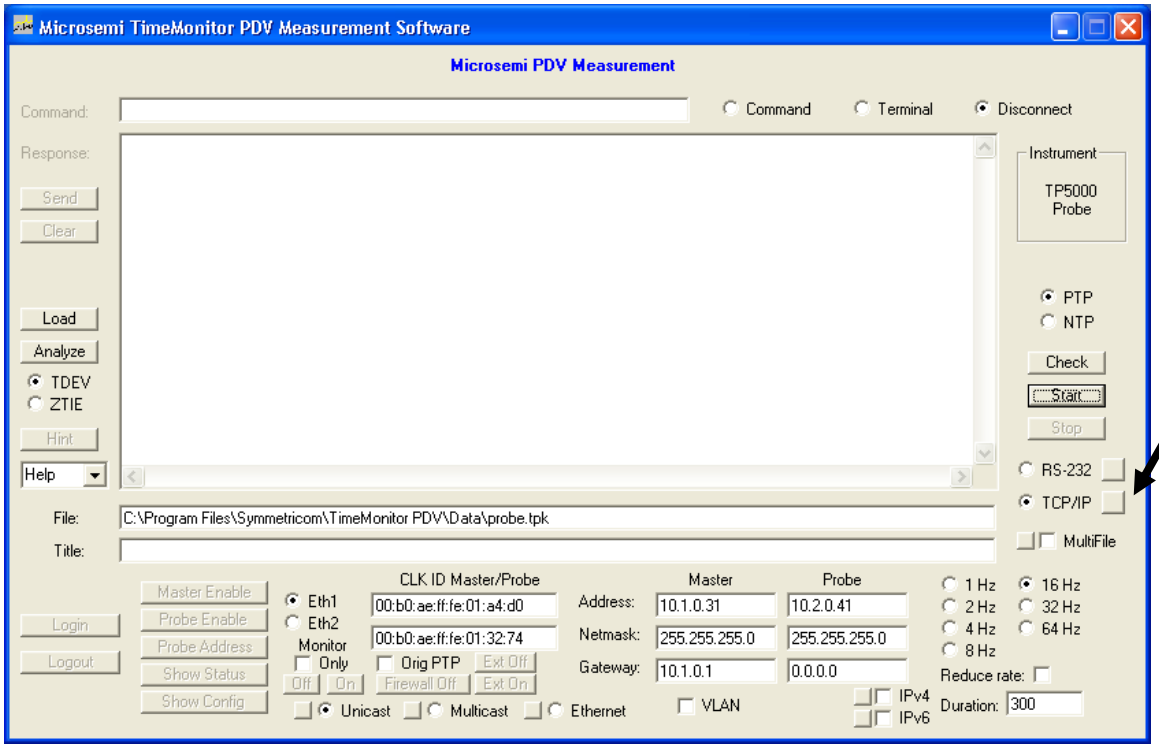
RS-232 setup

TP5000 craft port
57600 baud



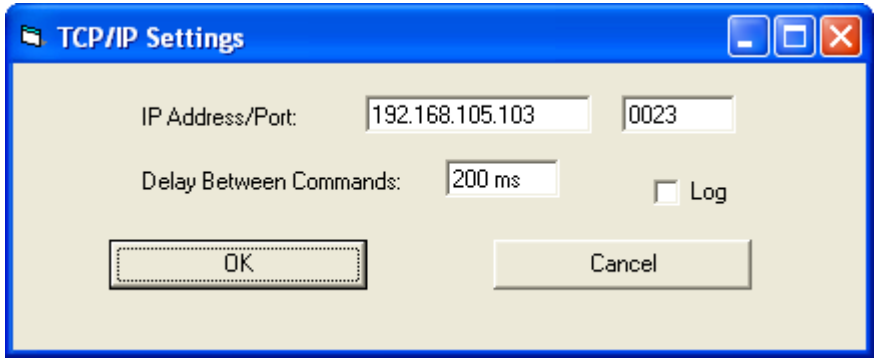
MICROCHIP

TimeMonitor PDV



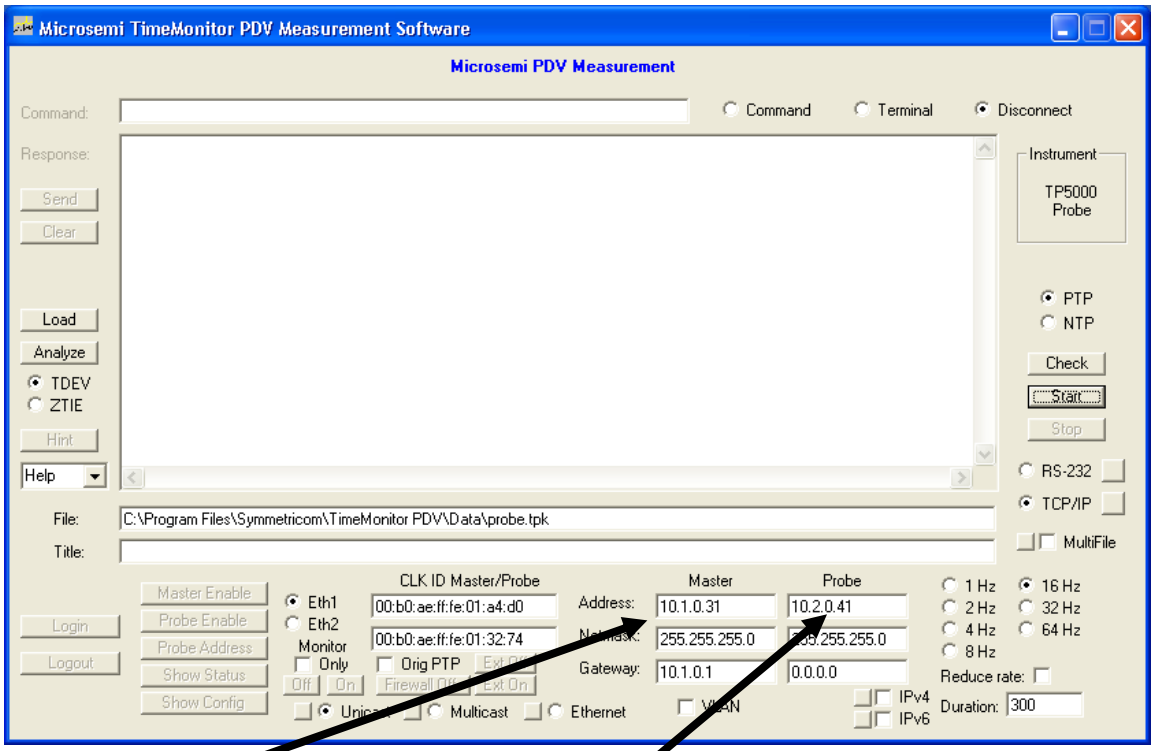
TCP/IP setup

TP5000 IMC management port



MICROCHIP

TimeMonitor PDV

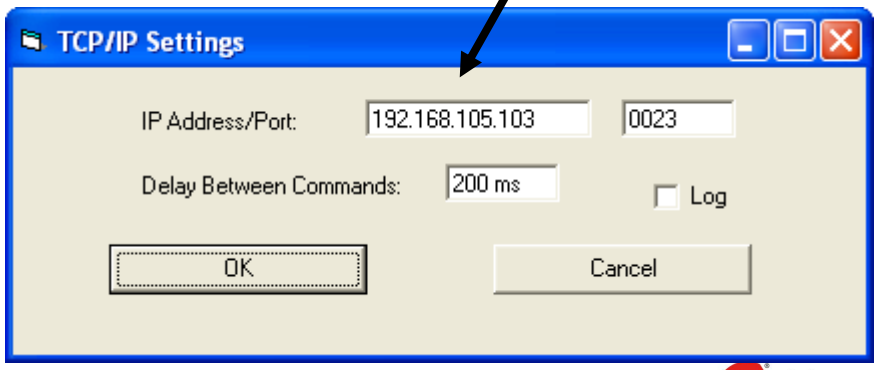


3 IP Addresses

TP5000 IMC management port IP

Grandmaster IP

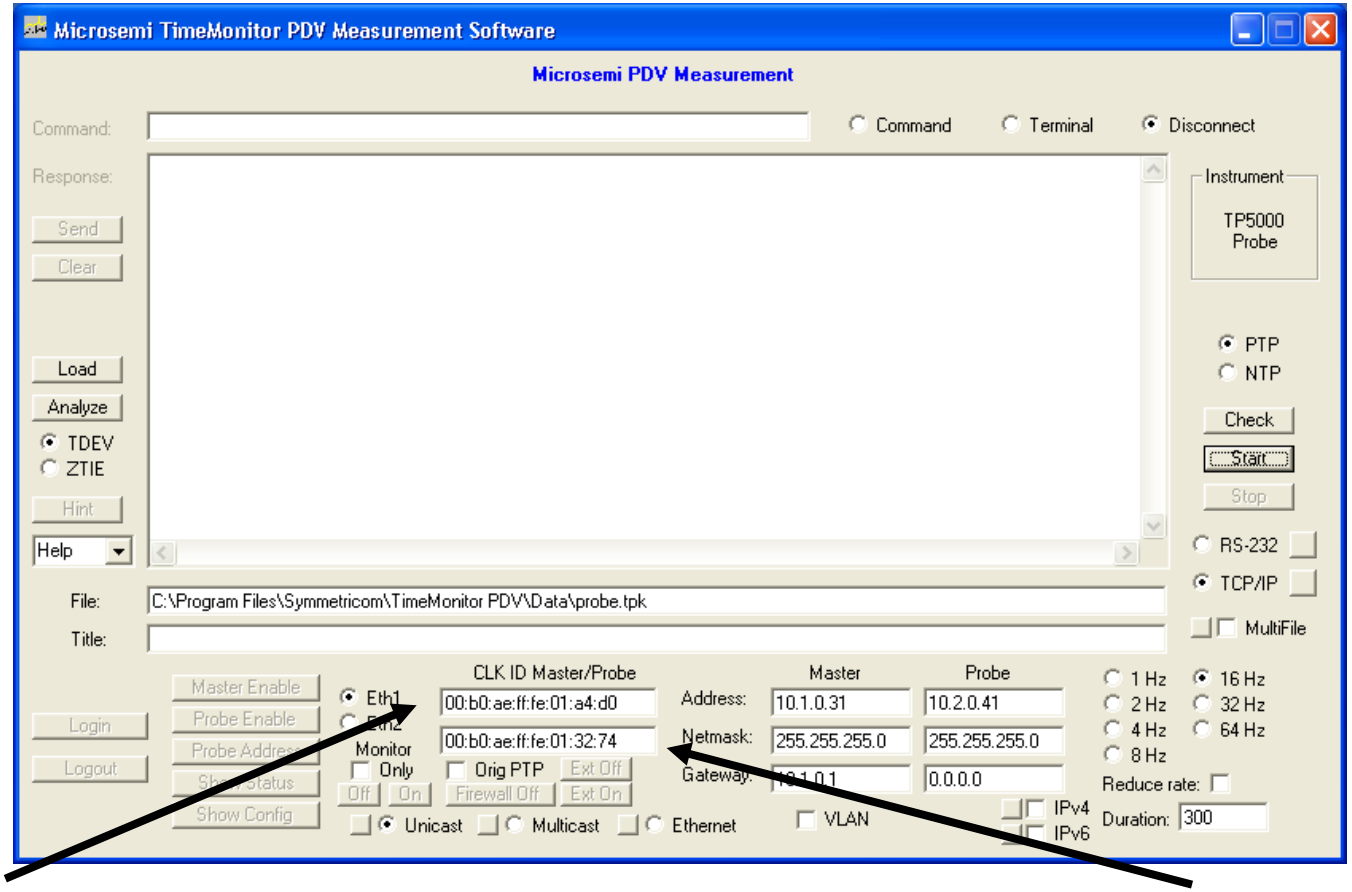
TP5000 Probe IOC IP



MICROCHIP

TimeMonitor PDV

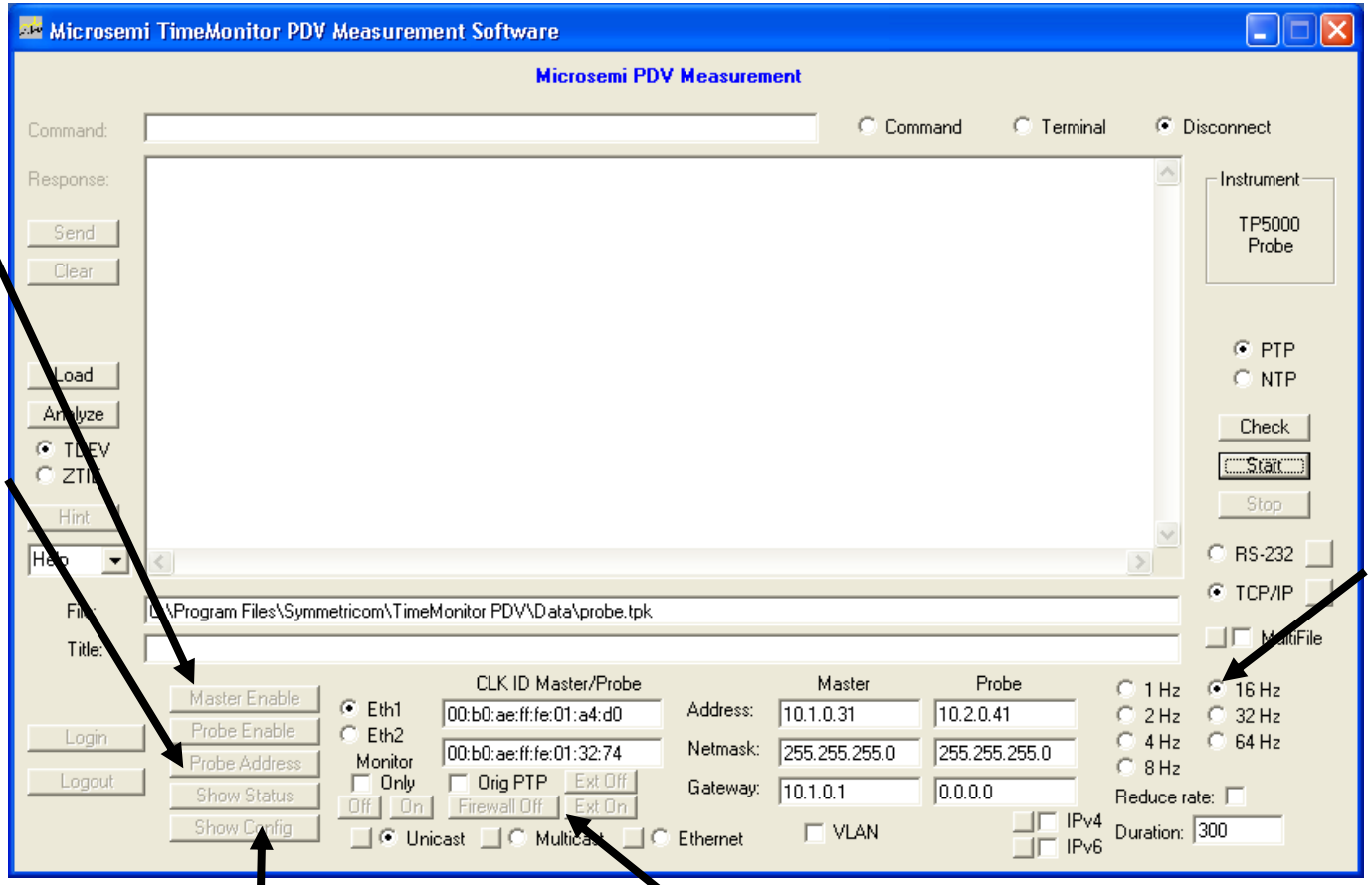
2 Clock ID's



Grandmaster CLK ID

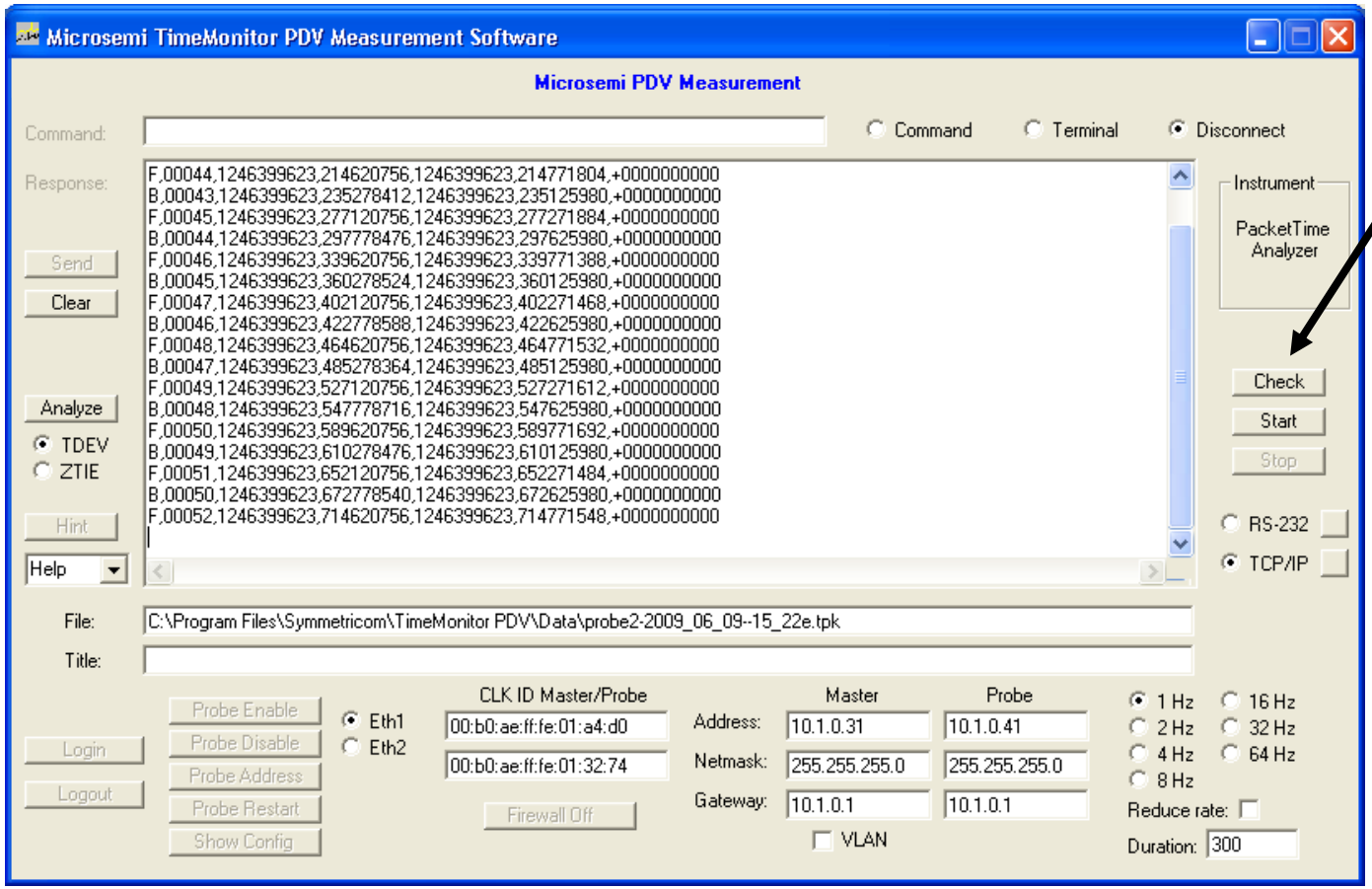
TP5000 Probe CLK ID

TimeMonitor PDV

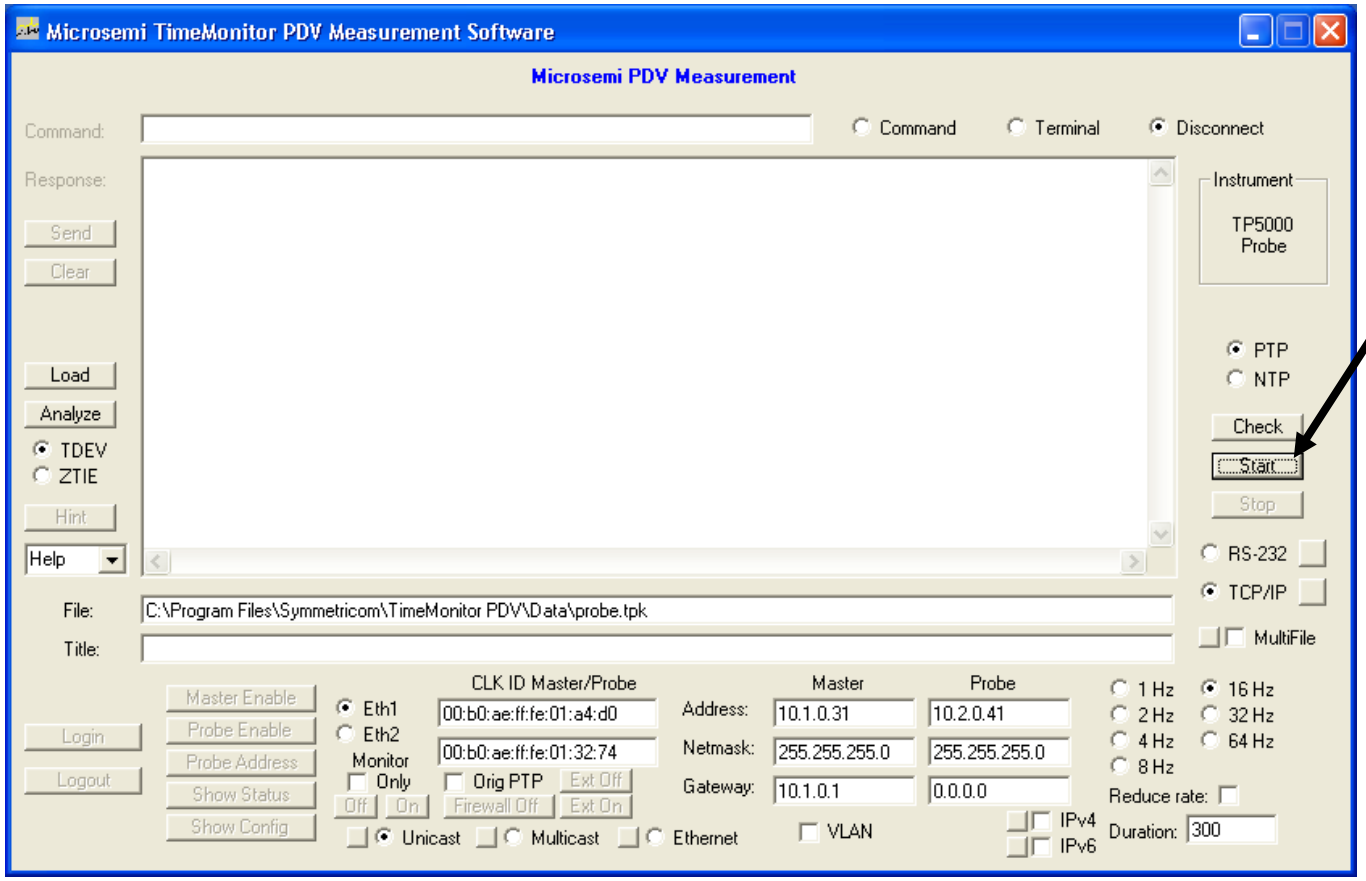


TimeMonitor PDV

Measurement Check



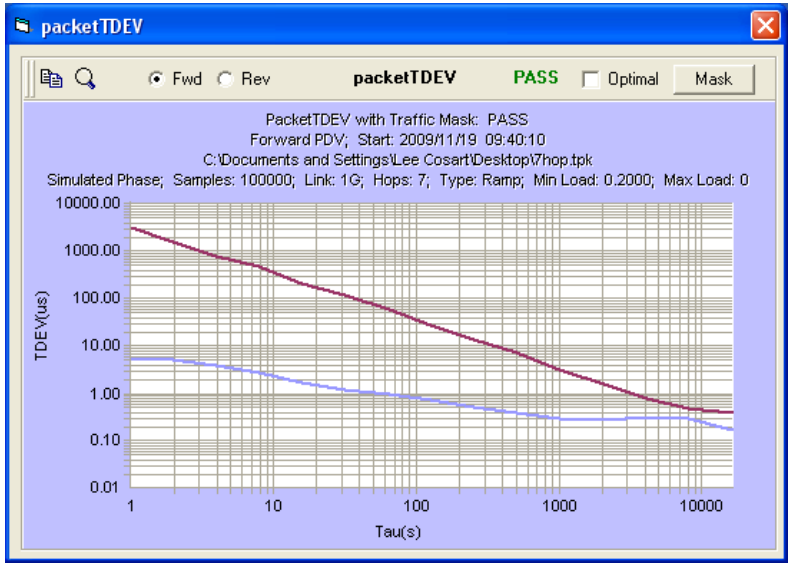
TimeMonitor PDV

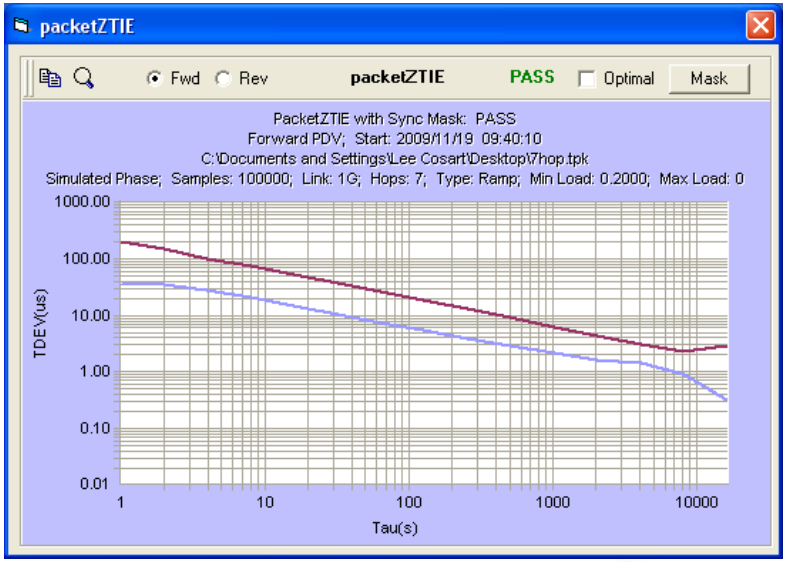


Measurement Collection

TimeMonitor PDV

Built-in Analysis

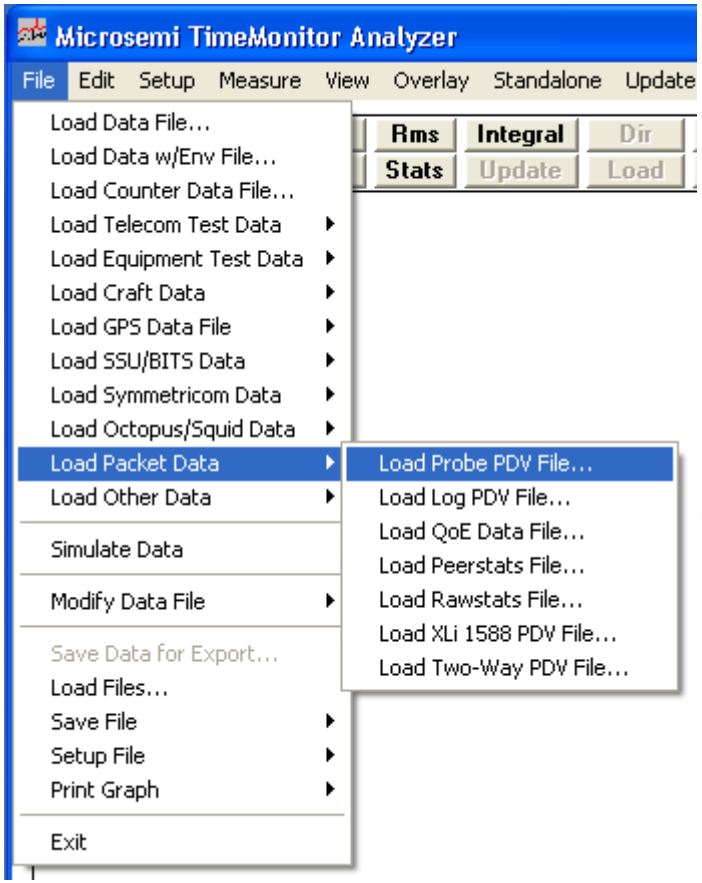


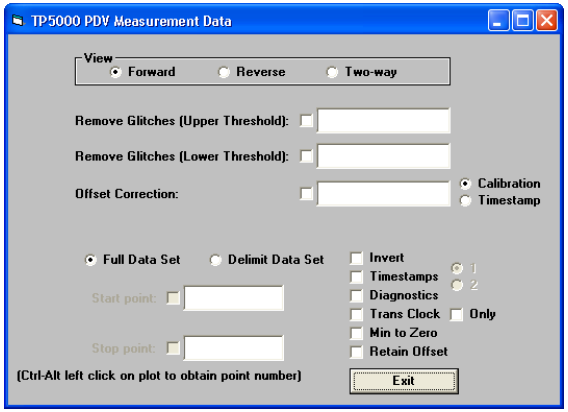


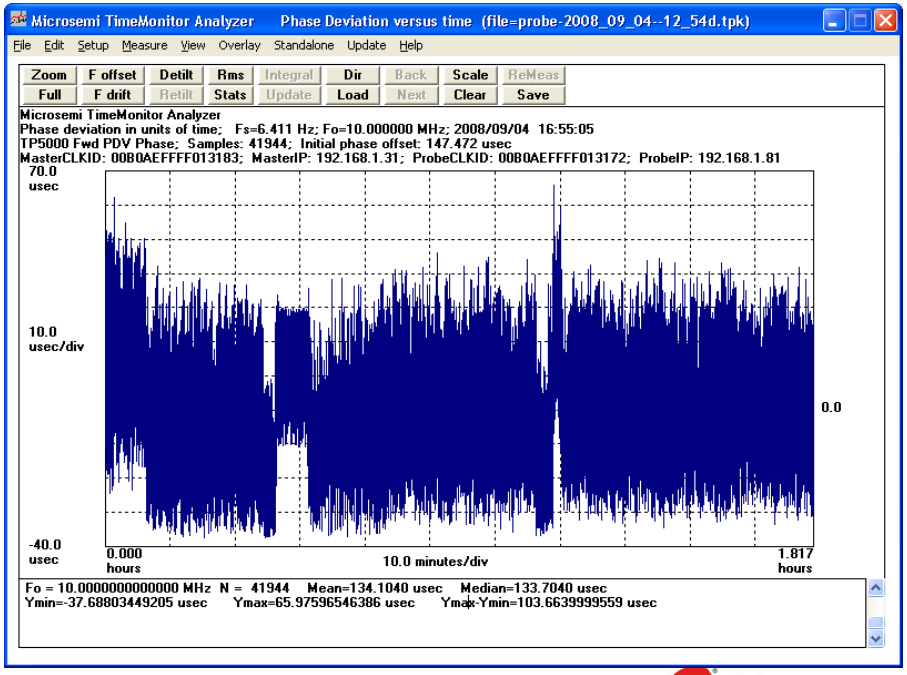
MICROCHIP

TimeMonitor PDV

Measurement View and Analysis with TimeMonitor Analyzer

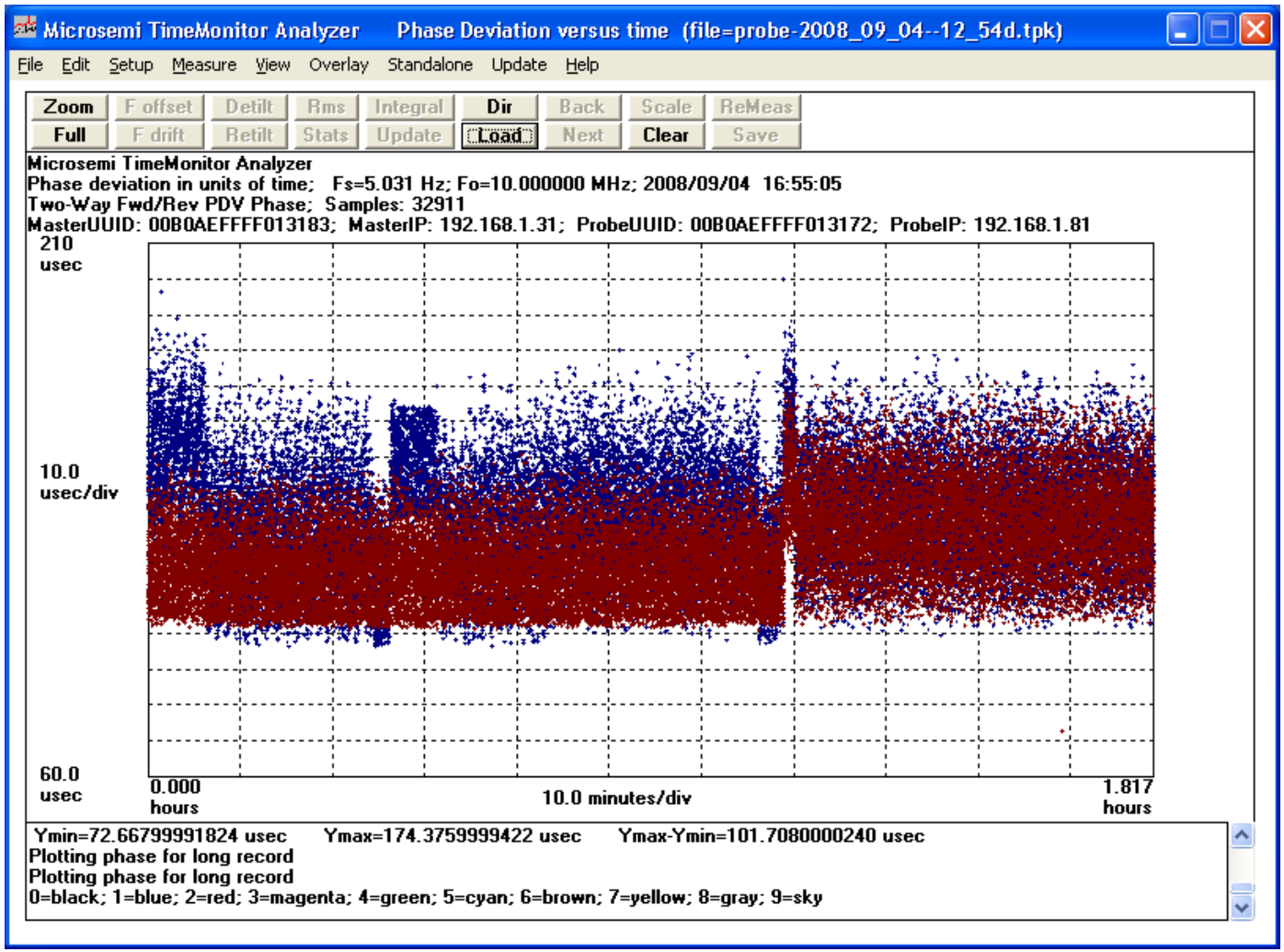






MICROCHIP

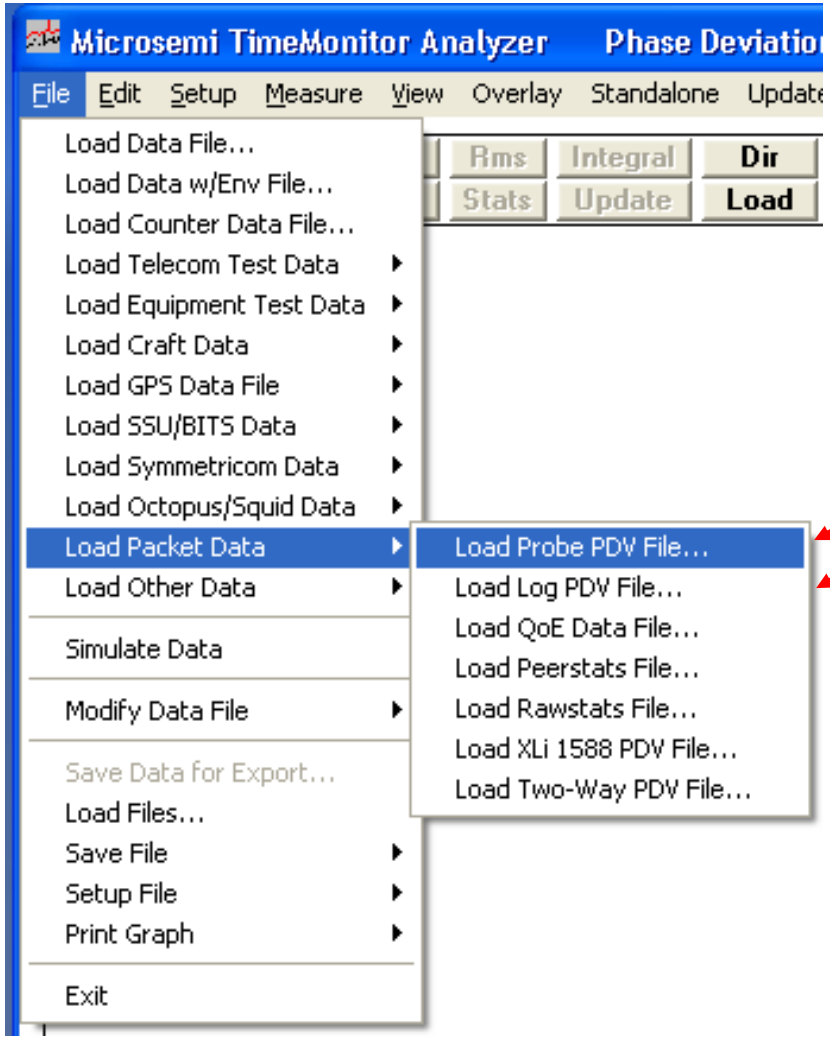
TimeMonitor Analyzer (Packet)



MICROCHIP

TimeMonitor Analyzer (Packet)

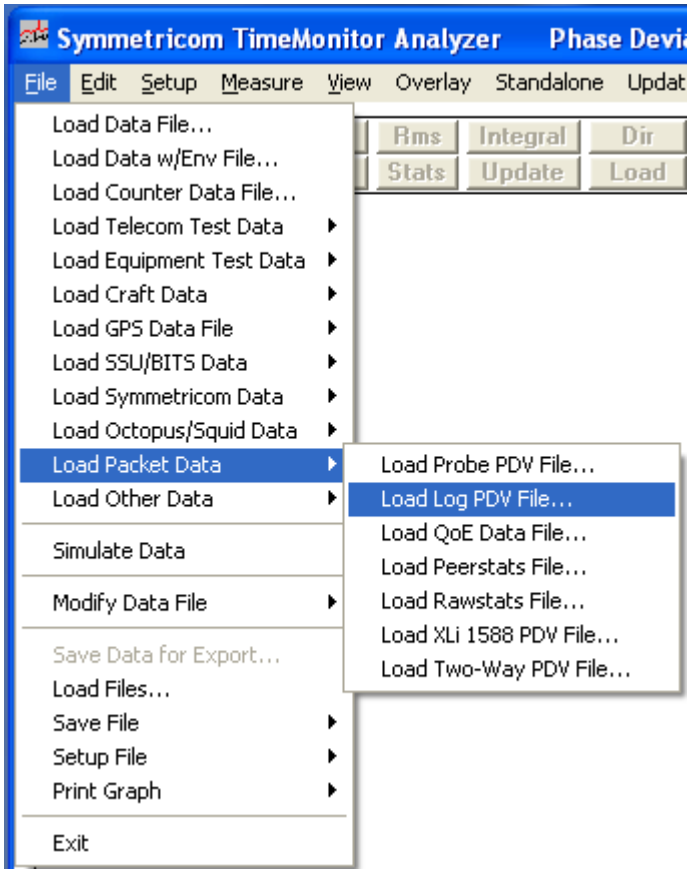
“Load Packet Data” Grouping



TP 5000 probe data
Ottawa PDV logs

TimeMonitor Analyzer (Packet)

Ottawa PDV logs

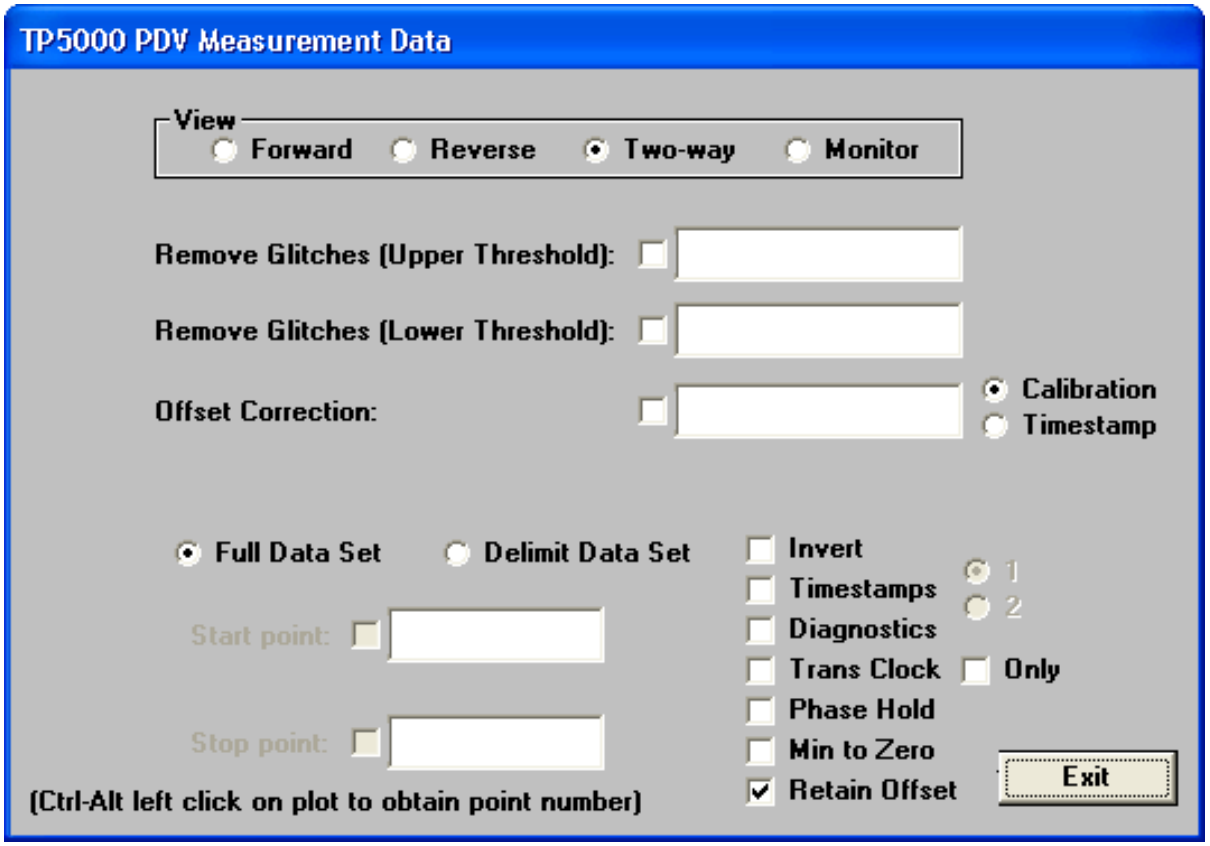


1. Capture Mode. (4 columns)
   44 0 1262972561.737006469 1262972557.397397065
2. Simulator Mode.
   0.000000e+000
   4.333500e-005
3. Raw timestamp Logging Mode. (text/numbers)
   Raw Input: Tx 00004EBCF794.06008FB4, Rx 000000000000.207827F4
4. Raw timestamp Logging Mode. (11 columns)
   0,1,0,0,1321006330,330976962,0,0,775020765,0,0
   0,0,0,0,880,768088716,0,1321006330,324050016,0,0

- .TXT extension except .DEC for simulator files

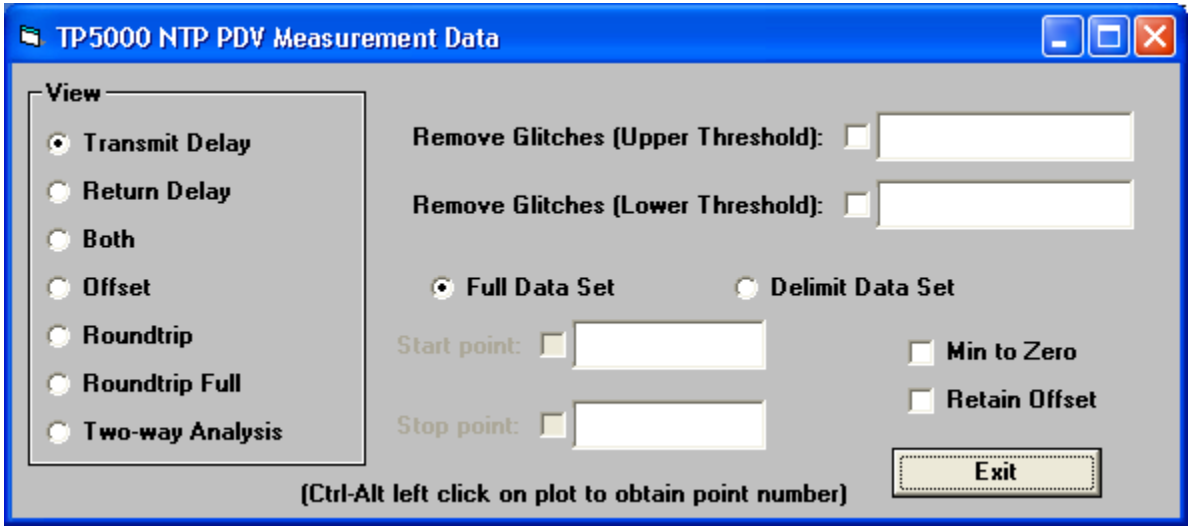
TimeMonitor Analyzer (Packet)

Packet Data Import: TP5000 Probe PTP



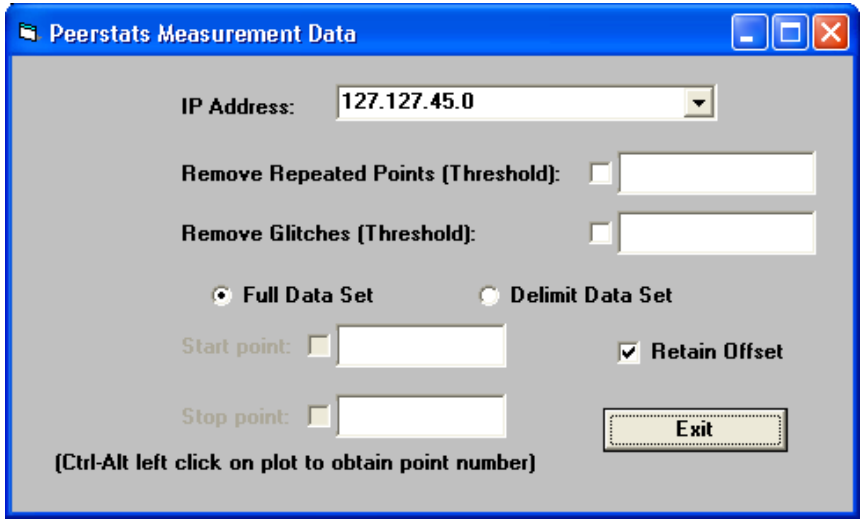
TimeMonitor Analyzer (Packet)

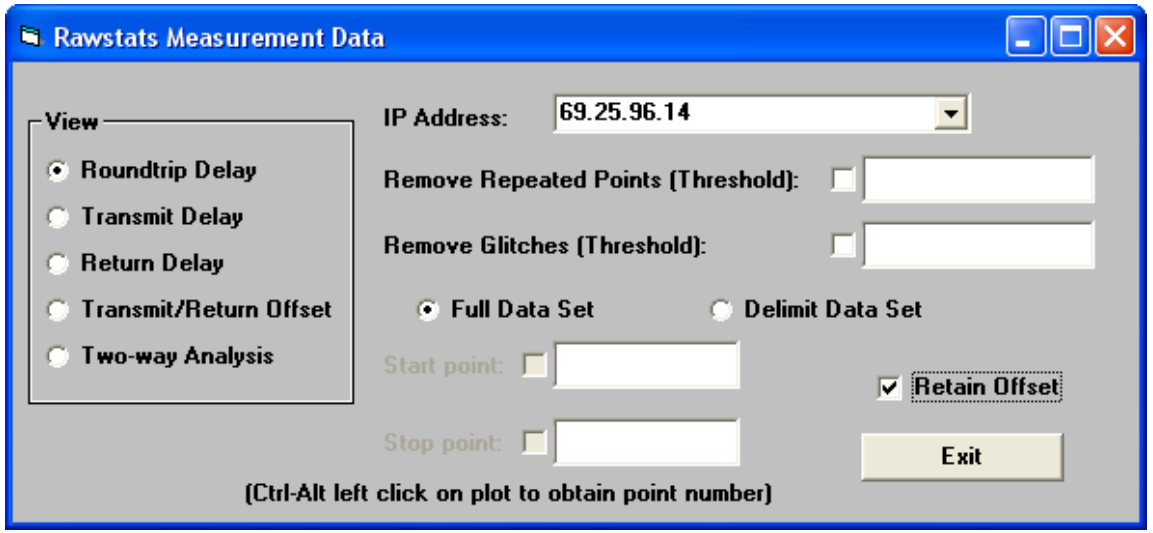
Packet Data Import: TP5000 Probe NTP



TimeMonitor Analyzer (Packet)

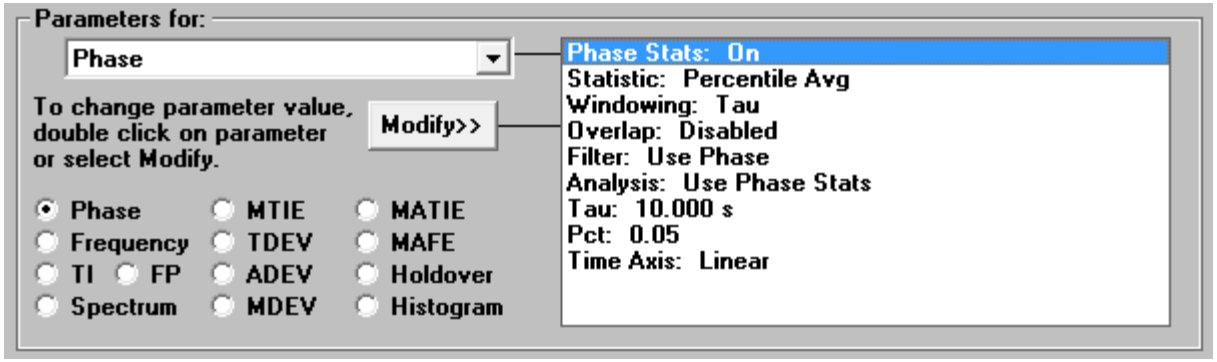
Packet Data Import: NTP Peerstats/Rawstats

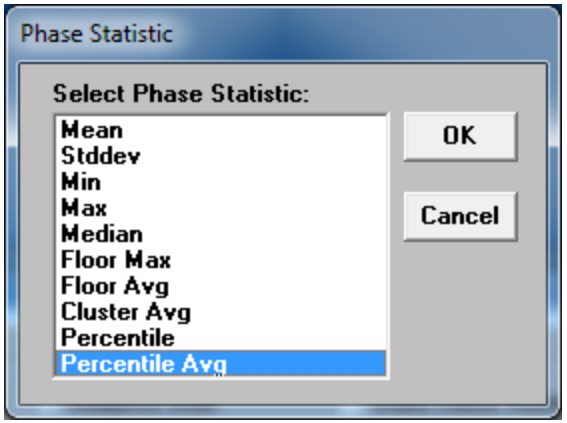




TimeMonitor Analyzer (Packet)

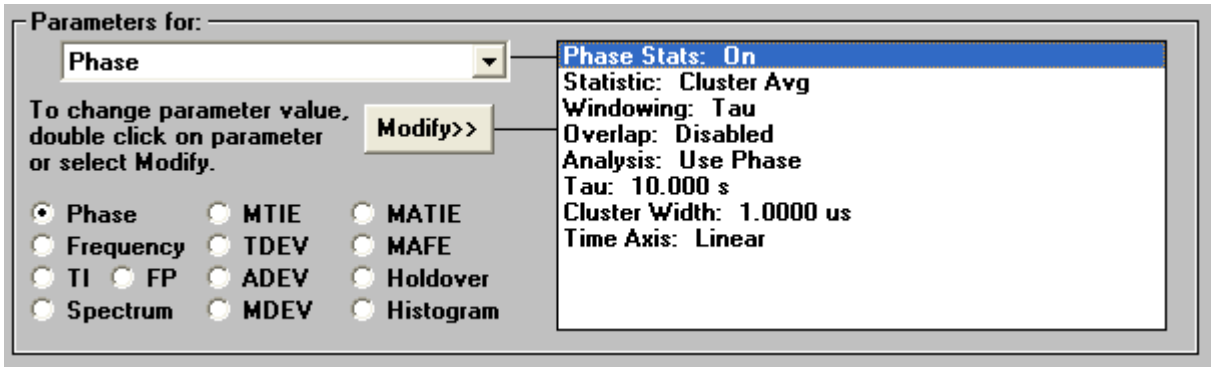
Percentile Average

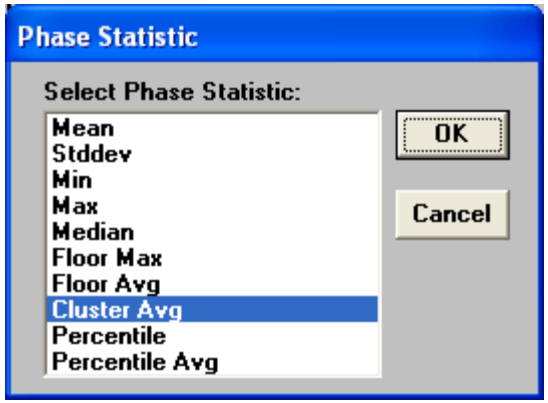




TimeMonitor Analyzer (Packet)

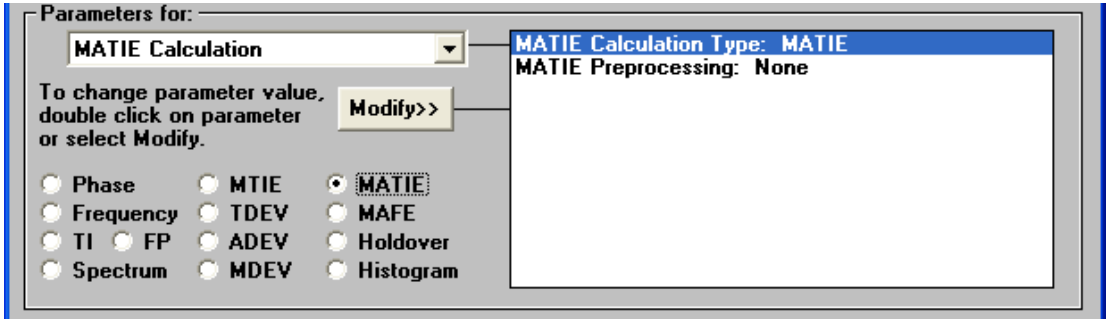
Cluster Average



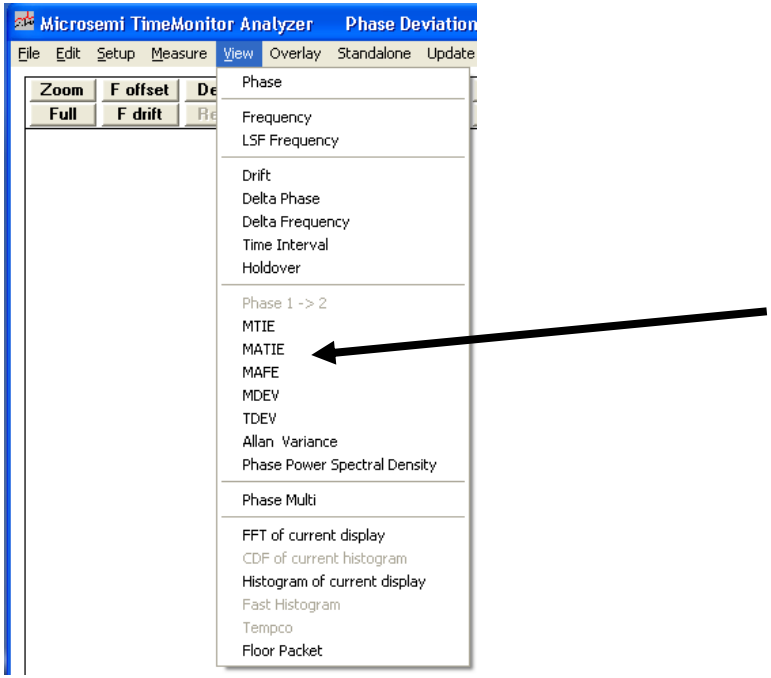


TimeMonitor Analyzer (Packet)

MATIE/MAFE Calculations



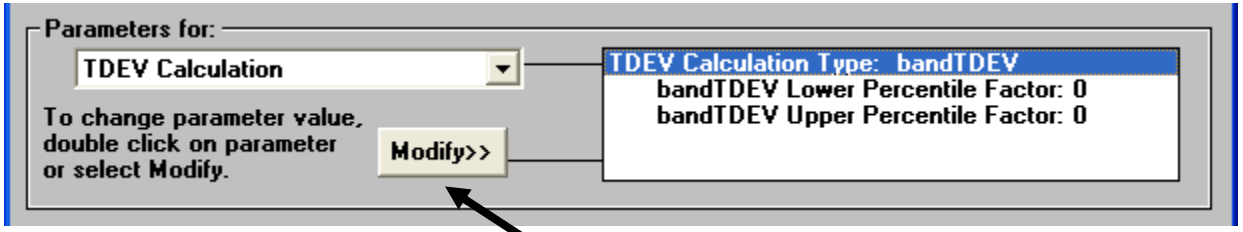
(in View Setup)



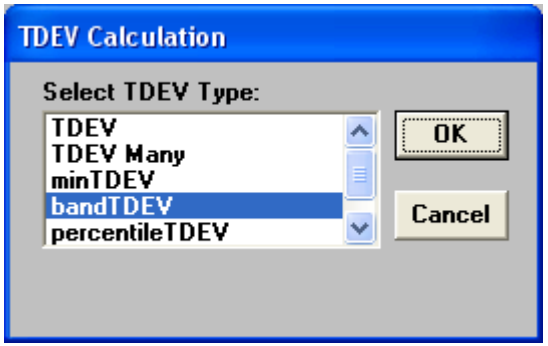
MICROCHIP

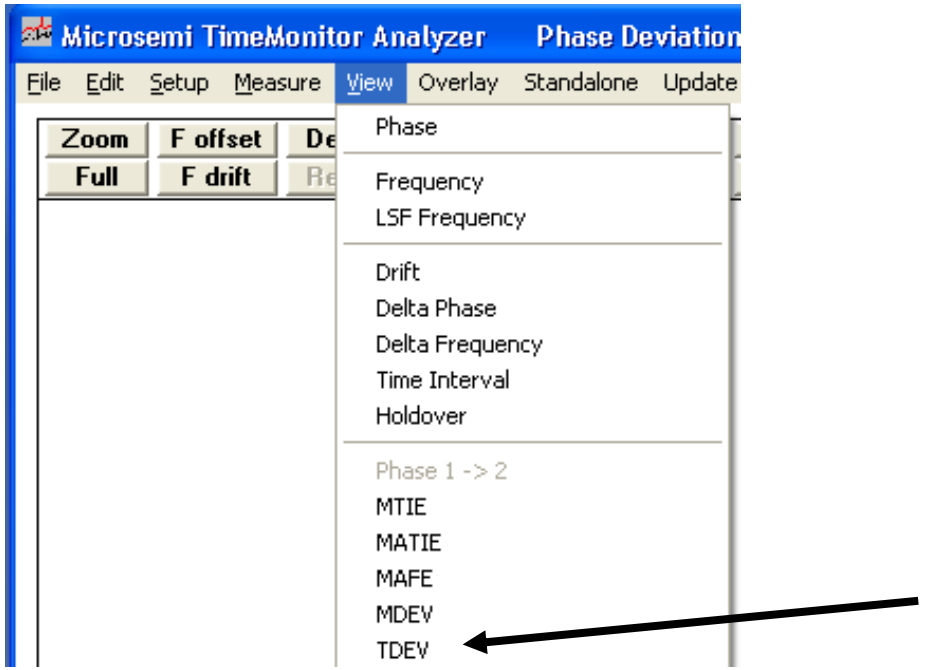
TimeMonitor Analyzer (Packet)

minTDEV/percentileTDEV/bandTDEV Calculations



(in View Setup)

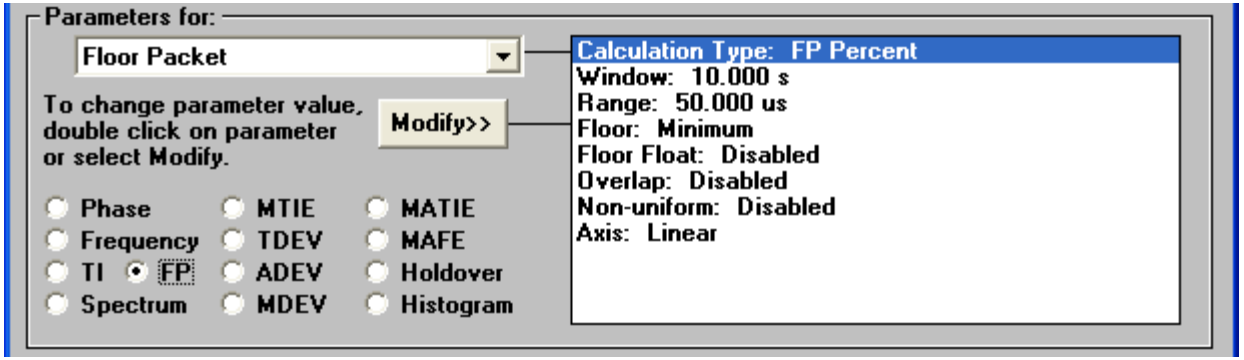




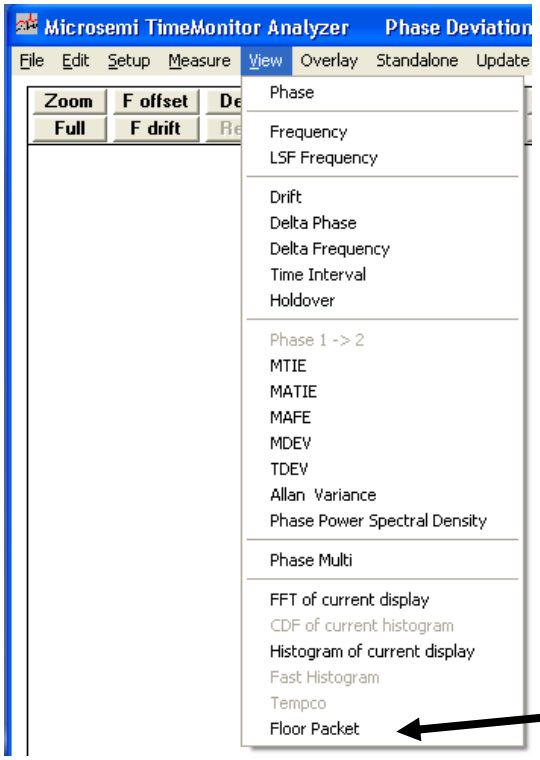
MICROCHIP

TimeMonitor Analyzer (Packet)

FPP Calculations

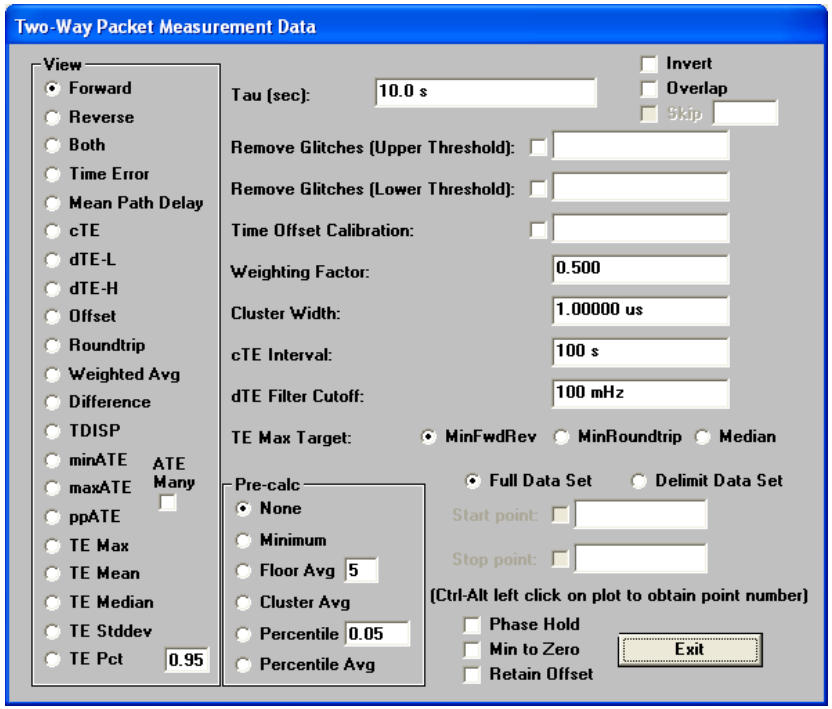


(in View Setup)

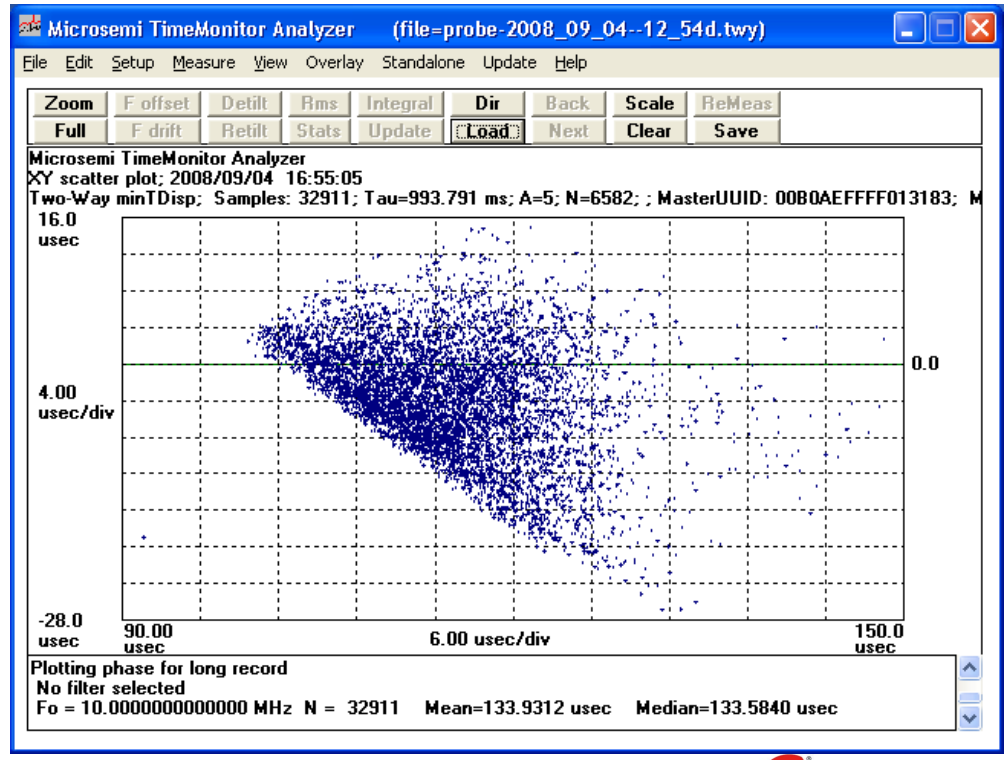


MICROCHIP

TimeMonitor Analyzer (Packet)



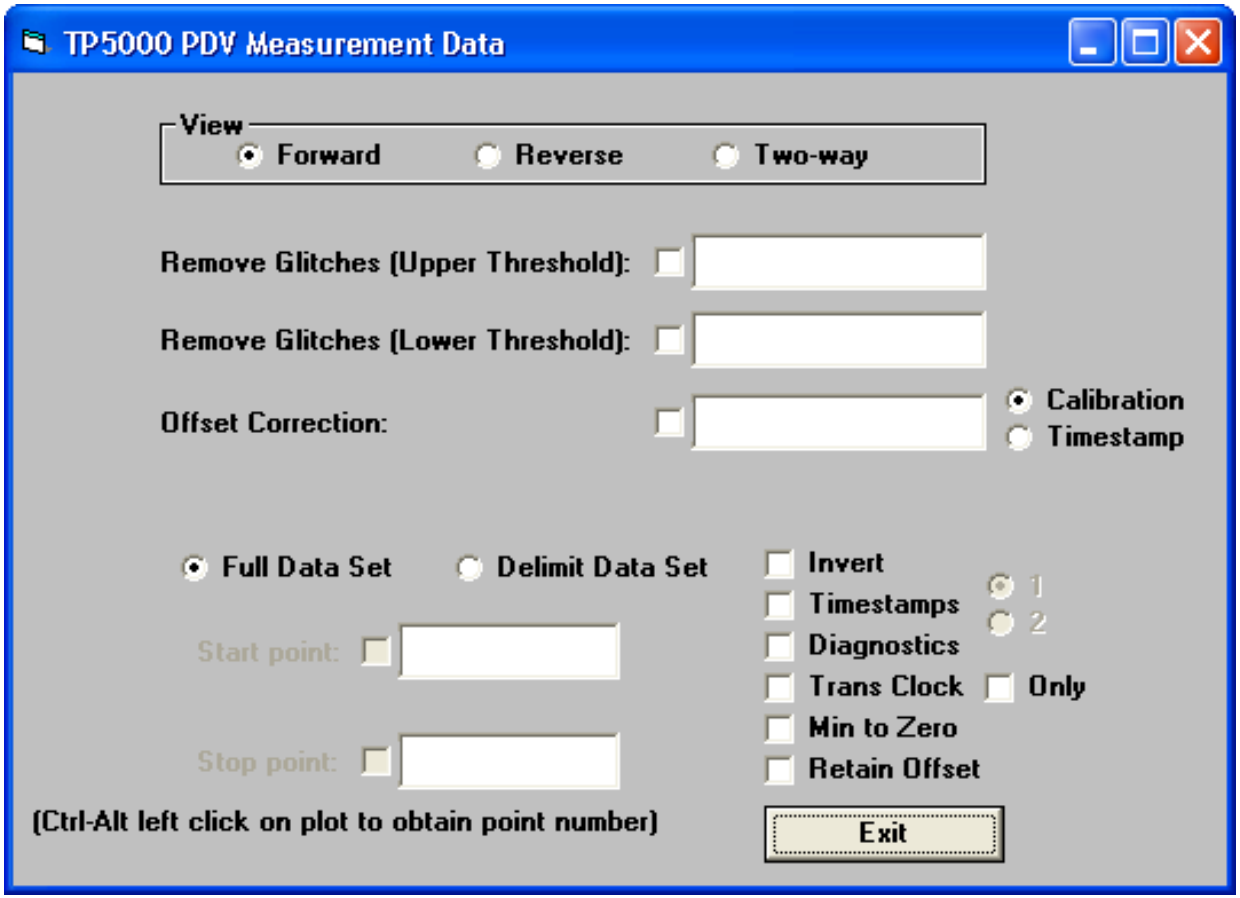
Two-way Data Import



MICROCHIP

TimeMonitor Analyzer (Packet)

TP5k Probe Diagnostics



MICROCHIP

TimeMonitor Analyzer (Packet)

TP5k Probe Diagnostics

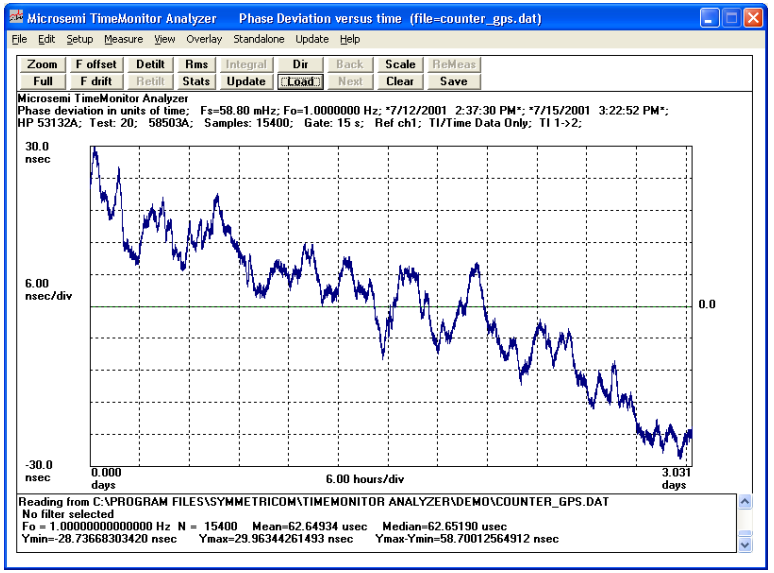
- Forward PDV: ***f.tpk***
- Reverse PDV: ***b.tpk***
- Cleaned file: ***clean.tpk***
- Header: ***header.txt***
- Other lines: ***debug.txt***
- Timestamps: ***t1.cap, t2.cap, t3.cap, t4.cap***
- Missing SeqID: ***seqf.txt, seqb.txt***
- Backwards timestamps: ***backf.txt, backb.txt***
- Repeated timestamps: ***repf.txt, repb.txt***
- Delay below lower threshold: ***lowf.txt, lowb.txt***
- Delay above upper threshold: ***highf.txt, highb.txt***

TMA “Command Line”

Integration: Launch TimeMonitor Analyzer with another application

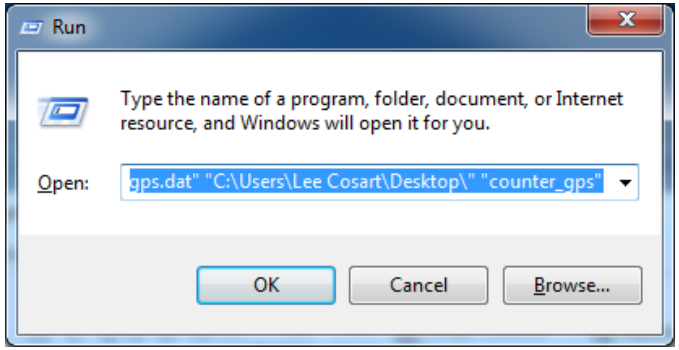
Automation: Test automation

"C:\Program Files (x86)\Microchip\TimeMonitor Analyzer\phasana.exe" -launch -phase "C:\Program Files (x86)\Microsemi\TimeMonitor Analyzer\Demo\counter_gps.dat" "C:\Users\John Doe\Desktop\" "counter_gps"

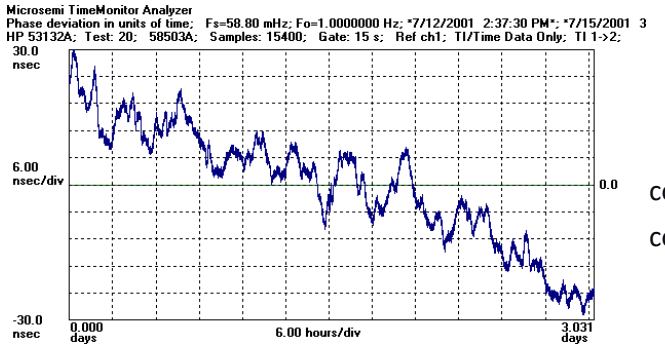


MICROCHIP

TMA “Command Line”

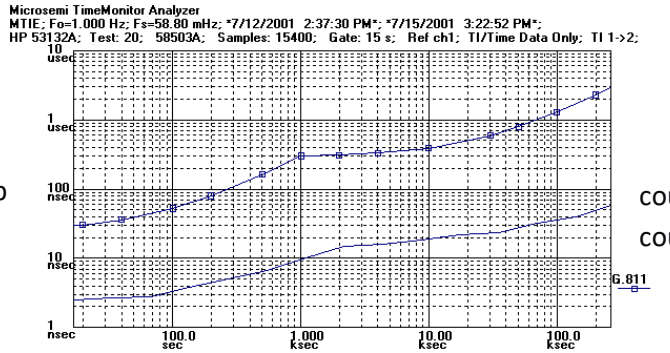


"C:\Program Files (x86)\Microchip\TimeMonitor Analyzer\phasana.exe" -plot -file -setup -phase -freq -mtie -tdev "C:\Program Files (x86)\Microchip\TimeMonitor Analyzer\Demo\counter_gps.dat" "C:\Users\John Doe\Desktop\" "counter_gps" "c:\Temp\g811.stp"



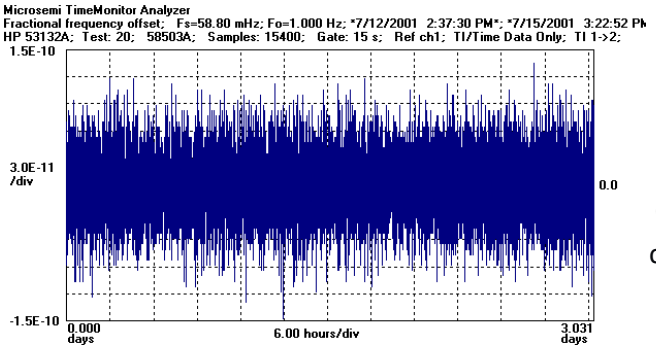
counter_gpsPhase.bmp

counter_gpsPhase.txt



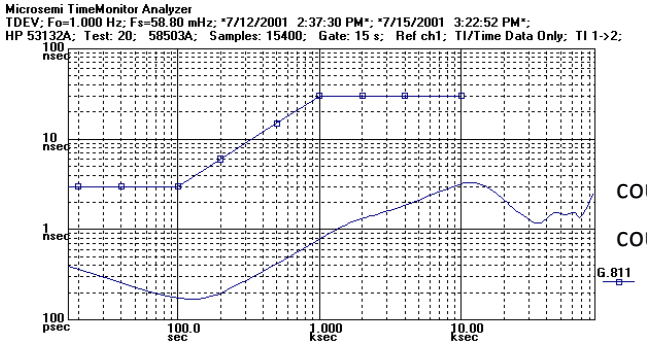
counter_gpsMTIE.bmp

counter_gpsMTIE.txt



counter_gpsFreq.bmp

counter_gpsFreq.txt



counter_gpsTDEV.bmp

counter_gpsTDEV.txt

MICROCHIP

TMA “Command Line”

- **Script (e.g. Python, Perl, Tcl, LabVIEW) or other calling program (e.g. C) can be used to process measurement files:**
  - Counter (DAT, ASC)
  - Single/Dual Column (TXT)
  - Packet Probe (TPK, AIT, TWY)
  - Other extensions than these six processed as single/dual column
- **Uses “inisetup.stp” (or optional “.stp” file in command)**
  - Setup masks, calculation parameters etc.
- **Supports all calculations**
  - -phase, -freq, -lsffreq, -mtie, -tdev, -adev, -mdev, -matie, -mafe
  - -hist, -cdf, -drift, -dphase, -dfreq, -ti, -ppsd, -fp, -tempco
- **Writes BMP files for script selected calculations**
  - Script can then be used to automatically place plots in a document
- **Writes dual column TXT files for script selected calculations**
  - These results can then be post-processed (mask pass/fail for example)

TMA “Command Line”

- **Example “Command Line”**
  - "C:\Program Files (x86)\Microsemi\TimeMonitor Analyzer\phasana.exe“ -plot -file -setup –slast -phase -freq -mtie -tdev "C:\Program Files (x86)\Microsemi\TimeMonitor Analyzer\Demo\counter_gps.dat" "C:\Users\John Doe\Desktop\" "counter_gps" “C:\Temp\g811.stp"
- **Parsing the “Command Line”**
  - TimeMonitor EXE: “C:\Program Files (x86)\Microsemi\TimeMonitor Analyzer\phasana.exe”
  - Indicate plot function: -plot
  - Indicate file function: -file
  - Indicate setup file (optional): -setup
  - Indicate setup file loaded last (optional): -slast
  - Choose calculation(s): -phase -freq -mtie -tdev
  - Source file: "C:\Program Files (x86)\Microsemi\TimeMonitor Analyzer\Demo\counter_gps.dat“
  - Destination directory: "C:\Users\John Doe\Desktop\“
  - BMP/TXT file names: counter_gps
  - Setup file name: “C:\Temp\g811.stp"
- **This “Command Line” produces four BMP and four dual column TXT files**
  - counter_gpsPhase.bmp, counter_gpsFreq.bmp, counter_gpsMTIE.bmp, counter_gpsTDEV.bmp, counter_gpsPhase.txt, counter_gpsFreq.txt, counter_gpsMTIE.txt, counter_gpsTDEV.txt

TMA “Command Line”

Setup file options

1. **Use “inisetup.stp” if -setup and “<setup file name>” not in command**
   - “inisetup.stp” is in the TimeMonitor installation directory

2. **With -setup and file name without directory**
   - e.g. … -setup … “g811.stp”
   - Looks for setup file in TimeMonitor Analyzer installation directory

3. **With -setup and file name with directory**
   - e.g. … -setup … “C:\Temp\g811.stp“
   - Looks for setup file in the “C:\Temp\” directory in this case

4. **With -setup and -slast**
   - TimeMonitor Analyzer will load the setup file ***after*** loading the data file

TMA “Command Line”

- **Delimiting**
  - Optional input file delimiting is available
  - Delimits the input file according to point numbers in the file, for example, a 1000 point file could be delimited to start with the 150th point and stop with the 300th point with all analysis performed on that delimited sequence rather than the full 1000 points
  - The syntax is to add -start and/or -stop parameters with each followed by a space and then an integer
  - Example: "phasana.exe“ -plot -file -start 800 -phase -freq -mtie -tdev "C:\Data\counter_gps.dat“ "C:\Results\" "counter_gps"
  - Example: "phasana.exe“ -plot -file -stop 1600 -phase -freq -mtie -tdev "C:\Data\counter_gps.dat“ "C:\Results\" "counter_gps"
  - Example: "phasana.exe“ -plot -file -start 800 -stop 1600 -phase -freq -mtie -tdev "C:\Data\counter_gps.dat“ "C:\Results\" "counter_gps"

TMA “Command Line”

- **Overlays**
  - Command line supports saving results as overlays
  - Command line supports plotting overlay results as a BMP file
- **Save as Overlay**
  - Numbered overlays range from 0 to 9
  - Parameter is –saveoverlay[N]
  - Example: "phasana.exe“ -saveoverlay1 -phase -freq -mtie -tdev "C:\Data\counter_gps.dat“ "C:\Results\" "counter_gps“
  - Example: "phasana.exe“ -plot -file -saveoverlay1 -phase -freq -mtie -tdev "C:\Data\counter_gps.dat“ "C:\Results\" "counter_gps"
- **Plot Overlay**
  - Overlays are individually selected
  - Example: "phasana.exe“ -phase -mtie -tdev -overlay1 -overlay5 -overlay7 "C:\Results\" "counter_gps“
- **Overlay Options**
  - -phase, -freq, -mtie, -tdev, -adev, -mdev, -matie, -mafe
  - -hist, -cdf, -ppsd, -fp, -generic, -scatter, -timestats

TMA “Command Line”

- **Debug mode (optional)**
  - -debug parameter is used to invoke
  - Dialog box content is directed to file “cmd_debug.txt”
  - File “cmd_debug.txt” is located in the TimeMonitor Analyzer installation directory and in the “output” directory specified in the command as long as it exists
  - In debug mode, message dialog box content is directed to that file and message dialog boxes are suppressed
  - File “cmd_debug.txt” shows the parsing of the command (and the content of any message dialog box)
  - Example: "phasana.exe“ -debug -plot -file -phase -freq -mtie -tdev "C:\Data\counter_gps.dat“ "C:\Results\" "counter_gps"
- **Debug file example:**

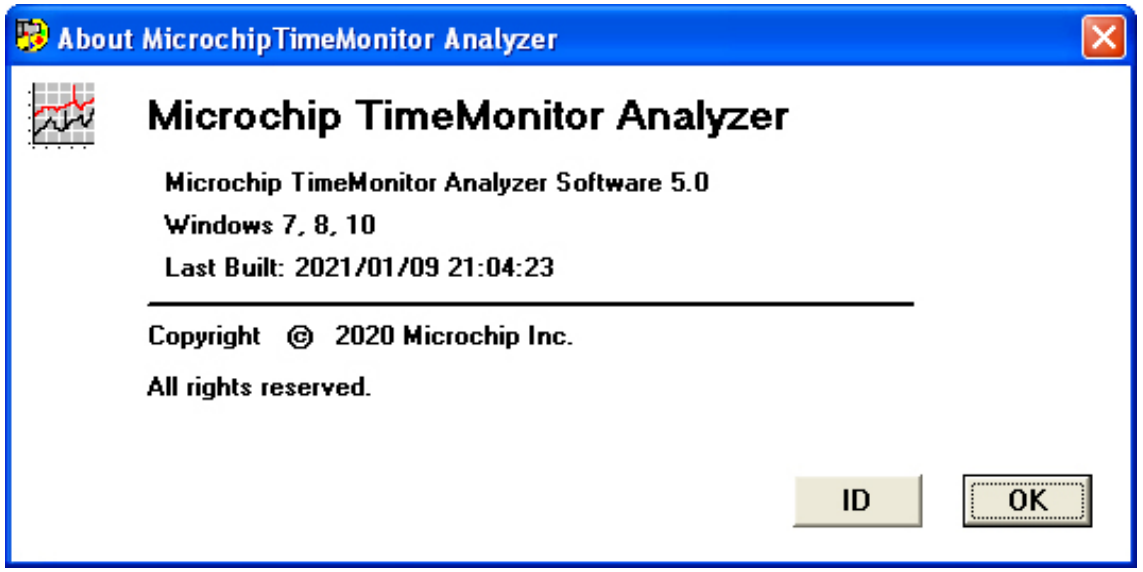
Input file: counter_gps.dat
Input directory:
C:\Vb\Office\Vb6\Projects\Phasana\Builds\b20140110\
Output file: counter_gps
Output directory: C:\Users\John Doe\Desktop\
Output bitmap selected
Output file selected
Delimiting selected
Start: 900
Stop: 1800
Phase calculation
Frequency calculation
MTIE calculation
TDEV calculation

TMA “Command Line”

Summary

- **Three options for directing calculations**
  - -plot: BMP files
  - -file: TXT dual column files
  - -saveoverlay<N>: save as overlay (e.g. –saveoverlay1)
- **Any combination of the three options can be selected in a single command**
- **Plot Overlays**
  - BMP files produced
- **Debug mode**
  - Writes parse of command to a file
  - The file also includes any message dialog box content with message dialog boxes suppressed

TMA “Command Line”



TimeMonitor Analyzer 4.0 or later required for “Command Line” functionality

TimeMonitor Analyzer 5.0 is required for full “Command Line” functionality