PRECISION TIME by GPS for Observational Astronomy

“How to” Guide for Windows XP Standalone System using the Garmin 18 LVC OEM GPS Device

Andrew S. Mount

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Mountain Rest Astronomical Observatory (MRAO)
Mountain Rest, South Carolina, USA

Why "Precision" Time?

- MRAO is in a remote location and requires NIST traceable high precision timekeeping on all of its computer and sensor systems.
- In order to accomplish this task, an external (non-internet) time signal needs to be collected and processed on site.
- High Precision GPS Timekeeping via a dedicated GPS sensor and Network Time Protocol (NTP) Computer software is an ideal solution.

Approach

- There are a network of 24 GPS satellites in orbit around the Earth.
- Each satellite orbits at an altitude of 20,000 km from the ground, at an orbital speed of 14,000 km/hour with an orbital period of ~12 hours.
- Each satellite carries an atomic clock that "ticks" with an accuracy of 1 nanosecond (1 billionth of a second).
- The Garmin 18 LVC receiver receives the atomic time data from the satellite as a time statement (GPRMC) and as a pulse per second (PPS) measurement signal.
- This GPS time data is transmitted from the receiver to the computer via a serial port connection.
- Open Source Network Protocol Software (NTP) installed in the host Windows XP computer processes the GPS time data.
- NTP data processing includes statistical file generation (loopstats) and continually setting and adjustment of the computer system clock based on the GPS "True Time" input.
- A fully implemented –GPS –XP –NTP clock has a precision of 20 microseconds
- NTP enables the GPS time information to be distributed across a local area network (LAN) , thus provide a NIST reference high precision time to every connected computer running NTP.

How PPS Works

4.4.1 One-Pulse-Per-Second (PPS) Output (GPS 18x LVC Only)

The highly accurate one-pulse-per-second (PPS) output is provided for applications requiring precise timing measurements. After the initial position fix has been calculated, the PPS signal is generated and continues until the unit is powered down. The rising edge of the signal is aligned to the start of each GPS second within 1 μs for all conditions in which the re ceiver has reported a valid and accurate position for at least the previous 4 seconds.

The NMEA 0183 sentences that follow each rising edge of the PPS signal tell when you were and where you were at that previous rising edge of the PPS signal, beginning with the GPRMC sentence as the lead sentence in any particular NMEA 0183 record.

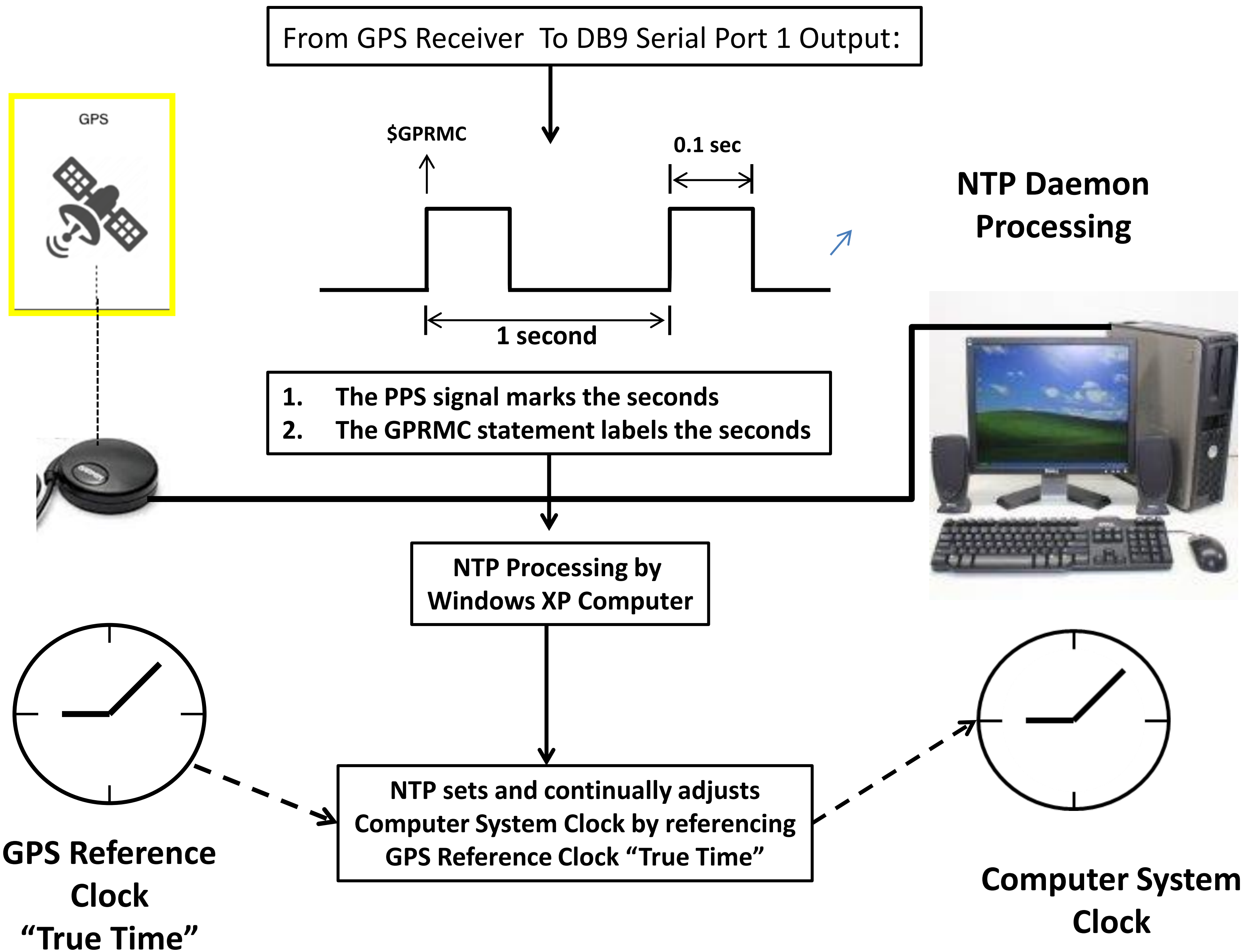
Regardless of the selected baud rate, the information transmitted by the GPS 18x series products is referenced to the pulse immediately preceding the NMEA 0183 RMC sentence.

The accuracy of the one-pulse-per-second output is maintained only while the GPS receiver is computing a valid position fix. To obtain the most accurate results, the one-pulse-per-second output should be calibrated against a local time reference to compensate for cable and internal receiver delays and the local time bias.

The default pulse width is 100 ms, however; it may be programmed in 20 ms increments between 20 ms and 980 ms as described in $PGRMC section 4.1.2 Sensor Initialization Information (PGRMI), field <13>.

- Garmin Manual

Standalone XP Stratum 1 GPS NTP- How it Works



Transmitted Time and the $GPRMC Statement

The GPS sensor outputs Coordinated Universal Time (UTC) date and time of day in the transmitted sentences. Before the initial position fix, the on-board clock provides the date and time of day. After the initial position fix, the date and time of day are calculated using GPS satellite information and are synchronized with the measurement pulse output.

The GPS 18x-5Hz outputs a UTC with a tenths-of-a-second precision: 123456.8, for example.

The GPS sensor uses information obtained from the GPS satellites to add or delete UTC leap seconds and correct the transmitted date and time of day. The transmitted date and time of day for leap second correction follow the guidelines in *"National Institute of Standards and Technology Special Publication 432 (Revised 1990)"* (for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, U.S.A.).

When a positive leap second is required, one second is inserted at the beginning of the first hour (0h 0m 0s) of the day that the positive leap is occurring. The minute containing the leap second is 61 seconds long. The GPS sensor would have transmitted this information for the leap second added December 31, 1998 as follows:

$GPRMC,235959,A,3851.3651,N,09447.9382,W,000.0,221.9,071103,003.3,E*69

$GPRMC,000000,A,3851.3651,N,09447.9382,W,000.0,221.9,081103,003.3,E*67

$GPRMC,000000,A,3851.3651,N,09447.9382,W,000.0,221.9,081103,003.3,E*67

$GPRMC,000001,A,3851.3651,N,09447.9382,W,000.0,221.9,081103,003.3,E*66

If a negative leap second should be required, one second will be deleted at the end of some UTC month. The minute containing the leap second will be only 59 seconds long. In this case, the GPS sensor will not transmit the time of day 0h 0m 0s (the "zero" second) for the day from which the leap second is removed.

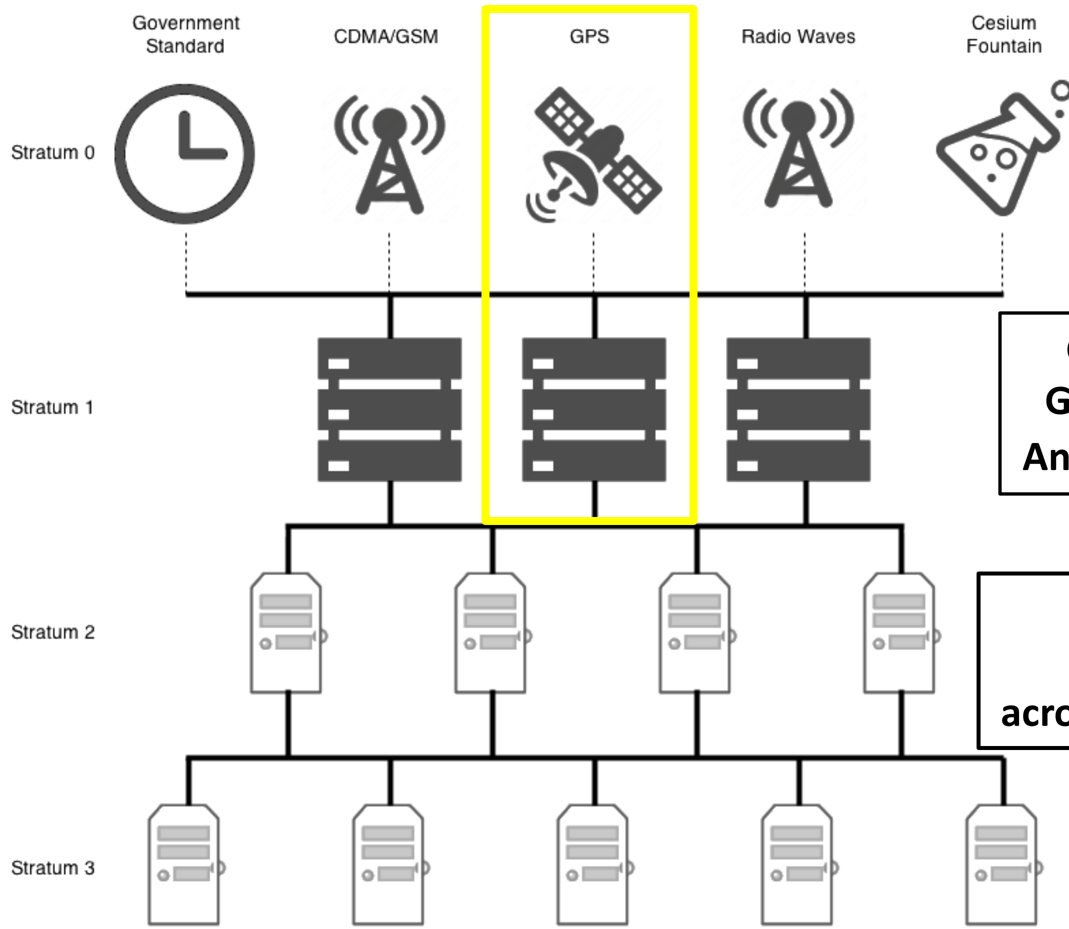
$GPRMC,235959,A,3851.3650,N,09447.9373,W,000.0,000.0,111103,003.3,E*69

$GPRMC,000001,A,3851.3650,N,09447.9373,W,000.0,000.0,121103,003.3,E*6A

$GPRMC,000002,A,3851.3650,N,09447.9373,W,000.0,000.0,121103,003.3,E*69

- Garmin Manual

Network Time Protocol Stratums



GPS signal received by
Garmin 18x LVC Receiver
And Windows XP Computer

NTP installed on LAN
will coordinate time
across the computer network

Four Basic Steps

- **Hardware** – Wiring the Garmin 18 LVC OEM GPS Unit and installation on desktop computer.
- **Software** – Installation of drivers, and free open source software.
- **Implementation**, serial port configuration, set-up of Garmin GPS unit, NTP configuration files.
- **Evaluation** and testing of Clock Performance.

Step 1: Hardware

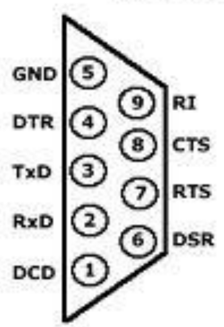
- The **Garmin 18x LVC GPS** - has a white connector that can be snipped off.
- **Gigaware™ 6-Ft. Serial RS-232C 9M-9F Cable-(**Radio Shack Catalog #: 26-1402) – cut to desired length and use female end.
- **USB- A connector** – for 5 volt power only (two wire red & black).

Wiring Diagram

Garmin 18X LVC Wire Color	Function	To DB- 9 Female Pin #	Gigaware ser. cable -Wire Color
Yellow	PPS Pulse	1	Black (Wh)
White	TXD fr GPS	2	Brown
Green	RXD to GPS	3	Red
Black - thin	Signal Grd	5	Yellow
Wire Color	**Function**	**USB**	**USB-Color**
Red	+5 volt	+	Red
Black-thick	Pwr Grd	Grd	Black

At the Computer Port:

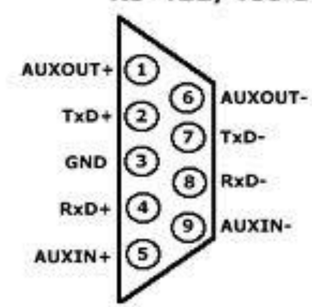
RS-232 DB-9 Male Pinout



PIN 1: Data Carrier Detect
PIN 2: Receive Data
PIN 3: Transmit Data
PIN 4: Data Terminal Ready
PIN 5: Signal Ground
PIN 6: Data Set Ready
PIN 7: Request to Send
PIN 8: Clear to Send
PIN 9: Ring Indicator

At the Serial Cable End :

RS-422/485 DB-9 Female Pinout



PIN 1: Auxiliary Output+
PIN 2: Data Output+
PIN 3: Signal Ground
PIN 4: Data Input+
PIN 5: Auxiliary Input+
PIN 6: Auxiliary Output-
PIN 7: Data Output-
PIN 8: Data Input-
PIN 9: Auxiliary Input-

Garmin Pinouts and Wiring Diagram

The GPS 18x LVC/18x-5Hz wires are terminated with a six-wire connector that is used by Garmin for testing purposes. You can remove this connector without voiding your warranty (see section 1.2 Limited Warranty).

2.1 GPS 18x LVC & GPS 18x -5Hz PINOUT

GPS 18x Pin #	Color	Signal Name	Wire Gauge
1	Yellow	Measurement Pulse Output	28
2	Red	Vin	26
3	Black	Ground	28
4	White	Transmit Data	28
5	Black	Ground	26
6	Green	Receive Data	28

Table 1: GPS 18x LVC & GPS 18x-5Hz Wire Pinout

2.2 GPS 18x LVC & GPS 18x -5Hz WIRING DIAGRAMS

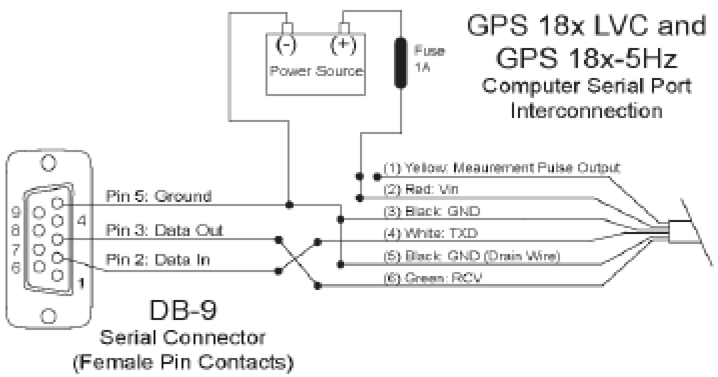


Figure 1: Computer Serial Port Interconnection

Wiring Procedure

- On the GPS unit , cut off the white connector and strip between 0.25 to 0.5” off of each wire.
- Strip the same amount off the USB- A connector.
- Cut the Giga ware female connector end of the serial cable to the desired length, then strip off between 0.25 to 0.5” off of each wire in the cable.
- Wire the USB-A and Gigaware serial cables according to the wiring diagram.
- Use a Multi-Meter to check for both continuity and correct wiring configuration.
- Solder the connections and wrap the wires with electrical tape to relieve strain .

Software Overview

- There are three software open source components that are required:
- **Network Time Protocol** – NTP – is an internet protocol used to synchronize the clocks of computers to some time reference. NTP requires a reference clock that defines the *true time* to operate. All clocks are set towards that **true time**. NTP can operate across a network of computers via a hierarchy via one common reference, in this case the Garmin GPS receiver.
- **Windows Serial Port Drivers** to link the GPS Receiver to the computer via a DB9 serial port link.
- **Garmin Operating Software** – to set the parameters of the GPS receiver to work with NTP – using the NMEA standard.

Step 2A: Software Installation

1. **Install Meinberg NTP Software.**
   (http://www.meinbergglobal.com/english/sw/ntp.htm)
   Keep all defaults.
   Account name: ntp (use whatever you want)
   Account pass: ntpntp
2. **Install** ntp-time-server-monitor-1.04.exe **from the Meinberg Website**
3. **Stop NTP**
4. **Go to** http://davehart.net/ntp/refclock/
   Download and install serialpps-20120321.zip **(latest version)**
   Run “install.bat”
   Ensure that “serialpps.sys” was copied to “C:\Windows\system32\drivers”
   Copy “serialpps-ppsapi-provider\x86\serialpps-ppsapi-provider.dll” to “C:\”
   Right-click “My Computer”, go to properties.
   Click “Advanced” tab
   Click “Environment Variables” button
   Under “System variables”, Click “New” button
   Name: PPSAPI_DLLS
   Value: C:\serialpps-ppsapi-provider.dll

Step 2B: Software Installation

6. **Configure GPS (for Garmin)** Go to: http://www8.garmin.com/support/download_details.jsp?id=925
   - Run "SNSRCFG.exe"
   - Connect to GPS
   - Configure
   - Set baud rate to 4800
   - Enable "Pulse Per Second"
   - Press F7
   - Enable GPRMC, disable other sentences
   - Send config to GPS
7. **Configure NTP – See my configuration file suggestion below or use**:
   - Edit "C:\Program Files\NTP\etc\ntp.conf"
   - Remove all entries, add the following
   - driftfile "C:\Program Files\NTP\etc\ntp.drift"
   - enable stats
   - statsdir "C:\Program Files\NTP\etc\"
   - statistics loopstats
   - server 127.127.22.1 minpoll 4 #PPS
   - server 127.127.20.1 iburst prefer minpoll 4 maxpoll 7 #GPS
   - #fudge 127.127.20.1 time1 0.4 refid GPS #uncomment and change time1 as needed
8. **Ensure GPS is connected to serial port 1**
9. **Restart computer**

Step 2C: Software Installation

10. Unplug GPS and disable Microsoft Ball-mouse (if listed)
    Go to device manager: My Computer->Properties->Hardware->Device Manager
    Under “Mice and other pointing devices”, right-click and disable “Microsoft Serial BallPoint”
11. Reconnect GPS Restart computer
12. Start NTP server
13. Monitor NTP server
    by “NTP Time Server Monitor” from Meinberg
14. To Uninstall PPS driver, run “uninstall.bat”.

- For more details refer to: http://blogs.cae.tntech.edu/jwlangston21/2009/12/07/installing-and-using-ntp-with-a-garmin-18-gps-with-pps/
- And http://www.satsignal.eu/ntp/NTP-on-Windows-serial-port.html

Step 3- Software Installation
Create the NTP Config File

Explained…

driftfile C:\Program Files\NTP\etc\ntp.drift
#
The GPS receiver on COM1 at 4800 baud
mode 0 = use any statements
mode 1 = use $GPRMC statements
minpoll 4 = use 16-second sampling
maxpoll 4 = and don't increase it
#
flag1 1 = enable PPS processing
flag3 1 = enable Kernel PPS discipline
refid = text string to define the reference as ".PPS."
#
server 127.127.20.1 mode 0 minpoll 4 maxpoll 4 prefer
fudge 127.127.20.1 flag1 1 flag3 1 refid PPS
#
#--# statistic section #--#
enable stats
statsdir C:\NTP
statistics loopstats
/var/log/peerstats:
mjd sec.frac paddr/caddr offs delay disp rmsjitter
/var/log/loopstats:
mjd sec.frac offs freq rmsjitter
/var/log/sysstats:
mjd sec.frac uptime timecode
#-# end of statistic section #--#

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Actual File…

driftfile C:\Program Files\NTP\etc\ntp.drift

server 127.127.20.1 mode 0 minpoll 4 maxpoll 4 prefer

fudge 127.127.20.1 flag1 1 flag3 1 refid PPS

enable stats

statsdir C:\NTP

statistics loopstats

/var/log/peerstats:

mjd sec.frac paddr/caddr offs delay disp rmsjitter

/var/log/loopstats:

mjd sec.frac offs freq rmsjitter

/var/log/sysstats:

mjd sec.frac uptime timecode

Step 4 –Evaluation and Testing of Performance

- To check for successful GPS-Computer system integration, all software must be downloaded and installed.
- Stop NTP.
- Download and install Serial Port LEDs program from http://www.satsignal.eu/software/net.htm#SerialPortLEDs
- If the CTS blinks once per second, then all the hardware and software are operating.
- To monitor NTP and develop a precision time data base use the Meinberg NTP Monitoring Program.
- To evaluate clock performance, offset and jitter download and install: NTP Plotter (http://www.satsignal.eu/software/net.htm)

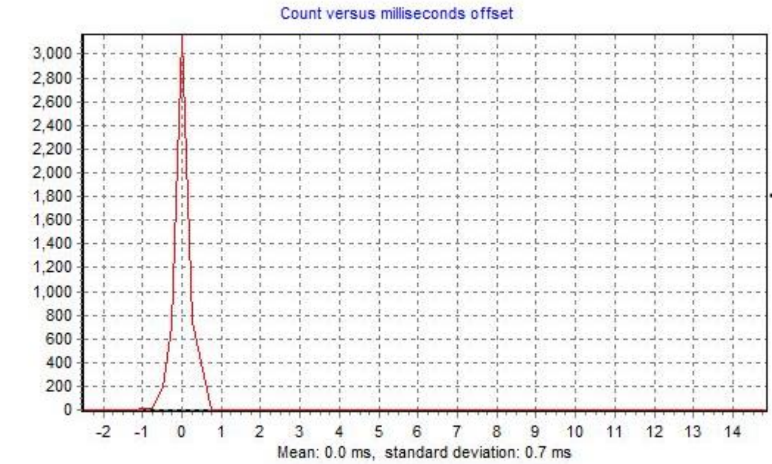
MRAO Precision Time Results
Definition of Terms

- **Resolution**- smallest possible increase of time that a particular model of clock allows.
- **Precision** – is the random uncertainty of a measured value, expressed by the standard deviation of by a multiple of the standard deviation.
- **Jitter** – Second derivation of the difference of a repeated time measure.
- **Accuracy**- how close a clock agrees with an official time reference such as UTC. It is the closeness of the agreement between the result of the a measurement and a true value of the measurand.
- **Frequency –** An error of 0.001% equals one second per day, hence 1 Part Per Million (PPM) is 0.0001% . The Frequency error of a typical clock is several PPM. 12 PPM corresponds to one second per day.
- **Reliability** – is the time a clock can keep the time within a specified accuracy
- **Wander** – long term variations in clock frequency, a measure of stability.
- **Offset** – the additional remaining correction to the system clock.
- **Freq** – the automatic periodic correction to the system clock, Positive values make the clock go faster while negative values slow it down.
- **Time** – the current time.

Garmin 18x LVC on Windows XP NTP Clock Performance

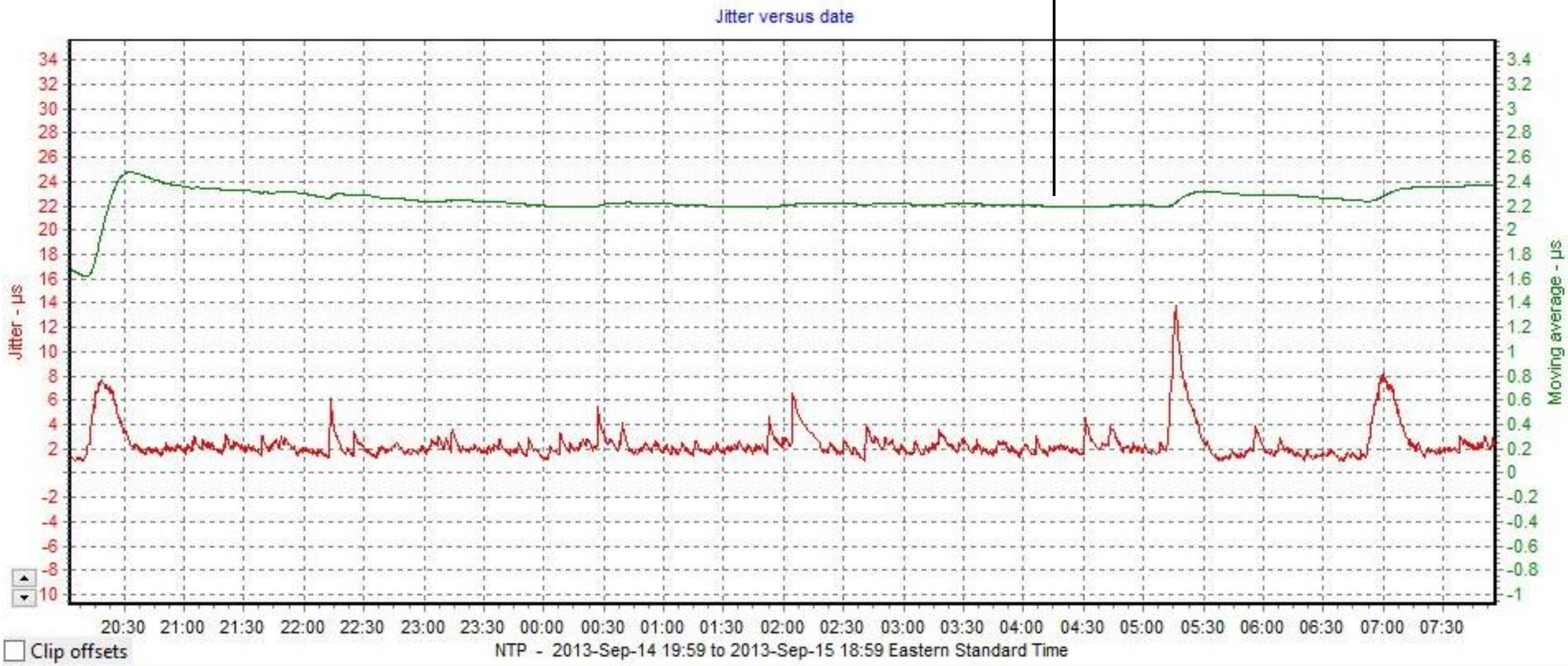
Version:	NTPD 4.2.6
Stratum:	1
Resolution :	1 pulse per sec (PPS)
Precision:	21 microseconds
Root delay:	0.000 seconds
Offset:	-0.110 seconds
Frequency:	-12.904 ppm
Clock jitter:	0.002 seconds
System jitter:	0.007 seconds
Clock wander:	0.000 seconds

NTP- SEP 14-15, 2013

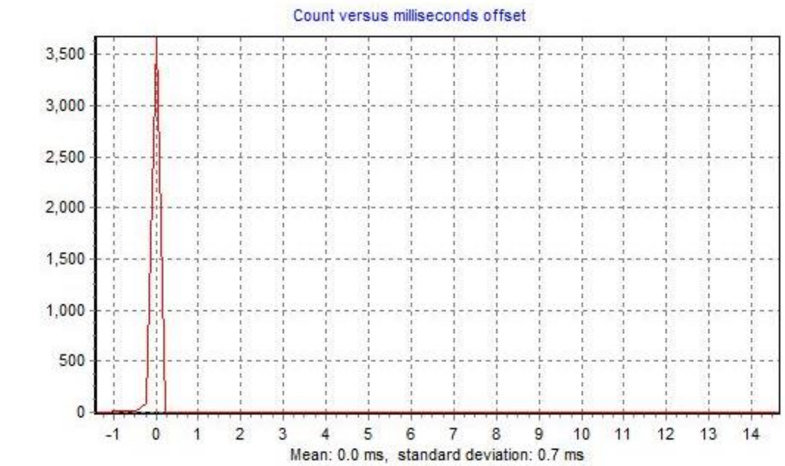


Offset: 0.0 ± 0.7 milliseconds

Jitter: ~ 2-2.4 microseconds moving average (green line)

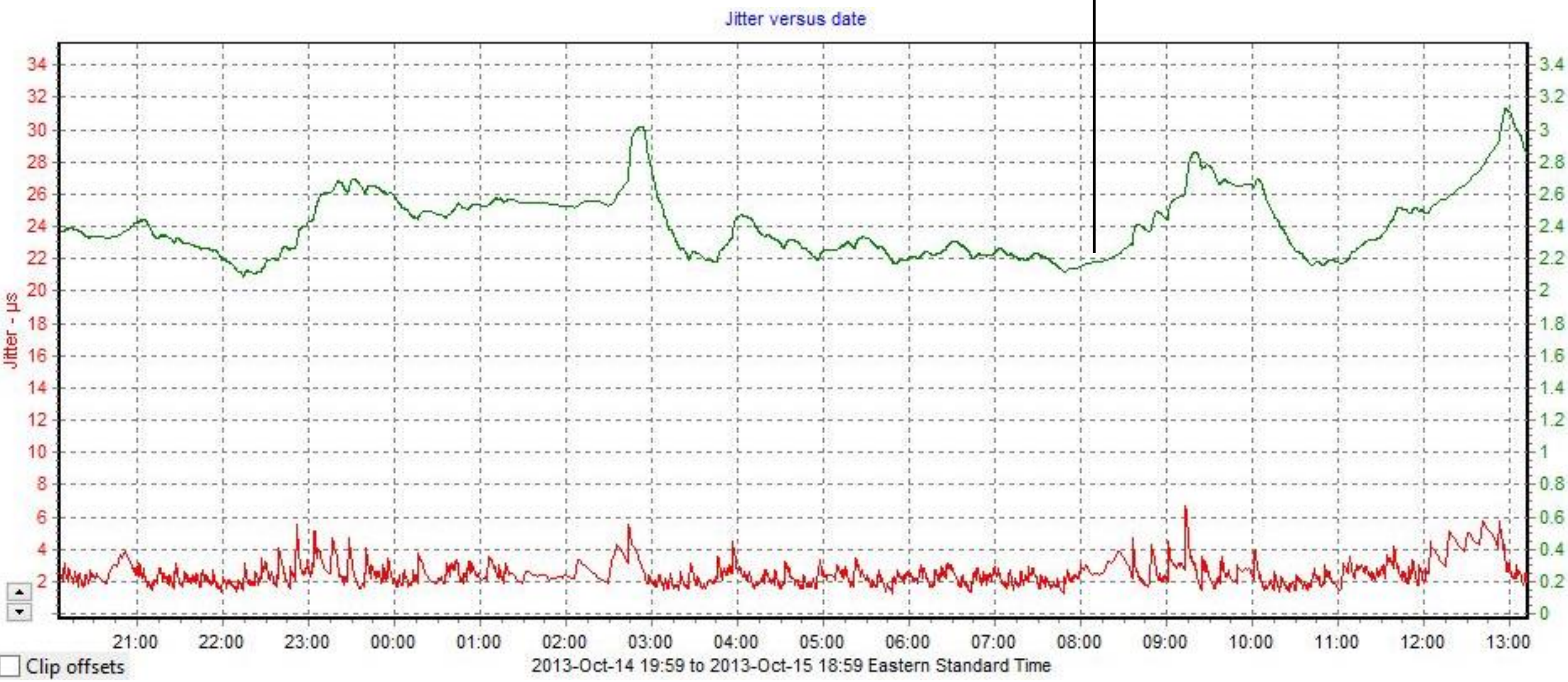


NTP- OCT 14-15, 2013

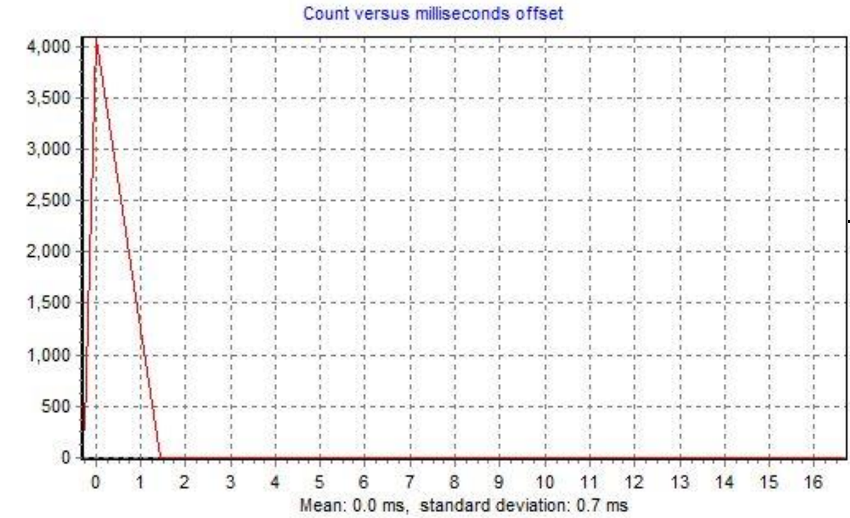


Offset: 0.0 ± 0.7 milliseconds

Jitter: ~ 2-3 microseconds moving average (green line)

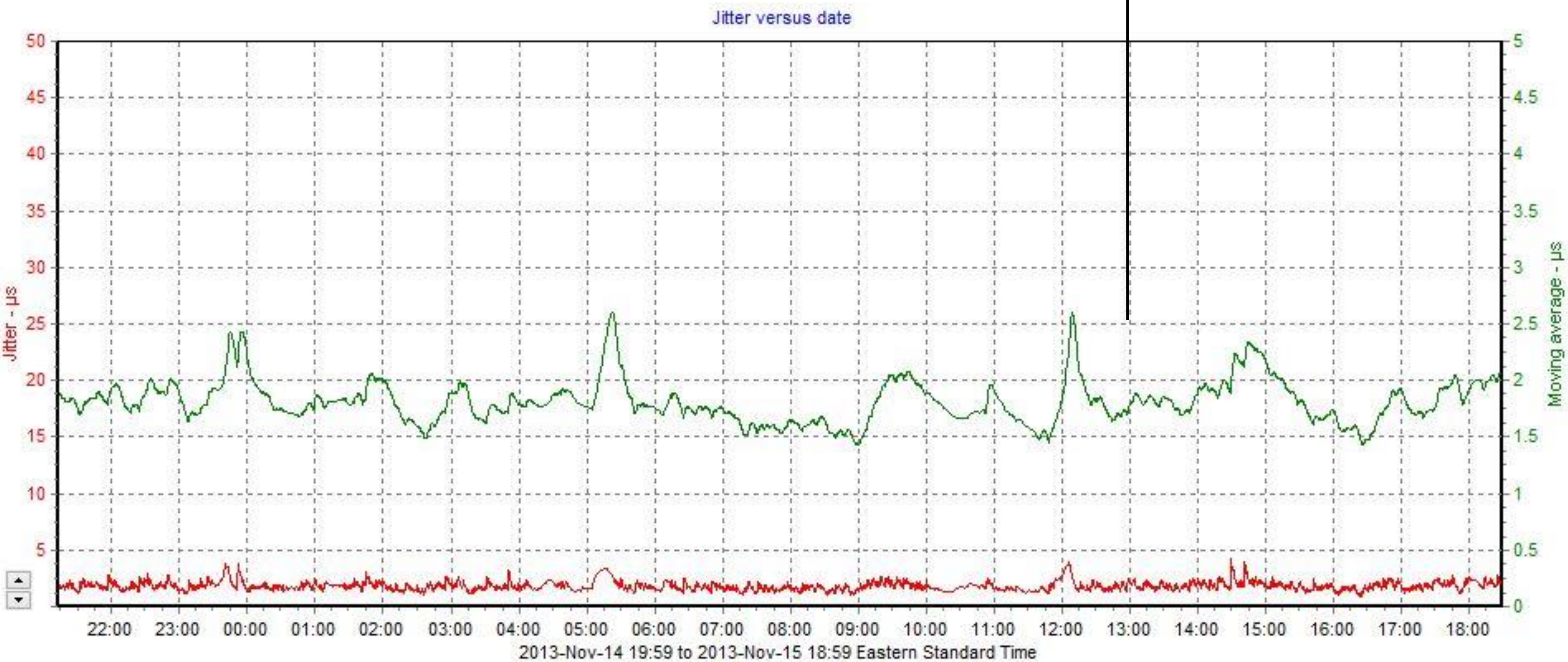


NTP- NOV 14-15, 2013



Offset: 0.0 ± 0.7 milliseconds

Jitter: ~ 2 microseconds moving average (green line)



Summary

- The longer the GPS-NTP system runs the better the clock precision and performance.
- To obtain overall clock performance at the XP Computer Windows command prompt type: ntpq –c rl
- David's Taylor website is a primary source of enabling "how to" information:
- http://www.satsignal.eu/ntp/NTP-on-Windows-serial-port.html
- Have Fun!