

GpsNtp-Pi Network Time Server ~ Supplement

Whitham D. Reeve

1. Introduction

This document applies to manufactured GpsNtp-Pi units and is meant to supplement the general description and installation guide documents:

- ⚙ **GPS Network Time Server on Raspberry Pi: GpsNtp-Pi** ~ {[GNPiDesc](#)}
- ⚙ **GpsNtp-Pi: Installation & Operation Guide** ~ {[GNPiSetup](#)}

Items supplied:

- ⚙ GpsNtp-Pi
- ⚙ GPS antenna
- ⚙ 2.1 x 5.5 mm locking dc coaxial plug for power cable
- ⚙ Micro-SD memory card adapter (this adapter may be used for temporary storage of the micro-SD card equipped in the GpsNtp-Pi if it is removed)

Caution

If you improperly remove power from the GpsNtp-Pi you may corrupt the memory card. If this happens, you will need to rewrite the software image. Proper shutdown is covered in this document.



2. Quick Start

1. Obtain the documents mentioned in the introduction and become familiar with them.
2. It is highly recommended that prior to use the GpsNtp-Pi software image be downloaded (URL available on request) and written to a spare micro-SD memory card having at least 8 GB capacity (some units are equipped with 4 GB cards). Alternately, the software image on the GpsNtp-Pi internal micro-SD memory card should be backed up prior to use; refer to the Maintenance section of this document for procedures to access and backup the card. Always have a backup plan.
3. Connect the supplied antenna to the GpsNtp-Pi antenna connector on the front panel. Torque the connector to 0.34 to 0.56 N-m (3 to 5 lb-in). Place the antenna where it has a clear view of the sky; an indoor windowsill may be suitable but is far from ideal. The antenna cable is 3 m long; see next section for additional details.
4. Connect your LAN to the 10/100BaseT Ethernet jack on the front panel. The LAN must have a DHCP server to automatically supply an IP address to the GpsNtp-Pi.
5. Assemble a power cable using the supplied 2.1 x 5.5 mm locking coaxial plug, center positive.
6. Check that the power switch on the GpsNtp-Pi rear panel is in the off (down) position.
7. Connect the GpsNtp-Pi to your power source through the coaxial power jack on the rear panel. The operating voltage range of the GpsNtp-Pi is 8 to 16 Vdc. Use a power supply rated at least 5 W and within the allowable voltage range.

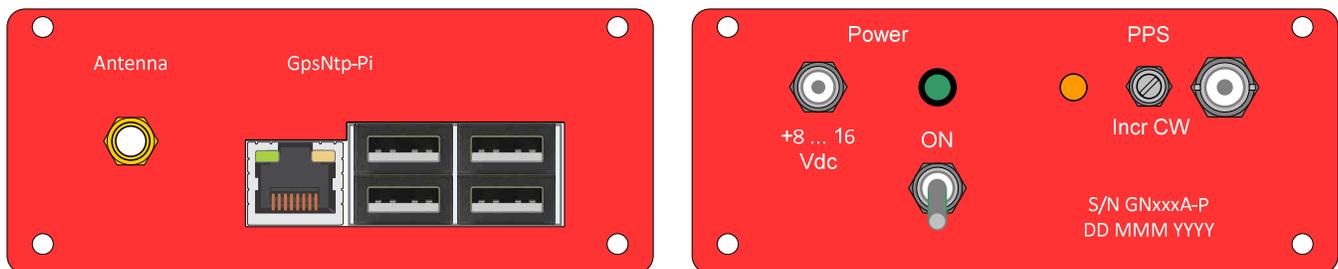
8. Turn the power switch on (up). The green LED on the rear panel should light. The GpsNtp-Pi requires several tens of seconds to boot. Never remove power from the GpsNtp-Pi without first shutting down the software; see section 3.
9. Wait about 1 minute and then find the GpsNtp-Pi IP address on your network. Your router or DHCP server user interface may be used to discover the assigned IP address, or refer to sect. 4 of the installation and operation guide, ***Install a Secure Shell Terminal Program***. The hostname is GpsNtp-Pi.
10. The GpsNtp-Pi may require up to 30 minutes to start tracking satellites from a cold start at a new location. Tracking can be determined from the fix indicating LED or optional PPS LED; see section 3. After tracking has started, the GpsNtp-Pi may require several hours for the NTP to learn clock characteristics and provide low offset. Refer to the documents referenced in section 1 for additional details.
11. Enter the IP address you discovered in the previous step in your client PC's time server list. For testing, delete or comment out all other time servers. Depending on your NTP client software, you can force immediate synchronization of the client PC with the GpsNtp-Pi. Confirm synchronization of the client PC at intervals determined by your NTP client program. It may be necessary to open network port 123 (the NTP port) on your Windows firewall or network router or both.

3. Additional Details

Identification: There are small variations in manufactured GpsNtp-Pi units, the most significant being the type of GNSS receiver. Either a uBLOX receiver from HAB Supplies or a GTop receiver from Adafruit may be used, but all except some early units use the GTop receiver. Other receivers may be used in future versions. The receiver type is identified by the serial number suffix on the GpsNtp-Pi rear panel. Currently, the suffixes are A for Adafruit and H for HAB Supplies, as in GNxxxA or GNxxxH. Serial numbers of units with the PPS option (see below) have – P appended to the end of the serial number, as in GNxxxA-P or GNxxxH-P.

Enclosure color: Enclosures with various colors are used during manufacture including blue, red, green and gold.

Panel drawing: The drawing shows the layout of manufactured units including the PPS option (see below).



Power Input: Power is connected through a 2.1 x 5.5 mm coaxial dc power jack on the rear panel. The corresponding plug supplied with the GpsNtp-Pi is a locking type and it must be soldered to a 2-conductor power cable by the user. The plug will accept up to 18 AWG stranded wire and is wired center positive. The power on/off switch and power indicating LED also are on the rear panel. Voltage range is 8 to 16 Vdc and requires ≥ 5 W power supply.

Power cycle: Never cycle, turn off or remove power to the GpsNtp-Pi without first shutting down the software (see next item). If the software becomes corrupted by improper shutdown, it will have to be reloaded onto the micro-SD card (see below for access to the micro-SD memory card on the Raspberry Pi platform).

Login and shutdown: Eventually you will need to log into the GpsNtp-Pi using an SSH terminal. Manufactured units use the following default user and password:

User: **pi**

Password: **GpsNtp-Pi**

In order to shut down, you will need to install a secure shell (SSH) terminal program on your PC, log into the GpsNtp-Pi and shut it down. Sect. 4 of the installation guide describes installing a suitable SSH terminal program. You will need to login with the user and password noted above. Once logged in enter at the prompt:

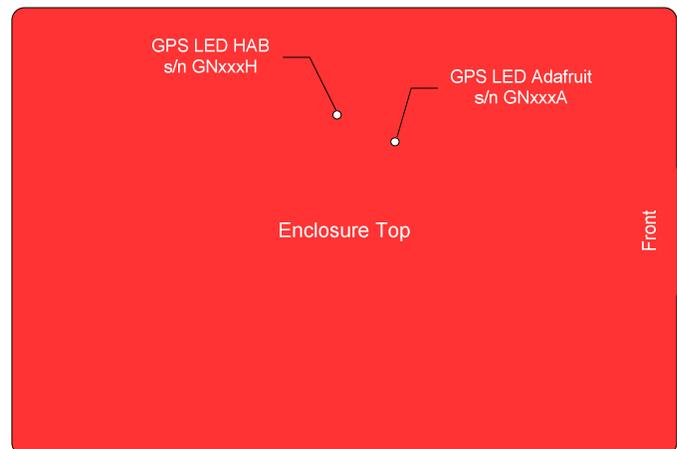
```
sudo halt
```

or

```
sudo shutdown -h now
```

Raspberry Pi power and activity LEDs: The power and CPU activity LEDs on the Raspberry Pi printed circuit board are not visible in the GpsNtp-Pi. The fix indicating LED on the GNSS receiver is visible as explained in the next item.

Position Fix indicating LED: The red fix indicating LED may be seen through the small (1.5 mm) hole on the top of the enclosure – see image right. Look straight down on the enclosure. For the Adafruit receiver, while attempting to obtain a position fix, the LED flashes 1 per second. When the receiver has obtained a fix and is tracking, the LED flashes 1 per 15 seconds. When the GpsNtp-Pi is first powered up at a new location, the initial fix can require from < 1 minute to tens of minutes depending on the number of satellites in view. Once the receiver has obtained a fix at a given location, subsequent fixes after a power cycle will require only a few seconds but this can vary with the number of satellites in view. See also next item.



Optional PPS output: Manufactured units equipped with the PPS output option can be recognized by the LED, screwdriver adjust trimmer resistor and 3.5 mm or BNC-F output jack on the rear panel. Also, the serial number has the -P suffix as noted above. Only units with Adafruit receivers have the PPS option. When the GpsNtp-Pi receiver is tracking satellites, the LED will flash at a 1 Hz rate. The output level is set to a no-load voltage 100 mVpk during manufacture but it can be adjusted from approximately zero to 3.0 Vpk with the trimmer resistor. The PPS is capacitor coupled to the output jack. Note that the GPS receiver and PPS indicating LED are not controlled by the RPI platform; thus, as long as power is available to the receiver and the antenna is in view of satellites, the PPS provides an output.

Antenna location: The best location for the antenna is above all obstructions and with a clear view of the southern sky. If the GpsNtp-Pi cannot obtain a fix or cannot continually track satellites, the antenna will need to

be moved to a location with a better view of the sky. The supplied cable is 3 m long. If the antenna is located beyond the available length, an extension cable will be needed that has an SMA-F connector on the antenna end and SMA-M connector on the receiver end. The cable should be LMR-195 (or equivalent) or larger; do not use RG-58 type coaxial cable because of its very wide quality variations. Satellite status can be viewed with built-in software tools, either `gpsmon` or `cgps`. Once logged in to the RPi console enter at the prompt:

```
gpsmon
```

or

```
cgps -s
```

To exit both tools, enter CTRL-C.

Network connection: All manufactured GpsNtp-Pi are setup for a wired LAN with DHCP via the 10/100BaseT Ethernet connector on the front panel. The user's LAN router or DHCP server should be setup to reserve an IP address for the GpsNtp-Pi. Alternately, the GpsNtp-Pi can be setup to use a static IP address (see next item). In either case, the assigned IP address is used in the NTP client PCs as described below. A reserved or static IP address will prevent loss of NTP client PC synchronization if the GpsNtp-Pi address is inadvertently changed by the router or DHCP server.

Static IP: To setup the GpsNtp-Pi with a static IP address, see ***Setup Static IP Address on Raspberry Pi*** [{RPIStatic}](#).

Wireless LAN: The user can add wireless LAN access to the GpsNtp-Pi. Due to the nature of WLANs, a GpsNtp-Pi using only a wireless connection will serve time with higher jitter than a wired connection. It is suggested that the GpsNtp-Pi initially be used in its original configuration (wired LAN) for familiarization and to verify operation. After operation has been verified, then changes can be made. See ***Setup Wireless LAN (WLAN) on Raspberry Pi*** [{RPIWAN}](#).

Leap seconds: All manufactured GpsNtp-Pi include the latest leap second file available at time of delivery. Leap second data is updated by various administrations at six month intervals, so leap second additions are announced six months prior to their effect. The user should keep the most current leap-second file on the GpsNtp-Pi at all times. See sect. 9 of the installation guide for details.

Final adjustments: The shared memory serial data (refid GPSD) reference clock in the GpsNtp-Pi may need adjustment after the GpsNtp-Pi is installed in its working environment. See sect. 10 of the installation guide. If the GpsNtp-Pi is to be used with a time server pool, see sect. 11 of the installation guide.

Week Number RollOver (WNRO): The GPS receivers used in the GpsNtp-Pi have a date and time operating limit of 1024 weeks after firmware build (receiver manufacturer). This means that a receiver manufactured in 2014 will not suffer a WNRO problem until after 2034. There is no easy way to determine when the receivers used in the GpsNtp-Pi were manufactured but they were purchased new in 2015, 2016 and 2018. The GTop receiver uses an embedded MT3339 receiver, which was first announced by its original equipment manufacturer in June 2011. Therefore, worst-case WNRO problem would be 2031 earliest.

NTP daemon patch level: Manufactured units are shipped with patch levels determined at the time of manufacture but generally no later than v4.2.8p8. Later patch versions have been found to be incompatible with

the GpsNtp-Pi configuration. Use the NTP query tool to determine the patch level. Login to the RPi console and enter:

```
ntpq -crv
```

Look for something like `version="ntpd 4.2.8p8@1.3265 Tue Nov 20 17:22:10 UTC 2018 (1)"`, which indicates NTPD version 4.2.8, patch 8. See installation guide for additional details on the NTP query tool. Other useful reference information is provided in the **Appendix** and also [{NTPQ-1}](#) and [{NTPQ-2}](#).

Operating system: The GpsNtp-Pi uses the Raspbian version of Debian 7 - Wheezy.

4. Setup Client PC for NTP

Many NTP client software applications are available that can use the GpsNtp-Pi time server. It is necessary to specify the GpsNtp-Pi's IP address (determined above) in the client software. The client software should be setup to open and synchronize whenever the PC is started.

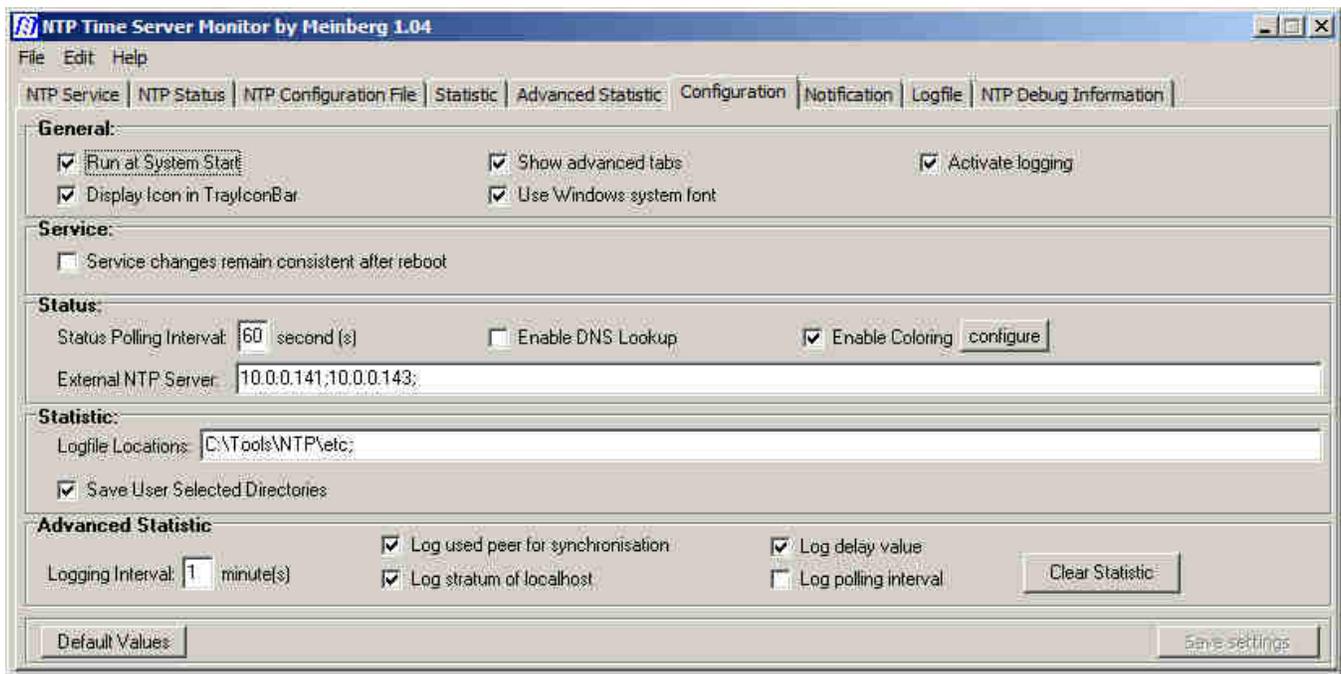
It is recommended that the Meinberg **NTP Time Server Monitor** software be used on client PCs; instructions for downloading and installing this program can be found at [{NTPInstall}](#) and instructions for its use can be found at [{Meinberg}](#). This software allows easy access to client statistics and logs and modification to the NTP configuration file (`ntp.conf`) on a Windows PC. Use the **NTP Time Server Monitor** on the client PC to change the NTP configuration file to use the GpsNtp-Pi IP address.

Note that the NTP daemon (NTPD) used on Windows PCs is simply a version compiled for Windows and is operationally identical to the Linux NTPD in the GpsNtp-Pi. It is possible a client PC does not have NTP installed. This will be apparent when the **NTP Time Server Monitor** is run because a warning window pops up. If it is necessary to install NTP on your PC, see [{NTPInstall}](#).

To setup the GpsNtp-Pi time server in the NTP configuration file, add the GpsNtp-Pi server details anywhere in the file. You can access and edit the configuration file under the NTP Configuration File tab in **NTP Time Server Monitor**. The example below shows three GpsNtp-Pi servers with one of them commented out (unused) with the hash character `#`. Be sure to use the IP address for your own GpsNtp-Pi rather than those shown in this example. If you have only one GpsNtp-Pi, you will add only one line (plus the comment line, which will help you later if you need to troubleshoot the GpsNtp-Pi):

```
# Use specific NTP servers
server 10.0.0.143 iburst
# server 10.0.0.141 iburst
server 10.0.0.131 iburst
```

The screenshot below shows the example servers on the Configuration tab after they were entered in the configuration file. This tab also can be used to set the NTP status polling interval (60 seconds is shown) and activate statistics. The Meinberg default setting is 10 seconds. There is no apparent harm in using shorter intervals (except more LAN traffic).



For testing purposes, comment out the existing time server pools specified in the NTP configuration file. The comment character # can be removed later if desired:

```
# Use a NTP server from the ntp pool project (see http://www.pool.ntp.org)
# Please note that you need at least four different servers to be at least protected against
# one falseticker. If you only rely on internet time, it is highly recommended to add
# additional servers here.
# The 'iburst' keyword speeds up initial synchronization, please check the documentation for
# more details!
# server 0.us.pool.ntp.org iburst
# server 1.us.pool.ntp.org iburst
# server 2.us.pool.ntp.org iburst
```

If a server pool is to be used along with the GpsNtp-Pi server, it is recommended that the global NIST time server address (time.nist.gov) be used in the USA rather than the ntp.org pools. See [{NIST}](#) for a brief description of how the global address works. The NIST time servers are implemented by entering the following in the NTP configuration file immediately after the GpsNtp-Pi time server address (this location is for convenience and is not critical):

```
# NIST time server global address
server time.nist.gov iburst
```

There are other optional parameters in the NTP configuration file. For a brief overview of other optional parameters in the NTP configuration, download the “NTP Cheatsheet” [{NTPCheat}](#) or refer to the NTP documentation. After changing the configuration file, be sure to save it.

5. Maintenance

The GpsNtp-Pi requires no regular maintenance other than to clean dust from the enclosure.

Cleaning: Use a soft damp cloth with special care around the panel labels; never use chemicals.

Memory card access for backup: If it is necessary to access the Raspberry Pi (RPi) micro-SD memory card inside the enclosure follow these procedures for units that do not have the PPS option; see below for units with the PPS option:

1. Place the GpsNtp-Pi on a shop cloth on the workbench. The enclosure is a tubular aluminum extrusion and the RPi printed circuit is accessed through the ends;
2. Turn the enclosure upside down and remove the four front panel screws. All manufactured GpsNtp-Pi use self-threading Torx T10 screws. The SMA-F antenna connector on the front panel is connected by a small coaxial cable to the U.FL miniature RF connector on the receiver board. This connector has limited cycle life so do not unnecessarily disconnect and reconnect the PCB end of the cable. After the panel screws have been removed do not pull on the panel or cable; allow the panel to sit loosely on the workbench;
3. Remove the four M2.5 x 6 mm (some units have M3.0 x 6 mm) screws and washers that hold the RPi to the enclosure bottom near the enclosure front. While removing the screws, reach inside and hold the receiver to prevent it falling inside the enclosure. In addition to the RF cable the RPi has a connectorized cable to the power supply near the enclosure rear. Also, units equipped with the optional PPS output have a cable from the GPS mezzanine board to the rear panel. Do not pull on these cables;
4. Carefully move the RPi toward the enclosure opening far enough to access the micro-SD memory card on its rear underside. The card is push to insert/push to eject. When removing the card, note its orientation and be sure to replace it with the same orientation. Do not force the card;
5. If it is necessary to reload the software image, follow the procedures in ***Raspberry Pi Backup and Restore Procedures*** {[RPiBackup](#)};
6. After reinserting the memory card in the RPi, reassemble the enclosure in the reverse order. Carefully move the RPi printed circuit board to line-up the screw holes on the enclosure bottom and replace the screws and washers. To prevent cross-threading, insert the screw and slowly turn it counter-clockwise until you hear a click. The threads are now engaged. Carefully turn the screw clockwise until snug against the enclosure. Now, put the front panel in position and replace the screws using the same procedure: Insert the screw and slowly turn it counter-clockwise until you hear a click, then carefully turn the screw clockwise until snug against the panel.

For units with the PPS option, it is necessary to add the following to steps 3 and 6 in the above procedure:

3. Reach in with fingers and an insulated wire chasing tool and disconnect the PPS cable (yellow and black leads). It is friction lock and polarized.
6. After remounting the RPi but before replacing the front panel, reconnect the PPS cable. Use your fingers and a wire chasing tool to guide the connector into locked position.

6. References

{GNPDesc} http://www.reeve.com/Documents/Articles%20Papers/Reeve_GpsNtp-Pi.pdf

{GNPiSetup} http://www.reeve.com/Documents/Articles%20Papers/Reeve_GpsNtp-Pi_Setup.pdf
{Meinberg} http://www.reeve.com/Documents/Articles%20Papers/Reeve_MeinbergMonGuide.pdf
{NIST} <https://tf.nist.gov/tf-cgi/servers.cgi>
{NTPCheat} <https://www.meinbergglobal.com/english/sw/ntp.htm>
{NTPInstall} http://www.reeve.com/Documents/Articles%20Papers/Reeve_NTP-MeinMon_Install.pdf
{NTPQ-1} <http://doc.ntpq.org/4.1.0/ntpq.htm>
{NTPQ-2} <https://www.eecis.udel.edu/~mills/ntp/html/ntpq.html>
{RPIBackup} http://www.reeve.com/Documents/Articles%20Papers/Reeve_RPi_BackupRestore.pdf
{RPIStatic} http://www.reeve.com/Documents/Articles%20Papers/Reeve_RPi_StaticIP.pdf
{RPIWAN} http://www.reeve.com/Documents/Articles%20Papers/Reeve_RPi_WLANSetup.pdf

Appendix

NTP Query *Billboard* Details (ntpq -crv) (example below)

Variable	Description
status	system status word
version	NTP software version and build time
processor	hardware platform and version
system	operating system and version
leap	leap warning indicator (0-3)
stratum	stratum (1-15)
precision	precision (log2 s)
rootdelay	total roundtrip delay to the primary reference clock
rootdisp	total dispersion to the primary reference clock
peer	system peer association ID
tc	time constant and poll exponent (log2 s) (3-17)
mintc	minimum time constant (log2 s) (3-10)
clock	date and time of day
refid	reference ID or kiss code
reftime	reference time
offset	combined offset of server relative to this host (ms)
sys_jitter	combined system jitter (ms)
frequency	frequency offset relative to hardware clock (PPM)
clk_wander	clock frequency wander (PPM)
clk_jitter	clock jitter (ms)
tai	TAI-UTC offset (s)
leapsec	NTP yyyyymmddssss when the next leap second is/was inserted
expire	NTP yyyyymmddssss when the NIST leapseconds file expires

```
pi@GpsNtp-Pi: ~  
pi@GpsNtp-Pi ~ $ ntpq -crv  
associd=0 status=0115 leap_none, sync_pps, 1 event, clock_sync,  
version="ntpd 4.2.8p3@1.3265 Mon Oct 12 21:41:15 UTC 2015 (1)",  
processor="armv6l", system="Linux/4.1.10+", leap=00, stratum=1,  
precision=-18, rootdelay=0.000, rootdisp=1.105, refid=KPPS,  
reftime=dfa32688.0350ba82 Sat, Nov 24 2018 1:23:20.012,  
clock=dfa3268f.712f37b0 Sat, Nov 24 2018 1:23:27.442, peer=410, tc=4,  
mintc=3, offset=-0.000885, frequency=-13.155, sys_jitter=0.003815,  
clk_jitter=0.004, clk_wander=0.000, tai=37, leapsec=201701010000,  
expire=201706010000  
pi@GpsNtp-Pi ~ $
```

NTP Query Peers Details (ntpq -p) (example below)

Remote: Peers specified in the NTP configuration (ntp.conf) file

- * Remote peer or server presently used as the primary reference
- # Source selected, distance exceeds maximum value
- o PPS peer; system synchronization is derived from a pulse-per-second (PPS) signal, either indirectly via the PPS reference clock driver or directly via the kernel interface
- + Source selected, included in final set
- x Source false ticker, out of tolerance
- . Source selected from end of candidate list
- Source discarded by cluster algorithm
- blank Source discarded high stratum, failed sanity

refid: Remote synchronization source

stratum: Stratum level of the source

t: Types available

- l local (such as a GPS, WWVB)
- u unicast (most common)
- m multicast
- b broadcast
- netaddr

when: When last polled (s)

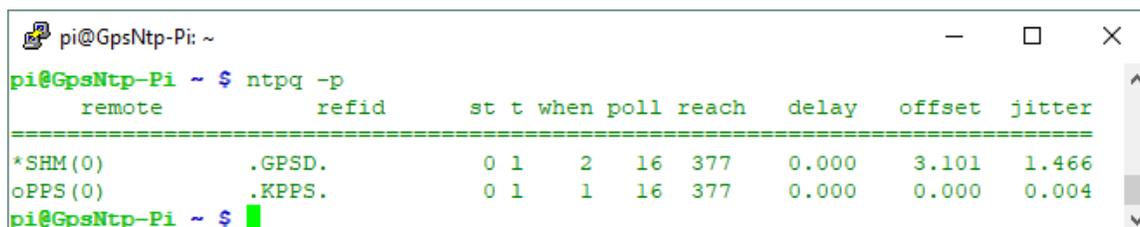
poll: Source polling interval (s)

reach: Octal 8-bit left-shift register value recording polls (bit set = successful, bit reset = fail)

delay: Round trip delay to the remote peer or server (ms)

offset: Mean offset (phase) in the times reported between this local host and the remote peer or server, positive for 'remote time' ahead of 'local time' (ms)

jitter: Mean deviation (jitter) in the time reported for the remote peer or server, rms of difference between multiple time samples (ms)



```
pi@GpsNtp-Pi: ~  
pi@GpsNtp-Pi ~ $ ntpq -p  
-----  
remote          refid          st t when poll reach  delay  offset  jitter  
-----  
*SHM(0)         .GPSD.         0 1  2  16 377  0.000  3.101  1.466  
oPPS(0)         .KPPS.         0 1  1  16 377  0.000  0.000  0.004  
pi@GpsNtp-Pi ~ $
```

Document information

Author: Whitham D. Reeve

Copyright: © 2015, 2018 W. Reeve

Revision: 0.0 (Original draft started, 10 Oct 2015)
0.1 (Final changes for distribution, 12 Oct 2015)
1.0 (Distribution, 12 Oct 2015)
1.1 (Minor clarifications, 16 Oct 2015)
1.2 (Revised shutdown item, 18 Oct 2015)
1.3 (Minor edits to Maintenance, 10 Nov 2015)
1.4 (Updated reference to leap seconds and minor edits, 28 Jul 2016)
1.5 (Added comments about antenna cable extension, 28 Jul 2018)
1.6 (Added panel drawing and PPS option description, 14 Aug 2018)
1.7 (Added week number rollover, 27 Aug 2018)
1.8 (Added NTP patch level info and minor edits, 12 Nov 2018)
1.9 (Added GPS software tools, 18 Nov 2018)
2.0 (Added Appendix, 23 Nov 2018)
2.1 (Revised memory card removal/replacement procedures for PPS option, 26 Nov 2018)
2.2 (Added NIST time server global address, 06 Jul 2019)

Word count: 3687

File size: 3885056