GPS Disciplined NTP

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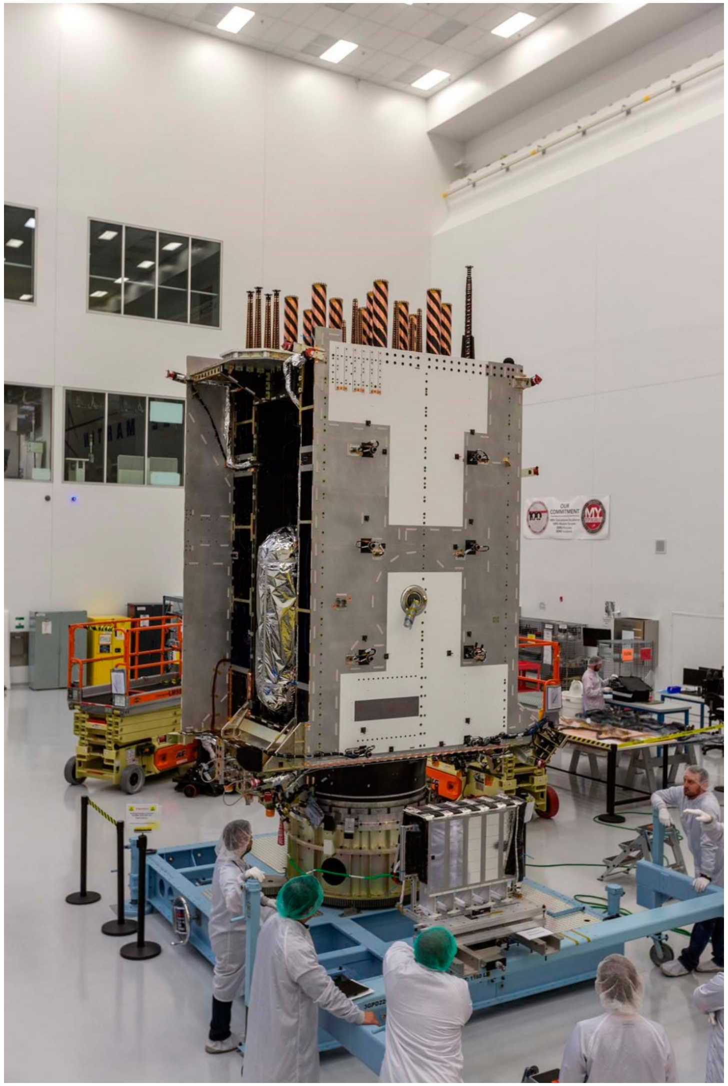
GPS Time

- The US GPS system is made up of a constellation of satellites in orbit to provide seamless coverage of the entire globe.
- Currently 31 satellites are in orbit with a minimum of 24 required for operation.
- By comparing the time based signals sent from each satellite a GPS receiver can triangulate its position on the earth.
- In order to accomplish this location calculation, the GPS receiver must synchronize its internal clock with the received GPS signals.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GPS Receivers

- All GPS receivers must be able to accurately synchronize their internal clock in order to function, but not all chipsets make this available externally.
- PPS – Pulse per second is a function where the chipset will modulate an output pin at 1Hz synchronized to its internal clock.
- More advanced receivers can be configured to output at different frequencies above or below 1Hz
- Receivers typically interface via RS-232/UART. USB receivers are most often simple serial converters.

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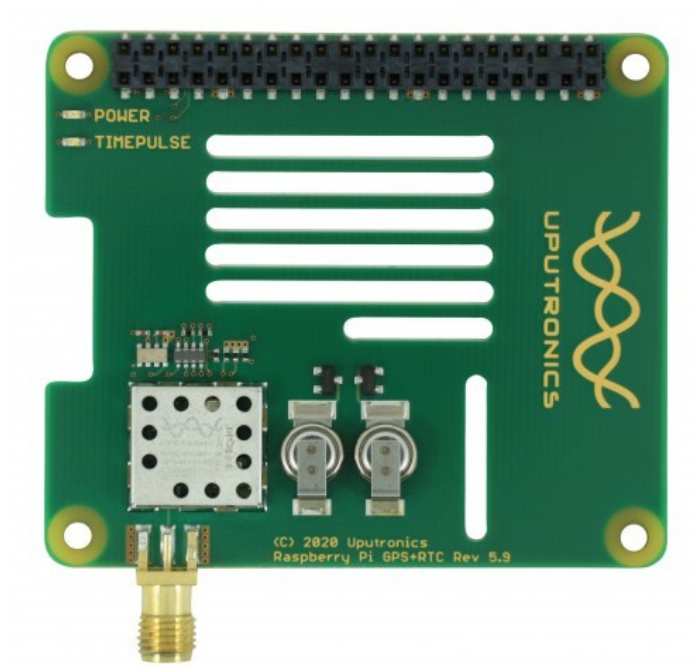

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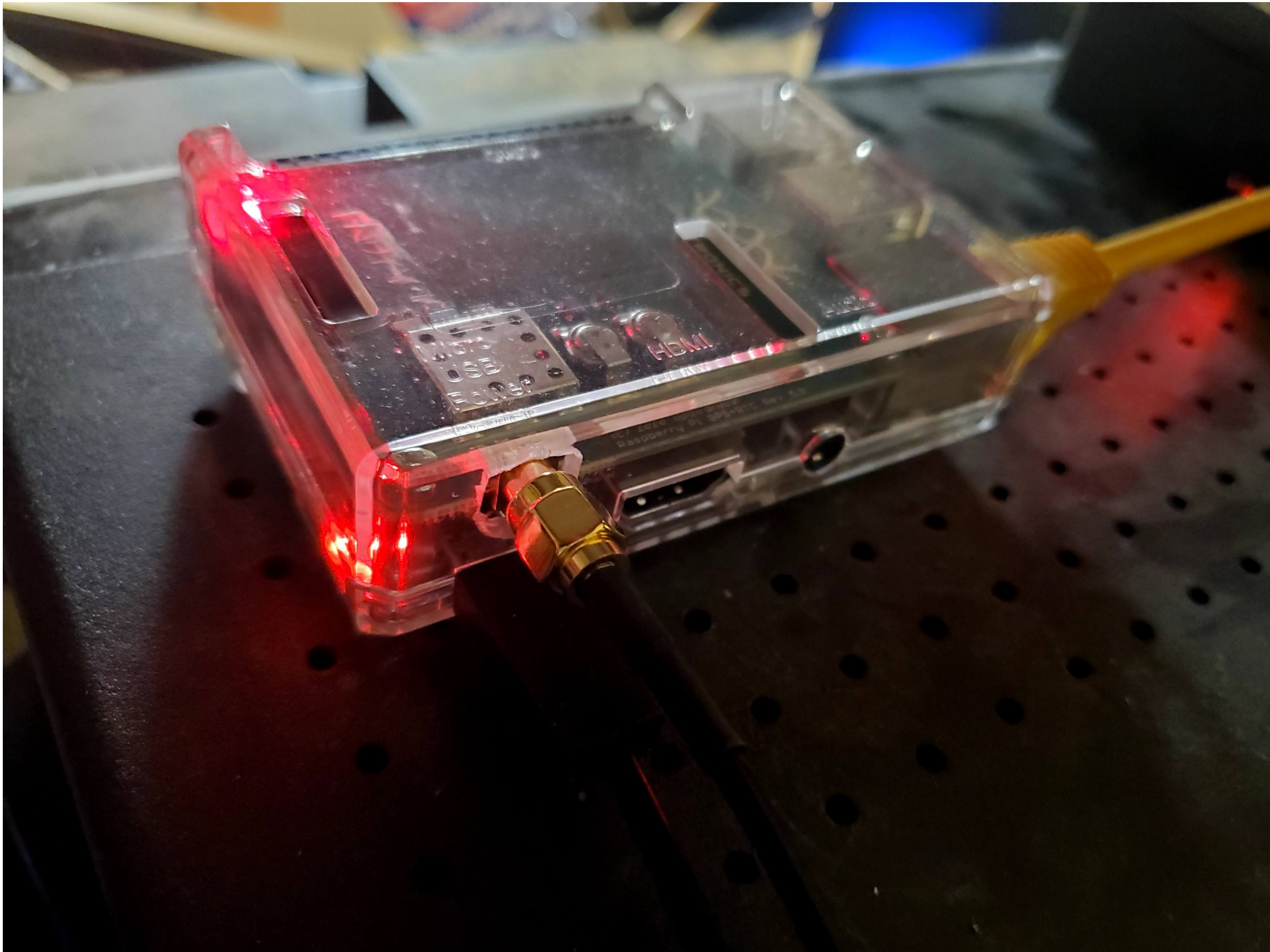

HDMI

Chipset Communication

- Several “Standards” have been established to define the communication protocols used by GPS chipsets.
- NMEA-0183 defines a standard set of ASCII messages that a receiver will output, and a standard format for sending control messages to the receiver.
- SiRF defines their own binary message and command format which is widely used and supported due to the prevalence of devices.
- Manufacturers provide full command references for modern chipsets.

GPS Signal Reception

- GPS satellites orbit at approximately 20,000KM above earth with a meager transmitter power of only 25W
- Received signal strength on earth is approximately -128dBm in ideal conditions.
- Nearly all receivers employ an active antenna which contains an internal amplifier to increase the level of received signal.
- At 1575Mhz cable loss is significant and must be accounted for when pairing a receiver with an antenna.

GPS L1 Link Budget

Satellite Tranmitter

Transmitter Power (25 Watts)	14.25 dBW	
RF Losses in trasmitter path	-1.25 dB	
Antenna Gain (with respect to an isotrope)	13.5 dBi	
Satellite EIRP (wrt isotropic radiator)	**26.50 dBW**	**446.68 Watts**

Propagation

Atmoshperic and Polarization Losses	-0.5 dB

$$\textit{Free Space Path Loss} = -10 \times \log_{10}\left[\left(\frac{4\pi d}{\lambda}\right)^2\right]$$

where d = distance from antenna =	2.52E+07 meters
c = speed of light =	3.00E+08 m/sec
f = frequency =	1.58E+09 Hz
lambda = wavelength = c/f =	1.90E-01 meters

$$= -10\log_{10}\left[3.17E{+}08 \big/ 1.90E{-}01\right]^2$$

$$= -10\log_{10}\left[1.67E{+}09\right]^2$$

Free Space Path Loss over Distance -184.43 dB

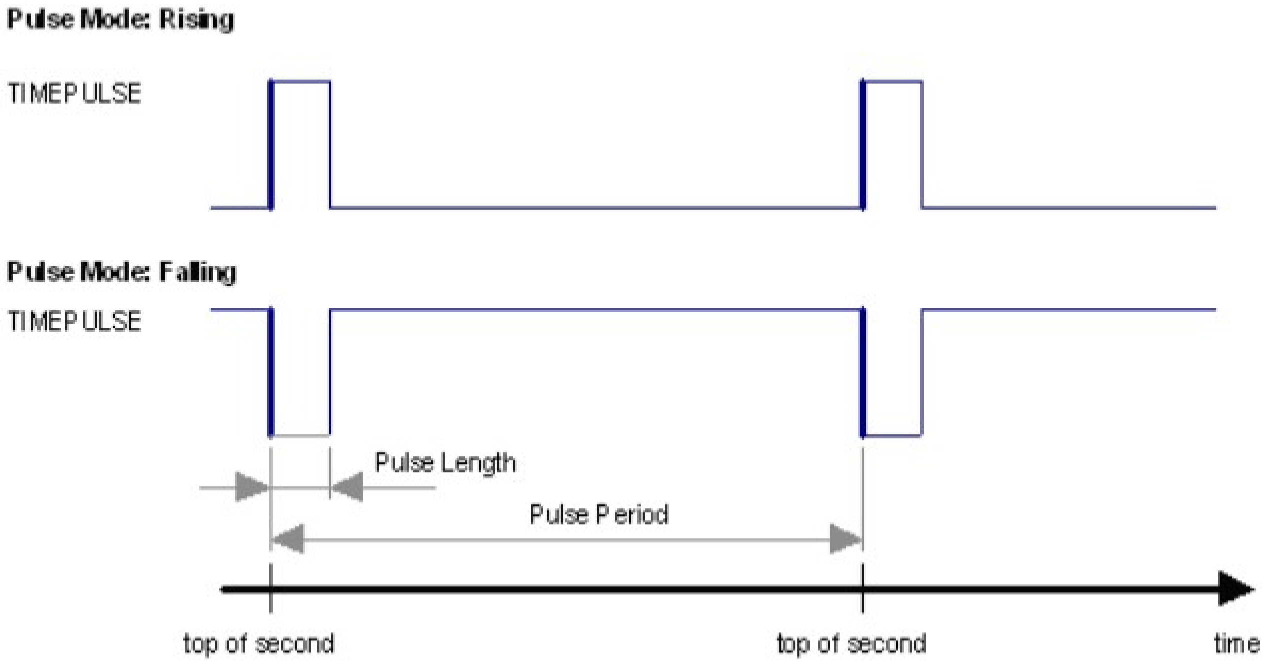
Received Power on Earth	**-158.43 dBW**	
	-128.43 dBm	**1.44E-04 pW**

GNSS		GPS	GLONASS
Horizontal position accuracy [3]	Autonomous SBAS	2.5 m 2.0 m	4.0 m
Max navigation update rate [4]		18 Hz	18 Hz
MAX-8Q Time-To-First-Fix [5]	Cold start	29 s	30 s
	Hot start	1 s	1 s
	Aided starts [6]	2 s	2 s
Sensitivity [7]	Tracking & Navigation	–166 dBm	–166 dBm
	Reacquisition	–160 dBm	–156 dBm
	Cold start	–148 dBm	–145 dBm
	Hot start	–157 dBm	–156 dBm
MAX-8C Time-To-First-Fix [5]	Cold start	30 s	33 s
	Hot start	1 s	1 s
	Aided starts [6]	3 s	3 s
Sensitivity [7]	Tracking & Navigation	–164 dBm	–163 dBm
	Reacquisition	–159 dBm	–156 dBm
	Cold start	–147 dBm	–145 dBm
	Hot start	–156 dBm	–155 dBm

Table 1: MAX-8 performance in different GNSS modes (default: single reception of GPS incl. SBAS and QZSS)

RaspberryPi I/O

- The Rpi's GPIO pins make it an excellent candidate for interfacing with a GPS chipset.
- UART serial used for receiving location data from the chipset and sending commands.
- i^2c used to communicate with the internal RTC in the chipset
- Pulse per second sends logic high to selected GPIO pin



Time Pulse Graph Copyright, ublox

GPSd

- Many implementation guides for GPS time include the use of GPSd to read the time signals from the receiver.
- Serial devices are typically exclusive access which limits you to a single consumer on the system.
- GPSd provides a standard socket interface that provides time and location data in JSON format.
- By distributing the data with GPSd multiple services can consume the location data simultaneously.
- To achieve accurate distribution of PPS data, GPSd uses shared memory segments.

NTP Configuration

- NTP has built in support for many types of reference clocks, including GPS & PPS.
- PPS alone cannot provide the current time to NTP.
- For NTP to function fully there must be a second source of “full time” in addition to the PPS signal.
- Secondary time can be provided by GPS, or even another NTP server.
- The secondary time source does not need to be precisely accurate as long as it stays within the PPS timing.

Limitations

- Antenna unknowns
- Receiver unknowns
- OS Jitter
- Network Jitter
- Temperature changes
- User error