TangerineSDR Clock Module Requirements and GPS Performance Testing

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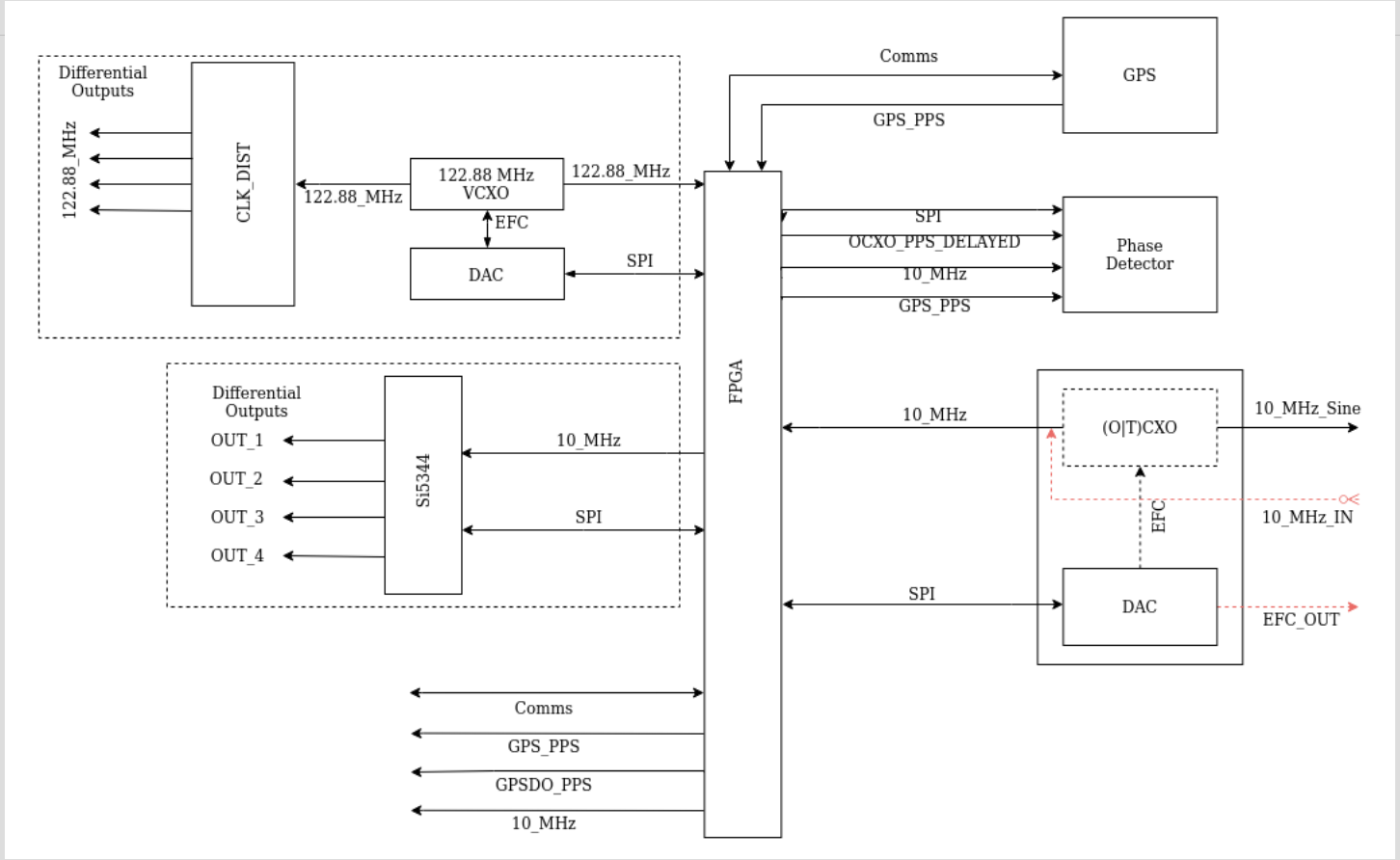
Clock Module Overview

- GPS Disciplined Oscillator with outputs:
  - 122.88 MHz for receiver ADC and transmitter DAC
  - 1 PPS for timestamping
  - TOD message
  - (Optional) 10 MHz for external use
  - (Optional) Synthesized outputs from 100 Hz to 1024 MHz
- FPGA serves as a switch matrix (among other things).
- PCB can be populated with components appropriate for required performance or functionality
- **Usable separately from TangerineSDR** via interface board

Clock Module Hardware Block Diagram



Clock Module Performance Criteria

Clock Module Performance Criteria

Dear Scientists:
Please tell us what

(a) You *Want*
(b) You *Need*

Thank you.

Sincerely,
The Engineers

Clock Module Performance Criteria

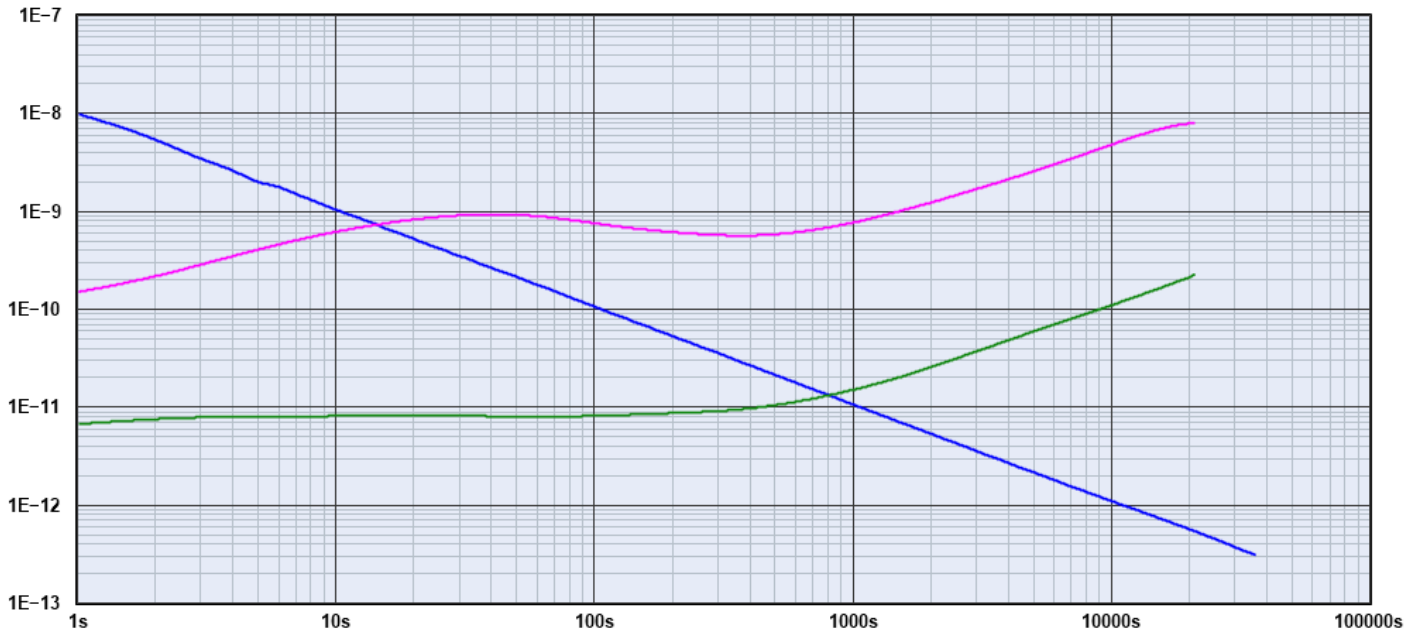
- Frequency Accuracy/Long Term Stability (vs. NIST)
  - How closely does the frequency follow USFS on average?
- Short-term Frequency Stability
  - How much does the signal wander over seconds/minutes/hours?
- Phase Noise
  - How much phase modulation is on the ADC/DAC clock source?
- Timestamp Accuracy (vs. USNO)
  - How closely does TangerineTime track USNO?
- Timestamp Stability
  - How much jitter does the timestamp have?

Clock Module Performance Criteria

- **Frequency Accuracy/Long Term Stability**
  - In GPSDO, typically limited by GPS system capability but in freestanding system, XO aging is dominant
  - **Parts in 10^{13} realistic over 24 hours with GPS**

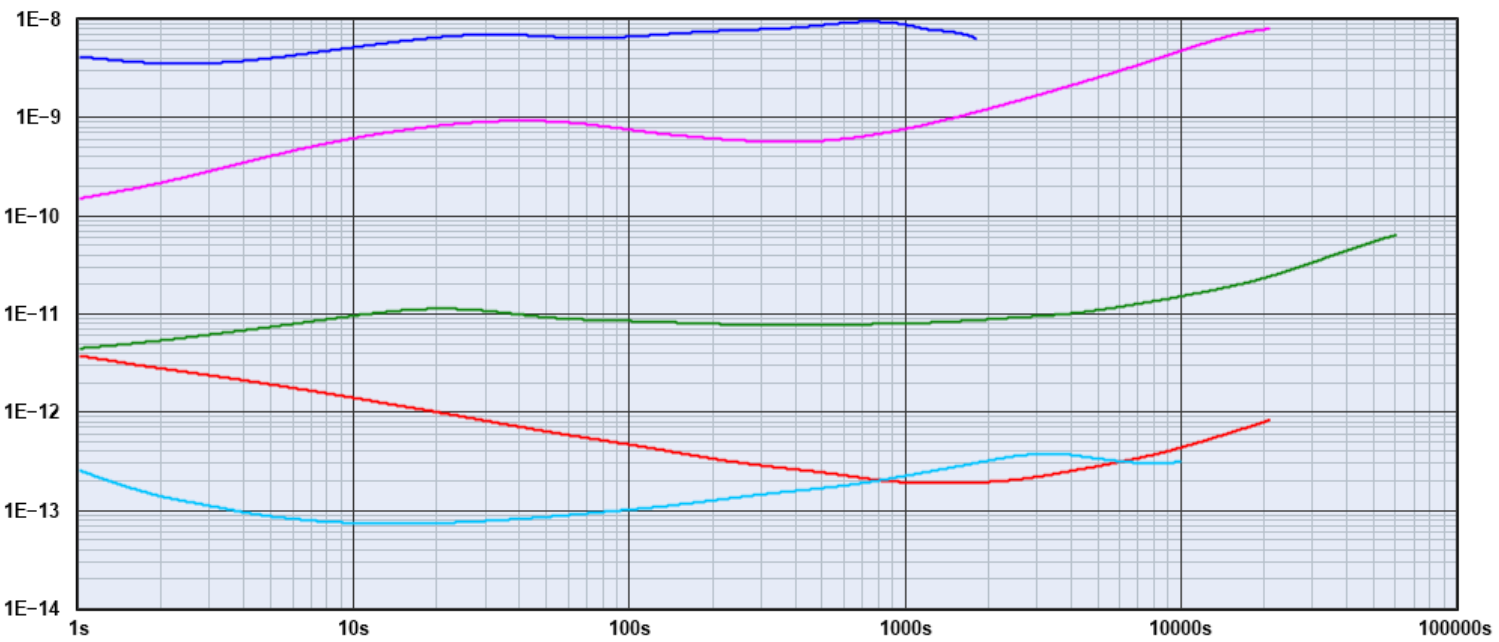
- **Short-term Frequency Stability**
  - How much does the signal wander over seconds/minutes/hours?
  - Dependent on quality of oscillators, (=$$$)

What a GPSDO Does



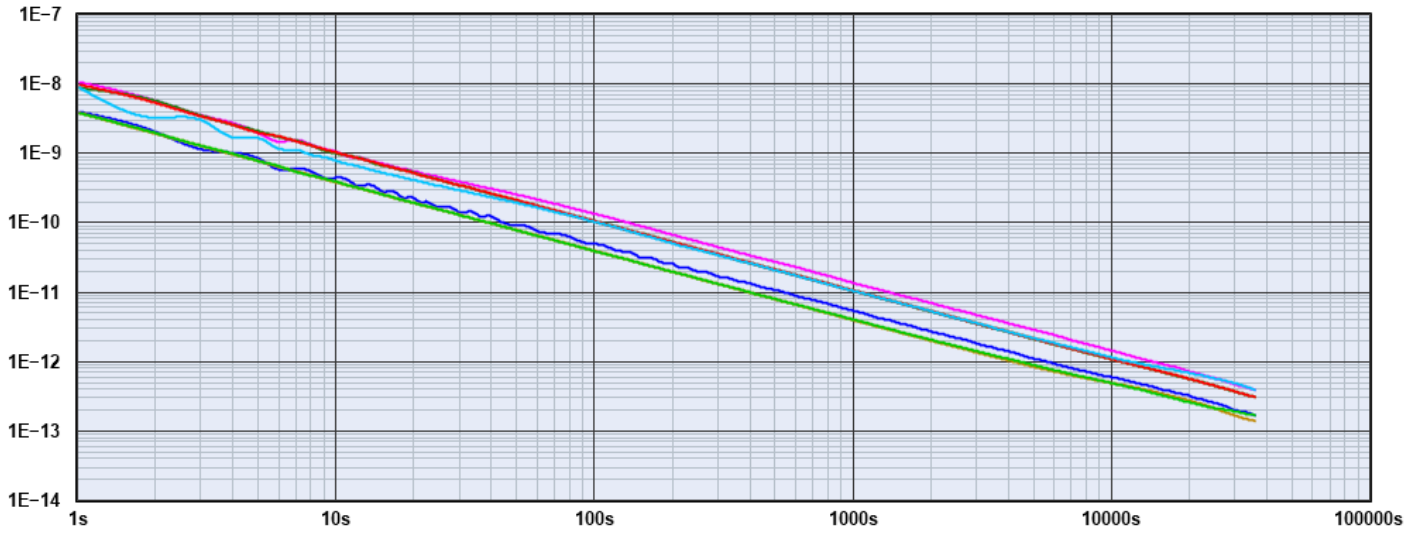
Trace	Notes	Sample Interval	Duration	Acquired	Instrument
NEO-M8T (Unsaved)	vs HP 5071A	1 s	1d 17h 55m 3s	150903 pts	multi-TICC
Crystek CHOX-20 TCXO	vs. HP 5071A	1 s	1d 0h 0m 0s	86400 pts	TimePod 5330A
Isotemp OCXO131-100 OCXO	vs. HP 5071A	1 s	1d 0h 0m 0s	86400 pts	TimePod 5330A

Typical Oscillator Short Term Stability



Trace	Notes	Input Freq	Sample Interval	Acquired
Hermes v3.3 Free Run	vs HP 5065A	14.2 MHz	1 s	7200 pts
Crystek CHOX-20 TCXO	vs. HP 5071A	10.000 MHz	1 s	86400 pts
Isotemp OCXO130-100	vs. HP5065A	10.000 MHz	1 s	259200 pts
RFG-M-RB	vs. OSA 8607-008 BVA	10.000 MHz	1 s	86400 pts
OSA 8607-008	vs. maser	5 MHz	1 s	43200 pts

uBlox GPS Receiver PPS Performance



Trace	Notes	Sample Interval	Duration	Acquired	Instrument
NEO-M8F (Unsaved)	vs HP 5071A	1 s	1d 17h 55m 3s	150903 pts	multi-TICC
NEO-M8N (Unsaved)	vs HP 5071A	1 s	1d 17h 55m 3s	150903 pts	multi-TICC
NEO-M8P (Unsaved)	vs HP 5071A	1 s	1d 17h 55m 3s	150903 pts	multi-TICC
NEO-M8T (Unsaved)	vs HP 5071A	1 s	1d 17h 55m 3s	150903 pts	multi-TICC
NEO-M9N (Unsaved)	vs HP 5071A	1 s	1d 17h 55m 3s	150903 pts	multi-TICC
ZED-F9P (Unsaved)	vs HP 5071A	1 s	1d 17h 55m 3s	150903 pts	multi-TICC
ZED-F9T (Unsaved)	vs HP 5071A	1 s	1d 17h 55m 3s	150903 pts	multi-TICC

Clock Module Performance Criteria

- **Phase Noise**
  - Phase modulation imparted to the ADC/DAC
  - Measured in dBc/Hz at offset frequencies from carrier
  - For TangerineSDR, dominated by 122.88 MHz signal source (VCXO or synthesizer)
  - **Realistic targets are:**
    - **About -100 to -115 dBc/Hz @ 100 Hz**
    - **About -145 to -160 dBc/Hz @ 100 kHz**

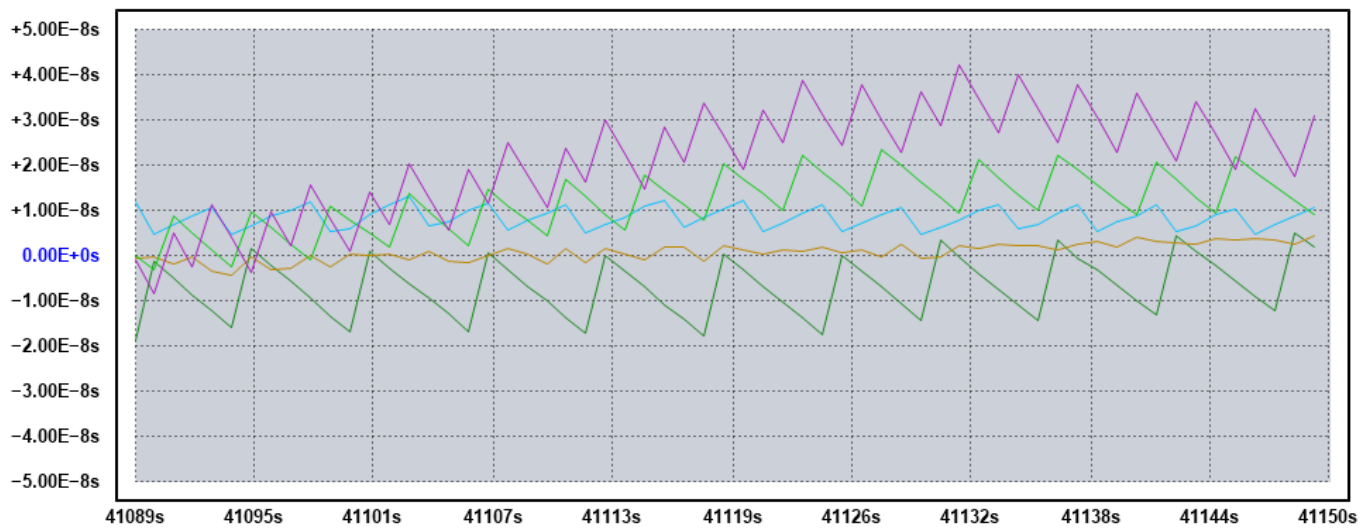
Clock Module Performance Criteria

- **Timestamp Accuracy**
  - Using low-cost GPS, relative to USNO:
    - **100 ns is easy**
    - **10 ns is hard but possible with user care**
    - **<10 ns is not practical in HamSci environment**

- **Timestamp Stability**
  - **Raw** GPS PPS has peak-to-peak, RMS, jitter ranging from about **4 to 20 ns** (occasional excursions 10x that)
  - GPSDO **smoothed** PPS can be **<4 ns** exclusive of logic and propagation delays, without larger excursions.
  - See next chart.

uBlox GPS Receiver PPS Performance

uBlox GPS Receiver PPS Performance



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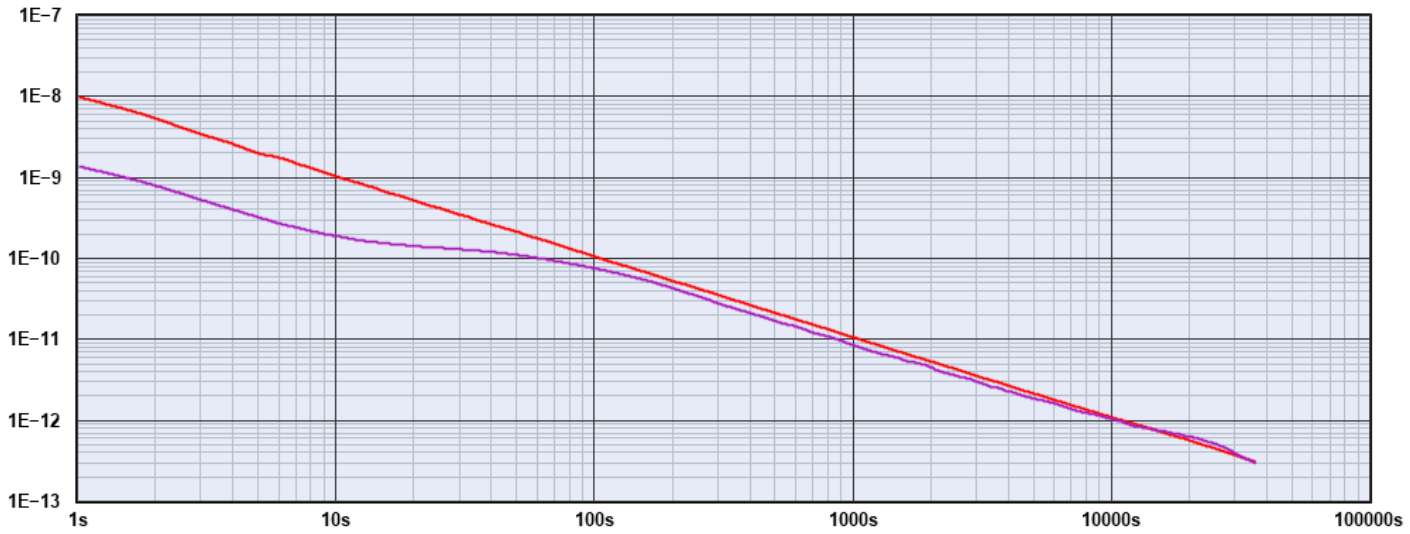
CNS-II	vs HP 5071A	1 s	1d 4h 10m 15s	101415 pts	multi-TICC
NEO-M8P (Unsaved)	vs HP 5071A	1 s	1d 4h 10m 37s	101437 pts	multi-TICC
NEO-M8T (Unsaved)	vs HP 5071A	1 s	1d 4h 10m 51s	101451 pts	multi-TICC
ZED-F9P (Unsaved)	vs HP 5071A	1 s	1d 4h 11m 1s	101461 pts	multi-TICC
ZED-F9T (Unsaved)	vs HP 5071A	1 s	1d 4h 11m 18s	101478 pts	multi-TICC
NEO-M8F (Unsaved)	vs HP 5071A	1 s	1d 4h 11m 28s	101488 pts	multi-TICC
NEO-M9N (Unsaved)	vs HP 5071A	1 s	1d 4h 11m 44s	101504 pts	multi-TICC
NEO-M8N (Unsaved)	vs HP 5071A	1 s	1d 4h 12m 2s	101522 pts	multi-TICC

uBlox GPS Receiver PPS Performance



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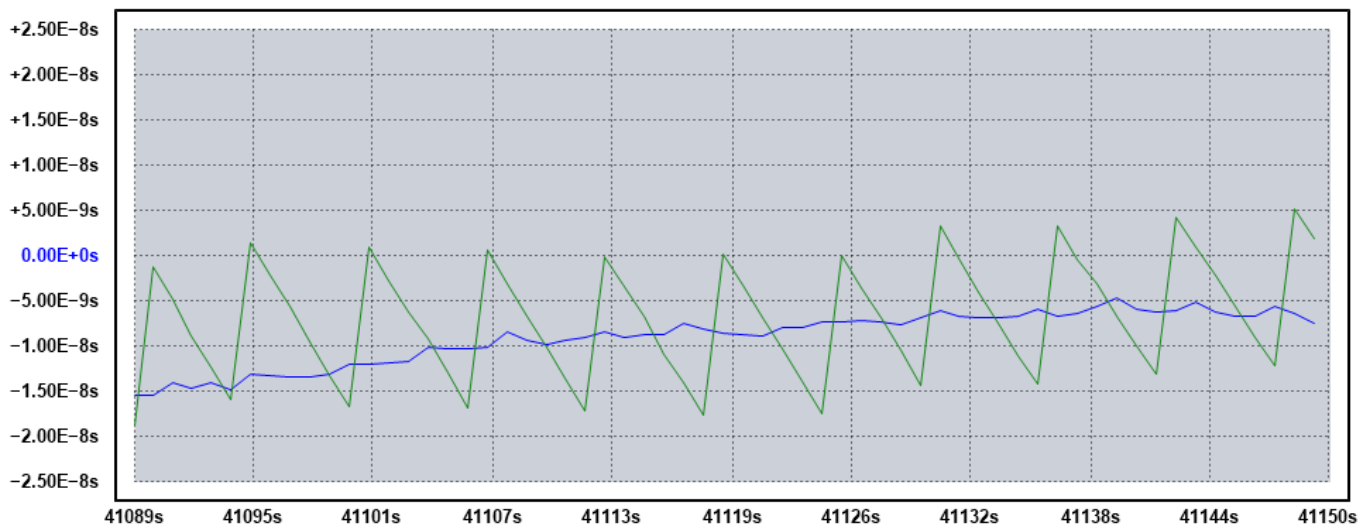

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