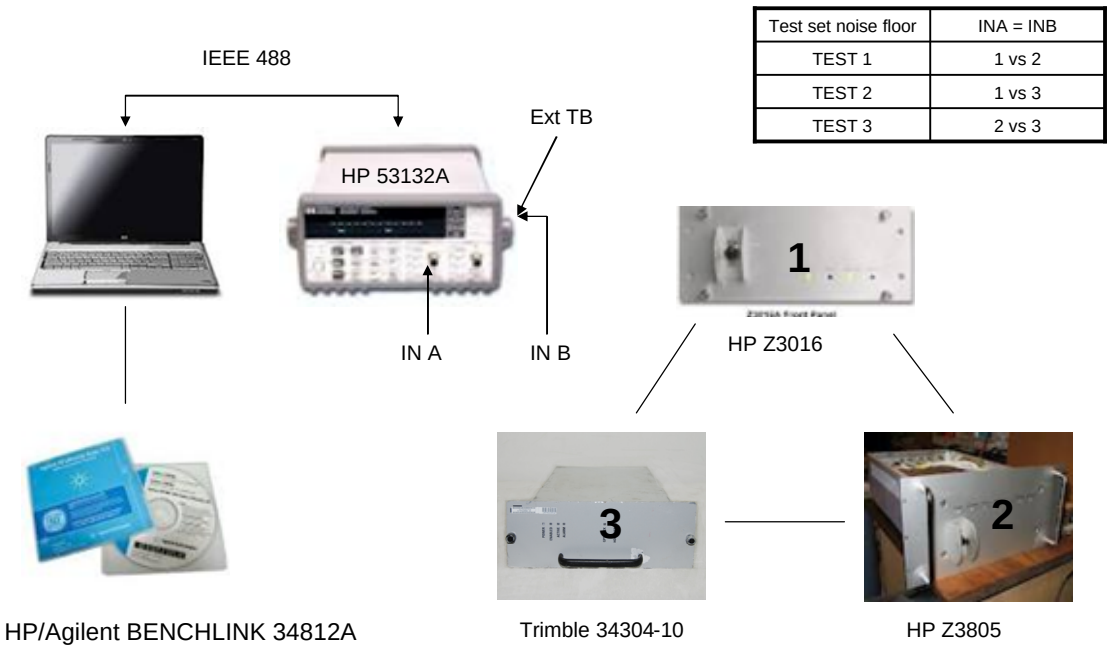
GPSDO frequency reliability

The accuracy of the GPS system for long-term observations is widely known and is a valuable aid in the calibration of remote references.

This study aims to analyze and identify the maximum precision obtained by a one shot frequency measurement using an GPSDO as reference. The published literature (1) states an uncertainty that varies from E-9 and E-13 for observation times ranging from short to long time (1 second up to 1 day and over).
To better check for errors related to a single model GPSDO, we compared three receivers, an HP3816, an HP Z3805 and a Trimble 34304-10.

The test set is described in the following figure:

Test set



Test set noise floor	INA = INB
TEST 1	1 vs 2
TEST 2	1 vs 3
TEST 3	2 vs 3

The software used is “Bench link” from HP, unfortunately obsolete, but that it' still a reliable and easy to use.

The tests were organized on two levels:

Level 1: Comparison of three different reference sources GPSDO.
Level 2: Frequency measure of an high-stability, low phase noise OCXO

Level 1

The GPSDO are numbered 1 through 3 to simplify the tables. Each GPSDO are compared with others in pairs using one as external time base of the time interval counter and the other in the A input. For each pair of GPSDO we have done 5 tests of 1 hour each.
In total we have 15 tests for a total duration of 15 hours.
These are the results:

Gate time 2 seconds
Each test duration 1 hour
GPSDO1 to 3 connected to the same antenna

GPSDO 1 HP Z3816
GPSDO 2 HP Z3805
GPSDO 3 Trimble 34304-10

TEST number	GPSDO	Min freq. Hz	Max freq. Hz	Mean freq. Hz	Standard deviation
1	1 vs 2	9999999.999710	10000000.00034	9999999.999987	0.014789016384
2	1 vs 2	9999999.999690	10000000.00020	9999999.999964	0.012885552842
3	1 vs 2	9999999.999700	10000000.00033	9999999.999947	0.016459138612
4	1 vs 2	9999999.999700	10000000.00019	9999999.999957	0.018001697105
5	1 vs 2	9999999.999650	10000000.00021	9999999.999961	0.012185127649
6	1 vs 3	9999999.999600	10000000.00037	9999999.999981	0.010658545216
7	1 vs 3	9999999.999420	10000000.00057	9999999.999420	0.017246808621
8	1 vs 3	9999999.999160	10000000.00060	9999999.999930	0.014780742808
9	1 vs 3	9999999.999680	10000000.00033	9999999.999983	0.008868445685
10	1 vs 3	9999999.999630	10000000.00039	9999999.999977	0.017378670610
11	2 vs 3	9999999.999660	10000000.00029	9999999.999982	0.014486162666
12	2 vs 3	9999999.999690	10000000.00030	9999999.999992	0.012195335330
13	2 vs 3	9999999.999700	10000000.00030	9999999.999986	0.012885552842
14	2 vs 3	9999999.999530	10000000.00029	9999999.999968	0.011449114148
15	2 vs 3	9999999.999710	10000000.00033	9999999.999981	0.008868445685

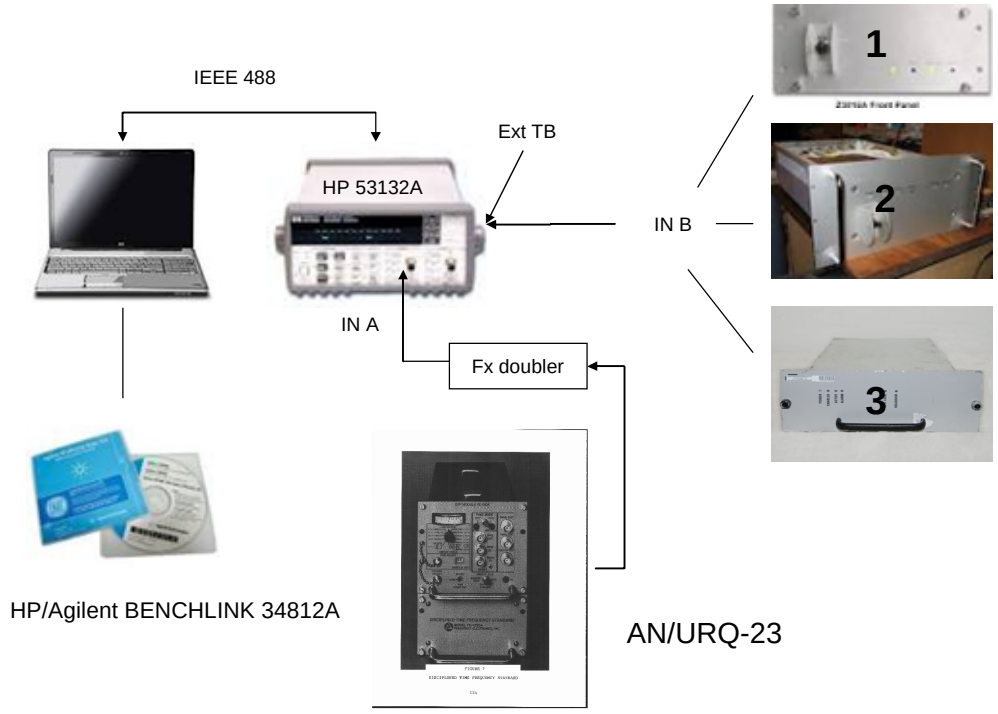
Test number	GPSDO	Frequency error Hz pp	reliability over the mean over 5 hours Freq. Hz
1-5	1 vs 2	0.00069	9.999999.999947 mean error 5.3 E-12
6-10	1 vs 3	0.0010	9999999.999420 mean error 5.8 E-11
11-15	2 vs 3	0.0008	9999999.999968 mean error 3.2 E-12

Looking this summary, seem the HP Z3805 is the most accurate of the three GPSDO, but….

Level 2

Each GPSDO are now compared with a Frequency Electronic AN/URM-23 double oven high stability and low phase noise frequency standard.

Test set Level 2



Characteristic of AN / ARQ-23 Frequency Electronics inc.

frequency aging:
0.1 sec 6 parts 10^{12}
1.0 sec 2 parts 10^{12}
10 sec 2 parts 10^{12}
100 sec 3 parts 10^{12}
1.0 day 6.6 parts 10^{11}

For each GPSDO compared we have done 1 tests, 1 hour duration.

These are the results:

Test number	GPSDO	Min. freq. MHz	Max. freq. MHz	Frequency error Hz pp	reliability over the mean over 1hours Freq. Hz
1	FEI vs Z3816	9999999.999640	10000000.00060	0.00096	10000000.00005
2	FEI vs Z3805	9999999.999540	10000000.00037	0.00083	9999999.999950
3	FEI vs 34304 -10	9999999.999640	10000000.00040	0.00076	10000000.00001

These tests are more significant than the previous ones (Level 1) because the source of reference (OCXO) is not related to the GPS network and the logic of the OCXO frequency disciplining.

As you can see in the column "Frequency error Hz pp " that represents the window of the readings over an hour, the ranking of quality places first the Trimble, then the Z3805 and Z3816. The differences between the three GPSDO are minimal.

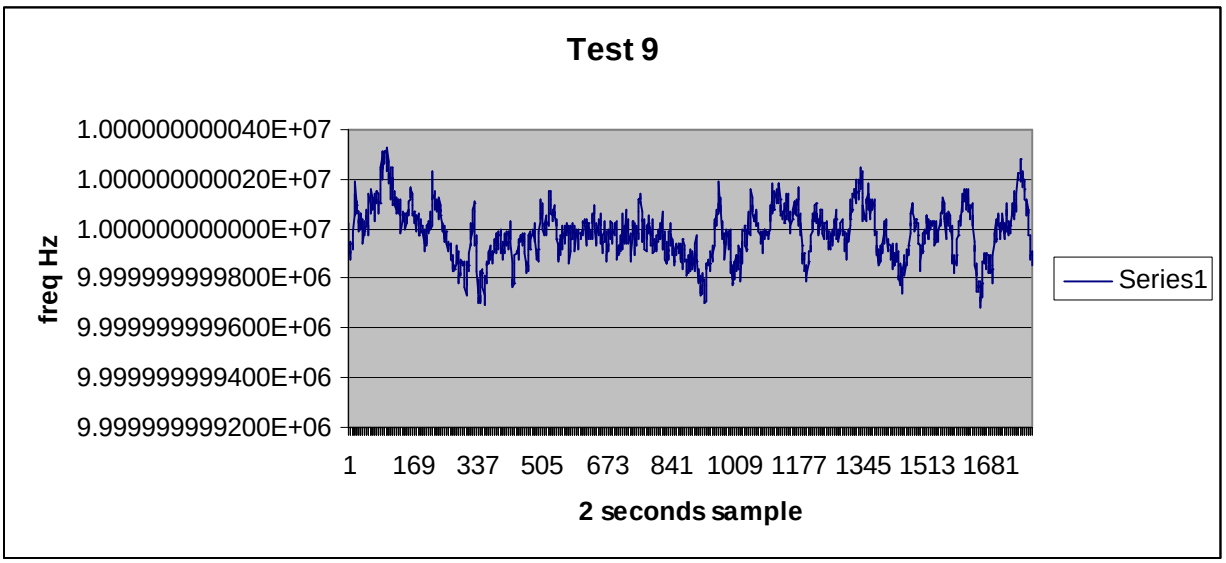
Conclusion

From the measurements made we can say the three GPSDO have similar characteristics and that the Z3805 and 34304-10 guarantee us a precise frequency reference, a short-term accuracy of 10 digits, error less than 1E-10 or better than 1 Hz on 10 GHz.

Note

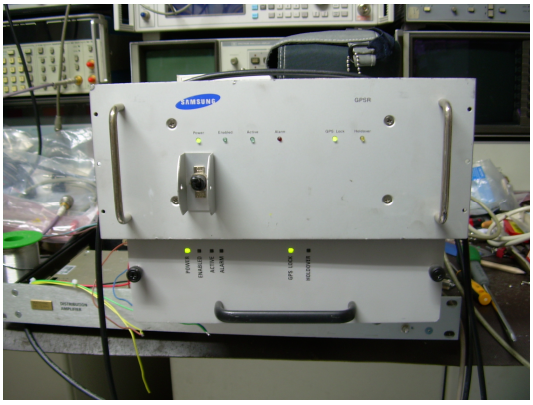
1) Typical output formatted data from the bench link:

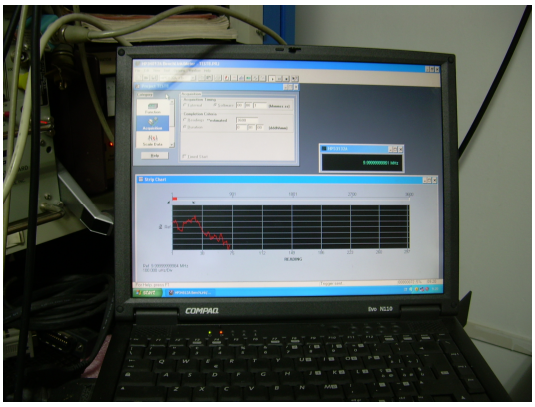
39:46.0	1.000000000002E+07
39:49.1	9.999999999890E+06
39:51.1	9.999999999930E+06
39:53.0	9.999999999950E+06
39:55.2	9.999999999900E+06
39:57.0	9.999999999910E+06
39:59.0	9.999999999880E+06
40:01.1	9.999999999940E+06
40:03.1	9.999999999940E+06
40:05.1	9.999999999920E+06
40:07.1	9.999999999970E+06
40:09.1	9.999999999980E+06
40:11.1	9.999999999990E+06



Example of 1 hour strip chart extract from excel file.

Some pictures:





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References

1) Renato Mannucci, Franco Cordara “Misurare il tempo e la frequenza”
Print: Il Rostro