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1st Quarter 1997

History of Frequency Traceability at HP-Santa Clara

Bob Pitcock/Hewlett-Packard

Introduction

Traceability to the National Institute of Standards and Technology (NIST) or the United States Naval Observatory (USNO) for time and frequency measurements has been a concern for some customers of Hewlett-Packard for many years. Even though our cesium beam frequency standards are recognized as primary frequency standards, some customers still request traceability. Without physically traveling with an operating frequency standard, the only way to achieve traceability is through some type of satellite transfer. This is fine, and is accepted by most customers, but there were still a few that wanted to see a "paper trail."

History

Flying Clock

In the early days of Department of Defense (DoD) coordinated precision time keeping, the standards lab at HP-Santa Clara was an official DoD time keeping station. This was partly due to the fact that the cesium beam frequency standards were (and still are) manufactured at Santa Clara. Representatives of the Time Services Department of USNO would make several "flying clock" trips to coordinate time at the DoD stations in the Pacific region. The flying clocks consisted of an HP 5061A Cesium Beam Frequency standard and a very heavy battery supply that could be recharged in a car or in an airplane. It took two people to handle and transport the clock. They would make stops at Santa Clara three to four times each year. The "flying clock's" time would be checked at USNO in Washington DC prior to, and after, the trip to obtain closure for all the measurements taken during the trip. A report would be sent out, approximately one month after the trip, indicating time errors. That report would be used with previous reports to estimate the long term frequency error of the Santa Clara Division Time and Frequency Standard.

DAS

After the development and widespread usage of Global Positioning Satellite System (GPS) timing receivers, it became unnecessary for USNO to make the flying clock trips. They would coordinate the timing of DoD installations using GPS time as a reference. A single channel GPS receiver was acquired by SCD to use as a timing reference. Since the original block of GPS satellites did not have SA (selective availability) installed, it was quite easy to achieve very good results. SA is the process of dithering the signals of commercial applications for security purposes. With SA, positioning can only be guaranteed to 100 meters or so. A USNO Data Acquisition System (DAS) was then installed at SCD and used as the primary reference for time and frequency until recently. The DAS con-

HP 5071A Primary Frequency Standard.

sisted of the previously mentioned GPS receiver, LORAN C receiver, computer, time interval counter, modem, and a switching system. The 1 pps output of the SCD reference clock was used as the time interval start pulse for all readings. To make a long story short, the SCD-GPS reading was used by USNO to determine SCD's time error. An automatic e-mail message was sent from USNO to SCD each day with time error information. The information on those messages was used to determine long term frequency accuracy. After all the original satellites became unusable and SA was here to stay, the readings were quite unstable. An HP 58503A GPS Time and Frequency Reference Receiver was put into the system and the GPS readings improved dramatically. There was still one problem. There was still a "paper trail" traceability issue.

FMAS

The NIST Frequency Measurement and Analysis System (FMAS) is our current method of maintaining frequency traceability to NIST. The Accuracy of the FMAS is based on the Global Positioning Satellite System. GPS was originally intended for very precise navigation. Each satellite in the system contains at least one cesium standard, so time can be controlled and monitored very accurately. The timing of the clocks in the satellites is controlled by the United States Naval Observatory. In a perfect system, navigation can be accomplished with an accuracy of inches. Timing would be accurate to a few nanoseconds. Because of national security demands, selective availability (SA) was installed for commercial GPS users. With SA, the GPS signals are dithered, so that the guaranteed accuracy for navigation is approximately 100 meters, and timing accuracy is 300 nanoseconds.

The FMAS system consists of an Intel™ 486 PC, GPS receiver, time interval counter with 40 picosecond resolution, and a modem. The signal from the GPS receiver is compared to our primary frequency standard. Over a period of time, 30 days for us, we can obtain very accurate frequency uncertainties. In order to improve our uncertainty, we have replaced the NIST GPS receiver with our HP 58503A. The performance of the system is at least ten times better now than it was before. Over a 30 day period our frequency measurement uncertainty is better than 1 part in 10 to the -13. The reason for the long term measurement is to average out the effect of SA. The traceability issue is resolved with FMAS because NIST issues a certificate each month indicating daily frequency uncertainties.

HP 58503A GPS Time and Frequency Reference Receiver.

Frequency Calibrations

With the FMAS system it is possible to calibrate four oscillators at one time. The measurements are made against our primary standard. Since the system has already given us an uncertainty for our primary standard, we can use that uncertainty as our own measurement uncertainty for the other calibrations.

HP GPS (58503A)

The 58503A has outputs of 1 pps and 10 MHz. The specifications of both outputs are identical. It incorporates a combination of enhanced GPS and Smart Clock technology. With enhanced GPS, proper antenna installation, and the receiver locked and operating properly, the maximum timing error is 110 nanoseconds. Frequency accuracy is 1 part in 10 to the -12 for a 24 hour average.

Conclusion

Hewlett-Packard has been the world's leader in commercial primary frequency standards and clocks for more than 30 years. They have been manufactured at HP-Santa Clara for more than 25 years. It is therefore absolutely necessary for the Santa Clara Division Standards Lab to maintain a very accurate frequency standard system. Reference frequencies of 1, 5, and 10 MHz are distributed throughout the division via a complex distribution system. Frequency uncertainty is maintained at 1×10 to the 13. This has been verified using the HP 58503A GPS receiver and the NIST FMAS system. Readings are averaged for 30 days to eliminate effects of GPS noise caused by SA. Using the FMAS system, we can calibrate up to four oscillators simultaneously. We welcome customer owned equipment, such as cesium standards and GPS receivers. We provide 10 MHz output data for HP GPS receivers in both locked and holdover modes. For more information please call:

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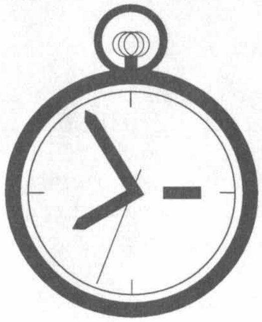
(408) 553-2380

Timebase Test/Adjustment Procedure



In a previous issue of *Bench Briefs* we defined the "Calibration of Time Base Oscillators. In that issue a long and detailed process was provided. The following is a redefinition of that process, simplified for future reference.

The purpose of this procedure is to check/adjust timebase frequency offset. However, before meaningful offset measurements may be taken, the timebase must be warmed up.

Formula 1. To calculate "allowable offset" for specific timebases, use the following formula.

Allowable Offset = [(Aging Spec) • (Cal Interval/4)] + [Temp Spec]

Where,

'Aging Spec' is expressed as a unitless fraction per unit of time (i.e., 5E-10/day).

'Cal Interval' is expressed in the same unit of time as the 'Aging Spec' above. (i.e., If 'Aging Spec' is a fraction per day, then 'Cal Interval' is expressed in days.)

'Temp Spec' is the frequency stability specification over a range of temperatures. It's typically listed in the specification/data sheet, and is expressed in unitless, fractional frequency (i.e., 7E-9).

Example:

Given,

Aging Spec=5E-10/day

Cal Interval=1 year=365 days

Temp Spec=7E-9

A.O.=[(5E-10/day) • (365 days/4)] + [7E-9] = 5.3E-8

Procedure

1. Allow enough time for the oscillator to warm up as evidenced by it meeting or approaching its aging specification. At least 24 hours, but not more than three days.
2. If stability cannot be realized in three days there may be a problem that needs to be corrected.
3. If necessary, remove any offset by adjusting the frequency back to nominal (usually 10 MHz). Use either Table 1 (as a general guide) or Formula 1 (for more specific guidance) to determine if adjustment is necessary.

Note: As a minimum, timebases should be adjusted if "allowable offset" limits are exceeded. For some cases, a customer's specific application/requirement may supersede this "minimum requirement." For example, you may require your HP 105B Oscillator be reset to 5E-9 or better.

Special Note: Timebase offset is not normally a warranted specification. Therefore do not use these "allowable offset" limits to determine any out-of-tolerance status. Use the limits soley as a guide to determine when to readjust timebases. □

Table 1. How to Determine When to Adjust Offset. (For typical timebases, assume one year calibration interval.)

Timebase Type	Allowable Offset
XO	6E-6
TCXO	1E-6
Medium Perf.	
OvenXO	1E-7
High Perf.	
OvenXO	5E-8

ISO Guide 25 Draft 5

ISO Guide 25 Draft 5 is now available for review. It was released in late January 1997. For a copy contact:

ANSI
11 West 42nd Street
New Youk, NY 10036
212-642-4900 □

Visit a Hewlett-Packard Metrology WEB Page

Hewlett-Packard's support center in the United Kingdom has developed special interest web pages catering for all things metrological.

Visit the Metrology Forum at:

http://www-uktm.external.hp.com/~mikehut/forum2.html □

Safety-Related Service Notes

Service Notes from Hewlett-Packard relating to personal safety and possible equipment damage are of vital importance to our customers. To make you more aware of these important notes, they are printed on paper with a red border, and the service note number has an "-S" suffix. In order to make you immediately aware of any potential safety problems, we are re-highlighting safety-related service notes here with a brief description of each problem. Also, in order to draw your attention to safety-related service notes in the service note index, each safety-related service note is highlighted with a contrasting color.

85942A Video Signal Monitor

Serial Numbers Affected:

0000U00000/3607U00187

Situation:

These instruments have a line module assembly (85942-61002) that includes 3 wires connected to the power supply assembly. The power supply connection is made using crimps on each wire. On some line module assemblies these wires have been inadequately attached to the crimp and can become easily disconnected. This could result in the instrument chassis going live under a double fault condition—failure of the crimp contact and failure of the customer to earth/ground the instrument via the power cord.

Hewlett-Packard strongly recommends that you return the instrument immediately to the nearest HP Customer Repair Center for inspection, and if required, repair at no charge. For more information, you may order a safety service note document from HP First. For 85942A-02-S order document id 6732. If you do not have access to a FAX machine, order this service note from your nearest HP Office.

J2301B/J2302B/J2522B/J2523B Internet Advisors

Serial Numbers Affected:

J2301B— US35340000/
US35359999 EC: Label #9
J2302B— US35340000/
US35359999 EC: Label #9
J2522B— US35310000/
US35319999 EC: Label #9
J2523B— US35310000/
US35319999 EC: Label #9

Situation:

One of the chassis screws that secure the power supply to the bottom of the chassis may be excessive in length to the point it may compromise the insulation on a primary circuit capacitor. If the screw compromises the capacitor's insulation, primary voltage may be present on the chassis.

Hewlett-Packard strongly recommends that you return the instrument immediately to the nearest HP Customer Repair Center for inspection, and if required, repair at no charge. For more information, you may order a safety service note document from HP First. For document id numbers refer to the list of service notes at the end of *Bench Briefs*. If you do not have access to a FAX machine, order this service note from your nearest HP Office. □

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T & M Service Notes - Press 2
Enter the Password - 76683

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Service Note Types

IO Information Only
MA Modification Available
MR Modification Recommended
SA Safety
PS Priority Safety

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