Performance Verification Test

Fluke 9640A Internal Time-base Stability

Revision 1.0

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Revision History (For Internal Use Only)

Revision 1.0	
Test Name:	Internal Time base stability
Application:	Fluke 9640A RF reference source
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Date:	January 4, 2026

Specification:

Time Base

Internal Time Base Stability

Aging Rate: After 24hr warmup: 2x10-9/day.
Continuous operation: ≤ 2x10-8/month, ≤ 4x10-8 over 1 year

Description:

This procedure verifies that the Reference source under test meets its Internal Time base aging rate specification. The DUT's internal time-base is monitored with a frequency counter that is locked to a GPS time-standard receiver to insure sufficient accuracy to specification.

The Time base aging rate is defined for this test as:

$$Aging_{PPM} = \left[\frac{(F_2 - F_1)}{F_1}\right] \cdot (1 \times 10^6) \text{, in ppm/day}$$

Where: $Aging_{PPM}$ = the *aging rate* of the 10 MHz Reference output of the DUT.

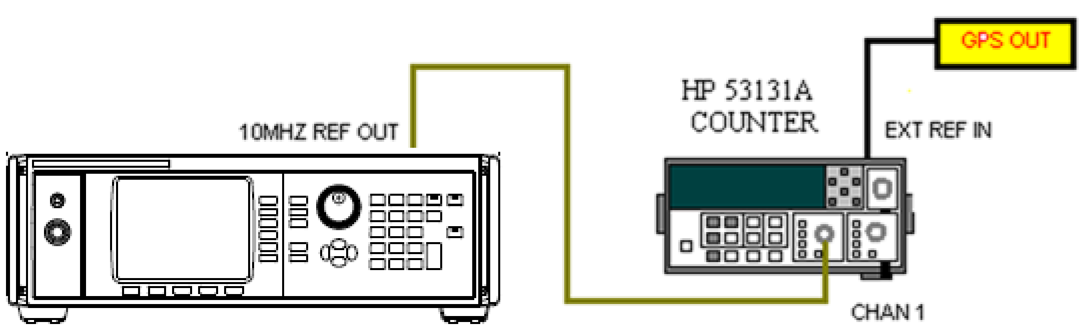
F_1 = Reference time-base frequency reading, in Hz;

F_2 = Time-base frequency reading, in Hz, taken exactly 1 day (24 hrs.) later

Equipment:

Instrument	**Critical Specifications (for this test)**	**Recommended Model**
Universal Counter	Frequency Range to 225 MHz Resolution to .0001 Hz External Time base Input	Agilent 53131A or Agilent 53132A
Primary Frequency Standard	Frequency 10 MHz Stability $> 1x10^{-12} / perday$	Fluke 910R

Connection Diagram for Time Base stability Measurement



Test Procedure:

Set Test Equipment as follows:

Universal Counter

Parameter	Setting
Function	Frequency Channel 1
Gate Time	**10 Seconds**
External Time Base	ON – with GPS Reference input
Resolution	**0.0001 Hz**

1. Preset the DUT and all equipment to normal power-up conditions.
2. Allow the DUT to warm-up for approximately **24 Hours or more**.
3. Record the frequency of the DUT's 10-MHz reference output, as indicated by the universal counter, as F_1. Record the time as T_1
4. Wait exactly 24 hours.
5. Record the frequency of the DUT's 10-MHz reference output, as indicated by the universal counter, as F_2.
6. Compute the daily time-base aging rate as: $Aging_{PPM} = \left(\frac{(F_2 - F_1)}{F_1} \cdot (1 \times 10^6) \right)$, in ppm/day
7. Apply the expanded measurement uncertainty:

   $Aging + U_{EXP}(Aging) \leq$ Specification

Measurement Uncertainty Analysis:

1.0 Measurands

F_1, First frequency reading by the counter, in Hz

F_2, Second frequency reading by the counter, in Hz

2.0 Measurement Equation

$$Aging_{PPM} = \frac{(F_2 - F_1)}{F_1} \cdot (1 \times 10^6)$$

Leaving aside the scaling factor for ppm:

$$A = \frac{(F_2 - F_1)}{F_1}$$

3.0 Uncertainty Equation

Following the ISO-GUM method, the general form for the uncertainty equation is:

$$u^2(A) = C_{F1}^2 \cdot u^2(F_1) + C_{F2}^2 \cdot u^2(F_2)$$

Note that the conversion factor K_{PPM} has disappeared, since it is a definition and has no uncertainty.

$$C_{F1} = \frac{\partial A}{\partial F_1} = \frac{F_1 \cdot (-1) - (F_2 - F_1) \cdot 1}{F_1^2} = \frac{-F_2}{F_1^2}$$

$$C_{F2} = \frac{\partial A}{\partial F_2} = \frac{1}{F_1}$$

$$u^2(A) = \left[\frac{F_2}{F_1^2}\right]^2 \cdot u^2(F_1) + \left[\frac{1}{F_1}\right]^2 \cdot u^2(F_2)$$

Covariance

Since the terms in the measurement equation are independent of one another, there are no covariance terms in the uncertainty equation.

4.0 Standard Uncertainty: u(x)

All of the standard uncertainties listed in this section are Type B.

$u(F_1) = u(F_2)$ = the uncertainty of measuring the frequency of the DUT's 10MHz time-base.

From the Agilent ***53131A/53132A Frequency Counter Operating Guide***, page 3-8, the uncertainty of measuring the frequency of a signal is:

$U(F) = \pm U_{SYSTEMATIC} \pm 2 * U_{RMS\,RESOLUTION}$ *For 2 sigma confidence*

And $U(F) = \pm U_{SYSTEMATIC} \pm U_{RMS\,RESOLUTION}$ *For 1sigma confidence*

$$U(F)=\left\{\begin{matrix}\left[\pm Time\,Base\,Error\pm\frac{t_{ACC}}{GateTime}\right]\\ \pm\left[\frac{4*\sqrt{t_{RES}^2+\left(2*(Trigger\,Error)^2\right)}}{GateTime*\sqrt{Number\,of\,Samples}}+\frac{t_{JITTER}}{GateTime}\right]\end{matrix}\right\}\times F$$

NOTE: ***The parameter values shown below are determined from the specifications of the 53131A and from the*** **53131A Operating Guide*****, section 3. Each value is assumed to represent 95% (2σ) of a Gaussian distribution, or twice the standard uncertainty of the variable in question.***

Time-base Error

For this test, a Fluke 910R GPS Time/Frequency Standard is used as the time-base reference for the counter.

The specified accuracy of the 910R is $1X10^{-12}$.

Therefore: $Time\ Base\ Error = 1.0\times 10^{-12}$

t_{ACC}, t_{RES}, t_{JITTER}

These parameters are not specified for the 53131A. They are given typical or worst case values on page 3-5 of the *53131A/53132A Operating Guide*. TABLE 1 lists the values that are used for this measurement.

Gate Time

Selected as 10 sec.

(See **APPENDIX A** for a verification that the selected gate time will provide sufficient measurement resolution for this test.)

Trigger Error

From page 8 of the *53131A/53132A Data Sheet,* the expression for trigger error is:

$$Trigger\,Error=\frac{\sqrt{(E_{AMP})^2+(E_{SIGNAL})^2}}{Input\,signal\,slew\,rate\,at\,trigger\,point}$$, in seconds

E_{AMP} Is the RMS noise contributed by the input amplifier of the frequency counter. The *Operating Guide* suggests using **1 mV RMS** as the worst case value for this parameter.

E_{SIGNAL} Is the RMS noise of the input signal over the counter's 225 MHz measurement bandwidth. The noise level associated with the 10 MHz frequency reference output is specified to be at least 80 dB below the 10 MHz signal. Therefore, E_{SIGNAL} will be set to **zero**.

Input signal Slew rate at the trigger point:

The DUT's 10 MHz reference oscillator provides a sine-wave input signal to the counter. The nominal level given in the 9640A data sheet for the internal reference-oscillator output is 0.53 V RMS.

$$P_{REF} = \frac{(0.53v)^2}{50\Omega} = 5.6mW$$

Choose the 50% voltage level of the sine wave signal as the trigger level.

Then:

Slew Rate = $(0.5) \cdot \sqrt{3} \cdot \pi \cdot f$ (see **APPENDIX B**)

For a 10 MHz sine-wave signal: Slew Rate = $27.2x10^6$ volts/sec

$$Trigger\ Error = \frac{\sqrt{\left(1\times10^{-3}\right)^2 + (0.0)^2}}{27.2\times10^6} = \frac{1\times10^{-3}\ volt}{27.2\times10^6\ \frac{volts}{\sec}} = 3.62\times10^{-11}\sec$$

Number of Samples

From page 3-5 of the *53131A/53132A Operating Guide:*

For $F_{MEAS} > 200\ kHz$, $N_{SAMPLES} = (Gate\,Time)\times 200{,}000$

For Gate Time =10 sec: $N_{SAMPLES} = (10)\times 200{,}000 = 2{,}000{,}000$

TABLE 3: Specifications for TIME-arming

Parameter	Calculated or Specified Value
Frequency	1×10^7 Hz
Time Base Error	1×10^{-12}
t_{ACC}	350×10^{-12} sec
t_{JITTER}	50×10^{-12} sec
t_{RES}	500×10^{-12} sec
Trigger Error	3.62×10^{-11} sec.
Number of Samples	2,000,000
Gate Time**	10.0 sec.

** Chosen to provide 0.0001 Hertz resolution at the nominal measured frequency of 10 MHz.

5.0 Combined Uncertainty

$$u(F_1)=u(F_2)=u(F)=\left\{\begin{gathered}\left[\pm Time\,Base\,Error \pm \frac{t_{ACC}}{Gate Time}\right] \\ \pm\left[\frac{4*\sqrt{t_{RES}^2 + \left(2*(Trigger\,Error)^2\right)}}{GateTime*\sqrt{Number\,of\ Samples}} + \frac{t_{JITTER}}{Gate Time}\right]\end{gathered}\right\}\times F$$

$$U(F) = \left\{ \begin{array}{l} \left[\pm 1.0\times10^{-12} \pm \dfrac{350\times10^{-12}}{1} \right] \\ \pm \left[\dfrac{4 * \sqrt{\left(500\times10^{-12}\right)^2 + \left(2 * \left(3.62\times10^{-11}\right)^2\right)}}{(10) * \sqrt{2,000,000}} + \dfrac{50\times10^{-12}}{10} \right] \end{array} \right\} \times 10\times10^6\ Hz = \pm 0.00041 Hz$$

NOTE: The values given in the counter's data sheet for the various parameters are not divided by a coverage factor to produce a standard deviation of the parameter. The formula given in the Operating Guide was developed by the counter's design team and the values given in the data sheet are used directly in the uncertainty equation.

Recall: $u(F_1) = 0.00041\ Hz$

$u(F_2) = 0.00041\ Hz$

Assume: $F_1 = 10,000,001.005\ Hz$

$F_2 = 10,000,001.01 Hz$

$$U_C^2(A) = \left[\frac{10,000,001.01 Hz}{(10,000,001.005 Hz)^2} \right]^2 \cdot (0.00041 Hz)^2 + \left[\frac{1}{10,000,001.005 Hz} \right]^2 \cdot (0.00041 Hz)^2$$

$$U_C(A) = \sqrt{2.37\times10^{-21}} = 4.86\times10^{-11}$$

7.0 Expanded Uncertainty: $U_{EXP}(Aging)$

Using a coverage factor of k = 2 to provide a 95% confidence interval for the true value:

$$U_{EXP}(Aging) = \left(2 \cdot \left(4.86\times10^{-11}\right)\right) \times \left(1\times10^{6}\right) = 0.000097\ \text{ppm/day}$$

APPENDIX A: Gate Time vs Resolution

Selecting the Gate Time to produce the required readout resolution

In this procedure, a nominal frequency of 10 MHz is being measured by the universal counter. The specified *daily* aging rate is < 1x10^{-9} ppm.

Multiplying 0.002 ppm by the nominal time-base reference frequency of 10 MHz yields a daily allowable frequency change (aging) of **0.02 Hz**. The universal counter must be able to discern this difference with acceptable uncertainty.

The resolution of the universal counter's frequency indication is determined by inserting the chosen value for Gate Time into the equation below, which is taken from page 3-5 of the 53131/*53132A Operating Guide (p/n 53131-90055, Oct. 1999)*. The resolution is stated in terms of the frequency increment represented by the least-significant digit of the counter's readout.

$$LSD = F_{MEAS} \times \left[\frac{2\sqrt{2} * t_{RES}}{GateTime + \sqrt{GateTime * 200{,}000}} + \frac{t_{JITTER}}{GateTime} \right] Hz$$

EXAMPLE:

For a Gate Time of **10 sec.** at $F_{MEAS} = 10\ MHz$:

$$LSD = \left(1.0 \times 10^{7}\right) \times \left[\frac{2\sqrt{2} * \left(500 \times 10^{-12}\right)}{10 + \sqrt{(10)} * 200{,}000} + \frac{50 \times 10^{-12}}{10} \right] Hz$$

$$LSD = \left(1.0 \times 10^{7}\right) \times \left[9.93 \times 10^{-13} + 5 \times 10^{-12}\right] Hz = 0.00006\ Hz$$

This resolution easily verifies a daily aging rate of 0.02 Hz.

APPENDIX B: Slew Rate

Derivation of the Slew Rate equation

For a sinusoidal waveform: $f(t) = A\sin\omega t$

Define slew rate as: $\dfrac{d\,f(t)}{d\,t} = \omega A\cos\omega t$

Choose the half-peak sine-wave voltage as the trigger threshold.

For a sinusoid, $f(t) = \dfrac{A}{2}$ when $\omega t = \dfrac{\pi}{6} = 0.52\,radian$

Evaluating the slew rate expression at this angle:

$$\omega A\cos\omega t = (2\pi f)A\cos(0.52) = 2\pi fA\frac{\sqrt{3}}{2} = \pi f A\sqrt{3}$$

For a signal whose power is P:

$$P = \frac{V_{RMS}^2}{R} = \frac{V_{RMS}^2}{50\Omega} \quad \text{So,} \quad V_{RMS} = \sqrt{P \times 50}$$

$$A = V_{PEAK} = \sqrt{2} \times V_{RMS}$$

Slew Rate = $= \pi f A\sqrt{3} = \pi f \left(\sqrt{3}\right)\left(\sqrt{2}\right)\left(\sqrt{P \times 50}\right)$

For this test, $P = 0.0056 Watt$:

Slew Rate = $= \pi f A\sqrt{3} = \pi f\left(\sqrt{3}\right)\left(\sqrt{2}\right)\left(\sqrt{0.0056 \times 50}\right) = (0.5)\cdot\sqrt{3}\cdot\pi\cdot f$

NOTE: Maximum slew rate for a sinusoidal wave occurs at zero crossings,

Where $\omega t = 0, \pi, 2\pi, \ldots$

$$\frac{d\,f(t)}{dt} = \omega A\cos\omega t = (2\pi f)\times A \times 1 = 2\pi f A$$