PN2060 Phase Noise Analyzer

User Guide

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PN2060C / PN2060D V2 / PN2060E

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https://qsl.net/bg6khc/pn2060c_phase_noise_analyzer.htm

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1 Introduction

1.1 Overview

The PN2060 is a digital cross-correlation phase noise analyzer. It measures the phase noise and amplitude noise of free-running, high-performance RF sources through digital processing and cross-correlation. Two independent reference inputs feed two receiving channels. Cross-correlation between the channels averages the analyzer's own noise out of the result, so the achievable noise floor lies well below the noise of either receiving channel.

This guide covers the following members of the instrument family.

- **PN2060C** — 1–200 MHz direct-sampling analyzer in a compact USB-powered enclosure with **DUT1**, **DUT2**, **REF1** and **REF2** SMA connectors on the front panel and USB 3.0 Type-C on the rear.
- **PN2060D** — an all-in-one 1 MHz–7 GHz analyzer that adds two internal down-converters and two internal 102.4 MHz references to the same measurement engine (Section 7).
- **PN2060E** — an integrated 1–150 MHz analyzer with four internal reference oscillators and two input bands (Section 8).

These instruments are operated by the same `PN2060.exe` Windows application described in this guide.



Figure 1: PN2060C front panel with REF1, DUT1, DUT2 and REF2 connectors.

1.2 Features (PN2060C)

- Independent input and reference frequencies from 1 to 200 MHz
- Supports free-running DUTs and calibration-free phase-noise measurement
- Dual reference-oscillator inputs allow cross-correlation measurements
- USB 3.0 interface with high-speed data exchange and a single high-quality cable for both data and power
- Phase noise at offsets from 0.001 Hz to 8 MHz, with levels typically below −180 dBc/Hz (10 MHz carrier, long correlation)
- Allan deviation with two-channel cross-correlation ($< 3 \times 10^{-15}$ at 1 s typical)
- Frequency-difference and phase-difference recording with a high-resolution frequency-counter function
- Real-time TCP data streaming to other applications that can receive the data stream

1.3 Specifications (PN2060C)

Table 1: Published system noise floor for a 10 MHz carrier and 90-minute correlation.

Offset	Noise floor (dBc/Hz)
0.1 Hz	−120
1 Hz	−140
10 Hz	−155
100 Hz	−165
1 kHz	−175
10 kHz	−180
>100 kHz	−180

Table 2: General specifications (PN2060C).

Input frequency range	1–200 MHz (best accuracy 1–60 MHz, see Section A.2)
Offset range	0.001 Hz–8 MHz
Input signal level	+10 dBm maximum
Input impedance	50 Ω
Signal type	sine wave
Connectors	SMA inputs on front (DUT1, DUT2, REF1, REF2), USB Type-C on rear
Power	USB 3.0 bus power, approx. 1.1–1.5 A
Operating temperature	0–35 °C
Size / weight	11 × 10 × 4 cm / 0.5 kg
Operating system	Windows 7 / 10 / 11 (64-bit)

Note

Dual-reference cross-correlation lowers the displayed noise floor with measurement time. The longer the run, the lower the floor – particularly near 1 Hz offset, where data update rates are slow.

2 Hardware Requirements and Driver Installation

2.1 Computer requirements

The software processes a real-time data stream and performs extensive scientific computation, which places high demands on CPU, memory and the motherboard's USB power delivery. The stream rate scales with the selected **Max Frequency Offset** (Section 4.4). With two channels, the rate is approximately 2 Mbyte/s per MHz of span. This gives 2 Mbyte/s at the 1 MHz span, 16 Mbyte/s at 8 MHz and up to 40 Mbyte/s at the 20 MHz span of the PN2060D. **Four Channel** doubles the rate.

- Windows 7 / 10 / 11 (64-bit)
- Intel 14th-generation i5 or better
- At least 8 GB of memory
- SSD storage for raw-data recording
- A verified B760M-series motherboard (H610-series boards often cannot supply enough USB 3.0 current)
- Dedicate the computer to the measurement. Heavy background services can interrupt the stream and cause a *Data Packet Loss* error (Section 11).

Caution

The 16 MHz and 20 MHz offset ranges (PN2060D) produce very high data rates and require a powerful desktop PC with an Intel 14th-generation i5 or better.

2.2 USB 3.0 power

The PN2060C draws its full operating power (up to ≈1.5 A) from one USB 3.0 port, and on many motherboards all USB 3.0 ports share one supply.

- Connect directly to a desktop PC's *rear-panel* USB 3.0 port. Front-panel ports and USB hubs are unsupported.
- Disconnect other power-hungry USB devices.
- If the supply is still insufficient, install a powered USB 3.0 PCIe expansion card from the extensively tested models shown in Figure 2.
- On a laptop, use a built-in USB 3.0 port and prefer battery operation. Switching AC adapters can inject noise (Section 11). External USB adapters and docks generally fail to provide a working link.



Figure 2: USB 3.0 PCIe expansion cards verified with the PN2060.

Note

Hardware version 1.4 and later has an optimized internal power supply, and most PCs run the analyzer directly without an expansion card.

2.3 Driver installation

Connect the PN2060 to the computer with the supplied USB 3.0 Type-C cable, open the Windows *Device Manager* and locate the entry **FX3** (under *Other devices*). Follow the driver-installation sequence illustrated in Figure 3.

1. Right-click **FX3** and choose *Update driver*.
2. Select *Browse my computer for drivers*.
3. Point the search to the `driver` folder of the software package (choose the sub-folder matching your Windows version) and click *Next*.
4. Windows reports *Cypress FX3 USB StreamerExample Device* installed.

After the driver installation completes, **unplug the USB cable and restart the computer** (important). Then reconnect the device and run `PN2060.exe` from the software package.

Caution

If a `libusb-win32` driver (or similar) is present from other tools, remove it in Device Manager first – it conflicts with the FX3 driver. Use the supplied data cable to provide the USB 3.0 wiring required by the analyzer.

2.4 Connection checklist

- Connect the analyzer directly to a compatible USB 3.0 port. USB 2.0 ports, hubs and many laptop Type-C ports are unsupported.
- If the device is not detected, rotate the Type-C plug by 180° and re-insert it. Wait 3–5 s before starting the application, then check Device Manager for the FX3 entry.
- Occasional contact problems of the 24-pin Type-C connector show up as nonsense level readings (e.g. `Inf` dBm) – re-seat or rotate the plug, or use another USB 3.0 port.

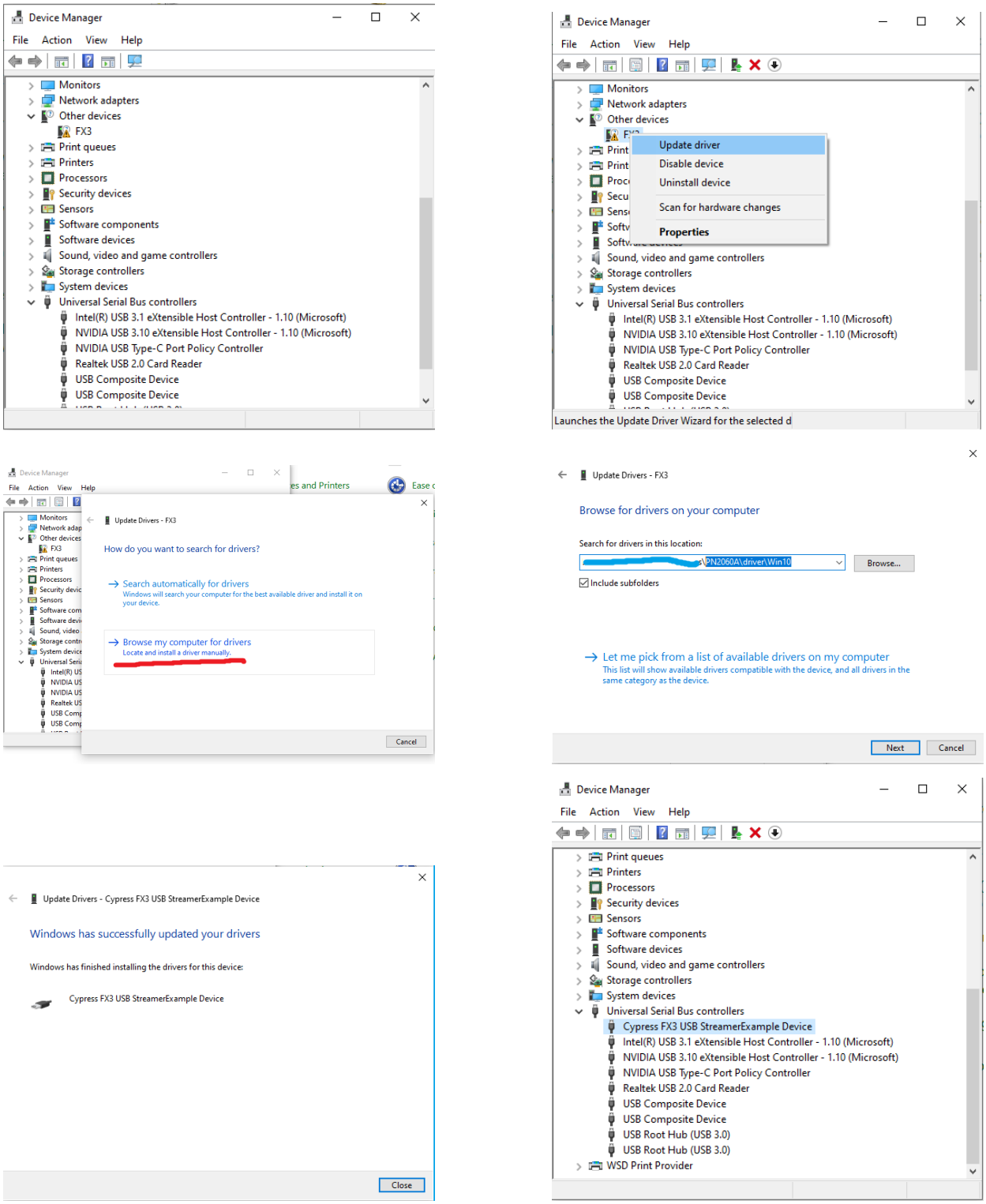


Figure 3: Driver installation sequence (Device Manager).

3 Measurement Setup

3.1 General precautions

Any environmental interference (transformers, switching power supplies, vibration, air flow), as well as poor cables or noisy power supplies, can add noise that is difficult to eliminate.

- Power both the references and the DUT from batteries or from high-performance linear supplies (HP/Agilent class) whenever possible.
- Preserve the *independence* of the two reference sources by powering each from a separate supply.
- Filter the DUT and references effectively. Harmonics can cause 3–5 dB errors at far offsets (Section B.4).
- Use short, well-shielded RF cables.
- Prefer high-isolation power splitters. A 6 dB attenuator in series with the DUT improves impedance matching (Section B.3).

3.2 Recommended dual-reference setup

Extensive testing has shown dual-reference operation to be the most reliable method (Figure 4).

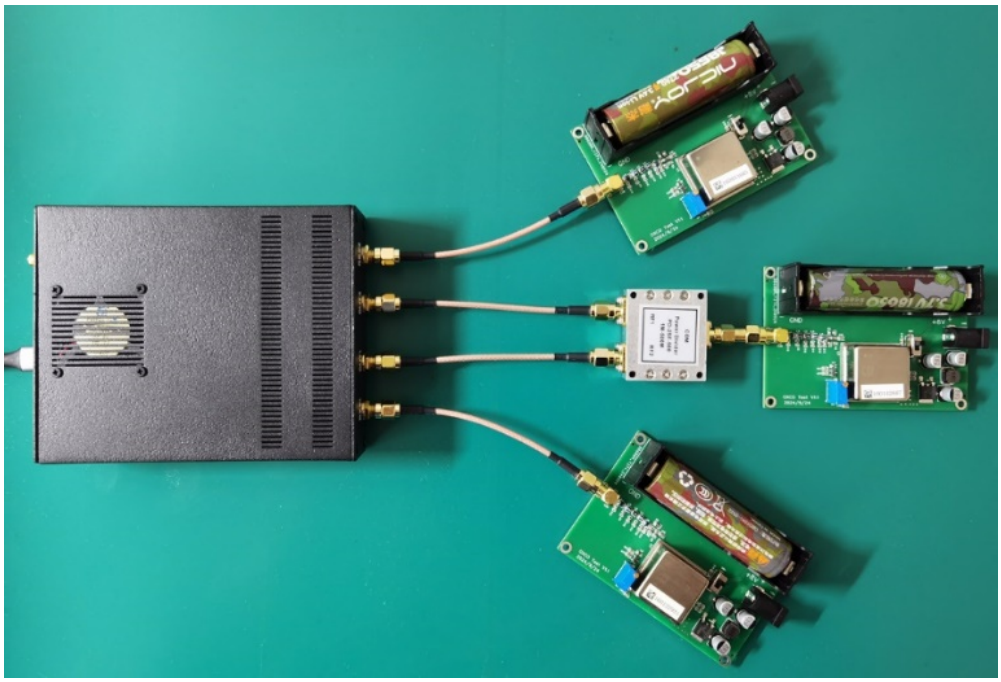


Figure 4: Dual-reference cross-correlation setup.

1. Split the DUT output with a power splitter into **DUT1** and **DUT2**.
2. Connect two *independent* reference sources to **REF1** and **REF2** – same nominal frequency, separate power supplies.
3. On the PN2060C, keep reference input power close to the +10 dBm limit for the available dynamic range. If a source exceeds this level, insert an attenuator. Use the model-specific limits and connection procedures in Sections 7 and 8 for the integrated models.
4. Start the software, enter **REF1 FREQ**, **REF2 FREQ** and **DUT FREQ** (Section 4.4.2), confirm **SYS CLK**, and click **Apply**.
5. Allow approximately 30 minutes for the analyzer, references and DUT to reach a stable operating condition. Then click **Start** to begin the recorded measurement.
6. A run typically lasts from a few minutes to several hours. Save the results from the **File** menu (CSV, PNP or Excel formats, Section 6).

3.3 Frequency planning rules

- Set **REF1 and REF2 to the same nominal frequency**. They are independent oscillators, so their exact frequencies differ slightly – that is expected and harmless.
- In direct-sampling operation, the supported **DUT/REF ratio** is $f_{\mathrm{DUT}}/f_{\mathrm{REF}} < 16$. The program refuses to start beyond this limit.
- In direct-sampling operation, **Max Frequency Offset** settings of **8 MHz and above** additionally require $f_{\mathrm{DUT}}/f_{\mathrm{REF}} \leq 3$. Exceeding this ratio triggers a warning and a fallback to 4 MHz.
- Choose a **10 MHz reference** for DUTs up to about 30 MHz. Scaling this reference to 30 MHz increases its effective phase noise by about 10 dB. Scaling to 100 MHz increases it by about 20 dB, making far-offset floors unreachable. For DUTs at or above 160 MHz use a 100 MHz-class reference.
- Choose a reference with **phase noise at least as low as the DUT**, especially near 1 Hz offset where averaging is slow. A noisier reference can require measurement times exceeding 8 h. At 100 kHz–1 MHz offsets a somewhat worse reference is acceptable, because those frequencies average quickly.

3.4 Close-in measurements at 1 Hz and below

Air movement, vibration and electromagnetic coupling can change the measured close-in phase noise of a high-performance oscillator. Allow the analyzer, DUT and references to reach thermal equilibrium before starting the run. Place the DUT and the two reference oscillators in separate shielded containers and use separate reference power supplies. Keep the two reference sources physically separated to preserve their independence.

Use short, well-shielded RF cables and fit a local supply-decoupling capacitor close to each oscillator package. Values in the 0.1–2 μF range are used in the supplied measurement guidance. A quiet room and a stable thermal environment help make repeated close-in measurements comparable. If strong FM or television signals couple into the setup, test in a different location and check the shielding and cabling. Use the timed measurement function for an unattended acquisition, then compare repeated runs under the same setup conditions.

3.5 Running a measurement – workflow summary

1. Connect signals as described in Section 3.2 and check the four level readouts for **REF1**, **DUT1**, **DUT2** and **REF2** in dBm on the **Measure Control** tab.
2. Change parameters only in the stopped state, then press **Apply**.
3. Press **Start** and watch the trace build from high offsets toward low offsets. The green numbers along the bottom of the plot are the per-decade correlation (averaging) counts.
4. Stop the run (or let the **Measure Timer** stop it), then save data via the **File** menu.

4 User Interface Reference

4.1 Main window layout

Figure 5 shows a loaded 10 MHz self-correlation measurement in the current application. Its four main areas provide measurement controls, plot navigation and connection status.

1. **Menu bar** – **File**, **View**, **Measurement**, **Options** and **Help** (Section 4.3).
2. **Plot area** – the active measurement view with title, status line, legend, markers and spot-noise table (Section 4.2).
3. **Control panel** – the **Plot Control**, **Measure Control** and **Advanced Control** tabs (Sections 4.4–4.6).
4. **USB status bar** – green `USB3.0 CONNECTED` when the instrument link is up, red `USB3.0 DISCONNECTED` otherwise.

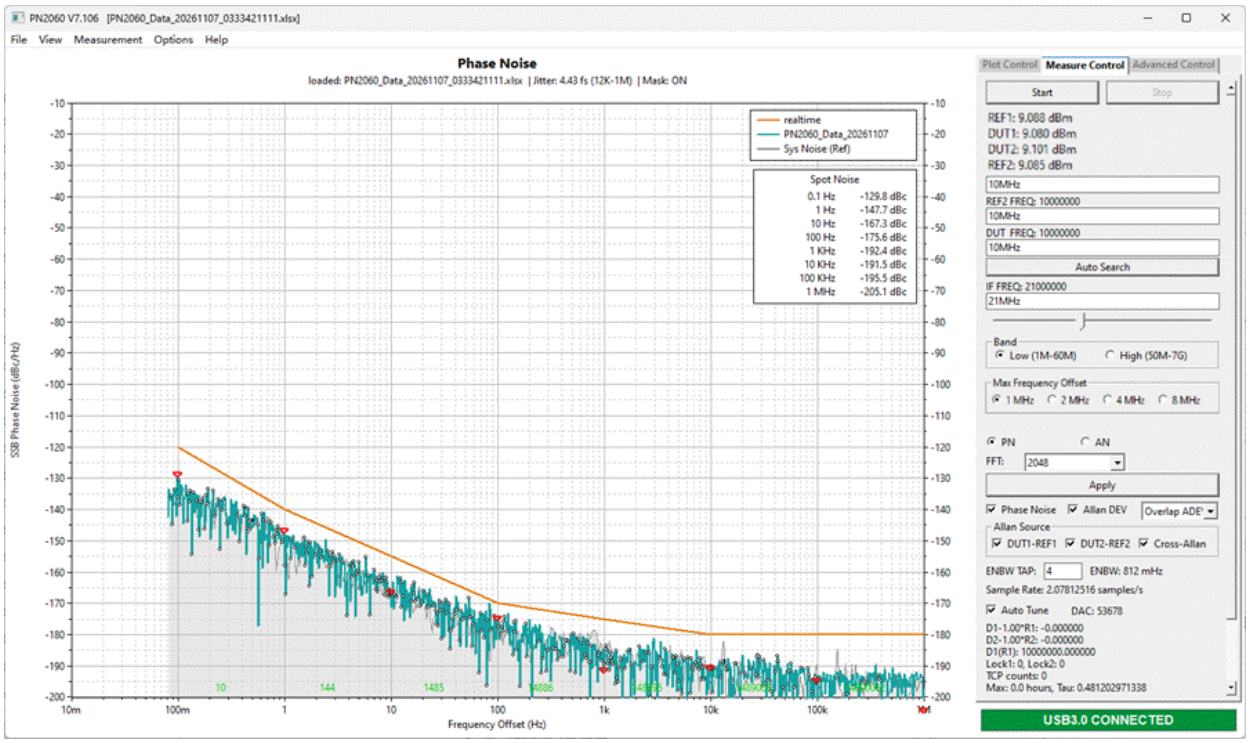


Figure 5: Current main window displaying a loaded 10 MHz self-correlation phase-noise result.

4.2 Plot area

Title and status line

The first line names the active view (*Phase Noise*, *Allan Deviation*, ...). The second line combines the following status information.

- the data source – `realtime` during acquisition, `idle` before the first run, or the loaded file name (Section 6).
- `Elapsed: hh:mm:ss` – time since **Start**.
- in the phase-noise view, `Jitter: ... fs (12K-1M)` – the RMS jitter integrated over the configurable jitter band (Section 4.6).
- in the Allan view, the selected estimator (`Overlap ADEV` or `MDEV`).
- in the difference views, the selected signal pair and the equivalent noise bandwidth.

Legend

Measured (teal) is the cross-correlated result. *Sys Noise (Ref)* (grey) is the estimated instrument noise floor for the current run, drawn when **Show Reference Noise** is enabled. The measured trace is valid where it stands clearly above the grey floor.

Spot noise table and markers
Show Spot Noise Points enables red markers at decade offsets. **Show Spot Noise Table** displays the smoothed spot values. The current example includes 0.1 Hz, 1 Hz, 10 Hz, 100 Hz, 1 kHz, 10 kHz, 100 kHz and 1 MHz. The available rows depend on the plotted span and window size.

Averaging counts
The green numbers along the bottom edge are the correlation counts per decade. Low-offset decades accumulate slowly, with the estimated floor improving as the counts grow.

Axes
The frequency-offset axis is logarithmic, with a default 10 mHz–1 MHz range adjusted in **Plot Control**. The phase-noise axis is linear in dB.

4.3 Menu bar

4.3.1 File

Save Plot PNG
Writes the current plot area to `capture.png` in the program folder.

Save Data CSV . . .
Opens a save dialog (default `PNdata.csv`) and writes the measurement data as CSV. It also generates a converted `.PNP` file alongside the CSV for use in compatible frequency-analysis software.

Save All Data (Excel) . . .
Saves the complete session (all views and settings) into a single `.xlsx` workbook, default name `PN2060_Data_YYYYMMDD_hhmmss.xlsx`.

Load Data . . .
Loads a previously saved `.xlsx` workbook for offline review (available only while stopped). The status line shows the file name in place of `realtime`.

Exit
Closes the application.

4.3.2 View

Show Reference Noise, **Show Spot Noise Points**, **Show Spot Noise Table** and **Show Grid** toggle the corresponding plot elements. These options mirror the checkboxes on the **Plot Control** tab (Section 4.5).

4.3.3 Measurement

Select the active view from **Phase Noise**, **Allan Deviation**, **Frequency Difference DUT1-REF1**, **Frequency Difference DUT2-REF2**, **Phase Difference DUT1-REF1**, **Phase Difference DUT2-REF2** (Section 5). Switching the view does not interrupt the acquisition.

4.3.4 Help

About PN2060 . . . shows the program version and license information.

4.4 Measure Control tab

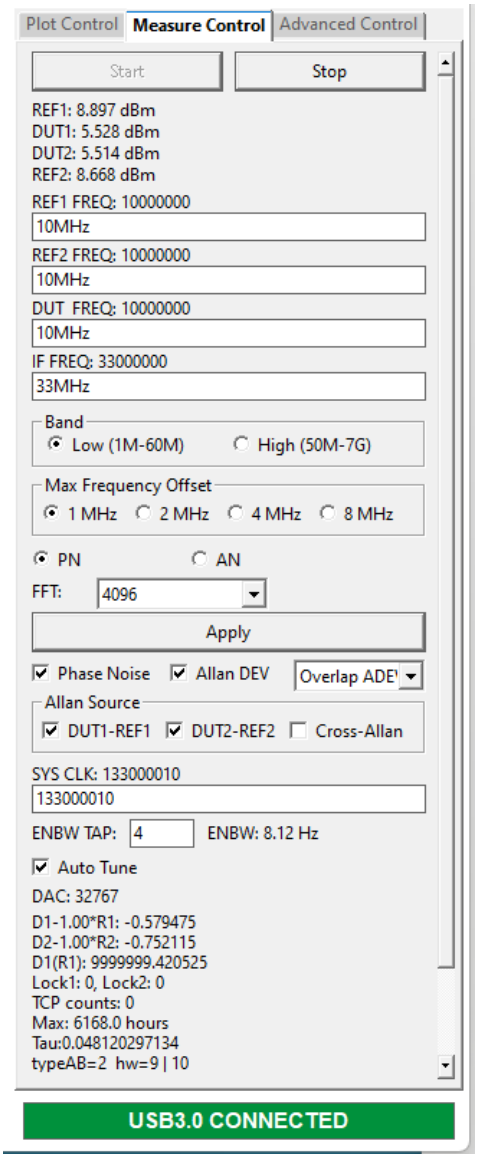


Figure 6: Measure Control tab during a run.

4.4.1 Run control and level readouts

Start / Stop
Begin and end the acquisition. **Start** is greyed while running, and **Stop** is greyed while idle. Change measurement parameters only while stopped, then press **Apply**.

REF1 / DUT1 / DUT2 / REF2 (dBm)
Live input power at the four RF ports. On the PN2060C, keep all inputs at or below +10 dBm and the reference levels close to this limit for the available dynamic range. Follow the model-specific input limits for the PN2060D and PN2060E in Sections 7 and 8. The PN2060E high-band external input must remain below 7 dBm. A reading of `Inf` indicates a USB contact problem (Section 2).

4.4.2 Frequency inputs

The four frequency boxes accept plain Hz values (e.g. `10000000`), values with digit grouping (`10 000 000` – spaces are inserted automatically while typing), or engineering suffixes `K`, `M`, `G` (e.g.

`10MHz`, `102.4M`). On leaving a box the entry is normalized to engineering notation. The label above each box shows the exact applied value in Hz. The *Tab* key cycles between the frequency boxes.

REF1 FREQ
Frequency of the reference source connected to **REF1**.

REF2 FREQ
Frequency of the reference source connected to **REF2**. **Set REF1 and REF2 to the same nominal frequency** and use physically independent sources (Section 3.3).

DUT FREQ
Frequency of the device under test (the signal split into **DUT1** and **DUT2**). Observe the DUT/REF ratio limits of Section 3.3 for direct sampling. For integrated high-band measurements, use the carrier and conversion settings in Sections 7 and 8.

IF FREQ
Intermediate frequency – used only in the **High (50M-7G)** band of the PN2060D, where the internal local oscillator runs at $f_{LO} = f_{DUT} + f_{IF}$ (high-side injection) and the analyzer digitizes the IF. Typing a DUT frequency auto-fills a default IF near 33 MHz such that the LO lands on a whole MHz. You can overwrite this value before **Apply**. In the **Low** band the value is ignored. For the PN2060D IF selection rules see Section 7.3.

4.4.3 Acquisition settings

Band
Low (1M-60M) selects the direct-sampling input path. **High (50M-7G)** selects the down-converting front end of the PN2060D. On a PN2060C leave **Low** selected.

Max Frequency Offset
Selects an analysis span of 1, 2, 4 or 8 MHz on the PN2060C. The PN2060D adds 16 and 20 MHz. The USB data rate and CPU load scale with the span (Section 2.1). Use a powerful desktop PC with an Intel 14th-generation i5 or better for 16/20 MHz spans. In direct-sampling operation, spans $\geq$8 MHz require DUT/REF ≤ 3 (Section 3.3). Reduce the span on slower computers.

PN / AN
Selects phase-noise or amplitude-noise measurement. After switching, close and restart the software, or a *Data Loss* error may follow. Treat results from the experimental AN function as indicative.

FFT
Sets the FFT length per decade from 128 to 16384. Larger values raise the frequency resolution of the analysis and slow the trace update. For PN2060D high-band measurements, see the FFT selection guidance in Section 7.4.

Apply
Writes all panel settings to the instrument. Use it after every parameter change, while stopped.

4.4.4 Result selection

Phase Noise / Allan DEV
Select the results for the run. **Allan DEV** enables Allan-deviation accumulation. The adjacent combo box selects **Overlap ADEV** or **MDEV**.

Allan Source
Choose the **DUT1-REF1**, **DUT2-REF2** and **Cross-Allan** traces. The example in Figure 17 selects all three, allowing the individual pairs and their two-channel cross-correlated result to be viewed together.

4.4.5 Clock and filter settings

SYS CLK
The exact ADC sampling-clock frequency in Hz (nominal 133 000 010). The label shows the applied value. Enter a corrected value when the actual clock deviation has been measured. Confirm this value before starting because it scales the frequency axis and all readouts.

ENBW TAP
Selects the decimation-filter tap for the Allan and difference-data path. Read the displayed equivalent noise bandwidth, sample rate and sample interval for the active configuration. The close-in Allan example in Figure 17 uses TAP 5, approximately 0.812 Hz ENBW, 2.078 samples/s and a 0.4812 s interval. A wider bandwidth updates faster with more trace noise. A narrower bandwidth gives a slower, smoother trace.

Auto Tune
Continuously steers the internal sampling clock. The current DAC word is displayed below. Keep this control enabled for normal operation, including long acquisitions.

DAC
Read-only display of the clock-steering DAC word.

4.4.6 Diagnostic readouts

The diagnostic block below the controls reports the following live values.

D1-m*R1: / D2-m*R2:
Measured frequency difference (Hz) between each DUT channel and its reference, scaled by the nominal ratio $m = f_{\mathrm{DUT}}/f_{\mathrm{REF}}$.

D1(R1):
Absolute DUT frequency computed against REF1 – the frequency-counter readout (see also Section 5.3).

Lock1 / Lock2
PLL lock flags of the two internal LO synthesizers. On the **PN2060D**, 1 means locked and 0 means unlocked. On the PN2060C, both flags read 0.

TCP counts
Number of samples streamed to TCP clients (Section 4.6).

Max: ... hours
Capacity of the Allan record at the current τ_0 – the maximum run length that can be accumulated.

Tau:
The base sampling interval τ_0 (s) of the Allan record.

typeAB / hw
Instrument identification (hardware version, feature level and license status), useful when requesting support. Units with a reduced maximum span additionally show `[8M max]`.

4.5 Plot Control tab

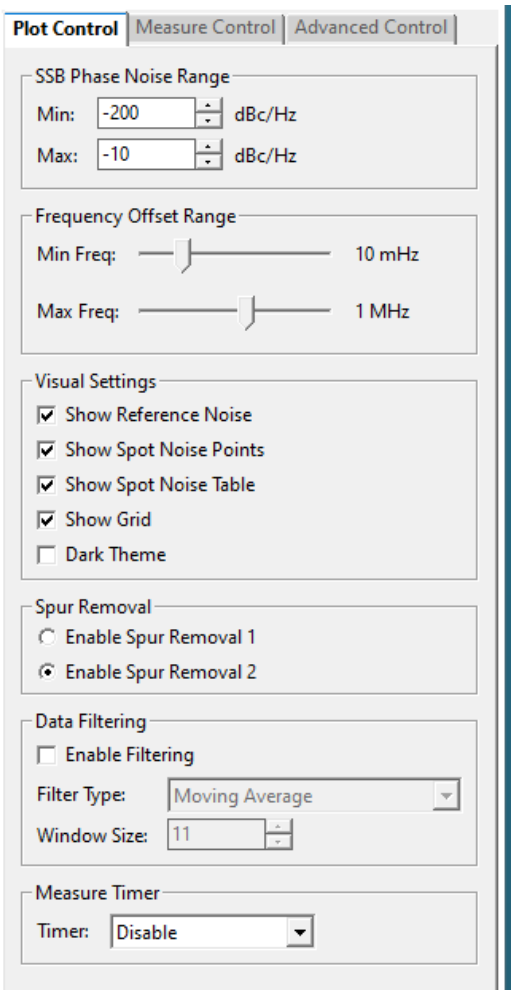


Figure 7: Plot Control tab.

SSB Phase Noise Range

Min / **Max** set the vertical axis of the phase-noise plot in dBc/Hz (default −200 to −10). The spinners step in whole dB.

Frequency Offset Range

Min Freq / **Max Freq** sliders limit the displayed offset range (10 mHz–1 MHz by default). The value labels show the current limits. The upper limit also defines the default upper bound of the jitter integration (`Max` keyword, Section 4.6).

Visual Settings

- **Show Reference Noise** – draw the grey estimated system noise floor (*Sys Noise (Ref)*).
- **Show Spot Noise Points** – red markers at decade offsets.
- **Show Spot Noise Table** – numeric spot-noise table in the plot (position adapts to the window size).
- **Show Grid** – plot grid lines.
- **Dark Theme** – dark color scheme for the whole window.

Spur Removal

The experimental algorithms add CPU load. **Enable Spur Removal 1** uses classification. **Enable Spur Removal 2** removes every detected spur. Disable these controls if processing cannot keep up with acquisition.

Data Filtering
Smooths the displayed trace. Select **Enable Filtering**, choose a filter type (**Moving Average**, **Median Filter** or **Savitzky-Golay**) and set an odd **Window Size** (default 11).

Measure Timer
Stops acquisition after the selected duration. Choices include 10 min, 30 min, 1–12 h and 1–1095 days. Select **Disable** to control the duration manually. Use the timer for unattended long runs.

4.6 Advanced Control tab

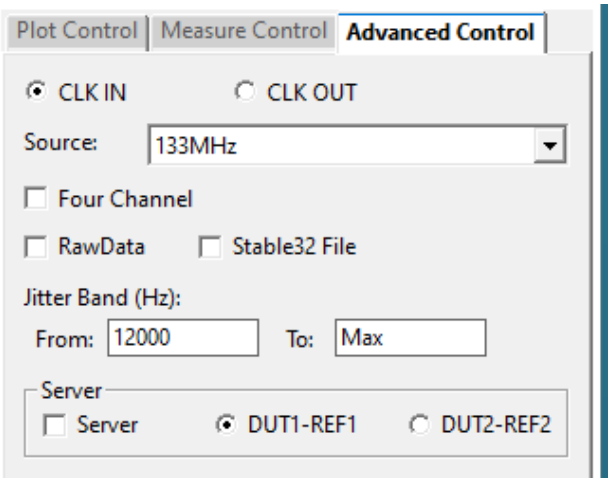


Figure 8: Advanced Control tab.

CLK IN / CLK OUT
Reserved for external clock input/output. **This function is still under development and is not supported** – leave the setting at its default (**CLK IN**).

Source
Sampling-clock source selector. **Only the 133MHz setting is supported at present – do not change it.**

Four Channel
Uploads all four ADC channels to the PC, doubling the data rate. The rate follows the **Max Frequency Offset** selection (Section 2.1), e.g. 32 Mbyte/s at the 8 MHz span. This enables the frequency-counter readouts for REF2 and DUT (Section 5.3) and extends the diagnostic block with the per-channel frequency estimates (`f_ADC`, `f_R1`, `f_D1`, `f_D2`, ...).

RawData
Streams the raw ADC data to disk after **Apply** + **Start**. The rate scales with the selected span in the same way (tens of Mbyte/s). A solid-state drive is required. Use for offline post-processing with the supplied scripts.

Stable32 File
Additionally writes a sigma–tau text file compatible with the *Stable32* frequency-stability software.

Jitter Band (Hz)
Integration limits (**From** / **To**) for the RMS-jitter figure in the plot status line. Default `12000` to `Max`, where `Max` tracks the upper limit of the displayed offset range.

Server
Enables the TCP timing-data server on `localhost:8888`. The radio buttons choose the streamed pair (**DUT1-REF1** or **DUT2-REF2**). Other applications that can receive the data stream can connect and record in real time. The `TCP counts` diagnostic shows the number of streamed samples.

5 Measurement Views

All views share the same acquisition. You can switch views during a run using the **Measurement** menu or the **Phase Noise**/**Allan DEV** selectors.

5.1 Phase Noise

The primary view plots single-sideband phase noise $\mathcal{L}(f)$ in dBc/Hz versus log frequency offset (Figure 5). The trace fills from high offsets toward low offsets as the per-decade correlation counts grow. Judge validity against the grey system-noise floor.

5.2 Allan Deviation

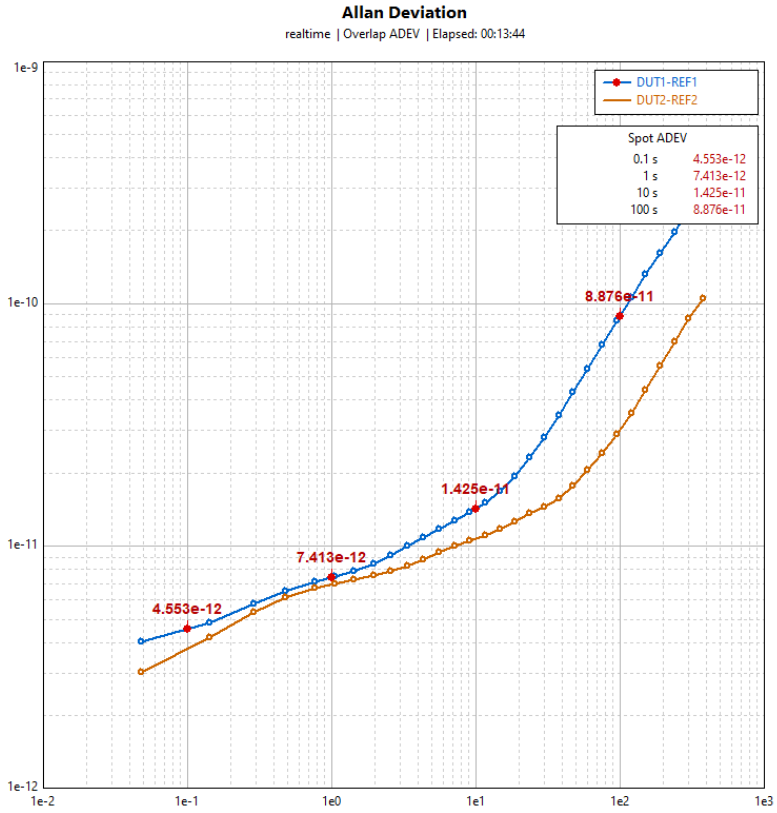


Figure 9: Allan-deviation view (**Overlap ADEV**) showing the **DUT1-REF1** and **DUT2-REF2** branches of two 10 MHz OCXOs. The spot table lists decade τ values.

Enable **Allan DEV** *before* starting the run (the record accumulates from **Start**). Choose **Overlap ADEV** or **MDEV**. Select the individual branches (**DUT1-REF1**, **DUT2-REF2**, as in Figure 9) or the **Cross-Allan** cross-correlated result. The spot table reports decade τ points. The `Max`/`Tau` diagnostics show the record capacity and the base interval. The **ENBW TAP** filter setting (Section 4.4) trades update rate against trace smoothness.

5.3 Frequency Difference

Plots the zero-based frequency difference of the selected pair (**DUT1-REF1** or **DUT2-REF2**) versus time. The table reports the absolute DUT frequency averaged over 0.1/0.3/1/3/10 s together with the fractional error – a high-resolution frequency counter. With **Four Channel** enabled the interface also displays the frequencies of REF2 and DUT. The accuracy of these frequency readouts depends on REF1.

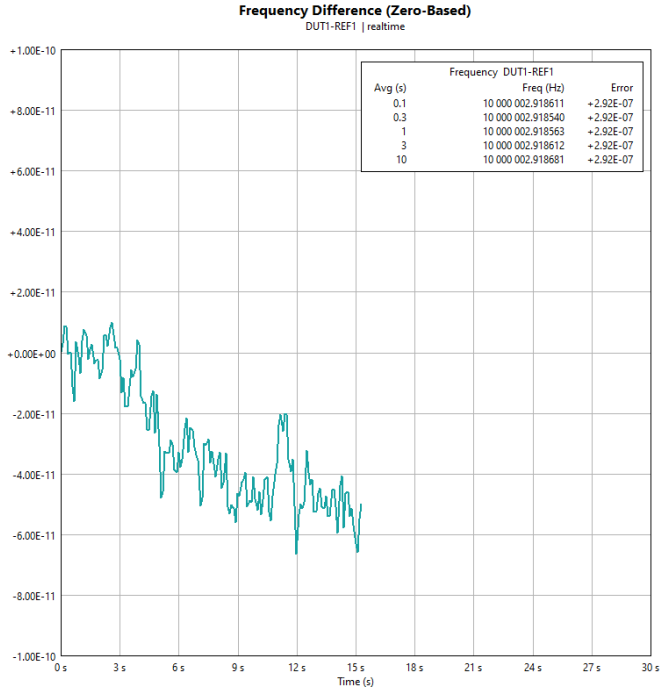


Figure 10: Frequency-difference view with multi-τ averaging table.

5.4 Phase Difference

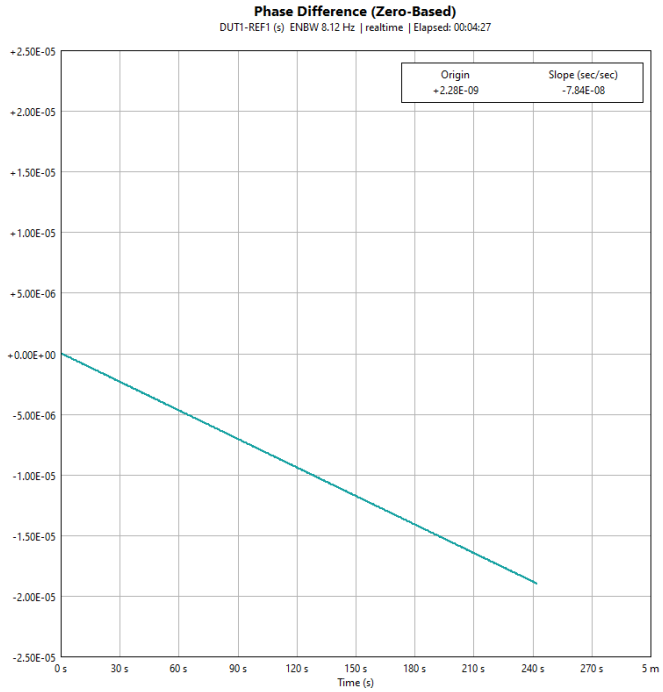


Figure 11: Phase-difference view with a table of the fitted origin and slope.

Plots the zero-based phase difference (in seconds) of the selected pair versus time. The inset reports the fitted origin and slope (s/s – the mean fractional frequency offset). The view re-initializes for a few seconds when selected.

6 Data Files and Interfaces

Table 3: Output files and interfaces.

Output	Where	Content
`PNdata.csv`	File → Save Data CSV	Phase-noise trace as frequency/level pairs (name selectable).
`.PNP` file	generated with the CSV	Converted format readable by other frequency-analysis software.
`.xlsx` workbook	File → Save All Data / Load Data	Complete session containing all views and settings, reloadable for offline review.
`capture.png`	File → Save Plot PNG	Bitmap of the current plot area, written to the program folder.
Raw data stream	**RawData** checkbox	Raw ADC samples to disk, ≈32 Mbyte/s at 8 MHz with Four Channel enabled (SSD required, Section 2.1).
Sigma–tau file	**Stable32 File** checkbox	Stability data for *Stable32*.
TCP stream	**Server** checkbox	Live timing data on `localhost:8888` (pair selectable) for other applications that can receive the data stream.

Note

TCP port 8888 serves one PN2060 application instance at a time. The server reports an error when the port is already occupied.

7 PN2060D (1 MHz–7 GHz) Operation

7.1 Overview

The PN2060D packs the measurement engine of the PN2060C together with two phase-locked down-converters and two internal 102.4 MHz OCXO references into one enclosure (Figure 12). The front panel has two signal input ports identified by their panel labels, one for the 1–50 MHz band and one for the 50 MHz–7 GHz band. Both bands pass internal 60 MHz low-pass filters. The rear panel carries the USB Type-C data port and a +7.5 V power input. The current product-page specification lists a 4 A adapter. Use the supplied adapter and the rating shown on the instrument. Connect the USB data cable first, then connect the external power supply to the PN2060D. Supply quality can affect spurious signals.



Figure 12: PN2060D 1 MHz–7 GHz phase noise analyzer.

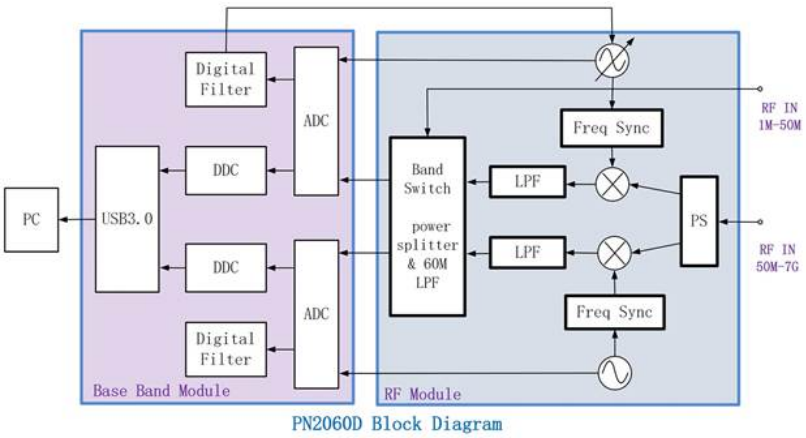


Figure 13: PN2060D V2 signal path showing the band switch, splitter, mixers, 60 MHz low-pass filtering, ADCs, digital down-conversion and USB 3.0 interface.

7.2 Specifications (PN2060D)

Table 4: PN2060D specifications.

Frequency range	1 MHz–7 GHz (1–50 MHz and 50 MHz–7 GHz bands)
Input power level	≤13 dBm (≤10 dBm preferred)
Offset range	0.01 Hz–20 MHz (**Max Frequency Offset** up to 20 MHz)
Internal references	two 102.4 MHz OCXOs
Signal type	sine wave
Input impedance	50 Ω
Capability	phase noise / amplitude noise (AN experimental)
OS support	Windows 7 / 8 / 10 / 11
Size / weight	265 × 260 × 70 mm / 3.5 kg
PC connection	USB 3.0 Type-C
Power supply	+7.5 V / 4 A (use the supplied rated adapter)

Carrier-specific results and their acquisition settings are presented in Section 10. The available floor depends on the carrier, reference sources, input level, IF and correlation depth.

7.3 High-band measurement procedure

The PN2060D uses a frequency-converting receiver. Apply the following model-specific settings together with the general measurement procedure.

1. **Band selection.** Set **Band** to **Low (1M-60M)** for the direct input or **High (50M-7G)** for the down-converting input. All changes take effect after **Apply**.
2. **References.** Keep **REF1 FREQ** and **REF2 FREQ** at `102400000` (the internal OCXOs).
3. **IF selection.** In the high band, enter the DUT frequency and set **IF FREQ** such that the LO ($f_{LO} = f_{DUT} + f_{IF}$) sits above the DUT. Use an IF of 11–20 MHz for high-performance OCXOs or 15–23 MHz for noisier synthesized sources. Avoid very small IFs – a larger IF reduces errors at far offsets (the internal low-pass filters are 60 MHz). For measurements using the full 20 MHz offset span, an IF near 31 MHz is a good choice. LO frequencies that are simple integer multiples of the signal tend to produce more spurs. Shift the IF slightly in that case.
4. **FFT selection.** Use FFT 8192 for comparable high-frequency measurements to resolve spurious components and obtain the normal system-noise floor (Section 7.4).
5. **Lock indicators.** `Lock1`/`Lock2` must both read 1 (locked) for valid results (Section 4.4.6).
6. **Input level.** Keep the displayed DUT1/DUT2 levels below 6 dBm to minimize spurs and distortion. Use less than 10 dBm at the input during normal measurement. The absolute input limit is 13 dBm.

7.4 FFT selection for high-frequency measurements

For PN2060D high-band measurements, insufficient FFT resolution can leave spurious components poorly resolved and raise the displayed system-noise floor. In the 7 GHz example below, FFT 2048 raises the floor and FFT 8192 restores normal floor behavior. The grey **Sys Noise (Ref)** curve shows the effect most clearly. Use FFT 8192 for comparable measurements.

Stop acquisition before changing **FFT**, press **Apply**, and start a new run. Allow digital phase locking to settle before evaluating the result. Both screenshots use a 23.00214 MHz IF, two 102.4 MHz references and a 20 MHz maximum offset. The acquisition durations are 28 s and 48 s, respectively.

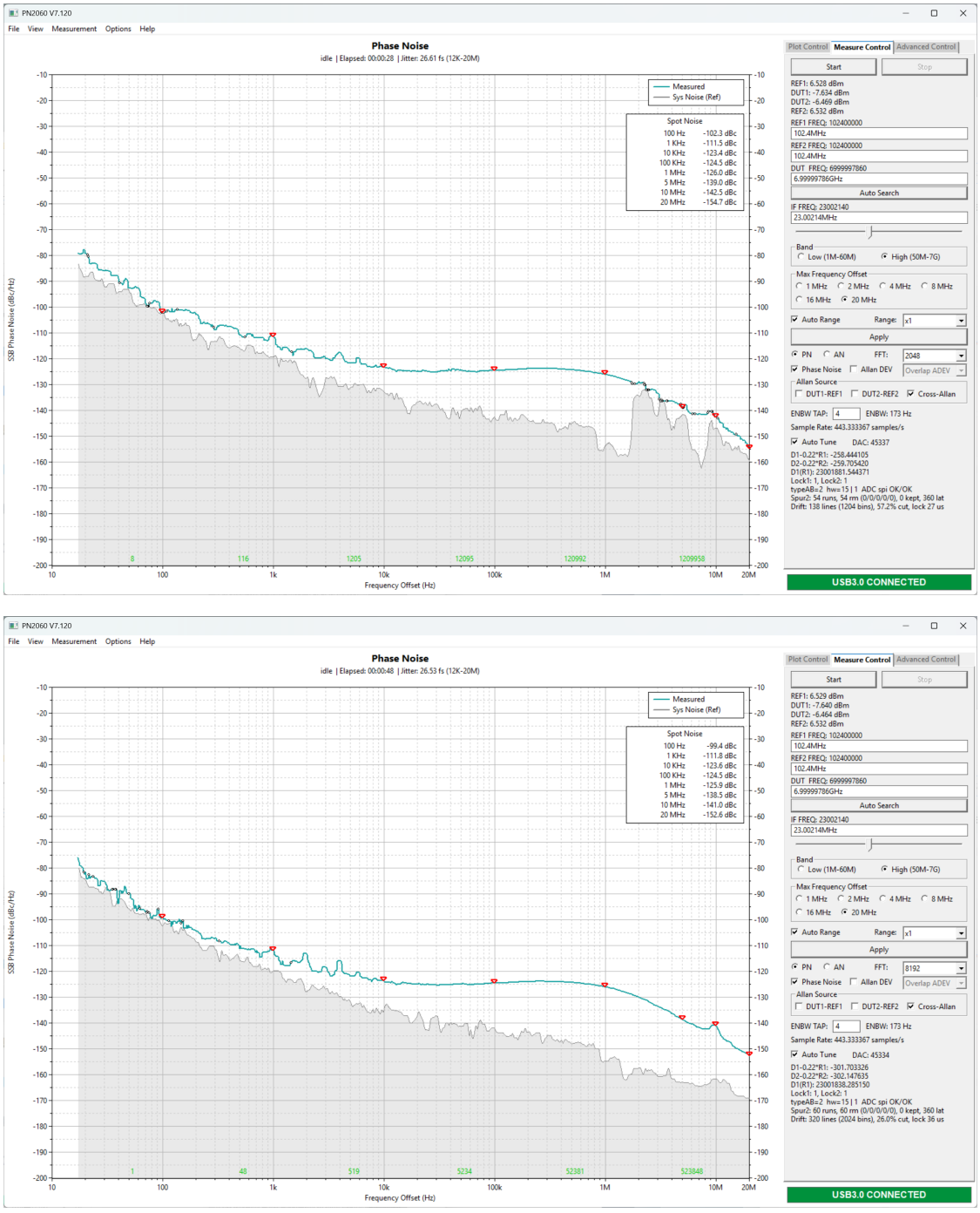


Figure 14: PN2060D at a 6.99999786 GHz carrier. The upper image uses FFT 2048 and shows a raised system-noise floor. The lower image uses FFT 8192 and shows normal floor behavior.

7.5 Digital phase locking

After **Start** (or a DUT frequency change) the frequency differences DUT1–REF1 and DUT2–REF2 converge under digital phase locking (Figure 15). The process takes from tens of seconds to a few minutes and must complete before results are valid – watch the difference readouts settle. The phase-locked design suppresses nearly all instrument-generated spurs.

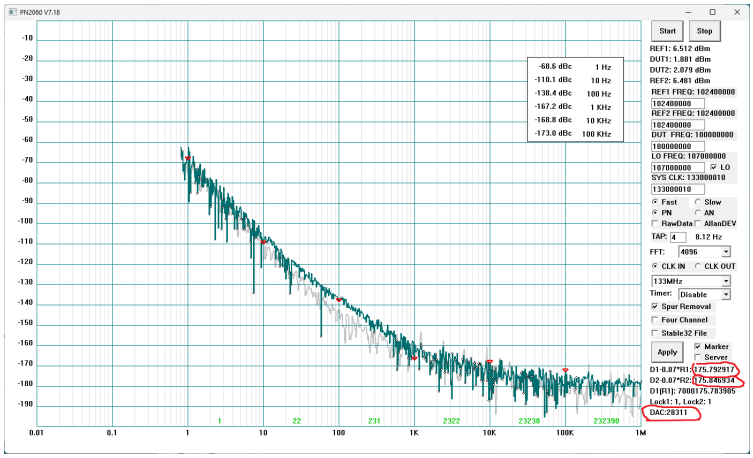


Figure 15: Convergence of the digital phase lock after a frequency change (100 MHz OCXO example, virtually spur-free).

Note

If the program remains in an unlocked state, close it, delete `pninit.bin` in the program folder and restart.

Note

Keep **Auto Tune** enabled during normal operation. Allow the references and analyzer to reach thermal equilibrium before a long acquisition.

8 PN2060E Operation

The PN2060E integrates four reference oscillators and covers 1–150 MHz through two input bands. It is intended for high-performance oscillator measurements, including the 100 MHz region. The front panel provides 1–50 MHz and 50–150 MHz inputs. The rear panel has a USB Type-C data connection and a separate 7.5 V power input. Use the supplied power adapter and the rating shown on the instrument.

Table 5: PN2060E band settings from the supplied operating guide.

	Low band	**High band**
Input port	1–50 MHz	50–150 MHz
Reference frequencies	10 MHz for REF1 and REF2	102.4 MHz for REF1 and REF2
DUT frequency	Actual DUT carrier	Actual DUT carrier
LO setting	Direct input	102.4 MHz
Input power limit	13 dBm maximum	Below 7 dBm
Displayed DUT1/DUT2 level	Check for overload	Below 5 dBm

Stop acquisition before changing settings, then click **Apply**. In software versions that use an **LO** checkbox for band selection, clear it for the low band and select it for the high band. Keep **Auto Tune** enabled for normal operation. Check the input levels and locking indicators before starting the measurement.

9 PN2060C Self-Correlation Noise Floor Verification

A self-correlation measurement feeds the same clean source to all four inputs. The current product-page example uses a 10 MHz CTI OCXO, an amplifier and a four-way splitter feeding **REF1**, **REF2**, **DUT1** and **DUT2**. The displayed input levels are approximately +9.1 dBm. The Allan-deviation measurement uses an ENBW of approximately 0.8 Hz.

Allow the analyzer and source to warm up. Use short, well-shielded cables and matched paths. Check the splitter isolation, impedance match and filtering because they can affect the cross-spectrum result. Longer correlation is especially important at close-in offsets.

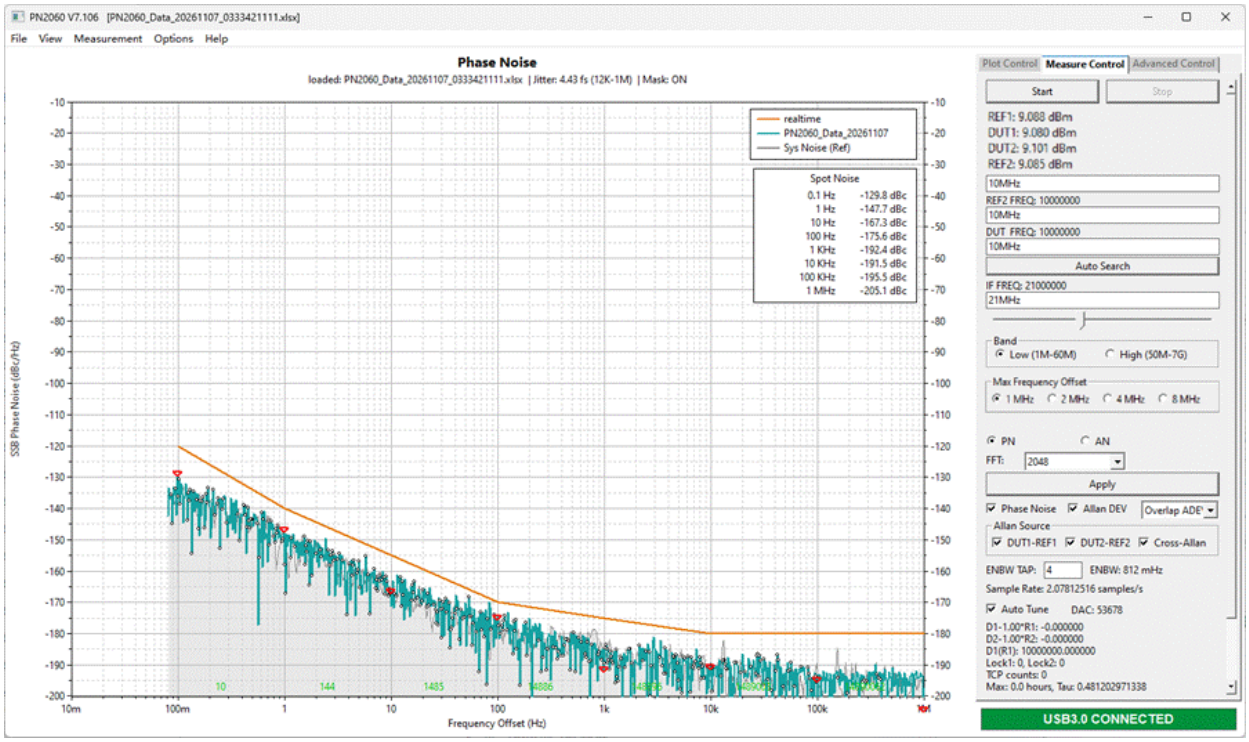


Figure 16: Current product-page self-correlation phase-noise result at a 10 MHz carrier. The displayed markers are approximately −129.8 dBc/Hz at 0.1 Hz and −147.7 dBc/Hz at 1 Hz. The published 90-minute specification remains the table in Section 1.3.

The numerical markers in Figure 16 describe this recorded measurement. Use the specification table when stating the instrument's published noise floor. Measurement conditions and correlation depth influence the achieved result.

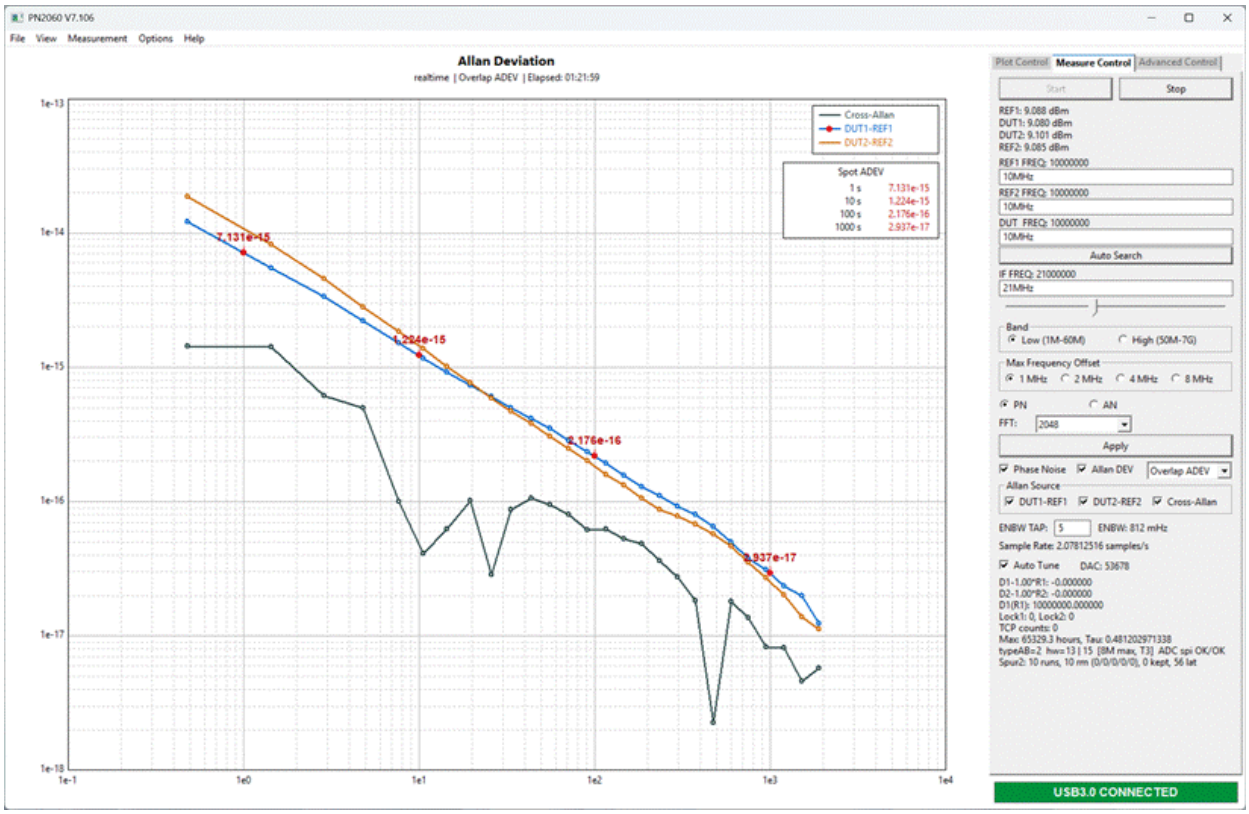


Figure 17: Allan-deviation traces from the product-page self-correlation example. The two colored traces are the individual DUT–REF pairs. The dark trace is the cross-correlated Allan result. The displayed sample interval is approximately 0.4812 s.

10 Measurement Examples

Each example records a specific DUT and measurement configuration. The published analyzer specification is given in Section 1.3. Keep carrier frequency, IF, reference settings, input levels and acquisition duration with exported results so that comparisons can be repeated.

10.1 Crystal and oven-controlled oscillators

10.1.1 A 1 GHz NEL OCXO

The product-page example shows a 1 GHz NEL OCXO measured with the PN2060D down-converting input. The displayed setup uses a 1.000 GHz DUT frequency, a 1.019 GHz local oscillator, two 102.4 MHz references and a 4096-point FFT. The resulting IF is 19 MHz. Figure 18 reproduces the product-page measurement. The displayed phase-noise markers are approximately −88.5 dBc/Hz at 10 Hz, −118.9 dBc/Hz at 100 Hz and −146.7 dBc/Hz at 1 kHz.

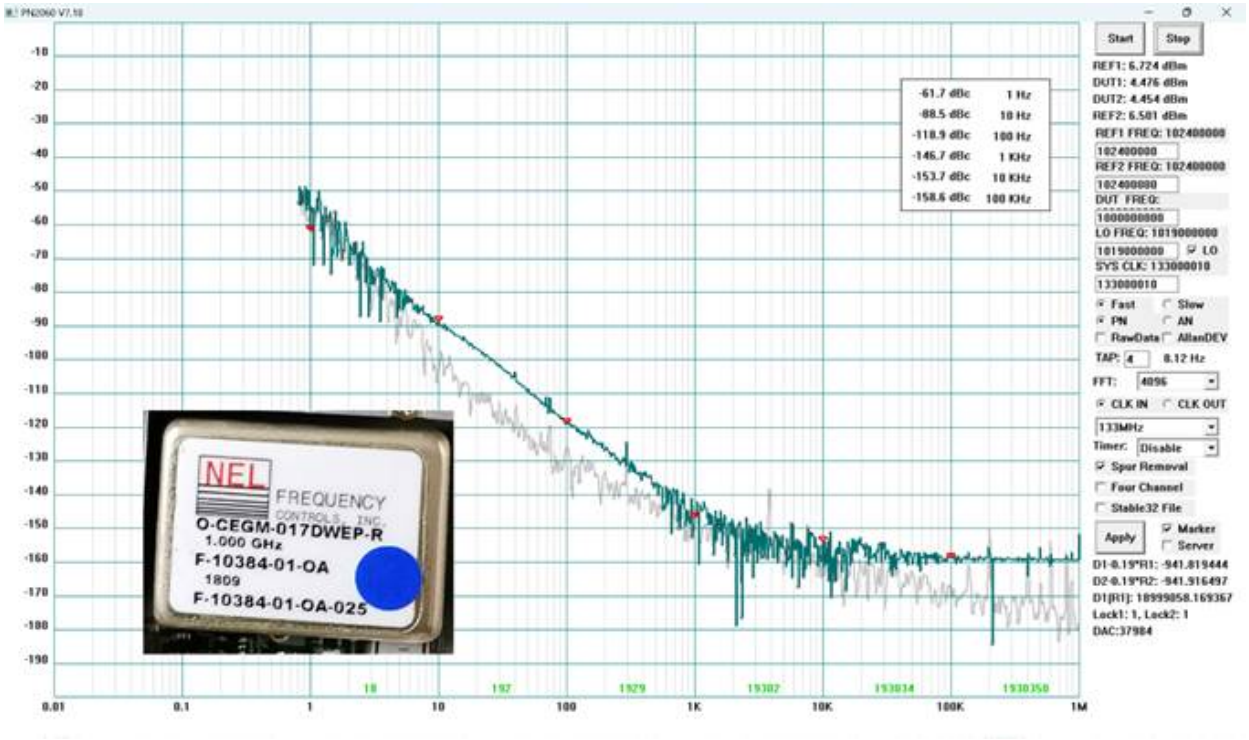


Figure 18: Product-page measurement of a 1 GHz NEL OCXO with a 19 MHz IF and two 102.4 MHz references.

10.1.2 Comparing 133 MHz crystal oscillators

The HCI AC, HCI VE and TAITIEN records illustrate differences among 133 MHz oscillator samples. Each workbook specifies a carrier of 133.00005 MHz, a 154 MHz local oscillator and a 20.99995 MHz IF. The two reference frequencies are 102.4 MHz. HCI VE and TAITIEN use 2048-point FFTs. HCI AC uses a 4096-point FFT.

Figure 19 compares the three stored phase-noise traces. Table 6 transcribes the individual measurement screens. HCI VE has lower phase noise at the displayed 100 Hz and 1 kHz offsets. TAITIEN has lower phase noise at the displayed 10 kHz, 100 kHz and 1 MHz offsets. The integrated jitter uses the same 12 kHz–20 MHz integration range for all three records.

Table 6: Displayed results for the three 133 MHz oscillator samples. Phase-noise entries are in dBc/Hz.

Quantity	HCI AC	HCI VE	TAITIEN
100 Hz offset	−89.7	−117.6	−111.0
1 kHz offset	−112.0	−144.9	−141.8
10 kHz offset	−125.6	−154.8	−157.7
100 kHz offset	−135.7	−156.8	−162.6
1 MHz offset	−145.6	−165.1	−168.0
Jitter, 12 kHz–20 MHz	262.63 fs	37.84 fs	27.43 fs
Displayed duration	2 min 44 s	2 min 1 s	2 min 20 s

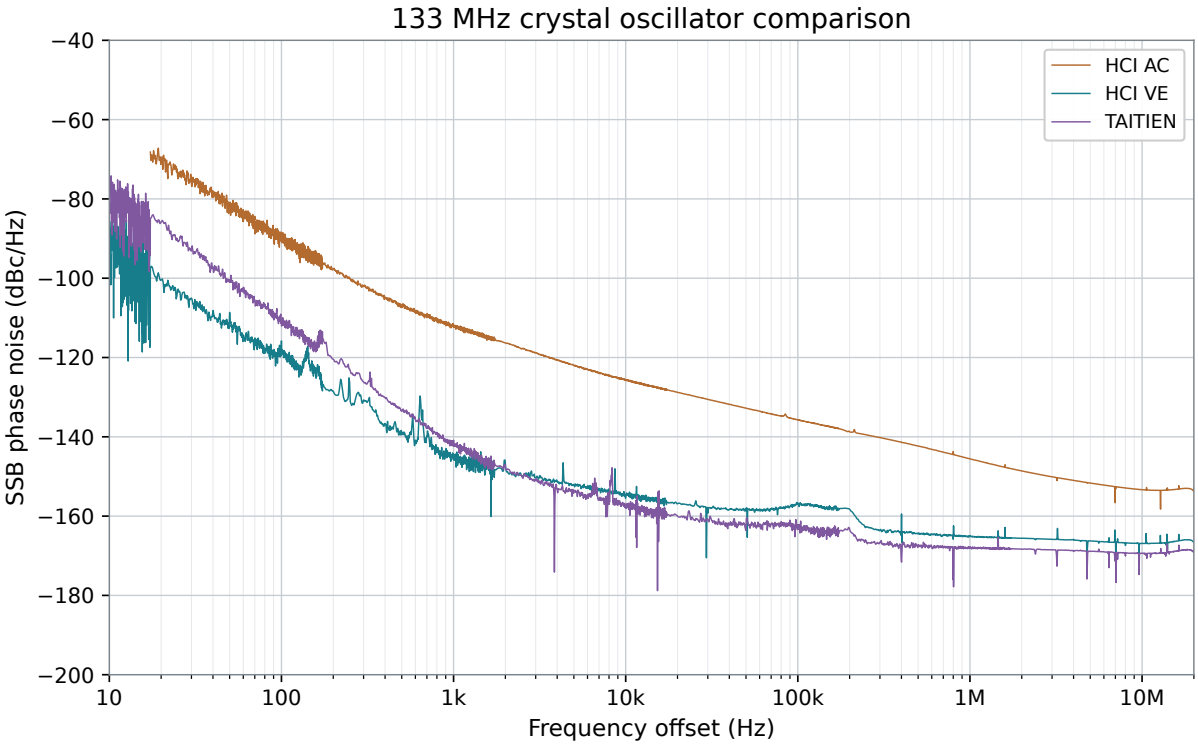


Figure 19: HCI AC, HCI VE and TAITIEN 133 MHz oscillator spectra from the original valid FFT bins without additional smoothing. The table reports the acquisition software's displayed spot readings.

10.1.3 SCTF 156.25 MHz Comparison

The website compares a 156.25 MHz SCTF oscillator using an Agilent E5052A and a PN2060D V2. The PN2060 setup shows two 102.4 MHz references, a 213.25 MHz LO and a 57 MHz IF. Its selected offset span is 20 MHz, with a displayed measurement duration of 3 minutes 53 seconds.

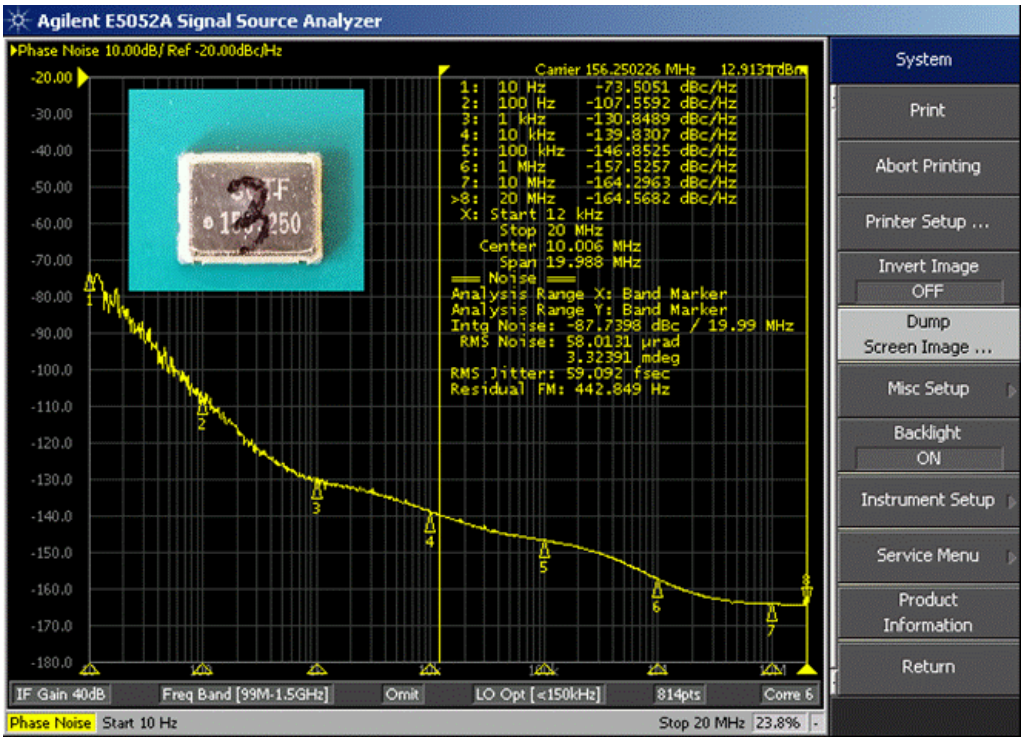


Figure 20: Agilent E5052A measurement of the 156.25 MHz SCTF oscillator.

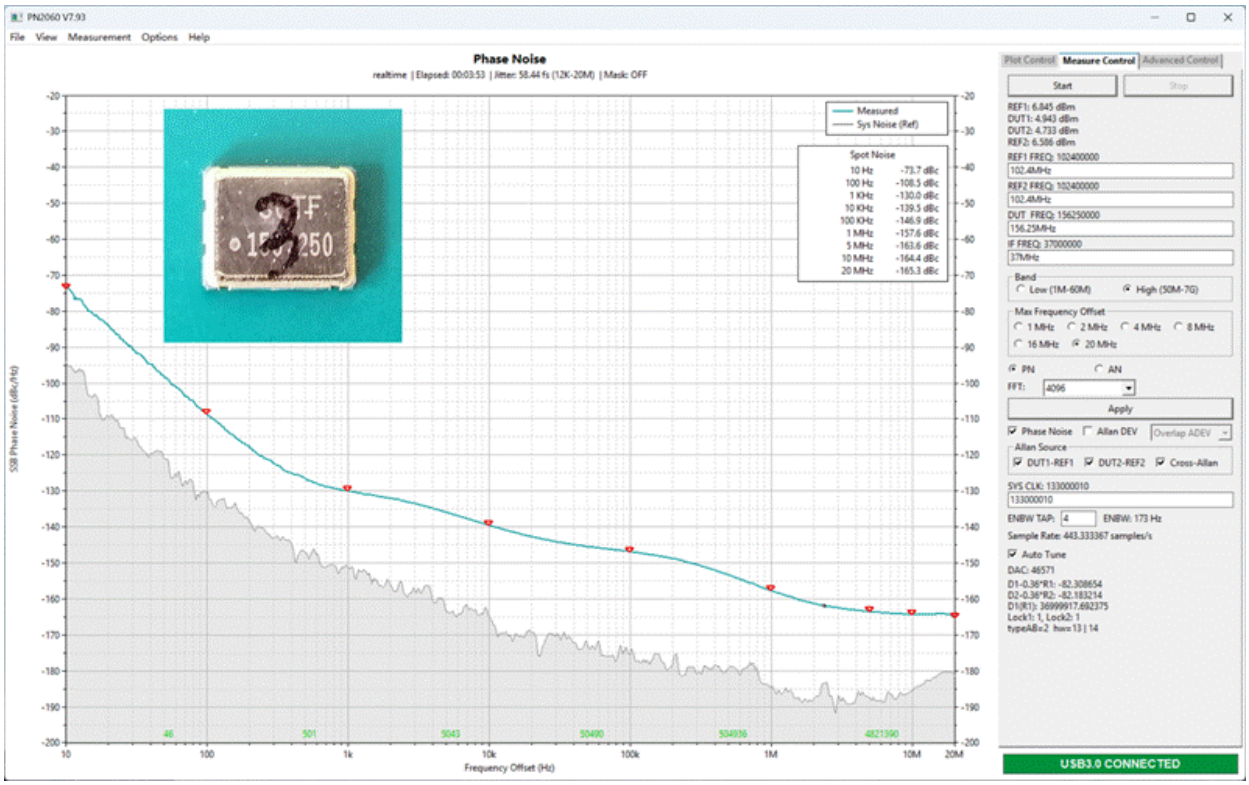


Figure 21: PN2060D V2 measurement of the same 156.25 MHz SCTF oscillator.

Table 7: Approximate phase-noise markers read from the two website screenshots, in dBc/Hz.

Offset	Agilent E5052A	PN2060D V2
10 Hz	−73.5	−73.7
100 Hz	−107.6	−108.5
1 kHz	−130.3	−130.0
10 kHz	−139.8	−139.5
100 kHz	−146.9	−146.9
1 MHz	−157.5	−157.6

10.1.4 Comparison with a Microchip 53100A

A 53100A measured a 10 MHz OCXO for 10 minutes, and the PN2060C measured the same unit for about 5 minutes. The results are nearly identical (Figure 22). In production screening of 10 MHz oscillator batches, a PN2060C cycle takes 3–9 minutes versus about 10 minutes on the 53100A.

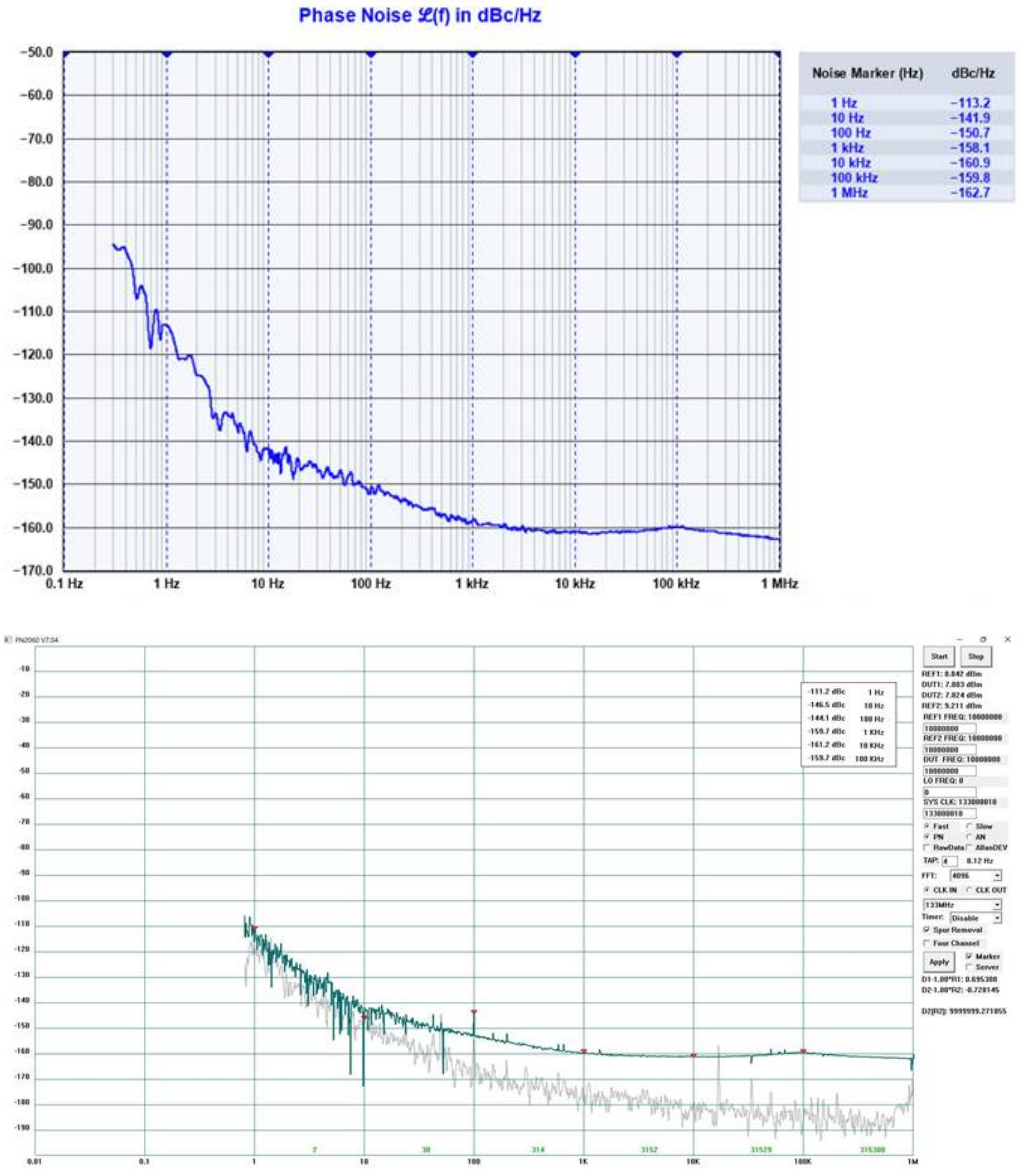


Figure 22: 53100A result above and PN2060C result below for the same 10 MHz OCXO.

10.2 Dielectric resonator oscillators

10.2.1 A 1 GHz DRO with a 20 MHz offset span

Figure 23 shows a DRO measured at 999.861867 MHz using the high-frequency input band. The recorded local oscillator frequency is 1.020 GHz, giving an IF of 20.138133 MHz. Both reference inputs are set to 102.4 MHz. The measurement uses a 4096-point FFT and a 20 MHz maximum offset.

The displayed acquisition duration is 27 minutes. The reported integrated jitter is 3.41 fs over 12 kHz–20 MHz. The spot readings are −112.7 dBc/Hz at 1 kHz, −140.0 dBc/Hz at 10 kHz, −163.7 dBc/Hz at 100 kHz and −170.8 dBc/Hz at 1 MHz. These readings characterize this DRO and the recorded measurement setup. The teal curve shows measured DUT phase noise. The gray curve is the software's **Sys Noise (Ref)** indicator.

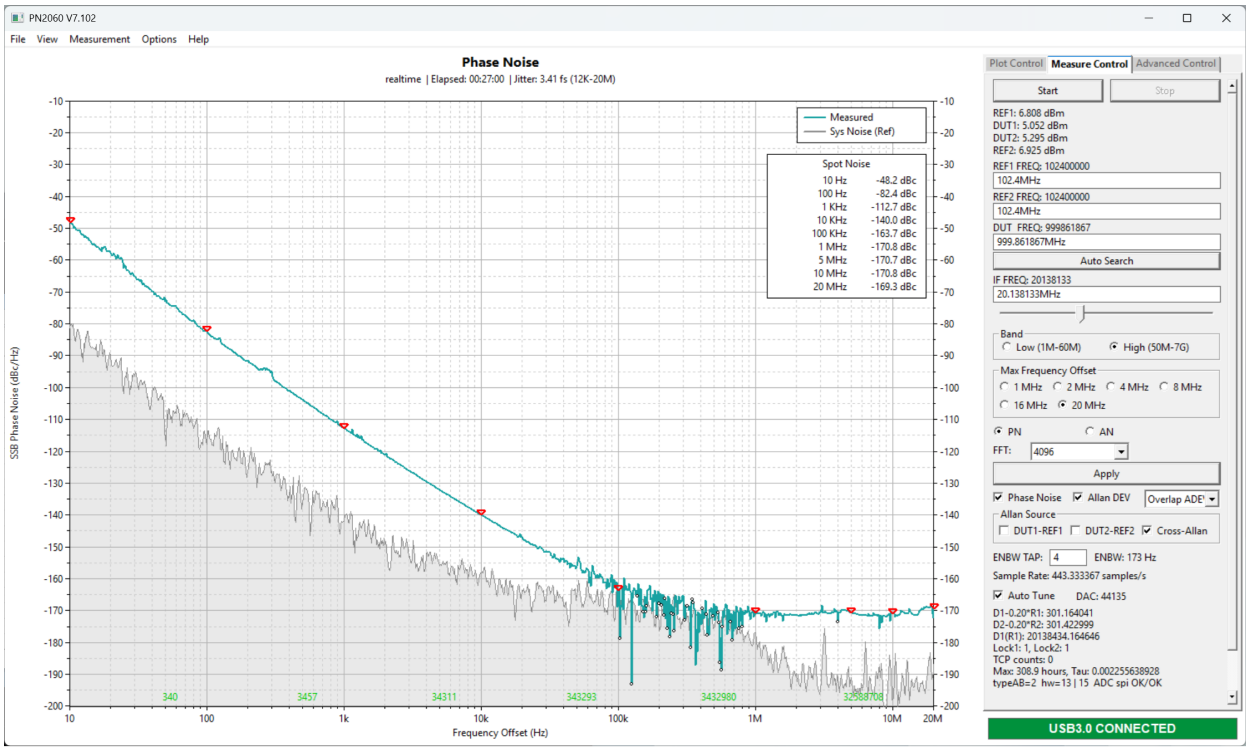


Figure 23: DRO phase noise at 999.861867 MHz, with a 20.138133 MHz IF. The screen records a 27-minute acquisition and 3.41 fs integrated jitter over 12 kHz–20 MHz.

10.2.2 PN2060D: 6.62 GHz DRO with stability measurement

The completed 62-second PN2060D record in Figure 24 measures a DRO at 6.619350127 GHz (approximately 6.62 GHz). The local oscillator is set to 6.640 GHz, producing a 20.649873 MHz IF. Both reference inputs are set to 102.4 MHz. The acquisition uses an 8192-point FFT, the high-frequency band and a 20 MHz maximum offset. Phase-noise and overlapping Allan deviation acquisition are enabled together, with **Cross-Allan** selected.

The displayed phase-noise readings are −43.8 dBc/Hz at 100 Hz, −73.5 dBc/Hz at 1 kHz, −101.8 dBc/Hz at 10 kHz, −126.4 dBc/Hz at 100 kHz and −149.2 dBc/Hz at 1 MHz. At 10 MHz and 20 MHz offset the displayed readings are −176.2 and −179.0 dBc/Hz, respectively. The displayed integrated jitter is 19.14 fs over 12 kHz–20 MHz.

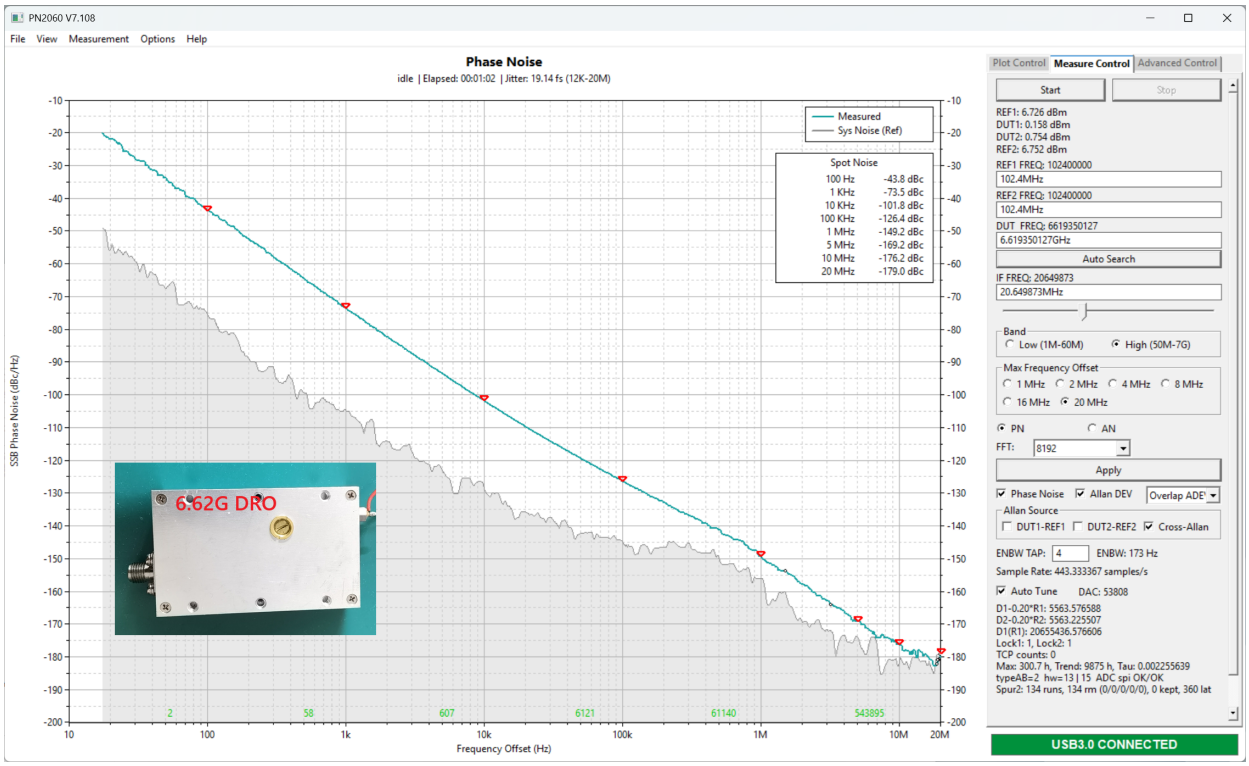


Figure 24: PN2060D phase-noise measurement of a 6.619350127 GHz DRO. The 6.640 GHz local oscillator gives a 20.649873 MHz IF.

Figure 25 shows the corresponding overlapping cross-Allan-deviation display. The spot values are 1.846×10^{-9} at 0.01 s, 2.429×10^{-9} at 0.1 s, 9.046×10^{-9} at 1 s and 8.289×10^{-8} at 10 s. The rising long-τ result documents the stability behavior of this DRO during the short acquisition.

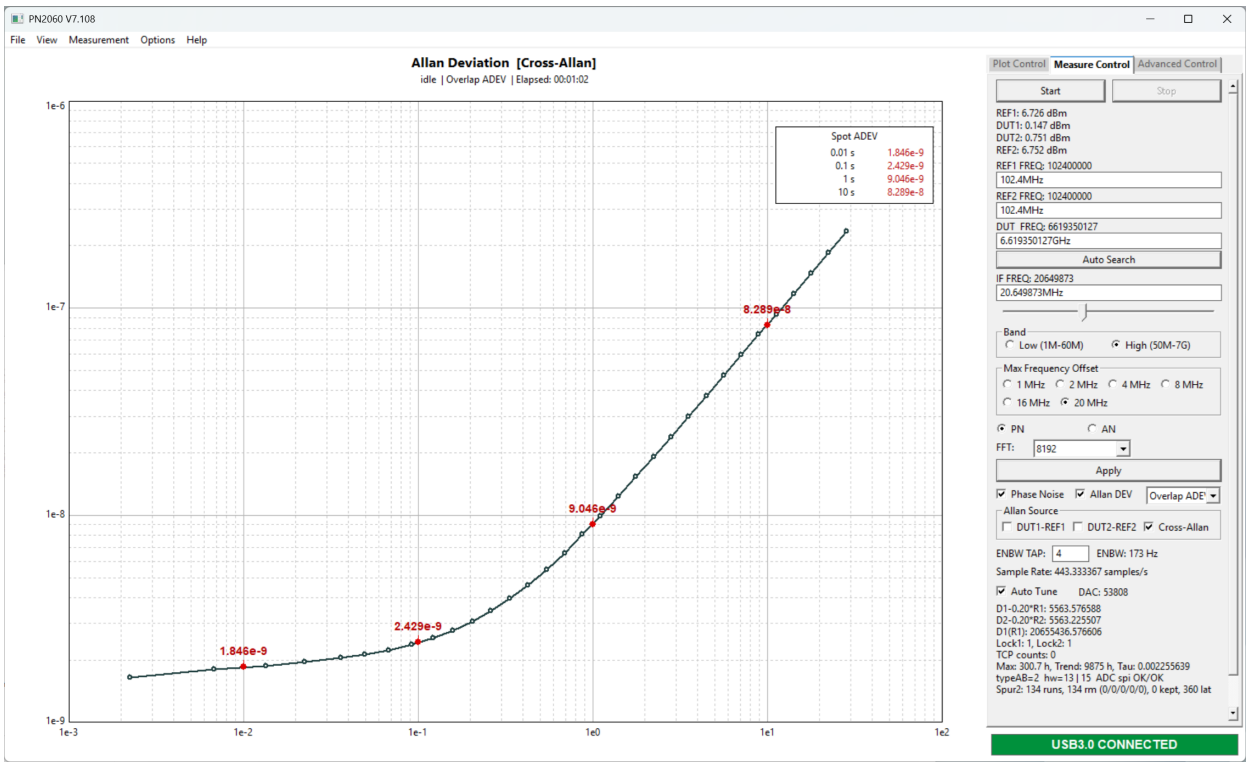


Figure 25: Overlapping cross-Allan deviation for the same completed 6.619350127 GHz DRO record.

10.3 Signal generators and frequency multipliers

10.3.1 HP8664A at 1 GHz

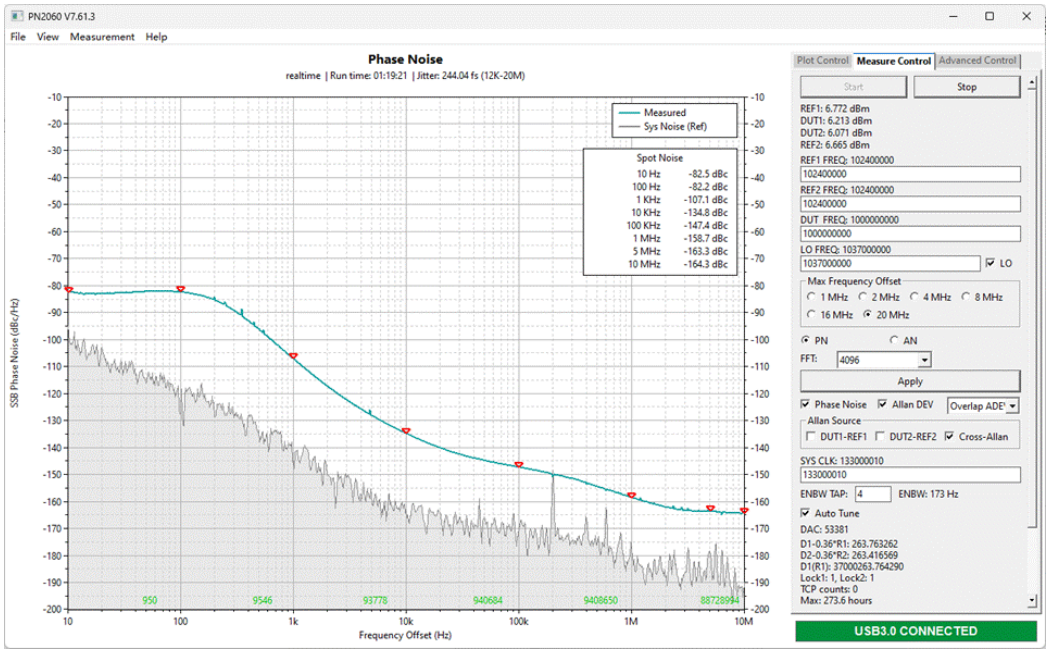


Figure 26: HP8664A (option 004) signal generator, 1 GHz output. Although the unit is more than 25 years old, the measured phase noise matches its specification well.

10.3.2 HP8664A at 3 GHz

The current product page includes an HP8664A signal generator with option 004 measured at a 3 GHz carrier. The displayed LO is 3.037 GHz, placing the IF near 37 MHz. The selected offset span is 20 MHz. The example shows approximately −96.3 dBc/Hz at 1 kHz and −153.7 dBc/Hz at 1 MHz after a displayed 1 minute 31 second run.

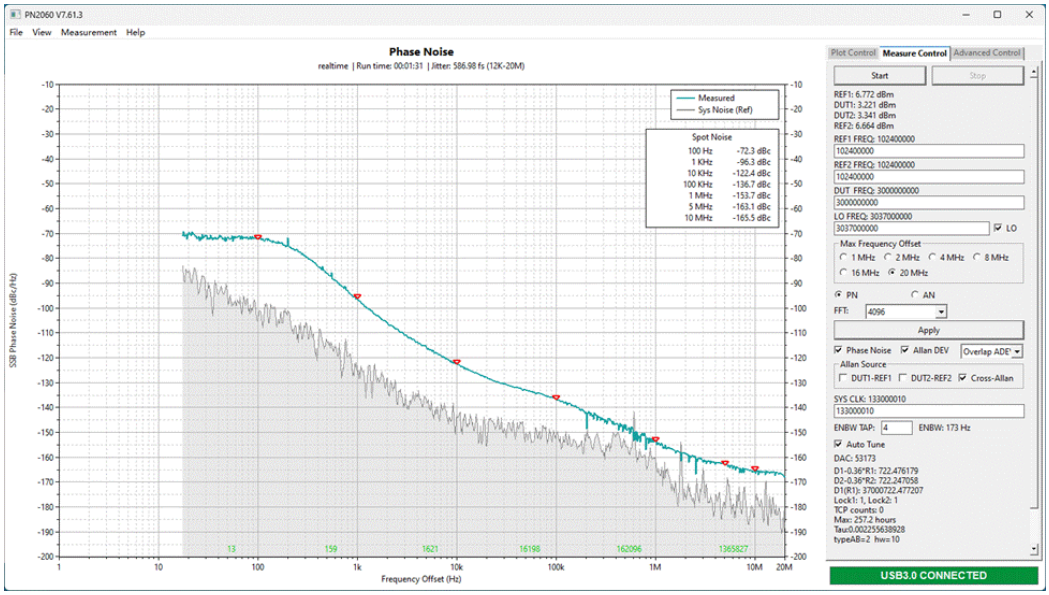


Figure 27: HP8664A option 004 at a 3 GHz carrier using a 37 MHz IF. The measured trace and the imaginary reference trace are displayed together.

10.3.3 A 6 GHz LMX2820 measurement

The LMX2820 example uses a 100 MHz NEL OCXO reference and a doubled 200 MHz reference input to the synthesizer. The PN2060D acquisition uses a 6 GHz DUT frequency, a 33 MHz IF, internal 102.4 MHz analyzer references, a 20 MHz offset span and an FFT length of 8192. The displayed acquisition lasts 67 s. The following values are read from the supplied measurement screenshots. They describe this DUT and setup.

Table 8: Common markers from the 6 GHz LMX2820 measurement.

Offset	PN2060D (dBc/Hz)	Comparison trace (dBc/Hz)
1 kHz	−108.1	−107.62
10 kHz	−116.0	−116.41
100 kHz	−119.3	−119.76
1 MHz	−125.7	−126.08
10 MHz	−149.6	−150.03

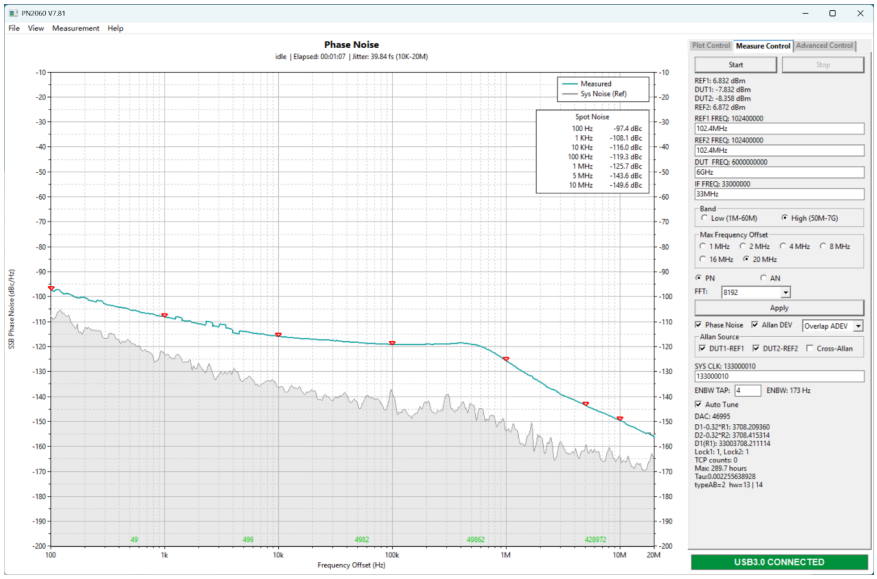


Figure 28: PN2060D acquisition of the LMX2820 at 6 GHz.

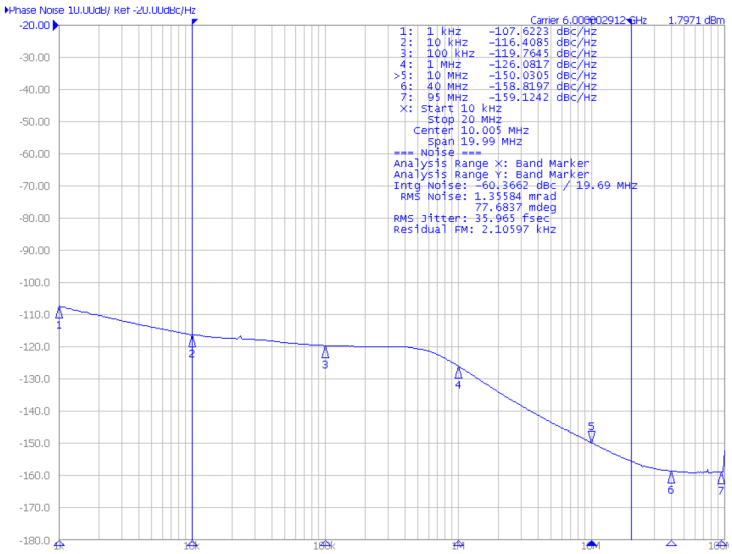
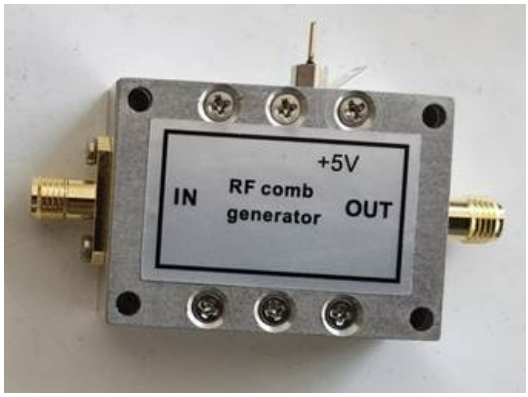
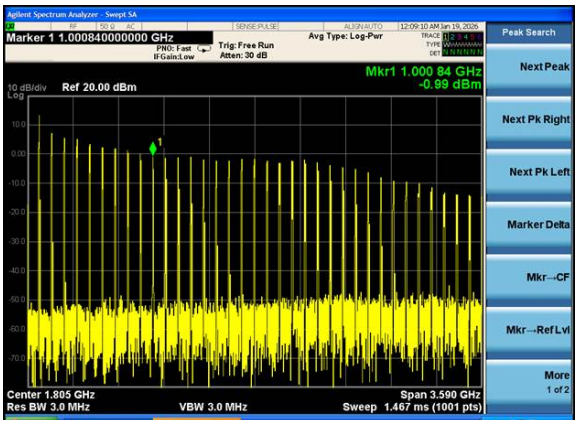


Figure 29: Comparison trace supplied with the 6 GHz LMX2820 example. The common phase-noise markers agree within approximately 0.5 dB.

10.3.4 SRD frequency multiplication





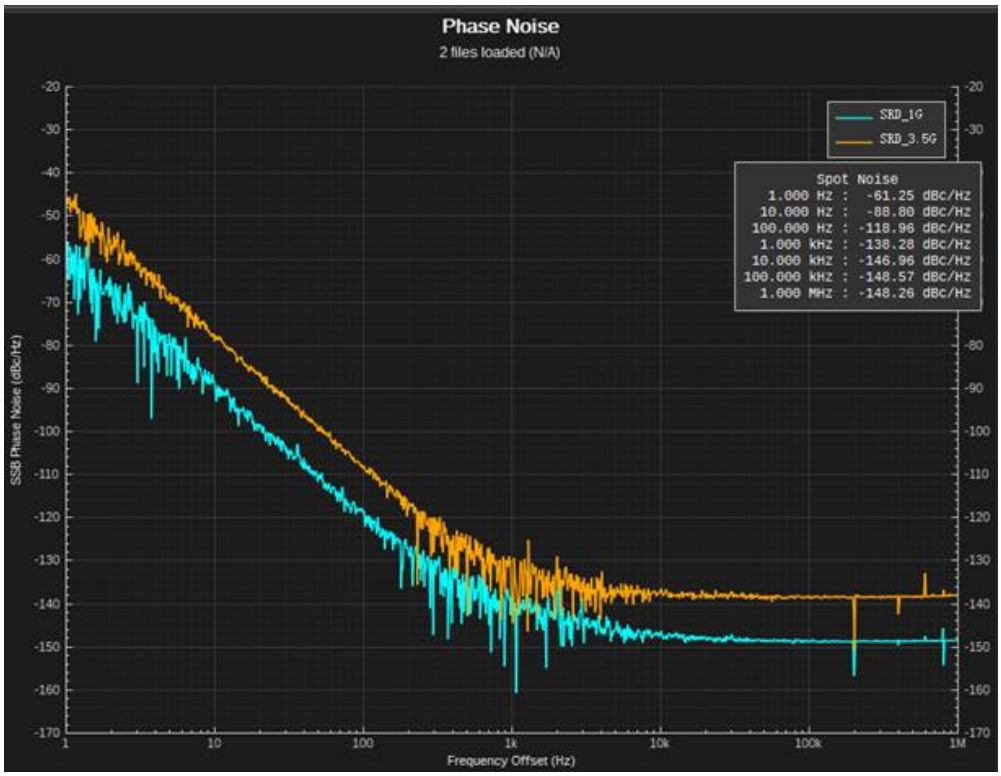


Figure 30: SRD frequency-multiplier module driven by a customized 100 MHz OCXO. The illustrations show the comb generator, its output spectrum and the band-pass-filtered phase noise measured at 1 GHz and 3.5 GHz.

11 Troubleshooting

11.1 Signs of insufficient USB power

- Device not recognized, or the driver cannot be installed.
- The program starts, power consumption rises by ≈40 %, then the program crashes or the computer becomes unresponsive.
- Test interruptions after some period (frequent on laptops whose USB 3.0 current limit is marginal).

Use a rear-panel USB port and disconnect other USB loads. If the problem persists, use a powered USB 3.0 expansion card (Section 2).

11.2 Data Packet Loss error

Heavy background services or an overloaded CPU interrupt the real-time stream. Close the software, disconnect the USB cable, reconnect, and restart the software. Reduce processing load by disabling **Spur Removal**, reducing **Max Frequency Offset** and closing background programs.

11.3 Laptop operation

Computer power designs affect the noise coupled into the measurement. When using a laptop, compare battery operation with operation from its AC adapter under the same measurement conditions. Repeat the comparison to check whether power-supply interference limits the achieved noise floor.

11.4 Quick checklist

- `Inf` level readouts → re-seat/rotate the Type-C plug or try another USB 3.0 port.
- No FX3 device → follow Section 2.3 and remove conflicting `libusb-win32` class drivers.
- Rapid drift at run start → allow ≈30 min warm-up (instrument and sources).
- Far-offset errors of 3–5 dB → missing low-pass filter (Section B.4).
- Strange artifacts/notches → isolation or impedance mismatch (Section B.3).

A Frequency Planning and Conversion

A.1 Extending the Frequency Range

Choose reference oscillators with frequencies and phase-noise performance suited to the DUT. Higher carrier frequencies increase the reference noise referred to the DUT, so 100 MHz-class references are useful for high-frequency measurements. Select filtering for the actual DUT spectrum and receiver band.

Down-conversion places a high-frequency DUT in the receiver's first Nyquist zone. A single converter adds its LO noise to the result, so the LO must have phase noise at least 6 dB below the DUT over the offsets of interest. A mixer followed by a suitable low-pass filter provides the basic signal path in Figure 31.

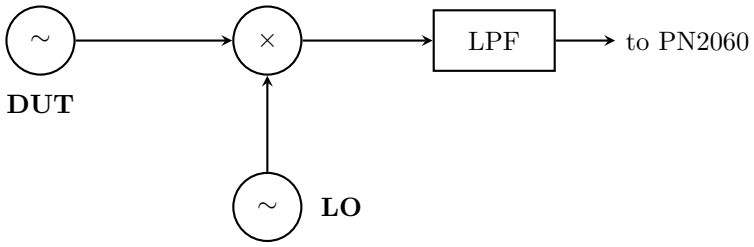


Figure 31: Single-channel down-conversion with a mixer and low-pass filter.

Two independent down-converter channels allow uncorrelated receiver and LO noise to average down through cross-correlation. The PN2060D integrates this signal path. Its operating procedure is given in Section 7. The 1 GHz NEL and 6.62 GHz DRO examples in Section 10 demonstrate complete frequency plans with the carrier, LO and IF documented.

For external mixers feeding a direct input, enter the converted IF as the receiver input frequency and retain the original carrier with the measurement record. For integrated down-conversion, enter the actual DUT carrier and configure the instrument's IF or LO controls as described in the model chapter.

A.2 Frequency Bands, Aliasing and the 50–150 MHz Method

A.2.1 Why digital analyzers care about bands

Aliasing and harmonic interference depend on the sampling frequency, input filtering and source spectrum. Splitter isolation and impedance matching also affect the measured cross spectrum. Figure 32 illustrates setup-dependent differences in measurements of a 100 MHz XO.

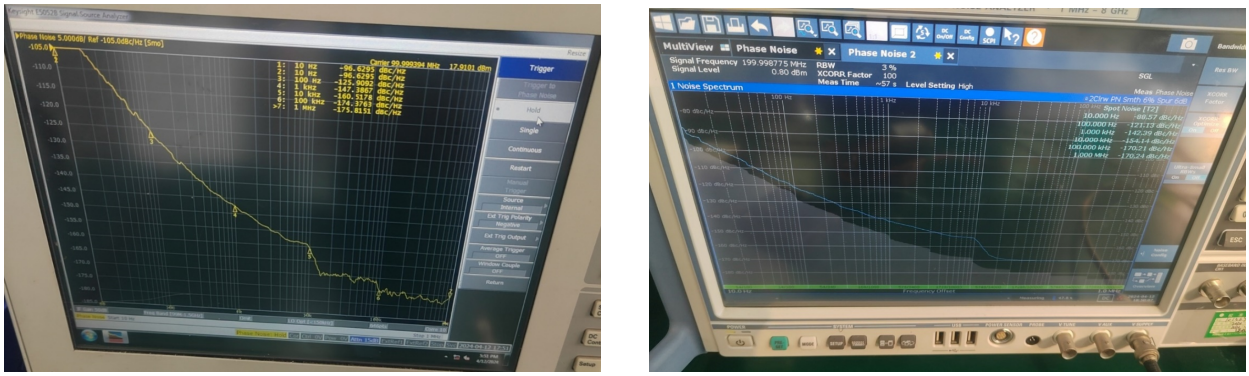


Figure 32: 100 MHz XO comparison traces supplied with the original operating guide.

A.2.2 Bands of the PN2060 (sampling at 133 MHz)

1. **1–66.5 MHz** is the first Nyquist zone. The recommended 1–60 MHz operating range allows margin for low-pass filtering.
2. **66.5–133 MHz** is the second Nyquist zone. Under-sampling makes the result sensitive to aliasing and test-port filtering.
3. **133–199.5 MHz** is the third Nyquist zone. Aliasing, ADC aperture jitter and filter choice strongly affect the result.

Down-conversion places the signal in the first Nyquist zone, where filtering and alias control are more manageable. The PN2060D implements this internally (Section A.1).

A.2.3 Recommended 50–150 MHz method

The following setup uses two external mixer channels connected to the direct receiver inputs, with two reference OCXOs as shown in Figure 33. Integrated D and E models use the settings in Sections 7 and 8.

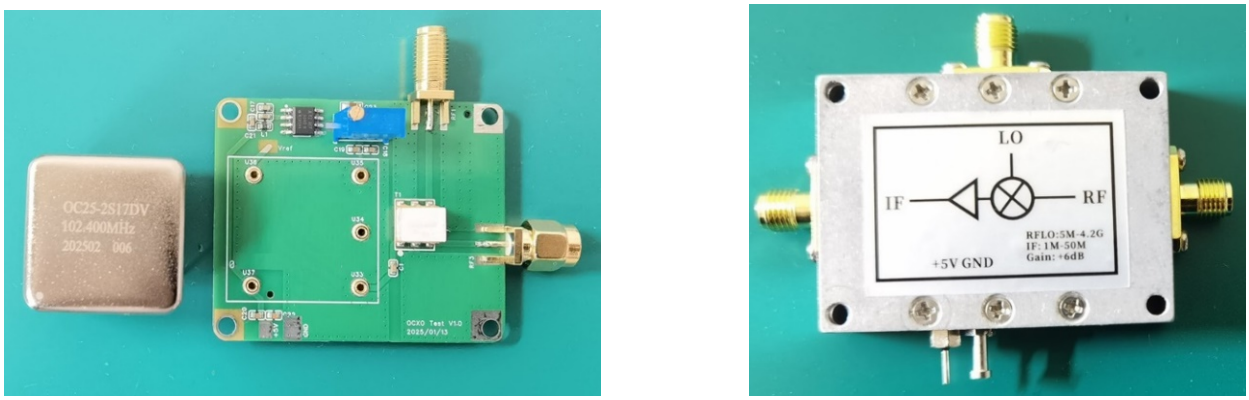


Figure 33: 102.4 MHz reference OCXO board and mixer/isolation-amplifier module used for second-Nyquist-zone testing.

1. Keep the DUT–LO frequency difference above 1 MHz and within 10 MHz. Use two 102.4 MHz references for a 100 MHz DUT, or two 100 MHz references for a 102.4 MHz DUT. A 120 MHz and 122.88 MHz pairing also meets this frequency-difference requirement.
2. Reference (LO) power ideally ≥10 dBm – low LO power reduces dynamic range.
3. Keep the power into the analyzer below 3 dBm. Measure the source level and add enough attenuation to meet this limit. Many oscillators deliver more than 7 dBm.
4. Offset the two references by roughly 30 Hz from each other to move the resulting spur family to 30 Hz and its harmonics, away from the decade points (10 Hz, 100 Hz, 1 kHz, . . .).
5. Enter the *difference* frequency as the DUT frequency (e.g. 102.4 − 100 = 2.4 MHz) – take care not to mistype it.
6. The DUT needs no band-pass filter in this method.

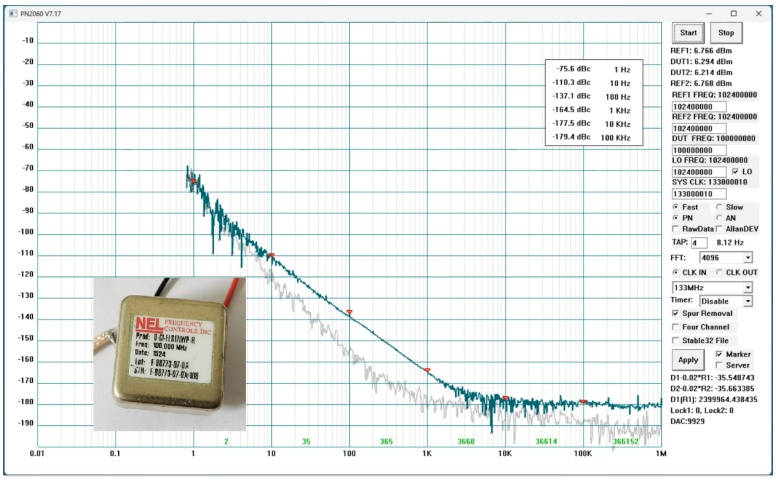


Figure 34: A 100 MHz OCXO measurement using the 50–150 MHz down-conversion method.

Other bands use the same frequency-planning method with suitable reference oscillators or multiplied references. Keep RF cables short and well-shielded. Record the IF, levels and filtering with each measurement.

B RF Connections and Oscillator Power

B.1 Power-Supply Impact on Phase Noise

Low-cost “linear regulator” bricks and some digitally-controlled bench supplies degrade phase noise dramatically – in places by more than 20 dB across 1 Hz–1 MHz – and add dense discrete components. Figure 35 shows the same DUT powered by a Longwei PS-6405F bench supply and by batteries.

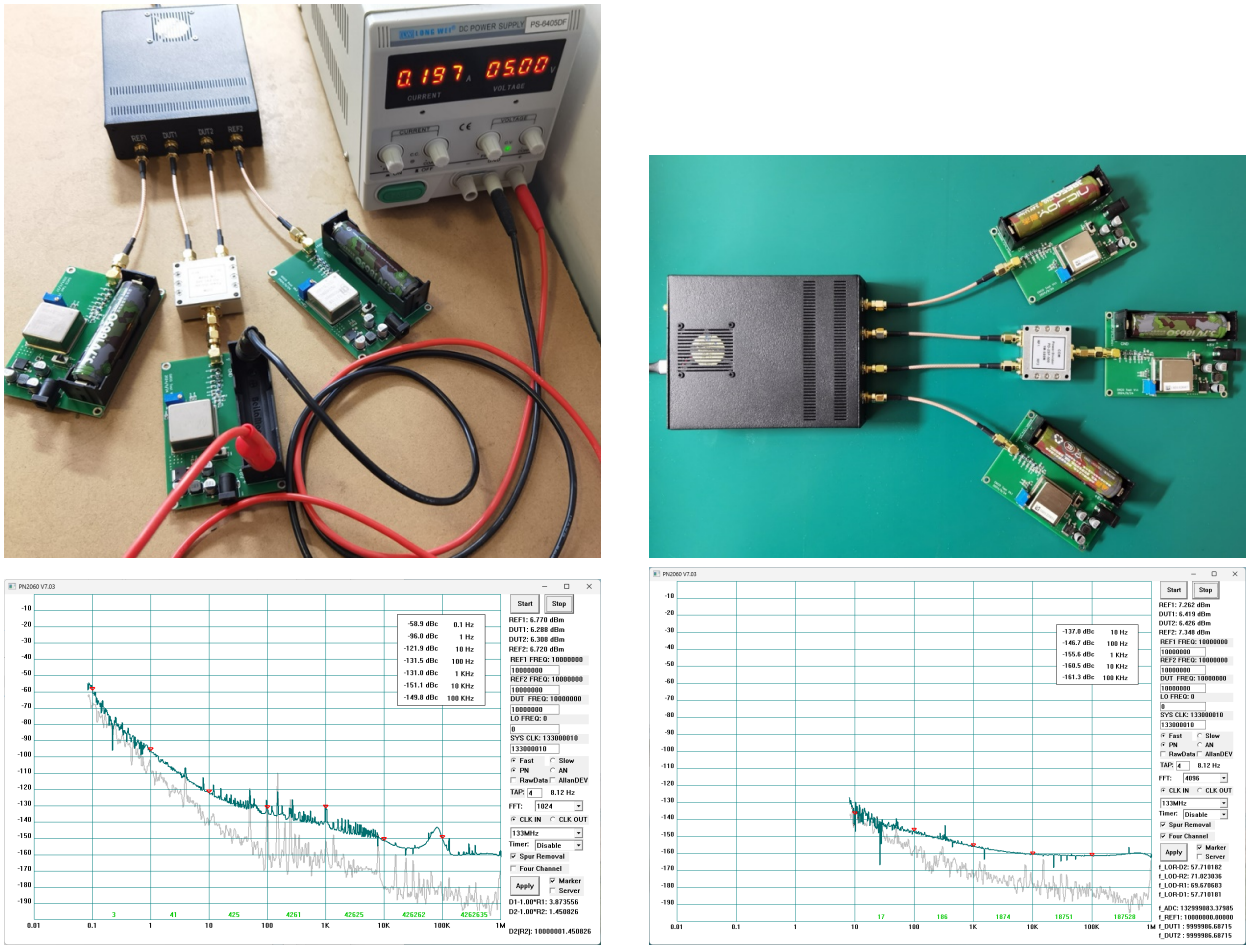


Figure 35: Bench-supply setup and result on the left, with the battery-powered setup and result on the right. Differences in this comparison exceed 20 dB.

Verify the noise of every supply before use. Prefer batteries (e.g. 18650 cells) or verified low-noise linear supplies for the DUT and both references.

B.2 Oscillator Supply Decoupling and Output Coupling

Some crystal oscillators require supply decoupling at the package for accurate measurement. The example records a 49.152 MHz DUT setting. The oscillator feeds a 10 dB attenuator for impedance matching, followed by a harmonic filter. One 2.2 μF capacitor must sit as close as possible to the XO, plus an isolation capacitor blocking DC toward the output (Figure 36).

Note

A slightly low supply voltage (e.g. 3.1 V from a tired battery) can degrade the far-offset phase noise of some crystals.

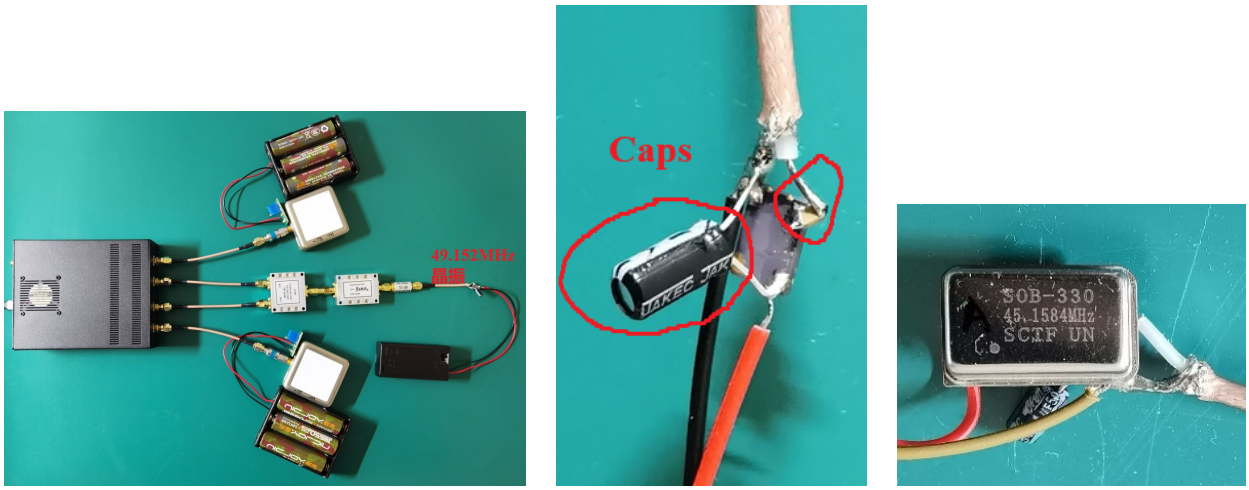


Figure 36: Test-chain, capacitor-placement and oscillator-package illustrations.

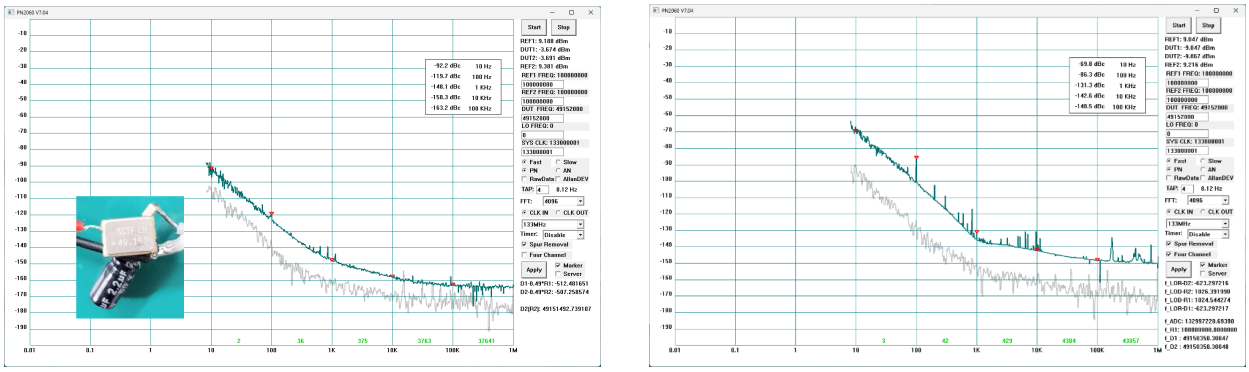


Figure 37: PN2060 measurements with the supply-decoupling and output-coupling capacitors fitted on the left and with both capacitors removed on the right.

B.3 Isolation and Impedance-Mismatch Failures

Cross-spectrum artifacts can arise from impedance mismatch, poor isolation and aliasing [1]. Their severity depends on the combination of splitters (3/6/10 dB or active), filters, attenuators and OCXOs used in the setup. The following measures address these causes.

- Series attenuator (e.g. 6 dB) at the DUT to improve matching.
- Nyquist low-pass filter (e.g. Mini-Circuits SLP-50+) to remove aliases.
- Isolation amplifiers for OCXOs with poor reverse isolation – some units of the older DATUM 2750013-1, for example, deviate significantly without one.

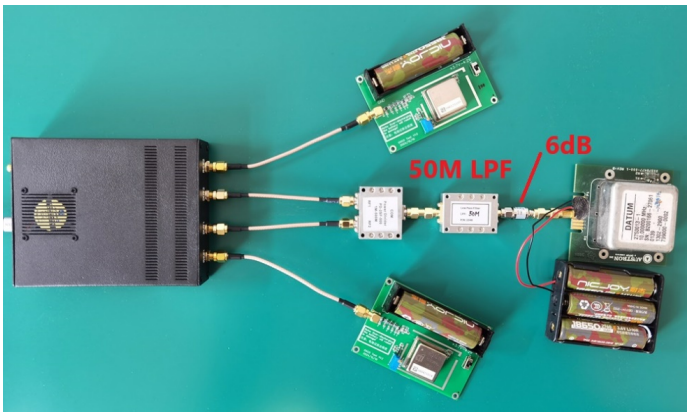


Figure 38: Test setup for an OCXO with poor isolation, using a 50 MHz LPF and a 6 dB attenuator.

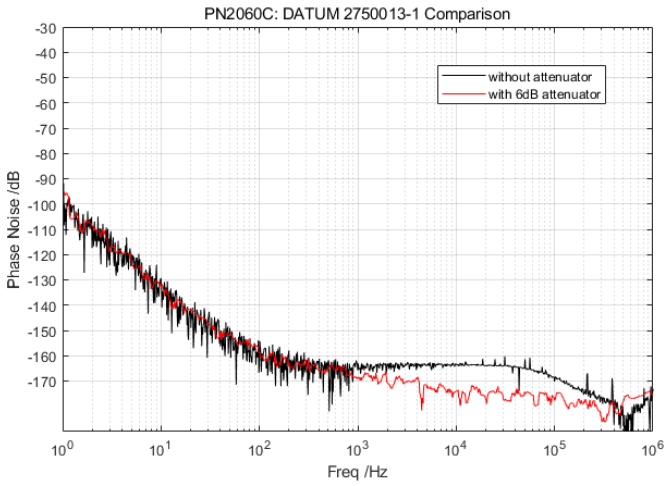


Figure 39: DATUM 2750013-1 measured with and without a 6 dB attenuator.

B.4 Low-Pass Filter Selection Warning

Low-pass filter choice affects measurements of very low-noise DUTs. The SCTF oscillator example below shows approximately −164 dBc/Hz at 1 kHz offset with the SLP-50 filter. The original test notes report verification on an E5052A.

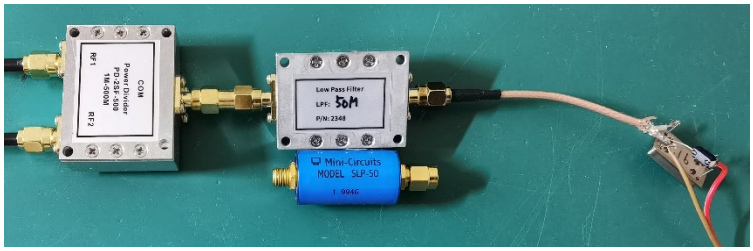


Figure 40: Test chain with splitter, low-pass filter and attenuator.

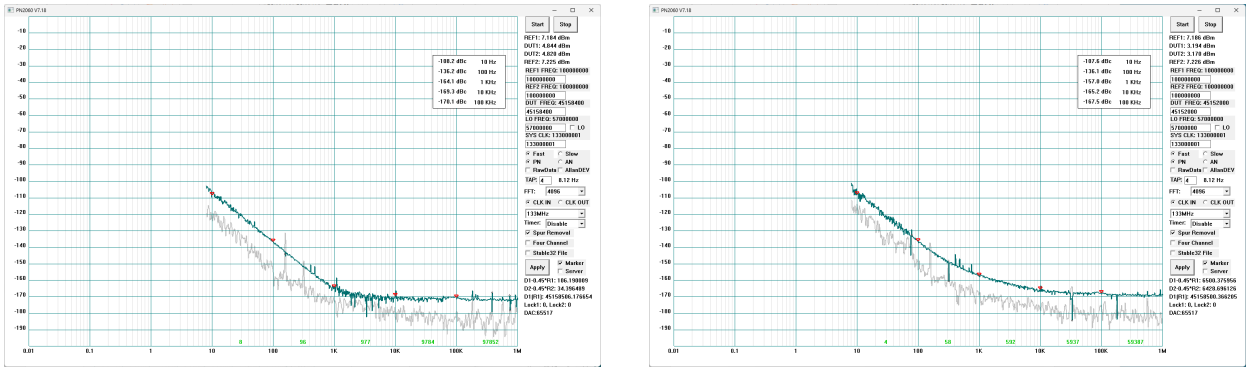


Figure 41: Mini-Circuits SLP-50 result on the left and the older LPF-50M result on the right. The older LPF-50M produces significant deviation near 1 kHz offset. A revised LPF design resolves the observed deviation.

Acknowledgments

This project was initially based on Andrew Holme's work. I am grateful for his assistance during early development and his permission to use parts of his source code. Nearly all Verilog algorithms have since been rewritten, and the PC algorithms have undergone substantial changes. Some elements of the original structure remain in the current release.

I am also grateful to Jim Henderson, Paul Hsieh, and Drew Wollin for their valuable feedback and discussions. Jim Henderson implemented a mixer-based down-converter to extend the frequency range. Drew Wollin wrote a beginner-friendly introduction and review. Paul Hsieh contributed many insightful discussions on potential improvements.

Finally, special thanks to IW3AUT for providing the file converter that enables the measurement data to be used with other applications.

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