PN2060 Phase Noise Analyzer

User Guide

Software version V7.69 · PN2060C / PN2060D

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

Contents

1 Introduction

1.1 Overview

The PN2060 is a digital cross-correlation phase noise analyzer. It measures the phase noise and amplitude noise of high-performance RF sources without phase locking and without measurement calibration. 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.

The instrument family covered by this guide:

- **PN2060C** — 1–200 MHz direct-sampling analyzer in a compact USB-powered enclosure (front panel: **DUT1**, **DUT2**, **REF1**, **REF2** SMA connectors; rear panel: USB 3.0 Type-C).
- **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).

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

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

1.2 Features

- Independent input and reference frequencies from 1 to 200 MHz
- No phase-locking or measurement calibration required
- Dual reference-oscillator inputs allow cross-correlation measurements
- USB 3.0 interface with high-speed data exchange; a single high-quality USB 3.0 cable carries both data and power
- Phase noise at offsets from 0.001 Hz to 8 MHz, with levels typically below −185 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; 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: System noise floor, 10 MHz carrier, 90-minute correlation.

Offset	Noise floor (dBc/Hz)
0.1 Hz	−130
1 Hz	−150
10 Hz	−160
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 App. C)
Offset range	0.001 Hz–8 MHz
Input signal level	+10 dBm maximum
Input impedance	50 Ω
Signal type	sine wave
Connectors	front: SMA (DUT1, DUT2, REF1, REF2); rear: USB Type-C
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, approximately 2 Mbyte/s per MHz of span – e.g. 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.

- **OS:** Windows 7 / 10 / 11 (64-bit)
- **CPU:** Intel 12th-generation i5 or better
- **Memory:** 8 GB or more
- **Storage:** SSD (mandatory when recording raw data)
- **Motherboard:** B760M series recommended and verified (H610-series boards often cannot supply enough USB 3.0 current)
- Dedicate the computer to the measurement; avoid heavy background services – they can interrupt the stream and cause a *Data Packet Loss* error (Section 8).

> **Caution**
>
> The 16 MHz and 20 MHz offset ranges (PN2060D) produce very high data rates. They require a powerful desktop PC with an Intel 14th-generation i5 or better – a laptop is *not* sufficient for these spans.

2.2 USB 3.0 power

The analyzer 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.

- Use a *rear-panel* USB 3.0 port of a desktop PC; front-panel ports and USB hubs are not supported.
- Disconnect other power-hungry USB devices.
- If the supply is still insufficient, install a powered USB 3.0 PCIe expansion card (Figure 2); the models shown have been extensively tested.
- Laptops: use a built-in USB 3.0 port and prefer battery operation – switching AC adapters inject noise (Section 8). External USB adapters/docks generally do *not* work.

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

Note

Hardware version 1.4 and later (June 2024 onward) 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*). Then proceed as 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; not all USB-C cables are wired for USB 3.0.

2.4 Connection checklist

- USB 3.0 only: the analyzer does not work on USB 2.0 ports, on hubs, or on many laptop Type-C ports.
- If the device is not detected, rotate the Type-C plug by 180° and re-insert; wait 3–5 s after plug-in before starting the application, and 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.

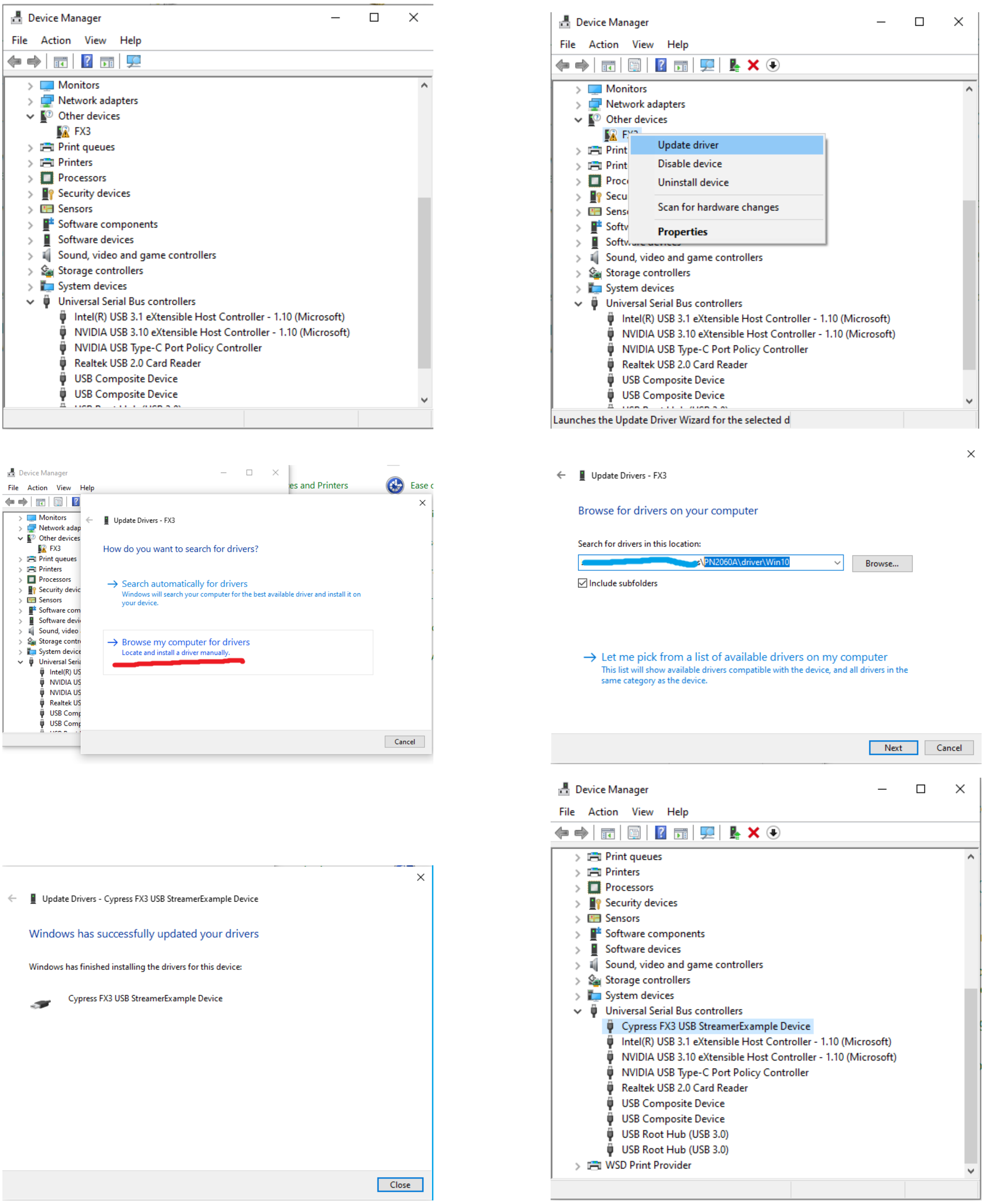

Figure 3: Driver installation sequence (Device Manager).

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.
- The *independence* of the two reference sources is crucial: never share one power supply between them.
- Filter the DUT and the references effectively (harmonics cause 3–5 dB errors at far offsets; see App. G).
- Use short, well-shielded RF cables.
- Prefer high-isolation power splitters; a 6 dB attenuator in series with the DUT improves impedance matching (App. E).

3.2 Recommended setup: dual references

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

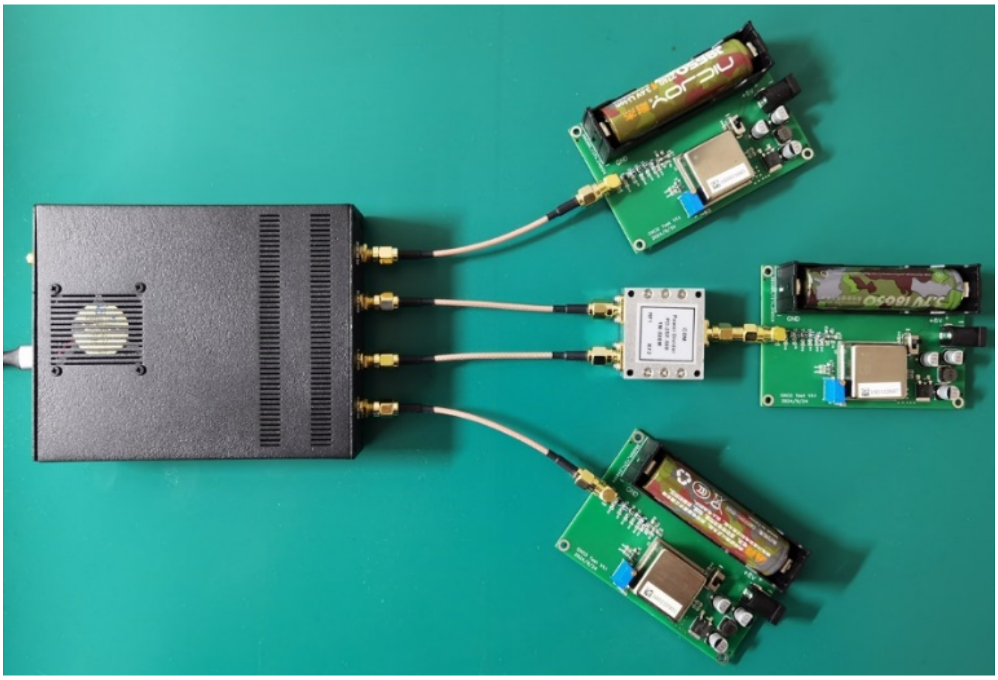

Figure 4: Dual-reference cross-correlation setup.

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. Keep the reference input power close to the maximum (+10 dBm); lower reference power reduces the dynamic range. If a source delivers more than +10 dBm, insert an attenuator to avoid overload or damage.
4. Start the software, enter **REF1 FREQ**, **REF2 FREQ** and **DUT FREQ** (Section 4.4.2), confirm **SYS CLK**, and click **Apply**.
5. Click **Start**. Let the instrument warm up: the internal clock needs roughly 30 minutes to stabilize, and measurements started immediately after power-on show rapid drift.
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

- **REF1 = REF2 (nominal):** both references must have the same nominal frequency. They are independent oscillators, so their exact frequencies differ slightly – that is expected and harmless.
- **DUT/REF ratio:** the analyzer supports $f_{\mathrm{DUT}}/f_{\mathrm{REF}} < 16$. The program refuses to start beyond this limit.
- **Wide spans: Max Frequency Offset** settings of 8 MHz and above additionally require $f_{\mathrm{DUT}}/f_{\mathrm{REF}} \leq 3$; otherwise the program warns and falls back to 4 MHz.
- **Reference choice:** use a 10 MHz reference for DUTs up to about 30 MHz. Scaled to 30 MHz, a 10 MHz reference is effectively about 10 dB worse; scaled to 100 MHz it would be about 20 dB worse, making far-offset floors unreachable. For DUTs at or above 160 MHz use a 100 MHz-class reference.
- **Reference quality:** the reference should not be worse than the DUT, especially near 1 Hz offset, where averaging is slow; otherwise unacceptably long measurement times (>8 h) result. At 100 kHz–1 MHz offsets a somewhat worse reference is acceptable, because those frequencies average quickly.

3.4 Running a measurement – workflow summary

1. Connect signals per Section 3.2; check the four level readouts (**REF1**/**DUT1**/**DUT2**/**REF2**, in dBm) on the **Measure Control** tab.
2. Change parameters only in the stopped state, then press **Apply**.
3. Press **Start**; 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 the main window during a 10 MHz measurement. The window has four areas:

1. **Menu bar** – **File**, **View**, **Measurement**, **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** – three tabs: **Plot Control**, **Measure Control**, **Advanced Control** (Sections 4.4–4.6).
4. **USB status bar** – green `USB3.0 CONNECTED` when the instrument link is up, red `USB3.0 DISCONNECTED` otherwise.

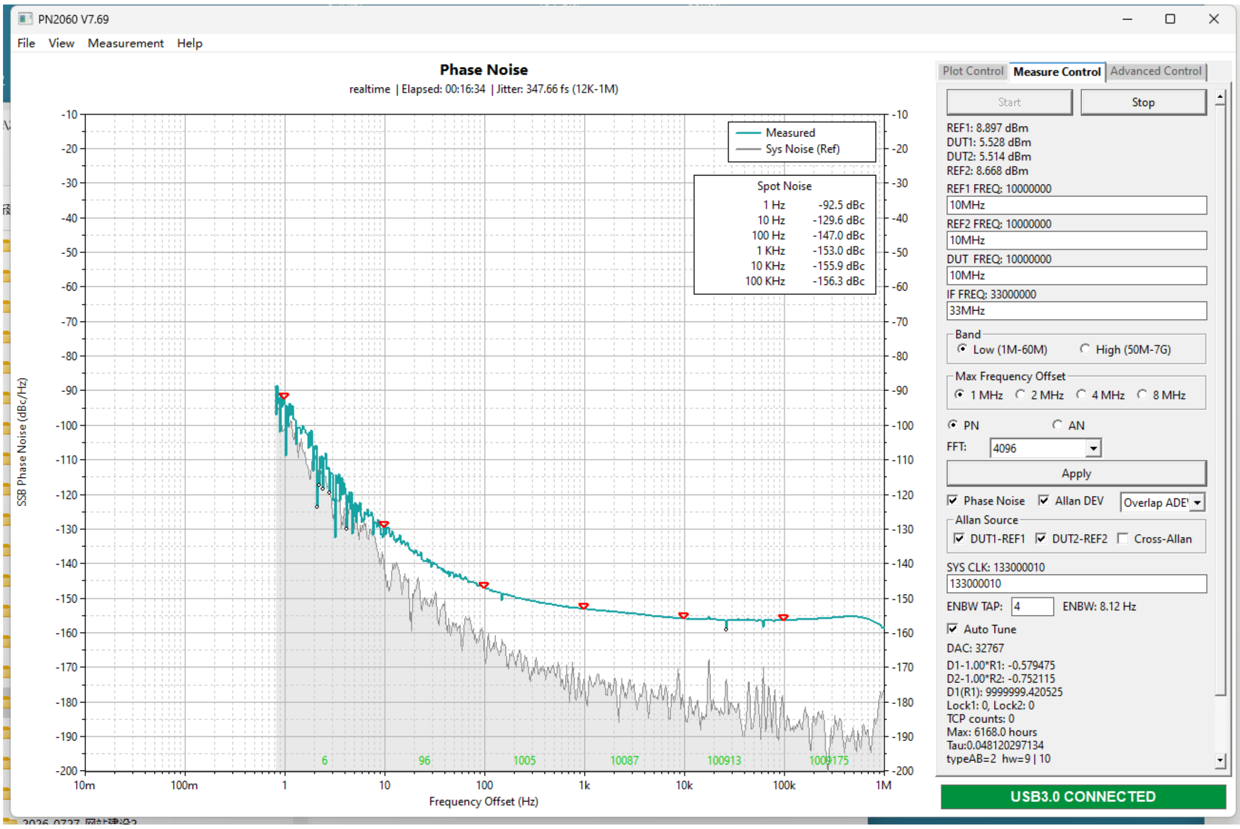

Figure 5: Main window: 10 MHz DUT versus two 10 MHz references (phase-noise view, running).

4.2 Plot area

Title and status line

The first line names the active view (*Phase Noise*, *Allan Deviation*, . . .). The second line shows, from left to right:

- 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
With **Show Spot Noise Points** enabled, red markers flag the decade offsets; with **Show Spot Noise Table** enabled, a table reports the smoothed spot values at 1 Hz, 10 Hz, 100 Hz, 1 kHz, 10 kHz and 100 kHz (the set of rows adapts to 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; their noise floor keeps improving as the counts grow.

Axes
Log frequency-offset axis (10 mHz–1 MHz shown by default; range set in **Plot Control**); linear dB axis for phase noise.

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; a converted `.PNP` file is generated alongside automatically, readable by other 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; they mirror the checkboxes on the **Plot Control** tab (Section 4.5).

4.3.3 Measurement

Selects the active view: **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

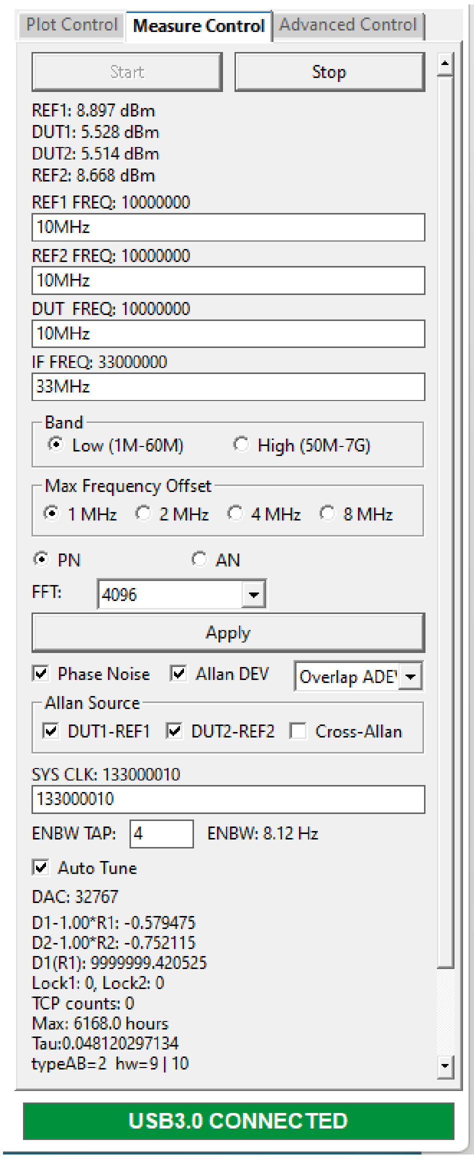

Figure 6: Measure Control tab during a run.

4.4.1 Run control and level readouts

Start / Stop

Begin and end the acquisition. **Start** is greyed while running; **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. Keep all inputs at or below +10 dBm; keep the references close to the maximum for best dynamic range. 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 always 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**. **REF1 and REF2 must be set to the same nominal frequency**; they remain 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.

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 it 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
Analysis span: 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); the 16/20 MHz spans require a powerful desktop PC (Intel 14th-gen i5 or better – not a laptop). Spans $\geq$8 MHz require DUT/REF ≤ 3 (Section 3.3). Reducing the span is also the remedy for 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. The AN function is experimental; treat its results as indicative only.

FFT
FFT length per decade: 128 ... 16384. Larger values raise the frequency resolution of the analysis but slow the trace update.

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 which result the plot shows; **Allan DEV** also enables Allan-deviation accumulation for the run. The adjacent combo box picks the estimator: **Overlap ADEV** or **MDEV**.

Allan Source
Input pair for the Allan computation: **DUT1-REF1**, **DUT2-REF2**, or **Cross-Allan** (two-channel cross-correlation, the default and the recommended setting).

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 only if the actual clock is known to deviate; confirm it is correct before starting (it scales the frequency axis and all readouts).

ENBW TAP
Decimation-filter tap selection, 1–4 (typical 4), for the Allan/difference data path. The resulting equivalent noise bandwidth is displayed next to it (`ENBW: 8.12 Hz` at TAP 4). A larger bandwidth updates faster but with more trace noise; a smaller bandwidth is slower and smoother.

Auto Tune
Continuously steers the internal sampling clock (the current DAC word is shown below). Leave it on for normal use. On the PN2060D, heavy USB downstream traffic can disturb the data upload; after warm-up, **Auto Tune** may be switched off to improve very long unattended runs (Section 7).

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

4.4.6 Diagnostic readouts

Below the controls, the panel reports live diagnostics:

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. **PN2060D only** (1 = locked, 0 = unlocked); on the PN2060C these always read 0 and can be ignored.

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

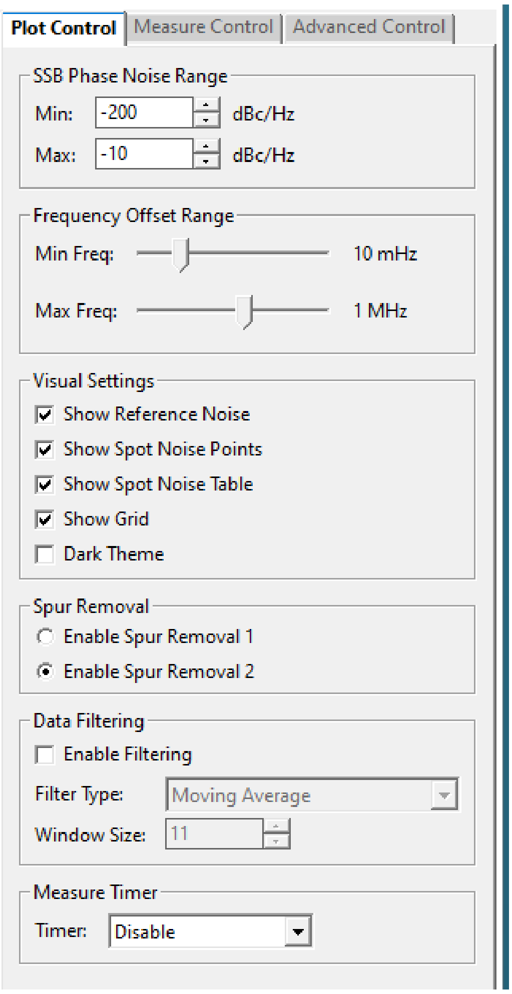

Figure 7: Plot Control tab.

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
Two algorithms for suppressing instrument-generated spurs: **Enable Spur Removal 1** (classification-based, current algorithm) and **Enable Spur Removal 2** (removes every detected spur, previous algorithm). Spur removal is experimental; it also adds CPU load – disable it on weak computers.

Data Filtering
Display smoothing of the trace: **Enable Filtering**, filter type (**Moving Average**, **Median Filter**, **Savitzky-Golay**) and odd **Window Size** (default 11). Filtering affects the display only, not the stored data.

Measure Timer
Automatic stop after a preset duration: **Disable**, 10 min, 30 min, 1–12 h, 1 day . . . 1095 days. Use it for unattended long runs.

4.6 Advanced Control tab

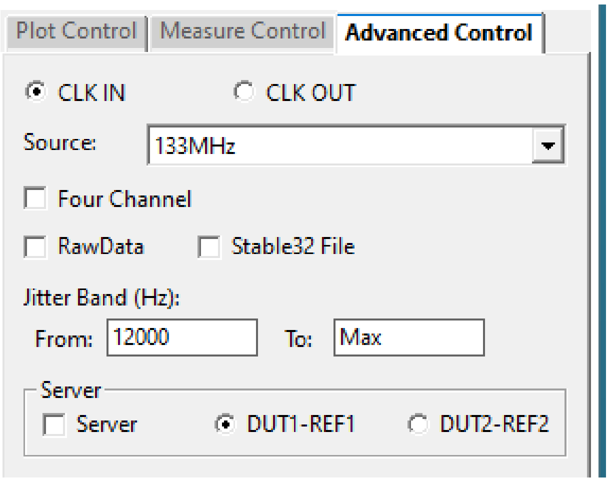

Figure 8: Advanced Control tab.

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 span selection 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 run from the same acquisition; switching between them (menu **Measurement**, or the **Phase Noise**/**Allan DEV** selectors) does not interrupt the run.

5.1 Phase Noise

The primary view (Figure 5, plot area): single-sideband phase noise $\mathcal{L}(f)$ in dBc/Hz versus log frequency offset. 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

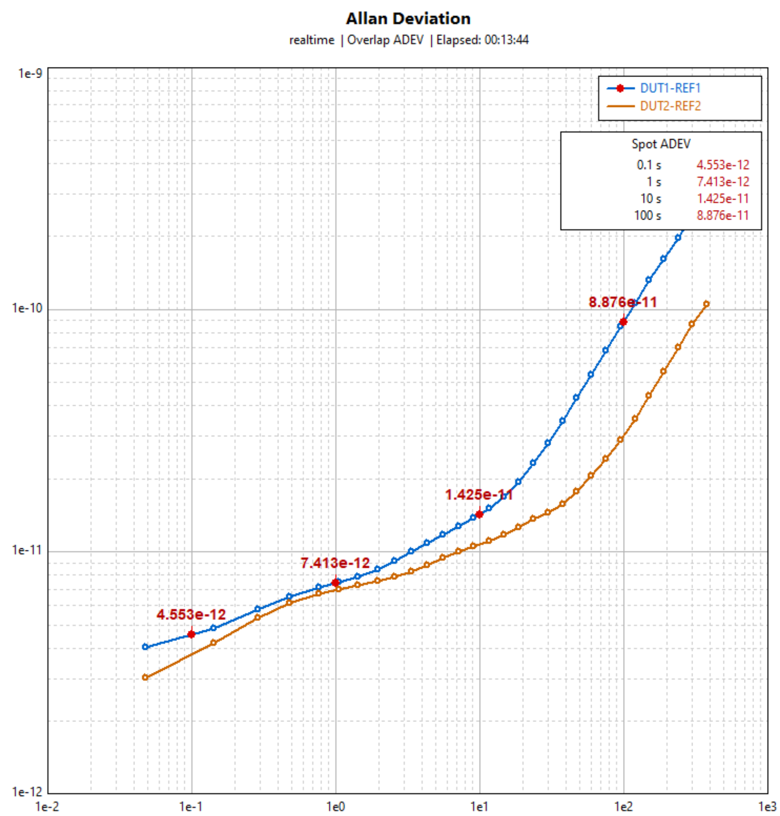

Figure 9: Allan-deviation view (**Overlap ADEV**): the **DUT1-REF1** and **DUT2-REF2** branches of two 10 MHz OCXOs; the spot table lists decade τ values.

Enable **Allan DEV** *before* starting the run (the record accumulates from **Start**). Choose **Overlap ADEV** or **MDEV** and the source: the individual branches (**DUT1-REF1**, **DUT2-REF2**, as in Figure 9) or **Cross-Allan** cross-correlation. 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; when REF1 is sufficiently accurate these readouts exceed the precision of conventional bench counters.

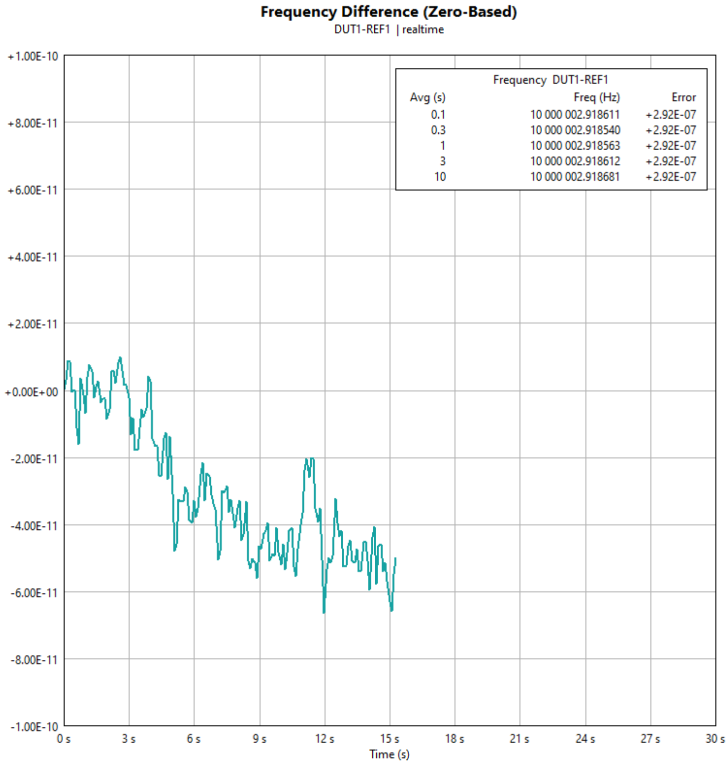

Figure 10: Frequency-difference view with multi-τ averaging table.

5.4 Phase Difference

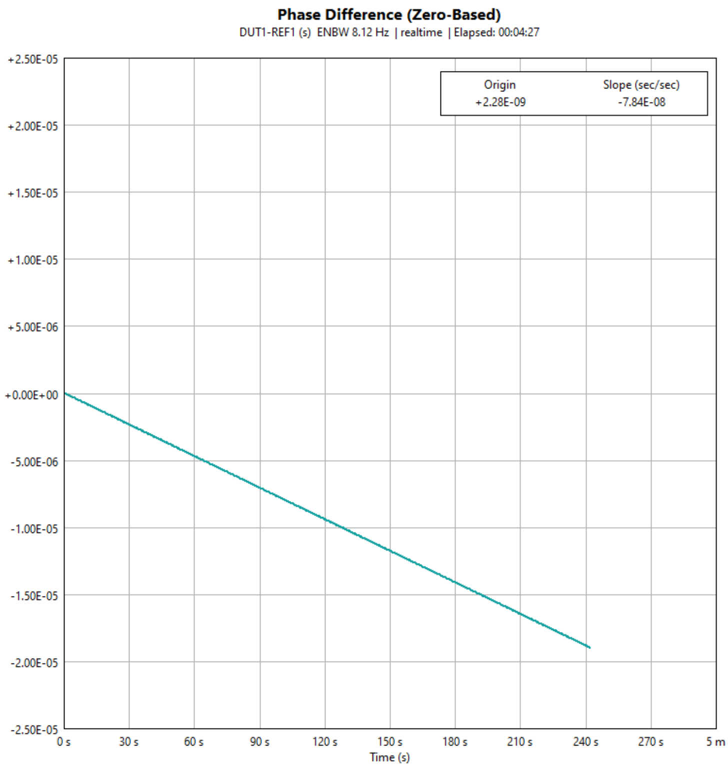

Figure 11: Phase-difference view; the table reports origin and slope.

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 (all views and settings); reload 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 (SSD required).
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

Only one PN2060 application instance can serve TCP port 8888 at a time; if the port is busy the server reports an error.

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: the *left* port for the 1–50 MHz band and the *middle* port 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/3 A power input (the unit consumes roughly 20 W after warm-up; a higher-quality supply measurably reduces spurs).

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

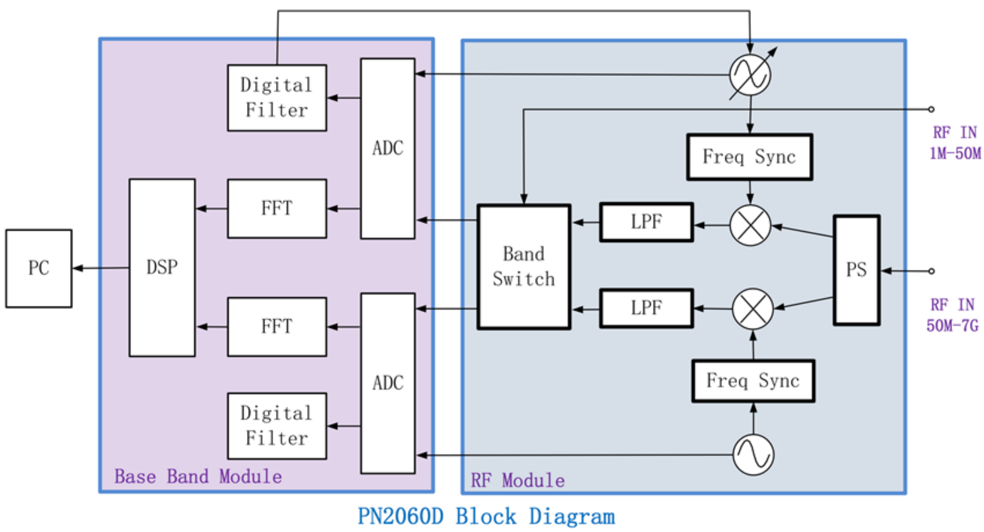

Figure 13: PN2060D block diagram: RF module (band switch, mixers, LPFs, frequency synchronization) and baseband module (ADCs, FFT, digital filters, DSP).

7.2 Specifications (PN2060D)

7.3 High-band measurement procedure

The PN2060D uses a frequency-converting receiver. Operation matches the PN2060C except for the following:

Table 4: PN2060D specifications.

Frequency range	1 MHz–7 GHz (two bands: 1–50 MHz, 50 MHz–7 GHz)
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 / 3 A (mains adapter included)

Table 5: PN2060D typical noise floor (30-minute correlation).

Offset	100 MHz carrier	1 GHz carrier
10 Hz	−125 dBc	−100 dBc
100 Hz	−145 dBc	−130 dBc
1 kHz	−160 dBc	−145 dBc
10 kHz	−170 dBc	−160 dBc
>100 kHz	−178 dBc	−165 dBc

1. **Band selection. Band** switches the active test port: **Low (1M-60M)** for the direct input, **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: for high-performance OCXOs an IF of 11–20 MHz suffices; for noisier synthesized sources use 15–23 MHz. 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. **Lock indicators.** `Lock1`/`Lock2` must both read 1 (locked) for valid results (Section 4.4.6).
5. **Input level.** Keep the displayed DUT1/DUT2 levels below 6 dBm to minimize spurs and distortion; never exceed 10 dBm at the input.

7.4 Digital phase locking

After **Start** (or a DUT frequency change) the frequency differences DUT1–REF1 and DUT2–REF2 converge under digital phase locking (Figure 14). 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.

Note

If phase lock is never reached (rare software state): close the program, delete `pninit.bin` in the program folder, and restart.

Note

Auto Tune: after warm-up, switching **Auto Tune** off can improve stability during very long unattended runs, because USB downstream traffic may disturb the data upload (Section 4.4).

7.5 Measurement examples

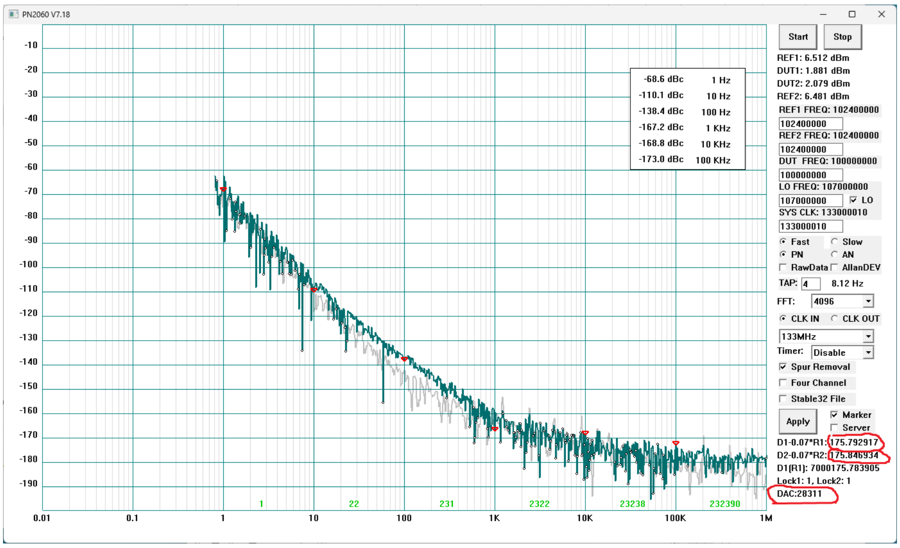

Figure 14: Convergence of the digital phase lock after a frequency change (100 MHz OCXO example, virtually spur-free).

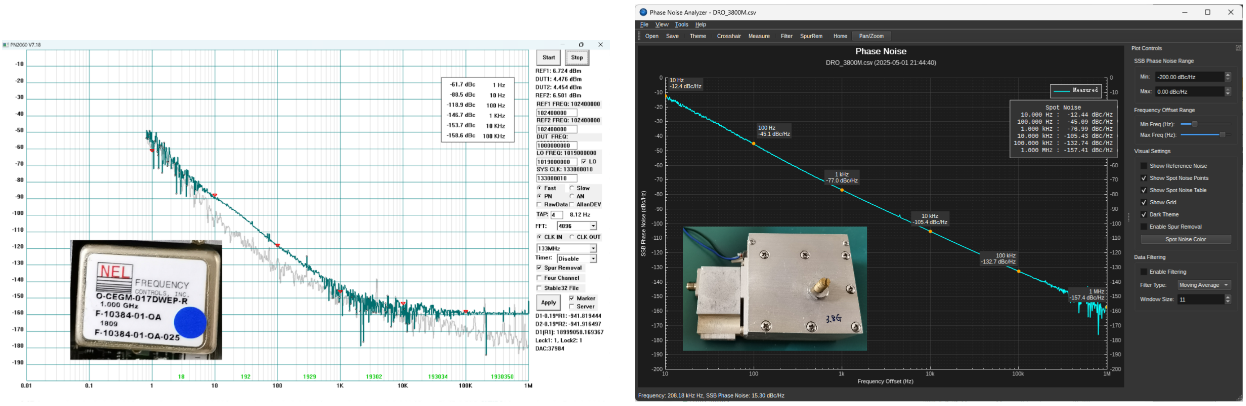

Figure 15: PN2060D examples. Left: NEL 1 GHz OCXO measured with the phase-locked method – nearly all instrument spurs eliminated. Right: 3.8 GHz DRO (result shown in the file-management viewer).

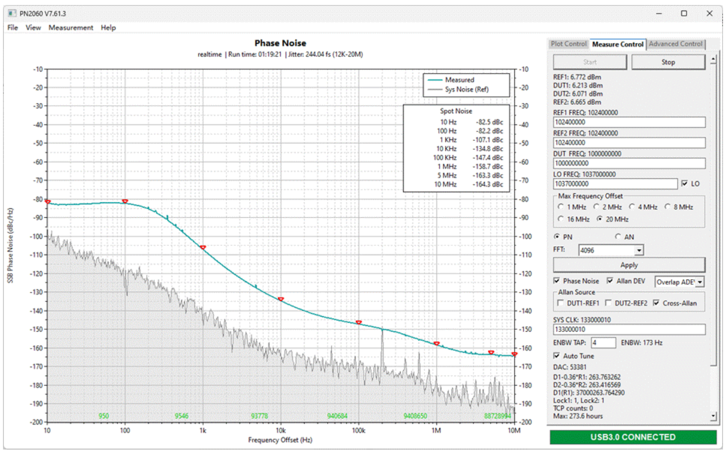

Figure 16: HP8664A (option 004) signal generator, 1 GHz output. Although the unit is more than 25 years old, the measured phase noise matches its specification well.

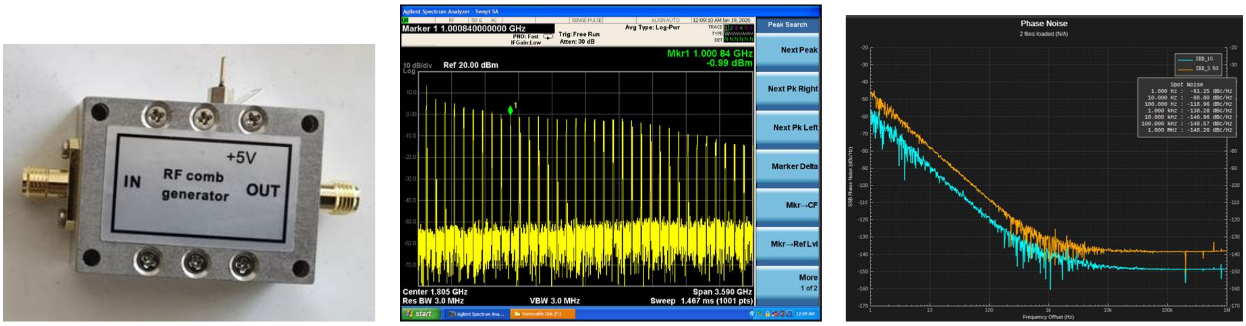

Figure 17: SRD frequency-multiplier module driven by a customized 100 MHz OCXO (floor ≈ -169 dBc/Hz): the comb-generator module, its output spectrum, and the band-pass-filtered phase noise measured at 1 GHz and 3.5 GHz.

8 Troubleshooting

8.1 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).

Remedies: rear-panel port, disconnect other USB loads, powered USB 3.0 expansion card (Section 2).

8.2 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 the load: disable **Spur Removal**, reduce **Max Frequency Offset**, close background programs.

8.3 Laptop operation

Laptop power designs vary widely; desktop supplies are generally quieter. When using a laptop, disconnect the AC adapter and run from battery – comparative tests (battery vs. adapter) can differ visibly in the achieved noise floor. Below −180 dBc/Hz, a battery-powered laptop can outperform an AC desktop. Run several desktop-vs-laptop comparisons if in doubt.

8.4 External power option (PN2060C)

Not recommended (risk of added noise), but possible for difficult PCs: feed the dedicated power port from a *clean linear* supply (never a phone charger or switching adapter): first power the dedicated port, then connect the data cable – the data-line power path disconnects automatically (Figure 18). With hardware version ≥1.4 the internal supply is optimized and this option is rarely needed.

Figure 18: External linear-supply option.

8.5 Quick checklist

- `Inf` level readouts → re-seat/rotate the Type-C plug; try another USB 3.0 port.
- No FX3 device → Section 2.3; remove `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 (App. G).
- Strange artifacts/notches → isolation or impedance mismatch (App. E).

A Extending the Frequency Range

A.1 100 MHz reference setup

For DUTs beyond the reach of 10 MHz references, use high-performance 100 MHz-class references (e.g. the NEL model shown) and a band-pass filter matched to the DUT (for a 500 MHz DUT, a 480–520 MHz BPF):

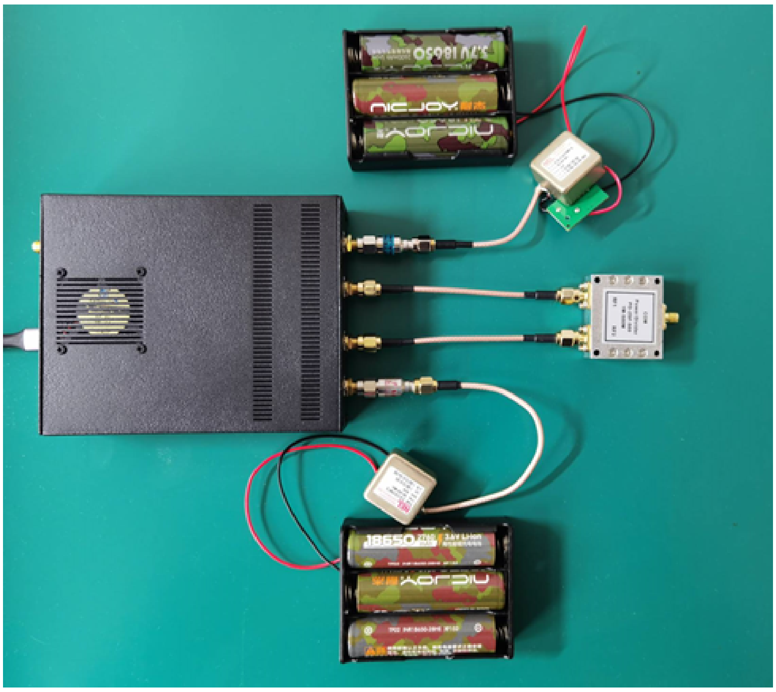

Figure 19: Extended-range setup with 100 MHz references and a band-pass filter.

Figure 20: Reference-class 100 MHz OCXO (example).

As the measurement frequency rises the direct capability decreases. A 1 GHz signal can still be tested directly (100 MHz reference + effective BPF): Figure 21 shows a Crystek CCSO-914X3 1 GHz DRO – with only −28 dBm reaching the inputs, results are accurate for offsets below 10 kHz and degrade beyond.

A.2 Down-conversion

To measure beyond the direct range accurately, down-convert the DUT to below 50 MHz.

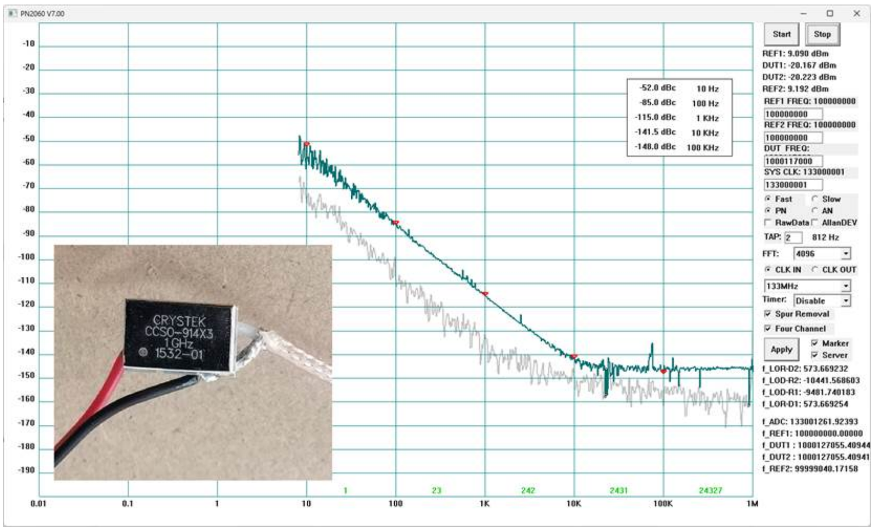

Figure 21: Direct 1 GHz DRO measurement (accurate below 10 kHz offset).

Single-channel down-converter. A passive mixer followed by a <30 MHz low-pass filter (Figure 22). The LO must be at least 6 dB better than the DUT across the whole offset range (e.g. R&S SMA100B class).

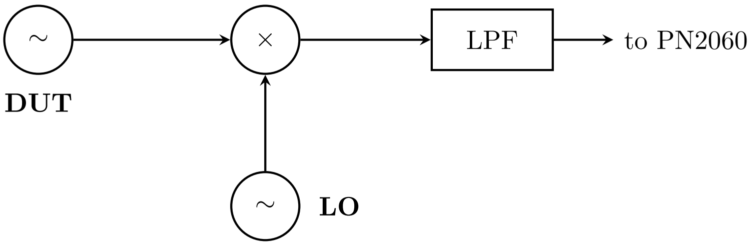

Figure 22: Single-channel down-conversion (mixer + low-pass filter).

Dual-channel down-converter (PN2060DV2). Two independent converter channels preserve the cross-correlation gain: noise floor ≈ −170 dBc/Hz at 1 GHz and down to ≈ −180 dBc/Hz at 100 MHz. Figure 24 compares the newest 491.52 MHz test (an HP8664A signal, measured in the high band with the 20 MHz offset span) with an Agilent E5052A.

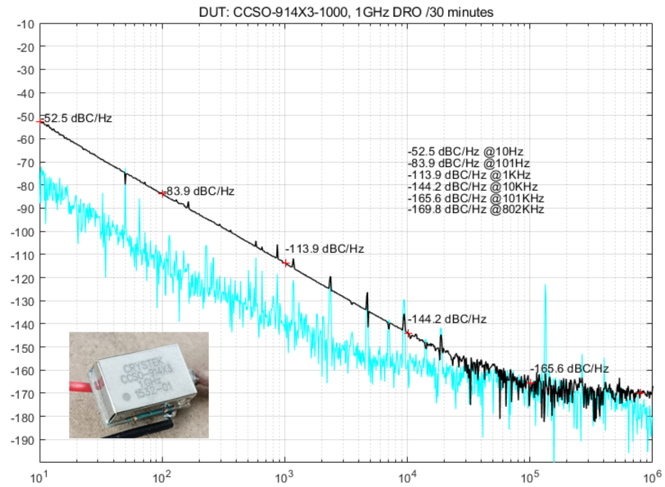

Figure 23: 1 GHz DRO after dual-channel down-conversion (30 min); the instrument floor is ≈ -170 dBc/Hz.

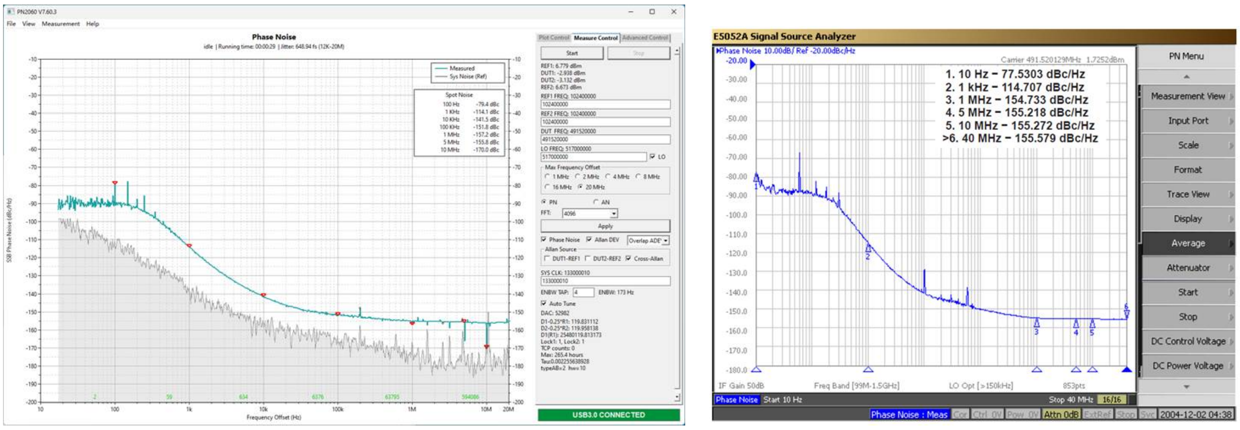

Figure 24: 491.52 MHz test, newest result: PN2060 measurement with the 20 MHz offset span (left) versus Agilent E5052A (right).

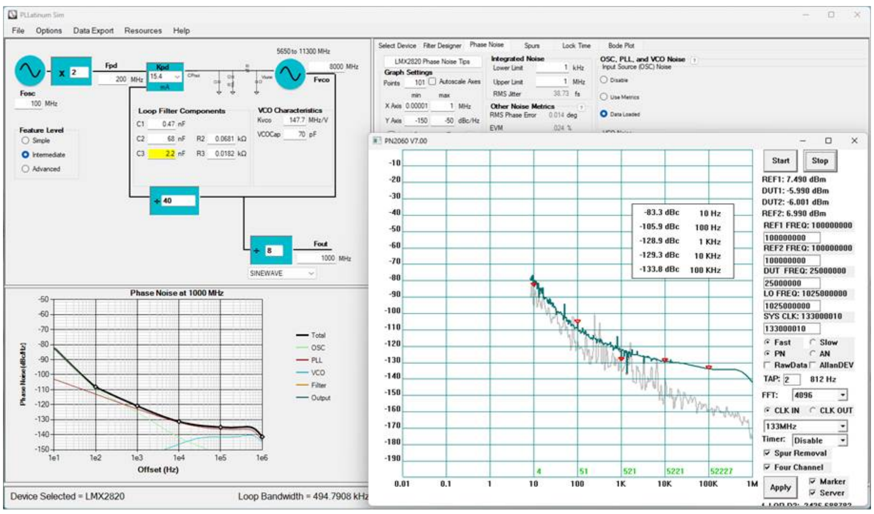

Figure 25: Further validation: measurement versus PLL simulation.

B 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 26 shows the same DUT powered by a Longwei PS-6405F bench supply and by batteries.

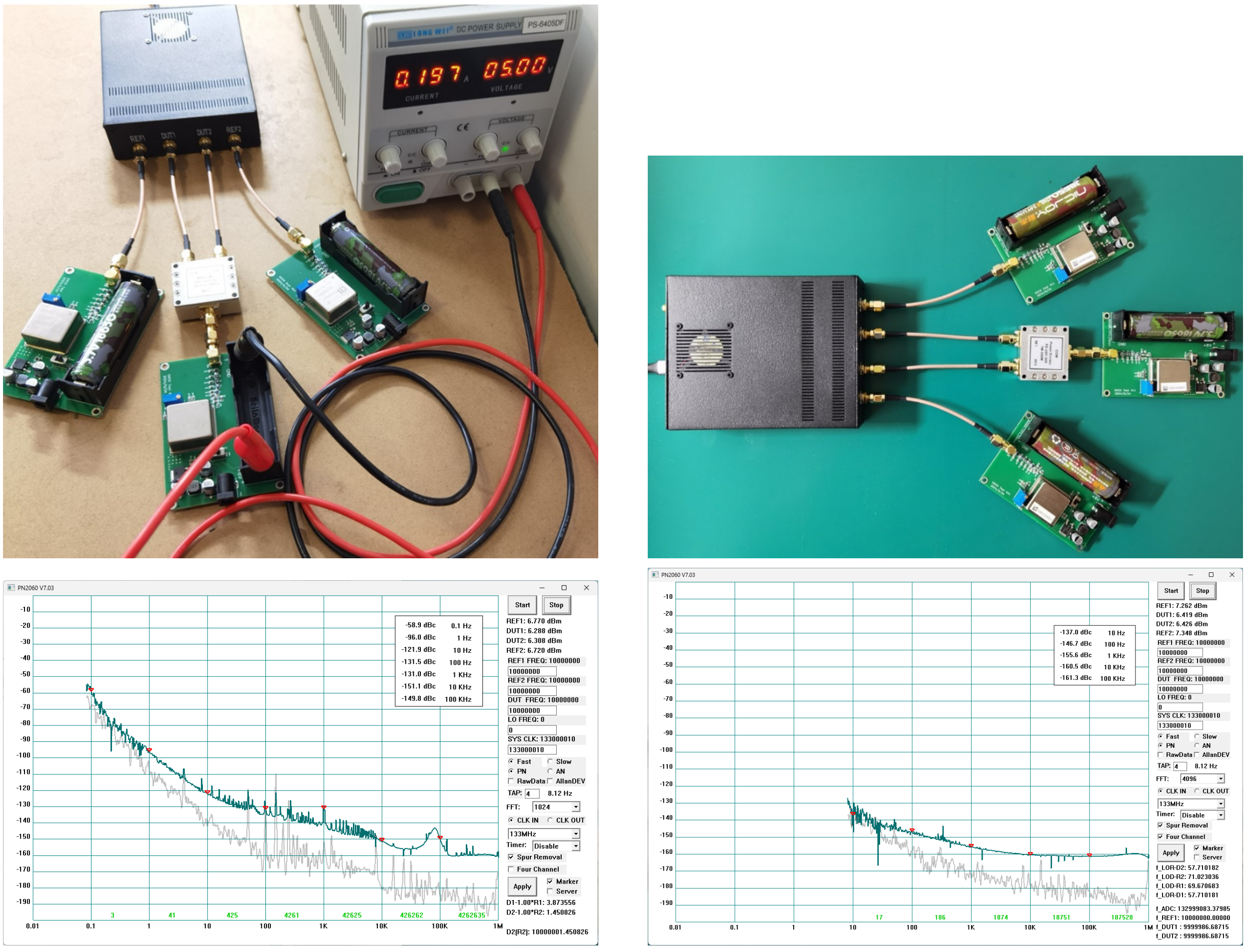

Figure 26: Left: bench-supply powering and its result; right: battery powering and its result. Differences exceed 20 dB.

Recommendation: 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.

C Frequency Bands, Aliasing and the 50–150 MHz Method

C.1 Why digital analyzers care about bands

Digital phase noise analyzers need no analog phase locking of the DUT – a major advantage over older architectures (e.g. HP3048-derived instruments), visible in comparative XO measurements (Figure 27). Their weakness is frequency-domain aliasing and harmonic interference, aggravated by unsuitable splitters and filters.

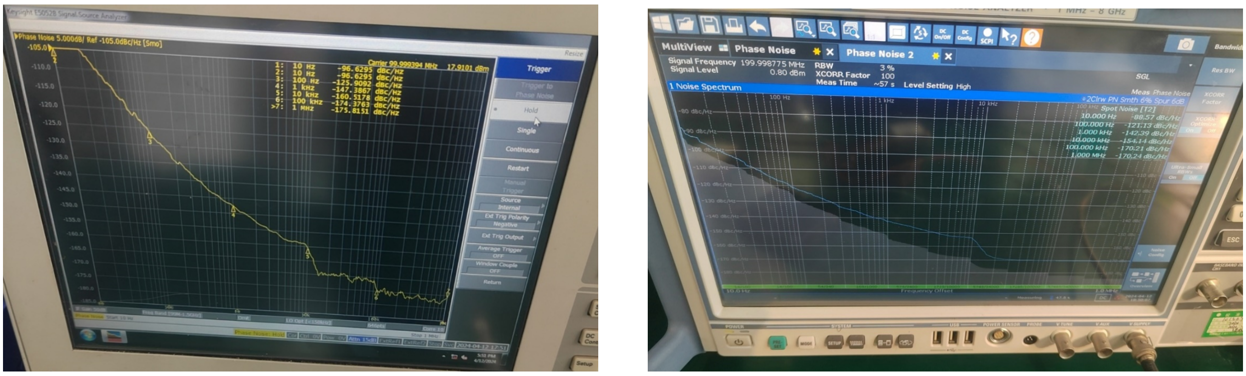

Figure 27: 100 MHz XO measured by an analog-PLL-era instrument (left) versus a modern digital analyzer (right).

C.2 Bands of the PN2060 (sampling at 133 MHz)

1. **1–67 MHz** – first Nyquist zone; highest accuracy. Low-pass filters solve most problems; best results 1–60 MHz.
2. **67–133 MHz** – second Nyquist zone (under-sampling); subject to aliasing, sensitive to the filters at the test port.
3. **133–200 MHz** – third Nyquist zone; aliasing plus ADC aperture jitter; filter choice strongly affects results.

The robust solution mirrors the R&S FSWP approach: sample only in the first Nyquist zone and down-convert everything else into it (Appendix A; done internally by the PN2060D).

C.3 Recommended 50–150 MHz method

Down-convert with two reference OCXOs (Figure 28):

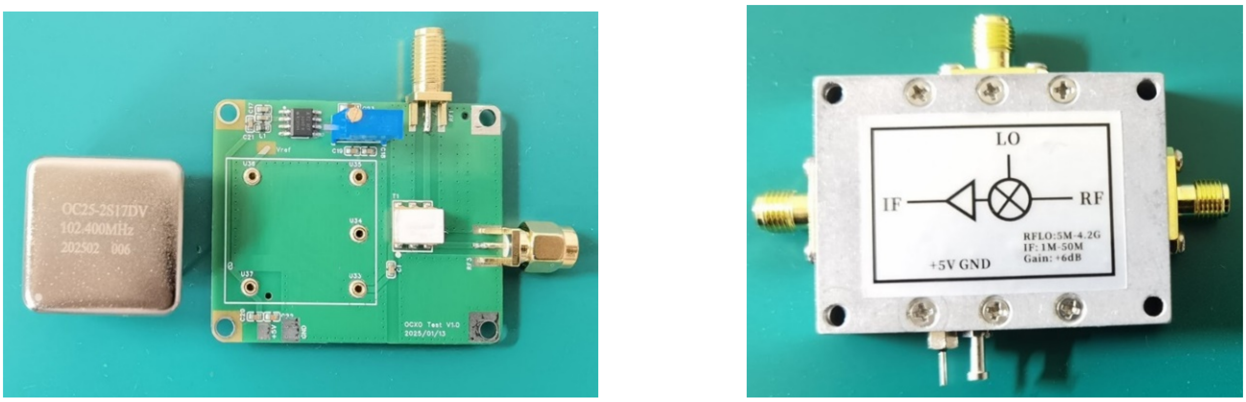

Figure 28: 102.4 MHz reference OCXO board and mixer/isolation-amplifier module used for second-Nyquist-zone testing.

1. Keep the DUT–LO frequency difference above 1 MHz. Two 102.4 MHz references suit 100 MHz OCXO testing (not the 102.4 MHz point itself – for that, use two 100 MHz references). Pairs such as 120 MHz/122.88 MHz and 100 MHz/102.4 MHz test each other well; keep the difference within 10 MHz for best results.
2. Reference (LO) power ideally ≥10 dBm – low LO power reduces dynamic range.
3. Keep the power into the analyzer below 3 dBm; most oscillators deliver more than 7 dBm, so insert an attenuator (but do not over-attenuate weak sources).
4. Offset the two references by roughly 30 Hz from each other: the spur family then falls on 30 Hz and harmonics, leaving the decade points (10 Hz, 100 Hz, 1 kHz, . . .) clean.
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.

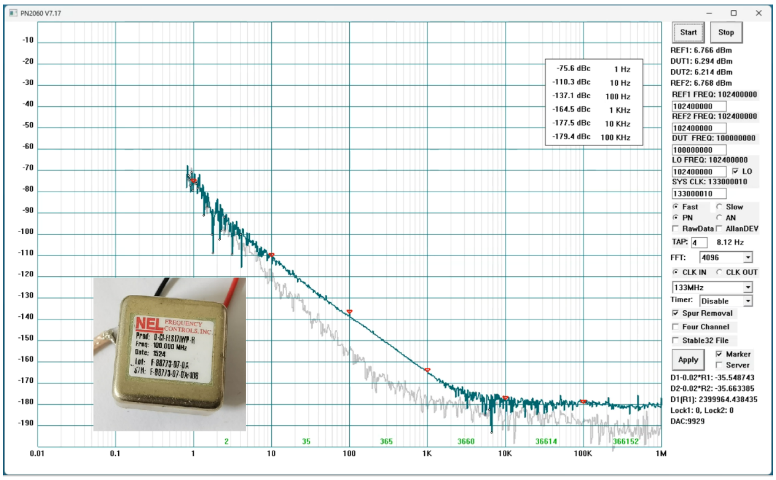

Figure 29: 100 MHz OCXO via the 50–150 MHz method: floor below −180 dBc within minutes, −170 dBc/Hz at 1 kHz, nearly spur-free.

Performance (results and speed) is comparable to the R&S FSWP; the best 100 MHz oscillators on the market (>180 dBc/Hz floors) can be fully characterized. Other bands follow the same pattern with OCXOs of suitable frequencies or multiplied references. Keep RF cables short and well-shielded.

D Crystal Oscillators: Load Capacitors Matter

Some crystal oscillators require proper supply decoupling at the package to measure correctly. Test setup: XO → 10 dB attenuator (impedance matching) → harmonic filter; DUT: SCTF LN 49.152M. One 2.2 μF capacitor must sit as close as possible to the XO, plus an isolation capacitor blocking DC toward the output (Figure 30).

> **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.

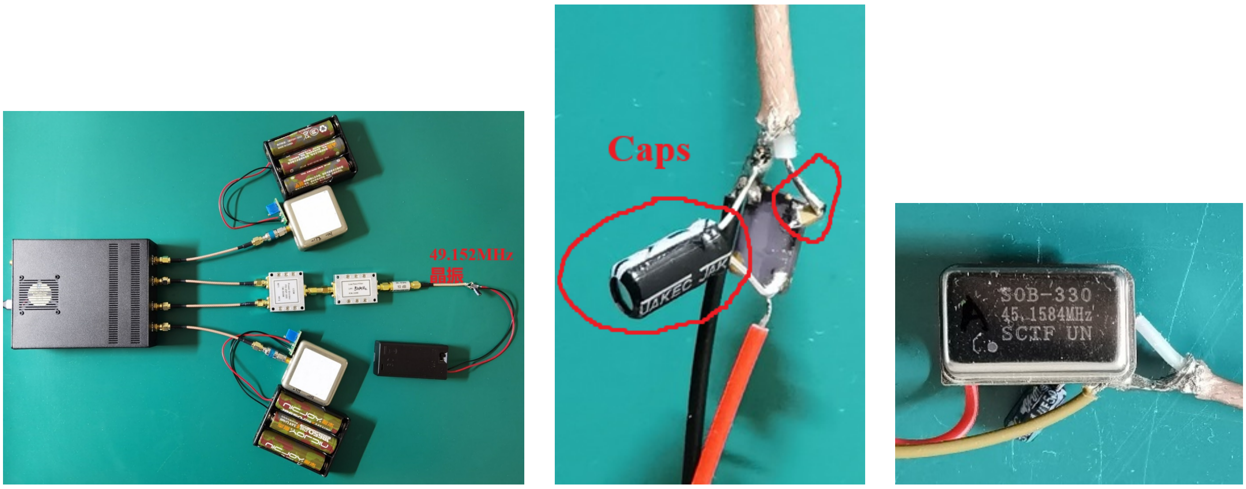

Figure 30: Battery-powered XO test chain; the two critical capacitors; the DUT.

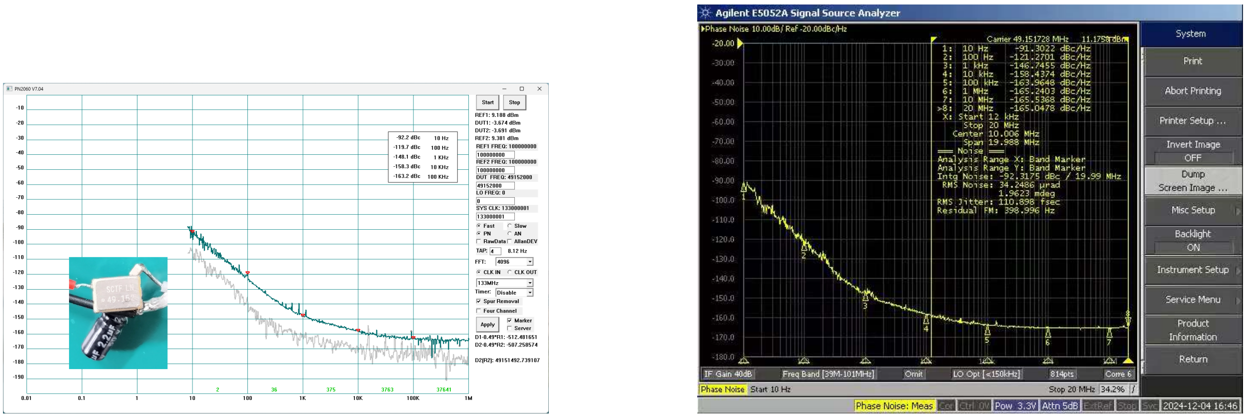

Figure 31: Correct setup: PN2060 (left) agrees with an Agilent E5052A (right).

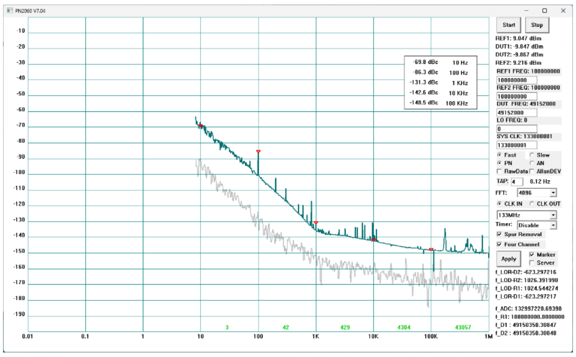

Figure 32: Same DUT with the two capacitors removed – large measurement errors.

E Isolation and Impedance-Mismatch Failures

As with every cross-spectrum analyzer, artifacts can occur. All phenomena reported in the literature [1] can be reproduced with specific combinations of splitters (3/6/10 dB, active), filters, attenuators and particular OCXOs: impedance mismatch, poor isolation and aliasing are the root causes.

Solutions:

- 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.

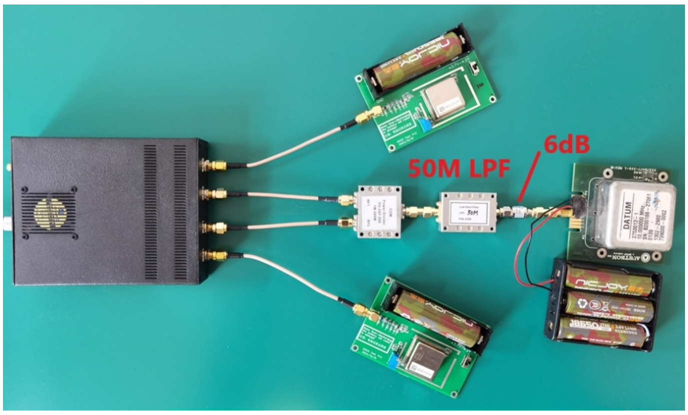

Figure 33: Testing an OCXO with poor isolation: note the 50 MHz LPF and 6 dB attenuator.

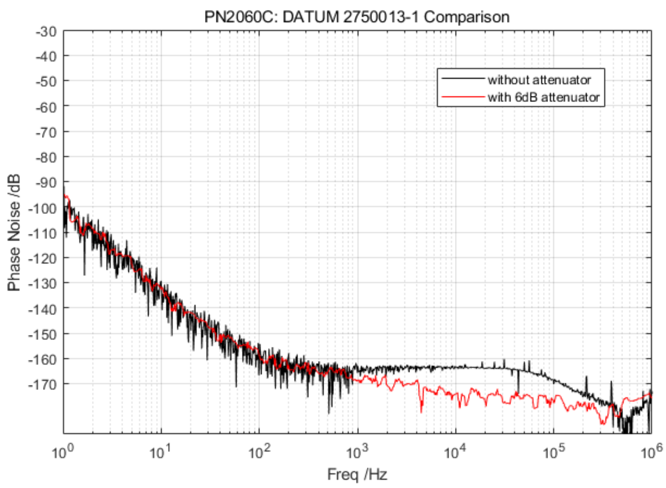

Figure 34: DATUM 2750013-1 measured with and without a 6 dB attenuator.

F Comparison with a Microchip 53100A

A 53100A measured a 10 MHz OCXO for 10 minutes; the PN2060C measured the same unit for about 5 minutes. The results are nearly identical (Figure 35). In production screening of 10 MHz oscillator batches, a PN2060C cycle takes 3–9 minutes versus about 10 minutes on the 53100A.

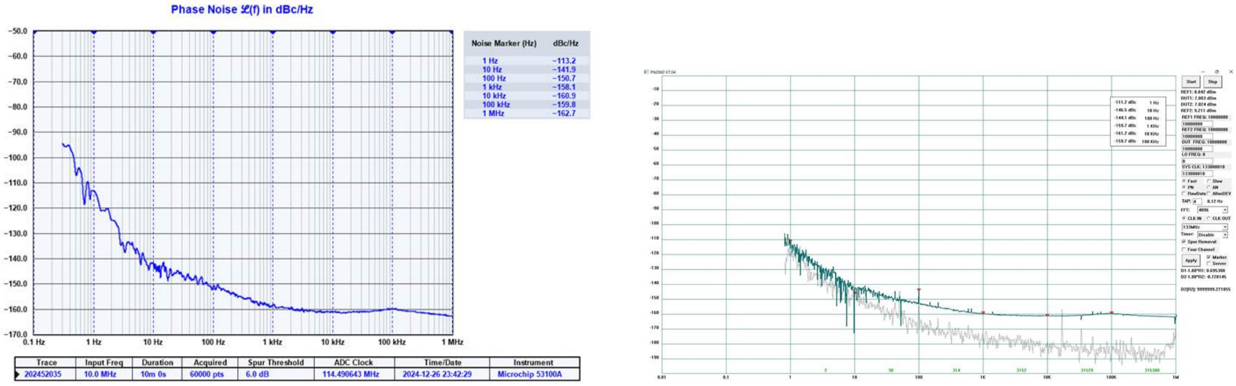

Figure 35: 53100A result (left) versus PN2060C result (right), same 10 MHz OCXO.

G Low-Pass Filter Selection Warning

When measuring very high-performance DUTs the low-pass filter itself becomes critical. Example: SCTF 45.152 MHz XOs with −164 dBc at 1 kHz (verified on an E5052A).

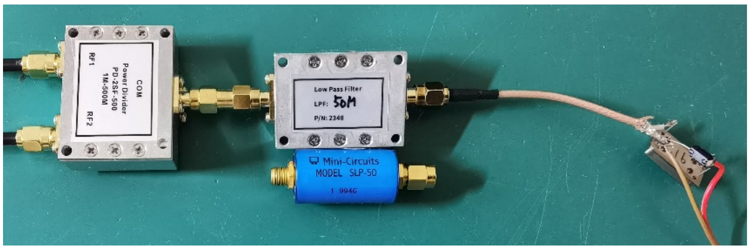

Figure 36: Test chain: splitter, low-pass filter, attenuator.

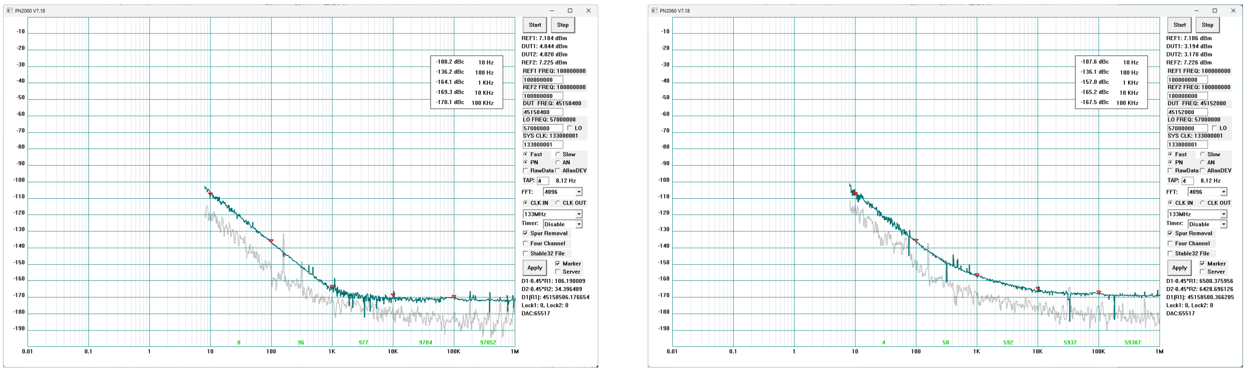

Figure 37: Left: Mini-Circuits SLP-50 – correct result at 1 kHz offset. Right: an older LPF-50M design – significant deviation at 1 kHz (the redesigned LPF resolves this).

H Self-Loop Noise-Floor Verification

To verify the instrument's own limit, split one clean source into all four inputs using three identical power splitters (Figure 38), with the signal amplified and thoroughly filtered and the level close to +10 dBm.

- The longer the run, the lower the self-loop floor near 1 Hz.
- Measure only after the analyzer and the source are fully warmed up.
- Keep the four paths matched: equal-length cables, minimal phase and amplitude differences (phase differences between DUT and REF paths can create artifacts).

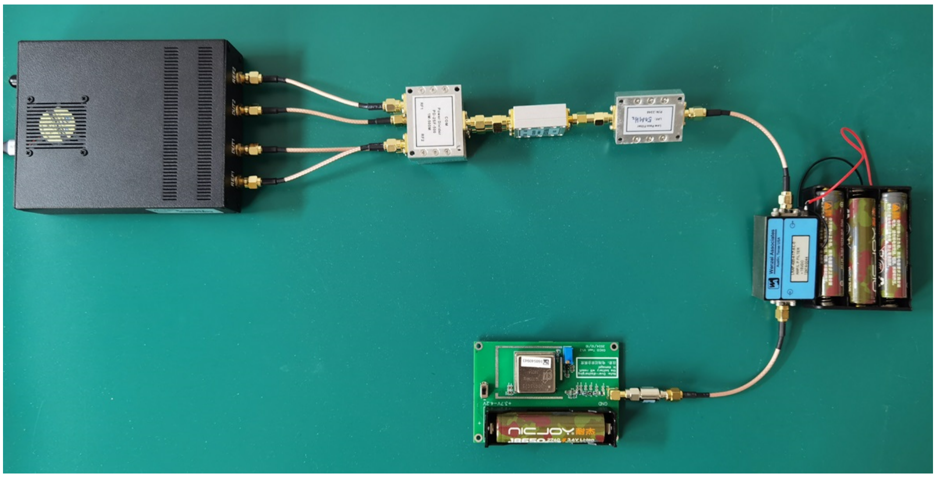

Figure 38: Self-loop limit test: one source, three splitters, four equal paths.

Acknowledgments

I would like to express my sincere gratitude to Andrew Holme. This project was initially based on his work. At the very beginning of this PNA's development, I also asked for help. The current release still use part of his source code with his permission. In the past several years, this project has evolved substantially, where nearly all the Verilog algorithms have been rewritten, and the PC algorithms have also undergone major changes, although some elements of the original structure still remain.

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; and 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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