PNA1
Intensity Noise Analyzer

User Guide



Table of Contents

Chapter 1 Safety 1

1.1 System Power Requirements 1

1.1.1 Operation 1

Chapter 2 Description 2

2.1 Introduction 2

2.2 Included Components 2

2.3 Theory of Operation 2

2.3.1 Application Basics 2

2.3.2 Digital Sampling Basics 5

2.3.3 Power Spectral Density and Windowing 6

2.3.4 Relative Intensity Noise 7

2.3.5 Integration of Spectral Data 7

2.3.6 Frequency Tiering 8

Chapter 3 Enclosure Features 9

Chapter 4 Setup 10

4.1 Basics 10

4.2 Ground Loops and the INA 10

Chapter 5 Software Overview 13

5.1 Launching the Software 13

5.2 Frequency-Domain Software Tab 14

5.3 Time-Domain Software Tab 17

5.4 Saved Data 18

5.5 Software Development Kit (SDK) 18

Chapter 6 Specifications 19

6.1 Operating Specifications 19

6.2 Electrical and Data Specifications 19

6.3 User PC System Requirements 19

Chapter 7 Mechanical Drawing 20

Chapter 8 Certifications and Compliance 21

Chapter 9 Warranty and RMA Information 22

9.1 Return of Devices 22

Chapter 10 Thorlabs Worldwide Contacts 23

Chapter 1 Safety

All statements regarding safety of operation and technical data in this instruction manual will only apply when the unit is operated correctly in accordance with this user manual.



Caution
This instrument should be kept clear of environments where liquid spills or condensing moisture are likely. It is not water resistant. To avoid damage to the instrument, do not expose it to spray, liquids, or solvents.

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

1.1 System Power Requirements

The unit operates as a high-power USB 2.0 device. Its maximum current draw is 0.5 A at 5 V, 2.5 W.

1.1.1 Operation

Prior to initializing and operating your PNA1 Intensity Noise Analyzer, please consult the following list to ensure that the unit can be safely operated.

- Read the user's manual thoroughly.
- Inspect the unit for any signs of damage.
- Ensure that both the unit and any connected devices are properly grounded.
- When operating with any light sources, ensure that appropriate personal protective equipment (PPE) is worn and that the light is directed in safe directions.

The INA has two status LEDs: one labeled Data and one labeled Power. The Power LED will illuminate once the device is plugged into a USB host. The Data LED will illuminate briefly when initially plugged into a USB host. Thereafter, the Data LED will illuminate and remain illuminated while data is transferred from the device to the host.

Chapter 2 Description

2.1 Introduction

Thorlabs' PNA1 Intensity Noise Analyzer (INA) is an instrument for measuring noise in optical systems, typically through the output from a transducer such as a photodiode. The PNA1 noise analyzer is a high-precision (18-bit analog-to-digital conversion) device capable of distinguishing very small changes in voltage, with a 9 Hz minimum resolution bandwidth. In particular, the PNA1 noise analyzer is an ideal tool for identifying environmental noise sources, such as ambient lighting incidence or electrical line noise, in an optical experiment.

This INA samples voltage data with 18-bit resolution through a coaxial BNC input port. To provide high frequency-axis resolution at low frequencies, data acquisition occurs at three separate sample rates: 12.5 MHz, 781.25 kHz, and 48.83 kHz. Both the signal conditioning hardware and digital logic design of the INA are optimized for low noise, high-resolution data acquisition. This data is transmitted to a client PC over a Hi-Speed USB 2.0 connection. Thorlabs' Intensity Noise Analyzer software can then display this data in either the frequency or the time domain. Users may choose between visualizing frequency-domain data as either Power Spectral Density (PSD) or Relative Intensity Noise (RIN).

2.2 Included Components

The PNA 1 Intensity Noise Analyzer is delivered with the following components:

1. Quick Start Card
2. USB-ABL-60 USB 2.0 Type-A to Mini-B cable with Locking Screw, Length = 1.5 m
3. PNA1 Intensity Noise Analyzer Unit

2.3 Theory of Operation

2.3.1 Application Basics

It is often desirable to know the level of relative noise within a laboratory setup or system. A common situation where this measurement is desired is in analyzing the stability and noise on a laser source. In a typical setup, a sample of a laser beam is directed onto a photodetector, which produces a current proportional to the intensity, $I(t)$, of the light incident on the detector. This current is converted to a voltage, $V(t)$, when the current flows through a resistor, such as the terminating resistor in the INA.

$$V(t) \propto I(t)$$

This signal is then digitized by electronics within the INA.

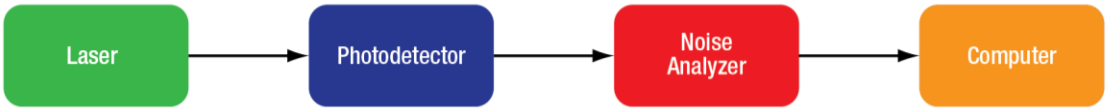


Figure 1 Typical Optical System Setup for Frequency-Domain Measurements

At this stage the signal is a time-domain signal; each measured sample is recorded as a function of time. However, it is often useful to isolate sources of noise in an experiment by identifying signal components in the frequency domain, where each measured amplitude is represented as a function of frequency. The INA performs this process, converting the time-domain signal to a frequency-domain representation according to the process described in Section 2.3.2. The frequency content of the voltage signal can be described using the power spectral density (PSD) or amplitude spectral density (ASD), which have units of (V_{RMS}^2/Hz, dBV_{RMS}^2/Hz) or (V_{RMS}/√Hz),

respectively. The mathematical operations to convert a signal from time-domain voltages to V_{RMS}^2/Hz or dBV_{RMS}^2/Hz are described in Section 2.3.3.

Although PSD provides an extensive representation of the signal power density as a function of frequency, the noise in a system can be more intuitively understood using Relative Intensity Noise (RIN), which is the PSD normalized by the total power in the signal. RIN usually has the units dBc/Hz (power in dB below the carrier per unit bandwidth). This general definition of RIN can be interpreted in several ways, depending on the desired information. If one is analyzing small power fluctuations on a laser beam, the signal is predominantly a DC voltage with small variations around that average value.

Examining RIN, or another frequency-domain measurement of signal power, may be useful for finding noise sources in a particular system. For example, if there was a large peak at 60 Hz for an optical system located in the United States, it could indicate AC line noise is getting into the signal chain and could indicate potential paths to diagnose the noise. Typical noise frequencies in optical setups are listed below:

Noise Type	Frequency Range
AC Line Noise, United States	60 Hz, 120 Hz
AC Line Noise, Europe and China	50 Hz, 100 Hz
Acoustic Noise	20 Hz - 20,000 Hz
Seismic and Ground Noise	<1 Hz - 100s of Hz
Power Supply Switching Noise	10s of kHz to 10s of MHz
Air Current Noise	<1 Hz - 10s of Hz
Shot Noise	White (Flat with Frequency)

Many techniques exist to remove noise from various sources such as optical table vibration isolation to address seismic noise sources, acoustic/air-tight enclosures to address microphonic noise sources, and electrical filters to address power supply noise sources. However, it is critical to inform any noise reduction effort by quantifying the level of noise mitigation required for the application. To this end, often the RIN spectrum is integrated over a finite bandwidth to determine the total noise contained within that bandwidth and is expressed as a percent variation. The formulas for computing integrated RIN are shown in Section 2.3.4. Very low-noise laser sources will have an integrated RIN less than 0.02%.

Figures 2, 3, and 4 show a typical signal as time-domain data, frequency-domain PSD, and frequency-domain RIN. In the time domain, the signal is recognizable as a 10 kHz sine wave with some noise and distortion. This same signal, viewed as PSD, is dominated by the 10 kHz carrier sine wave, with a broadband noise floor defined by the amplitude of the noise in the original signal. Although the shape of the frequency-domain RIN and PSD curves are identical, the Y-axis offset of each representation of the frequency-domain signal is different since the RIN curve is normalized by the average power in the signal. Also, the integrated RIN curve superimposed on the frequency-wise RIN curve shows a sharp inflection point at the carrier signal and terminates at the integrated RIN value for the entire trace.

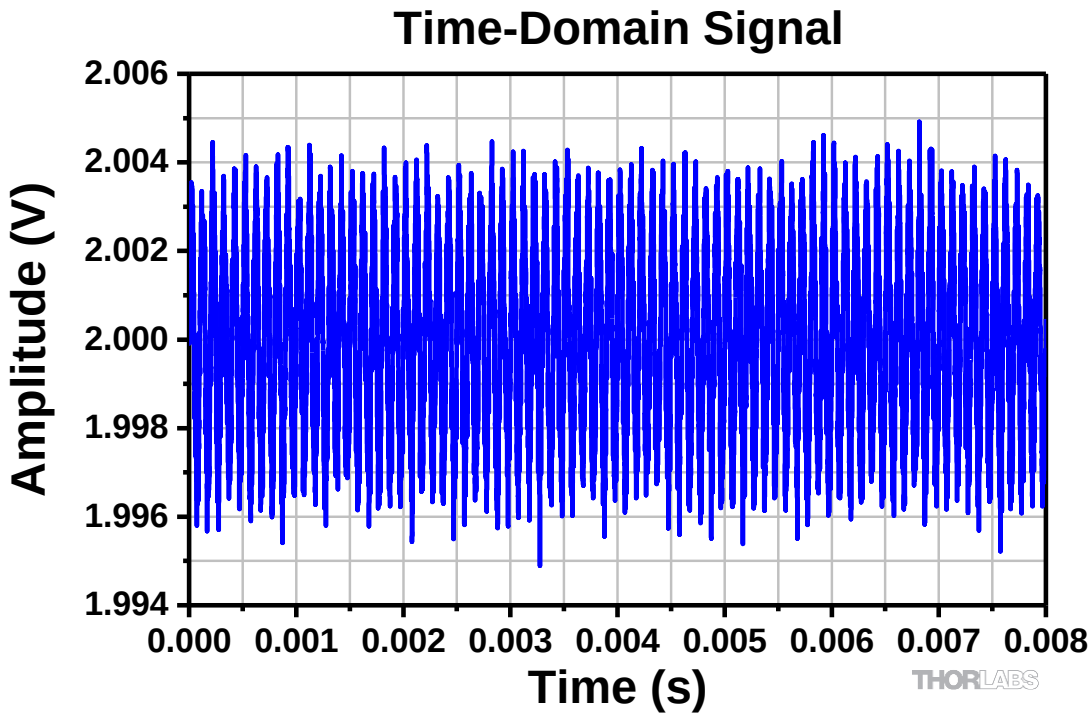


Figure 2 A noisy sine wave with a DC offset. The random noise is Gaussian with an RMS voltage of 0.0009 Volts. The sine wave amplitude is 2.8284 mV (2 mV RMS) with a frequency of 10 kHz. The DC offset is 2.000 V.

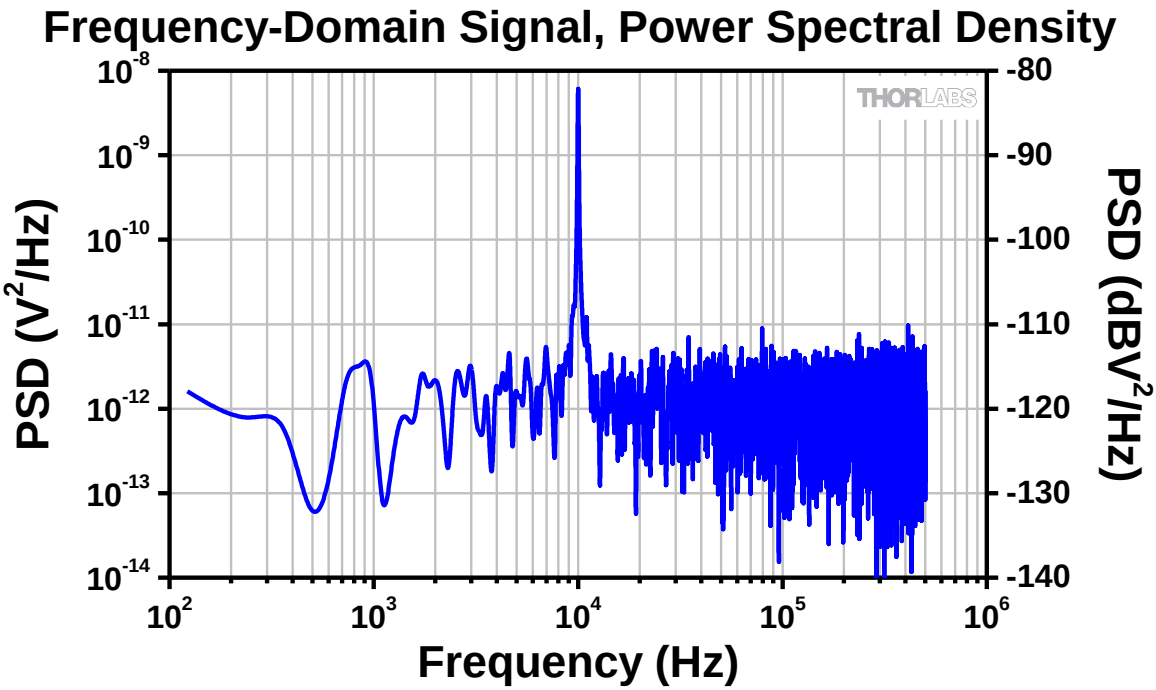


Figure 3 Power Spectral Density trace for the curve shown in Figure 2. Note the significant peak at the sine signal frequency, 10 kHz.

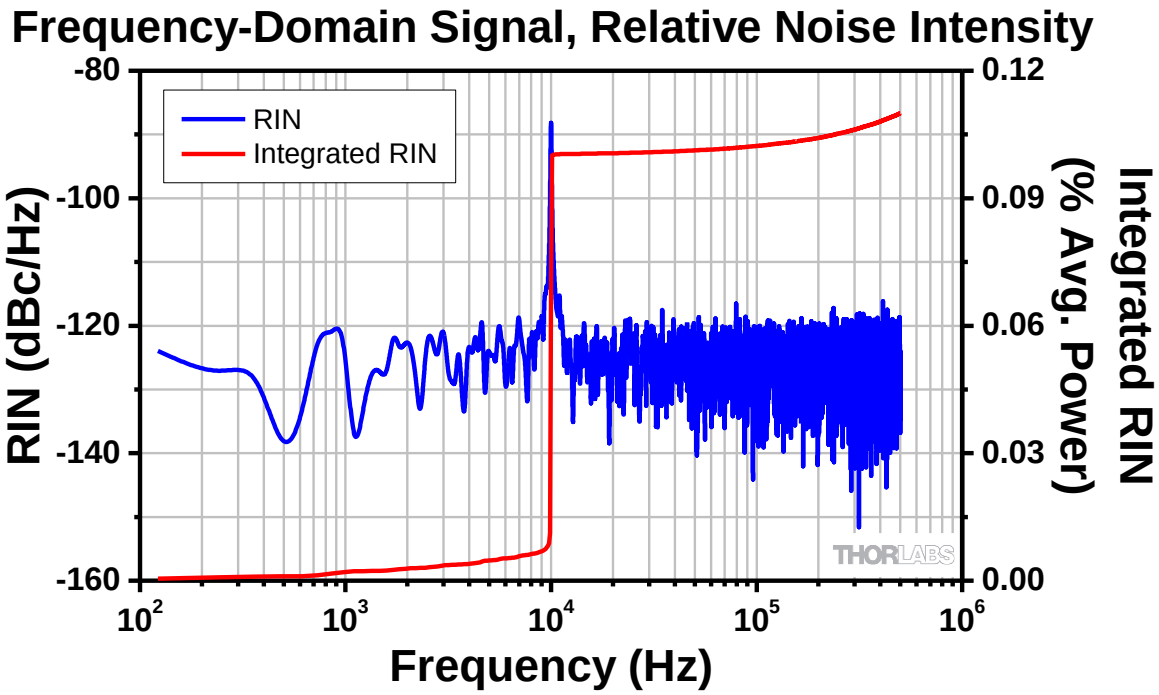


Figure 4 RIN trace obtained by normalizing the proceeding PSD trace by the RMS power in the signal with the frequency-wise integrated RIN trace superimposed in red. Note the significant inflection point in the integrated RIN curve at the signal frequency, which represents a 0.10 % increment in integrated noise. The noise from the Gaussian white noise adds in quadrature with the 10 kHz signal to a final percentage of roughly 0.11% integrated RIN.

2.3.2 Digital Sampling Basics

Flow of information through the INA begins with voltage sampling at the BNC input to the device. This input is internally terminated with a 10 kΩ impedance. Lower terminating impedances may be achieved by adding a feed-through terminator. The voltage across the input termination is low-pass filtered by an active, analog filter to prevent aliasing. The low-pass filtered signal is then digitized by a high-resolution, 18-bit analog-to-digital converter (ADC).

Digitized data is retrieved from the ADC by a field programmable gate array (FPGA). This device further digitally low-pass filters the incoming data stream and then separates the data into several separate data streams of equal length with successively lower sample rate. The sample rate reduction enables higher frequency-axis resolution for low frequencies. The time-domain data may be converted to the frequency domain through a Fast Fourier Transform (FFT). The result of an FFT is a complex number whose real component represents the cosine amplitude of the digitized voltage signal and whose imaginary component represents the sine amplitude of the digitized voltage signal. The FFT is simply a fast means of calculating a Discrete Fourier Transform (DFT), which is shown below for an equally spaced series of N time-domain data points, x. The term j in the equation below is the imaginary number. The term n denotes a zero-referenced index in the time-series data, x.

$$X[k] = \sum_{n=0}^{N-1} x[n] \cos\left(\frac{2\pi\ k\ n}{N}\right) - \sum_{n=0}^{N-1} j\ x[n] \sin\left(\frac{2\pi\ k\ n}{N}\right)$$

$X[k]$ is a vector of complex numbers, representing the sine and cosine components of the time-domain signal at an index k . Each k index represents one equal division of the sample rate of the acquired signal. The magnitude of $X[k]$, $Y[k]$, corresponds to the magnitude of the input signal at the frequency relevant to index k.

$$Y[k] = (Re(X[k])^2 + Im(X[k])^2\ )^{\frac{1}{2}}$$

In the case of the INA, x has units of volts (V), X has units of V, and Y has units of V. X and Y differ in that X is the sum of two orthogonal basis functions, whereas Y is the magnitude of X. Y^2 then has units of V^2, such as if the square root on the right side of the equation were omitted. Y^2 also relates linearly to the power in the input signal, by a factor of the inverse of the input termination, since electrical power is $\frac{V^2}{R}$. It is also noteworthy that X is symmetric about $N/2$. With that detail in mind, the total signal power at one frequency index is $2\ (Y[k])^2$, with an exception for the zeroth point in the series.

2.3.3 Power Spectral Density and Windowing

Oftentimes the density of power at a given frequency index is preferred to the total signal power, or the Power Spectral Density (PSD), which may be calculated according to:

$$PSD = 2\frac{Y[k]^2\ N}{f_s}$$

where f_s is the sample frequency and N is the number of samples in the time-domain signal. PSD, in the context of the INA, has units of $\frac{V^2}{Hz}$.

The previously provided definition of PSD overlooks an important practical consideration in the acquisition of time-series voltage data; the time-series is of finite length. This effectively implies that the time-domain signal is mixed with a rectangular unit step function. The frequency-domain character of such a signal is a sinc function. Thus, mixing the rectangular function with the time-series voltage data effectively convolves its frequency response with the time-series voltage data's frequency-domain representation and adds substantial ripple to the frequency-domain representation of the original time-domain signal. To address this, a "windowing function" is often applied to time-domain data, which seeks to compensate for the implied rectangular window due to a finite length time-domain data series. Numerous selections are available. The Intensity Noise Analyzer applies a Hann window whose coefficients are computed according to the following formula:

$$w[n] = \sin^2\left(\frac{\pi n}{N}\right)$$

The application of the window function, w, impacts the PSD by spreading the power in each frequency-domain series index out over adjacent indices. When examining a PSD, this power spreading should be accounted for. An equivalent noise bandwidth (ENBW) is introduced as:

$$ENBW = \frac{f_s S_2}{S_1^2}$$

where f_s is the sample rate in Hz, and S_1 and S_2 are

$$S_1 = \sum_{n=0}^{N-1} w[n]$$

$$S_2 = \sum_{n=0}^{N-1} (w[n])^2$$

PSD for windowed time series data may then be computed as:

$$PSD = 2\frac{(Y[k])^2}{S_1^2\ ENBW}$$

which for a rectangular window ($w[N-1:0]=1$), is algebraically equivalent to the prior provided expression for PSD. Typically, PSD is displayed as a decibel unit. This conversion is performed by the INA software as follows:

$$PSD_{\frac{dBV^2}{Hz}}[i] = 10\log_{10}(PSD[i])$$

With the subscript $\frac{dBV^2}{Hz}$ denoting that $PSD_{\frac{dBV^2}{Hz}}$ is in units of $\frac{dBV^2}{Hz}$ rather than $\frac{V_{RMS}^2}{Hz}$.

2.3.4 Relative Intensity Noise

Alternatively, INA measurements may be shown as RIN. In this case the PSD is normalized to the average power of the time-domain signal as follows:

$$RIN[n] = \frac{PSD[n]}{(V_{RMS})^2}$$

where V_{RMS} is the Root Mean Square (RMS) voltage of the time-domain signal computed as:

$$V_{RMS} = \sqrt{\frac{1}{N}\left(\sum_{n=0}^{N-1} V[n]^2\right)}$$

2.3.5 Integration of Spectral Data

The integrated RIN (RIN_{int}) or Power Spectrum (PS) in a frequency-domain data series may be useful and may be obtained through integrating these values over the frequency span of the spectral data.

$$RIN_{int} = \int_0^{f_n} RIN(f)\,df$$

$$PS = \int_0^{f_n} PSD(f)\,df$$

where f_n is the Nyquist frequency of the time-domain data. The Nyquist frequency is one-half the sample rate. Although these integrals are written as continuous integrals for theoretical purposes, in practice they are computed numerically from discrete data series according to the trapezoidal rule.

$$\int f(x)\,dx \approx \sum_{i=1}^{i=N-1} \frac{\big(f(x[i]) + f(x[i-1])\big)}{2}(x[i] - x[i-1])$$

This integration is particularly useful in interpreting RIN measurements. When captured with the same bandwidth, the integrated RIN can be equivalent to the standard deviation of the mean of the time-domain data. The shape of the integrated curve can indicate how much of the total integrated noise is contained within a particular noise spectrum (where spurious noise peaks are, for example). Consider a DC signal with a single sinusoidal noise signal superimposed:

$$V_{sig} = V_A + V_n \sin(2\pi f_{noise})$$

where V_{sig} is the signal voltage, V_A is the DC signal voltage, V_n is the noise amplitude voltage, and f_{noise} is the noise frequency in Hz. If V_n is small with respect to V_A, the average power in V_{sig} will be dominated by V_A. Integrating RIN from DC to the Nyquist frequency would naturally result in a final integrated RIN of unity. However, if the DC component were omitted, either by changing the limits of integration or by subtracting the DC offset of the signal from the time-domain data, the final integrated RIN value, RIN_{AC}, obtained would represent the non-DC (AC) elements of the noise spectrum, effectively:

$$RIN_{AC} = \frac{(V_n \sin(2\pi f_n))^2}{\left(V_{sig\ RMS}\right)^2}$$

This value is physically insightful as to the extent of noise in the system since it is the ratio of the integrated noise sources divided by the average power of the signal.

To better understand the physical meaning of this measurement, consider Figure 4. There is a significant inflection point at the dominant signal frequency, 10 kHz. The change in integrated RIN, ΔRIN, across this inflection is equivalent to the RMS signal voltage squared divided by the average power in the signal:

$$\Delta RIN = \frac{\left(V_{f,RMS}\right)^2}{(V_{RMS})^2}$$

where $V_{f,RMS}$ is the RMS voltage at a single frequency and V_{RMS} is the RMS voltage of the time-domain signal. In the case of the example shown in Figure 4, the input signal that drives the inflection point in the integrated RIN trace is a 1 mV RMS sine wave at 10 kHz. The RMS voltage of the entire time-domain signal is the quadrature sum of the RMS voltage of the three signal components: the white noise, the 10 kHz tone, and the DC offset voltage, approximately 2 V. Since the 10 kHz test tone is confined to a narrow bandwidth, the inflection in the integrated RIN curve may be computed as the ratio of the integrated power in a narrow band around 10 kHz to the average power of the time-domain signal. Therefore, the RIN that accumulates in the frequency-domain point nearest to 10 kHz may be calculated as:

$$\Delta RIN = \frac{2\ mV_{RMS}}{2\ V_{RMS}} = 0.1\%$$

2.3.6 Frequency Tiering

The spacing of points on the frequency axis of a DFT is often referred to as the resolution bandwidth or RBW. This figure is simply the ratio of the sample rate of the time data, F_s, prior to performing the DFT, to the number of points in the time-series data, N.

$$RBW = \frac{F_s}{N} K_w$$

where K_w is a correction factor to account for the effect of any windowing operation. This correction factor is a secondary consideration in resolution bandwidth. The windowing operation has the effect of spreading out the signal power in a given frequency segment of the FFT to the adjacent frequency segments, since the approximately sinc-function frequency-domain response of the window function is convolved with the input signal. For the Hann window applied in the INA calculation, a value of 1.5 is used for K_w, and the values shown in the Operating Specifications table reflect this. In the case of no window function, which is a rectangular window, K_w is simply 1 and the RBW is simply the nominal ratio of sample rate to number of samples.

Smaller RBW is naturally advantageous when trying to discriminate noise sources close to one another or at low frequencies. To reduce the nominal RBW in the expression shown above, either the number of points in the DFT may be increased or the sample rate may be reduced. To provide useful RBW across the full bandwidth of the INA, three sample rates are used in the INA. The initial sample rate of the device is reduced and then reduced again. By so doing, the RBW is adjusted to three separate bandwidths. The data displayed by the INA is the sample point with the smallest RBW; priority is given to the lowest sample rate data where the data series overlap.

Chapter 3 Enclosure Features

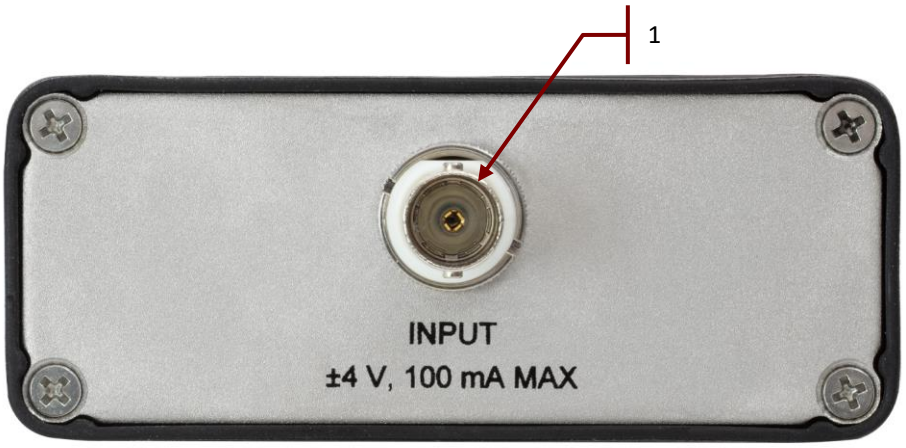


Figure 5 Front Panel

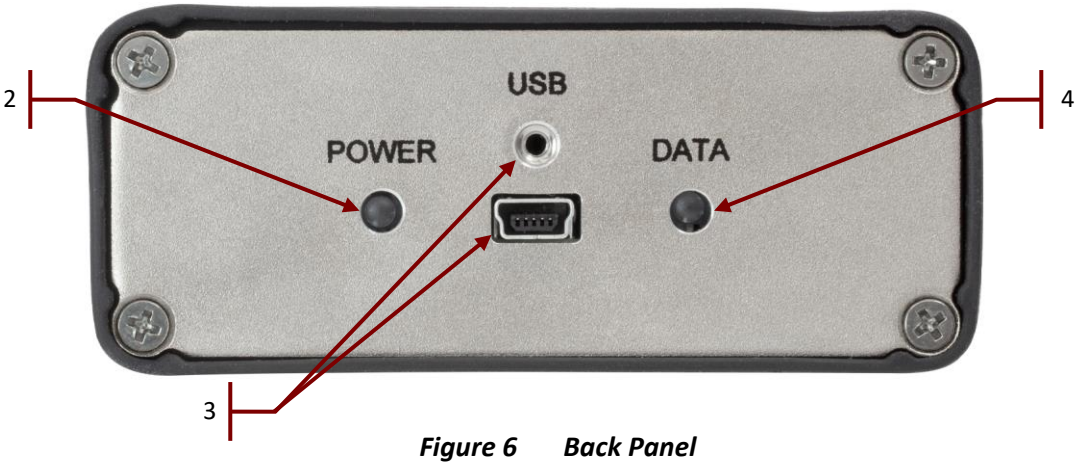


Figure 6 Back Panel

Callout	Description
1	Signal Input (BNC Female)
2	Power Status Indicator LED
3	USB Mini-B Output with Locking Screw
4	USB Status Indicator LED

Chapter 4 Setup

4.1 Basics

Setup for the PNA1 Intensity Noise Analyzer is straight-forward. First, connect the PNA1 to the transducer in the optical setup using a BNC cable (not included). Then, connect a USB 2.0 cable (included) from the back panel of the device housing to a PC, which must have the Intensity Noise Analyzer Software Installed.

4.2 Ground Loops and the INA

The outer diameter (OD) of the BNC connector on the INA input is connected to the device ground internally and provides the zero reference for the signal source to see the terminating impedance of the INA input. However, the enclosure of the INA and the INA power supply ground within the USB connection also share this ground. Therefore, depending on the connection to the User PC, the INA input signal BNC OD may be common to the earth ground in the customer's environs. This can cause apparently irregular behavior in the measurement output, particularly at low frequencies, when the signal source BNC is also common to earth ground. Typically, a laptop power supply or signal source device power supply with 3-pins will result in a finite impedance between the device's BNC OD and the building's earth ground.

This issue is simple to address and nearly all experiments fit into one of four categories.

1. Both the INA ground and the signal source ground are floating with respect to the building earth ground. An example of this scenario is when the INA is connected to a laptop operating from battery power and the signal source is a Thorlabs DET10A2 detector also operating from battery power. Neither the signal source nor the INA interface with earth ground.
    a. **There is no ground loop issue in this scenario.**

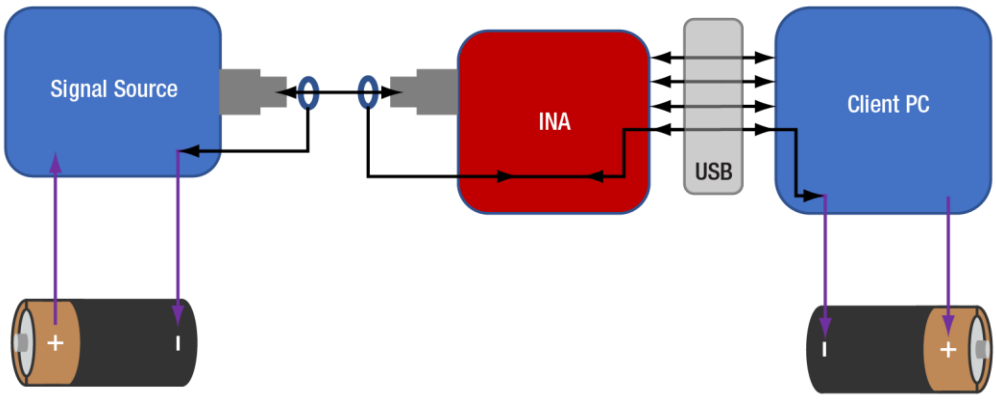


Figure 7 Diagram of grounding scenario 1, where both the INA and the signal source operate from isolated power supplies. There is no issue here since the both the INA and the signal source are operating independently of earth ground. Purple traces indicate power, blue rings indicate the return voltage node of a coaxial cable, and black arrows indicate in-specific electrical connections.

2. The INA ground is floating with respect to earth ground and the signal source power supply is referenced to earth ground. An example of this scenario is when the INA is connected to a laptop operating from battery power and the signal source is an arbitrary waveform generator (AWG) with a power supply derived from line voltage.
    a. **There is no ground loop issue in this scenario.**

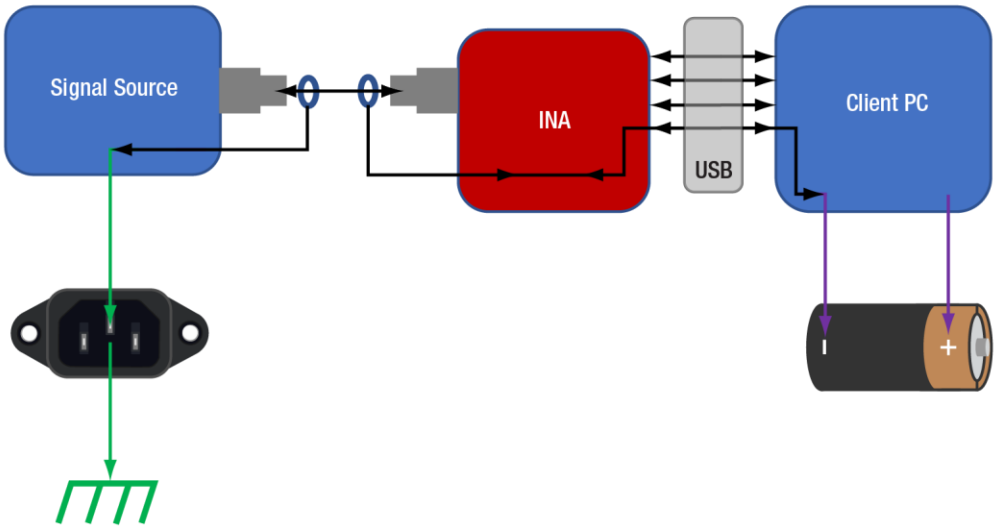


Figure 8 Diagram of grounding scenario 2. There is no issue here since the INA operates independently from earth ground. The green trace indicates an earth ground connection.

3. The INA ground is common to earth ground and the signal source power supply is floating with respect to earth ground. An example of this scenario is an INA connected to a desktop PC or laptop connected to its charger and the signal source is a Thorlabs DET10A2 operating from battery power.
    a. **There is no ground loop issue in this scenario.**

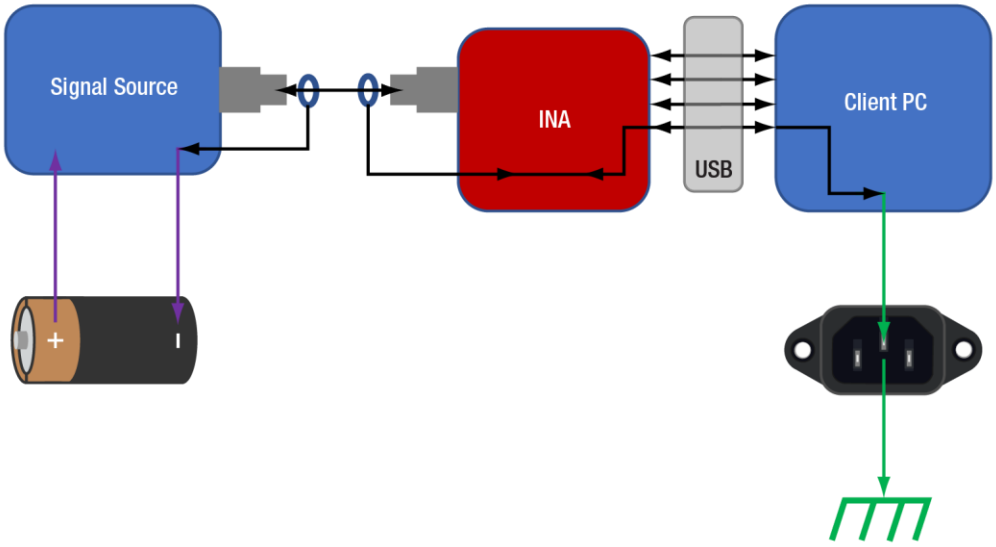


Figure 9 Diagram of grounding scenario 3. There is no issue here since the signal source operates independently from earth ground.

4. The INA ground is common to earth ground and the signal source power supply is referenced to earth ground. An example of this scenario is an INA connected to a desktop PC or laptop connected to its charger and the signal source is an AWG with a power supply derived from line voltage.
    a. **There is a likelihood of a ground loop issue in this scenario. Fortunately, this can be addressed in one of several ways.**
        i. Connect the INA to a laptop operating from battery power instead of a desktop PC.

ii. Connect the INA to the same client PC with a USB ground loop isolator between the INA and the client PC.

iii. Replace the signal source with a floating alternative.

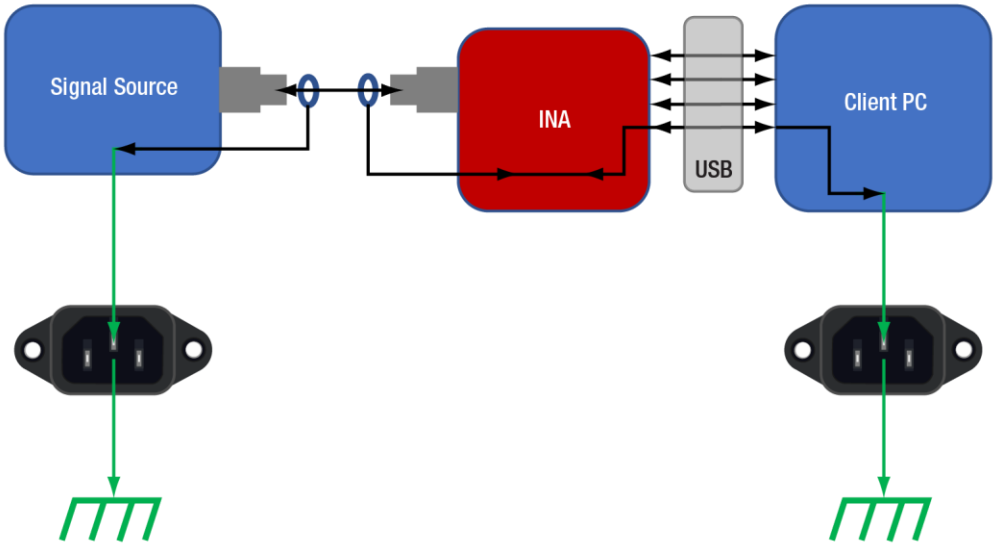


Figure 10 Diagram of scenario 4, where a ground loop is likely to occur with both the signal source and INA operating with earth grounded power supplies. Note the two paths to the earth ground symbol.

Chapter 5 Software Overview

The primary interface to the INA is through a Windows application, IntensityNoiseAnalyzer.exe. This software may be downloaded from the Thorlabs product page and installed on any Microsoft Windows 64-bit machine. The software is available here: **https://www.thorlabs.com/software**.

5.1 Launching the Software

After launching the software, click “Connect” to enumerate available INA devices. Only one INA may be communicated with at a time.

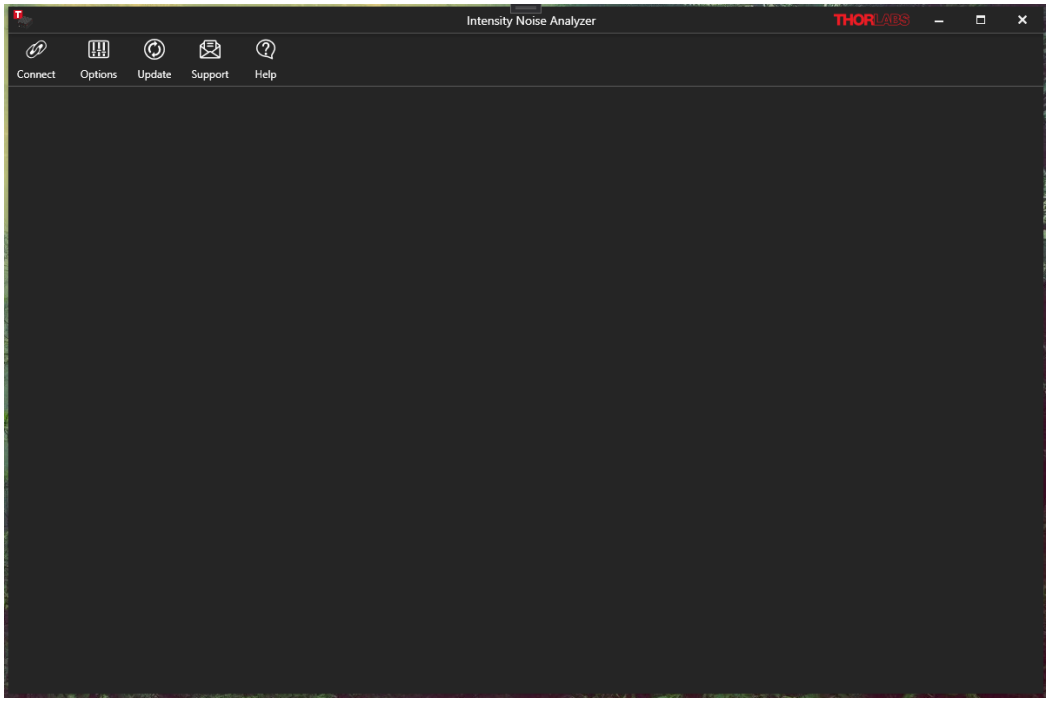


Figure 11 Launch screen for the INA software.

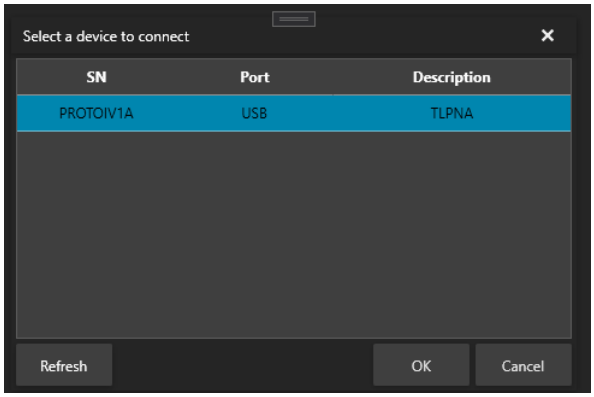


Figure 12 Device selection window. Click OK to connect to the device selected.

5.2 Frequency-Domain Software Tab

The frequency-domain display in the software is the default tab once the user successfully connects to a device. Pressing the “play” arrow in the top left will begin measurement display. The frequency-domain tab allows the user to configure frequency-domain display of data from their setup.



Figure 13 Frequency-Domain Display

- **Show Measured Spectrum:** Checking the box shows measured spectrum.
- **Show Reference Spectrum:** Checking the box shows reference spectrum.
- **Show Background Spectrum:** Checking the box shows background spectrum.
- **X Gridlines**: Checking the box enables X gridlines.
- **Y Gridlines:** Checking the box enables Y gridlines.
- **Run / Pause Button:** Pressing this button commences / stops the update of graphical information on the display.
- **RIN / PSD:** These radio buttons allow a user to switch between RIN or PSD units. PSD units are the default on startup. One of these two buttons will always be selected during frequency-domain display.
- **Current RMS (V):** Displays current RMS in volts of live frequency spectrum.

- **Arbitrary RMS (V):** Displays arbitrary RMS voltage (user entered) to be applied to live spectrum. Can only be changed when RIN units are displayed.
- **Arbitrary RMS Checkbox:** Checking the box computes the RIN of the live spectrum with the arbitrary RMS voltage. The arbitrary RMS voltage is also used to compute the RIN of the background spectrum if a background spectrum is loaded. The arbitrary RMS checkbox can only be checked when RIN units are displayed.
- **Average Scans:** Toggling this switch enables and disables averaging in the frequency domain.
- **Scans to Avg.**: This numeric control determines the number of scans that may be averaged. Minimum is 1 scan and maximum is 100 scans. The up and down arrows on a keyboard increase and decrease the number of scans in the average. Similarly, the up and down buttons adjacent to the control increase and decrease the number of scans in the average. The user may also type in the number of scans they wish to average.
- **Reference Spectrum Panel:**
    - **Load**: Pressing this button in the Reference Spectrum panel allows a user to select a reference spectrum that is saved on the client PC.
    - **Save:** Pressing this button in the Reference Spectrum panel allows a user to save the currently displayed frequency data to their PC. After clicking this button, a save file dialog will allow the user to choose the storage location and enter the file name for their data. The data saves as a Comma-Separated Values (CSV) file.
- **Background Spectrum Panel:**
    - **Load:** Pressing this button in the Background Spectrum panel allows a user to select a background spectrum that is saved on the client PC. A loaded background spectrum can be subtracted from the live spectrum. In RIN mode, the RMS voltage of the live spectrum is used to compute the RIN of the background spectrum. If an arbitrary RMS voltage is being used, the arbitrary RMS voltage is used to compute the RIN of the background spectrum.

      Note: The loaded background spectrum and loaded reference spectrum have distinct behaviors. A loaded reference spectrum is <u>not</u> altered and is entirely for reference.
    - **Subtract Background Spectrum:** Toggling switch to the on position will subtract the loaded background spectrum from the live spectrum. Toggle control only appears when a background spectrum is loaded.
- The units of the reference spectrum will follow the selection of RIN / PSD.
- **Auto Scale Y**: Checking the box enables automatic determination of the Y Axis display limits.
- **Auto Scale X:** Checking the box enables automatic determination of the X Axis display limits.
- **Log X Axis:** Checking the box toggles between a logarithmic and linear X axis display.
- **Integrated Axis:** Checking the box enables and disables the display of integrated data.

The user may also use the mouse to change the extent of the displayed information:

- The mouse wheel zooms in and out towards the current position of the mouse pointer on the plot.

- SHIFT + Click changes the mouse pointer to a plus sign. Thereafter the left-mouse button will zoom in on the position of the mouse pointer by a factor of 3. The user may also drag and select a region of the chart to zoom to fit.
- ALT + Click changes the mouse pointer to a minus sign. Thereafter the left-mouse button will zoom out from the position of the mouse pointer by a factor of 3.
- Spread and pinch gestures on a mouse pad or touch screen will zoom in and out of the chart respectively.
- After scrolling, clicking the left-mouse button will allow the user to pan by dragging the mouse.
- Right clicking the chart will restore the default position of the chart.

5.3 Time-Domain Software Tab

The time-domain display in the software may be selected after the user successfully connects to a device. Pressing the “play” arrow in the top left will begin measurement display. The time-domain tab allows the user to configure time-domain display of data from their setup.

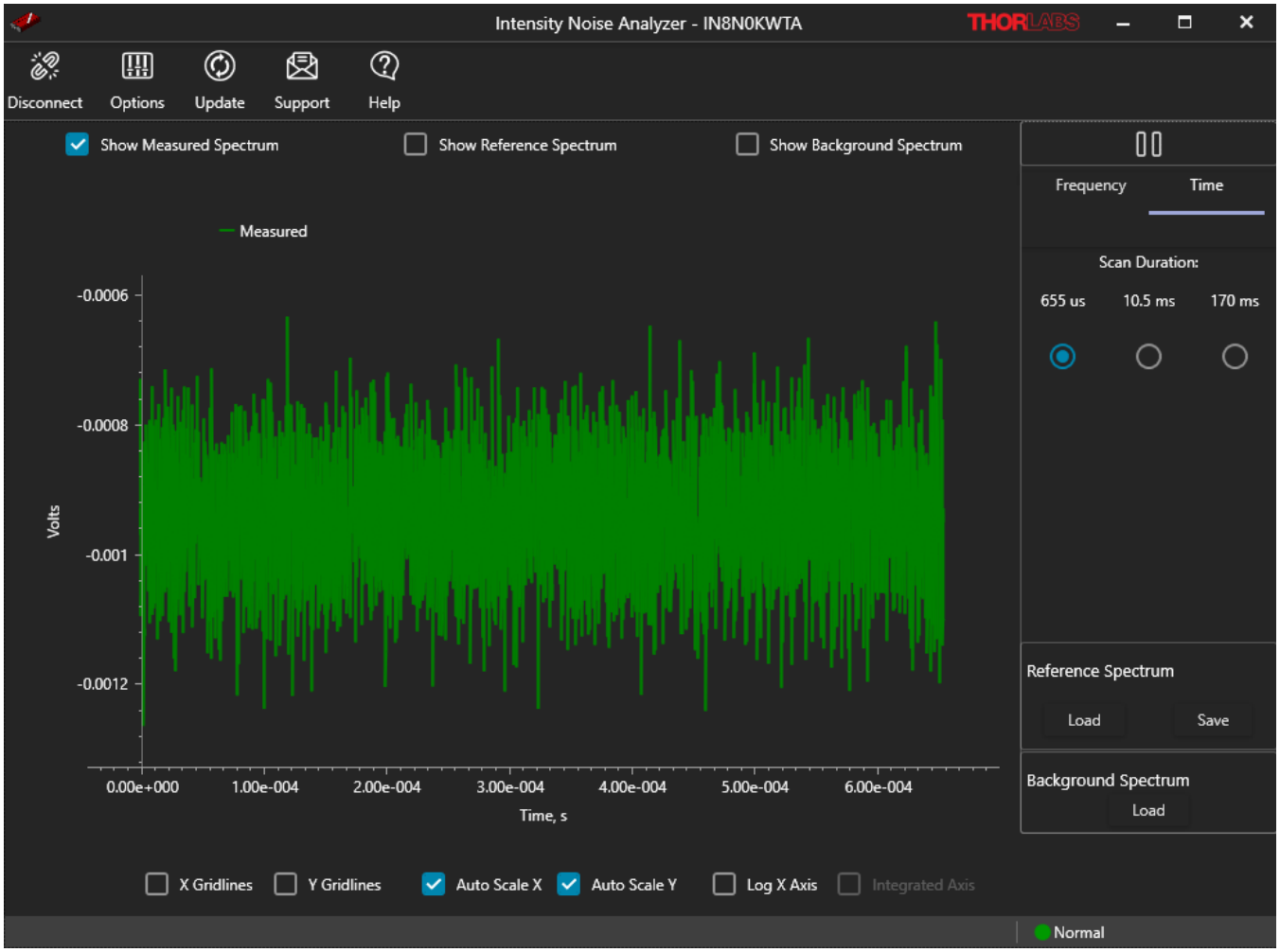


Figure 14 Time-Domain Display

Most of the controls on the Time-Domain display have the same effect as on the frequency-domain display, with a few exceptions. Controlling the zoom and display extents of the chart with the mouse is the same in the time domain view as in the frequency-domain view.

- A reference trace may not be displayed in the time domain.
- The **Scan Duration** radio button selects the signal source from one of three sample rates.
- The integrated axis is not functional in the time domain.

The purpose of the time-domain trace is to allow a user to understand if their measurement is saturating or if there is recognizable periodic content in the time-domain signal.

5.4 Saved Data

Data is saved in Comma-Separated Values (CSV) format. A brief header retains pertinent data from the data being saved. If the format of this CSV is altered, the software may be unable to recover a reference spectrum. Therefore, the user is encouraged to save their data in a separate spreadsheet file if they intend to do any independent analysis.

	A	B	C	D	E	F
1	Timestamp	03.11.2024:08:02:16				
2	Scans in Average	1				
3	Termination	10000				
4	V_RMS(V)	0.00094933				
5	V_DC (V)	-0.000947992				
6	RMS_Noise %	8.463904013				
7	Frequency (Hz)	Mag^2 (V^2 / Hz)	PSD (dBV^2 / Hz)	RIN (dBc / Hz)	Integrated Volts RMS	Integrated RIN (%RMS)
8	0	7.40799259801861	-131.3029938	-70.85134125	0	0
9	5.960464	1.16685532702832	-139.329834	-78.87817383	5.05519912849839E-07	0.053250174
10	11.92093	9.81947891887103	-150.0791168	-89.62745667	5.41527297269307E-07	0.0570431

If a background spectrum is loaded, columns G-K are added to the saved file. If background spectrum subtraction is enabled, columns L-P are added to the saved file.

G	H	I	J	K	L	M	N	O	P
BG Mag^2 (V^2 / Hz)	BG PSD (dBV^2 / Hz)	BG RIN (dBc / Hz)	BG Integrated Volts RMS	BG Integrated RIN (%RMS)	Subtracted Mag^2 (V^2 / Hz)	Subtracted PSD (dBV^2 / Hz)	Subtracted RIN (dBc / Hz)	Subtracted Integrated Volts RMS	Subtracted Integrated RIN (%RMS)
7.973995948132 65E-1	-130.9832458	-70.53158569	0	0	1E-20	-200	-139.5483398	0	0
1.807901532202 13E-1	-137.4282532	-76.97660065	5.3992892027605E-07	0.056874731	1E-20	-200	-139.5483398	0	2.57171487081481E-05
3.001081777835 24E-1	-145.2272186	-84.7755661	5.95270391504151E-07	0.06270426	1E-20	-200	-139.5483398	0	3.63695404886288E-05

Figure 15 Saved data from the INA viewed with a common spreadsheet software.

5.5 Software Development Kit (SDK)

A Python SDK is available in the software install directory.

“C:\Program Files (x86)\Thorlabs\IntensityNoiseAnalyzer\SDK”

HTML documentation of each SDK file is available in the same directory as this manual.

“C:\Program Files (x86)\Thorlabs\IntensityNoiseAnalyzer\Manual”

Chapter 6 Specifications

6.1 Operating Specifications

Operating Specifications		
Quiescent Noise Floor[a]		<-140 dBV ^{2}/Hz
Broadband Noise Density[b]		<60 nV/√Hz
Bandwidth		DC to 3 MHz
Nominal Input Sampling Resolution		18-Bit
Measurable Input Signal Voltage[c]		±3.85 V
Maximum Input Voltage		±4 V
Maximum Input Current		100 mA
Sample Rates		12.5 MHz, 781.25 kHz, 48.83 kHz
Resolution Bandwidth[d]	**390 kHz - 3 MHz**	2.3 kHz
	24.5 kHz - 390 kHz	140 Hz
	DC - 24.5 kHz	9 Hz
Input Termination		10 kΩ

a. Verified prior to shipment. Small quiescent noise peaks may fluctuate depending on host device characteristics and environmental conditions.
b. Based on the verification of Quiescent Noise Floor.
c. Based on a minimum input supply voltage of 4.75 VDC.
d. Adjusted for the Hann window applied in the device calculation.

6.2 Electrical and Data Specifications

Electrical Requirements	
Supply Voltage from USB	4.75 - 5.25 VDC
Frequency	DC
Supply Current	500 mA (Max)
Max USB Baud Rate	480 Mb/s
Temperature Range[a]	0 °C to 70 °C

a. Temperature range over which the device may be operated without damage. Optimal measurements occur close to room temperature.

6.3 User PC System Requirements

System Requirements	
Operating System	Windows 10® (Recommended) or 11, 64 Bit Required
Memory (RAM)	4 GB
Hard Drive	300 MB (Min) of Available Disk Space
Interface	Hi-Speed USB 2.0
Minimum Screen Resolution	1200 x 800

Chapter 7 Mechanical Drawing

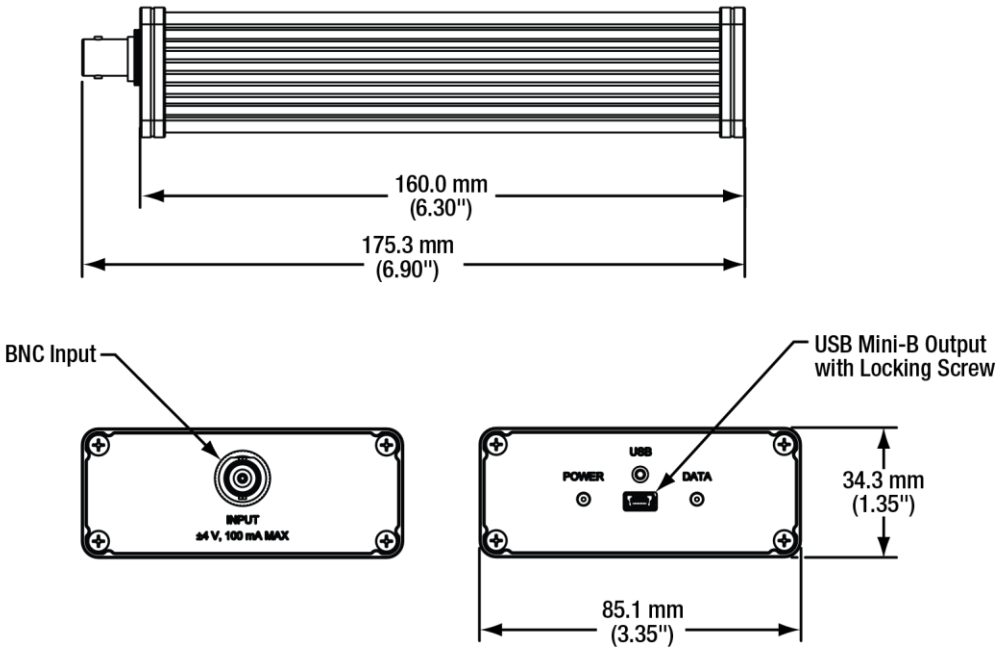
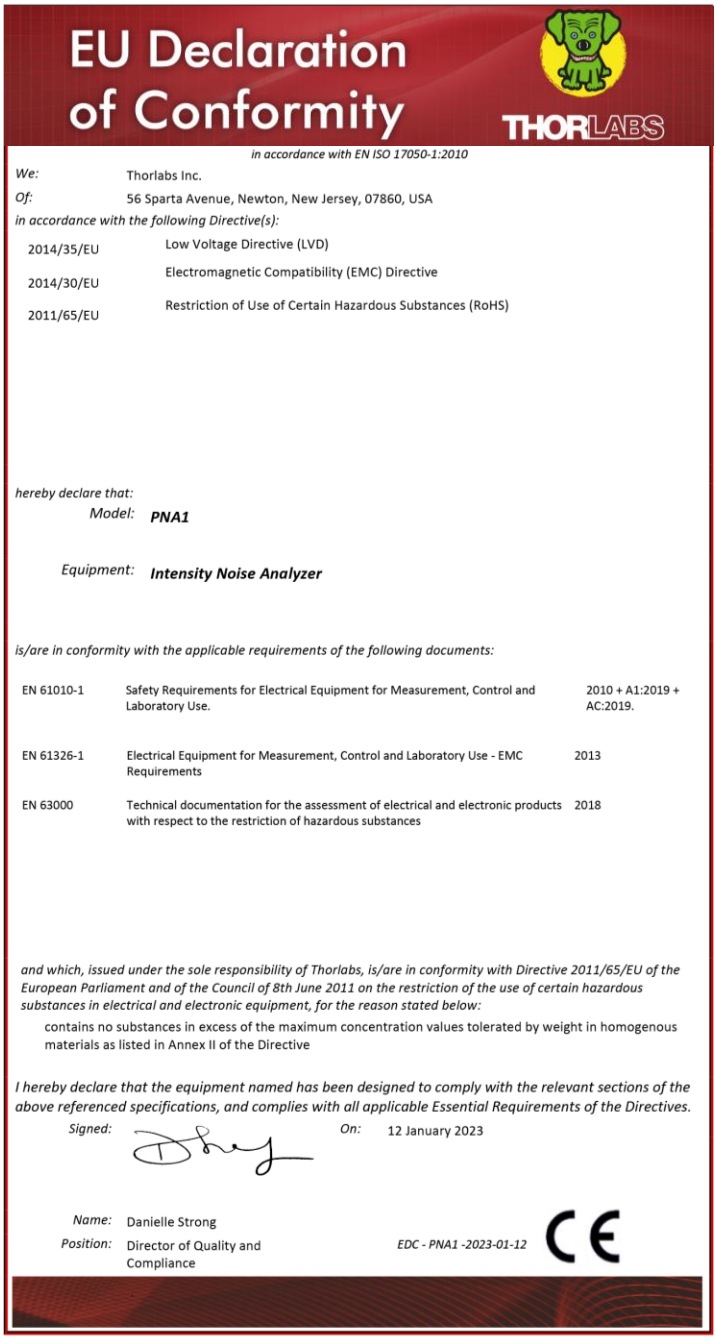


Figure 16 PNA1 Intensity Noise Analyzer Mechanical Drawing

Chapter 8 Certifications and Compliance



EU Declaration of Conformity

THORLABS

in accordance with EN ISO 17050-1:2010

We: Thorlabs Inc.

Of: 56 Sparta Avenue, Newton, New Jersey, 07860, USA

in accordance with the following Directive(s):

2014/35/EU	Low Voltage Directive (LVD)
2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: ***PNA1***

Equipment: ***Intensity Noise Analyzer***

is/are in conformity with the applicable requirements of the following documents:

EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use.	2010 + A1:2019 + AC:2019.
EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2013
EN 63000	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances	2018

and which, issued under the sole responsibility of Thorlabs, is/are in conformity with Directive 2011/65/EU of the European Parliament and of the Council of 8th June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, for the reason stated below:

contains no substances in excess of the maximum concentration values tolerated by weight in homogenous materials as listed in Annex II of the Directive

I hereby declare that the equipment named has been designed to comply with the relevant sections of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.

Signed: *On:* 12 January 2023

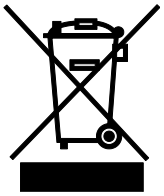
Name: Danielle Strong

Position: Director of Quality and Compliance

EDC - PNA1 -2023-01-12

CE

Chapter 9 Warranty and RMA Information



Annex I

Thorlabs verifies our compliance with the WEEE (Waste Electrical and Electronic Equipment) directive of the European Community and the corresponding national laws. Accordingly, all end users in the EC may return "end of life" Annex I category electrical and electronic equipment sold after August 13, 2005 to Thorlabs, without incurring disposal charges. Eligible units are marked with the crossed out "wheelie bin" logo (see right), were sold to and are currently owned by a company or institute within the EC and are not dissembled or contaminated. Contact Thorlabs for more information. Waste treatment is your own responsibility. "End of life" units must be returned to Thorlabs or handed to a company specializing in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site. It is the user's responsibility to delete all private data stored on the device prior to disposal.

9.1 Return of Devices

This precision device is only serviceable if returned and properly packed into the complete original packaging including the complete shipment plus the cardboard insert that holds the enclosed devices. If necessary, ask for replacement packaging. Refer servicing to qualified personnel.

Chapter 10 Thorlabs Worldwide Contacts

For technical support or sales inquiries, please visit us at **www.thorlabs.com/contact** for our most up-to-date contact information.



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chinasales@thorlabs.com


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