BumbleBee
INSTRUMENTS PRIVATE LIMITED
An IIT Palakkad Incubated Company

ScopeX Advanced Oscilloscope

Application Manual

GUI Framework for the ScopeX Kit

ScopeX Integrated Framework

- Dual-Channel Digital Storage Oscilloscope (DSO)
- Integrated DDS Analog Signal & Digital Frequency Generator
- Fixed +5VDC and High-Precision Bipolar ±12V Dual Rail Supply
- 4-Bit Programmable Digital Input/Output Interface
- Hardware-Adjustable DC Offset and Signal Gain Controls

2026

Platform: Windows 10/11 · Linux (Ubuntu 20.04+) and Mac

Contents

1 Introduction

The **ScopeX Advanced Oscilloscope** is a cross-platform Qt-based graphical user interface (GUI) developed to interface with the **ScopeX hardware kit** from Bumblebee Instruments, turning a standard Windows or Linux laptop into a full instrumentation workstation.

1.1 Key Capabilities

- **Dual-channel oscilloscope** with Sinc / linear / auto interpolation and trigger support
- **Signal generator** for sine, square, triangle, sawtooth and arbitrary waveforms (1 Hz – 50 kHz)
- **Bode plot analyser** with automated sine sweep, magnitude (dB) and phase (°) display
- **Digital I/O** control: 4 output lines, 4 input indicators, built-in digital frequency generator
- **Real-time measurements**: frequency, amplitude, peak-to-peak, min, max, period
- **Math module**: arithmetic operations (CH1 $\pm \times \div$ CH2) overlaid on the display
- **Data export**: CSV waveform data and PNG screenshots; Bode data export
- **One-click installer** (Windows `.bat` script with automated driver verification)

1.2 How to Use This Manual

Each section covers one tab or feature area. Annotated screenshots with numbered badges correspond directly to the reference tables beneath them. Look up any numbered badge for a full description of that control.

2 System Requirements & Installation

2.1 System Requirements

Requirement	Details
Operating System	Windows 10/11 (64-bit) or Linux Ubuntu 20.04+
USB Port	One free USB-A port for the ScopeX kit
Driver	ScopeX USB-UART driver (auto-installed on Windows)
Python (Linux)	Python 3.8+ with `PyQt5`, `pyserial`, `numpy`, `scipy`
RAM	2 GB minimum (4 GB recommended)
Display	1280×720 or higher resolution

2.2 Windows Installation

1. Right-click `Run-ScopeX-Installer.bat` and select **Run as Administrator**.
2. The script calls `Check-ScopeX-Drivers.ps1` to verify driver presence, then `Install-ScopeX-Windows.ps1` to install all dependencies.
3. A desktop shortcut is created upon completion.
4. Connect the ScopeX kit via USB, then launch the application.

2.3 Linux Installation

1. Install dependencies: `pip3 install PyQt5 pyserial numpy scipy`
2. Navigate to the application folder and run: `python3 main.py`
3. You may need to add your user to the `dialout` group for serial access: `sudo usermod -aG dialout $USER` (then log out and back in)

3 Getting Started — Connecting the Device

1. Connect the ScopeX hardware kit to your PC via the given USB cable.
2. Launch the ScopeX application.
3. In the **Connection** panel (top-left), select the correct COM port from the **Port** dropdown. The status bar at the bottom of the window lists all detected ports with their VID/PID for identification.
4. Click **Connect**. On successful connection the device signature is read and the Student Info fields (Digital tab) are populated automatically.
5. Click **Run** to begin continuous acquisition. The waveform display will start updating.

Note

If the device disconnects unexpectedly, ScopeX automatically attempts to reconnect. You can also click **Stop** then **Run** to manually restart acquisition. If trigger-related issues cause a stale display, use the **Rerun** capability to clear and restart.

4 Interface Overview

The application window is divided into four regions:

Region	Contents
Top Bar	Connection, Acquisition and Interpolation control panels
Main Canvas	Large waveform / plot display area
Right Panel	Tab-based control panels: Scope, Signal Generator, Bode Plot, Digital
Bottom Bar	Measurement readouts (6 cells) and channel / function blocks

The four tabs in the right panel completely change the context of the right-panel controls, but the top bar, main canvas and bottom bar remain visible at all times.

5 Scope Tab

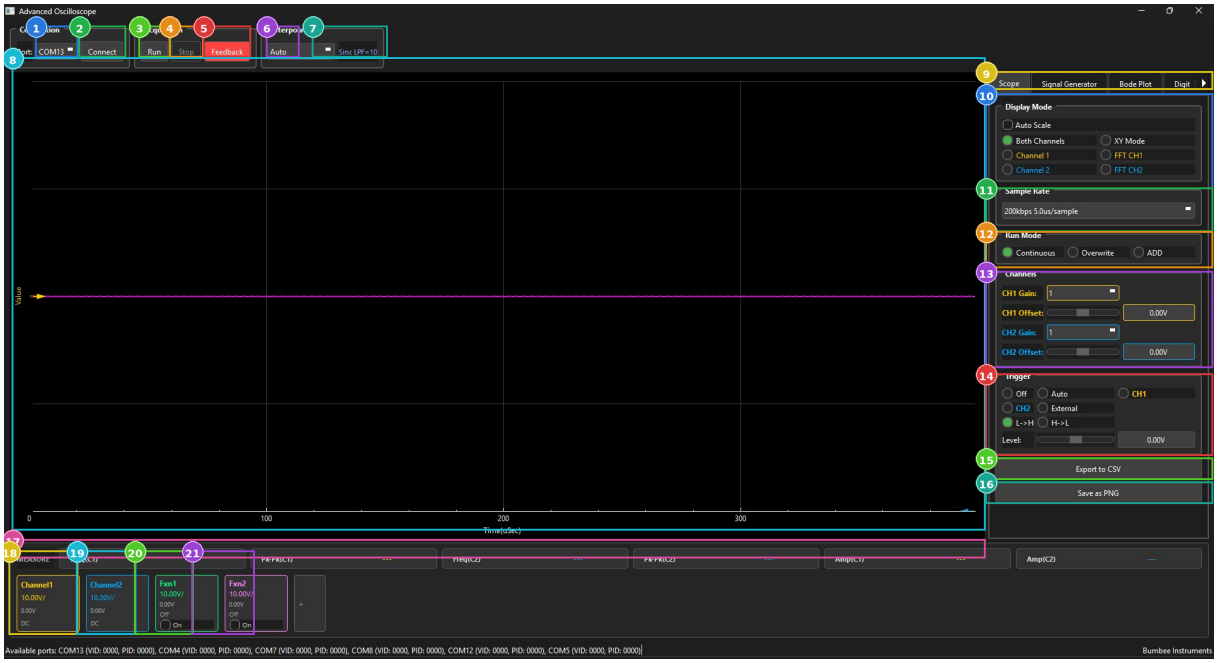

Figure 1: Scope tab — all interface elements annotated

5.1 Top Bar Controls (Badges 1–7)

#	Element	Description
1	**Port Dropdown**	Selects the serial COM port to which the device is connected. Lists all detected ports.
2	**Connect**	Opens the serial connection on the selected port. Reads the device signature and Students can enter their Name and Roll number in the Digital Tab while saving their waveforms.
3	**Run**	Starts continuous data acquisition. The waveform display begins updating at the configured sample rate.
4	**Stop**	Pauses acquisition. The last captured frame remains on screen.
5	**Feedback**	If any bugs or discrepancies are detected, kindly fill the google form, our engineers will fix it.
6	**Interpolation Dropdown**	Selects the interpolation algorithm applied to acquired samples: **Auto** (recommended), **Linear**, or **Sinc**. In Auto mode the algorithm adapts to the active waveform type.
7	**Sinc LPF Label**	Displays the current Sinc low-pass filter setting (e.g. `Sinc LPF=10`).

5.2 Waveform Canvas (Badge 8)

#	Element	Description
8	**Waveform Display**	The main oscilloscope canvas. The X-axis shows time in microseconds (µs); the Y-axis shows voltage. An arrow on the left edge indicates the trigger level. Math channel results are overlaid as additional coloured traces. The color of the waveforms can be changed.

5.3 Right Panel — Scope Controls (Badges 9–16)

#	Element	Description
9	**Tab Bar**	Switches between the four control panels: **Scope**, **Signal Generator**, **Bode Plot**, **Digital** , **Image to Netlist**. The scroll arrow (>) reveals additional hidden tabs. **Note:** The image to netlist is currently under development. Its an advanced AI driven validation that generates the Netlist of the circuit from an Image the user uploads and validates the correctness of the circuit.
10	**Display Mode**	Controls what is rendered on the canvas. **Auto Scale**: auto-fits the Y-axis. **Both Channels**: show CH1 and CH2 simultaneously (default). **XY Mode**: Lissajous plot (CH1 on X, CH2 on Y). **Channel 1** or **Channel 2**: single-channel display. **FFT CH1/CH2**: Fast Fourier Transform frequency-domain view.
11	**Sample Rate**	Sets the acquisition rate. Default: **200 kbps / 5.0 µs per sample**. Lower rates capture longer time windows; higher rates resolve fast signals. Use the dropdown to select a pre-defined rate.
12	**Run Mode**	Determines how successive acquisition frames are handled. **Continuous**: streams frames indefinitely (normal use). **Overwrite**: captures one frame and replaces it on each trigger. **ADD**: accumulates frames for a persistence-style display.
13	**Channels (Gain & Offset)**	Sets vertical scaling and offset for each channel. **CH1/CH2 Gain**: multiplies the voltage range (1×, 2×, 4×, etc.). **CH1/CH2 Offset**: shifts the channel trace vertically by the entered voltage value.
14	**Trigger**	Configures the acquisition trigger. **Off**: free-running (no trigger). **Auto**: triggers automatically. **CH1/CH2**: trigger on respective channel edge. **External**: uses the hardware external trigger input. **L→H**: rising-edge trigger (default). **H→L**: falling-edge. **Level** slider: voltage threshold for trigger detection.
15	**Export to CSV**	Saves the current waveform buffer as a `.csv` file containing time-stamped voltage columns for CH1 and CH2. Suitable for import into Excel, Python (pandas), or MATLAB.

#	Element	Description
16	**Save as PNG**	Captures a screenshot of the waveform canvas and saves it as a `.png` image, ready for inclusion in lab reports.

5.4 Bottom Bar (Badges 17–21)

#	Element	Description
17	**Measurement Bar**	Multiple real-time measurement cells updated on every acquisition frame: **Freq(C1)**, **Pk-Pk(C1)**, **Freq(C2)**, **Pk-Pk(C2)**, **Amp(C1)**, **Amp(C2)**, **.etc**. Values show `---` when the signal is absent or below the noise threshold. Always visible regardless of which tab is active.
18	**Channel 1 Block**	Shows the current vertical scale (V/div) and DC offset for Channel 1 (yellow trace). Click to expand channel configuration options.
19	**Channel 2 Block**	Shows the current vertical scale and DC offset for Channel 2 (blue/magenta trace). Click to configure.
20	**Fxn1 (Math Channel 1)**	Displays the result of a math operation on CH1 and CH2. Shows V/div, current value and operation mode. Toggle with the **On** checkbox. When enabled the computed waveform is overlaid on the canvas with auto-scaling.
21	**Fxn2 (Math Channel 2)**	Second independent math function block, supporting a different operation from Fxn1 simultaneously.

6 Signal Generator Tab

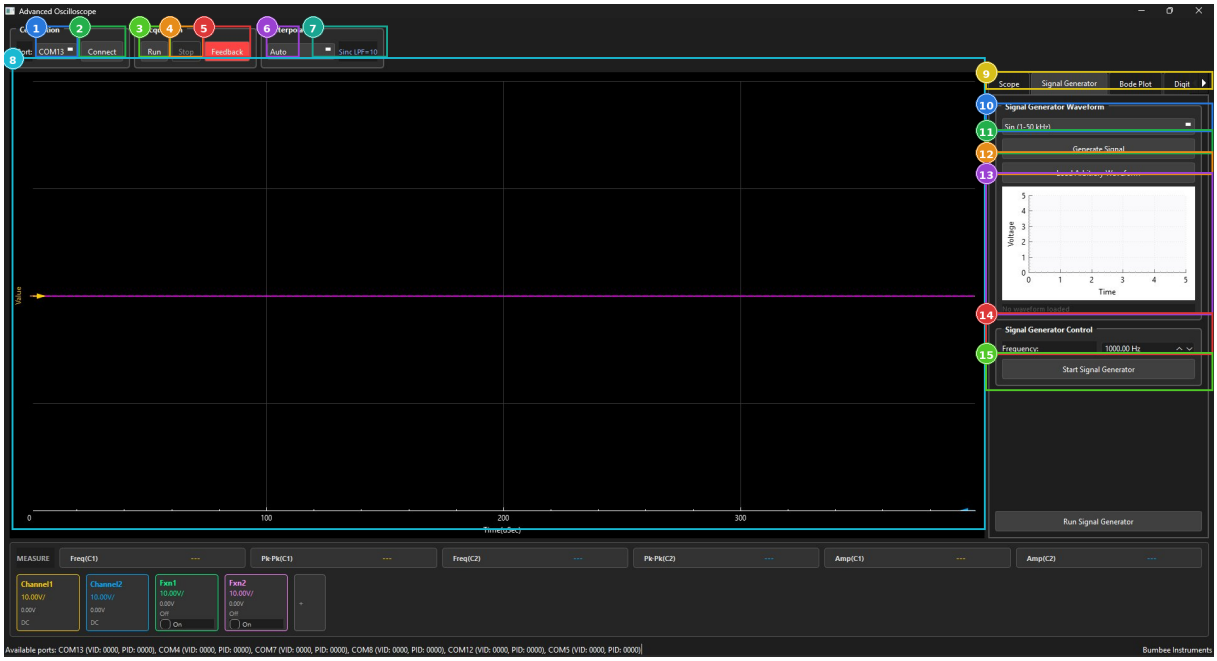

Figure 2: Signal Generator tab — all controls annotated

Badges 1–9 (top bar, canvas, tab bar) are identical to those described in Section 5. The right panel controls specific to this tab are described below.

6.1 Signal Generator Controls (Badges 10–16)

#	Element	Description
10	**Waveform Type**	Dropdown to select the output waveform shape. Available options: **Sin (1–50 kHz)**, **Square**, **Triangle**, **Sawtooth**, **DC , Ramp-Up, Ramp-Down.**. The selected waveform appears in the preview plot below.
11	**Generate Signal**	Configures the ScopeX hardware to produce the selected waveform type. Must be clicked *before* starting the generator. Uploads waveform parameters to the device.
12	**Load Arbitrary Waveform**	Opens a file picker to load a user-defined waveform from a CSV file. The custom waveform is uploaded to the hardware memory and shown in the preview plot. Enables generation of any arbitrary periodic signal.
13	**Waveform Preview Plot**	Displays the currently loaded or selected waveform shape as a small voltage vs. time graph. Shows *No waveform loaded* until a waveform is configured or loaded. Voltage axis: 0–5 V; time axis: normalised.
14	**Signal Generator Control**	Section header grouping the frequency setting and start button.
15	**Frequency**	Input field for the output frequency of the signal generator. Type a value or use the up/down arrows. Default: **1000.00 Hz**. Range depends on waveform type (up to 50 kHz for sine).
16	**Start Signal Generator**	Starts the hardware signal generator output. Now the desired signal is available in the Pin **SIG** from the Kit.

For square waves, the duty cycle can be adjusted in real time using the potentiometer on the ScopeX hardware board. The on-screen preview updates to reflect the current duty cycle via the Feedback loop.

7 Bode Plot Tab

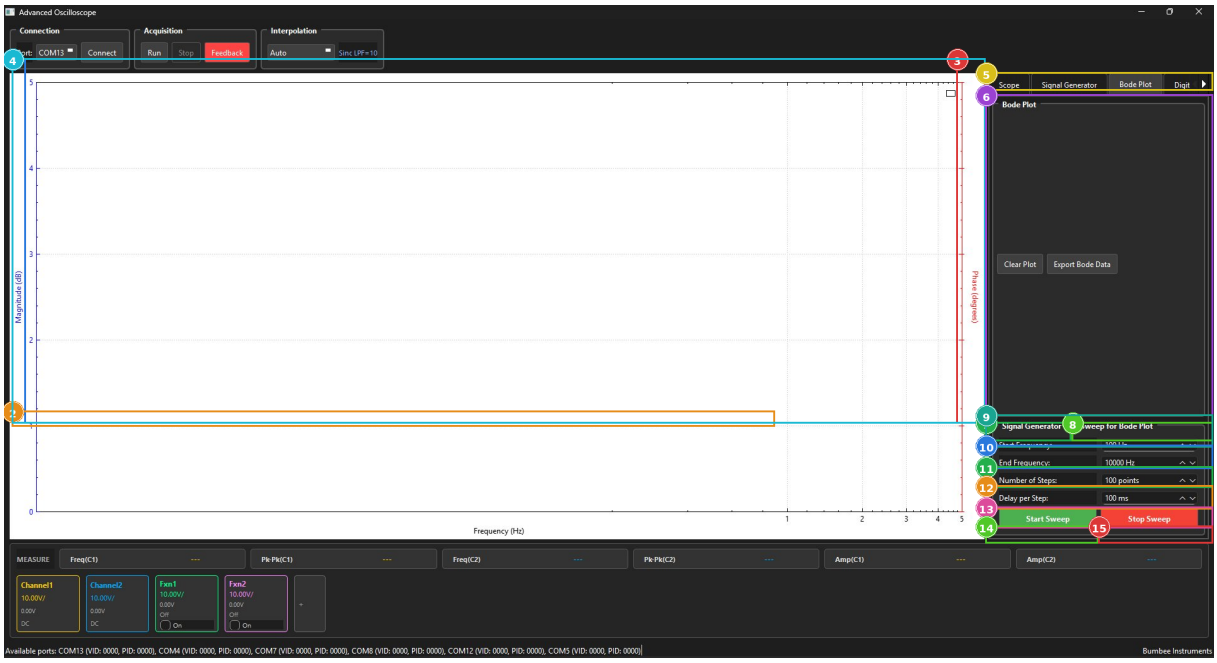

Figure 3: Bode Plot tab — all controls annotated

The Bode Plot tab characterises the frequency response of a circuit connected between the signal generator output and the oscilloscope input channels. It automatically sweeps frequency, measures gain and phase at each step, and plots the result in real time.

Note

Setup: Connect the signal generator output to your circuit input. Connect CH1 to the circuit input (reference) and CH2 to the circuit output (response). ScopeX computes gain as $|V_{CH2}|/|V_{CH1}|$ in dB and phase as $\angle V_{CH2} - \angle V_{CH1}$.

7.1 Main Canvas (Badges 1–4)

#	Element	Description
1	**Magnitude Axis (Y-left)**	Left vertical axis showing gain in decibels (dB). Scale adjusts automatically to the measured range. The magnitude curve is plotted in **blue/black**.
2	**Frequency Axis (X)**	Horizontal axis showing frequency in Hz. Scale may be linear or logarithmic depending on the sweep span. Tick labels update to match the Start/End frequencies.
3	**Phase Axis (Y-right)**	Right vertical axis (*Phase (degrees)*, red label). The phase curve is plotted in **red**. Range auto-scales to ±180°.
4	**Bode Plot Canvas**	White plot area rendering both magnitude (left axis) and phase (right axis) curves simultaneously as the sweep progresses. A legend icon (top-right corner) can be toggled for axis identification.

7.2 Right Panel Controls (Badges 5–15)

#	Element	Description
5	**Tab Bar**	Switches between the four control panels (same as all tabs).
6	**Bode Plot Mini Panel**	Small dark preview panel in the right panel, labelled **Bode Plot**. Displays a thumbnail of the current plot for quick reference while adjusting sweep settings.
7	**Clear Plot**	Erases all curves from the Bode canvas, resetting it for a fresh sweep.
8	**Export Bode Data**	Saves the complete sweep data to a `.csv` file with columns: Frequency (Hz), Magnitude (dB), Phase (°). Suitable for post-processing in MATLAB, Python or Excel.
9	**Sweep Section Header**	**Signal Generator Sine Sweep for Bode Plot** — section grouping all sweep configuration parameters.
10	**Start Frequency**	Lowest frequency in the sweep. Default: **100 Hz**. Use the dropdown to select common values or type a custom frequency.
11	**End Frequency**	Highest frequency in the sweep. Default: **10 000 Hz** (10 kHz). Must be greater than Start Frequency.
12	**Number of Steps**	How many discrete frequency points are measured between Start and End frequencies. Default: **100 points**. More steps produce a smoother curve but increase total sweep time.
13	**Delay per Step**	Settling time between frequency steps, allowing the circuit under test to stabilise. Default: **100 ms**. Increase for circuits with large capacitors or inductors, or when using a high-Q filter.
14	**Start Sweep**	Begins the automated frequency sweep. The signal generator steps through each frequency point, the oscilloscope measures both channels, and the gain/phase are plotted in real time. Total time ≈ (steps × delay).
15	**Stop Sweep**	Immediately halts an in-progress sweep.

8 Digital I/O Tab

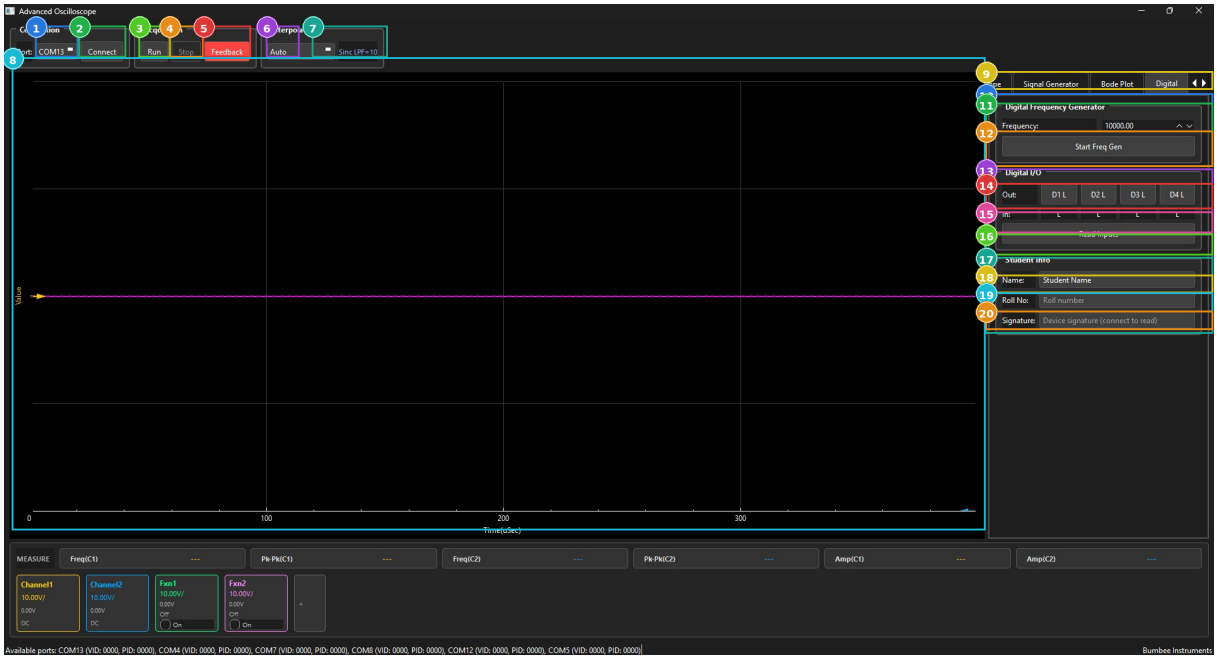

Figure 4: Digital I/O tab — all controls annotated

The Digital tab provides direct control of the four digital output lines and monitoring of four digital input lines on the ScopeX kit. It also includes a dedicated digital frequency generator and displays device identity information.

Badges 1–9 (top bar, canvas, tab bar) are identical to Section 5.

8.1 Digital Frequency Generator (Badges 10–12)

#	Element	Description
10	**Digital Freq Generator**	Section containing the square-wave digital output generator, independent from the analogue signal generator.
11	**Frequency Input**	Sets the frequency of the digital square wave output in Hz. Default: **10 000 Hz** (10 kHz). Can be adjusted by entering a custom value.
12	**Start Freq Gen**	Starts/stops the digital frequency generator. When running, the hardware outputs a 50 % duty-cycle square wave at the set frequency on the digital output pin.

8.2 Digital I/O (Badges 13–16)

#	Element	Description
13	**Digital I/O Section**	Groups all four digital output and input controls.

#	Element	Description
14	**Output Lines D1L–D4L**	Four toggle buttons, one per digital output line. Each button displays the current state: **L** (logic Low, 0 V) or **H** (logic High, 3.3 V). Click a button to toggle its output state immediately.
15	**Input Level Indicators**	Four read-only labels (In: **L L L L**) showing the current logic level on each digital input line. Updated by clicking Read Inputs.
16	**Read Inputs**	Queries the hardware and refreshes all four input level indicators with the live digital state of each input line.

8.3 Student Info (Badges 17–20)

#	Element	Description
17	**Student Info**	Section displaying identity data stored in the connected device firmware.
18	**Name**	Name of the registered user, can be entered by student while storing waveforms.
19	**Roll No**	Roll number or user identifier.
20	**Signature**	Number read from device.

9 Math Module

The Math Module enables arithmetic operations between Channel 1 and Channel 2 signals, with the result displayed as an additional trace overlay on the waveform canvas.

9.1 Enabling the Math Module

1. Ensure both channels are active and displaying signals.
2. In the bottom bar, click the **Fxn1** block (5.4 badge 20) to expand it.
3. Check the **On** checkbox to enable Fxn1.
4. Select the desired operation from the dropdown menu.
5. The result waveform appears as an additional coloured trace with auto-scaling.
6. Repeat for **Fxn2** (5.4 badge 21) to have two simultaneous math channels.

9.2 Available Operations

Operation	Description
CH1 + CH2	Adds the two channel voltages sample-by-sample. Useful for summing two signals.
CH1 − CH2	Subtracts CH2 from CH1. Classic differential measurement; removes common-mode noise.
CH1 × CH2	Multiplies the signals sample-by-sample. Useful for power calculations ($P = V \cdot I$).
CH1 ÷ CH2	Divides CH1 by CH2. Exercise caution when CH2 passes through zero.

10 Interpolation & Signal Processing

ScopeX reconstructs the acquired discrete samples into a smooth continuous waveform using one of three algorithms, selectable via badges 6–7 in the top bar.

Mode	Description
Auto	**(Recommended)** Automatically selects the best algorithm for the active waveform type and sample rate. Switches between Linear and Sinc dynamically.
Linear	Straight-line segments between consecutive samples. Low processing overhead. Best for slow signals or where sharp edges must be preserved (e.g. square waves).
Sinc (LPF=N)	Windowed Sinc low-pass interpolation with N taps. Produces smooth, ripple-free reconstruction of band-limited signals (e.g. sine waves). Higher N yields sharper reconstruction at the cost of computation time. Default: $N = 10$.

For sinusoidal signals use **Sinc LPF**. For square/digital signals use **Linear**. Leave on **Auto** for general use — the application adapts automatically when the signal generator type changes.

The oversampling rate and number of Sinc lobes are optimised per waveform type in Auto mode, based on empirical calibration performed during development.

11 Data Export

Action	How to Trigger	Output
Export Waveform (CSV)	Badge 15 in Scope tab	`.csv` with columns: Time (µs), CH1 (V), CH2 (V)
Save Screenshot (PNG)	Badge 16 in Scope tab	`.png` image of the waveform canvas
Export Bode Data	Badge 8 in Bode tab	`.csv` with columns: Frequency (Hz), Magnitude (dB), Phase (°)

A save-file dialog appears for each export action, letting you choose the filename and directory.

12 Troubleshooting

Symptom	Solution
Device not detected / COM port absent	Check USB cable connection. Run `Check-ScopeX-Drivers.ps1` (Windows) or check `/dev/ttyUSB*` (Linux). Try a different USB port. Add user to `dialout` group on Linux.
Flat line after clicking Run	Click Stop then Run again. Verify probe connections to the ScopeX kit. Confirm the correct COM port is selected.
Measurement bar shows "---"	Signal level is below noise threshold. Increase CH Gain, verify a signal source is connected, or reduce the sample rate.
Signal generator output not visible on scope	Click Generate Signal then Start Signal Generator. Check that the ScopeX analogue output is physically connected to a probe input.
Bode plot shows no data after sweep	Ensure CH2 monitors the input reference and CH1 monitors the circuit output. Verify the Start Sweep button was pressed and that the signal generator is running.
App crashes on Linux	Run `pip3 install PyQt5 pyserial numpy scipy` to install missing dependencies. Confirm Python 3.8+.
Sinc interpolation is sluggish	Reduce the LPF lobe count in the Interpolation dropdown (e.g. from 10 to 5), or switch to **Auto** mode.
Noisy or glitchy waveform	Enable Sinc LPF interpolation. Ensure probe ground clips are connected. Use shielded probes. Check USB cable for interference.
Trigger not firing / stale frame	Switch Trigger to **Auto** briefly, then back to your desired mode. Use the Rerun function to reset the trigger state. Adjust the Level slider to be within the signal's amplitude range.

13 Specifications Summary

Parameter	Value	Notes
Input channels	2 (CH1, CH2)	Simultaneous
Sample rate (default)	200 kbps / 5 µs	Configurable
Signal gen. waveforms	Sine, Square, Triangle, Sawtooth, DC	Arbitrary included
Frequency range	1 Hz – 50 kHz	Waveform-dependent
Bode sweep range	1 Hz – user-defined	Default 100 Hz–10 kHz
Digital I/O lines	4 outputs + 4 inputs	3.3 V logic
Digital gen. range	1 Hz – hardware limit	Default 10 kHz
Interpolation	Auto / Linear / Sinc	Sinc up to 30 lobes
Export formats	`.csv`, `.png`	Name and Roll no. included
Platform	Windows 10/11, Linux	Cross-platform Qt

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