Impedance measurement device manual

Version 1.1

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Contents

Introduction

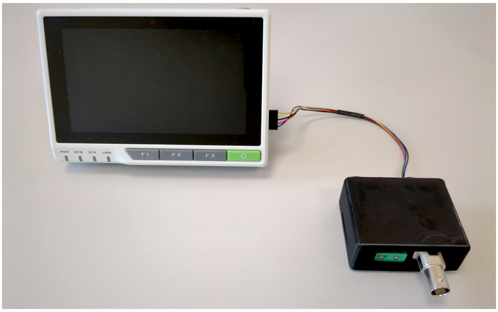

Figure 1: Photo of the device with control terminal and attached measurement board

The device is a combination of an industrial computer in the form of a “Seeedstudio reTerminal” and a custom PCB with impedance and temperature measurement capability. Unknown complex impedances (magnitude and phase) can be characterized via frequency sweeps or continuous measurements at a fixed frequency over time. The Analog Devices AD5933 IC is used for impedance conversion and a Microchip MCP9600 serves as a thermocouple interface.

Technical specifications

- 5” 1280×720 capacitive touchscreen
- networking capability via Ethernet and Wi-Fi
- 32 GB of onboard storage
- two USB ports for external storage or other peripherals
- excitation frequency range: 10 kHz to 100 kHz
- impedance measurement ranges by magnitude (based on estimates):
  - 1: 15 Ω to 675 Ω
  - 2: 1 kΩ to 45 kΩ
  - 3: 100 kΩ to 450 kΩ
  - 4: > 1 MΩ
- thermocouple measurement accuracy: ±1.5 °C
- thermocouple measurement resolution: 0.0625 °C

Basic operation

Overview

You can turn on the device by pressing the button on the top left. A cold boot should take around 15 seconds. You will be greeted with a touch-enabled user interface grouped into five tabs:

1. *Sweep*: for frequency sweeps. The plot shows magnitude and phase over frequency.
2. *Continuous*: for continuous measurements. The plot shows magnitude over time at a fixed frequency.
3. *Setup*: provides a way to set parameters for both measurement modes. This includes
    - measurement range
    - start frequency
    - frequency increment
    - number of increments
4. *Export*: for saving acquired measurement data to disk
5. *Debug*: technical info helpful for troubleshooting

The front buttons labeled “F1”, “F2” and “F3” allow quick switching between the first three tabs. The green button is a shortcut for starting a measurement and works both in sweep and continuous modes.

Plot settings

These settings are largely the same between the two modes. You can select between linear and logarithmic scaling for the vertical axis. By default, axis scaling is performed automatically based on the measured data. You can override this behavior by unchecking “Auto-scale” and setting the desired “y-min” and “y-max” values. This comes into effect after the next measurement.

Measurements

Before you can start a measurement, you have to perform a calibration step. The terminals have to be left unconnected (floating) during this process. After hitting "Calibrate current range", the currently selected range will be calibrated using onboard calibration resistors. This process usually takes less than ten seconds. From here on out, the calibration values reside in memory, meaning re-calibration is necessary after power cycling the device. If you desire the best accuracy, you should first wait for the device to warm up and then periodically perform calibrations in between measurements. The latter is especially important, if the ambient temperature is not stable.

Sweep measurements

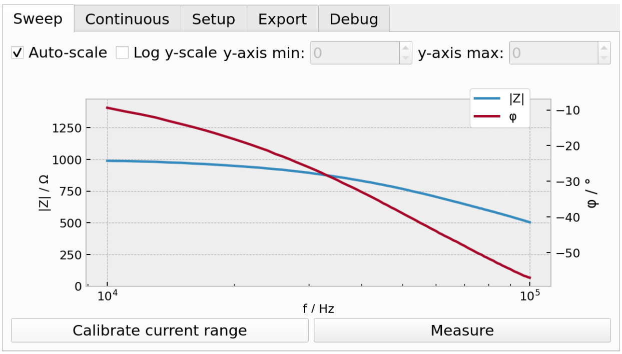

Figure 2: Screenshot of the "Sweep" tab — the plot scale can be adjusted with the controls on top

Select the sweep parameters and the desired range in the "Setup" tab, before hitting "Measure" or pushing the green button. The plot will show both magnitude and phase over a logarithmically-scaled frequency axis. See "Plot settings" for parameters affecting the y-axis.

Continuous measurements

As before, you can set the measurement parameters in the "Setup" tab. The "Start frequency" parameter from the sweep settings doubles as the fixed measurement frequency in this mode. In contrast to the sweep mode,

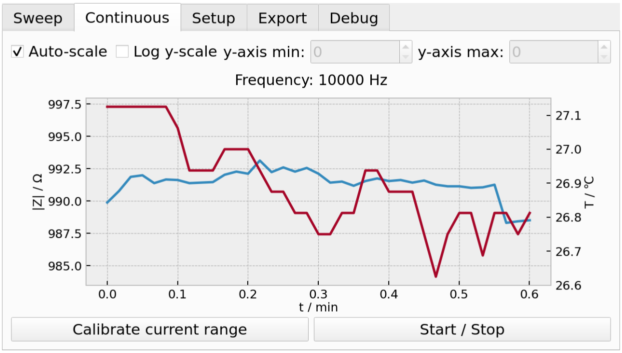

Figure 3: Screenshot of the "Continuous" tab — the "Measure" button is replaced with a "Start / Stop" button

which is a one-shot measurement, the continuous measurement has to be stopped explicitly — either via touch control or the physical button. The plot will also update as new data is acquired. Because this is a potentially long-running process, the drawing and measurement steps are offloaded to separate background threads. This means, that you can navigate to a different tab, while the measurement continues to run. This makes it possible to check the log for errors in the "Debug" tab, for instance.

Exporting data

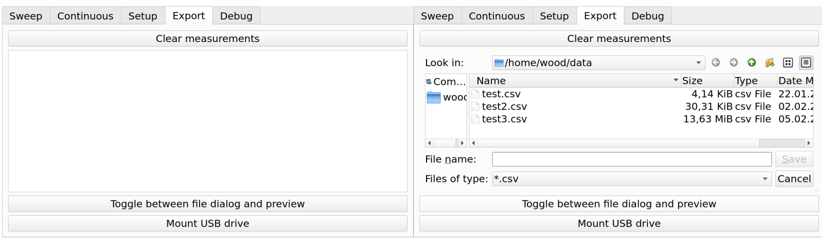

Figure 4: Screenshot of the "Export" tab — a CSV preview of the current buffer is shown in the left image and the file picker is shown in the right image

The following is a general explanation of the data acquisition process. Repeated measurements are saved to a temporary buffer located in memory.

Individual measurement series are tagged with an index that starts at zero and is incremented by one for each series. The buffer is cleared in two situations:

- The user selects “Clear measurement” in the “Export tab”.
- The user switches between one of the two measurement modes and initiates a new measurement — only one type of data can reside in the buffer at the same time.

The “Export” tab features a preview of said buffer in CSV format and allows writing the data to a file. The available columns shown in the preview depend on the measurement mode. The above-mentioned index is represented as a separate column and is always present.

At this point one can optionally mount an external drive with the “Mount USB drive” button. The next step in the export process is to toggle to the file dialog and select a target directory and file name. The starting directory in this dialog is either a local directory or the root of an external drive, depending on whether one was mounted in the previous step. Hit “Save” to write the file and complete the process. Afterwards you can unmount the external drive, if present, and/or clear the buffer.

Advanced topics

Measuring at low excitation frequencies

The AD5933 has an internal, fixed clock source running at 16 MHz. The accuracy figures from the data sheet have been derived in this mode of operation. Unfortunately, this has the side effect of severely limiting low excitation frequency measurement performance, due to artifacts arising in the DFT engine when clocked at this comparatively high rate. It is however possible to connect an external clock signal to one of the AD5933’s pins to mitigate this issue. In the current revision of this device this is accomplished by dividing down the crystal oscillator signal from the connected terminal and then feeding it to the AD5933.

In effect this means that if you want to measure at frequencies lower than around 3 kHz, you will have to lower the clock frequency from the startup default of 9 MHz. The parameters in the following table should ensure an accuracy of about $\pm 5\,\%$.

Table 1: Clock frequencies and associated lower excitation frequency limits

Clock frequency	Lower excitation frequency
9 MHz	3 kHz
2.25 MHz	1 kHz
1.25 MHz	500 Hz
281250 Hz	200 Hz
140625 Hz	100 Hz
22500 Hz	70 Hz

It is not possible to generate clock frequencies below 22.5 kHz. For the best possible phase accuracy you should stick to frequencies that can be integer divided from 54 MHz (Raspberry Pi crystal oscillator) without remainder:

$$f_{\mathrm{clk}} = \frac{f_{\mathrm{osc}}}{n}$$

$$f_{\mathrm{osc}} \bmod n = 0$$

This is because integer division yields the least amount of clock jitter. Keep in mind that there is no one single clock frequency that can cover all frequency ranges. For instance, at the lowest possible clock frequency, you have a useful bandwidth of 70 Hz to 1000 Hz. If you desire a wideband spectrum, you have to split it into multiple sweeps with calibrations in between.

Remote control via SSH

After you have established a network connection, you can connect to the device via SSH. This enables you to transfer files from the internal storage or run the GUI on your local machine using X11 forwarding. Assuming the device has “10.0.0.2” as its IP address — check the “Debug” tab for the currently assigned address — you can type the following to connect to it:

```
ssh -XC wood@10.0.0.2
```

The password is “knock”. After establishing a connection, you can type:

```
start-gui -x
```

This will pop up a new window with the measurement GUI on your local machine. The behavior is exactly identical to the touchscreen on the device itself, with the added benefit of being able to resize the window, as well as having a physical keyboard. Once you are done, just type “exit” at the prompt to close the connection.

For file transfer you can use the “sftp” program or graphical file managers like “FileZilla” or “WinSCP”.

Additional steps for Windows users

The process as described above assumes you have a working X server setup, which is the case by default on Linux and is easily enabled on macOS. For Windows users the quickest path is to set up “Windows Subsystem for Linux” (WSL) — notably version two.

On recent Windows versions (later versions of Windows 10, Windows 11) you can open up a PowerShell prompt and then execute the following command:

```
wsl --install
```

You will be prompted for a username and password along the way. If the command finishes successfully, you should be able to find a “WSL” item in the start menu. This will launch a shell in the WSL environment and from hereon out the steps are identical to what is described above.

If you encounter any problems, please refer to the documentation provided by Microsoft:

```
https://learn.microsoft.com/en-us/windows/wsl/insta
ll
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