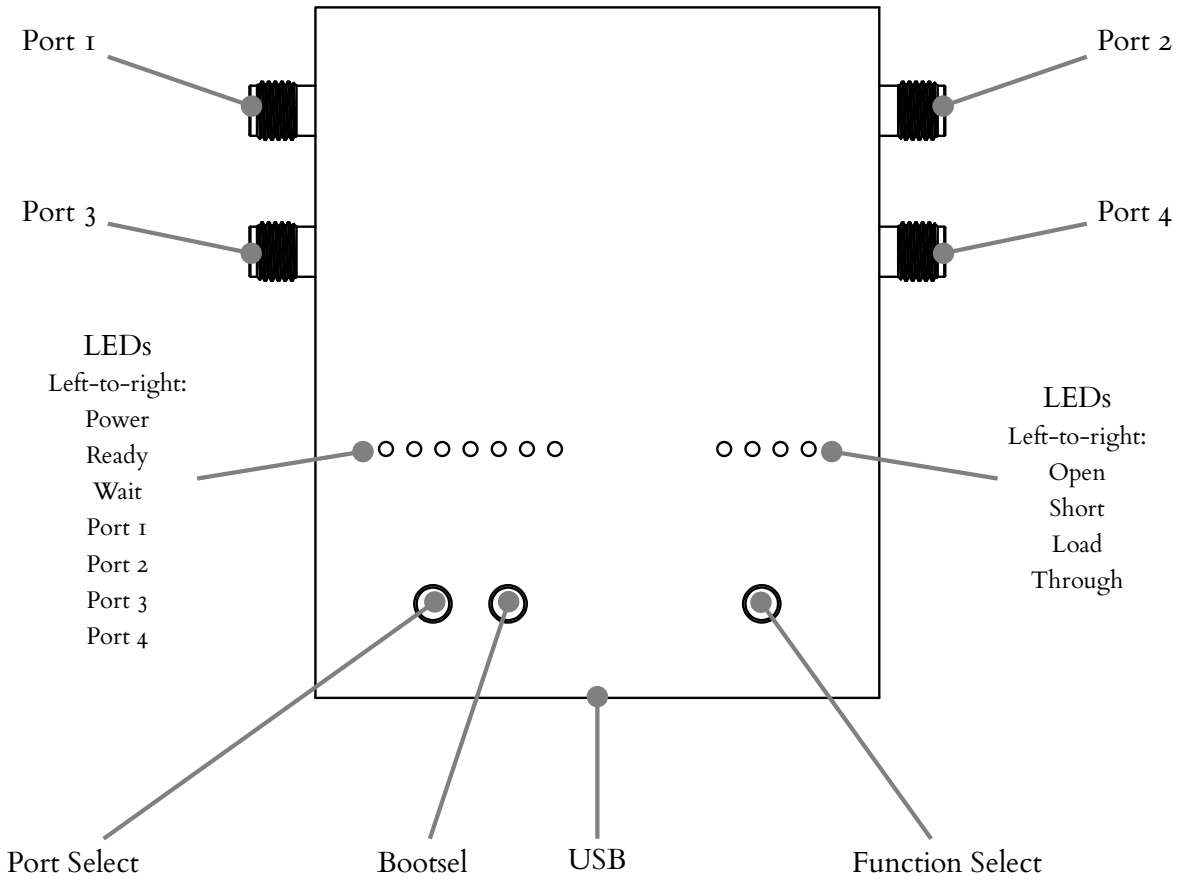
LibreCAL User Manual

June 1, 2025

Contents

1 Overview



1.1 Ports

The four calibration ports use SMA connectors.

1.2 Heater

The critical components are kept at a constant temperature with a resistive heater. The heater is working whenever the LibreCAL is powered and can not be disabled.

1.3 Buttons

There are three buttons available:

- **Port Select:** Selects the port when manually changing calibration standards.
- **Bootsel:** When pressed while applying power, the LibreCAL enters the bootloader mode for firmware updates.
- **Function Select:** Selects the standard when manually changing calibration standards.

1.4 LEDs

- **Power:** Always on.
- **Ready:** On or blinking when the heater has reached the required temperature.
- **Wait:** On or blinking while temperature has not yet settled. Do not make calibration measurements while this LED is on.
- **Port[1-4]:**

  - **While manually changing settings:** The LED corresponding to the currently selected port flashes.
  - **Any other time:** LED is on for any port that is active (has a standard enabled)
- **Open,Short,Load,Through:**
  - **While manually changing settings:** The LEDs show the selected standard of the currently selected port.
  - **Any other time:** Each LED is on if the corresponding standard is used at any port.

1.5 USB

The LibreCAL uses a USB-C connector as the power supply and for data transmission. It requires 5 V and draws up to 0.5 A of current.

2 Firmware Update

The LibreCAL uses the RP2040 microcontroller and its USB bootloader. To enter the bootloader, hold the "Bootsel" button pressed down while applying power. The LibreCAL will show up as a mass storage device. Copy the firmware file to the mass storage and wait for LibreCAL to reboot.

3 Manual control

The LibreCAL is most useful when automatically controlled by the LibreVNA-GUI or a script. However, it is also possible to configure the calibration standards for each port manually using the "Port Select" and "Function Select" buttons.

1. Press "Port Select" to start the manual mode. The LED of the selected port will start flashing and if the port has a calibration standard defined, the corresponding LED will also light up.
2. Press "Port Select" to switch the port you want to change.
3. Press "Function Select" to change the calibration standard of the selected port.
4. After not pressing any button for 3 seconds, the LibreCAL will leave manual mode. Changes made in the manual mode are persistent until they are overwritten through USB or a reboot is performed.

4 USB control

Please see the SCPI API[1] for detailed information.

5 Calibration coefficients

For accurate calibrations, the LibreCAL provides the calibration coefficients for all calibration standards. There is one default set of calibration coefficients ("FACTORY") as well as the option to add your own (useful if you have additional components permanently mounted to the LibreCAL such as port savers).

Each coefficient set consists of a name and the calibration coefficients (as S-parameters) for every reflection and transmission standard. In total there are 18 different coefficients for every coefficient set:

[1] https://github.com/jankae/LibreCAL/blob/main/Documentation/SCPI_API.pdf

- P1_OPEN
- P1_SHORT
- P1_LOAD
- P2_OPEN
- P2_SHORT
- P2_LOAD
- P3_OPEN
- P3_SHORT
- P3_LOAD
- P4_OPEN
- P4_SHORT
- P4_LOAD
- P12_THROUGH
- P13_THROUGH
- P14_THROUGH
- P23_THROUGH
- P24_THROUGH
- P34_THROUGH

There are three ways to read calibration coefficients:
- Read them through the SCPI API.
- Use the LibreCAL-GUI to extract them and export them as touchstone files (uses the SCPI API internally).
- Read the touchstone files directly from the LibreCAL.

For the last option, the LibreCAL shows up as two mass storage devices: "LIBRECAL_R" and "LIBRECAL_RW". LIBRECAL_R is read-only and is reserved for the factory calibration coefficient set. User-defined calibration coefficient sets can be found in LIBRECAL_RW.

5.1 Adding user-defined coefficients

User-defined calibration coefficient sets can be added in the LIBRECAL_RW mass storage device. Each coefficient set must reside in its own folder. The name of the folder will be used as the coefficient set name and the folder must be in the root directory of LIBRECAL_RW.

The coefficient set folder should include all required coefficients as touchstone files, file naming must follow these names:
- P1_OPEN.s1p
- P1_SHORT.s1p
- P1_LOAD.s1p
- P2_OPEN.s1p
- P2_SHORT.s1p
- P2_LOAD.s1p
- P3_OPEN.s1p
- P3_SHORT.s1p
- P3_LOAD.s1p
- P4_OPEN.s1p
- P4_SHORT.s1p
- P4_LOAD.s1p
- P12_THROUGH.s2p
- P13_THROUGH.s2p
- P14_THROUGH.s2p
- P23_THROUGH.s2p

- P24_THROUGH.s2p
- P34_THROUGH.s2p

Files may be omitted if the corresponding ports are never going to be used (e.g. when only using two ports of the LibreCAL).

The touchstone format of all files must use the following settings:
- Frequency in GHz
- S-parameters
- S-parameter data in real/imag form
- 50 Ohm reference impedance

In other words, the touchstone option line must be

```
# GHz S RI R 50.0
```

If the touchstone file uses any other format, it must either be converted before copying it to LIBRECAL_RW or the LibreCAL-GUI must be used to import the touchstone file and create the coefficient from that.

6 USB modes

The LibreCAL is primarely used to calibrate the LibreVNA with the functions and protocol described in this document. VNAs from other manufacturers usually have their own proprietary protocol and will not detect the LibreCAL. However, for some VNAs and protocols it is possible to reverse engineer their functions and add an emulation mode to the LibreCAL. That way, it can be used to automatically calibrate these VNAs as well.

To enable an emulation mode, the calibration coefficients must be stored on the LibreCAL in the reverse engineered format. This can be achieved with the supplied scripts[2].

When the LibreCAL starts and detects this data, it will automatically enter the corresponding emulation mode. This is indicated by a blinking wait or ready LED (which would be constantly on in the default mode). When an emulation mode is active, the LibreCAL will not be recognized by the LibreCAL-GUI or LibreVNA-GUI anymore. You can press and hold the function button while applying power to force the LibreCAL into its default mode.

Currently emulation modes for the following VNAs from other manufacturers are supported:
- Siglent SVA1000X series
- Siglent SNA5000A series

If you have access to electronic calibration modules from unsupported manufacturers and the capability to reverse engineer their protocols please get in touch to extend this list.

[2] https://github.com/jankae/LibreCAL/blob/main/Software/Scripts