

500 ppm* LCR meter

First-time set-up

Document updated: April 1, 2013 - 9 pm

Before reading this document and performing the adjustments it describes, you should first read the Operating Instructions, in particular section 4.3 *User interface*, and the articles published in Elektor January – May 2013.

Once all the components have been fitted on the main board, check everything visually very carefully before applying power. The measurements and adjustments to be made are:

1. Check power rails
2. Load microcontroller bootloader
3. Load firmware into microcontroller
4. Offset compensation
5. Phase shift compensation
6. Resistor calibration

The preliminaries required are:

- The **first** time you power up, you need a PC running **Windows** and an FTDI *USB Debug Adapter* cable (e.g. RS part no. 1186943) for loading the microcontroller bootloader via the JTAG interface (J15).

You need to have installed Silicon Labs' *Flash Programming Utility* [1].

- If the driver needed to communicate with the PC has not yet been installed, you need to download it from the FTDI website [2], in the version corresponding to the PC's operating system.

Select the most recent stable *Virtual Com Port* version. Follow the instructions in the document '... Installation guide' to install this driver.

- You need to have downloaded the bootloader file (*LCR3A__Bootloader.hex*), the *firmware* (*LCR3A_update_Vxxx.hex*), and the *AU2011* PC program [3].
- If you're using an older computer, the current supplied by its USB interface may be limited to 100 mA (low power) at a Vbus voltage that can be as low as 4.4 V. Now this device draws more than 100 mA, so the USB interface on the computer used must be of the 'high power' type capable of supplying up to 500 mA and guaranteeing a minimum Vbus voltage of 4.75 V.

Note: It is possible to indicate the nature of our peripheral (high-power bus-powered device) by modifying the *Max Bus Power* parameter of the *USB_Config_Descriptors* in the FT232R's EEPROM to set it to 500 mA (see the documentation for the FT_Prog utility on the FTDI website

www.ftdichip.com/Support/Documents/AppNotes/AN_124_User_Guide_For_FT_PROG.pdf

[or] <http://goo.gl/USPOS>).

If you are using a modern PC, this modification probably serves no purpose.

The display & keypad extension is not connected. Switch SW1 is OFF (button in, on side opposite USB connector).

Connect the board to the PC via a USB cable. Only the FT232R IC (U19) is powered; D8 and D9 should be seen to light up briefly, indicating that exchanges have taken place with the PC; follow the instructions on your PC to install the new hardware.

Note: If you have several devices connected to one of the COM ports (serial ports under Windows), **disconnect them** to make it easier to identify the LCR meter.

1. Checking power rails

Set SW1 to ON and check the voltages:

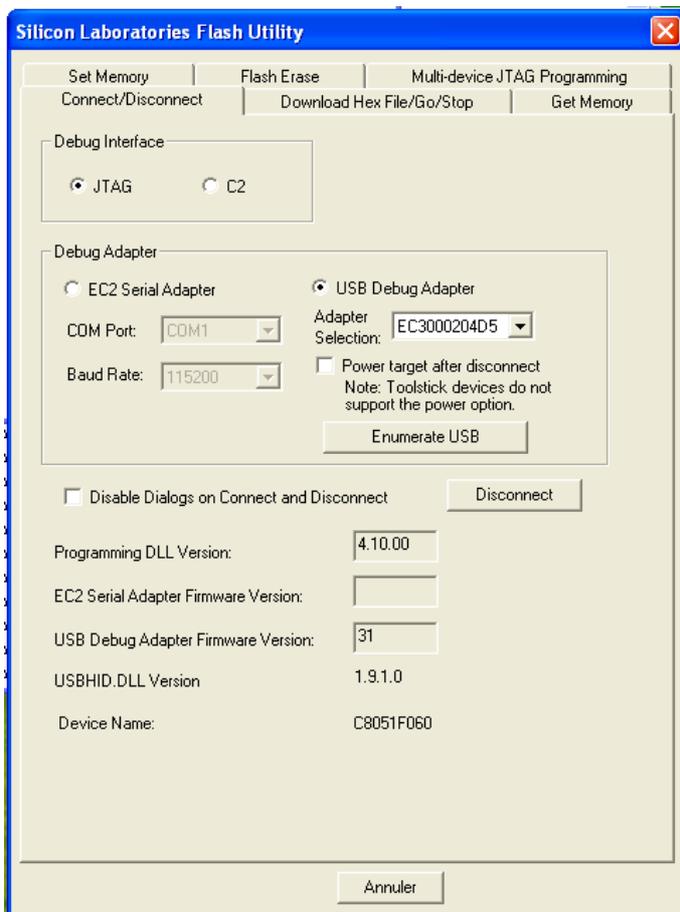
- TP12: + 4.6 V
- TP13: – 4.6 V
- TP15: + 3.0 V
- TP14: – 2.5 V
- TP8: + 2.50 V (U10 reference voltage)

You can take the 0 V from J4 or J5 (GND)

Set SW1 to OFF.

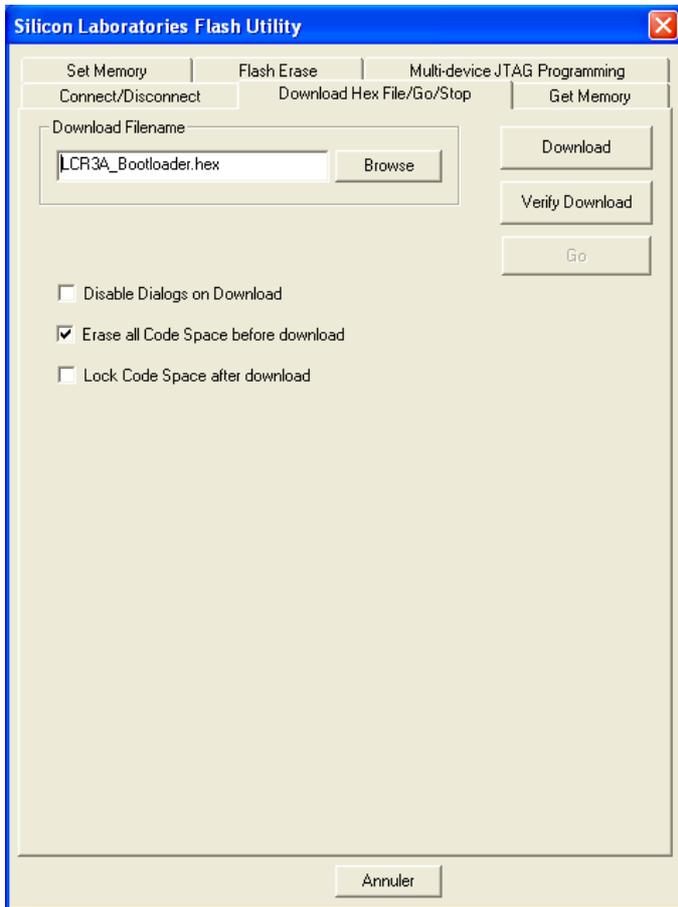
2. Loading the microcontroller bootloader

Connect up the *USB Debug Adapter* cable to J15 on the board and the PC and set SW1 to ON. Run the *FlashUtil* program located in the *Flash Utility* installation folder.



Select the *Connect/Disconnect* tab and set the parameters as in this screen shot (*JTAG* and *USB Debug Adapter*). Click the **Connect** button.

A window appears to tell you the connection has been successful, and the button changes to **Disconnect**.



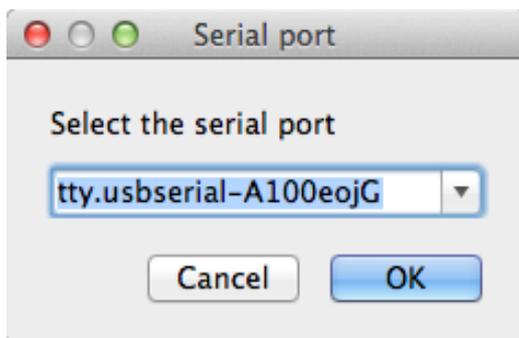
Then select the *Download Hex File/Go/Stop* tab. Check the *Erase all Code Space before download* box and select the file to load (*Download Filename*). Lastly, click the **Download** button. A succession of windows will appear as the operation progresses, ending with a window confirming it has been successful.

Quite the *FlashUtil* program, set SW1 to OFF and unplug the *USB Debug Adapter* cable.

Normally, you only ever have to perform this operation once. From this point on, firmware updates will be performed via this now-resident bootloader.

3. Loading the firmware

Set SW1 to ON and run the AU2011 program. A window opens and prompts you to select the port to be used; the port offered is an existing port, so make sure you choose the right one! This will be memorized.

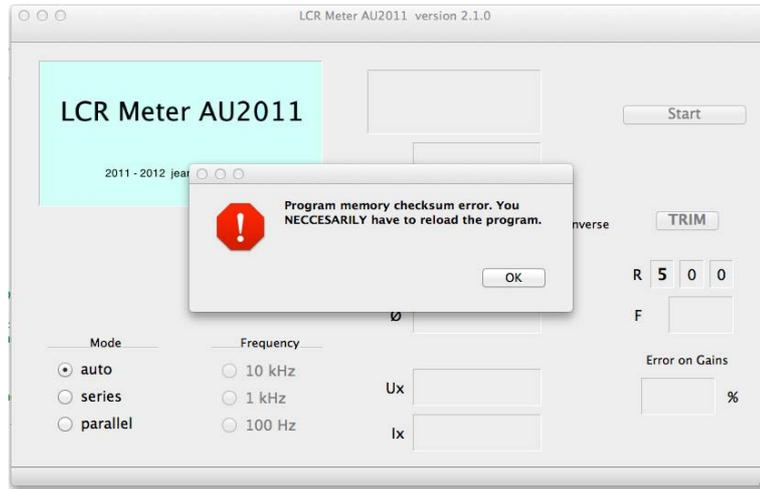


Under OSX (similar under Linux)

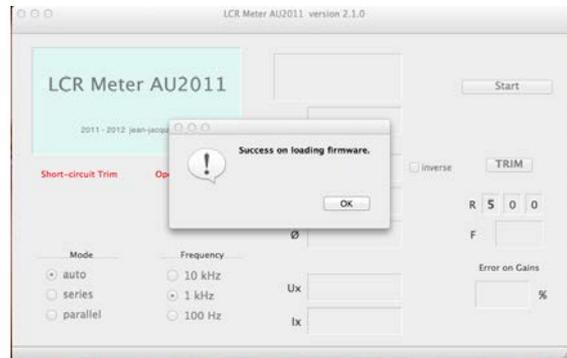
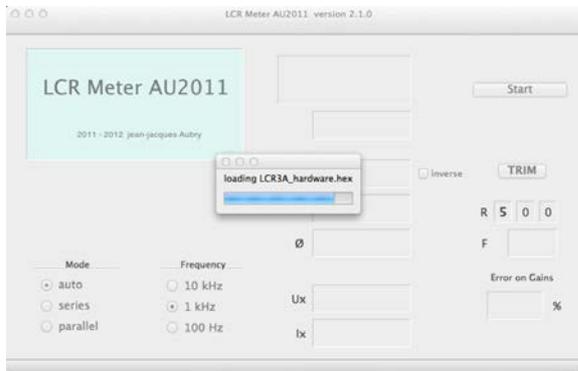


Under Windows (XP)

Make the selection and confirm with OK. A dialog window will immediately warn you that the firmware is corrupted and must be reloaded. In actual fact, there isn't a program at all yet! Click OK.



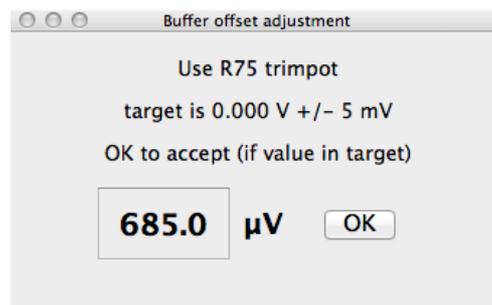
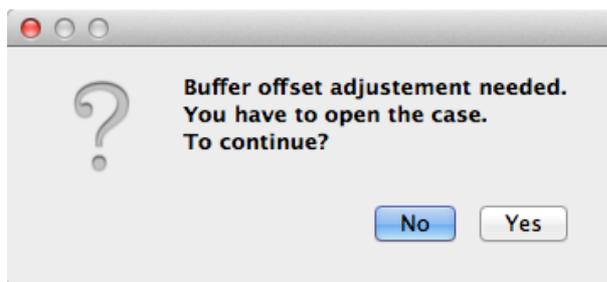
Browse to select the *LCR3A_firmware_Vxxx.hex* file (select the most recent file available on the website) and click OK. In a few seconds a loading progress window appear, with a success message when loading is finished.



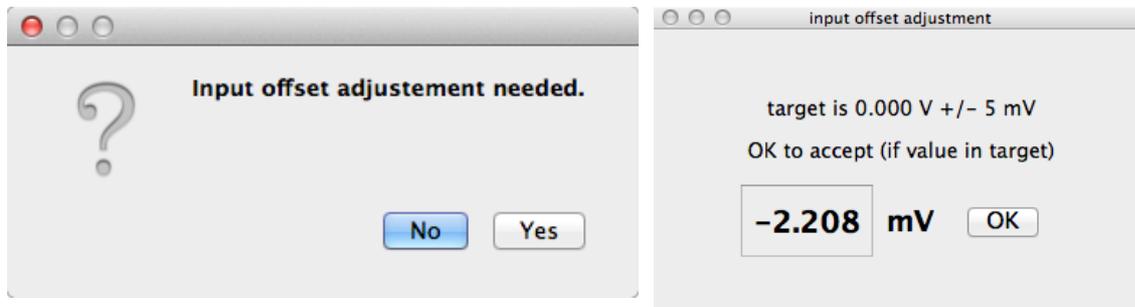
4. Offset compensation

The program then prompts you to carry out:

- Buffer offset adjustment (by R75; no need to even open the case!)



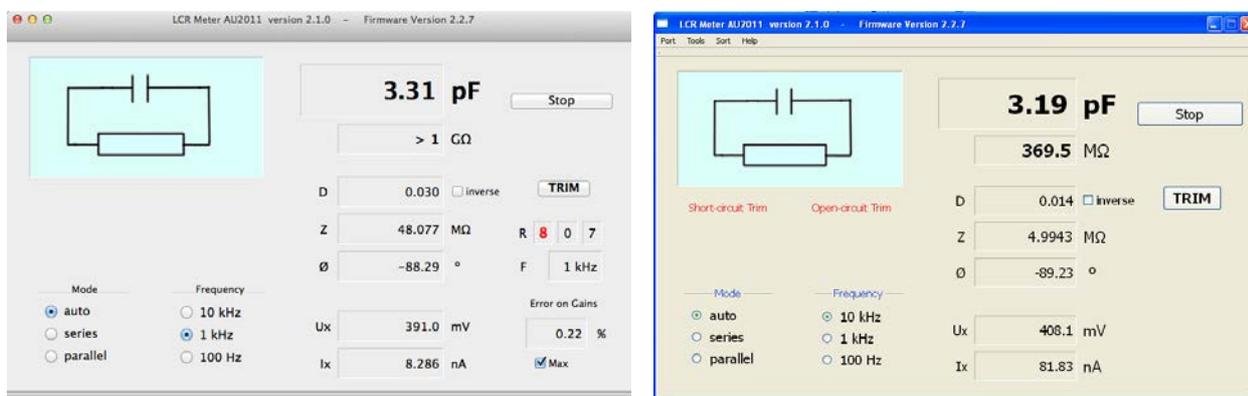
- Input offset adjustment (automatic)
- Sinewave generator offset adjustment (automatic)



It is only possible to validate an operation if the target value is achieved.

At this point, the device is already (almost) operational.

Click the **Start** button at the top right of the main window (see screenshots in ¶ 3 above). Once started, this same button changes **Stop**. Depending on your operating system, you should see a screen like this:

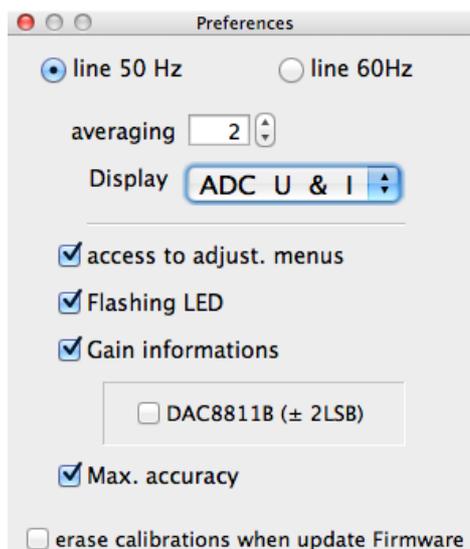


The time has come to adjust the **amplitude of the sinewave signal**.

Open the Preferences menu. Check:

- access to adjust. menus (attention, this option is **not memorized**, as in normal operation you'll not need to use these menus again)
- Gain informations

Select your line frequency.
Set the averaging value to 2.
In the 'Display' dropdown menu, select **ADC U & I**, as in this screenshot.
Close this menu.



Fit jumpers to **J21**, **J22**, and **J1**. Select the 10 kHz frequency (using the buttons in the main window's 'Frequency' panel). Adjust R100 to obtain **ADC I** ≤ 4.60 V Then select the 100 Hz and 1 kHz frequencies.

Adjust R7 to obtain an **ADC I** value ≤ 4.60 V (the value for one or other of these two frequencies will undoubtedly be slightly lower).

All that's left to do now is the two Trim or compensation operations, which consist in measuring the parameters of the measuring device (cables) in open-circuit and then short-circuit, so as to then apply these as corrections when measuring the DUT; this makes it possible to display 0.00 pF when no DUT is connected, instead of say 2.31 pF. Click the **TRIM** button in the main window, below the Start/Stop button. We can follow the operation in the display window, and if everything is OK, the success message is displayed and the flashing red 'Short-circuit Trim' warning disappears.

Remove jumper from J1.

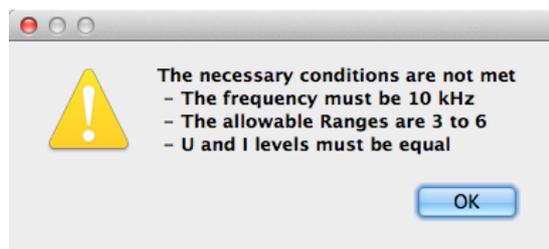
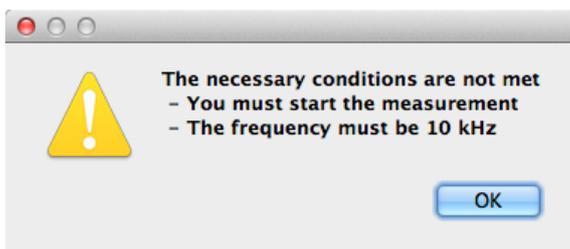
Click the **TRIM** button. If everything is OK, the success message is displayed and the flashing red 'Open-circuit Trim' warning disappears

All that now remains is to adjust the phase compensations for the IU_converter and for the *PGA103* and to calibrate the R_{sense} resistors. **When adjusting the phase compensations, due to the tolerance of the components measured in performing them, it may prove necessary to re-adjust R100. If this is the case, at the end of ¶6 you will need to go back and do it again in accordance with the previous instructions.**

5. Input phase adjustments menu

The phase shifts introduced by the IU_converter have to be compensated. To do this, we must stay in ranges 3–6 and have the same value for the steps of the multiplying DAC in *U* and *I* measurements, in order to eliminate any additional **differential phase shift**. We do this by measuring a capacitor with an impedance at the measuring frequency that is practically equal to the value of R_{sense} .

Note: the following conditions are required: **measurements must be started, frequency = 10 kHz, ranges 3, 4, 5, or 6, and the same values for the U and I steps (levels) in the final amplifier**. If one or more of these conditions are not met, an error message will remind you of them.



To obtain these **essential conditions**, it may be necessary to re-adjust the test signal level slightly using R100.

A number of NP0/C0G capacitors are fitted on the PCB, each of them brought into use by a jumper:

| | | | | |
|--------|----------------------------|---------------------------|----------------------------|----------------------------|
| Ranges | 3 2 2 | 4 0 0 | 5 0 0 | 6 0 0 |
| | R_{sense} 100 Ω | R_{sense} 1 k Ω | R_{sense} 10 k Ω | R_{sense} 100 k Ω |
| jumper | J6 (C \approx 156 nF) | J7 (C \approx 15 nF) | J8 (C \approx 1.5 nF) | J9 (C \approx 150 pF) |

Select the 10 kHz frequency using the buttons in the main window's 'Frequency' panel.

Fit jumper **J6**. The phase must be as close as possible to **-90.000** ° (read in the main window).

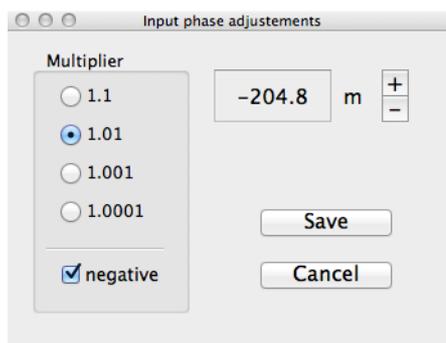
Go into the ‘Tools’ menu, select Adjustments / Input phase adjustments. A window appears.

The compensation (and its sub-multiples) are displayed.

It can be modified using the [-] and [+] buttons.

A negative value can be obtained by checking the ‘negative’ box.

The multiplier can be selected using the corresponding radio button.



You need to start with a high multiplier in order to see a noticeable change in the phase. Each time you make a change, wait for the value to stabilize.

‘Save’ to save the final value, or else ‘Cancel’ to exit without saving.

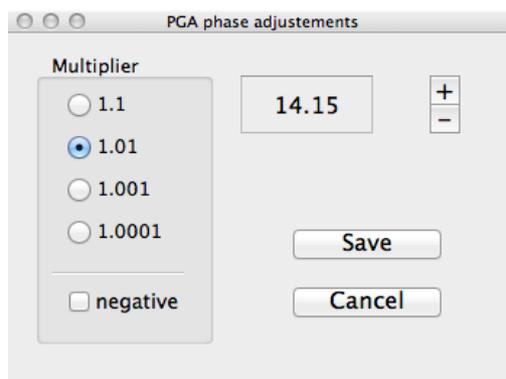
Then do the same thing using the jumper on **J7**, then on **J8**, and finally on **J9**.

6. PGA phase adjustments menu

We must now compensate for the differential phase shift introduced by the PGA103 programmable amplifier. We shall use measuring range 2 for a PGA gain of 10, and range 1 for a PGA gain of 100, as this allows us to use 1 Ω and 10 Ω resistors, while stray elements (series inductance and parallel capacitance) are negligible for this use.

| | | |
|--------|------------------|--------------------|
| Ranges | 2 0 0 | 1 0 0 |
| jumper | J2 (R ≃ 10 Ω) | J3 (R ≃ 920 mΩ) |

The method will be the same as for the *Input phase adjustments* menu, except that here we are aiming to achieve a **phase shift of zero**.



Select the **10 kHz** frequency.

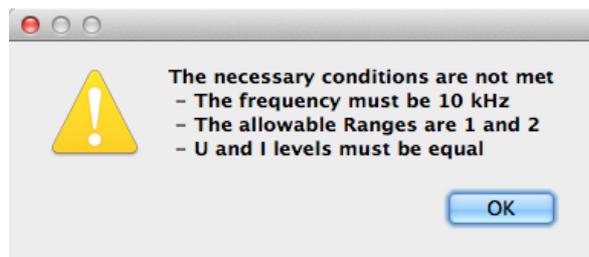
Fit the jumper on **J2** (selects the 10 Ω resistor) and from the ‘Tools’ menu, select Adjustments / PGA phase adjustments.

The procedure is the same as in ¶5 above.

Then do the same with the jumper on **J3** (selects the 1 Ω resistor).

Note 1: the following conditions are required: **measurements must be started, frequency = 10 kHz, ranges 1 or 2, and the same values for the U and I steps (levels) in the final**

amplifier. If one or more of these conditions are not met, an error message will remind you of them.



If the values for the U and I steps of the final amplifier are different, you'll need to slightly modify the value measured by fitting/modifying resistors in positions R15 (in parallel with R16) and R17 (in parallel with R19). Start by trying a value of 100 Ω for R15; a 10 Ω resistor is already fitted as R17.

Note 2: When the jumper is on **J3** (measuring the 1 Ω resistor), pay attention to the contact resistance of this jumper: The theoretical value measured is 910 m Ω + 10–20 m Ω for the resistance of the tracks

When everything is finished, don't forget to remove the jumpers from **J21** and **J22**.

If R100 has been adjusted, you will need to re-do the adjustment described in ¶4.

7. Calibrating the resistors

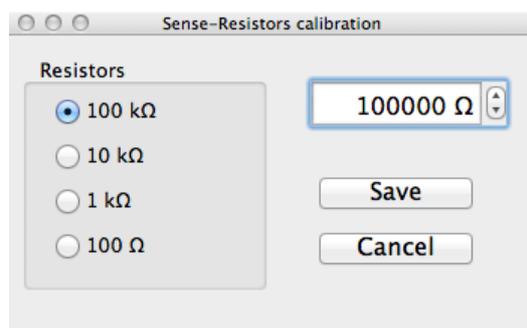
The accuracy of the LCR meter is closely linked to the R_{sense} resistors used.

The resistors to be fitted are size 0805 SMD resistors, with an accuracy of 0.05 % and a temperature coefficient of 5 or 10 ppm/ $^{\circ}$ C. If you're happy to leave it at that, then there's nothing more to be done!

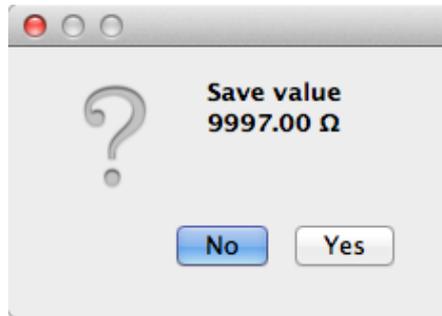
If the actual values of your R_{sense} resistors are known, i.e. have been measured **before fitting** with a precision better than 0.05 %, then you must enter their values manually.

From the 'Tools' menu, select Adjustments / Resistor calibration

The resistor adjustment window opens:



All you have to do is select the Resistor values one after another, enter the corresponding actual R_{sense} value using the up/down arrows, then Save. A window appears asking for confirmation.



Another procedure is possible if you can get hold of a set of calibration resistors for the time it takes to do the calibration (ideally $\pm 0.01\%$) in 100 Ω , 1 k Ω , 10 k Ω , and 100 k Ω values.

From the 'Tools' menu, select Adjustments / Resistor calibration and check that the stored values are the default values (100.00 Ω , 1.0000 k Ω , 10.000 k Ω , and 100.00 k Ω)

Connect up the measuring leads (Kelvin clips) to **HD-HS** on one side and **LD-LS** on the other. Measure a short-circuit (e.g. on a resistor lead) and click the **TRIM** button to obtain the compensation of the residual resistance of the measuring leads.

Select a frequency of 1 kHz. Attention – this is in bold because it's important!

Here too, you must obtain the **same values for the U and I steps** of the final amplifier, and it may be necessary to correct the test signal level using R7.

Connect the calibration resistors one after another and note down the values measured by the device. Calculate the values to be saved, which will be equal to:

$$R_{sense_actual} = R_{sense_current} \times R_{calibration} / R_{measured}$$

For example, if

- $R_{calibration} = 100.00$ k Ω ,
- $R_{sense_current} = 100.00$ k Ω
- $R_{measured} = 100.05$ or 100.06 k Ω (take the average 100.055 k Ω)

You'll need to enter the value 99.945 k Ω (R_{sense_actual})

If R7 has been adjusted, you will need to re-do the adjustment described in ¶4.

Note 1: Whichever method you use, do note down the saved values so you can enter them again if the memory gets erased, which will happen if you've checked the 'erase calibrations when update firmware' option (*Preferences* window) and have updated the firmware.

Note 2: In the "Accuracy of the main parameter" table in the first article (published in the March 2013 issue of *Elektor*) it is noted under 'Conditions' that the accuracies indicated are obtained *using 0.01% resistors (100 Ω , 1 k Ω , 10 k Ω , 100 k Ω) in the current/voltage converter*. Thanks to the dual footprints for R18 and R20–R22 (size 0805 SMD and holes on 5.08 mm pitch), it is possible to fit either 0.01% SMD resistors (watch out for the temperature coefficient, which should be ≤ 10 ppm/ $^{\circ}$ C) or conventional resistors, e.g. the RCK02 type available from RS.

8. Display & keypad extension

In 'standalone' mode, there are no adjustments other than the display contrast.

Set SW1 to OFF and connect the extension to J16. Hold in any button on the mini keypad and set SW1 to ON, then release the button. The message < **BOOTLOADER V2.0** > appears briefly, followed by the welcome message and the measurement window. Press the *Menus* key for a few seconds until they appear. Scroll through to the *Adjust Contrast* menu and press *ok*. Adjust the contrast to suit yourself and press *ok*. This setting is memorized in the microcontroller's EEPROM.

Links

[1] <http://www.silabs.com/products/mcu/Pages/FlashProgrammingUtilities.aspx>

[2] <http://www.ftdichip.com/FTDrivers.htm>

[3] www.elektor.com/110758