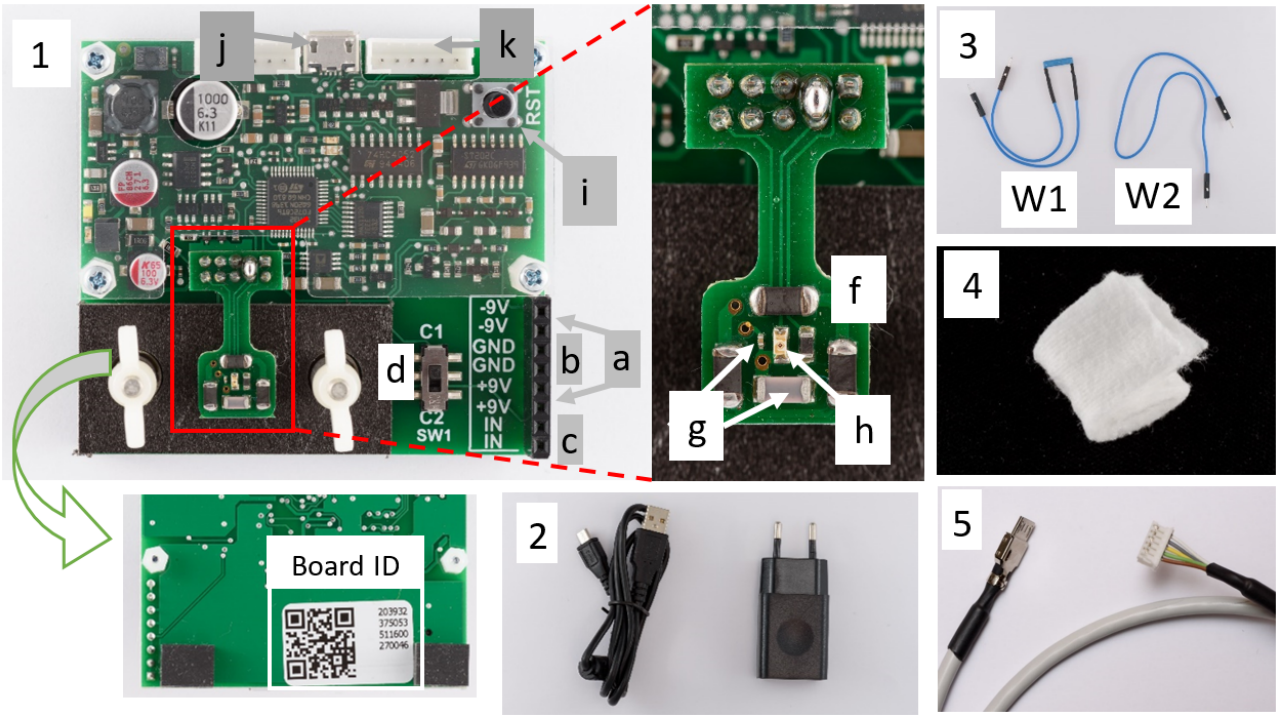
Experimental Examination - Overall Guide

The experimental examination lasts 5 hours and consists of 2 separate experiments worth 10 points each. Equipment is partially shared between two experiments, so read these instructions carefully before starting your work.

Equipment list:

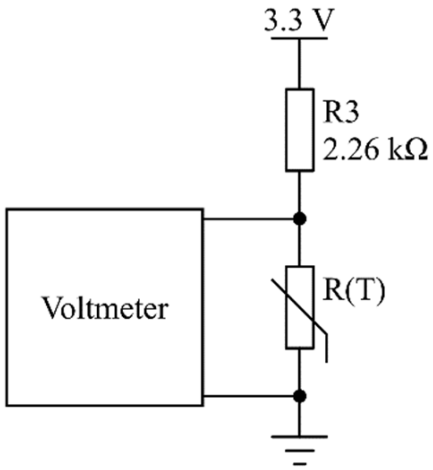
1. Measurement and sample board containing:
   (a) +9 V and -9 V constant voltage source (two equivalent terminals available for each),
   (b) Two equivalent ground terminals,
   (c) Two equivalent capacitor terminals,
   (d) Capacitor selection switch (can be set to C1 or C2),
   (e) Voltmeter with low input current (in the board),
   (f) Thermostat with heater and temperature sensor (in the board),
   (g) Sample capacitors C1 and C2,
   (h) LED connected to a constant current source and voltmeter,
   (i) RESET button,
   (j) USB power port,
   (k) 6-PIN data port for connecting to the tablet.
2. Power source for the board with USB Micro-B plug.
3. Jumper wires – W1 (with 100 MΩ resistor R1 inside) and W2 (0 Ω).
4. Heat insulating material for the thermostat.
5. Connector cable between the board and tablet, with USB Micro-B plug on the tablet side.
6. Touchscreen tablet running IPhO 2021 Experiments app (app user manual provided below).
7. Thermometer (available in examination hall).



Thermostat's temperature is measured using NTC (Negative Temperature Coefficient) thermistor, its resistance depends on absolute temperature T (in Kelvin) as follows:

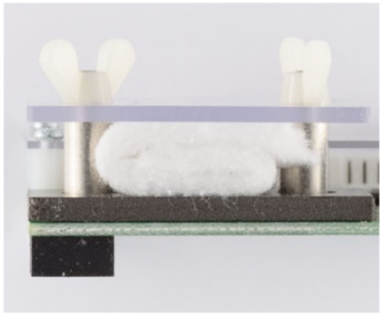
$$R(T) = R_0 \mathrm{e}^{B/T}, \tag{1}$$

$B = 3500\ \mathrm{K}$, R_0 – constant, has to be calculated from the known environment temperature before turning on the heating. The value of this constant is necessary for both experiments. The temperature of the thermostat can be controlled by changing the heating current (via the app). After changing the heating current, it is necessary to wait to let system reach a stable temperature. On the other hand, the thermal equilibrium between the components (capacitors, NTC and LED) is assumed to happen "instantly", and no significant delay is observed.



To ensure more stable thermal conditions, a layer of insulating material has been placed over thermostat

and pressed onto it using a small plastic plate held by two screws.



Caution:
Avoid damaging the board and sockets on it, make sure you're plugging everything correctly without excessive force.
Liquids do not mix well with electronics, so be careful while handling liquids (like drinking water) near the experimental setup. Don't accidentally spit on it.

IPhO 2021 Experiments app user manual

IPhO 2021 Experiments software can be launched from tablet's home screen (or from an app drawer, accessible by swiping screen from bottom to top) by tapping on IPhO icon.

In order to get values measured on the board to the tablet:

1. power the board using USB charger;
2. connect the board and the tablet using the connector cable (*6-pin on the board side and Micro-USB on the tablet side);*
3. confirm the USB access and reset the board in 10 seconds when the app asks you to do so.

Caution: if at some moment

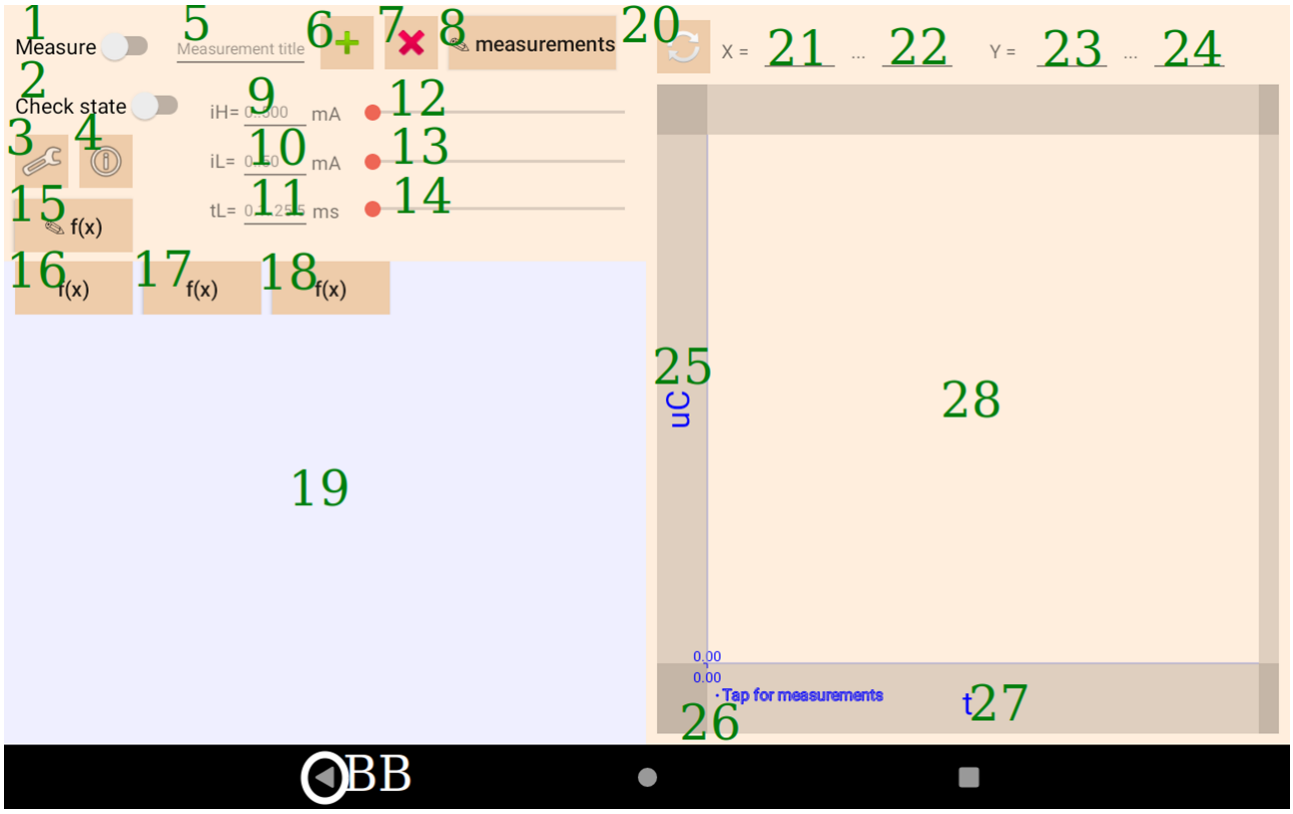
- **the board stops responding and returns no measurements (in either "Check state" or Measurement mode),**
- **heating / LED current has no change (thermistor voltage does not change and LED does not glow even at maximum LED current),**

press RESET button on the board and do the step 3 "confirm the USB access...".

If it does not help:

- **exit the app by tapping the Back button twice,**
- **unplug the board,**
- **open the app again,**
- **reconnect the board again and do the step 3 described above.**

Controls and fields are (the numbers will be used as references later):



The main window of the app.

- **1** – Tapping this toggle starts a measurement session. Tapping it again stops it.
- **2** – When this toggle is selected, the screen shows the live values of the measurements.
- **3** – Opens settings.
- **4** – Pops up short summary of settings.
- **5** – Measurement title to be saved or deleted.
- **6** – Saves a newly measured or selected measurement under a new name.
- **7** – Deletes selected measurement.
- **8** – Selects a previously saved measurement.
- **9, 10, 11** – Text fields to manually enter heating current (**9**), LED current (**10**), LED current pulse duration (**11**) values. Empty values mean 0. **tL** (LED current pulse duration) **= 0** means constant direct current).
- **12, 13, 14** – Seekbars to change the corresponding values (*LED current changes exponentially!*).
- **15** – Opens functions editor.
- **16, 17, 18** – Selects variables or functions for measurement table columns.
- **19** – Measurement table area.

- **20** – Manually replots measurements in a chart.
- **21, 22** – *X* axis min and max limits (can be entered manually and replot button pressed).
- **23, 24** – *Y* axis min and max limits.
- **25, 27** – selects *Y* and *X* axes of the chart.
- **26** – selects measurements to be plotted on the chart.
- **28** – chart area.
- **BB** – the Android OS Back button (tap twice to close the app).

Setting up a sweep I-V curve measurement

Additional LED controls are available for the LAB 2 by tapping the settings button (**3**) of the main window. **In the window that opens select:**

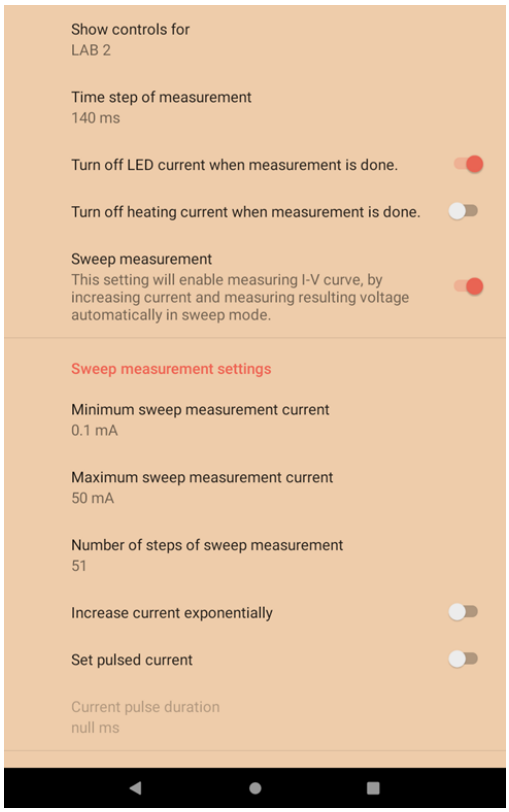
- ”LAB 2” or “ANY LAB” in the ”**Show controls for**” section.
- activate the ”**Sweep measurement**” option.

Other settings are:

- ”**Minimum...**” and ”**Maximum sweep measurement current**” set the starting value and the last value of LED current during sweep measurement respectively.
- ”**Number of steps of sweep measurement**” means how much measurement steps will be made.
- choose ”**Increase current according to geometric progression**” if you want current to increase exponentially.
- choose ”**Set pulsed current**” and set ”**Current pulse width**” if you want each value to be measured using limited time pulse of LED current.

*E.g., if the number of steps is 51, “**Increase current according to geometric progression**” is off, LED current changes from 0 mA to 50 mA respectively, the LED current during measurement will be 0 mA, 1 mA, ... 49 mA and 50 mA.*

Now you can start measuring I-V curve after returning back to the main window by pressing the Back button.



Editing functions

Tapping the (**15**) button of the main window opens functions editing window.

The functions created can accept some of the variables (and their derivatives) directly measured on the board.

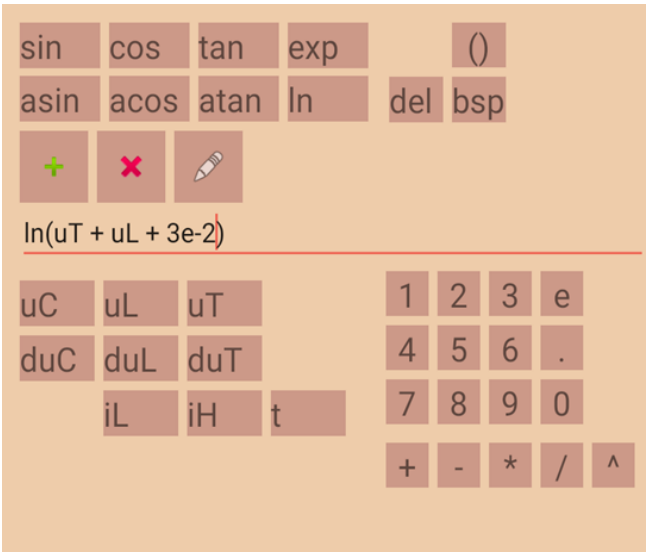
They are:

- **voltages (in V):**
  - **uC** – at the selected capacitor (C1 or C2);
  - **uT** – at the thermistor;
  - **uL** – at the LED;
- their derivatives with respect to time ($\mathrm{d}y/\mathrm{d}t$) (in V/s):
  - **duC**
  - **duT**
  - **duL**
- the currents (in mA):
  - **iL** – at LED (in mA);
  - **iH** – heating current (in mA);
- time **t** (in s).

It is possible to enter a custom function using these variables and mathematical functions (using helper buttons or a standard Android keyboard) of your choosing and save it by pressing a **green +** button afterwards. The saved functions can be used as the graph axes or as the measurement table columns. The pencil button selects existing functions. The selected functions can be deleted by pressing **red x** button.

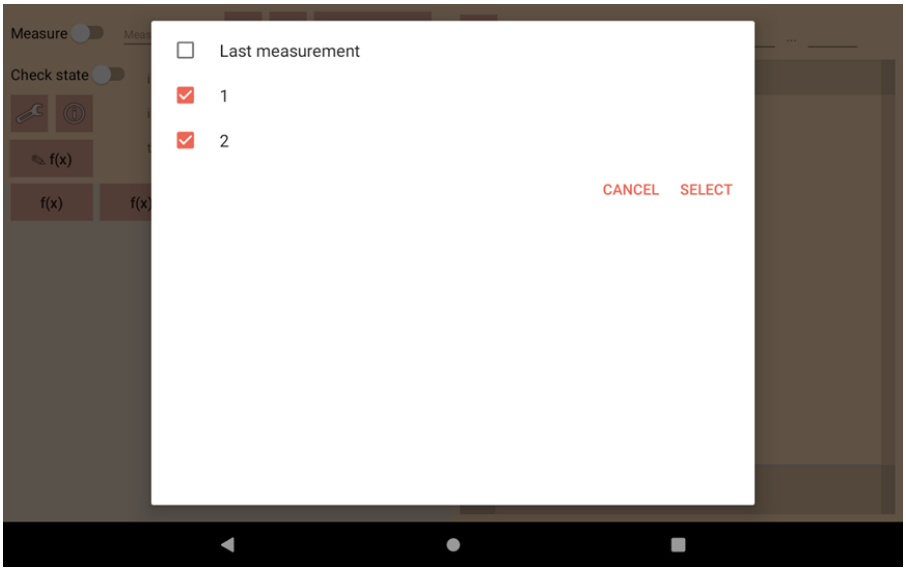
Both casual decimal format (e.g. **25.02**) and scientific format (e.g. **2.502e+1**) are acceptable for numbers.

- ***** is multiplication operator,
- / is division operator,
- ˆ is power operator.

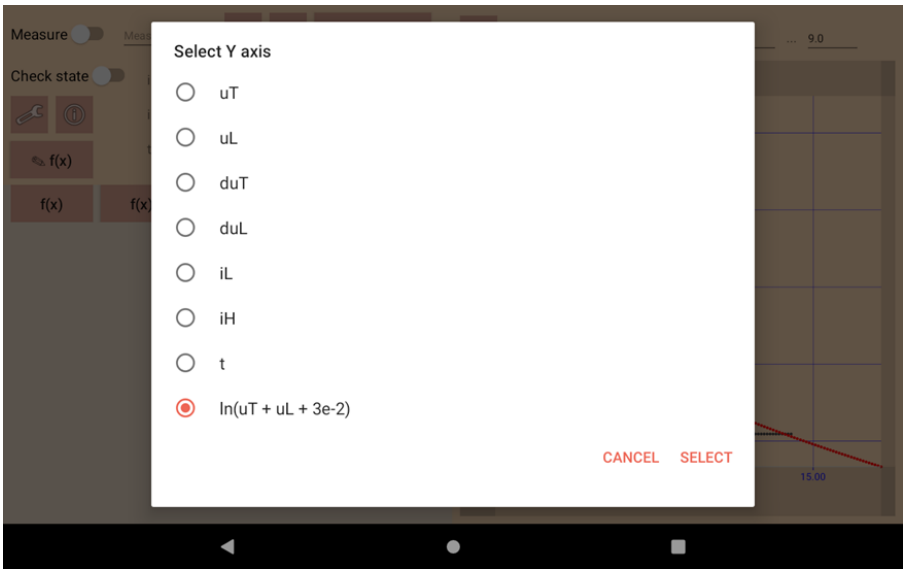


Viewing measurements

The finished measurement can be saved by entering its name into the (**5**) field in the main window and pressing a **green +** button (**6**) nearby. The raw measurement data is saved, which can be displayed on any other axes later. The saved measurements can be displayed on the chart by tapping area near the corner of the chart (**26**).



You can pan/zoom the chart, and if you tap it at the exact point, either the closest point of the measurement (if no close measurement points to the tapped exist) or the point itself will be marked and its coordinates displayed.



Axis can be chosen by tapping existing axis labels (chart areas **25** and **27**).