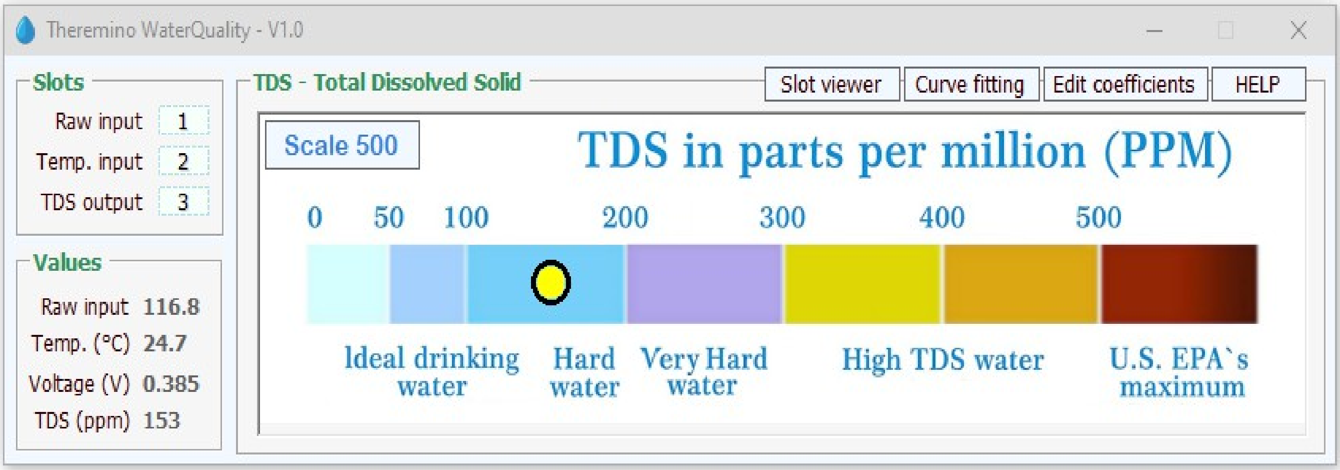
Theremino **System**

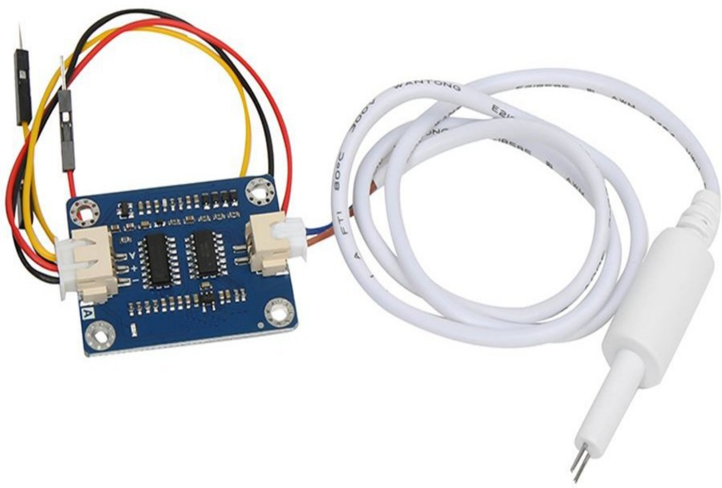


Theremino WaterQuality V1.0

Starting the application

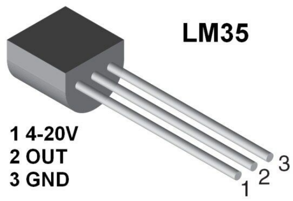
This application requires a TDS-Sensor module (there are several types), connected to a Theremino_Master module.

The TDS-Sensor



https://www.cqrobot.com/index.php?route=product/product&product_id=1122
https://www.seeedstudio.com/Grove-TDS-Sensor-p-4400.html
https://it.farnell.com/dfrobot/sen0244/kit-misur-sensore-tds-analogico/dp/3517934

The temperature sensor (optional)



https://www.theremino.com/en/hardware/inputs/meteorology-sensors#temperature

The Master

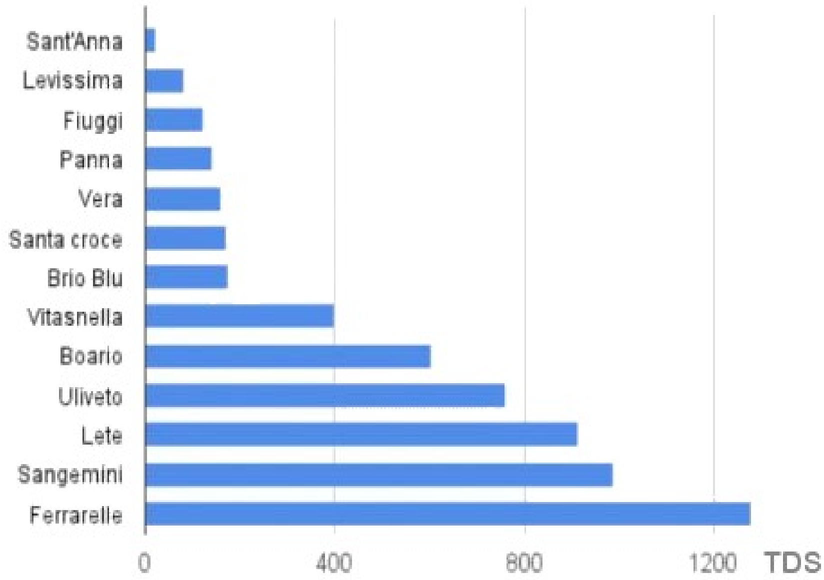
https://www.theremino.com/en/hardware/devices
https://www.theremino.com/en/contacts/producers#hardware

The bottled water TDS values

It is interesting to note that the TDS of common bottled waters (which are normally considered similar) varies by almost a hundred times between the "lightest" and the most mineralized.

In Italy they range from a 14 (Lauretana) to a 1300 (Ferrarelle).

These are useful data, but they are not an incentive to buy the "light" bottled water.



Many recommend using soft water but this belief is not justified by scientific evidence, indeed numerous studies have shown that the hardness of the water is a protective factor for kidney stones. Therefore very light water, or even worse demineralized or distilled water, should be avoided.

Clinical and epidemiological studies mainly suggest drinking plenty of water and intervening in the diet, favoring a diet in which mono or polyunsaturated fats are preferred to saturated fats, reducing proteins in favor of a greater consumption of fruit and vegetables.

All scientific studies confirm how important it is to drink at least 2 liters of water a day, without worrying about fixed residue, limescale or other. To prevent the formation of kidney stones and stay healthy, you need to drink a lot and the tap water is the most economical, ecological and safe choice for everyone.

\- - - - -

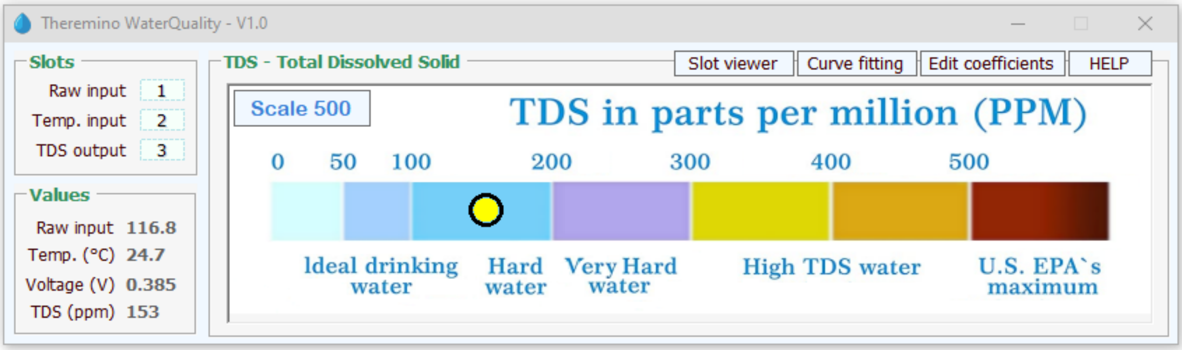
We did not write the "Water Quality" application to encourage the use of micro-filtration and reverse osmosis equipment ***(1)***. These appliances can be useful if the tap water tastes unpleasant or if it is polluted and dangerous, but in many cases they only serve to make producers money.

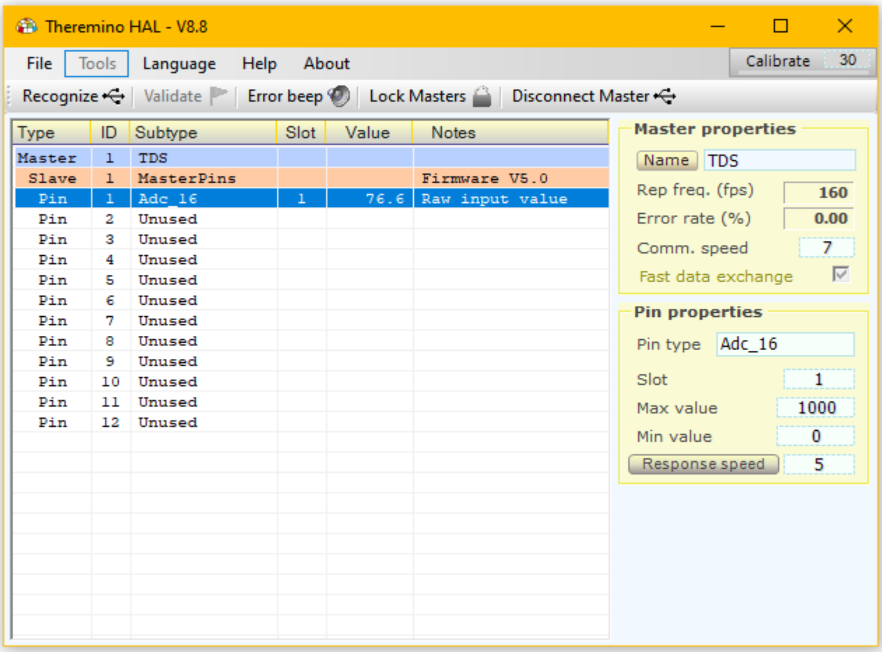
(Note 1) The micro-filtration selectively retains the suspended substances, chlorine and its by-products, keeping the mineral salts. Instead, reverse osmosis retains everything that is not recognized as a water molecule (H_2O).

The HAL application settings

The input of the Master to which the module is connected must be configured in Theremino_HAL application as Adc16.

If a temperature sensor is also connected, then a second input is also set as Adc16.



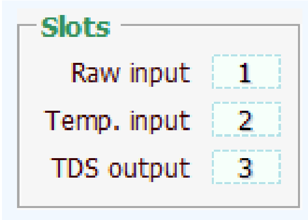


To make the measurement more stable, adjust the "Response speed" box of the used input with very low values (less than 10) and possibly also press the "Response speed" button which further stabilizes the readings.

We recommend that you minimize the HAL application after adjusting its boxes, so it will consume less resources and will not take up any space on the screen.

The HAL application will be started and closed automatically by the Water Quality application and will remain minimized if you last closed it from minimized.

The "Slots" panel

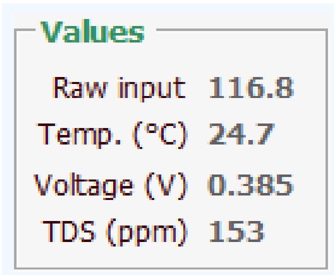


Raw input The same Slot set in the HAL for the TDS sensor input.

Temp. input The same Slot set in the HAL for the temperature sensor.

TDS output To send the TDS value to other applications (-1 if not used)

The "Values" panel

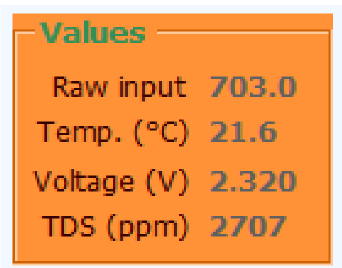


Raw input The raw value measured by the ADC ranging from zero to about 700.

Temp. (°C) The measured temperature (if there is also a temperature sensor).

Voltage (V) The voltage produced by the TDS-Sensor module, measured in Volt.

TDS (ppm) The value calculated for the "Total Dissolved Solid" in parts per million.



The "Values" panel turns red if "Raw input" is greater than 700. In these conditions the TDS value is no longer valid because the electronics is working in the saturation zone.

The upper bar buttons

Slot viewer

Opens the Slot Viewer application which can be used to make tests with test values.

To send test values, you close the HAL application and move the SlotViewer bar with the mouse or with the arrow keys.

Eventually you can also press the CTRL, SHIFT and ALT keys to change speed and if you use the right mouse button you will get integer values.

Curve Fitting

Opens the application used to compute coefficients.

Edit coefficients

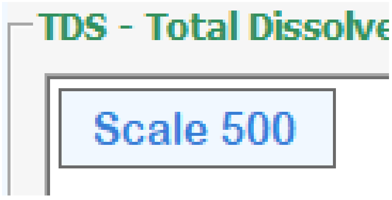
Opens the file "Theremino_WaterQuality_Configuration.txt" which contains the interpolation coefficients to make the TDS measurements of the three scales more precise.

Furthermore, the calibration points of the temperature sensor and the correction points of the TDS for the various temperatures are also written in the configuration.

HELP

Opens this instruction file.

The PPM scales



The first two scales **500** and **1000** are for drinking water, the third scale **50K** is used to measure brackish water and sea water. The fourth scale **Test values** is explained in the ***last pages*** of this document.

Each scale requires a suitable cell with its scale coefficients.

For the first two scales (500 and 1000) you use the cell supplied with the module (K=0.5) and the following coefficients, whose give you a fairly good result:

```
-------------------------------
Scale 500
-------------------------------
ProbeK   0.5
C0       0
C1       857.39
C2       255.86
C3       133.42
```

For the third scale you have to build a cell with a very high K (about 40) and set the proper coefficients for that cell, as in the following examples:

```
-------------------------------
Scale 50000
-------------------------------
ProbeK   40
C0       0
C1       857.39
C2       255.86
C3       133.42
```

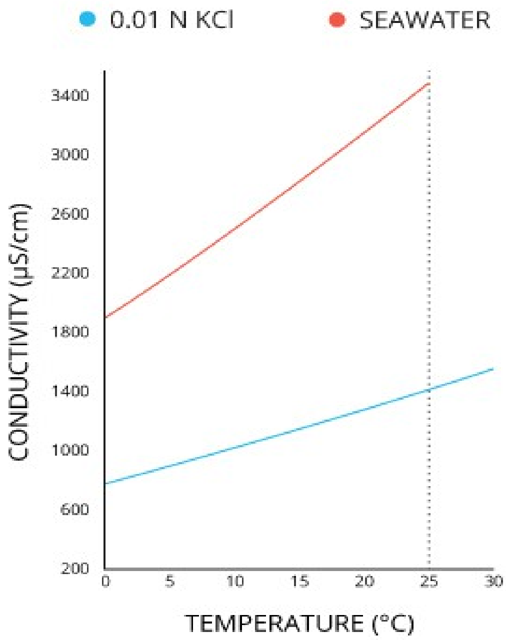
In the next example the values C1, C2 and C3 also include the Probe K

```
-------------------------------
Scale 50000
-------------------------------
ProbeK   1
C0       0
C1       34296
C2       10234
C3       5337
```

To test and eventually modify the coefficients for the three scales you press the button "Edit coefficients" (see the configuration page).

The correction by temperature

To make the temperature correction:



- Connect a ***temperature sensor*** to the Master.
- In the HAL application, configure the sensor Pin as Adc16.
- Always in the HAL the sensor Pin must have the same Slot that is set in "Temp. Input" of this same Water Quality application.
- There must be at least two TempSensorTrimming lines in the configuration.
- Always in the configuration there must be at least two TempCorrection lines.

The TempSensorTrimming lines indicate how to translate the raw value measured by the ADC of the Master in degrees centigrade.

If you are using the LM35 sensor which provides ten millivolts per degree centigrade the calibration lines are as follows, otherwise you will have to calculate them with the sensor data used or set different calibration points by measuring with a thermometer.

```
TempSensorTrimming    0    0
TempSensorTrimming  100   33
TempSensorTrimming  300   99
```

The TempCorrection lines show how to correct the TDS value according to the water temperature. The Italian ***gazzettaufficiale*** provides the following corrections.

```
TempCorrection 5  1.613
TempCorrection 10 1.411
TempCorrection 15 1.247
TempCorrection 20 1.112
TempCorrection 25 1.000
TempCorrection 30 0.907
```

If you set the "Temp. Input" Slot with -1 then the calculated TDS is not corrected for the temperature.

To check and possibly modify the coefficients for the temperatures you use the "Edit coefficients" button (see next page).

The configuration file

Pressing the "Edit coefficients" button opens the configuration file for checking and editing. Then when you close the application you are using (usually Notepad) the file is automatically reloaded by the Water Quality application and the new values are immediately used.

If the configuration file contains errors the Water Quality application displays one or more error messages and then uses the default values.

To avoid errors, use the examples on the previous two pages as a reference and follow these rules:

- Any comment lines must start with special characters, for example --- or any other character other than a letter from A to Z.

- There must be three stair configuration sections and they must start with the `Scale 500` , `Scale 1000` and `Scale 50000` rows in ascending order.
- Each scale configuration section must contain the five lines starting with `ProbeK, C0, C1, C2 e C3` and following with a numeric value.
- The TDS value is then calculated with the formula `TDS = ProbeK * (C0 + C1 * v + C2 * v^2 + C3 * v^3` where v is the voltage measured in volts.

- The "Temperature sensor trimming" section can contain any number of calibration points, but they must be at least two. Each line must begin with the word `TempSensorTrimming` and continue with two numeric values. The first is the raw value measured by the ADC and the second is the temperature in degrees centigrade. The raw values must be in ascending order.

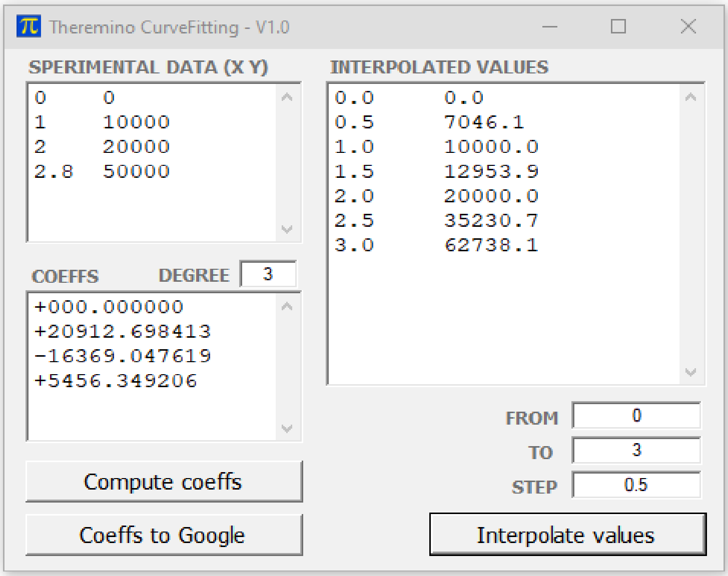
- The "Temperature corrections" section can contain any number of calibration points, but they must be at least two. Each line must begin with the word `TempCorrection` and continue with two numberic values. The first is the temperature in degrees centigrade and the second the correction coefficient. The temperature values must be in ascending order.

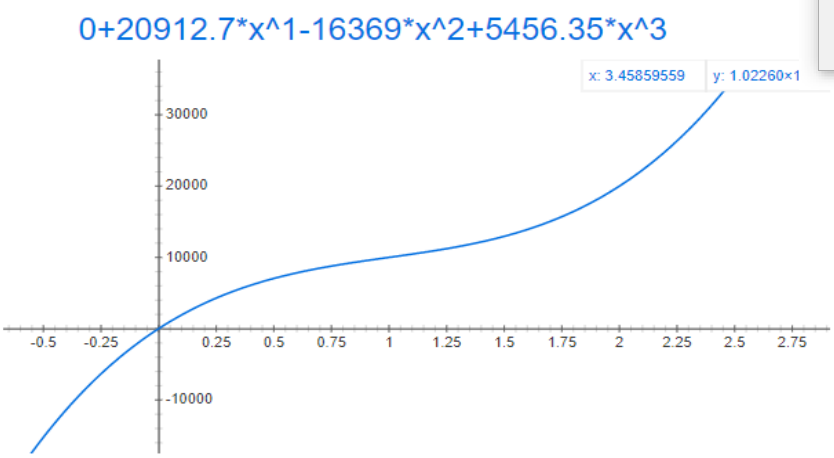
At the end of these sections, an `END OF CONFIGURATION` line is added to specify that the configuration is finished. Everything that comes after is not read, you can write everything, instructions, comments and examples to copy.

The CurveFitting application

With the Curve Fitting application you can calculate the coefficients of a polynomial that best approximates some calibration points.

This can be useful to improve the coefficients proposed by the manufacturer for the scales 500 and 1000, or to calibrate a self made probe for the high concentrations.





Calibration points can be obtained using standard solutions with known TDS, or by comparison with commercial devices.

- Open the CurveFitting application with the "Curve fitting" button.
- Insert 3 (or 4) calibration points in the "Sperimental data" list.
- Set "Degree" = 3
- Press the "Compute coeffs" button and eventually press "Coeffs to Google" to see the calculated curve in a graph.
- If necessary, check the data with the "Interpolate values" button.
- Copy the four coefficients in the configuration in C0 / C1 / C2 and C3
- Set the configuration line ProbeK = 1 because the K is already included in the computed coefficients.

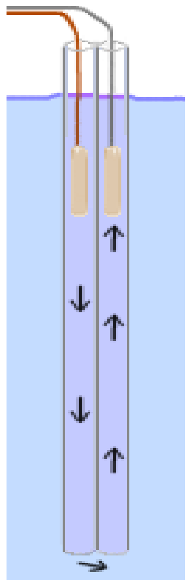
The TDS value is then calculated with the formula `TDS = ProbeK * (C0 + C1 * v + C2 * v^2 + C3 * v^3` where v is the voltage measured in volts

The K constant

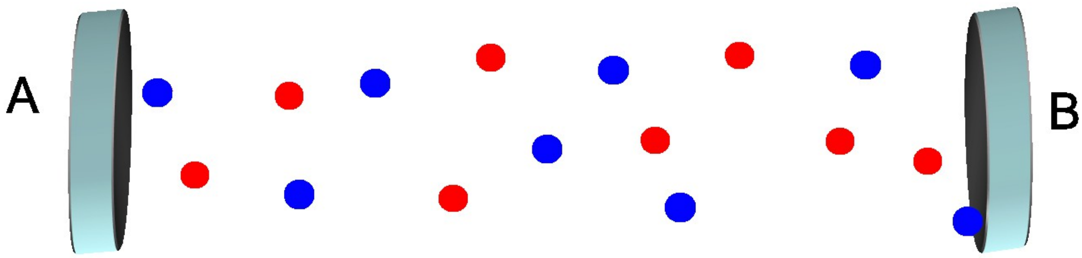
The cell supplied with the TDS sensor has a K of 0.5, so it is suitable for TDS values from 0 to 1000, i.e. waters of rivers, lakes, aqueducts, bottled mineral waters and purified water.

To measure brackish water, sea water and salt lake water, special probes must be used, with a high constant K.

High K probes must have a much greater distance between the electrodes, even 50 or 100 times greater. This distance is achieved by forcing the ions to travel a longer path by means of two small tubes.

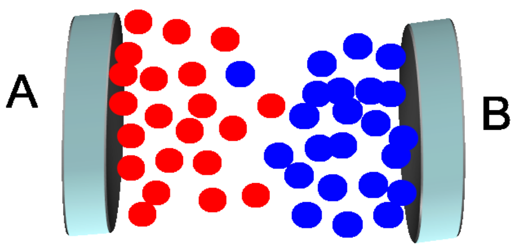


The high conductivity solutions require cells with a high constant K.



Otherwise the ions are no longer free to move

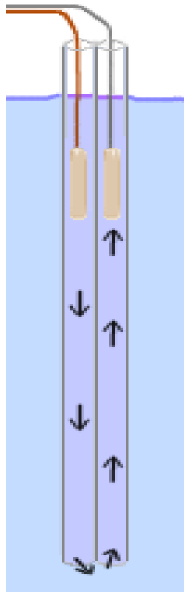
because their density is too high.



Under these conditions the electrodes become polarized

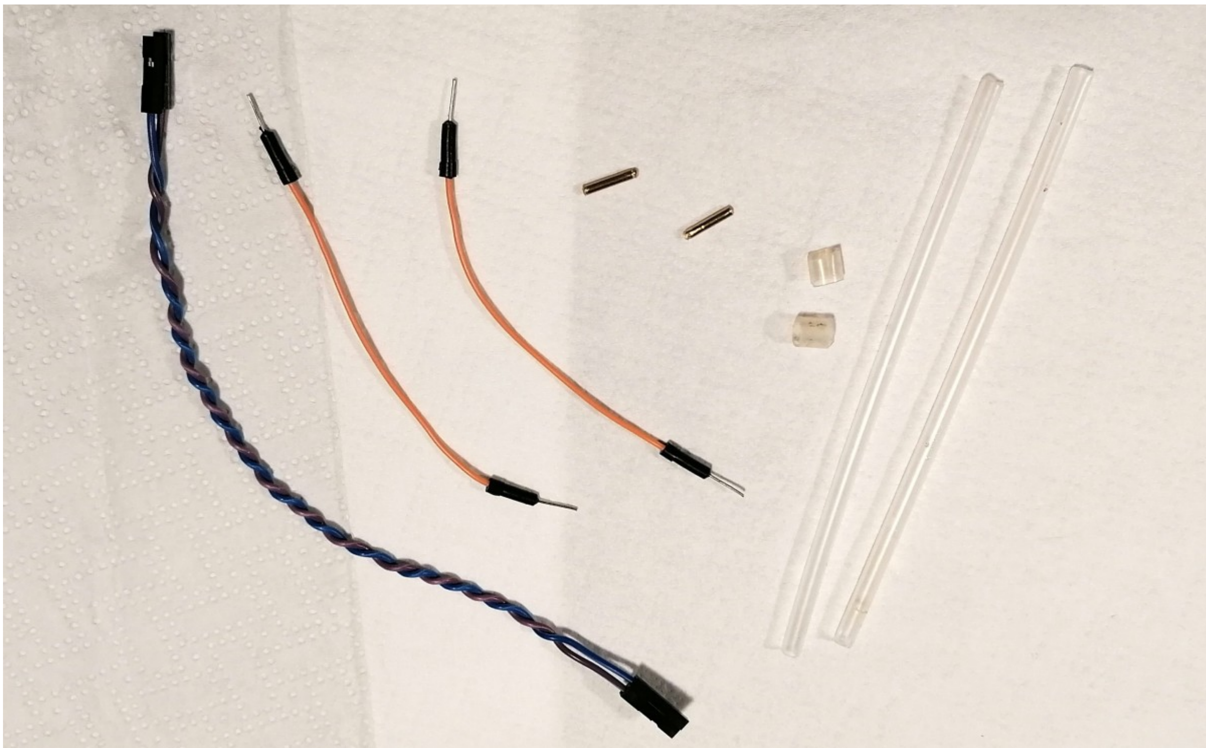
and values are measured considerably lower than the real ones.

Build a cell with very high K



To increase the constant K, the length of the path that the ions have to travel to go from one electrode to the other is increased.

In the next image we see the material needed to build a cell with a very high coefficient K.



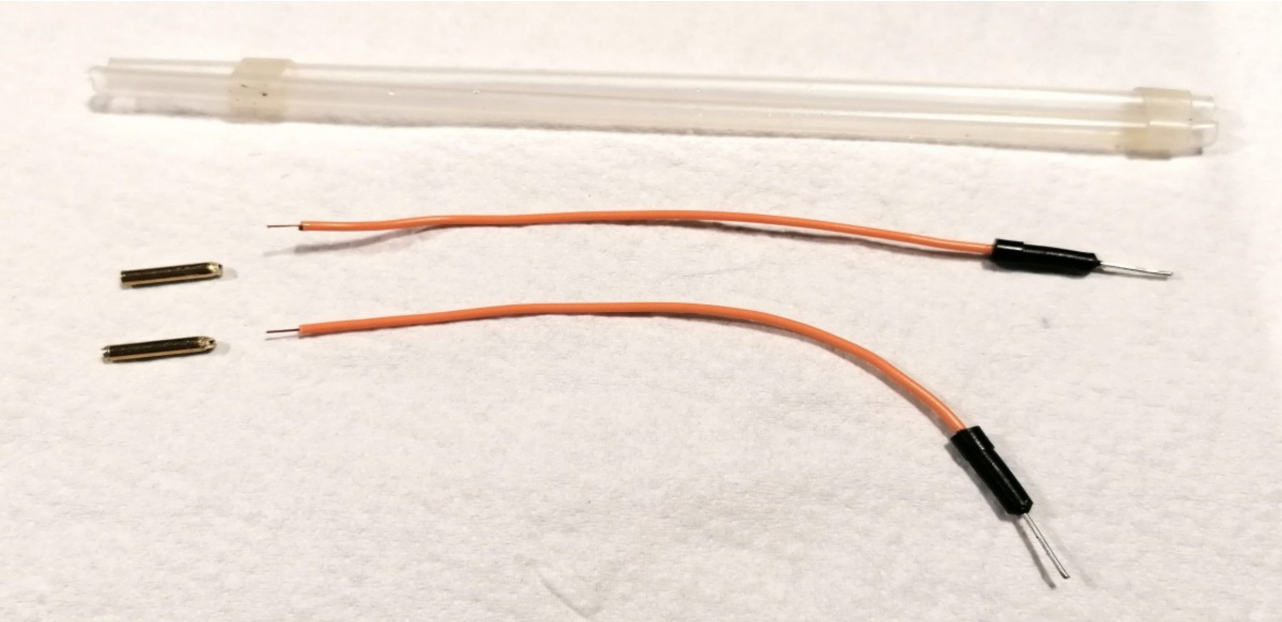
You will need (from left to right in the image):

- Two female Dupont cables of about 20 or 30 centimeters.
- Two 4-inch cables that are male on at least one side.
- Two pieces of brass tube with an external diameter of 2 mm, cut to a length of 10 mm. You can find the brass tube at model aircraft stores.
- Two pieces of elastic tube that will be used to join the two long tubes, as you will see better in the following pages.
- Two transparent plastic tubes, with an internal diameter ranging from 3 to 6 mm. The internal diameter must not be greater otherwise the tubes would have to be to much long and the probe would become awkward to use.

You can find transparent plastic tubes, of various diameters, in the cleaning product sprayers.

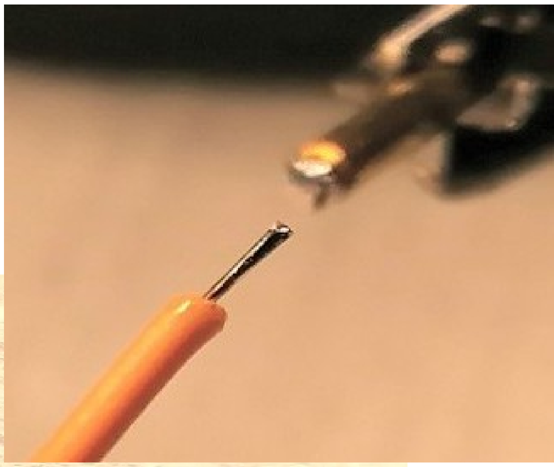
Cell construction

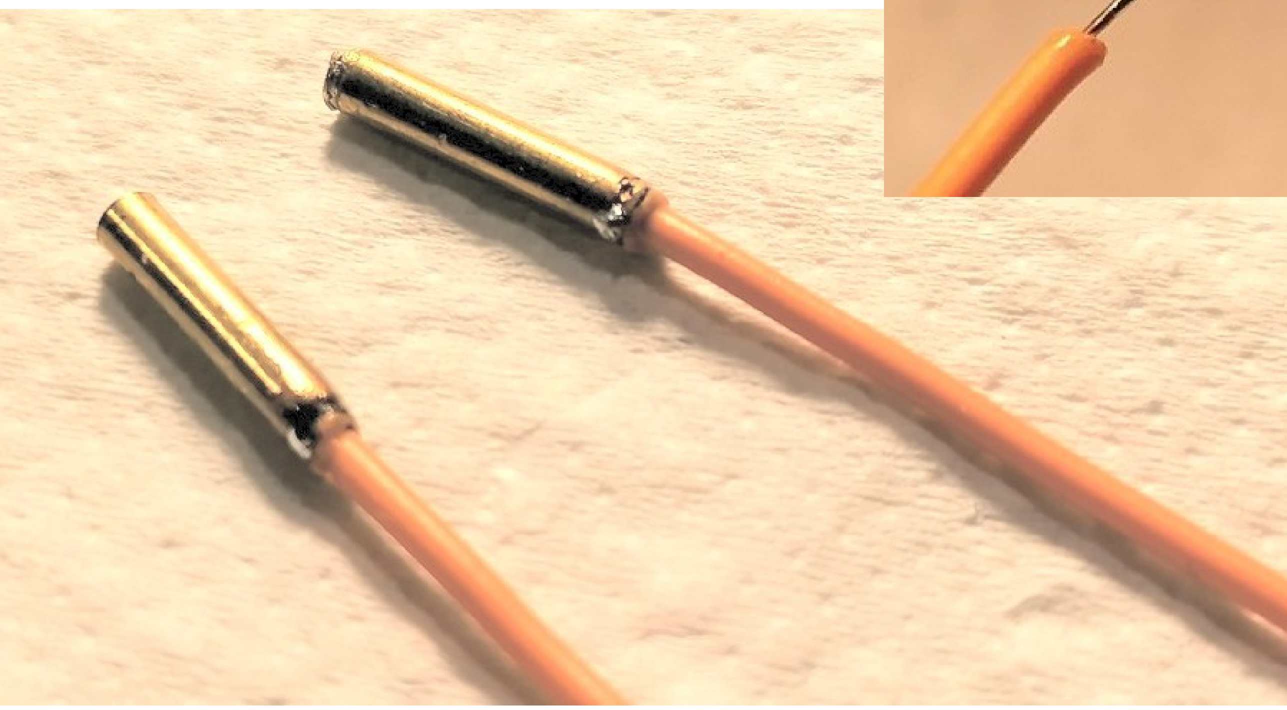
Join the two long tubes with the two pieces of elastic tube



Tin the two tubes on one side.

Cut the two 10 cm cables, peel them, tin them and weld them to the two tubes.

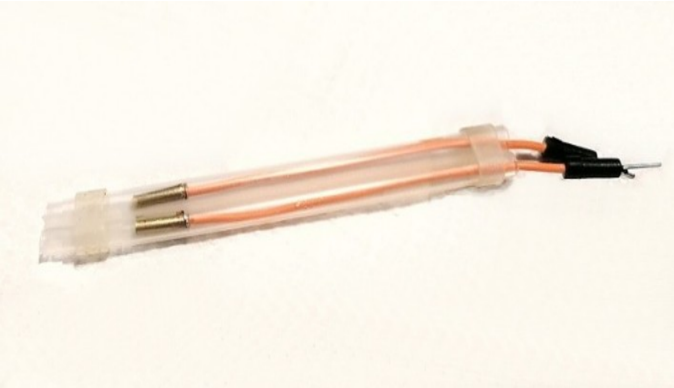


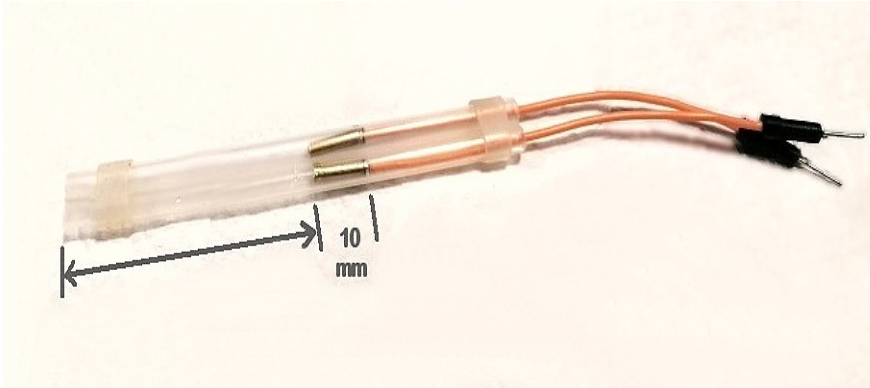


Cell trimming

In the following two images you can see that it is possible to slide the brass tubes up and down along the transparent tubes.

By adjusting the position of the brass tubes, the K of the cell changes.





You could start with 120 mm long tubes. If the internal diameter is small even shorter would be enough, but it is better to have them long and cut them at the end, after checking which length is needed to have the right conductivity.

If the transparent tubes have an internal diameter of 3 mm and you want to obtain a K of 40, which is eighty times greater than the cell supplied, then the brass tubes must be set approximately at a distance of 15 mm from the bottom.

The theoretical formula to calculate the K of the cell is K = L / (R * R * PI)

- L is the total length of the path in centimeters, so about twice the length from the bottom.
- R is the internal radius of the tubes (always in centimeters) and R * R * PI is the internal area, also in centimeters.

Here are some examples:

Length from the bottom	Total path length	Internal diameter	Internal area	K of the cell
1.5 cm	3 cm	0.3 cm	0.070 cm2	42.8
2.5 cm	5 cm	0.4 cm	0.126 cm2	39.7
4 cm	8 cm	0.5 cm	0.197 cm2	40.6
6 cm	12 cm	0.6 cm	0.283 cm2	42.4

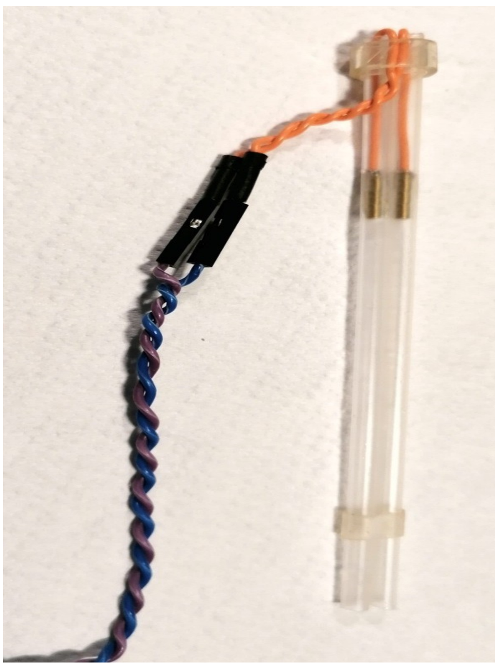
Test the cell K

A cell suitable for measuring sea water must have approximately a K of 40, which is 80 times greater than that supplied.

To check that you have obtained an adequate K, proceed as follows:

- Prepare a bottle of mineral water cut to a height of 16 centimeters and fill it with 1/2 liter of water.
- Add 17.5 grams of salt (NaCl) and mix well.
- The position of the brass tubes is adjusted to read about 260 as "Raw input"
- Fix everything in that position with an elastic tube or with a drop of hot glue.
- Pay attention that the upper part of the transparent tubes must remain open. Air must be able to pass through the upper openings to allow water to enter and exit at the bottom.

To use this cell you will have to adjust the coefficients using calibrated solutions and the CurveFitting application.



The K of the original probe

We searched on the net for the characteristics of the probe that you buy together with the TDS-Sensor but no one specifies its K coefficient, so we tried to calculate it.

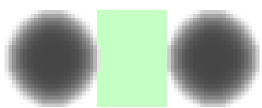
By measuring the electrodes with the caliper, these data are obtained:

Length 6 mm

Diameter 1 mm

Distance 1.54 mm

The formula to calculate K wants the data in centimeters so:



Distance = 0.154 cm

Area (6 mm x 1 mm) = 0.06 cm2

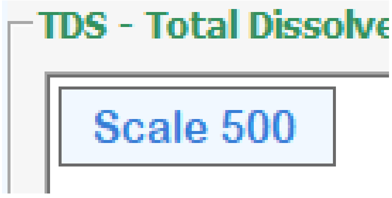
K = 0.154 / 0.06 = 2.6

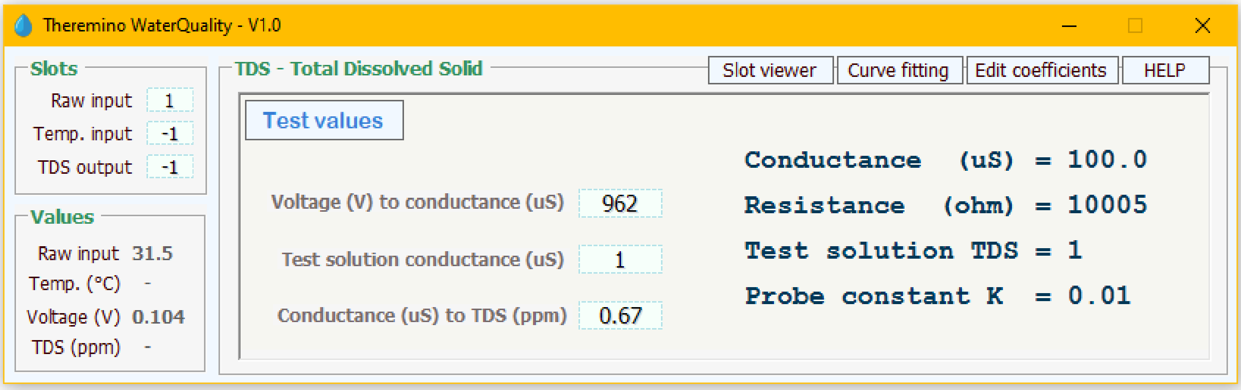
The theoretical calculation of K would therefore give a value of 2.6

But the true K is less than 0.9 because the ions also pass outside the cube of the theoretical calculation and therefore the actual measured volume is considerably greater.

The "Test values" scale

Clicking several times on the button that changes the scales you get the "Test values scale that you see in the next image.





This is actually not really a "scale" but just a panel that contains constants and calculated values.

Using this panel you can make checks and calculations to estimate the K coefficient of unknown cells or artisan cells built with various sizes and with the materials available.

Before continuing it is important to remember that these are approximate measurements, which suffer from considerable errors and non-linearity, caused by the ions moving in the liquid and partly also by the meter electronics.

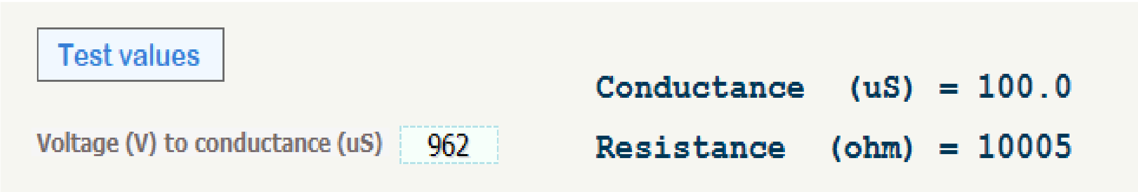
So do not exaggerate to look for precise values, what you need when building a cell is only roughly estimate its K, to verify that it is suitable for the measurements to be made.

The K values to be obtained will be roughly from 0.01 to 0.1 for distilled or filtered water, from 0.3 to 1.5 for drinking water, from 10 to 50 for brackish and marine waters and also from 50 to 100 for concentrated acids.

The calibration and linearization of the cell will be carried out later, using sample solutions or by comparison with commercial devices.

Estimate the K with the "Test values" scale

First of all you have to check the electronics of the meter, connecting a ten thousand ohm (10K) resistor to the two electrode poles and then adjusting the "Voltage (V) to conductance (uS)" box until you measure a conductance of about 100 microsiemens and therefore a resistance of about 10 000 ohms.



If the electronics are working well this value will be around 1000. In this example it was 962 but it could be fine even if it was 10% lower or higher, so approximately 900 to 1100.

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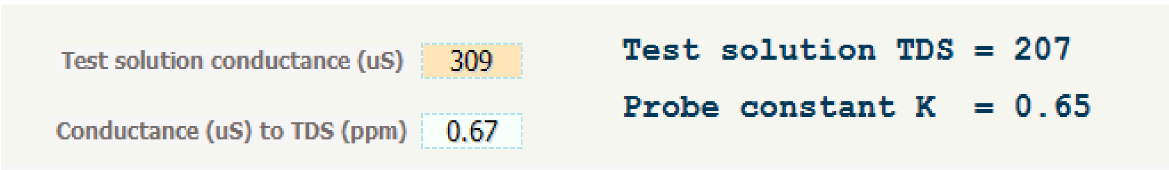
Then we will have to get a sample solution whose conductance or TDS we know, for example by dissolving a known amount of salt or acid in pure water, or by measuring any solution with a commercial meter.

But be careful that it must be an adequate solution for the cell whose K we want to estimate. So with this the cell must give voltage values from 0.25 to 1.5 V

Then the "Test solution conductance (uS)" value is adjusted with the conductance value of the sample solution.



If instead of conductance the TDS is known then the conductance box is adjusted until the "Test solution TDS" becomes the desired one. To make this calculation the program uses the value "Conductance (uS) to TDS (ppm)". The literature suggests different values depending on the type of solution, but for the rough measurement we have to make the value 0.67 is adequate.

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Finally, the probe is immersed in the sample solution and the estimated value of K is read in the "Probe constant K" line.