CONDUCTIVITY SENSOR

Description D0382

Figure 1. The Conductivity Sensor

Short Description

The Conductivity Sensor can be used to measure either solution conductivity or total ion concentration of aqueous samples being investigated in the field or in the laboratory.

Conductivity is one of the easiest environmental tests for aquatic samples. Even though it does not tell you specific ions that are present, it does quickly determine the total concentration of ions in a sample. It can be used to perform a wide variety of experiments to determine the changes in or levels of total dissolved ions or salinity:

- Confirmation of the direct relation between conductivity and ion concentration in an aqueous solutions. Concentration of unknown samples can be determined.
- Qualitative comparison of the difference between the ionic and molecular nature of substance in aqueous solution. This can include differences in strength of weak acids and bases, or the number of ions that an ionic substance dissociates into per formula unit.
- Measurement of changes in conductivity resulting from photosynthesis in aquatic plants, with the resulting decrease in bicarbonate-ion concentration from carbon dioxide.
- Monitoring the rate of reaction in a chemical reaction in which dissolved ions and solution conductivity varies with time due to ionic specie being consumed or produced.
- Performing a conductivity titration to determine when stoichiometric quantities of two substances have been combined.
- Finding the rate at which ionic species diffuses through a membrane such as dialysis tubing.
- Monitoring changes in conductivity or total dissolved solids in an aquarium containing aquatic plants and animals. These changes could be due to photosynthesis or respiration.

The sensor is delivered with a BT-plug and can be connected to the following interfaces:

- UIA/UIB through Measuring console (via 0520 adapter)
- CoachLab
- CoachLab II
- SMI (via 0520 adapter)
- Texas Instruments CBL™ data-logger.

There is an adapter (art. 0520) to connect sensors with BT-plugs to 4-mm inputs.

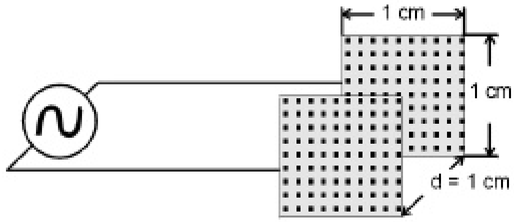
How the Conductivity Sensor works

The Conductivity Sensor measures the ability of a solution to conduct an electric current between two electrodes. In solution, the current flows by ion transport. Therefore, an increasing concentration of ions in the solution will result in higher conductivity values.

The probe is actually measuring conductance, defined as the reciprocal of resistance. When resistance is measured in ohms, conductance is measured in siemens (formerly known as a *mho.*) Since 1 siemens is a very large unit, aqueous samples are commonly measured in microsiemens μS. Even though the Conductivity Sensor is measuring conductance we are often interested in finding conductivity of a solution. Conductivity C is found using the following formula:

$C = G * k_c$ G = conductance

k_C = cell constant



The cell constant is determined for a sensor using the following formula:

$k_c = d / A$ d = distance between two electrodes (in cm)

A = area of the electrode surface (in cm^2)

Example:

The cell in figure has a cell constant k_C = d/A = 1.0 cm / 1.0 cm^2 = 1.0 cm^{-1}. Since the Conductivity Sensor also has a cell constant of 1.0 cm^{-1} its conductivity and conductance have the same numerical value. For a solution with a conductance value 1000 μS, the conductivity would be:

$$C = G \times k_C = (1000\ \mu S) \times 1.0\ cm^{-1} = 1000\ \mu S/cm$$

A potential difference is applied to the two probe electrodes in the Conductivity Sensor. The resulting current is proportional to the conductivity of the solution. This current is converted into voltage to be read by an interface.

Alternating current is supplied to prevent the complete ion migration to the two electrodes. Thus solution that are being measured for conductivity are not fouled. It also reduces redox products from forming on the relatively inert graphite electrodes.

One of the most common uses of the Conductivity Sensor is to find the concentration of total dissolved solids, or TDS, in a sample of water. This can be accomplished because there is generally a direct relationship between conductivity and the concentration of ions in a solution. The relation persists until very large ion concentrations are reached.

The Conductivity Sensor has three sensitivity range settings:

- 0 to 200 μS (0 to 100 mg/l TDS)
- 0 to 2000 μS (0 to 1000 mg/l TDS)
- 0 to 20000 μS (0 to 10000 mg/l TDS)

These ranges are selected using a toggle switch on the end of the amplification box attached to the probe. It is very important to consider this setting when loading or performing a calibration; no single calibration can be used for all three settings.

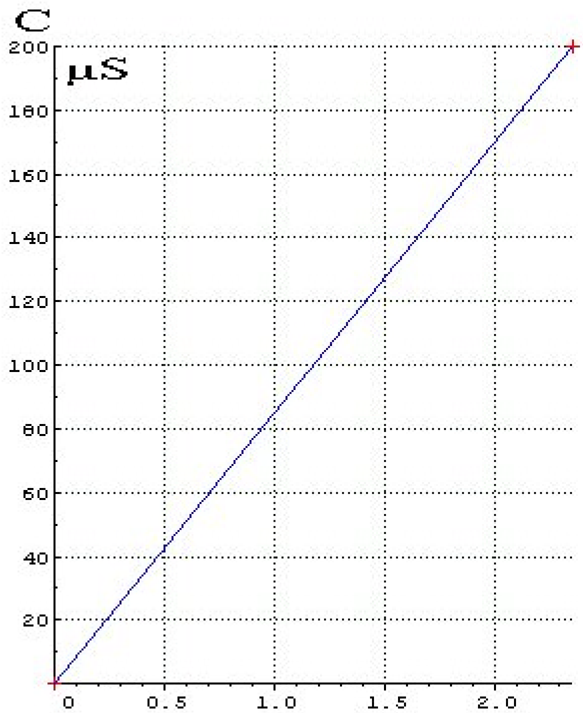
Items included with the Conductivity Sensor
Check to be sure that each items is included:

- The conductivity sensor (conductivity electrode with amplifier box),
- Sodium Chloride Calibration Standard (equivalent to 1000 µS/cm , 491 mg/l NaCl or 500 mg/l TDS),
- MSDS- data sheet for Sodium Chloride Standard Solution,
- This manual.

Preparing the Conductivity Sensor for use
To help ensure that the electrode surfaces are free of residues, soak the lower portion of the probe in distilled water for about 10 minutes. Blot the electrode surfaces dry (on the *inside* of the elongated hole near the probe tip).
Connect the sensor to one of the ports (channels) of your interface.

Calibration of the sensor
We recommend performing the calibration whenever sensor is used.

- Select the conductivity range settings on the probe box:
  low: 0 – 200 µS,
  medium: 0 – 2000 µS,
  high: 0 – 20000 µS.
- **Zero calibration point**
  Simple perform this calibration point with the probe of any liquid or solution (e.g. in the air). A very small voltage reading will be displayed on the computer. Call this value 0 µS or 0 mg/l.
  - **Standard solution Calibration Point**
  Place the sensor into a standard solution (solution of known concentration), such as the sodium chloride standard that is supplied with your sensor. Be sure the entire elongated hole with electrode surfaces is submerged in the solution. Wait for displayed voltage to stabilize. Enter the value of the standard solution (e.g. 1000µS, 491 mg/l as NaCL or 500 mg/L as TDS).
- For even better results, the two-point calibration can be performed using two standard solutions that bracket the expected range of conductivity or concentration values.



µS.

Taking measurements using the Conductivity Sensor
Once the sensor has been calibrated you are ready for measurements:

- Rinse the tip of the sensor with distilled water. Optional: blot the inside of the electrode cell dry only if you are concerned about water droplets diluting or contaminating the sample to be tested.
- Insert the tip of the sensor into the sample. Be sure the electrode surfaces in the elongated cell are completely submerged in the liquid.
- While gently swirling the probe, wait for the reading to stabilise. This should take no more than 5 to 10 seconds.
- Rinse the end of the probe with distilled water before taking another measurement.
- If you are taking readings at temperatures below 15°C or above 30°C, allow more time for the temperature compensation to adjust and provide a stable conductivity reading.

Warning: Do not place the electrode in viscous, organic liquids, such as heavy oils, glycerin (glycerol), or ethylene glycol. Do not place the probe in acetone or non-polar solvents, such as pentane or hexane.

When you finished using the sensor, simply rinse it off with distilled water and blot it dry using a paper towel. The probe can be stored dry.

If the probe cell surface is contaminated, soak it in water with mild detergent for 15 min. Then soak it in dilute acid solution (0.1 M hydrochloric acid or 0.5 M acetic acid works well) for another 15 minutes. Then rinse it well with distilled water.

The Sodium Chloride Standard Calibration solution

Having accurate standard solutions is essential for performing good calibrations. The sodium chloride calibration solution, which is included with your probe, can last a long time if it is not contaminated with a wet or dirty probe.

You should perform calibration with the probe while it is new and uncontaminated. To prepare own standard solutions use a container with accurate volume markings (e.g. volumetric flask) and add the amount of solid shown in the first column of the table below.

Amount of NaCl to make 1 liter of solution	TDS an Conductivity values equivalent to the NaCl concentration in the first column	
	TDS	Conductivity (μS/cm)
0.0474 g (47.4 mg/l)	50 mg/l TDS	100 μS/cm
0.491 g (491 mg/l)	500 mg/l TDS	1000 μS/cm
1.005 g (1005 mg/l)	1000 mg/l TDS	2000 μS/cm
5.566 g (5566 mg/l)	5000 mg/l TDS	10000 μS/cm

Automatic temperature compensation

The conductivity sensor is automatically temperature compensated between temperatures of 5°C and 35°C. Readings are automatically referenced to a conductivity value at 25°C – therefore the sensor will give the same conductivity in a solution that is at 15°C at it would if the same solution were warmed to 25°C. This means that one calibration can be used for measurements in water samples of different temperatures. Without temperature compensated the conductivity readings change as temperature changed, even though the actual ion concentration did not changed.

Using the Conductivity Sensor with other sensors

It is very important to know that the Conductivity Sensor will interact with some other sensors, if they are placed in the same solution (in the same aquarium or beaker, for example), and they are connected to the same interface. This situation arises because the conductivity sensor outputs a signal in the solution, and this signal can affect the reading of another sensor. The following sensors can not be connected to the same interface and placed in the same solutions:

- oxygen sensors
- pH sensors
- ion specific sensors.

If you wish to use the CMA temperature sensor (-18°C to 120°C) together with the conductivity sensor wrap the metal part of the sensor with, for example Parafilm, to isolate the sensor electronically.

More sensors can be connected at the same time to the interface but only one at the time can be placed inside the solution and can take readings.

Suggestions for experiments

Properties of the solutions: Electrolytes and Non-electrolytes

In the first part of this experiment students measure the conductivity of three chloride solutions (NaCl, KCl and $CaCl_2$) with the same concentration (0.005 M) Based on these data, students discover that each of these compounds produce different ratios of ions when they dissociate in water. It turns out that the ratio of conductivity values is very close to the mole ratio of ions formed when each compound dissociates. Another part of the experiment has students place the conductivity sensor in 0.005 M acid solutions (from weakest to strongest): CH_3COOH (142 μS), H_3PO_4 (1230 μS), HCl (1990 μS).

Saltwater Conductivity

In this experiment, concentrated sodium chloride solution is added drop by drop to distilled water. After each drop is added, a conductivity reading is made.

Equivalence point during titration

Students perform a titration using the conductivity sensor by adding 0.080 M sulphuric acid to 0.01 M barium hydroxide:

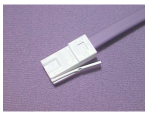
$Ba^{2+}(aq) + 2\ OH^{-}(aq) + 2\ H^{+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s) + H_2O(l)$

This reaction results in a minimum conductivity value at the equivalence point, since the barium sulphate precipitate and water products yield very few aqueous ions.

Diffusion through membranes
In this experiment, a potassium chloride or sodium chloride solution is allowed to diffuse through dialysis tubing into distilled water. The conductivity sensor is used to monitor the increase in concentration as the potassium chloride diffuses through membrane.

Sampling in streams, lakes, sea salt water
It is best to sample away from shore and below the water surface, if possible. In the free-flowing streams there will usually be good mixing of the water, so that samples taken from near the current will be quite representative of the stream as a whole. If you are sampling an impounded stream or lake, there will be a very little mixing – therefore it is important to sample away from shore and at different depths. The electrode is not constructed to withstand higher pressure, so seepage into electronic components of the electrode might result. As an alternative, we recommend that you devise an extended sampling device that allows to reach out into a stream from shore, downward from a bridge. Many ecology books suggest various designs of such sampling devices from inexpensive materials.
Although it is better to take readings at the collection site, readings of total dissolved solids or conductivity should not change significantly if you collect samples and take readings at a later time. However, be sure that samples are capped to prevent evaporation. If samples bottles are filled brim full, then a gas such a carbon dioxide, which is capable of forming ions species in solution, is prevented from dissolving in the water sample.
Salt-water samples may exceed the high range of the Conductivity Sensor, 0 to 20000 μ. Seawater has a conductivity value circa 53000 μS/cm (27000 mg/l NaCl). Sample in this range will need to be diluted in order for them to be monitored using the high range. For example you can take a sample of sea water, and dilute it to ¼ of its original concentration by adding 100 ml of the salt-water sample to 300 ml of distilled water.

Technical data

Conductivity Range	Low: 0 to 200 μS/cm Medium: 0 to 2000 μS/cm High: 0 to 20000 μS/cm
Resolution using 12 bits 5V AD converter	Low: 0.082 μS/cm (0.041 mg/l TDS) Medium: 0.82 μS/cm (0.41 mg/l TDS) High: 8.2 μS/cm (4.1 mg/l TDS)
Accuracy	±1% of full-scale reading for each range
Respond time	98% of full-scale reading in 5 s, 100% in 15 s.
Temperature - compensation - range	 automatic from 5°C and 35°C. can be placed in 0°C to 80°C.
Cell constant	1.0 cm^{-1}
Connection	 BT (British Telecom) plug

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