Conductivity Probe
(Order Code CON-BTA)

The Conductivity Probe 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 of 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 tests or planned experiments to determine the changes in or levels of total dissolved ions or salinity:

- Allow students to qualitatively see 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.
- Use the probe to confirm the direct relationship between conductivity and ion concentration in an aqueous solution. Concentrations of unknown samples can then be determined.
- Measure changes in conductivity resulting from photosynthesis in aquatic plants, with the resulting decrease in bicarbonate-ion concentration from carbon dioxide.
- Use this sensor for an accurate on-site measurement of total dissolved solids (TDS) in a stream or lake survey.
- Monitor the rate of reaction in a chemical reaction in which dissolved ions and solution conductivity varies with time due to an ionic specie being consumed or produced.
- Perform a conductivity titration to determine when stoichiometric quantities of two substances have been combined.
- Use the Conductivity Probe to determine the rate at which an ionic species diffuses through a membrane, such as dialysis tubing.
- Monitor changes in conductivity or total dissolved solids in an aquarium containing aquatic plants *and* animals. These changes could be due to photosynthesis *or* respiration.

Collecting Data with the Conductivity Probe

This sensor can be used with the following interfaces to collect data:

- Vernier LabQuest® as a standalone device or with a computer
- Vernier LabQuest® Mini with a computer
- Vernier LabPro® with a computer, TI graphing calculator, or Palm® handheld
- Vernier Go!®Link
- Vernier EasyLink®
- Vernier SensorDAQ®
- CBL 2™

Here is the general procedure to follow when using the Conductivity Probe:

1. Connect the Conductivity Probe to the interface.
2. Start the data-collection software[1].
3. The software will identify the Conductivity Probe and load a default data-collection setup. You are now ready to collect data.

Data-Collection Software

This sensor can be used with an interface and the following data-collection software.

- **Logger *Pro* 3** This computer program is used with LabQuest, LabQuest Mini, LabPro, or Go!Link.
- **Logger *Pro* 2** This computer program is used with ULI or Serial Box Interface.
- **Logger Lite** This computer program is used with LabQuest, LabQuest Mini, LabPro, or Go!Link.
- **LabQuest App** This program is used when LabQuest is used as a stan-alone device.
- **EasyData App** This calculator application for the TI-83 Plus and TI-84 Plus can be used with CBL 2, LabPro, and Vernier EasyLink. We recommend version 2.0 or newer, which can be downloaded from the Vernier web site, www.vernier.com/easy/easydata.html, and then transferred to the calculator. See the Vernier web site, www.vernier.com/calc/software/index.html for more information on the App and Program Transfer Guidebook.
- **DataMate program** Use DataMate with LabPro or CBL 2 and TI-73, TI-83, TI-84, TI-86, TI-89, and Voyage 200 calculators. See the LabPro and CBL 2 Guidebooks for instructions on transferring DataMate to the calculator.
- **Data Pro** This program is used with LabPro and a Palm handheld.
- **LabVIEW** National Instruments LabVIEW™ software is a graphical programming language sold by National Instruments. It is used with SensorDAQ and can be used with a number of other Vernier interfaces. See www.vernier.com/labview for more information.

NOTE: This product is to be used for educational purposes only. It is not appropriate for industrial, medical, research, or commercial applications.

Taking Measurements with the Conductivity Probe

- Rinse the tip of the Conductivity Probe 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 probe into the sample to be tested. **Important:** Be sure the electrode surfaces in the elongated cell are completely submerged in the liquid.
- While gently swirling the probe, wait for the reading on your computer, calculator screen, or Palm device to stabilize. This should take no more than 5 to 10 seconds. **Note:** Do not completely submerge the sensor. The handle is not waterproof.

[1] If you are using Logger *Pro* 2 with either a ULI or SBI, the sensor will not auto-ID. Open an experiment file for the Conductivity Probe in the Probes & Sensors folder.

- 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.
- **Important:** 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.

Storage and Maintenance of the Conductivity Probe

- When you have finished using the Conductivity Probe, simply rinse it off with distilled water and blot it dry using a paper towel or lab wipe. The probe can then be stored dry.
- If the probe cell surface is contaminated, soak it in water with a mild detergent for 15 minutes. Then soak it in a 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. **Important** Avoid scratching the inside electrode surfaces of the elongated cell.

This sensor is equipped with circuitry that supports auto-ID. When used with LabQuest, LabQuest Mini, LabPro, Go! Link, SensorDAQ, EasyLink, or CBL 2, the data-collection software identifies the sensor and uses pre-defined parameters to configure an experiment appropriate to the recognized sensor.

Specifications

Range of Conductivity Probe:

• Low Range:	0 to 200 µS/cm (0 to 100 mg/L TDS)
• Mid Range:	0 to 2000 µS/cm (0 to 1000 mg/L TDS)
• High Range:	0 to 20,000 µS/cm (0 to 10,000 mg/L TDS)

13-bit Resolution (with SensorDAQ):

• Low Range:	0.05 µS/cm (0.025 mg/L TDS)
• Mid Range:	0.5 µS/cm (0.25 mg/L TDS)
• High Range:	5 µS/cm (2.5 mg/L TDS)

12-bit Resolution (with LabQuest, LabQuest Mini, LabPro, Go!Llink, EasyLink):

• Low Range:	0.1 µS/cm (0.05 mg/L TDS)
• Mid Range:	1 µS/cm (0.5 mg/L TDS)
• High Range:	10 µS/cm (5 mg/L TDS)

10-bit Resolution (with CBL 2):

• Low Range:	0.4 µS/cm (0.2 mg/L TDS)
• Mid Range:	4 µS/cm (2.0 mg/L TDS)
• High Range:	40 µS/cm (20 mg/L TDS)

Accuracy:	±1% of full-scale reading for each range
Response time:	98% of full-scale reading in 5 seconds, 100% of full-scale in 15 seconds
Temperature compensation:	automatic from 5 to 35°C
Temperature range (can be placed in):	0 to 80°C
Cell constant:	1.0 cm^{-1}
Description:	dip type, ABS body, parallel carbon (graphite) electrodes
Dimensions:	12 mm OD and 150 mm length

How the Conductivity Probe Works

The Vernier Conductivity Probe 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 Conductivity Probe is actually measuring *conductance*, defined as the reciprocal of resistance. When resistance is measured in ohms, conductance is measured using the SI unit, *siemens* (formerly known as a *mho*). Since the siemens is a very large unit, aqueous samples are commonly measured in microsiemens, or µS.

Even though the Conductivity Probe is measuring conductance, we are often interested in finding *conductivity* of a solution. Conductivity, *C*, is found using the following formula:

$$C = G \cdot k_C$$

where G is the conductance, and k_C is the cell constant. The cell constant is determined for a probe using the following formula:

$$k_C = d / A$$

where d is the distance between the two electrodes, and A is the area of the electrode surface.

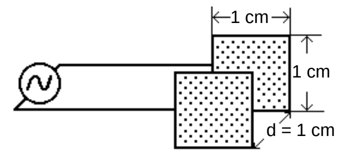


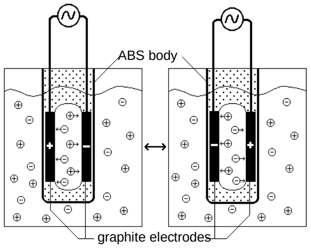
Figure 2

For example, the cell in Figure 2 has a cell constant: $k_C = d / A = 1.0\ cm / 1.0\ cm^2 = 1.0\ cm^{-1}$. The conductivity value is found by multiplying conductance and the cell constant. Since the Vernier Conductivity Probe 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 of 1000 µS, the conductivity, C, would be

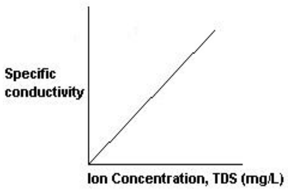
$$C = G \cdot k_C = (1000\ \mu S) \times (1.0\ cm^{-1}) = 1000\ \mu S/cm$$

A potential difference is applied to the two probe electrodes in the Conductivity Probe. The resulting current is proportional to the conductivity of the solution. This current is converted into a voltage.

Alternating current is supplied to prevent the complete ion migration to the two electrodes. As shown in the figure here, with each cycle of the alternating current, the polarity of the electrodes is reversed, which in turn reverses the direction of ion flow. This very important feature of the Conductivity Probe prevents most electrolysis and polarization from occurring at the electrodes. Thus, the solutions that are being measured for conductivity are not fouled. It also greatly reduces redox products from forming on the relatively inert graphite electrodes.



One of the most common uses of the Conductivity Probe 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, as shown here. The relationship persists until very large ion concentrations are reached.



Do I Need to Calibrate the Conductivity Probe?

You should not have to perform a new calibration when using the Conductivity Probe in the classroom. We have set the sensor to match our stored calibration before shipping it. You can simply use the appropriate calibration file that is stored in your data-collection program from Vernier

If you are using the Conductivity Probe for water quality analysis, you may choose to calibrate for more accurate readings. The Conductivity Probe can be easily calibrated at two known levels, using any of the Vernier data-collection programs. The calibration units can be µS/cm, mg/L as TDS, mg/L as NaCl, or salinity, in ppt.

- Select the conductivity range setting on the probe box: low = 0 to 200 µS, medium = 0 to 2000 µS, and high = 0 to 20,000 µS. Note: If you are not sure which setting to use, you may first want to load a stored Vernier calibration for one or more of the settings to determine an approximate value for the solution to be sampled.
- **Zero Calibration Point:** Simply perform this calibration point with the probe out of any liquid or solution (e.g., in the air). A very small voltage reading will be displayed. Call this value 0 µS or 0 mg/L.
- **Standard Solution Calibration Point:** Place the Conductivity Probe into a standard solution (solution of known concentration), such as the sodium chloride standard that is supplied with your probe. Be sure the entire elongated hole with the electrode surfaces is submerged in the solution. Wait for the displayed voltage to stabilize. Enter the value of the standard solution (e.g., 1000 µS, 491 mg/L as NaCl, or 500 mg/L as TDS). For further information on preparing and interpreting standard solutions, see subsequent sections on calibration.

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 you will be testing. For example, if you expect to measure conductivity in the range of 600 mg/L to 1000 mg/L (TDS), you may want to use a standard solution that is 500 mg/L for one calibration point and another standard that is 1000 mg/L for the second calibration point.

Maintaining and Replacing the Sodium Chloride Standard Calibration Solution

If you choose to calibrate the Conductivity Probe, you will want accurate standard solutions. The 1000 µS/cm Standard that shipped with the Conductivity Probe will last a long time if you take care not to contaminate it with a wet or dirty probe. This is a good concentration to calibrate your Conductivity Probe in the middle range (0 to 2000 µS/cm). Vernier sells three Conductivity Standards, one appropriate for each range of the Conductivity Probe. They come in 500 mL bottles. Order codes are:

Low Range (150 µS/cm)	CON-LST
Medium Range (1413 µS/cm)	CON-MST
High Range (12880 µS/cm)	CON-HST

To prepare your own standard solutions using solid NaCl or KCl:

- Use a container with accurate volume markings (e.g., volumetric flask) and add the amount of solid shown in the first column of Table 1. This standard can be used to calibrate using the amount shown in mg/L as NaCl (first column), mg/L as TDS (second column), or µS/cm (third column).

Table 1

Add this amount of NaCl to make 1 liter of solution	**TDS and Conductivity values equivalent to the NaCl concentration in the first column:**	
	total dissolved solids (TDS)	**conductivity (microsiemens/cm)**
0.0474 g (47.4 mg/L)	50 mg/L as TDS	100 µS/cm
0.491 g (491 mg/L)	500 mg/L as TDS	1000 µS/cm
1.005 g (1005 mg/L)	1000 mg/L as TDS	2000 µS/cm
5.566 g (5566 mg/L)	5000 mg/L as TDS	10,000 µS/cm

- Note also that standard solutions of lower concentration can be prepared by diluting standard solutions of higher concentration. For example, if you have a solution that is 1000 mg/L, and want to dilute it to obtain a solution that is 200 mg/L, simply take 100 mL of the 1000 mg/L solution and add enough distilled water to it to yield 500 mL of solution (~400 mL of water is added). The new solution has a concentration of 1000 mg/L x (100 mL / 500 mL) = 200 mg/L.

Automatic Temperature Compensation

Your Vernier Conductivity Probe is automatically temperature compensated between temperatures of 5 and 35°C. Note that the temperature of a solution is being read by a thermistor that extends into the space between the graphite electrodes. Readings are automatically referenced to a conductivity value at 25°C—therefore the Conductivity Probe will give the same conductivity reading in a solution that is at 15°C as it would if the same solution were warmed to 25°C. This means you can calibrate your probe in the lab, and then use these stored calibrations to take readings in colder (or warmer) water in a lake or stream. If the probe was not temperature compensated, you would notice a change in the conductivity reading as temperature changed, even though the actual ion concentration did not change.

Using the Conductivity Probe with Other Vernier Sensors

It is very important to know that the Conductivity Probe will interact with some other Vernier sensors and probes, *if* they are placed in the same solution (in the same aquarium or beaker, for example), *and* they are connected to the same interface box (e.g., the same LabPro). This situation arises because the Conductivity Probe outputs a signal in the solution, and this signal can affect the reading of another probe. The following probes *cannot* be connected to the *same interface* as a Conductivity Probe and placed in the same solution:

- Dissolved Oxygen Probe
- pH System
- Ion Selective Electrodes

If you wish to take simultaneous readings using any of the probe combinations listed above, here are some alternative methods:

- To take simultaneous conductivity and dissolved oxygen or conductivity and pH readings, you can connect the probes to *two different* interface boxes. If the two probes in question are connected to separate interfaces, the two probes will read correctly in the same solution.
- If you are sampling a lake or stream and want to use two of the probes with a single interface, you can connect the two probes in question to the same interface and load their respective calibrations. Place one probe in the water first and take its reading. Then remove it and place the second probe in the solution to take its reading.

The Stainless Steel Temperature Probe can be used in the same container with the Conductivity Probe.

Sampling in Streams and Lakes

It is best to sample away from shore and below the water surface, if possible. In free-flowing streams, there will usually be good mixing of the water, so that samples taken near the current will be quite representative of the stream as a whole. If you are sampling an impounded stream or a lake, there will be very little mixing—therefore, it is important to sample away from shore and at different depths, if possible. We do not recommend that you drop the Vernier Conductivity Probe so that the entire electrode is submerged. The electrode is not constructed to withstand higher pressures, so seepage into electronic components of the electrode might result. 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 sample bottles are filled brim full, then a gas such as carbon dioxide, which is capable of forming ionic species in solution, is prevented from dissolving in the water sample.

Since the probe has built-in temperature compensation, you can do your calibration in the lab. This means that even though you will be sampling in water that has a different temperature than your calibration temperature, the probe will take correct readings at the new sampling temperature.

Sampling in Ocean Salt Water or Tidal Estuaries: SALINITY

Salinity is the total of all non-carbonate salts dissolved in water, usually expressed in parts per thousand (1 ppt = 1000 mg/L). Unlike chloride (Cl^-) concentration, you can think of salinity as a measure of the total salt concentration, comprised mostly of Na^+ and Cl^- ions. Even though there are smaller quantities of other ions in seawater (e.g., K^+, Mg^{2+}, or SO_4^{2-}), sodium and chloride ions represent about 91% of all seawater ions. Salinity is an important measurement in seawater or in estuaries where freshwater from rivers and streams mixes with salty ocean water. The salinity level in seawater is fairly constant, at about 35 ppt (35,000 mg/L), while brackish estuaries may have salinity levels between 1 and 10 ppt.

The salinity range of the Conductivity Probe is 0 to 13 ppt. Seawater has a salinity of 35 ppt, so any seawater samples will need to be diluted before making measurements with this sensor. We recommend that you dilute seawater samples (or other samples that initially give readings above 13 ppt) to 1/4 of their original concentration, then multiply their measured salinity reading by 4 to obtain a final salinity value, in ppt. Brackish water in coastal estuaries is often in the range of 0 to 10 ppt, well within the high range of the probe. Note: Vernier also sells a Salinity Sensor (order code SAL-BTA) with a range of 0 to 50 ppt.

Since there is no stored salinity calibration for a Conductivity Probe, perform a two-point calibration using 5-ppt and 10-ppt salinity standards. Write down the displayed intercept and slope calibration values after the calibration is completed. You can immediately use the calibration, save the calibration along with an experiment file if you are using a computer, or load the calibration manually at a later time if you are using a calculator.

You will need to prepare two standard solutions to calibrate for salinity:

Low Standard (5 ppt salinity)

- Add 4.60 g of NaCl to enough distilled water to prepare 1 liter of solution.

High Standard (10 ppt salinity)

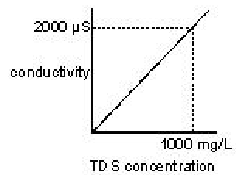
- Add 9.20 g of NaCl to enough distilled water to prepare 1 liter of solution.

More about Conductivity

Conductivity is an easy and informative water quality test. It is sometimes used as a “watchdog” environmental test—any change in the ionic composition of a stream or lake can quickly be detected using a conductivity probe. Conductivity values will change when ions are introduced to water from salts (e.g., Na^+, Cl^-), acids (H^+), bases (OH^-), hard water (Ca^{2+}, HCO_3^-, CO_3^{2-}), or soluble gases that ionize in solution (CO_2, NO_2, or SO_2). However, a conductivity probe will not tell you the *specific* ion responsible for the increase or decrease in conductivity. It simply gives a general indication of the level of total dissolved solids (TDS) in the stream or lake. Subsequent tests can then help to determine the specific ion or ions that contributed to the initial conductivity reading (e.g., pH for H^+, a titration for hard water as Ca^{2+}, or a colorimetric test for NO_3^-).

State and local regulations often place upper limits on the level of total dissolved solids in drinking water. These levels vary from state to state, but often must be at a level less than 1100 mg/L TDS. A conductivity probe can give a quick and accurate reading for such a determination.

Since there is a nearly linear relationship between conductivity and concentration of a specific ion or salt, the Conductivity Probe can be used to determine the concentration of an ion. A curve similar to the one shown here can be obtained if you prepare or purchase standard solutions (solutions with known concentrations). Note in this figure the 2:1 ratio between conductivity in µS/cm and TDS concentration in mg/L.



Even though total dissolved solids is often defined in terms of this 2:1 ratio, it should be understood that a TDS reading of 500 mg/L can have a different meaning in a sample that is mostly NaCl than in another sample that is composed primarily of hard water ions such as Ca^{2+} and HCO_3^-. The relationship between conductivity and sodium chloride concentration is *approximately* a 2:1 ratio and is very nearly a direct relationship. Table 1 shows some corresponding values for conductivity (µS/cm), concentration (mg/L as NaCl), and concentration (mg/L TDS).

Conductivity probes can provide students with important clues as to the ionic or molecular nature of compounds. Non-ionizing molecular compounds, such as methanol, will give readings of nearly zero conductivity. Note: Solutions that give a zero conductivity reading will be rare. Even in very pure distilled water, ions will be produced from dissociation of water into H^+ and OH^- ions or carbon dioxide dissolving and producing HCO_3^- ions. Water-soluble ionic compounds will give significant conductivity values, the size of which depends on such factors as ionic radius, charge of ions, and mobility of ions. Ionizing molecular compounds such as weak acids will yield conductivity values that can be used to relate the relative strength of these acids—an aqueous solution of a strong acid such as hydrochloric acid will give a much higher conductivity value than a weak acetic acid solution of equal concentration.

Table 2

Sodium chloride concentration (mg/L)	Total dissolved solids (TDS) (mg/L)	Conductivity (µS/cm)
1.0	1.1	2.2
5.0	5.4	10.8
10	10.7	21.4
20	21.4	42.7
50	52.5	105
100	105	210
150	158	315
200	208	415
500	510	1020
1000	995	1990
1500	1465	2930
2000	1930	3860
5000	4482	8963
10250	9000	18000

Warranty

Vernier warrants this product to be free from defects in materials and workmanship for a period of five years from the date of shipment to the customer. This warranty does not cover damage to the product caused by abuse or improper use.

Measure. Analyze. Learn.™

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