
CONDUCTIVITY SENSOR BT27i

USER'S GUIDE



CENTRE FOR MICROCOMPUTER APPLICATIONS

<http://www.cma-science.nl>

Short description

The CMA Conductivity sensor BT27i can be used to measure the conductivity of a solution. It has three measurement ranges, which can be selected using a switch located on the side of the sensor box:

- 0 to 200 $\mu\text{S}/\text{cm}$
- 0 to 2000 $\mu\text{S}/\text{cm}$
- 0 to 20000 $\mu\text{S}/\text{cm}$

The Conductivity sensor consists of a conductivity electrode and an amplifier. The conductivity electrode is a simple ABS-bodied 2-cell graphite type. It can be used for measuring salinity and changes in conductivity of a water sample. Although it will not identify the specific ions that are present, it can be used to determine the total concentration of ions in a sample.

The Conductivity sensor can be directly connected to analog BT inputs of the CMA interfaces. The sensor cable BT - IEEE1394 needed to connect the sensor to an interface is not supplied with the sensor and has to be purchased separately (CMA Article BTsc_1).

Sensor recognition

The Conductivity sensor has a memory chip (EEPROM) with information about the sensor: its name, measured quantity, unit and calibration. Through a simple protocol this information is read by the CMA interfaces and the sensor is automatically recognized when it is connected to these interfaces.

Notice that for the Conductivity sensor each of its measurement ranges has own EEPROM information. The switch position determines which information is used. To be able to detect to which of the ranges the sensor is set first disconnect the sensor from an interface, select the desired measurement range with the switch and then connect the sensor to the interface again.

If your Conductivity sensor is not automatically detected by an interface you have to manually set up your sensor by selecting it from the Coach Sensor Library.

How the sensor works

The Conductivity sensor measures the ability to conduct electricity in water solutions. When salts and other inorganic chemicals dissolve in water, they break apart into electrically charged ions. Ions increase the water's ability to conduct electrical current. Common ions in water that conduct electrical current include sodium, chloride, calcium, and magnesium. Organic compounds, such as sugars, oils, and alcohols, do not form ions.

The principle by which the sensor measures conductivity is simple - two graphite plates (cells) are placed in the sample, a potential is applied across the plates and the

current is measured. The Conductivity sensor actually measures the conductance of the solution (the inverse of the resistivity R), which is determined from the voltage and current values according to Ohm's law ($G = 1/R = I/V$).

The specific cell constant (K) of the conductivity electrode is used to determine the conductivity (C). The conductivity is the cell conductance multiplied by the cell constant, $C=G*K$. The electrode separation distance divided by the electrode area determines the cell constant. The supplied electrode has a nominal cell constant K of 1.0 cm^{-1} .

The SI unit of conductance is Siemens (S). Since S is a very large unit, conductance of aqueous samples is commonly measured in μS , and conductivity in $\mu\text{S/cm}$. Some typical conductivity ranges of hydrous solutions are:

Sample	Conductivity ($\mu\text{S/cm}$)
Pure water	0.055
Distilled water	0.5
Deionized water	0.1 – 10
Rain water	20 - 100
Drinking water	50 - 200
Tap water	100 - 1500
River water	250 - 800
Brackish water	1000 - 8000
KCl 0.01 M	1410
MgSO ₄	5810
KCl 0.1 M	12900
Ocean water	53000
H ₂ SO ₄	82600
KCl 1.0 M	112000

In order to prevent complete ion migration to the two electrodes, the sensor uses alternating current. With each cycle of alternative current the polarity of the electrodes are reversed which in turn reverses the direction of ion flow. This will prevent electrolysis and polarization.

Calibration

The CMA Conductivity sensor BT27i is supplied calibrated. The output of the sensor is linear with respect to conductivity. Each of its measurement ranges has its own calibration. The supplied calibration functions are:

- Measurement range 0 .. 200 $\mu\text{S/cm}$: $C (\mu\text{S/cm}) = 65.7 * V_{\text{out}}(\text{V})$
- Measurement range 0 .. 2000 $\mu\text{S/cm}$: $C (\mu\text{S/cm}) = 847.2 * V_{\text{out}}(\text{V})$

- Measurement range 0 .. 20000 $\mu\text{S}/\text{cm}$: $C (\mu\text{S}/\text{cm}) = 7819 * V_{\text{out}}(\text{V})$

The Coach 6 program allows selecting the calibration supplied by the sensor memory (EEPROM) or the calibration stored in the Coach 6 Sensor Library. For better accuracy the pre-defined calibration can be shifted.

For even more accurate measurements a new user calibration can be performed in the Coach. Before starting the sensor calibration be sure that the conductivity electrode is clean. Soak the tip of the electrode in distilled water for about 10 minutes. If this is not possible, rinse the tip thoroughly with distilled water before use. Wipe the outer part of the electrode body with a clean paper towel. Shake vigorously to remove any droplets from the cell chamber. The electrode surface should be dry.

- Select the desired conductivity range on the sensor box.
- **Zero calibration point** - perform this calibration point with the electrode out of any solution (e.g. in air). This is 0.0 $\mu\text{S}/\text{cm}$ value.
- **Standard solution calibration point** - place the electrode into a standard solution (solution of known conductivity). Be sure the entire elongated hole with electrode surfaces is submerged in the solution. Wait for the displayed voltage to stabilize. Enter the value of the standard solution e.g. 1000 $\mu\text{S}/\text{cm}$.

For even better results, a more-point calibration can be performed using standard solutions that cover the expected range of conductivity values. Selecting standards is very important; you should always choose one that has the approximate conductivity of the solution to be measured. In order to verify proper operation of your electrode, you should select another standard either above or below your first standard.

Having accurate standard solutions is essential for performing good calibrations. You can prepare your own standard solutions as shown in the table.

Amount of NaCl to make 1 liter of solution	Equivalent Conductivity values
0.0474 g	100 $\mu\text{S}/\text{cm}$
0.491 g	1000 $\mu\text{S}/\text{cm}$
1.005 g	2000 $\mu\text{S}/\text{cm}$
5.566 g	10000 $\mu\text{S}/\text{cm}$

There is no exact relationship between Conductivity in $\mu\text{S}/\text{cm}$ and total solids TDS in ppm (parts per million). It has been discovered experimentally that for particular types of water there is an approximate relationship. In water with a higher proportion of sodium chloride, to get to ppm just multiply the $\mu\text{S}/\text{cm}$ reading by 0.5. For most other water solutions use a factor of 0.67 instead.

Automatic temperature compensation

Temperature has a large effect on conductivity. The Conductivity electrode has a built-in temperature sensor that is used to compensate for changes in the conductivity of solutions with a temperature between 5 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 as 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 compensation the conductivity readings change with temperature, even though the actual ion concentration did not.

Collecting data

To take measurements:

- Soak the tip of the Conductivity electrode in distilled water for about 10 minutes. If this is not possible, rinse the tip thoroughly with distilled water.
- Wipe the outer part of the electrode body with a clean paper towel. Shake vigorously to remove any droplets from the cell chamber.
- Select the desired measurement range with the switch.
- Connect the sensor to an interface. In most cases the sensor will be automatically detected. If this not happen manually select the Conductivity sensor BT27i from the Coach Sensor Library.
- Place the Conductivity electrode in the sample to be tested. The sample must be at least 3 cm deep to ensure the cell chamber is fully submerged.
- Stir the solution gently to get rid of any air bubbles that could be trapped in the cell chamber. Wait for 10 seconds to allow the readings to stabilize.
- If you are taking readings in a solution that has a temperature below 10°C or above 35°C, allow more time for the readings to stabilize.
- Rinse the end of the probe with distilled water before taking another measurement.
- Clean thoroughly when the measurement is completed to avoid any contamination for the electrode's next use.

Warning:

Do not place the electrode:

- in viscous, organic liquids, such as heavy oils, glycerin (glycerol) or ethylene glycol.
- in acetone or non-polar solvents, such as pentane or hexane.

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 and they are connected to the same interface (e.g. the same VinciLab). 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 cannot be connected to the same interface and placed in the same solutions:

- dissolved oxygen sensor,
- pH sensor,
- salinity sensor.

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

Suggested experiments

The Conductivity sensor can be used to perform a wide variety of experiments:

- Confirmation of the direct relation between conductivity and ion concentration in aqueous solutions. Concentration of unknown samples can be determined.
- Measurement of changes in conductivity resulting from photosynthesis in aquatic plants, with the resulting decrease in bicarbonate-ion concentration due to the carbon dioxide consumption.
- Monitoring the rate of reaction in a chemical reaction in which dissolved ions and solution conductivity varies with time due to ionic species 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 diffuse 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.

Cleaning, storage and maintenance of the Conductivity electrode

The Conductivity electrode needs to be kept clean. Depending on the sample application, the electrode may require cleaning periodically to ensure accurate measurements.

- In most situations, water with a mild liquid detergent is an effective cleanser. Soak the electrode in warm water and a mild detergent for 15 minutes.
- Ethanol may be used to clean the electrode as long as the wash time is limited to a maximum of 5 minutes.
- Lime or hydroxide coating can be removed by soaking in a dilute acid solution such as 0.1 M hydrochloric acid or 0.5 M acetic acid for 15 minutes.

- To prevent cell damage, abrasives or sharp objects should not be used to clean an electrode.
- After cleaning, rinse well with distilled water, shake vigorously and leave to air-dry.
- Store the electrode dry.

Practical information

- Avoid scratching the inside electrode surfaces of the probe.
- The most common reason for inaccurate measurements is cross contamination of samples. Take care not to transfer droplets of one sample to another. Clean the electrode with distilled water between different samples.
- Be sure that samples are capped to prevent evaporation. It is best to fill sample bottles to the brim to prevent a gas such as carbon dioxide dissolving in the water sample.
- Do not use the sensor in a situation that could result in damage to the graphite plates in the cell chamber. Do not attempt to blot or wipe the inside of the cell.
- The automatic temperature compensation for this electrode operates over the range 5°C to 35°C, but it can be placed in solutions within a temperature range of 0 to 80°C.
- The conductivity electrode not only measures conductivity between the graphite plates but also, to a lesser extent, in a field to the sides of the electrode. In a narrow vessel, the walls may interfere with this field. If the electrode is held too close to the top of the liquid level or other objects (e.g. the bottom of a beaker) an incorrect reading may result.

Technical Specifications

<i>Sensor kind</i>	Analog, generates an output voltage between 0 - 5 V
<i>Measuring ranges</i>	
<i>Low:</i>	0 to 200 $\mu\text{S}/\text{cm}$
<i>Medium:</i>	0 to 2000 $\mu\text{S}/\text{cm}$
<i>High:</i>	0 to 20000 $\mu\text{S}/\text{cm}$
<i>Resolution using 12- bits 5V AD converter</i>	
<i>Low:</i>	0.1 $\mu\text{S}/\text{cm}$
<i>Medium:</i>	1 $\mu\text{S}/\text{cm}$
<i>High:</i>	10 $\mu\text{S}/\text{cm}$
<i>Accuracy</i>	$\pm 1\%$ of full-scale reading for each range
<i>Response time</i>	98% of full-scale reading in 5 s, 100% in 15 s.
<i>Temperature</i>	Compensation: automatic between 5°C and 35°C. Range: between 0°C and 80°C
<i>Cell constant</i>	1.0 cm^{-1} , dip type, ABS body, parallel carbon (graphite) electrodes
<i>Calibration functions</i>	
<i>Low:</i>	$C (\mu\text{S}/\text{cm}) = 65.7 * V_{\text{out}}(\text{V})$
<i>Medium:</i>	$C (\mu\text{S}/\text{cm}) = 847.2 * V_{\text{out}}(\text{V})$
<i>High:</i>	$C (\mu\text{S}/\text{cm}) = 7819 * V_{\text{out}}(\text{V})$
<i>Connection</i>	IEEE1394 connector for BT-IEEE1394 sensor cable. Sensor cable not delivered with the sensor.

Warranty:

The Conductivity sensor BT27i is warranted to be free from defects in materials and workmanship for a period of 12 months from the date of purchase provided that it has been used under normal laboratory conditions. This warranty does not apply if the sensor has been damaged by accident or misuse.

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

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