



## Module 2, Add on Lesson – Conductivity Sensor

**Student**

**90 minutes**

### **Purpose of this lesson**

- Investigate the variation of resistance with conductivity
- Construct a sensor to measure the conductivity of water
- Graph data and reason about curves and linear relationships
- Calibration of the constructed conductivity sensor
- Write an NXT program to collect conductivity measurements

### **Materials**

Copy of the lesson

1 Wooden pencil

2 Solid copper wires (not twisted) (12 gauge), about 9 inches long, with one end stripped

1 Half of an NXT cable

1 NXT

Electrical tape

4 feet of Hook-up wire

Solder and soldering iron

Liquid electrical tape

2 plastic teaspoons of salt (plain table salt)

1 plastic teaspoon

2 plastic 16 oz. cups

Graph paper (or Excel)

Preparation of three solutions with varying salinities for assessing sensors

### **Background and Discussion**

#### **What is conductivity?**

Electrical conductivity (EC) is a measure of the ability of an aqueous solution (in this case water) to pass an electrical current. Conductivity in water is affected by:

- Inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge)

- Sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge)
- Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current well and have a low conductivity when in water
- Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 degrees Celsius (25 C).

Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize (dissolve into ionic components) when washed into the water. On the other hand, streams that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water. Ground water inflows can have the same effects depending on the bedrock they flow through.

Discharges to streams can change the conductivity depending on their make-up. A failing sewage system or runoff would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity.

A piece of wire or other conductor has a *resistance* measured in Ohms ( $\Omega$ ). The longer the wire, the more resistance it has, so we can also think in terms of *resistivity* - a property of the material which the wire is made of. Resistivity has units of Ohms per meter or  $\Omega /m$ .

The Standard International (SI) unit of measurement of electrical *conductance* is the siemens (symbol: S). Electrical *conductance* is the inverse of *resistance*, i.e. a resistor having resistance  $2 \Omega$  will have a conductance of  $\frac{1}{2}S$ .

*Conductivity* is conductance per meter, i.e. it is the inverse of *resistivity* It therefore has units of siemens per meter (S/m) (i.e. the higher the resistivity and resistance, the lower the conductivity and conductance).

The measurement of the salinity of a solution, or the amount of dissolved salts in the

solution, is based on the electrical conductivity measurement of the solution. The dissolved salts measured in this experiment will primarily be sodium chloride (NaCl).

### ***Sampling and equipment Considerations***

Conductivity is useful as a general measure of stream water quality. Each stream tends to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular conductivity measurements. Significant changes in conductivity could then be an indicator that a discharge or some other source of pollution has entered a stream.

In this lesson, a conductivity probe will be created by passing electric current through the water between the two electrodes. By measuring the voltage between the electrodes, it is possible to calculate the resistance of the water from the equation  $V=IR$ . One divided by this resistance gives us the *conductance*. By knowing the distance between the probes, we can convert *conductance* into *conductivity*.

### **Procedure**

#### **Part 1 – Constructing a conductivity probe**

- 1) Cut or obtain from your teacher two foot long sections of solid wire.
- 2) Strip one end of each wire. Strip approximately one inch of coating from each end.
- 3) Place a wire section on either side of a pencil. Secure the solid wire sections to the pencil with electrical tape. Let the unstripped ends stick out past the end of the pencil by about 1 inch, as shown below in Figure 1. The two unstripped ends should be even with each other. This device is the conductivity probe.



**Figure 1**

- 4) Strip approximately one inch of outer plastic coating off of one half of an NXT cable.
- 5) Strip approximately one half inch of plastic coating off of the black and white wires contained in the NXT cable.
- 6) Solder the black wire to a 1 to 4 foot long section of hook-up wire (the length of the hook-up wire will determine the length of the lead to the sensor).
- 7) Solder the white wire to a 1 to 4 foot long section of hook-up wire.
- 8) Solder the black wire/hook-up wire to one of the stripped ends of the solid wires on the salinity probe.
- 9) Solder the white wire/hook-up wire to the other solid wire on the salinity probe.
- 10) Cover the solder joints with liquid electrical tape.

## **Part 2 – Create NXT program**

### **Background and Discussion**

The NXT contains analog-to-digital converters which measure a voltage and converts the measurement into a number that the computer can store and read.

Ports 1, 2, 3, and 4 on the NXT each contain an analog-to-digital converter and is built into each port as part of a circuit that also contains a 5 V power supply, which acts like a battery, and a 10 kΩ resistor.

The circuit inside each NXT port is shown in Figure 2. The white wire and the black wire are two of the wires in the 6-wire NXT connector that plugs into these ports. The device can read voltages between 0 and 5 V.

If it reads zero volts, it will send the number 0 to the computer. If it reads 5 volts, it will send the number 1023 to the computer. If it reads a number between zero and 5 volts, the number is sends to the computer will be proportional to the voltage that it reads. So if the voltage is x, and the number sent to the computer is n, n and x will be related by equation 1:

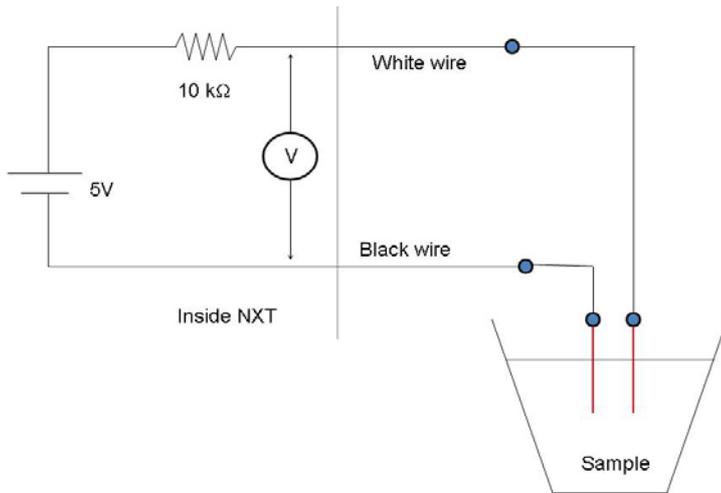
$$\frac{x}{5} = \frac{n}{1023}$$

(Equation 1)

Rearrange the equation:

$$x = 5 * n/1023$$

This is what is coded in the NXT through the steps below.



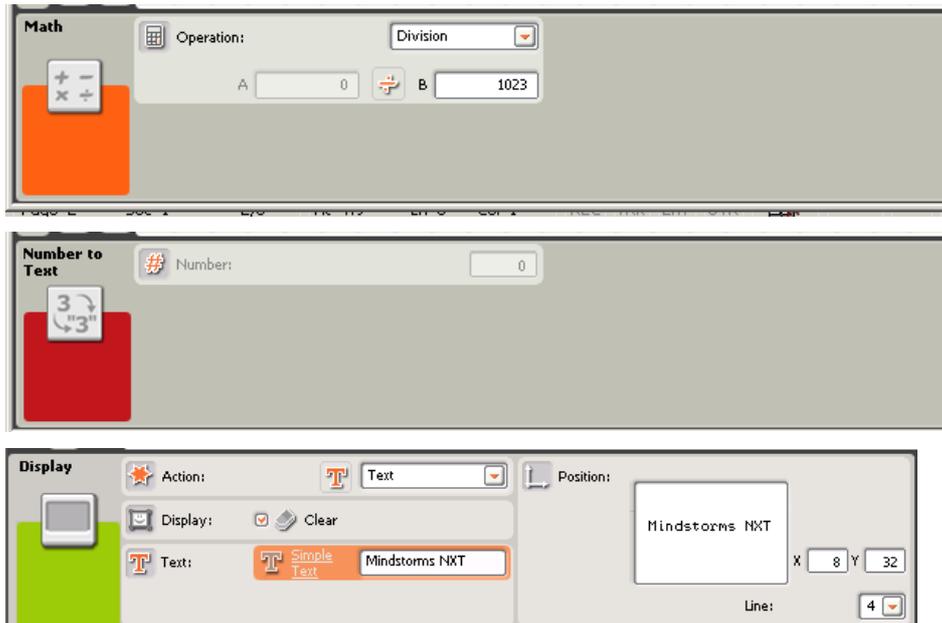
**Figure 2.** The NXT voltage reading circuit. It measures the voltage between the white and black wires.

### Procedure

1) Write and save the following program:

The screenshot shows the NXT-G programming environment with the following blocks:

- Loop:** Control: Forever. Show:  Counter.
- Touch Sensor:** Port: 1. Action:  Pressed,  Released,  Bumped. A Reset button is visible.
- Math:** Operation: Multiplication. A = 0, B = 5.



This program should take a reading from your sensor and display it on the NXT screen in units of volts.

**Part 3 – Calibrate the conductivity probe (prepare the solutions and allow to stand for at least two hours before performing the calibration exercise)**

- 1) Calibrate the conductivity probe with water with known salinities.
- 2) 1 gram/Liter = 1 part per thousand, 4 grams/Liter = 4 part per thousand
- 3) Dissolve 4 grams of salt in 1 Liter (1,000 ml) of water, creating a 4 ppt (parts per thousand) solution. Dissolve 3 grams of salt in 1 Liter, creating a 3 ppt solution, 3 grams and 1 gram respectively. In addition, fill a cup with fresh (0 ppt) water.
- 4) Submerge the end of the conductivity probe into the 4 ppt solution.
- 5) To obtain a stable reading, move the probe around in the water, while ensuring the ends of the probe wires always stay in the water. A good way to do this is to move the probe in a circle at a speed of about 4 circles per second. Wait a few seconds until the reading becomes fairly stable, then record the voltage measurement in Table 1 on the following page, and remove the probe from the 4 ppt solution.
- 6) Remove the probe from the solution and rinse with fresh water or dip into a container of fresh water.
- 7) Submerge the end of the conductivity probe into the 3 ppt solution, obtain a stable reading and record the voltage measurement in Table 1.

**Table 1**

<b>Salinity (g/L)</b>	4.0	3.0	2.0	1.0	0
<b>Voltage (V)</b>					

**NOTE:** In the SENSE IT project, the conductivity sensor data is used to indicate salinity. Salinity is a measure of the total amount of dissolved material, or the salt content, in water.

Salinity is the number of grams (g) of material in 1000g of water. For example, if seawater has 35g of salt in 1000g of water, it has a salinity of 35‰ (parts per thousand).

1 gram/Liter = 1 part per thousand (ppt)

Practical Salinity Units (PSU) are often used to describe salinity: a salinity of 35‰ equals 35 PSU.

1 gram/Liter = 1 part per thousand (ppt) = 1 Practical Salinity Unit (PSU)

**Assessment**

- 1) Plot a graph of salinity versus voltage.
- 2) Obtain three samples of solutions with unknown salinity concentrations from your teacher. Using the conductivity sensor, measure and record the voltages in the table below. Use the graph created in the last step to determine the salinity of each sample based on the voltage and record the results below.

	<b>Solution 1</b>	<b>Solution 2</b>	<b>Solution 3</b>
<b>Salinity (g/L)</b>			
<b>Voltage (V)</b>			