

30 minutes

Purpose of this lesson

- Utilize positive, negative and inverse mathematical relationships in data.
- Program mathematical operators on the NXT computer.
- Program the NXT to produce an output which varies positively with temperature.

Materials

Copy of the lesson

Computer with Mindstorms software

1 NXT

Graphs plotted in Lessons 1 and 2 which show “NXT raw value” versus temperature

Graph paper

Part 1 - creating an output which varies positively with temperature

The relationship between NXT output and temperature should be positive and approximately linear. In module 1, we did this with the original circuit by measuring the voltage across the 10kΩ resistor rather than across the thermistor itself. We will use the same trick here.

Remember:

In module 1, your circuit looked like this:

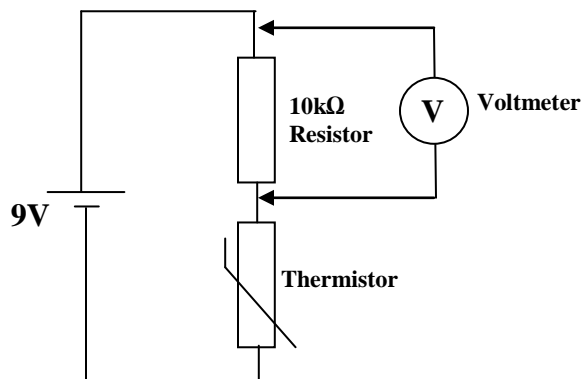


Fig. 1a. Temperature sensor circuit from module 1.

NXT circuit is like this:

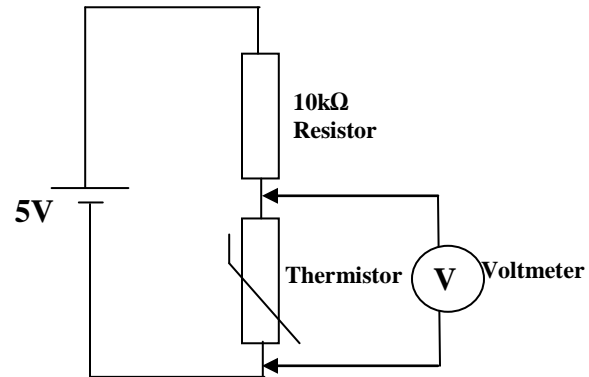


Fig. 1b. Internal circuit of NXT when connected to an external thermistor. The Voltmeter shown here is built inside the NXT and sends voltage readings to your programs.

Also remember that the voltage measured by the NXT (call this V_{NXT}) is the voltage across the thermistor, and is given by the potential divider equation:

$$V_{NXT} = \frac{R_T}{(10000\Omega + R_T)} \times 5 \quad \text{equation 1}$$

Where R_T is the resistance of the thermistor, which varies with temperature (see module 1, lessons 4 and 5).

The total voltage across the potential divider circuit inside the NXT is 5V, and this is the total voltage across both the 10k Ω resistor and the thermistor together. In other words:

$$5 = V_{NXT} + V_T \quad \text{equation 2}$$

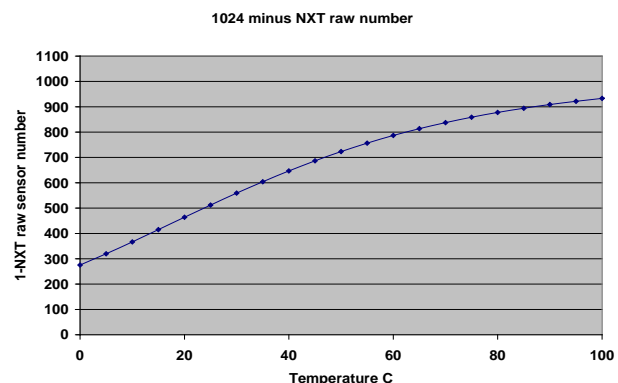
where V_{NXT} is the voltage across the 10k Ω resistor (which is the voltage measured by the NXT's internal voltmeter), and V_T is the voltage across the thermistor. Therefore you can calculate the voltage across the 10k Ω resistor alone, as simply 5 minus the voltage across the thermistor, i.e.

$$V_T = 5 - V_{NXT} \quad \text{equation 2}$$

Remember the NXT measures voltages as raw numbers from 0-1024, where 1024 represents 5V. Therefore, equivalent $(5 - V_{NXT})$ in voltage is equivalent to $(1024 - \text{NXT raw value})$.

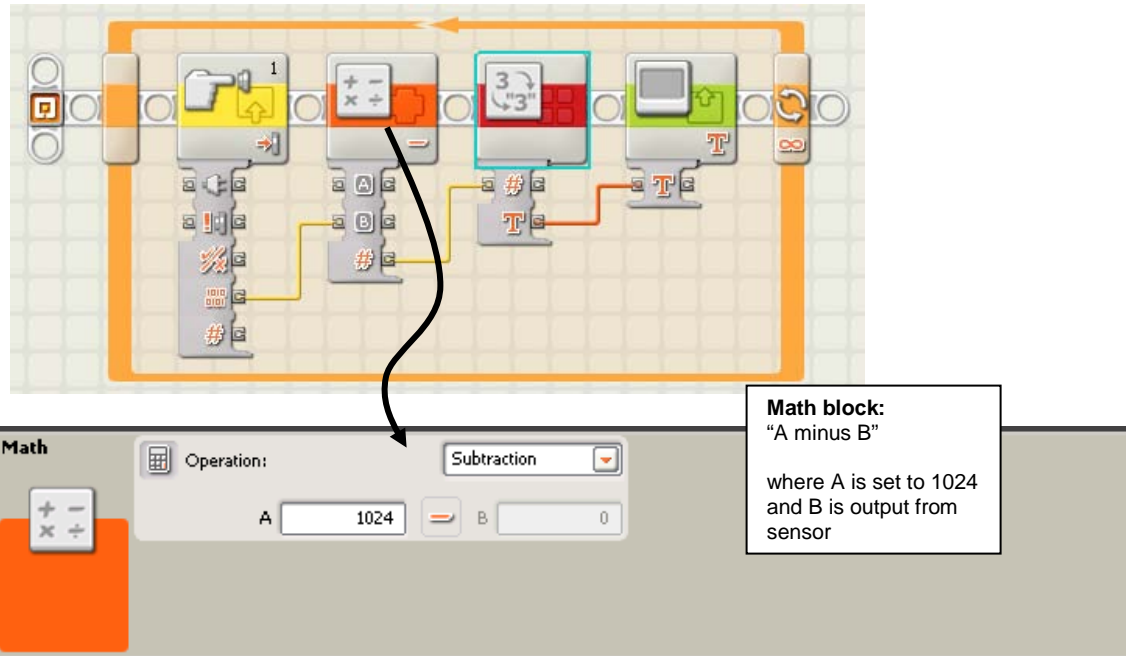
Assessment

Try predicting the graph of these values $(1024 - \text{NXT raw value})$ versus temperature. You will need to use the graphs plotted in Lessons 1 and 2 which show "NXT raw value" versus temperature. On this new plot, use the vertical axis (y-axis) for $1024 - \text{NXT raw value}$, and use the horizontal axis (x-axis) for temperature.



Part 2 – programming the NXT to output values which vary positively with temperature

1) Use the Mindstorms software to create the program below:



The image shows a screenshot of the Mindstorms software interface. At the top, a program loop is visible, consisting of several blocks: a loop block, a sensor block, a math block, a text display block, and a repeat block. A callout box points to the math block, which is configured for subtraction. Below the main interface, a detailed view of the Math block is shown. The 'Operation' dropdown is set to 'Subtraction'. The 'A' input field is set to '1024' and the 'B' input field is set to '0'. A text box next to it explains: 'Math block: "A minus B" where A is set to 1024 and B is output from sensor'.

This program means:

In an infinitely repeated loop:

Read the raw sensor value (0-1024 from the voltmeter in the sensor port)

Subtract the raw value from 1024

Convert the resulting number into text

Display this text on the NXT screen

Keep on repeating

Use the math block to do the subtraction. When you insert the math block you will see a panel appear at the bottom of your screen where you can configure the block to perform subtraction, and set "A – B" to be 1024 – raw sensor value.

Assessment

How does adding this extra step make the NXT circuit more like the sensor you built in Module 1, Lesson 5?

Answer: The output varies positively with temperature. A better answer is, now the sensor output will behave the same as in the earlier sensor when we took the voltage reading across the resistor instead of the thermistor.