

Making an Arduino thermometer from a diode

By Leon Harris

Australian National Curriculum Standards:

Math ACMNA215 -Sketch linear graphs using the coordinates of two points and solve linear equations

Science ACSIS203 -Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies

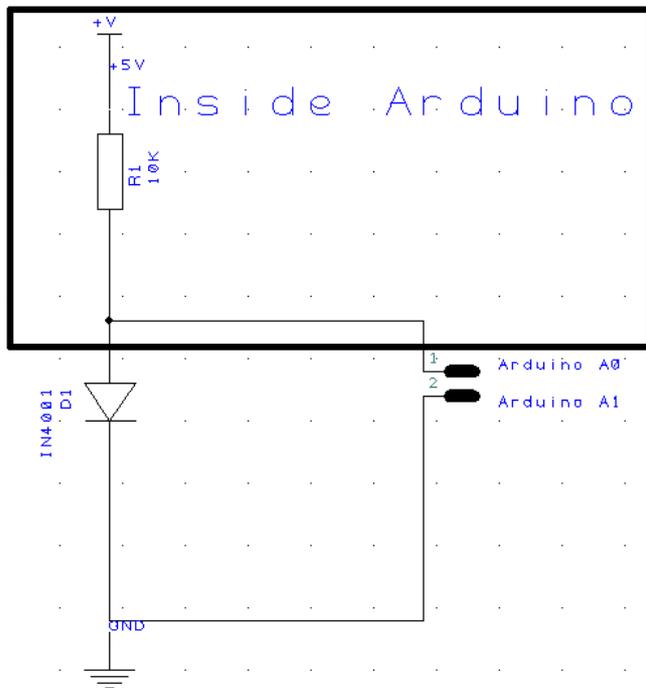
Background

Silicon diodes are devices made of two types of silicon that meet to form a junction. In order for there to be a flow of current (electricity) through the diode, a minimum potential difference must exist across the junction of the diode. That potential difference is dependent on temperature, and declines by 2 millivolts per degree centigrade. The relationship between temperature and potential difference across the diode (its band gap) is known to be a linear function.

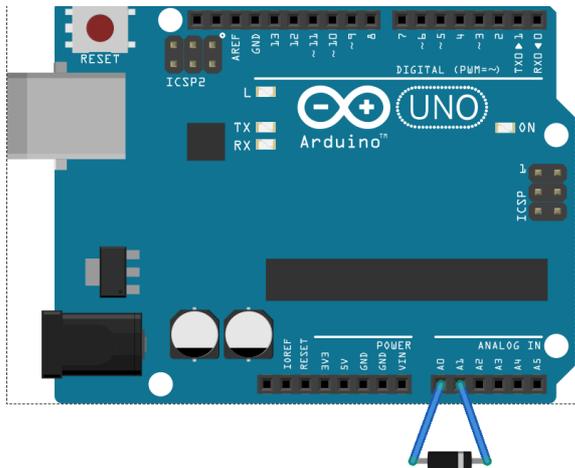
A good circuit simulator of a diode can be found at www.falstad.com, and details on how to use this are shown in the reference, for those who might be interested in understanding the electrical behaviour of these devices. Unfortunately, the simulation does not include the effect of temperature – for most applications involving diodes, the temperature effect is inconsequential.

Our goal in this exercise is to make a cheap and accurate thermometer. To do this we will do some linear algebra and graphing. The key insight that this exercise should give is that hidden in nearly every modern device that measures something is a calibration curve that translates the raw signal (often measured in volts, or as with here in raw numbers without units) into the physical quantity that you are interested in. The theory that you learn in this lab today will allow you to make an enormous number of different sensors – such as light, alcohol, gas, colour, and sound.

In this exercise, we will build the following circuit:



This means placing just one component, the diode, between pins A0 and A1 as shown.



To make this circuit, we must first connect the internal 10K ohm resistor to the anode pin of the diode. One of the great things about Arduinos is that we can control the behaviour of the Analog ports (A0-A5) to be either inputs or outputs. We do this in the software using the line in the software

```
pinMode(A0,INPUT_PULLUP);
```

This “pulls up” the voltage on pin A0 to 5v via the internal 10K resistor.

The next thing that we need to do is to connect the cathode end of the diode to 0 volts.

We do this with the following two lines of code:

```
pinMode(A1,OUTPUT);
```

```
digitalWrite(A1,LOW);
```

“Low” just means “connected to ground(ov)”.

Activity Sheet for Arduino thermometer

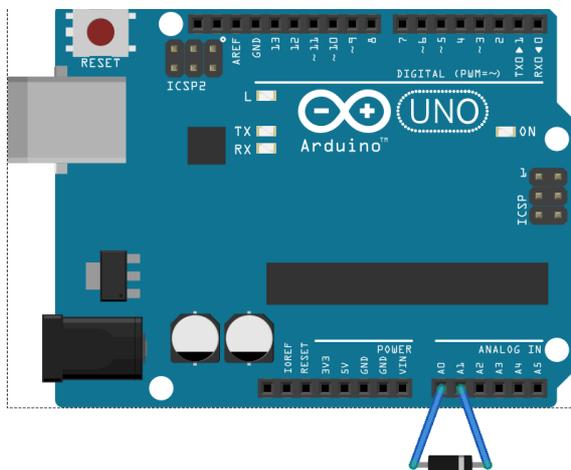
Materials Needed:

- 1x Arduino Uno board
- 1x USB to Arduino cable
- 1x Windows or Macintosh PC with Arduino IDE software obtainable from here http://arduino.cc/en/Main/Software#_UxFoTYW4zCs
- 1x 1N4001 diode (or any other small silicon diode)
- Graph paper and pencil, or Excel program
- 2 polystyrene cups.
- Hot and cold water
- A regular thermometer
- Cling film
- The Arduino sketch <https://drive.google.com/file/d/0B8NyMDTl1ovXbFRiRWU0Z3ZPYUU/edit?usp=sharing>

Instructions:

Part A: Getting the software to work.

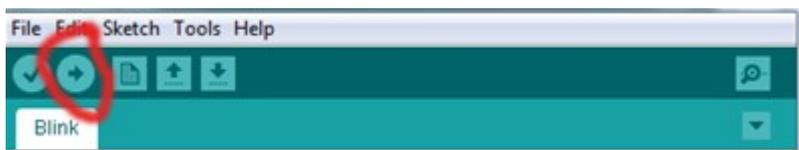
1. Insert the diode into the A0 and A1 pins of the Arduino as shown.



2. Plug your Arduino board into the usb port of your computer



3. Click the Arduino icon
4. Download the Arduino software (the sketch) from <https://drive.google.com/file/d/0B8NyMDTl1ovXbFRiRWU0Z3ZPYUU/edit?usp=sharing> and open it in notepad, or another text editor.
5. Copy all of the text into the Arduino sketch, then press the “compile and upload” button to transfer it to the Arduino board. as shown.



6. Once the sketch is compiled and uploaded, click the magnifying glass icon (the serial window) on the top right hand side of the Arduino IDE window, and observe the numbers that appear once per second. These are unscaled measurements which are proportional to temperature.

Part B: Calibrating your thermometer

1. Place a layer of cling film or Gladwrap over your Arduino, and make the smallest possible hole for the diode to poke out.
2. Place cold water and a thermometer into polystyrene cup, and then just place the diode part of your circuit into the beaker. DO NOT GET THE ARDUINO WET !
3. Wait until you get a stable temperature reading on both the thermometer, and in the serial window.
4. Record both the temperature, and the value in the serial window.
5. Place hot water and the thermometer into another polystyrene cup. Cover the cup with Clingfilm or Gladwrap to minimise heat loss by evaporation.
6. Place the diode from your circuit so that it is just under the surface of the water. DO NOT GET THE ARDUINO WET !
7. Wait until you get a stable temperature reading on both the thermometer, and in the serial window.
8. Record both the temperature, and the value in the serial window.

Part C: Processing the data

Record your results in the table below

Arduino Output	Temperature (°C)

It is known that there is a linear relationship between temperature and voltage drop across a diode. The general formula for a straight line is

This means that

Notice that we are putting the independent and dependent variables around the opposite way to how you usually do in a science report. That is fine – we are using the graph and calculations to let us convert a measured value from the Arduino into a temperature value. From this perspective, the independent and dependent variables are swapped. So Temperature must go on the y axis, and Arduino output on the x axis.

To calculate the slope of the line, we can use the general formula

In our case, this means

In the box below, calculate m for your diode using the data that you have collected.

Answer: $m = \dots\dots\dots$

Was your slope a negative number? Great! Your sum looks correct!

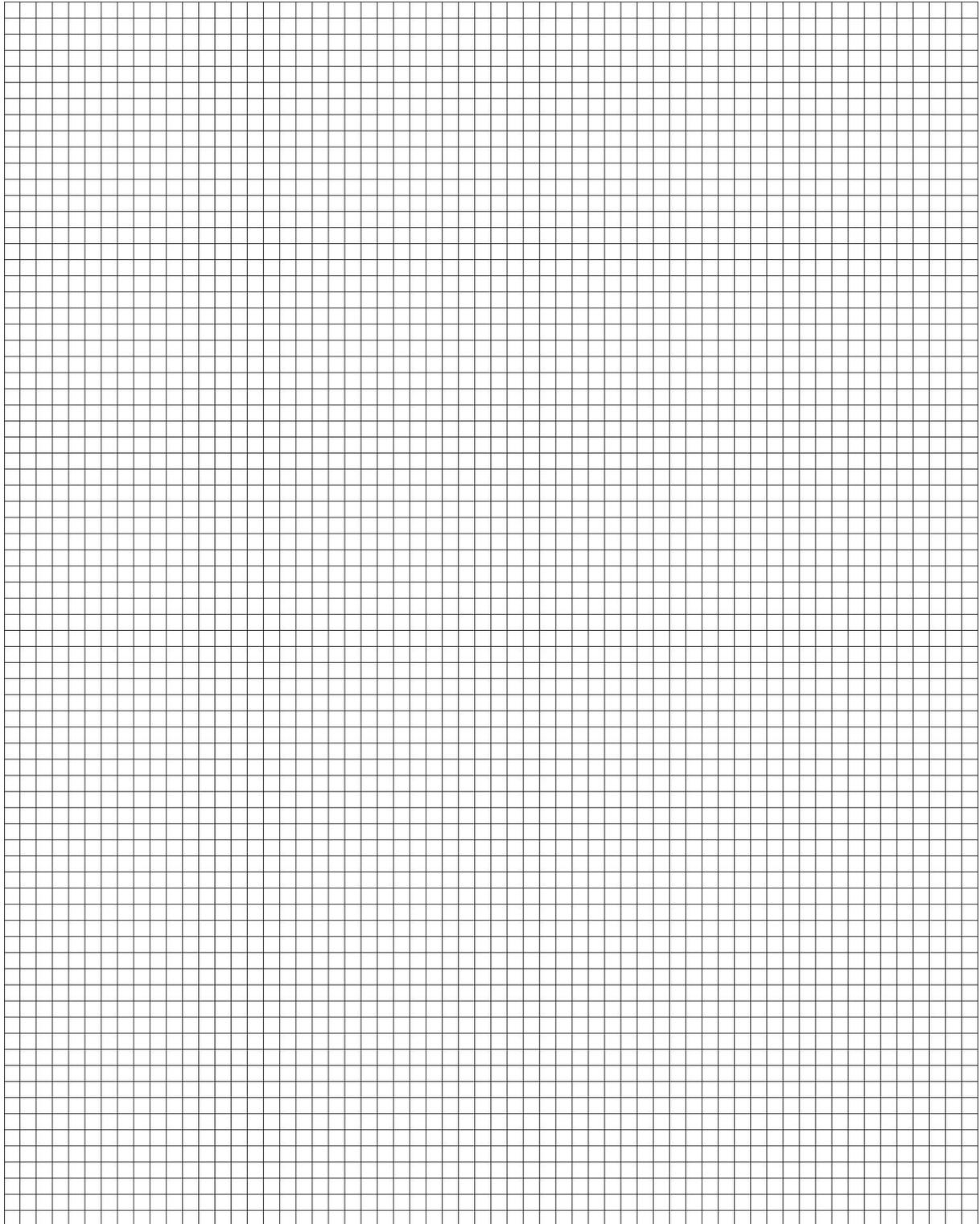
Now all we need to do is to calculate the offset, which is the point where the line crosses y or temperature axis. To do this, we rearrange our equation to find the offset.

Rearranged to get:

In the box below, calculate the offset using one pair of data points from your results

Answer: Offset =

Check your answer graphically by plotting Temperature (y axis) versus Arduino output (x axis)



Extension Activity:

Write, or modify the Arduino sketch so that it prints the temperature in degrees Celsius on the serial port.

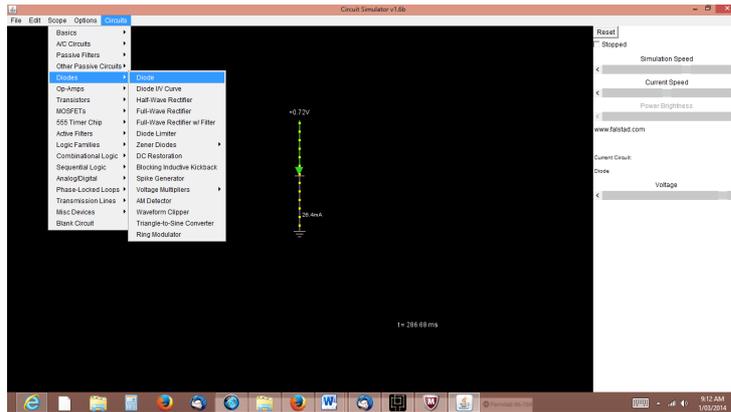
For help, have a look at the sample sketches in File->examples, or browse the site at <http://arduino.cc>

References

<http://www.australiancurriculum.edu.au/science/Curriculum/F-10> Australian National Curriculum-Science, accessed 28 Feb 2014

<http://www.australiancurriculum.edu.au/mathematics/Curriculum/F-10> Australian National Curriculum - Mathematics, accessed 28 Feb 2014

<http://www.falstad.com/circuit/> A good circuit simulator. You need to have java enabled in your browser. When the applet loads, click on the circuits menu -> diodes -> diode, and adjust the voltage slider on the right hand side.



<http://arduino.cc> Arduino homepage. Here you will find the Arduino IDE, support forums, tutorials, and heaps more. accessed 1 March 2014