https://www.halvorsen.blog

Temperature Sensors

Hans-Petter Halvorsen

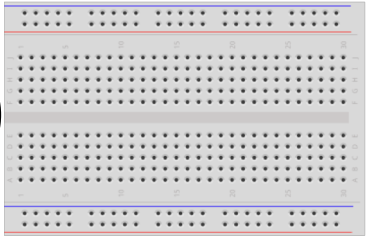
Temperature Sensors

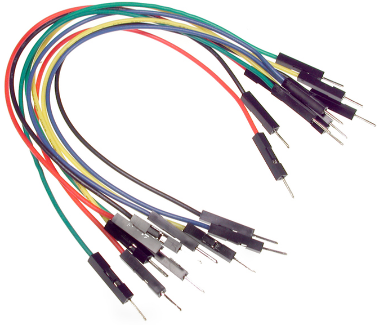
Here are some examples of Temperature Sensors:

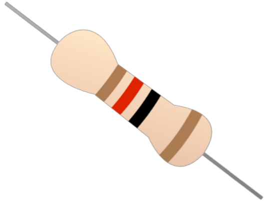
- TMP36 Temperature Sensor
- Thermistor 10K

Hardware

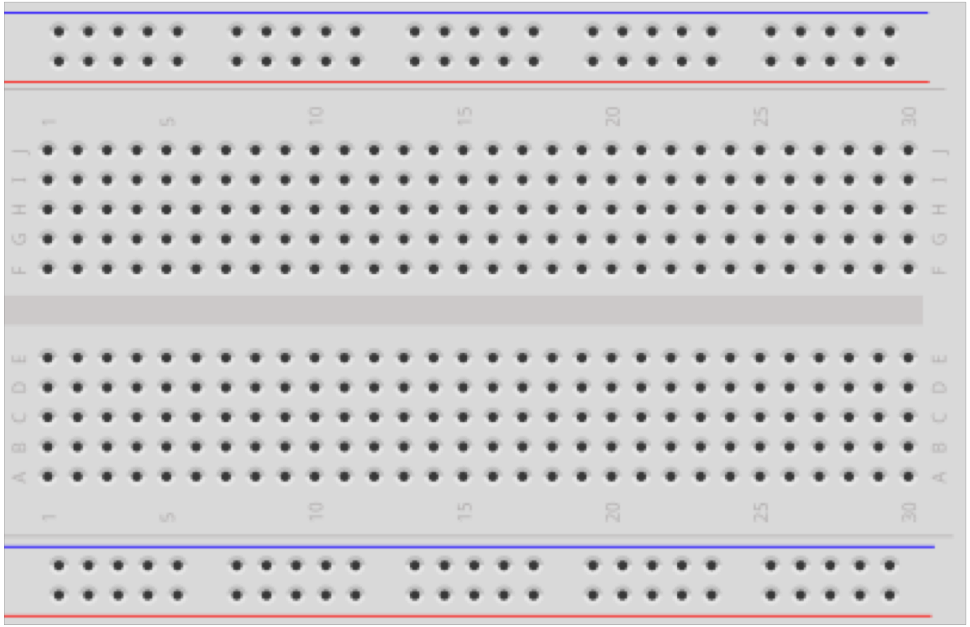
- DAQ Device (e.g., USB-6008)
- Breadboard
- TMP36 Temperature Sensor
- Thermistor 10K (Temperature Sensor)
- Resistor, $R = 10k\Omega$
- Wires (Jumper Wires)



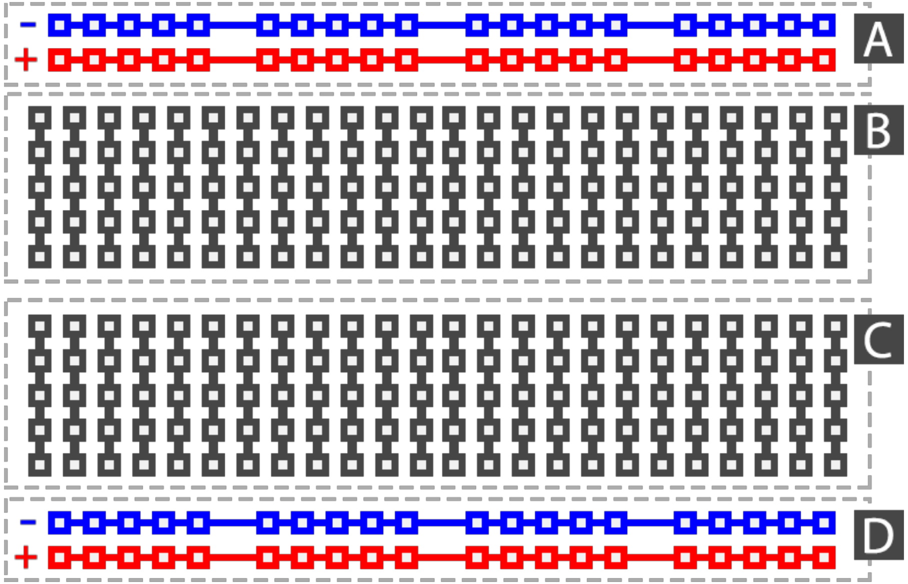




Breadboard

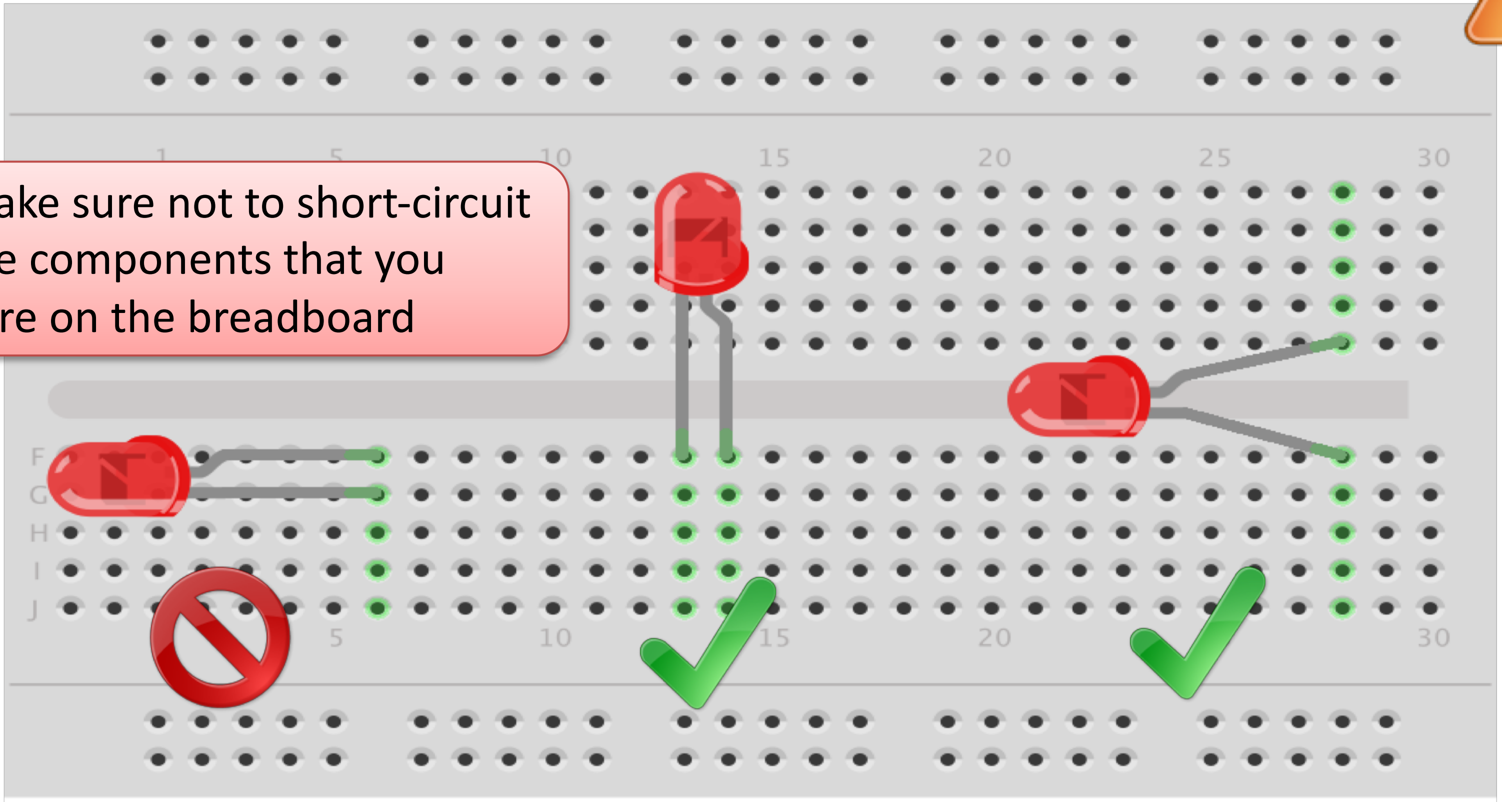


A breadboard is used to wire electric components together



Breadboard Wiring

Make sure not to short-circuit the components that you wire on the breadboard



The Breadboard is used to connect components and electrical circuits

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TMP36

Hans-Petter Halvorsen

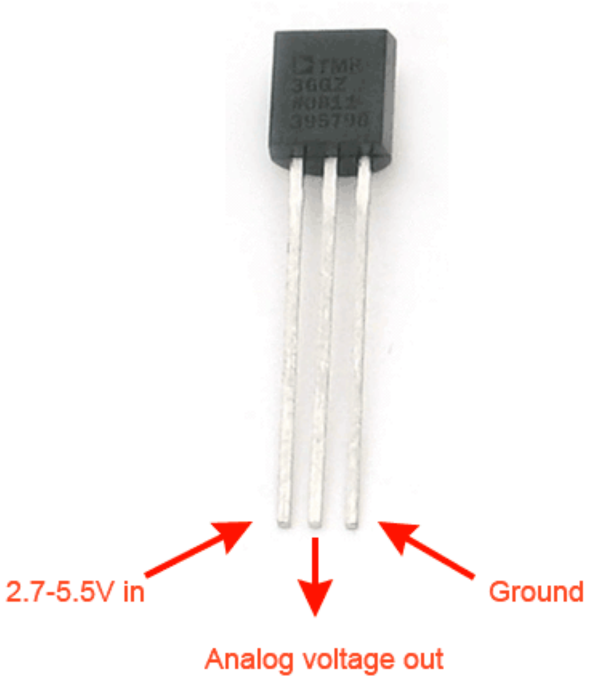
TMP36

TMP is a small, low-cost temperature sensor and cost about $1 (you can buy it “everywhere”)

TMP36

Temperature measurement range	-40...+125 °C
Accuracy	±2 °C
Power supply	2.3...5.5 V
Package	TO-92
Temperature sensitivity, voltage	10 mV/°C

TMP36 Temperature Sensor

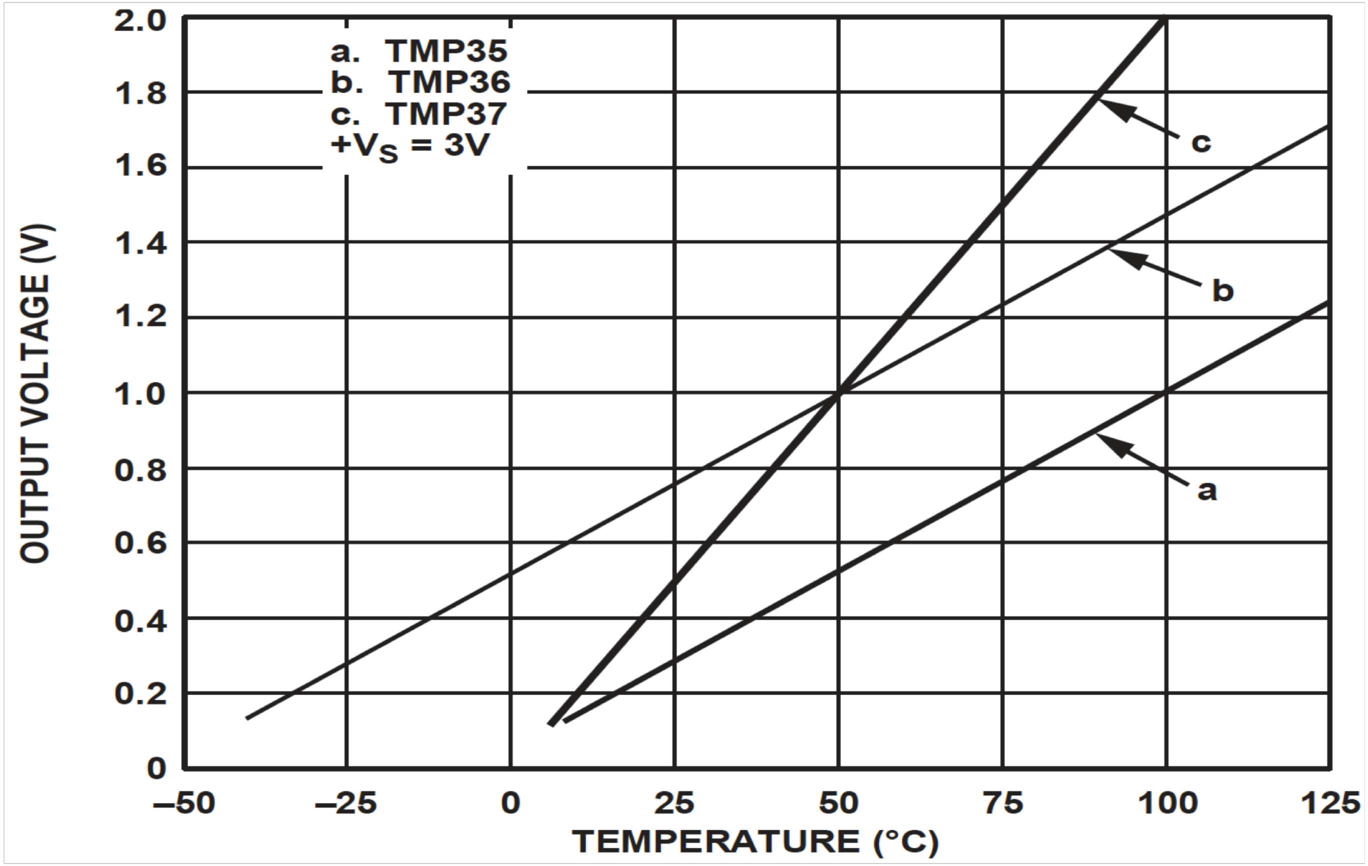


A Temperature sensor like TM36 use a solid-state technique to determine the temperature.

They use the fact as temperature increases, the voltage across a diode increases at a known rate.

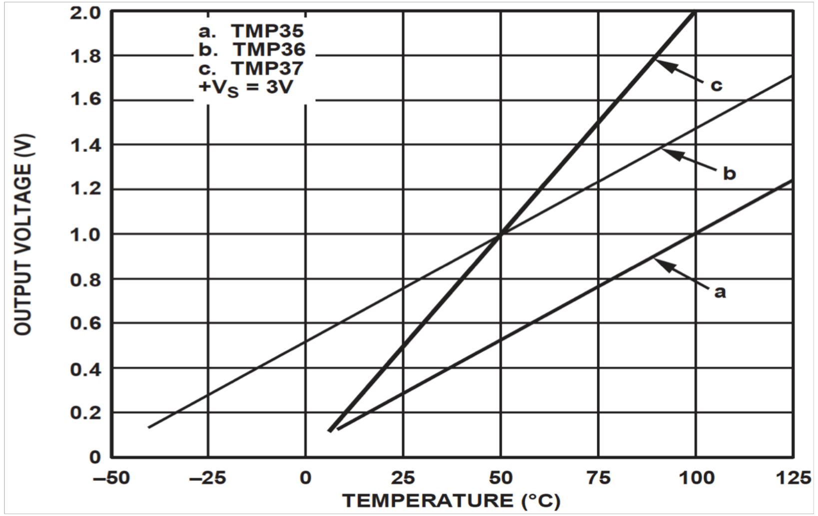
https://learn.adafruit.com/tmp36-temperature-sensor

TMP36 Datasheet



http://no.rs-online.com/webdocs/14cd/0900766b814cd0a1.pdf

Linear Scaling



Convert form Voltage (V) to degrees Celsius

From the Datasheet we have:

$$(x_1, y_1) \;=\; (0.75V, 25°C)$$
$$(x_2, y_2) \;=\; (1V, 50°C)$$

There is a linear relationship between Voltage and degrees Celsius:

$$y = ax + b$$

We can find a and b using the following known formula:

$$y - y_1 = \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$$

This gives:

$$y - 25 = \frac{50 - 25}{1 - 0.75}(x - 0.75)$$

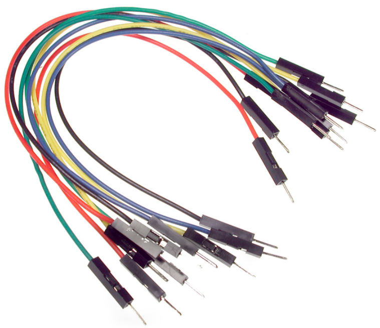
Then we get the following formula:

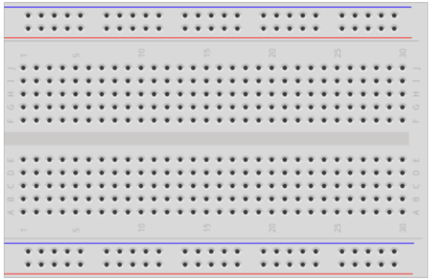
$$y = 100x - 50$$

Necessary Equipment

- PC
- DAQ Module, e.g., USB-6008

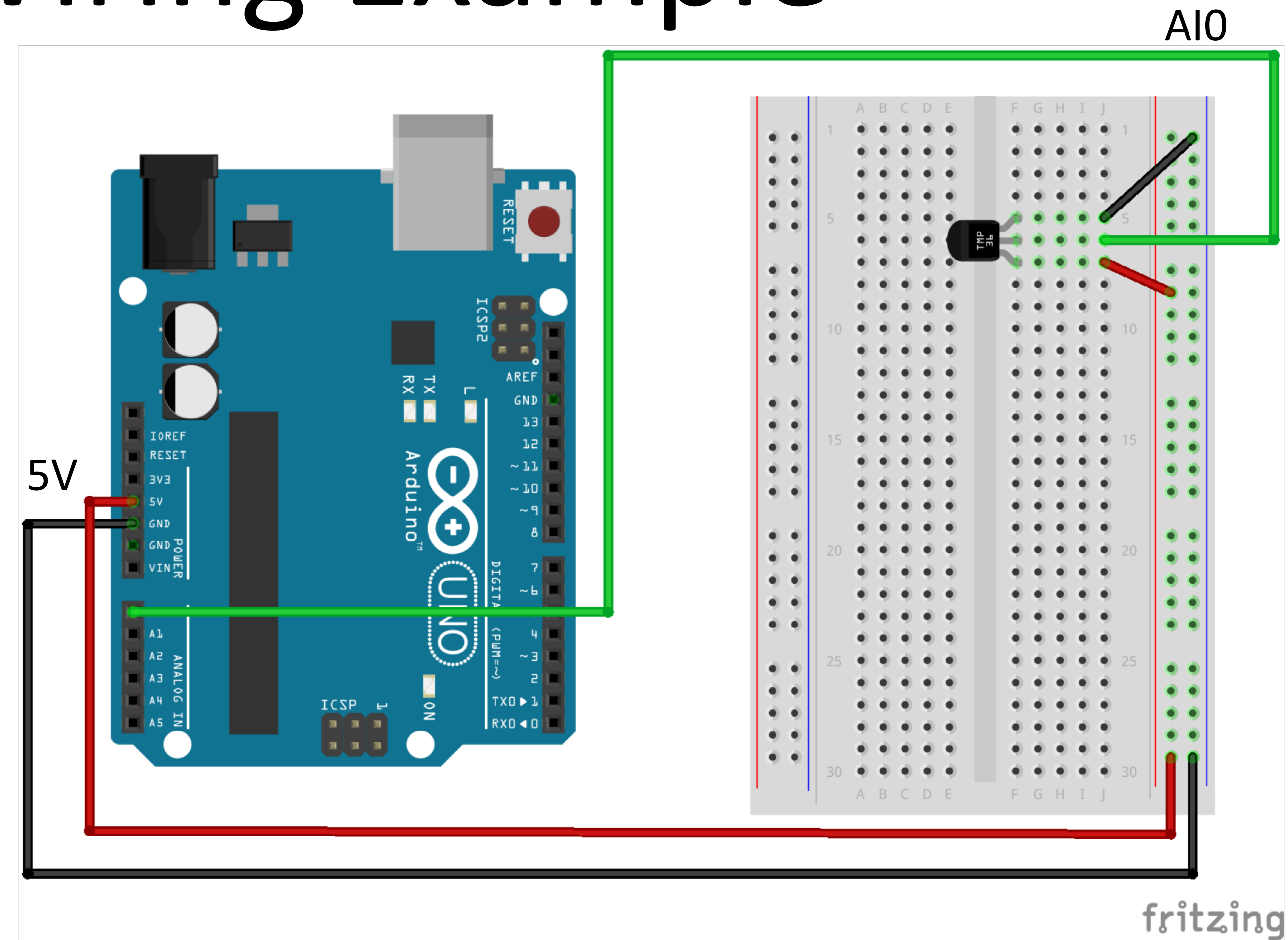
- Breadboard
- TMP36
- Wires (Jumper Wires)



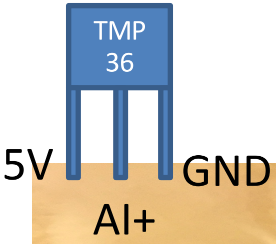


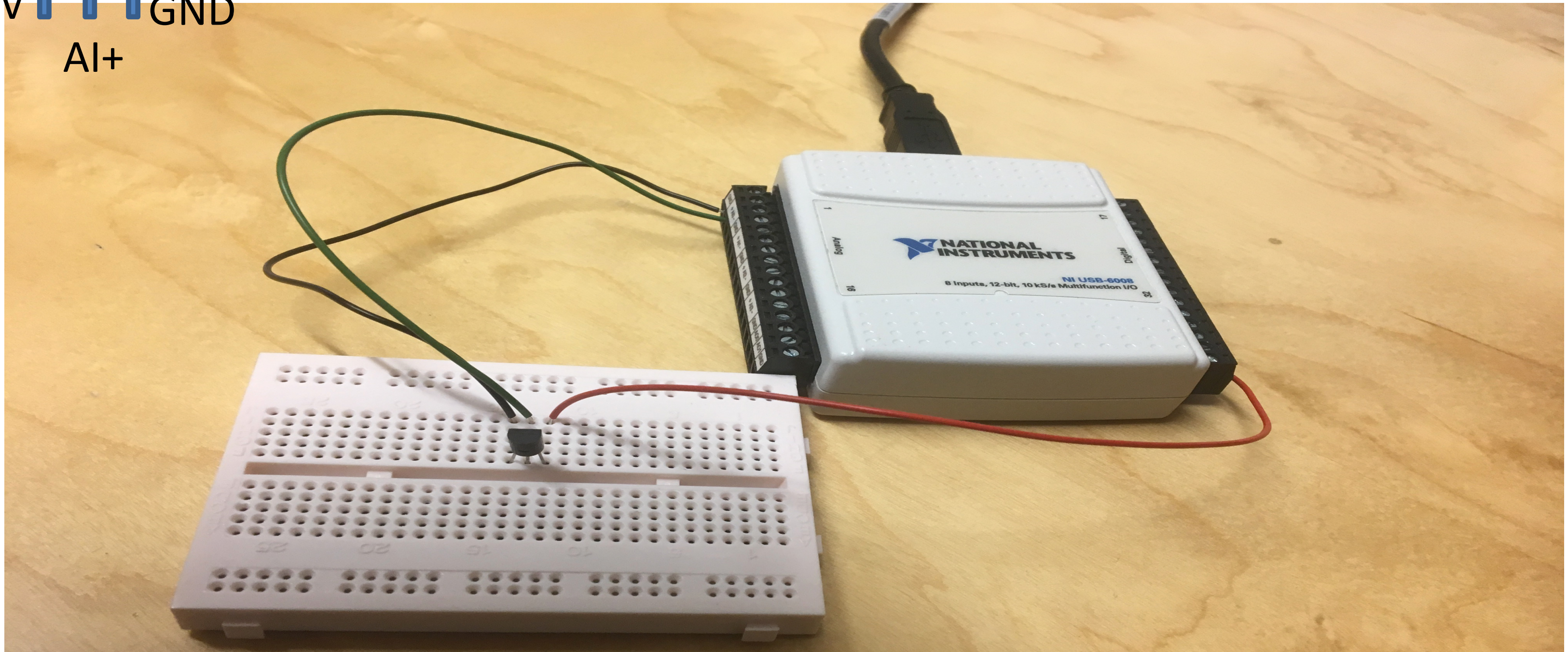
Wiring Example

Here you see a wiring examples using Arduino. You make the same wiring using a DAQ device like USB-6008 or similar.



USB-6008 Wiring Example





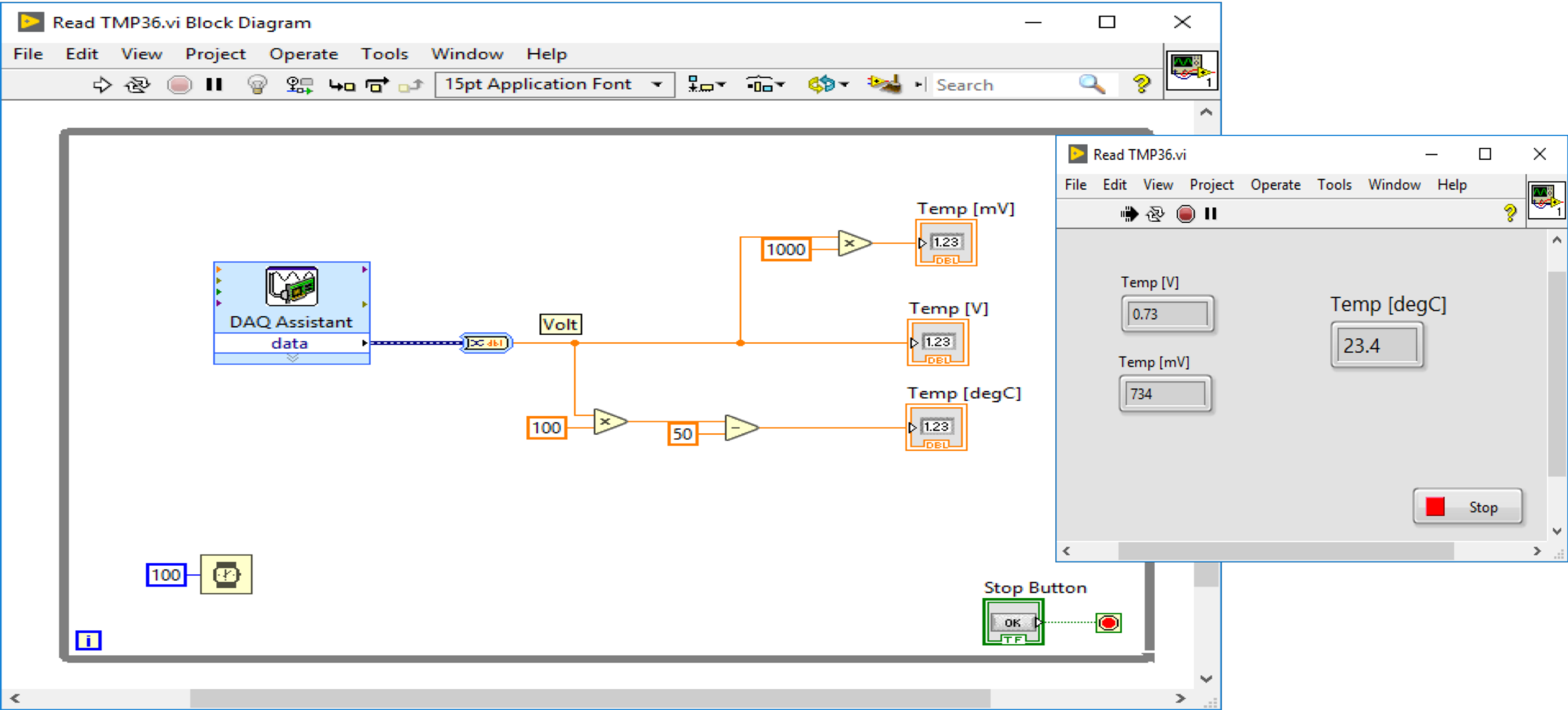
We connect the TMP36 to LabVIEW using a USB DAQ Device from National Instruments, e.g., USB-6001, USB-6008 or similar. I have used a breadboard for the wiring.

Pseudo Code

We want to present the value from the sensor in degrees Celsius:

1. Read Signal from DAQ Device (0-5V)
2. Convert to degrees Celsius using information from the Datasheet
3. Show/Plot Values in your Application GUI

LabVIEW Example



Arduino Example

```
const int temperaturePin = 0;

float adcValue;
float voltage;
float degreesC;

void setup()
{
  Serial.begin(9600);
}

void loop()
{

  adcValue = analogRead(temperaturePin);

  voltage = (adcValue*5)/1023;

  degreesC = 100*voltage - 50;

  Serial.print("ADC Value: ");
  Serial.print(adcValue);

  Serial.print("  voltage: ");
  Serial.print(voltage);

  Serial.print("  deg C: ");
  Serial.println(degreesC);

  delay(1000);
}
```

Convert from ADC-value (0-1023) to Voltage (0-5V)

Convert from Voltage to degrees Celsius

Celsius to Fahrenheit Conversion

In Norway we typically use Celsius as temperature unit, while in US they use Fahrenheit.

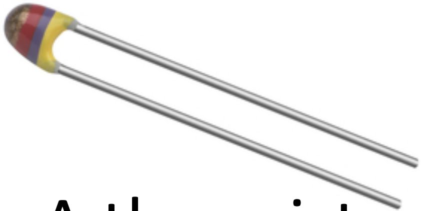
Conversion between these are as follows:

$$T_F = \frac{9}{5} T_C + 32$$

https://www.halvorsen.blog

Thermistor 10kΩ

Hans-Petter Halvorsen



Thermistor

A thermistor is an electronic component that changes resistance to temperature - so-called Resistance Temperature Detectors (RTD). It is often used as a temperature sensor.

Our Thermistor is a so-called NTC (Negative Temperature Coefficient). In a NTC Thermistor, resistance decreases as the temperature rises.

There is an non-linear relationship between resistance and excitement. To find the temperature we can use the following equation (Steinhart-Hart equation):

$$\frac{1}{T} = A + B\ln(R) + C(\ln(R))^3$$

[Wikipedia]

where A, B, C are constants given below

$A = 0.001129148, B = 0.000234125 \; and \; C = 8.76741E - 08$

Steinhart-Hart equation

To find the Temperature we can use Steinhart-Hart equation:

$$\frac{1}{T_K} = A + B\ln(R) + C(\ln(R))^3$$

This gives:

$$T_K = \frac{1}{A + B\ln(R) + C(\ln(R))^3}$$

$$A = 0.001129148,$$
$$B = 0.000234125$$
$$C = 0.0000000876741$$

Where the Temperature T_K is in Kelvin

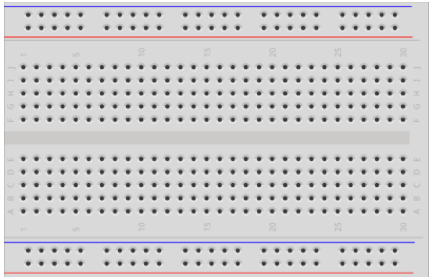
$A, B\ and\ C$ are constants

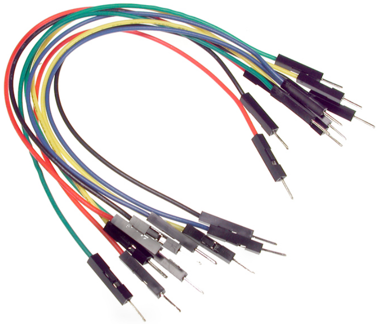
The Temperature in degrees Celsius will then be:

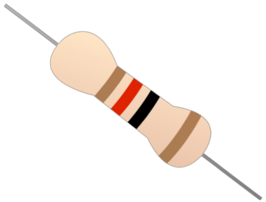
$$T_C = T_K - 273.15$$

Necessary Equipment

- PC
- DAQ Module, e.g., USB-6008
- Breadboard
- Thermistor
- Resistor 10 kΩ
- Wires (Jumper Wires)

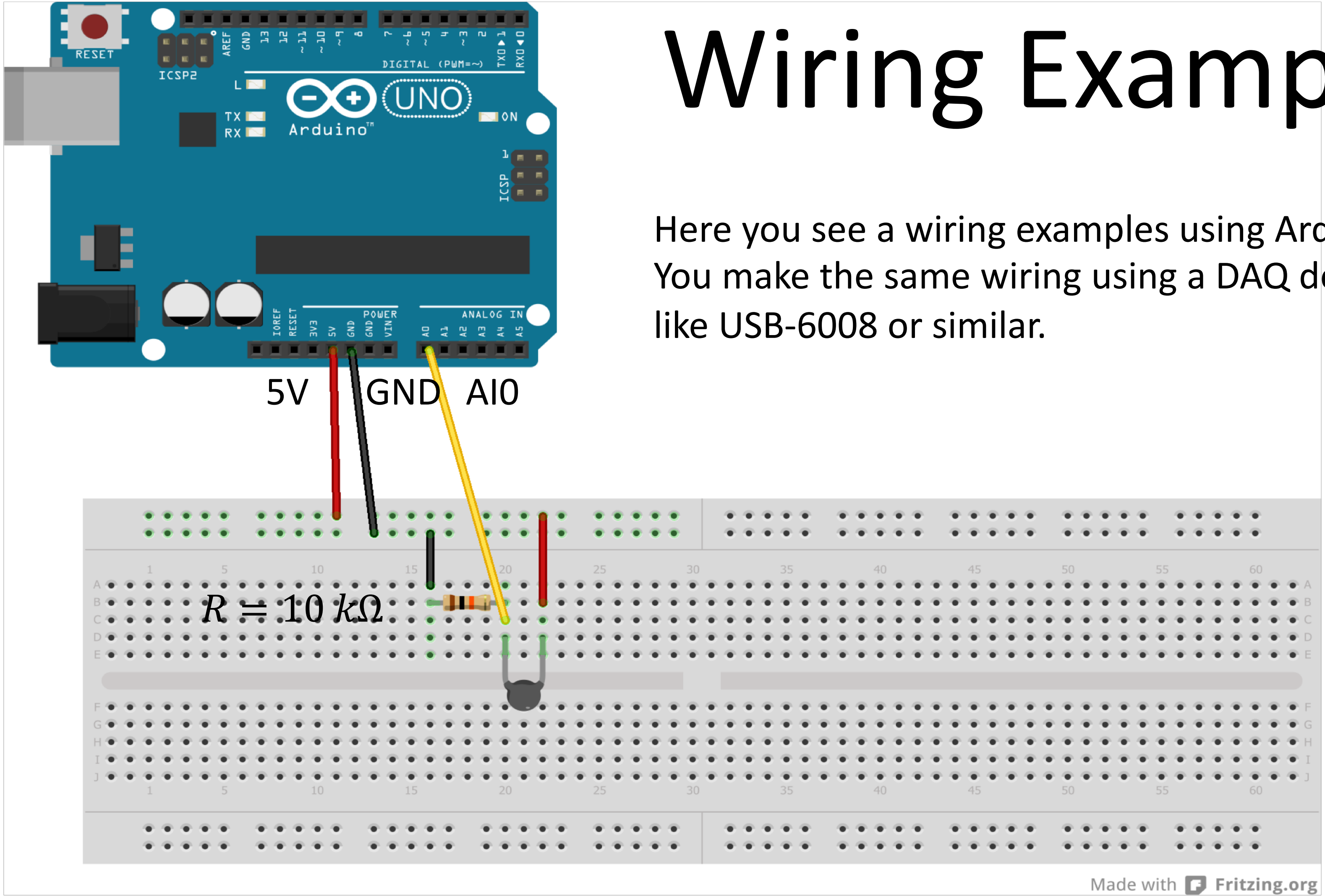




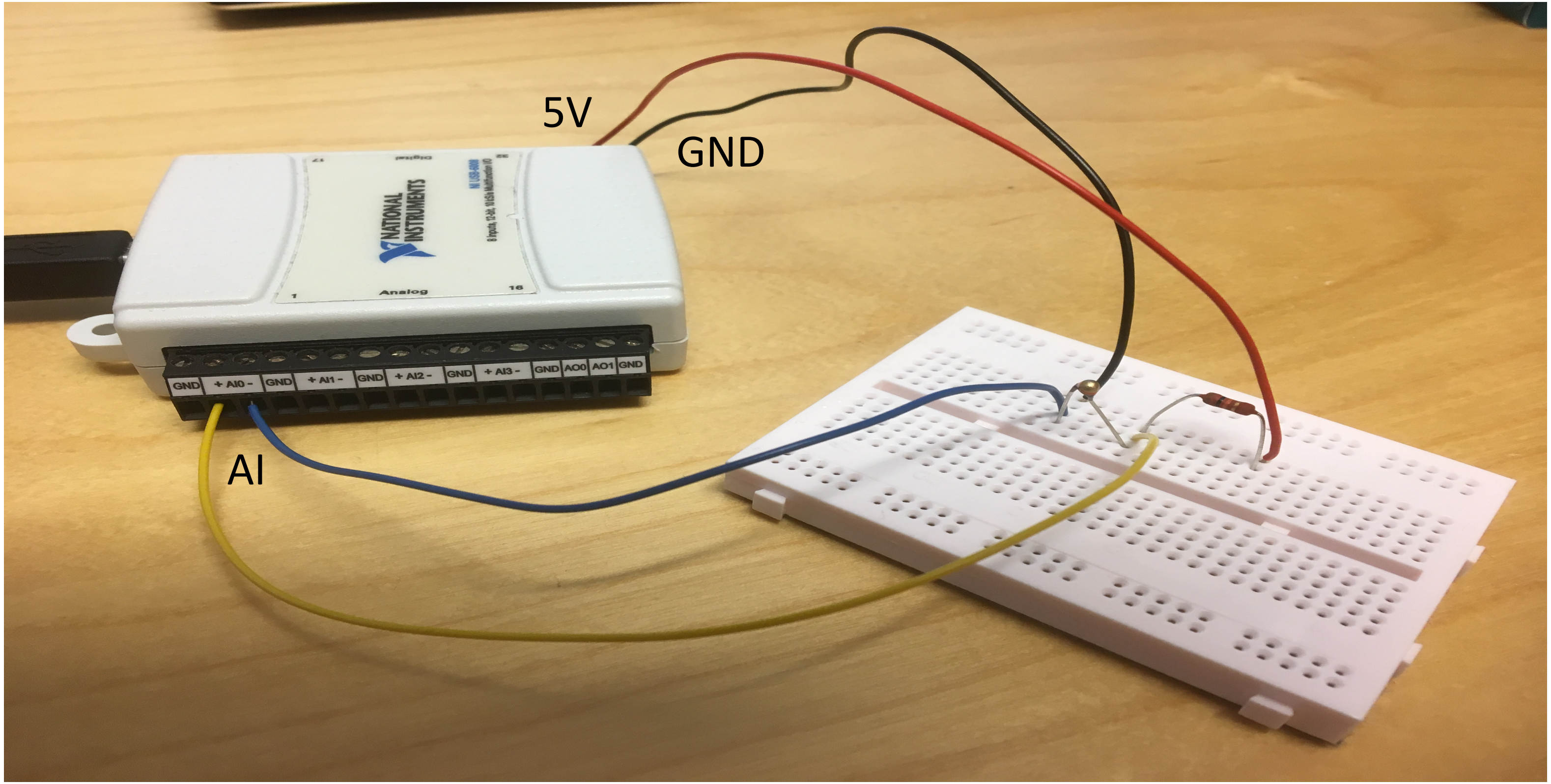


Wiring Example

Here you see a wiring examples using Arduino. You make the same wiring using a DAQ device like USB-6008 or similar.



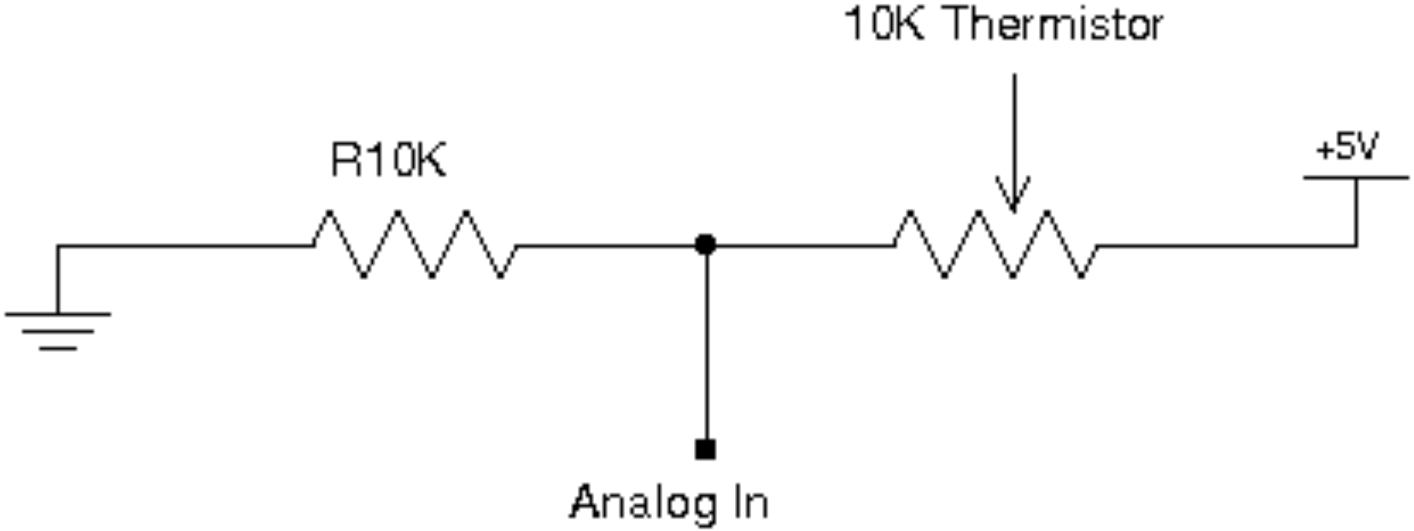
USB-6008 Wiring Example



We connect the TMP36 to LabVIEW using a USB DAQ Device from National Instruments, e.g., USB-6001, USB-6008 or similar. I have used a breadboard for the wiring.

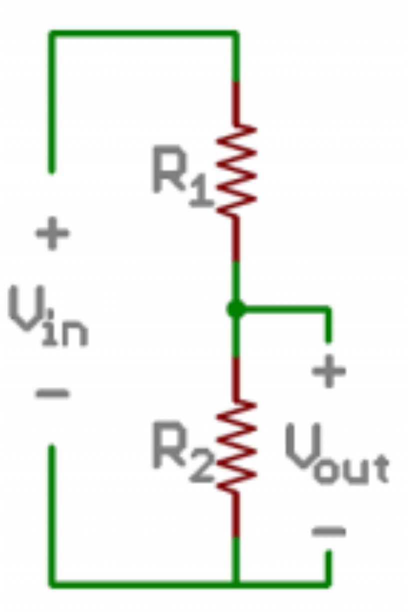
Wiring

The wiring is called a “Voltage divider”:



[https://en.wikipedia.org/wiki/Voltage_divider]

General Voltage Divider



$$V_{out} = V_{in} \cdot \frac{R_2}{R_1 + R_2}$$

https://learn.sparkfun.com/tutorials/voltage-dividers/all

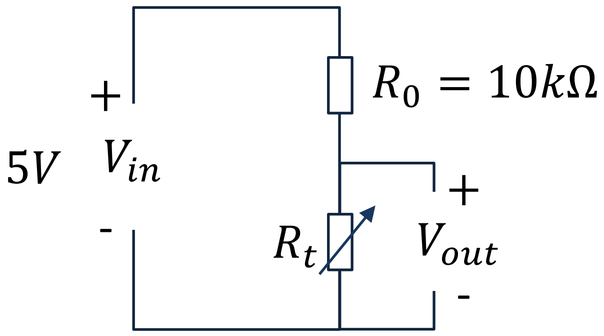
Voltage Divider for our system

Voltage Divider Equation:

$$V_{out} = V_{in} \frac{R_t}{R_0 + R_t}$$

We want to find R_t:

$$R_t = \frac{V_{out} R_0}{V_{in} - V_{out}}$$

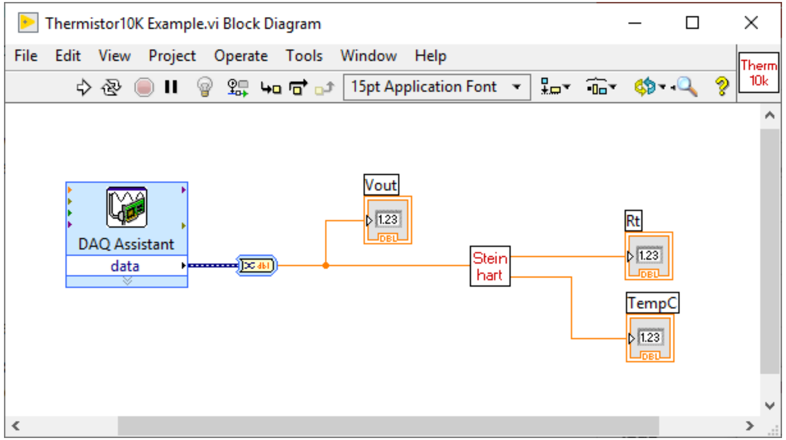


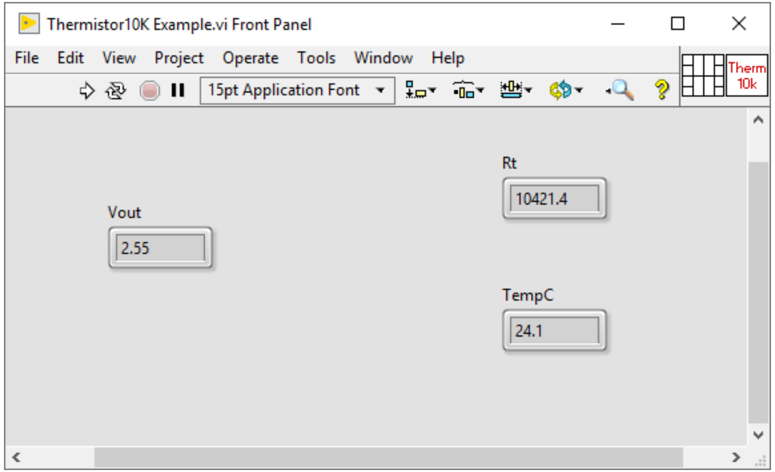
R_t - 10k Thermistor. This varies with temperature. From Datasheet we know that $R_t = 10k\Omega$ @25℃

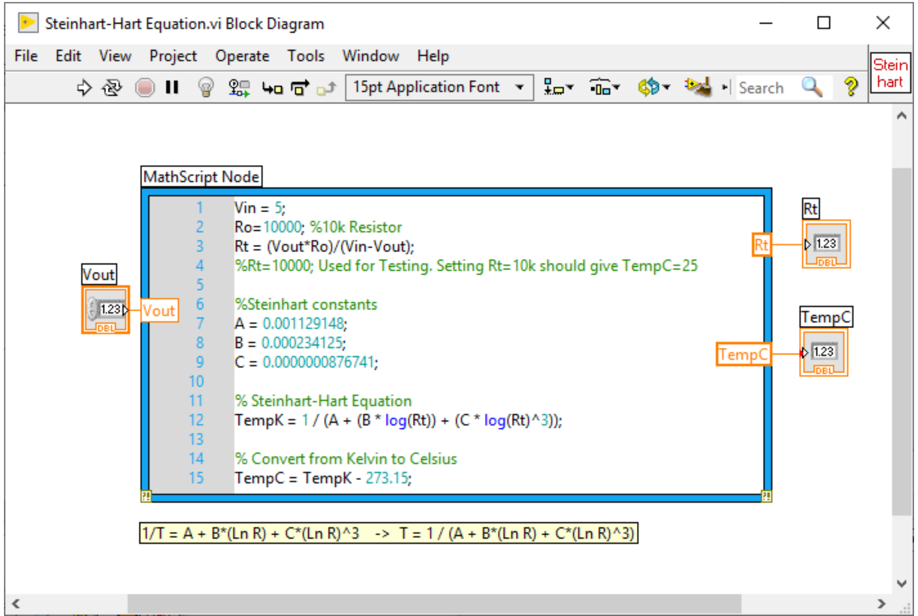
Steps:

1. We wire the circuit on the Breadboard and connect it to the DAQ device
2. We measure V_{out} using the DAQ device
3. We calculate R_t using the Voltage Divider equation
4. Finally, we use Steinhart-Hart equation for finding the Temperature

LabVIEW Example







Arduino Example

```
const int temperaturePin = 0;

void setup()
{
  Serial.begin(9600);
}

void loop()
{
  int temperature = getTemp();
  Serial.print("Temperature Value: ");
  Serial.print(temperature);
  Serial.println("*C");
  delay(1000);
}

double getTemp()
{
  // Inputs ADC Value from Thermistor and outputs Temperature in Celsius

  int RawADC = analogRead(temperaturePin);
  long Resistance;
  double Temp;

  // Assuming a 10k Thermistor.  Calculation is actually: Resistance = (1024/ADC)
  Resistance=((10240000/RawADC) - 10000);

  // Utilizes the Steinhart-Hart Thermistor Equation:
  // Temperature in Kelvin = 1 / {A + B[ln(R)] + C[ln(R)]^3}
  // where A = 0.001129148, B = 0.000234125 and C = 8.76741E-08

  Temp = log(Resistance);
  Temp = 1 / (0.001129148 + (0.000234125 * Temp) + (0.0000000876741 * Temp * Temp * Temp));
  Temp = Temp - 273.15;  // Convert Kelvin to Celsius
  return Temp;  // Return the Temperature
}
```

Celsius to Fahrenheit Conversion

In Norway we typically use Celsius as temperature unit, while in US they use Fahrenheit.

Conversion between these are as follows:

$$T_F = \frac{9}{5} T_C + 32$$

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University of South-Eastern Norway

www.usn.no

E-mail: hans.p.halvorsen@usn.no

Web: https://www.halvorsen.blog