ThermistorNTC library

ARDUINO© THERMISTORNTC

Library to used to derive a precise temperature of a thermistor, fastest Calc. (14~29% faster than others)

Introduction

The thermistor changes its resistance drastically with temperature. "Thermistor" word comes from “thermally sensitive resistor". The resistance of ordinary materials rises slightly as temperature rises, whereas NTC (negative temperature coefficient) thermistors exhibit a sharp decrease in resistance. For information about thermistor see manufacturer information. Shibaura manufacturer has a lot of thecnical information about NTC thermistors.

The Steinhart-Hart equation is the most widely used tool to interpolate the NTC thermistor resistance/temperature curve. It is a third order polynomial ecuation which provides very good curve fitting.

$$\boxed{\frac{1}{T} = A + B * \ln\left(R\right) + C * \ln^2\left(R\right) + D * \ln^3\left(R\right)}$$

In the standard Steinhart-Hart equation the C parameter is set to zero. However, some manufacturers use all 4 coefficients. So we can use standard Steinhart-Hart ecuation with 3 coefficients.

$$\boxed{\frac{1}{T} = A + B * \ln\left(R\right) + D * \ln^3\left(R\right)}$$

where:

- **T** is the temperature (in kelvins),
- **R** is the resistance at T (in ohms),
- **A**, **B**, **C** and **D** are the Steinhart–Hart coefficients, which vary depending on the type and model of thermistor and the temperature range of interest. These can usually be found in

the data sheet.

Other expressions

Other form of the equation is the use of B (beta) parameter

where:

$$\boxed{R = NTC * e^{\left(\beta * \left(\frac{1}{T} - \frac{1}{T_0}\right)\right)}}$$

- **T** is the temperature (in kelvins)
- **T0** is 298'15 ºK (25 ºC)
- **R** is the resistance at T (in ohms),
- **NTC** is the resistence of thermistor at 298'15 ºK (25 ºC)
- **beta** is the Steinhart-Hart beta coefficient that vary depending on the type and model of Thermistor. It can usually be found in the data sheet.

Some manufacturers have begun providing regression coefficients as an alternative to Steinhart–Hart coefficients. See this document for more information. "Comments on the Steinhart–Hart Equation" (PDF). Building Automation Products Inc. 11 November 2015. Retrieved 8 July 2020.

The most general form of the equation can be derived from extending the B parameter equation to an infinite series:

$$\boxed{R = R_0 * e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)}}$$

$$\frac{R}{R_0} = e^{\left(\beta * \left(\frac{1}{T} - \frac{1}{T_0}\right)\right)}$$

$$\ln\left(\frac{R}{R_0}\right) = \beta * \left(\frac{1}{T} - \frac{1}{T_0}\right)$$

$$\frac{1}{T} = \frac{1}{T_0} + \frac{1}{\beta}\left(\ln\frac{R}{R_0}\right) = a_0 + a_1 \ln\frac{R}{R_0}$$

$$\boxed{\frac{1}{T} = \sum_{n=0}^{\infty} a_n \left(\ln\frac{R}{R_0}\right)^n}$$

You can get more information in this document: Matus, Michael (October 2011). Temperature Measurement in Dimensional Metrology – Why the Steinhart–Hart Equation works so well. MacroScale 2011. Wabern, Switzerland

More Information

Thermistor is the principal element of temperature sensor.

Look here for more information about Steinhart-Hart ecuations.

See this page for info about NTC Thermistors Steinhart and Hart Equation

You can learn more about temperature coefficient here.

More information:

- Arrhenius equation.
- Q10 temperature coefficient.

Fast Calc

In this library, it is take the beta ecuation and calculate temperature of the thermistor from it.

$$\boxed{\frac{R}{NTC} = e^{\left(\beta * \left(\frac{1}{T} - \frac{1}{T_0}\right)\right)}}$$

$$\ln\left(\frac{R}{NTC}\right) = \beta * \left(\frac{1}{T} - \frac{1}{T_0}\right)$$

$$\frac{\ln\left(\frac{R}{NTC}\right)}{\beta} = \frac{1}{T} - \frac{1}{T_0}$$

$$\frac{1}{T} = \frac{1}{T_0} + \frac{\ln\left(\frac{R}{NTC}\right)}{\beta}$$

$$\boxed{\frac{1}{T} = \frac{\beta + T_0 * \ln\left(\frac{R}{NTC}\right)}{\beta * T_0}}$$

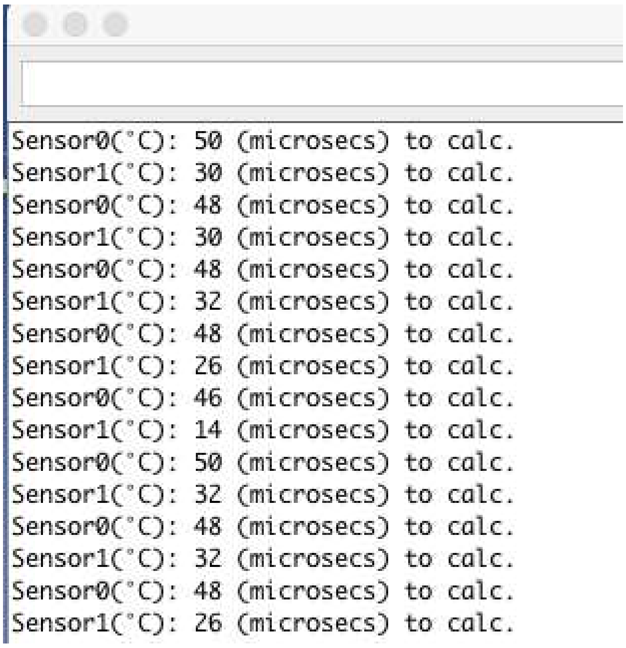
So we can solve using this formula:

$$T = \frac{\beta * T_0}{\beta + T_0 * \ln\left(\frac{R}{NTC}\right)}$$

where:

- **T** is the temperature (in kelvins)
- **T0** is 298'15 ºK (25 ºC)
- **R** is the resistance at T (in ohms),
- **NTC** is the resistence of thermistor at 298'15 ºK (25 ºC)
- **beta** is the Steinhart-Hart beta coefficient that vary depending on the type and model of Thermistor.

The library is 14-29% faster than others libraries to get temperature from Thermistor if we compare this library with libraries based on beta equation. And it depends on the board used. Tested on LGT8F328P-SOPP, LGT8F328P-QF32 and Arduino pro mini boards. If it is compared Fast Calc with Steinhart-Hart three orden equation, it is 35-44% faster, depends on microcontroller used. See example for test.



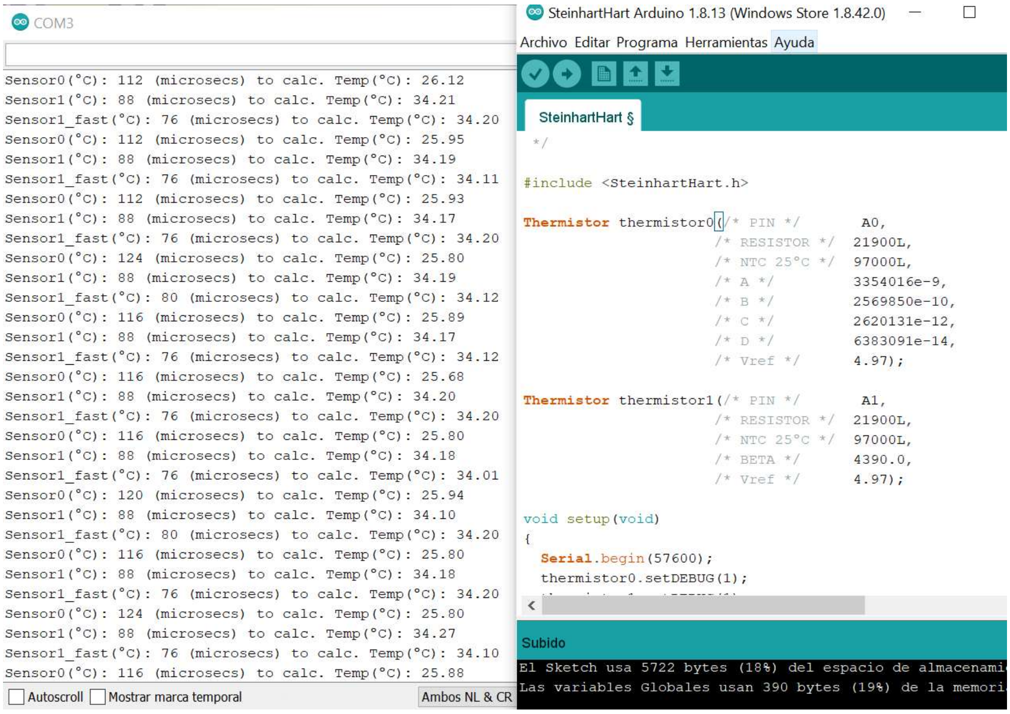
Testing **sensor0** Steinhart-Hart three orden equation, **sensor1** Fast Calc equation. LGT8F328P-SOPP board. (32 MHz 5v.)

```
Sensor0(°C): 48 (microsecs) to calc.
Sensor1(°C): 38 (microsecs) to calc.
Sensor1_fast(°C): 30 (microsecs) to calc.
Sensor0(°C): 50 (microsecs) to calc.
Sensor1(°C): 36 (microsecs) to calc.
Sensor1_fast(°C): 16 (microsecs) to calc.
Sensor0(°C): 50 (microsecs) to calc.
Sensor1(°C): 40 (microsecs) to calc.
Sensor1_fast(°C): 28 (microsecs) to calc.
Sensor0(°C): 46 (microsecs) to calc.
Sensor1(°C): 38 (microsecs) to calc.
Sensor1_fast(°C): 32 (microsecs) to calc.
Sensor0(°C): 48 (microsecs) to calc.
Sensor1(°C): 38 (microsecs) to calc.
Sensor1_fast(°C): 28 (microsecs) to calc.
```

Testing **sensor0** Steinhart-Hart three orden equation, **sensor1** beta equation and **sensor1_fast** Fast Calc equation. LGT8F328P-QF32 board. (32 MHz 5v.)

```
Sensor0(°C): 112 (microsecs) to calc. Temp(°C): -5.26
Sensor1(°C): 84 (microsecs) to calc. Temp(°C): -5.76
Sensor1_fast(°C): 68 (microsecs) to calc. Temp(°C): -5.13
Sensor0(°C): 112 (microsecs) to calc. Temp(°C): -5.67
Sensor1(°C): 84 (microsecs) to calc. Temp(°C): -6.49
Sensor1_fast(°C): 72 (microsecs) to calc. Temp(°C): -5.11
Sensor0(°C): 112 (microsecs) to calc. Temp(°C): -6.08
Sensor1(°C): 84 (microsecs) to calc. Temp(°C): -6.97
Sensor1_fast(°C): 72 (microsecs) to calc. Temp(°C): -5.19
Sensor0(°C): 112 (microsecs) to calc. Temp(°C): -6.61
Sensor1(°C): 84 (microsecs) to calc. Temp(°C): -7.23
Sensor1_fast(°C): 76 (microsecs) to calc. Temp(°C): -5.17
Sensor0(°C): 112 (microsecs) to calc. Temp(°C): -7.20
Sensor1(°C): 84 (microsecs) to calc. Temp(°C): -7.23
Sensor1_fast(°C): 72 (microsecs) to calc. Temp(°C): -5.23
Sensor0(°C): 112 (microsecs) to calc. Temp(°C): -7.71
Sensor1(°C): 88 (microsecs) to calc. Temp(°C): -7.07
Sensor1_fast(°C): 72 (microsecs) to calc. Temp(°C): -5.38
```

Testing **sensor0** Steinhart-Hart three orden equation, **sensor1** beta equation and **sensor1_fast** Fast Calc equation. Atmega328p board. (16 MHz 5v.)



Testing with 100k thermistors and 22kohms. Testing **sensor0** Steinhart-Hart three orden equation, **sensor1** beta equation and **sensor1_fast** Fast Calc equation. Atmega328p board. (16 MHz 5v.)

Calculation of beta

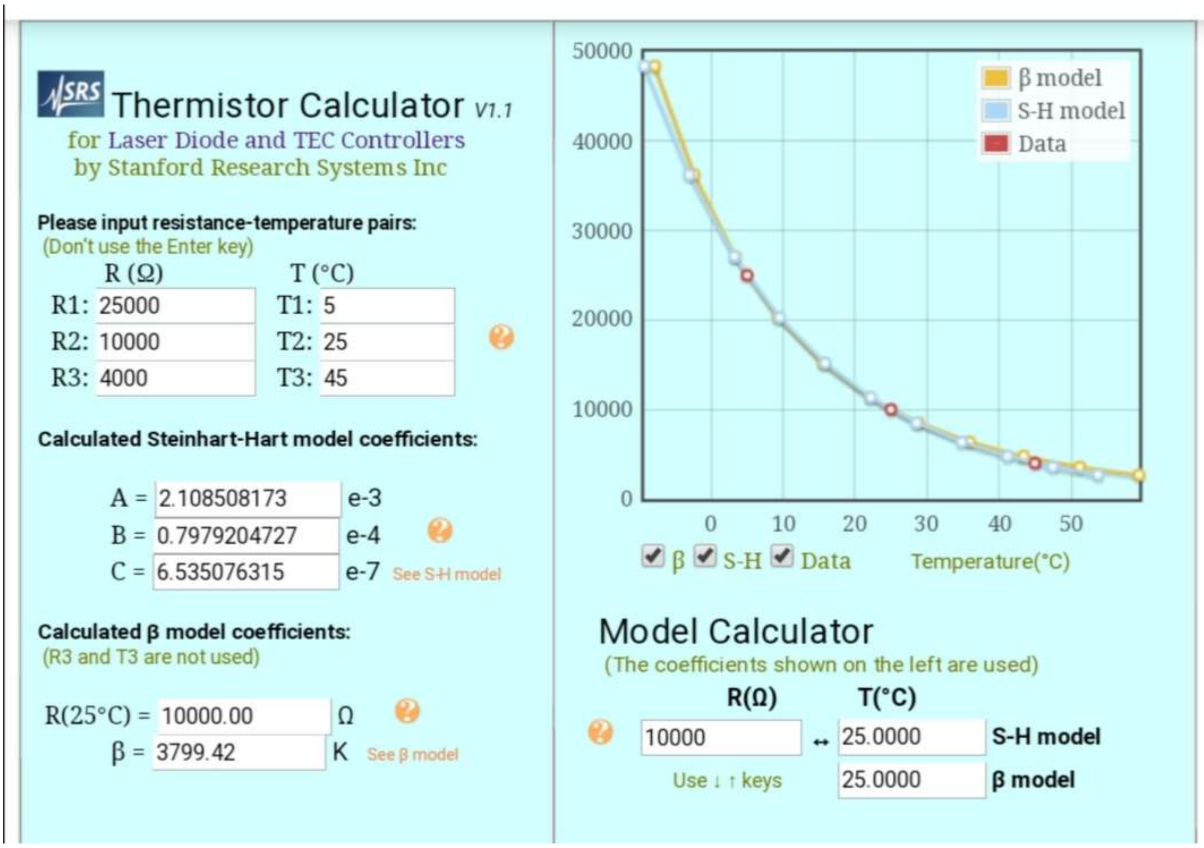
Beta is measured in degrees Kelvin (K) and is computed based on this equation:

$$\boxed{\beta = \left(\frac{\ln\left(\frac{R_{T_1}}{R_{T_2}}\right)}{\frac{1}{T_1} - \frac{1}{T_2}} \right)}$$

Where:

- **Rt1** = Resistance at Temperature 1 (ohms)
- **Rt2** = Resistance at Temperature 2 (ohms)
- **T1** = Temperature 1 in (Kelvin)
- **T2** = Temperature 2 in (Kelvin)

How to Calc beta of NTC Thermistor, you can see this page.



Using the Thermistor Calculator V1.1 you can de termine the unknowns parameters of a thermistor.

For more information about NTC thermistors and Steinhart-Hart equation to calc the parameters using three pairs of values (temperature, NTC resistence) see NTC Thermistors Steinhart and Hart Equation

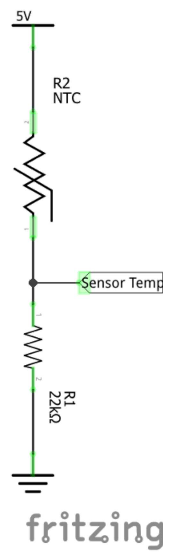
How to use Thermistor as temperature sensor

Thermistor values denote their resistance at 25°C. A popular type would be an NTC 10K which would give roughly 10 kOhms at that temperature point.

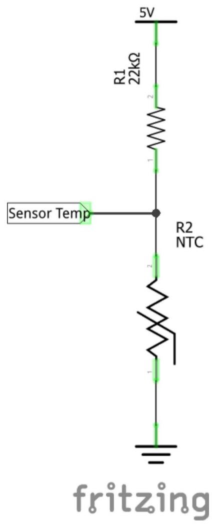
Although there are ways to calculate the coefficients yourself experimentally it might be cheaper and easier to just buy a thermistor with known specs. This page can help to calculate thats coefficients. Thermistor Calculator V1.1.

To get readings from a thermistor into your Arduino you will have to use a conventional voltage divider circuit. It can used two forms of configurations.

Connecting NTC thermistor to VCC:



Or connecting NTC thermistor to GND:



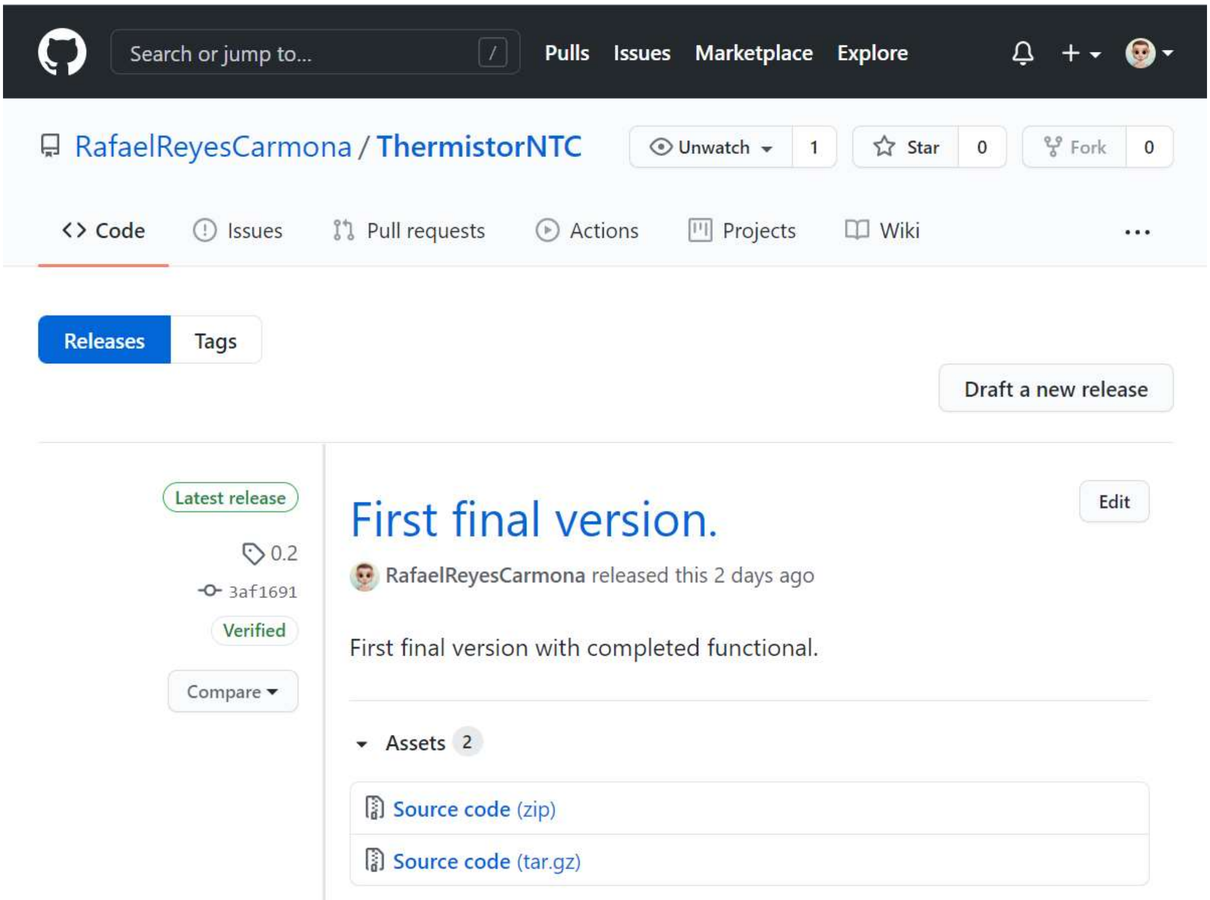
Installation

Arduino IDE

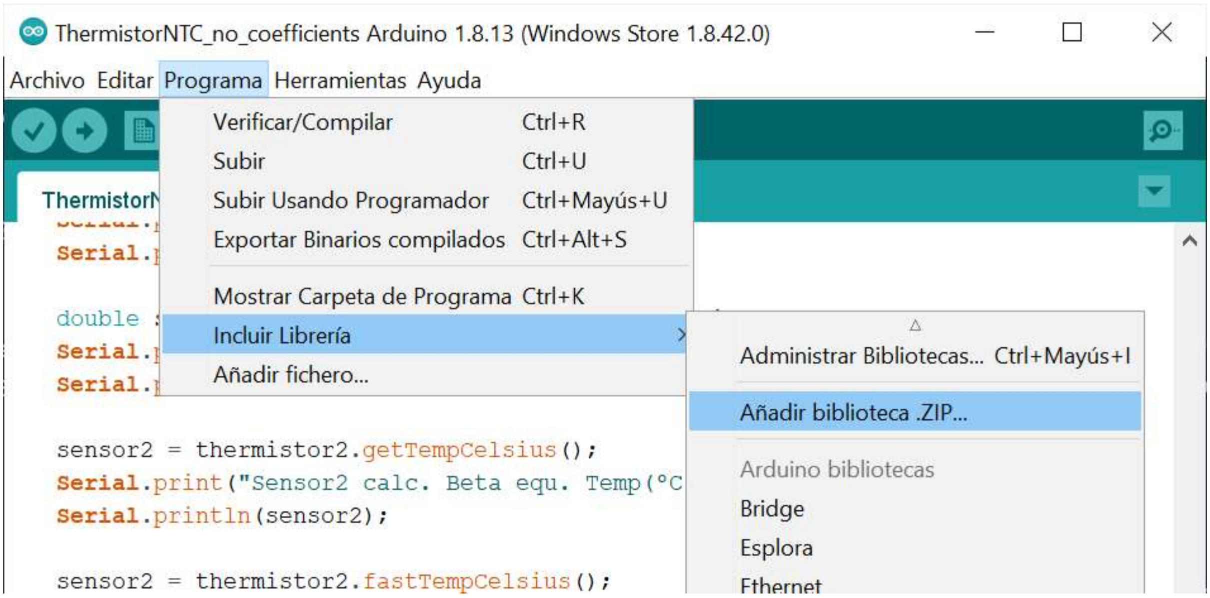
For a tutorial on how to install new libraries for use with the Arduino development environment please refer to the following website:
http://www.arduino.cc/en/Reference/Libraries

--- or ---

1. Download the ZIP file from the page releases to your machine.



2. In the Arduino IDE, choose Sketch/Include Library/Add Zip Library.



3. Navigate to the ZIP file, and click Open.

PlatformIO

How to use the library in PlatformIO see documentation of Library Manager.

The only one simple step is to define dependencies in “platformio.ini” (Project Configuration File). For example,

```
[env:pro16MHzatmega328]
platform = atmelavr
board = pro16MHzatmega328
framework = arduino
lib_deps = rafaelreyescarmona/ThermistorNTC

[env:LGT8F328]
board = LGT8F328P
board_build.f_cpu = 32000000
platform = lgt8f
framework = arduino
lib_deps = rafaelreyescarmona/ThermistorNTC@^0.2.1
```

For Manual installation in PlatformIO Core:

1. Run a terminal and type for search the library:

```
pio lib search ThermistorNTC
```

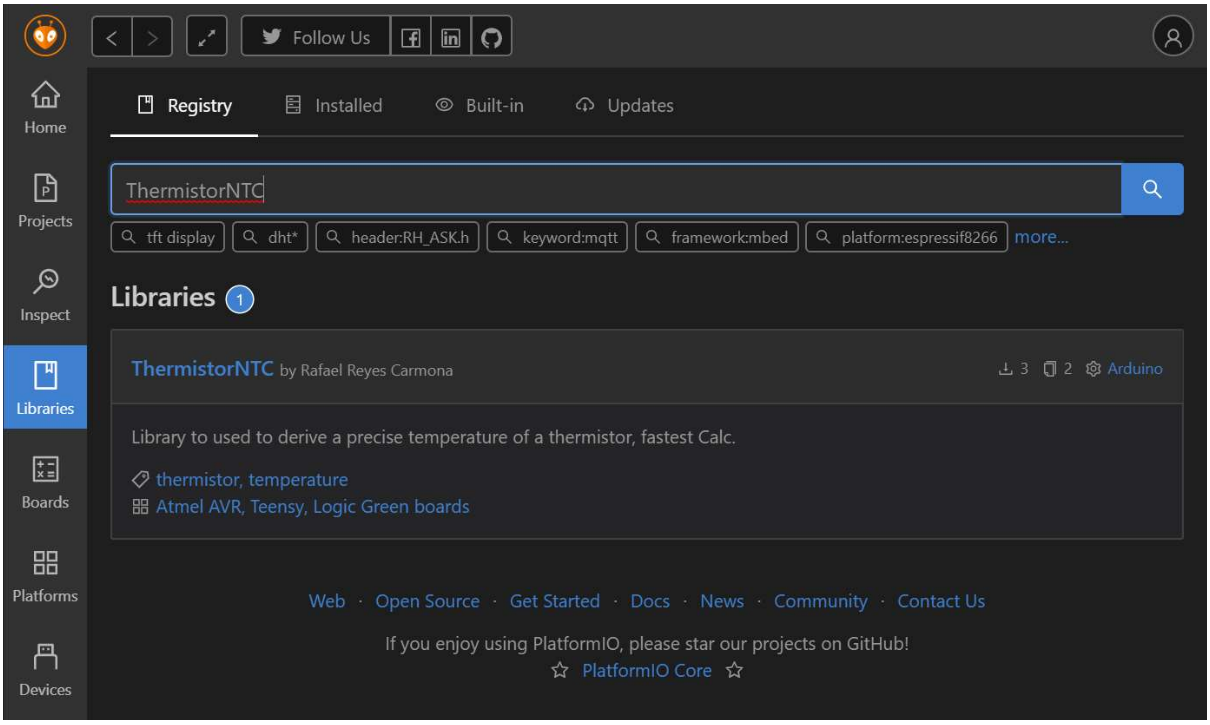
```
PS C:\Users\recaf\Documents\PlatformIO\Projects\Ejemplo> pio lib search ThermistorNTC
Found 1 libraries:

ThermistorNTC
=============
#ID: 12115
Library to used to derive a precise temperature of a thermistor, fastest Calc.

Keywords: thermistor, temperature
Compatible frameworks: Arduino
Compatible platforms: Atmel AVR, Teensy, Logic Green boards
Authors: Rafael Reyes Carmona
```

2. Type for install:

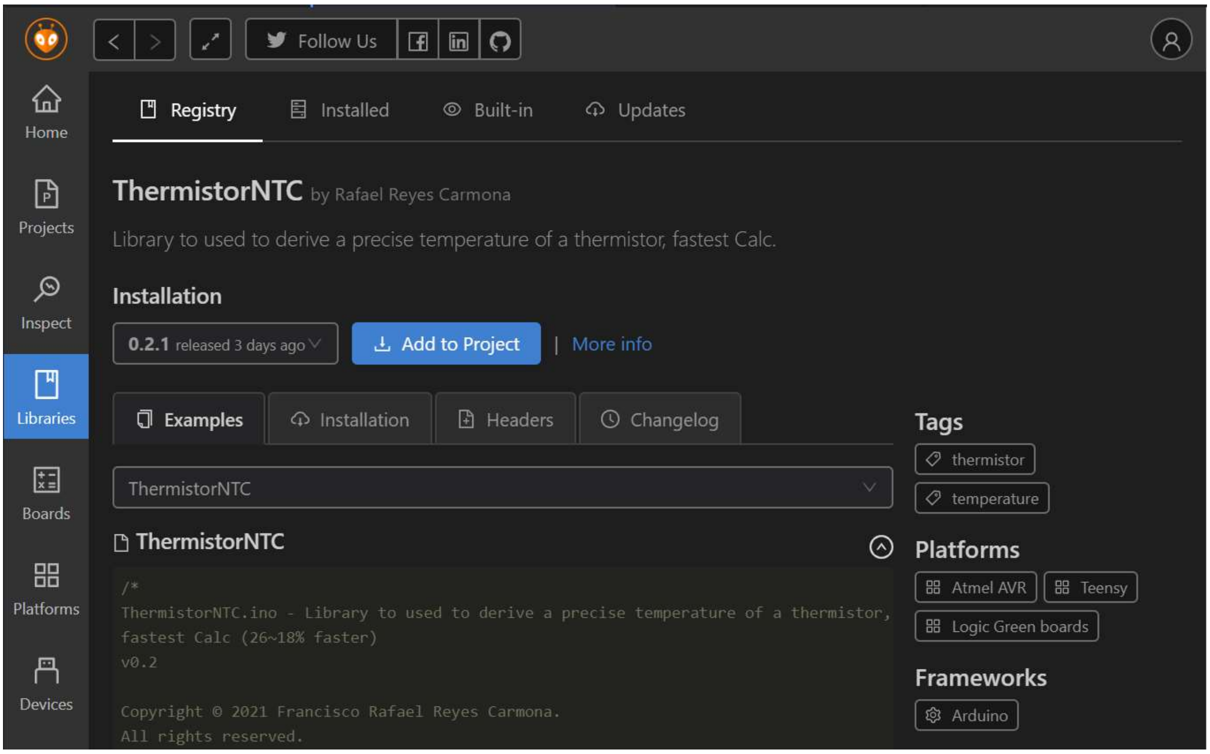
```
pio lib install 12115
```

--- or ---

1. Search "ThermistorNTC" in search box of *Libraries* of panel.

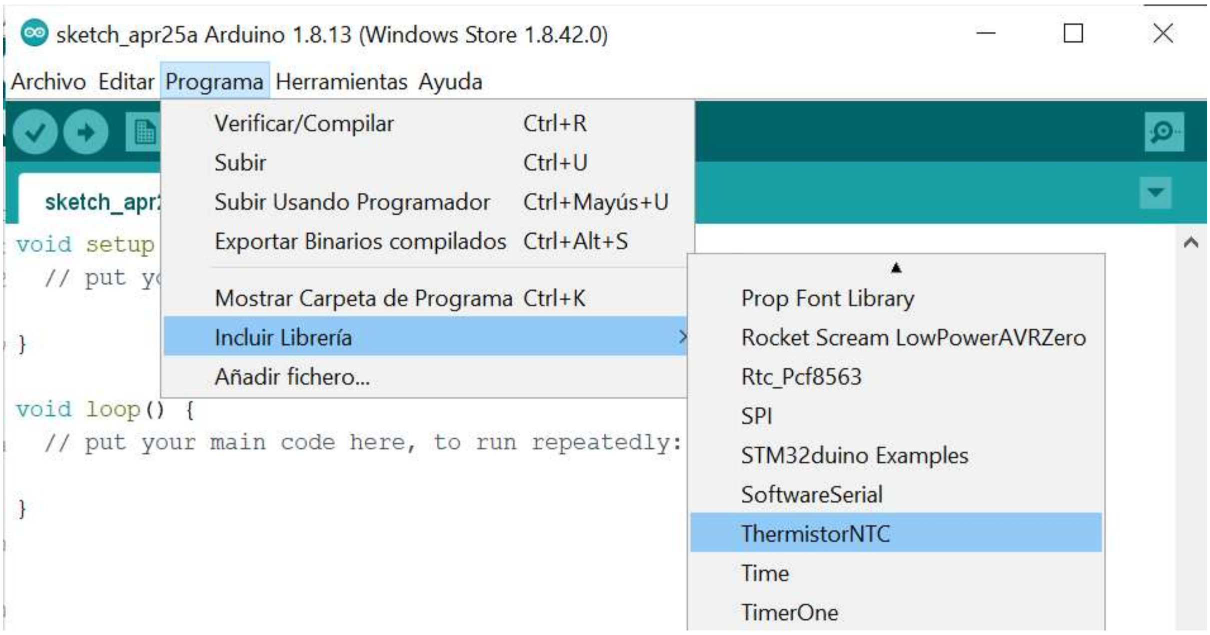


2. Click *Add to project* button. Library will be included in the project and "platformio.ini" updated.

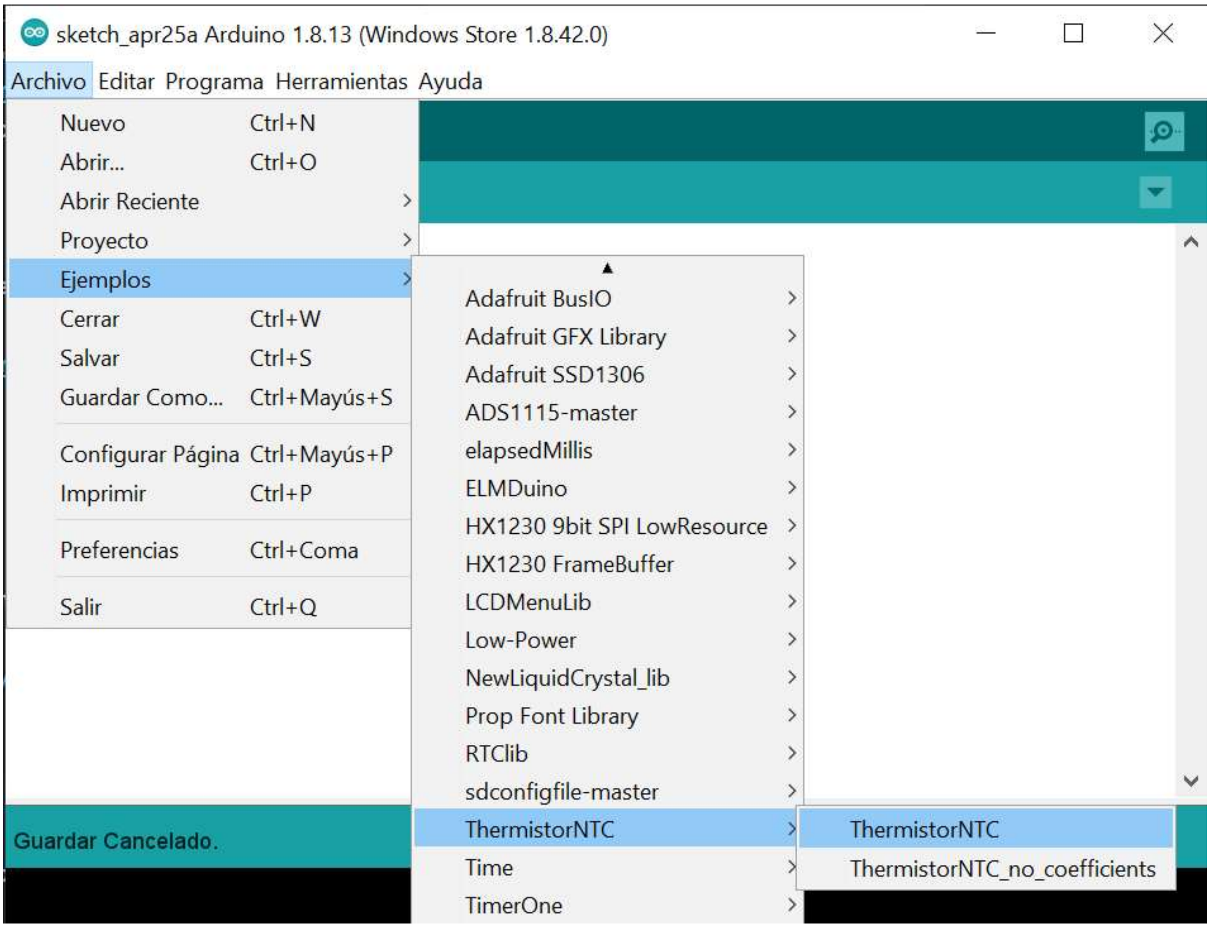


How to use the library

In Arduino IDE, Choose Sketch/Include Library/Scroll and select "ThermistorNTC".



There are a two examples files with the library. In the Arduino IDE, choose File/Examples/ThermistorNTC, and you can see "ThermistorNTC" and "ThermistorNTC_no_coefficients".



--- or ---

See the example code in section Simple example above.

The library implement the type:

```
enum Thermistor_connection {
  VCC,
  GND
  };
```

Usage:

```
// VCC or GND where thermistor configuration.
//   If no value, use VCC as default.
//
double sensor0 = thermistor0.getTempCelsius(VCC);
//double sensor0 = thermistor0.getTempCelsius(GND);
//double sensor0 = thermistor0.getTempCelsius();  /* VCC as default. */
```

Constructors

```
// Constructor for thermistor 4 coefficients Steinhart-Hart equation.
Thermistor::Thermistor(int PIN,
                       long RESISTOR,
                       long NTC_25C,
                       double A,
                       double B,
                       double C,
                       double D,
                       float VREF)

// Constructor for thermistor 3 coefficients Steinhart-Hart equation.
//   Some manufacturers use C coefficient equal to 0 for simplicity.
Thermistor::Thermistor(int PIN,
                       long RESISTOR,
                       long NTC_25C,
                       double A,
                       double B,
                       double D,
                       float VREF)

// Constructor for thermistor beta equation.
Thermistor::Thermistor(int PIN,
                       long RESISTOR,
                       long NTC_25C,
                       float BETA,
                       float VREF)

// Constructor for unknowns thermistor parameters. (3 measures)
Thermistor::Thermistor(int PIN,
```

```
                           long RESISTOR,
                           long NTC_1,
                           float TEMP_1,
                           long NTC_2,
                           float TEMP_2,
                           long NTC_3,
                           float TEMP_3,
                           float VREF)
// Constructor for unknowns thermistor parameters. (4 measures)
Thermistor::Thermistor(int PIN,
                           long RESISTOR,
                           long NTC_1,
                           float TEMP_1,
                           long NTC_2,
                           float TEMP_2,
                           long NTC_3,
                           float TEMP_3,
                           long NTC_4,
                           float TEMP_4,
                           float VREF)
```

Where:

- **PIN** - Analog port for get ADC (analogRead() function)
- **RESISTOR** - Value in ohms of resistor in voltage divisor.
- **NTC_25C** - Resistance value of NTC thermistor at 298.15ºK (25ºC)
- **A**, **B**, **C**, **D** - NTC Thermistor coefficients
- **BETA** - Beta coefficient of NTC thermistor.
- **VREF** - Voltage aplied to voltage divisor (usually VCC.)
- **NTC_1**, **NTC_2**, **NTC_3**, **NTC_4** - Resistance value of NTC thermistor at differents temperatures.
- **TEMP_1**, **TEMP_2**, **TEMP_3**, **TEMP_4** - Temperature value in (ºC). Meassures of Temperature should be TEMP_1 < TEMP_2 < TEMP_3 < TEMP_4, for get better estimated values, but not mandatory. The temperatures should be evenly spaced and at least 10 degrees apart for better results.

Functions implamented

```
void setADC(int);
void setEMA(float);

double getTempKelvin(Thermistor_connection ConType);
double getTempCelsius(Thermistor_connection ConType);
double getTempFahrenheit(Thermistor_connection ConType);
```

```
double fastTempKelvin(Thermistor_connection ConType);
double fastTempCelsius(Thermistor_connection ConType);
double fastTempFahrenheit(Thermistor_connection ConType);

double getTempKelvin_SteinHart(Thermistor_connection ConType);
double getTempCelsius_SteinHart(Thermistor_connection ConType);
double getTempFahrenheit_SteinHart(Thermistor_connection ConType);
```

- **setADC** - Set maximal value of ADC. For 10-bits ADC resolution, will be 2^10 = 1024. For 12-bits ADC resolution, the value will be 2^12 = 4096. Library autodetect for Atmega328, ATmega168 and LGT8F328P.
- **setEMA -** Set value for EMA Filter ADC readings. Default is 0,91. The library gets 15 values from ADC port at maximal resolution every time it is called for estimated the temperature. It is used the EMA filtered ADC value with formula: **Y[n] = alpha * X[n] + (1 - alpha) * Y[n-1]**, to estimate the temperature. For more info about EMA (Exponential Moving Average) see Exponential Moving Average, and how to implement it EMA C++ Implementation.
- **getTemp...** Return the temperature in the respective range using Beta equation.
- **fastTemp...** Return the temperature in the respective range using Fast equation. More fast than the other methods. It is used beta parameter.
- **getTemp..._Steinhart** Return the temperature in the respective range using Steinhart-Hart equation.

Simple Example

```
#include <ThermistorNTC.h>

Thermistor thermistor0(/* PIN */       A0,
                      /* RESISTOR */  21900L,
                      /* NTC 25ºC */  9950L,
                      /* A */         3354016e-9,
                      /* B */         2569850e-10,
                      /* C */         2620131e-12,
                      /* D */         6383091e-14,
                      /* Vref */      5.03);

Thermistor thermistor1(/* PIN */       A1,
                      /* RESISTOR */  21900L,
                      /* NTC 25ºC */  9950L,
                      /* BETA */      4190.0,
                      /* Vref */      5.03);

void setup(void)
```

```
{
  Serial.begin(57600);
}


void loop(void)
{
  double sensor0 = thermistor0.getTempCelsius_SteinHart(VCC);
  Serial.print("Sensor0 - Temp(ºC): ");
  Serial.println(sensor0);

  double sensor1 = thermistor1.getTempCelsius(); // VCC default if not expresed.
  Serial.print("Sensor1 - Temp(ºC): ");
  Serial.println(sensor1);

  double sensor1_fast = thermistor1.fastTempCelsius();
  Serial.print("Sensor1 fast calc - Temp(ºC): ");
  Serial.println(sensor1_fast);

  delay(1000);
}
```

Thermistor with unknowns coefficients

```
Thermistor thermistor1(/* PIN */      A1,
                       /* RESISTOR */  22170L,
                       /* NTC_T1 */    355000L,
                       /* T1 (ºC) */   0.0,   // 273,15 ºK
                       /* NTC_T2 */    157500L,
                       /* T1 (ºC) */   28.0, // 301,15 ºK
                       /* NTC_T3 */    58300L,
                       /* T1 (ºC) */   35.0, // 308,15 ºK
                       /* Vref */      5.072);
```

Or:

```
Thermistor thermistor2(/* PIN */      A2,
                       /* RESISTOR */  22170L,
                       /* NTC_T1 */    355000L,
                       /* T1 (ºC) */   0.0,   // 273,15 ºK
                       /* NTC_T2 */    157500L,
                       /* T2 (ºC) */   14.0, // 287,15 ºK
                       /* NTC_T3 */    79300L,
                       /* T3 (ºC) */   28.0, // 301,15 ºK
                       /* NTC_T4 */    58300L,
                       /* T4 (ºC) */   35.0, // 308,15 ºK
                       /* Vref */      5.072);
```

When the coefficients are unknowns, It can use the above Constructor. The library calculate all the coefficients. It can use although getTemp... and fastTemp... Functions. It must measure the thermistor resistance at three or four different temperatures. The temperatures should be evenly spaced and at least 10 degrees apart for better results.

When it is used the Constructors above the library calc **A**, **B**, **C**, **D**, **BETA** and **NTC_25C** parameters. So, it can use any function to get the temperature. When use three pair of values (Resistance of NTC, Temperature ºC), **A**, **B** and **D** parameters are estimated. As you can get with Thermistor Calculator V1.1. But if it use four pairs of them (Resistance of NTC, Temperature ºC), **A**, **B**, **C** and **D** parameters are estimated.

Unknow coefficients whith 3 measures of Resistence and Temperature

$$\frac{1}{T_1} = A + B * \ln\left(R_1\right) + D * \ln^3\left(R_1\right)$$
$$\frac{1}{T_2} = A + B * \ln\left(R_2\right) + D * \ln^3\left(R_2\right)$$
$$\frac{1}{T_3} = A + B * \ln\left(R_3\right) + D * \ln^3\left(R_3\right)$$

$$\begin{bmatrix} 1 & \ln R_1 & \ln^3 R_1 \\ 1 & \ln R_2 & \ln^3 R_2 \\ 1 & \ln R_3 & \ln^3 R_3 \end{bmatrix} \begin{bmatrix} A \\ B \\ D \end{bmatrix} = \begin{bmatrix} \frac{1}{T_1} \\ \frac{1}{T_2} \\ \frac{1}{T_3} \end{bmatrix}$$

$$L_1 = \ln R_1, \quad L_2 = \ln R_2, \quad L_3 = \ln R_3$$

$$Y_1 = \frac{1}{T_1}, \quad Y_2 = \frac{1}{T_2}, \quad Y_3 = \frac{1}{T_3}$$

$$\gamma_2 = \frac{Y_2 - Y_1}{L_2 - L_1}, \quad \gamma_3 = \frac{Y_3 - Y_1}{L_3 - L_1}$$

$$\Rightarrow D = \frac{\gamma_3 - \gamma_2}{(L_3 - L_2)(L_1 + L_2 + L_3)}$$

$$\Rightarrow B = \gamma_2 - D\left(L_1^2 + L_1 L_2 + L_2^2\right)$$

$$\Rightarrow A = Y_1 - L_1\left(B + D L_1^2\right)$$

You can get **A**, **B** and **D** parameters with Thermistor Calculator V1.1 or solving the system of equations above. For this, there are a utility that can help to solve the system (Resolución de ecuaciones lineales.)

Unknow coefficients whith 4 measures of Resistence and Temperature

$$\frac{1}{T_1} = A + B * \ln\left(R_1\right) + C * \ln^2\left(R_1\right) + D * \ln^3\left(R_1\right)$$
$$\frac{1}{T_2} = A + B * \ln\left(R_2\right) + C * \ln^2\left(R_2\right) + D * \ln^3\left(R_2\right)$$
$$\frac{1}{T_3} = A + B * \ln\left(R_3\right) + C * \ln^2\left(R_3\right) + D * \ln^3\left(R_3\right)$$
$$\frac{1}{T_4} = A + B * \ln\left(R_4\right) + C * \ln^2\left(R_4\right) + D * \ln^3\left(R_4\right)$$

$$\begin{bmatrix} 1 & \ln R_1 & \ln^2 R_1 & \ln^3 R_1 \\ 1 & \ln R_2 & \ln^2 R_2 & \ln^3 R_2 \\ 1 & \ln R_3 & \ln^2 R_3 & \ln^3 R_3 \\ 1 & \ln R_4 & \ln^2 R_4 & \ln^3 R_4 \end{bmatrix} \begin{bmatrix} A \\ B \\ C \\ D \end{bmatrix} = \begin{bmatrix} \frac{1}{T_1} \\ \frac{1}{T_2} \\ \frac{1}{T_3} \\ \frac{1}{T_4} \end{bmatrix}$$

$$L_1 = \ln R_1, \quad L_2 = \ln R_2, \quad L_3 = \ln R_3, \quad L_4 = \ln R_4$$

$$Y_1 = \frac{1}{T_1}, \quad Y_2 = \frac{1}{T_2}, \quad Y_3 = \frac{1}{T_3}, \quad Y_4 = \frac{1}{T_4}$$

$$\begin{aligned} DSA_1 &= (L_3^2 - L_1^2) * (L_2 - L_1) - (L_2^2 - L_1^2) * (L_3 - L_1), \\ DSA_2 &= (L_4^3 - L_1^3) * (L_2 - L_1) - (L_2^3 - L_1^3) * (L_4 - L_1), \\ DSB_1 &= (L_4^2 - L_1^2) * (L_2 - L_1) - (L_2^2 - L_1^2) * (L_4 - L_1), \\ DSB_2 &= (L_3^3 - L_1^3) * (L_2 - L_1) - (L_2^3 - L_1^3) * (L_3 - L_1), \\ DY_1 &= (Y_3 - Y_1) * (L_2 - L_1) - (Y_2 - Y_1) * (L_3 - L_1), \\ DY_2 &= (Y_4 - Y_1) * (L_2 - L_1) - (Y_2 - Y_1) * (L_4 - L_1), \\ DS &= (DSA_1 * DSA_2) - (DSB_1 * DSB_2), \\ DC &= (DY_1 * DSA_2) - (DY_2 * DSB_2), \\ DD &= (DY_2 * DSA_1) - (DY_1 * DSB_1) \end{aligned}$$

$$\Rightarrow D = \frac{DD}{DS}, \quad C = \frac{DC}{DS}$$

$$\begin{aligned} Z_1 &= Y_1 - C * L_1^2 - D * L_1^3, \\ Z_2 &= Y_2 - C * L_2^2 - D * L_2^3 \end{aligned}$$

$$\Rightarrow B = \frac{Z_2 - Z_1}{L_2 - L_1}, \quad A = \frac{(Z_1 * L_2) - (Z_2 * L_1)}{L_2 - L_1}$$

To get **A**, **B**,**C** and **D** parameters there are a utility that can help to solve the system (Resolución de ecuaciones lineales.)

License

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This proyect began as a fork of SteinhartHart work by Andreas Tacke. If you want to know more about this work, visit the Github page.

Credits

Thermometer icon at the beginning is from Flaticon.es designed by Those Icons and licensed by free license.