

# PT-100 Hardware Assignment

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## CONTENTS

**Abstract**—This document contains a lab report on the modeling of the voltage-temperature characteristics of the PT-100 RTD (Resistance Temperature Detector) using least squares method.

**Training Data** The training data gathered by the PT-100 to train the Arduino is shown in Table ??.

Temperature (°C)	Voltage (V)
25.2	4.604
30.5	4.609
54.1	4.637
62.7	4.647
57.1	4.638
81.6	4.653
85.0	4.658
90.2	4.663
91.6	4.679
93.8	4.690

TABLE 1: Training data.

The C++ source codes/data.cpp was used along with *platformio* to drive the Arduino.

## 1 MODEL

For the PT-100, we use the Callendar-Van Dusen equation

$$V(T) = V(0)(1 + AT + BT^2) \quad (1)$$

$$\Rightarrow c = \mathbf{n}^T \mathbf{x} \quad (2)$$

where

$$c = V(T), \quad \mathbf{n} = V(0) \begin{pmatrix} 1 \\ A \\ B \end{pmatrix}, \quad \mathbf{x} = \begin{pmatrix} 1 \\ T \\ T^2 \end{pmatrix} \quad (3)$$

For multiple points, (??) becomes

$$\mathbf{X}^T \mathbf{n} = \mathbf{C} \quad (4)$$

where

$$\mathbf{X} = \begin{pmatrix} 1 & 1 & \dots & 1 \\ T_1 & T_2 & \dots & T_n \\ T_1^2 & T_2^2 & \dots & T_n^2 \end{pmatrix} \quad (5)$$

$$\mathbf{C} = \begin{pmatrix} V(T_1) \\ V(T_2) \\ \vdots \\ V(T_n) \end{pmatrix} \quad (6)$$

and  $\mathbf{n}$  is the unknown.

## 2 SOLUTION

We approximate  $\mathbf{n}$  by using the least squares method. Using the pseudo-inverse method, the solution to (??) is

$$\mathbf{n} = (\mathbf{X}\mathbf{X}^T)^{-1} \mathbf{X}\mathbf{C} \quad (7)$$

The Python code codes/lsq.py solves for  $\mathbf{n}$ .

The calculated value of  $\mathbf{n}$  is

$$\mathbf{n} = \begin{pmatrix} 4.5855 \\ 9.954729 \times 10^{-4} \\ -4.5250 \times 10^{-7} \end{pmatrix} \quad (8)$$

The approximation is shown in Fig. ??.

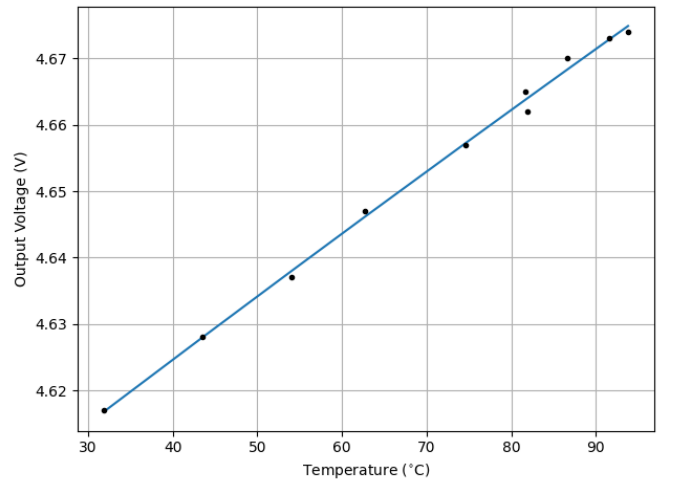


Fig. 1: Training the model.

### 3 VALIDATION

The validation dataset is shown in Table ?? . The results of the validation are shown in Fig. ?? .

TABLE 2: Validation data.

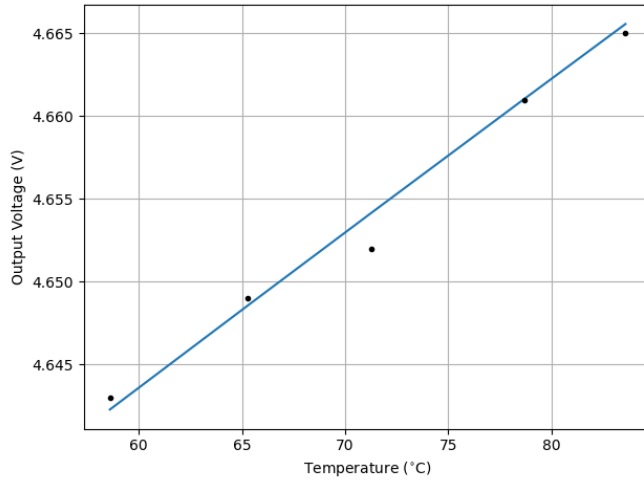


Fig. 2: Validating the model.

### 4 CONCLUSION

This lab experiment demonstrates how machine learning methods can be used to model the behaviour of an unknown device, and find the right parameters that fit the model. It also shows how to use Python libraries and frameworks to collect data and perform optimization.