periNODE 0-10V

periNODE 0-10V Polynomial Determination Application Note

Application Note

Perinet
Seamless IoT Connectivity

Abstract

The periNODE 0-10V is the *Perinet* Smart Component that operates with general sensors in the range 0-10 Volts. Despite being easily configured through the RESTFul API, periNODE 0-10V still needs to know the polynomial function that should be applied to fit to the used sensor. Therefore, the subject of this application note is to obtain the polynomial function that should be configured in the periNODE 0-10V. The linear and nonlinear regression methods with examples are explained and a guide to configure the periNODE 0-10V is also presented in this document.

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1 Introduction

Sensors have a high variety of properties like the sensing range (40-300 mm, 50-1200 mm) which needs to be calculated accordingly before providing a meaningful value in the desired unit to the endpoints (MQTT and HTTP).

The due transformation of the value read in the sensor is executed by the firmware running in the device. The periNODE 0-10V has the capability to interpolate the value with a user configured polynomial function. This feature makes the device generic to fit as many sensors as possible without any effort to adapt the firmware.

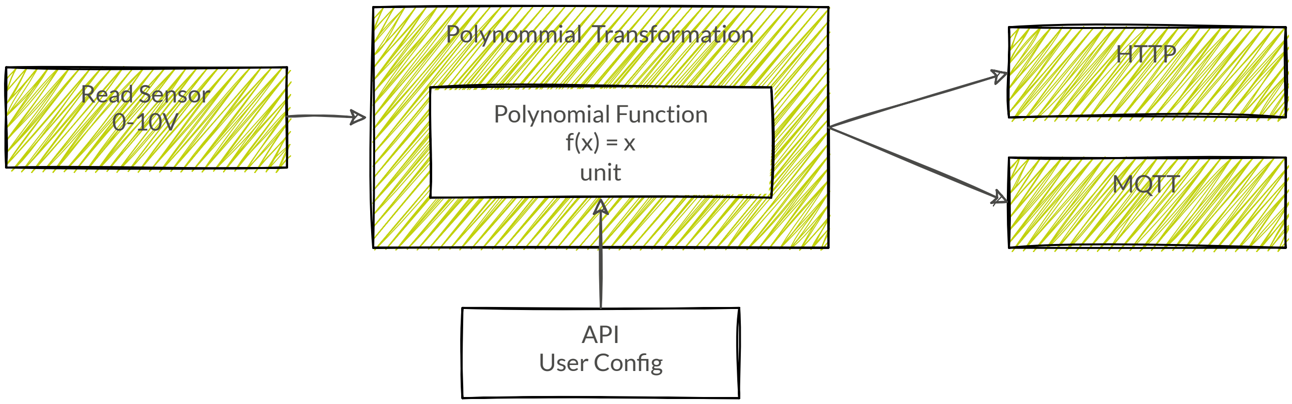

Figure 1: Overview of the Polynomial Transformation

Figure 1 presents the dataflow: the data is read in the sensor, a *Polynomial function* interpolated the value and after that the sample is distributed to the endpoints (HTTP and MQTT). Through the RESTful API the user can configure the unit, a polynomial function to be applied and the maximal and the minimal value allowed.

Since the periNODE 0-10V is already able to interpolate the value and can be adapted to work with different sensors, it is necessary to know how to determine the function that should be used.

This application note explains the methods of *Linear* and *Nonlinear Regression* that can be used to obtain the polynomial function and each method is followed by the instructions on how the user can use the WebUI to configure the device.

2 Linear Regression

Regression is a mathematical method used to establish the relationship between two values. After proceeding with a regression analysis, a function is obtained and can be used to predict the value of a variable, called dependent variable, based on the other variable, called independent variable. The simplest method of regression is called *Linear Regression* and it is used in case of a known linear output.

The linearity of a sensor is provided by its manufacturer and depends on how it was designed, the temperature of operation and others variables. When the sensor presents high linearity in the operation range required, it is possible to obtain the function to predict the values using the method of *Linear Regression*.

The chart of the output of this kind of sensor can be represented as a straight line. In order to determine the polynomial function for these sensors, only two samples are required and it is possible to use a single formula to calculate the function.

The generic formula of a straight line is given as:

$$y = ax + b \tag{1}$$

To obtain the coefficient a and the independent variable b the following formula is used:

$$a = \frac{y_1 - y_2}{x_1 - x_2} \tag{2}$$

After obtaining the coefficient a, it is possible to replace the value in the formula to get the b.

$$b = y - ax \tag{3}$$

This section presents an example and applies this method to determine the function using *Linear Regression* followed by the configuration on the periNODE 0-10V.

2.1 Applying Linear Regression to obtain the Polynomial Function

Basically to proceed with the method is needed to collect two samples, and apply a given equation which will provide the coefficient of the variable (x) and the independent value for the equation. To proceed with this method follow the steps below:

1. Collect samples

   In this example a distance sensor is used and works with a range of 30 to 310 millimeters (mm). The first step is to collect the sensor values for the points within the given range. For this use a precise pachymeter and place an object from 30 mm from the sensor. Take the voltage read. After that measure 310 mm and place the obstacle in this distance to the sensor. Take the second voltage read.

   Samples collected are shown in the table below and plotted in Figure 2:

Sensor Voltage (V)	Distance (mm)
1.09725	30
0.00449	310

Table 1: Values taken for apply linear regression

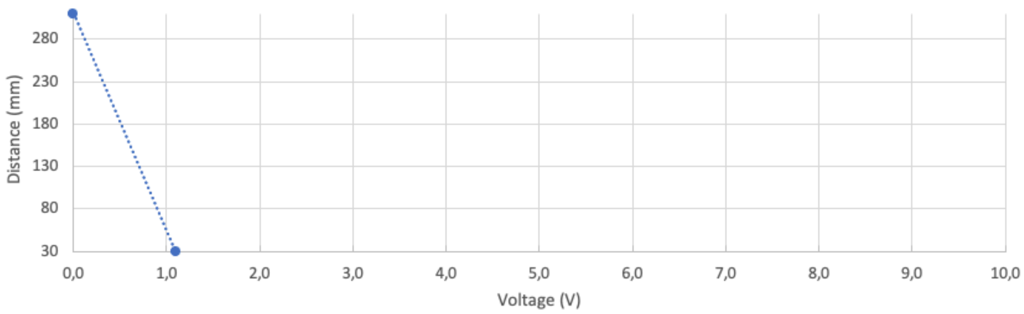

Figure 2: Plot of collected samples

2. Apply the formulas to obtain a and b:

$$a = \frac{y_1 - y_2}{x_1 - x_2}$$

$$a = \frac{310 - 30}{0.00449 - 1.09725} = \frac{280}{-1.09276} = -256.2319$$

Finally, it is possible to calculate b replacing a calculated with formula:

$$b = y - ax$$

$$b = 30 - a * 1.09725 = 30 - (-256.2319 * 1.09725) = 311.1504$$

The *result* polynomial function is shown below and this is the one that needs to be configured in periNODE-0-10V in order to provide the distance in millimeter unit.

$$f(x) = -256.2319x + 311.1504$$

2.2 Configure the periNODE 0-10V

Go to the *Configuration* page of periNODE-0-10V, seen in Figure 3:

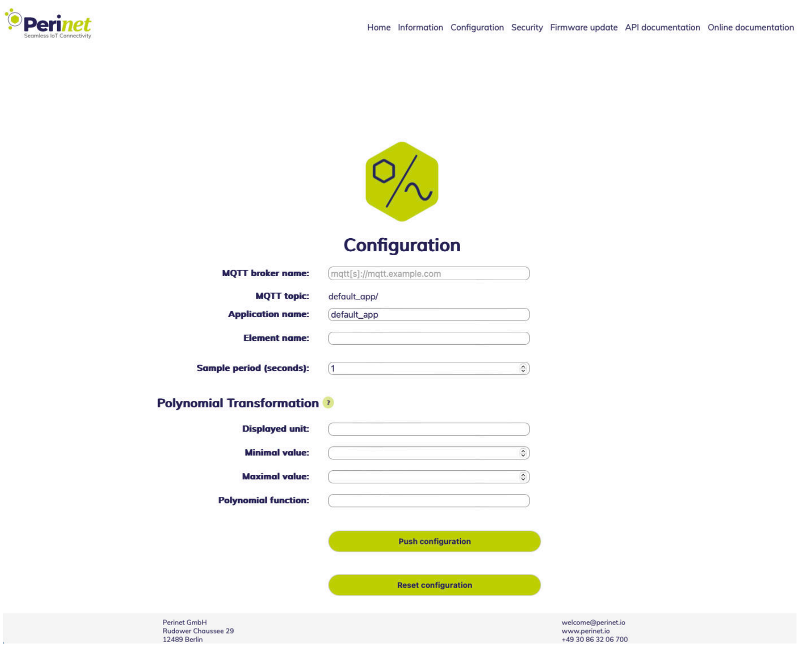

Figure 3: periNODE 0-10V configuration page

In the section *Polynomial Transformation* it is possible to input the *unit*, the *polynomial function* and the *Minimal and Maximal values*. These parameters will be used to present the final samples provided by the periNODE 0-10V.

Figure 4: Example Polynomial Transformation Configuration Linear Regression

Input the parameters and click on the button *Push Configuration*. A confirmation message will pop up and the periNODE-0-10V will reboot. From now on, sample values provided by the API, which is shown on the periNODE *Home* page (Figure 5), and also available through the MQTT should be displayed according to the function to the provided function.

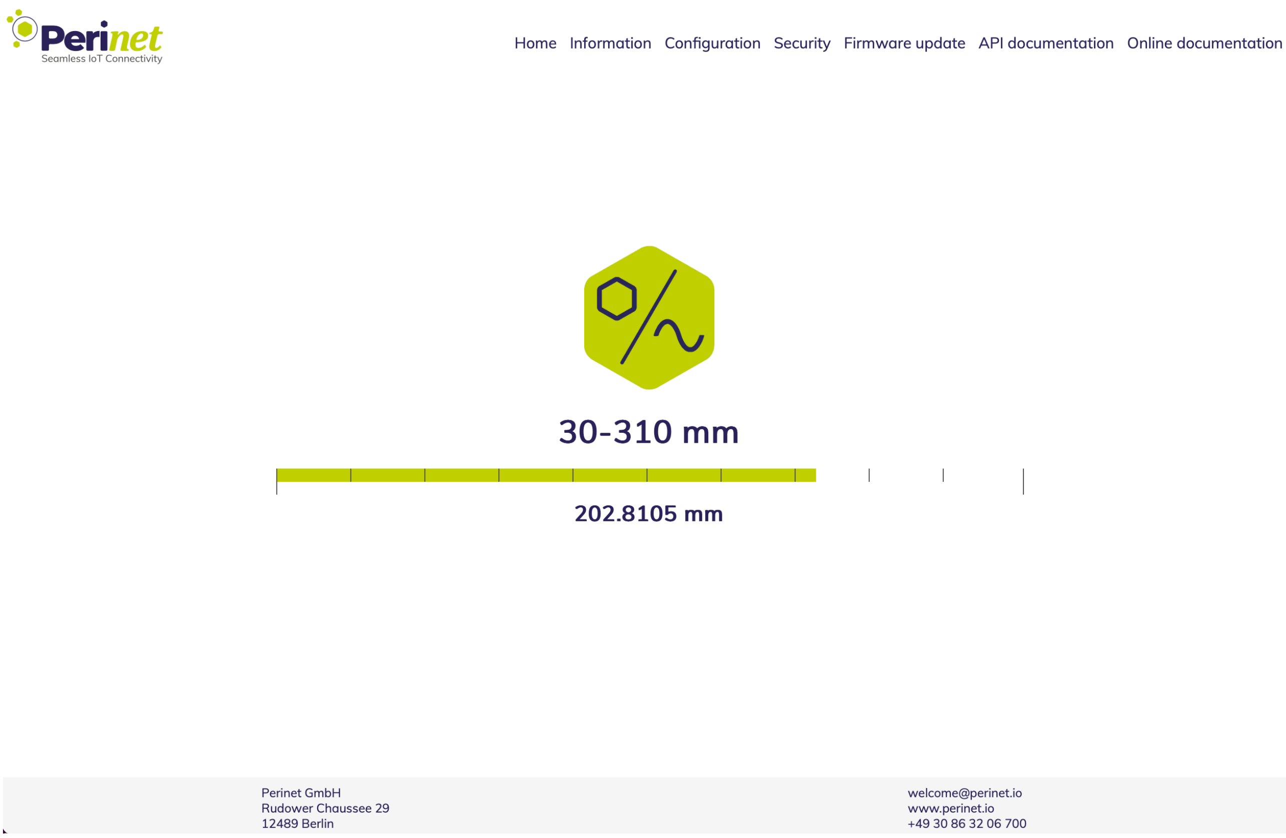

Figure 5: Home Page Configured

3 Nonlinear Regression

Nonlinear regression is a method to obtain a function that provides nonlinear output. In the case of sensors that present nonlinear output, or to consider a wider range and obtain the closest values in the output, it is necessary to use the adequate regression method for this case, this is called *Nonlinear regression*. A commonly used method is the *least square* which provides a function by successive approximations.

The function obtained with the *Nonlinear Regression* analysis has degree 2 or more and require more input samples.

The method can be manually done through the least square method with the formulas presented below. Considering $\mathbf{n}$ the number of samples, the basic formulas are:

$$\sum y = an + b\sum x + c\sum x^2 \tag{4}$$

$$\sum xy = a\sum x + b\sum x + c\sum x^2 \tag{5}$$

$$\sum x^2y = a\sum x^2 + b\sum x^3 + c\sum x^4 \tag{6}$$

To solve this system of equations, more algebra is necessary. In order to avoid mistakes and to make this task easier, this section presents a process using Microsoft Excel©.

3.1 How to use Microsoft Excel to proceed Nonlinear Regression

The Microsoft Excel© is a powerful and widely used tool to manipulate data and to proceed numeric analysis between many others features available.

Here, a step-by-step guide to find the polynomial function is presented which will be used by periNODE-010V to interpolate the samples.

Even though it is encouraged to use Microsoft Excel© to proceed with this operation, please pay attention to the fact that the formula presented might be inaccurate, as is reported in the Office Products Troubleshooting [13].

Note: Make sure to use the *Category Number* and increase the *Decimal places* to calculate the formula with more precision.

1. First step is collect some samples, which have been collected from the sensor, like shown in Table 2. In Figure 6 is possible to observe that for these samples a straight line will not represent the points well.

Sensor Voltage (V)	Distance (cm)
0	10
1	1.8
2	1.3
3	2.5
4	6.5

Table 2: Values taken for apply nonlinear regression

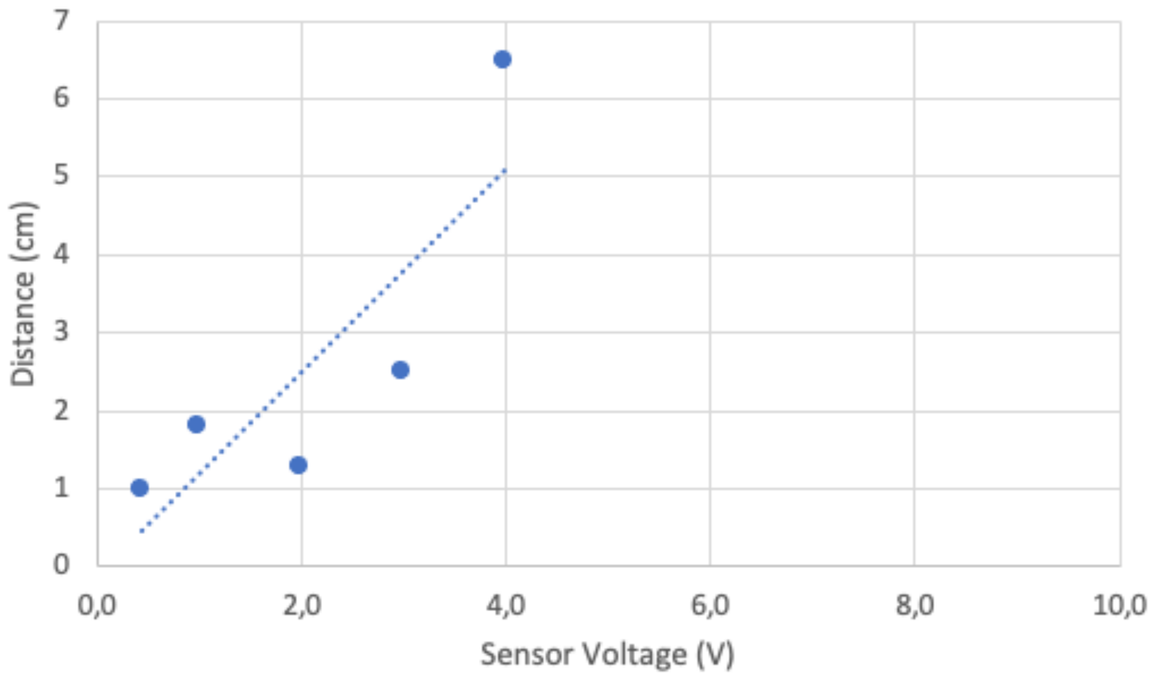

Figure 6: periNODE 0-10V Plot of collected data

2. Place the samples collected in the Microsoft Excel© sheet like the shown in Table 2.
3. Go to *Insert* menu →click on *scatter* like shown below:

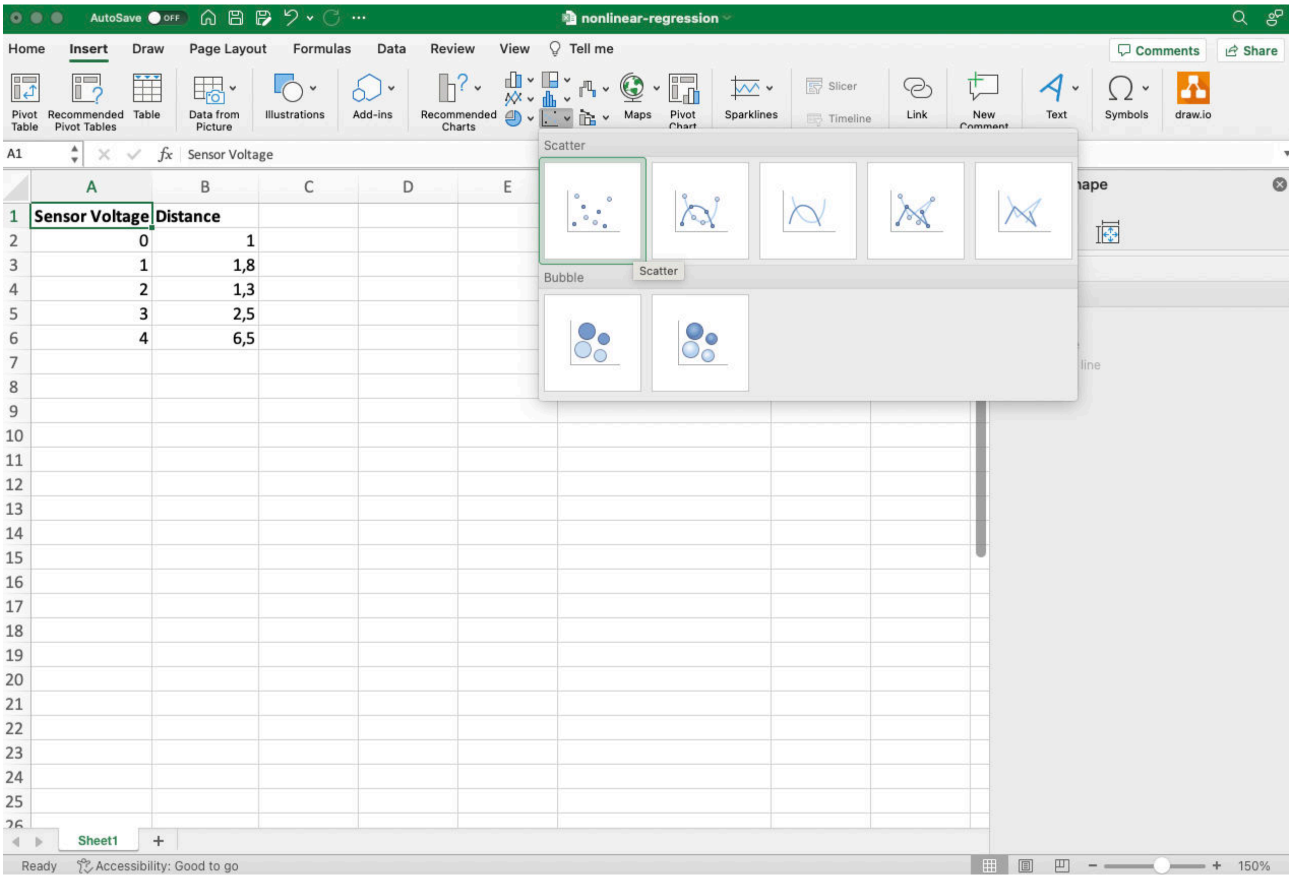

Figure 7: Microsoft Excel Insert Scatter

The scatter will be created with single dots.

4. Go to *Add Chart Element* → *Trendline* → *Linear*.
5. To configure the scatter go to *Add Chart Element* → *Trendline* → *More Trendline Options...*.

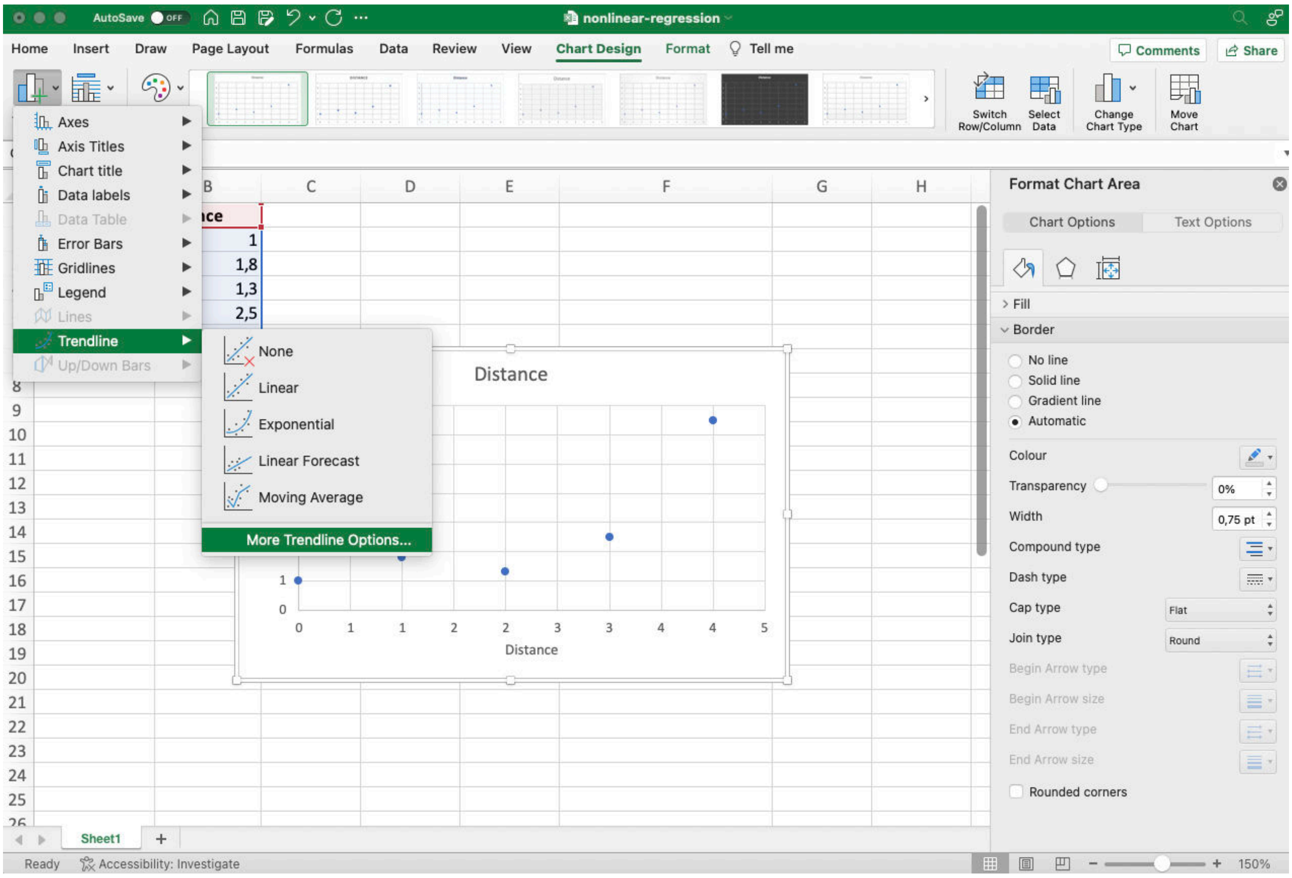

Figure 8: Configuration of the Trendline

6. To determine the order of the function that should be used, simply increase the *Order* and compare the function (see Figure 9). The user can decide how exact the function will be. A higher order will result in greater correlation while increasing the number of parameters.

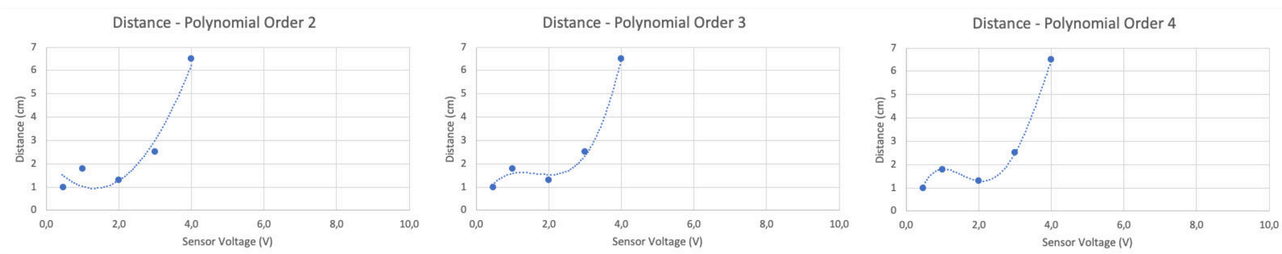

Figure 9: Compare Polynomial Order

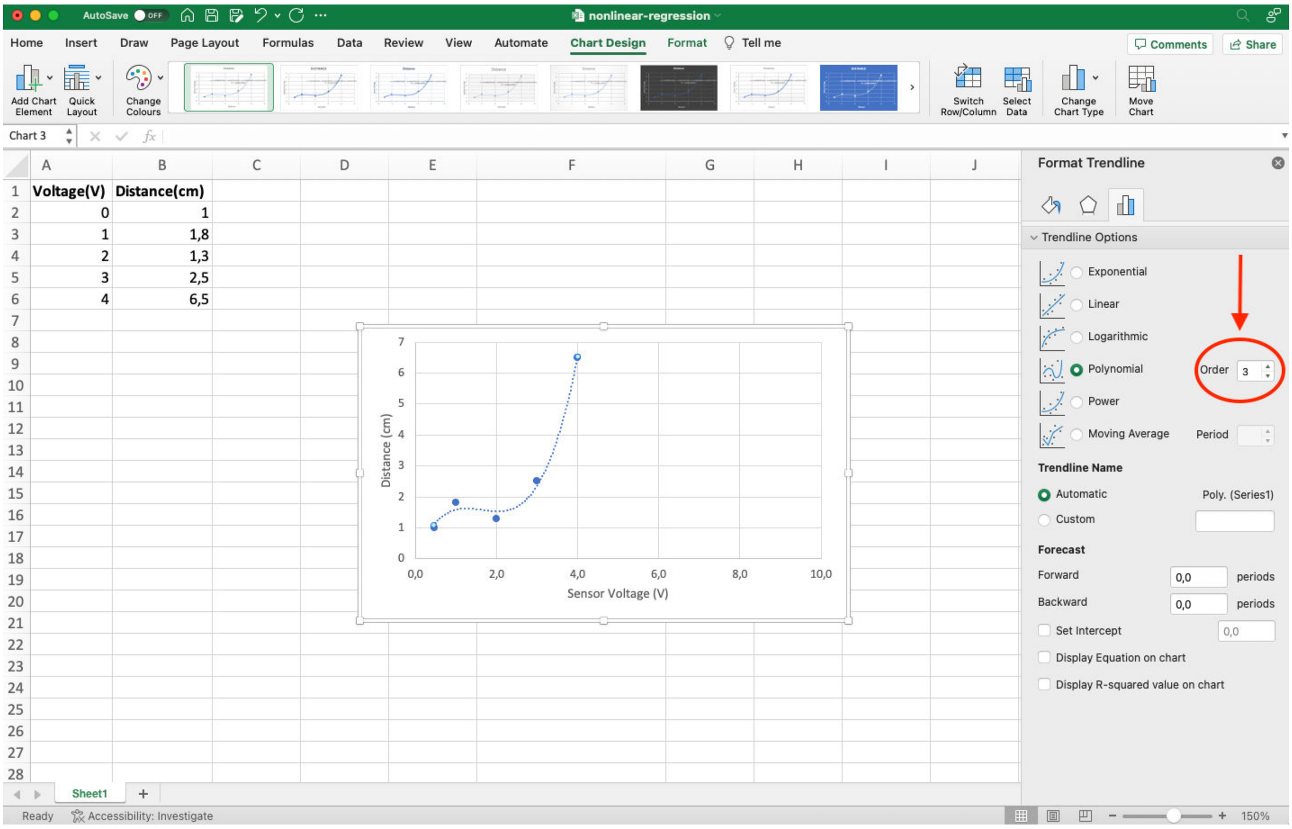

Figure 10: Select polynomial order

7. Marking *Display equation on chart* will show the polynomial function with the coefficients and independent variables that can be copied, pasted and adapt into the configuration page of the periNODE 0-10V.

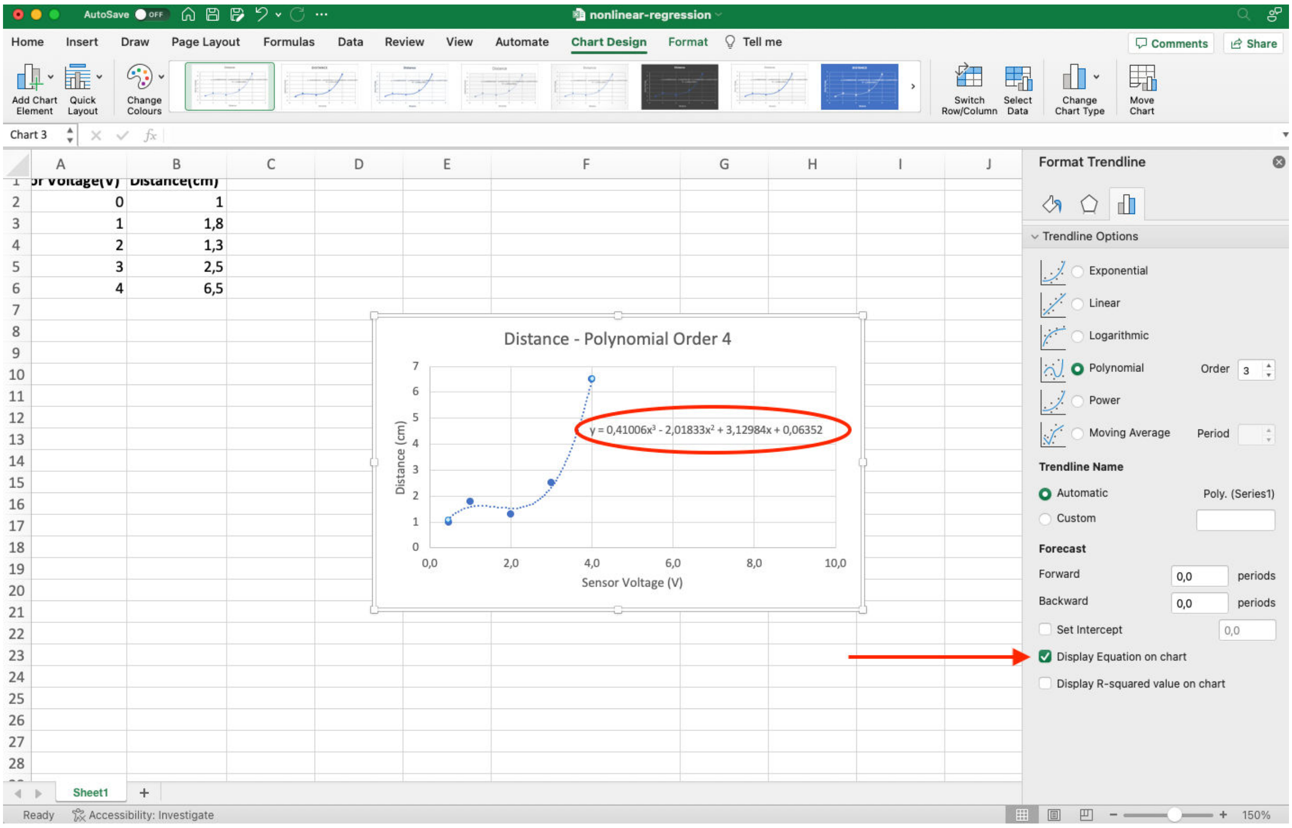

Figure 11: Select the order and mark "Display equation on chart"

The polynomial function obtained is:

$$f(x) = 0.41006x^3 - 2.01833x^2 + 3.12984x + 0.06352$$

Note: Make sure the values used to calculate the formula are *Numbers* and increase the *Decimal Places* to obtain more accurate results as described in Section 3.2.

3.2 Ensure the Accuracy of the Formula

As already mentioned in the beginning of the Section 3.1, the calculated formula is not accurate yet. The following instructions can be used to ensure the accuracy of the formula:

1. Double-click on the formula and set the *Category* to *Number*. See the Figure 12.

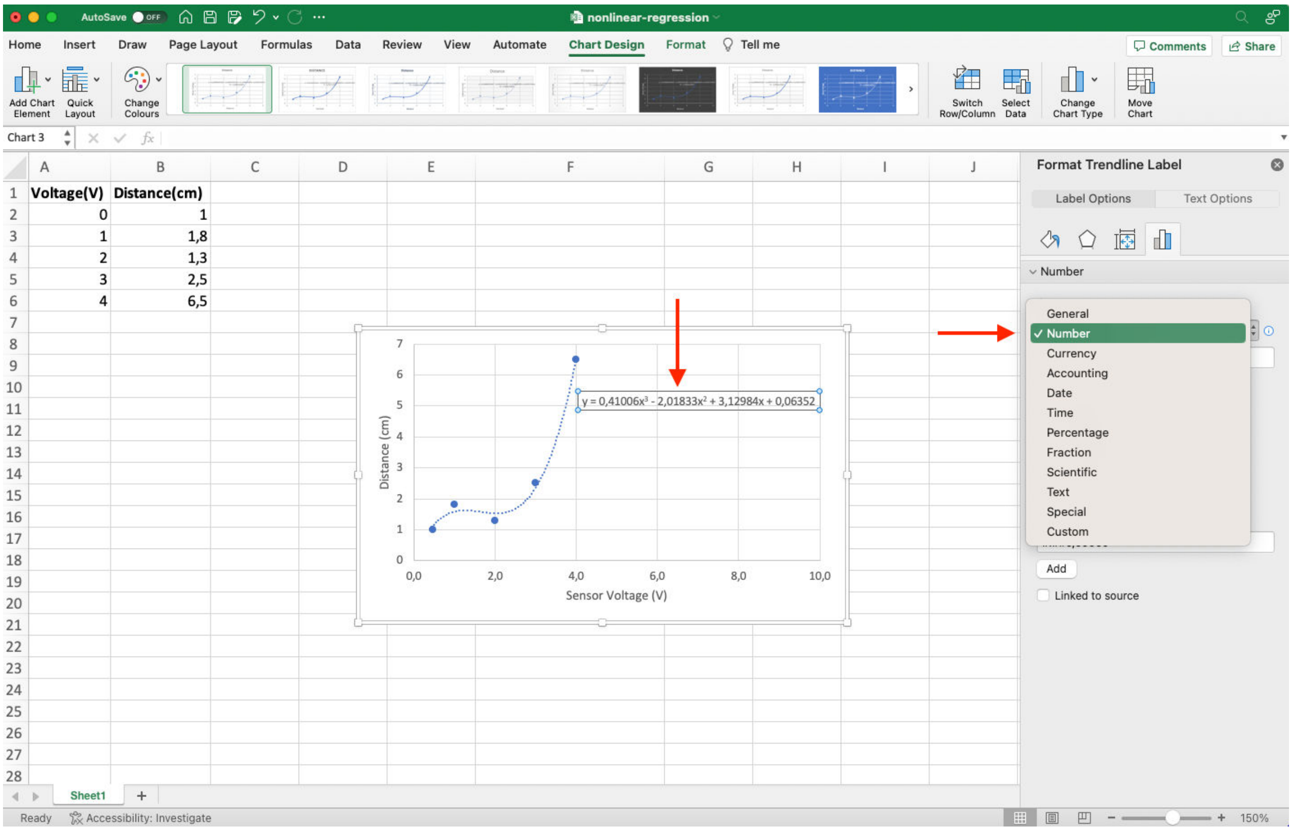

Figure 12: Select the Category Number

2. From the same option tab(*Format Trendline Label*), it is possible to setup the *Decimal Places* required, like presented in Figure 13.

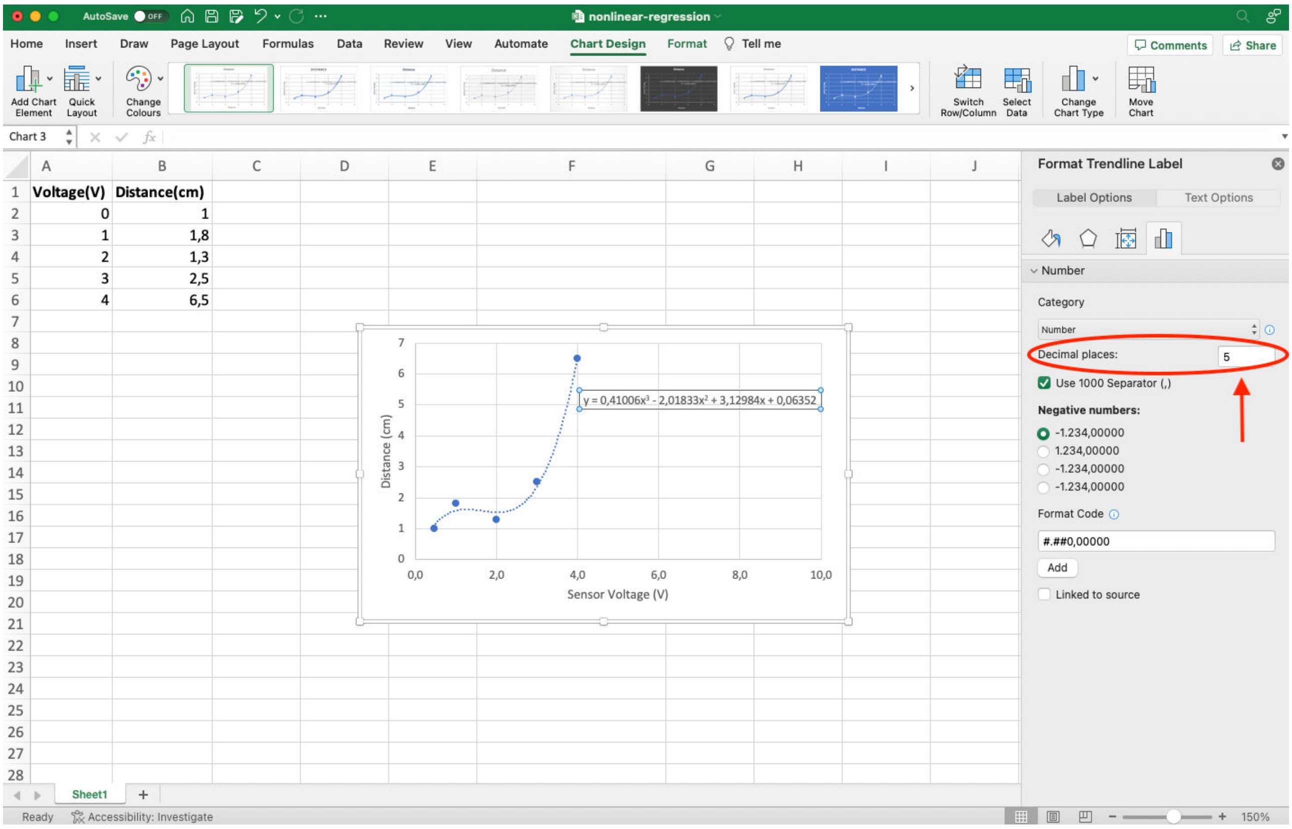

Figure 13: Set Decimal Places

3.3 Configure the periNODE 0-10V

After the function is obtained it needs to be configured in periNODE 0-10V. To do this open the *Config Page* on periNODE. The Configuration page is shown in Figure 14 below:

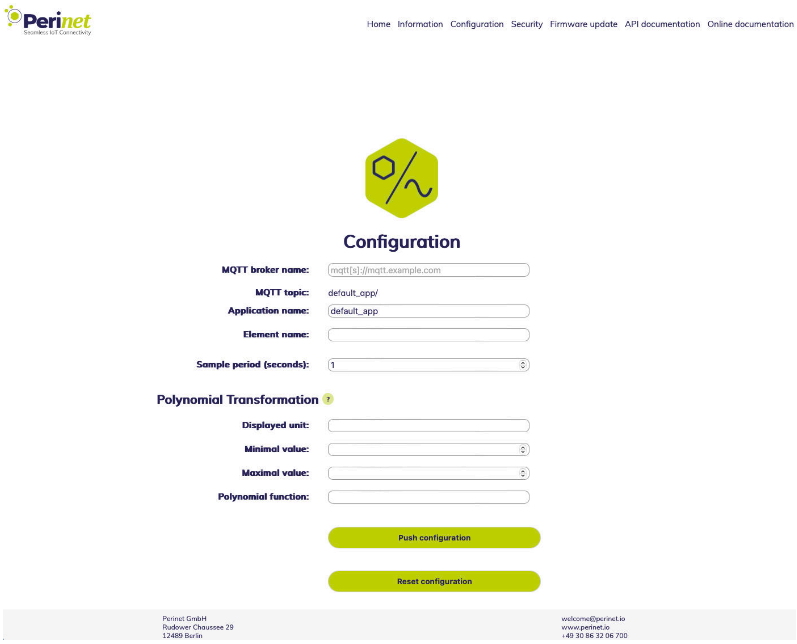

Figure 14: periNODE 0-10V Configuration Page

In the section *Polynomial Transformation* input the parameters like shown in Figure 14:

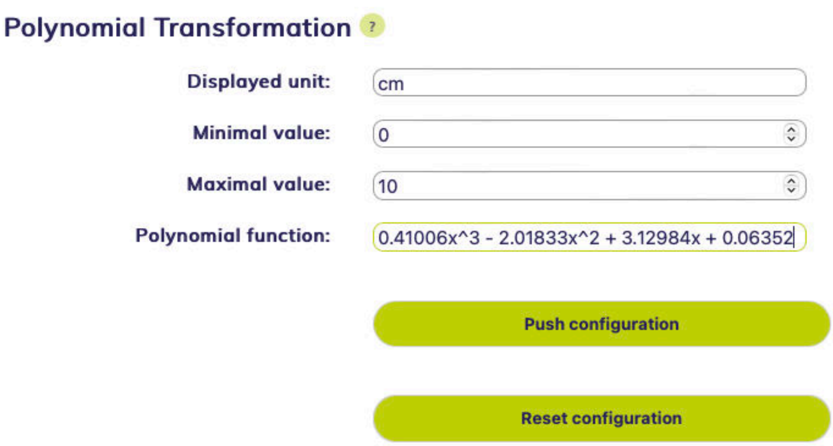

Figure 15: Example polynomial transformation configuration nonlinear regression

Note: It is possible *Copy and paste* the formula from Microsoft Excel© directly in the periNODE 0-10V *Polynomial function* field. Just remember to replace the power (^) symbols and the decimal separators that should be points(.).

When going back into *Home* page, where the samples are shown, it now is possible to see the new values presented in Figure 16.

Figure 16: Example nonlinear regression home page configured

4 Further Documentation

4.1 Perinet Smart Components

Document Name	Description
periLINE Product Summary [6]	A product features summary documentation for the product *periLINE*.
periNODE 0-10V Product Summary [7]	A product features summary documentation for the product *periNODE 0-10V*.
periNODE Pt100 Product Summary [9]	A product features summary documentation for the product *periNODE Pt100*.
periNODE GPIO Product Summary [8]	A product features summary documentation for the product *periNODE GPIO*.
periSWITCH 3-port Product Summary [11]	A product features summary documentation for the product *periSWITCH 3-port*.
periSTART Standard Product Summary [10]	A product features summary documentation for the product *periSTART standard*.
Smart Components Datasheet [12]	A detailed reference documentation of the Smart Components products (*periLINE*, *periNODE 0-10V*, *periNODE Pt100*, *periNODE GPIO*, *periSWITCH 3-port*, *periSTART standard*).

4.2 periCORE

Document Name	Description
periCORE Product Summary [5]	A product features summary documentation for the product *periCORE*.
periCORE Datasheet [1]	A detailed reference documentation of the product *periCORE*.
periCORE Development Kit Product Summary [2]	A product features summary documentation for the product *periCORE Development Kit*.
periCORE Development Kit Setup Application Note [3]	A setup guide for the product *periCORE Development Kit*. The starting point when you are new to the product which describes how to quickly set up a development environment for firmware development for a periCORE based product.
periCORE Development Kit User Guide [4]	A guide and reference documentation for the product *periCORE Development Kit*.

5 Contact & Support

For customer support, please call us at **+49 30 863 206 701** or send an e-mail to *support@perinet.io*.

For complete contact information visit us at www.perinet.io

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C Glossary

API Application Programming Interface. 3, 7

HTTP Hypertext Transfer Protocol is an application-layer protocol for transmitting hypermedia documents, such as HTML. 3

mm millimeters. 3, 4

MQTT Message Queuing Telemetry Transport is a lightweight, publish-subscribe based network protocol that transports messages between devices. 3, 7

REST REpresentational State Transfer, a web API style. 1, 3

UI User Interface. 3

D References

[1] Perinet GmbH. periCORE Datasheet. PRN.100.375. https://docs.perinet.io/PRN100375-periCOREDatasheet.pdf.

[2] Perinet GmbH. periCORE Development Kit Product Summary. PRN.100.546. https://docs.perinet.io/PRN100546-periCOREDevelopmentKitProductSummary.pdf.

[3] Perinet GmbH. periCORE Development Kit Setup Application Note. PRN.100.376. https://docs.perinet.io/PRN100376-periCOREDevelopmentKitSetupApplicationNote.pdf.

[4] Perinet GmbH. periCORE Development Kit User Guide. PRN.100.378. https://docs.perinet.io/PRN100378-periCOREDevelopmentKitUserGuide.pdf.

[5] Perinet GmbH. periCORE Product Summary. PRN.100.301. https://docs.perinet.io/PRN100301-periCOREProductSummary.pdf.

[6] Perinet GmbH. periLINE Product Summary. PRN.100.386. https://docs.perinet.io/PRN100386-periLINEProductSummary.pdf.

[7] Perinet GmbH. periNODE 0-10V Product Summary. PRN.100.380. https://docs.perinet.io/PRN100380-periNODE0-10VProductSummary.pdf.

[8] Perinet GmbH. periNODE GPIO Product Summary. PRN.100.382. https://docs.perinet.io/PRN100382-periNODEGPIOProductSummary.pdf.

[9] Perinet GmbH. periNODE Pt100 Product Summary. PRN.100.381. https://docs.perinet.io/PRN100381-periNODEPt100ProductSummary.pdf.

[10] Perinet GmbH. periSTART Standard Product Summary. PRN.100.383. https://docs.perinet.io/PRN100383-periSTARTstandardProductSummary.pdf.

[11] Perinet GmbH. periSWITCH 3-port Product Summary. PRN.100.385. https://docs.perinet.io/PRN100385-periSWITCH3-portProductSummary.pdf.

[12] Perinet GmbH. Smart Components Datasheet. PRN.100.387. https://docs.perinet.io/PRN100387-SmartComponentsDatasheet.pdf.

[13] Microsoft. *Chart trendline formula is inaccurate in Excel*. URL: https://learn.microsoft.com/en-us/office/troubleshoot/excel/inaccurate-chart-trendline-formula.

E Revision History

Revision	Date	Author(s)	Description
1	2023-02-13	dshe	Initial Release