EcoStruxure Machine Expert - Basic Example Guide

Analog Scaling with Multiple Operands xSample_Analog_Scaling_Multioperand.smbe

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Table of Contents

Safety Information

Important Information

NOTICE

Read these instructions carefully, and look at the equipment to become familiar with the device before trying to install, operate, service, or maintain it. The following special messages may appear throughout this documentation or on the equipment to warn of potential hazards or to call attention to information that clarifies or simplifies a procedure.

The addition of this symbol to a "Danger" or "Warning" safety label indicates that an electrical hazard exists which will result in personal injury if the instructions are not followed.

This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

DANGER

DANGER indicates a hazardous situation which, if not avoided, **will result in** death or serious injury.

WARNING

WARNING indicates a hazardous situation which, if not avoided, **could result in** death or serious injury.

CAUTION

CAUTION indicates a hazardous situation which, if not avoided, **could result** in minor or moderate injury.

NOTICE

NOTICE is used to address practices not related to physical injury.

PLEASE NOTE

Electrical equipment should be installed, operated, serviced, and maintained only by qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this material.

A qualified person is one who has skills and knowledge related to the construction and operation of electrical equipment and its installation, and has received safety training to recognize and avoid the hazards involved.

BEFORE YOU BEGIN

Do not use this product on machinery lacking effective point-of-operation guarding. Lack of effective point-of-operation guarding on a machine can result in serious injury to the operator of that machine.

⚠ WARNING

UNGUARDED EQUIPMENT

- Do not use this software and related automation equipment on equipment which does not have point-of-operation protection.
- Do not reach into machinery during operation.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

This automation equipment and related software is used to control a variety of industrial processes. The type or model of automation equipment suitable for each application will vary depending on factors such as the control function required, degree of protection required, production methods, unusual conditions, government regulations, etc. In some applications, more than one processor may be required, as when backup redundancy is needed.

Only you, the user, machine builder or system integrator can be aware of all the conditions and factors present during setup, operation, and maintenance of the machine and, therefore, can determine the automation equipment and the related safeties and interlocks which can be properly used. When selecting automation and control equipment and related software for a particular application, you should refer to the applicable local and national standards and regulations. The National Safety Council's Accident Prevention Manual (nationally recognized in the United States of America) also provides much useful information.

In some applications, such as packaging machinery, additional operator protection such as point-of-operation guarding must be provided. This is necessary if the operator's hands and other parts of the body are free to enter the pinch points or other hazardous areas and serious injury can occur. Software products alone cannot protect an operator from injury. For this reason the software cannot be substituted for or take the place of point-of-operation protection.

Ensure that appropriate safeties and mechanical/electrical interlocks related to point-of-operation protection have been installed and are operational before placing the equipment into service. All interlocks and safeties related to point-of-operation protection must be coordinated with the related automation equipment and software programming.

NOTE: Coordination of safeties and mechanical/electrical interlocks for point-of-operation protection is outside the scope of the Function Block Library, System User Guide, or other implementation referenced in this documentation.

START-UP AND TEST

Before using electrical control and automation equipment for regular operation after installation, the system should be given a start-up test by qualified personnel to verify correct operation of the equipment. It is important that arrangements for such a check be made and that enough time is allowed to perform complete and satisfactory testing.

⚠ WARNING

EQUIPMENT OPERATION HAZARD

- Verify that all installation and set up procedures have been completed.
- Before operational tests are performed, remove all blocks or other temporary holding means used for shipment from all component devices.
- Remove tools, meters, and debris from equipment.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

Follow all start-up tests recommended in the equipment documentation. Store all equipment documentation for future references.

Software testing must be done in both simulated and real environments.

Verify that the completed system is free from all short circuits and temporary grounds that are not installed according to local regulations (according to the National Electrical Code in the U.S.A, for instance). If high-potential voltage testing is necessary, follow recommendations in equipment documentation to prevent accidental equipment damage.

Before energizing equipment:
- Remove tools, meters, and debris from equipment.
- Close the equipment enclosure door.
- Remove all temporary grounds from incoming power lines.
- Perform all start-up tests recommended by the manufacturer.

OPERATION AND ADJUSTMENTS

The following precautions are from the NEMA Standards Publication ICS 7.1-1995 (English version prevails):

- Regardless of the care exercised in the design and manufacture of equipment or in the selection and ratings of components, there are hazards that can be encountered if such equipment is improperly operated.
- It is sometimes possible to misadjust the equipment and thus produce unsatisfactory or unsafe operation. Always use the manufacturer's instructions as a guide for functional adjustments. Personnel who have access to these adjustments should be familiar with the equipment manufacturer's instructions and the machinery used with the electrical equipment.
- Only those operational adjustments actually required by the operator should be accessible to the operator. Access to other controls should be restricted to prevent unauthorized changes in operating characteristics.

About the Book

At a Glance

Document Scope

This document describes how to acquire analog data and scale it to other limits—in particular back to the original physical values—by using multiple operations in a single Operation Block.

The example described in this document is intended for learning purposes only. It must not be used directly on products that are part of a machine or process.

⚠ WARNING
UNINTENDED EQUIPMENT OPERATION Do not include any wiring information, programming or configuration logic, or parameter values from any of the examples in your machine or process without thoroughly testing your entire application. **Failure to follow these instructions can result in death, serious injury, or equipment damage.**

This document and its related EcoStruxure Machine Expert - Basic project file focus on specific instructions and function blocks provided with EcoStruxure Machine Expert - Basic, and on specific features available in EcoStruxure Machine Expert - Basic. They are intended to help you understand how to develop, test, commission, and integrate applicative software of your own design in your control systems.

The example is intended for new EcoStruxure Machine Expert - Basic users who already have some degree of expertise in the design and programming of control systems.

Validity Note

This document has been updated for the release of EcoStruxure™ Machine Expert - Basic V1.0.

Product Related Information

⚠ WARNING

LOSS OF CONTROL

- The designer of any control scheme must consider the potential failure modes of control paths and, for certain critical control functions, provide a means to achieve a safe state during and after a path failure. Examples of critical control functions are emergency stop and overtravel stop, power outage and restart.
- Separate or redundant control paths must be provided for critical control functions.
- System control paths may include communication links. Consideration must be given to the implications of unanticipated transmission delays or failures of the link.
- Observe all accident prevention regulations and local safety guidelines.[1]
- Each implementation of this equipment must be individually and thoroughly tested for proper operation before being placed into service.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

[1] For additional information, refer to NEMA ICS 1.1 (latest edition), "Safety Guidelines for the Application, Installation, and Maintenance of Solid State Control" and to NEMA ICS 7.1 (latest edition), "Safety Standards for Construction and Guide for Selection, Installation and Operation of Adjustable-Speed Drive Systems" or their equivalent governing your particular location.

⚠ WARNING

UNINTENDED EQUIPMENT OPERATION

- Only use software approved by Schneider Electric for use with this equipment.
- Update your application program every time you change the physical hardware configuration.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

⚠ WARNING

UNINTENDED EQUIPMENT OPERATION

Do not include any wiring information, programming or configuration logic, or parameter values from any of the examples in your machine or process without thoroughly testing your entire application.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

Chapter 1
Example Description

What Is in This Chapter?

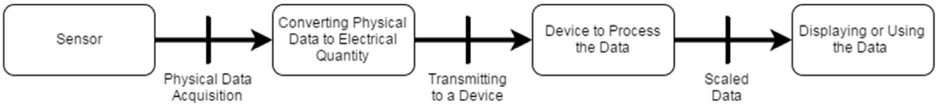
This chapter contains the following topics:

Overview

General

This example guide and its corresponding project template, included with EcoStruxure Machine Expert - Basic, helps you to scale the analog inputs of the M221 Logic Controller by using multiple operands in a single Operation Block. It also shows the use of subroutines and multi-token Grafcet (SFC) POUs.

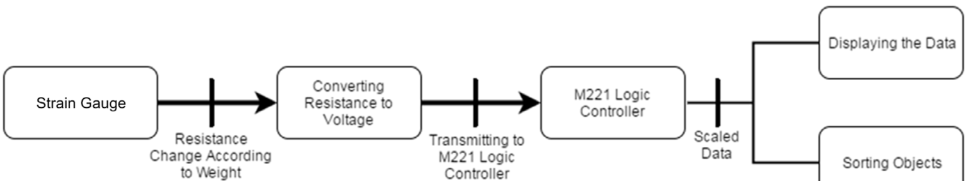
The following graphic illustrates an analog scaling process:



A sensor measures physical data, which is then converted to an electrical quantity. In this example, the physical data is mass and the electrical quantity is electrical potential (voltage). The converted data is then transmitted to a device, which processes and scales it.

The data can be used within the application, for purposes such as sorting objects according to their weight, or it can be displayed in a human machine interface (HMI).

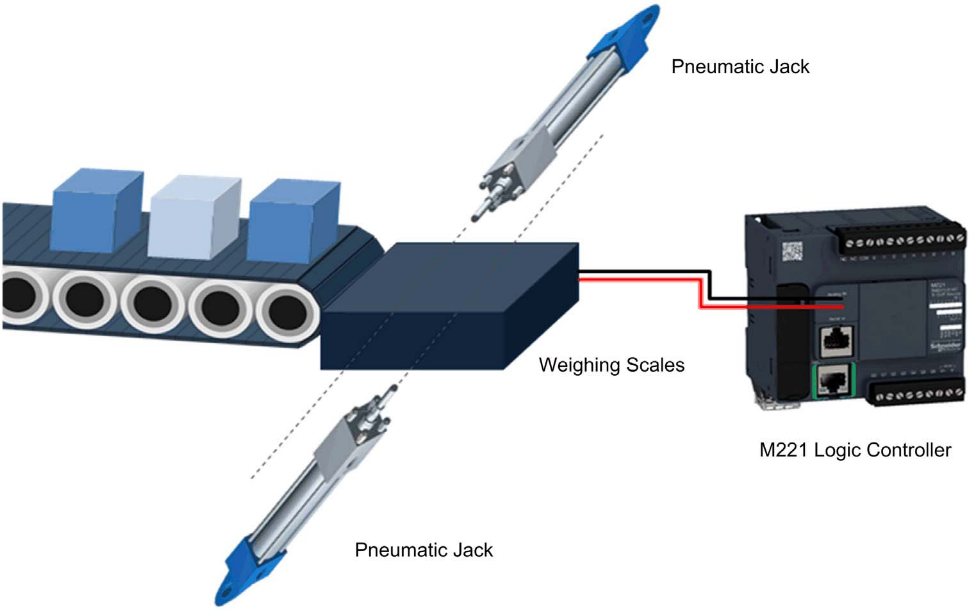
In this example guide, the process is implemented as shown in the following graphic:



A strain gauge in a weighing scale measures physical data, the mass, by its changing resistance. The resistance is then converted to an electrical quantity (electrical potential).

The data is transmitted to an M221 Logic Controller, which processes and scales it. The M221 Logic Controller sends commands to pneumatic jacks, which sort the objects according to their mass. At the same time, the data is displayed in an HMI.

These operations can be seen as a part of the machine process shown in the following graphic:



The objective of this example guide and its associated template is to describe the data processing part of the process so that you can integrate the project template in your application.

Theoretical Background

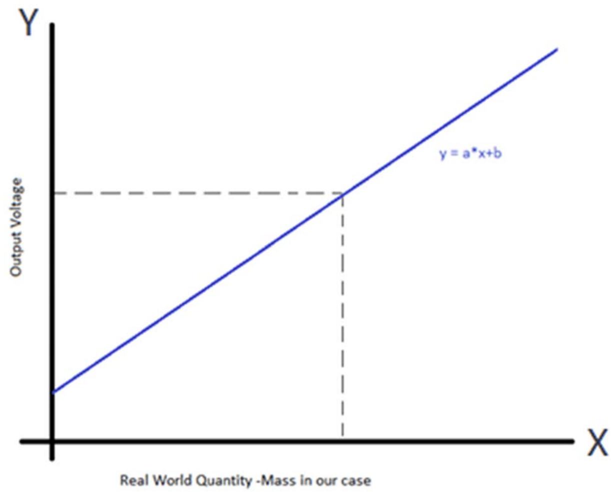
This part shows the logic behind the calculations made for scaling in the project template. See also the setup description *(see page 18)* or the example description *(see page 11)*.

The main objective in this guide is to explain linear scaling. However, you can find the theoretical background information in the appendix *(see page 33)* for other functions (exponential and second degree polynomial).

Linear Variations

A system is said to be linear if the output changes at a constant proportion as a function of the input.

This is illustrated in the following graphic:



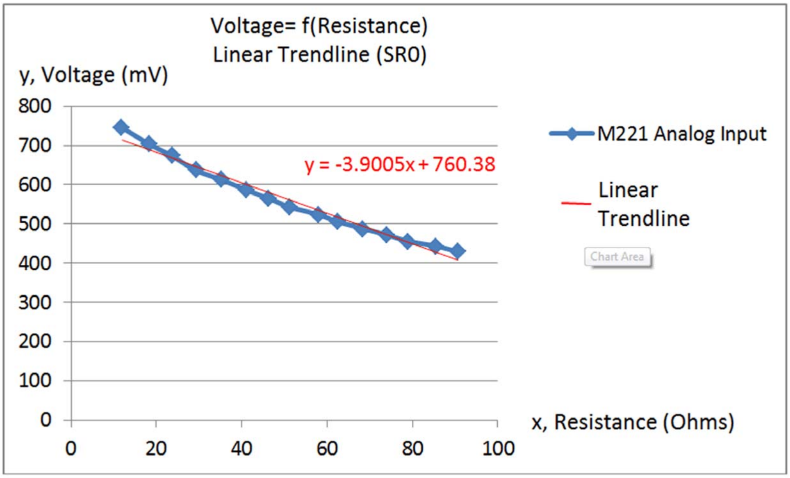
In this example guide, the x-axis is the mass and the y-axis is the analog input of the M221 Logic Controller.

A linear system is characterized by two parameters: the constant `b` and the slope `a`.

However, in this example, there are two systems:

1. Conversion form mass to resistance.
2. Conversion from resistance to voltage. This is not linear, but can be approximated with a linear system.

This approach is called a linear trend line and it is illustrated in the following graphic:

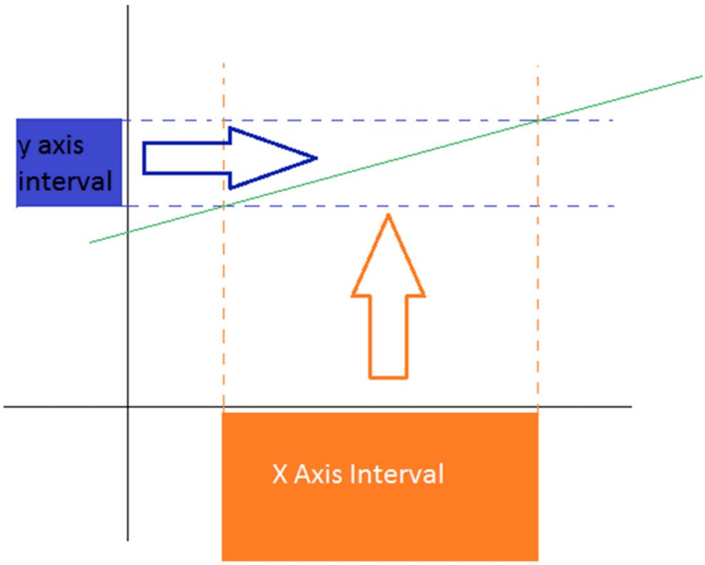


If you need more precision, you can consult the appendices *(see page 33)* for other types of scaling techniques to use.

In this equation, the slope `a` is equal to -3.9005 and the constant `b` is 760.38.

Before using the voltage values in an application, they must be scaled. Scaling involves converting the `x` or `y` values to another axis using a custom equation.

This is illustrated in the following graphic:



The green line represents the equation to be used to pass from one set of axis values to another.

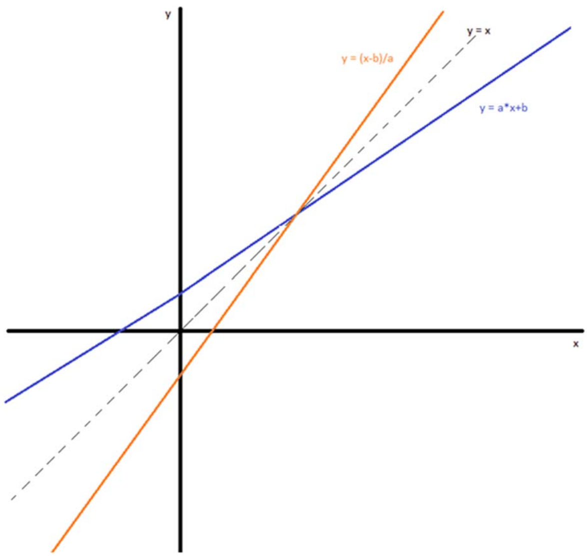
In this template, both of these scaling systems are used. In the first system, the resistance values (x-axis) are converted to mass values (y-axis). In the second system, the voltage values (y-axis) are converted to resistance values (x-axis).

A particular case of passing from y-axis to x-axis is to take the inverse of the function. In the template, this is when voltage values are converted to resistance values in the second system.

Taking the Inverse of a Linear Equation

Taking the inverse of a linear equation can be represented visually as the mirror image of the function with respect to the `y = x` line.

This is illustrated in the following graphic:



However, a visual representation such as this one does not allow you to calculate the actual values.

The inverse of a linear equation of the form `y = a*x+b` is `x = (y/a) - (b/a).`

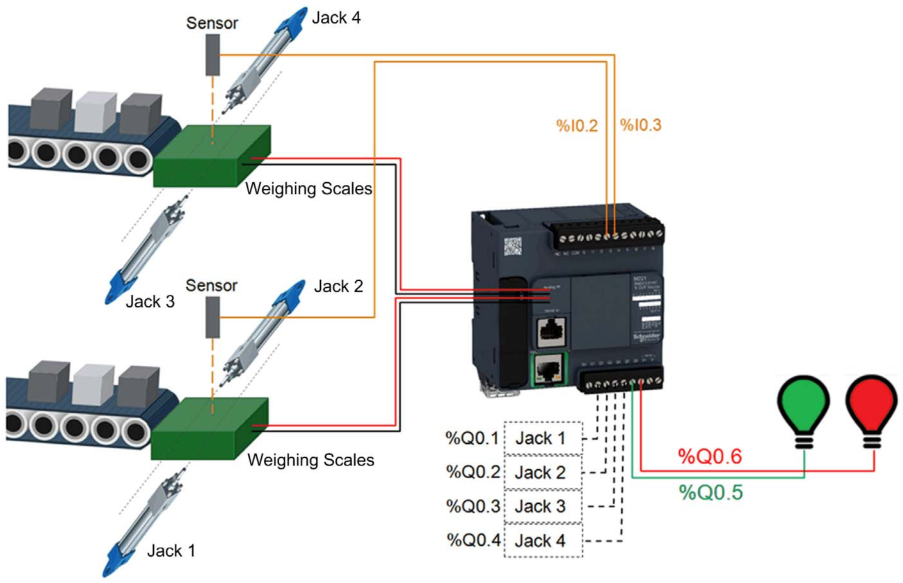
In the project template, this calculation is used in subroutine 0.

Setup Description

Setup Description

The template is based on the machine mentioned in the overview *(see page 12)*.

The following graphic shows a more detailed description of the machine, with specific inputs and outputs shown:



There are two weighing scales for sorting small boxes arriving from two conveyor belts. Depending on its mass, the pneumatic jacks push each small box right or left into larger boxes. The conveyor belts and the larger boxes are not in the scope of this example template.

Chapter 2
Project Template Description

What Is in This Chapter?

This chapter contains the following topics:

Project Template Description

Project Template Description

Open the associated template in EcoStruxure Machine Expert - Basic and follow the explanations given in the template.

Configuration of Analog Inputs

In this example, only the embedded analog inputs of the M221 Logic Controller are used:

Analog inputs

Used	Address	Symbol	Type	Scope	Minimum	Maximum	Filter level	Filter Unit	Sampling	Units	Comment
☑	%IW0.0	ANALOG_DAT	0 - 10 V	Normal	0	1000	0				Contains the first scale's voltage output
☑	%IW0.1	ANALOG_DAT	0 - 10 V	Normal	0	1000	0				Contains the second scale's voltage output

In EcoStruxure Machine Expert - Basic, embedded analog inputs are not configurable. For your application, therefore, you should consider using TMC2 cartridges or TM2/TM3 expansion modules. This allows you to:

- Use smaller intervals (min/max values) to trade precision for stability.
- Use filtering for more stability (the acquisition time is longer).

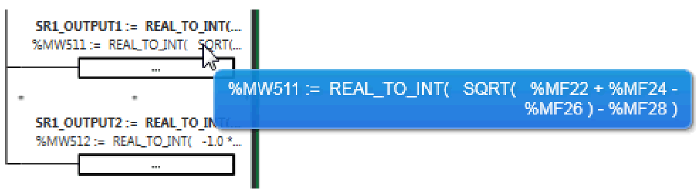
Implemented Features

In this project template, the following EcoStruxure Machine Expert - Basic features are used:

- Multiple Operands
- Function Search
- Multitoken Grafcet (SFC)
- Subroutines

Multiple Operands

With EcoStruxure Machine Expert - Basic V1.0, it is possible to perform multiple operations in a single Operation Block:



Function Search

With EcoStruxure Machine Expert - Basic V1.0, it is possible to search for a function, display its description, and insert it directly in an Operation Block.

When typing in an Operation Block, you can click on the small icon on the right to access this feature.

Clicking the icon displays the following window:

In this window, you can select a function to insert.

Multitoken Grafcet (SFC)

In EcoStruxure Machine Expert - Basic, it is possible to have several Grafcet (SFC) POUs active at the same time. This feature is used in this project template to manage the two weighing scales simultaneously.

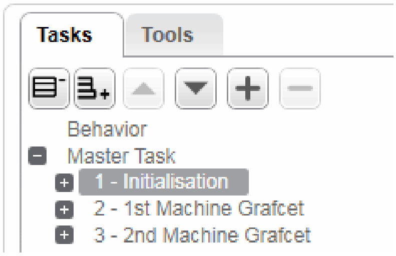
Subroutines

In this project template, subroutines are used as functions and called multiple times from different parts of the code. This reduces redundancy.

Project Template Structure

Overview

The project template is organized into three POUs. POU 1 is a Ladder language POU. POU 2 and POU 3 are Grafcet (SFC) POUs. In these Grafcet POUs, there are multiple calls to 4 subroutines:



The first POU initializes the scaling parameters. It is called only once at the beginning of the program.

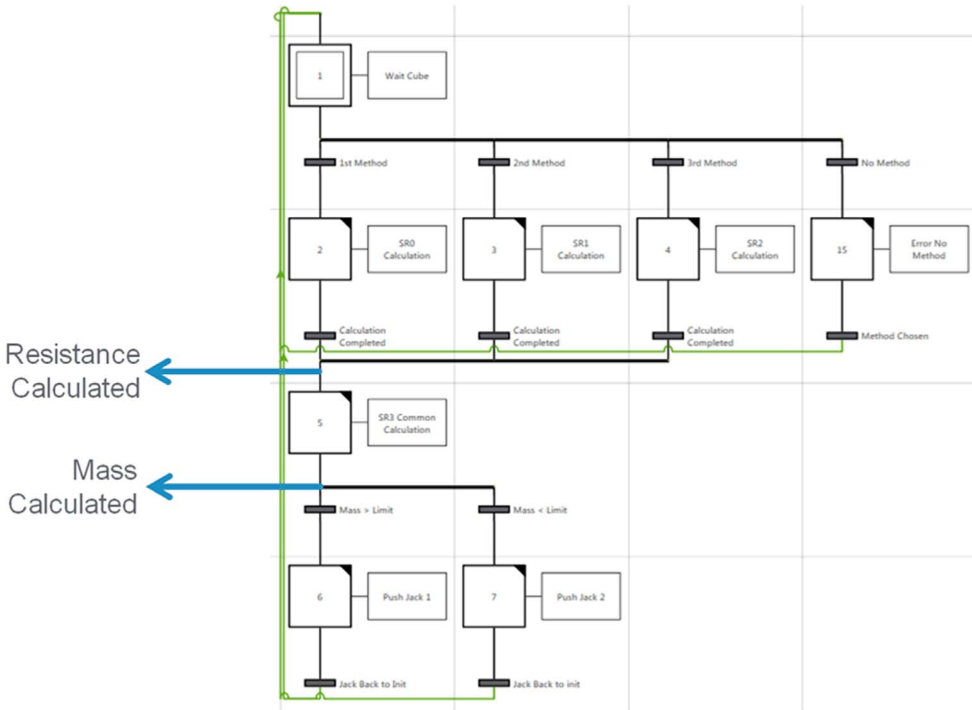
The second POU manages the first sorting machine.

The third POU manages the second sorting machine.

Refer also to Subroutines *(see page 25)*.

POU 2 and POU 3 - Grafcet (SFC) POUs to Manage the Sorting Machines

The Grafcet (SFC) code in POU 2 and POU 3 is almost identical. The difference between them is that the transitions are validated on different digital inputs. From now on, they will be considered to be identical.



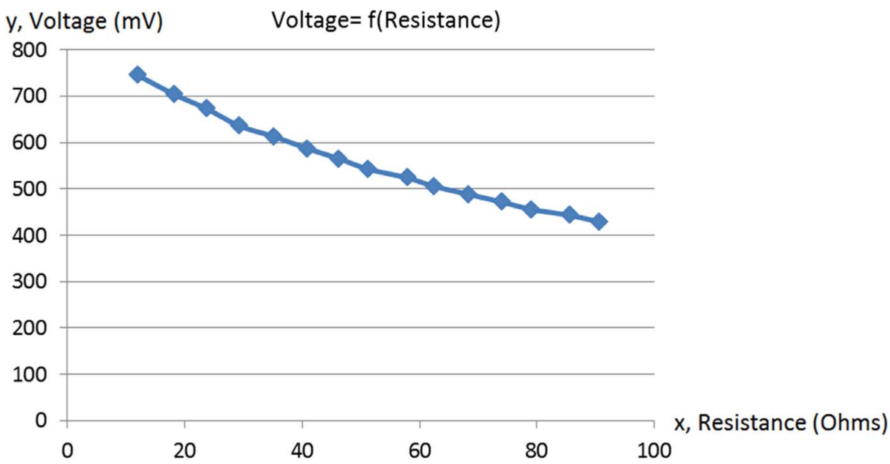
Initially, the machine is in the first step and jumps directly to step 15. This is the error state when there is no method selected and the signal light is red. As described in Setup Description *(see page 18)*, the red signal light is mapped to digital output `%Q0.6`.

There are three methods to calculate the resistance values from the analog input. Each method is called in different Grafcet steps: 2, 3, and 4 (calls to subroutine 0, 1, and 2 respectively). When a method is chosen and a small box is detected on the weighing scale (`%I0.2` and `%I0.3`), the signal light is green.

After the resistance has been calculated, subroutine 3 is called to calculate the mass from the resistance values. This step is executed regardless of the chosen method. Depending on the mass value calculated with subroutine 3, one of the pneumatic jacks is activated to push the small boxes left or right.

Subroutines

The analog input voltage value changes according to the resistance of the weighing scale. In this template, the voltage values change as shown below:



In the subroutines 0, 1 and 2, a trend line is taken into account and its inverse is used for calculations.

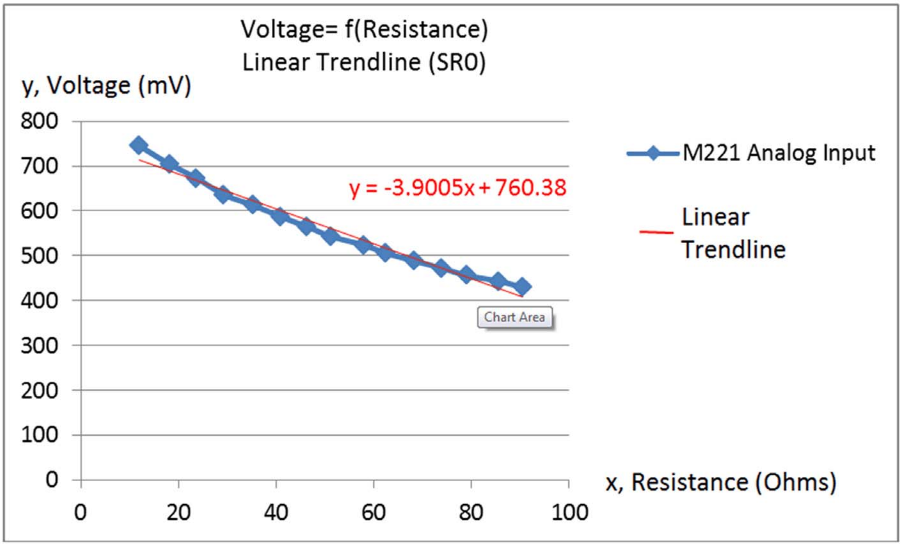
A trend line is a mathematical technique for imitating the original data using mathematical functions. Using trend lines, it is possible to calculate the evolution of voltage with respect to resistance in a mathematical function.

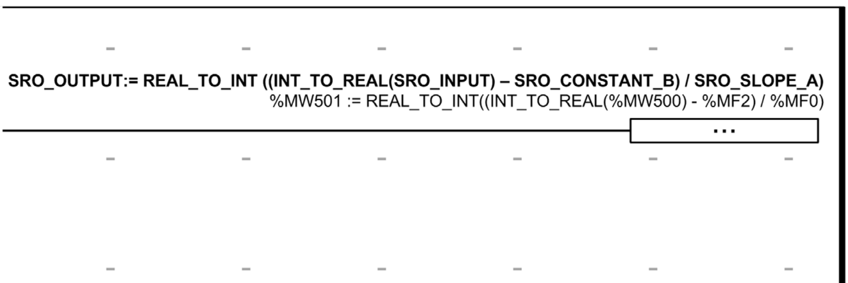
This mathematical function is:

Voltage = f (Resistance).

In the subroutines, f^{-1}(Voltage) = Resistance is implemented, meaning the y-axis values are used to calculate the x-axis values.

`SR0`: This subroutine calculates the inverse of the following linear trend line (in red):





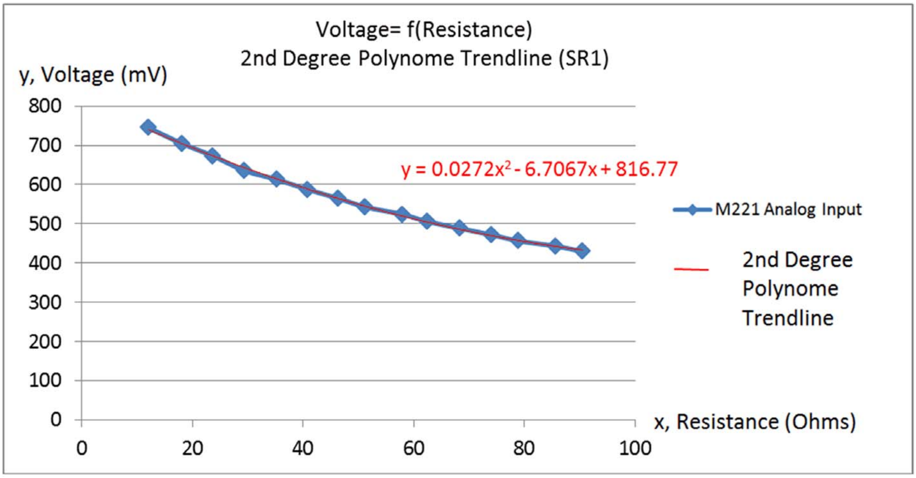
The parameters are entered in `%MF0` and `%MF2` in the initialization POU and usually need to be modified for your application. This subroutine takes the input (y-axis values) from `%MW500` and returns the output (x-axis values) in `%MW501`.

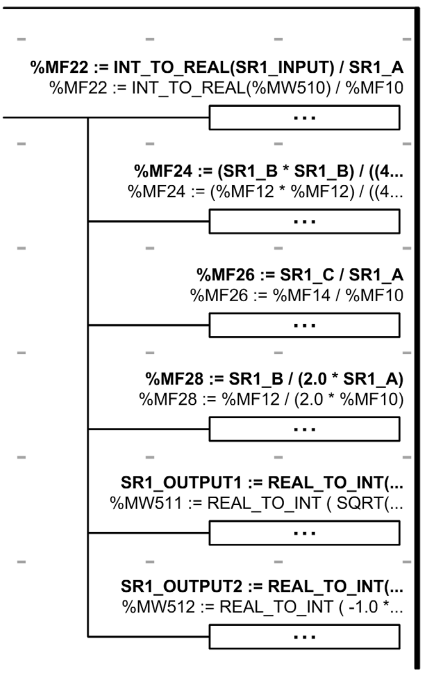
The subroutine uses the following equation to find the return value:

$$x = (y - b)/a$$

This method is simple but not precise.

`SR1`: This subroutine calculates the inverse of the following second degree polynomial trend line (in red):





The parameters are entered in `%MF10`, `%MF12`, and `%MF14` in the initialization POU and usually need to be modified for your application. This subroutine takes the input (y-axis) from `%MW510` and returns the output (x-axis) in `%MW511` and `%MW512`.

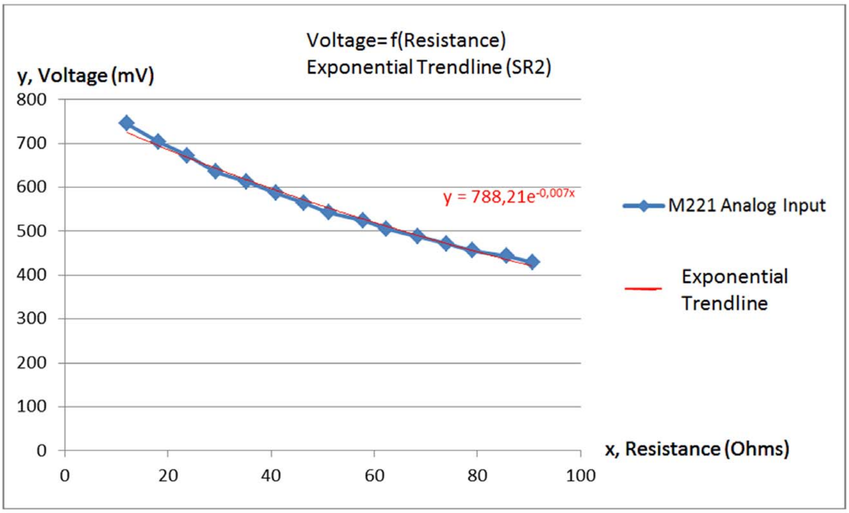
It uses the following equation to find these two return values:

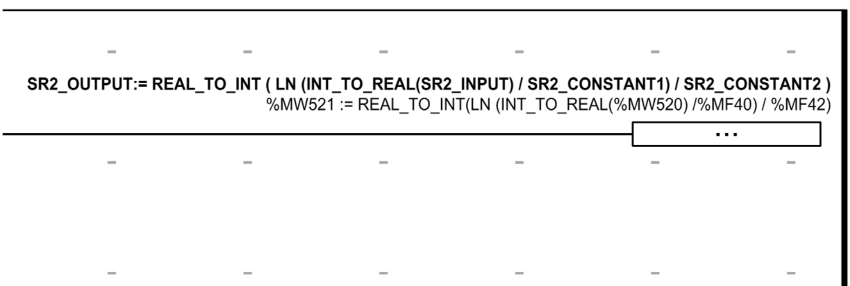
$$x = \pm \sqrt{\frac{y}{a} + \frac{b^2}{4a^2} - \frac{c}{a} - \frac{b}{2a}}$$

Depending on your application, you should use either `%MW511` or `%MW512`, then perform tests to verify your choice.

This method is more complex and precise.

`SR2`: This subroutine calculates the inverse of the following exponential trend line (in red):





The parameters are entered in `%MF40` and `%MF42` in the initialization POU and usually need to be modified for your application. This subroutine takes the input (y-axis) from `%MW520` and returns the output (x-axis) in `%MW521`.

It uses the following equation to find the return value:

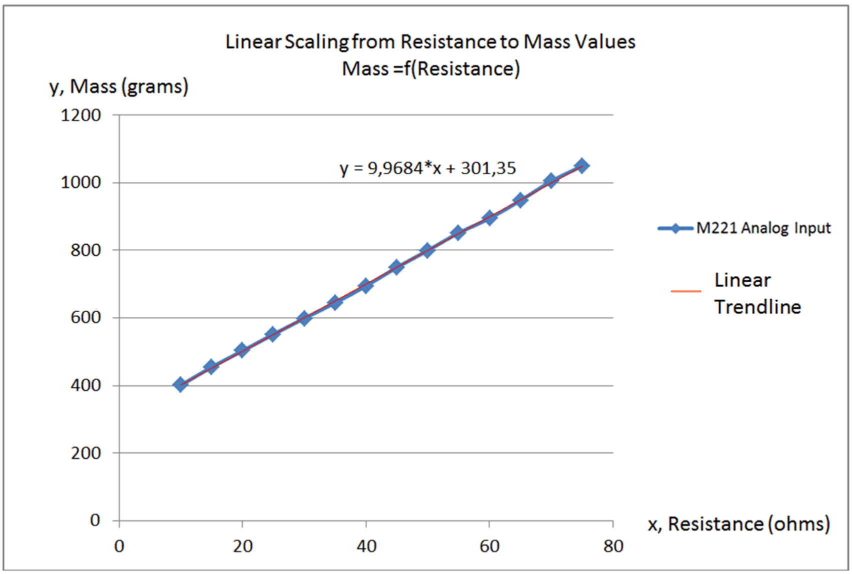
$$x = \frac{\ln\left(\frac{y}{a}\right)}{b}$$

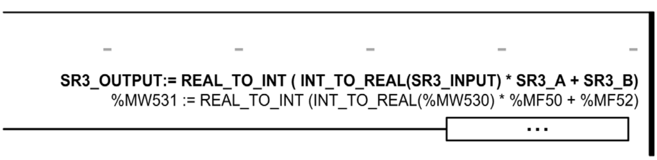
This method is a compromise in terms of complexity and precision.

Select the method that is appropriate for the needs of your application. If you have a linear variation, then using a linear trend line may be appropriate.

`SR3`: This subroutine scales (converts) the resistance values to match the mass values. It uses a linear equation: y = a*x+b

This equation is illustrated below with the trend line (in red):





The parameters are entered in `%MF50` and `%MF52` in the initialization POU and usually need to be modified for your application. This subroutine takes the input (x-axis) from `%MW530` and returns the output (y-axis) in `%MW531`.

`%MW531` can be used as the value to be displayed in the HMI.

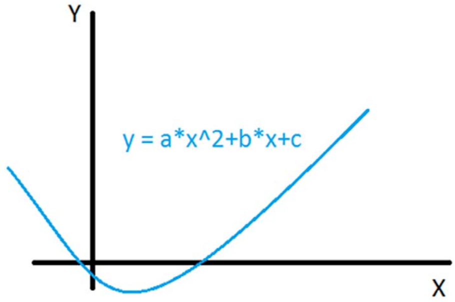
Appendices

Appendix A
Scaling Techniques

Scaling Techniques

Second Degree Polynomials

A second degree polynomial is a function, illustrated in the following graphic:



It can be inserted as a trend line for your values instead of a linear trend line for more precision.

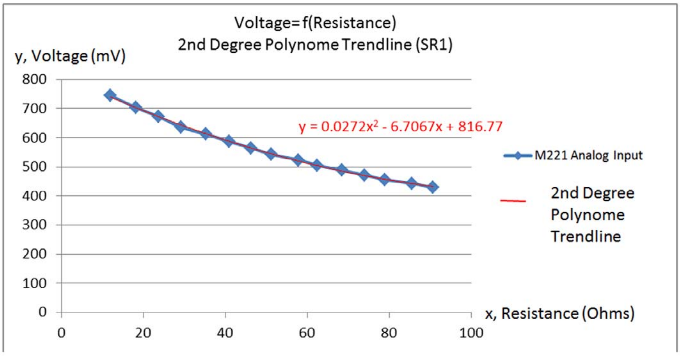
It has 3 parameters:

A: Coefficient for the second degree

B: Coefficient for the first degree

C: The constant

In the template, the second degree polynomial trend line is inserted, as shown in the graphic below:



The coefficients can be deduced as:

A = 0.0272

B = -6.7067

C = 816.77

Taking the Inverse of a Second Degree Polynomial

The scaling in the second method is based on taking the inverse of a function. If you use a second degree polynomial as the trend line, you have to take its inverse.

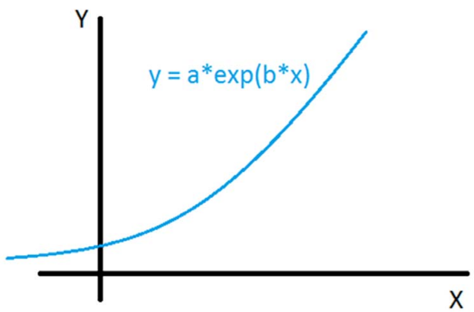
This can be done by solving the equation for x. This produces two solutions, from which you must choose the appropriate solution by inserting a value, for example. The following equation is the result of the inversion:

$$x = \pm\sqrt{\frac{y}{a} + \frac{b^2}{4a^2} - \frac{c}{a}} - \frac{b}{2a}$$

In the project template, the solution with the negative sign is used in the subroutine 1.

Exponential Function

An exponential function is illustrated in the following graphic:



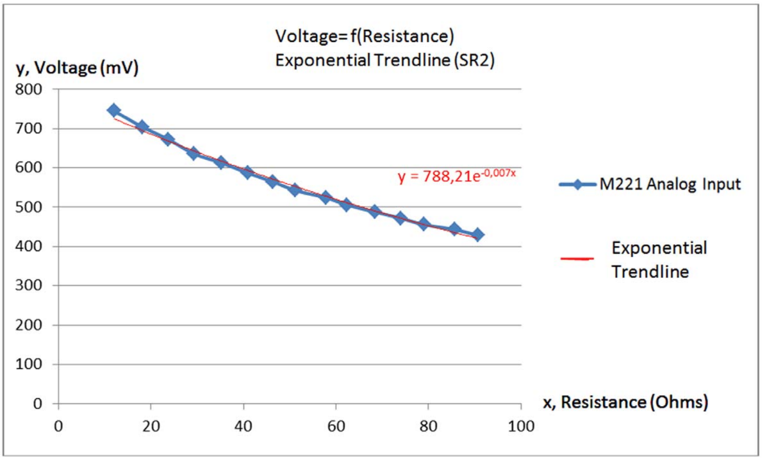
An exponential function can be inserted as a trend line for your values instead of a linear trend line for more precision.

It has two parameters:

A: First coefficient

B: Second coefficient

In the template, the exponential function trend line is inserted, as shown below:



The coefficients can be deduced as:

A = 788.21

B = -0.007

Taking the Inverse of an Exponential Function

The scaling in the second system is based on taking the inverse of a function. If you use an exponential function as the trend line you have to take its inverse.

This can be done by solving the equation for x. The following equation is the result of the inversion:

$$x = \frac{\ln\left(\frac{y}{a}\right)}{b}$$

This solution is used in subroutine 2 of the project template.