ControlLogix and CompactLogix Programmable Logic Controllers

Original Operating Instructions

FESTO

Process Automation

User Guide



Festo Didactic
en
585159

Process Automation

ControlLogix and CompactLogix Programmable Logic Controllers

Original Operating Instructions

User Guide

585159

Order no.: 585159 (Printed version) 591783 (Electronic version)
First Edition 2012/02
Revision level: 2026/01

By the staff of Festo Didactic

© Festo Didactic Ltée/Ltd, Quebec, Canada 2010
Internet: www.festo.com
e-mail: services.didactic@festo.com

Printed in Canada
All rights reserved
ISBN 978-2-89640-557-2 (Printed version)
ISBN 978-2-89747-208-5 (Electronic version)
Legal Deposit - Bibliothèque et Archives nationales du Québec, 2010
Legal Deposit - Library and Archives Canada, 2010

The purchaser shall receive a single right of use which is non-exclusive, non-time-limited and limited geographically to use at the purchaser's site/location as follows.

The purchaser shall be entitled to use the work to train his/her staff at the purchaser’s site/location and shall also be entitled to use parts of the copyright material as the basis for the production of his/her own training documentation for the training of his/her staff at the purchaser’s site/location with acknowledgement of source and to make copies for this purpose. In the case of schools/technical colleges, training centers, and universities, the right of use shall also include use by school and college students and trainees at the purchaser’s site/location for teaching purposes.

The right of use shall in all cases exclude the right to publish the copyright material or to make this available for use on intranet, Internet, and LMS platforms and databases such as Moodle, which allow access by a wide variety of users, including those outside of the purchaser’s site/location.

Entitlement to other rights relating to reproductions, copies, adaptations, translations, microfilming, and transfer to and storage and processing in electronic systems, no matter whether in whole or in part, shall require the prior consent of Festo Didactic.

Information in this document is subject to change without notice and does not represent a commitment on the part of Festo Didactic. The Festo materials described in this document are furnished under a license agreement or a nondisclosure agreement.

Festo Didactic recognizes product names as trademarks or registered trademarks of their respective holders.

All other trademarks are the property of their respective owners. Other trademarks and trade names may be used in this document to refer to either the entity claiming the marks and names or their products. Festo Didactic disclaims any proprietary interest in trademarks and trade names other than its own.

Table of Contents

Document Preliminaries **3**

Learning Unit 1 - PLC Fundamentals **9**

PLC hardware 9
Programming methods 9
Programming languages 10
Ladder logic 10
Ladder logic 11
Sequential function chart 12
Function block diagram 13
Other languages 14
Addressing 14
Alias tags 15
Communication 16
Industrial applications 16
Advantages and limitations 16

Learning Unit 2 - Familiarization with the PLC **19**

Prerequisites for downloading a project to the PLC 19
Downloading and running a PLC project file 19
Project structure 24
Controller tags 25
Alias 26
Modifying the value of a tag 27
Adding an extra control loop 28
FOUNDATION Fieldbus versions of the programs 31
Using an analog input or output with FOUNDATION Fieldbus 32

Learning Unit 3 - On-Off Control **35**

Connecting the PLC to the process loop 35
Configuring the PLC for On-Off control 35
Running the on-off program 39

Learning Unit 4 - PIDE Control **43**

Connecting the PLC to the process loop 44
Configuring the PLC for PIDE control 44
Running the PIDE control program 48
PIDE output initialization and diagnostic parameters 51

Learning Unit 5 - Cascade Control **53**

Connecting the PLC to the process loop 53
Configuring the PLC for cascade control 53
Running the PIDE cascade program 56
Setting the control loops for cascade control 58

Learning Unit 6 - PLC Fundamentals **61**

Ratio Control 61
Connecting the PLC to the process loop 61
Configuring the PLC for ratio control 62
Running the PIDE ratio program 64

© Festo Didactic

Setting the control loop for ratio control 66

Learning Unit 7 - Split-Range Control 69

Connecting the PLC to the process loop 69
Configuring the PLC for split-range control 70
Running the PIDE split-range program 74
Setting the control loop for split-range control 75

Appendix A - Characteristics of the ControlLogix PLC 79

Description 79
Components 79
Front panel 85
HART protocol 86

Appendix B - Characteristics of the CompactLogix PLC 87

Appendix C - PLC Installation and Configuration 95

Connecting the PLC to a computer 95
Installing the PLC software 95
How to connect the PLC to your computer 96
Configuring your computer and software for Ethernet communication with the PLC 97
Configuring the Ethernet card 97
RSLinx configuration 100

Appendix D - PID Control and Cascade PID Control 105

Dependent gains 105
Independent gains 105
PID control 106
PID cascade control 109

Appendix E - PID Ratio Control and PID Split-Range Control 113

PID ratio control 113
PID split-range control 114

Appendix F - Using Trends 119

Appendix G - List of Faults on the ControlLogix PLC 127

Appendix H - List of Faults on the CompactLogix PLC 129

© Festo Didactic

Document Preliminaries

Introduction to the learning system

Automated process control provides many advantages over manual control and is therefore used in most modern industrial processes. Breweries, wastewater treatment plants, mining operations, and the automotive industry are examples of industries that rely on automated process control systems.

Keeping process variables such as pressure, flow, level, temperature, and pH within defined operating ranges is essential to produce products with consistent composition and quality.

The Instrumentation and Process Control Training System reproduces an industrial environment using modern, industrial-grade equipment. Throughout the course, students develop skills in installing and operating process control equipment, combining theoretical knowledge with hands-on practice.

The system's modular design allows instructors to select equipment that matches specific course objectives. Two mobile workstations form the core of the system. Optional components for pressure, flow, level, temperature, and pH control, as well as valves, calibration equipment, and software, can replace basic components with the same function as needed. Different controllers can be used interchangeably during control exercises, depending on instructional needs.

We hope your experience with the Instrumentation and Process Control Training System is the first step toward a successful career in the process control industry.

LVProSim, a software application used in the system's courses, can be downloaded here:

LVProSim

http://bit.ly/LVPROSIM32600

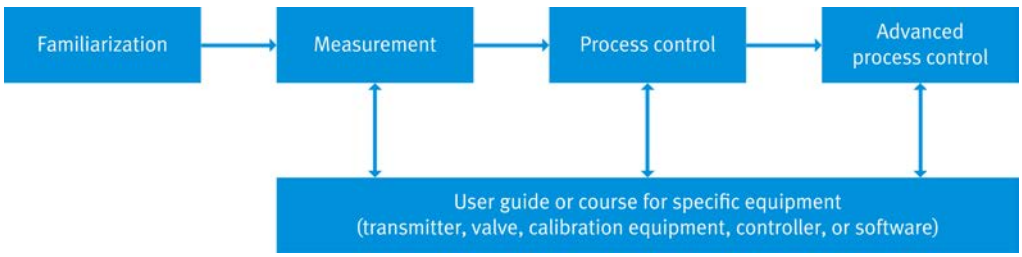


Figure 1: Standard learning path for the Instrumentation and Process Control Learning System.

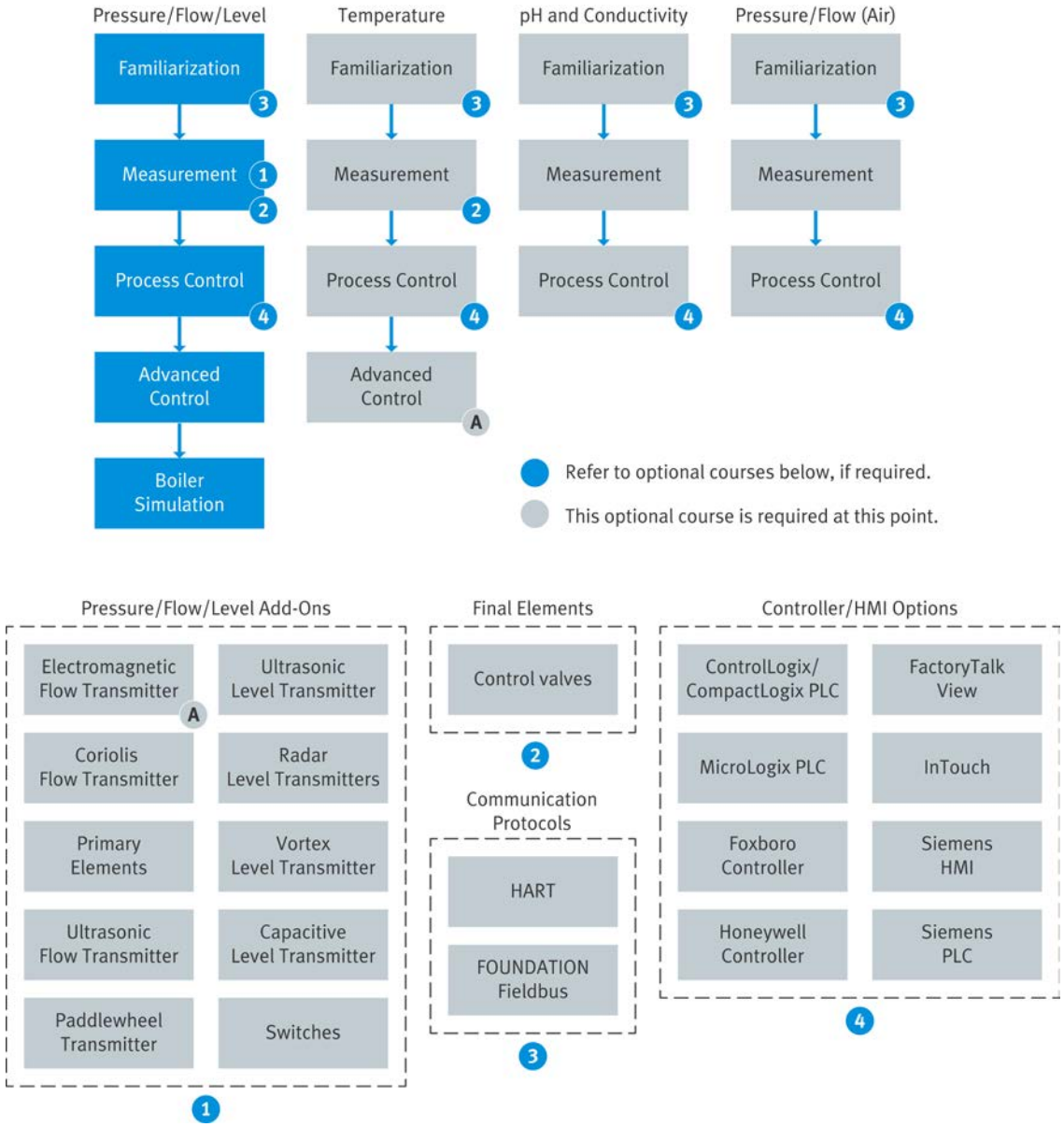


Figure 2: Instrumentation and Process Control Learning System.

Safety Symbols and Procedures

The following table lists the safety and common symbols that may be used in this document and on the equipment. Before performing procedures with the equipment, you should read all sections regarding safety in the User Guide accompanying the equipment. Additional safety procedures are given before any task requiring specific safety precautions.

Symbol	Description
⚠ DANGER	**DANGER** indicates a hazard with a high level of risk, which, if not avoided, will result in death or serious injury.

© Festo Didactic

Symbol	Description
	**WARNING** indicates a hazard with a medium level of risk, which, if not avoided, could result in death or serious injury.
	**CAUTION** indicates a hazard with a low level of risk, which, if not avoided, could result in minor or moderate injury.
	**NOTICE** indicates a hazard with a potentially hazardous situation, which, if not avoided, may result in property damage.
	Caution, risk of danger. Consult the relevant user documentation.
	Caution, risk of electric shock.
	Caution, lifting hazard.
	Caution, hot surface.
	Caution, risk of fire.
	Caution, risk of explosion.
	Caution, belt drive entanglement hazard.
	Caution, chain drive entanglement hazard.
	Caution, gear entanglement hazard.

Symbol	Description
	Caution, hand crushing hazard.
	Static sensitive contents. Observe precautions for handling electrostatic discharge sensitive devices.
	Notice, non-ionizing radiation.
	Consult the relevant user documentation.
	Radio Equipment Directive (RED) geographical restrictions – consult the relevant user documentation.
	Direct current.
	Alternating current.
	Both direct and alternating current.
	Three-phase alternating current.
	Earth (ground) terminal.
	Protective conductor terminal.
	Frame or chassis terminal.
	Equipotentiality.

© Festo Didactic

Symbol	Description
	On (supply).
	Off (supply).
	Equipment protected throughout by double insulation or reinforced insulation.
	In position of a bi-stable push control.
	Out position of a bi-stable push control.

© Festo Didactic

PLC Fundamentals

PLC hardware

Programmable logic controllers (PLCs) are small computers used to automate industrial processes. Like personal computers, PLCs use a microprocessor, but they are designed to operate under harsh conditions such as wide temperature ranges, dust, vibration, and mechanical shock. A major difference from personal computers is the PLC input/output arrangement. PLCs connect to sensors (for example, push buttons, limit switches, and temperature, flow, level, pressure, or pH transmitters) and to actuators (for example, motor starters, relays, valves, or solenoids). The input/output interfaces can be integrated into the PLC or implemented using external input/output modules. The following figure shows the main components of a typical PLC.

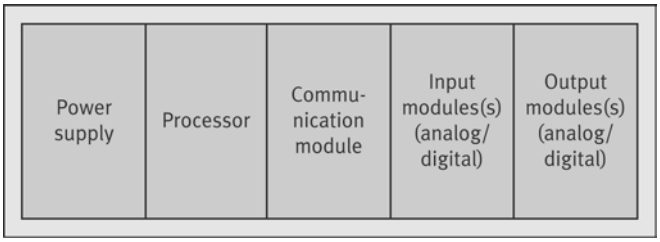


Figure 3: Main components of a PLC.

Power supply: Provides power to the components of the PLC and proper voltage to the digital outputs.

Processor (CPU): This is the core of the PLC. It includes the microprocessor and memory. The processor reads input data, executes the stored program, and sends commands to the output modules.

Communication module: PLCs include at least one communication port used for programming, troubleshooting, data exchange, connecting a visual display, interfacing with a modem, or connecting to a network. PLCs are often connected to the plant communication network, allowing integration into a larger control system and remote access.

Input/output module: Inputs receive signals from external devices such as push buttons, limit switches, and electronic sensors. Outputs receive commands from the processor to activate or deactivate connected devices. Input and output ports can be discrete or analog.

Programming methods

Different types of PLCs can be programmed in different ways. For most models, the programming is done using one of the following methods:

© Festo Didactic

- **Dedicated buttons:** The program of some small PLCs can be entered with the help of dedicated buttons and a LCD screen on the PLC.

- **Handheld terminal:** Portable programming units can be connected to the PLCs. Those rugged devices have a display screen and buttons allowing programming. They can usually store backup copies of programs and communicate with computers.

- **Computer:** PLC manufacturers provide software for programming PLCs. This method is preferred because computers offer large storage capacity and display more information at once than a PLC LCD. When PLCs are networked, they can be accessed remotely from a computer. Laptops also provide portability for local PLC programming.

Programming languages

Modern PLCs offer a wide range of programming tools to create simple and efficient programs for most manufacturing applications. PLC programming typically follows the IEC 61131-3 standard, which defines five programming languages and promotes uniformity. Some languages are graphical (ladder logic, function block diagram, and sequential function chart), while others are textual (structured text and instruction list). The following sections describe their main characteristics.

Ladder logic

Ladder logic was developed to simplify PLC programming for electricians. It uses electrical symbols to represent program rules and conditions. A ladder diagram consists of two vertical uprights connected by horizontal rungs. The uprights, also called power rails, supply power to the rungs. Each rung contains a series of electrical-symbol operators. When all conditions on a rung are true, power flows through the rung. Conditions are represented by contacts, such as normally open (NO or XIC) and normally closed (NC or XIO). When current can flow through all contacts on a rung, one or more coils are energized. Contacts are often considered inputs, and coils are considered outputs.



Normally open and normally closed contacts are also called Examine If Closed (XIC) and Examine If Open (XIO), respectively. Coils are also called Output Energize (OTE).

Consider an example to illustrate ladder logic operation. The following figure a shows a circuit in which a light turns on when a normally open push button is pressed. The ladder logic equivalent is shown in the following figure b. In this example, the normally open push button is represented as a normally open contact (the input). The light is the output and is represented by the coil on the right side of the ladder diagram.

© Festo Didactic

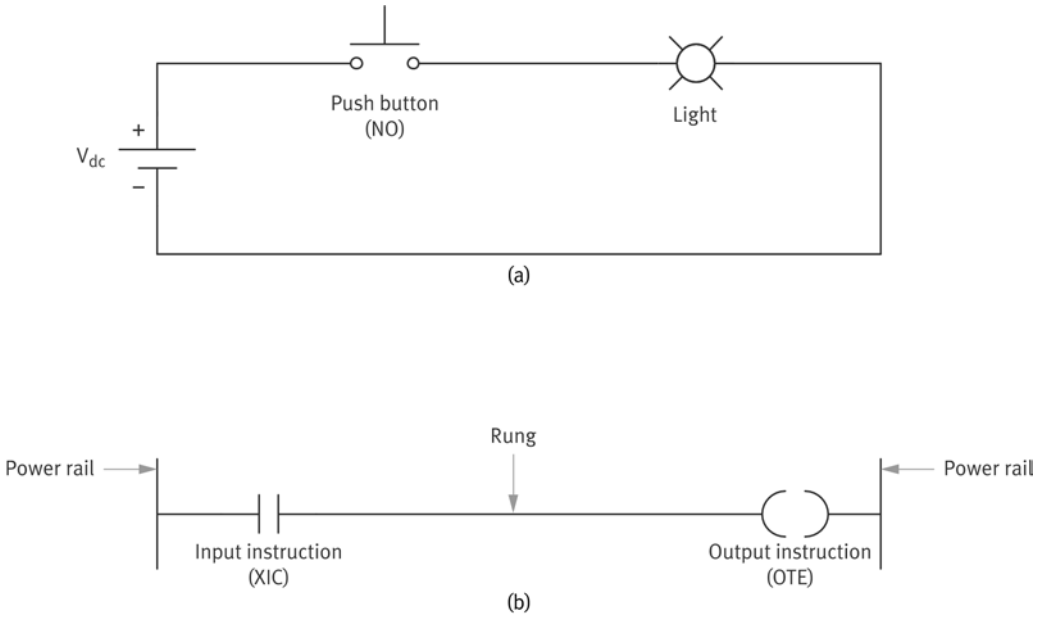


Figure 4: Push button and light ladder diagram.

The following figure shows how this circuit can be connected to a PLC. In this case, the push button is connected to input 1 and the light is connected to output 3.

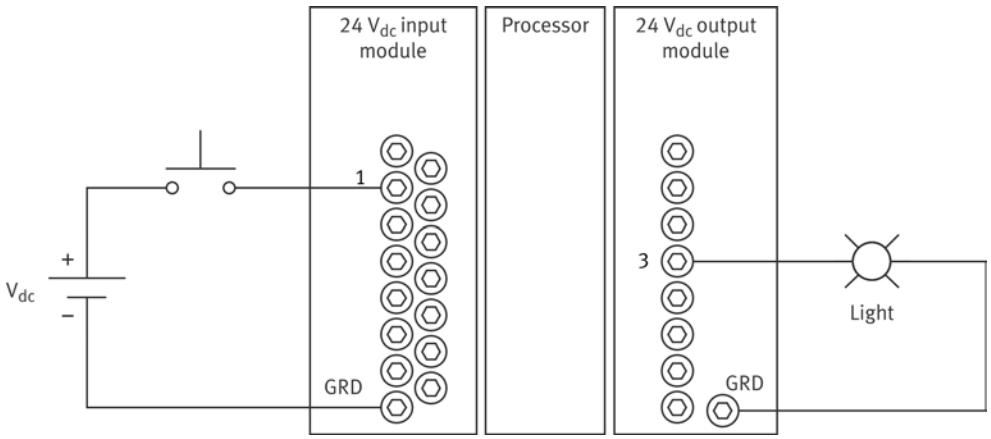


Figure 5: Connection of a push button and a light to a PLC.

Ladder logic

The PLC performs the logical operations between inputs and outputs, so system behavior is no longer limited by physical wiring. The following figure shows two different ladder diagram programs used to interface the push button with the light. The first ladder diagram turns on the light when the push button is pressed, which is the same behavior as in Figure 4.

The second ladder diagram controls the same push button and light circuit in a different way without changing the physical arrangement. The normally open contact is replaced with a normally closed contact. As a result, in (b) of the following figure, the light is on unless the push button is pressed.

© Festo Didactic

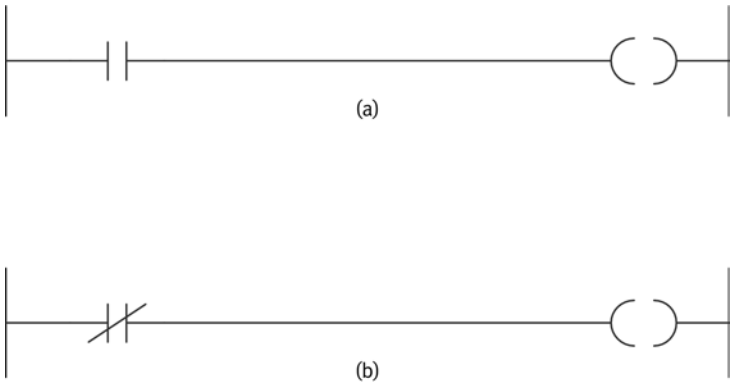


Figure 6: Two different ladder diagrams for the push button and light circuit.

This example shows that all input devices, such as buttons, sensors, or switches, are connected to the PLC 24 V input module. Output devices, such as lights, ac drives, and actuators, are connected to the output module. All control logic between inputs and outputs is handled by the PLC.

Sequential function chart

Sequential function chart programming is well suited for condition-dependent processes. A sequential function chart consists of steps and conditions. Steps define actions, while conditions determine whether a step is executed. Starting from the beginning of the chart, each step is executed only if its associated condition is true. If a condition is not met, the controller stops evaluating the chart at that point. Branches can be used to control complex processes and to allow concurrent execution. The following figure shows a simple sequential function chart.

© Festo Didactic

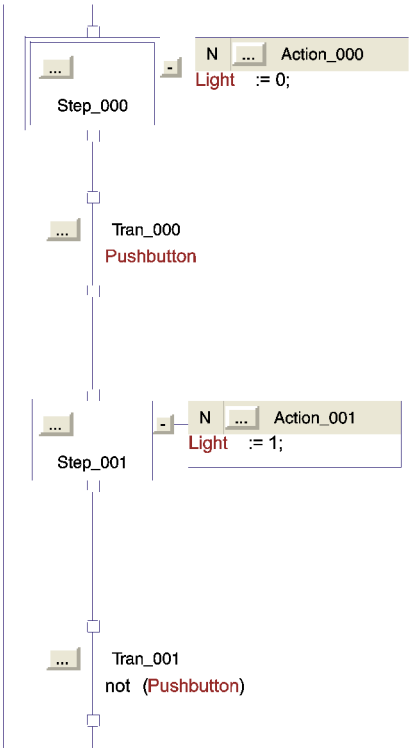


Figure 7: Sequential function chart program.

Function block diagram

Like ladder diagrams, function block diagram programming provides a graphical interface inspired by electrical circuit diagrams. Each block represents a functional element connected to others by lines. A block receives input signals, processes them using defined operators, and produces output signals. These outputs can then serve as inputs to other blocks. The following figure shows an example of a function block diagram.

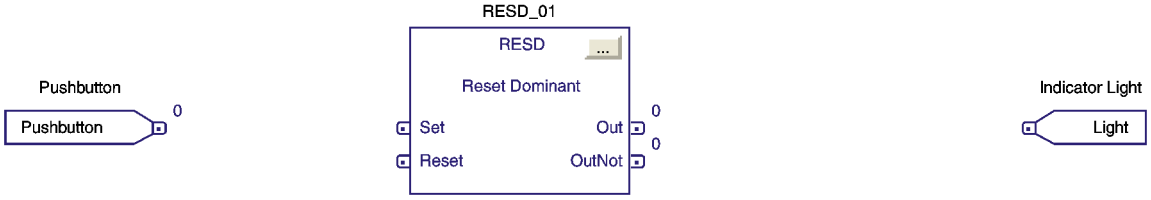


Figure 8: Function block diagram program.

Other languages

Structured text is a high-level programming language used to develop complex programs. It includes logical and arithmetic operators (not, and, +, =, <=, etc.), conditional statements (if, then, else, case, etc.), loops (repeat, for, do, while, etc.), and other instructions typical of high-level languages. Its structure is similar to C and the older Pascal language. Structured text is often used for actions in sequential function chart programs.

Instruction list is a low-level language similar to the assembly language.

Addressing

The terminals on the PLC input and output modules are identified by addresses. Allen-Bradley's PLC addresses have the following format:

- Location:Slot:Type.Member.SubMember.Bit

For example, in the push button and light example presented above, the address of the push button connected to input 1 is Local:1:I.Data.1. The following table details the different parts of an address. As shown, the address Local:1:I.Data.1 identifies digital input number 1 on an input module installed in slot 1 of the controller chassis.

As another example, channel 5 of an analog input module located in slot 4 has the address Local:4:I.Ch5Data. Many channel-related parameters can be accessed using specific addresses. For instance, Local:4:I.Ch5BrokenWire indicates whether the circuit connected to channel 5 is open (parameter set to 1) or closed (parameter set to 0). Other parameters, such as Local:4:I.Ch5HAlarm, Local:4:I.Ch5Overrange, and Local:4:I.Ch5Underrange, are also addressable and can be used for monitoring and diagnostics.

© Festo Didactic

Table 1: PLC-address structure.

	Stands for / Value	Example
Location	Local if the module is on the same chassis as the controller. If not, the adapter name is used instead.	**Local**:1:I.Data.1
Slot	Slot identification number of the input or output module (the smaller the identification number, the closer the module is to the controller).	Local:**1**:I.Data.1
Type	The type of data associated with the address: I (input), O (output), C (configuration), or S (status).	Local:1:**I**.Data.1
Member	Data if digital modules are used or a channel member if analog modules are used.	Local:1:I.**Data**.1
SubMember	Specific data related to a Member.	(no SubMember in this example)
Bit	The bit number of the physical input or output on the module.	Local:1:I.Data.**1**

Alias tags

To simplify programming and improve readability, alias tags can replace input or output addresses. For example, if a red push button is connected to input Local:2:I.Data.1, an alias such as red_button can be assigned. This allows the use of the descriptive tag red_button instead of repeatedly referencing Local:2:I.Data.1. The following figure shows an alias tag replacing an input address in a ladder diagram. A description, Emergency push button, is also added for clarity.

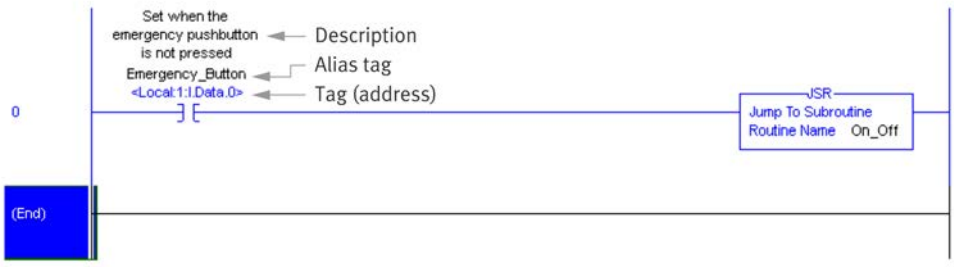


Figure 9: Alias tag in a ladder diagram.

Tags can be edited and monitored using the options in the Logic menu of Studio 5000 Logix Designer. The following figure shows how tag information is displayed in Studio 5000 Logix Designer. Section 2 explains how to access and edit tags and alias tags.

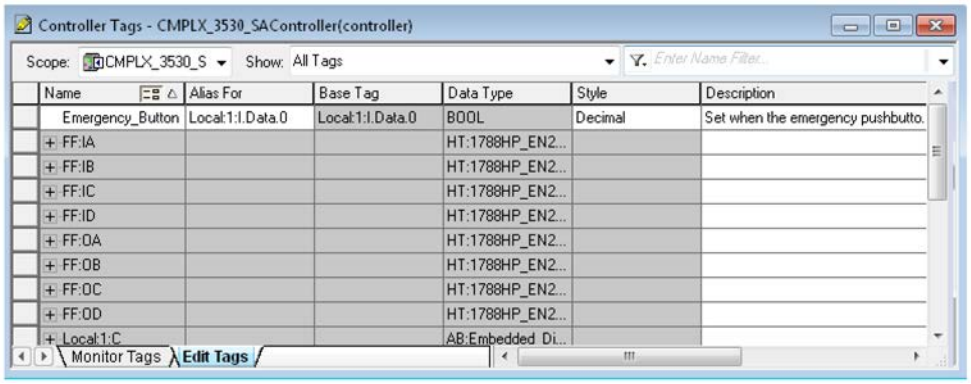


Figure 10: Studio 5000 Logix Designer tags window.

Communication

PLCs are often accessed directly, typically using a serial cable. They can also be integrated into a network and must then be configured to exchange data with other network devices. This setup enables remote programming, control, and monitoring.

PLC programming is performed using software such as Studio 5000 Logix Designer, whereas PLC control and monitoring are handled by a Supervisory Control and Data Acquisition (SCADA) program. SCADA software can run on a computer or on a dedicated Human Machine Interface (HMI).

Industrial applications

Depending on its size, a single PLC can replace many control relays, timers, and counters, significantly reducing hardwiring and troubleshooting time. PLCs also provide greater flexibility than conventional wiring. When a control process must be changed, the program can be modified instead of rewiring the system. For these reasons, PLCs are widely preferred in modern manufacturing.

Advantages and limitations

PLCs are widely used in industry because of their versatility. Their main advantages are:

- easily reconfigurable
- easy to install
- wide range of applications
- robust design
- network connectivity

© Festo Didactic

However, some limitations must be considered:

- higher hardware cost per unit than a custom circuit
- programs are not always interchangeable between PLC platforms

© Festo Didactic

© Festo Didactic

Familiarization with the PLC

Prerequisites for downloading a project to the PLC

This unit explains how to download a project to the PLC. Before starting, verify the following:

- The PLC is properly connected.
- RSLinx is running on the computer.
- Ethernet communication between the computer and the PLC is functional (refer to Appendix B for details).
- Studio 5000 Logix Designer is installed on the computer.



Allen-Bradley uses terminology that differs from most textbooks. They use PV (process variable) instead of controlled variable and CV (control variable) instead of manipulated variable. Using this terminology, the level in a level control application is the process variable (PV), and the valve opening is the control variable (CV).

Downloading and running a PLC project file

1. Start Studio 5000 Logix Designer (The following figure). This software allows you to program the PLC using four different programming languages: ladder diagram, structured text, sequential function chart, and block diagram.

© Festo Didactic

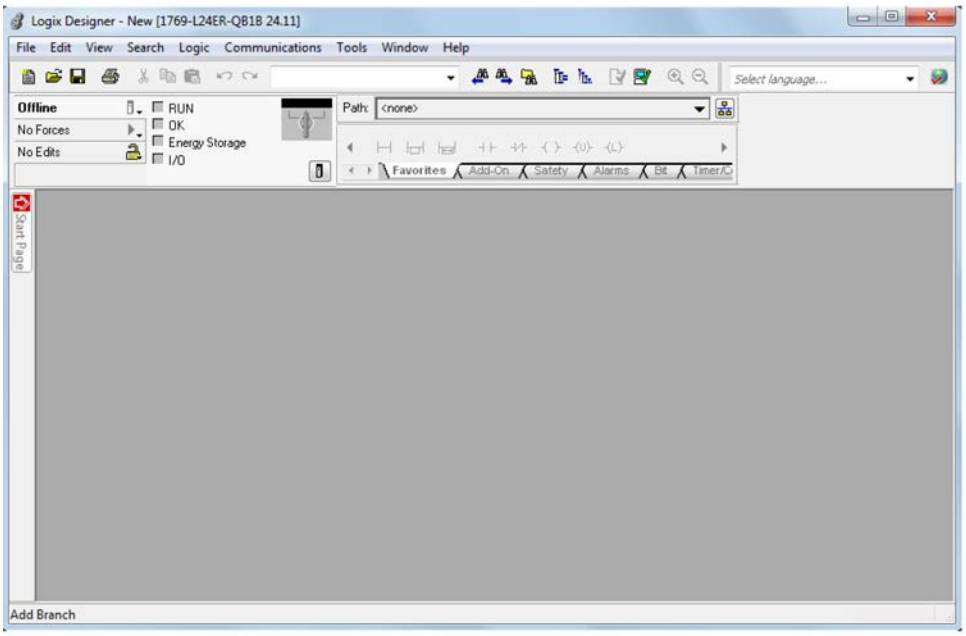


Figure 11: Studio 5000 Logix Designer.

2. The following resource file contains projects for both the CompactLogix and the ControlLogix that will allow you to use these PLCs as controllers for the process control system. From Studio 5000 Logix Designer, click on the File menu and select Open to display the Open Project window (see the following figure).

Resource file for CompactLogix and the ControlLogix PLCs.

https://lx.festo.com/media/5a65d483e2fe4e139add2eb6cad7a5c7

3. Select the project file that corresponds to the PLC you are using (CLX_3530_SAController.ACD if you are using a ControlLogix controller or CMPLX_3530_SAController.ACD if you are using a CompactLogix controller) and click on the Open button.

© Festo Didactic

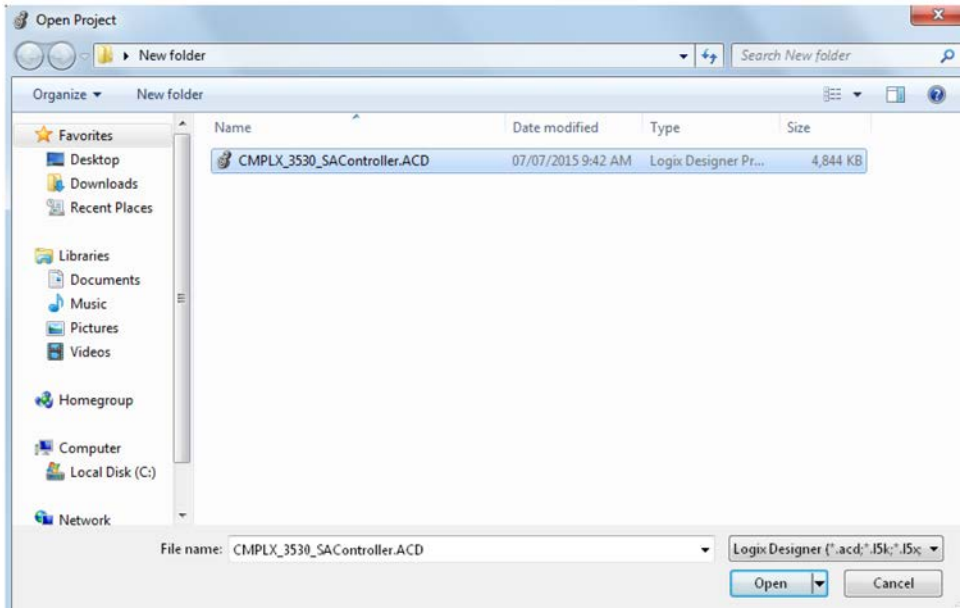


Figure 12: Opening a project file.

4. Studio 5000 Logix Designer opens the project file and displays its tree structure in the controller organizer at the left of the software window as shown in the following figure. If the control organizer is not displayed, select Controller Organizer from the View menu to display it.

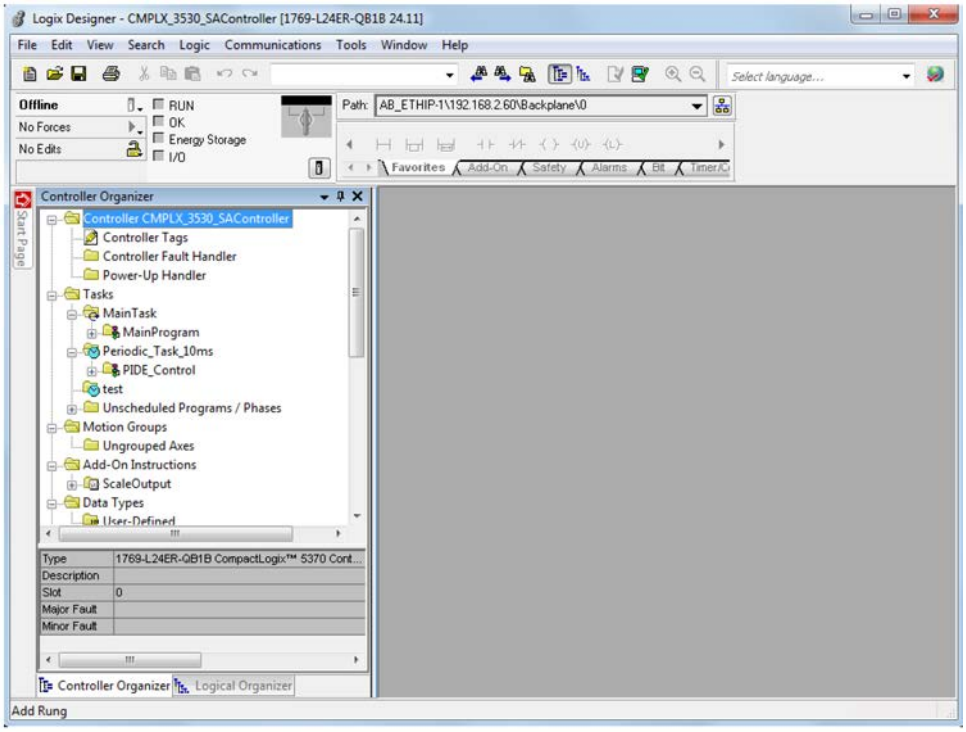


Figure 13: The main Studio 5000 Logix Designer window (with the controller organizer window).

5. Before you can download the project to the PLC, you must select the PLC with which Studio 5000 Logix Designer will communicate. From the Communications menu, select Who Active to display the Who Active window (see the following figure).

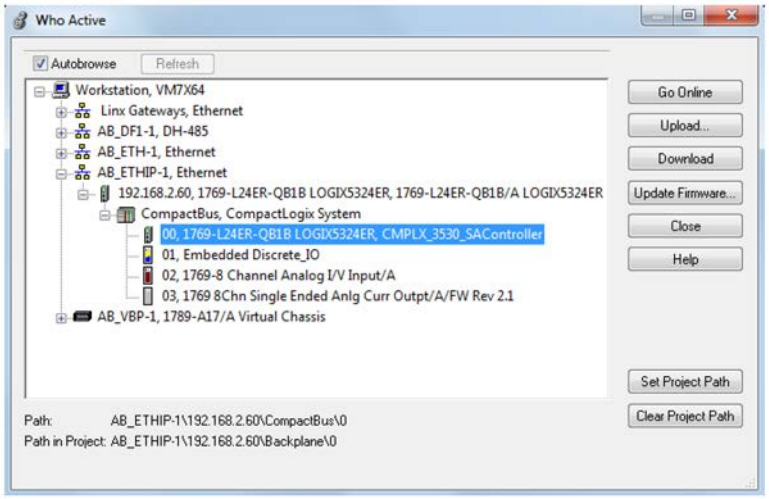


Figure 14: Who Active window.

Make sure the PLC key is set to the REM position.

6. Click on the + symbol beside AB_ETHIP-1, Ethernet to expand the network tree and select the PLC from the list. The identification may vary depending upon your PLC model.

7. Click on Download to transfer the project to the PLC.

8. A warning window (see the following figure) pops up. Click Download to proceed.

© Festo Didactic

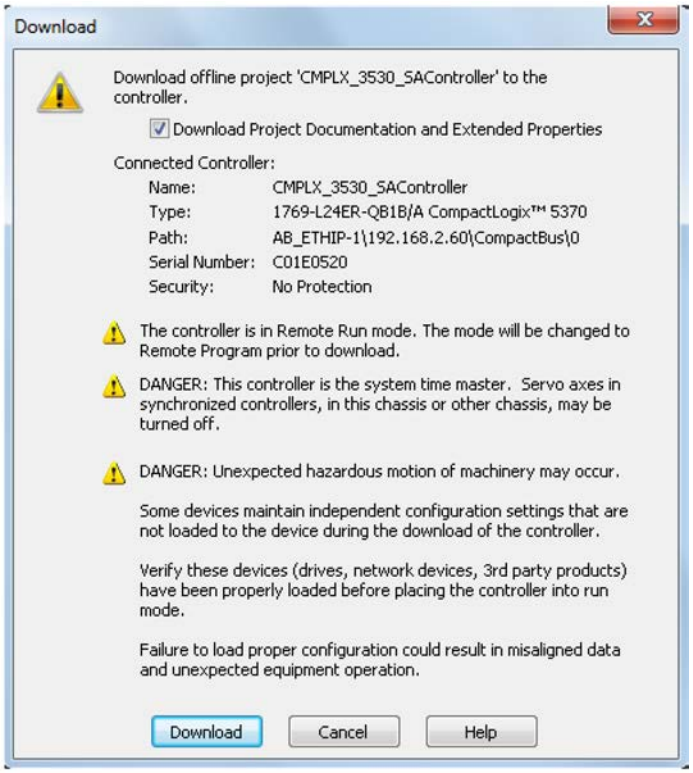


Figure 15: The Download window.

9. A Downloading window (see the following figure) shows the progression of the download. Wait for the download to complete.

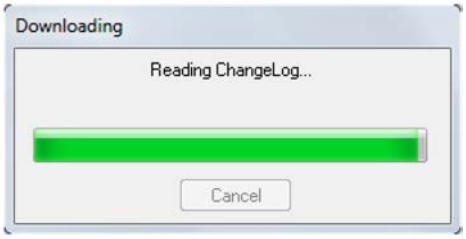


Figure 16: Downloading window.

10. After the download is complete, Studio 5000 Logix Designer automatically goes online with the PLC. The PLC key position and LED status indicators are displayed in the upper corner of the Studio 5000 Logix Designer window.

11. You must then select the control program to run. The program depends on the process to be controlled. All available programs are listed in the Unscheduled Programs / Phases folder in the Controller Organizer. To run a program and enable the corresponding control mode, drag and drop the program folder into the Periodic_Task_10ms folder. The following figure shows the PIDE_Control program running as a periodic task in the controller.

© Festo Didactic

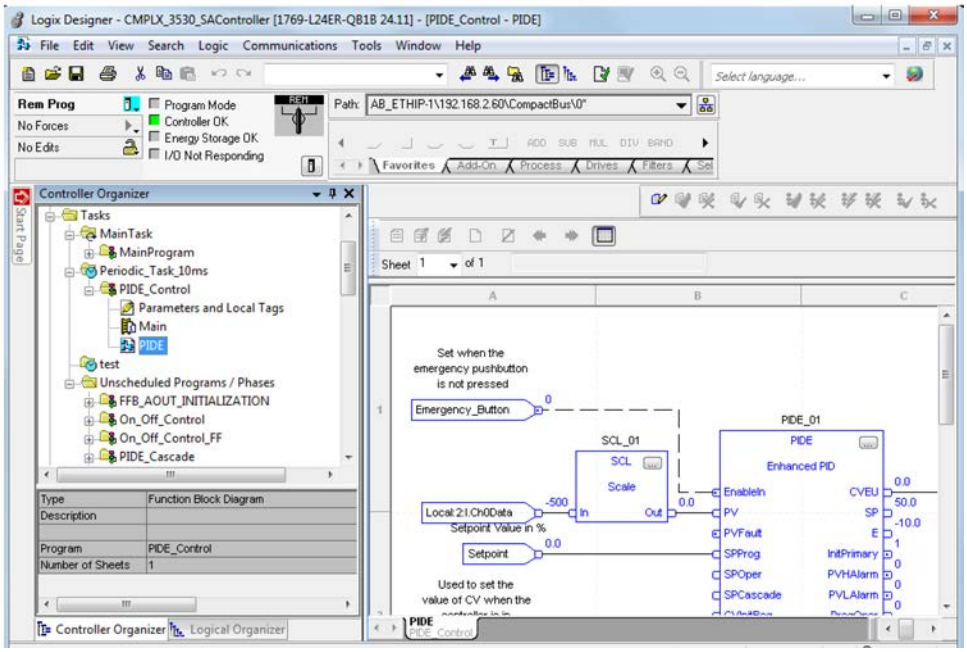


Figure 17: Running project.

Project structure

After the project is downloaded to the PLC, you can switch between modes (Program, Run, and Test) or go offline using the Communications menu. You are then ready to edit the project. Before doing so, review how the project is organized in the PLC. On the left side of the Studio 5000 Logix Designer window, the Controller Organizer displays the project structure. The following figure shows the Controller Organizer for a CompactLogix controller running the CMPLX_3530_SAController.ACD project.

In the Controller Organizer, three main folders are relevant: the Controller folder, the Tasks folder, and the I/O Configuration folder.

© Festo Didactic

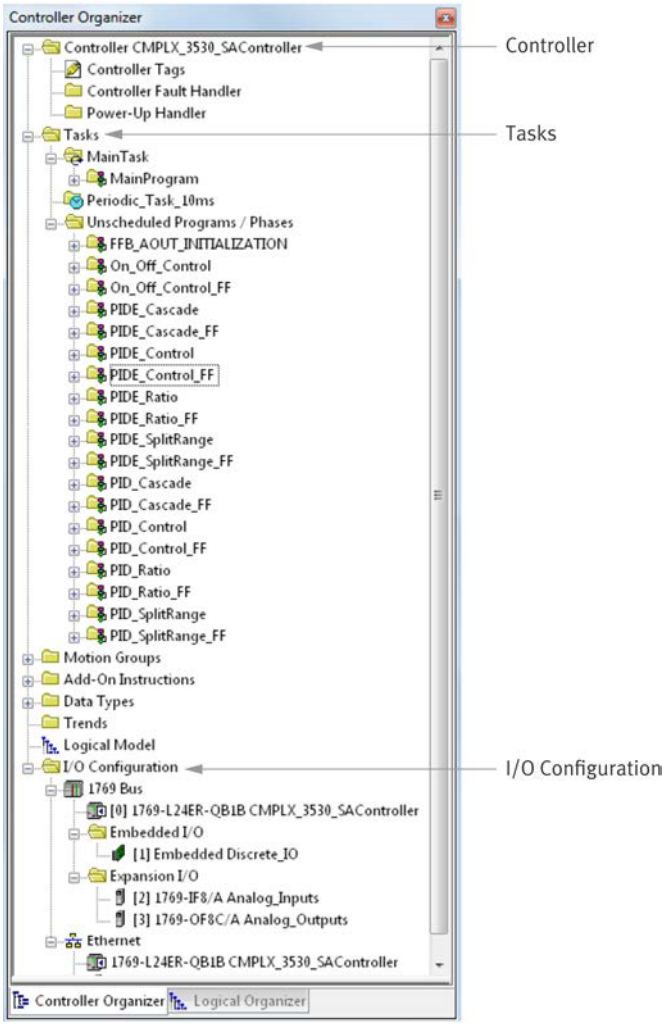


Figure 18: Project structure.

Controller tags

The Controller folder includes the Controller Tags item. Selecting it displays the controller tags (see the following figure). Tags are used to address physical PLC components or internal registers. The addressing method used on Allen-Bradley PLCs is described in Learning Unit 1. Tags fall into two categories. Controller tags are accessible by all programs and subroutines and are stored in the Controller folder; they are analogous to global variables. Program tags are accessible only within a specific program. Each program, such as PIDE_Control or On_Off_Control, has its own Program Tags list. Program tags are accessible only by the main routine and subroutines of that program and are analogous to local variables.

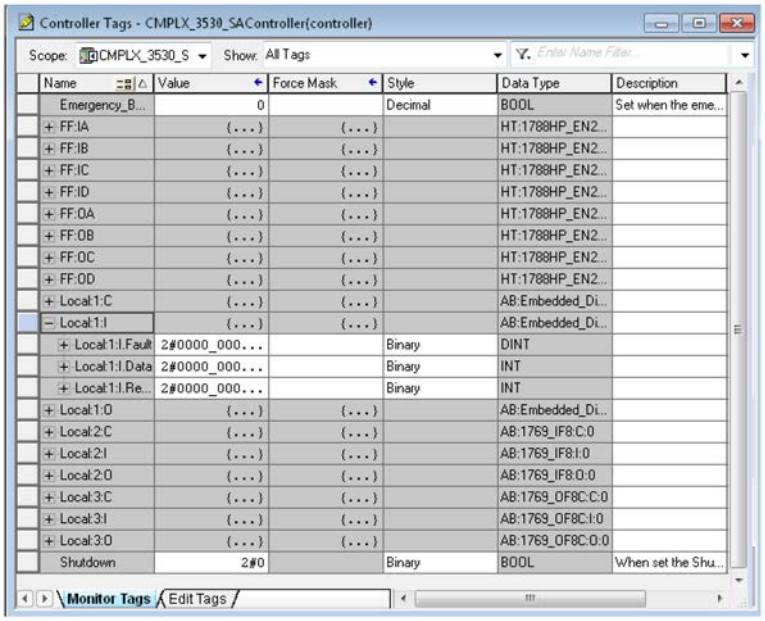


Figure 19: Tags.

Alias

Using tags from the I/O configuration for PLC programming can be inefficient because they do not clearly describe the function of inputs or outputs. Studio 5000 Logix Designer allows the use of alias tags, which provide meaningful names for inputs and outputs. For example, in the CompactLogix project for the process control system, Emergency_Button is used as an alias for the tag Local:1:I.Data.0.

To create an alias, select the tag in the Edit Tags tab, right-click to open the context menu, and choose New Tag which aliases..., as shown in the following figure.

To display the alias associated with each tag, you may need to enable the Alias For column in the tags list of Studio 5000 Logix Designer. Right-click any column header, open the Toggle Column menu, and select Alias For.

© Festo Didactic

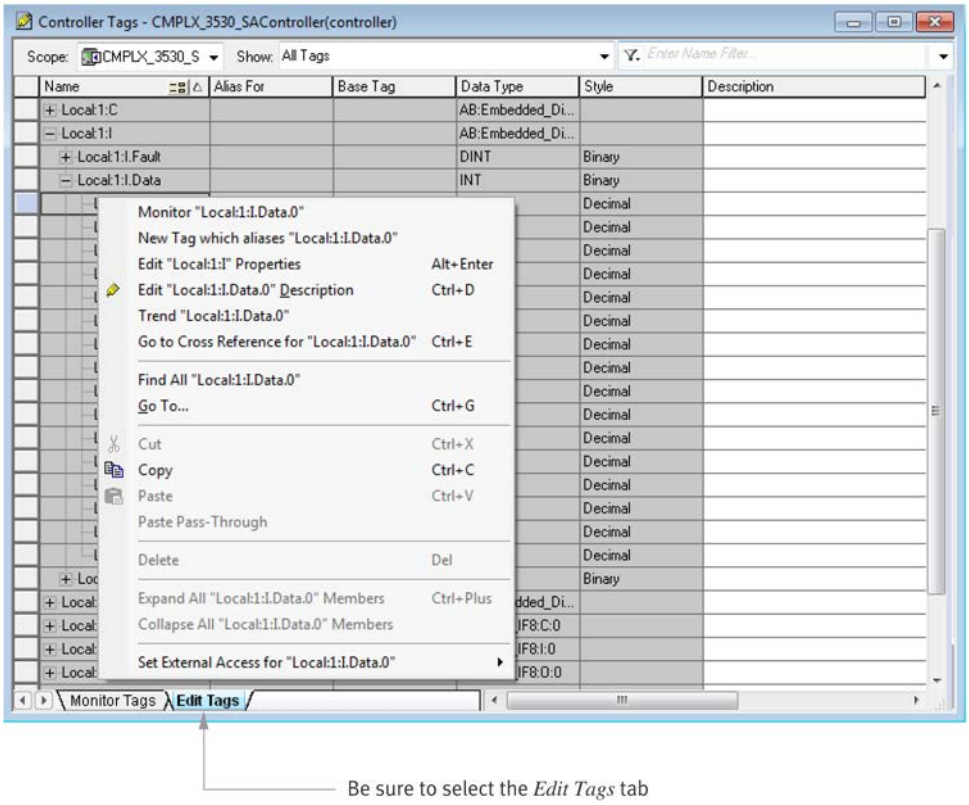


Figure 20: Adding an alias.

Modifying the value of a tag

To use the projects provided with the PLC to control a process, you must be able to modify program tag values. This allows you, for example, to change a controller setpoint.

After a project is downloaded to the PLC and at least one program is running as a periodic task, you can modify program tag values in the Monitor Tags tab. The following figure shows how to change a tag value by editing its Value field.

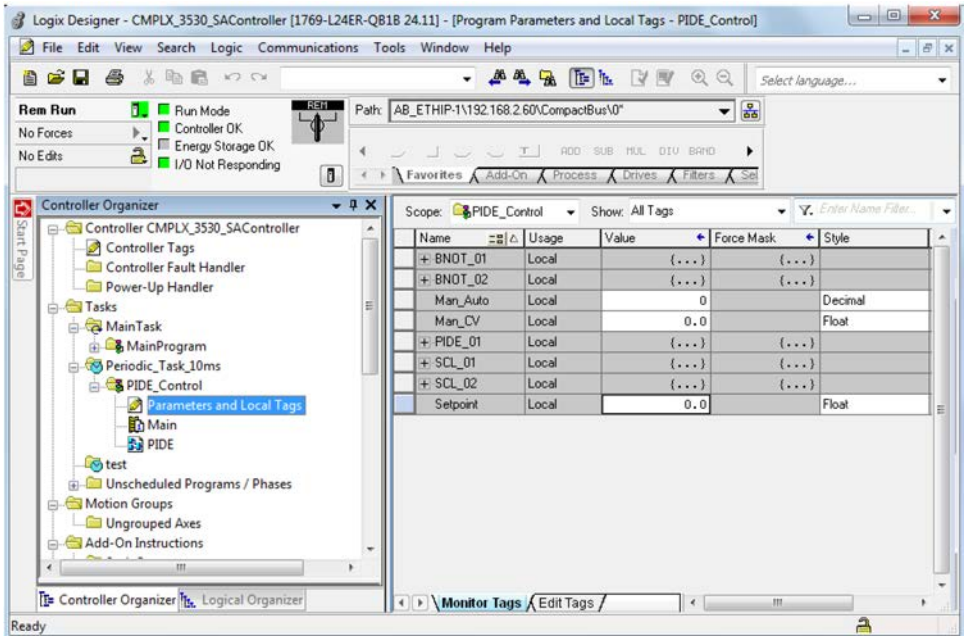


Figure 21: Modifying the value of a tag.

Adding an extra control loop

You can use multiple control loops for a single process or to allow multiple teams to work with the same PLC. In practice, the number of control loops is limited by the number of available analog outputs. The following steps describe how to add an additional control loop to a project using an On-Off control loop as an example.

1. For the additional On-Off control loop, select one available input channel and one available output channel (analog input channel 1 and analog output channel 1 are recommended). Connect the transmitter of the additional control loop to the selected analog input and connect the control element to the selected analog output.

2. If Studio 5000 Logix Designer is not running, start it and open the provided PLC project file. Ensure that Studio 5000 Logix Designer is in offline mode. In the Unscheduled Programs / Phases folder of the project tree, select the program folder corresponding to the control type required for the additional loop (for example, On_Off_Control). Drag and drop this folder into the Unscheduled Programs / Phases folder, as shown in the following figure. This action creates a copy of the control routine.

© Festo Didactic

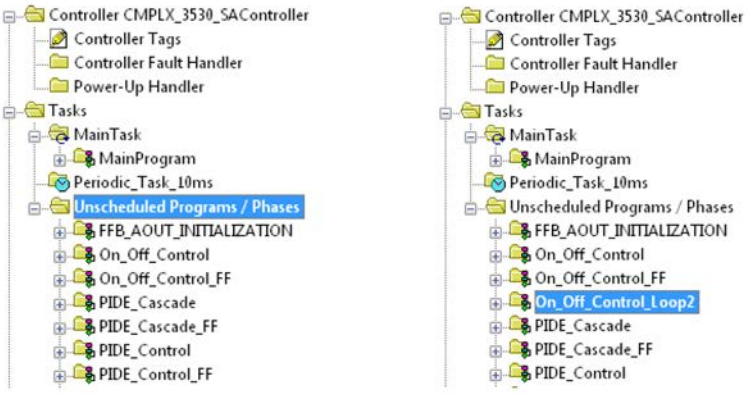


Figure 22: Duplicating a control routine.

3. Select the folder of the newly created routine and press Alt+Enter (or right-click the folder and select Properties) to open the program properties. Rename the program using a clear, descriptive name, such as On_Off_Control_Loop2 (see the following figure).

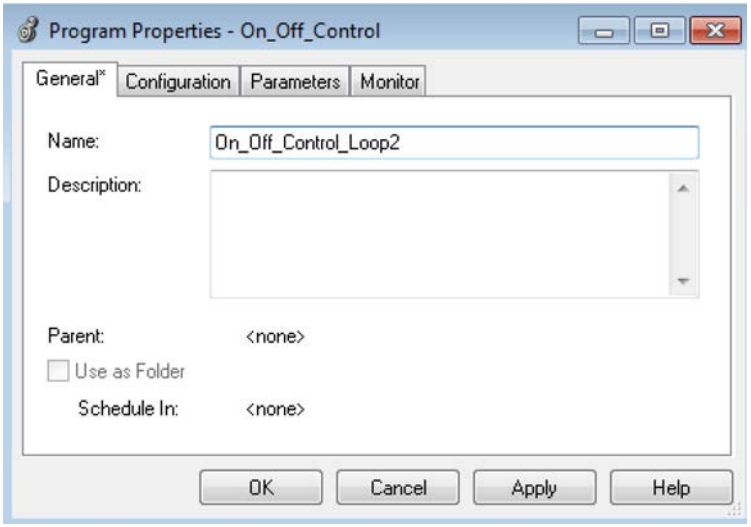


Figure 23: Renaming a control routine.

4. The original routine and its copy currently use the same inputs and outputs. This configuration must be modified.

   Expand the folder of the copied routine (for example, On_Off_Control_Loop2) and double-click the program file (in this case, the On_Off file). The function block diagram shows that the routine currently uses analog input channel 0 and analog output channel 0.

5. Double-click the input reference linked to analog input 0, then click the ▼ symbol. Select the required channel from the list and press Enter. Figure 24 and Figure 25 show how to make these changes on a ControlLogix PLC using an On-Off control program. The procedure is identical for a CompactLogix PLC, except that the I/O addresses differ (see Appendix B).

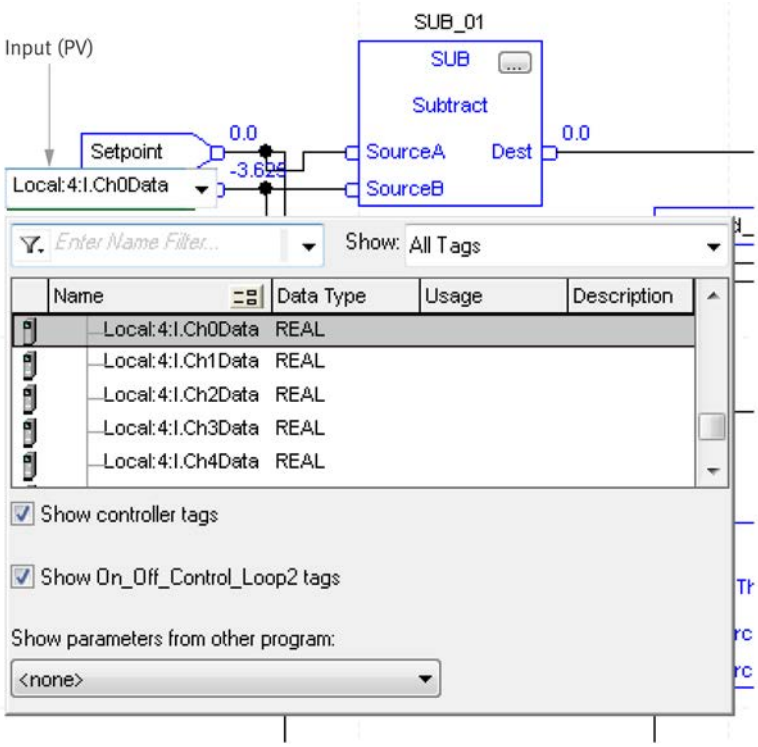


Figure 24: Changing the input of the control routine (example for a ControlLogix PLC).

6. Do the same thing with the output reference currently linked to analog output 0.

© Festo Didactic

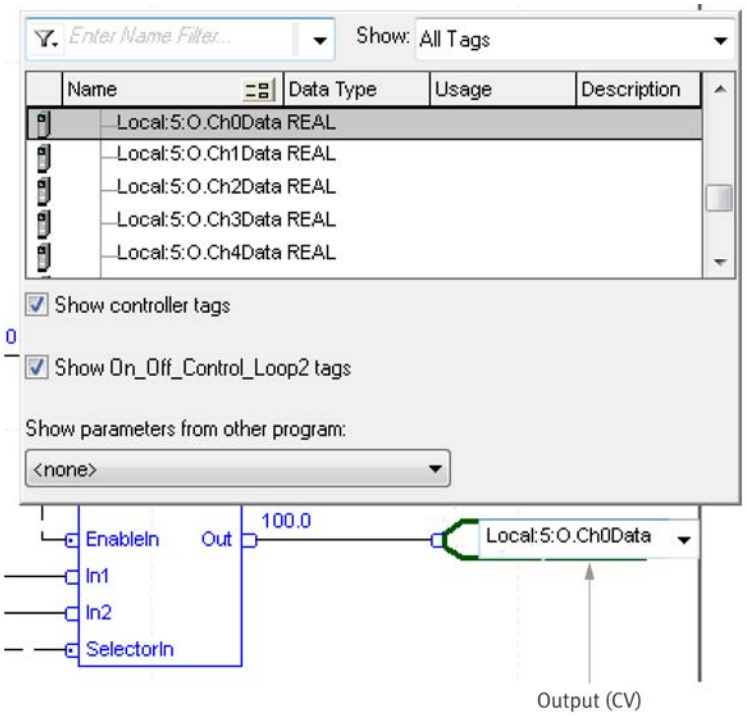


Figure 25: Changing the output of the control routine (example for a ControlLogix PLC).

7. The copy of the routine possesses its own set of parameters which are distinct from the parameters of the original routine.

   Set the routine parameters using the Watch window to appropriate values and then drag all required control routines from the Unscheduled Tasks / Phases folder into the Periodic_Task_10ms folder (see the following figure).



Figure 26: Two control routines in the Periodic Task folder.

FOUNDATION Fieldbus versions of the programs

The provided PLC programs include standard control tasks for 4–20 mA inputs and outputs, as well as corresponding FOUNDATION Fieldbus versions. If your process loop uses Fieldbus, select the FOUNDATION Fieldbus version of the required task. Fieldbus tasks are identified by the _FF suffix in the task name. To use a Fieldbus task, you must also drag the FFB_AOUT_INITIALIZATION task into the Periodic Task folder.

In the Fieldbus versions, inputs and outputs are transmitted to the Fieldbus bridge and compliant devices through the network connection. For additional details, consult the FOUNDATION Fieldbus manuals (86002- and 86003-E0).

© Festo Didactic

Use the Controller Tags window to identify the available FFLD variables on the controller.

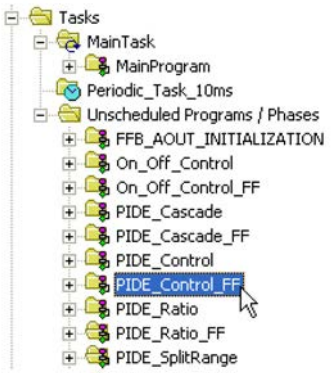


Figure 27: Selecting the FOUNDATION Fieldbus version of a task.

Using an analog input or output with FOUNDATION Fieldbus

You may choose to use a 4–20 mA analog input or output on the PLC even if the FOUNDATION Fieldbus protocol is used for most device communications. This is useful when integrating devices that are not Fieldbus compliant, such as a trend recorder.

To use a 4–20 mA input or output together with the Fieldbus protocol, modify the routine to reference the appropriate variables and apply scaling when required, such as on a CompactLogix controller.

The following figure shows an example in which the output of a PIDE instruction, normally sent to a Fieldbus output value, is also scaled (for a CompactLogix controller) and routed to analog output channel 0. This analog output can be connected to a paperless trend recorder or another device. In the same figure, a second example shows the analog input on channel 0 being scaled and sent to Fieldbus input value 2 of the controller.

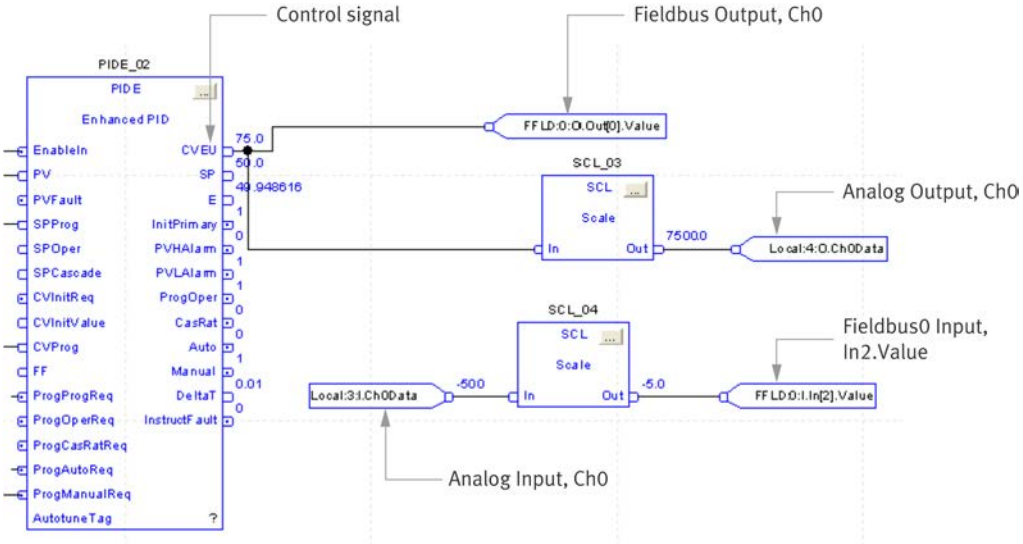


Figure 28: Example of using analog inputs and outputs with the FOUNDATION Fieldbus protocol (CompactLogix version).

© Festo Didactic

Scaling is required only with the **CompactLogix** PLC and must be applied using the following parameters:

When converting an analog input to a FOUNDATION Fieldbus signal, use the following Scale function parameters: InRawMax = 10000, InRawMin = 0, InEUMax = 100, and InEUMin = 0.

When converting a FOUNDATION Fieldbus signal to an analog output, use the following Scale function parameters: InRawMax = 100, InRawMin = 0, InEUMax = 10000, and InEUMin = 0.

Simply ignore the scale functions for the analog I/O in the case of a **ControlLogix**.

© Festo Didactic

© Festo Didactic

On-Off Control

A PLC can implement On-Off control for a process. This basic control method is suitable for slowly changing processes. The PLC analog input is used for the process variable (PV), and the analog output is used for the control variable (CV). Three parameters must be configured to meet process requirements: Setpoint, Deadband, and Forward_Reverse (controller action).

Connecting the PLC to the process loop

1. Connect the PLC to the process as shown in the following figure.

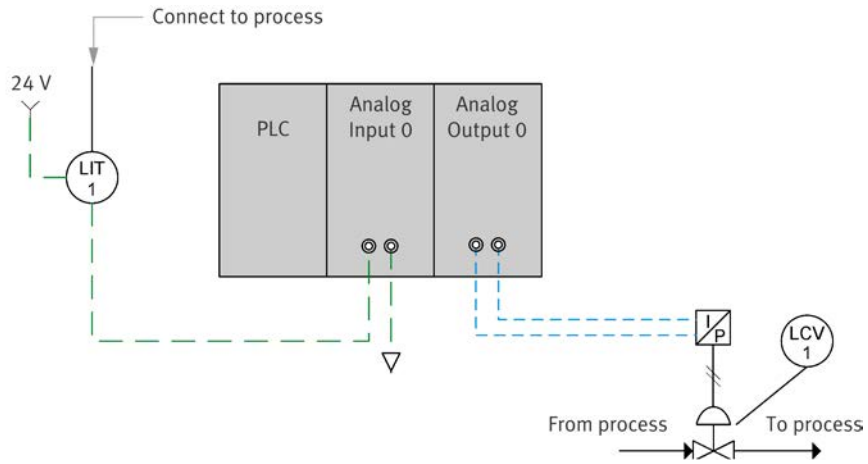


Figure 29: Typical connection of a PLC for on-off control.

Configuring the PLC for On-Off control

2. Make sure the PLC and your computer are set up as explained in Appendix B. RSLinx should be working and displaying your PLC in the RSWho window.

3. Launch Studio 5000 Logix Designer and load the provided PLC project file appropriate to your controller.

4. The project tree displays the list of tasks of the PLC. Press to expand the list of Unscheduled Programs / Phases (see the following figure).

© Festo Didactic

You can find the project files in the resource file below. The CLX_3530_SAController.ACD project file is for the ControlLogix PLC and the CMPLX_3530_SAController.ACD file caters to the CompactLogix PLC.

Resource file for CompactLogix and the ControlLogix PLCs.

https://lx.festo.com/media/5a65d483e2fe4e139add2eb6cad7a5c7

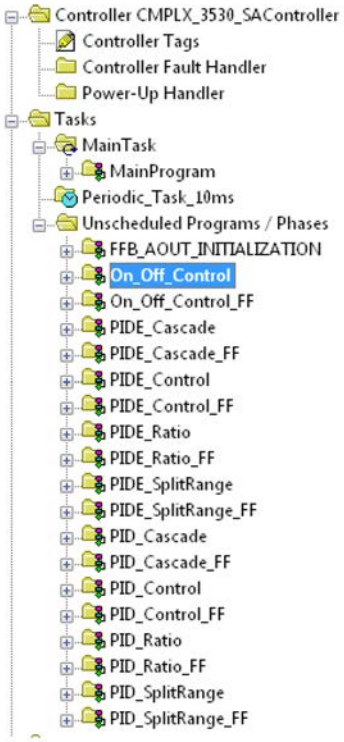


Figure 30: The project tree.

5. A list of available control routines are displayed in the Unscheduled Programs / Phases folder. Drag the On_Off_Control folder into the Periodic_Task_10ms folder (see the following figure). The On-Off routine will be activated once the project is downloaded into the PLC and will be called every 10 ms.

© Festo Didactic

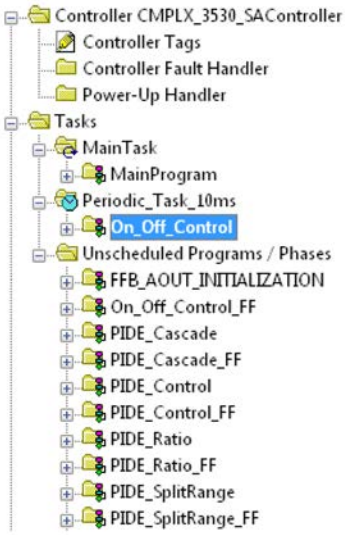


Figure 31: Select the On-Off Control program folder and drag it into the Periodic Task folder.

6. Expand the On_Off_Control folder and double click on the file titled On_Off to open the function block diagram of the routine and explore its logic (see the following figure).

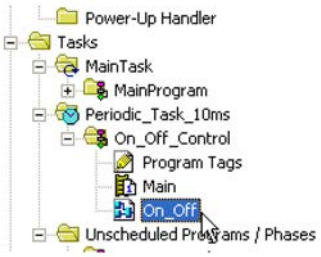


Figure 32: Opening the program of the On-Off routine.

7. In the On-Off routine shown in the following figure, analog input 0 is used as the process variable (PV). The program output is the control variable (CV) and is linked to analog output 0. Logic blocks compute the error (SP – PV) and check whether this error exceeds the deadband. Based on this result, the output is set to either 0% or 100% and sent to the PLC output.

© Festo Didactic

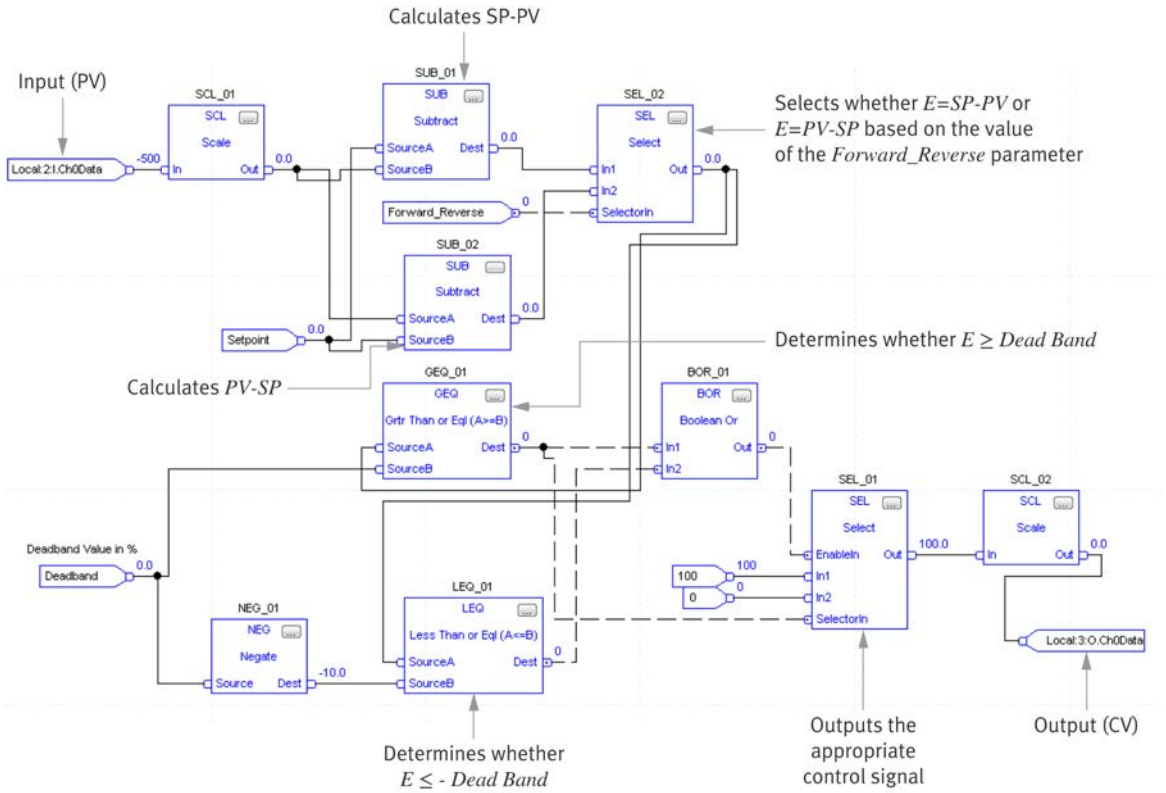


Figure 33: The On_Off routine.

8. Open the Watch window using the View ▶ Watch menu of Studio 5000 Logix Designer (or use the Alt+3 keyboard combination). From the Watch window, you can set the parameters shown in the following table.

   Adjust the parameters as required for your process. You can modify them later if necessary.

Table 2: User-adjustable parameters for on-off control.

Parameter	Description
Setpoint	Target value of PV. Can be set between 0% and 100%.
Deadband	Size of the minimum error necessary to change the value of CV.
Forward_Reverse	Selects between forward action (bit set to 0) and reverse action (bit set to 1).

© Festo Didactic

Running the on-off program

9. To transfer the project to the PLC, open the Who Active window by selecting Communications ▶ Who Active in the menu. Your PLC should appear in the list under its IP address. Locate the module containing the PLC processor and click on the Go Online button (see the following figure).

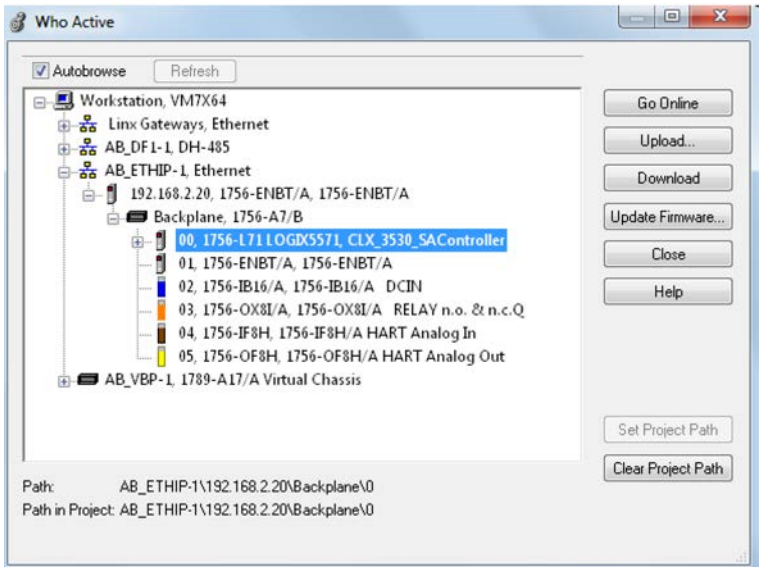


Figure 34: Going online with Studio 5000 Logix Designer.

10. A window informing you that the current project in the PLC is different from the one active in Studio 5000 Logix Designer appears (unless the project in the PLC is exactly the same as the one you want to use). Click Download to transfer the project into the PLC (see the following figure).

© Festo Didactic

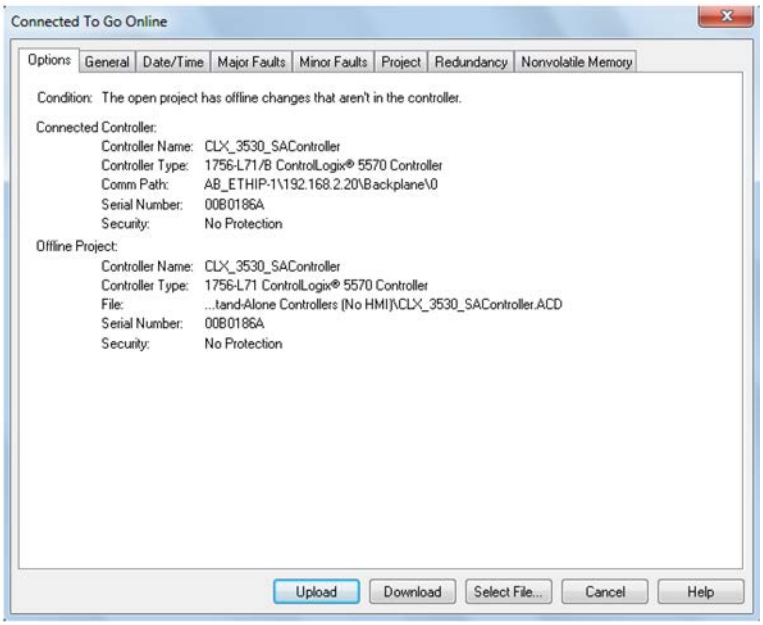


Figure 35: The Connected to Go Online window.

11. One more window warns you about updating the PLC. Read the information and click Download (see the following figure).

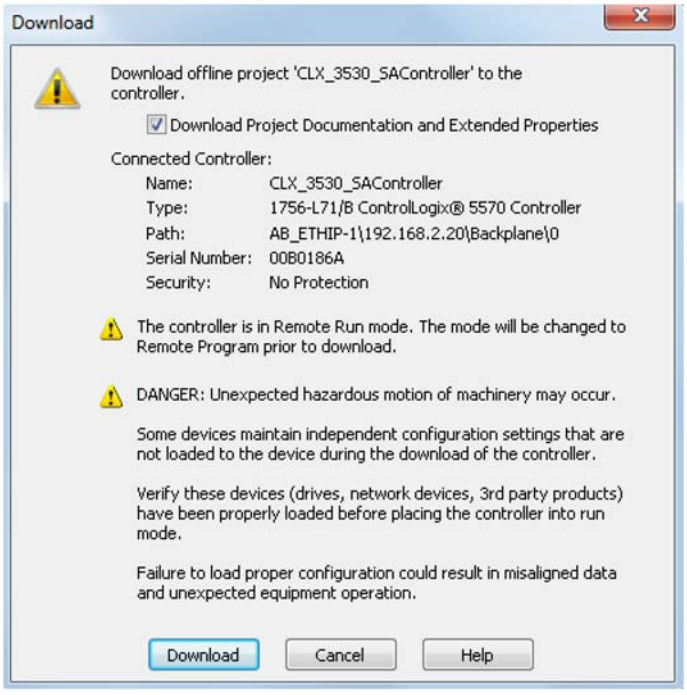


Figure 36: The Download window.

© Festo Didactic

12. The PLC must be in Run mode to execute instructions correctly. If the PLC was already in Run mode, Studio 5000 Logix Designer prompts you to return to that mode after the download. Select Yes. If the PLC was not in Run mode, set it to Run mode now (Communications ▶ Run Mode). The PLC is now running the project.

13. This project requires an emergency button for safety. If PLC digital input 0 is not powered, all processes are shut down. Connect PLC digital input 0 to a 24 V dc switched output on the electrical unit of the Instrumentation and Process Control Training System. Use the switched output jacks that lose power when the emergency button is pressed.

14. The parameters of a control scheme can be modified while you are in run mode from the Watch window (see the following figure). Adjust them to fit the need of the process loop as required.



Figure 37: Changing the parameters in the Watch window.

15. The On-Off routine is now running and controlling your process.

© Festo Didactic

PIDE Control

PIDE (Enhanced PID) control is widely used to regulate most industrial processes. It is similar to standard PID control but provides greater flexibility and advanced features. PIDE control can generally replace PID control with minimal changes, although some specific characteristics are discussed in this section.

An important characteristic of PIDE routines is that they use the velocity form of the PID algorithm. In the classical position form, the output signal (CV) depends mainly on the magnitude of the control error. In contrast, the velocity form operates in discrete time steps. The output value at step n, (CV_n), is calculated from the output at the previous step, (CV_{n-1}), plus the change produced by the control algorithm (ΔPIDE):

$$CV_n = CV_{n-1} + \triangle PIDE$$

In its **independent form**, the control algorithm takes the following mathematical form:

$$CV_n = CV_{n-1} + K_p(E_n - E_{n-1}) + \frac{K_I}{60} E_n \triangle t + 60 K_D \frac{E_n - 2E_{n-1} + E_{n-2}}{\triangle t}$$

where

CV_n	is the control variable at step n
E_n	is the error $(PV - SP)$ at step n
$\triangle t$	is the update time (in second) used by the loop
K_p	is the proportional gain
K_I	is the integral gain (in minute^{-1}). A larger K_I causes a larger integral response
K_D	is the derivative gain (in minute)

Changing one K gain coefficient does not affect the actions associated with the other gain coefficients. The equation can be rewritten in the dependent form using the following relations:

$$K_P = K_C$$

$$K_I = \frac{K_C}{T_I}$$

$$K_D = K_C T_D$$

The **dependent form** of the control algorithm is:

$$CV_n = CV_{n-1} + K_C \left(E_n - E_{n-1} + \frac{1}{60 T_I} E_n \triangle t + 60 T_D \frac{E_n - 2E_{n-1} + E_{n-2}}{\triangle t} \right)$$

© Festo Didactic

where

K_C is the controller gain

T_I is the integral time (in minute). A larger T_I causes a smaller integral response

T_n is the derivative time (in minute)

In the dependent form, a change in the value of K_C also affects both the integral and derivative actions of the controller.

The update time (Δt) corresponds to one period of the periodic task because this control routine runs as a periodic PLC task. The default update time is 10 ms. It can be modified by changing the period parameter in the properties of the Periodic_Task_10ms folder.

PIDE routines can operate in either program mode or operator mode. Program mode is used when the control strategy is managed by the program. Operator mode is typically used when a user interacts with the PLC through an interface. Each mode has its own setpoint and parameters. Although it is possible to switch between modes, this manual uses program mode only.

Connecting the PLC to the process loop

1. Connect the PLC to the process as shown in the following figure.

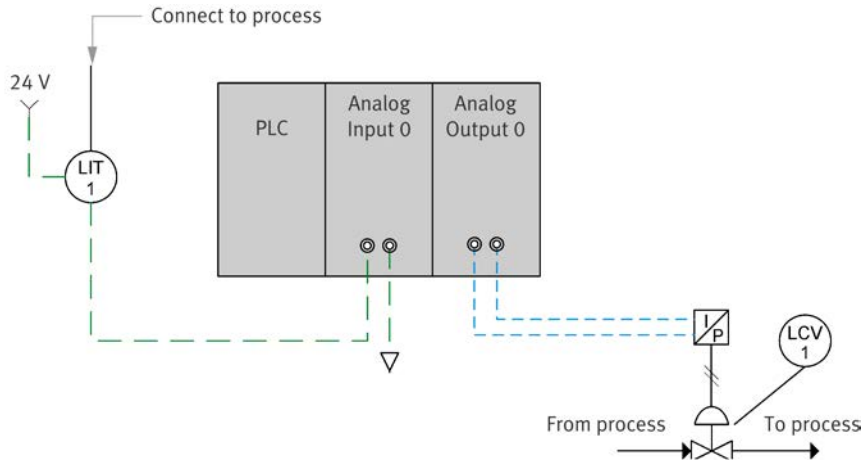


Figure 38: Typical connection of a PLC for PIDE control.

You can connect more control loops to your PLC if required by using the other available analog inputs and outputs. See Learning Unit 1 for details.

Configuring the PLC for PIDE control

2. Make sure the PLC and your computer are set up as explained in Appendix B. RSLinx should be working and your PLC should be displayed in the RSWho window.

© Festo Didactic

3. Launch Studio 5000 Logix Designer and load the provided PLC project file appropriate to your controller.

4. The project tree displays the list of tasks of the PLC. Press the + symbol to expand the list of Unscheduled Programs / Phases (see the following figure).

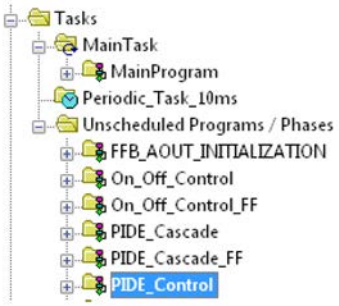


Figure 39: The project tree.

5. A list of available control routines are displayed in the Unscheduled Programs / Phases folder. Drag the PIDE_Control folder into the Periodic_Task_10ms folder (see the following figure). The PIDE routine will be activated once the project is downloaded into the PLC.

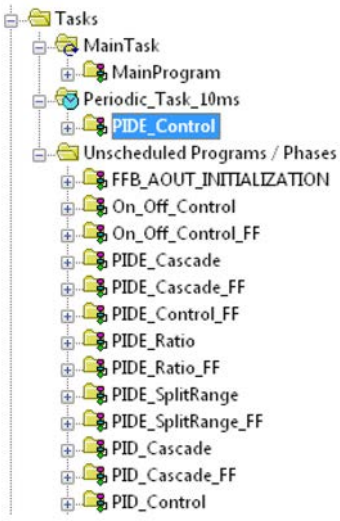


Figure 40: Select the PIDE_Control program folder and drag it into the Periodic Task folder.

6. Expand the PIDE_Control folder and double click on the file titled PIDE to open the function block diagram of the routine and explore its logic (see the following figure).

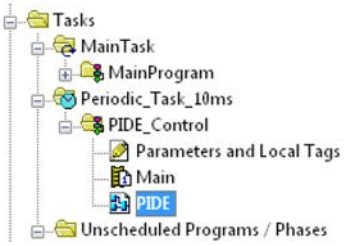


Figure 41: Opening the program of the PIDE routine.

7. The first thing to notice with the PIDE routine (see the following figure) is that analog input 0 is used as the process variable (PV). The output is the control variable (CV) and is linked to analog output 0. Note also that the PIDE block is not enabled unless the Emergency_Button alias is set to 1 (i.e., a 24 V signal must be sent to digital input 0 of the PLC).

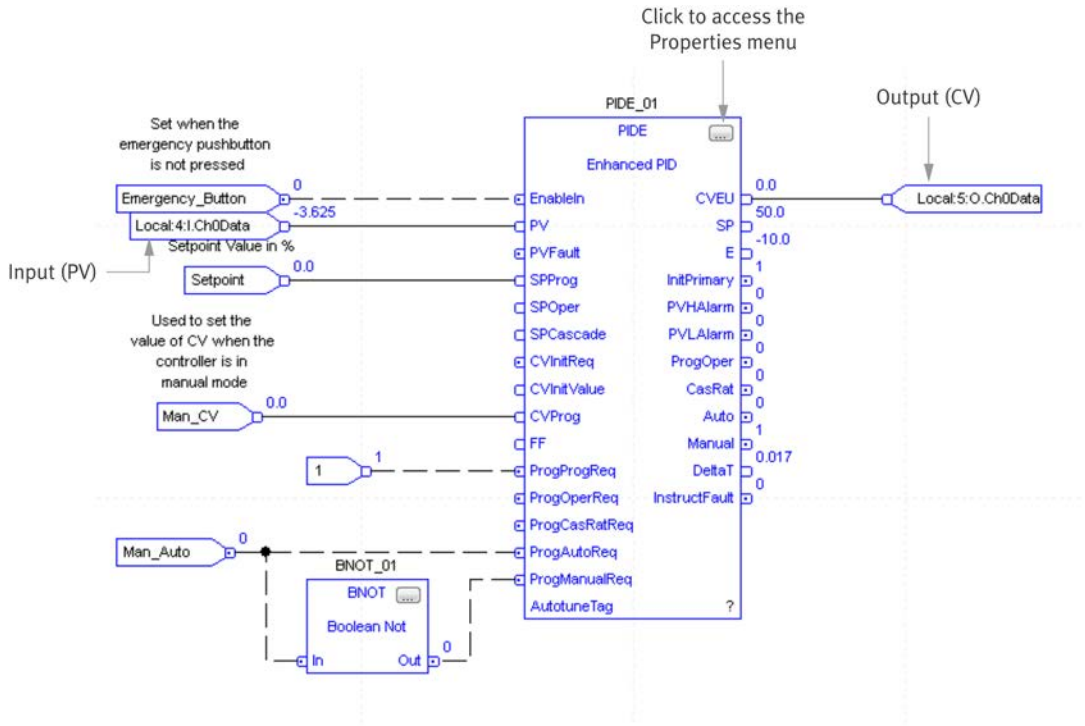


Figure 42: The PIDE routine.

8. Open the Watch window using the View ▶ Watch menu of Studio 5000 Logix Designer (or use the Alt+3 keyboard combination). From the Watch window, you can set the parameters shown in the following table.

© Festo Didactic

Table 3: User-adjustable parameters for PIDE control.

Parameter	Description
Setpoint	Target value of PV. Can be set between 0% and 100%.
Man_Auto	Used to select either manual mode (reset to 0) or automatic mode (set to 1).
Man_CV	Value of CV when the controller is in manual mode. Can be set between 0% and 100%.

9. Next, locate the "..." symbol in the top-right corner of the function block. Clicking on it allows you to access the Properties window (see the following figure) of the block where you can change many of the parameters of the PIDE loop. Consult Table 4 for the list of parameters to set in the General Configuration tab of the Properties window.

   Enter the required parameters for your PIDE loop. If you do not know the value of the tuning parameters at this point you can enter a rough estimate. You will still be able to change those parameters once the PLC is online, but the output of the PIDE loop will not change unless you assign a non-null value to at least one of the tuning parameters.

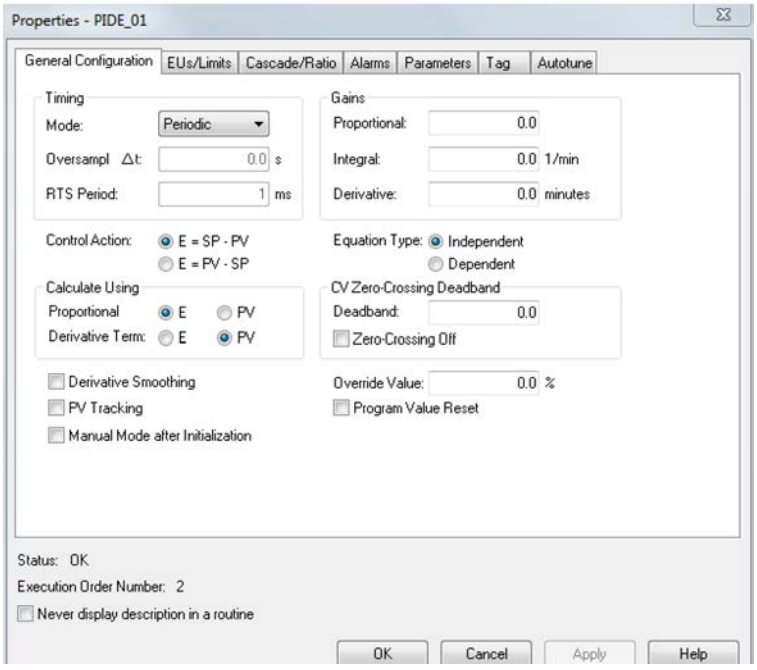


Figure 43: The PIDE Properties window.

Table 4: Important parameters of the PIDE function block.

Parameter	Description
Control Action	Choose either direct (Error = PV-SP) or reverse (Error = SP-PV) control action.
Equation Type	Choose one of the two forms of the PIDE equation (independent or dependent).
Gains	Specify the relevant tuning parameters for the form of the PIDE equation used: **Independent** • K_P Proportional gain • K_I Integral gain (min^{-1}) • K_D Derivative gain (min) **Dependent** • K_C Controller gain • T_I Integral time (min) • T_D Derivative time (min)
Calculate using	Specify if you want the proportional action and the derivative action to be calculated based on the error (E) or on the process variable (PV) only.
Deadband	Enter the deadband value (in %). Leave the field empty or set it to 0 to disable this option. Select Zero-crossing off if the error does not need to cross 0 before the deadband is applied.
Derivative smoothing	When activated, this option reduces the effects of a noisy PV signal by smoothing the derivative action. On the other hand it may limit the effectiveness of derivative action, especially for large gains.
PV Tracking	When this parameter is set, the value of SP will track the value of PV when the controller is in manual mode.

Running the PIDE control program

10. To transfer the project to the PLC, open the Who Active window by selecting Communications ▶ Who Active. The PLC should appear in the list under its IP address. Select the module containing the PLC processor and click Go Online (see the following figure).

© Festo Didactic

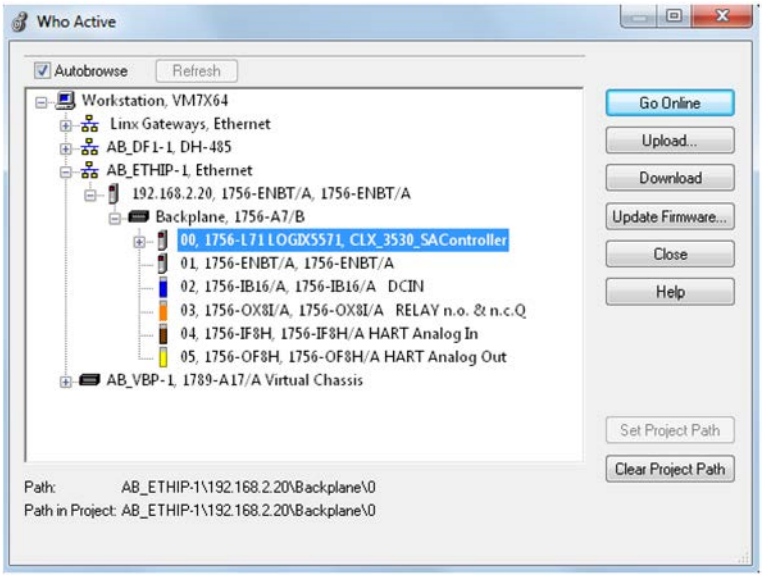


Figure 44: Going online with Studio 5000 Logix Designer.

11. A window appears indicating that the project currently stored in the PLC differs from the project open in Studio 5000 Logix Designer, unless both projects are identical (see the following figure). Click Download to transfer the project to the PLC.

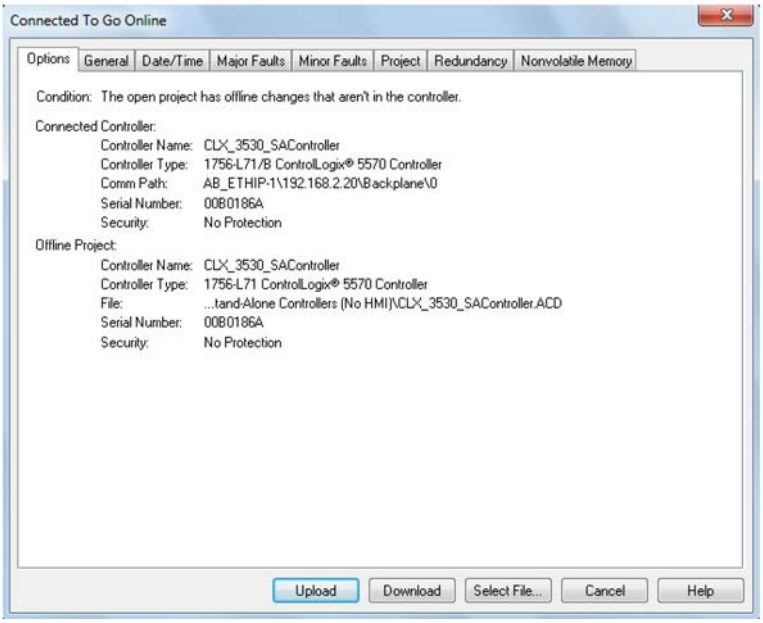


Figure 45: The Connected to Go Online window.

12. One more window warns you about updating the PLC. Read the information and click Download (see the following figure).

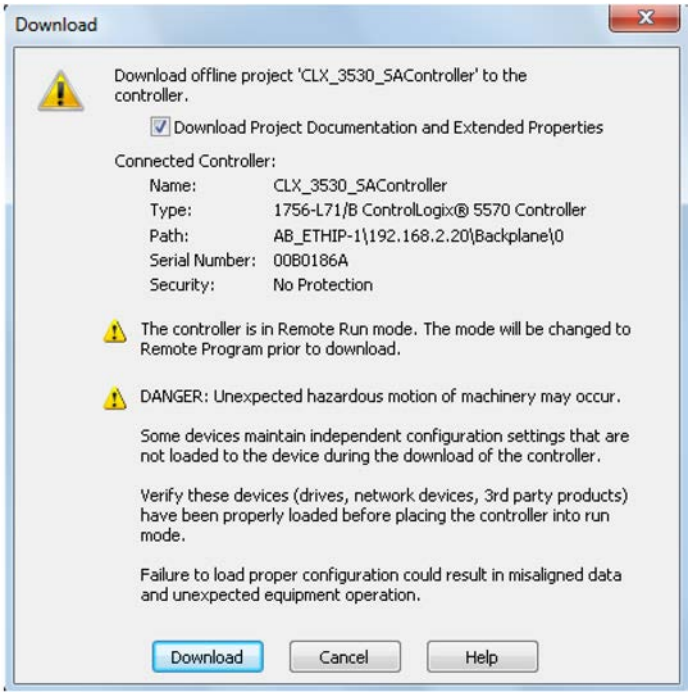


Figure 46: The Download window.

13. The PLC must be in Run mode to execute instructions correctly. If it was already in Run mode, Studio 5000 Logix Designer prompts you to return to that mode after the download. Select Yes. If the PLC was not in Run mode, switch it now (Communications ▶ Run Mode). The PLC is now running the project.

14. This project requires an emergency button for safety. If PLC digital input 0 is not powered, all processes are shut down. Connect PLC digital input 0 to a 24 V dc switched output on the electrical unit of the Instrumentation and Process Control Training System. Use the switched output jacks that lose power when the emergency button is pressed.

15. Return to the PIDE routine and open the Watch window (see the following figure).

    Verify that the Man_Auto parameter is set to 0. If not, change it to 0. This setting places the PIDE controller in **manual mode**. In manual mode, you can directly change the controller output to test the final control element or apply step changes for process characterization. Modify the Man_CV parameter in the Watch window and observe that the control loop output changes accordingly.

© Festo Didactic

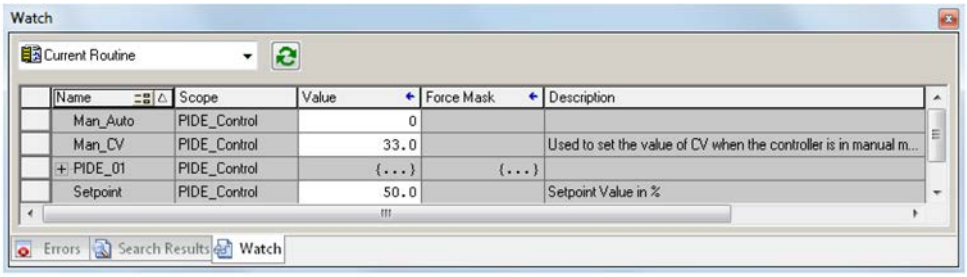


Figure 47: The parameters to list in the Watch window for PIDE control.

16. You can now switch the PIDE controller to **automatic mode**. To do so, set the Man_Auto parameter to 1 in the Watch window. You can change the controller setpoint from the Watch window by modifying the Setpoint parameter.

    The PIDE routine is now running and controlling the process. You can adjust tuning parameters, controller action, and other settings in the Properties window of the PIDE loop, which is accessible by clicking the "..." symbol on the PIDE function block.

PIDE output initialization and diagnostic parameters

Example

The output value of a PIDE function block is calculated from the output at the previous step plus a change determined by the process. This change can be zero, causing the output to remain constant at a value that may be unsuitable for the process. This situation can occur when the controller operates in P or PD mode. To adjust the CVEU value, proceed as follows:

- Set the CVInitValue parameter to the desired PIDE controller output value.
- Set the CVInitReq parameter to 1 so the control algorithm uses CVInitValue for the next calculation. Then reset CVInitReq to 0 to resume normal operation. The output is now adjusted.

This method is also useful if the output (CVEU) saturates and must be returned to an appropriate value.

Another important parameter is the InstructFault status bit of the PIDE function block. Its normal value is 0. A value of 1 indicates a configuration problem. If InstructFault is set to 1, the bits set in the Status1 parameter indicate the cause of the fault. Refer to the PLC manufacturer documentation for a complete list of possible faults and corresponding status bits (Reference: 1756-rm006, Logix5000 Controllers Process Control and Drives Instructions).

© Festo Didactic

© Festo Didactic

Cascade Control

Cascade control is useful when a fast secondary process variable provides early information about the behavior of a primary variable. Using this additional information improves control performance and typically results in tighter overall control. On a PLC, cascade control can be implemented by combining two PIDE control function blocks.

Connecting the PLC to the process loop

1. Connect the PLC to the process as shown in the following figure.

   Additional control loops can be connected to the PLC, if required, by using the remaining analog inputs and outputs. Refer to Adding an extra control loop in Section 2 for details.

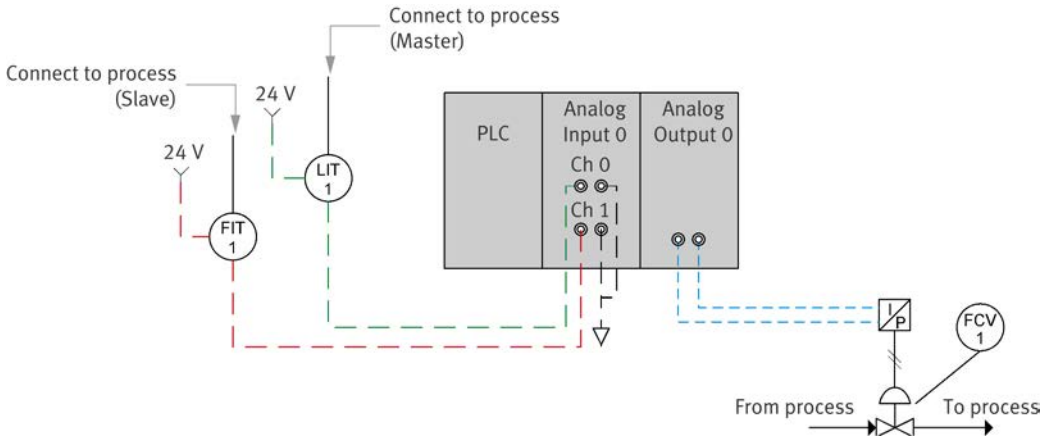


Figure 48: Typical connection of a PLC for cascade control.

Configuring the PLC for cascade control

2. Verify that the PLC and the computer are configured as described in Appendix B. Ensure that RSLinx is running and that the PLC appears in the RSWho window.

3. Launch Studio 5000 Logix Designer and open the provided PLC project file corresponding to your controller.

© Festo Didactic

4. In the project tree, locate the list of PLC tasks and expand the Unscheduled Programs / Phases folder (see the following figure).

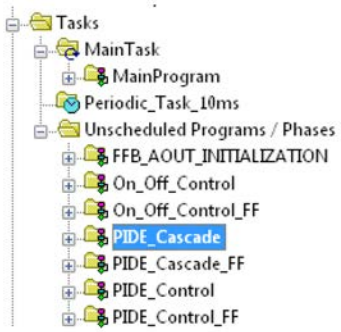


Figure 49: The project tree.

5. The Unscheduled Programs / Phases folder displays the available control routines. Drag the PIDE_Cascade folder into the Periodic_Task_10ms folder (see the following figure). The PIDE_Cascade routine is activated when the project is downloaded to the PLC and is executed every 10 ms.

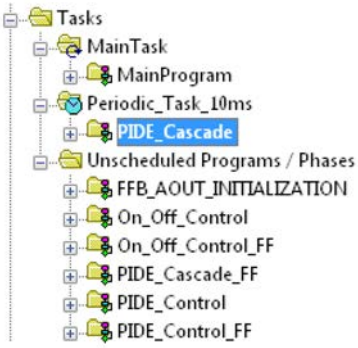


Figure 50: Select the PIDE_Cascade program folder and drag it into the Periodic Task folder.

6. Expand the PIDE_Cascade folder and double click on the file titled PIDE_Cascade to open the function block diagram of the routine and explore its logic (see the following figure).

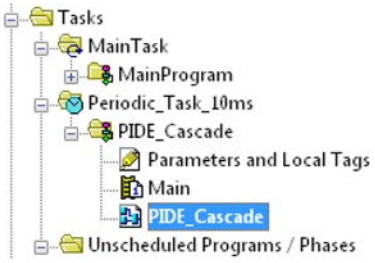


Figure 51: Opening the program of the PIDE_Cascade routine.

© Festo Didactic

7. In the cascade routine shown in the following figure, two PIDE function blocks are connected to implement cascade control. The left PIDE function block acts as the master loop and uses analog input 0 as its process variable (PV_{master}). The output of the master loop is passed directly to the slave loop and used as a remote setpoint. The second PIDE function block acts as the slave loop, using analog input 1 as its process variable (PV_{slave}) and analog output 0 as the control variable (CV).

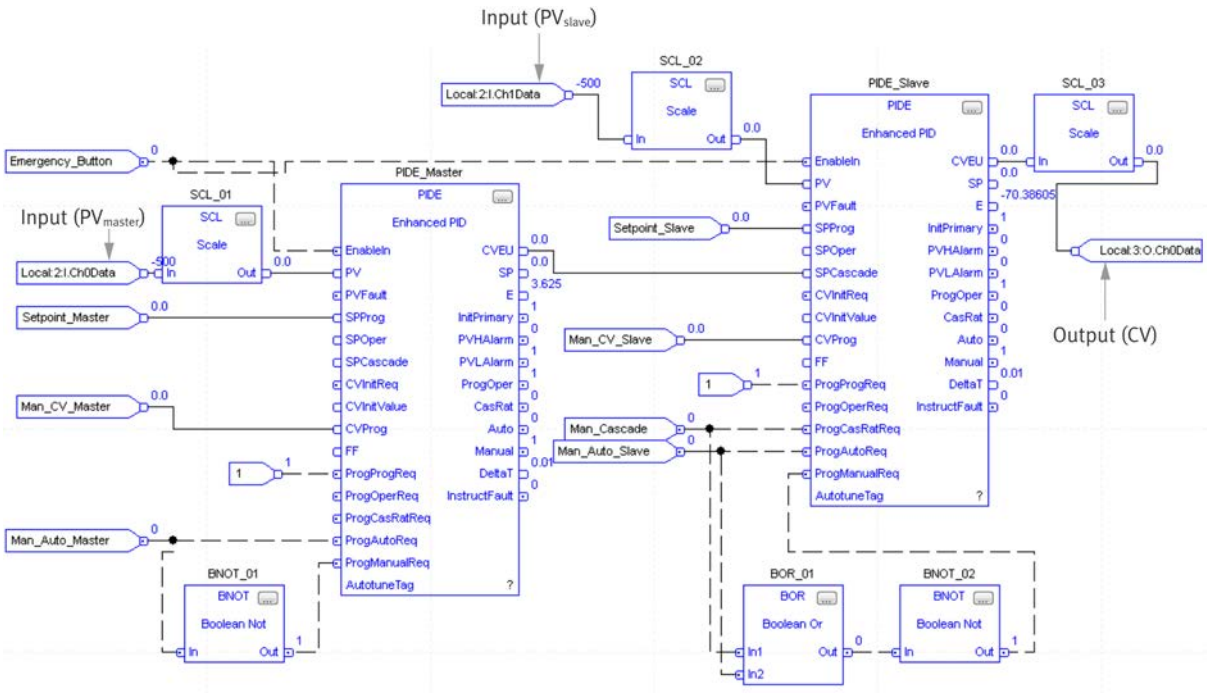


Figure 52: The PIDE_Cascade routine.

8. Open the Watch window using the View ▶ Watch menu of Studio 5000 Logix Designer (or use the Alt+3 keyboard combination). From the Watch window, you can set the parameters shown in the following table.

Table 5: User-adjustable parameters for PIDE Cascade control.

Parameter	Description
Setpoint_Master	Target value of PVmaster. Can be set between 0% and 100%.
Setpoint_Slave	Target value of PVslave. This parameter is only relevant when the slave loop is not operating in cascade mode. It can be set between 0% and 100%.
Man_Auto_Master	Used to select either manual mode (reset to 0) or automatic mode (set to 1) for the master controller.
Man_Auto_Slave	Used to select either manual mode (reset to 0) or automatic mode (set to 1) for the slave controller.
Man_CV_Master	Value of the output of the master loop when the master controller is in manual mode. Gives control over the cascade set point of the slave loop. Can be set between 0% and 100%.
Man_CV_Slave	Value of CV when the slave controller is in manual mode. Can be set between 0% and 100%.
Man_Cascade	Applies to the slave controller only. Selects either manual set-point mode (reset to 0) or cascade set-point mode (set to 1).

Each PIDE controller in the cascade (master and slave) has its own PID parameters and settings, which can be adjusted in the Properties window of the corresponding function block. Each Properties window is accessed by clicking the "..." symbol on the relevant block. Both control loops must be configured correctly for cascade control to operate properly. See Figure 43 and Table 4 for details on the available settings.

Running the PIDE cascade program

9. To transfer the project to the PLC, open the Who Active window by selecting Communications ▶ Who Active. The PLC should appear in the list under its IP address. Select the module containing the PLC processor and click Go Online (see the following figure).

© Festo Didactic

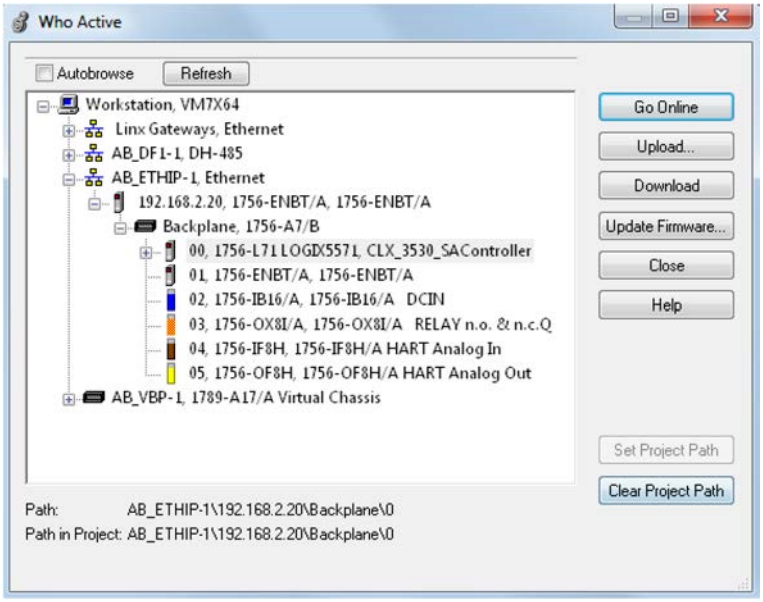


Figure 53: Going online with Studio 5000 Logix Designer.

10. Unless the project stored in the PLC is identical to the project open in Studio 5000 Logix Designer, a window appears indicating that the two projects differ (see the following figure). Click Download to transfer the project to the PLC.

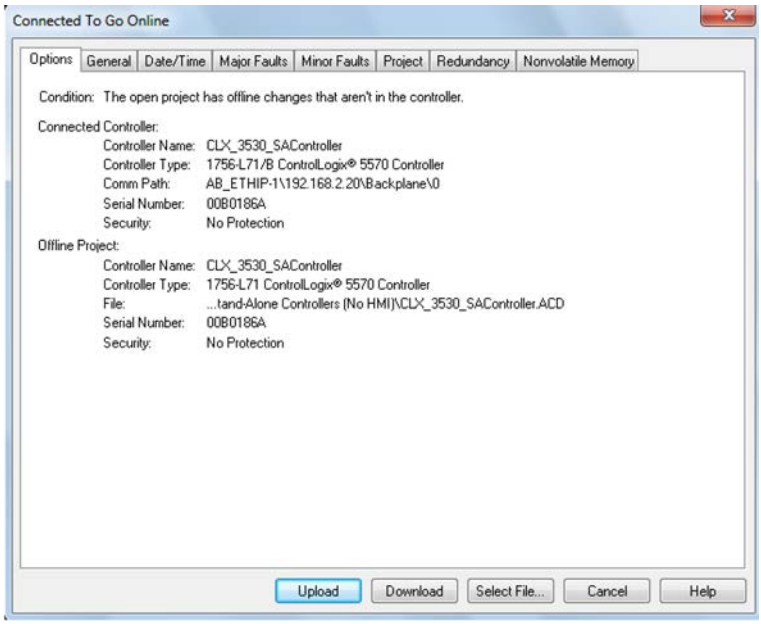


Figure 54: The Connected to Go Online window.

11. One more window warns you about updating the PLC. Read the information and click Download (see the following figure).

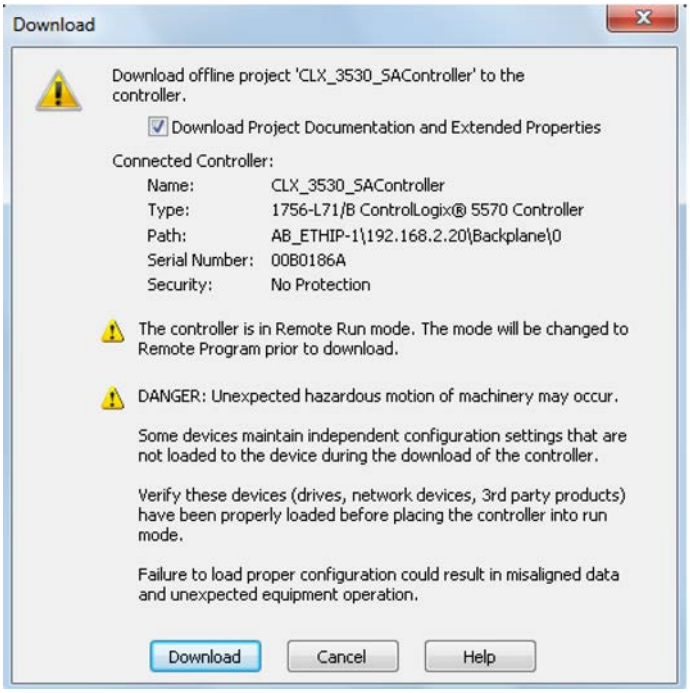


Figure 55: The Download window.

12. The PLC must be in Run mode to execute instructions correctly. If it was already in Run mode, Studio 5000 Logix Designer prompts you to return to that mode after the project download. Select Yes. If the PLC was not in Run mode, switch it to Run mode now (Communications ▶ Run Mode). The PLC is now running the project.

13. This project requires an emergency button for safety. If PLC digital input 0 is not powered, all processes shut down. Connect PLC digital input 0 to a 24 V dc switched output on the electrical unit. Use the switched output jacks that lose power when the emergency button is pressed.

Setting the control loops for cascade control

14. Ensure that the slave control loop operates in manual setpoint mode (Man_Cascade set to 0). Select the appropriate control action and PIDE equation type in the function block properties.

    - When tuning the slave loop using a step-change method (for example, Ziegler–Nichols), set the loop to manual mode (Man_Auto_Slave set to 0). Adjust Man_CV_Slave to apply the step change, calculate the PID parameters, and enter them in the slave loop function block properties.

    - When using a trial-and-error or ultimate-cycle tuning method, set the loop to automatic mode (Man_Auto_Slave set to 1). Adjust the PID coefficients as required in the slave loop function block properties. You can change the slave controller setpoint using the Setpoint_Slave parameter.

© Festo Didactic

After completing the initial tuning of the slave loop, test it in automatic mode (Man_Auto_Slave set to 1) at different setpoints and fine-tune as needed.

Keep the slave loop in automatic mode and enable cascade setpoint mode by setting Man_Cascade to 1. The slave loop setpoint is then driven by the output of the master loop.

15. The master controller can now be tuned. Select the appropriate control action and the PIDE equation type in the function block properties window.

    - When tuning the master loop using a step-change method (for example, Ziegler–Nichols), set the loop to manual mode (Man_Auto_Master set to 0). Adjust Man_CV_Master to apply the step change, calculate the PID parameters, and enter them in the master controller function block properties.

    - When using a trial-and-error or ultimate-cycle tuning method, set the controller to automatic mode (Man_Auto_Master set to 1). Adjust the PID coefficients as required in the master controller function block properties. The master loop setpoint can be changed using the Setpoint_Master parameter.

    After completing the initial tuning of the master loop, test it in automatic mode (Man_Auto_Master set to 1) at different setpoints and fine-tune as required.

    The PIDE Cascade routine is now configured and controlling the process.

© Festo Didactic

© Festo Didactic

PLC Fundamentals

Ratio Control

A PLC controller can perform ratio control when a fixed ratio must be maintained between two process variables, typically two fluid flows. This section explains how to configure the controller to use a ratio setpoint.

Consider two measured variables, A (process 1) and B (process 2), representing the flow rates of two fluids to be mixed while maintaining a fixed ratio R between them, such that:

$$R = \frac{A}{B}$$

First, tune the controller to regulate process variable A. Once tuning is complete, define a ratio setpoint such that $SP_{A,Ratio} = B \cdot R$. This ensures that the target value of A remains proportional to B.

Connecting the PLC to the process loop

1. Connect the PLC to the process as shown in the following figure.

   You can connect more ratio control loops to your PLC, if required, by using the other available analog inputs and outputs. See Learning Unit 1 for details.

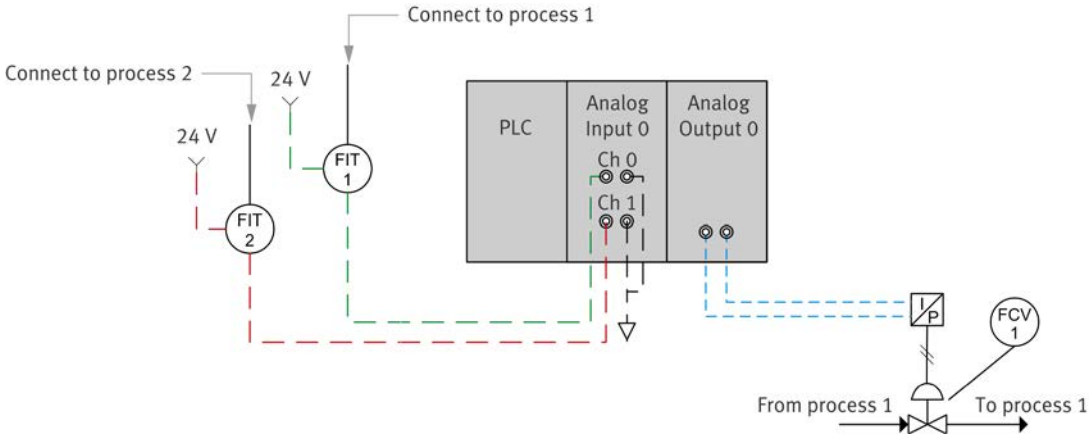


Figure 56: Typical connection of a PLC for ratio control.

Configuring the PLC for ratio control

2. Make sure the PLC and your computer are set up as explained in Appendix B. RSLinx should be working and displaying your PLC in the RSWho window.

3. Launch Studio 5000 Logix Designer and load the provided PLC project file appropriate to your controller.

4. The project tree displays the list of tasks of the PLC. Press to expand the list of Unscheduled Programs / Phases (see the following figure).

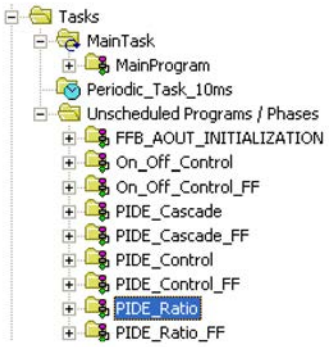


Figure 57: The project tree.

5. The Unscheduled Programs / Phases folder displays the available control routines. Drag the PIDE_Ratio folder into the Periodic_Task_10ms folder (see the following figure). The PIDE Ratio routine is activated when the project is downloaded to the PLC and is executed every 10 ms.

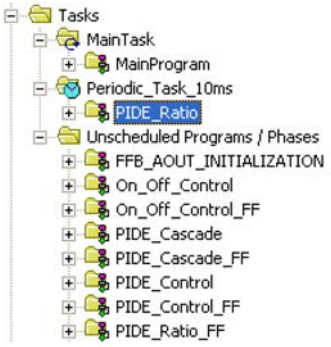


Figure 58: Select the PIDE_Ratio program folder and drag it into the Periodic Task folder.

6. Expand the PIDE_Ratio folder and double click the file titled PIDE_Ratio to open the function block diagram of the routine and explore its logic (see the following figure).

© Festo Didactic

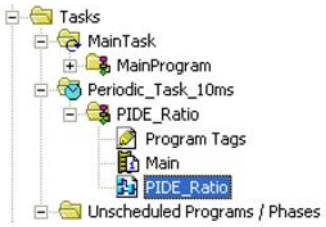


Figure 59: Opening the program of the PIDE_Ratio routine.

7. In the ratio routine shown in the following figure, two analog inputs are connected to a single PIDE function block. Analog input 0 is used as the process variable (variable A), while analog input 1 is used as a cascade setpoint (variable B), although no cascade control is implemented. Analog output 0 is used as the control variable (CV).

   The cascade setpoint is used when ratio mode is enabled. The Ratio variable defines the required process ratio, $R = A/B$.

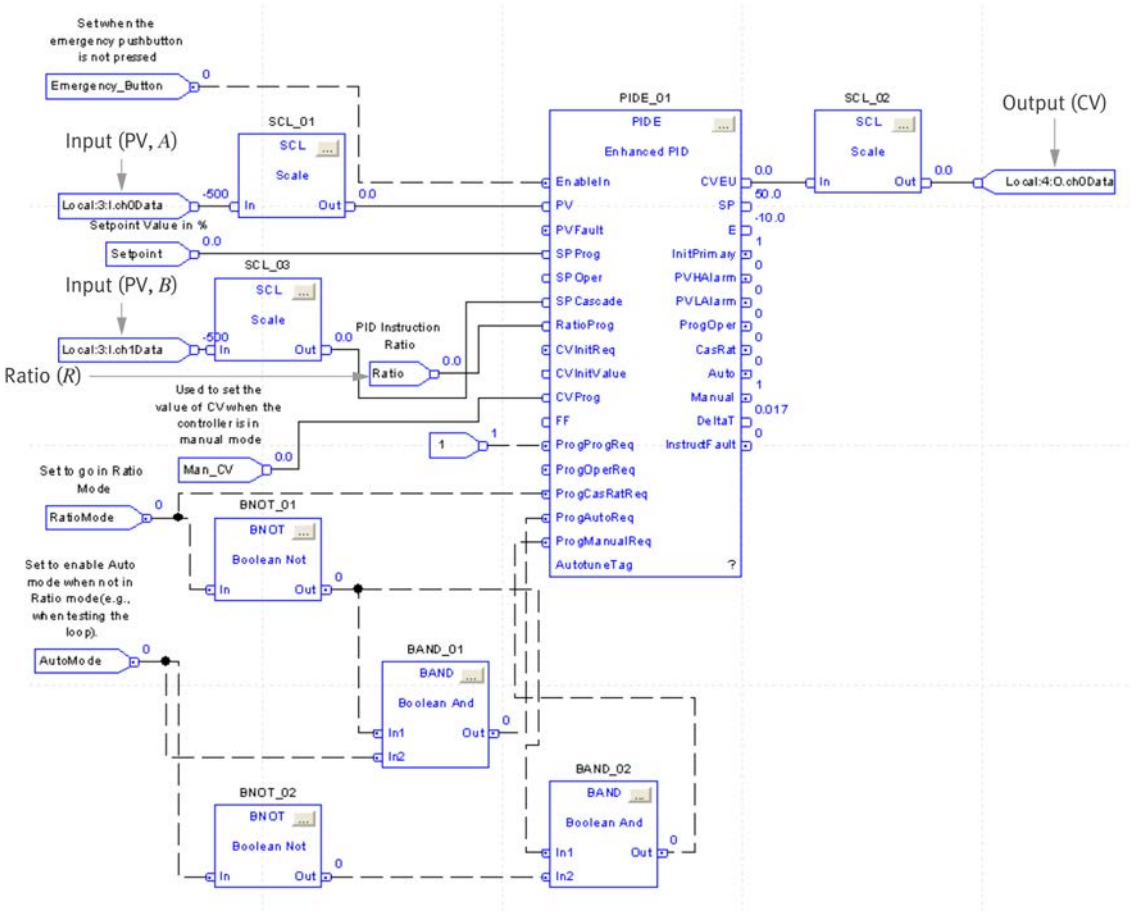


Figure 60: The PIDE_Ratio routine (CompactLogix version).

8. Open the Watch window using View ▶ Watch in Studio 5000 Logix Designer (or press Alt+3). From the Watch window, you can set the parameters listed in the following table.

   PID parameters and PIDE instruction settings can be modified in the Properties window of the function block. This window is also accessible by clicking the "..." symbol on the function block. Correct configuration of options and parameters is required for ratio control to operate properly. See Figure 43 and Table 4 for details on selected settings.

Table 6: User-adjustable parameters for PIDE ratio control.

Parameter	Description
Setpoint	Target value of PV. Can be set between 0% and 100%. This is used when testing the tuning of the loop before enabling the ratio mode.
AutoMode	Used to select either manual mode (reset to 0) or automatic mode (set to 1) in order to test and tune the loop before using the ratio mode.
Ratio	Target value of the R=A⁄B ratio. This parameter is used when the ratio mode is enabled.
RatioMode	Used to deactivate ratio mode (reset to 0) or activate ratio mode on automatic (set to 1).
Man_CV	Value of the output of the loop while the controller is in manual mode. Can be set between 0% and 100%.

Running the PIDE ratio program

9. To transfer the project to the PLC, open the Who Active window by selecting Communications ▶ Who Active. The PLC should appear in the list under its IP address. Select the module containing the PLC processor and click Go Online (see the following figure).

© Festo Didactic

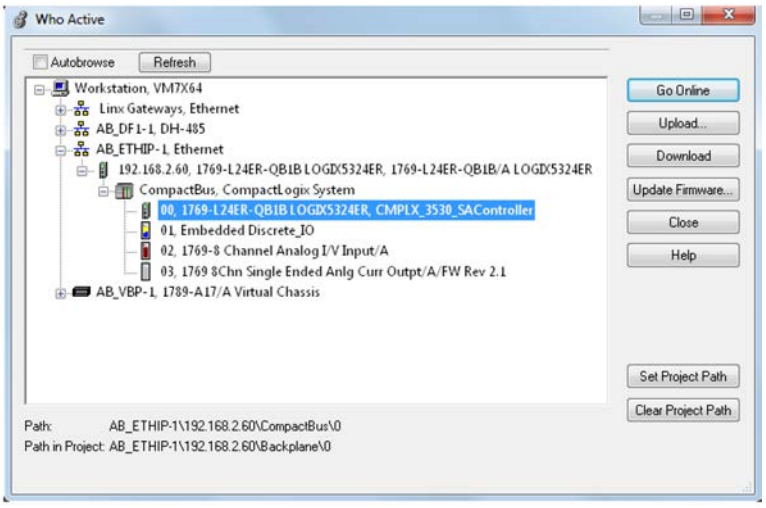


Figure 61: Going online with Studio 5000 Logix Designer and a CompactLogix.

10. Unless the project stored in the PLC is identical to the project open in Studio 5000 Logix Designer, a window appears indicating that the two projects differ (see the following figure). Click Download to transfer the project to the PLC.

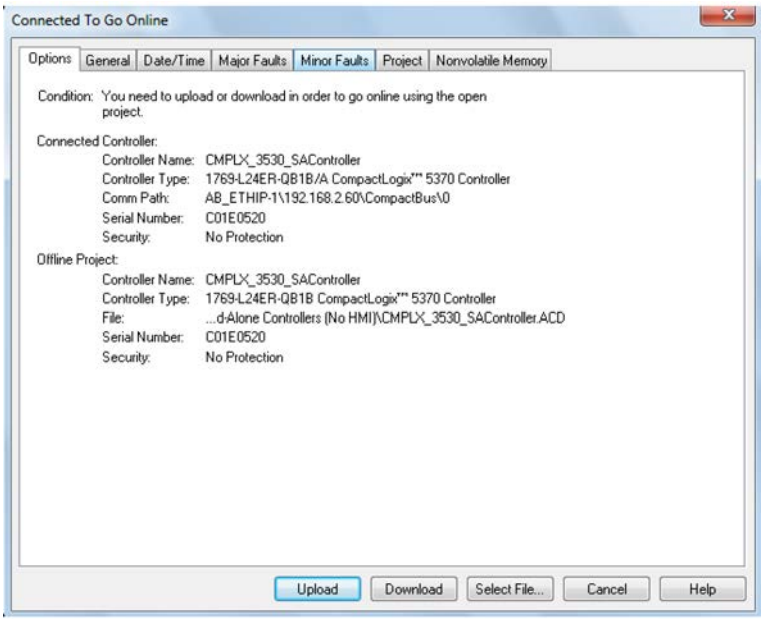


Figure 62: The Connected to Go Online window.

11. One more window warns you about updating the PLC. Read the information and click Download (see the following figure).

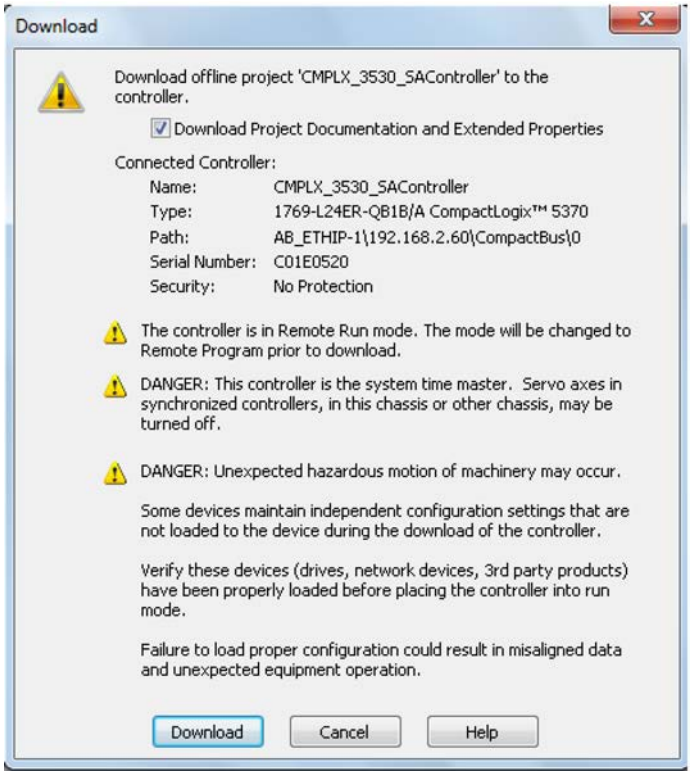


Figure 63: The Download window.

12. The PLC must be in Run mode to execute instructions. If it was already in Run mode, Studio 5000 Logix Designer prompts you to return to that mode after the project download. Select Yes. If the PLC was not in Run mode, switch it now (Communications ▶ Run Mode). The PLC is now running the project.

13. This project requires an emergency button for safety. If PLC digital input 0 is not powered, all processes shut down. Connect PLC digital input 0 to a 24 V dc switched output on the electrical unit. These output jacks lose power when the emergency button is pressed.

Setting the control loop for ratio control

14. Tune the controller using the method of your choice to control the first variable (A):

    - When using a step-change method (such as Ziegler-Nichols), set the loop to manual mode (AutoMode set to 0). Adjust the Man_CV parameter to apply the step change, calculate the PID parameters, and enter them in the loop function block properties.

    - When using a trial-and-error or ultimate-cycle tuning method, set the loop to automatic mode (AutoMode set to 1). Adjust the PID coefficients as required in the loop function block properties. You can change the controller setpoint using the Setpoint parameter.

© Festo Didactic

After the initial tuning, test the loop in **automatic** mode (AutoMode set to 1) at different setpoints and fine-tune as required.

Use the Properties window of the PIDE function block to modify the PID parameters, as explained in Learning Unit 1 and in the following figure. Ensure that the Allow Cascade/Ratio Mode and Use Ratio options are enabled in the Cascade/Ratio tab of the Properties menu. The ratio limits can be adjusted in the same menu.

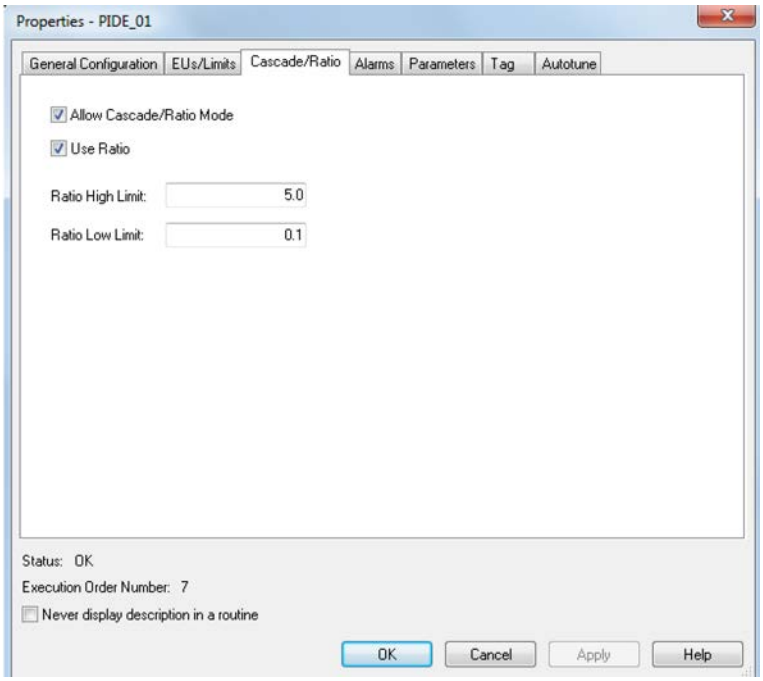


Figure 64: The Cascade/Ratio tab.

15. Set the Ratio variable to the value of the $R = A/B$ ratio you want for your process. Finally, activate the ratio mode (RatioMode set to 1) and watch as the controller works to adjust the first variable in order to maintain the requested ratio as the second variable changes. Modify the process value of the second variable by changing the appropriate flow rate, level, pressure, or temperature on your station, or simply use a calibrator.

    The PIDE Ratio routine is now configured and controlling your process.

© Festo Didactic

Split-Range Control

This section explains how to configure a controller to perform split-range control.

PLCs such as ControlLogix or CompactLogix support split-range control by distributing the range of a single control variable across multiple 4–20 mA analog outputs. This approach allows one process variable to be controlled using several distinct control elements, with one control element required per output.

The controller output range is divided into configurable segments. In the example shown in the following figure, three ranges are defined. Output AOUT0 increases as the control variable (CV) rises from 0 to the first split point (for example, 40%). Output AOUT1 then increases as CV rises from the first split point (for example, 40%) to the second split point (for example, 80%). Finally, AOUT2 decreases from 100% to 0% as CV increases from the second split point (for example, 80%) to 100%.

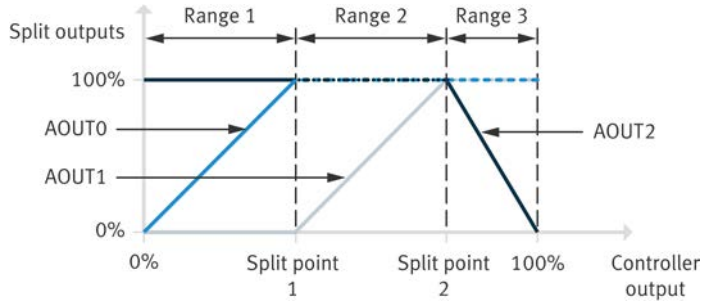


Figure 65: Example of a split-range application.

This scheme provides flexibility to accommodate different processes. The split-range tasks preprogrammed in the PLC include three output variables. You can adjust the operating range and direction (direct or reverse) of each variable. Variables can be added or removed by modifying the program.

For the experiments proposed in the Advanced Process Control course, the PID tuning parameters of all PIDE function blocks must be set to identical values. Using different tuning parameters for each range is optional and allows further exploration of control behavior.

Connecting the PLC to the process loop

1. Connect the PLC to the process as shown in the following figure.

   Split-range control requires at least two control elements. A third output, which requires an additional control element, is preprogrammed but optional.

   Additional control elements can be added, if required, by using other available analog outputs and making minor program modifications.

© Festo Didactic

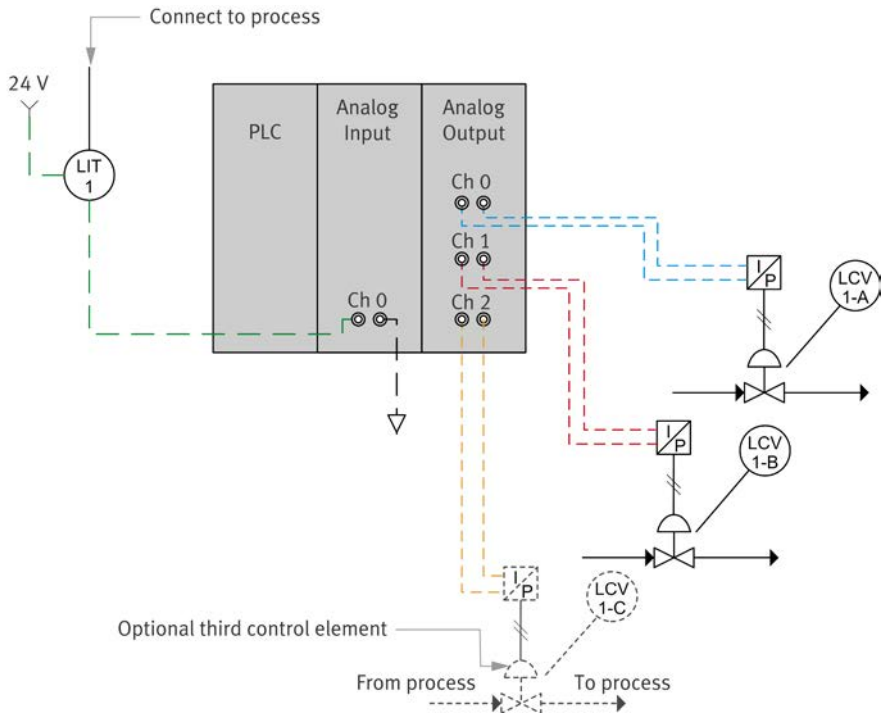


Figure 66: Typical connection of a PLC for split-range control.

Configuring the PLC for split-range control

2. Verify that the PLC and the computer are configured as described in Appendix B. Ensure that RSLinx is running and that the PLC appears in the RSWho window.

3. Launch Studio 5000 Logix Designer and open the provided PLC project file corresponding to your controller.

4. In the project tree, locate the list of PLC tasks and expand the Unscheduled Programs / Phases folder (see the following figure).

© Festo Didactic

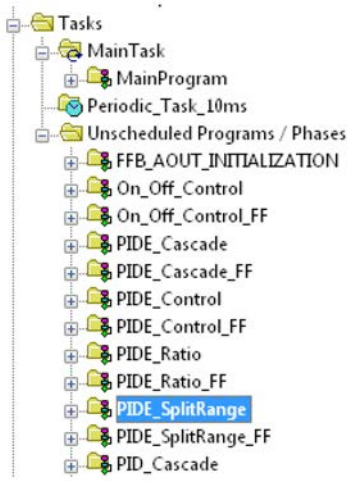


Figure 67: The project tree.

5. The Unscheduled Programs / Phases folder displays the available control routines. Drag the PIDE_SplitRange folder into the Periodic_Task_10ms folder (see the following figure). The PIDE split-range routine is activated when the project is downloaded to the PLC and is executed every 10 ms.

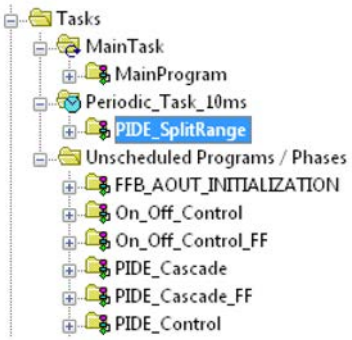


Figure 68: Select the PIDE_SplitRange program folder and drag it into the Periodic Task folder.

6. Expand the PIDE_SplitRange folder and double click the file titled PIDE_SplitRange to open the function block diagram of the routine and explore its logic (see the following figure).

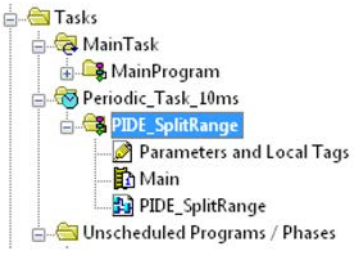


Figure 69: Opening the program of the PIDE_SplitRange routine.

7. The split-range routine is shown in Figure 70. It consists of three PIDE instructions that share the same process variable (PV) and setpoint. Each PIDE instruction drives a different control variable (CV) connected to a Scale instruction, which defines the operating range of each control output.

   Negate and Add instructions are located next to each output Scale instruction but are not initially connected. They are used to reverse the action of a specific control variable within a given range without affecting the others. To reverse the action of a control variable, modify the connections as shown in Figure 71.

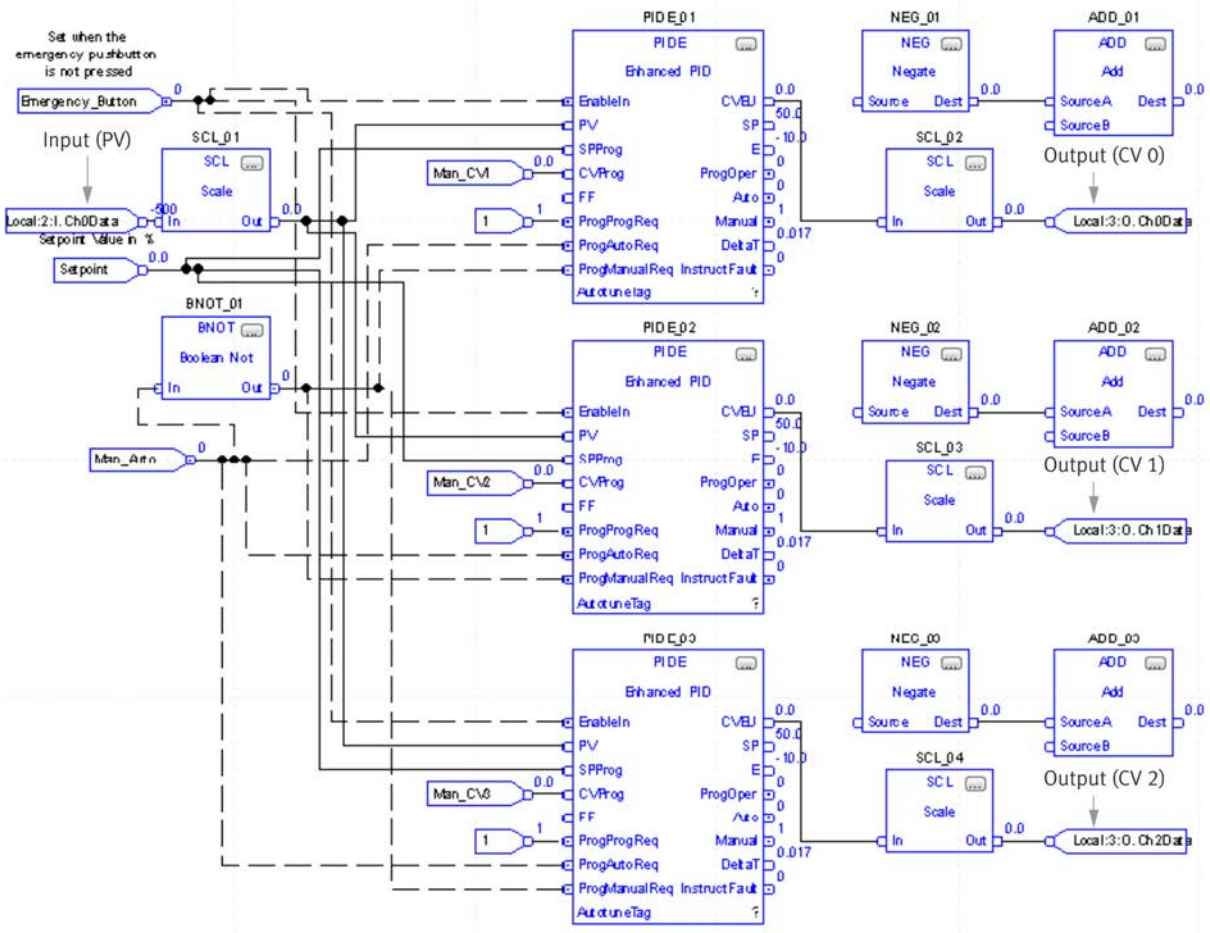


Figure 70: The PIDE_SplitRange routine (CompactLogix version).

© Festo Didactic

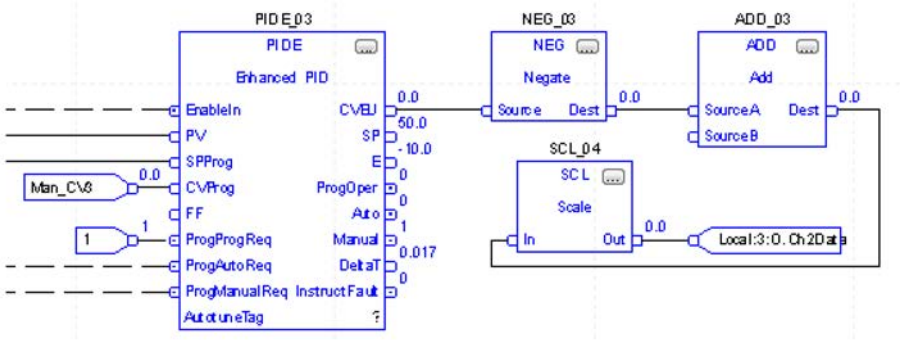


Figure 71: Inverting the action of one of the CV in a split-range routine.

8. Open the Watch window using View ▶ Watch in Studio 5000 Logix Designer (or press Alt+3). From the Watch window, you can set the parameters listed in the following table.

   PID parameters and PIDE instruction settings can be modified in the Properties window of each function block. This window is also accessible by clicking the "..." symbol on the function block. See Figure 43 and Learning Unit 4 for details on selected settings.

   In most cases, including the experiments in the Advanced Process Control manual, all control loops in this routine should use identical PID parameters. Different PID parameters may be used when this constraint does not apply.

Table 7: User-adjustable parameters for PIDE split-range control.

Parameter	Description
Setpoint	Target value of PV. Can be set between 0% and 100%.
ManAuto	Used to select either manual mode (reset to 0) or automatic mode (set to 1) for all of the PIDE routines taking part in the split-range control scheme.
Man_CV1	Value of the output of the loop while the controller is in manual mode. Can be set between 0% and 100%.
Man_CV2	Value of the output of the loop while the controller is in manual mode. Can be set between 0% and 100%.
Man_CV3	Value of the output of the loop while the controller is in manual mode. Can be set between 0% and 100%.

© Festo Didactic

Running the PIDE split-range program

9. To transfer the project to the PLC, open the Who Active window by selecting Communications ▶ Who Active. The PLC should appear in the list under its IP address. Select the module containing the PLC processor and click Go Online (see the following figure).

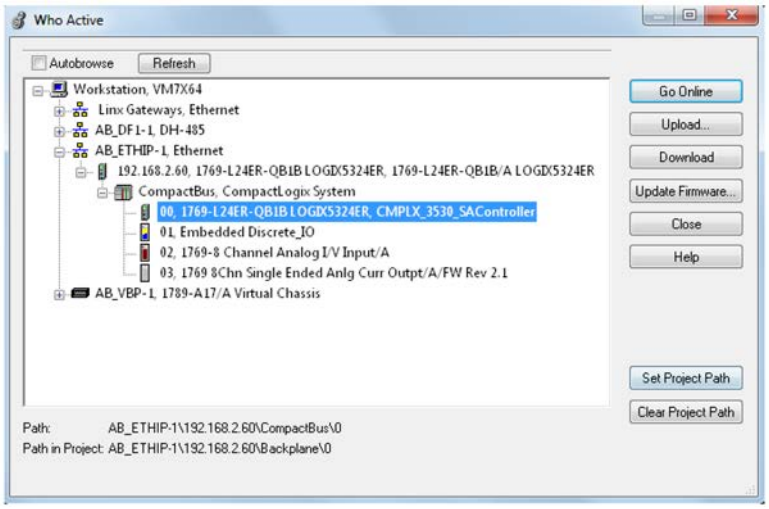


Figure 72: Going online with Studio 5000 Logix Designer and a CompactLogix.

10. Unless the project already stored in the PLC is identical to the project open in Studio 5000 Logix Designer, a window appears indicating that the two projects differ (see the following figure). Click Download to transfer the project to the PLC.

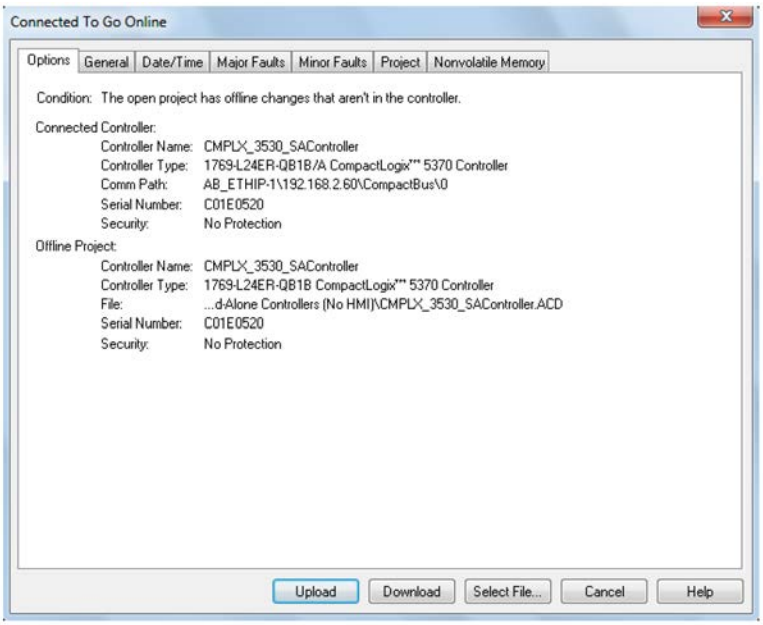


Figure 73: The Connected to Go Online window.

© Festo Didactic

11. One more window warns you about updating the PLC. Read the information and click Download (see the following figure).

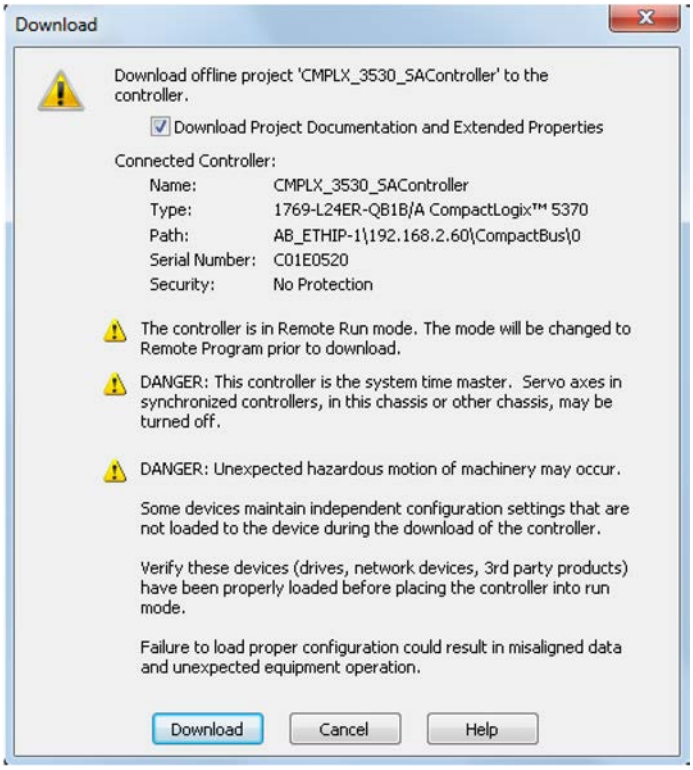


Figure 74: The Download window.

12. The PLC must be in Run mode to execute instructions correctly. If it was already in Run mode, Studio 5000 Logix Designer prompts you to return to that mode after the project download. Select Yes. If the PLC was not in Run mode, switch it now (Communications ▶ Run Mode). The PLC is now running the project.

13. This project requires an emergency button for safety. If PLC digital input 0 is not powered, all processes shut down. Connect PLC digital input 0 to a 24 V dc switched output on the electrical unit. These output jacks lose power when the emergency button is pressed.

Setting the control loop for split-range control

14. Define the ranges over which the control variable acts on each output. To do this, click the "..." symbol on the Scale function block of each output variable and enter the required range values by adjusting the InRawMax and InRawMin parameters. The InEUMax and InEUMin parameters are set to 100 and 0 for ControlLogix, or 10 000 and 0 for CompactLogix.

    The following figure shows an example with three control variables: variable 1 operates from 0 to 20%, variable 2 from 20 to 70%, and variable 3 from 70 to 100%. Each output variable is rescaled to a 0 to 100% signal within its assigned range.

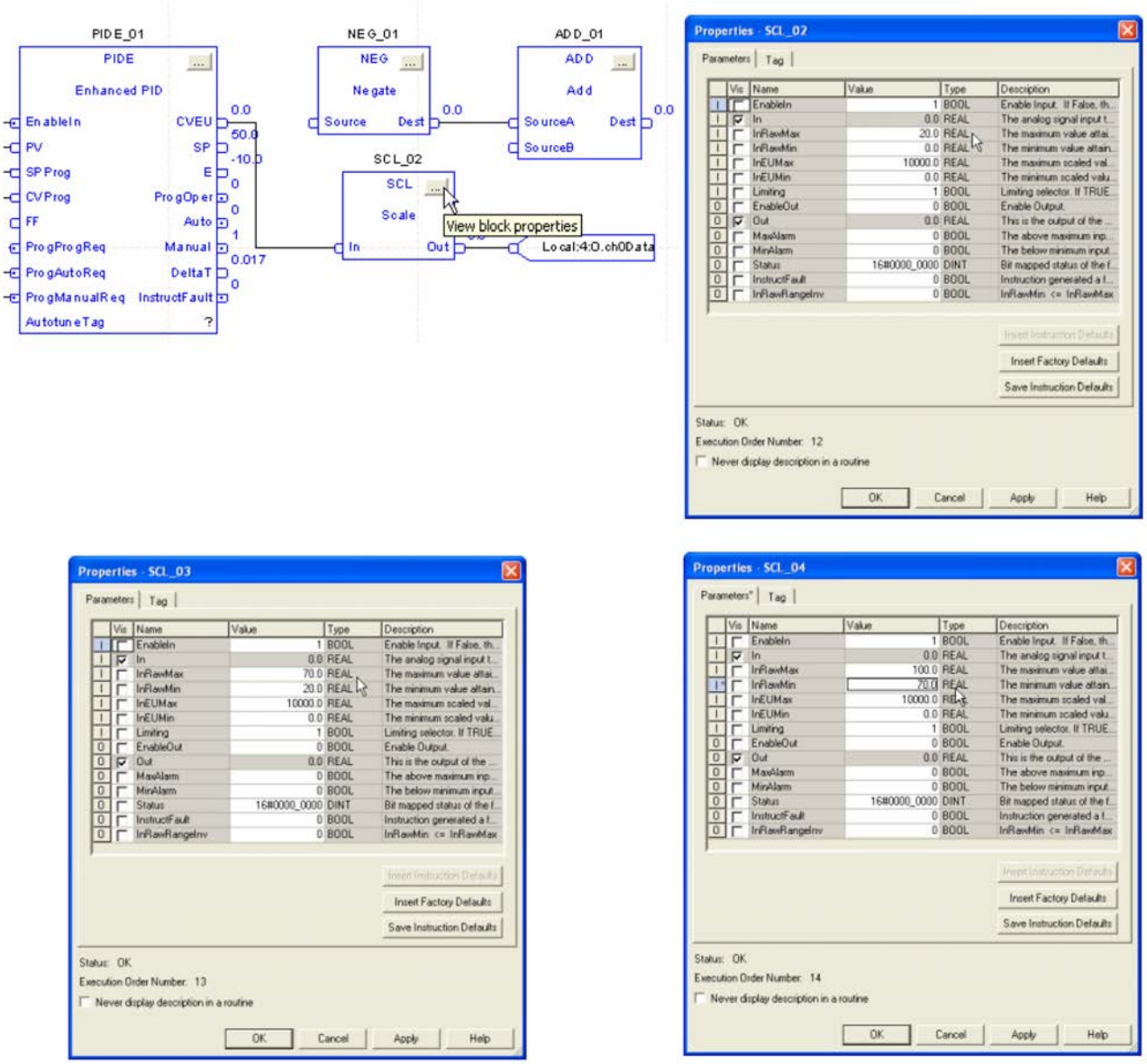


Figure 75: Adjusting the range of each variable in a split-range scheme.

15. To edit the program while the PLC is online (for example, to invert the action of a control-variable output), click Start Pending Routine Edits (see Figure 76), perform the required modifications, and then click Finalize All Edits in Program (see Figure 77).

    If the action of an output is inverted, the associated scaling function must also be updated. An output that produces a minimum value at X% of the control variable and a maximum value at Y% must be rescaled after inversion so that InRawMax is set to 100%–X% and InRawMin is set to 100%–Y%.

    For example, if an output operates over the range 70% to 100%, inverting its action requires setting InRawMax to 30% and InRawMin to 0%.

© Festo Didactic

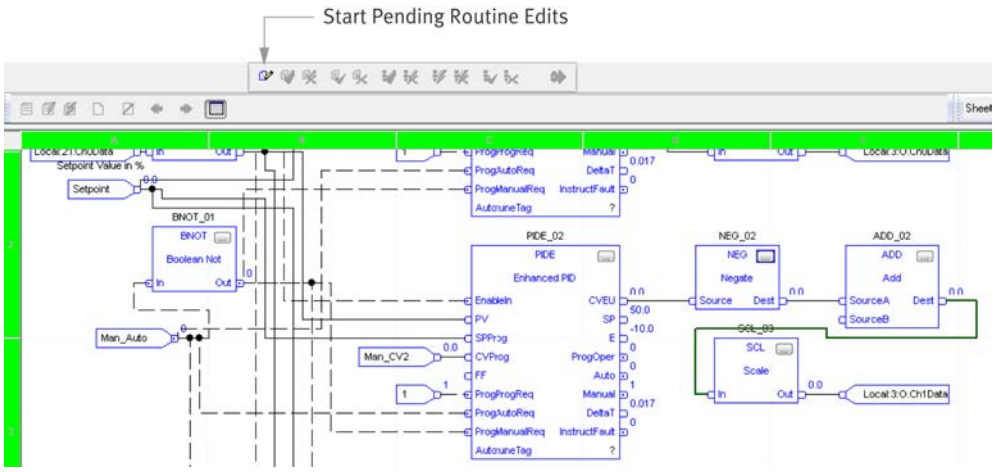


Figure 76: Modifying the program while online.

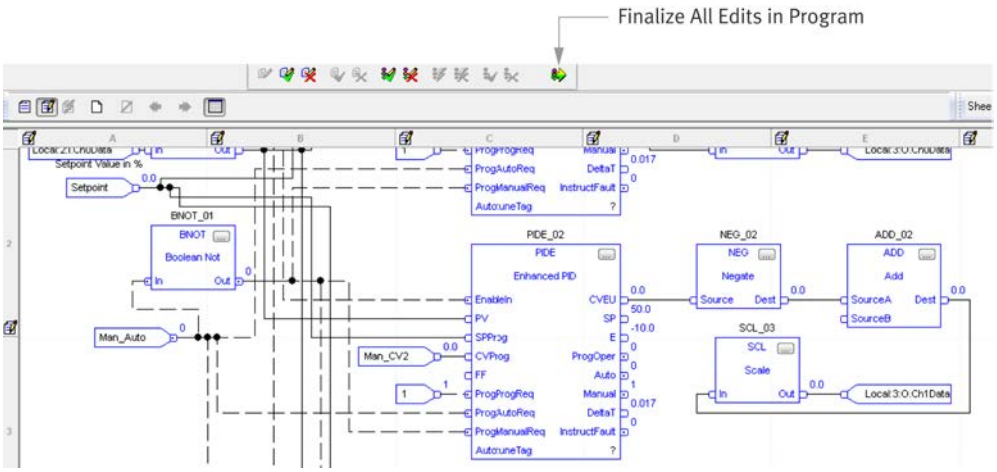


Figure 77: Finalizing the modifications in a program while online.

16. The final step is to properly tune the PIDE parameters for your process. In a split-range control scheme, the same parameters are typically used for all PIDE instructions. Tune the controller using a trial-and-error method or determine the process characteristics to calculate the PID parameters.

    Set the Man_Auto variable to 1 to switch to automatic mode and adjust the set point. Test the control loop.

    The PIDE split-range routine is now configured and controlling the process.

© Festo Didactic

Characteristics of the ControlLogix PLC

Description

This PLC is manufactured by Rockwell and belongs to the ControlLogix family. It consists of modules mounted on a seven-slot chassis. The PLC is integrated into a panel designed for easy installation on the instrumentation workstation. Wiring can be performed using either the banana jacks or the terminal screws provided on the panel. The following figure shows the main elements of the ControlLogix PLC, Model 46965-1. A brief description and the technical specifications of each PLC module are provided below.

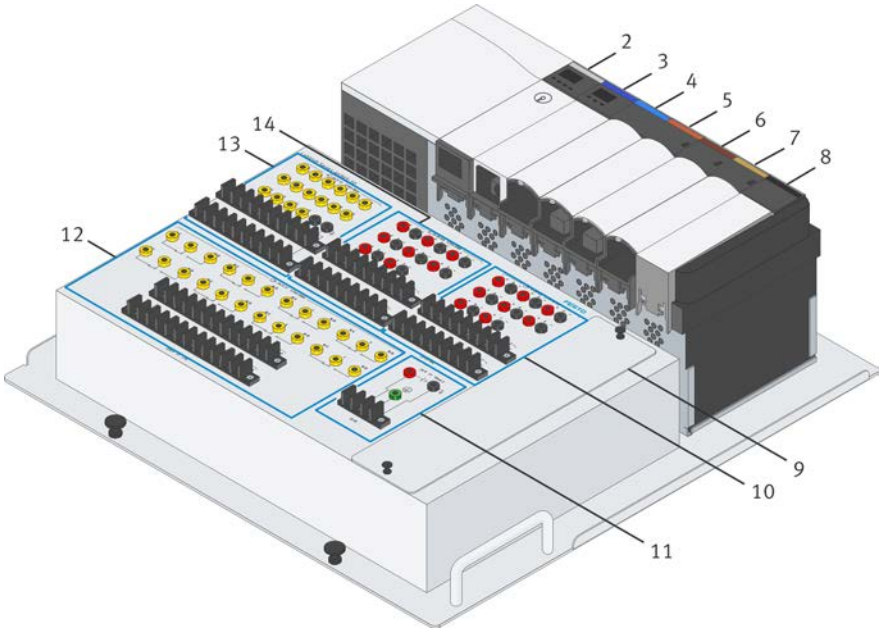


Figure 78: ControlLogix PLC, Model 46965-10.

Components

1. **Power Supply.** When the power input connectors (11) are connected to a 24 V dc source, the power supply is energized and it provides power to all modules located on the chassis. A green LED status indicator turns on when the power supply module is energized.

Table 8: Power supply specifications.

Characteristic	Value
Input voltage range	18-32 V dc
Nominal input voltage	24 V dc
Maximum input power	95 W
Maximum inrush current	30 A

2. **Controller module.** This is the module containing the processor and the memory. The controller module has several LED indicators and a mode selection key. Their functions are described in the following table and Table 10.

Table 9: Controller module LED indicators.

Indicator	Color	Description
RUN	Off	The controller is in program mode or test mode.
	Green	The controller is in run mode.
FORCE	Off	No tags contain I/O force values.
	Amber	I/O forces are enabled. I/O force values can be configured.
	Flashing amber	One (or more) input or output address has been forced to an On or Off condition, but the forces have not been enabled.
SD	Off	No activity is occurring with the SD card.
	Green	The controller is reading from or writing to the SD card. Do not remove the SD card while the controller is reading or writing.
	Flashing green	
	Red	The controller does not recognize the SD card.
	Flashing red	The SD card does not have a valid file system.
OK	Off	No power is applied to the controller.

© Festo Didactic

Indicator	Color	Description
	Flashing red	Either of the following is true: it is a new controller and it requires a firmware upgrade or it is a previously used or in use controller and a major fault has occurred.
	Red	One of the following is true: The controller is completing power-up diagnostics. – The charge of the capacitor in the ESM is being discharged upon power down. – The controller is powered, but is inoperable. – The controller is loading a project to a non volatile memory.
	Green	The controller is operating normally.

Table 10: Controller module mode-selection key.

Key position	Description
RUN	The controller executes the program. No modification to the program is allowed in this mode.
REM	The controller executes the program and it is possible to remotely program the PLC using Studio 5000 Logix Designer. The key should remain at the REM position if you want to perform the exercises in the student manuals.
PROG	The controller does not execute the program. Program changes can be downloaded to the PLC when the key is in this position.

3. **Ethernet communication module.** This module enables data communication with computers or other devices connected to the same local network. The following table summarizes the characteristics of the Ethernet module and Table 12 describes the LED indicators.

Table 11: Ethernet module specifications.

Characteristic	Value
Transfer speed	10/100 Mb/s
Ethernet connector	RJ45 Cat. 5
Isolation voltage (continuous)	30 V
Default IP address	192.168.2.20
Default network mask	255.255.255.0

Table 12: Ethernet module LED indicators.

Indicator	Color	Description
Alphanumeric display	N/A	During normal operation, the display should alternates between OK and the Ethernet address of the module.
LINK	Off	No data transmission.
	Green	Ready.
	Flashing green	Transmitting.
NET	Off	No power on the module or no IP address.
	Flashing green	No connections are established.
	Green	CIP connection(s) established.
	Flashing red	Connection timeout.
	Red	Duplicate IP address.
OK	Off	No power.
	Flashing green	Standby.

© Festo Didactic

Indicator	Color	Description
	Green	Operational.
	Flashing red	Minor fault.
	Red	Major fault.
	Flashing red and greed	Self test.

4. **Digital-input module.** The ControlLogix PLC has a digital-input module that provides on-off detection. This module has 16 digital inputs and an input-state display that shows the status of each input (numbered from 0 to 15). If an input is active, the corresponding input number on the display is yellow. An OK indicator is steady green if the inputs are in normal operating state.

Table 13: Digital-input module specifications.

Characteristic	Value
Number of inputs	16
On-state voltage range	10-31.2 V dc
Maximum off-state voltage	5 V dc
Maximum impedance at 31.2 V dc	3.12 kΩ
Isolation voltage (continuous)	250 V

5. **Relay-output module.** The ControlLogix PLC has a relay-output module with 8 output relays that can be wired as normally open or normally closed contacts. An output-state display shows the status of each relay output (numbered from 0 to 7). If an output is active, the corresponding output number on the display is yellow. An OK indicator is steady green if the outputs are in normal operating state.

© Festo Didactic

Table 14: Relay output module specifications.

Characteristic	Value
Number of outputs	8 (N.O. and N.C. with common)
Output voltage range	5-30 V dc at 2.0 A (resistive)
Power rating	60 W maximum (30 V dc resistive output)
Maximum switching frequency	0.3 Hz (at rated load)
Isolation voltage (continuous)	250 V

6. **Analog-input module (HART).** This module converts 4-20 mA signals to digital values that can be used by the controller. It also supports the HART communications protocol. Thus, if a HART signal is superimposed on the analog current signal, the module decodes it and makes the decoded information accessible to the controller. The analog-input module has 8 inputs. An OK indicator is steady green if the inputs are in normal operating state and a CAL indicator shows if the module is in calibration mode.

Table 15: Analog-input module specifications.

Characteristic	Value
Number of inputs	8
Input range	4-20 mA
Resolution	16-21 bits
Data format	IEEE 32-bit floating point
Impedance (current)	250 Ω
Isolation voltage (continuous)	50 V

7. **Analog-output module (HART).** This module converts digital values to 4 20 mA signals. It also supports the HART communications protocol. Thus, a HART signal can be superimposed on the analog current signal. The analog-output module has 8 outputs. An OK indicator is steady green if the outputs are in normal operating state and a CAL indicator shows if the module is in calibration mode.

© Festo Didactic

Table 16: Analog-output module specifications.

Characteristic	Value
Number of outputs	8
Output range	4-20 mA
Resolution	15-16 bits
Data format	IEEE 32-bit floating point
Isolation voltage (continuous)	50 V

8. **Blank module.** This module is used to fill an empty slot on the PLC chassis.

Front panel

9. **Fault panel.** There are ten available fault switches that can be activated by the instructor in order to insert one or more electrical faults. The faults are activated when the switch is in the on position (I). Ensure that these faults are in the off position (O) if you are not performing a troubleshooting exercise.

10. **Analog output connectors.** Internally connected to the analog-output module (see 7).

11. **Power-input connectors.** Used to supply the PLC with a 24 V dc source. These connectors are internally connected to the PLC power supply. Connect the PLC to a 24 V dc output on the electrical unit that remains energized when the emergency push button is pressed (that is, connectors 2 and 3 of the electrical unit). This ensures that the PLC continues operating during an emergency.

12. **Relay-output connectors.** Internally connected to the relay-output module (see 5). When used to activate devices, be sure to connect the relays to a 24 V dc output on the electrical unit that will de-energize if the emergency push button is pressed (i.e., connectors 0 and 1 of the electrical unit). This ensures that these devices will stop in case of an emergency.

13. **Digital-input connectors.** Internally connected to the digital-input module (see 4).

14. **Analog-input connectors.** Internally connected to the analog-input module (see 6).

© Festo Didactic

HART protocol

The ControlLogix is equipped with one analog input module and one analog output module with HART capability. The letters HART stand for Highway Addressable Remote Transducer. This communication protocol transfers digital data over standard 4-20 mA analog cables. It is an open standard maintained by process automation instrument manufacturers that are members of the HART Communication Foundation. HART-compatible instruments are widely used because they work with existing installations and therefore require minimal additional cost to connect field devices to a host system such as a programmable logic controller (PLC), a distributed control system (DCS), or a handheld device. The additional digital data provides access to device configuration, diagnostics, troubleshooting, additional measurements, and other information.

This protocol can operate in point-to-point or multidrop mode. In point-to-point mode, a single instrument is connected to one cable pair that carries both the 4-20 mA signal and the digital communication. In multidrop mode, the loop current is fixed at 4 mA, and digital signals from multiple instruments are transmitted over a single cable pair.

General information on the HART protocol and its use on the training system is provided in the HART Software Configurator manual (P/N 86050).

© Festo Didactic

Characteristics of the CompactLogix PLC

This PLC is manufactured by Rockwell and belongs to the CompactLogix family. It consists of modules mounted on a DIN rail installed on a panel designed for easy installation on the instrumentation workstation. Wiring can be performed using either the banana jacks or the terminal screws provided on the panel. The following figure shows the main elements of the CompactLogix PLC, Model 46966-10. A brief description and the technical specifications of each PLC module are provided below.

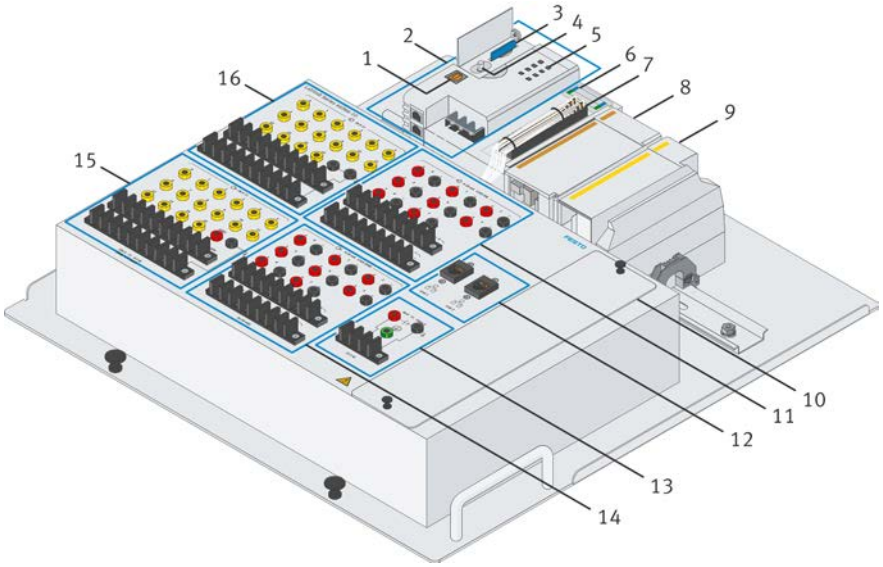


Figure 79: CompactLogix PLC, Model 46966-10.

1. **USB port.**

   The USB port, type B, is used for temporary connection to a computer.

2. **Controller.**

   The controller module contains the processor, the memory, the Ethernet connectors, digital inputs, and digital outputs. The controller is energized when the power input connectors are connected to a 24 V dc source. When the controller is energized all modules on the DIN rail are powered.

Table 17: Controller specifications.

Characteristic	Value
Input voltage range	19.2-31.2 V dc
Nominal input voltage	24 V dc
Maximum inrush current	30 A at 31.2 V dc

3. **SD memory card**

   The SD memory card offers nonvolatile memory to store a user program and tag data on a controller. Through the programming software, the user can manually trigger the controller to save to or load from nonvolatile memory or configure the controller to load from nonvolatile memory on power up.

4. **Mode key**

Table 18: Controller module mode-selection key.

Key position	Description
RUN	The controller executes the program. No modification to the program is allowed in this mode.
REM	The controller executes the program and it is possible to remotely program the PLC using Studio 5000 Logix Designer. The key should remain at the REM position if you want to perform the exercises in the student manuals.
PROG	The controller does not execute the program. Program changes can be downloaded to the PLC when the key is in this position.

5. **CPU indicators**

© Festo Didactic

The controller module has several LED indicators to indicate the CPU state. Their functions are described in the following table.

Table 19: Controller module LED indicators.

Indicator	Color	Description
RUN	Off	The controller is in program or test mode.
	Green	The controller is in run mode.
FORCE	Off	No tags contain I/O force values. I/O forces are disabled.
	Amber	I/O forces are enabled. I/O force values can be configured.
	Flashing amber	One (or more) input or output address has been forced to an On or Off condition, but the forces have not been enabled.
I/O	Off	No devices in the I/O configuration of the controller. No project in the controller memory.
	Green	There is communication between the controller and all the devices in the I/O configuration.
	Flashing green	One (or more) device(s) in the I/O configuration is not responding.
	Flashing red	No communication can be established with any device(s) or the controller is faulted.
OK	Off	No power is applied.
	Flashing red	One of the following is true: The controller requires a firmware update. – A controller firmware update is in process. – A major recoverable fault occurred on the controller. – A major non-recoverable fault occurred on the controller and cleared the program from memory. – An embedded I/O module firmware update is in process.
	Red	The controller detected a non-recoverable major fault and cleared the project from memory.
	Green	The controller is OK.

Indicator	Color	Description
	Flashing Green	The controller is storing a project to or loading a project from the SD card.
	Dim green to red	Save to flash at power-down
NS	Off	The port is not initialized; it does not have an IP address and is operating in BOOTP or DHCP mode.
	Green	The port has an IP address and CIP connections are established.
	Flashing green	The port has an IP address but no CIP connections are established.
	Red	The port has detected that the assigned IP address is in use.
	Flashing red/ green	The port is performing its power-up self-test.
Link 1/Link 2	Off	One of the following conditions exists: No link. – Port administratively disabled. – Port disabled because rapid ring fault condition was detected (link 2).
	Green	A 100 Mbps or 10 Mbps link exists but there is no activity. Ring network is operating normally and the controller is the active supervisor. Ring network has encountered a rare partial network fault and the controller is the active supervisor.
	Flashing green	A 100 Mbps or 10 Mbps link exists and there is activity.
SD	Off	No activity is occurring with the SD card.
	Flashing green	The controller is reading from or writing to the SD card.
	Flashing red	The SD card does not have a valid file system.

6. Digital-input display

The CompactLogix PLC has 16 built-in digital inputs that provide on-off detection. The status of each input can be monitored on the digital-input display that shows the status of each input (numbered from 0 to 15). If an input is ON, the LED indicator below the corresponding input number on the display is yellow.

© Festo Didactic

Table 20: Digital-input specifications.

Characteristic	Value
Number of inputs	16
On-state voltage range	10-28.8 V dc
Maximum off-state voltage	5 V dc
Input impedance (at 24 V dc)	5.2 kΩ
Isolation voltage (continuous)	75 V

7. Digital-output display

The CompactLogix PLC has 16 built-in digital outputs that provide on-off signals. The status of each output can be monitored on the digital-output display that shows the status of each output (numbered from 0 to 15). If an output is ON, the LED indicator below the corresponding output number on the display is yellow.

Table 21: Digital-output specifications.

Characteristic	Value
Number of outputs	16
Operating voltage range	20.4-26.4 V dc,
Minimum switching frequency	2 kHz
Isolation voltage (continuous)	75 V

8. Analog-input module

The analog-input module converts 4-20 mA signals to digital values that can be used by the controller. The analog-input module has 8 inputs. An OK indicator is steady green when the inputs are in normal operating state.

Note that the analog inputs must be scaled by a factor of 100 (divide the input by 100) in order to use engineering units from 0 to 100% in your block functions and ladder instructions.

© Festo Didactic

Table 22: Analog-input module specifications.

Characteristic	Value
Number of inputs	8
Input range	4-20 mA
Resolution	15-16 bits
Impedance (current)	250 Ω
Input group to bus isolation (IEC Class 2 reinforced insulation)	30 V dc

9. Analog-output module

The analog-output module converts digital values to 4-20 mA signals. The analog-output module has 8 outputs. An OK indicator is steady green when the outputs are in normal operating state.

Note that the engineering units in the block functions and ladder instructions must be scaled by a factor of 100 (multiply the engineering output by 100) in order to convert the results properly to the analog outputs.

Table 23: Analog-output module specifications.

Characteristic	Value
Number of outputs	8
Analog normal operating range	4-20 mA
Digital resolution	16 bits
Output group to bus isolation (IEC Class 2 reinforced insulation)	30 V dc

10. Fault panel

There are ten available fault switches that can be activated by the instructor to insert one or more electrical faults. The faults are activated when the switch is in the on position (I). Ensure that these faults are in the off position (O) if you are not performing a troubleshooting exercise.

11. Analog-input connectors

Internally connected to the analog-input module of the PLC (see 8).

© Festo Didactic

12. Ethernet I/P remote connectors

The Ethernet I/P remote connectors are internally connected to the Ethernet connectors of the PLC. The following table summarizes the Ethernet characteristics of the controller.

Table 24: Ethernet specifications.

Characteristic	Value
Transfer speed	10/100 Mb/s
Ethernet connector	RJ45 Cat. 5
Isolation voltage (continuous)	30 V
Default IP address	192.168.2.60
Default network mask	255.255.255.0

13. Power-input connectors

Used to energize the PLC with a 24 V dc source. These connectors are internally linked to the PLC power supply.

14. Analog-output connectors

Internally connected to the analog-output module of the PLC (see 9).

15. Digital-output connectors

Internally connected to the digital outputs of the PLC (see 7).

16. Digital-input connectors

Internally connected to the digital inputs of the PLC (see 6).

© Festo Didactic

© Festo Didactic

PLC Installation and Configuration

Connecting the PLC to a computer

To use either the ControlLogix or the CompactLogix PLC to control a process, you must connect the PLC to a computer Ethernet card and use the appropriate software to modify (if required) the PLC project and download it to the PLC. The project files required to use the PLCs as process controllers are provided in the following resource file.



Resource file for CompactLogix and the ControlLogix PLCs.

https://lx.festo.com/media/5a65d483e2fe4e139add2eb6cad7a5c7

This section explains how to configure your computer for Ethernet communication with the PLC.

Installing the PLC software

Both the ControlLogix and CompactLogix use Studio 5000 Logix Designer software, which is used to create, modify, and download PLC projects. Two additional software applications must also be installed: RSLinx and FactoryTalk Activation Server. RSLinx enables Ethernet communication with the PLC, and FactoryTalk Activation Server manages the activation of Rockwell software licenses. All three programs are available on the Studio 5000 Logix Designer CD-ROM. The list below summarizes the hardware and software required to use the ControlLogix or CompactLogix with the system.

- A computer with at least one Ethernet port
- A switch or router with two standard Ethernet cables or a cross-over Ethernet cable. (A cross-over cable is required to connect the PLC directly to a computer Ethernet card.)
- Studio 5000 Logix Designer (software)
- RSLinx (software)
- FactoryTalk Activation Server (software)

Installing the three software components is straightforward. Insert the Studio 5000 Logix Designer CD-ROM into your computer and follow the installation wizard. Using the default settings installs all three programs correctly. During installation, register the product using the serial number and product key provided with the CD-ROM. Product activation is typically completed over an Internet connection, but alternative methods are available (see the software documentation).

© Festo Didactic

How to connect the PLC to your computer

There are two ways to connect the PLC to your computer. If the PLC is the only Ethernet device, connect it directly to the computer Ethernet card using a crossover Ethernet cable. If multiple Ethernet devices are used, connect a switch or router to the computer Ethernet card and use standard Ethernet cables to connect the PLC and the other devices to the switch or router. The following two figures illustrate both connection methods.

The PLC uses a specific IP address, and the IP address of the Ethernet card connected to the PLC must be compatible with it. For this reason, the computer must have an Ethernet card dedicated to PLC communication. If the computer also needs access to a local network, it must be equipped with two Ethernet cards.

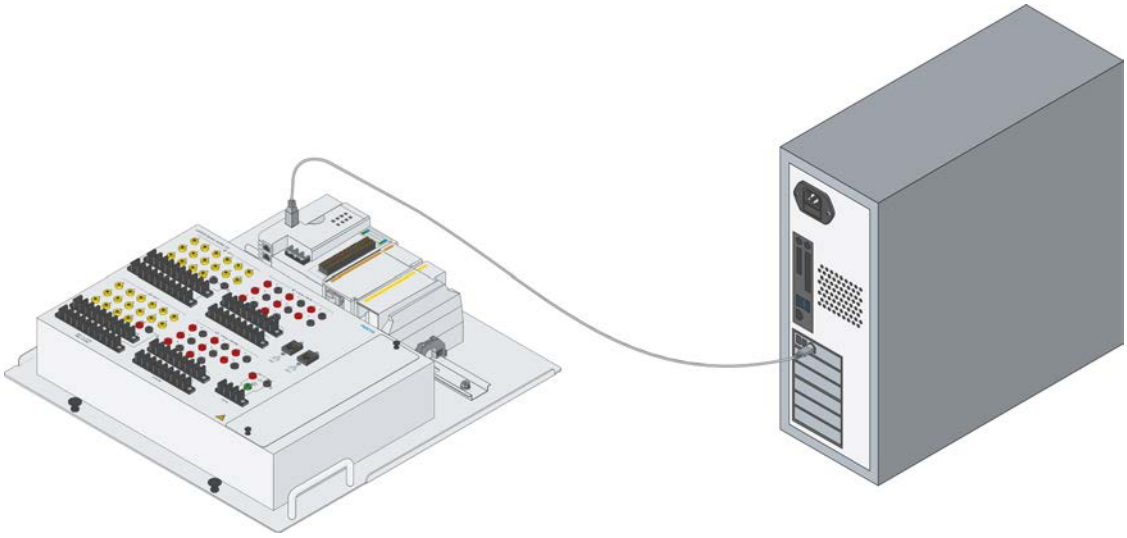


Figure 80: Connecting the PLC directly to your computer using a cross-over Ethernet cable.

© Festo Didactic

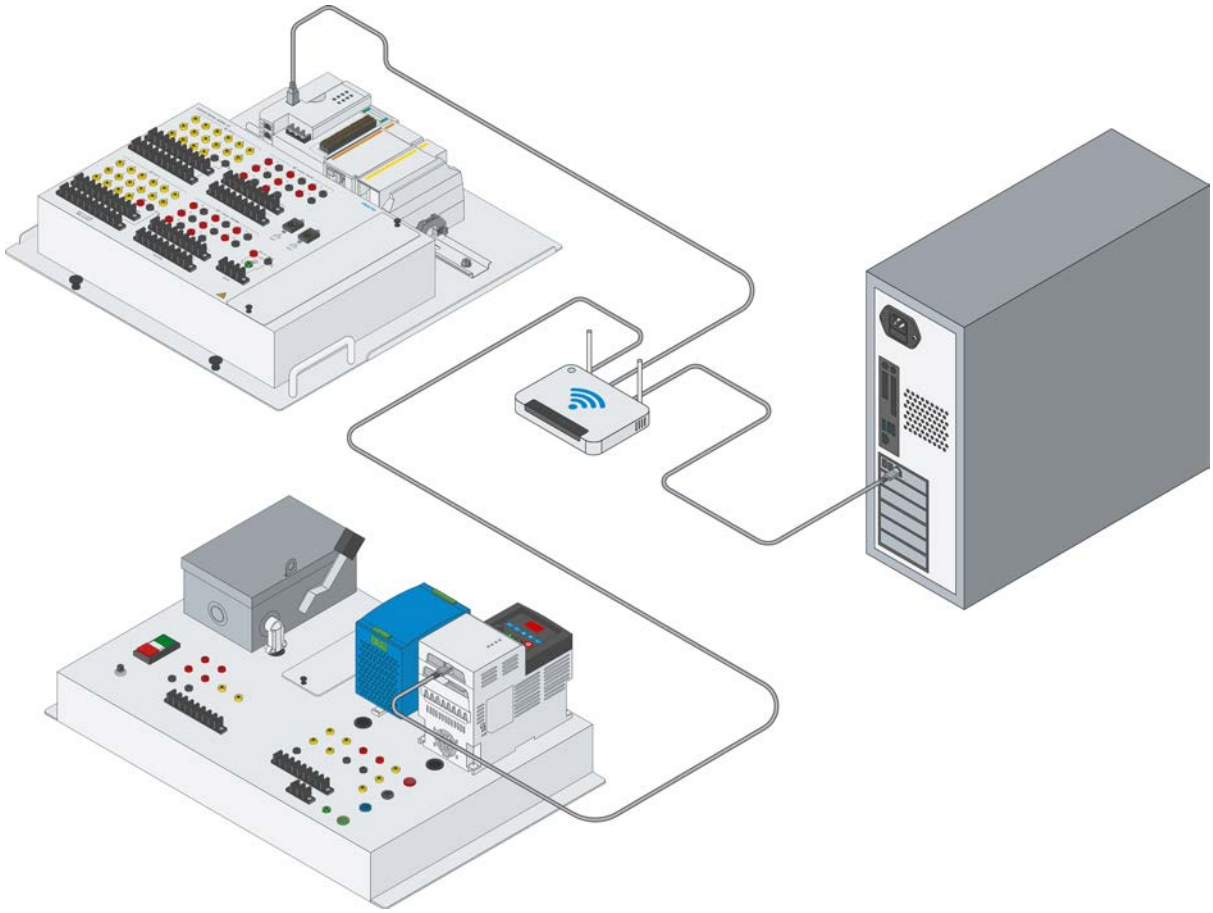


Figure 81: Connecting the PLC and other Ethernet devices to your computer via a switch or router.

Configuring your computer and software for Ethernet communication with the PLC

After connecting the PLC to your computer as described above, configure the computer for PLC use. This includes configuring the Ethernet card, RSLinx, and Studio 5000 Logix Designer. If the PLC is connected to a dedicated Ethernet card, this procedure only needs to be completed once.

Configuring the Ethernet card

1. Verify that the PLC is correctly connected to your computer.

2. From the computer Control Panel, open the Network Connections folder and double-click Local Area Connection to open the Local Area Connection Status window (see the following figure). This allows you to modify the LAN (Local Area Network) settings.

   If more than one connection is listed in the Network Connections folder, double-click the Local Area Connection associated with the Ethernet card connected to the equipment.

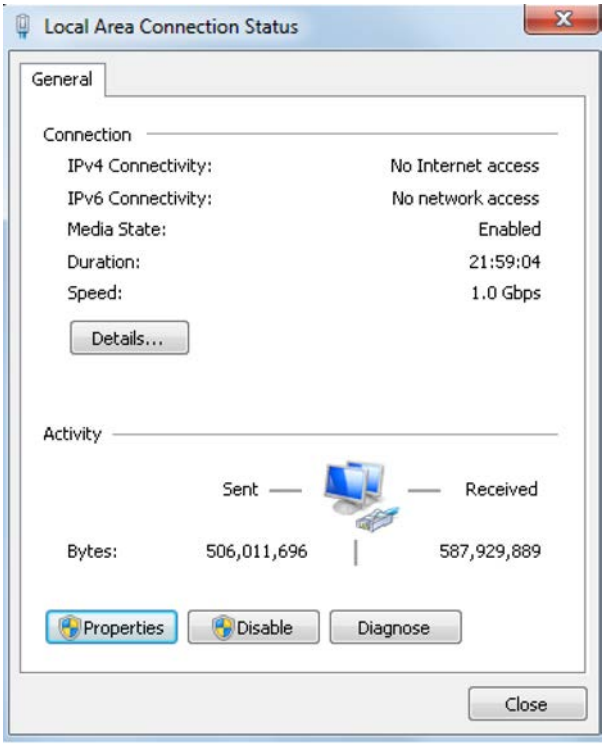


Figure 82: Local Area Connection Status window.

3. Click on Properties (see the following figure) to display the Local Area Connection Properties window.

4. Double-click on the Internet Protocol (TCP/IP) item to open the Internet Protocol (TCP/IP) Properties window.

© Festo Didactic

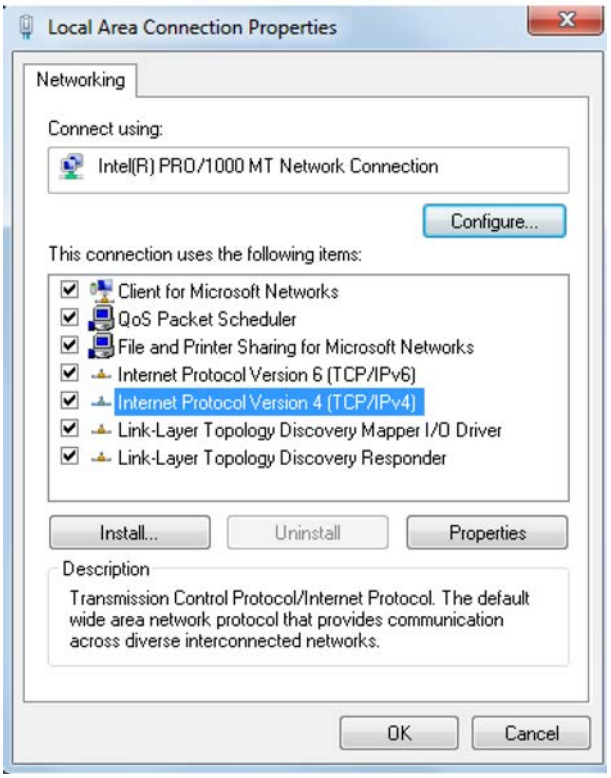


Figure 83: Local Area Connection Properties window.

5. Select Use the following IP address and enter 192.168.2.40 in the IP address section and 255.255.255.0 in the Subnet mask section as shown in the following figure.

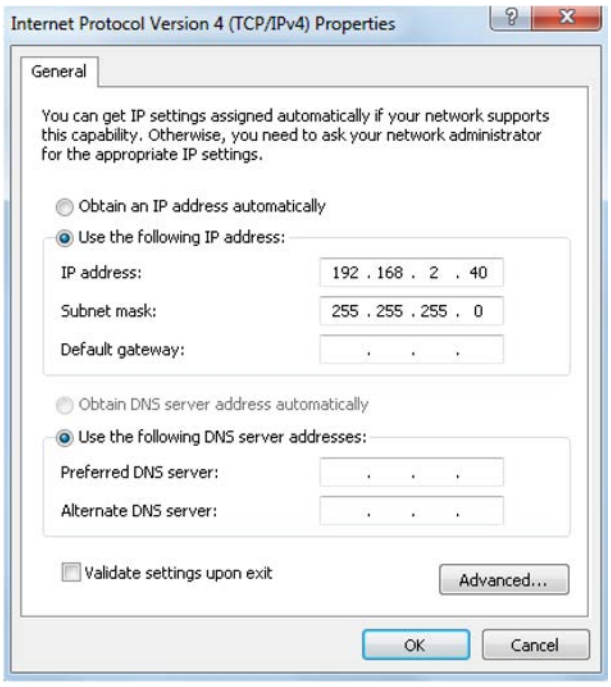


Figure 84: Internet Protocol (TCP/IP) Properties window.

6. Once the IP address and subnet mask are entered, click OK to apply the changes and close the Internet Protocol (TCP/IP) Properties window.

7. Click OK to close the Local Area Connection Properties window.

8. Click Close to close the Local Area Connection Status window.

9. The network configuration is complete. You can configure the RSLinx for communication with the PLC.

RSLinx configuration

10. Start RSLinx (see the following figure). This software drives the communication between the computer and the PLC.

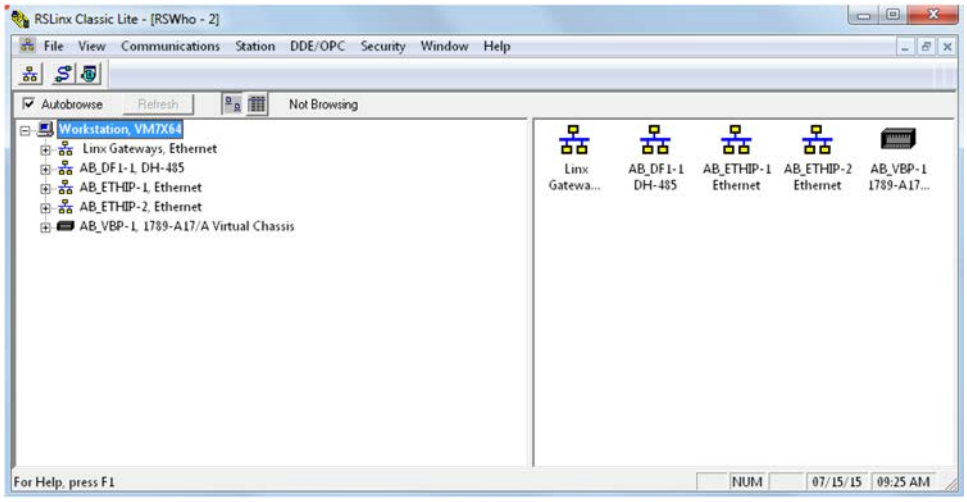


Figure 85: RSLinx.

11. From the Communications menu, select Configure Drivers to open the Configure Drivers window (see the following figure).

© Festo Didactic

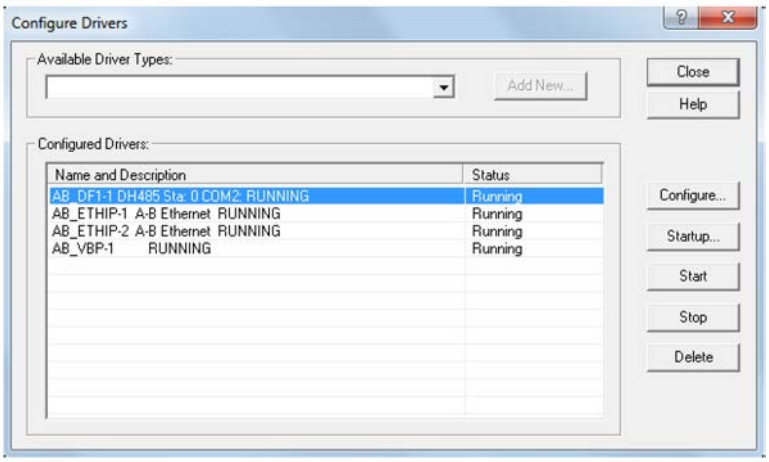


Figure 86: Configure Drivers window.

12. From the Available Driver Types drop-down list, select Ethernet/IP Driver (see the following figure).

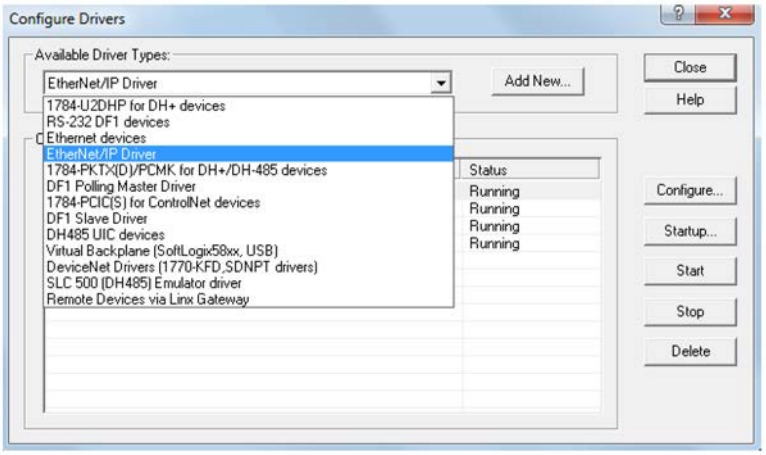


Figure 87: Available Driver Types drop-down list.

13. Click on Add New to display the Add New RSLinx Classic Driver window shown in the following figure.

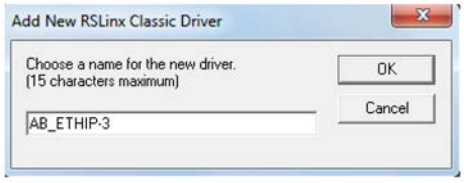


Figure 88: Add New RSLinx Classic Driver window.

14. This window allows you to choose a name for the Ethernet/IP driver. Keep the default name (AB_ETHIP-1) and click OK.

15. The Configure driver: AB_ETHIP-1 window appears (see the following figure). Select the local subnet with the 192.168.2.40 IP address. Click OK to accept the changes.

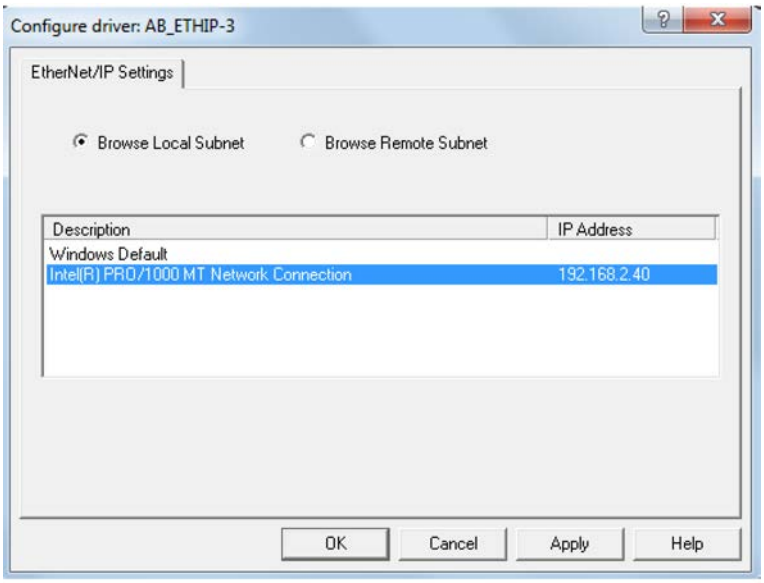


Figure 89: Configure driver: AB_ETHIP-1 window.

16. The added driver appears in the Configured Drivers list (see the following figure). Click Close to close the Configure Drivers window.

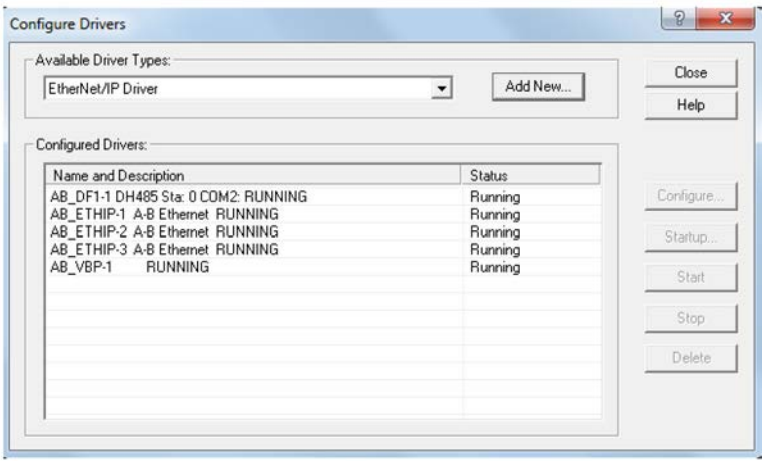


Figure 90: Configure Drivers window.

17. Make sure the PLC is connected as detailed previously and power it using a 24 V dc source.

© Festo Didactic

18. If it is not already active, open the RSWho window in RSLinx (see the following figure). To do so, select RSWho from the Communications menu.

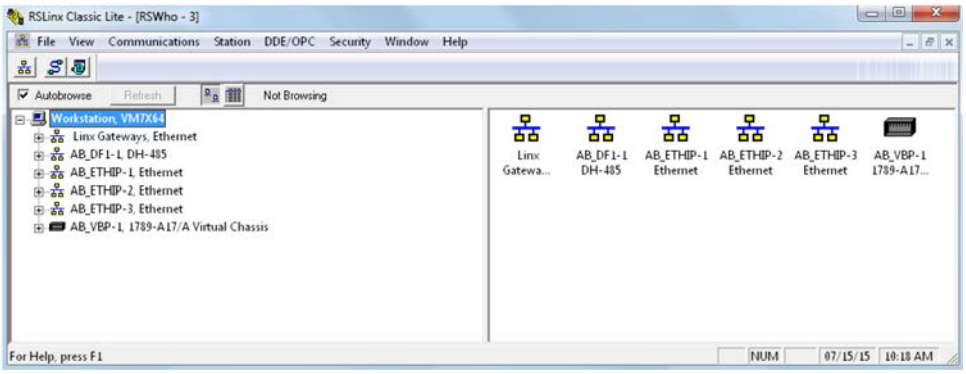


Figure 91: RSWho window.

19. Click the + symbol next to AB_ETHIP-1, Ethernet to expand the network tree, and wait for the PLC to appear in the device list (see the following figure). RSLinx may take several seconds to detect the device.

If the PLC does not appear in the device list, check the physical connections between the PLC, the switch or router, and the computer. Verify that the indicator lights on the switch or router are active.

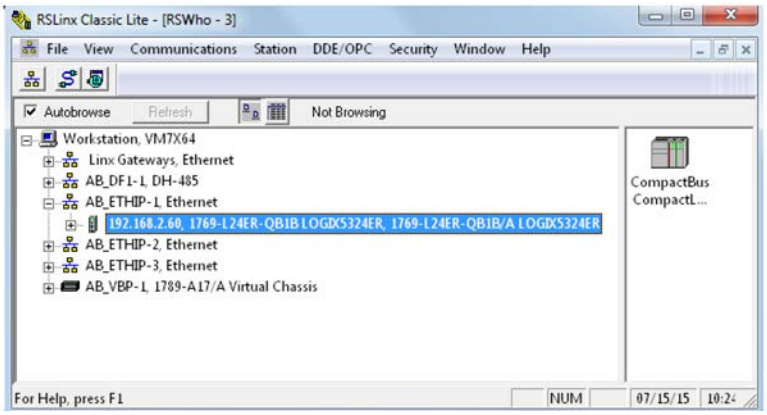


Figure 92: Browsing the network devices using RSWho (CompactLogix L23E).

20. When completely expanded, the AB_ETHIP-1, Ethernet network tree looks as shown in the following figure.

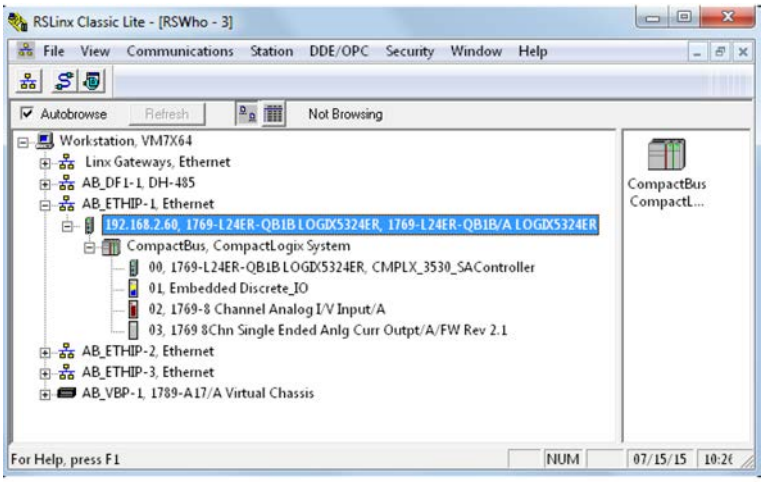


Figure 93: AB_ETHIP-1, Ethernet network tree.

21. From the File menu, select Exit to close the RSLinx window (the software continues running). To reopen the RSLinx window, click the RSLinx Communications Service icon in the Windows taskbar notification area.

22. The Ethernet network configuration is complete. You should now be able to communicate with the PLC using Studio 5000 Logix Designer.

© Festo Didactic

PID Control and Cascade PID Control

This manual mainly focuses on control algorithms based on PIDE function blocks. However, the classical PID algorithm can also be used with both ControlLogix and CompactLogix controllers. This appendix highlights the main features and differences of PID control.

The main difference between PID and PIDE control is that PID uses the classical position form instead of the velocity form presented in Learning Unit 1. The position form is simpler and exists in two variations:

Dependent gains

$$CV = K_c \left(E + \frac{1}{T_i} \int_0^{t'} Edt + T_d \frac{dE}{dt} \right) + Bias$$

where

CV	is the control variable
E	is the error (PV-SP) – direct action or (SP-PV) – reverse action
K_c	is the controller gain
T_i	is the integral time (in minute). A larger T_i causes a smaller integral response
T_d	is the derivative time (in minute)
$Bias$	is a user-defined offset

In this version, the controller gain has an effect on all three components of the equation (proportional, integral, and derivative).

Independent gains

$$CV = K_p E + K_i \int_0^{t'} Edt + K_d \frac{dE}{dt} + Bias$$

© Festo Didactic

where

K_p is the proportional gain

K_i is the integral gain (in minute^{-1}). A larger K_i causes a larger integral response

K_d is the derivative gain (in minute)

Each gain coefficient affects only one control action: proportional, integral, or derivative.

Because the PID algorithm in Studio 5000 Logix Designer predates the PIDE function block, it supports fewer advanced features. It is not intended for function block diagrams and is instead implemented using ladder logic or structured text. These differences are minor, and the PID instruction remains straightforward to use for most control loops.

PID control

To use PID Control, simply follow steps 1 to 5 in Learning Unit 1, replacing mentions of PIDE_Control by PID_Control. Expand the PID_Control folder and double click on the file titled Main to access the PID ladder program (see the following figure).

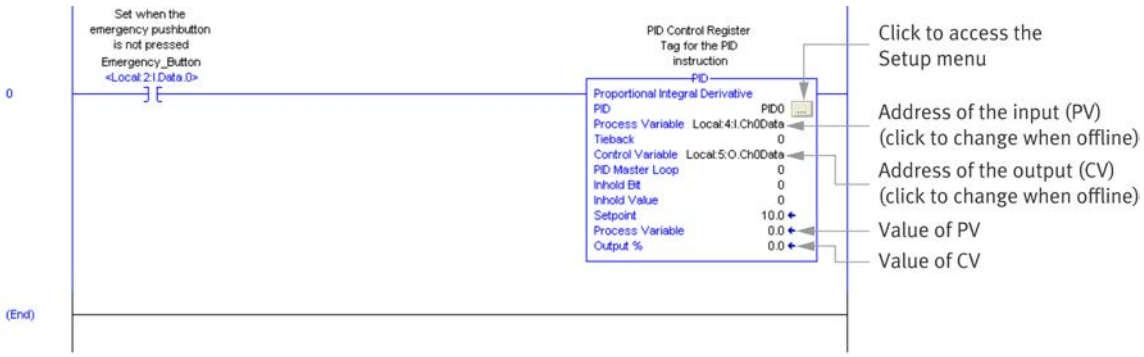


Figure 94: The PID control routine.

The control loop parameters can be set in the PID Setup window of the PID instruction (opened by clicking the "..." icon in the upper-right corner of the PID instruction). Most parameters are located in the Tuning and Configuration tabs and can be viewed and modified while the loop is running (see the following two figures and two tables).

© Festo Didactic

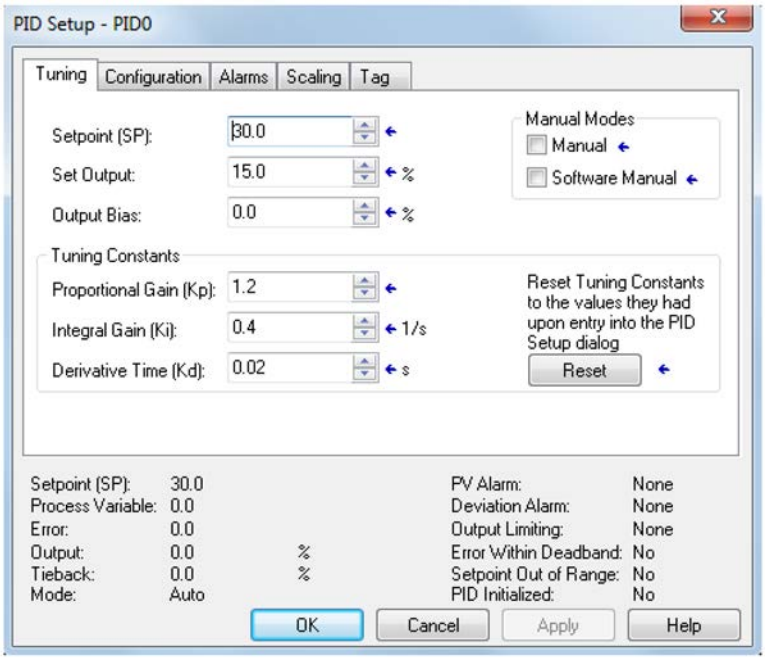


Figure 95: The PID Setup window - Tuning tab.

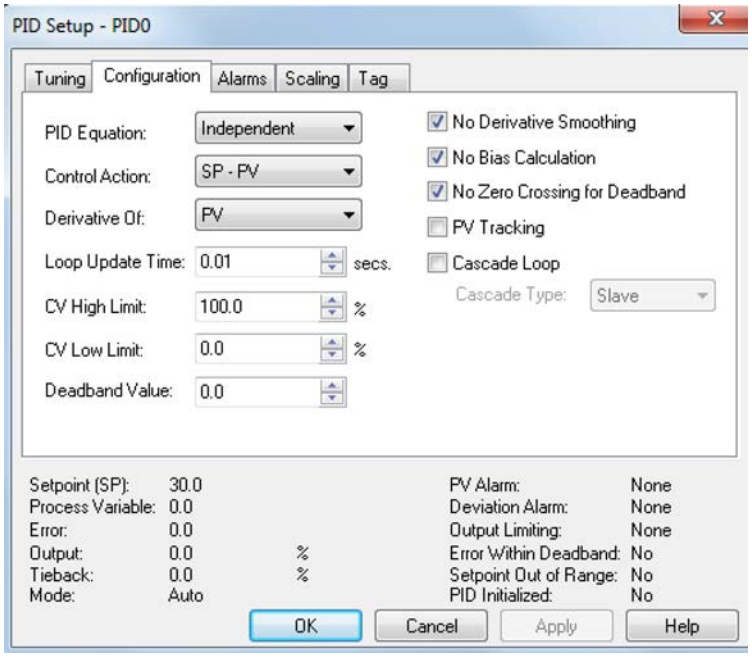


Figure 96: The PID Setup window - Configuration tab.

Table 25: Parameters of the PID Setup window – Tuning tab.

Parameter	Description
Setpoint (SP)	Specify the desired set point. Can be set between 0% and 100%.
Set Output	Specify the value used as the output when the PID instruction is in software manual mode. Can be set between 0% and 100%.Displays the current value of the output when in automatic mode.
Output Bias	Specify the desired output bias. This option is useful to adjust the value of CV for a given error when no integral action is used.
Gains	Specify the value of the tuning parameters required for your control loop.Dependent: K_c, T_i, and T_d Independent: K_p, K_i, and K_d
Manual Modes	The PID controller operates in automatic mode when neither manual option is selected. Select the Software Manual option to operate the controller in manual mode and directly set the output from Studio 5000 Logix Designer. The Manual option, which overrides Software Manual mode when enabled, uses the tieback variable as the manual control variable (CV). This variable can be linked to a PLC input. This mode is rarely used and is beyond the scope of basic PID loops.

Table 26: Parameters of the PID Setup window – Configuration tab.

Parameter	Description
PID Equation	Select which type of PID equation to use: Dependent or Independent
Control Action	Choose either direct (Error: E = PV-SP) or reverse (Error: E = SP-PV) control action.
Derivative Of	Specify if you want the derivative action to be calculated based on the error (E) or on the process variable (PV) only.
Loop Update Time	Enter the update time of the instruction. This value is the same as the period set in the properties of the Periodic Tasks. The default is 0.010 s.

© Festo Didactic

Parameter	Description
CV High/Low Limit	Specify the maximum and the minimum values (in %) which the control loop can output. Default values are respectively 100% and 0%.
Deadband Value	Enter the size of the dead band (in %) you want to use. Leave the field empty or at 0 to disable this option.
No Derivative smoothing	When this option is not selected, the effect of a noisy PV signal is reduced by smoothing the derivative action. However, this can reduce the effectiveness of the derivative action, especially at high gain values.
No Bias Calculation	Disables bumpless transfer from manual to automatic mode.
No Zero-crossing	Check the No Zero-crossing option if you do not require the error to pass by 0 before the dead band is activated.
PV Tracking	When this parameter is checked, the value of SP will track the value of PV when the controller is in manual mode.
Cascade Loop	Specifies whether a PID controller operates in cascade mode or not.

The next step is to download the project to the controller and switch it to remote run mode. For details, follow steps 10 to 14 in Learning Unit 4.

You can now tune the controller from the Setup window. Select the appropriate control action and PID equation type.

- When tuning the PID loop using a step-change method (such as Ziegler–Nichols), set the loop to **software manual** mode (select the appropriate option in the Tuning tab of the Setup window). Adjust the Set Output parameter to apply the step change, then calculate and enter the PID gains.
- When using a trial-and-error or ultimate-cycle tuning method, set the loop to **automatic** mode (no manual options selected) and adjust the PID coefficients in the Tuning tab. Change the controller set point using the Setpoint (SP) parameter.

After initial tuning, test the loop in **automatic** mode (no manual options selected) at different set points and fine-tune as needed.

The PID routine is now configured and controlling the process.

PID cascade control

To use PID cascade control, first review the previous sections on PID control, then follow steps 1 to 5 in Learning Unit 1, replacing PIDE_Cascade with PID_Cascade. Expand the PID_Cascade folder and double-click the file named Main to open the PID cascade ladder program (see the following figure).

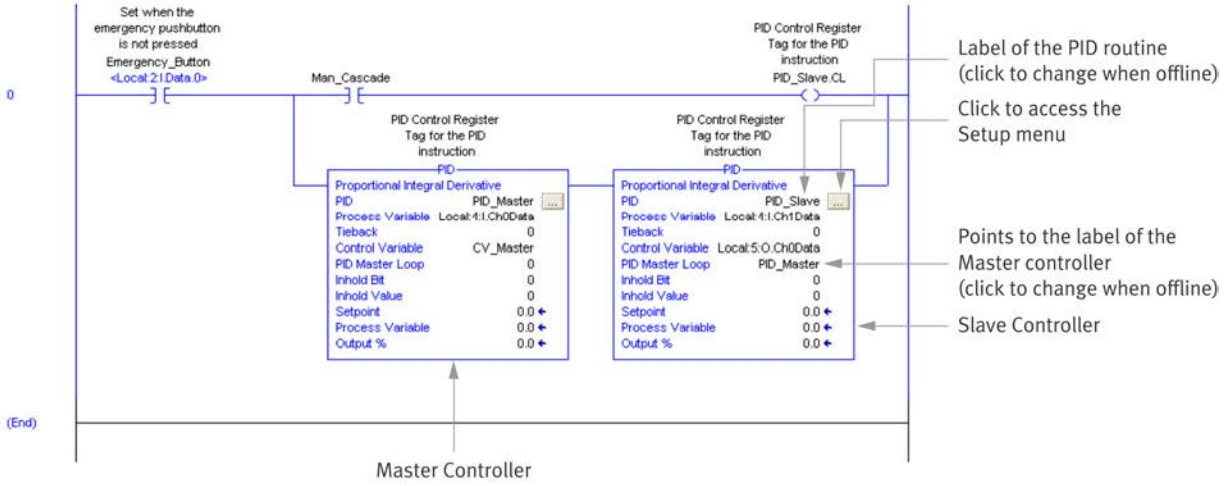


Figure 97: The PID cascade routine.

Basic cascade control uses two PID instructions, each with a different process variable. When cascade mode is enabled, the output of the master PID controller becomes the set point of the slave controller, but it is not connected to any PLC output. Only the control variable of the slave loop is physically connected to the process. A Boolean variable named Man_Cascade directly affects the PID_Slave.CL parameter, allowing the cascade mode to be switched on (Man_Cascade set to 1) or off (Man_Cascade reset to 0) easily from the Watch window.

The parameters of both control loops are set in their respective PID Setup windows (opened by clicking the "..." icon in the upper-right corner of the PID instructions). Most parameters are located in the Tuning and Configuration tabs and can be viewed and modified while the loops are running. See Table 25 and Table 26 for a complete description of PID instruction parameters.

The next step is to download the project to the controller and switch it to remote run mode. For details, follow steps 9 to 13 in Learning Unit 5.

Begin by tuning the slave controller. Ensure that the Man_Cascade parameter is set to 0. Select the appropriate control action and PID equation type.

- If you tune the slave loop using a step-change method (such as Ziegler-Nichols), set the loop to **software manual** mode (select the appropriate option in the Tuning tab of the Setup window). Adjust the Set Output parameter to apply the step change, then calculate and enter the PID gains.

- If you use a trial-and-error or ultimate-cycle tuning method, set the control loop to **automatic** mode (no manual options selected) and adjust the PID coefficients in the Tuning tab. Change the controller set point using the Setpoint (SP) parameter.

After the initial tuning of the slave loop, test it in **automatic** mode at different set points and fine-tune as needed. Leave the slave loop in automatic mode and set the Man_Cascade parameter to 1 to activate cascade mode.

Next, tune the master loop and select the appropriate control action and PID equation type.

© Festo Didactic

- If you tune the master loop using a step-change method (such as Ziegler-Nichols), set the loop to **software manual** mode (select the appropriate option in the Tuning tab of the Setup window). Adjust the Set Output parameter to apply the step change, then calculate and enter the PID gains for the master loop.
- If you use a trial-and-error or ultimate-cycle tuning method, set the control loop to **automatic** mode (no manual options selected) and adjust the PID coefficients in the Tuning tab of the master loop Setup window. Change the controller set point using the Setpoint (SP) parameter.

After initial tuning, test the master loop in **automatic** mode at different set points and fine-tune as required.

The PID cascade routine is now configured and controlling the process.

© Festo Didactic

PID Ratio Control and PID Split-Range Control

This manual mainly focuses on control algorithms using PIDE function blocks. However, the classical PID algorithm can also be used with both ControlLogix and CompactLogix controllers. The main features and differences of PID instructions are described in Appendix B.

Ratio and split-range control routines based on PID instructions are provided with the programs supplied with your equipment. This appendix explains how to use these versions. Reading the first pages of Learning Unit 1 (Ratio) and Learning Unit 1 (Split-Range) remains useful for understanding the control schemes.

PID ratio control

To use PID ratio control, follow steps 1 through 5 in Learning Unit 1, replacing PIDE_Ratio with PID_Ratio. Expand the PID_Ratio folder and double-click the file named Main to open the PID ratio ladder program (see the following figure).

The control loop parameters are set in the PID Setup window of the PID instruction (opened by clicking the "..." icon in the upper-right corner of the PID instruction). Most parameters are located in the Tuning and Configuration tabs and can be viewed and modified while the loop is running. Refer to Appendix B for details on using the PID instruction, if needed.

© Festo Didactic

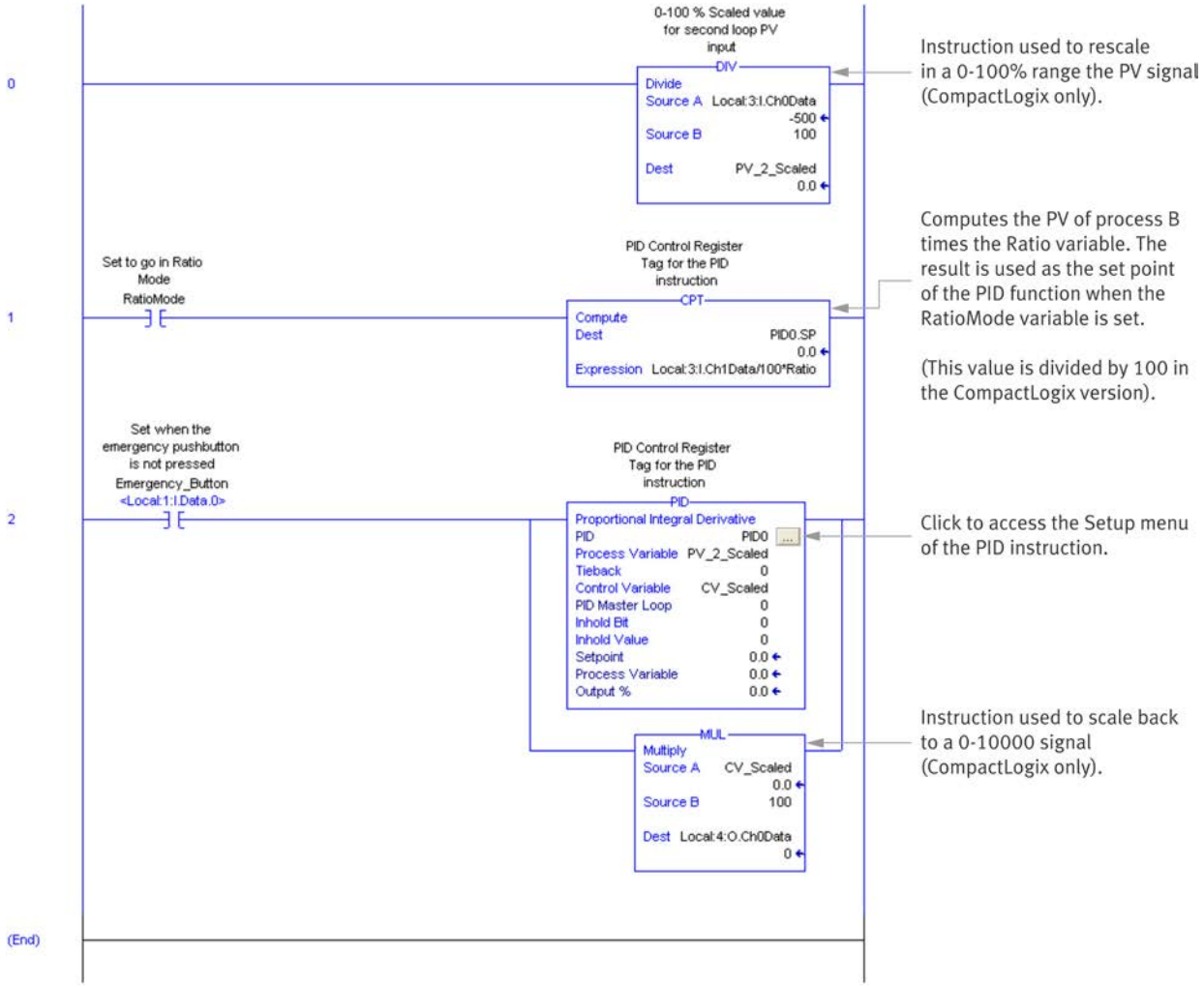


Figure 98: The PID ratio routine (CompactLogix version).

Download the project to the controller and switch it to run mode. If needed, refer to steps 9 to 12 in Learning Unit 1. Connect digital input 0 of the PLC to a 24 V dc switched output on the electrical unit.

Tune the PID instruction controlling variable A using the method of your choice. If required, refer to Appendix B. Once tuning is satisfactory, set the Ratio variable to the desired value (Ratio = A / B) and set the RatioMode variable to 1 to enable ratio mode using the Watch window (Alt+3). Ensure the PID instruction is in automatic mode.

Test the control scheme as the value of B changes. The controller should maintain the specified ratio between the two process variables.

The PID ratio routine is now configured and controlling the process.

PID split-range control

To use PID split-range control, first read the section on PIDE split-range control, then follow steps 1 through 5 in Learning Unit 1, replacing PIDE_SplitRange with PID_SplitRange. Expand the PID_SplitRange folder and double-click the file named Main to open the PID split-range ladder program (see the following two figures).

© Festo Didactic

The control loop parameters are set in the PID Setup window of the PID instructions (opened by clicking the "..." icon in the upper-right corner of a PID instruction). Most parameters are located in the Tuning and Configuration tabs and can be viewed and modified while the loop is running. Refer to Appendix B for details on using the PID instructions, if required.

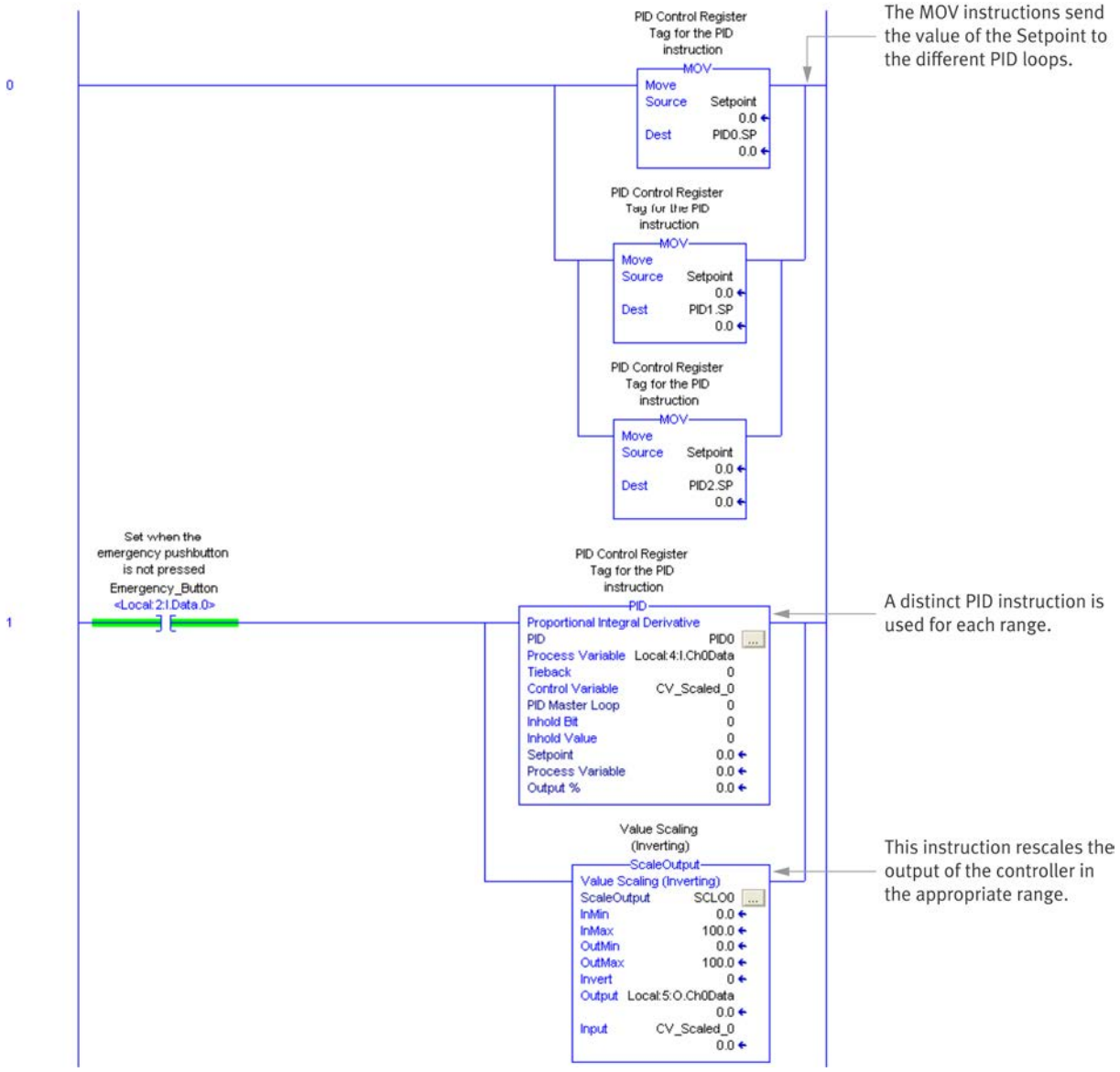


Figure 99: The PID split-range routine – Part 1 - (ControlLogix version).

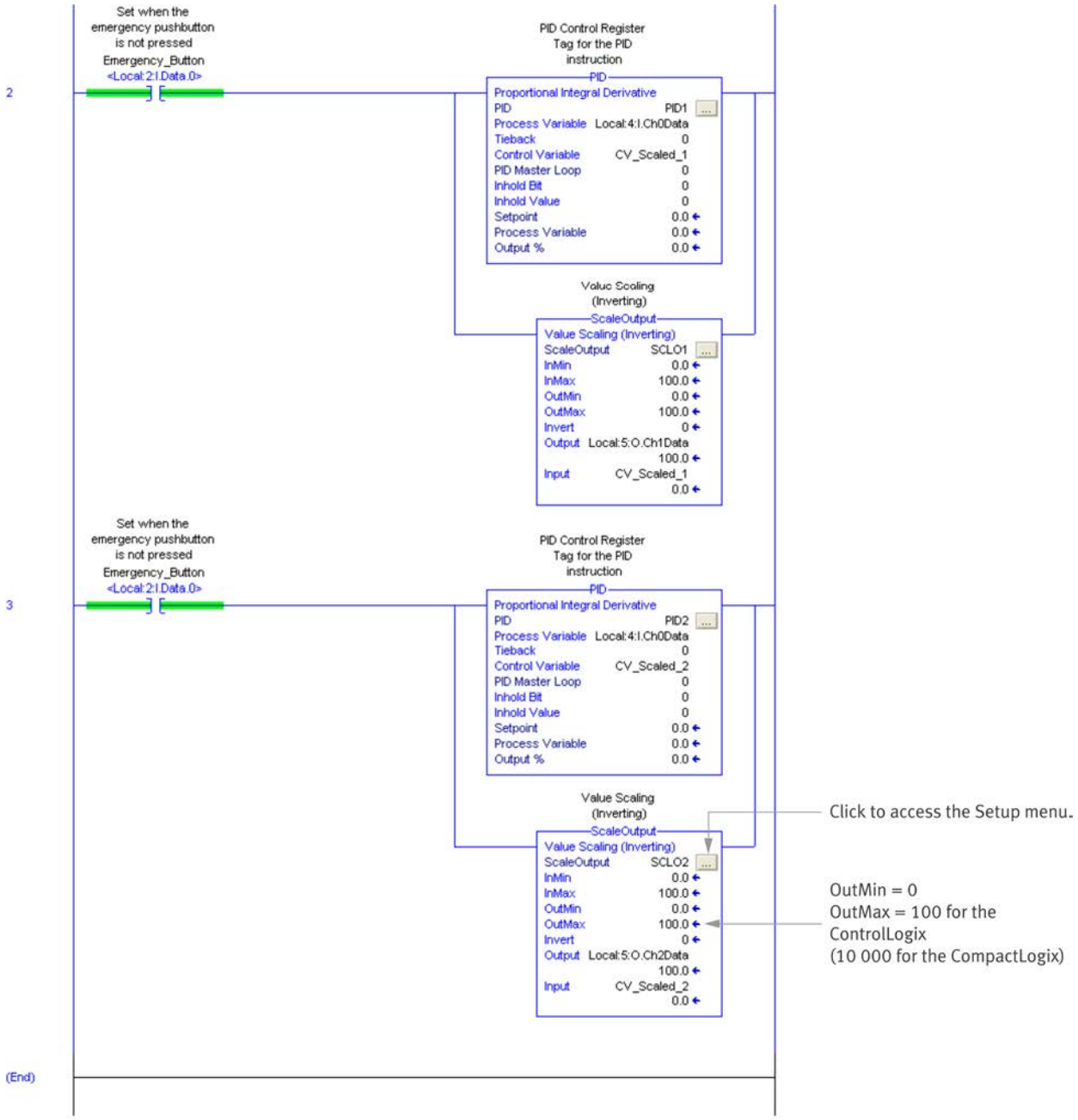


Figure 100: The PID split-range routine – Part 2 (ControlLogix version).

Download the project to the controller and switch it to run mode. If needed, refer to steps 9 to 12 in Learning Unit 1. Connect digital input 0 of the PLC to a 24 V dc switched output on the electrical unit.

Adjust the active range of each output variable. To do this, open the setup menu (click the "..." icon) of each ScaleOutput function associated with an output of interest. Leave OutMax and OutMin at their default values of 100 and 0 (or 10 000 and 0 for a CompactLogix, due to the specific scaling of this model I/O). Then set InMax and InMin to the range over which you want the output variable to change. In the example in Figure 101, output 1 changes when the control variable is between 30% (InMin) and 70% (InMax). This setting makes the output vary as shown by the red line in the graph in Figure 102, with split points at 30% and 70%.

© Festo Didactic

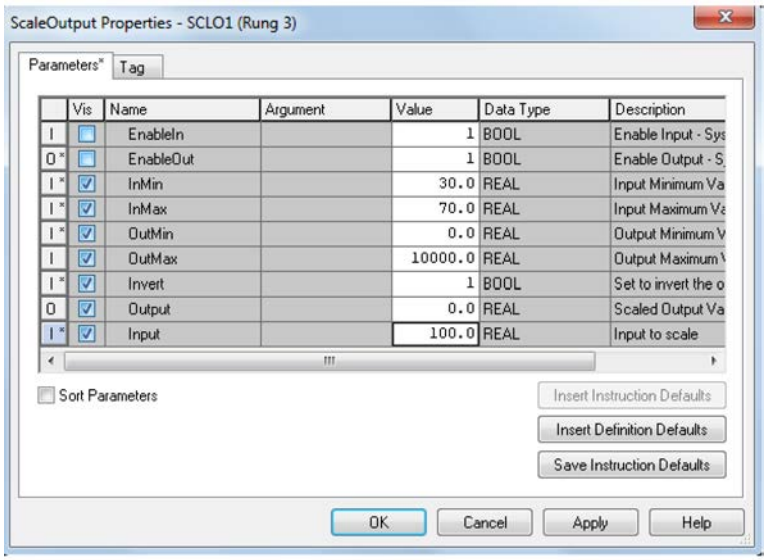


Figure 101: Adjusting the range of an output.

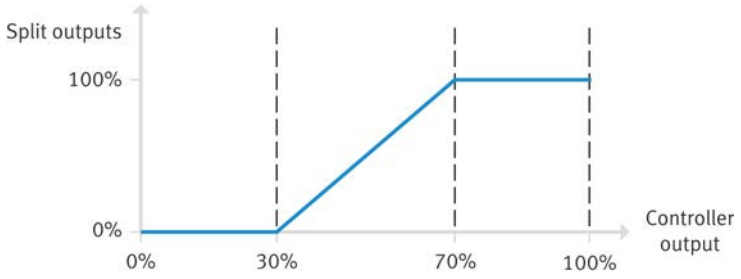


Figure 102: Typical output with the Invert parameter set to 0.

To invert the action of a variable, set the Invert variable to 1. This makes the output minimum (0%) when the control signal is maximum (70% in this example) and maximum (100%) when the control signal is minimum (30%), as shown in the following figure.

Tune the PID parameters for all loops used in this control scheme. In most cases, the same parameters are used for all loops. Fine-tune the parameters as needed.

The PID split-range routine is now configured and controlling the process.

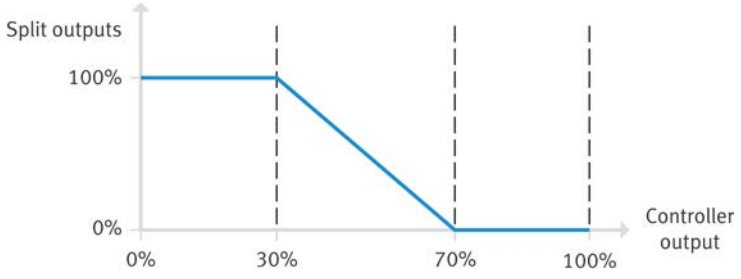


Figure 103: Typical output with the Invert parameter set to 1.

© Festo Didactic

Using Trends

Studio 5000 Logix Designer includes a trend editor that allows you to visualize the behavior of PLC I/O and variables over time. This appendix describes the basic features of the editor to help you obtain meaningful graphs and data.

The instructions below assume that you are using the PIDE control routine. Trends can also be used with other control routines, but minor adjustments, not described here, may be required. You can also adapt the instructions to monitor different variables.

1. Locate the Trends folder in the project tree. Right-click the Trends folder and select New Trend... to create a new trend (see the following figure).

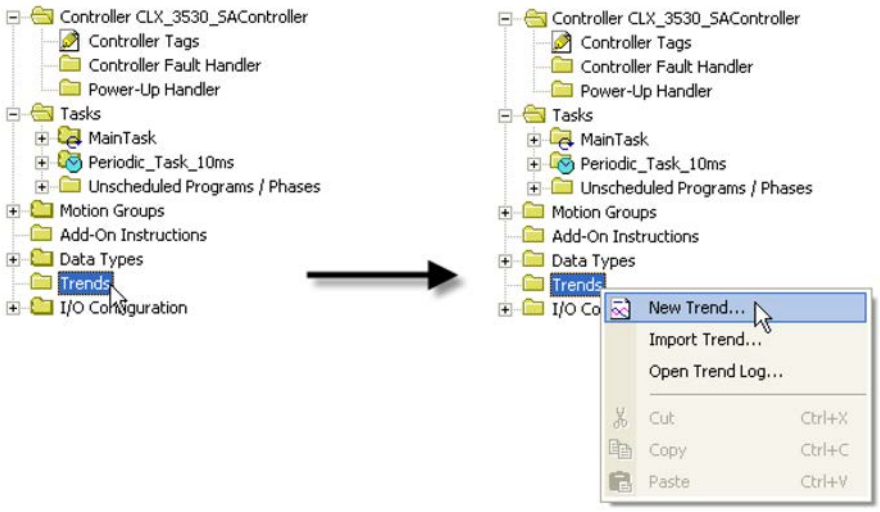


Figure 104: Adding a trend to a project.

2. Enter a name for the trend in the New Trend window (see the following figure). Optionally, enter a description. Then specify the sampling period, avoiding over- or undersampling. Slowly changing processes typically require a sampling period of about 1 s, whereas fast processes may require a much shorter period, such as 10 ms. Selecting an appropriate sampling rate depends on experience and trial and error.

   In this example, a sampling period of 250 ms is selected for a PIDE control loop, resulting in four samples per second.

   Click Next to continue.

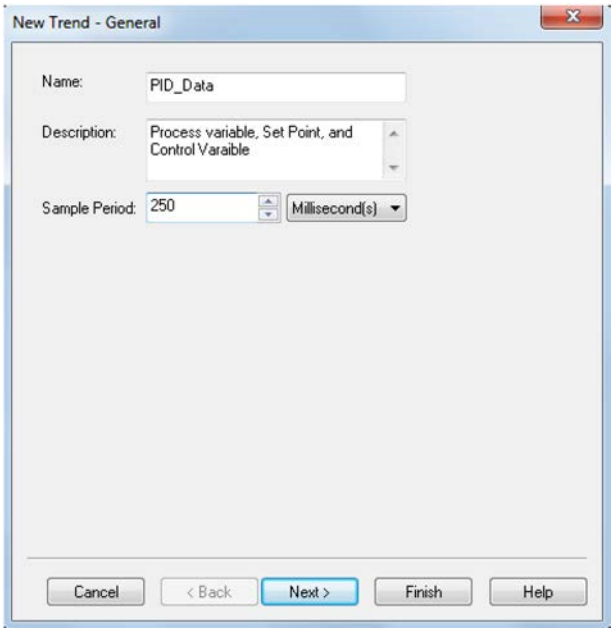


Figure 105: Naming the new trend.

3. Select the tags to monitor. You can choose PLC inputs and outputs (from the controller scope) and variables linked to the control routine (for example, from the PIDE_Control scope). Select a tag, then click Add. Repeat for each tag to be monitored (up to eight tags). Finally, click Finish (see the following figure).

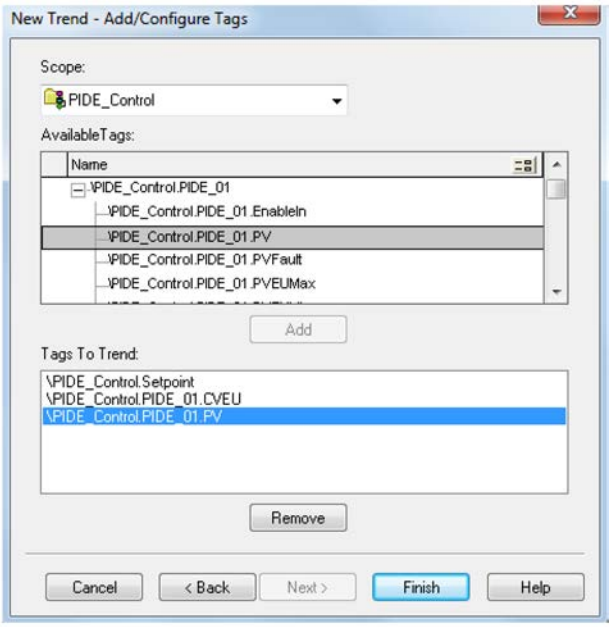


Figure 106: Choosing the tags of the trend.

4. In the project tree, right-click on the trend you just created, then click on Properties from the contextual menu to access its Properties window (see the following figure).

© Festo Didactic

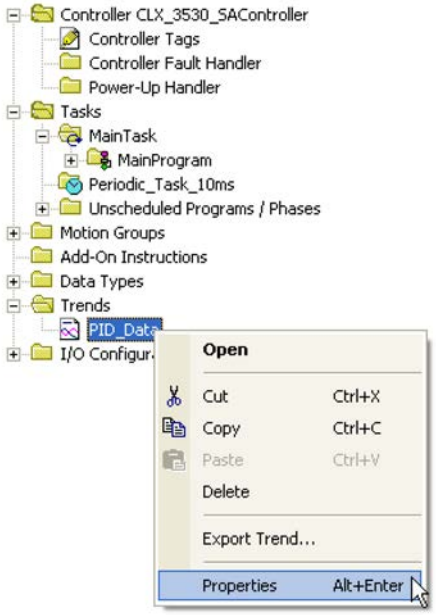


Figure 107: Opening the Properties window of a trend.

5. The Properties window contains several tabs with parameters and options. Open the Pens tab to view the list of monitored tags (see the following figure). For each tag, you can change the trace color, visibility, minimum and maximum values, and other settings. You can also add or remove tags using the Add/Configure Tags button. Make the required adjustments.

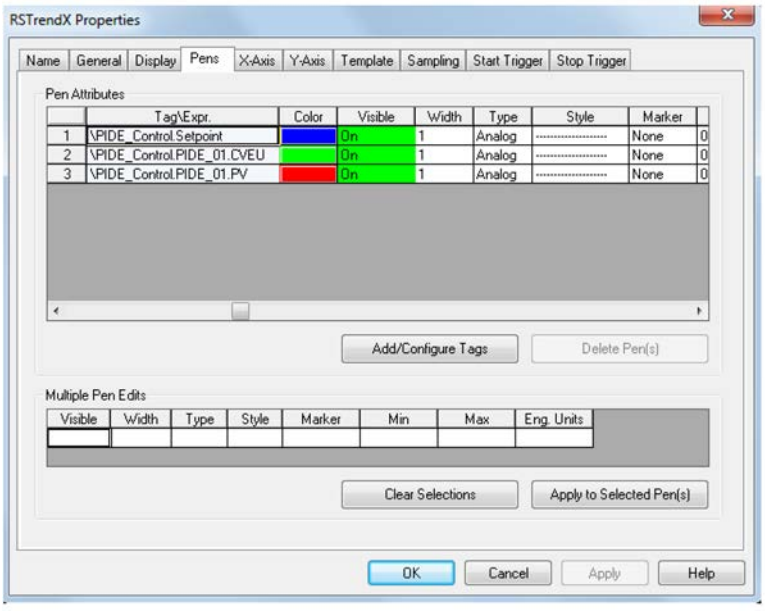


Figure 108: The Pens tab of the properties window.

6. Open the X-Axis tab (see the following figure). The key parameter in this menu is the Time Span. The graph displays traces over a time window equal to this interval. Set it to a value that allows clear interpretation of the results.

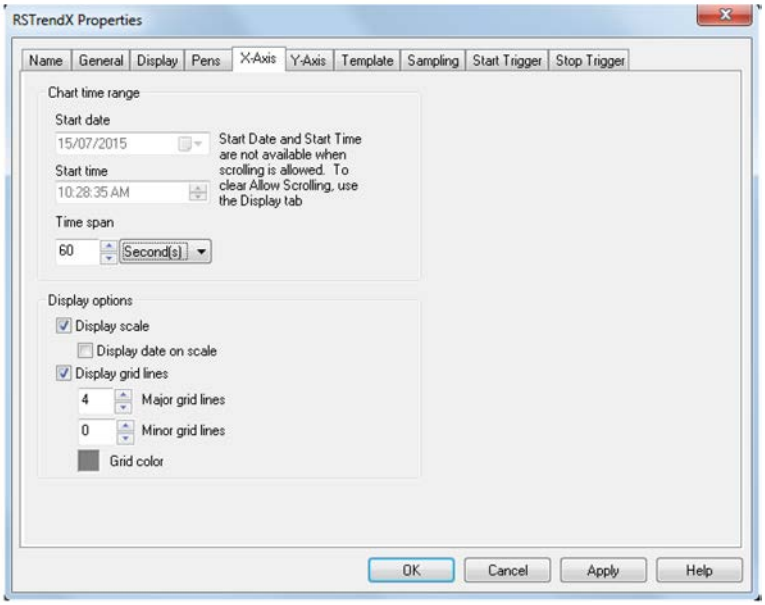


Figure 109: The X-Axis tab of the properties window.

7. Open the Y-Axis tab (see the following figure). This menu lets you define the y-axis span for the different tags. Select Automatic, Preset, or Custom.

   Preset is recommended if the minimum and maximum values were correctly defined in the Pens tab. The Each pen on independent scale option usually works well.

   Custom is appropriate if you know the exact span to use and all tags can be displayed within the same scale.

   You can scale the results as a percentage by selecting the Scale as percentage option.

© Festo Didactic

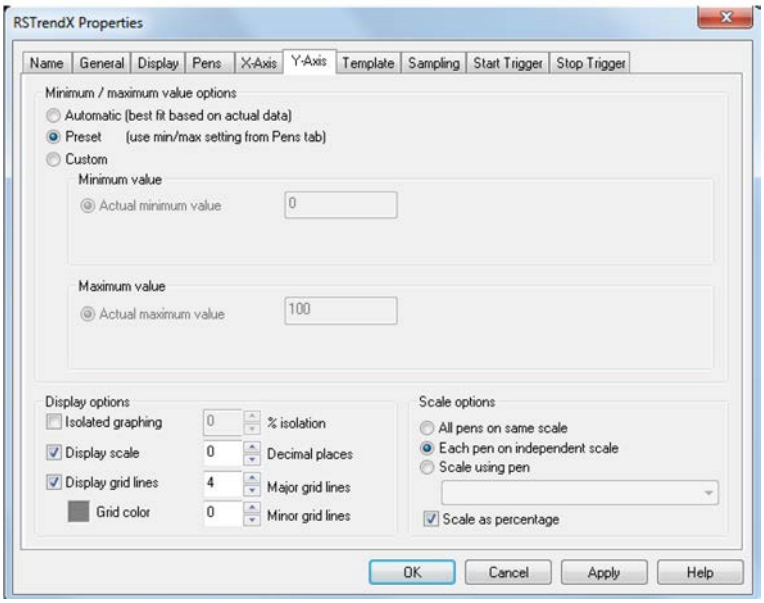


Figure 110: The Y-Axis tab of the properties window.

8. Open the Sampling tab (see the following figure). This menu allows you to change the sampling interval (Sample Period) and set the maximum number of samples that can be recorded. Alternatively, you can define the maximum sampling duration using the Time Period option. This helps keep data files at a manageable size.

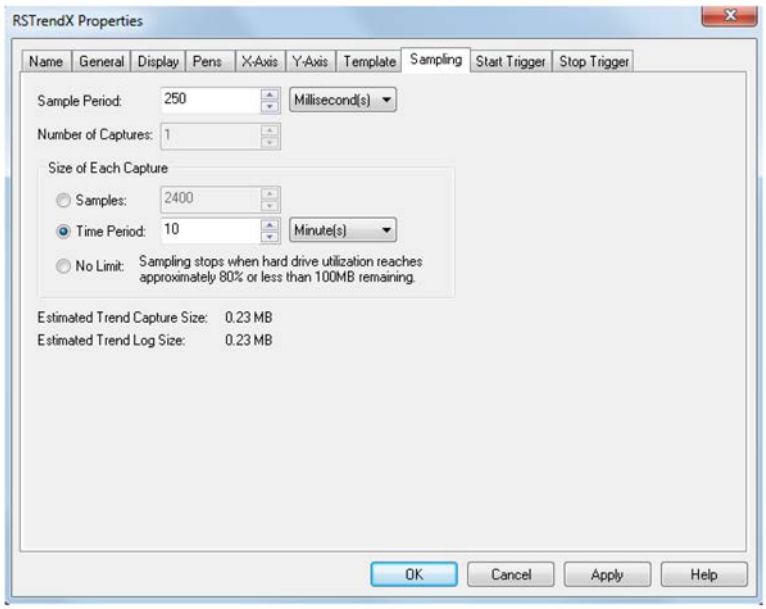


Figure 111: The Sampling tab of the properties window.

9. If you are not already connected to the PLC, go online and set it to remote run mode. You are now ready to record data.

A row of buttons is located at the top of the Trend window (see the following figure). Click Run to start recording data.

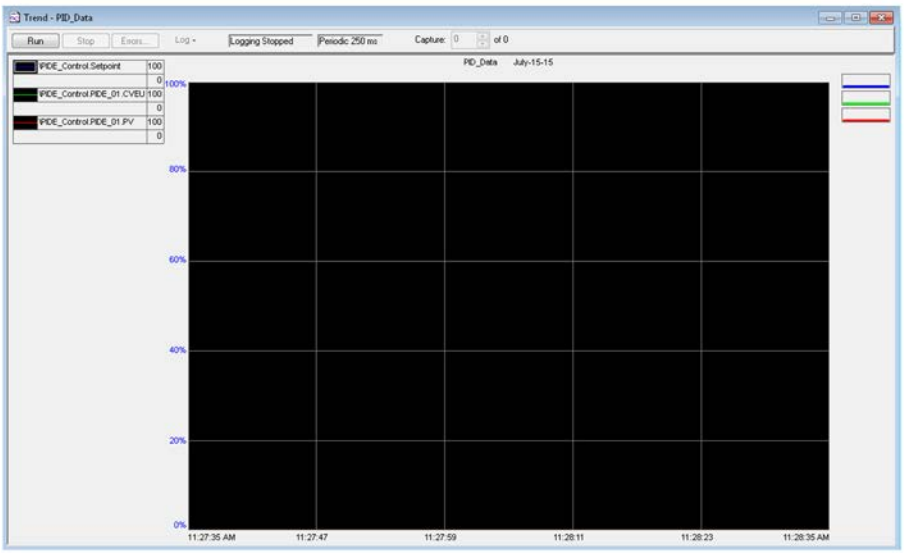


Figure 112: Launching the recording of data.

10. The data is plotted in real time in the graph area, allowing you to observe the process dynamics (see the following figure).

    When data recording is complete, click Stop.

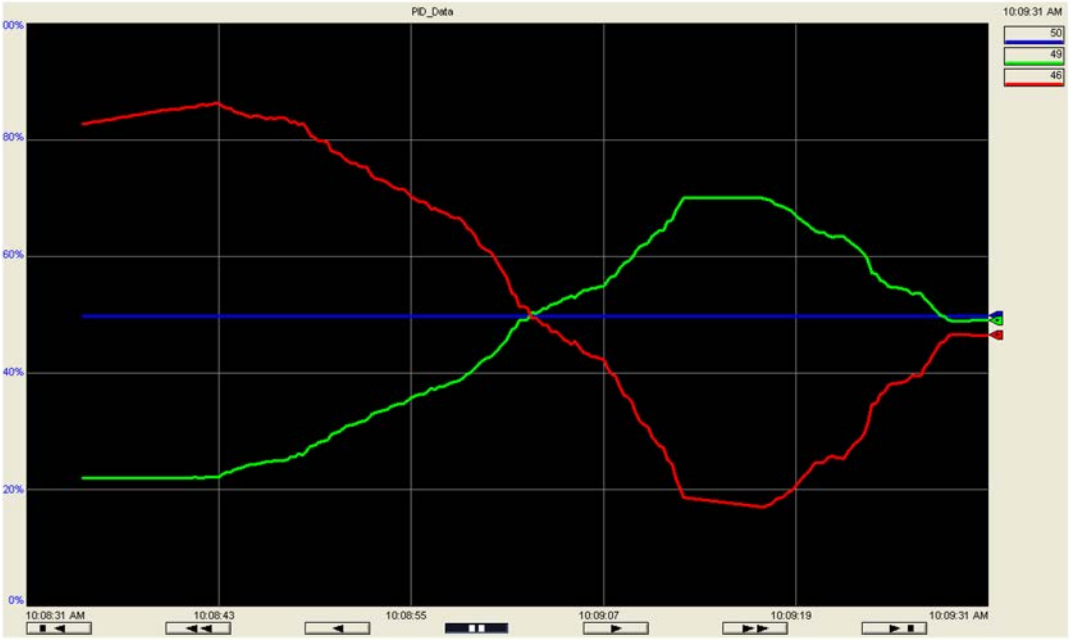


Figure 113: Recording a data trend.

© Festo Didactic

11. The data can be exported to spreadsheet software. To do so, click Log ▶ Save Trend Log As. You can save the data as a .TBS or .CSV file. Choose .TBS to reuse the file in Studio 5000 Logix Designer. Choose .CSV to export the data to other software.



A .csv file (comma-separated values) can usually be opened with most spreadsheet software. Microsoft Excel 2007 does not automatically recognize .csv files. To import one, open Excel 2007, go to the Data tab, and select From Text. Locate the .csv file and click Import. In the Text Import Wizard, select Delimited, then choose Comma as the delimiter. Complete the wizard and select where to place the data.

This concludes the basic presentation of trends in Studio 5000 Logix Designer. You can now explore its advanced features.

© Festo Didactic

© Festo Didactic

List of Faults on the ControlLogix PLC

Table 27: List of faults – ControlLogix PLC, Model 46965-1.

Fault	Fault Description
1	Opens digital input 1.
2	Inverses the wiring between digital inputs 3 and 4.
3	Opens the common wire of the digital inputs (this disables all digital inputs).
4	Opens analog input 2.
5	Inverses the wiring between analog outputs 0 and 1.
6	Opens analog output 3.
7	Creates a short circuit between digital inputs 6 and 7.
8	Opens relay 0 N.O. circuit.
9	Opens relay 1 N.O. circuit.
10	Opens analog input 0.

© Festo Didactic

© Festo Didactic

List of Faults on the CompactLogix PLC

Table 28: List of faults – CompactLogix controller, Model 46966-1.

Fault	Fault Description
1	Opens digital input 1.
2	Inverts the wiring between digital inputs 3 and 4.
3	Opens the common wire of the digital inputs (this disables all digital inputs).
4	Opens analog input 2.
5	Inverts the wiring between analog outputs 0 and 1.
6	Opens analog output 3.
7	Creates a short circuit between digital inputs 6 and 7.
8	Opens digital output 0.
9	Opens digital output 1.
10	Opens analog input 0.

© Festo Didactic

FESTO

User Guide

ControlLogix and CompactLogix Programmable Logic Controllers

CE Importer:
Festo Didactic SE
Rechbergstr. 3
73770 Denkendorf
Germany
Tel.: +49 711 3467-0
did@festo.com

US Importer:
Festo Didactic Inc.
607 Industrial Way West
Eatontown, NJ 07724
United States
Tel.: +1 732 938-2000
Toll Free: +1-800-522-8658
services.didactic@festo.com

CA Manufacturer:
Festo Didactic Ltée/Ltd
675, rue du Carbone
Québec (Québec) G2N 2K7
Canada
Tel.: +1 418 849-1000
Toll Free: +1-800-522-8658
services.didactic@festo.com

UK Importer:
Festo Ltd
Applied Automation Centre
Brackmills
Northampton, NN4 7PY
United Kingdom
T +44 800 626 422
info_gb@festo.com

www.festo.com

0000585159000000000100