MicroLogix Programmable Logic Controller

FESTO

Process Automation

User Guide



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General Safety Symbols and Procedures

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

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Symbol	Description
	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.
	Caution, hand crushing hazard.
	Static sensitive contents. Observe precautions for handling electrostatic discharge sensitive devices.
	Notice, non-ionizing radiation.

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Symbol	Description
	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.

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.

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PLC Fundamentals

PLC Hardware

Programmable Logic Controllers (PLCs) are small computers used for the automation of industrial processes. Like personal computers, PLCs use a microprocessor. Some PLCs are built to sustain extended temperature ranges, dirty or dusty conditions, vibrations, and impacts. The special input/output arrangement of PLCs is significantly different than computers. PLCs are connected to sensors (e.g., push buttons, limit switches, and temperature, flow, level, pressure, or pH transmitters) and actuators (e.g., motor starters, magnetic relays, valves, or solenoids). The input/output arrangements may be built into a simple PLC or the PLC may have external input/output modules. The following figure shows the main components of a typical PLC.

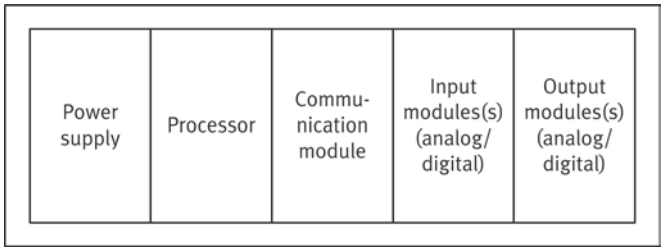


Figure 1: Main components of a PLC.

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

Processor (CPU). This is the brain of the PLC system. It comprises the microprocessor and the memory. The processor reads the input data, executes the stored program, and sends commands to output module(s).

Communication module. PLCs have at least one communication port used for programming, troubleshooting, sharing data, attaching a visual display, interfacing with a modem, or connecting to a network. PLCs are often connected to the plant's communication network which enables them to be part of a larger control system and to be remotely accessed.

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

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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:

- **Dedicated buttons**. The programs 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. These rugged devices have a display screen and buttons for use in programming. They can usually store backup copies of programs and communicate with computers.
- **Computer**. PLC manufacturers offer software to program PLCs. This is often the preferred method because computers have large data storage capacity and their screen displays more information at the same time than the LCD of a PLC. When PLCs are connected to a network, they can be accessed remotely via a computer. Also, laptops offer some portability if a PLC needs to be programmed locally.

Programming Languages

Today's PLCs provide a wide variety of programming tools to build simple and efficient programs that fit almost any manufacturing application. Most PLC programming applications tend to follow the IEC 61131-3 standard that defines five different languages and helps ensure uniformity in PLC programming. Some of these languages are graphical (ladder logic, function block diagram, and sequential function chart) while others are textual (structured text and instruction list).

The MicroLogix PLC relies on a set of instructions compatible with RSLogix 500. This PLC programming software only supports ladder logic.

Ladder logic

Ladder logic was initially developed to make PLC programming easier for electricians. Ladder logic uses electrical symbols to represent the rules and conditions in a program. A ladder diagram contains two uprights connected together by rungs. Hence the name: ladder diagram. The uprights (sometimes called power rails) provide the power to the rungs; each rung contains a series of electrical-symbol operators. When all conditions on a rung are true, power can flow through that rung. The conditions on a rung are represented by contacts such as normally open (NO or XIC) or normally closed contact (NC or XIO). When all contacts on a rung are set so that current can flow, one or more coils are turned on. Contacts are sometimes referred to as inputs and coils as outputs.



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

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Let us look at an example to see how ladder logic works. For this, we will use the circuit shown in (a) of the following figure where a light is turned on when a normally open push button is pressed. The ladder logic version of this circuit is shown in (b) of the following figure. In this example, the normally open push button becomes a normally open contact (the input). The light is the output and is represented by the coil at the right of the ladder diagram.

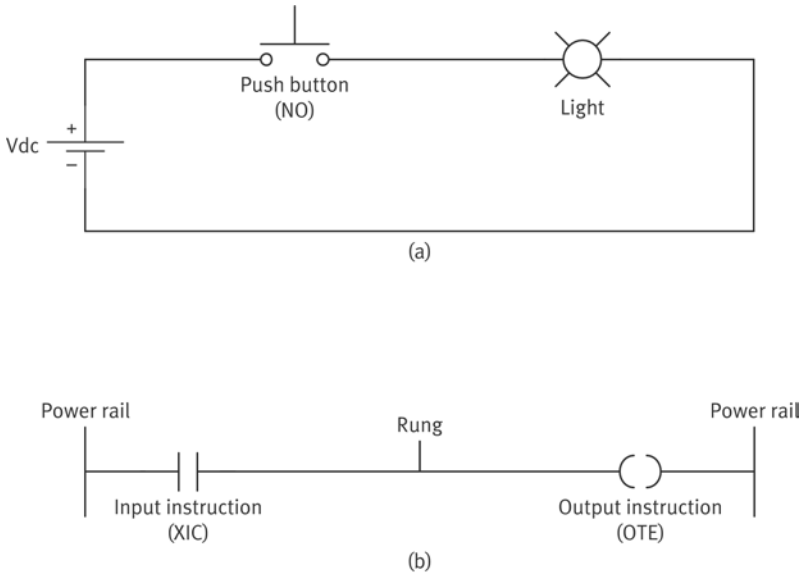


Figure 2: Push button and light ladder diagram.

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.

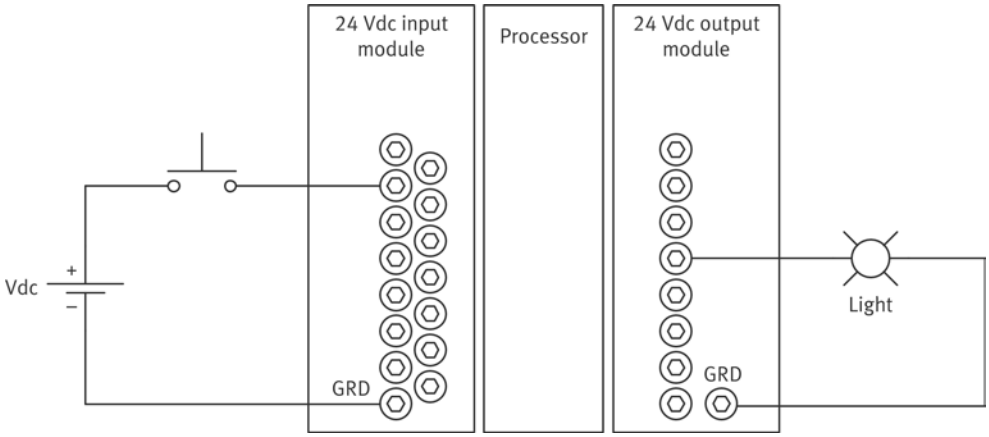


Figure 3: Connection of a push button and a light to a PLC.

The PLC takes care of the logical operations between the input and the output. Thus, the system is no longer limited by the physical wiring. The following figure shows two with the light. The ladder diagram in (a) of the following figure turns on the light when the push button is pressed. This is the same behavior as shown in Figure 2.

The ladder diagram in (b) of the following figure controls the same push button and light circuit in a completely different way without changing the physical arrangement. The normally open contact in the ladder diagram has been replaced with a normally closed contact. In this example the light is always on, unless the push button is pressed.

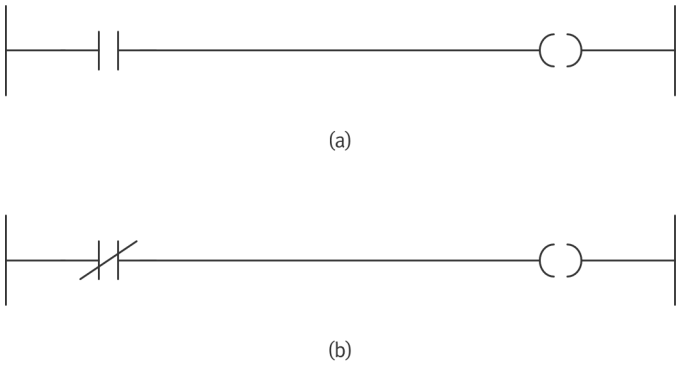


Figure 4: Two different ladder diagrams for the push button and light circuit.

As in the previous example, all the components used as input devices (whether they are buttons, sensors, or switches) are connected to the 24 V input module of the PLC while the output devices (lights, ac drives, actuators, etc.) are connected to the output module and everything in between is taken in charge by the PLC.

Data files and addressing

Data file organization

The data files are the part of the PLC memory that contains I/O values and files where data is monitored, manipulated, and modified for control purposes. As the following table shows, there are several types of data files. Each type is represented by a letter identifier and a file number.

The data files are divided into 16-bit word elements. Some data files consist of single-word elements, while some are made of 3-word elements. Input and output data files are made of single-word elements representing the state of the PLC inputs or outputs.

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Table 1: Types of data files.

Default Data Files		
File Type	**Identifier**	**File Number**
Output	O	0
Input	I	1
Status	S	2
Bit	B	3
Timer	T	4
Counter	C	5
Control	R	6
Integer	N	7
Float	F	8

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User-Defined Data Files		
File Type	**Identifier**	**File Number**
Bit	B	9-255
Timer	T	
Counter	C	
Control	R	
Integer	N	
PID	PD	
Message	MG	
Long	L	

Instruction Addressing

The address you specify for an instruction when designing a ladder program depends on the type of data file used to store the instruction status. You can address data file elements, words, or bits. The address format depends on the type of addressed file. The following table indicates the address formats that can be used to program your MicroLogix PLC. As the table shows, addresses consist of alphanumeric characters separated by delimiters (colon, slash, and period):

- colons [:] are used to separate a file type and number;
- slashes [/] are used to separate a bit from an element or word;
- periods [.] are used to separate an element from a word within that element, or a word from a slot number.

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Table 2: PLC address format.

File Type	Address Format	Explanation
Output	O:e/b	O = Output e = Slot Number (0 for the PLC, 1 for the I/O analog module) b = Output bit
Input	I:e/b	I = Input e = Slot Number (0 for the PLC, 1 for the I/O analog module) b = Input bit
Status	S:e/b	S = Status e = Element number b = Bit location within the element
Bit	Bf:e/b or Bf/b	B = Bit f = File number (3 is the default number) e = Element number (0 to 255). 1-word elements, 16 bits/element b = Bit location within the file
Timer	Tf:e.s or Tf:e/b	T = Timer f = File number (4 is the default number) e = Element number s = Word (1 or PRE for preset value, 2 or ACC for accumulated value) b = Bit location within the element
Counter	Cf:e.s or Cf:e/b	C = Counter f = File number (5 is the default number) e = Element number s = Word (1 or PRE for preset value, 2 or ACC for accumulated value) b = Bit location within the element
Control	Rf:e	R = Control f = File number (6 is the default number) e = Element number

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File Type	Address Format	Explanation
Integer	Nf:e/b	N = integer f = File number (7 is the default number) e = Element number (0 to 255) b = Bit location within the element

Here are a few examples of possible addresses:

- N7:15 is an address referring to the integer number 15 stored in the N7 data file.
- T4: 7.ACC is the address of the accumulator (a 16-bit word) of element 7 stored in file T4.
- B3: 64/15 is the address of bit number 15 of element 64 of the B3 file.

To refer to a specific bit of a digital input of the controller, use an address starting at I:0.0/0 for input 0 and so on. For example, Input 1 uses the second bit at address I:0.0/1. For the analog inputs located on the I/O analog module expansion card (e = 1), the address of analog inputs 0 and 1 are I:1.0 and I:1.1 (Note that an analog signal is stored in a 16-bit word). Outputs use the same format, starting at O:0.0/0 for the digital outputs. Addresses of the analog outputs located on the expansion card are O:1.0 and O:1.1.

Symbols

To make programming easier and more understandable, symbols acting as aliases can be created to replace the addresses assigned to inputs or outputs. If a red push button is connected to input I:0/1, an alias such as RED_BUTTON can be created. Thus, instead of constantly referring to I:0/1, the more descriptive tag RED_BUTTON can be used. The following figure shows how an alias can replace an input address in a ladder diagram. The description Emergency push button is also added for clarity. The same goes for the output O:0/0 which is labeled RED_LIGHT.

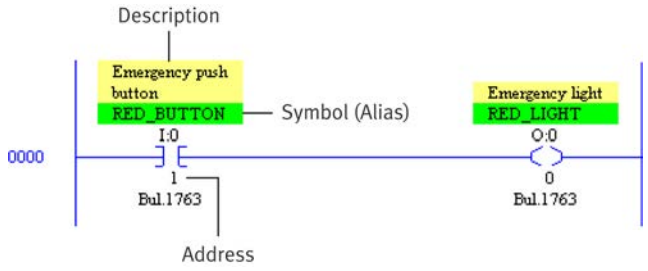


Figure 5: Symbol in a ladder diagram.

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A bulletin number corresponding to the PLC model used is shown under the address in the ladder diagram. The screen captures of the RSLogix software used in this course were taken with a MicroLogix 1100 (Bulletin 1763). The same logic can be applied to other MicroLogix PLCs, such as the MicroLogix 1400 (Bulletin 1766).

Symbols can be edited and monitored from the Address/Symbol menu. This feature can be found under the Database folder in the project tree of RSLogix 500. The following figure shows how symbol information is displayed in RSLogix 500. Learning Unit 2 details how to access and edit symbols and descriptions.

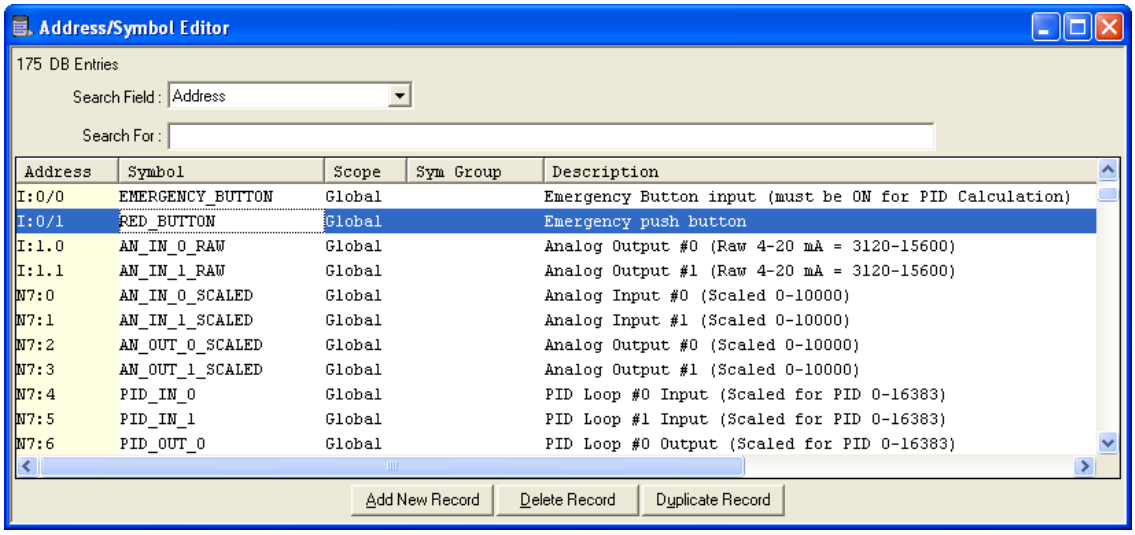


Figure 6: RSLogix 500 address/symbol editor window.

Communication

PLCs are often accessed directly, typically with a serial cable. But they can also be part of a network and, as such, need to be configured to permit data transfer with the other elements of the network. This arrangement allows remote programming, control, and monitoring.

Whereas PLC programming is accomplished with programming software such as RSLogix, PLC control and monitoring is performed through a Supervisory Control and Data Acquisition (SCADA) program. SCADA programs can be installed either on a computer or on a dedicated Human Machine Interface (HMI).

Industrial applications

Depending on its size, a single PLC can be programmed to replace a considerable number of control relays, timers, and counters, hence saving a lot of hardwiring and troubleshooting time. Furthermore, PLCs offer more flexibility than conventional wiring. Indeed, when a control process needs to be changed, the program can simply be modified, which is much easier than rewiring the entire process. This is another reason why PLCs are so often preferred in today's world of manufacturing.

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Advantages and limitations

PLCs are versatile and used extensively in the industry. Their main advantages are:

- Easily reconfigurable
- Easy to install
- Wide range of applications
- Robust
- Network connectivity

However, some limitations are to be considered:

- Greater hardware cost per unit compared to a custom circuit
- Programs are not necessarily interchangeable among PLCs

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Familiarization with the PLC and the Software

First things first

This section explains how to download a project to the PLC. Before proceeding with this section, be sure that:

- the PLC is properly connected
- RSLinx is running on your computer
- the Ethernet communication between the computer and the PLC is functional (refer to Appendix B for details)
- RSLogix 500 is properly installed on your computer



Allen-Bradley uses a terminology to identify process variables that is slightly different from what is found in most textbooks. They use PV (process variable) in place of controlled variable and CV (control variable) in place of manipulated variable. Using the Allen-Bradley terminology, the level in a level process control application is the process variable (PV) and the variable affecting the control valve is the control variable (CV).

Opening a PLC project file

1. Start RSLogix 500 (see the following figure). This software allows you to program the PLC using the ladder diagram programming language.

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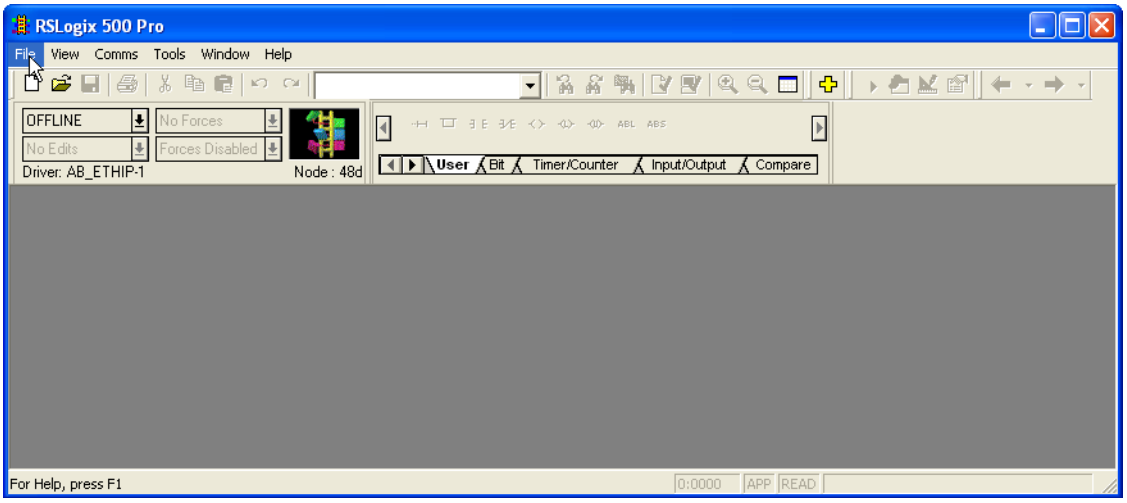


Figure 7: RSLogix 500.

2. The PLC Resource Kit CD-ROM (P/N 86948) contains the project for the MicroLogix that will allow you to use your PLC as a controller for the process control system. From the RSLogix 500 File menu, select Open to display the Open/Import Project window (see the following figure).

3. Select the project file that corresponds to the PLC you are using (MLX_3530_SAController.RSS) and click on the Open button.

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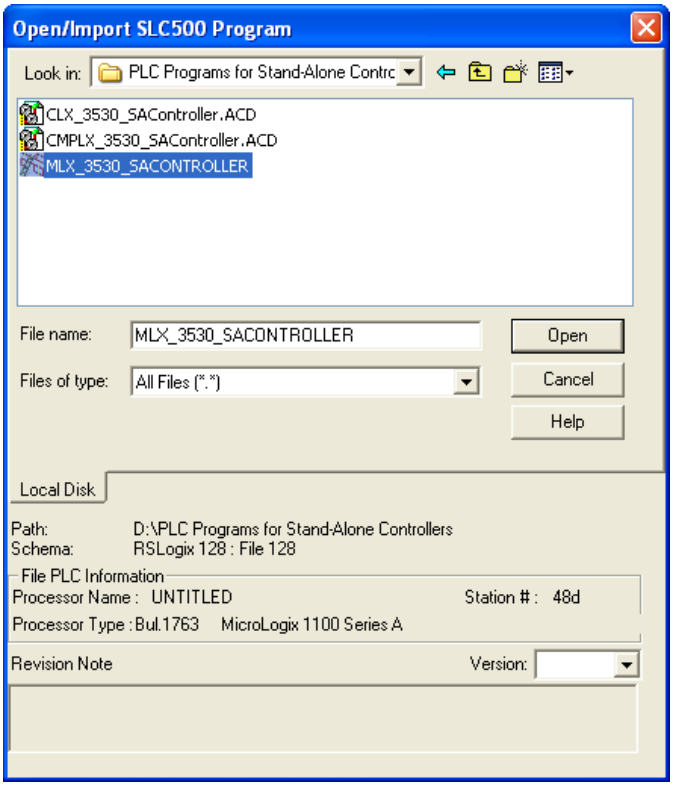


Figure 8: Opening a project file.

4. RSLogix 500 opens the project file and displays the tree structure of the project at the left of the software window as shown in the following figure.

Selecting a Control Scheme

The specific control scheme (either On-Off, PID, or Cascade) you want to use must be chosen at this point, before the project is downloaded to the PLC. To do so, a parameter must be set in the main routine. This parameter will specify the subroutine which will take care of your control needs.

Observe that the project is made of eight program files (see following figure). You can explore the content of the program files (except for the first two) by double-clicking on them in the project tree.

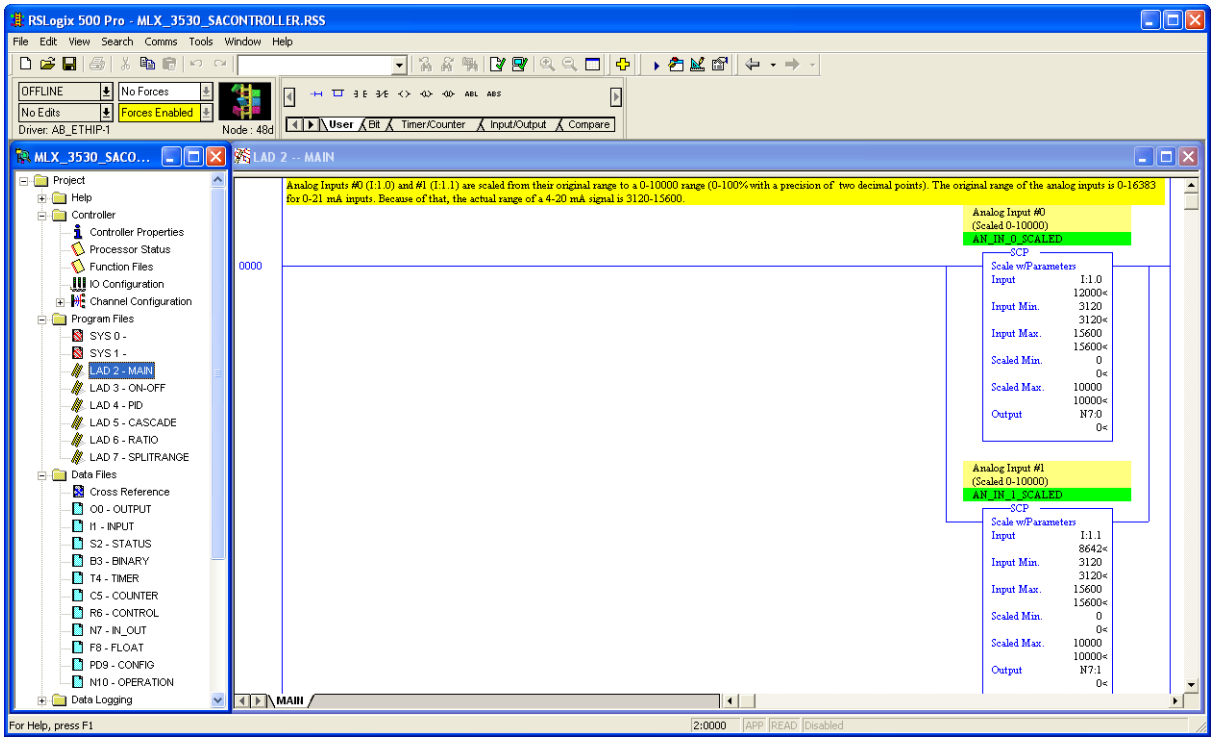


Figure 9: The main RSLogix 500 window (with the project tree on the left).

- The SYS 0, and SYS 1 files are reserved for the project and cannot be edited.
- The LAD 2 – MAIN file contains the logic to properly scale the I/O of the PLC and to ensure that the emergency button is connected. It also calls one of the five subroutines responsible for a specific type of control.
- LAD 3 – ON-OFF, LAD 4 – PID, LAD 5 – CASCADE, LAD 6 – RATIO, and LAD 7 – SPLITRANGE are subroutines used to implement a specific control scheme.

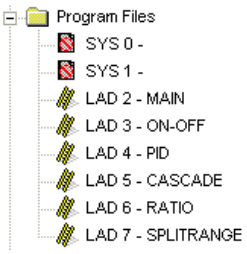


Figure 10: The Program Files directory of the project.

5. To select your control scheme: Locate rung 0001 in the LAD2 – MAIN file. This rung contains a jump to a subroutine (the JSR instruction) which will execute the subroutine specified by the SBR File Number parameter.

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Edit the SBR File Number parameter to either U:3 (for On-Off control), U:4 (for PID control), or U:5 (for Cascade control).

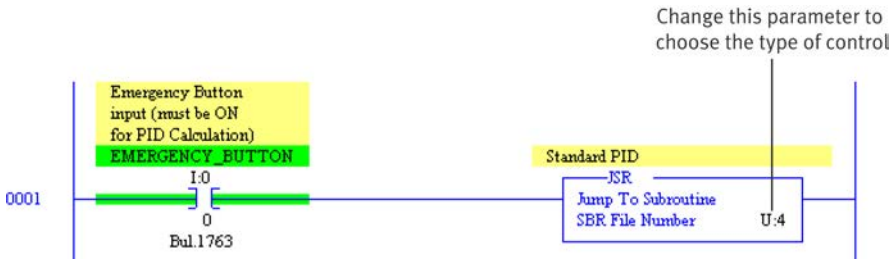


Figure 11: Rung 0001 of the MAIN program file.

6. Save the changes to the project.

7. A window such as the one shown in the following figure may pop up, prompting you for revision notes. Check the Do not prompt me for revision notes again box if you do not wish to see this message again. Click OK to proceed.

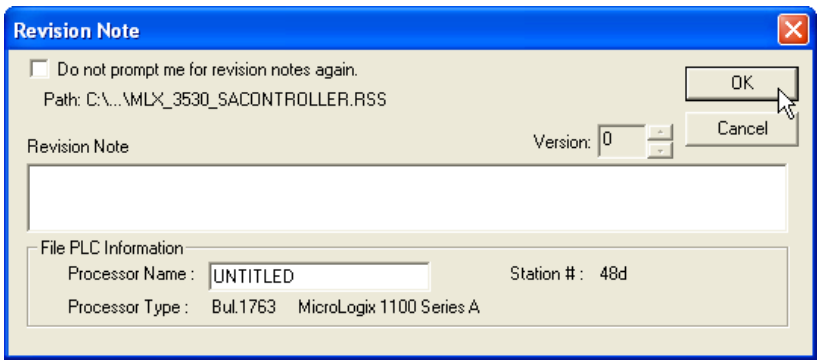


Figure 12: Revision note window.

Downloading a project

8. Before you can download the project to the PLC, you must select the PLC with which RSLogix 500 will communicate. From the Comms menu, select System Comms... to display the Communications window (see the following figure).

Make sure the PLC mode is set to REMOTE.

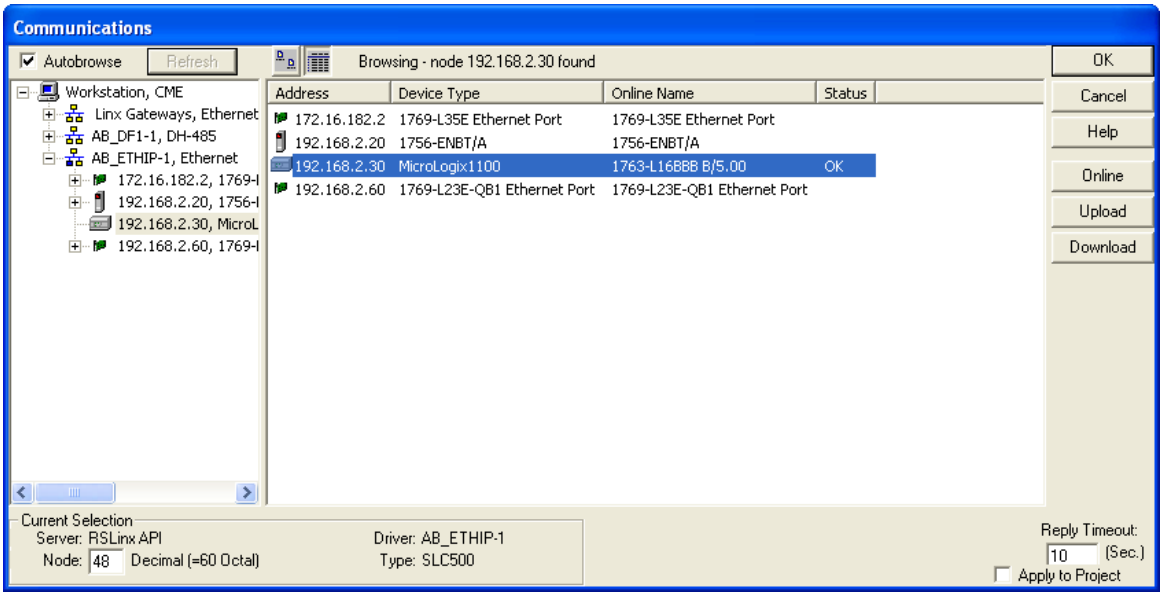


Figure 13: Communications window (may vary depending on the connected devices).

9. Click on the symbol "+" beside AB_ETHIP-1, Ethernet to expand the Network tree and select your PLC from the list. The MicroLogix PLC should be identified by its allocated IP address.

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

11. A window will ask you whether you want to proceed with the download. Another may warn you that the PLC must be switched to remote program mode. Answer positively in each cases.

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

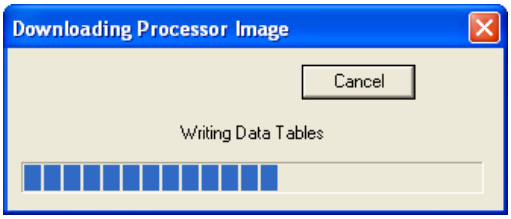


Figure 14: Downloading.

13. Once the download is complete, RSLogix will ask you if you want to go back to run mode and if you want to go online. Answer positively in each case again.

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The software should state that you are in **Remote Run** mode (as shown in the following figure). Otherwise, from the pull-down menu, choose Go Online (see Figure 16). Once online, the mode entitled **Run** should also be selected from the same menu if it is not already activated.

The project is now running on your PLC.



Figure 15: The Remote Run mode.

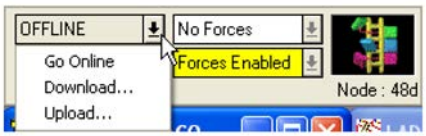


Figure 16: Going online from RSLogix 500.

Editing symbols and their descriptions

As previously explained in Learning Unit 1, RSLogix 500 supports the use of symbols. To make changes to the project, such as creating or editing a symbol, the controller must be offline.

14. Open your project file with RSLogix 500 as explained at the beginning of this section and locate the Address/Symbol menu in the Database folder of the project tree. Double-click on Address/Symbol to open the editor window.

15. To create a new symbol, click on the Add New Record button.

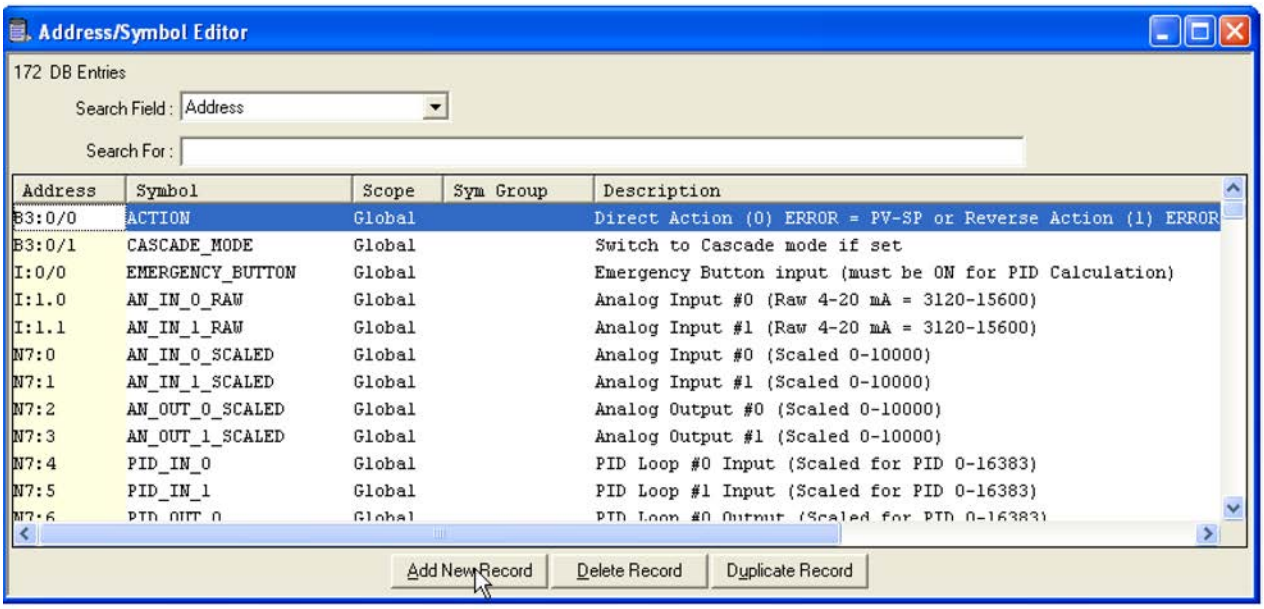


Figure 17: Creating a new symbol.

16. Type the relevant information for each field of your new symbol. In the example given in the following figure, the address I:0/7 (digital input 7) is linked to a symbol named TEST_SYMBOL and is given a description.

    You can also specify if the scope of the symbol is global (i.e., any routine or subroutine can use it) or if it is limited to a specific routine or subroutine. In the given example, TEST_SYMBOL can only be used by program file number four (i.e., by the PID subroutine).

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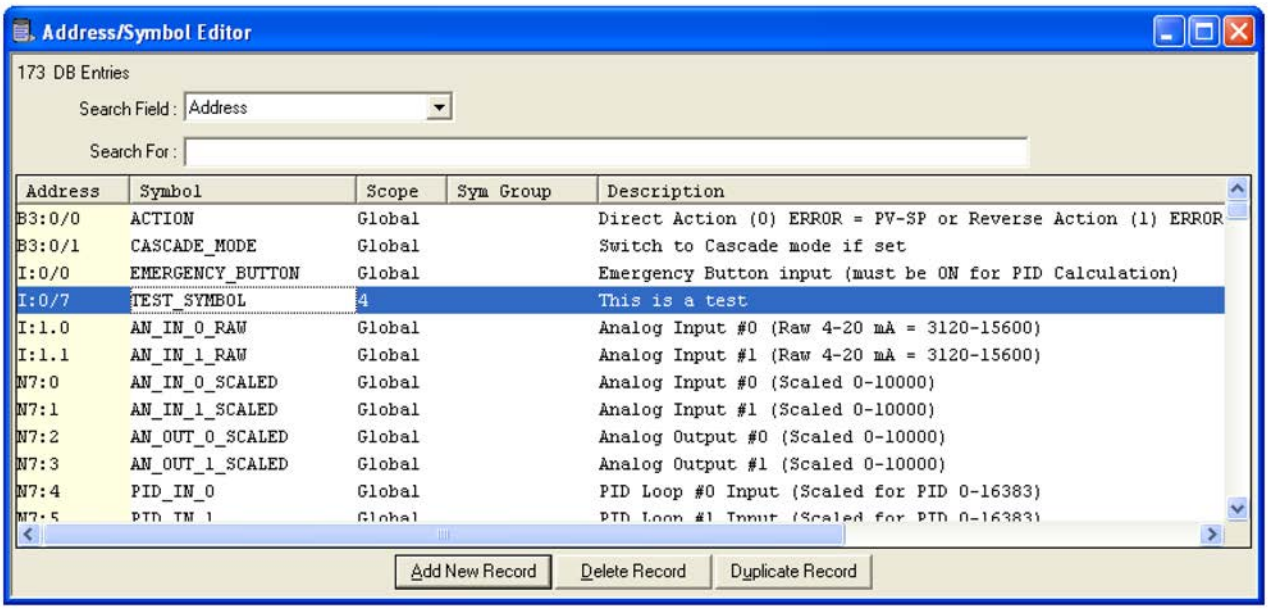


Figure 18: Editing a new symbol.

17. A symbol which is not required anymore can simply be deleted by pressing the Delete Record button.

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On-Off Control

A PLC can be used to implement On-Off control for a process. This basic type of control can be used effectively for slowly changing processes. An analog input and an analog output of the PLC are used for the process variable (PV) and for the control variable (CV) respectively. Three parameters must be set according to the requirements of the process: the set point, the value of the deadband, and the action of the controller.

Connecting the PLC to the process loop

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

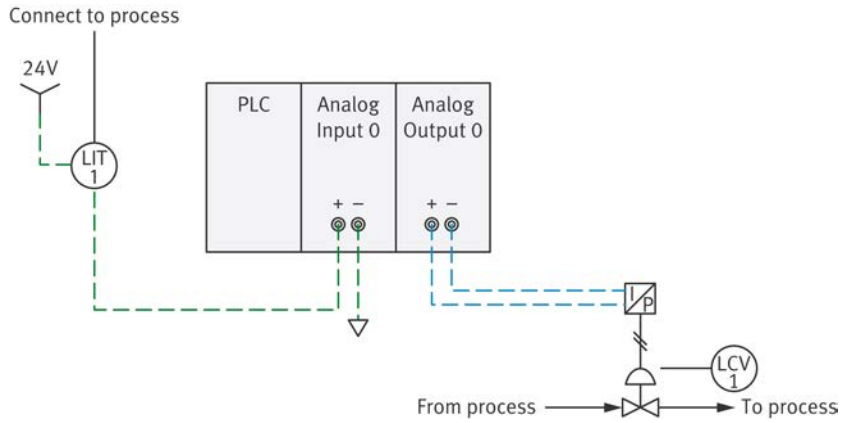


Figure 19: Typical connection of a PLC for on-off control.

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 RSLogix 500 and load the provided PLC project file appropriate to your controller.

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You can find the project files on the PLC Resource Kit CD-ROM (P/N 86948). The MLX_3530_SAController.RSS project file is the one pertaining to the MicroLogix PLC.

4. In the MAIN ladder file, go to rung 0001 and set the SBR File number to U:3 to use On-Off control See Learning Unit 2 and following for details). Save the file.

5. You can now explore the logic of the On-Off subroutine by double-clicking on LAD 3 – ON-OFF in the project tree.

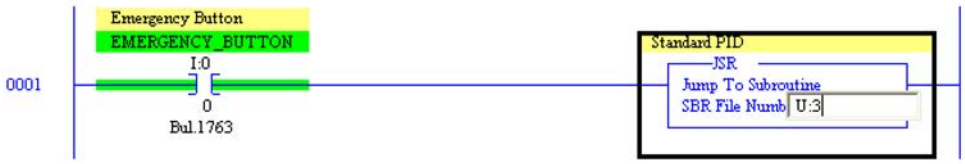


Figure 20: Setting the SBR File Parameter to U:3 for on-off control.

6. The parameters related to On-Off control should be adjusted now before going online even though they can be modified later once the controller is running the program. The parameters are shown in the following table.

   To edit a parameter, go in the Data files section of the project tree and double-click on the appropriate file (B3 - Binary for the action or N10 – Operation for set point and deadband).

Table 3: User-adjustable parameters for on-off control.

Parameter	Address	Description
Setpoint	N10:1	Target value of PV. Can be set between 0 (0%) and 10000 (100%).
Deadband	N10:0	Size of the minimum error necessary to change the value of CV. Can be set between 0 (0%) and 10000 (100%).
Action	B3:0/0	Selects between direct action (bit set to 0, Error = PV -SP) and reverse action (bit set to 1, Error = SP - PV).

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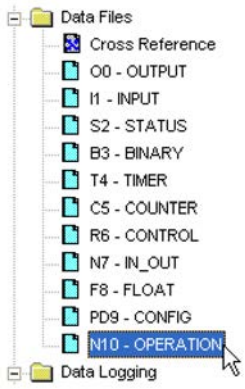


Figure 21: The Data Files section of the project tree.

You will be able to edit the value of your parameters from those data files. Note that the radix parameter which controls the base in which the values are represented (binary, octal, decimal, or hexadecimal) may need to be used to improve legibility of values or to allow easy bitwise modification.

In the example given in the following figure, the SETPOINT (N10:1) parameter is being changed to 5000 (i.e., 50.00 %). The field to the left is the DEADBAND parameter. The other fields need not be considered for now.

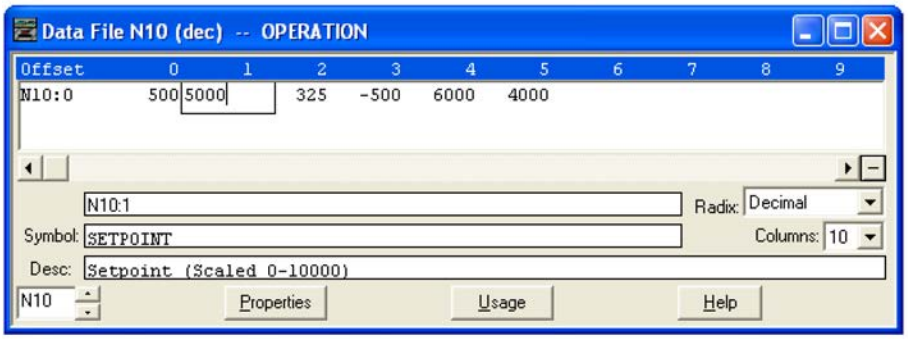


Figure 22: Editing the SETPOINT parameter.

In the following figure, the ACTION parameter is adjusted to direct action as the B3:0/0 bit is reset to 0.

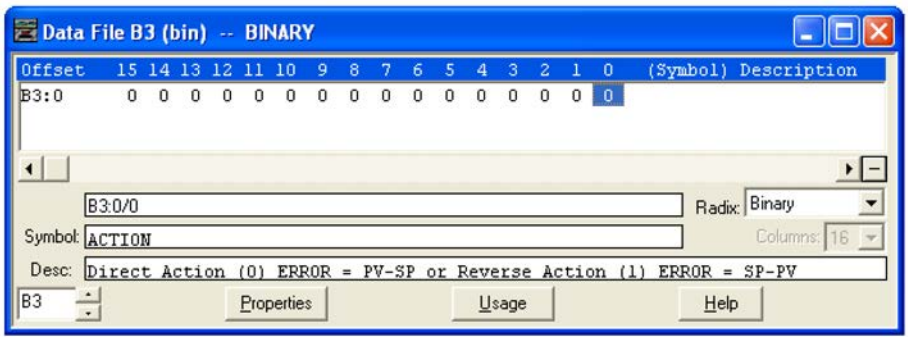


Figure 23: Editing the B3 data file (Note: B3:0/0 is the action parameter).

Adjust the parameters as required for your process. You can modify them later if necessary. Save the changes to the project file.

7. This project requires you to connect an emergency button for increased safety. If the PLC digital input 0 is not powered, all processes are shut down. Connect digital input 0 of your PLC to a 24 V dc switched output source on the electrical unit of the Instrumentation and Process Control Training System. The switched output jacks are the ones which become unpowered when the emergency button is pressed.

Running the PLC control program

8. Download your project to the PLC and go online. Follow the procedure in Learning Unit 1, steps 8 to 13 if needed.

9. The analog output and the analog input can be monitored from the O0 – OUTPUT and the I1 – INPUT data files as shown in the following figures. The programs are designed to work in a 0–10000 basis (0–100%). For technical reasons, the inputs and outputs of the PLC are designed to operate in a 3120-15600 basis when 4-20 mA signals are used. Setting the radix to decimal helps in interpreting the results.

   The parameters of a control scheme can be modified from the data files windows while you are in run mode. Edit them if required.

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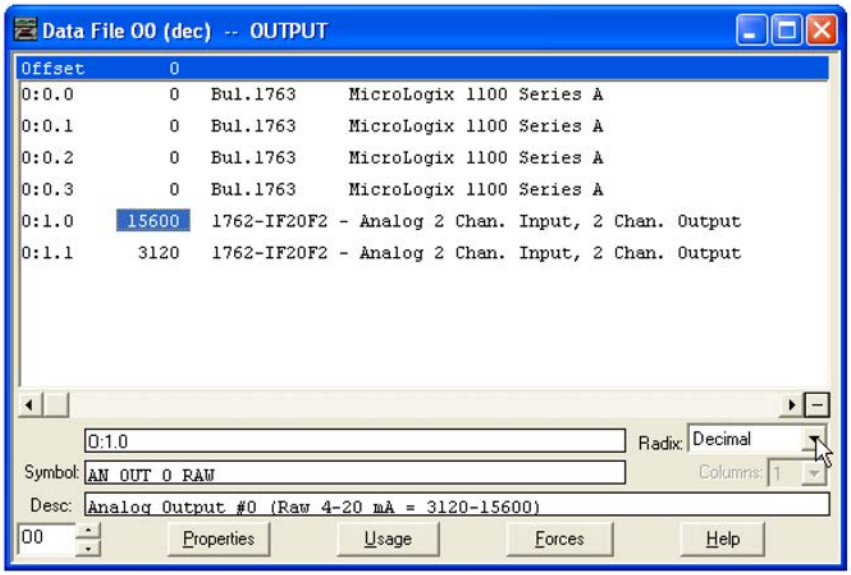


Figure 24: Expansion card analog output monitoring (channel 0 corresponds to O:1.0).

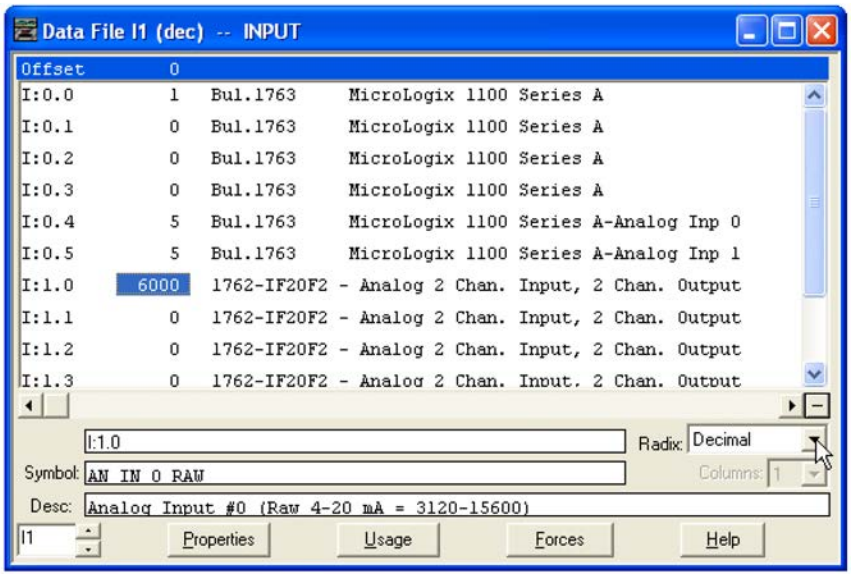


Figure 25: Expansion card analog input monitoring (channel 0 corresponds to I:1.0).

Using the on-off trend (optional)

10. It is possible to use a graphical interface to plot the different variables of interest from this process. To do so, go into the Trends section of the project tree and double-click on the trend related to your process in order to obtain a preconfigured graph.

The graph will look like the one shown in the following figure. Note that you can make changes to a specific chart by right-clicking on the graph area of the chart and selecting the Chart Properties menu.

To export data, simply right-click on the graph area of the chart and select Create Snapshot... This allows you to save the data to a .dbf file which can be opened with Excel. The whole time span set in the properties of the graph (Chart Properties -> x-axis tab -> Time span) will be exported to the .dbf file. Adjust the time span **prior** to recording a process.

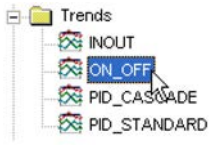


Figure 26: Opening the ON_OFF trend from the Trends menu.

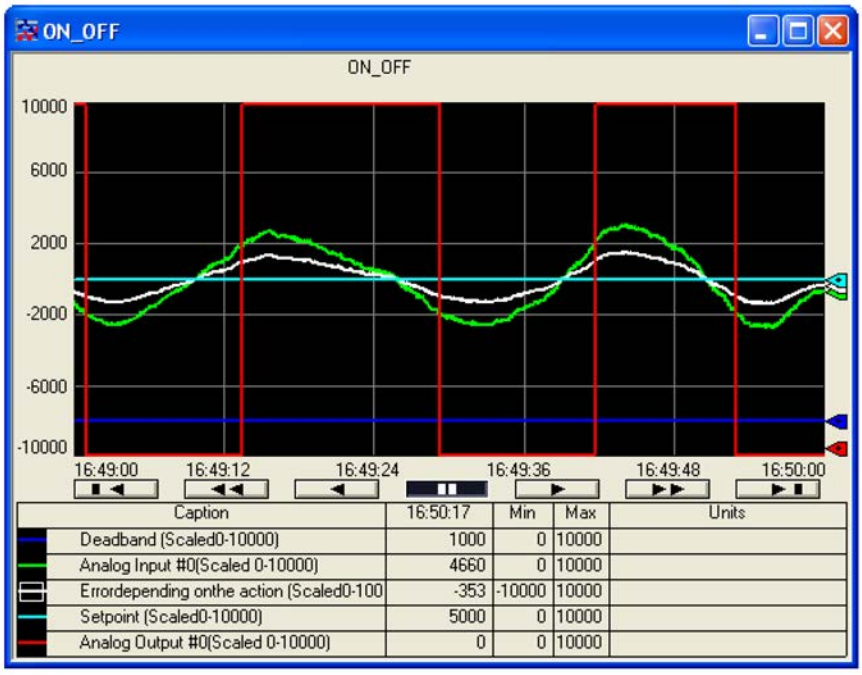


Figure 27: The ON_OFF trend.

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PID Control

The MicroLogix PLC can be used to implement PID control for a process. This basic type of control can be used effectively for many types of processes. An analog input and an analog output of the PLC are used for the process variable (PV) and for the control variable (CV) respectively. A series of parameters must be set according to the requirements of the process. Note that RSLogix 500 only works with the dependent form of the PID equation.

Connecting the PLC to the process loop

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

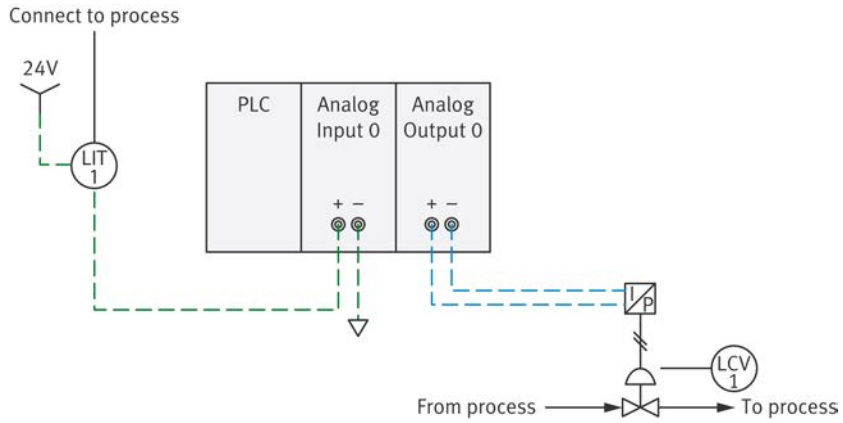


Figure 28: Typical connection of a PLC for PID control.

Configuring the PLC for PID 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 RSLogix 500 and load the provided PLC project file appropriate to your controller.

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You can find the project files on the PLC Resource Kit CD-ROM (P/N 86948). The MLX_3530_SAController.RSS project file is the one pertaining to the MicroLogix PLC.

4. In the MAIN ladder file, go to rung 0001 and set the SBR File number to U:4 to use PID control (See Learning Unit 1 and following for details). Save the file.

5. Double-click on LAD 4 – PID in the project tree in order to open the PID subroutine.



Figure 29: Setting the SBR File Parameter to U:4 for PID control.

6. Go to rung 0002 in the LAD4-PID ladder file. This rung contains the PID instruction. Observe that it stores parameters in the PD9 data file. Also, the input (PV) is read from integer file N7 at the address N7:4 and the output is written to an integer variable at the address N7:6.

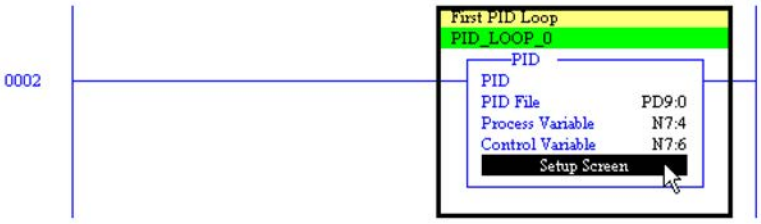


Figure 30: The PID instruction in the LAD4 - PID ladder file.

The PID instruction works in a 0-16383 range as 14 bits are used. Appropriate scaling is performed by the program to take this into account.

7. Double-click on the Setup Screen option in the PID instruction to open the window where you will be able to set all parameters, except the **set point** (the set point will be adjusted in a different manner).

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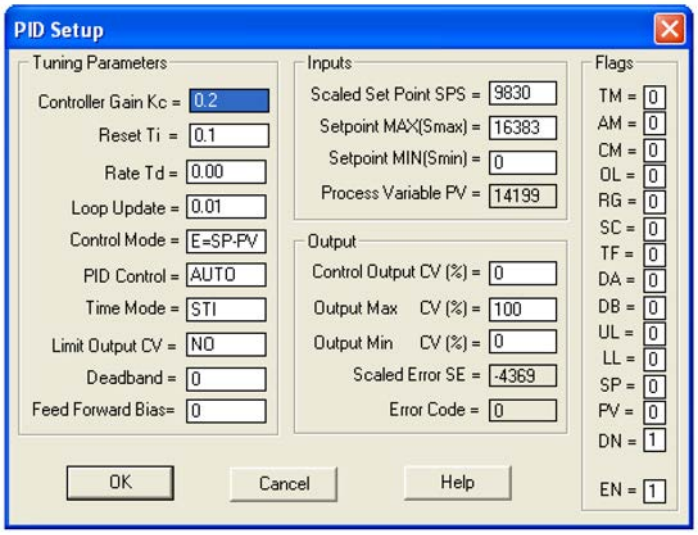


Figure 31: The PID Setup window.

The main parameters of this menu are detailed in the following table. The parameters related to PID control should be adjusted now before going online even though they can be modified later once the controller is running the program. If you plan to use a tuning method for your controller, set the controller to the appropriate control mode (either Manual or Auto) and enter relevant initial values for the tuning parameters (K_c, T_i, and T_d).

Table 4: User-adjustable parameters for PID control.

Parameter	Description
Tuning Parameters	Includes the controller gain K_c (ranging from 0 to 3276.7), the reset time T_i (min/repeat), and the rate time T_d (min). The values must be entered with the correct number of digits. If you type 15 for K_c, it will be interpreted as 1.5
Control Mode	Choose either direct (E = PV-SP) or reverse (E = SP–PV) action for the controller.
PID Control	Can be set to either Auto or Manual. In automatic operation, the PID instruction controls the control variable (CV). In manual operation, the user/control program controls the CV.

Parameter	Description
Control Output CV (%)	Monitors the value (in %) of CV while in Automatic mode. Allows you to specify the required CV (from 0 to 100%) while in Manual mode. Changing the value of CV with this parameter is also used to perform step changes.
Time Mode	STI or Timed. In STI mode, the PID loop is updated every time the PID instruction is scanned. In timed mode, the instruction is updated at a fixed time interval. Default is STI.
Loop Update Time	Time interval between PID calculations in timed mode. Must also be equal to the STI time interval value. Default is 0.01 second.
Deadband	The deadband extends above and below the set point by the value entered. The range goes from 0 to 16383.
Feed Forward Bias	This parameter is used to adjust the value of CV, especially when no reset action is used.

The last parameter is the set point. This parameter should not be set from the PID Setup window as it is simpler to work with the version scaled in a 0-100% range. To edit the set point, go in the N10 data file and edit parameter N10:1. Learning Unit 3, step 6 for details.

Table 5: The Setpoint parameter.

Parameter	Address	Description
Setpoint	N10:1	Target value of PV. Can be set between 0 (0%) and 10000 (100%).

Adjust the parameters as required for your process. You can modify them later if necessary. Save the changes to the project file.

8. This project requires you to connect an emergency button for increased safety. If the PLC digital input 0 is not powered, all processes are shut down. Connect digital input 0 of your PLC to a 24 V dc switched output source on the electrical unit of the Instrumentation and Process Control Training System. The switched output jacks are the ones which become unpowered when the emergency button is pressed.

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Running the PLC control program

9. Download your project to the PLC and go online. Follow the procedure in Learning Unit 1, steps 8 to 13 if needed.

10. The analog output and the analog input can be monitored from the O0 – OUTPUT and the I1 – INPUT data files as shown in the following figures (data may vary depending on the PLC mode used). Setting the radix to decimal helps in interpreting the results.

As previously explained, the inputs and outputs are in a 3120-15600 range. You may prefer to monitor N7:0 (input) and N7:2 (output) which use a 0-10000 scale.

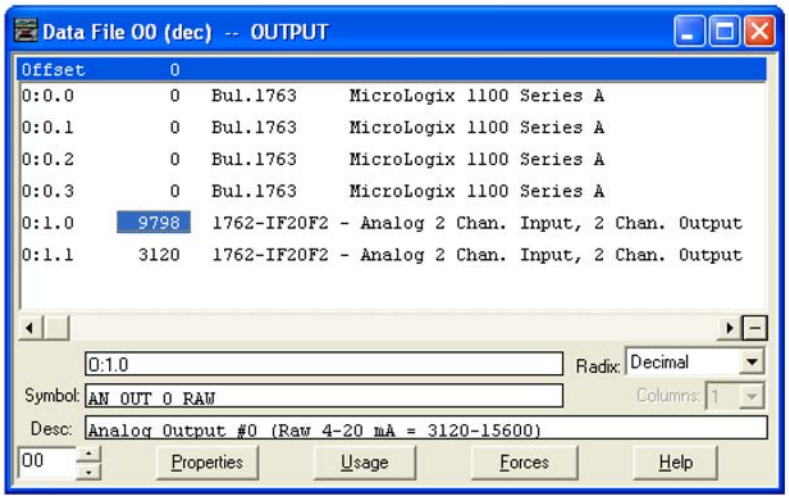


Figure 32: Expansion card analog output monitoring (channel 0 corresponds to O:1.0).

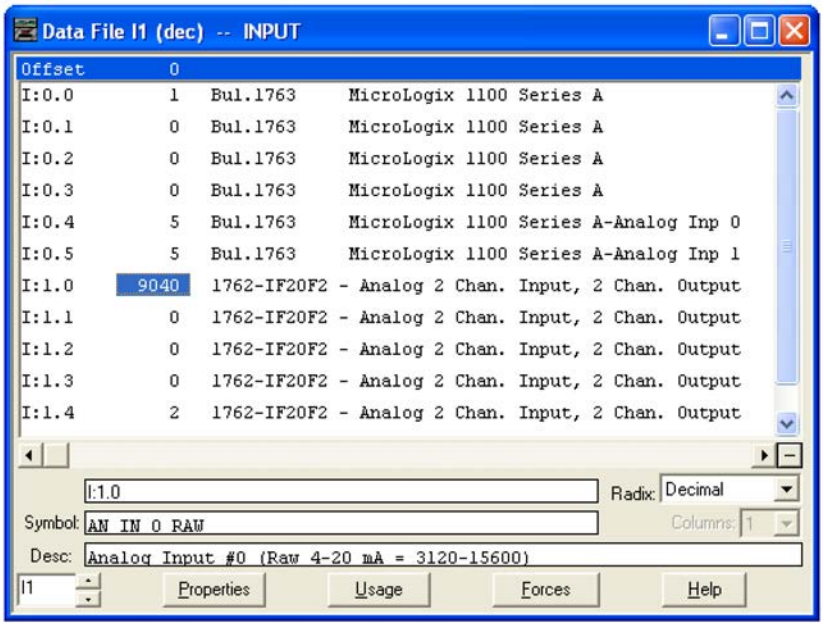


Figure 33: Expansion card analog input monitoring (channel 0 corresponds to I:1.0).

11. Perform the tuning of your PID loop by either adjusting the tuning parameters while in Auto mode (Trial-and-error or ultimate-cycle method), or by performing a step change in Manual mode and proceeding with the Ziegler-Nichols calculations. In any case, fine-tune your process so it meets your control expectations.

Using the PID standard trend (optional)

12. It is possible to use a graphical interface to plot the different variables of interest from this process. To do so, go into the Trends section of the project tree and double-click on the trend related to your process in order to obtain a preconfigured graph.

    The graph will look like the one shown in Figure 35. Note that you can make changes to a specific chart by right-clicking on the graph area of the chart and selecting the Chart Properties menu.

    To export data, simply right-click on the graph area of the chart and select Create Snapshot... This allows you to save the data to a .dbf file which can be opened with Excel. The whole time span set in the properties of the graph (Chart Properties -> x-axis tab -> Time span) will be exported to the .dbf file. Adjust the time span **prior** to recording a process.

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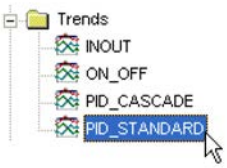


Figure 34: Opening the PID_STANDARD trend from the Trends menu.

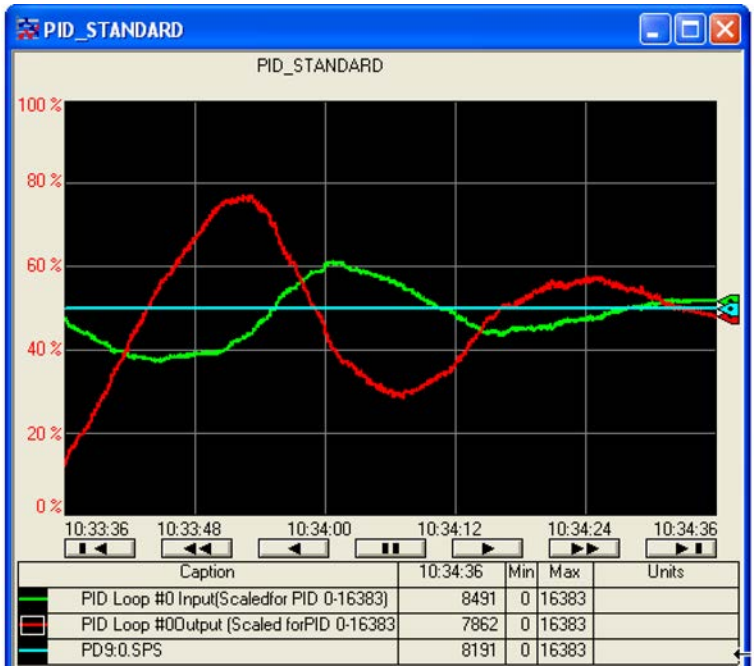


Figure 35: The PID_STANDARD trend.

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Cascade Control

Cascade control is a type of control which can be very useful when a fast-changing secondary process variable yields information about the behavior of the primary variable. The added information results in tighter control and the ensuing cascade scheme typically yields better overall performances. This type of control can be implemented on a MicroLogix PLC simply by combining two PID control instructions.

Two analog inputs and one analog output are used for the two process variables (PV) and for the control variable (CV) respectively. A series of parameters must be set according to the needs of the process. Note that RSLogix 500 only offers the dependent form of the PID equation.

It is essential that you be familiar with PID control on a MicroLogix PLC before using cascade control. Refer to Learning Unit 1 as necessary.

Connecting the PLC to the process loop

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

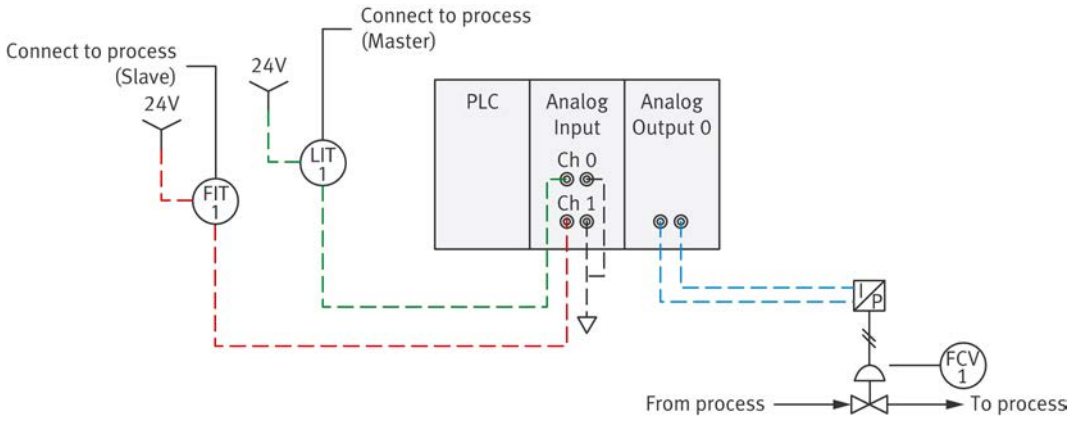


Figure 36: Typical connection of a PLC for cascade control.

Configuring the PLC for cascade control

2. Make sure the PLC and your computer are set up as explained in Learning Unit 1. RSLinx should be working and displaying your PLC in the RSWho window.

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3. Launch RSLogix 500 and load the provided PLC project file that is appropriate for your controller.

You can find the project files on the PLC Resource Kit CD-ROM (P/N 86948). The MLX_3530_SAController.RSS project file is the one pertaining to the Micro-Logix PLC.

4. In the MAIN ladder file, go to rung 0001 and set the SBR File number to U:5 to use cascade control (See Learning Unit 1 and following for details). Save the file.



Figure 37: Setting the SBR File Parameter to U:5 for cascade control.

5. Double-click on LAD 5 – CASCADE in the project tree in order to open the cascade subroutine.

6. Go to rungs 0005 and 0006 in the LAD5-CASCADE ladder file. Those rungs contain the two PID instructions required for cascade control.

   Observe that the first PID instruction stores parameters in the PD9:0 register. Also, its input (PV) is read from integer file N7 at the address N7:4 and the output is written to an integer variable at the address N7:6. This loop is the master loop of the cascade scheme.

   The second PID instruction (the slave loop) uses register PD9:1, one input (PV, stored in N7:5), and one output (CV, stored in N7:7).

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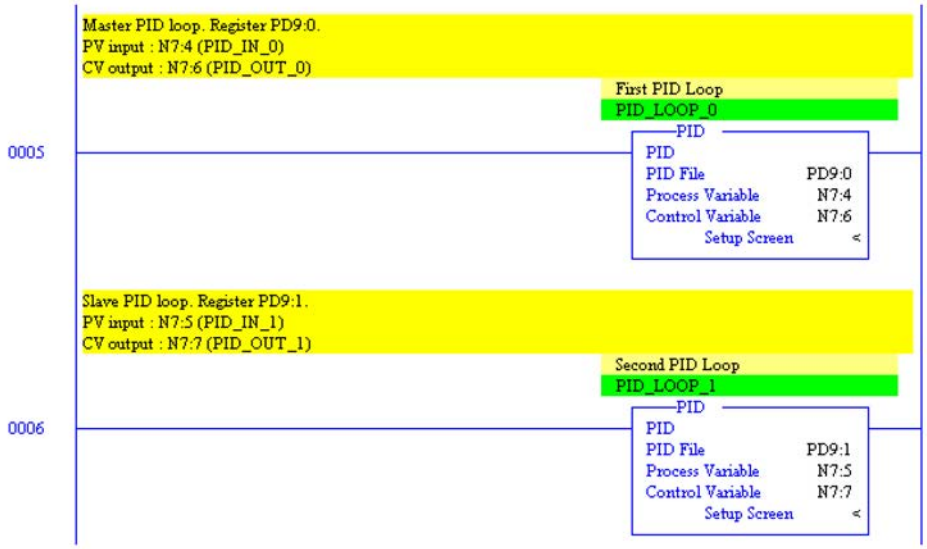


Figure 38: The PID instructions in the LAD5 - CASCADE ladder file.

The numerous changes of variable and the different scales involved might be confusing at first. Keep in mind that the master loop basically uses analog input 0 as its process variable. The slave loop uses analog input 1 as its process variable and analog output 0 as the control variable.

The output of the master loop will be used (when in cascade mode) as the set point of the slave loop. This output does not have any other use and is simply ignored when the cascade mode is inactive. The following figure shows how rung 0004 moves the output of the master loop to the set point of the slave loop. This is done when bit B3:0/1 is set to 1.



Figure 39: Rung 0004 of the CASCADE routine.

7. Make sure bit B3:0/1 in the B3-Binary data file is reset to 0 (meaning that cascade mode is not activated).

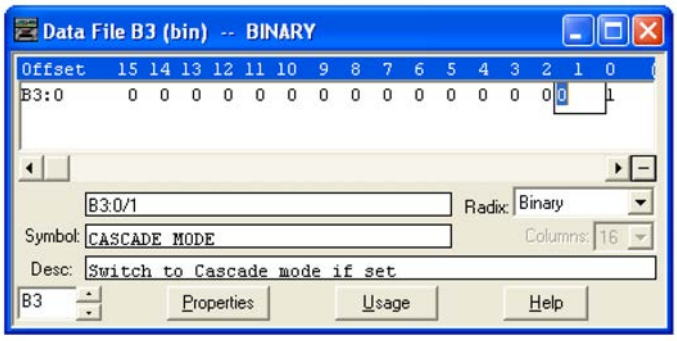


Figure 40: The B3 - BINARY data file.

8. The master and slave loops (rungs 0005 and 0006) should both be in manual mode for now. Adjust the other parameters (such as the action and the tuning parameters) to allow a smooth transition once online. Refer to step 7 of Learning Unit 4 for details on how to change the parameters of a PID loop if necessary.

   Note that the set points for the two PID loops are stored in the N10-OPERATION data file (See the following figure). The N10:5 integer stores the set point of the slave loop (when the cascade mode is not activated) and N10:4 stores the set point of the master loop. Both are defined in a 0-10000 range (0.00-100.00%). This is where the set points must be changed when required.

   Save the changes to the project file.

9. This project requires you to connect an emergency button for increased safety. If the PLC digital input 0 is not powered, all processes are shut down. Connect digital input 0 of your PLC to a 24 V dc switched output source on the electrical unit of the Instrumentation and Process Control Training System. The switched output jacks are the ones which become unpowered when the emergency button is pressed.

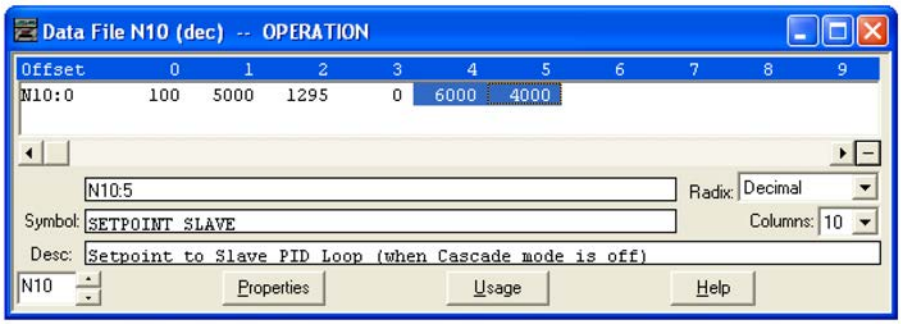


Figure 41: The N10 - OPERATION data file (N10:4 and N10:5 are the set points).

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Downloading the PLC control program

10. Download your project to the PLC and go online. Follow the procedure in Learning Unit 1, steps 8 to 13 if needed.

11. The analog output and the analog inputs can be monitored from the O0 – OUTPUT and the I1 – INPUT data files as shown in the following figures. The analog input of the master loop is I:1.0 and the analog input of the slave loop is I:1.1. Setting the radix to decimal helps in interpreting the results.

As previously explained, the inputs and outputs are in a 3120-15600 range. You may prefer to monitor N7:0 and N7:1 for the inputs and N7:2 and N7:3 for the outputs which all use a 0-10000 scale (0-100%).

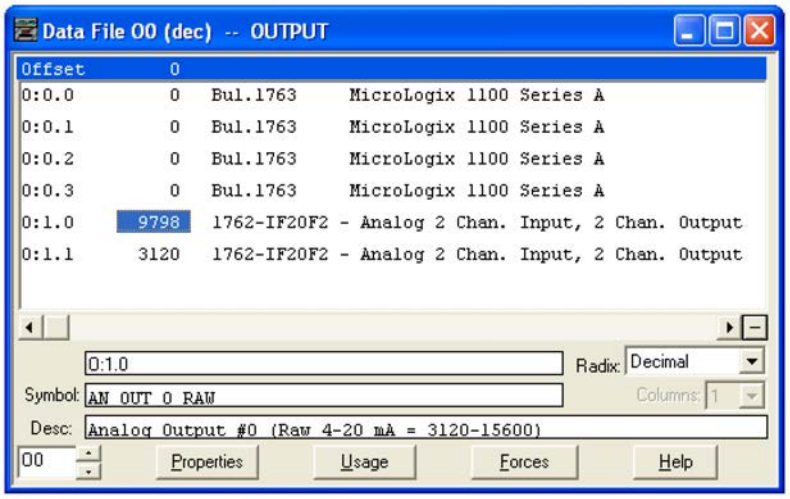


Figure 42: Expansion card analog output monitoring (channel 0 corresponds to O:1.0).

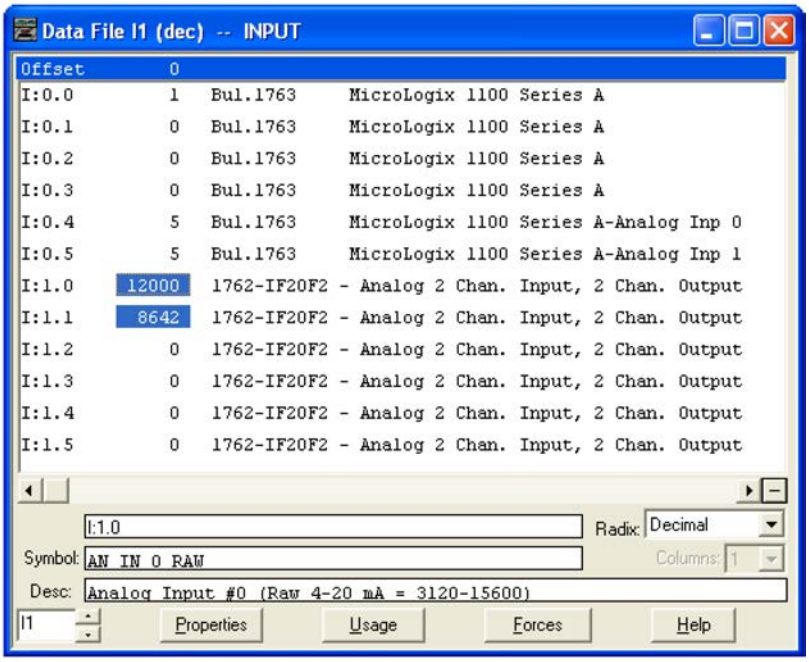


Figure 43: Expansion card analog input monitoring (channel 0 and 1 corresponds to I:1.0 and I:1.1).

Tuning the control loops

Tuning the slave loop

12. Perform the tuning of the PID slave loop by either adjusting the tuning parameters while in Auto mode, or by performing a step change in Manual mode and proceeding with the Ziegler-Nichols calculations. In any case, fine-tune your process so it meets your control expectations.

    Keep in mind that the slave and the master loops work on different variables. In the archetypical example, the slave loop controls the flow going into a tank while the master loop controls the level in the tank.

    Once the slave loop is tuned, leave it in Auto mode and set bit B3:0/1 to 1 to activate Cascade mode. The master loop now controls the set point of the slave loop.

Tuning the master loop

13. Perform the tuning of the PID master loop by either adjusting the tuning parameters while in Auto mode, or by performing a step change in Manual mode and proceeding with the Ziegler-Nichols calculations. In any case, fine-tune your process so it meets your control expectations.

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Leave the master loop in Auto mode. The PLC is now controlling your process in cascade.

Using the PID cascade trend (optional)

14. It is possible to use a graphical interface to plot the different variables of interest from this process. To do so, go into the Trends section of the project tree and double-click on the trend related to your process in order to obtain a preconfigured graph.

    The process variables relevant to cascade control will look like those shown in the following figure (curves are not actual experimental results). Note that you can make changes to a specific chart by right-clicking on the graph area of the chart and selecting the Chart Properties menu.

    To export data, simply right-click on the graph area of the chart and select Create Snapshot... This allows you to save the data to a .dbf file which can be opened with Excel. The whole time span set in the properties of the graph (Chart Properties -> x-axis tab -> Time span) will be exported to the .dbf file. Adjust the time span **prior** to recording a process.

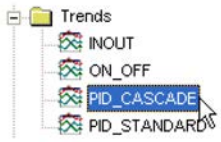


Figure 44: Opening the PID_CASCADE trend from the Trends menu.

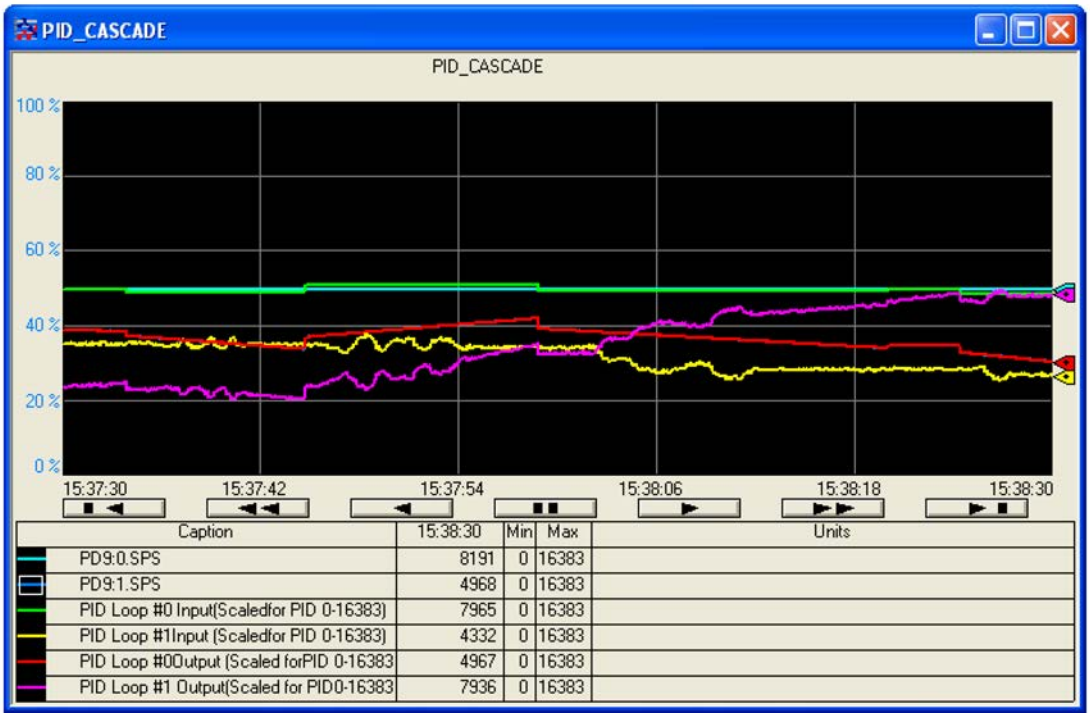


Figure 45: The PID_CASCADE trend.

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Ratio Control

The MicroLogix PLC controller can be used to perform ratio control whenever you need to maintain a certain ratio between two process variables, often two fluid flows. This section explains how to configure your controller to use a ratio set point with proficiency.

Suppose we have two measurement variables, A (process 1) and B (process 2), that represent the flow of two different fluids that you want to mix together while keeping a strict proportion R between the two flows so that:

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

The first step is to adjust the parameters of the controller to control the process variable A. Once the controller is correctly tuned, program a ratio set point such that $SP_{\mathrm{A,Ratio}} = B \cdot R$. This ensures that the targeted value of A is always in the proper proportion with respect to B.

Connecting the PLC to the process loop

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

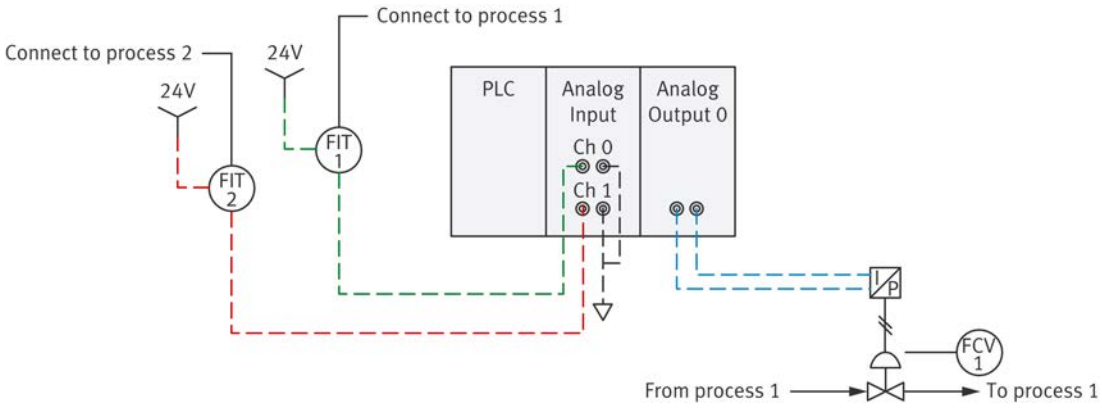


Figure 46: Typical connection of a PLC for ratio control.

Configuring the PLC for ratio control

2. Make sure the PLC and your computer are set up as explained in Learning Unit 1. RSLinx should be working and displaying your PLC in the RSWho window.

3. Launch RSLogix 500 and load the provided PLC project file appropriate to your controller.

You can find the project files on the PLC Resource Kit CD-ROM (P/N 86948). The MLX_3530_SAController.RSS project file is the one pertaining to the Micro-Logix PLC.

4. In the MAIN ladder file, go to rung 0001 and set the **SBR File number** to U:6 to use ratio control (See Learning Unit 1 and following for details). Save the file.



Figure 47: Setting the SBR File Parameter to U:6 for ratio control.

5. Double-click LAD 6 – RATIO in the project tree in order to open the RATIO subroutine.

6. The variables you will need to edit to use the ratio routine are:

   The RatioMode variable should be reset to 0 to allow you to tune the controller before using the ratio mode. Also set the Setpoint and Ratio variables to appropriate values (e.g., 5000 and 0.75, respectively).

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Table 6: The ratio routine parameters.

Variable	Address	Description
RatioMode	B3:0/2	Target value of PV. Can be reset to 0 to use a normal set point or it can be set to 1 to use the ratio mode.
Setpoint	N10:4	Target value of PV_1 . Can be set between 0 (0%) and 10 000 (100%). Used when RatioMode is reset to 0.
Ratio	F8:0	The value of the Ratio variable times PV_2 becomes the target value of PV_1 . Used when RatioMode is set to 1.

7. Go to rung 0004 in the LAD6-RATIO ladder file. This rung contains the PID instruction. Observe that it stores parameters in the PD9 data file. Also, the input (PV) is read from integer file N7 at the address N7:4 and the output is written to an integer variable at the address N7:6.

   You can access the Setup Screen menu of the PID loop and edit the parameters to appropriate initial values at this point.

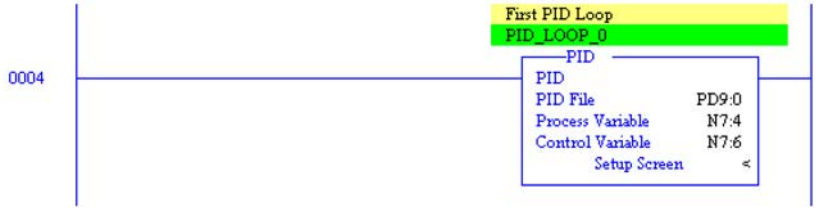


Figure 48: The PID instruction in the LAD6 - RATIO ladder file.

8. This project requires you to connect an emergency button for increased safety. If the PLC digital input 0 is not powered, all processes are shut down. Connect digital input 0 of your PLC to a 24 V dc switched output source on the electrical unit of the Instrumentation and Process Control Training System. The switched output jacks become unpowered when the emergency button is pressed.

Running the PLC control program

9. Download your project to the PLC and go online. Follow the procedure in Learning Unit 1, steps 8 to 13 if needed.

10. The analog output and the analog inputs can be monitored from the O0 – OUTPUT and the I1 – INPUT data files, as shown in the following figures. Setting the radix to decimal helps in interpreting the results.

As previously explained, the inputs and outputs are in a 3120-15600 range. You may prefer to monitor N7:0 and N7:1 (inputs), or N7:2 (output), which use a 0-10000 scale.

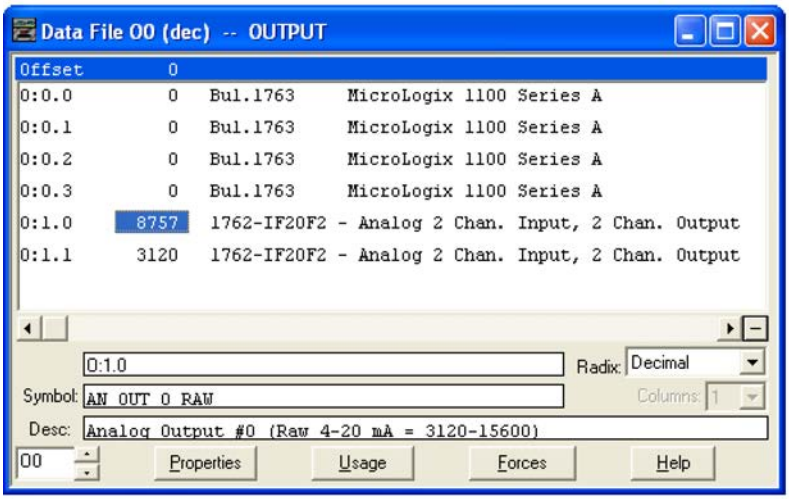


Figure 49: Expansion card analog output monitoring (channel 0 corresponds to O:1.0).

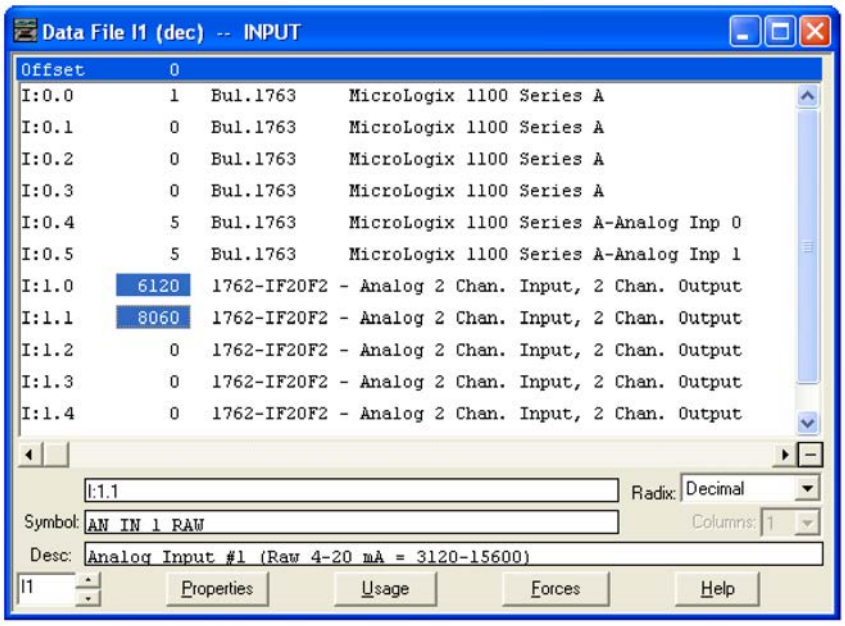


Figure 50: Expansion card analog input monitoring (channel 0 and 1 correspond to I:1.0 and I:1.1 respectively).

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11. Perform the tuning of your PID loop so the first variable (A) is properly controlled. Make sure the RatioMode variable is reset to *0*. Refer to Learning Unit 1 if you need information on how to tune your PID loop. The set point of the loop is linked to variable N10:4 at this point.

12. Once the loop is properly tuned, set the Ratio variable (F8:0) to the desired value and set RatioMode (B3:0/2) to *1* to enable the ratio mode. The set point of your PID loop is now equal to the Ratio variable times PV_B (i.e., PV_2).

    Your controller is now operating in ratio mode.

Using the ratio trend (optional)

13. It is possible to use a graphical interface to plot the different variables of interest related to this process. To do so, go into the Trends section of the project tree and double-click the trend related to your process in order to obtain a preconfigured graph.

    Note that you can make changes to a specific chart by right-clicking the graph area of the chart and selecting the Chart Properties menu.

    To export data, simply right-click the graph area of the chart and select Create Snapshot... This allows you to save the data to a .dbf file which can be opened with Excel. The whole time span set in the properties of the graph (Chart Properties -> x-axis tab -> Time span) is exported to the .dbf file. Adjust the time span **prior** to recording a process.

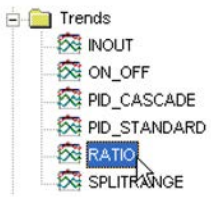


Figure 51: Opening the RATIO trend from the Trends menu.

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Split-Range Control

This section explains how to configure your controller to perform split-range control with proficiency.

A PLC controller such as a MicroLogix allows you to split the range of the controller output to two analog 4-20 mA outputs. (A controller with more analog outputs could split the total range of the controller output into even more sections.) This is performed in specific schemes to control a single process variable with distinct control variables. **A distinct control element is required for each control variable used.**

In this split-range control routine, the total range of the controller is split into two different, customizable parts. In the example given in the following figure, two ranges are configured. As can be seen, the output signal AOUT0 increases as CV goes from 0 to the split point (e.g., 50%). Then, AOUT1 increases as CV goes from the split point up to 100%.

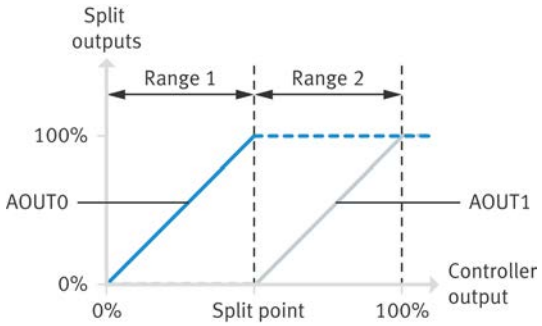


Figure 52: Example of a split-range application.

Such a scheme gives a lot of flexibility to accommodate different processes. The split-range tasks pre-programmed for your PLC feature a total of two output variables. You can adjust the range of operation of the variables, as well as their direction of operation (direct or reverse).

Note that the PID tuning parameters of each of the PID loops must be set to the same values in order to perform the experiments suggested in the Advanced Process Control manual. Using different sets of tuning parameters for each range gives you more flexibility and allows you to explore the effects involved, but this is entirely optional.

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Connecting the PLC to the process loop

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

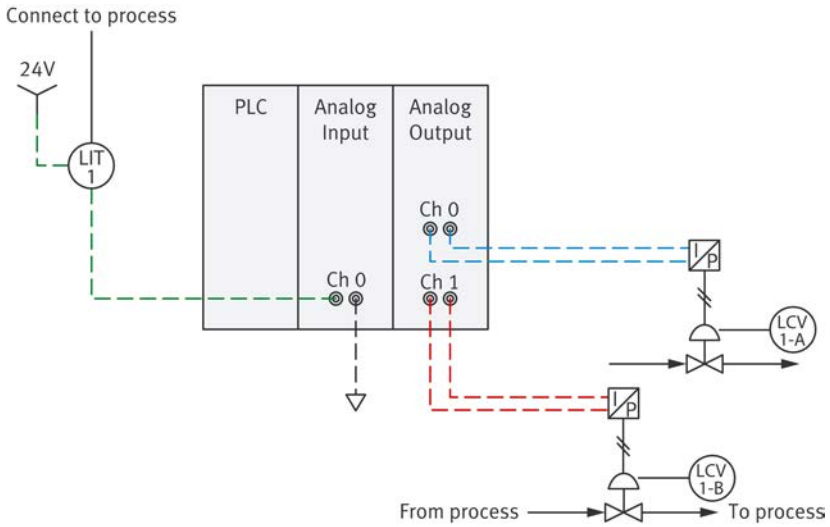


Figure 53: Typical connection of a PLC for split-range control.

Configuring the PLC for split-range control

2. Make sure the PLC and your computer are set up as explained in Learning Unit 1. RSLinx should be working and displaying your PLC in the RSWho window.

3. Launch RSLogix 500 and load the provided PLC project file appropriate to your controller.

You can find the project files on the PLC Resource Kit CD-ROM (P/N 86948). The MLX_3530_SAController.RSS project file is the one pertaining to the MicroLogix PLC.

4. In the **MAIN** ladder file, go to rung 0001 and set the **SBR File number** to U:7 to use split-range control (see Learning Unit 1 and following for details). Save the file.

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Figure 54: Setting the SBR File Parameter to U:7 for split-range control.

5. Double-click LAD 7 – SPLITRANGE in the project tree in order to open the split-range control subroutine.

6. The relevant variables to use the split-range routine are indicated in the following table.

   Adjust the Setpoint variable to an appropriate value (e.g., 5000 (50%)). Set the INV_OUT_0 and INV_OUT_1 variables as required by your process. It is possible to adjust those parameters at any later time, as well.

Table 7: The split-range routine parameters.

Variable	Address	Description
Setpoint	N10:4	Target value of PV. Can be set between 0 (0%) and 10000 (100%).
INV_OUT_0	B3:0/3	When this parameter is set to 1, output 0 is inverted. Default value is reset to 0.
INV_OUT_1	B3:0/4	When this parameter is set to 1, output 1 is inverted. Default value is reset to 0.

7. Go to rungs 0002 and 0003 in the LAD7-SPLITRANGE ladder file. Each rung contains a PID instruction. Observe that it stores parameters in the PD9 data files. The first loop uses file PD9:0 while the second one uses file PD9:1.

   Both loops use the same input (PV) read from integer file N7 at the address N7:4. Each loop has an output written in either variable N7:6 or N7:7.

   You can access the Setup Screen menu of each PID loops and edit the parameters to appropriate initial values at this point. Remember that both PID loops should be configured exactly in the same way (tuning parameters, action...).

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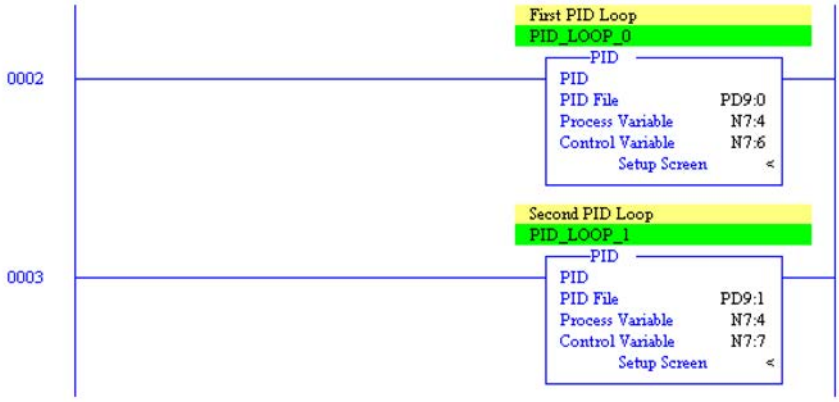


Figure 55: The PID instruction in the LAD6 - RATIO ladder file.

8. This project requires you to connect an emergency button for increased safety. If the PLC digital input 0 is not powered, all processes are shut down. Connect digital input 0 of your PLC to a 24 V dc switched output source on the electrical unit of the Instrumentation and Process Control Training System. The switched output jacks are the ones which become unpowered when the emergency button is pressed.

Running the PLC control program

9. Download your project to the PLC and go online. Follow the procedure in Learning Unit 1 , steps 8 through 13, if needed.

10. The next step is to adjust the range of operation of the two outputs of the split-range control scheme. Go to rungs 0004 (for output 0) and 0007 (for output 1), and observe that the Input Min. and Input Max parameters of each SCP instructions are linked to variables in file N11 (the following figure).

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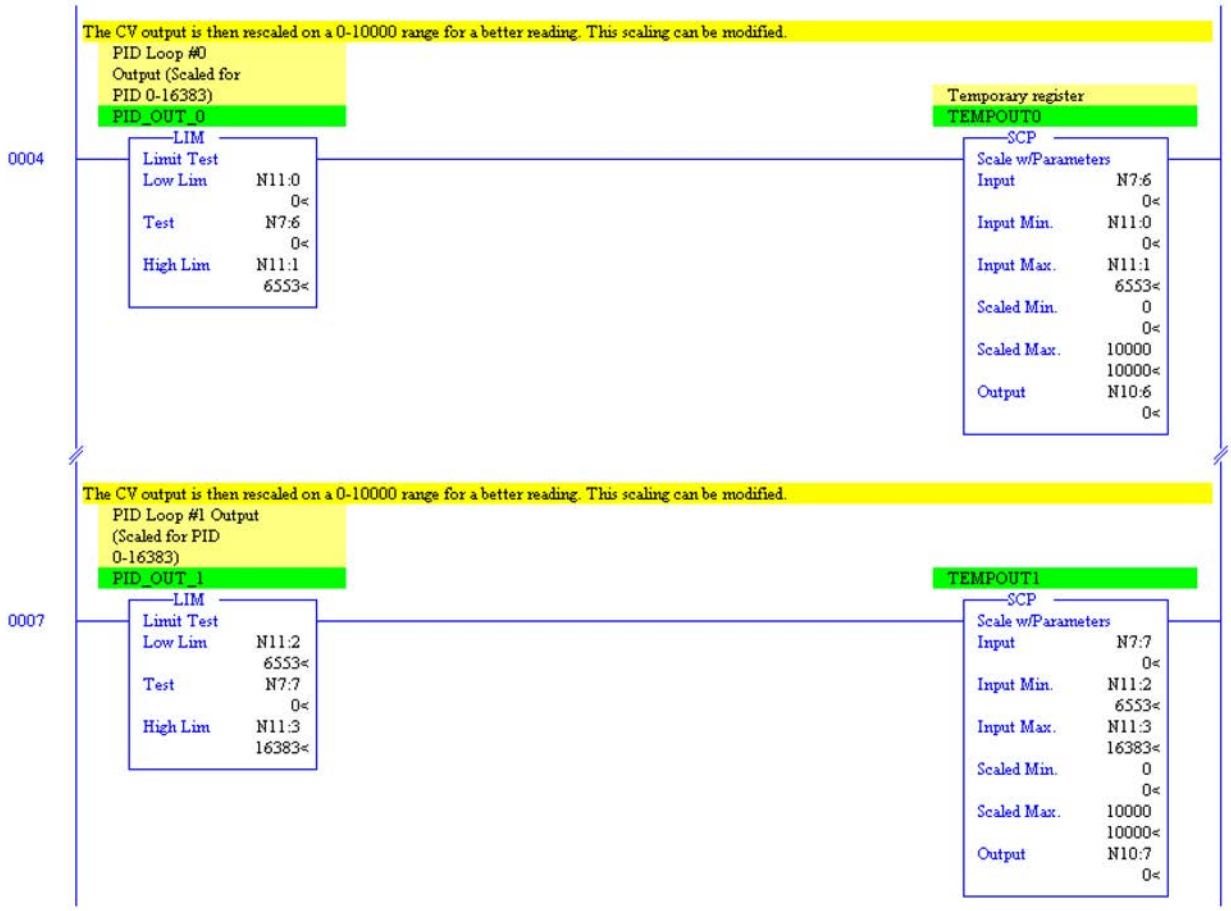


Figure 56: The scaling functions in a split-range routine.

Leave the Scaled Min. and Scaled Max. parameters to their default values of 0 and 10000. To change the limits of operation of the output variables, open file N11 – SPR_LIMITS and edit the four variables.

Table 8: The N11 data file parameters.

Variable	Address	Description
AN_OUT_0_IN_MIN	N11:0/0	Value at which output 0 starts to change.
AN_OUT_0_IN_MAX	N11:0/1	Value at which output 0 ceases to change.
AN_OUT_1_IN_MIN	N11:0/2	Value at which output 1 starts to change.
AN_OUT_1_IN_MAX	N11:0/3	Value at which output 1 ceases to change.

Consequently, if you want output 1 to be active, for example, from 0 to 40% and output 2 to be active from 40 to 100%, adjust the parameters as shown in the following figure. Remember that the control variables vary from 0 to 16383 out of the PID instructions and that 40% corresponds to 16383 times 0.40 = 6553.

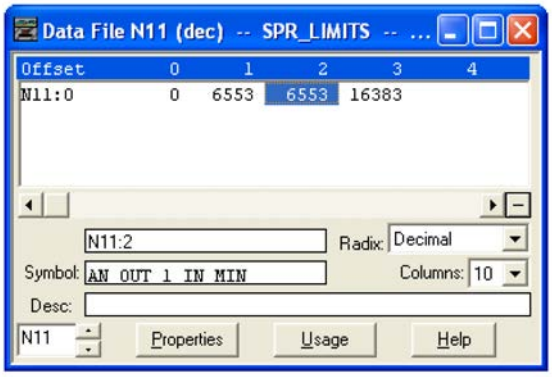


Figure 57: Editing the N11 parameter file.

11. The analog outputs and the analog input can be monitored from the **O0 – OUTPUT** and the **I1 – INPUT** data files, as shown in the following figures. Setting the radix to decimal helps in interpreting the results.

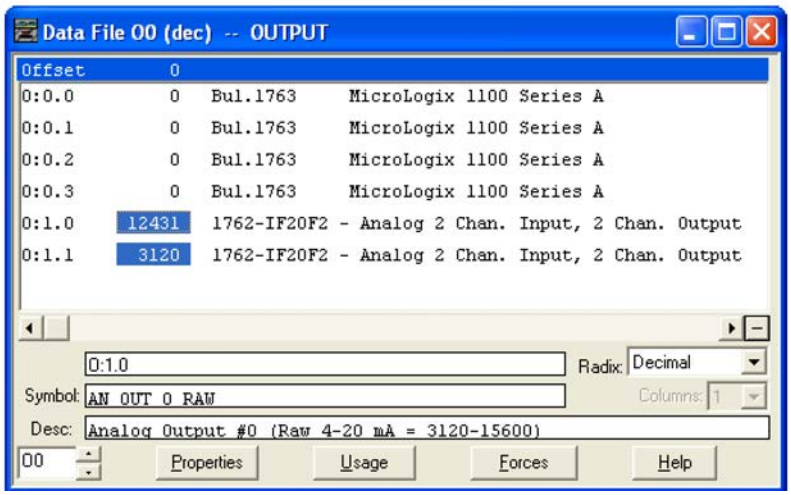


Figure 58: Expansion card analog output monitoring (channel 0 and 1 correspond to O:1.0 and O:1.1 respectively).

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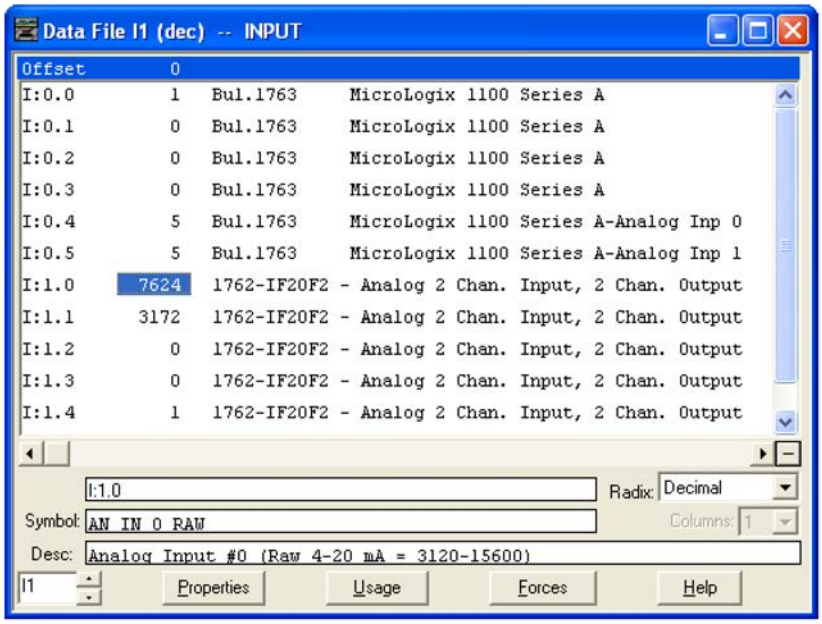


Figure 59: Expansion card analog input monitoring (channel 0 corresponds to I:1.0).

As previously explained, the final inputs and outputs are in a 3120-15600 range. You may prefer to monitor N7:0 (input), and N7:2 and N7:3 (outputs) which use a 0-10000 scale.

12. Perform the tuning of your PID loop by either adjusting the tuning parameters while in Auto mode (Trial-and-error or ultimate-cycle method), or by performing a step change in Manual mode and proceeding with the Ziegler-Nichols calculations. In any case, fine-tune your process so it meets your control expectations.

    Remember to tune both loops using the exact same tuning parameters.

Using the split-range trend (optional)

13. It is possible to use a graphical interface to plot the different variables of interest for this process. To do so, go into the Trends section of the project tree and double-click the trend related to your process in order to obtain a preconfigured graph.

    To export data, simply right-click the graph area of the chart and select Create Snapshot... This allows you to save the data to a .dbf file, which can be opened with Excel. The whole time span set in the properties of the graph (Chart Properties -> x-axis tab -> Time span) is exported to the .dbf file. Adjust the time span **prior** to recording a process.

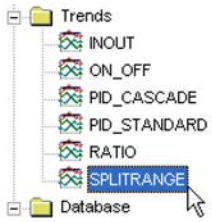


Figure 60: Opening the SPLITRANGE trend from the Trends menu.

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MicroLogix PLC

This PLC is manufactured by Rockwell and is part of the MicroLogix family. It is a simple model that has been divided into a main PLC and an expansion module dedicated to analog I/O. The PLC can be wired to different devices and electrical elements using either the banana jacks or the terminal screws available on the panel. The following figure shows the main elements of the MicroLogix 1100 PLC, Model 46964 and MicroLogix 1400 PLC, Model 46964-10. A brief description and the technical specifications are given below and in the following subsections for each PLC component.

1. Communication ports
2. PLC module
3. Analog I/O expansion module
4. Digital input terminals
5. Digital output terminals
6. Analog input terminals
7. Analog output terminals
8. Power-input connectors
9. Fault panel at the back of the module

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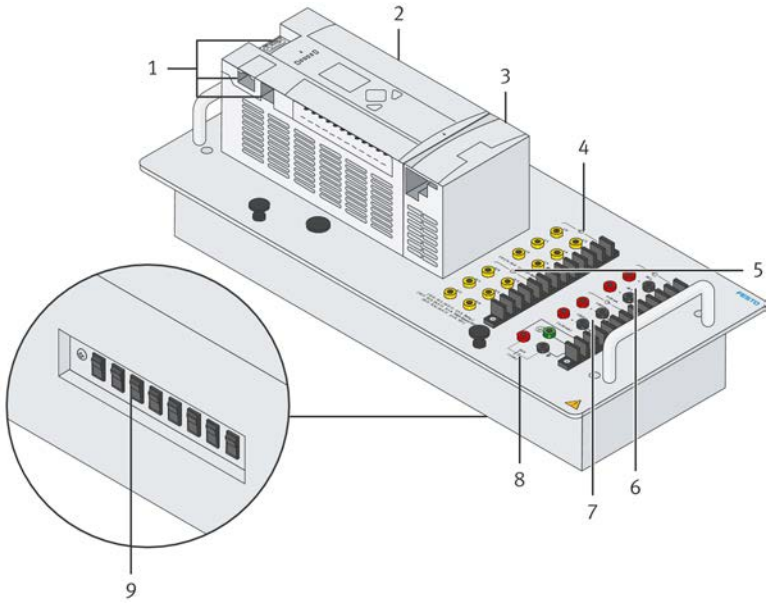


Figure 61: MicroLogix 1400 PLC, Model 46964-10.

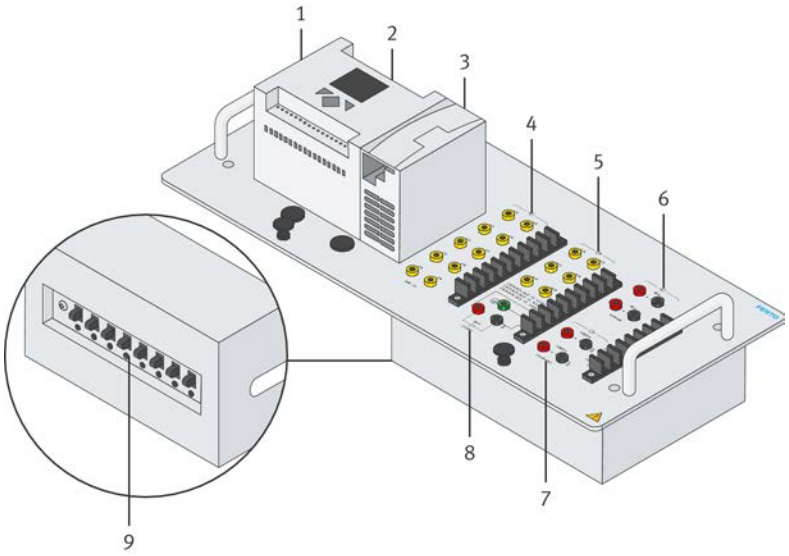


Figure 62: MicroLogix 1100 PLC, Model 46964.

Communication ports

The MicroLogix 1100 has two communication ports: one RS-232/RS-485 combo port and one Ethernet port, both located on the left side of the PLC. The MicroLogix 1400 features three communication ports: one RS-232/RS-485 combo port and one Ethernet port located at the bottom. An additional RS-232 port is also available on the front panel.

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The isolated RS232/485 communication port (channel 0) can be used to connect the PLC to a PC with a DF1 full duplex protocol. A special cable is required for this connection. The Ethernet port (channel 1) is the preferred way to communicate with your PLC from a computer. The IP address of your PLC can be displayed along with the MAC address on the LCD screen by going into the menu and choosing: Advanced Set -> ENET Cfg.

Table 9: Ethernet port specifications.

Characteristic	Value
Transfer speed	10/100 Mb/s
Ethernet connector	RJ45 Cat. 5
Isolation voltage (continuous)	30 V
Default IP address	192.168.2.30
Default network mask	255.255.255.0

PLC module

The main module comprises all the components of a PLC in a compact system. It includes a power supply, the processor, memory, and the basic inputs and outputs.

A series of four LED indicators are located on the PLC at the left of the LCD. Those indicators give important information regarding the status of the PLC.

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Table 10: MicroLogix status LEDs.

LED	Color	Status
POWER	Off	No power input or there is a power-related error
	Green	Power on
RUN	Off	The PLC is not executing a user program
	Green	The PLC is executing the user program in run mode
	Flashing green	Transfer from the memory module in progress
FAULT	Off	No fault detected by the PLC
	Flashing Red	Fault(s) detected with the application
	Red	Fault(s) detected with the hardware
FORCE	Off	Forces are disabled
	Amber	Forces are enabled

The PLC also includes an LCD panel which can be used to monitor the status of the digital inputs and outputs, as well as to obtain information on the system. The default screen of the LCD after the start-up of the PLC is the one shown in the following figure. If you want to go back to that screen, press the ESC key to go to the main menu (you may have to press ESC a few times if you are in certain submenus), then choose I/O Status and press the OK key.

When displaying the I/O status, a darkened rectangle corresponds to a bit in the on position (set to 1) and a blank one to a bit in the off position (reset to 0). Read the manufacturer's guide for more information regarding the possibilities of the LCD.

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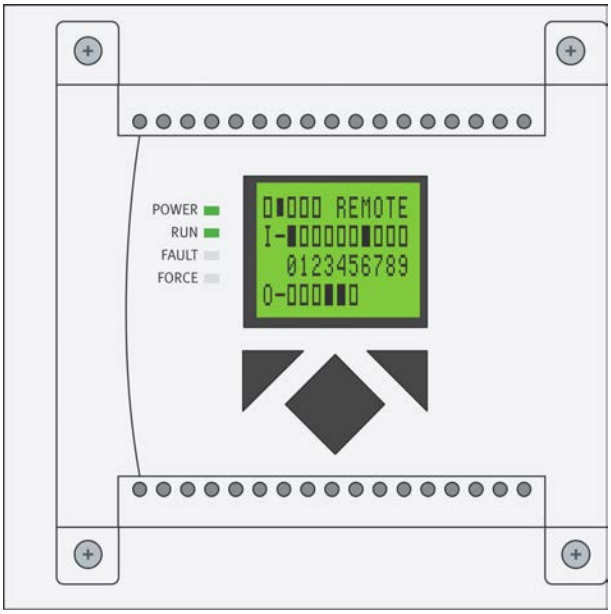


Figure 63: The LCD panel and the status LEDs.

The PLC has three modes of operation which can be selected from the LCD in the menu -> Mode Switch -> Program, or Run. The typical mode of operation is Remote.

Table 11: Controller module modes.

Mode	Description
RUN	The controller executes the program. No modification to the program is allowed in this mode.
REMOTE	The controller executes the program and it is possible to remotely program the PLC using RSLogix500. The PLC should remain in this mode to perform the exercises in the student manuals.
PROGRAM	The controller does not execute the program. Program changes can be downloaded to the PLC when this mode is selected.

Analog I/O expansion module

This expansion module adds analog capabilities to the MicroLogix PLC. Two analog input channels (6) are added as well as two analog output channels (7). The expansion module is connected directly to the main PLC and gets its power from the same supply.

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Digital input terminals

Digital inputs have the following specifications depending on the model of PLC you are using. The status of each input can be monitored on the LCD.

The MicroLogix 1400 PLC has 20 built-in digital inputs that provide on-off detection.

High-speed digital-input

- Inputs 0 through 11 are high-speed DC inputs able to operate at higher frequencies.

Table 12: High-speed digital-input specifications (ML1400).

Characteristic	Value
Number of inputs	12
On-state voltage range	4.5-24 V dc
Maximum off-state voltage	0 to 1.5 V dc
Nominal impedance	2 KΩ
Operating frequency	0–100 kHz

Standard digital-input

- Inputs 12 through 19 are standard DC inputs.

Table 13: Standard digital-input specifications (ML1400).

Characteristic	Value
Number of inputs	8
On-state voltage range	10-24 V dc
Maximum off-state voltage	0-5 V dc
Nominal impedance	5.5 KΩ
Operating frequency	0–1 kHz

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The MicroLogix 1100 PLC has 10 built-in digital inputs that provide on-off detection.

High-speed digital-input

- Inputs 0 through 3 are high-speed DC inputs able to operate at higher frequencies.

Table 14: High-speed digital-input specifications (ML1100).

Characteristic	Value
Number of inputs	4
On-state voltage range	14-24 V dc
Maximum off-state voltage	5 V dc
Nominal impedance	3.1 KΩ
Operating frequency	0–40 kHz

Standard digital-input

- Inputs 4 through 9 are standard DC inputs.

Table 15: Standard digital-input specifications (ML1100).

Characteristic	Value
Number of inputs	6
On-state voltage range	10-24 V dc
Maximum off-state voltage	5 V dc
Nominal impedance	3.1 KΩ
Operating frequency	0–1 kHz

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Digital output terminals

Digital outputs have the following specifications depending on the model of PLC you are using. The status of each output can be monitored on the LCD.

You can use any of these outputs in most situations, but in some specific cases the different specifications must be taken into account.

The MicroLogix 1400 PLC has 12 built-in digital outputs that provide on-off signals. There are three different types of outputs:

Relay outputs

- Outputs 0, 1, and 8 to 11 are ordinary relays.

Table 16: MicroLogix 1400 relay outputs specifications.

Characteristic	Value
Number of outputs	6
Maximum continuous current	2.5 A per channel
Minimum turn-on / turn-off time	10 ms / 10 ms
Maximum load	1080 VA

High-speed FET outputs

- Outputs 2, 3 and 4 are high-speed FET which can be used to output pulse trains or pulse-width modulations.

Table 17: MicroLogix 1400 high-speed FET outputs specifications.

Characteristic	Value
Number of outputs	3
Output voltage	24 V dc
Maximum turn-on / turn-off time	28 ns / 3.5 µs
Maximum load	0.1 A

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FET outputs

- Outputs 5 to 7 are FET outputs.

Table 18: MicroLogix 1400 FET outputs specifications.

Characteristic	Value
Number of outputs	3
Output voltage	24 V dc
Maximum turn-on / turn-off time	11 µs / 89 µs
Maximum load	1.5 A @ 30 deg C

The MicroLogix 1100 PLC has 6 built-in digital outputs that provide on-off signals. There are three different types of outputs:

Relay outputs

- Outputs 0 and 1 are ordinary relays.

Table 19: MicroLogix 1100 relay outputs specifications.

Characteristic	Value
Number of outputs	2
Output voltage	24 V dc
Minimum turn-on / turn-off time	10 ms / 10 ms
Maximum load	1.1 A

High-speed FET outputs

- Outputs 2 and 3 are high-speed FET which can be used to output pulse trains or pulse-width modulations.

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Table 20: MicroLogix 1100 high-speed FET outputs specifications.

Characteristic	Value
Number of outputs	2
Output voltage	24 V dc
Maximum turn-on / turn-off time	6 µs / 18 µs
Maximum load	0.1 A

FET outputs

- Outputs 4 and 5 are FET outputs.

Table 21: MicroLogix 1100 FET outputs specifications.

Characteristic	Value
Number of outputs	2
Output voltage	24 V dc
Maximum turn-on / turn-off time	0.1 ms / 1.0 ms
Maximum load	1.5 A

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Analog input terminals

The analog expansion module converts 4-20 mA input signals to digital values that can be used by the controller. The analog-input module has 2 inputs.

Table 22: Analog-input module specifications.

Characteristic	Value
Number of inputs	2
Input range	4-20 mA
Resolution (scaled for PID)	12 bits (using bits 2 to 13)
Impedance (current)	250 Ω

Analog output terminals

The analog expansion module converts digital values to 4 20 mA output signals. The analog-output module has 2 analog outputs.

Table 23: Analog-output module specifications.

Characteristic	Value
Number of outputs	2
Output range	4-20 mA
Resolution (scaled for PID)	12 bits (using bits 2 to 13)
Resistive load	0-500 Ω

Power-input connectors

Used to energize the PLC with a 24 V dc source. These connectors are internally linked to the PLC power supply. Be sure to connect the PLC to a 24 V dc output on the electrical unit that will not de-energize if the emergency push button is pressed (i.e., connectors 2 and 3 of the electrical unit). This ensures that the PLC will keep running in case of an emergency.

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Fault panel at the back of the module

There are eight 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.

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Installation and Configuration

Connecting the PLC to a computer

To use the MicroLogix 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 file required to use the MicroLogix as a process controller is provided with the system on the PLC Resource Kit CD-ROM (P/N 86948).

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

Installing the PLC software

The MicroLogix PLC uses a software called RSLogix 500, this software allows you to create, modify, and download projects to the PLC. In addition to RSLogix 500, two other pieces of software must be installed on your computer: RSLinx and FactoryTalk Activation Server. RSLinx enables Ethernet communication with the PLC while FactoryTalk Activation Server allows activation of the license for the software manufactured by Rockwell. All three software programs are available on the RSLogix 500 CD ROM. The list below summarizes the hardware and software required to use the PLC with your system.

- A compatible computer with at least one Ethernet port
- A switch, or a router, with two standard Ethernet cables or a cross-over Ethernet cable. *A cross-over cable is required to connect the PLC directly (without a switch or a router) to the Ethernet port of a computer.
- RSLogix 500 (software)
- RSLinx (software)
- FactoryTalk Activation Server (software)

The installation of the three aforementioned software components is quite straightforward; insert the RSLogix 500 CD ROM into your computer CD ROM drive and follow the instructions of the installation wizard. Following the installation wizard instructions without changing any of the default settings should install each of the three pieces of software correctly. Throughout the installation process, you will have to register your product using the serial number and product key provided with the RSLogix 500 CD ROM. The activation of this product is typically performed over an Internet connection, but alternatives are available (refer to the software documentation).

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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 you are using, you can connect it directly to the Ethernet card of your computer using a cross-over Ethernet cable. If you are using multiple Ethernet devices, you must connect a switch, or a router, to the Ethernet card of your computer and use regular Ethernet cables to connect the PLC and the other devices to the router. The following figure and Figure 65 illustrate the connections for both of these cases.

The PLC has a specific IP address and the IP address of the Ethernet card to which the PLC is connected must be compatible with the PLC IP address. Therefore, your computer must have an Ethernet card dedicated to the communication with the PLC. If you want your computer to be connected to a local network and to the PLC, your computer must be equipped with two Ethernet cards.

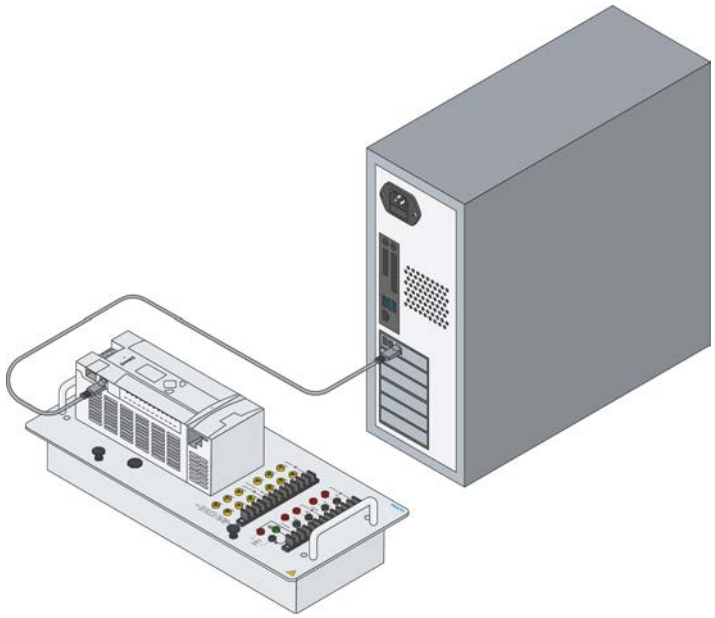


Figure 64: Connecting the PLC directly to your computer using a cross-over Ethernet cable.

How to configure your computer and the software for Ethernet communication with the PLC

Once the PLC is connected to your computer as described previously, you must configure your computer for use with the PLC. This implies configuring the Ethernet card, RSLinx, and RSLogix 500. You should have to go through this procedure only once if the PLC is connected to a dedicated Ethernet card on your computer.

1. Be sure the PLC is properly connected to your computer.

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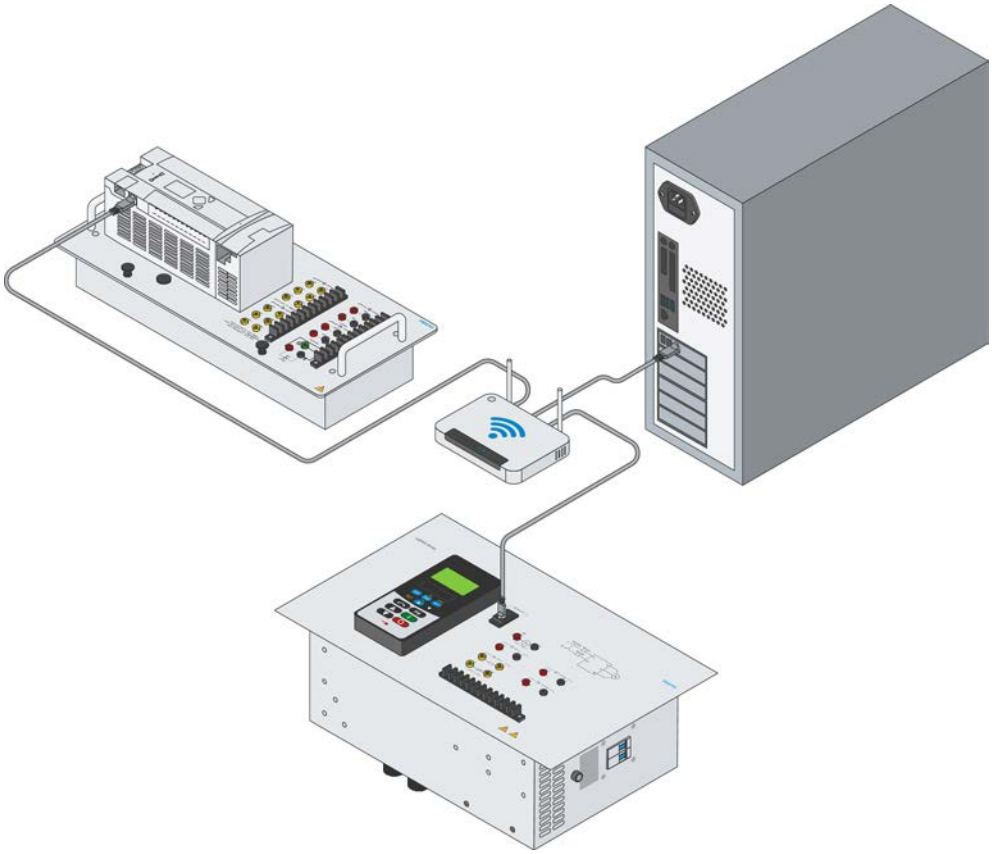


Figure 65: Connecting the PLC and other Ethernet devices to your computer via a switch or a router.

How to configure the Ethernet card

2. From the computer Control Panel, open the Network Connections folder and double-click on Local Area Connection to open the Local Area Connection Status window. This allows you to change your LAN (Local Area Network) parameters.

If there is more than one connection available in the Network Connections folder, make sure to double-click on the Local Area Connection associated with the Ethernet card to which the equipment is connected.

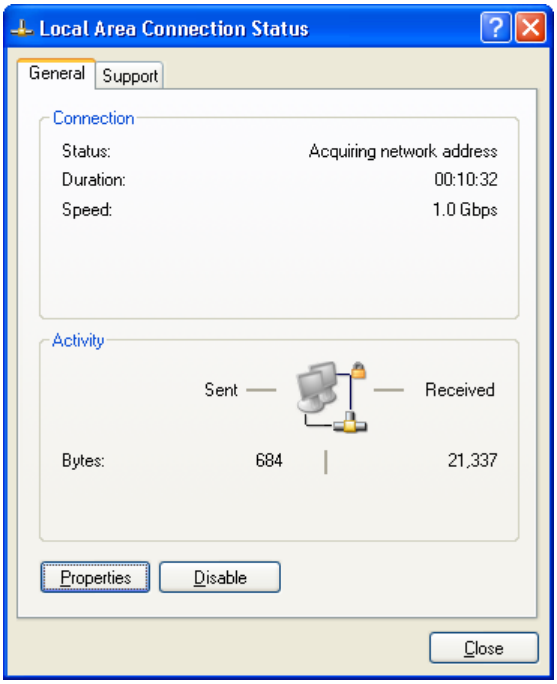


Figure 66: Local Area Connection Status window.

3. Click on Properties to display the Local Area Connection Properties window as the following figure shows.

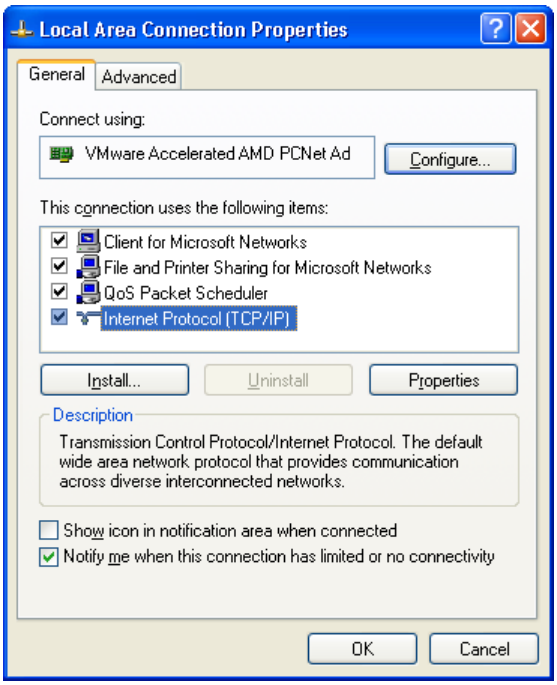


Figure 67: Local Area Connection Properties window.

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

   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.

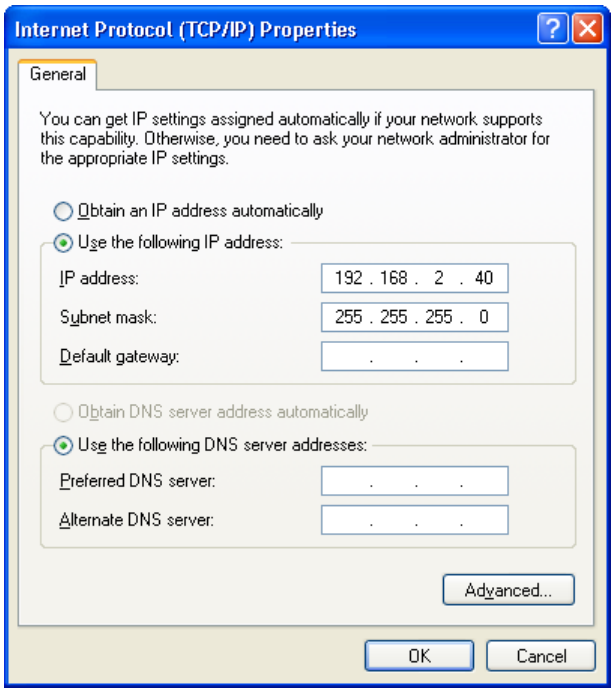


Figure 68: Internet Protocol (TCP/IP) Properties window.

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

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

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

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

RSLinx configuration

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

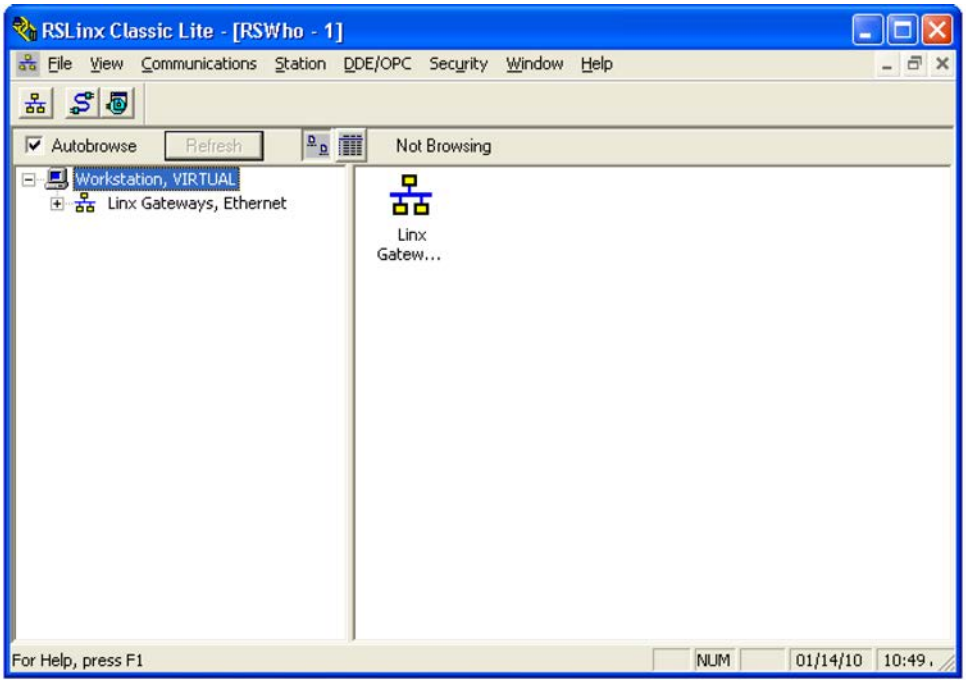


Figure 69: RSLinx.

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

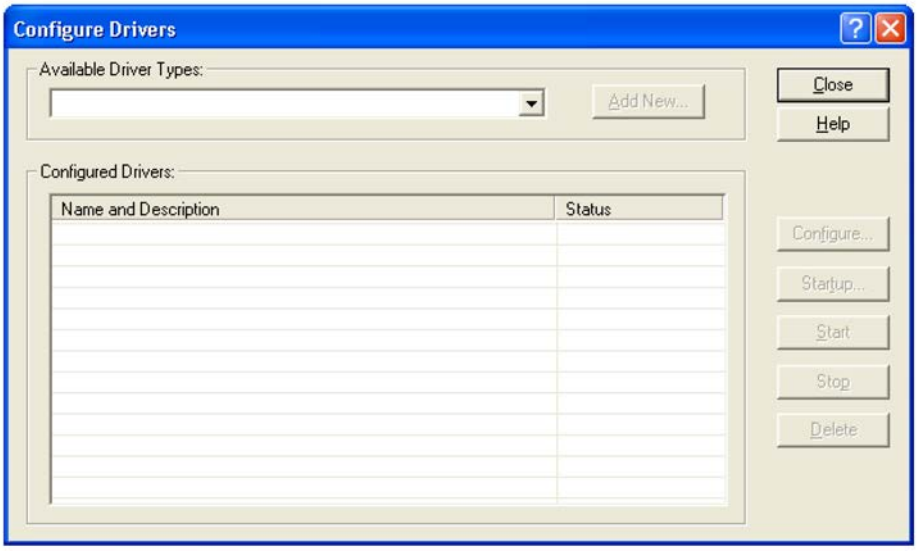


Figure 70: Configure Drivers window.

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

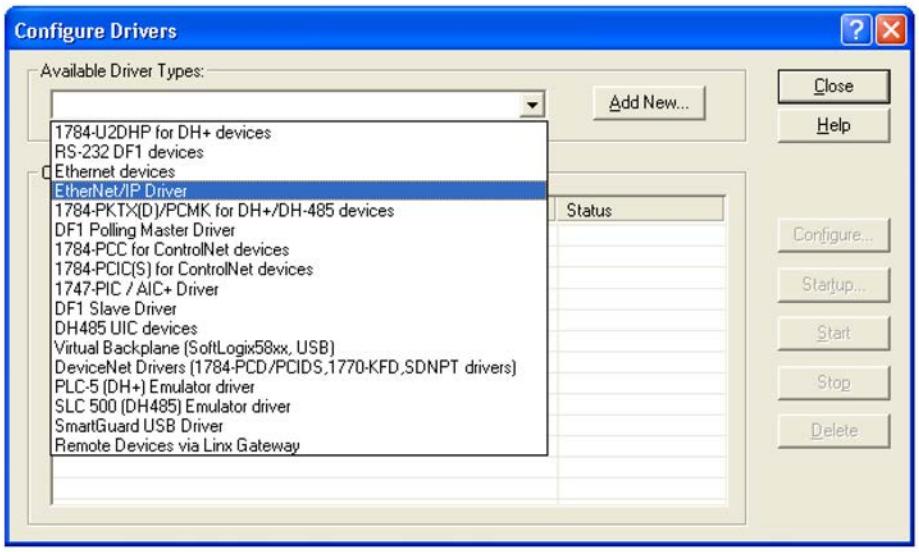


Figure 71: Available Driver Types drop-down list.

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

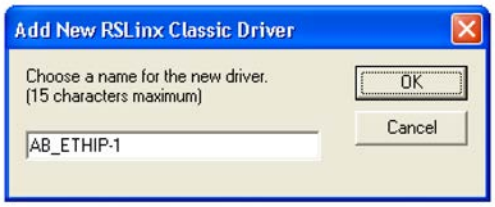


Figure 72: Add New RSLinx Classic Driver window.

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

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

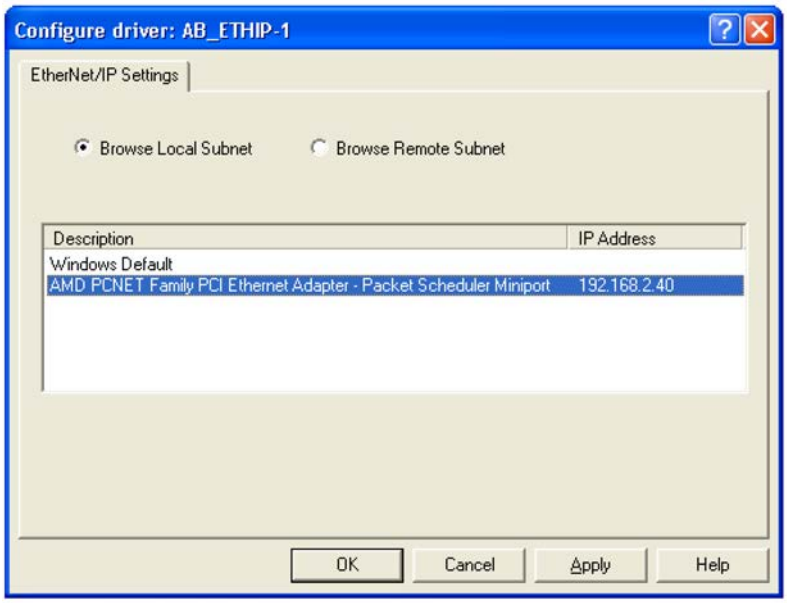


Figure 73: Configure driver: AB_ETHIP-1 window.

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

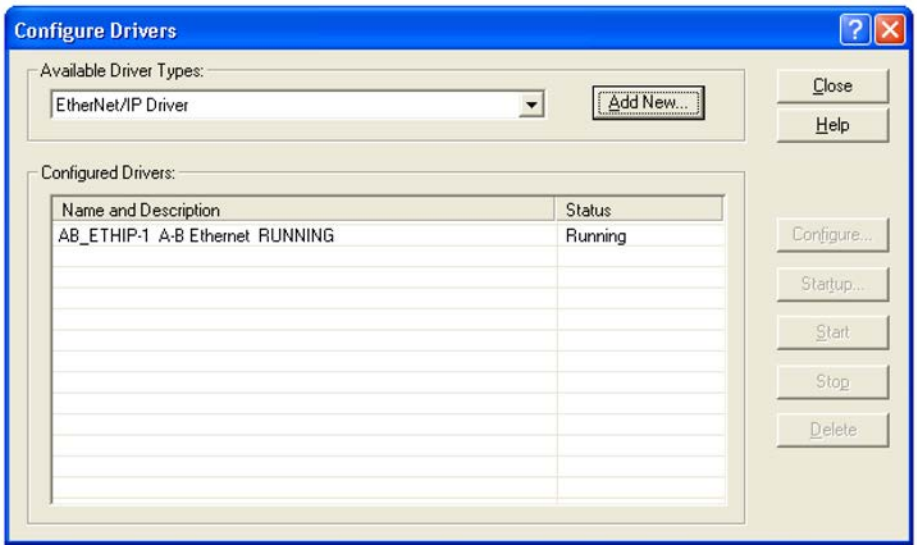


Figure 74: Configure Drivers window.

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

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

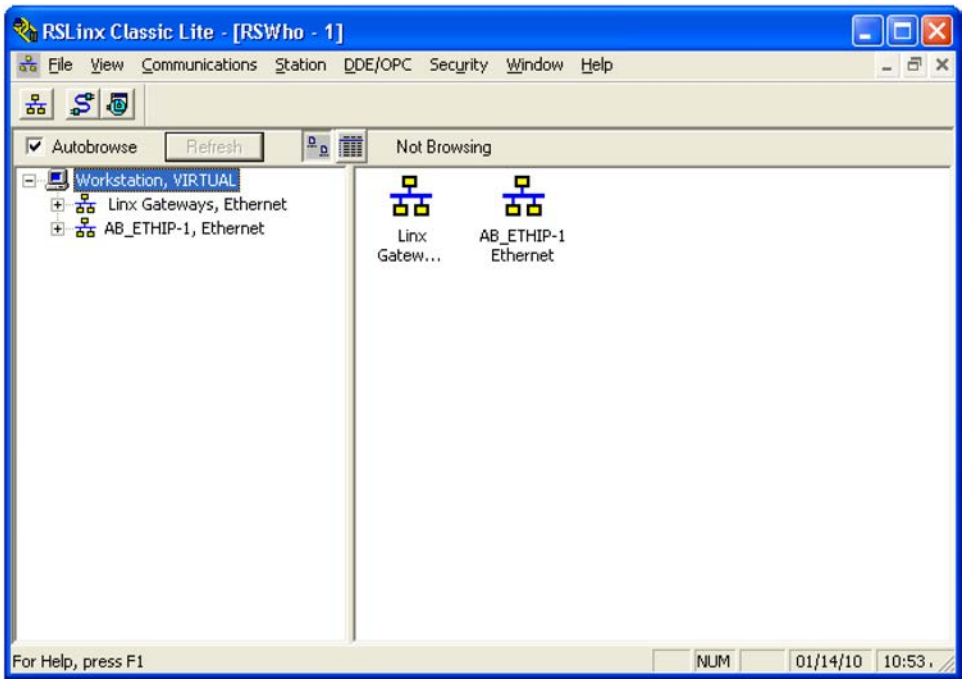


Figure 75: RSWho window.

18. Click on the "+" symbol beside AB_ETHIP-1, Ethernet to expand the network tree and wait for the PLC to appear in the devices list (see the following figure). It can take several seconds before RSLinx detects the new device.

19. From the File menu, select Exit to close the RSLinx window (the software remains active). To open the RSLinx window again, click on the RSLinx Communications Service icon located in the notification area of the Windows taskbar.

20. The Ethernet network configuration is completed. You should be able to communicate with the PLC using RSLogix 500.

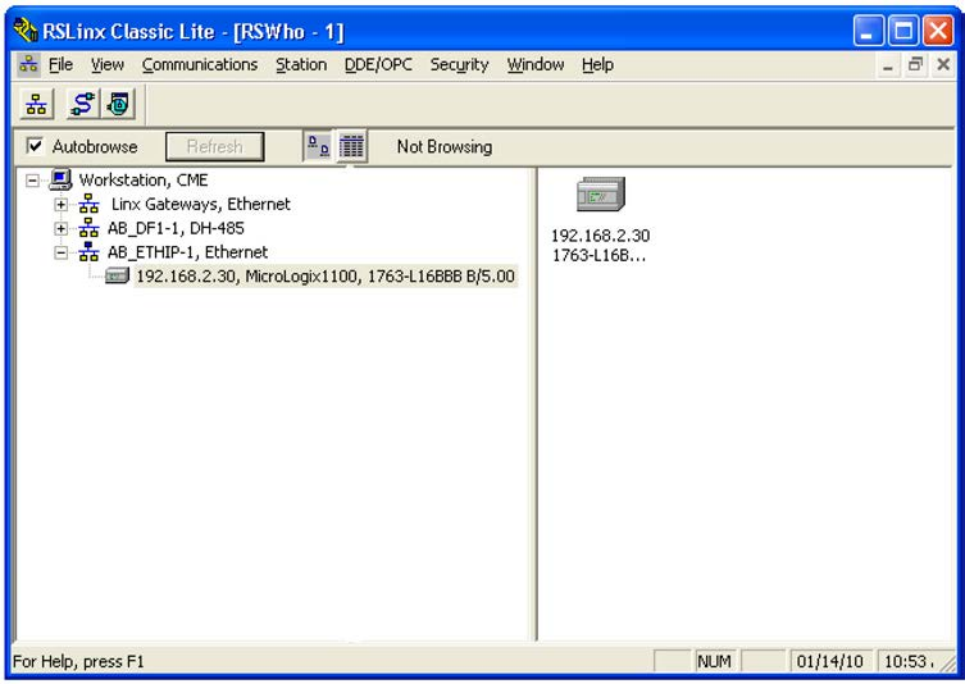


Figure 76: Browsing the network devices using RSWho.

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

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List of Faults on the MicroLogix PLC

Table 24: List of faults – MicroLogix 1400 controller, Model 46964-10.

Fault	Fault Description
1	Opens digital input 0.
2	Opens digital input 5.
3	Creates a short circuit between digital inputs 2 and 3.
4	Cuts the power to the PLC.
5	Opens digital output 0.
6	Opens digital output 5.
7	Opens analog input 0+.
8	Opens analog input 1+.

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Table 25: List of faults – MicroLogix 1100 controller, Model 46964.

Fault	Fault Description
1	Opens digital input 0.
2	Opens digital input 3.
3	Creates a short circuit between digital inputs 7 and 8.
4	Cuts the power to the PLC.
5	Inverses the wiring between digital outputs 0 and 1.
6	Opens digital output 5.
7	Inverses the wiring between the positive (+) jacks of analog inputs 0 and 1. The negative (-) jacks remain as they were. The result is an incorrect transmission of current.
8	Opens analog output 0.

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User Guide

MicroLogix Programmable Logic Controller

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