Industrial Maintenance

Programmable Logic Controller

Student Manual

39436-00

Order no.: 39436-00
First Edition
Revision level: 09/2015

By the staff of Festo Didactic

Internet: www.festo-didactic.com
e-mail: did@de.festo.com

Printed in Canada

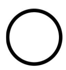
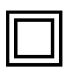
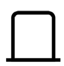
ISBN 978-2-89640-128-4 (Printed version)
ISBN 978-2-89640-703-3 (CD-ROM)
Legal Deposit – Bibliothèque et Archives nationales du Québec, 2007
Legal Deposit – Library and Archives Canada, 2007

Safety and Common Symbols

The following safety and common symbols may be used in this manual and on the equipment:

Symbol	Description
⚠ DANGER	**DANGER** indicates a hazard with a high level of risk which, if not avoided, will result in death or serious injury.
⚠ WARNING	**WARNING** indicates a hazard with a medium level of risk which, if not avoided, could result in death or serious injury.
⚠ CAUTION	**CAUTION** indicates a hazard with a low level of risk which, if not avoided, could result in minor or moderate injury.
CAUTION	**CAUTION** used without the *Caution, risk of danger* sign ⚠, indicates a hazard with a potentially hazardous situation which, if not avoided, may result in property damage.
	Caution, risk of electric shock
	Caution, hot surface
	Caution, risk of danger
	Caution, lifting hazard
	Caution, hand entanglement hazard
	Notice, non-ionizing radiation
⎓	Direct current
∿	Alternating current
⏦	Both direct and alternating current
3∿	Three-phase alternating current
⏚	Earth (ground) terminal

Safety and Common Symbols

Symbol	Description
	Protective conductor terminal
	Frame or chassis terminal
	Equipotentiality
	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

We invite readers of this manual to send us their tips, feedback, and suggestions for improving the book.

Please send these to did@de.festo.com.

The authors and Festo Didactic look forward to your comments.

Table of Contents

Preface

The Lab-Volt PLC Training System, model 8036-20, introduces the use of programmable logic controllers (PLCs) to control electric motors.

This training system is part of the Industrial Controls training program which provides a thorough understanding of the theory and operation of electric motor controllers.

We hope that your learning experience will be the first step of a successful career.

About This Manual

The exercises in this manual, *Programmable Logic Controller*, complement the exercises contained in the manual *Basic Controls*. They provide the knowledge necessary to realize motor controls with the help of a PLC.

The present manual is divided into two units:

- Unit 1 introduces the PLC and its main functions;
- Unit 2 includes PLC circuits that are equivalent to those realized in the manual *Basic Controls*.

Each unit contains exercises which provide a systematic and realistic means of learning the subject matter. Each exercise is divided into the following sections:

- A clearly defined *Exercise Objective*;
- A *Discussion* of the theory involved in the exercise;
- A *Procedure Summary* which provides a bridge between the theoretical *Discussion* and the laboratory *Procedure*;
- A step-by-step laboratory *Procedure* in which the students observe and quantifies important principles covered in the *Discussion*;
- A *Conclusion* to summarize the material presented in the exercise;
- *Review Questions* to verify that the material has been well assimilated.

A ten-question test at the end of each unit allows the student’s knowledge of the unit material to be assessed.

Safety Considerations

Make sure that you are wearing appropriate protective equipment before performing any of the exercises in this manual. Remember that you should never perform an exercise if you have any reason to think that a manipulation could be dangerous to you or your teammates.

Reference Material

Refer to the PLC’s user manual from Moeller for detailed information on how to use the device.

Prerequisite

To perform the exercises in this manual, you should have completed the manual Basic Controls, Lab-Volt part number 39163 (or 87774).

Before performing an exercise, you should have read the pages of the PLC's user manual that deal with the covered topics. Ask your instructor for a copy, or download the file from Moeller's web site.

About This Manual

PLC programming

There are two ways of programming the Moeller's EASY™ programmable logic controller supplied with the training system:

- By using the buttons located on the PLC. This is the method that will be shown throughout the exercises;

- With the help of the EASY-SOFT™ software. This method, requiring a PC running under a Microsoft Windows™ operating system, is explained in Appendix C.

Programmable Logic Controller

UNIT OBJECTIVE

Upon completion of this unit, you will be able to implement small control programs using the Lab-Volt Programmable Logic Controller module.

DISCUSSION OF FUNDAMENTALS

As you have seen in the manual *Basic Controls*, motors can be controlled in a variety of ways. You have learned that they can be started, reversed, jogged, or stopped using individual controllers and relays. However, you can well imagine that employing a multitude of single-purpose devices can soon become time-consuming, with each apparatus requiring particular wiring.

Programmable Logic Controllers (PLCs) are small computers used for automation of industrial processes, such as control of machinery on factory assembly lines. 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 arrangements of PLCs is a major difference with computers. PLCs are connected to sensors (push buttons, limit switches, temperature indicators) and actuators (motor starters, magnetic relays or solenoids). The input/output arrangements may be built into a simple PLC, or the PLC may have external input/output modules.

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. In effect, 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.

PLC hardware

The main components of PLC systems are:

- **Power supply**: Provides constant output voltage from the incoming system voltage. The Lab-Volt Industrial Control System includes a separate DC power supply. The DC Power Supply, Model 3139, shown in Figure 1-1, provides 24 V dc to the PLC and other DC components of the system.

Figure 1-1. DC Power Supply, Model 3139.

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

- **Processor section**: This is the "brain" of the PLC system, comprising the microprocessor and the memory. The processor reads the input data, executes the stored software program, and sends commands to output modules.

- **Programming section**: PLCs have at least one communication port used for programming, troubleshooting, sharing data, attaching a visual display, attaching a modem, or connecting to a network. PLCs are often connected to the plant's communication network. This enables the PLC to be part of a larger control system and to be remotely accessed.

PLC software

PLCs may be programmed in different ways:

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

- **Handheld terminal**: Portable programming unit that can be connected to the PLC. This rugged device has a display screen and buttons to permit programming. It can usually store backup copies of programs and communicate with computers.

- **Computer**: PLC manufacturers offer software that permits PLC programming. This is often the preferred method, because computers have large data storage capacity and a wider screen, which displays more information at the same time. Also, laptops offer the same portability as handheld devices, although they are more fragile.

Different programming languages exist for PLCs. Some are graphical (ladder logic, function block diagram, sequential function chart) while others are textual (structured text, instruction list). Figure 1-2 shows an example of the most popular language: the ladder logic. As the figure shows, this type of circuit resembles schematic diagrams and therefore, makes it easy for technicians to understand the circuit and trace the problems. In ladder logic, the "rails" represent the power lines and the "rungs" contain the items of the process sequence. This manual will concentrate on ladder logic.

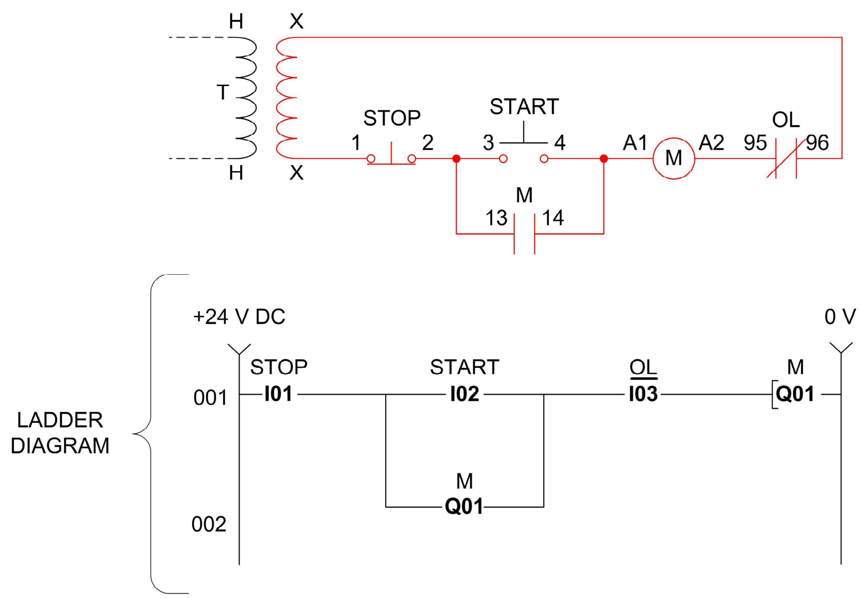


Figure 1-2. Schematic and ladder logic diagrams.

PLC Overview

EXERCISE OBJECTIVE

- Familiarize yourself with the Programmable Logic Controller module.
- Program and test a basic ladder logic circuit.

DISCUSSION

A programmable logic controller is a solid-state device used for implementing logic functions previously performed by electromagnetic relays. Some of the instructions represent the internal and external output devices connected to the PLC. Other instructions are internal and are used to establish the conditions under which the PLC will energize or de-energize output devices, with relation to the status of the input devices.

The most popular programming format for PLCs is the ladder diagram, which uses a symbology similar to schematic diagrams of hardwired circuits. A major difference between hardwired and ladder circuits resides in the fact that a hardwired circuit's rung requires "electrical" continuity to energize a coil, whereas a PLC ladder rung requires "logical" continuity to actuate an output.

Figure 1-3 shows the Programmable Logic Controller module, Model 3128, which includes the EASY 512-DC-R PLC from Moeller. This PLC can be programmed directly on the device, via dedicated buttons, or by downloading a program created through the EASY-SOFT software. The eight input and four output terminals of the PLC can be accessed through banana jacks mounted on the module faceplate.

Figure 1-3. Programmable Logic Controller module, Model 3128.

Input and output terminals

The PLC input terminals provide a means of connecting external input signals to the PLC. Each input terminal is numbered (from I1 to I8) to permit the use of its corresponding variable in the PLC programs. Examples of input devices are limit switches, flow switches, proximity switches, float switches, and thermal switches. The LCD screen shows, at the top of the status display, which input signals are actuated. In the status display shown in Figure 1-4, inputs I1 and I2 are actuated.

Figure 1-4. Programmable Logic Controller status display.

The PLC controls output devices via its output relays. The contacts of these output relays open and close depending on program instructions. Examples of output devices connected are lights, contactors, relays, motor starters for pumps, fans, etc. When a PLC output terminal is enabled (closed contact), the corresponding output number appears at the bottom of the status display. In the status display shown in Figure 1-4, output Q1 is actuated.

Ladder program editing

Figure 1-5 shows a ladder program on the circuit diagram display of the PLC. As shown in this figure, the ladder programs of this PLC contain four columns. Three of them are contact fields and one is a coil field. Every program row corresponds to a rung and the lines linking the different elements are logical connections.

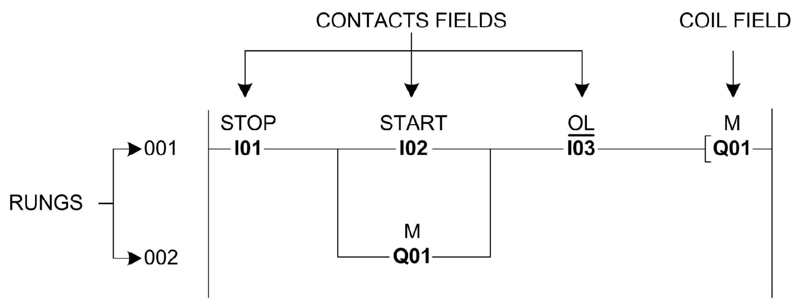


Figure 1-5. PLC ladder program.

The contacts and coils of the PLC program can be inputs and outputs connected to the PLC terminals, but they can also be located inside the PLC. Examples of such internal relays are comparators, counters, and markers.

The list of the supported contacts and coils of the EASY 512-DC-R PLC is presented in Table 1-1.

CONTACT DESCRIPTION	RANGE	COIL FUNCTION	PARAMETERS
Analog value comparator	A1 to A16	NO	YES
Counter function relay	C1 to C16	YES	YES
Text marker function relay (1)	D1 to D16	YES	YES
Input terminal	I1 to I8	NO	NO
Marker	M1 to M16	YES	NO
Marker	N1 to N16	YES	NO
Operating hours counter	O1 to O4	YES	YES
Cursor button (2)	P1 to P4	NO	NO
Output terminal	Q1 to Q4	YES	NO
Timing relay	T1 to T16	YES	YES
Jump label	:1 to :8	YES	NO
Master reset	Z1 to Z3	YES	NO

1 Text marker function relays (D) can only be edited via the Easy-Soft programming software.
2 Cursor buttons (P) are not activated by default.

Table 1-1. Contacts and coils of the EASY 512-DC-R PLC.

Note: *Unsupported contacts such as the 7-day switch function relays* (◷)*, expansion input* (R)*, and output* (S) *terminals, or Year time switch* (Y) *can be programmed into the PLC but will always remain at logic 0.*

The program coils are represented by three symbols. For example, the coil in Figure 1-5 is represented by -[Q01, where:

-[is the contactor coil function,
Q means output terminal,
01 stands for the first coil of this kind (the 0 is omitted in the circuit diagram display of the PLC).

The switching behavior of a relay changes according to its coil function:

COIL FUNCTION	SYMBOL	DESCRIPTION
Contactor	-[	The make contact is set to logic 1 as long as the coil is actuated. [1]
Negated contactor	]-	The make contact is set to logic 1 as long as the coil is **NOT** actuated.
Set	**S**	The make contact is maintained to logic 1 once the set coil is actuated, even for a short period.
Reset	**R**	The make contact is maintained to logic 0 once the reset coil is actuated, even for a short period.
Falling edge pulse		The make contact is switched to logic 1 for the duration of one cycle with a change in coil state from 1 to 0.
Rising edge pulse		The make contact is switched to logic 1 for the duration of one cycle with a change in coil state from 0 to 1.
Impulse relay		The contacts switch every time the coil goes from state 0 to state 1.

1 Make contacts close when the corresponding coil is energized, whereas break contacts open when the matching coil is actuated.

Table 1-2. Coil functions.

Note: *Using twice the same coil function (for instance two times SQ1) can lead to unpredictable results. However, you can use more than one coil function for the same coil (i.e., SQ1 and RQ1), or use the associated contact as often as necessary.*

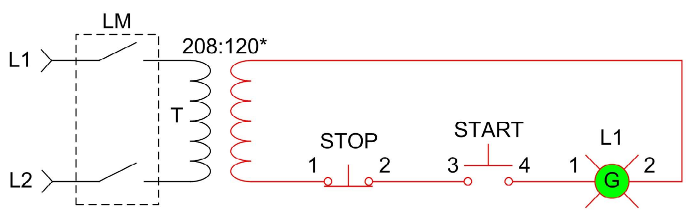
PLC start-up procedure

Upon start-up, the PLC may be in the RUN or STOP mode depending on whether or not it has a valid program, or how it has been set to start. If the PLC is set to start in the RUN mode and has a valid program, the program will start automatically when powered. This may lead to unwanted events, if the operator does not follow proper start-up procedures.

A general start-up procedure should be performed whenever a controller system is to be put into operation. The purpose of this procedure is to isolate problems such as wiring errors, input and output device malfunctions, and programming errors in a systematic, controlled manner. Following a start-up procedure is particularly important when working on automated electromechanical systems because the functions being performed by a programmed system may not be readily apparent to the operator.

Procedure Summary

In this exercise, you will implement the simple push button circuit shown in Figure 1-6 using the Programmable Logic Controller module. In order to program the PLC, you will navigate through the different menus.



*208:120 FOR 120 V - 60 Hz NETWORK
380:110 FOR 220 V - 50 Hz NETWORK
415:110 FOR 240 V - 50 Hz NETWORK
380:120 FOR 220 V - 60 Hz NETWORK

LEGEND

L1	=	START PILOT LIGHT (GREEN)
START	=	START PUSH BUTTON (MOMENTARY CONTACT)
STOP	=	STOP PUSH BUTTON (MOMENTARY CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 1-6. Schematic diagram of the push button circuit.

You will then press the START and STOP push buttons to test if the PLC works the way it should.

In this circuit, the green pilot light turns on when the START push button is pressed, unless the STOP push button is pressed as well.

EQUIPMENT REQUIRED

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required for this exercise.

PROCEDURE

⚠ WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

☐ 1. Perform the Basic Setup procedure shown in section I of Appendix D.

Programmable Logic Controller module connection

☐ 2. Connect the Programmable Logic Controller module as follows:

- Connect the Control Transformer terminals H1 and H2 to terminals L1 and L2 of the Lockout Module.
- Connect the DC Power Supply to terminals X1 and X2 of the Control Transformer.
- Connect the Programmable Logic Controller module to the DC Power Supply, using mini banana jack leads and respecting polarity.

PLC programming

☐ 3. Perform the Energizing procedure shown in Section III of Appendix D.

☐ 4. The LCD window of the PLC turns on and presents the state of the different inputs and outputs. Press the OK button to switch from the status display to the main menu shown in Figure 1-7.

Note: *If the PLC is in the RUN mode, press the down arrow cursor and the OK button to switch to the STOP mode. The PLC may only be programmed while in the STOP mode.*

Figure 1-7. PLC main menu.

☐ 5. Using the arrows, select the PROGRAM item and press the OK button.

In the next menu, select the DELETE PROG. item, then press the OK button twice to delete the existing program.

Select the PROGRAM item, then press the OK button to reach the circuit diagram display shown in Figure 1-8. The display is currently empty and a cursor flashes at the top left.

Figure 1-8. Circuit diagram display.

☐ 6. Enter the program shown in Figure 1-9.

> **Note:** *An overview of the PLC buttons and functions is given in Appendix C. Refer to the user manual of the PLC to obtain detailed instructions.*

Programming tips

- *To insert an element in the circuit, press OK and select the appropriate input/output item with the cursor buttons. Press OK again to confirm your choice.*
- *The direction buttons are also used to change position in the window.*
- *The ALT button permits the insertion of a line.*
- *The DEL button deletes unwanted elements.*
- *The first three columns are the contact (input) fields and the remaining column is the coil (output) field. The sign (* **[** *) before Q1 indicates that the output behaves like a contactor.*
- *When all contact fields of a rung are not used, the last contact must be wired directly to the coil field. To wire the contact to the coil, press ALT to activate the arrow and press the cursor buttons to move it.*

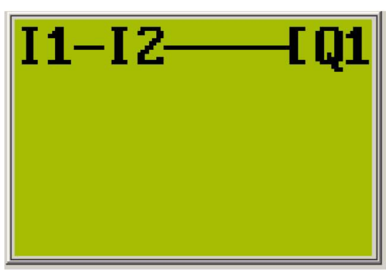


Figure 1-9. PLC ladder program.

☐ 7. Once the program is entered, press the ESC button.

Press OK to save the program, then set the PLC to the RUN mode.

☐ 8. Perform the Lockout/Tagout procedure shown in Section II of Appendix D.

☐ 9. Connect the PLC inputs and outputs according to the Figure 1-10 connection diagram. I1 is the START push button input, and I2 is the STOP push button input. The green pilot light is connected to output Q1.

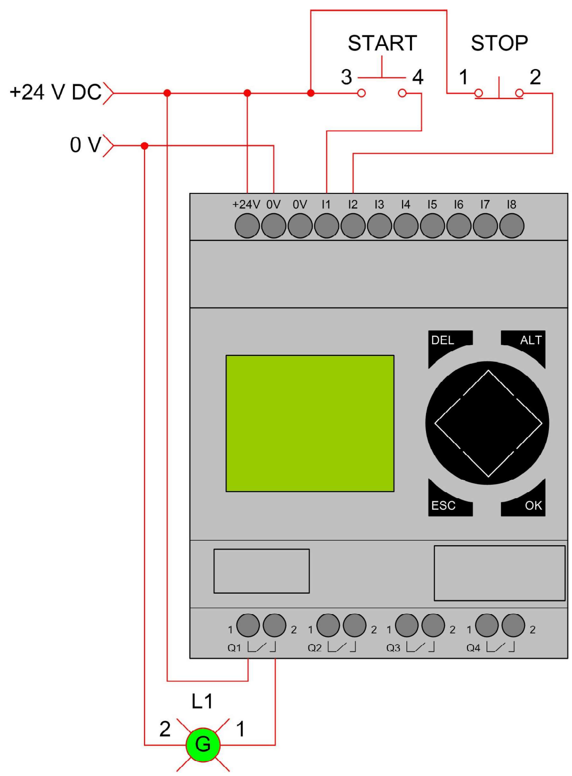


Figure 1-10. Circuit connection diagram.

☐ 10. Perform the Energizing procedure.

☐ 11. You should obtain the display shown in Figure 1-11.

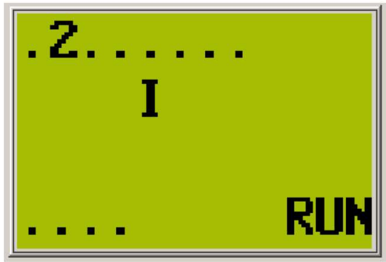


Figure 1-11. PLC's status display after the Energizing procedure.

☐ 12. Press the different push button combinations. Indicate if a "1" appears at the bottom left of the LCD display, meaning that output Q1 is activated when:

- No button is pressed: ☐ Yes ☐ No
- Only the START push button is pressed: ☐ Yes ☐ No
- Only the STOP push button is pressed: ☐ Yes ☐ No
- Both push buttons are pressed simultaneously: ☐ Yes ☐ No

☐ 13. Does the green pilot light illuminate when:

- No button is pressed: ☐ Yes ☐ No
- Only the START push button is pressed: ☐ Yes ☐ No
- Only the STOP push button is pressed: ☐ Yes ☐ No
- Both push buttons are pressed simultaneously: ☐ Yes ☐ No

☐ 14. Does the pilot light illuminate following the "1" indicator at the bottom of the status display?

☐ Yes ☐ No

☐ 15. Set the PLC to the STOP mode.

Turn the individual power switch of the AC Power Supply off, disconnect the circuit, and return the equipment to the storage location.

CONCLUSION

In this exercise, you familiarized yourself with the Programmable Logic Controller module. You learned how to enter a basic ladder program into the PLC and you verified that the output responded correctly to the input signals.

REVIEW QUESTIONS

1. In what mode does the Programmable Logic Controller module start by default, if a valid program is entered?

   a. DISPLAY
   b. PROGRAM
   c. RUN or STOP
   d. PARAMETER

2. Which device can appropriately be connected to a PLC's "Q" terminal?

   a. Push button
   b. Limit switch
   c. Pilot light
   d. Power supply

3. Which device can appropriately be connected to a PLC's "I" terminal?

   a. Pilot light
   b. Limit switch
   c. Motor starter
   d. Power supply

4. What does a PLC rung require to energize an output?

   a. Electrical continuity
   b. Logical continuity
   c. Break in continuity
   d. None of the above is correct.

5. If you keep the connections shown in Figure 1-10, but change the program shown in Figure 1-9 for the following one (Figure 1-12):

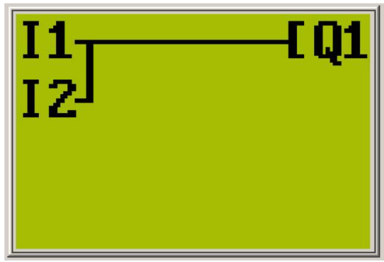


Figure 1-12. Question 5 PLC ladder program.

Under which circumstances would the pilot light **NOT** be illuminated?

a. When both push buttons are pressed.
b. When no push button is pressed.
c. When only the start push button is pressed.
d. When only the stop push button is pressed.

Control Relay Functions

EXERCISE OBJECTIVE

- Use a PLC for replacing the functions of a control relay.

DISCUSSION

PLC circuits offer several advantages over conventional circuits using control relays:

- Less wiring;
- Configurability;
- Ease of expandability;
- Reduced space requirements;
- High reliability;
- Low power consumption.

Normally open (NO) and normally closed (NC) contacts in PLC programs are sometimes referred to as make and break contacts. Make contacts close when the corresponding coil is energized, whereas break contacts open when the corresponding coil is actuated. In PLC programs, break contacts are differentiated by a horizontal line located above the contact letter.

Often, normally open and normally closed switches are both represented by a make instruction in a PLC program. This apparent contradiction actually makes sense when considering that the ladder diagram must be evaluated in terms of logical continuity rather than electrical continuity. Thus, the normally open or normally closed mechanical action of a switch is not a consideration when programming a ladder instruction for this switch.

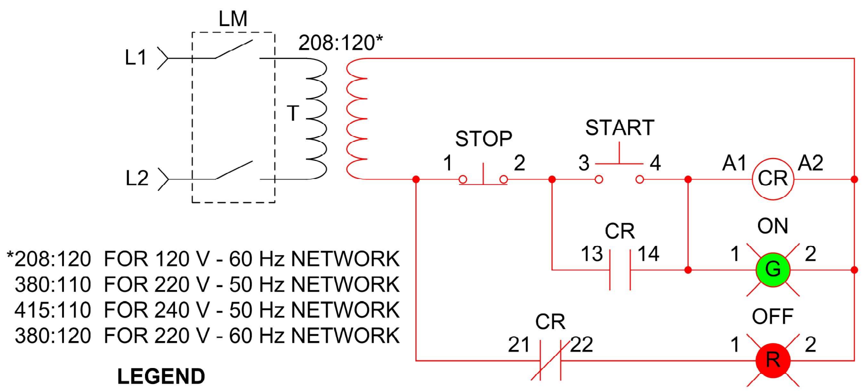
The amount of time the PLC takes to read all inputs, execute the program, and update all outputs, is called scan time. The Programmable Logic Controller module circuit diagrams, for instance, are processed cyclically every 2 to 40 ms, depending on their complexity.

When editing ladders, it is a good practice to minimize the number of programming steps, since PLCs have limited memory space to store program instructions. For example, the Programmable Logic Controller module may contain a maximum of 128 lines of logic, each line having 3 contact fields and 1 coil field.

Latching (holding) circuits

Latching circuits allow to keep an output energized, even if the input is not kept actuated. A good example of this is a start push button, with a latching (holding) circuit in parallel, used to activate a motor. When an operator presses and releases the START push button, the motor keeps running until the STOP push button is pressed, because the latching contact stays closed. Traditionally, latching circuits are implemented using a control relay or a contactor NO contact.

Figure 1-13 shows a hardwired latching circuit controlling red and green pilot lights. When the START push button is pressed, the control relay contact closes, keeping the green pilot light on as long as the STOP push button is not pressed.



LEGEND

CR	=	CONTROL RELAY
OFF	=	OFF PILOT LIGHT (RED)
ON	=	ON PILOT LIGHT (GREEN)
START	=	START PUSH BUTTON (MOMENTARY CONTACT)
STOP	=	STOP PUSH BUTTON (MOMENTARY CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 1-13. Latching circuit with a control relay.

This last circuit can be translated into an equivalent ladder program, as Figure 1-14 shows. When input I1 (START) is energized, the Q1 contactor output (green pilot light) switches to logic 1 and the green pilot light illuminates. The Q1 output then keeps itself actuated through its corresponding make contact. When input I2 (STOP) is pressed, the rung de-energizes. The red pilot light (Q2) illuminates when the green pilot light (Q1) does not.

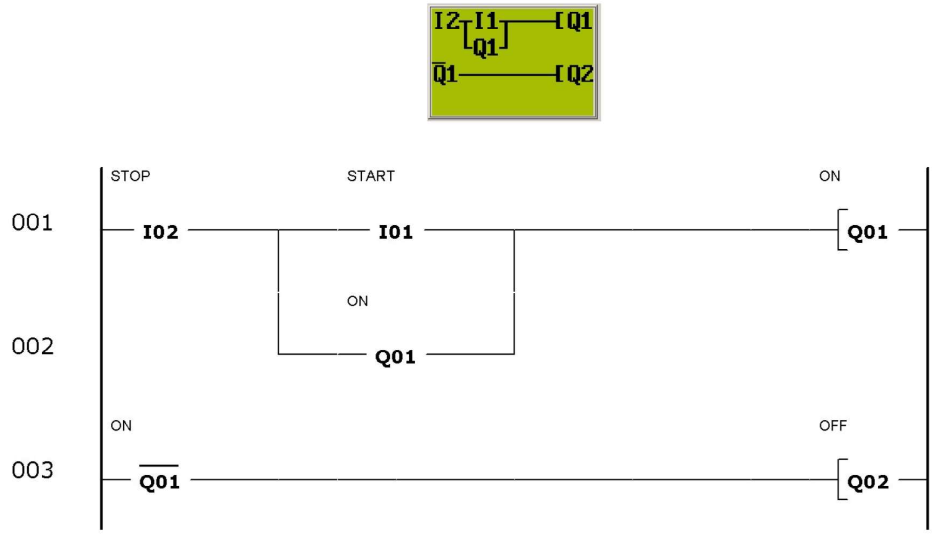


Figure 1-14. Latching circuit ladder program and equivalent circuit diagram display.

Another way of implementing this latching circuit is with the help of the set and reset instructions, as represented in Figure 1-15. When input I1 (START) is energized, output Q1 (green pilot light) is set to logic 1. To reset the Q1 coil, the STOP push button connected to I2 must be pressed. The I2 break contact is used because the STOP push button is a NC contact.

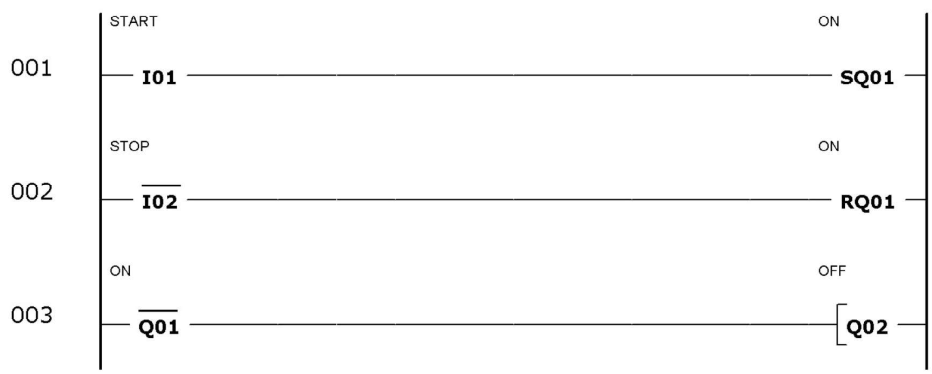


Figure 1-15. Latching circuit using the set and reset instructions ladder program.

Power flow display

While troubleshooting a PLC circuit, it is often desirable to know which parts of the circuit are energized. Although it is possible to physically inspect all inputs and outputs of the PLC, it is often more convenient to observe the operation of the circuit graphically. The Programmable Logic Controller module enables visualization of which logical line is powered during PLC operation. This is done by accessing the circuit diagram display once in the RUN mode. The thick (or double) lines on the circuit represent logic 1 (powered) links, and thin lines represent connections of logic O (unpowered). In the power flow display of Figure 1-16, only the line connecting the break contact Q1 and the coil Q2 is energized.

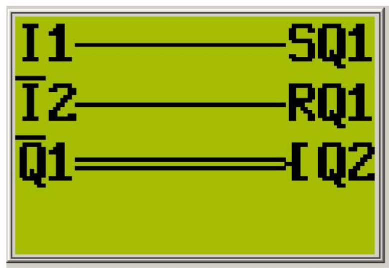


Figure 1-16. Power flow display.

Procedure Summary

In the first part of this exercise, you will connect and test a circuit employing a hardwired relay to control two pilot lamps.

In the second part of the exercise, you will substitute the relay of the preceding circuit for a PLC and verify that this programmed circuit may function in a way equivalent to a hardwired circuit. To do so, you will program and test two different ladder programs.

Finally, you will observe the behavior of the program rungs during PLC operation with the help of the power flow display screen.

EQUIPMENT REQUIRED

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required for this exercise.

PROCEDURE

⚠ WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

☐ 1. Perform the Basic Setup and Lockout/Tagout procedures.

Latching circuit using a control relay

☐ 2. Figure 1-13 shows the schematic diagram of a basic latching circuit with a control relay.

Set up the circuit. Make sure that you are using the Pilot Lights, model 3115, and Push Buttons, model 3110 (AC modules).

☐ 3. Perform the Energizing procedure.

☐ 4. Does latching occur when you press the START push button?

☐ Yes ☐ No

☐ 5. Does pressing the STOP push button stop the latching?

☐ Yes ☐ No

☐ 6. Perform the Lockout/Tagout procedure, disconnect the circuit and remove the Pilot Lights, Push Buttons, and Control Relay modules.

Latching circuit in PLC program

☐ 7. Connect the Programmable Logic Controller module as described in Exercise 1-1.

☐ 8. Perform the Energizing procedure.

☐ 9. Enter the program shown in Figure 1-14.

Programming tip

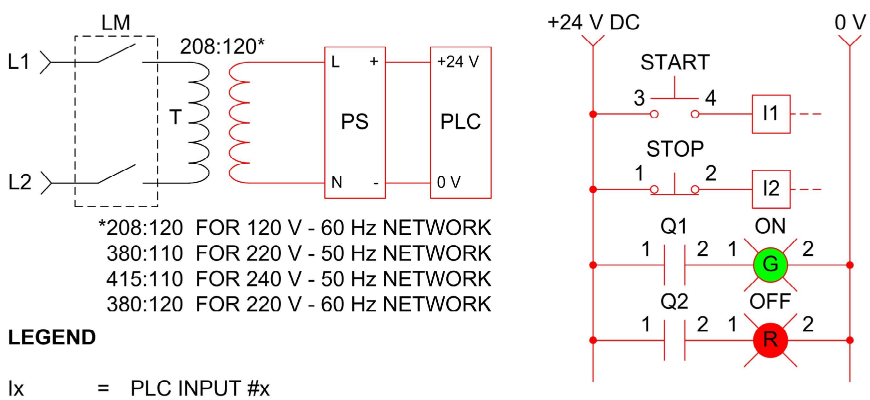
Perform the following steps to program a break contact:

- *Position the cursor on the desired contact.*
- *Press OK and ALT once to obtain a line above the contact letter.*
- *Then, press OK twice to confirm the change. The presence of a line above the contact letter indicates a break contact.*

☐ 10. Once the program is entered, press the ESC and OK buttons to save the program.

Perform the Lockout/Tagout procedure.

☐ 11. Connect the PLC inputs and outputs according to Figure 1-17. Make sure that you are using the Switches, model 3112, and Pilot Lights, model 3115-A (DC modules).



LEGEND

Ix	=	PLC INPUT #x
ON	=	ON PILOT LIGHT (GREEN)
OFF	=	OFF PILOT LIGHT (RED)
PLC	=	PROGRAMMABLE LOGIC CONTROLLER
PS	=	DC POWER SUPPLY
Qx	=	PLC OUTPUT RELAY #x
START	=	START PUSH BUTTON (MOMENTARY CONTACT)
STOP	=	STOP PUSH BUTTON (MOMENTARY CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 1-17. PLC input and output connections.

☐ 12. Perform the Energizing procedure.

Note: *Make sure that the PLC is set to the RUN mode.*

☐ 13. Check the pilot lights and the output numbers on the status display. Does latching occur when you press the START push button?

☐ Yes ☐ No

☐ 14. Does pressing the STOP push button stop the latching?

☐ Yes ☐ No

☐ 15. Are this program and the hardwired circuit equivalent in terms of functionality?

☐ Yes ☐ No

☐ 16. Set the Programmable Logic Controller module to the STOP mode.

Set and reset latching circuit

☐ 17. Delete the existing program, then enter and save the program shown in Figure 1-15.

☐ 18. Set the Programmable Logic Controller module to the RUN mode.

Check the pilot lights and output numbers on the status display. Does latching occur when you press the START push button?

☐ Yes ☐ No

☐ 19. Does pressing the STOP push button stop the latching?

☐ Yes ☐ No

☐ 20. Are this program and the preceding one equivalent in terms of functionality?

☐ Yes ☐ No

Power flow display

☐ 21. While the program is still running, access the main menu and press OK on the PROGRAM item to check the power flow display.

Note: *It is not possible to modify the program while in the RUN mode. However, as you will see later in this manual, some parameter values may be changed for testing purposes.*

Press the START push button. Which rung(s) is(are) powered while the push button is pressed?

☐ Rung 1 ☐ Rung 2 ☐ Rung 3

☐ 22. Press the STOP push button. Which rung(s) is(are) powered while the push button is pressed?

☐ Rung 1 ☐ Rung 2 ☐ Rung 3

☐ 23. Set the PLC to the STOP mode.

Turn the individual power switch of the AC Power Supply off, disconnect the circuit, and return the equipment to the storage location.

CONCLUSION

In hardwired control relay diagrams, reference is made to actual control relay coils and contacts.

In PLC ladder programs, control relays are simulated, with NO or NC contacts becoming make or break instructions. Because of the limited PLC memory space, it is recommended that the number of rungs be reduced as much as possible.

In this exercise, you realized two PLC programs and found out that they were both performing the same functions as a hardwired control relay circuit. After that, you examined the power flow display to see which PLC program lines were energized.

REVIEW QUESTIONS

1. Which advantage do PLCs have over control relays?

   a. Reduced-space requirements
   b. Ease of expandability
   c. Higher reliability
   d. All of the above are correct.

2. To what can we compare the make instruction?

   a. Set instruction
   b. NO contacts
   c. NC contacts
   d. Parallel rung

3. Why should the number of PLC program rungs be minimized?

   a. To increase the number of contacts in the program.
   b. To increase processor scan time.
   c. The PLC memory size is limited.
   d. None of the above is correct.

4. Which PLC instruction is used to make an output retain logic 1 value?

   a. Reset
   b. Set
   c. Contactor
   d. Negated contactor

5. Which display of the Programmable Logic Controller module shows which program rung parts are powered?

   a. Power flow display
   b. Main menu
   c. Status display
   d. Parameter display

Boolean Logic and Markers

EXERCISE OBJECTIVE

- Use Boolean logic and markers to solve implementation problems.

DISCUSSION

Because PLCs are limited in memory size, it is often necessary to circumvent those limitations by using some logic equivalents. The Programmable Logic Controller module, for instance, enables only three contacts per rung and does not permit backward wiring, which causes improper results. Figure 1-18 represents a series of four ANDed input contacts that is not implemented correctly.

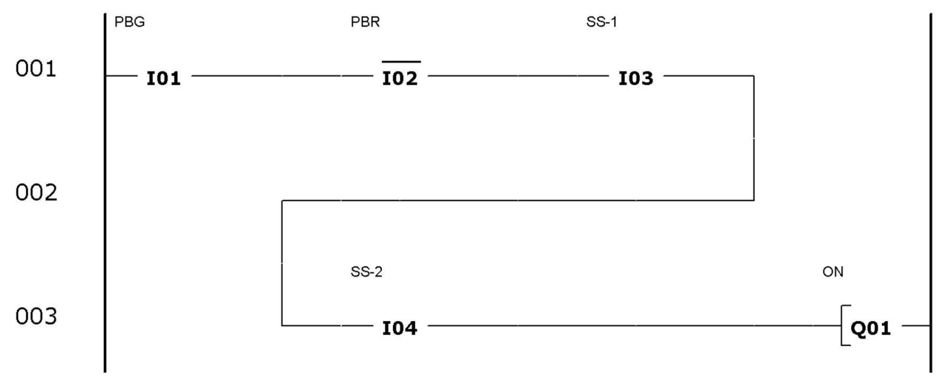


Figure 1-18. Do not use backwards wiring.

The first method of solving the problem is to use markers to cut a long ANDed series of contacts. The Programmable Logic Controller module uses "M" and "N" markers to store values. Figure 1-19 shows how the preceding example may be implemented correctly with a marker.

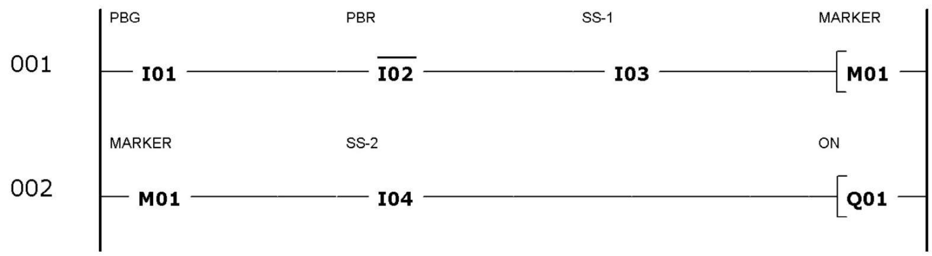


Figure 1-19. Using markers to avoid backwards wiring.

A second method of implementing the same circuit function is to use the principles of Boolean algebra reviewed in Appendix E. Knowing that a series of ANDed contacts is equivalent to ORed inverted contacts on a negated coil, we obtain the result in Figure 1-20. Note that make contacts are now break contacts and the break contact has become a make contact. The contactor coil is now a negated contactor coil (the coil contactor sign is inverted). This method, however, requires a greater number of rungs.

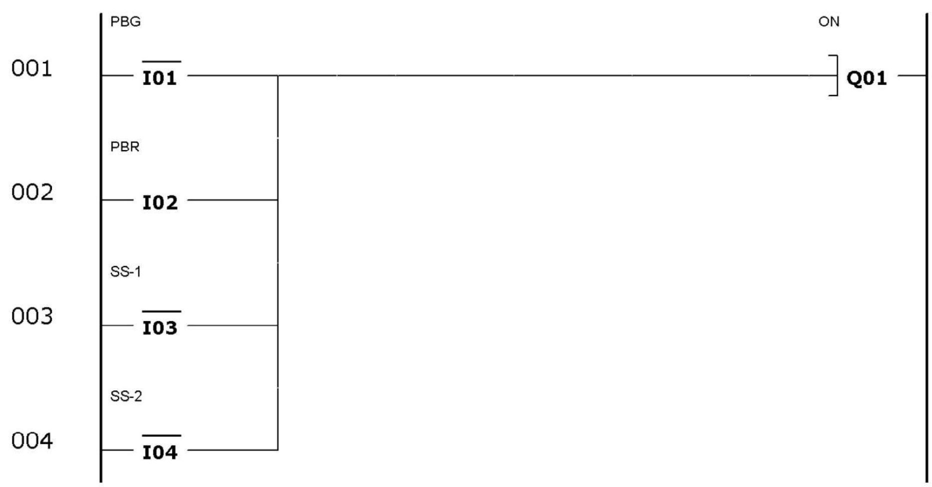


Figure 1-20. Boolean logic equivalent.

Procedure Summary

The Programmable Logic Controller module enables only three contacts and one output per rung. In this exercise, you will have to implement a series of four contacts. To solve the problem, you will write three different ladder programs:

- Division of a series of contacts into two rungs using a marker;
- Application of boolean logic principles;
- Backwards wiring.

You will find out that the first two solutions give acceptable results, while the last one is impractical.

EQUIPMENT REQUIRED

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required for this exercise.

PROCEDURE

WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

☐ 1. Perform the Basic Setup procedure.

Division of a series of contacts into two rungs using a marker

☐ 2. Connect the Programmable Logic Controller module as described in Exercise 1-1.

Perform the Energizing procedure.

Enter and save the program shown in Figure 1-19.

Perform the Lockout/Tagout procedure.

☐ 3. Connect the PLC inputs and outputs according to Figure 1-21.

> **Note:** *You will need two Switches modules. Use PBR, PBG, and L on the first module, and R on the second module.*

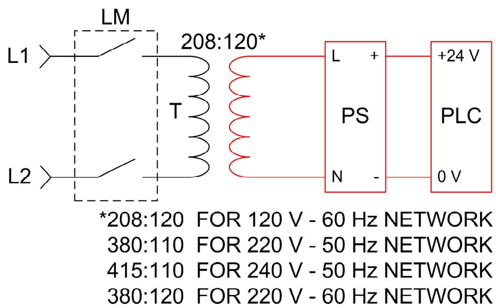
☐ 4. Set the selector switch of the Switches modules to the O position.

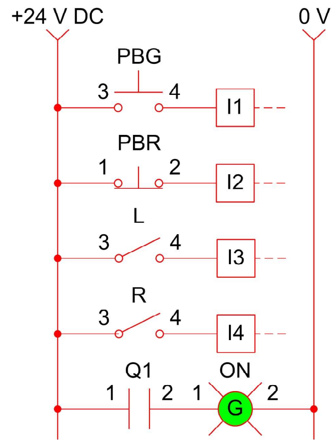
Perform the Energizing procedure.

> **Note:** *Make sure that the PLC is set to the RUN mode.*

☐ 5. According to the numbers you see on top of the status display, which switch(es) is(are) NC?

☐ I1 ☐ I2 ☐ I3 ☐ I4





LEGEND

Ix	=	PLC INPUT #x
ON	=	ON PILOT LIGHT (GREEN)
PBG	=	GREEN PUSH BUTTON (MOMENTARY CONTACT)
PBR	=	RED PUSH BUTTON (MOMENTARY CONTACT)
PLC	=	PROGRAMMABLE LOGIC CONTROLLER
PS	=	DC POWER SUPPLY
Qx	=	PLC OUTPUT RELAY #x
L	=	SELECTOR SWITCH #1 (MAINTAINED CONTACT)
R	=	SELECTOR SWITCH #2 (MAINTAINED CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 1-21. PLC input and output connections.

☐ 6. Access the PROGRAM menu to observe the power flow display as you modify the state of the different inputs.

Which input(s) do you have to activate to energize marker M1?

☐ I1 ☐ I2 ☐ I3 ☐ I4

☐ 7. Which input(s) do you have to activate to energize output Q1?

☐ I1 ☐ I2 ☐ I3 ☐ I4

Application of Boolean logic principles

☐ 8. Set the Programmable Logic Controller module to the STOP mode.

Enter and save the program shown in Figure 1-20. The input/output connections remain the same.

Set the Programmable Logic Controller module to the RUN mode.

☐ 9. Which input(s) do you have to activate to energize output Q1?

☐ I1 ☐ I2 ☐ I3 ☐ I4

☐ 10. Do the circuits shown in Figures 1-19 and 1-20 behave similarly, in terms of what it takes to energize output Q1?

☐ Yes ☐ No

Backward wiring

☐ 11. Set the Programmable Logic Controller module to the STOP mode.

Enter and save the program shown in Figure 1-18.

Set the Programmable Logic Controller module to the RUN mode.

☐ 12. Are you able to energize the output contactor Q1?

☐ Yes ☐ No

☐ 13. Is backward wiring supported by the PLC program?

☐ Yes ☐ No

☐ 14. Set the PLC to the STOP mode.

Turn the individual power switch of the AC Power Supply off, disconnect the circuit, and return the equipment to the storage location.

CONCLUSION

In this exercise, you programmed three ladder diagrams that were meant to implement a long series of ANDed contacts. While backward wiring was not supported by the program, the use of a marker and an equivalent Boolean logic circuit turned out to be good practices to circumvent the problem.

REVIEW QUESTIONS

1. What is the minimum number of program lines that you will need if you are implementing a circuit made of six inputs placed in series in the Programmable Logic Controller module?

    a. 1
    b. 2
    c. 3
    d. 4

2. What is the name of the PLC's auxiliary relays used to store values for later use?

    a. Relays
    b. Marker relays
    c. Output relays
    d. None of the above is correct.

3. What are contacts placed in series called?

    a. ANDed contacts;
    b. ORed contacts;
    c. NOTed contacts;
    d. NANDed contacts.

4. Which programming technique does the PLC not support?

    a. Using a marker
    b. Using equivalent boolean logic circuit
    c. Using backwards wiring
    d. All of the above are correct.

5. In Figure 1-19, if marker M1 is changed for marker N4 at the end of rung 1, which contact must start rung 2 to make the circuit work in the same manner?

    a. M1
    b. N1
    c. M4
    d. N4

Timing Relay Functions

EXERCISE OBJECTIVE

- Review PLC timing relay functions.

DISCUSSION

Besides replacing electromechanical control relays, PLCs are also able to replace timing relays. While hardwired time-delay circuits are limited by the number of contacts or cams of their relays, PLC timing circuits are only limited by the memory space of the PLC.

Timing relay circuits are used in industrial control systems when an action is required after a specific delay time. They are used, for example, to postpone the startup of a motor, solenoid, or other electrically-driven device. They are also used to produce a delay before an electrically-driven device is de-energized.

The Programmable Logic Controller module includes 16 integrated timers that have the following coil functions:

- **On-delay (X)**: As long as the rung conditions are true, the timer's accumulated value is incremented until it reaches a preset time value (I1). At that moment, the timer coil is triggered and the make contact is closed. The timer is reset when the rung conditions become false.

- **Random on-delay (?X)**: Same as the on-delay function, except that the time needed to trigger the coil is randomly chosen within the setpoint value range (I1). For instance, if the setpoint is 10 seconds, the triggering time will be somewhere between 0 and 10 s.

- **Off-delay (■)**: The timer coil is triggered and the make contact is closed when rung conditions are true. As soon as the rung conditions become false, the timer's accumulated value is incremented until it reaches a preset value (I1). After that delay, the timer coil de-energizes and the make contact opens. The timer accumulated value is reset when the rung conditions become true again.

- **Random off-delay (?■)**: Same as the off-delay function, except that the time to de-energize the timer coil is randomly chosen within the setpoint value (I1) range.

- **On and off delay (X■)**: Time delays are applied both for energizing and de-energizing the timing relay coil. For that reason, two different time values must be entered. The first one (I1) is for the on-delay and the second one (I2) is for the off-delay.

- **Random on and off delay (?X■)**: Same as the on and off delay, except that the two delays are randomly chosen within the setpoint values (I1 and I2) range.
- **Single pulse switching (⊓)**: Every time the rung conditions are true, the timer coil is triggered for the set time (I1) duration.
- **Flash switching (⊓⊔)**: Every time the rung condition is true, the timer coil switches alternately on and off. The first time value entered (I1) is the pulse duration. The second value (I2) is the pause time.

Each PLC timer has three different coils:

- **Trigger (T) coil**; Starts the timer when a rung becomes true (logic 1).
- **Stop (H) coil**: Halts the corresponding timer accumulator as long as it is enabled.
- **Reset (R) coil**: Resets the timing relay coil and contacts.

The time value in the Programmable Logic Controller module can be set according to different time bases, which have the following range:

- **Seconds (S)**: From 0.000 to 99.999 s.
- **Minutes (M:S)**: From 00:00 to 99:59.
- **Hours (H:M)**: From 00:00 to 99:59.

Procedure Summary

In this exercise, you will program a ladder circuit that uses the on and off delay function to control the turning on and turning off of two pilot lights. This program will resemble the hardwired circuit in Figure 1-22.

You will verify that the ladder program operates properly when the PLC's inputs and outputs are connected to switches and pilot lights.

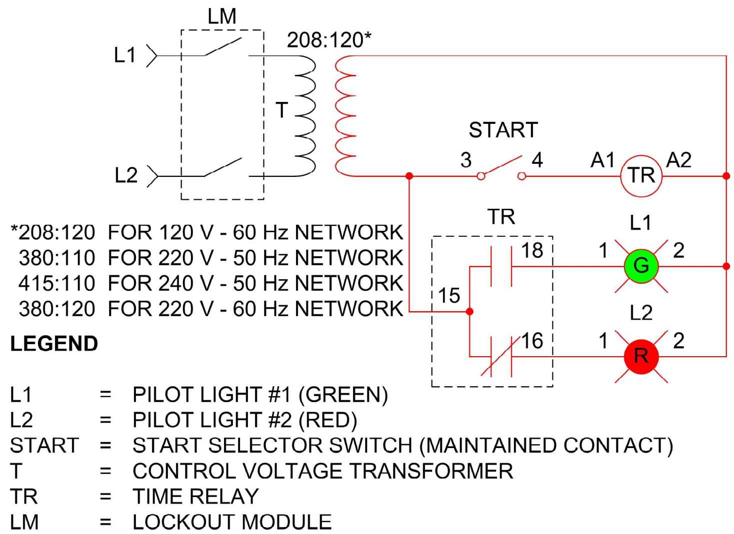


Figure 1-22. Hardwired timing relay circuit.

EQUIPMENT REQUIRED

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required for this exercise.

PROCEDURE

WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

☐ 1. Perform the Basic Setup procedure.

Familiarization with the on and off delay function

☐ 2. Connect the Programmable Logic Controller module as described in Exercise 1-1.

Perform the Energizing procedure.

Enter and save the program shown in Figure 1-23, with the following timing relay (T1) parameter values:

- Coil function: trigger
- Mode: on and off delay
- Setpoint I1: 5 s
- Setpoint I2: 2 s

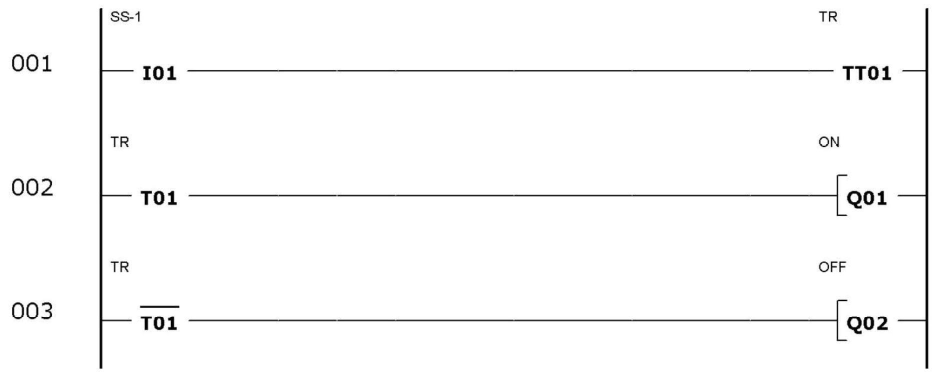
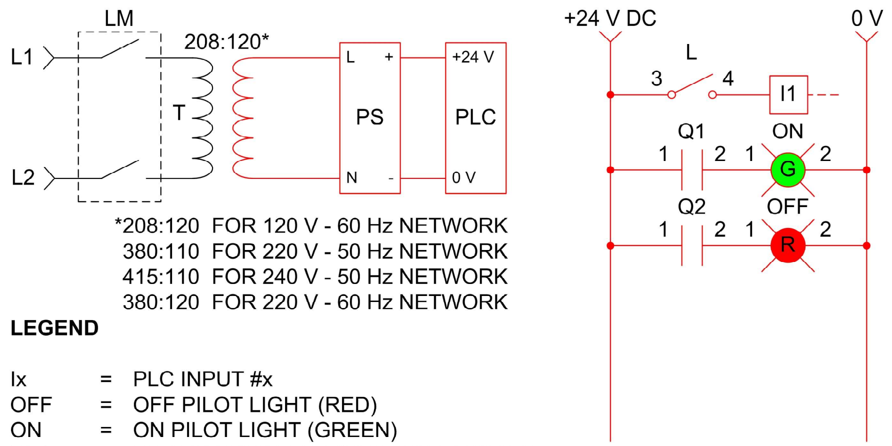


Figure 1-23. PLC timing relay ladder program.

Perform the Lockout/Tagout procedure.

☐ 3. Connect the PLC inputs and outputs according to Figure 1-24.



LEGEND

Ix	=	PLC INPUT #x
OFF	=	OFF PILOT LIGHT (RED)
ON	=	ON PILOT LIGHT (GREEN)
PLC	=	PROGRAMMABLE LOGIC CONTROLLER
PS	=	DC POWER SUPPLY
Qx	=	PLC OUTPUT RELAY #x
L	=	SELECTOR SWITCH (MAINTAINED CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 1-24. Connection diagram of the PLC timing relay circuit.

☐ 4. Set the selector switch of the Switches module to the O position.

Perform the Energizing procedure.

Note: *Make sure that the PLC is set to the RUN mode.*

☐ 5. According to the numbers you see on the status display, which input and/or output(s) are activated?

☐ I1 ☐ Q1 ☐ Q2

☐ 6. To what physical device(s) do these inputs and outputs correspond?

____

____

☐ 7. Access the circuit diagram display of the PLC. According to the power flow display, which rung(s) is(are) totally energized?

☐ Rung 1 ☐ Rung 2 ☐ Rung 3

☐ 8. Set the selector switch of the Switches module to the L position.

According to the power flow display, which rung(s) is(are) totally energized after 5 s?

☐ Rung 1 ☐ Rung 2 ☐ Rung 3

☐ 9. Set the selector switch of the Switches module to the O position. Does the green pilot light turn off?

☐ Yes, immediately
☐ Yes, after a time delay of 2 s
☐ No

☐ 10. According to the power flow display, which rung(s) is(are) now totally energized?

☐ Rung 1 ☐ Rung 2 ☐ Rung 3

☐ 11. Why cannot the red and green pilot lights be on at the same time?

____

____

☐ 12. Set the selector switch of the Switches module to the L position. Does the green pilot light turn on?

☐ Yes, immediately
☐ Yes, after a time delay of 5 s
☐ No

☐ 13. Access the circuit diagram display, then place the cursor on the TT1 item.

Press OK to access the timer 1 parameter display. Give a brief description of the following items shown on this display (refer to the PLC's user manual if necessary):

T1: ______________________________

X■: ______________________________

S: ______________________________

+: ______________________________

I1: ______________________________

I2: ______________________________

■: ______________________________

T: ______________________________

Familiarization with the operation of the reset and stop coils

☐ 14. Set the Programmable Logic Controller module to the STOP mode.

Modify your PLC program to include a reset coil (RT1) and a stop coil (HT1) as shown in the ladder program of Figure 1-25.

Perform the following steps:

- Use push button PBR to control the stop coil (connect to input I2) and PBG to control the reset coil (connect to input I3).
- Change the time setpoint 1 (I1) to 10 s.
- Set the selector switch of the Switches module to the O position.

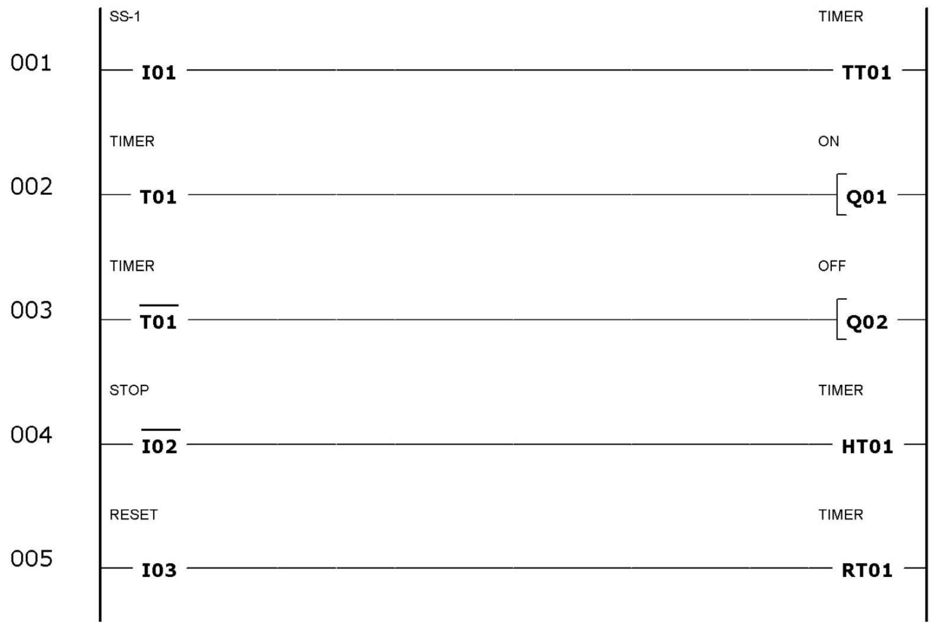


Figure 1-25. Ladder program of the PLC timing relay circuit.

☐ 15. Set the Programmable Logic Controller module to the RUN mode.

☐ 16. Access the circuit diagram display, then place the cursor on TT1. Press OK to access the timer 1 parameter display.

Set the selector switch of the Switches module to the L position while observing the timer's actual value at the bottom of the display.

How long does it take before the green pilot light turns on (when the timer's actual value stops)?

____

☐ 17. Does that correspond to the on delay preset value?

☐ Yes ☐ No

☐ 18. Set the selector switch of the Switches module to the O position, the green pilot light will turn off after 2 s.

☐ 19. Familiarize yourself with the operation of the stop coil and reset coil by stopping and resetting the timer value during the on delay timing (before the timer attains 10 s).

☐ 20. Set the PLC to the STOP mode.

Turn the individual power switch of the AC Power Supply off, disconnect the circuit, and return the equipment to the storage location.

CONCLUSION

In this exercise, you entered a PLC program resembling a hardwired timing relay circuit. You used the PLC on and off delay instruction to produce delays of 5 (on) seconds and 2 (off) seconds.

You connected switches and lights like in the hardwired circuit. However, the control and timing relays of the hardwired circuit were substituted for the Programmable Logic Controller module. You verified that the PLC on and off delay circuit worked just like the corresponding hardwired version by manipulating the different controls.

Finally, you familiarized yourself with the operation of the stop coil and reset coil.

REVIEW QUESTIONS

1. What can a timing relay circuit be used for, in industrial controls?

   a. Delay the startup of a motor.
   b. Delay the deactivation of an electrically-driven device.
   c. Make a pilot light flash.
   d. All of the above are correct.

2. In Figure 1-25 program, which contact replaces the control relay (NO) holding contact of the hardwired circuit?

   a. TT1
   b. T1
   c. I1
   d. None of the above is correct.

3. In the Figure 1-25 program, which contact replaces the timing relay (NO) contact of the hardwired circuit?

   a. M1
   b. T1
   c. I1
   d. Q1

4. In the Figure 1-25 program, why cannot both pilot lights be on at the same time?

   a. The timing relay controls Q1 coil.
   b. Q2 output rung becomes true when Q1 output is actuated.
   c. Q2 output rung becomes true when Q1 output is not actuated.
   d. None of the above is correct.

5. How many setpoints are necessary in the on and off delay function of the Programmable Logic Controller module?

   a. 1
   b. 2
   c. 3
   d. 4

Counter and Comparator Functions

EXERCISE OBJECTIVE

- Review PLC counter and comparator functions.

DISCUSSION

Counters

Programmable counters can perform the same functions as mechanical counters. They can count up, down, or both up and down. Counters are used when parts of a system must be activated and/or deactivated after a definite number of events has occurred.

The Programmable Logic Controller module includes 16 integrated counters that have the following coil functions:

- **Counter input (C)**: Each time the counter rung makes a false-to-true transition, the actual value is incremented or decremented by one count.
- **Counting direction (D)**: Counting up when the coil is not triggered, counting down when the coil is triggered.
- **Counter reset (R)**: Actual value resets to 00000 when the coil is triggered.

The counter preset value specifies the value (setpoint) that the counter must reach before the counter's make contact actuates.

The counters of the Programmable Logic Controller module count between 0 and 32 000. If they reach one of these limits, the value is retained until the count direction is changed.

Analog Value Comparators

PLC comparator instructions can be used in conjunction with timer and/or counter instructions to control sequential processes. The time and counter actual values are compared between them, or with preset values. The comparator outputs "true" or "false" logic, depending upon whether or not the condition is met.

The comparator instructions of the Programmable Logic Controller module are listed below. Each instruction compares a pair of numerical values (I1 and I2).

- **Less than (LT)**: True when I1 is less than I2.
- **Less than/equal to (LE)**: True when I1 is less than or equal to I2.

- **Equal to (EQ)**: True when I1 is equal to I2.
- **Greater than (GT)**: True when I1 is greater than I2.
- **Greater than/equal to (GE)**: True when I1 is greater than or equal to I2.

Note: *The Not equal (NE) instruction is obtained by changing the make contact of an EQ comparator for a break contact.*

When entering a comparison instruction, the sources of the two values to be compared (I1 and I2) must be specified. They can be constants, actual values of counter or timing relays, or analog input signals (usually from sensors). The Programmable Logic Controller module provides two (0-10 V) analog inputs, namely I7 and I8.

The I1 and I2 compared values can be modified by the following parameters:

- **Gain factors (F1 and F2)**: F1 is the gain factor for I1 (I1 = F1 × actual I1 value). F2 is the gain factor for I2.
- **Offset (OS)**: Offset for the value of I1 (I1 = OS + actual value of I1).
- **Hysteresis (HY)**: Switching hysteresis for I2. This value applies both to positive and negative hysteresis.

Procedure Summary

In this exercise, you will program a ladder circuit employing counter and comparator functions.

The circuit will be activated by a selector switch. Upon starting, the timer T1 will be triggered. Every time the COUNT push button is pressed, the counter's actual value increases.

At the count of five, the green pilot light will turn on. At the count of ten, the comparator will cause the red pilot light to start flashing alternately, due to a timer function. The counter can be reset by pressing the RESET push button.

EQUIPMENT REQUIRED

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required for this exercise.

PROCEDURE

⚠ WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

☐ 1. Perform the Basic Setup procedure.

Familiarization with the counter and comparator functions

☐ 2. Connect the Programmable Logic Controller module as described in Exercise 1-1.

Perform the Energizing procedure.

Enter and save the program shown in Figure 1-26, with the following parameter values:

Timer relay (T1)

- Coil function: trigger
- Mode: flash switching
- Setpoint I1: 0.5 s
- Setpoint I2: 0.5 s

Counter relay (C1)

- Coil function: count pulse
- Operand: constant
- Setpoint: 5

Comparator (A1)

- Comparator function: GE (greater than/equal to)
- Comparison value 1: counter C1
- Comparison value 2: 10

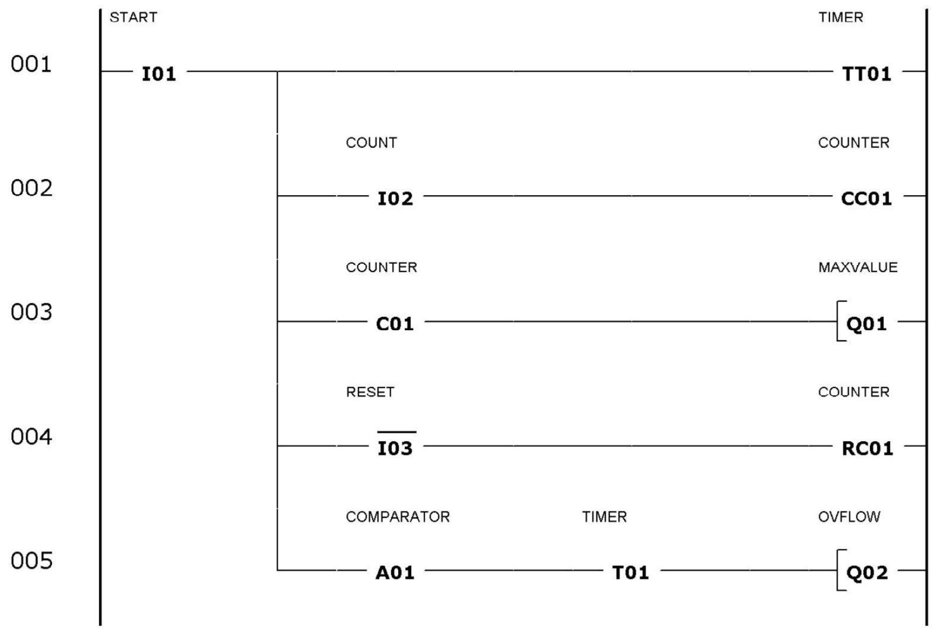


Figure 1-26. PLC counter and comparator circuit.

☐ 3. Access the circuit diagram display, then place the cursor on C1.

Press OK to access the counter 1 parameter display. Give a brief description of the following items shown on this display:

C1: ______________________

N: ______________________

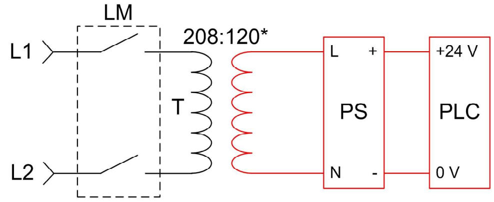
+: ______________________

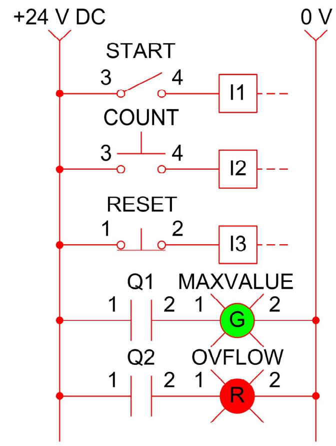
S: ______________________

C: ______________________

☐ 4. Perform the Lockout/Tagout procedure.

☐ 5. Connect the PLC inputs and outputs according to Figure 1-27.





*208:120 FOR 120 V - 60 Hz NETWORK
380:110 FOR 220 V - 50 Hz NETWORK
415:110 FOR 240 V - 50 Hz NETWORK
380:120 FOR 220 V - 60 Hz NETWORK

LEGEND

COUNT = COUNT UP PUSH BUTTON (MOMENTARY CONTACT)
Ix = PLC INPUT #x
MAXVALUE = MAXIMUM VALUE REACHED PILOT LIGHT (GREEN)
OVFLOW = OVERFLOW VALUE REACHED PILOT LIGHT (RED)
PLC = PROGRAMMABLE LOGIC CONTROLLER
PS = DC POWER SUPPLY
Qx = PLC OUTPUT RELAY #x
RESET = RESET PUSH BUTTON (MOMENTARY CONTACT)
START = START SELECTOR SWITCH (MAINTAINED CONTACT)
T = CONTROL VOLTAGE TRANSFORMER
LM = LOCKOUT MODULE

Figure 1-27. Connection diagram of the PLC counter and comparator circuit.

☐ 6. Set the START switch to the O position.

Perform the Energizing procedure.

Note: *Make sure that the PLC is set to the RUN mode.*

☐ 7. In your PLC program, what are the necessary conditions for the green pilot light to turn on?

____

____

☐ 8. What are the necessary conditions for the red pilot light to start flashing?

____

____

☐ 9. Set the START selector switch to the L position.

☐ 10. Press the COUNT push button five times. The green pilot light will illuminate. In your program, which contact closes at the count of 5?

☐ A1 ☐ C1 ☐ T1

☐ 11. Press the COUNT push button another five times. The red pilot light will start flashing.

☐ 12. In your program, which contact closes at the count of 10?

☐ A1 ☐ C1 ☐ T1

☐ 13. In your program, which contact opens and closes alternately?

☐ A1 ☐ C1 ☐ T1

☐ 14. Access the counter 1 parameter display.

Set the START selector to switch to the O position, and then back to the L position.

What is the value of the counter retained (as shown on the counter parameter display)?

____

☐ 15. Press the RESET push button. What is now the value of the counter?

____

☐ 16. Set the PLC to the STOP mode.

Turn the individual power switch of the AC Power Supply off, disconnect the circuit, and return the equipment to the storage location.

CONCLUSION

In this exercise, you used PLC comparator and counter functions to switch pilot lights following count events.

In the ladder program, a counter coil was actuated after 5 count pulses to light on a green pilot light. The counter accumulated value was increased by count pulses provided by a push button and reset by actuating the reset coil of the counter. At the count of ten, a comparator caused the red pilot light to start flashing alternately, due to a timer function.

REVIEW QUESTIONS

1. Which of the following PLC instructions are counter coil functions?

   a. Counter input (C)
   b. Counting direction (D)
   c. Counter Reset (R)
   d. All of the above are correct.

2. What happens when the PLC counter setpoint is reached?

   a. The counter's brake contact closes.
   b. The counter's make contact closes.
   c. The counter's actual value is reset.
   d. None of the above is correct.

3. What happens when the PLC counter counts over the maximum value of 32 000?

   a. The actual value is reset to 0.
   b. The count direction is changed.
   c. The value of 32 000 is retained.
   d. None of the above is correct.

4. Where can test values of a PLC comparator function come from?

   a. Counter relay
   b. Timing relay
   c. Set value (constant)
   d. All of the above are correct.

5. When is the EQ comparator instruction true?

   a. When I1 is lower than I2.
   b. When I1 is not equal to I2.
   c. When I1 is equal to I2.
   d. When I1 is greater than I2.

Unit Test

1. Which devices can be replaced by a PLC?

   a. Timing relay
   b. Counter relay
   c. Control relay
   d. All of the above are correct.

2. What can we compare the PLC break instructions to?

   a. Set instruction
   b. NO contacts
   c. NC contacts
   d. Parallel rung

3. By what means can a PLC be programmed?

   a. Dedicated buttons on the PLC
   b. Handheld terminal
   c. Separate computer
   d. All of the above are correct.

4. How is the "brain" section of the PLC called?

   a. Processor section
   b. Programming section
   c. Power supply
   d. Input/output section

5. Which programming method involves cutting a ladder program rung into sections to circumvent a PLC rung length limitation?

   a. Using a marker
   b. Using equivalent Boolean logic circuit
   c. Using backwards wiring
   d. All of the above are correct.

6. What is the name of the time PLCs take to process an entire circuit diagram?

   a. Drop-out time
   b. Pick-up time
   c. Cycle time
   d. Scan time

7. When is a delay produced with an on and off delay timing relay instruction?

   a. After relay trigger coil becomes true or false
   b. After relay trigger coil becomes true
   c. After relay trigger coil becomes false
   d. After relay stop coil becomes true or false

8. What has to be done to slightly modify a PLC control process?

   a. Replace the PLC
   b. Reprogram the PLC
   c. Rewire the entire process
   d. None of the above are correct.

9. When does the PLC counter instruction increment its actual value by one count?

   a. When the counter rung makes a true-to-false transition.
   b. When the counter rung makes a false-to-true transition.
   c. When the counter rung remains energized for at least one second.
   d. None of the above is correct.

10. When is the GT comparator instruction true?

    a. When I2 is lower than I1
    b. When I2 is not equal to I1
    c. When I2 is equal to I1
    d. When I2 is greater than I1

PLC Control Circuits

UNIT OBJECTIVE

Upon completion of this unit, you will be able to interface AC and DC voltages within a motor starter circuit. You will also be able to implement PLC motor starters enabling reversing, jogging, and overload control.

DISCUSSION OF FUNDAMENTALS

A motor circuit can be made of subcircuits operating at different voltages. In the Industrial Controls Training System, there can be three different voltages:

- AC supply voltage from the AC Power Supply;
- AC control voltage from the Control Transformer;
- DC control voltage from the DC Power Supply.

Low AC and DC voltages are mainly used in control circuits to provide a safer working environment for the operator. A "bridge" must however be implemented between low and high voltage circuits. This bridge allows control devices to have an effect in a power circuit and feedback signals from the power circuit to be received by the control circuit.

In the manual *Basic Controls*, you have seen that the coil of a contactor can be actuated with AC control (low) voltage. You have also seen that the NO power contacts of the same contactor can switch motor supply (high) voltage on and off. This example shows that a relay-type device can take a signal of a given voltage to have an effect on a circuit of a different voltage. Relay-type devices can therefore act as bridges between two subcircuits operating at different voltages.

The same principle applies to the Interposing Relays module, Model 3129. This device provides a way of bridging AC and DC control voltages in both ways (AC to DC and DC to AC). This feature is useful in applications where the 24 V dc PLC interacts with the system's AC devices.

Motor Control Circuits using a PLC

PLCs can replace wired logic. When changes are made to a control circuit, there is usually not much rewiring necessary, except connecting the new devices to the PLC. The main job typically consists of modifying the PLC program.

In the manual *Basic Controls*, you implemented various motor control circuits to run or jog a motor in forward or reverse direction. Exercises 2 and 3 will concentrate on presenting alternative ways of implementing these circuits with the help of a PLC. The last exercise will also deal with the way to handle a motor overload condition within a PLC circuit.