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ABSTRACT

These materials were developed for a seven-unit secondary or postsecondary education course on programmable logic controllers (PLCs) that treats most of the skills needed to work effectively with PLCs as programming skills. The seven units of the course cover the following topics: fundamentals of programmable logic controllers; contracts, timers, and counters; sequencers and registers; editing and programming functions; installation and troubleshooting; types of PLCs and programming; and industrial program applications. The first section of the manual is designed to show teachers how to use the materials and includes an explanation of instructional elements; an instructional task analysis for each unit; a list of tools, equipment, and materials; and a list of 14 references. Each instructional unit includes some or all of these basic components: performance objectives; suggested activities; information sheets; transparency masters; assignment sheets; job sheets; tests; and test answers. Some elements, such as the information sheets, include photographs, diagrams, and line drawings. (CML)

Programmable Logic Controllers

MAVCC

Teacher Edition

90-007158

CN602601


North Dakota
South Dakota
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PROGRAMMABLE LOGIC CONTROLLERS

Written by

Bob Rauh

and

Stan Kaltwasser

Edited by

Dan Fulkerson

Developed by

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Mid-America Vocational Curriculum Consortium, Inc.
1500 West Seventh
Stillwater, Oklahoma 74074-4364

PROGRAMMABLE LOGIC CONTROLLERS

TABLE OF CONTENTS

Unit I:	Fundamentals of Programmable Logic Controllers	1
Unit II:	Contacts, Timers, and Counters	89
Unit III:	Sequencers and Registers	189
Unit IV:	Editing and Programming Functions	303
Unit V:	Installation and Troubleshooting	371
Unit VI:	Types of PLCs and Programming	429
Unit VII:	Industrial Program Applications	483

FORWARD

When we talk about programmable logic controllers, the emphasis almost has to be on "programmable" because programs that can be written on-site for a specific control objective are really what programmable controllers are all about. MAVCC's text treats the skills required to effectively work with PLCs as mostly programming skills. We feel that a student trained to prepare and program ladder logic diagrams for defined objectives will have a highly marketable skill in the workplace. Programmable logic controllers first began as replacements for hard-wired relays, but their applications have literally mushroomed into all phases of industrial controls. PLCs are a significant new part of electrical/electronic installations, and technicians with appropriate skills can look forward to good jobs, excellent pay, promising futures in an exciting new job area. For many students interested in acquiring new skills or expanding present skills, MAVCC's *Programmable Logic Controllers* could be the start of something big.

Ann Masters, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

Jim Steward
Executive Director
Mid-America Vocational
Curriculum Consortium

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Bill Ashley	Northwest Louisiana Vo-Tech School, Minden, Louisiana
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USE OF THIS PUBLICATION

Instructional Units

Programmable Logic Controller contains seven units of instruction. Each instructional unit includes some or all of the basic components of a unit of instruction; performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, practical tests, and answers to the tests. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

A. The amount of material that can be covered in each class period.

B. The skills which must be demonstrated

1. Supplies needed

2. Equipment needed

3. Amount of practice needed

4. Amount of class time needed for demonstrations

C. Supplementary materials such as pamphlets or filmstrips that must be ordered

D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms; unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the ends of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

Suggested Activities for the Instructor

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledge which is a necessary prerequisite to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

Practical Tests

Practical tests provide the instructor with an evaluation instrument for each of the job sheets.

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking achievement of the objectives.

PROGRAMMABLE LOGIC CONTROLLERS

INSTRUCTIONAL / TASK ANALYSIS

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT I: FUNDAMENTALS OF PROGRAMMABLE LOGIC CONTROLLERS

1. Terms and definitions
2. Job opportunities related to PLCs
3. Programmable logic controllers
4. How PLCs differ from computers
5. PLC components and their functions
6. Programming PLCs
7. Ladder relay diagrams
8. Ladder logic diagrams
9. Logic states and status bits
10. Normally open and normally closed contacts
11. Examine On and Examine OFF instructions
12. Symbols for coils
13. Seal-in circuits
14. AND, OR, and NAND, NOR circuits in relay diagrams
15. Inputs/outputs and internal logic
16. Fundamentals of PLC programming
17. A simple AND logic circuit
18. A simple OR logic circuit

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)		RELATED INFORMATION: What the Worker Should Know (Cognitive)
	19.	A simple NAND logic circuit
	20.	A simple NOR logic circuit
	21.	Operating modes and their functions
	22.	Instructions
	23.	Keyboarding
24. Draw ladder relay diagrams to demonstrate basic logic functions. (Assignment Sheet #1)		
25. Draw ladder logic diagrams to demonstrate AND, OR, NAND, and NOR logic functions using normally closed switches in a circuit. (Assignment Sheet #2)		
26. Use a programmer to program, enter, and run a PLC program using AND, OR, NAND, and NOR logic. (Job Sheet #1)		

UNIT II: CONTACTS, TIMERS, AND COUNTERS

	1.	Terms and definitions
	2.	Auxiliary contacts
	3.	Examine OFF auxiliary contacts
	4.	Internal relays
	5.	RTO timers
	6.	How an RTC times
	7.	Basic RTO programming
	8.	RTF timers
	9.	Basic RTF programming
	10.	CTUs (up counters)

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)		RELATED INFORMATION: What the Worker Should Know (Cognitive)
	11.	CTDs (down counters)
	12.	Up-down counters
	13.	How a CTU counts
	14.	How an up-down counter works
	15.	Special function program keys

16. Write a ladder logic program using auxiliary contacts to energize an output. (Assignment Sheet #1)

17. Write and confirm a ladder logic program using an internal relay and its auxiliary contacts to energize an output. (Job Sheet #1)

18. Examine and confirm an existing RTO program. (Job Sheet #2)

19. Write and confirm a ladder logic program for an RTO timer. (Job Sheet #3)

20. Write and confirm a ladder logic program for an RTF timer. (Job Sheet #4)

21. Write and confirm a ladder logic program for an up counter. (Job Sheet #5)

22. Write and confirm a ladder logic program for a down counter. (Job Sheet #6)

23. Write and confirm a ladder logic program for an up-down counter. (Job Sheet #7)

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT III: SEQUENCERS AND REGISTERS

1. Terms and definitions
2. Comparing sequencers with timers and counters
3. Sequencer operations
4. Time-driven and event-driven sequencer operations
5. Accumulated values (AC) and preset values (PR)
6. Dynamics of SQO instructions
7. Dynamics of SQI instructions
8. Basic operation of a time-driven SQO instruction
9. Numbering systems and their structures
10. Working with sequencer data
11. The sequencer data form
12. Programming a time-driven SQO instruction
13. A typical SQO instruction
14. A typical SQI instruction
15. MCR and ZCL instructions
16. Cascading SQO sequencers
17. Reversing sequencers
18. Steps in a reversing sequencer operation

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)		RELATED INFORMATION: What the Worker Should Know (Cognitive)
	19.	Using sequencer input to drive sequencer output
	20.	Sequencer input monitoring sequencer output
	21.	Sequencer jump instructions
	22.	Shift registers
	23.	Shift register instructions
	24.	Event-driven shift register instructions
	25.	Time-driven shift register instructions
	26.	Cascading shift registers
	27.	Circulating shift registers
	28.	Shift register outputs

29. Convert decimals to binary coded decimals and binary coded decimals to decimals. (Assignment Sheet #1)

30. Convert bit address data into hexadecimal program codes. (Assignment Sheet #2)

31. Write and confirm an event-driven SQO instruction. (Job Sheet #1)

32. Write and confirm an event-driven SQI instruction. (Job Sheet #2)

33. Write and confirm a reversing SQO instruction. (Job SHeet #3)

34. Write and confirm an SQI instruction driving an SQO instruction. (Job Sheet #4)

35. Write and confirm an event-driven shift right register instruction. (Job Sheet #5)

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT IV: EDITING AND PROGRAMMING FUNCTIONS

1. Terms and definitions
2. Pocket programmer abbreviations and symbols
3. The pocket programmer display
4. Keyboard editing
5. Program modes and display modes
6. The CANCEL CMD function and error codes
7. NEXT and LAST key functions
8. The SEARCH function
9. The INSERT/REMOVE functions
10. The PRT/UNPRT functions
11 The FRC ON/RFC OFF functions
12. One-shot instructions
13. Fine time instructions

14. Use error codes to identify programming errors. (Job Sheet #1)
15. Enter, confirm, and revise and confirm a ladder logic program. (Job Sheet #2)
16. Revise an event-driven SQO instruction to a time-driven SQO instruction and confirm the revision. (Job Sheet #3)
17. Determine program scan time in milliseconds and program a fine time instruction. (Job Sheet #4)

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT V: INSTALLATION AND TROUBLESHOOTING

1. Terms and definitions
2. Enclosure standards
3. Guidelines for PLC enclosures
4. Installing a PLC
5. Wiring incoming power to a PLC
6. Wiring input devices to a PLC
7. Wiring output devices to a PLC
8. Grounding PLC systems
9. Emergency shutdown systems for PLCs
10. Other installation considerations
11. Inspection before start-up
12. Guidelines for system start-up
13. Troubleshooting guidelines
14. Power supply troubleshooting
15. Back-up battery troubleshooting
16. PLC maintenance
17. Use a force function to verify an input. (Job Sheet #1)
18. Use a force function to verify an output. (Job Sheet #2)
19. Use FRC ON/FRC OFF functions for troubleshooting. (Job Sheet #3)
20. Replace the power supply fuse on a PLC. (Job Sheet #4)
21. Replace the back-up battery on a PLC. (Job Sheet #5)

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT VI: TYPES OF PLCs AND PROGRAMMING

1. Terms and definitions
2. Comparing PLCs
3. Modular structure
4. Compatibility
5. Programming the Cutler-Hammer MPC1
6. The Cutler-Hammer MPC1 programmer
7. Register formats in the MPC1
8. Special registers in the MPC1
9. Other special features of the MPC1
10. Special MPC1 programming
11. Boolean programming basics
12. Boolean instruction sets
13. Grafcet programming
14. General structure of Grafcet
15. How Grafcet works
16. Grafcet programming
17. Putting a Grafcet program to work
18. Program protection schemes and devices
19. Translate ladder logic instructions into Boolean instructions. (Assignment Sheet #1)

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT VII: INDUSTRIAL PROGRAM APPLICATIONS

	1. Terms and definitions
	2. Applications inputs
	3. Common input devices and their applications
	4. START/STOP station conventions
	5. Putting logic to work in a START/ STOP station
	6. Limit switches as inputs
	7. Analog inputs
	8. Application outputs
	9. Power and grounding
10. Plan, wire, program, and confirm a conventional start/stop station. (Job Sheet #1)	
11. Connect relay coils to a start/stop station and verify interlocks. (Job Sheet #2)	
12. Connect a linear positioner, motor, and limit switches to simulate a positioning application. (Job Sheet #3)	
13. Program and confirm an up counter in a positioning application. (Job Sheet #4)	
14. Program and confirm a retentive timer in a positioning application. (Job Sheet #5)	
15. Program and confirm a two-cycle positioning application with manual stop. (Job Sheet #6)	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
16. Program and confirm a two-cycle positioning application with automatic stop. (Job Sheet #7)	
17. Program a positioning application with sequencer input driving sequencer output. (Job Sheet #8)	
18. Program a positioning application with sequencer input driving sequencer output with start/stop control. (Job Sheet #9)	
19. Program an extended SQI driving an SQO positioning application with start/stop control. (Job Sheet #10)	
20. Program and verify a jump command in a positioning application. (Job Sheet #11)	

21

TOOLS, EQUIPMENT, AND MATERIAL LIST

Important!

Safety glasses are required for all performance activities in this text.

Basic hand tools

Flat blade and Phillips screwdrivers
Combination wrench set
Combination slip-joint pliers
Needlenose pliers
Electricians pliers

Equipment

SLC™100 programmable logic controller or equivalent
User's manual for selected PLC
Normally open and normally closed switches safely mounted
Conventional start/stop station
Proximity switches
Photoelectric switches
Pushbutton switches
Limit switches
Other input devices as selected
Solenoid
AC motor
Motor Relays
DC motor
Other output devices as selected
Linear positioner
#14 AWG color-coded wiring as required
Student work station with ground-fault protection

Materials

Sequencer instruction data forms
Pen or pencil
Wooden yard stick
Lined writing tablet

PROGRAMMABLE LOGIC CONTROLLERS
(References used in developing this text)

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FUNDAMENTALS OF PROGRAMMABLE LOGIC CONTROLLERS

UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to differentiate between ladder relay diagrams used in conventional electrical circuits and ladder logic diagrams used in programmable logic controller circuits. The student should also be able to relate both relay and logic symbols to their functions in a circuit and define Examine On and Examine Off conditions in PLC programming. These competencies will be evidenced by correctly completing the procedures outlined in the assignment and job sheets and by scoring a minimum of 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to programmable logic controllers with their correct definitions.
2. Select true statements concerning job opportunities related to PLCs.
3. Complete statements concerning programmable logic controllers.
4. Complete statements concerning how PLCs differ from computers.
5. Match PLC components with their functions.
6. Select true statements concerning programming PLCs.
7. Select true statements concerning ladder relay diagrams.
8. Select operating conditions of ladder logic diagrams.
9. Select operating conditions of logic states and status bits.
10. Solve problems concerning normally open and normally closed contacts.
11. Select true statements concerning Examine On and Examine OFF instructions.
12. Identify symbols for coils.
13. Complete statements concerning seal-in circuits.
14. Identify AND, OR, and NAND, NOR circuits in relay diagrams.

OBJECTIVES SHEET

15. Select true statements concerning inputs/outputs and internal logic.

16. Select fundamentals of PLC programming.

17. Identify the diagram for a simple AND logic circuit.

18. Identify the diagram for a simple OR logic circuit.

19. Identify the diagram for a simple NAND logic circuit.

20. Identify the diagram for a simple NOR logic circuit.

21. Match basic operating modes with their functions.

22. Complete statements concerning instructions.

23. Solve problems concerning keyboarding.

24. Draw ladder relay diagrams to demonstrate basic logic functions. (Assignment Sheet #1)

25. Draw ladder logic diagrams to demonstrate AND, OR, NAND, and NOR logic functions using normally closed switches in a circuit. (Assignment Sheet #2)

26. Demonstrate the ability to use a programmer to program, enter, and run a PLC program using AND, OR, NAND, and NOR logic. (Job Sheet #1)

FUNDAMENTALS OF PROGRAMMABLE LOGIC CONTROLLERS
UNIT I

SUGGESTED ACTIVITIES

Read Me First

Procedures in this text are presented for demonstration only and should not be used in actual industrial applications. Graphic materials from manufacturers are presented for the purpose of illustration only and no liability is assumed for their use otherwise. Persons using this text assume liability for demonstration and for any equipment damaged in demonstration. Administration of these materials should be by a qualified instructor only in a safety-proven environment.

A. Provide students with objective sheet.

B. Provide students with information and assignment sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Arrange for students to visit a local or area industry that uses PLCs in their operation, and have students report their findings.

G. Invite a PLC manufacturer's representative to talk to the class about PLC design and the variety of PLC applications.

H. Review general safety, electrical safety, and discuss particular safety requirements for working with and around PLCs.

I. Use Handouts #1 and #2 to acquaint students with the Allen Bradley SLC™100, explain why this particular PLC has been selected for activities in this text, and review the features highlighted in Handout #2 so students will better appreciate the convenience that the SLC™100 provides for PLC training.

J. Give test.

Special Note

For educational discounts on Allen-Bradley products, contact your local Allen-Bradley Sales Office or an Allen-Bradley distributor.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *A Study Guide to Programmable Controllers*. Chattanooga, TN 37405: Tel-A-Train, Inc., 1984.

B. Atrich, Walter M. *Electric Motor Controls (Fourth Edition)*. Albany, NY: Delmar Publishers, 1988.

C. *User's Manual Bulletin 1745 SLC™ 100 Programmable Controller*. Milwaukee, WI 43204: Allen-Bradley Company, 1985.

D. *User's Manual Bulletin 1745 SLC™ 100 Programmable Controller*. Milwaukee, WI 43204: Allen-Bradley Company, 1984.

FUNDAMENTALS OF PROGRAMMABLE LOGIC CONTROLLERS
UNIT I

INFORMATION SHEET

I. **Terms and definitions**

A. **Address** — The numerical location of a particular status bit in the permanent memory of a PLC processor

B. **Examine OFF** — A basic statement in PLC logic that directs a status bit to look for a condition where power in a circuit is OFF

C. **Examine ON** — A basic statement in PLC logic that directs a status bit to look for a condition where power in a circuit is ON

D. **NC (Normally Closed)** — A switch or contact which is closed and passing power when it is inactive, and open and not passing power when it is active

E. **NO (Normally Open)** — A switch or contact which is open and not passing power when it is inactive, and closed and passing power when it is active

F. **PLC (Programmable Logic Controller)** — A microprocessor-based control system designed to respond to user input in executing a control objective

G. **User program** — A set of instructions which can be entered into processor memory at a local time and place by a programmer

H. **Hard-wired** — An electrical control design built around relays where components have to be physically wired to one another to complete electrical continuity

I. **Grafcet** — A graphical method of programming PLCs in steps and transitions that speed up programming and scan time

II. **Job opportunities related to PLCs**

A. Although there is no specific job title called programmable controller technician, programmable controllers are profuse in industry, and technicians with skills in PLCs have the upper hand in getting and keeping a variety of jobs.

B. Maintenance electricians perform routine electrical troubleshooting, and this frequently includes troubleshooting PLCs.

C. Instrumentation technicians perform maintenance on everything from transmitters to control valves, frequently calibrate instruments such as pressure gauges, and need enough knowledge to troubleshoot and program PLCs.

D. Maintenance supervisors must have a broad range of knowledge and experience in all phases of industrial electricity/electronics, and skills in installing, troubleshooting, and programming PLCs.

INFORMATION SHEET

E. Plant engineers usually have an associate or advanced degree from a technical school or university, and this includes skills in planning and executing applications of PLCs.

F. Pay for experienced maintenance and control technicians is above the average for comparable fields such as computer technicians.

G. Salaries for supervisory personnel in industrial electricity/ electronics is excellent and promises to improve as more PLCs find their place in industry.

III. Programmable logic controllers

A. Programmable logic controllers are so named because they use logic to control input/output devices, and they can be programmed by a user.

B. In a hard-wired relay panel, circuits or loads can be energized only with closed contacts, and a switch can be used only with the load to which it is directly connected.

C. To change the operating objectives of a hard-wired relay panel requires physically redesigning and changing the wiring.

D. When timing functions are required with a hard-wired relay panel, they have to be added and wired into the system.

E. With a PLC, switches or sensors are connected to inputs, loads are connected to outputs, and the programming logic interfaces inputs to outputs as the user designs and dictates.

F. With a PLC, timing and counting functions can be programmed and do not require additional hardware.

G. With a PLC, one switch can be used in either a normally open or normally closed state to activate multiple outputs.

H. The power of a PLC lies in its computing power, but a PLC is not a computer.

IV. How PLCs differ from computers

A. Computers are designed to work in clean environments while PLCs are designed to function in hostile environments including temperature extremes and areas contaminated with dust, dirt, vapors, and oil.

B. Computers may be programmed with a variety of languages, some of which are difficult to learn, but PLCs can be programmed with ladder logic diagrams and minimal programming skills.

(NOTE: PLCs have had various names including Programmable Controller, but PC also stands for Personal Computer, so the name PLC evolved to clearly distinguish the programmable logic controller from the personal computer.)

INFORMATION SHEET

V. PLC components and their functions (Transparency 1)

A. Programmer — A device where a set of instructions stored in memory can be used to tell a controller how to manage a specific operation

B. Input module — A component that gathers signals from a process and sends information about the process on to a controller

C. Controller — The brains of a PLC where logic solving and decision making are performed and appropriate signals sent to an output module

D. Output module — A component that receives controller output and forwards signals on to real-world devices such as motors and relays to accomplish a control objective

VI. Programming PLCs

A. Properly connecting inputs and outputs to a PLC begins with an activity called programming.

B. Programming means using an operator terminal with a keyboard to enter commands that will tell the PLC controller what action is desired at an output in response to a certain input.

Example: If a temperature sensor sends an input which indicates a drying oven has reached 350°F, a properly programmed controller would activate a solenoid which would open the oven door so the product could be moved out.

C. Because electrical circuits are frequently complex, programming PLCs is accomplished with a format based on ladder logic diagrams which are similar to ladder relay diagrams.

(NOTE: Not all PLCs are programmed with ladder logic diagrams, and other forms of programming will be discussed in a later unit of instruction.)

D. Ladder relay diagrams indicate **electrical continuity,** but ladder logic diagrams indicate **logical continuity.**

VII. Ladder relay diagrams

A. Ladder relay diagrams use pictorial symbols to represent buttons, switches, relays, coils, and other electrical devices. (Transparencies 2, 3, 4, and 5)

B. Ladder relay diagrams have a traditional form: (Transparency 6)

1. The left and right vertical lines are called RAILS.

2. The horizontal lines are called RUNGS.

3. The left rail is labeled L1 to indicate the high side or supply side of an electrical circuit.

INFORMATION SHEET

4. The right rail is labeled L2 to indicate the low side or return side of a circuit.

(NOTE: The form outlined is true for circuits with 110 voltage.)

C. Ladder relay diagrams show conditions where only closed contacts can energize an output, and that is why these diagrams are sometimes called "hard-wired" diagrams because components have to be physically wired to each other to complete electrical continuity.

VIII. Ladder logic diagrams

A. Ladder logic diagrams use straight and crossing lines, closed or open circles and brackets, and numbers and letters as symbols for electrical devices. (Transparency 7)

B. In ladder logic diagrams, components do not have to be wired to each other to complete a circuit.

C. In a ladder logic diagram, an OPEN switch or a CLOSED switch either one can energize an output, depending on how the switches are programmed.

D. Because ladder logic diagrams are the basis of the programming format for many PLCs, they show logical continuity, not electrical continuity.

E. Logic ladder diagrams have rungs numbered in a 1, 2, 3 order starting from the top, and should be read in a logical order:

1. Start on the top rung at the left rail.
2. Read left to right toward the right rail.
3. Read down to the left rail of the next rung.
4. Continue reading left to right and down.

IX. Logic states and status bits

A. With most PLCs, the programming format is the ladder logic diagram, but the diagram has to be physically entered into the PLC memory before an input/control/output activity can happen.

B. Entering a program means giving the controller instructions about how to handle input and output.

C. To handle instructions, the controller uses "discrete" signals which are 0 or 1 (zero or one) to indicate a condition that is either OFF or ON.

D. Logic state 1 indicates a condition that is ON and therefore TRUE.

E. Logic state 0 indicates a condition that is OFF and therefore FALSE.

INFORMATION SHEET

F. The conditions that can be programmed are stored in controller memory at specific addresses which are numbered so they can be entered on the keyboard of a programmer.

G. Programming a PLC requires knowing the address of the status bit required to provide a controller with the TRUE/FALSE information needed to activate or not activate an input or output.

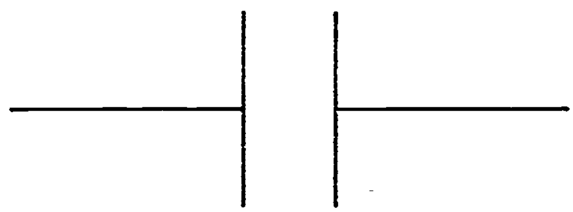
X. Normally open and normally closed contacts

A. In all electrical circuits, contacts open or close to activate relays and switches, and the normal state of contacts is an important basic of ladder logic programming.

B. A normally open contact will be OPEN and NOT passing power in its inactive state.

C. Normally open is abbreviated NO, and for programming has the same symbol in both relay and logic diagrams. (Figure 1)

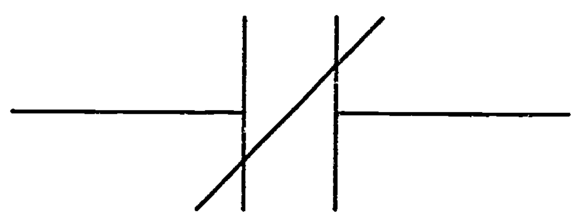
FIGURE 1



D. A normally closed contact will be CLOSED and PASSING power when it is in its inactive state.

E. Normally closed is abbreviated NC, and for programming has the same symbol in both relay and logic diagrams. (Figure 2)

FIGURE 2



F. The important thing to remember about NO and NC contacts is that they change to opposite states when ACTIVATED:

1. A NO contact when activated will CLOSE and PASS POWER.

2. A NC contact when activated will OPEN and NOT PASS POWER.

INFORMATION SHEET

XI. Examine ON and Examine OFF instructions

A. The symbols for NO and NC contacts have additional importance in PLC programming.

B. In programming and ladder logic, the symbol -| |- means more than Normally Open, it means Examine ON.

C. Examine ON means that when a controller finds there IS VOLTAGE at a certain address, the instruction at that address is TRUE

D. When there is NO VOLTAGE at an Examine ON address, the instruction is FALSE.

E. The symbol -|/|- means more than Normally Closed, it means Examine OFF.

F. Examine OFF means that when a controller finds there is NO VOLTAGE at a certain address, the instruction at that address is TRUE.

G. When there IS VOLTAGE at an Examine OFF address, the instruction is FALSE.

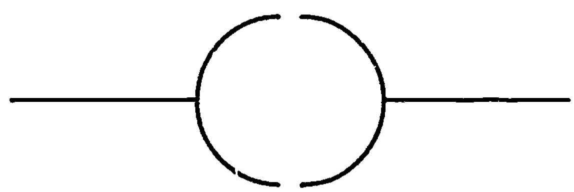
XII. Coils and their symbols

A. In order for a controller to activate an external device it uses a coil to send an ON/OFF signal to an output module.

B. A coil is programmed much like a contact is programmed in that it sends a signal when it is ENERGIZED and does not send a signal when it is NOT ENERGIZED.

C. A normal coil symbol resembles circular brackets. (Figure 3)

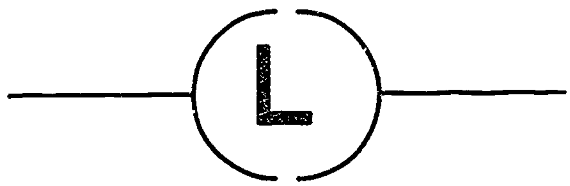
FIGURE 3



INFORMATION SHEET

D. Certain coils are used to be sure an output device is in a proper state during an operation, and these are called LATCHED coils as indicated by the letter "L". (Figure 4)

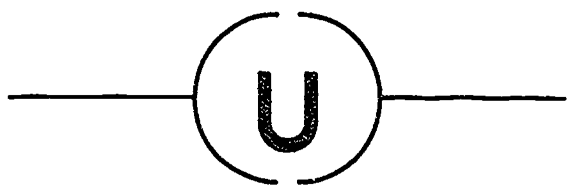
FIGURE 4



E. When power is applied to a PLC, a latched coil will usually return to the state it was in before power was removed, and for this reason, latched coils are used with safety devices such as alarms, fans, and guards.

F. On most PLCs a latched coil remains latched even when the rung changes state, and in these cases an UNLATCHED COIL (indicated by the letter "U") is required to change the output of the rung. (Figure 5)

FIGURE 5



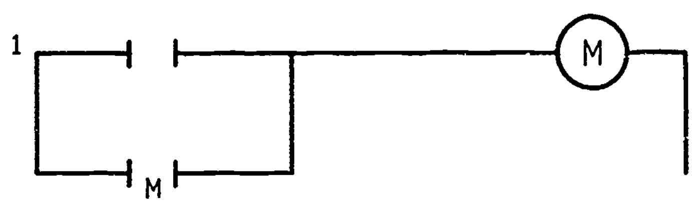
XIII. Seal-in circuits

A. Seal-in circuits are used to keep a motor running after it has been started with a momentary switch.

B. A seal-in circuit is usually a set of contacts in the motor starter which close and keep power supplied to the motor after the momentary start button has been released.

C. Seal-in circuits are easy to identify in ladder logic diagrams because they almost always appear in a branch circuit below the rung where the motor is located. (Figure 6)

FIGURE 6



D. Seal-in circuits also demonstrate how parallel circuits function as logical OR circuits because either the start switch or the seal-in circuit can be used to energize the motor starter which then energizes the motor.

INFORMATION SHEET

E. Seal-in circuits are almost always required for event sequencing circuits using timers and counters.

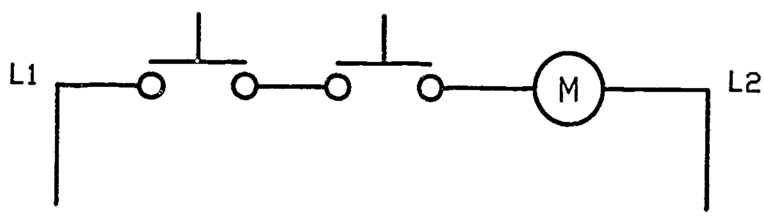
F. Programming seal-in circuits requires a procedure called "branching."

XIV. AND, OR and NAND, NOR circuits in relay diagrams

A. AND, OR, NAND, and NOR are definitions of logic functions directly related to series and parallel circuits.

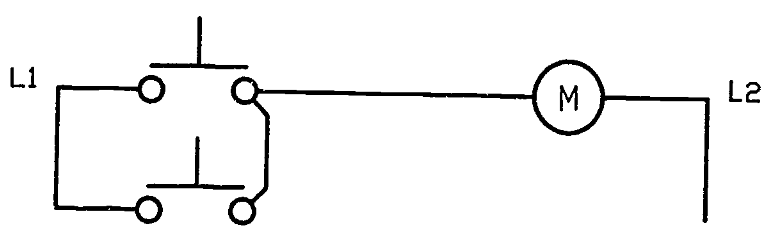
B. With an AND function all switches in series with a load must be CLOSED to energize that load. (Figure 7)

FIGURE 7



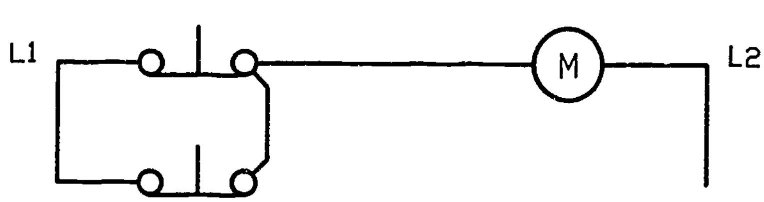
C. With an OR function, any switch in series with a load may be CLOSED to energize that load. (Figure 8)

FIGURE 8



D. With a NAND function, which is the direct opposite of the AND function, all switches in parallel with the load must be OPENED to DE-ENERGIZE the load. (Figure 9)

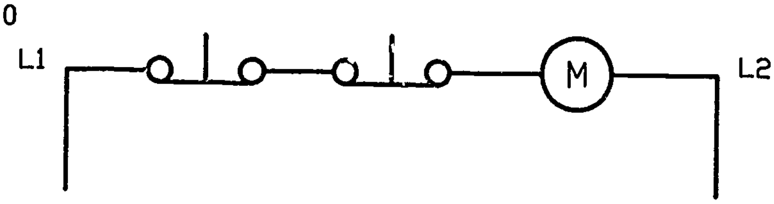
FIGURE 9



INFORMATION SHEET

E. With a NOR function, which is the direct opposite of the OR function, any switch in series with the load may be OPENED to DE-ENERGIZE the load. (Figure 10)

FIGURE 10



F. The functions of AND, OR, NAND, and NOR logic are employed frequently in PLC programming, and the important part of the process is to remember:

1. AND and OR functions are accomplished with NO contacts.

2. NAND and NOR functions are accomplished with NC contacts.

XV. Inputs/outputs and internal logic

A. Inputs are devices such as limit switches and contacts that initiate or stop a voltage signal to the input terminals on a PLC.

B. Outputs are contacts in an output module that provide a closure used to turn ON/OFF field devices such as motors or solenoids.

C. Internal logic is that part of a PLC that receives information from inputs, makes decisions based on programmed conditions, and sets outputs to programmed objectives.

D. Inputs/outputs and internal logic are all controlled in the controller memory with status bits that must be addressed.

E. PLC addresses are grouped in order:

1. Specific addresses are for inputs only.

2. Specific addresses are for outputs only.

3. Specific addresses are for internal logic only.

4. Other addresses are for special functions associated with registers.

Example: In the Allen-Bradley SLC™100, the addresses for inputs 1 through 10 are the numbers 001 through 010.

INFORMATION SHEET

XVI. Fundamentals of PLC programming

A. In hard-wired relays, NC and NO contacts and switches have traditional functions and can do only what they are wired to do.

B. In PLC functions, a contact or switch does what it is programmed to do whether it is NO or NC.

C. An AND circuit with two NO switches will serve to demonstrate basic PLC programming: (Refer to Figure 11)

1. First, physically wire the two NO switches to inputs #1 and #2 on the PLC.

2. Next, prepare a ladder logic diagram that will make the switches function as an AND circuit.

3. Begin the ladder logic diagram by entering a 1 beside the left rail to indicate the run number, and continue left to right to complete the rung.

4. Add the symbols for two NO contacts at points along the left half of the rung.

5. Assume that in controller memory, the addresses for the two input contacts are 001 for switch #1 and 002 for switch #2.

6. Enter 001 above the first NO contact on the rung and 002 above the second NO contact on the rung.

7. Add an output coil to the right side of the rung to complete the rung because no rung is complete without an output.

8. The address for the coil is 11, so enter the address to complete the rung for the AND circuit.

9. Finally, use a programming device to keyboard the rung with its proper addresses into controller memory.

   (NOTE: Keyboarding and initiating a simple program will be presented in later objectives and in a job sheet.)

D. When the appropriate elements in a rung are TRUE, then the rung or the output is said to be TRUE, and controller logic will energize the contact required to start a motor or whatever the programmed output is.

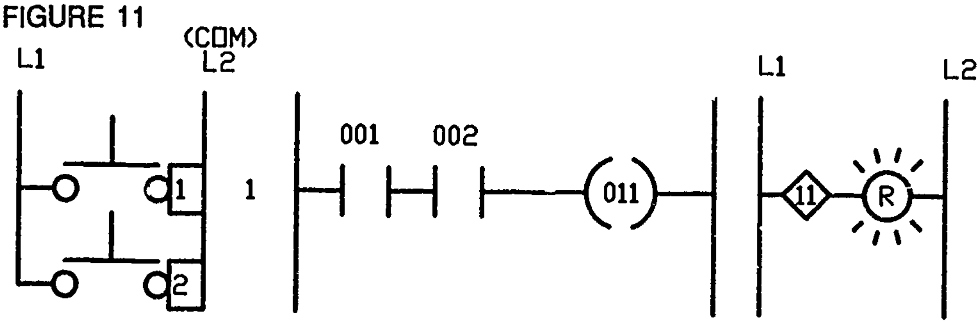
INFORMATION SHEET

XVII. Dynamics of a simple AND logic circuit

NOTE: The following objectives include elements of both ladder relay and ladder logic diagramming to better demonstrate what happens in the interrelation of inputs, internal logic, and outputs.

A. Figure 11 shows switches 1 and 2 physically connected to input addresses 1 and 2 on a PLC, the ladder logic diagram shows an AND circuit using NO switches and a coil, and the output indicates a contact that turns a light on. (Figure 11)

FIGURE 11



B. When switch 1 is operated, it applies power to input address 1 which makes the Examine ON status bit TRUE at address 001.

C. When switch 2 is operated, it applies power to input address 2 which makes the Examine ON status bit TRUE at address 002 which gives LOGICAL CONTINUITY to Rung 1.

D. With logical continuity established, Rung 1 coil 11 is energized, which energizes the contact at output address 11, and the output (bulb) lights up.

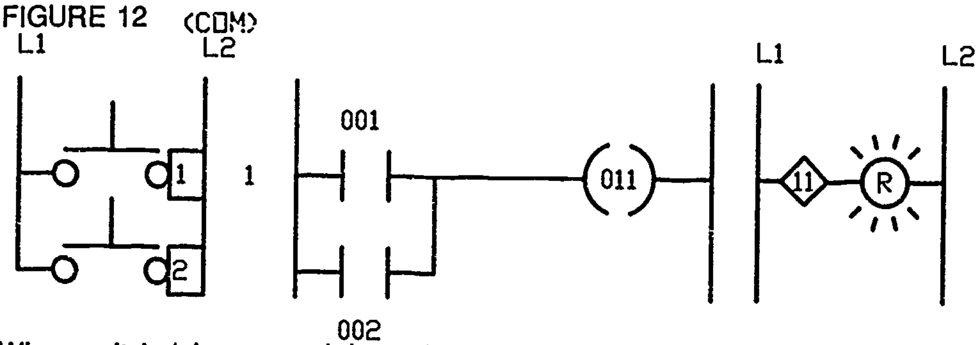
E. The simple circuit in Figure 11 demonstrates how two NO switches are used to perform an AND logic function because both switch 1 AND switch 2 must be closed to give logical continuity to the rung.

INFORMATION SHEET

XVIII. Dynamics of a simple OR logic circuit

A. Figure 12 shows switches 1 and 2 physically connected to input addresses 1 and 2 on a PLC, the ladder logic diagram shows an OR circuit using NO switches and a coil, and the output indicates a contact that turns a light on. (Figure 12)

FIGURE 12



B. When switch 1 is operated, it applies power to input address 1 which makes the Examine ON status bit at address 001 TRUE which gives LOGICAL CONTINUITY to Rung 1, energizes the coil, and lights the light.

C. When switch 2 is operated, it will make the Examine ON status bit at address 002 TRUE and also give logical continuity to Rung 1.

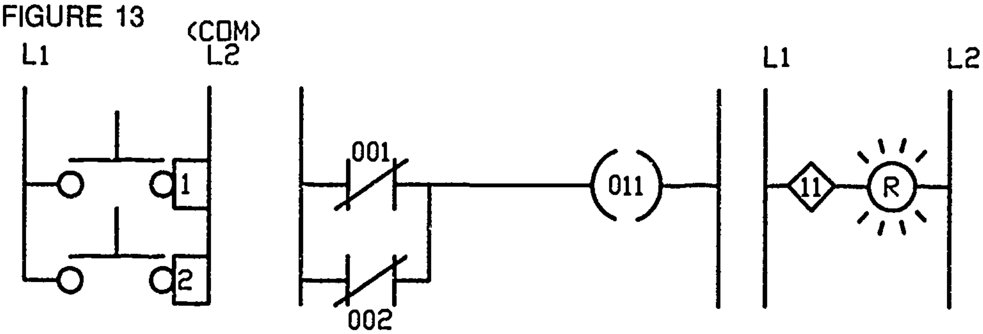
D. The circuit in Figure 12 demonstrates how two NO switches can be used to perform an OR logic function because 001 or 002 can give logical continuity to the rung.

INFORMATION SHEET

IX. Dynamics of a simple NAND logic circuit

A. Figure 13 shows switches 1 and 2 physically connected to input addresses 1 and 2 on a PLC, the ladder logic diagram shows a NAND circuit using NO switches and a coil, and the output indicates a contact that turns a light on. (Figure 13)

FIGURE 13



B. When switch 1 is operated it applies power to input address 1 which makes the Examine OFF status bit at address 001 FALSE but the output remains energized because the Examine OFF status bit at address 002 remains TRUE and gives the rung LOGICAL CONTINUITY.

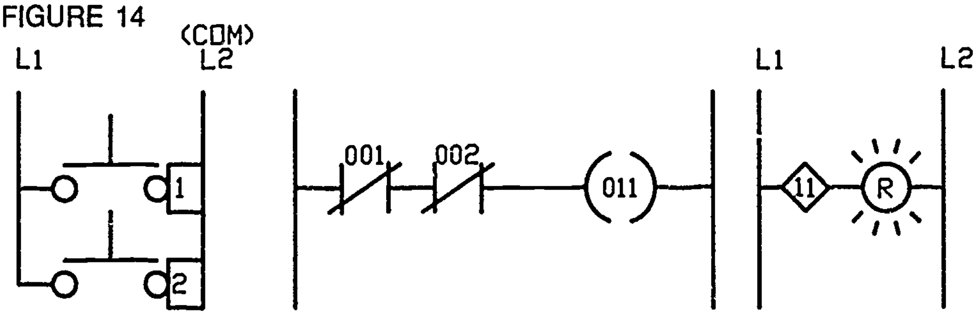
C. When switch 2 is operated, the status bit at address 002 becomes FALSE, and since the status bit at address 001 is already FALSE, there is no logical continuity on the rung and the output will not energize.

D. The simple circuit in Figure 13 demonstrates how two NO switches are used to perform a NAND logic function, and it also demonstrates the power of PLCs because this function cannot be accomplished with NO switches in a hard-wired circuit.

XX. Dynamics of a simple NOR logic circuit

A. Figure 14 shows switches 1 and 2 physically connected to input addresses 1 and 2 on a PLC, the ladder logic diagram shows the NOR circuit using NO switches and a coil, and the output indicates a contact that turns a light on. (Figure 14)

FIGURE 14



INFORMATION SHEET

B. When switch 1 is operated it makes the Examine OFF status bit at address 001 FALSE, there is NO LOGICAL CONTINUITY in the rung, and the output de-energizes even though the status bit at address 002 is still TRUE.

C. When switch 2 is operated it makes the Examine OFF status bit at address 002 FALSE, there is still no logical continuity on the rung, and the output remains de-energized.

D. The circuit in Figure 14 demonstrates how two NO switches are used to perform a NOR logic function.

XXI. Basic operating modes and their function

A. Mode 1 — Clears programmer memory so a new program can be entered

B. Mode 2 — Permits the input of a new user program or the update of an existing program

C. Mode 3 — Tells the PLC processor to scan and execute the user program

(NOTE: There are other operating modes for testing certain program functions, and they will be presented in a later unit of instruction.)

XXII. Instructions

A. Instructions are classified as either condition instructions or output instructions, and the two together form an instruction set. (Transparency 8)

B. Instructions are all assigned addresses which are associated with particular status bits in PLC memory.

C. Instructions are always stored in the same order in which they are entered, and the PLC processor executes the instructions in that same order.

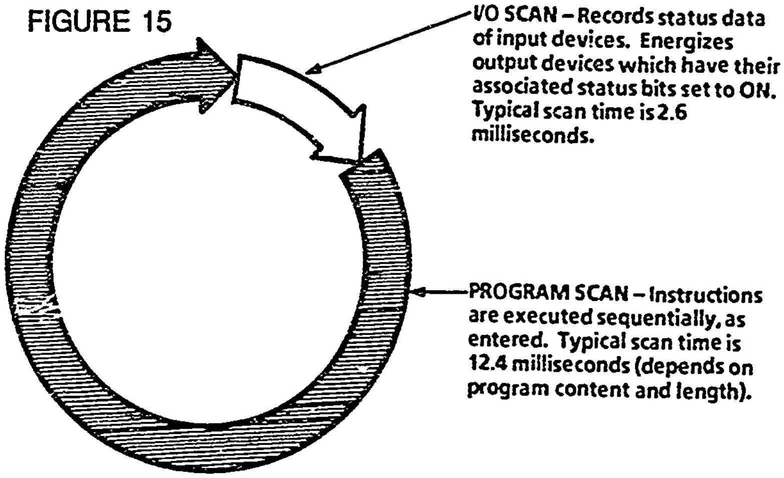
D. The PLC processor operates on instructions in a single operating cycle called a scan which is divided into two parts: (Figure 15)

1. The I/O Scan records the status of input devices and energizes output devices which have their associated status bits set to ON.

INFORMATION SHEET

2. The Program Scan reads inputs, executes the scan, and updates outputs.

FIGURE 15



XXIII. Keyboarding

A. Programming is the physical act of using a keyboard on a programmer to place a ladder logic diagram into PLC memory. (Transparency 9)

B. A typical keyboarding process requires:

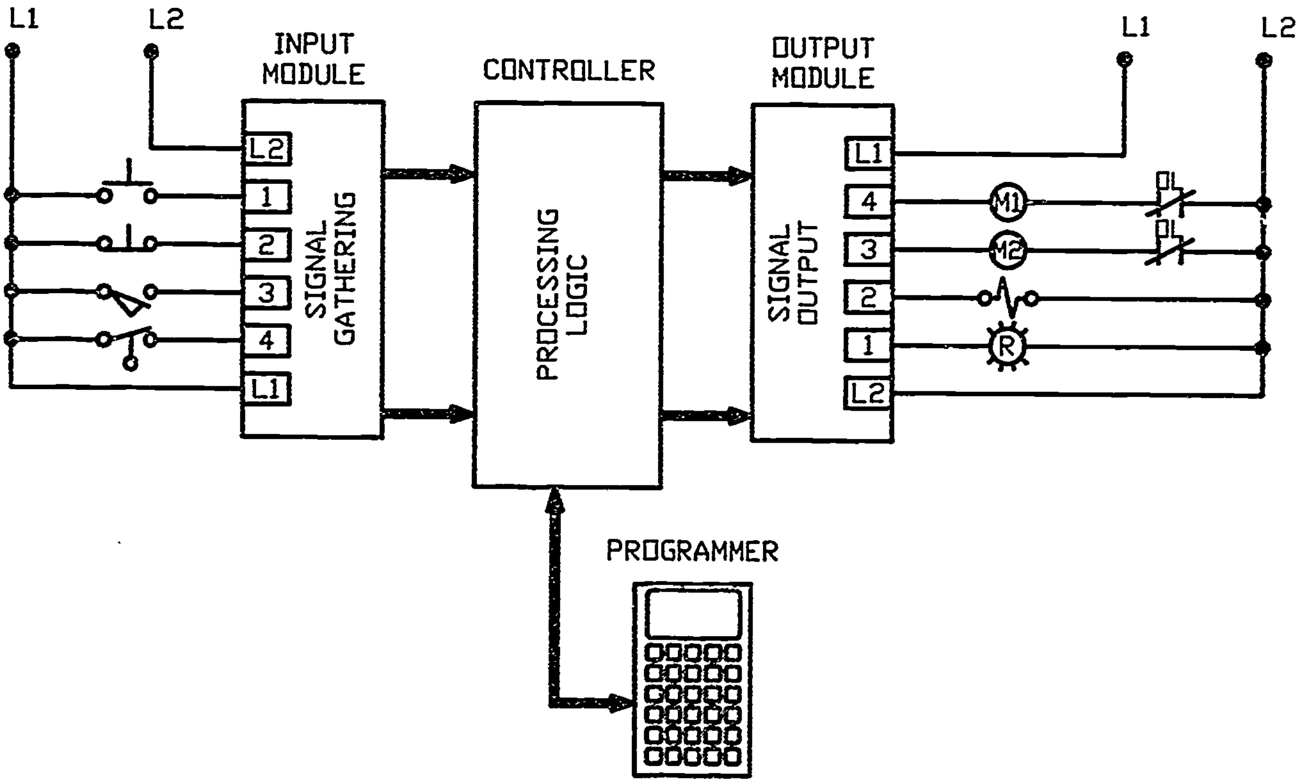
1. Placing the programmer in the program mode.
2. Clearing PLC memory so a new program can be entered.
3. Selecting condition instructions and output instructions that reflect the logic diagram.
4. Addressing all instructions with their specific numbers as they are stored in memory. (Transparency 10)
5. Completing each rung with an output instruction, and completing rungs in order.
6. Ending the program.
7. Transferring the program to PLC memory.
8. Confirming program execution by running the program on the PLC.

INFORMATION SHEET

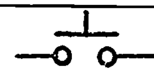
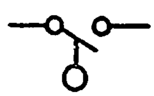
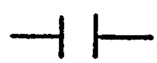
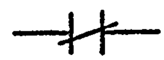
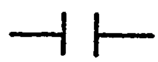
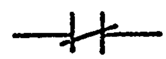
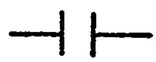
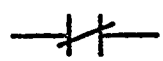
C. Keys on a programmer have a combination of words, abbreviations, and symbols that can be pressed to select a function, and usually an ENTER key to place the function into memory.

(NOTE: The keyboard in Transparency 9 is for the SLC™ 100 Pocket Programmer which is recommended for programming activities with this unit of instruction. Other programmers will be discussed in later units.)

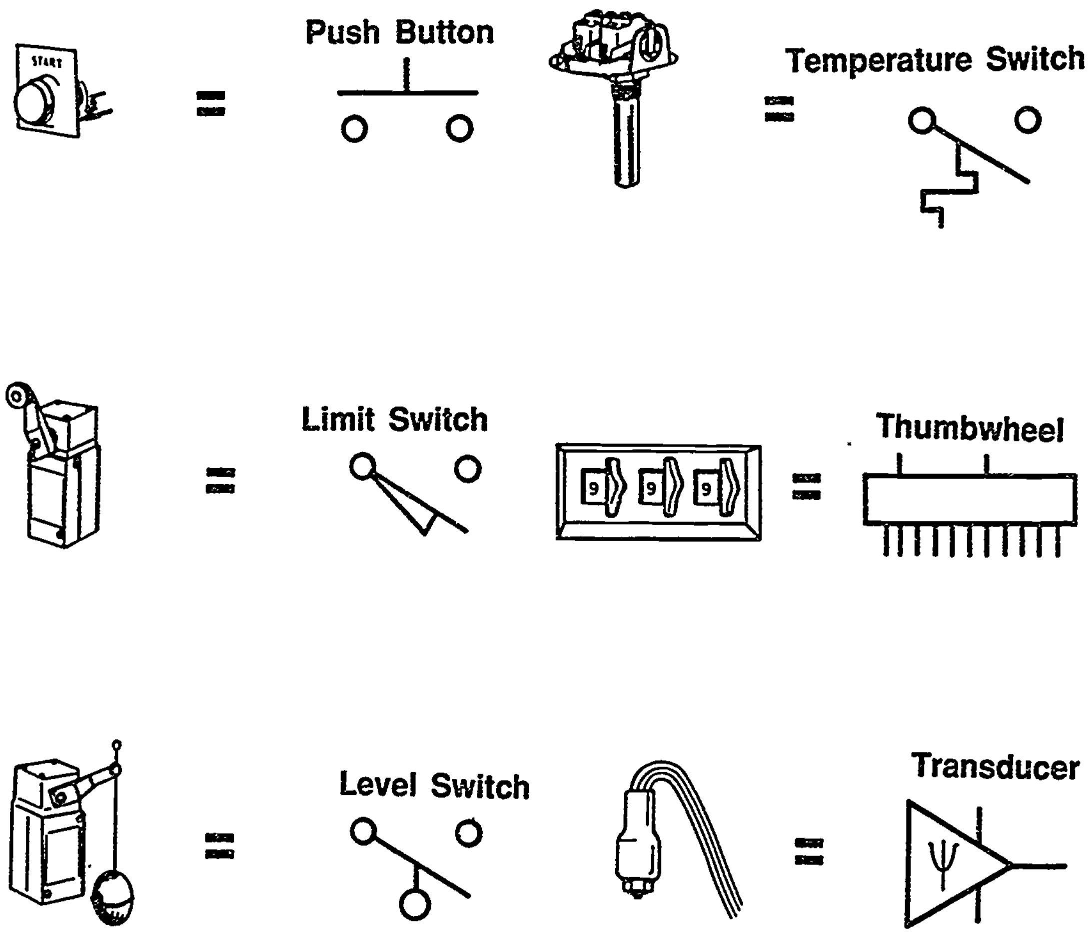
Components of a Programmable Controller



Relay Contact Symbols

Device Type	Contact Symbology: Normally Open	Contact Symbology: Normally Closed
Push Button (PB)		
Limit Switch (LS)		
Temperature Switch (TAS)		
Flow Switch (FLS)		
Level Switch (FS)		
Control Relay (CR)		
Latching Relay (CRL)		
Counter (CTR)		
Time Delay Relay (TR) Delay Begins When Coil is Energized		
Delay Begins When Coil is De-Energized		

Input Symbols



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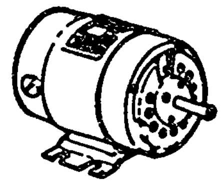
Output Symbols



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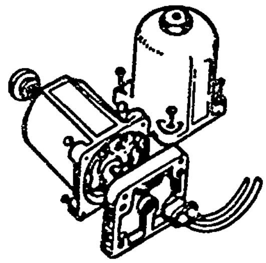
Motor



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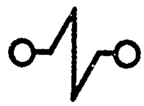
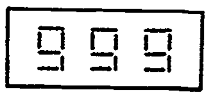
Solenoid





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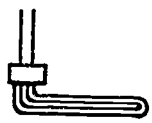
LED Display



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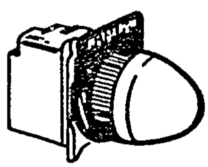
Heater



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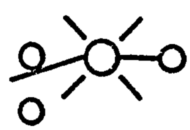
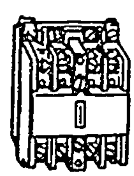
Lamp





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Motor Starter

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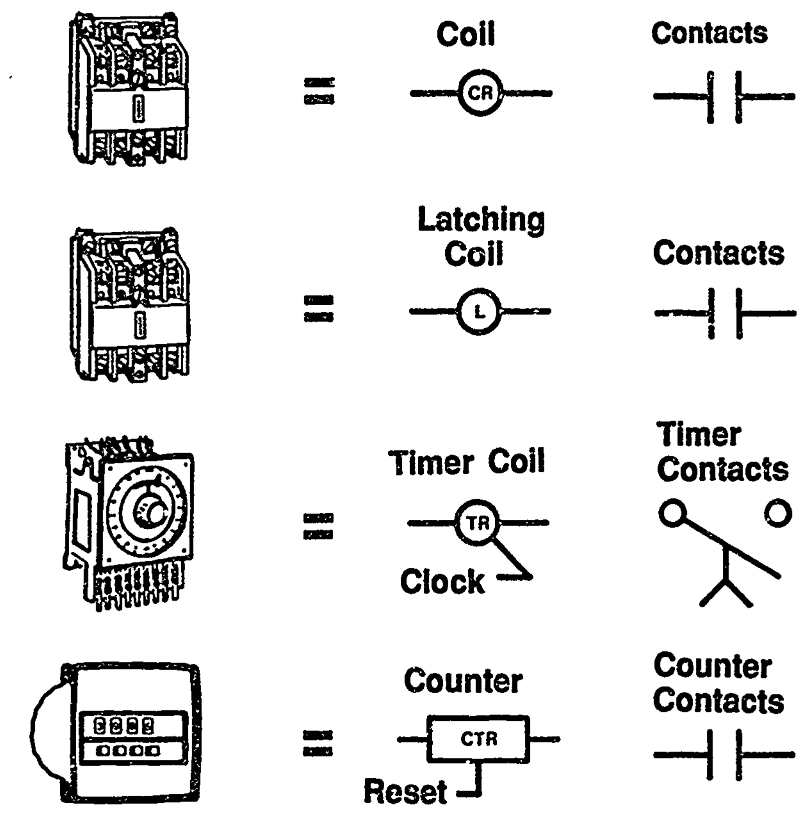
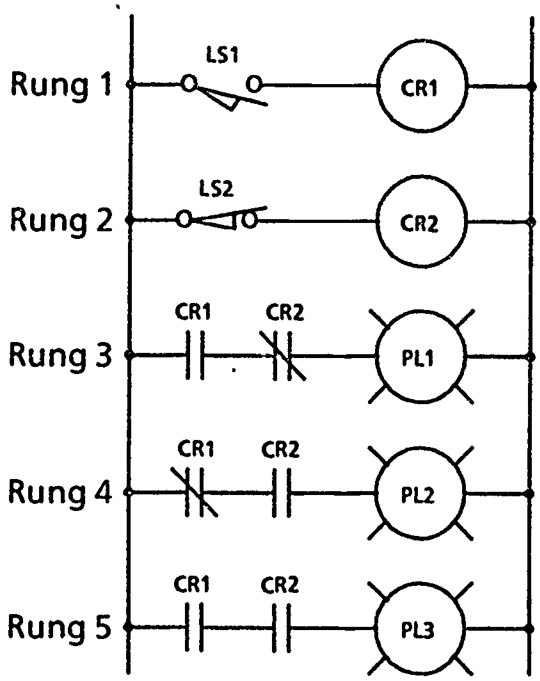
Logic Symbols

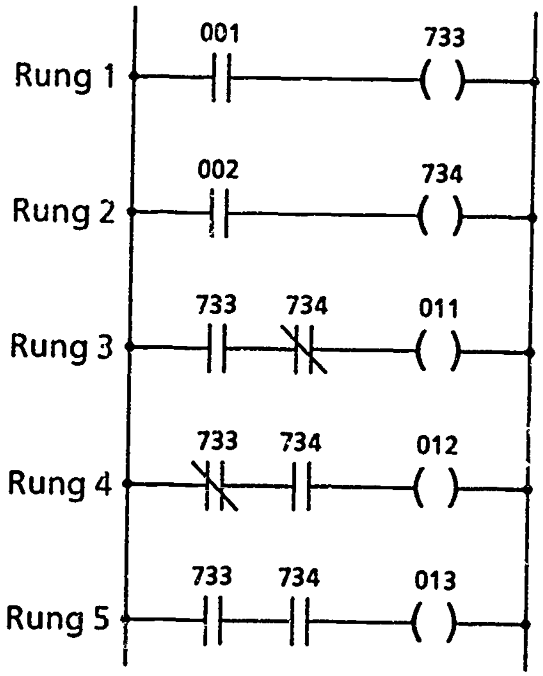


Ladder Relay Diagram



Hard-wired circuit

Ladder Logic Diagram



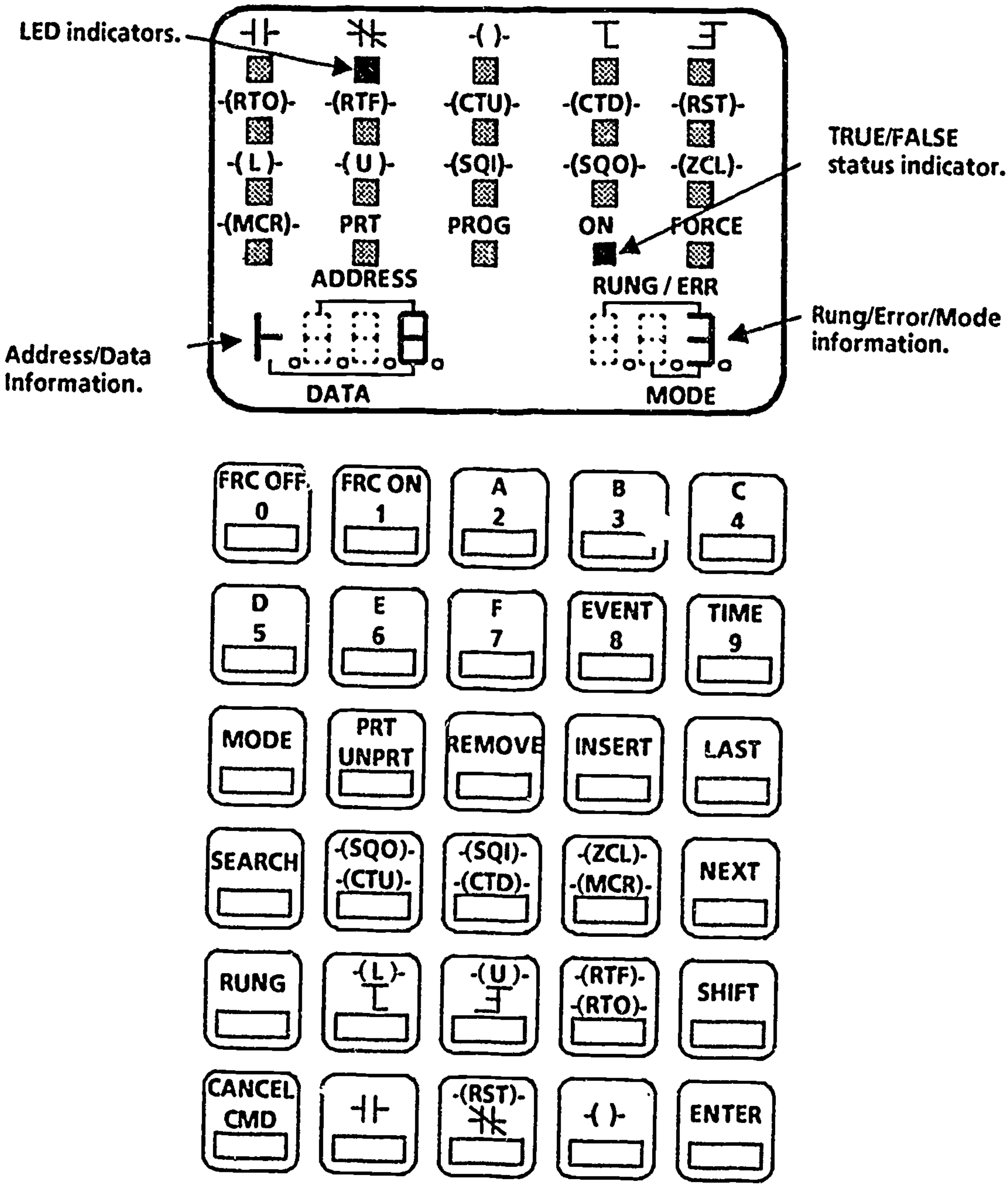
User program

Condition and Output Instructions

Condition Instructions –] [–
EXAMINE ON
EXAMINE OFF
BRANCH OPEN
BRANCH CLOSE

Output Instructions –( )–	
-( )-	OUTPUT ENERGIZE
-(L)-	LATCH
-(U)-	UNLATCH
-(RTF)- -(RTO)-	RETENTIVE TIMER OFF-DELAY RETENTIVE TIMER ON-DELAY
-(SQO)- -(CTU)-	SEQUENCER OUTPUT UP COUNTER
-(SQI)- -(CTO)-	SEQUENCER INPUT DOWN COUNTER
-(RST)-	RESET
-(ZCL)- -(MCR)-	ZONE CONTROL LAST STATE MASTER CONTROL RESET

Pocket Programmer Keyboard



Instruction Addresses for the SCL™ 100

Address	Function
001-010	Relay-Type instructions used for external inputs on processor unit.
011-016	Relay-Type instructions used for external outputs on processor unit.
017-018	Internal Relay-Type instructions.
101-110	Relay-Type instructions used for external inputs on expansion unit 1.
111-116	Relay-Type instructions used for external outputs on expansion unit 1.
117-118	Internal Relay-Type instructions.
201-210	Relay-Type instructions used for external inputs on expansion unit 2.
211-216	Relay-Type instructions used for external outputs on expansion unit 2.
217-218	Internal Relay-Type instructions.
301-310	Relay-Type instructions used for external inputs on expansion unit 3.
311-316	Relay-Type instructions used for external outputs on expansion unit 3.
317-318	Internal Relay-Type instructions.
701-867	Internal Relay-Type instructions.
868	Program initialization instruction. Used internally.
876	Internal Relay-Type instruction - Auto/Man switch. ON in Auto.
901-932	Timer/Counter/Sequencer instructions. Used internally.
951-982	Status instructions for Timers/Counters/Sequencers. Used internally.

FUNDAMENTALS OF PROGRAMMABLE LOGIC CONTROLLERS
UNIT I

HANDOUT #1 — THE SLC™ 100 PROGRAMMABLE CONTROLLER

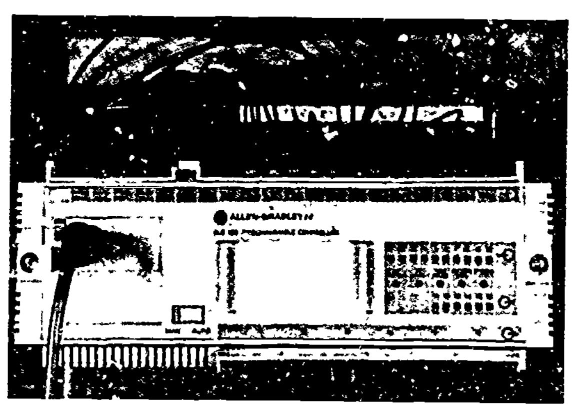
Purpose

The SLC™ 100 by Allen-Bradley is so popular in industrial applications that technicians and engineers usually refer to it by its more familiar name, the "Slick One Hundred." The SLC™ in the name means "small logic controller," and the 100 is representative of an entire class of PLCs whose low cost and performance have brought dramatic changes to the world of automatic controls. Because it is typical of a broad class of PLCs, because it is present in industrial applications around the world, and because its relative low cost makes it affordable for training objectives, the SLC™ 100 has been selected as the training vehicle for MAVCC's *Programmable Logic Controllers.*

The SLC™ 100 processor unit

The basic element of the SLC™ 100 is the processor unit which contains the interface circuitry for 10 inputs and 6 outputs. The inputs are identified with address numbers 1 through 10, and there is a red LED for each input so that when an input circuit is energized, a corresponding LED will be lit. The LEDs provide a direct visual reference for verifying both input and output. The design serves training purposes well because external outputs do not have to be wired in order to verify an output, an output LED will be lit. This is another reason the Slick One Hundred was selected for this training activity. (Figure 1)

FIGURE 1



HANDOUT #1

Other features of the SLC™ 100

The pocket programmer that connects to the processor unit is tynical of the programming interface used in small logic controllers. Since there is no need to keep the programmer connected during normal controller operation, one programmer can serve any number of controllers. The programmer keyboard and status displays are easy to learn and use, and the user-friendly environment of the programming interface is another reason the SLC™ 100 is an excellent training vehicle. (Figure 2)

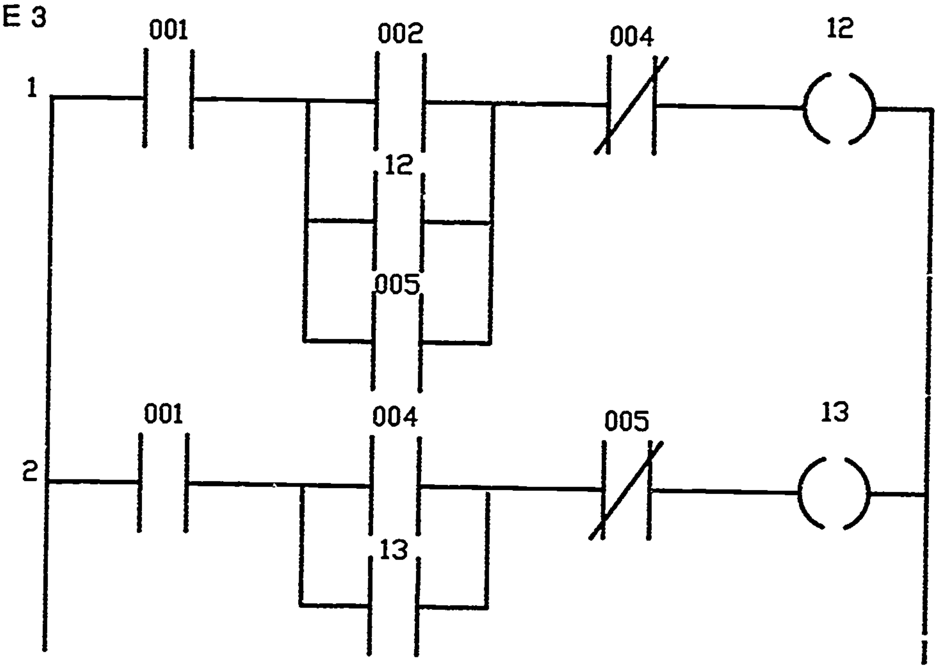
FIGURE 2

Ladder logic programming

Another element that makes the SLC™ 100 a good training vehicle is its programming format. Ladder logic programming is the format used most frequently in PLC programming. Ladder logic is actually a programming language that is well adopted to the linear sequence actions that controllers perform best. Ladder logic programming mirrors ladder relay diagrams that have been used for ages around electrical installations. The relationship of the two forms provides a natural transition from the world of hard-wired electricity into the world of digital electronics. Boolean logic, block programming, and Grafcet are other vital programming forms, but all of them are based on ladder logic, and ladder logic is the heart of programming for the SLC™ 100. (Figure 3)

HANDOUT #1

FIGURE 3



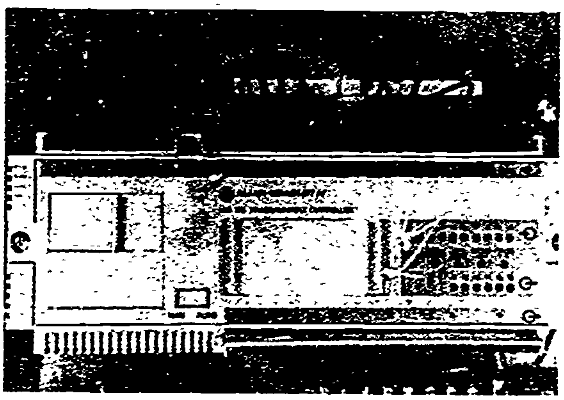
Conclusion

Programmable logic controllers have revolutionized industrial controls and created a need for a new breed of technician. Activities in *Programmable Logic Controllers* address vital elements of basic ladder logic programming and advanced programming concepts. Other programming formats need to be examined to appreciate the broader field of programming, but being able to program timers, counters, sequencers, and special applications such as force functions will provide a head start for would-be PLC technicians. The SLC™ 100 provides an inexpensive, durable vehicle for PLC training, and *Programmable Logic Controllers* offers the materials that make the slick click.

FUNDAMENTALS OF PROGRAMMABLE LOGIC CONTROLLERS
UNIT I

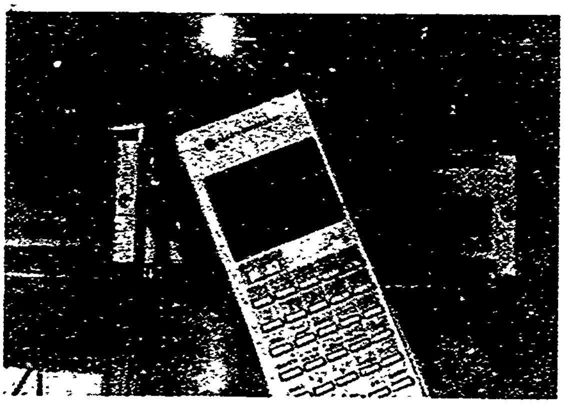
HANDOUT #2 — FEATURES OF THE ALLEN-BRADLEY SLC™100

Processor unit



The processor unit houses the solid state circuitry that processes and manages programmed information.

Pocket programmer



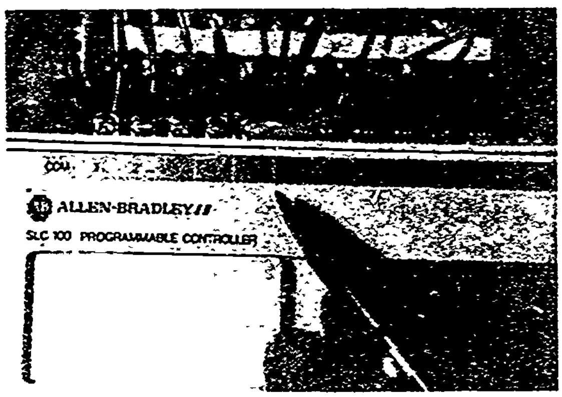
Programmed information is enetered into processor unit memory with a hand-held pocket programmer that has a user friendly keyboard and LED status lights to indicate programming activity in progress.

HANDOUT #2

Incoming line wiring terminals

These terminals have self-lifting pressure plates that allow for easy insertion of two #14 AWG wires. The terminals also have a protective cover.

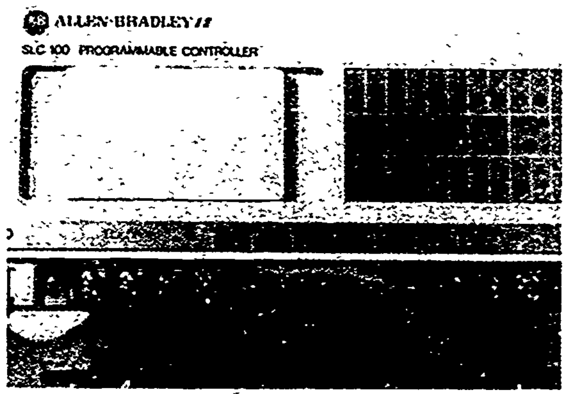
Input circuit wiring terminals



These have the same construction of the line terminals, but the protective cover has write-on areas for identification of cuircuits and the cover is color-coded to identify circuit voltage level.

HANDOUT #2

Output wiring terminals



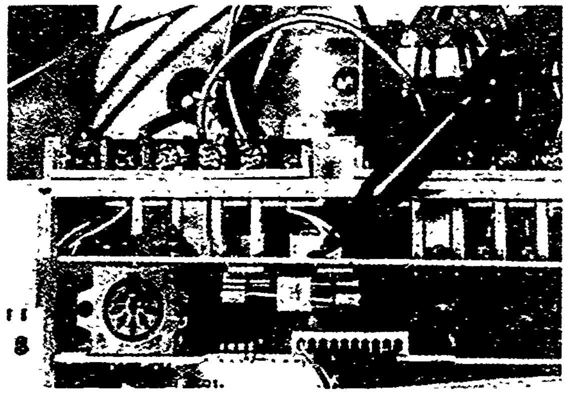
These have the same construction and features as input terminals including write-on areas for identification of external circuits.

Diagnostic Indicators

These five LED diagnostic indicators indicate that the unit is energized and DC power is being auplied with a DC power green LED, a green PC RUN LED indicates the unit is operating in the RUN mode, a red CPU FAULT LED indicates that the processor has detected an error and operational is automatically stopped, a red BATTERY LOW LED indicates the back-up battery should be replaced, and the amber LED for the FORCED I/O indicates that one or more inputs or outputs have been forced ON or OFF.

HANDOUT #2

Input power fuse



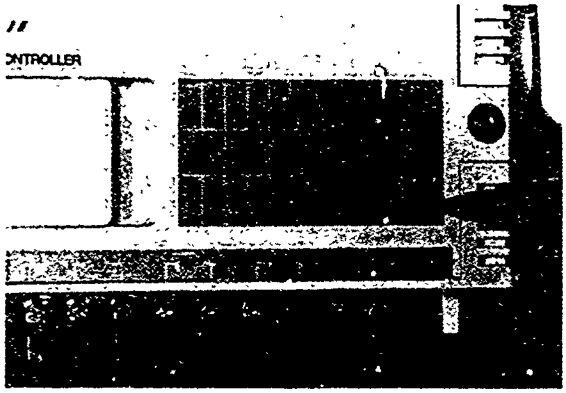
When the DC POWER LED is not lit, this fuse may be blown. It is located behind the processor unit cover.

Input status indicators

These ten red LEDs have addresses 1 through 10 to correspond to numbers 1 through 10 on the input device wiring terminals. The status indicators light when the corresponding circuit is energized.

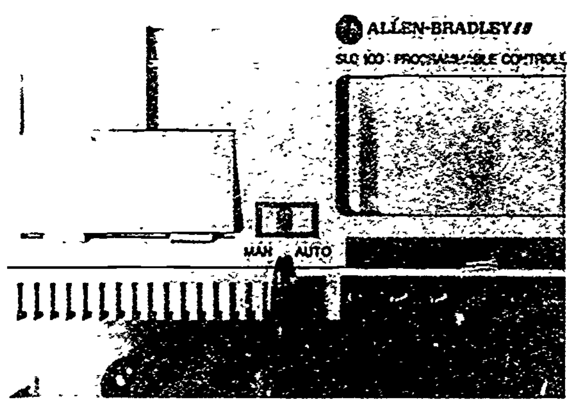
HANDOUT #2

Output status indicators



These six Red LEDs have addresses 11 through 16 to correspond to the numbers 11 through 16 on the output wiring terminals. When a programmed output instruction is TRUE, the corresponding output status LED will be lit and the corresponding output contact will close.

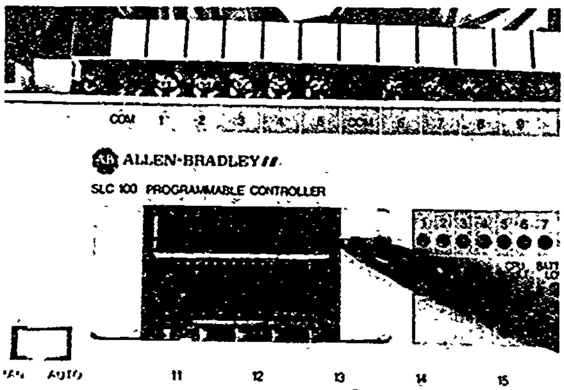
Auto/manual switch



This switch controls restart of the unit after a power loss. On power up in the Auto position, the processor goes through normal diagnostics and automatically enters the Run mode. On power up in Manual position, the processor goes through diagnostics but will not enter the Run mode until switched to Auto or programmed with the pocket programmer.

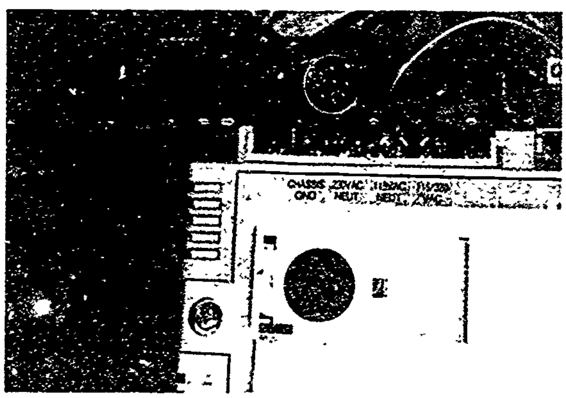
HANDOUT #2

EEPROM memory modul compartment



This optional memory module can be plugged into the processor unit to store a program or to load a program in the processor unit.

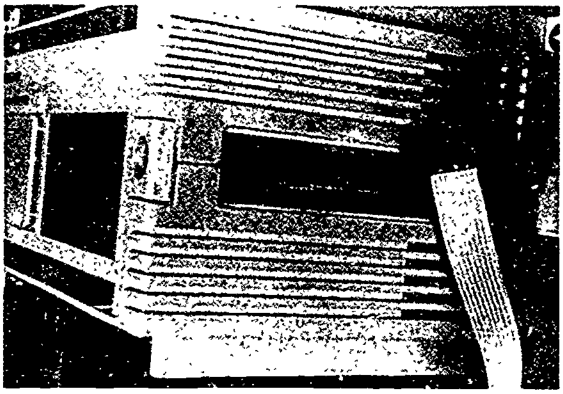
Programmer connection



This connects the pocket programmer interconnect cable into the processor for programming, monitoring, and editing activities. The interconnect cable is part of the pocket programmer.

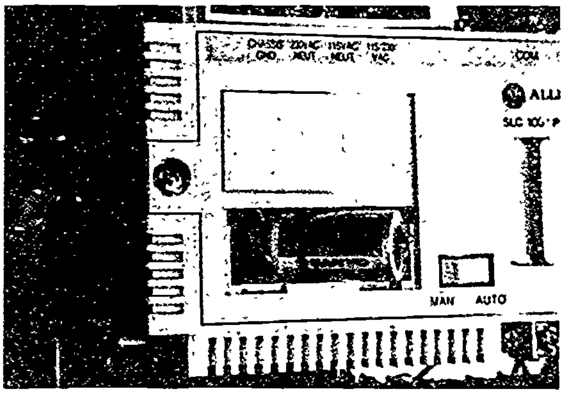
HANDOUT #2

Expansion unit connection



The expansion unit is plugged into this socket.

Battery compartment



The lithium battery which provides back-up power for two to three years is housed in this compartment which is accessible from the front of the processor unit.

FUNDAMENTALS OF PROGRAMMABLE LOGIC CONTROLLERS
UNIT I

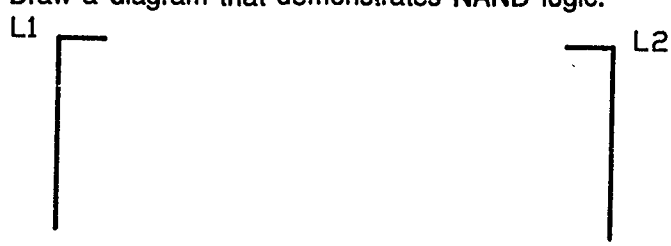
ASSIGNMENT SHEET #1
DRAW LADDER RELAY DIAGRAMS TO DEMONSTRATE BASIC LOGIC FUNCTIONS

Directions: Use the ladder relay diagram symbols for switches and motors to demonstrate the following logic functions.

1. Draw a diagram that demonstrates AND logic.

2. Draw a diagram that demonstrates OR logic.

3. Draw a diagram that demonstrates NAND logic.



4. Draw a diagram that demonstrates NOR logic.

FUNDAMENTALS OF PROGRAMMABLE CONTROLLERS
UNIT I

ASSIGNMENT SHEET #2
DRAW LADDER LOGIC DIAGRAMS TO DEMONSTRATE AND, OR, NAND, AND NOR LOGIC FUNCTIONS USING NORMALLY CLOSED SWITCHES IN A CIRCUIT

Directions: Assume a situation where normally closed switches #1 and #2 are physically connected to input addresses 1 and 2 on a PLC. Assume further that the status bits for the switches are at addresses 001 and 002 in internal logic and that logical continuity on a rung will energize coil #11 which is at address 011. Complete ladder logic diagrams as indicated, and enter rung numbers as required.

1. Draw a ladder logic diagram for a simple AND logic function.

2. Draw a ladder logic diagram for a simple OR logic function.

3. Draw a ladder logic diagram for a simple NAND logic function.

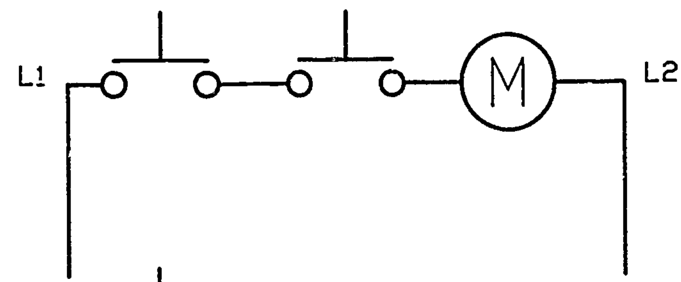
4. Draw a ladder logic diagram for a simple NOR logic function.

FUNDAMENTALS OF PROGRAMMABLE LOGIC CONTROLLERS
UNIT I

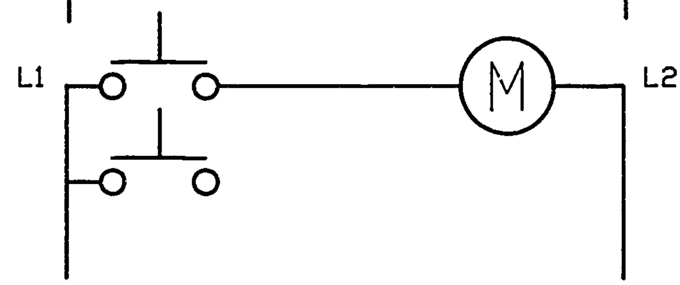
ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

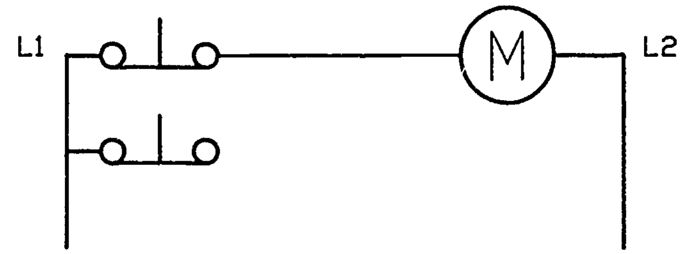
1.



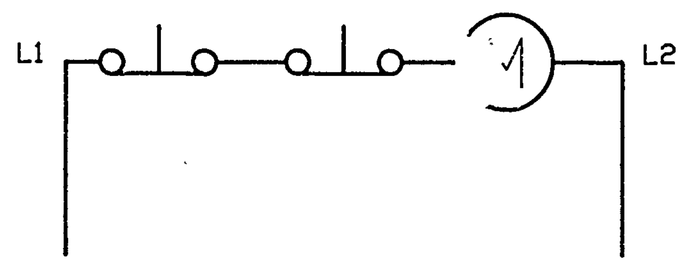
2.



3.



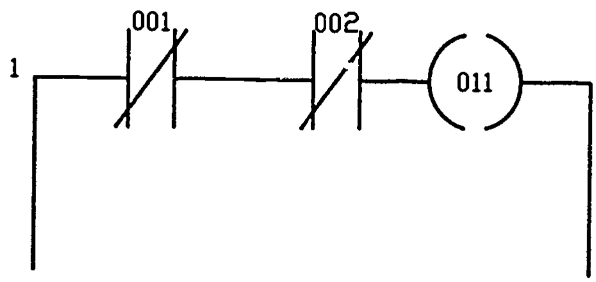
4.



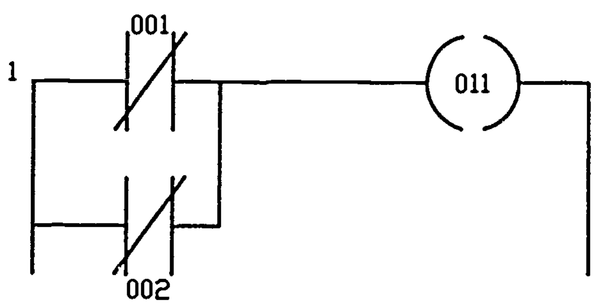
ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #2

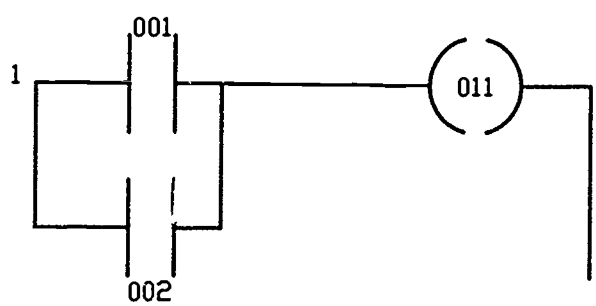
1.



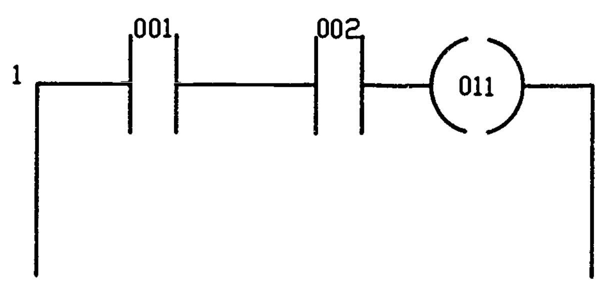
2.



3.



4.



FUNDAMENTALS OF PROGRAMMABLE LOGIC CONTROLLERS
UNIT I

JOB SHEET #1
USE A PROGRAMMER TO PROGRAM, ENTER, AND RUN PLC PROGRAMS USING AND, OR, NAND, AND NOR LOGIC

A. Tools and materials

1. PLC as selected by instructor

   (NOTE: An Allen-Bradley SLC 100 is used to demonstrate procedures in this job sheet. If another brand or model is used, appropriate modifications should be made in all routines.)

2. Programmer for selected PLC
3. User's Guide for selected PLC
4. Two single-pole, single-throw switches, mounted
5. 115v industrial lamp, mounted
6. Three-conductor 16-gauge power cord
7. Pen or pencil
8. Safety glasses

CAUTION: All switches and lamps used in the following routines should be safely mounted, and the routines should be completed only with the permission and guidance of your instructor.

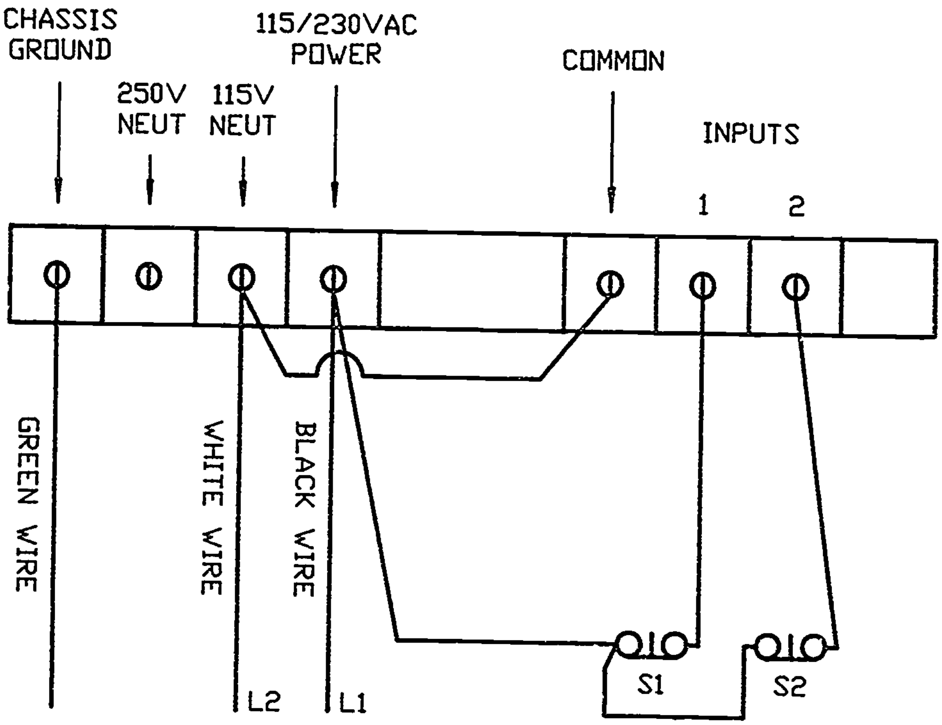
B. Routine #1 — Connecting power and inputs to the PLC

1. Put on safety glasses.
2. Make sure the power cord is not plugged into a power source.
3. Connect chassis ground, neutral, and power wires to the appropriate inputs on the PLC as demonstrated in Figure 1.

JOB SHEET #1

4. Connect the two single-pole switches so that Switches 1 and 2 will have power from the PLC 115/240v power input and connect to inputs 1 and 2 as shown in Figure 1.

FIGURE 1



5. Connect switches 1 and 2 to their appropriate input addresses on the PLC (refer to Figure 1).

☐ Have your instructor check your work.

C. Routine #2 — Connecting outputs to the PLC

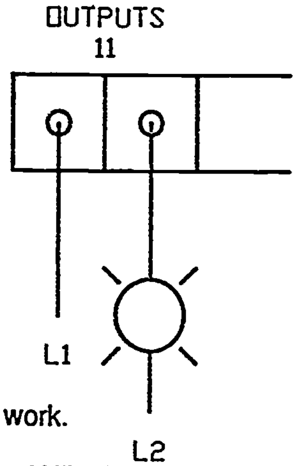
1. Put on safety glasses.

2. Connect the L1 power wire to the left terminal of output 11 (see Figure 2)

JOB SHEET #1

3. Connect the 115v lamp to the right side of the #11 input (see Figure 2)

FIGURE 2



☐ Have your instructor check your work.

D. Routine #3 — Writing a program for an AND circuit using NC switches

1. Enter the rails and rungs required to complete the ladder logic diagram in Figure 3.

2. Draw Rung 1 complete with symbols for an AND circuit using two NC switches.

3. Enter the appropriate symbol for output coil #11 at its appropriate address.

4. Enter appropriate addresses for the NC switches.

FIGURE 3

☐ Have your instructor check your work.

E. Routine #4 — Preparing the pocket programmer

1. Put on safety glasses.

2. Be sure power is OFF at the PLC.

JOB SHEET #1

3. Complete the following if this is the first time the controller has been used:

   a. Plug the programmer into the PLC unit and watch for the DC ON indicator light that signals the correct DC voltage is being supplied to the internal logic.

   b. Turn the programmer ON, watch for a series of diagnostic checks, and then watch for a display of three error codes E1, E6, and E8.

   c. After each error code appears, press CANCEL CMD and then ENTER to clear each code and put the programmer in program mode.

4. Complete the following if the controller has already been used:

   a. Repeat Step 3a.

   b. Turn the programmer switch ON, and watch for SLC-100 to appear on the display followed by a series of diagnostic checks.

   c. Watch for a display of the operating mode the programmer was in when last used.

   d. Press the MODE key, the 1 key, then the ENTER key and watch for the display to show SurE?

      (NOTE: The question mark is there to give the programmer time to think it over to avoid erasing a program that should not be erased.)

   e. Press the ENTER key again, watch for donE to show briefly on the display, and then 885 End which indicates memory is cleared and that there are 885 available words left in memory.

F. Routine #5 — Programming the AND circuit

1. Be sure power to the PLC is OFF when plugging in the pocket programmer.

JOB SHEET #1

2. Plug the pocket programmer into the PLC. (Figure 4)

FIGURE 4

3. Plug the power cord of the PLC into a 115v power source.

4. Turn the programmer ON.

   (NOTE: With the SLC 100, turning the programmer ON activates PLC memory for programming.)

5. Prepare the programmer/PLC as outlined in Routine #4.

6. Press the MODE key, then press the 1 key and look for CLEAR in the DATA display and a 1 in the MODE display.

7. Press ENTER and look for SurE in the DATA display and a ? in the MODE display.

8. Assume there is no problem with erasing what is presently in memory and press ENTER.

9. Look for donE to flash briefly followed by 885 in the DATA window and an End in the MODE window.

10. Watch for a light on the display under the PROG function to indicate the programmer is ready to be programmed.

11. Press the -|/|- (Examine OFF) key, and note the display:

    a. DATA shows three dashes.

    b. RUNG 1 is indicated.

    c. PROG is still lit.

    d. -|/|- is lit.

JOB SHEET #1

12. Press the 1 key and note the display:

    a. DATA shows two dashes and a 1.

    b. RUNG 1 is indicated.

    c. PROG is still lit.

    d. -|/|- is still lit.

13. Press the -|/|- key again and note the display:

    a. DATA shows three dashes.

    b. RUNG 1 is still indicated.

    c. PROG is still lit.

    d. -|/|- is still lit.

14. Press the 2 key and note the display:

    a. DATA shows two dashes and a 2.

    b. RUNG 1 is still indicated.

    c. PROG is still lit.

    d. -|/|- is still lit.

15. Press the -( )- (cutout coil) key and note the display:

    a. DATA shows three dashes.

    b. RUNG 1 is still indicated.

    c. PROG is still lit.

    d. -( )- is lit.

16. Press the 1 key two times and note the display:

    a. DATA shows one dash and an 11.

    b. RUNG 1 is still indicated.

    c. PROG is still lit.

    d. -( )- is still lit.

JOB SHEET #1

17. Press ENTER and note the display:

    a. DATA shows 882 to indicate three words of memory have been used

    b. MODE indicates End of the rung.

    c. PROG is still lit.

    d. No other functions are lit.

18. Press the MODE key and look for:

    a. DATA displays prog.

    b. MODE displays 2 to indicate the program mode.

19. Press the 3 key and note the display:

    a. DATA blinks and shows run.

    b. MODE shows 3 to indicate that when ENTER is pressed the programmer will be in the run mode.

20. Press ENTER and note how DATA indicates 882 and MODE displays End to indicate that the program is completed and that three words have been used for the program.

    (NOTE: There were 885 words available, 3 words were used for your program, and 882 words are still available.)

☐ Have your instructor check your work.

G. Routine #6 — Confirming the AND program

1. Put on safety glasses.

2. Note that output light 11 is OFF and that LEDs 1 and 2 are lit to indicate input switches are closed and that there is power at input addresses 1 and 2.

3. Activate Switch 1.

4. Note that output light 11 remains OFF.

5. Keep Switch 1 activated as you activate Switch 2.

6. Note that output light 11 comes ON.

JOB SHEET #1

7. Compare the program execution with your ladder logic diagram to confirm the logic and the program.

☐ Have your instruction check your work.

H. Routine #7 — Writing a program for an OR circuit using NC switches

1. Put on safety glasses.

2. Enter the rails and rungs required for the ladder logic diagram, and remember than an OR circuit requires a branch. (Complete Figure 5)

3. Draw Rung 1 complete with symbols for an OR circuit using NC switches.

4. Enter the symbol for output coil #11.

5. Enter addresses for the switches and coil.

FIGURE 5

☐ Have your instructor check your work.

I. Routine #8 — Programming the OR circuit

1. Clear the existing program as previously outlined and note that the pocket programmer is in MODE 2, the program mode.

2. Press ENTER and look for 885 End on the display.

3. Press the ⌶ (branch open) key and look for bro in DATA and 1 under RUNG.

4. Press the -|/|- (Examine OFF) key and look for three dashes in DATA and a 1 under RUNG.

5. Press the 1 key and look for two dashes and a 1 in DATA and a 1 under RUNG.

6. Press the ⌶ (branch open) key again, and look for bro in DATA and 1 under RUNG.

JOB SHEET #1

7. Press the -|/|- (Examine OFF) key and look for three dashes in DATA and a 1 under RUNG.

8. Press the 2 key and look for two dashes and a 2 in DATA and a 1 under RUNG.

9. Press the ⊣ (branch close) key and look for bnd in DATA and a 1 under RUNG.

10. Press the -( )- (output coil) key and look for three dashes in DATA and a 1 under RUNG.

11. Press the 1 key two times and look for a dash and two ones in DATA and a 1 under RUNG.

12. Press ENTER an look for 879 in DATA and End under RUNG.

    (NOTE: In your previous program, the AND circuit took only 3 words, but the OR circuit you have just programmed has used 6 words, so the three additional words were required to program instructions.)

☐ Have your instructor check your work.

J. Routine #9 — Confirming the OR program

1. Put on safety glasses.

2. Note that the NC switches are passing power to input addresses 1 and 2 (the LEDs should be lit) and that output 11 is OFF.

3. Activate Switch 1, which means you are opening Switch 1, and note that Output 11 is energized.

4. Deactivate Switch 1 and activate Switch 2, and note that Output 11 is still energized.

5. Compare the program execution with your ladder logic diagram to confirm the logic and the program.

☐ Have your instructor check your work.

K. Routine # 10 — Writing a program for a NAND circuit using NC switches

1. Put on safety glasses.

JOB SHEET #1

2. Draw the ladder logic program with appropriate symbols for a NAND circuit with NC switches and an output coil. (Complete Figure 6)

   (NOTE: A NAND circuit requires a branch.)

3. Use switch and coil addresses as used in previous routines.

FIGURE 6

☐ Have your instructor check your work.

L. Routine #11 — Confirming the NAND program

1. Put on safety glasses.
2. Activate switches as required to test the program.
3. Compare the program execution with your ladder logic diagram to confirm the logic and the program.

☐ Have your instructor check your work.

M. Routine #12 — Writing a program for a NOR circuit using NC switches

1. Put on safety glasses.
2. Draw the ladder logic program with appropriate symbols for a NOR circuit using NC switches and an output coil. (Complete Figure 7)

JOB SHEET #1

3. Use switch and coil addresses as used in previous routines.

FIGURE 7

☐ Have your instructor check your work.

N. Routine #13 — Confirming the NOR program

1. Put on safety glasses.
2. Activate switches as required to test the program.
3. Compare the program execution with your ladder logic diagram to confirm the logic and the program.

☐ Have your instructor check your work.

4. Clean area and return tools and equipment to proper storage.

FUNDAMENTALS OF PROGRAMMABLE CONTROLLERS
UNIT I

PRACTICAL TEST #1
JOB SHEET #1 — USE A PROGRAMMER TO PROGRAM, ENTER, AND RUN PLC PROGRAMS USING AND, OR, NAND, AND NOR LOGIC

Student's name ______________________________ Date ______________

Evaluator's name ____________________________ Attempt no. __________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATION NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Worked safely.	☐	☐
2. Prepared PLC and programmer properly.	☐	☐
3. Wrote, ran, and confirmed an AND program.	☐	☐
4. Wrote, ran, and confirmed an OR program.	☐	☐
5. Wrote, ran, and confirmed a NAND program.	☐	☐
6. Wrote, ran, and confirmed a NOR program.	☐	☐
7. Cleaned area and properly stored equipment.	☐	☐

Evaluator's comments: ____

____

JOB SHEET #1 — PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Wiring PLC	4	3	2	1
Testing pocket programmer	4	3	2	1
Writing and entering programs	4	3	2	1
Confirming programs	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

FUNDAMENTALS OF PROGRAMMABLE LOGIC CONTROLLERS
UNIT I

UNIT TEST

Name ____ Score __________

1. Match terms related to programmable logic controllers with their correct definitions.

_____a.	The numerical location of a particular status bit in the permanent memory of a PLC processor	1. NO
		2. Examine ON
_____b.	A basic statement in PLC logic that directs a status bit to look for a condition where power in a circuit is OFF	3. Address
		4. NC
		5. User program
_____c.	A basic statement in PLC logic that directs a status bit to look for a condition where power in a circuit is ON	6. Examine OFF
		7. PLC
_____d.	A switch or contact which is closed and passing power when it is inactive, and open and not passing power when it is active	8. Hard-wired
		9. Grafcet
_____e.	A switch or contact which is open and not passing power when it is inactive, and closed and passing power when it is active	
_____f.	A microprocessor-based control system designed to respond to user input in executing a control objective	
_____g.	A set of instructions which can be entered into processor memory at a time and place by a programmer	
_____h.	An electrical control design built around relays where components have to be physically wired to one another to complete electrical continuity	
_____i.	A graphical method of programming PLCs in steps and transitions that speed up programming and scan time	

TEST

2. Complete statements concerning job opportunities related to PLCs by circling the material that best completes each statement.

   a. Although there is no specific job title called programmable controller technician, programmable controllers are profuse in industry, and technicians with skills in PLCs have the upper hand in getting and keeping (a variety of jobs) (PLC related jobs).

   b. (Maintenance) (all) electricians perform routine electrical troubleshooting, and this frequently includes troubleshooting PLCs.

   c. (Instrumentation) (Industrial) technicians perform maintenance on everything from transmitters to control valves, frequently calibrate instruments such as pressure gauges, and need enough knowledge to troubleshoot and program PLCs.

   d. Maintenance (supervisors) (technicians) must have a broad range of knowledge and experience in all phases of industrial electricity/electronics, and skills in installing, troubleshooting, and programming PLCs.

   e. Plant (engineers) (technicians) usually have an associate or advanced degree from a technical school or university, and this includes skills in planning and executing applications of PLCs.

   f. Pay for experienced maintenance and control technicians is (equal to) (above) the average for comparable fields such as computer technicians.

   g. Salaries for supervisory personnel in industrial electricity/electronics is (excellent) (good) and promises to improve as more PLCs find their place in industry.

3. Complete statements concerning programmable logic controllers by circling the material that best completes each statement.

   a. Programmable logic controllers are so named because they use logic to control input/output devices, and they can be programmed by a (user) (manufacturer).

   b. In a hard-wired relay panel, circuits or loads can be energized only with (closed) (programmed) contacts, and a switch can be used only with the load to which it is directly connected.

   c. To change the operating objectives of a hard-wired relay panel requires (physically) (graphically) redesigning and changing the wiring.

   d. When timing functions are required with a hard-wired relay panel, they have to be (added and wired) (programmed) into the system.

   e. With a PLC, switches or sensors are connected to inputs, loads are connected to outputs, and the programming logic interfaces inputs to outputs as the (user designs and dictates) (manufacturer dictates).

TEST

f. With a PLC, timing and counting functions can be (wired in) (programmed) and do not require additional hardware.

g. With a PLC, one switch can be used in either a normally open or normally closed state to activate (multiple) (two) outputs.

h. The power of a PLC lies in its (source) (computing) power, but a PLC is not a computer.

4. Complete statements concerning how PLCs differ from computers by circling the material that best completes each statement.

   a. Computers are designed to work in (industrial) (clean) environments while PLCs are designed to function in hostile environments including temperature extremes and areas contaminated with dust, dirt, vapors, and oil.

   b. Computers may be programmed with a variety of languages, some of which are difficult to learn, but PLCs can be programmed with ladder logic (diagrams) (algebra) and minimal programming skills.

5. Match PLC components with their functions.

_____a. A device where a set of instructions stored in memory can be used to tell a controller how to manage a specific operation

_____b. A component that gathers signals from module a process and sends information about the process on to a controller module

_____c. The brains of a PLC where logic solving and decision making are performed and appropriate signals sent to an output module

_____d. A component that receives controller output and forwards signals on to real-world devices such as motors and relays to accomplish a control objective

1. Controller
2. Programmer
3. Output module
4. Input module

TEST

6. Select true statements concerning programming PLCs by choosing correct answers to the following:

   a. Programming is the use of a keyboard to enter commands that tell a PLC controller what output response is required in relation to what, a certain system configuration or a certain input?

      Answer ______________________________

   b. Ladder logic programs used in programming PLCs are similar to what, basic electrical schematics or ladder relay diagrams?

      Answer ______________________________

   c. Ladder logic diagrams indicate what, electrical continuity or logical continuity?

      Answer ______________________________

7. Select true statements concerning ladder relay diagrams by placing an "X" beside each statement that is true.

   (NOTE: For a statement to be true, all parts of the statement must be true.)

   _____a. Ladder relay diagrams have a traditional form:

   1) The left and right vertical lines are called RAILS.

   2) The horizontal lines are called RUNGS.

   3) The left rail is labeled L1 to indicate the high side or supply side of an electrical circuit.

   4) The right rail is labeled L2 to indicate the low side or return side of a circuit.

   _____b. Ladder relay diagrams show conditions where only closed contacts can energize an output, and that is why these diagrams are sometimes called "hard-wired" diagrams because components have to be physically wired to each other to complete electrical continuity.

8. Select operating conditions of ladder logic diagrams by choosing correct answers to the following:

   a. To complete a circuit in a ladder logic diagram, components have to be wired to one another or do not have to be wired to one another?

      Answer ______________________________

   b. In a ladder logic diagram an output can be energized by what, only a CLOSED switch or either a CLOSED or OPEN switch?

      Answer ______________________________

TEST

c. In reading a ladder logic diagram, it is generally best to start where, on the top rung at the right rail or on the top rung at the left rail?

Answer ______

9. Select operating conditions of logic states and status bits by choosing correct answers to the following:

a. Discreet signals use 0 or 1 to indicate a condition that is what, active or inactive or ON or OFF?

Answer ______

b. Logic state 1 indicates what, a condition that is OFF and therefore TRUE or a condition that is ON and therefore TRUE?

Answer ______

c. Logic state 0 indicates what, a condition that is OFF and therefore FALSE or a condition that is OFF and therefore TRUE?

Answer ______

d. Conditions that can be programmed are stored where in controller memory, in an input register or at specific addresses?

Answer ______

10. Solve problems concerning normally open and normally closed contacts by answering the following questions.

a. A normally open contact will be OPEN in its inactive state, and what else?

Answer ______

b. A normally closed contact will be CLOSED in its inactive state, and what else?

Answer ______

c. When NO or NC contacts are activated, they do what?

Answer ______

d. When activated a NO contact will CLOSE and what else?

Answer ______

e. When activated, a NC contact will OPEN and what else?

Answer ______

TEST

11. Select true statements concerning Examine ON and Examine OFF instructions by placing an X beside each statement that is true.

______a. The symbols for NO and NC contacts have additional importance in PLC programming.

______b. In programming and ladder logic, the symbol means more than Normally Open, it means Examine ON.

______c. Examine ON means that when a controller finds there IS VOLTAGE at a certain address, the instruction at that address is FALSE.

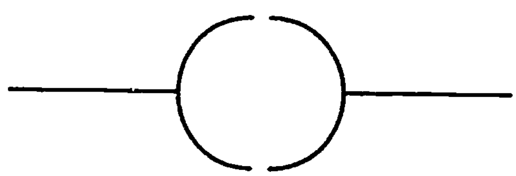
______d. When there is NO VOLTAGE at an Examine ON address, the instruction is FALSE.

______e. The symbol means more than Normally Closed, it means Examine OFF.

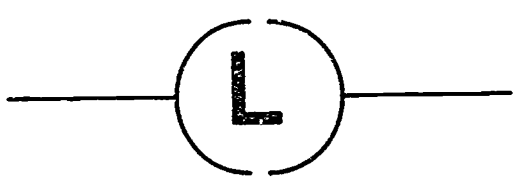
______f. Examine OFF means that when a controller finds there is NO VOLTAGE at a certain address, the instruction at that address is FALSE.

______g. When there IS VOLTAGE at an Examine OFF address, the instruction is FALSE.

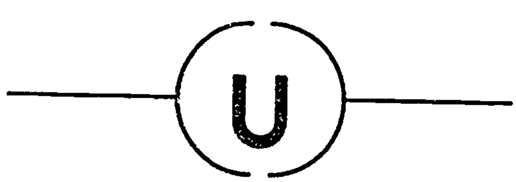
12. Identify symbols for coils by indicating in the following illustrations which is a normal coil, a latched coil, and an unlatched coil.



a. ______________________________



b. ______________________________



c. ______________________________

TEST

13. Complete statements concerning seal-in circuits by circling the material that best completes each statement.

    a. Seal-in circuits are used to keep a motor running after it has been started with a (momentary) (capacitor) switch.

    b. A seal-in circuit is usually a set of contacts (in the motor starter) (inside the motor) which close and keep power supplied to the motor after the momentary start button has been released.

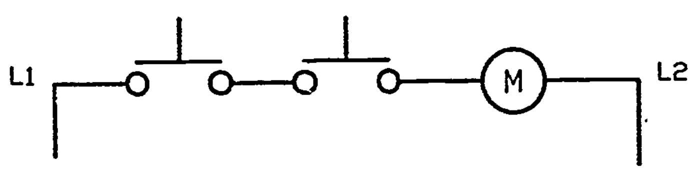
    c. Seal-in circuits are easy to identify in ladder logic diagrams because they almost always appear in a branch circuit (below) (beside) the rung where the motor is located.

    d. Seal-in circuits also demonstrate how (parallel) (series) circuits function as logical OR circuits because either the start switch or the seal-in circuit can be used to energize the motor starter which then energizes the motor.

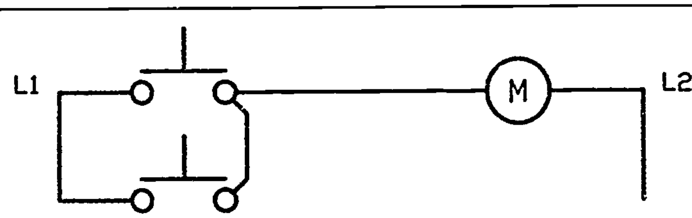
    e. Seal-in circuits are almost always required for event sequencing circuits using (timers and counters) (start switches).

    f. Programming seal-in circuits requires a procedure called (duplicating) (branching).

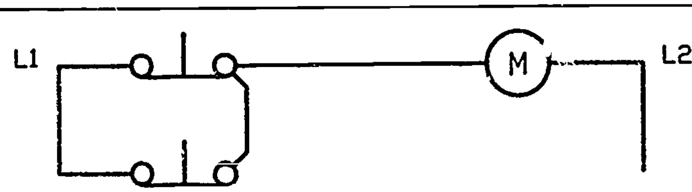
14. Identify AND, OR and NAND, NOR circuits in the following relay diagrams by inserting the correct circuit name beside the appropriate diagram.



a. ______________________________

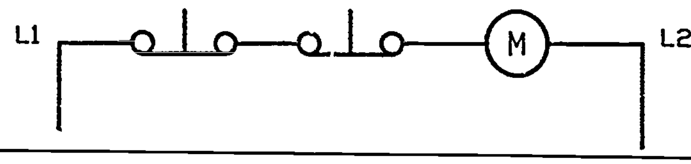


b. ______________________________



c. ______________________________

TEST

d. 

15. Select true statements concerning inputs/outputs and internal logic by placing an X beside each statement that is true.

(NOTE: For a statement to be true, all parts of the statement must be true.)

_____a. Inputs are devices such as limit switches and contacts that initiate or stop a voltage signal to the output terminals on a PLC.

_____b. Outputs are contacts in an output module that provide a closure used to turn ON/OFF field devices such as motors or solenoids.

_____c. Internal logic is that part of a PLC that receives information from inputs, makes decisions based on programmed conditions, and sets outputs to programmed objectives.

_____d. Input/outputs and internal logic are all controlled in the controller memory with status bits that must be addressed. PLC addresses are grouped in order:

1) Specific addresses are for inputs only.

2) Specific addresses are for outputs only.

3) Specific addresses are for internal logic only.

4) Other addresses are for special functions associated with registers.

16. Select fundamentals of PLC programming by choosing correct answers to the following:

a. In hard-wired relays, NC and NO contacts and switches do what, serve multiple outputs or only what they are wired to do?

Answer ____

b. In PLC functions, a NO or NC contact or switch does what, serves multiple outputs or what it is programmed to do?

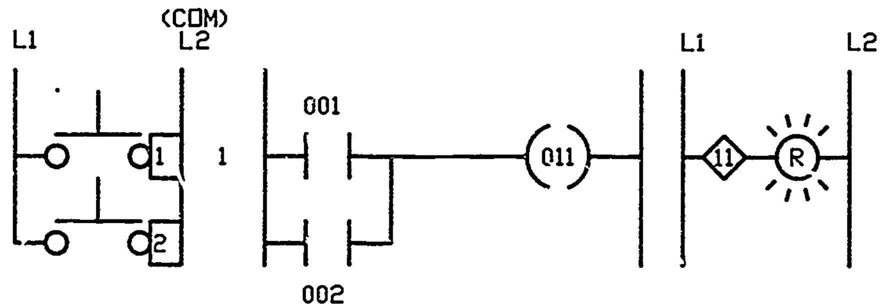
Answer ____

TEST

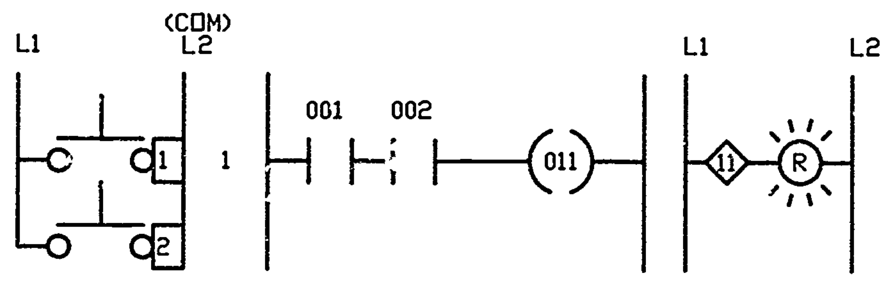
c. When the appropriate elements in a ladder diagram are TRUE, then the rung is what, TRUE or FALSE?

Answer ______________________________

17. Identify the diagram for a simple AND logic circuit by placing an X beside the AND circuit in the following illustrations.

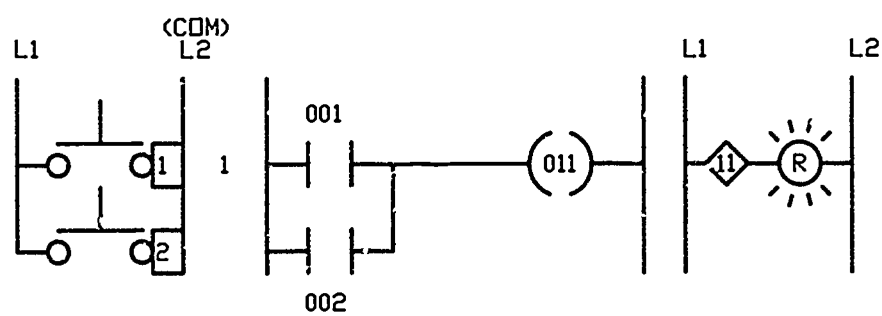


a. ______________________________



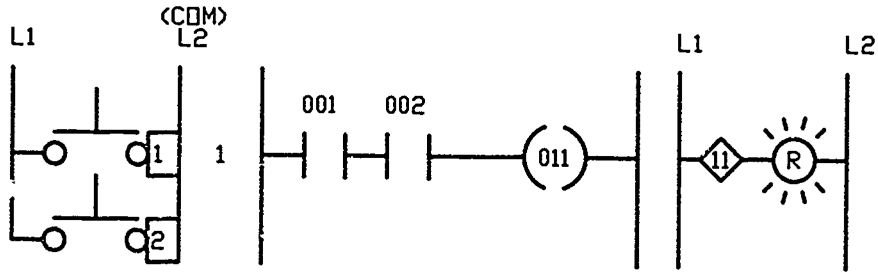
b. ______________________________

18. Identify the diagram for a simple OR logic circuit by placing an X beside the OR circuit in the following illustrations.



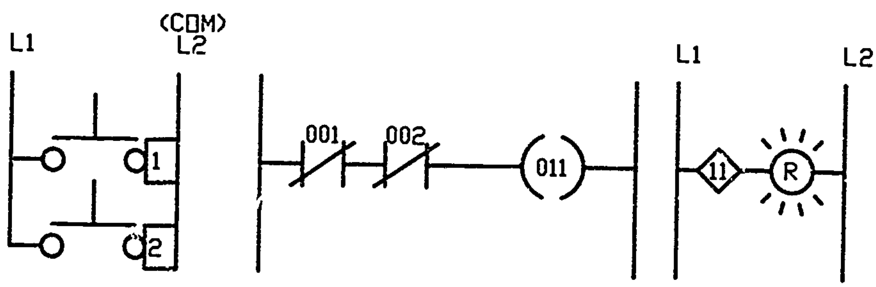
a. ______________________________

TEST

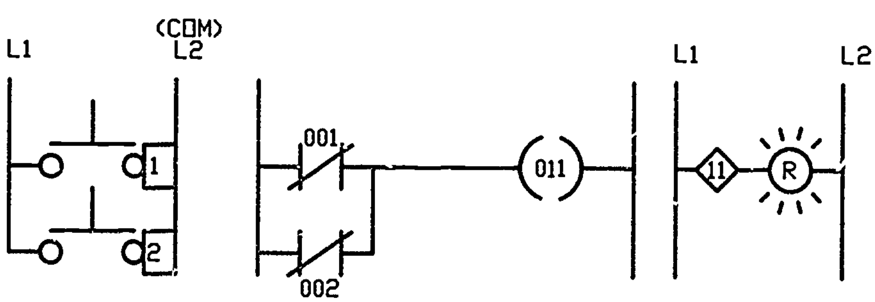


b. ____________________

19. Identify the diagram for a simple NAND logic circuit by placing an X beside the NAND circuit in the following illustrations.



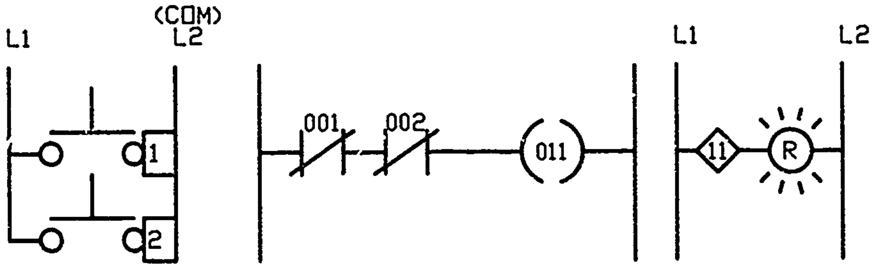
a. ____________________



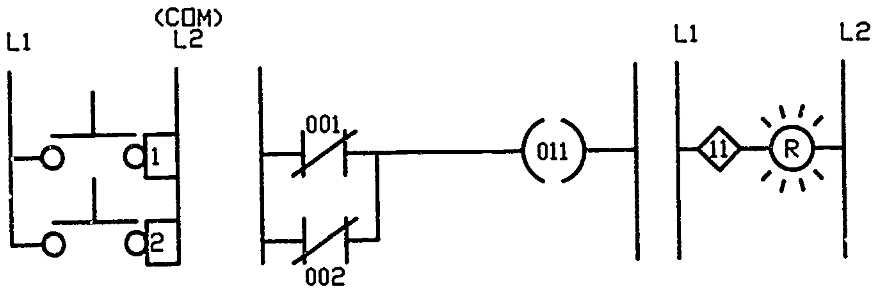
b. ____________________

TEST

20. Identify the diagram for a simple NOR logic circuit by placing an "X" beside the NOR circuit in the following illustrations.



a. ______________________________



b. ______________________________

21. Match basic operating modes with their functions.

_____a.	Clears programmer memory so a new program can be entered	1.	Mode 3
_____b.	Permits the input of a new user program or the update of an existing program	2.	Mode 1
_____c.	Tells the PLC processor to scan and execute the user program	3.	Mode 2

22. Complete statements concerning instructions by circling the material that best completes each statement.

    a. Instructions are classified as either condition instructions or output instructions, and the two together form an instruction (set) (program).

    b. Instructions are all assigned addresses which are associated with particular (status bits) (outputs) in PLC memory.

TEST

c. Instructions are always stored in the same order in which they are entered, and the PLC processor executes the instructions in (that same order) (a reverse order).

d. The PLC processor operates on instructions in a single operating cycle called a scan which is divided into two parts:

1) The (I/O scan) (first scan) records the status of input devices and energizes output devices which have their associated status bits set to ON.

2) The (Program Scan) (second scan) reads inputs, executes the scan and updates outputs.

23. Solve problems concerning keyboarding by answering the following questions.

a. When keyboarding, a pocket programmer has to be first placed in what mode?

Answer ____

b. PLC memory has to be cleared so what can happen?

Answer ____

c. All condition instructions when keyboarding should follow what?

Answer ____

d. Rungs should be ended with what?

Answer ____

e. How is a program confirmed?

Answer ____

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

24. Draw ladder relay diagrams to demonstrate basic logic functions. (Assignment Sheet #1)

25. Draw ladder logic diagrams to demonstrate AND, OR, NAND, and NOR logic functions using normally closed switches in a circuit. (Assignment Sheet #2)

26. Demonstrate the ability to use a programmer to program, enter, and run a PLC program using AND, OR, NAND, and NOR logic. (Job Sheet #1)

FUNDAMENTAL OF PROGRAMMABLE LOGIC CONTROLLERS

UNIT I

ANSWERS TO TEST

1.
a.	3	e.	1
b.	6	f.	7
c.	2	g.	5
d.	4	h.	8
		i.	9

2. a. A variety of jobs
   b. Maintenance
   c. Instrumentation
   d. Supervisors
   e. Engineers
   f. Above
   g. Excellent

3. a. User
   b. Closed
   c. Physically
   d. Added and wired
   e. User designs and dictates
   f. Programmed
   g. Multiple
   h. Computing

4. a. Clean
   b. Diagrams

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

6. a. A certain input
   b. Ladder relay diagrams
   c. Logical continuity

7. a,b

ANSWERS TO TEST

8. a. Do not have to be wired to one another
   b. Either a CLOSED or OPEN switch
   c. On the top rung at the left rail

9. a. ON or OFF
   b. A condition that is ON and therefore TRUE
   c. A condition that is OFF and therefore FALSE
   d. At specific addresses

10. a. NOT passing power
    b. Passing power
    c. Change to opposite states
    d. Pass power
    e. Not pass power

11. a, b, d, e, g

12. a. Normal coil
    b. Latched coil
    c. Unlatched coil

13. a. Momentary
    b. In the motor starter
    c. Below
    d. Parallel
    e. Timers and counters
    f. Branching

14. a. AND
    b. OR
    c. NAND
    d. NOR

15. b, c, d

16. a. Only what they are wired to do
    b. What it is programmed to do
    c. TRUE

17. b

18. a

ANSWERS TO TEST

19. a

20. b

21. a. 2
    b. 3
    c. 1

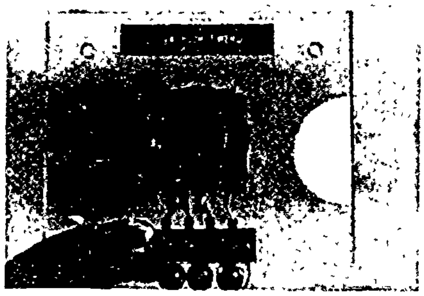
22. a. Set
    b. Status bits
    c. That same order
    d. 1) I/O Scan
       2) Program Scan

23. a. The program mode
    b. A new program can be entered
    c. The logic diagram
    d. An output instruction
    e. By running the program on the PLC

24. Evaluated to the satisfaction of the instructor

25. Evaluated to the satisfaction of the instructor

26. Evaluated according to criteria in Practical Test #1



CONTACTS, TIMERS, AND COUNTERS
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to relate auxiliary contacts and external and internal relays to their functions in PLC programming. The student should also be able to write ladder logic programs for timers and counters. These competencies will be evidenced by completing the procedures outlined in the assignment and job sheets and by scoring a minimum of 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to contacts, timers, and counters with their correct definitions.
2. Solve problems concerning auxiliary contacts.
3. Solve problems concerning applications of Examine OFF auxiliary contacts.
4. Complete statements concerning internal relays.
5. Select true statements concerning RTO timers.
6. Complete statements concerning how an RTO times.
7. Solve problems concerning basic RTO programming.
8. Select true statements concerning RTF timers.
9. Solve problems concerning basic RTF programming.
10. Complete statements concerning CTUs (up counters).
11. Complete statements concerning CTDs (down counters).
12. Complete statements concerning up-down counters.
13. Solve problems concerning how a CTU counts.
14. Solve problems concerning how an up-down counter works.
15. Select true statements concerning special function program keys.

OBJECTIVE SHEET

16. Write a ladder logic program using auxiliary contacts to energize an output. (Assignment Sheet #1)

17. Demonstrate the ability to:

    a. Write and confirm a ladder logic program using an internal relay and its auxiliary contacts to energize an output. (Job Sheet #1)

    b. Examine and confirm an existing RTO program. (Job Sheet #2)

    c. Write and confirm a ladder logic program for an RTO timer. (Job Sheet #3)

    d. Write and confirm a ladder logic program for an RTF timer. (Job Sheet #4)

    e. Write and confirm a ladder logic program for an up counter. (Job Sheet #5)

    f. Write and confirm a ladder logic program for a down counter. (Job Sheet #6)

    g. Write and confirm a ladder logic program for an up-down counter. (Job Sheet #7)

CONTACTS, TIMERS, AND COUNTERS
UNIT II

SUGGESTED ACTIVITIES

Read Me First

Procedures in this text are presented for demonstration only and should not be used in actual industrial applications. Graphic materials from manufacturers are presented for the purpose of illustration only and no liability is assumed for their use otherwise. Persons using this text assume liability for demonstration and for any equipment damaged in demonstration. Administration of these materials should be by a qualified instructor only in a safety-proven environment.

A. Provide students with objective sheet.

B. Provide students with information and assignment sheets.

C. Make transparencies.

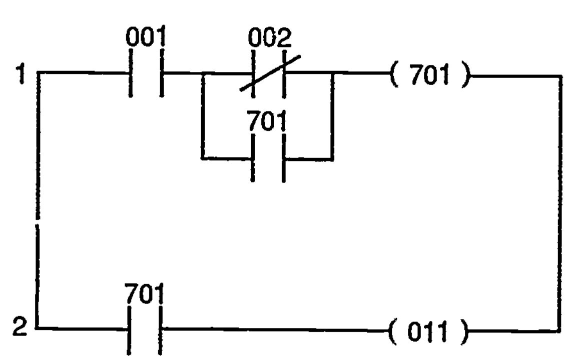
D. Discuss unit and specific objectives.

E. Read the tools and equipment list for each of the job sheets and prepare safely mounted switches and lights so that student programs can be confirmed after they are written.

F. The illustrations in the transparencies and in the assignment and job sheets are designed to best demonstrate the particular function with which they appear. Certain programs may be written in different order, but if any programs are rewritten, be sure they advance the objective of this unit of instruction.

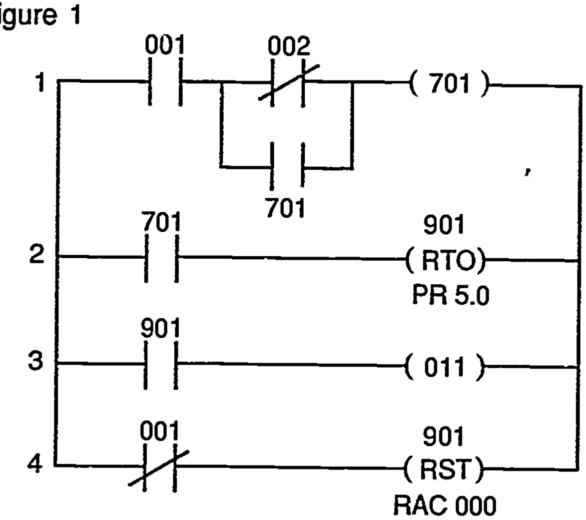
G. Suggested diagrams required for students to fulfill the objectives in the job sheets are included here for examination as you review the job sheets:

1. Job Sheet #1, Figure 1

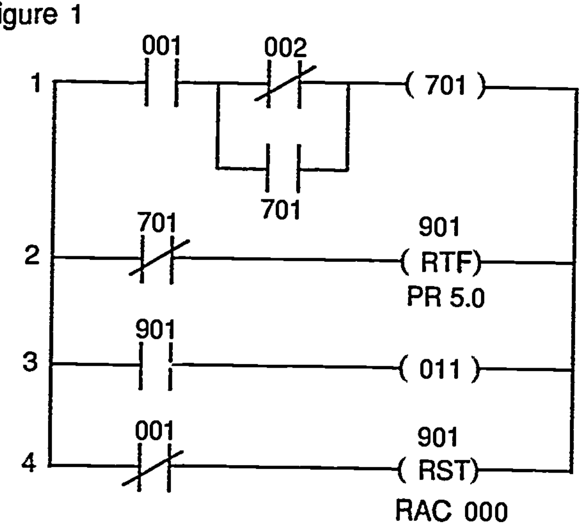


SUGGESTED ACTIVITIES

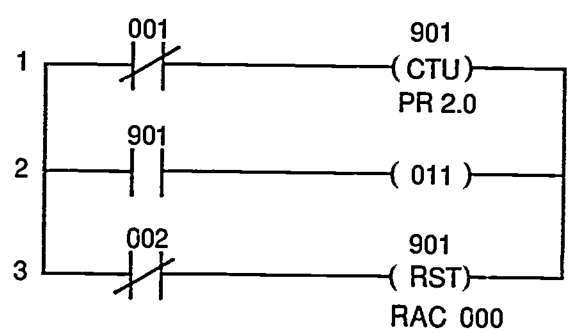
2. Job Sheet #3, Figure 1



3. Job Sheet #4, Figure 1

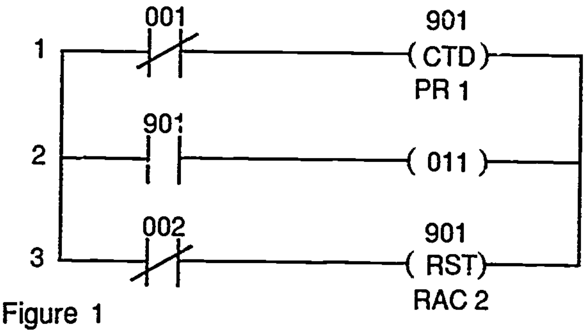


4. Job Sheet #5, Figure 1

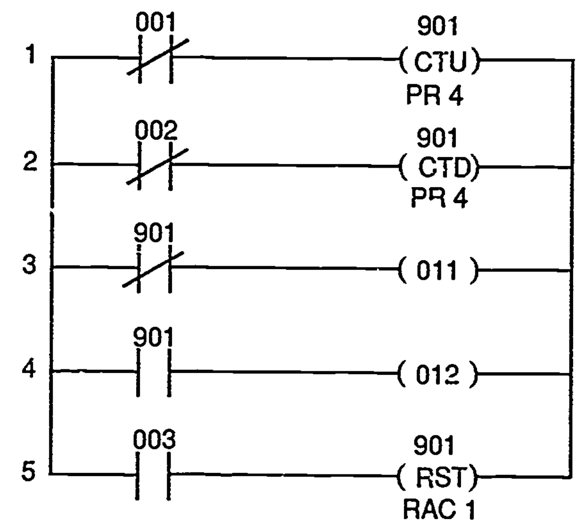


SUGGESTED ACTIVITIES

5. Job Sheet #6, Figure 1



6. Job Sheet #7, Figure 1



H. Give test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *User's Manual Bulletin 1745 SLC ™ 100 Programmable Controller.* Milwaukee, WI 43204: Allen-Bradley Company, 1985.

B. *User's Manual Bulletin 1745 SLC™ 100 Programmable Controller.* Milwaukee, WI 43204: Allen-Bradley Company, 1987.

CONTACTS, TIMERS, AND COUNTERS
UNIT II

INFORMATION SHEET

I. **Terms and definitions**

A. **Auxiliary contacts** — Examine ON/Examine OFF status bits associated with output addresses

B. **CTU (up counter)** — A counter whose accumulated value increases by 1 for each FALSE/TRUE transition

C. **CTD (down counter)** — A counter whose accumulated value decreases by 1 for each FALSE/TRUE transition

D. **RTO (Retentive Timer On-Delay)** — A timer which increments until it reaches a reset accumulated value

E. **RTF (Retentive Timer Off-Delay)** — A timer that decrements until it reaches a reset accumulated value

F. **Increment** — A process of changing values by consecutive additions

G. **Decrement** — A process of changing values by consecutive subtractions

H. **PR (Preset Value)** — The amount of time programmed for a timing function

I. **AC (Accumulated Value)** — The amount of time that has passed at any interval between the start and end of a timing function

J. **RAC (Reset Accumulated Value)** — The value that a timer is programmed to start timing from, usually 0000

II. **Auxiliary contacts**

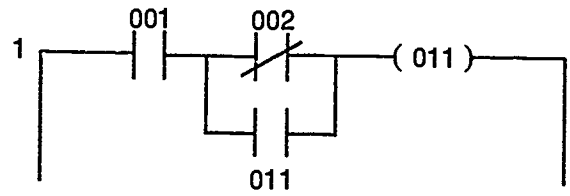
A. Auxiliary contacts are Examine ON/Examine OFF status bits associated with output addresses.

Example: An output coil at address 011 has Examine ON/Examine OFF status bits associated with it, and these status bits can be used to energize or de-energize outputs on other rungs, to start timers, to input counters, and for a variety of applications that give a PLC unequaled control capabilities.

INFORMATION SHEET

B. Auxiliary contacts can be well demonstrated in a circuit using two NC switches. (Figure 1)

FIGURE 1



C. Figure 1 shows switch 1 is passing power to input 1, making the Examine ON condition at status bit 001 TRUE on Rung 1.

D. Figure 1 also shows that the Examine OFF condition at status bit 002 is FALSE until NC switch 2 is opened, and then the Examine OFF condition at 002 becomes TRUE, there is logical continuity on Rung 1, and output coil 011 is TRUE.

E. When output coil 011 becomes TRUE, the internal auxiliary contact 011 automatically becomes TRUE and works as a seal-in circuit for the output.

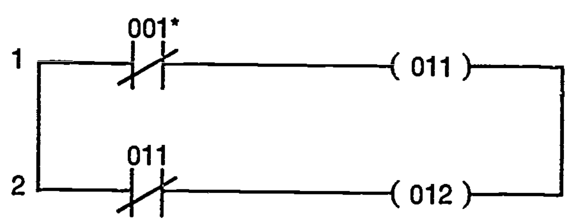
F. With auxiliary contact 011 TRUE, switch 2 can be deactivated to make status bit 002 FALSE, but the output will remain energized because auxiliary contact 011 maintains logical continuity on Rung 1.

III. **Applications of Examine OFF auxiliary contacts** (Figure 2)

A. Because auxiliary contacts are associated with outputs, auxiliary contacts can be programmed for Examine OFF conditions.

B. In Figure 2, Rung 2 shows the Examine OFF condition of the auxiliary contact at address 011, but output 011 in Rung 1 is TRUE, so the Examine OFF condition at status bit 011 in Rung 2 is FALSE and there is no logical continuity on Rung 2 and output 012 is FALSE. (Figure 2)

FIGURE 2



* **Switch must be normally open.**

INFORMATION SHEET

C. If switch 1 input to Rung 1 is deactivated, Rung 1 output goes FALSE and the auxiliary contact 011 on Rung 2 becomes TRUE to provide logical continuity to Rung 2 and energize output 012.

D. Since auxiliary contacts may be used to the extent there are available words in memory, the application of auxiliary contacts becomes a function of the programmer's ability and imagination.

IV. **Internal relays** (Transparency 1)

A. External outputs and internal relays are the same except that external outputs are limited in number while internal relays number more than a hundred.

(NOTE: On the Allen-Bradley SLC™100, there are six external outputs compared with 166 internal relays at addresses 701 through 867, and these internal relays also have auxiliary contacts associated with them that will accomplish what auxiliary contacts accomplish with output coils.)

B. Internal relays also have auxiliary contacts that can be programmed just like auxiliary contacts on external outputs.

C. Transparency 1 demonstrates how only one NC or NO switch can be used to control multiple outputs.

D. In Transparency 1, with the switch NC, Rung 1 is FALSE and Rung 2 is TRUE, but the moment switch 1 is activated, Rung 1 becomes TRUE and Rung 3 becomes FALSE.

E. Transparency 1 also shows how Rungs 3, 4, 5, 6, 7, and 8 change status dependent upon the input condition of switch 1, and outputs on all rungs are controlled by the auxiliary contacts for internal relays, not auxiliary contacts for output relays.

F. Selecting the most effective auxiliary contacts becomes important in advanced programming.

V. **RTO timers**

A. RTO means Retentive Timer On-Delay, and the symbol is -(RTO)-.

B. RTOs have addresses from 901 to 932, they have Examine ON/Examine OFF auxiliary contacts that have the same addresses as the timer coil, and they have a reset coil with the same address.

C. The 901 timer coil has a PR value (preset value) at which the auxiliary contacts change states.

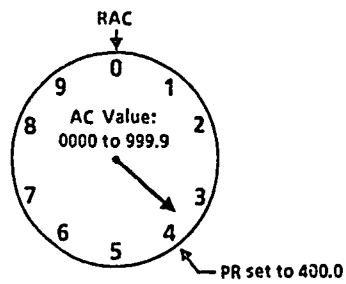
Example: A PR (preset) value could be 10 seconds.

INFORMATION SHEET

D. As an RTO advances, it accumulates time, and this is called the AC (accumulated) value. (Figure 3)

FIGURE 3

RTO Timer Rung Conditions		
TRUE	FALSE	TRUE
Timer is counting.	Counting stops. AC value retained.	Counting resumes.
AC value represents the cumulative time during which rung is TRUE.		



E. With an RTO, the Examine ON contacts are FALSE when the AC value is less than the PR value.

F. With an RTO, the Examine On contacts are TRUE when the AC value is equal to or greater than the PR value.

G. The RESET coil has a value called RAC (reset accumulated value), and that is the value that the timer is programmed to start timing from.

VI. **How an RTO times** (Transparency 2)

A. There are two important elements in RTO timing:

1. The timer never times when the rung with the RST (reset) is TRUE.

2. The RST rung must be FALSE and the RTO rung must be TRUE for the RTO to time.

B. The RTO times in tenths of a second, .10, and the maximum is 999.9, and then the timer rolls over to 000.0 again.

C. As the RTO passes 999.9 it sets a status bit at the RTO address plus 50 (901 + 50 = 951) at an Examine ON condition.

D. The Examine ON status bit goes TRUE as the timer rolls over and the Examine OFF status bit at the same address goes FALSE.

E. The TRUE/FALSE transition happens only the first time the counter rolls over without being reset.

F. An RTO is reset by making the reset rung TRUE, and this can be accomplished by the program or by physically reactivating a switch.

INFORMATION SHEET

VII. **Basic RTO programming** (Transparency 3)

A. Transparency 3 demonstrates how an RTO might be programmed and the dynamics of the program.

(NOTE: Assume in the following demonstration that the inputs are two NC switches.)

B. By activating NC switch 2, the RST coil 901 on Rung 4 resets the AC value of the RTO to 2.0 seconds.

C. When switch 2 is deactivated and switch 1 is activated, RTO 901 on Rung 1 becomes TRUE, the timer starts, and the AC value starts incrementing from 2.0 seconds.

D. Note that as the timer starts timing, output 011 on Rung 2 is FALSE, and output 012 on Rung 3 is TRUE.

E. As long as Rung 1 remains TRUE, the AC value will continue incrementing, but when the AC value reaches the PR of 10.0 seconds, Rung 2 becomes TRUE and Run 3 becomes FALSE.

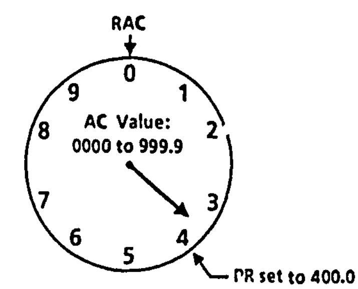
F. When the RTO passes 999.9, Examine ON status bit 951 becomes TRUE, output 013 is energized, and the RTO rolls over to start again at 000.0

VIII. **RTF Timers** (Figure 4 and Transparency 4)

A. RTF means Retentive Timer Off-Delay and the symbol is -(RTF)-. (Figure 4)

FIGURE 4

RTF Timer Rung Conditions		
FALSE	TRUE	FALSE
Timer is counting.	Counting stops. AC value retained.	Counting resumes.
AC value represents the cumulative time during which rung is FALSE.		



B. RTFs have the same addresses as RTOs, 901 to 932, Examine ON/Examine OFF auxiliary contacts that have the same addresses as the timer, and a reset coil with the same address.

INFORMATION SHEET

C. The difference between an RTF and RTO is that they function as opposites: (Transparency 4)

1. The RTF coil must be FALSE in order for the AC value to increment while the RTO coil must be TRUE in order for the AC value to increment.

2. With the RTF, the Examine ON status bits are TRUE when the AC value is less than the PR value, but with the RTO timer, the Examine ON status bits are FALSE when the AC value is less than the PR value.

3. With the RTF, the Examine ON status bits are true when the AC value is less than the PR value.

4. With the RTO, the Examine ON status bits are true when the AC value is equal to or greater than the PR value.

D. The RTF timer Examine OFF status bit remains FALSE until the PR value is reached, then the status bit goes TRUE until it is reset.

IX. **Basic RTF programming** (Transparency 5)

A. Transparency 5 demonstrates how an RTF is programmed and the dynamics of the process.

(NOTE: Assume in the following demonstration that the inputs are two NC switches.)

B. By activating NC switch 2, the RST coil 901 on Rung 4 resets the AC value of the RTF to 2.0 seconds.

C. Since switch 1 is ON, the Examine ON status bit 001 on Rung 1 is TRUE, and RTF 901 on Rung 1 is TRUE, but not timing because the RTF timer is looking for a FALSE rung.

D. On Rung 2, Output 011 is TRUE because it is below the PR value of 10.0 (remember, the RAC is 2.0).

E. Rung 3 is FALSE because Examine OFF status bit 901 on Rung 3 is FALSE.

F. When switch 1 is activated, Rung 1 becomes FALSE and the RTF starts timing.

G. As the AC value increments to 10.00, Rung 2 goes FALSE, Rung 3 goes TRUE, and will remain TRUE until switch 2 is activated to reset the RTF.

H. When the RTF passes 999.9, Examine ON status bit 951 becomes TRUE, output 013 is energized, and the RTF rolls over to start again at 000.0.

INFORMATION SHEET

X. CTUs (Up Counters)

A. CTUs on the SLC™ 100 are at internal addresses 901-932.

B. As the name implies, a CTU increments in increasing values of 1.

C. A CTU symbol has letters inside the coil symbol with an address above: -(CTU)-.

D. Like an RTO or an RTF, a CTU is retentive and must be reset with a RST instruction.

E. CTU instructions count successive FALSE-to-TRUE instructions of the rung containing the counter instructions as long as the RST is FALSE.

F. After each count, the rung must return to FALSE before another count can take place.

G. With CTUs the existing count is called the AC (accumulated value), and the AC value increases by 1 for each FALSE-to-TRUE transition.

H. CTUs are programmed with a PR (preset value) and a RAC (reset accumulated value) just as timers are.

XI. CTDs (Down Counters)

A. CTDs on the SLC™ 100 are at internal addresses 901-932.

B. As the name implies, a CTD decrements in decreasing values of 1.

C. A CTD symbol has lotters inside the coil symbol with an address above: -(CTD)-.

D. A CTD is retentive and must be reset with a RST instruction.

E. CTD instructions count successive FALSE-to-TRUE instructions of the rung containing the counter instructions as long as the RST is FALSE.

F. After each count, the rung must return to FALSE before another count can take place.

G. With CTDs, the existing count is called the AC (accumulated value), and the AC value decreases by 1 for each FALSE-to-TRUE transition.

H. CTDs are programmed with a PR (preset value) and a RAC (reset accumulated value) just as timers are.

INFORMATION SHEET

XII. **Up-down Counters**

A. The up-down counter has both an up counter rung and a down counter rung.

B. With an up-down counter, the AC value both increases and decreases in response to FALSE-to-TRUE conditions on the respective up/down rungs.

C. PR (preset value), AC (accumulated value), and RAC (reset accumulated value) are used in all counter programming.

(NOTE: As you work with counters, you will see that programming counters is similar to programming timers.)

XIII. **How a CTU counts** (Transparency 6)

A. Transparency 6 demonstrates how a CTU is programmed and the dynamics of the program.

(NOTE: Assume in the following demonstration that the inputs are two NC switches.)

B. With a CTU program ready to run, the ladder logic diagram should show:

1. Rung 1 is FALSE.

2. Rung 2 is FALSE.

3. Rung 3 is TRUE.

4. Rung 4 is FALSE.

C. When switch 2 is activated, Rung 4 becomes TRUE and the RAC is reset to 000.

D. As switch 2 is deactivated and switch 1 is activated, CTU 901 on Rung 1 is TRUE and the counter starts counting in increments of 1 in response to the FALSE-to-TRUE transition on Rung 1, and the AC value becomes 1.

E. When switch 1 is activated again, another FALSE-to-TRUE transition occurs on Rung 1, the CTU increments by 1, and the AC value becomes 2.

F. Activating switch 1 continues the FALSE-to-TRUE transitions on Rung 1 until the AC value reaches 5 which equals the PR value of 5, and the CTU program is complete.

G. As the CTU reaches its PR value, Rung 2 goes from FALSE to TRUE and Rung 3 goes from TRUE to FALSE.

INFORMATION SHEET

H. As Rungs 2 and 3 change states, their outputs can function to turn real-world devices ON/OFF and accomplish a control objective.

(NOTE: A ladder logic program for a CTD is presented in Transparency 7 so you can compare the CTU and CTD programs for variations and similarities.)

XIV. How an up-down counter works

A. A ladder logic diagram using two NC switches and one NO switch as inputs demonstrates how an up-down counter works. (Transparency 8)

B. Activating switch 1 starts the counter which increments 1 unit at a time.

C. When the up counter increments to 4 or greater than 4, Rung 4 becomes TRUE and Rung 3 goes FALSE.

D. Activating switch 2 starts the down counter which decrements 1 unit at a time.

E. When the down counter decrements to 3 or less, Rung 3 becomes TRUE and Rung 4 goes FALSE.

(NOTE: The AC value for the up counter can be equal to or greater than the PR value, but the AC value of the down counter must be less than the PR value in order to make the FALSE/TRUE transition for up/down counting.)

F. Activating switch 3 resets both AC values.

XV. Special function program keys

A. Many keys on a programmer have duel functions which are indicated by numbers and symbols on the faces of the keys.

B. Pressing the SHIFT key on the programmer changes the key function to the function indicated in blue on the top of the key.

Example: To program the reset at the end of a timing or counting program, press SHIFT; then the -(RST)- key, the -(RST)- symbol will light on the upper display, and three dashes, - - -, will appear in the ADDRESS window so that the 3-number RST address can be entered.

C. When an output such as a timer or counter requires additional data such as a PR or an RAC, four dashes, - - - -, appear in the ADDRESS window to indicate additional data should be entered.

D. When four dashes, - - - -, appear in the ADDRESS window they will remain there until required data is entered and the pocket programmer will reject inappropriate entries.

INFORMATION SHEET

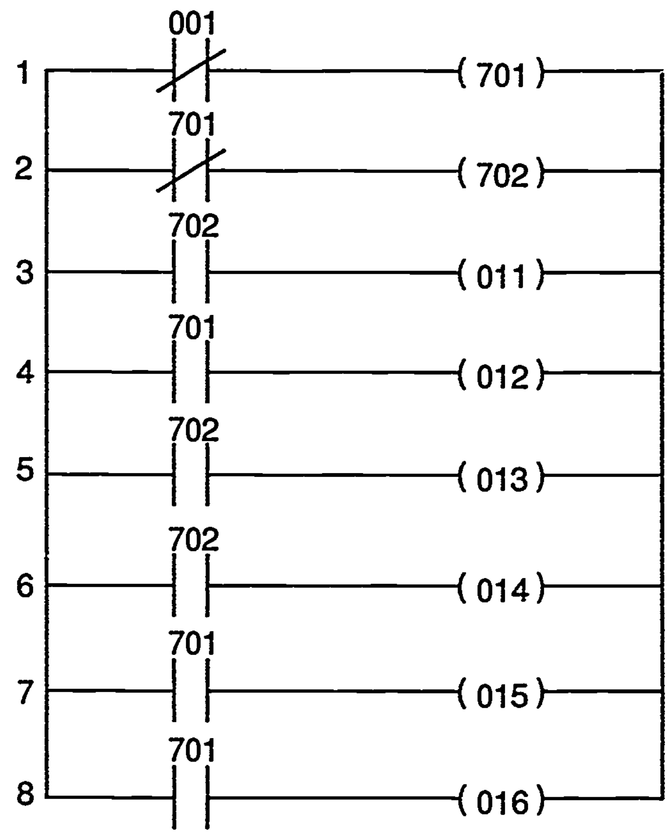
E. The LAST and NEXT keys permit a programmer to go back and check an instruction by pressing the LAST key and then pressing the NEXT key to get back to the original spot in the program.

F. The LAST and NEXT keys become handy tools when programming becomes complex because you can move back several rungs to check specific instructions and then return to your starting point.

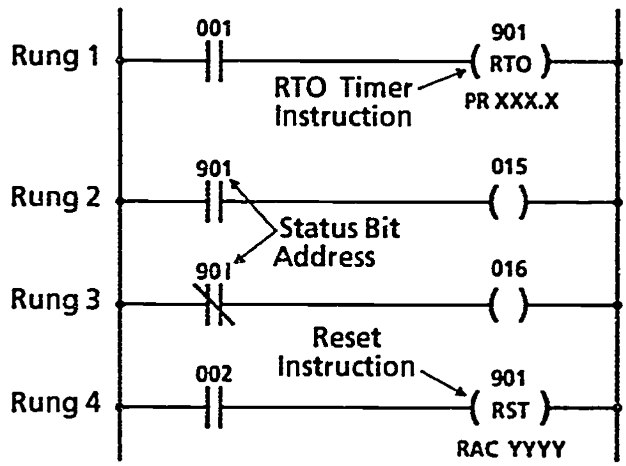
G. The NEXT and LAST functions are also handy for monitoring any selected instruction while a program is running.

H. By pressing the RUNG key, then the rung number, and then the ENTER key, a programmer can check any rung desired and check a program, rung by rung, as it is running.

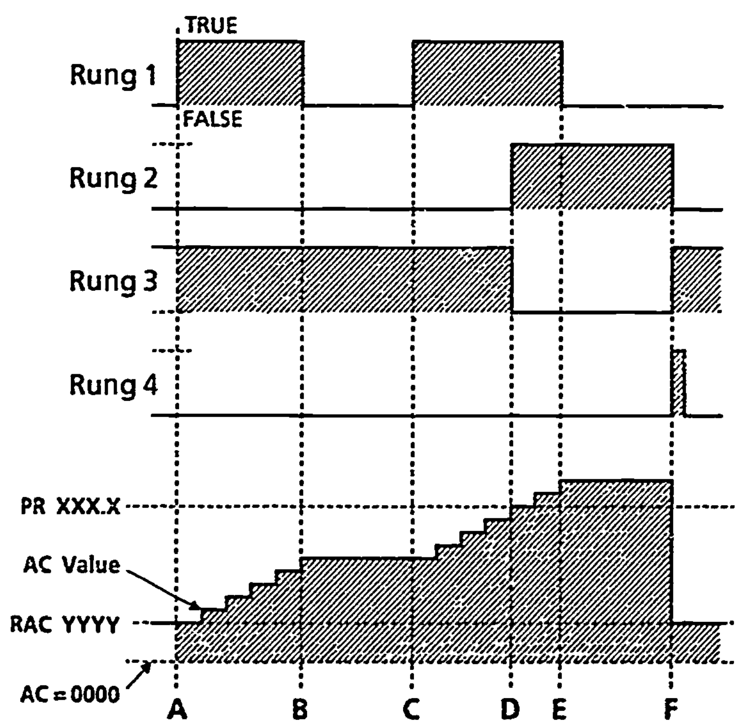
Internal Relays



RTO Timers

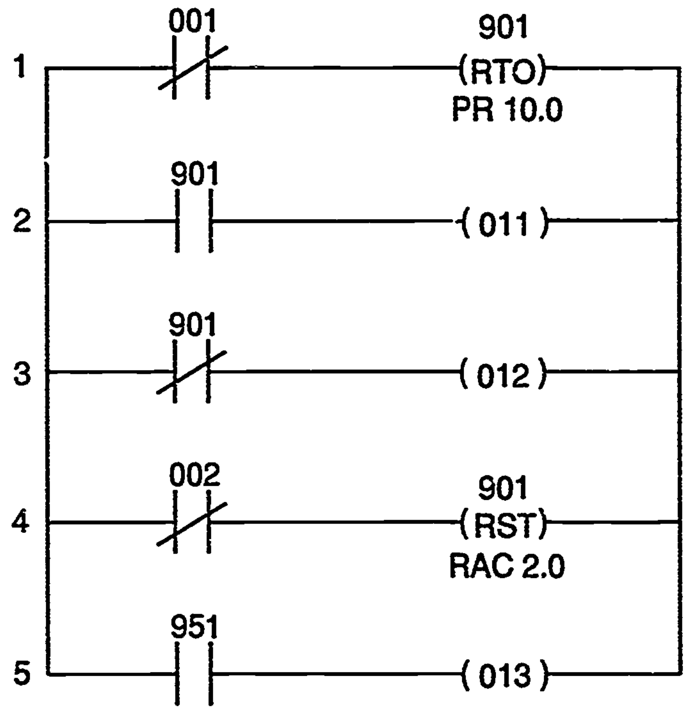


Ladder Diagram

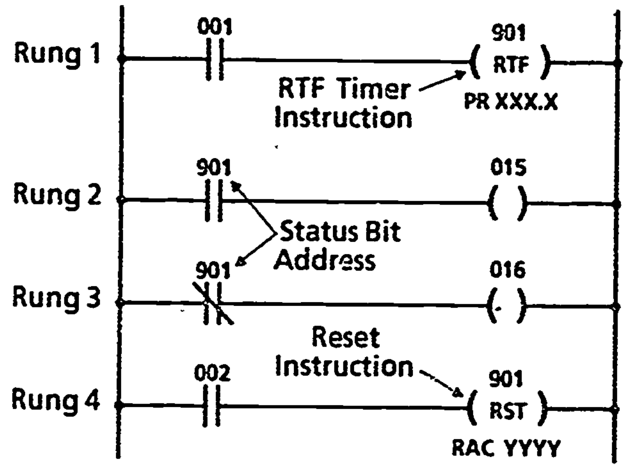


Timing Diagram

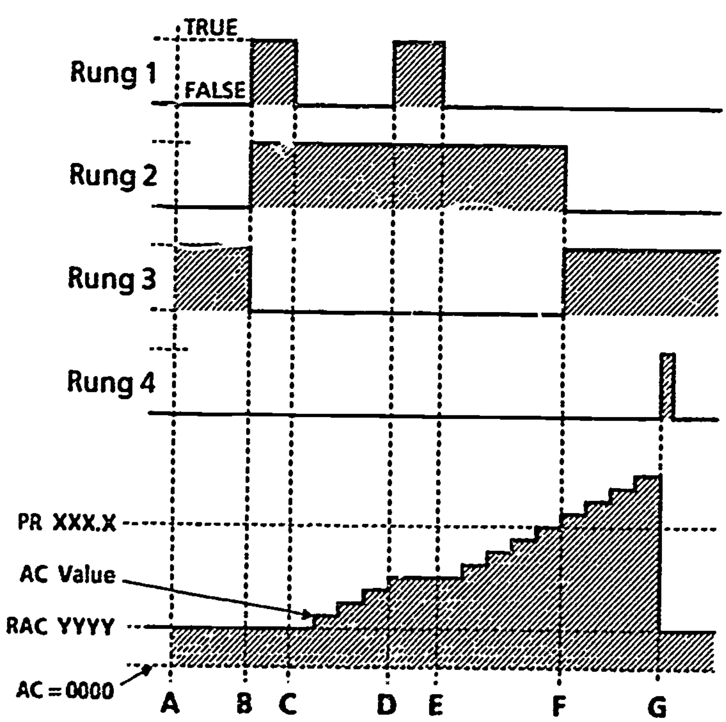
RTO Programming



RTF Timers

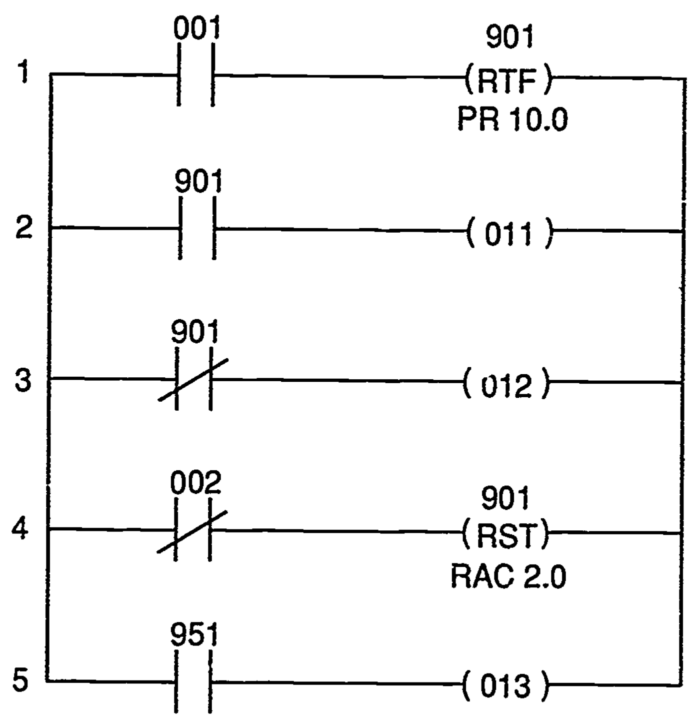


Ladder Diagram

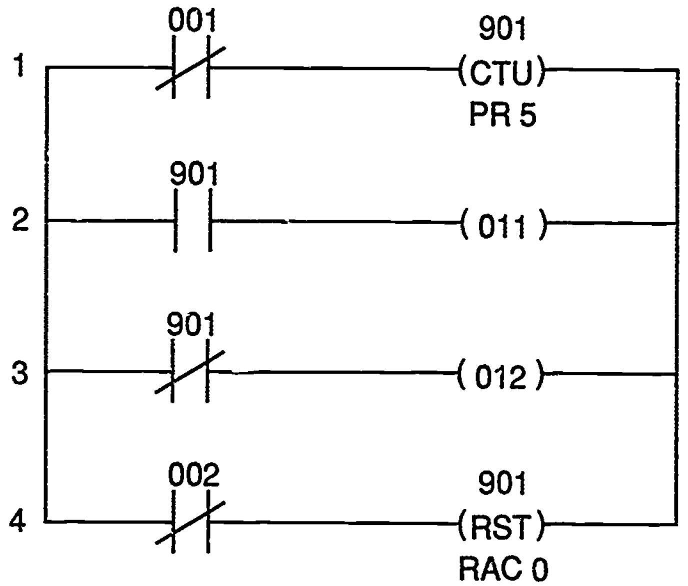


Timing Diagram

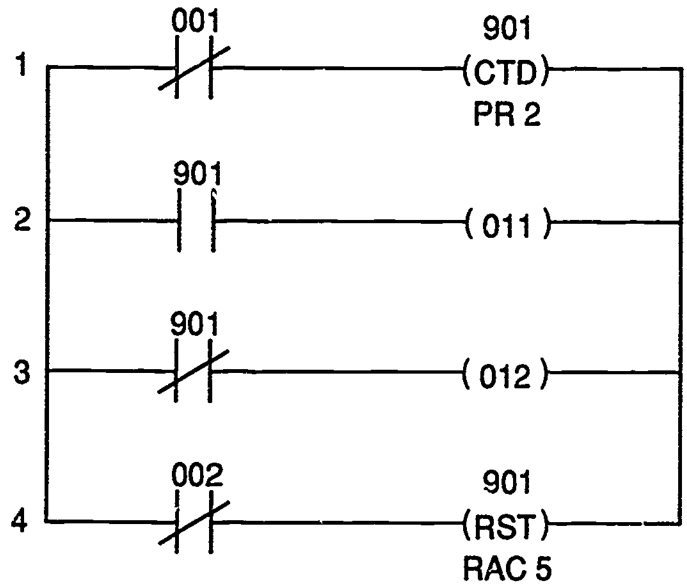
RTF Programming



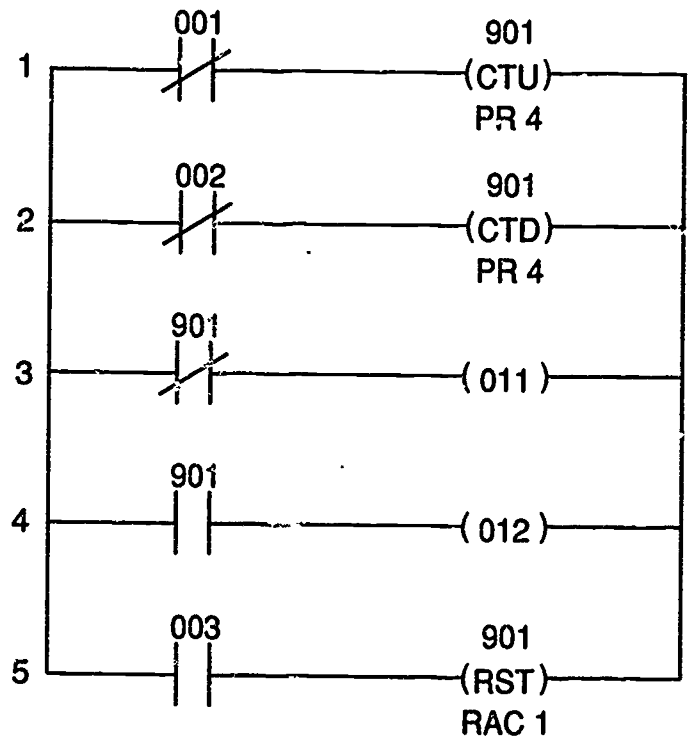
CTU (Up Counter)



CTD (Down Counter)



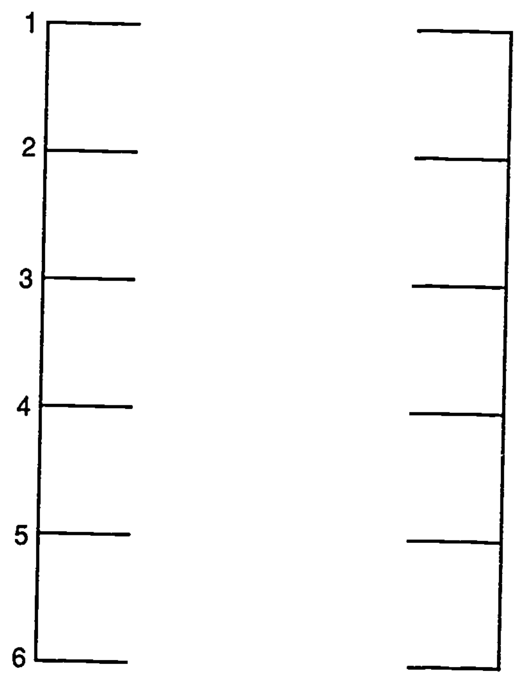
Up-Down Counter



CONTACTS, TIMERS, AND COUNTERS
UNIT II

ASSIGNMENT SHEET #1 — WRITE A LADDER LOGIC PROGRAM USING AUXILIARY CONTACTS TO ENERGIZE AN OUTPUT

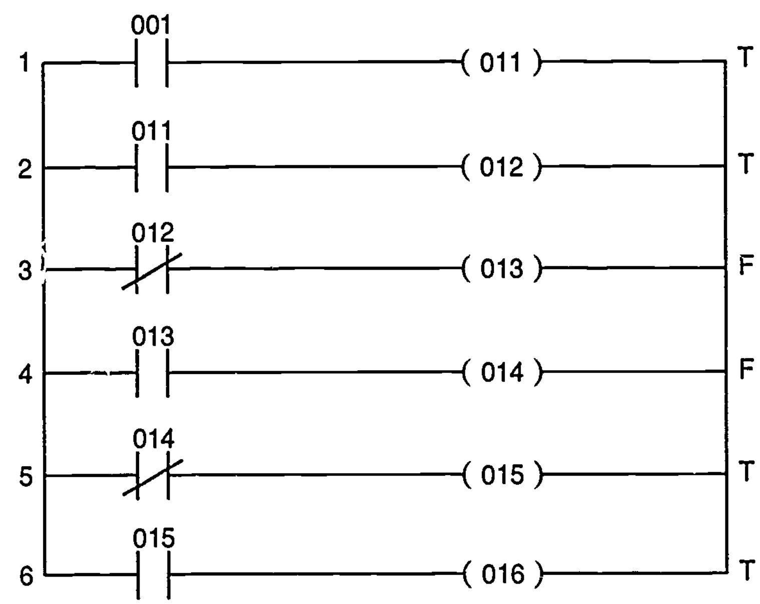
Directions: The focus of this activity is to demonstrate how one input can be used to control multiple outputs through the use of auxiliary contacts. Have switch 1 at address 001 turn on output 11 at address 011 on Rung 1. Use auxiliary contacts from output 11 to energize output 12. Use an auxiliary contact from output 12 so that when output 12 is TRUE, output 13 is FALSE. Use an auxiliary contact from output 13 to energize output 14. Write the program so that when 14 is TRUE, 15 is FALSE; and when 15 is TRUE, 16 is TRUE. Remember that external and internal coils can be used only one time. Remember that you are working with normally closed switches.



CONTACTS, TIMERS, AND COUNTERS
UNIT II

ANSWERS TO ASSIGNMENT SHEET

Assignment Sheet #1



CONTACTS, TIMERS, AND COUNTERS
UNIT II

JOB SHEET #1 — WRITE AND CONFIRM A LADDER LOGIC PROGRAM USING AN INTERNAL RELAY AND ITS AUXILIARY CONTACTS TO ENERGIZE AN OUTPUT

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. Two single-pole, single-throw switches, mounted NC
5. 115v industrial lamp, mounted
6. Three-conductor, 16-gauge power cord
7. Pen or pencil
8. Safety glasses

B. Routine #1 — Writing the ladder logic program

1. Put on safety glasses.
2. Place the Figure 1 guideline that accompanies this job sheet alongside your instructions and use it to complete your ladder logic diagram.
3. Enter the addresses 001 and 002 on Rung 1 to show the Examine ON condition at address 001 and the Examine OFF condition at address 002.
4. Complete Rung 1 by entering the symbol and proper address for Internal Relay 701.
5. Enter a branch around 002 to include an auxiliary contact in the Examine ON condition at address 701.
6. Complete Rung 2 showing an auxiliary contact in the Examine ON condition at address 701, and an output coil at address 011.

☐ Have your instructor check your work.

C. Routine #2 — Entering, running, and confirming the program

1. Put on safety glasses.
2. Check the PLC for proper electrical connections.

JOB SHEET #1

3. Plug the programmer into the PLC.

4. Clear the programmer and enter your new ladder logic program.

5. End the program and enter it into controller memory.

6. Run the program.

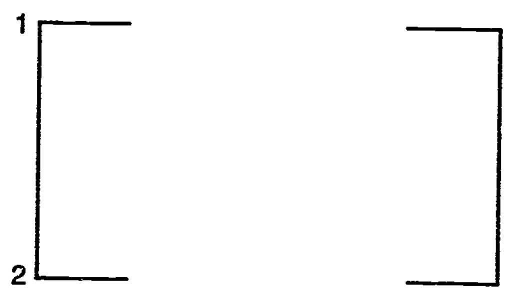
7. Activate the appropriate start switch to confirm the program.

☐ Have your instructor check your work.

8. Clean area and return tools and equipment to proper storage.

JOB SHEET #1

FIGURE 1



CONTACTS, TIMERS, AND COUNTERS
UNIT II

JOB SHEET #2 — EXAMINE AND CONFIRM AN EXISTING RTO PROGRAM

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. Two single-pole, single-throw switches, mounted
5. 115v industrial lamp, mounted
6. Three-conductor, 16-gauge power cord
7. Pen or pencil
8. Stop watch or watch with second hand
9. Safety glasses

B. Routine #1 — Examining an RTO program

1. Put on safety glasses.
2. Take Figure 1 that accompanies this job sheet and lay it out beside this page so you can follow the ladder logic diagram step by step.
3. Assume that you are working with two NC switches as inputs.
4. Scan the diagram and note the initial condition of each rung:
   a. Rung 1 is FALSE.
   b. Rung 2 is TRUE.
   c. Rung 3 is FALSE.
   d. Rung 4 is FALSE.
5. Note the RAC value of 000 on Rung 4, and the PR value of 4.0 (4 seconds) on Rung 1.
6. Activate switch 1 input and status bit 001 on Rung 1 goes TRUE making Rung 1 TRUE, which starts RTO 901 incrementing from 000 (zero).
7. Note that RTO 901 will continue incrementing as long as Rung 1 remains TRUE and RUNG 4 remains FALSE.

JOB SHEET #2

8. Note that at an AC value of 4.0 seconds, RUNG 2 goes FALSE, RUNG 3 goes TRUE, and RUNG 3 remains TRUE until the RTO is reset to a value of less than 4.0

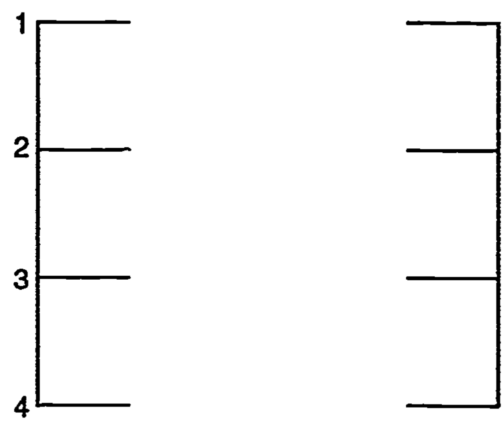
9. Note the dynamics of the program: as RUNG 3 goes TRUE, Rung 1 goes FALSE and will remain FALSE until the 901 RST in Rung 4 is activated.

10. Activate switch 2 input and the program changes back to initial conditions.

11. Activate switch 1 input again and the RTO will begin incrementing and repeat the cycle.

12. Lay Figure 1 aside, and write the program you have been working with on a ladder logic diagram of your own by completing Figure 2.

FIGURE 2



☐ Have your instructor check your work.

C. Routine #2 — Entering, running, and confirming an RTO program

1. Put on safety glasses.

2. Use your own diagram from Routine 1, Figure 2 as you complete the rest of this routine; do not use Figure 1.

3. Prepare the SLC 100 and the Pocket Programmer as previously outlined.

4. Turn the programmer ON, Press MODE and the 1 key, and look for Clear above the DATA display and a 1 above MODE.

5. Press ENTER and look for SurE above DATA and a ? above MODE.

6. Press ENTER, note donE shows above DATA momentarily and then DATA shows 885 to indicate the number of words available for programming and MODE shows End to indicate the programmer is ready for new entries.

JOB SHEET #2

7. Note that the PROG function is lit on the display.

8. Press the Examine OFF key and note that three dashes, - - -, come up in the ADDRESS window and that the RUNG display indicates you are ready to program RUNG 1.

9. Press the 1 key and look for the 1 to show in the ADDRESS window to indicate you have entered the Examine OFF condition for address 001.

10. Press the RTO key, look for the RTO function to light up on the display and three dashes in the ADDRESS window, and a 1 in the RUNG window to indicate you are still programming Rung 1.

11. Press 901 and look for the number of the RTO address to appear in the ADDRESS window.

12. Press ENTER and look for four dashes, - - - -, in the DATA window to indicate that you have additional data to enter at the end of the rung.

13. Note also that Pr shows in the MODE window to indicate the data required is for the PR value.

14. Press the 4 key and then the 0 key, look for two dashes, - -, in the DATA window followed by 4.0 (four point zero), and the Pr in the MODE window.

15. Press ENTER and note DATA displays 883 to indicate two words of memory have been used to program Rung 1, and End in the MODE window verifies Rung 1 is programmed.

16. Press the Examine OFF key, look for three dashes, - - -, in the ADDRESS window, and a 2 in the RUNG window to indicate you are programming Rung 2.

17. Enter 901 for the address of the Examine OFF status bit in Rung 2.

18. Press the -( )- (output coil) key and look for three dashes, - - -, in ADDRESS and a 2 in RUNG.

19. Press the 1 key twice to enter the address (11) of the output coil, and look for -11 in ADDRESS and 2 in RUNG.

20. Press ENTER and look for DATA to display 881 to indicate two words of memory were used to program Rung 2, and an End in MODE to indicate Rung 2 has been programmed.

21. Press the Examine ON key and look for three dashes, - - -in the ADDRESS and a 3 in the RUNG to indicate you are ready to program RUNG 3.

22. Press 901 to enter the address for the Examine ON status bit.

JOB SHEET #2

23. Press the -( )- (output coil) key and look for three dashes, - - -, in the ADDRESS window and a 3 in the RUNG window to indicate you are still programming Rung 3.

24. Press 1 and then 2 to enter the address for output coil 12.

25. Press ENTER and look for an 879 in the DATA display and an End in the MODE display to indicate that Rung 3 has been programmed.

26. Press the Examine OFF key and look for three dashes, - - -, in the ADDRESS window and a 4 in the RUNG window to indicate you are ready to begin programming Rung 4.

27. Press the 2 key to enter address for the Examine OFF status bit 002, and look for two dashes, - -, a 2 in the ADDRESS window, and 4 in the RUNG window.

28. Press the SHIFT key and note that a period (.) appears after the 4 in the RUNG window.

29. Press the RST key and note that the period (.) after the 4 disappears.

30. Press 901 to enter the address for the RST and look for 901 in the ADDRESS window and a 4 in the RUNG display.

31. Press ENTER and look for three dashes and a zero, - - - 0, under ADDRESS and rAc (reset accumulation value) under RUNG.

32. Press ENTER again and look for 876 in DATA to indicate that a total of 9 words have been used for the complete RTO program.

33. Press the MODE key and look for prog in DATA and a 2 in MODE.

34. Press the 3 key and look for a flashing run in DATA and a 3 in MODE to indicate the program is ready to be run on the PLC.

35. Press ENTER and look for 876 in DATA and End in MODE to indicate the program can now be confirmed.

36. Press RUNG and then the 1 key and look for two dashes and a 1, - - 1, under ADDRESS.

37. Press ENTER and look for 901 in ADDRESS and 1 in RUNG; note that the display indicates the RTO function on Rung 1.

38. Press the NEXT key and look for 4.0 in DATA and Pr under MODE.

39. Press the NEXT key again and look for .0 in DATA and Ac in MODE.

40. Activate switch 1 and watch as the RTO increments in seconds and tenths of a second in the DATA window.

JOB SHEET #2

41. Watch output 11, which is ON, and 12, which is OFF, change states when the PR reaches 4.0 seconds.

    (NOTE: If you are using mechanical relay outputs you should actually be able to hear a click when the 4.0 PR value is reached and the relays de-energize and energize.)

42. Press the NEXT key and look for a 901 in ADDRESS and a 2 in RUNG.

43. Press the NEXT key and note that output 11 on Rung 2 is not ON.

44. Press the NEXT key again and look for 901 in ADDRESS and 3 in RUNG, and note that status bit 901 is ON in the upper display.

45. Press the NEXT key again and look for a 12 in the ADDRESS and a 3 in Rung to indicate that output 12 is ON.

46. Press the NEXT key again and look for a 2 in ADDRESS and a 4 in RUNG; notice that the Examine OFF status bit is OFF or FALSE.

47. Press the NEXT key another time and look for 901 in ADDRESS and 4 in RUNG to indicate Rung 4 is FALSE. Since the RST on Rung 4 is therefore FALSE, this confirms the program because the RST has to be FALSE for the RTO on Rung 1 to increment.

48. Press the RUNG key and look for rung in DATA, then press the 1 key and look for two dashes and a 1, - - 1, in DATA.

49. Press ENTER and note that the RTO function lights on the upper display, 901 is in ADDRESS and 1 is in RUNG, and 901 is ON only if the rung is TRUE.

50. Press the NEXT key and look for 4.0 (the PR value) in DATA.

51. Press the NEXT key again and look at the DATA display for seconds and tenths of a second as the RTO continued to increment.

52. Deactivate switch 1 and note that the RTO stops incrementing, and the ON light goes off on the RTO on the display.

53. Activate switch 2 and note that the AC value is reset to .0 and that output 12 is OFF or FALSE and output 11 is ON or TRUE.

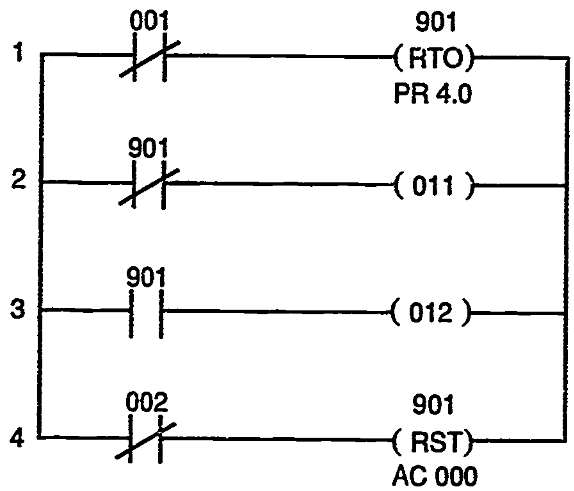
54. Activate switch 1 again and note that the RTO starts incrementing again and repeats the timing cycle to once again confirm your program.

☐ Have your instructor check your work.

55. Clean up area and return tools and equipment to proper storage.

JOB SHEET #2

FIGURE 1



CONTACTS, TIMERS, AND COUNTERS
UNIT II

JOB SHEET #3 — WRITE AND CONFIRM A LADDER LOGIC PROGRAM FOR AN RTO TIMER

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. Two single-pole, single-throw switches, mounted NC
5. 115v industrial lamp, mounted
6. Three-conductor, 16 gauge power cord
7. Pen or pencil
8. Stop watch (or watch with second hand)
9. Safety glasses

B. Routine #1 — Writing the RTO ladder logic diagram

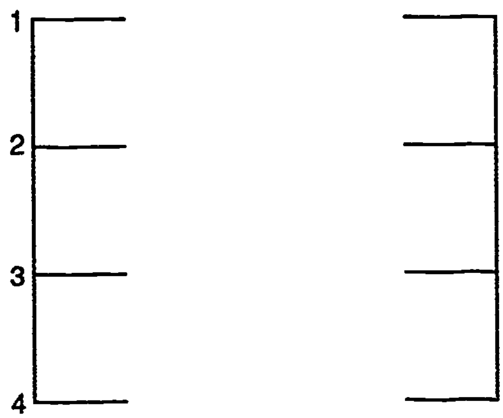
1. Put on safety glasses.

   (NOTE: Assume that you are programming a start/stop function using two NC switches to turn on output #11 5.0 seconds after the START button is pressed. The program objective is to use auxiliary contacts with an RTO timer to turn off output #11 when the STOP button is pressed.)

2. Complete your ladder logic diagram using Figure 1 as a guide, and make all entries in order.

JOB SHEET #3

FIGURE 1



3. Enter the addresses 001 and 002 on Rung 1 to show the Examine ON condition at address 001 and the Examine OFF condition at address 002.

4. Enter a branch around 002 to include an auxiliary contact in the Examine ON condition at address 701.

5. Complete Rung 1 by entering the symbol and proper address for Internal Relay 701.

6. Complete Rung 2 showing an auxiliary contact in the Examine ON condition at address 701, and an RTO output at address 901 to complete Rung 2.

7. Be sure to add the PR 50 to indicate the preset for the RTO at 901.

8. Complete Rung 3 showing an auxiliary contact in the Examine ON condition at address 901, and output coil #11 at address 011.

9. Complete Rung 4 showing an Examine OFF condition at address 001, and a reset, RST, at address 901.

10. Be sure to add the reset accumulated value, RAC, of 000 at the 901 RST in Rung 4.

11. Take a minute or two to examine your logic diagram to make sure that pressing Switch 2 will START output #11, and that pressing Switch 1 will STOP output #11.

JOB SHEET #3

12. Check your program to be sure that after your press START, there will be a 5.0 second delay before output #11 is energized.

    (NOTE: Remember that an RTO means Retentive Timer On-Delay.)

☐ Have your instructor check your work.

C. Routine #2 — Confirming the RTO program

1. Put on safety glasses.
2. Check the PLC for proper and safe electrical connections.
3. Plug the programmer into the PLC.
4. Clear the programmer and enter your new ladder logic program.
5. End the program and enter it into controller memory.
6. Place the program in the RUN mode.
7. Perform the following two steps at the same moment:
   a. Press the START switch.
   b. Start the stop watch.
8. Note the time delay before Output #11 turns On.
9. Enter the time delay here: __ _____.
10. Compare your time delay entry with the programmed delay time of 5.0 seconds to confirm the start/time delay part of your program.
11. Press the STOP switch.
12. Verify that Output #11 goes OFF immediately to confirm the final part of your program.

    (NOTE: If you left the stop watch running, you may want to note the full time between START and STOP, and then note that the program time can end ONLY when the STOP switch is pressed either manually or by a programmed device such as a limit switch.)

13. Repeat Steps 7 through 11 to confirm your program a second time.

☐ Have your instructor check your work.

14. Clean area and return tools and equipment to proper storage.

CONTACTS, TIMERS, AND COUNTERS
UNIT II

JOB SHEET #4 — WRITE AND CONFIRM A LADDER LOGIC PROGRAM FOR AN RTF TIMER

A. Tools and materials

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. Two single-pole, single-throw switches, mounted
5. 115v industrial lamp, mounted
6. Three conductor, 16-gauge power cord
7. Pen or pencil
8. Stop watch or watch with second hand
9. Safety glasses

B. Routine #1 — Writing the RTF ladder logic program

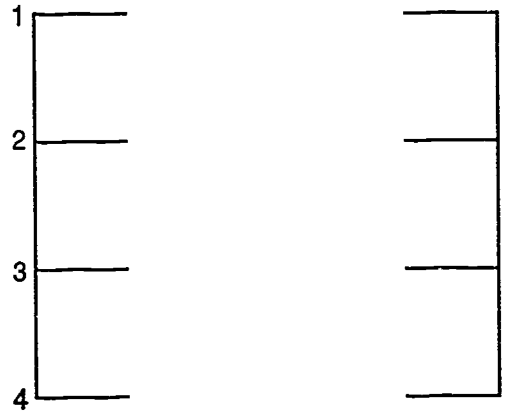
1. Put on safety glasses.

   (NOTE: Assume that you are programming a start/stop function using to NC switches to control a program where Output #11 is initially ON, but goes OFF 5.0 seconds after Switch 2 is pressed. The program uses an RTF timer.)

2. Complete your ladder logic diagram using Figure 1 as a guide, and make all entries in order.

JOB SHEET #4

FIGURE 1



3. Enter the addresses 001 and 002 on Rung 1 to show the Examine ON condition at status bit 001 and the Examine OFF condition at status bit 002.

4. Enter a branch around 002 to include an auxiliary contact in the Examine ON condition at status bit 701.

5. Complete Rung 1 by entering the symbol and proper address for Internal Relay 701.

6. Complete Rung 2 showing an auxiliary contact in the Examine OFF condition at status bit 701, and an RTF output address 901 to complete Rung 2.

7. Be sure to enter the PR 50 to indicate the preset for the RTF at 901.

8. Complete Rung 3 showing an auxiliary contact in the Examine ON condition at status bit 901, and output coil #11 at address 011.

9. Complete Rung 4 showing an Examine OFF condition at status bit 001, and a reset, RST, at address 901.

10. Be sure to add the reset accumulated value, RAC, of 000 at the 901 RST in Rung 4.

11. Take a minute or two to examine your logic diagram to make sure that pressing Switch 2 will STOP output #11, and that pressing Switch 1 will start output #11 again and energize it for 5.0 seconds.

JOB SHEET #4

12. Take a minute or two to examine your logic diagram to make sure that pressing Switch 1 activates RST 901 so that the RTF will be reset to 000. Make sure that activating Switch 2 will start the RTF by making Rung 2 FALSE, and that output #11 goes OFF after 5.0 seconds.

☐ Have your instructor check your work.

C. Routine #2 — Confirming the RTF program

1. Put on safety glasses.
2. Check the PLC for proper and safe electrical connections.
3. Plug the programmer into the PLC.
4. Clear the programmer and enter your new ladder logic program.
5. End the program and enter it into controller memory.
6. Place the program in the RUN mode.
7. Note that output #11 is ON.
8. Perform the following two steps at the same moment.
   a. Press Switch 2.
   b. Start the stop watch.
9. Note the time delay before Output #11 goes OFF.
10. Enter the time delay here:_______.
11. Compare your time delay entry with the programmed time delay of 5.0 seconds to confirm your program.

☐ Have your instructor check your work.

12. Clean area and return tools and materials to proper storage.

CONTACTS, TIMERS, AND COUNTERS
UNIT II

JOB SHEET #5 — WRITE AND CONFIRM A LADDER LOGIC PROGRAM FOR AN UP COUNTER

A. Tools and materials

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. Two single-pole, single-throw switches, mounted NC
5. 115v industrial lamp, mounted
6. Three conductor, 16 gauge power cord
7. Pen or pencil
8. Safety glasses

B. Routine #1 — Writing the up counter program

1. Put on safety glasses.
2. Assume that you are working with two NC closed switches for inputs #1 and #2.
3. Lay the Figure 1 sketch that accompanies this job sheet alongside these instructions to help make the job easier.
4. Write an Examine OFF condition for the status bit at address 001 on Rung 1.
5. Complete Rung 1 with a CTU output at address 901 with a PR value of 2.0.
6. Start Rung 2 with an Examine ON condition for the status bit at address 901.
7. Complete Rung 2 showing an output coil at address 011.
8. Start Rung 3 with an Examine OFF condition for the status bit at address 002.
9. Complete Rung 3 with a RST output at address 901 and an RAC value of 000.

JOB SHEET #5

10. Start with your initial condition of two NC switches and follow the logic through the program to check your program.

☐ Have your instructor check your work.

C. Routine #2 — Programming and confirming the up counter program

1. Put on safety glasses.

   (CAUTION: Check power cords and all electrical connections before starting this routine to make sure you are working safely.)

2. Set up the pocket programmer and the PLC as outlined in a previous routine.

3. Lay your completed program from Figure 1 alongside the programmer so it can be easily referenced.

4. Clear the programmer.

5. Start on Rung 1 and make all entries in order.

6. Enter the program in PLC memory.

7. Place the programmer in the run mode and confirm the program by observing the following:

   a. Output #11 should be off.

   b. Pressing input switch 1 two times should energize output #11.

   c. Pressing input switch 2 should turn output #11 OFF.

8. Run the program a second time to reconfirm.

☐ Have your instructor check your work.

9. Clean up area and return tools and equipment to proper storage.

JOB SHEET #5

FIGURE 1

CONTACTS, TIMERS, AND COUNTERS
UNIT II

JOB SHEET #6 — WRITE AND CONFIRM A LADDER LOGIC PROGRAM FOR A DOWN COUNTER

A. Tools and materials

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. Two single-pole, single-throw switches, mounted NC
5. 115v industrial lamp, mounted
6. Three-conductor, 16 gauge power cord
7. Pen or pencil
8. Safety glasses

B. Routine #1 — Writing the down counter program

1. Put on safety glasses.
2. Assume that you are working with two NC switches for inputs #1 and #2.
3. Use the guideline sketch in Figure 1 that accompanies this job sheet to complete your program.
4. Write an Examine OFF condition for the status bit at address 001 on Rung 1.
5. Complete Rung 1 with a CTD output at address 901 with a PR value of 1.
6. Start Rung 2 with an Examine ON condition for the status bit at address 901.
7. Complete Rung 2 showing an output coil at address 011.
8. Start Rung 3 with an Examine OFF condition at address 002.
9. Complete Rung 3 with a RST output at address 901 with a RAC value of 2.

   (NOTE: In this case the RAC value is greater than the PR value because this is a down counter.)

10. Start with your initial condition of two NC switches and follow the logic through the program to check your program.

☐ Have your instructor check your work.

JOB SHEET #6

C. Routine #2 — Programming and confirming the down counter program

1. Put on safety glasses.

   (CAUTION: Check power cords and all electrical connections before starting this routine to make sure you are working safely.)

2. Set up the pocket programmer and the PLC as outlined in a previous routine.

3. Lay your completed program from Figure 1 alongside the programmer so it can be easily referenced.

4. Clear the programmer.

5. Start on Rung 1 and make all entries in order.

6. Enter the program in PLC memory.

7. Place the programmer in the run mode and confirm the program by observing the following:

   a. Activate Switch 2.

   b. Output #11 should be ON.

   c. Pressing Input Switch 1 two times should turn Output #11 OFF.

   d. Pressing Input Switch 2 should turn Output #11 ON.

8. Run the program a second time to reconfirm, but this time monitor the AC value with the following procedure:

   a. Press the RUNG key.

   b. Press the 1 key.

   c. Press the NEXT key until you see the AC value in the MODE display.

9. Activate input switch 1 one time and look for the AC value to go from 2 to 1.

10. Activate input switch 1 a second time and look for the AC value to go from 1 to 0.

11. Activate input switch 2 and look for the AC value to return to 2.

☐ Have your instructor check your work.

12. Clean up area and return tools and materials to proper storage.

JOB SHEET #6

FIGURE 1

CONTACTS, TIMERS, AND COUNTERS
UNIT II

JOB SHEET #7 — WRITE AND CONFIRM A LADDER LOGIC PROGRAM FOR AN UP-DOWN COUNTER

A. Tools and materials

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. Two single-pole, single-throw switches, mounted NC
5. One single-pole single-throw switch mounted NO
6. 115v industrial lamp, mounted
7. Three-conductor, 16-gauge power cord
8. Pen or pencil
9. Safety glasses

B. Routine #1 — Writing the up-down counter program

1. Put on safety glasses.
2. Assume that you are working with two NC switches for Inputs #1 and #2 and one NO switch at Input #3.
3. Use the guidelines in Figure 1 that accompanies this job sheet to complete your program.
4. Write an Examine OFF condition for the status bit 001 on Rung 1.
5. Complete Rung 1 with a CTU output at address 901 with a PR value of 4.
6. Start Rung 2 with an Examine OFF condition for the 002.
7. Complete Rung 2 with a CTD output at address 901 with a PR value of 4.
8. Start Rung 3 with an Examine OFF condition at address 901.
9. Complete Rung 3 with an output coil at address 011.
10. Start Rung 4 with an Examine ON condition at address 901.
11. Complete Rung 4 with an output coil at address 012.
12. Start Rung 5 with an Examine ON condition at address 003.

JOB SHEET #7

13. Complete Rung 5 with an RST output at address 901 with a RAC value of 1.

14. Start with your initial conditions and follow the logic through the program to check your program.

☐ Have your instructor check your work.

C. Routine #2 — Programming and confirming the up-down counter program

1. Put on safety glasses.

   (CAUTION: Check power cords and all electrical connections before starting this routine to make sure you are working safely.)

2. Set up the pocket programmer and the PLC as outlined in a previous routine.

3. Lay your completed program alongside the programmer so it can be easily referenced.

4. Clear the programmer.

5. Start on Rung 1 and make all entries in order.

6. Enter the program into PLC memory.

7. Place the programmer in the run mode and confirm the program by observing the following:

   a. Output #11 is lit.

   b. Press RUNG and 1 and monitor the AC value of Rung 1.

   c. Activate input switch 1 and look for the AC value to increment 1.

   d. Keep activating switch 1 and watch the AC value increment by 1 each time switch 1 is activated.

   e. Start activating switch 2 and look for the AC value to decrement 1 each time switch 2 is activated.

      (NOTE: You could program Rung 2 for monitoring, but there is no need because the AC value is a value shared by Rungs 1 and 2.)

   f. Activate switch 1 until the AC value goes past the PR of 4.

   g. Activate switch 2 until the AC value goes back to 0.

   h. Activate switch 3 and look for the RST to take Rungs 1 and 2 back to an AC of 1.

JOB SHEET #7

(NOTE: Output #11 is OFF and Output #12 is ON when the AC value is 4 or greater, and Output #11 is ON and Output #12 is OFF when the AC value is 3 or less.)

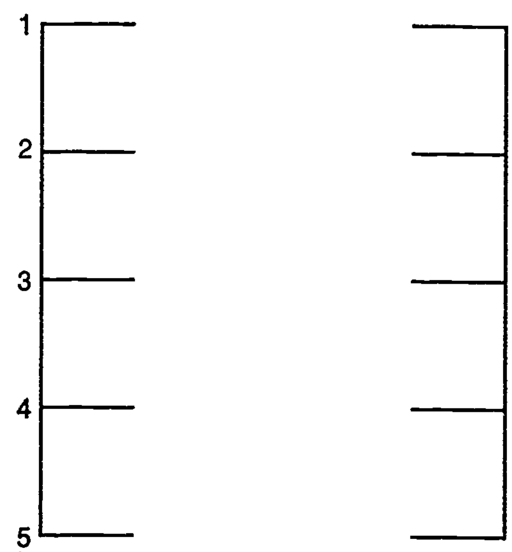
8. Run the up-down counter program again to reconfirm the program.

☐ Have your instructor check your work.

9. Clean up area and return tools and materials to proper storage.

JOB SHEET #7

FIGURE 1



CONTACTS, TIMERS, AND COUNTERS
UNIT II

PRACTICAL TEST #1
JOB SHEET #1 — WRITE AND CONFIRM A LADDER LOGIC PROGRAM USING AN INTERNAL RELAY AND ITS AUXILIARY CONTACTS TO ENERGIZE AN OUTPUT

Stud .nt's name ______________________________ Date ______________

Evaluator's name ______________________________ Attempt no. ___________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "process Evaluation" must receive a "yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATION NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Wrote program properly.	☐	☐
2. Entered new program properly.	☐	☐
3. Ran the program properly.	☐	☐
4. Confirmed program.	☐	☐
5. Worked safely.	☐	☐
6. Returned tools and equipment to proper storage.	☐	☐

Evaluator's comments: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Safety with equipment	4	3	2	1
Program writing	4	3	2	1
Program keyboarding	4	3	2	1
Program confirmation	4	3	2	1

EVALUATOR'S COMMENTS:______________________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training
3 —**Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CONTACTS, TIMERS, AND COUNTERS
UNIT II

PRACTICAL TEST #2
JOB SHEET #2 — EXAMINE AND CONFIRM AN EXISTING RTO PROGRAM

Student's name ______________________ Date ____________

Evaluator's name ______________________ Attempt no. ____________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "process Evaluation" must receive a "yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATION NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Examined RTO program.	☐	☐
2. Rewrite RTO program properly.	☐	☐
3. Keyboarded all entries in order.	☐	☐
4. Ran RTO program properly.	☐	☐
5. Confirmed RTO program.	☐	☐
6. Returned tools and equipment to proper storage.	☐	☐

Evaluator's comments: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Safety with equipment	4	3	2	1
Program writing	4	3	2	1
Program keyboarding	4	3	2	1
Program confirmation	4	3	2	1

EVALUATOR'S COMMENTS: ______________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CONTACTS, TIMERS, AND COUNTERS
UNIT II

PRACTICAL TEST #3
JOB SHEET #3 — WRITE AND CONFIRM A LADDER LOGIC PROGRAM FOR AN RTO TIMER

Student's name ______________________________ Date ______________

Evaluator's name ______________________________ Attempt no. ____________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "process Evaluation" must receive a "yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATION NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Wrote RTO program properly.	☐	☐
2. Set up programmer and PLC properly.	☐	☐
3. Keyboarded all entries in order.	☐	☐
4. Ran RTO program properly.	☐	☐
5. Confirmed RTO program.	☐	☐
6. Returned tools and equipment to proper storage.	☐	☐

Evaluator's comments: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Safety with equipment	4	3	2	1
Program writing	4	3	2	1
Program keyboarding	4	3	2	1
Program confirmation	4	3	2	1

EVALUATOR'S COMMENTS:____

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CONTACTS, TIMERS, AND COUNTERS
UNIT II

PRACTICAL TEST #4
JOB SHEET #4 — WRITE AND CONFIRM A LADDER LOGIC PROGRAM FOR AN RTF TIMER

Student's name ______________________________ Date ______________

Evaluator's name______________________________ Attempt no. ____________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "process Evaluation" must receive a "yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATION NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Wrote RTO program properly.	☐	☐
2. Set up programmer and PLC properly.	☐	☐
3. Keyboarded all entries in order.	☐	☐
4. Ran RTF program properly.	☐	☐
5. Confirmed RTF program.	☐	☐
6. Returned tools and equipment to proper storage.	☐	☐

Evaluator's comments: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Safety with equipment	4	3	2	1
Program writing	4	3	2	1
Program keyboarding	4	3	2	1
Program confirmation	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CONTACTS, TIMERS, AND COUNTERS
UNIT II

PRACTICAL TEST #5
JOB SHEET #5 — WRITE AND CONFIRM A LADDER LOGIC PROGRAM FOR AN UP COUNTER

Student's name ______________________ ____________ Date __________________

Evaluator's name ________________________________ Attempt no. ____________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "process Evaluation" must receive a "yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATION NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Wrote program properly.	☐	☐
2. Set up programmer and PLC properly.	☐	☐
3. Keyboarded all entries in order.	☐	☐
4. Ran up counter program properly.	☐	☐
5. Confirmed up counter program.	☐	☐
6. Returned tools and equipment to proper storage.	☐	☐

Evaluator's comments: ____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Safety with equipment	4	3	2	1
Program writing	4	3	2	1
Program keyboarding	4	3	2	1
Program confirmation	4	3	2	1

EVALUATOR'S COMMENTS:____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CONTACTS, TIMERS, AND COUNTERS
UNIT II

PRACTICAL TEST #6
JOB SHEET #6 — WRITE AND CONFIRM A LADDER LOGIC DIAGRAM FOR A DOWN COUNTER

Student's name ______________________________ Date ________________

Evaluator's name_____________________________ Attempt no. ____________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "process Evaluation" must receive a "yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATION NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Wrote properly.	☐	☐
2. Set up programmer and PLC properly.	☐	☐
3. Keyboarded all entries in order.	☐	☐
4. Ran down counter program properly.	☐	☐
5. Confirmed down counter program.	☐	☐
6. Returned tools and equipment to proper storage.	☐	☐

Evaluator's comments: ____

____

JOB SHEET #6 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Safety with equipment	4	3	2	1
Program writing	4	3	2	1
Program keyboarding	4	3	2	1
Program confirmation	4	3	2	1

EVALUATOR'S COMMENTS:____

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CONTACTS, TIMERS, AND COUNTERS
UNIT II

PRACTICAL TEST #7
JOB SHEET #7 — WRITE AND CONFIRM A LADDER LOGIC PROGRAM FOR AN UP-DOWN COUNTER

Student's name ______________________ Date ______________

Evaluator's name ______________________ Attempt no. ______________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "process Evaluation" must receive a "yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATION NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

		YES	NO
1.	Wrote program properly.	☐	☐
2.	Set up programmer and PLC properly.	☐	☐
3.	Keyboarded all entries in order.	☐	☐
4.	Ran up-down counter program properly.	☐	☐
5.	Confirmed up-down counter program.	☐	☐
6.	Returned tools and equipment to proper storage.	☐	☐

Evaluator's comments: ____

____

JOB SHEET #7 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Safety with equipment	4	3	2	1
Program writing	4	3	2	1
Program keyboarding	4	3	2	1
Program confirmation	4	3	2	1

EVALUATOR'S COMMENTS:____

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CONTACTS, TIMERS AND COUNTERS
UNIT II

TEST

NAME____ SCORE ____________________

1. Match terms related tc ɔontacts, timers, and counters with their correct definitions.

_____a.	Examine ON/Examine OFF status bits associated with output addresses	1.	RTO
		2.	Increment
_____b.	A counter whose accumulated value increases by 1 for each FALSE/TRUE transition	3.	Auxiliary ɔontacts
		4.	RTF
_____c.	A counter whose accumulated value decreases by 1 for each FALSE/TRUE transition	5.	Decrement
		6.	CTU
_____d.	A timer which increments until it reaches a reset accumulated value	7.	CTD
_____e.	A timer that decrements until it reaches a reset accumulated value	8.	RAC
		9.	PR
_____f.	A process of changing values by consecutive additions	10.	AC
_____g.	A process of changing values by consecutive subtractions		
_____h.	The amount of time programmed for a timing function		
_____i.	The amount of time that has passed at any interval between the start and end of a timing function		
_____j.	The value that a timer is programmed to start timing from, usually 0000		

2. Solve problems concerning auxiliary contacts by correctly answering the following questions.

   a. If you were programming with only Examine ON conditions could you use auxiliary contacts, and if or if not so, why?

      Answer ____

      ____

TEST

b. If you were working with input addresses, could you use auxiliary contacts, and if so or if not, why?

Answer: ____

____

3. Solve problems concerning application of Examine OFF auxiliary contacts by answering the following questions.

   a. How would you determine how many auxiliary contacts could be used in a program?

   Answer ____

   ____

   b. A programmer's ability in programming auxiliary contacts could probably only be limited by what two things?

   Answer ____

   ____

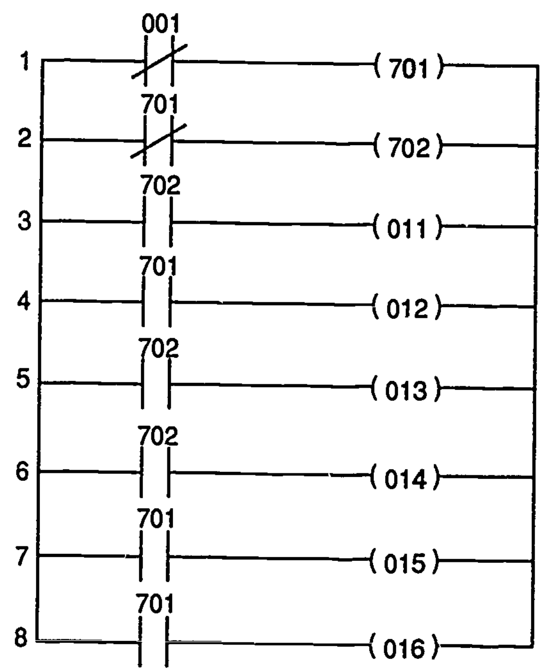
4. Complete statements concerning internal relays by circling the material that best completes each statement.

   a. External outputs and internal relays are the same except that external outputs are (limited) (infinite) in number while internal relays (number more than a hundred) (are limited).

   b. Internal relays also have auxiliary contacts that can be programmed (just) (almost) like auxiliary contacts on external outputs.

TEST

c. The following illustration demonstrates how only (one) (two) NC or NO (switch (switches) can be used to control multiple outputs.



d. In the above illustration, with the switch NC, Rung 1 is FALSE and Rung 2 is TRUE, but the moment Switch 1 is activated, Rung 1 becomes (TRUE) (FALSE) and Rung 2 becomes (FALSE) (TRUE).

e. The illustration also shows how Rungs 3, 4, 5, 6, 7, and 8 change status dependent upon the input condition of switch 1, and outputs on all rungs are controlled by the auxiliary contacts for (internal) (output) relays, not auxiliary contacts for (output) (internal) relays.

f. Selecting the most effective auxiliary contacts becomes important in (advanced) (basic) programming.

5. Select true statements concerning RTO timers by placing an X beside each statement that is true.

_____a. RTO means Retentive Timer On-Delay, and the symbol is -(RT)-.

TEST

_____b. RTOs have addresses from 901 to 932, they have Examine ON/Examine OFF auxiliary contacts that have the same addresses as the timer coil, and they have a reset coil with a reverse address.

_____c. The 901 timer coil has a PR value at which the auxiliary contacts change states.

_____d. As an RTO advances, it accumulates time, and this is called the time advance.

_____e. With an RTO, the Examine ON contacts are FALSE when the AC value is less than the PR value.

_____f. With an RTO, the Examine ON contacts are TRUE when the AC value is equal to or greater than the PR value.

_____g. The RESET coil has a value called RAC and that is the value that the timer is programmed to start timing from.

6. Complete statements concerning how an RTO times by circling the material that best completes each statement.

   a. There are two important elements in RTO timing:

      1) The timer never times when the rung with the RST is (TRUE) (FALSE).

      2) The RST rung must be (TRUE) (FALSE) and the RTO rung must be (FALSE) (TRUE) for the RTO to time.

   b. The RTO times in (hundredths) (tenths) of a second, (.010) (.10) and the maximum is 999.9, and then the timer rolls over to 000.0 again.

   c. As the RTO passes 999.9 it sets a status bit at the RTO address plus 50 at an Examine (ON) (OFF) condition.

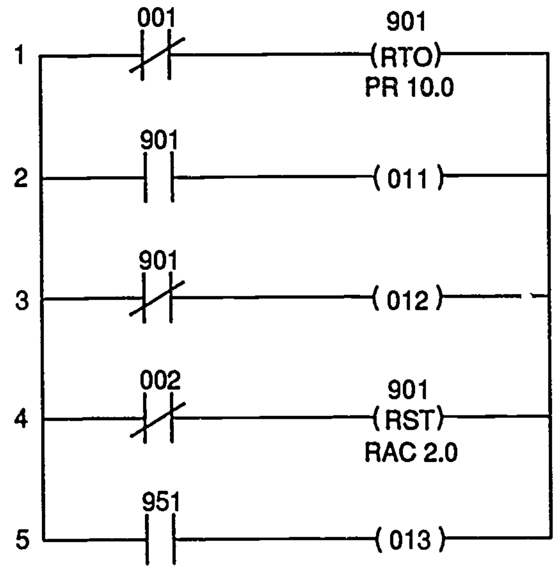
   d. The Examine (ON) (OFF) status bit goes TRUE as the timer rolls over and the Examine (OFF) (ON) status bit at the same address goes FALSE.

   e. The TRUE/FALSE transition happens only the first time the counter rolls over without being (reset) (reprogrammed).

   f. An RTO is reset by making the reset rung (TRUE) (FALSE), and this can be accomplished by the program or by physically reactivating a switch.

TEST

7. Solve problems concerning basic RTO programming by referencing the following illustration and answering the following questions.



a. By activating NC switch 2, the RST coil 901 on Rung 4 resets the RTO to what, 1.0 second or 2,0 seconds?

Answer ______________________

b. When the timer starts timing, output 011 on Rung 2 is FALSE, and output 012 on Rung 3 is what, TRUE or FALSE?

Answer ______________________

c. As long as Rung 1 remains TRUE, the AC value will do what?

Answer ______________________

d. What happens when the RTO reaches 999.9?

Answer ______________________

8. Select true statements concerning RTF timers by placing an X beside each statement that is true.

(NOTE: For a statement to be true, all parts of the statement must be true.)

_____a. RTF means Retentive Timer FORWARD and the symbol is -(RTF)-.

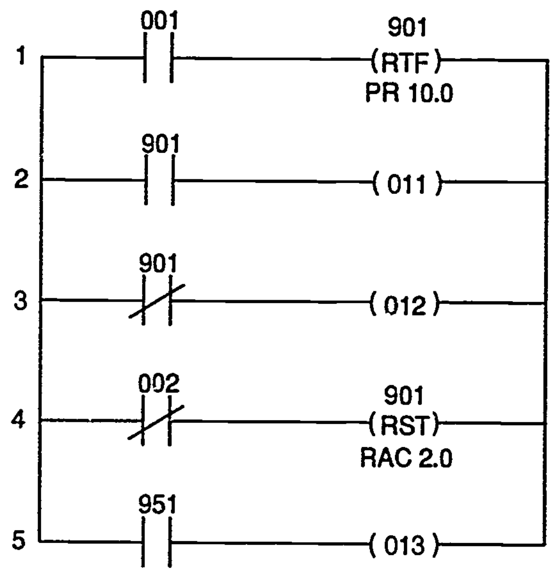
TEST

_____b. RTFs have the same addresses as RTOs, 901 to 932, Examine ON/Examine OFF auxiliary contacts that have the same addresses as the timer, and a reset coil with the same address.

_____c. There is no difference between an RTF and RTO timer.

_____d. The RTF timer Examine OFF status bit remains FALSE until the PR value is reached, then the status bit goes TRUE until it is reset.

9. Solve problems concerning basic RTF programming by referencing the following illustration and answering the following questions.



a. When NC switch 2 is activated, the RST coil 901 on Rung 4 does what?
Answer ____________________

b. Since switch 1 is ON, the Examine ON status bit 001 on Rung 1 is TRUE, and the RTF on Rung 1 is TRUE, but not timing because of what?

Answer ____________________

c. The timer starts timing when?

Answer ____________________

d. When the RFT rolls over, it starts again where?

Answer ____________________

TEST

10. Complete statements concerning CTUs by circling the material that best completes each statement.

    a. CTUs on the SLC™ 100 are at internal addresses (901-932) (801-832).

    b. As the name implies, a CTU increments in increasing values of (1) (10).

    c. A CTU symbol has letters inside the coil symbol with (nothing) (an address) above: -(CTU',

    d. Like an RTO or an RTF, a CTU is (retentive) (a clock) and must be reset with a RST instruction.

    e. CTU instructions count successive FALSE-to-TRUE instructions of the rung containing the counter instructions as long as the RST is (FALSE) (TRUE).

    f. After each count, the rung must return to (FALSE) (TRUE) before another count can take place.

    g. With CTUs the existing count is called the AC and the AC value increases by (1) (10) for each FALSE-to-TRUE transition.

    h. CTUs are programmed with a PR and a RAC just as (timers) (clocks) are.

11. Complete statements concerning CTDs by circling the material that best completes each statement.

    a. CTDs on the SLC™ are at internal addresses (901-932) (801-832).

    b. As the name implies, a CTD (decrements) (increments) in (decreasing) (increasing) values of 1.

    c. A CTD symbol has letters inside the symbol and (nothing) (an address) above.

    d. A CTD is retentive and must be reset with (a RST) (an RAC) instruction.

    e. CTD instructions count successive FALSE-to-TRUE instructions of the rung containing the counter instructions as long as the RST is (TRUE) (FALSE).

    f. After each count, the rung must be (TRUE) (FALSE) before another count can take place.

    g. With CTDs, the existing count ' called the AC and the AC value decreases by (2) (1) for each FALSE-to-TRUE transition.

    h. CTDs are programmed with a PR and an RAC just as (clocks) (timers) are.

TEST

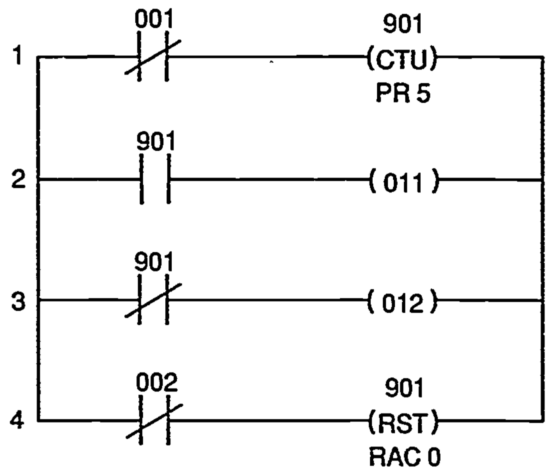
12. Complete statements concerning up-down counters by circling the material that best completes each statement.

    a. The up-down counter has both an up counter (setting) (rung) and a down counter (rung) (setting).

    b. With an up-down counter, the (AC) (PR) value both increases and decreases in response to FALSE-to-TRUE conditions on the respective up/down rungs.

    c. PR, AC, and (CTU) (RAC) are used in all counter programming.

13. Solve problems concerning how a CTU counts by referencing the following illustration and answering the following questions.



    a. With a CTU ready to run, the ladder logic program should show what of the following:

        1) Rung 1 is TRUE or FALSE? ____________________

        2) Rung 2 is TRUE or FALSE? ____________________

        3) Rung 3 is TRUE or FALSE? ____________________

        4) Rung 4 is TRUE or FALSE? ____________________

TEST

b. If the PR value of a CTU program is 5, and the CTU increments by 1 until it reaches 5, what will happen?

Answer ______________________________

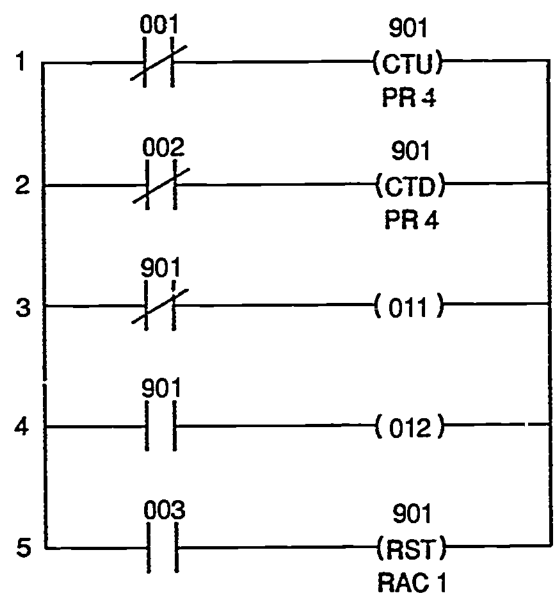
c. What happens to Rung 2 as the CTU reaches its PR value?

Answer ______________________________

d. What happens to Rung 3 as the CTU reaches its PR value?

Answer ______________________________

14. Solve problems concerning how an up-down counter works by referencing the following illustration and answering the following questions.



a. Activating switch 1 starts the counter which does what?

Answer ______________________________

b. Activating switch 2 does what?

Answer ______________________________

c. What has to happen to reset both AC values?

Answer ______________________________

TEST

15. Select true statements concerning special function program keys by placing an "X" beside each statement that is true.

_____a. Many keys on a programmer have duel functions which are indicated by numbers and symbols on the faces of the keys.

_____b. Pressing the SHIFT key on the programmer changes the key function to the function indicated in blue on the top of the key.

_____c. When an output such as a timer or counter requires additional data such as a PR or an RAC, four dashes, - - - - , appear in the ADDRESS window to indicate additional data should be entered.

_____d. When four dashes, - - - -, appear in the ADDRESS window they will remain there until required data is entered and the programmer will reject inappropriate entries.

_____e. The LAST and NEXT keys permit a programmer to go back and check an instruction by pressing the LAST key and then pressing the NEXT key to get back to the original spot in the program.

_____f. The LAST and NEXT keys become handy tools when programming becomes complex because you can move back several rungs to check specific instructions and then return to your starting point.

_____g. The NEXT and LAST functions cannot be used for monitoring any selected instruction while a program is running.

_____h. Be pressing the RUNG key, then the rung number, and then the ENTER key, a programmer can check any rung desired and check a program rung by rung as it is running.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

16. Write a ladder logic program using auxiliary contacts to energize an output. (Assignment Sheet #1)

17. Demonstrate the ability to:

    a. Write and confirm a ladder logic program using an internal relay and its auxiliary contacts to energize an output. (Job Sheet #1)

    b. Examine and confirm an existing RTO program. (Job Sheet #2)

    c. Write and confirm a ladder logic program for an RTO timer. (Job Sheet #4)

    d. Write and confirm a ladder logic program for an RTF timer. (Job Sheet #4)

    e. Write and confirm a ladder logic program for an up counter. (Job Sheet #5)

TEST

f. Write and confirm a ladder logic program for a down counter. (Job Sheet #6)

g. Write and confirm a ladder logic program for an up-down counter. (Job Sheet #7)

CONTACTS, TIMERS, AND COUNTERS

UNIT II

ANSWERS TO TEST

1. a. 3
   b. 6
   c. 7
   d. 1
   e. 4
   f. 2
   g. 5
   h. 9
   i. 10
   j. 8

2. a. Yes because auxiliary contacts can be either Examine ON or Examine OFF
   b. No because auxiliary contacts are associated only with output addresses

3. a. By finding out how much memory is available
   b. By available memory or imagination

4. a. Limited, number more than a hundred
   b. Just
   c. One, switch
   d. TRUE, FALSE
   e. Internal, output
   f. Advanced

5. a, c, e, f, g

6. a. 1) TRUE
      2) FALSE, TRUE
   b. Tenths, .10
   c. ON
   d. ON, OFF
   e. Reset
   f. TRUE

7. a. 2,0 seconds
   b. TRUE
   c. Continue to increment
   d. It starts again at 000.0

8. b, d

ANSWERS TO TEST

9. a. Resets the AC value of the RTF to 2.0 seconds
   b. The RTF is looking for a FALSE rung
   c. When switch 1 is activated and Rung 1 becomes FALSE>
   d. At 000.0

10. a. 901-932
    b. 1
    c. An address
    d. Retentive
    e. FALSE
    f. FALSE
    g. 1
    h. Timers

11. a. 901-932
    b. Decrements, decreasing
    c. An address
    d. A RST
    e. FALSE
    f. FALSE
    g. 1
    h. Timers

12. a. Rung, rung
    b. AC
    c. RAC

13. a. 1) Rung 1 is FALSE
       2) Rung 2 is FALSE
       3) Rung 3 is TRUE
       4) Rung 4 is FALSE
    b. The CTU program will be completed
    c. The rung goes from FALSE to TRUE
    d. The rung goes from TRUE to FALSE

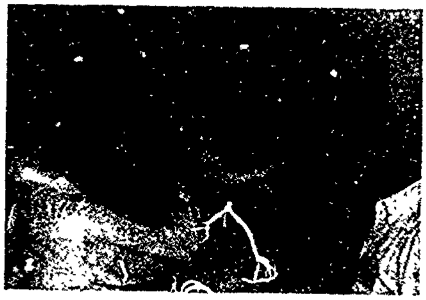
14. a. Increments 1 unit at a time
    b. Causes the counter to start decrementing
    c. Switch 3 has to be activated

15. a, b, c, d, e, f, h

16. Evaluated to the satisfaction of the instructor

ANSWERS TO TEST

17. a. Evaluated according to criteria in Practical Test #1
    b. Evaluated according to criteria in Practical Test #2
    c. Evaluated according to criteria in Practical Test #3
    d. Evaluated according to criteria in Practical Test #4
    e. Evaluated according to criteria in Practical Test #5
    f. Evaluated according to criteria in Practical Test #6
    g. Evaluated according to criteria in Practical Test #7



SEQUENCERS AND REGISTERS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to differentiate between sequencer out (SQO) and sequencer in (SQI) instructions and be able to prepare SQO and SQI data forms. The student should also be able to program variations in sequencer applications and shift register applications. These competencies will be evidenced by correctly completing the procedures outlined in the assignment and job sheets and by scoring a minimum of 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to sequencers and registers with their correct definitions.
2. Complete statements concerning comparing sequencers with timers and counters.
3. Select true statements concerning sequencer operations.
4. Complete statements concerning time-driven and event-drive sequencer operations.
5. Solve problems concerning accumulated values (AC) and preset values (PR).
6. Select conditions concerning the dynamics of SQO instructions.
7. Select conditions concerning the dynamics of SQI instructions.
8. Match numbering systems with their structures.
9. Select true statements concerning working with sequencer data.
10. Complete statements concerning the sequencer data form.
11. Program a time-driven SQO instruction.
12. Select conditions concerning a typical SQO instruction.
13. Select conditions concerning a typical SQI instruction.
14. Complete statements concerning MCR and ZCL instructions.
15. Complete statements concerning cascading SQO sequencers.

SPECIFIC OBJECTIVES

16. Select conditions concerning reversing sequencers.

17. Arrange in order the steps in a reversing sequencer operation.

18. Select conditions concerning using sequencer input to drive sequencer output.

19. Select conditions concerning sequencer input monitoring sequencer output.

20. Solve problems concerning sequencer jump instructions.

21. Complete statements concerning shift registers.

22. Select conditions concerning shift register instructions.

23. Select conditions concerning event-drive shift register instructions.

24. Select conditions concerning time-driven shift register instructions.

25. Complete statements concerning cascading shift registers.

26. Select conditions concerning circulating shift registers.

27. Solve problems concerning shift register outputs.

28. Convert decimals to binary coded decimals and binary coded decimals to decimals. (Assignment Sheet #1)

29. Convert bit address data into hexadecimal program codes. (Assignment Sheet #2)

30. Demonstrate the ability to:

    a. Write and confirm an event-driven SQO instruction. (Job Sheet #1)

    b. Write and confirm an event-driven SQI instruction. (Job Sheet #2)

    c. Write and confirm a reversing SQO instruction. (Job Sheet #3)

    d. Write and confirm an SQI instruction driving an SQO instruction. (Job Sheet #4)

    e. Write and confirm an event-driven shift right register instruction. (Job Sheet #5)

SEQUENCERS AND REGISTERS
UNIT III

SUGGESTED ACTIVITIES

Read Me First

Procedures in this text are presented for demonstration only and should not be used in actual industrial applications. Graphic materials from manufacturers are presented for the purpose of illustration only and no liability is assumed for their use otherwise. Persons using this text assume liability for demonstration and for any equipment damaged in demonstration. Administration of these materials should be by a qualified instructor only in a safety-proven environment.

A. Provide students with objective sheets.

B. Provide students with information and assignment sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Read the tools and equipment list for each of the job sheets and prepare safely mounted switches to duplicate event-driven sequencer and register instructions presented in the job sheets.

F. The following completed data forms are included to assist with evluation of the job sheets.

Job Sheet #1:

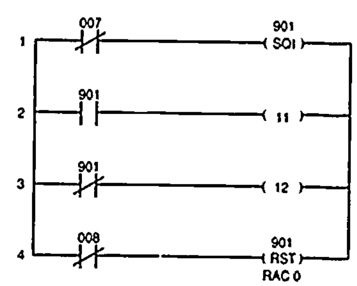
SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: 901 ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER: 0

BIT ADDRESS DATA	B				A				PROGRAM CODE		PRESET VALUES
Bit Addresses →	18	17	16	15	14	13	12	11	Data B	Data A	
Mask Data →	1	1	1	1	1	1	0	1	F	D	
Step Data → 0	1	0	0	1	1	0	⊗	1	9	9	1
1	0	1	1	1	1	1	⊗	1	7	D	1
2	0	0	0	0	1	0	⊗	0	0	8	2
3	1	1	1	1	1	1	⊗	1	F	D	1
4											
5											
6											
7											
8											
9											
10											

Job Sheet #2:

SEQUENCER CLASSIFICATION: ☒ -(SQI)- ☐ -(SQO)- ADDRESS: 901 ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER: 07

BIT ADDRESS DATA	B				A				PROGRAM CODE		PRESET VALUES
Bit Addresses →	8	7	6	5	4	3	2	1	Data B	Data A	
Mask Data →	0	0	1	1	1	1	1	1	3	F	
Step Data → 0	⊗	⊗	0	1	0	1	0	1	1	5	1
1	⊗	⊗	1	0	1	0	1	0	2	A	2
2	⊗	⊗	0	0	1	1	1	1	0	F	1
3	⊗	⊗	1	1	0	0	0	1	3	1	1
4											
5											
6											
7											
8											
9											
10											

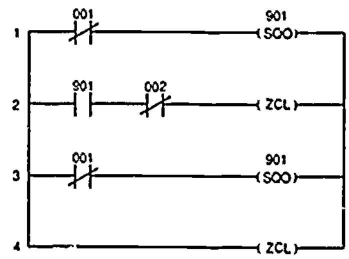


SUGGESTED ACTIVITIES

Job Sheet #3:
(Part 2)

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: 901 ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER: 38

BIT ADDRESS DATA	B				A				PROGRAM CODE Data B	PROGRAM CODE Data A	PRESET VALUES
Bit Addresses →											
Mask Data →									F	F	
Step Data → 0									0	2	1
1									0	3	1
2									0	0	2
3									0	1	1
4											
5											
6											
7											
8											
9											
10											



Job Sheet #4:
(Part 1)

SEQUENCER CLASSIFICATION: ☒ -(SQI)- ☐ -(SQO)- ADDRESS: 901 ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER: 07

BIT ADDRESS DATA	B				A				PROGRAM CODE Data B	PROGRAM CODE Data A	PRESET VALUES
Bit Addresses →	8	7	6	5	4	3	2	1			
Mask Data →	0	0	1	1	1	1	1	1	3	F	
Step Data → 0	⊗	⊗	0	1	0	1	0	1	1	5	1
1	⊗	⊗	1	0	1	0	1	0	2	A	1
2	⊗	⊗	0	0	1	1	1	1	0	F	1
3	⊗	⊗	1	1	0	0	0	1	3	1	1
4											
5											
6											
7											
8											
9											
10											

Job Sheet #4:
(Part 2)

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS 901 ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER 0

BIT ADDRESS DATA	B				A				PROGRAM CODE Data B	PROGRAM CODE Data A	PRESET VALUES
Bit Addresses →	18	17	16	15	14	13	12	11			
Mask Data →	1	1	1	1	1	1	0	1	F	D	
Step Data → 0	1	0	0	1	1	0	⊗	1	9	9	1
1	0	1	1	1	1	1	⊗	1	7	D	1
2	0	0	0	0	1	0	⊗	0	0	8	1
3	1	1	1	1	1	1	⊗	1	F	D	1
4											
5											
6											
7											
8											
9											
10											

G. Give test.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *User's Manual Bulletin 1745 SLC 1745 SLC™ 100 Programmable Controller.* Milwaukee, WI 53204: Allen-Bradley Company, 1985.

B. Cox, Richard A. *Technician's Guide to Programmable Controllers.* Albany, NY 12212: Delmar Publishers, Inc., 1989.

SUGGESTED ACTIVITIES

C. Petruzella, Frank D. *Programmable Logic Controllers.* New York, NY: McGraw-Hill, Inc., 1989.

D. Jones, C.T. and L. A. Bryan. *Programmable Controllers Concepts and Applications.* Atlanta, GA: Clarence T. Jones and Luis A. Bryan, 1983 (Published by International Programmable Controls, Inc.)

SEQUENCERS AND REGISTERS
UNIT III

INFORMATION SHEET

I. **Terms and definitions**

A. **Event driven** — An instruction that requires response to an external happening to step a program through its cycle

B. **Time-driven** — An instruction that requires the passage of a given number of seconds or minutes to step a program through its cycle

C. **Cycle completion bit** — An instruction address bit that is set to ON when a program completes all its steps

D. **Input satisfied bit** — An SQI instruction address bit that is set to ON when the bit address matches programmed data for a current step

E. **Group number** — A number assigned to identify numerically related groups of bit addresses

F. **Instruction** — The combination of addresses and other data that sets the conditions which must be met for a PLC to perform a control objective

G. **Program code** — A number or number/letter used to express the hexadecimal value of binary data formed in bit addressing

H. **SQI (sequencer in) instruction** — An instruction that addresses status bits related to conditions that must be met for inputs to be ON at given times in a PLC program

I. **SQO (sequencer out) instruction** — An instruction that addresses status bits related to conditions that must be met for outputs to be ON at given times in a PLC program

J. **Least significant bit** — The digit representing the smallest value in a byte, an odd-numbered value which serves as the address of a shift left register

K. **Most significant bit** — The digit representing the largest value in a byte, an even-numbered value which serves as the address for a shift right register

II. **Comparing sequencers with timers and counter**

A. The real power of PLCs lies in their ability to manage multiple inputs/outputs to accomplish complex control objectives.

INFORMATION SHEET

B. A timer, basically, has two conditions, Examine ON/Examine OFF, and they change states at the PR (preset) value to complete a timing program and start the program cycle again.

C. The SQO instruction can control the Examine ON/examine OFF status of as many as 8 bit addresses for up to 100 steps in a time-driven program.

Example: If programmed to do so, the time-driven SQO instruction can control up to 8 outputs simultaneously with timing ranging from .1 second to 999.9 seconds, and it can do this up to 100 times before it reaches a PR value.

D. A counter, basically, has two conditions, Examine ON/Examine OFF, and they change states at a PR value to complete a counting program and then must be RST (reset) to start another program cycle.

E. The SQO instruction can control the Examine ON/Examine OFF status of as many as 8 bit addresses for up to 100 steps and the RST (reset) is automatic in an event-driven program.

Example: If programmed to do so, the event-driven SQO instruction could control up to 8 bit addresses (3 external, 2 internal) simultaneously and keep them at a programmed condition for a specified length of time.

III. Sequencer operations

A. Sequencers operate two types of program instructions: input and output.

B. Sequencer input is identified in ladder logic as -(SQI)-.

C. Sequencer output is identified in ladder logic as -(SQO)-.

D. Both input and output sequencers have to be addressed by numbers.

(NOTE: With the SLC™ 100, both SQI and SQO have addresses from 901 to 932.)

E. Both SQI and SQO sequencers are retentive which means that if power is turned OFF, the process will be at the same step when power is turned ON again.

F. Both SQI and SQO sequencers may be time-driven or event-driven.

IV. Time-driven and event-driven sequencer operations

A. A sequencer that is event-driven responds to a FALSE/TRUE transition on the rung containing sequencer instructions.

B. Event-driven sequencers have functions similar to counters.

INFORMATION SHEET

C. A sequencer that is time-driven responds to an accumulated value (AC) that is programmed in tenths of a seconds (.1).

D. Time-driven sequencers have functions similar to timers.

Example: When an operation does not demand exact positioning of an object, a time-driven sequence is often selected. In a car wash where an auto is moved through on a constant velocity chain, the wash cycle could begin with a soap/water spray timed for 20 seconds followed by a 40 second timing for bushing, a 20 second timing for rinsing, and finally, the blowers would come on for 20 seconds as the car moves through the final step. Exact positioning is not required and the time-driven SQO gets the job done on schedule.

V. **Accumulated values (AC) and preset (PR) values**

A. Like timers and counters, sequencers use both AC and PR values, and the PR values have to be programmed.

B. AC values provide windows for monitoring how much time has passed in an SQI or SQO operating cycle.

Example: If the first step in a sequence is timed for 20 seconds and the AC value indicates 10 seconds, it means 10 seconds of the step have passed and there are 10 seconds left before the sequencer moves the program on to the next step.

C. Monitoring AC values is an effective part of confirming new programs and an excellent trouble-shooting technique.

VI. **Dynamics of SQO instructions** (Figure 1)

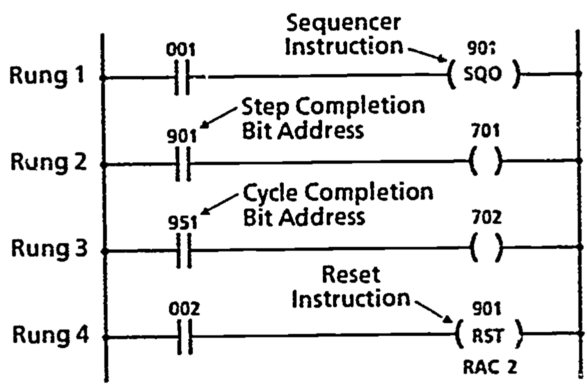
A. The SQO instruction sets the Examine ON/Examine OFF status of up to 8 bit addresses for each step.

(NOTE: On the SLC™ 100, the group of bit addresses can be 6 external output addresses plus 2 internal addresses, or all 8 addresses can be internal.)

INFORMATION SHEET

B. The SQO uses a **step completion bit** which is set ON for a single program scan each time the SQO instruction completes a step. (Figure 1)

FIGURE 1



C. As each SQO step is completed, Examine ON instructions at the bit address go TRUE and Examine OFF instructions go FALSE.

D. Time-driven sequencers count 0.1 second internals while the sequencer rung is TRUE.

E. When the AC value reaches the PR value, the sequencer advances to the next step and the AC value increments from 0000 again.

F. After the final step, the sequencer continues with 0.

G. Event-driven sequencers count FALSE/TRUE transitions of the sequencer rung.

H. When the AC value reaches the PR value, the sequencer advances to the next step, the AC value increments from 0000 again, and after the final step the sequencer continues with 0.

I. The SQO **step completion bit** uses the sequencer instruction address of 901.

J. The SQO **cycle completion bit** is assigned the sequencer address, 901, plus 50, or 951.

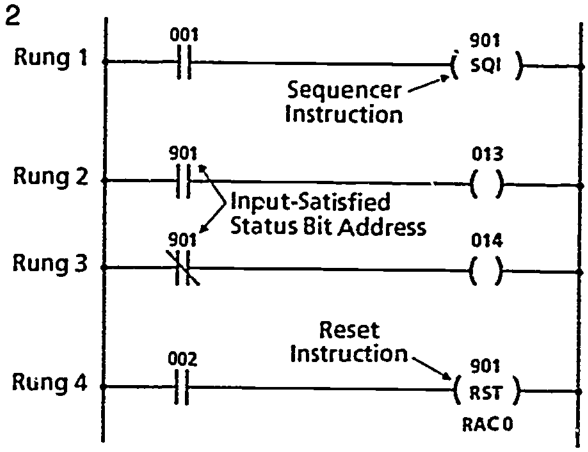
K. The SQO **cycle completion bit** is set ON when the sequencer completes its final step as Examine ON instructions at the bit address go TRUE and Examine OFF instructions go FALSE.

INFORMATION SHEET

VII. Dynamics of SQI instructions (Figure 2)

A. The SQI instruction examines the ON/OFF status of up to 8 bit addresses for each step and sets an **input-satisfied status bit** ON when the status of the bit addresses matches programmed data. (Figure 2)

FIGURE 2



B. The group of bit addresses for the SQI instruction can be selected as either external input addresses or internal addresses.

C. The SQI instruction can also be time-driven or event-driven and in both cases uses AC and PR values to advance to the next step, to the final step, and then the sequencer continues with step 0.

D. The SQI **input-satisfied status bit** uses the sequencer instruction address of 901.

VIII. Numbering systems and their structures (Transparency 1 and Handout #1)

A. Decimal numbering system — A numbering system with a base of 10 with place values in multiples of 10

B. Binary numbering system — A numbering system with a base of 2 with place values in multiples of 2

C. Hexadecimal numbering system — A numbering system with a base of 16 with place values in multiples of 16 where the numbers 0 to 9 represent the numbers 0 to 9 and the letters, A, B, C, D, E, and F represent the numbers 10 through 15

D. Octal numbering system — A numbering system with a base of 8 with place values in multiples of 8

INFORMATION SHEET

E. Binary coded decimal — The representation of four digit binary numbers with their decimal equivalents with binary numbers evaluated separately, but expressed in decimal order

IX. **Working with sequencer data (Transparency 2)**

A. When programming sequencer instructions it is essential to know what address groups are reserved for inputs and outputs and how address groups differ for SQO and SQI instructions.

B. With the SLC™100, group numbers 0 through 6 are reserved for the external and internal bit addresses for SQO instructions.

C. The SLC™100 reserves group numbers 7 through 15 for bit addresses 001 through 610 for external input addresses for SQI instructions.

D. With the SLC™100, group numbers 16 through 37 are reserved for addresses 701 through 876 which are internal bit addresses for SQO or SQI instructions.

E. Program codes express bit address data in hexadecimal.

F. Using group numbers and program codes helps avoid errors when programming SQO and SQI instructions and speeds the process of confirming and troubleshooting sequencer programs.

X. **The sequencer data form (Transparency 3)**

A. When programming sequencer instructions, a data form of some kind should be used so that bit address groups can be identified and each address in each step can be properly documented.

B. Mask data should include 1s (ones) under all addresses to be used and 0s (zeros) under all addresses that will not be used.

C. Addresses that will not be used should be indicated in each step with a ⊗ (a zero with an x through it), and these entries retain a 0 value when determining program codes.

D. Program codes should reflect the hexadecimal value of each address group in each step of the sequencer instruction.

(NOTE: The hex value of each address group becomes a significant parameter in programming a sequencer instruction.)

E. Preset values should be entered to indicate the length of each step in a time-driven sequence or the number of events in each step of an event-driven sequence.

F. For programming accuracy, a ladder logic diagram should be prepared to indicate how the sequencer instruction will be started, how the cycle will be completed, and how the sequencer reset will be accomplished.

INFORMATION SHEET

XI. Programming time-driven SQO instructions

A. Timers and counters are relatively easy to program from ladder logic diagrams, but sequencer instructions should first be entered on a data form where all instructions can be viewed in relation to the other parts of the program.

B. To begin a time-driven SQO instruction, use a data form similar that in Figure 3, enter the sequencer classification, SQO or SQI, note the time-driven status of the program, and enter the group number of the bit addresses.

C. Complete the initial entries by listing the bit addresses in two groups with the highest address to the left in the B group and the lowest address to the right in the A group.

FIGURE 3

CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: 901 ☒ TIME DRIVEN ☐ EVENT DRIVEN GROUP NUMBER: 0

	BIT ADDRESS DATA								PROGRAM CODE		PRESET VALUES
	B				A				Data B	Data A	
Bit Addresses →	018	017	016	015	014	013	012	011			
Mask Data →											
Step Data → 0											
1											
2											
3											

D. Continue with the mask data by entering a 1 under each address to be controlled by the sequencer and a 0 under the addresses the program will not use.

(NOTE: Observe in Figure 4 that only 5 output addresses are used with addresses 015, 016, and 018 excluded. The addresses not used permit a faster scan time and can still be used elsewhere in the program.)

INFORMATION SHEET

E. Enter step data by inserting a 1 to indicate an ON condition for each address and each step, and a 0 to indicate an OFF condition. (Figure 4)

FIGURE 4

CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: 901 ☒ TIME DRIVEN ☐ EVENT DRIVEN GROUP NUMBER: 0

BIT ADDRESS DATA	B				A				PROGRAM CODE		PRESET VALUES
Bit Addresses →	018	017	016	015	014	013	012	011	Data B	Data A	
Mask Data →	0	1	0	0	1	1	1	1			
Step Data → 0		0			0	0	0	0			
1		0			1	0	1	0			
2		1			1	1	1	0			
3		1			0	0	1	1			

F. Mask out the address bit 018, 016, and 015 at all steps, using a zero with an x through it, ⊗. (Figure 5)

G. Translate the digital codes produced by the 1s and 0s in each group into hexadecimal program codes and enter them under the program code data.

Example: Under mask data, group B has the binary value of 0100 which in hexadecimal is 4, and group A has a binary value of 1111 which in hexadecimal is F (15).

H. Enter the preset values in tenths of a second to indicate the timing of each step. (Figure 5)

FIGURE 5

CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: 901 ☒ TIME DRIVEN ☐ EVENT DRIVEN GROUP NUMBER: 0

BIT ADDRESS DATA	B				A				PROGRAM CODE		PRESET VALUES
Bit Addresses →	018	017	016	015	014	013	012	011	Data B	Data A	
Mask Data →	0	1	0	0	1	1	1	1	4	F	
Step Data → 0	⊗	0	⊗	⊗	0	0	0	0	0	0	5.0
1	⊗	0	⊗	⊗	1	0	1	0	0	A	20.0
2	⊗	1	⊗	⊗	1	1	1	0	4	E	60.0
3	⊗	1	⊗	⊗	0	0	1	1	4	3	10.0

⊗ Masked addresses are 0 for coding.

INFORMATION SHEET

I. When the data form is complete, the SQO instruction should be programmed directly from it.

XII. Typical SQO instruction (Transparency 4)

A. A typical SQO begins with rung 1 FALSE and the SQO instructions on step O.

(NOTE: Refer to Transparency 4 and compare the data form and ladder logic diagram for the SQO instruction used in this demonstration.)

B. When rung 1 is TRUE, external addresses 12 and 15 go ON and internal address 17 goes ON.

C. As long as rung 1 is TRUE, the sequencer advances from one step to the next each time the PR value of the current step is reached.

D. At the beginning of each step, but addresses 012, 013, 014, and 017 are set ON or OFF as indicated by the 1s and 0s in the data form.

(NOTE: Remember that addresses 011, 013, and 018 are not used.)

E. Rung 2 demonstrates how the step completion bit functions, because each time a step is completed, the step completion bit is set to ON for a single program scan of approximately 5 milliseconds, and during this time the Examine ON instruction in rung 2 will be TRUE.

(NOTE: The step completion bit is also used in shift register applications as will be demonstrated in a later objective.)

F. Rung 3 demonstrates how the cycle completion bit functions because the first time the sequencer recycles from the final (9th) step back to step 0, the cycle completion bit is ON, causing the examine ON condition in rung 3 to go TRUE.

G. The cycle completion bit stays ON until the sequencer is reset.

H. Rung 4 contains the RST (reset) instruction, and when rung 4 goes TRUE, the sequencer is reset to step 2, corresponding to the RAC value, and when rung 4 goes TRUE, the cycle completion bit is set to OFF.

I. While the RST instruction is TRUE, the sequencer is disabled, and operation continues only when rung 4 goes FALSE again.

INFORMATION SHEET

XIII. **A typical SQI instructions (Transparency 5)**

A. In a typical SQI operation, FALSE/TRUE transitions of rung 1 move the sequencer form one step to the next.

(NOTE: Follow the ladder logic diagram and data form in Transparency 5 which helps demonstrate a 10-step, event-driven SQI instruction that examines 7 internal input addresses, 002-008, with address 001 no used.)

B. Since all PR values are set at 1, a single FALSE/TRUE transition on rung 1 advances the sequencer.

C. The ON/OFF states of the external inputs determine whether the input-satisfied bits in rungs 2 and 3 will be ON or OFF.

D. For step 2, inputs 008 and 007 have no voltage, and inputs 006, 005, 004, 003, and 002 do have voltage applied to the input, and rung 2 is TRUE because the program conditions have been met.

E. When rung 2 is TRUE, rung 3 is FALSE, but when the program conditions for step 2 are not met, rung 2 is FALSE and rung 3 is TRUE.

Example: If input 005 has no voltage in step 2, program conditions are not met and the Examine ON condition in rung 2 will make the rung FALSE.

F. Rung 4 contains the RST instruction, and when this rung goes TRUE it corresponds to the RAC value and the sequencer is reset to step 0.

G. While the RST instruction is TRUE, the sequencer is disabled until rung 4 goes FALSE and operation can resume.

XIV. **MCR and ZCL instructions (Transparency 6)**

A. MCR (Master Control Reset) and ZCL (Zone Control Last State) instructions permit the use of one set of instructions to control multiple outputs and are sometimes used with sequencer instructions.

B. Both MCR and ZCL instructions are programmed to control zones, and the start rung contains the condition instructions which control the zone, but the end rungs contain no conditions.

C. Any number of rungs may be programmed between the start and end rungs of MCR and ZCL instructions, but the zones must be clear of any other MCR or ZCL instructions within the zones.

D. When the start rung is TRUE, output instructions in the zone function normally, but when the start rung is FALSE, outputs within the zone are overridden and controlled by the MCR or ZCL instruction.

INFORMATION SHEET

E. MCR and ZCL instructions can interrupt or stop other instructions, but they are not designed to provide emergency stop capability that permits an operator to shut down I/O power.

(NOTE: A hard-wired master control relay can be wired to control and overall function and should be used to provide emergency stop capability.)

F. The MCR instruction will reset all nonretentive outputs to an OFF state when the zone logic is FALSE, but the ZCL instruction will leave all outputs in their last state when the logic is FALSE.

G. MCR and ZCL instructions are programmed without addresses.

XV. **Cascading SQO sequencers (Transparency 7)**

A. Where a control application demands more than 8 bit addresses, SQO instructions can be cascaded so that 16 bit addresses can be controlled.

B. Cascaded SQO instructions use two sequencer instructions to control the same conditions, but each sequencer is programmed on a separate rung.

C. The two sequencers can control the same addresses, but one sequencer must control one address group and the second sequencer must control a second address group.

D. Step data for each sequencer is programmed as the application requires, and data for each sequencer may vary.

E. A single RST instructions can be used to reset both sequencers in a cascaded operation.

XVI. **Reversing sequencers (Transparency 8)**

A. Sequencers may be operated in both forward or reverse step order with a reversing sequencer instruction.

B. When programming a reversing operation, the forward operating sequencer is normally on rung 1 and the reverse operating sequencer is on rung 3.

C. Rung 3 has identical conditions with rung 1, but rung 3 is within a ZCL zone which is programmed on rungs 2 and 4.

D. Data for rung 1 uses program codes as previously referenced (Transparency 2), but data for rung 3 must include a special group number that corresponds to the address number of the sequencer. (Figure 6)

(NOTE: In the example, 901 is the sequencer, and the corresponding group number would be, in this case, 38.)

INFORMATION SHEET

FIGURE 6

Address	Group No.	Address	Group No.	Address	Group No.	Address	Group No.
901	38	909	46	917	54	925	62
902	39	910	47	918	55	926	63
903	40	911	48	919	56	927	64
904	41	912	49	920	57	928	65
905	42	913	50	921	58	929	66
906	43	914	51	922	59	930	67
907	44	915	52	923	60	931	68
908	45	916	53	924	61	932	69

E. The step data for the reversing sequencer must be entered in decimal form, not the coded step data used for the forward sequencer programmed on rung 1.

F. The decimal coding for the reversing sequencer has a special order:

1. For step 0, enter the second from last step (in the example, an 8).

2. For step 1, enter the last step number (in the example, a 9).

3. For step 2 and up, enter the step number minus 2 which means that step 2 minus 2 would equal 0, step 3 minus 2 would equal 1, and on to step 9 which minus 2 equals 7.

4. Mask data remains the same as for the forward sequencer.

G. Preset values for both sequencers remain the same (in the example, 1).

XVII. Steps in reversing sequencer operation (Transparency 8)

A. When rung 1 is TRUE and rung 2 is FALSE, the sequencer operates in a forward step order.

B. During step forward operation, rung 3 is TRUE, but inoperative because the ZCL instruction is FALSE.

C. When rung 2 goes TRUE, rung 3 becomes operative and reverses the step order beginning with the step in effect at the time.

D. When rung 2 goes FALSE again, the sequencer operates in a forward step order again.

XVIII. Using sequencer input to drive sequencer output (Transparency 9)

A. An SQI instruction can be used to advance the step number in an SQO instruction by taking advantage of the input-satisfied bit of the SQI instruction.

INFORMATION SHEET

B. To drive sequencer output with sequencer input, both instructions are assigned the same address, and (in the example) both instructions are event-driven with a preset of 1 for each step.

C. The input-satisfied status bit of the SQI instruction is used in rungs 1 and 2 to advance both the SQI and SQO steps.

D. With the SQI instruction, step 0, when status bit 005 is ON and bit addresses 006, 007, and 008 are OFF, conditions meet program data and the input-satisfied bit goes ON.

E. As the input-satisfied bit in rung 1 goes ON, the SQO and SQI instructions both advance to step 1, and SQO outputs 012 and 014 go ON.

F. The operation continues from step to step with the input-satisfied bits of the SQI instruction driving each step in the SQO instruction.

XIX. Sequencer input monitoring sequencer output

A. A variation of programming SQI/SQO sequencers together is to use sequencer input to monitor a sequencer output step.

B. The monitoring SQI input-satisfied bit goes ON when the monitored sequencer reaches a specified step.

C. Programming a monitoring SQI instruction has four basic program commands:

1. Assign the SQI instruction an address between 901 and 932.

2. When prompted to select a time-driven or event-drive option, select either one because operation will be the same.

3. When prompted for a group number, use a number corresponding to the address of the SQO instruction being monitored, and select from the special group numbers indicated in Figure 7.

   (NOTE: In the following example, group 38 corresponds to the 901 address of the SQO instruction.)

FIGURE 7

Address	Group No.	Address	Group No.	Address	Group No.	Address	Group No.
901	38	909	46	917	54	925	62
902	39	910	47	918	55	926	63
903	40	911	48	919	56	927	64
904	41	912	49	920	57	928	65
905	42	913	50	921	58	929	66
906	43	914	51	922	59	930	67
907	44	915	52	923	60	931	68
908	45	916	53	924	61	932	69

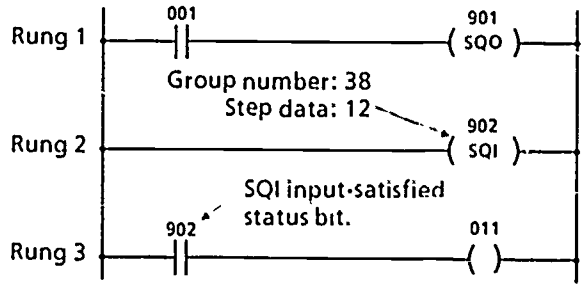
INFORMATION SHEET

4. When prompted to enter a step number, enter the number directly as 1, 2, or as in the example, a 12.

D. As the SQO instruction reaches the programmed step data, the input-satisfied bit of the SQI instruction will go ON and energize the programmed output. (Figure 8)

(NOTE: In the example, when the SQO instruction completes step 12, it sets the SQI input-satisfied bit on rung 3 to ON, and output 011 is energized.)

FIGURE 8



XX. Sequencer jump instructions (Figure 9)

A. A sequencer jump operation is a special application of using an SQI instruction to monitor an SQO instruction, but the jump operation permits specified steps to be skipped.

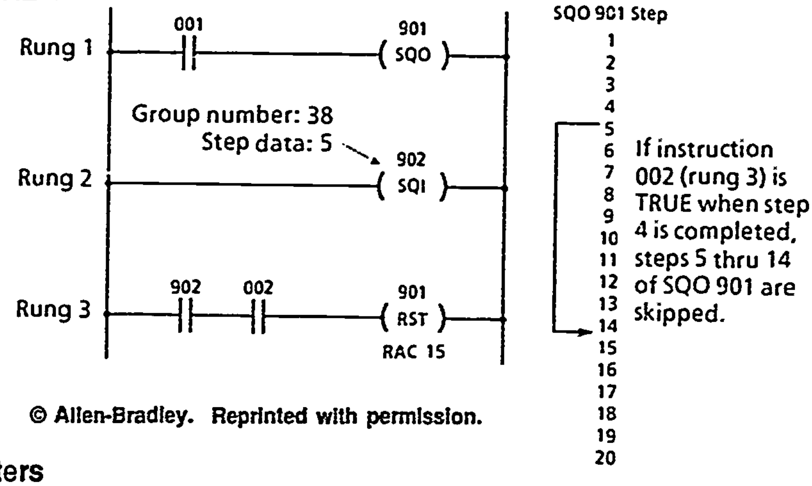
B. In the example, SQI 902 is monitoring step 5 of SQO 901.

C. When instruction 002 on rung 3 is TRUE and SQO 901 reaches step 5, SQO 901 will be RST to step 15 by the 901 RST instruction in rung 3.

INFORMATION SHEET

D. The monitoring instruction will skip steps 5 through 14 only when instruction 002 is TRUE, but if instruction 002 is FALSE when SQO step 4 is completed, the SQO will continue in order from steps 5 through 20. (Figure 9)

FIGURE 9



XXI. Shift registers

A. Shift registers are internal and external addresses where status data is stored so it can be accessed and acted upon by the PLC controller.

B. The shift registers in the Allen-Bradley SLC™100 are all 8-bit registers where data is automatically shifted through the registers from one bit address to the next on a time-driven or event-driven basis.

(NOTE: There are other register formats that will be discussed in later units, but this and following objectives are confined to the 8-bit shift registers in the SLC™100.)

C. Shift registers provide another way to handle data used in control applications where parts in a process or on a conveyor belt are shifted from one position to another.

XXII. Shift register instructions

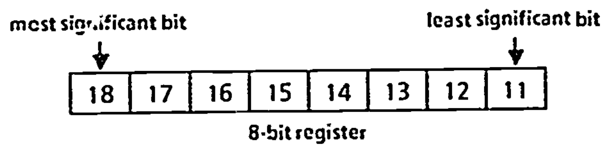
A. Shift register instructions are either shift right or shift left.

B. A shift right register is assigned the address of its most significant bit which is the digit representing the greatest value in a byte. (Figure 10)

INFORMATION SHEET

C. A shift left register is assigned the address of the least significant bit which is the digit representing the smallest value in a byte. (Figure 10)

FIGURE 10



D. The shift right register addresses for the most significant bit include the following: (Figure 11)

FIGURE 11

18, 118, 218, 318, 418, 518, 618,
708, 716, 724, 732, 740, 748,
756, 764, 772, 780, 788, 796,
804, 812, 820, 828, 836, 844,
852, 860.

E. The shift left register addresses for the least significant bit include the following: (Figure 12)

FIGURE 12

11, 111, 211, 311, 411, 511, 611,
701, 709, 717, 725, 733, 741,
749, 757, 765, 773, 781, 789,
797, 805, 813, 821, 829, 837,
845, 853, 861.

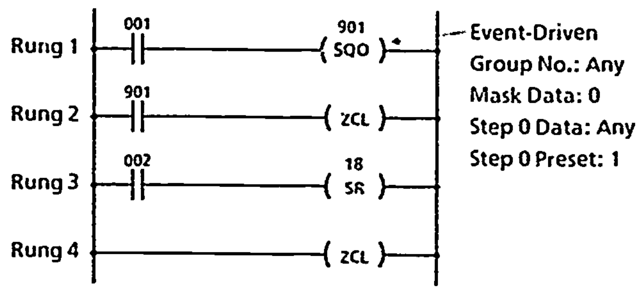
F. Shift register instructions use a ZCL zone to control the shifting process and a sequencer instruction controls the shift rate.

INFORMATION SHEET

XXIII. Event-driven shift register instructions

A. In an event-driven shift right register instruction, rung 1 is a 1-step, event-driven sequencer and rungs 2, 3, and 4 include the shift right register instruction within a ZCL zone. (Figure 13)

FIGURE 13

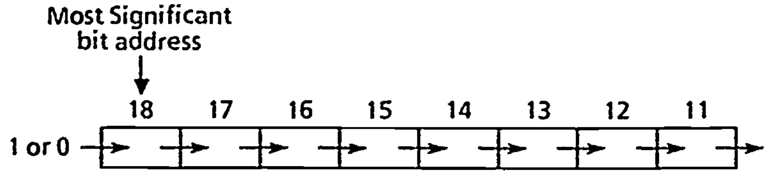


B. Each time instruction 001 in rung 1 goes from FALSE to TRUE, step 0 of the sequencer is completed and the ZCL zone is TRUE for one program scan.

C. If instruction 002 is TRUE during the scan, rung 3 is TRUE, and a 1 is shifted into the most significant bit address of the register. (Figure 14)

D. If instruction 002 is FALSE, a 0 is shifted into the register, and simultaneously, all other status data in the register is shifted right to the next address which means that status bit 11 is shifted out of the register. (Figure 14)

FIGURE 14

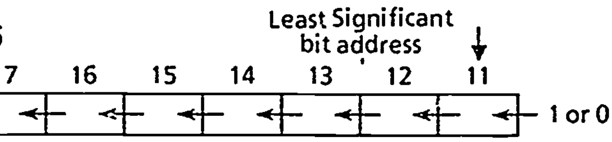


Status data shifts on each FALSE to TRUE transition of SQO

INFORMATION SHEET

E. The event-driven instruction could be easily changed to a shift left instruction by assigning the least significant bit, 11, to the register instruction in rung 3, and data would be shifted left with each FALSE/TRUE transition of the SQO instruction. (Figure 15)

FIGURE 15

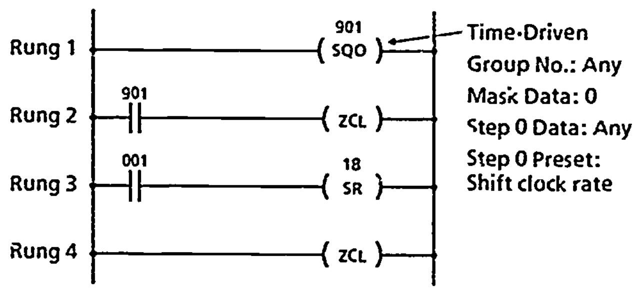


Status data shifts on each FALSE to TRUE transition of SQO

XXIV. Time-driven shift register instructions

A. In a time-driven shift right register instruction, rung 1 is a 1-step, time-driven sequencer and rungs 2, 3, and 4 include the shift right register instruction within a ZCL zone. (Figure 16)

FIGURE 16



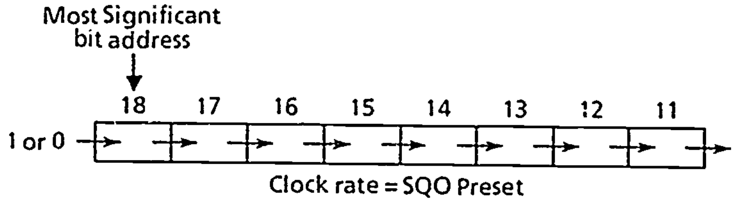
B. Each time the AC value reaches the PR value, step 0 of the sequencer is completed and the ZCL zone is TRUE for one program scan.

C. If instruction 001 is TRUE during the scan, rung 3 is TRUE, and a 1 is shifted into the most significant bit address of the register, and if the instruction 001 is FALSE, a 0 is shifted into the register.

D. Simultaneously, all other status data in the register is shifted right to the next address which means that status bit 11 is shifted out of the register. (Figure 17)

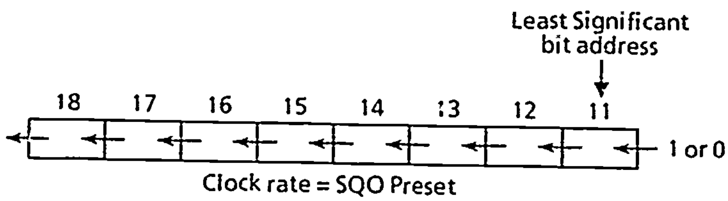
INFORMATION SHEET

FIGURE 17



E. The time-driven instruction could be changed to a shift left instruction by assigning the least significant bit, 11, to the register instruction in rung 3, and data would be shifted left with each FALSE/TRUE transition of the SQO instruction. (Figure 18)

FIGURE 18



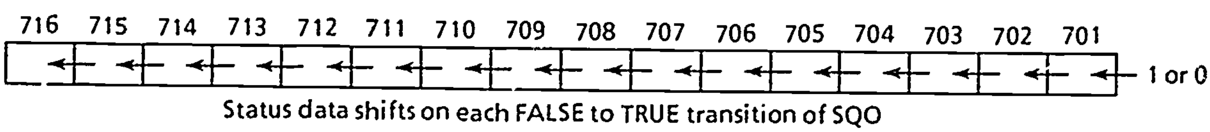
XXV. Cascading shift registers

A. Just like sequencers, shift registers can be cascaded to double their control capabilities.

B. In order to create the 16-bit shift register, two 8-bit registers must be cascaded so that the beginning bit of the second register must be a number that continues the consecutive order of the data. (Figure 19)

(NOTE: In the example of the shift left register, bit 708 of register 701 shifts data into register 709.)

FIGURE 19

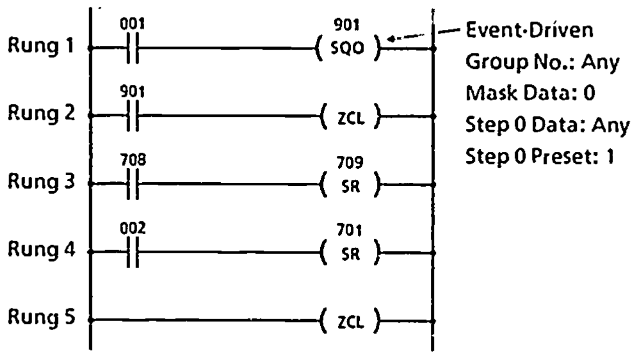


INFORMATION SHEET

C. In programming cascaded shift registers, the shift register into which data is entered must follow the rung containing the second shift register. (Figure 20)

(NOTE: In the example, shift register 701 on rung 3 follows shift register 709 on rung 3.)

FIGURE 20



A 16-bit event-driven shift left register

XXVI. Circulating shift registers

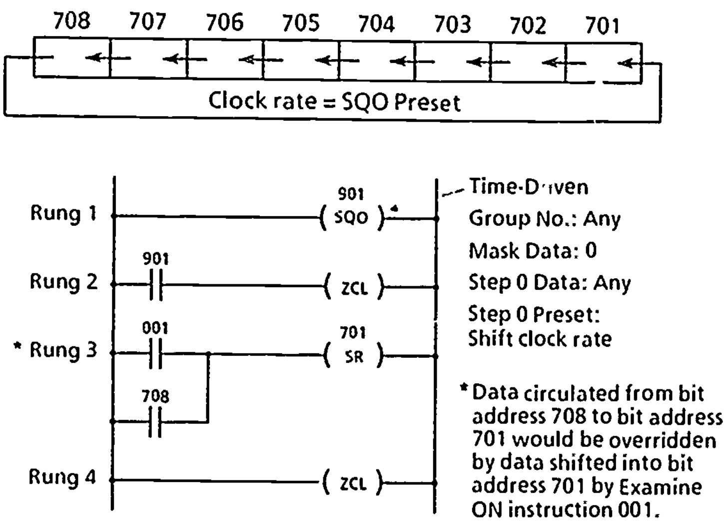
A. A variation in shift register instructions is the circulating shift register where a shift left register is used at the end of an 8-bit register to repeat the cycle.

B. In a time-driven circulating shift left register, status data may be entered by instruction 001 on rung 3 (in the example) and shifted left from bit address 701 to bit address 708. (Figure 21)

C. In rung 3, bit address 708 is used to shift the status data back into bit address 701 so the cycle can be repeated. (Figure 21)

INFORMATION SHEET

FIGURE 21



An 8-bit circulating shift register

XXVII. Shift register outputs

A. By using an unlatching instruction in a shift register instruction, shift registers can be used to produce external outputs.

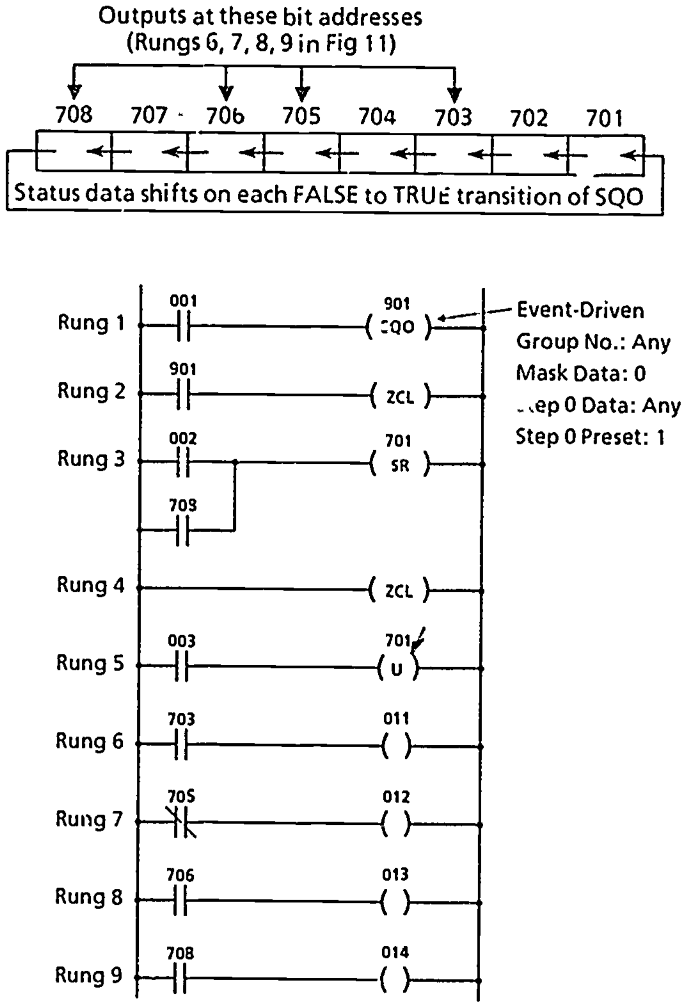
B. In programming a shift left register, the external outputs are entered outside the ZCL zone that includes the basic shift register instruction. (Figure 22)

C. Status data (in the example) is entered by instruction 002 in rung 3. (figure 22)

D. The 1s (ones) entered intc the circulating register can be changed to 0s (zeros) with instruction 003 in rung 5, which unlatches a bit address 701.

INFORMATION SHEET

FIGURE 22



Circulating shift left register using outputs for bit addresses 703, 705, 706, and 708

Numbering Systems Table

Decimal	Hexadecimal	Octal	Binary	BCD
0	0	0	0000	0000
1	1	1	0001	0001
2	2	2	0010	0010
3	3	3	0011	0011
4	4	4	0100	0100
5	5	5	0101	0101
6	6	6	0110	0110
7	7	7	0111	0111
8	8	10	1000	1000
9	9	11	1001	1001
10	A	12	1010	0001 0000
11	B	13	1011	0001 0001
12	C	14	1100	0001 0010
13	D	15	1101	0001 0011
14	E	16	1110	0001 0100
15	F	17	1111	0001 0101

Group Numbers and Program Codes

Group Numbers

External Output Bit Addresses and Internal Bit Addresses (SQO Sequencers)			
Bit Addresses	Group Number	Bit Addresses	Group Number
011-016 (output) 017-018 (internal)	0	411-416 (output) 417-418 (internal)	4
111-116 (output) 117-118 (internal)	1	511-516 (output) 517-518 (internal)	5
211-216 (output) 217-218 (internal)	2	611-616 (output) 617-618 (internal)	6
311-316 (output) 317-318 (internal)	3		

External Input Bit Addresses (SQI Sequencers)	
Bit Addresses	Group Number
001-008 101-108 201-208 301-308	7 8 9 10
009-010 109-110 209-210	14
309-310 409-410 509-510 609-610	15

Internal Bit Addresses (SQO or SQI Sequencers)			
Bit Addresses	Group Number	Bit Addresses	Group Number
701-708 709-716 717-724 725-732	16 17 18 19	789-796 797-804 805-812 813-820	27 28 29 30
733-740 741-748 749-756 757-764	20 21 22 23	821-828 829-836 837-844 845-852	31 32 33 34
765-772 773-780 781-788	24 25 26	853-860 861-868 869-876	35 36* 37*

Program Codes

Bit Address Data	Program Code
0000 0001 0010 0011	0 1 2 3
0100 0101 0110 0111	4 5 6 7
1000 1001 1010 1011	8 9 A 8
1100 1101 1110 1111	C D E F

Example - For data 0001 1111, enter code 1 for Data 8, and code F for Data A.

Thus: $\underbrace{0001}_{1}\ \underbrace{1111}_{F}$

*Note: Group 36 includes bit address 868. Refer to Page 3-3 and Chapter 8 for operating characteristics.
Group 37 includes fine time base bit addresses and auto/manual switch bit Refer to Page 3-3 and Chapter 9 for operating characteristics.

TM 2

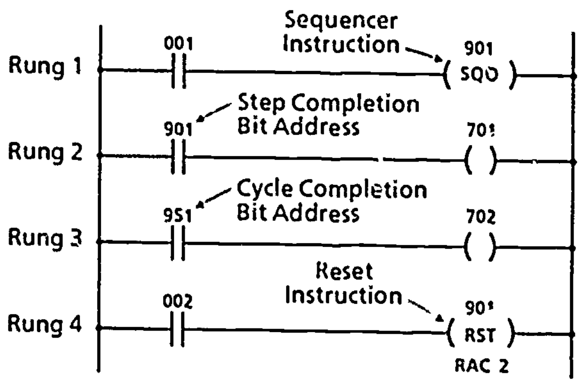
Sequencer Instruction Data Form

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☐ -(SQO)-   ADDRESS: ____   ☐ TIME DRIVEN ☐ EVENT DRIVEN   GROUP NUMBER: ____

	BIT ADDRESS DATA								PROGRAM CODE		PRESET VALUES			
	B				A				Data B	Data A				
Bit Addresses →														
Mask Data →														
Step Data → 0														
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

A Typical SQO Instruction



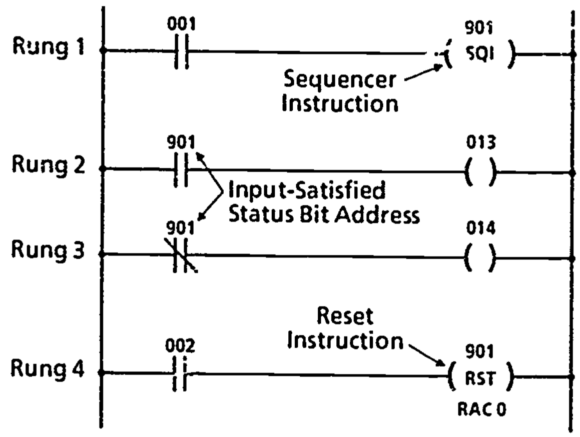
Ladder Diagram

CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: 901 ☒ TIME DRIVEN ☐ EVENT DRIVEN GROUP NUMBER: 0

BIT ADDRESS DATA	B				A				PROGRAM CODE Data B	PROGRAM CODE Data A	PRESET VALUES
Bit Addresses →	018	017	016	015	014	013	012	011			
Mask Data →	0	1	1	1	1	0	1	0	7	A	
Step Data → 0	⊗	1	0	1	0	⊗	1	⊗	5	2	5 0
1	⊗	1	0	1	1	⊗	0	⊗	5	8	5 0
2	⊗	0	1	0	0	⊗	0	⊗	2	0	2. 5
3	⊗	1	0	1	0	⊗	0	⊗	5	0	1 0
4	⊗	0	0	0	1	⊗	1	⊗	0	A	1 0
5	⊗	1	0	1	1	⊗	0	⊗	5	8	1 0
6	⊗	1	1	0	0	⊗	0	⊗	6	0	0 5
7	⊗	1	0	0	1	⊗	1	⊗	4	A	0 5
8	⊗	0	1	1	1	⊗	0	⊗	3	8	1 5
9	⊗	0	1	1	1	⊗	1	⊗	3	A	3 0

⊗ Masked address Used as 0 for coding purposes

A Typical SQI Instruction



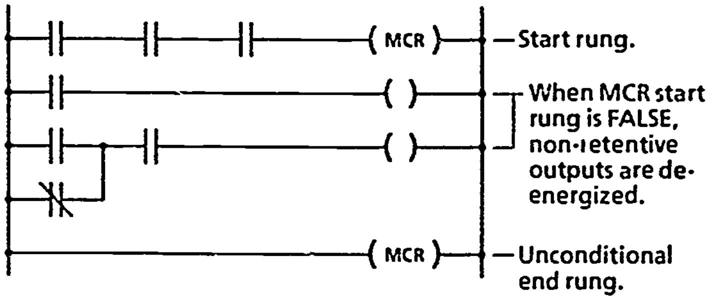
Ladder Diagram

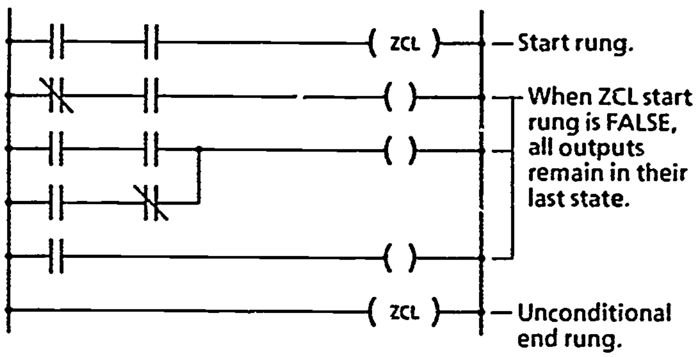
CLASSIFICATION: ☒ -(SQI)- ☐ -(SQO)- ADDRESS: 901 ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER: 7

	BIT ADDRESS DATA								PROGRAM CODE		PRESET VALUES
	B				A						
Bit Addresses →	008	007	006	005	004	003	002	001	Data B	Data A	
Mask Data →	1	1	1	1	1	1	1	0	F	E	
Step Data → 0	1	1	0	0	1	1	1	⊗	C	E	1
1	0	0	0	1	1	0	0	⊗	1	8	1
2	0	0	1	1	1	1	1	⊗	3	E	1
3	1	1	0	0	1	1	1	⊗	C	E	1
4	1	1	0	0	0	0	0	⊗	C	0	1
5	1	0	0	0	0	0	0	⊗	8	0	1
6	0	1	0	0	0	1	0	⊗	4	4	1
7	0	0	1	0	0	0	0	⊗	2	0	1
8	1	0	1	0	1	0	1	⊗	A	A	1
9	0	1	0	0	1	1	1	⊗	4	E	1

⊗ Masked address. Used as 0 for coding purposes

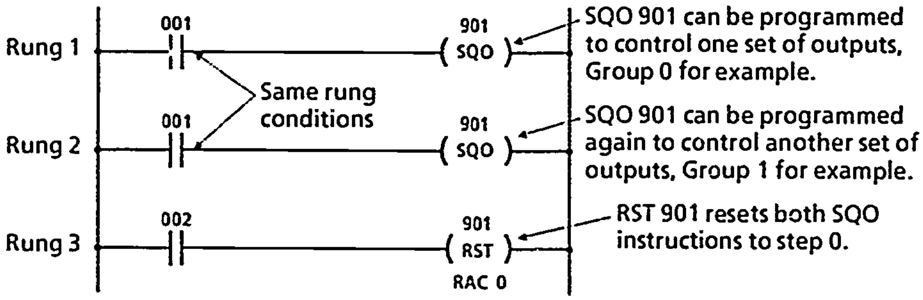
MCR and ZCL Instructions





Instruction	MCR Zone Start Rung FALSE	ZCL Zone Start Rung FALSE
Non-Retentive Outputs	De-energized	Remain in last state
Latch/Unlatch	Remain in last state	
Timers/Counters	AC value stops incrementing, value retained Status, overflow, and underflow bits remain in last state.	
Sequencers	AC value stops incrementing, value retained. Step number retained. Bit addresses remain in last state.	
Reset	Remains in last state. Instructions cannot be reset.	

Cascading Sequencers



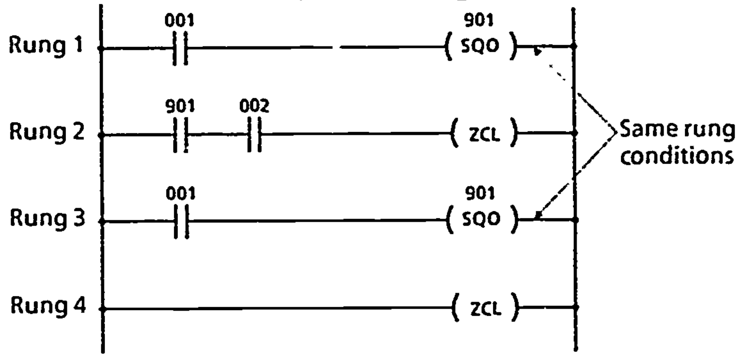
CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: 901 ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER: 0

BIT ADDRESS DATA									PROGRAM CODE		PRESET VALUES
	B				A				Data B	Data A	
Bit Addresses →	018	017	016	015	014	013	012	011			
Mask Data →	1	1	1	1	1	1	1	1	F	F	
Step Data → 0	1	1	0	1	0	0	0	1	D	1	1
1	0	0	1	0	1	0	1	0	2	A	1
2	1	1	0	0	0	1	0	0	C	4	1
3	0	0	0	1	0	0	0	1	1	1	1

CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: 901 ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER: 1

BIT ADDRESS DATA									PROGRAM CODE		PRESET VALUES
	B				A				Data B	Data A	
Bit Addresses →	118	117	116	115	114	113	112	111			
Mask Data →	1	1	1	1	1	1	1	1	F	F	
Step Data → 0	1	1	0	0	1	1	0	0	C	C	1
1	1	0	0	0	1	0	0	0	8	8	1
2	0	1	0	0	1	1	0	1	4	D	1
3	1	0	1	0	0	1	0	0	A	4	1

Reversing Sequencers



CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: 901 ☒ TIME DRIVEN ☐ EVENT DRIVEN GROUP NUMBER: 0

BIT ADDRESS DATA	B				A				PROGRAM CODE Data B	PROGRAM CODE Data A	PRESET VALUES
Bit Addresses →	018	017	016	015	014	013	012	011			
Mask Data →	1	1	1	1	1	1	1	1	F	F	
Step Data → 0	0	0	0	0	0	0	0	0	0	0	1. 0
1	0	0	0	0	1	0	1	0	0	C	1 0
2	0	0	1	1	0	0	0	0	3	0	1. 0
3	1	0	1	0	0	0	0	0	C	0	1. 0
4	0	1	0	1	0	1	0	1	5	5	1. 0
5	0	0	0	1	0	0	0	1	1	1	1. 0
6	0	0	1	0	0	0	1	0	2	2	1 0
7	0	1	0	0	0	1	0	0	4	4	1 0
8	0	0	1	0	1	0	0	0	2	8	1 0
9	1	0	0	0	0	0	0	1	8	1	1 0

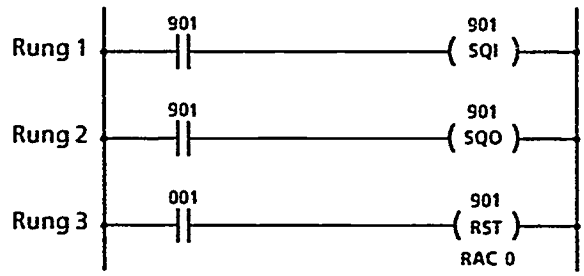
Sequencer data form for rung 1

CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: 901 ☒ TIME DRIVEN ☐ EVENT DRIVEN GROUP NUMBER: 38

BIT ADDRESS DATA	B				A				PROGRAM CODE Data B	PROGRAM CODE Data A	PRESET VALUES
Bit Addresses →											
Mask Data →									F	F	
Step Data → 0									0	8	1. 0
1									0	9	1. 0
2									0	0	1. 0
3									0	1	1 0
4									0	2	1. 0
5									0	3	1 0
6									0	4	1 0
7									0	5	1 0
8									0	6	1 0
9									0	7	1 0

Sequencer data form for rung 3

Sequencer Input Driving Sequencer Output



CLASSIFICATION: ☒ -(SQI)- ☐ -(SQO)-   ADDRESS: 901   ☐ TIME DRIVEN ☒ EVENT DRIVEN   GROUP NUMBER: 7

BIT ADDRESS DATA									PROGRAM CODE		PRESET VALUES
	B				A				Data B	Data A	
Bit Addresses →	008	007	006	005	004	003	002	001			
Mask Data →	1	1	1	1	0	0	0	0	F	0	
Step Data → 0	0	0	0	1	⊗	⊗	⊗	⊗	1	0	1
1	0	0	1	0	⊗	⊗	⊗	⊗	2	0	1
2	0	1	0	0	⊗	⊗	⊗	⊗	4	0	1
3	1	0	0	0	⊗	⊗	⊗	⊗	8	0	1

⊗ Masked addresses are 0 for coding.

CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)-   ADDRESS: 901   ☐ TIME DRIVEN ☒ EVENT DRIVEN   GROUP NUMBER: 0

BIT ADDRESS DATA									PROGRAM CODE		PRESET VALUES
	B				A				Data B	Data A	
Bit Addresses →	018	017	016	015	014	013	012	011			
Mask Data →	1	1	1	1	1	1	1	1	F	F	
Step Data → 0	0	0	0	0	0	0	0	0	0	0	1
1	0	0	0	0	1	0	1	0	0	A	1
2	0	0	1	1	1	1	1	0	3	E	1
3	1	1	0	0	0	0	1	1	C	3	1

SEQUENCERS AND REGISTERS
UNIT III

HANDOUT #1 — NUMBERING SYSTEMS

Background

Numbering systems provide an orderly, mathematical reference for counting. Since counting is a mathematical function, numbering systems help us add subtract, multiply and divide with precision. Numbering systems start with a base number and proceed from right to left with place values that are multiples of the base number. The basic numbering systems are the decimal, binary, octal, and hexadecimal, and a combination called binary coded decimal which is really not a numbering system, but it functions like a numbering system so we need to know about.

The Decimal Numbering System

The decimal numbering system is the one we're most familiar with because we use it in everyday life. The decimal numbering system has a base of 10, meaning that each place value from right to left is multiplied by 10. The digits 0 through 9 are used to represent all numbers in the decimal numbering system.

Example: Moving right to left, each place value in the decimal system has its value multiplied by 10, and that is what's meant by a base 10 numbering system.

	x10		x10		x10		x10	
10,000		1,000		100		10		1

The Binary Numbering System

Many people assume the binary numbering system is a product of the computer age, but it was actually devised by an English mathematician named George Boole back in the mid 1800s. The construct became known as Boolean algebra and was used to express symbolic logic. Designers of modern computers use Boole's binary numbering system to express the two conditions in digital electronics. Something is either ON or OFF or TRUE or FALSE. The binary numbering system has a base of 2, and uses only the digits 0 and 1 to represent all numbers in the system.

Example: Moving right to left, each place value in the binary system doubles in value, and only the digits 0 and 1 represent all numbers in the binary numbering system.

	x2		x2		x2		x2		x2		x2		x2	
128		64		32		16		8		4		2		1

HANDOUT #1

When a 0 appears in a place value, there is no number value, but when a 1 appears in a place value, the number value is equal to the place value and the number value is the total of all the place values that have a 1 in them.

1024	512	256	128	64	32	16	8	4	2	1
0	0	0	0	0	0	0	1	0	1	0 = 10
0	0	1	0	0	0	0	0	0	0	0 = 256
0	0	1	1	1	1	1	1	1	0	0 = 508

The logic gates you have worked with in previous units, and the TRUE/FALSE conditions on ladder logic rungs reflect binary conditions that are at the heart of PLC programming.

The Hexadecimal Numbering System

Since hex is the Greek word for six, hex combined with decimal, or 10, is 16. The hexadecimal numbering system has a base of 16 and uses the digits 0 through 9 to represent the numbers 0 through 9 and the letters A through F to represent the numbers 10 through 15. The effect of combining digits with letters "crunches" numbers to make them easier for a PLC controller to read and use.

Example: To find the hexadecimal value of 3E8, start right to left and total the values, remembering that each place value is multiplied by 16. 8 + (E x 16) + (3 x 256). we total values in parenthesis first, and since E = 14 in hexadecimal, 14 x 16 - 224. Then 3 x the third place value of 16 x 16 is equal to 3 x 256 or 768, and hexadecimal 3E8 is 8 + 224 + 768 = 1000

Let's have a look at the "crunching" power of the hexadecimal numbering system. Look back at the example for the binary numbering system for the binary value of 256. It is 1 0000 00000. In hexadecimal it would be 100 because the four binary, zeros to the right become a 0, the second four zeros become a 0, and 1 is 1. You can see why the spacesaving hexadecimal numbering system would speed operations. In turn, a PLC controller can quickly convert hexadecimal data into binary for operational use. Since hexadecimal is a long word, the abbreviation "hex" is often used in its place.

Binary Coded Decimals

A binary coded decimal is the four-digit binary representation of a decimal number. A four-digit binary number represents a single decimal, and in the case of larger decimals, the four-digit binary codes are evaluated separately and then placed in right to left order just like the place values in a numbering system.

Example:	Binary coded decimal	0010	0101	0110
	decimal	2	5	6

And what do binary coded decimals accomplish? They provide a convenient translation that permits an operator to work with the familiar decimal system. Thumbwheels and readouts on PLCs use binary coded decimals to provide a user friendly display for operator. What's more, binary coded decimals permit an operator to enter decimals directly into a binary format.

HANDOUT #1

The Octal Numbering System

The octal numbering system has a base of 8 and each place value is multiplied by 8. The octal system was used in early computers, and is still used for referencing I/O memory in some PLCs.

Conclusion

Working with numbering systems permits PLC designers to increase the amount of information a PLC can handle as well as the speed with which a PLC handles information. The easy dialogue between numbering systems still leaves an operator a user-friendly environment where PLC power can be easily programmed and monitored.

SEQUENCERS AND REGISTERS
UNIT III

ASSIGNMENT SHEET #1 — CONVERT DECIMALS TO BINARY CODED DECIMALS AND BINARY CODED DECIMALS TO DECIMALS

Instructions: Examine the following decimals and binary coded decimals and make conversions as indicated.

A. Decimals 078 =

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ BCD

B. Decimal 493 =

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ BCD

C. Decimal 206 =

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ BCD

D. Decimal 851 =

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ BCD

E. 0101-0001-0110 BCD =

___ ___ ___ Decimal

F. 0011-1001-0010 BCD =

___ ___ ___ Decimal

G. 0010-1000-0111 BCD =

___ ___ ___ Decimal

SEQUENCERS AND REGISTERS UNIT

ASSIGNMENT SHEET #2 — CONVERT BIT ADDRESS DATA INTO HEXADECIMAL PROGRAM CODES

Instructions: The following Sequencer Instruction Data Form lists bit address data for mask data and data for steps 0, 1, 2, and 3. Convert the bit address data from groups B and A into two-digit hex program codes.

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: 901 ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER: 0

BIT ADDRESS DATA									PROGRAM CODE		PRESET VALUES			
	B				A				Data B	Data A				
Bit Addresses →	18	17	16	15	14	13	12	11						
Mask Data →	1	1	1	1	1	1	⊗	1						
Step Data → 0	1	0	0	1	1	0	⊗	1						1
1	0	1	1	1	1	1	⊗	1						1
2	0	0	0	0	1	0	⊗	0						2
3	1	1	1	1	1	1	⊗	1						1
4														
5														
6														
7														
8														
9														
10														

Data form from Allen-Bradley.

SEQUENCERS AND REGISTERS
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

ASSIGNMENT SHEET #1

A. 0000-0111-1000

B. 0100-1001-0011

C. 0010-000-0110

D. 1000-0101-0001

E. 516

F. 392

G. 287

ASSIGNMENT SHEET #2

A. Mask data: FD

B. Step data 0: 99

C. Step data 1: 7D

D. Step data 2: 08

E. Step data 3: FD

SEQUENCERS AND REGISTERS
UNIT III

JOB SHEET #1 — WRITE AND CONFIRM AN EVEN-DRIVEN SQO INSTRUCTION

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. Two single-pole, single-throw NC switches
5. Three-conductor 16-gauge power cord
6. Pen or pencil
7. Sequencer/data instruction form
8. Safety glasses

B. Route #1 — Preparing the event-driven SQO instruction data

1. Put on safety glasses

   (NOTE: With timers and counters, ladder logic diagrams provide the best programming guide, but with sequencers, the instruction data form becomes the primary programming reference, and the ladder logic diagram is used to clarify rung structure before and after sequencer programming.)

2. Place the Sequencer Instruction Data Form that accompanies this job sheet beside these written instructions so that entries will be easier to make.
3. Make check marks on the form to indicate that you are preparing an SQO instruction that is event-driven.
4. Select group number zero (check Transparency 2), and indicate the group number on your data form.
5. Enter address 901 of the SQO instruction.
6. Enter the group B and A bit addresses by numbering from right to left so that the group A addresses are 11, 12, 13, and 14 and the group B addressees are 15, 16, 17, and 18.
7. Enter the mask data for each address by entering a 1 under every address except 12.

JOB SHEET #1

8. Determine the hex value of each group and enter those values in the B and A data groups under Program Code; in this case, program code B will be F, and program code A will be D.

9. Enter 1s in the 0 step data to indicate the following addresses must be ON to satisfy step 0 conditions: 18, 15, 14, and 11.

10. Enter 0s in the 0 step data to indicate the following addresses must be OFF to satisfy step 0 conditions: 17, 16 and 13; remember address 12 is not used.

11. Determine the hex value of each group in step 0 and make the appropriate program code entries, B data should be 9 and A data should be 9.

12. Enter a 1 in the far right column of the preset values to indicate step 0 will require one FALSE/TRUE transition to step the program to step 1.

13. Enter 1s in the 1 step data to indicate the following addresses must be ON to satisfy step 1 conditions: 17, 16, 15, 14, 13, and 11.

14. Enter a 0 in the 1 step data to indicate address 18 must be OFF to satisfy step 1 conditions; remember 12 is not used.

15. Determine the hex value of each group in step 1 and make the appropriate program code entries, B data should be 7 and A data should be D.

16. Enter a 1 in the far right column of the preset values to indicate step 1 will require one FALSE/TRUE transition to step the program to step 2.

17. Enter a 1 under address 14 to indicate that the address must be ON to satisfy step 2 conditions.

18. Enter 0s to indicate the following addresses must be OFF to satisfy step 2 conditions: 18, 17, 16, 15, 13, 11; remember 12 is not used.

19. Determine the hex values of each group in step 2 and make the appropriate program code entries, B data will be 0 and A data will be 8.

20. Enter a 2 in the far right column of the preset values to indicate step 2 will require two FALSE/TRUE transitions to step the program to step 3.

21. Enter 1s under all addresses in group A and B to indicate that all addresses must be ON to satisfy step 3 conditions: remember 12 is not used.

22. Make no 0 data entries for step 3.

23. Determine the hex values of each group in step 3 and make the appropriate program code entries, B data should be F and A data will be D.

24. Enter a 1 in the far right column of the preset values to indicate step 3 will require one FALSE/TRUE transition to step the program back to step 0.

JOB SHEET #1

C. Routine #2 — Writing a ladder logic diagram for an SQO instruction

1. Put on safety glasses

2. Prepare a 3-rung ladder logic diagram to execute the data entered in Routine #1.

3. Place an Examine OFF instruction on rung 1 at address 001 so it can serve to monitor the event that will generate FALSE/TRUE conditions on rung 1.

4. Enter the SQO instruction at address 901 on rung 1.

5. Enter an Examine ON instruction at address 951 on rung 2 and an output coil 12 on rung 2.

   (NOTE: Since address 12 was masked out in the SQO instruction , it can be used for any program purpose, and the 951 address is simply the SQO address 901 plus 50 which serves as a cycle completion status bit to indicate the SQO instruction has been completed and the program turns address 12 ON to control a motor, solenoid, or whatever the program specifies.)

6. Enter an Examine OFF instruction at address 002 on rung 3 and a RST instruction at address 901 on rung 3 with an RAC value of 0 so that the program will return to step 0.

☐ Have your instructor check your work.

D. Routine #3 — Entering data for an SQO instruction

1. Put on safety glasses

2. Prepare the programmer as outlined in previous job sheets.

3. Place the SQO ladder logic diagram and the SQO data form alongside the programmer so that can be easily referenced.

4. Clear the programmer.

5. Press the MODE key and then the 2 key to place the programmer in the program mode.

6. Press the Examine OFF key and enter address 001 on rung 1 as indicated by your ladder logic diagram.

   (NOTE: Remember that after clearing the programmer it will automatically go to rung 1 for programming.)

7. Press the SHIFT key to access the upper program function, and then press the -(SQO)- key, and then enter address 901 for the SQO instruction.

JOB SHEET #1

8. Press the ENTER key and watch for MODE window on the programmer to display a C or an E which means to select a time-driven or an event-driven option.

9. Press the SHIFT then EVENT keys to enter the event-driven command as indicated on your data form.

10. Watch for an E to come up in the programmer DATA window.

11. Press ENTER again and watch for MODE to display grp to indicate group.

12. Press 0 to indicate the group on the data form, and then press ENTER.

13. Watch for MODE to display USE which means that the mask data from the data form should be entered at this time.

14. Press SHIFT F, then SHIFT D to enter the mask data hex codes.

15. Press ENTER and watch for MODE to display and 0 which means the hex data for step 0 should now be entered, which is 9 and 9.

16. Press ENTER, watch for MODE to display P O and DATA to display 1 which is the normal default value, and in this case since 1 is also the preset value for step 0, simply press ENTER.

17. Watch for MODE to display d 1 which means that the hex data for step 1 should now be entered.

18. Press 7 and then press SHIFT D to enter the 7D hex data for step 1.

19. Press ENTER and watch for MODE to display P 1 and DATA to display 1 which is the normal default value, and in this case since 1 is the also the preset value for step 1, simply press ENTER.

20. Watch for d 2 in MODE and enter the 0 8 hex data for step 2 and press ENTER.

21. Watch for MODE to display P 2 which indicates the preset for step 2, but notice the default value in DATA is automatically 1.

22. Change the default to 2 to indicate the proper preset value for step 2 by pressing 2 and then ENTER.

23. Watch for MODE to display d 3 which means that the hex data for step 3 should now be entered.

24. Press SHIFT F and SHIFT D to enter the hex data for step 3, and then press ENTER.

25. Watch for MODE to display P 3 which indicates the preset for step 3 and the default under DATA shows a default of 1.

JOB SHEET #1

26. READ THIS INFORMATION CAREFULLY BEFORE COMPLETING THE NEXT STEP: Entering the preset of 1 for step 3 ends the program, and you would normally press ENTER. You do indeed press enter, but you must press ENTER two times so that the step 3 preset will be entered AND THE ENTIRE SQO instruction will be entered. Failure to press ENTER twice will lead to programming problems.

27. Press ENTER twice.

28. Watch for DATA to display 874 and MODE to display End to indicate that the sequencer program has been exited and the next rung is ready to program.

29. Press the Examine ON key, and then press 951 in order to enter the 951 address on rung 2.

30. Press the -( )- key and then add the address 12 to the output coil on rung 2.

31. Press ENTER and watch for DATA to display 872 and MODE to display End to indicate that rung 2 is completed and you are ready for rung 3.

32. Press the Examine OFF instruction and enter address 002 on rung 3.

33. Press SHIFT RST and then 901 in order and press ENTER.

34. Watch for DATA to display 0 which indicates no default value, and MODE to display r A c to indicate reset is programmed.

35. Press ENTER and watch for MODE to display END and DATA to display 869 to indicate how many words have been used to complete the SQO event-driven instruction.

☐ Have your instructor check your work.

E. Routine #4 — Confirming the SQO instruction

1. Put on safety glasses.
2. Activate the NC switch which would simulate an event-driven operation.
3. Check outputs to confirm that they agree with conditions for step 0.
4. Repeat the procedure for all steps in the SQO instruction.

☐ Have your instructor check your work.

5. Reprogram and reconfirm as required.

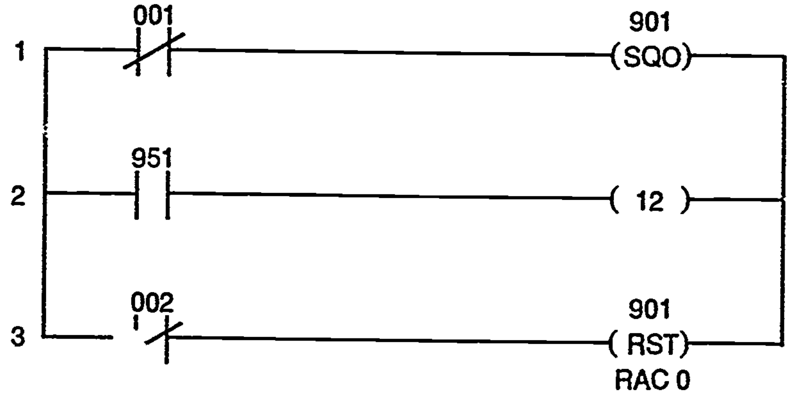
JOB SHEET #1

FIGURE 1

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☐ -(SQO)-   ADDRESS: ____   ☐ TIME DRIVEN ☐ EVENT DRIVEN   GROUP NUMBER: ____

BIT ADDRESS DATA									PROGRAM CODE		PRESET VALUES
	B				A				Data B	Data A	
Bit Addresses→											
Mask Data→											
Step Data→0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											



Data form from Allen-Bradley.

SEQUENCERS AND REGISTERS
UNIT III

JOB SHEET #2 — WRITE AND CONFIRM AN EVENT-DRIVEN SQI INSTRUCTION

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. NC switches as required
5. Three-conductor 16-gauge power cord
6. Pen or pencil
7. Sequencer instruction data form
8. Safety glasses

B. Routine #1 — Preparing the event-driven SQI instruction data

1. Put on safety glasses.
2. Place the sequencer instruction data form that accompanies this job sheet beside these written instructions so that entries will be easier to make.
3. Make check marks on the form to indicate that you are preparing an SQI instruction that is event-driven.
4. Select group number 7 (check Transparency 2), and indicate the group number on your data form.
5. Enter address 901 for the SQI instruction.
6. Enter the group B and A bit addresses by numbering from right to left in group A so that the group A addresses are 1, 2, 3, and 4 and group B addresses are 5, 6, 7, and 8.
7. Enter the mask data for each address by placing a 1 under addresses 1, 2, 3, 4, 5, and 6; addresses 7 and 8 will not be used in the SQI instruction, but will be used externally.
8. Determine the hex value of each group in the mask data and enter the values under B and A data under Program Code; B data should be 3 and A data F.
9. Enter 1s in the 0 step data to indicate the following addresses must be ON to satisfy step 0 conditions; 5, 3, and 1.

JOB SHEET #2

10. Enter 0s in the 0 step data to indicate the following addresses must be OFF to satisfy step 0 conditions; 6, 4, and 2; addresses 8 and 7 are not used.

11. Determine the hex value of each group in step 0 and enter the values under Program Code: B is 1 and A is 5.

12. Enter the preset value of 1 in the far right column of step 0.

13. Enter 1s in step 1 data to indicate the following addresses must be ON to satisfy step 1 conditions: 6, 4, and 2.

14. Enter 0s in the step 1 data to indicate the following addresses must be OFF to satisfy step 1 conditions. 5, 3, and 1; addresses 7 and 8 are not used.

15. Determine the hex value of each group in step 1 and enter the values under Program Code: B is 2 and A is A.

16. Enter the preset value of 2 in the far right column of step 1.

17. Enter 1s in step 2 data to indicate the following addresses must be ON to satisfy step 2 conditions: 4, 3, 2, and 1.

18. Enter 0s in step 2 data to indicate the following addresses must be OFF to satisfy step 2 conditions: 6 and 5; addresses 7 and 8 are not used.

19. Determine the hex value of each group in step 2 and enter the values under Program Code: B is 0 and A is F.

20. Enter the preset value of 1 in the far right column of step 2.

21. Enter 1s in the step 3 data to indicate the following addresses must be ON to satisfy step 3 conditions: 6, 5, and 1.

22. Enter 0s in step 3 data to indicate the following addresses must be OFF to satisfy step 3 conditions: 4, 3, and 2; addresses 7 and 8 are not used.

23. Determine the hex value of each group in step 3 and enter the values under Program Code: B is 3 and A is 1.

24. Enter the preset value of 1 in the far right column of step 3.

☐ Have your instructor check your work.

C. Routine #2 — Writing a ladder logic diagram for an SQI instruction

1. Put on safety glasses.

2. Prepare a 4-rung ladder logic diagram to execute the data entered in Routine #1.

3. Place an Examine OFF instruction on rung 1 at address 007.

JOB SHEET #2

4. Place the SQI instruction at address 901 on rung 1.

5. Place an Examine ON instruction on rung 2 at address 901 followed by an output coil at address 11.

6. Place an Examine OFF instruction on rung 3 at address 901 followed by an output coil at address 12.

7. Place an Examine OFF instruction at address 008 on rung 4 followed by a RST instruction at address 901 with an RAC of 0.

☐ Have your instructor check your work.

D. Routine #3 — Entering data for an SQI instruction

1. Put on safety glasses.

2. Prepare the programmer as outlined in previous job sheets.

3. Place the SQI ladder logic diagram and the SQI data form alongside the programmer so they will be easier to reference.

4. Clear the programmer.

5. Press the MODE key and then the 2 key to place the programmer in the program mode.

6. Press the Examine OFF key and enter address 007 on rung 1.

7. Press the SHIFT key to access the upper program function, and then press the -(SQI)- key, and enter address 901 for the SQI instruction.

8. Press the ENTER key and watch for the MODE window on the programmer to display a C or an E which means to select a time-driven or event-driven option.

9. Press the SHIFT then EVENT keys to enter the event-driven command as indicated on your data form.

10. Press ENTER again and watch for the MODE window to display grp to indicate group.

11. Press 7 to indicate the group on the data form, and then press ENTER.

12. Watch for the MODE window to display USE which means that the mask data from the data form should be entered at this time.

13. Press 3 and SHIFT F to enter the mask data hex codes.

14. Press ENTER and watch for MODE to display d 0 which means the hex data for step 0 should be entered, which is 1, 5.

JOB SHEET #2

15. Press ENTER and watch for MODE to display P O and DATA to display 1 which means that the preset for step 0 is 1.

16. Press ENTER and watch for MODE to display d 1 which means that the hex data for step 1 should now be entered.

17. Press 2 and SHIFT A to enter the hex data for step 1.

18. Press ENTER and watch for MODE to display P 1 and DATA to display 1 which is the normal default value, and since, in this case 2 is the preset value for step 1, press 2 and then ENTER.

19. Watch for D 2 in MODE, and enter the O SHIFT F hex data for step 2.

20. Press ENTER and watch for MODE to display P 2 and DATA to display the automatic default value of 1.

21. Keep the default at 1 for step 2 by pressing ENTER.

22. Watch for MODE to display d 3 which means that the hex data for step 3 should now be entered.

23. Press 3 and then 1 to enter the hex data for step 3 , and then press ENTER.

24. Watch for MODE to display P 3 which indicates the preset for step 3 while DATA shows the automatic default of 1.

25. READ THIS INFORMATION CAREFULLY BEFORE COMPLETING THE NEXT STEP: Entering the preset of 1 for step 3 ends the program, and you would normally pres ENTER. You do press ENTER, but you must press ENTER TWO TIMES. By pressing twice on the ENTER key, the step 3 preset will be entered and the second ENTER will place the entire SQI instruction in memory. The secret is to press ENTER twice to avoid problems with later programming.

26. Press ENTER twice.

27. Press the Examine ON key and enter address 901 on rung 2.

28. Press the -( )- key and enter 11 for the output address on rung 2.

29. Press the Examine OFF key and enter address 901 on rung 3.

30. Press the -( )- key and enter 12 for the output address on rung 3.

31. Press the Examine OFF key and enter the address 008 on rung 4.

32. Press the -(RST)- key and enter the address 901 for the RST.

33. Watch for the rAc to appear in MODE and a 0 to appear in data and press ENTER to enter 0 for the reset.

JOB SHEET #2

34. Watch for MODE to display END and DATA to display 867 to indicate how many words have been used to complete the SQI event-driven instruction.

☐ Have your instructor check your work.

E. Routine #4 — Confirming the SQI instruction

1. Put on safety glasses.
2. Activate the NC switch which would simulate an event-driven operation.
3. Check outputs to confirm that they agree with conditions for step 0.
4. Repeat the procedure for all steps in the SQI instruction.
5. Check outputs 11 and 12 in order.
6. Check the 901 reset in the final rung.

☐ Have your instructor check your work.

7. Reprogram and reconfirm as required.

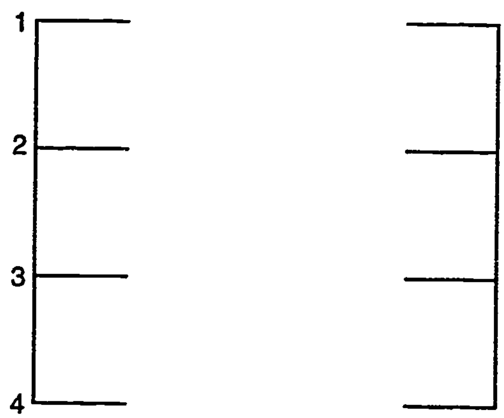
JOB SHEET #2

FIGURE 1

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☐ -(SQO)- ADDRESS: ____ ☐ TIME DRIVEN ☐ EVENT DRIVEN GROUP NUMBER: ____

BIT ADDRESS DATA									PROGRAM CODE		PRESET VALUES			
	B				A				Data B	Data A				
Bit Addresses →														
Mask Data →														
Step Data → 0														
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														



Data form from Allen-Bradley.

SEQUENCERS AND REGISTERS
UNIT III

JOB SHEET #3 — WRITE AND CONFIRM A REVERSING SQO INSTRUCTION

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. NC switches as required
5. Three-conductor 16-gauge power cord
6. Pen or pencil
7. Sequencer instruction data form
8. Safety glasses

B. Routine #1 — Preparing the event driven instruction data

1. Put on safety glasses.
2. Place the sequencer instruction data form that accompanies this job sheet beside these written instructions so that entries will be easier to make.
3. Take the sequencer instruction data form from Job Sheet #1 and transfer all information from that form to the data form provided with this job sheet.

   (NOTE: Using what you have already worked with will help you better understand the sequencer reversing instruction.)
4. Return the data form from Job Sheet #1 to its proper place.
5. Continue with the lower sequencer data form in Figure 1 by marking the SQO instruction at address 901, an event-driven, but make the group number 38 from the special group number for reversing instructions.
6. Enter FF as the mask data hex program codes because the FF code is required for special group numbers 38 to 69.
7. Enter for step 0 under data B a 0, and under data A, enter the next to last step number in the original SQO instruction, which in this case is 2.
8. Enter for step 1 under data B a 0, and under data A, enter the last step number in the original SQO instruction, which in this case is 3.
9. Enter for step 2 under data B a 0, and under data A enter the step number minus 2, which in this case is 0.

JOB SHEET #3

10. Enter for step 3 under data B a O, and under data A enter the step number minus 2, which in this case is 1.

11. Enter all preset values in the same step order as they appear in the original SQO instruction.

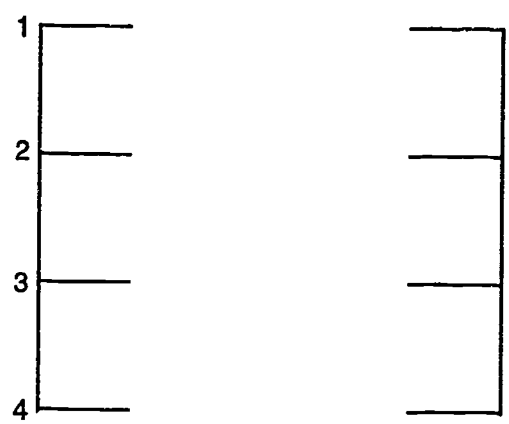
☐ Have your instructor check your work.

C. Routine #2 — Writing a ladder logic diagram for a reversing SQO instruction

1. Put on safety glasses.

2. Prepare a 4-rung ladder logic diagram to execute the data entered in Routine #1. (Figure 2)

FIGURE 2



3. Place an Examine OFF instruction on rung 1 at address 001.

   (NOTE: Be sure to enter data at this point.)

4. Place the SQO instruction at address 901 on rung 1.

5. Place an Examine ON instruction at address 901 on rung 2 followed by an Examine OFF instruction at address 002 on rung 2.

6. Place a ZCL instruction as the output on rung 2.

JOB SHEET #3

7. Place an Examine OFF instruction at address 001 on rung 3.

8. Place an SQO instruction at address 901 on rung 3.

   (NOTE: Be sure to enter data at this point.)

9. Place a ZCL instruction as the output on rung 4.

☐ Have your instructor check your work.

D. Routine #3 — Entering data for the reversing SQO instruction.

1. Put on safety glasses.

2. Program the original SQO instruction as it appears in Job Sheet #1.

   (NOTE: If you need to refer to Job Sheet #1, do so, but if you can program the SQO instruction without referring to Job Sheet #1, you're on your way to becoming a PLC programmer.)

3. Be sure to press ENTER twice to enter the preset value of 1 for step 3 from the original program and to place the SQO instruction in memory.

4. Look for MODE to display END and DATA to display 874 to indicate the words used for the SQO instruction.

5. Press the Examine ON key and enter address 901 on rung 2.

6. Press the Examine OFF key and enter address 002 on rung 2.

7. Press SHIFT -(ZCL)- to place the zone command at the output of rung 2.

8. Press ENTER and look for MODE to display END and DATA to display 871 to indicate that 3 words have been used for the zone command.

9. Press the Examine OFF key and enter address 001 on rung 3.

10. Press SHIFT -(SQO)- and enter address 901 for the output on rung 3.

11. Press ENTER and look for MODE to display the C-E option.

12. Press SHIFT EVENT and then press ENTER.

13. Look for MODE to display grp, press 38 and then press ENTER.

14. Look for MODE to display USE, and enter the mask data from the reversing instruction, press SHIFT F, SHIFT F, and then press ENTER.

15. Look for DATA to display d O and press 0 and 2 and then ENTER to enter the data for step 0.

JOB SHEET #3

16. Look for MODE to display P O and DATA to display the default value of 1, and since 1 is the preset for step 0, press ENTER.

17. Look for MODE to display d 1, press 0 3 and then ENTER to enter the data for step 1.

18. Look for MODE to display P 1, and since the preset for step 1 is 1, just press ENTER.

19. Look for MODE to display d 2 and press 0 0 and then ENTER to enter the data for step 2.

20. Look for MODE to display P 2 and DATA to display the default value of 1, so press 2, the preset for step 2, and then press ENTER.

21. Look for MODE to display d 3, press 0 1, and then ENTER to enter the data for step 3.

22. Look for MODE to display P 3 and DATA to display the default value of 1, and since 1 is the preset for step 3, just press ENTER.

23. Press ENTER once again and look for MODE to display END and DATA to display 861 to indicate that 10 words have been used to program the reversing instruction.

24. Go back to your ladder logic diagram and program rung 4 by pressing SHIFT -(ZCL)- and then press ENTER.

25. Look for MODE to display END and DATA to display 860 to indicate that 1 word was used to program the end of the zone instruction.

☐ Have your instructor check your work.

E. Routine #4 — Confirming the reversing SQO instruction

1. Put on safety glasses.

2. Press the MODE key, then 3, then the ENTER key.

3. Look for MODE to display 3 and DATA to display a flashing run to indicate that you can now run the program.

4. Press ENTER and look for MODE to display 1 and DATA to display the 001 address at the first Examine OFF instruction.

5. Press the NEXT key and look for MODE to stay on rung 1 and DATA to show the SQO instruction at address 901 on rung 1.

6. Press NEXT again and check for grp 0, then NEXT again to check for USE and the mask data.

JOB SHEET #3

7. Press NEXT again and look for the step 0 data.

8. Activate switch 001 to simulate an event and give a FALSE/TRUE transition on rung 1.

9. Look for MODE and DATA to indicate that the SQO instruction has moved to step 1.

10. Activate switch 1 again and look for the instruction to move to step 2.

11. Activate switch 1 again and look for the instruction to move to stay on step 2 because of the preset value of 2.

12. Activate switch 1 again and look for the instruction to move to step 3.

13. Activate switch 2 and hold it in to keep it TRUE, and then activate switch 1 and look for the SQO instruction to reverse its order.

☐ Have your instructor check your work.

14. Reprogram and reconfirm as required.

JOB SHEET #3

FIGURE 1

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☐ -(SQO)- ADDRESS: ____ ☐ TIME DRIVEN ☐ EVENT DRIVEN GROUP NUMBER: ____

BIT ADDRESS DATA									PROGRAM CODE		PRESET VALUES			
	B				A				Data B	Data A				
Bit Addresses →														
Mask Data →														
Step Data → 0														
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☐ -(SQO)- ADDRESS: ____ ☐ TIME DRIVEN ☐ EVENT DRIVEN GROUP NUMBER: ____

BIT ADDRESS DATA									PROGRAM CODE		PRESET VALUES			
	B				A				Data B	Data A				
Bit Addresses →														
Mask Data →														
Step Data → 0														
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

SEQUENCERS AND REGISTERS
UNIT III

JOB SHEET #4 — WRITE AND CONFIRM AN SQI INSTRUCTION DRIVING AN SQO INSTRUCTION

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. NC switches as required
5. Three-conductor 16-gauge power cord
6. Pen or pencil
7. Sequencer instruction data form
8. Safety glasses

B. Routine #1 — Preparing the event-driven SQI and SQO instruction

1. Put on safety glasses.
2. Place the sequencer instruction data form that accompanies this job sheet beside these written instruction so that entries will be easier to make.
3. Use the upper data form to indicate an event-driven SQI instruction at address 901, using addresses in group 7.
4. Take the SQI instruction data form from Job Sheet #2 and transfer all information to the appropriate places in the upper data form that accompanies this job sheet, but make all preset values 1.
5. Take the SQO instruction data form from Job Sheet #1 and transfer all information to the appropriate places in the lower data form that accompanics this job sheet, but make all preset values 1.

☐ Have your instructor check your work.

C. Routine #2 — Entering the SQI/SQO instructions

1. Put on safety glasses.
2. Prepare the PLC and programmer as previously instructed.
3. Press MODE and the 1 key to clear the programmer.

JOB SHEET #4

4. Press ENTER and watch for the SurE ? prompt and then press ENTER again.

5. Look for done to appear briefly in DATA and then the End display in MODE and a DATA display indicating 885 words as a starting point.

   (NOTE: Keeping track of the words used as each segment of the instruction is entered will help you check yourself as you input the instruction.)

6. Press the Examine ON key and enter address 901 on rung 1.

7. Press SHIFT SQI and then enter the 901 SQI address on rung 1 and press ENTER.

8. Look for MODE to display the C-E option and press SHIFT EVENT and then press ENTER.

9. Look for MODE to display grp, press 7, and then press ENTER.

10. Look for MODE to display USE, and press 3 and SHIFT F to enter the program code for the SQI mask data, and press ENTER.

11. Look for MODE to display d 0, and press 1 and 5 and then ENTER to enter the program code for step 0.

12. Look for MODE to display P O and DATA to display a default of 1, and since 1 is the preset value for step 0, press ENTER.

13. Look for MODE to display d 1, and press 2 and SHIFT A and the ENTER to enter the program code for step 1.

14. Look for MORE to display P 1 and DATA to display a default of 1, and since the preset value for step 1 is 1, press ENTER.

15. Look for MODE to display d 2, and press 0 and SHIFT F and then ENTER to enter the program code for step 2.

16. Look for MODE to display P 2 and DATA to display a default of 1, and since 1 is the preset value for step 2, press ENTER.

17. Look for MODE to display d 3, and press 3 and 1 and then ENTER to enter the program code for step 3.

18. Look for MODE to display P 3 and DATA to display a default of 1, and since 1 is the preset for step 3, press ENTER.

19. Pres ENTER one more time and look for MODE to display End and DATA to display 874 to indicate that 11 words have been used to program the SQI instruction.

20. Press the Examine ON key and enter address 901 on rung 2.

JOB SHEET #4

21. Press SHIFT -(SQO)- and then enter the 901 SQO address on rung 2 and press ENTER.

22. Look for MODE to display the C-E option and press SHIFT EVENT and then press ENTER.

23. Look for MODE to display grp, press 0, and then press ENTER.

24. Look for MODE to display USE, and press SHIFT F, SHIFT D and press ENTER to enter the program code for the SQO mask data.

25. Look for MODE to display d O and press 9, 9 and ENTER to enter the program code for step 0.

26. Look for MODE to display P O and DATA to display a default of 1, and since 1 is the preset value for step 0, press ENTER.

27. Look for MODE to display d 1 and press 7, SHIFT D and ENTER to enter the program code for step 1.

28. Look for MODE to display P 1 and DATA to display a default of 1, and since 1 is the preset value for step 1, press ENTER.

29. Look for MODE to display d 2 and press 0, 8 and press ENTER to enter the program code for step 2.

30. Look for MODE to display P 2 and DATA to display a default of 1, and 1 is the preset value for step 2, press ENTER.

31. Look for MODE to display d 3 and press SHIFT F, SHIFT D and ENTER to enter the program code for step 3.

32. Look for MODE to display P 3 and DATA to display a default of 1, and since 1 is the preset value for step 3, press ENTER.

33. Press ENTER again and look for MODE to display End and DATA to display 864 to indicate that 10 words have been used to program the SQO instruction and that 21 words have been used to program the entire instruction to this point.

34. Press the Examine OFF key and enter address 007 on rung 3.

35. Press SHIFT -(RST)-, enter the reset address 901 and press ENTER.

36. Look for MODE to display rAc and DATA to display 0, and since the RAC is 0, press ENTER.

37. Look for MODE to display End and DATA to display 861 to indicate that 3 words were used to program the reset instruction and end the program.

☐ Have your instructor check your work.

JOB SHEET #4

D. Routine #3 — Confirming the SQI instruction driving an SQO instruction

1. Put on safety glasses.
2. Press the MODE key, then 3, then press ENTER to put the programmer in the run mode.
3. Press RUNG, then 1, then ENTER.
4. Look for MODE to display rung 1 and DATA to display the 901 address.
5. Press NEXT four times to step through the SQI instruction until MODE displays d 0 and DATA shows the 15 program code for step 0 of the SQI instruction.
6. Monitor the PLC to confirm that outputs #15, 14, and 11 are activated to indicate that the SQO instruction is on step 0.
7. Activate power to inputs 1, 3, and 5 to make SQI step 0 TRUE and that both the SQI and SQO instructions advance to step 1.
8. Monitor the PLC to confirm at outputs 16, 15, 14, 13, and 11 are activated to indicate the SQO instruction is on step 1.
9. Activate power to inputs 2, 4, and 6 to make the SQI step 1 TRUE and to advance both the SQI and SQO instructions to step 2.
10. Monitor the PLC to confirm that output #14 is activated to indicate the SQO instruction is one step 2.
11. Activate power to inputs 1, 2, 3, and 4 to make the SQI step 2 TRUE and to advance both the SQI and SQO instruction to step 3.
12. Monitor the PLC to confirm that outputs #11, 13, 14, 15, and 16 are activated to indicate the SQO instruction is on step 3.
13. Activate power to inputs, 1, 5, and 6 to make the SQI step 3 TRUE and advance both the SQI and SQO instructions back to step 0.

☐ Have your instructor check your work.

JOB SHEET #4

SEQUENCER INSTRUCTION DATA FORM

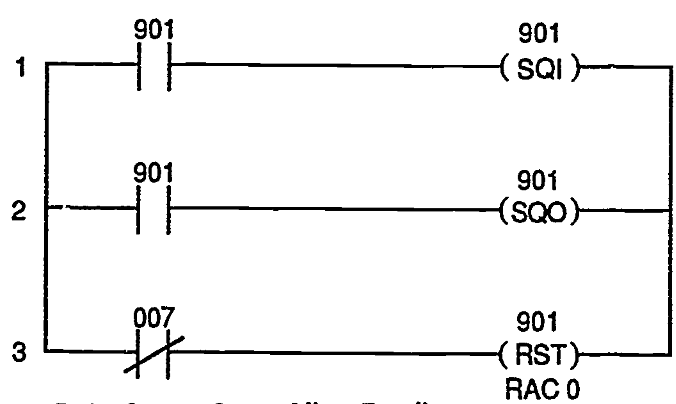
FIGURE 1

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☐ -(SQO)-   ADDRESS: ____   ☐ TIME DRIVEN ☐ EVENT DRIVEN   GROUP NUMBER: ____

	BIT ADDRESS DATA								PROGRAM CODE		PRESET VALUES			
	B				A				Data B	Data A				
Bit Addresses →														
Mask Data →														
Step Data → 0														
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☐ -(SQO)-   ADDRESS: ____   ☐ TIME DRIVEN ☐ EVENT DRIVEN   GROUP NUMBER: ____

	BIT ADDRESS DATA								PROGRAM CODE		PRESET VALUES			
	B				A				Data B	Data A				
Bit Addresses →														
Mask Data →														
Step Data → 0														
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														



Data forms from Allen-Bradley.

SEQUENCERS AND REGISTERS
UNIT III

JOB SHEET #5 — WRITE AND CONFIRM AN EVENT-DRIVEN SHIFT RIGHT REGISTER INSTRUCTION

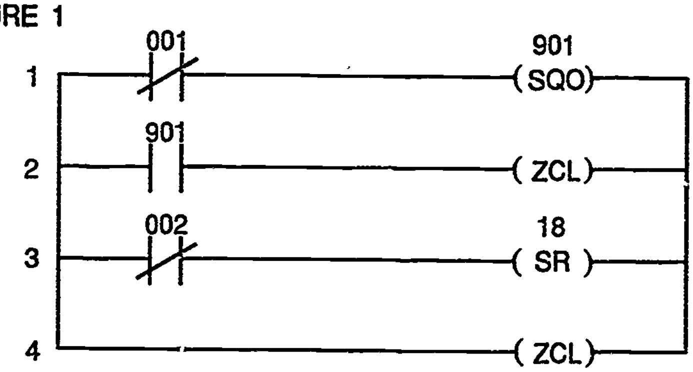
A. Tools and Equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. NC switches as required
5. Three-conductor 16-gauge power cord
6. Pen or pencil
7. Safety glasses

B. Routine #1 — Preparing the shift right register instruction

1. Put on safety glasses.
2. Follow the ladder logic diagram in Figure 1 as you enter the shift right register instruction.

FIGURE 1



3. Prepare the PLC and programmer as outlined in previous job sheets.
4. Clear the programmer so that MODE displays End and DATA displays 885 words left for programming.
5. Press the Examine OFF key and enter address 001 on rung 1.
6. Press SHIFT -(SQO)-, enter address 901 and press ENTER.
7. Look for DATA to display the C-E option, press SHIFT EVENT and ENTER.

JOB SHEET #5

8. Look for DATA to display grp, press 0 and ENTER.

9. Look for DATA to display USE, press 0 and ENTER.

10. Look for DATA to display D O, press O and ENTER.

11. Look for DATA to display P O, press 1 and ENTER.

12. Press ENTER again.

13. Press the Examine ON key and enter address 901 on rung 2.

14. Press SHIFT -(ZCL)- and the ENTER to complete rung 2.

15. Press the Examine OFF key and enter address 002 on rung 3.

16. Press SHIFT and then the output coil key, -( )-, to select the SF (shift register) function, then enter 18, the most significant bit required for a shift right register instruction, and then press ENTER to complete rung 3.

17. Press SHIFT -(ZCL)- and then ENTER to complete rung 4.

18. Look for MODE to display End and DATA to display 874 to indicate that 11 words were used to program the shift right register instruction.

☐ Have your instructor check your work.

C. Routine #2 — Confirming the shift right register instruction

1. Put on safety glasses.

2. Press MODE, then 3, then ENTER so you can run the program to confirm it.

3. Activate switch 002 and keep it ON, then press switch 001 two times.

4. Deactivate switch 002.

5. Activate switch 001 again and watch for the PLC outputs to indicate that the bits are shifting each time 001 is activated.

☐ Have your instructor check your work.

6. Reprogram and reconfirm as required.

SEQUENCERS AND REGISTERS
UNIT III

PRACTICAL TEST #1

JOB SHEET #1 — WRITE AND CONFIRM AN EVENT-DRIVEN SQO INSTRUCTION

Student's name ______________________________ Date ____________

Evaluator's name ______________________________ Attempt no. ________

Student instructions: When you are ready to perform this task, ask you instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Prepared the SQO instruction data.	☐	☐
2. Wrote a ladder logic diagram for the instruction.	☐	☐
3. Prepared programmer properly.	☐	☐
4. Entered the SQO instruction.	☐	☐
5. Confirmed the SQO instruction.	☐	☐
6. Returned tools and equipment to storage.	☐	☐

EVALUATOR'S COMMENTS: ____

____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted or evaluation.)

Criteria:				
Instruction data entries	Complete 4	Acceptable 3	Poor 2	Unacceptable 1
Programming procedure	Excellent 4	Acceptable 3	Poor 2	Unacceptable 1
Program confirmation	Excellent 4	Acceptably done 3	Poorly done 2	Unacceptably done 1
Safety	Well observed 4	Acceptably observed 3	Poorly observed 2	Unacceptably observed 1

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Produce Evaluation" and divide by the total number of criteria.)

SEQUENCERS AND REGISTERS
UNIT III

PRACTICAL TEST #2

JOB SHEET #2 — WRITE AND CONFIRM AN EVENT-DRIVEN SQI INSTRUCTION

Student's name ______________________________ Date ____________

Evaluator's ame ______________________________ Attempt no. ________

Student instructions: When you are ready to perform this task, ask you instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Prepared the SQO instruction data.	☐	☐
2. Wrote a ladder logic diagram for the instruction.	☐	☐
3. Prepared programmer properly.	☐	☐
4. Entered the SQO instruction.	☐	☐
5. Confirmed the SQO instruction.	☐	☐
6. Returned tools and equipment to storage.	☐	☐

EVALUATOR'S COMMENTS: ______________________________________

____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted or evaluation.)

Criteria:

Instruction data entries	Complete 4	Acceptable 3	Poor 2	Unacceptable 1
Programming procedure	Excellent 4	Acceptable 3	Poor 2	Unacceptable 1
Program confirmation	Excellent 4	Acceptably done 3	Poorly done 2	Unacceptably done 1
Safety	Well observed 4	Acceptably observed 3	Poorly observed 2	Unacceptably observed 1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Produce Evaluation" and divide by the total number of criteria.)

SEQUENCERS AND REGISTERS
UNIT III

PRACTICAL TEST #3

JOB SHEET #3 — WRITE AND CONFIRM A REVERSING SQO INSTRUCTION

Student's name ______________________________ Date ____________

Evaluator's name ______________________________ Attempt no. ________

Student instructions: When you are ready to perform this task, ask you instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Prepared the SQO instruction data.	☐	☐
2. Prepared the reversing instruction.	☐	☐
3. Wrote a ladder logic diagram for the instruction.	☐	☐
4. Entered the reversing SQO instruction.	☐	☐
5. Confirmed the reversing SQO instruction.	☐	☐
6. Returned tools and equipment to storage.	☐	☐

EVALUATOR'S COMMENTS: ____

____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted or evaluation.)

Criteria:

Instruction data entries	Complete 4	Acceptable 3	Poor 2	Unacceptable 1
Programming procedure	Excellent 4	Acceptable 3	Poor 2	Unacceptable 1
Program confirmation	Excellent 4	Acceptably done 3	Poorly done 2	Unacceptably done 1
Safety	Well observed 4	Acceptably observed 3	Poorly observed 2	Unacceptably observed 1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Produce Evaluation" and divide by the total number of criteria.)

SEQUENCERS AND REGISTERS
UNIT III

PRACTICAL TEST #4

JOB SHEET #4 — WRITE AND CONFIRM AN SQI INSTRUCTION DRIVING AN SQO INSTRUCTION

Student's name ______________________________ Date ____________

Evaluator's name ______________________________ Attempt no. ________

Student instructions: When you are ready to perform this task, ask you instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Prepared the SQI instruction data.	☐	☐
2. Prepared the SQO instruction.	☐	☐
3. Entered the SQI/SQO instructicns.	☐	☐
4. Write a ladder logic diagram for the instructions.	☐	☐
5. Confirmed the SQI/SQO instructions.	☐	☐
6. Returned tools and equipment to storage.	☐	☐

EVALUATOR'S COMMENTS: ____

____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted or evaluation.)

Criteria:

Instruction data entries	Complete 4	Acceptable 3	Poor 2	Unacceptable 1
Programming procedure	Excellent 4	Acceptable 3	Poor 2	Unacceptable 1
Program confirmation	Excellent 4	Acceptably done 3	Poorly done 2	Unacceptably done 1
Safety	Well observed 4	Acceptably observed 3	Poorly observed 2	Unacceptably observed 1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Produce Evaluation" and divide by the total number of criteria.)

SEQUENCERS AND REGISTERS
UNIT III

PRACTICAL TEST #5

JOB SHEET #5 — WRITE AND CONFIRM AN EVENT-DRIVEN SHIFT RIGHT REGISTER INSTRUCTION

Student's name ______________________________ Date ____________

Evaluator's name ______________________________ Attempt no. ________

Student instructions: When you are ready to perform this task. ask you instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactori' achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Prepared the programmer.	☐	☐
2. Followed the ladder logic diagram.	☐	☐
3. Entered the register instructions.	☐	☐
4. Confirmed the shift right register instruction.	☐	☐
5. Returned tools and equipment to storage.	☐	☐

EVALUATOR'S COMMENTS: ____

____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted or evaluation.)

Criteria:				
Instruction data entries	Complete 4	Acceptable 3	Poor 2	Unacceptable 1
Programming procedure	Excellent 4	Acceptable 3	Poor 2	Unacceptable 1
Program confirmation	Excellent 4	Acceptably done 3	Poorly done 2	Unacceptably done 1
Safety	Well observed 4	Acceptably observed 3	Poorly observed 2	Unacceptably observed 1

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Produce Evaluation" and divide by the total number of criteria.)

SEQUENCERS AND REGISTERS
UNIT III

TEST

NAME ______________________________ SCORE __________

1. Match the terms on the right with their correct definitions.

_____a. An instruction that requires response to an external happening to step a program through its cycle

_____b. An instruction address bit that is set to ON when a program completes all its steps

_____c. A number assigned to identify numerically related groups of bit addresses

_____d. An SQI instruction address bit that is set to ON when the bit address matches programmed data for a current step

_____e. The combination of addresses and other data that sets the conditions which must be met for a PLC to perform a control objective

_____f. A number or number/letter used to express the hexadecimal value of binary data formed in bit addressing

_____g. An instruction that addresses status bits related to conditions that must be met for inputs to be ON at given times in a PLC program

_____h. An instruction that addresses status bits related to conditions that must be met for outputs to be ON at given times in a PLC program

_____i. An instruction that requires the passage of a given number of seconds or minutes to step a program through its cycle

1. Program code
2. SQI instruction
3. Cycle completion bit
4. Time-driven
5. SQO instruction
6. Event-driven
7. Instruction
8. Input satisfied bit
9. Group number
10. Most significant bit
11. Least significant bit

TEST

_____j. The digit representing the smallest value in a byte, an odd-numbered value which serves as the address of a shift left register

_____k. The digit representing the largest value in a byte, an even-numbered value which serves as the address for a shift right register

2. Complete statements concerning comparing sequencers with timers and counters by circling the material that best completes each statement.

   a. The real power of PLCs lies in their ability to manage (minimal) (multiple) inputs/outputs to accomplish complex control objectives.

   b. A timer, basically, has two conditions, Examine ON/Examine OFF, and they change states at the PR value to complete a timing program and (start the program cycle again) (end the program).

   c. The SQO instruction can control the Examine ON/Examine OFF status of as many as 8 bit addresses for up to (100) (500) steps in a time-driven program.

   d. A counter, basically, has two conditions, Examine ON/Examine OFF, and they change states at a PR value to complete a counting program and then (must be RST to) (automatically) start another program cycle.

   e. The SQO instruction can control the Examine ON/Examine OFF status of as many as 8 bit addresses for up to 100 steps and the RST is (automatic) (manual) in an event-driven program.

3. Select true statements concerning sequencer operations by placing an X beside each statement that is true.

_____a. Sequencers operate two types of program instructions: input and output.

_____b. Sequencer input is identified in ladder logic as -(SI)-.

_____c. Sequencer output is identified in ladder logic as -(SO)-.

_____d. Both input and output sequencers have to be addressed by numbers.

_____e. Both SQI and SQO sequencers are retentive which means that if power is turned OFF, the process will be at the same step when power is turned ON again.

_____f. Only SQI sequencers may be event-driven.

TEST

4. Complete statements concerning time-driven and event-driven sequencer operations by circling the material that best completes each statement.

   a. A sequencer that is (event-driven) (time-driven) responds to a FALSE/TRUE transition on the run containing sequencer instruction.

   b. Event-driven sequencers have functions similar to (counters) (timers).

   c. A sequencer that is time-driven responds to an accumulated value that is programmed in (tenths of a second) (seconds).

   d. Time-driven sequencers have functions similar to (timers) (counters).

5. Solve problems concerning accumulated values and preset values by answering the following questions.

   a. What part of programming timers and counters is similar to programming sequencers?

      Answer ____________________

   b. If you were troubleshooting a sequencer program, what would be a good way to do it?

      Answer ____________________

6. Select conditions concerning dynamics of SQO instructions by answering the following questions.

   a. The SQO instruction uses a special reference each time the instruction completes a step, and that reference is what, a cycle completion bit or a step completion bit?

      Answer ____________________

   b. While a sequencer rung is TRUE, time-driven SQO instructions do what, count 1 second intervals or count 0.1 second intervals?

      Answer ____________________

   c. The SQO step completion bit uses the sequencer address of what, 901 or 951?

      Answer ____________________

   d. The SQO cycle completion bit uses the sequencer address of what, 901 or 951?

      Answer ____________________

TEST

7. Select conditions concerning the dynamics of SQI instructions by answering the following questions.

   a. An SQI instruction uses what as an operating reference, a step completion bit or an input-satisfied status bit?

   Answer ____

   b. The SQO instruction uses both PR and AC values, but what does the SQI instruction use, both PR and AC values or only AC values?

   Answer ____

   c. If the SQI instruction address is 901, what would the input-satisfied bit address be, 901 or 951?

   Answer ____

8. Match numbering systems with their structures.

_____a.	A numbering system with a base of 10 with place values in multiples of 10	1.	Octal numbering system
_____b.	A numbering system with a base of 2 with place values in multiples of 2	2.	Binary numbering system
_____c.	A numbering system with a base of 16 with place values in multiples of 16 where the numbers 0 to 9 represent the numbers 0 to 9 and the letters A, B, C, D, E, and F represent the numbers 10 through 15	3.	Decimal numbering system
		4.	Binary coded decimal
		5.	Hexadecimal numbering system
_____d.	A numbering system with a base of 8 with place values in multiples of 8		
_____e.	The representation of four digit binary numbers with their decimal equivalents with binary numbers evaluated separately, but expressed in decimal order		

9. Select true statements concerning working with sequencer data by placing an X beside each statement that is true.

   _____a. When programming sequencer instructions it is essential to know what address groups are reserved for inputs and outputs and how address groups differ for SQO and SQI instructions.

   _____b. With the SLC™100, group numbers 0 through 6 are reserved for the external and internal bit addresses for SQO instructions.

TEST

_____c. The SLC™100 reserves group numbers 7 through 15 for bit addresses 001 through 610 for external input addresses for SQI instructions.

_____d. With the SLC™100, group numbers 16 through 37 are reserved for addresses 701 through 876 which are internal bit addresses for SQO or SQI instructions.

_____e. Program codes express bit address data in binary.

_____f. Using group numbers and program codes helps avoid errors when programming SQO and SQI instructions and speeds the process of confirming and troubleshooting sequencer programs.

10. Complete statements concerning the sequencer data form by circling the material that best completes each statement.

    a. When programming sequencer instructions, (a data form) (an outline) of some kind should be used so that bit address groups can be identified and the address in each step can be properly documented.

    b. (Mask)(Program) data should include 1s under all addresses to be used and 0s under all addresses that will not be used.

    c. Addresses that will not be used should be indicated in each step with a ⊗, and these entries retain a 0 value when determining (program codes) (PR values).

    d. Program codes should reflect the (total binary) (hexadecimal) value of each address group in each step of the sequencer instruction.

    e. Preset values should be entered to indicated the length of each step in a time-driven sequence or the number of events in each step of (an event-driven sequence) (other types of instructions).

    f. For programming accuracy, a ladder logic diagram should be prepared to indicate how the sequencer instruction will be started, how the cycle will be completed, and how the sequencer (programming) (reset) will be accomplished.

11. Program a time-driven SQO instruction by completing the following sequencer instruction data form using data following the data form:

CLASSIFICATION: ☐ -(SQI)- ☐ -(SQO)- ADDRESS: ___ ☐ TIME DRIVEN ☐ EVENT DRIVEN GROUP NUMBER: ___

	BIT ADDRESS DATA								PROGRAM CODE		PRESET VALUES
	B				A				Data B	Data A	
Bit Addresses →											
Mask Data →											
Step Data → 0											
1											
2											
3											

TEST

a. The program is an event-driven SQO instruction at address 901, using address group number 0.

b. The addresses used will be 011, 012, 013, 014 in group A and 015, 016, 107, and 018 in group B.

c. Mask data will include ON conditions at all addresses except 012, and address 012 will not be used in this instruction.

d. For step 0, bit addresses at 018, 015, 014, and 011 must be ON to set step 0 conditions.

e. For step 1, bit addresses at 017, 016, 015, 014, 013, 011 must be ON to set step 1 conditions.

f. For step 2, only the bit address at 014 must be ON to set step 2 conditions.

g. For step 3, bit addresses 018, 107, 016, 015, 014, 013, and 011 must be on to set step 3 conditions.

h. Preset values for steps 0, 1, and 3 are 5 seconds, and for step 2, 11 and ½ seconds.

i. Assume the RAC is 0.

12. Select conditions concerning a typical SQO instruction by answering the following questions.

a. A typical SQO instruction beings with rung 1 in what logic state, TRUE or FALSE?

Answer ______________________________

b. A typical SQO instruction begins with the instruction on what step, 1 or 0?

Answer ______________________________

c. What happens to the step completion bit each time a step is completed, is it ON for a single scan or OFF for a single scan?

Answer ______________________________

d. The cycle completion bit is ON when an instruction recycles from a final step back to step 0, but how long does the cycle completion bit stay on, until the sequencer is reset or until rung 1 goes TRUE?

Answer ______________________________

TEST

13. Select conditions concerning a typical SQI instruction b, answering the following questions.

    a. In a typical SQI instruction, the sequencer moves from one step to the next when, each time rung 1 goes FALSE or with each FALSE/TRUE transition on rung 1?

       Answer ______________________________

    b. The SQI instruction functions with what control reference, a step completion bit or an input-satisfied bit?

       Answer ______________________________

    c. The RST instruction in an SQI instruction corresponds to what, the PR value of step 0 or the RAC value?

       Answer ______________________________

14. Complete statements concerning MCR and ZCL instructions by circling the material that best completes each statement.

    a. MCR and ZCL instructions permit the use of one set of instructions to control multiple outputs and are (sometimes) (always) used with sequencer instructions.

    b. Both MCR and ZCL instructions are programmed to control zones, and the start rung contains the condition instructions which control the zone, but the end rungs contain (no conditions) (RST instructions).

    c. (Any number of) (Up to 3) rungs may be programmed between the start and end rungs of MCR and ZCL instructions, but the zones must be clear of any other MCR of ZCL instructions within the zones.

    d. When the start rung is TRUE, output instructions in the zone function normally, but when the start rung is FALSE, outputs within the zone are overridden and controlled by the (MCR or ZCL instruction) (sequencer instruction).

    e. MCR and ZCL instructions are programmed (without) (with) addresses.

    f. MCR and ZCL instructions can interrupt or stop other instructions, (and they are) (but they are not) designed to provide emergency stop capability that permits an operator to shut down I/O power.

    g. The MCR instruction will reset all nonretentive outputs to an (ON) (OFF) state when the zone logic is FALSE, but the ZCL instruction will leave all outputs in their last state when the logic is FALSE.

TEST

15. Complete statements concerning cascading SQO sequencers by circling the material that best completes each statement.

    a. When a control application demands more than 8 bit addresses, SQO instructions ca be cascaded so that (16) (12) bit addresses can be controlled.

    b. Cascaded SQO instructions use (two sequencer instructions to control the same conditions,) (one sequencer instruction to control two conditions,) but each sequencer is programmed on a separate rung.

    c. The two sequencers can control the same addresses, but one sequencer must control one address group and the second sequencer must control (a second address group) (the same address group on a different rung).

    d. Step data for each sequencer is programmed as the application requires, and data for each sequencer (may vary) (must be the same).

    e. A (single) (double) RST instruction can be used to reset both sequencers in a cascaded operation.

16. Select conditions concerning reversing sequencers by answering the following questions.

    a. A reversing sequencer instruction is a good example of an instruction that uses a what, an MCR zone or a ZCL zone?

       Answer ______________________________

    b. Step data for a reversing sequencer is entered in what form, decimal or hexadecimal?

       Answer ______________________________

    c. In coding a reversing sequencer, you enter the next to last step from the original instruction as step 0, and the last step from the original instruction as step 1, but how do you code step 2 and up, by entering the original step number of by entering the original step number minus 2?

       Answer ______________________________

17. Arrange in order the steps in reversing sequencer operation by placing a 1, 2, 3, or 4 beside each of the following statements.

    _____a. When rung 2 goes TRUE, rung 3 become operative and reverses the step order beginning with the step in effect at the time.

    _____b. When rung 1 is TRUE and rung 2 is FALSE, the sequencer operates in a forward step order.

    _____c. When rung 2 goes FALSE again, the sequencer operates in a forward step order again.

TEST

_____d. During step forward operation, rung 3 is TRUE, but inoperative because the ZCL instruction is FALSE.

18. Select conditions concerning using sequencer input to drive sequencer output by answering the following questions.

    a. To advance the step number in an SQO instruction an SQI instruction uses what, the status of the completion bit or the status of the input-satisfied bit?

    Answer ____________________

    b. When an SQI instruction is used to drive and SQO instruction, what addresses do the instructions use, the same, or is the SQO instruction one address higher?

    Answer ____________________

    c. When an input-satisfied bit goes TRUE, it advances what, only the SQI instruction or both the SQI and SQO instructions?

    Answer ____________________

19. Select conditions concerning sequencer input monitoring sequencer output by answering the following questions.

    a. When an SQI instruction is used to monitor an SQO instruction, the input-satisfied bit goes on when, when the input reaches a specified step or when the monitored sequencer reaches a specified step?

    Answer ____________________

    b. When using an SQI instruction to monitor an SQO instruction how is it programmed, as only a time-driven instruction or as either a time-driven or event-driven instruction.

    Answer ____________________

20. Solve problems concerning sequencer jump instructions by answering the following questions.

    a. If you were programming a jump instruction, what similar program could you use as a pattern?

    Answer ____________________

    b. If the conditions of a jump program are not met, what happens to your program?

    Answer ____________________

TEST

21. Complete statements concerning shift registers by circling the material that best completes each statement.

    a. Shift registers are (internal and external) (internal) addresses where status data is stored so it can be accessed and acted upon by the PLC controller.

    b. The shift registers in the Allen-Bradley SLC™100 are all (8-bit) (16-bit) registers where data is automatically shifted through the registers from one bit address to the next on a time-driven or event-driven basis.

    c. Shift registers provide (another way) (the only way) to handle data used in control applications where parts in a process or on a conveyor belt are shifted from one position to another.

22. Select conditions concerning shift register instructions by answering the following questions.

    a. Shift register instructions are what, always shift right or shift right or left?

       Answer ______________________________

    b. A shift right register is assigned the address of what, the address of its most significant bit or the address of its least significant bit?

       Answer ______________________________

    c. Shift register instructions use a ZCL instruction to control the shifting process, but what is used to control the shift rate, a timer instruction or a sequencer instruction?

       Answer ______________________________

23. Select conditions concerning event-driven shift register instructions by answering the following questions.

    a. A typical event-driven shift right register instruction would open with what, a counter instruction or a 1-step event-driven sequencer instruction?

       Answer ______________________________

    b. The event-driven shift register instruction is usually included in what, the sequencer program or the ZCL zone?

       Answer ______________________________

    c. Would an event-driven register instruction work from a TRUE/FALSE transition on rung 1 or when the AC value reaches the PR value of the sequencer instruction?

       Answer ______________________________

TEST

24. Select conditions concerning time-driven shift register instructions by answering the following questions.

    a. A typical time-driven shift register right instruction would open with what, a timer instruction or a 1-step time-driven sequencer instruction?

    Answer ______________________________

    b. The time-driven shift register instruction is usually included in what, the sequencer program or a ZCL zone?

    Answer ______________________________

    c. Would a time-driven register instruction work from a TRUE/FALSE transition on rung 1 or when the AC value reaches the PR value of the sequencer instruction?

    Answer ______________________________

25. Complete statements concerning cascading shift registers by circling the material that best completes each statement.

    a. Just like (timers) (sequencers) shift registers can be cascaded to double their control capabilities.

    b. In order to create the 16-bit shift register, two 8-bit registers must be cascaded so that the beginning bit of the second register must be a number that (continues) (reverses) the consecutive order of the data.

    c. In programming cascaded shift registers, the shift register into which data is entered must follow the rung containing the (second) (first) shift register.

26. Select conditions concerning circulating shift registers by answering the following questions.

    a. Basically, a circulating shift register is used at the end of an 8-bit register to what, step an instruction to the next step or repeat the cycle?

    Answer ______________________________

    b. In a typical circulating shift register, if status data is shifted left from address 701 to 708, what shift would be made to complete the cycle, from 701 to 708 or from 708 to 701?

    Answer ______________________________

TEST

27. Solve problems concerning shift register outputs by answering the following questions.

    a. You want to use a shift register for an external output, what sort of instruction will you need?

       Answer ________ ______________________________

    b. You are programming a shift left register with external outputs, but where should the outputs be entered with respect to the ZCL zone?

       Answer ______________________________________

(NOTE: If the following activities have not been accomplished prior to the test, ask you instructor when they should be completed.)

28. Convert decimals to binary coded decimals and binary coded decimals to decimals. (Assignment Sheet #1)

29. Convert bit address data into hexadecimal program codes. (Assignment Sheet #2)

30. Demonstrate the ability to:

    a. Write and confirm an event-driven SQO instruction. (Job Sheet #1)

    b. Write and confirm an event-driven SQI instruction. (Job Sheet #2)

    c. Write and confirm a reversing SQO instruction. (Job Sheet #3)

    d. Write and confirm an SQI instruction driving an SQO instruction. (Job Sheet #4)

    e. Write and confirm an event-driven shift right register instruction. (Job Sheet #5)

SEQUENCERS AND REGISTERS
UNIT III

ANSWERS TO TEST

1. a. 6
   b. 3
   c. 9
   d. 8
   e. 7
   f. 1
   g. 2
   h. 5
   i. 4

2. a. Multiple
   b. Start the program cycle again
   c. 100
   d. Must be RST to
   e. Automatic

3. a, d, e

4. a. Event-driven
   b. Counters
   c. Tenths of a second
   d. Timers

5. a. Both PR and AC values have to be programmed
   b. Monitor the AC values

6. a. A step completion bit
   b. Count 0.1 second intervals
   c. 901
   d. 951

7. a. An input-satisfied bit
   b. Both PR and AC values
   c. 901

8. a. 3
   b. 2
   c. 5
   d. 1
   e. 4

9. a, b, c, d, f

ANSWERS TO TEST

10. a. A data form
    b. Mask
    c. Program codes
    d. Hexadecimal
    e. An event-driven sequence
    f. Reset

11.

CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: 901 ☐ TIME DRIVEN ☐ EVENT DRIVEN GROUP NUMBER: 0

	BIT ADDRESS DATA								PROGRAM CODE		PRESET VALUES
	B				A				Data B	Data A	
Bit Addresses →	018	017	016	015	014	013	012	011			
Mask Data →	1	1	1	1	1	1	⊗	1	F	D	
Step Data → 0	1	0	0	1	1	0	⊗	1	9	9	1
1	0	1	1	1	1	1	⊗	1	7	D	1
2	0	0	0	0	1	0	⊗	0	0	8	2
3	1	1	1	1	1	1	⊗	1	F	D	1

12. a. FALSE
    b. Step C
    c. ON for a single scan
    d. Until the sequencer is reset

13. a. With each FALSE/TRUE transition on rung 1
    b. An input-satisfied bit
    c. The RAC value

14. a. Sometimes
    b. No conditions
    c. Any number of
    d. MCR and ZCL instruction
    e. Without
    f. But they are not
    g. OFF

ANSWERS TO TEST

15. a. 16
    b. Two sequencer instructions to control the same conditions
    c. A second address group
    d. May vary
    e. Single

16. a. A ZCL zone
    b. Decimal
    c. Entering the original step number minus 2

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

18. a. The status of the input-satisfied bit
    b. The same
    c. Both the SQI and SQO instructions

19. a. When the monitored sequencer reaches a specified step
    b. Either a time-driven or event-driven instruction

20. a. Using an SQI instruction to monitor an SQO instruction
    b. The original steps are completed in order

21. a. Internal and external
    b. 8-bit
    c. Another way

22. a. Shift right or left
    b. The address of its most significant bit
    c. A sequencer instruction

23. a. The 7-step event-driven sequencer instruction
    b. The ZCL zone
    c. A TRUE/FALSE transition on rung 1

24. a. A 1-step time-driven sequencer instruction
    b. A ZCL zone
    c. When the AC value reaches the PR value of the sequencer instruction

ANSWERS TO TEST

25. a. Sequencers
    b. Continues
    c. Second

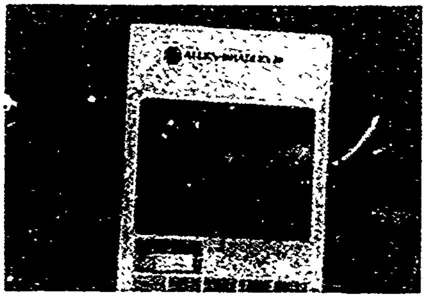
26. a. Repeat the cycle
    b. From 708 to 701

27. a. An unlatching instruction
    b. Outside the ZCL zone

28. Evaluated to the satisfaction of the instructor

29. Evaluated to the satisfaction of the instructor

30. a. Evaluated according to criteria in Practical Test #1
    b. Evaluated according to criteria in Practical Test #2
    c. Evaluated according to criteria in Practical Test #3
    d. Evaluated according to criteria in Practical Test #4
    e. Evaluated according to criteria in Practical Test #5



EDITING AND PROGRAMMING FUNCTIONS UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to execute procedures for reviewing and editing PLC programs. The student should also be able to interpret error codes, revise simple program errors, and replace event-driven sequencer instructions with time-driven instructions. These competencies will be evidenced by correctly completing the procedures outlined in the job sheets and by scoring a minimum of 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to editing and program functions with their correct definitions.
2. Select true statements concerning pocket programmer abbreviations and symbols.
3. Select conditions concerning the pocket programmer display.
4. Select true statements concerning keyboard editing.
5. Select conditions concerning program modes and display symbols.
6. Complete statements concerning the CANCEL CMD function and error codes.
7. Select conditions concerning NEXT and LAST key functions.
8. Select true statements concerning the SEARCH function.
9. Solve problems concerning the INSERT/REMOVE functions.
10. Complete statements concerning the PRT/UNPRT functions.
11. Select conditions concerning the FRC ON/FRC OFF functions.
12. Complete statements concerning one-shot instructions.
13. Select true statements concerning fine time instructions.

SPECIFIC OBJECTIVES

14. Demonstrate the ability to:

    a. Use error codes to identify programming errors. (Job Sheet #1)

    b. Enter, confirm, and revise and confirm a ladder logic program. (Job Sheet #2)

    c. Revise an event-driven SQO instruction to a time-driven SQO instruction and confirm the revision. (Job Sheet #3)

    d. Determine program scan time in milliseconds and program a fine time instruction. (Job Sheet #4)

EDITING AND PROGRAMMING FUNCTIONS
UNIT IV

SUGGESTED ACTIVITIES

Read Me First

Procedures in this text are presented for demonstration only and should not be used in actual industrial applications. Graphic materials from manufacturers are presented for the purpose of illustration only and no liability is assumed for their use otherwise. Persons using this text assume liability for demonstration and for any equipment damaged in demonstration. Administration of these materials should be by a qualified instructor only in a safety-proven environment.

A. Provide students with objective sheets.

B. Provide students with information and assignment sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss and demonstrate the procedures outlined in the job sheets.

F. Invite a PLC programmer from a local industry to talk to the class about programming PLC and the need for programmers to have editing skills.

G. Use the following data form as a guide for evaluating the SQO revision in Job Sheet #3:

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: 901 ☒ TIME DRIVEN ☐ EVENT DRIVEN GROUP NUMBER: 0

BIT ADDRESS DATA	B				A				PROGRAM CODE		PRESET VALUES
Bit Addresses →	18	17	16	15	14	13	12	11	Data B	Data A	
Mask Data →	1	1	1	1	1	1	⊗	1	F	D	
Step Data → 0	1	0	1	1	0	0	⊗	1	B	1	50
1	0	0	1	1	1	1	⊗	1	3	D	150
2	1	0	0	0	1	1	⊗	0	8	C	200
3	0	0	0	1	1	1	⊗	1	1	D	300
4											
5											
6											
7											
8											
9											
10											

SUGGESTED ACTIVITIES

H. Give test.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *User's Manual Bulletin 1745 SLC™ 100 Programmable Controller.* Milwaukee, WI 53204: Allen-Bradley Company, 1985.

B. Cox, Richard A. *Technician's Guide to Programmable Controllers.* Albany, NY 12212. Delmar Publishers, Inc., 1989.

C. Petruzella, Frank D. *Programmable Logic Controllers.* New York, NY: McGraw-Hill, Inc., 1989.

D. Jones, C. T. and L. A. Bryan. *Programmable Controllers Concepts and Applications.* Atlanta, GA: Clarence T. Jones and Luis A. Bryan, 1983 (Published by International Programmable Controls. Inc.)

EDITING AND PROGRAMMING FUNCTIONS
UNIT IV

INFORMATION SHEET

I. **Terms and definitions**

A. **Editing** — The process of monitoring a PLC program and changing program parameters as required to correct or enhance performance

B. **Parameter** — Any instruction or part of an instruction that sets up a condition which must be met at any point in the execution of a program

C. **Keyboard** — A device, often hand-held, where keys coded with program symbols may be pressed in selected order to write a program

D. **Program** — The combination of commands input from a programmer and stored in PLC memory to set the conditions that must be met for a control objective to be accomplished

II. **Pocket programmer abbreviations and symbols (Transparency 1)**

A. Programming requires the preparation of data and a ladder logic diagram that can be referenced as program entries are made.

B. Programmer keys display abbreviations and symbols to help make program entries logical and easy.

C. Programmer keys also serve the purpose of permitting a programmer to monitor a program step by step and rung by rung.

D. Programmer keys also permit a programmer to delete, change, or add to a program and this process is generally called editing.

E. Certain programmer keys are reserved for editing functions and their proper use is essential in program evaluation and troubleshooting.

III. **The pocket programmer display (Transparency 2)**

A. To provide visual documentation of programming and editing activities, programmers have a display lighted with individual LEDs to indicate the status of programming or editing activity.

B. The display is a vital reference for monitoring and troubleshooting because it generates vital address and execution information that must be referenced to properly confirm and edit programs.

C. Error codes generated on the display help with troubleshooting because they identify both input and output errors and help isolate them to speed troubleshooting.

(NOTE: For programming convenience, the SLC™100 has the error codes listed on the back of the programmer along with mode descriptions and addressing information.)

INFORMATION SHEET

D. The display has another extremely important element called the CURSOR which moves to each function on command and indicates what function is active by lighting an LED.

E. Following the cursor location assures accuracy and saves time in all editing and programming activities.

F. The LED also indicates the ON/OFF status of an address by lighting up to indicate ON and not lighting to indicate OFF.

IV. **Keyboard editing**

A. The need for editing evidences itself when initial review of a program indicates an error or when the program fails to meet program objectives during execution.

B. Editing functions range from correction of improper entries to complete program changes.

C. The ability to edit is a skill that a good PLC programmer must have to evaluate new programs and to troubleshoot existing programs.

D. The editing process begins with an understanding of keyboard functions reserved for editing and how to use those functions to meet program demands.

V. **Program modes and display symbols** (Transparencies 3 and 4)

A. A programmer works in several different modes which have to be selected by pressing the MODE key and then the mode number. (Transparency 3)

B. Mode 1 clears programmer memory and automatically puts the programmer in Mode 2, the program mode.

C. Mode 3, the Run mode, is used to monitor a program or for changing a program.

D. Modes 4 through 9 have special functions ranging from single and continuous test scans to self-checking diagnostic tests.

(NOTE: Other program modes will be discussed in Unit V, "Installation and Troubleshooting.")

E. Display symbols are those symbols which appear on the display unit of the programmer during programming activities. (Transparency 4)

VI. **The CANCEL CMD function and error codes**

A. Since it's relatively easy to press a wrong key or number, the CANCEL CMD key provides a quick remedy for erasing improper commands.

B. The CANCEL CMD function can be used as long as the cursor position has not been moved ahead, back, or to another instruction.

INFORMATION SHEET

C. The CANCEL CMD function can also be used to erase any previous commands to the left so long as the CANCEL CMD key is pressed in order as often as required.

D. When an inadvertent error is made in programming, the display will light to indicate a programming error which can be erased with CANCEL CMD.

E. Internal processor errors are indicated by a CPU Fault LED that lights on the display, and the CANCEL CMD will not correct these errors because all outputs will be disabled.

(NOTE: Troubleshooting CPU faults will be discussed in Unit V, "Installation and Troubleshooting.")

VII. The NEXT and LAST key functions (Transparency 5)

A. The NEXT and LAST keys permit a programmer to move back and forth in a program to monitor a single instruction or a rung.

B. Pressing the NEXT key moves the cursor to the following instruction, or one instruction to the right.

C. Pressing the LAST key moves the cursor to the previous instruction, or one instruction to the left.

D. Pressing RUNG, NEXT moves the cursor to the start of the following rung.

E. Pressing RUNG, LAST moves the cursor to the start of the previous rung.

F. The NEXT and LAST keys also provide access to data for timers, counters, and sequencers.

VIII. The SEARCH function (Transparency 6)

A. The SEARCH key provides time-saving access to any point in a program.

B. To search for a specific instruction, find the instruction, then press SEARCH, ENTER and the programmer will find the next place in the program where that instruction appears.

C. To move to a specific rung, press SEARCH, RUNG and then the rung number.

D. The NEXT and LAST functions can be combined with SEARCH as follows:

1. To move to the start of a rung, press SEARCH, LAST.

2. To move to the end of a rung, press SEARCH, NEXT.

E. For checking a specific sequencer step, locate the cursor on any sequencer data, SQO or SQI, press SEARCH, then the step number, and ENTER.

INFORMATION SHEET

F. The SEARCH function is a handy editing tool for quickly finding specific instructions or the start or end of a program.

IX. **The INSERT/REMOVE functions (Transparency 7)**

A. To use the INSERT or REMOVE functions requires the pocket programmer to be in the PROG (program) mode.

B. Press the LAST key to position the cursor on the instruction to be removed, press REMOVE and watch for the display to show rE to indicate the REMOVE function.

C. Press ENTER after the rE prompt to REMOVE the data or instruction.

D. Press the LAST key to position the cursor on the instruction following the point where the new instruction will be.

E. Press INSERT and watch for the display to show "in" to indicate the INSERT function.

F. Press ENTER after the "in" prompt to INSERT the new material.

G. The REMOVE and INSERT functions permit you to work with single instructions or a rung, a branch, or a sequencer step.

X. **The PRT/UNPRT functions**

A. The PRT (protect) function protects the PR value of a timer or counter while other changes are being made.

B. Locate the cursor on the PR value and press the PRT key to protect the PR value which will also protect the AC value.

C. The UNPRT (unprotect) function will return a PR (and an AC) value to an unprotected state.

D. Locate the cursor on the PR value and press the UNPRT key to remove the protected status of the PR and AC values.

XI. **The FRC ON/FRC OFF functions**

A. The ability to monitor, control, and change a program as it is running is an invaluable tool for troubleshooting.

B. With a controller in RUN or TEST MODE, the force functions FRC ON and FRC OFF can force an external I/O address to an ON/OFF state regardless of its actual bit status.

(NOTE: The force functions are excellent troubleshooting tools and will be covered more thoroughly in Unit V, "Installation and Troubleshooting.")

INFORMATION SHEET

C. When forcing an input address, the actual status bit of the I/O address is forced ON or OFF, but when forcing an output address only the output terminal is forced ON/OFF, but the status bit of the address is not affected.

D. Programmed I/O addresses cannot be accessed in a user program, but they can be forced ON or OFF by pressing INSERT, -( )- (output coil), the address (such as 1,6), ENTER, SHIFT, and FRC ON.

E. To remove a FRC ON function, press REMOVE, -( )- (output coil), the address (such as 1,6) SHIFT, FRC ON, and ENTER.

F. Forcing functions can be used to force external I/O addresses, to monitor timer, counter, and sequencer data, and to change PR, AC, and RAC values.

G. A warning to remember is that the effects of machine operation should always be examined BEFORE a force command to make sure there will be no personal injury or equipment damage.

XII. One-shot instructions

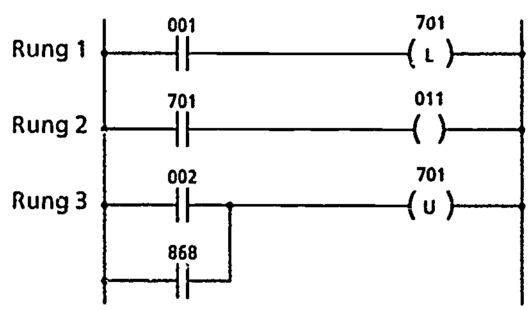
A. A one-shot instruction works for only one scan cycle and is used to initialize a program to a known state on power up.

B. A one-shot instruction can be an effective troubleshooting tool after a system shut down.

C. With the SLC™ 100, the one-shot is called a one-scan instruction and will work when power is switched on to the processor unit in the run or test modes or when the programmer is used to place the processor unit in the run or test modes.

D. The bit address 868 can be set ON for the first and only the first program scan to initialize timers, counters, or latch instructions.

Example: The following figure shows a one-scan program for a non-retentive latch instruction where on power up the 868 instruction in rung 3 will go TRUE for the first scan. Instruction 701 will initially be unlatched, but note that instruction 002 on rung 3 in used to unlatch 701 during normal program operation.



INFORMATION SHEET

XIII. Fine time instructions

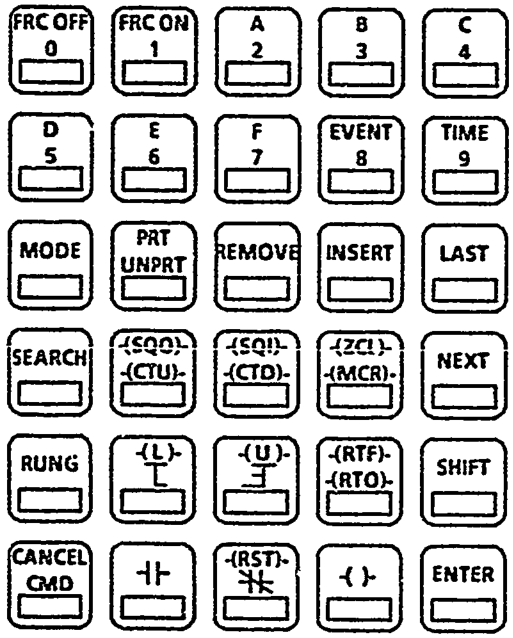
A. Standard timers have a resolution of 0.1 second, but this resolution can be speeded up when an application requires faster timing.

B. Faster timing resolution on the SLC™ 100 is accomplished by programming an up counter with a special instruction that provides a corresponding time increment.

C. The special internal address used for fine timing requires that you know the scan time of the program being modified.

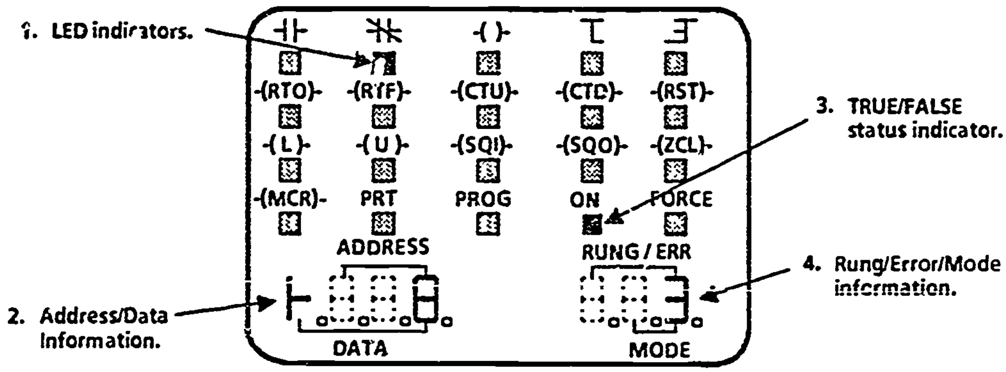
(NOTE: The fine time instruction procedure is presented in Job Sheet #4 of this unit.)

Programmer Symbols



Abbreviations and Symbols	
FRC OFF	Force OFF
FRC ON	Force ON
PRT	Protect
UNPRT	Not Protect
-(SQO)-	Sequencer Output
-(SQI)-	Sequencer Input
-(CTU)-	Up Counter
-(CTD)-	Down Counter
-(ZCL)-	Zone Control Last State
-(MCR)-	Master Control Reset
-(L)-	Latch
-(U)-	Unlatch
-(RTF)-	Retentive Timer Off-Delay
-(RTO)-	Retentive Timer On-Delay
CANCEL CMD	Cancel Command
-(RST)-	Reset
⌊	Branch Open
⌋	Branch Close
-| |-	Examine ON
-|/|-	Examine OFF
-( )-	Output Energize

Programmer Display



ERROR CODE	DESCRIPTION
	INTERNAL PROCESSOR ERRORS
1 thru 4	Processor hardware problem
5 thru 8	Processor memory problem
9	Processor scan time problem
10 thru 25	Communication problem
26	Expansion unit problem
51	EEPROM module problem
52	CAUTION – Program changes not saved in EEPROM module
53 thru 59	Programmer hardware problem
	PROGRAMMING ERRORS
60	Incomplete rung (no output instruction)
61	Invalid address for instruction
62	User memory exceeded
63	Instruction cannot be forced
64	Branch error (short circuit)
65	Branch error (incomplete branch)
66	Invalid access code

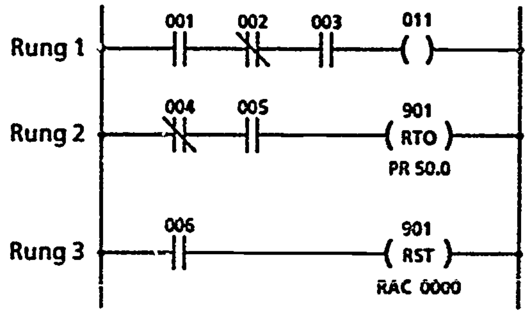
Program Modes

Mode Number	Description	Display Symbol
1	Clear Memory. Selecting this mode erases the contents of the on-board RAM memory. Upon completion, the programmer automatically switches to mode 2, Program.	CLEr
2	Program. Used to enter a new program or up-date an existing one in the RAM memory.	prog
3	Run. In this mode, the processor scans and executes the user program. Input devices are monitored and output devices are energized accordingly. In this mode, the programmer can be used to monitor the user program, force I/O, and change timer/counter preset and accumulated values. Sequencer preset values can also be changed.	run
4	Test–Single Scan. This mode causes the processor to complete a single scan of the user program each time the ENTER key is pressed. No outputs will be energized. Timer and time-driven sequencer accumulated values will be incremented by 0.1 on each scan if rung conditions are correct. The programmer can be used to monitor the user program, force I/O, and change counter/timer/sequencer values.	SScn
5	Test–Continuous Scan. This mode causes the processor to operate from the user program without energizing any outputs The programmer can be used to monitor the user program, force I/O, and change counter/timer/sequencer values.	CScn
6	Store User Program in EEPROM Module. This mode allows you to *save* a program, that is, store a program contained in the on-board RAM memory to an EEPROM memory module.	SAUE
7	Load User Program from EEPROM Module. This mode allows you to *read* a program into memory, that is, load a program contained in an EEPROM module into the on-board RAM memory. You can then remove the EEPROM module or leave it in place. The processor operates from the RAM only.	rEAd
8	Enter/Change Access Code. This mode allows you to enter or change an access code or *password.*	PASS
9	Diagnostic Test–Programmer. A sequence of self-checking diagnostic tests. Refer to Section 6, Maintenance and Troubleshooting, for details.	d IA9

Display Symbols

Display Symbols	Meaning	Display Symbols	Meaning
A	Accumulated (AC) value, sequencers	PASS	Mode 8, Enter/Change Access Code
Ac	Accumulated (AC) value, timers/counters	Pr	Preset (PR) value, timers and counters
bnd	Branch close	prog	Mode 2, Program
bro	Branch open	r	Rung
C	Time-driven (Clock), sequencers	rAc	Reset Accumulated (RAC) value
C-E	Select time- or event-driven, sequencers	rE	Remove
CLEr	Mode 1, Clear Memory	rE F	Remove force
CScn	Mode 5, Test Continuous	rE r	Remove rung
d	Step data, sequencers	rE ?	Remove faulty branch error
dIAG	Mode 9, Diagnostic Test - Programmer	rEAd	Mode 7, Load Program from EEPROM
donE	Done processing	run	Mode 3, Run
E	Event-driven, sequencers, or Error	rung	Rung
-EL-	Enter logic element	SAVE	Mode 6, Store Program in EEPROM
End	End	SLC-100	Start-up display
F	Forced I/0	SScn	Mode 4, Test-Single Scan
FAIL	Failed internal test or password	SrCH	Search
Frn	Firmware revision number	SurE ?	Sure you want to continue?
grp	Group number, sequencers	USE	Mask data, sequencers
in r	Insert rung	ZCL	Zone Control Last State
in	Insert	•	Shift key in effect
Mcr	Master Control Reset	⊢	Start of rung
nF	Not found	--_ ---_ ----	Prompt for data
P	Preset (PR) value, sequencers		

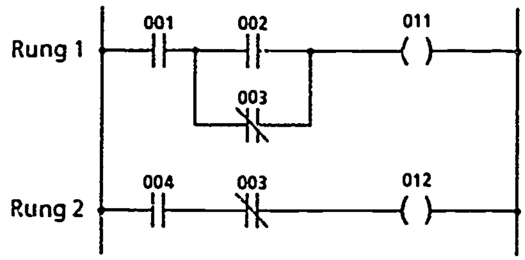
NEXT and LAST Functions



Ladder Diagram

Press these keys	This LED will be lit (PROG remains lit)	Display will show: Address Data	Display will show: Rung/Err Mode	Explanation
	PROG	875	End	After you enter the ladder diagram, there will be 875 words remaining.
LAST 7 times	-] [-	3	1	You have located the cursor on the Examine ON instruction in rung 1.
NEXT 2 times	-]/[-	⊢ 4	2	The cursor is now on the Examine OFF instruction in rung 2. The start rung symbol shown at the left in the display indicates this is the first instruction in the rung.
RUNG, NEXT	-] [-	⊢ b	3	You have moved the cursor to the first instruction in rung 3.
RUNG, LAST	-]/[-	⊢ 4	2	The cursor has returned to the first instruction in rung 2.
NEXT 2 times	-(RTO)-	901	2	You have moved the cursor to the RTO instruction in rung 2.
NEXT	-(RTO)-	50.0	Pr	The display is showing the PR value you entered earlier.
NEXT	-] [-	⊢ b	3	The cursor has moved to the next instruction in your program.
LAST	-(RTO)-	901	2	The cursor has moved back to the RTO instruction. Notice that you did not return to the PR value. You must use the NEXT key to access data.

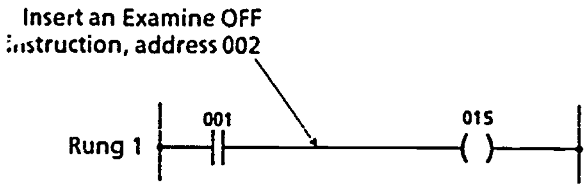
The SEARCH Function



Ladder Diagram

Press these keys	This LED will be lit (PROG remains lit)	Display will show: Address Data	Display will show: Rung/Err Mode	Explanation
	PROG	875	End	After you enter the ladder diagram, there will be 875 words remaining.
SEARCH		SrCH		You are in a search operation.
-]/[-	-]/[-	---		An Examine OFF instruction is specified. Dashes are prompting you for an address.
3	-]/[-	--3		Address 003 is entered.
ENTER	-]/[-	3	1	Search begins at cursor location. The rung number is displayed when the instruction is found.
SEARCH, ENTER	-]/[-	3	2	Pressing SEARCH, ENTER will locate the next occurrence of the specified instruction.
SEARCH		SrCH		You have initiated a new search operation.
RUNG, 1		--1		You are searching for rung 1, the start of your program.
ENTER	-] [-	⊢ 1	1	Search is completed. The cursor is on the first instruction of rung 1.
SEARCH, RUNG, 9, 9, 9		999		To find the end of the program, you enter a rung number which is certain to exceed the number of rungs in your program. 999 is a good choice.
ENTER		875	End	The cursor is at the end of your program.

The INSERT/REMOVE Functions



Ladder Diagram

Press these keys	This LED will be lit (PROG remains lit)	Display will show: Address Data	Display will show: Rung/Err Mode	Explanation
	PROG	883	End	After you enter the ladder diagram, there will be 883 words remaining.
LAST	-( )-	15	1	The cursor is positioned on the instruction following the point where the new instruction is to be.
INSERT		in		Display is prompting you to insert an instruction.
-]/[-	-]/[-	---	1	Prompt for an address.
2	-]/[-	--2	1	Address 002 is entered.
ENTER	-( )-	15	1	The instruction has been entered. The cursor has moved to the next instruction.
LAST	-]/[-	2	1	Cursor is positioned on the newly entered instruction. Now we'll remove it.
REMOVE	-]/[-	rE		Display indicates the remove function.
ENTER	-( )-	15	1	The instruction has been removed. The cursor has moved to the next instruction.
LAST	-] [-	⊢ 1	1	The cursor has moved to the first instruction in the rung, verifying the removal of the Examine OFF instruction.

EDITING AND PROGRAMMING FUNCTIONS
UNIT IV

JOB SHEET #1 — USE ERROR CODES TO IDENTIFY PROGRAMMING ERRORS

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. Three-conductor 16-gauge power cord
5. NC switches as required
6. Pen or pencil
7. Safety glasses

B. Routine #1 — Correcting invalid output addresses

1. Put on safety glasses.
2. Find the reference for address codes in the User's Manual.
3. Prepare the PLC and programmer as previously outlined.
4. Clear the programmer and put it in the program mode.
5. Look for MODE to display End and DATA to display 885.
6. Review the rung in Figure 1 before continuing.

FIGURE 1

7. Press the Examine ON key and enter address 001.

   (NOTE: Remember, you do not have to enter the lead zeros in an examine address, so you will save time by just pressing 1.)

8. Press the -( )- key and enter address 10.
9. Press ENTER.
10. Look for MODE to display E 61 and DATA to display SLC.

JOB SHEET #1

11. Turn the programmer over and note what error code 61 means:

____

12. Return to the keyboard and press CANCEL CMD.

13. Look for MODE to display 1 (rung 1) and DATA to display --- (three dashes) to indicate the prompt for an address.

14. Press 1,0 and ENTER.

15. Look for the previous error code to be displayed again.

16. Press the LAST key and note that nothing happens.

17. Press the NEXT key and note that nothing happens.

18. Press CANCEL CMD, then enter address 11 and press ENTER.

19. Look for MODE to display End and DATA to display 883 to indicate that 2 words have been used to properly program rung 1.

20. Note that rung 1 could not be programmed when the output coil was given an invalid address.

☐ Have your instructor check your work.

C. Route #2 — Correcting logic problems

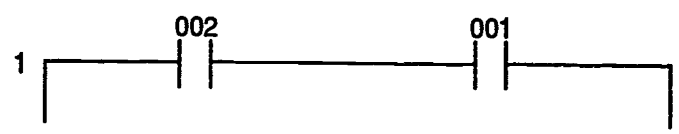
1. Put on safety glasses.

2. Clear the programmer and put it in the program mode.

3. Look for MODE to display End and DATA to display 885.

4. Review the rung in Figure 2 before continuing.

FIGURE 2



5. Press the EXAMINE ON key, then 2 to enter the address.

6. Press the EXAMINE ON key again, then 1, and then ENTER.

7. Look for MODE to display 1 (rung 1) and DATA to display -EL-.

8. Turn the programmer over and indicate whether or not you find EL under error codes: Yes _____ No _____.

JOB SHEET #1

9. Reference Transparency 4 to interpret the -EL- error indicated in the DATA window.

10. Press CANCEL CMD and note what happens: Previous command cancelled ________ Nothing happens ________.

11. Press the -( )- (output coil) key and note that MODE indicates rung 1 and the DATA prompt, - - -, is waiting for a valid output address.

12. Enter 11 and press ENTER.

13. Look for MODE to display End and DATA to display 882 to indicate that the proper logic element (EL) was entered to provide rung 1 with a valid output.

☐ Have your instructor check your work.

14. Repeat Routine #2 to see if using the LAST, NEXT keys can solve the program error or if REMOVE, INSERT can be used, and then discuss your findings with your instructor.

15. Remember that EL means you must enter a valid logic element to complete a rung.

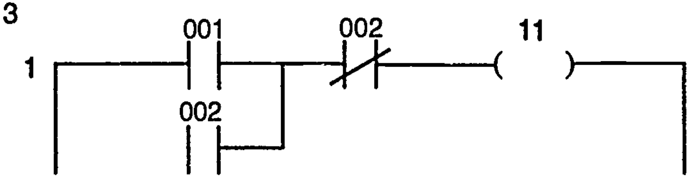
D. Routine #3 — Correcting branch error problems

1. Put on safety glasses.

2. Prepare programmer so that MODE displays End and DATA displays 885.

3. Review the rung in Figure 3 before continuing.

FIGURE 3



4. Press the Examine ON key and enter address 001.

5. Press the Branch Open key, look for the bro prompt in the DATA window, press the Examine ON key and enter the address 002.

6. Press the Branch Close key.

7. Press the Examine OFF key and enter address 002.

8. Press the output coil key and enter address 11.

9. Press ENTER.

JOB SHEET #1

11. Turn the programmer over to determine the E 65 error code and write it here:

    ____

12. Review the ladder logic diagram for rung 1 as you compare the diagram with the key strokes you used to enter it, and try to isolate the problem.

    (NOTE: Since the rung contains a branch instruction and the error code indicates it is a problem with the branch instruction, isolating the problem is easy, but to determine what is wrong with the branch instruction is the real task at hand.)

13. Press CANCEL CMD and then use the LAST key to step back through the program so you can confirm each entry.

14. Note that the Branch Close entry has been made, that the 002 address has been entered at the Examine On instruction and that the initial Examine On address 001 has been entered.

15. Remember the rule about entering branch instructions: the Branch Open instruction has to go BEFORE the first examine instruction, and you have identified the problem.

16. Clear the programmer and reprogram the rung with a Branch Open command, the Examine ON instruction, the 001 address, the Branch Open command, the Examine ON instruction, the address 002, and the Branch Close command.

    (NOTE: In a longer program, REMOVE and INSERT could be used to make corrections, but in this exercise, it's faster to erase the rung and quickly reprogram it.)

17. Follow your corrected branch instruction with standard entries to properly program the rung.

☐ Have your instructor check your work.

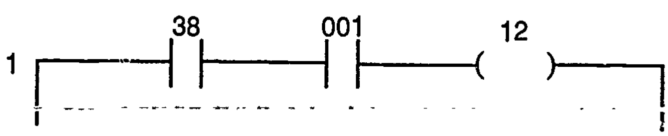
E. Routine #4 — Correcting invalid input addresses

1. Put on safety glasses.

2. Prepare the programmer so that MODE displays End and DATA displays 885.

3. Review the rung in Figure 4 before continuing.

FIGURE 4



4. Press the Examine ON key and enter address 38.

JOB SHEET #1

5. Look for MODE to display E 61 and DATA to display SLC to indicate an error.

6. Consider that only one entry has been made and isolating the error is simple: 38 is not a valid input address.

7. Check addressing codes in the User's Manual and select a valid input address, clear the programmer, and reprogram the rung using a valid input address.

☐ Have your instructor check your work.

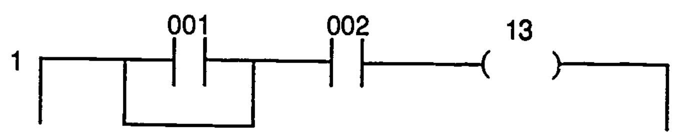
F. Routine #5 — Correcting branching errors

1. Put on safety glasses.

2. Prepare the programmer so that MODE displays End and DATA displays 885.

3. Review the rung in Figure 5 before continuing.

FIGURE 5



4. Press the Branch Open key, the Examine ON key, enter address 001, and then press the Branch Close key.

5. Press the Examine ON key and enter the 002 address.

6. Press the output coil key and address 13.

7. Press ENTER.

8. Look for MODE to display E 65 to indicate a branch error.

9. Locate the problem by going back to the branch instruction and you can quickly determine that there is no examine contact or address for a branch instruction.

   (NOTE: At this point you would normally reprogram the branch instruction, but for now, follow the routine as indicated to experience another branching problem that is frequently encountered.)

10. Clear the programmer and start over at End and 885.

11. Press the Branch Open key, the Examine ON key, and enter address 001.

12. Press the Branch Open key again and then the Branch Close key.

JOB SHEET #1

13. Press the Examine ON key and enter address 002.

14. Press the output coil key and enter address 13.

15. Press ENTER.

16. Look for MODE to display E 64 which is a different kind of branch error.

17. Review the logic diagram and your key strokes to determine why you got an E 64 error code instead of the E 65 code.

18. Note that entering the Open Branch command twice has compounded the branching problem.

19. Erase the program, give the branch instruction an Examine ON command and the address 002, and complete the program properly.

    (NOTE: Many problems with programming branches stem from the improper use of the Branch Open command coupled with the lack of an examine contact and an address.)

☐ Have your instructor check your work.

EDITING AND PROGRAMMING FUNCTIONS
UNIT IV

JOB SHEET #2 — ENTER, CONFIRM, AND REVISE AND CONFIRM A LADDER LOGIC PROGRAM

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. Three-conductor 16-gauge power cord
5. NC switches as required
6. Pen or pencil
7. Safety glasses

B. Routine #1 — Entering the program

1. Put on safety glasses.
2. Clear the programmer so that you will start with 885 words.
3. Review the ladder logic diagram in Figure 1 that accompanies this job sheet before continuing.
4. Place the Figure 1 ladder logic diagram alongside the programmer so the ladder logic elements will be easier to reference.
5. Press the Examine ON key and enter address 001 on rung 1.
6. Press the Examine ON key and enter address 002 on rung 1.
7. Press the output coil key and enter address 12.
8. Press ENTER and look for MODE to display End and DATA to indicate 882 words are left to work with.
9. Press the Examine ON key and enter address 001 on rung 2.
10. Press the output coil key and enter address 13 as the output on rung 2.
11. Press ENTER and look for MODE to display End and DATA to indicate 880 words are left to work with.
12. Press the Examine OFF key and enter address 001 on rung 3.
13. Press the Examine ON key and enter address 002 on rung 3.

JOB SHEET #2

14. Press the output coil key and enter address 14 as the output on rung 3.

15. Press ENTER and look for MODE to display End and DATA to indicate 877 words are left to work with.

16. Press the LAST key to confirm output 14 on rung 3.

17. Press the LAST key to confirm address 002 on rung 3.

18. Press the LAST key to confirm address 001 on rung 3.

19. Press the LAST key to confirm output 13 on rung 2.

20. Press the LAST key to confirm address 001 on rung 2.

21. Press the LAST key to confirm output 12 on rung 1.

22. Press the LAST key to confirm address 002 on rung 1.

23. Press the LAST key to confirm address 001 on rung 1.

24. Press the NEXT key to step the program back to the end of rung 3 until End and 877 are indicated again on the displays.

☐ Have your instructor check your work.

C. Routine #2 — Revising and confirming instructions

1. Put on safety glasses.

2. Assume that the program entered in Routine #1 needs to be revised so that it agrees with the corrected ladder logic diagram shown at the bottom of Figure 1.

3. Press the LAST key until the cursor is positioned at the Examine ON condition for address 002 on rung 1.

4. Press the REMOVE key and then ENTER.

5. Look for MODE to display rung 1 and DATA to display 12 which is the rung 1 output address.

6. Press the LAST key to verify that the Examine ON command at address 002 has been removed.

7. Look for MODE to indicate rung 1 and DATA to show the 001 address at the Examine ON command to confirm that the 002 address has been removed from rung 1.

8. Press the NEXT key until the cursor is on the output coil at address 13 on rung 2 so that the cursor is on the point following the point where you want to insert an instruction.

JOB SHEET #2

9. Press INSERT and look for the "in" display to indicate the prompt for an insert instruction.

10. Press the Examine ON key and look for MODE to indicate rung 2 and a three-dash, - - -, prompt to indicate the address should be entered.

11. Enter 002 and press ENTER.

12. Look for MODE to display rung 2 and DATA to indicate the rung 2 output coil address at 13.

13. Press the LAST key to confirm that the Examine ON command at address 002 is now on rung 2 just to the left of the output coil.

14. Press the NEXT key until the cursor is on the output coil address 14 on rung 3.

15. Press the INSERT key and look for the DATA window to display "in."

16. Press the Branch Open key, look for the bro prompt, and then press the Examine ON key and the address 003.

17. Press the Branch Close key and then ENTER.

18. Look for MODE to step back to the output coil address 14.

19. Press the LAST key to confirm the Branch Close, bnd, instruction, then LAST to confirm the 003 address, and LAST again to confirm the Branch Open, bro, instruction.

20. Press the LAST key so that the 002 address shows in the DATA display on rung 3.

21. Press INSERT key, look for the "in" prompt, and then press the Branch Open key.

22. Press ENTER and look for DATA to step back to the 002 address.

23. Press the LAST key twice to take rung 3 back to its initial 001 Examine Off address.

24. Press the NEXT key to confirm the bro (branch open) command before address 002, then press NEXT to confirm the 002 address.

25. Press NEXT again to confirm the bro (branch open) command, NEXT again to confirm the 003 address, and NEXT again to confirm the bnd (branch close) command.

26. Press NEXT to confirm the output coil address on rung 3.

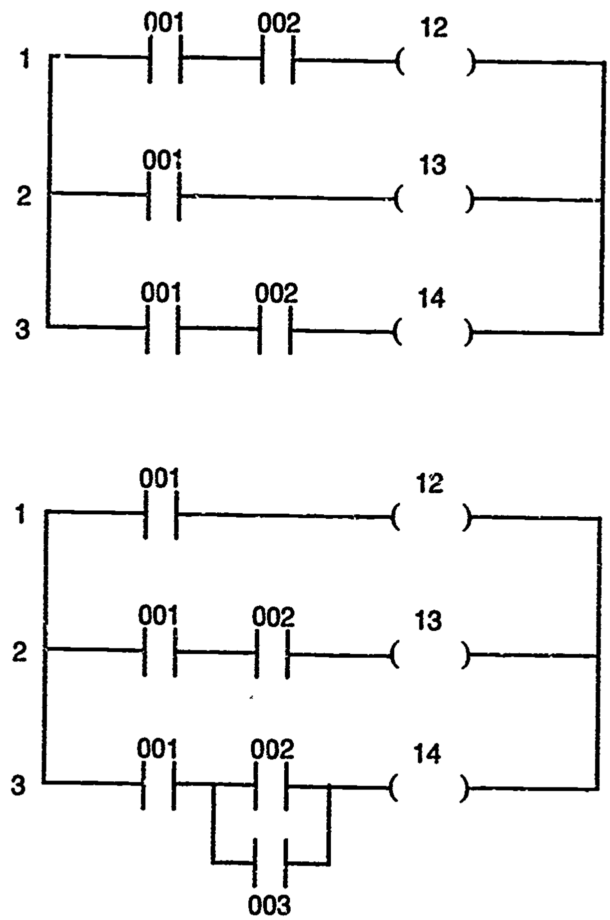
JOB SHEET #2

27. Press NEXT again for End and a final word count of 873.

☐ Have your instructor check your work.

JOB SHEET #2

FIGURE 1



EDITING AND PROGRAMMING FUNCTIONS
UNIT IV

JOB SHEET #3 — REVISE AN EVENT-DRIVEN SQO INSTRUCTION TO A TIME-DRIVEN SQO INSTRUCTION AND CONFIRM THE REVISION

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. Three-conductor 16-gauge power cord
5. NC switches as required
6. Sequencer instruction date form
7. Safety glasses

B. Routine #1 — Entering the original event-driven SQO instruction

1. Put on safety glasses.
2. Prepare the PLC and programmer as outlined in previous job sheets.
3. Clear the programmer so that MODE displays End and DATA shows 885 words.
4. Go to the sequencer data and ladder logic diagram in Figure 1 that accompanies this job sheet, and enter the SQO instruction indicated.
5. Lay the data form and ladder logic diagram alongside the programmer so that the entries will be easier to reference.
6. Press the Examine OFF key and enter address 001 on rung 1 as indicated by your ladder logic diagram.

   (NOTE: Remember that after clearing the programmer it will automatically go to rung 1 for programming.)
7. Press the SHIFT key to access the upper program function, and then press the -(SQO)- key, and then enter address 901 for the SQO instruction.
8. Press the ENTER key and watch for MODE to display a C or an E which means to select a time-driven or an event-driven option.
9. Press the SHIFT then EVENT keys to inter the event-driven command as indicated on your data form.
10. Watch for an E to come up in the programmer DATA window.

JOB SHEET #3

11. Press ENTER again and watch for MODE to display the grp prompt.

12. Press 0 to indicate the group on the data form, and then press ENTER.

13. Watch for MODE to display USE which means that the mask data from the data form should be entered at this time.

14. Press SHIFT F D to enter the mask data hex codes.

15. Press ENTER and watch for MODE to display a d 0 which means the hex data for step 0 should now be entered, so enter 9 and 9.

16. Press ENTER, watch for MODE to display P 0 and DATA to display 1 which means that the preset for step 0 is 1.

17. Press ENTER and watch for MODE to display d 1 which means that the hex data for step 1 should now be entered.

18. Press 7 and then press SHIFT D to enter the 7d hex data for step 1.

19. Press ENTER and watch for MODE to display P 1 and DATA to display 1 which is the normal default value, and in this case since 1 is also the preset value for step 1, simply press ENTER.

20. Watch for d 2 in MODE, and enter the 0 8 hex data for step 2 and press ENTER.

21. Watch for MODE to display P 2 which indicates the preset for step 2, but notice the default value in DATA is automatically 1.

22. Change the default to 2 to indicate the proper preset value for step 2 by pressing 2 and then ENTER.

23. Watch for MODE to display d 3 which means that the hex data for step 3 should now be entered.

24. Press SHIFT F and SHIFT D to enter the hex data for step 3, and then press ENTER.

25. Watch for MODE to display P 3 which indicates the preset for step 3 and the default under DATA shows a default of 1.

26. **READ THIS INFORMATION CAREFULLY BEFORE COMPLETING THE NEXT STEP:** Entering the preset of 1 for step 3 ends the program, and you would normally press ENTER. You do indeed press ENTER, but you must press ENTER two times so that the step 3 preset will be entered AND THE ENTIRE SQO instruction will be entered. Failure to press ENTER twice will lead to programming problems.

27. Press ENTER twice.

28. Watch for DATA to display 874 and MODE to display End to indicate that the sequencer program has been exited and the next rung is ready to program.

JOB SHEET #3

29. Press the Examine ON key, then press 951 to enter the 951 address on rung 2.

30. Press the -( )- key and then add address 12 to the output coil on rung 2.

31. Press ENTER and watch for DATA to display 872 and MODE to display End to indicate that rung 2 is completed and you are ready to program rung 3.

32. Press the Examine OFF instruction and enter address 002 on rung 3.

33. Press SHIFT RST and then 901 in order and press ENTER.

34. Watch for DATA to display 0 which indicates no default value, and MODE to display r A c to indicate reset is programmed.

35. Press ENTER and watch for MODE to display END and DATA to display 869 to indicate how many words have been used to complete the SQO event-driven instruction.

☐ Have your instructor check your work.

C. Routine #2 — Confirming the SQO instruction

1. Put on safety glasses.

2. Activate the NC switch which would simulate an event-driven operation.

3. Check outputs to confirm that they agree with conditions for step 0.

4. Repeat the procedure for all steps in the SQO instruction.

☐ Have your instructor check your work.

D. Routine #3 — Revising the SQO instruction

1. Put on safety glasses.

2. Assume that a tooling modification requires that the event-driven SQO instruction from Routine #1 needs to be changed to a time-driven SQO instruction complete with new addresses and presets.

3. Use the blank data instruction form in Figure 2 that accompanies this job sheet to make the new entries before you begin editing the original event-driven instruction.

   (NOTE: In reality, a program as short as the event-driven instruction could probably be completely reprogrammed faster than it can be edited, but if the event-driven instruction were part of a longer program, say a 721 word program, the editing procedure would be the time-saving option, and this exercise provides you an opportunity to edit and confirm an entire SQO instruction.)

JOB SHEET #3

4. Indicate on your new data form that you are preparing a time-driven SQO instruction at address 901 for group number 0.

5. The bit addresses in group 0 should be entered in groups of 4 from right to left starting with 11 as the first entry on the right in group A and 18 as the last entry on the left in group B.

6. Mask data should indicate with 1s that all addresses except 12 will be used in the instruction.

7. Step 0 data should indicate that address bits 18, 16, 15, and 11 must be ON to meet the conditions for step 0.

8. Step 1 data should indicate that address bits 16, 15, 14, 13, and 11 must be ON to meet the conditions for step 1.

9. Step 2 data should indicate that address bits 18, 14, and 13 must be ON to meet the conditions for step 2.

10. Step 3 data should indicate that address bits 15, 14, 13, and 11 must be ON to meet the conditions for step 3.

11. Evaluate the four-digit binary codes for mask data and enter the hex values for the program code.

12. Evaluate the four-digit binary codes for step 0 and enter the hex values for the program code.

13. Evaluate the four-digit binary codes for step 1 and enter the hex values for the program code.

14. Evaluate the four-digit binary codes for step 2 and enter the hex values for the program code.

15. Evaluate the four-digit binary codes for step 3 and enter the hex values for the program code.

16. Enter the preset values for steps 0 through 3 as follows:

    a. Step 0: 5 seconds
    b. Step 1: 15 seconds
    c. Step 2: 20 seconds
    d. Step 3: 30 seconds

    (NOTE: Be sure to reserve the far right column of the preset value for tenths of a second, the middle column for 1 through 9 seconds, and the next from left column for 10 through 99 seconds, and the far left column for 100 through 999 seconds.)

JOB SHEET #3

17. Check your new time-driven SQO instruction to make sure that all data has been properly entered and that the hex values in the program codes are what they should be.

☐ Have your instructor check your data form.

E. Routine #4 — Editing the original SQO event-driven instruction

1. Put the pocket programmer in MODE 2 for programming.
2. Check the programmer to make sure that MODE displays End and DATA shows 869 words left to work with.
3. Press LAST or NEXT as required to accomplish step 2.
4. Press the LAST key to confirm the 901 address on rung 3, then press LAST again to confirm the Examine OFF 002 address on rung 3.
5. Press LAST to confirm the output coil address 12 on rung 2 and then LAST again to confirm the Examine ON address 951 on rung 2.
6. Look for DATA to display E 901 and MODE to indicate rung 1.
7. Press SHIFT SQO and look for DATA to display a - - - (three-dash) prompt.
8. Enter the 901 address and press ENTER.
9. Look for MODE to display the C - E option and press SHIFT, TIME, look for DATA to display C to indicate the time option has been selected, and then press ENTER.
10. Look for MODE to display grp and DATA to display the former group number, 0.
11. Press ENTER to keep the group 0 number.
12. Look for MODE to display the USE prompt for the mask data program code and DATA to display Fd, and since Fd is the program code for the mask data in the new time-driven program, just press ENTER.
13. Look for MODE to display d 0 and DATA to display 99.
14. Press SHIFT B and 1 and then ENTER to insert the new program code for step 0.
15. Look for MODE to display P 0 to prompt for the preset entry for step 0.
16. Note that the DATA display shows .1 of a second, so to enter the 5 second preset for step 0, pres 5, 0 and then ENTER.
17. Look for MODE to display d I and DATA to display the event-driven program code of 7d.

JOB SHEET #3

18. Press 3, SHIFT F and then ENTER to insert the new program code for step 1.

19. Look for MODE to display P 1 to prompt for the preset entry for step 1.

20. Press 1, 5, 0 and then ENTER to enter the new time-driven preset for step 1.

21. Look for MODE to display d 2 and DATA to display the event-driven program code of 0 8.

22. Press 8, SHIFT C and then ENTER to insert the new program code for step 2.

23. Look for MODE to display P 2 to prompt for the preset entry for step 2.

24. Press 2, 0, 0, and then ENTER to insert the new time-driven preset for step 2.

25. Look for MODE to display d 3 and DATA to display the event-driven program code of Fd.

26. Press 1, SHIFT D and then ENTER to insert the new program code for step 3.

27. Look for MODE to display P 3 to prompt for the preset entry for step 3.

28. Press 3, 0, 0 and then ENTER to insert the new time-driven preset for step 3.

29. Look for MODE to display d 4 and press ENTER again.

30. Look for DATA to display the Examine ON address 951 on rung 2.

31. Press LAST to confirm the time-driven SQO at address 901 on rung 1.

32. Press NEXT to confirm grp O.

33. Press NEXT to confirm FD as the mask data (USE) program code.

34. Press NEXT to confirm the B1 program code for step 0.

35. Press NEXT to confirm the 5.0 second preset for step 0.

36. Press NEXT to confirm the 3D program code for step 1.

37. Press NEXT to confirm the 15.0 second preset for step 1.

38. Press NEXT to confirm the 8C program code for step 2.

39. Press NEXT to confirm the 20.0 second preset for step 2.

40. Press NEXT to confirm the ID program code for step 3.

JOB SHEET #3

41. Press NEXT to confirm the 30.0 second preset for step 3.

42. Press NEXT and look for the instruction to step to the Examine ON 951 address on rung 2 and confirm that the new time-driven SQO instruction has been completed.

☐ Have your instructor check your program.

F. Routine #5 — confirming the time-driven SQO instruction

1. Put on safety glasses.

2. Activate the NC switch that initiates the program.

3. Look for the DATA display to indicate the elapsed time in each step as the MODE display indicates the accumulated value of each step.

4. Watch for output LEDs on the PLC to light and indicate step conditions for each time segment are met.

5. Listen for the instruction to step forward at the end of each time segment.

6. Watch for the complete SQO instruction to reach completion of the cycle at the end of the 30.0 second preset for step 3, and then reset to step 0 and start the sequence again.

☐ Have your instructor check your work.

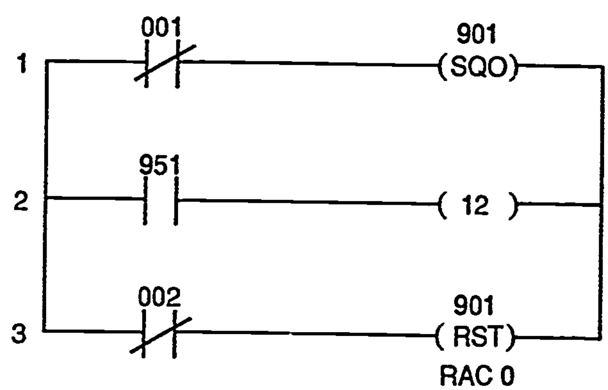
JOB SHEET #3

FIGURE 1

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)-   ADDRESS: 901   ☐ TIME DRIVEN ☒ EVENT DRIVEN   GROUP NUMBER: 0

BIT ADDRESS DATA	B				A				PROGRAM CODE		PRESET VALUES
Bit Addresses →	18	17	16	15	14	13	12	11	Data B	Data A	
Mask Data →	1	1	1	1	1	1	[illegible]	1	F	D	
Step Data → 0	1	0	0	1	1	0	X	1	9	9	1
1	0	1	1	1	1	1	X	1	7	D	1
2	0	0	0	0	1	0	X	0	0	8	2
3	1	1	1	1	1	1	X	1	F	D	1
4											
5											
6											
7											
8											
9											
10											



Data Form courtesy Allen-Bradley

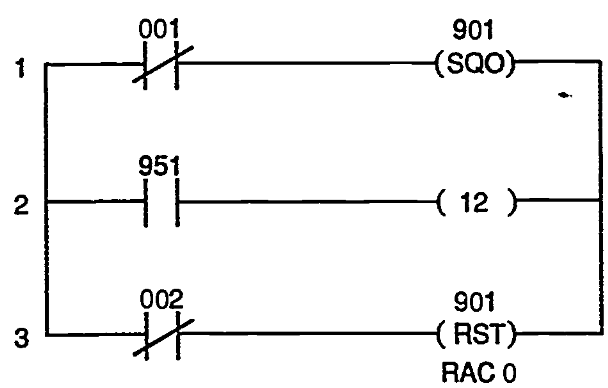
JOB SHEET #3

FIGURE 2

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☐ -(SQO)- ADDRESS: ____ ☐ TIME DRIVEN ☐ EVENT DRIVEN GROUP NUMBER: ____

BIT ADDRESS DATA									PROGRAM CODE		PRESET VALUES			
	B				A				Data B	Data A				
Bit Addresses →														
Mask Data →														
Step Data → 0														
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														



Data Form courtesy Allen-Bradley

EDITING AND PROGRAMMING FUNCTIONS
UNIT IV

JOB SHEET #4 — DETERMINE PROGRAM SCAN TIME IN MILLISECONDS AND WRITE A FINE TIME PROGRAM

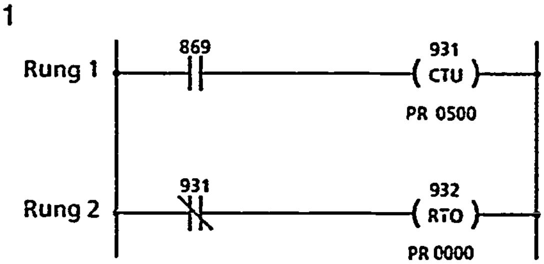
A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. Pencil and paper
5. Previously confirmed ladder logic program
6. Safety glasses

B. Routine #1 — Determining program scan time in milliseconds

1. Put on safety glasses.
2. Set up PLC and programmer as previously instructed.
3. Enter any previously ladder logic program you have used into the controller.
4. Add the following two rungs to the end of your program:

FIGURE 1



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5. Enter Mode 5, the test-continuous scan mode, and immediately turn off the programmer so that scan time measurement will be more accurate.
6. Leave the programmer off for at least two minutes to make sure that scan time is complete and that RTO 932 has measured the time it takes to perform 1000 scans.

   (NOTE: For a typical program, the scan time will be 15 seconds which is 15 milliseconds x 1000.)

7. Turn the programmer back on and monitor the AC value of the RTO instruction at address 932, and enter the value here: __________.

JOB SHEET #4

8. Subtract 1.0 millisecond from the value recorded in Step 7 to make up for the added 0.5 millisecond scan time of the rungs added to your program and another 0.5 millisecond scan time added by sub routines in the test mode, and enter that value here: ___________.

9. Subtract the value in Step 8 from the value in Step 7 to determine your program scan time and enter the scan time here: ___________.

   (NOTE: If you need to repeat the measurement, you have to reset counter 931 and timer 932 to zero.)

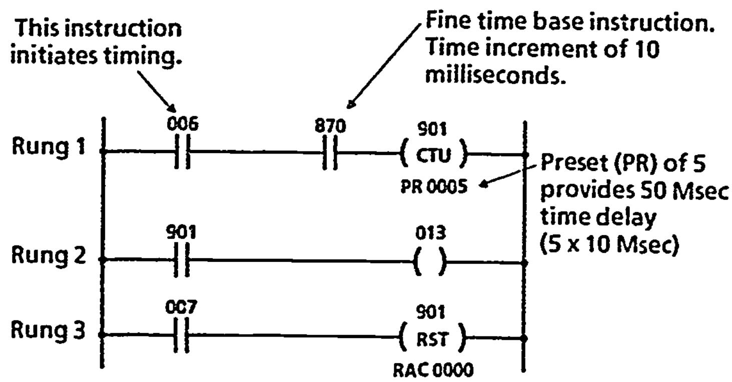
☐ Have your instructor check your work.

C. Routine #2 — Programming the fine time instruction

1. Delete the final two scan-time rungs you added to your original program.

2. Add the following three rungs to your program: (Figure 2)

   FIGURE 2



3. Change the address of the 870 fine time instruction as required or if required to an address compatible with the following values:

   a. If your scan time in milliseconds was less than 5.0, use 870.

   b. If your scan time in milliseconds was 5.0 to 9.9, use 871.

   c. If your scan time in milliseconds was 10.0 to 19.9, use 872.

   d. If your scan time in milliseconds was 20.0 to 39.9, use 873.

4. Enter the PR value for the 901 CTU on rung 1 according to the following:

   a. If your fine time instruction is 870, make the PR value 0005 so that you will have a scan time of 5 x 10 ms or 50 ms.

JOB SHEET #4

b. If your fine time instruction is 871, make the PR value 0003 so that you will have a scan time of 3 x 20 ms or 60 ms.

c. If your fine time instruction is 872, make the PR value 0002 so that you will have a scan time of 2 x 40 ms or 80 milliseconds.

d. If your fine time instruction is 873, make the PR value 0001 so that you will have a scan time of 1 x 80 ms or 80 milliseconds.

(NOTE: The PR values selected reflect an effort to improve the scan time from the 100 ms available with normal timing to a rate below 100 ms. If a new scan rate of 50 milliseconds is the most desireable, the PR figures given in the selections reflect the PR that will come closest to the 50 ms mark without falling below it.)

5. Enter the fine time program into the processor.

6. Confirm the program and then monitor the RAC value of the 901 RST in rung 3 to confirm the new scan time.

7. Write the new scan time here: ___________.

☐ Have your instructor check your work.

8. Return tools and equipment to proper storage.

EDITING AND PROGRAMMING FUNCTIONS
UNIT IV

PRACTICAL TEST #1

JOB SHEET #1 — USE ERROR CODES TO IDENTIFY PROGRAMMING ERRORS

Student's name ______________________________ Date ______________

Evaluator's name ______________________________ Attempt no. __________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" boxes to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	Yes	No
1. Prepared programmer properly.	☐	☐
2. Corrected invalid output addresses.	☐	☐
3. Corrected logic problems.	☐	☐
4. Corrected branch error problems.	☐	☐
5. Corrected invalid input addresses.	☐	☐
6. Corrected branching errors.	☐	☐
7. Returned tools and equipment to storage.	☐	☐
8. Worked safely.	☐	☐

Evaluator's comments: ____

____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Programmer Preparation	Excellent 4	Good 3	Poor 2	Unacceptable 1
Output address correction	Complete 4	Acceptable 3	Poor 2	Unacceptable 1
Input address correction	Complete 4	Acceptable 3	Poor 2	Unacceptable 1
Branch error corrections	Complete 4	Acceptable 3	Poor 2	Unacceptable 1

EVALUATOR'S COMMENTS: ______________________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

EDITING AND PROGRAMMING FUNCTIONS
UNIT IV

PRACTICAL TEST #2

JOB SHEET #2 — ENTER, CONFIRM, AND REVISE AND CONFIRM A LADDER LOGIC PROGRAM

Student's name ______________________________ Date ______________

Evaluator's name ____________________________ Attempt no. __________

> Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" boxes to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	Yes	No
1. Prepared programmer properly.	☐	☐
2. Entered initial program properly.	☐	☐
3. Confirmed initial entries.	☐	☐
4. Revised instructions properly.	☐	☐
5. Confirmed revised instructions.	☐	☐
6. Returned tools and equipment to storage.	☐	☐
7. Worked safely.	☐	☐

Evaluator's comments: ____

____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

Programmer preparation	Excellent 4	Good 3	Poor 2	Unacceptable 1
Initial program entries	Excellent 4	Good 3	Poor 2	Unacceptable 1
Revised program entries	Excellent 4	Good 3	Poor 2	Unacceptable 1
Confirmation of revisions	Excellent 4	Good 3	Poor 2	Unacceptable 1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

EDITING AND PROGRAMMING FUNCTIONS
UNIT IV

PRACTICAL TEST #3

JOB SHEET #3 — REVISE AN EVENT-DRIVEN SQO INSTRUCTION TO A TIME-DRIVEN SQO INSTRUCTION AND CONFIRM THE REVISION

Student's name ______________________ Date ____________

Evaluator's name ______________________ Attempt no. ________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" boxes to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	Yes	No
1. Prepared programmer properly.	☐	☐
2. Entered the event-driven SQO instruction.	☐	☐
3. Confirmed the SQO instruction.	☐	☐
4. Revised the SQO to a time-driven instruction.	☐	☐
5. Edited the original SQO instruction.	☐	☐
6. Confirmed the time-driven SQO instruction.	☐	☐
7. Returned tools and equipment to storage.	☐	☐
8. Worked safely.	☐	☐

Evaluator's comments: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Programmer preparation	Excellent 4	Good 3	Poor 2	Unacceptable 1
Initial SQO entry	Complete 4	Acceptable 3	Poor 2	Unacceptable 1
Revision and editing	Well done 4	Acceptable 3	Unsure 2	Unacceptable 1
Confirmation of revision	Complete 4	Acceptable 3	Poor 2	Unacceptable 1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

EDITING AND PROGRAMMING FUNCTIONS
UNIT IV

PRACTICAL TEST #4

JOB SHEET #4 — DETERMINE PROGRAM SCAN TIME IN MILLISECONDS AND WRITE A FINE TIME PROGRAM

Student's name ______________________________ Date ____________________

Evaluator's name ____________________________ Attempt no. ______________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Prepared programmer properly.	☐	☐
2. Entered new program.	☐	☐
3. Added CTU and RTO instructions.	☐	☐
4. Monitored and recorded scan time.	☐	☐
5. Programmed fine time instructions.	☐	☐
6. Verified fine time program.	☐	☐
7. Returned tools and equipment to storage.	☐	☐
8. Worked safely.	☐	☐

Evaluator's comments: ____

____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

Programmer Preparation	Excellent 4	Good 3	Poor 2	Unacceptable 1
Scan time computation	Complete 4	Acceptable 3	Poor 2	Unacceptable 1
Fine time programming	Complete 4	Acceptable 3	Poor 2	Unacceptable 1
Fine time verification	Complete 4	Acceptable 3	Poor 2	Unacceptable 1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — **Skilled**—Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile total the designated points in "Product Evaluation" and divide by the total number of criteria.)

EDITING AND PROGRAMMING FUNCTIONS
UNIT IV

TEST

NAME_______________________________________ SCORE ____________________

1. Match the terms on the right with their correct definitions.

_____ a.	The process of monitoring a PLC program and changing program parameters as required to correct or enhance performance	1. Keyboard
_____ b.	Any instruction or part of an instruction that sets up a condition which must be met at any point in the execution of a program	2. Editing
_____ c.	A device, often hand-held, where keys coded with program symbols may be pressed in selected order to write a program	3. Program
_____ d.	The combination of commands input from a programmer and stored in PLC memory to set the conditions that must be met for a control objective to be accomplished	4. Parameter

2. Select true statements concerning pocket programmer abbreviations and symbols by placing an X beside each statement that is true.

_____ a. Programming requires the preparation of data and a ladder logic diagram that can be referenced as program entries are made.

_____ b. Programmer keys display abbreviations and symbols to help make program entries logical and easy.

_____ c. Programmer keys also serve the purpose of permitting a programmer to monitor a program step by step and rung by rung.

_____ d. Programmer keys also permit a programmer to delete, change, or add to a program and this process is generally called reprogramming.

_____ e. Certain programmer keys are reserved for editing functions and their proper use is essential in program evaluation and troubleshooting.

TEST

3. Select conditions concerning the pocket programmer display by answering the following questions.

   a. The pocket programmer is a good troubleshooting tool because it specifically locates problems how, by lighting LEDs on the display or by generating error codes?

   Answer ______________________________

   b. The pocket programmer display indicates the status of an address function by doing what, showing it in the DATA window or lighting or not lighting an LED on the display?

   Answer ______________________________

   c. The device that moves to each function on command and indicates that function by lighting an LED is called what, an indicator or a cursor?

   Answer ______________________________

4. Select true statements concerning keyboard editing by placing an X beside each statement that is true.

   ______ a. The need for editing evidences itself when initial review of a program indicates an error or when the program indicates editing is required by lighting the EDIT LED.

   ______ b. Editing functions range from correction of improper entries to complete program changes.

   ______ c. The ability to edit is a skill that a good PLC programmer must have to evaluate new programs and to troubleshoot existing programs.

   ______ d. The editing process begins with an understanding of keyboard functions reserved for editing and how to use those functions to meet program demands.

5. Select conditions concerning program modes and display modes by answering the following questions.

   a. A program mode can be selected by what, pressing the MODE key only or pressing the MODE key and a number?

   Answer ______________________________

   b. To clear the programmer, one would use which mode, 1 or 2?

   Answer ______________________________

   c. To monitor or change a program requires putting the programmer in mode 3 which is also called what, the test mode or the run mode?

   Answer ______________________________

TEST

6. Complete statements concerning the CANCEL CMD and error codes by circling the material that best completes each statement.

   a. Since it's relatively easy to press a wrong key or number, the (CANCEL CMD) (ERROR) key provides a quick remedy for erasing improper commands.

   b. The (CANCEL CMD) (ERROR) function can be used as long as the cursor position has not been moved ahead, back, or to another instruction.

   c. The CANCEL CMD function can also be used to erase any previous commands to the left so long as the CANCEL CMD key is pressed (in order as often as required) (only once).

   d. When an inadvertent error is made in programming, the display will light to indicate a programming error which can be erased with (CANCEL CMD) (MODE1).

   e. Internal processor errors are indicated by a (rung) (CPU) Fault LED that lights on the display, and the CANCEL CMD will not correct these errors because all outputs will be disabled.

7. Select conditions concerning NEXT and LAST key functions by answering the following questions.

   a. The NEXT and LAST keys permit a programmer to do what, monitor a single function or move back and forth in a complete program?

      Answer ________________________________

   b. The NEXT key moves the cursor to the following instruction which is to say the cursor moves where, right or left?

      Answer ________________________________

   c. The LAST key moves the cursor to the last instruction which is to say the cursor moves where, right or left?

      Answer ________________________________

   d. Can access to data for timers, counters, and sequencers be gained by using the NEXT and LAST keys?

      Answer ________________________________

8. Select true statements concerning the SEARCH function by placing an X beside each statement that is true.

   (NOTE: For a statement to be true, all parts of the statement must be true.)

   ______ a. The SEARCH key provides time-saving access to any point in a program.

______ b. To search for a specific instruction, find the instruction, then press SEARCH, ENTER and the programmer will find the next place in the program where that instruction appears.

______ c. To move to a specific rung, press SEARCH, RUNG and then the rung number.

______ d. The NEXT and LAST functions can be combined with SEARCH as follows:

1) To move to the start of a rung, press SEARCH, NEXT.

2) To move to the end of a rung, press SEARCH, LAST.

______ e. For checking a specific sequencer step, locate the cursor on any sequencer data, SQO or SQI, press SEARCH, then the step number, and ENTER.

______ f. The SEARCH function is a handy editing tool for quickly finding specific instructions or the start or end of a program.

9. Solve problems concerning the INSERT/REMOVE functions by answering the following questions.

a. You have found an instruction that is in error; where would you place the cursor to use the REMOVE function?

Answer ____

b. You want to insert a new instruction, so where should the cursor be in relation to the INSERT instruction?

Answer ____

10. Complete statements concerning the PRT/UNPRT functions by circling the material that best completes each statement.

a. The PRT function protects the (AC) (PR) value of a timer or counter while other changes are being made.

b. Locate the cursor on the PR value and press the PRT key to protect the PR value which will also protect the (AC value) (entire rung).

c. The UNPRT function will (return a PR value to an unprotected state) (keep a PR value protected).

d. Locate the cursor (on the PR value) (to the left of the PR value) and press the UNPRT key to remove the protected status of the PR and AC values.

TEST

11. Select conditions concerning the FRC ON/FRC OFF functions by answering the following questions.

    a. The advantage of a force command is that it can force an external I/O address to an ON or OFF state under what circumstances, when it is ON or regardless of its actual status?

    Answer ______________________________

    b. The force functions are valuable troubleshooting tools because they permit monitoring and changing a program while it is what, on hold or running?

    Answer ______________________________

    c. To avoid personal injury or equipment damage, the effects of machine operation should always be examined when, during a force function or prior to a force function?

    Answer ______________________________

12. Complete statements concerning one-shot instructions by circling the material that best completes each statement.

    a. A one-shot instruction works for only one scan cycle and is used to (initialize) (check) a program to a known state on power up.

    b. A one-shot instruction can be an effective troubleshooting tool (after a system shut down) (when editing).

    c. With the SLC™100, the one-shot is called a (one-scan) (fast-scan) instruction and will work when power is switched on to the processor unit in the run or test modes or when the programmer is used to place the processor unit in the run or test modes.

    d. The bit address (868) (686) can be set ON for the first and only the first program scan to initialize timers, counters, or latch instructions.

13. Select true statements concerning fine time instructions by placing an X beside each statement that is true.

    ______a. Standard timers have a resolution of 0.1 second, but this resolution can be speeded up when an application requires faster timing.

    ______b. Faster timing resolution on the SLC™100 is accomplished by programming an up counter with a special instruction that provides a corresponding time increment.

    ______c. The special internal address used for fine timing requires that you know all internal addresses for timers and counters.

TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask you instructor when they should be completed.)

14. Demonstrate the ability to:

    a. Use error codes to identify and correct programming errors. (Job Sheet #1)

    b. Enter, confirm, and revise and confirm a ladder logic program. (Job Sheet #2)

    c. Revise an event-drive SQO instruction to a time-driven SQO instruction and confirm the revision. (Job Sheet #3)

EDITING AND PROGRAMMING FUNCTIONS
UNIT IV

ANSWERS TO TEST

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

2. a, b, c, e

3. a. By generating error codes
   b. Lighting or not lighting an LED on the display
   c. A cursor

4. b, c, d

5. a. Pressing the MODE key and a number
   b. 1
   c. The run mode

6. a. CANCEL CMD
   b. CANCEL CMD
   c. In order as often as required
   d. CANCEL CMD
   e. CPU

7. a. Move back and forth in a complete program
   b. Right
   c. Left
   d. Yes

8. a, b, c, e, f

9. a. On the instruction to be removed
   b. On the instruction following the point where the instruction will be inserted

10. a. PR
    b. AC value
    c. Return a PR value to an unprotected state
    d. On the PR value

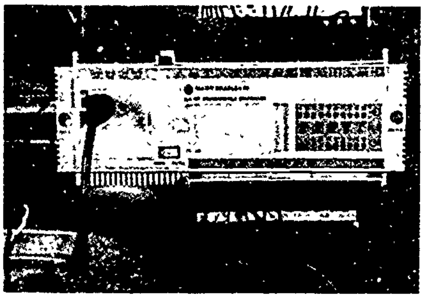
ANSWERS TO TEST

11. a. Regardless of its actual status
    b. Running
    c. Prior to a force function

12. a. Initialize
    b. After a system shut down
    c. One-scan
    d. 868

13. a, b

14. a. Evaluated according to criteria in Practical Test #1
    b. Evaluated according to criteria in Practical Test #2
    c. Evaluated according to criteria in Practical Test #3
    d. Evaluated according to criteria in Practical Test #4



INSTALLATION
AND
TROUBLESHOOTING
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss the importance of enclosures in PLC installations, how to wire PLC inputs and outputs, and the requirements for grounding and a master control relay. The student should also be able to troubleshoot PLC malfunctions and program force functions to isolate system problems. These competencies will be evidenced by correctly completing the procedures in the job sheets, and by scoring a minimum of 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to installation and troubleshooting with their correct definitions.
2. Select true statements concerning enclosure standards.
3. Complete statements concerning guidelines for PLC enclosures.
4. Solve problems concerning installing a PLC.
5. Solve problems concerning wiring incoming power to a PLC.
6. Select conditions concerning wiring input devices to a PLC.
7. Select conditions concerning wiring output devices to a PLC.
8. Complete statements concerning grounding PLC systems.
9. Select statements concerning emergency shutdown systems for PLCs.
10. Select true statements concerning other installation considerations.
11. Select conditions concerning inspection before start-up.
12. Select true statements concerning guidelines for system start-up.
13. Complete statements concerning troubleshooting guidelines.

SPECIFIC OBJECTIVES

14. Select conditions concerning power supply troubleshooting.
15. Solve problems concerning back-up battery troubleshooting.
16. Complete statements concerning PLC maintenance.
17. Demonstrate the ability to:
    a. Use a force function to verify an input. (Job Sheet #1)
    b. Use a force function to verify an output. (Job Sheet #2)
    c. Use FRC ON/FRC OFF functions for troubleshooting. (Job Sheet #3)
    d. Replace the power supply fuse on a PLC. (Job Sheet #4)
    e. Replace the back-up battery on a PLC. (Job Sheet #5)

INSTALLATION AND TROUBLESHOOTING
UNIT V

SUGGESTED ACTIVITIES

Read Me First

Procedures in this text are presented for demonstration only and should not be used in actual industrial applications. Graphic materials from manufacturers are presented for the purpose of illustration only and no liability is assumed for their use otherwise. Persons using this text assume liability for demonstration and for any equipment damaged in demonstration. Administration of these materials should be by a qualified instructor only in a safety-proven environment.

A. Provide students with objective sheet.

B. Provide students with information sheet.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Check with local codes or responsible agencies to determine the disposal procedure for lithium batteries.

H. Give test.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *A Study Guide to Programmable Controllers.* Chattanooga, TN 37405: Tel-A-Train, Inc., 1984.

B. Atrich, Walter M. *Electric Motor Controls (Fourth Edition).* Albany, NY: Delmar Publishers, 1988.

C. *User's Manual Bulletin 1745 SLC™100 Programmable Controller.* Milwaukee, WI 43204: Allen-Bradley Company, 1985.

INSTALLATION AND TROUBLESHOOTING
UNIT V

INFORMATION SHEET

I. Terms and definitions

A. **Constant voltage transformer** — A transformer that holds voltage level within ±5V AC for applications where extreme voltage variances could be harmful to equipment

B. **DIN (Deutsche Industrie Normen)** — A registered mark of the German Institute for Standardization used to indicate a variety of manufacturing standards

C. **Isolation transformer** — A transformer that separates a piece of equipment from other equipment on a common feeder, but does not change voltage levels

D. **Master control relay** — A hard-wired circuit designed to cut off power quickly in the event of an operating emergency

E. **Surge suppressor** — A device installed in coils of relays, contactors, and motor starters to protect against voltage spikes and transients when coil circuits are opened

F. **Transient** — High voltage created across contacts of an inductive device when it is switched off

II. Enclosure standards

A. Enclosures are the cabinet-like boxes that house electrical switches and other controls and protect them from their environments.

B. Enclosures for electrical equipment, including PLCs, must meet standards set by NEMA (The National Electrical Manufacturers Association), NEC (The National Electrical Code), and local electrical codes.

C. Enclosure standards vary depending on the application and an enclosure for indoor service is different from an outdoor enclosure that will be subjected to rain, windblown dust, icing, and other critical weather and service conditions.

D. Enclosures are basically designed to protect electrical equipment from contaminants such as dust and moisture, but certain enclosures have special designs for protection from hazardous gas and industrial corrosives.

E. All enclosures should meet standards set for the environment where they are installed, and safety for operators and equipment should be the most important considerations in selecting an enclosure.

III. Guidelines for PLC enclosures

A. To make maintenance and troubleshooting easier, a PLC enclosure must be mounted so that its doors can be opened 90 degrees.

INFORMATION SHEET

B. A PLC enclosure should be large enough that the controller and add-on modules can be placed far enough apart to safely dissipate heat.

C. When heat from nearby equipment poses a heat problem, a blower-type fan should be installed to help dissipate heat in the enclosure.

D. To control contaminants, cooling air introduced into a PLC enclosure should be filtered, and filters should be cleaned or changed at specified intervals.

E. PLC enclosures should be placed in locations where they will not be affected by vibrations from other equipment.

F. When an emergency disconnect switch is mounted inside an enclosure, the switch operating handle should be outside the enclosure so an operator can reach it without having to open the enclosure.

IV. Installing a PLC

A. By drilling and tapping holes at proper spacings, a PLC and its expansion modules can be mounted directly to the back panel of an enclosure.

B. When drilling holes through an enclosure, be sure that no power bus or power cable is behind the points where holes will be drilled.

C. An option for PLC mounting is to use a standard DIN mounting rail which can be screwed or welded to the back panel of the enclosure.

D. Using 35mm x 7.5mm DIN mounting rails permits snap-in mounting of a PLC and expansion modules, and saves maintenance and troubleshooting time when devices have to be removed.

E. When expansion units are installed with a PLC, they should be spaced far enough apart to allow for heat dissipation. (Transparency 1)

(NOTE: Transparency 1 shows spacing configurations recommended by Allen-Bradley for the SLC™100 PLC with three expansion units.)

V. Wiring incoming power to a PLC

A. Many future problems with a PLC installation can be averted by first making sure that there are no excessive line voltage variations in the incoming power source.

(NOTE: A constant voltage transformer can be used to correct voltage variations, and that process will be discussed in a later objective.)

B. To help minimize electrical interference, the controller power supply should have the same power source as the input and output devices.

C. Route incoming power to the processor and expansion units by a separate path from wiring to I/O devices.

INFORMATION SHEET

D. Do not run power wiring and signal wiring in the same conduit, and if their paths must cross, be sure the intersections are perpendicular.

E. Make sure 115VAC, 230VAC or 24VDC power wires are connected to the proper incoming line terminals and that ground connections are properly made through the chassis ground to the grounding bus in the enclosure. (Transparency 2)

(NOTE: Transparency 2 shows incoming line terminals and grounding requirements for the SLC™100.)

F. Input terminal coverplates on the SLC™100 are color coded according to voltage: (Transparency 3)

1. 115VAC is red.
2. 230VAC is black.
3. 24VDC is blue.

VI. Wiring input devices to a PLC

A. Before installing and wiring I/O devices, disconnect power from the controller and any other power source to I/O devices.

B. For input devices with different signal characteristics, wiring into the enclosure should be routed along separate paths.

C. Wiring with similar electrical characteristics can be bundled together.

D. All input wiring should be labeled with tape or shrink tubing or wires can be used so that the insulation color denotes service.

Example: DC I/O wiring might be blue and AC I/O wiring could be red.

E. If wiring ducts or terminal strips are used they should be kept at least 2 inches away from each other and the processor and expansion units.

F. As inputs are wired, identify terminals on the write-on area of the terminal coverplates.

G. Input wires may be jumpered between terminals of the same voltage.

H. Most PLCs will accept 115VAC, 230VAC, or 24VDC input, and a rule of thumb is to match input voltage with output voltage.

VII. Wiring output devices to a PLC

A. Before installing and wiring I/O devices, disconnect power from the controller and any other power source I/O devices.

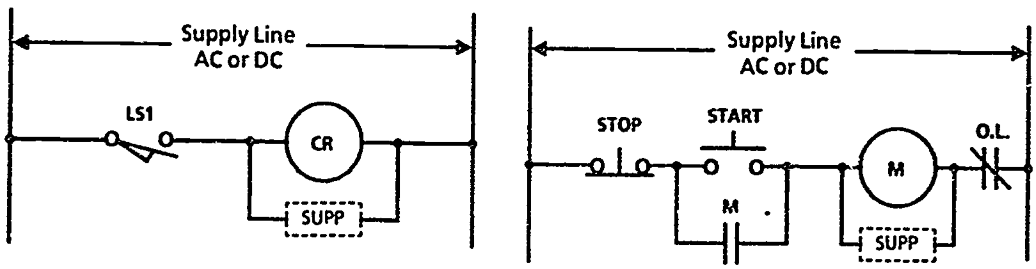
B. Tag output wiring or use insulation colors to match outputs to inputs.

INFORMATION SHEET

C. Inductive output devices such as motor starters and solenoids can cause arcing at output contacts if the output circuits are not protected with some type of surge suppression.

D. Surge suppression circuits should be connected directly across the output device and located as close to the output device as possible. (Figure 1)

FIGURE 1



E. Transient conditions for output devices vary with application, and surge suppressors should be properly rated.

F. For AC output devices, Allen-Bradley recommends a varistor, RC network, or a surge suppressor, and for DC output devices, a diode, varistor, or surge suppressor. (Transparency 4)

G. Noise suppression circuits may be required for high frequency welding or large AC motor installations that generate high noise levels, and noise suppression circuits should be located as close to the devices as possible.

H. Output devices should be protectec from short circuits and overloads with properly selected fuses.

I. As a rule of thumb, output voltages should match input voltages.

VIII. Grounding PLC systems

A. Every PLC application should have the controller and enclosure grounded to an equipment grounding conductor.

B. Ground connections should run from the chassis ground terminal on each processor and each expansion unit to a grounding bus.

C. Each controlled device in a PLC system should be grounded so that each device has a separate path to the grounding conductor.

D. To ensure proper grounding, scrape paint away from points where the processor or expansion units meet the enclosure.

E. Ground wires can be jumpered between sets of terminals as desired.

F. Grounding must meet local codes as well as NEC standards.

INFORMATION SHEET

G. The first reason for a properly grounded system is safety to personnel and equipment, but with the solid state structure of PLCs, grounding also limits the effect of noise generated by EMI (electromagnetic induction).

IX. Emergency shutdown systems for PLCs (Transparency 5)

A. When a PLC operation poses danger to personnel or equipment, there must be a means for quickly shutting the system down.

B. A hard-wired master control relay is the safest, fastest way to execute emergency shutdown.

C. An effective master control relay should have emergency stop switches in locations that can be quickly and easily reached.

D. Emergency stop switch placement is frequently controlled by local codes, but in all cases they should be highly visible, properly labeled, and in clear, open access.

E. An emergency stop switch must have a mushroom head.

F. Overtravel limit switches, emergency stop switches, interlocks, and other devices in a master control relay system should be wired in series so that when any one device opens, the master control relay will de-energize and remove power to the system.

G. Even with power to I/Os removed, a properly designed master control relay will continue to provide power to the controller so that diagnostic indicators can still be monitored and force functions can still be executed.

H. Emergency stop switches should never be programmed into a PLC program.

X. Other installation considerations

A. When voltage variations from a power source are difficult to control, a constant voltage transformer can be used.

B. When a constant source transformer is used, it must have a sufficient power rating for its load.

C. The transformer should be connected to the controller power supply and all input devices connected to the PLC.

D. When a constant voltage transformer is used, output devices should be connected to the same power line, but their connections should be made along the power line before the location of the transformer.

E. It is important to use the correct wire gauge for all wiring, and #14 AWG (American Wire Gauge) stranded wires are recommended.

F. *DO NOT* install power wires, input wires, or output wires when a controller is under power.

INFORMATION SHEET

G. *DO NOT* run testing or troubleshooting routines without notifying all personnel in the area what will be happening, and make sure someone is standing by to operate the master control relay if emergency shut-down is required.

H. *DO NOT* disable the master control relay or any associated emergency stop switches for any reason.

I. *DO NOT* use a metal rod to disable I/O devices: use a wooden stick such as a flat, wooden yard-long ruler rigid enough to do the job and long enough to keep a person safely away from motion-causing devices.

XI. Inspection before start-up (Transparency 6)

A. Before running a program in a newly installed system, the installation should be inspected to make sure the controller and other devices are securely mounted.

B. Inspect all wiring to the processor, expansion units, inputs and outputs, and master control relay.

C. Check all connections and terminals to make sure wires are secure.

D. Measure incoming line voltage to make sure it corresponds to controller requirements.

E. Check the installation for proper spacing of terminal blocks or wiring ducts and for the correct positioning of suppression devices.

F. If an isolation transformer and/or a constant voltage transformer are used, check for proper circuit wiring.

XII. Guidelines for system start-up

A. After the inspection before start-up and before power is connected, disconnect motors and all other motion-causing devices.

(NOTE: Procedures for properly disconnecting motion-causing devices are covered in the job sheets that accompany this unit of instruction.)

B. Test inputs by entering a test rung and manually opening and closing the addressed input device in a safe manner.

C. Test output devices by using the pocket programmer to force instructions.

(NOTE: Testing inputs and outputs will be presented in the job sheets that accompany this unit of instruction.)

D. Enter and verify a test program.

E. Reconnect the motion-causing devices and check the system again.

F. Make a dry run of the total application.

INFORMATION SHEET

XIII. Troubleshooting guidelines

A. Troubleshooting a PLC should begin by taking advantage of the diagnostic powers built into the controller and the programmer.

B. Diagnostics should quickly isolate the problem and identify the source which will usually be:

1. In the controller or the expansion unit.

2. In wiring or cables connecting devices.

3. In input or output devices.

C. When a problem is isolated in the controller or expansion unit, the problem is usually in the power supply or a fault within the unit itself.

D. Wiring problems and input/output problems can be isolated with troubleshooting routines using force functions.

(NOTE: Force functions are demonstrated in the job sheets that accompany this unit of instruction.)

E. When input/output devices are at fault, the problem can be verified by replacing the suspect device with a known-good device when it is practical.

XIV. Power supply troubleshooting

A. The power supplies in SLC™100 controllers and expansion modules monitor three incoming voltages that must remain within allowable ranges. (Figure 2)

FIGURE 2

Specified Voltage	Allowable Voltage Range
115 VAC	85-132 VAC
230 VAC	170-265 VAC
24 VDC	18-30 VDC

B. If any of the voltages exceed the allowable range, outputs are automatically disabled and the PC RUN LED on the unit will go out.

C. Look for problems with:

1. Incoming power terminals and connections.

2. Incoming power voltage levels.

3. The power fuse supply for the DC voltage required for the controller, programmer, and the EEPROM module.

INFORMATION SHEET

D. When the DC power LED is not lit, chances are the power supply fuse needs to be replaced. Remember that variations in AC supply power might still permit the DC LED to remain lit because enough voltage for the DC function could still be available.

(NOTE: Replacing a fuse is a relatively easy task that is covered in a job sheet that accompanies this unit.)

E. Be sure to make supply power corrections or correct faulty connections before replacing the DC fuse.

F. The MAN/AUTO switch on the controller can be placed on MAN after power supply troubleshooting so that the controller will not automatically go into the run mode.

G. In the MAN mode the controller will go through its normal diagnostic routines to assist with troubleshooting, but for safety, outputs will be disabled.

(NOTE: The above is true if the controller was in the run mode when power was cut off, and if the controller is left in AUTO, it will return to AUTO operation after power up.)

XV. Back-up battery troubleshooting

A. The BATTERY LOW indicator on the controller diagnostic LEDs lights up when the back-up battery power falls below a specified voltage.

B. When external power is removed from the controller, the back-up battery supplies power to processor RAM.

C. When the BATTERY LOW LED is lit, the back-up battery should be replaced, and although the replacement process is simple, the lithium battery and its replacement must be handled with care.

(NOTE: Battery replacement is detailed in a job sheet that accompanies this unit of instruction.)

D. Handle lithium batteries with the following precautions:

1. Never attempt to charge a lithium battery or it might explode.
2. Never attempt to puncture or open a lithium battery because it contains corrosive, toxic, and flammable materials.
3. Never attempt to solder a lithium battery or incinerate one because there is a danger of explosion.
4. Dispose of used lithium batteries immediately.

INFORMATION SHEET

XVI. PLC Maintenance

A. PLC circuit boards must be protected from contaminants such as dirt, oil, and moisture, and this requires inspection of the enclosure at specified intervals.

B. To avoid improper controller function or system damage because of vibration, check terminal connections for tightness at specified intervals, and be sure incoming power is OFF when inspecting terminals.

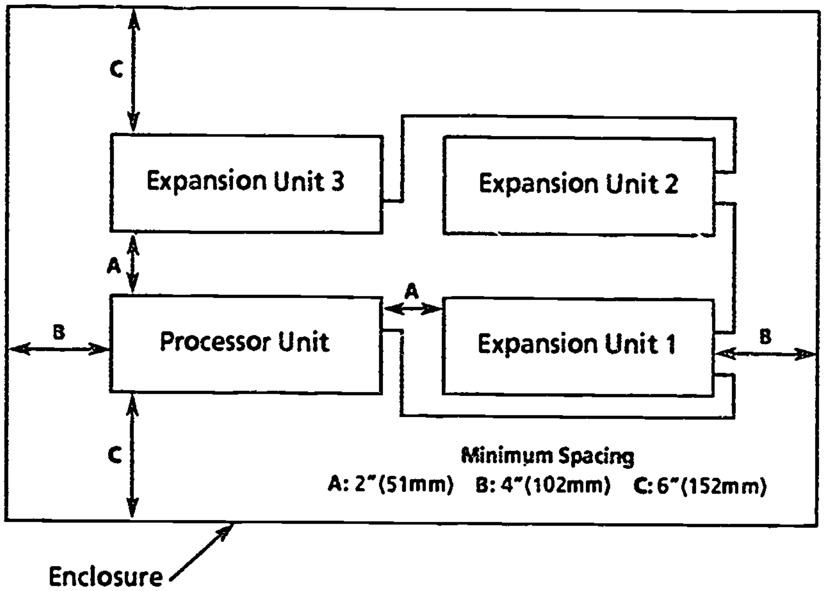
C. Stock enough spare parts so that you will have a minimum of one item for each part that might need replacing.

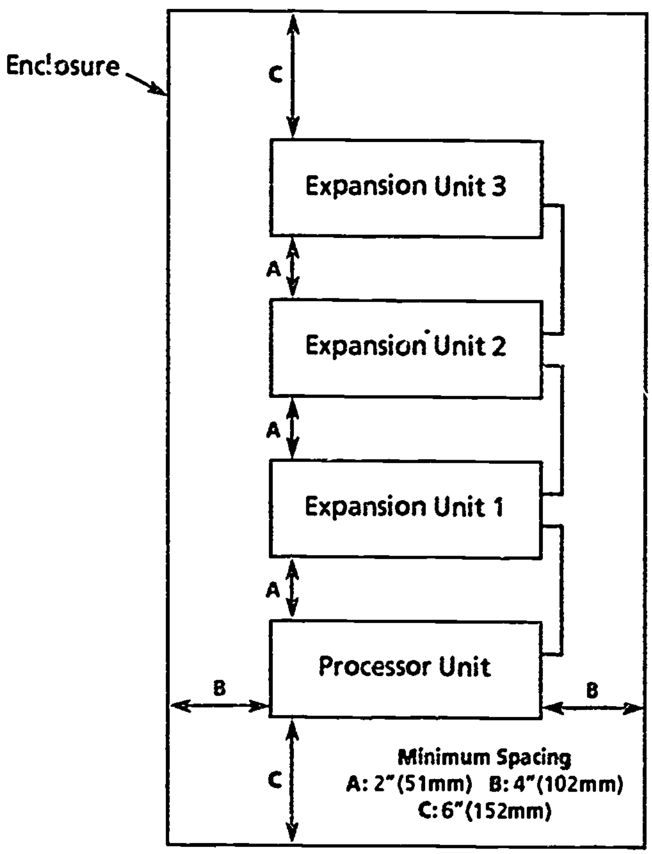
(NOTE: For SLC™ spare parts, Allen-Bradley recommends a processor unit, an expansion unit, fuses for both the AC and DC power supplies, a lithium battery for RAM memory, and replacement relay boards for both the processor unit and the expansion unit.)

D. When ordering replacement parts, list parts by name and catalog number, and be sure to note the correct voltage on parts that are available in more than one voltage rating.

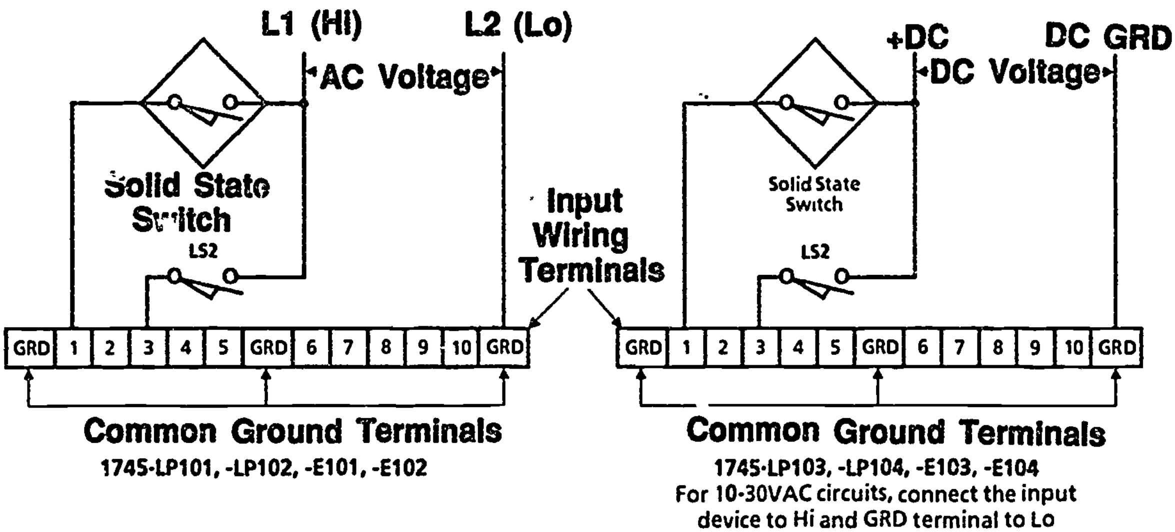
E. The lack of an inexpensive replacement part could contribute to costly downtime.

System Layout



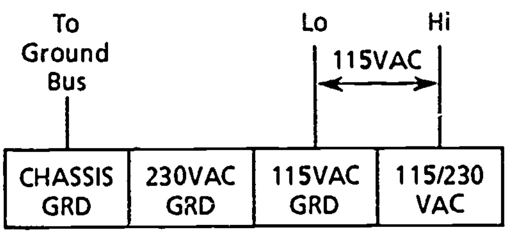


Grounding Requirements

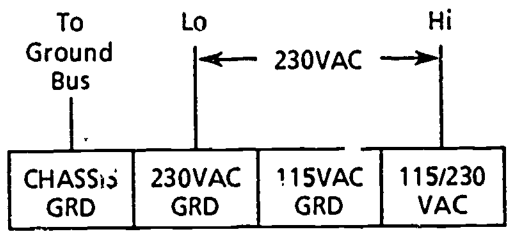


Incoming Line Terminals

Wiring Incoming Power — AC processor/expansion units, Catalog Nos. 1745-LP101, -LP102, -LP103, -E101, -E102, and -E 103 can be connected to either a 115VAC or 230 VAC source as follows:

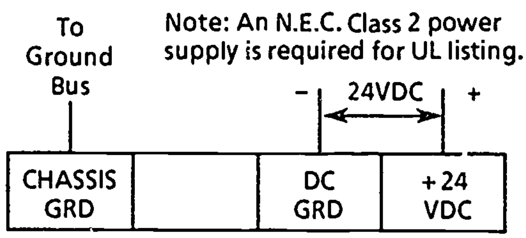


Incoming Line Terminals



Incoming Line Terminals

Connect DC processor/expansion units, Catalog Nos. 1745-LP104 and 1745-E104 as follows:

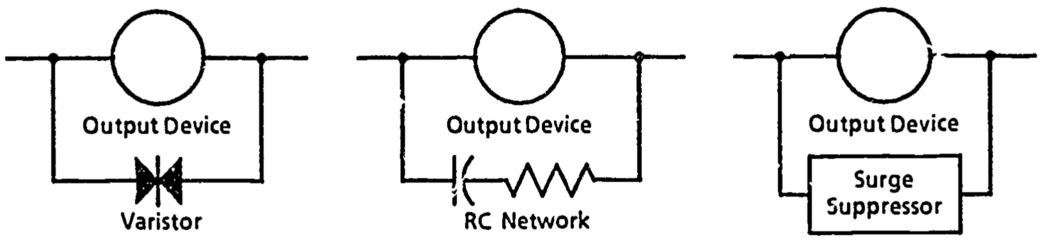


Incoming Line Terminals

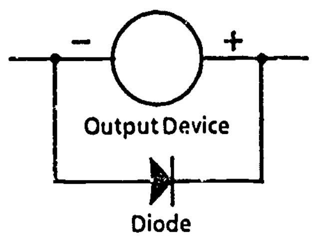
Make ground connections to the grounding bus in your enclosure.

Surge Suppression

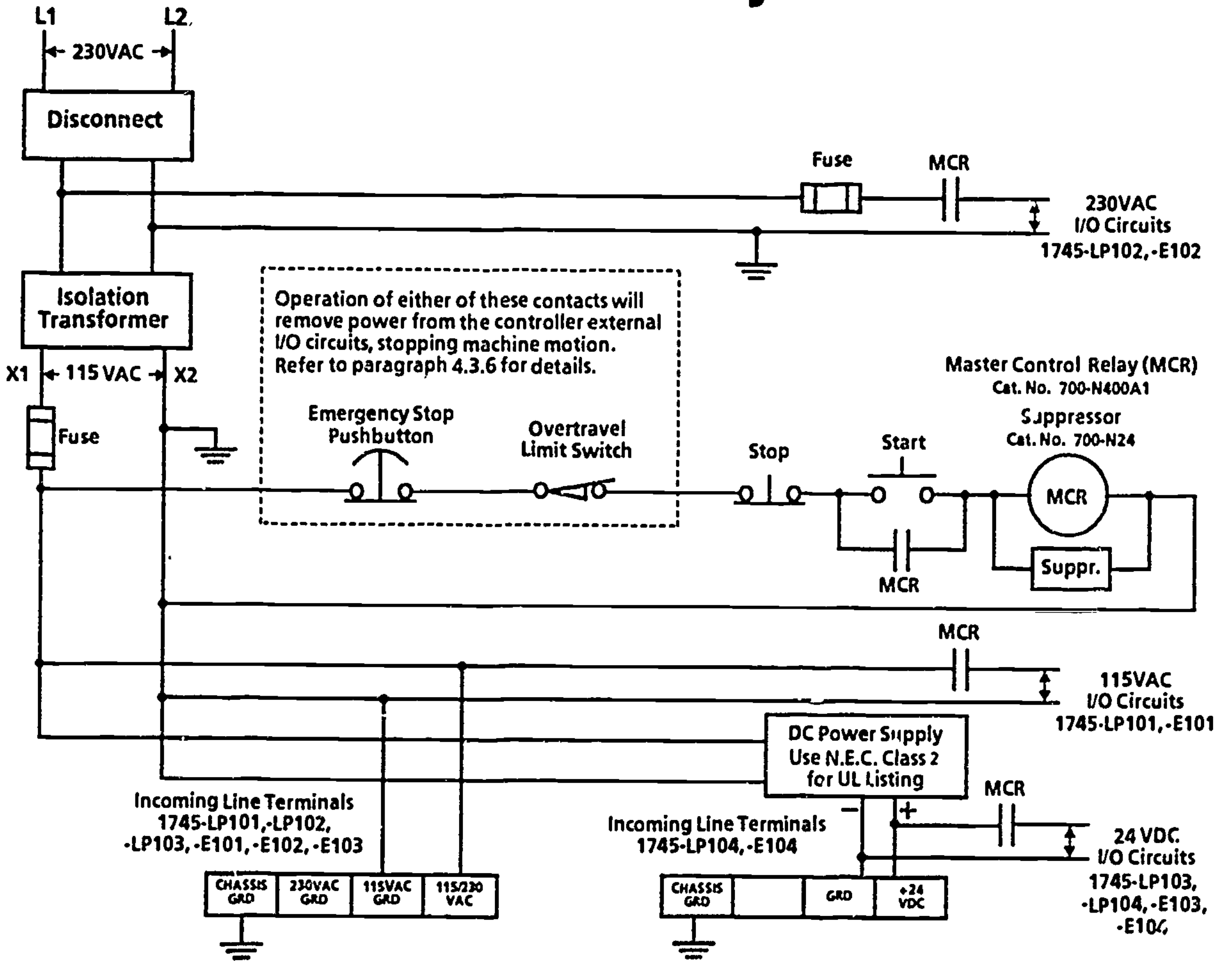
Surge Suppression for Inductive AC Output Devices



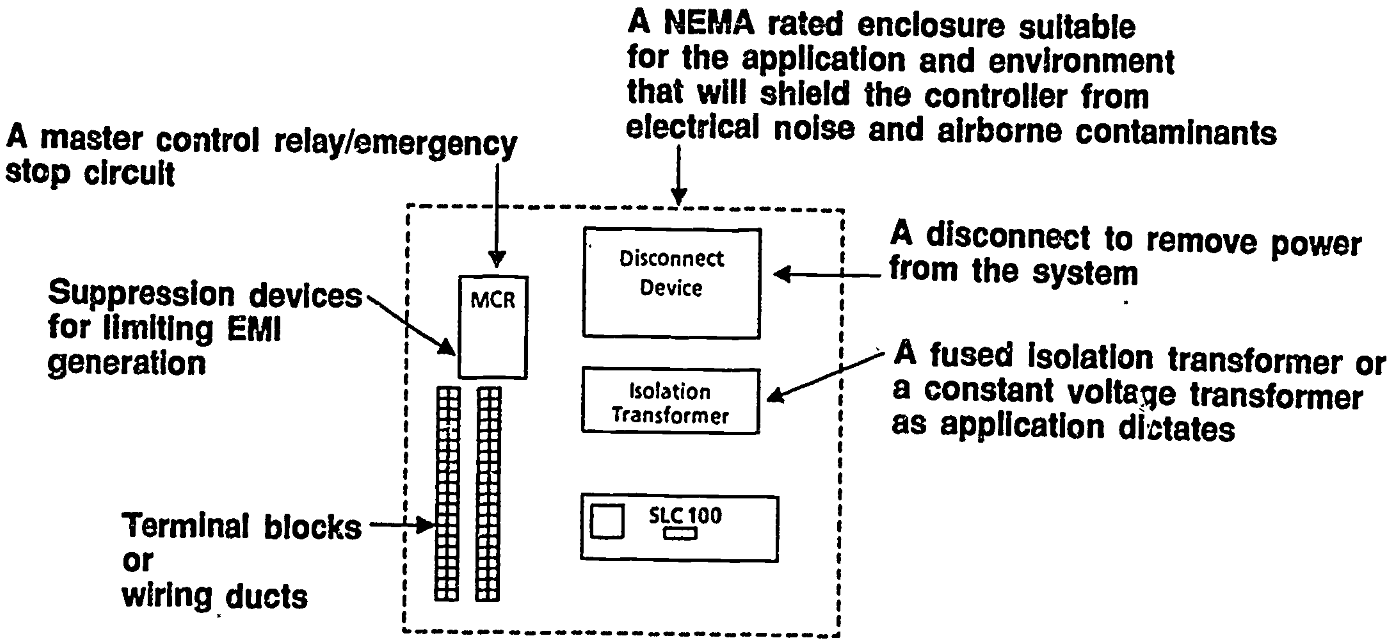
Surge Suppression for Inductive DC Output Devices



Master Control Relay Circuit



Installation Inspection



INSTALLATION AND TROUBLESHOOTING
UNIT V

JOB SHEET #1 — USE A FORCE FUNCTION TO VERIFY AN INPUT

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. I/O devices as selected by instructor
5. Pencil and paper
6. Safety glasses

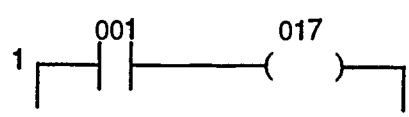
B. Procedure

1. Put on safety glasses.

   (NOTE: This procedures assumes NC input switches.)

2. Turn on power to the controller.
3. Connect the pocket programmer and clear memory by pressing ENTER when the SurE? prompt appears.
4. Look for DATA to display 885, MODE to display End, and then program the following:
5. Enter an Examine ON instruction at address 001 as indicated in the test rung in Figure 1.
6. Enter an output coil at address 017 as indicated in Figure 1.

   FIGURE 1

   (NOTE: Since an internal address cannot be forced, the 017 cannot activate an output, but the input can still be forced for testing, and this is a valuable troubleshooting feature of the force function.)

7. Press MODE, 3, and then ENTER to place the programmer in the run mode.

   (NOTE: Force functions can be used in modes 4 and 5, but mode 3 affords more articulate use of the force functions.)

8. Press LAST to move the cursor back to the Examine ON instruction at address 001.

JOB SHEET #1

9. Press SHIFT, FRC ON and look for F 1 in DATA and 1 in MODE to indicate that the address 001 on rung 1 has been forced on.

10. Note that the FORCE LED, the ON LED (only if there is voltage at the input), and the Examine ON LED are lit on the programmer display.

11. Note that the FORCE I/O LED is lit in the middle row of diagnostic LEDs on the controller.

    (NOTE: Both the programmer and diagnostic LEDs are valuable troubleshooting tools and should be referenced at all times when working with force functions or any troubleshooting activity.)

12. Press NEXT and look for DATA to display 17, MODE to display 1, and note that the FORCE LED, ON LED (only if there is voltage at the input), and output coil LED are lit on the programmer display.

13. Note that the output coil is ON at address 017 although the 017 address has not been forced, and note also that although the 017 address is ON to make the logic on the test rung TRUE, there is no output device activated and selecting the 017 internal address has served as a safety feature for the force function.

    (CAUTION: When an instruction is forced, contacts associated with the same address and condition are also forced, and contacts directly associated with the forced instruction change state, so force instructions have to be managed with regard for a total program although single rung I/Os may be under test.)

14. Use LAST to cursor back to the Examine ON condition at address 001.

15. Activate the number 1 input and watch the 001 input LED on the controller display to verify that the LED is lit.

16. Deactivate the number 1 input and watch the input LED go out.

☐ Have your instructor check your work.

17. Leave the cursor at the Examine ON instruction at address 001.

18. Press REMOVE, look for DATA to display rE F (remove force function), and then press ENTER to remove the force function.

19. Return tools and equipment to proper storage.

INSTALLATION AND TROUBLESHOOTING
UNIT V

JOB SHEET #2 — USE A FORCE FUNCTION TO VERIFY AN OUTPUT

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. I/O devices as selected by instructor
5. Pencil and paper
6. Safety glasses

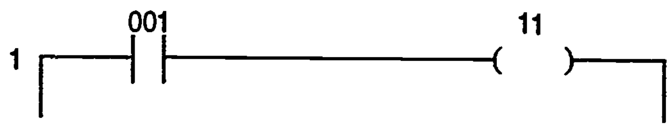
B. Procedure

1. Put on safety glasses.

   (NOTE: This procedure assumes NO input switches.)

2. Turn on power to the controller.
3. Connect the pocket programmer and clear memory by pressing ENTER when the SurE? prompt appears.
4. Look for DATA to display 885 and MODE to display End, and then program the following:
5. Enter an Examine ON instruction at address 001 as indicated on the test rung in Figure 1.
6. Enter an output coil at address 011 as indicated on the test rung in Figure 1.

   FIGURE 1



7. Press MODE, 3, and ENTER to put the programmer in the run mode.
8. Look for DATA to display 883 and MODE to display End.
9. Press LAST to cursor back to the 011 output address on rung 1.
10. Press SHIFT, FRC ON, and ENTER.
11. Look for DATA to display F 11 and MODE to display 1 to indicate that output coil 11 on rung 1 has been forced.

JOB SHEET #2

12. Note on the programmer display that the FORCE LED is lit and that the output coil LED is lit, but that the ON LED is not lit, only if the NO switch is to input 001.

    (NOTE: With a forced input, associated contacts are affected, but with a forced output, associated contacts are not affected, and this is a built-in safety feature of the force function in the run mode.)

13. Note that the output LED for the #11 output on the controller is ON to indicate that the 011 output has been forced ON even though the test rung logic is FALSE.

☐ Have your instructor check your work.

14. Press REMOVE, look for rE F in the DATA display, and then press ENTER to remove the force function.

15. Observe that the #11 output LED on the controller is no longer lit after the output force is removed.

16. Return tools and equipment to proper storage.

INSTALLATION AND TROUBLESHOOTING
UNIT V

JOB SHEET #3 — USE FRC ON/FRC OFF FUNCTIONS FOR TROUBLESHOOTING

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. I/O devices as selected by instructor
5. Pencil and paper
6. Safety glasses

B. Routine #1 — Entering and confirming the program

1. Put on safety glasses.
2. Turn on power to the controller.
3. Connect the pocket programmer and clear memory by pressing ENTER when the SurE? prompt appears.
4. Refer to Figure 1 that accompanies this job sheet and enter the program in order beginning with the Examine ON instruction at address 001 in rung 1 and ending with the output coil address 015 on rung 6.
5. Look for DATA to display 873 and MODE to display End to indicate that you have used 12 words for your program.
6. Use the LAST and NEXT keys to step through your program to verify all entries.

☐ Have your instructor check your work.

C. Routine #2 — Using force functions with Examine ON/Examine OFF instructions

1. Press MODE, 3, and ENTER.
2. Press RUNG, 1, and ENTER.
3. Press LAST to move the cursor back to the Examine ON condition at address 001 on rung 1.
4. Press SHIFT, FRC ON, and check the programmer display to verify that the Examine ON instruction has been forced.

JOB SHEET #3

5. Check the output LEDs on the controller to verify that outputs #11, #13, and #14 are lit.

   (NOTE: The above is true only if you're working with a NO switch.)

6. Activate input 1 and note that nothing happens on the programmer display or with the controller output LEDs.

7. Deactivate input 1 and note that nothing happens on the programmer display or with the controller output LEDs.

8. Press NEXT twice to move the cursor to the Examine OFF condition at address 002 on rung 2.

9. Activate the 002 input and note that the ON LED is lit on the programmer display and that output coil #12 on the controller LEDs is lit.

10. Press LAST twice to move the cursor back to the FRC ON instruction at address 001 on rung 1.

11. Press REMOVE, ENTER to remove the FRC ON function at address 001 and return the program to its starting conditions.

12. Note that when an Examine ON instruction is force ON, all Examine ON instructions with the same address become TRUE, and that when an Examine OFF instruction is forced OFF, all Examine OFF instructions with the same address become TRUE.

☐ Have your instructor check your work.

D. Routine #3 — Disabling an output with the FRC OFF function

1. Move the cursor back to output coil 011 on rung 1.

2. Press SHIFT, FRC OFF to force the 011 output coil OFF.

3. Activate input 1 and note that output LED #11 on the controller is not lit, but that other outputs associated with Examine ON address 001 are lit.

   (NOTE: The above is true only if a NO switch is used.)

4. Note that the FRC OFF function permits a single output to be selectively turned OFF while retaining the logical continuity in the rest of the program.

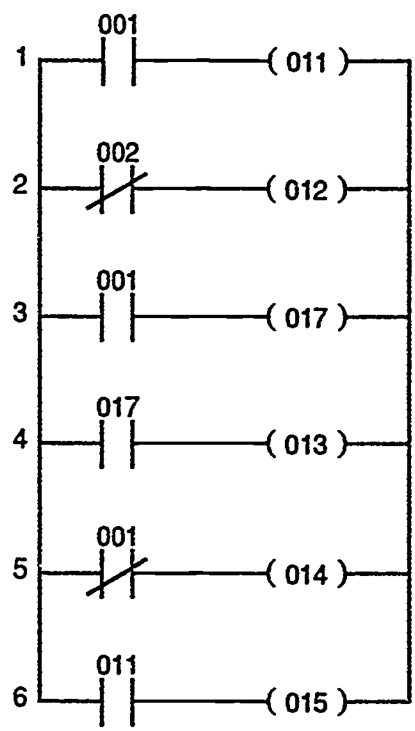
5. Press REMOVE, ENTER to remove the FRC OFF function.

☐ Have your instructor check your work.

6. Return tools and equipment to proper storage.

JOB SHEET #3

FIGURE 1



INSTALLATION AND TROUBLESHOOTING
UNIT V

JOB SHEET #4 — REPLACE THE POWER SUPPLY FUSE ON A PLC

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. Small fuse puller
5. Replacement fuse per specifications
6. Safety glasses

B. Procedure

1. Put on safety glasses.
2. Remove all system power before starting this procedure.
3. Verify that troubleshooting for excessive line voltage or internal power supply malfunction has been completed so that the replacement fuse will not blow, too.
4. Remove the EEPROM module.
5. Loose the two cover screws located at each end of the panel on the front of the controller.
6. Move the cover aside carefully to locate the fuse.

   (NOTE: The cover does not have to be completely removed, but connecting wires are short, so handle the cover with care.)
7. Use a small fuse puller to remove the fuse from its holder, and discard the old fuse.
8. Put the replacement fuse in place.

☐ Have your instructor check your work.

9. Replace the cover, but be careful not to tighten the screws too tightly.
10. Restore power to the unit, and verify that the DC POWER LED is lit.

☐ Have your instructor check your work.

11. Return tools and equipment to prcper storage.

INSTALLATION AND TROUBLESHOOTING
UNIT V

JOB SHEET #5 — REPLACE THE BACK-UP BATTERY ON A PLC

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. Replacement back-up battery per specifications
5. Safety glasses

B. Procedure

1. Put on safety glasses.
2. Remove all system power before starting this procedure.

   (NOTE: In a typical application, a battery can be safely replaced without turning power off, but for this procedure, power should be off.)

3. Remove the battery compartment door, just below the programmer connection port on the front of the controller.
4. Remove the battery from the compartment and unplug the lead wires from the processor unit.
5. Align the battery lead with the key in processor lead and snap the lead into place.
6. Slip the new battery into place and replace the battery compartment cover.
7. Apply power to the unit and verify that the BATTERY LOW LED is not lit to indicate that the back-up battery is providing proper voltage.

☐ Have your instructor check your work.

8. Dispose of the old lithium battery according to local procedures for safe handling.

   (NOTE: Check with your instructor for local procedures.)

9. Return tools and equipment to proper storage.

INSTALLATION AND TROUBLESHOOTING
UNIT V

PRACTICAL TEST #1

JOB SHEET #1 — USE A FORCE FUNCTION TO VERIFY AN INPUT

Student's name ______________________ Date ______________

Evaluator's name ______________________ Attempt no. ______________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Entered PRC ON program properly.	☐	☐
2. Selected run mode to verify force functions.	☐	☐
3. Activated number 1 input for verification.	☐	☐
4. Confirmed input with force function.	☐	☐
5. Removed force function.	☐	☐
6. Returned tools and equipment to storage.	☐	☐
7. Worked safely.	☐	☐

Evaluator's comments: ____

____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Equipment preparation	4	3	2	1
Programming	4	3	2	1
Testing	4	3	2	1
Verification	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INSTALLATION AND TROUBLESHOOTING
UNIT V

PRACTICAL TEST #2
JOB SHEET #2 — USE A FORCE FUNCTION TO VERIFY AN OUTPUT

Student's name ______________________ Date ______________

Evaluator's name ______________________ Attempt no. ______________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Entered RFC ON program properly.	☐	☐
2. Selected run mode to verify force function.	☐	☐
3. Verified output coil ON.	☐	☐
4. Removed force function.	☐	☐
5. Returned tools and equipment to storage.	☐	☐
6. Worked safely.	☐	☐

Evaluator's comments: ____

____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Equipment preparation	4	3	2	1
Programming	4	3	2	1
Testing	4	3	2	1
Verification	4	3	2	1

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INSTALLATION AND TROUBLESHOOTING
UNIT V

PRACTICAL TEST #3

JOB SHEET #3 — USE PRC ON/FRC OFF FUNCTIONS FOR TROUBLESHOOTING

Student's name ______________________ Date ______________

Evaluator's name ______________________ Attempt no. ______________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Entered and verified program.	☐	☐
2. Used FRC ON to force on Examine ON.	☐	☐
3. Tested conditions at other addresses.	☐	☐
4. Removed FRC ON function.	☐	☐
5. Used FRC OFF to force an output coil OFF.	☐	☐
6. Verified FRC OFF function.	☐	☐
7. Removed FRC OFF function.	☐	☐
8. Returned tools and equipment to storage.	☐	☐
9. Worked safely.	☐	☐

Evaluator's comments: ____

____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Equipment preparation	4	3	2	1
Programming	4	3	2	1
Testing	4	3	2	1
Verification	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INSTALLATION AND TROUBLESHOOTING
UNIT V

PRACTICAL TEST #4

JOB SHEET #4 — REPLACE THE POWER SUPPLY FUSE ON A PLC

Student's name ______________________ Date ______________

Evaluator's name ______________________ Attempt no. ______________

Student instructions: When you are ready to perform this task. ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Prepared system safely.	☐	☐
2. Removed EEPROM module.	☐	☐
3. Removed cover properly.	☐	☐
4. Removed and replaced fuse.	☐	☐
5. Replaced cover properly.	☐	☐
6. Replaced EEPROM module.	☐	☐
7. Returned tools and equipment to storage.	☐	☐
8. Worked safely.	☐	☐

Evaluator's comments: ____

____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
System preparation	4	3	2	1
EEPROM module handling	4	3	2	1
Cover removal and replacement	4	3	2	1
Fuse removal and replacement	4	3	2	1

EVALUATOR'S COMMENTS: ________________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INSTALLATION AND TROUBLESHOOTING
UNIT V

PRACTICAL TEST #5

JOB SHEET #5 — REPLACE THE BATTERY BACK-UP ON A PLC

Student's name ______________________ Date ______________

Evaluator's name ______________________ Attempt no. ______________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Prepared system safely.	☐	☐
2. Removed old battery safely.	☐	☐
3. Connected and placed new battery properly.	☐	☐
4. Verified new battery operation.	☐	☐
5. Disposed of old battery properly.	☐	☐
6. Returned tools and equipment to storage.	☐	☐
7. Worked safely.	☐	☐

Evaluator's comments: ______________________________

____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
System preparation	4	3	2	1
Battery handling	4	3	2	1
Verification	4	3	2	1
Battery disposal	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE. If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INSTALLATION AND TROUBLESHOOTING
UNIT V

TEST

NAME______________________________ SCORE ________________

1. Match the terms on the right with their correct definitions.

_____ a.	A transformer that holds voltage level within ±5V AC for applications where extreme voltage variances could be harmful to equipment	1.	Master control relay
_____ b.	A transformer that separates a piece of equipment from other equipment on a common feeder, but does not change voltage levels	2.	Transient
_____ c.	A hard-wired circuit designed to cut off power quickly in the event of an operating emergency	3.	Constant voltage transformer
_____ d.	A device installed in coils or relays, contactors, and motor starters to protect against voltage spikes and transients when coil circuits are opened	4.	Isolation transformer
_____ e.	High voltage created across contacts of an inductive device when it is switched off	5.	Surge suppressor
_____ f.	A registered mark of the German Institute for Standardization used to indicate a variety of manufacturing standards	6.	DIN

2. Select true statements concerning enclosures by placing an X beside each statement that is true.

_____ a. Enclosures are the cabinet-like boxes that house electrical switches and other controls and protect them from their environments.

_____ b. Enclosures for electrical equipment, including PLCs, must meet standards set by NEMA, NEC, and local electrical codes.

_____ c. Enclosure standards never vary and an enclosure for indoor service is the same as an outdoor enclosure.

_____ d. Enclosures are basically designed to protect electrical equipment from contaminants such as dust and moisture, but certain enclosures have special designs for protection from hazardous gas and industrial corrosives.

TEST

______ e. All enclosures should meet standards set for the environment where they are installed, and safety for operators and equipment should be the most important considerations in selecting an enclosure.

3. Complete statements concerning guidelines for PLC enclosures by circling the material that best completes each statement.

   a. To make maintenance and troubleshooting easier, a PLC enclosure should be mounted so that its doors can be (fully opened) (opened 90 degrees).

   b. A PLC enclosure should be large enough that the controller and add-on modules can be placed far enough apart to (safely dissipate heat) (provide access).

   c. When heat from nearby equipment poses a heat problem, (a blower-type fan) (air conditioning) should be installed to help dissipate heat in the enclosure.

   d. To control contaminants, cooling air introduced into a PLC enclosure should be filtered, and filters should be cleaned or changed at (specified) (monthly) intervals.

   e. PLC enclosures should be placed in locations where they will not be affected by (vibrations) (noise) from other equipment.

   f. When an emergency disconnect switch is mounted inside an enclosure, the switch operating handle should be outside the enclosure so an operator can reach it without having to (open the enclosure) (move more than three feet).

4. Solve problems concerning installing a PLC by answering the following questions.

   a. You have to drill holes to mount a PLC to the back of an enclosure; what should be your prime concern?

      Answer ____

      ____

   b. You have to choose mounting devices for a PLC and two expansion units; what would you choose and why?

      Answer ____

      ____

5. Solve problems concerning wiring incoming power to a PLC by answering the following questions.

   a. What is the first thing you would check about incoming wiring to a PLC installation?

      Answer ____

      ____

TEST

b. Since electrical interference is a problem with some PLC installations, what can you do to minimize interference?

Answer ______________________________

____

c. It appears that running signal wiring and power wiring in the same conduit would save money; should this be done?

Answer ______________________________

____

6. Select conditions concerning wiring input devices to a PLC by answering the following questions.

a. When routing incoming signals with different characteristics into an enc osure, it is best to what, use the same gauge wire or route the signals on separate paths?

Answer ______________________________

____

b. Since most PLCs will accept 115V AC, 230V AC, or 24V DC inputs, what is the rule of thumb concerning input/output voltages, to match input voltage with output voltage or to convert everything to DC voltage?

Answer ______________________________

____

7. Select conditions concerning wiring output devices to a PLC by answering the following questions.

a. Surge suppressors are usually required with inductive output devices in order to control what, arcing at output contacts or high voltage surges?

Answer ______________________________

____

b. Surge suppression circuits should be connected directly across an inductive output device, and how close, as close as possible or within three feet?

Answer ______________________________

____

TEST

8. Complete statements concerning grounding PLC systems by circling the material that best completes each statement.

   a. Every PLC application should have the controller and enclosure (connected) (grounded) to an equipment grounding conductor.

   b. Ground connections should run from the chassis ground terminal on each processor and each expansion unit to a grounding (bus) (terminal).

   c. Each controlled device in a PLC system should be grounded so that each device has (the same) (a separate) path to the grounding conductor.

   d. To ensure proper grounding, scrape paint away from points where the processor or expansion units meet the (enclosure) (terminals).

   e. Ground wires (can be) (cannot be) jumpered between sets of terminals as desired.

   f. Grounding must meet (local) (military) codes as well as NEC standards.

   g. The first reason for a properly grounded system is safety to personnel and equipment, but with the solid state structure of PLCs, grounding also limits the effect of noise generated by (EMI) (static electricity).

9. Select true statements concerning emergency shutdown systems for PLCs by placing an X beside each statement that is true.

   ______a. When a PLC operation poses danger to personnel or equipment, there must be a means for quickly shutting the system down.

   ______b. A hard-wired master control relay is the safest, fastest way to execute emergency shutdown.

   ______c. An effective master control relay should have emergency stop switches in locations that can be quickly and easily reached.

   ______d. Emergency stop switch placement is frequently controlled by local codes, but in all cases they should be highly visible, properly labeled, and in clear, open access.

   ______e. Overtravel limit switches, emergency stop switches, interlocks, and other devices in a master control relay system should be wired in parallel.

   ______f. Even with power to I/Os removed, a properly designed master control relay will continue to provide power to the controller so that diagnostic indicators can still be monitored and force functions can still be executed.

   ______g. Emergency stop switches should always be programmed into a PLC program.

   ______h. Emergency stop switches can be of any shape.

TEST

10. Select true statements concerning other installation considerations by placing an X beside each statement that is true.

_____a. When voltage variations from a power source are difficult to control, a constant voltage transformer can be used.

_____b. When a constant source transformer is used, it must have a sufficient power rating for its load.

_____c. The transformer should be connected to the controller power supply and all input devices connected to the PLC.

_____d. When a constant voltage transformer is used, output devices should be connected to the same power line, but their connections should be made along the power line before the location of the transformer.

_____e. It is important to use the correct wire gauge for all wiring, and #14 AWG stranded wires are recommended.

_____f. *DO NOT* install power wires, input wires, or output wires when a controller is under power.

_____g. *DO NOT* run testing or troubleshooting routines without notifying all personnel in the area what will be happening, and make sure someone is standing by to operate the master control relay if emergency shutdown is required.

_____h. *DO NOT* disable the master control relay or any associated emergency stop switches for any reason.

_____i. *DO NOT* use a metal rod to disable I/O devices; use a wooden stick such as a flat, wooden yard-long ruler rigid enough to do the job and long enough to keep a person safely away from motion-causing devices.

11. Select conditions concerning inspection before start-up by answering the following questions.

    a. If incoming line voltage has been checked prior to installation should it be checked again before start-up, yes or no?

       Answer ______________________________

    b. All wiring should be inspected before start-up, but where is a logical place to inspect for loose wires, at outputs or at connections and terminals?

       Answer ______________________________

       ____

TEST

12. Select true statements concerning guidelines for start-up by placing an X beside each statement that is true.

    _____a. After the inspection before start-up and before power is connected, disconnect motors and all other motion-causing devices.

    _____b. Test inputs by entering a test rung and manually opening and closing the addressed input device with a long metal rod.

    _____c. Test output devices by using a wooden stick.

    _____d. Enter and verify a test program.

    _____e. Reconnect the motion-causing devices and check the system again.

    _____f. Make a dry run of a single input/output.

13. Complete statements concerning troubleshooting guidelines by circling the material that best completes each statement.

    a. Troubleshooting a PLC should begin by taking advantage of the (diagnostic) (computing) powers built into the controller and the programmer.

    b. Diagnostics should quickly isolate the problem and identify the source which will usually be:

       1) In the controller or the (expansion) (output) unit.

       2) In (wiring or cables) (terminals) connecting devices.

       3) In input or output (devices) (programs).

    c. When a problem is isolated in the controller or expansion unit, the problem is usually in the (cables) (power supply) or a fault within the unit itself.

    d. Wiring problems and input/output problems can be isolated with troubleshooting routines using (force functions) (a wooden stick).

    e. When input/output devices are at fault, the problem can be verified by replacing the suspect device with (a known-good device) (any same-voltage device) when it is practical.

14. Select conditions concerning power supply troubleshooting by answering the following questions.

    a. If any voltages on a SLC™100 exceed allowable ranges, what happens to outputs, are they automatically disabled or do they switch to MANUAL mode?

       Answer ____

       ____

TEST

b. When the DC power LED is not lit, it usually means what, the back-up battery is low or the power supply fuse needs to be replaced?

Answer ______________________________

____

c. After power supply troubleshooting, the controller will still go through diagnostics, but for safety, outputs will be disabled if the controller is powered up in what mode, manual or automatic?

Answer ______________________________

15. Solve problems concerning back-up battery troubleshooting by answering the following questions.

a. You suspect that the battery back-up has failed; what would verify your suspicion?

Answer ______________________________

b. Since lithium back-up batteries can be recharged, what would be the best procedure, recharge or replace?

Answer ______________________________

c. What is the rule about disposing of lithium batteries?

Answer ______________________________

16. Complete statements concerning PLC maintenance by circling the material that best completes each statement.

a. PLC circuit boards must be protected from contaminants such as dirt, oil, and moisture, and this requires inspection of the enclosure at (specified) (daily) intervals.

b. To avoid improper controller function or system damage because of (vibration) (dirt), check terminal connections for tightness at specified intervals, and be sure incoming power is OFF when inspecting terminals.

c. Stock enough spare parts so that you will have a minimum of (one item) (two items) for each part that might need replacing.

d. When ordering replacement parts, list parts by (name) (size) and catalog number, and be sure to note the correct voltage on parts that are available in more than one voltage rating.

TEST

e. The lack of an inexpensive replacement part could contribute to (costly downtime) (system shutdown).

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

17. Demonstrate the ability to:

    a. Use a force function to verify an input. (Job Sheet #1)

    b. Use a force function to verify an output. (Job Sheet #2)

    c. Use FRC ON/FRC OFF functions for troubleshooting. (Job Sheet #3)

    d. Replace the power supply fuse on a PLC. (Job Sheet #4)

    e. Replace the back-up battery on a PLC. (Job Sheet #5)

INSTALLATION AND TROUBLESHOOTING

UNIT V

ANSWERS TO TEST

1. a. 3
   b. 4
   c. 1
   d. 5
   e. 2
   f. 6

2. a, b, d, e

3. a. Opened 90 degrees
   b. Safely dissipate heat
   c. A blower-type fan
   d. Specified
   e. Vibrations
   f. Open the enclosure

4. a. That no power cables are behind the area where holes will be drilled
   b. A standard DIN mounting saves troubleshooting and maintenance time

5. a. Make sure there are no excessive line voltage variations with incoming power
   b. Use the same power supply for both the controller and input/output devices
   c. No!

6. a. Route the signals on separate paths
   b. Match input voltage with output voltage

7. a. Arcing at output contacts
   b. As close as possible

8. a. Grounded
   b. Bus
   c. A separate
   d. Enclosure
   e. Can be
   f. Local
   g. EMI

9. a, b, c, d, f

ANSWERS TO TEST

10. a, b, c, d, e, f, g, h, i

11. a. Yes
    b. At connections and terminals

12. a, d, e

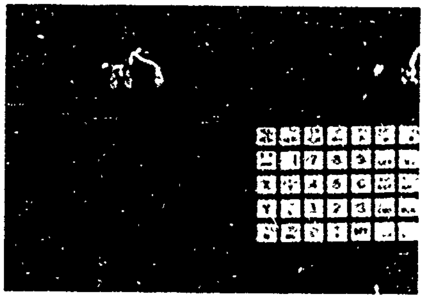
13. a. Diagnostic
    b. 1) Expansion
       2) Wiring or cables
       3) Devices
    c. Power supply
    d. Force functions
    e. A known-good device

14. a. Automatically disabled
    b. The power supply fuse needs to be replaced
    c. Manual

15. a. The BATTERY LOW LED lights up
    b. Replace
    c. Do it immediately

16. a. Specified
    b. Vibration
    c. One item
    d. Name
    e. Costly downtime

17. a. Evaluated according to criteria in Practical Test #1
    b. Evaluated according to criteria in Practical Test #2
    c. Evaluated according to criteria in Practical Test #3
    d. Evaluated according to criteria in Practical Test #4
    e. Evaluated according to criteria in Practical Test #5



TYPES OF PLCs AND PROGRAMMING
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss PLCs in general and the features that make each PLC unique. The student should also be able to compare programming features of formats in ladder logic, Boolean, and Grafcet. These competencies will be evidenced by correctly completing the assignment sheet, and by scoring a minimum of 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to types of PLCs and programming with their correct definitions.
2. Complete statements concerning comparing PLCs.
3. Select true statements concerning modular structure.
4. Select conditions concerning compatibility.
5. Select conditions concerning programming the Cutler-Hammer® MPC1.
6. Select true statements concerning the Cutler-Hammer® MPC1 programmer.
7. Complete statements concerning register formats in the MPC1.
8. Solve problems concerning special registers in the MPC1.
9. Complete statements concerning other special features of the MPC1.
10. Select conditions concerning special MPC1 programming.
11. Select true statements concerning Boolean programming basics.
12. Select conditions concerning Boolean instruction sets.
13. Complete statements concerning Grafcet programming.
14. Solve problems concerning the general structure of Grafcet.

SPECIFIC OBJECTIVES

15. Complete statements concerning how Grafcet works.

16. Select conditions concerning Grafcet programming.

17. Select conditions concerning putting a Grafcet program to work.

18. Complete statements concerning program protection schemes and devices.

19. Translate ladder logic instructions into Boolean instructions. (Assignment Sheet #1)

TYPES OF PLCs AND PROGRAMMING
UNIT VI

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information and assignment sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Invite a Cutler-Hammer representative to demonstrate wire number programming to the class and discuss Cutler-Hammer PLCs in general.

G. Invite an Omron representative to class to talk about the use of Boolean in programming and how it is used in Omron PLCs.

H. Invite a GE representative to talk to the class about the modular construction of the GE Series Six™ PLCs and the advantage of modular construction in control applications.

I. Invite a Telemecanique representative to class to talk about the Telemecanique programming languages and especially about GRAFCET and how it is programmed.

J. Give test.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Cutler-Hammer MPC1 Programmable Controller Instruction Manual.* Milwaukee, WI 53216: Cutler-Hammer Products, No date.

B. *Sysmac-C20 programmable Controller.* Omron Tateisi Electronics Co., No date.

C. *PL7-1 Basic Training, Boolean Programming of Ladder and GRAFCET for the TSX 17.* Westminster, MD 21157: Telemecanique Inc., 1988.

D. *Technical Overview of General Electric Series Six™ Programmable Controllers. And a Brief Review of Smaller GE PCs.* Charlottesville, VA 22906: General Electric Company, 1986.

E. *Series Five™, Series Six™, Series One™ - Series Three™ Product Summary, Programmable Control Products.* Charlottesville, VA 22906: GE Fanuc Automation, 1989.

TYPES OF PLCs AND PROGRAMMING
UNIT VI

INFORMATION SHEET

I. Terms and definitions

A. **Boolean operators** — The AND, OR, and NOT gates that are part of the logic gates in Boolean algebra and have been adapted for use in the programming of sequential devices such as PLCs

B. **Instruction set** — The symbols, letters, and numbers that collectively define the unique operations that can be performed with the memory structure of a given PLC

C. **Mnemonics (pronounced knee-monics)** — The expression of a term or condition in an abbreviated form that makes it easier to remember

EXAMPLE: RST means reset and JMP means jump

D. **ms (millisecond)** — One thousandth of a second, expressed in decimal as 0.001 second, and in scientific notation as 10^{-3}

II. Comparing PLCs

A. All PLCs have similar operating characteristics, but each PLC is unique because of its hardware, instruction set, and programming devices.

B. PLC hardware refers to the physical parts of a PLC that house the CPU and the circuitry that serve as the brains of a PLC system.

C. A PLC instruction set contains the logical conditions that have to be met before contacts and coils can accomplish a control objective.

D. The instruction set is really a computer language that an operator uses to address or talk to a PLC.

E. Making the instruction set work is a matter of programming which means using one of four formats:

1. Ladder logic diagrams

2. Boolean logic

3. Grafcet programming

4. Combinations of programming formats

F. Programming devices range from hand-held units with integrated keyboards to full-size computers that work with programming software, but almost all programming devices are relatively easy to program and that's why "user friendly" programming is a feature of PLC power.

INFORMATION SHEET

III. Modular structure

A. Another powerful element of PLCs is their modular construction which permits the selection of expansion units as required for specific applications.

B. Most PLC installations have standard panel or rack designs which permit the addition of selected modules without having to redesign the installation.

C. The standard rack panel design includes the power supply required to operate the module or modules that are placed in the rack or panel.

D. Expansion modules are especially suitable for adding analog I/O modules designed to work with analog as opposed to discrete signals.

IV. Compatibility

A. Many PLC manufacturers have models that are built with different power levels (number of I/Os), but still retain the same programming language and addressing format to permit less powerful models to be used alongside more powerful models.

B. Compatibility affords industry an opportunity to expand control applications as money and need dictate without facing the need to retrain programmers or maintenance personnel in basic system operations.

C. The General Electric Series Six™ programmable controllers demonstrate how a family of controllers is designed for compatibility (Transparency 1)

D. The GE models 60, 600, and 6000 vary greatly in power from 256 I/Os for the model 60 up to 2000 I/Os for the model 6000, but all three models use many of the same modules. (Figure 1)

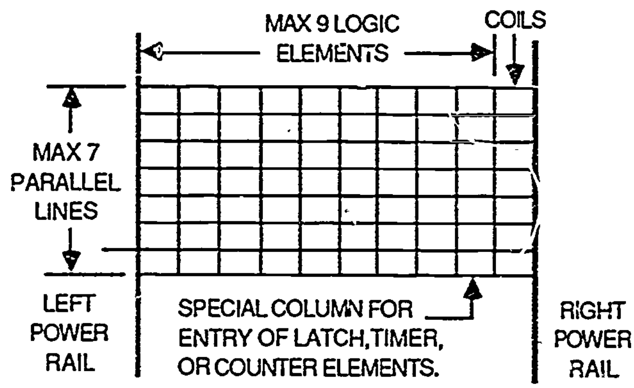
FIGURE 1

MODULE NAME	MODULE NUMBER	UTILIZED ON MODEL 6000	600	60
Power Supply	PM500/541	X	X	X
I/O Control	CB503	X	X	X
Communications Control	CB514/516/517	X	X	X
Logic Control	CB501/02	X	X	X
Arithmetic Control	CB500	X	X	X
Internal Memory	CB504	X	X	
Combined Memory	CM552/554			X
Register Storage	CB508/507/511	X	X	
Logic Memory	CM54X	X	X	
Auxiliary I/O	CB513	X		

INFORMATION SHEET

E. To maintain compatibility among the Series Six™ controllers, the ladder logic programming allows up to nine elements in series and up to seven parallel paths. (Figure 2)

FIGURE 2

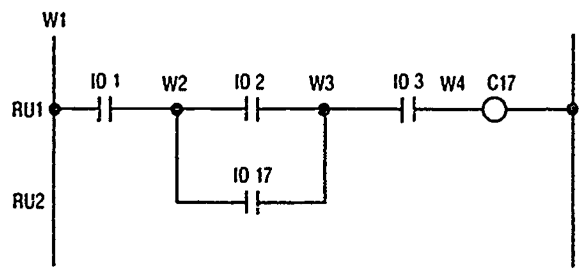


V. Programming the Cutler-Hammer® MPC1

A. The Cutler-Hammer® MPC1 is programmed with relay ladder logic combined with a unique concept called "wire number programming."

B. Wire number programming limits wire numbers to just two locations: where a vertical connection is made creating parallels, and just prior to terminating a coil. (Figure 3)

FIGURE 3



Courtesy EATON/Cutler-Hammer

C. Programming is rung by rung moving from left to right, and wire number 001 is programmed automatically to the left of the first rung with wire numbers 002 to 254 left available for programming.

D. Wire number programming exploits the power of the MPC1 microprocessor by solving wire number relations first, a programming concept that significantly reduces scan time.

INFORMATION SHEET

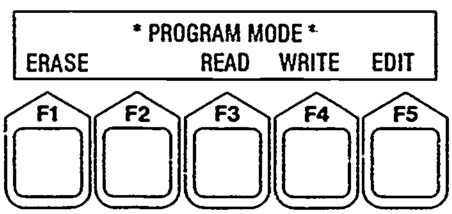
VI. The Cutler-Hammer MPC1 programmer

A. The MPC1 programmer has a liquid crystal display 24 characters wide and two rows deep.

B. The top row of the programmer displays ladder logic elements such as contacts and coils along with error messages and diagnostics.

C. The bottom row displays "prompt" messages that list the functions for the five keys below the display. (Figure 4)

FIGURE 4



Courtesy EATON/Cutler-Hammer

D. The F (function) keys F1 through F5 program the functions prompted on the second row of the display, and each key can control several functions.

E. The programmer is "user friendly" because of the self-prompting messages and the logical sequence in which they occur on the upper display.

F. The programmer can directly access program modes, editing functions, mathematical and compare functions, and FORCE functions which permit inputs/outputs to be turned ON or OFF independent of the PC program or actual input/output status.

VII. Register formats in the MPC1

A. MPC1 registers take advantage of wire number programming by permitting register functions to be programmed on a single rung, except for shift registers which require two rungs.

B. The MPC1 has 32 registers numbered 1 through 32, and all register applications are strictly defined by the user and any register can be used for each register function.

C. The register functions include a point register (PTR) used to identify the register used in an operation, a bit register (BIT) used for comparison and assignment operations, and a clear register (CLR) that permits any of the 32 registers to be cleared with a single instruction.

D. Any of the 32 registers can be used as a timer register (TMR), an UP counter register, a DOWN counter register, or a SHIFT register (SR) which is the only register that requires two rungs to program.

INFORMATION SHEET

VIII. Special registers in the MPC1

A. Functions on the keyboard give the MPC1 the power to add, subtract, and assign values from one register to another.

B. Compare functions give the MPC1 the power to compare two registers with each other or to compare one register with a numeric constant of 0 or 1.

C. The compare functions with the MPC1 include:

1. Less Than (<)
2. Equal To (=)
3. Greater Than (>)
4. Not Equal To (≠)
5. Assignment (→)

D. The comparison features uses the wire number programming by turning the output wire of the register ON or OFF to indicate that conditions for the comparison function specified have been met, ON, or have not been met, OFF.

E. In the case of an add or subtract function, after two registers are added together in an addition function or after one register is subtracted from another in a subtraction function, another operation must follow so that the result of the addition or subtraction will not be lost, and this is accomplished by using an assignment function.

IX. Other special features of the MPC1

A. Optional program packages for the MPC1 include a back-up program storage cartridge which can be installed as part of the programmer, and an EEPROM cartridge which also serves program back-up but can be removed from the programmer.

B. The MPC1 Register Access Module provides a remote display of the stored contents of any of the 32 registers.

C. With the Register Access Module, the registers can be programmed as non-viewable, viewable non-accessible, meaning values cannot be changed, or viewable accessible, meaning values can be changed.

D. The Register Access Module has a 14-button keyboard that can be used for entering new data for a register, but only register contents can be manipulated, the ladder logic program cannot be changed.

E. Another unique feature of the MPC1 is its built-in ladder diagram printout capability which uses a standard RS232C serial interface directly from the programmer to a printer to provide a hard copy of a ladder logic program. (Transparency 2)

INFORMATION SHEET

X. Special MPC1 programming

A. THe MPC1 presents programming versatility that expands both power and applications and can accomplish such activities as changing the value of a register by using an external device.

B. The MPC1 timer automatically increments every .10 seconds, a tenth of a second or 100 milliseconds, but where greater accuracy is required, timing can be programmed so that timing is within ± of one scan time of the MPC-1 or about 14 ms instead of 100 ms. (See Handout #1)

C. Multiplication and division can both be accomplished with programs that manipulate register contents using the transfer command. (See Handout #1)

D. When operation requires loading values to a register using a BCD device such as a thumbwheel, the MPC1 uses groups of four bits within the 16-bit registers to represent decimal values in weights that are related to the binary ones, tens, hundreds, and thousands according to a weight resulting from the binary sum. (See Handout #1)

E. A unique programming activity of the MPC1 is "first closure memory" which permits a troubleshooter to find the first contact to open even though several contacts have opened during an orderly shut down. (See Handout #1)

XI. Boolean programing basics

A. Ladder logic diagrams are actually symbolic programming languages that are based upon the manipulation of logic gates built into the PLC memory.

B. Boolean algebra as a programming language does the same thing that ladder logic programming does, but the addressing is more direct, excess commands before conditions are eliminated, and scan time is faster.

C. Boolean programming has basic rules that are actually mirrors of ladder logic programming because the conditions for contacts are still set by the equivalent of Examine ON and Examine OFF conditions.

D. In a typical ladder logic program, an Examine ON instruction at address 001 would be —| |— , but in Boolean, this command would simply be STR 1 or LOD 1 (Store 1 or Load 1).

E. With a ladder logic program, the 001 address would have to be entered, the Examine OFF instruction would have to be entered, and then the instruction would itself have to be entered by pressing ENTER or an equivalent key on a programmer or computer keyboard.

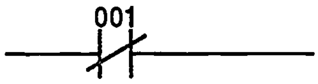
F. With Boolean programming, the STR 1 or LOD 1 command accomplishes everything at once because STR and LOD automatically create an Examine ON condition at the address specified, and also starts a new rung.

INFORMATION SHEET

G. To create an Examine OFF instruction in Boolean requires storing or loading a NOT logic gate which would be expressed as LOD N1 or STR N1. (Figure 5)

FIGURE 5

LOD N1 =



H. To create two Examine ON conditions on the same rung in Boolean requires the use of an AND logic gate which would be programmed as LOD 1 AND 2 or STR 1 AND 2. (Figure 6)

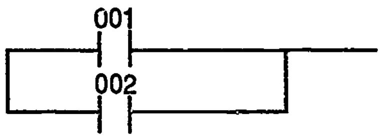
FIGURE 6

LOD 1 AND 2 =

I. To create a combination Examine ON, Examine OFF condition in a parallel circuit in Boolean requires the use of an OR logic gate which would be programmed as LOD 1 OR 2 or STR 1 OR 2. (Figure 7)

FIGURE 7

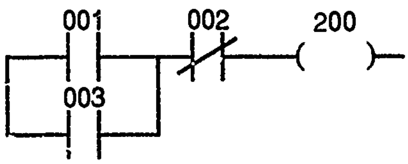
LOD 1 OR 2 =



J. Creating Examine ON, Examine OFF conditions requires use of the AND, OR, and NOT gates as expressed in Boolean, and outputs are usually created simply by using OUT. (Figure 8)

FIGURE 8

LOD 1 OR 3 AND N2 OUT 200 =



K. The AND, OR, and NOT gates used in Boolean programming are called the Boolean operators, and other abbreviated commands such as JMP (jump) and FUN (function) are called mnemonics.

XII. Boolean instruction sets

A. A Boolean instruction set mirrors ladder logic instruction sets because of the commonality of logic gates and Examine On/Off conditions required to make both program formats work. (See Handout #2)

B. In a sense, a Boolean programmer "crunches" commands to reduce the number of required programming steps, and the reduced programming time is reflected in reduced scan time.

INFORMATION SHEET

C. Boolean programming takes on more sophisticated aspects with FUNCTION instructions that range from shift register operations to math functions. (See Handout #2)

XIII. **Grafcet programming**

A. The Grafcet standard is a product of an AFCET committee of international engineers formed in 1975 to plan a graphical method for specifying sequential control functions.

B. Telemencanique was the first manufacturer to incorporate Grafcet into a working PLC.

C. Grafcet is a sequential flow chart that operates in steps and transitions in a unique format that makes programming faster and provides a scan time that is much faster than any other programming format.

XIV. **General structure of Grafcet (Transparencies 3 and 4)**

A. The general structure of Grafcet has three sections:

1. The pre-processing section is used to process operator commands and all outside events that will affect the program.

2. The sequential processing section contains the Grafcet program and defines the sequence of the program.

3. The post-processing section defines the actions and commands, controls auxiliary functions such as timers and counters, and processes the safety interlocks such as over-run detectors and emergency steps.

B. There are only ten Grafcet symbols and three basic rules for their use, but the rules and symbols combine to add unequaled power to PLC programming.

XV. **How Grafcet works (Transparency 5)**

A. Grafcet has three basic rules:

1. All Grafcet flow charts must have an initial step.

2. A transition must follow a step.

3. A step must follow a transition.

B. An initial step defines where a sequence begins, other steps define action, and conditions stated in steps are confirmed or solved in the transitions.

INFORMATION SHEET

C. Because PLCs scan from top to bottom, the longer the program the longer the scan time; but with Grafcet programming, the controller scans each step and transition like a single program and scan time is greatly reduced.

(NOTE: Telemecanique advertises that scan time for their controllers using Grafcet is usually close to or less than 5 milliseconds regardless of the length of the program.)

D. The unique step, transition format of Grafcet permits rapid reprogramming because changes can be quickly made into single steps as needed without complete program revision.

E. Troubleshooting with Grafcet is almost automatic because the shut-down will be within the step where the scanning is taking place and the problem can be rapidly isolated.

XVI. Grafcet programming (Transparency 6)

A. As the rules state, all Grafcet charts must begin with an initial step which is programmed as a double-lined box while other steps are programmed as single-lined boxes.

B. Steps are created by simply pressing the appropriate key on the programmer.

C. The Boolean "L" automatically creates a new rung when it is pressed, "I" indicates an input, and "O" indicates an output.

Example: L I0,01 means to load an Examine ON instruction at input module 1, address 1

D. The # (pound) sign is a GO TO statement just like the ones used in computer programming.

Example: # 02 means go to step 2.

E. Post-processing is indicated with a new initial step box, and the X step bits initiate the action called for in each of the steps.

XVII. Putting a Grafcet program to work (Transparency 6)

A. In the sample program in Transparency 6, the Grafcet program sets up specific conditions for the operation of a drill press.

B. The wait condition in step 1 means the program is waiting for the start button to be pushed, and as this happens, the transition after step 1 confirms conditions have been met and sends the program on to step 2.

C. The drill starts and as it reaches limit switch 1, the high speed windings move it downward toward the workpiece.

D. When the drill reaches limit switch 2, the low speed windings slow the drill down as it drills through the workpiece.

INFORMATION SHEET

E. As the drill completes the workpiece, limit switch 4 activates the high speed windings and the drill motor goes into reverse as the bit is raised from the workpiece and the drill returns to step 1 or the initiating position.

F. The X commands in post processing control the action of the drill by keeping the drill running after the start button is released and during all the steps in the program.

G. The program will start again when the start button is pressed.

H. When compared with the ladder logic program or the Boolean program required for the same program, it becomes evident that Grafcet accomplishes significant programming economy. (Transparency 7)

XVIII. Program protection schemes and devices

A. Programs and applications require protection because of product information that needs to be kept secret or confidential.

B. Some PLCs have physical interlocks that use a key to lock the processor into a mode, and the processor can be accessed only by a party authorized to carry a key.

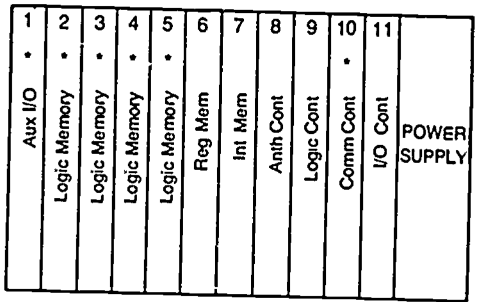
C. Other PLCs use access codes or passwords which must be entered into a programmer before the programmer or the processor can be accessed.

D. Another protection scheme uses an identification number which is entered so that a programmer will not permit a program to be read back.

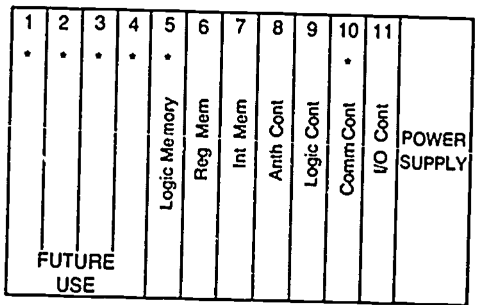
(NOTE: The Cutler-Hammer® MPC1 uses proprietary program protection like that in item D with its MPC1 PLC.)

E. Program and process protection serve to guard against industrial espionage, but the protection also guards against random program changes by practical jokers or untrained personnel.

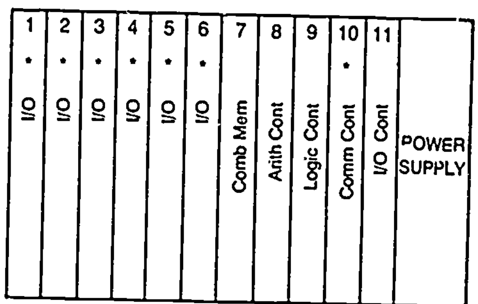
GE Series Six™ Programmable Controllers



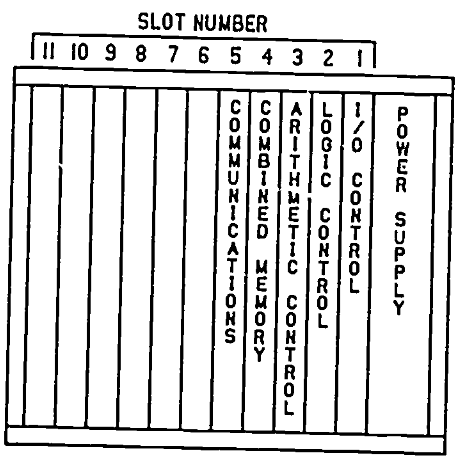
MODEL 6000



MODEL 600



MODEL 60



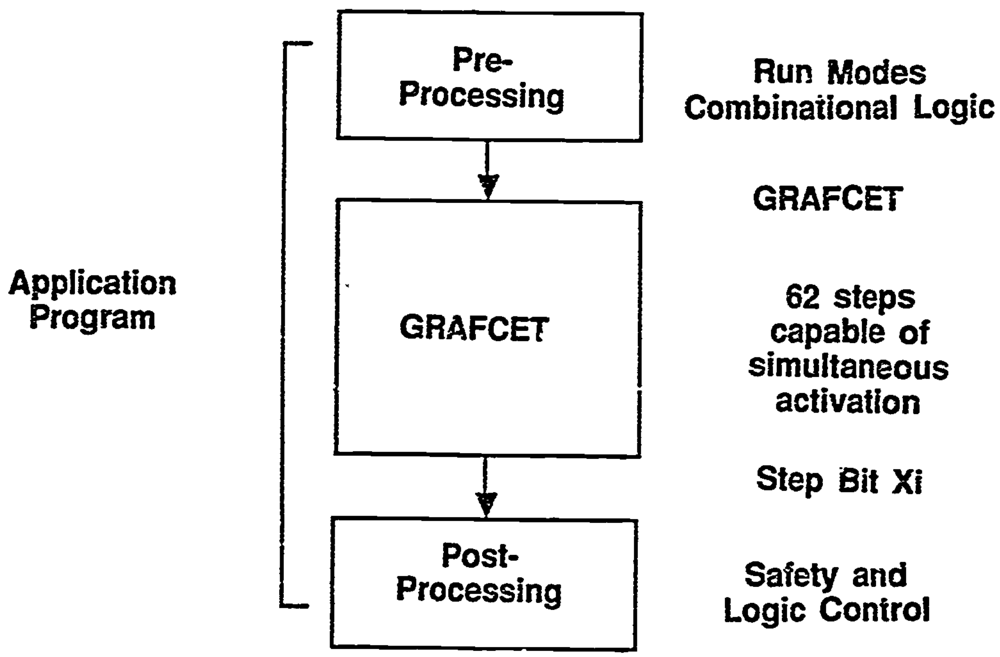
Ladder Logic Diagram Printout

PROGRAM NUMBER XXX VERSION_____ DATE_____ PAGE___

```
RUNG
 |                                                                            |
 |    INPUT      CR       LCR                                           CR    |
 |     123       001      005                                           001   |
001o--o--]/[--o--] [--o--] [--o--------o-------o-------o-------o--------o--( )--o
 (1)               (002)      (003)                                   (003)   |
 |                   |          |                                             |
 |                   |          |                                             |
 |                   |  INPUT   |                                       LCR   |
 |                   |   002    |                                       005   |
002o                 o---] [---o                                     o--(L)--o
 |                 (002)      (003)                                  (006)    |
 |                              |                                      |      |
 |                              V                                      |      |
 |                             005                                     |      |
 |                                                                     |      |
 |    INPUT   ONESHOT   COUNT                                      COUNT      |
 |     008      01       01                                          02 |     |
003o--o--] [--o--]^[--o[  UP  ]o-------o-------o-------o-------o[  UP ]o      o
 (1)          (010)                                              (006)        |
 |              |                                                             |
 |              |                                                             |
 |              |COUNT   CONST.   COUNT   CONST.    COUNT    COUNT        CR  |
 |              | 01               02                01       02         006  |
004o            o[REG = 1234  ]o[REG = 4321  ]o[CLEAR]o[CLEAR]o-------o--( )--o
 |            (010)                          (100)          (007)  (007)      |
 |                                             |                              |
 |             002                             |                              |
 |              V                              |                              |
 |       CR     |                              |                        CR    |
 |      001     |                              |                        052   |
005o--o--]/[--o                                o--------o--------o--------o--( )--o
 (1)          (003)                                                   (100)   |
 |                                                                            |
 |                                                                            |
                                                                      PAGE (__)
```

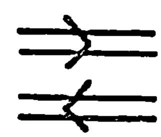
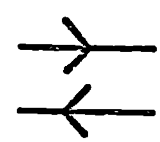
Courtesy EATON/Cutler-Hammer

Grafcet Structure



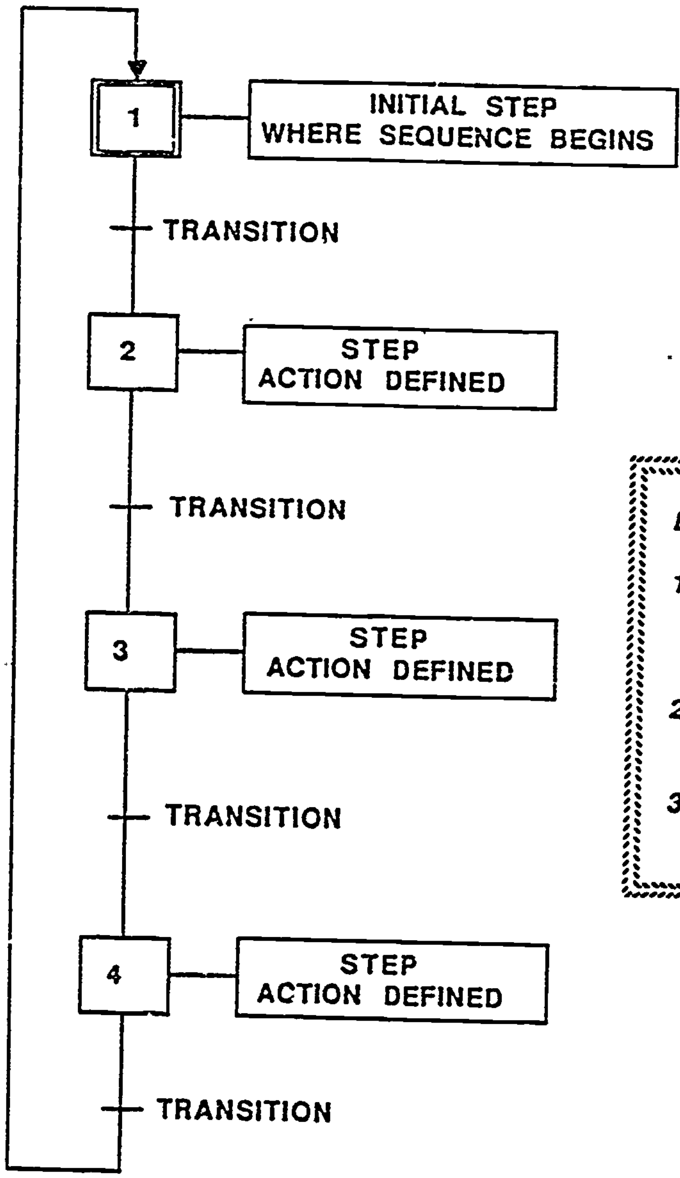
Courtesy of Telemecanique Inc.

Grafcet Symbols

STEP	$\boxed{1}$
INITIAL STEP	$\boxed{4}$
TRANSITIONS	
SIMULTANEOUS ACTIVATION AND DEACTIVATION OF STEPS	
RIGHT LINKS LEFT LINKS	
ORIGIN AND DESTINATION CONNECTORS	
DIRECTIVE LINKS	
NEXT STEP COILS	-(#)-

Courtesy of Telemecanique Inc.

Grafcet Structure

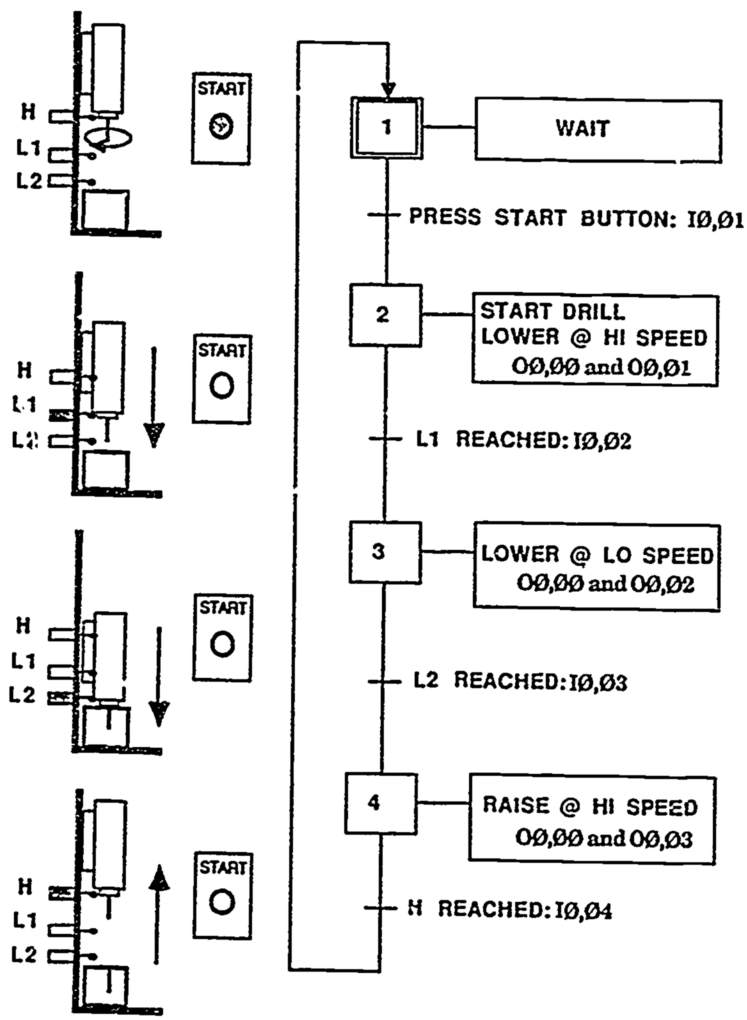


BASIC RULES:

1. *All GRAFCET flow charts must have an Initial Step.*
2. *A Transition must follow a Step.*
3. *A Step must follow a Transition*

Courtesy of Telemecanique Inc.

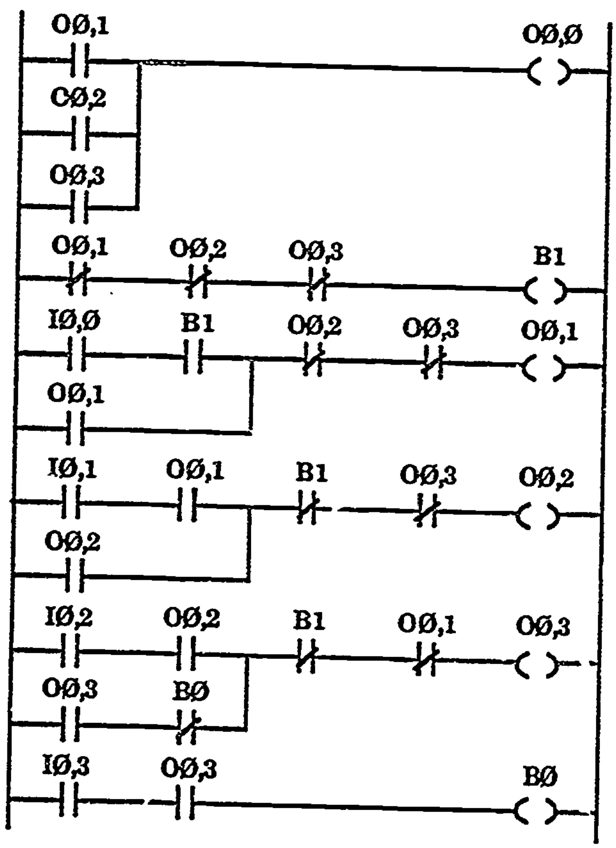
Grafcet Drill Press Program




```
=*=  Ø1
 L   IØ,Ø1
 #   Ø2
-*-  Ø2
 L   IØ,Ø2
 #   Ø3
-*-  Ø3
 L   IØ,Ø3
 #   Ø4
-*-  Ø4
 L   IØ,Ø4
 #   Ø1
=*=  POST
 L   X2
 O   X3
 O   X4
 =   OØ,ØØ
 L   X2
 =   OØ,Ø1
 L   X3
 =   OØ,Ø2
 L   X4
 =   OØ,Ø3
```

Courtesy of Telemecanique Inc.

Drill Press Program




```
L    OØ,1
O    OØ,2
O    OØ,3
=    OØ,Ø
LN   OØ,1
AN   OØ,2
AN   OØ,3
=    B1
L    IØ,Ø
A    B1
O    OØ,1
AN   OØ,2
AN   OØ,3
=    OØ,1
L    IØ,1
A    OØ,1
O    OØ,2
AN   B1
AN   OØ,3
=    OØ,2
L    IØ,2
A    OØ,2
L    OØ,3
AN   BØ
O    IM
AN   B1
AN   OØ,1
=    OØ,3
L    IØ,3
A    OØ,3
=    BØ
```

Courtesy of Telemecanique Inc.

TYPES OF PLCs AND PROGRAMMING
UNIT VI

HANDOUT #1 — SPECIAL PROGRAMMING FEATURES OF THE CUTLER-HAMMER MPC1

Purpose

Just as PLCs have similarities, each of them has features that make it unique. The following items pin-point programming features that help make the Cutler-Hammer MPC1 unique.

NOTE:	**The following information and graphics are courtesy of EATON/Cutler-Hammer.**

Precision Timer

PURPOSE:

When an MPC1 register is used as a timer, it is automatically incremented every 100 milliseconds, (.10 sec.). In some applications, greater accuracy is required.

This program provides such accuracy. This permits timing to within ± one scan time of the PC. (If, for example, scan time is 14 ms, actual delay will be within 14 ms of the preset delay.)

HANDOUT #1

EXPLANATION:

Rungs 1-6 — The first six rungs are only active for the first few seconds after power up. Reg. 1 is a timer (rung 3) and Reg. 2 is a counter (rung 4) for only the first 1000 scans.

After 1000 scans (rung 5) Reg. 3 contains the time required to do 1000 scans, to the nearest one tenth of a second. (This number may also be interpreted as the time to do one scan to the nearest tenth of a millisecond.)

After the scan time has been captured in Reg. 3, CR127 is energized. This disables rungs 3-5 and enables rungs 6-10.

The desired preset time should be loaded into Reg. 4. (The number 1150 would mean 115.0 ms.)

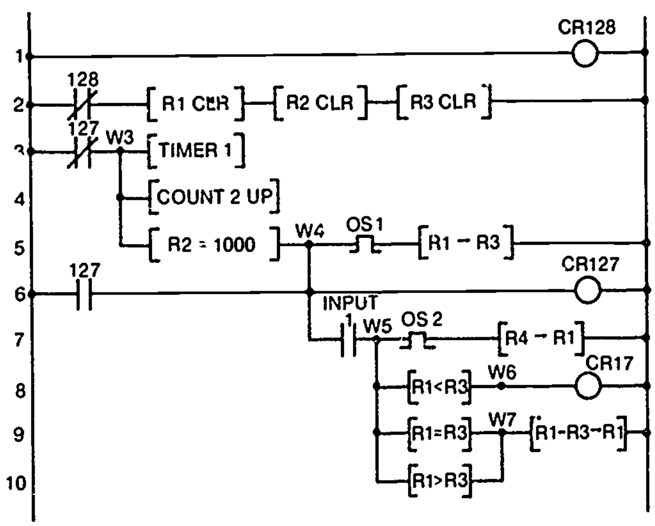
Rungs 7-10 — One rung 7 the preset time in Reg. 4 is transferred to Reg. 1 the instant that input 1 is turned on. (Remember that Reg. 1 is no longer being used as a timer.)

On rungs 9 & 10 the scan time in Reg. 3 is subtracted from Reg. 1 for every scan where Reg. 1 is equal to or greater than R3. Thus, Reg. 1 contains that amount of preset time still remaining.

When Reg. 1 is less than Reg. 3, less than one scan time remains and CR17 is turned on.

Now nothing further will happen unless input is turned off and then back on. At that time the entire cycle (rungs 7-10) will be repeated.

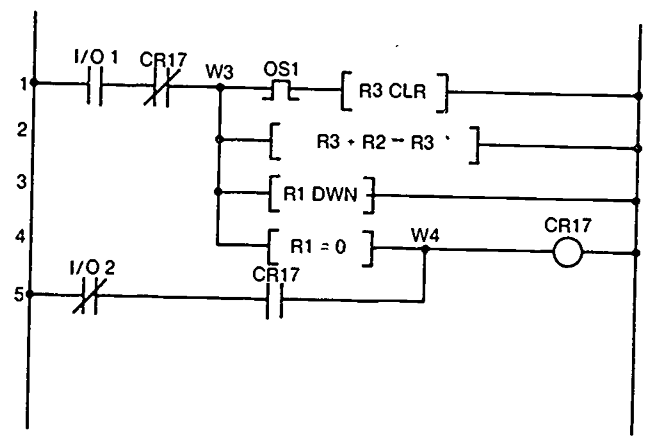
Note: In this example, Reg. 4 contains the preset time, Input 1 starts the timer and CR17 turns on after the time delay.



HANDOUT #1

Multiplication Program

Reg. 1 is the multiplier...the first number.
Reg. 2 is the multiplicand...the second number.
Reg. 3 holds the answer at the end of the multiplication process.



Rung 1 — Reg. 3 is cleared. This happens once, the first scan through because of One Shot #1.

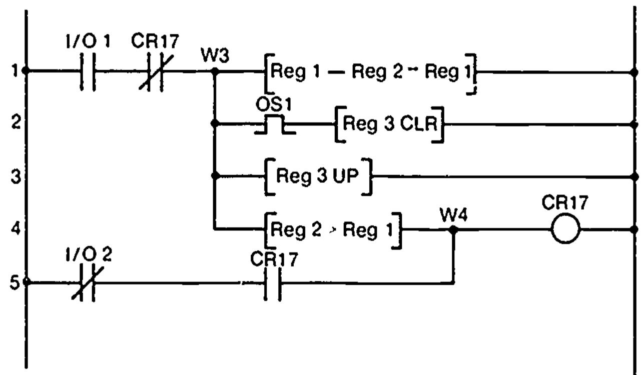
Rung 2 & 3 — The value of Reg. 3 is added to the value of Reg. 2 and the sum is put back into Reg. 3. This happens once each scan of the PC. Counter Reg. 1 counts down 1 digit each scan of the program.

Rung 4 & 5 — Counting down continues until the statement [Reg. 1 = 0] is true, at which time CR17 comes on, drops out the multiplication circuit and holds itself on. When CR17 comes on the answer is ready in Reg. 3. Input 2 de-energizes CR17 and resets the program. Time required to execute program = (Scan time) x (Multiplier in Reg. 1.)

HANDOUT #1

Division Program

Reg. 1 is the dividend at the beginning of the division operation.
Reg. 1 is also the remainder at the end of the division 1 operation.
Reg. 2 is the divisor at all times.
Reg. 3 holds the answer (quotient) at the end.



Rungs 1 & 2 — The value of Reg. 1 is decreased by whatever the value of Reg. 2 is; and the answer is put back in Reg. 1. This happens each scan of the PC when I/O is closed. Next Reg. 3 is cleared. This happens once, the first scan through, because of One Shot #1.

Rung 3 — Reg. 3 becomes an active counter as long as Wire 3 remains energized. Reg. 3 will count up 1 each scan of the program.

Rungs 4 & 5 — Counting up continues until the statement [Reg. 2 > Reg. 1] becomes true at which time CR17 comes on, drops out the division circuit, and holds itself on. When CR17 comes on the answer to the division (quotient) is found in Reg. 3, while the remainder is located in Reg. 1. Input 2 de-energizes CR17 and resets the program.

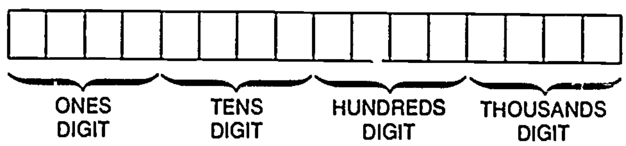
Time required to execute the program = (Scan time) x (Quotient in Reg. 3.)

HANDOUT #1

Binary Coded Decimal Input/Output

MPC1 Registers can store numbers from 0-9999. These numbers are stored in a form called BCD (Binary Coded Decimal).

Each register consists of 16 bits of information. The 16 bits of information are divided into 4 groups of 4. Each group represents one of the 4 possible digits of a stored number.



(Least significant digits appear on the left in MPC1)

The bits of information may be either "ON" (=1) or "OFF" (=0). The different combinations of these 1's and 0's represent the decimal digits. While there are 16 possible combinations in a group of 4, only ten are used (0-9). The ten combinations are shown below:

0 0 0 0 = 0	1 0 1 0 = 5
1 0 0 0 = 1	0 1 1 0 = 6
0 1 0 0 = 2	1 1 1 0 = 7
1 1 0 0 = 3	0 0 0 1 = 8
0 0 1 0 = 4	1 0 0 1 = 9

Another way to think of these groups is as if each bit in a group has a decimal weight. The weights are shown below:

WEIGHT	1	2	4	8
BIT				

By adding up the weights where a one is present, the decimal number represented is equal to the sum.

For example:

	1	2	4	8
7 =	1	1	1	0

1 + 2 + 4 + 0 = 7

5 =	1	0	1	0

1 + 0 + 4 + 0 = 5

HANDOUT #1

Once BCD is understood, the task of loading values to a register from a thumbwheel or similar BCD device becomes easy. When inputs are used to load 1's and 0's to a register, a decimal value is stored. To illustrate this, try the following:

Start left to right and add the weights of the following bit pattern:

1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0

The bit pattern gives a decimal reading of: 5

Try one more:

1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0

The decimal value is: 3

BCD inputs are used both to load values to registers and to output information to BCD devices.

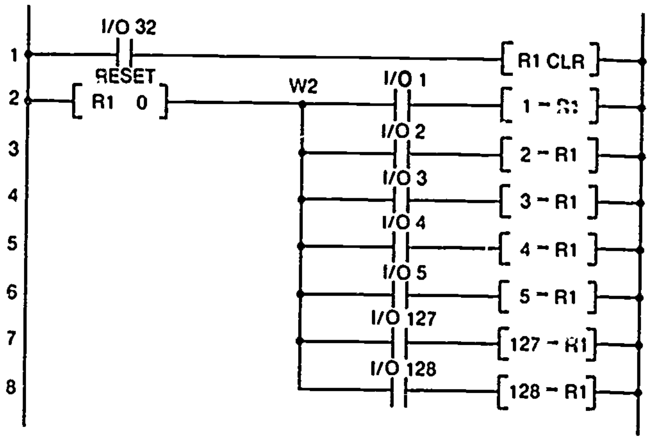
HANDOUT #1

First Closure Memory

Control systems normally contain many permissive circuits. These circuits monitor the system; if one circuit opens it will cause others to open in rapid succession, giving an orderly shut down.

It would be helpful to determine which was the first contact to open and locate the original cause of the trouble.

The example shown here will "Trap" the first signal that occurs. This simplifies maintenance by allowing personnel to go directly to the original cause of the problem.



Rung 1 — When the reset button (I/O 32) is pushed Register 1 is set to zero.

Rungs 2-8 — When the system is reset (R1=0) wire No. 2 turns on.

Should any fault occur, a number corresponding to that fault will be placed into Register 1. For example if fault 3 occurs, Register 1 will equal 3. Since Register 1 is no longer zero, wire 2 turns off, preventing any other number from being loaded.

Monitoring Register 1 with the programmer or register access panel will then show which fault happened first.

Conclusion

Hardware, memory size, and programming features help make all PLCs unique, but their similarities also give PLCs general references that are easy to transfer from one PLC type to another.

TYPES OF PLCs AND PROGRAMMING
UNIT VI

HANDOUT #2 — BOOLEAN INSTRUCTIONS

Purpose

Programming languages based on Boolean algebra accomplish the same things that ladder logic program accomplish, but they do it in a different way. To begin, addressing is more direct, excess commands are eliminated, and there are other facets that add up to faster programming and scan time. An examination of the use of Boolean for basic instructions and applied instructions will help you better understand both the simplicity and complexity of Boolean programming.

Basic Instructions

Instruction	Symbol	Mnemonic	Operand	Function	Data
LOAD		LD	Relay No.	Logical start operation	Relay No. Input/output relays 0000 to 0915 Internal auxiliary relays 1000 to 1907 Holding relays HR000 to 915 Timers TIM00 to 47 Counters CNT00 to 47 Temporary memory relays TR0 to 7 (Temporary memory relays can only be used with the LD instruction.)
LOAD NOT		LD NOT	Relay No.	Logical NOT start operation	
AND		AND	Relay No.	Logical AND operation	
AND NOT		AND NOT	Relay No.	Logical AND NOT operation	
OR		OR	Relay No.	Logical OR operation	
OR NOT		OR NOT	Relay No.	Logical OR NOT operation	
AND LOAD		AND LD		Logical AND operation with the previous condition	
OR LOAD		OR LD		Logical OR operation with the previous condition	
OUT		OUT	Relay No.	Outputs the result of a logical operation to the specified output relay, internal auxiliary relay, latching relay, or shift register.	Relay No. Output relay 0500-0915 Internal auxiliary relays 1000 to 1807 Holding relays HR000 to 915 Temporary memory TR0 to TR7
TIMER	TIM	TIM	Timer No. Set value	ON-delay timer operation Set time: 0 to 999.9sec	Timers/counters 00 to 47 Set value Constant # 0000 to 9999
COUNTER	CP R CNT	CNT	Counter No. Set count value	Down counter operation Set value: 0 to 9999	

Courtesy Omron Electronics

HANDOUT #2

Applied Instructions

FUN No.	Instruction	Symbol	Mnemonic	Operand	Function	Data
00	NO FUNCTION		FUN 0 0		Use this instruction when an instruction is added in the future. This instruction is also used for minute adjustment of scan time.	
01	END	END	FUN 0 1		End of a program	
02	INTERLOCK	IL	FUN 0 2		Causes all the relay coils between this instruction and the ILC instruction to be reset or not reset according to the result immediately before this instruction.	
03	INTERLOCK CLEAR	ILC	FUN 0 3		Clears the IL instruction.	
10	SHIFT REGISTER	IN, CP, R — SFT	FUN 1 0	Start CH-No. CH-No. End	Shift register operation 15 0 15 0 End CH … Start CH ←IN	Channel Numbers Output relay : 05 to 09CH Internal auxiliary relay : 10 to 17CH Holding relay : 0 to 9CH Start CH ≤ END CH Start and end channel can be same channel.
11	LATCHING RELAY	SET, RESET — KEEP	FUN 1 1	Relay No.	Latching relay operation	Relay No. Input output relay 0500 to 0915 Internal auxiliary relay 1000 to 1807 Holding relay HR000 to 915
13	DIFFERENTIATION UP	DIFU	FUN 1 3	Relay No.	Causes a specified relay to operate for one scan time at the leading edge of the result of a logical arithmetic operation.	
14	DIFFERENTIATION DOWN	DIFD	FUN 1 4	Relay No.	Causes a specified relay to operate for one scan time at the trailing edge of the result of a logical arithmetic operation.	
15	HIGH-SPEED TIMER	TIMH	FUN 1 5	Timer No. Set value	Performs a high-speed on-delay (down type) timer operation. Set time: 00.00 to 99.99 sec	Timers/counters 00 to 47 Set value Constant # 0000 to 9999

Courtesy Omron Electronics

HANDOUT #2

Other Instructions

FUN No.	Instruction	Symbol	Mnemonic	Operand	Function	Data
20	COM-PARE	CMP	FUN 2 0	S1 S2	Compares a channel data or a 4-digit constant against another channel data. $S_1 \lesseqgtr S_2$	S , S1 , S2 Input/output relays 00CH to 09CH Internal auxiliary relays 10CH to 19CH Holding relays HR0 to 9 Timers TIM00 to 47 Counters CNT00 to 47 Constant # 0000 to FFFF D Output relay 05 to 09CH Internal auxiliary relay 10 to 17CH Holding relay HR0 to 9CH
21	MOVE	MOV	FUN 2 1	S D	Transfers a channel data or a 4-digit constant (16 bits) to a specified channel. $S \rightarrow D$	
22	MOVE NOT	MVN	FUN 2 2	S D	Inverts a channel data or a 4-digit constant and transfers it to a specified channel. $\bar{S} \rightarrow D$	
30	ADD	ADD	FUN 3 0	S1 S2 D	Performs BCD addition of a channel data or a 4-digit constant to a specified channel data. $S_1 + S_2 + \boxed{CY} = D, \boxed{CY}$	S1 S2 Input /output relay 00 to 19CH Holding relay HR0 to 9CH TIM/CNT00 to 47 Constant # 0000 to 9999 D Output relay 05 to 09CH Internal auxiliary relay 10 to 17CH Holding relay HR0 to 9CH
31	SUB-TRACT	SUB	FUN 3 1	S1 S2 D	Performs BCD subtraction of a channel data or a 4-digit constant from a specified channel data. $S_1 - S_2 - \boxed{CY} = D, \boxed{CY}$	
40	SET CARRY (STC)	STC	FUN 4 0		Sets the carry (CY) to "1". $1 \rightarrow \boxed{CY}$	
41	CLEAR CARRY (CLC)	CLC	FUN 4 1		Clears the carry (CY) to "0". $0 \rightarrow \boxed{CY}$	

Courtesy Omron Electronics

Conclusion

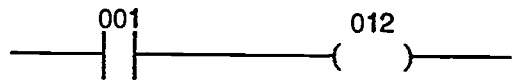
For certain programming activities, Boolean programming speeds programming itself and accomplishes other programming functions at a faster speed. Comparing Boolean commands with ladder logic commands can be the first step in providing PLC technicians with the diverse programming skills required at some installations.

TYPES OF PLCs AND PROGRAMMING
UNIT VI

ASSIGNMENT SHEET #1 — TRANSLATE LADDER LOGIC INSTRUCTIONS INTO BOOLEAN INSTRUCTIONS

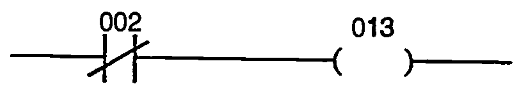
Directions: Assume that you are working with a Boolean-based PLC that uses the LOD to mean Load and OUT to mean output. Translate the following simple program from ladder logic to Boolean.

a. Ladder logic:



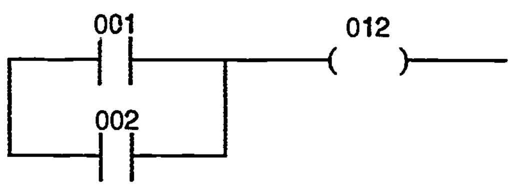
Boolean:

b. Ladder logic:



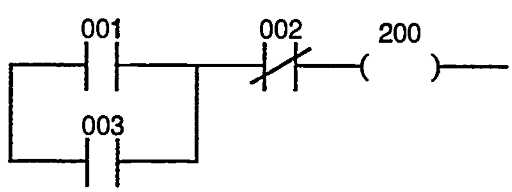
Boolean:

c. Ladder logic:



Boolean:

d. Ladder logic:



Boolean:

TYPES OF PLCs AND PROGRAMMING
UNIT VI

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

a. LOD1 OUT012

b. LOD N2 OUT013

c. LOD1 OR 2 OUT 012

d. LOD1 OR 3 AND N2 OUT200

TYPES OF PLCs AND PROGRAMMING
UNIT VI

UNIT TEST

NAME________________________________ SCORE ________________

1. Match the terms on the right with their correct definitions.

_____a. The AND, OR, and NOT gates that are part of the logic gates in Boolean algebra and have been adapted for use in the programming of sequential devices such as PLCs	1.	Instruction set
	2.	ms
	3.	Boolean operators
_____b. The symbols, letters, and numbers that collectively define the unique operations that can be performed with the memory structure of a given PLC	4.	Mnemonics
_____c. The expression of a term or condition in an abbreviated form that makes it easier to remember		
_____d. One thousandth of a second, expressed in decimal as 0.001 second, and in scientific notation as 10^{-3}		

2. Complete statements concerning comparing PLCs by circling the material that best completes each statement.

   a. All PLCs have similar operating characteristics, but each PLC is (unique) (similar) because of its hardware, instruction set, and programming devices.

   b. PLC hardware refers to the physical parts of a PLC that house the CPU and the circuitry that serves as the (brains) (nervous system) of a PLC system.

   c. A PLC instruction set contains the (relay) (logical) conditions that have to be met before contacts and coils can accomplish a control objective.

   d. The instruction set is really a (computer language) (code) that an operator uses to address or talk to a PLC.

   e. Making the instruction set work is a matter of programming which means using one of four formats:

      1) Ladder (logic) (relay) diagrams

      2) Boolean (logic) (diagrams)

      3) Grafcet (programming) (pictures)

TEST

4) (Combinations) (expansion) of programming units

f. Programming devices range from hand-held units with integrated keyboards to full-size computers that work with programming software, but almost all programming devices are relatively easy to program and that's why ("user friendly") ("easy access") programming is a feature of PLC power.

3. Select true statements concerning modular structure by placing an X beside each statement that is true.

_____a. Another powerful element of PLCs is their modular construction which permits the selection of expansion units as required for specific applications.

_____b. Most PLC installations have standard panel or rack designs which permit the addition of selected modules without having to redesign the installation.

_____c. The standard rack panel design includes the power supply required to operate the module or modules that are placed in the rack or panel.

_____d. Expansion modules are not well designed for adding analog I/O modules designed to work with analog as opposed to discrete signals.

4. Select conditions concerning compatibility by answering the following questions.

a. Compatibility affords industry the opportunity to what, experiment for less money or expand control applications as money and need dictate?

Answer ____

b. A series of compatible controllers is sometimes referred to as what, a function group or a family?

Answer ____

c. A major contribution to compatibility is that controllers of different power still use what, the basic input/output structure or the same programming language and addressing format?

Answer ____

5. Select conditions concerning programming the Cutler-Hammer MPC1 by answering the following questions.

a. The MPC1 uses ladder logic programming, but it is combined with a unique concept called what, wire number programming or direct rung addressing?

Answer ____

TEST

b. The MPC1 format improves programming by what, reducing programming time or significantly reducing scan time?

Answer ______________________________

6. Select true statements concerning the Cutler-Hammer MPC1 programmer by placing an X beside each statement that is true.

_____a. The MPC1 programmer has an LED display 24 characters wide and two rows deep.

_____b. The top row of the programmer displays ladder logic elements such as contacts and coils along with error messages and diagnostics.

_____c. The bottom row displays other logic messages that list the functions for the five keys below the display.

_____d. The F keys F1 through F5 program the functions prompted on the second row of the display, and each key can control several functions.

_____e. The programmer is "user friendly" because of the self-prompting messages and the logical sequence in which they occur on the upper display.

_____f. The programmer can directly access program modes, editing functions, mathematical and compare functions, and FORCE functions which permit inputs/outputs to be turned ON or OFF independent of the PC program or actual input/output status.

7. Complete statements concerning register formats in the MPC1 by circling the materials that best complete each statement.

a. MPC1 registers take advantage of wire number programming by permitting register functions to be programmed on a single rung, except for shift registers which require (two) (three) rungs.

b. The MPC1 has 32 registers numbered 1 through 32, and all register applications are strictly defined by the user and any register can be used for (each) (only its designated) register function.

c. The register functions include a point register used to identify the register used in an operation, a bit register used for comparison and assignment operations, and a Clear Register that permits any of the 32 registers to be (cleared) (programmed) with a single instruction.

d. (Any of the 32) (The first half of) registers can be used as a Timer Register an UP counter register, a DOWN counter register, or a SHIFT register.

TEST

8. Solve problems concerning special registers in the MPC1 by answering the following questions.

   a. The MPC1 can compare one register with another: How does it make the comparison?

      Answer ______________________________

   b. In the case of an add or subtract function so that the result will not be lost, what has to happen?

      Answer ______________________________

9. Complete statements concerning other special features of the MPC1 by circling the material that best completes each statement.

   a. Optional program packages for the MPC1 include a back-up program storage cartridge which can be installed as part of the programmer, and an EEPROM cartridge which also serves program back-up but can be (removed from the) (used as a) programmer.

   b. The MPC1 Register Access Module provides a remote display of the (first instruction) (stored contents) of any of the 32 registers.

   c. With the Register Access Module, the registers can be programmed as non-viewable, viewable, non-accessible, meaning values cannot be changed or viewable accessible, meaning values can be (changed) (added to only).

   d. The Register Access Module has a 14-button keyboard that can be used for entering new data for a register, but only register contents can be manipulated, the ladder logic program (cannot be changed) (can only be edited).

   e. Another unique feature of the MPC1 is its built-in ladder diagram printout capability which uses a standard RS232C serial interface directly from the programmer to a printer to provide a (hard copy) (display) of a ladder logic program.

10. Select conditions concerning special MPC1 programming by answering the following questions.

    a. With the MPC1, timing can be programmed so that scan time can be speeded up to 14 ms instead of the usual what, 100 ms or 250 ms?

       Answer ______________________________

    b. One unique programming activity permits a troubleshooter to find the first contact to open in a shut down, and this is called what, key programming or first closure memory?

       Answer ______________________________

TEST

11. Select true statements concerning Boolean programming basics by placing an X beside each statement that is true.

_____a. Ladder logic diagrams are actually symbolic programming languages that are based upon the manipulation of logic gates built into the PLC memory.

_____b. Boolean algebra as a programming language does the same thing that ladder logic programming does, but the addressing is more direct, excess commands before conditions are eliminated, and scan time is faster.

_____c. Boolean programming has basic rules that are actually mirrors of ladder logic programming because the conditions for contacts are still set by the equivalent of Examine ON and Examine OFF conditions.

_____d. In a typical ladder logic program, an Examine ON instruction at address 001 would be , but in Boolean, this command would simply be STR 1 or LOD 1.

_____e. With a ladder logic program, the 001 address would have to be entered, the Examine OFF instruction would have to be entered, and then the instruction would itself have to be entered by pressing ENTER or an equivalent key on a programmer or computer keyboard.

_____f. With Boolean programming, the STR 1 or LOD 1 command accomplishes everything at once because STR and LOD automatically create an Examine ON condition at the address specified, and also starts a new rung.

_____g. To create an Examine OFF instruction in Boolean requires storing or loading a NOT logic gate which would be expressed as LOD N1 or STR N1.

_____h. To create two Examine ON conditions on the same rung in Boolean requires the use of an AND logic gate which would be programmed as LOD 1 AND 2 or STR 1 AND 2.

_____i. To create a combination Examine ON, Examine OFF condition in a parallel circuit in Boolean requires the use of an OR logic gate which would be programmed as LOD 1 OR 2 or STR 1 OR 2.

_____j. Creating Examine ON, Examine OFF conditions requires use of the AND, OR, and NOT gates as expressed in Boolean, and outputs are usually created simply by using OUT.

_____k. The AND, OR, and NOT gates used in Boolean programming are called the Boolean operators, and other abbreviated commands such as JMP and FUN are called the instruction set.

TEST

12. Select conditions concerning Boolean instruction sets by answering the following questions.

    a. Boolean instruction sets mirror ladder logic instruction sets because of what, the similarity of symbols or the commonality of logic gates and Examine ON/Examine OFF conditions?

    Answer ______________________

    b. Boolean programming reduces scan time because commands are what, accelerated or crunched?

    Answer ______________________

    c. Shift register activities and math activities are accomplished in Boolean with what, function instructions or direct access programming?

    Answer ______________________

13. Complete statements concerning Grafcet programming by circling the materials that best complete each statement.

    a. The Grafcet standard is a product of an AFCET committee of (American) (international) engineers formed in 1975 to plan a graphical method for specifying sequential control functions.

    b. Telemencanique was the first manufacturer to incorporate Grafcet into (a programming language) (a working PLC).

    c. Grafcet is a (sequential flow chart) (map-like chart) that operates in steps and transitions in a unique format that makes programming faster and provides a scan time that is much faster than any other programming format.

14. Solve problems concerning the general structure of Grafcet by answering the following questions.

    a. You have been asked to explain the pre-processing section of Grafcet. How would you describe its function?

    Answer ______________________

    b. If you needed to check sequential elements of a program, what part of Grafcet would you check?

    Answer ______________________

    c. How would you describe functions of Grafcet's post-processing section?

    Answer ______________________

TEST

15. Complete statements concerning how Grafcet works by circling the materials that best complete each statement.

    a. Grafcet has three basic rules:

        1) All Grafcet flow charts must have (an initial step) (an introduction).

        2) A (transition) (program) must follow a step.

        3) (A step) (an output) must follow a (transition) (step).

    b. An initial step defines where a sequence begins, other steps define action, and conditions stated in steps are confirmed or solved in the (transitions) (other steps).

    c. Because PLCs scan from top to bottom, the longer the program the longer the scan time, but with Grafcet programming, the controller scans each step and transition like a single program and scan time is (greatly) (slightly) reduced.

    d. The unique step, transition format of Grafcet permits rapid reprogramming because changes can be quickly made into single steps as needed without complete (program) (transition) revision.

    e. Troubleshooting with Grafcet is almost automatic because the shut-down will be within the step where the scanning is taking place and the problem can be (rapidly) (relatively quickly) isolated.

16. Select conditions concerning Grafcet programming by answering the following questions.

    a. An initial step in Grafcet is programmed as what, a rectangle, a single-lined box, or a double-lined box?

       Answer ______________________________

    b. The Boolean L does what when it is pressed, load an Examine ON statement or start a new rung or both?

       Answer ______________________________

    c. The # sign in Grafcet is actually what, a Go To instruction or a math instruction?

       Answer ______________________________

17. Select conditions concerning putting a Grafcet program to work by answering the following questions.

    a. In a transition after step 1, what is taking place, output activation or confirmation that conditions in the step have been met?

       Answer ______________________________

TEST

b. The X command in post processing helps control action of a drill by doing what, initiating high-speed windings or keeping the drill running after the start button is released?

Answer ______________________________

c. After a complete program cycle, what will happen when the start button is pressed, will the program start again or will the program wait for a designated time?

Answer ______________________________

18. Complete statements concerning program protection schemes and devices by circling the materials that best complete each statement.

    a. Programs and applications require protection because of product information that needs to be kept secret or (confidential) (top secret).

    b. Some PLCs have physical interlocks that use a key to lock the processor into a mode, and the processor can be accessed only by a (party authorized to carry a key) (supervisor).

    c. Other PLCs use access codes or (passwords) (keys) which must be entered into a programmer before the programmer or the processor can be accessed.

    d. Another protection scheme uses an identification number which is entered so that a programmer will not permit a program to be (read back) (run).

    e. Program and process protection serve to guard against (theft) (industrial espionage), but the protection also guards against random program changes by practical jokers or untrained personnel.

(NOTE: If the following activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

19. Translate ladder logic instructions into Boolean instructions. (Assignment Sheet #1)

TYPES OF PLCs AND PROGRAMMING
UNIT VI

ANSWERS TO TEST

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

2. a. Unique
   b. Brains
   c. Logical
   d. Computer language
   e. 1) Logic
      2) Logic
      3) Programming
      4) Combinations
   f. User friendly

3. a, b, c

4. a. Expand control applications as money and need dictate
   b. A family
   c. The same programming language and addressing format

5. a. Wire number programming
   b. Significantly reducing scan time

6. b, d, e, f

7. a. Two
   b. Each
   c. Cleared
   d. Any of the 32

8. a. By using a numeric constant of 0 or 1
   b. An assignment function has to be used

9. a. Removed from the
   b. Stored contents
   c. Changed
   d. Cannot be changed
   e. Hard copy

ANSWERS TO TEST

10. a. 100 ms
    b. First closure memory

11. a, b, c, d, e, f, g, h, i, j

12. a. The commonality of logic gates and Examine ON/Examine OFF conditions
    b. Crunched
    c. Function instructions

13. a. International
    b. A working PLC
    c. Sequential flow chart

14. a. It processes operator commands and outside events
    b. The Grafcet program
    c. Controls functions such as timers, counters, and alarms

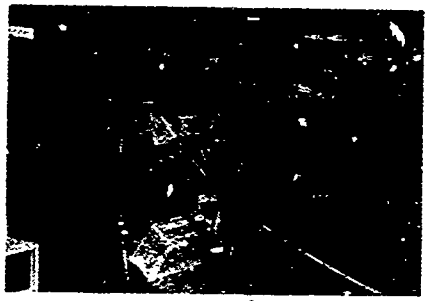
15. a. 1) An initial step
       2) Transition
       3) Step
    b. Transitions
    c. Greatly
    d. Program
    e. Rapidly

16. a. A double-lined box
    b. Both
    c. A Go To instruction

17. a. Confirmation that conditions in the step have been met
    b. Keeping the drill running after the start button is released
    c. The program will start again

18. a. Confidential
    b. Party authorized to carry a key
    c. Passwords
    d. Read back
    e. Industrial espionage

19. Evaluated to the satisfaction of the instructor



INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss PLC inputs/outputs and typical industrial applications. The student should also be able to plan, wire, program, and confirm a conventional start/stop station, plan and wire a linear positioning station with limit switches, and program and confirm a series of programs that demonstrate positioning control with a PLC. These competencies will be evidenced by completing the procedures outlined in the job sheets and by scoring a minimum of 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to industrial program applications with their correct definitions.
2. Complete statements concerning application inputs.
3. Match common input devices with their applications.
4. Select conditions concerning START/STOP station conventions.
5. Select problems concerning putting logic to work in a START/STOP station.
6. Complete statements concerning limit switches as inputs.
7. Select true statements concerning analog inputs.
8. Select true statements concerning application outputs.
9. Complete statements concerning guidelines for application wiring.
10. Solve problems concerning power and grounding.
11. Demonstrate the ability to:
    a. Plan, wire, program, and confirm a conventional start/stop station. (Job Sheet #1)
    b. Connect relay coils to a start/stop station and verify interlocks. (Job Sheet #2)
    c. Connect a linear positioner, motor, and limit switches to simulate a positioning application. (Job Sheet #3)

SPECIFIC OBJECTIVES

d. Program and confirm an up counter in a positioning application. (Job Sheet #4)

e. Program and confirm a retentive timer in a positioning application. (Job Sheet #5)

f. Program and confirm a two-cycle positioning application with manual stop. (Job Sheet #6)

g. Program and confirm a two-cycle positioning application with automatic stop. (Job Sheet #7)

h. Program a positioning application with sequencer input driving sequencer output. (Job Sheet #8)

i. Program a positioning application with sequencer input driving sequencer output with start/stop control. (Job Sheet #9)

j. Program an extended SQI driving an SQO positioning application with start/stop control. (Job Sheet #10)

k. Program and verify a jump command in a positioning application. (Job Sheet #11)

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

SUGGESTED ACTIVITIES

Read Me First

Procedures in this text are presented for demonstration only and should not be used in actual industrial applications. Graphic materials from manufacturers are presented for the purpose of illustration only and no liability is assumed for their use otherwise. Persons using this text assume liability for demonstration and for any equipment damaged in demonstration. Administration of these materials should be by a qualified instructor only in a safety-proven environment.

A. Provide students with objective sheet.

B. Provide students with information sheets.

C. Discuss unit and specific objectives.

D. Discuss items in the information sheet.

E. Demonstrate and discuss the procedures outlined in the job sheets.

F. Invite a local or area engineer or technician who programs PLCs to talk about a PLC applications in your area and the control objective(s) it accomplishes.

G. Examine the physical requirements for the job sheets carefully and prepare equipment so that all activity will meet safety requirements.

H. Give test.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Bulletin 1745 SLC™ 100 Programmable Controller.* Milwaukee, WI 53204: Allen-Bradley, a Rockwell International Company, September, 1985.

B. *Bulletin 1745 SLC™ Programmable Controllers.* Milwaukee, WI 53204: Allen-Bradley, a Rockwell International Company, November, 1987.

C. *Analog Input Module.* Cleveland, OH 44143: Allen-Bradley, a Rockwell International Company, March, 1987.

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

INFORMATION SHEET

I. Terms and definitions

A. **Closure** — The physical touching of contacts that cause a device such as a switch to complete a circuit and pass power

B. **Engineering units** — The quantities or degrees used to measure, expressed in units reflecting specific phenomena such as gallons per minute or miles per hour

C. **AWG (American Wire Gauge)** — A standard for measuring the diameter of electrical wire where the smaller the number the larger the wire diameter

D. **Convention** — A method of doing something that has been done for so long that it is accepted as a standard way of doing that thing

II. Application inputs

A. An input to a PLC must be a device that can provide a closure that will send a signal to a physical input terminal on a PLC.

B. The closure means that the active device is sending voltage to the input, or if the device is inactive, there is no closure and no voltage.

C. Application inputs must create the ON/OFF conditions to which PLC inputs can respond in order to create the control signals that will in turn activate or control outputs.

D. Some common input devices used with PLC applications include:

1. Proximity switches
2. Photoelectric switches
3. Pushbutton switches
4. Limit switches

(NOTE: There are literally dozens of input devices, but those listed are the most common. The push buttons and limit switches will be demonstrated in the job sheets that accompany this unit of instruction.)

INFORMATION SHEET

III. Common input devices and their applications

A. **Proximity switches** — Switches that sense the presence or absence of objects without physically touching the objects (Figure 1)

FIGURE 1

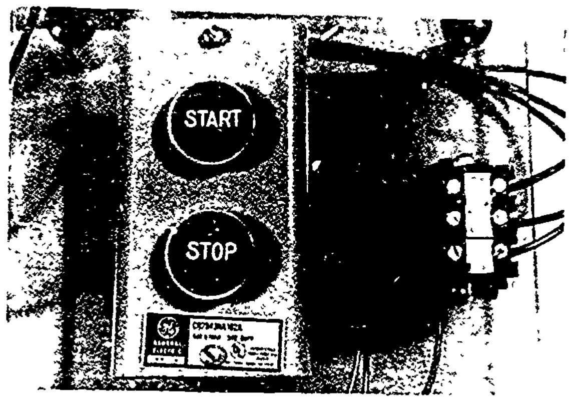
B. **Photoelectric switches** — Switches that sense the presence or absence of objects by using a continuous beam of light which unbroken indicates absence and which broken indicates presence (Figure 2)

FIGURE 2

INFORMATION SHEET

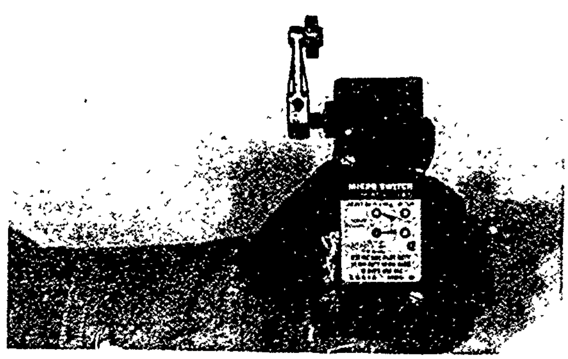
C. **Pushbutton switches** — Switches which may be wired as normally open or normally closed, and are typically used to start or stop a motor or controlled output (Figure 3)

FIGURE 3



D. **Limit switches** — Switches which indicate position by effecting a closure or an opening when an object physically contacts a switch (Figure 4)

FIGURE 4



IV. START/STOP station conventions

A. One of the most common applications of push-button switches is in a conventional START/STOP station where the START switch is pushed to start something and the STOP switch is pushed to stop something.

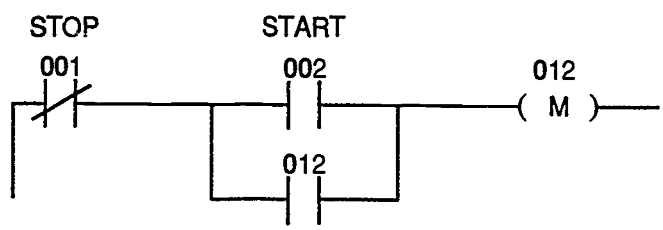
B. By convention a START switch is NO and a STOP switch is NC so that either switch can be activated by pushing it with a thumb or finger.

C. The pushing action is more natural and easier that a pulling action and that's why pushbutton switches are common in industrial applications.

INFORMATION SHEET

D. The NO START switch and NC STOP switch are frequently constructed as a unit for use as a START/STOP station, and their normal states are easy to program.

EXAMPLE: For motor control, once a START button is pressed, we want the motor to start, but we want the motor to continue running after the START button is released. When the STOP button is pressed, we want the motor to stop and remain stopped even after the STOP button is released. In ladder logic, the program employs a seal-in circuit.



E. The ladder logic for the conventional START/STOP station is relatively simple:

1. The (STOP button) Examine ON at 001 is TRUE and provides logical continuity to 002.

2. When START switch 2 is pressed, logical continuity is established for the rung, activating the START 012 contact in the seal-in circuit.

3. As the START button is released, the motor continues to run because logical continuity is maintained and auxiliary contact 012 remains TRUE

4. When STOP button 1 is pressed, the rung goes FALSE and the output is de-energized and remains de-energized until the START button is pressed again.

V. Putting logic to work in a START/STOP station

A. By convention, in a START/STOP station the START button is NO and the STOP button is NC, yet the conditions can be reversed so that both switches would function the opposite of their conventional applications.

B. The control problem presented in item A could be solved by physically changing the locations of the two switches or by rewiring the inputs to the controller, but that defeats the purpose of using a PLC in the first place.

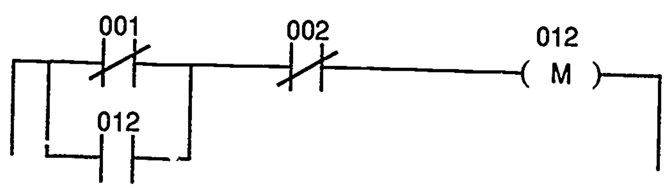
C. When something like a conventional START/STOP station is repeated and repeated in application after application, it leaves a mind set that carries over into other notions about all electrical applications — wires have to be changed to change the application.

D. With a PLC, logic can change the function of the START/STOP switches without having to change location or move one wire.

INFORMATION SHEET

E. By switching the function of the switches in the ladder logic, the START switch 1 is used to stop the motor, and the STOP switch 2 is used to start the motor.

EXAMPLE:



F. By using logic to reverse the functions of START/STOP switches, the power of the PLC is put to work, and the value of creative programming is demonstrated.

VI. Limit switches as inputs

A. Limit switches are popular in positional control because their three-terminal structure makes them easy to wire as either NO or NC to help customize an application.

B. Limit switches are made to order for positional control and are frequently the input devices for sophisticated applications such as pick-and-place robots.

C. Limit switches are used in conjunction with other movement-oriented control devices ranging from product-moving conveyors to linear positioners.

D. Adapting limit switches to specific applications is a challenge to both physical design and programming, and in both cases, creativity is the order of the day.

(NOTE: Several of the job sheets that accompany this unit of instruction will provide you with hands-on experience in managing limit switches with linear positioners.)

VII. Analog inputs

A. Devices such as thermocouples and potentiometers produce analog as opposed to digital signals, and these analog inputs must be converted to digital signals so they can be used by a PLC controller.

B. The analog-to-digital conversion takes place in special PLC modules that can be tailored to meet specific needs of the various analog input devices used to measure such phenomena as flow, pressure, temperature, and level.

C. Analog input modules typically convert unscaled data to engineering units such as gallons per minute, pounds per square inch, inches of Mercury, or degrees C or F.

INFORMATION SHEET

D. The conversion from analog input to engineering scale is programmed, usually with computer software, to minimum and maximum scaling values that change, for instance, the voltage output from an industrial thermometer into degrees C.

VIII. Application outputs

A. One of the most common output applications of a PLC is to activate motor starters which in turn activate motors.

B. Another common output application for PLCs is to control relays which can be readily designed to provide hard-wired safety interlocks to avoid shorting out motors or other output devices.

(NOTE: The use of hard-wired and programmed safety interlocks are demonstrated in job sheets that accompany this unit of instruction.)

C. Contactors are electromagnetic switches designed specifically to handle large currents and have to be used in certain applications.

D. Solenoids take advantage of small voltage supplies to provide the muscle it takes to activate valves and other large control devices.

E. Other output devices used in PLC applications range from lights and alarms to bells and whistles.

F. In cases where an output is an analog device such as a servo valve, the signal of the controller must go through a digital-to-analog conversion module.

G. The design and placement of motors and other devices that have to be activated by PLC outputs is part of installation design, and it is important to remember that inputs control the output devices.

IX. Guidelines for application wiring

A. All wiring should be insulated and selected according to the AWG number recommended by the PLC manufacturer or as required by the input/output device.

B. In all cases where it can be accomplished, wire colors should be used with standard references for L1, L2, and ground.

C. Intermediate terminal strips are recommended to interface both inputs and outputs with the terminals on the controller.

D. When properly positioned, terminal strips provide a good display for visual identification of wire routing, and will help avoid wear and tear on the controller terminals.

E. Connecting ends of wires should be stripped to a uniform length to promote good contact with terminals and to give the installation a professional look.

INFORMATION SHEET

F. The end of a connecting wire at a terminal should be so placed that the free end turns clockwise as the terminal is tightened clockwise.

X. **Power and grounding**

A. For PLC installations that are used for training, a standard 120VAC power supply with overcurrent protection is recommended.

B. Source power should be grounded so that it can provide grounding for the PLC and attached inputs and outputs.

C. Because current to ground failure is life threatening, a recommended safety addition for training installations is a ground fault interrupt which is designed to interrupt a system short circuit fast enough to protect someone working with the circuit.

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

JOB SHEET #1 — PLAN, WIRE, PROGRAM, AND CONFIRM A CONVENTIONAL START/STOP STATION

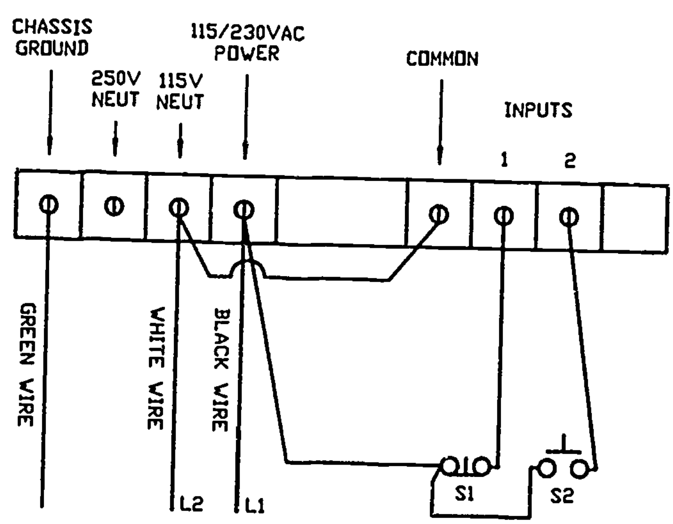
A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's Manual for selected PLC
4. One NO push-button START switch
5. One NC push-button STOP switch
6. AWG #18 insulated wiring as required
7. Basic wiring tools
8. Mounting surface as required
9. Pencil and paper
10. Safety glasses

B. Routine #1 — Wiring the START/STOP station

1. Put on safety glasses.
2. Refer to Figure 1 to confirm all your wiring connections. (Figure 1)

FIGURE 1



JOB SHEET #1

3. Connect the green wire from the three-wire power supply cord to the chassis ground terminal.

4. Connect the white wire from the three-wire power supply cord to the 115V Neut terminal on the controller; this will be your L2 wire.

5. Connect the black wire from the three-power supply cord to the 115/230VAC terminal on the controller; this will be your L1 wire.

6. Use a jumper wire to connect the 115V Neut lead (the white wire) to the Common terminal on the controller inputs.

7. Strip insulation from wires as required to complete all wiring, and keep the connecting ends of the wires uniform in length so that your installation is professional.

8. Make all terminal connections so that the connecting wires turn clockwise with the terminal connections as they are tightened.

9. Make terminal connections secure, but do not over tighten or you run the risk of stripping terminal threads or cracking the plastic terminal bus.

10. Use a jumper wire to connect the L1 black wire from the 115/230VAC power terminal on the controller to the power side of NC switch 1.

11. Use a jumper wire to connect the L1 black wire from the power side of NC switch 1 to the power side of the NO switch 2.

    (NOTE: Some packaged START/STOP stations have continuity built in and will not require a jumper wire.)

12. Connect switch 1 to input 1 on the controller, and connect switch 2 to input 2 on the controller.

13. Inspect all wiring to make sure that power, switch, and input wiring are all correct.

14. Inspect all terminal connections to make sure wiring is neat and secure.

☐ Have your instructor check your work.

C. Routine #2 — Programming the START/STOP station

1. Plan a program that will accomplish the following with the START/STOP station:

    a. When switch 1 is pushed, output #12 will be TRUE or ON.

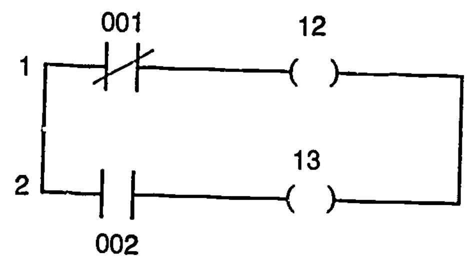
    b. When switch 2 is pushed, output #13 will be TRUE or ON.

    c. When both switches are pushed, both outputs will be TRUE or ON.

JOB SHEET #1

2. Plug the controller in, activate the programmer, then enter the following program into controller memory: (Figure 2)

FIGURE 2



3. Run the program to confirm that you can activate a PLC output without being connected to an output device.

4. Push switch 1 and indicate here which output lights up: ______________.

5. Push switch 2 and indicate here which output lights up: ______________.

6. Push both switches at one time and indicate what happens here:

__________.

☐ Have your instructor check your work.

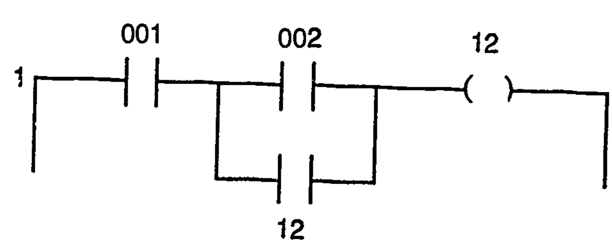
D. Routine #3 — Planning and programming a conventional START/STOP station

1. Continue with the physical conditions you have set up in previous routines, but modify your program so that you will have a conventional START/STOP station.

(NOTE: A START/STOP station is usually used to start a motor, and once the start button is pushed, the motor starts, but when the start button is released, the motor should continue running. Likewise, when the stop button is pushed, the motor should stop running, and when the stop button is released, the motor should remain stopped.)

2. Delete your previous program, and enter the following program, which contains a seal-in circuit, into program, and enter the following program into controller memory: (Figure 3)

FIGURE 3



JOB SHEET #1

3. Run the new program and verify the START/STOP station according to the following:

   a. Pushing the NO START switch 2 should cause output 12 to come ON.

   b. Releasing NO START switch 2 should leave output 12 ON.

   c. Pushing NC STOP switch 1 should cause output 12 to go OFF.

   d. Releasing NC STOP switch 1 should leave output 12 OFF.

4. Repeat the cycle to verify the START/STOP station performance.

☐ Have your instructor check your work.

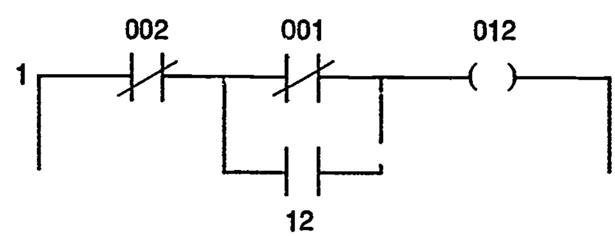
E. Routine #4 — Using logic to manipulate switch functions

1. Continue with the physical conditions you have set up in previous routines, but modify your program so that the START/STOP functions will be reversed.

   (NOTE: Physically changing the switches could solve the control problems posed in Step 1, but the power of a PLC lies in its capacity to manipulate inputs with logic and manipulating logic is in the hands of a creative programmer.)

2. Delete the previous program and enter the following program into controller memory: (Figure 4)

   FIGURE 4



3. Run the new program and verify the logical reversal of the START/STOP switches according to the following:

   a. Pushing the NC STOP switch 1 should cause output 12 to come ON.

   b. Releasing the NC STOP switch 1 should leave output 12 ON.

   c. Pushing the NO START switch 2 should cause output 12 to go OFF.

   d. Releasing NO START switch 2 should leave output 12 OFF.

JOB SHEET #1

4. Repeat the cycle to verify the STOP/START station performance with the conventional switches reversed.

5. Discuss with your instructor how the power of PLCs lies in their capacity to logically control inputs and avoid the cost and problems of physically changing input devices or rewiring input circuits.

☐ Have your instructor check your work.

6. Secure the installation and return equipment to storage.

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

JOB SHEET #2 — CONNECT RELAY COILS TO A START/STOP STATION AND VERIFY INTERLOCKS

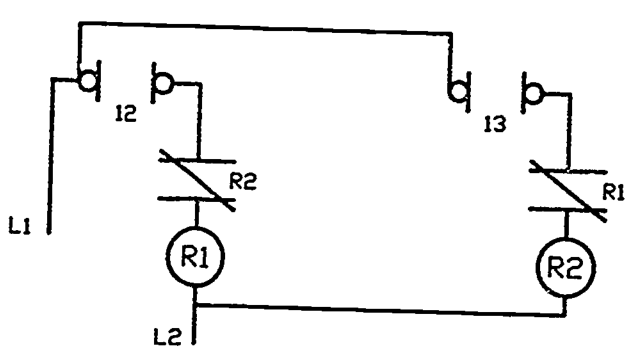
A. Tools and Equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. Conventional START/STOP station
5. Two relay coils as selected by instructor
6. AWG #14 insulated wiring as required
7. Basic wiring tools
8. Mounting surfaces as required
9. Pencil and paper
10. Safety glasses

B. Routine #1 — Connecting relay coils

1. Put on safety glasses.
2. Prepare PLC with power, input, and other wiring as outlined in previous job sheet.
3. Wire the two relay coils so that they are electrically interlocked as indicated in the following schematic: (Figure 1)

FIGURE 1



12 and 13 are PLC output connections.

JOB SHEET #2

4. Connect the relay coils to outputs #12 and #13 on the controller as indicated in the previous schematic.

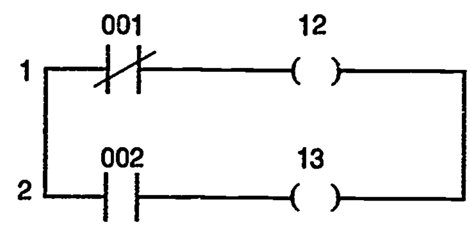
5. Check all wiring for neatness, and check terminals for secure connections.

☐ Have your instructor check your work.

C. Routine #2 — Verifying a hard-wired interlock

1. Plug the controller in and use the programmer to enter the following program into controller memory: (Figure 2)

FIGURE 2



2. Press switch 1 and listen for the click of the relay as output 12 comes ON.

3. Press switch 2 and listen for the click of the relay as output 13 comes ON.

4. Press switches 1 and 2 simultaneously, listen for a single click, and watch for outputs 12 and 13 to light up on the controller to indicate that although controller outputs 12 and 13 are energized, only one output relay is activated because of the hard-wired interlock.

5. Discuss with your instructor the value of a hard wired interlock in relay circuits.

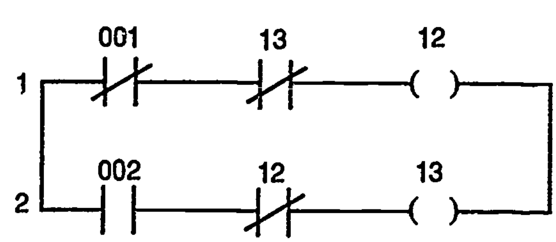
(NOTE: In a worst-case scenario, the lack of the interlock could easily cause a short circuit straight to a motor and burn the motor out.)

☐ Have your instructor check your work.

D. Routine #3 — Verifying a logical interlock

1. Continue with the conditions previously set up for relay wiring, but delete the previous program and enter the following program: (Figure 3)

FIGURE 3



JOB SHEET #2

2. Start the program and push both switches at once.

3. Listen for only one relay click and watch for only one output to come ON.

4. Note that the relays have a hard-wired interlock and that your new program has introduced a logical interlock.

5. Discuss with your instructor the value of interlocks in output control and especially in motor controls.

☐ Have your instructor check your work.

6. Secure the installation and return equipment to storage.

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

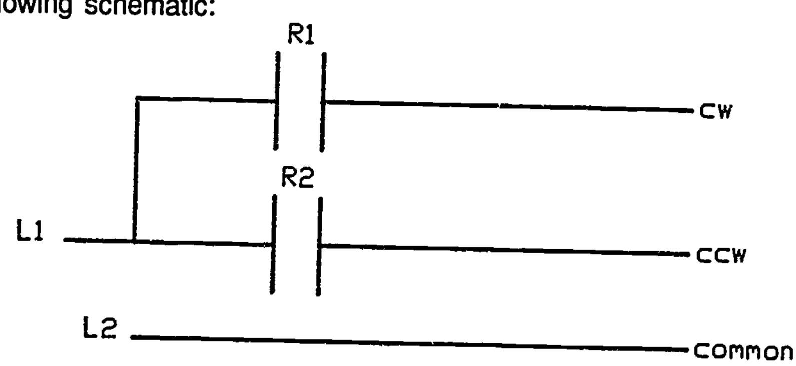
JOB SHEET #3 — CONNECT A LINEAR POSITIONER, MOTOR, AND LIMIT SWITCHES TO SIMULATE A POSITIONING APPLICATION

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. Bi-directional motor and linear positioner
5. Mounting surface for motor and positioner
6. Four single-pole, double-throw limit switches
7. AWG #14 insulated wiring as required
8. Basic wiring tools
9. Pencil and paper
10. Safety glasses

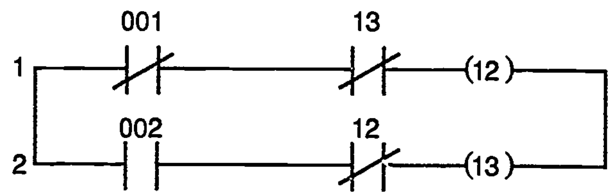
B. Routine #1 — Preparing the linear positioner

1. Put on safety glasses.
2. Place the bi-directional motor and linear positioner in a suitable rack or on a prepared mounting surface so that limit switches can later be conveniently placed along the positioner.
3. Connect the relay contacts to the bi-directional motor as indicated in the following schematic:



JOB SHEET #3

4. Run the program with the logical interlocks that you used in a previous job sheet, or reprogram and run as required:



5. Note which direction the motor moves as each of the switches is pressed and circle the information about directional movement:

   a. Pushing switch 1 causes the motor to move: clockwise counterclockwise

   b. Pushing switch 2 causes the motor to move: clockwise counterclockwise

6. Note also which direction each activated output drives the positioner by circling the appropriate direction:

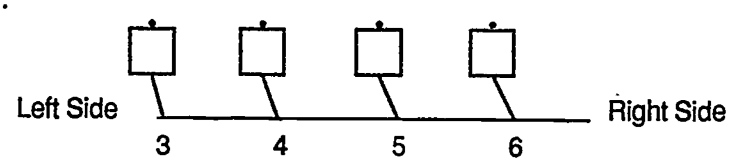
   a. Output 12 drives the positioner: right left

   b. Output 13 drives the positioner: right left

☐ Have your instructor check your work.

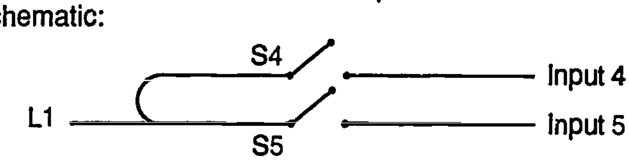
C. Routine #2 — Preparing limit switches for indicating position

1. Mount four single-pole double-throw limit switches along the linear positioner so that they are about two inches apart and are numbered left to right as indicated:



(NOTE: If you are working with a pre-assembled positioner, continue with the next step, but make sure you reference limit switches by their appropriate number.)

2. Connect the NO contacts of limit switch 4 to PLC input address 4 and the NO contacts of limit switch 5 to the PLC input address 5 as indicated in the following schematic:



JOB SHEET #3

3. Assume from your information in Step 6 of Routine #1 that output #12 drives the positioner left toward the limit switch connected to input #4.

   (NOTE: If you have entered information other than that assumed in Step 3, ask your instructor about changing wiring as required so the remainder of the steps in this routine will be easier to follow.)

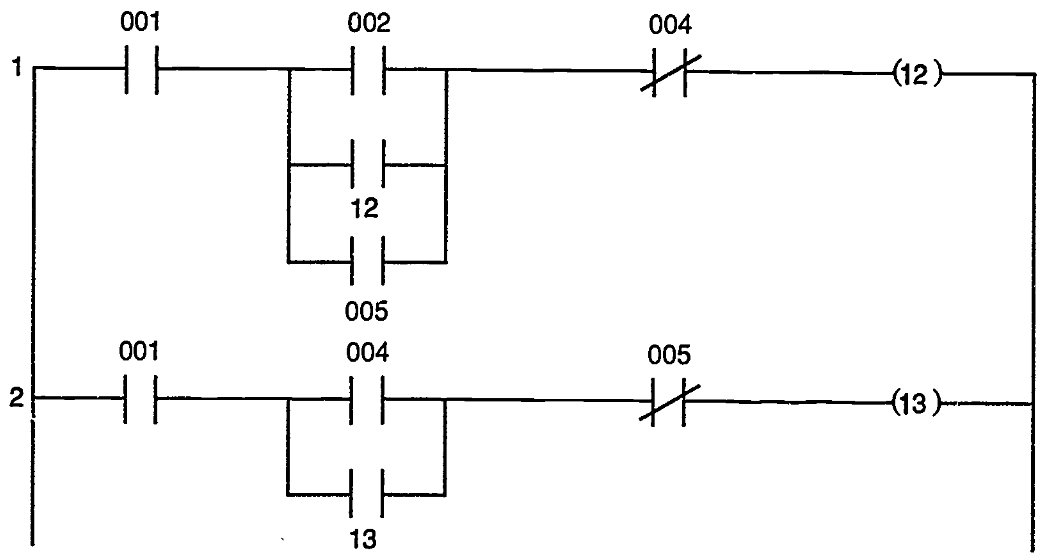
☐ Have your instructor check your work.

D. Routine #3 — Write and confirm a positioning program

1. Assume that a positioning installation requires that the positioner move back and forth between the two middle limit switches #4 and #5.

2. Remember that you are working with a conventional START/STOP station where pushing START button 2 will initiate action and pushing STOP button 1 will stop action.

3. Clear your programmer and enter the following program into controller memory:



4. Examine the program carefully before you attempt to confirm it, and note how the program works:

   a. Since 001 in both rungs is TRUE with voltage, until STOP switch 1 is pushed, 001 is TRUE in both rungs.

   b. 002 is TRUE with voltage, so START switch 2 is FALSE until it is pushed.

   c. 004 is TRUE without voltage, so the Examine OFF at 004 is TRUE only until limit switch 4 is activated.

JOB SHEET #3

d. When START switch 2 is pushed, output #12 is TRUE, and the positioner moves towards limit switch 4 until switch 4 is activated.

e. As limit switch 4 is activated, output #12 goes FALSE and the Examine ON at 004 on rung 2 goes TRUE, activating output #13.

f. As Examine ON 13 in rung 2 goes TRUE to seal in rung 2, output #13 remains TRUE and drives the positioner toward limit switch 5.

g. When the positioner activates limit switch 5, output 13 is activated which in turn makes 005 TRUE in rung 1, and output #12 is activated and starts moving the positioner back toward limits switch 4.

h. The positioner moves back and forth between the #4 and #5 limit switches until STOP switch 1 is pushed, but will repeat the cycle when START switch 2 is pushed again.

5. Read through the dynamics of the program a second time and follow the ladder logic carefully.

6. Run the program to verify the ladder logic.

7. Discuss with your instructor the many elements that make this program function, including the interlock hard-wire used for motor protection.

☐ Have your instructor check your work.

8. Secure the installation and return equipment to storage.

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

JOB SHEET #4 — PROGRAM AND CONFIRM AN UP COUNTER IN A POSITIONING APPLICATION

A. Tools and equipment

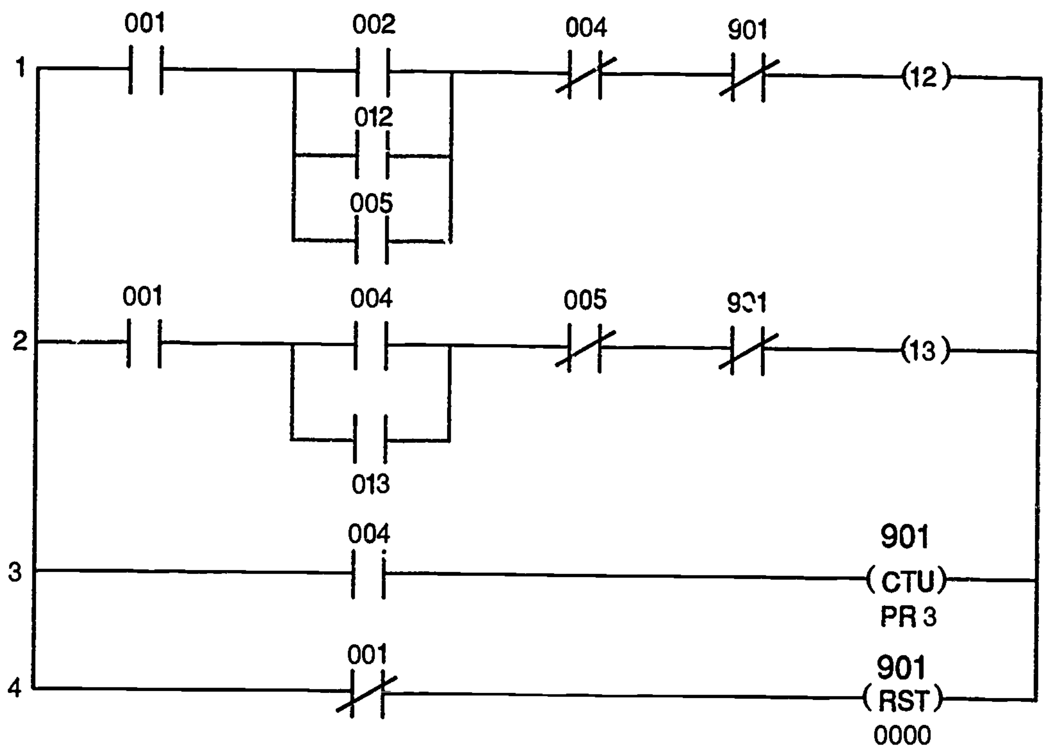
1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. Linear positioner
5. Pencil and paper
6. Safety glasses

B. Procedure

1. Put on safety glasses.
2. Continue with the physical conditions set up in previous routines, and continue using a conventional START/STOP station.
3. Assume that your program application requires that the positioner stop after limit switch 4 has been activated three times.
4. Assume further that the START switch will not restart the positioner until the STOP switch is pushed to reset the CTU (up counter), and then pressing the START switch will start the positioner again.

JOB SHEET #4

5. Delete the previous program and enter the following program into controller memory:



6. Examine the program carefully before you attempt to confirm it, and note how the program moves:

   a. The Examine OFF 901 is TRUE when the AC value is less than the PR of 3.

   b. At a count of 3 or more, Examine OFF 901 is FALSE, turning OFF both outputs #12 and #13.

   c. Examine OFF 001 is FALSE until STOP switch #1 is pushed, at which time it becomes TRUE and resets the CTU to 0000.

   d. The START switch 2 will not energize the circuit.

   e. Note that the FALSE to TRUE transition clocks the counter one count each time limit switch 4 is activated.

   f. It is a common programming error to make the reset in rung 4 hold TRUE when trying to run the program.

7. Run the program to confirm that it functions as planned.

☐ Have your instructor check your work.

8. Secure the application and return equipment to storage.

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

JOB SHEET #5 — PROGRAM AND CONFIRM A RETENTIVE TIMER IN A POSITIONING APPLICATION

A. Tools and equipment

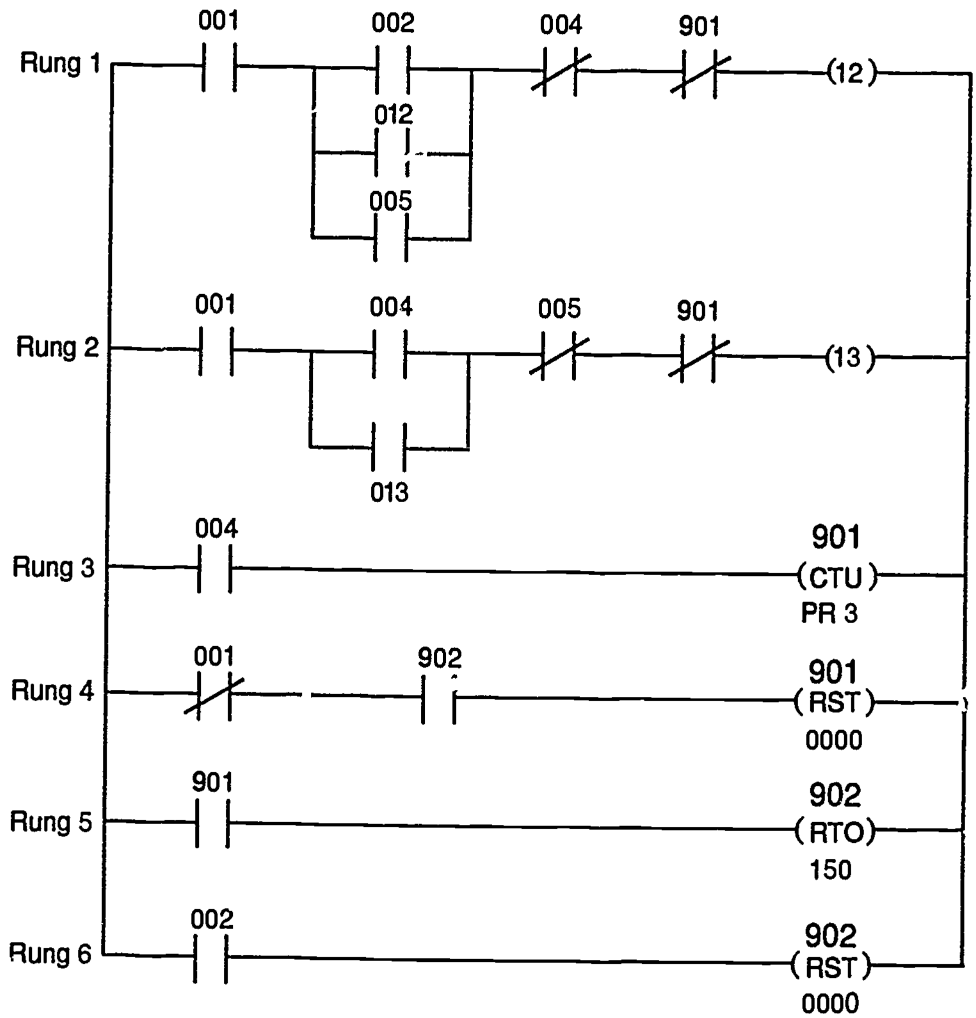
1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. Linear positioner
5. Pencil and paper
6. Safety glasses

B. Procedure

1. Put on safety glasses.
2. Continue with the physical conditions set up in previous routines, and continue using a conventional START/STOP station.
3. Assume that your program application requires that the positioner stop after limit switch 4 has been activated three times, and that the CTU cannot be reset by switch 1 until 15 seconds after the 901 up counter has reached its PR of 3.0

JOB SHEET #5

4. Delete the previous program and enter the following program into controller memory:



5. Examine the program carefully before you attempt to confirm it, and note how the program moves:

   a. The secret to this program is to put the 902 contact in rung 4, but many programmers try to put either the Examine ON or Examine OFF 902 in rungs 1 and 2, and this does not work.

   b. Note also the 002 Examine ON in rung 6 is used to reset (RST) 902 when START switch 2 is pushed.

   c. Another important item to note is that STOP switch 1 must be pushed AFTER the Examine ON 902 is TRUE or the CTU 901 will not work.

6. Study the program until you are certain of the programming structure, and then run the program to confirm it.

JOB SHEET #5

- [ ] Have your instructor check your work.

7. Secure the application and return equipment to storage.

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

JOB SHEET #6 — PROGRAM AND CONFIRM A TWO-CYCLE POSITIONING APPLICATION WITH MANUAL STOP

A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. Two NC limit switches
5. AWG #14 insulated wiring as required
6. Basic wiring tools
7. Linear positioner
8. Pencil and paper
9. Safety glasses

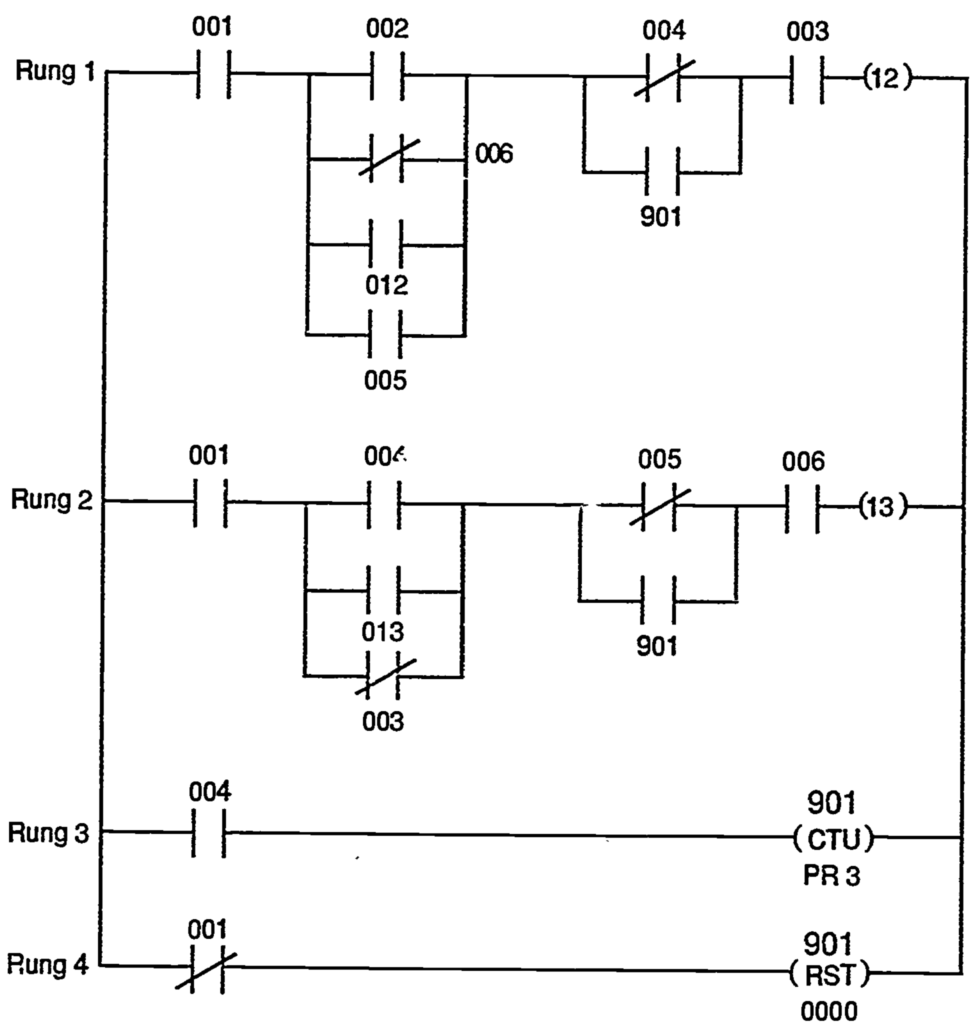
B. Procedure

1. Put on safety glasses.
2. Continue with the physical conditions set up in previous routines, and continue using a conventional START/STOP station.
3. Assume that your program application requires that the positioner move back and forth three times between the middle limit switches #4 and #5, and then goes on to move back and forth between limit switches #3 and #6 until STOP switch 1 is pushed.
4. Assume also that START switch #2 will start the process over again when it is pushed.
5. Modify your previous program by removing the RTO 902 timer, its RST, and its Examine OFF 902 instruction.

JOB SHEET #6

6. Delete the previous program and enter the following program into controller memory:

Solution



7. Examine the program carefully before you attempt to confirm it, and note how the program moves:

   a. The Examine ON 901 in rungs 1 and 2 are FALSE until the CTU PR of 3 is reached.

   b. When the PR is less than 3, Examine OFF 004 and Examine OFF 005 go FALSE and the other rung goes TRUE as in previous programs.

   c. When the PR of 3 is reached, the Examine ON 901 goes TRUE and the positioner moves past the #4 or #5 limit switch until it reaches either the #6 or #3 limit switch.

JOB SHEET #6

d. As the positioner reaches limit switch #3 or #6, the limit switch will go FALSE and the other rung becomes TRUE so that the positioner cycles and moves to the other outside limit switch, and the cycle continues until STOP switch 1 is pushed.

8. Run the program to confirm that it does cycle properly and continue to run until manually stopped.

☐ Have your instructor check your work.

9. Discuss with your instructor other ways in which the same program could be written.

10. Secure the application and return equipment to storage.

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

JOB SHEET #7 — PROGRAM AND CONFIRM A TWO-CYCLE POSITIONING APPLICATION WITH AUTOMATIC STOP

A. Tools and equipment

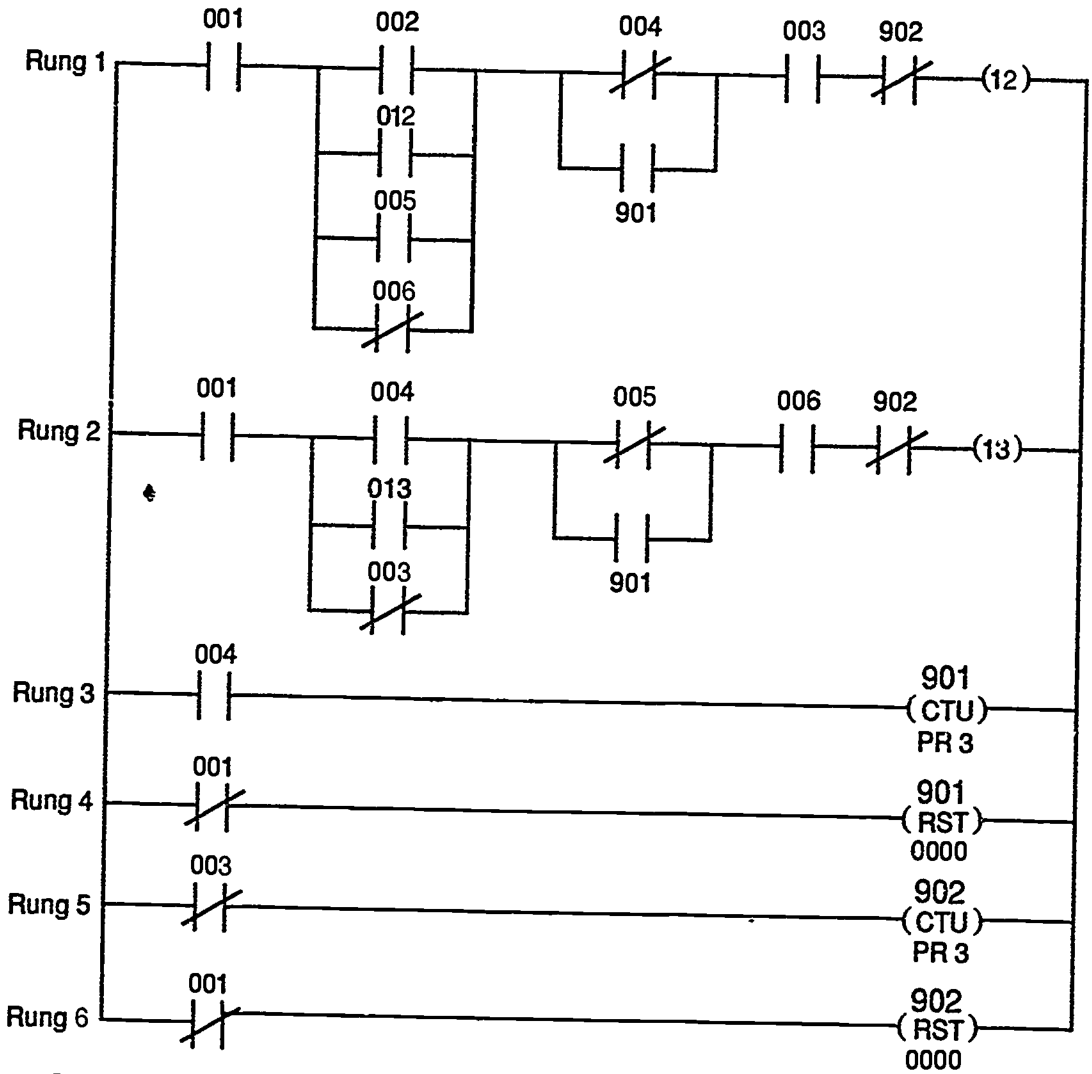
1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. Linear positioner
5. Pencil and paper
6. Safety glasses

B. Procedure

1. Put on safety glasses.
2. Continue with the physical conditions set up in previous routines, and continue using a conventional START/STOP station.
3. Assume that your program application requires the same conditions outlined in Job Sheet #6, but that a second up counter (CTU) needs to be added to stop the back and forth second cycle after the positioner has moved three times between limit switches #3 and #6.

JOB SHEET #7

4. Keep the program from Job Sheet #6, but add to it as indicated in the following so that the CTUs and their RSTs are contained on rungs 3 through 6:



5. Compare the program with the program in Job Sheet #6 so the CTU programming can be fully appreciated.

6. Run the program to confirm that it does stop automatically after the positioner has cycled three times between limit switches #3 and #6.

☐ Have your instructor check your work.

7. Secure the application and return equipment to storage.

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

JOB SHEET #8 — PROGRAM A POSITIONING APPLICATION WITH SEQUENCER INPUT DRIVING SEQUENCER OUTPUT

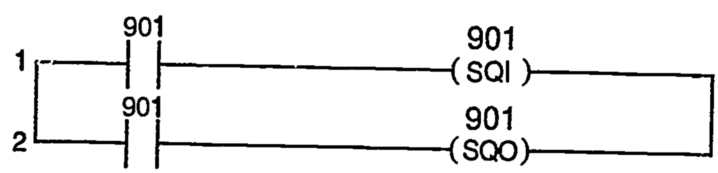
A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. Linear positioner
5. Sequencer data forms as required
6. Pencil and paper
7. Safety glasses

B. Routine #1 — Setting up the basic sequencer program

1. Put on safety glasses.
2. Continue with the physical conditions set up in previous routine, but do not use the START/STOP station in the first part of this application.
3. Assume that your first program will run a positioner back and forth between the two middle limit switches #4 and #5.
4. Assume also that the program will continue to run from the time the programmer is placed in Mode 3, the run mode, until the programmer is taken out of run mode.
5. Enter the following SQI instruction in Figure 1 followed by the data in the accompanying event driven data form in Figure 2, and then enter the SQO instruction in Figure 1 followed by the data in the accompanying event driven data form in Figure 2.

FIGURE 1



(NOTE: If you have any difficulty programming the SQI or SQO data, please review the appropriate materials from your user's manual or from Unit III, "Sequencers and Registers," from this text.)

JOB SHEET #8

6. Note how the program functions before you attempt to confirm it:

   a. When the step data of line 0 on the SQI is TRUE, the Examine ON 901 contact becomes TRUE and steps both the SQI and SQO to the next step data line.

   b. When the program is run, the #12 output is TRUE, causing the positioner to move toward limit switch #4.

   c. When limit switch #4 is activated, step data 0 of the SQI is TRUE and both the SQI and SQO move to step data 1.

   d. With the move to step data 1, output #13 is TRUE, causing the positioner to move to limit switch #5.

   e. When limit switch #5 is activated, it passes power to input 5 which makes step data 1 TRUE on the SQI, and this steps both the SQI and SQO to the next step, which, in this case, is step 0.

   f. As the program moves back to step 0, the sequence is repeated and the positioner continues to run back and forth between limit switches #4 and #5 until the programmer is taken out of the run mode.

7. Place the programmer in Mode 3 and permit the program to run to verify that the positioner is moving properly and that the SQI instruction is driving the SQO instruction and causing the cycle to repeat itself.

☐ Have your instructor check your work.

8. Take the programmer out of the run mode to stop the program.

9. Secure the application and return equipment to storage.

JOB SHEET #8

FIGURE 2

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: 901 ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER: 00

BIT ADDRESS DATA	B				A				PROGRAM CODE Data B	PROGRAM CODE Data A	PRESET VALUES
Bit Addresses →	18	17	16	15	14	13	12	11			
Mask Data →	⊗	⊗	⊗	⊗	⊗	1	1	⊗	0	6	
Step Data → 0						0	1		0	2	1
1						1	0		0	4	1
2											
3											
4											
5											
6											
7											
8											
9											
10											

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☒ -(SQI)- ☐ -(SQO)- ADDRESS: 901 ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER: 07

BIT ADDRESS DATA	B				A				PROGRAM CODE Data B	PROGRAM CODE Data A	PRESET VALUES
Bit Addresses →	8	7	6	5	4	3	2	1			
Mask Data →	⊗	⊗	⊗	1	1	⊗	⊗	⊗	1	8	
Step Data → 0				0	1				0	8	1
1				1	0				1	0	1
2											
3											
4											
5											
6											
7											
8											
9											
10											

Data forms courtesy Allen-Bradley

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

JOB SHEET #9 — PROGRAM A POSITIONING APPLICATION WITH SEQUENCER INPUT DRIVING SEQUENCER OUTPUT WITH START/STOP CONTROL

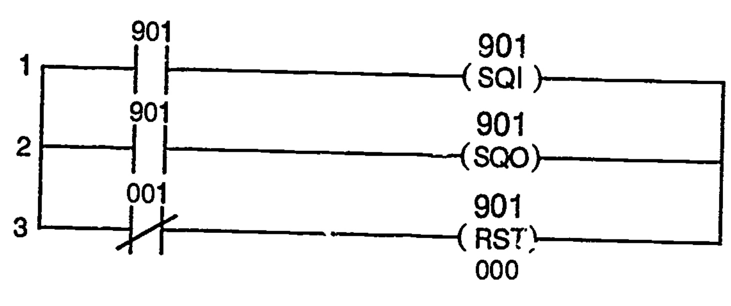
A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. Linear positioner
5. Sequencer data forms as required
6. Pencil and paper
7. Safety glasses

B. Procedure

1. Put on safety glasses.
2. Continue with the physical conditions set up in previous routines, and use the START/STOP station once again for this application.
3. Assume that the START switch must be pushed to start your program, that the SQI instruction driving an SQO instruction will cause the positioner to move back and forth between limit switches 4 and 5, and that the STOP switch must be pushed to stop the positioner.
4. Enter the following program in Figure 1 and add the data from the accompanying SQI and SQO data sheets in Figure 2.

FIGURE 1



JOB SHEET #9

5. Note how the program functions before you attempt to confirm it:

   a. When the program is at step 0, the positioner will not run because the SQO does not energize any outputs in step data 0, and you will not that program data for the SQO step data 0 is 0.

   b. The SQI step data 0 will not go TRUE until START switch 2 is pushed to make the step data 0 line TRUE and cause the SQI and the SQO to step to step 1.

   c. The program continues through step data 4, causing the positioner to move back and forth between limit switches #4 and #5.

   d. As the program moves back to step data 0, the positioner stops.

   e. The positioner can be stopped anytime by pushing STOP switch 1 because this makes the RST line TRUE and returns the program to step data 0.

   f. To start the positioner, press START switch 2.

6. Run the program to verify, and use the START/STOP switches a few times to test program control.

☐ Have your instructor check your work.

7. Secure the application and return equipment to storage.

JOB SHEET #9

FIGURE 2

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☒ -(SQI)- ☐ -(SQO)- ADDRESS: ____ ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER: 07

BIT ADDRESS DATA	B				A				PROGRAM CODE Data B	PROGRAM CODE Data A	PRESET VALUES
Bit Addresses →	8	7	6	5	4	3	2	1			
Mask Data →	X	X	X	1	1	X	1	X	1	A	
Step Data → 0				0	0		1		0	2	1
1				0	1		0		0	8	1
2				1	0		0		1	0	1
3				0	1		0		0	8	1
4				1	0		0		1	0	1
5											
6											
7											
8											
9											
10											

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: ____ ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER: 00

BIT ADDRESS DATA	B				A				PROGRAM CODE Data B	PROGRAM CODE Data A	PRESET VALUES
Bit Addresses →	18	17	16	15	14	13	12	11			
Mask Data →	X	X	X	X	X	1	1	X	0	0	
Step Data → 0						0	0		0	0	1
1						0	1		0	2	1
2						1	0		0	4	1
3						0	1		0	2	1
4						1	0		0	4	1
5											
6											
7											
8											
9											
10											

Data forms courtesy Allen-Bradley

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

JOB SHEET #10 — PROGRAM AN EXTENDED SQI DRIVING AN SQO POSITIONING APPLICATION WITH START/STOP CONTROL

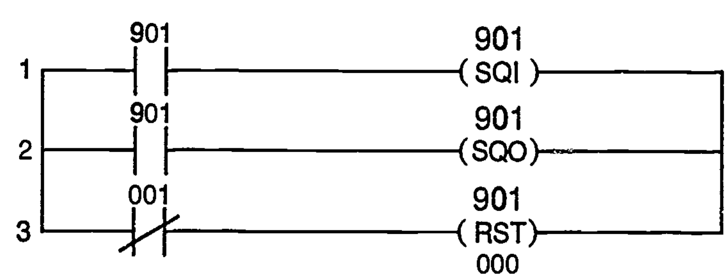
A. Tools and equipment

1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. Linear positioner
5. Sequencer data forms as required
6. Pencil and paper
7. Safety glasses

B. Procedure

1. Put on safety glasses.
2. Continue with the physical conditions set up in previous routines, and use the START/STOP station once again for this application.
3. Assume that the START switch must be pushed to start your program, that the SQI instruction driving the SQO instruction will cause the positioner to move back and forth between limit switches 3 and 6, and that the STOP switch must be pushed to stop the positioner.
4. Enter the following program from Figure 1 and add the data from the accompanying SQI and SQO data sheets in Figure 2.

FIGURE 1



5. Note that the program extends the program used in the previous job sheet so that the positioner now moves out to limit switches #3 and #6.
6. Note also that the program still uses a conventional START/STOP station to start and stop the positioner.

JOB SHEET #10

7. Note how the additional elements of tne program function before you attempt to confirm the program:

   a. The data sheets now include limit switches #3 and #6 which are NC switches.

   b. Because they are NC, limit switches #3 and #6 are passing power to inputs #3 and #6 when they are NOT activated — it is important to note that these conditions are opposite to limit switches #4 and #5.

   c. Look at step data 0 of the SQI, and note that inputs 3, 4, 5, and 6 are TRUE and that only input 2 is FALSE; this means the START switch must be pushed to make input 2 TRUE.

8. Run the program to verify it, and use the START/STOP switches a few times to test program control.

☐ Have your instructor check your work.

9. Secure the application and return equipment to storage.

JOB SHEET #10

FIGURE 2

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☒ -(SQI)- ☐ -(SQO)- ADDRESS: ____ ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER: 07

BIT ADDRESS DATA	B				A				PROGRAM CODE Data B	PROGRAM CODE Data A	PRESET VALUES
Bit Addresses →	8	7	6	5	4	3	2	1			
Mask Data →	⊗	⊗	1	1	1	1	1	⊗	3	E	
Step Data → 0			1	0	0	1	1		2	6	
1			1	0	1	1	0		2	C	
2			1	1	0	1	0		3	4	
3			1	0	1	1	0		2	C	
4			1	1	0	1	0		3	4	
5			1	0	1	1	0		2	C	
6			0	0	0	1	0		0	4	
7			1	0	0	0	0		2	0	
8			0	0	0	1	0		0	4	
9			1	0	0	0	0		2	0	
10			0	0	0	1	0		0	4	
11			1	0	0	0	0		2	0	

SEQUENCER INSTRUCTION DATA FORM

SEQUENCER CLASSIFICATION: ☐ -(SQI)- ☒ -(SQO)- ADDRESS: ____ ☐ TIME DRIVEN ☒ EVENT DRIVEN GROUP NUMBER: 00

BIT ADDRESS DATA	B				A				PROGRAM CODE Data B	PROGRAM CODE Data A	PRESET VALUES
Bit Addresses →	18	17	16	15	14	13	12	11			
Mask Data →	⊗	⊗	⊗	⊗	⊗	1	1	⊗			
Step Data → 0						0	0		0	0	
1							1		0	2	
2						1			0	4	
3							1		0	2	
4						1			0	4	
5							1		0	2	
6						1			0	4	
7							1		0	2	
8						1			0	4	
9							1		0	2	
10						1			0	4	
11							1		0	2	

Data forms courtesy Allen-Bradley

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

JOB SHEET #11 — PROGRAM AND VERIFY A JUMP COMMAND IN A POSITIONING APPLICATION

A. Tools and equipment

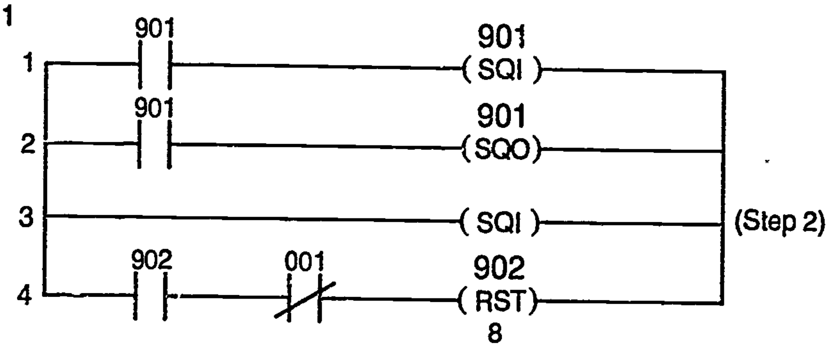
1. PLC as selected by instructor
2. Programmer for selected PLC
3. User's manual for selected PLC
4. Linear positioner
5. Data sheets as required
6. Pencil and paper
7. Safety glasses

B. Procedure

1. Put on safety glasses
2. Continue with the physical conditions set up in previous routines, and use the START/STOP station once again for this application.
3. Assume that your program is the same as that used in Job Sheet #10, but that a jump operation will be inserted so that if certain conditions are met at a given point in the program, certain steps in the program will be skipped or jumped.
4. Modify your program from Job Sheet #10 to include the instruction that will cause the program to jump from step 2 to step 8 if all conditions are met to make step 2 TRUE: (Figure 1)

   (NOTE: There is no need to re-enter the SQI and SQO step data from the last program.)

FIGURE 1



JOB SHEET #11

5. Examine the program carefully before you run it so you see what conditions have to be met for the program to jump steps 3, 4, 5, 6, and 7:

   a. The key is in the programming: enter the 902 address, then the group 38, and then enter the hex code EE after the USE prompt, press ENTER, insert the step data, in this case 2, and press ENTER again.

   b. The hex code EE has to be entered after the USE prompt or the program will not work.

6. Run the program to verify and the START/STOP switches a few times to test program control.

☐ Have your instructor check your work.

7. Secure the application and return equipment to storage.

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

PRACTICAL TEST #1

JOB SHEET #1 — PLAN, WIRE, PROGRAM, AND CONFIRM A CONVENTIONAL START/STOP STATION

Student's name ______________________ Date ______________

Evaluator's name ______________________ Attempt no. ______________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" boxes to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	Yes	No
1. Wired start/stop station properly.	☐	☐
2. Inspected start/stop station.	☐	☐
3. Programmed and confirmed start/stop station.	☐	☐
4. Planned a conventional start/stop station.	☐	☐
5. Reprogrammed to show use of logic.	☐	☐
6. Secured area and returned equipment.	☐	☐

Evaluator's comments: ____

____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Initial Wiring	4	3	2	1
Program Preparation	4	3	2	1
Program Confirmation	4	3	2	1
Safety	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

PRACTICAL TEST #2

JOB SHEET #2 — CONNECT RELAY COIL TO A START/STOP STATION AND VERIFY INTERLOCKS

Student's name ______________________________ Date ______________

Evaluator's name ______________________________ Attempt no. __________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" boxes to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	Yes	No
1. Wired relay coils properly.	☐	☐
2. Verified a hard-wire interlock.	☐	☐
3. Verified a logical interlock.	☐	☐
4. Secured area and returned equipment.	☐	☐

Evaluator's Comments:____

____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Relay Wiring	4	3	2	1
Hard-Wire Interlock Verification	4	3	2	1
Logical Interlock Verification	4	3	2	1
Safety	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

PRACTICAL TEST #3

JOB SHEET #3 — CONNECT A LINEAR POSITIONER, MOTOR, AND LIMIT SWITCHES TO SIMULATE A POSITIONING APPLICATION

Student's name ______________________ Date __________

Evaluator's name ______________________ Attempt no. __________

> Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" boxes to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

		Yes	No
1.	Prepared linear positioner properly.	☐	☐
2.	Prepared limit switches for indicating.	☐	☐
3.	Wrote a positioning program.	☐	☐
4.	Confirmed a positioning program.	☐	☐
5.	Verified logical interlock.	☐	☐
6.	Secured area and returned equipment.	☐	☐

Evaluator's Comments: ____

____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Station and Switch preparation	4	3	2	1
Positioning Program	4	3	2	1
Logical Interlock Verification	4	3	2	1
Safety	4	3	2	1

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

PRACTICAL TEST #4

JOB SHEET #4 — PROGRAM AND CONFIRM AN UP COUNTER IN A POSITIONING APPLICATION

Student's name ______________________ Date ____________

Evaluator's name ______________________ Attempt no. ________

> Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" boxes to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

		Yes	No
1.	Began with conventional start/stop station.	☐	☐
2.	Deleted previous program.	☐	☐
3.	Programmed up counter with a PR of 3.	☐	☐
4.	Ran and verified program.	☐	☐
5.	Secured area and returned equipment.	☐	☐

Evaluator's Comments: ____

____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Initial Conditions Planning	4	3	2	1
Up Counter Programming	4	3	2	1
Program Verification	4	3	2	1
Safety	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

PRACTICAL TEST #5

JOB SHEET #5 — PROGRAM AND CONFIRM A RETENTIVE TIMER IN A POSITIONING APPLICATION

Student's name ______________________________ Date ______________

Evaluator's name ______________________________ Attempt no. __________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" boxes to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

		Yes	No
1.	Began with conventional start/stop station.	☐	☐
2.	Deleted previous program.	☐	☐
3.	Programmed program with retentive timer.	☐	☐
4.	Ran and verified program.	☐	☐
5.	Secured area and returned equipment.	☐	☐

Evaluator's Comments: ____

____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Initial Conditions Planning	4	3	2	1
Retentive Timer Programming	4	3	2	1
Program Verification	4	3	2	1
Safety	4	3	2	1

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

PRACTICAL TEST #6

JOB SHEET #6 — PROGRAM AND CONFIRM A TWO-CYCLE POSITIONING APPLICATION WITH MANUAL STOP

Student's name ______________________________ Date ______________

Evaluator's name ______________________________ Attempt no. __________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" boxes to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	Yes	No
1. Began with conventional start/stop station.	☐	☐
2. Removed RTO and RST from previous program.	☐	☐
3. Entered new up counter program.	☐	☐
4. Ran and confirmed two-cycle program with manual stop.	☐	☐
5. Secured area and returned equipment.	☐	☐

Evaluator's Comments: ____

____

____

JOB SHEET #6 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Initial Conditions Planning	4	3	2	1
CTU Programming	4	3	2	1
Program Verification	4	3	2	1
Safety	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

PRACTICAL TEST #7

JOB SHEET #7 — PROGRAM AND CONFIRM A TWO-CYCLE POSITIONING APPLICATION WITH AUTOMATIC STOP

Student's name ______________________________ Date ____________

Evaluator's name ______________________________ Attempt no. ________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE. Place a check mark in the "Yes" or "No" boxes to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	Yes	No
1. Began with conventional start/stop station.	☐	☐
2. Removed CTUs and RSTs.	☐	☐
3. Ran and confirmed two-cycle application with automatic stop.	☐	☐
4. Secured area and returned equipment.	☐	☐

Evaluator's Comments: ____

____

____

JOB SHEET #7 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Initial Conditions Planning	4	3	2	1
CTU Programming	4	3	2	1
Program Verification	4	3	2	1
Safety	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

PRACTICAL TEST #8

JOB SHEET #8 — PROGRAM A POSITIONING APPLICATION WITH SEQUENCER INPUT DRIVING SEQUENCER OUTPUT

Student's name ______________________ Date ____________

Evaluator's name ______________________ Attempt no. ________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" boxes to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	Yes	No
1. Began without conventional start/stop station.	☐	☐
2. Removed CTUs and RSTs.	☐	☐
3. Ran and confirmed two-cycle application with automatic stop.	☐	☐
4. Secured area and returned equipment.	☐	☐

Evaluator's Comments: ____

____

____

JOB SHEET #8 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Initial Conditions Planning	4	3	2	1
SQI and SQO Programming	4	3	2	1
Program Verification	4	3	2	1
Safety	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

PRACTICAL TEST #9

JOB SHEET #9 — PROGRAM A POSITIONING APPLICATION WITH SEQUENCER INPUT DRIVING SEQUENCER OUTPUT WITH START/STOP CONTROL

Student's name ________________________ Date ____________

Evaluator's name ________________________ Attempt no. ________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" boxes to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	Yes	No
1. Began with conventional start/stop station.	☐	☐
2. Reprogrammed SQI and SQO instructions.	☐	☐
3. Ran and verified program.	☐	☐
4. Verified start/stop control.	☐	☐
5. Secured area and returned equipment.	☐	☐

Evaluator's Comments: ____

____

____

JOB SHEET #9 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Initial Conditions Planning	4	3	2	1
SQI and SQO Programming	4	3	2	1
Start/Stop Verification	4	3	2	1
Safety	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

PRACTICAL TEST #10

JOB SHEET #10 — PROGRAM AN EXTENDED SQI DRIVING AND SQO POSITIONING APPLICATION WITH START/STOP CONTROL

Student's name ______________________________ Date ____________

Evaluator's name ______________________________ Attempt no. ________

> Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" boxes to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	Yes	No
1. Began with conventional start/stop station.	☐	☐
2. Reprogrammed SQI and SQO instructions.	☐	☐
3. Ran and verified extended program.	☐	☐
4. Verified start/stop control.	☐	☐
5. Secured area and returned equipment.	☐	☐

Evaluator's Comments: ____

____

____

JOB SHEET #10 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Initial Conditions Planning	4	3	2	1
SQI and SQO Programming	4	3	2	1
Start/Stop Verification	4	3	2	1
Safety	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

PRACTICAL TEST #11

JOB SHEET #11 — PROGRAM AND VERIFY A JUMP COMMAND IN A POSITIONING APPLICATION

Student's name ______________________ Date ______________

Evaluator's name ______________________ Attempt no. __________

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" boxes to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	Yes	No
1. Began with conventional start/stop station.	☐	☐
2. Modified program with jump instruction.	☐	☐
3. Entered jump instruction properly.	☐	☐
4. Verified jump instruction.	☐	☐
5. Verified program control.	☐	☐
6. Secured area and returned equipment.	☐	☐

Evaluator's Comments: ______________________________________

____

____

JOB SHEET #11 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:				
Initial Conditions Planning	4	3	2	1
Jump Command Programming	4	3	2	1
Program Verification	4	3	2	1
Safety	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — **Skilled** — Can perform job with no additional training.
3 — **Moderately skilled** — Has performed job during training program; limited additional training may be required.
2 — **Limited skill** — Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INDUSTRIAL PROGRAM APPLICATIONS
UNIT VII

TEST

NAME______________________________ Score ______________

1. Match the terms on the right with their correct definitions.

_____a.	The physical touching of contacts that cause a device such as a switch to complete a circuit and pass power	1. Engineering units
_____b.	The quantities or degrees used to measure, expressed in units reflecting specific phenomena such as gallons per minute or miles per hour	2. AWG
_____c.	A standard for measuring the diameter of electrical wire where the smaller the number the larger the wire diameter	3. Convention
_____d.	A method of doing something that has been done for so long that it is accepted as a standard way of doing that thing	4. Closure

2. Complete statements concerning application inputs by circling the material that best completes each statement.

   a. An input to a PLC must be a device that can provide a closure that will send a signal to a (physical) (logical) input terminal on a PLC.

   b. The closure means that the active device is sending voltage to the input, or if the device is inactive, there is (no closure and no voltage) (negative voltage).

   c. Application inputs must create the ON/OFF conditions to which PLC inputs can respond in order to create the control signals that will in turn activate or control (outputs) (other inputs).

   d. Some common input devices with PLC applications include:

      1) (Proximity) (area) switches

      2) (Photoelectric) (electric eye) switches

      3) (Pushbutton) (normal) switches

      4) (Limit) (shutoff) switches

TEST

3. Match common input devices with their applications.

_____a.	Switches that sense the presence or absence of objects without physically touching the objects	1. Limit switches
_____b.	Switches that sense the presence or absence of objects by using a continuous beam of light which unbroken indicates absence and which broken indicates presence	2. Photoelectric switches
_____c.	Switches which may be wired as normally open or normally closed, and are typically used to start or stop a motor or controlled output	3. Proximity switches
_____d.	Switches which indicate position by effecting a closure or an opening when an object physically contacts a switch	4. Pushbutton switches

4. Select conditions concerning START/STOP station conventions by answering the following questions.

   a. By convention, a start switch is normally open or normally closed?

   Answer ____

   b. Pushbutton switches are common in industrial applications because they are easier than foot switches or pull-type switches?

   Answer ____

   c. The logic in a START/STOP station program that keeps a motor running after the start button is pressed and released is another output rung or a seal-in circuit?

   Answer ____

5. Select true statements concerning putting logic to work in a START/STOP station by placing an X beside each statement that is true.

   _____a. By convention, in a START/STOP station the START button is NO and the STOP button is NC, yet the conditions can be reversed so that both switches would function the opposite of their conventional applications.

   _____b. The control problem presented in item a could be solved only by physically changing the locations of the two switches or by rewiring the inputs to the controller.

TEST

_____c. When something like a conventional START/STOP station is repeated and repeated in application after application, it leaves a mind set that carries over into other notions about all electrical applications — wires have to be changed to change the application.

_____d. With a PLC, logic can change the function of the START/STOP switches without having to change location or move one wire.

_____e. By switching the function of the switches in the ladder logic, the START switch 1 is used to stop the motor, and the STOP switch 2 is used to start the motor.

_____f. By using logic to reverse the functions of START/STOP switches, the power of the PLC is put to work, and the value of creative programming is demonstrated.

6. Complete statements concerning limit switches as inputs by circling the material that best completes each statement.

   a. Limit switches are popular in (positional) (counting) control because their three-terminal structure makes them easy to wire as either NO or NC to help customize an application.

   b. Limit switches are made to order for positional control and are frequently the input devices for sophisticated applications such as (pick-and-place robots) (assembly line placement).

   c. Limit switches are used in conjunction with other (movement-oriented) (industrial) control devices ranging from product-moving conveyors to linear positioners.

   d. Adapting limit switches to specific applications is a challenge to both physical design and programming, and in both cases (creativity) (programming) is the order of the day.

7. Select true statements concerning analog inputs by placing an X beside each statement that is true.

_____a. Devices such as thermocouples and potentiometers produce analog as opposed to digital signals, and these analog inputs must be converted to digital signals so they can be used by a PLC controller.

_____b. The analog-to-digital conversion takes place in special PLC modules that can be tailored to meet specific needs of the various analog input devices used to measure such phenomena as flow, pressure, temperature, and level.

_____c. Analog input modules typically convert unscaled data to engineering units such as gallons per minute, pounds per square inch, inches of Mercury, or degrees C or F.

_____d. The conversion from analog input to engineering scale is programmed with a hand-held programmer.

TEST

8. Select true statements concerning application outputs by placing an X beside each statement that is true.

_____a. One of the most common output applications of a PLC is to activate motor starters which in turn activate motors.

_____b. Another common output application for PLCs is to control relays which can be readily designed to provide hard-wired safety interlocks to avoid shorting out motors or other output devices.

_____c. Contactors are electromagnetic switches designed specifically to handle small currents and have to be used in certain applications.

_____d. Solenoids take advantage of larger voltage supplies to provide the muscle it takes to activate valves and other large control devices.

_____e. Other output devices used in PLC applications range from lights and alarms to bells and whistles.

_____f. In cases where an output is an analog device such as a servo valve, the signal of the controller must go through a digital-to-analog conversion module.

_____g. The design and placement of motors and other devices that have to be activated by PLC outputs is part of installation design, and it is important to remember that inputs control the output devices.

9. Complete statements concerning guidelines for application wiring by circling the material that best completes each statement.

a. All wiring should be insulated and selected according to the (AWG) (ASE) number recommended by the PLC manufacturer or as required by the input/output device.

b. In all cases where it can be accomplished, wire (colors) (sizes) should be used with standard references for L1, L2, and ground.

c. Intermediate terminal (strips) (ground blocks) are recommended to interface both inputs and outputs with the terminals on the controller.

d. When properly positioned, terminal strips provide a good display for visual identification of wire routing, and will help avoid wear and tear on the (controller terminals) (wire ends).

e. Connecting ends of wires should be stripped to a uniform length to promote good contact with terminals and to give the installation a (professional look) (greater safety factor).

f. The end of a connecting wire at a terminal should be so placed that the free end turns (clockwise) (counterclockwise) as the terminal is tightened clockwise.

TEST

10. Select conditions concerning power and grounding by answering the following questions.

    a. Source power should be grounded so that it can provide grounding for the PLC and what else — outputs only or input and outputs?

    Answer ____________________

    b. Because a current to ground failure is life threatening, what is recommended for a PLC system, an overload fuse or a ground fault protector?

    Answer ____________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

11. Demonstrate the ability to:

    a. Plan, wire, program, and confirm a conventional start/stop station. (Job Sheet #1)

    b. Connect relay coils to a start/stop station and verify interlocks. (Job Sheet #2)

    c. Connect a linear positioner, motor, and limit switches to simulate a positioning application. (Job Sheet #3)

    d. Program and confirm an up counter in a positioning application. (Job Sheet #4)

    e. Program and confirm a retentive timer in a positioning application. (Job Sheet #5)

    f. Program and confirm a two-cycle positioning application with manual stop. (Job Sheet #6)

    g. Program and confirm a two-cycle positioning application with automatic stop. (Job Sheet #7)

    h. Program a positioning application with sequencer input driving sequencer output. (Job Sheet #8)

    i. Program a positioning application with sequencer input driving sequencer output with start/stop control. (Job Sheet #9)

    j. Program an extended SQI driving an SQO positioning application with start/stop control. (Job Sheet #10)

    k. Program and verify a jump command in a positioning application. (Job Sheet #11)

INDUSTRIAL PROGRAM APPLICATION
UNIT VII

ANSWERS TO TEST

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

2. a. Physical
   b. No closure and no voltage
   c. Outputs
   d. 1) Proximity
      2) Photoelectric
      3) Pushbutton
      4) Limit

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

4. a. Normally open
   b. Pull-type switches
   c. A seal-in circuit

5. a, c, d, e, f

6. a. Positional
   b. Pick-and-place robots
   c. Movement-oriented
   d. Creativity

7. a, b, c

8. a, b, e, f, g

9. a. AWG
   b. Colors
   c. Strips
   d. Controller terminals
   e. Professional look
   f. Clockwise

ANSWERS TO TEST

10. a. Inputs and outputs
    b. Ground fault protector

11. a. Evaluated according to criteria in Practical Test #1
    b. Evaluated according to criteria in Practical Test #2
    c. Evaluated according to criteria in Practical Test #3
    d. Evaluated according to criteria in Practical Test #4
    e. Evaluated according to criteria in Practical Test #5
    f. Evaluated according to criteria in Practical Test #6
    g. Evaluated according to criteria in Practical Test #7
    h. Evaluated according to criteria in Practical Test #8
    i. Evaluated according to criteria in Practical Test #9
    j. Evaluated according to criteria in Practical Test #10
    k. Evaluated according to criteria in Practical Test #11