**SECOND EDITION**

**First Printing, September 2000**

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# Introduction

Look upon this CELL Guide as a fixture at this station because it is to remain here. It is designed to provide what you need to operate the Automation and Material Handling CELL. For example, the first section, "Getting Started," starts you in the CELL program.

As you get into the Guide, you will see that it offers information not only on how to access and run the CELL but also supporting data such as topic skills, overview, objectives, equipment required, and terms used. You will find activity objectives too. More importantly, when you close the TW presentation to use the DOS Armdroid software, it provides the procedures required to perform the tasks in an activity. In the Appendices you will find information about help windows, safety, internet resources, a bibliography, and a Consumable Parts List Order Form.

The Table of Contents steers you to whatever area you want to work in. Make good use of this guide and remember that it is here for all who work at this station, so handle it with care.

# GETTING STARTED

## Desktop

After the Tech-Lab System is installed, the **TechLab** icon appears on the desktop.

1. Click on the **TechLab** icon on the desktop; a Student Logon window appears.

2. Select your name and click on **Logon**.

3. Enter your password and click on *OK*. (If you are creating your password, enter four alphanumeric characters. The system will ask you to enter your password again for verification. Keep a record of your password.)

4. Continue the previous two steps until all members of your team have logged on, then click on **Complete**.

5. When the Module-CELLs window appears, highlight the appropriate CELL and click on the right-arrow (or double-click on the CELL name).

6. A Tech-World window with the name of the CELL and a list of topics for that CELL appears. Highlight the topic you want to begin and click on the right-arrow (or double-click on the topic name). The topic title page appears and you are ready to begin.

### Selecting Topics or Exiting the CELL

1. Clicking on **Exit**, when in a topic returns you to the CELL topic window.

2. If you wish to select another topic, highlight and click on the right-arrow.

3. If you wish to exit the CELL, click on the left-arrow. The Module-CELL screen appears.

4. If you wish to exit Tech-World, click on the **Log-Off** icon (open door).

## Navigation

The navigation bar at the bottom of the screen contains the buttons to navigate through the multimedia presentation.

Figure 1 illustrates the right-hand area of the navigation bar while in a topic or activity.

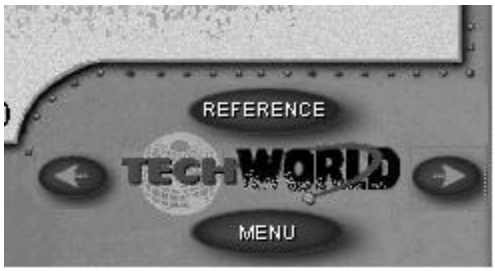



Figure 1

Students navigate through the curriculum by using the mouse to click on the arrow buttons or the **Reference** and **Menu** buttons. The buttons function as follows:

**Menu** – Clicking on this button activates one of three menus: **Topic**, **Activity**, or **Reference**. The menu activated depends on your current position in the curriculum. If viewing a Topic screen, the **Topic** menu appears. If viewing an Activity screen, the **Activity** menu appears, and if viewing a Reference screen, the **Reference** menu appears.

**Right arrow** – forward to next screen.

**Left arrow** – back to previous screen.

**Reference** – Clicking on the **Reference** button activates the **Reference** menu. References for that topic are listed on this screen. To access a reference, click on the reference title.

When viewing the references, the **Reference** button is changed to a **Return** button (Figure 2). When you have finished looking at the references, you click on the **Return** button to get back to your previous activity screen.

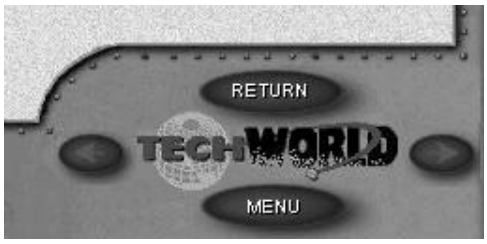



**Figure 2**

The control buttons in the left-hand part of the navigation bar are displayed in Figure 3.

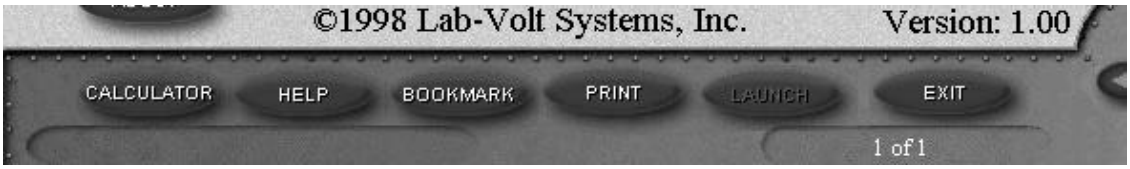



Figure 3

These control buttons provide the following functionality:

**Calculator** – provides a pop-up calculator window that can be switched between standard and scientific.

**Help** – provides additional information.
System help – information common to all CELLs
Topic help – extra information for the topic

**Bookmark** – marks your place within the curriculum. Clicking again returns you to the position marked.

**Print** – prints the screen.

**Launch** – starts third party software.

**Exit** – exits the curriculum.

Topic, activity, and reference menus enable you to move to any part of the multimedia presentation.

Hot words and hot spots on graphics give you similar ability to get information just when it's needed. For a more detailed explanation of the navigation, refer to Topic 1, Finding Your Way, in Fundamentals of Manufacturing.

# TOPIC 1 – INTRODUCTION AND REVIEW OF AUTOMATION AND MATERIAL HANDLING

## Objective

When you have completed this topic, you will have reviewed the skills necessary to prepare you to operate the entire Armdroid system in an integrated program. You will run both the 5100 and 5200 robots, the peripheral feeders and conveyors, and the PLC trainer.

## Overview

Before getting into an overview of Topic 1, a preview of Level 2 is in order. Level 2 builds and expands on your experiences in Level 1. The entire Level 2 CELL is focused on your use of all the equipment in a final topic that integrates both the 5200 and 5100 robots, the feeders, conveyors, and the PLC trainer.

The earlier topics take you one at a time through the exercises that will later become part of the final master activity in Topic 6. You will use the sensors to identify and sort materials coming down the conveyor. You will coordinate the two robots in a program. You will use the feeders and conveyors. You will see how the Armdroid system is truly a flexible manufacturing cell. As you did in Level 1, you will also experience supporting references that relate to these activities.

Topic 1 is primarily a review of Level 1, but it also is an introduction to Armdroid 5100. If you worked with the 5100 in Tech-Design, then view this as a refresher.

Activity 1 introduces the 5100 and provides exercises to familiarize you with its operation. Activity 2 follows with a review of the 5200. You will create a program similar to ones you did in Level 1. You will review control devices and conveyors because of the important part they play in any flexible manufacturing system.

Activity 3 is a refresher on the PLC trainer. You will download a simple program and run it to prepare you for later exercises with the PLC.

You have an eventful journey awaiting you. Enjoy all the stops.

## New Terms and Words

**accuracy** – is also known as **resolution**, which is the standard term for describing the smallest increment in which the robot can move.
**armature** – the movable part of an electromagnetic device.
**articulating** – jointed; a robot configuration similar to the human arm.
**buffer** – any of various devices for reducing shock or damage due to contact; a temporary storage unit, especially one that accepts information at one rate and delivers it at another.
**continuity** – in electrical circuits, a completed pathway that allows electrical currents to flow. In ladder logic, a rung where all conditions have been met so that the final logical outcome is a high.
**electromagnetic** – a piece of soft iron wrapped in wires that creates a strong magnetic force when electricity flows through the wires.
**executive programs** – programs supplied by the manufacturer that direct and perform the routine operation of the PLC. Examples include the program routines that scan input devices and the updating of information to output devices.
**feature-rich** – capable of performing several valuable functions.
**flexible manufacturing cells** – a group of related machines controlled by the same computer and connected through a common material-handling system. They are usually set up to manufacture particular parts.
**hard home** – a function performed by Armdroid to reset the parameters of its motors in starting mode; it goes to the extreme of each movement in its work envelope.
**manipulator** – a mechanical device for handling objects.
**microprocessor** – an integrated circuit that consists of the microcircuitry that performs the logic, control, and arithmetic functions of a small computer system.
**microswitch** – a small, highly sensitive switch which responds to very little contact; used especially in automatic control devices.
**momentary contact** – means that when a pushbutton is spring loaded, it returns to the first position when pressure is taken off the switch or button.
**motherboard** – the main circuit board of a computer system which includes interface circuitry for the microprocessor, memory chips, and peripheral devices.
**multitasking** – performing multiple applications concurrently.
**optical encoder** – consists of a small LED (light-emitting diode) and light detector on opposite sides of a spinning disk with many slots. As the light detector senses flickering light through the slots, it sends pulses to a controller that interprets these pulses as positional information.
**parameters** – measurements by which limits of an object are set.
**points** - movement or control (such as wait) steps.
**potentiometer** – a variable resistor connected with three terminals to provide a variable voltage; a device for converting mechanical motion into an electrical-feedback signal.

**semiconductor** – a material whose conductivity is between that of a good conductor of electricity and a good insulator.
**solid-state –** made of electronic components that control electron flow through solid materials such as crystals. Some examples are the transistors used in the circuit board of your computer.
**spool valve** – consists of a plunger and a spool or spools that fit tightly against the walls of the DCV housing in the same way that a piston fits in a cylinder.
**ultrasonics** – sound waves and vibrations above the frequency at which humans can hear.

## Equipment Needed

Armdroid 5100 with teach pendant
Armdroid Model 5200 with teach pendant
Gravity feeder
Conveyor
Rotary carousel
PLC and sensor trainer
- PLC
- sensor input box
- interface converter
- sensor 6377-A0 (diffuse photoelectric)

Automated and Material Handling CELL (Computer Enhanced Learning Location) Guide
Block 2x2x1½in. (4)
Block 2x2x1-in. slotted block (1)
Piece of square stock (plain or steel)
Four-way serial switcher
*RS Logix 500*® software
*RS Linx Lite*® software

# Activity 1 – Armdroid 5100

## Objective

When you have completed this activity, you will have the knowledge and skills to operate Armdroid 5100 and create the programs in Level 2.

You will be able to:

- operate Armdroid 5100 using the teach pendant.
- create a program with the Armdroid 5100.

## Procedures

### The 5100 Teach Pendant

You will familiarize yourself with the parts of Armdroid 5100 by operating it. Follow all instructions carefully while using the arm. It is a fine piece of machinery that deserves your respect.

Turn on the power supply. On the startup screen of the teach pendant, you should see *D&M Computing, Inc. Armdroid 1001*.

Press any key to go to the **Main** menu.

Select item number 6 **Setup**.

Press 3 to turn tasking off.

Press the *Set Speed* key and enter 99.

Press the *Teach Menu* key. This menu is used to manipulate the robot arm and define or record points.

You are now ready to operate Armdroid 5100. Perform the following steps to learn what each key does.

1. Press and hold the *Base* + key to rotate the arm clockwise on its base, moving it about 180 degrees.
2. Press the *Base* - key to rotate the arm counterclockwise 90 degrees back.
3. Press the *Shdr* + key to raise the arm a few degrees. Notice that the arm moves at the shoulder joint.
4. Press the *Shdr* – key to lower the arm to its former position.
5. Press the *Pitch* + key briefly. Don't let the gripper pitch sharply enough to touch the forearm.
6. Press the *Pitch* – key to return the gripper to its former position.

7. Press the *Roll* + key to observe how the gripper rotates counterclockwise.
8. Press the *Roll* – key to observe how the gripper rotates clockwise on the wrist.
9. Press the *Grip* + key and note how the gripper opens.

Press the *Grip* – key and note how the gripper closes. Don't close it all the way.

Press the *Main Menu* key. Next, press *3 (Initial*) and then *2 (Move Home)* to return to the home position.

Before creating the program, you will have to perform the following.

**Preliminary Steps**

1. Turn the power switch on.
2. At the D&M start-up screen press any kP
3. Press the *Set Speed* key, then enter "99."
4. Press the *Teach Menu* key. Remember, you need to be in the *Teach Menu* to move the robot and record points.
5. Using movement commands, position the arm at right angles to and about a foot above the conveyor as shown. You will make this the Home point.
6. Press *Main Menu*, then *3 Initial*. This brings up the Initialize Menu screen; press *1 Reset Home* to set a new Home.
7. Make sure that there are at least four blocks in the gravity feeder.

**The Program**

1. Press *Base* – to rotate the robot counterclockwise to a point above the blocks. Define or record the point by pressing the *Data* <· > dot key.

   **NOTE:** From this point forward, to record a point, press the *Data* <· > key. Remember, if you don't record a point, it does not become part of the program.

2. Press *Grip* + to open the gripper wide enough (about 3 inches) to hold a block. Record the point.
3. At this point you want to slow the robot down because of the precise movements needed to remove the block from the gravity feeder. Using the *Arm* – , *Shdr* –, and *Base* +/- keys (if necessary) lower the gripper down around the lowest block in the chute.
4. Use the *Pitch* +/- keys so that the fingers are at right angles to the block and centered as shown. Record the point. Press the *Set Speed* key, then enter "99."
5. Close the fingers on the block by pressing the *Grip* – key and holding it for at least 10 seconds after the grippers touch the block. Since the gripper is spring loaded, you must do this to get a firm grip. Record the point.
6. Then, using the *Shdr* + key, raise the block about ¾ of an inch. Record this point.

7. Use the *Pitch* – key to remove the block from the feeder. The gripper should now be 90 degrees to the table top. Record the point.
8. Using the *Arm* + and *Shdr* + keys, raise the block up about 8 inches and record the point.
9. Press *Base* + to swing the block around clockwise to a point above the conveyor. Record the point.

**NOTE:** You will not run the conveyor in this program.

10. Using the *Arm* – and *Shdr* – keys, lower the block close (1/8 to ¼ inch) to the surface of the conveyor belt. Record the point.
11. Press *Grip* + to open the gripper, releasing the block onto the conveyor belt. Record the point.
12. Raise the gripper 8 inches. Record the point.
13. Press *Base* – (counterclockwise) to rotate the robot so that the gripper is positioned above the lowest block in the chute of the gravity feeder. Record the point.
14. Lower the gripper to within an inch or two above the block. Record the point.
15. To slow the speed down again, press the *Set Speed* key, then enter "50."
16. Lower the gripper's fingers down around the block in the chute. Record the point. Press the *Set Speed* key and set the speed back to 99.
17. Close the gripper on the block, holding the *Grip* – key about 10 seconds until the robot has a good grip on the block. Record the point.
18. Then, using the *Shdr* + key, raise the block about ¾ of an inch. Record this point.
19. Use the *Pitch* – key to remove the block from the feeder. Hold the key down until the gripper is 90 degrees to the table top. Record the point.
20. Raise the block about 8 inches above the chute. Record the point.
21. Press *Base* + to rotate the robot and carry the block to a point above the block on the conveyor. Record the point.
22. After slowing the robot down, lower the block close (1/8 to ¼ inch) to the top of the other block, and open the gripper to place it on the other block. Record the point.
23. Use the *Arm* + key to raise the gripper at least 4 inches above the blocks. Record the point.

You may add to your program by stacking two more blocks. Simply repeat the steps just performed, placing the blocks further along the conveyor.

To run your program, do the following:

1. Place the blocks back into the gravity feeder.
2. Go to the **Main menu** and press *2 Execute*. This brings up the **Execute menu**.
3. Press *1 Once* to run through your program one time.

**NOTE:** The *2 Forever* option runs the program over and over until you stop it by pressing the *ESC* key.

# Activity 2 – Review of Armdroid 5200 and Peripheral Equipment

## Objective

When you have completed this activity, you will have the knowledge and skills necessary to operate Armdroid, Model 5200, and peripheral equipment and recall supporting technology in control devices and conveyors.

You will be able to:

- operate Armdroid 5200, the gravity feeder, the conveyor , and the carousel while creating a program.
- recall types of conveyors and control devices.

## Procedures

### Starting Up Armdroid

**WARNING:** Whenever you work around moving equipment, be sure you are wearing nothing that might get caught such as a tie or hanging jewelry. If your hair is long, tie it up.

**CAUTION:** Do not remove or insert any cable connections while power is on. Doing so will damage the controller.

1. Make sure that the emergency stop button is in the up position.
2. Turn on the power to Armdroid at the controller by pressing the rocker power switch labeled *I* for input (on) and *O* for output (off) at the left rear of the controller.
3. Once the power to Armdroid is activated, the **Main** menu appears in the teach pendant window after several screens are displayed.
4. Press the *4* key to access the **Motion Control** menu.
5. Press *4* (**Hard Home***)* then *Enter* to perform a hard home.

**NOTE:** Whenever you power up Armdroid, the first thing you should do is to perform a hard home to establish the robot's default parameters. This is necessary so that the starting point, when creating and running programs is always the same.

Press the *Teach Menu* key to get to the **Teach** menu. Press 0 to access the *Set Speed* slider. By pressing numbers 2 through 9, you can set the speed by tens (2 for 20, 9 for 90). You can also use the left and right arrows to decrease or increase your speed respectively by ones. However, if you do this, you won't see the slider.

When you are at the Set Speed screen, press *Enter* to return to the **Teach** menu.

Press *T* (*Base CW*) to rotate the robot clockwise at its base. Hold the key down until the robot has rotated 90 degrees.

Press *6* (*Base CCW*) to rotate the robot counterclockwise. Hold the key down until the robot has returned 90 degrees.

Press *S* (*Shoulder Down)* to lower the upper arm 5 to 10 inches.

Press 5 (*Shoulder Up*) to raise the upper arm an equal distance.

Press *J* (*Wrist Pitch Up*). Note that it raises the gripper (also known as end-of-arm tooling or end effector) at the wrist.

Press *3* (*Wrist Pitch Down*). Note that it lowers the gripper at the wrist.

Press *2 (Wrist Rotate CW)* to rotate the gripper clockwise at the wrist.

Press *I* (*Wrist Rotate CCW*) to rotate the gripper counterclockwise at the wrist

Press *1* (*Gripper Open*) to open the gripper fingers. Don't extend them more than 2 inches for now.

Press *H* (*Gripper Close*) to close the gripper fingers but don't close them tightly.

## Creating a Program with the 5200 System

Perform the following program to refresh your memory on how to create a program. Make sure there are at least two blocks in the gravity feeder. The gravity feeder is an example of another kind of conveyor.

1. As usual, perform a hard home. (In the **Main** menu, press *4 (Motion Control)*, then *4 (Hard Home.)*
2. From the **Teach** menu, move the robot to a point where the gripper is facing the gravity feeder. Record this move or point by pressing the *Dot* key.

> **CAUTION:** All movements must be recorded; the robot will not perform an unrecorded movement when you run the program. Not recording a point could be dangerous. If an omitted point avoided an obstacle, the robot will hit that obstacle when you run the program.
>
> **NOTE:** Remember, press the *Dot* key to record all movements.

Lower the gripper to about 4 inches above the first block in the gravity feeder. Record the point.

At this point, you want to insert a control or wait point so that Armdroid will wait if there is no block in the gravity feeder. Press the *G (Digital Input)* key to bring up the **Digital Input** menu.

If the gravity feeder wires are plugged into the NC (normally closed) jack, you want the robot to wait until the light on the controller goes on (high). Press the number corresponding to the color code of the jack (for example, red is *2*, *4* is yellow) to which the wires are connected on the controller. An *H* for high should replace the *X* in the **Input** menu.

Press *Enter* to return to the **Teach** menu.

Press the *Star (*)* key to get to the Save Control window. Give the point a name (P5, for example) and press *Enter*. If the gravity feeder is empty, the robot will wait until a block is installed.

> **NOTE:** If the wires are plugged into the NO (normally open) jack, this setup is reversed; you want the robot to wait until the light goes out (L for low). You can check if you selected the correct wait point and port by leaving blocks out of the gravity feeder and observing how the robot responds when you run your program.

Open the gripper wide enough to grasp the block. Record the point.

You might want to slow the robot down at this point because the next few moves must be precise. Press the *zero* (*0*) key to bring up the speed slider and press *2* or *3* to set the speed at 20 or 30.

> **NOTE:** Remember, you can lower the speed one point at a time by pressing the left arrow.

To return to the **Teach** menu, press *Enter*.

Lower the gripper around the lowest block in the gravity feeder. Record the point.

Close the gripper on the block. Make sure the gripper fingers don't grab the sides of the chute on the gravity feeder. Record the point.

Lift the block out of the feeder gently, using the *5 (Shoulder Up)* and *R (Elbow Up)* keys. Record the point.

Increase the robot's speed to 90 to shorten the time needed to reach the carousel.

> **NOTE:** You can also speed up the robot by pressing the right arrow.

Move the robot to the carousel by pressing the *8 (Extn2 Forward* key). Record the point.

At the carousel, lower the block to within an inch of the first empty square on the index plate attachment. You will probably have to swivel the gripper (the *2* key for CW, the *I* key for CCW) to fit the block snugly into the square. Record the point.

Slow the robot way down here (about 20) because it is a tight fit getting the block into the square.

Ease the block into the square hole and record the point.

Raise the block about a foot and rotate it so that it will be facing the carousel when it arrives there. Record the point.

Open the gripper, by pressing *1* (*Gripper Open*) to release the block. Record the point.

Raise the gripper above of the carousel. Record the point.

Raise the gripper by pressing, using *5 (Shoulder Up)* and *R (Elbow Pitch Up).* Record the point.

Rotate the carousel 90 degrees clockwise by pressing *8 (Ext2 Forward).* Record the point.

> **NOTE:** Channels 7 and 8 on the controller are interchangeable. It is possible that the carousel is connected to Channel 7 and therefore would be controlled by the 7 *Ext1* keys. If so, then the linear slide would be operated by the *8 Ext2* keys since it would connected to Channel 8.

Return the robot to the gravity feeder by pressing the *Z (Ext1 Backward)* key. Swivel the robot on its base to face the gravity feeder. Record the point. Transfer another block to the carousel. Don't forget to record all your movements. Once you have deposited the second block into an empty square, rotate the carousel 90 degrees CCW by pressing the / *(Ext2 Backward)* key. This brings the first block back to its original position. Record the point.

Here is a quick reference for the teach pendant key functions:

| KEY | ACTION | KEY | ACTION |
|---|---|---|---|
| 1 | GRIPPER OPEN | H | GRIPPER CLOSE |
| 2 | WRIST ROTATE CW | I | WRIST ROTATE CCW |
| 3 | WRIST PITCH DOWN | J | WRIST PITCH UP |
| 4 | ELBOW PITCH DOWN | R | ELBOW PITCH UP |
| 5 | SHOULDER UP | S | SHOULDER DOWN |
| 6 | BASE CCW | T | BASE CW |
| 7 | EXT1 FORWARD | Z | EXT1 BACKWARD |
| 8 | EXT2 FORWARD | / | EXT2 BACKWARD |

These remaining keys do not move the robot but have other functions:

| | | | |
|---|---|---|---|
| F | DIGITAL OUTPUT | Y | CNC CHANNEL 2 |
| G | DIGITAL INPUT | . | SAVE ABS POINT |
| P | RELAY POINT | # | SAVE REL POINT |
| Q | TIME DELAY | * | SAVE CONTROL |
| X | CNC CHANNEL 1 | | |

## Activity 3 – Review of the PLC and Sensor Trainer

### Objective

When you have completed this activity, you will have the knowledge and skills necessary to operate the PLC and sensor trainer.

You will be able to:

- recall the place of sensors, PLCs, and ladder logic in manufacturing.
- load a program into the PLC.
- verify the operation of the PLC.

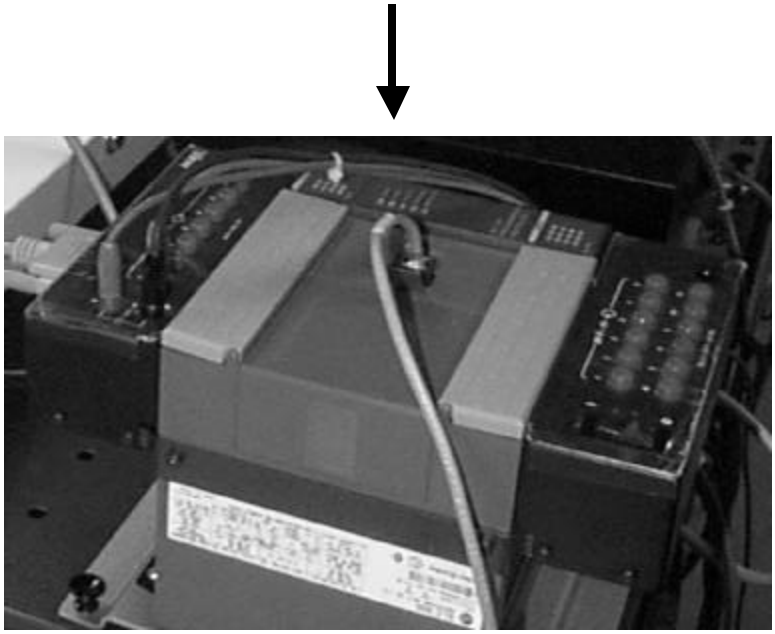
### Procedure: Connecting a Computer, a PLC, and a Conveyor

Insert the female connector on one end of the RS-232 cable into the serial connector on the back of the computer.

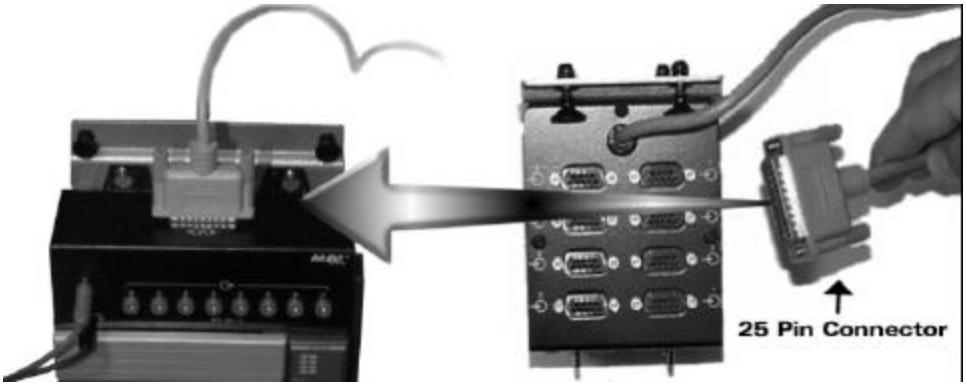
Connect the other end of the RS-232 cable into the female ribbon connector from the SLC500 personal computer interface converter.

> **NOTE**: If the computer is close to the SLC500, then the RS-232 cable is not needed. Plug the SLC500 ribbon connector directly into the computer serial port.

Lift the cover flap in the center of the PLC. Connect the cable connector (it looks like a telephone connector) from the SLC500 personal computer interface converter to the female connector on the front of the PLC.



Connect the 25-pin connector of the sensor input box into the rear of the PLC.



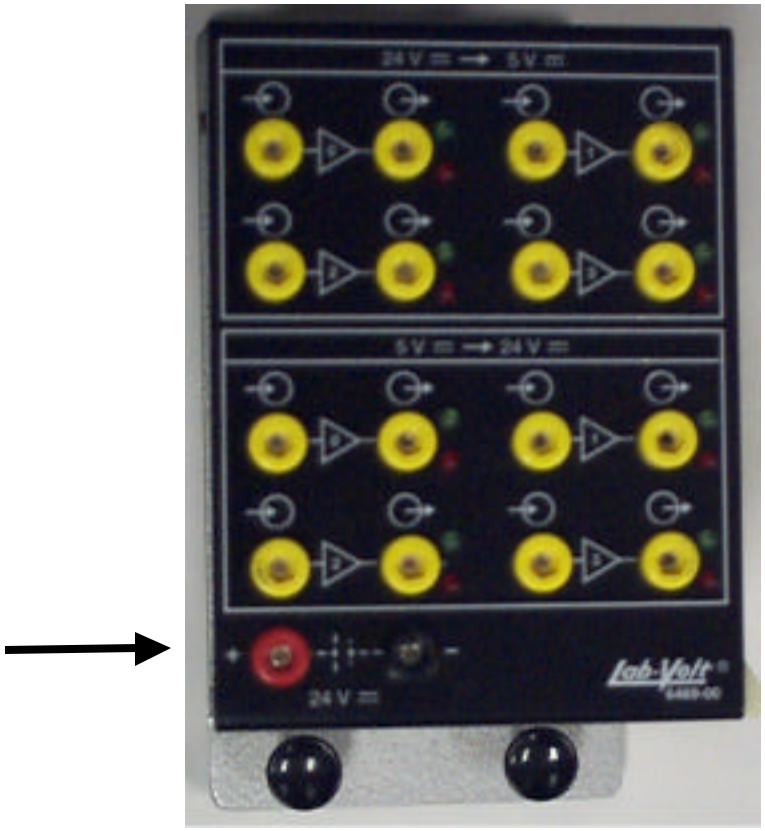
Move the power supply switch to the off (0) position. Insert two separate jumper cables with piggy-back connectors into the two holes on the face of the 24-volt power supply. Plug the power cord into a 115-volt receptacle.

Insert the other end of the jumper cable (the one inserted into the "+" receptacle of the power supply) into the receptacle at the upper left (the "+" receptacle) on the PLC.

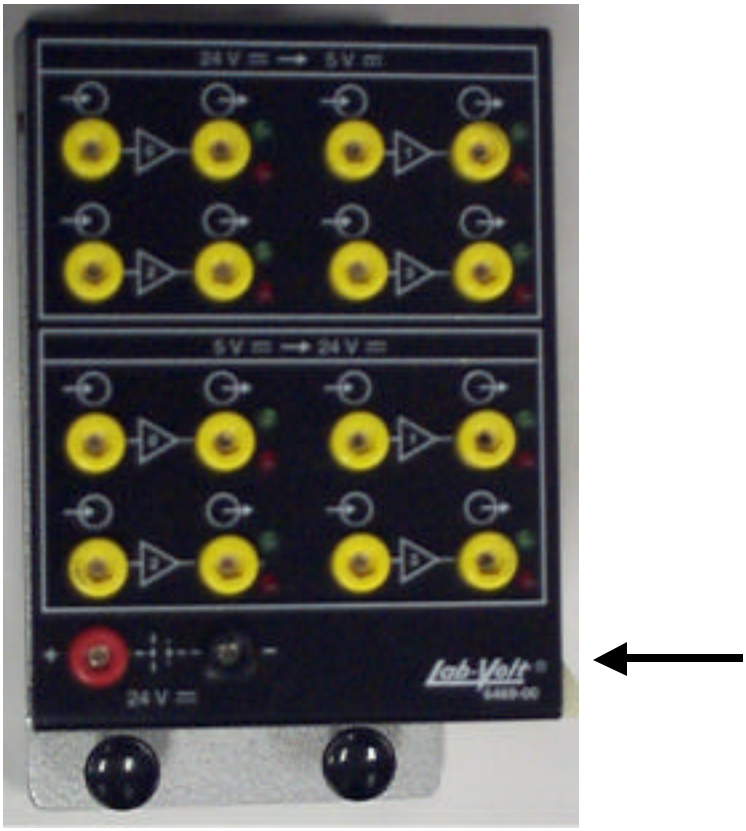
Insert the other end of the jumper cable (the one inserted into the "–" (minus) receptacle of the power supply) into the receptacle at the upper left (the "–" receptacle) on the PLC.

When both connectors are in place and the power is turned on, the power supply will provide 24 volts to the PLC. For now, leave the power switch at the lower left of the PLC in the off (0) position.

Insert another jumper into the positive (+) terminal of the power supply. Insert the other end of that jumper into the positive (red) receptacle of the 6469 voltage level converter.

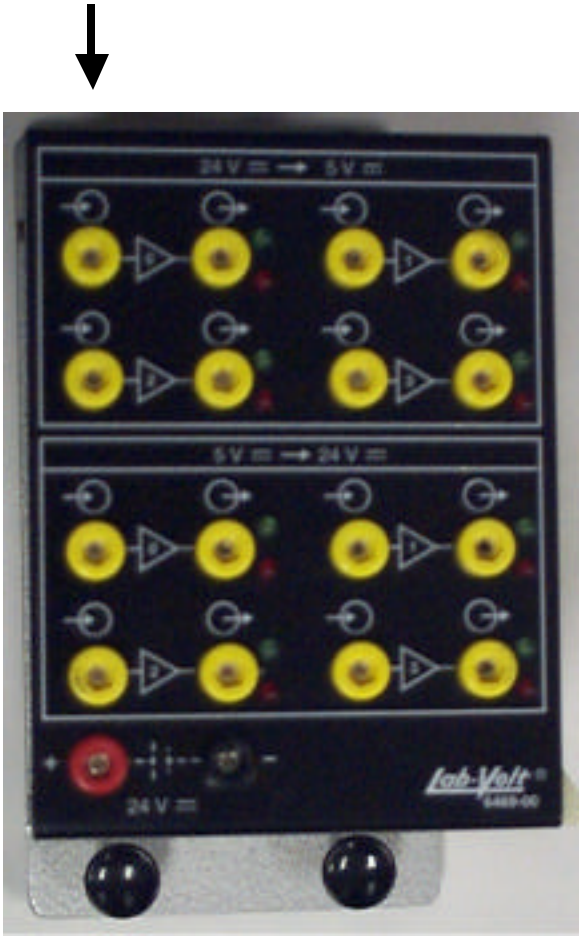


Insert another jumper into the negative (–) terminal of the power supply. Insert the other end of that jumper into the negative (black) receptacle of the 6469 voltage level converter.



Insert another jumper into the zero (0) terminal (near the + and – terminals at the upper left) of the PLC.

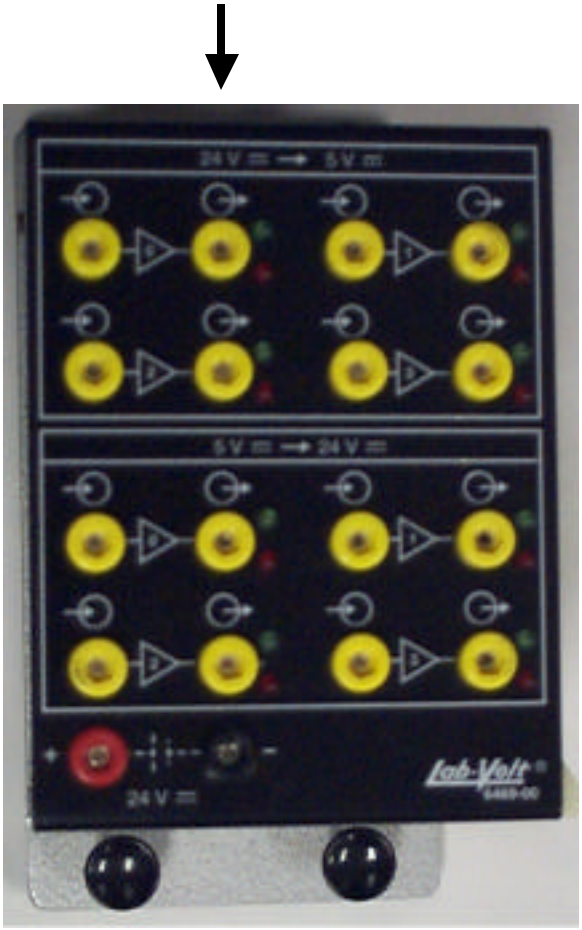
Insert the other end of the jumper (the one in the zero receptacle of the PLC) into the left, uppermost terminal of the voltage level converter.



Insert another jumper into the negative (black) receptacle of the 6469 voltage level converter.

Insert the other end into the GND (black) receptacle on the conveyor panel (below the *Remote Signal* receptacle).

Insert another jumper into the second upper receptacle of the voltage level converter.



Insert the other end of that second, upper receptacle jumper into the *Remote Signal* (violet) receptacle of the conveyor panel.

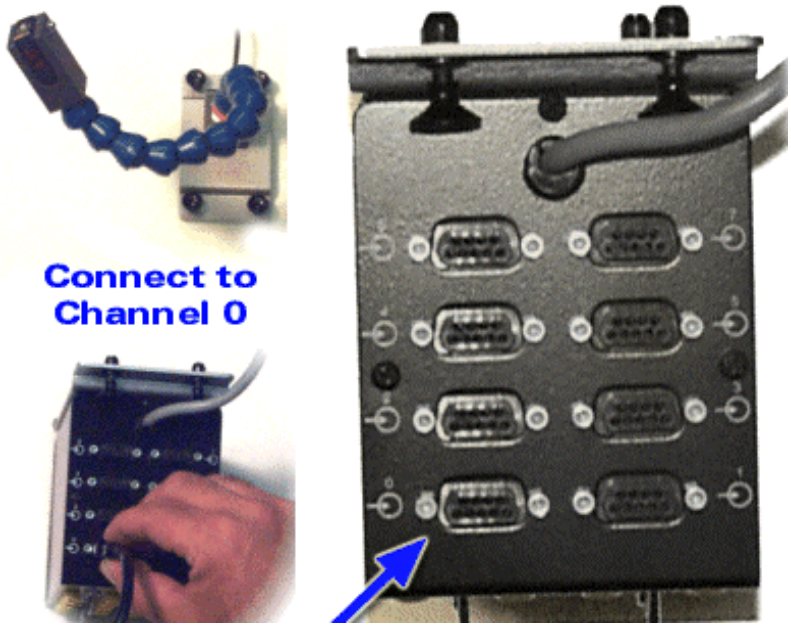
Plug the power cable of the conveyor into a 115-volt receptacle.

You have completed the wiring of the control circuit from the computer to the conveyor.

For the conveyor to work properly, the switches must be set this way:

- Under *Motor* the switch must be set on *Remote*.
- Under *Direction*, the switch must be set to *Remote* also.
- Under *Stop On Signal*, the switch must be set on *Low*.

Connect sensor number 6377-A0 to channel 0 on the sensor input box.



Turn the power switch of the PLC on. To make sure that your circuit is working, wave your hand in front of the sensors. An indicator on the right of the PLC should light.

Power Switch

Although lights appear on the front of the PLC, you did not program it to start or stop the conveyor. Your next task is to program the PLC so it starts and stops the conveyor in response to objects moving in front of the sensors.

## Directions Window #3-1

1. Pull down the **File** menu and choose **Open**.

2. In the Open window, click on the file First.RSS. The file loads into the RSLogix windows.

   **NOTE:** In this activity, we are using only one sensor (6377-A0) in the PLC program.

3. Place a square piece of stock (supported by a block) in front of the sensor.

4. Check to see if the indicator lamp numbered 0 in the lower right of the PLC lights up. Adjust the sensor so that the lamp does light.

5. Place the block with that same piece of square stock in it on the conveyor one foot away from the sensor 6377-A0 (diffuse photoelectric).

### *RSLogix* Windows, Tool Bar, and Menus

There are two windows that open when you start *RSLogix*: Project and Ladder Logic Diagram.

You use the Project window to select Help, Controller, and Program files. The Ladder Logic Diagram window is where you build your program diagram. It allows you to add, delete, or insert rungs; add or delete branches; and delete or edit controls.

6. Click on the down arrow next to the word "Offline."

7. Click on **Download**. The computer downloads the program to the PLC. Click **Yes** on all prompts.

8. On the conveyor, press the power switch on the left side of the control panel to turn the power on. The switch will light and the conveyor belt will begin to move.

9. When the stock passes in front of the sensor connected to Channel 0 on the sensor box, the conveyor stops.

   **NOTE:** When a normally closed instruction in the PLC receives a signal from the sensor, it stops the conveyor. When the conveyor stops, you will see the closed circuit rung, which was highlighted on your screen, darken.

10. Shut down the power switches on the conveyor, power supply, and PLC.

11. Go to the **File** menu and click on **Exit**.

12. Click on the **Return** button. The Directions window closes.

# TOPIC 2 – RSLOGIX PROGRAMMING

## Objective

When you have completed this topic, you will have gained the knowledge necessary to program timers, counters, math, and compare functions in *RSLogix*.

## Overview

Programmable logic controllers can perform more tasks than just checking inputs and energizing outputs. You will see how *RSLogix* and a PLC can be used for other functions such as counting, timing, and mathematics. You will learn how numbers are stored and used by different functions. You also will become familiar with the Project Tree files, editing, downloading, and other elements of *RSLogix*.

## New Terms and Words

**bit** – a spot in PLC memory that holds the ON/OFF status of a particular function. Bits are labeled 1 for ON and 0 for OFF. Bits can also be used as inputs anywhere in a ladder diagram.
**mechanical limit switch** – a switch that requires physical contact in order to sense the presence of an object. The lever must move far enough to change the position of a switch within the device.
**noninteger**– a number that is not whole, such as 1.234, 1 ¾ 5.5.
**synchronous** – starting and stopping at timed intervals.
**solid state** – devices that use semiconductors and electronic components instead of mechanical relay contacts.
**thumbwheel switch** – a device that allows you to input numerical digits.

## Equipment Required

PLC Sensor Trainer
Conveyor 2001
*RSLogix 500*
*RSLinx Lite*
Block 2 x 2 x 1½in. (5)

# Activity 1 – Using Timers

## Objective

When you have completed this activity, you will have the knowledge and skills to program a timer in *RSLogix*.

You will be able to:

- program and address inputs and outputs in the timer rung.
- program the Timer On-Delay function.
- use the sensors and conveyor with the timer function.

## Procedures

### Setting up Programming

Before you begin programming, you must know which input and output devices will be used. This will reduce confusion when addressing.

In this activity, you will be using the fiber optic sensor as the input and the conveyor as the output. Locate these items now.

Before you continue, make sure that the power to the PLC, the conveyor, and 24V-power supply is turned off.

Plug the cable from the fiber optic sensor into connection 0 on the back of the sensor interface box. This is automatically connected to input 0 of input module 0. Therefore, the address of this input is I:0/0.

Keep in mind that there are 12 inputs available on this SLC 500. Their addresses are I:0/0 to I:0/11. Remember that the first 0 signifies the first input module.

Next, using one of the shorter wires provided, connect Output 0 of the PLC to the 0 input connection on the voltage level converter. Make sure you are plugging into the 24V-> 5V section of the converter. This step is very important, it converts the 24V output of the PLC into 5V, which is compatible with the conveyor. If you do not do this properly, you may damage the conveyor motor.

Then, connect the other 0 connection of the voltage level converter to the remote input on the front panel of the conveyor. Make sure you put this wire in the purple hole in the *Motor* section. Also make sure that the switch next to the holes is set to *Remote*.

Double check to make sure that the power leads are connected from the 24V power supply to the red and black power connections on the output module of the PLC. If not, make these connections.

Next, connect a wire from the ground (black) connector on the power supply to the black connector on the conveyor motor. Again, make sure that it is connected to the black hole just under the purple hole in the *Motor* section.

Your hardware is now setup to for this portion of this activity.

### Directions Window #1-1

1. Open *RSLinx* by double-clicking the **RSLinx.exe** icon on the desktop. (You may need to drag the windows on the screen to find the icon.)
2. Click on the minimize button in the RSLinx window.
3. In the RSLogix 500 Starter window, click on the **File** menu, select **New**. *If a message asks you if you want to close a processor or save changes, click **Yes** (this message may not appear).
4. In the Select Processor Type window, scroll to the bottom of the list and select processor number 1747-L20C/F.
5. Click on the **User** tab in the editing toolbar so that it turns white.
6. Click once on the **Insert Rung** icon, which is the first icon above the **User** tab. A new rung should appear, and small e's in a red box become visible to the left of it.
7. Click on the **Normally Open (XIC) Contact** icon in the editing toolbar. This is the third icon from the left. An XIC instruction should appear on the first rung.
8. Next, click on the **Timer/Counter** tab so that it is white, then click **TON**, the first function in the toolbar. A timer should appear on the right side of the rung.
9. Click on the **XIC Instruction** so that a black bar with a question mark appears. Give the instruction the address of the fiber optic sensor. Type "I:0/0".
10. Click on the question mark in timer function so that a black bar appears. This is how you give the timer an address. Type "T4:0".
11. Press *Enter*, select the Time Base value and select 0.01 as the time base, and hit *Enter*.
12. In the Preset value field, type 1000, then hit *Enter*.
13. Do not type any values into the Accum value area.
14. Now verify the rung by clicking on the **Verify** icon at the top of the toolbars. It looks like a computer with a green checkmark on it. Your ladder should not have any errors, if there are errors, close without saving and start over.
15. Goto the **File** menu, select **Save As**, and type "Timer On".
16. Look at the top left area of the screen under the **File** menu. Click on the arrow next to the word "Offline" and select **Download**. If any dialog boxes appear, click **Yes**.

17. If the processor is not in the **Remote Run** mode at the top left of the screen, click on the arrow next to **Remote Prog**. Select **Run** from the menu. The rails of the ladder should now be green.
18. Place your hand in front of the fiber optic sensor and hold it there. The input I:0/0 should now energize (you can see this because the instruction will turn light green)
19. Look at the Accum value in the Timer. This number will increase until it reaches 1000. When 1000 is reached, remove your hand from the front of the fiber optic sensor.
20. Place your hand in front of the sensor again, wait until the count reaches 500, and then take your hand away. You should notice that timer reset itself when you pulled your hand away.
21. Now, hold your hand in front of the sensor until 1000 is reached, remove your hand, and place it back in front. Become aware of the way the timer functions when its input logic is true (energized) and not true (de-energized).
22. When you have finished examining the Timer, click on the **File** menu, and select **Exit**.

Click the **Return** button. Continue to the next page to resume the activity.

### Directions Window #1-2

1. If *RSLinx* is not open, open it from the desktop, minimize it, and go back to *RSLogix*.
2. Go to the **File** menu in *RSLogix*, and select **Open**. Double click on the file Timer On.
3. Click on **0001** in the ladder diagram to make the red box appear just to the left of the rung.
4. Click on the **User** tab so it is white, then click on the **New Rung** icon 3 times. Remember, the **New Rung** icon is the first icon above the **User** tab.
5. Now, click on **Rung 0001** again, then click on the **Normally Open Instruction (XIC)** icon.
6. Click on **Rung 0002**, click on the **XIC** icon. Repeat for **Rung 0003**.
7. Next locate **Output Energize Instruction** icon, which is the 5$^{th}$ icon above the **User** tab. Click and drag the icon into the ladder and drop it on the red box at the end of rung 0001. The red box will turn green to let you know that this instruction can go here. Repeat this step for rungs 0002 and 0003.
8. In the Project Tree, double click on the T4-Timer file, under the Data Files folder. Move the window that opens so it is not blocking the inputs you just added to the ladder. You will use this window to assign addresses to the inputs.
9. Click on the **0** under the EN in the first timer element. This is called the EN bit. (T4:0 is considered the first timer "element.")
10. Drag the **0** to the instruction on rung 0001 and let it go when the red box turns green.

11. Click on the TT bit (the zero under TT) and drag that to the input instruction on rung 0002.
12. Click and drag the DN bit to the input of rung 0003. Now you can close the Data File T4 window by clicking on the X in the upper right hand corner.
13. In the Project Tree, double click on the **O0 – Outputs File**. Make sure that the window does not block the outputs on rungs 0001, 0002, 0003.
14. Click on **Bit 1** (the zero located under the 1 column heading) and drag it to the output instruction of rung 0001.
15. Click on **Bit 2** (the zero located under the 2 column heading) and drag it to the output instruction of rung 0002.
16. Click on **Bit 3** and drag it to the output instruction of rung 0003.
17. Close the Data File - O0 window.
18. Verify the new rungs by clicking on the **Verify** icon at the top of the menu bar. (The icon looks like a computer with a green checkmark in front of it.) There should not be any errors in your program. If there are, close the file without saving and start again from step 1, you must have missed something.
19. Select **Save As** from the **File** menu and type "Timer On1."
20. Download the program to the processor by clicking on the arrow to the right of **Offline** and selecting **Download**. (You do this right below the **File** menu) Click **Yes** when prompted by any dialog boxes.
21. If the processor mode is not **Remote Run**, change it from **Remote Program** to **Run**. (Do this in the same area as step 19).
22. Place an object, or your hand, in front of the fiber optic sensor and leave it there. You should notice that the inputs to rungs 0001 and 0002 are on while the timer is accumulating. When the timer stops, the inputs to rungs 0001 and 0003 are energized.
23. Notice that as long as your hand is in front of the sensor, the EN bit is energized.
24. Notice that while your hand is in front of the sensor and the timer is accumulating, both the EN and TT bits are energized and the DN bit is de-energized.
25. Notice that when your hand is in front of the sensor and the timer is finished timing, both the EN and DN bits are energized and the TT bit is de-energized.
26. Notice that when nothing is in front of the sensor, none of the bits are energized.

### Directions Window #1-3

1. If *RSLinx* is not open, open it from the desktop, minimize it, and go back to *RSLogix*.
2. Go to the **File** menu in *RSLogix*, select **Open**, and double click on the file Timer On1.
3. You will now learn some editing functions of *RSLogix*. You will edit this ladder to meet the conditions in your plan.

4. In the first rung, the input I:0/0 is the correct input for this process. The timer is the right one, but you need to change 1000 to 500. Click on the value, and type 500. This sets the timer for 5 seconds (500 x .01 seconds = 5 seconds).
5. You know that you need to get rid of two rungs that are not used in this program, rung 0001 and rung 0003 (since the DN and EN bits will not be used). Right click on the number 0003 to the left of the rung, and select **Delete** from the pop up menu. Repeat this for rung 0001.
6. Now, you are left with two rungs, but the input instruction on rung 0001 is not what you need, you need the normally closed (XIO) instruction. Right click on the normally open input T4:0/TT and select **Change Instruction Type**.
7. Type XIO where you currently see XIC. This changes the instruction from normally open to normally closed.
8. The output you will use is connected to O:0/0. The output on this rung is set for O:0/2, so you need to edit this instruction too. Click on the output instruction and type "O:0/0" and hit *Enter*.
9. You have now programmed the ladder to meet the conditions of your plan.
10. Click on the **Verify** icon at the top of the page. If any errors are present, close without saving and start over at number 1 of this Directions window.
11. Go to the **File** menu, select **Save As** and type "Timer On2."
12. Download the ladder to the PLC by clicking the arrow next to **Offline** and selecting **Download**.
13. If any dialog boxes appear, click **Yes**.
14. On the conveyor control panel, switch the **Motor** mode from **Off** to **Remote**.
15. Make sure the sensor is positioned so that it senses the presence of an object moving down the conveyor.
16. Place a block on the conveyor so that it moves toward the sensor.
17. When the block passes in front of the sensor the conveyor stops. Notice that the timer is timing, and the normally closed instruction in rung 0001 is not energized.
18. When the 5 seconds is up, the normally closed instruction in rung 0001 is energized, and the conveyor turns back on.
19. You can pick up the block and place it back on the conveyor so that the program repeats. Or, you can use more than one block on the conveyor.
20. Take time to watch the ladder function as the program is executed by the PLC.
21. The conveyor will continue to run unless you move the switch on the conveyor control panel from **Remote** to **Off**.

Click the **Return** button. Continue to the next page to resume the activity.

# Activity 2 – Using Counters

## Objective

When you have completed this activity, you will have the knowledge and skills to program a counter in *RSLogix*.

You will be able to:

- program and address inputs and outputs in the counter rung.
- use the counter function to initiate other events in a routine.
- use the sensors and conveyor with the counter function.

## Procedures

None required.

> **NOTE:** In the following Directions, you will be asked to "Click here" sometimes to see a graphic. In those instances, you will have to maximize the Directions window on screen to follow the instructions.

### Directions Window #2-1

1. Open *RSLinx* by double-clicking the **RSLinx.exe** icon on the desktop. (You may need to drag the windows on the screen to find the icon.)
2. Click on the minimize button in the **RSLinx** window.
3. In the *RSLogix 500* Starter window, click on the **File** menu, select **New**. *If a message asks you if you want to close a processor or save changes, click **Yes** (this message may not appear).
4. In the Select Processor Type window, scroll to the bottom of the list and select processor number 1747-L20C/F.
5. Click on the **User** tab in the editing toolbar so that it turns white.
6. Click twice on the **Insert Rung** icon, which is the first icon above the **User** tab. Two new rungs should appear.
7. Select the first rung, 0000, and click on the **Normally Open (XIC) Contact** icon in the editing toolbar. This is the third icon from the left. An XIC instruction should appear on the first rung.
8. Select the second rung, 0001, and click on the **Normally Open (XIC) Contact** icon in the editing toolbar.
9. Click on the input instruction in rung 0000. Click on the **Timer/Counter** tab so that it is white, and click **CTU**, the fourth function in the toolbar. A counter should appear on the right side of the rung.
10. Select the input instruction in the second rung, 0001, and click the **RES** button. This places the reset output on the end of the rung.

11. Click on the XIC instruction in rung 0000 so that a black bar with a question mark appears. Give the instruction the address of the fiber optic sensor. Type the following: I:0/0
12. Click on the question mark in the counter function so that a black bar appears. This is how you give the counter an address. Type "C5:0".
13. In the Preset Value field, type "10", then hit *Enter*.
14. Do not type any values into the Accum value area.
15. Click on the XIC instruction in rung 0001 and type "C5:0/DN". This instruction will energize when the counter reaches the preset.
16. Click on the RES output in rung 0001. Type "C5:0". This tells the PLC to reset counter C5:0 whenever the input logic to this output is true.
17. Now verify the rungs by clicking on the **Verify** icon at the top of the toolbars.
18. Go to the **File** menu, select **Save As**, and type "Counter".
19. Look at the top left area of the screen under the **File** menu. Click on the arrow next to the word **Offline** and select **Download**. If any dialog boxes appear, click **Yes**.
20. If the processor is not in the **Remote Run** mode at the top left of the screen, click on the arrow next to **Remote Prog**. Select **Run** from the menu. The rails of the ladder should now be green.
21. With your fingers together, move your hand slowly across front of the fiber optic sensor. The input I:0/0 energizes and de-energizes. You may not see this if you move your hand too fast. Move your hand slowly again and watch the input.
22. Look at the Accum value in the Counter. This number will increase until it reaches 10.
23. Move your hand back and forth until the counter reaches 10. Notice that after 9 is reached, the Counter is reset to 0.
24. Take some time to watch the Counter while passing your hand at different speeds across the sensor, with your fingers closed and spread apart. You may notice that the counter counts each of your fingers when they are spread apart.
25. When you have finished examining the Counter, click on the **File** menu, and select **Exit**.

### Directions Window #2-2

1. If *RSLinx* is not open, open it from the desktop, minimize it, and go back to *RSLogix*.
2. Turn on the power to the PLC, 24V power supply, and conveyor. Make sure the *Motor* switch on the front of the conveyor control box is switched to *Off*. Also, make sure that the direction is switched to *Forward*.
3. Go to the **File** Menu in *RSLogix*, and select **Open**. Double click on the **File Counter**.
4. When the file opens, click on the Counter function and change the preset value to 5 by clicking on the 10 and typing 5.

5. In rung 0001, right click on the XIC instruction and select **Change Instruction Type**. Type XIO to change the instruction to a normally closed contact.
6. Right click on the **RES Instruction** and select **Change Instruction Type.** Type "OTE" to change the instruction to an output energize instruction.
7. On the same instruction, click **C5:0** and type "O:0/0". This changes the output to the conveyor connected to output 0 of module 0.
8. Verify the ladder and save it as Counter1.
9. Download the file to the processor (select **Download** from the window just below the **File** menu). Click **Yes** if any dialog boxes appear.
10. Place 5 blocks 2 inches from each other in a line on the conveyor so that when the conveyor is turned on, the blocks travel toward the fiber optic sensor. Also make sure that the fiber optic sensor is in a position to sense the blocks from the side.
11. Switch the conveyor motor switch from *Off* to *Remote*. The blocks should now travel toward the fiber optic sensor.
12. Watch the counter accumulator to make sure each block in seen by the sensor. If a block is missed, put it back at the end of the line so it gets counted.
13. When the counter accumulator reaches 5, the conveyor stops. You will notice that if you pass your hand in front of the sensor, the counter continues to accumulate.

You also should notice that the DN bit assigned to the normally closed instruction remains energized.

When you have finished examining the Counter, click on the **File** menu, and select **Exit**.

## Preparation for Programming the PLC

For the next exercise in this activity, you will need to locate the diffuse sensor, #6377-A0.

Turn off the power switches to the PLC, conveyor, and 24V power supply.

Connect the sensor to input 1 of the sensor interface box. Position the sensor so that it will detect the block from the side. Also, position the diffuse sensor so that it is closest to the conveyor control panel. Move the fiber optic sensor #6378-A0 to the other end of the conveyor.

Be sure there is enough room for all 5 blocks to pass the sensors without falling off the end of the conveyor.

Next, locate one short wire and two long wires that can extend from the Voltage Level Converter to the front of the Conveyor Control Panel.

Using the short wire, connect Output 1 of the PLC to the 1 input connection on the voltage level converter. Make sure you are plugging into the 24V⇒5V section of the converter. This step is very important, it converts the 24V output of the PLC into 5V, which is compatible with the conveyor.

> **CAUTION**: If you do not do this properly, you may damage conveyor components.

Next, connect the output from the voltage level converter to the yellow connector of the conveyor motor *Direction* section on the conveyor control panel.

Make a connection from the black (ground) connection of the PLC to the black connection just under the yellow connection on the conveyor control panel.

### Directions Window #2-3

1. If *RSLinx* is not open, open it from the desktop, minimize it, and go back to *RSLogix*.
2. Turn on the power to the PLC, 24V power supply, and conveyor. Make sure the *Motor* switch on the front of the conveyor control box is switched to *Off*.
3. Go to the **File** menu in *RSLogix*, and select **Open**. Double click on the file Counter1.
4. Click on the **Insert Rung** icon and drag a rung into the ladder diagram. Drop the rung in the red box that appears just above rung 0001. (Remember, the box will turn green to let you know that is the location where the instruction will be dropped.)
5. Click once on the **Insert Rung** icon, a new rung will automatically appear below rung 0001.
6. Click and drag the **Normally Open (XIC) Instruction** icon and drop it in the first red box that appears on rung 0001. Type "I:0/1" to give the instruction the address of the diffuse sensor.
7. Click on the **Timer/Counter** tab. Click and drag the **CTU** button into the ladder and let it go on the right-most red box of rung 0001.
8. Click on the question mark inside the new counter. Type C5:1, hit *Enter*, type 5, hit *Enter* again. Click **here** (Hot word in the Directions window) to see what the rung should look like at this point.
9. Click on the User tab. Click and drag an XIC instruction and let it go on the red box in rung 0002. Give the instruction the address C5:0/DN.
10. Click once on the input in rung 0002, then click once on the **Branch** icon (second from left). A branch will appear in rung 0002. Click and drag the vertical red box on the branch to the left of the input C5:0/DN.
11. Click and drag the **Normally Open (XIC) Instruction** icon and drop it in the first red box that appears on the bottom line of the branch.

12. Type "C5:1/DN" to give the instruction an address.
13. Click on the **Timer/Counter** tab. Click and drag the **TON** button to the red box on the right of rung 0002.
14. Click on the question mark inside the timer and type "T4:0", hit *Enter* and select time base 0.01, hit *Enter* and type 500 for the preset value. Click **Here** (on screen) to see what the rung should look like at this point.
15. Click once on the normally closed (XIO) instruction in rung 0003 and type T4:0/TT. Click **Here** (Hot word in the Directions window) to see what the rung should look like at this point.
16. Click on 0003 on the same rung (so that the solid red box appears). Click on the **User** tab, and click the **Insert Rung** icon 4 times.
17. Click and drag the **Normally Open (XIC) Instruction** icon and let it go on rung 0004. Repeat this for rungs 0005, 0006, 0007.
18. As a precaution, you should save the file as Counter 2.
19. Click on the XIC instruction in rung 0004, type "C5:1/DN".
20. Click on the XIC instruction in rung 0005, type "C5:0/DN".
21. Click on the XIC instruction in rung 0006, type "I:0/0".
22. Click on the XIC instruction in rung 0007, type "I:0/1".
23. Make sure the **User** tab is selected, and click and drag the **Output Latch** icon, -(L)-, to the rightmost red box in rung 0004. Type "O:0/1".
24. Click and drag the **Output Unlatch** icon, -(U)-, and drop it in the red box on the right of rung 0005. Type "O:0/1".
25. Click on the **Timer/Counter** tab. Click and drag the **RES** button (second from right) to the right side of rung 0006. Repeat this step for rung 0007.
26. Click on the RES instruction in rung 0006, type "C5:1".
27. Click on the RES instruction in rung 0007, type "C5:0". Click **Here** (Hot word in the Directions window) to see what rungs 0004, 0005, 0006, 0007 should look like at this point.
28. Verify and save the file and download it to the processor. If any errors were found, you should try to fix them or start over from a new file.
29. Place 4 blocks 2 inches away from each other in a line down the length of the conveyor. Make sure the blocks lie in between the two sensors.
30. Turn the switch on the front of the conveyor panel to *Remote.*
31. Notice that when each block passes the sensor, the counter advances one count.
32. When the fourth block is seen by the sensor, the conveyor stops. The timer begins counting for 5 seconds. When 5 seconds is up, the conveyor begins to travel in the other direction. Notice that the counter still counts the blocks moving in the opposite direction, even though it has reached its maximum.
33. When the 4 blocks pass the sensor at the other end, the counter counts to 5, stops for 5 seconds, and reverses. This routine will run perpetually until the conveyor is switched from *Remote* to *Off.*

Watch the ladder diagram a few times as the program is running. Take time to notice what happens in each rung.

# Activity 3 – Math Functions

## Objective

When you have completed this activity, you will have the knowledge and skills to program math functions in *RSLogix*.

You will be able to:

- describe the values needed to program a math function.
- add a math function to the ladder diagram and insert the correct values.
- program a compare function.
- run a program that uses the math and compare functions.

## Directions Window #3-1

1. Open *RSLinx* by double-clicking the **RSLinx.exe** icon on the desktop. (You may need to drag the windows on the screen to find the icon.)
2. Click on the minimize button in the **RSLinx** window.
3. In the **RSLogix 500** Starter window, click on the **File** menu, select **New**. If a message asks you if you want to close a processor or save changes, click **Yes.** (This message may not appear.)
4. In the Select Processor Type window, scroll to the bottom of the list and select processor number 1747-L20C/F.
5. Click on the **User** tab in the editing toolbar so that it turns white.
6. Click twice on the **New Rung** icon. Two new rungs should appear.
7. Select the first rung, 0000, and click on the **XIC** icon.
8. Select the second rung, 0001, and click on the **XIC** icon.
9. Click on the **Input Instruction** in rung 0000. Type "I:0/0".
10. Click on the **Timer/Counter** tab so that it is white and click **CTU**. A counter should appear on the right side of the rung.
11. Click on the question mark in the counter function and type "C5:0". Hit *Enter* and type "20" for the preset and hit *Enter*.
12. Under the **User** tab, click and drag the **Rung Branch** icon into the ladder and drop it on the red box to the left of the counter function in rung 0000.
13. Click and drag the tall red box on the right leg of the branch and drop it in the red box on the right side of the counter function.
14. To the left of the **User** tab, click on the triangle that points to the right until the **Compute/Math** tab is visible. Click on the **Compute/Math** tab.
15. Click and drag the **SUB** button and drop it on the red square in the bottom line of the branch that you just inserted.
16. Click on the question mark next to Source A in the counter function and type "20" and hit *Enter*. This is the constant that will be used in this program.
17. Click on **Source B** and type "C5:0.ACC". The number that is in the C5:0.ACC register will be subtracted from Source A, 20.

18. Click on **Destination** and type "N7:0". The result of the subtraction will be stored in this integer register, N7:0. Click **Here** (Hot word in the Directions window) to see what rung 0000 should look like.
19. Click on the input instruction in rung 0001 and type "C5:0/DN".
20. Click on the **Timer/Counter** tab. Click and drag the **RES** button the red box on the right of rung 0001. Type "C5:0".
21. Verify the program and save it as Math<your name>.
22. Download the program to the processor and make sure the processor is in the **Remote Run** mode. If not, select **Run** by clicking on the arrow next to **Remote Program**.
23. Pass your hand in front of the diffuse sensor a few times; this is called triggering the input. You should notice that the count increases by one.
24. While triggering the sensor input, you should also notice that the value in Source B of the SUB function is identical to the Accum value of the counter. This is because they both are displaying the value held in the register C5:0.ACC. Double-click on the **C5 - Counter** file in the **Project Tree** to see this value in the register under the ACC column.
25. Finally, you should notice that the value in the Dest (Destination) field decreases by one each time the counter increases by one. Double-click on the N7 – Integer file in the Project Tree to see this value.
26. When you are finished examining the SUB function and how it works, close *RSLogix*.

### Directions Window #3-2

1. If *RSLinx* is not open, open it from the desktop, minimize it, and go back to *RSLogix*.
2. Turn on the power to the PLC, 24V power supply, and conveyor. Make sure the *Motor* switch on the front of the conveyor control box is switched to *Off*. Also, make sure that the direction is switched to *Forward*.
3. Go to the **File** menu in *RSLogix*, and select **Open**. Double-click on the file Math.
4. Right click on the SUB function in rung 0000 and select **Change Instruction Type**. Type "CTU".
5. Click on the 20 next to the word Counter in the new count up function. Type "C5:1". Hit *Enter*.
6. Type "20" for the preset, hit *Enter*.
7. Type "10" for the Accum, value and hit *Enter*.
8. Right click on rung 0001 and select **Delete**. Click **here** (Hot word in the Directions window) to see what the ladder should look like at this point.
9. Click on the **New Rung** icon 6 times.
10. Click on the right arrow to the left of the **User** tab until you can click the **Compare** tab.
11. Click and drag the **EQU** button into rung 0001. Type "C5:0.ACC" for Source A and "C5:1.ACC" for Source B.
12. Click and drag the **NEQ** button to rung 0002.

13. Click and drag the **LES** button to rung 0003.
14. Click and drag the **LEQ** button to rung 0004.
15. Click and drag the **GRT** button to rung 0005.
16. Click and drag the **GEQ** button to rung 0006.
17. In rung 0001, click and drag the address C5:0.ACC to Source A in the NEQ function in rung 0002.
18. Click and drag the address from Source A in 0002 to Source A in 0003. Then drag the address from 0003 to Source A in 0004, then from 0004 to Source A in 0005, and finally from 0005 to Source A in 0006.
19. Next, drag the address C5:1.ACC from Source B in rung 0001 to Source B in rung 0002. Then, drag it from rung 0003 to 0004, 0005, 0006.
20. Click and drag an **Output Energize (OTE)** instruction onto the right side of rungs 0001 through 0006.
21. Click on the **OTE** instruction on the right of rung 0001. Type "O:0/0".
22. In the output of rung 0002, type "O:0/1".
23. In the output of rung 0003, type "O:0/2".
24. In the output of rung 0004, type "O:0/3".
25. In the output of rung 0005, type "O:0/4".
26. In the output of rung 0006, type "O:0/5".
27. Verify the program and save it as Compare<your name>.
28. Download the program to the processor.
29. If the processor is in **Run** mode, skip to 30. If the processor is not in the **Run** mode, click the arrow next to **Remote Prog** and select **Run**.
30. You should immediately notice that outputs 1, 2, and 3 are all energized. This is because the values of the counters in rung 0000 are being compared constantly. Since the value in C5:0/ACC is 0 and the value in C5:1/ACC is 10, Source A is less than Source B in all of the compare functions. Only the **NEQ, LES** and **LEQ** functions are energized since they are true. Study each compare function to see why or why not its output is energized.
31. Click on the **Accum** value of the C5:0 counter and type "10". Three of the outputs should be energized. Since the Value in C5:0/ACC is now the same as the value in C5:1/ACC, the **EQU, LEQ** and **GEQ** compare functions are all energized.
32. Click on the **Accum** value of the C5:0 counter again and type "15". Now you should notice that the **NEQ, GRT** and **GEQ** compare functions are all energized. Study them to find out why.
33. When you are finished studying the compare functions, close *RSLogix*.

### Directions Window #3-3

1. If *RSLinx* is not open, open it from the desktop, minimize it, and go back to *RSLogix*.
2. Turn on the power to the PLC, 24V power supply, and conveyor. Make sure the *Motor* switch on the front of the conveyor control box is switched to *Off*. Also, make sure that the direction is switched to *Forward*.

3. In the *RSLogix 500 Starter* window, click on the **File** menu, select **New**. If a message asks you if you want to close a processor or save changes, click **Yes.**
4. In the Select Processor Type window, scroll to the bottom of the list and select processor number 1747-L20C/F.
5. Click on each rung number below to see how they should be programmed. Try to program the ladder by looking at every rung below. When you finish programming your rung, it should be identical to the rung graphic that you selected. If you want more detailed instructions on how to program this ladder, click the **Next** button.

   **Rung 0000**
   **Rung 0001**
   **Rung 0002**
   **Rung 0003**
   **Rung 0004**
   (The ladder diagram is on page 50)

When you have completed programming the ladder, click the **Next** button and go to step 21.

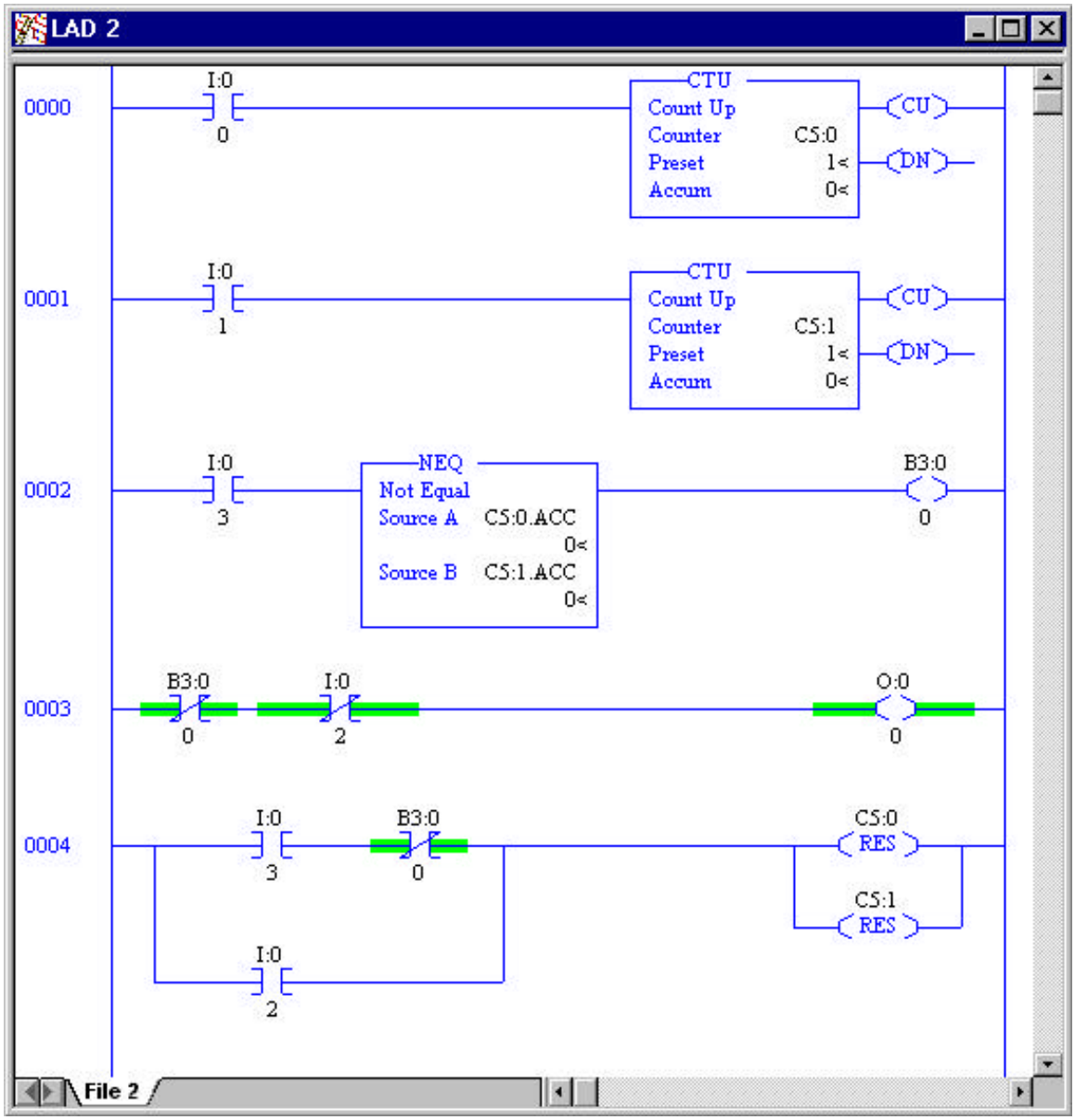
1. Select the **User** tab and click on the **New Rung** icon five times.
2. Drag an **XIC** instruction in rung 0000 and give it the address I:0/0.
3. Click on the **Timer/Counter** tab and drag a **Count Up** function to the right of rung 0000. Give it the address C5:0 and preset of 1. The rung should look like **This**. (Hot word in the Directions window).
4. Click on the **User** tab, and place an **XIC** instruction into rung 0001 and give it the address I:0/1.
5. Drag a Count Up function to the right of rung 0001. Give it the address C5:1 and preset of 1. Click **Here**. (Hot word in the Directions window) to see what the rung should now look like.
6. Place an **XIC** instruction on rung 0002 and give it the address of the fiber optic sensor, I:0/3.
7. Click on the **Compare** tab. Click and drag the **NEQ** button and drop it to the right of the **XIC** instruction in rung 0002.
8. In Source A, type "C5:0.ACC". In Source B type "C5:1.ACC".
9. Click the **User** tab and drag an **OTE** instruction to the right side of rung 0002. Give it the address **B3:0/0.**[1] If you want to see what the rung should look like, click **Here** (Hot word in the Directions window).
10. Place two **XIO** instructions on rung 0003, and give them the addresses B3:0/0 and I:0/2.

[1] This is referred to as a bit or internal relay, you may remember that they are found in the B3 – Binary File of the Project Tree. Internal relays function like an output, but there is no real output attached to it. Bits can be used elsewhere in the ladder as inputs.

11. Drag an **OTE** instruction to the right of rung 0003. Give the output the address O:0/0. **This** (Hot word in the Directions window) is what the rung should look like now.
12. Drag one **XIC** and one **XIO** instruction into rung 0004. Give the **XIC** instruction the address I:0/3. Give the **XIO** instruction the address B3:0/0.
13. Click on the **Rung Branch** icon and drag it to the leftmost red box of rung 0004. Click on the right side of the branch and drag it to the red box just to the right of the B3:0/0 **XIO** instruction.
14. Place an **XIC** instruction on the branch and give it the address I:0/2.
15. From the **Timer/Counter** tab, click and drag a **Reset** instruction to the right of rung 0004. Give it the address C5:0.
16. Drag a **Rung Branch** to the red box just to the left of the **RES** instruction in rung 0004. Click on the right side of the branch and drag it to the right side of the **Reset** instruction.
17. Drag a **RES** instruction to branch under C5:0 in rung 0004.
18. Give the new **RES** instruction the address C5:1. Rung 0004 should now look like **This** (Hot word in the Directions window).
19. If you haven't already, place five blocks on the conveyor about an inch from each other behind the conveyor control panel. Make sure that the diffuse and back suppression sensors can accurately count the blocks. Also make sure that the motor switch on the conveyor panel is set to *Off*.
20. **Switch *1*** (Hot word in the Directions window to show graphic) on top of the sensor interface box is a reset switch. If something goes wrong while trying to setup the program, turn the conveyor motor switch to *Off* and then turn switch *1* off, then on again, and start over.
21. Verify and save the file as Compare1<your name> and download it to the processor.
22. If the processor is in **Run** mode, skip to 23. If the processor is not in the **Run** mode, click the arrow next to **Remote Prog** and select **Run**.
23. Turn the motor switch on the front of the conveyor control panel from *Off* to *Remote*.
24. Watch the C5:0 counter Accum value to make sure that all blocks are counted. If all five are not counted, turn the conveyor motor switch off and put the blocks back in the starting position and make the necessary changes so that all five blocks will be counted. To reset the counter, flick the switch on the top of the sensor interface box on then off again after you figure out why the blocks are not counted.
25. Once all five blocks pass the diffuse sensor, watch the ladder diagram. All five blocks should pass the sensor, they should continue until all of the blocks pass the fiber optic sensor and fall off the end of the conveyor. This is simulating a process that moves verified sets of pieces from one conveyor to another.

26. When all pieces are present, the counters should reset automatically. If not, reset the timer and counters by moving the switch on top of the sensor interface box from *Off* to *On* to *Off* again. Turn the conveyor *Motor* switch from *Remote* to *Off* and replace the blocks in the starting position.
27. Start the conveyor. When all five blocks pass the first sensor, take one off the conveyor.
28. You should notice that the conveyor stopped when the first block reached the fiber optic sensor. This is because the B3:0 output of rung 0002 is energized when the **NEQ** compare function is true. This turns off the **XIO** instruction in rung 0003, which stops the conveyor, O:0/0.
29. If this were a continuous operation in a manufacturing facility, the conveyor would need a manual reset when a block is missing. This guarantees that someone knows that parts are missing on the line and will remove the set, and restart the process.
30. If all five blocks are present in both locations, the conveyor continues to check every set of five blocks. When the fiber optic sensor senses the first block of a set of 5, the counters reset, allowing for continuous monitoring of the process.
31. To reset the process, turn switch *1* on the on the sensor interface box off. Place the blocks on the conveyor in the starting position and turn switch *1* back on.
32. Continue to place blocks on the conveyor and notice how the ladder diagram changes during the process. You will need to pay careful attention so that you can successfully complete the authentic assessment for this activity. You may perform this exercise with 2 or more blocks.
33. When you are finished studying this system, close *RSLogix*.

This is the ladder diagram for Directions window #3-3.



# TOPIC 3 – TASKING

## Objective

When you have completed this topic, you will be able to create and use flowcharts to provide visual representations of manufacturing operations. You will be gain the knowledge and skills necessary to initiate and program tasks using both the 5100 and 5200 robotic systems.

## Overview

Up to this point in your study of automation you have created isolated programs using individual components of your CELL system. In this topic you will begin to learn and experiment how your individual components can work as systems.

The reaction of system component to an input state is the basic premise of system interaction and control. The use of programming statements that will decide the sequence of events that will take place in a system will be explored and experimented.

## New Terms and Words

**conditional statements** - an event that is dependent on the state or condition of one or more variables.
**articulating** - a robot configuration similar to the human arm.
**tendon technology** – the use of cables and springs to adjust tension on the gripper.
**charts** - can mean map, table, graph, or diagram. Here we mean a graphic which doesn't use numerical interpretation
**hierarchy** - the organization of persons or things according to rank, order, grade, or class.

## Equipment Required

5200 Robot mounted on Linear Slide
5100 Robot
Conveyor
Conveyor limit switch and mounting hardware
Connecting wires
Pneumatic feeder
Delrin block 2 X 2 X 1½(1)
Delrin rods ¾X 2½in (5)
Student Guide/Portfolio
*LEVEL 4 ROBOTIC SOFTWARE*
Blank floppy disk

# Activity 1 – Flowcharts in Manufacturing

## Objective

When you have completed this activity, you will have the knowledge and skills to create flowcharts as visual representations of manufacturing operations.

You will be able to:

- use the basic methods of flowcharts to portray an operation.
- read flowcharts without difficulty.
- explain how flowcharts are used.
- understand other types of charts.

## Activity 2 – Creating a Task with the 5200

### Objective

When you have finished this activity, you will have the knowledge and skills necessary to initiate tasks using *Level 4 Robotic Software.*

You will be able to:

- create a points program from the 5200 teach pendant.
- upload a points program from the teach pendant into *Level 4 Robotic Software.*
- add input and output conditions to your program.
- implement conditional statements into your program.
- control the conveyor system from your program.
- compile and run your program from *Level 4 Robotic Software.*

### Directions Window #2-1

1. Click on **File** and then click on **New**.

2. In the **Program Information** dialog box, click in **Author.**

3. Hit **Backspace** or **Delete** on your keyboard until Student is erased.

4. Type in your full name under **Author**.

5. Click on **Project**.

6. Type in **Project #1**.

7. When you are completed filling in the information, click on **OK**.

8. Click on **Robot** and than click on **Online**. This will transfer your robot from teach pendant control to computer control.

9. Click on **Window** and than click on **Point Editor**. This will bring up the Level 4 point editor window. All robot control happens in this window.

10. Click on **Robot**, click on **Upload to** and than click on **Point Editor**. This will upload your point program from the teach pendant into the level 4 point editor. A dialog box will open during the download, keep your cursor arrow of your mouse inside this box.

11. From the Point Editor window you can execute the points. Double click on **HOME**. Home should be highlighted and the cursor should be pointing to it.

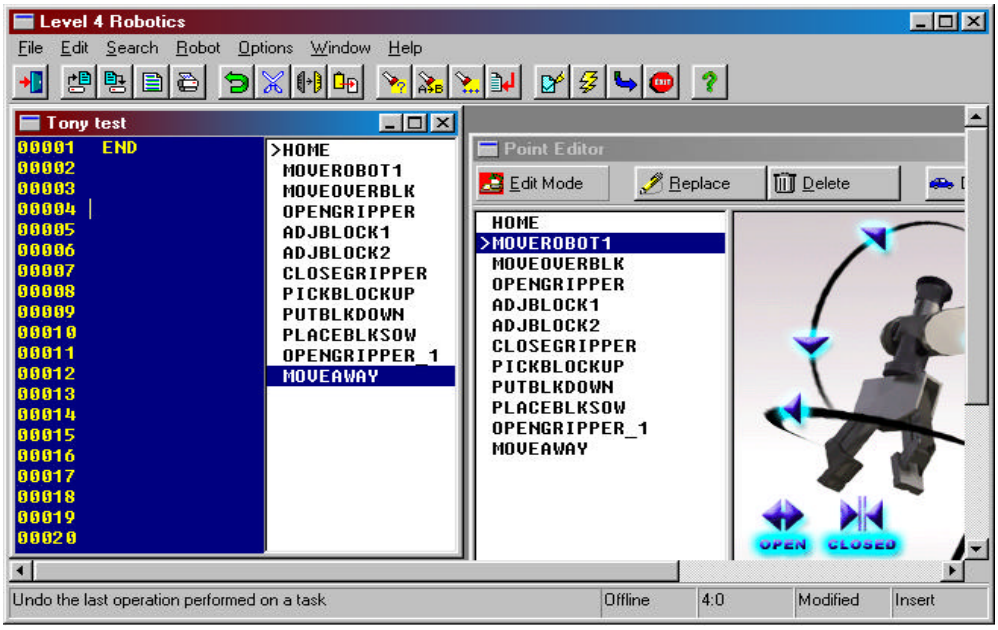
12. Click on **Execute** on the menu, the program will now run your point program.

13. When the points program has completed. Double click on **HOME.**

14. Click on **MOVEROBOT1** then click on **Move** on the menu. The robot will move to that position.

15. Now click on **MOVEOVERBLK** then click on **Move**. The robot will now move to this position.

You now need to get the point program over to the program window.




16. Click on **MOVEROBOT1** and drag and drop it over to the right side of the program window. This is the right side of the window with the white **not** blue background.

17. Continue to drag and drop all the points over to the program window.

Now you are ready to program the task.

18. Click on the **END** statement on line 00001. Hit **Backspace** or **Delete** on your keyboard until **END** is erased.

19. Type the following on line 00001: **HOME**

20. Type the following on line 00002: **OUTPUT (1) OFF**

21. Type the following on line 00003: **MOVETO MOVEROBOT1**

22. Type the following on line 00004: **WHILE INPUT (1) LOW**

23. Type the following on line 00005: **OUTPUT (2) ON**

24. Type the following on line 00006: **OUTPUT (1) ON**

25. Type the following on line 00007: **INPUT (2) LOW**

26. Type the following on line 00008: **OUTPUT (1) OFF**

27. Type the following on line 00009: **SPEED 49**

28. Type the following on line 00010: **MOVETO MOVEOVERBLK**

29. Type the following on line 00011: **SPEED 99**

30. Type the following on line 00012: **MOVETO OPENGRIPPER**

31. Type the following on line 00013: **MOVETO ADJBLOCK1**

32. Type the following on line 00014: **SPEED 49**

33. Type the following on line 00015: **MOVETO ADJBLOCK2**

34. Type the following on line 00016: **MOVETO CLOSEGRIPPER**

35. Type the following on line 00017: **MOVETO PICKBLOCKUP**

36. Type the following on line 00018: **MOVETO PUTBLKDOWN**

37. Type the following on line 00019: **MOVETO PLACEBLK**

38. Type the following on line 00020: **MOVETO OPENGGRIP2**

39. Type the following on line 00021: **SPEED 99**
40. Type the following on line 00022: **MOVETO MOVEAWAY**

41. Type the following on line 00023: **IF INPUT (1) LOW**

42. Type the following on line 00024: **REPEAT**

43. Type the following on line 00025: **ENDIF**

44. Type the following on line 00026: **RESTART**

45. Type the following on line 00027: **END**

Now that you have entered your program, you must save it.

46. Click on **File** and then click on **Save as.** In the Save as dialog box, type in your name (example: Gabriella Smith) and then click **Save**.

47. To compile your program, click on **Robot** and then click on **Compile**.

48. Set the conveyor **MOTOR** and **DIRECTION** to **REMOTE** set the conveyor speed to **very slow**.

49. Set a block onto the conveyor near the conveyor limit switch.

50. To run your program, click on **Robot** and then click on **Run**.

51. A Run Point dialog box will open, keep the cursor arrow of your mouse inside this box.

You will see that the robot will move from its HOME position to position MOVEROBOT1. You should notice that the program will loop between the WHILE and REPEAT statement as long as the Start Switch is HIGH.

52. Toggle the Start Switch to make it go low, the CHANNEL 1, INPUT LED on the front of the controller will go out.

The robot will now continue with the program, it will continue to pick-up and place the block away from the conveyor limit switch as long as the start Switch is low. If you set the start switch to high, the robot will go back to its wait state.

53. To stop the program click on **Cancel**.

54. Click on **File** and then click on **Exit**.

55. Click on **Return** to return back to your activity.

# Activity 3 – Creating a Task with the 5100

## Objective

Upon completion of this activity, you will have the knowledge and skills necessary to initiate tasks using inputs with the Armdroid 5100.

You will be able to:

- program inputs to initiate tasks using the Armdroid 5100 teach pendant.
- save programs to the computer using the *5100 Server* software.
- turn an output on and off using control points.

## Directions Window #3-1

1. Set the serial switcher to *B* so that the computer can communicate with the 5100.
2. The first window that opens verifies that the file directory is **Data** and the communications port is **COM1**. Click **OK**.
3. Double click on the Green icon in the system tray (lower right) on the Windows task bar. A small window should appear. There are three fields in the window. This window should be visible whenever attempting to load or save a file. If a screen saver appears when you try to save or load, you will not be able to see the files on the teach pendant.
4. Turn on the Armdroid 5100 power supply. You should see *Lab-Volt Inc. Armdroid 1001 Version 1.02.00* on the startup screen of the teach pendant. Press any key to get to the **Main** menu.
5. Press the *Teach Menu* key.
6. Program the Armdroid so that the entire arm points straight upward. Record this point.
7. Press the *Main Menu* key. Select menu item number **2 (Execute)**. Select **1 (Once)**.
8. When the program is complete, press the *Main Menu* key. Select **5 File I/O**. The Armdroid immediately looks for the server.
9. Next, select **2 (Save)** from the menu. Since you are saving a new file, select **1, (New File)**.
10. A window will open on the screen of the PC, in front of the 5100 Server window that is normally visible. Type in the name of the file here, Act31. Use your initials or the first 3 letters of your name in the file name, such as “Act31Dav” or something similar. When you have typed the name, hit *Enter*.
11. The program is now saved on the hard drive of the PC. It can be loaded into the Armdroid memory at anytime.
12. Turn the Armdroid power switch off and then on again. The memory is now cleared.
13. From the **Main** menu, select **5 File I/O**. Press **1 Load**.

14. Press the number that has the file you just saved listed next to it.
15. After a few seconds, when the message on the pendant no longer reads "recv," press the *ESC* key, then the *Main Menu* key.
16. Select **2 Execute**, then **1 Once.**
17. Once the program has been executed, click the **Return** button. Continue to the next page to resume the activity.

### Directions Window #3-2

1. Turn on the 5100 power supply. You should see *Lab-Volt Inc. Armdroid 1001* on the startup screen of the teach pendant.
2. Press any key to go to the **Main** menu.
3. Press the *Teach Menu* key.
4. Position the robot so that the gripper is about 8 inches above the rod in the pneumatic feeder.
5. Press the *Main Menu* key.
6. Select menu item **3, Initial**. This brings up the **Initialize** menu.
7. Select **1, Reset Home**, then select **1 Yes**. The position it is in now is the home point.
8. Open the program you just saved. In the **Main menu**, select **5 FileI/O**. Then, select **1 Load**, and select the file Act31<yourname>.
9. Press *ESC*, then the *Main Menu* key and select **2 Execute**, then **1 Once**.
10. You should notice when the robot stops that it does not point directly upward as you had programmed it to do before it goes back to the home position. Since the home point was changed, the robot cannot perform the routine you intended it to perform. You will have to reprogram it with the current home setting if you wanted it to point toward the ceiling.
11. Make sure the robot is home, shut it down, start it up, and reset the home position.
12. Press the *Teach Menu* key. Program the Armdroid to go to the straight up position again. Don't forget to record the point.
13. Save the program by doing the following. Press *Main Menu* key, select **5 File I/0**, select **2 Save**, then select **1 New File**. On the PC, name the file ACT32<3 letters of your name>.
14. Press *ESC*, then the *Main Menu* key. Select **3 Initial**, then select **2 Move Home.**
15. Turn off the power to the Armdroid, then switch it on again.
16. Press any key to get to the **Main Menu**.
17. Select **3 Initial**, then select **1 Reset Home,** then **1 Yes.** Now the robot is in the same starting position as it was when you programmed it.
18. Press the *Main Menu* key, select **5 File I/O**, then **1 Load**. Select the file that you just saved.
19. Press *ESC*, then the *Main Menu* key, select **2 Execute**, then **1 Once**.

20. The Armdroid should go to the straight up position. This is because you returned the robot to its home position when you shut down, and reset the home position when you switched it back on. You must remember to do this every time you shut down and start up the robot. If you don't do this, all of your saved programs will not run properly.
21. Make sure the robot is back to its home position (select **Move Home** in the **Initial** option of the **Main** menu) and turn the power off. Don't forget to save this as the home position as soon as the robot is switched on.

## Procedure

Make sure the pneumatic feeder is connected properly, according to this CELL guide. Connect the NO yellow wire output and black ground from the end of the pneumatic feeder to input 3 and ground, respectively, of the 5100 robot control box. The yellow wire and black wire should come from the same microswitch (there are two microswitches at the end of the pneumatic feeder). There should not be any rods loaded into the feeder yet.

Place a two-holed block on the conveyor behind the conveyor control panel. The 5100 should be able to easily reach the block to place the rod in one of the holes.

Turn on the Armdroid 5100, and save the home position before doing anything else. (**Main** menu, **3 Initial**, **1 Reset Home, 1 Yes**)

The default mode of the 5100 has tasking turned off. You must select a task number for a program in order to turn tasking on.

In the **Main** menu, select **6 Setup**.

In the **Setup** menu, choose **2 Select Task (1-4)**.

Press *1* to select task 1. Remember, tasks 1-4 are initiated using inputs 3-6 on the 5100 controller. Inputs 1 and 2 cannot be used to initiate tasks.

> **NOTE**: Once tasking is turned on, you will not be able to load files that were created when tasking was turned off. You will only be able to load files without tasks when tasking is off.

Press the *Teach Menu* key to begin programming the points for task 1.

Place a rod in the pneumatic feeder. Using the teach keys, program the 5100 to pick up the rod from the pneumatic feeder and place it in the hole in the block. Remember to record each point using the *Data* <.>(dot) key.

You do not have to program any special commands to get the robot to wait for the input 3 signal. The robot automatically will wait until input 3 goes from hi to low. If a rod is in the pneumatic feeder when you run the program, the 5100 will start immediately. If not, a screen will appear with the words "Waiting for Tasks."

When you are finished programming the task, go to the **Main** menu and select **2 Execute**. The Waiting for Tasks screen will appear.

Load a rod into the pneumatic feeder. When the rod is ready to be picked up, the 5100 should begin task 1.

Once the task is complete, you should save the program. Click the **Launch** button to open the *5100 Server* software.

### Directions Window #3-3

1. Hit the *ESC* key, then go to the **Main Menu**, select **5 File I/O**.
2. Select **2 Save** from the **File I/O** Menu, then **1 Newfile**.
3. Type in the file name Act33<your name> in the window that opens on the PC screen, click **OK**.
4. Send the 5100 to the Home position and shut down the power supply.

### Procedure

If you look at the robot's base, you'll notice that there are four color coded outputs with green grounds. From left to right, these are outputs one through four. Outputs 1 and 2 are normally on, and outputs 3 and 4 are normally off.

On the base of the 5100, connect a wire to the green ground jack of the third output. Connect another wire to the orange output just above the output 3 ground. Click **here**[2] to see these connections.

Connect the other ends of the wires to the inputs of the conveyor *Motor* section. Make sure the wire connected to the black jack on the robot is connected to the black jack on the conveyor control panel. Set the *Motor* switch on the conveyor control panel to *Remote*. The *Direction* switch should be set to the *Forward* position. Place a block on the conveyor, within reach of the 5100.

Next you are going to program the robot to pick up a rod from the pneumatic feeder, and place it in the block on the conveyor. The 5100 will then turn the conveyor on.

Power up the 5100 and save the home position. Also, turn on the power switch to the conveyor.

[2] [Pop-up graphic – Show picture of connections to the robot outputs.]

In the **Main** menu, select **6 Setup**, then **2 Select Task**, then select **Task 1**.

Go to the **Teach** menu and program the robot to pick up the rod and place it in the block on the conveyor. Remember to record each point.

Once the rod is in the block and the gripper is moved away, press the *Output* key on the teach pendant. Press *3* to turn on output 3, so that the screen looks like **This** (hot word on screen). Press the *Data* dot <•> key to enter the point. The conveyor will start.

Rotate the robot base so it points toward the pneumatic feeder. Record the point.

Press the *Output* key, and then press *3* to turn the conveyor off. Record the point.

Run the program. You may have to align the hole in the block under the rod as the robot approaches.

Press the *Launch* button to open the *5100 File Server* Software and save the program.

### Directions Window #3-4

1. Hit the *Esc* key, then go to the **Main** menu, select **5 File I/O**.
2. Select **2 Save** from the **File I/O** Menu.
3. Type in the file name Act34<your name> in the window that opens on the PC screen, click **OK**.
4. Send the 5100 to the home position and shut down the power supply.

# TOPIC 4 – PLANT MANAGEMENT TODAY

## Objective

When you have completed this topic, you will be able to identify flexible manufacturing cells and systems, computer-integrated manufacturing (CIM), and proportional, integral, and derivative (PID) controls. You will be able to explain the impact of computer-integrated manufacturing, what local area networks (LANs) and wide area networks (WANs) are, and how PID control works. You will also learn of the latest advances made in robotics. Finally, you will learn what fuzzy logic is and how it is applied.

## Overview

This topic deals mainly with how modern computerized plants are organized and how they function as integrated units.

Activity 1 carries flexible manufacturing a step or two further from Level 1. It talks about how flexible manufacturing developed. It introduces the idea of programmable logic controllers (PLCs) controlling flexible manufacturing cells and flexible manufacturing systems. It also opens a window on the advances made in robotics, including microrobotics, nanorobotics, and medical robotics.

Activity 2 describes and evaluates computer-integrated manufacturing (CIM). It explains local area networks (LANs) and wide area networks (WANs) which CIM depends on to function.

Activity 3 expands on industrial controls which were introduced in Level 1. In this activity, PID (proportional, integral, derivative) control is discussed along with the new approach called fuzzy logic.

Put simply, Topic 4 provides a brief look at the status of manufacturing at the beginning of the 21st century.

## New Terms and Words

**algorithm** – a formal procedure for any mathematical operation.
**analogies** – comparisons between things that are similar yet not identical; similarities, likenesses.
**autonomous** – capable of operating without outside control; self-contained.
**CNC** – a self-contained numerical control (NC) system for a single machine tool that uses a dedicated computer, controlled by stored instructions to perform some or all of the basic functions of an NC machine.
**dedicated** – given over to a particular purpose or function.

**derivative** – something that comes from, grows out of, or results from a fundamental state or condition.
**distributive control** – a design approach in which factory or machine control is divided into several subsystems, each managed by a unique programmable controller, yet all interconnected to form a single entity.
**femur** – the longest and largest human bone, extending from the hip to the knee; thigh bone.
**gene therapy** – the insertion of normal or genetically altered genes into cells, often to replace defective genes, especially in the treatment of genetic disorders.
**hysteresis** – the lagging of a physical effect on a body behind its cause; for example, it is the time between a cause (a furnace is turned on) and its effect (the air temperature begins to rise)**.**
**inertia** – the tendency of matter to remain at rest or in uniform motion in the same straight line unless acted upon by some external force.
**innovation** – bringing in new things or new ways of doing things.
**logistics** – the handling of the details of a project.
**materials science** – the scientific study of the properties and applications of materials of construction or manufacture such as ceramics, polymers, metals, or composites.
**microns** – thousandths of a millimeter.
**nanometer** – one billionth of a meter.
**nodes** – receiving and/or transmitting stations such as computer terminals in an electronic communications network.
**oscillation** – a swinging or moving back and forth; fluctuation.
**offset** – discrepancy or deviation.
**PID** – means proportional integral derivative.
**protocol** – a set of conventions governing the treatment and especially the formatting of data in an electronic communications system; established rules of conduct.
**semantics** – the study of meanings and the development of meanings of words.
**servo** – refers to self-regulating feedback systems.
**solenoid** – a coil of wire usually in cylindrical form that, when carrying a current, acts like a magnet drawing in a movable core (piston); used especially as a switch or valve.
**time integral** – where the rate of change of the output signal is proportional to the input signal.
**topologies** – configurations or shapes.
**viscosity** – the property of resistance to flow in a fluid or semifluid.

## Equipment Required

Graymark Model 602 Line Tracer Robot
Tape, Electrical Vinyl ¾in.

# Activity 1 – Implementing Flexible Manufacturing Systems

## Objective

When you have completed this activity, you will have the knowledge and skills to identify flexible manufacturing systems (FMSs) and their functions and explain the advances in robotics.

You will be able to:

- identify FMSs.
- understand the relationship between an FMC and an FMS.
- trace the organization of an entire modern industrial facility.
- explain the latest advances in robotics.

# Activity 2 – Computer-Integrated Manufacturing

## Objective

When you have completed this activity, you will have the knowledge and skills to identify computer-integrated manufacturing (CIM), understand its functions, and explain its importance in modern industry.

You will be able to:

- recognize CIM and its place in the modern industrial world.
- understand the relationship of flexible manufacturing cells (FMCs) and flexible manufacturing systems (FMSs) with CIM.
- explain the functions of CIM.

# Activity 3 – Process Control Strategies

## Objective

When you have completed this activity, you will have the knowledge and skills to understand and explain PID and fuzzy logic.

You will be able to:

- explain the kinds of controls available in industry.
- understand and explain how proportional, integral, and derivative function.
- appreciate why certain controls do better than others in particular operations.
- apply fuzzy logic to simple, practical situations.
- recognize how fuzzy logic refines the industrial process.

# Topic 5 – Troubleshooting an Automated System

## Objective

When you have completed this activity, you will have the knowledge and skills to properly document and monitor ladder logic in *RSLogix*.

You will be able to:

- identify and insert symbols, address/instruction descriptions, rung comments, and titles.
- use the online monitoring tools to view real time processes of the PLC.

# Activity 1 – Documentation and Monitoring

## Objective

When you have completed this activity, you will have the knowledge and skills to properly document and monitor ladder logic in *RSLogix*.

You will be able to:

- identify and insert symbols, address/instruction descriptions, rung comments, and titles.
- use the online monitoring tools to view real time processes of the PLC.

## Procedures

None required.

## Directions Window #1-1

> **NOTE:** In the following Directions, you will be asked to "Click **Here**," sometimes to see a graphic. The hot word could be "**This**" to bring up a graphic. In those instances, you will have to maximize the Directions window on screen to see the graphics.

1. Open *RSLinx* by double-clicking the **RSLinx.exe** icon on the desktop. (You may need to drag the windows on the screen to find the icon.)
2. Click on the minimize button in the **RSLinx** window.
3. In the **RSLogix 500** Starter window, click on the **File** menu, select **Open.**
4. Double click on the file Counter1<your name>.
5. Right click on the white background between rungs and select **Properties** from the pop up menu.
6. Click on the **Comment Display** tab.
7. At the bottom of the window, make sure that the **Show Symbol and Address** button is selected. Click **OK**.
8. Right click on the **XIC** in rung 0000 and select **Edit Symbol**.
9. Type "Fiber Optic Sensor" and hit *Enter*.
10. Using the same procedure, assign the XIO instruction in rung 0001 with the symbol Block Counter Done.
11. Next, give the output of rung 0001 the symbol Conveyor. The ladder should now look like **this**.
12. Now, add the address descriptions to the following addresses:
    I:0.0 – Block Sensor
    C5:0 Counter – Block Counter
    C5:0.DN – De-energizes when C5 is finished counting
    O:0.0 – Conveyor should stop when 5 blocks are present

13. Your ladder should now look like **this.**
14. Add the following comment to rung 0000: Counter advances by one when Fiber Optic Sensor sees a block.
15. Add the following comment to rung 0001: 5 blocks must be present for assembly. **This** is what your ladder should look like.

Add this title to rung 0000: Delrin Block Counter. Your ladder diagram should look like **this.**

Save the file as Docum1 <your name>.

Open and examine the Project Tree files in the Database folder: **Address/Symbol** and **Rung Comments/Page Title**. Try to figure out how you can use these files to your advantage if you had to troubleshoot this program.

When you have finished, click on the **File** menu and select **Exit**.

Click the **Return** button. Continue to the next page to resume the activity.

### Directions Window #1-2

1. Open *RSLinx* by double-clicking the **RSLinx.exe** icon on the desktop. (You may need to drag the windows on the screen to find the icon.)
2. Click on the minimize button in the **RSLinx** window.
3. In the **RSLogix 500** Starter window, click on the **File** menu, select **Open.**
4. Double click on the file Counter1<your name>.
5. Insert **this** rung into the ladder after rung 0001. Include all the documentation. Remember, the RES instruction is found in the **Timer/Counter** tab.
6. Verify and save the file, then download it to the processor.
7. Set up the five blocks on the conveyor as you did in Topic 2, Activity 2. Place five blocks 2 inches from each other in a line on the conveyor so that, when the conveyor is turned on, the blocks travel toward the fiber optic sensor. Also make sure that the fiber optic sensor is in a position to sense the blocks from the side.
8. Switch the conveyor *Motor* switch from *Off* to *Remote*. The blocks should now travel toward the fiber optic sensor.
9. Watch the ladder diagram carefully while the process is underway. Read the descriptions and comments of instructions that energize. When all five blocks pass the sensor, switch the conveyor motor from *Remote* to *Off*. Place the five blocks on the conveyor in the starting position. Switch the conveyor motor back the *Remote* position. When you pass your hand in front of the fiber optic sensor, the counter will reset and the conveyor will move.
10. Open the following files from the Project Tree: C5 – Counter, O-0 Outputs, I-1 Inputs. Place them on screen so that you can see all 3 windows. If any windows disappear behind the ladder, use the **Window** menu to bring them to the front.

11. Replace the blocks and switch the conveyor motor from *Off* to *Remote*. Study the process again using the data files to monitor the input, output and counter. You should notice that the only address you must watch in both the Input and Output tables is the address in the 0 column, the rightmost address. Watch the input status change from 0 to 1 as the ACC value in the Counter file accumulates at the same time.
12. Continue to reset the counter and replace the blocks so that you can fully understand the documentation.
13. When you have finished, click on the **File** menu and select **Exit**.

Click the **Return** button. Continue to the next page to resume the activity.

### Directions Window #1-3

1. Open *RSLinx* by double-clicking the **RSLinx.exe** icon on the desktop. (You may need to drag the windows on the screen to find the icon.)
2. Click on the minimize button in the RSLinx window.
3. In the RSLogix 500 Starter window, open the file Counter2<your name>.
4. It is up to you to set up the system to work with this ladder diagram. You need the following devices to properly connect the system:

**Diffuse Sensor**
**Fiber Optic Sensor**
**Sensor Interface**
**Voltage Level Converter (VLC)**
**PLC**
**24V Power Supply**
**Conveyor**
**5 Blocks**

> **HINT:** The diffuse sensor is connected to input 1 of the sensor interface box.

5. Check your final ladder diagram against the one in your CELL guide. They won't be identical, but they should be close.

If you need more hints, click on the component name above to see how the wires should be connected. Click the **Next** button to proceed.

# Activity 2 – Troubleshooting the PLC and Field Devices

## Objective

When you have completed this activity, you will have the knowledge and skills to troubleshoot the PLC system for connection or program errors.

You will be able to:

- determine the best starting point for finding programming errors, equipment malfunctions, or improper connections.
- locate problems that prevent the system from operating properly.
- repair the system so that it will function the way you intended it to.

## Directions Window #2-1

1. Open *RSLinx* by double-clicking the **RSLinx** icon on the desktop. (You may need to drag the windows on the screen to find the icon.)
2. Click on the minimize button in the RSLinx window.
3. In the RSLogix 500 Starter window, click on the **File** menu, select **New.** Choose 1747-L20C/F from the list of processors.
4. Insert two new rungs into the ladder diagram.
5. Insert an XIC and an OTE in rung 0000.
6. Insert and XIC and a TON in run 0001.
7. For the XIC in rung 0000, type in the improper address "I:O/0" (use a capital “o” instead of zero). Listen carefully when you hit enter. The computer should play an alarm sound when you hit enter. This typically is what happens when *RSLogix* catches an error as you are programming. Do not correct the error yet.
8. For the OTE in the same rung, type the improper address "O:1/0". You should hear the alarm again when you hit enter.
9. For the XIC in rung 0001, type in the incorrect address "I:1/0". Assign the timer the address T4:0 and time base 1.0; do not enter a preset or accum value.
10. Click on the **Verify File** icon to view the errors in the ladder. A window with four errors listed should appear at the bottom of the screen. The error window should look like **this** (hot word in Directions window).
11. Before fixing the errors, try to download the program to the processor.
12. Your request to download the program should have been denied since there were errors that were not fixed.
13. Now you know what type of errors might occur during programming and how you can detect the errors. As discussed in the reference, you will become familiar with the more common errors that are made during programming.
14. Fix the errors by clicking on each listed error and making the necessary corrections. Try to fix the ladder so that the verify process finds no errors. If you need a quick hint, click **Here** (hot word in Directions window).

Click the **Return** button. Continue to the next page to resume the activity.

### Directions Window #2-2

1. If it isn't already open, open *RSLinx* by double-clicking the **RSLinx** icon on the desktop. (You may need to drag the windows on the screen to find the icon.)
2. Click on the **Minimize** button in the RSLinx window.
3. Change the serial switcher to port *B*, which is not the correct port for the PLC.
4. Open any one of the program files you have created to this point.
5. Try to download the program to the processor.
6. Notice the error message that you receive, and remember the conditions that led to the error message.
7. Change the serial switcher to port A and turn the power to the PLC off.
8. Make another attempt to download the program to the processor.
9. You should get the same error message that you got in the previous attempt to download. Now you see the importance of familiarity with common errors, often two dissimilar problems may give you the same error message or malfunction. It is up to you to find the problem with the setup, based on what you have experienced.
10. Turn on the power switch to the processor.
11. Click on the **Controller Properties** menu item in the Project Tree window.
12. Select the incorrect processor 1747-L40A.
13. Try to download the program to the processor.
14. Take notice of the error message that appears.
15. In the same field where you would download a program, select **Offline**.
16. In the Controller Properties window, change the processor back to 1747-L20C/F.

Click the **Return** button. Continue to the next page to resume the activity.

### Directions Window #2-3

1. If *RSLinx* is not open, open it by double-clicking the **RSLinx** icon on the desktop. (You may need to drag the windows on the screen to find the icon.)
2. Click on the **Minimize** button in the RSLinx window.
3. In *RSLogix*, open the file Docum2<your name>.
4. Read the documentation that you inserted into the program in the last activity. You will need to set up the system so that you can run the program as you normally would. Try to set up everything without looking back in the lesson, but if you need help, refer to Activity 1 of this topic.
5. When you have set up the system properly, run the program and make sure that five blocks are counted and the conveyor is reversed to repeat the process.
6. Stop the process by turning the PLC off then on again.
7. Remove the fiber optic sensor cable from the sensor interface box input 0.
8. In *RSLogix*, select **Remote Run**.
9. The five blocks should continue down the conveyor, past the fiber optic sensor. This is because the sensor is not detecting the objects. You should notice that the I:0/0 instruction does not energize in the ladder diagram when it is supposed too. This would be a very simple malfunction for you to find.

10. Turn the PLC off and set up the system again.
11. Remove the wire from the yellow jack of the conveyor control panel *Direction*.
12. Set the processor to the **Remote Run** mode.
13. When the program is executed by the PLC, you should notice that the system exhibits identical malfunction symptoms as when the input was disconnected. The five blocks go past the fiber optic sensor, which does sense them if you look at the ladder, but the conveyor does not reverse when it is supposed to. If you look at the ladder diagram, the output to reverse the direction is energized, yet the conveyor keeps moving forward. This identifies the problem as a bad output connection or device.
14. Although this error may have been picked up during the quick fix, it is important to learn the proper steps to take to isolate an output error. You may have interpreted this as an input error if you did not look at the ladder diagram since the same symptom was seen when the input was purposely disconnected.
15. Next, have one of your group members, or the instructor, disconnect an input or output, or change an address of an input in the ladder diagram. See if you can find the problem that is purposely inserted. If any changes are made to the ladder diagram, do not save them.

Click the **Return** button. Continue to the next page to resume the activity.

# TOPIC 6 – AUTOMATED MANUFACTURING PROJECT

## Objective

When you have completed this topic, you will be able to design, integrate, program and test an operational flexible manufacturing system (FMS). To complete the topic project, you will design and develop a flow chart, input/output map, wiring diagram and various software programs. You will also be required to troubleshoot the FMS for connection and program errors.

## Overview

This topic calls upon all the skills you have learned over the course of this CELL. You have learned how to program the 5100 and 5200 robots, you also have learned how to integrate them with various other components. You have integrated components with the PLC and created and tested PLC programs.

In this topic you will be given an assignment that will require you to integrate the 5100, 5200, PLC training system, gravity feeder, pneumatic feeder and conveyor to create a FMS.

## New Terms and Words

None

## Equipment Required

Armdroid 5100
Armdroid 5200
Gravity Feeder
Pneumatic Feeder
Rotary Carousel
Connecting Wires
PLC and Sensor Trainer
Conveyor
Delrin Block 2 X 2 X 1½(3)
Delrin Rods
Student Guide
*RSLogix 500*
*RSLinx Lite*
Level 4 Robotic Software
*5100 File Server Software*

# Activity 1 – The Integrated Work Cell

## Objective

When you have completed this activity, you will have the knowledge and skills to integrate the PLC with the Armdroid 5100.

You will be able to:

- develop a plan to integrate the PLC with the 5100 robot.
- make the correct wiring connections between the 5V and 24V equipment.
- program the 5100 to accept inputs from, and send outputs to, the PLC.
- program the PLC to initiate tasks and accept inputs from the 5100.

## Direction Windows #1-1

1. Set the serial switcher to *B* so that the computer can communicate with the 5100.

2. The first window that opens verifies that the file directory is **Data** and the communications port is **COM1**. Click **OK**.

3. Double click on the green icon in the system tray (lower right) on the *Windows* task bar. A small window should appear. There are three fields in the window. This window should be visible whenever attempting to load or save a file. If a screen saver appears when you try to save or load, you will not be able to see the files on the teach pendant.

4. Press any key to get to the **Main Menu**.

5. Select **5 File I/O**. The Armdroid immediately looks for the server.

6. Next, select **2 Save** from the menu. Since you are saving a new file, press **1, New File**.

7. A window will open on the screen of the PC, in front of the 5100 Server window that is normally visible. Type in the name of the file here, **Top6act1**. Use your initials or the first 3 letters of your name in the file name, such as "**Top6act1Dav**" or something similar. When you have typed the name, hit ***Enter***.

8. The teach pendant command line will change from **Save** to **Send** and then back to **Save** when it is finished.

9. The program is now saved on the hard drive of the PC. It can be loaded into the Armdroid memory at anytime.

10. Click the **Return** button. Continue to the next page to resume the activity.

## Direction Window #1-2

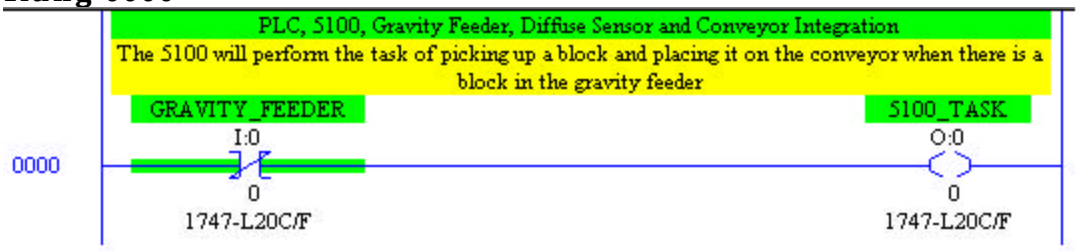
1. Open *RSLinx* by double-clicking the **RSLinx.exe** icon on the desktop. (You may need to drag the windows on the screen to find the icon.)

2. Click on the minimize button in the *RSLinx* window.

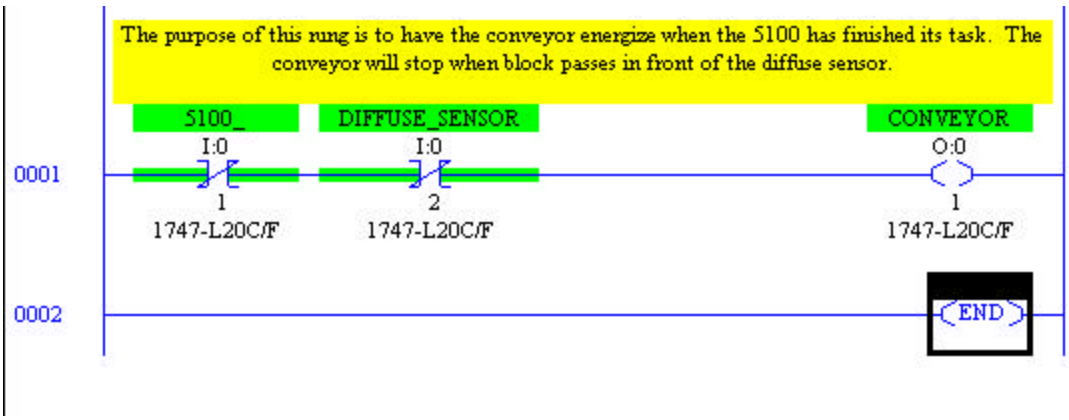
3. In the *RSLogix 500* Starter window, open a new file.

4. Click on each rung number to program the rungs one at a time. You should include all documentation as well.

**Rung 0000**




**Rung 0001**




5. Verify and save the program as top6task1<your name>.

6. When you finish programming the ladder, download the program to the PLC, but DO NOT run it.

## Direction Window #1-3

1. Turn-on the 24 Vdc power supply, the PLC and conveyor.

2. Go online to the processor by selecting **Go Online** from the drop down menu under the **File** menu.

3. The system will be online and the PLC will be running your program.

4. To start the 5100 program, press **main menu**.

5. Press key **2** for Execute.

6. The 5100 will be in standby mode.

7. To start the task, place a block into the gravity feeder.

8. The robot program should start to pick up the block from the gravity feeder.

9. It will place the block on the conveyor.

10. When the robot has finished, it will send a signal to the PLC.

11. The PLC will then turn on the conveyor.

12. The block will move down the conveyor until it passes in front of the diffuse sensor.

13. The PLC will turn the conveyor off when the block is seen by the sensor.

14. The program is a success.

15. If there are any problems with the program, use the troubleshooting techniques that you learned in a previous topic.

# Activity 2 – The Final Project

## Objective

When you have completed this activity, you will have the knowledge and skills to design, wire, integrate and program a flexible manufacturing system.

You will be able to:

- design and develop a flow chart to based on a flexible manufacturing system specification.
- generate an input/output map for the PLC, 5100 and 5200 robot.
- wire a flexible manufacturing system.
- program the PLC to work within the system.
- develop a point program with the 5200 robot.
- develop and integrate a program using the *Level 4 Robotic Software.*
- develop a point program with the 5100 robot.
- test and troubleshoot a flexible manufacturing system.

# APPENDIX A – HELP WINDOWS

Students access the help windows by clicking on the **Help** button on the screen footer. Help can be accessed at any time during the multimedia course. The **Help** menu contains two types of help, labeled topic and system.

## Topic Help Menu

**Topic** help contains all the new terms and words that are used for that topic and **Math** help. The menu selections include the following:

- New Terms and Words
- Math Help

From the Math selection, a student can access a **Math Help** menu that has the following help windows:

- Scientific Notation
- Engineering Notation
- Metric Prefixes

## System Help Menu

The **System Help** menu contains an explanation of all the control buttons in the screen footer.

# APPENDIX B – SAFETY

Working in the Armdroid Robotics System is not very dangerous. However, working around any moving equipment has a potential for accidents. As in industrial and commercial documentation, a caution alerts the student to possible damage to equipment and a warning against personal injury. Students are admonished in the following manner in Topic 2 when they first begin operating Armdroid.

**WARNING:** Whenever you work around moving equipment, be sure you are not wearing anything that might get caught, such as a tie or jewelry. If your hair is long, tie it up.

**CAUTION:** Do not remove or insert any cable connections while power is on. Doing so will damage the controller.

**CAUTION:** Do not insert or remove any cable connections while the power cable is plugged in.

# APPENDIX C – INTERNET RESOURCES

The students should be encouraged to access the following websites on the internet to expand their reference base and to explore career opportunities. These sites were valid at the time of printing, but are subject to change by their owners at any time.

Automation, Robotics, and Simulation Division
NASA Johnson Space Center
Houston, Texas 77058

http://tommy.jsc.nasa.gov/

Provides information on related organizations, projects, labs, publications, education, and research.

**Robots On Line**

http:/www.robotics.org/

Website of the **Robotics Industries Association**. It provides information on industry, news, publications, library resources, standards, calendar of events, and contacts.

# APPENDIX D – BIBLIOGRAPHY

**Books:**

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Asfahl, Ray C. 1992. *Robots and Manufacturing Information*. New York: John Wiley & Sons, Inc.

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Mager, Robert F. *Troubleshooting the Troubleshooting Course or Debug d'Bugs.* Center for Effective Performance, 1982.

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Salvendy, Gavriel. 1982. *Handbook of Industrial Engineering*. New York: John Wiley & Sons, Inc.

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**On-Line Articles:**

Attaran, Mohsen. 1996. "Barriers to Effective CIM Implementation." Information Systems Management, Fall96, Vol. 13 Issue 4, p52, 5p. 3 Dec 1999 <http://www.epnet.com/ehost/login.html>

Coates. Joseph F.; Wolff, M.F. "Customization Promises Sharp Competitive Edge." Resource Technology Management, Nov/Dec95, Vol. 38 Issue 6, p6, 2p. 3 Dec 1999 <http://www.epnet.com/ehost/login.html>

Johansen, John & Karmarkar, Uday S. 1995. "Computer Integrated Manufacturing Systems: Empirical Implications for Industrial Information Systems." Journal of Management Information Systems, Fall95, Vol. 12 Issue 2, p59, 24p. MasterFile Premier on-line. EBSCO Publishing.3 Dec 1999 <http://www.epnet.com/ehost/login.html>

**Other Resources:**

**Lab-Volt Systems, Inc.**:
Programmable Logic Controller Basic Principles (30518-00)
Programmable Logic Controller Basic Principles Instructor's Guide (30518-10)
Programmable Logic Controller Industrial Applications (30605-00)
Programmable Logic Controller Industrial Applications Instructor's Guide (30605-10)
Programmable Logic Controller Programming Software and Applications (30606-00)
Programmable Logic Controller Programming Software and Applications Instructor's Guide (30606-10)

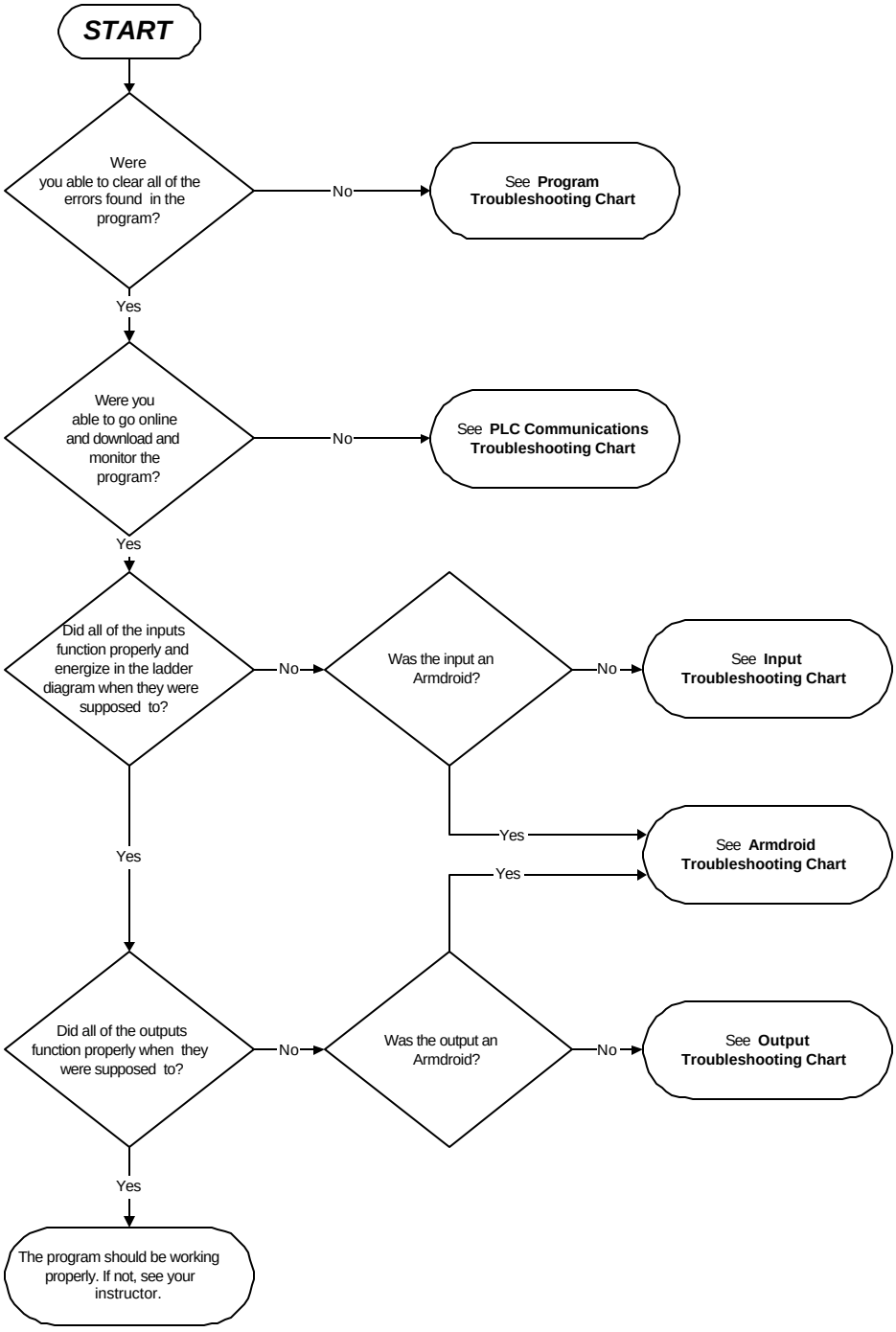
**Graymark**:
Model 602 Line Tracer Robot Manual

**Palmer Animated Training**:
Programmable Logic Controller, P-SIM 2000 Instructor's Guide, Palmer Management, Inc., 1996

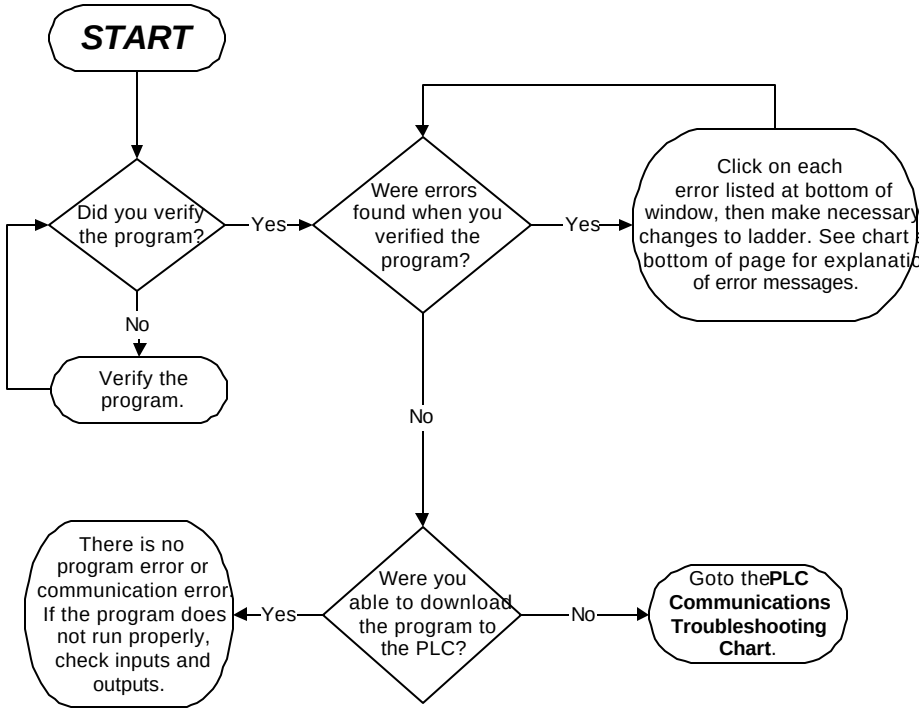
**Allen-Bradley/Rockwell Software**:
*RSLogix 500* Documentation
*RSLinx Lite*

# APPENDIX E – TROUBLESHOOTING CHARTS

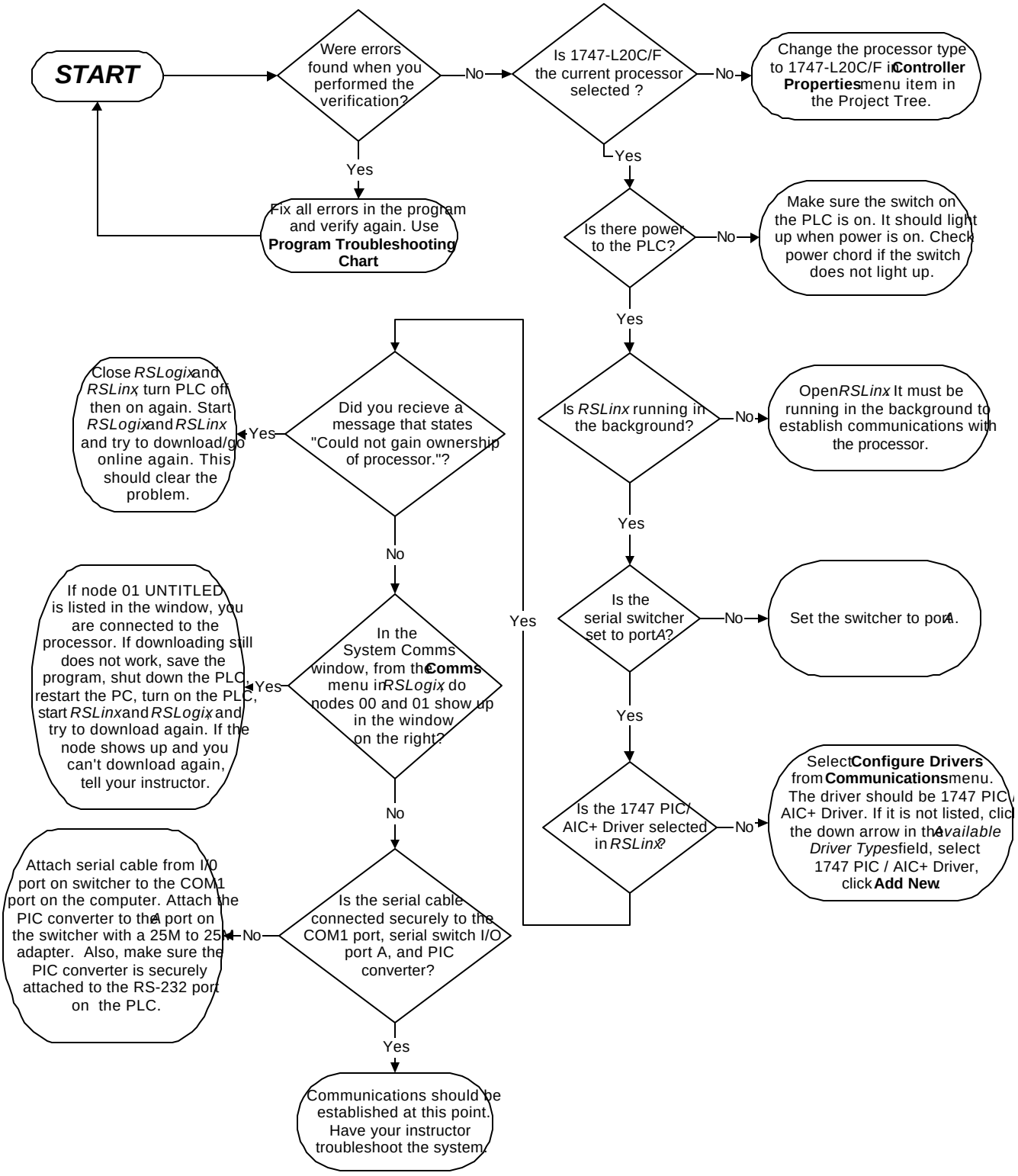
## System Troubleshooting Chart



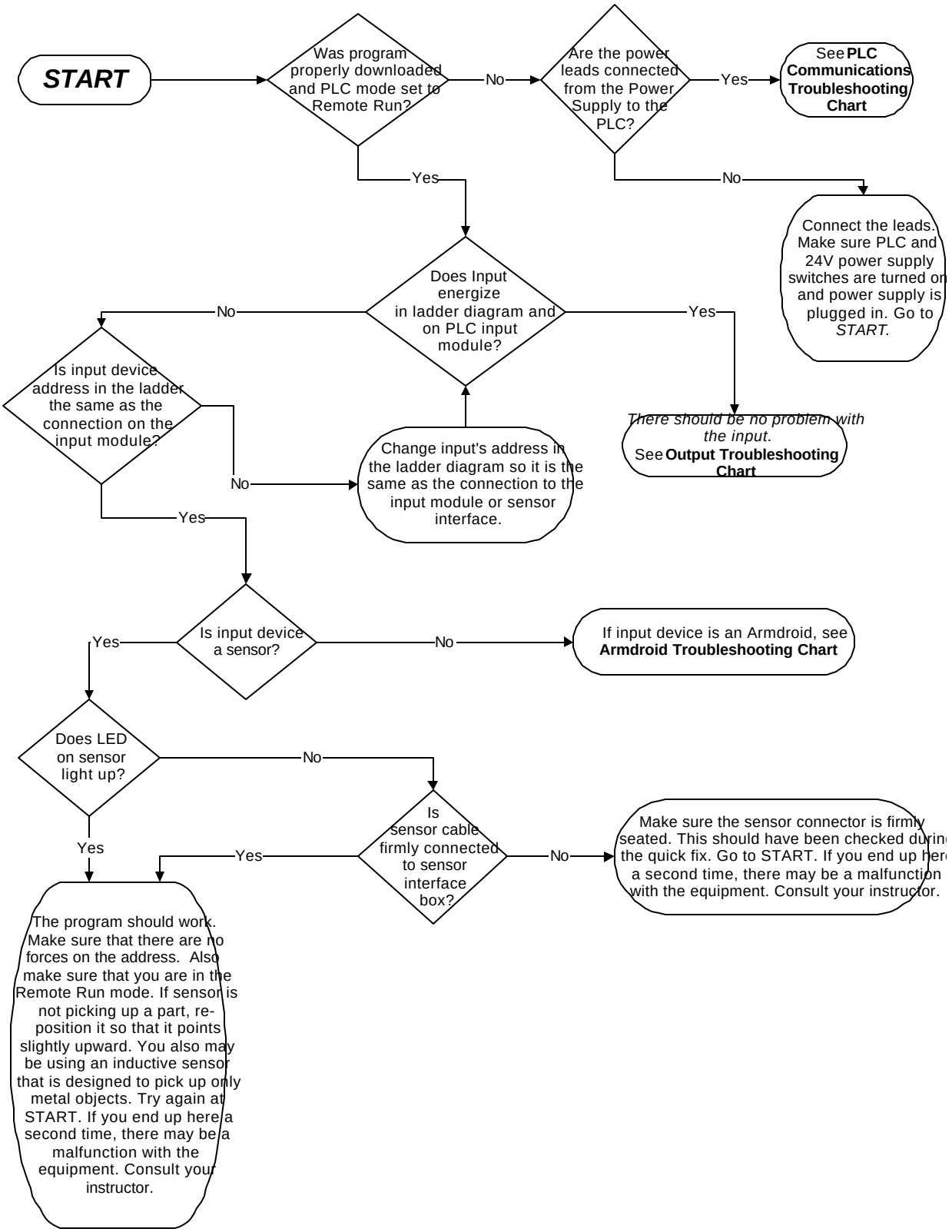
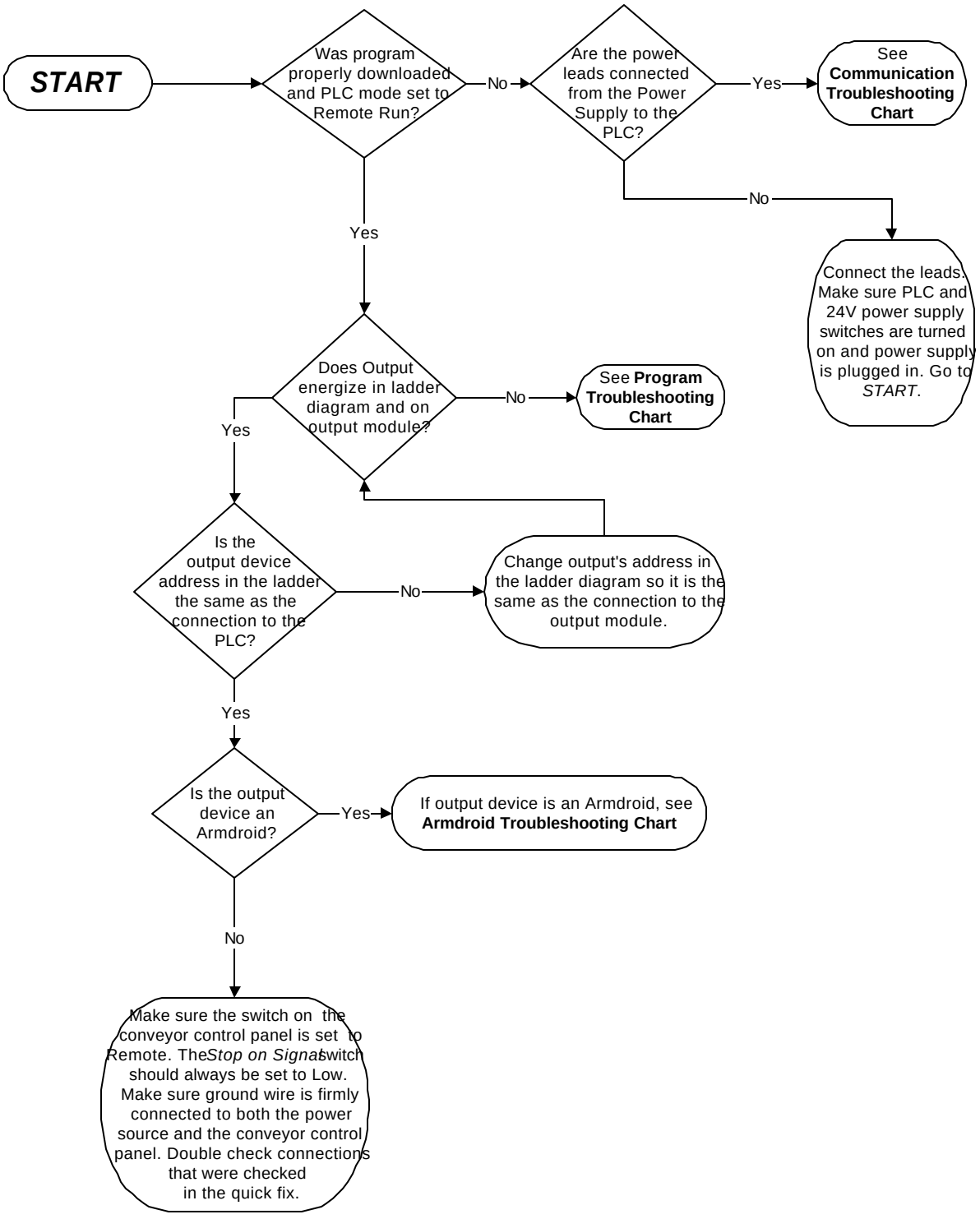
# Program Troubleshooting Chart



# PLC Communications Troubleshooting Chart



# Input Troubleshooting Chart



# Output Troubleshooting Chart