tekLINK

FLEXIBLE MANUFACTURING SYSTEM

SCORBOT-ER 4u and spectraLIGHT 200

Student Activities Book

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Flexible Manufacturing System SCORBOT-ER 4u and spectraLIGHT 200 Activities Book

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Table of Contents

About this Activities Book

This Activities Book is a lab manual which contains 15 **Activities**, each of which can be completed in one 45-minute lab session.

At the beginning of each activity you will encounter several lists:

- Objectives are the goals you will achieve.
- SCANS Skills are the competencies you will develop.
- Materials are the specific items you will need for each activity.

The **Overview** introduces you to the subjects you will explore in each activity.

The **Procedures** contain a series of **Tasks**, or operations. The first time an operation is to be performed, instructions are given in a tutorial manner. In subsequent tasks you should be able to perform these operations without guidance.

Many tasks are best performed when each team member takes on a different role. One student may, for example, handle the hardware while another student manages the software. The activities are designed so that team members can switch roles and repeat tasks, thereby allowing everyone more “hands-on” time.

Questions and tables for entering results and observations appear throughout the tasks. Questions for discussion and review conclude each activity. All questions and tables are printed on a set of **Worksheets** supplied with this book. Record your answers in the worksheets, or as directed by your instructor. ***Do not write in this book.***

The **Academics** section at the end of each activity contains enrichment material, such as industrial applications and opportunities, or the scientific background upon which the tekLINK technology is based.

In TEAM tekLINKs which include hardware (e.g., panel, robot), you will be directed to perform inventory and safety checks at the beginning of every working session, and to shut down the system properly at the end of each activity.

In TEAM tekLINKs which utilize software, it is assumed that you are familiar with the PC and are comfortable working in the Windows operating environment. However, instructions are explicit enough to allow novices to use the tekLINK's specific software.

Safety

Safety

Safety is of the utmost importance when working with the FMS system. Like any machine, the SCORBOT robot and the spectraLIGHT mill can be dangerous if you do not follow rules of safety and common sense.

Safety precautions in the robotic work environment serve to protect the human operators as well as the robotic equipment.

*You must **use caution** when working with the system to avoid personal injury and damage to equipment.*

The **most important safety instructions** for you to remember are the following:

- Dress properly. Tie back loose hair and clothing. Remove jewelry.
- *Wear safety glasses* when working with the mill.
- Review and check off all items on the Safety Check lists before using the robot and the mill.
- Obtain the instructor's permission before turning on the system.

SCORBOT Robot and Controller Safety

- Make sure you know how to stop the robot in an emergency.
  - Press the Emergency Stop button on the Controller-USB power box.
  - Press the Emergency Stop button on the teach pendant.
  - Click on the STOP icon in the SCORBASE window.
- Make sure the robot base is properly and securely bolted in place.
- Make sure the robot arm has ample space in which to operate freely.
- Do not enter the robot's work area or touch the robot when the system is in operation.
- Do not overload the robot arm. The combined weight of the workload and gripper may not exceed 1kg (2.2 lbs.).
- Do not use physical force to move or stop any part of the robot arm.
- Do not drive the robot arm into any object or physical obstacle.

spectraLIGHT Mill Safety

- Make sure you know how to stop the mill in an emergency:
  - Push the Emergency Stop button on the front of the mill.
  - Simultaneously press the [Ctrl] key and the spacebar on the computer keyboard.
- Keep the safety shield closed whenever the mill is operating.

  Press the Emergency Stop button before opening the safety shield.
- Release the Emergency Stop button only after closing the safety shield.
- Make sure you have the correct tool for the job. Make sure the cutter is securely mounted.
- Make sure the workpiece is securely clamped.
- Never make adjustments while the mill is operating.
- Remove all loose parts and pieces from the machine.
- Remove all tools and wrenches from the machine and work area.
- Make sure the mill is plugged into a three-hole grounded outlet.
- Do not operate the mill in a damp or wet location.
- Before running a new part program on a CNC mill:
  - Verify new part programs by means of the computer simulation.

    Make sure the machine is properly initialized.
  - Dry run the program on the mill without a workpiece.
- Use a brush to remove chips after the mill has completely stopped

Activity 1

Getting Started

Do not write in this book.

Before you begin this activity, **take the Pre-Test** according to your teacher's instructions. Allow 15 minutes for the test.

The purpose of this Pre-Test is to measure your knowledge and skills in the field of computer aided manufacturing. *This test will not affect your tekLINK grade*!

When you have finished the test, hand it in to your teacher. Then proceed to this activity.

Objectives

In this activity you will accomplish the following:

- Measure your knowledge of Flexible Manufacturing Systems (FMS).
- Learn the safety measures for working with the FMS lab station.
- Identify hardware components and software.

Skills

In this activity you will develop the following skills:

- Technology: maintain equipment.
- Systems: understand systems.
- Resources: manage time.
- Interpersonal: participate as a member of a team.
- Information: acquire/evaluate information.
- Basic: reading and writing.
- Thinking: knowing how to learn.
- Personal: responsibility and self-management.

Materials

In this activity you will need the following materials:

- The Flexible Manufacturing System (FMS) lab station
- Pre-Test and Pre-Test Answer sheet
- Worksheets for Activity 1

Overview

What is a Flexible Manufacturing System?

FMS has been defined by the U.S. government as a series of automatic machine tools or items of fabrication equipment linked together with an automatic material handling system, a common hierarchical digital programmed computer control, and provision for random fabrication of parts or assemblies that fall within predetermined families.

Basically, an FMS is made up software and hardware. Hardware elements may be CNC machine tools, pallet queuing carousels (part parking lots), material handling equipments (robots and automatic guided vehicles), central chip removal and coolant systems, tooling systems, coordinates measuring machines (CMM), part cleaning stations, and computer hardware equipments. Software elements may include NC programs, traffic management software, tooling information, CMM program work order files, and sophisticated FMS software.

Source: California State University, Northridge;
URL: http://www.csun.edu/~hbecs123/fms.html

PROCEDURES

What is the purpose of FMS

The principle objectives of FMS are:

1 Improve operational control through:

- Reduction in the number of uncontrollable variables.
- Providing tools to recognize and react quickly to deviations in the manufacturing plan.
- Reducing dependence on human communication.

2 Reduce direct labor through:

- Removing operators from the machining sites.
- Eliminating dependence on high skilled machinists.
- Provide a catalyst to introduce and support unattended or lightly attended machine operation.

3 Improve short-run responsiveness consisting of:

- Engineering changes.
- Processing changes.
- Machine downtime or unavailability.
- Cutting tool failure.
- Late material delivery.

4 Improve long-run accommodations through quicker and easier assimilation of :

- Changing product volume.
- New product additions and introductions.
- Different part mix.

5 Increase machine utilization by:

- Eliminating machine setup.
- Utilizing automated features to replace manual intervention.
- Provide quick transfer devices to keep machines in the cutting cycle.

6 Reduce inventory by:

- Reducing lot size.
- Improving inventory turnovers.
- Providing the planning tools for just-in-time manufacturing.

Source: California State University, Northridge:
URL: http://www.csun.edu/~hbecs123/fms.html.

The FMS Lab System Components

The FMS Lab station is an educational model of an industrial FMS installation. Figure 1-1 is a diagram of the FMS lab station.

The FMS cell contains a CNC milling machine system and a robotic system. The robot tends the mill and performs other materials handling tasks. In addition, the cell contains an automatic parts feeder and a sorting bin (packaging pallet) for parts.

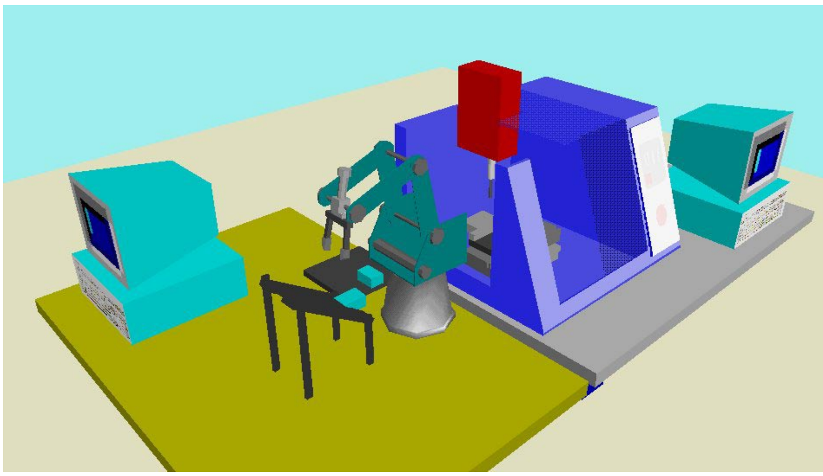


Figure 1-1

SCORBOT-ER 4u Robot System Components

Figure1-2 shows some of the elements of the robot system.

- SCORBOT-ER 4u Robot. The SCORBOT robot is an instructional robot which provides an inexpensive yet reliable simulation of industrial robots.
- Controller-USB : The robot controller is based on a RISC 32-bit microcontroller and has a plug and play USB connection to the PC.
- Computer with SCORBASE software.
- Teach Pendant. A hand-held control pendant for direct operator control of the robot.

CNC Milling System Components

The milling system, shown in Figure 1-3, includes the following components:

- ♦ The spectraLIGHT Mill is a CNC tabletop milling machine. Like other mills, it has a spindle, which holds the cutter. A pneumatically operated vise, mounted on a cross slide, holds the workpiece. Motors move the cross slide horizontally (X and Y) while other motors move the spindle vertically (Z) and rotate the cutter.
- ♦ The Controller is connected between the computer and the mill. The controller houses the electronics that interpret part programs and send them to the mill in a form the mill can understand.
- ♦ Computer loaded with the WSLM Control Program; used to create and run CNC programs.

Figure 1-2

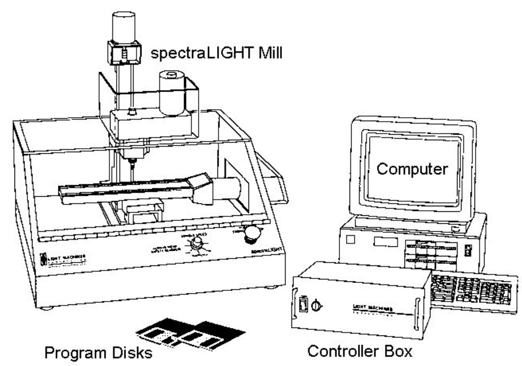


Figure 1-3

Additional Devices in the FMS Cell

- ♦ Parts Feeder. This device supplies parts by means of gravity. The feeder includes a microswitch sensor whose signal indicates to the robot controller that a part is available for pickup.
- ♦ Collection Bin. This box is used to collect and palletize parts.

Safety

Safety is of the utmost importance when working with the FMS system. Like any machine, the SCORBOT robot and the spectraLIGHT mill can be dangerous if you do not follow rules of safety and common sense.

Safety precautions in the robotic work environment serve to protect the human operators as well as the robotic equipment.

You must use caution when working with the system to avoid personal injury and damage to equipment.

The **most important safety instructions** for you to remember are the following:

- Dress properly. Tie back loose hair and clothing. Remove jewelry.
- Wear safety glasses when working with the mill.
- Review and check off all items on the Safety Check lists before using the robot and the mill.
- Obtain the instructor's permission before turning on the system.

SCORBOT Robot and Controller Safety

- Make sure you know how to stop the robot in an emergency.
  - Press the Emergency Stop button on Controller-USB.
  - Press the Emergency Stop button on the teach pendant.
  - Click on the STOP icon in the SCORBASE window.
- Make sure the robot base is properly and securely bolted in place.
- Make sure the robot arm has ample space in which to operate freely.
- Do not enter the robot's work area or touch the robot when the system is in operation.
- Do not overload the robot arm. The combined weight of the workload and gripper may not exceed 1kg (2.2 lb).
- Do not use physical force to move or stop any part of the robot arm.
- Do not drive the robot arm into any object or physical obstacle.

spectraLIGHT Mill Safety

- Make sure you know how to stop the mill in an emergency:
  - Push the Emergency Stop button on the front of the mill.
  - Simultaneously press the [Ctrl] key and the spacebar on the computer keyboard.
- Keep the safety shield closed whenever the mill is operating.
- Press the Emergency Stop button before opening the safety shield.
- Release the Emergency Stop button only after closing the safety shield.
- Make sure you have the correct tool for the job. Make sure the cutter is securely mounted.
- Make sure the workpiece is securely clamped.
- Never make adjustments while the mill is operating.
- Remove all loose parts and pieces from the machine.
- Remove all tools and wrenches from the machine and work area.
- Make sure the mill is plugged into a three-hole grounded outlet.
- Do not operate the mill in a damp or wet location.
- Before running a new part program on a CNC mill:
  - Verify new part programs by means of the computer simulation.
  - Make sure the machine is properly initialized.
- Dry run the program on the mill without a workpiece.
- Use a brush to remove chips after the mill has completely stopped.

PROCEDURES

Task 1-1: Safety Guidelines and Inventory Check

Turn to the Overview section in this activity, and read the section Safety Guidelines.

Then answer the following questions on your worksheet.

Q *Does your FMS workcell conform with the safety guidelines?*

Q *List points in the system which are the most dangerous to touch?*

Task 1-2: Identifying FMS Cell Components

Refer to the actual FMS cell. In the figure on the worksheet, mark the following items:

- Robot
- Mill
- Parts Feeder
- Collection Bin

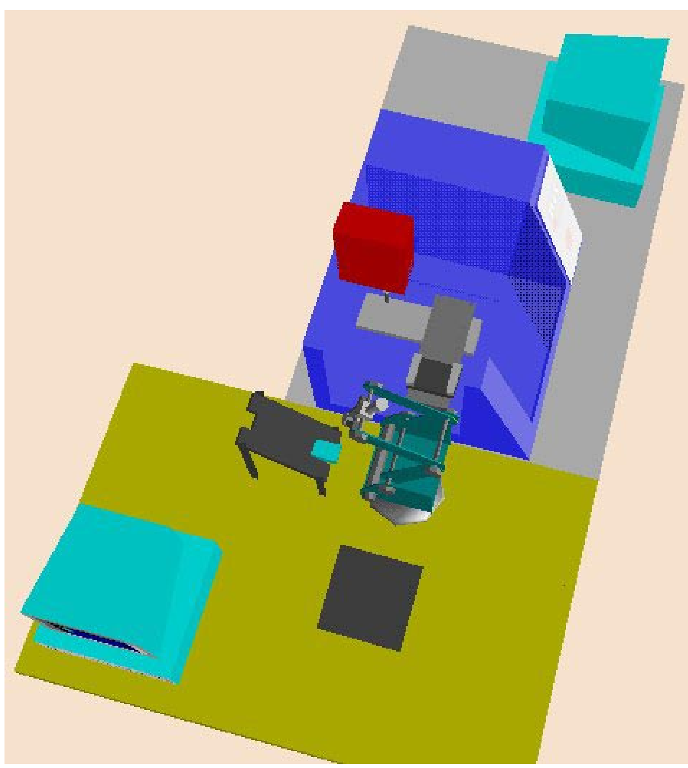


Figure 1-4

Task 1-3: Team Discussion and Review

Q *What is the function of the robot in the FMS?*

Q *What is the function of the milling machine in the FMS?*

Q *What are the functions of the computers in the FMS?*

Q *What are the most important safety rules to remember during operation of the robot?*

Q *What are the most important safety rules to remember during operation of the mill?*

ACADEMICS

Vocabulary

Automation

The automatic operation and control of machinery or processes by devices that make and execute decisions without human intervention. Such devices use self-correcting control systems that employ feedback; i.e., they use part of their output to control their input. Because of their ability to store, select, record, and present data, computers are widely used to direct automated systems.

Industrialism

An economic and social system based on the development of large-scale industries and marked by the production of large quantities of inexpensive manufactured goods and the concentration of employment in urban factories.

Activity 2

Preparing the Mill for Automation

OBJECTIVES

In this activity you will accomplish the following:

- Activate the spectraLIGHT Mill system.
- Set the workpiece origin (initialization).
- Load and run two mill-engraving programs.
- Understand how the mill is programmed for tending by the robot.

SKILLS

SCANS

- Technology: apply technology to task.
- Systems: understand systems, monitor and correct performance.
- Resources: manage time.
- Interpersonal: participate as a member of a team.
- Information: interpret and communicate information.
- Basic: reading and writing.
- Thinking: reasoning and problem solving.
- Personal: responsibility and self-management.

MATERIALS

In this activity you will need the following materials:

- spectraLIGHT Mill and Controller
- Pneumatic vise and spacer
- Computer with WSLM Control Program
- NC programs: MILLA.NC and MILLB.NC
- Wax block
- Worksheets for Activity 2

OVERVIEW

Safety

Like any machine tool, the spectraLIGHT Mill is potentially dangerous.

Be sure to follow the basic rules of safety when working with the mill.

The safety guidelines appear on a sticker on the mill's safety shield.

Be sure you know the ways to stop the machine in case of emergency:

- Press the Emergency Stop button on the front of the mill.
- Simultaneously press the [Ctrl] key and the spacebar on the computer keyboard.

Opening the safety shield while a program is running will automatically interrupt the program and stop machine motion. This is a safety feature, and is not recommended as the proper method for stopping the machine in an emergency.

Pneumatic Vise

The pneumatic vise, shown in Figure 2-1, enables automated tending of the spectraLIGHT mill by the SCORBOT robot.

The vise is mounted on the cross slide. The left side of the vise is fixed in place, while the right side is extended and retracted by means of a pneumatic piston. When the vise is open, a robot gripper can insert or remove a wax block. After a workpiece is inserted into the vise and a command is given to close the vise, the piston pushes the right side of the vise until it presses the workpiece against the left side of the vise. The pneumatic pressure maintains the clamping while the workpiece is being milled.

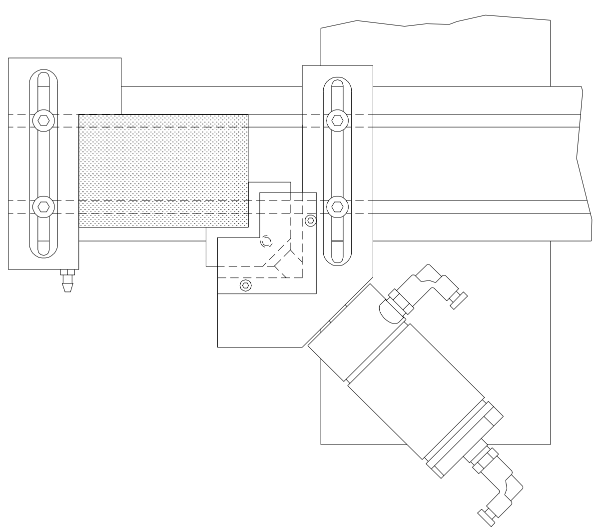


Figure 2-1

Mill Initialization

Initialization is typically performed by bringing the tip of the cutting tool to the left, front, top corner of the workpiece, as shown in Figure 2-2.

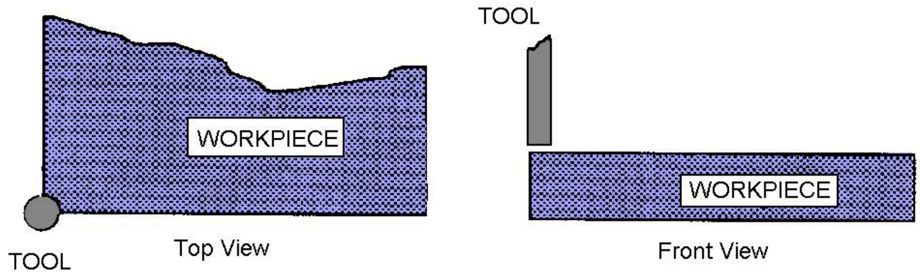


Figure 2-2

This location is then assigned the values X=0, Y=0, Z=0. These coordinates (0,0,0) then serve as a reference position for the milling commands performed on the workpiece.

The coordinates of the position at which the robot can load and unload a workpiece to and from the vise are defined as an offset from the workpiece origin.

PROCEDURES

Task 2-1: Inventory and Safety Checks

1 Check whether all materials required for this activity are available at your lab station.

2 Check whether your lab station conforms to the Safety Guidelines for the FMS workcell. In addition:

- Tie back loose hair and clothing. Remove all jewelry.
- Put on safety glasses.
- Get your instructor's permission to turn on the system.

3 Complete the Inventory and Safety Check List on the Worksheet for this activity

Task 2-2: Activating the Milling Machine

1 Power up the computer (always do this first).

2 Turn on the spectraLIGHT controller .

3 Pull out the Emergency Stop Button if it is not already released.

4 Activate Windows. Then start the Control Program, by selecting WSLM in the WSLM program group.

The WSLM application window will open.

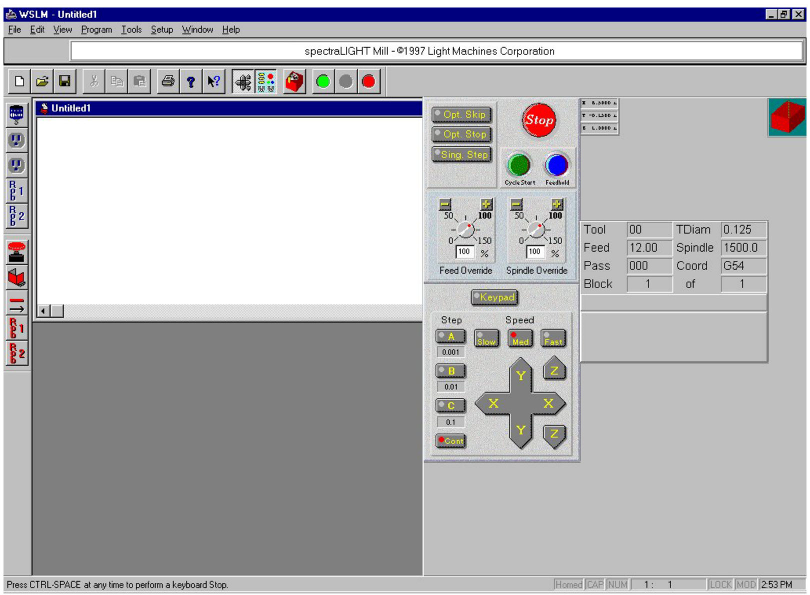


Figure 2-3

Task 2-3: Setting the Workpiece Origin

1 Make sure the spindle is far enough away from the vise so that a workpiece can be placed in the vise.

Select Jog Control from the View Menu (or from the toolbar). The Jog Keypad appears.

Using the cursor, click on the Z+button to raise the spindle. If necessary, also move the X and Y axes

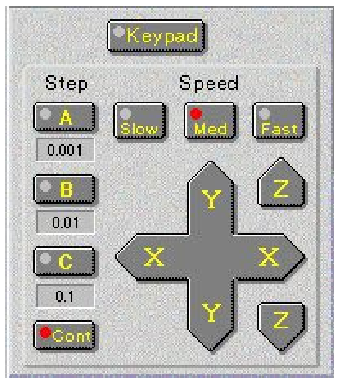
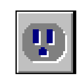


Figure 2-4

2 Press the Emergency Stop button on the milling machine.
Open the safety shield.

3 Make sure your compressed air supply is turned on.

Open the pneumatic vise by clicking on the Acc2 button in the Outputs toolbar.



Insert a 1" spacer into the pneumatic vise on the cross slide.

Place a machinable wax block on top of the spacer.

4 Clamp the pneumatic vise, again by clicking on the Acc2 button in the Outputs toolbar.

Make sure the block is held securely in place.

5 Close the safety shield and pull out the Emergency Stop button.

6 Use the Jog Keypad to jog the tool to the top of the front left corner of the workpiece, as shown in Figure 2-5. Stop just before the tool touches the top of the workpiece.

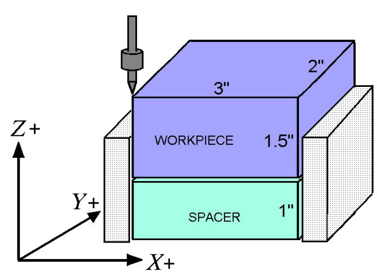


Figure2-7

7 From the Setup Menu, select Set Position. The Set Position dialog appears.

8 Enter 0 (zero) in the X, Y and Z boxes.

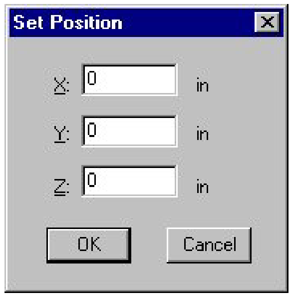


Figure 2-5

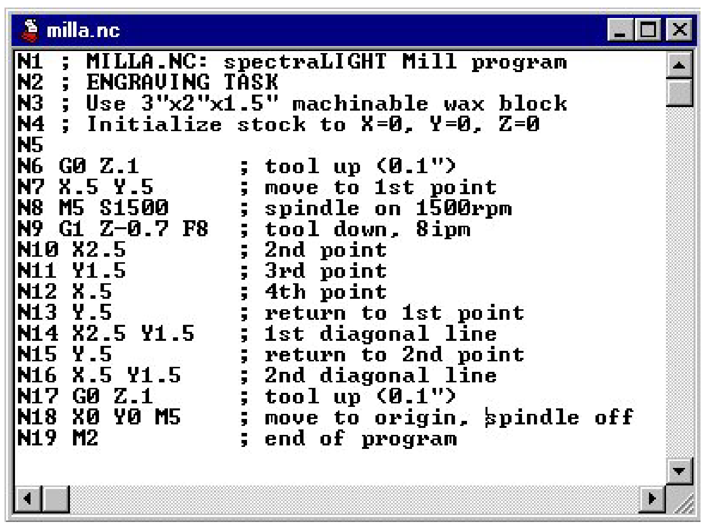
click on OK. The values in the Position Readout are updated

9 Raise the cutting tool away from the workpiece.

Task 2-4: Loading and Running a Milling Program

Be sure you are wearing your safety glasses.

1 From the File menu, select Open, and load the program MILLA. This program will now appear on the screen.




```
N1 ; MILLA.NC: spectraLIGHT Mill program
N2 ; ENGRAVING TASK
N3 ; Use 3"x2"x1.5" machinable wax block
N4 ; Initialize stock to X=0, Y=0, Z=0
N5
N6 G0 Z.1        ; tool up (0.1")
N7 X.5 Y.5       ; move to 1st point
N8 M5 S1500      ; spindle on 1500rpm
N9 G1 Z-0.7 F8   ; tool down, 8ipm
N10 X2.5         ; 2nd point
N11 Y1.5         ; 3rd point
N12 X.5          ; 4th point
N13 Y.5          ; return to 1st point
N14 X2.5 Y1.5    ; 1st diagonal line
N15 Y.5          ; return to 2nd point
N16 X.5 Y1.5     ; 2nd diagonal line
N17 G0 Z.1       ; tool up (0.1")
N18 X0 Y0 M5     ; move to origin, spindle off
N19 M2           ; end of program
```

Figure 2-6

2 From the Program menu, select Run/Continue. The Run Program dialog box appears.

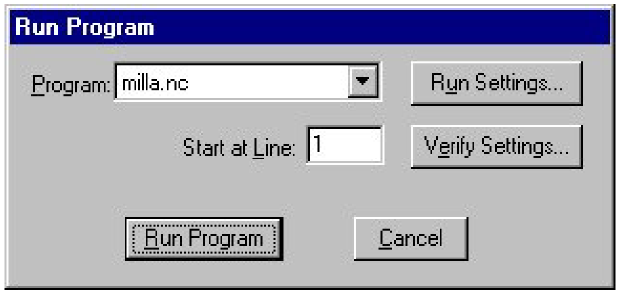


Figure 2-8

3 Make sure MILLA.NC appears in the Program field. Also make sure that the Start Line box is set to line 1 of the program.

Click on the Run Program button to begin program execution.

The part shown in Figure 2-9 will now be milled.

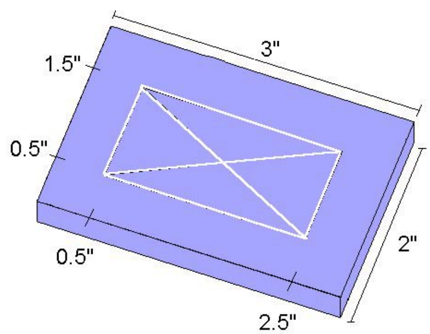


Figure 2-9

4 After the part is machined, and the spindle has come to a full stop, raise the cutting tool away from the workpiece.

5 Open the pneumatic vise by clicking on the **Acc2** button in the Outputs toolbar.

6 Press the Emergency Stop button and open the safety shield.

7 Take the finished part, turn it over, and place it back into the vise (with the non-engraved side facing up).

8 Close the pneumatic vise by clicking on the **Acc2** button.
Close the safety shield and pull out the Emergency Stop button.

Task 2-5: Running an FMS Milling Program

The engraving task in program MILLA is identical to the one in program MILLB. However, MILLB includes commands which move the cross slide to a position at which the robot can load and unload a part from the vise.

Be sure you are wearing your safety glasses.

1 From the File menu, select Open, and load the program MILLB. This program will now appear on the screen.

Millb.nc

```
N1 ; MILLB.NC spectraLIGHT Mill program
N2 ; ENGRAVING TASK & MOVE TO LOAD/UNLOAD
N3 ; Use 3"x2"x1.5" machinable wax
N4 ; Initialize stock to X=0, Y=0, Z=0
N5
N6 G1 Z1.0            ; tool up (1")
N7 G0 X6.5 Y-0.15     ; move to load/unload position
N8 G04 F2             ; pause 2 seconds (load)
N9 X.5 Y.5            ; move to 1st point
N10 M5 S1500          ; spindle on 1500rpm
N11 G1 Z-0.7 F8       ; tool down, 8ipm
N12 X2.5              ; 2nd point
N13 Y1.5              ; 3rd point
N14 X.5               ; 4th point
N15 Y.5               ; return to 1st point
N16 X2.5 Y1.5         ; 1st diagonal line
N17 Y.5               ; return to 2nd point
N18 X.5 Y1.5          ; 2nd diagonal line
N19 G0 Z.1            ; tool up (0.1")
N20 X0 Y0 M5          ; move to origin, spindle off
N21 G1 Z1.0           ; tool up (1")
N22 G0 X6.5 Y-0.15    ; move to load/unload position
N23 G04 F2            ; pause 2 seconds (unload)
N24 M2                ; end of program
```

Figure 2-10

2 From the Program menu, select Run/Continue. The Run Program dialog box will open.

3 Click on the Run Program button to begin program execution. Watch the motions of the mill. Pay close attention to the vise.

4 After the part is machined, and the spindle has come to a full stop, open the pneumatic vise by clicking on the Acc2 button in the Outputs toolbar.

5 Press the Emergency Stop button. Open the safety shield, remove the finished part, and close the safety shield.

6 Compare milling programs MILLA and MILLB.
On the worksheet for this activity:

- Mark the lines which define the engraving task.
- Mark the lines which have been added to program MILLB.

Q *Describe or sketch the location of the vise as a result of the codes which have been added to program MILLB.*

Task 2-6: Team Discussion and Review

Q *If you were to run program MILLB twice in succession, what will happen to the vise when the program starts the second time?*

Q *Why does the mill in the FMS require a pneumatic (automatically operated) vise?*

Task 2-7: Inventory Check and Shut Down

1. Make sure there are no parts in the milling machine.
2. Make sure all materials required for this activity have been returned to their proper place.
3. Complete the Inventory Check List on the worksheet for this activity.
4. Select Exit from the File menu to exit the WSLM control program.
5. Turn off the spectraLIGHT mill controller .
6. Exit Windows and shut off the computer.

ACADEMICS

Industrial Applications

Machine Tools

A machine tool is a power-operated tool used for shaping or finishing metal parts by removing chips, shavings, large pieces, or extremely small particles. Machine tools vary in size from hand-held devices used for drilling and grinding to large stationary machines that perform a number of different operations. The lathe, for example, can turn, face, thread, and drill. The working surfaces of a machine tool are made of such substances as high-speed steels, sintered carbides, and diamonds substances that can withstand the great heat generated by the action of the working surface against the workpiece.

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History

Machine Tools

About 1540 an Italian craftsman named Torriano was commissioned to build a planetary clock for King Charles V of Spain. The clock contained over 1800 gear wheels and took over three and a half years to build. To facilitate production, Torriano devised a method of adapting a lathe to contain a vertical spindle, a horizontal index plate, and an adjustable depth of cut. This mighty machine turned out three gear wheels per day.

In 1785 Thomas Jefferson toured France and observed a gunsmith using a process commonly referred to today as interchangeable manufacturing. He spread the word in the United Stated, where the idea was picked up by Eli Whitney and incorporated into his machines. In 1798 Eli Whitney was given a government contract to make ten thousand muskets with interchangeable parts.

About 1775 John Wilkinson constructed a horizontal boring machine. The first engine lathe followed in the mid-1790s, developed by Henry Maudslay. By 1830 Joseph Whitworth developed measuring instruments which were accurate to a millionth of an inch. This new found accuracy brought greater demand for and use of Wilkinson's and Maudslay's machines. Manufacturers now had the ability to measure with high accuracy and the means to produce identical parts within close tolerances.

Originally developed by the Pentagon, modern numerical control NC machine tools began appearing in the 1950s. These evolved into the computerized CNC machines of today.

Hohler, Wayne, Wahoo's CNC Machine PageIntroduction and Brief History (1995). http://www.neca.com.~wahoo/cncist.html

Activity 3

Homing and Manipulating the Robotic Axes

OBJECTIVES

In this activity you will accomplish the following:

- ♦ Activate and use SCORBASE robotic control software.
- ♦ Home the robotic axes.
- ♦ Use the teach pendant to manipulate the robot gripper and axes.

SKILLS

In this activity you will develop the following skills:

- ♦ Technology: maintain equipment.
- ♦ Systems: understand systems, monitor and correct performance.
- ♦ Resources: manage time.
- ♦ Interpersonal: participate as a member of a team.
- ♦ Information: interpret and communicate information.
- ♦ Basic: reading and writing.
- ♦ Thinking: reasoning and problem solving.
- ♦ Personal: responsibility and self-management.

MATERIALS

In this activity you will need the following materials:

- ♦ SCORBOT-ER 4u Robot and Controller-USB and teach pendant
- ♦ Computer with SCORBASE software
- ♦ Wax block
- ♦ Diskette or personal directory on computer hard disk
- ♦ Worksheets for Activity 3

Overview

Robot Axes

The SCORBOT robot has five joints (or axes) and a gripper. The joints move the links of the robot in a rotating manner, just like the joints in the human body. This flexibility of movement allows the robot arm to place

the gripper, which is like a hand, at different points in space. The gripper can then perform its task on the workpiece.

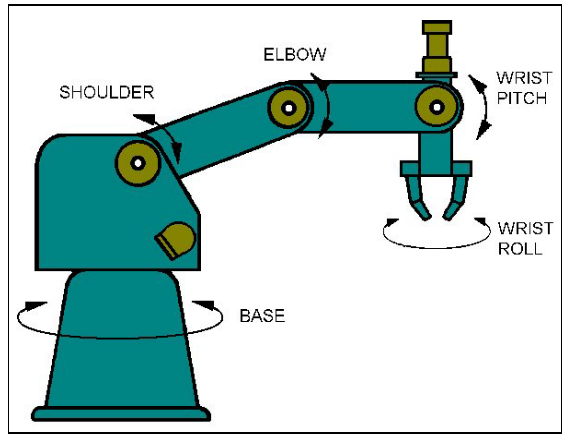


Figure 3-1

Each axis in the robot system is identified by a number. The robot base is axis 1, the shoulder is axis 2, the elbow is axis 3, the wrist pitch is axis 4 and the wrist roll is axis 5. The gripper is considered axis 6.

The robot controller can also control two additional (peripheral) axes, such as a conveyor, slidebase or rotary table.

Homing the Axes

Since the robot requires a fixed reference point to enable accurate repetition of programs and movements, the axes must be homed at the start of each working session.

The home position for the robot is factory-defined. The robot finds its home position by means of microswitches which are mounted on each of the joints and monitored by the controller. The homing routine moves each axis, and the software indicates whether or not the axis have reached the home position. The home position for each joint is the point at which its microswitch goes from ON to OFF. Figure 3-2 shows the home position of the SCORBOT-ER 4u robot.

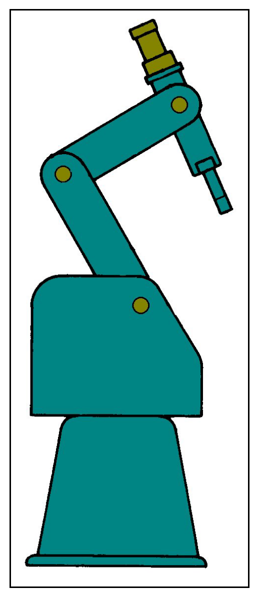


Figure 3-2

SCORBASE Software

SCORBASE is a robotics control software package, which provides a user-friendly tool for robot programming and operation.

The software can be used in three different levels – 1, 2 and Pro. The activities in this book have been written for **Level Pro**.

Teach Pendant

The teach pendant, shown in Figure3-3, is a portable terminal for operating and controlling the axes connected to the controller The teach pendant is equipped with an EMERGENCY STOP push button and a DEADMAN switch.

The teach pendant can be either hand-held or mounted in a special fixture outside the robot's working envelope.

When the teach pendant is hand-held, the deadman switch must remained pressed. If it is released, the teach pendant immediately becomes inoperable.

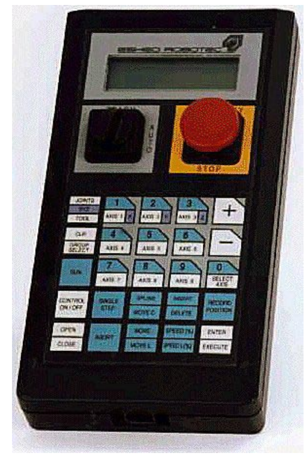


Figure 3-3

Safety in the Robot Environment

Although smaller and slower than an industrial robot, the SCORBOT robot is potentially dangerous. ***Be sure to follow the rules of safety when working with the robot***. Maintain a proper distance from the robot whenever the system is in use.

Emergency Stops

In this activity you will operate the robot, the gripper and the conveyor through the SCORBASE software, and by means of the teach pendant. Should it be necessary to stop motion immediately, do the following:

- Press the red EMERGENCY button on the robot controller.
- Press the red EMERGENCY button on the teach pendant.
- If the teach pendant is hand-held, release the deadman switch.

PROCEDURES

Task 3-1: Inventory and Safety Checks

1 Check whether all materials required for this activity are available at your lab station.

2 Check whether your lab station conforms to the Safety Guidelines for the FMS workcell. In addition:

- Tie back loose hair and clothing. Remove all jewelry.
- Put on safety glasses.
- Get your instructor's permission to turn on the system.

3 Complete the Inventory and Safety Check List on the Worksheet for this activity.

Task 3-2: Activating the System

1 Turn on the SCORBASE computer.

2 Turn on the controller.

3 Start SCORBASE.

Select **File | New Project**.

The application window opens with the SCORBASE Teach & Edit screen layout, as shown in Figure 3-4

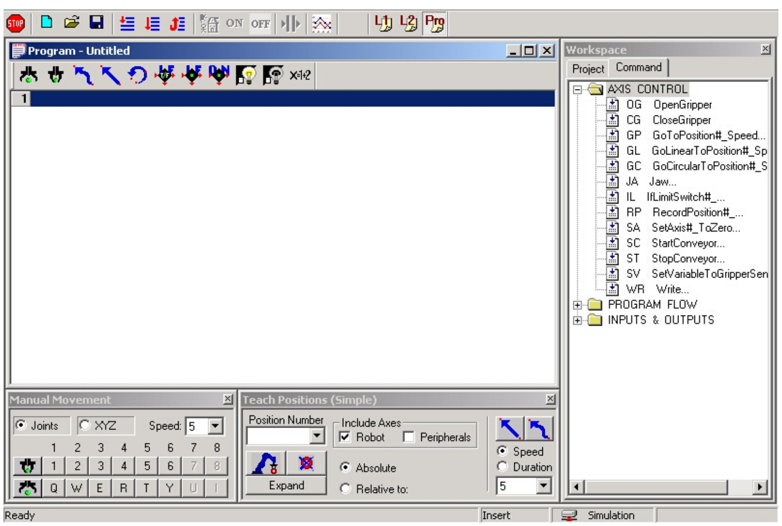


Figure 3-4: Teach & Edit screen

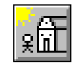
The Teach & Edit screen is a set of dialog boxes which are used for manipulating the robot, recording positions and writing programs.

4 You may want to resize and move the dialog boxes to fit your screen.

Task 3-3: Homing the Robot

1 To start the homing routine, do either of the following:

- Click the Search Home icon.
- Select **Run | Search Home - All Axes**.



2 Observe the robot during the robot homing routine.

Q *Describe the homing of the robot.*

Task 3-4: Operating the Gripper

1 Select the Manual Movement dialog box, and then do the following:

Figure 3-5

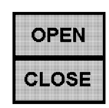
- Click the Open Gripper button to open the gripper.
  The gripper will open. (If the gripper is already open, it will not move).
- Click the Close Gripper button to close the gripper.

The Open Gripper and Close Gripper icons at the top left of the screen create open/close commands during program editing; they do not directly control robot movement.

2 On the teach pendant, **set the AUTO/TEACH switch to TEACH** to transfer control of the axes to the TP.

If the teach pendant is not in its safety mount, make sure to keep the DEADMAN switch pressed down.

- Press the [OPEN/CLOSE] key.
- Press the [OPEN/CLOSE] key again.



Each time you press this key, the gripper will alternate between completely open and completely closed.

3 Take a wax block and hold it between the open gripper fingers.

- Close the gripper on the object.
- Carefully place your hand under the part in the gripper. Open the gripper and catch the object before it falls.

4 Turn the wax block around and try closing the gripper along each side of the block (length, width, height).

Q *Was the gripper able to grasp the wax block on each of its sides?*

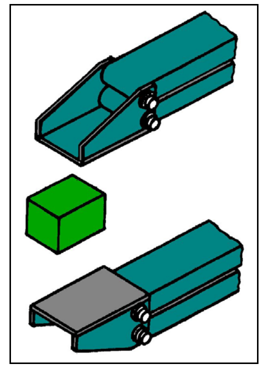
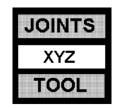


Figure 3-6

Task 3-5: Moving the Axes in Joint Coordinate System

1 To rotate the robot on its base joint from the teach pendant, do the following:

- Press the key [JOINTS / XYZ / TOOL] until the display shows **Joints**.



- Press the key [**Axis 1**/X] to select the robot's base joint.

  Note that **Group:A** appears in the teach pendant display.

  Group A refers to the group of robot axes.

- *Press and hold the key* [+] to move the base joint in the positive direction.
- *Press and hold the key* [-] to move the base joint in the negative direction.

Movement will continue as long as the + or key is depressed, or until the axis limit is reached.

2 Press the key [**Axis 2**/Y] to select the robot's shoulder joint.

- Press and hold the key [-] to move the joint in the negative direction.
- Press and hold the key [+] to move the conveyor in the positive direction.

Movement will continue as long as the + or key is depressed, or until the axis limit is reached.

3 Try moving other axes, as you did in steps 1 and 2.

4 Set the AUTO/TEACH switch on the teach pendant to AUTO to transfer control of the axes to the SCORBASE software.

The Manual Movement dialog box also allows you to assume direct control of the robot and peripheral axes.

By clicking with the mouse on the screen, or pressing keys on the keyboard, you move the axes.

Make sure **Joints** is selected in the Manual Movement dialog box and practice moving the axes from the SCORBASE software.

Task 3-6: Homing the Axes from the Teach Pendant

The axes can be homed from the TP by means of a RUN command.

In order to home the robot axes, **Group A** must be displayed on the teach pendant.

Use the EMERGENCY button, if necessary, to abort the homing.

1 Set the AUTO/TEACH switch on the teach pendant to TEACH to transfer control of the axes to the TP.

2 To home the robot axes from the TP, do the following:

- Make sure Group A appears in the teach pendant display. (Press a robot axis key [1, 2, 3, 4 or 5] to select Group A.)
- Press the following keys: [RUN][0][ENTER/EXECUTE].

Task 3-7: Team Discussion and Review

Q *Describe the difference between using the SCORBASE software and the teach pendant to control the axes.*

Q *What is the best way for the robot gripper to hold a wax block in order to place it into the vise in the milling machine?*

Task 3-8: Inventory Check and Shut Down

1 Make sure there are no objects in the robot's gripper.

2 *The robotic axes should always be brought to their home positions before the system is shut down.*

Send all axes to their home positions. Select the SCORBASE option: **Run | Go Home - All Axes.**

(*Do not use* the TP command RUN0, or the **Run | Search Home - All Axes** option, which execute the entire homing routine.)

3 Exit SCORBASE. Turn off the controller, then turn off the computer.

4 Make sure all materials required for this activity have been returned to their proper place.

5 Complete the Inventory Check List on the Worksheet for this activity.

Industrial Applications

Robotic Grippers

The end effector is attached to the last link of the robot arm. Like the human hand, it is moved by the arm to different points in space, where it performs various operations. The difference between the robot end effector and the human hand is that the latter has a very complex finger structure, whereas a robot end effector is usually a simple **gripper** or **tool**, such as a screwdriver or a welding gun.

The remarkable capability and versatility of the human hand as a gripper was realized with the first attempts to use robots on assembly lines, when it became evident that complex grippers were required to put together even the simplest assemblies. Most assembly operations involve gripping parts of different shapes and sizes, and would require a multipurpose gripper. Since such grippers are highly complex and often unreliable, manufacturers tend to prefer the use of various simple grippers, each of which is suited for gripping a different part.

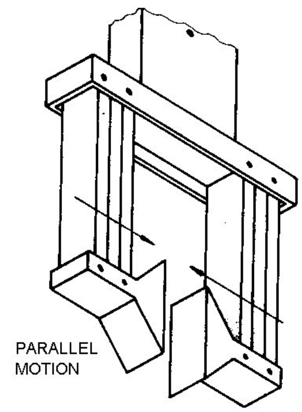


Figure 3-7

As a result, each robot is dedicated to a specific gripper, or has the ability to exchange grippers.

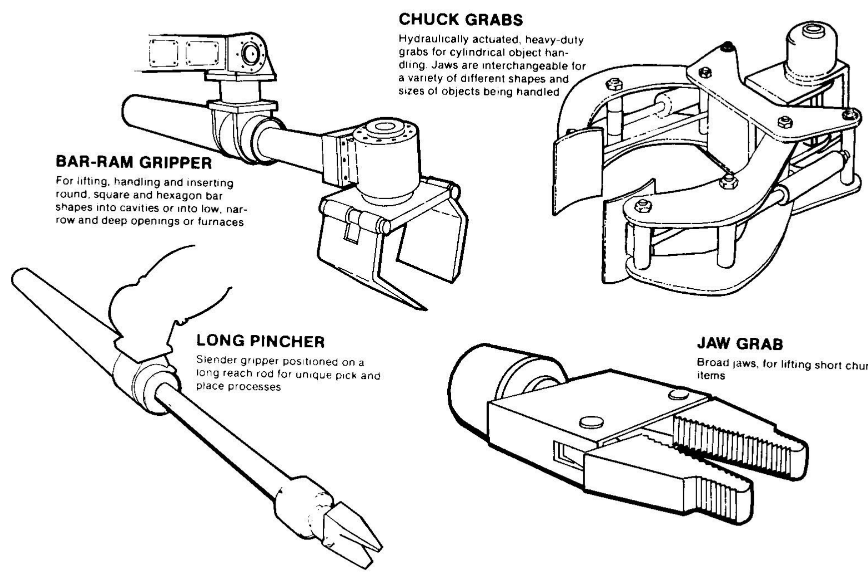


Figure 3-8

Activity 4

Moving the Robot in the FMS Cell

Objectives

In this activity you will accomplish the following:

- Move the robot in Joint and Cartesian (XYZ) coordinate systems.
- Move the axes at different speeds.
- Move the robot to different locations in the FMS cell.
- Instruct the robot to pick up workpieces from the parts feeder and place them in the sorting bin.

Skills

In this activity you will develop the following skills:

- Technology: apply technology to task.
- Systems: understand systems, monitor and correct performance.
- Resources: manage time.
- Interpersonal: participate as a member of a team.
- Information: interpret and communicate information.
- Basic: reading and writing.
- Thinking: reasoning and problem solving.
- Personal: responsibility and self-management.

Materials

In this activity you will need the following materials:

- SCORBOT-ER 4u Robot, Controller-USB and teach pendant
- Computer with SCORBASE software
- Parts Feeder
- Sorting bin
- Wax blocks
- Diskette or personal directory on computer hard disk
- Worksheets for Activity 4

OVERVIEW

Joint Coordinate System

When the axes move, the encoders attached to the motors generate a series of electrical signals. The number of signals is proportional to the amount of axis motion. The robot controller counts the signals and determines how far an axis has moved.

When working in the Joint coordinate system, the position coordinates specify the location of each axis in degrees relative to the home position of each axis.

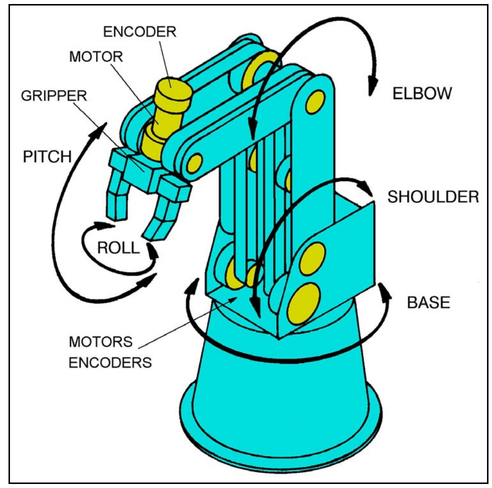


Figure 4-1

Cartesian (XYZ) Coordinate System

The Cartesian, or XYZ, coordinate system is a geometric system used to specify the position of the robot's TCP (tool center point commonly the tip of gripper).

When working in the XYZ coordinate system, the position coordinates define the distance of the TCP from the robot's point of origin (the center bottom of its base). The distance is measured in millimeters along three linear axes, as shown in Figure 4-2. To complete the position definition, the pitch and roll are specified in angular units (degrees).

When robot motion is executed in XYZ mode, all or some of the axes move in order to move the TCP along an X, Y or Z axis.

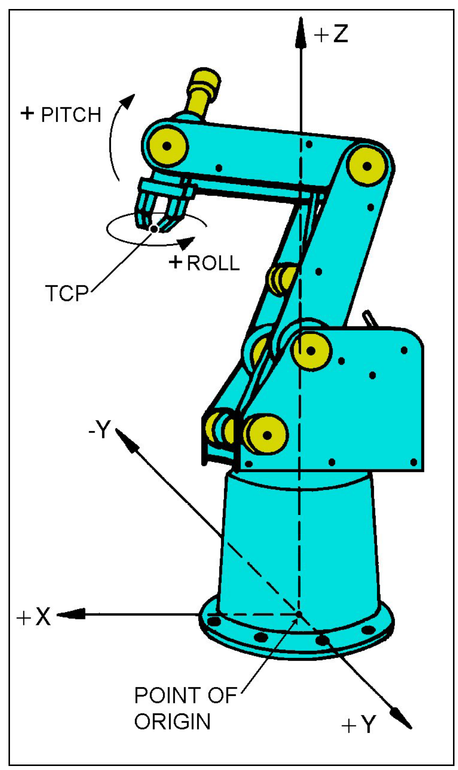


Figure 4-2

SCORBOT Self-Protection

Robots may hit obstacles in their environment or even parts of their own structure. Robots which are incapable of identifying and responding to impact conditions may suffer damage to motors, gears or transmissions, or to components in controller. The SCORBOT robot, however, can identify obstacles and stop its motors without loss of exact positioning. Thus, once the obstacle is removed, work can be resumed immediately.

Never intentionally force the robot into an obstacle.

However, if you encounter the position or impact error messages shown below, click on OK and move the specified joint in the other direction.

Figure 4-3

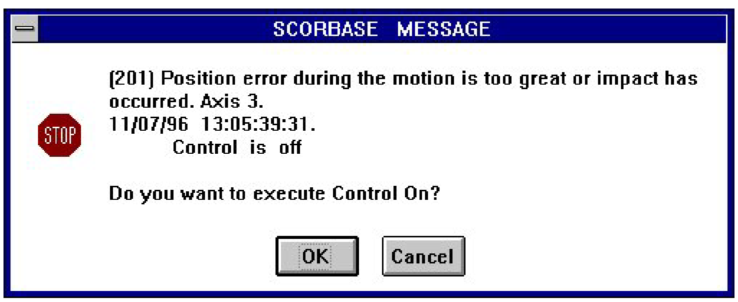


Figure 4-4

Teach Pendant AUTO/TEACH Switch

As you saw in the previous activity, when the AUTO/TEACH switch is in the TEACH position, the TP has full control of the axes. SCORBASE commands and functions which affect axis movement, such as the Manual Movement dialog box, cannot be activated from SCORBASE. All other SCORBASE functions remain available.

When the switch is in the AUTO position, the TP is disabled, and SCORBASE has full control of the axes.

When alternating between using the teach pendant and the SCORBASE software, remember to turn the AUTO/TEACH switch to the proper setting.

Procedures

Task 4-1: Inventory and Safety Checks

1 Check whether all materials required for this activity are available at your lab station.

2 Check whether your lab station conforms to the Safety Guidelines for the FMS workcell. In addition:

- Tie back loose hair and clothing. Remove all jewelry.
- Put on safety glasses.
- Get your instructor's permission to turn on the system.

3 Complete the Inventory and Safety Check List on the Worksheet for this activity.

Task 4-2: Moving the Axes in the Cartesian (XYZ) Coordinate System

1 Turn on the SCORBASE computer. Turn on the robot controller.

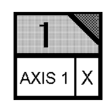
Start SCORBASE.

Home all the axes.

2 Set the AUTO/TEACH switch on the teach pendant to TEACH.
The teach pendant should be in its mount. If it is hand-held, be sure the Deadman switch remains pressed at all times.

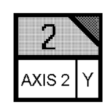
3 Press the key [JOINTS / XYZ / TOOL] until the display shows **XYZ**.

4 Using the TP, move the tip of the gripper along the X axis.



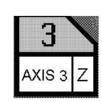
- Press the key [Axis 1/X] to select movement along the X axis.
- Press and hold the [+] and [-] keys to move the tip of the gripper along the X axis.

5 Using the TP, move the tip of the gripper along the Y axis.



- Press the key [Axis 2/Y] to select movement along the Y axis.
- Press and hold the [+] and [-] keys to move the tip of the gripper along the Y axis.

6 Using the TP, move the tip of the gripper along the Z axis.



- Press the key [Axis 3/Z] to select movement along the Y axis.
- Press and hold the [+] and [-] keys to move the tip of the gripper along the Z axis.

7 Move Axis 4 (pitch) while in the XYZ mode.
Move Axis 5 (roll) while in the XYZ mode.
Note the movement of the tip of the gripper.

8 Change the coordinate mode to Joints.

- Move Axis 4 (pitch) while in the Joint mode.
- Move Axis 5 (roll) while in the Joint mode.
- Note the movement of the tip of the gripper.

Q *Describe the difference in the response of the tip of the gripper when the pitch and roll axes are moved in Joint and XYZ modes.*

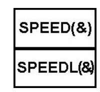
9 Set the AUTO/TEACH switch on the teach pendant to AUTO.

- In the Manual Movement dialog box, select XYZ.
- Practice moving the robot axes in XYZ mode from SCORBASE.

10 end all axes to their home position.(**Run | Go Home-All Axes**).

Task 4-3: Setting the Speed of Movement

The speed of manual axis movement can be set from the teach pendant by means of the [SPEED(%) / SPEEDL (%)] key.



- If **Joint** mode is selected, the joint SPEED is displayed.
- If in **XYZ** mode is selected, the linear SPEEDL is displayed.

1 Set the AUTO/TEACH switch on the teach pendant to TEACH.
Press the key [JOINTS/XYZ/TOOL] until the display shows Joints.

2 Press the key [SPEED(%)/SPEEDL(%)]. Make sure SPEED(%) is displayed.
Press [Enter] to accept the displayed default speed.
Move one of the robot joints.

3 Again press [SPEED(%)/SPEEDL(%)].
Press the keys [9] [0] for a fast (90%) speed, and press [Enter].
Move the same joint again at this fast speed.

4 Repeat step 3, using a speed setting of 20%.

5 Practice moving the other robot axes at different speeds.

6 Switch to XYZ mode. Practice moving the axes at different speeds.

7 Send all axes to their home positions.

Task 4-4: Moving to a Location in the FMS Cell

1 Identify a target location in the FMS cell, such as the top of the sorting bin or the edge of the parts feeder.

With Joints mode selected, bring the tip of the robot gripper as close as possible to the target location.

Change the speed setting to a lower speed as the robot approaches the target.

2 Send all axes to their home positions.

Select XYZ mode, and repeat the movement to the same target.

3 Send all axes to their home positions.

Q *Describe your observations. Was it easier to reach the target when in Joints mode or XYZ mode?*

Q *What error did you receive when you tried to move the robot in XYZ mode?*

Task 4-5: Guiding the Robot in a Pickup Task

In this task you will use the teach pendant to guide the robot to the parts feeder and to pick up a block of wax.

You may alternate between Joints and XYZ mode as often as needed.

You may change speeds as often as needed.

1 Make sure the parts feeder is loaded with blocks of wax, as shown in Figure 4-5.

2 Rotate the robot so that it faces the feeder.

3 Make sure the robot gripper is open.

4 Bring the open gripper towards the block of wax in the parts feeder, as shown in Figure 4-5.

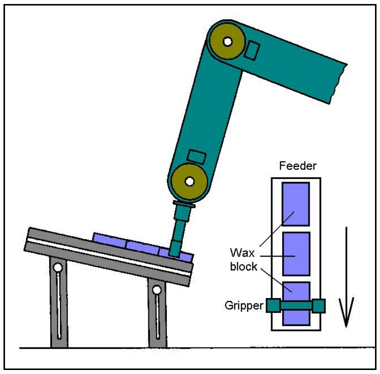


Figure 4-5

When you are certain the gripper can firmly grasp the block of wax, close the gripper.

5 With the part in its grasp, carefully raise the gripper away from the parts feeder. (Hint: use the shoulder axis.)

6 Bring the robot gripper with the part to the sorting bin. When you are certain the part can be placed properly, open the gripper.

7 If time permits, send the robot back to the parts feeder, and repeat this task for a second block of wax.

8 Send all axes to their home positions.

Task 4-6: Team Discussion and Review

Q *The accuracy of the robot arm is a measure of how close it is able to come to a target position. How does speed affect accuracy?*

Task 4-7: Inventory Check and Shut Down

1 Make sure there are no objects in the robot's gripper.

2 Send the robot and peripheral axes to their home positions.

3 Exit SCORBASE. Turn off Controller-USB, then turn off the computer.

4 Make sure all materials required for this activity have been returned to their proper place.

5 Complete the Inventory Check List on the Worksheet for this activity.

ACADEMICS

History

Robotics and Automation

1917: The word robot first appears, coined by playwright Karel Capek, who derived it from the Czech word robotnik (slave) or robota (drudgery).

1938: Isaac Asimov coins the term robotics in his science fiction novels, and formulates the Three Laws of Robotics which prevent robots from harming humans.

1954: The first United Kingdom robotics patent, No. 781465, is granted in England on March 29.

1958: Joseph F. Engleberger and George C. Devol name their first robot Unimate. The first Unimate is installed at a General Motors plant to work with heated die-casting machines.

1961: George C. Devol obtains the first U.S. robot patent, No. 2,998,237.

1964: A robot is used to paint wheelbarrows in a Norwegian factory during a human labor shortage.

1966: The U.S. robotic spacecraft, Surveyor, lands on the moon.

1970: The Russian lunar rover Lunakhod, wheels about on the moon.

1970: General Motors becomes the first company to use machine vision in an industrial application.

1971: Japan establishes the Japanese Industrial Robot Association (JIRA), and becomes the first nation to have such an organization.

1974: The Robotics Industries Association (RIA) is founded.

1974: Hitachi uses touch and force sensing with its Hi-T-Hand robot, allowing the robot hand to guide pins into holes.

1975: Cincinnati Milacron introduces its first T3 robot for drilling applications.

1976: The U.S. robotic spacecraft, Viking, lands on the Martian surface.

1977: The British Robotics Association (BRA) is founded.

1980: Robotics programming languages are developed.

More robotics and automation history appears in the Academics section of Activity 10.

Activity 5

Recording Robot Positions for Parts Handling

OBJECTIVES

In this activity you will accomplish the following:

- Record absolute and relative robot positions for parts handling.
- Save position and program files.
- Move the robot to the recorded positions.

SKILLS

In this activity you will develop the following skills:

- Technology: apply technology to task.
- Systems: understand systems, monitor and correct performance
- Interpersonal: participate as a member of a team.
- Information: acquire and evaluation information, interpret and communicate information.
- Basic: reading and writing.
- Thinking: reasoning and problem solving, mental visualization.
- Personal: responsibility and self-management

MATERIALS

In this activity you will need the following materials:

- SCORBOT-ER 4u robot, Controller-USB and teach pendant
- Computer with SCORBASE software
- Parts feeder
- Sorting bin
- Wax blocks
- Diskette or personal directory on computer hard disk
- Worksheets for Activity 5

OVERVIEW

Recording Positions

Once you have moved the robot to a location in space, you can record this position. A recorded position, which is identified by a number, is a set of coordinates which defines the distance each axis has moved in relation to the home position. The coordinates are recorded in the currently active coordinate system (Joints or XYZ).

Once a position is recorded, you can give the robot a command to go to it. Before you exit SCORBASE, recorded positions should be saved to a position data file. The positions can then be reloaded and used later.

Robot (Group A) Positions

When robot positions are recorded from the **teach pendant**, they are attached to an array of positions, called SCORA, which is associated with the robot axes control group A. If the robotic system contains peripheral axes, positions recorded from the teach pendant for those axes are attached to an array called SCORB.

When positions are recorded by means of the SCORBASE software Teach Positions dialog box, the coordinates for the robot axes (SCORA) and any peripheral axes (SCORB) are saved together in one set of coordinates.

Relative Positions

Absolute robot positions are positions whose coordinates define the distance each axis has moved in relation to the home position.

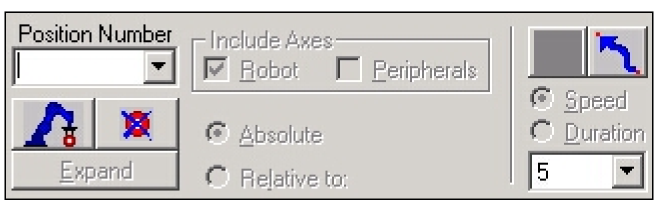


Figure 5-1

On the other hand, relative positions are positions whose coordinates define a specific offset from another position. A relative position is linked to a reference position. If the coordinates of the reference position change, the relative position moves along with it, maintaining the same offset.

Relative positions are useful when programming the path of the robot for pick-and-place tasks. For example, a relative position, defined as a vertical offset of a few centimeters from the pick position, will enable the robot to approach and leave the pick location without hitting other equipment in the system. If the pick position has to be adjusted and re-recorded, it will not be necessary to readjust and rerecord the relative position.

Relative positions cannot be recorded from the teach pendant. Relative positions must be recorded from the Teach Positions (Expanded) dialog box, and are always specified in XYZ coordinates.

Linear Movement

The Teach Positions (Simple) dialog box and the Command List have two options for instructing the robot to move to a position:

- Go Linear: This command sends the robot to a recorded position in a straight line. This is termed point-to-point (PTP) movement.
- Go Position: This command sends the robot to a recorded position along a path calculated by the controller, not necessarily a straight line, and usually a curved path. This is termed continuous path (CP) movement.

The Teach Positions (Expanded) dialog box and the Command List also offer a third movement option, Go Circular, which will not be used in these activities.

PROCEDURES

Task 5-1: Inventory and Safety Checks

1 Check whether all materials required for this activity are available at your lab station.

2 Check whether your lab station conforms to the Safety Guidelines for the FMS workcell. In addition:

- Tie back loose hair and clothing. Remove all jewelry.
- Put on safety glasses.
- Get your instructor's permission to turn on the system.

3 Complete the Inventory and Safety Check List on the Worksheet for this activity.

Task 5-2: Preparing a Folder (Directory) for Program and Position Files

1 Turn on the computer.

2 If you will be saving your work to a *diskette*, make sure your diskette is ready for use.

If you will be saving your work to the *hard disk*, prepare a working directory (folder) for the files you will save in this tekLINK, as follows:

- Browse to **Intelitek | SCORBASE | ER4u**.
- Create a new folder and rename it to your **USER** name.

  Do not type USER. Use a short name which identifies you or your team, such as BRAD, JANE.

  From now on, when instructions tell you to save to or load from your personal (USER) directory, be sure to use the folder you named here.

Task 5-3: Recording Positions from the Teach Pendant

1 Turn on the SCORBASE computer, then turn on the Controller-USB.

Activate the SCORBASE software.

Home all the axes.

Make sure the AUTO/TEACH switch on the teach pendant is set to TEACH.

2 Refer to Figures 5-2 and 5-3. Without moving any of the axes, record the position of the **robot** from the TP as position #100.

- Make sure Joints mode is displayed.

- Make sure Group A is displayed. (Press any robot axis key.)
- Press the key [RECORD POSITION].
  The position array SCORA_ is displayed.
- Press the keys [1] [0] [0].
- Press the key [ENTER/EXECUTE].

3 Moving only the robot base, turn the robot so that it faces the mill. Record the robot's position from the TP as position #99.

4 Again moving only the robot base, turn the robot so that it faces the sorting bin. Record the robot's position from the TP as position #98.

5 Again moving only the robot base, turn the robot so that it faces the parts feeder. Record the robot's position from the TP as position #97.

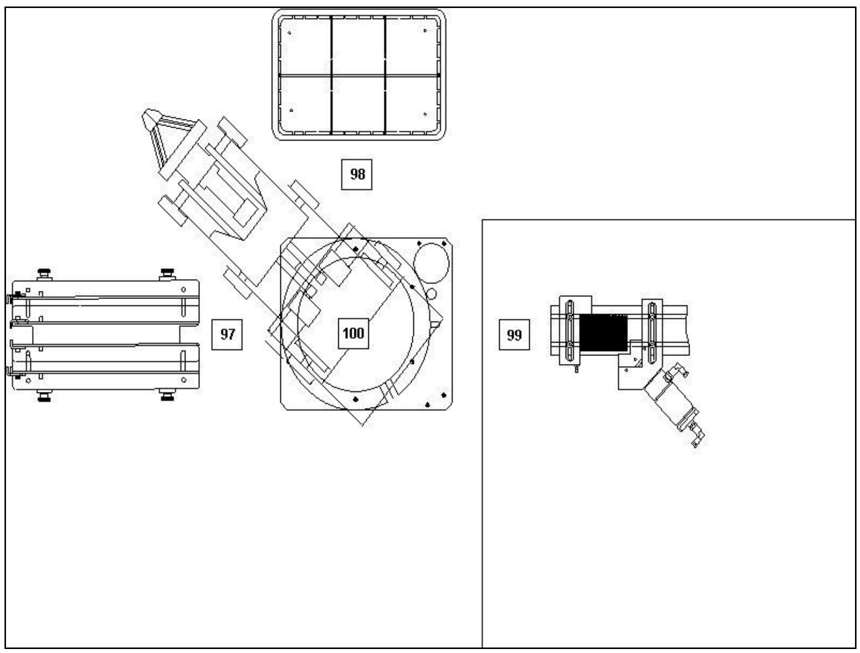


Figure 5-2

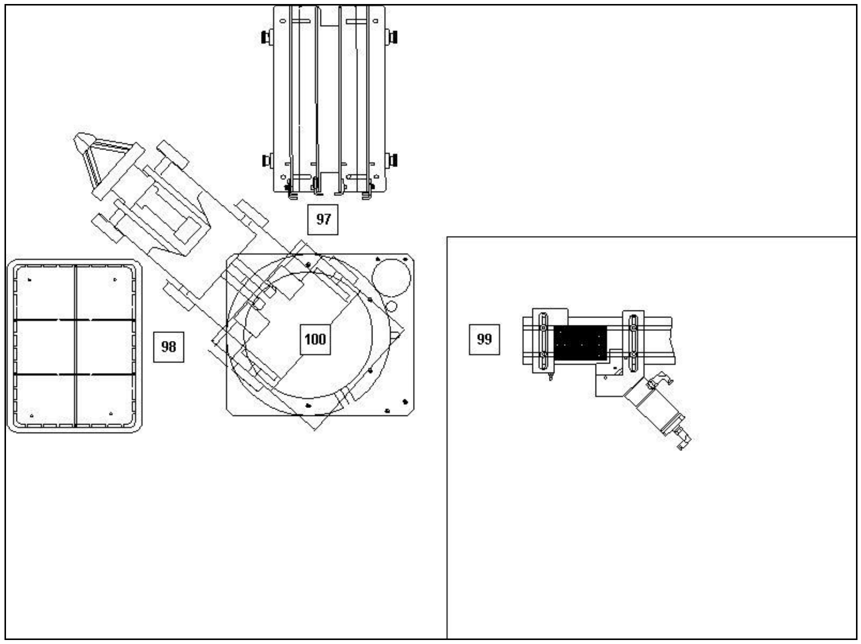


Figure 5-3

The following chart describes the robot positions you have recorded.

Position	Description of Position
100	Robot Home
99	robot facing mill
98	robot facing sorting bin
97	robot facing gravity feeder

Note that the coordinates of these positions will vary according to the specific setup of your FMS cell, as seen in the figures above.

Task 5-4: Moving to Recorded Positions

1 Using the TP, move the robot back to position #98.

- Make sure Joints mode is displayed.
- Make sure Group A is displayed.
- Press the key [MOVE/MOVEL]. Move SCORA is displayed.
- Press the keys [9] [8].
- Press and hold the key [ENTER/EXECUTE].

Continue pressing the Execute key until the robot reaches the target position. At that point the TP will briefly display the message Motion Completed.

If the Execute key is released before the movement is completed, motion stops immediately, and the command is aborted.

2 Repeat Step 1, and send the robot to position #99.

3 Send the robot to position #97, and then to position #98.

4 Use the SCORBASE software to move to positions:

- Switch the AUTO/TEACH switch on the teach pendant to AUTO.
- Select the Teach Positions (Simple) dialog box.
- Click the arrow next to the Position Number field to view the list of recorded positions. You should see positions 97, 98, 99, 100.
- Type or select any position. Then click on **Go Position**.
- Select another position number and again click on Go Position.

Task 5-5: Displaying and Saving Positions

1 Select **View | List Positions**.

The List Positions dialog box will appear, as shown in Figure 5-4.

You should see a listing of the coordinates for positions 100, 99, 98 and 97, which you recorded in the previous task.

#	Coor.	Axis 1 X (mm)	Axis 2 Y (mm)	Axis 3 Z (mm)	Axis 4 Pitch (deg)	Axis 5 Roll (deg)	Axis 7 (mm/deg)	Axis 8 (mm/deg)	Type
97	Joint	90.27	-120.28	95.02	88.81	0.00			Abs. (Joint)
	XYZ	-0.79	169.03	504.33	-63.55	0.00			
98	Joint	0.05	-120.28	95.02	88.81	0.00			Abs. (Joint)
	XYZ	169.03	0.14	504.33	-63.55	0.00			
99	Joint	-89.97	-120.28	95.02	88.81	0.00			Abs. (Joint)
	XYZ	0.08	-169.03	504.33	-63.55	0.00			
100	Joint	0.00	-120.28	95.02	88.81	0.00			Abs. (Joint)
	XYZ	169.03	0.00	504.33	-63.55	0.00			

Figure 5-4

The list of positions must appear as shown in the Figure 5-4 (though values may differ). If they do not, send all axes to their home positions, and rerecord the positions.

Q *Which position (97, 98 or 99) is the same as position 100?*

2 Delete position #100.

3 Close the List Positions dialog box.

- In the Command List, double click on **Remark**.

  The Remark dialog box will open.
- In the text field, enter a simple comment, such as POSITIONS.

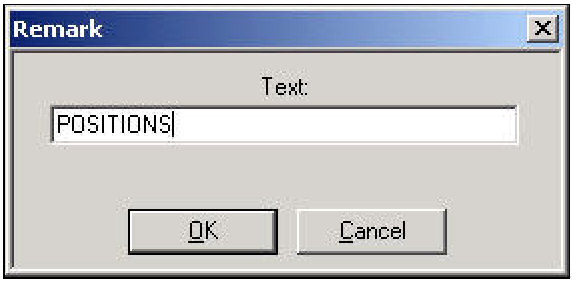


Figure 5-5

- Click OK to close the dialog box.
- In the Program box, you will now see a command line: Remark: POSITIONS.

This single line is the first line of a robot program. Creating it will simplify future save and load operations.

4 Select **File | Save**
The Save Project dialog box will open.

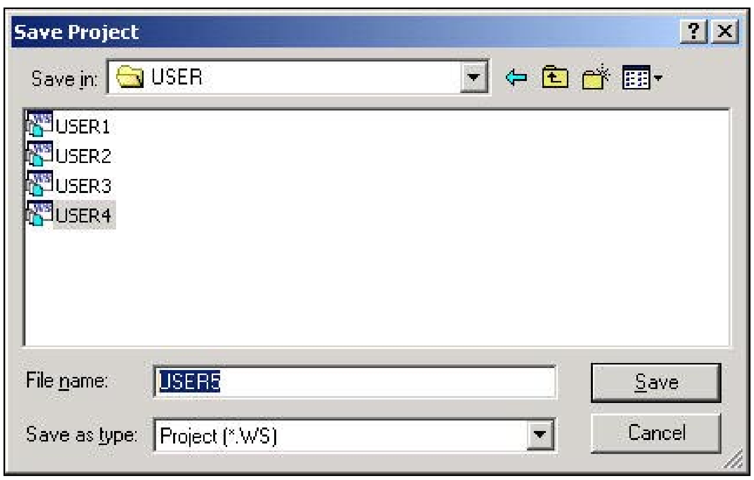


Figure 5-6

- Enter USER5 (where USER is replaced by four characters which identify an individual student or team; e.g., JOHN, FOXY) and choose SAVE.

Task 5-6: Recording Relative Positions for the Parts Feeder

In this task you will record the positions which will enable the robot to pick up a block of wax from the parts feeder.

Unless instructed otherwise, you may use either the TP or SCORBASE to perform this task.

1 Make sure the parts feeder is loaded with blocks of wax, as shown in Figure 5-7.

Make sure the robot is at position #97.

Make sure the robot gripper is open.

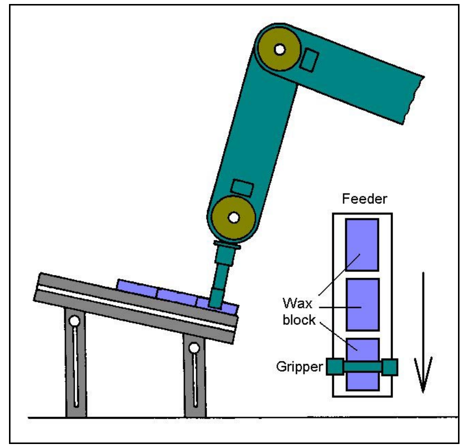


Figure 5-7: position 2

2 Bring the open gripper towards the block of wax in the parts feeder, and slowly lower the arm so that the gripper encompasses the block of wax. The gripper should be aligned with the robot forearm when approaching the block.

Close the gripper. Make sure it grasps the block evenly. If not, open the gripper, adjust the position, and close the gripper again.

3 When the gripper successfully grasps the block, record this as position #2.

4 In the Teach Positions dialog box, click on Expand.

The Teach Positions (Expanded) dialog box opens, as shown in Figure 5-8.

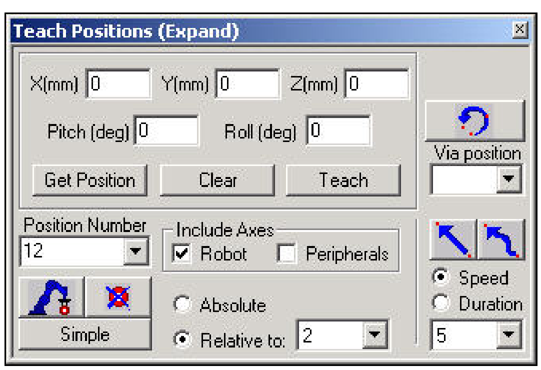


Figure 5-8

5 In the Teach Positions (Expanded) dialog box, do the following **to record a relative position:**

- In the Position Number field, enter 12.

- Select **Relative To**, and enter 2 for the reference position.

  All XYZ coordinate fields are blank or show 0.

- In the Z(mm) field, enter **100**.
- Click **Teach**.

You have now recorded a new position, #12.

Position 12 is diagonally above position #2.

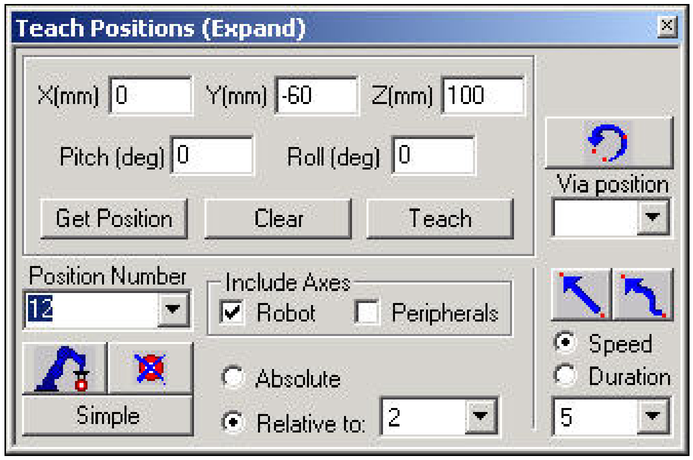


Figure 5-9

6 Using the Go Linear command in the Teach Positions (Expanded) dialog box, send the robot to position #12. It should move to the location shown in Figure 5-10.

7 Carefully place your hand under the part in the gripper. Open the gripper and catch the part before it falls. Set the part aside.

8 With the gripper still open, instruct the robot to pick up another block of wax:

- Go Linear to position #2.
- Close gripper.
- Go Linear to position #12.

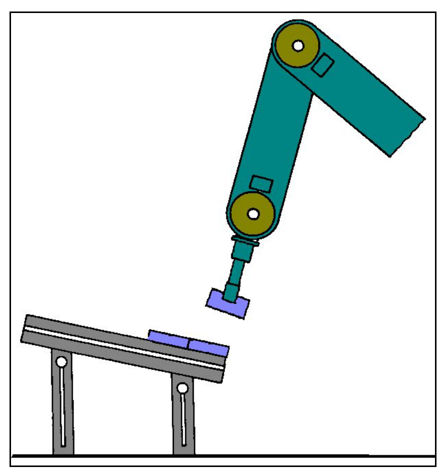


Figure 5-10: position 12

If the block is not cleanly extracted from the feeder, adjust the coordinates of relative position #12, and again check the pickup movement.

Do not remove the block from the gripper.

9 If the operation was successful, perform another save to file USER5.

You will use these positions throughout these activities. The positions must be exact.

Task 5-7: Recording Relative Positions for the Sorting Bin

In this task you will record the positions which will enable the robot to take the part from the part feeder to the sorting bin.

1 With the robot still holding the block of wax, send the robot to position #98.

2 Refer to Figure 5-11.

Bring the gripper to a point just above the middle compartment of the sorting bin.

Record this as position #4.

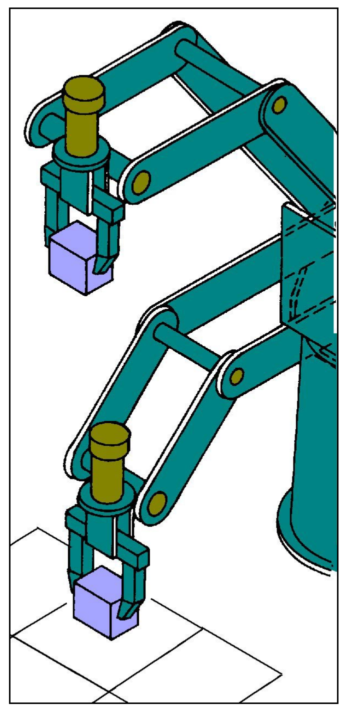


Figure 5-11: Positions 14 and 4

3 Using the Teach Positions (Expanded) dialog box, record position #14. Make it relative to position #4 by 200mm on the Z axis.

4 Using the Go Linear command in the Teach Positions (Expanded) dialog box, send the robot to position #14.

5 Send the robot back to position #4 and open the gripper. The block of wax should drop into the sorting bin.

6 Send the robot to get another part from the parts feeder, and deliver it to the sorting bin.

7 If the operation was successful, again save the positions in the file USER5. If not, adjust the positions, and then save.

You will use these positions throughout these activities. The positions must be exact.

Task 5-8: Team Discussion and Review

Q *What is the purpose of recording and using relative positions?*

Q *How can relative positions be recorded and used for placing parts in different compartments in the sorting bin?*

Q *Which positions in the FMS cell require extreme precision, and which positions do not?*

Task 5-9: Inventory Check and Shut Down

1. Make sure there are no objects in the robot's gripper.
2. Makes sure there are no objects in the feeder or sorting bin.
3. Send the robot and peripheral axes to their home positions.
4. Exit SCORBASE. Turn off Controller-USB, then turn off the computer.
5. Make sure all materials required for this activity have been returned to their proper place.
6. Complete the Inventory Check List on the Worksheet for this activity.

Physics

Work Envelope

The work envelope is all of the places a single robot can reach in its surroundings, within its range of motion.

The length of the links and the degree of rotation of the joints determine the robot's work envelope. The top and side views in Figure 4-7, show the dimensions and reach of the SCORBOT-ER 4u robot.

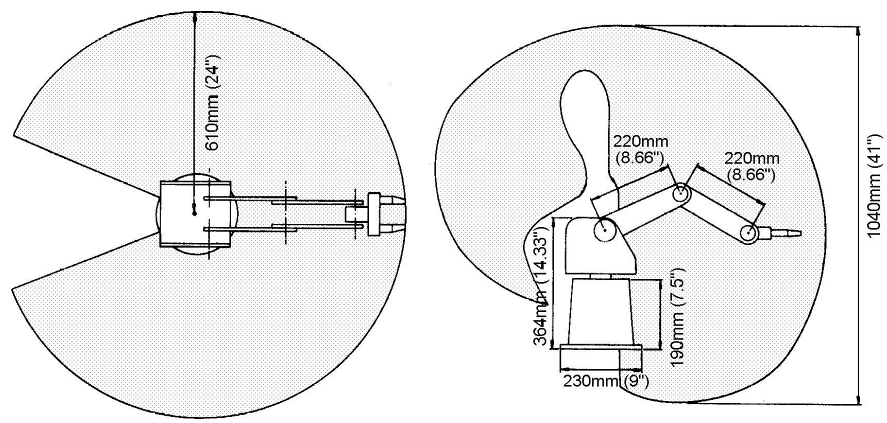


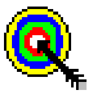
Figure 5-12

The work envelope of each robot is suited to the job it is programmed to accomplish, and can vary considerably from one robot to another. The base of the robot is commonly fixed to a stationary work surface. Attaching the robot to a slidebase results in an extended working range.

Activity 6

Writing and Running a Robot Program

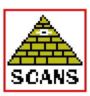
OBJECTIVES



In this activity you will accomplish the following:

- Write, edit and save a robot program.
- Run the robot program in off-line mode.
- Run the robot program on-line.
- Abort the program execution.
- Use conditional and unconditional jump commands in a program.

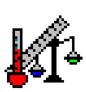
SKILLS



In this activity you will develop the following skills:

- Technology: apply technology to task.
- Systems: understand systems, monitor and correct performance.
- Resources: manage time.
- Interpersonal: work as a member of a team.
- Information: interpret and communicate information.
- Basic: reading and writing.
- Thinking: reasoning and problem solving.
- Personal: responsibility and self-management.

MATERIALS



In this activity you will need the following materials:

- SCORBOT-ER 4u robot and Controller-USB
- Computer with SCORBASE software
- Parts feeder
- Sorting bin
- Wax blocks
- Diskette or personal directory on computer hard disk
- Worksheets for Activity 6

Overview

Robot Programs

A robot program is a series of commands, which tell the robot which tasks to perform. You have already used commands for opening and closing the gripper and moving the robot to different positions. These same commands are used when writing the robot program. Once written, a program may be stored on a disk together with the positions recorded for the robot. Permanent storage of operating programs and positions allows the programs to be reloaded and rerun at a later time.

A SCORBASE program can be written and debugged on a computer, without using the robot controller; this is called off-line programming. The system must be operating on-line with the robot only when the robot is being taught the positions required by the program.

Emergency Stops During Program Execution

Program execution may be stopped for any of the following three reasons:

- *Emergency stop initiated by operator*. Pressing a red EMERGENCY pushbutton immediately halts any running program and robot motion.
- *Regular stop initiated by operator*. Pressing the SCORBASE Stop icon halts a running program as soon as the command currently in progress is completed (such as a robot movement).
- *Stop initiated by software:* If the SCORBASE software identifies mechanical failure in any motor, it will stop the routine and display an error message, which indicates the problem.

Parts Feeder

The parts feeder operates automatically by means of gravity. The remaining blocks of wax slide down the feeder each time a block is removed.

A microswitch at the front of the feeder is depressed whenever a block is present at the pickup point. This sends a signal to the robot controller's input 7. A lit LED on controller-USB also provides an indication of the block's availability for pickup.

Conditional program commands allow the robot to respond to the input signal and prevent it from moving to an empty feeder. If the input is on, it means there is a block available for pickup and the robot will move to pick it up. If the input is off, it means there is no block available, and the robot will not move to the feeder.

PROCEDURES

Task 6-1: Inventory and Safety Checks

1 Check whether all materials required for this activity are available at your lab station.

2 Check whether your lab station conforms to the Safety Guidelines for the FMS workcell. In addition:

- Tie back loose hair and clothing. Remove all jewelry.
- Put on safety glasses.
- Get your instructor's permission to turn on the system.

3 Complete the Inventory and Safety Check List on the Worksheet for this activity.

Task 6-2: Loading a Program File

1 Turn on the SCORBASE computer, then turn on controller-USB.

Activate SCORBASE.

2 Home all axes.

3 Select **File | Open Project**, and load the file USER5, which you saved in the previous activity.

4 Select **View | List** Positions to check the positions which were saved in this file.

5 Select **File | Save Project As**, and save as USER6.

Task 6-3: Writing a Simple Robot Program

1 Bring the cursor to the first line in the Program box.

Remark: POSITIONS

Press the [Del] key to delete this line.

2 Bring the cursor to the Command List box.

Double click the command **Open Gripper**.

A command line now appears in the first line in the Program box:

1 Open Gripper

|

You have just written the first program line. The system is now waiting for you to enter another command.

3 Bring the cursor to the Command List box.

Double click the command **Go to Position**.

The Go to Position dialog box appears, as shown in Figure 6-1.

Figure 6-1

- Type or select 97 in the Target Position field.
- Select Fast for the speed setting.
- Choose OK.

  Another command line now appears in the Program box:

  2 Go to Position 97 fast

  |

4 Enter another movement command.

3: Go to Position 12 fast

5 Bring the cursor to the Command List box.

Double click the command **Go Linear To Position**.

The Go To Position dialog box will open with Linear selected.

The Linear movement command ensures that the robot will move in a straight line to the target position. Movements to and from relative positions should always be linear.

Movements to and from pick/place positions should always be at a slow speed.

- Type or select **2** in the Target Position field.
- Select **Speed** and then enter **2** for the speed setting.
- Choose OK.

Another command line now appears in the Program box:

4: Go Linear to position 2 speed 2

6 Enter the commands which instruct the robot to take a part from the feeder and deliver it to the sorting bin:

5: Close Gripper

6: Go Linear to position 12 speed 5

7: Go to Position 98 fast

8: Go to Position 14 fast

9: Go Linear to position 4 speed 2

10: Open Gripper

11: Go Linear to position 14 speed 5

7 Your program should now appear as shown in Figure 6-2. **Use the scroll bar to move down to line 11**. If necessary, make corrections.

8 Again perform a save operation to file USER6.

Task 6-4: Running the Robot Program (Off-Line)

1 Select **Options | Off-Line**.

In Off-Line mode, SCORBASE does not communicate with the controller and the robot will not move. The cursor will quickly scroll through the program lines, stopping only if there is an error in the program. Off-line mode is therefore useful for checking and debugging programs.

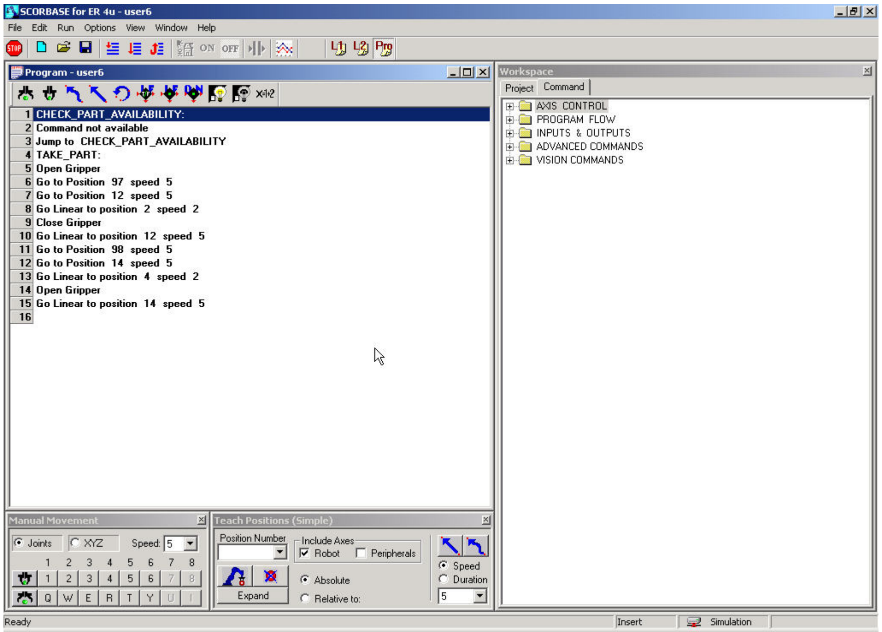
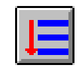


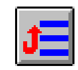
Figure 6-2

2 Bring the cursor to the first line of the program.



Press F7, or click the second icon (Single Cycle).One complete cycle of the program will be executed.

3 With the cursor on the first line of the program, press F8, or click the third icon (Run Continuous). The program will be executed in continuous loops.



Press the Stop icon to halt program execution.

Task 6-5: Executing a Dry-Run of the Robot Program (On-Line)

A dry-run of the robot program performs all operations, but no materials are handled.

1 Make sure there are no blocks of wax in the parts feeder.

Make sure there are no blocks in the sorting bin.

2 Select **Options | On-Line**.

3 **Run | Home all axes**.

When the system reverts to on-line operation after running off-line, the homing routine must be executed.

4 With the cursor on the first line of the program, execute a single cycle.

5 If the single cycle was successful, run the program continuously.

Do not stop program execution. Continue to the next task.

Task 6-6: Aborting Program Execution

1 While the program is still running, press F9 or click the Stop icon.

The robot will stop immediately.

2 Press the Run option functions key or icon to resume continuous execution of the program from where it was halted.

3 Assume a real emergency has occurred:

- Press the EMERGENCY button on the Controller-USB (or on the teach pendant). Confirm the prompt for Control Off.
- Release the EMERGENCY button. Confirm the prompts for Control On.
- Resume program execution.

Stop the program normally (F9 or Stop icon).

Task 6-7: Executing the Robot Program

1 Place two blocks of wax in the parts feeder.

Make sure there are no blocks in the sorting bin.

2 Send the robot to its home position by selecting **Run | Go Home-Robot**.

3 Execute a single program cycle.

4 If the single cycle was successful, execute the program continuously.

Q *What happens when the feeder runs out of wax blocks?*

Task 6-8: Conditional Program Jumps

As you saw in the previous task, the robot does not know that the supply of blocks has run out. To prevent the robot from moving to an empty feeder, conditional commands are used. These commands check the input signal from the parts feeder, and direct program flow accordingly.

In this task you will insert four command lines at the beginning of the program which will make the robot's movement to the feeder conditional upon the availability of wax blocks in the feeder.

1 Select **View | Edit**.

2 Bring the cursor to the first line in the Program box.

3 In the Command List box, double click on the command **Label**.

The Label dialog box will open, as shown in Figure 6-3.

Type in the text CHECK_PART_AVAILABILITY, and click OK.

Be sure to include an underscore between each word.

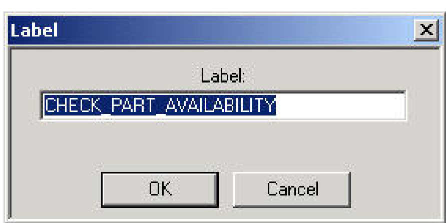


Figure 6-3

4 Make sure the cursor is now at the second line of the program.

In the Command List box, double click on the command **If Input**.

The If Input dialog box will open, as shown in Figure 6-4.

Type in 7 for the Input Number. Make sure **On** and **Jump to Label** are selected.

Type in the text TAKE_PART, and click OK.

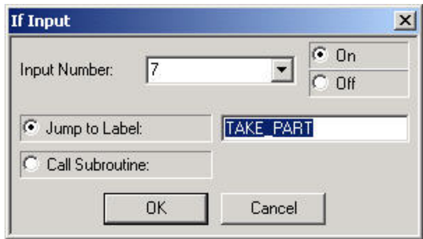


Figure 6-4

5 Make sure the cursor is now at the third line of the program.

In the Command List box, double click on the command **Jump to**.

The Jump to Label dialog box will open, as shown in Figure 6-5.

Type in the text CHECK_PART_AVAILABILITY, and click OK.

Be sure to include an underscore between each word.

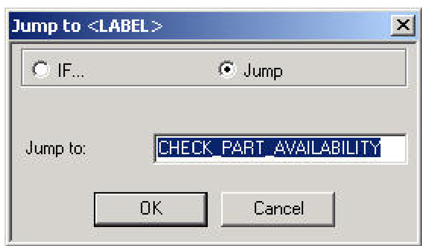


Figure 6-5

6 Make sure the cursor now at the fourth line of the program.

In the Command List box, double click on the **Label** command.

In the Label dialog box enter the text TAKE_PART, and click on OK.

7 Your program should now appear as follows:

1: CHECK_PART_AVAILABILITY:
2: On Input Interrupt 7 on jump to TAKE_PART
3: Jump to CHECK_PART_AVAILABILITY
4: TAKE_PART:
5: Open Gripper
6: Go to Position 97 speed 5
7: Go to Position 12 speed 5
8: Go Linear to position 2 speed 2
9: Close Gripper
10: Go Linear to position 12 speed 5
11: Go to Position 98 speed 5
12: Go to Position 14 speed 5
13: Go Linear to position 4 speed 2

14: Open Gripper

15: Go Linear to position 14 speed 5

If necessary, make corrections.

8 Save again to file USER6.

9 Make sure there are *no parts* in the parts feeder. Give the command to execute a single program cycle.

Q *Describe the program execution when there are no parts in the feeder.*

10 Press the Stop icon to stop program execution.

Place the cursor at the first list of the program.

11 Place two blocks of wax in the parts feeder.

Make sure there are no blocks in the sorting bin.

12 Run the program continuously. Watch the robot, the parts feeder and the LED for input 7 on controller-USB.

Q *Describe the program execution when the feeder has been stocked with parts*

Task 6-9: Team Discussion and Review

Q *What are the differences and similarities of off-line and on-line execution of a robot program?*

Q *What is the purpose of using conditional (IF) commands in a robot program?*

Task 6-10: Inventory Check and Shut Down

1 Make sure there are no objects in the robot's gripper.

Make sure there are no parts in the feeder or sorting bin.

2 Send the robot to its home position.

3 Exit SCORBASE. Turn off controller-USB, then turn off the computer.

4 Make sure all materials required for this activity have been returned to their proper place.

5 Complete the Inventory Check List on the Worksheet for this activity.

Career Opportunities

Careers in manufacturing appeal to those who enjoy working with their hands to help produce products. The skills required to do this type of work vary. Some jobs require physical strength to assemble large objects like airplanes and ships. Other jobs require the ability to pay attention to detail, for example in cabinet finishing. The work is changing because of new computer technology and the use of robots. Entry level requirements vary. Often specialized training at a community college is required. Advancement usually results from a combination of further training and experience. The following is a sample of the many career opportunities in robotics and manufacturing.

Energy Auditor

Track the energy consumption of robots used in manufacturing and elsewhere, and the energy being used in industry and manufacturing to identify ways to reduce this usage.

This is a new occupation and requirements are not in place. However, preference is for a community college diploma in a related field such as Robotics and Electronics.

Machinist

Make or repair metal tools, machines or parts by using metal working machining tools such as lathes, boring machines, milling machines and cutting machines. Includes aircraft machinists, cam makers, gear finishers, jig borers, lathe machinists, pattern makers and radial-drill press operators.

Requires some secondary school education and completion of an apprenticeship program or community college diploma and on-the-job experience.

Robot Attendant

Operate robots used in manufacturing and monitor their performance. Make minor repairs as needed.

Requires some secondary school education and on-the-job training.

Robotic Application Engineer Technician

Install, maintain and test robot systems which are mainly used in manufacturing to perform duties such as running an assembly line.

Requires community college diploma or institute of technology diploma in either Electronics Technology, Robotics and Automation Technology, or related field.

Tool and Die Maker

Make and repair tools, dies and fixtures subsequently used to cut, form or process materials, usually metal, often by operating numerically operated or computer programmable machinery.

Requires some secondary school and completion of apprenticeship in tool and die making.

Source: Human Resources Development Canada. Career Considerations: Manufacturing. http://www.globalx.net/ocd/career/car-eng/man.html#7.

Activity 7

Recording Robot Positions for Mill Tending

Objectives

In this activity you will accomplish the following:

- Record and save absolute and relative robot positions for mill tending.
- Move the robot to the recorded positions.

Skills

In this activity you will develop the following skills:

- Technology: apply technology to task.
- Systems: understand systems, monitor and correct performance.
- Resources: manage time.
- Interpersonal: participate as a member of a team.
- Information: interpret and communicate information.
- Thinking: reasoning and problem solving.
- Personal: responsibility, self-esteem, self-management.

Materials

In this activity you will need the following materials:

- SCORBOT-ER 4u robot, Controller-USB and teach pendant
- Computer with SCORBASE software
- spectraLIGHT Mill and controller
- Pneumatic vise and spacer
- Computer with WSLM mill control software and EXCHANGE .NC program
- Parts feeder and sorting bin
- Wax blocks
- Diskette or personal directory on computer hard disk
- Worksheets for Activity 7

Record and Teach Commands

Although the terms **teach** and **record** are often used interchangeably in robotics, SCORBASE for Windows makes the following distinction:

- Record position: the controller automatically records the position according to the current coordinates of the robot and/or peripheral axes.

  Record commands always record Joint coordinates.

- Teach position: the user records the position by specifying values for the position coordinates.

  Teach commands always record XYZ coordinates.

Although you can enter coordinates for all five axes (XYZPR), the Teach Position function is most effectively used for **position modification**; that is, for changing only one of the coordinates of a position. You can therefore adjust a position's location. Or you can use the coordinates of an existing position to create a new position whose location differs slightly from the first.

FMS Cell Positions

The following diagram and table give the positions needed for robot operation in the FMS cell. Note that the diagram may not accurately reflect the placement of the devices in your FMS cell.

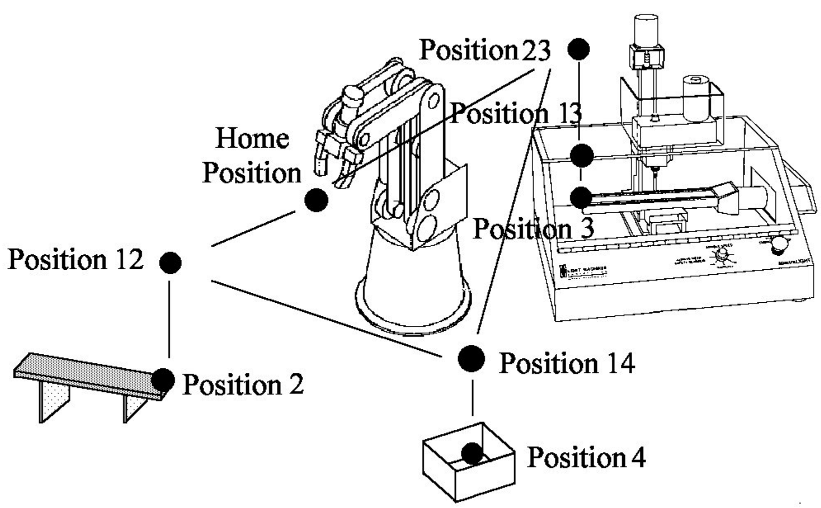


Figure 7-1

Note that the diagram does not accurately reflect the placement of the devices in the FMS cell.

The following table lists and describes the positions in the FMS cell. The shaded positions are absolute; non-shaded positions are recorded as relative positions.

Area Tended	Position	Description of Position
	99	robot home, facing mill
	98	robot facing sorting bin
	97	robot facing gravity feeder
Parts Feeder	**2**	Position at which robot picks up block from gravity feeder.
	12	Intermediate position, above position 2 (relative to position 2)
Mill Vise	**3**	Position at which robot loads and unloads the block to and from the vise.
	13	Intermediate position, above position 3 (relative to position 3)
	23	Intermediate position, above position 13 (also relative to position 3)
Sorting Bin	**4**	Place position. Position at which robot places the block into the sorting bin.
	14	Intermediate position, above position 4 (relative to position 4).

You have already recorded most of these positions.

In this activity you will record the robot positions at the milling machine. Some of these positions must be very exact. Remember that the Teach Position function can help you record the precise coordinates.

PROCEDURES

Task 7-1: Inventory and Safety Checks

1 Check whether all materials required for this activity are available at your lab station.

2 Check whether your lab station conforms to the Safety Guidelines for the FMS workcell. In addition:

- Tie back loose hair and clothing. Remove all jewelry.
- Put on safety glasses.
- Get your instructor's permission to turn on the system.

3 Complete the Inventory and Safety Check List on the Worksheet for this activity.

Task 7-2: Loading and Running a Saved Robot Program

1 Turn on the SCORBASE computer, then turn on controller-USB.

Activate the SCORBASE software.

Home all the axes.

Make sure the AUTO/TEACH switch on the teach pendant is set to AUTO.

2 Select **File | Open Project** and Load the file you saved as USER6 in the previous activity.

3 Select **View | List** Positions.

The List Positions dialog box will appear, and show the positions which you recorded in the previous activities.

4 Place wax blocks in the feeder.

Execute one cycle of program USER6. Be prepared to abort the program if an error occurs.

Make sure the program runs correctly and the robot properly handles the wax block.

5 If successful, select **File | Save Project As**, and save the program and positions to file USER7.

Task 7-3: Activating and Initializing the Milling Machine

1 Power up the milling machine computer, then turn on the mill controller.

Activate the WSLM Control Program, by selecting WSLM in the WSLM program group.

2 Make sure the spindle is far enough away from the vise so that a workpiece can be placed in the vise. From the Jog Keypad, click on the Z+ button to raise the spindle. If necessary, also move the X and Y axes.

3 Press the Emergency Stop button on the milling machine.

Open the safety shield.

4 Open the pneumatic vise by clicking on the **Acc2** button in the Outputs toolbar.

Insert a 1" spacer into the pneumatic vise on the cross slide.

Place a machinable wax block on top of the spacer.

5 Clamp the pneumatic vise, again by clicking on the **Acc2** button in the Outputs toolbar.

Make sure the block is held securely in place.

6 Close the safety shield and pull out the Emergency Stop button.

7 Use the Jog Keypad to jog the tool to the top of the front left corner of the workpiece, as shown in Figure 7-2. Stop just before the tool touches the top of the workpiece.

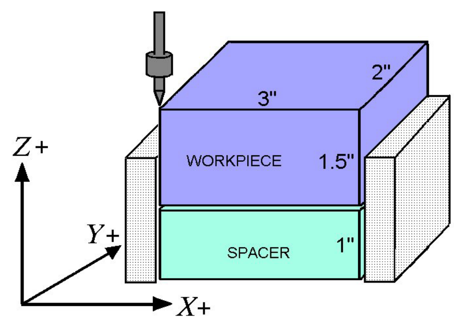


Figure 7-2

8 Select **Setup | Set Position**. The Set Position dialog box appears.

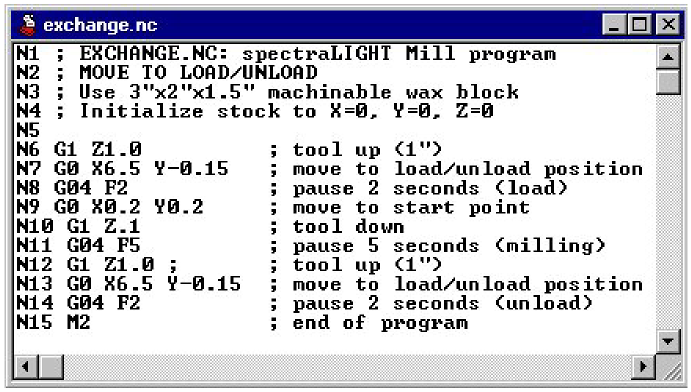
9 Enter 0 (zero) in the X, Y and Z boxes.

Click OK. The values in the Position Readout are updated.

10 Raise the cutting tool away from the workpiece.

Task 7-4: Sending the Vise to the Robot Load/Unload Position

1 From WSLM, select **File | Open**, and load the program EXCHANGE.NC. This program will now appear on the screen.



```
N1 ; EXCHANGE.NC: spectraLIGHT Mill program
N2 ; MOVE TO LOAD/UNLOAD
N3 ; Use 3"x2"x1.5" machinable wax block
N4 ; Initialize stock to X=0, Y=0, Z=0
N5
N6 G1 Z1.0          ; tool up (1")
N7 G0 X6.5 Y-0.15   ; move to load/unload position
N8 G04 F2           ; pause 2 seconds (load)
N9 G0 X0.2 Y0.2     ; move to start point
N10 G1 Z.1          ; tool down
N11 G04 F5          ; pause 5 seconds (milling)
N12 G1 Z1.0 ;       ; tool up (1")
N13 G0 X6.5 Y-0.15  ; move to load/unload position
N14 G04 F2          ; pause 2 seconds (unload)
N15 M2              ; end of program
```

Figure 7-3

2 Select **Program | Run / Continue**.

3 In the Run Program dialog box, make sure that the Start Line box is set to line 1 of the program. Then click on the Run Program button to begin program execution.

4 Once the program has been executed, open the pneumatic vise by clicking on the **Acc2** button in the Outputs toolbar.

5 Remove the wax block from the open vise, and place it in the parts feeder.

Task 7-5: Recording Robot Positions at the Milling Machine

Use the SCORBASE Teach Positions (Expanded) dialog box to record relative positions.

1 Set the AUTO/TEACH switch on the teach pendant to TEACH.

Make sure the robot gripper is fully open.

Instruct the robot to pick up the wax block from the parts feeder (move to positions #12 and #2 and close gripper.)

Move the robot to position #97.

Move the robot to position #99.

2 Refer to Figures 7-4, 7-5 and 7-6.

Turn the robot so that the block is vertically above the vise.

Change robot speed to Speed 1.

Lower the block carefully into the open vise.

Do not open the gripper.

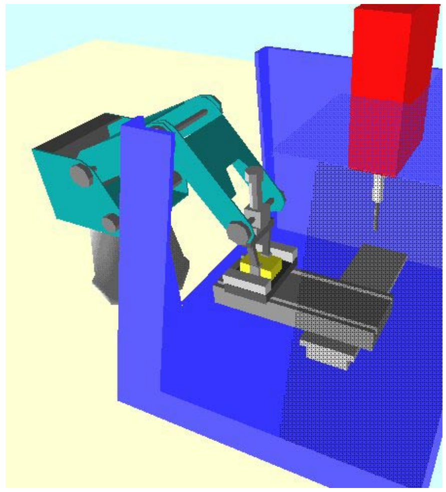


Figure 7-4: Position 3

3 Once the gripper has successfully placed the block in the vise, record this position as **robot position 3**, as shown in Figure 7-4.

4 Set the AUTO/TEACH switch on the teach pendant to AUTO.

Using the Teach Positions (Expanded) dialog box, record position 13. Make this position relative to **position #3** by +50mm on the Z axis.

5 Record **position 23**. Make this position relative to position #13 by +90 mm on the Z axis.

6 Send the robot to positions #13, #23, and then #99, to verify that the robot gripper with the block moves free of the mill.

7 Adjust the Z axis offset values if necessary.

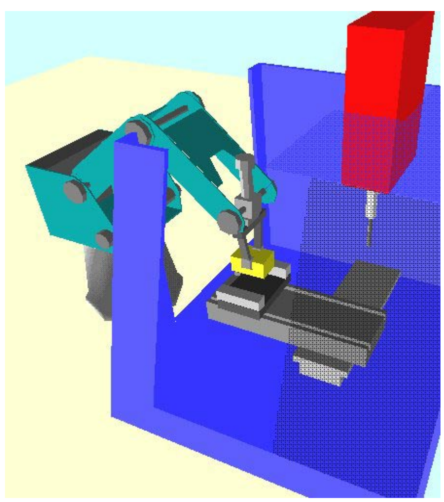


Figure 7-5: Position 13

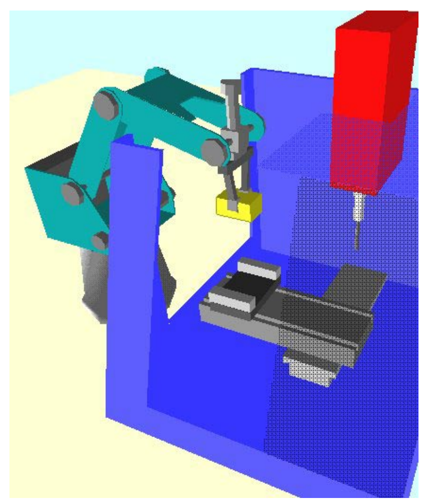


Figure 7-6: Position 23

Task 7-6: Verifying and Using Recorded Positions

1 In the List Positions dialog box, verify the positions which you have recorded.

2. Using the TP or the Teach Positions dialog box, send the robot to position #3 (via positions #23 and #13), release the block into the vise, and return to position #13 and then #23.
3. Send the robot back to position #13 and then #3 to pick up the workpiece.
4. Send the robot back to position #13 and then #23.
5. Send the robot to position #99.
6. Send the robot to position #98.
7. Send the robot to position #14 and then #4.
8. Open the gripper. The block should fall into the bin.
9. Save to USER7.

If time permits, place blocks of wax in the parts feeder and/or in the vise, and practice moving the robot to the various locations in the FMS cell and picking up and placing workpieces.

Task 7-7: Team Discussion and Review.

Q *Why is it preferable for positions 12, 13, 23 and 14 to be recorded as relative positions and not absolute positions?*

Task 7-8: Inventory Check and Shut Down

1. Make sure there are no objects in the robot's gripper, milling machine, feeder or sorting bin.
2. Send all axes to their home position.
3. Exit SCORBASE. Turn off controller-USB, then turn off the SCORBASE computer
4. Exit the WSLM control program. Turn off the spectraLIGHT mill, then turn off the WSLM computer.
5. Make sure all materials required for this activity have been returned to their proper place.
6. Complete the Inventory Check List on the Worksheet for this activity.

Vocabulary

Assembly Line

An arrangement of workers, machines, and equipment in which the product being assembled passes consecutively from operation to operation until completed. Also called production line.

Conveyor

A mechanical apparatus, such as a continuous moving belt, that transports materials, packages, or items being assembled from one place to another.

Feeder

A worker or device that feeds materials into a machine for further processing.

On-Line

(1)Under the control of a central computer, as in a manufacturing process or an experiment. (2)Connected to a computer network. (3)Accessible via a computer or computer network: an on-line database.

Real-Time

(1)The actual time in which a physical process under computer study or control occurs. (2)The time required for a computer to solve a problem, measured from the time data are fed in, to the time a solution is received.

The American Heritage Dictionary of the English Language, Third Edition copyright 1992 by Houghton Mifflin Company.

Activity 8

More FMS Robot Programming

OBJECTIVES

In this activity you will accomplish the following:

- Write a robot program for moving the robot to all positions in the FMS cell.
- Run the program with and without the robot handling workpieces.
- Control and test program flow by simulating input signals.

SKILLS

In this activity you will develop the following skills:

- Technology: apply technology to task.
- Systems: understand systems, monitor and correct performance.
- Resources: manage time.
- Interpersonal: participate as a member of a team.
- Information: interpret and communicate information.
- Thinking: reasoning and problem solving.
- Personal: responsibility, self-esteem, self-management.

MATERIALS

In this activity you will need the following materials:

- SCORBOT-ER 4u Robot and Controller-USB
- Computer with SCORBASE software
- spectraLIGHT Mill and Controller Box
- Pneumatic vise and spacer
- Computer with WSLM Control Program and EXCHANGE.NC
- Parts Feeder and Sorting bin
- Wax blocks
- Diskette or personal directory on computer hard disk
- Worksheets for Activity 8

OVERVIEW

Robots in the FMS Environment

When integrated into an automated environment, robots are often used to move a work piece from one place to another. When a robot is transferring a work piece from one location to another, its path must be clearly defined to ensure that the robot does not bump into obstacles along the way, and accurately reaches its destination with the work piece properly oriented.

To coordinate the movements of the robot with the other equipment in the system, the speed and location of the robot must be carefully controlled. WAIT commands, for example, can halt the robot at certain points in the program where it must wait for another operation to be completed.

PROCEDURES

Task 8-1: Inventory and Safety Checks

1 Check whether all materials required for this activity are available at your lab station.

2 Check whether your lab station conforms to the Safety Guidelines for the FMS workcell. In addition:

- Tie back loose hair and clothing. Remove all jewelry.
- Put on safety glasses.
- Get your instructor's permission to turn on the system.

3 Complete the Inventory and Safety Check List on the Worksheet for this activity.

Task 8-2: Preparing the FMS Cell for Operation

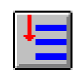
1 Turn on the SCORBASE computer, then turn on Controller-USB.

Activate SCORBASE.

Home all the axes.

2 Load the file you saved as USER7 in the previous activity.

Place one block of wax in the feeder.



Execute one cycle of program USER7 line by line, by continuously clicking on the **single step** icon.

Make sure the program runs correctly and the robot properly handles the wax block.

If successful, select **File | Save project As**, and save as **USER8**.

3 Turn on the milling machine computer, then turn on the Controller Box.

Activate the WSLM mill control software.

Place a block of wax in the pneumatic vise, clamp it, and initialize the mill. (Set the workpiece origin.)

4 From WSLM, select **File | Open**, and load the program EXCHANGE.NC.

Run the program. Then open the pneumatic vise.

5 Leave the wax block in the open vise.

Task 8-3: Writing an FMS Robot Program

1 Select **View | Edit**.

You will now insert additional program lines to the program which you wrote and saved in previous activities, shown in Figure 8-1.

```
1: CHECK_PART_AVAILABILITY:
2: If Input 7 on jump to TAKE_PART
3: Jump to CHECK_PART_AVAILABILITY
4: TAKE_PART:
5: Open Gripper
6: Go to Position 97 fast
7: Go to Position 12 fast
8: Go Linear to position 2 speed 2
9: Close Gripper
10: Go Linear to position 12 speed 5
11: Go to Position 98 fast
12: Go to Position 14 fast
13: Go Linear to position 4 speed 2
14: Open Gripper
15: Go Linear to position 14 speed 5
```

Figure 8-1

To enter the WAIT command, double click on the Wait command in the Command List. The Wait dialog box will open.

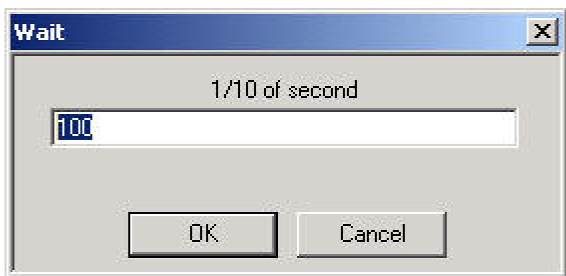


Figure 8-2

Add the following **bolded** commands to the program, in the order presented below. (Non-bolded commands already exist.)

1: CHECK_PART_AVAILABILITY:

2: If Input 7 on jump to TAKE_PART

3: Jump to CHECK_PART_AVAILABILITY

4: TAKE_PART:

5: Open Gripper

6: Go to Position 97 speed 5

7: Go to Position 12 speed 5

8: Go Linear to position 2 speed 2

9: Close Gripper

10: Go Linear to position 12 speed 5

11: Go to Position 98 speed 5

12: Go to Position 99 speed 5

13: Go to Position 23 speed 5

14: Go Linear to position 13 speed 5

15: Go Linear to position 3 speed 2

16: Open Gripper

17: Go Linear to position 13 speed 2

18: Go Linear to position 23 speed 5

19: Go to Position 99 speed 5

20: WaiT 100 (10 ths of seconds)

21: Go to Position 23 speed 5

22: Go Linear to position 13 speed 5

23: Go Linear to position 3 speed 2

24: Close Gripper

25: Go Linear to position 13 speed 2

26: Go Linear to position 23 speed 5

27: Go to Position 99 speed 5

28: Go to Position 98 speed 5

29: Go to Position 14 speed 5

30: Go Linear to position 4 speed 2

31: Open Gripper

32: Go Linear to position 14 speed 5

33: Go to Position 98 speed 5

34: Go to Position 97 speed 5

2 Your program should now appear as shown in Figure 8-3.

```
1: CHECK_PART_AVAILABILITY:
2: If Input 7 on jump to TAKE_PART
3: Jump to CHECK_PART_AVAILABILITY
4: TAKE_PART:
5: Open Gripper
6: Go to Position 97 fast
7: Go to Position 12 fast
8: Go Linear to position 2 speed 2
9: Close Gripper
10: Go Linear to position 12 speed 5
11: Go to Position 23 fast
12: Go Linear to position 13 speed 5
13: Go Linear to position 3 speed 2
14: Open Gripper
15: Go Linear to position 13 speed 2
16: Go Linear to position 23 speed 5
17: WaiT 100 [10 ths of seconds]
18: Go Linear to position 13 speed 5
19: Go Linear to position 3 speed 2
20: Close Gripper
21: Go Linear to position 13 speed 2
22: Go Linear to position 23 speed 5
23: Go to Position 98 fast
24: Go to Position 14 fast
25: Go Linear to position 4 speed 2
26: Open Gripper
27: Go Linear to position 14 speed 5
28: Go to Position 98 fast
29: Go to Position 12 fast
```

Figure 8-3

3 If necessary, make corrections.

Again perform a save operation to file USER8.

Task 8-4: Testing the Robot Program with Input Simulation

1 Select Options | Off-Line.

Select **View | Run Screen**.

Make sure program USER8 appears in the Program box.

2 Bring the cursor to the first line of the program. Then run the program **continuously**.

3 While the program is running, go to the Digital Inputs dialog bar. (If it is not already displayed, select **View | Dialog Bars | Digital Input**)

- Right-click the Input 7 box and choose **FORCE**. A checkmark will appear, as shown in Figure 8-4. This will now allow you to simulate receiving an input signal.

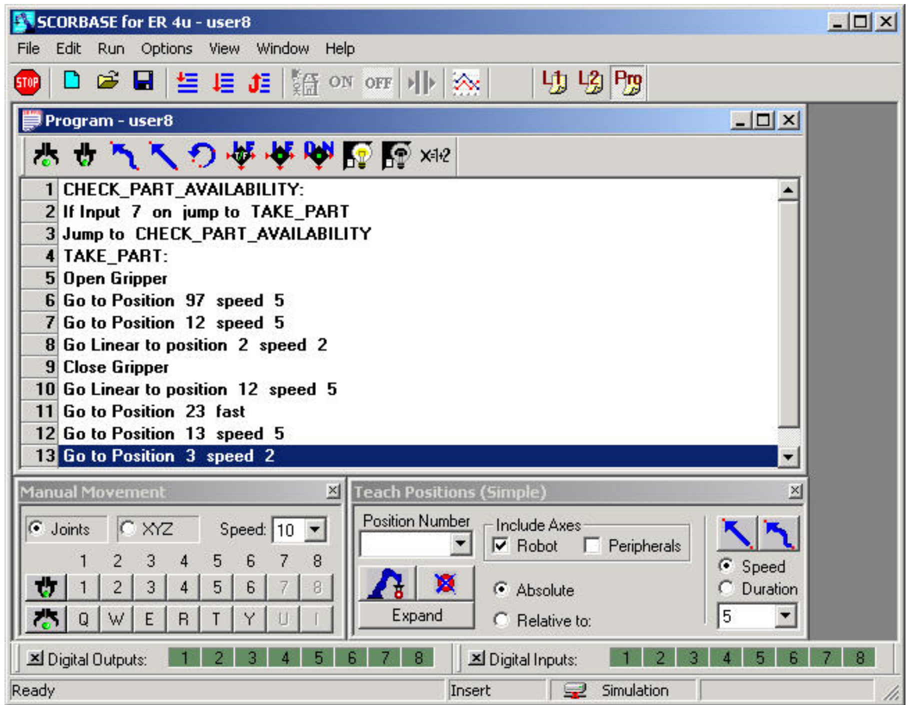


Figure 8-4

- Click the Input 7 box. A The box will change color, as shown in Figure 8-5. This serves as an Input On signal.

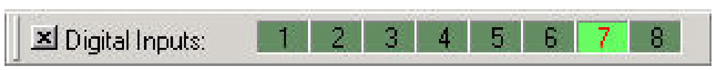


Figure 8-5

4 While the program pauses on the Wait command, again click the Input 7 box. The box will change its color back. The input is now off.

5 After observing the effect of the input simulation on the running program, click the Force checkbox to clear it.

Task 8-5: Executing a Dry-Run with Input Simulation

1 Select **Options | On-Line**.

Make sure there are no blocks of wax in the parts feeder, bin or milling machine vise.

2 **Home all axes**.

When the system reverts to on-line operation after running off-line, the homing routine must be executed.

3 Run a single cycle of the program. Use the Digital Inputs dialog box to simulate input 7.

Task 8-6: Executing the Robot Program

1 Place two blocks of wax in the parts feeder.

Make sure there are no blocks in the sorting bin or in the milling machine vise. Make sure the milling machine vise is open.

2 Run the program continuously.

Task 8-7: Team Discussion and Review

Q *Describe the similarities and difference between a WAIT command and an IF...JUMP command block. Give an example of how each can be used in FMS operations.*

Task 8-8: Inventory Check and Shut Down

1 Make sure there are no objects in the robot's gripper, milling machine, feeder or sorting bin.

2 Send all axes to their home position.

3 Exit SCORBASE. Turn off Controller-USB, then turn off the SCORBASE computer.

4 Exit the WSLM mill control software. Turn off the mill controller, then turn off the WSLM computer.

5 Make sure all materials required for this activity have been returned to their proper place.

6 Complete the Inventory Check List on the Worksheet for this activity.

Educational and Career Opportunities

FIRST Competition

FIRST is an acronym which stands for: For Inspiration and Recognition of Science and Technology. It is a non-profit organization whose mission is to generate an interest in science and engineering among today's youth. Currently, the primary means of accomplishing this goal is through annual robot competitions, which began in 1992.

The FIRST Competition is a national engineering contest which immerses high school students in the exciting world of engineering. Teaming up with engineers from businesses and universities, students get a hands-on, inside look at the engineering profession. In six intense weeks, students and engineers work together to brainstorm, design, construct and test their champion robot. With only six weeks, all jobs are critical path. The teams then compete in a spirited, no-holds-barred tournament complete with referees, cheerleaders and time clocks.

The partnerships developed between schools, businesses, and universities provide an exchange of resources and talent, highlighting mutual needs, building cooperation, and exposing students to new career choices. The result is a fun, exciting and stimulating environment in which all participants discover the important connection between classroom lessons and real world applications.

Each year, the Competition is different, so returning teams always have a new challenge. 113 teams built robo-gladiators and competed in the 1997 National Championship at Walt Disney World's EPCOT in Orlando, Florida in April 1997. The top five teams were:

- Beatty Machine and Manufacturing & Hammond Schools (Hammond, IN)
- Delphi Interior and Lighting Systems & Pontiac Central High School (Troy, MI)
- General Motors Powertrain Group & Pontiac North High School (Pontiac, MI)
- International Fuel Cells & South Windsor High School (South Windsor, CT)
- Dart Container Corporation & Mason High School (Mason, MI)

Learn more about FIRST and its robot competitions at: http://www.usfirst.org/compinfo.html

Find out about the many robot contests and competitions around the world through the listing at: http://www.ncc.com/misc/rcfaq.htmlOVERVIEW

Activity 9

Optimizing the FMS Robot Program

Objectives

In this activity you will accomplish the following:

- Measure the time it takes to complete the production cycle.
- Determine ways to optimize (reduce) production time.

Skills

In this activity you will develop the following skills:

- Technology: apply technology to task.
- Systems: understand systems, monitor and correct performance.
- Resources: manage time.
- Interpersonal: participate as a member of a team.
- Information: use computer to process information.
- Thinking: mental visualization and reasoning.

Materials

In this activity you will need the following materials:

- SCORBOT-ER 4u robot, Controller-USB and teach pendant
- Computer with SCORBASE software
- spectraLIGHT mill and controller
- Pneumatic vise and spacer
- Computer with WSLM mill control program and EXCHANGE.NC
- Parts feeder and sorting bin
- Wax blocks
- Clock or timer
- Diskette or personal directory on computer hard disk
- Worksheets for Activity 9

OVERVIEW

Time and Motion Study

Time and motion study is the analysis of the operations required to produce a manufactured article in a factory, with the aim of increasing efficiency. Each operation is studied minutely and analyzed in order to eliminate unnecessary motions and thus reduce production time and raise output.

The first effort at time study was made by F.W. Taylor in the 1880s. Early in the 20th century, Frank and Lillian Gilbreth developed a more systematic and sophisticated method of time and motion study for industry, taking into account the limits of human physical and mental capacity and the importance of a good physical environment.

> *The Concise Columbia Encyclopedia is licensed from Columbia University Press. Copyright 1995 by Columbia University Press.*

In this activity you will perform a time and motion study of the robot, and determine ways of optimizing the time it takes to complete a FMS production cycle.

PROCEDURES

Task 9-1: Inventory and Safety Checks

1 Check whether all materials required for this activity are available at your lab station.

2 Check whether your lab station conforms to the Safety Guidelines for the FMS workcell. In addition:

- Tie back loose hair and clothing. Remove all jewelry.
- Put on safety glasses.
- Get your instructor's permission to turn on the system.

3 Complete the Inventory and Safety Check List on the Worksheet for this activity

Task 9-2: Preparing the FMS Cell for Operation

1 Turn on the SCORBASE computer, then turn on Controller-USB.

Activate SCORBASE.

Home all the axes.

2 Turn on the milling machine computer, then turn on the Controller.

Activate the WSLM mill control software.

Place a block of wax in the pneumatic vise, clamp it, and initialize the mill. (Set the workpiece origin.)

3 From WSLM, load the program EXCHANGE.NC.

Run the program. Then open the pneumatic vise.

4 Remove the wax block from the open vise and place it in the parts feeder.

5 From SCORBASE, load the file you saved as USER8 in the previous activity.

Execute one cycle of program USER8 line by line, by continuously clicking on the **single step** icon.

Make sure the program runs correctly and the robot properly handles the wax block.

If successful, select **File | Save Project As**, and save to project file **USER9**.

Task 9-3: Editing the Program

In the following tasks you will measure the time it takes to complete a completed production cycle and segments of the production cycle.

To assist you in the time study, it is useful to insert comments (Remarks) into the program which will define the various segments of the program.

1 Figure 9-1 shows program USER8, which you have just saved as USER9.

```
4: TAKE_PART:
5: Open Gripper
6: Go to Position  97  fast
7: Go to Position  12  fast
8: Go Linear to position  2  speed  2
9: Close Gripper
10: Go Linear to position  12  speed  5
11: Go to Position  23  fast
12: Go Linear to position  13  speed  5
13: Go Linear to position  3  speed  2
14: Open Gripper
15: Go Linear to position  13  speed  2
16: Go Linear to position  23  speed  5
17: WaiT  100  ( 10 ths of seconds )
18: Go Linear to position  13  speed  5
19: Go Linear to position  3  speed  2
20: Close Gripper
21: Go Linear to position  13  speed  2
22: Go Linear to position  23  speed  5
23: Go to Position  98  fast
24: Go to Position  14  fast
25: Go Linear to position  4  speed  2
26: Open Gripper
27: Go Linear to position  14  speed  5
28: Go to Position  98  fast
29: Go to Position  12  fast
```

Figure 9-1

```
4: Jump to  CHECK_PART_AVAILABILITY
5: TAKE_PART:
6: Open Gripper
7: Go to Position  97  fast
8: Go to Position  12  fast
9: Go Linear to position  2  speed  2
10: Close Gripper
11: Go Linear to position  12  speed  5
12: _:
13: Remark :  TAKE PART TO MILL
14: Go to Position  23  fast
15: Go Linear to position  13  speed  5
16: Go Linear to position  3  speed  2
17: Open Gripper
18: Go Linear to position  13  speed  2
19: Go Linear to position  23  speed  5
20: _:
21: Remark :  WAIT FOR MILLING
22: WaiT  100  ( 10 ths of seconds )
23: _:
24: Remark :  REMOVE PART FROM MILL
25: Go Linear to position  13  speed  5
26: Go Linear to position  3  speed  2
27: Close Gripper
28: Go Linear to position  13  speed  2
29: Go Linear to position  23  speed  5
30: _:
31: Remark :  TAKE PART TO BIN
32: Go to Position  98  fast
33: Go to Position  14  fast
34: Go Linear to position  4  speed  2
35: Open Gripper
36: Go Linear to position  14  speed  5
37: _:
38: Remark :  GO HOME
39: Go to Position  98  fast
```

Figure 9-2

2 With the cursor at the first line of the program, double click on the command **Remark** in the Command List. The Remark dialog box will open.

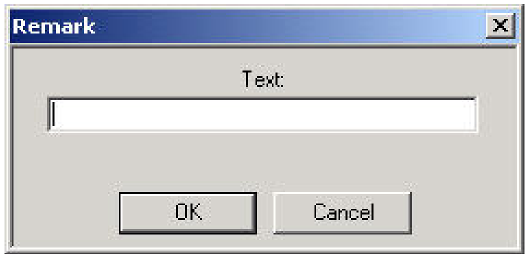


Figure 9-3

Enter the text GET PART FROM FEEDER.

This remark, at line 1, will mark the segment in which the robot goes to pick up a part from the parts feeder.

3 At the end of this segment, at line 12, use the **Label** command to enter an empty line. Since the Label must contain at least one character, enter a single underscore or any simple character, as shown in Figure 9-2.

(Blank lines cannot be entered in a SCORBASE program; the Label or Remark command can be used for entering an empty line.)

4 Now enter the remark TAKE PART TO MILL.

5 Continue entering remarks and empty lines, as shown in Figure 9-2.

6 At the end of the program replace the last two lines with the GO HOME segment, which will send the robot to its home positions.

7 When you are certain that your program is identical to the one shown in Figure 9-2, again perform a save to file USER9.

Q *Explain the difference between Remarks (comments) and Labels in the robot program.*

Task 9-4: Timing the Production Cycle

In this task you will measure the time it takes to complete one production cycle, and the time it takes to complete segments of the cycle. You will then consider ways to reduce the production time.

1 Make sure all axes are at their home position.

Make sure the vise is open.

Make sure there are wax blocks in the parts feeder.

Have a clock or timer ready.

2 Simultaneously start the timer and a single cycle of the robot program.

Note the time as soon as the production cycle ends.

Record your result in the Cycle 1 column of the table ***in the worksheet*** for this activity.

3 Measure the time it takes to complete each segment, as defined below. Start measuring the time as soon as the Single Cycle icon is pressed.

Record your result in the Cycle 2 column of the table *in the worksheet*.

Segment	Time to Complete Task	
	Cycle 1	Cycle 2
Get workpiece from feeder	not timed	
Deliver workpiece to mill	not timed	
Wait for milling operation	not timed	
Remove workpiece from mill	not timed	
Deliver workpiece to collection bin	not timed	
Return to home position	not timed	
TOTAL TIME		

4 Compare the total time results of the two cycles. If they are not similar, rerun the cycle and check your results.

5 Study the robot program and consider which, if any, commands can be changed or deleted in order to reduce production time.

Remember that speed may affect the robot's accuracy.

Task 9-5: Optimizing the Production Cycle

1 Edit SCORBASE program USER9 according to your considerations in the previous task, perhaps at a higher speed.

Do not change the Wait time (10 seconds). It must be assumed that the milling operation is the same for all cycles.

2 Save the edited program as **USER9A**.

3 Make sure all axes are at their home positions.

Make sure the vise is open.

Make sure there are wax blocks in the parts feeder.

Have a clock or timer ready.

4 Simultaneously start the timer and a single cycle of the robot program.

Measure the time it takes to complete each segment. Start measuring the time as soon as the Single Cycle icon is pressed.

Record your result in the Cycle 3 column of the table *in the worksheet*.

5 Again run a complete production cycle to check the total time.

Record your results in the Cycle 4 column of the table *in the worksheet.*

Segment	Time to Complete Task	
	Cycle 3 (Optimized)	Cycle 4 (Optimized)
Get workpiece from feeder		
Deliver workpiece to mill		
Wait for milling operation		
Remove workpiece from mill		
Deliver workpiece to collection bin		
Return to home position		
TOTAL TIME		

6 Compare the time results for each segment of the cycles 3 and 4.

If they are not similar, rerun the cycle and check your results.

Task 9-6: Team Discussion and Review

Q *Compare the segment and total times of the original cycles and the optimized cycles. Describe the results. Calculate the reduction in time as a percentage of the original cycle.*

Task 9-7: Inventory Check and Shut Down

1 Make sure there are no objects in the robot's gripper, milling machine, feeder or sorting bin.

2 Send all axes to their home position.

3 Exit SCORBASE. Turn off Controller-USB, then turn off the SCORBASE computer.

4 Exit the WSLM mill control software. Turn off the mill controller, then turn off the WSLM computer.

5 Make sure all materials required for this activity have been returned to their proper place.

6 Complete the Inventory Check List on the Worksheet for this activity.

Economics

Productivity

Productivity is the output of any aspect of production per unit of input. It is a measure of the output of a worker, machine, or an entire national economy in the creation of goods and services to produce wealth. Output can be measured in output per acre for land, per hour for labor, or as a yearly percentage for capital. A high national productivity typically indicates efficient production of goods and services and a competitive economy.

Division of Labor

Division of labor is the specialization of the functions and roles involved in making the separate parts of a product. It is closely tied to the standardization of production, the introduction and perfection of machinery, and the development of large-scale industry. As a result of mass-production techniques, total production is many times what it would be had each worker made the complete product. Problems created by the division of labor include job monotony, technological unemployment, and eventually chronic unemployment if the economy does not expand quickly enough to reabsorb the displaced labor.

Activity 10

Robot and Mill Handshaking

Objectives

In this activity you will accomplish the following:

- Activate robot controller outputs.
- Send output signals from the robot to the mill.
- Send output signals from the mill to the robot.
- Edit an NC program to include output commands

Skills

In this activity you will develop the following skills:

- Technology: apply technology to task.
- Systems: understand systems, monitor and correct performance.
- Resources: manage time.
- Interpersonal: participate as a member of a team.
- Information: interpret and communicate information.
- Basic: reading and writing.
- Thinking: mental visualization and reasoning.

Materials

In this activity you will need the following materials:

- Controller-USB (Robot not required)
- Computer with SCORBASE software
- spectraLIGHT mill and controller
- Pneumatic vise and spacer
- Wax block
- Computer with WSLM mill control software; EXCHANGE.NC program
- Diskette or personal directory on computer hard disk
- Worksheets for Activity 10

Overview

SCORBOT Robot Outputs

The SCORBOT's digital relay outputs are essentially on/off switches, which are activated by robot program commands. They can also be turned on and off from the SCORBASE Digital Inputs and Digital Outputs dialog bars. These outputs serve the following purposes:

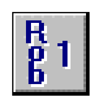
- Signaling to other machines and devices, such as a mill controller, to notify them of status (e.g., free or busy).
- Current switching to operate an external device, such as a buzzer or warning lamp in the FMS cell. For example, when the switch is open, current cannot pass and the lamp does not light; when the switch is closed the lamp lights up.

The robot controller sends signals to the mill controller by means of Output 8.

spectraLIGHT Mill Outputs and Inputs

By now you have probably noticed that the LED for Input 8 on the robot controller is constantly turned on. Input 8 is the channel through which the robot controller receives signals from the mill controller output Rob1 (blue button).

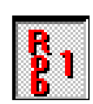
Due to reverse logic in the spectraLIGHT controller, I/O responses in this FMS differ from the typical responses which you may have observed previously. Note the following:



- When spectraLIGHT output Rob1 emits a LOW (off) signal, SCORBOT input 8 turns ON.
- When spectraLIGHT output Rob1 emits a HIGH (on) signal, SCORBOT input 8 turns OFF.

The same reverse logic holds for the milling system inputs.

The mill controller input Rob1 (red button) receives signals from robot controller Output 8. You may also have noticed that this icon is constantly pressed, indicating an input on signal, although robot controller output 8 is off. Again note:



- When SCORBOT outputs 8 emits an OFF signal, spectraLIGHT input Rob1 goes HIGH (turns ON; icon is pressed).
- When SCORBOT output 8 emits an ON signal, spectraLIGHT input Rob1 goes LOW (turns OFF; icon is not pressed).

PROCEDURES

Task 10-1: Inventory and Safety Checks

1. Check whether all materials required for this activity are available at your lab station.
2. Check whether your lab station conforms to the Safety Guidelines for the FMS workcell. In addition:
   - Tie back loose hair and clothing. Remove all jewelry.
   - Put on safety glasses.
   - Get your instructor's permission to turn on the system.
3. Complete the Inventory and Safety Check List on the Worksheet for this activity.

Task 10-2: Preparing the FMS Cell for Operation

1. Turn on the SCORBASE computer, then turn on Controller-USB.

   Start SCORBASE.

   (You do not need to home the axes for the tasks in this activity.)
2. Turn on the milling machine computer, then turn on the mill controller.

   Activate the WSLM mill control software.

   Place a block of wax in the pneumatic vise, clamp it, and initialize the mill. (Set the workpiece origin.)
3. From WSLM, load the program EXCHANGE.NC.

   Run the program. Then open the pneumatic vise.
4. Remove the wax block from the open vise and set it aside.

Task 10-3: Sending Robot Output Signals

In previous activities you used the SCORBASE Digital Inputs dialog bar to simulate (force) input signals to the robot controller.

The Output dialog box allows you to send output signals manually, without having to write and execute them in a robot program.

1. If the Digital Outputs dialog bar is not already on the screen, select **View | Dialog Bars | Digital Output**.
2. Click the box for Output 1. The box will light up. An output signal is being sent.

   Look at the Output 1 LED on the robot controller. It should also be lit.

3 Again click the checkbox for Output 1.The box will darken. The output is off. The controller LED should now be off.

4 Repeat Steps 2 and 3, but this time turn output 2 on and off.

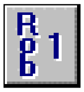
Task 10-4: Sending Output Signals To and From the Mill

1 Make sure you have read the Overview to this activity and understand the reverse logic at work in robot-mill communication.

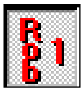
2 Make sure none of the inputs or outputs are turned on in the SCORBASE Digital Inputs and Digital Outputs dialog bars, except Input 8 and possibly output 1. Confirm this by checking the LEDs on the robot controller.

Output 1 represents the status of the gripper. When the gripper is open the output is on. When the gripper is closed the output is off.

In the WSLM toolbar, the blue Rob1 input button should be off (not pressed), while the red Rob1 output button should be on (depressed).



3 In the SCORBASE Digital Outputs dialog bar, click the checkbox for output 8. Look at the red Rob1 input button and at the LED for output 8 on the robot controller.



Click on this checkbox again.

4 In the WSLM toolbar, click on the blue Rob1 output button. Look at the SCORBASE Digital Inputs dialog bar and at the LED for input 8 on the robot controller.

Click on this button again.

Q *Were the output and input signals sent and received according to the reverse logic described in the Overview?*

Task 10-5: Writing an NC Program for I/O Communication

1 Make sure program EXCHANGE.NC appears on the screen:

exchange.nc

```
N1 ; EXCHANGE.NC: spectraLIGHT Mill program
N2 ; MOVE TO LOAD/UNLOAD
N3 ; Use 3"x2"x1.5" machinable wax block
N4 ; Initialize stock to X=0, Y=0, Z=0
N5
N6 G1 Z1.0           ; tool up (1")
N7 G0 X6.5 Y-0.15    ; move to load/unload position
N8 G04 F2            ; pause 2 seconds (load)
N9 G0 X0.2 Y0.2      ; move to start point
N10 G1 Z.1           ; tool down
N11 G04 F5           ; pause 5 seconds (milling)
N12 G1 Z1.0 ;        ; tool up (1")
N13 G0 X6.5 Y-0.15   ; move to load/unload position
N14 G04 F2           ; pause 2 seconds (unload)
N15 M2               ; end of program
```

Figure 10-1

2 Save this program as **USER10.NC** (where USER is replaced by the same four characters which you have been using when saving your SCORBASE programs.)

Do not make any changes to the original program EXCHANGE.NC.

3 In order to edit the NC file, the program must be unlocked.

- Locked programs are displayed on a gray background.
- Unlocked (editable) programs are displayed on a *white* background.

Select **Edit | Lock** to unlock and lock the program you want to edit.

4 Edit program USER10.NC so that it is the same as the program which appears below. The bolded lines are the codes and comments to be added.

NC program files can be edited in the WSLM mill control software by means of the keyboard and by the usual Windows editing functions, such as cut, copy and paste.

Program USER10.NC

N1	THIS FILE FOR spectraLIGHT MILL
N2	USE 3" X 2" X 1.5" MACHINABLE WAX
N3	INITIALIZE STOCK TO X=0, Y=0, Z=0
N4	
N5 M11	**Open Vise**
N6 M26	**Output 1 Low (off) to Robot**
N7 G1 Z1.0	Raise spindle
N8 G0 X6.5 Y-0.15	Move to Load/Unload Position
N9	
M25	**Output 1 High (on) to Robot**
N10 G26	**Wait for Input Low from Robot**
N11 G04 F2	**Pause 2 seconds**
N12 M26	**Output 1 Low (off) to Robot**
N13 M10	**Close Vise**
N14 G04 F2	Pause 2 seconds (load)
N15 G0 X0.2 Y0.2	Move to Workpiece Origin
N16 G1 Z.1	Lower spindle
N17 G04 F5	Pause 5 seconds (milling
N18 G1 Z1.0	Raise spindle
N19 G0 X6.5 Y-0.15	Move to Load/Unload Position
N20 G04 F2	Pause 2 seconds (unload)
N21 M2	End of Program

Task 10-6: Executing a Program with Mill-Robot I/O Communication

You have just written the beginning of the FMS program for the mill.

In this program the vise is opened (M11) and sent to the load/unload position. At that point a signal is sent to the robot.

Before the mill can close the vise and move the workpiece, the mill must know that the robot has placed a part in the vise. The program you have written includes a command which causes the mill to wait (G26) until an input signal from the robot indicates that the part is in the vise and the robot has cleared the mill.

Once the mill receives the input signal from the robot, the workpiece is moved to the spindle. In this program no milling is performed. The mill simply pauses for 5 seconds before the vise is sent back to the load/unload position.

In this task you will run the milling program without using an actual workpiece. In addition, you will manually send a signal from SCORBOT Output 8 to the mill.

1 Make sure there is no workpiece in the vise.

2 Run program USER10.NC from line 1.

Watch the SCORBASE Digital Inputs and Digital Outputs dialog boars.

Watch the LEDs on the robot controller.

3 Program execution will pause when the following line is reached:

```
G26     ; Wait for Input Low (wait for Robot output on)
```

Click the checkbox for Output 8 in the SCORBASE Digital Output dialog bar.

The program should now complete its execution.

4 Run the program again. Note that the command to move the vise to the load/unload position will have no effect if the vise is already in position.

Task 10-7: Team Discussion and Review

Q *Draw a flow chart which illustrates the commands which synchronize the mill with the robot. (Hint: you can peek at the complete flow chart for the FMS operation which appears in Activity 12.)*

Task 10-8: Inventory Check and Shut Down

1 Make sure there are no objects in the robot's gripper, milling machine, feeder or sorting bin.

2 Send all axes to their home position (if the robot has been moved).

3 Exit SCORBASE. Turn off Controller-USB, then turn off the SCORBASE computer.

4 Exit the WSLM mill control software. Turn off the mill controller, then turn off the WSLM computer.

5 Make sure all materials required for this activity have been returned to their proper place.

6 Complete the Inventory Check List on the Worksheet for this Activity.

History

Robotics

1982: A robot is used to clean up after a nuclear fuel spill at an atomic power plant.

1993: The University of Michigan's CARMEL (computer-aided robotics for maintenance, emergency, and life support) robot wins first place at the 1992 Robot Competition sponsored by the American Association for Artificial Intelligence (AAAI).

1994: Dante II, a tethered walking robot developed at Carnegie Mellon University's Field Robotics Center, descended into Mt. Spurr, a volcano on the Aleutian Range in Alaska. High-temperature, fumarole gas samples are prized by volcanic science, yet their sampling poses significant challenge. In 1993, eight volcanologists were killed in two separate events while sampling and monitoring volcanoes. The use of robotic explorers, such as Dante II, opens a new era in field techniques by enabling scientists to remotely conduct research and exploration.

July 1997: Sojourner, a 25-pound, six-wheeled robotic explorer was deployed and roamed across an ancient Martian flood plain after the Mars Pathfinder lander touched down on the planet's surface.

Activity 11

More Robot and Mill Handshaking

OBJECTIVES

In this activity you will accomplish the following:

- Write a robot program which synchronizes the robot's movements with the mill's operations.
- Simultaneously execute the robot and mill programs and observe their handshaking.

SKILLS

In this activity you will develop the following skills:

- Technology: apply technology to task.
- Systems: understand systems, monitor and correct performance.
- Resources: manage time.
- Interpersonal: participate as a member of a team.
- Information: interpret and communicate information.
- Basic: reading and writing.
- Thinking: reasoning and problem solving.
- Personal: responsibility and self-management.

MATERIALS

In this activity you will need the following materials:

- SCORBOT-ER 4u robot and Controller-USB
- Computer with SCORBASE software
- spectraLIGHT mill and controller
- Pneumatic vise and spacer
- Wax blocks
- Computer with WSLM mill control software
- Diskette or personal directory on computer hard disk
- Worksheets for Activity 11

OVERVIEW

NC Codes for Mill-Robot Communication

In the previous activity you programmed the NC codes which enable mill communication with the robot. The specific NC codes used for communication between the SCORBOT robot and spectraLIGHT mill are as follows:

G25: Wait for High signal (wait for SCORBOT output to be OFF)

G26: Wait for Low signal (wait for SCORBOT output to be ON)

M25: Transmit High signal (turn SCORBOT input OFF)

M26: Transmit Low signal (turn SCORBOT input ON)

The mill outputs a low signal (SCORBOT controller input stays on) when in steady state, and even when the system is shut off. Mill output signals also revert to low after an emergency stop.

Therefore, to ensure that the robot receives and responds appropriately to the intended signals from the mill, only mill output HIGH signals (M25) are used for handshaking with the robot. In other words, the robot is programmed to respond only to HIGH signals from the mill.

M26 codes are used to ensure that the mill outputs a low signal which maintains the SCORBOT input in its ON state.

In this activity you will program the SCORBASE commands which will enable the robot to communicate with the mill.

PROCEDURES

Task 11-1: Inventory and Safety Checks

1. Check whether all materials required for this activity are available at your lab module.
2. Check whether your lab module conforms to the Safety Guidelines for the FMS workcell. In addition:
   - Tie back loose hair and clothing. Remove all jewelry.
   - Put on safety glasses.
   - Get your instructor's permission to turn on the system.
3. Complete the Inventory and Safety Check List on the Worksheet for this activity.

Task 11-2: Preparing the FMS Cell for Operation

1. Turn on the SCORBASE computer, then turn on controller-USB.

   Activate SCORBASEpro software.

   Home all the axes.
2. Turn on the milling machine computer, then turn on the mill controller.

   Activate the WSLM mill control software.

   Place a wax block in the pneumatic vise, clamp it and initialize the mill. (Set the workpiece origin.)
3. From WSLM, load the program EXCHANGE.NC.

   Run the program. Then open the pneumatic vise.
4. Remove the wax block from the open vise and set it aside.

Task 11-3: Editing the Robot Program for Communication with the Mill

1. From SCORBASE, open **USER8**.

   Immediately Save As **USER11**.

```
1: CHECK_PART_AVAILABILITY:
2: If Input 7 on jump to TAKE_PART
3: Jump to CHECK_PART_AVAILABILITY
4: TAKE_PART:
5: Open Gripper
6: Go to Position 97 fast
7: Go to Position 12 fast
8: Go Linear to position 2 speed 2
9: Close Gripper
10: Go Linear to position 12 speed 5
11: Go to Position 23 fast
12: Go Linear to position 13 speed 5
13: Go Linear to position 3 speed 2
14: Open Gripper
15: Go Linear to position 13 speed 2
16: Go Linear to position 23 speed 5
17: WaiT 100 [10 ths of seconds]
18: Go Linear to position 13 speed 5
19: Go Linear to position 3 speed 2
20: Close Gripper
21: Go Linear to position 13 speed 2
22: Go Linear to position 23 speed 5
23: Go to Position 98 fast
24: Go to Position 14 fast
25: Go Linear to position 4 speed 2
26: Open Gripper
27: Go Linear to position 14 speed 5
28: Go to Position 98 fast
29: Go to Position 12 fast
```

Figure 11-1: USER8

```
1: CHECK_PART_AVAILABILITY:
2: If Input 7 on jump to TAKE_PART
3: Jump to CHECK_PART_AVAILABILITY
4: TAKE_PART:
5: Open Gripper
6: Go to Position 97 fast
7: Go to Position 12 fast
8: Go Linear to position 2 speed 2
9: Close Gripper
10: Go Linear to position 12 speed 5
11: Go to Position 23 fast
12: _:
13: WAIT_FOR_MILL_READY:
14: If Input 8 off jump to PLACE_PART_IN_VIS
15: Jump to WAIT_FOR_MILL_READY
16: PLACE_PART_IN_VISE:
17: _:
18: Go Linear to position 13 speed 5
19: Go Linear to position 3 speed 2
20: Open Gripper
21: Go Linear to position 13 speed 2
22: Go Linear to position 23 speed 5
23: _:
24: Turn on output 8
25: WaiT 100 [10 ths of seconds]
26: Turn off output 8
27: _:
28: Go to Position 98 fast
```

Figure 11-2: USER11, after editing

2 Edit program USER11 as follows. Figure 11-2 shows how program USER11 will appear after you edit it.

- Delete lines 18 through 29.
- Bring the cursor to line 12, and insert the following conditional program loop:

```
12: _:
13: WAIT_FOR_MILL_READY:
14: If Input 8 off jump to PLACE_PART_IN_VIS
15: Jump to WAIT_FOR_MILL_READY
16: PLACE_PART_IN_VISE:
17: _:
```

Figure 11-3

- Before the Wait command, insert an empty line and then a command to turn on output 8.
- After the Wait command, add a command to turn off output 8, and another empty line.

```
21: Go Linear to position  13  speed  2
22: Go Linear to position  23  speed  5
23: _:
24: Turn on output  8
25: WaiT  100  [10 ths of seconds]
26: Turn off output  8
```

Figure 11-4

- At the end of the program, make sure you have a command which will send the robot to position 98.

3 When you are certain that your program is identical to the one shown in Figure 11-2, again perform a save to file USER11.

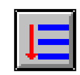
Task 11-4: Testing the Robot Program — Off-Line

1 Select Options | Off-Line.

Make sure Control On appears in the status line at the bottom of the screen. if not, click on the Control On icon.

Make sure Input 8 is on. All other inputs and outputs should be off.

2 Start execution of a single program cycle.



3 When the program pauses at CHECK PART AVAILABILITY, go to the Digital Inputs dialog bar, right-click the Input 7 box and choose **Force**.

Then click the **Input** box for Input 7.

The dialog box will now appear as shown in Figure 11-5, and program execution will continue.

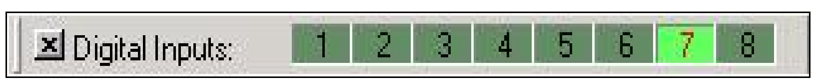


Figure 11-5

4 When the program pauses at If Input 8 off ... go to the Digital Inputs dialog bar, right-click the Input 8 box and choose **Force**.

Then click the Input 8 box to turn it off.

Note that this is a simulated state only. The LED for Input 8 on the robot controller remains lit.

Program execution will continue and finish.

Task 11-5: Testing the Robot Program — Dry Run

1 In the Digital Inputs and Digital Outputs dialog bars, make sure all boxes are cleared, except for Input 8. Make sure all I/O LEDS on the robot controller are turned off, except for Input 8.

2 Make sure there no parts in the robot's gripper, milling machine, feeder or sorting bin.

Make sure the pneumatic vise is at the robot load/unload position (Program EXCHANGE.NC has been executed).

3 Select Options | **On-Line**.

4 Home all the axes.

5 Start execution of one cycle of program USER11.

Simulate the input states from the Digital Inputs & Outputs dialog box, as you did in the previous task.

Task 11-6: Running the Robot Program with Materials

1 In the Digital Inputs and Digital Outputs dialog bars, make sure all checkboxes are cleared, except for Input 8. Make sure all I/O LEDS on the robot controller are turned off, except for Input 8.

2 Make sure there no parts in the robot's gripper, milling machine or sorting bin.

Place one block of wax in the parts feeder. Input 7 will turn on.

Make sure the pneumatic vise is at the robot load/unload position (EXCHANGE.NC program has been executed).

Make sure the vise is open.

3 Start execution of one cycle of program USER11.

Simulate the state of Input 8 from the Digital Inputs & Outputs dialog box, as you did in the previous task.

Task 11-7: Running Mill and Robot Programs Simultaneously—Dry Run

1 Make sure there no parts in the robot's gripper, milling machine, feeder or sorting bin.

From WSLM, load the program USER10.NC.

```
N1 ; MILL10.NC: spectraLIGHT Mill program
N2 ; ROBOT-MILL HANDSHAKE
N3 ; Use 3"x2"x1.5" machinable wax block
N4 ; Initialize stock to X=0, Y=0, Z=0
N5
N6 M10              ; Open Vise
N7 M26              ; Output 1 Low (off) to Robot
N8 G1 Z1.0          ; tool up (1")
N9 G0 X6.5 Y-0.15   ; move to load/unload position
N10 M25             ; Output 1 High (on) to Robot
N11 G26             ; Wait for Input Low from Robot
N12 G04 F2          ; pause 2 seconds
N13 M26             ; Output 1 Low (off) to Robot
N14 M11             ; Close Vise
N15 G04 F2          ; pause 2 seconds (load)
N16 G0 X0.2 Y0.2    ; move to start point
N17 G1 Z.1          ; tool down
N18 G04 F5          ; pause 5 seconds (milling)
N19 G1 Z1.0 ;       ; tool up (1")
N20 G0 X6.5 Y-0.15; move to load/unload position
N21 G04 F2          ; pause 2 seconds (unload)
N22 M2              ; end of program
```

Figure 11-6

This is the mill program you wrote in the previous activity. When run concurrently with the robot program which you have just written, the movements and operation of the two systems will be synchronized

2 From the WSLM mill control software start execution of program USER10.NC from line 1.

Watch the SCORBASE Digital Inputs and Digital Outputs dialog bars and the LEDs on the robot controller. Watch the robot and the mill.

3 From SCORBASE, start execution of a single cycle of program USER11.

Since there are no parts in the feeder, use the Digital Inputs and Digital Outputs dialog bars to simulate (force) Input 7 on.

The program will complete execution.

4 In the Digital Inputs and Digital Outputs dialog bars, make sure all checkboxes are cleared, except for Input 8. Make sure all I/O LEDs on the robot controller are turned off, except for Input 8.

Task 11-8: Running Mill and Robot Programs Simultaneously with Part

1 Place one wax block in the parts feeder.

Make sure there no parts in the robot's gripper, milling machine or sorting bin.

2 From the WSLM mill control software start execution of program USER10.NC from line 1.

3 From SCORBASE, start execution of a single cycle of program USER11.WS.

Task 11-9: Team Discussion and Review

Q *In this activity the robot program concludes with commands which send the robot away from the mill. Should the robot wait at the mill for the part to be returned to the load/unload position? Describe an application which explains your answer.*

Task 11-10: Inventory Check and Shut Down

1. Make sure there are no objects in the robot's gripper, milling machine, feeder or sorting bin.
2. Send all axes to their home position.
3. Exit SCORBASE. Turn off Controller-USB, then turn off the SCORBASE computer.
4. Exit the WSLM mill control software. Turn off the mill controller, then turn off the WSLM computer.
5. Make sure all materials required for this activity have been returned to their proper place.
6. Complete the Inventory Check List on the Worksheet for this activity.

Economics

Robot Orders Top $1 Billion in 1996

U.S. based robotics companies received more than $1 billion in new orders in 1996, surpassing the billion-dollar mark for the first time and smashing records set in 1995 by nearly 25%.

“New robot orders have more than doubled since 1992, as the robotics industry continues its powerful growth in both automotive and non-automotive markets,” said Donald A. Vincent, Executive Vice President of Robotic Industries Association (RIA). He cited strong demand in material handling, spot welding, arc welding and coating applications as the key factor in helping the robotics industry set new records in 1996. He also pointed to new applications, such as the award-winning automated flexible feeding process at Honeywell Home & Building Control, as evidence that users continue to find innovative ways to successfully apply robots.

“Honeywell applied robots, machine vision, and flexible feeding technologies to a process it had been trying to automate for a decade, but wasn't able to cost justify with traditional automation approaches. Advances in robots and vision proved to be the answer, and the company fully justified its investment in just over a year,” explained Vincent.

Vincent thinks orders should remain strong in 1997, fueled in part by the Robots & Vision Show in Detroit in May 1997. “The show brings together nearly every major robotics supplier to showcase their newest products. Users take this opportunity to comparison shop and exhibitors often cite an immediate surge in orders following the show,” he said.

http://www.robotics.org/htdocs/robot.html

RIA estimates that some 78,000 robots are now at work in U.S. factories, placing the U.S. second in the world to Japan.

http://www.robotics.org/htdocs/2qtrstats.html

Activity 12

Completing the FMS Programs

OBJECTIVES

In this activity you will accomplish the following:

- ♦ Complete the NC program which synchronizes the mill with the robot.
- ♦ Complete the SCORBASE program which synchronizes the robot with the mill.

SKILLS

In this activity you will develop the following skills:

In this activity you will develop the following skills:

- ♦ Technology: apply technology to task.
- ♦ Systems: understand systems, monitor and correct performance.
- ♦ Resources: manage time.
- ♦ Interpersonal: participate as a member of a team.
- ♦ Information: interpret and communicate information.
- ♦ Basic: reading and writing.
- ♦ Thinking: reasoning and problem solving.
- ♦ Personal: responsibility and self-management.

MATERIALS

In this activity you will need the following materials:

- ♦ Controller-USB (Robot operation not required)
- ♦ Computer with SCORBASE software
- ♦ spectraLIGHT controller (Mill operation not required)
- ♦ Computer with WSLM mill control software
- ♦ Diskette or personal directory on computer hard disk
- ♦ Worksheets for Activity 12

OVERVIEW

Mill and Robot Program Editing

In this activity you will finish writing and editing the NC and SCORBASE program which allows the mill and robot controllers to communicate and synchronize the operation of the mill and the robot.

In the tasks in this activity you will combine existing programs in order to create the complete programs for the FMS operation:

- In SCORBASE you will use program USER6 and USER8 to create the robot program **USER12**.
- In WSLM you will combine MILLA.NC and USER10 to create the mill program **USER12**.

Both SCORBASE and the WSLM mill control software use the usual Windows functions which allow you to edit these files. For example:

- Cut: Deletes selected text or lines from the program file and places it on the clipboard.
- Copy: Places a copy of selected text or lines from the program file on the clipboard.
- Paste: Inserts the contents of the clipboard into the program file.

In addition, both software programs allow you to have multiple program files open. This will allow you to mark and copy blocks of program commands from one file to another.

Remember that in order to edit the NC file, the program must be unlocked (appears on a white background). From the Edit menu, click on **Lock** to unlock and lock the program you want to edit.

Also be certain that the program file you want to save is the currently active file.

The flowchart in Figure 12-1 illustrates the program commands which synchronize the robot and the mill. This flow chart will help you understand the programs you are creating.

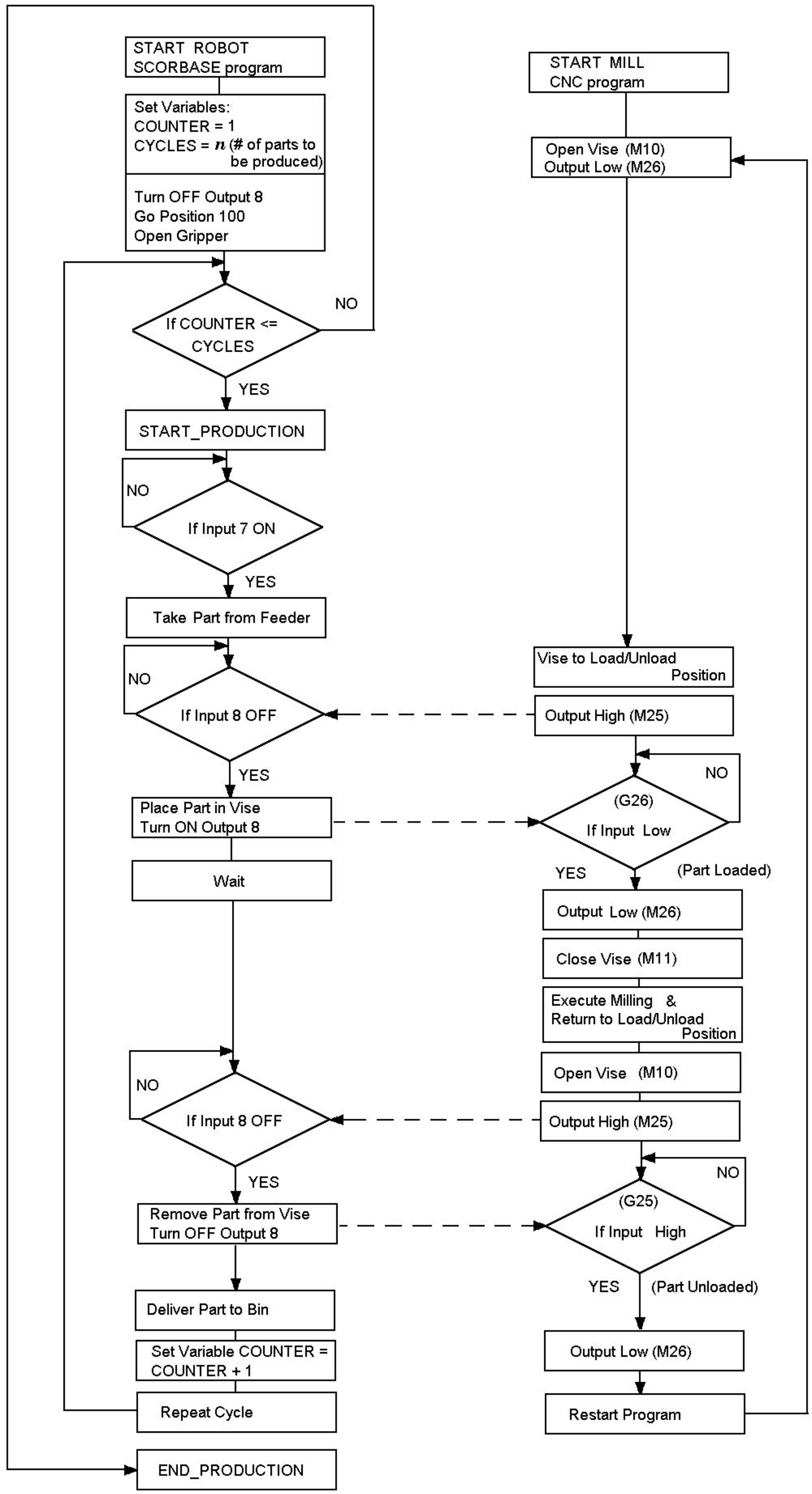

START ROBOT
SCORBASE program
Set Variables:
COUNTER = 1
CYCLES = n (# of parts to be produced)
Turn OFF Output 8
Go Position 100
Open Gripper
If COUNTER <=
CYCLES
NO
YES
START_PRODUCTION
NO
If Input 7 ON
YES
Take Part from Feeder
NO
If Input 8 OFF
YES
Place Part in Vise
Turn ON Output 8
Wait
NO
If Input 8 OFF
YES
Remove Part from Vise
Turn OFF Output 8
Deliver Part to Bin
Set Variable COUNTER =
COUNTER + 1
Repeat Cycle
END_PRODUCTION
START MILL
CNC program
Open Vise (M10)
Output Low (M26)
Vise to Load/Unload
Position
Output High (M25)
NO
(G26)
If Input Low
YES
(Part Loaded)
Output Low (M26)
Close Vise (M11)
Execute Milling &
Return to Load/Unload
Position
Open Vise (M10)
Output High (M25)
NO
(G25)
If Input High
YES
(Part Unloaded)
Output Low (M26)
Restart Program

Figure 12-1

PROCEDURES

Task 12-1: Inventory and Safety Checks

1 Check whether all materials required for this activity are available at your lab station.

2 Check whether your lab station conforms to the Safety Guidelines for the FMS workcell. In addition:

- Tie back loose hair and clothing. Remove all jewelry.
- Put on safety glasses.
- Get your instructor's permission to turn on the system.

3 Complete the Inventory and Safety Check List on the Worksheet for this activity

Task 12-2: Preparing the FMS Cell for Operation

1 Turn on the SCORBASE computer, then turn on Controller-USB.

Activate SCORBASE.

You do not need to home the axes for the tasks in this activity.

2 Turn on the milling machine computer, then turn on the controller.

Activate the WSLM mill control software.

You do not need to initialize the mill for the tasks in this activity.

Task 12-3: Completing the NC Program for FMS Operation

1 From WSLM, load two NC programs: USER10 and MILLA.

2 Save program USER10 as program USER12.NC.

Unlock program USER12.NC if it is locked.

3 Using the WSLM editing tools, edit program USER12.NC so that it appears exactly like the program shown in Figure12-2.

The instructions which follow will guide you through the editing task.

- Leave lines N1-N17 in the program.
- Delete line N18, which commands a 5 second pause.

  Insert (copy) the engraving task from file MILLA.NC (lines N7-N20) into USER12.NC
- Leave lines N19-N21 in the program.
- Delete line N22

Add the final commands for mill-robot communication:

M10	; open vise
M25	; output 1 high (turn off Robot input)
G25	; wait for input high (wait for Robot output off)
G4 F2	; pause 2 seconds
M26	; output 1 low (turn on Robot input)

Your program should now read as follows.

```
N1 ; MILL12.NC: spectraLIGHT Mill program
N2 ; ROBOT-MILL SYNCHRONIZATION
N3 ; Use 3"x2"x1.5" machinable wax block
N4 ; Initialize stock to X=0, Y=0, Z=0
N5
N6 M10              ; Open Vise
N7 M26              ; Output 1 Low (off) to Robot
N8 G1 Z1.0          ; tool up (1")
N9 G0 X6.5 Y-0.15   ; move to load/unload position
N10 M25             ; Output 1 High (on) to Robot
N11 G26             ; Wait for Input Low from Robot
N12 G04 F2          ; pause 2 seconds
N13 M26             ; Output 1 Low (off) to Robot
N14 M11             ; Close Vise
N15 G04 F2          ; pause 2 seconds (load)
N16 G0 X0.2 Y0.2    ; move to start point
N17 G1 Z.1          ; tool down

N7 X.5 Y.5        ; move to 1st point
N8 M5 S1500       ; spindle on 1500rpm
N9 G1 Z-0.7 F8    ; tool down, 8ipm
N10 X2.5          ; 2nd point
N11 Y1.5          ; 3rd point
N12 X.5           ; 4th point
N13 Y.5           ; return to 1st point
N14 X2.5 Y1.5     ; 1st diagonal line
N15 Y.5           ; return to 2nd point
N16 X.5 Y1.5      ; 2nd diagonal line

N19 G1 Z1.0 ;       ; tool up (1")
N20 G0 X6.5 Y-0.15; move to load/unload position
N21 G04 F2          ; pause 2 seconds (unload)

    M10               ; open vise
    M25               ; output 1 high (on) to robot
    G25               ; wait for input high from robot
    G04 F2            ; pause 2 seconds
    M26               ; output 1 low (off) to robot
    M47               ; start new cycle
```

Figure 12-2

4 Delete any blank lines (but not N5) in the program.

When you are certain that your program is the same as the one shown in Figure 12-2, select **Edit | Renumber**. A dialog box opens, as shown in Figure 12-3. Accept these settings.

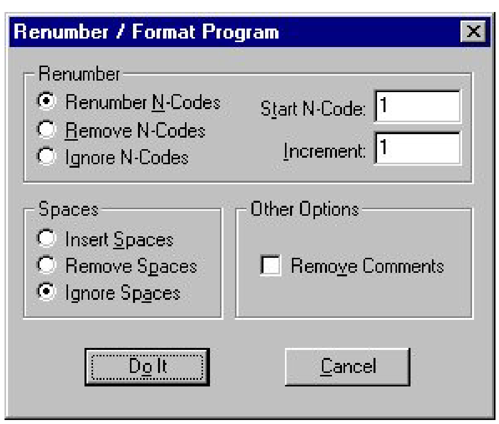


Figure 12-3

5 After renumbering the lines, your program should appear as shown in Figure 12-4. When you are certain that your program is identical to the one shown here, again perform a save to file USER12.NC.

```
N1 ; MILL12.NC: spectraLIGHT Mill program
N2 ; ROBOT-MILL SYNCHRONIZATION
N3 ; Use 3"x2"x1.5" machinable wax block
N4 ; Initialize stock to X=0, Y=0, Z=0
N5
N6 M10              ; Open Vise
N7 M26              ; Output 1 Low (off) to Robot
N8 G1 Z1.0          ; tool up (1")
N9 G0 X6.5 Y-0.15   ; move to load/unload position
N10 M25             ; Output 1 High (on) to Robot
N11 G26             ; Wait for Input Low from Robot
N12 G04 F2          ; pause 2 seconds
N13 M26             ; Output 1 Low (off) to Robot
N14 M11             ; Close Vise
N15 G04 F2          ; pause 2 seconds (load)
N16 G0 X0.2 Y0.2    ; move to start point
N17 G1 Z.1          ; tool down
N18 X.5 Y.5       ; move to 1st point
N19 M5 S1500      ; spindle on 1500rpm
N20 G1 Z-0.7 F8   ; tool down, 8ipm
N21 X2.5          ; 2nd point
N22 Y1.5          ; 3rd point
N23 X.5           ; 4th point
N24 Y.5           ; return to 1st point
N25 X2.5 Y1.5     ; 1st diagonal line
N26 Y.5           ; return to 2nd point
N27 X.5 Y1.5      ; 2nd diagonal line
N28 G1 Z1.0 ;       ; tool up (1")
N29 G0 X6.5 Y-0.15; move to load/unload position
N30 G04 F2          ; pause 2 seconds (unload)
N31 M10             ; open vise
N32 M25             ; output 1 high (on) to robot
N33 G25             ; wait for input high from robot
N34 G04 F2          ; pause 2 seconds
N35 M26             ; output 1 low (off) to robot
N36 M47             ; start new cycle
```

Figure 12-4: Program MILL12.NC

Task 12-4: Completing the Robot Program for FMS Operation

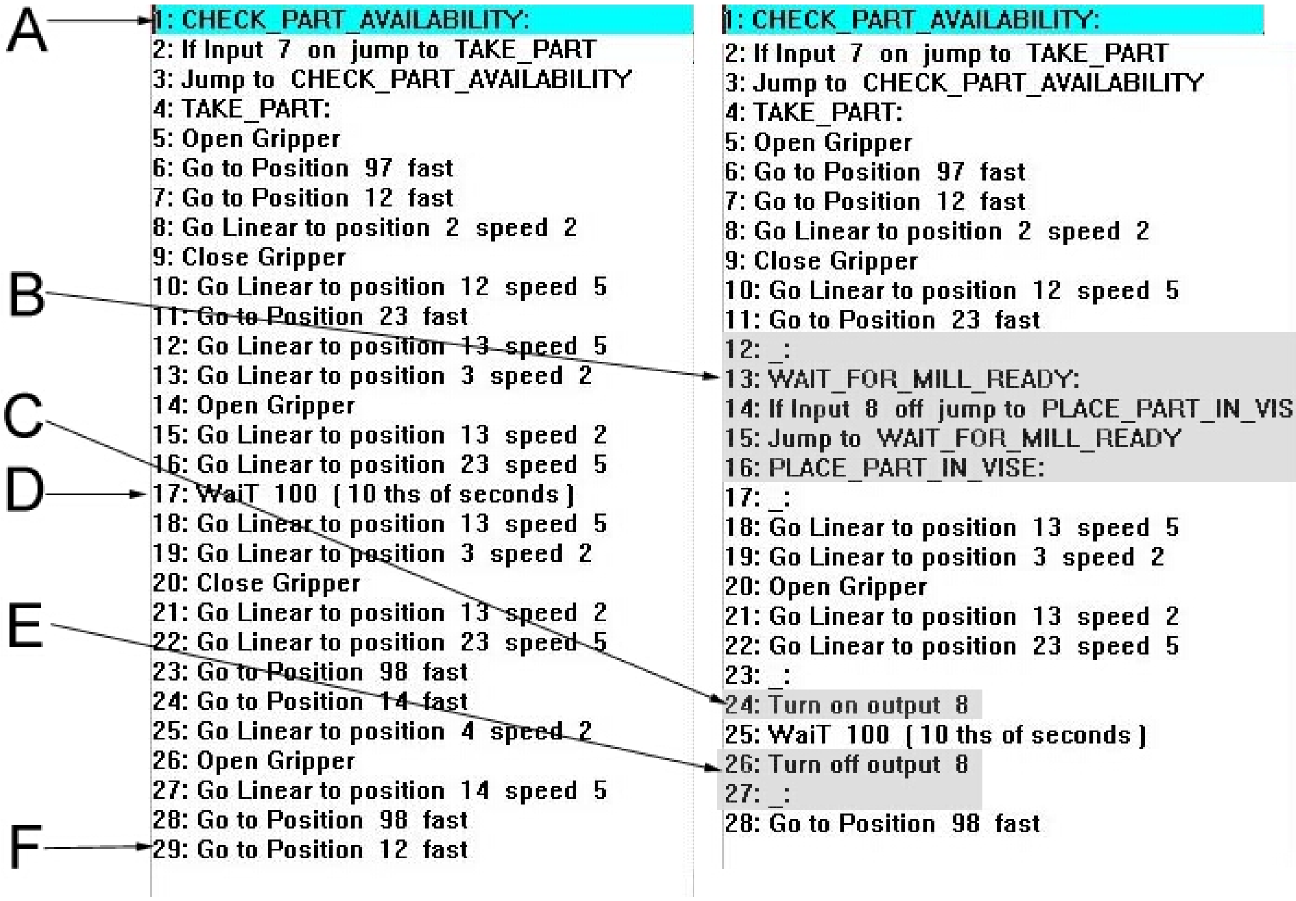
1 In SCORBASE load two program files: USER8 and USER11.

2 Save program USER8 as USER12.

3 Using the SCORBASE editing tools, edit program USER12 according to the instructions and explanations which follow.

Figures 12-5 and 12-6 show how program USER8 / USER11 is edited and transformed into a complete FMS robotic program.

Figure 12-12 shows the finished program




```
1: CHECK_PART_AVAILABILITY:
2: If Input 7 on jump to TAKE_PART
3: Jump to CHECK_PART_AVAILABILITY
4: TAKE_PART:
5: Open Gripper
6: Go to Position 97 fast
7: Go to Position 12 fast
8: Go Linear to position 2 speed 2
9: Close Gripper
10: Go Linear to position 12 speed 5
11: Go to Position 23 fast
12: Go Linear to position 13 speed 5
13: Go Linear to position 3 speed 2
14: Open Gripper
15: Go Linear to position 13 speed 2
16: Go Linear to position 23 speed 5
17: WaiT 100 [10 ths of seconds]
18: Go Linear to position 13 speed 5
19: Go Linear to position 3 speed 2
20: Close Gripper
21: Go Linear to position 13 speed 2
22: Go Linear to position 23 speed 5
23: Go to Position 98 fast
24: Go to Position 14 fast
25: Go Linear to position 4 speed 2
26: Open Gripper
27: Go Linear to position 14 speed 5
28: Go to Position 98 fast
29: Go to Position 12 fast
```

Figure 12-5

```
1: CHECK_PART_AVAILABILITY:
2: If Input 7 on jump to TAKE_PART
3: Jump to CHECK_PART_AVAILABILITY
4: TAKE_PART:
5: Open Gripper
6: Go to Position 97 fast
7: Go to Position 12 fast
8: Go Linear to position 2 speed 2
9: Close Gripper
10: Go Linear to position 12 speed 5
11: Go to Position 23 fast
12: _:
13: WAIT_FOR_MILL_READY:
14: If Input 8 off jump to PLACE_PART_IN_VIS
15: Jump to WAIT_FOR_MILL_READY
16: PLACE_PART_IN_VISE:
17: _:
18: Go Linear to position 13 speed 5
19: Go Linear to position 3 speed 2
20: Open Gripper
21: Go Linear to position 13 speed 2
22: Go Linear to position 23 speed 5
23: _:
24: Turn on output 8
25: WaiT 100 [10 ths of seconds]
26: Turn off output 8
27: _:
28: Go to Position 98 fast
```

Figure 12-6

A Insert the 12 lines shown in Figure 12-7 at the beginning of the program.

```
1: INITIALIZATION:
2: Set Variable COUNTER = 0
3: Set Variable CYCLES = 2
4: Turn off output 8
5: Go to Position 98 fast
6: Open Gripper
7: _:
8: REPEAT:
9: IF COUNTER<CYCLES jump to START_PRODUCTION
10: Jump to END_PRODUCTION
11: START_PRODUCTION:
12: _:
```

Figure 12-7

The explanations below will help you understand and write some of the command lines.

1: INITIALIZATION:

A label, followed by a set of commands which defines variables, and resets the robot position and the state of input 8. If the program has been aborted and restarted, these commands ensure that the robot system is properly set for operation.

2: Set Variable COUNTER = 0

A variable called COUNTER is used to ensure the end of the production after the specified number of CYCLES.

Select **Set Variable** from the Command List and enter (Name) **COUNTER** and (Value or Expression) **0**.

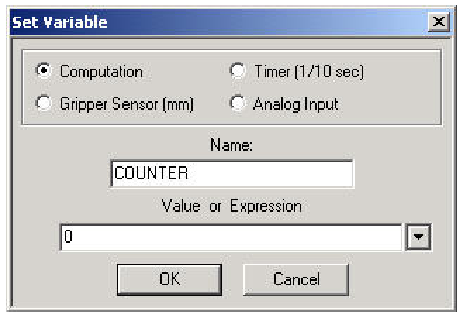


Figure 12-8

3: Set Variable CYCLES = 2

A variable called CYCLES is used for defining the number of the parts to be milled. Select **Set Variable** from the Command List and enter (Name) **CYCLES** and (Value or Expression) **2**.

9: IF COUNTER<CYCLES jump to START_PRODUCTION

A conditional jump command is used to direct the program flow according to the value of COUNTER. Select **If Jump** from the Command List and enter (If) **COUNTER<CYCLES**, and (Jump to) **START_PRODUCTION**

10: Jump to END_PRODUCTION

An unconditional jump command is used to direct the program flow. Select Jump To from the Command List and enter START PRODUCTION

B Copy and paste the 5 lines (B) from program USER11 into program USER12 at line 24.

C Add the command Turn on output 8 into program USER12 at line 34.

D Add the 5 lines shown in Figure 12-9 into program USER12 at line 36.

```
36: _:
37: WAIT_FOR_MILLING:
38: If Input 8 off jump to TAKE_FINISHED_PART
39: Jump to WAIT_FOR_MILLING
40: TAKE_FINISHED_PART:
```

Figure 12-9

E Copy and paste the 2 lines (E) from program USER11 into program USER12 at line 46.

F Add the 3 lines shown in Figure 12-10 to the end of the program.

```
55: Set Variable COUNTER = COUNTER+1
56: Jump to REPEAT
57: END_PRODUCTION:
```

Figure 12-10

55: Set Variable COUNTER = COUNTER+1

Increments the value of the counter, to indicate that a production cycle has been completed. Select Set Variable from the Command List and enter (Name) **COUNTER** and (Value or Expression) **COUNTER+1**.

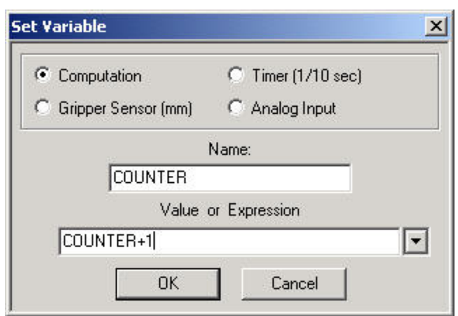


Figure 12-11

9 When you are certain that your program is identical to the one shown in Figure 12-12, again perform a save to file USER12.

```
C:\SBW_ER4\LEVEL3\USER12.SB3
1: INITIALIZATION:
2: Set Variable  COUNTER  =  0
3: Set Variable  CYCLES  =  2
4: Turn off output  8
5: Go to Position  98   fast
6: Open Gripper
7: _:
8: REPEAT:
9: IF  COUNTER<CYCLES  jump to  START_PRODUCTION
10: Jump to  END_PRODUCTION
11: START_PRODUCTION:
12: _:
13: CHECK_PART_AVAILABILITY:
14: If Input  7  on  jump to  TAKE_PART
15: Jump to  CHECK_PART_AVAILABILITY
16: TAKE_PART:
17: Open Gripper
18: Go to Position  97  fast
19: Go to Position  12  fast
20: Go Linear to position  2  speed  2
21: Close Gripper
22: Go Linear to position  12  speed  5
23: Go to Position  23  fast
24: _:
25: WAIT_FOR_MILL_READY:
26: If Input  8  off  jump to  PLACE_PART_IN_VISE
27: Jump to  WAIT_FOR_MILL_READY
28: PLACE_PART_IN_VISE:
29: Go Linear to position  13  speed  5
30: Go Linear to position  3  speed  2
31: Open Gripper
32: Go Linear to position  13  speed  2
33: Go Linear to position  23  speed  5
34: Turn on output  8
35: WaiT  100  ( 10 ths of seconds )
36: _:
37: WAIT_FOR_MILLING:
38: If Input  8  off  jump to  TAKE_FINISHED_PART
39: Jump to  WAIT_FOR_MILLING
40: TAKE_FINISHED_PART:
41: Go to Position  13  speed  5
42: Go Linear to position  3  speed  2
43: Close Gripper
44: Go Linear to position  13  speed  2
45: Go Linear to position  23  speed  5
46: Turn off output  8
47: _:
48: Go to Position  98  fast
49: Go to Position  14  fast
50: Go Linear to position  4  speed  2
51: Open Gripper
52: Go Linear to position  14  speed 5
53: Go to Position  98  fast
54: Go to Position  12  fast
55: Set Variable  COUNTER  =  COUNTER+1
56: Jump to  REPEAT
57: END_PRODUCTION:
```

Figure 12-12: Program USER12.WS

Task 12-5: Team Discussion and Review

Q *What is the difference between the way the mill and robot are programmed to respond to input signals?*

Q *How many parts can be milled by executing SCORBASE program USER12?*

Task 12-6: Inventory Check and Shut Down

1. Exit SCORBASE. Turn off Controller-USB, then turn off the SCORBASE computer.
2. Exit the WSLM mill control software. Turn off the mill controller, then turn off the WSLM computer.
3. Make sure all materials required for this activity have been returned to their proper place.
4. Complete the Inventory Check List on the Worksheet for this activity.

Industrial Applications

Workspace

The workspace required for a task is determined by the furthest point that the robot must reach in each direction. Figure 12-13 shows a typical robot workcell the robot takes an object from conveyor belt A, places it on the loading bay of an inspection machine B and then takes the object from the loading bay and puts it into a packing case on pallet C. If the inspection machine finds the object to be faulty, the robot discards it in the reject bin D. The distance between the robot and A, B, C and D determines the size of the work space.

The shape of the workspace is also determined by the layout (or position) of the points that must be reached. In Figure 12-13, the points A, B, C and D are the only points that need to be reached and they are laid out in a line. This rectangular workspace is suitable to a Cartesian robot.

The size of the workspace can usually be reduced by bringing objects closer to the robot. The workspace in Figure 12-14 is much smaller than in Figure 12-13 since A, B, C and D have been moved closer together. The shape of the work space has now become cylindrical, since A, B, C and D are now positioned around the robot. This is also an advantage since a cylindrical robot would move faster between A, B, C and D than a Cartesian robot

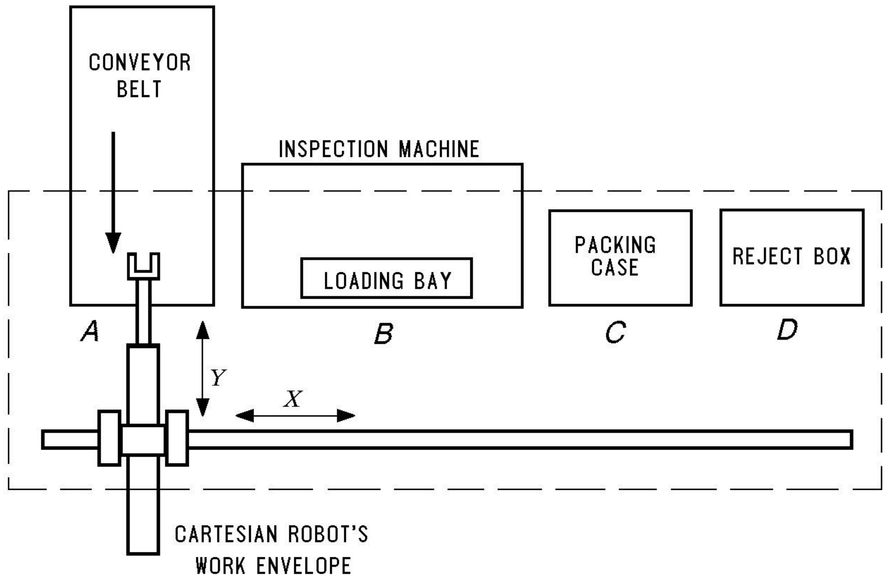


Figure 12-13

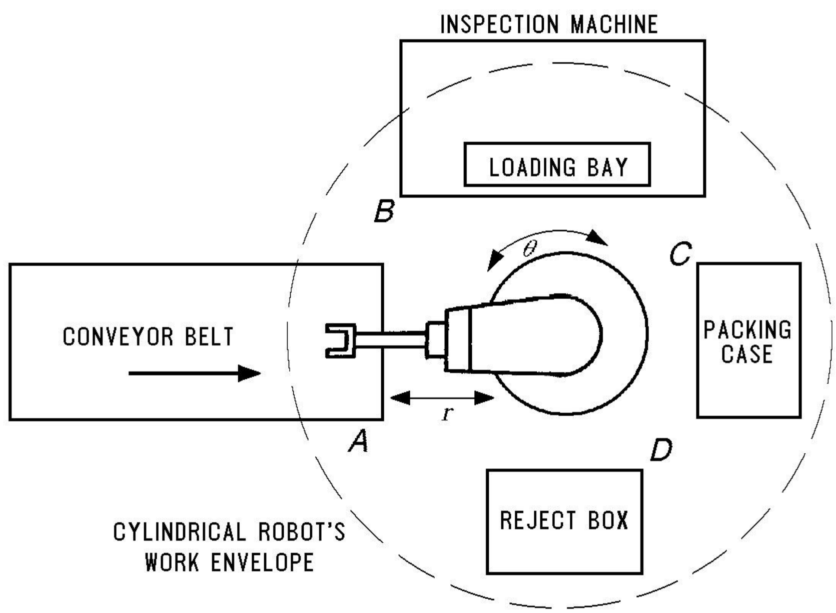


Figure 12-14

Activity 13

Running an FMS Production Cycle

Objectives

In this activity you will accomplish the following:

- Execute a dry run of the complete FMS production cycle.
- Execute an actual production cycle.

Skills

In this activity you will develop the following skills:

- Technology: apply technology to task.
- Systems: understand systems, monitor and correct performance.
- Resources: manage time.
- Interpersonal: participate as a member of a team.
- Information: interpret and communicate information.
- Basic: reading and writing.
- Thinking: reasoning and problem solving.
- Personal: responsibility and self-management.

Materials

In this activity you will need the following materials:

- SCORBOT-ER 4u robot and Controller-USB
- Computer with SCORBASE software
- spectraLIGHT mill and controller
- Pneumatic vise and spacer
- Computer with WSLM mill control software
- Parts Feeder and Sorting bin
- 3 or more wax blocks
- Diskette or personal directory on computer hard disk
- Worksheets for Activity 13

OVERVIEW

Running an FMS Production Cycle

This activity brings together all the aspects of FMS programming which you have learned so far.

In the preceding activities you have accomplished the following:

- Prepared the NC program for the mill's operation.
- Recorded positions and programmed the path of the robot for its tasks in the FMS cell.
- Programmed the robot for input/output communication.
- Programmed the milling machine for input/output communication.

The programs USER12.WS and USER12.NC which you have created enable *handshaking* between the robot and the milling machine. After the robot has placed the workpiece into the vise, the robot controller outputs a signal to the milling machine controller, which then starts the machining tasks. When the mill finishes its operation, its controller outputs a signal to the robot controller. The robot will unload the part, and continue its tasks.

In this activity you will execute the two programs for robot and mill handshaking. Instructions are very brief. By now you should know how to perform each of the tasks without guidance.

PROCEDURES

Task 13-1: Inventory and Safety Checks

1 Check whether all materials required for this activity are available at your lab station.

2 Check whether your lab station conforms to the Safety Guidelines for the FMS workcell. In addition:

- Tie back loose hair and clothing. Remove all jewelry.
- Put on safety glasses.
- Get your instructor's permission to turn on the system.

3 Complete the Inventory and Safety Check List on the Worksheet for this activity.

Task 13-2: Preparing the FMS Cell for Operation

1 Turn on the SCORBASE computer, then turn on Controller-USB.

Activate SCORBASE.

Home all the axes.

2 Turn on the milling machine computer, then turn on the mill controller.

Activate the WSLM mill control software.

Place a spacer and a block of wax in the pneumatic vise, clamp the vise, and initialize the mill. (Set the workpiece origin.)

Open the pneumatic vise. Remove the wax block and set it aside.

Task 13-3: Executing a Dry Run of the Production Cycle

1 Make sure there are no workpieces anywhere in the FMS cell.

2 From the WSLM computer, load the program **USER12.NC**.

3 From the SCORBASE computer, load the USER12 project file.

4 Start execution of USER12.NC

5 Start execution of a **single** cycle of USER12.WS.

You do not need to start execution simultaneously. The programs will synchronize by means of their I/O commands.

6 Whenever necessary, simulate the presence of a workpiece in the feeder by forcing robot controller Input 7 to an ON state. After the robot has left the feeder, turn the input off.

Q *How many production cycles should be completed when a single cycle is executed? Explain.*

Task 13-4: Executing an Actual Production Cycle

1. Load one wax block in the mill parts feeder.
2. Make sure there are no workpieces anywhere else in the FMS cell.
3. In the Digital Inputs and Digital Outputs dialog bars, make sure all boxes are dark, except for Input 8. Make sure all I/O LEDS on the robot controller are turned off, except for Input 8.
4. Start execution of USER12.NC
5. Start execution of a **single** cycle of SCORBASE USER12 project.
6. How many production cycles were completed? What causes production to stop?
7. Load several wax blocks into the parts feeder.
8. Again start execution of USER12.NC

Again start execution of a **single** cycle of SCORBASE USER12 project. How many production cycles were completed? What causes production to stop?

Task 13-5: Team Discussion and Review

Q *In your own words write a description of the FMS production cycle.*

Task 13-6: Inventory Check and Shut Down

1. Make sure there are no objects in the robot's gripper, milling machine, feeder or sorting bin.
2. Send all axes to their home position.
3. Exit SCORBASE. Turn off Controller-USB, then turn off the SCORBASE computer.
4. Exit the WSLM mill control software. Turn off the mill controller, then turn off the WSLM computer.
5. Make sure all materials required for this activity have been returned to their proper place.
6. Complete the Inventory Check List on the Worksheet for this activity.

ACADEMICS

Industrial Applications

Robots Today and in the Future

Industrial robots have been used in a wide variety of manufacturing applications. Hot, dirty, dangerous foundry work in which molten metal is poured into casting was one of the first jobs in which robots were successfully used. Welding operations, in which consistency of the spot or seam weld is essential but which also produces a hot, ozone atmosphere annoying or hazardous to humans, has become another widely used application. Hazardous spray painting is another application in which robots are important, because robots can safely apply extremely thin coats of paint consistently, which significantly reduces the amount of paint needed per part. Back-breaking, dangerous, and tedious machine loading and unloading is another task to which robots are often applied. Assembly of automobiles, electric motors, computers and even robots are newly proven areas of robot application.

Most robots used in these applications are deaf, dumb, blind, and stationary. Thus, these robots are not used so differently from other kinds of automated machines. However, an entirely new phase in robotics applications has been opened with the development of intelligent robots. An intelligent robot is basically one that is equipped with some sort of sensory apparatus that enables it to sense and respond to variables in its environment. Much of the research in robotics has been and is still concerned with how to equip robots with seeing eyes and tactile fingers. Artificial intelligence that will enable the robot to respond, adapt, reason, and make decisions in reaction to changes in the robot's environment are also inherent capabilities of the intelligent robot.

The development of sensors coupled with recent innovations in robot mobility have enabled robots to move out of factories and into such varied environments as orange groves, sheep farms, and hospitals. Robots are also used in domestic and entertainment applications. We can expect many new industries to develop around the creation and applications of robots. The potential applications of these new robots seem limited only by human imagination and creativity.

Activity 14

FMS Project

OBJECTIVES

In this activity you will accomplish the following:

- Apply the skills you have acquired in robot programming.
- Apply the skills you have acquired in NC programming.
- Create and execute a FMS production cycle.

SKILLS

In this activity you will develop the following skills:

- Technology: apply technology to task.
- Systems: understand systems, design systems.
- Resources: manage time.
- Interpersonal: participate as a member of a team.
- Information: organize and maintain information.
- Thinking: problem solving and knowing how to learn.

MATERIALS

In this activity you will need the following materials:

- SCORBOT-ER 4u robot and Controller-USB (TP optional)
- Computer with SCORBASE software
- spectraLIGHT mill and controller
- Pneumatic vise and spacer
- Computer with WSLM mill control software
- Parts feeder and sorting bin
- 3 or more wax blocks
- Diskette or personal directory on computer hard disk
- Worksheets for Activities 14 and 15

OVERVIEW

Final Project

In this activity you will select and perform a final project which utilizes the programming skills you have acquired through the FMS tekLINK.

If you have already had experience in robot and NC programming, and have programs on file, you may want to utilize them in your final project.

Depending on the project you select, you will program the robot, the mill, or both.

PROCEDURES

Task 14-1: Inventory and Safety Checks

1. Check whether all materials required for this activity are available at your lab station.
2. Check whether your lab station conforms to the Safety Guidelines for the FMS workcell. In addition:
   - Tie back loose hair and clothing. Remove all jewelry.
   - Put on safety glasses.
   - Get your instructor's permission to turn on the system.
3. Complete the Inventory and Safety Check List on the Worksheet for this activity.

Task 14-2: Final Projects

You will have more time in Activity 15 to complete this project.

1. Select **one** of the following projects:

   A Load the SCORBASE USER12 project, which you used for the FMS production cycle. Alter the program so that the robot takes completed parts to different compartments in the sorting bin. Record positions for this program as necessary. Save the new program as SCORBASE USER14 project.

   Plan to run this program together with the milling program USER12.NC.

   B Replace the milling codes in program USER12.NC, which you used for the FMS production cycle, with codes for a different engraving program. Save the new program as USER14.NC.

   Plan to run this program together with the SCORBASE USER12 project.

C Do **both** A and B. Plan to run USER14.NC and SCORBASE USER14 project together.

D Be creative. Design and run another FMS application.

2 Execute a dry run of the application you have created.

3 Execute actual production.

4 On the worksheet, describe the application and present a copy of the program(s) you wrote.

Task 14-3: Inventory Check and Shut Down

1 Make sure there are no objects in the robot's gripper, milling machine, feeder or sorting bin.

2 Send all axes to their home position.

3 Exit SCORBASE. Turn off Controller-USB, then turn off the SCORBASE computer.

4 Exit the WSLM mill control software. Turn off the mill controller, then turn off the WPLM computer.

5 Make sure all materials required for this activity have been returned to their proper place.

6 Complete the Inventory Check List on the Worksheet for this activity.

Activity 15

Conclusion

OBJECTIVES

In this activity you will accomplish the following:

- Measure your knowledge in the field of robot and NC programming and FMS production.
- Complete the programming and execution of a FMS application.

SKILLS

In this activity you will develop the following skills:

- Technology: apply technology to task.
- Systems: understand systems and designs systems.
- Resources: manage time.
- Interpersonal: participate as a member of a team.
- Information: acquires and evaluates information.
- Basic: reading.
- Thinking: problem solving and knowing how to learn.
- Personal: responsibility and self-management.

MATERIALS

In this activity you will need the following materials:

- SCORBOT-ER 4u robot and Controller-USB (TP optional)
- Computer with SCORBASE software
- spectraLIGHT mill and controller
- Pneumatic vise and spacer
- Computer with WSLM mill control software
- Parts Feeder and Sorting bin.
- 3 or more wax blocks
- Diskette or personal directory on computer hard disk
- Worksheets for Activities 14

OVERVIEW

Post-Test

This activity concludes the Flexible Manufacturing Systems tekLINK.

The test you will now take will measure your knowledge and skills in the field of robotics, CNC milling and FMS production.

Take the post-test according to your teacher's instructions. Allow 30 minutes for the test.

When you have finished the test, hand it in to your teacher.

PROCEDURES

Task 15-1: Final Project - Continued

Complete the work on the final project, which you began in Activity 14.

Task 15-2: Inventory Check and Shut Down

1. Make sure there are no objects in the robot's gripper, milling machine, feeder or sorting bin.
2. Send all axes to their home position.
3. Exit SCORBASE. Turn off Controller-USB, then turn off the SCORBASE computer.
4. Exit the WSLM mill control software. Turn off the mill controller, then turn off the WSLM computer.
5. Make sure all materials required for this activity have been returned to their proper place.
6. Complete the Inventory Check List on the Worksheet for this activity.