FUNDAMENTALS OF ROBOTICS: RHINO LAB MANUAL

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PREFACE

This lab manual is written as a companion piece to the text FUNDAMENTALS OF ROBOTICS; THEORY AND APPLICATIONS. Both of these publications are dsigned for the beginning student in robotics and industrial automation.

These materials are meant to be used in a <u>survey</u> course in secondary or postsecondary schools, industrial training or universities. In this class the student is introduced to the basics of robotics such as the mechanical instructures of different robots, robotic programming, BASIC programming, auxillary equipment use and workcell operation. Once these basics have been explored, the student will be ready to study the topics in more detail. The survey class, offered before in-depth study, allows the students to get a feel for each subject and devoting large amounts of time to the topic. If properly implemented the survey class will provide the students with a effective introduction to the field of robotics.

In line with the philosophy outlined above, the workbook includes a great deal of step-by-step instruction. Many students will not need the amount of detail given. They should be able to complete the material rapidly and try more challenging experiments for each lab. Students who have had no computer experience before starting the course will appreciate the detailed instructions and the many visual aids. The material does not require prior competency in mathematics or programming.

It is important to realize that although Rhino has numerious versions and possible configurations of equipment along with its many optional accessories, it is impossible to address each of these within the space of this lab manual. For this reason, the major differences and conepts are addressed in each lab. To gain the full benefits of this manual, you should use the owners' manual for each piece of equipment in conjuction with this manual.

The labs in this manual can be done in several different sequences. First, of course, the labs can be presented in their existing order. In industrial training situations were there is limited time and the students may already have considerable background, instruction might begin with Unit Three: TEACH PENDANT PROGRAMMING. In a university, considerable emphasis might be placed on Unit Four: OFF-LINE PROGRAMMING. If this is done, Chapter 3 of the text will also need to be emphasized. Also by stressing the mathematics involved in locating the position of the robot and the tool center point, the students will be prepared to generate new languages and control systems for other types of configurations.

Unit 1, INTRODUCTION TO COMPUTERS AND ROBOTS - This set of labs introduces the student to computer concepts, set-up and operations. The student first learns to use selected DOS commands, save a program on disk and load amd run a program. These concepts are then related to the robot with procedures for installation of the interface cards and Rhino-Apple IIe hook-up.

UNIT 2, ROBOT OPERATION - Rhino has developed various software programs to operate the XR Series robotic system. Several of these are explained in detail in this section. By learning these introductory programming techniques, the student will be able to more easily adapt to the programming of industrial robots.

UNIT 3, TEACH PENDANT PROGRAMMING - In this set of labs, the student is introduced to the advantages and applications of teach pendant programming. This knowledge is then applied with procedures for writing, editing, saving, and loading teach pendant programs.

UNIT 3, OFF-LINE PROGRAMMING - Some of the ideas and concepts necessary for this emerging technology are explored in this unit. To apple these concepts, the student learns to operate a demonstration program that calculates the coordinates of moves for each axis of the XR arm, set the Rhino XR default values, operate the Rhino XYZ program, and write a program using the XYZ coordinates.

UNIT 5, BASIC PROGRAMMING - Here, the student is introduced to programming with BASIC using specified BASIC commands, branching commands and arrays. These labs will help the student to have a much better udnerstanding of robotic programming. Included in this unit is instruction on the Rhino Com Language Card, which allows the implementation of some special BASIC commands. Another special feature of this section is a program that allows teach pendant programs to be converted to BASIC data lines and therefore used in conjuction with the full capabilities of BASIC.

UNIT 6, END-OF-ARM TOOLING - Some of the Rhino optional finger attachments are used in this set of labs to explore various end effector concepts and applications. Vacuum and magnetic pick-up devices are explained in detail.

UNIT 7, WORKCELLS - All of the skills and knowledge learned in the earlier units is drawn upon here as the student completes the final labs. The procedures in these labs introduce the student to pallateizing operations with the conveyor, workcell design and programming, and workcell interfacing.

For the main supplementary teaching material, students and instructors should refer to the XR Owner's Manual, the XR Teach Pendant Manual and the XR Software Manual, the XR Owner's Manual includes an explanation of the kernal commands that reside in the XR Controller operating system. These commands can be used to design a variety of software for special robot applications.

The Teach Pendant Manual contains a lengthy section on strategies and principles of teach pendant programming, along with tutorial examples and a full discussion of teach pendant capabilities and feedback displays.

The Software Manual includes a comprehensive guide to RoboTalk (TM), Rhino's new robotic control language, as well as details concerning other Rhino software programs. The RoboTalk (TM) language provides an ideal vehicle for design and operation of work cell configurations. It integrates teach pendant with host computer programming and gives the user control over the eight encoded motor ports, the two DC auxiliary motor ports, and the 8 non-designated input and output lines. The RoboTalk (TM) manual contains two complete tutorials and manu partial demonstration programs to illustrate RoboTalk (TM) commands.

From the above, it should be clear that the Student Workbook and Instructor's Guide are only one part of the total Rhino courseware program. Other Rhino documentation provides an important extension of the courseware. Since the XR was designed as an educationaltraining robotic system, all documentation has a strong eductional focus. Educators will find that Rhino offers a truly integrated package consisting of many hardware, software and courseware elements, all contributing to its instructional and training function.

LABORATORY 1

INTRODUCTION TO THE COMPUTER

INTRODUCTION

The computer is the element that has made the industrial robot possible. Apple computers are one of the most popular brands of computers and are used as one of two primary computers for operating the Rhino XR series robotic system. The Apple computer is easy to operate. In this lab, you will be introduced to the operation of the computer and some commands.

Figure 1.1 Apple computer with monitor and disk drive.

A computer has to be told what to do to control a robot. The computer plans each move of the robot and keeps track of where it is at all times. This is a complex task since many robots have five or more axes moving simultaneously. A computer program is used to do this. A program is a list of things for the computer to do, which it follows to the letter. To save time, the program is usually stored on a device from which it can later be retrieved. The most popular devices today for storing programs are cassette tapes and floppy disks. Industrial robots use tapes and disks, while most personal computers use disks.

OBJECTIVES

When you finish this lab, you will be able to:

1. Start the computer.

2. Use selected DOS commands.

   a. LIST
   b. SAVE
   c. CATALOG
   d. LOAD
   e. RUN
   f. DELETE
   g. NEW
   h. PR#6

3. Save a program on the disk.

4. Load and run a program from the disk.

LIST OF EQUIPMENT

1. Apple IIe computer with disk drive and monitor (hereinafter referred to as Apple IIe computer system).

RELATED INFORMATION

A computer system consists of a computer, disk drive, monitor, and peripherals if desired.

Starting a computer causes several things to occur. As the computer comes on, it checks to see what equipment is connected to it and then responds in a preset way for each device. When you turn on the Apple, it starts in the BASIC language mode. Since a disk drive is connected to the computer, the computer also starts a program called a Disk Operating System or DOS. The DOS program manages the recording and reading of information on the disk.

A floppy disk is similar to both a record and cassette tape. It is like a record because it is round. It is like a cassette tape because it is coated with a magnetic material. The disk is sealed in a protective cover which contains both lubricants and cleaners to help prolong the life of the diskette. It is sometimes referred to as a floppy disk because the disk itself is flexible as opposed to a hard disk which resembles a record even more.

You must use caution when handling a disk because it is fragile. Take care not to bend it and do not touch the brown or gray surface that is exposed. When you are not using a disk, put it back in the paper pocket that it came in so that it will not collect dust. When you write on the label, always use a felt tipped pen. A floppy disk is shown in Figure.1.2.

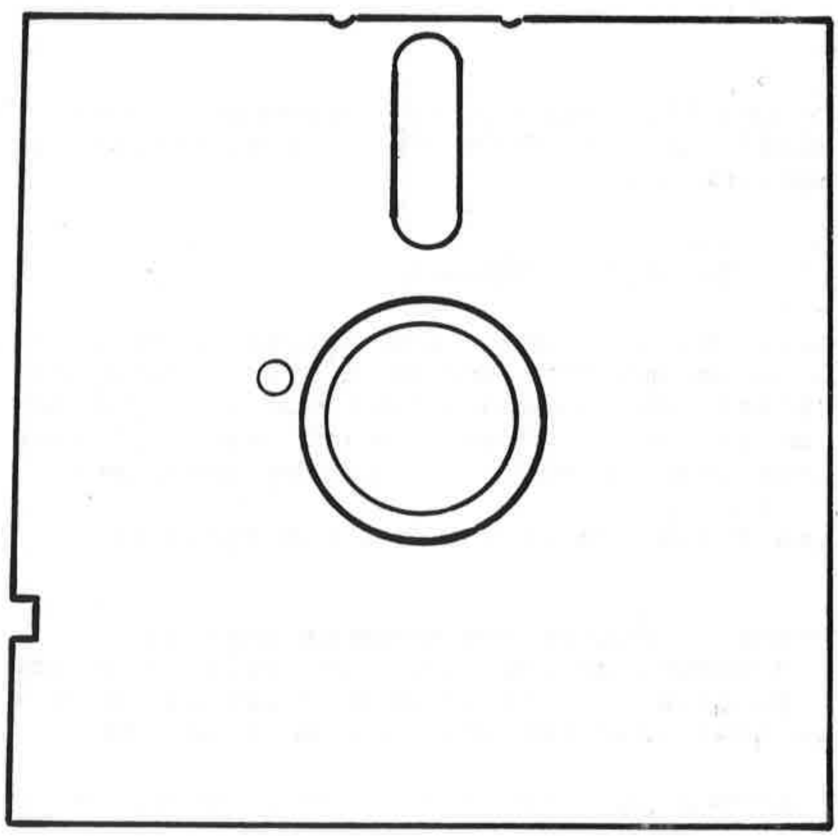

Figure 1.2 Disk

You will notice a notch cut in the left side of the disk; this is the write protect notch. It is similar to the tab on a cassette tape. When the notch is open, the disk can have new data stored on it. When covered with tape, information from the computer can not be stored on the disk. Keep this in mind if you have a disk you do not want erased or written on.

Before the computer system can be used, you must get it running. This is called bootstrapping, or "booting" the computer. There are three ways of accomplishing this.

1. You can boot the computer by turning the power on with a disk in the drive. If there is not a disk in the drive, the drive will keep running until you press the RESET key. On the Apple IIe computer, you will have to press the CONTROL key at the same time.

2. The way to get DOS started when the computer is already on is to enter "PR#6" with a disk in the drive.

3. On the IIe, you can simultaneously press the CONTROL, RESET, and the OPEN APPLE keys, releasing the RESET key first.

DISK OPERATING SYSTEM (DOS) COMMANDS

Once you have the disk operating system running, you can save and run programs that are on a disk. Here are the commands, called DOS commands, that you will use and a brief explanation of each. These commands function with the BASIC language that is operative in the computer.

LIST - Gives a listing of the BASIC program in memory.

SAVE 'filename' - Stores the program that is currently in memory on the disk and calls it by the name that you give it. It is good practice to give files names that describe what the programs do.

CATALOG - Gives a listing of all the programs on a disk.

LOAD 'filename' - Takes a program called 'filename' from the disk and loads it in the computer. Any program in computer memory at the time is erased.

RUN - Executes the program that is in the computer memory.

DELETE 'filename' - Erases the file on the disk.

NEW - Erases memory without restarting the disk drive.

PR#6 - Starts the disk drive and clears the memory of the computer.

To use these commands, all you have to do is type them and press RETURN. Other DOS commands are listed in your DOS manual. You can look them up if you are interested but these are all you need to know for most of the labs in this book. Other DOS commands will be explained as they are needed.

PROCEDURE

You are going to boot the computer, enter a simple program and save it on the disk. You will then view the catalog to make sure the program was saved, reload the program, and run it.

____1. Get the lab disk and slide it into the disk drive by holding the disk in your right hand with your thumb over the label. Carefully insert the disk all the way and close the door; then turn on the computer. A blinking cursor will appear in the lower left corner of the monitor.

____2. Type the following program.

```
10 INPUT"WHAT IS YOUR NAME? ";N$
20 PRINT:"HELLO ";N$
30 END
```

Use the LIST command, typing the word LIST and then pressing the RETURN key, to check your typing. The program listing should appear on the monitor just like it is above.

____3. Run the program by typing the word RUN and pressing the RETURN key. Be sure to type in your name when the question mark appears to see how the program operates.

____4. Save the program, giving it the filename LAB 1. You do this by typing:

SAVE LAB 1

The disk drive should start to whirl. If not and you get a "SYNTAX ERROR" message, it means DOS has not been booted correctly. If it starts to whirl but stops and you get an "I/O ERROR" message, check to see if the drive door is closed.

____5. Use the CATALOG command to see if your program is on the disk. The name you gave your program, "LAB 1," should be one of the programs listed.

-----6. Reboot the computer using the PR#6 command. This will clear the memory of the computer. Before you do anything else, type RUN. Notice that the computer does nothing. This proves that there is not a program in the computer. Load the program you just saved using the LOAD command.

LOAD LAB 1

The disk should act like it did in step 3 when you saved your program. When the drive stops, see if your program was loaded by using the LIST command again.

-----7. Next, type RUN and the program in memory will run. This program is the same program you loaded in step 6.

-----8. Another way to load a program from memory is to type 'RUN filename'. This loads and runs the program in one step. To demonstrate this idea, type NEW. The NEW command clears the memory without doing the PR#6 exercise. Check that the memory is really clear by again typing RUN. Once you are sure the memory is clear, enter RUN LAB 1. The program should operate as it has before.

-----9. The final command you will learn in this lab is DELETE. DELETE removes a file from the disk. Enter DELETE LAB 1. To make sure the file has been removed from the disk, enter CATALOG. LAB 1 should not be on the list of programs now on the display.

REFERENCES:

Apple IIe Reference Manual

Apple DOS Manual

Fundamentals of Robotics: Theory and Applications, Chapter 8, "Microcomputers".

NAME______________________________

DATE______________________________

CLASS_____________________________

INSTRUCTOR________________________

QUESTIONS

1. T F All programs are stored on floppy disks.

2. A notch on the left side of the disk in the drive means:

a. The disk is defective.
b. Information can not be stored on the disk.
c. Information can be stored on the disk.
d. The disk is in the drive upside down.

3. What does it mean to "boot" the computer?

4. List the DOS commands used in this lab and explain each.

5. T F You must always load a program before you can run it.

LABORATORY 2

INTERFACING WITH THE COMPUTER

INTRODUCTION

Computers have become very useful partially because it is possible to connect them to many different devices. The connection process is called "interfacing." Interfacing the computer to any external device requires matching the technical features of the computer with operation of controlled equipment. By connecting the Apple computer to the Rhino XR robot system, it is possible to operate the robot and use the full capabilities of the computer for the control process.

A great deal of information has to be collected and processed in order to control a robot. The computer is perfect for this task. This information includes step by step instructions for the robot and detailed information on all the actions of the robot. This is true for both industrial robots such as the Unimate Puma 200 and educational robotic systems such the Rhino XR Series.

In this lab, you will become more familiar with the Apple IIe computer. You will see how the circuits that connect the computer and the robot system are installed and adjusted for proper operation. This is critical for the correct functioning of the robot system.

OBJECTIVES

After completing this lab, you will be able to:

1. Recognize a 7710A Serial Card, an Apple Super Serial Card and the Rhino Com Language Card.

2. Install an interface card in the computer.

3. Explain what the term "BAUD rate" means.

4. Set the BAUD rate on an interface card.

LIST OF EQUIPMENT

1. Apple IIe computer system

2. 7710A Serial Card (FG0893), Apple Super Serial Card (FG0894) or Rhino Com Language Card (FG0702).

RELATED INFORMATION

To exchange information, computers use a code called the ASCII code. The ASCII code is a numerical representation of letters, numbers, and special symbols. Each letter has an eight bit binary representation. For example, the letter "A" is 0100 0001 in ANSII.

Signals sent between two computers or between a computer and some external device, such as a robot, are usually sent serially. Serial communication is the transmission of information sent one piece after another. To send the letter "A", a 0 would be sent, the a 1, then a string of 5 zeros and finally a 1. This transmission of data is done very fast so the comunication does not take all day.

Information can also be sent from one place to another in parallel. Parallel transmission of the binary data is usually done inside the computer or between the computer and the disk drive. Parallel data transmission requires a separate wire for each data bit. Notice the wide cable connecting the disk drive to your Apple computer. To send the ASCII code, eight parallel lines are used and are usually called a DATA BUS.

To send information to an external device from a computer, the information is frequently converted from a parallel to a serial format. Converting the data from parallel to serial is done by an electronic circuit card that fits inside the slots at the back of the Apple computer. This card is called an interface card and has two major functions:

1. It converts the data from parallel to serial.

2. It sets the rate at which the data will be transmitted.

Just as there are different manufacturers of computers, there are different manufacturers of interface cards. The three that are recommended for use with the Rhino XR system and the Apple IIe are the 7710A Serial Card (made by California Computer Products), the Apple Super Serial Card and the Rhino Com Language Card.

The rate at which the computer sends and receives information is called the BAUD rate. The BAUD rate is user controlled by setting the proper switches on the interface card. The settings used in this manual for the 7710A and the Apple Super Serial cards are shown in Figure 1 below. The BAUD rate on the Rhino Com Language Card is set in software.

Formatting the data so it is sent and received properly is done by a standard developed by the Electronics Industry Association. This standard is designated as the "RS-232" configuration. The RS-232 standard defines what voltages represent 1s and 0s and exactly how the data will be sent. To read more about interfacing and BAUD rates, refer to chapter 11 in Fundamentals of Robotics: Theory and Applications.

Settings for CCS 7710A Serial Card

SWITCH	1	2	3	4	1	2	3	4
POSITION	OFF	ON	OFF	OFF	ON	ON	ON	OFF
BAUD		300				9600		

Settings for Apple Super Serial Card
(Only the first four switches are used.)

SWITCH	1	2	3	4	1	2	3	4
POSITION	ON	OFF	OFF	ON	OFF	OFF	OFF	ON
BAUD		300				9600		

Figure 2.1 BAUD rate settings for interface cards

The Apple Super Serial Card, 7710A Card, and Rhino Com Language Card all accomplish the data communication function; however, there are some differences between them. The Rhino Com Language Card also implements some special instructions that make it easier to program the Rhino XR. The details of these special instructions are explained in Lab 19. Both the Rhino Com Language Card and Super Serial Card are physically larger than the 7710A Card and have two sets of switches. Also, both the 7710A Card and Super Serial Card have their names printed on the component side of the board.

In the computer, the interface card is inserted into sockets called I/O (input/output) slots. It is through these slots that the computer exchanges information with the interface card. There are eight slots in the Apple, and some of these are designated for specific cards. For example, slot six is the standard slot for a disk drive card. Slot one is usually where a printer interface card is inserted. The RS-232 for the Rhino XR is usually in slot two.

PROCEDURE

In the following procedure, you will examine the inside of the computer and also an interface card to determine the BAUD rate. Always treat this equipment with care and consideration. The equipment is delicate, hard to replace and expensive. Your cooperation will help make the equipment last longer.

SPECIAL NOTE - This lab calls for you to remove cards from the computer. The work that is to be done can also be done with the cards still in the computer. Ask your instructor if you are to remove the cards or change the switches with the cards still in the computer, before proceeding.

You will probably have access to the 7710A card, the Super Serial Card or the Rhino Com Language Card, but not all three. Since the BAUD rate of the Rhino Com Language Card is set through software and this is covered in Lab 19, it is preferable that you use one of the other two cards in this lab.

-----1. Be sure that the computer is turned off. Clear the top of the computer and remove the cover by lifting the back corners until the fasteners pop apart. Now slide the cover to the back. Notice the numbers above the slots. In the Apple II+, the numbers are from 0 to 7. In the Apple IIe, the numbers are from 1 to 7. A picture of the slots in the Apple IIe is shown below in Figure 2.2.

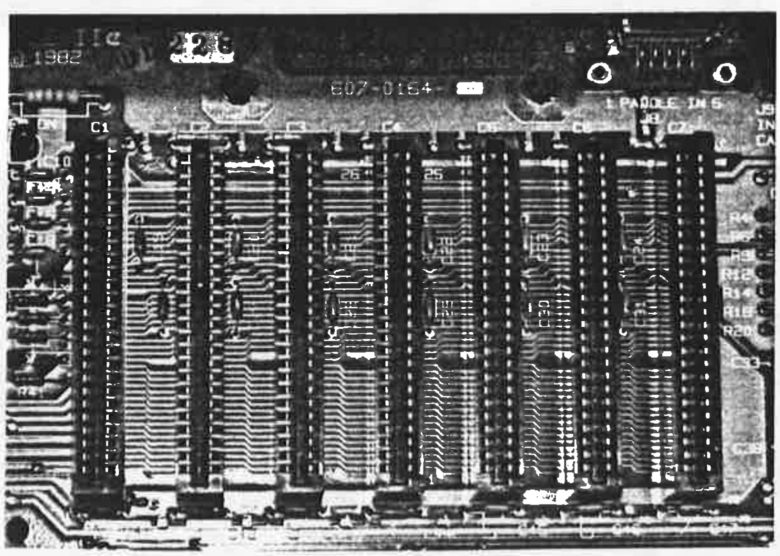

Figure 2.2 Apple IIe

____2. If there is a card already in slot 2, remove it (if told to) by gently rocking it back and forth while pulling up on the card. You may have to disconnect the cable from the card. Be sure to note its orientation so that you can replace it properly. If there is no card in your computer, ask your instructor for a card.

____3. Determine which RS-232 card you have by comparing it with the pictures of the cards in Figure 2.3. Note that the Super Serial Card has two sets of switches. On the Super Serial Card, you only need to be concerned with the first four switches on the left. It is important that you not change the other switches. You will not change any switches on the Rhino Com Language Card.

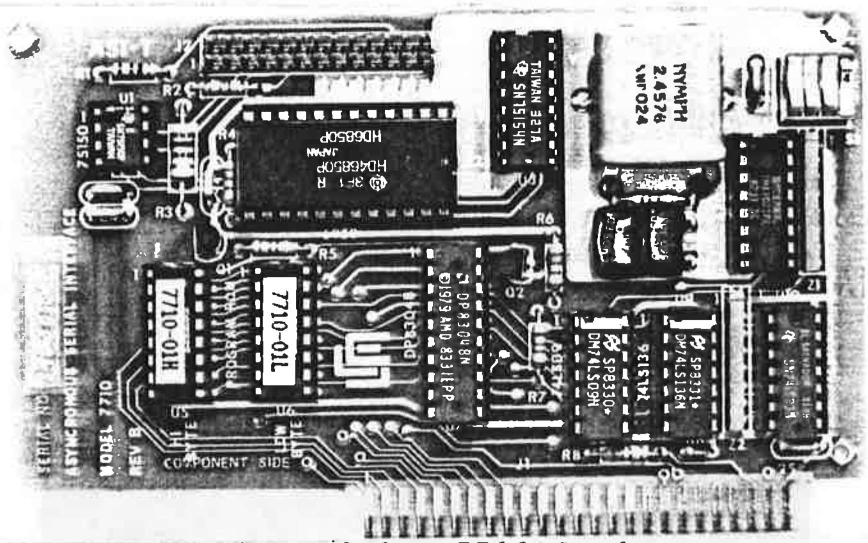

Figure 2.3a 7710 Card

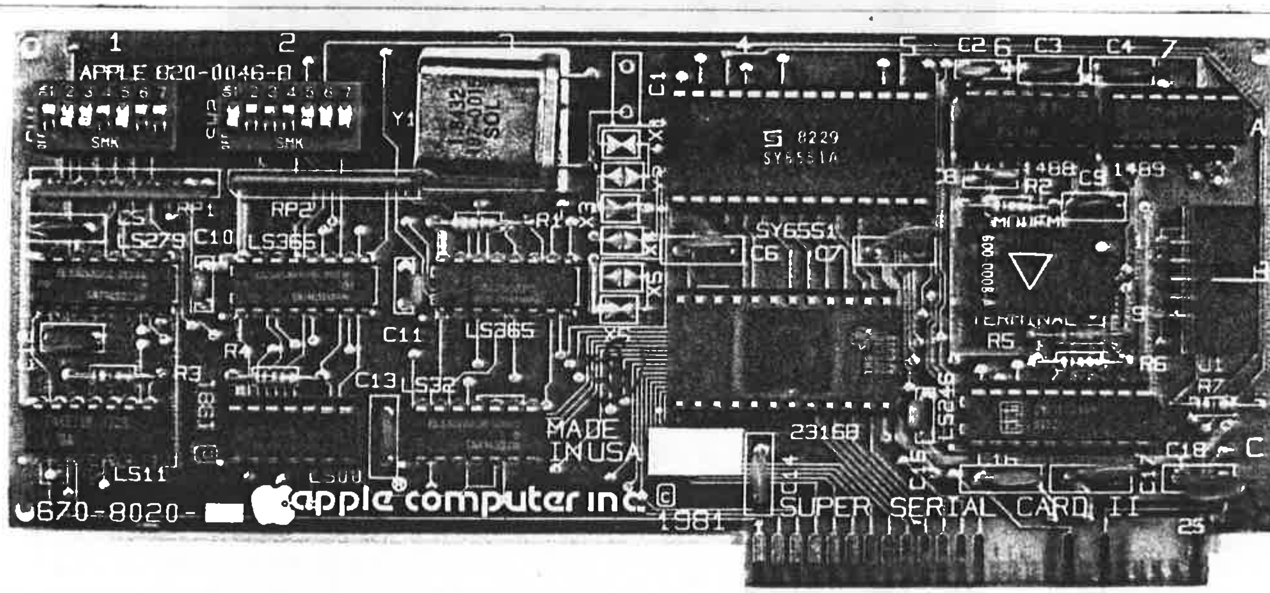

Figure 2.3b Apple Super Serial Card

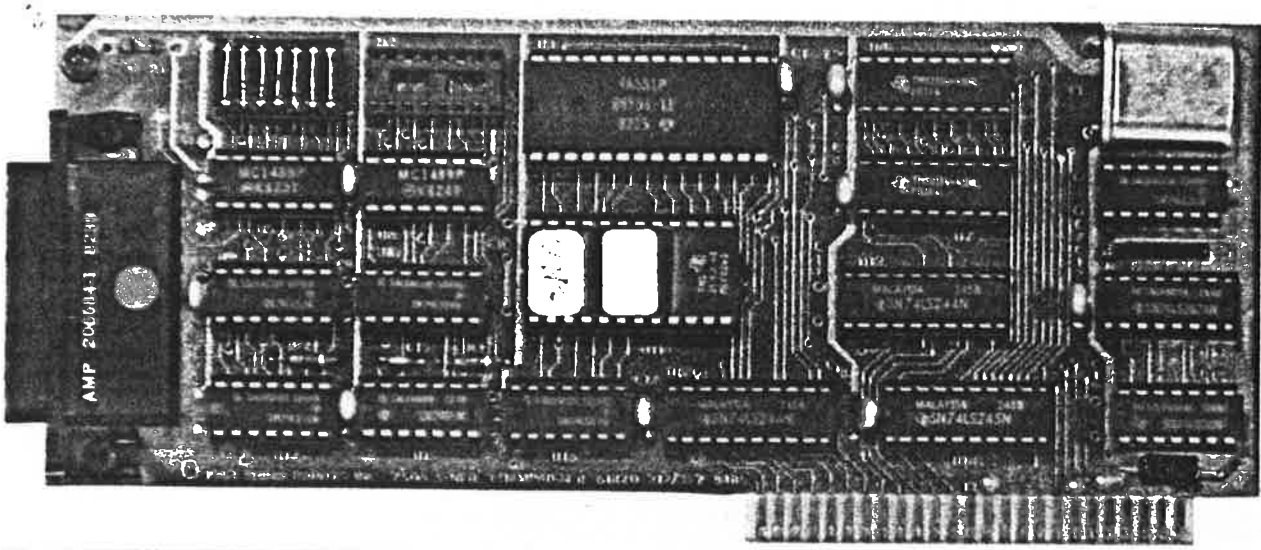

Figure 2.3c Rhino Com Language Card

____4. Determine the BAUD rate by examining Figure 2.1 and selecing 9600 BAUD. Set the switches with a sharp pencil. On the Rhino Com Language Card, simply note the features and compare them to the picture so you will recognize the card.

____5. Replace the card carefully (if you removed it). Make sure it fits securely in the slot. Reconnect the cable if necessary.

____6. Replace the cover of the computer and set up the monitor and all other parts of the computer as they were when you started the lab.

NOTE: If in later labs, the robot does not seem to be responding when you first turn it on, you should check the BAUD rate. Someone may have used the computer for something else and not reset the BAUD rates when they finished.

REFERENCES

Apple IIe Reference Manual

Apple DOS Manual

Apple Super Serial Card Manual

Manual for 7710A Card

Manual for Rhino Com Langauge Card

Fundamentals of Robotics: Theory and Applications, for Chapter 11, "Interfacing."

NAME ______________________

DATE ______________________

CLASS ______________________

INSTRUCTOR ______________________

QUESTIONS

1. What is the difference between serial transmission and parallel transmission?

2. Define BAUD rate.

3. Name the most common type of serial interface.

4. Describe the differences between a 7710A Serial Card, a Super Serial Card and the Rhino Com Language Card.

5. What are the slot numbers for the Apple II+ and the Apple IIe?

LABORATORY 3

INTRODUCTION

CONNECTING THE RHINO SYSTEM

Of all the components of a robot system, the controller is probably the most complex. It also varies a great deal from one type of robotic system to the next. The controller, which is essentially a special purpose computer typically has all the elements found in computer, such as a microprocessor, memory, and input/output capabilities.

The Rhino XR Series robot is controlled by both the XR controller and a personal computer (for our discussions, an Apple IIe). It is the XR controller that actually tells the robot to execute the commands sent to it by the Apple. The Apple computer does all the calculations and keeps track of moves as well as storing programs.

Inside the latest XR controller, the Mark III, there is a 6502A microprocessor. (Older XR controllers have 8748 microprocessors.) The program burned into the microprocessor consists of a scanning routine. The function of the scanning routine is to constantly monitor the output of the computer at the RS-232C interface, and also to scan the operation and location of the eight optical encoders on the motors of the XR robot.

The computer and the XR controller do all the tasks for the Rhino XR system that the industrial robot controller does for the industrial robot.

Connections between the XR controller, the RS-232 interface in the Apple computer, and the motors on the XR robot are made by means of various connectors and ribbon cables. The purpose of this lab is to identify the proper hardware and procedures necessary connect these components. You will also experiment with the XR motors to see how they stay in place and return to that location as you turn the motor power on and off.

To read more about how robot systems are put together, read Chapter 1 of <u>Fundamentals of Robotics: Theory and Applications</u>.

OBJECTIVES

When you finish this lab activity, you will be able to:

1. Identify the connector and ribbon cable going to the controller from the Apple computer.

2. Identify and locate all switches and port openings on the controller.

3. Identify and locate each of the six motors on the Rhino XR robot, and the corresponding cables and connectors.

4. List all hardware necessary to connect the Apple computer to the contorller, and the controller to the Rhino XR robot,

5. Connect each of these components to each other.

6. Demonstrate how the controller keeps the motors in a specific position.

LIST OF EQUIPMENT

1. Rhino XR Series robot and controller.

2. Apple IIe computer system.

3. Rhino/Apple (RS-232) cable.

RELATED INFORMATION

Whether you are dealing with an educational robot such as the Rhino XR, or a very complex industrial robot such as one of the Prab robot models, proper set-up and installation are critical. For example, the Prab FC has a lifting capacity of up to 2000 pounds. For this reason it is critical that the robot be securely fastened to the floor. Remember that a robot follows a predetermined program which depends heavily on being held in a fixed position so that when it finishes its cycle, it returns to its starting position.

If the robot moves from its mounted base even 0.1 inch in any direction, it will throw the whole program off by exactly that amount, rendering it useless until repositioned. Repositioning time means down time for whatever process the robot was doing. Even if the robot was just one small link in a much larger assembly line, it might mean shutting down the entire line. Usually down time for any reason is very expensive and severely frowned upon by an industry. Therefore, proper set-up is crucial to attain consistency and accuracy in robotic performance.

In addition to the set-up of a robot, it is important to understand the normal operation of the robot. The Rhino XR controller manipulates data that is collected from the motors and keeps track of how many steps the motors have moved. It uses this data to determine whether or not the robot is in the proper position and how far it needs to move, in either direction, to get to the programmed position. In this lab, you will see how the Rhino XR controller does this.

Figure 3.1a Mark III Controller with optional teach pendant port and teach pendant.

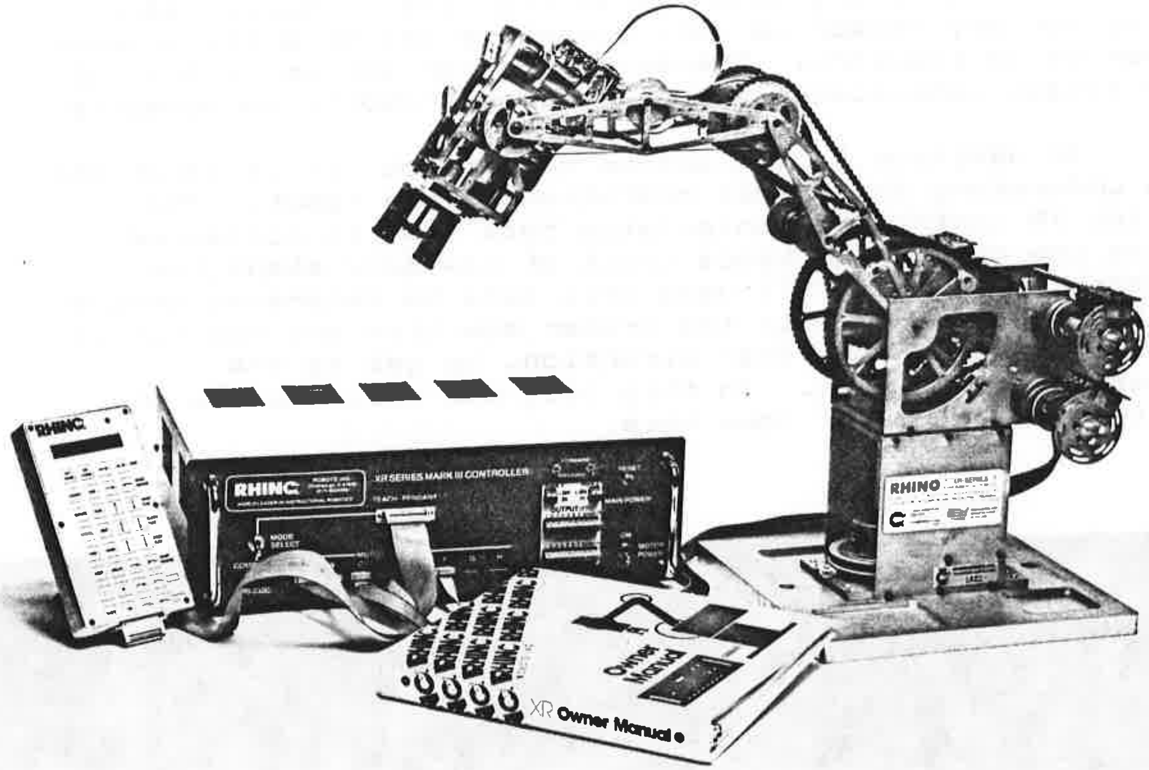

Figure 3.1b XR Series robotic arm, Mark III controller and teach pendant, fully connected.

Briefly study the controller you will be using, comparing it with the Mark III controller shown in Figure 3.1a. The Mark III controller can be distinguished by the I/O panel at the right. If you are using a Mark III controller, most likely your controller will be a combo, with the teach pendant system built in, shown fully connected in figure 3.1 b.

NOE: The following procedure refers to the Mark III controller. If you are using an older version controller, consult its Owner's Manual for hook-up instructons and ask your teacher for supervision.

In Figure 3.1a, notice the reset switch, power indicator light, and motor power switch on the right side of the contoller. The main power switch for the Mark III controller is on the back panel of the controller cabinet. As a precaution against possibly damaging the controller make it a habit to turn this switch ON first and OFF last. The switch on the front of the Mark III controller labeled MOTOR POWER controls only the power going to the motors. Both switches must be ON for the robot to operate. The function of the push button switch labeled RESET is to reset the microprocessors in the controller. It should be used when the robot starts to do anything that might be harmful to it. The main power light indicates when the power is on.

PROCEDURE

The first step in making the proper connections between the Apple Computer, the XR controller, and the Rhino XR robot is to become fully acquainted with the various port openings and switches which are located on the front of the XR controller.

____1. There will be a round gray cable coming from the Apple computer with a twenty-five pin connector on the end. This is the RS-232 cable. In some cases you will have a cable with connectors on both ends. One end will go to the Apple computer and the other end to the XR controller.

____2. Referring to Figure 3.1a, on the left hand corner of the controller there is a twenty-five pin port opening labeled RS-232C. This is where you plug the connector coming from the Apple computer into the controller.

____3. After completing this connection, the hook-up between the controller and the computer is done, and you will no longer have to be concerned with the computer at this time.

____4. With the Rhino XR robot in front of you, trace back each of the six ribbon cables to their corresponding connectors, from the motor on the robot. Do this by examining the robot and carefully tracing from where the cable attaches to a circuit card, through the cable bundle, to the end connector.

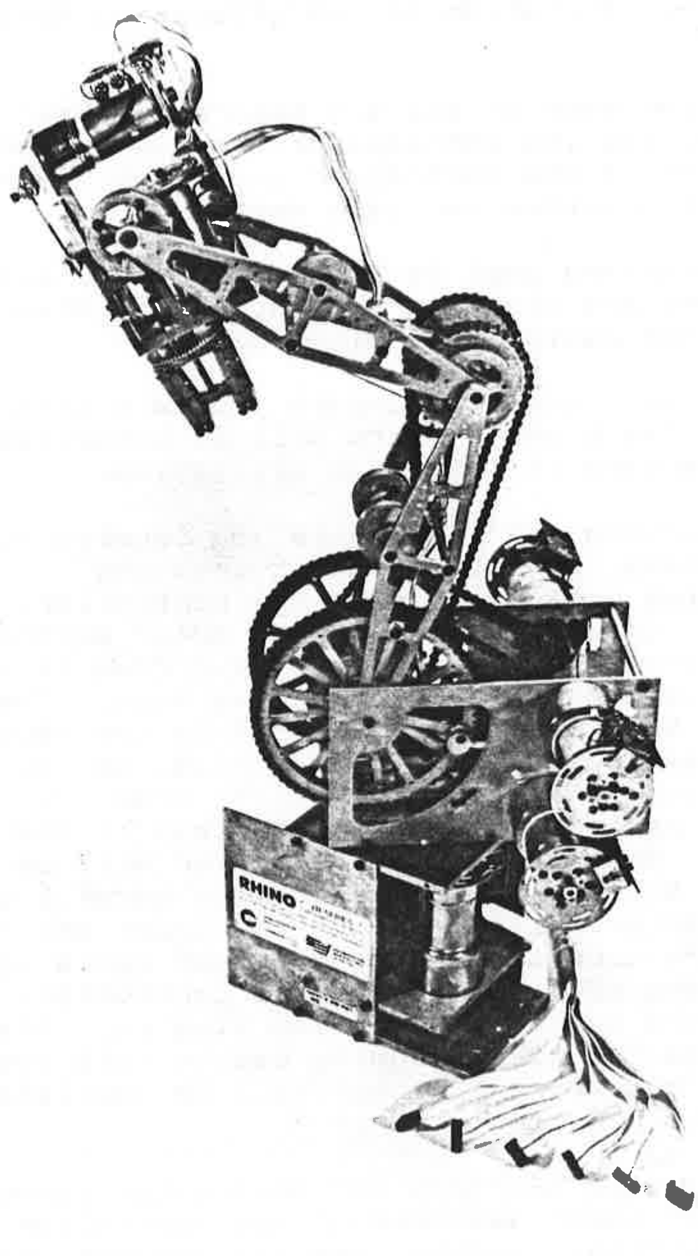

Figure 3.2 XR Series Robotic Arm, with Motors and Cables in the foreground.

_____5. Because it is an absolute must to attach each of these motors correctly, it may be useful to label each of the cables, if they are not already labeled. For example, the motor which operates the opening and closing of the gripper is motor A. The motor which operates the revolution of the gripper is motor B, etc.

_____6. After each of the six motors has been identified, and its corresponding cable lettered, you must go back to the controller and identify the proper port openings for each motor.

_____7. Referring back to Figure 3.1a, you will notice there are eight port openings, labeled A through H and designated MOTOR PORTS.

NOTE: You will need to concern yourself with ports A-F only. The G and H ports will be connected to auxiliary motors in later lab activities.

_____8. Starting with the cable you labeled A, coming from the Rhino XR robot, plug it into the corresponding port opening on the controller, also labeled A. Carefully look at the motor port openings on the controller. You will see two rows of pins: one has five pins and the other has four. The same applies to the connectors coming from the robot. A plug has been put in one of the holes, so you must make sure you line up the five pins from the controller port with the five openings in the connector. Otherwise, the controller will be damaged when it is turned on. Be especially careful that the cable connector fits over both the upper and lower rows of pins. Continue plugging each cable into its corresponding port opening in the controller. F should be the last connector you plug in. After you have plugged the corresponding cables into motor ports A-F, the Rhino XR robot will be completely connected to the controller.

_____9. With the XR robot and controller connected. be sure both power switches on the controller are in the OFF position. Gently turn the encoder wheel attached to motor A. The encoder wheel should move freely.

____10. Rotate the encoder wheel on motor A until the gripper is closed.

____11. Turn both switches on the controller to the ON position. What happened to the gripper? There should have been no change in its position.

____12. Gently try to move the encoder wheel on motor A one quarter of a turn. Did the it move freely? When the controller detects a change in the position of the motor, it tries to return the motor to its original position. You should have felt the motor resisting your attempt to move it. You may want to try this same action on one of the motors mounted on the base of the robot since they have more encoder slots and are more sensitive to moves.

____13. Turn the motor switch off and rotate the encoder wheel on motor A until the jaws on the robot are open.

____14. Turn the motor switch on and notice what happens to the gripper. Why do you think this happens?

____15. Repeat the process you did in steps 13 and 14 for motor D that controls the elbow. Turn the motor power switch OFF; move the motor several rotations by hand and then turn the motor power back ON.

This action occurs because the microprocessor is counting the number of encoder slots the motors are. rotated. This is done through the electronic circuitry that is mounted on the optically encoded servo motors. The counting happens even when the motor power is turned OFF. When the motor power is turned back on, the controller returns the motor to its original position by moving the motor until the count is zero. The motor location count is stored in the controller by the 6502A computer.

REFERENCES:

Fundamentals of Robotics: Theory and Applications, Chapter 1, "Introduction to Roboticcs," and Chapter 11, "Interfacing."

Rhino XR Owner's Manual

NAME ____________________

DATE ____________________

CLASS ____________________

INSTRUCTOR ________________

QUESTIONS

1. How many connections are necessary to attach the Apple Computer to the Rhino controller?

2. How many connections are necessary to attach the Rhino robot to the Rhino controller?

3. Through what device does the Apple computer communicate with the Rhino robot?

4. What kind of routine is burned into the 8748 microprocessor in the controller?

5. How do you know that the motor count for each motor in the controller is zero?

LABORATORY 4

INTRODUCTION TO THE RHINO SYSTEM PROGRAMS

INTRODUCTION

In this lab, you will be introduced to four different programs that can be used with the Rhino XR Series robot. These are KEYBOARD MOVES (Lab 5), MOVE ALL JOINTS (Lab 8), TEACH Program (Lab 9), and XYZ Program (Labs 14 and 15). Each program introduces a different concept in robotic programming, but at the same time builds upon the one you previously studied. For this reason it is important to do each of the five labs in the order in which they are numbered.

Because of the variety of programs available on the Lab Disk, we are using this lab just to familiarize you with the screens and options available. In labs 5,7,8,14, and 15, you will learn to operate each program specifically.

The different types of programs that Rhino XR has developed help you explore different aspects of robot programming. One of the most interesting ideas that is just now being developed by the industrial robot manufacturers is the simulation of a robot on a computer screen to allow the design of robotic workcells. By designing the system on the screen of the computer, rather than buying the equipment first, the company can check the full operation of the system before investing the money.

This type of programming capability goes along with Computer Aided Design, CAD; Computer Aided Manufacturing, CAM; and Computer Integrated Manufacutring, CIM. CIM is a combination of both CAD and CAM with heavy emphasis on the use of robotics. CIM is what the manufacturing industry is moving to, an entire factory controlled by a computer. This would include robots, different types of machine tools, conveyors, linear tables, and mobile transporters.

The XYZ program simulates a robotic workcell by having you move the robot through a defined work area, measured in millimeters. The teach pendant programs simulate standard industrial robot pendants. As you learn about these programs, you will probably think of many innovative uses for the different programming techniques.

OBJECTIVES

When you finish this lab activity, you will be able to:

1. Identify each of the four different programming techniques discussed.

2. Give a basic explanation of the programs.

3. Access all of the programs on the lab disk.

4. Identify the major uses of the different programming techniques.

LIST OF EQUIPMENT

1. Rhino XR Series robot and controller.

2. Apple IIe computer system.

3. Rhino Lab DIsk for Apple IIe.

RELATED INFORMATION

In this activity, you will first learn how to access the different programs on the Rhino Lab Disk. You will then be introduced to the basic characteristics of and prompts for each program. It is critical that you understand the material in this Lab before trying to go on to the next lab.

PROCEDURE

KEYBOARD MOVES PROGRAM

The first of the four programs we are going to look at is the KEYBOARD MOVES program. In this program, you will be introduced to the basic operation of the Rhino XR through the use of various keys on the computer.

_____1. Insert the Lab Disk into the computer disk drive. To access these programs from the computer, you must have the complete robot system connected and turned ON. If necessary, refer back to the directions in Lab 3 for connecting the Rhino system. First, you will be asked to indicate which interface card you are using. Do so and press the return key.

NOTE: The controller must be ON>

_____2. The first prompt to appear will be the Main Menu for the Lab disk. The programs you will be working with are labeled as Rhino Programs, selection 1. Type in 1, and press return. The screen should look like Figure 4.1.

```
        RHINO SERIAL #UPDT
          XO ZO DEFAULTS

              XO=100
              ZO=310

     CHANGE THESE VALUES? (Y/N)
```

Figure 4.1

Type N, and press the return key.

_____3. The next prompt will look like Figure 4.2.

```
      PRESS R OR F UNTIL THE
     TWO BASE HALVES LINE UP

         TYPE X TO EXIT
```

Figure 4.2

Reset the XR system by pressing the RESET button on the controller. The robot should go through its hard home routine. If you have a Mark III controller, make sure that the mode select switch is set for computer operation. Type X to exit.

____4. You will now come to the Main Menu, this will look like Figure 4.3.

MAIN MENU
1...INSTRUCTIONS
2...RUN PROGAMS
3...END PROGRAMS

YOUR CHOICE? (1-3)

Figure 4.3

Choose the first selection, Instructions, by typing the number 1, and pressing return.

____5. The screen should now look like Figure 4.4.

INSTRUCTIONS AVAILABLE

1...KEYBOARD MOVES
2...MOVE ALL JOINTS
3....TEACH PROGRAM
4.....XYZ PROGRAM

TYPE X TO EXIT

YOUR CHOICE? (1-4)

Figure 4.4

Now type in the number 1, for Keyboard Moves instructions, and press return.

____6. A paragraph of instructions should now appear on the screen. Read them carefully, and proceed to the next set by pressing the space bar on the computer. There should be ten separate screens of instructions in all. Upon pressing the space bar after the last screen of instructions, you will encounter the same screen you did in Figure 4.4.

____7. Type in X, and press return. This will bring you back to the Main Menu, Figure 4.3. This time type in the number 2 for Run Programs, and press the return key.

____8. A prompt shown in Figure 4.5 should now be present. This prompt is asking you which program you would like to load. Since we are working with the Keyboard Moves program, you should respond here by typing the numbeer 1 and pressing return.

PROGRAMS AVAILABLE

1...KEYBOARD MOVES
2...MOVE ALL JOINTS
3....TEACH PROGRAM
4.....XYZ PROGRAM

TYPE X TO EXIT

YOUR CHOICE? (1-4)

Figure 4.5

You will now see the operations screen for the KEYBOARD MOVES program, Figure 4.6. Since you turned the controller off earlier in this activity, the robot will not respond to any commands at this time. This screen identifies which key on the computer controls which axis on the robot. For example, keys R and F on the computer control the base movement of the robot, and keys T and G control the movement at the shoulder. All this program allows you to do is move the robot using specific keys on the keyboard. Through he use of this program, you should gain a good understanding of how the robot moves and how the movement of one axis affects the others. Figure 4.6 shows the keys which operate the Rhino XR.

H	MOTOR KEYS	W,S
G	MOTOR KEYS	E,D
BASE	KEYS	R,F
SHOULDER	KEYS	T,G
ELBOW	KEYS	Y,H
HAND	UP/DOWN	U,J
FINGER	ROTATE	I,K
FINGER	O/C	O,L

PRESS "REPT" FOR LONG MOVES

TYPE X TO EXIT

Figure 4.6

_____9. To exit this screen, press X and the return key. This will bring you to the Programs Available menu, Figure 4.5. Press X and return again. This will bring you to the Main Menu, Figure 4.3.

MOVE ALL JOINTS PROGRAM

In the MOVE ALL JOINTS program, you will explore a different way of moving the robot other than using specific keys to move each axis. In this program, the movement of the robot is determined by entering a value for a specific asix of the robot. This value is actually the number of motor steps you want to move an axis. For example, if you wanted to move the base of the robot, you would have to enter a value for that movement.

In order to accurately determine how far to mvoe a particular motor on the robot, you would have to determine how manu motor steps are equal to one motor revolution, and then how far one motor revolution will actually move the robot. If you had moved the robot base 500 motor steps and you then wanted to move it back to where it was, you would need to enter a value of -500 for the motor steps.

This is the way all of the axes on the robot work in this program. The advantage of this type of program over a program like the KEYBOARD MOVES is that you can determine exactly how far to move each axis.

____10. Load the instructions for this program by first typing in a 1, at the Main Menu, to get the Instructions Menu and then a 2 which indicates you want instructions for the MOVE ALL JOINTS program. Read all of the instructions for this program carefully; there should be ten screens in all.

____11. After reading the instructions for the MOVE ALL JOINTS program, press X twice to get back to the Main Menu.

____12. Now select option #2 to RUN the program and #2 again to load the operations screen of the MOVE ALL JOINTS program.

____13. You should now see the MOVE ALL JOINTS program operations screen, Figure 4.7.

PLEASE ENTER # OF STEPS

```
H    MOTOR STEPS
G    MOTOR STEPS
BASE       STEPS
SHOULDER STEPS
ELBOW      STEPS
HAND     UP/DOWN
FINGER    ROTATE
FINGER       O/C
```

FORMAT IS (+/-) 0.....2000 STEPS

TYPE X TO EXIT

Figure 4.7

Do not enter any values or concern yourself with motors H and G at this time.

_____14. What you would do now is enter a value next to the axis which you wanted to move. After typing in this value, you can enter it and move to the next axis by pressing the return key. After entering the last value, press return again, and the robot will move through the moves you just programmed. and then stop, until you enter more values. In this program, the robot moves in relation to its last ending position, meaning that there is no fixed home position.

_____15. Type X and press return twice; this will bring you back to the Main Menu again.

TEACH PROGRAM

The next program we will be discussing is the TEACH program. The TEACH program will enable you to do quite a bit more with the robot than either of the other two programs we have discussed. In this program, you will have to set a Home position. You will also be able to create a program, save that program, modify or make additions to it, and then run it.

In the TEACH program, there are four separate modes available. They are:

1. Create A Move Sequence
2. Modify A Move Sequence
3. Save A Move Sequence

4. Run A Move Sequence.

_____16. At the Main Menu, Choose #1 for INSTRUCTIONS.

_____17. This time when you see the names of the programs, choose #3 for the TEACH program.

_____18. When you have finished reading instructions, exit back to the main menu and then select the RUN PROGRAM OPTION (#2).

_____19. This will bring you to the screen which looks like Figure 4.4. Type in the number 3 for TEACH program, and press return.

_____20. The screen should now look like Figure 4.8. Type in the number 1, for Create A Move Sequence, and press return.

```
              DO YOU WANT TO

      1...CREATE A MOVE SEQUENCE
      2...MODIFY A MOVE SEQUENCE
      3...SAVE   A MOVE SEQUENCE
      4...RUN    A MOVE SEQUENCE

           YOUR CHOICE (1-4)

             TYPE X TO EXIT
```

Figure 4.8

If you notice, the operations screen for the Create A Move Sequence is identical to that of the KEYBOARD MOVES program. It also operates in the same fashion, except for some minor additions. In this program you will make a series of moves, called a sequence. Upon entering your last move of the sequence, you will have to type the letter A to save the sequence. Then a prompt will ask you if you would like to program another sequence of moves or stop ("More moves Y/N").

Now: Respond with N for No and you will return to the main menu (Figure 4.8). Choose option #4 to RUN a sequence.

_____21. Turn the controller POWER switch ON. Leave the MOTOR switch OFF. Press the RESET key on the computer, type RUN, and press RETURN. You need to do this in order to use this portion of the program. If you were actually using this program, the controller would have already been on, so this step would not have been necessary.

____22. Now press a few of the keys. Nothing will happen to the robot because it is turned off. However, the computer and controller are remembering your entries.

____23. Press the A key and you should get a prompt which reads as shown below. Type in N and press return.

MORE MOVES (Y/N)

This is how a sequence is entered. Now that would be only one sequence. If you wanted another, you would have needed to type in a Y for Yes, more moves. Then you could just keep entering more and more moves until you have completed your program.

____24. Type in the number 2 for Modify A Move Sequence (as shown in Figure 4.9) and press return.

1...MODIFY A SEQUENCE NOW ON DISK

2...MODIFY THE CURRENT SEQUENCE ONLY

TYPE (X) TO EXIT

YOUR CHOICE (1-2)

Figure 4.9

____25. The first choice would be used to modify a sequence of moves that you have already stored on disk. The second choice would be used to modify a sequence which you just created. For example, let us say that you really did enter some moves in the previous step. You would want the second choice, because that sequence has not been stored on a disk yet. Type X to exit.

____26. Type in the number 3. for Save A Move Sequence. The screen should now look like Figure 4.10.

1...SAVE WITH A SEQUENCE NOW ON DISK

2...SAVE WITH THE CURRENT SEQUENCE ONLY

TYPE (X) TO EXIT

YOUR CHOICE? (1-2)

Figure 4.10

The first choice would be used if you had a program stored on a disk, and you wanted to add another program onto it. This is different from modifying in that when you modify, you can change the moves you have, but you cannot add any. With this selection, you can add an entirely separate program onto one that you previously saved. The second choice is used to save a sequence of moves that you have just created. As an added safety precaution, you should always save your program as soon as you finish creating it. This gives you a copy on disk, which you can always refer to. If you do not save right away, there is always the possiblity that you might accidently erase it or lose it from the computer memory.

_____27. Type X to exit, and then type the number 4 to enter the Run A Move Sequence, as shown in Figure 4.11.

1...RUN A SEQUENCE NOW ON DISK

2...RUN THE CURRENT SEQUENCE ONLY

TYPE (X) TO EXIT

YOUR CHOICE? (1-2)

Figure 4.11

Again you have two choices. Choice number 1 would be to run a move sequence which you previously stored on a disk, and would now like to run. (If you followed the suggestion previously mentioned, this should be your choice.) Remember to always save a sequence before you try to run it. If you tried to run one before saving it, the computer would run it perfectly, but only once; then that sequence would be automatically purged and lost forever. Choice number 2 would be used if you just wanted to run the program once. This selection would run it, then purge it from the computer memory.

_____28. Type X and press return three times to get back to the Main Menu.

XYZ PROGRAM

For the next program the contorller must be turned ON. BE VERY CAREFUL TO FOLLOW DIRECTIONS. DO NOT PRESS ANY KEYS OR ENTER ANY VALUES WHICH ARE NOT LISTED IN THIS PORTION OF THE LAB. DOING SO MAY CAUSE DAMAGE TO THE ROBOT. The XYZ program is designed such that it allows the robot to be positioned anywhere in a coordinate system based on XYZ coordinates. This is in reference to an imaginary zero point on the robot where the three coordinates axes meet (Figure 4.12). As in the MOVE ALL JOINTS program, all positional entries are made in numerical values. The base or wrist movement, the shoulder movement, and the elbow are all recorded in millimeters. This means that if you wanted the waist to move a predetermined distance, you would have to measure that distance in millimeters and enter the value for that coordinate.

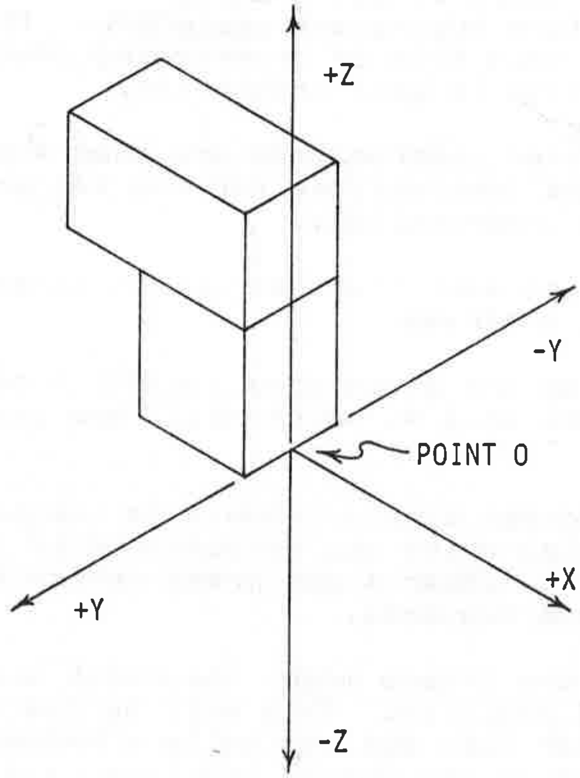

FIgure 4.12 Cartesian Coordinate Diagram

The hand movement and gripper revolution are measured in degrees. For example, if you wanted the gripper to revolve one quarter of a turn, you would have to enter a value of 90 degrees. The gripper opening and closing action is measured in motor steps. This is the same value used in the TEACH program.

The XYZ program uses the same four operation modes as the teach progam, although with some minor differences.

Again these modes are:

1. Create A Move Sequence
2. Modify A Move Sequence
3. Save A Move Sequence
4. Run A Move Sequence

We will cover these differences as we go through this program.

The advantages of being able to program by a coordinate system are quite significant. It is entirely possible to lay out on the computer the exact path you want the robot to follow, simply by making measurements in millimeters and determining certain angles in degrees. The robot would not even have to be present. As was mentioned earlier, this is extremely helpful because an entire assembly line could be designed and tested at the computer terminal before buying any equipment. The savings pssible with this type of programming check system are extremely attractive to most industries.

____29. Type 1 for instructions and then 4 to indicate you want instructions for the XYZ program. Read all of the instructions.

____30. Type X to exit the instruction screen and then a 2 to run programs.

____31. Since we are discussing the XYZ program, you will want to type in a 4, which will load the program.

____32. This screen display should be identical to the screen display which you encountered in Figure 4.8. Type in the number 1 and press return to enter the Create A Move Sequence.

Once you enter the Create mode, the robot will move into a HARDWARE HOME position. This will be discussed in more detail in a later lab, but basically a HARDWARE HOME is a pre-set position of the waist, shoulder, and elbow axes. Whenever you enter the Create mode, the robot will home itself.

____33. The screen on the computer should now look like Figure 4.13. The cursor should also be blinking across from the X coordinate, meaning it is waiting for an entry. If you were programming the robot, you would enter a value for X and press return. DO NOT ENTER ANY VALUES. Pressing return both enters the value and moves the cursor down to the next coordinate. After studying the screen and the diagram, type in X to exit this mode.

X	(0-350)
Y	(0-350)
Z	(0-350)
HAND ROT	(0-360)
FING ROT	(0-360)
FING O/C	(0-150)

TYPE (X) TO EXIT

Figure 4.13

_____34. Now let us take a look at the modify portion of this program. Type in 2 and press return, for Modify A Move Sequence. The robot should again go through its HARDWARE HOME routine. You should see the same two choices that you encountered in the modify portion of the TEACH program.

The modify mode will enable you to make changes in a program you have just designed, or one that is already on disk. What the computer does when you indicate that you want to modify is to run the robot move by move, displaying the value for that move, and giving you the opportunity to change it. Values are changed the same way they are entered. You just type over the old value and press return to enter the new value. The modify mode also offers you the opportunity to add two programs together. This is called "Appending". We will cover this portion of the program in more depth in a later lab.

_____35. Press X to exit modify and then press 3 to enter the Save mode.

The SAVE mode operates in the same manner as in the TEACH program. Remember it is always a good idea to save as soon as you finish creating a file. This will help you avoid the possibility of losing a valuable program. It is also a good idea to use a simple, easily remembered name when creating a file in the SAVE mode. For example, you might use the first three letters in your name or your initials.

_____36. Press the X key and return to exit the SAVE mode. Then type in 4 and return to enter the RUN mode.

The RUN mode in the XYZ program operates identically to the RUN mode in the TEACH program. Again, if you enter the RUN mode before you save the program, you will lose that program after the computer runs it once.

____37. You may now remove the lab disk from the disk drive and turn the computer and controller off.

When you have finished this lab, be sure to store the disk properly and turn all the equipment OFF.

REFERENCES:

<u>Fundamentals of Robotics: Theory and Applications</u>, Chapter 2, "Operating Robots" (pp. 29-50) and Chapter 3, "Off-Line Programming" (Introduction only).

NAME ____________________

DATE ____________________

CLASS ____________________

INSTRUCTOR ____________________

QUESTIONS

Multiple choice questions may have more than one correct response. Circle all correct answers.

1. Off-Line programming is only possible with which of the following programs:

a. KEYBOARD MOVES
b. MOVE ALL JOINTS
c. TEACH program
d. XYZ program

2. With the MOVE ALL JOINTS program, it is possible to:

a. Create a move sequence
b. Modify a move sequence
c. Save a move sequence
d. All of the above
e. None of the above

3. How many keys are used to operate the robot when using KEYBOARD MOVES program?

a. 12
b. 10
c. 13
d. 11

4. The T and G keys on the computer operate what axes of the robot in the KEYBOARD MOVES program?

a. Waist or base.
b. Elbow
c. Shoulder
d. Gripper revolution

5. In the MOVE ALL JOINTS program, all entries are made in units of:

a. Inches.
b. Motor Steps.

c. Millimeters.
d. Degrees.

6. If you are at the Main Menu and you want to load the MOVE ALL JOINTS program, how many commands do you have to give the computer?

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

7. T F In the TEACH program, it is not necessary to identify a Home position.

8. List the four modes used to operate the TEACH program.

9. In which of the four modes do you actually program the robot?

a. Command mode.
b. Run mode.
c. Create mode.
d. Modify mode.

10. What should you do after creating a program?

11. In the XYZ program, all entries are made in units of:

a. Millimeters
b. Centimeters
c. Degrees
d. Motor steps

12. T F When is using a program such as the XYZ program, it not possible to design a program for the robot without having the robot present.

13. If you enter the Run mode directly after creating a program, what will happen after the robot completes the sequence?

14. The name given to the Home position in the XYZ program is:

a. Pre-set position.
b. Software home.
c. Rhino home.
d. Hardware home.

15. T F In the Modify mode of the XYZ program, you can run your program.

LABORATORY 5

RUNNING THE KEYBOARD MOVES PROGRAM

INTRODUCTION

The Rhino XR Series robot has five separate joints or axes (plus gripper) which are capable of moving independently of each other. In this particular activity, you will become more familiar with the different parts of the robot and learn to identify which motor is responsible for each movement. You will also learn to operate the KEYBOARD MOVES program of the Lab Disk; this designates specific keys on the computer keyboard to operate each of the six robot motors. The KEYBOARD MOVES program is structured so the operator can make both short and continuous moves with the robot, to any of its possible locations.

OBJECTIVES

When you finish this lab activity, you will be able to:

1. Identify all five axes and gripper of the Rhino XR Series robot.

2. Describe the function of each of the six motors on the robot.

3. Operate the KEYBOARD MOVES program.

LIST OF EQUIPMENT

1. Rhino XR Series robot and controller.

2. Apple IIe computer system.

3. Rhino Lab Disk for Apple IIe.

4. Three two inch (50.8 mm) square wooden blocks.

5. One sheet of notebook paper.

RELATED INFORMATION

Whether you are using industrial robots or educational robots, there are specific operating procedures which you must be followed. The operation of robots must be studied carefully and mastered before you will fully understand how to use them. Although all robots are different, once you have gained a basic understanding of the operation of one, learning to use the others will be much simpler.

The Rhino is constructed so that when any one axis is moved, it does not change the relative orientation of the parts connected to it. This means the XR is an "articulated" arm. For example if the shoulder is moved with the gripper in a vertical position, the gripper will travel along at an equidistance from the shoulder axis and always remain vertical.

PROCEDURE

In the first part of this lab, you will load the disk. In later steps, you will operate the program.

_____1. Load the Lab Disk, which your instructor will provide for you, into the disk drive. KEYBOARD MOVES is one of the RHINO PROGRAMS.

_____2. The computer will ask if you want to change some values. Press the N key and then the RETURN key.

_____3. The next prompt to appear will be:

PRESS R OR F UNTIL THE TWO BASE HALVES LINE UP

Even though you are not yet familiar with the components of the Rhino XR, press either one of the above keys, located on the computer keyboard, and you will see the base portion of the Rhino XR move. Continue to press one or the other key, until the two halves of the base are square with each other.

_____4. You will then use the following prompt at the bottom of the screen.

TYPE X TO EXIT

Press the X key. You do not have to press the RETURN key.

_____5. The screen will now display the Main Menu. Press the 1 key and then the RETURN key to get the Instructions menu.

_____6. The screen will now show the Instructions menu. You want the first choice, for KEYBOARD MOVES.

_____7. The screen will now display instructions for using the KEYBOARD MOVES program. Read these instructions carefully and proceed to the next set of instructions by pressing any key except B or X. There are ten sets of instructions in all.

_____8. After reading the instructions you will be back at the Instructions menu.

_____9. Enter X to exit the Instructions menu and return to the Main Menu.

_____10. You now want to run the KEYBOARD MOVES program so pick the second choice, for Run Programs.

____11. Since we are wanting to run the KEYBOARD MOVES, type in the number 1 and press the RETURN key.

____12. You are now in the KEYBOARD MOVES program. The rest of the procedures in this lab will be concerned strictly with the operation of the robot itself.

Figure 5.1 is a picture of the computer keyboard. The highlighted keys are the ones that operate the robot in the KEYBOARD MOVES program.

Figure 5.1 Computer Keyboard

_____13. Press the letter O on the keyboard. As you can see, this key operates the opening of the gripper of the robot. The gripper is controlled by motor A.

_____14. Press letter L on the keyboard of the computer. As you can see, this key operates the closing action of the gripper. Notice this closing action is also controlled by motor A. This opening and closing of the gripper is obtained by running DC current through the motor first in one direction to open, and then in the other direction to close the gripper.

The opening and closing of the gripper is not considered to be a robot "axis". The next five robot movements discussed are considered to be axes and will be identified as such.

_____15. Next press the I key on the computer. This key rotates the gripper in a clockwise direction. Pressing the K key will rotate the gripper in a counter clockwise direction. Motor B is responsible for this movement, gripper rotation.

_____16. Press the U key to move the robot's hand in an upward direction. By pressing the J key, you can move it in the downward direction. Motor C is responsible for this movement, the wrist flex.

_____17. By pressing the Y key, you can move the forearm of the robot in an upward direction. It can be moved in a downward direction by pressing the H key. This is the elbow axis and is moved by motor D.

_____18. The T key controls the E motor, which moves the shoulder joint in an upward direction. The G key moves it in a downward direction. This axis is also called the bicep axis.

_____19. The last of the axes is the waist axis. It is controlled by the R and F keys which move it to the right and left, respectively. Motor F controls this axis.

_____20. Now make a chart which lists all six motors, starting with motor A, and identifies what keys control each motor and joint.

Now that you have a basic understanding of how to operate the KEYBOARD MOVES program, we will use the program to move some blocks around.

____21. Tape a piece of notebook paper in front of the robot. Now line up the three wooden blocks in a row about six inches in front of the robot and trace around them.

____22. Using the KEYBOARD MOVES program, stack the blocks one on top of the other off to one side.

____23. Now unstack the blocks and return them to their original location.

REFERENCES:

Fundamentals of Robotics: Theory and Applications, Chapter 2, "Operating Robots", pp. 52-59.

NAME ____________________

DATE ____________________

CLASS ____________________

INSTRUCTOR ______________

QUESTIONS

1. What is the name of the program you used to move the robot?

2. When you read the instructions for the KEYBOARD MOVES program, what is the command to move on to the next set of instructions?

3. What motor on the robot is responsible for the movement of the shoulder?

4. Which motor opens and closes the gripper?

5. T F The opening and closing of the gripper is considered to be an axis.

6. How many motors are there on the Rhino XR robot?

7. How is it possible for motor C to move the wrist in both an upward and a downward direction?

8. How many different axes does the Rhino XR have?

9. What is the purpose of having two keys assigned to each motor?

10. T F Pressing the L key on the computer moves the gripper in a clockwise direction.

LABORATORY 6

ROBOT SAFETY AND MAINTENANCE

INTRODUCTION

Safety and maintenance are probably the two of the least exciting topics you can think of, but they are both very important. If you have been to an industrial plant and seen a robot pick up a 250 pound load and swing it at 50 inches per second, you will have much greater respect for robotic safety principles.

Two major aspects of safety need to be considered. First and foremost is human safety. Robots are just machines; they do no have the intelligence to watch out for people. Warning signs, limited access and every other means possible should be used to keep people out of the robotic work area.

The second safety concern is the safety of the robot. This may seem a little strange at first. Why worry about a machine's safety? Primarily because the robot represents a major financial investment that should be earning more money, not broken and in need of repairs. More importantly than just the cost of the robot is the critical role the robot usually plays in the production process. If the robot is down for any reason, the total manufacturing process might have to be halted. Add to these concerns the added costs of damaged or defective product and the expenses of repairing those products and you can quickly understand the need to protect the robot.

Robot safety is just as important with educational robots like the Rhino system as it is with industrial robots. You will be very unhappy if you severely pinch a finger or get a bad cut from working with the robot. You will also be upset if everytime you get ready to use the robot, someone else has broken it and not told anyone. Safety and maintenance are important, even in the school environment!

Safety and maintenance are closely related topics. If the machine is properly maintained on a regular schedule, it will tend not to breakdown. Accidents often occur when people get inside the working envelope of the robot while the power is turned on. The only people that should get that close to the robot are the maintenance people. So the people that are in the greatest danger from the robots are the people that maintain them. By carefully following safety rules, and applying liberal doses of common sense, you can work with robots and never get injured. The most important rule of all is to THINK BEFORE ACTING.

In this lab you will read through some safety suggestions (Rules) and then lay out the work envelope for the Rhino robot system. You will also learn some about robotic maintencence by adjusting the XR arm.

OBJECTIVES

When you complete this lab activity, you will be able to:

1. List several (at least five) safety precautions that need to be followed when working with the Rhino XR Series robotic system.

2. Demonstrate good safety practices while working with the Rhino XR Series robotic system.

3. Lay out the operating area of a robot system.

4. Adjust each of the axes of the robot to the proper position.

LIST OF EQUIPMENT

Apple IIe computer system.

Rhino XR Series robot and controller.

Set of Allen wrenches (tool kit).

Three pieces of paper approximately 3' x 3'(.914m X .914m).

Felt tipped marker.

RELATED INFORMATION

Robots never operate in isolation. They are used in conjunction with conveyors, machining centers, and all other kinds of equipment. Because of this system complexity, the safety concerns must take into consideration the operation of ALL the machines that interact with the robot, not just the robot.

The Rhino robot system simulates the industrial robotic systems by having additional motor ports and input/output for use with accessories. In this lab, you will connect the rotary carousel and the conveyor to the controller to simulate a workcell. For safety concerns, the total area of the workcell must be considered as off limits to any unauthorized people.

It is a standard industrial practice to have fences around workcells. These usually have safety interlocks that disconnect the power when ANYONE enters. Maintenance people usually have lock out tags on power panels. These tags warn other people not to turn the power on because someone is working on equipment and that would be dangerous to the repairmen.

A well designed workcell will have safety sensors indicating that the product is properly placed and ready to be handled by the robot. If the parts are not aligned, and could damage the robot or fixtures, then the process will automatically shut down and call the attention of the maintenance people.

The following suggestions for safe operation of the Rhino system are listed to help you focus on specific ideas that will protect you and the robots.

Robot Safety Precautions

1. Although the Rhino is relatively small in size, it is very stong and fast. You must respect its power and quickness.

2. Keep the robot work area free of debris and all foreign objects. Everything that is not part of a lab activity or workcell should be removed.

3. Make sure the robot is in good operating condition at all times. Report any unusual sounds, smoke, heat, or damaged components to your instructor immediately.

4. Be aware that it is possible for the robot to move unexpectedly any time it is operating. Unpredicted movement can be caused by the control program, human error, or system malfunction.

5. Do not open, attempt operation, or adjust components of the Rhino system unless you are specifically authorized to do so by your instructor.

6. Protective devices must be connected and in place before you operate the Rhino system.

7. Observe extreme care when connecting or disconnecting electrical plugs and components of the robot system. ALWAYS turn all power OFF before changing any electrical connections. This will keep the equipment from being damaged.

8. If for any reason the robot goes out of control, an emergency stop can be made by pushing the red reset button on the front of the controller.

9. Never exceed the maximum lifting capacity of the robot which is 5 pounds (2.27 kilograms).

10. Do not stick your fingers or other items like clothing, pens, or pencils into the workings of the robot. It is designed to be open so that you can see what is going on.

11. Do not perform any maintenance on the robot until you have received authorization to do so from your instructor.

12. Do not leave your robot unattended while it is operating.

13. Turn the robot system off before cleaning the robot or work area.

14. Shut off power to the robot system when you leave the work area and at the end of your class.

15. If you do not know the proper prcedure for a particular lab activity, ask your instructor for assistance.

These safety ideas are suggested for starters. As you work with the robots and you think of other ideas, be sure to mention them to your instructor.

PROCEDURE

This lab has two major activities. The first one has you lay out the safety lines for a single robot and the second activity involves making several adjustments to the cams and gears of the robot.

SAFETY ACTIVITIES

____1. Place a large sheet of paper (at least 3' by 3') or cardboard under the robot and outline the work area with a marker. To do this you will need to have the Rhino robot and controller with the Apple computer all connected and ready to operate. Locate the robot in the center of the table with the paper between the table and the robot. Use the KEYBOARD MOVES program to extend the robot arm into fully horizontal position. Slowly move the Rhino through a 360 degree motion and use the marker to scribe a circle 3 inches larger than the actual reach of the robot. Also draw a line around the base of the robot to indicate exactly where it is placed. Figure 6.1 shows the layout of the safety line.

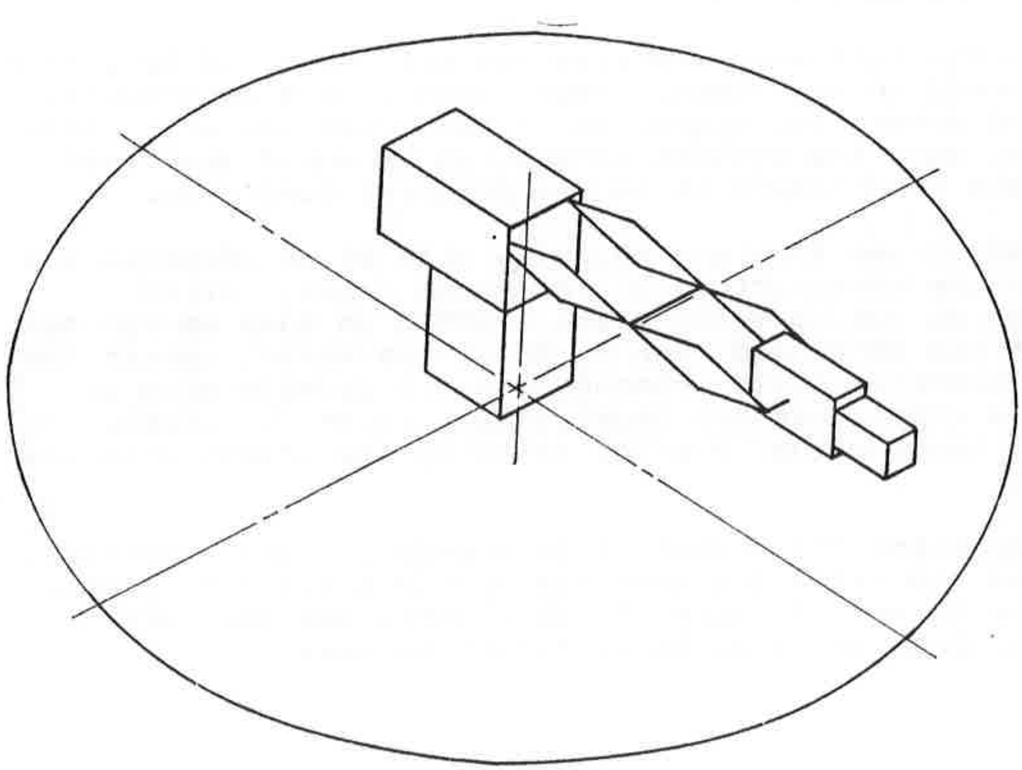

Figure 6.1 Robot Safety Line

____2. Label this paper SINGLE ROBOT SAFETY LINES.

____3. Remove the paper and store it away where you can use it for any labs that have you set up a single robot to do some work.

____4. Draw similar outlines for a complete workcell. Do this by placing the rotary carousel and conveyor on a new piece of paper along with the robot system. Place the table and conveyor so you could move a part from the conveyor to the table with the robot. Use the KEYBOARD MOVES program to take the robot through the potential moves. To make the carousel and conveyor operate, plug them into slots G and H of the controller.

____5. When you have finished making the outlines, label the paper WORKCELL SAFETY LINES, and then store it for later use.

MAINTENANCE ACTIVITIES

In the following exercise you will have you make four adjustments on the robot. Your robot should be properly adjusted before you start, so in each case you will loosen a screw, move the element to see how it would move when loose and then return it to the original condition.

Set screws that are adjusted with allen wrenches are used in the construction of the Rhino robot. Allen wrenches do not have the sizes printed on them so you must look at the screw and then by trial and error, select the proper wrench. Allen wrenches are six sided pieces of hardened steel that are usually bent in an 'L' shape. The shape gives you the leverage to twist the wrench with your fingers.

Selecting the proper allen wrench is very important. You have the right one when the wrench slips very tightly into the screw. A loose fit will strip out the hole in the set screw and also be difficult to use.

____6. Use the KEYBOARD MOVES program to place the robot in a vertical position. Have all the elements pointing straight up, including the hand.

____7. Turn the system off and then remove the robot cables from the controller.

____8. Place the robot on a table in front of you so the three large motors are closest to you (this will be called the "back" of the robot).

NOTE: Figure 6.2 shows the back of the robot and how you use one of the allen wrenches to adjust the axis.

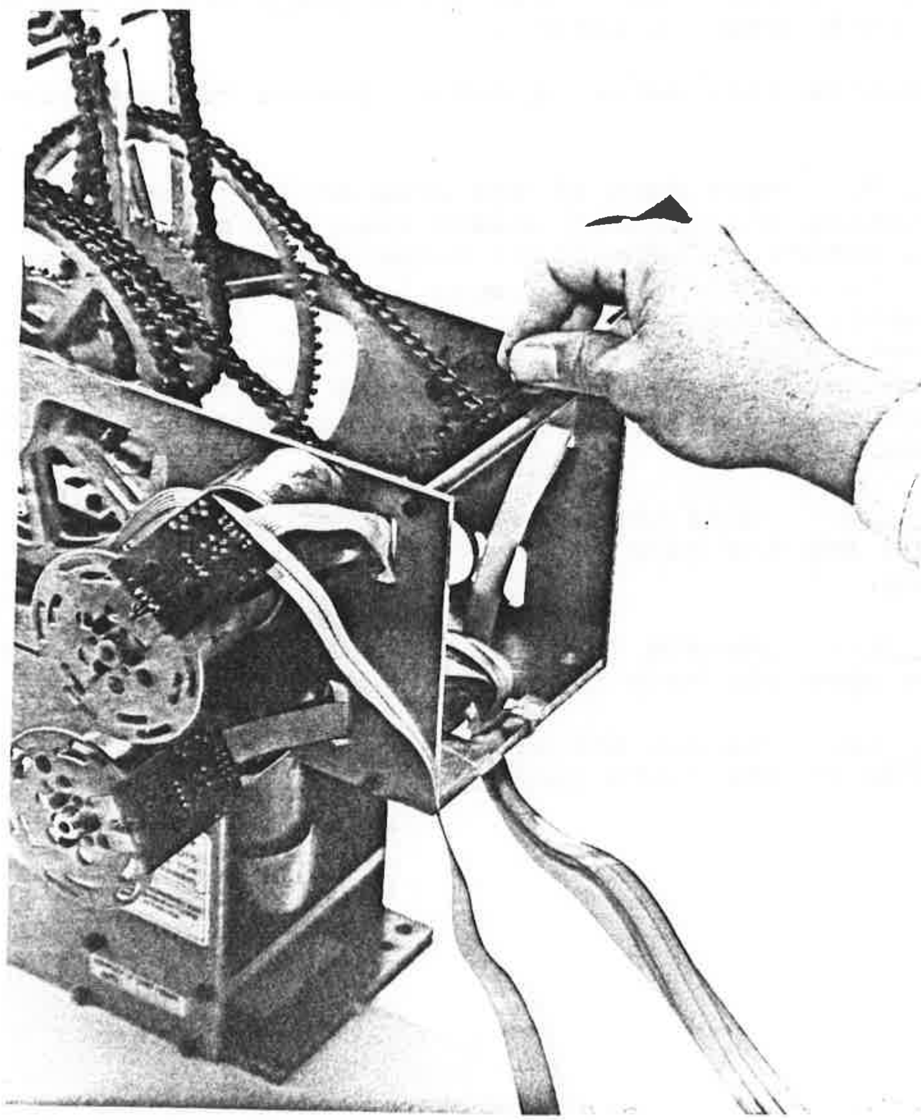

Figure 6.2 Adjusting an Axis

The four adjustments you are to make can all be easily accomplished with the robot in this position.

1. The first adjustment is to the tension cam for the hand "clutch" cable. Notice the blue cable that connects the hand to a set of gears at the elbow. The cam in the middle of the forearm controls how tightly the blue cable is stretched.

2. The three large motors (C, D, and E) at the back of the robot drive the shoulder, elbow and wrist. There are two motors on the left and one on the right side of the robot. The right motor (D motor) drives the gear train up the right side of the robot to move the forearm.

3. Wrist motion is caused by the gears and chains located on the left side of the robot that are closest to the center of the machine. These wrist gears are driven by the top left motor (C motor).

4. The bottom left motor (E motor) powers the shoulder motion.

_____9. Move each of the axes of the robot by rotating the encoder wheels that are on the ends of the motors. These disks interrupt a light beam so the controller can count locations to know exactly where each axis is located. The encoder wheels are sometimes called "optical choppers" because they are 'chopping' the light beam. Move each disk 4 or 5 rotations to view the motion of each axis.

_____10. Hold the forearm of the robot with one hand and the hand of the robot with your other hand.

_____11. Rotate the hand of the robot and notice how hard you have to push and pull.

_____12. Select the allen wrench that fits the set screw on the cable tension cam. Loosen the cam;

then move the hand again noticing the amount of pressure needed. Finally, retighten the cam in its original position.

____13. Hold the bar across the back of the robot with one hand and try to move the upper arm and the forearm of the robot with the other hand. DON'T USE TOO MUCH FORCE. YOU SHOULD NOT BE ABLE TO MOVE THE ARM PARTS.

____14. Loosen the set screw that connects the drive gear to the motor shaft on the right hand motor (D motor that drives forearm). Carefully move the forearm and notice that the motor does not turn. Move the arm back and forth three or four times to see that the arm moves while the motor does not. Now tighten the set screw and check that you again cannot move it using reasonable pressure.

____15. Repeat step 14 for the two left hand motors. (C and E). Be careful to not apply excessive force!

Make sure that all the set screws that you loosened are tight before you quit. Do not tighten the screws so much that other people will not be able to loosen them, this is not a test of your strength! In normal operation, these set screws tend to work loose. Therefore, you will want to check all the screws on the Rhino routinely so as to achieve the best repeatability possible.

NAME ____________________

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QUESTIONS

Please answer the following questions to demonstrate your mastery of the material in this lab.

1. What is the lifting capacity of the Rhino?

2. T F Robot safety is just as important with the Rhino Robot as it is with an industrial robot.

3. List five specific safety precautions that need to be followed while working with the Rhino robotic system.

4. Why would you want to provide safety measures to protect a robot?

5. What type of system is usually used to keep people away from an operating robot?

LABORATORY 7

RUNNING THE MOVE ALL JOINTS PROGRAM

INTRODUCTION

There are several different ways of programming the Rhino XR robot. Teach pendant programming is one method and will be discussed in a later lab activity. Computer programming is a more versatile method. Computer programs can simulate different types of robot operations. MOVE ALL JOINTS is a program available with the Rhino Lab Disk. This program allows the operator to move all of the Rhino robots motors a specific number of steps.

OBJECTIVES

When you complete this lab activity, you will be able to:

1. Determine the number of motor steps required to move the robot to a specific position.

2. Operate the MOVE ALL JOINTS program.

LIST OF EQUIPMENT

1. Rhino XR Series robot and controller

2. Apple IIe computer system

3. Rhino Lab Disk for Apple IIe.

4. Three 2 inch (50.8 mm) square wooden blocks.

5. A sheet of notebook paper.

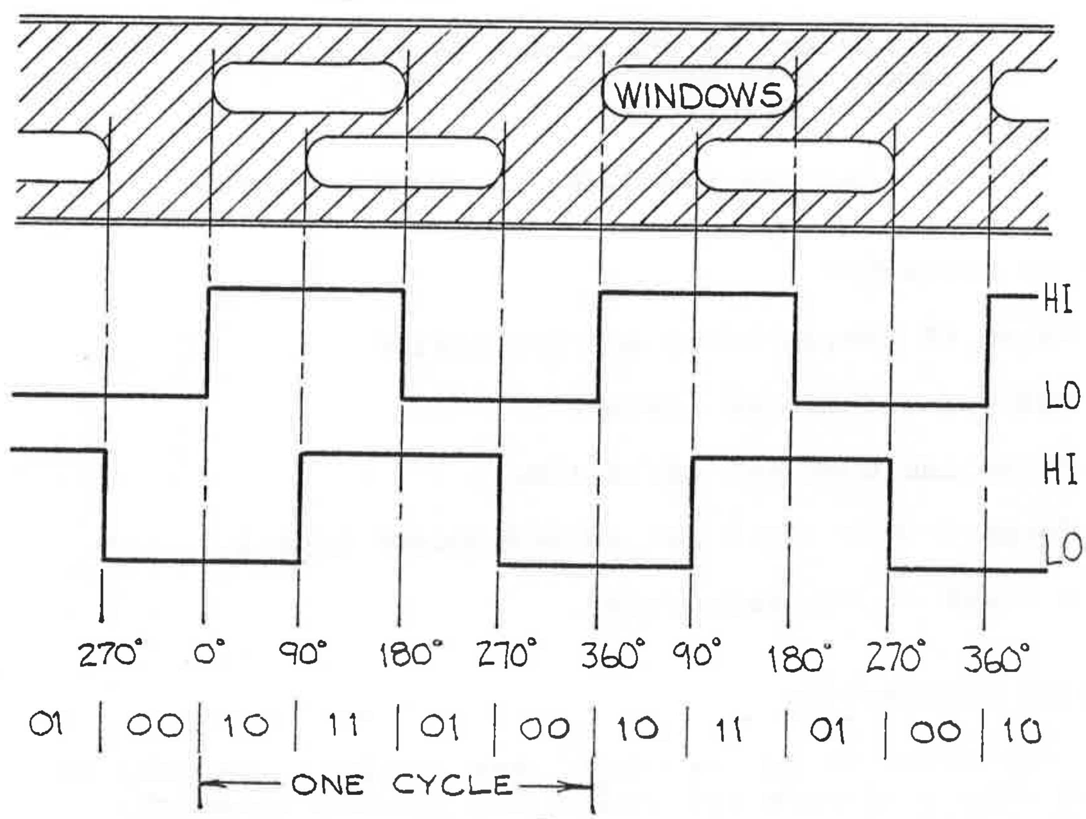
RELATED INFORMATION

The Rhino XR Series robot uses optically encoded DC servo motors to move its joints and achieve feedback. Feedback allows a system to indicate the current position of its moving parts. This current position can always be compared to the target position to see if the difference is zero. When the difference is zero, the target position has been reached.

Optical encoders are the feedback system used on the Rhino

XR. The optical encoders tell how far each motor has moved and in what direction the motors are rotating. Each optical encoder consists of two light emitting diodes, two phototransistors, and an encoder wheel.

The light emitting diodes provide a light source which is detected by the phototransistors. The encoder wheel is a disk on the end of the motor that has six sets of slots (on the wheels that are used on the large motors) or two sets of slots (on the wheels that are used on the small A and B motors) cut in it near the edge. The phototransistor senses when the light beam is interupted by the wheel. The slots are off-set making it possible to count in binary; 0,1,2,3. Each number represents on step of the motor. The controller can tell the direction each motor is moving by the way the numbers change.



PROCEDURE

In this lab activity, you will be guided through the operation of the MOVE ALL JOINTS program. As stated in the introduction, the MOVE ALL JOINTS program allows you to control all of the Rhino XR motors by moving each motor a specific number of steps.

_____1. Turn on both power switches of the controller.

_____2. Load the Lab Disk into the computer disk drive and turn on the computer.

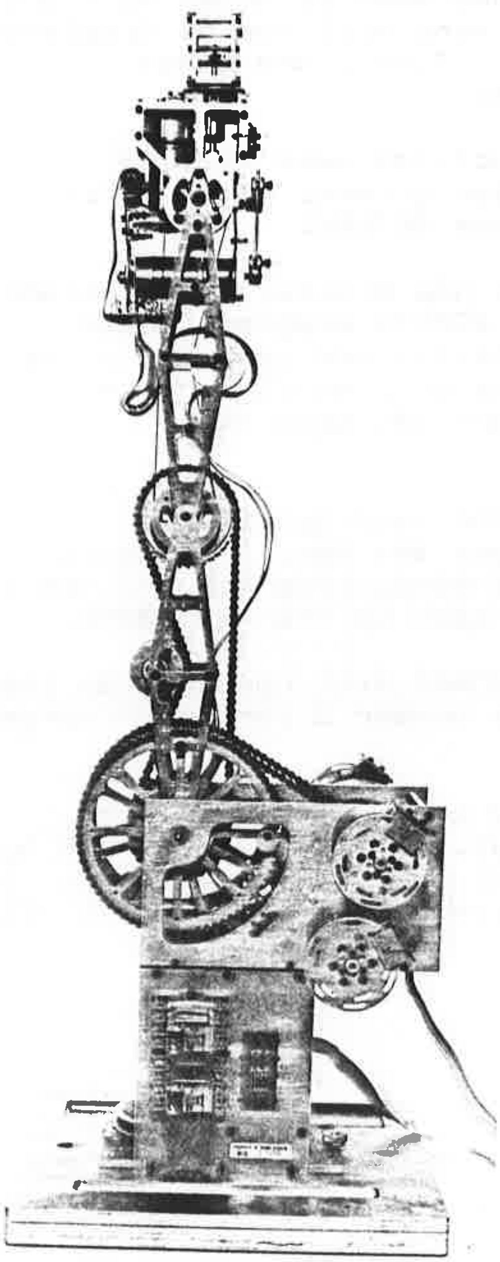


Figure 7.1

XR Series Robotic Arm, in Vertical position

____3. It is very important to realize when operating the MOVES ALL JOINTS program that the movements of the robot are all relative to where the robot was located when the data was entered. Thus, the HOME position of the robot must be defined and the data entered in accordance to this HOME position. For this lab activity, the Rhino XR robot will be located in the vertical position, shown in Figure 7.1.

____4. Use the KEYBOARD MOVES program to move the robot into the vertical position. Then exit the KEYBOARD MOVES program.

____5. Exit the Programs menu by pressing X and then RETURN. The Main menu will now be displayed on the computer screen. Type 1 and press RETURN, for Instructions.

____6. Next the Instructions menu will be displayed on the computer screen. Type 2 for MOVE ALL JOINTS and press RETURN.

____7. The screen will now display instructions for using the MOVE ALL JOINTS program. Read these instructions carefully and proceed to the next set of instructions by pressing any key except B or X. There are ten sets of instructions in all.

____8. After reading the last set of instructions, again press any key. This will bring you back to the Instructions menu. Type X and press RETURN to go back to the Main menu.

____9. The computer screen will now display the Main menu. Type in the number 2 for Run Programs and press RETURN.

____10. The computer screen will display the Programs menu for execution. Type 2 for MOVE ALL JOINTS and press RETURN. This will allow you to enter the operating phase of the MOVE ALL JOINTS program.

____11. The computer screen will display the following information:

```
              RHINO ROBOTS
        DEMONSTRATION DISKETTE
              VERSION 0.3

        PLEASE ENTER # OF STEPS

              H    MOTOR STEPS
              G    MOTOR STEPS
              BASE       STEPS
              SHOULDER   STEPS
              ELBOW      STEPS
              HAND     UP/DOWN
              FINGER    ROTATE
              FINGER       O/C

      FORMAT IS (+/-) 0..2000 STEPS

              TYPE  (X) TO EXIT
```

____12. To operate this program, you must enter a value or press RETURN and the cursor will move down to the next line. After the last value has been entered and you press RETURN, the motors will each move their respective number of steps.

____13. In this lab activity, you will not be using the H or G motors. To indicate this, press the RETURN key twice.

____14. The blinking cursor should now be on line three, Base Steps. Enter the value 670.
Press the RETURN key until the cursor disappears.
After a brief delay, the robot base will rotate 90 degrees in the counterclockwise direction.
RETURN to line three as before. Now enter the value of -670 and press RETURN as done previously. After a brief delay, the robot base will rotate 90 degrees in the clockwise direction. The robot should now be back to its vertical HOME position. Now reverse the values and observe the results.

_____15. Press the RETURN key until the blinking cursor is on line four, Shoulder Steps. Enter the value of 750. Press the RETURN key until the blinking cursor disappears. After a brief delay, the robot shoulder will move 90 degrees downward. Now enter the value of -750 and proceed as before. The robot will return to its HOME position.

_____16. Press the RETURN key until the blinking cursor is on line five, Elbow Steps. Enter the value of 750. Press the RETURN key until the blinking cursor disappears. After a brief delay, the robot elbow will move 90 degrees backward. Now enter the value of -750; this will return the robot to the HOME position.

_____17. Press the RETURN key until the blinking cursor is on line six, Hand Up/Down. Enter the value of 800. Press the RETURN key until the blinking cursor disappears. The robot hand will move 90 degrees backward. Return the robot to the HOME position by entering the value of -800.

_____18. Locate the blinking cursor on line seven, Finger Rotate. Enter the value 90. Press the RETURN key until the blinking cursor disappears. The robot gripper will rotate 90 degrees in the counterclockwise direction. Enter the value -380 and robot gripper will rotate 90 degrees in the clockwise direction.

_____19. Locate the blinking cursor on line eight, Finger O/C. Enter the value 90. Press the RETURN key until the blinking cursor disappears. The robot fingers will close. Enter the value -90 and the robot fingers will open to their original position.

____20. Now that you have moved the robot using single moves, you can try multiple moves. Enter the following values:

H MOTOR	STEPS	0
G MOTOR	STEPS	0
BASE	STEPS	335
SHOULDER	STEPS	375
ELBOW	STEPS	375
HAND	UP/DOWN	400
FINGER	ROTATE	190
FINGER	O/C	45

Enter the same values, but make them negative. The robot should return to its original HOME position. Reverse the values and observe the results.

Operating the MOVE ALL JOINTS program is a little different than operating the KEYBOARD MOVES program, but not difficult. Each time you learn a new method, the learning process will be easier. To apply what you have learned, now complete the following steps.

____21. Stack three blocks using the MOVE ALL JOINTS program like you did using the KEYBOARD MOVES program in the previous lab.

____22. After you finish moving the blocks, think of a new activity of your own that you can have the robot do. Complete the new task and have your teacher watch the operation.

When you are finished with the lab activities, be sure to return the robot to its storage position and turn all the power off.

REFERENCES:

Fundamentals of Robotics: Theory and Applications. Chapter 12, "The Robot Controller," pp. 348 -353, and Chapter 3,

"Robot Coordinate Systems", pp 98-101.

NAME ____________________

DATE ____________________

CLASS ____________________

INSTRUCTOR ____________________

QUESTIONS

Answer the following questions to demonstrate that you have mastered the MOVE ALL JOINTS program.

1. Which of the following are menu driven software programs that operate the Rhino XR robot?

a. The teach pendant
b. MOVE ALL JOINTS
c. Your host computer
d. KEYBOARD MOVES

2. What type of motors are used on the Rhino XR robot?

3. T F The Rhino XR's motors can rotate in only one direction.

4. How many motors can be operated with the MOVE ALL JOINTS program?

LABORATORY 8

RUNNING THE TEACH PROGRAM

INTRODUCTION

In industry there may be many robots on one assembly line. The actions of all of these robots can be controlled by one computer. This is made possible by the fact that computers are capable of exchanging large amounts of information and can process information very quickly.

Industries are now working on development of factories that are completely controlled by computers. This is called Computer Integrated Manufacturing, or CIM. Due to this and other developments, it is important to be able to program a robot entirely from the keyboard of a computer. This lab develops the ideas and techniques of programming a robot from a computer terminal, through discussion and operation of the Rhino TEACh program.

OBJECTIVES

When you finish this lab activity, you will be able to:

1. Explain the importance of defining a HOME position for the robot.

2. Operate the TEACH program.

3. Write a program for the Rhino XR Series robot.

4. Store the program for the Rhino XR Series robot on a disk.

5. Modify the program which you stored on the disk.

6. Run the program that you write.

LIST OF EQUIPMENT

1. Rhino XR Series robot and controller.

2. Apple IIe computer system.

3. Rhino Lab Disk for Apple IIe.

RELATED INFORMATION

In this activity you will be taken through the operation of the TEACH program. The TEACH program of the Lab Disk allows the operator to teach the robot a sequence of steps and modify those steps, save the program, and run the program. Thus, the TEACH program has four major parts: the create mode, the modify mode, the save mode, and the run mode. A short explanation of each is given below.

Mode 1, CREATE A MOVE SEQUENCE, displays the same menu as the KEYBOARD MOVES program. In this mode, the keyboard of the computer is used as a means of manipulating the Rhino XR robot. This will be the stage of the program where you will put the Rhino XR through a sequence of moves and have the computer remember them by pressing the A key on the computer keyboard.

Mode 2, MODIFY A MOVE SEQUENCE, is used to either modify or change the program you just created in mode one. This is not done by actually repositioning the robot, but rather by changing numerical values which represent motor revolutions for each axes.

Mode 3, SAVE A MOVE SEQUENCE, is used to save the sequence you designed in mode one. It is usually a good idea to skip mode 2, modify a sequence, until after you have saved your program. You can always go back and modify after you have saved, but there is a chance that if you don't save right away, you might lose your program.

Mode 4, RUN A MOVE SEQUENCE, is used to run the program which you designed, saved, and modified in the previous three modes.

Before you start moving the Rhino XR through a desired sequence of moves, it will be necessary to designate a HOME position: There are two different types of HOME positions, one is a HARDWARE HOME, the other is a SOFTWARE HOME. Basically a HOME position is a predetermined position of each of the robots axes.

The first type of HOME position is called a HARDWARE HOME. When the HARD HOME command is given, the robot moves around and finds the exact center of the three microswitches on the D, E, and F motors.* These provide an absolute position from which the robot can LEARN a move sequence. The HARDWARE HOME (Figure 8.1) can be changed; it is always the same. The HARDWARE HOME position for the Rhino XR robot is shwon in Figure 8.1.

The SOFTWARE HOME is set and can be changed by the user. Also, it is concerned with all eight axes (controlled by motors A-G) not just the three that HARD HOME refers to. SOFT HOME is set by the user at a convenient location and the robot returns to this position whenever the "GO SOFT HOME" command is given. The use of SOFT HOME increases robot efficiency since with it, the robot does not need to return all the way to HARD HOME when it runs a move sequence.

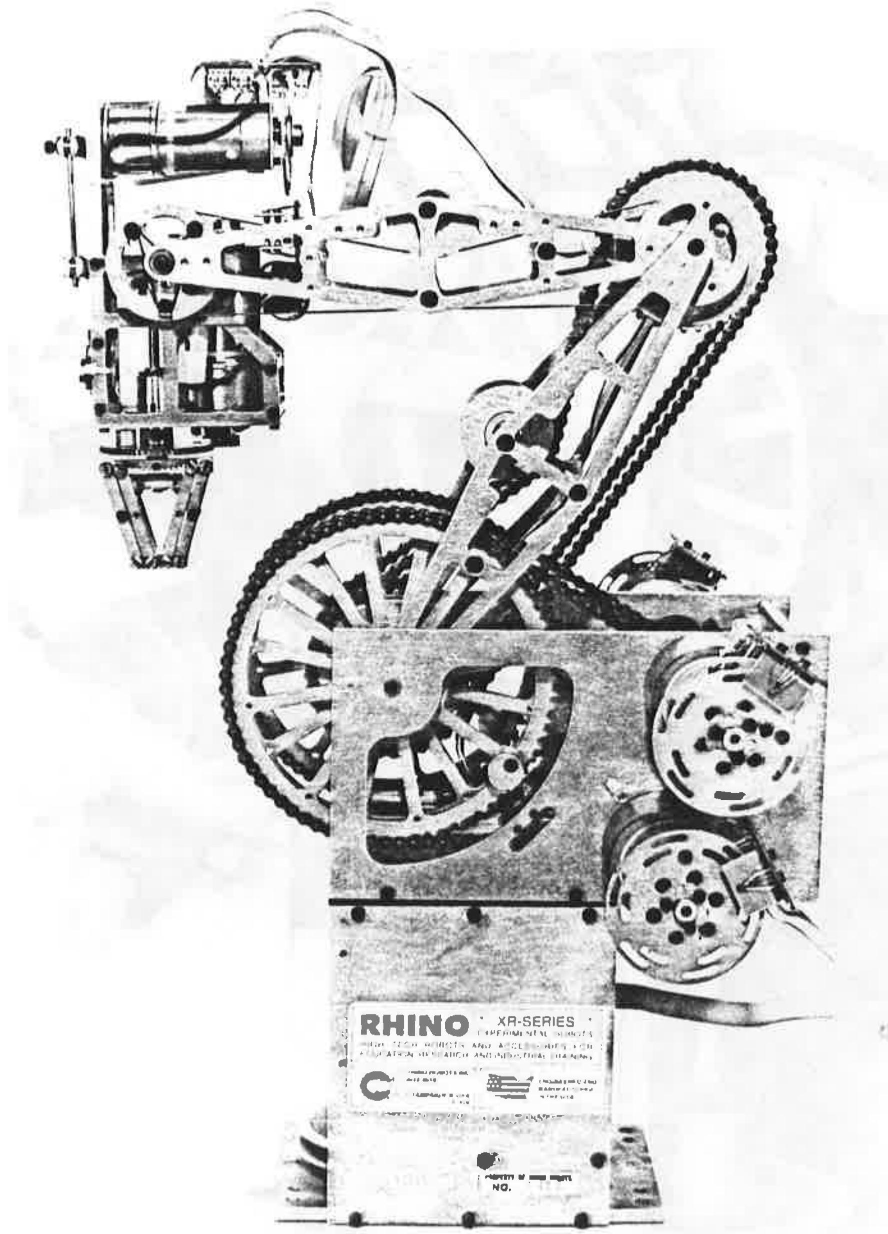


Figure 8.1 Rhino XR Hardware Home Position

*NOTE: On the Rhino XR robot, there is a microswitch which is mounted next to each gear of each axis, as shown in Figure 8.2. On each gear, there is a small cam which trips the microswitch each time it passes it. When you give the computer the prompt to send the robot to its HARDWARE HOME position, it will automatically move each of the robot axes until the cam on the robot gear trips the microswitch. After the switch has been tripped once, the computer reverses the motors and counts the number of motor revolutions until the switch is tripped again. The computer then positions the robot axes axactly in the middle of these two points.

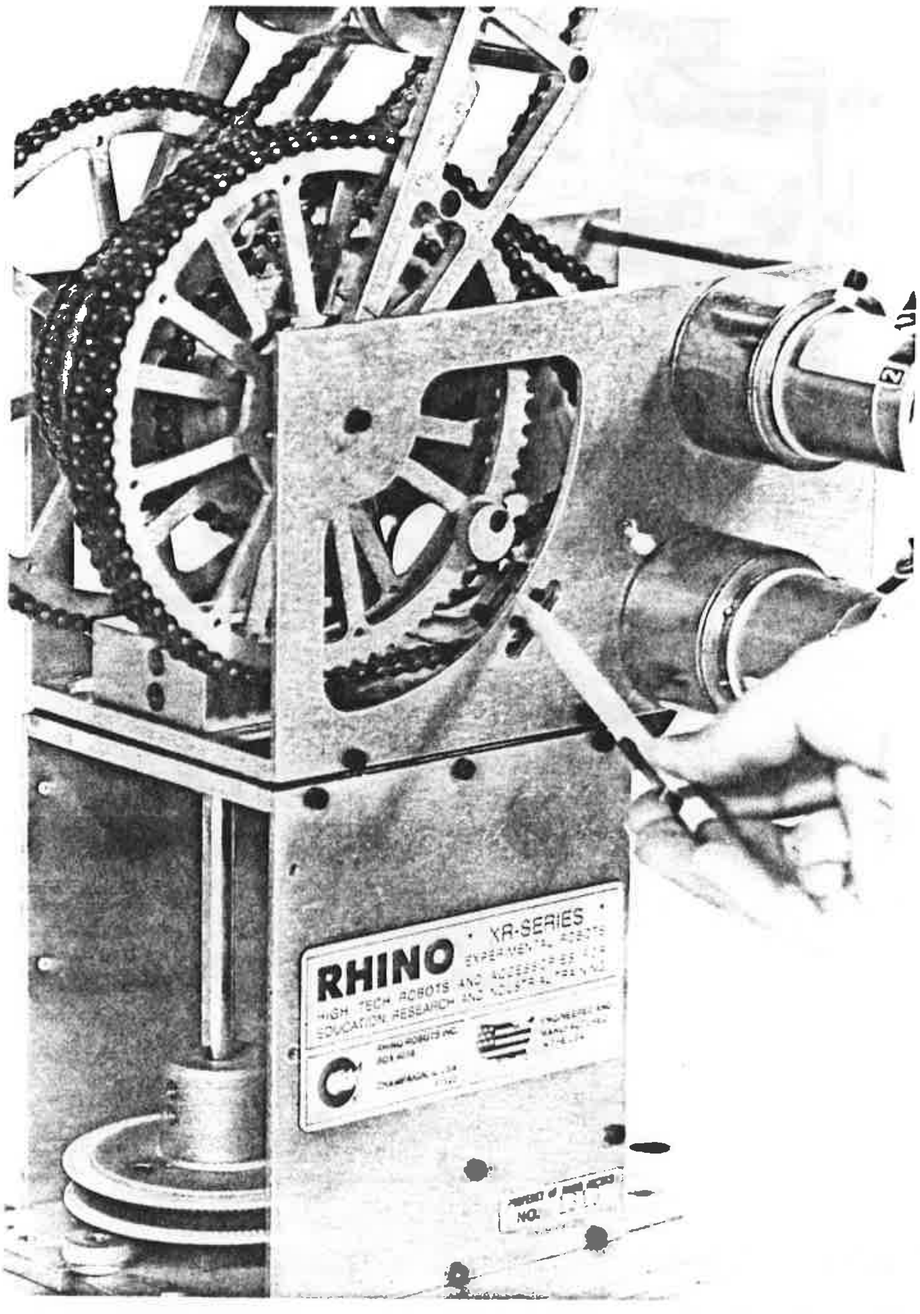


Figure 8.2 Microswitch on XR Series Robot

Without a HOME position, it would not be possible to program a robot to go through any sequence of moves more than once, unless you manually repositioned the robot to that exact same starting or HOME position. For example, let's say you wanted a robot to pick up a part which was passing on a conveyor and put it in a box. Without a designated HOME position, the robot would do this job perfectly once. But as soon as it let go of the part it deposited in the box, it would try to start the exact same program it just ran, from a different starting position. Obviously the robot would be way off when it went to reach for that second block on the conveyor. This is the reason for having to designate a HOME position, to enable the robot to repeat itself.

In this activity, it will be your job to designate a HOME position for the robot, by actually marking on the robot the position of each axis when you start.

PROCEDURE

In this activity, you will learn to use a software package which actually enables you to program the Rhino XR robot from the computer keyboard. This program will have you enter the number of steps you want each motor to move and then record the moves into a program to be run again later. You will also become learn to set a HOME position to which the robot can return.

____1. Turn the XR controller on. Load the Lab Disk into the computer disk drive.

____2. Call up the TEACH program.

____3. The following prompt will appear:

CHANGE THESE VALUES? (Y/N)

Type in N and press the RETURN key.

____4. The next prompt to appear will be:

PRESS R OR F UNTIL THE TWO BASE HALVES LINE UP

After lining up the base halves of the Rhino XR, press the X key.

____5. This will bring you to the Main menu. Type 1 and press RETURN, to get INSTRUCTIONS. Now type 3 and press RETURN again.

____6. The screen will now display instructions for using the TEACh program. Read these instructions carefully and proceed to the next set of instructions by pressing any key except B or X. There are ten sets of instructions in all.

____7. After reading the last set of instructions, again press any key, which will bring you back to the same screen display as you encountered in step 5.

____8. Now type X and press the RETURN key. This will bring you back to the MAIN menu.

____9. Type in the number 2, which will give you a choice of programs available.

____10. Since we will only be concerned with the TEACH program, type in the number 3 and press the RETURN key. The display which is in front of you should now offer four choices.

1. CREATE A MOVE SEQUENCE
2. MODIFY A MOVE SEQUENCE
3. SAVE A MOVE SEQUENCE
4. RUN A MOVE SEQUENCE

____11. As was previously mentioned, it will be necessary to set the Rhino XR robot in a HOME position. To do this, call up the KEYBOARD MOVES program according to the procedure described in a previous lab.

____12. Now using this program, position the robot as shown in Figure 8.3.

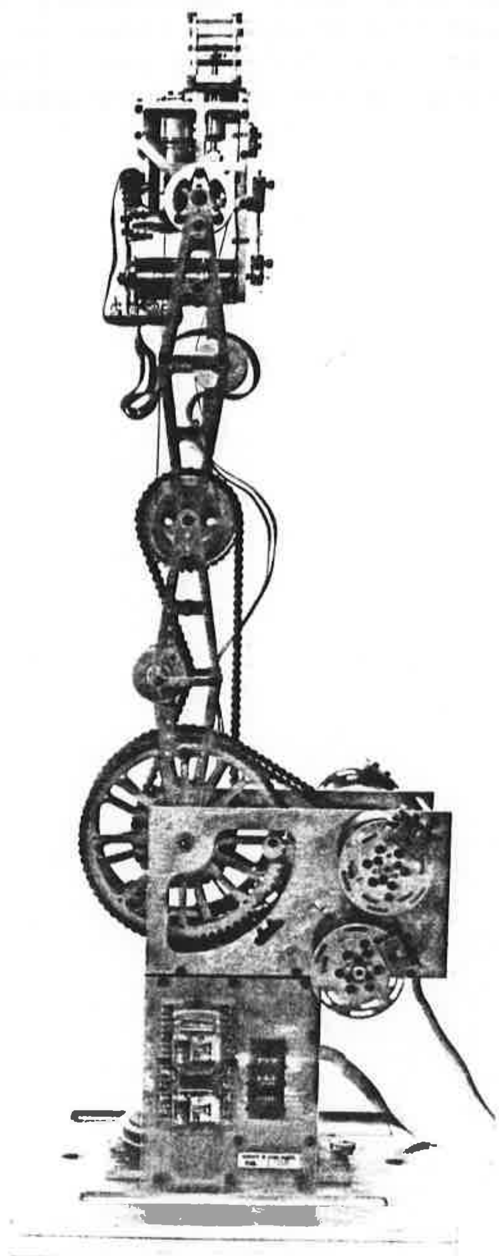


Figure 8.3 Rhino XR Series Robotic Arm, in a vertical position.

_____13. When you have the Rhino XR in this position, take a pencil and put a mark at each axis so that after moving the robot you can bring it back to the same position by lining up the pencil marks. This is how you will designate the robot's HOME position in this activity.

_____14. Now exit the KEYBORAD MOVES program and get back into the TEACH program, at the point where you were at Step 10 of this procedure. This should be the screen displaying the four mode choices.

_____15. Type in the number 1 and press RETURN for the CREATE A MOVE SEQUENCE. You will now see the same screen you encountered in the KEYBOARD MOVES program.

_____16. At the bottom of the computer screen, you will see the prompt:

TYPE (A) TO ENTER MOVE

Type in the letter A. By typing in A, you tell the robot that this is the first position you want to enter. This is not a HOME position, but rather a first location the robot should return to in order to complete a loop of moves.

_____17. Now, at the bottom of the computer screen there will be the following prompt:

MORE MOVES (Y/N)

Type in Y and press the RETURN, which means you want to enter more moves.

_____18. Now type in key R fifteen times. This will move the base to the right fifteen steps of the motor. Do this with letters T,Y.U and I.

_____19. This was your first sequence of moves, so you must now type in the letter A to enter them, and then the letter Y and RETURN, to tell the computer you would like to enter another sequence.

_____20. Now type in the letters F.G,H,J, and K, each fifteen times. This should bring the Rhino XR back to its erect position.

_____21. You must now type in the letter A again to enter the second sequence of moves. This time instead of typing in Y, type in N and RETURN, which indicates to the computer that this was also your last sequence of moves. Upon typing in the NO command, the computer screen will return to display the four mode choices again.

____22. You will now want to save the program you just created, so type in the number 3 and press RETURN, which will put you in the SAVE A MOVE SEQUENCE.

____23. The computer screen should now display two more prompts:

1. SAVE WITH A SEQUENCE NOW ON DISC.
2. SAVE WITH THE CURRENT SEQUENCE ONLY

Since we just want to save the current sequence, type in the number 2.

____24. The next prompt to appear will read:

SAVE TO YOUR FILE OR SYS FILE? (Y/N)

You will be saving this program on the system file, or the disk that is now in the disk drive. So type in the letter S and RETURN.

____25. The computer prompt will now read:

YOUR FILE?

It is asking you to designate a name for the file you are saving. Type in a name, of no more than three letters (usually the first three letters of your name is the easiest to remember) and press the RETURN key. If you choose the SYS file option (S) as in Step 24 but do not designate a name for the file, your file will be overwritten the next time you save to SYS file.

____26. This will again bring you back to the four mode choices. Type in the number 4 and press RETURN to access the RUN A MOVE SEQUENCE.

____27. Two more prompts will now appear:

1. RUN A SEQUENCE NOW ON DISK
2. RUN THE CURRENT SEQUENCE ONLY

Since we just finished saving a file on the disk, the only correct response to this question would be number 1 and press the RETURN key.

____28. You will again be confronted with the prompt:

READ YOUR FILE OR SYS FILE? (Y/S)

As was stated earlier since you stored this program on the lab disk, your answer would be S. Type in S and press the RETURN key.

____29. The computer will now ask for your file name. Type in your file name and again press the RETURN key.

____30. The computer will now come up with the prompt:

REPETITION FACTOR?

The computer is asking you to indicate how many times do you want the robot to repeat the program. Lets start with five times; type in the number 5, and press the RETURN key.

____31. After the robot has completed the program, the computer screen will again RETURN to the four mode choices. Now we are going to modify this program. Press the number 2 key, and then press the RETURN key.

____32. The prompts that are now on the screen should read:

1. MODIFY A SEQUENCE NOW ON DISK
2. MODIFY THE CURRENT SEQUENCE ONLY

Again, since we stored the program on the master disk, the only correct choice would be number 1, so type in the number 1, and press the RETURN key.

____33. You must again press the S key and then return, indicating to the computer to read off the master disk.

____34. Enter your file name and press RETURN. The modifying sequence is done not by repositioning the Rhino XR with the keyboard commands, but rather by changing a numerical value for each robot motor. This numerical value corresponds with the number of motor rotations. If you followed this procedure carefully, the computer screen should now look like Figure 8.2.

SEQUENCE #1

H +0000
G +0000
F +0000
E +0000
D +0000
C +0000
B +0000
A +0000

Figure 8.2 Screen Display

____35. Upon pressing the RETURN key in step 34, the robot will move into its first sequence. Of course the first sequence was actually just a starting position, so the robot will not make any movements. On this same screen you will also see the following prompt:

MODIFY THIS MOVE? (Y/N)

Type in the letter N and press RETURN, to indicate that you do not want to modify this sequence of moves.

____36. After pressing the RETURN key, the robot will move into the second sequence of moves. You will again be confronted with the modify prompt. This time you will type in Y and press RETURN to indicate that you would like to modify this sequence.

____37. The cursor will now move to the top of the column, across from the letter H. Press the RETURN key until the cursor is across from the letter F. The value for F should be +0225. You aren't going to change the numerical value but rather just change the + or - value, which denotes a positive robot direction or a negative robot direction. So in front of the F value on the screen type -0225, and press the RETURN key which will both enter that value and advance you to the next position. Do this for the remaining values through B. Refer to Figure 5.

SEQUENCE #1 ORIGINAL		SEQUENCE #1 MODIFIED		SEQUENCE #2 ORIGINAL		SEQUENCE #2 MODIFIED	
H	+0000	H	+0000	H	+0000	H	+0000
G	+0000	G	+0000	G	+0000	G	+0000
F	+0225	F	-0225	F	-0225	F	+0225
E	-0225	E	+0225	E	+0225	E	-0225
D	+0225	D	-0225	D	-0225	D	+0225
C	+0225	C	-0225	C	-0225	C	+0225
B	+0225	B	-0225	B	-0225	B	+0225
A	+0000	A	+0000	A	+0000	A	+0000

_____38. After you have modified sequence #1, as shown in Figure 5, press the RETURN key. The screen will now display sequence #2.

_____39. Using the same procedure, now modify sequence #2, also shown in Figure 5.

_____40. After modifying the last value in sequence #2, press the RETURN key. The computer will now ask:

SAVE THIS SEQUENCE (Y/N)

Type in Y, and press RETURN.

_____41. The computer will now ask:

SAVE TO YOUR OR SYS FILE? (Y/S)

Type in S.

_____42. Enter your file name and press RETURN.

You have just completed the modifying sequence. What you have done by changing the plus and minus values is to reverse the order in which the Rhino XR will run its moves. Instead of leaning backwards and than righting itself, the Rhino XR will now lean forwards and then right itself.

_____43. Get into the run mode and run the Rhino XR through its new program.

_____44. Place a sheet of notebook paper approximately twelve inches in front of the robot. Place another piece of paper approximately twelve inches to the right of the first. Tape both pieces of paper to the table securely.

_____45. Now place a 1 inch square block in the middle of the first sheet of paper and trace around it. Mark this location as A.

_____46. Trace a second location on the other sheet of paper and mark it as location B.

_____47. Using the KEYBOARD MOVES program, approximately locate the Rhino XR in between the two sheets of paper.

_____48. Now using the TEACH program, create a move sequence such that the Rhino XR will pick up the block from location A, move it to location B, and then return it to is original starting position.

A. Save this program using the filename ONE.

____49. Create a new program which will have the robot move the block from location B back to location A and then position itself back to the starting location.

____50. Once both of these programs work to your satisfaction, join the two of the, by using choice one in the save mode. 1. SAVE WITH A SEQUENCE NOW ON DISK. Name this new file END. The XR arm should now do the following.

A. Pick up the block at location A.

B. Move it to location B.

C. Return it to the starting position.

D. Pick it up at location B.

E. Return it to location A.

F. Then go back to its original starting position and stop.

____51. After you have this new program operating satisfactorily, enter the modify mode and record the numerical value of each of the axes in Table 1.

REFERENCES:

Fundamentals of Robotics: Theory and Applications, Chapter 5, "Off-line programming," pp 148-158.

Rhino Software manual (documentation for RASP 1.0).

NAME ______________________

DATE ______________________

CLASS ______________________

INSTRUCTOR ______________________

QUESTIONS

1. What is the purpose of defining a HOME position for a robot?

2. List two different methods used for defining a HOME position for a robot.

3. The programs you used in this lab activity were:

a. TEACH MOVES
b. KEYBOARD MOVES
c. TEACH PROGRAM
d. ALL MOVES

4. How many commands were necessary to enter a move when in the create mode, and what were the commands you used?

5. How many mode selections are in the TEACH program and what are they called?

6. In what mode did you define the starting location for the Rhino XR?

7. The first sequence of moves that you created operated which axes on the Rhino XR robot?

8. In mode 3 (SAVE A MOVE SEQUENCE) when it was necessary to type in theletter S, what was the purpose of this command?

9. What is the first thing you should do after creating a file (if you plan to use that file in the future)?

10. When in the modify mode, you were able to change the program you created by:

11. The numerical values which were displayed in mode 2, represented:

a. The number of times the motors turned on and off.
b. The number of times you pressed the keys on the computer for each motor.
c. The distance in degrees which the robot axes traveled.
d. The number of steps the robot motors moved.

12. Why was it necessary to give a filename when in mode 3, SAVE A MOVE SEQUENCE?

LABORATORY 9

USING THE COMPUTER AS A TEACH PENDANT: RASP 3.0

INTRODUCTION

The RASP (Rhino/Apple Software Program) 3.0 software is essentially a program which allows the computer to be used as a teach pendant. This software allows the user to program movements of the robot, using certain keys on the computer keyboard instead of the teach pendant keys, and edit, save, and run these programs.

OBJECTIVES

When you finish this lab, you will be able to:

1. Identify and correctly use the 16 move key s and the 3 move distance keys on the computer keyboard.

2. Control the movement of the Rhino XR robot using RASP 3.0.

3. Develop and edit programs for the Rhino XR robot system.

LIST OF EQUIPMENT

1. Rhino XR Series robot and controller

2. Apple IIe computer system.

3. Rhino Lab Disk for Apple IIe.

4. Two one-inch (25.4 mm blocks).

RELATED INFORMATION

In this lab, you will learn how to operate the Rhino XR robot while in the PLAY mode using 12 of the 16 move keys and the 3 move distance keys of RASP 3.0. The move keys are those 16 keys on the upper left hand side of the keyboard. The 12 move keys you will use are the following:

MOTOR	DIRECTION	KEY
F (waist)	Counter clockwise	7
	Clockwise	U
E (shoulder)	Forward	6
	Backward	Y
D (elbow)	Up (+)	5
	Down (-)	T
C (wrist)	Up	4
	Down	R
B (wrist)	Clockwise	3
	Counterclockwise	E
A (hand)	Open	2
	Closed	W

In part of this lab activity, you will be operating the robot while in the PLAY mode. This mode of operation allows you to move any axis motor on the robot without saving moves.

Follow all instructions carefully throughout this lab activity. Take care not to lose control of the robot. Remember, by taking your fingers off the keys, you can stop the movement of the robot.

The second part of the lab will have you learn to program the robot and then edit the programs you have developed. The programming instructions include:

1. C Key - This causes the computer to go into the learn mode. This means that the moves will be recorded as part of the program.

2. X Key - Sets a software home for all eight axes of the robot system.

3. V Key - Enters the positions of the motors to record a move. The robot may be moved about but none of the moves will be remembered until the V key is pressed.

4. S Key - Sends the robot back to the software home position that was set with the X key. Use this key carefully since the robot may return to the home position in a manner that might touch parts of a complex equipment setup.

5. A Key - Enters a delay of about 1.5 seconds. Longer delays can be entered by entering the delay key several times.

6. D Key - When the program is done, press the D key. This is very important since it signals the computer that the program is ended. This command is easy to forget since you only use it once per program.

7. F Key - This key causes the robot system to RUN the program you have developed. The program will run until you press any key; then it will stop at the end of the current cycle.

8. J Key - Causes the robot to go to the hard home position. This returns the three major axes of the robot to positions defined by the positions of the three microswitches.

The editing commands with this program are very easy. The commands include;

1. G Key - Press this key to enter the editing mode.

2. N Key - This key advances you to the next motor that you may wish to change.

3. H Key - Moves you back to the last motor that was displayed.

The editing process is easy because when you enter it, a motor value is displayed after the robot moves to the first position. Only the motor displayed will be active and can be changed. As motor values are displayed, you change the ones you want and that defines the new moves.

PROCEDURE

_____1. Gather all equipment onto an open work surface. Place robot in the center of the work area. Place the controller behind the robot on the left side and the computer on the right side.

_____2. As in Lab 3, connect the robot motor cables to motor parts A-F of the controller.

_____3. Insert the interface card you are using, as in Lab 2 and place the pin connector through an opening in the back of the computer.

_____4. Set the BAUD rate on your interface card to 9600. The switches should be set according to the diagram in Lab 2. This will not be necessary if you have the Rhino Com Language Card.

_____5. Take one end of the RS-232C cable and connect it to the pin connector that sticks out of the back of the computer. Plug the other end of the RS-232C cable into the Rhino XR controller in the lower left hand side labeled RS-232C CONTROLLER.

_____6. Plug the controller power cord into a 115 VAC outlet and turn on the 2 power switches. Check the red MAIN POWER light which indicates the unit is working.

_____7. Insert the Lab Disk into the disk drive of you computer and turn on both the computer and the monitor.

_____8. The selection you need is the RASP 3.0. Once you select this, you will also need to specify the interface card you are using and then adjust the Rhino XR so the base is aligned. When you have completed these steps you will be in the RASP 3.0 program.

_____9. The screen on your monitor should now read:

RHINO ROBOTS
RASP VERSION 3.0
MAIN MENU

1 CLEAR MEMORY
2 LOAD A FILE
3 SAVE A FILE
4 HELP SCREEN
5 RESUME PROG
6 END PROGRAM

YOUR CHOICE? (1-6) =>

_____10. The information on the screen is the RASP 3.0 Main menu. You will return to the Main menu many times as you learn how to run the Rhino XR robot with the RASP 3.0 software program.

_____11. To begin, first press the 1 key on the computer keyboard which will clear the memory of the computer. This prevents any possibility that previously stored information will interfere with your work.

_____12. Next, press choice number 4 which will display the HELP SCREEN. Your screen should now read:

RHINO ROBOTS
RASP VERSION 3.0
HELP SCREEN

MOTOR ABCDEFGH
+ KEY 23456789
- KEY WERTYUIO

MOTOR STEPS	HOME
100 STEPS=L	SET HOME=X
10 STEPS=K	GO HOME=S
1 STEPS=,	HARD HOME=J

TEACH MODE	EDIT
X=SET HOME	G=START EDIT
C=LEARN MODE	N=NEXT MOTOR
V=ENTER MOVE	H=LAST MOTOR
D=END TEACH	

F=RUN N=DELAY

PRESS ANY KEY TO CONTINUE

_____13. At the top of the HELP SCREEN, you will find a listing of which keys control which motors. Keys 2, 3, 4, 5, 6, and 7 can be used to move the robot motors in a positive (+) direction. Notice that you will only be working with 6 motors instead of 8; the remaining two motors are optional. To move the motors in a negative (-) direction, you will press keys W, E, R, T, Y, and U.

_____14. To practice moving these six motors on the robot in both positive and negative directions, first press any key on the computer keyboard as indicated on the HELP SCREEN. This will take you back to the Main menu.

_____15. Enter choice number 5 on the keyboard, RESUME PROG.

_____16. Notice at the top of the screen, the third line from the top reads MAIN PROGRAM. You are now in the part of the menu called RESUME PROGRAM, which allows you to move the robot. To move the robot, refer to the middle of the screen for motor key information.

_____17. Press the number 2 key, which should close the gripper on the robot. Notice that the axis moved only a certain distance. By pressing the number 2 key, the computer told the robot to move the grip 10 steps. This number is built into the RASP 3.0 program, but can be changed to either a higher or lower number.

_____18. Now press the W key to open the gripper. Notice that you are now moving the gripper in a negative direction! Continue to press the W key until you open the gripper completely. WHEN YOU REACH THE MAXIMUM OPENING, THEN STOP! CONTINUING TO PRESS THE KEY COULD DAMAGE THE ROBOT.

_____19. Now practice rotating the gripper using the 3 and E keys. Notice the direction they move (either + or -). To rotate the gripper in a continuous manner, simply hold down eigher the 3 or E key.

_____20. Now practice moving the wrist using the 4 and R keys. Again, notice the positive and negative direction movements.

_____21. Practice moving the elbow of the robot using the 5 and the T keys.

_____22. Practice moving the shoulder of the robot using the 6 and the Y keys.

____23. Practice moving the base of the robot by using the 7 and U keys.

____24. Press B to return to the Main menu. When in the Main menu, press number 4 to take you to the HELP SCREEN.

_____25. Notice the left middle portion of the screen which is labeled MOTOR STEPS. The move distance you have been working at was 10 steps. By pressing letter K while in the RESUME PROG mode, you can tell the computer to move a distance of 10 steps. This is the normal moving distance of the robot. Let's decrease the move distance. Remember the move distance keys: L, K, and ,.

_____26. Press any key to return you to the Main menu. Now press number 5 to get you into RESUME PROG.

_____27. Before moving the robot, first press the comma key which will tell the computer to move the robot at its minimum move distance. This move distance can be used to move the robot in order to make fine and precise movements.

_____28. Now that you have moved all of the axes at the minimum distance, press the L key so you can move the robot at the maximum move distance. Remember, if you forget which key to press in order to change the move distance, you can return to the HELP Screen for instructions.

_____29. Now practice moving each axis in both directions. Remember to use the information in the middle of the screen concerning which keys to use. Press the keys only once. LARGE MOVEMENTS COULD MAKE THE ROBOT RUN INTO ITSELF AND CAUSE DAMAGE.

_____30. Now that you have moved each axis in each of the different move distances, press the K key and set the move distance to 10 steps.

Now that you are familiar with the RASP 3.0 program, you will use it to do the following activity. You will have the robot pick up a block and stack it on another, then return to Soft HOME and then unstack the blocks putting the one where it was originally.

____31. Tape a piece of paper to the table in front of the robot. Place the two wooden blocks on the paper, one to the left and the other to the right. Trace around the blocks to mark their locations.

____32. Using what you just learned, pick up the block on the right and place it on the block to the left. Use the larger move distances to make long moves and the smallest to make small moves.

____33. Send the robot to Soft HOME.

____34. Now put the block back where it was.

This concludes the activity to move the robot. The next step is to learn to develop a program on the robot. Programming the robot is a very easy process if you follow the correct sequence of steps.

Follow the next sequence exactly until you are very skillful with the programming of the robot system. Once you are skillful, you may want to try modifying some of the steps.

1. Press J - This sends the robot to the HARD HOME position. Then orient the wrist and fingers in a position that is easy to remember. Usually place the hand vertically and the fingers open with the gripper parallel to the sides of the hand.

2. Press C - This has the computer enter the LEARN mode.

3. Press X - This sets the software home at the same position as the hardware home plus defines the position of the wrist and hand.

4. Press V - This enters the software home as the first move of the program. Now move the robot to all the different positions you wish to program. For your first program or two, only enter three or four positions. You may make as many moves of the arm as you want but the system will remember the points where you pressed the V key.

5. Press S as your last move of the program. This will take the robot back to the software home. Be sure to enter V after the robot is back to the software home.

6. Press D - This ends the program. Be sure to not forget this entry.

7. Press F to see the program run.

____35. Follow the above sequence to develop a program that has the robot move to three or four positions that are at least six inches form the table or any other obstacles. Once this program is developed, run it again to make sure it does what you expect.

_____36. Save this program on your disk by pressing B to leave the programming mode and then by pressing 3 to select the SAVE A FILE program. This step will ask for a filename. Make up a name for this program and enter it; then press return. The disk will engage and your file will be saved on the disk.

____37. Now press 1 on the MAIN MENU. This clears the memory of the program you have just developed. Select 5 to Resume Programming. Now enter F to see if a program will run. The robot should do nothing because you have erased the program form memory.

____38. Go to the MAIN MENU and then select 2 to LOAD A FILE. When it asks for the name of the file, enter the name you used a few minutes age. Once this is loaded, run it to make sure it is the same program you developed earlier.

____39. Develop a program now that will pick up the blocks and stack them as you did in the first part of this lab. Be sure to save this program on your disk.

You now know how to move the robot around and how to develop a program. The final step is to see how to edit a program.

As mentioned earlier, the editing process is very easy. Once you have entered the editing mode, the display will show the positions of the motors in the H,G,F,E,D,C,B,A sequence. As each motor value is displayed, you can change that position by pressing the appropriate keys on the computer. The N key takes you to the next motor and the H key causes the sequence to reverse. If you move a motor, you have changed its position and therefore edited the program.

_____40. Clear the memory of the computer and then load the first program you developed into the computer. Now practice editing the program by changing one or two of the positions.

You are now an official robot programmer. The fun of robotics comes in developing programs that do interesting activities. As you progress through this manual, you will be learning other ways of programming the robot and will be able to do a greater variety of creative things with the system.

REFERENCES:

Fundamentals of Robotics: Theory and Applications, Chapter 5, "Off-Line Programming," pp 148-158.

Rhino Software Manual (documentation for RASP 3.0).

NAME ____________________

DATE ____________________

CLASS ____________________

INSTRUCTOR ______________

QUESTIONS

1. How many motors can be controlled by RASP 3.0?

2. How many axes does the Rhino XR have?

3. By pressing any move key once, you can move the robot one increment of steps at a time. What could you do to move a robot axis in one continuous movement?

a. Press the K key
b. Press the Control key
c. Press the REPEAT key and the move key.
d. Hold down the move key

4. What is meant by move distance?

5. What is the 100 step move distance most useful for?

6. When using the RASP 3.0 software disk, which of the choices listed below provide you with information in terms of what keys to press, motor move distance information, etc?

a. MAIN MENU
b. MAIN PROGRAM
c. HELP MENU
d. HELP SCREEN

7. When using the RASP 3.0 software disk, which of the choices listed below provide you with actual control of the robot using the keyboard?

a. MAIN MENU
b. MAIN PROGRAM
c. HELP MENU
d. HELP SCREEN

8. Which set of keys listed below will cause all six axes (including gripper) of the robot to move in a positive (+) direction?

a. WERTYU
b. 234567
c. SDFGHJ
d. XCVBNM

LABORATORY 10

USING THE TEACH PENDANT

INTRODUCTION

Teach pendants are very useful tools for programming robots. A teach pendant is a programming device, separate from the robot's computer, which enables the programmer to lead the robot through different moves of specific routines.

Teach pendants offer many advantages. First of all, withe a teach pendant, an operator can control a robot without having any knowlege of a formal programming language. For example, maintenance and repair personnel can conduct extensive tests of robot motion without having formal programming skills. Also, since the pendant computer is transparent to the user, students can be introduced to robot systems without discussing the computer that is part of the teach pendant system. Unlike robotic control languages, all teach pendants are similar and usually use a readily understood pictorial language that can be mastered within a short time.

Teach pendants usually have 2 pushbutton keys for each axis independently in each direction with these keys. In addition, the pendant contains programming keys, which allow the programmer to write, store, and edit programs.

The XR Series teach pendant system, which is designed to closely emulate industrial teach pendants, consists of a 32 key, hand held pendant in an aluminum case, a microprocessor based computer card, a cable for connecting the teach pendant to the teach pendant computer, a software diskette containing the SAVE/LOAD program (this will be discussed in Lab 12, and a manual. The computer card that forms the heart of the teach pendant system can be mounted either in a combination cabinet together with the XR controller or in a separate controller.

The teach pendant is controlled by a dedicated 6502 microprocessor. The microprocessor is controlled by an operating system requiring 4K of EPROM. The computer also has 4K of static RAM available for programming, which is enough memory for 149 moves, including delays. Each move in the sequence can involve a change in position of up to 8 motors. (NOTE: The version 1 teach pendant has memory only for 127 moves and the Mark III teach pendant also allows control of the I/O of the Mark III controller with its 149 moves).

Because of the various versions of the XR Series teach pendant and controller that exists, you will need to check with your teacher about which version and configuration (combination or separate controller) you have. Since it is impossible for us to cover each version, your teacher may need to have you make some adjustments in the procedure instructions, depending upon which version you have.

You will also find it helpful to consult the Teach Pendant Owner's Manual.

Most XR users will have either a version 2 (2.0,2.1, or 2.3) teach pendant or a Mark III teach pendant. The main difference between these is that the Mark III teach pendant has new programming functions that allow full use of the I/O on the Mark III controller through the teach pendant. Also, new commands have been added so that all keys except for the SHIFT serve multiple functions and new displays have been added to give the user increased feedback. The handheld pendants for the versions 2 and Mark III are shown in figures 10.1a and 10.1b.

This lab will take you through all of the steps necessary to hook up the XR teach pendant. You will learn how to control all five axes plus gripper using the teach pendant in the PLAY mode. Labs 11 and 12 will help you expand upon your teach pendant skills by introducing you to the LEARN and EDIT modes.

OBJECTIVES

When you finish this lab you will be able to:

1. Hook up the XR robot, controller and teach pendant correctly.

2. Identify and correctly use the 16 MOVE keys and the 1, 10, and 100 MOVE DISTANCE keys on the teach pendant.

3. Control the Rhino XR Series robot solely by means of the teach pendant.

LIST OF EQUIPMENT

1. Rhino XR Series robot and controller.

2. Rhino teach pendant (FG1069 or FG0649).

3. Two one-inch (25.4 mm) blocks.

RELATED INFORMATION

The XR Series teach pendant has four modes of operation. These are PLAY, LEARN, EDIT, and RUN. In PLAY, you can try out various motor moves and get a feel for running a robot without recording any moves. In the LEARN mode, you can teach the robot a designated sequence of moves. You can then use the EDIT mode to modify and fine tune the sequence you have taught. You run the taught sequence through its paces in the RUN mode.

In this lab, you will learn how to operate the Rhino XR Series robot in the PLAY mode using the 16 MOVE keys and the MOVE DISTANCE keys on the teach pendant. The MOVE keys are those 16 keys on the righthand side of the pendant which have arrows on them as shown in Figure 10.1a and 10.1b. Explanation of the rmaining keys is reserved for later lab activities.

Throughout this lab activity, you will be operating the robot in the PLAY mode. The PLAY mode is designated by a P in the first position of the red LED readout on your pendant.

If you should lose control of the robot at any time (eg if you send,the arm on a path where it is about to crash into an object), you should immediately press the RESET button on the front of the controller and the robot will stop. The newer systems also have a RESET button on the front of the teach pendant as well as on the robot controller; in this case, either button can be used to RESET the system. Resetting the system will allow you to regain control of the robot and resume your activity.

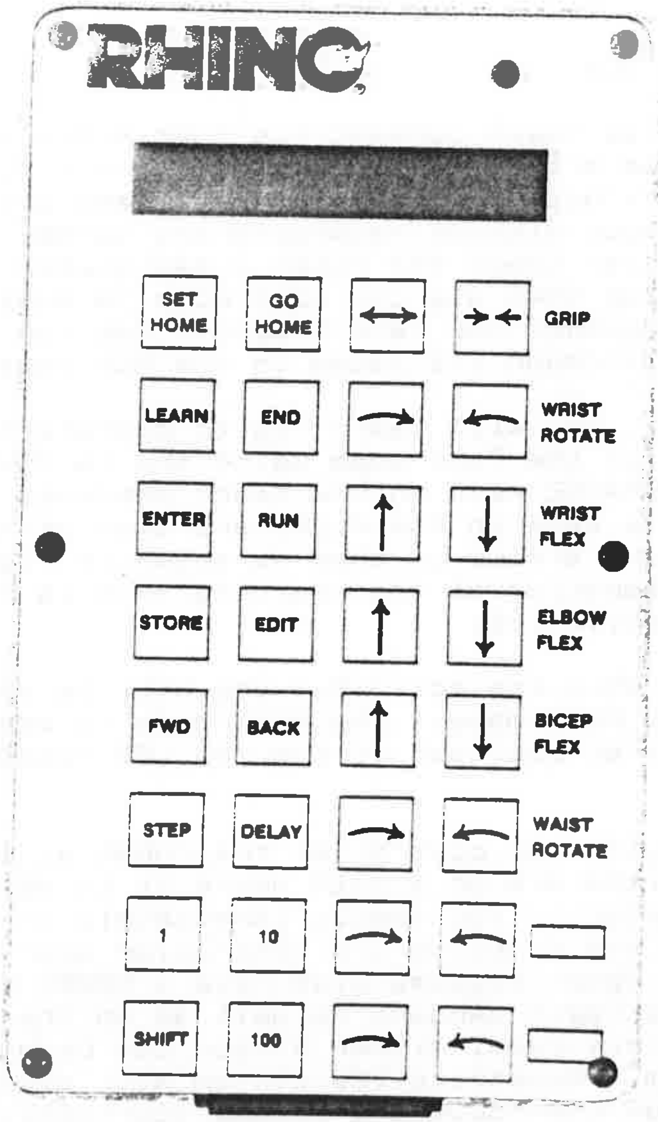


Figure 10.1a Rhino Version 2 Teach Pendant

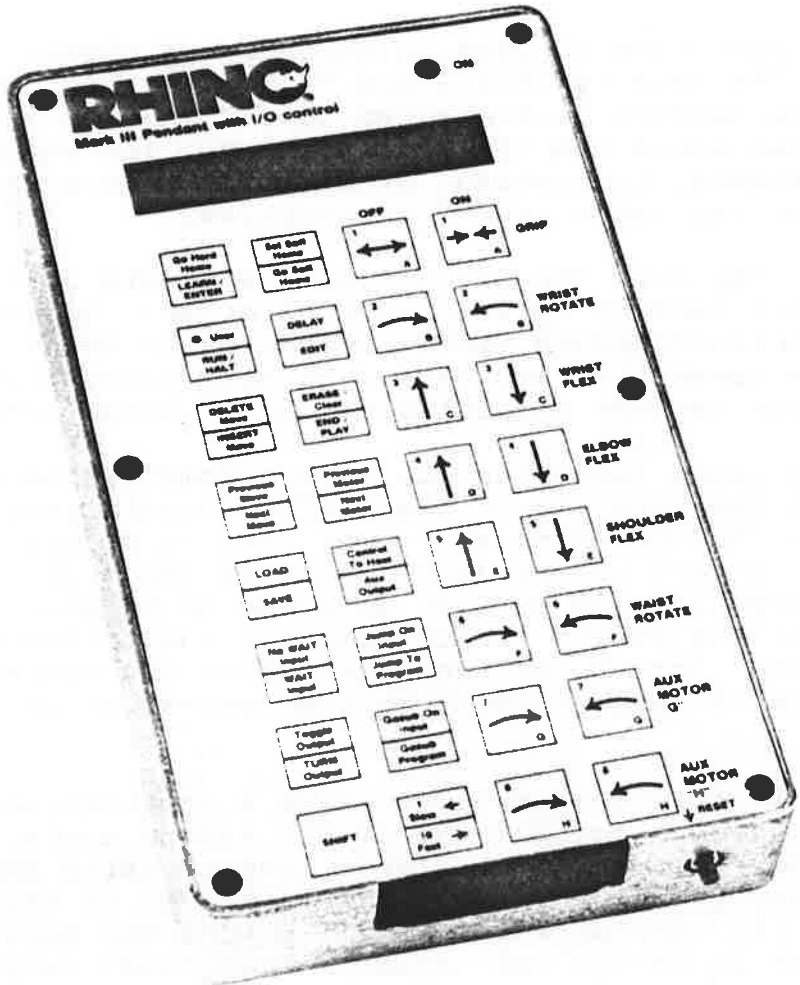


Figure 10.1b Rhino Mark III Teach Pendant

PROCEDURE

____1. Gather all equipment onto an open work surface. Place the robot in the center of the work area. Place the controller next to or behind the robot.

____2. As in Lab 3, connect the robot motor cables to the controller.

Axes G and H can be used to control additional equipment. The keys for the G and H parts should not be pressed while nothing is connected to the G and H parts, since this can cause the robot to lock up. (On the Mark III teach pendant, the pendant will simply inform the operator that the motor is OFF or inactive.

____3. You will now connect the hand held portion of the teach pendant to your XR controller. However, since this procedure varies according to which version controller you have, you will need to check with your teacher and consult your XR Owner's Manual.

Mark II users (assuming you have a combination unit) will need to plug one end of the RS-232 C cable into the slot labeled CONTROLLER on the lower left hand side of the controller. Insert the opposite end into the slot directly above, labeled RS-232C as shown in Figure 10.2a. Next, connect the 25 pin ribbon cable to the bottom of the teach pendant. Insert the opposite end of the cable into the slot labeled TEACH PENDANT on the controller or computer.

Mark III users (assuming you have a combination unit) will simply need to connect the 25 pin ribbon cable to the bottom of the teach pendant. Insert the opposite end of the cable into the slot labeled TEACH PENDANT on the front of the Mark III controller. Then make sure the mode select switch is in the "up" position for teach pendant use.

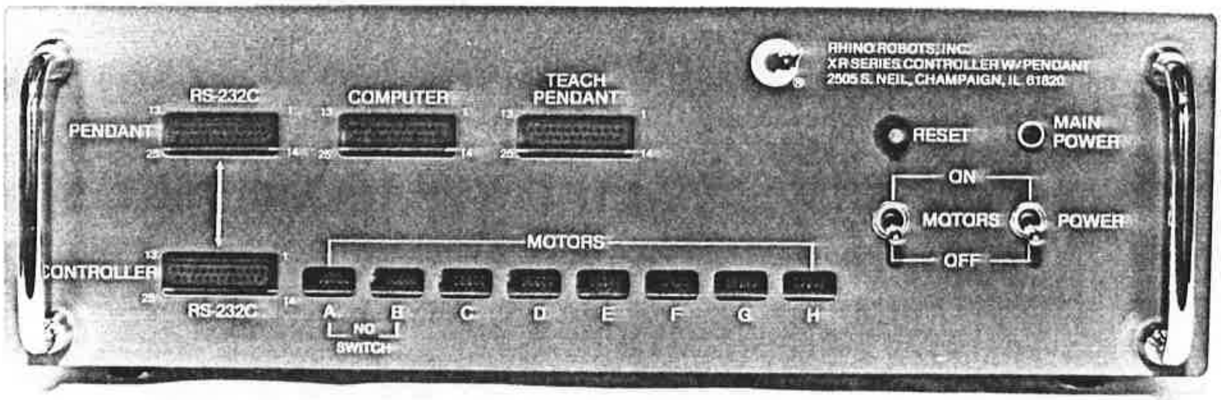


Figure 10.2 Rhino Mark II Controller with built-in Teach Pendant Computer

_____4. Plug the controller powe cord into a 115V AC outlet. This power source will power the controller, teach pendant and robot. (NOTE: If you have a separate teach pendant controller, you will have an additional power cord).

_____5. Turn the MAIN POWER switch on. Watch to see that the power light is lit. This switch provides power to the controller, but not the robot.

_____6. Turn the MOTORS or MOTOR POWER power switch on. Slight movements of the motors may be detected as the motors reorient themselves. Such movement is normal. The robot now has power.

_____7. Pick up the teach pendant and study it closely. A red light should be lit in the upper right hand corner. The light indicates that the pendant has power.

_____8. Examine the 7 character LED display. The display should show the word DELAY; then a P should appear in the lefthand position. This indicates that the teach pendant is in the PLAY mode. The remainder of this activity will be conducted with the pendant in this mode.

_____9. Examine the two right hand columns of keys on the pendant as shown in Figure 10.1.a or 10.1b (depending upon which version you are using). To the right of each pair of keys, you will see the name of each axis plus two unnamed axes. Each pair of keys controls the movements of the axis which appears to the right. Notice that each pair of keys contains arrows which represent the corresponding movements of the axis.

_____10. Press the left GRIP key and the gripper should open. The word OPEN will appear in the display. Press the right GRIP key and the gripper should close. The word CLOSE will appear and the fingers will close all the way.

_____11. Press the left WRIST ROTATE key and the gripper should rotate clockwise. Press the right WRIST ROTATE key and the gripper should rotate counterclockwise. Notice that the display starts with PB 0000 then the numbers change as you move the axis. The P indicates that you are in the PLAY mode and B indicates that you are moving the wrist rotate axis (B motor). The numbers indicate the number of slots the encoder wheel for the axis you are moving has rotated.

Continue to press the remaining MOVE keys (for the A-F motors only), noticing the direction of movement of each axis, the letter that designates each axis and the count. You will then need to restart the program. Continue to move all 5 axes plus gripper until you are confortable with operation the Rhino XR with the teach pendant.

_____12. Press the 1 key. This is one of the MOVE DISTANCE keys. The 1 Key is used for fine tuning moves. For instance, it should be used anytime you are within an inch or two of your pickup or release point. Now, press each MOVE key once. Note the distance treveled by each axis. The 1 key causes the motors to turn one encoder position of the encoder wheel each time one of the 16 MOVE keys is pressed. Holding the MOVE keys down activates and auto-repeat function which continues the robot's motion in increments of one encoder movement.

_____13. Press the 10 key. This is another of the

MOVE DISTANCE keys. Again, press the 16 MOVE keys and watch the distance traveled by each axis. The 10 key causes the motors to turn ten encoder positions each time one of the MOVE keys is pressed. Holding the MOVE keys down activates the auto-repeat function by increments of ten encoder positions.

Note that the default value for this is 10. Whenever the robot is turned on, the distance default value is automatically set at 10 until the operator changes it by pressing either the 1 or the 100 (Version 2 or earlier teach pendants only) keys.The numbers will change accordingly.

_____14. Press the 100 key. (Users of version 2 or earlier teach pendant only). Repeat the same procedure as above. Note the distance traveled by each axis. The 100 key causes the motors to turn one-hundred encoder positions each time one of the 16 MOVE keys is pressed. Here again, the auto-repeat function is activated when a key is held down. The 100 key is most useful for long moves.

NOTE: If you use the 100 key, you will need to be very careful since it is much easier to crash the robot in this mode.

Now that you have had the opportunity to familiarize yourself with the teach pendant and its operation, you will use what you have learned to stack a block on another block in the PLAY mode.

_____15. Tape a piece of paper to the table in front of the robot. Place the two wooden blocks on the paper, one to the left, and the other to the right. Trace around the blocks to mark their locations.

_____16. Using what you just learned, pick up the block of the left and place it on top of the block on the right. Use the larger MOVE DISTANCE keys to make long moves and the smallest to make small moves.

_____17. Now return the block back to its original position. Then stack the second block on tope of the first and then return it to its original position.

REFERENCES:

Fundamentals of Robotics: Theory and Applications. Chapter 4, "Teach Pendant Progamming."

Rhino Teach Pendant Manual

NAME ____________________

DATE ____________________

CLASS ____________________

INSTRUCTOR ____________________

QUESTIONS

1. How many motors can be controlled by the Rhino XR teach pendant?

2. How many positions will the encoder move if a MOVE key is pressed while the MOVE DISTANCE is set at 1?

3. What is meant by default value of the MOVE DISTANCE?

4. What is the default value of the MOVE DISTANCE?

5. What is the 100 step MOVE DISTANCE key most useful for?

6. How is the auto-repeat function activated?

7. What does P in the left hand LED display stand for?

8. Which part of the robot is indicated by each of the following letters?

a. Motor A
b. Motor C
c. Motor D
d. Motor F

LABORATORY 11

TEACH PENDANT PROGRAMMING

INTRODUCTION

The ability to edit a program is very important for efficient robot operation. In many industrial situations, a program may be written off-line, away from the operating site. Then, the operator will bring the program to the plant floor and make final adjustments using a teach pendant. Another common example of teach pendant editing occurs with a program that requires minor changes, due to a change of pick-up or delivery point. When that occurs, it is far more efficient to edit the program than to re-write the entire program.

OBJECTIVES

When you finish this lab, you will be able to:

1. Match each of the 32 keys on the Rhino XR Series teach pendant to their correct functions.

2. Create a teach pendant program.

3. Edit a teach pendant program.

LIST OF EQUIPMENT

1. Rhino XR Series robot and controller.

2. Rhino teach pendant (FG1069 or FG0649).

3. Sheet of paper and pencil.

RELATED INFORMATION

In this lab, you will use both the LEARN and the EDIT modes.

If you are using a Mark III teach pendant, you will have many more functions at your disposal than you will be using in this lab. Once you have completed Labs 10, 11, and 12, you may want to perform additional lab exercises using these additional teach pendant functions. Use of the Mark III teach pendant to control the I/O of the Mark III controller, as well as its other additional functions, is covered extensively in the Teach Pendant Owner's Manual for that version. For this lab, only functions that are common to both versions 2 and Mark III teach pendants will be discussed.

Most of the keys on the version 2 teach pendants have a single function, while other keys such as GO HOME, STORE, BACK, and END have more than one function. All of the keys except SHIFT on the Mark III teach pendant have multiple functions. The second function for each of the multiple function keys is activated by first pressing the SHIFT key and then pressing the key desired while still holding the shift key down.

The EDIT mode cannot be used unless you have used the LEARN mode to ENTER a program. If you have forgotten to use the ENTER key and push EDIT, the display will remind you that there is no program in memory by displaying "nodAtA." You can enter the EDIT mode only from the PLAY mode.

Listed below are the EDIT keys and their particular functions. Familiarize yourself with the functions of these keys. Since different keys are used to achieve the same functions for the version II or older and Mark III teach pendnat, these are briefly described for each. You will want to disregard the notes for the teach pendant version you are NOT using.

EDIT - Puts the system into the EDIT mode and executes the first instruction in the move buffer. The EDIT mode permits the alteration of learned motor moves (and I/O with the Mark III teach pendant and controller). To enter the EDIT mode, the robot system must be in the PLAY mode. WITH THE MARK III teach pendant, when the EDIT key is pressed and the robot makes the first move in the move sequence, "EStP 1" will appear in the display. WITH VERSION 2 teach pendants, "EH 0000" will appear. The E indicates that the system is in the EDIT mode, the H (or other letter) indicates the motor in use, and the 0000 (or other numbers) indicates the position of that motor. Only the motor indicated in the display can be moved. If this motor is moved, the new position is stored.

STEP (Version 2 or older) or NEXT MOVE (Mark III) - This key is used only in the EDIT mode and causes the robot to go to the next compound move in the program and display the value of the H motor. Once you are at a new step, you can go to the individual axis by pressing FWD or NEXT MOTOR.

SHIFT/STEP (Version 2 or older) or SHIFT/PREVIOUS MOVE (Mark III) - This key simply takes you back to the previous step. It is active only in the EDIT mode.

FWD (Version 2 or older) or NEXT MOTOR (Mark III) - This key is active only in the EDIT mode and is used to step to the next motor in a move sequence. The position of each motor is displayed as you step through the move sequence and can be changed by moving the appropriate axis keys. Only the axis being displayed will be active and can be changed. WITH VERSION 2 or older teach pendants, this key will begin with the H motor and end with the A motor. WITH THE MARK III teach pendant, the NEXT MOTOR key will move the EDITing function from the A motor to the H motor. After the H motor is addressed with the Mark III, the NEXT MOTOR key will move the EDITING function to the INPUT, OUTPUT LEVEL, OUTPUT TOGGLE, AUXILIARY PORTS, DELAY, JUMP, and finally LABEL function. Then if the NEXT MOTOR key is pressed again, the system will wrap around to the A motor.

BACK (Version 2 or older) or SHIFT/PREVIOUS MOTOR (Mark III) - This key is active only in the EDIT mode and is used to step back to the previous motor in a move sequence. WITH VERSION 2 or older teach pendants, the order of the motors begins with A and ends with H. WITH THE MARK III teach pendant, the motors are accessed from H to A. After the A motor display, the system wraps around to display the other functions just like the NEXT MOTOR key function does.

SHIFT/FWD (Version 2 or older) or INSERT MOVE (Mark III) - This key is active only in the EDIT mode. When this key is pressed, a move is inserted immediately after the last move that was executed. The word nS" (Mark III) or "INSRT" (Version 2 or older) will appear in the display briefly.

SHIFT/BACK (Version 2 or older) or SHIFT/DELETE MOVE - This key is active only in the EDIT mode. Upon pressing DELETE, the current move in the EDIT buffer is erased, and the word "DEL" (Mark III) or "DELETE" (Version 2 or older) appears in the display briefly. Then the robot executes the next move in the sequence.

You will also be using the RUN key:

RUN - This key is active in the PLAY mode and is used to make the robot run the move sequence in memory. The robot executes the sequence until it is stopped. With version 2 or older teach pendants, the robot is stopped at the end of the sequence by pressing any key. With the Mark III teach pendant, the robot is stopped with either the HALT key or the END key. (Once the Mark III is in the RUN mode, the RUN key becomes the HALT key and can be used to stop the operation of the robot.) While the robot is in the RUN mode, the rightmost digits of the display will show the number of the current move.

PROCEDURE

PART 1

In this lab activity, you will become familiar with the LEARN MODE while using the teach pendant. You will first teach the robot to pick up a pencil, turn it 180 degrees and then set it down in its original position.

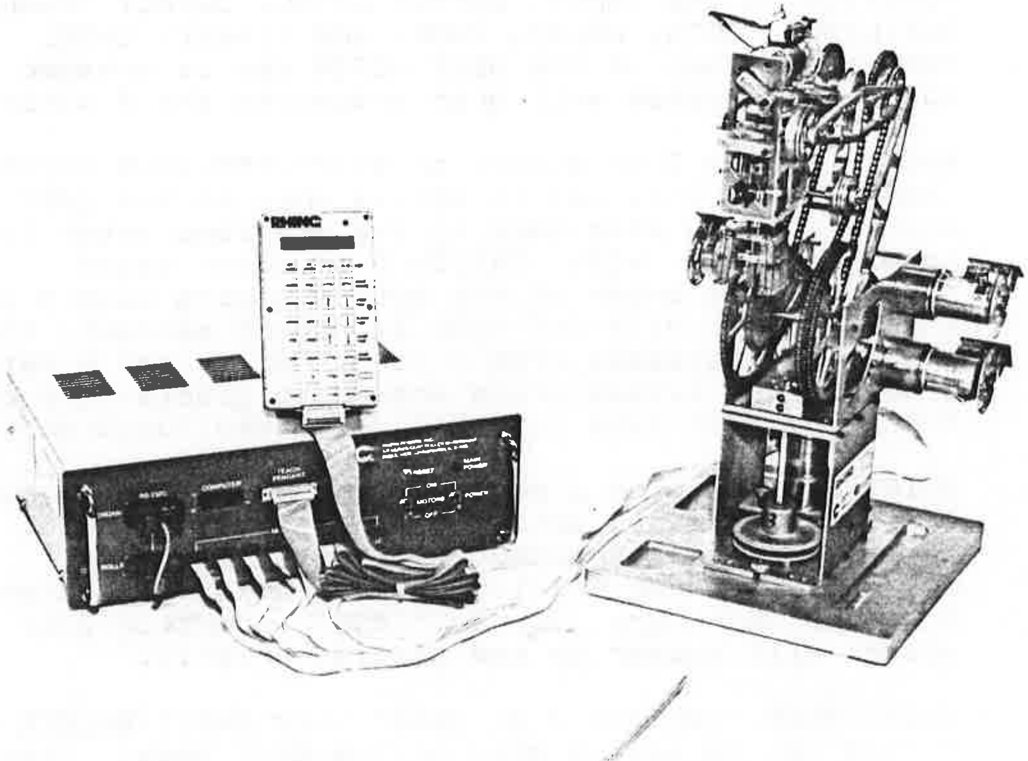


Figure 11.3 Set-up for Lab Activity 1
(Shown using Mark II controller and teach pendant)

_____1. Locate the robot and the controller on a table, as shown in Figure 11.3.

____2. Using masking tape, tape the four corners of the piece of paper to the table and place it about 6 inches in front of the robot.

____3. Take the pencil and place it on the paper in front of the robot with the pencil point toward the robot, shown in Figure 11.4.

____4. Using another pencil, trace a line around the pencil that is lying on the paper. This will mark the location where the pencil should be each time your run your program.

____5. Turn the switches on the controller ON.

____6. Using the teach pendant, put the robot in a position similar to the one shown in Figure 11.3.

____7. Press the SHIFT and the GO HOME (Version 2 or older) or the SHIFT and GO HARD HOME (Mark III) keys at the same time. This will send the robot to its HARDWARE HOME.

____8. Now press the SET HOME key (version 2 or older) or SHIFT/SET SOFT HOME (Mark III) to enter the eight axis software home. In this case, the SOFTWARE HOME will be the same as HARDWARE HOME. The word SET (version 2 or older) or SFtSEt (Mark III) will appear briefly in the display as you set SOFTWARE HOME.

____9. Press the LEARN key. This will enter the LEARN mode of the robot. In order to make the SOFTWARE HOME you just set the first location in your program, press the ENTER key.

____10. Press the GRIP key to fully open the gripper and press the ENTER key.

____11. Press the BICEP FLEX (Version 2 or older) or SHOULDER FLEX (Mark III) and position the gripper outward until it is over the pencil and about 15 inches above the pencil. Press the ENTER key.

____12. Press the ELBOW FLEX key to move the gripper downward over the pencil point. Stop about 6 inches above the table and press the ENTER key.

____13. Change the number of steps the motors move by pressing the 1 key.

____14. Again press the BICEP FLEX or SHOULDER FLEX key to move the gripper downward until it is about 1/16 inch above the paper. Press the ENTER key.

_____15. Press the GRIP key to close the gripper on the pencil. Press the ENTER key.

_____16. Change the motor steps by pressing the 10 key.

_____17. Press the BICEP FLEX or SHOULDER FLEX key and move the robot arm upward and stop when the gripper is half way between the paper and the robot stand. Press the ENTER key.

_____18. Press the WRIST ROTATE key to turn the gripper 180 degrees in either direction. Press the ENTER key.

_____19. Press the BICEP FLEX or SHOULDER FLEX key to move the pencil downward to within one inch of the paper and stop. Press the ENTER key.

_____20. Change the motor steps by pressing the 1 key.

_____21. Press the BICEP FLEX key to move the pencil downward until it touches the paper. Press the ENTER key.

_____22. Change the motor steps by pressing the 10 key.

_____23. Press the GRIP key to open the gripper and drop the pencil. Press the ENTER key.

_____24. Press the GO HOME (Version 2 or older) or Go SOFT HOME (Mark III) key. This will send the robot to its original starting position, SOFTWARE HOME. Press the ENTER key.

_____25. Press the END key. This exits the LEARN mode.

_____26. Press the RUN key to send the robot through its series of movements. After watching the robot RUN the sequence, stop the program by pressing any key (version 2 or older) or the HALT or END (Mark III) keys.

PART 2

Now you are ready to enter the EDIT MODE in order to make a minor change in your program. To practice using the EDIT mode, you will edit your program to move the robot pick up the pencil and rotate the gripper 360 degrees instead of the original 180 degrees. For this part of the lab activity, you will use the same equipment that you used in Part I.

_____1. Press the EDIT key. This will place you in the EDIT mode. Notice the LED display now reads E H 0000. The letter E indicates that you are now in the EDIT mode. The letter E will appear throughout the entire editing process. You will note that in EDIT, you will see a display for every motor (and I/O command for Mark III) in every record.

_____2. Press the FWD (Version 2 or older) or NEXT motor (Mark III) key once and you should notice a change in the second letter in the LED display. It will now be either an H or a A, depending upon which version teach pendant you are using. Continue pressing the FWD or NEXT MOTOR key until the second letter in the LED display reads a letter A (Version 2 or older) or H (Mark III). What you have done is to progress through the 8 axis motors.

_____3. Now press the BACK (Version 2 or older) or SHIFT/PREVIOUS MOTOR (Mark III) key to progress backwards within the same move. While doing this, read the four digits to the right side of the LED display. Notice that each time you step backwards using the BACK or SHIFT/PREVIOUS MOTOR key, the LED display reads 0000 for each motor. This indicates the starting point for all eight axes of the robot. You did not move any of the motors before pressing ENTER the first time so all 8 motors were set at 0000.

_____4. Now press the FWD or NEXT MOTOR key and hold it down until the robot moves. At this point, the gripper should open.

_____5. Again press the FWD or NEXT MOTOR key and hold it down until the robot moves. The bicep/shoulder should have moved. Press the FWD or NEXT MOTOR key until you come to the E motor.

_____6. Press the FWD or NEXT MOTOR key and hold it down until the robot moves. The elbow should move. Press the FWD or NEXT MOTOR key until you reach the D motor. What is the reading for this motor? Does it have a negative sign in front of the number? The negative sign indicates that the elbow moved in a downward directions.

____7. Press the FWD or NEXT MOTOR key and hold it down until the robot moves. Did the bicep/shoulder move?

____8. Press the FWD or NEXT MOTOR key and hold it down until the robot moves. Did the gripper move?

____9. Press the FWD or NEXT MOTOR key and hold it down until the robot moves. Did the bicep/shoulder move again?

____10. Press the FWD or NEXT MOTOR key and hold it down until the robot moves. Did the wrist move?

____11. At this stage, you are going to edit this move for motor B. The original move for motor B at this point was a 180 degree rotation for the gripper. You will edit this move by adding an additional 180 degrees of rotation for a total of 360 degrees. To do this, press the WRIST ROTATE key and double the reading you have for motor B in the LED display. (For example: if motor B reads 0740, then adding another 0740 will make a total of 1480). This should now have turned the pencil in the gripper an additional half turn. You have now edited this axis.

____12. Press the FWD or NEXT MOTOR key and hold it down until the robot moves. Did the bicep/shoulder move?

____13. Press the FWD or NEXT MOTOR key and hold it down until the robot moves. Did the motor A move?

____14. Press the FWD or NEXT MOTOR key and hold it down until the robot moves. Did the gripper open?

____15. Press the FWD or NEXT MOTOR key and hold it down until the robot moves. Now press the FWD or NEXT MOTOR key until the LED display lists motor B. Motor B controls the Wrist Rotate function. Before you have the robot set the pencil down, you will rotate the pencil 180 degrees. The reading of motor B should read 0000. Press the WRIST ROTATE key to move the gripper and pencil in a clockwise direction. Watch the LED display as the numbers change. Stop pressing the key when the LED display reads 0740. You should now have rotated the gripper 180 degrees and completed the editing function for this motor.

____16. Press the FWD or NEXT MOTOR key and hold it down until the robot moves. Did motor E move?

_____17. Press the FWD or NEXT MOTOR key and hold it down until the robot moves. Did the gripper move?

_____18. Press the FWD or NEXT MOTOR key and hold it down until the robot moves. Did the robot move to its HARDWARE HOME?

_____19. Press the END key to exit the EDIT mode key. The LED display should show a P to indicate that you are now in the PLAY mode.

_____20. To check the changes you have just made in your program, press the RUN key. Remember that the gripper will now rotate one 360 degree circle after picking up the pencil and one 180 semi-circle before setting the pencil back down.

We will now learn how to use the INSERT and DELETE functions. Inserting and deleting moves is made possible with two simple commands. While in the EDIT mode pressing SHIFT/FWD (Version 2 or older) or INSERT MOVE (Mark III) will allow you to insert a new location. SHIFT/BACK (Version 2 or older) or SHIFT/DELETE MOVE (Mark III) makes it possible to delete a move.

DELETING A MOVE is done by STEPPING in the editor until you reach the mvoe you wish to delete. When you press SHIFT/BACK or SHIFT/DELETE MOVE, the robot will back up one move and then move to the new location which will be the position after the one you deleted.

Thinking of this as a sequence of 5 moves will allow you to develop a clear picture of the process. In the edit mode you move to step 3 if that is the move you wish to delete. The robot will back up to position 2 and then proceed to position 4. This process eliminates step3.

INSERTING A MOVE works in a manner very similar to the deletion process. If you want to insert a move between moves 3 and 4, you move the robot to position 4 and then pres the SHIFT/FWD or INSERT MOVE combination of keys. The robot backs up to the position 3 in the edit mode. Move through the motors until you activate the ones you want to move. When you have finished programming in the new position you simply press STEP or NEXT MOVE and the robot goes to the old position 4.

_____21. Now that you have discovered these new commands, develop a simple program with only 4 or 5 moves. Use this simple program to try these new commands. Trying them in a simple program allows you to see what is happening much better than experimenting with a complex program.

This concludes the activities for this lab. The next lab will show you how to save a teach pendant program onto disk and then load it back into the teach pendant computer.

REFERENCES:

Fundamentals of Robotics: Theory and Applications, Chapter 4, "Teach Pendant Programming.

Rhino Teach Pendant Manual.

NAME ______________________

DATE ______________________

CLASS ______________________

INSTRUCTOR ______________________

QUESTIONS

1. Name the mode of operation used when teaching the robot a series of moves?

2. What is the function of each of these keys: ENTER, SET HOME, LEARN?

3. What two keys do you press on the teach pendant to send the robot to a HARDWARE HOME?

4. When do you set the HARDWARE HOME: before or after entering the LEARN mode?

5. How many moves is the 6502 microprocessor of the Rhino teach pendant system capable of storing?

6. What is the mode of operation that allows you to make fine adjustments to your teach pendant program?

7. Which key would you press while in the EDIt mode that would allow you to progress through the motors in this order H,G,F,E,D,C,B,A (for the Version 2 or older teach pendant)

a. FWD
b. BACK
c. EDIT
d. LEARN

8. If the display on the teach pendant shows E E - 0550.

a. What does the first letter indicate?

b. What does the second letter indicate?

c. Does the arm move in a upward or downward direction?

9. If you want to edit the BICEP FLEX function on your teach pendant program, which motor do you use?

10. After completing all editing while in the EDIT mode, what mode do you then go into?

LABORATORY 12

SAVING AND LOADING TEACH PENDANT PROGRAMS

INTRODUCTION

In the previous two laboratory activities, you learned how to teach the robot a series of moves while in the LEARN mode and to edit certain movements in the EDIT mode. It was not possible however, to turn off the controller power switch and still be able to run the same teach pendant program the next day. A programmed sequence remains in the teach pendant only until the memory is cleared or until the power is turned off. This is because the 6502 micro-processor uses violatile RAM which is erased when power is disconnected.

In industry as well as in the next two lab activities, it will become necessary to save a program and to be able to recall or LOAD the program later. This procedure saves industry time as well as money since with it, robots do not have to be reprogrammed on a daily basis. Once you have saved a program, you only have to load into the computer memory and then run the program.

In this lab, you will learn to save a teach pendant program you have written for the XR robot and then load it for later use, using the Rhino upload/download software.

OBJECTIVES

When you finish this activity, you will be able to:

1. Save a teach pendant progam.

2. Load a saved teach pendant program.

LIST OF EQUIPMENT

1. Rhino XR Series robot and controller.

2. Rhino teach pendant (FG1069 or FG0649).

3. Apple IIe computer system.

4. Rhino Lab Disk for Apple IIe.

5. CSS 7710A Serial Card (FG0893), Apple Super Serial Card (FG0894) or Rhino Com Language Card (FG0702).

RELATED INFORMATION

The Rhino XR Series controller alone is unable to save software program. However, this can be overcome by using a computer and a disk drive to save programs onto a disk.

In order that we may save a teach pendant program, you will be taking the stored information from the microprocessor inside the Rhino XR controller and transfer it to the microprocessor inside the Apple computer using a program designed for this purpose. After transfering the information, you will insert a different disk and have the microprocessor inside the Apple computer transfer the information onto your disk. The disk can then be removed for later use.

You will then take your disk with the stored program on it and reload the program into the computer. Again, using the Teach Pendant software, you will transfer the information; only this time it will be in the opposite order used in the first part of the procedure. You will end up transfering the program information back into the microprocessor located inside the XR controller. When the program is entered back into the memory of the controller, you will then run it.

PROCEDURE

_____1. Set-up and connect the XR robot, controller, teach pendant, and the Apple IIe computer.

_____2. Install the CCS 7710A card, Apple Serial Card, or Rhino Com Language Card into your computer. Make sure that the BAUD rate of your particular card is set at 9600.

_____3. Using the skills you learned in Labs 10 and 11, use the teach pendant to write a short program. This program will have the robot rotate its base 90 degrees in a clockwise direction, and bend over backwards as shown in Figure 12.1. Remember to press the ENTER key after each movement of the robot!

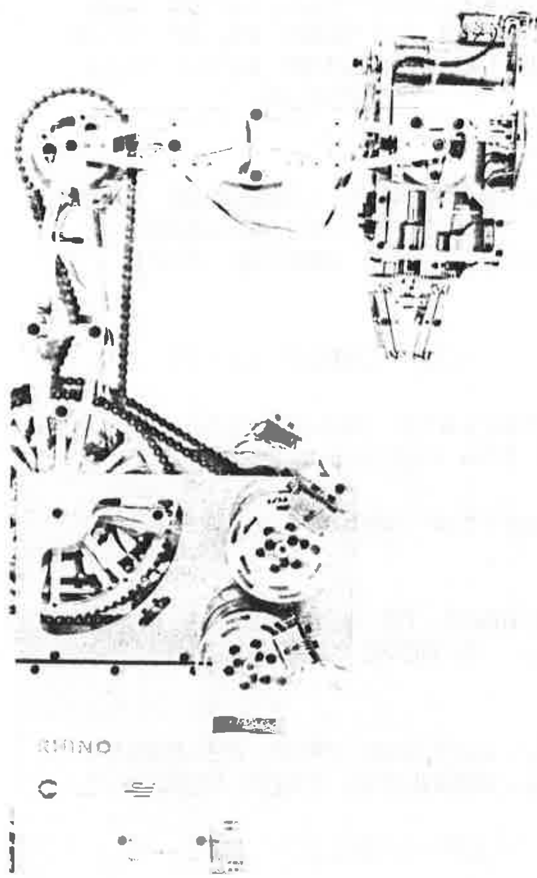


Figure 12.1 XR position after move sequence.

_____4. Once you have taught the robot this program, use the RUN mode to try the program out. If any modifications are necessary, use the EDIT mode to make these.

_____5. As the first step in saving your teach pendant program, insert the Lab Disk into the disk drive.

_____6. Now turn on your computer and monitor to boot the disk. Select the Uoload/Download Software from the menu (#35/L). On the next screen, indicate which teach pendant version you are using.

_____7. The monitor should now read:

RHINO ROBOTS INC.
UPLOAD/DOWNLOAD

THREE INTERFACE CARDS CAN
BE USED IN SLOT #2 OF THIS
APPLE COMPUTER WITH THIS
PROGRAM:

1...RHINO-COM LANGUAGE CARD
2...CCS 7710A CARD
3...SUPER SERIAL CARD

YOUR CARD? (1-3)

Make the appropriate choice for the card you have in your computer and press the return key.

_____8. The monitor should now read:

DO YOU WANT TO UPLOAD OR DOWNLOAD
A MOVE SEQUENCE?

1...UPLOAD FROM PENDANT
2...DOWNLOAD FROM PENDANT

YOUR CHOICE? (1/2)

Enter choice number 1 and press the RETURN key. This will permit you to load the program from the controller into the computer.

_____9. The monitor should now show:

TO UPLOAD A MOVE SEQUENCE

TYPE "1" ON HOST KEYBOARD THEN

PRESS "STORE" ON PENDANT

Press the number 1 key on the computer; then press the STORE key on the teach pendant. After you do this, the screen on the computer should fill up with zeros and ones. Each column represents information recorded from the eight motor axes. There will be 8 columns representing the 8 motors. At the top of the first column, a number indicates the total number of moves in your teach pendant sequence. The first row should be all zeros if you entered the HOME position as the first step. Subsequent rows show you the number of counts in each motor in that step. Notice that, if you sent the robot back home at the end of your sequence, the last row reverses each motor that has left HOME during your program so that all buffers return to zero.

The bottom of the screen should read as follows:

SEQUENCE UPLOADED

NAME FOR SAVING FILE

____10. The teach pendant program information has now been transfered from the 6502 microprocessor located inside the teach pendant controller to the 6502 microprocessor inside the Apple computer.

____11. Name the file and press return.

____12. Take out the Lab Disk and insert your own disk. Press the RETURN key on the computer keyboard and watch the red light on the disk drive. When this light comes on, it means that the computer is saving your program onto your disk.

____13. Run your program again now by typing RUN on the keyboard and pressing the RETURN key.

In this part of the lab, you will be responsible for learning how to LOAD the teach pendant program you saved into the first part of the lab. You will actually first be transferring the program from your disk into the computer and from there into the 6502 microprocessor of the controller. Then you will press the RUN key on the teach pendant to run the robot through its movements.

____14. Next you will be reversing the process which you just completed, so select option 2 (download) on the Upload/Download menu.

_____15. The monitor on the computer should now show a selection of files that are saved on your disk. If you only have one program listed, it will be the program from the previous activity. However, if you have saved a lot of programs on the left side of the monitor screen and it is completely full, then press the SPACE BAR on the computer to list the rest of the programs on your disk.

_____16. The bottom of the screen on your monitor should read:

WHICH FILE FOR DOWNLOADING?

Type the name of the file that you want to use and then press the RETURN key.

_____17. Turn the power and motors switches OFF and then turn them back ON. This clears the memory of the controller.

_____18. The monitor should now read:

TO DOWNLOAD A MOVE SEQUENCE

HOLD DOWN "SHIFT" KEY, PRESS "STORE"
ON HANDHELD KEYBOARD
THEN TYPE "2" ON THE HOST KEYBOARD

Using the teach pendant, press the SHIFT key and hold it, then press the STORE key. Now take both fingers off the keys.

_____19. Type the number 2 key on the computer and watch the monitor screen. The screen should again print out zeros and ones in eight columns, each pertaining to one of the eight axes motors. You are now transfering the program information from the computer to the controller.

_____20. The monitor should now read:

SEQUENCE DONWLOADED

CHECK BY PRESSING "RUN" ON PENDANT

TYPE "RUN" TO RESTART

_____21. Now press the RUN key on the teach pendant to run the robot through its sequence of moves.

_____22. Type the word RUN on the computer and press the RETURN key; this takes you back to the beginning of the load sequence. After doing this, repeat steps 14through 21.

REFERENCES:

Rhino Teach Pendant Manual

NAME ______________________

DATE ______________________

CLASS ______________________

INSTRUCTOR______________________

QUESTIONS

1. What is the purpose of saving your teach pendant program on a disk?

2. After the robot is taught a series of movements while in the LEARN mode, the teach pendant program is stored in:

a. The host computer.
b. The teach pendant controller.
c. The hand held teach pendant.

3. T F Turning the controller OFF can erase a program that is stored in the controller's memory.

4. What is the BAUD rate on the interface card set at?

a. 9600
b. 750
c. 300
d. 175

5. What particular piece of equipment links the controller to the computer?

a. The disk drive
b. A short RS-232 cable
c. The teach pendant
d. A long RS-232 cable

6. The sequence of transfering a teach pendant program from the controller to the computer is refered at as:

a. UPLOADING

b. DOWNLOADING

7. You can only save your teach pendant program during the:

a. UPLOADING SEQUENCE
b. DOWNLOADING SEQUENCE

8. T F When your teach pendant program was stored on a disk, you had to give it a filename.

9. You can only load your teach pendant program during the:

a. UPLOADING SEQUENCE.
b. DOWNLOADING SEQUENCE.

10. Which card allows you to save and load your teach pendant programs?

a. CCS 7710A
b. Rhino Com Language Card.
c. Apple Super Serial
d. All the above.

LABORATORY 13

COORDINATE SYSTEM CONVERSIONS

INTRODUCTION

Robots with segmented arms, such as the XR Series robot, have a feature that helps simplify the analysis of the moves they make. This means that if one joint is moved, the other points of the arm will maintain the same relative position that they and before that joint was moved.

It is helpful in analyzing complex moves to have a common system of rotation. To meet this need, the X, Y, Z positional system can be used to keep track of exactly where points within a three dimensional area are located. In reference to the robot arm, its position can be found when it is rotated through an angle by determining the values for X, Y, Z at the end of the arm. This end-of-arm point is commonly referred to as tool center point (TCP).

To analyze the location of the total robot arm after one compound move of one axis, note that the other parts of the robot arm will have their coordinates changed by the amount of the change of the original move. For example, if once the bicep is moved, the elbow is moved, the new coordinates of the bicep should be used to analyze the elbow move. In this manner, it is possible to calculate the position of the TCP after any given sequence of moves.

Of course, it would be impractical to do these calculations manually everytime you needed to program the robot. For this reason, we have computer programs that can do these calculations.

In this lab, you will learn to use a program that calculates the moves of the XR arm and then moves the robot to a new TCP position.

The teach pendant programs and the XYZ programs record positions that the robot is to move to and then direct the move. With these programs it is important to be able to calculate the moves the robot is to make. The details of how to calculate the angles and distances for robot moves are presented in Chapter 3 of the text <u>Fundamentals of Robotics: Theory and Applications</u>. This material is not presented in this chapter so be sure to read the text carefullly.

In this lab, you will operate a program that calculates the moves of the XR arm and then moves the robot to a new TCP position.

OBJECTIVES

Upon completing this lab, you will be able to:

1. Operate a demonstration program that calculates the coordinates of moves for all five axes of the robot.

2. Operate the robot with a similar program that moves the robot through the moves after the calculations have been made.

LIST OF EQUIPMENT

1. Rhino XR Series robot and controller.
2. Apple IIe computer system.
3. Rhino Lab Disk for Apple IIe.
4. Two large carpenter's squares.

RELATED INFORMATION

Chapter three of the text Fundamentals of Robotics: Theory and Applications, presents a mathematical development of how to calculate the moves for each axis of a robot for a desired placement of the tool center point. This means that if the robot is in a home position and you decide that you want to move the robot to a new location, there are formulas that will help you know exactly how far to move each axis of the robot. If you reflect on the problem, it seems obvious that you would have to calculate these moves very carefully to be able to operate the robot.

By carefully reviewing the formulas and procedures in the Fundamentals of Robotics, you will develop a clear picture of what is occurring in this lab. Since you have not studied BASIC programming yet in this lab manual, the program for operating the robot is not presented. That program is listed in the appendix for those who are interested. Once you have mastered BASIC, you may want to come back to this lab to get a better idea of how the calculations are done.

As you study robotic programming more in detail, a major difference between the programming of educational robots and industrial robots should become apparent. This difference is that educational robots are programmed by moving individual axes whereas industrial robots move the tool center point.

At first glance, this may not seem to be a major difference, but it is very significant. It is very difficult to have the educational robot draw a straight line on a piece of paper. The reason is that you can move one axis a little, then another until you move from one point to another, but the moves have to be extremely small to even closely approximate a straight line. Also the motors on the educational robots cannot move at variable speeds; therefore all motions tend to be jerky.

The controllers for industrial robots calculate the moves that are to made and then set the speed for each motor. In this manner, with variable speed motors and precalculation of the moves, the robots are able to make very precise, smooth motions. The industrial robots are also able to move the TCP in a variety of modes because the controller is calculating all the moves for each axis. If you are programming the robot, you direct the TCP to go in a straight line between points A and B. You don't need to worry about how to move each of the robots axes to make the robot move from A to B.

Once you have operated this lab and seen the action of the moves, you will appreciate how important the calculations of the moves can be. It may also become apparent to you how these calculations can be the foundation for the development of other robot languages.

PROCEDURE

In this procedure, you will become familiar with the operation of the Rhino Mover program. There are two versions of the Rhino Mover program. The version you will use first displays the number of holes each motor is to move on the monitor. The second program, which you will use later, sends the same information to the motors rather than to the screen. The program you are using first is named the Rhino Mover Demonstration program.

To get started with this program, do the following steps.

____1. Insert the lab disk into the disk drive and turn on the computer.

____2. Select the Rhino Mover program. The first page of the program gives you information on the Rhino's starting position. The wrist must be straight down and the gripper closed. (Note: A number of the activities do not work in the same way if you use a different gripper from the standard model, i.e. if you rotate a double length open gripper, it requires a much larger work space.)

Note that the program gives you two options. If you press C, you will obtain the result of the calculations but the moves will not be executed. The E option gives you calculations and execution. When you leave this page the robot goes into a Hard Home routine.

___3. The first prompt you see should look like Figure 13.1.

BELOW ARE THE VALUES OF SOME PHYSICAL
CONSTANTS USED IN THE PROGRAM.

TABLE TO SHOULDER DISTANCE: 9.75 INCHES
SHOULDER TO ELBOW DISTANCE: 9.00 INCHES
ELBOW TO WRIST DISTANCE: 9.00 INCHES
WRIST TO T.C.P. DISTANCE 5.25 INCHES

PRESS "Y" IF YOU NEED TO CHANGE ANYTHING

PRESS "N" IF NO CHANGES ARE REQUIRED

Figure 13.1

The distances are measured from center to center of the joints. The TCP is the end of what ever gripper you have on the end of the robot. To check these values, you must measure them on the robot you have. In the next section of this lab, you will measure the values and change them if necessary. In this section, you will just run through the prompts to see what choices are possible.

____4. Press Y to indicate that you wish to change the values. Just to see how the program works, preten to change the values by reentering the ones already given. Note that the program does not accept D for default values. It asks you for each distance measure and then has you confirm your answer by responding Y for Yes when asked whether you are sure.

_____1. The next screen, Fig. 13.2 gives you the coordinates of the home position and the position of the gripper.

____2.

BELOW ARE THE COORDINATES OF THE HOME

POSITION AND THE POSITION OF THE GRIPPER

(MEASURED IN INCHES AND DEGREES)

X=3.33	Y=0.00
Z=11.50	PITCH=0.00
ROLL=0.00	GRIPPER 100% CLOSED

PRESS "Y" IF YOU NEED TO CHANGE ANYTHING

PRESS "N" IF NO CHANGES ARE REQUIRED

____3. The orientation of the coordinate axes is shown in Figure 13.4.

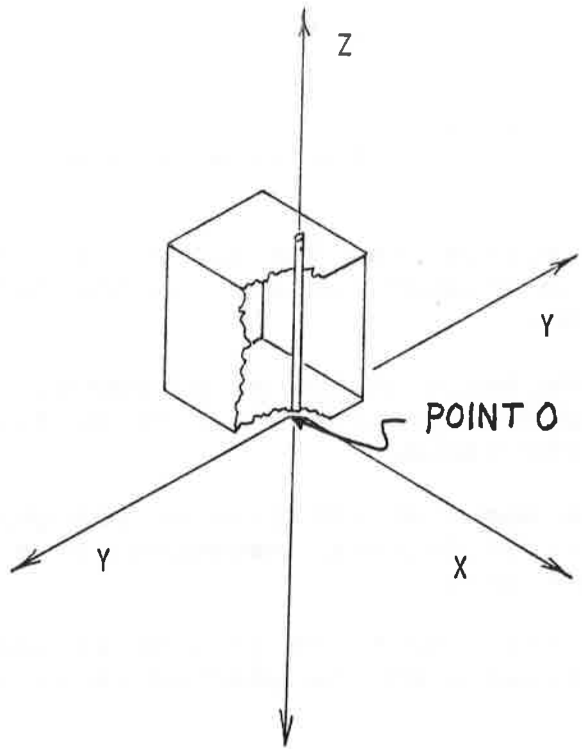


Figure 13.4 XYZ coordinate system in relationship to the robot.

The values of the coordinates are determined as follows:

X is the distance from the center line of the waist rotation to the center line of the gripper rotation, when the two halves of the base line up.

Y is the distance to the right, positive, or left, negative, of the center line of the waist rotation.

Z is the distance from the surface of the table to the end of the gripper parallel to the center line of waist rotation.

Pitch is the angle of the wrist above, positive, or below, negative of a line parallel to the surface of the table.

Roll is the angle of rotation of the gripper to the right, positive, or left, negative, of a line parallel to the Y axis.

Gripper is the amount the gripper is open. The gripper is 0% closed when the opening is at its maximum.

Press return to continue

____5. As in step 4, assume that you needed to change the values to go through above in step 4 the exercise but then reenter the values shown in Fig. 13.2. You cannot use D for default values but follow the prompts to enter the correct numbers.

____6. When you have finished, the screen should again look like Figure 13.2.

____7. Press RETURN to continue and the prompt shown in Figure 13.3 should appear.

```
ENTER THE FOLLOWING TO GO BACK "HOME"

X=3.33                 Y=0
Z=11.50                PITCH=0
ROLL=0            GRIPPER 150% CLOSED

___________________________

THE PRESENT LOCATION IS:

X=3.33                 Y=0
Z=11.50                PITCH=0
ROLL=0            GRIPPER 150% CLOSED

___________________________

ENTER X,Y,Z
```

Figure 13.3

_____8. At this point, you enter the XYZ coordinates...TCP. Enter 5.5.13. These values will move the X axis point 1.67 inches forward (5.00-3.33=1.67), the Y axis point 5 inches to the left (5.00-0.00=5.00), and thr Z axis 1.5 inches down (13.00-11.50=1.50). This move will keep the robot from crashing into anything and it will be able to reach the designated point. It will also give you an idea of a typical move.

_____9. You should now see a prompt asking for the pitch and roll of the wrist. Enter -45,45. These are simply example moves.

_____10. You should now see a prompt asking how far you want the gripper to open., Enter 50.

_____11. Enter RETURN to continue. Each time you enter new values, the location number will change along with the values.

Below the horizontal line, you will find the results of calculating the change in coordinate positions into axis DEGREE CHANGE and motor STEP CHANGE. The last column gives you the TOTAL STEP COUNT of all changes in coordinate positions since the robot left its home position.

As usual, you have a choice of entering another position or exiting the program. If you enter values that are outside of the normal working envelope of the robot, you will receive a message indicating that the position specified is OUT OF RANGE.

Once you have finished entering values, press N to leave the program the program. You are now finished with the first part of the lab.

This portion has taken you through a simple move and displayed the results on the monitor. In the next section, have it move to each of these points.

In this part of the procedure, you will use the Rhino Mover program to move the robot to any reasonable point you want. Reasonable points for the robot are points that the robot can reach, without running into anything. It would be silly to have it try to move to an XYZ of 100,100,100 because the robot isn't that big!

The Rhino Mover Demo program took you through the mechanics of using the Rhino Mover program. You will need to check the values for the physical constants and the home position before you use the program. Failure to make any required changes could result in damage to the robot.

____12. Enter the Rhino Mover program. Be sure you enter the Rhino Mover, not the Rhino Mover Demo. program. You should see the prompt shown in Figure 13.1.

If no changes are required, press N and go on to the next step. If any of the values are different than the ones shown, press Y to make the changes following steps 6 and 7, entering the correct values where they are required. After all the changes are made, continue to the next step.

____13. The prompt you now see should be the same as the one shown in Figure 13.2. The next figures show how to measure the coordinate of the home position.

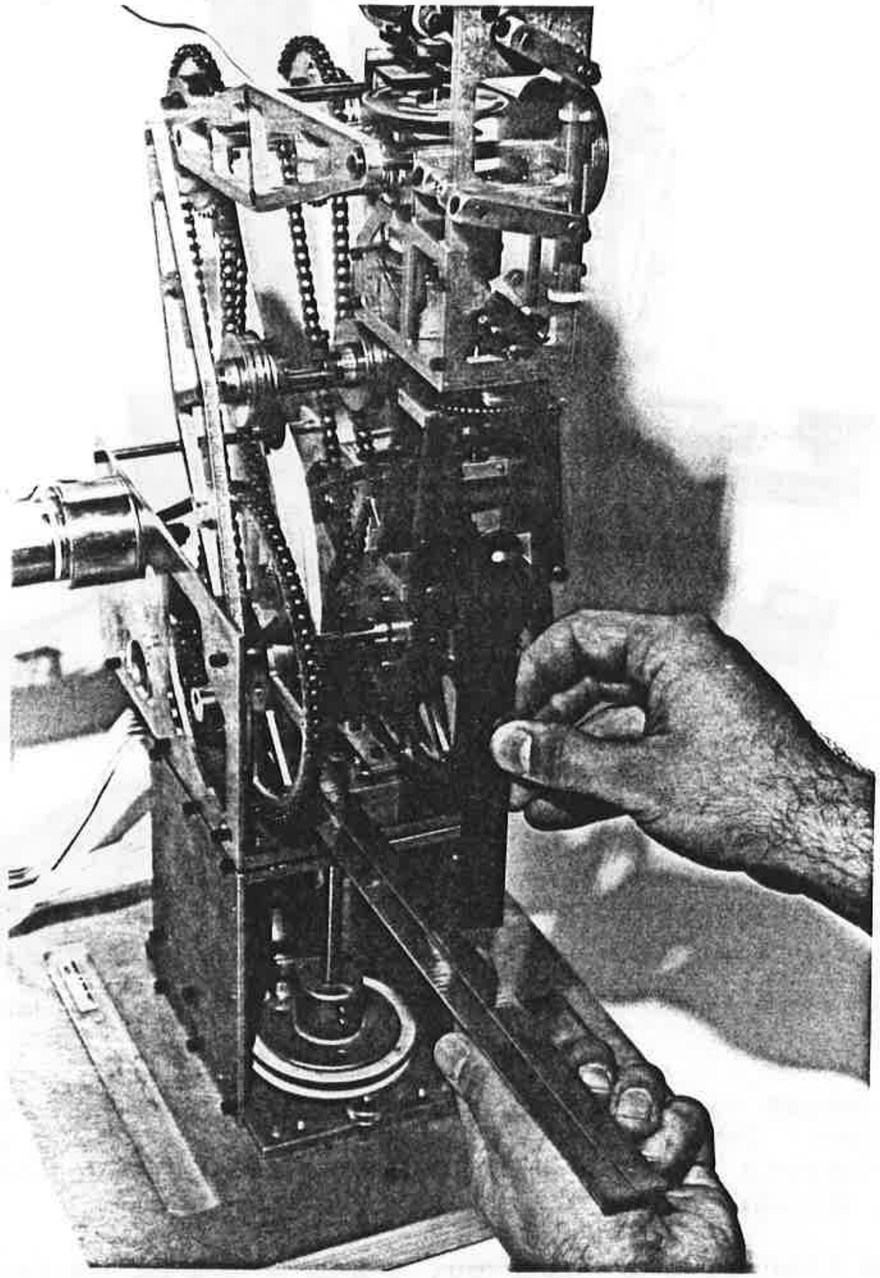


Figure 13.4 Finding the X coordinate of the Home position.

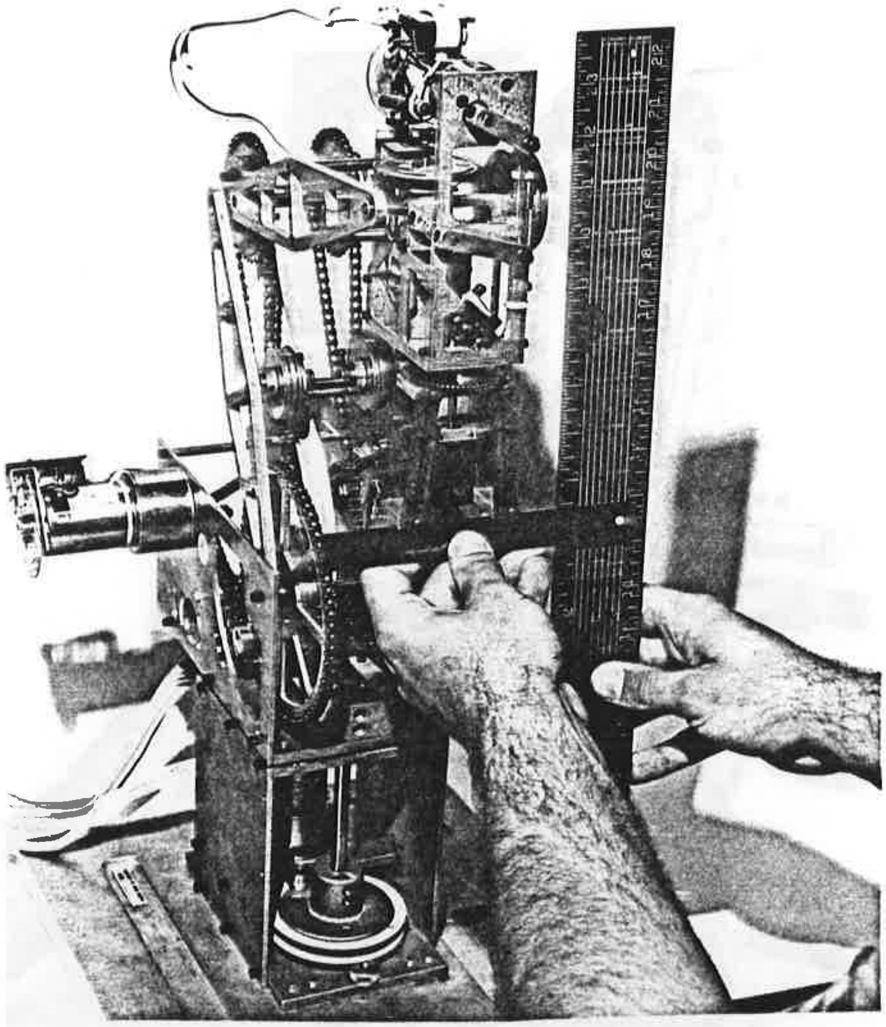


Figure 13.5 Finding the Z coordinate of the Home position.

The values of the pitch, roll, and gripper can be approximated. Be as accurate as you can. The value of the Y coordinate will be zero if the two halves of the base line up squarely.

If no changes are required, press N and go on to the next step. If any of the values are different than the ones shown, press Y to make the changes following steps 6 and 7, entering the correct values where they are required. After all the changes are made, continue to the next step.

____14. Follow the same procedure you did in steps 8-10. Enter the same values for the point. After entering the value for the gripper, the robot should start to move. As you can see, it moved to the point that you told it to. Experiment with the program by entering different points. Be careful that you do not give the robot a point that will cause it to run into itself or that it can't reach.

Be sure to operate the program at least 6 or 7 times to get a feel for the valid points and the points that are both close to the robot and near its limits of reach. Also notice that it makes a great deal of difference how you orient the hand when you want to reach points near the robot.

REFERENCES:

__Fundamentals of Robotics: Theory and Applications,__ Chapter 3, "Robot Coordinate System," (pp 76-108)

NAME______________
DATE______________
CLASS______________
INSTRUCTOR______________

QUESTIONS

1. How are the values of the physical constants determined?

2. The distance from the center line of the waist rotation to the center line of the gripper rotation, when the two halves of the base line up is the ______coordinate.

a. X
b. Y
c. Z
d. Pitch
e. Roll

3. The distance from the surface of the table to the end of the gripper parallel to the center line of waist rotation is the _______ coordinate.

a. X
b. Y
c. Z
d. Pitch
e. Roll

4. The distance to the right, positive, or left, negative, of the center line of the waist rotation is the ______ coordinate.

a. X
b. Y
c. Z
d. Pitch
e. Roll

5. The angle of rotation of the gripper to the right, positive, or left, negative, of a line parallel to the Y axis is the ______ coordinate.

a. X
b. Y
c. Z
d. Pitch
e. Roll

6. The angle of the wrist above, positive, or below, negative of a line parallel to the surface of the table is the ______ coordinate.

a. X
b. Y
c. Z
d. Pitch
e. Roll