

# **SCORA-ER 14**

## **User's Manual**

Catalog # 100067 Rev.B





# **WARNING!**

**The SCORA-ER 14 ROBOT is  
DANGEROUS  
and can cause severe injury.**

**USE WITH EXTREME CAUTION.**

**Set up a protective screen or guardrail  
around the robot to  
KEEP PEOPLE AWAY  
from its working range.**



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**SCORBOT** is a registered trademark, and **ACL** is a trademark, of Eshed Robotec (1982) Ltd.

Read this manual thoroughly before attempting to install or operate the robot. If you have any problems during installation or operation, call your agent for assistance.

Save the original carton and all packing material. You may need them later for shipment.



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# Unpacking and Handling

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- ◆ *Read this chapter carefully before you unpack the SCORA-ER 14 robot and controller.*

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## Unpacking and Handling the Robot

The robot is packed in expanded foam.

**Save the original packing materials** and shipping carton. You may need them later for shipment or for storage of the robot.

The robot arm weighs 35 kilos (77 pounds). Two people are needed in order to lift or move it.

**Lift and carry the robot arm by grasping its column and/or base.**

Do not lift or carry the robot arm by its horizontal links.

---

## Repacking for Shipment

Be sure all parts are back in place before packing the robot.

The robot should be repacked in its original packaging for transport.

If the original carton is not available, wrap the robot in plastic or heavy paper. Put the wrapped robot in a strong cardboard box at least 15 cm (about 6 inches) longer in all three dimensions than the robot. Fill the box equally around the unit with resilient packing material (shredded paper, bubble pack, expanded foam chunks).

**Seal the carton with sealing or strapping tape.** Do not use cellophane or masking tape.

# Acceptance Inspection

After removing the robot arm from the shipping carton, examine it for signs of shipping damage. If any damage is evident, do not install or operate the **SCORA**. Notify your freight carrier and begin appropriate claims procedures.

The following items are standard components in the **SCORA-ER 14** package. Make sure you have received all the items listed on the shipment's packing list. If anything is missing, contact your supplier.

Item	Description
<b>SCORA-ER 14</b> Robot Arm	Includes: Cabling with air hoses; Hardware for mounting robot: 4 M8x60 bolts; 4 M8 washers; 4 M8 nuts.
<b>Gripper:</b> 2 options	<b>Pneumatic Gripper</b> includes pneumatic solenoid valve and 6 M4x8 screws for mounting gripper.
	<b>Electric DC Servo Gripper</b> with encoder includes 4 M4x10 screws for mounting gripper.
<b>ACL Controller-B</b>	Includes: Power Cable 100/110/220/240VAC; RS232 Cable; 3 driver cards for 6 axes
	Optional: Emergency By-Pass Plug (required when TP not connected); Additional driver cards for control of up to 12 axes; Auxiliary multiport RS232 board, cable and connectors.
<b>Teach Pendant:</b> optional	Includes: mounting fixture; connector adapter plug. <i>Teach Pendant for Controller-B User's Manual</i>
<b>Software</b>	ATS (Advanced Terminal Software) diskette; includes <b>ACLOff-line</b> software.
	<b>SCORBASE</b> Level 5 Software diskette
<b>Documentation</b>	<i>SCORA-ER 14 User's Manual</i>
	<i>ACL Controller-B User's Manual</i>
	<i>ACL for Controller-B Reference Guide</i>
	<i>ATS for Controller-B Reference Guide</i>
	<i>ACLOff-line User's Manual</i>
	<i>SCORBASE Level 5 for Controller-B Version Reference Guide</i>

# Specifications

The following table gives the specifications of the **SCORA-ER 14** robot arm.

Robot Arm Specifications	
Mechanical Structure	Horizontal articulated (SCARA)
Arm Length	
Link 1	270mm (10.6")
Link 2	230mm (9.0")
Axis Movement	Axis Range                      Effective Speed
Axis 1: Rotation	288°                              117°/sec
Axis 2: Rotation	218°                              114°/sec
Axis 3: Translation	182mm                          211mm/sec
Axis 4: Roll; without gripper cable: or Roll; with gripper cable:	unrestricted                      370°/sec ±527°
Links 1 and 2 combined	1.5m/sec
Maximum Operating Radius	Minimum 230mm (9.06") Maximum 500 mm (19.69")
End Effector	Pneumatic Gripper Electric DC servo Gripper
Hard Home	Fixed position on all axes
Feedback	Incremental optical encoders with index pulse
Actuators	DC servo motors
Transmission	Harmonic Drive gears
Maximum Payload	2 kg (4.4 lb.)
Position Repeatability	±0.05mm (±0.002")
Weight	30 kg (66 lb.)
Ambient Operating Temperature	2°–40°C (36°–104°F)

# Structure

The SCORA-ER 14 is a horizontal articulated (SCARA) robot.

The first two joints are revolute and determine the position of the end effector in the XY plane. The third joint is prismatic and determines the height (Z coordinate) of the end effector.

Figure 2-1 identifies the joints and links of the mechanical arm.

Each joint is driven by a servo DC motor via a Harmonic Drive gear transmission.

The following table describes the movement of the axes:

Axis No.	Motion
1	Rotates Link 1 in horizontal (XY) plane.
2	Rotates Link 2 in horizontal (XY) plane.
3	Translates (raises and lowers) the end effector along Z axis.
4	Rotates the end effector.

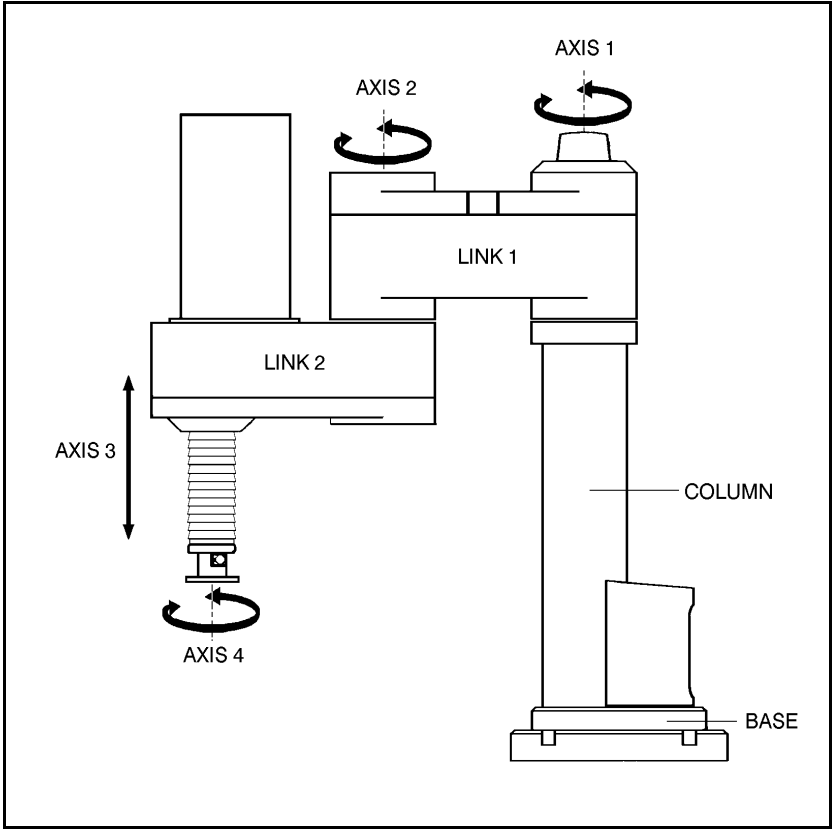


Figure 2-1: SCORA-14 Mechanical Arm

## Work Envelope

The length of the links and the degree of rotation of the joints determine the robot's work envelope. Figures 2-2 and 2-3 show the dimensions of the **SCORA-ER 14**, while Figure 2-4 gives a top view of the robot's work envelope.

The base of the robot is normally fixed to a stationary work surface. It may, however, be attached to a slidebase, resulting in an extended working range.

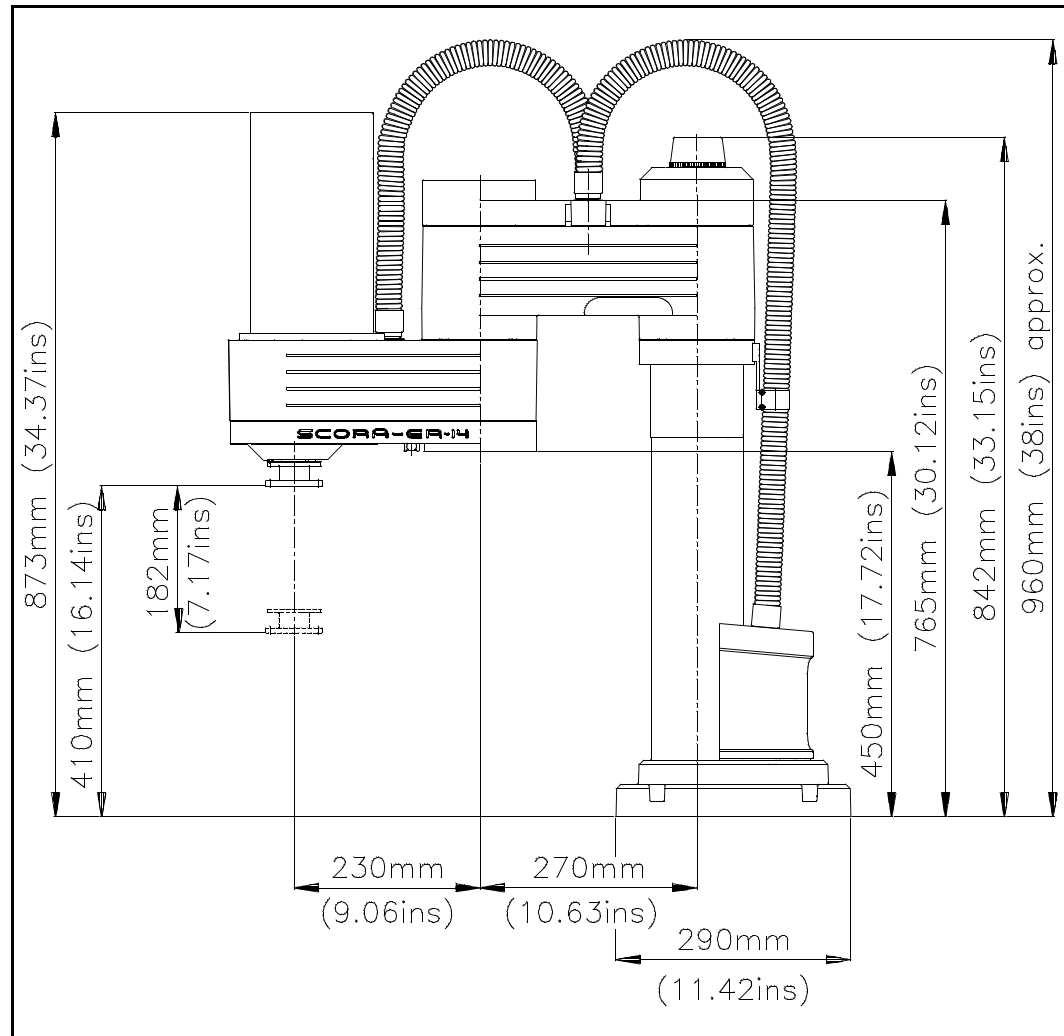


Figure 2-2: Dimensions (Side View)

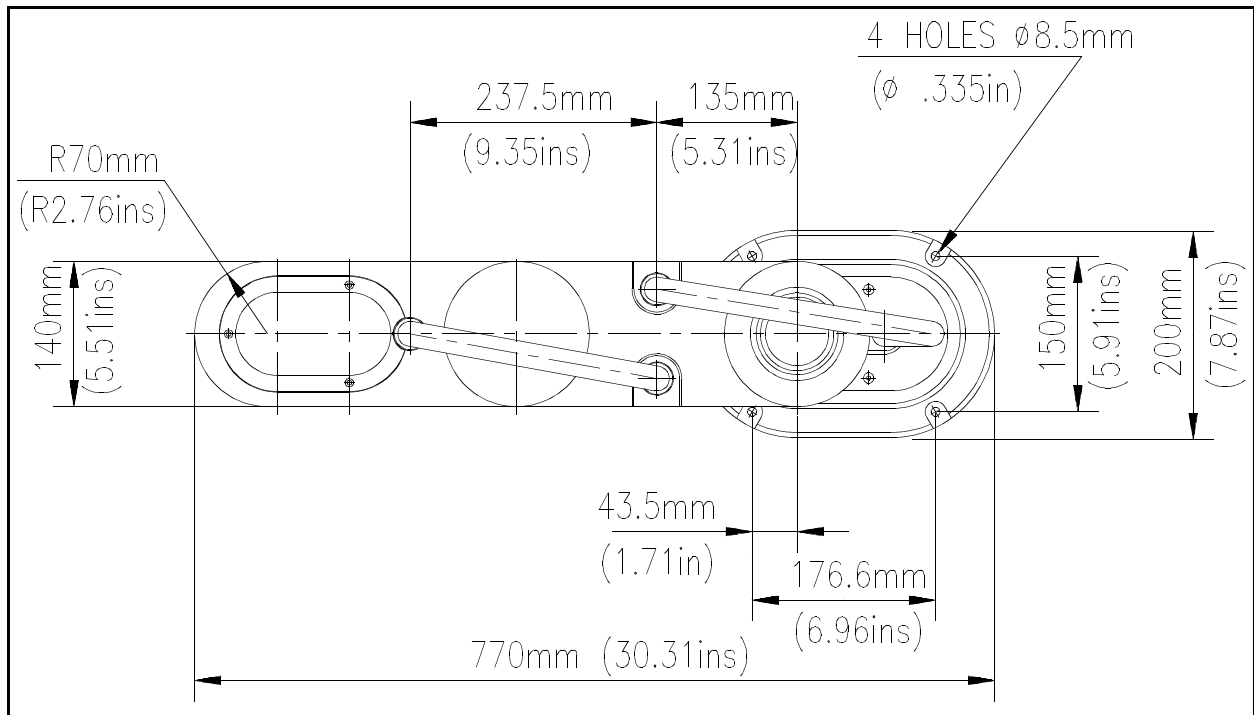


Figure 2-3: Dimensions (Top View)

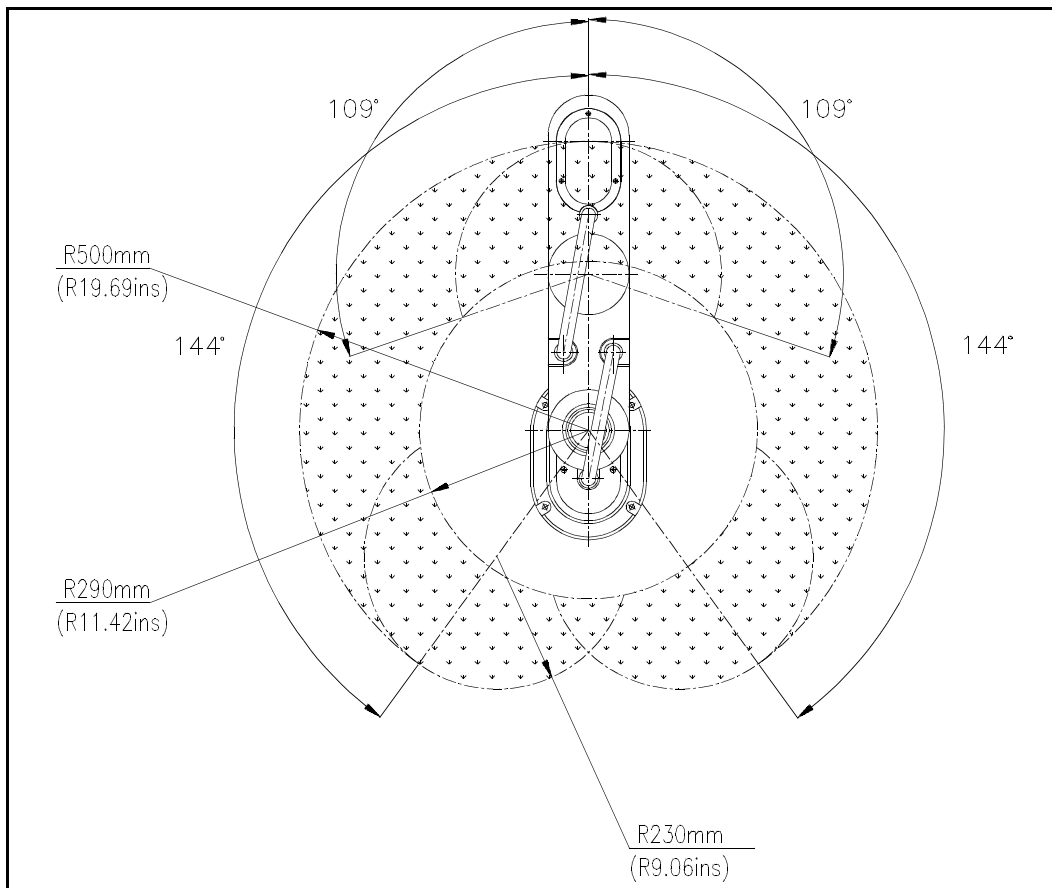


Figure 2-4: Working Range (Top View)

# Safety

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The **SCORA-ER 14** is a potentially dangerous machine. Safety during operation is of the utmost importance. Use extreme caution when working with the robot.

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## Precautions

The following chapters of this manual provide complete details for proper installation and operation of the **SCORA-ER 14**. The list below summarizes the most important safety measures.

1. Make sure the robot base is properly and securely bolted in place.
2. Make sure the robot arm has ample space in which to operate freely.
3. Make sure both the encoder cable and the robot power cable are properly connected to the controller before it is turned on.
4. Make sure a guardrail or rope has been set up around the **SCORA-ER 14** operating area to protect both the operator and bystanders.
5. Do not enter the robot's safety range or touch the robot when the system is in operation.
6. Press the controller's EMERGENCY switch before you enter the robot's operating area.
7. Turn off the controller's POWER switch before you connect any inputs or outputs to the controller.

◆ *To immediately abort all running programs and stop all axes of motion, do any of the following:*

- *press the teach pendant's EMERGENCY button;*
- *use the ACL command A <Enter>;*
- *press the controller's red EMERGENCY button.*

---

## Warnings

1. Do not operate the **SCORA-ER 14** until you have thoroughly studied both this *User's Manual* and the *ACL Controller-B User's Manual*. Be sure you follow the safety guidelines outlined for both the robot and the controller.
2. Do not install or operate the **SCORA-ER 14** under any of the following conditions:
  - Where the ambient temperature drops below or exceeds the specified limits.
  - Where exposed to large amounts of dust, dirt, salt, iron powder, or similar substances.
  - Where subject to vibrations or shocks.
  - Where exposed to direct sunlight.
  - Where subject to chemical, oil or water splashes.
  - Where corrosive or flammable gas is present.
  - Where the power line contains voltage spikes, or near any equipment which generates large electrical noises.
3. Do not abuse the robot arm:
  - Do not operate the robot arm if the encoder cable is not connected to the controller.
  - Do not overload the robot arm. The weight of the payload may not exceed 2kg (4.4 lb.). It is recommended that the workload be grasped at its center of gravity.
  - Do not use physical force to move or stop any part of the robot arm.
  - Do not drive the robot arm into any object or physical obstacle.
  - Do not leave a loaded arm extended for more than a few minutes.
  - Do not leave any of the axes under mechanical strain for any length of time. Especially, do not leave the gripper grasping an object indefinitely.



# Installation

## Preparations

Before you make any cable connections, set up the system components according to the following “Preparation” instructions.

### Controller and Computer/Terminal Setup

Place the controller and computer at a safe distance from the robot—well outside the robot’s safety range.

Make sure the setup complies with the guidelines defined in the chapter, “Safety,” in the *ACL Controller-B User’s Manual*.

### Robot Setup

Refer to Figures 4-1 and 4-2.

1. Set up the **SCORA-ER 14** on a sturdy surface with at least 70 cm of free space all around the robot.
2. Set up the robot so that it faces in the proper direction— towards the application or machine it will serve.
3. Fasten the base of the robot to the work surface with four sets of bolt, washer and nut.

Make sure the robot is securely bolted in place. Otherwise the robot could become unstable and topple over while in motion.

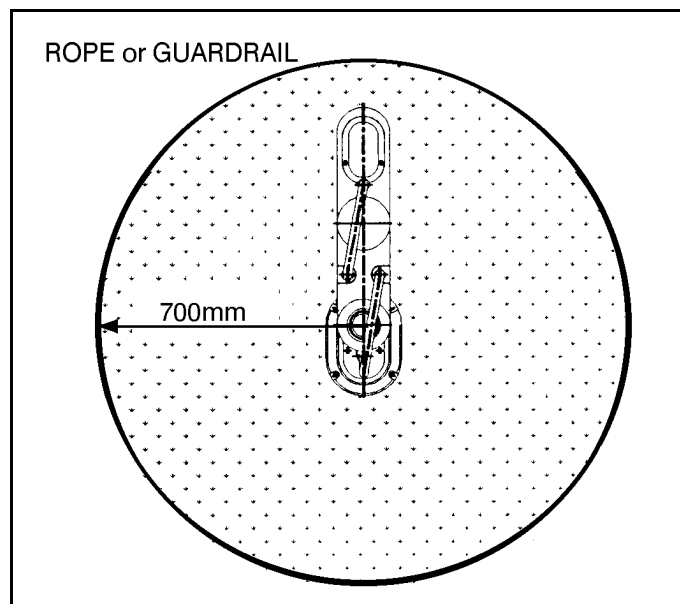


Figure 4-1: Robot Safety Range

4. Set up a guardrail or rope around the **SCORA-ER 14** operating area to protect both the operator and bystanders.

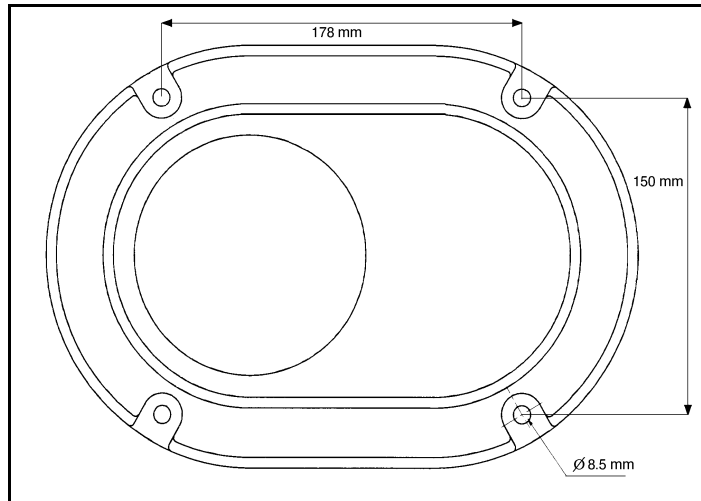


Figure 4-2: Robot Base Layout

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## SCORA-ER 14 Installation

### Controller Installation

Perform the installation procedures detailed in the following sections of Chapter 2, “Installation,” in the *ACL Controller-B User’s Manual*:

- **Computer/Terminal–Controller Installation**
- **Power On**
- **Controller Configuration**

- ◆ When the Peripheral Setup screen appears at the end of the controller configuration, select **Gripper Connection: None**. (You will change this setting after the gripper is installed.) Refer to the section, “Peripheral Devices and Equipment--Robot Gripper,” in the *ACL Controller-B User’s Manual*.

### Robot Installation

- ◆ *Before you begin, make sure the controller POWER switch is turned off.*

Refer to Figures 4-3 and 4-4. Refer also to the wiring information and diagram in Chapter 8.

1. Connect the safety ground wires:
  - Unscrew and remove the nuts and washers from the safety ground studs on both the robot and controller connector panels.
  - Connect the green/yellow wires from both the robot cable and the encoders cable to the safety ground studs on both the robot and controller connector panels.

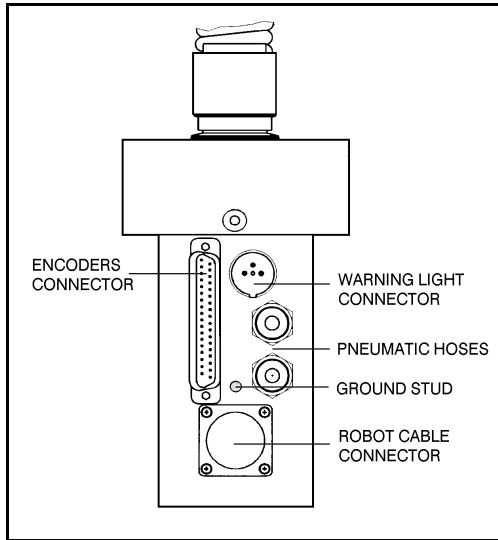


Figure 4-3: Robot Connector Panel

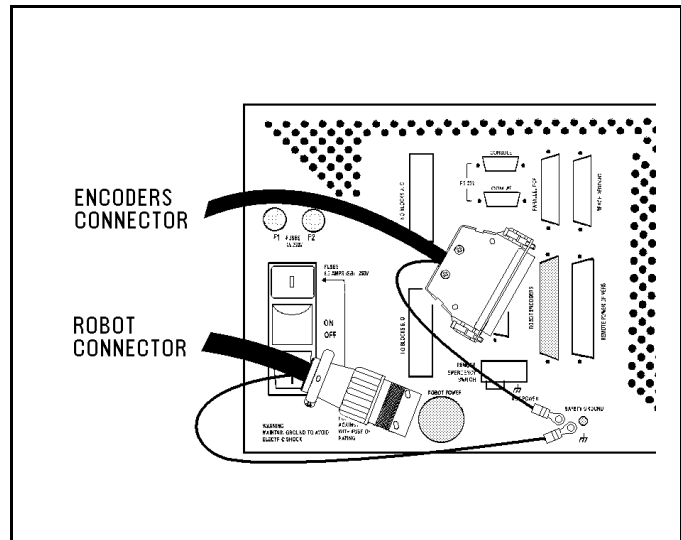


Figure 4-4: Controller Connector Panel

- After you have placed the ground wire terminals onto the studs, replace and tighten the washers and nuts.
2. Connect the two cables which connect the robot and the controller.
    - Plug the the D37 connectors on the encoder cable into the Robot Encoders port on the controller and into the port on the robot's connector panel. Tighten the retaining screws on the connector.
    - Plug the 19-pin round connectors on the robot cable into the Robot Power port on the controller and into the port on the robot's connector panel.
  3. Connect the robot warning light to the controller:
    - Plug the 3-pin round connector on the warning light cable into the Warning Light port on the robot. Connect the red and black wires to any unused relay output terminal: one wire to NO and one wire to C on the same output.
    - Write a routine which will turn on the output whenever the controller is in CON state and turn off the output whenever the controller is in COFF state. For automatic activation of this routine, include it in the user-reserved **ACL** program **BACKG**. Refer to the *ACL for Controller-B Reference Guide* for more information on **BACKG**.

**Note:** When disconnecting the robot from the controller, do it in the opposite order:

- Disconnect the warning light connections.
- Disconnect the power cable connections.
- Disconnect the encoders cable connections.
- Disconnect the ground wires.

## Homing the Robot

After you have completed the robot installation, execute the robot's Home routine, as described below.

- ◆ *The robot must be homed before you mount the gripper.*
- ◆ *Before you begin the homing procedure, make sure the robot has ample space in which to move freely and extend its arm.*

1. Turn on the controller. Turn on the computer.
2. From the ATS diskette or directory, activate the ATS software. Type:

```
ats <Enter>
```

If the controller is connected to computer port COM2, type:

```
ats /c2
```

3. When the ATS screen and > prompt appear, you may proceed.
4. Give the ACL command to home the robot. Type:

```
home <Enter>
```

The monitor will display:

```
WAIT!! HOMING...
```

During the Home procedure, the robot joints move and search for their home positions in the following sequence: axis 3 (vertical stroke), axis 2, axis 4 (roll) and axis 1.

If home is found, a message is displayed:

```
HOMING COMPLETE (ROBOT)
```

If the HOME process is not completed, an error message identifying the failure is displayed. For example:

```
*** HOME FAILURE AXIS 3
```

If the home switch is found, but not the encoder's index pulse, the following message is displayed:

```
* * * INDEX PULSE NOT FOUND AXIS 2
```

# Gripper Installation

The gripper is attached to the flange at the end of the robot arm whose layout is shown in Figure 4-5.

## Pneumatic Gripper

The pneumatic gripper, shown in Figure 4-6, is controlled by a 5/2 solenoid pneumatic valve which is activated by one of the controller's relay outputs. The valve may be 12VDC or 24VDC and can draw its power from the controller's User Power Supply.

◆ *The robot must be homed before you mount the gripper.*

1. Using a 3mm hex wrench and six M4x8 socket screws, attach the gripper to the robot arm flange.
2. Connect the coiled double hose from the gripper to the quick coupling on the underside of Link 2, as indicated in Figure 4-7.

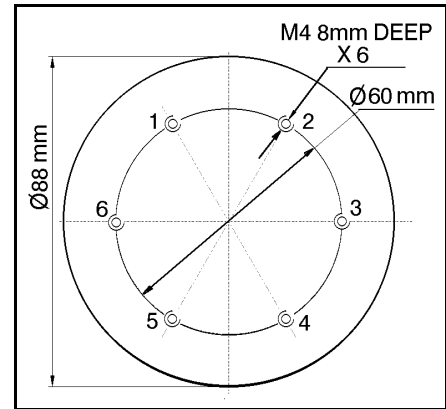


Figure 4-5: Gripper Mounting Flange Layout

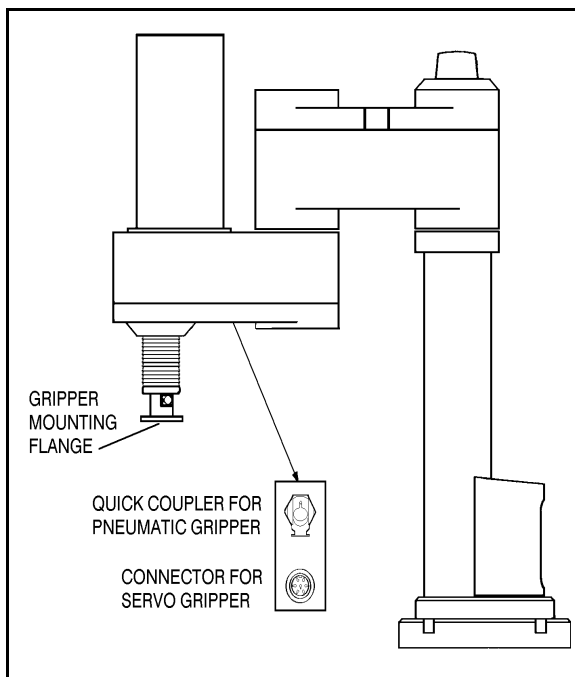


Figure 4-7: Gripper Connectors

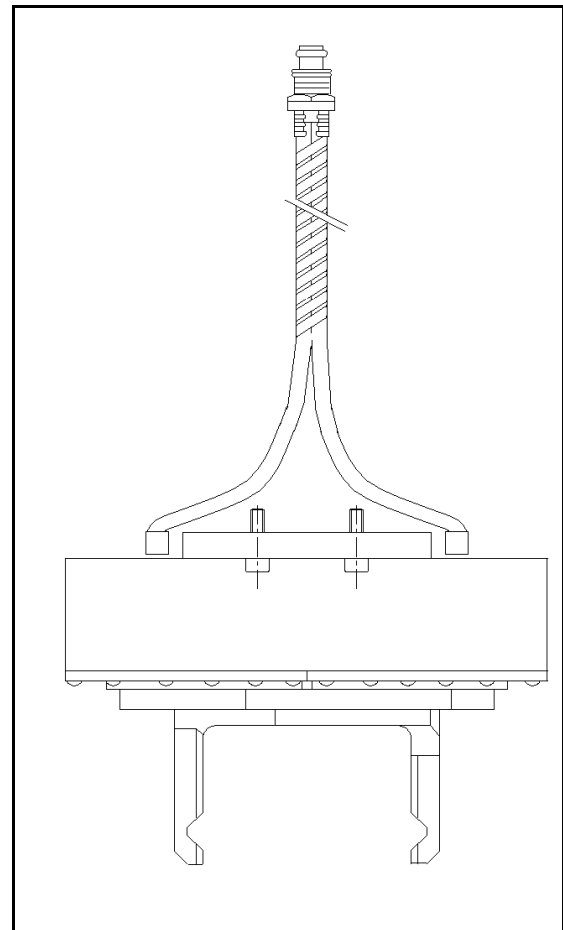


Figure 4-6: Pneumatic Gripper

3. Refer to Figure 4-8.
  - Connect the two transparent 1/4" O.D. hoses from the robot to the CYL ports on the pneumatic valve.
  - Connect a 5 bar/90 PSI air supply to the IN port on the valve.

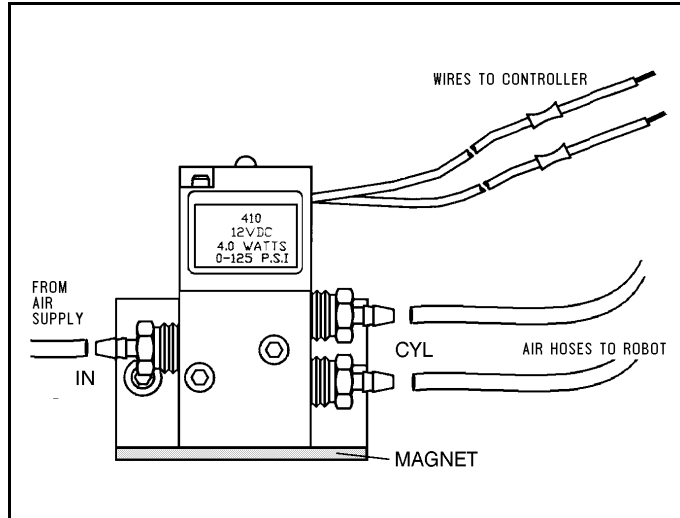


Figure 4-8: Pneumatic Solenoid Valve

4. Refer to Figure 4-9.  
Connect the valve to the controller's User Power Supply as follows:

- Connect the black wire to a common terminal.
- Connect the red wire to the normally open (NO) terminal of any unused relay output.

5. Connect 12VDC or 24VDC (in accordance with your valve's specification) to the common (C) terminal of the **same** relay output, as shown in Figure 4-9.
6. Attach the valve to the controller or any other metallic surface by means of the valve's magnetic base.

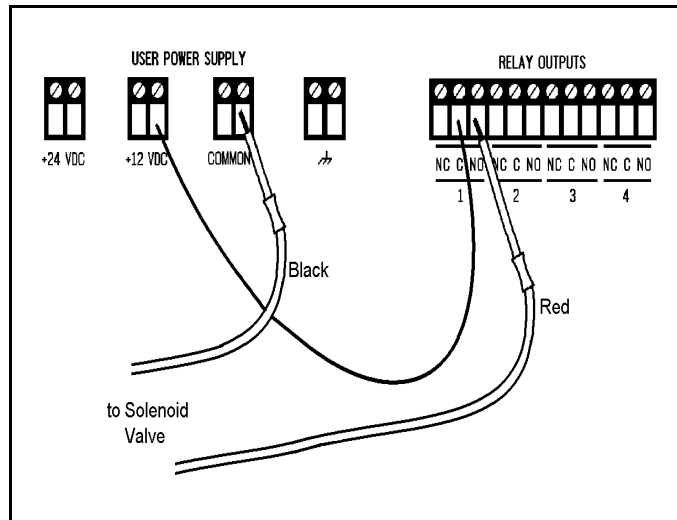


Figure 4-9: Valve—Controller Connections

## Servo Gripper

The electrical servo gripper is shown in the inset in Figure 4-10.

◆ *The robot must be homed before you mount the gripper.*

1. Using a 3 mm hex wrench and four M4x10 socket screws, attach the gripper to the gripper mounting flange at the end of the robot arm.
2. Connect the gripper cable to the electrical connector on the robot arm. Make sure the connector is oriented as shown in Figure 4-10.
3. Make sure the gripper cable is positioned as shown in both Figure 4-10 and Figure 4-11.

**Refer to A-A in Figure 4-10.** Fit the two cable clamps onto the two gripper cables. Place the clamps on the flange. Fit the spacer on the cable clamp screw, and then tighten the screw onto the flange.

4. Carefully execute the robot HOME command. Stay close to the teach pendant or controller. If the gripper cable becomes entangled or excessively stretched during the homing, abort the procedure immediately.
5. The gripper has a rotation of  $\pm 270^\circ$ . Do not attempt to move the gripper beyond this limit.
6. At the end of each work session (before turning off the controller), or before homing the robot, make sure the gripper's position is as shown in Figure 4-11.

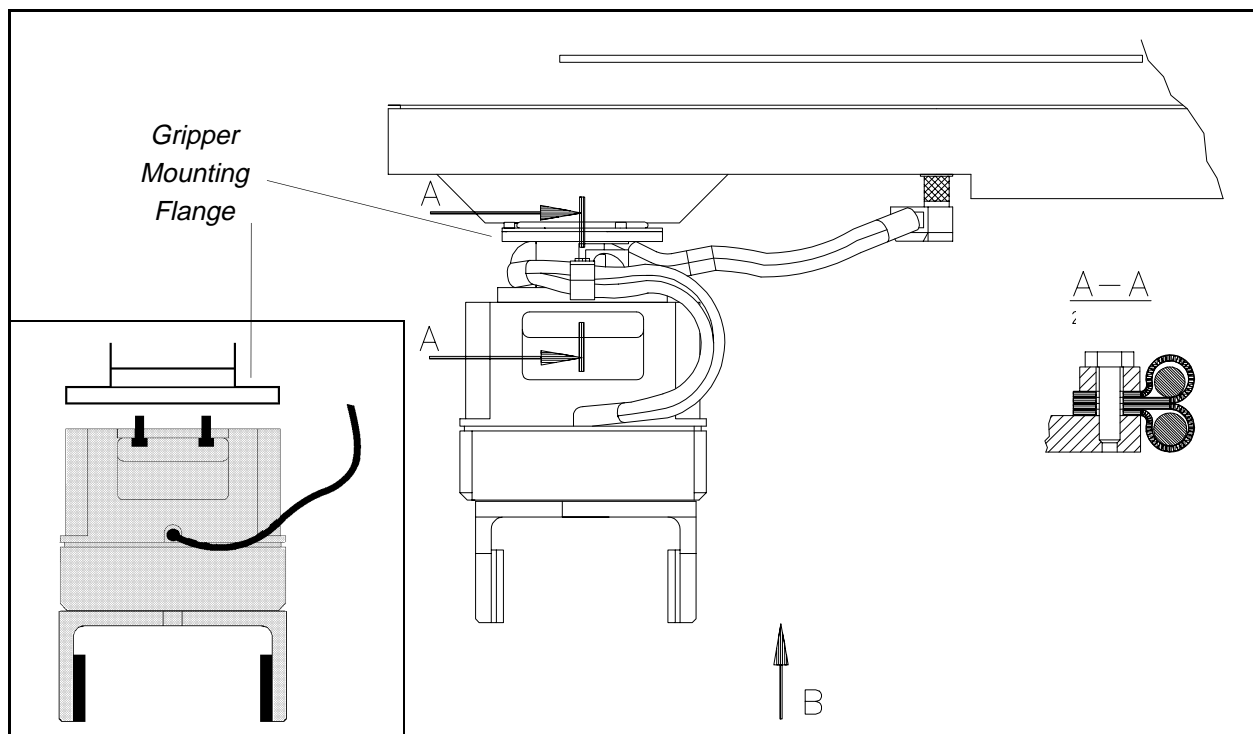


Figure 4-10: Connecting Gripper to SCORA-ER 14

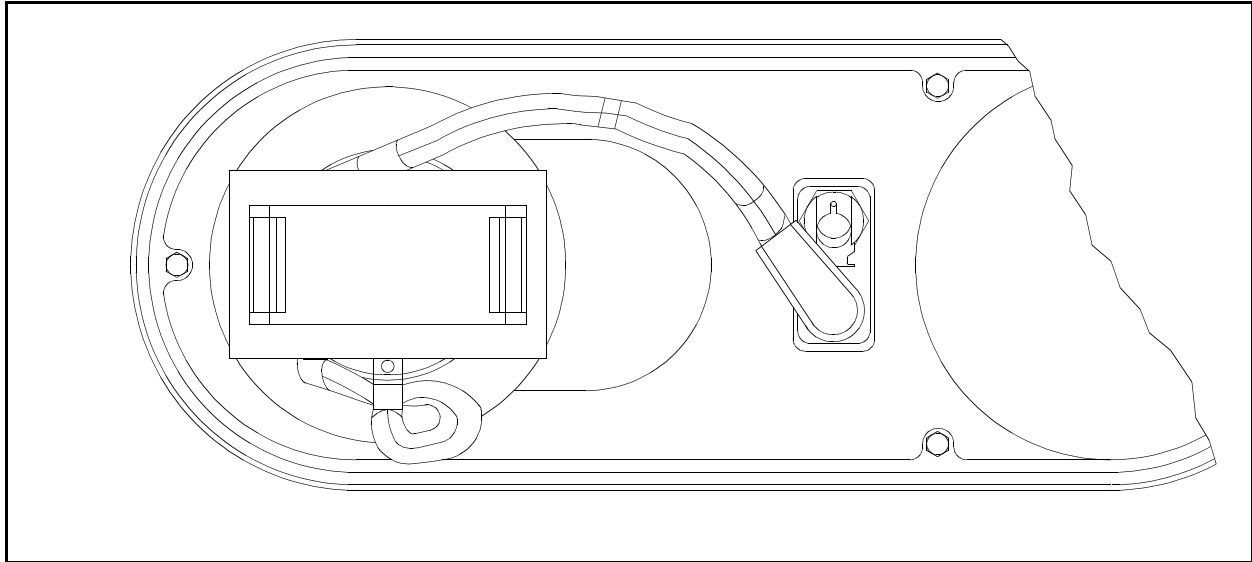


Figure 4-11: Connecting Gripper to SCORA-ER 14

- ◆ Axis 5 is reserved by default controller configuration for a servo gripper. To connect a different device as axis 5, you must change the system configuration by means of the ACL command CONFIG.

## Activating the Gripper

1. Activate **ATS**. Press <Ctrl>+F3 to activate the Peripheral Setup screen.
2. Change the robot gripper definition according to the gripper you have installed. Refer to the section, “Peripheral Devices and Equipment--Robot Gripper,” in Chapter 2 of the *ACL Controller-B User’s Manual*.
3. Open and close it in order to verify that it is functioning. The following commands work for both the electric and the pneumatic gripper.

### PC

Type:

```
open <Enter>
```

The gripper opens.

Type:

```
close <Enter>
```

The gripper closes.

### TP

Key in:

**Open/Close**

The Open/Close key toggles the gripper between its open and closed states. programs you have just written.



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# Operating Methods

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The **SCORA-ER 14** robot can be programmed and operated in a number of ways.

The *ACL Controller-B User's Manual* includes two chapters which guide you through the basic commands for operating and programming the robot.

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## Software

### ACL

**ACL**, Advanced Control Language, is an advanced, multi-tasking robotic programming language developed by Eshed Robotec. **ACL** is programmed onto a set of EPROMs within **Controller-B**, and can be accessed from any standard terminal or PC by means of an RS232 communication channel.

**ACL** features include the following:

- Direct user control of robotic axes.
- User programming of robotic system.
- Input/output data control.
- Simultaneous and synchronized program execution (full multi-tasking support).
- Simple file management.

The *ACL Reference Guide for Controller-B* provides detailed descriptions and examples of the **ACL** commands and functions.

### ATS

**ATS**, Advanced Terminal Software, is the user interface to the **ACL** controller. **ATS** is supplied on diskette and operates on any PC. The software is a terminal emulator which enables access to the **ACL** environment from a PC host computer.

**ATS** features include the following:

- Short-form controller configuration.
- Definition of peripheral devices.
- Short-cut keys for command entry.
- Program editor.
- Backup manager.
- Print manager.

The *ATS Reference Guide for Controller-B* is a complete guide to **ATS**.

## **ACLoff-line**

**ACLoff-line** is a preprocessor software utility, which lets you access and use your own text editor to create and edit **ACL** programs even when the controller is not connected or not communicating with your computer.

After communication is established, the **Downloader** utility lets you transfer your program to the controller. The **Downloader** detects the preprocessor directives, and replaces them with a string or block of **ACL** program code.

**ACLoff-line** also enables activation of **ATS**, Advanced Terminal Software, for on-line programming and system operation.

**ACLoff-line** is described fully in the *ACLoff-line User's Manual*.

## **SCORBASE**

**SCORBASE** Level 5 is a robot control software package which is supplied on diskette with the controller. Its menu-driven structure and off-line capabilities facilitate robotic programming and operation.

**SCORBASE** runs on any PC system and communicates with **ACL**, the controller's internal language, by means of an RS232 channel.

The *SCORBASE Level 5 for Controller-B Reference Guide* provides detailed descriptions and examples of the **SCORBASE** commands.

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## **Teach Pendant**

The teach pendant is a hand-held terminal which is used for controlling the **SCORA-ER 14** robot and peripheral equipment. The teach pendant is most practical for moving the axes, recording positions, sending the axes to recorded positions and activating programs. Other functions can also be executed from the teach pendant.

The *Teach Pendant for Controller-B User's Manual* fully describes the various elements and functions of the teach pendant.

# Drive System

The SCORA-ER 14 utilizes several different mechanical transmissions for transferring motion from the motors to the joints.

The structure and operation of the various components used to drive the SCORA axes are described in this chapter.

◆ *Note that the illustrations of components shown in this chapter are for descriptive purposes, and may not be the actual components used in the SCORA-ER 14.*

## Axes 1 and 2

The main components of the drive system for axes 1 and 2 are the motor, the coupling and the Harmonic Drive gear, as shown in Figure 6-1.

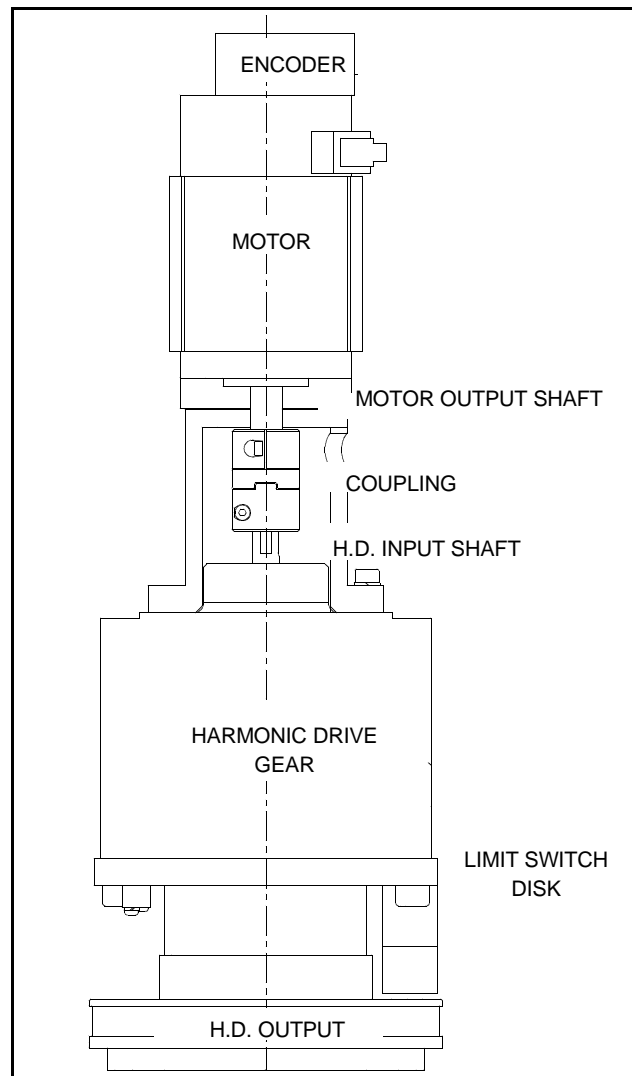


Figure 6-1: Drive System Axes 1 and 2

## Axis 3

The drive system for axis 3 produces the linear motion of the Z-axis. Its main components are the motor, pulleys and a timing belt, and a ball bearing lead screw with nut, as shown in Figure 6-2.

## Axis 4

The drive system for axis 4 (Z-roll) produces the rotation of the end effector flange. Its main components are the motor, a worm gear and a spline, as shown in Figure 6-3.

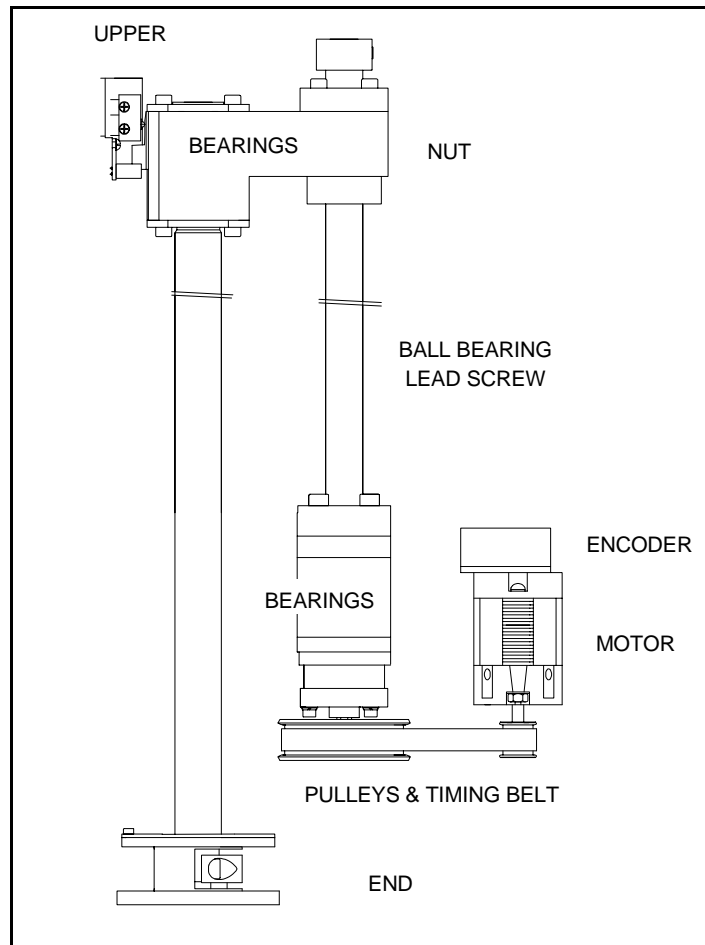


Figure 6-2: Drive System Axis 3

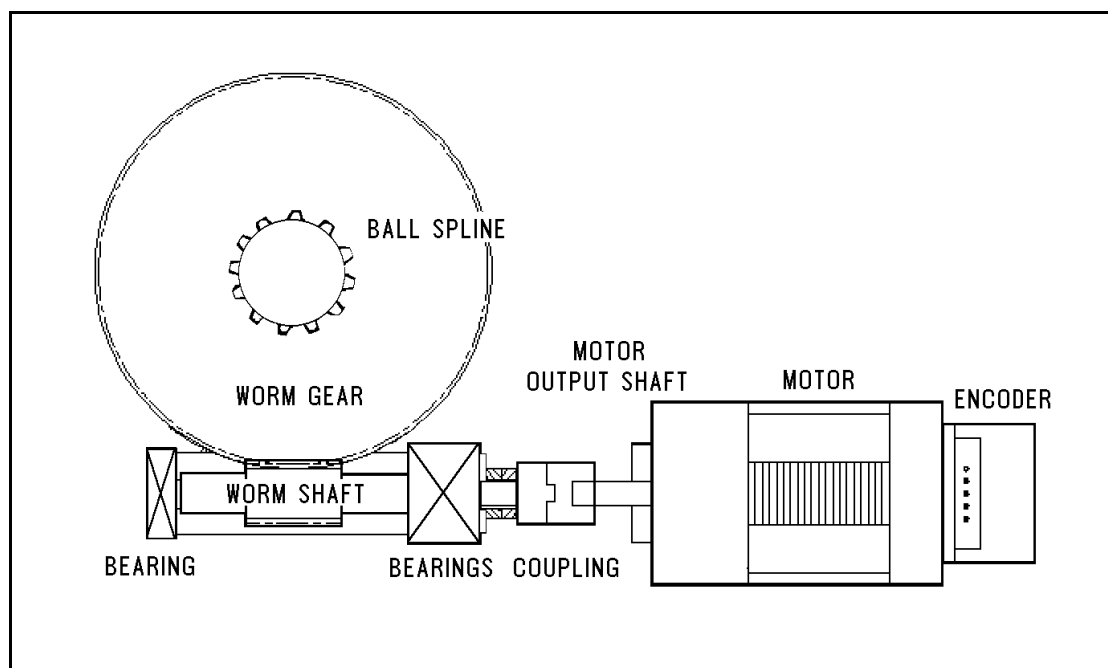


Figure 6-3: Drive System Axis 4

# Motors

An electric motor is an actuator—a device which transforms electric power into mechanical power. The motor converts signals from the controller into rotations of its shaft.

A robot arm such as the **SCORA-ER 14** imposes severe requirements on the actuators, such as the following:

- The robot motor must rotate at different speeds, and with a high degree of accuracy. For example, if the robot is to be used for a spray painting application, it must be able to accurately follow the defined path at the specified speed.
- The robot motor must allow fine speed regulation so that the robot will accelerate and decelerate as required by the application.
- The robot motor must supply large torques throughout its speed range and also when the joint is stationary.
- The robot motor must be able to stop extremely quickly without overshooting the target position, and perform rapid changes in direction.
- Since mounting motors on the robot arm adds to the robot's weight and inertia, the robot motors must be light and compact, yet powerful. As shown in Figure 6-4, the motors of the **SCORA-ER 14** are located close to the axes they drive.

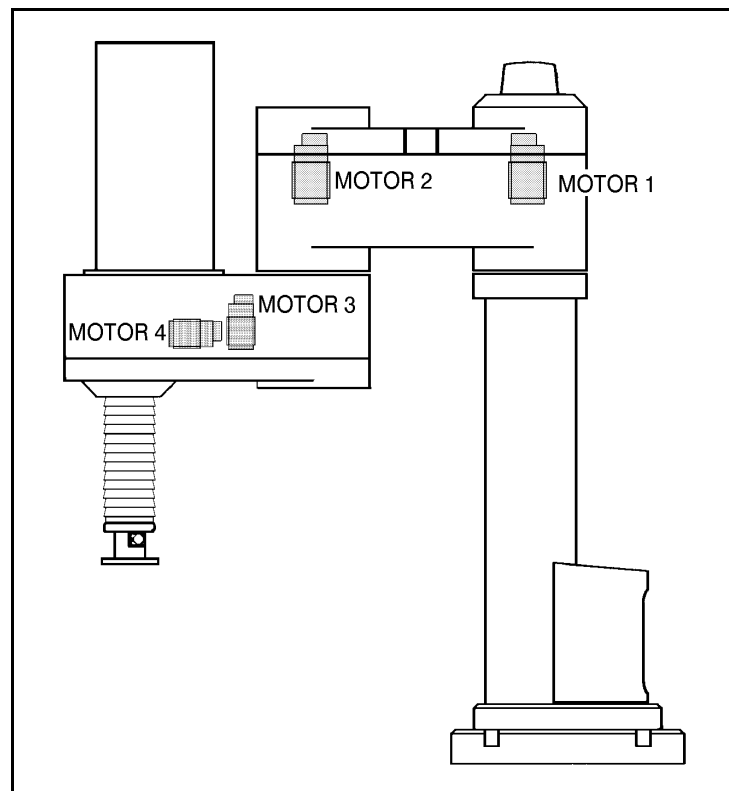


Figure 6-4: Motor Locations in SCORA-ER 14

# DC Motor Structure

The principles of operation of electrical motors in general, and DC motors in particular, are based on an electrical current flowing through a conductor situated within a magnetic field. This situation creates a force which acts on the conductor.

Figure 6-5 shows the basic structure and components of a DC motor comparable to the structure of the motors used in the SCORA-ER 14. This motor has three main components:

- **Stator:** This is a static component which creates the magnetic field. The stator may be a permanent magnet, or an electromagnet consisting of a coil wound around thin iron plates.
- **Rotor:** This is the component which rotates within the magnetic field. The external load is connected to the rotor shaft. The rotor is generally composed of perforated iron plates, and a conducting wire is wound several times around the plates and through the perforations. The two ends of the conductor are connected to the two halves of the commutator, which are connected to the electric current via the brushes.
- **Brushes:** These connect the rotating commutator to the electric current source.

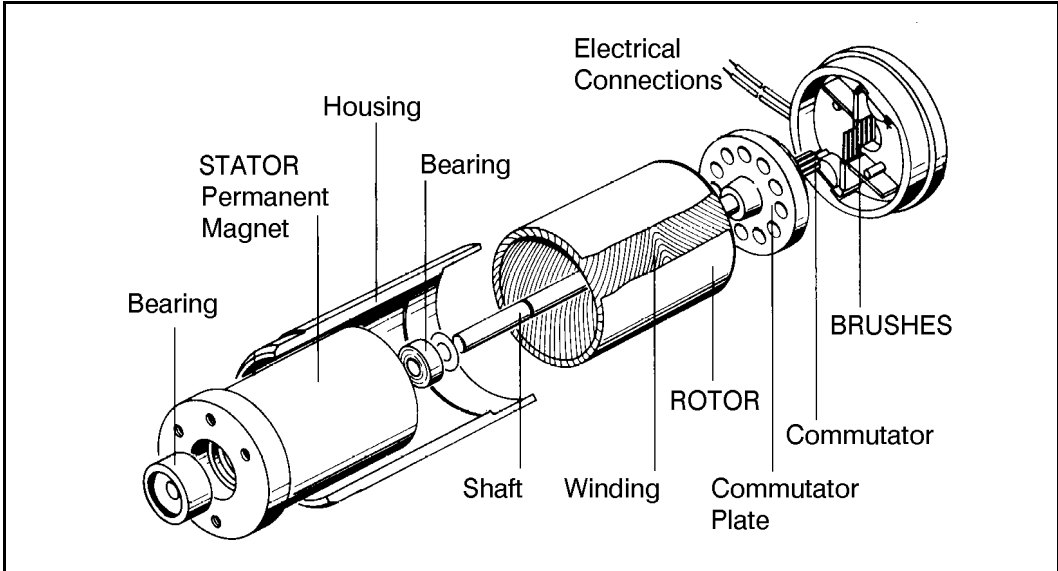


Figure 6-5: Basic Structure of a DC Motor

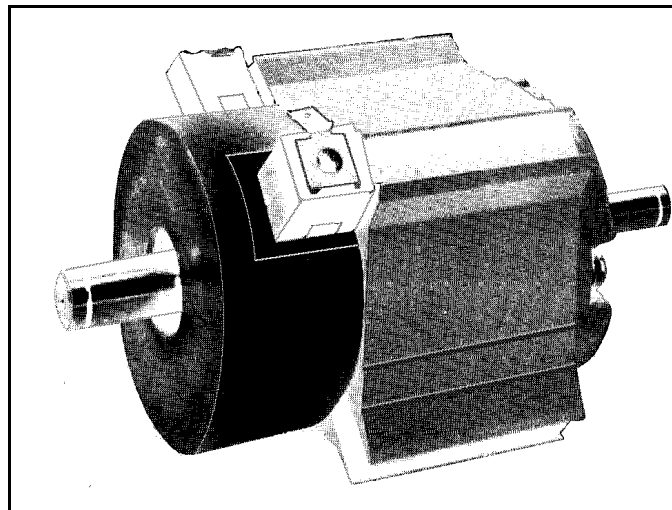
## SCORA-ER 14 Motors

The SCORA-ER 14 uses permanent magnet DC motors to drive the axes.

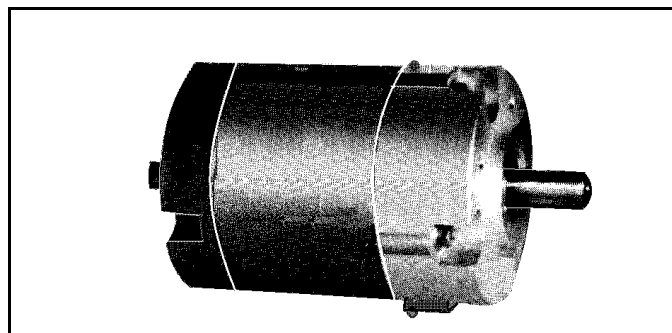
Axes 1 and 2 of the SCORA ER-14 are powered by the motor shown in Figure 6-6. Axes 3 and 4 are powered by the motor shown in Figure 6-7.

These motors are able to move at extremely high rates of revolution, to move loads with high torques, and (with encoder attached) to achieve a very high resolution.

Motor Specifications		
	Motor Axes 1 and 2	Motor Axes 3 and 4
Peak Rated Torque	143 oz-in	27.8 oz-in
Rated Torque	32 oz-in	12.5 oz-in
Maximum Operating Speed	4000 rpm	4500 rpm
Weight	1.29 k / 2.84 lb	0.28 k / 0.62 lb



*Figure 6-6: Motor on Axes 1 and 2*



*Figure 6-7: Motor on Axes 3 and 4*

## Harmonic Drive Gear

The Harmonic Drive transmission used in the **SCORA-ER 14**, shown in Figure 6-8, offers a very high gear ratio.

The Harmonic Drive gears used in the **SCORA-ER 14** have four main components:

- **Circular spline:**  
a solid steel ring, with internal gear teeth, usually fixed to the robot link.
- **Wave generator:**  
a slightly elliptical rigid disk, which is connected to the input shaft, with a ball bearing mounted on the outer side of the disk.
- **Flexspline:**  
a flexible, thin-walled cylinder, with external gear teeth, usually connected to the output shaft.
- **Dynamic spline:** a solid steel cylinder, with internal gear teeth.

The external gear teeth on the flexspline are almost the same size as the internal gear teeth on the circular spline except there are two more teeth on the circular spline, and the teeth only mesh when the wave generator pushes the flexspline outwards.

Because the wave generator is elliptical, the flexspline is pushed out in two places. As the motor rotates the input shaft, the wave generator rotates and the location of meshing teeth rotates with it. However, because there are two less teeth on the flexspline, it has to rotate backwards slightly as the wave generator rotates forwards. For each complete rotation of the input shaft, the flexspline moves backwards by two teeth.

Figures 6-9 and 6-10 show the different steps in this process.

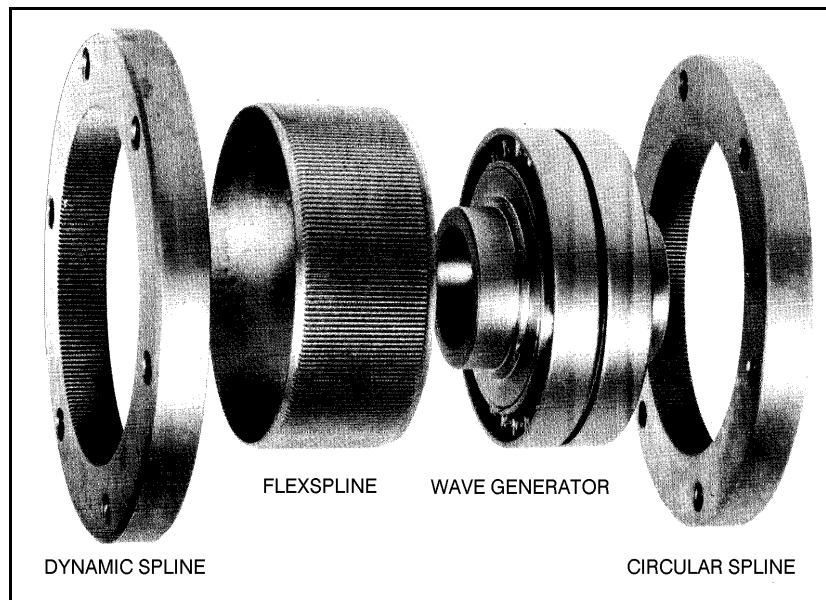


Figure 6-8: Harmonic Drive Structure



As in all gears, the gear ratio of the Harmonic Drive is the ratio of the input speed to the output speed. If the number of teeth on the flexspline is  $N_f$ , then for every revolution of the input shaft, the output shaft rotates by  $2/N_f$  of a revolution (that is, two teeth out of  $N_f$  teeth). Hence:

$$HD \text{ gear ratio} = \frac{1}{\left(\frac{2}{N_f}\right)} = \frac{N_f}{2}$$

The Harmonic Drive gear ratio for axis 1 and axis 2 of the SCORA-ER 14 is 160:1

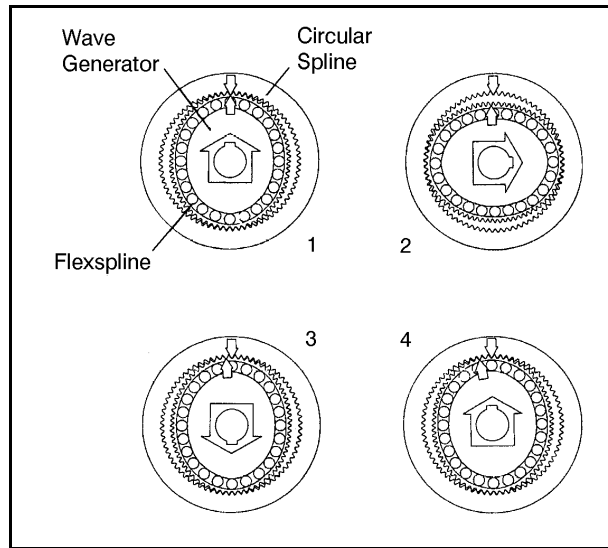


Figure 6-9: Operation of the Harmonic Drive

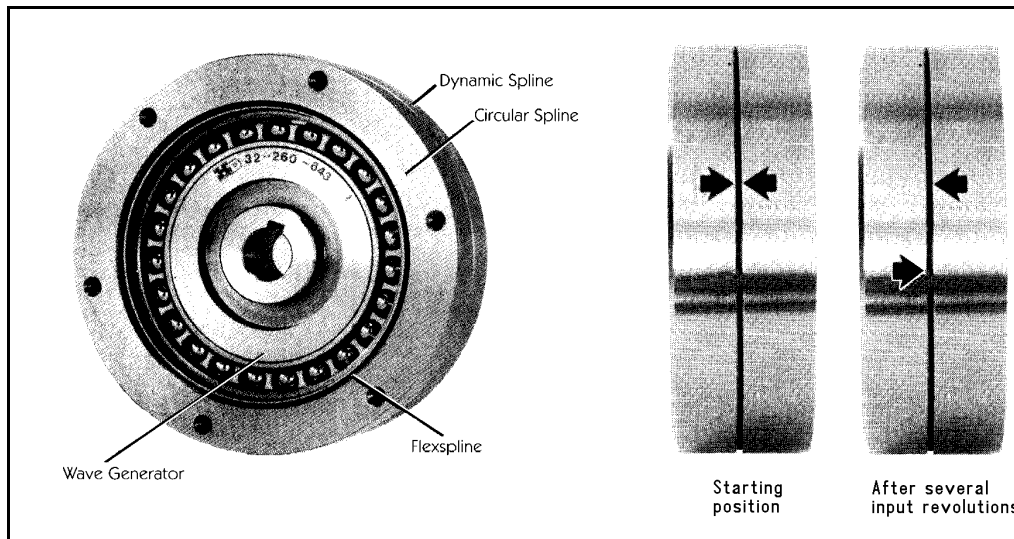


Figure 6-10: Operation of the Harmonic Drive

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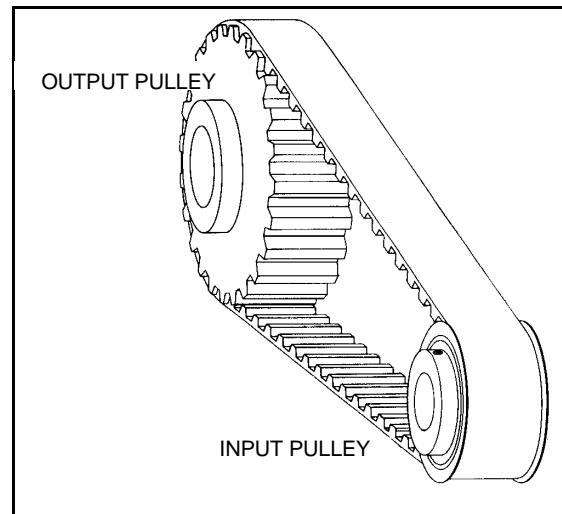
## Pulleys and Timing Belt

The axis 3 transmission contains two pulleys and a timing belt, as illustrated in Figure 6-11. The input pulley is mounted on the motor output shaft and the output pulley is connected to the lead screw.

The gear ratio of the belt drive is the ratio of the output pulley to the input pulley, calculated according to the number of teeth on each pulley.

The belt drive used in the **SCORA-ER 14** has a ratio of 80:21.

Thus, for each rotation ( $360^\circ$ ) of the input pulley, the output pulley moves  $94^\circ$ , or approximately one-quarter of a rotation.



*Figure 6-11: Pulleys and Timing Belt*

## Ball Bearing Screw

A ball bearing lead screw converts the rotation of the motor to the linear motion of the Z-axis.

In lead screw transmissions, the screw is rotated by the motor, and the shaft is connected to the nut, or sleeve, as illustrated in Figure 6-12. In the **SCORA-ER 14** the screw rotates and the nut travels along the length of the screw.

As shown in Figure 6-13, a ball bearing screw thread is actually a hardened ball race. The nut consists of a series of bearing balls circulating in a similar race. The bearing balls are transferred from one end of the nut to the other by return tubes.

The low-friction ball-bearing lead screw provides more accurate and enduring performance.

The lead screw used in the **SCORA-ER 14** has a 16mm lead. That is, for each rotation of the screw, the nut travels a linear distance of 16mm.

The lead screw of the **SCORA-ER 14** is fitted with a brake which halts motion of the Z-axis when motor power is cut off.

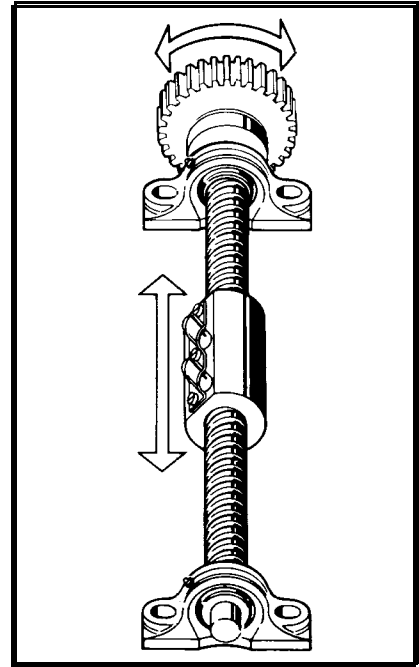


Figure 6-12: Lead Screw Transmission

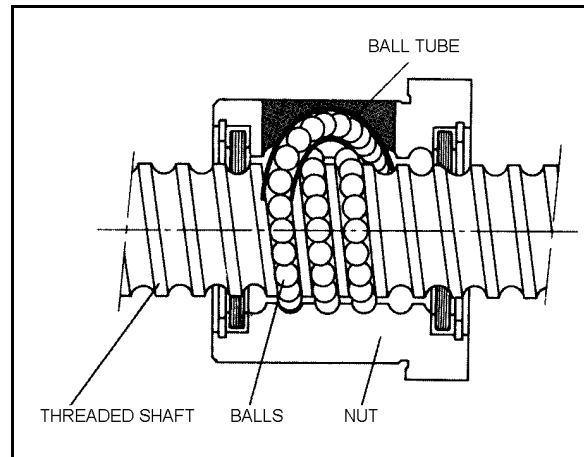


Figure 6-13: Ball Bearing Screw

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## Worm Gear

A worm gear transmission, shown in Figure 6-14, is used in the SCORA-ER 14 to transfer the rotation of motor 4 to the rotation of the Z-axis.

The ratio of a worm gear transmission is defined as:

$$\frac{\# \text{ teeth on worm gear}}{\# \text{ of starts on worm shaft}}$$

The worm gear used in the SCORA-ER 14 has 100 teeth and the shaft has two starts. Thus, the worm gear transmission has a ratio of 50:1.

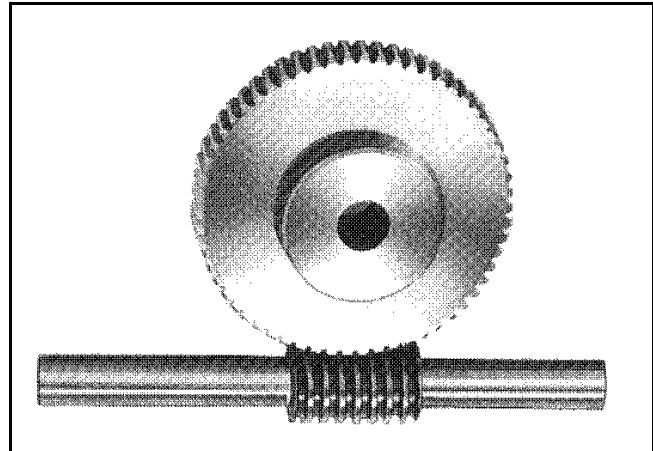


Figure 6-14: Worm Gear Transmission

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## Ball Bearing Spline

The SCORA-ER 14 uses a ball bearing spline, shown in Figure 6-15, to transmit torque from the worm gear to the Z-axis (slider) shaft, while allowing linear motion of the axis.

Ball bearing splines are similar to ball bearing screws in that they both employ the rolling contact principle of balls recirculating in a path between a shaft (spline) and a matching nut (sleeve). In a ball bearing spline, however, the path of the rolling balls is straight, rather than helical.

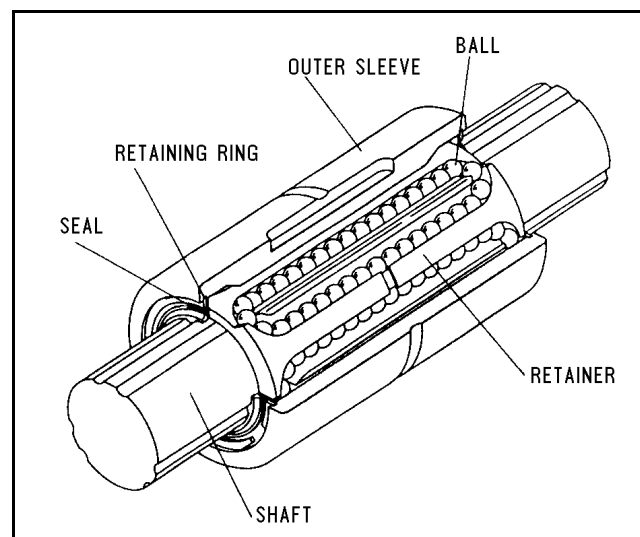


Figure 6-15: Ball Bearing Spline

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## Axis Gear Ratios

The overall gear ratio of the output shaft which moves the axis is the product of the ratios of the transmissions in each drive.

Axes 1 and 2 are driven by Harmonic Drive gears with a gear ratio of 160:1.

Thus, one rotation ( $360^\circ$ ) of the output shaft of motor 1 or 2 moves the axis  $2.25^\circ$ .

Axis 3 is driven by a belt drive with a ratio of 80:21, and a lead screw which converts each rotation of the output pulley to a linear movement of 16 mm.

Thus, for each rotation ( $360^\circ$ ) of motor 3 output shaft, the Z-axis will move a linear distance of 4.2 mm.

Axis 4 is driven by a worm gear with a ratio of 50:1.

Thus, one rotation ( $360^\circ$ ) of motor 4 output shaft causes the end effector flange to rotate  $7.2^\circ$ .



# Position and Limit Devices

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This chapter describes the various elements in the **SCORA-ER 14** which play a part in the positioning of the robot arm and the limiting of its motion.

- Encoders
- End of Travel Switches
- Hard Stops
- Home Switches

◆ *Note that the illustrations of components shown in this chapter are for descriptive purposes, and may not be the actual components used in the **SCORA-ER 14**.*

---

## Encoders

The location and movement of an axis is commonly measured by an electro-optical encoder attached to the motor which drives the axis. The encoder translates the rotary motion of the motor shaft into a digital signal understood by the controller.

Figure 7-1 shows the encoder mounted on a **SCORA-ER 14** motor.

The encoder used on the **SCORA-ER 14** contains a single light emitting diode (LED) as its light source. Opposite the LED is a light detector integrated circuit. This IC contains several sets of photodetectors and the circuitry for producing a digital signal. A perforated, rotating disk is located between the emitter and detector IC.

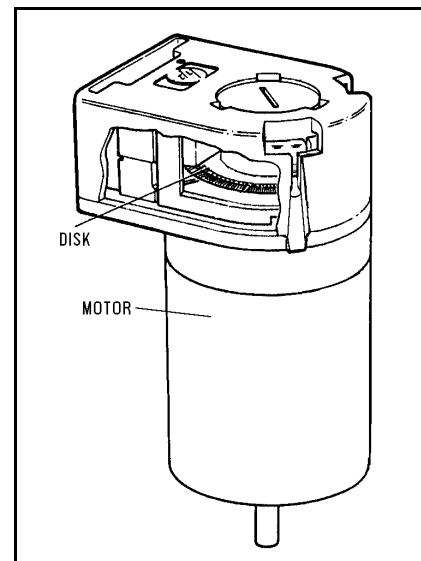


Figure 7-1:  
SCORA-ER 14 Encoder

As the encoder disk rotates between the emitter and detectors, the light beam is interrupted by the pattern of “bars” and “windows” on the disk, resulting in a series of pulses received by the detectors.

The **SCORA-ER 14** encoders have 512 slots, as shown in Figure 7-2. An additional slot on the encoder disk is used to generate an index pulse (C-pulse) once for each full rotation of the disk. This index pulse serves to determine the home position of the axis.

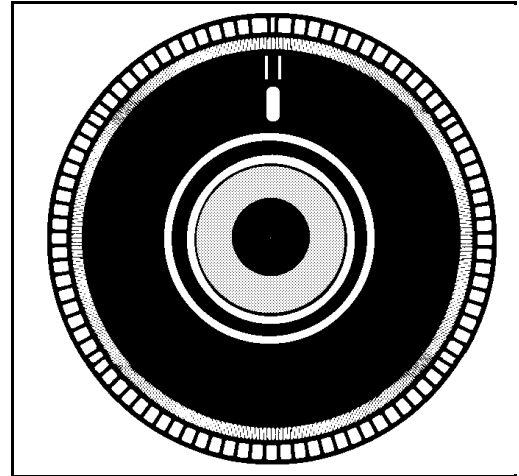


Figure 7-2:  
SCORA-ER 14 Encoder Disk

The photodetectors are arranged so that, alternately, some detect light while others do not. The photodiode outputs are then fed through the signal processing circuitry, resulting in the signals A,  $\bar{A}$ , B,  $\bar{B}$ , I and  $\bar{I}$ , as shown in Figure 7-3.

Comparators receive these signals and produce the final digital outputs for channels A, B and I. The output of channel A is in quadrature with that of channel B ( $90^\circ$  out of phase), as shown in Figure 7-4. The final output of channel I is an index pulse.

When the disk rotation is counterclockwise (as viewed from the encoder end of the motor), channel A will lead channel B. When the disk rotation is clockwise, channel B will lead channel A.

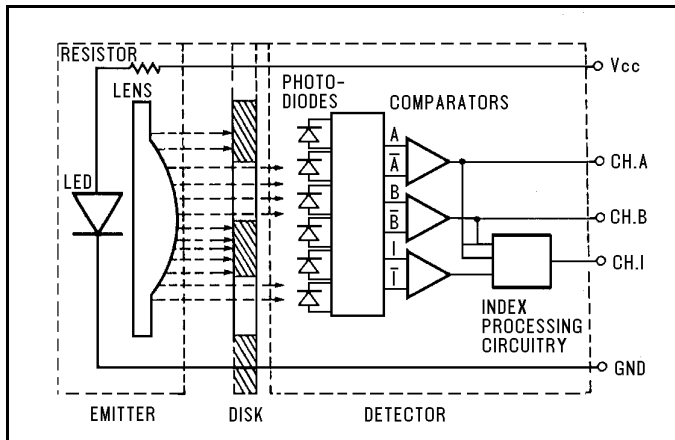


Figure 7-3: Encoder Circuitry

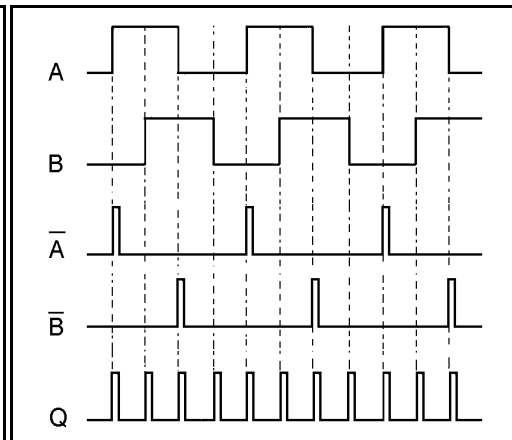


Figure 7-4: Encoder Output Signals



## Encoder Resolution

From the quadrature signal the **SCORA-ER 14** controller measures four counts for each encoder slot, thus quadrupling the effective resolution of the encoder.

The resolution of the encoder is expressed as:

$$S_E = \frac{360^\circ}{n}$$

Where:

$S_E$  is the resolution of the encoder.

$n$  is the number of counts per encoder revolution.

The encoders used in the **SCORA-ER 14** have 512 slots, generating 2048 counts per motor revolution. The encoder resolution is therefore:

$$S_E = \frac{360^\circ}{2048} = .176^\circ$$

When the encoder resolution is divided by the overall gear ratio of the axis, the resolution of the joint is obtained.

Since the encoder is mounted on the motor shaft, and turns along with it, the resolution of the joint is expressed as:

$$S_{JOINT} = \frac{S_E}{N_{AXIS}}$$

Thus, for example, the resolution of joint 2 of the **SCORA-ER 14** is therefore as follows:

$$S_{J2} = \frac{0.176^\circ}{160} = .0011$$

The resolution is the smallest possible increment which the control system can identify and theoretically control. The accuracy of the axis—that is, the precision with which it is positioned—is affected by such factors as backlash, mechanical flexibility, and control variations.

## End of Travel (Limit) Switches

The **SCORA-ER 14** uses limit switches to prevent the joints from moving beyond their functional limits. When a control error fails to stop the axis at the end of its working range, the limit switch serves to halt its movement. The switch is part of an electric circuit within the robot arm, independent of the robot controller.

The limit switches used in the **SCORA-ER 14** are shown in Figure 7-5.

Axes 1 and 2 each has two limit switches—one at each end of the axis' working range.

The limit switches are mounted on a disk which is attached to the robot's frame, as shown in Figure 7-6.

The output shaft of the Harmonic Drive moves relative to the microswitch disk. As the joint moves, a cam on the Harmonic Drive output shaft reaches a point at which it forces the actuating button of the limit switch into a position which activates the switch.

Axis 3 has two limit switches—one at the upper limit and one at the lower limit of the axis' range. The switches are mounted on the bracket alongside the spline (slider).

Axis 4 (roll) has no travel limit switches; it can rotate endlessly. When a gripper is attached to axis 4, its movements are controlled and limited by means of software only (encoder).

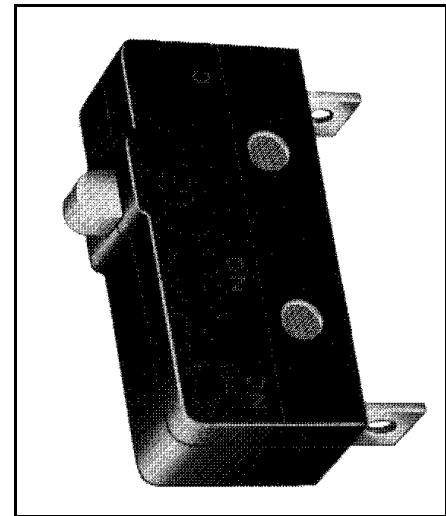


Figure 7-5:  
SCORA-ER 14 Limit Switch

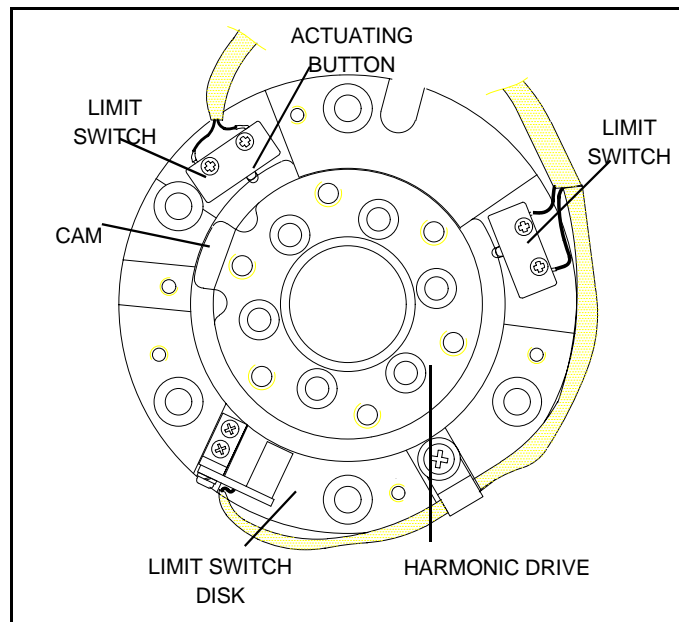


Figure 7-6: Limit Switch Activation

As shown in Figure 7-7A, when limit switch 1 is activated (that is, when the button is depressed), the relay contact opens and the relay is deenergized. The motor cannot move the joint beyond this point. The diode allows the motor to reverse direction, thus permitting the joint to move away from the limit switch.

When the limit switch is activated, it causes a control error, resulting in the activation of COFF, and an impact protection message.

CON must be activated and the robot arm must be manually moved (using keyboard or teach pendant) away from the impact condition.

As long as the axis has not reached one of its limits, the relay contact remains closed, and the diode has no effect on the circuit, as shown in Figure 7-7B. Current can flow in either direction; the motor is thus able to rotate in either direction.

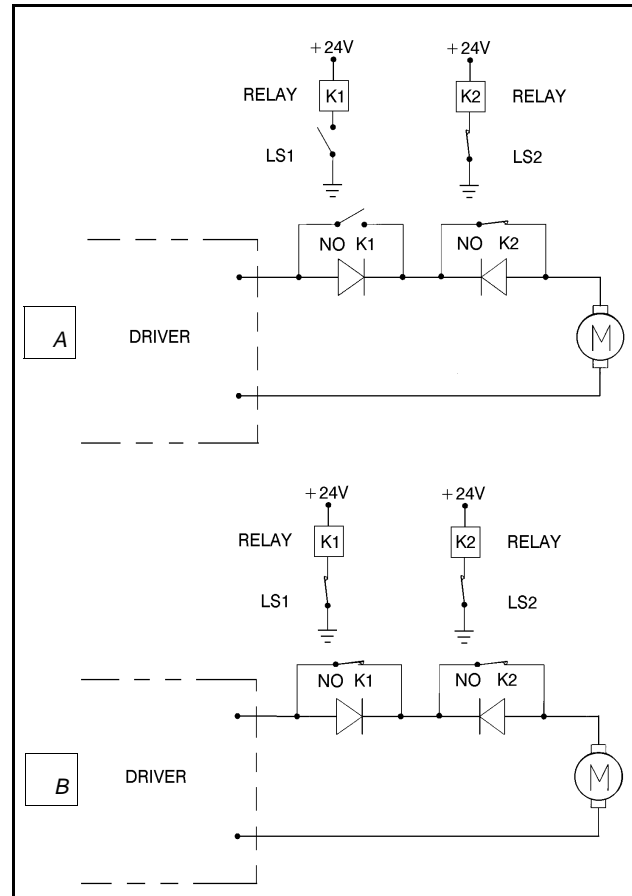


Figure 7-7: Axis Limit Circuit

## Hard Stops

When the software limits and/or the end of travel switches fail to halt the movement of the robot arm, it is possible that the momentum of the robot arm will drive it until it reaches its mechanical limit.

When the joint reaches this hard stop, the impact protection and thermic protection processes detect an error, thus activating COFF.

CON must be activated and the robot arm must be manually moved away from the impact condition.

# Home Switches

The SCORA-ER 14 uses an optical home switch on each axis to identify the fixed reference, or home, position.

For axes 1 and 2 the home switch is mounted on the same disk as the end of travel switches, and a “flag” is attached to the Harmonic Drive output shaft, as shown in Figure 7-8.

The home switch for axis 3 is located near the top of the bracket alongside the spline (slider), just below the axis’ upper limit switch.

The home switch for axis 4 is located within the worm gear housing.

During the homing procedure, the robot joints are moved, one at a time. Each axis is moved until the flag cuts the beam of light. When that occurs, the optical detector on each joint sends a specific signal to the controller.

Once the home switch location has been detected, the axis motor continues to rotate until its encoder produces an index pulse. The point at which that occurs is the axis home position.

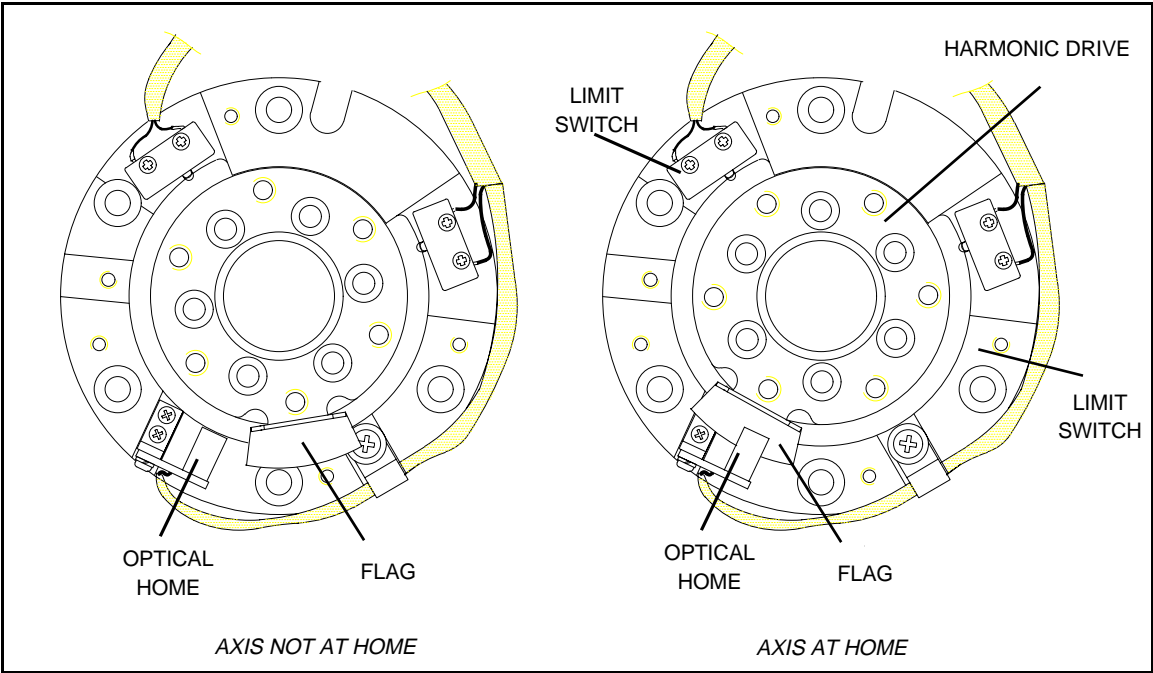


Figure 7-8: Home Switch Activation

# Wiring

Figure 8-1 is a schematic diagram of the **SCORA-ER 14** cable connections.

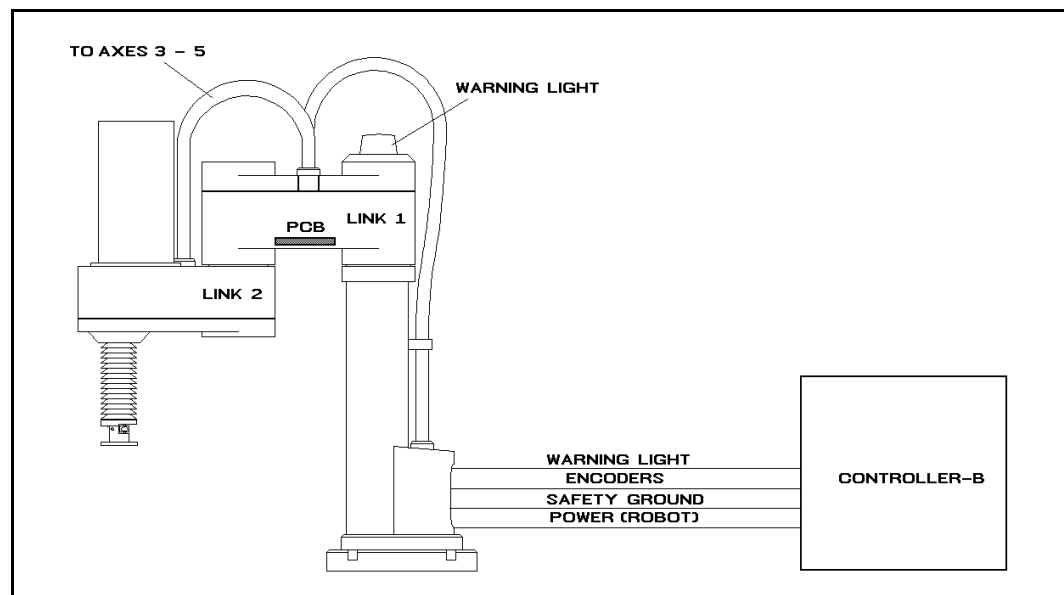


Figure 8-1: SCORA-ER 14 Cabling

The power (robot) cable, encoder cable and warning light cable connect the **Controller-B** to the connector panel of the **SCORA-ER 14** robot. Safety ground wires from the robot and the encoder cables are connected to safety ground studs on the connector panel and on the controller back panel.

The robot cable supplies power to the motors and +24VDC to the printed circuit board (PCB) located in link 1. The encoder cable carries information from the encoders and the home switches to the controller, and the warning light cable controls the warning light.

A wire braid links the connectors on the panel to the PCB, located in Link 1. A second braid connects the elements in axes 3 – 5 (motors, encoders, limit and home switches, brake) to the PCB.

## Power (Robot) Cable and Connector

The power (robot) cable, which connects the controller to the robot motors, contains 12 leads in 6 pairs.

Figure 8-2 shows the Burndy 19 pin female connector that joins the power cable to the connector panel at the base of the robot.

The following table describes the connector pin functions and the cable wiring.

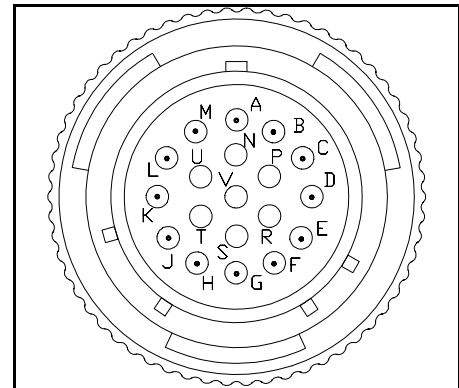


Figure 8-2. Burndy 19 Pin Connector

Robot (Power) Cable and Connector				
Pin ID	Pin Description Robot Side (J1)	Wire Type and Color		Pin Description Controller Side (P1)
A	Motor 1 -	Twisted Pair	black	M0_A
M	Motor 1 +		brown	M0_B
C	Motor 2 -	Twisted Pair	black	M1_A
L	Motor 2 +		red	M1_B
E	Motor 3 -	Twisted Pair	black	M2_A
H	Motor 3 +		blue	M2_B
B	Motor 4 -	Twisted Pair	black	M3_A
K	Motor 4 +		yellow	M3_B
D	Motor 5 -	Twisted Pair	black	M4_A
J	Motor 5 +		green	M4_B
R	+24V to PCB	Twisted Pair	white	+24V
S	24VRET to PCB		black	24VRET

# Encoder Cable and Conenctor

The encoder cable, which connects the controller to the motor encoders and optical home switches, contains 38 leads in 19 pairs. Only 14 pairs are used.

Figure 8-3 shows the D37 female connector that joins the encoder cable to the connector panel at the base of the robot.

The following table details the connector pin functions and the describes the cable wiring.

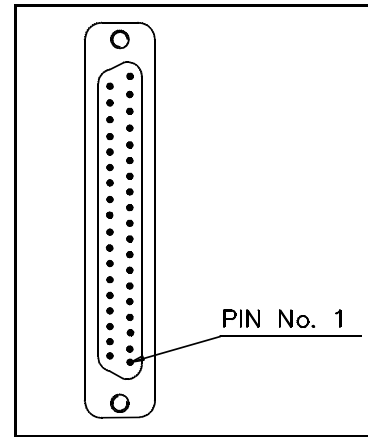


Figure 8-3. D37 Connector

Encoder Cable and Connector					
Pin ID	Pin Description Robot Side (J4)	Axis	Wire Type and Color		Pin Description Controller Side (J2)
1	+5V	-	Twisted Pair	red	+5V
2	+5V	-		black	+5V
5	A1(Encoder Pulse A)	1	Twisted Pair	brown	CHA 0
6	B1(Encoder Pulse B)			black	CHB 0
7	C1(Encoder Index Pulse)		Twisted Pair	brown	CHC 0
8	COMMON 1			red	COMMON 0
31	H1 (Home)		Twisted Pair	white	MSWITCH 0
			with J2 – 32		
9	A2 (Encoder Pulse A)	2	Twisted Pair	red	CHA 1
10	B2 (Encoder Pulse B)			white	CHB 1
11	C2 (Encoder Index Pulse)		Twisted Pair	red	CHC 1
12	COMMON 2			blue	COMMON 1
32	H2 (Home)		Twisted Pair	black	MSWITCH 1
			with J2 – 31		
13	A3 (Encoder Pulse A)	3	Twisted Pair	orange	CHA 2
14	B3 (Encoder Pulse B)			black	CHB 2
15	C3 (Encoder Index Pulse)		Twisted Pair	orange	CHC 2
16	COMMON 3			red	COMMON 2
33	H3 (Home)		Twisted Pair	blue	MSWITCH 2
			with J2 – 34		

Encoder Cable and Connector					
Pin ID	Pin Description Robot Side (J4)	Axis	Wire Type and Color		Pin Description Controller Side (J2)
17	A4 (Encoder Pulse A)	4	Twisted Pair	yellow	CHA 3
18	B4 (Encoder Pulse B)			black	CHB 3
19	C4 (Encoder Index Pulse)		Twisted Pair	yellow	CHC 3
20	COMMON 4			red	COMMON 3
34	H4 (Home)		Twisted Pair	black	MSWITCH3
		with J2 – 33			
21	A5 (Encoder Pulse A)	5	Twisted Pair	green	CHA 4
22	B5 (Encoder Pulse B)			black	CHB 4
23	C5 (Encoder Index Pulse)		Twisted Pair	green	CHC 4
24	COMMON 5			red	COMMON4
35	H5 (Home)		Twisted Pair	green	MSWITCH4
		with free yellow			

## Warning Light Cable and Connector

The warning light cable which connects the controller to the warning light contains three leads.

Figure 8-4 shows the Amphenol three pin female connector that joins the warning light cable to the panel at the base of the robot.

The following table details the warning light cable and connector.

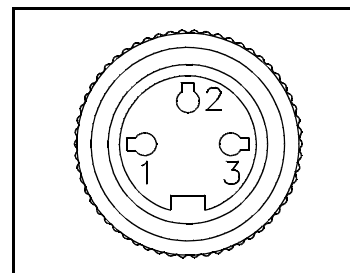


Figure 8-4. Amphenol 3 Pin Connector

Warning Light Cable and Connector			
Pin #	Pin Description Robot Side (J3)	Wire Color	Pin Description Controller Side
1	NO	red	NO
2	COM	black	COM



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# Maintenance

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The maintenance and inspection procedures recommended below will ensure the best possible performance of the robot over an extended period.

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## Daily Operation

At the start of each working session, check the robot and controller, in the following order:

1. Before you power on the system, check the following items:
  - The installation meets all safety standards.
  - All cables are properly and securely connected.  
Cable connector screws are fastened.
  - The gripper is properly connected.  
The air supply (for a pneumatic gripper) is functioning properly.
  - Any peripheral devices or accessories which will be used, such as the teach pendant or a remote emergency button, are properly connected to the controller.
2. After you have powered on the system, check the following items:
  - No unusual noises are heard.
  - No unusual vibrations are observed in any of the robot axes.
  - There are no obstacles in the robot's working range.
3. Bring the robot to a position near home, and activate the Home procedure. Check the following items:
  - Robot movement is normal.
  - No unusual noise is heard when robot arm moves.
  - Robot reaches home position in every axis.

---

## Periodic Inspection

The following inspections should be performed regularly:

- Check robot mounting bolts for looseness using a wrench. Retighten as needed.
- Check all visible bolts and screws for looseness using a wrench and screwdriver. Retighten as needed.
- Check cables. Replace if any damage is evident.

The following robot components may require replacing after prolonged use of the robotic arm causes them to wear or fail:

- DC Servo Motors
- Motor Brushes
- Timing Belts
- V-Rings
- Harmonic Drives
- Cross-Roller Bearings

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## Troubleshooting

Whenever you encounter a problem with your system, try to pinpoint its source by exchanging the suspected faulty component—for example, robot, controller, teach pendant, cable—with one from a functioning system.

In general, when trying to determine the source of a malfunction, first check the power source and external hardware, such as controller switches, LEDs and cable connections. Then check fuses; you may also open the controller to check components, according to the procedures and instructions detailed in the *Controller-B User's Manual*.

In addition, make sure the controller is properly configured for the robot and gripper, the software commands have been correctly issued, and system parameters are properly set.

*All troubleshooting procedures described in the section can be performed by the user.*

◆ ***Do not attempt to open the robot arm. There are no user-serviceable parts inside.***

If you are unable to determine and/or correct the problem, contact your service representative. Only qualified technicians may remove and/or replace robot components.

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1. *Controller's MOTORS switch does not turn on; the green LED does not light.*

- Make sure the Emergency button is released.
- Turn off the controller, disconnect it from the power source, and open the cover.
- Check the 0.5A (SB) fuse (marked FAN/POWER/RELAYS)

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2. *Controller functioning, but the robot cannot be activated.*

- Make sure an obstacle is not blocking the robot.
- Make sure the controller's MOTORS switch is on and the green LED is lit.
- Make sure the controller is in the control off (COFF) state. Then activate the control on (CON) state from PC or TP.
- Make sure all robot and encoder cables are properly connected.
- Check driver card fuses. Each driver card has a pair of LEDs and a pair of fuses (accessible from controller back panel). The upper LED and fuse correspond to the axis number at the top of the card; the lower LED and fuse correspond to the axis number at the bottom of the card.  
Both LEDs on each card in use should be lit, indicating that power is being supplied to the axis driver. If one of the LEDs is not lit, remove the fuse for the corresponding axis and examine it. (To remove the fuse, press it in and rotate counter-clockwise.)

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3. *Robot does not find Home position in one or all of the axes.*

- Make sure the homing command was properly issued.
- Make sure all robot and encoder cables are properly connected.
- If the robot has just undergone maintenance or repair, use the command ZSET. Then issue the home command.
- Make sure system homing parameters have not been erased.  
Make sure system homing parameters are properly set.  
Refer to the *ACL Reference Guide*.
- Check whether the optical home switch for this axis is functioning.  
Manually move the faulty axis (from teach pendant or keyboard) and check the value of system variable HS[n] (where *n* is the index of the axis). The value of HS will change to either 1 or 0 (defined by parameter 560+axis) when the home switch is detected.  
To help you perform this test, prepare and continuously run a simple ACL program, as follows:

```
LABEL 1
PRINTLN HS[n]
DELAY 20
GOTO 1
```

If the value of HS does not change, possible causes:

- Faulty arm circuitry.
  - Faulty optical switch; optical switch not properly mounted.
  - Faulty driver circuitry
  - Problem in controller power supply unit +5V1.
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4. *One of the axes does not function.*

- Check the driver card LED for this axis at the back of the controller. If the LED is not lit, check the corresponding fuse.
- Check the motor drive circuitry.
- Check the encoder:  
Enter the command SHOW ENCO to display the encoder readings.  
Enter the command COFF (to disable servo control) and then *physically* move the axis in question in both directions.

The encoder reading should rise for rotation in one direction and fall for rotation in the opposite direction. If this does not occur, there is a problem in the encoder or its circuitry.

If the encoder readings do not change, check whether the encoder connector is properly connected to the rear controller panel.

The problem may be caused by faulty encoder connectors on the robot's internal PCB's.

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5. *Motors suddenly stop. No message on screen. No response to keyboard entries.*

- Check the power source.
- Make sure the MOTORS power switch is on; make sure the Emergency button is not depressed.
- Turn off the controller and open up the cover. Turn on the controller. Check the yellow "watchdog" LED on the main board. If it is lit, it indicates that that one of the following fuses on the power supply unit has blown out: +12VA, -12VA, +12VDR, -12VDR.

Turn off the controller and disconnect it from the power source. Check each of these four fuses. Replace the blown fuse.

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6. *Errors in the repeatability of the robot.*

- Try to identify the faulty axis. If many or all axes are faulty, look for an electrical noise source in your environment.
- Check the controller's ground and the robot's ground connection to the safety ground terminal at the back of the controller.
- Check the encoder.

Bring the robot to a starting position. Using a pencil, draw a fine, continuous line on the robot which crosses from the cover of one link to the cover of the adjacent link at the joint in question.

Enter the command `SHOW ENCO` to display the encoder readings. Enter the command `COFF` (to disable servo control) and then *physically* move the axis to another position. Then return to the starting position marked by the line you drew. Check the encoder reading for the axis again. It should be within 5 counts of the previous reading; if not, the encoder needs to be replaced.

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7. *Unusual noise.*

- Loose screws.
- Poor lubrication.
- Ratcheting.
- Worn motor brushes.
- Worn timing belt.
- Damaged harmonic drive.

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8. *Unusual smell.*

- A motor has burnt out and needs to be replaced.

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9. *Axis/axes vibrating, too weak to carry load, motion not smooth, or jerks during or at end of motion.*

- System parameters are not properly adjusted.  
Refer to the *ACL Reference Guide*.
- Problem in axis driver card(s) in the controller.  
Refer to the *Controller-B User's Manual*.

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10. *Pneumatic gripper does not respond.*

- Check that all air hoses are connected properly.
- Make sure the gripper is connected to the proper controller output.
- Check the relay output to which the gripper is connected.

Check whether the relays have been switched (LED is lit):

- In output OFF, NC is shorted to COM, NO is disconnected from COM.
- In output ON, NO is shorted to COM, NC is disconnected from COM.

If outputs have not been switched, check the flat cable in the controller connecting the main board (J17) and the I/O card.

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## Messages

Following is a alphabetical listing of system messages which indicate a problem or error in the operation of the robot arm. Refer to the *ACL Reference Guide* for additional error messages.

### **Axis disabled.**

(1) A movement command could not be executed because servo control of the arm has been disabled (COFF).

(2) A previous movement of the arm resulted in an Impact or Trajectory error, thereby activating COFF and disabling the arm.

- Check the movements of the robot, and correct the command(s).

### **CONTROL DISABLED.**

Motors have been disconnected from servo control. Possible causes:

(1) COFF (control off) command was issued.

(2) CON (control on) has not been issued; the motors have not been activated.

(3) A previous error (such as Impact Protection, Thermic Overload or Trajectory Error) activated COFF, thereby disabling the arm.

### **\*\*\* HOME FAILURE AXIS *n*.**

The homing procedure failed for the specified axis. Possible causes:

(1) The home microswitch was not found.

(2) The motor power supply is switched off.

(3) Hardware fault on this axis.

### **Home on group/axis not done.**

You attempted to move the arm to a recorded positions, or to record a position, before homing was performed on the group or axis.

### **\*\*\* IMPACT PROTECTION axis n**

The controller has detected a position error which is too large. The system aborted all movements of that axis group, and disabled all axes of that group. The user routine CRASH, if it exists, has been executed. Possible causes:

- (1) An obstacle prevented the movement of the arm.
- (2) An axis driver fuse has blown.
- (3) The motor power switch is turned off.
- (4) An encoder fault.
- (5) A mechanical fault.
- (6) The axis is not connected.

- Determine and correct the cause of the position error. Then reenable servo control of the motors (CON), and restart the program.

### **INDEX pulse not found axis n**

The index pulse of the encoder was not found during the homing of the specified axis. Possible causes:

- (1) The distance between the index pulse and the home switch transition position has changed, due to a mechanical fault on the axis or a maintenance procedure (such as replacement of the motor, motor belt, encoder, or gear).

- Enter the command ZSET. Then retry homing.

- (2) Index pulse faulty.

- Check the encoder and wiring.

### **\*\*\* LOWER LIMIT AXIS n.**

During keyboard or TP manual movement of the specified axis, its encoder attained its minimum allowed value.

- Move the axis in the opposite direction.

### **Motor power switch is OFF.**

Be sure the controller's MOTORS switch is on. Activate CON. Then repeat the motor or movement command.

### **No hard homing axis n.**

The specified axis has not been configured for hard homing.

- Use the HOME command (instead of HHOME). OR
- Check the type of homing suitable for that axis. If necessary, change the system parameters to allow hard homing of the axis.

### **No homing.**

The homing parameters for the axis (PAR 460+axis and PAR 600+axis) are set to 0; as a result, the homing procedure will not be performed on the axis.

**\*\*\* OUT OF RANGE axis n**

An attempt was made to record a position (HERE, HEREC, etc. ) while the robot arm was out of its working envelope.

- Manually move the arm to a location within its working envelope. Then repeat the command.

**\*\*\* THERMIC OVERLOAD axis n**

Through a software simulation of motor temperature, the system has detected a dangerous condition for that motor. The system aborted all movements of that axis group, and disabled all axes of that group. The user routine CRASH, if it exists, has been executed. Possible causes:

(1) The arm attempted to reach a position, which could not be reached due to an obstacle (for example, a position defined as being above a table, but actually slightly below the table's surface). The impact protection is not activated because the obstacle is close to the target position. However, integral feedback will increase the motor current and the motor will overheat, subsequently causing the Thermic Protection to be activated.

(2) An axis driver is faulty or its fuse has blown.

(3) The robot arm is near to the target position, but does not succeed in reaching it, due to a driver fault. The software will then detect an abnormal situation.

(4) The Thermic Protection parameters are improperly set, or have been corrupted by improper loading of parameters.

- Check the positions, the axis driver card and parameters. Reenable servo control of the motors ( CON ).

**\*\*\* TOO LARGE SPEED axis n.**

Possible causes:

(1) The controller has detected a movement which is too fast; that is, the required displacement of the encoder, as calculated from the speed limit parameter, PAR 180+axis, is too great.

(2) Since the trajectory is not calculated prior to a linear or circular movement, the linear or circular movement may cause one of the joints to move too fast.

- Lower the value of speed for that movement.



**\*\*\* TRAJECTORY ERROR !**

During movement, the robot arm reached its envelope limits, and the system aborted the movement. This may occur when executing the following types of movements: linear (MOVEL), circular (MOVEC) , MOVES, and SPLINE. Since the trajectory is not computed prior to motion, the movement may exceed the limits of the working envelope.

- Modify the coordinate values of the positions which define the trajectory.

**\*\*\* UPPER LIMIT AXIS *n***

During keyboard or TP manual movement of the specified axis, its encoder attained its maximum allowed value.

- Move the axis in the opposite direction.