The Robot Arm

This chapter details the specifications and components of the SCORBOT-ER Vplus robot arm.

Figure 2-1: SCORBOT-ER Vplus Robot Arm
Specifications

The following table details the robot arm specifications.

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<td>Axis 2: Shoulder rotation</td>
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Structure

The **SCORBOT-ER Vplus** is a vertical articulated robot, with five revolute joints. With gripper attached, the robot has six degrees of freedom. This design permits the end effector to be positioned and oriented arbitrarily within a large work space.

Figures 2-2 and 2-3 identify the joints and links of the mechanical arm.

The movements of the joints are described in the following table:

<table>
<thead>
<tr>
<th>Axis No.</th>
<th>Joint Name</th>
<th>Motion</th>
<th>Motor No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Base</td>
<td>Rotates the body</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Shoulder</td>
<td>Raises and lowers the upper arm.</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Elbow</td>
<td>Raises and lowers the forearm.</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Wrist Pitch</td>
<td>Raises and lowers the end effector (gripper).</td>
<td>4+5</td>
</tr>
<tr>
<td>5</td>
<td>Wrist Roll</td>
<td>Rotates the end effector (gripper).</td>
<td>4+5</td>
</tr>
</tbody>
</table>

*Figure 2-2: Robot Arm Links*  
*Figure 2-3: Robot Arm Joints*
Work Envelope

The length of the links and the degree of rotation of the joints determine the robot’s work envelope. Figures 2-4 and 2-5 show the dimensions and reach of the SCORBOT-ER Vplus.

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 2-4: Operating Range (Top View)

Figure 2-5: Operating Range (Side View)
**Motors**

The robot’s five axes and gripper are operated by DC servo motors. The direction of motor revolution is determined by the polarity of the operating voltage: positive DC voltage turns the motor in one direction, while negative DC voltage turns it in the opposite direction.

Each motor is fitted with an encoder for closed-loop control.

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**Encoders**

The location and movement of each axis is measured by an electro-optical encoder attached to the shaft of the motor which drives the axis.

When the robot axis moves, the encoder generates a series of alternating high and low electrical signals. The number of signals is proportional to the amount of axis motion. The sequence of the signals indicates the direction of movement.

The controller reads these signals and determines the extent and direction of axis movement.
Microswitches

Five microswitches are fitted onto the frame of the robot arm. When the robot assumes the position in which the microswitch for each joint is depressed (by means of a cam), this predetermined position is known as home. This is the point of reference for robot operation. Whenever the system is turned on, the robot should be sent to this position, by means of a software homing routine.

Transmissions

Several kinds of transmissions are used to move the links of the robot arm.

- Spur gears move the base and shoulder axes.
- Pulleys and timing belts move the elbow axis.
- Pulleys and timing belts, and a bevel gear differential unit at the end of the arm move the wrist pitch and roll axes.
- A lead screw transmission opens and closes the gripper.
Gripper

The **SCORBOT-ER Vplus** has a jaw gripper fitted with rubber pads. These pads can be removed to allow the attachment of other end effector devices, such as suction pads.

Three bevel gears form a differential gear train which moves the wrist joint. When motors 4 and 5 are driven in opposite directions, the wrist pitch moves up and down. When motors 4 and 5 are driven in the same direction, the wrist rolls clockwise and counterclockwise. A leadscrew coupled directly to motor 6 causes the gripper to open and close.

*Figure 2-10: SCORBOT-ER Vplus Gripper*
Coordinate Systems

The **SCORBOT-ER Vplus** can be operated and programmed in two different coordinate systems: Joint and Cartesian (XYZ) coordinates.

**Cartesian (XYZ) Coordinates**

The Cartesian, or XYZ, coordinate system is a geometric system used to specify the position of the robot’s TCP (tool center point=tip of gripper) by defining its distance, in linear units, from the point of origin (the center bottom of its base) along three linear axes, as shown in Figure 6-2.

To complete the position definition, the pitch and roll are specified in angular units.

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

**Joint Coordinates**

Joint coordinates specify the location of each axis in encoder counts. When the axes move, the optical encoders generate a series of alternating high and low electrical signals. The number of signals is proportional to the amount of axis motion; the controller counts the signals and determines how far an axis has moved. Similarly, a robot movement or position can be defined as a specific number of encoder counts for each axis, relative to the home position, or another coordinate.

When robot motion is executed in Joint mode, individual axes move according to the command.

If any peripheral devices are connected to the robotic system, the position of their axes is always stated in encoder counts.
SCORBOT-ER Vplus can be programmed and operated in a number of ways. This chapter introduces the robotic software and the teach pendant functions. Software and teach pendant operation is described in other chapters of this manual, and in the other manuals supplied with the system.

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-A, and can be accessed from any standard terminal or PC computer 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, synchronized and interactive program execution; full multi-tasking support.
- Simple file management.

ACL is described fully in the ACL Reference Guide.

ATS

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

ATS is described fully in the *ATS Reference Guide*.

**SCORBASE**

*SCORBASE* is a robotic control software package which can be used with *Controller-A*. Its menu-driven structure and off-line capabilities facilitate robotic programming and operation.

*SCORBASE* is supplied on diskette and operates on any PC system. *SCORBASE* communicates with *ACL*, the controller’s internal language, by means of an RS232 channel.

Levels 1, 2 and 3 of the *SCORBASE* software can be ordered separately, and are recommended for those who wish to learn robotic programming from the most basic stages.

*SCORBASE* is described fully in the *SCORBASE Level 5 Reference Guide*. 
Teach Pendant

*The teach pendant is an optional device.*

The teach pendant (TP) is a hand-held terminal, used for controlling the robot and axis connected to **Controller-A**. 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’s display panel is a 2-line, 32 character liquid crystal display (LCD). It shows the current status of the controller, the current user command, and system messages.

The teach pendant has 30 function keys. These functions are described in this chapter. Many of the command keys on the teach pendant are **ACL** commands; these commands are described fully in the **ACL Reference Guide**.

### Keypad Functions

The teach pendant’s keypad has 30 color-coded keys. Most of the keys are multi-functional; for example, some keys include both an axis drive command and a numeric function. The controller recognizes the keys from the order in which they are pressed. Thus, the numeric function will be active only if a function such as SPEED, RUN, or MOVE has been keyed in first; otherwise, the axis drive command will be active.

Following are descriptions of the teach pendant’s keys and instructions for activating them. Bulleted items indicate the different functions of multi-functional keys.

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*Figure 5-1: Teach Pendant*
Accepts and/or executes the command which has been entered. 
Starts execution of a program following a Run command.

A toggle key. Switches the command mode between Joints and Cartesian (XYZ).

- When used following a numeric function, this key acts as a backspace function; it cancels the last numeric entry and moves the cursor one position to the left.
- Enables TP control of a specific axis group. 
  Successively press for group A, group B, group C, and again for group A, and so on. When group C is displayed, enter the axis number on the numerical keys. Then press Enter. 
  The Record Position and Speed functions apply only to the currently selected group.

A toggle key. Enables (CON) and disables (COFF) control of the selected group.

- The Axis keys move axes 7 through 11 in two directions.
- The numeric keys are operative if one of the following functions has been activated: Speed, Run, Record Position, Go Position, Group Select.
In Joint mode: the **Base/X** keys move the base axis in two directions.
In XYZ mode: the **Base/X** keys move the TCP (tip of gripper) along the X-axis; Y and Z coordinates do not change.

In Joint mode: the **Shoulder/Y** keys move the shoulder axis in two directions.
In XYZ mode: the **Shoulder/Y** keys move the TCP (tip of gripper) along the Y-axis; X and Z coordinates do not change.

In Joint mode: the **Elbow/Z** keys move the elbow axis in two directions.
In XYZ mode, the **Elbow/Z** keys move the TCP (tip of gripper) along the Z-axis; X and Y coordinates do not change.

In Joint mode: the **Pitch** keys move the TCP (tip of gripper) up or down, without moving the other axes.
In XYZ mode: the **Pitch** keys move three axes (shoulder, elbow and pitch) in order to change the pitch angle without changing the position of the TCP (tip of gripper).

In both Joint and XYZ modes: the **Roll** keys move the roll axis in two directions.

A toggle key. Opens and closes the electrical gripper.
Sets the speed of manual axis movement of the current axis control group; that is, group A, B, or C. The speed is defined as a percentage (1-100) of maximum speed.

Press Speed. The current speed is displayed.
Press Enter to accept the displayed default speed. Or use the numerical keys to enter a different speed, and press Enter.

Defines and records a position.

Only numerical position names, of up to five digits, can be entered from the TP. The position is defined for the currently active group, and receives the current values of the axes in that group.

Press Record Position. Then press up to five digits for the position name. Then press Enter to record the position coordinates.

If you use a position name which has already been defined, the new coordinates will overwrite the existing ones.

This command is also used to record positions in a vector. The vector must first be attached to the teach pendant by means of the ACL command ATTACH.

Moves the axes to a target position.

Press Go Position. Then use the numeric keys to enter the position name. Then press Enter to execute the move.

In Joint mode: robot movement is by joints.
In XYZ mode: robot movement is linear.

To send the axes to their home position, enter the following commands:

- **Go Position 0** sends all the axes of group A to their HOME position.
- **Go Position 00** sends all the axes of group B to their HOME position.
Executes a program.

Press **Run**. Then press the program’s identity number on the numerical keys. The program name will be displayed in brackets. Then press **Enter** to begin program execution.

The controller automatically assigns an ID number to each user program. The **ACL** command DIR lists the programs and their assigned (IDENTITY) number.

Aborts execution of all running programs. Stops movement of the robot and all peripheral axes.

**The Display Panel**

The LCD panel shows the current status of the controller, the current user command, and system messages.

A resident note shows the coordinates system currently active: **JOINTS** or **XYZ**.

Another resident note shows the currently active group: **A**, **B**, or the **number** of one of the independent axes in control group C.
Homing the Robot and Peripheral Axes

The location of the robot axes is monitored by encoders which track the amount of movement relative to an initial—home—position. To obtain repeatable robot performance, this reference position must be identical each time the robot is used. Thus, whenever the system is activated, the homing program, which is internally programmed into the controller, must be executed.

During the homing procedure, the robot joints move and search for their home positions, one at a time, in the following sequence: shoulder (axis 2), elbow (axis 3), pitch (axis 4), roll (axis 5), base (axis 1), gripper (axis 6).

To find its home position, the axis is moved until the microswitch which is mounted on the joint sends a specific signal to the controller, indicating the axis is at home.

When the homing is completed, the robot assumes the position shown in Figure 6-1.

Before you begin the homing procedure, make sure the robot has ample space in which to move freely and extend its arm.

Figure 6-1: SCORBOT-ER Vplus Home Position

TP

Press:

Run

0

Axis 11

Enter

This instructs the controller to execute Program 0, the robot homing routine. The display panel on the teach pendant will show:

HOMING . .

When the Home search is successfully completed, the display panel will show:

HOMING COMPLETE

If the robot is unable to find a home position in one or more of the axes, you will see a message such as:

HOME FAIL [4]
To stop the homing while the operation is in progress, press the **Abort** key.
The peripheral axes are homed by means of the TP command **Run 00**.

**PC**

To home the robot axes (Group A), use the **ACL** command **HOME**.

**Type:**

```
home  <Enter>
WAIT!! HOMING...
```

If all axes reach their home position, a message is displayed:

```
HOMING COMPLETE (ROBOT)
```

If the homing process is not completed, an error message identifying the failure is displayed:

```
*** HOME FAILURE AXIS 4
```

To stop the homing while the operation is in progress, use the abort commands:

**Type:**

```
A <Enter>
or press:  <Ctrl>+A
```

To home peripheral axes, each axis must be homed individually; for example:

**Type:**

```
home 7 <Enter>
home 8 <Enter>
home 9 <Enter>
```

To home an axis, such as a slidebase, which uses a hard stop rather than a microswitch, use the **ACL** command **HHOME**.

**Type:**

```
hhome 8 <Enter>
```