eV+3

User's Manual

I651-E-02

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Revision History

Revision Code	Release Date	Details
A	July, 2020	Original release
B	August, 2020	Minor corrections and updates

Chapter 1: Introduction

This manual contains information that is necessary to use eV+. Please read this manual and make sure you understand the functionality of eV+ before attempting to use it.

1.1 Intended Audience

This manual is intended for the following personnel, who must also have knowledge of common programming practices and robotic control methods.

- Personnel in charge of introducing FA systems.
- Personnel in charge of designing FA systems.
- Personnel in charge of installing and maintaining FA systems.
- Personnel in charge of managing FA systems and facilities.

1.2 Related Manuals

Use the following related manuals for reference.

Table 1-1. Related Manuals

Manual	Description
eV+3 Keyword Reference Manual (Cat. No. I652)	Provides references to eV+ Keyword use and functionality.
Sysmac Studio Robot Integrated System Building Function with Robot Integrated CPU Unit Operation Manual (Cat. No. W595)	Learning about the operating procedures and functions of the Sysmac Studio to configure Robot Integrated System using Robot Integrated CPU Unit.
Robot User Guides	User Guide for the robot in use.
T20 Pendant User’s Manual (Cat. No. I601)	Describes the use of the optional T20 manual control pendant.
NJ-series Robot Integrated CPU Unit User's Manual (Cat. No. O037)	Describes the settings and operation of the CPU Unit and programming concepts for OMRON robot control.
Robot Safety Guide (Cat. No. I590)	Contains safety information for OMRON industrial robots.

1.3 System Overview

eV+ is an interpreted programming language and control system for OMRON industrial robots. This system offers a variety of keywords supporting robot motion, I/O, vision, file operations, and communication with other devices. Real-time interpretation and forward processing of programs in parallel tasks provides continuous path trajectory generation, as well as on-line program generation, debugging, and modification.

When the eV+ system is used with the NJ-series Robot Integrated CPU Unit, I/O, logic, safety, and motion control functions can be created using IEC 61131-3 programming language specifications. With the addition of shared variables, shared signals, and function blocks for interacting with V+ program execution, a user can develop an entire control solution from the Sysmac Studio software.

The eV+ Operating System runs on OMRON robots while communicating with other system objects to facilitate programming and runtime functionality. The general system overview is shown below.

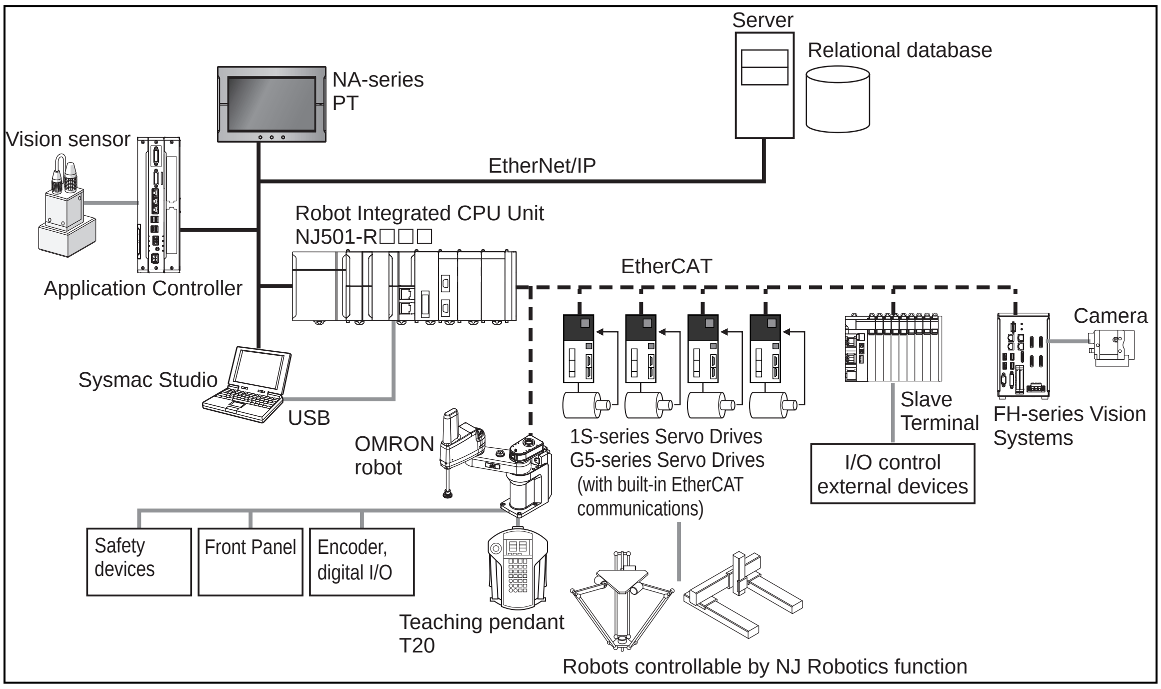


Figure 1-1. System Overview

The eV+ Operating System

The eV+ Operating System is automatically launched when the robot controller and NJ-series Robot Integrated CPU Unit are powered ON. The operating system accepts instructions from application programs, input from workcell peripheral devices, and operator input from the pendant. The tasks performed by the operating system include the following.

- Managing the execution of application programs.
- Managing the flow of information to and from storage devices.
- Monitoring external devices attached to the controller.
- Reporting errors generated during processing.

The eV+ Language

The eV+ language is comprised of keywords that provide control, data manipulation, and other application-specific functionality. These keywords are used in statements with specific syntax detailed in this document with examples. Statements are executed in a consecutive manner until the .END statement is reached. This is referred to as a program cycle. Keywords may be used to create V+ programs or issue individual commands in the Monitor Window. Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for other syntax and statement examples.

IMPORTANT: An error "Command not supported" will be returned if a keyword is issued on a system that does not include the NJ-series Robot Integrated CPU Unit as the Host System.

1.4 eV+ Keywords

eV+ keywords are a set of instructions that are used to perform various operations for a robot-based application. Keywords are used to create statements arranged in steps for the following programmatic functionality.

- Robot motion control
- Error processing and handling
- Arithmetic functions
- System parameter and switch manipulation
- Data management
- I/O control and external device communication
- Logic and other conditional evaluations
- Subroutine execution and control
- Executing various system functions
- T20 Pendant functions

Depending on the type of keyword, they can be used to build a program or they can be issued individually using the Monitor Window in the Sysmac Studio.

Keywords are categorized into six types as described below.

Table 1-2. eV+ Keyword Types

Keyword Type	Usage
Function keywords	Used to return values from the eV+ Operating System. Refer to Using Function Keywords on page 15 for more information.
Monitor command keywords	Used to issue individual operations in the Monitor Window or to create Monitor Command Programs. Refer to Using Monitor Command Keywords on page 16 for more information.
Other keywords	Used to specify units when using the SPEED program command keyword. Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information.
Program command keywords	Used to command operations in V+ programs. Refer to Using Program Command Keywords on page 17 for more information.
System parameter keywords	Used to manipulate system parameters in V+ programs or with the Monitor Window. Refer to Using System Parameter Keywords for more information.
System switch keywords	Used to manipulate system switches in V+ programs or with the Monitor Window. Refer to Using System Switch Keywords on page 20 for more information.

Keywords and Syntax

In order for keywords to work with the eV+ operating system, they must be issued with a specific syntax. This syntax generally consists of a keyword and associated parameters in a specific order, separated by characters such as commas, brackets, and parentheses. This syntax is detailed in this manual and also in the *eV+3 Keyword Reference Manual (Cat. No. I652)*. An example of keyword syntax is shown below.

```
        SET loc_name = SHIFT(loc_value BY 5, 5, 5)
```

When creating V+ programs with the Sysmac Studio, syntax is checked and formatted as the characters are input. Refer to the *Sysmac Studio Robot Integrated System Building Function with Robot Integrated CPU Unit Operation Manual (Cat. No. W595)* for more information.

1.5 Monitor Command Programs and V+ programs

There are two types of programs that the eV+ Operating System can execute: Monitor Command Programs and V+ programs.

V+ programs contain the logic, motion control, and vision keywords that control a robot during run-time. Refer to V+ programs on page 63 for more information.

Monitor Command Programs are used to perform system-level functions such as loading files, changing the default directory path, and executing main eV+ programs after system boot up. Refer to Monitor Command Programs on page 59 for more information.

1.6 eV+ File Management

The eV+ Operating System has a file management system very similar to other operating systems. Each file within a subdirectory must have a unique name. There are several file extensions that are used for different types of files in the eV+ system as described in File Types on page 12.

New files can be created with the Sysmac Studio or by issuing specific keywords. Refer to the *Sysmac Studio Robot Integrated System Building Function with Robot Integrated CPU Unit Operation Manual (Cat. No. W595)* and the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information.

File Name Requirements

The eV+ file name requirements are described below.

- File names can have a maximum of eight characters.
- File names must have an extension (file type) designation that is 1 to 3 characters in length. Refer to File Types on page 12 for more information.
- File names can only include alphanumeric characters and the underscore (_) character. No other special characters are permitted.
- File names cannot contain blank spaces.
- Keywords cannot be used as file names. Do not name files the same as any keywords.

NOTE: File names are not case-sensitive.

File Types

There are several file types that are used by the eV+ Operating System. File types that are used during system development, commissioning, debugging, and other typical operations are listed below.

IMPORTANT: Direct access and editing of these files is not necessary under normal use.

Table 1-3. eV+ File Type Descriptions

File Type	Description
.v2	V+ programs Global variables referenced by the programs and subroutines can be stored in the file. All of the subroutines referenced (directly or indirectly) by the specified program can be stored in the file. Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for information about storing programs and variables in a disk file using the STORE keyword. Refer to the Sysmac Studio Robot Integrated System Building Function with Robot Integrated CPU Unit Operation Manual (Cat. No. W595) for information about saving programs and variables to the controller.
.cal	System calibration data files.
.xml	Robot specification and other parameter files.
.rtf	Text files (Readme).
.pg	V+ program or group of programs (module) In addition to the programs specified to store in the file, any subroutines referenced by those programs are also stored in the file. Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for information about storing programs and variables in a disk file using the STOREP and STOREM keywords.

Programs and Subroutines

V+ is an interpreted language, therefore linking and compiling are not required. Main programs and subroutines always exist as separate programs. The eV+ file structure allows you to keep a main program and all the subroutines it calls or executes together in a single file so that when a main program is loaded, all the subroutines it calls are also loaded. A single file that contains a program and subroutines is also referred to as a module.

If a program calls a subroutine that is not resident in system memory, the error *Undefined program or variable name* will result.

Additional Information: Refer to the STORE_ and MODULE keyword descriptions in the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information.

Refer to the *Sysmac Studio Robot Integrated System Building Function with Robot Integrated CPU Unit Operation Manual (Cat. No. W595)* for more information about creating a program file.

Chapter 2: Keyword Usage

This chapter describes how to use the different types of keywords with the eV+ system.

2.1 Using Function Keywords

Function keywords are issued within V+ Program statements and can be used in several different ways as described below.

Additional Information: Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information about specific function keywords.

Function Keyword Syntax

eV+ provides you with a wide variety of predefined function keywords for performing string, mathematical, and other data manipulation. In most cases, you must provide the data that is input to a function keyword. The keyword then returns a value based on a specific operation on that data. Function keywords can be used anywhere that a value or expression would be used.

Correct syntax for function keywords must be observed when creating statements in V+ programs. If incorrect syntax is used, eV+ will return an *Illegal monitor command* error.

Variable Assignments and Data Types

When a function keyword is issued, a value is returned by the eV+ Operating System. The data type of the value that is returned must match the data type of the variable that is assigned to the function. For example, if the $TIME function keyword is issued, eV+ will return a string data type value. The examples below demonstrate various data types used with variable assignments.

```
$current_time = $MID($TIME(,time),11,8)

SET #pos1 = #PHERE

SETBELT %main.belt = BELT(%main.belt)
```

Additional Information: Refer to Variables and Data Types on page 41 for more information

Using Functions as Keyword Parameters

A function keyword can be used as a parameter as long as the data type returned by that function is the correct type. For example, consider the SQRT function statement shown below. The SQRT function keyword uses the syntax "SQRT(value)" for reference.

```
i = SQRT(SQR(x))
```

The statement above returns the absolute value of variable "x" and assignes it to variable "i". Any function that returns a numerical value can be substituted for "SQR(x)" in the statement above.

Function Keywords Used Within Expressions

A function keyword can be used as an expression as long as the data type returned by that function is the correct type. For example, consider the IF ... THEN conditional statement shown below. The IF ... THEN keyword uses the syntax "IF logical_exp THEN" for reference.

```
IF LEN($string_variable) > 12 THEN
```

The statement above evaluates the expression "LEN($string_variable) > 12". This expression includes the LEN function keyword that returns the number of characters in the variable "$string_variable". Any function that returns a numerical value can be substituted for LEN ($string_variable) in the statement above.

2.2 Using Monitor Command Keywords

Monitor command keywords can be issued in the Monitor Window or with the use of a Command Program. Most monitor command keywords include at least one parameter that controls how the eV+ system executes the operation. This additional information is specified when the keyword is issued in the Monitor Window. Parameters must be entered in the order they are listed and they must use correct syntax.

Additional Information: Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information about specific monitor command keywords.

Refer to the *Sysmac Studio Robot Integrated System Building Function with Robot Integrated CPU Unit Operation Manual (Cat. No. W595)* for more information about the Monitor Window.

Monitor Command Keyword Syntax

Correct syntax for monitor command keywords must be observed when creating statements in V+ programs. If incorrect syntax is used, eV+ will return an *Illegal monitor command* error.

In general, monitor command keywords have the following formats. The keyword is shown in uppercase and the arguments are shown in lowercase. Required keywords, parameters, and symbols such as equal signs and parentheses are shown in bold text. Optional keywords, parameters, and symbols are shown in regular text.

```
KEYWORD

KEYWORD req_param

KEYWORD (req_param)

KEYWORD opt_param

KEYWORD opt_param1, opt_param2, ... , opt_paramX

KEYWORD req_param, opt_param = value

KEYWORD @task:program_step(expression)

KEYWORD req_param1 = req_param2

KEYWORD req_param1 = req_param2 KEYWORD opt_param
```

Additional Information: All required or optional monitor command keyword parameters and associated syntax is described for each keyword in the *eV+3 Keyword Reference Manual (Cat. No. I652)*. Refer to specific keyword details in that manual for more information.

Monitor Command Keyword Parameter Entry

Monitor command keyword parameters can be optional or required. If a parameter is required, a value must be entered on the command line or the command will not execute correctly. A space is required between the keyword and the parameters that follow it. A comma is typically used to separate parameters but some monitor command keywords may require an equal sign (=) assignment operator.

If a parameter is optional, its value can be omitted and the system will substitute a default value. For example, the STATUS monitor command keyword can be issued as shown below. The STATUS syntax is "STATUS select" for reference, where "select" is an optional parameter.

```
STATUS
```

Issuing the STATUS monitor command keyword as shown above will return status information for all the program tasks.

Issuing the STATUS monitor command keyword with a parameter value as shown below will return status information for only system task number 1.

```
STATUS 1
```

Spaces before and after parameter separators are optional. If one or more parameters follow an omitted parameter, the parameter separator(s) must be typed. If all the parameters following an omitted parameter are optional, and those parameters are also omitted, the separators do not need to be typed. Refer to the example below that demonstrates these concepts. The XSTEP syntax is "XSTEP task program (param_list), cycles, step" with all parameters being optional, for reference.

```
XSTEP assembly,,23
```

2.3 Using Program Command Keywords

Program command keywords are used to create V+ programs for robot control and other functions such as I/O control, file operations, error handling, and data management. This section provides details about the usage of program command keywords when creating V+ programs.

Program Command Keyword Syntax

Correct syntax for program command keywords must be observed when creating statements in V+ programs. If incorrect syntax is used, the statement will cause errors in the V+ Editor and the program cannot be executed.

Symbols such as commas, brackets, and parentheses may be required for program command keyword syntax when parameters are present. program command keywords may contain parameters that define or specify information needed for the operation. Some program command keywords do not require any parameters while other program command keywords have required or optional parameters.

In general, program command keywords have the following formats (not an exhaustive listing). The keyword is shown in uppercase and the arguments are shown in lowercase. Required keywords, parameters, and symbols such as equal signs and parentheses are shown in **bold** text. Optional keywords, parameters, and symbols are shown in regular text.

KEYWORD

KEYWORD req_param

KEYWORD opt_param

KEYWORD (parameter)opt_param

```
KEYWORD opt_param1, opt_param2, ... , opt_paramX

KEYWORD req_param, opt_param = value

KEYWORD req_param1 = req_param2

KEYWORD req_param1 = req_param2 KEYWORD opt_param
```

Additional Information: All required or optional program command keyword parameters and associated syntax is described for each keyword in the *eV+3 Keyword Reference Manual (Cat. No. I652).* . Refer to a specific keyword details in that manual for more information.

No Required Parameters

Some program command keywords do not require any parameters such as LEFTY, RIGHTY, ABOVE, and BELOW. Keywords that do not require parameters can be used as shown below.

```
ABOVE
MOVE point1
BREAK
```

Required or Optional Parameters

Some program command keywords have parameters that are required or optional. When using a keyword that uses multiple parameters, symbols such as commas, brackets, and parentheses may be required. If required parameters or syntax is incorrect, an error will occur. Refer to Warning, Information, and Error Messages on page 87 for error information and the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information about the use of symbols to complete the correct syntax for eV+.

NOTE: When program lines are entered, extra blank spaces can be used between any elements in the line. The eV+ editor adds or deletes spaces in program lines to make them conform with the standard spacing. The editors also automatically format the lines to uppercase for all keywords and lowercase for all user-defined names.

2.4 Using System Parameter Keywords

System parameters determine certain operating characteristics of the eV+ system. These parameters have numeric values that can be changed from the Monitor Window or from within a program to suit particular system configurations and needs. The various parameters are described in this section along with the operations for displaying and changing their values.

Available System Parameters

Use the following table to understand the available system parameters and their basic functions. Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for setting details, examples, and other information.

Table 2-1. System Parameter Details

Parameter	Description
BELT.MODE	Set characteristics of the conveyor tracking feature of the eV+ system.
DEVIATION	Adds a path deviation from 1 to 100% to the motion in the singularity region when a robot is in singularity.

Parameter	Description
NOT.CALIBRATED	Represents the calibration status of the robot(s) controlled by the eV+ system.
VTIMEOUT	Sets a timeout value so that an error message is returned if no response is received following a vision command.
JOG.TIME	Sets the keep-alive time of a jog operation. Each time a jog operation is executed, this parameter setting specifies the time the axis or joint moves.

Viewing and Setting System Parameters

System parameters can be viewed and set in the Monitor Window. They can also be controlled by V+ programs. Use this section to understand how to view and set system parameters.

Viewing and Setting System Parameters with the Monitor Window

The PARAMETER monitor command keyword is used to view and set parameter values as shown in the examples below.

Viewing Parameter Values

The following example will display all parameters and their current values in the Monitor Window.

```
PARAMETER
```

The following example will display the BELT.MODE parameter current value in the Monitor Window.

```
PARAMETER BELT.MODE
```

Setting Parameter Values

The following example will set the BELT.MODE parameter to 4.

```
PARAMETER BELT.MODE = 4
```

Reading and Writing System Parameters with V+ Programs

Parameters can be set during V+ program execution by using the PARAMETER program command keyword.

> **NOTE:** It is common practice to use a Monitor Command Program to set parameters. Refer to Monitor Command Programs on page 59 for more information.

The following program statement will set the BELT.MODE system parameter to have bits 1 and 3 set to 1 (mask values 1 + 4) using the PARAMETER program command keyword.

```
PARAMETER BELT.MODE = 5
```

A parameter value can be returned during V+ program execution or using the Monitor Window.

The following program statement will return the current setting of the BELT.MODE system parameter in the Monitor Window.

```
TYPE "The BELT.MODE parameter is set to",  PARAMETER(BELT.MODE)
```

2.5 Using System Switch Keywords

System switches determine certain operating characteristics of the eV+ system. These switches can be turned ON or OFF from the Monitor Window or from within a program.. The various system switches are described in this section along with the operations for displaying and controlling them.

Available System Switches

Use the following table to understand the available system switches and their basic functions. Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for settings, details, examples, and other information.

Switch	Description
AUTO.POWER.OFF	When this switch is ON, errors will disable high power. When this switch is OFF, these errors stop the robot and signal the eV+ system, but do not cause high power to be turned OFF. The errors are defined as follows. • (-624) *force protect limit exceeded* • (-1003) *Time-out nulling errors* Mtr • (-1006) *Soft envelope error* Mtr
CP	Enables or disables continuous-path motion processing. Refer to Continuous-Path Trajectories on page 34 for more information.
DECEL.100	Enables or disables the use of 100 percent as the maximum deceleration for the ACCEL program command keyword.
DELAY.IN.TOL	Controls the timing of coarse or fine nulling after eV+ completes a motion segment (positioning tolerance). Refer to COARSE and FINE program command keyword details.
DRY.RUN	This switch enables or disables the transmission of motion commands to the robot. Turn this switch ON to test programs for proper logical flow and external communication functionality to prevent collisions. **NOTE:** The T20 pendant can still be used to move the robot when DRY.RUN is enabled if there is no task attached to the robot. Otherwise, a Robot Interlocked error (-621) will occur.
MESSAGES	Setting this switch to ON will allow messages to be displayed on the Monitor Window while using the TYPE program command keyword. Setting this switch OFF will prevent messages from being displayed on the Monitor Window with the TYPE program command keyword.
OBSTACLE	Enables or disables up to 4 different obstacles that are defined for a robot.
POWER	This switch controls and displays the robot high power. This switch is automatically enabled whenever robot high power is turned ON. If the robot timing specifications in the system configuration is non-zero, enabling high power is a two-step process. In this case, after enabling high power from the T20 Pendant, Monitor Window, or software, the sys-

Switch	Description
	tem flashes the high power indicator for the duration of the timing specification setting (in seconds). If a timeout occurs, the message *HIGH POWER button not pressed* will appear. Refer to Warning, Information, and Error Messages on page 87 for more information. Refer to the *Sysmac Studio Robot Integrated System Building Function with Robot Integrated CPU Unit Operation Manual (Cat. No. W595)* for more information about robot timing specification settings.
ROBOT	Enables or disables one robot or all robots.
SCALE.ACCEL	Enables or disables the scaling of acceleration and deceleration as a function of program speed as long as the program speed is below a preset threshold.
SCALE.ACCEL.ROT	Specifies whether or not the SCALE.ACCEL system switch accounts for the cartesian rotational speed during straight-line motions.
UPPER	Determines whether comparisons of string values will consider lowercase letters the same as uppercase letters. When this switch is ON, all lowercase letters are considered as though they are uppercase.

Viewing and Setting System Switches

System switches can be viewed and set in the Monitor Window. Then can also be controlled by V+ programs. Use this section to understand how to view and set system switches.

Viewing and Setting System Switches from the Monitor Window

The SWITCH monitor command keyword is used to view and set switches as shown in the examples below.

Viewing System Switches

The following example will display all switches and their current values in the Monitor Window.

```
SWITCH
```

The following example will display the POWER switch current state in the Monitor Window.

```
SWITCH POWER
```

Setting System Switches

The following example will turn ON the AUTO.POWER.OFF switch.

```
ENABLE AUTO.POWER.OFF
```

The following example will turn OFF the AUTO.POWER.OFF switch.

```
DISABLE AUTO.POWER.OFF
```

Chapter 3: eV+ System Operations

The following sections describe various eV+ system operations.

3.1 System Messages

System messages have designated numbers and strings for identification. These can be used to detect and recover from various eV+ conditions with V+ programs or using the Monitor Window.

Additional Information: Refer to Warning, Information, and Error Messages on page 87

Message Types

There are three different message types:

- Informational messages (message numbers 0 to 49)
- Warning messages (message numbers 50 to 299)
- Error messages (messages with negative values)

System Behavior

The eV+ system will behave differently depending on the type of message and eV+ state when the message occurs.

Informational and warning messages do not impact the system operation and can be used for observational purposes.

Errors messages have an impact on system operation. They will not completely stop the eV+ system, but individual tasks associated with the error will stop running.

System behavior after errors occur depend on the running task, robot status, and type of error. If the robot is running and on the same task where an error occurs, the robot will be stopped with maximum deceleration and an error message(s) will be generated. If an error occurs on a task that is not running a robot, only this task will be stopped and the robot will not be affected.

Message Handling

eV+ will internally store system message information in order to be accessed with the ERROR and REACTE keyword operations.

The following information is stored for access using the ERROR keyword operation.

- The last system message of a task (current or selected)
- The last system message of each attached robot
- The last message of the eV+ system
- A category, source, and name for each system message.

Additional Information: Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information about the ERROR and REACTE keyword operations.

3.2 Digital I/O Control

When eV+ starts, blocks of system memory are assigned to internal and external digital I/O detected by the system.

Several program command keywords are available for digital I/O control purposes. Digital input signals can be monitored for changes and outputs can be turned ON and OFF conditionally.

Refer to the robot user guide for more information about default signal allocation.

I/O Usage Considerations

The RESET and DEF.DIO program command keywords have no effect on Host I/O signal numbers 4001 to 4999.

The IO monitor command keyword will return the value of signals that are mapped in the host and returns "-" for signals that are not mapped.

The SIG.INS function keyword will return TRUE if the host signal is available and FALSE if it is not available (not mapped).

Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information.

Basic I/O Control

Use the following examples to understand basic I/O control functionality with program command keywords.

Input Signal Examples

The following example halts program execution until a switching device attached to digital input channel 1001 is closed.

```
WAIT SIG(1001)
```

The following example evaluates input signal 1002 and calls a program "service.feeder" when the signal turns ON.

```
IF SIG(1002) THEN
       CALL service.feeder()
END
```

NOTE: The example above will call "service.feeder" if signal 1002 is ON only when the condition is evaluated.

Output Signal Examples

The following example turns OFF digital output signal 33.

```
SIGNAL(-33)
```

The following example turns ON digital output signal 33.

```
SIGNAL(33)
```

The following example controls multiple digital output signals with a single statement.

```
SIGNAL(33),(-34),(35)
```

Soft Signals

Soft signals are provided in the range of 2001 to 2999. These signals are accessible with all V+ programs and can be used with the SIG and SIGNAL keywords for interaction between V+ programs on different tasks or interaction between V+ programs and functionality in an Application Manager..

3.3 Disk I/O Operations

The following sections describe the basic procedures and functions for disk I/O operations.

Logical Unit Numbers

All eV+ disk I/O operations reference an integer value called a Logical Unit Number (LUN). The LUN provides a method of identifying which device or file is being referenced by an I/O operation. A LUN device can refer to a robot, a disk, a TCP protocol device driver, a TFTP server, or a UDP protocol device driver.

The LUN specifier is a parameter used in several keywords listed below. Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information.

The following program command keywords use the LUN parameter.

- ATTACH
- DETACH
- FCMND
- FOPEN
- FSET
- READ
- WRITE

I/O Operation Error Status

Unlike most other eV+ keywords, I/O operations are expected to fail under certain circumstances. For example, when reading a file, an error status is returned to the program to indicate when the end of the file is reached. The program is expected to manage this error and continue execution.

For these reasons, eV+ I/O keywords normally do not stop program execution when an error occurs. Instead, the success or failure of the operation is saved internally for access by the IOSTAT real-valued function. For example, a reference to IOSTAT(5) returns a value indicating the status of the last I/O operation performed on LUN 5. The values returned by IOSTAT fall into one of following three categories.

Table 3-1. IOSTAT Keyword Return Values

Value	Description
1	The I/O operation completed successfully.
0	The I/O operation has not yet completed. This value appears only if a pre-read or no-wait I/O operation is being performed.
<0	The I/O operation completed with an error. The error code indicates what type of error occurred.

Additional Information: Refer to Warning, Information, and Error Messages on page 87 The $ERROR string function keyword can be used in a program (or with the LISTS monitor command keyword) to generate the text associated with most I/O errors.

NOTE: It is not necessary to use IOSTAT after use of a GETC keyword since errors are returned directly by the GETC keyword.

Attaching and Detaching Logical Units

An I/O device must be attached using the ATTACH program command keyword before it can be accessed by a program. Once a specific device (such as the teach pendant) is attached by one program task, it cannot be used by another program task.

Most I/O requests fail if the device associated with the referenced Logical Unit Number is not attached. When a program is finished with a device, it detaches the device with the DETACH program command keyword. This allows other programs to process any pending I/O operations.

A physical device type can be specified when the logical unit is attached. If a device type is specified, it supersedes the default, but only for the logical unit attached. The specified device type remains selected until the logical unit is detached.

When a control program completes execution normally, all I/O devices attached by it are automatically detached. If a program stops abnormally, most device attachments are preserved. If the control program task is resumed and attempts to reattach these logical units, it may fail because of the attachments still in effect.

Additional Information: The KILL monitor command forces a program to detach all the devices that it has attached.

If attached by a program, the Monitor Window and teach pendant are detached whenever the program halts or pauses for any reason, including error conditions and single-step mode. If the program is resumed, the Monitor Window and the teach pendant are automatically reattached if they were attached before the termination.

Attach Request Response Mode

An attach request can optionally specify immediate mode. Normally, an attach request is queued and the calling program is suspended if another control program task is attached to the device. When the device is detached, the next attachment in the queue will be processed. In immediate mode, the ATTACH program command keyword completes immediately with an error if the requested device is already attached by another control program task.

Attach requests can also specify no-wait mode. This mode allows an attach request to be queued without forcing the program to wait for it to complete. The IOSTAT function must then be used to determine when the attach has completed.

If a task is already attached to a logical unit, it will get an error immediately if it attempts to attach again without detaching, regardless of the type of wait mode specified.

Attaching and Detaching Disk Devices

Use the sections below to understand how to attach and detach disk devices.

Attaching Disk Devices

The type of device to be accessed is determined by the DEFAULT monitor command keyword or the ATTACH program command keyword. If the default device type set by the DEFAULT keyword is not appropriate at a particular time, the ATTACH keyword can be used to override the default.

The following example attaches to an available disk logical unit and returns the number of the logical unit in the variable "dlun", which can then be used in other disk I/O operations.

```
ATTACH (dlun, 4) "DISK"
```

If the device name is omitted from the keyword syntax, the default device for the specified LUN is used. It is recommended that you always specify a device name with the ATTACH keyword. The device SYSTEM refers to the device specified with the DEFAULT monitor command. Once the attachment is made, the device cannot be changed until the logical unit is detached. However, any of the units available on the device can be specified when opening a file. For example, the eV+ DISK units are A, C and D. After attaching a DISK device LUN, a program can open and close files on any of these disk units before detaching the LUN.

Detaching Disk Devices

When a disk logical unit is detached, any disk file that was open on that unit is automatically closed. However, error conditions detected by the close operation may not be reported. Therefore, it is good practice to use the FCLOSE keyword to close files and to check the error status afterwards. FCLOSE ensures that all buffered data for the file is written to the disk, and updates the disk directory to reflect any changes made to the file. The DETACH keyword frees up the logical unit.

The following example will close a file and detach a disk LUN.

```
FLCOSE(dlun)
   IF IOSTAT(dlun) THEN
       TYPE $ERROR(IOSTAT(dlun))
   END
DETACH(dlun)
```

Reading and Writing with I/O Devices

The READ program command keyword processes input from all devices. The basic READ keyword issues a request to the device attached on the indicated LUN and waits until a complete data record is received before program execution continues. The length of the last record read can be obtained with the IOSTAT function with its second argument set to a value of 2.

The GETC real-valued function returns the next data byte from an I/O device without waiting for a complete data record. It is commonly used to read data from the Monitor Window. It also can be used to read disk files in a byte-by-byte manner. Special mode bits to allow reading with no echo are supported for Monitor Window read operations.

Monitor Window input can be performed using the PROMPT program command keyword. The GET.EVENT real-valued function can be used to read input from the Monitor Window. This may be useful in writing programs that operate on both graphics and non-graphics-based systems. To read data from a disk device, a file must be open on the corresponding logical unit. The FOPEN_ program command keywords open disk files.

The WRITE program command keyword processes output to disk devices and to the Monitor Window. The basic WRITE keyword issues a request to the device attached on the indicated LUN, and waits until the complete data record is output before program execution continues. WRITE keywords accept format control specifiers that determine how output data is formatted, and whether or not an end of record mark should be written at the end of the record.

Monitor Window output can be performed using the PROMPT or TYPE keywords. A file must be opened using the FOPENW or FOPENA keywords before data can be written to a disk device. FOPENW opens a new file. FOPENA opens an existing file and appends data to that file.

> **Additional Information**: Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for usage considerations, details, and examples of the keywords described above.

Input Wait Modes

Normally, eV+ waits until the data from an input keyword is available before continuing with program execution. However, the READ keyword and GETC keyword accept an optional parameter that specifies no-wait mode.

In no-wait mode, these keywords return immediately with the error status -526 (No data received) if there is no data available. A program can loop and use these operations repeatedly until a successful read is completed or until some other error is received. The disk devices do not recognize no-wait mode on input and treat such requests as normal input-with-wait requests.

Output Wait Modes

Normally, eV+ waits for each I/O operation to be completed before continuing to the next program statement.

The following example causes eV+ to wait for the entire record of 50 spaces to be transmitted (about 50 ms for 9600 baud rate) before continuing to the next program statement.

```
TYPE /X50
```

Similarly, WRITE program command keywords to disk files will wait for any required physical output to complete before continuing.

This waiting is not performed if the /N (no wait) format control specifier is used in an output keyword. Instead, eV+ immediately executes the next program statement. The IOSTAT function checks whether or not the output has completed. It returns a value of zero if the previous I/O is not complete. If a second output keyword for a particular Logical Unit Number is encountered before the first no-wait operation has completed, the second statement automatically waits until the first is done. This scheme means the no-wait output is effectively double-buffered. If an error occurs in the first operation, the second operation is canceled, and the IOSTAT value is correct for the first operation. The IOSTAT function can be used with a second parameter of 3 to explicitly check for the completion of a no-wait write.

Disk File Operations

Disk file operations that are available with the eV+ system are described below.

The FDIRECTORY monitor command keyword is used to display the names of the files in a directory. A disk file can be accessed either sequentially, where data records are accessed from the beginning of the file to its end, or randomly, where data records are accessed in any order. Refer to Advanced Disk Operations on page 31 for more information about sequential and random access for disk files.

The FCMND program command keyword is used to perform the following operations.

- Rename a file
- Create a subdirectory
- Delete a subdirectory

> **Additional Information**: The FCMND keyword is similar to other disk I/O keywords in that a logical unit must be attached and the success or failure of the

command is returned via the IOSTAT real-valued function. Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information about the IOSTAT function.

Accessing the Disk Directories

The eV+ directory structure is identical to that used by the IBM PC DOS operating system. For each file, the directory structure contains the file name, attributes, creation time and date, and file size. Directory entries may be read after successfully executing an FOPEND keyword.

Each directory record returned by a READ keyword operation contains an ASCII string with the information shown in the following table.

Table 3-2. Disk Directory Format Description

Byte	Size (Bytes)	Description
1 to 7	7	Attribute codes that are padded with blanks on the right side. The attribute field is blank if no special attributes are indicated. The following characters are possible. • D: Subdirectory • P: File is protected and cannot be read or modified • R: File is read-only and cannot be modified • S: File is system file
9	1	ASCII tab character (9 decimal).
10 to 19	10	ASCII file size in sectors, right justified.
20	1	ASCII tab character (9 decimal).
20 to 28	9	File revision date with the format of dd-mm-yy. **NOTE:** The file revision date is blank if the system date and time had not been set when the file was created or last modified.
29	1	ASCII tab character (9 decimal).
30 to 38	9	File revision time with the format hh:mm:ss. **NOTE:** The file revision time is blank if the system date and time had not been set when the file was created or last modified.
39	1	ASCII tab character (9 decimal).
40+	---	ASCII file name and extension (size depends on file name length).

Opening a Disk File

Before a disk file can be opened, the disk the file is on must be attached. The FOPEN_ keywords open disk files (and file directories). These keywords associate a LUN with a disk file. Once a file is open, the READ, GETC, and WRITE keywords can be used to access the file. These keywords use the assigned LUN to access the file so that multiple files may be open on the same disk and the I/O operations for the different disk files will not affect each other.

NOTE: While a file is open for write or append access, another control program task cannot access that file. However, multiple control program tasks can access a file simultaneously in read-only mode.

Writing to a Disk

The following example writes the string stored in "$in.string" to the disk file open on "dlun".

```
WRITE (dlun) $in.string
```

The following example returns any error generated during the write operation example above to the "error" variable.

```
error = IOSTAT(dlun)
```

Reading from a Disk

The following example reads from the open file on "dlun" up to the first CR/LF or end of file if it is encountered, and stores the result in "$in.string". When the end of file is reached, eV+ error number -504 (Unexpected end of file) is generated. The IOSTAT function must be used to recognize this error and halt reading of the file.

```
DO
   READ (dlun) $in.string
   TYPE $in.string
UNTIL IOSTAT(dlun) == -504
```

Additional Information: The GETC function reads the file byte-by-byte if you want to examine individual bytes from the file or if the file is not delimited by CR/LFs.

Multi-functional Example

The following example creates a disk file, writes to the file, closes the file, reopens the file, and reads back its contents.

```
AUTO dlun, i
AUTO $file.name
$file.name = "data.tst"

ATTACH (dlun, 4) "DISK"
IF IOSTAT(dlun) < 0 GOTO 100

FOPENW (dlun) $file.name
IF IOSTAT(dlun) < 0 GOTO 100

FOR i = 1 TO 10
    WRITE (dlun) "Line "+$ENCODE(i)
    IF IOSTAT(dlun) < 0 GOTO 100
END

FCLOSE (dlun)
IF IOSTAT(dlun) < 0 GOTO 100

FOPENR (dlun) $file.name
IF IOSTAT(dlun) < 0 GOTO 100
READ (dlun) $txt
WHILE IOSTAT(dlun) > 0 DO
```

```
            TYPE $txt
            READ (dlun) $txt
        END
        IF (IOSTAT(dlun) < 0) AND (IOSTAT(dlun) <> -504) THEN
    100 TYPE $ERROR(IOSTAT(dlun))
        END
        FCLOSE (dlun)
        IF IOSTAT(dlun) < 0 THEN
            TYPE $ERROR(IOSTAT(dlun))
        END
        DETACH (dlun)
```

Advanced Disk Operations

This section provides additional information for using the FOPEN and FOPENR program command keywords for use with advanced disk operations in the eV+ system.

Variable Length Records

The default disk file access mode is variable-length record mode. In this mode, records can have any length up to a maximum of 512 bytes and can cross the threshold of 512-byte sectors. The end of a record is indicated by a Line-Feed character (10 decimal). The end of the file is indicated by the presence of a Ctrl+Z character (26 decimal) in the file.

Variable-length records should not contain any internal Line-Feed or Ctrl+Z characters as data. This format is used for loading and storing eV+ programs, and is compatible with the standard ASCII file format. Variable-length record mode is selected by setting the record length parameter with the FOPEN_ keyword to zero, or by omitting the parameter completely. In this mode, WRITE keywords automatically append Return (13 decimal) and Line-Feed characters to the output data, which makes it a complete record. If the /S format control specifier is used in an output specification, no Return/Line-Feed is appended. Then, any subsequent WRITE will have its data concatenated to the current data as part of the same record. If the /Cn format control specifier is used, n Return/Line-Feeds are written, creating multiple records with a single WRITE.

When a variable-length record is read using a READ keyword, the Return/Line-Feed sequence at the end is removed before returning the data to the eV+ program. If the GETC keyword is used to read from a disk file, all characters are returned as they appear in the file including Return, Line-Feed, and Ctrl+Z characters.

Fixed Length Records

In fixed-length record mode, all records in the disk file have the same specific length. Then there are no special characters embedded in the file to indicate where records begin or end. Records are contiguous and may freely cross the threshold of 512-byte sectors.

Fixed-length record mode is selected by setting the record length parameter in the FOPEN_ keyword to the size of the record, in bytes. WRITE keywords pad data records with zero bytes or truncate records as necessary to make the record length the size specified. No other data bytes are appended and the /S format control specifier has no effect.

In fixed-length mode, READ keywords always return records of the specified length. If the length of the file is such that it cannot be divided into an even number of records, a READ of the last record will be padded with zero bytes to make it the correct length.

Sequential Access Files

Normally, the records within a disk file are accessed in order from the beginning to the end without skipping any records. Such files are called sequential files. Sequential-access files may contain either variable-length or fixed-length records.

Random Access Files

eV+ supports random access only for files with fixed-length records. Random access is selected by setting the random-access bit in the mode parameter of the FOPEN_ keyword. A nonzero record length must also be specified.

A specific record is accessed by specifying the record number in a READ or WRITE keyword. If the record number is omitted, or is zero, the record following the one last accessed is used.

Records are numbered starting with 1. The position of the first byte in the random-access record can be computed with the statement below.

```
byte_position = 1 + (record_number -1) * record_length
```

Buffering and I/O Overlapping

All physical disk I/O occurs as 512-byte sector reads and writes. Records are unpacked from the sector buffer on input and additional sectors are read as needed to complete a record. To speed up read operations, eV+ automatically issues a read request for the next sector while it is processing the current sector. This request is called a preread.

Preread is selected by default for both sequential-access and random-access modes. It can be disabled by setting a bit in the mode parameter of the FOPEN_ keyword. If prereads are enabled, opening a file for read access immediately issues a read for the first sector in the file.

Preread operations may actually degrade system performance if records are accessed in truly random order, since sectors would be read that would never be used. In this case, prereads should be disabled and the FSEEK keyword should be used to initiate a preread of the next record to be used.

Additional Information: The function IOSTAT(lun, 1) returns the completion status for a pending preread or FSEEK operation.

On output, records are packed into sector buffers and written after the buffers are filled. If no-wait mode is selected for a write operation by using the /N format control specifier, the WRITE keyword does not wait for a sector to be written before allowing program execution to continue.

In random-access mode, a sector buffer is not normally written to disk until a record not contained in that buffer is accessed. The FEMPTY keyword empties the current sector buffer by immediately writing it to the disk.

A file may be opened in non-buffered mode, which is much slower than normal buffered mode, but it guarantees that information that is written will not be lost due to a system crash or power failure. This mode was intended primarily for use with log files that are left opened over an extended period of time and intermittently updated. For these types of files, the additional significant overhead of this mode is not as important as the benefit.

When a file is being created, information about the file size is not stored in the disk directory until the file is closed. Closing a file also forces any partial sector buffers to be written to the disk. Aborting a program does not force files associated with it to be closed. The files are not closed and the directory is not updated until a KILL keyword is executed or until the aborted program is executed again.

Chapter 4: Motion Control Operations

This section describes motion control operations with the eV+ system.

4.1 Motion Control Overview

eV+ executes motion control statements immediately and does not wait for motion to complete before continuing to the next statement. This forward processing is the normal method for basic motion control operations.

> **Additional Information**: The forward processing behavior can be changed by breaking continuous-path operation. Refer to Continuous-Path Trajectories on page 34 for more information.

In the example below, if the CP system switch is ON, the output signal 1 will turn ON immediately after the robot begins motion commanded by the first MOVE statement. The second MOVE statement will not be executed until the first MOVE to location "part.1" is complete. Signal 2 will turn ON immediately after the robot begins moving to location "part.2".

```
MOVE part.1
SIGNAL 1
BREAK
MOVE part.2
SIGNAL 2
```

4.2 Joint-interpolated Motion vs. Straight-line Motion

The path a robot takes when moving from one location to another can be either a joint-interpolated motion or a straight-line motion. Joint-interpolated motions move each joint at a constant velocity (except during the acceleration / deceleration phases) and are limited by the slowest joint.

Straight-line motions ensure that the robot tool tip traces a straight line from location-to-location in applications that are path sensitive.

The following statement will cause the robot to move to the location "pick" using joint-interpolated motion.

```
MOVE pick
```

The following statement will cause the robot to move to the location "pick" using straight-line motion.

```
MOVES pick
```

4.3 Safe Approaches and Departures

In many cases it is necessary to approach a location from a distance offset along the tool Z-axis or depart from a location along the tool Z-axis before moving to the next location.

The example below will cause the robot to safely approach and depart the "place" location with a 50 mm Z-axis distance. The robot will move with joint-interpolated motion with the following sequence.

1. Move to a location 50 mm above the "place" location.
2. Move down in the Z direction to the "place" location.
3. Move up in the Z direct 50 mm above the "place" location.

```
APPRO place, 50
MOVE place
DEPART 50
```

IMPORTANT: The APPRO operation is relative to the location specified and the DEPART operation is relative to the current tool orientation. For robots with 4 degrees of freedom using tool offsets of format X, Y, Z, 0, 180, Roll, the behavior of these keywords will be similar with motion aligned with the robot World Z-axis. For robots with 6 degrees of freedom or robots with 4 degrees of freedom using tool offsets with a different orientation in yaw and pitch, the behavior of these keywords will be different, and motion may not be aligned with the robot World Z-axis.

NOTE: Using the keywords APPROS, DEPARTS, and MOVES in the example above will cause the same sequence but with straight-line motion instead.

4.4 Continuous-Path Trajectories

Making smooth transitions between motion segments without stopping the robot motion is called continuous-path operation. This is the normal method eV+ uses to perform robot motions. If desired, continuous-path operation can be disabled with the CP system switch keyword. When the CP switch is disabled, the robot decelerates and stops at the end of each motion segment before beginning to move to the next location.

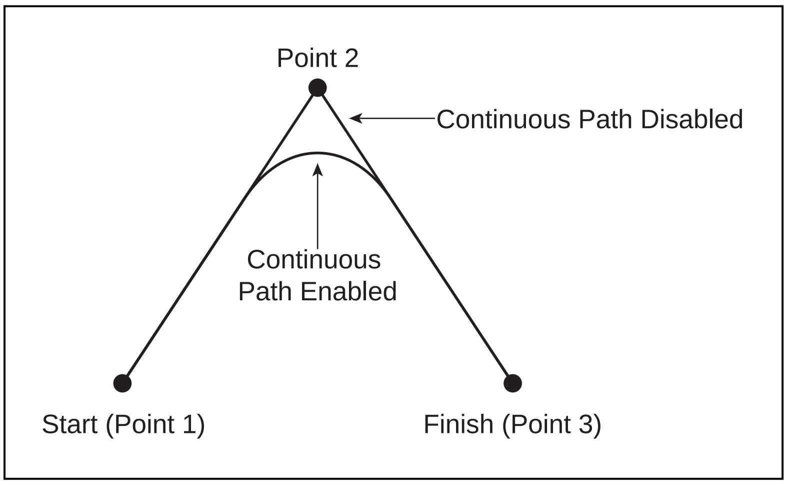


Figure 4-1. Continuous Path Enabled / Disabled

NOTE: Disabling continuous-path operation does not affect forward processing.

When a single motion keyword such as MOVE is executed by eV+, the robot begins moving toward the location by accelerating smoothly to the commanded speed. When the robot is close to the destination, the robot decelerates smoothly to a stop at the location specified. This motion is referred to as a single motion segment. The following statement will produce a single motion segment to a location defined as "pick".

```
MOVE pick
```

When a sequence of motion keywords are executed by eV+, the robot begins moving towards the first location by accelerating smoothly to the commanded speed. When the robot is close to the first destination, it does not decelerate to a stop. It will seamlessly transition with a trajectory towards the next location with a behavior referred to as blending. When the first motion segment reaches the deceleration portion of the motion, the robot will begin the acceleration portion of the next motion segment. The shape of the blended motion is determined by many parameters including the length, acceleration profiles, acceleration, deceleration, and speeds of both motion segments. The robot will decelerate to a stop when it reaches the last location in the sequence. The following statement demonstrates this and will produce a continuous-path trajectory with motion blending past the first location and then decelerating to a stop at the second location.

```
MOVE loc.1
MOVE loc.2
```

> **Additional Information**: Continuous-path transitions can occur between any combination of straight-line and joint-interpolated motions. For example, a continuous motion could consist of a straight-line motion with the DEPARTS keyword followed by a joint-interpolated motion with the APPRO keyword and a final straight-line motion with the MOVES keyword. Any number of motion segments can be combined this way.

> **NOTE:** The example above will decelerate to a stop between moves if the CP system switch is disabled. Refer to Using System Switch Keywords on page 20 for more information.

4.5 Breaking Continuous-Path Operation

Certain program command keywords cause program execution to be suspended until the current robot motion reaches its destination location and comes to a stop. This is called breaking continuous path. This functionality is useful when the robot must be stopped while some operation is performed (for example, closing the end-effector).

The following example demonstrates breaking the continuous path.

```
MOVE loc.1
BREAK
SIGNAL 1
```

In the example above, the MOVE keyword makes the robot move to "loc.1". Program execution continues and the BREAK operation is executed. This causes the program execution to temporarily stop forward processing of the program until the move to "loc.1" is completed. After the move is completed, the SIGNAL 1 operation is executed and the signal is turned ON.

> **Additional Information**: The keywords BREAK, CPOFF, DETACH(0), HALT, OPENI, PAUSE, and TOOL cause eV+ to suspend program execution until the robot stops.
>
> The robot decelerates to a stop when the BRAKE keyword is executed or when the REACTI operation is executed. These events could happen at any point within a motion segment.

The robot decelerates to a stop if no new motion control operation is executed before the current motion completes. This situation can occur with the following conditions.

- A WAIT or WAIT.EVENT keyword is executed if the condition is not satisfied before the robot motion completes.

- A PROMPT keyword is executed and no response is entered before the motion completes.
- Keyword execution between the motion operations takes longer to execute than the robot takes to perform its commanded motion.

4.6 Procedural Motion

The ability to move in straight lines and joint-interpolated arcs is built into the basic operation of eV+. The robot tool can also move along a path that is prerecorded, or described by a mathematical formula. These motions are performed with procedural motion.

Procedural motion utilizes a program loop that computes many short motions and issues the appropriate motion requests. The path is typically computed and stored in a array before starting the loop. The parallel execution of robot motions and non-motion keywords allows each successive motion to be defined without stopping the robot. The continuous-path feature of eV+ automatically smooths the transitions between the computed motion segments.

The following example demonstrates procedural motion where the robot tool is moved along a trajectory described by locations stored in the array path[]. The LAST keyword is used to determine the size of the array. The robot tool moves at the constant speed of 0.75 inch per second through each location defined in the array path[].

```
SPEED 0.75 IPS ALWAYS
FOR index = 0 TO LAST(path[])
    MOVES path[index]
END
```

Alternatively, it is common to space the locations equidistant along the path, increase the accleration / deceleration, and use the DURATION keyword to control the time the motion will take to complete the move to the next point. This will effectively define the velocity based on the distance between any two points in the path.

The following example demonstrates procedural motion where the robot tool is moved along a circular arc. The path is not prerecorded and it is described mathematically, based on the radius and center of the arc to be followed.

The program segment below assumes that a real variable radius has already been assigned the radius of the desired arc, and "x.center" and "y.center" have been assigned the respective coordinates of the center of curvature.

The variables start and last are assumed to have been defined to describe the portion of the circle to be traced. Finally, the variable "angle.step" is assumed to have been defined to specify the angular increment to be traversed in each incremental motion. Because the DURATION keyword is used, the program moves the robot tool "angle.step" degrees around the arc every 0.5 seconds.

When this program segment is executed, the X and Y coordinates of points on the arc are repeatedly computed. They are then used to create a transformation that defines the destination for the next robot motion segment.

```
DURATION 0.5 ALWAYS
FOR angle = start TO last STEP angle.step
    x = radius*COS(angle)+x.center
    y = radius*SIN(angle)+y.center
    MOVE TRANS(x, y, 0, 0, 180, 0)
END
DURATION 0 ALWAYS
```

Additional Information: It may be useful to increase acceleration during the procedural motion so that the program acceleration does not constrain the motion.

4.7 Motion Control Timing Considerations

Because of the computation time required by eV+ to perform the transitions between motion segments, there is a limit on how closely spaced commanded locations can be. When locations are too close together, there is not enough time for eV+ to compute and perform the transition from one motion to the next and there will be a break in the continuous-path motion. This means that the robot stops momentarily at intermediate locations.

The minimum spacing that can be used between locations before this effect occurs is determined by the time required to complete the motion from one location to the next. Straight-line motions can be used if the motion segments take more than twice the trajectory period each. Joint-interpolated motions can be used with motion segments as short as about one single trajectory period each.

4.8 Robot Speed and Performance

Robot speed is referred to in this manual as how fast the robot moves between the acceleration and deceleration phases of a motion. It can also be considered as the magnitude of the constant velocity portion of the velocity profile. Robot speed is sometimes more generally referred to as how fast the robot gets from one position to another (referred to in this manual as robot performance).

Robot Speed

The speed of a robot move based on full speed is determined by program speed and monitor speed as described below. With monitor speed and program speed set to 100, the robot moves at its full speed. With monitor speed set to 50 and program speed set to 50, the robot moves at 25% of its full speed.

- The program speed set with the SPEED program command keyword. This speed is set to 100 when program execution begins.
- The monitor speed set with the SPEED monitor command keyword or a SPEED program command keyword that specifies "MONITOR" in the units parameter. This speed is normally set to 50 at system startup. Monitor speed can also be set with the Sysmac Studio.

Additional Information: The effects of the two SPEED operations above are different. Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information. Refer to *Sysmac Studio Robot Integrated System Building Function with Robot Integrated CPU Unit Operation Manual (Cat. No. W595)* for information about setting an initial monitor speed that takes effect on boot up.

A robot move has the following three phases.

1. Acceleration phase where the robot accelerates to the maximum speed specified for the move.
2. Velocity phase where the robot moves at a rate not exceeding the specified maximum speed. The robot may not reach the specified maximum speed based on the acceleration / deceleration values and the distance of the move.
3. Deceleration phase where the robot decelerates to a stop (or transitions to the next motion).

The robot speed between the acceleration and deceleration phases is specified as either a percentage of full speed or an absolute rate of travel of the robot tool tip. Speed set as a percentage of full speed is the default specification.

Robot End-effector / Tool Tip Speed Considerations

To move the robot tool tip at an absolute rate of speed, a speed rate in inches per second or millimeters per second is specified in the SPEED program command keyword as shown in the example below. This example specifies an absolute tool tip speed of 25 millimeters per second for all robot motions until the next SPEED keyword is executed.

```
SPEED 25 MMPS ALWAYS
```

In order for the tool tip to move at the specified speed, the following must be considered.

- The monitor speed must be 100.
- The locations must be far enough apart so that the robot can accelerate to the desired speed and decelerate to a stop at the end of the motion.

Robot Performance

Robot performance is a function of the SPEED keyword settings and the following factors.

- The robot acceleration profile and ACCEL settings must be considered. The ACCEL keyword can scale down these maximum rates so that the robot acceleration and / or deceleration takes more time.
- SCALE.ACCEL and SCALE.ACCEL.ROT system switche states have an impact on robot performance. Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information.
- You can also define optional acceleration profiles that alter the rate of change for acceleration and deceleration.
- The location tolerance settings (COARSE / FINE, NULL / NONULL) for the move must be considered. The more accurately a robot must get to the actual location, the more time the move will take.
- Any DURATION setting must be considered. DURATION forces a robot move to take a minimum time to complete regardless of the SPEED settings.
- The maximum allowable velocity must be considered. Maximum velocity is factory set.
- The inertial loading of the robot and the tuning of the robot must be considered.
- Straight-line vs. joint-interpolated motions must be considered. Straight-line and joint-interpolated paths produce different dynamic responses and therefore different motion times.

Additional Information: Robot performance for a given application can be greatly enhanced or severely degraded by these settings. For example, a heavily loaded robot may actually show better performance with slower SPEED and ACCEL settings which lessens overshoot at the end of a move and allows the robot to settle more quickly. Applications such as picking up bags of product with a vacuum gripper do not require high accuracy and can generally run faster with a COARSE tolerance.

4.9 Motion Modifiers

The following keywords modify the characteristics of individual motions.

- ABOVE / BELOW
- ACCEL
- BREAK
- COARSE / FINE
- CPON / CPOFF
- DURATION
- FLIP / NOFLIP
- LEFTY / RIGHTY
- NOOVERLAP / OVERLAP
- NULL / NONULL
- BRAKE
- SINGLE / MULTIPLE
- SPEED

Additional Information: Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information.

Chapter 5: Variables and Data Types

This section describes variable creation and use for the eV+ system.

5.1 Variable Creation

Variables and their data types can be declared explicitly or with their first use in a program. The first use of a variable determines its data type and allocates storage for that variable. This method is referred to as dynamic allocation. Numeric data types, string data types, and transformation arrays up to three dimensions can be created with dynamic allocation.

To explicitly create a new variable without relying on dynamic allocation, simple statements can be used as shown below. If the variable has already been defined, the following statements will only assign new values to them.

```
real_var = 13.65

$string1 = "ABC123"
```

5.2 Variable Classifications

Variables can have a classification of External, Global, Local, or Automatic. This classification determines how a variable can be used and altered by different calling instances of a program.

Variable definition statements must occur at the top of a program before other keyword statements. Only the .PROGRAM statement, comments, and blank lines may appear before a variable definition statement.

Additional Information: Once a variable has been assigned to a classification, an attempt to assign the variable to a different classification will result in the error *Attempt to redefine variable class*.

NOTE: Variable declaration statements with the AUTO keyword cannot be added to a program that is currently running as a task on the stack. A program must be stopped and removed from the stack before adding additional AUTO variables is possible.

Use the information in this section to understand variable classification details.

Variable Classification Scope

The scope of a variable refers to the range of programs that can access that variable. The following figure shows the scope of the different variable classifications.

A variable can be altered by the program(s) indicated in the area of the box it is in plus any programs that are in smaller boxes.

NOTE: When a program defines an External, Automatic, or Local variable, any Global variables of the same name created in other programs are not accessible.

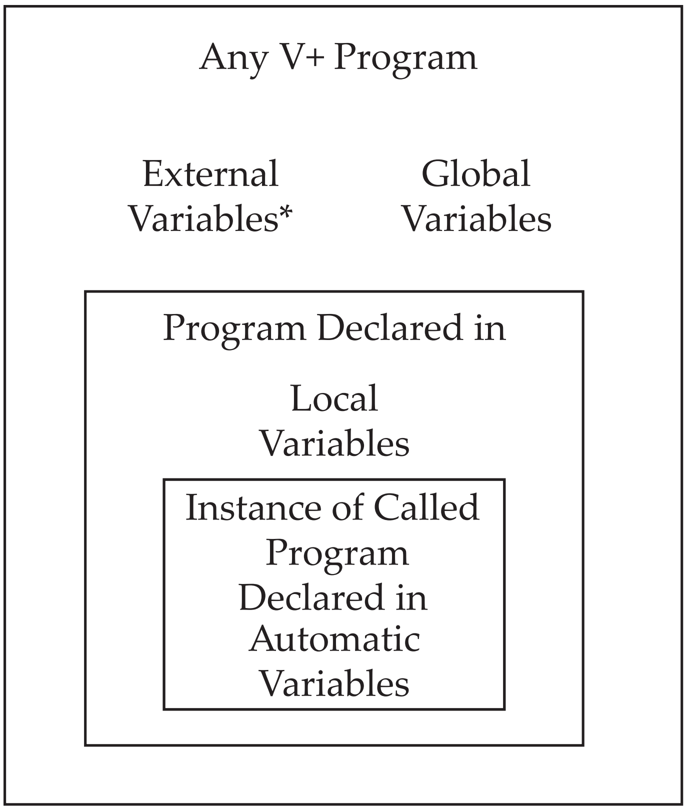


Figure 5-1. Variable Scoping

NOTE: External variables can only be used in a V+ Program when defined in the NJ-series Robot Integrated CPU Unit. Refer to External Variables on page 43 for more information.

Use the figure below to understand Global, Local, and Auto variable definitions when various program calls are made.

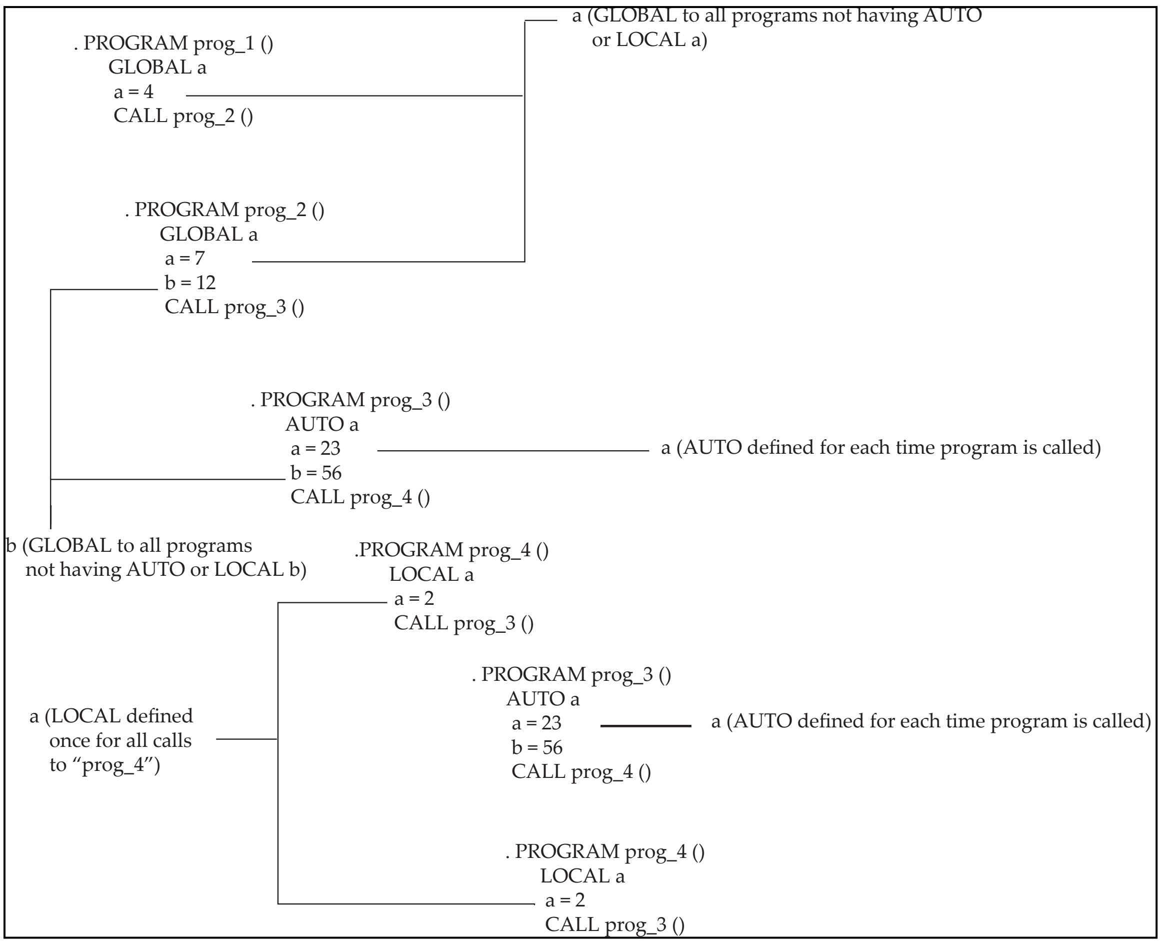


Figure 5-2. Variable Scope Example

External Variables

External variables are shared between the eV+ system and the NJ-series Robot Integrated CPU Unit. To use External variables, they must be defined in the NJ-series Robot Integrated CPU Unit and the eV+ system.

The EXTERNAL program command keyword is used to define External variables in the eV+ system. After the External variables are defined, they can be used in any V+ program executed in any task.

Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information about use of the EXTERNAL program command keyword. Refer to the *Sysmac Studio Robot Integrated System Building Function with Robot Integrated CPU Unit Operation Manual (Cat. No. W595)* for more information about External variable use with the NJ-series Robot Integrated CPU Unit.

Use the following considerations when creating External variables.

- A previously defined External variable will become unavailable if it is deleted or all V+ programs that reference it are removed from system memory (using a DELETE or ZERO keyword).
- External variables can be accessed from V+ programs and with the Monitor Window in the same way as Global variables.
- The name of the variables must be the same in the eV+ system and in the NJ-series Robot Integrated CPU Unit.
- Variable names must begin with a letter.

- Variable names can only use 0-9, a-z, period, or underscore character types.
- The maximum length of a variable name is 15 bytes. Only the first 15 characters in a variable name are significant.
- External variables cannot be defined with the same name of other variable classifications (GLOBAL, AUTO, LOCAL) in the same program. In the event an External and Global variable with the same name are defined in the eV+ system, an error will occur when the duplicated variable name is defined.
- When defining a new External variable within a V+ program, the EXTERNAL statement must precede any executable program statements other than comment lines or other variable type definition statements.
- External variables defined as an array must have an array size of 0 to 99. The array size is defined in the NJ-series Robot Integrated CPU Unit. Refer to the *Sysmac Studio Robot Integrated System Building Function with Robot Integrated CPU Unit Operation Manual (Cat. No. W595)* for more information.

External Variable Data Types

The External variable type and array size is defined in the NJ-series Robot Integrated CPU Unit. The eV+ system will automatically use the External variable as a double-precision data type. String, structure, variable length arrays, and other data types are not supported.

Errors Associated with External Variables

An error will occur during V+ program execution if any of the following conditions are present.

- An *Undefined program or variable name* (-406) error will occur if the External variable does not exist in the NJ-series Robot Integrated CPU Unit.
- An *Illegal array index* (-404) will occur if the array limits are exceeded [0 to 99].
- An *Illegal array index* (-404) will occur if the variable types differ between the eV+ definition and the NJ-series Robot Integrated CPU Unit.
- A *Variable type mismatch* (-465) will occur if the External variable types are not supported.

Global Variables

Global variables are available for use across all executing programs. Unless a variable has been defined as auto, local, or external, it will be considered global with the following considerations.

- Defining the same variable as local or auto in a program will override the variable's global classification.
- The global variable will persist in memory and will be available to any executing program until the variable is deleted or all programs that reference the variable are removed from system memory using the DELETE or ZERO keyword operations.

A global variable can be explicitly defined using the GLOBAL program command keyword as shown in the example below.

```
GLOBAL LOC my.loc
GLOBAL REAL my.real
GLOBAL DOUBLE my.double
GLOBAL $my.string
GLOBAL %my.beltvar
```

IMPORTANT: Global variables are very powerful and should be used selectively. Good programming practice suggests using local and automatic variables instead of global variables whenever possible.

Local Variables

Local variables are available only within an executing program that defines it. Local variables have the following properties.

- Local variables are local to all copies (calling instances) of a program, not just a particular calling instance of that program.
- A local variable can be referenced only within its own program.
- If a variable is listed in a LOCAL statement, any global variable with the same name cannot be accessed directly by that program.
- The names of local variables can be selected without regard for the names of local variables defined in other programs.
- Local variables can be changed only by the program in which they are defined.
- Local variables are allocated only once during program execution and their values are preserved between successive subroutine calls. These values are also shared if the same program is executed by multiple program tasks.
- The values of local variables are not saved or restored by the STORE or LOAD monitor command keywords.

IMPORTANT: If a program that uses local variables is called by several different program tasks or called recursively by a single task, the values of those variables can be modified by the different program instances and cause unpredictable program errors. Therefore, automatic variables should be used for all temporary local variables to minimize the chance of errors. Refer to Automatic Variables on page 45 for more information.

NOTE: Do not confuse a location variable (LOC) with a local variable (LOCAL).

A local variable can be explicitly defined using the LOCAL program command keyword as shown in the example below.

```
LOCAL LOC my.loc
LOCAL REAL my.real
LOCAL DOUBLE my.double
LOCAL $my.string
LOCAL %my.beltvar
```

Automatic Variables

An automatic variable is automatically created when the program that defines it is executed. It is defined only within the current program. Automatic variables have the following properties.

- An automatic variable can be referenced only by the specific calling instance of a program.
- An automatic variable has an undetermined value when a program is initially executed and has no value after the program exits.

- If a variable is listed in an AUTO statement, any global variables with the same name cannot be accessed directly by the program.
- The values of automatic variables are not saved or restored by the STORE or LOAD monitor command keywords.
- The names of automatic variables can be selected without regard for the names of variables defined in any other programs.
- Automatic variables are allocated each time the program is called and their values are not preserved between successive subroutine calls.
- A separate copy of an automatic variable is created each time a program is called, even if it is called simultaneously by several different program tasks or called recursively by a single task.
- The storage space for automatic variables is allocated on the program execution stack. If the stack is too small for the number of automatic variables defined, the task execution will stop.
- Automatic variables cannot be deleted with the DELETE_ program command keywords.

An automatic variable can be explicitly defined using the AUTO program command keyword as shown in the example below.

```
AUTO LOC my.loc
AUTO REAL my.real
AUTO DOUBLE my.double
AUTO $my.string
AUTO %my.beltvar
```

5.3 Variable Name Requirements

Use the following requirements when creating new variable names.

- Keywords cannot be used as variable names. Do not name variables the same as any keywords.
- Variable names must begin with a letter.
- Only letters, numbers, periods, and the underscore character (_) may be used in variable names.
- Variable names are limited to 15 characters in length. Variable name designations over 15 characters will automatically truncate without warning. For example, the variable name "variable_name_too_long" will automatically truncate to "variable_name_t".
- Because the eV+ system automatically creates default system variable names, avoid creating variable names that begin with two or three letters followed by a period to prevent coincidental variable name duplications. For example, sv.error, tsk.idx, and tp.pos1 are variable names that should be avoided.

5.4 Variable Initialization

Before a variable can be used it must be initialized. String and numeric variables can be initialized by placing them on the left side of an assignment statement. Use the following considerations when initializing variables.

- A variable can never be initialized on the right side of a statement.
- Strings, numeric variables, and location variables can be initialized by being loaded from a disk file.
- Strings and numeric variables can be initialized with the PROMPT keyword.

- Transformations and precision points can be initialized with the SET or HERE program command keywords. They can also be initialized with the HERE monitor command keyword or with the teach pendant.

The following statements initialize the variables "var_one" and "$var_two".

```
var_one = 36
$var_two = "two"
```

The following statement initializes "var_one" if "var_two" has already been initialized. If this statement is executed when "var_two" has not been initialized, an *Undefined value* error will be returned.

```
var_one = var_two
```

The following statement is valid only if "var_one" has been initialized in a previous statement.

```
var_one = var_one + 10
```

5.5 Variable Operators

The information in this section provides variable operator details.

Assignment Operators

The equal sign (=) is used to assign a value to a numeric or string variable. The variable being assigned a value must appear by itself on the left side of the equal sign. The right side of the equal sign can contain any initialized variable or value of the same data type as the left side, or any expression that resolves to the same data type as the left side.

Any variables used on the right side of an assignment operator must have been previously initialized. Location variables require the use of the SET keyword for a valid assignment statement.

The following statement is unacceptable for location and precision-point variables.

```
loc_var1 = loc_var2
```

eV+ can resolve an unknown transformation used in a compound transformation on the left side of an assignment operator. This is useful when initializing location variables relative to other frames. In the following example, "slot.offset" will be initialized as TRANS (200,200,200,0,0,0).

```
SET pallet_frame = TRANS(100,100,100,0,0,0)
SET taught_loc = TRANS(300,300,300,0,0,0)
SET pallet_frame:slot.offset = taught_loc
```

Mathematical Operators

The following mathematical operators are available for use.

Table 5-1. Mathematical Operators

Operator	Function
+	Addition
-	Subtraction or unary minus

Operator	Function
*	Multiplication
/	Division
MOD	Modular (remainder) division

Relational Operators

Relational operators are used in expressions that yield a boolean value. The resolution of an expression containing a relational operator is always -1 (true) or 0 (false) and indicates if the specific relation stated in the expression is true or false.

NOTE: A relational operator never changes the value of the variables on either side of the relational operator.

The most common use of relational expressions is with the control structures. eV+ uses the standard relational operators shown in the following table.

Table 5-2. Relational Operators

Operator	Function
==	Equal to
<	Less than
>	Greater than
<= or =<	Less than or equal to
>= or =>	Greater than or equal to
<>	Not equal to

The following boolean statements resolve to -1 (true) when "x" has a value of 6 and "y" has a value of 10.

```
x < y
y >= x
y <> x
```

The following boolean statements resolve to 0 (false) when "x" has a value of 6 and "y" has a value of 10.

```
x > y
x <> 6
x == y
```

Observe the difference between the assignment operator "=" and the relational operator "==" in the example below. In this statement, "z" is assigned a value of 0 since the boolean expression "x==y" is false and resolves to 0.

```
z = x == y
```

Logical Operators

Logical operators affect the resolution of a boolean variable or expression and combine several boolean expressions so they resolve to a single Boolean value. eV+ uses the standard logical operators shown in the following table.

Table 5-3. Logical Operators

Operator	Function
NOT	Complement the expression or value. Makes a true expression or value false. Makes a false expression or value true.
AND	Both expressions must be true before the entire expression is true.
OR	Either expression must be true before the entire expression is true.
XOR	One expression must be true and one must be false before the entire expression is true.

The following statements resolve to -1 (true) when "x" has a value 6 and "y" has a value of 10.

```
NOT(x == 7)
(x > 2) AND (y =< 10)
```

The following statements resolve to 0 (false) when "x" has a value 6 and "y" has a value of 10.

```
NOT(x == 6)
(x < 2) OR (y > 10)
```

String Operators

Strings can be concatenated (joined) using the plus sign.

The following statement results in the variable "$full_name" having the value "Omron Robotics and Safety Technologies, Inc."

```
$name = "Omron Robotics "
$incorp = ", Inc."
$full_name = $name + "and Safety Technologies" + $incorp
```

Order of Evaluation

Expressions containing more than one operator are not evaluated in a simple left to right manner. The following table lists the order in which operators are evaluated.

Within an expression, functions are evaluated first with operator priority according to the table. The order of evaluation can be changed using parentheses. Operators within each pair of parentheses, starting with the most deeply nested pair, are completely evaluated according to the rules in the following table before any operators outside the parentheses are evaluated. Operators on the same row of the table are evaluated strictly left-to-right.

Table 5-4. Operator Priority Levels

Priority Level	Operator
Highest	NOT, COM
...	- (Unary minus)
	*, /, MOD, AND, BAND
	+, -, OR, BOR, XOR, BXOR
Lowest	==, <=, >=, <, >, <>

Operator Evaluation Order Examples

Use the examples below to understand the operator order of evaluation in expressions.

The following example demonstrates evaluation priority for operators on different priority levels. Execution of this statement results in "1 + 1 x 3 = 4" displayed in the Monitor Window.

```
TYPE "1 + 1 x 3 = ", 1 + 1 * 3
```

The following example demonstrates the use of parentheses to change evaluation priority for operators on different priority levels. Execution of this statement results in "(1 + 1) x 3 = 6" displayed in the Monitor Window.

```
TYPE "(1 + 1) x 3 = ", (1 + 1) * 3
```

The following example demonstrates simple left-to-right evaluation priority for operators with the same priority level. The statement is evaluated from left-to-right and results with "10 MOD 3 AND 10 MOD 3 = 2 displayed in the Monitor Window.

```
TYPE "10 MOD 3 AND 10 MOD 3 = ",10 MOD 3 AND 10 MOD 3
```

5.6 Numeric Representation

Numeric values can be represented in the standard decimal notation or in scientific notation, as described in the previous section. Numeric values can also be represented in octal, binary, and hexadecimal form. The following table shows the required form for each integer representation.

Prefix	Representation	Example
None	Decimal	-193
^B	Binary with a maximum of 8 bits	^B1001
^	Octal	^346
^H	Hexadecimal	^H23FF
^D	Double-precision	^D20000000

NOTE: eV+ does not have a specific logical (Boolean) data type. Any numeric value, variable, or expression can be used as a logical data type. eV+ considers 0 to be false and any other value to be true. Refer to Logical Constants on page 52 for more information.

Numeric Expressions

In almost all situations where a numeric value of a variable can be used, a numeric expression can also be used. The following examples result in variable "x" having the same value of 3.

```
x = 3
x = 6/2
x = SQRT(9)
x = SQR(2) - 1
x = 9 MOD 6
```

5.7 String Data Types

Variables that include string data are preceded by a dollar sign ($). Values assigned to string variables must be enclosed with quotes. The following limitations exist with string variable values.

- A string variable can be assigned any ASCII value ranging from 32 (space) to 126 (~) with the exception of 34 (").
- Strings can contain up to 128 characters.
- String variables can contain values from 0 to 255.

NOTE: The dollar sign is not included in the 15 character limit for variable names.

The following statement will create a new variable with the name "string_variable" if the variable does not already exist, and a value of "ABC123" will be assigned to it.

```
$string_variable = "ABC123"
```

The following statement will return an error because an attempt to assign a real value to a string variable was made (refer to the $ENCODE keyword in the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information.

```
$string_variable = 123.0
```

ASCII Values

An ASCII value is the numeric representation of a single ASCII character. An ASCII value is specified by prefixing a character with an apostrophe ('). Any ASCII character from the space character (decimal value 32) to the tilde character (7e, decimal value 126) can be used as an ASCII constant. The following are valid ASCII constants.

```
'A    '1    'v    '%
```

Additional Information: The ASCII value '1 (decimal value 49) is not the same as the integer value 1 (decimal value 1) and not the same as the string value "1".

5.8 Real Integer Data Types

Numbers that have a whole number and a fractional part (or mantissa and exponent if the value is expressed in scientific notation) belong to the data type real. Numeric values having only a whole number belong to the data type integer. In general, eV+ does not require differentiation between these two data types.

If an integer is required and a real value is supplied, eV+ converts the real to an integer by rounding (not truncation). Where real values are required, eV+ considers an integer a special case of a real that does not have a fractional part.

The default real type is a signed, 32-bit IEEE single-precision number. Real values can also be stored as 64-bit IEEE double-precision numbers if they are specifically typed using the DOUBLE keyword.

Real and Integer Value Ranges

Use the ranges below when assigning values to real and integer variables.

Table 5-5. Real and Integer Value Ranges

Data Type	Range
Integer	-16,777,216 to 16,777,215

Data Type	Range
Single-precision Real	-1E+38 to 1E+38 with 24 bits of precision
Double-precision Real	-1E+307 to 1E+307 with 52 bits of precision

5.9 Logical Constants

The following logical constants are available with eV+. These constants can be used anywhere that a Boolean expression is expected.

- TRUE (resolves to -1)
- ON (resolves to -1)
- FALSE (resolves to 0)
- OFF (resolves to 0)

A logical value, variable, or expression can be used anywhere that an evaluation is required. In the following example, an input signal is evaluated. If the signal is ON (high) the variable 'dio.sample' is given the value true and the IF clause executes. Otherwise, the ELSE clause will execute.

```
dio.sample = SIG(1001)
IF dio.sample THEN
TYPE "The signal is ON"
ELSE
TYPE "The signal is OFF"
END
```

In the above example, the first two lines could be combined and replaced with the following statement.

```
IF SIG(1001) THEN
```

5.10 Location Data Types

Locations can be specified as transformations or precision points.

A transformation is a set of six components that identifies a location in cartesian space and the orientation of the motion device end-of-arm tooling at that location. A transformation can also represent the location of an arbitrary local reference frame.

Relative transformations allow you to make one location relative to another and to build local reference frames to which that transformation can be relative. For example, you may be building an assembly whose location in the workcell changes periodically. If all the locations on the assembly are taught relative to the world coordinate frame, each time the assembly is located differently in the workcell, all the locations must be retaught. If, however, you create a frame based on identifiable features of the assembly, you will have to reteach only the points that define the frame. Refer to Modifying Location Variables on page 53 for more information.

A precision point uniquely defines a location in space by including an element for each joint position of the mechanism's kinematics. A mechanism with four degrees of freedom will require precision points with four elements, while a mechanism with six degrees of freedom will require 6 elements. Rotational joint values are measured in degrees and translational joint values are measured in millimeters. These values are absolute with respect to the joint zero positions determined by the robot hardware calibration.

Creating Location Variables

The simplest method of creating a location variable is to place the robot at a location and then execute the following statement.

```
HERE loc_var
```

A location can be specified using either the six components or by specifying the state that the robot joints would be in when a location is reached. The former method results in a transformation variable. Transformations are the most flexible and efficient location variables because they can be used in various arm configurations. They can also be used in different contexts, for example, tool offsets or slot-offsets could be used in different arm positions or while accessing different pallet frames with the same pallet layout.

Precision points record the joint values of each joint of the robot. Precision points may be more accurate and they are the only way of extracting joint information that will allow you to move an individual joint. Precision points are identified by a leading pound sign (#).

The following statement will create the precision point "pick" that is equal to the current robot joint values.

```
HERE #pick
```

Modifying Location Variables

Use the following examples to understand the different methods used to modify location variables.

Additional Information: Transformations and precision points can be initialized with the SET or HERE Program Command Keywords

Duplicate a Location Variable

The following example will duplicate an existing location variable and give the value of "loc_value" to variable "loc_name".

```
SET loc_name = loc_value
```

Create Location Variables Based on Modifications to Existing Variables

The following example will create a location variable "loc_name" and shift the location 5 mm in the positive X, Y, and Z directions from the variable "loc_value".

```
SET loc_name = SHIFT(loc_value BY 5, 5, 5)
```

Using Relative Transformations

Use the statements below to generate locations shown in Figure 5-3. . In this figure, the transformation "loc_b" defines the transformation needed to get from the local reference frame defined by "loc_a" to the local reference frame defined by "loc_c".

The colon (:) operator used in the examples below represents a compound transformation operation. For example, loc_a:loc_b is the transformation loc_b relative to loc_a. The loc_b is a completely unique and independent location transformation as shown in Figure 5-3. , but when used relative to loc_a (whose pitch is 180 degrees), is the transformation to get to loc_c.

The following statements will define a simple transformation and then move the robot to that location.

```
SET loc_a = TRANS(300,50,350,0,180,0)
MOVE loc_a
BREAK
```

The following statements will move the robot to a location offset -50 mm in X, 20 mm in Y, and 30 mm in Z relative to "loc_a" position and orientation.

```
MOVE loc_a:TRANS(-50, 20, 30)
BREAK
```

The following statements will define "loc_b" to be the current location relative to "loc_a" where "loc_b" = -50, 20, 30, 0, 0, 0.

```
HERE loc_a:loc_b
BREAK
```

The following statements will define "loc_c" as the vector of "loc_a" and "loc_b" where "loc_c" = 350, 70, 320, 0, 180, 0.

```
SET loc_c = loc_a:loc_b
```

After the statements above are executed, "loc_b" exists as a transformation that is completely independent of "loc_a". The following statement moves the robot another -50 mm in the X direction, 20 mm in the Y direction, and 30 mm in the Z direction relative to "loc_c".

```
MOVE loc_c:loc_b
```

Multiple transformations can be associated. If we define "loc_d" to have the value of 0, 50, 0, 0, 0, 0, the following statements will move the robot to a position of X = -50 mm, Y =70 mm, and Z = 30 mm relative to "loc_a".

```
SET loc_d = TRANS(0,50)
MOVE loc_a:loc_b:loc_d
```

If the transformation is required to go in the opposite direction (from "loc_c" to "loc_a"), it can be calculated with the following statement.

```
INVERSE(loc_b)
```

The statement below will move the robot back to "loc_a".

```
MOVE loc_c:INVERSE(loc_b)
```

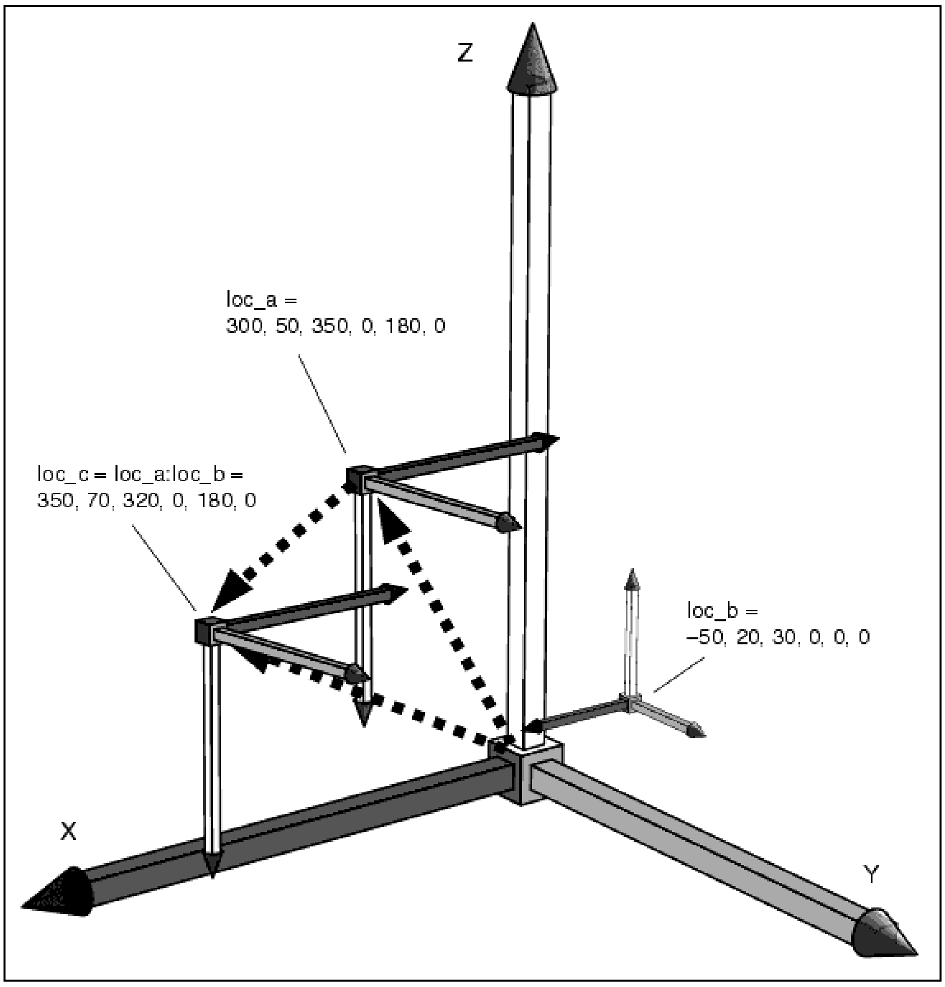


Figure 5-3. Relative Transformation

Decomposing Location Variables

In order to access the components of a location variable, the location variable must be decomposed into an array. This applies to both precision point and transformation variables.

```
DECOMPOSE jnt.angles[0] = #PHERE
DECOMPOSE curr.pos[0] = HERE
curr.z.pos = curr.pos[2]
```

5.11 Arrays

eV+ supports arrays of up to three dimensions. Any eV+ data type can be stored in an array. Unless they are declared to be automatic, array sizes do not have to be declared. In this document, row is the first element, column is the second element, and range is the third element.

NOTE: Array allocation is most efficient when the highest range index exceeds the highest column index and the highest column index exceeds the highest row index.

The following statement allocates space for a one-dimensional array named "array.one" and places the value 36 in element two of the array. The numbers inside the brackets ([ ]) are referred to as indices. An array index can also be a variable or an expression.

```
array.one[2] = 36
```

The following statement allocates space for a two-dimensional array named "array.two" and places "row 4, col 5" in row four, column five of the array.

```
        $array.two[4,5] = "row 4, col 5"
```

The following statement allocates space for a three-dimensional array named "array.three" and places the value 10.5 in row two, column two, range four.

```
        array.three[2,2,4] = 10.5
```

If any of the above statements were executed and the array had already been declared, the statment would merely place the value in the appropriate location. An error will occur if the data type of the value is differnent than the data type of the array.

The following statement results in allocation of array elements 0 to 15.

```
        any_array[2] = 50
```

The following statements result in allocation of array elements 0 to 31.

```
        any_array[2] = 50
        any_array[20] = 75
```

Global Array Access Restriction

eV+ has a feature where global and local arrays are automatically extended as they are used. For efficiency, there is no interlocking of the array extension process between multiple tasks. A crash can occur if one task is extending or deleting an array while another is trying to access it. Custom eV+ programs must be coded to avoid this problem using one of the following methods.

Method 1

If there is a known reasonable upper-bound on the array dimensions, define by assigning an arbitrary value to it the highest element of the array. For multi-dimensional arrays, assign the highest element of each possible sub-array. This assignment prevents the arrays from extending.

Method 2

Use the TAS function keyword to interlock access to the array. In this case, access to the array is handled exclusively from one or two subroutines that include the TAS to control access to the array.

5.12 Variable Context

When keywords are used to access local or automatic variables, the eV+ system must know which program's variables are to be accessed. You must specify the program context to be used. The general syntax for a command that can access local and automatic variables is shown below where "command" represents the keyword name and "parameters" represents the keyword parameters.

```
        command @task:program parameters
```

The optional element "@task:program" specifies the program context for any variables referenced in the keyword parameters. The "task" portion is an integer that specifies one of the system program tasks. The "program" portion of the context is the name of a program in the system memory.

The context can be specified in any of the formats described below. Refer to Interpretation of Context Specification for Variables on page 58 for a summary of the various context specifications that can be used.

1. "task:program" is blank ("@ " is used as syntax). The context for referenced variables will be one of the following.
   - A blank context specification in an MCS keyword. The following example indicates that the variables are treated as though they are referenced within the program containing the MCS keyword. A keyword used as in the example below can be used to delete local variables after they are used by a routine regardless of which task is assigned to the executing program.

     ```
     MCS "DELETEL @ parts[]"
     ```

   - Variables will be treated as though they are referenced within the program on the top of the stack for the robot control task (the last program listed by the STATUS keyword). For example, "STATUS 0".
2. "Task" is specified as a task number (0, 1, 2, etc.) and the portion ":program" is omitted, For example, "@1" is input. In this case, variables are treated as though they are referenced within the program on the top of the stack for the specified program task (the last program shown for that task by the STATUS keyword). For example, "STATUS 1".
3. "Task:" is omitted and "program" is specified (for example, "@sample" is used as syntax). In this case, variables are treated as though they are referenced within the most recent occurrence of the specified program on the task stack that is determined as follows.
   - If the program debugger is not in use in the Sysmac Studio, the stack for the main control task (task 0) is used.
   - If the program debugger is in use in the Sysmac Studio, the stack for the task being accessed by the debugger is used.
4. "Task:program" are both specified, where "task" is a task number (0, 1, 2, etc.), and "program" is a program name (for example, "@1:sample" is used as syntax). In this case the variables will be treated as though they are referenced within the most recent occurrence of the program on the stack for the specified program task.

When a context is specified, all the variables referenced in the statement will be considered as local or automatic in that program if applicable. Any variable referenced in the statement that is not found within that program will be considered a global variable. Because automatic variables and subroutine arguments exist only within a particular program instance and can vanish whenever that program exits, access to their values by monitor command keywords is limited by the following conditions.

- The program must be on a task stack. That is, it must appear in a program list shown by the STATUS keyword.
- The program task for the stack being referenced must not be active. This is to guarantee that the variable does not vanish while being accessed.

  NOTE: Failure to meet the conditions above results in the error message: *Undefined value in this context*.

If automatic variables or subroutine arguments need to be accessed during debugging, the desired program task can be paused, the variables accessed, and execution of the task resumed.

Interpretation of Context Specification for Variables

Use the table below to understand context specification for variables.

- "T" indicates the task that will be accessed.
- "P" indicates the program to be accessed.
- "None" indicates no specific task or program (global variables are accessed).
- "Current debug" indicates the task or program being accessed with the debugger in the Sysmac Studio.
- "Top of stack" indicates the program at the top of the execution stack for the indicated task.

Table 5-6. Context Specification for Variables

Context Specification	Interpretation When Not Using Debugger	Interpretation When Using Debugger
None	T = None	T = Current debug
	P = None	P = Current debug
@ (see note)	T = Task 0	T = Current debug
	P = Top of stack	P = Current debug
@number	T = Task number	T = Task number
	P = Top of stack	P = Top of stack
@program	T = Task 0	T = Current debug
	P = Program	P = Program
@number:program	T = Task number	T = Task number
	P = Program	P = Program

NOTE: If "@" is specified in an MCS keyword in a program, T = Current task P = Current program (top of stack).

Chapter 6: Monitor Command Programs

This section describes the functions and use of Monitor Command Programs.

6.1 Monitor Command Program Overview

Monitor Command Programs are special programs that typically consist of a series of monitor command keywords. These are used to automate system startup and other frequently executed keyword sequences. Monitor Command Programs can be started from the eV+ Monitor Window or from the teach pendant. They execute in a top-down manner from the first line to the last.

> **Additional Information**: Program command keywords can be used in Monitor Command Programs. Refer to Monitor Command Program Contents on page 59 for more information.

With the autostart feature, a Monitor Command Program can be started automatically when the system is turned ON. Monitor Command Programs are most commonly used in V+ based applications, as described in the following cases.

- At system startup, the controller autostart switch will launch the Monitor Command Program "auto" located in D:\AUTO.V2. Refer to Autostarting a Monitor Command Program on page 60 for more information.
- Monitor Command Programs can be used to save a V+ module and application variables. A Monitor Command Program will define the programs in a module and then perform a backup / save operation.

When the Sysmac Studio is used, this is not necessary because the V+ Module object saves the programs in the project. The same applies for V+ application variables contained in the V+ Global Variable Collection object.

> **Additional Information**: Refer to the *Sysmac Studio Robot Integrated System Building Function with Robot Integrated CPU Unit Operation Manual (Cat. No. W595)* for more information about V+ modules and V+ global variables.

6.2 Monitor Command Program Names

Monitor Command Program names can have up to 15 characters, must begin with a character, and can contain letters, numbers, periods, and underscore characters.

Monitor Command Programs are stored as objects in the eV+ disk file. The disk file name, not the command program name, must conform to eV+ disk file name conventions. Refer to File Name Requirements on page 12 for more information.

6.3 Monitor Command Program Contents

Normally, a Monitor Command Program contains only monitor command keywords. Program command keywords can be included by using the DO monitor command keyword if necessary. To include a program command keyword in a Monitor Command Program, use the following statement syntax.

```
MC DO keyword parameter, ...
```

Make the following considerations when creating a Monitor Command Program.

- Monitor Command Programs can contain all monitor command keywords except the DONE, TEACH and ZERO keywords.
- Control keywords (for example, GOTO and IF) are ignored in a Monitor Command Program.
- Every non-blank line of a Monitor Command Program must contain either a monitor command keyword, or a comment.

IMPORTANT: Ensure Monitor Command Program can execute correctly without operator response or intervention.

6.4 Executing Monitor Command Programs

Monitor Command Programs can be executed with the methods described below.

Executing Monitor Command Programs from the Monitor Window

Use the COMMANDS monitor command keyword to execute a Monitor Command Program from the Monitor Window.

Use the following statement to execute a Monitor Command Program named "my.cm-d.program" with the file name "my_cmd.pg".

```
LOAD my_cmd.pg
COMMANDS my.cmd.program
```

NOTE: The EXECUTE keyword expects programs that contain program command keywords and not monitor command keywords. If you use the EXECUTE keyword to execute a program with lines that begin with "MC", the program will abort and a message indicating that you cannot mix program command keywords and monitor command keywords will be returned.

Autostarting a Monitor Command Program

A Monitor Command Program will be loaded and started automatically when the controller is turned ON if the following conditions have been met.

- The autostart option must be enabled in the controller configuration settings.
- A disk file with the name "AUTO.V2" must reside on the default disk.
- The AUTO.V2 disk file must contain a program named "auto" and this program must be a Monitor Command Program. Other programs, and data, can be stored in the AUTO.V2 disk file.

If the conditions above are met, the following functions occur when the controller is powered ON.

- The eV+ operating system is loaded.
- The default disk specification is set.
- The following statements are issued automatically.

```
LOAD auto.v2
COMMANDS auto
```

eV+ does not wait for high power to be turned ON or for any other event or condition. The autostart Monitor Command Program must explicitly invoke any such functions or they must be performed by programs invoked by the Monitor Command Program. For example, if you want to require that the operator press the program start button on the controller when the Monitor Command Program is processed, you must include a WAIT.START statement in the Monitor Command Program.

Additional Information: A Monitor Command Program that is autostarted should load minimal information before executing a V+ program that can process more complicated logic and error handling.

Monitor Command Program Processing

When a Monitor Command Program is executed, it will process all of the statements until one of the following events occurs.

- The end of the Monitor Command Program is reached.
- A CYCLE.END statement is processed in the Monitor Command Program and the referenced program task is executing. This will suspend processing of the Monitor Command Program until the referenced program task finishes executing.

  NOTE: A Monitor Command Program will not be suspended when an EXECUTE statement is processed. The Monitor Command Program will initiate execution of the specified application program and then immediately continue with the next statement.

- CTRL+C is pressed. This will terminate processing of the Monitor Command Program. The statement being processed or a program invoked by the Monitor Command Program will continue to completion.
- Another Monitor Command Program is invoked from within the active command program. Unlike starting an executable program, control will not return to the first Monitor Command Program when the second Monitor Command Program completes.
- An error condition results when a statement is processing in the Monitor Command Program.

Chapter 7: V+ programs

This section describes the creation and use of V+ programs.

7.1 V+ program Format

V+ programs are used to generate robot motion and contain logic and functionality for other operations such as I/O control, data management, and various run-time tasks. V+ programs are created with program command and function keywords.

This section details the format that eV+ programs must follow. The format of the individual lines is described, followed by the overall organization of programs. This information applies to all V+ programs regardless of their intended use.

Program Lines

Each line or step of a program is interpreted by the eV+ system as a program statement. The general format of an eV+ program step has the syntax shown below.

```
step_number step_label operation ;Comment
```

The items in the syntax above are optional and described below.

Table 7-1. Program Line Item Description

Item	Description
step_number	Each step within a program is automatically assigned a step number. Steps are numbered consecutively and the numbers are automatically adjusted whenever steps are inserted or deleted. Step numbers are automatically present in V+ programs. These are used to reference V+ program errors and other program references. Step numbers are also referenced as line numbers.
step_label	Because step numbers change as a program is created, they are not useful for identifying steps for program-controlled branching. Therefore, program steps can contain a step label. A step label is a programmer-specified integer (0 to 65535) that is placed at the start of a program line to be referenced elsewhere in the program. These are typically used with GOTO statements.
operation	The operation portion of each step must be a valid statement and may contain parameters and additional keywords. Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information.
comment	The semicolon character (;) is used to indicate that the remainder of a program line is comment information to be ignored by eV+. When all the elements of a program step are omitted, a blank line results. When only the comment element of a program step is present, the step is called a comment line. Use comments to describe and explain the intent of the sections of the programs. These program notations will make it easier to modify and debug programs. **NOTE:** Blank program lines are acceptable in eV+ programs.

Item	Description
	Blank lines are often useful to separate program steps to make a program easier to read.

Blank Spaces and Case

When program lines are entered, extra blank spaces can be used between any elements in the line. The eV+ editor adds or deletes spaces in program lines to make them conform with the standard spacing. The editors also automatically format the lines to uppercase for all keywords and lowercase for all user-defined names.

Additional Information: When program line is completed by entering a carriage return, moving off a line, or exiting the editor, the editor checks the syntax of the line. If the line cannot be executed, it is displayed in red within the Sysmac Studio V+ editor. Refer to the *Sysmac Studio Robot Integrated System Building Function with Robot Integrated CPU Unit Operation Manual (Cat. No. W595)* for more information.

Program Structure

The first step of every V+ program must be a .PROGRAM keyword. This keyword names the program, defines any arguments it receives or returns, and has the following format.

```
.PROGRAM program_name(parameter_list) ;Comment
```

The program_name item is required but the parameter list and comment are optional.

After the .PROGRAM statement on the first line, there are only two restrictions that apply to the order of other statements that follow.

1. AUTO, EXTERNAL, LOCAL, or GLOBAL keyword statements must precede any other normal keyword statements at the top of the program. Only comment lines, blank lines, and other AUTO, LOCAL, or GLOBAL keywords are permitted between the .PROGRAM step and an AUTO, LOCAL, or GLOBAL keyword statement.
2. The end of a program is marked by a line beginning with .END. The V+ editors automatically add this line at the end of a program.

NOTE: The .PROGRAM and .END statements are automatically inserted by the Sysmac Studio program editor. If a different program editor is used, you must manually enter these two lines. In general, any editor that produces unformatted ASCII files can be used for programming.

7.2 V+ Program Execution

The eV+ system provides for simultaneous execution of up to 64 different programs. Execution of each program is administered as a separate program task by the system. The way program execution is started depends upon the program task to be used and the type of program to be executed.

The following sections describe program execution in detail.

Program Tasks

V+ programs are executed on one of the 64 available Tasks. Task number 0 has the highest priority and is typically used for the primary application program. Task 0 is normally used to execute the primary robot control program.

When execution of Task #0 begins, the Task automatically selects robot 1 and attaches the robot as soon as a motion related keyword is encountered. Execution of Task 0 is typically started by issuing the EXECUTE monitor command keyword. The ABORT monitor command or program command keyword stops Task #0 after the current robot motion completes. The CYCLE.END monitor command or program command keyword can be used to stop the program at the end of its current execution cycle.

For normal execution of a robot control program, the system switch keyword DRY.RUN must be disabled and the robot must be attached by the robot control program. Then, any robot related error will stop execution of the program unless an error-recovery program has been established. Refer to REACTE in the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information.

If program execution stops because of an error, a PAUSE statement, an ABORT statement, the monitor command keywords PROCEED or RETRY can be used to resume execution.

> **Additional Information**: While execution is stopped, the DO monitor command keyword can be used to execute a single program statement manually as though it were the next statement in the program that is stopped.

Execution of program Tasks other than 0 is generally the same as for Task 0. The following differences apply.

- The Task number must be explicitly included in all the statements that affect program execution, including EXECUTE, ABORT, PROCEED and RETRY.
- If the program controls the robot, it must explicitly SELECT and ATTACH the robot before executing any statements that control the robot.

Exclusive Control of a Robot

Use the following considerations to understand the restrictions for exclusive control of a robot with Tasks.

- Whenever a robot is attached by an active Task, no other Task can attach that robot or execute statements that affect it, except for the REACTI and BRAKE keywords. Refer to V+ Program Interrupts on page 72 for more information.
- When the robot control Task stops execution for any reason, the robot is detached until the Task resumes at which time the Task automatically attempts to reattach the robot. If another Task has attached the robot in the meantime, the first Task cannot be resumed.
- Task 0 always attempts to attach robot 1 when program execution begins. No other Tasks can successfully attach any robot unless explicit SELECT and ATTACH statements are executed.
- Since Task 0 attempts to attach robot 1, that Task cannot be executed after another Task has attached that robot. If another Task needs to control the robot and you want to execute task 0, you must follow this sequence of events:
  1. Start Task 0.
  2. Make Task 0 DETACH robot 1.
  3. Start the Task that will control robot 1. The program executing as Task 0 can start up another Task.
  4. Make that other Task ATTACH the robot.

> **NOTE:** Robots are attached even in DRY.RUN mode. In this case, motion statements issued by the Task are ignored and no other Task can access the robot.

EtherCAT Communication Errors

EtherCAT communication errors affect Task and robot behavior as described below.

EtherCAT Network Communication Error

An EtherCAT network communication error will cause the following system behavior.

- All running tasks are stopped and it is not possible to execute any Task that requires communication with the host system. All robots will become detached.
- All robots in the network will stop with maximum deceleration and high power is disabled.

EtherCAT Node Communication Error

If network communication stops for individual nodes, the following events occur.

- Running tasks associated with the problematic node are stopped, associated robots will become detached, and it is not possible to execute any Task that requires communication with the host system.
- The robot(s) nodes that have lost communications will stop running Tasks that are attached.

V+ program Processing

Program statements are normally executed sequentially from the beginning of a program to its end. This sequential flow may be changed when a GOTO or IF...GOTO statement or a control structure is encountered.

A CALL statement causes another program to be executed, but it does not change the sequential flow through the calling program because execution of the calling program resumes where it left off when a RETURN or RETURNE statement is executed by the called program.

A WAIT statement suspends execution of the current program until a condition is satisfied. The WAIT.EVENT statement suspends execution of the current program until a specified event occurs or until a specified time elapses.

The PAUSE and HALT statements both terminate execution of the current program. After a PAUSE statement, program execution can be resumed with a PROCEED monitor command keyword. The HALT program command causes a break and then terminates execution of the application program regardless of any program loops remaining to be completed. After termination by a HALT command, program execution cannot be resumed with a PROCEED or RETRY command.

A STOP statement may or may not terminate program execution. If there are more program execution cycles to perform, the STOP statement causes the main program to be restarted at its first step even if the STOP statement occurs in a subroutine. If no execution loops remain, STOP terminates the current program. Refer to V+ Program Interrupts on page 72 for more information.

7.3 Program Control

This section introduces the structures available in eV+ and other methods used to control program execution. eV+ supports looping branching structures common to many high-level languages as well as some keywords specific to eV+.

Unconditional Branching

The following keywords are described in this section for use with unconditional branching.

- GOTO
- CALL
- CALLS

GOTO Unconditional Branching

The GOTO keyword causes program execution to branch immediately to a label somewhere else in the program. The syntax for a GOTO statement is shown below.

```
GOTO label
```

The label item above is an integer entered at the beginning of a line of program code. Label is not the same as the program step numbers. Step numbers are assigned by the system and labels are entered by the programmer as the opening to a line of code.

The following example will go to label 100 and execute the TYPE statement "The GOTO keyword got me here."

```
        GOTO 100

    100 TYPE "The GOTO Keyword got me here."
```

A GOTO statement can branch to a label that is before or after the GOTO keyword.

IMPORTANT: Use GOTO keywords with care. GOTO statements can make program logic difficult to follow and debug, especially in a long or complicated program with many subroutine calls. A common use of GOTO is as an exit routine or exit on error statement.

CALL Unconditional Branching

The CALL keyword causes program execution to be suspended and execution of a new program to begin. When the new program has completed execution, execution of the original program resumes at the statement after the CALL keyword.

The simplified syntax for a CALL statement is shown below.

```
CALL program_1(arg_list)
```

The "program_1" item above is the name of the program to be called. The program name must be specified exactly and the program being called must be resident in system memory.

The arg_list item above is the list of arguments being passed to the subroutine. These arguments can be passed either by value or by reference and must agree with the arguments expected by the program being called. Refer to Exchanging Information Using the Program Argument List on page 78 for more information.

The following example suspends execution of the calling program, passes the arguments "locx", "locy", and "length" to program "check_data", executes "check_data", and after "check_data" has completed execution, resumes execution of the calling program at the statement that follows the CALL operation.

```
CALL check_data(locx, locy, length)
```

CALLS Unconditional Branching

The CALLS keyword is identical to the CALL keyword except for the specification of program. For a CALLS keyword, the string parameter is a string value, variable, or expression. This allows you to call different subroutines under different conditions using the same line of code. These different subroutines must have the same arg_list.

The simplified syntax for a CALLS statement is shown below.

```
CALLS string(arg_list)
```

The following example suspends execution of the calling program, passes the variables "length" and "width" to the program specified by array index "program_select" from the array "$program_list", executes the specified program, and resume execution of the calling program at the next step.

```
$program_name = $program_list[program_select]

CALLS $program_name(length, width)
```

Conditional Branching

The following sections discuss program control structures whose execution depend on an expression or variable with a boolean value (a variable that is either true or false or an expression that resolves to true or false). An expression can take into account any number of variables or digital input signals as long as the final resolution of the expression is a boolean value.

Conditional branching keywords allow you to execute blocks of code based on the current values of program variables or expressions. eV+ has three conditional branch keywords.

1. IF...GOTO
2. IF...THEN...ELSE
3. CASE value OF

Any number (real or integer) can satisfy this requirement. Zero is considered false and any nonzero number is considered true. There are four system constants: TRUE and ON that resolve to -1 and FALSE and OFF that resolve to 0.

IF...GOTO Conditional Branching

IF...GOTO behaves similarly to GOTO, but a condition is attached to the branch.

The following example will branch to label 100 if the "logical_expression" is true.

```
IF logical_expression GOTO 100
```

IF...THEN...ELSE Conditional Branching

IF...THEN...ELSE will conditionally execute one of two different actions depending on the result of a logical expression.

This keyword has two forms shown below.

```
IF expression THEN
       statement
END


IF expression THEN
       statement
ELSE
       statement
END
```

In the following example, if "num_parts" is greater than 75, CALL check_num(num_parts) is executed. If "num_parts" is not greater than 75, program execution continues with the statement following END..

```
IF num_parts > 75 THEN
       CALL check_num(num_parts)
END
```

In the following example, if signal 1033 is ON and "need_part" is true, the program executes the MOVE and DEPART statements. When the IF statement is false, the TYPE statement is executed and program execution continues with the statement following END.

```
IF SIG(1033) AND need_part THEN
       MOVE loc1
       DEPART 50
ELSE
       TYPE "Part not picked up"
END
```

CASE value OF Conditional Branching

The CASE structure will allow a program to take one of many different actions based on the value of a variable. The variable used must be a real or an integer.

The form of the CASE structure is shown below. If the "list_of_values" listing of real values (separated by commas) equals "target", the statements following that value statement is executed. Statements after the ANY step will be executed when "target" is not in any "list_of_values" listing.

```
CASE target OF
       VALUE list_of_values
               statements
       VALUE list_of_values
               statements
ANY
       statements
END
```

Looping Structures

In many cases, you will want the program to execute statements more than once. eV+ has three looping structures that allow you to execute statements a variable number of times as described below.

FOR Looping Structure

A FOR keyword creates an execution loop that will execute a given block of statements a specified number of times.

The basic form of a FOR loop is shown below. This loop will start by setting "index" to the value of "start_val". The loop checks that the value of "index" is withing the range of "start_val" to "end_val". If this is true, it executes any statements within the FOR loop. After a loop is executed, the value of "index" will be incremented by the value of "incr". This continues until the value of "index" is no longer in the range of "start_val" to "end_val".

```
FOR index = start_val TO end_val STEP incr
       statement
       ...
       statement
END
```

The following example will output even elements of array "$names" up to index 32.

```
FOR i = 2 TO 32 STEP 2
       TYPE $names[i]
END
```

The following example will output the values of the 2-dimensional array "values" in column and row form (10 rows by 10 columns).

```
FOR i = 1 TO 10
       FOR j = 1 to 10
               TYPE values[i,j], /S
       END
       TYPE " ", /C1
END
```

The following example will count backward from 10 to 1 by entering a negative value for the step increment.

```
FOR i = 10 TO 1 STEP -1
       TYPE i
END
```

Changing the value of index inside a FOR loop will cause the loop to behave improperly. To avoid problems with the index, make the index variable an auto variable and do not change the index from inside the FOR loop. Changes to the starting and ending variables do not affect the FOR loop once it is executing.

> **NOTE:** FOR loops can consume unneccessary processing time by executing more frequently than necessary. To avoid this, insert a WAIT or WAIT.EVENT statement within the FOR loop.

DO...UNTIL Looping Structure

DO...UNTIL is a looping structure that executes a group of statements an indeterminate number of times. Termination of the loop occurs when the boolean expression or variable that controls the loop becomes true. The boolean value is evaluated after each execution of group of statements and if the expression becomes true, the loop is not executed again. Since the expression is not evaluated until after the statements have been executed, the code block will always execute at least once.

> **NOTE:** The expression is any boolean statement and must eventually become true or the loop executes indefinitely.

The form for this looping structure is shown below.

```
DO
       Statement
       ...
       Statement
UNTIL expression
```

The following example will output the numbers 1 to 100 to the Monitor Window.

```
x = 1
DO
       TYPE x
       x = x + 1
UNTIL x > 100
```

The following example will echo up to 15 characters to the Monitor Window. The loop will stop when 15 characters or the "#" character has been entered.

```
x = 1
DO
       PROMPT "Enter a character: ", $ans
       TYPE $ans
       x = x + 1
UNTIL (x > 15) or ($ans == "#")
```

WHILE...DO Looping Structure

WHILE...DO is a looping structure similar to DO...UNTIL except the boolean expression is evaluated at the beginning of the loop instead of at the end. This means that if the condition indicated by the expression is true when the WHILE...DO statement is encountered, the code within the loop will be executed. WHILE...DO loops are susceptible to infinite looping just as DO...UNTIL loops are. The expression controlling the loop must eventually evaluate to false for the loop to terminate.

The form of the WHILE...DO looping structure is shown below.

```
WHILE expression DO
       statement(s)
END
```

The following example shows a WHILE...DO loop being used to validate input. Since the boolean expression is tested before the loop is executed, the code within the loop will be executed only when the operator inputs an unacceptable value.

```
PROMPT "Enter a number in the range 32 to 64.", ans
WHILE (ans < 32) OR (ans > 64) DO
       PROMPT "Number must be in the range 32-64.", ans
END
```

In the above code, an operator could enter a nonnumeric value in which case the program execution would stop. A more robust strategy would be to use a string variable in the PROMPT statement and then use the $DECODE and VAL keywords to evaluate the input.

In the following example, if digital signal 1033 is ON when the WHILE statement is reached, the loop does not execute and the program continues after the END keyword. If digital signal 1033 is OFF, the loop executes continually until the signal comes ON.

```
WHILE NOT SIG(1033) DO

END
```

Loading Programs and Variables to System Memory

eV+ cannot use programs and information stored in disk files until they are loaded into system memory (RAM). A file can be loaded with the Sysmac Studio or with the LOAD monitor command keyword. Refer to the *Sysmac Studio Robot Integrated System Building Function with Robot Integrated CPU Unit Operation Manual (Cat. No. W595)* for more information.

The LOAD keyword does not actually start a program executing. It simply places a copy of the disk file contents into system RAM so additional commands can start the program, modify the program, or modify the values of the program variables.

The LOAD keyword has the following syntax.

```
LOAD my_file
```

This statement places the contents of "my_file" into RAM.

NOTE: A single disk file can include multiple programs and variable information. Refer to eV+ File Management on page 12 for more information.

Additional Information: To view all programs that have been loaded into memory, use the DIRECTORY keyword.

To view all files on the SD card, use the FDIRECTORY keyword.

Removing Programs and Variables from System Memory

When a program completes, it is not automatically removed from system memory (RAM). If an *Out of memory* error message appears while loading a disk file, the only way to complete the load operation is to delete objects from system memory. To make system memory available for use by other programs and data, objects in memory must be specifically removed with a DELETE keyword.

NOTE: The LOAD keyword will not overwrite programs that reside in system memory. Therefore, if you want to load new programs with identical names, you must delete the programs currently in system memory.

Objects do not have to be removed from system memory before different disk files are loaded and other programs are executed, unless you are loading a program with the same name as one already in system memory.

The DELETE keyword does not delete a program that is being executed or is present on the stack for any task. The DELETE keyword does not affect the disk files from which the objects were loaded. After objects have been removed from system memory, they can be reloaded using the LOAD command.

7.4 V+ Program Interrupts

eV+ provides several ways of suspending or terminating program execution.

- A program can be put on hold until a specific condition becomes TRUE using the WAIT keyword. This may not be the most efficient use of processor time. Refer to WAIT.EVENT Program Interrupts on page 73 for more information.
- A program can be put on hold for a specified time period or until an event is generated in another task by the WAIT.EVENT keyword.
- A program can be interrupted based on a state transition of a digital signal with the REACT and REACTI keywords. Refer to REACT and REACTI Program Interrupts on page 73 for more information.
- Program errors can be intercepted and handled with a REACTE keyword.
- Program execution can be terminated with the HALT, STOP, and PAUSE keywords.

These keywords interrupt the program in which they are contained. Any programs running as other tasks are not affected. Robot motion can be controlled with the BRAKE, BREAK, and DELAY keywords. The ABORT and PROCEED monitor command keywords can also be used to suspend and proceed programs.

Use the information below to understand different program interrupt methods.

WAIT Program Interrupts

The WAIT keyword suspends program execution until a condition(s) becomes true.

The syntax for the WAIT keyword is shown below.

```
WAIT condition
```

The following example suspends execution until digital input signal 1032 is ON and 1028 is OFF.

```
WAIT SIG(1032, -1028)
```

The following example suspends program execution until timer 1 returns a value greater than 10.

```
WAIT TIMER(1) > 10
```

WAIT.EVENT Program Interrupts

The WAIT.EVENT keyword suspends program execution until a specified event has occurred or until a specified amount of time has elapsed.

The syntax for the WAIT.EVENT keyword is shown below.

```
WAIT.EVENT mask, timeout
```

Additional Information: This keyword is more efficient than waiting for a timer (WAIT TIMER(1) > 10) because the task does not have to loop continually to check the timer value.

The following example suspends program execution for 3.7 seconds.

```
WAIT.EVENT, 3.7
```

The following example suspends program execution until another task issues a SET.EVENT statement to the waiting task.

```
WAIT.EVENT
```

NOTE: If the SET.EVENT operation does not occur, the task waits indefinitely.

REACT and REACTI Program Interrupts

When a REACT or REACTI keyword is encountered, the program begins monitoring a digital input signal specified in the REACT statement. This signal is monitored in the background with program execution continuing normally until the specified signal transitions. When a transition is detected, the program suspends execution at the currently executing step and a call to a specified subroutine is made.

Additionally, REACTI issues a BRAKE operation to immediately stop the current robot motion. Both keywords specify a subroutine to be run when the digital transition is detected. After the specified subroutine has completed, program execution resumes at the step executing when the digital transition was detected.

Digital signals can be used with the REACT keyword. The signal monitoring initiated by REACT / REACTI is in effect until another REACT / REACTI or IGNORE keyword is encountered. If the specified signal transition is not detected before an IGNORE or second REACT / REACTI keyword is encountered, the REACT / REACTI keyword has no effect on program execution. The following signals can be used.

Signal Type	Range	Additional Informaiton
Digital Input	1001 to 1999	Signal numbers are available for use only if they also physically exist and are configured.
Software	2001 to 2999	

Signal Type	Range	Additional Informaiton
External	4001 to 4999	Signal numbers are available if they are mapped.

Additional Information: The LOCK keyword can be used to control execution of a program after a REACT or REACTI subroutine has completed.

The syntax for the REACT and REACTI keywords are shown below.

```
REACT signal_number, program, priority
REACTI signal_number, program, priority
```

The following example implements a REACT routine where the signal 1001 is evaluated for a change in state from ON to OFF. If a change is detected, a call to the subroutine "alarm" occurs with a priority setting of 10 and execution resumes at the next step. The main program has a default priority of 0.

If signal 1001 transitions during execution of the MOVE c statement MOVE c, MOVE d, and LOCK 0 complete since the program had been given a higher priority than REACT. Subroutine "alarm" is called and execution resumes at the MOVE e statement. The LOCK statement sets the program reaction lock-out priority to a value of 20.

```
REACT -1001, alarm, 10

MOVE a
MOVE b
LOCK 20
MOVE c
MOVE d
LOCK 0
MOVE e

IGNORE -1001
```

REACTE Program Interrupts

REACTE enables a reaction program that is run whenever a system error that causes program execution to terminate is encountered. This includes all robot errors, hardware errors, and most system errors (it does not include I/O errors). Unlike REACT and REACTI, REACTE cannot be deferred based on priority considerations.

The syntax for the REACTE keyword is shown below.

```
REACTE program_name
```

The following example enables monitoring of system errors and executes the program "trouble" whenever a system error is generated.

```
REACTE trouble
```

HALT, STOP, and PAUSE Program Interrupts

When a HALT keyword is encountered, program execution is terminated and any open disk units are detached and closed with the FCLOSE operation. PROCEED or RETRY will not resume execution.

When a STOP keyword is encountered, execution of the current program cycle is terminated and the next execution cycle resumes at the first step of the program. If the STOP keyword is encountered on the last execution cycle, program execution is terminated and any open disk units are detached and closed with the FCLOSE operation. PROCEED or RETRY will not resume execution.

When a PAUSE keyword is encountered, execution is suspended. After a PAUSE, the system prompt appears and monitor command keywords can be executed. This allows you to verify the values of program variables and set system parameters. This is useful during program debugging. The monitor command keyword PROCEED resumes execution of a program interrupted with the PAUSE keyword.

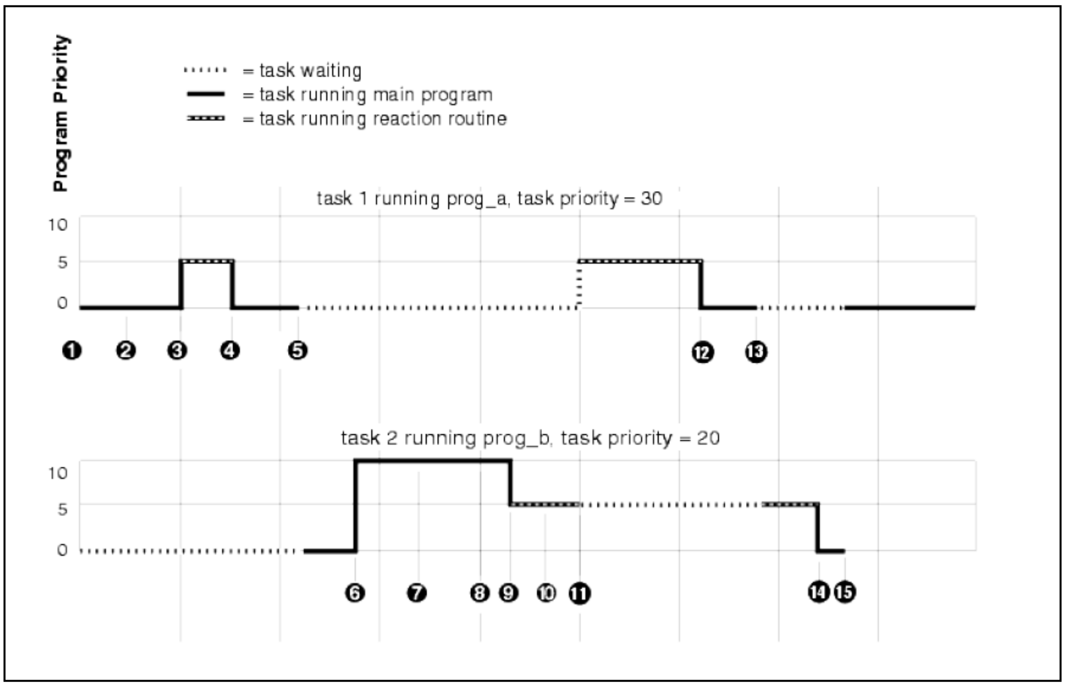
Additional Program Interrupt Keywords

You can specify a parameter in the I/O keywords ATTACH, READ, GETC, and WRITE that causes the program to suspend until the I/O request has been successfully completed. Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information.

Program Interrupt Example

The following figure shows how the task and program priority scheme works. It also shows how the asynchronous and program interrupt statements work within the priority scheme. The example makes the following assumptions.

- Task 1 runs in all time slices at priority 30.
- Task 2 runs in all time slices at priority 20.
- All system tasks are ignored.
- All system interrupts are ignored.



The illustration shows the timing of executing programs. A solid line indicates a program is running and a dotted line indicates a program is waiting. The Y axis shows the program priority. The X axis is divided into 16-millisecond major cycles.

The example shows two tasks executing concurrently with REACT routines enabled for each task. The LOCK keyword and triggering of the REACT routines change the program priority. The sequence of events for the example is described below.

1. Task 1 is running program "prog_a" at program priority 0. A reaction program based on signal 1003 is enabled at priority 5.
2. Signal 1003 is asserted externally. The signal transition is not detected until the next major cycle.
3. The signal 1003 transition is detected. The task 1 reaction program begins execution, interrupting "prog_a".
4. The task 1 reaction program reenables itself and completes by issuing a RETURN operation. "prog_a" resumes execution in task 1.
5. Task 1 "prog_a" issues a CLEAR.EVENT operation followed by a WAIT.EVENT operation to wait for its event flag to be set. Task 1 is suspended and task 2 resumes execution of "prog_b". Task 2 has a reaction program based on signal 1010 enabled at priority 5.
6. Task 2 "prog_b" issues a LOCK 10 statement to raise its program priority to level 10.
7. Signal 1010 is asserted externally. The signal transition is not detected until the next major cycle.
8. The signal 1010 transition is detected and the task 2 reaction is triggered. However, since the reaction is at level 5 and the current program priority is 10, the reaction execution is deferred.
9. Task 2 "prog_b" issues a LOCK 0 statement to lower its program priority to level 0. Since a level 5 reaction program is pending, it begins execution immediately and sets the program priority to 5.
10. Signal 1003 is asserted externally. The signal transition is not detected until the next major cycle.
11. The signal 1003 transition is detected which triggers the task 1 reaction routine and also sets the task 1 event flag. Since task 1 has a higher priority (30) than task 2 (20), task 1 begins executing its REACT routine and task 2 is suspended.
12. The task 1 reaction routine completes by issuing a RETURN keyword. Control returns to "prog_a" in task 1.
13. Task 1 "prog_a" issues a CLEAR.EVENT operation followed by a WAIT.EVENT operation to wait for its event flag to be set. Task 1 is suspended and task 2 resumes execution of its REACT routine. The task 2 REACT routine completes by issuing a RETURN keyword. Control returns to "prog_b" in task 2.
14. Task 2 "prog_b" issues a SET.EVENT 1 statement, setting the event flag for task 1. Task 2 now issues a RELEASE statement to yield control of the CPU.
15. Since the task 1 event flag is now set and its priority is higher than task 2, task 1 resumes execution and task 2 is suspended.

7.5 V+ program Stacks

When program calls are made, eV+ uses an internal storage area called a stack to save information required by the executing program. The following information is saved.

- The name and step number of the calling program.
- Data necessary to access subroutine arguments.
- The values of any automatic variables specified in the called program.

The eV+ system allows you to explicitly allocate storage to the stack for each program task. The amount of stack space can be adjusted for a particular application to optimize the use of system memory. Stacks can be made arbitrarily large, limited only by the amount of memory available on the system.

V+ Program Stack Requirements

When a V+ program is executed in a given Task, each program stack is allocated 32 kilobytes of memory. This value can be adjusted once the desired stack requirements are determined by using the STACK monitor command keyword. This is typically accomplished in a start-up Monitor Command Program.

Determining Stack Requirements

One method of determining the stack requirements of a program task is simply to execute its program. If the program runs out of stack space, it stops with the error message *Not enough program stack space*. After increasing the stack size, issue the RETRY keyword to continue program execution to avoid restarting the program from the beginning.

Additional Information: The STATUS keyword will return the amount of stack space a failed Task requested.

Alternatively, you can set a large stack size before running a program. After the program has been run and all the execution paths have been followed, use the STATUS monitor command keyword to examine the stack statistics for the program Task. The stack MAX value shows how much stack space the program Task needs in order to execute. The stack size can then be adjusted to accommodate the Task stack space requirements (it is recommended to add 10 to 20% extra as a safety factor).

If it is impossible to invoke all the possible execution paths, the theoretical stack limits can be calculated from the figures provided in the following table. You can calculate the worst-case stack size by summing the overhead for all the program calls that can be active at one time. Divide the total by 1024 to get the size in kilobytes. Use this number in the STACK monitor command statement to set the size.

Table 7-2. Stack Space Requirements

Item	Stack Space Requirements (Bytes)
The subroutine call.	20
Each subroutine argument (plus one of the following items below).	32
Each real subroutine argument or automatic variable.	4
Each double-precision real subroutine argument or automatic variable.	8
Each transformation subroutine argument or automatic variable.	48
Each precision-point subroutine argument or automatic variable.	Requires four bytes for each joint of the robot. For multiple robot systems, use the robot with the most joints.
Each belt variable argument or automatic variable.	84
Each string variable argument or automatic variable.	132

NOTE: If any subroutine argument or automatic variable is an array, the size shown must be multiplied by the size of the array (array indexes start at 0).

If a subroutine argument is always called by reference, the value can be omitted for that argument.

7.6 Exchanging Information Between V+ programs

There are three methods of exchanging information between V+ programs.

1. Global variables
2. Soft-signals
3. Program argument list

Exchanging Information Using Global Variables

When using global variables to exchange information between V+ programs, simply use the same variable names in the different programs.

Unless used carefully, this method can make program execution unpredictable and difficult to debug. It also makes it difficult to write generalized subroutines because the variable names in the main program and subroutine must always be the same.

Exchanging Information Using Soft-signals

Soft-signals are digital software switches whose state can be read and set by all tasks and programs. Refer to Soft Signals on page 25 for more information.

Exchanging Information Using the Program Argument List

Exchanging information through the program argument provides better control over changes made to variables. It also eliminates the requirement that the variable names in the calling program be the same as the names in the subroutine.

The following sections describe exchanging data through the program argument list.

Argument Passing

There are two important considerations when passing an argument list from a calling program to a subroutine.

1. Ensure the calling program passes arguments in the way the subroutine expects to receive them (mapping).
2. Determine how you want the subroutine to be able to alter the variables (passing by value or reference).

Mapping the Argument List

An argument list is a list of variables or values separated by commas. The argument list passed to a calling program must match the subroutine's argument list in number of arguments and data type of each argument or an error will occur.

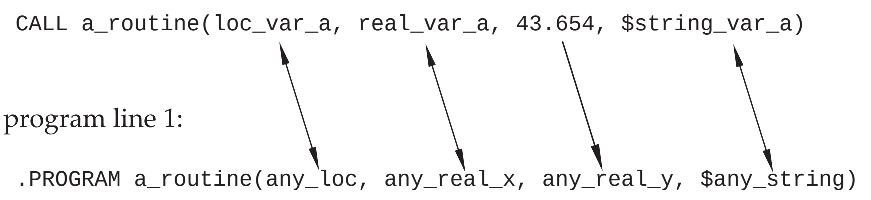
Additional Information: If the calling program omits an argument, either by leaving a blank in the argument list (e.g., arg_1, , arg_3) or by omitting arguments at the end of a list (e.g., arg_1, arg_2), the argument are passed as undefined. The subroutine receiving the argument list can test for this value using the DEFINED function keyword and take appropriate action.

The variable names do not have to match. When a calling program passes an argument list to a subroutine, the subroutine does not evaluate the variable names in the list. It only evaluates the position of the arguments in the list. The argument list in the CALL statement is mapped to the argument list of the subroutine. It is this mapping feature that allows you to write generalized subroutines that can be called by any number of different programs, regardless of the actual values or variable names the calling program uses.

The following diagram shows the mapping of an argument list in a CALL statement to the argument list in a subroutine. The arrows indicate that each item in the list must match in position and data type, but not necessarily in name. The CALL statement argument list can include values and expressions as well as variable names.

When the main program reaches a CALL statement as shown below, the subroutine "a_ routine" is called and the argument list is passed as indicated.

Statement in the calling program:

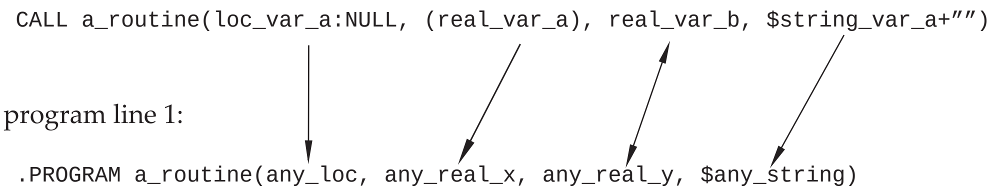


```
CALL a_routine(loc_var_a, real_var_a, 43.654, $string_var_a)
```

Called program line 1:

```
.PROGRAM a_routine(any_loc, any_real_x, any_real_y, $any_string)
```

Statement in the calling program:



```
CALL a_routine(loc_var_a:NULL, (real_var_a), real_var_b, $string_var_a+"")
```

Called program line 1:

```
.PROGRAM a_routine(any_loc, any_real_x, any_real_y, $any_string)
```

Additional Information: Refer to the CALL keyword in the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information on passing arrays.

Argument Passing by Value or Reference

Variables can be changed by a subroutine and the changed value can be passed back to the calling program. Argument passing by value occurs when a copy of the value is passed to the called subroutine and the change to the corresponding value in the subroutine is not passed back to the calling routine. This can be forced with the following methods described below. These methods may be useful if a subroutine is being called multiple times but the subroutine's modifier is only to be passed to the main routine during one instance.

If a calling program passes a variable to a subroutine but the subroutine cannot pass the variable back in an altered form, the variable is considered to be passed by value. Variables that require modification by a subroutine should be passed by reference.

To force the value of a real variable "real_1" to not be passed back to the calling routine "program", use the statement below that encloses the variable in parentheses.

```
CALL program((real_1))
```

To force the value of a string variable "string_1" to not be passed back to the calling routine "program", use the statement below that adds an empty string to the variable.

```
CALL program($string_1+"")
```

To force the value of a transformation variable "location_1" to not be passed back to the calling routine "program", use the statement below that compounds the transformation by null.

```
        CALL program(location_1:NULL)
```

If a calling program passes a variable to a subroutine and the subroutine can change the variable and pass the changed variable back to the calling program, the variable is considered passed by reference.

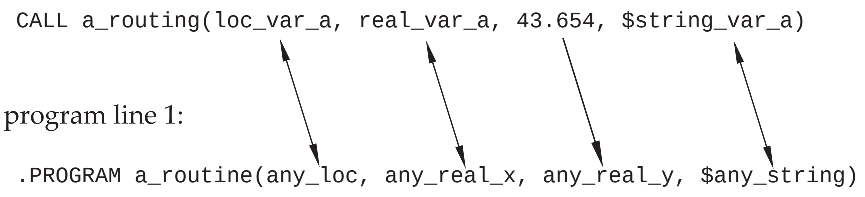
Changes made by the subroutine are reflected in the state of the variables in the calling program. Any argument that is to be changed by a subroutine and passed back to the calling routine must be specified as a variable (not an expression or value).

When calling a subroutine, it is acceptable to pass some arguments by value and others by reference. When a variable is passed by value, a copy of the variable, rather than the actual variable, is passed to the subroutine. The subroutine can make changes to the variable, but the changes are not returned to the calling program (the variable in the calling program has the same value it had when the subroutine was called).

The following diagram shows how to pass the different types of variables by value. Real numbers and integers are surrounded by parentheses, :NULL is appended to location variables, and +"" is appended to string variables.

In the following figure, "real_var_b" is still being passed by reference and any changes made in the subroutine will be reflected in the calling program. The subroutine cannot change any of the other variables. It can make changes only to the copies of those variables that have been passed to it. It is considered poor programming practice for a subroutine to change any arguments except those that are being passed back to the calling routine. If an input argument must be changed, it is recommended you make an automatic copy of the argument and manipulate that copy.

Statement in the calling program:

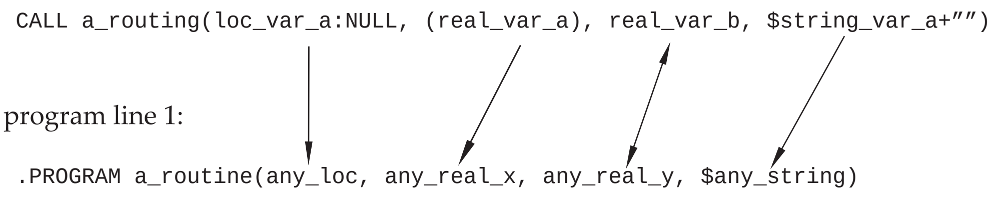


```
       CALL a_routing(loc_var_a, real_var_a, 43.654, $string_var_a)
```

Called program line 1:

```
       .PROGRAM a_routine(any_loc, any_real_x, any_real_y, $any_string)
```

Statement in the calling program:



```
       CALL a_routing(loc_var_a:NULL, (real_var_a), real_var_b, $string_var_a+””)
```

Called program line 1:

```
       .PROGRAM a_routine(any_loc, any_real_x, any_real_y, $any_string)
```

Values as well as variables can be passed by a CALL statement. The following example is an acceptable call to "a_routine".

```
        CALL a_routine(loc_1, 17.5, 121, "some string")
```

7.7 Reentrant and Recursive Programs

The following sections describe reentrant and recursive programs.

Reentrant Programs

The eV+ system allows the same program to be executed concurrently by multiple program Tasks. The program can be reentered while it is already executing. This allows different Tasks that are running concurrently to use the same general-purpose subroutine.

To make a program reentrant, you must observe the following guidelines when writing the program.

- Global variables can be read but must not be modified.
- Local variables should not be used.
- Only automatic variables and subroutine arguments can be modified.

In special situations, local variables can be used and global variables can be modified, but then the program must explicitly provide program logic to interlock access to these variables. The TAS real-valued function may be useful in these situations.

Recursive Programs

Recursive programs are subroutines that call themselves, either directly or indirectly. A direct call occurs when a program calls itself.

Indirect calls are more common and occur when program A calls program B, which eventually leads to another call to program A before program B returns. For example, an output routine may detect an error and call an error-handling routine, which in turn calls the original output routine to report the error. If recursive subroutine calls are used, the program must observe the same guidelines as for reentrant programs. Refer to Reentrant Programs on page 81 for more information.

IMPORTANT: Ensure that the recursive calls do not continue indefinitely. Otherwise, the program Task will run out of stack space.

7.8 Asynchronous Processing

A significant feature of eV+ system is the ability to respond to an event such as an external signal or error condition that occurs independently of the program's control structure. This type of program execution is considered to be asynchronous since its execution is not synchronized with the normal program flow. eV+ will react to an event by invoking a specified program as if a CALL statement had been executed, but only if event handling is properly enabled.

Asynchronous processing is enabled by the REACT, REACTE, and REACTI keywords. Each program Task can use these keywords to prepare for independent processing of events. In addition, the WINDOW keyword enables asynchronous processing of belt window violations when the robot is tracking a conveyor belt.

Sometimes a reaction must be delayed until a critical program section has completed. Since some events are more important than others, a program should be able to prioritize events. eV+ allows the relative importance of a reaction to be specified by a program priority value from 1 to 127. The higher the program priority setting, the more important the reaction.

A reaction subroutine is called only if the main program priority is less than that of the reaction program priority. If the main program priority is greater than or equal to the reaction program priority, execution of the reaction subroutine is deferred until the main program priority drops. Since the main program (for example, the robot control program) normally runs at program priority zero and the minimum reaction program priority is one, any reaction can normally interrupt the main program.

The main program priority can be raised or lowered with the LOCK program command keyword and its current value can be determined with the PRIORITY real-valued function. When the main program priority is raised to a certain value, all reactions of equal or lower priority are locked out.

When a reaction subroutine is called, the main program priority is automatically set to the reaction program priority, thus preventing any reactions of equal or lower program priority from interrupting it. When a RETURN statement is executed in the reaction program, the main program priority is automatically reset to the level it had before the reaction subroutine was called.

> **Additional Information**: Refer to the LOCK, PRIORITY, REACT, and REACTI in the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information about reactions and program priority.

Error Trapping

Normally, when an error occurs during execution of a program, the program is terminated and an error message is displayed on the Monitor Window. However, if the REACTE keyword has been used to enable an error-trapping program, the eV+ system invokes that program as a subroutine instead of terminating the program that encountered the error. Each program Task can have its own error trap enabled.

Before invoking the error-trapping subroutine, eV+ locks out all other reactions by raising the main program priority to 254.

> **Additional Information**: Refer to the description of the REACTE keyword in the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information on error trapping.

Chapter 8: T20 Pendant Programming

This section provides an overview of optional customization functions for the T20 pendant. Refer to the *T20 Pendant User's Manual (Cat. No. I601)* for information on installing and operating the pendant.

8.1 Attaching and Detaching the T20 Pendant

Before a V+ program can communicate with the pendant, the pendant must first be attached using the ATTACH keyword. The pendant should be detached when the associated V+ programs are finished.

> **NOTE:** The logical unit number (LUN) for the pendant is 1 in the following examples.
>
> As with all I/O devices, the IOSTAT keyword should be used to check for errors after each I/O operation.

When the pendant has been attached by a V+ program, the user can interact with the pendant without selecting manual mode.

The following example will attach the pendant with the ATTACH keyword.

```
t20_lun = 1
ATTACH (t20_lun)
```

The following example will detach the pendant with the DETACH keyword.

```
DETACH (t20_lun)
```

8.2 Writing to the T20 Pendant Display

The pendant allows users to display a title and a message body and to modify the labels for function keys F1 through F4. Any field may be an empty string (“”). The message body can process HTML-tagged code.

Use the following examples to understand how to write and clear messages from the pendant display.

The following example will display "Operator Control" as the title, "Select Option from buttons below" as the message, and create labels for the F1 and F2 buttons as shown in the figure below using the PDNT.WRITE keyword.

```
$p.title = "Operator Control"
$p.msg[0] = "Select Option from buttons below"
$p.f[1] = "Apps"
$p.f[2] = "Status"
$p.f[3] = ""
$p.f[4] = ""
PDNT.WRITE $p.title, $p.msg[], $p.f[1], $p.f[2], $p.f[3], $p.f[4]
```

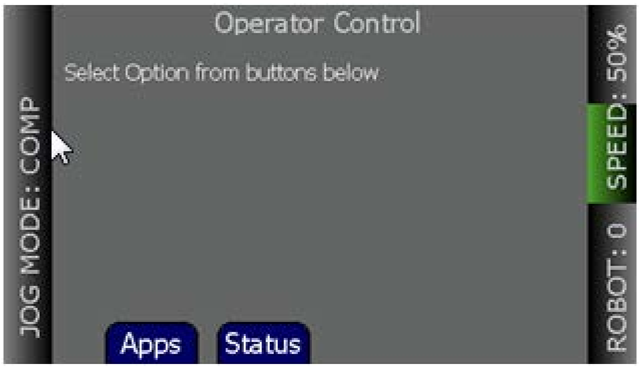
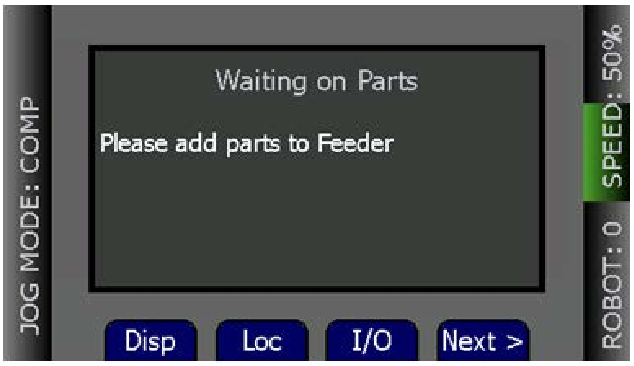


Figure 8-1. Writing to the Pendant with PDNT.WRITE

The following example will display "Waiting on Parts" and "Please add parts to Feeder" as shown in the figure below using the PDNT.NOTIFY keyword.

```
PDNT.NOTIFY "Waiting on Parts", "Please add parts to Feeder"
```


Waiting on Parts

Please add parts to Feeder

Figure 8-2. Writing to the Pendant with PDNT.NOTIFY

Additional Information: The PDNT.CLEAR keyword clears the pendant display and returns to the Home 1 screen.

8.3 Detecting User Input

Input from the pendant can be received from a single key press from any of the keys that can be detected. Single-key presses can be monitored in three different modes as detailed in this section.

1. Keyboard mode: the keys can be monitored like keys on a normal keyboard.
2. Toggle mode: the keys can be monitored in toggle mode (ON or OFF). The state of the key is changed each time the key is pressed.
3. Level Mode: the keys can be monitored in level mode. The state of the key is considered ON only when the key is held down.

Detecting Pendant Key Presses

Individual pendant key presses are detected with the PENDANT program command keyword. This keyword returns the number of the first acceptable key press.

There are three different key press modes for the pendant. The KEYMODE keyword sets which mode is to be used. The key press modes available are described below.

1. Keyboard Mode
2. Toggle Mode
3. Level Mode

The following figure provides a reference for the numbers of the keys on the T20 pendant.

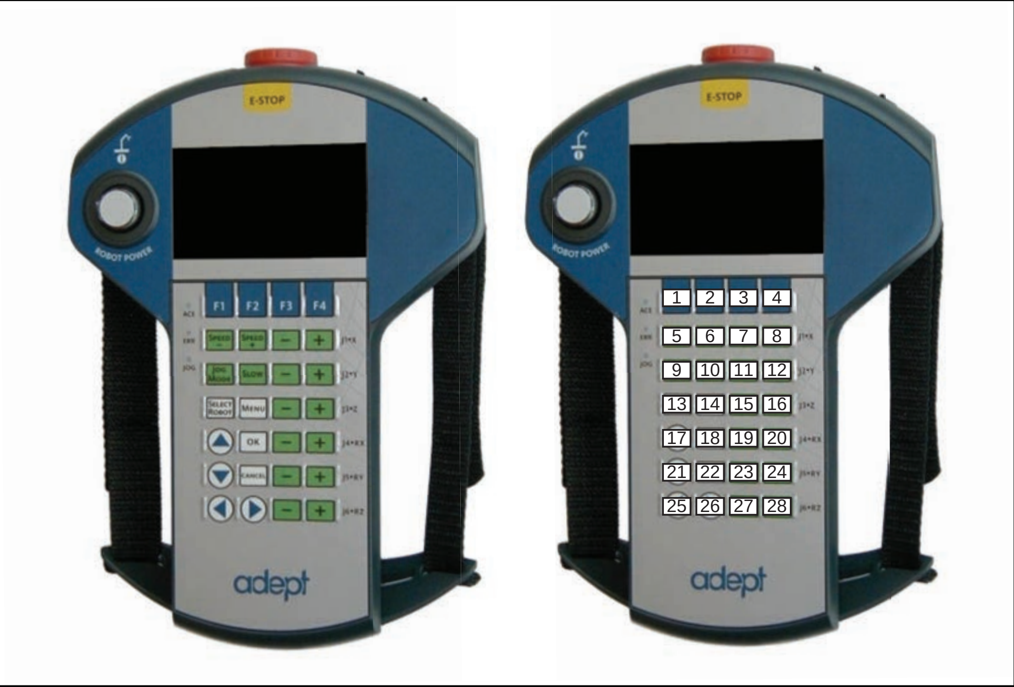


Figure 8-3. T20 Pendant Key Map

NOTE: On the T20 pendant, all green keys and Select Robot will still have their normal functionality when in a Custom Window (PDNT.WRITE). All other keys will have their primary functionality disabled. These keys are intended to be read by the V+ program through the PENDANT program command keyword.

8.4 Other Pendant Programming Functions

Other pendant functions listed below are possible with the use of the PENDANT program command. Refer to the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information.

- Monitor key states
- Monitor the state of the pendant
- Set keyboard modes
- Monitoring the speed signal setting
- Monitor the currently displayed screen number
- Monitor the version number of the pendant

Appendix

A.1 Warning, Information, and Error Messages

This section describes system errors, warnings, and information messages that can occur during system operation.

Additional Information: Refer to Error Trapping on page 82 and the REACTE keyword in the *eV+3 Keyword Reference Manual (Cat. No. I652)* for more information about message management.

System Warning Messages

Use the following information to reference system warning messages.

Table 9-1. eV+ System Warning Messages

Message Number	Error in Code	Error ID	Description
1	IE_WTMV	1010	Waiting for motion to complete
2	IE_WRNPOW	202	Power is now ON
3	IE_WRNPOF	203	Power is now OFF
4	IE_WRNCLS	101	Network connection closed
5	IE_WRNOPN	100	Network connection opened
6	IE_WRNHTR	58	Press and hold pendant enable switch
7	IE_WRNVFP	57	Press HIGH POWER button to enable power
8	IE_WNOHID	52	*Warning* Protected and read-only programs are not stored
9	IE_WNOCAL	51	*Warning* Not calibrated
10	IE_WRNDRY	50	Executing in DRY.RUN mode

System Information Messages

Use the following information to reference system information messages.

Table 9-2. eV+ System Information Messages

Message Number	Error in Code	Error ID	Description
11	IE_SSDONE	13	Flag single-step done
12	IE_BPTMES	17	Breakpoint hit
13	IE_PAUSEM	9	PAUSE instruction hit

Message Number	Error in Code	Error ID	Description
14	IE_FHALTM	8	HALT instruction hit
15	IE_DOHALT	6	DO done
16	IE_DOSTAR	5	Starting a DO command
17	IE_UHALT	4	Program task stopped
18	IE_FINI	3	Program completed
19	IE_USTART	2	Starting program execution
20	IE_SUCCESS	1	Success
21	IE_WARN	0	Warning

System Error Messages

Use the following information to reference system error messages.

Table 9-3. eV+ System Error Messages

Message Number	Error in Code	Error ID	Description
22	IE_NOTYET	-1	Not implemented
23	IE_OBSOL	-2	Obsolete Instruction
1	IE_NOEXIST	-3	Instruction does not exist
24	IE_ILLCMD	-300	Illegal monitor command
25	IE_NOPROG	-301	No program specified
26	IE_NODO	-302	DO not primed
27	IE_NOTAUTO	-303	Controller not in automatic mode
28	IE_BADFRE	-305	Storage area format error
29	IE_PRGNEX	-307	Program not executable
30	IE_PRGILK	-308	Program interlocked
31	IE_PRGDEF	-309	Program already exists
32	IE_HIDERR	-310	Can't access protected or read-only pro-gram
33	IE_PRGACT	-311	Invalid when program task active
34	IE_CANTPR	-312	Can't start while program running
35	IE_CNTPRO	-313	Can't go on, use EXECUTE or PRIME
36	IE_NOTENB	-314	Switch can't be enabled
37	IE_BADCFG	-315	Invalid software configuration
38	IE_BADCHK	-316	Software checksum error

Message Number	Error in Code	Error ID	Description
39	IE_PRNACT	-318	Program task not active
40	IE_PRNUSE	-319	Program task not in use
41	IE_NODPRG	-350	Can't delete .PROGRAM statement
42	IE_PRG1ST	-351	First statement must be .PROGRAM
43	IE_READER	-352	Invalid in read-only mode
44	IE_ONLYCU	-353	No other program referenced
45	IE_TOLONG	-354	Line too long
46	IE_NOEXIT	-355	Can't exit while lines attached
47	IE_NOFIND	-356	Not found
48	IE_DMMES	-357	Recursive macros illegal
49	IE_SCANCL	-358	Cancelled
50	IE_DEBUGE	-359	Illegal in debug monitor mode
51	IE_NOTDBG	-360	Must be in debug mode
52	IE_CNTSWC	-361	Can't change modes while task running
53	IE_NWPRGI	-362	Can't execute from SEE program instruction
54	IE_UNKECM	-363	Unknown editor command
55	IE_NOCCOM	-364	Can't create program in read-only mode
56	IE_WRIOER	-365	Illegal in read-write mode
57	IE_PONSTK	-366	Invalid when program on stack
58	IE_BPTNAL	-380	Breakpoint not allowed here
59	IE_ABORT	-400	Abort
60	IE_UNDVAR	-401	Undefined value
61	IE_BADNUM	-402	Illegal value
62	IE_BADASN	-403	Illegal assignment
63	IE_BADARR	-404	Illegal array index
64	IE_BADSIG	-405	Illegal digital signal
65	IE_UNDNAM	-406	Undefined program or variable name
66	IE_ILLARG	-407	Invalid argument
67	IE_SUBAMM	-408	Program argument mismatch
68	IE_ARITHO	-409	Arithmetic overflow
69	IE_NEGSQR	-410	Negative square root

Message Number	Error in Code	Error ID	Description
70	IE_NOFRES	-411	Not enough storage area
71	IE_MISLBL	-412	*Branch to undefined label* Step
72	IE_SUBERR	-413	Not enough program stack space
73	IE_MCERR	-414	Can't mix MC & program instructions
74	IE_STGOVF	-416	String variable overflow
75	IE_STRSHT	-417	String too short
76	IE_NXMERR	-418	Illegal memory reference
77	IE_CMDACT	-419	Illegal when command program active
78	IE_UNDVCX	-420	Undefined value in this context
79	IE_PRGNOT	-421	Program not on top of stack
80	IE_FALENB	-422	Function already enabled
81	IE_ILLOPR	-423	Illegal operation
82	IE_NOCALP	-425	Calibration program not loaded
83	IE_NOCALF	-426	Can't find calibration program file
2	IE_SYSABORT	-429	Aborted by system
84	IE_BADLIN	-450	Can't interpret line
85	IE_SWPERR	-451	Unexpected text at end of line
86	IE_ILLINS	-452	Unknown instruction
87	IE_AMBIG	-453	Ambiguous name
88	IE_NOARGU	-454	Missing argument
89	IE_INVNME	-455	Invalid program or variable name
90	IE_BADNFM	-456	Invalid number format
91	IE_RESWRD	-457	Reserved word illegal
92	IE_SYNERR	-458	Illegal expression syntax
93	IE_MISPAR	-459	Missing parenthesis
94	IE_MISQUO	-460	Missing quote mark
95	IE_ILLFMT	-461	Invalid format specifier
96	IE_UNKFUN	-462	Unknown function
97	IE_BADLBL	-463	Invalid statement label
98	IE_DUPLBL	-464	Duplicate statement label
99	IE_BADTYP	-465	Variable type mismatch
100	IE_ILLBLV	-466	Illegal use of belt variable
101	IE_BADPRG	-467	Illegal .PROGRAM statement

Message Number	Error in Code	Error ID	Description
102	IE_DUPARG	-468	Duplicate .PROGRAM arguments
103	IE_REDECL	-469	Attempt to redefine variable type
104	IE_RDFCLS	-470	Attempt to redefine variable class
105	IE_MISPDC	-471	Misplaced declaration statement
106	IE_CSFERR	-472	*Control structure error* Step
107	IE_BADCON	-473	Control structure error
108	IE_BADDIM	-474	Too many array indices
109	IE_MISBRK	-475	Missing bracket
110	IE_ILLSQL	-476	Invalid qualifier
111	IE_AMBAUT	-477	Ambiguous AUTO invalid
112	IE_FSTFPE	-500	File already exists
113	IE_NOFILE	-501	Nonexistent file
114	IE_BADIOC	-502	Illegal I/O device command
115	IE_CEFULL	-503	Device full
116	IE_IEEOF	-504	Unexpected end of file
117	IE_IEINI	-505	Initialization error
118	IE_IEFAO	-506	File already opened
119	IE_DEVNTR	-508	Device not ready
120	IE_IECHK	-510	Data checksum error
121	IE_BADFIL	-512	File format error
122	IE_IEFNO	-513	File not opened
123	IE_SUBNAME	-514	File or subdirectory name error
124	IE_LUNBSY	-515	Already attached to logical unit
125	IE_NOTATT	-516	Not attached to logical unit
126	IE_ILLCHAN	-518	Illegal I/O channel number
127	IE_ICE	-519	Driver internal consistency error
128	IE_IEDAT	-522	Data error on device
129	IE_IEDAO	-524	Communications overrun
130	IE_ILGRED	-525	Illegal I/O redirection specified
131	IE_NODATA	-526	No data received
132	IE_BADLUN	-527	Illegal user LUN specified
133	IE_BADRLN	-528	Illegal record length

Message Number	Error in Code	Error ID	Description
134	IE_IOOVER	-529	Output record too long
135	IE_IVHCFG	-533	Invalid hardware configuration
136	IE_IEPRO	-530	Protection error
137	IE_IETMO	-531	Communication time-out
138	IE_IENER	-536	Too many network errors
139	IE_IEUNN	-537	Unknown network node
140	IE_IEILC	-540	Invalid connection specified
141	IE_IEINP	-541	Invalid network protocol
142	IE_NETINE	-543	Illegal when network enabled
143	IE_NOTCFA	-544	Not configured as accessed
144	IE_NOSUBDIR	-545	Nonexistent subdirectory
145	IE_SUBINUSE	-547	Subdirectory in use
146	IE_IETMW	-550	Too many windows
147	IE_TOOMNY	-553	Too many arguments
148	IE_IENOOR	-559	Out of network resources
149	IE_ERNTIM	-562	Network timeout
150	IE_IENFTL	-569	File too large
151	IE_DNNOTCFG	-586	DeviceNet not configured
152	IE_HDWSTP	-600	Stopped due to servoing error
153	IE_NOARM	-601	Robot not attached to this program
154	IE_ARMALA	-602	Robot already attached to program
155	IE_NOTCMP	-603	COMP mode disabled
156	IE_PWISOF	-604	Robot power off
157	IE_NOTCAL	-605	Robot not calibrated
158	IE_AIRERR	-607	No air pressure
159	IE_PANBUT	-608	External E-STOP
160	IE_BADJTN	-609	Illegal joint number
161	IE_OUTRNG	-610	Location out of range
162	IE_CNTJI	-611	Must use straight-line motion
163	IE_CANCFG	-612	Straight-line motion can't alter configuration
164	IE_CNTMVE	-613	Illegal motion from here
165	IE_BLTER	-614	Attempt to modify active belt

Message Number	Error in Code	Error ID	Description
166	IE_NOBELT	-615	Belt not enabled
167	IE_WINERR	-616	Belt window violation
168	IE_BLTDED	-617	Belt servo dead
169	IE_LTOCLS	-618	Location too close
170	IE_BADORI	-619	Invalid orientation
171	IE_MANBTT	-620	Speed pot or STEP not pressed
172	IE_ROBILK	-621	Robot interlocked
173	IE_NOROBT	-622	No robot connected to system
174	IE_FPBSOF	-623	Stop-on-force triggered
175	IE_FPBPRT	-624	Force protect limit exceeded
176	IE_INVSDT	-625	Invalid servo initialization data
177	IE_CTBLAL	-626	Can't ALTER and track belt
178	IE_PONERR	-627	Robot power on
179	IE_MODERR	-628	*Robot module not loaded* ID:
180	IE_SYFERR	-629	SYSFAIL detected by CPU
181	IE_ESIERR	-630	Backplane E-STOP detected by CPU
182	IE_CTLHOT	-631	Controller overheating
183	IE_ROBPWF	-632	Power failure detected by robot
184	IE_PANCMD	-633	PANIC command
185	IE_FRCCER	-634	Force sensor communication error
186	IE_NOCTCL	-635	Cartesian control of robot not possible
187	IE_HSTOVRE	-636	overrun detected by host system
188	IE_SPNERR	-637	Illegal while joints SPIN'ing
189	IE_CNTSPN	-638	SPIN motion not permitted
190	IE_MNBRAK	-639	Manual brake release
191	IE_ESTROB	-640	E-STOP from robot
192	IE_ESTAMP	-641	E-STOP from amplifier
193	IE_ESTSYF	-642	SYSFAIL detected by robot
194	IE_ESTBAC	-643	E-STOP detected by robot
195	IE_MOVING	-644	Illegal while robot is moving
196	IE_PWDSBL	-645	Power disabled: Manual/Auto changed
197	IE_PWENBL	-646	HIGH POWER button not pressed
198	IE_EC3DED	-649	Timeout: MCP enable switch not

Message Number	Error in Code	Error ID	Description
			toggled
199	IE_TPFAIL	-650	Manual control pendant failure
200	IE_RSCDWN	-651	RSC communications failure
201	IE_RSCRST	-652	RSC reset
202	IE_RSCTMO	-653	RSC time-out
203	IE_RSCTER	-654	RSC transmission garbled
204	IE_RSCBAD	-655	RSC bad packet format
205	IE_RSCNCL	-656	RSC calibration load failure
206	IE_PENCON	-657	Pendant not connected
207	IE_HDWNPR	-658	Device hardware not present
208	IE_IEDERR	-660	Device error
209	IE_EEPCHK	-661	NVRAM data invalid
210	IE_DEVSER	-662	Device sensor error
211	IE_IEDRES	-663	Device reset
212	IE_INVCAL	-664	Invalid calibration data
213	IE_EEPBAT	-665	NVRAM battery failure
214	IE_NOTSYS	-666	Must use CPU #1
215	IE_PWFERR	-667	Power failure detected
216	IE_DEVINU	-668	Device in use
217	IE_ERSCHW	-669	RSC hardware failure
218	IE_ERSCPW	-670	RSC power failure
219	IE_ESR12F	-671	Servo board 12V fuse open
220	IE_ESRSLF	-672	Servo board solenoid fuse open
221	IE_ESRESF	-673	Servo board E-STOP fuse open
222	IE_SEROVR	-674	Servo task overloaded
223	IE_MOTPWF	-675	Timeout enabling power
224	IE_MIDWRG	-676	RSC module ID doesn't match robot
225	IE_IESVIN	-677	Servo protocol incompatible
226	IE_IEDUPS	-678	Duplicate servo node ID
227	IE_IENFSV	-679	Expected servo node not found
228	IE_IESNDN	-680	Servo node not downloaded
229	IE_VINOOB	-704	No objects seen
230	IE_VINRUN	-705	Camera not running

Message Number	Error in Code	Error ID	Description
231	IE_VIRUN	-706	Invalid request while camera running
232	IE_VIPROT	-707	Unknown prototype
233	IE_VINCAL	-713	Vision not calibrated
234	IE_VIONAL	-714	Camera already running
235	IE_VIOFAL	-719	Camera already off
236	IE_VININS	-720	Vision option not installed
237	IE_VINOCI	-722	Camera interface board absent
238	IE_VINPPD	-723	No picture data available
239	IE_VIILDM	-724	Illegal display mode
240	IE_VIILCL	-726	Bad camera calibration
241	IE_IEVTRN	-729	Invalid request while vision training
242	IE_IENINF	-730	Information not available
243	IE_IESUBP	-731	Unknown sub-prototype
244	IE_VIIVNM	-732	Invalid model name
245	IE_VINOMM	-733	Vision system out of memory
246	IE_ILVARG	-735	Invalid vision argument
247	IE_VABORT	-749	Vision aborted
248	IE_NVSSEL	-751	No vision system selected
249	IE_VINTER	-767	Vision internal error
250	IE_NOVISOPT	-770	The vision option is not licensed
251	IE_ILLASS	-771	Invalid Robot Vision Manager sequence
252	IE_ILLAST	-772	Invalid Robot Vision Manager tool index
253	IE_ILLASP	-773	Invalid Robot Vision Manager parameter ID
254	IE_ILLASP2	-774	Invalid Robot Vision Manager parameter index
255	IE_NOASSEQ	-775	Robot Vision Manager instance not found
256	IE_NOCAMIM	-776	Unable to acquire an image from the camera
257	IE_NOROBLAT	-777	Unable to read the robot position latch
258	IE_NOBELLAT	-778	No belt latch was detected
259	IE_UNKNER	-800	Unknown error code
260	IE_BDVFEA	-801	Invalid VFEATURE access

Message Number	Error in Code	Error ID	Description
261	IE_NCMARM	-802	Invalid camera calibration
262	IE_ILLCAM	-803	Illegal camera number
263	IE_NOOPT	-804	Option not installed
264	IE_NOHDWR	-805	Hardware not in system
265	IE_DBERR	-859	Database manager internal error
266	IE_COLDET	-901	Obstacle collision detected
267	IE_MSECME	-902	Interrupted multi-segment motion
268	IE_ESTUCK	-904	[Fatal] E-STOP signals are stuck off
269	IE_NOHPWR	-906	Robot power off requested
270	IE_ESTPWR	-907	E-STOP circuit relay failure
271	IE_ESTFP	-908	E-STOP from front panel button
272	IE_ESTMCP	-909	E-STOP from MCP E-STOP button
273	IE_CP44P3	-910	E-STOP from user E-STOP button
274	IE_CP44P5	-912	E-STOP from user enable switch
275	IE_ESTCPU	-919	E-STOP asserted by CPU
276	IE_AMSTUK	-920	[Fatal] Auto mode switch stuck on
277	IE_CP44P7	-921	E-STOP from user muted safety gate
278	IE_ESTINC	-922	E-STOP channels 1 and 2 do not match
279	IE_ESTSHR	-923	E-STOP circuit is shorted
280	IE_BADLIT	-924	Front panel HIGH POWER lamp failure
281	IE_CP48P7	-929	E-STOP from Line E-STOP input
282	IE_PWROVLD	-933	Power output overloaded on Belt/EXPIO
283	IE_HPSTUK	-934	[Fatal] HIGH POWER button stuck on
284	IE_NOSOL1	-935	Orientation out of range
285	IE_NOSOL2	-936	Kinematic solution not found
286	IE_BADKEY	-937	Robot already under manual control
287	IE_NOJNT	-938	Joint control of robot not possible
288	IE_ESTOPUNS TABLE	-939	E-STOP unstable
289	IE_ABORTX	-999	Aborted
290	IE_UNKSVE	-1001	Invalid servo error
291	IE_NOSOL	-1002	Position out of range
292	IE_NOTIME	-1003	Time-out nulling errors
293	IE_NOREF	-1004	No zero index

Message Number	Error in Code	Error ID	Description
294	IE_NOSYNC	-1005	Unexpected zero index
295	IE_EVLERR	-1006	Soft envelope error
296	IE_MSTALL	-1007	Motor stalled
297	IE_QADERR	-1008	Encoder quadrature error
298	IE_AMPERR	-1009	Timeout enabling amplifier
299	IE_MOTHOT	-1016	Motor overheating
300	IE_AMPER1	-1018	Motor amplifier fault
301	IE_DUTCYC	-1021	Duty-cycle exceeded
302	IE_SKWERR	-1022	Skew envelope error
303	IE_NOSOLM	-1023	Position out of range, motor
304	IE_ENCFLT	-1025	Encoder fault
305	IE_SWINC	-1026	Software incompatible
306	IE_HEVLER	-1027	Hard envelope error
307	IE_SSPDER	-1028	Soft overspeed error
308	IE_HSPDER	-1029	Hard overspeed error
309	IE_NGOVER	-1032	Negative overtravel
310	IE_PSOVER	-1033	Positive overtravel
311	IE_RBOVER	-1034	Overtravel
312	IE_SVDEAD	-1104	[Fatal] Servo dead Mtr
313	IE_NOCTRK	-1106	Calibration sensor failure Mtr
314	IE_SAFETYSYS TEMFAULT	-1109	Safety System Fault
315	IE_EC3EEP	-1111	E-STOP from safety system Code
316	IE_POWERSYS TEMFAILURE	-1115	Power System Failure
317	ENDMARKER	-3000	Unknown error code

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