ROBOTICS

Technical reference manual

RAPID kernel

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Technical reference manual

RAPID kernel

RobotWare 6.16.03

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Overview of this manual

About this manual

This manual contains a formal description of the ABB Robotics robot programming language RAPID.

This manual describes RobotWare 6.

Who should read this manual?

This manual is intended for someone with some previous experience in programming, for example, a robot programmer.

References

Reference	Document ID
Operating manual - IRC5 with FlexPendant	*3HAC050941-001*
Technical reference manual - RAPID Instructions, Functions and Data types	*3HAC050917-001*
Technical reference manual - RAPID Overview	*3HAC050947-001*
Technical reference manual - System parameters	*3HAC050948-001*

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-	Released with RobotWare 6.0.
A	Released with RobotWare 6.01. • Added information about *Nostepin modules on page 123*.
B	Released with RobotWare 6.03. • Minor corrections.
C	Released with RobotWare 6.04. • Added information to chapter *Motion error handling*, section *Limitations on page 114*.
D	Released with RobotWare 6.06. • Updated section *Motion error handling on page 112*.
E	Released with RobotWare 6.07. • Added information about comments in records to both *Comments on page 28* and *The record data types on page 33*.
F	Released with RobotWare 6.12. • Minor correction of displayed characters in *Character set on page 19*. • Removed information about .eng files, see *Text files on page 147*. Use .xml format instead.
G	Released with RobotWare 6.13. • Added support for division of pos, see *Multiplication operators on page 63*.
H	Released with RobotWare 6.13.02. • Clarified limitation for backward execution and execution errors.

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Continued

Revision	Description
J	Released with RobotWare 6.14. • Added support for scalar vector division of pos, see *Multiplication operators on page 63*.
K	Released with RobotWare 6.16.02. • Company name updated to reflect current legal entities.
L	Released with RobotWare 6.16.03. • Company name updated to reflect current legal entities.

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How to read this manual

Typographic conventions

Examples of programs are always displayed in the same way as they are output to a file or printer. This differs from what is displayed on the FlexPendant in the following ways:

- Certain control words that are masked in the FlexPendant display are printed, for example words indicating the start and end of a routine.
- Data and routine declarations are printed in the formal form, for example *VAR num reg1*;.

In descriptions in this manual, all names of instructions, functions, and data types are written in monospace font, for example: `TPWrite`. Names of variables, system parameters, and options are written in italic font. Comments in example code are not translated (even if the manual is translated).

Syntax rules

Instructions and functions are described using both simplified syntax and formal syntax. If you use the FlexPendant to program, you generally only need to know the simplified syntax, since the robot automatically makes sure that the correct syntax is used.

Example of simplified syntax

This is an example of simplified syntax with the instruction `TPWrite`.

```
TPWrite String [\Num] | [\Bool] | [\Pos] | [\Orient] [\Dnum]
```

- Compulsory arguments are not enclosed in brackets.
- Optional arguments are enclosed in square brackets [ ]. These arguments can be omitted.
- Arguments that are mutually exclusive, that is cannot exist in the instruction at the same time, are separated by a vertical bar |.
- Arguments that can be repeated an arbitrary number of times are enclosed in curly brackets { }.

The above example uses the following arguments:

- `String` is a compulsory argument.
- `Num`, `Bool`, `Pos`, `Orient`, and `Dnum` are optional arguments.
- `Num`, `Bool`, `Pos`, `Orient`, and `Dnum` are mutually exclusive.

Example of formal syntax

```
TPWrite
  [String ':='] <expression (IN) of string>
  ['\'Num':=' <expression (IN) of num> ] |
  ['\'Bool':=' <expression (IN) of bool> ] |
  ['\'Pos':=' <expression (IN) of pos> ] |
  ['\'Orient ':=' <expression (IN) of orient> ]
  ['\' Dnum':=' <expression (IN) of dnum]';'
```

- The text within the square brackets [ ] may be omitted.

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- Arguments that are mutually exclusive, that is cannot exist in the instruction at the same time, are separated by a vertical bar |.
- Arguments that can be repeated an arbitrary number of times are enclosed in curly brackets { }.
- Symbols that are written in order to obtain the correct syntax are enclosed in single quotation marks (apostrophes) ' '.
- The data type of the argument (italics) and other characteristics are enclosed in angle brackets < >. See the description of the parameters of a routine for more detailed information.

The basic elements of the language and certain instructions are written using a special syntax, EBNF. This is based on the same rules, but with some additions.

- The symbol ::= means *is defined as*.
- Text enclosed in angle brackets < > is defined in a separate line.

Example

```
GOTO <identifier> ';'
  <identifier> ::= <ident> | <ID>
  <ident> ::= <letter> {<letter> | <digit> | '_'}
```


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1 Introduction

1.1 Design objectives

The RAPID concept

The RAPID language supports a leveled programming concept where new routines, data objects, and data types can be installed for a specific robot system. This concept makes it possible to customize (extend the functionality of) the programming environment and is fully supported by the RAPID programming language.

In addition, RAPID includes a number of powerful features:

- Modular programming with tasks and modules
- Procedures and functions
- Type definitions
- Variables, persistents, and constants
- Arithmetic
- Control structures
- Backward execution support
- Error recovery
- Undo execution support
- Interrupt handling
- Placeholders

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1.2 Language summary

Tasks and modules

A RAPID application is called a *task*. A task is composed of a set of *modules*. A module contains a set of data and routine declarations. The *task buffer* is used to host modules that are currently in use (execution, development) in a system.

RAPID distinguishes between *task modules* and *system modules*. A task module is considered to be a part of the task/application while a system module is considered to be a part of the *system*. System modules are automatically loaded to the task buffer during system start-up and are aimed to (pre)define common, system specific data objects (tools, weld data, move data etc.), interfaces (printer, log file ..) etc.

While small applications usually are contained in a single task module (besides the system modules), larger applications may have a main task module that in turn references routines and/or data contained in one or more other task modules.

One task module contains the entry procedure of the task. Running the task really means that the entry routine is executed. Entry routines cannot have parameters.

Routines

There are three types of routines: *functions*, *procedures*, and *traps*.

- A *function* returns a value of a specific type and is used in expression context.
- A *procedure* does not return any value and is used in statement context.
- *Trap routines* provide a means to respond to interrupts. A trap routine can be associated with a particular interrupt and is then later automatically executed if that interrupt occurs.

User routines

User (defined) routines are defined using RAPID declarations.

A RAPID routine declaration specifies the routine name, routine parameters, data declarations, statements, and possibly a backward handler and/or error handler and/or undo handler.

Predefined routines

Predefined routines are supplied by the system and always available.

There are two types of predefined routines: *built-in routines* and *installed routines*.

- *Built-in routines* (like arithmetic functions) are a part of the RAPID language.
- *Installed routines* are application or equipment dependent routines used for the control of the robot arm, grippers, sensors etc.

Note

From the point of view of a user there is no difference between built-in routines and installed routines.

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Data objects

There are four types of data objects: *constants*, *variables*, *persistents*, and *parameters*.

- A *persistent* (data object) can be described as a "persistent" variable. It keeps its value between sessions.
- A *variable* value is lost (re-initialized) at the beginning of each new session, that is, when a module is loaded (module variable) or a routine is called (routine variable).

Data objects can be structured (record) and dimensioned (array, matrix etc.).

Statements

A statement may be *simple* or *compound*. A compound statement may in turn contain other statements. A *label* is a "no operation" statement that can be used to define named (`goto`) positions in a program. Statements are executed in succession unless a `goto`, `return`, `raise`, `exit`, `retry`, or `trynext` statement, or the occurrence of an interrupt or error causes the execution to continue at another point.

The *assignment* statement changes the value of a variable, persistent, or parameter.

A *procedure call* invokes the execution of a procedure after associating any arguments with corresponding parameters of the procedure. RAPID supports late binding of procedure names.

The `goto` statement causes the execution to continue at a position specified by a label.

The `return` statement terminates the evaluation of a routine.

The `raise` statement is used to raise and propagate errors.

The `exit` statement terminates the evaluation of a task.

The `connect` statement is used to allocate an interrupt number and associate it with a trap (interrupt service) routine.

The `retry` and `trynext` statements are used to resume evaluation after an error.

The `if` and `test` statements are used for selection. The `if` statement allows the selection of a statement list based on the value of a condition. The `test` statement selects one (or none) of a set of statement lists, depending on the value of an expression.

The `for` and `while` statements are used for iteration. The `for` statement repeats the evaluation of a statement list as long as the value of a loop variable is within a specified value range. The loop variable is updated (with selectable increment) at the end of each iteration. The `while` statement repeats the evaluation of a statement list as long as a condition is met. The condition is evaluated and checked at the beginning of each iteration.

Backward execution

RAPID supports stepwise, backward execution of statements. Backward execution is very useful for debugging, test and adjustment purposes during RAPID program

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development. RAPID procedures may contain a backward handler (statement list) that defines the backward execution "behavior" of the procedure.

Error recovery

The occurrence of a runtime detected error causes suspension of normal program execution. The control may instead be passed to a user provided error handler. An error handler may be included in any routine declaration. The handler can obtain information about the error and possibly take some actions in response to it. If desirable, the error handler can return the control to the statement that caused the error (`retry`) or to the statement after the statement that caused the error (`trynext`) or to the point of the call of the routine. If further execution is not possible, at least the error handler can assure that the task is given a graceful abortion.

Undo execution

A routine can be aborted at any point by moving the program pointer out of the routine. In some cases, when the program is executing certain sensitive routines, it is unsuitable to abort. Using an undo handler it is possible to protect such sensitive routines against an unexpected program reset. The undo handler is executed automatically if the routine is aborted. This code should typically perform clean-up actions, for example closing a file and should be as fast as possible, since the user is probably not aware of that any execution has started.

Interrupts

Interrupts occur as a consequence of a user defined (interrupt) condition turning true. Unlike errors, interrupts are not directly related to (synchronous with) the execution of a specific piece of the code. The occurrence of an interrupt causes suspension of normal program execution and the control may be passed to a trap routine. After necessary actions have been taken in response to the interrupt the trap routine can resume execution at the point of the interrupt.

Data types

Any RAPID object (value, expression, variable, function etc.) has a *data type*. A data type can either be a *built-in type* or an *installed type* (compare installed routines), or a *user-defined type* (defined in RAPID). Built-in types are a part of the RAPID language while the set of installed or user-defined types may differ from site to site.



Note

From the point of view of a user there is no difference between built-in, installed, and user-defined types.

There are three kinds of types: *atomic types*, *record types*, and *alias types*. The definition of an atomic type must be built-in or installed, but a record or alias type could also be user-defined.

- Atomic types are "atomic" in the sense that they are not defined upon any other type and they cannot be divided into parts or components.

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- Record types are built up by a set of named, ordered components.
- An alias type is by definition equal to another type. Alias types make it possible to classify data objects.

In addition to the atomic, record, or alias classification of types, each type has a *value class*. There are three value classes of types: *value types*, *non-value types*, and *semi-value types*.

- An object of value type represents some form of value, for example *3.55* or *John Smith*).
- A non-value (type) object represents a hidden or encapsulated description of some physical or logical object, for example a file.
- Semi-value objects have two types, one *basic non-value type* and one *associated value type* that may be used to represent some property of the non-value type.

Built-in data types

The built-in atomic types are `bool`, `num`, `dnum`, and `string`.

- `bool` is an enumerated type with the value true or false, and provides a means of performing logical and relational computations.
- The `num` type supports exact and approximate arithmetic computations.
- The `string` type represents character sequences.

The built-in record types are `pos`, `orient`, and `pose`.

- The `pos` type represents a position in space (vector).
- The `orient` type represents an orientation in space.
- The `pose` type represents a coordinate system (position/orientation combination).

The built-in alias types are `errnum` and `intnum`. `Errnum` and `intnum` are both aliases for `num` and are used to represent errors and interrupt numbers.

Operations on objects of built-in types are defined by means of arithmetic, relational and logical operators, and predefined routines.

Installed data types

The concept of installed types supports the use of installed routines by making it possible to use appropriate parameter types. An installed type can be either an *atomic*, *record*, or *alias* type.

User-defined data types

The user-defined types make it easier to customize an application program. They also make it possible to write a RAPID program which is more readable.

Placeholders

The concept of *placeholders* supports structured creation and modification of RAPID programs. Placeholders may be used by offline and online programming tools to temporarily represent "not yet defined" parts of a RAPID program. A program that contains placeholders is syntactically correct and may be loaded to (and saved from) the task buffer. If the placeholders in a RAPID program do not

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cause any semantic errors (see *Error classification on page 18*), such a program can even be executed, but any placeholder encountered causes an execution error (see *Error classification on page 18*).

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1.3 Syntax notation

Context-free syntax

The context-free syntax of the RAPID language is described using a modified variant of the Backus-Naur Form - EBNF.

- Boldface, upper case words denote reserved words and placeholders, for example **WHILE**
- Quoted strings denote other terminal symbols, for example '+'
- Strings enclosed in angle brackets denote syntactic categories, non-terminals, for example <constant expression>
- The symbol `::=` means *is defined as*, for example `<dim> ::= <constant expression>`
- A list of terminals and/or non-terminals denotes a sequence, for example `GOTO<identifier> ';'`
- Square brackets enclose optional items. The items may occur zero or one time, for example `<return statement> ::= RETURN [ <expression> ] ';'`
- The vertical bar separates alternative items, for example `OR | XOR`
- Braces enclose repeated items. The items may appear zero or more times. For example `<statement list> ::= { <statement> }`
- Parentheses are used to hierarchically group concepts together, for example `(OR|XOR)<logical term>`

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1.4 Error classification

Types of errors

Based on the time of detection errors may be divided into *static errors* or *execution errors*.

Static errors

Static errors are detected either when a module is loaded into the task buffer (see *Task modules on page 119*) or before program execution after program modification.

Type of error	Example	Description of example
Lexical errors, illegal lexical elements	`b := 2E52786;`	Exponent out of range
Syntax errors, violation of the syntax rules	`FOR i 5 TO 10 DO`	Missing `FROM` keyword
Semantic errors, violation of semantic rules, typically type errors	`VAR num a;` `a := "John";`	Data type mismatch
Fatal (system resource) errors	-	Program to complex (nested)

Execution errors

Execution errors occur (are detected) during the execution of a task.

- Arithmetic errors, for example division by zero
- I/O errors, for example no such file or device
- Fatal (system resource) errors, for example execution stack overflow

The error handler concept of RAPID makes it possible to recover from non-fatal execution errors. See *Error recovery on page 97*.

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2 Lexical elements

2.1 Character set

Definition

The RAPID language is constructed using the standard ISO 8859-1 (Latin-1) character set. In addition newline, tab, and formfeed control characters are recognized. Everything such as names of modules, variables, folders, etc. must use symbols from the ISO 8859-1 character set, as defined below.

Supported symbols of ISO 8859-1

The following symbols in ISO 8859-1 are supported:

```
<character> ::= -- ISO 8859-1 (Latin-1)--
<newline> ::= -- newline control character --
<digit> ::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9
<hex digit> ::= <digit> | A | B | C | D | E | F | a | b | c | d |
     e | f
<letter> ::= <upper case letter> | <lower case letter>
<upper case letter> ::=
  A | B | C | D | E | F | G | H | I | J
  | K | L | M | N | O | P | Q | R | S | T
  | U | V | W | X | Y | Z | À | Á | Â | Ã
  | Ä | Å | Æ | Ç | È | É | Ê | Ë | Ì | Í
  | Î | Ï | Ð | Ñ | Ò | Ó | Ô | Õ | Ö | Ø
  | Ù | Ú | Û | Ü | Ý | Þ | ß
<lower case letter> ::=
a | b | c | d | e | f | g | h | i | j
| k | l | m | n | o | p | q | r | s | t
| u | v | w | x | y | z | ß | à | á | â | ã
| ä | å | æ | ç | è | é | ê | ë | ì | í
| î | ï | ð | ñ | ò | ó | ô | õ | ö | ø
| ù | ú | û | ü | ý | þ | ÿ
```


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2.2 Lexical units

Definition

A RAPID sentence is a sequence of lexical units, also known as *tokens*. The RAPID tokens are:

- identifiers
- reserved words
- literals
- delimiters
- placeholders
- comments

Limitations

Tokens are indivisible. Except for string literals and comments, space must not occur within tokens.

An identifier, reserved word, or numeric literal must be separated from a trailing, adjacent identifier, reserved word, or numeric literal by one or more spaces, tabs, formfeed, or newline characters. Other combinations of tokens may by separated by one or more spaces, tabs, formfeed, or newline characters.

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2.3 Identifiers

Definition

Identifiers are used for naming objects.

```
<identifier> ::= <ident> | <ID>
<ident> ::= <letter> {<letter> | <digit> | '_'}
```

Limitations

The maximum length of an identifier is 32 characters.

All characters of an identifier are significant. Identifiers differing only in the use of corresponding upper and lower case letters are considered the same.

The placeholder <ID> (see *Placeholders on page 15*, and *Placeholders on page 27*) can be used to represent an identifier.

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2.4 Reserved words

Definition

The words listed below are reserved. They have a special meaning in the RAPID language and thus must not be used as identifiers.

They may not be used in any context not specially stated by the syntax.

There are also a number of predefined names for data types, system data, instructions, and functions, that must not be used as identifiers.

ALIAS	AND	BACKWARD	CASE
CONNECT	CONST	DEFAULT	DIV
DO	ELSE	ELSEIF	ENDFOR
ENDFUNC	ENDIF	ENDMODULE	ENDPROC
ENDRECORD	ENDTEST	ENDTRAP	ENDWHILE
ERROR	EXIT	FALSE	FOR
FROM	FUNC	GOTO	IF
INOUT	LOCAL	MOD	MODULE
NOSTEPIN	NOT	NOVIEW	OR
PERS	PROC	RAISE	READONLY
RECORD	RETRY	RETURN	STEP
SYSMODULE	TEST	THEN	TO
TRAP	TRUE	TRYNEXT	UNDO
VAR	VIEWONLY	WHILE	WITH
XOR			

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2.5 Numerical literals

Definition

A numerical literal represents a numeric value.

```
<num literal> ::=
  <integer> [ <exponent> ]
  | <decimal integer>) [<exponent>]
  | <hex integer>
  | <octal integer>
  | <binary integer>
  | <integer> '.' [ <integer> ] [ <exponent> ]
  | [ <integer> ] '.' <integer> [ <exponent> ]
<integer> ::= <digit> {<digit>}
<decimal integer> ::= '0' ('D' | 'd') <integer>
<hex integer> ::= '0' ('X' | 'x') <hex digit> {<hex digit>}
<octal integer> ::= '0' ('O' | 'o') <octal digit> {<octal digit>}
<binary integer> ::= '0' ('B' | 'b') <binary digit> {<binary digit>}

<exponent> ::= ('E' | 'e') ['+' | '-'] <integer>

<digit> ::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9
<hex digit> ::= <digit> | A | B | C | D | E | F | a | b | c | d |
     e | f
<octal digit> ::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7
<binary digit> ::= 0 | 1
```

Limitations

A numerical literal must be in the range specified by the ANSI IEEE 754 Standard for Floating-Point Arithmetic.

Example

For example: 7990 23.67 2E6 .27 2.5E-3 38.

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2.6 Bool literals

Definition

A bool literal represents a logical value.

```
<bool literal> ::= TRUE | FALSE
```


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2.7 String literals

Definition

A string literal is a sequence of zero or more characters enclosed by the double quote (") character.

```
<string literal> ::= '"' { <character> | <character code> } '"'
     <character code> ::= '\' <hex digit> <hex digit>
```

The possibility to use character codes provides a means to include non-printable characters (binary data) in string literals. If a back slash or double quote character should be included in a string literal it must be written twice.

Example

```
"A string literal"
"Contains a "" character"
"Ends with BEL control character\07"
"Contains a \\ character"
```


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2.8 Delimiters

Definition

A delimiter is one of the following characters:

{ } ( ) [ ] , . = < > + -* / : ; ! \ ?

A delimiter can also be one of the following compound symbols:

:= <> >= <=

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2.9 Placeholders

Definition

Placeholders can be used by offline and online programming tools to temporarily represent "not yet defined" parts of a RAPID program. A program that contains placeholders is syntactically correct and can be loaded to (and saved) from the task buffer. If the placeholders in a RAPID program does not cause any semantic errors (see *Error classification on page 18*), such a program can even be executed, but any placeholder encountered causes an execution error (see *Error classification on page 18*).

RAPID recognizes the following placeholders:

Placeholder	Description
<TDN>	(represents a) data type definition
<DDN>	(represents a) data declaration
<RDN>	routine declaration
<PAR>	parameter declaration
<ALT>	alternative parameter declaration
<DIM>	array dimension
<SMT>	statement
<VAR>	data object reference (variable, persistent, or parameter)
<EIT>	else if clause of if statement
<CSE>	case clause of test statement
<EXP>	expression
<ARG>	procedure call argument
<ID>	identifier

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2.10 Comments

Definition

A comment starts with an exclamation mark (!) and is terminated by a newline character. A comment can never include a newline character.

<comment> ::= '!' { <character> | <tab> } <newline>

Comments have no effect on the meaning of a RAPID code sequence; their sole purpose is to clarify the code to the reader.

Each RAPID comment and may occur either as:

- an element of a type definition list (see data declaration list)
- an element of a record component list (see *Comments in a record on page 28*)
- an element of a data declaration list (see *Procedure declarations on page 90*)
- an element of a routine declaration list (see *Module declarations on page 120*)
- an element of a statement list (see *Statement lists on page 67*)

Comments located between the last data declaration (see *Data declarations on page 40*) and the first routine declaration (see *Routine declarations on page 85*) of a module, are regarded to be a part of the routine declaration list. Comments located between the last data declaration and the first statement of a routine, are regarded to be a part of the statement list (see *Statement lists on page 67*).

Example

```
! Increase length
length := length + 5;
IF length < 1000 OR length > 14000 THEN
  ! Out of bounds
  EXIT;
ENDIF
...
```

Comments in a record

In a record definition, it is not allowed to have a comment in a separate line unless it is the last line.

```
RECORD my_rec
  ! DISALLOWED COMMENT
  num mynum; ! allowed comment (not separate line)
  string mystring;
  ! allowed comment on last line
ENDRECORD
```


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2.11 Data types

Definition

A RAPID data type is identified by its name and can be built-in, installed, or user-defined (defined in RAPID).

```
<data type> ::= <identifier>
```

Built-in types are part of the RAPID language while the set of installed or user-defined types may differ from site to site. The concept of installed types supports the use of installed routines by making it possible to use appropriate parameter types. The user-defined types make it possible to prepare understandable and easy programmable application packets for the application engineer. From the point of view or the user there is no difference between built-in, installed, and user-defined types.

There are three different types:

- *The atomic data types on page 31*
- *The record data types on page 33*
- *The alias data types on page 36*

A type definition introduces an alias or a record by associating an identifier with a description of a data type. A type definition can be represented by the placeholder <TDN>.

```
<type definition> ::=
  [LOCAL] ( <record definition> | <alias definition> )
  | <comment>
  | <TDN>
```

Type definitions can occur in the heading section of modules (see *Task modules on page 119*).

The optional local directive classifies the data object being local, otherwise global (see *Scope rules for data objects on page 43*).

Example

Record definition

```
LOCAL RECORD object
  num usecount;
  string name;
ENDRECORD
```

Alias definition

```
ALIAS num another_num;
```

Definition for placeholder

```
<TDN>
```


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2.12 Scope rules for data types

Definition

The scope of a type definition denotes the area in which the type is visible and is determined by the context and position of its declaration.

The scope of a predefined type comprises any RAPID module.

A user-defined type is always defined inside a module. The following scope rules are valid for module type definitions:

- The scope of a local module type definition comprises the module in which it is contained.
- The scope of a global module type definition in addition comprises any other module in the task buffer.
- Within its scope a module type definition hides any predefined type with the same name.
- Within its scope a local module type definition hides any global module type with the same name.
- Two module objects declared in the same module may not have the same name.
- Two global objects declared in two different modules in the task buffer may not have the same name.

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2.13 The atomic data types

Definition

The atomic data types are "atomic" in the sense that they are not defined upon any other type and cannot be divided into parts or components. The internal structure (implementation) of an atomic type is hidden.

The built-in atomic types are the numeric types `num` and `dnum`, the logical type `bool`, and the text type `string`.

The type num

A `num` object represents a numeric value. The `num` type denotes the domain specified by the ANSI IEEE 754 Standard for Floating-Point Arithmetic.

Within the subdomain -8388607 to (+)8388608, `num` objects may be used to represent integer (exact) values. The arithmetic operators +, -, and * (see *Operators on page 63*) preserves integer representation as long as operands and result are kept within the integer subdomain of `num`.

Examples with `num`

Example	Description
`VAR num counter;`	declaration of a variable
`counter := 250;`	`num` literal usage

The type dnum

A `dnum` object represents a numeric value. The `dnum` type denotes the domain specified by the ANSI IEEE 754 Standard for Floating-Point Arithmetic.

Within the subdomain -4503599627370496 to (+)4503599627370496, `dnum` objects may be used to represent integer (exact) values. The arithmetic operators +, -, and * (see *Operators on page 63*) preserves integer representation as long as operands and result are kept within the integer subdomain of `dnum`.

Examples with `dnum`

Example	Description
`VAR dnum value;`	declaration of a variable
`value := 2E+43;`	`dnum` literal usage

The type bool

A `bool` object represents a logical value.

The `bool` type denotes the domain of two-valued logic, *TRUE* or *FALSE*.

Examples with `bool`

Example	Description
`VAR bool active;`	declaration of a variable
`active := TRUE;`	`bool` literal usage

Continues on next page

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The type `string`

A `string` object represents a character string.

The `string` type denotes the domain of all sequences of graphical characters (ISO 8859-1) and control characters (non ISO 8859-1 characters in the numeric code range 0 .. 255). A string may consist of 0 to 80 characters (fixed 80 characters storage format).

Examples with `string`

Example	Description
`VAR string name;`	declaration of a variable
`name := "John Smith";`	`dnum` literal usage

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2.14 The record data types

Definition

A record data type is a composite type with named, ordered components. The value of a record type is a composite value consisting of the values of its components. A component can have atomic type or record type.

The built-in record types are `pos`, `orient`, and `pose`. The available set of installed and user-defined record types is by definition not bound by the RAPID specification.

Record definition

A record type is introduced by a record definition.

```
<record definition> ::=
  RECORD <identifier> <record component list>
  ENDRECORD
<record component list> ::=
  <record component definition> | <record component definition>
       <record component list>
<record component definition> ::=
  <data type> <record component name> ';'
```

For example:

```
RECORD newtype
  num x;
ENDRECORD
```

Record value

A record value can be expressed using an aggregate representation.

The following example shows the aggregate value for a `pos` record.

```
[ 300, 500, depth ]
```

Assigning values to components

A specific component of a record data object can be accessed by using the name of the component.

The following example assigns a value to the x-component of the `pos` variable `p1`.

```
p1.x := 300;
```

Default domain

Unless otherwise stated the domain of a record type is the Cartesian product of the domains of its components.

Comments in a record

In a record definition, it is not allowed to have a comment in a separate line unless it is the last line.

```
RECORD my_rec
  ! DISALLOWED COMMENT
  num mynum; ! allowed comment (not separate line)
  string mystring;
  ! allowed comment on last line
```

Continues on next page

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```
ENDRECORD
```

The type pos

A `pos` object represents a vector (position) in 3D space. The `pos` type has three components, `[x, y, z]`.

Component	Data type	Description
`x`	`num`	x-axis component of position
`y`	`num`	y-axis component of position
`z`	`num`	z-axis component of position

Examples with `pos`

Example	Description
`VAR pos p1;`	declaration of a variable
`p1 := [ 10, 10, 55.7 ];`	aggregate usage
`p1.z := p1.z + 250;`	component usage
`p1 := p1 + p2;`	operator usage

The type orient

An `orient` object represents an orientation (rotation) in 3D space. The `orient` type has four components, `[q1, q2, q3, q4]`.

Component	Data type	Description
`q1`	`num`	first quaternion component
`q2`	`num`	second quaternion component
`q3`	`num`	third quaternion component
`q4`	`num`	fourth quaternion component

The quaternion representation is the most compact way to express an orientation in space. Alternate orientation formats (for example Euler angles) can be specified using predefined functions available for this purpose.

Examples with `orient`

Example	Description
`VAR orient o1;`	declaration of a variable
`o1 := [ 1, 0, 0, 0];`	aggregate usage
`o1.q1 := -1;`	component usage
`o1 := Euler(a1,b1,g1);`	function usage

The type pose

A `pose` object represents a 3D frame (coordinate system) in 3D-space. The `pose` type has two components, `[ trans, rot ]`.

Component	Data type	Description
`trans`	`pos`	origin of translation

Continues on next page

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Component	Data type	Description
rot	orient	rotation

Examples with pose

Example	Description
`VAR pose p1;`	declaration of a variable
`p1 := [[ 100, 100, 0 ], o1];`	aggregate usage
`p1.trans := homepos;`	component usage

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2.15 The alias data types

Definition

An alias data type is defined as being equal to another type. The alias types provide a means to classify objects. The system may use the alias classification to look up and present type related objects.

An alias type is introduced by an alias definition.

```
<alias definition> ::=
  ALIAS <type name> <identifier> ';'
```

Note

One alias type cannot be defined upon another alias type. The built-in alias types are `errnum` and `intnum` - both are alias for `num`.

Examples with alias

Example	Description
`ALIAS num newtype;`	The type `newtype` is alias for `num`
`CONST level low := 2.5;` `CONST level high := 4.0;`	Usage of alias type `level` (alias for `num`)

The type `errnum`

The `errnum` type is an alias for `num` and is used for the representation of error numbers.

The type `intnum`

The `intnum` type is an alias for `num` and is used for the representation of interrupt numbers.

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2.16 Data type value classes

Definition

With respect to the relation between object data type and object value, data types can be classified as being either:

- value data type
- non-value (private) data type
- semi-value data type

The basic value types are the built-in atomic types `num`, `dnum`, `bool`, and `string`. A record type with all components being value types is itself a value type, for example the built-in types `pos`, `orient`, and `pose`. An alias type defined upon a value type is itself a value type, for example the built-in types `errnum` and `intnum`.

A record type having at least one semi-value component and all other components have value type is itself a semi-value type. An alias type defined upon a semi-value type is itself a semi-value type.

All other types are non-value types, for example record types with at least one non-value component and alias types defined upon non-value types.

Arrays have the same value class as the element value class.

Value data type

An object of value type is simply considered to represent some form of "value" (for example 5, [10, 7, 3.25], "John Smith", TRUE). A non-value (type) object instead represents a hidden/encapsulated description (descriptor) of some physical or logical object, for example the iodev (file) type.

Non-value data type

The content ("value") of non-value objects can only be modified using installed routines ("methods"). Non-value objects may in RAPID programs only be used as arguments to `var` or `ref` parameters.

For example: Use of non-value object `logfile`

```
VAR iodev logfile;
...
! Open logfile
Open "flp1:LOGDIR" \File := "LOGFILE1.DOC ", logfile;
...
! Write timestamp to logfile
Write logfile, "timestamp = " + GetTime();
```

Semi-value data type

Semi-value objects are special. They have two types, one "basic" non-value type and one associated (value) type that may be used to represent some property of the non-value type. RAPID views a semi-value object as a value object when used in value context (see table below) and a non-value object otherwise. The semantics (meaning/result) of a read or update (value) operation performed upon a semi-value type is defined by the type itself.

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For example: Use of semi-value object `sig1` in value context (the associated type of `signaldi` is `num`).

```
VAR signaldi sig1;
...
! use digital input sig1 as value object
IF sig1 = 1 THEN
  ...
...
! use digital input sig1 as non-value object
IF DInput(sig1) = 1 THEN
  ...
```

Note that a semi-value object (type) can reject either reading or updating "by value".

For example, the following assignment will be rejected by `sig1` since `sig1` represents an input device.

```
VAR signaldi sig1;
...
sig1 := 1;
```

Possible and impossible combinations of object usage and type value class

The tables below show which combinations of object usage and type value class that are possibly legal ("X" in the tables) and which are impossible or illegal ("-" in the tables).

Object declaration	Value	Non-value	Semi-value
Constant	X	-	N.A.
Persistent	X	-	N.A.
Variable with initialization	X	-	N.A.
Variable without initialization	X	X	X
Routine parameter: in	X	-	-
Routine parameter: var	X	X	X
Routine parameter: pers	X	-	-
Routine parameter: ref (only installed routines)	X	X	X
Routine parameter: inout var	X	-	-
Routine parameter: inout pers	X	-	-
Function return value	X	-	-

Object reference	Value	Non-value	Semi-value
Assignment [i]	X	-	X [ii]
Assignment	X	X [iii]	X *iii*
Assignment [iv]	X	-	X *ii*

i See more about targets in *Assignment statement on page 69*, and *The Connect statement on page 78*.

ii The associated type (value) is used.

iii Argument to `var` or `ref` parameter.

iv Object used in expression.

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2.17 Equal type

Definition

The types of two objects are equal if the objects have the same structure (degree, dimension, and number of components) and either:

- Both objects have the same type name (any alias type name included is first replaced by its definition type).
- One of the objects is an aggregate (array or record) and the types of (all) corresponding elements/components are equal.
- One of the objects has a value type, the other object has a semi-value type and the type of the first object and the associated type of the semi-value object are equal. Note that this is only valid in value context.

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2.18 Data declarations

Definition

There are four kinds of data objects:

- constant, CONST
- variable, VAR
- persistent, PERS
- parameter

Except for predefined data objects (see *Predefined data objects on page 42*) and for loop variables (see *The For statement on page 81*) all data objects must be declared. A data declaration introduces a constant, a variable, or a persistent by associating an identifier with a data type. See *Parameter declarations on page 86* for information on parameter declarations.

A data declaration can be represented by the placeholder <DDN>.

```
<data declaration> ::=
[LOCAL] ( <variable declaration> | <persistent declaration> |
     <constant declaration> )
| TASK ( <variable declaration> | <persistent declaration>
| <comment>
| <DDN>
```

About persistent data objects

A persistent (data object) can be described as a "persistent" variable. While a variable value is lost (re-initialized) at the beginning of each new session - at module load (module variable) or routine call (routine variable) - a persistent keeps its value between sessions. This is accomplished by letting an update of the value of a persistent automatically lead to an update of the initialization value of the persistent declaration. When a module (or task) is saved, the initialization value of any persistent declaration reflects the current value of the persistent. In addition, the persistent data objects are stored in a system public "database" and can be accessed (updated, referenced) by other components of the control system.

Declarations and accessibility

Data declarations can occur in the heading section of modules (see *Task modules on page 119*) and routines (see *Routine declarations on page 85*).

The optional local directive classifies the data object being local, otherwise global (see *Scope rules for data objects on page 43*). Note that the local directive only may be used at module level (not inside a routine).

The optional task directive classifies persistent data objects and variable data objects being task global as opposed to system global. In the scope rules there is no difference between the two global types.

However the current value of a task global persistent will always be unique to the task and not shared among other tasks. System global persistents in different tasks share current value if they are declared with the same name and type.

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Declaring a variable as task global will only be effective in a module that is installed shared. System global variables in loaded or installed modules are already unique to the task and not shared among other tasks.

Note

The task directive only may be used at module level (not inside a routine).

Examples

Example	Description
`LOCAL VAR num counter;`	declaration of variable
`CONST num maxtemp := 39.5;`	declaration of constant
`PERS pos refpnt := [100.23, 778.55, 1183.98];`	declaration of persistent
`TASK PERS num lasttemp := 19.2;`	declaration of persistent
`<DDN>`	declaration placeholder

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2.19 Predefined data objects

Definition

A predefined data object is supplied by the system and is always available. Predefined data objects are automatically declared and can be referenced from any module. See *Built-in data objects on page 137*.

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2.20 Scope rules for data objects

Definition

The scope of a data object denotes the area in which the object is visible and is determined by the context and position of its declaration.

The scope of a predefined data object comprises any RAPID module.

Module data object

A data object declared outside any routine is called a module data object (module variable, module constant or persistent). The following scope rules are valid for module data objects:

- The scope of a local module data object comprises the module in which it is contained.
- The scope of a global module data object in addition comprises any other module in the task buffer.
- Within its scope a module data object hides any predefined object with the same name.
- Within its scope a local module data object hides any global module object with the same name.
- Two module objects declared in the same module may not have the same name.
- Two global objects declared in two different modules in the task buffer may not have the same name.
- A global data object and a module may not share the same name.

Routine data object

A data object declared inside a routine is called a routine data object (routine variable or routine constant). Note that the concept of routine data objects in this context also comprises routine parameters (see *Parameter declarations on page 86*).

The following scope rules are valid for routine data objects:

- The scope of a routine data object comprises the routine in which it is contained.
- Within its scope a routine data object hides any predefined or user defined object with the same name.
- Two routine data objects declared in the same routine may not have the same name.
- A routine data object may not have the same name as a label declared in the same routine.
- See *Routine declarations on page 85* and *Task modules on page 119* for information on routines and task modules.

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2.21 Storage class

Definition

The storage class of a data object determines when the system allocates and de-allocates memory for the data object. The storage class of a data object is determined by the kind of data object and the context of its declaration and can be either static or volatile.

Constants, persistents, and module variables are static. The memory needed to store the value of a static data object is allocated when the module that declares the object is loaded (see *Task modules on page 119*). This means that any value assigned to a persistent or a module variable always remains unchanged until the next assignment.

Routine variables (and in parameters, see *Parameter declarations on page 86*) are volatile. The memory needed to store the value of a volatile object is allocated first upon the call of the routine in which the declaration of the variable is contained. The memory is later de-allocated at the point of the return to the caller of the routine. This means that the value of a routine variable is always undefined before the call of the routine, and is always lost (becomes undefined) at the end of the execution of the routine.

In a chain of recursive routine calls (a routine calling itself directly or indirectly) each instance of the routine receives its own memory location for the "same" routine variable - a number of instances of the same variable are created.

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2.22 Variable declarations

Definition

A variable is introduced by a variable declaration.

```
<variable declaration> ::=
  VAR <data type> <variable definition> ';'
<variable definition> ::=
  <identifier> [ '{' <dim> { ',' <dim> } '}' ] [ ':=' <constant
       expression> ]
<dim> ::= <constant expression>
```

For example:

```
VAR num x;
VAR pos curpos := [b+1, cy, 0];
```

As described in *Data declarations on page 40*, variables can be declared as local, task, or system global.

Declaring array variables

Variables of any type (including installed types) can be given an array (of degree 1, 2, or 3) format by adding dimension information to the declaration. The dimension expression must represent an integer value (see *The type num on page 31*) greater than 0.

For example:

```
! pos (14 x 18) matrix
VAR pos pallet{14, 18};
```

Declaring value type variables

Variables with value types (see *Data type value classes on page 37*) may be initialized (given an initial value). The data type of the constant expression used to initialize a variable must be equal to the variable type.

For example:

```
VAR string author_name := "John Smith";
VAR pos start := [100, 100, 50];
VAR num maxno{10} := [1, 2, 3, 9, 8, 7, 6, 5, 4, 3];
```

Initial value for un-initialized variables

An un-initialized variable (or variable component/element) receives the following initial value.

Data type	Initial value
num (or alias for num)	0
dnum (or alias for dnum)	0
bool (or alias for bool)	FALSE
string (or alias for string)	""
Installed atomic types	all bits 0'ed

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2.23 Persistent declarations

Definition

A persistent is introduced by a persistent declaration. Note that persistents can only be declared at module level (not inside a routine). A persistent can be given any value data type.

```
<persistent declaration> ::=
PERS <data type> <persistent definition> ';'
<persistent definition> ::=
<identifier> [ '{' <dim> { ',' <dim> } '}' ] [':=' <literal
     expression>]
```

Note

The literal expression may only be omitted for system global persistents.

For example:

```
PERS num pcounter := 0;
```

Declaring array persistents

Persistents of any type (including installed types) can be given an array (of degree 1, 2, or 3) format by adding dimension information to the declaration. The dimension expression must represent an integer value (see *The type num on page 31*) greater than 0.

For example:

```
! 2 x 2 matrix
PERS num grid{2, 2} := [[0, 0], [0, 0]];
```

Initial value for persistents

As described in *Data declarations on page 40*, persistents can be declared as local, task global or system global. Local and task global persistents must be initialized (given an initial value). For system global persistents the initial value may be omitted. The data type of the literal expression used to initialize a persistent must be equal to the persistent type. Note that an update of the value of a persistent automatically leads to an update of the initialization expression of the persistent declaration (if not omitted).

For example:

```
MODULE ...
  PERS pos refpnt := [0, 0, 0];
  ...
  refpnt := [x, y, z];
  ...
ENDMODULE
```

If the value of the variables x, y, and z at the time of execution is 100.23, 778.55, and 1183.98 respectively and the module is saved, the saved module will look like this:

```
MODULE ...
  PERS pos refpnt := [100.23, 778.55, 1183.98];
```

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```
    ...
    refpnt := [x, y, z];
    ...
ENDMODULE
```

Initial value for un-initalized persistents

A persistent without initial value (or persistent component/element) receives the following initial value.

Data type	Initial value
`num` (or alias for `num`)	0
`dnum` (or alias for `dnum`)	0
`bool` (or alias for `bool`)	FALSE
`string` (or alias for `string`)	""
Installed atomic types	all bits 0'ed

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2.24 Constant declarations

Definition

A constant represents a static value and is introduced by a constant declaration. The value of a constant cannot be modified. A constant can be given any value data type.

```
<constant declaration> ::=
  CONST <data type> <constant definition> ';'
<constant definition> ::=
  <identifier> [ '{' <dim> { ',' <dim> } '}' ] ':=' <constant
       expression>
<dim> ::= <constant expression>
```

For example:

```
CONST num pi := 3.141592654;
CONST num siteno := 9;
```

Declaring array constants

A constant of any type (including installed types) can be given an array (of degree 1, 2 or 3) format by adding dimensioning information to the declaration. The dimension expression must represent an integer value (see *The type num on page 31*) greater than 0. The data type of the constant value must be equal to the constant type.

For example:

```
CONST pos seq{3} := [[614, 778, 1020], [914, 998, 1021], [814, 998,
     1022]];
```


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3 Expressions

3.1 Introduction to expressions

Definition

An expression specifies the evaluation of a value. An expression can be represented by the placeholder <EXP>.

```
<expression> ::=
  <expr>
  | <EXP>
<expr> ::= [ NOT ] <logical term> { ( OR | XOR ) <logical term> }
<logical term> ::= <relation> { AND <relation> }
<relation> ::= <simple expr> [ <relop> <simple expr> ]
<simple expr> ::= [ <addop> ] <term> { <addop> <term> }
<term> ::= <primary> { <mulop> <primary> }
<primary> ::=
  <literal>
  | <variable>
  | <persistent>
  | <constant>
  | <parameter>
  | <function call>
  | <aggregate>
  | '(' <expr> ')'
<relop> ::= '<' | '<=' | '=' | '>' | '>=' | '<>'
<addop> ::= '+' | '-'
<mulop> ::= '*' | '/' | DIV | MOD
```

Evaluation order

The relative priority of the operators determines the order in which they are evaluated. Parentheses provide a means to override operator priority. The rules above imply the following operator priority:

Priority	Operators
Highest	* / DIV MOD
	+ -
	< > <> <= >= =
	AND
Lowest	XOR OR NOT

An operator with high priority is evaluated prior to an operator with low priority. Operators of the same priority are evaluated from left to right.

Example expression	Evaluation order	Comment
a + b + c	(a + b) + c	Left to right rule
a + b * c	a + (b * c)	* higher than +
a OR b OR c	(a OR b) OR c	Left to right rule

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Example expression	Evaluation order	Comment
`a AND b OR c AND d`	`(a AND b) OR (c AND d)`	`AND` higher than `OR`
`a < b AND c < d`	`(a < b) AND (c < d)`	`<` higher than `AND`

A binary operator is an operator that takes two operands, that is +, -, * etc. The left operand of a binary operator is evaluated prior to the right operand. Note that the evaluation of expressions involving AND and OR operators is optimized so that the right operand of the expression will not be evaluated if the result of the operation can be determined after the evaluation of the left operand.

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3.2 Constant expressions

Definition

Constant expressions are used to represent values in data declarations.

```
<constant expression> ::= <expression>
```

Note

A constant expression is a specialization of an ordinary expression. It may not at any level contain variables, persistents or function calls!

Examples

```
CONST num radius := 25;
CONST num pi := 3.141592654;
! constant expression
CONST num area := pi * radius * radius;
```


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3.3 Literal expressions

Definition

Literal expressions are used to represent initialization values in persistent declarations.

```
<literal expression> ::= <expression>
```

A literal expression is a specialization of an ordinary expression. It may only contain either a single literal value (+ or - may precede a numerical literal) or a single aggregate with members that in turn are literal expressions.

Examples

```
PERS pos refpnt := [100, 778, 1183];
PERS num diameter := 24.43;
```


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3.4 Conditional expressions

Definition

Conditional expressions are used to represent logical values.

```
<conditional expression> ::= <expression>
```

A conditional expression is a specialization of an ordinary expression. The resulting type must be `bool` (true or false).

Examples

```
counter > 5 OR level < 0
```


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3.5 Literals

Definition

A literal is a lexical element (indivisible) that represents a constant value of a specific data type.

```
<literal> ::=
  <num literal>
  | <string literal>
```

Examples

Example	Description
`0.5, 1E2`	numerical literals
`"limit"`	`string` literal
`TRUE`	`bool` literal

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3.6 Variables

Definition

Depending on the type and dimension of a variable it may be referenced in up to three different ways. A variable reference may mean the entire variable, an element of a variable (array), or a component of a variable (record).

```
<variable> ::=
  <entire variable>
  | <variable element>
  | <variable component>
```

A variable reference denotes, depending on the context, either the value or the location of the variable.

Entire variable

An entire variable is referenced by the variable identifier.

```
<entire variable> ::= <ident>
```

If the variable is an array the reference denotes all elements. If the variable is a record the reference denotes all components.

> **Note**
>
> The placeholder <ID> (see *Identifiers on page 21*) cannot be used to represent an entire variable.

```
VAR num row{3};
VAR num column{3};
...
! array assignment
row := column;
```

Variable element

An array variable element is referenced using the index number of the element.

```
<variable element> ::= <entire variable> '{' <index list> '}'
<index list> ::= <expr> { ',' <expr> }
```

An index expression must represent an integer value (see *The type num on page 31*) greater than 0. Index value 1 selects the first element of an array. An index value may not violate the declared dimension. The number of elements in the index list must fit the declared degree (1, 2, or 3) of the array.

Example	Description
`column{10}`	Reference of the tenth element of column
`mat{i * 10, j}`	Reference of matrix element

Variable component

A record variable component is referenced using the component name (names).

```
<variable component> ::= <variable> '.' <component name>
<component name> ::= <ident>
```

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Note

The placeholder <ID> (see *Identifiers on page 21*) cannot be used to represent a component name.

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3.7 Persistents

Definition

A persistent reference may mean the entire persistent, an element of a persistent (array) or a component of a persistent (record).

```
<persistent> ::=
  <entire persistent>
  | <persistent element>
  | <persistent component>
```

The rules concerning persistent references comply with the rules concerning variable references, see *Variables on page 55*.

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3.8 Constants

Definition

A constant reference may mean the entire constant, an element of a constant (array) or a component of a constant (record).

```
<constant> ::=
  <entire constant>
  | <constant element>
  | <constant component>
```

The rules concerning constant references comply with the rules concerning variable references, see *Variables on page 55*.

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3.9 Parameters

Definition

A parameter reference may mean the entire parameter, an element of a parameter (array) or a component of a parameter (record).

```
<parameter> ::=
  <entire parameter>
  | <parameter element>
  | <parameter component>
```

The rules concerning parameter references comply with the rules concerning variable references, see *Variables on page 55*.

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3.10 Aggregates

Definition

An aggregate denotes a composite value, which is an array or record value. Each aggregate member is specified by an expression.

```
<aggregate> ::= '[' <expr> { ',' <expr> } ']'
```

Example	Description
`[x, y, 2*x]`	`pos` aggregate
`["john", "eric", "lisa"]`	`string` array aggregate
`[[ 100, 100, 0 ], [ 0, 0, z ]]`	`pos` array aggregate
`[[1, 2, 3], [a, b, c]]`	`num` matrix (2*3) aggregate

Data type for aggregates

The data type of an aggregate is (must be able to be) determined by the context. The data type of each aggregate member must be equal to the type of the corresponding member of the determined type.

In the following example, the `IF` clause is illegal since the data type of neither of the aggregates can be determined by the context.

```
VAR pos p1;
! Aggregate type pos - determined by p1
p1 := [1, -100, 12];
IF [1,-100,12] = [a,b,b] THEN
  ...
```


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3.11 Function calls

Definition

A function call initiates the evaluation of a specific function and receives the value returned by the function. Functions can be either predefined or user defined.

```
<function call> ::= <function> '(' [ <function argument list> ]
     ')'
<function> ::= <ident>
```

Arguments

The arguments of a function call is used to transfer data to (and possibly from) the called function. Arguments are evaluated from left to right. The data type of an argument must be equal to the type of the corresponding parameter (see *Parameter declarations on page 86*) of the function. An argument may be required, optional, or conditional. Optional arguments may be omitted but the order of the (present) arguments must be the same as the order of the parameters. Two or more parameters may be declared to mutually exclude each other, in which case at most one of them may be present in the argument list. Conditional arguments are used to support smooth propagation of optional arguments through chains of routine calls.

```
<function argument list> ::=
  <first function argument> { <function argument> }
<first function argument> ::=
  <required function argument>
  | <optional function argument>
  | <conditional function argument>
<function argument> ::=
  ',' <required function argument>
  | <optional function argument>
  | ',' <optional function argument>
  | <conditional function argument>
  | ',' <conditional function argument>
<required function argument> ::=
  [ <ident> ':=' ] <expr>
<optional function argument> ::=
  '\' <ident> [ ':=' <expr>]
<conditional function argument> ::=
  '\' <ident> '?' <parameter>
```

Required arguments

A required argument is separated from a proceeding (if any) argument by ", ". The parameter name may be included, or left out.

Example	Description
`polar(3.937, 0.785398)`	two required arguments
`polar(dist := 3.937, angle := 0.785398)`	using names

Continues on next page

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Optional or conditional arguments

An optional or conditional argument is preceded by `'\'` and the parameter name. The specification of the parameter name is mandatory. Switch (see *Parameter declarations on page 86*) type arguments are somewhat special; they are used only to signal presence (of an argument). Switch arguments do therefore not include any argument expression. Switch arguments may be propagated using the conditional syntax.

Example	Description
`cosine(45)`	one required argument
`cosine(0.785398\rad)`	one required argument and one switch (optional)
`dist(pnt:=p2)`	one required argument
`dist(\base:=p1, pnt:=p2)`	one required argument and one optional

A conditional argument is considered to be "present" if the specified optional parameter (of the calling function) is present (see *Parameter declarations on page 86*), otherwise it is simply considered to be "omitted". Note that the specified parameter must be optional.

For example, `distance := dist(\base ? b, p);` is interpreted as `distance := dist(\base := b, p);` if the optional parameter b is present otherwise as `distance := dist( p);`

The concept of conditional arguments thus eliminates the need for multiple "versions" of routine calls when dealing with propagation of optional parameters.

For example:

```
IF Present(b) THEN
  distance := dist(\base:=b, p);
ELSE
  distance := dist(p);
ENDIF
```

More than one conditional argument may be used to match more than one alternative of mutually excluding parameters (see *Parameter declarations on page 86*). In that case at most one of them may be "present" (may refer a present optional parameter).

For example the function `FUNC bool check (\switch on | switch off`, thus may be called as `check(\on ? high \ off ? low`, if at most one of the optional parameters `high` and `low` are present.

Parameter list

The parameter list (see *Parameter declarations on page 86*) of a function assigns each parameter an access mode. The access mode of a parameter puts restrictions on a corresponding argument and specifies how RAPID transfers the argument. See *Routine declarations on page 85*, for the full description on routine parameters, access modes, and argument restrictions.

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3.12 Operators

Definition

The available operators can be divided into four classes.

- Multiplying operators
- Adding operators
- Relational operators
- Logical operators

The following tables specify the legal operand types and the result type of each operator. Note that the relational operators = and <> are the only operators valid for arrays. The use of operators in combination with operands of types not equal to (see *Equal type on page 39*) the types specified below will cause a type error (see *Error classification on page 18*).

Multiplication operators

Operator	Operation	Operand types	Result type
*	multiplication	num * num	num [i]
*	multiplication	dnum * dnum	dnum [i]
*	scalar vector multiplication	num * pos or pos * num	pos
*	vector product	pos * pos	pos
*	linking of rotations	orient * orient	orient
/	division	num / num	num
/	division	dnum / dnum	dnum
/	scalar vector division	pos / num	pos
DIV	integer division	num DIV num [i]	num
DIV	integer division	dnum DIV dnum [ii]	dnum
MOD	integer modulo; remainder	num MOD num [i]	num
MOD	integer modulo; remainder	dnum MOD dnum [ii]	dnum

i Must represent an integer value.
ii `dnum` must represent a positive integer value (≥0).

Addition operators

Operator	Operation	Operand types	Result type
+	addition	num + num	num [i]
+	addition	dnum + num	dnum [i]
+	unary plus; keep sign	+num or dnum or +pos	same [ii] , [i]
+	vector addition	pos + pos	pos
+	string concatenation	string + string	string
-	subtraction	num - num	num [i]
-	subtraction	dnum - dnum	dnum [i]

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Operator	Operation	Operand types	Result type
-	unary minus; change sign	-num or -dnum or -pos	same [ii], [i]
-	vector subtraction	pos - pos	pos

i Preserves integer (exact) representation as long as operands and result are kept within the integer sub-domain of the numerical type.

ii The result receives the same type as the operand. If the operand has an alias data type, the result receives the alias "base" type (`num`, `dnum` or `pos`).

Relational operators

Operator	Operation	Operand types	Result type
<	less than	`num < num`	`bool`
<	less than	`dnum < dnum`	`bool`
<=	less than or equal to	`num <= num`	`bool`
<=	less than or equal to	`dnum <= dnum`	`bool`
=	equal to	any [i] = any	`bool`
>=	greater than or equal to	`num >= num`	`bool`
>=	greater than or equal to	`dnum >= dnum`	`bool`
>	greater than	`num > num`	`bool`
>	greater than or equal to	`dnum > dnum`	`bool`
<>	not equal to	any <> any	`bool`

i Only value data types. Operands must have equal types.

Logical operators

Operator	Operation	Operand types	Result type
`AND`	and	`bool AND bool`	`bool`
`XOR`	exclusive or	`bool XOR bool`	`bool`
`OR`	or	`bool OR bool`	`bool`
`NOT`	unary not; negation	`NOT bool`	`bool`

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4 Statements

4.1 Introduction to statements

Definition

The concept of using installed routines (and types) to support the specific needs of the robot application programmer has made it possible to limit the number of RAPID statements to a minimum. The RAPID statements support general programming needs and there are really no robot model specific RAPID statements. Statements may only occur inside a routine definition.

```
<statement> ::=
  <simple statement>
  | <compound statement>
  | <label>
  | <comment>
  | <SMT>
```

Simple or compound statements

A statement is either *simple* or *compound*. A compound statement may in turn contain other statements. A label is a "no operation" statement that can be used to define named (`Goto`) positions in a program. The placeholder `<SMT>` can be used to represent a statement.

```
<simple statement> ::=
  <assignment statement>
  | <procedure call>
  | <goto statement>
  | <return statement>
  | <raise statement>
  | <exit statement>
  | <retry statement>
  | <trynext statement>
  | <connect statement>
<compound statement> ::=
  <if statement>
  | <compact if statement>
  | <for statement>
  | <while statement>
  | <test statement>
```


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4.2 Statement termination

Definition

Compound statements (except for the compact if statement) are terminated by statement specific keywords. Simple statements are terminated by a semicolon (;). Labels are terminated by a colon (:). Comments are terminated by a newline character (see *Comments on page 28*). Statement terminators are considered to be a part of the statement.

Example	Description
`WHILE index < 100 DO`	
`! Loop start`	newline terminates a comment
`next:`	":" terminates a label
`index := index + 1;`	";" terminates assignment statement
`ENDWHILE`	"endwhile" terminates the while statement

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4.3 Statement lists

Definition

A sequence of zero or more statements is called a statement list. The statements of a statement list are executed in succession unless a `goto`, `return`, `raise`, `exit`, `retry`, or `trynext` statement, or the occurrence of an interrupt or error causes the execution to continue at another point.

```
<statement list> ::= { <statement> }
```

Both routines and compound statements contain statement lists. There are no specific statement list separators. The beginning and end of a statement list is determined by the context.

Example	Description
`IF a > b THEN`	
`pos1 := a * pos2;`	start of statement list
`! this is a comment`	
`pos2 := home;`	end of statement list
`ENDIF`	

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4.4 Label statement

Definition

Labels are "no operation" statements used to define named program positions. The `goto` statement (see *The Goto statement on page 72*) causes the execution to continue at the position of a label.

```
<label> ::= <identifier> ':'
```

For example

```
next:
...
GOTO next;
```

Scope rules for labels

The following scope rules are valid for labels.

- The scope of a label comprises the routine in which it is contained.
- Within its scope a label hides any predefined or user defined object with the same name.
- Two labels declared in the same routine may not have the same name.
- A label may not have the same name as a routine data object declared in the same routine.

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4.5 Assignment statement

Definition

The assignment statement is used to replace the current value of a variable, persistent or parameter (assignment target) with the value defined by an expression. The assignment target and the expression must have equal types. Note that the assignment target must have value or semi-value data type (see *Data type value classes on page 37*). The assignment target can be represented by the placeholder <VAR>.

```
<assignment statement> ::= <assignment target> ':=' <expression>
     ';'
<assignment target> ::=
  <variable>
  | <persistent>
  | <parameter>
  | <VAR>
```

Examples

Example	Description
`count := count +1;`	entire variable assignment
`home.x := x * sin(30);`	component assignment
`matrix{i, j} := temp;`	array element assignment
`posarr{i}.y := x;`	array element/component
`assignment <VAR> := temp + 5;`	placeholder use

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4.6 Procedure call

Definition

A procedure call initiates the evaluation of a procedure. After the termination of the procedure the evaluation continues with the subsequent statement. Procedures can be either predefined or user defined. The placeholder <ARG> may be used to represent an undefined argument.

```
<procedure call> ::= <procedure> [ <procedure argument list> ] ';'
<procedure> ::=
  <identifier>
  | '%' <expression> '%'
<procedure argument list> ::=
  <first procedure argument> { <procedure argument> }
<first procedure argument> ::=
  <required procedure argument>
  | <optional procedure argument>
  | <conditional procedure argument>
  | <ARG>
<procedure argument> ::=
  ',' <required procedure argument>
  | <optional procedure argument>
  | ',' <optional procedure argument>
  | <conditional procedure argument>
  | ',' <conditional procedure argument>
  | ',' <ARG>
<required procedure argument> ::=
  [ <identifier> ':=' ] <expression>
<optional procedure argument> ::=
  '\' <identifier> [ ':=' <expression> ]
<conditional procedure argument> ::=
  '\' <identifier> '?' ( <parameter> | <VAR> )
```

Procedure name

The procedure (name) may either be statically specified by using an identifier (early binding) or evaluated during runtime from a (string type) expression (late binding). Even though early binding should be considered to be the "normal" procedure call form, late binding sometimes provides very efficient and compact code.

The following example shows early binding compared to late binding.

Early binding	Late binding

`TEST product_id CASE 1:`
`  proc1 x, y, z;`
`CASE 2:`
`  proc2 x, y, z;`
`CASE 3:`
`  ...`
	Example 1:
	`% "proc" + NumToStr(product_id, 0) % x, y, z;`
	`...`
	Example 2:
	`VAR string procname {3} := ["proc1", "proc2", "proc3"];`
	`...`
	`% procname{product_id} % x, y, z;`
	`...`

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The string expression in the statement %<expression>% is in the normal case a string with the name of a procedure found according to the scope rules, but the string could also have an enclosing description prefix that specify the location of the routine.

"name1:name2" specify the procedure "name2" inside the module "name1" (note that the procedure "name2" could be declared local in that module). ":name2" specify the global procedure "name2" in one of the task modules, this is very useful when a downwards call must be done from the system level (installed built in object).

Late binding

Note that late binding is available for procedure calls only, not for function calls.

The general rules concerning the argument list of the procedure call are exactly the same as those of the function call. For more details, see *Function calls on page 61*, and *Routine declarations on page 85*.

Example	Description
`move t1, pos2, mv;`	procedure call
`move tool := t1, dest := pos2, movedata := mv;`	with names
`move \reltool, t1, dest, mv;`	with switch `reltool`
`move \reltool, t1, dest, mv \speed := 100;`	with optional `speed`
`move \reltool, t1, dest, mv \time := 20;`	with optional `time`

Normally the procedure reference is solved (bind) according to the normal scope rules, but late binding provide a way to do a deviation from that rule.

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4.7 The Goto statement

Definition

The `goto` statement causes the execution to continue at the position of a label.

```
<goto statement> ::= GOTO <identifier> ';'
```

Note

A `goto` statement may not transfer control into a statement list.

For example:

```
next:
i := i + 1;
...
GOTO next;
```


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4.8 The Return statement

Definition

The `return` statement terminates the execution of a routine and, if applicable, specifies a return value. A routine may contain an arbitrary number of return statements. A `return` statement can occur anywhere in the statement list or the error or backward handler of the routine and at any level of a compound statement. The execution of a `return` statement in the entry (see *Task modules on page 119*) routine of a task terminates the evaluation of the task. The execution of a `return` statement in a trap (see *Trap routines on page 116*) routine resumes execution at the point of the interrupt.

```
<return statement> ::= RETURN [ <expression> ] ';'
```

Limitations

The expression type must be equal to the type of the function. Return statements in procedures and traps must not include the return expression.

For example:

```
FUNC num abs_value (num value)
  IF value < 0 THEN
    RETURN -value;
    ELSE
    RETURN value;
  ENDIF
ENDFUNC

PROC message ( string mess )
  write printer, mess;
  RETURN; ! could have been left out
ENDPROC
```


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4.9 The Raise statement

Definition

The `raise` statement is used to explicitly raise or propagate an error.

```
<raise statement> ::= RAISE [ <error number> ] ';'
<error number> ::= <expression>
```

Error numbers

A `raise` statement that includes an explicit error number raises an error with that number. The error number (see *Error recovery on page 97*) expression must represent an integer value (see *The type `num` on page 31*) in the range from 1 to 90. A `raise` statement including an error number must not appear in the error handler of a routine.

A `raise` statement with no error number may only occur in the error handler of a routine and raises again (re-raises) the same (current) error at the point of the call of the routine, that is propagates the error. Since a trap routine can only be called by the system (as a response to an interrupt), any propagation of an error from a trap routine is made to the system error handler (see *Error recovery on page 97*).

For example:

```
CONST errnum escape := 10;
...
RAISE escape; ! recover from this position
...
ERROR
  IF ERRNO = escape THEN
    RETURN val2;
  ENDIF
ENDFUNC
```


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4.10 The Exit statement

Definition

The `exit` statement is used to immediately terminate the execution of a task.

```
<exit statement> ::= EXIT ';'
```

Task termination using the `exit` statement, unlike returning from the entry routine of the task, in addition prohibits any attempt from the system to automatically restart the task.

For example:

```
TEST state
  CASE ready:
  ...
  DEFAULT :
  ! illegal/unknown state - abort
  write console, "Fatal error: illegal state";
  EXIT;
ENDTEST
```


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4.11 The Retry statement

Definition

The `retry` statement is used to resume execution after an error, starting with (reexecuting) the statement that caused the error.

```
<retry statement> ::= RETRY ';'
```

The `retry` statement can only appear in the error handler of a routine.

For example:

```
...
! open logfile
open \append, logfile, "temp.log";
...
ERROR
  IF ERRNO = ERR_FILEACC THEN
    ! create missing file
    create "temp.log";
    ! resume execution
    RETRY;
  ENDIF
  ! propagate "unexpected" error RAISE; ENDFUNC
  RAISE;
ENDFUNC
```


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4.12 The Trynext statement

Definition

The `trynext` statement is used to resume execution after an error, starting with the statement following the statement that caused the error.

```
<trynext statement> ::= TRYNEXT ';'
```

The `trynext` statement can only appear in the error handler of a routine.

For example:

```
...
! Remove the logfile
delete logfile;
...
ERROR
  IF ERRNO = ERR_FILEACC THEN
    ! Logfile already removed - Ignore
    TRYNEXT;
  ENDIF
  ! propagate "unexpected" error
  RAISE;
ENDFUNC
```


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4.13 The Connect statement

Definition

The `connect` statement allocates an interrupt number, assigns it to a variable or parameter (*connect target*) and connects it to a trap routine. When (if) an interrupt with that particular interrupt number later occurs the system responds to it by calling the connected trap routine. The connect target can be represented by the placeholder <VAR>.

```
<connect statement> ::= CONNECT <connect target> WITH <trap> ';'
<connect target> ::=
  <variable>
  | <parameter>
  | <VAR>
<trap> ::= <identifier>
```

Prerequisites

The `connect` target must have `num` (or alias for `num`) type and must be (or represent) a module variable (not a routine variable). If a parameter is used as `connect` target it must be a `VAR` or `INOUT/VAR` parameter, see *Parameter declarations on page 86*. An allocated interrupt number cannot be "disconnected" or connected with another trap routine. The same connect target may not be associated with the same trap routine more than once. This means that the same `connect` statement may not be executed more than once and that only one of two identical connect statements (same connect target and same trap routine) may be executed during a session. Note though, that more than one interrupt number may be connected with the same trap routine.

For example:

```
VAR intnum hp;
PROC main()
...
CONNECT hp WITH high_pressure;
...
ENDPROC

TRAP high_pressure
  close_valve\fast;
  RETURN;
ENDTRAP
```


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4.14 The IF statement

Definition

The IF statement evaluates one or none of a number of statement lists, depending on the value of one or more conditional expressions.

```
<if statement> ::=
  IF <conditional expression> THEN <statement list>
  {ELSEIF <conditional expression> THEN <statement list> | <EIT>
       }
  [ ELSE <statement list> ]
  ENDIF
```

The conditional expressions are evaluated in succession until one of them evaluates to true. The corresponding statement list is then executed. If none of them evaluates to true the (optional) else clause is executed. The placeholder <EIT> can be used to represent an undefined elseif clause.

For example:

```
IF counter > 100 THEN
  counter := 100;
ELSEIF counter < 0 THEN
  counter := 0;
ELSE
  counter := counter + 1;
ENDIF
```


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4.15 The compact IF statement

Definition

In addition to the general, structured if-statement, see *The IF statement on page 79*, RAPID provides an alternative, compact if statement. The compact if statement evaluates a single, simple statement if a conditional expression evaluates to true.

```
<compact if statement> ::=
  IF <conditional expression> ( <simple statement> | <SMT> )
```

The placeholder <SMT> can be used to represent an undefined simple statement.

For example:

```
IF ERRNO = escape1 GOTO next;
```


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4.16 The For statement

Definition

The `for` statement repeats the evaluation of a statement list while a loop variable is incremented (or decremented) within a specified range. An optional step clause makes it possible to select the increment (or decrement) value.

The loop variable:

- is declared (with type `num`) by its appearance.
- has the scope of the statement list (`do .. endfor`).
- hides any other object with the same name.
- is readonly, that is cannot be updated by the statements of the `for` loop.

```
<for statement> ::=
  FOR <loop variable> FROM <expression>
  TO <expression> [ STEP <expression> ]
  DO <statement list> ENDFOR
<loop variable> ::= <identifier>
```

Initially the from, to and step expressions are evaluated and their values are kept. They are evaluated only once. The loop variable is initiated with the from value. If no step value is specified it defaults to 1 (or -1 if the range is descending).

Before each new (not the first) loop, the loop variable is updated and the new value is checked against the range. As soon as the value of the loop variable violates (is outside) the range the execution continues with the subsequent statement.

The from, to and step expressions must all have `num` (numeric) type.

For example:

```
FOR i FROM 10 TO 1 STEP -1 DO
  a{i} := b{i};
ENDFOR
```


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4.17 The While statement

Definition

The `while` statement repeats the evaluation of a statement list as long as the specified conditional expression evaluates to true.

```
<while statement> ::=
  WHILE <conditional expression> DO
  <statement list> ENDWHILE
```

The conditional expression is evaluated and checked before each new loop. As soon as it evaluates to false the execution continues with the subsequent statement.

For example:

```
WHILE a < b DO
  ...
  a := a + 1;
ENDWHILE
```


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4.18 The Test statement

Definition

The `test` statement evaluates one or none of a number of statement lists, depending on the value of an expression.

```
<test statement> ::=
  TEST <expression>
  { CASE <test value> { ',' <test value> } ':' <statement list> )
       | <CSE> }
  [ DEFAULT ':'<statement list> ]
  ENDTEST
<test value> ::= <expression>
```

Each statement list is preceded by a list of test values, specifying the values for which that particular alternative is to be selected. The `test` expression can have any value or semi-value data type (see *Data type value classes on page 37*). The type of a test value must be equal to the type of the test expression. The execution of a test statement will choose one or no alternative. In case more than one test value fits the test expression only the first is recognized. The placeholder `<CSE>` can be used to represent an undefined case clause.

The optional default clause is evaluated if no case clause fits the expression.

For example:

```
TEST choice
CASE 1, 2, 3 :
  pick number := choice;
CASE 4 :
  stand_by;
DEFAULT:
  write console, "Illegal choice";
ENDTEST
```


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5 Routine declarations

5.1 Introduction to routine declarations

Definition

A routine is a named carrier of executable code. A user routine is defined by a RAPID routine declaration. A predefined routine is supplied by the system and is always available.

There are three types of routines: *procedures*, *functions*, and *traps*.

A function returns a value of a specific type and is used in expression context (see *Function calls on page 61*).

A procedure does not return any value and is used in statement context (see *Procedure call on page 70*).

Trap routines provide a means to respond to interrupts (see *Interrupts on page 115*). A trap routine can be associated with a specific interrupt (using the connect statement, see *The Connect statement on page 78*) and is then later automatically executed if that particular interrupt occurs. A trap routine can never be explicitly called from RAPID code.

A routine declaration can be represented by the placeholder <RDN>.

```
<routine declaration> ::=
  [LOCAL] ( <procedure declaration>
    | <function declaration>
    | <trap declaration> )
  | <comment>
  | <RDN>
```

The declaration of a routine specifies its:

- Name
- Data type (only valid for functions)
- Parameters (not for traps)
- Data declarations and statements (body)
- Backward handler (only valid for procedures)
- Error handler
- Undo handler

Limitations

Routine declarations may only occur in the last section of a module (see *Task modules on page 119*). Routine declarations cannot be nested, that is it is not possible to declare a routine inside a routine declaration.

The optional local directive of a routine declaration classifies a routine to be local, otherwise it is global (see *Scope rules for routines on page 89*).

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5.2 Parameter declarations

Definition

The parameter list of a routine declaration specifies the arguments (actual parameters) that must/can be supplied when the routine is called. Parameters are either required or optional. An optional parameter may be omitted from the argument list of a routine call (see *Scope rules for data objects on page 43*). Two or more optional parameters may be declared to mutually exclude each other, in which case at most one of them may be present in a routine call. An optional parameter is said to be present if the routine call supplies a corresponding argument, not present otherwise. The value of a not present, optional parameter may not be set or used. The predefined function `Present` can be used to test the presence of an optional parameter. The placeholders `<PAR>`, `<ALT>`, `<DIM>` can be used to represent undefined parts of a parameter list.

```
<parameter list> ::=
  <first parameter declaration> { <next parameter declaration> }
<first parameter declaration> ::=
  <parameter declaration>
  | <optional parameter declaration>
  | <PAR>
<next parameter declaration> ::=
  ',' <parameter declaration>
  | <optional parameter declaration>
  | ',' <optional parameter declaration>
  | ',' <PAR>
<optional parameter declaration> ::=
  '\' ( <parameter declaration> | <ALT> ) { '|' ( <parameter
       declaration> | <ALT> ) }
<parameter declaration> ::=
  [ VAR | PERS | INOUT ] <data type> <identifier> [ '{' ( '*' {
       ',' '*' } ) | <DIM> '}' ]
  | 'switch' <identifier>
```

Prerequisites

The data type of an argument must be equal to the data type of the corresponding parameter.

Access modes

Each parameter has an access mode. Available access modes are `in` (default), `var`, `pers`, `inout`, and `ref`. The access mode specifies how RAPID transfers a corresponding argument to a parameter.

- An `in` parameter is initialized with the value of the argument (expression). The parameter may be used (for example assigned a new value) as an ordinary routine variable.
- A `var`, `pers`, `inout`, or `ref` parameter is used as an alias for the argument (data object). This means that any update of the parameter is also an update of the argument.

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Note

RAPID routines cannot have `ref` parameters, only predefined routines can.

The specified access mode of a parameter restricts a corresponding argument as legal ("X" in the following table) or illegal ("-" in the following table).

Argument	in	var	pers	inout	ref
constant	X				X
readonly variable [i]	X				X
variable	X	X		X	X
parameter `in`	X	X	-	X	X
parameter `var`	X	X	-	X	X
parameter `pers`	X	-	X	X	X
parameter `inout var`	X	X	- *ii*	X	X
parameter `inout pers`	X	- [ii]	X	X	X
any other expression	X	-	-	-	-

[i] For example `FOR` loop variables (see *The For statement on page 81*), `errno`, `intno`.
[ii] Execution error (see *Error classification on page 18*).

Built-in routines

The built-in routines `IsPers` and `IsVar` can be used to test if an `inout` parameter is an alias for a variable or persistent argument.

Switch

The special type `switch` may (only) be assigned to optional parameters and provides a means to use "switch arguments", that is arguments given only by their names (no values). The domain of the switch type is empty and no value can be transferred to a switch parameter. The only way to use a switch parameter is to check its presence using the predefined function `Present`, or to pass it as an argument in a routine call.

For example:

```
PROC glue ( \switch on | switch off, ... ! switch parameters
  ...
  IF Present(off ) THEN
    ! check presence of optional parameter 'off'
    ...
ENDPROC
glue\off, pos2; ! argument use
```

Arrays

Arrays may be passed as arguments. The degree of an array argument must comply with the degree of the corresponding parameter. The dimension of an array parameter is "conformant" (marked by '*'). The actual dimension is later bound by the dimension of the corresponding argument of a routine call. A routine can determine the actual dimension of a parameter using the predefined function `Dim`.

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For example:

```
... , VAR num pallet{*,*}, ...
! num-matrix parameter
```


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5.3 Scope rules for routines

Definition

The scope of an object denotes the area in which the name is *visible*. The scope of a predefined routine comprises any RAPID module. The following scope rules are valid for user routines:

- The scope of a local user routine comprises the module in which it is contained.
- The scope of a global user routine in addition comprises any other module in the task buffer.
- Within its scope a user routine *hides* any predefined object with the same name.
- Within its scope a local user routine *hides* any global module object with the same name.
- Two module objects declared in the same module may not have the same name.
- Two global objects declared in two different modules in the task buffer may not have the same name.
- A global user routine and a module may not share the same name.

Other scope rules

The scope rules concerning parameters comply with the scope rules concerning routine variables. For information on routine variable scope, see *Scope rules for data objects on page 43*.

For information on task modules, see *Task modules on page 119*.

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5.4 Procedure declarations

Definition

A procedure declaration binds an identifier to a procedure definition.

```
<procedure declaration> ::=
  PROC <procedure name>
  '(' [ <parameter list> ] ')'
  <data declaration list>
  <statement list>
  [ BACKWARD <statement list> ]
  [ ERROR [ <error number list> ] <statement list> ]
  [ UNDO <statement list> ]
  ENDPROC
<procedure name> ::= <identifier>
<data declaration list> ::= { <data declaration> }
```

A data declaration list can include comments, see *Comments on page 28*.

Evaluation and termination

The evaluation of a procedure is either explicitly terminated by a return statement (see *The Return statement on page 73*) or implicitly terminated by reaching the end (ENDPROC, BACKWARD, ERROR, or UNDO) of the procedure.

For example, multiply all elements of a num array by a factor:

```
PROC arrmul( VAR num array{*}, num factor)
  FOR index FROM 1 TO Dim( array, 1 ) DO
    array{index} := array{index} * factor;
  ENDFOR
ENDPROC ! implicit return
```

The predefined Dim function returns the dimension of an array.

Late binding

Procedures which are going to be used in late binding calls are treated as a special case. That is the parameters for the procedures, which are called from the same late binding statement, should be matching as regards optional/required parameters and mode, and should also be of the same basic type. For example if the second parameter of one procedure is required and declared as VAR num then the second parameter of other procedures, which are called by the same late binding statement, should have a second parameter which is a required VAR with basic type num. The procedures should also have the same number of parameters. If there are mutually exclusive optional parameters, they also have to be matching in the same sense.

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5.5 Function declarations

Definition

A function declaration binds an identifier to a function definition.

```
<function declaration> ::=
  FUNC <data type>
  <function name>
  '(' [ <parameter list> ] ')'
  <data declaration list>
  <statement list>
  [ ERROR [ <error number list> ] <statement list> ]
  [ UNDO <statement list> ]
  ENDFUNC
<function name> ::= <identifier>
```

Functions can have (return) any value data type (including any available installed type). A function cannot be dimensioned, that is a function cannot return an array value.

Evaluation and termination

The evaluation of a function must be terminated by a return statement, see *The Return statement on page 73*.

For example, return the length of a vector.

```
FUNC num veclen(pos vector)
  RETURN sqrt(quad(vector.x) + quad(vector.y) + quad(vector.z));
  ERROR
    IF ERRNO = ERR_OVERFLOW THEN
      RETURN maxnum;
    ENDIF
    ! propagate "unexpected" error
    RAISE;
ENDFUNC
```


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5.6 Trap declarations

Definition

A trap declaration binds an identifier to a trap definition. A trap routine can be associated with an interrupt (number) by using the connect statement, see *The Connect statement on page 78*. Note that one trap routine may be associated with many (or no) interrupts.

```
<trap declaration> ::=
  TRAP <trap name>
  <data declaration list>
  <statement list>
  [ ERROR [ <error number list> ] <statement list> ]
  [ UNDO <statement list> ]
  ENDTRAP
<trap name> ::= <identifier>
```

Evaluation and termination

The evaluation of the trap routine is explicitly terminated using the return statement (see *The Return statement on page 73*) or implicitly terminated by reaching the end (`endtrap`, `error`, or `undo`) of the trap routine. The execution continues at the point of the interrupt.

For example, respond to low pressure interrupt.

```
TRAP low_pressure
  open_valve\slow;
  ! return to point of interrupt
  RETURN;
ENDTRAP
```

For example, respond to high pressure interrupt.

```
TRAP high_pressure
  close_valve\fast;
  ! return to point of interrupt
  RETURN;
ENDTRAP
```


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6 Backward execution

6.1 Introduction to backward execution

Definition

RAPID supports stepwise, backward execution of statements. Backward execution is very useful for debugging, test, and adjustment purposes during RAPID program development. RAPID procedures may contain a backward handler (statement list) that defines the backward execution "behavior" of the procedure (call).

Limitations

The following general restrictions are valid for backward execution:

- Only simple (not compound) statements can be executed backwards.
- It is not possible to step backwards out of a routine at the top of its statement list (and reach the routine call).
- Simple statements have the following backward behavior:
- Procedure calls (predefined or user defined) can have any backward behavior - take some action, do nothing or reject[I] the backward call. The behavior is defined by the procedure definition.
- The arguments of a procedure call being executed backwards are always (even in case of reject) executed and transferred to the parameters of the procedure exactly in the same way as is the case with forward execution. Argument expressions (possibly including function calls) are always executed "forwards".
- Comments, labels, assignment statements and connect statements are executed as "no operation" while all other simple statements rejects[I] backward execution.
- When executing backward handlers and there is an execution error, it will not be possible to handle the error in an error handler.

[I] No support for backward step execution, no step is taken.

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6.2 Backward handlers

Definition

Procedures may contain a backward handler that defines the backward execution of a procedure call.

The backward handler is really a part of the procedure and the scope of any routine data also comprises the backward handler of the procedure.

For example:

```
PROC MoveTo ()
  MoveL p1,v500,z10,tool1;
  MoveC p2,p3,v500,z10,tool1;
  MoveL p4,v500,z10,tool1;
BACKWARD
  MoveL p4,v500,z10,tool1;
  MoveC p2,p3,v500,z10,tool1;
  MoveL p1,v500,z10,tool1;
ENDPROC
```

When the procedure `MoveTo` is called during forward execution, the first 3 instructions are executed, as numbered in the following code. The backward instructions (last 3) are not executed.

```
PROC MoveTo ()
  1. MoveL p1,v500,z10,tool1;
  2. MoveC p2,p3,v500,z10,tool1;
  3. MoveL p4,v500,z10,tool1;
BACKWARD
  MoveL p4,v500,z10,tool1;
  MoveC p2,p3,v500,z10,tool1;
  MoveL p1,v500,z10,tool1;
ENDPROC
```

When the procedure `MoveTo` is called during backwards execution, the last 3 instructions are executed, as numbered in the following code. The forward instructions (first 3) are not executed.

```
PROC MoveTo ()
  MoveL p1,v500,z10,tool1;
  MoveC p2,p3,v500,z10,tool1;
  MoveL p4,v500,z10,tool1;
BACKWARD
  1. MoveL p4,v500,z10,tool1;
  2. MoveC p2,p3,v500,z10,tool1;
  3. MoveL p1,v500,z10,tool1;
ENDPROC
```

Limitations

Instructions in the backward or error handler of a routine may not be executed backwards. Backward execution cannot be nested, that is two instructions in a call chain may not simultaneously be executed backwards.

See also *Limitations for `Move` instructions in a backward handler on page 96*.

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Procedures with no backward handler

A procedure with no backward handler cannot be executed backwards. A procedure with an empty backward handler is executed as *no operation*.

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6.3 Limitations for Move instructions in a backward handler

Limitations

The Move instruction type and sequence in the backward handler must be a mirror of the movement instruction type and sequence for forward execution in the same routine. In the following example, the instructions are numbered to show in which order they are executed.

```
PROC MoveTo ()
  1. MoveL p1,v500,z10,tool1;
  2. MoveC p2,p3,v500,z10,tool1;
  3. MoveL p4,v500,z10,tool1;
BACKWARD
  3. MoveL p4,v500,z10,tool1;
  2. MoveC p2,p3,v500,z10,tool1;
  1. MoveL p1,v500,z10,tool1;
ENDPROC
```

Note that the order of CirPoint p2 and ToPoint p3 in the MoveC should be the same.

By Move instructions is meant all instructions that result in some movement of the robot or additional axes such as MoveL, SearchC, TriggJ, ArcC, PaintL ...

CAUTION

Any departures from this programming limitation in the backward handler can result in faulty backward movement. Linear movement can result in circular movement and vice versa, for some part of the backward path.

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7 Error recovery

7.1 Error handlers

Definition

An execution error (see *Error classification on page 18*) is an abnormal situation, related to the execution of a specific piece of RAPID program code. An error makes further execution impossible (or at least hazardous). "Overflow" and "division by zero" are examples of errors. Errors are identified by their unique error number and are always recognized by the system. The occurrence of an error causes suspension of the normal program execution and the control is passed to an error handler. The concept of error handlers makes it possible to respond to, and possibly recover from errors that arise during program execution. If further execution is not possible, at least the error handler can assure that the task is given a graceful abortion.

Any routine may include an error handler. The error handler is really a part of the routine and the scope of any routine data object (variable, constant, or parameter) also comprises the error handler of the routine. If an error occurs during the evaluation of the routine the control is transferred to the error handler.

For example:

```
FUNC num safediv(num x, num y)
  RETURN x / y;
ERROR
  IF ERRNO = ERR_DIVZERO THEN
    ! return max numeric value
    RETURN max_num;
  ENDIF
ENDFUNC
```

ERRNO

The predefined (readonly) variable ERRNO contains the error number of the (most recent) error and can be used by the error handler to identify the error. After necessary actions have been taken the error handler can:

- Resume execution starting with the statement in which the error occurred. This is made using the RETRY statement, see *The Retry statement on page 76*.
- Resume execution starting with the statement after the statement in which the error occurred. This is made using the TRYNEXT statement, see *The Trynext statement on page 77*.
- Return control to the caller of the routine by using the RETURN statement, see *The Return statement on page 73*. If the routine is a function the RETURN statement must specify an appropriate return value.
- Propagate the error to the caller of the routine by using the RAISE statement, see *The Raise statement on page 74*. "Since I'm not familiar with this error it's up to my caller to deal with it".

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System error handler

If an error occurs in a routine that does not contain an error handler or reaching the end of the error handler (ENDFUNC, ENDPROC, or ENDTRAP), the system error handler is called. The system error handler just reports the error and stops the execution.

> **Note**
>
> It is not possible to recover from or respond to errors that occur within an error handler or backward handler. Such errors are always propagated to the system error handler.

In a chain of routine calls, each routine may have its own error handler. If an error occurs in a routine with an error handler, and the error is explicitly propagated using the RAISE statement, the same error is raised again at the point of the call of the routine the error is propagated. If the top of the call chain (the entry routine of the task) is reached without any error handler found or if reaching the end of any error handler within the call chain, the system error handler is called. The system error handler just reports the error and stops the execution. Since a trap routine can only be called by the system (as a response to an interrupt), any propagation of an error from a trap routine is made to the system error handler.

Errors raised by the program

In addition to errors detected and raised by the system, a program can explicitly raise errors using the RAISE statement, see *The Raise statement on page 74*. This can be used to recover from complex situations. For example it can be used to escape from deeply nested code positions. Error numbers in the range from 1 to 90 may be used.

For example:

```
CONST errnum escape1 := 10;
  ...
  RAISE escape1;
  ...
ERROR
  IF ERRNO = escape1 THEN
    RETURN val2;
  ENDIF
ENDFUNC
```


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7.2 Error recovery with long jump

Definition

Error recovery with long jump may be used to bypass the normal routine call and return mechanism to handle abnormal or exceptional conditions. To accomplish this, a specific error recovery point must be specified. By using the `RAISE` instruction the long jump will be performed and the execution control is passed to that error recovery point.

Error recovery with long jump is typically used to pass execution control from a deeply nested code position, regardless of execution level, as quickly and simple as possible to a higher level.

Execution levels

An execution level is a specific context that the RAPID program is running in. There are three execution levels in the system, *Normal*, *Trap*, and *User*:

- Normal level: All program are started at this level. This is the lowest level.
- Trap level: Trap routines are executed at this level. This level overrides the normal level but can be overridden by the user level.
- User level: Event routines and service routines are executed at this level. This level overrides normal and trap level. This level is the highest one and cannot be overridden by any other level.

Error recovery point

The essential thing for error recovery with long jump is the characteristic error recovery point.

The error recovery point is a normal `ERROR` clause but with an extended syntax, a list of error numbers enclosed by a pair of parentheses, see example below.

```
MODULE example
  PROC main()
    ! Do something important
    myRoutine;
    ERROR (56, ERR_DIVZERO)
      RETRY;
  ENDPROC
ENDMODULE
```

Syntax

An error recovery point has the following syntax: (EBNF)

```
[ ERROR [ <error number list> ] <statement list> ]
<error number list> ::= '(' <error number> { ',' <error number>}
     ')'
<error number> ::=
  <num literal>
  | <entire constant>
  | <entire variable>
  | <entire persistent>
```

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Using error recovery with long jump

```
MODULE example2
  PROC main()
    routine1;
    ! Error recovery point
    ERROR (56)
      RETRY;
  ENDPROC

  PROC routine1()
    routine2;
  ENDPROC

  PROC routine2()
    RAISE 56;
  ERROR
    ! This will propagate the error 56 to main
    RAISE;
  ENDPROC
ENDMODULE
```

The system handles a long jump in following order:

- The raised error number is search, starting at calling routine's error handler and to the top of the current call chain. If there is an error recovery point with the raise error number, at any routine in the chain, the program execution continues in that routine's error handler.
- If no error recovery point is found in the current execution level the searching is continued in the previous execution level until the NORMAL level is reached.
- If no error recovery point is found in any execution level the error will be raised and handled in the calling routine's error handler, if any.

Error recovery through execution level boundaries

It is possible to pass the execution control through the execution level boundaries by using long jump, that is the program execution can jump from a TRAP, USER routine to the `Main` routine regardless how deep the call chains are in the TRAP, USER, and NORMAL level. This is useful way to handle abnormal situation that requires the program to continue or start over from good and safely defined position in the program.

When a long jump is done from one execution level to another level there can be an active instructions at that level. Since the long jump is done from one error handler to another, the active instruction will be undone by the system (for example an active `MoveX` instruction will clear its part of the path).

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Additional information

By using the predefined constant `LONG_JMP_ALL_ERR` it is possible to catch all kinds of errors at the error recovery point. Observe the following restrictions when using error recovery with long jump:

- Do not assume that the execution mode (cont, cycle, or forward step) is the same at the error recovery point as it was where the error occurred. The execution mode is not inherited at long jump.
- Be careful when using `StorePath`. Always call `RestoPath` before doing a long jump, otherwise the results are unpredictable.
- The numbers of retries are not set to zero at the error recovery point after a long jump.
- Be careful when using `TRYNEXT` at the error recovery point, the result can be unpredictable if the error occurs in a function call as in the following example.

For example:

```
MODULE Example3
  PROC main
    WHILE myFunction() = TRUE DO
      myRoutine;
    ENDWHILE
    EXIT;
  ERROR (LONG_JMP_ALL_ERR)
    TRYNEXT;
  ENDPROC
ENDMODULE
```

If the error occurs in the function `myFunction` and the error is caught in the main routine, the instruction `TRYNEXT` will pass the execution control to the next instruction, in this case `EXIT`. This is because the `WHILE` instruction considers to be the one that fails.

UNDO handler

When using long jump, one or several procedures may be dropped without executing the end of the routine or the error handler. If no undo handler is used these routine may leave loose ends. In the following example, `routine1` would leave the file log open if the long jump was used and there was no undo handler in `routine1`.

To make sure that each routine cleans up after itself, use an undo handler in any routine that may not finish the execution due to a long jump.

For example:

```
MODULE example4
  PROC main()
    routine1;
    ! Error recovery point
  ERROR (56)
    RETRY;
  ENDPROC
```

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7.2 Error recovery with long jump
Continued

```
  PROC routine1()
    VAR iodev log;
    Open "HOME:" \File:= "FILE1.DOC", log;
    routine2;
    Write log, "routine1 ends with normal execution";
    Close log;
  ERROR
    ! Another error handler
  UNDO
    Close log;
  ENDPROC

  PROC routine2()
    RAISE 56;
  ERROR
    ! This will propagate the error 56 to main
    RAISE;
  ENDPROC
ENDMODULE
```


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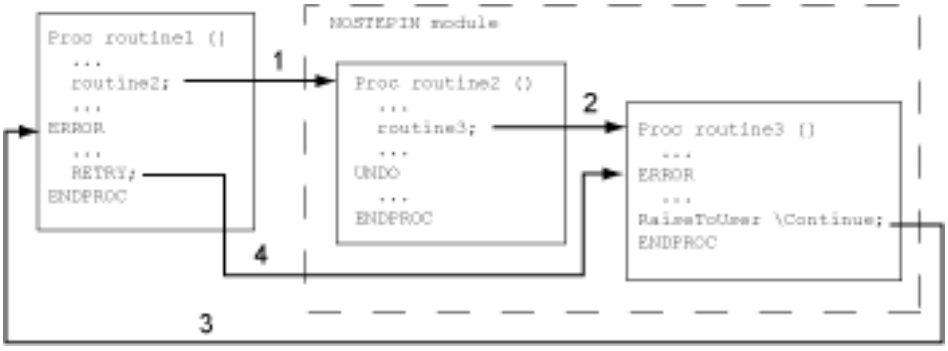
7.3 Nostepin routines

Definition

The nostepin routines in a nostepin module can call each other in call chains. Using the `RAISE` instruction in the error handler of one of the routines in the call chain will propagate the error one step up in the call chain. In order to raise the error to the user level (outside the nostepin module) with the `RAISE` instruction, every routine in the call chain must have an error handler that raise the error.

By using the `RaiseToUser` instruction, the error can be propagated several steps up in the call chain. The error will then be handled by the error handler in the last routine in the call chain that is not a nostepin routine.

If `RaiseToUser` is called with the argument `\Continue`, the instruction (in the nostepin routine) that caused the error will be remembered. If the error handler that handles the error ends with `RETRY` or `TRYNEXT`, the execution will continue from where the error occurred.



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1	`routine2` is called
2	`routine3` is called
3	The error is raised to user level
4	The execution returns to the execution in `routine3` that caused the error

Note

One or several routines may be dropped without executing the end of the routine or the error handler. In the example this would have been the case for `routine2` if `RaiseToUser` had used the argument `\BreakOff` instead of `\Continue`. To make sure such a routine does not leave any loose ends (such as open files) make sure there is an undo handler that cleans up (for example close files).

Note

If the routine that calls the nostepin routine (`routine1` in the example) is made to a nostepin routine, the error will no longer be handled by its error handler. Changing a routine to a nostepin routine can require the error handler to be moved to the user layer.

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7.4 Asynchronously raised errors

About asynchronously raised errors

If a movement instruction ends in a corner zone, the next move instruction must be executed before the first move instruction has finished its path. Otherwise the robot would not know how to move in the corner zone. If each move instruction only moves a short distance with large corner zones, several move instructions may have to be executed ahead.

An error may occur if something goes wrong during the robot movement. However, if the program execution has continued, it is not obvious which move instruction the robot is carrying out when the error occur. The handling of asynchronously raised errors solves this problem.

The basic idea is that an asynchronously raised error is connected to a move instruction and is handled by the error handler in the routine that called that instruction.

Two types of asynchronously raised errors

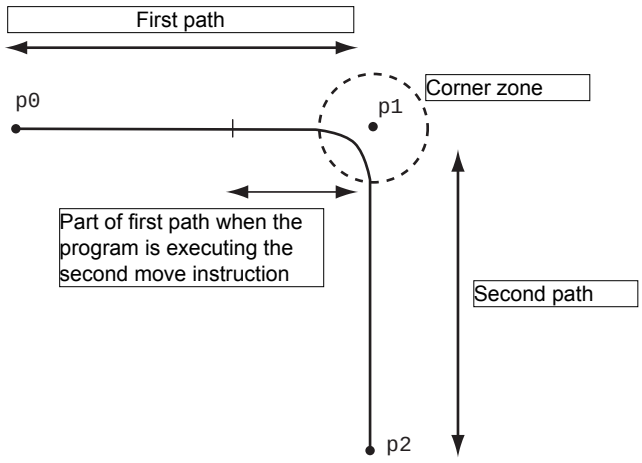
There are two ways of creating asynchronously raised errors, resulting in slightly different behavior.

- `ProcerrRecovery \SyncOrgMoveInst` creates an asynchronous error that is connected to the move instruction which created the current robot path.
- `ProcerrRecovery \SyncLastMoveInst` creates an asynchronous error that is connected to the move instruction that is currently being executed. If no move instruction is being executed this error is connected to the next move instruction that will be executed.

If an error occurs during the first path but when the program is calculating the second path (see illustration below), the behavior depends on the argument of `ProcerrRecovery`. If the error is created with `\SyncOrgMoveInst`, it is connected to the first move instruction (the instruction that created the first path). If the error is created with `\SyncLastMoveInst`, it is connected to the second move instruction (the instruction that created the second path).

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Attempt to handle errors in the routine that called the move instruction

If you create a routine with error handling to take care of process errors that may occur during robot movement, you want these errors to be handled in this routine. If the error is raised when the program pointer is in a subroutine, you do not want the error handler of that subroutine to handle the error.

Asynchronously raised errors are connected to the path that the robot is currently performing. An asynchronously raised error can be handled by the error handler in the routine whose move instruction created the path the robot is carrying out when the error occurs.

In the example shown below, a process error occurs before the robot has reached `p1`, but the program pointer has already continued to the subroutine `write_log`.

Program example

```
PROC main()
  ...
  my_process;
  ...
ERROR
  ...
ENDPROC
PROC my_process()
  ...
  MoveL p1, v300, z10, tool1;
  write_log;
  MoveL p2, v300, z10, tool1;
  ...
ERROR
  ...
ENDPROC
PROC write_log()
  ...
ERROR
```

Continues on next page

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```
    ...
ENDPROC
```

Description of the example

If there was no handling of asynchronously raised errors, an error that was raised when the program pointer was in `write_log` would be handled by the error handler in `write_log`. The handling of asynchronously raised errors will make sure that the error is handled by the error handler in `my_process`.

An asynchronous error created with `ProcerrRecovery \SyncOrgMoveInst` would instantly be handled by the error handler in `my_process`. An asynchronous error created with `ProcerrRecovery \SyncLastMoveInst` would wait for the program pointer to reach the second move instruction in `my_process` before being handled by the error handler in `my_process`.

Note

If a subroutine (`write_log` in the example) was to have move instructions and `\SyncLastMoveInst` is used, the error might be handled by the error handler in the subroutine.

If the error handler in `my_process` ends with `EXIT`, all program execution is stopped.

If the error handler in `my_process` ends with `RAISE`, the error is handled by the error handler in `main`. The routine calls to `my_process` and `write_log` are dropped. If the error handler in main ends with `RETRY`, the execution of `my_process` starts over.

If the error handler in `my_process` ends with `RETRY` or `TRYNEXT`, the program execution continues from where the program pointer is (in `write_log`). The error handler should have solved the error situation and called `StartMove` to resume the movement for the instruction that caused the error. Even if the error handler ends with `RETRY`, the first `MoveL` instruction is not executed again.

Note

In this case `TRYNEXT` works the same way as `RETRY` because the system can be restarted from where the error occurred.

What happens when a routine call is dropped?

When the execution reach the end of a routine, that routine call is dropped. The error handler of that routine call cannot be called if the routine call has been dropped. In the example below, the robot movement will continue after the first `my_process` routine call has been dropped (since the last move instruction has a corner zone).

Program example

```
PROC main()
  ...
  my_process;
  my_process;
```

Continues on next page

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```
  ...
ERROR
  ...
ENDPROC
PROC my_process()
  ...
  MoveL p1, v300, z10, tool1;
  MoveL p2, v300, z10, tool1;
  ...
ERROR
  ...
ENDPROC
```

Description of the example

If the program pointer is in main when an error originating from the first `my_process` occurs, it cannot be handled by the error handler in the `my_process` routine call. Where this error is handled will then depend on how the asynchronous error is created.

- If the error is raised with `ProcerrRecovery \SyncOrgMoveInst`, the error will be handled one step up in the call chain. The error is handled by the error handler in the routine that called the dropped routine call. In the example above, the error handler in main would handle the error if the `my_process` routine call has been dropped.
- If the error is raised with `ProcerrRecovery \SyncLastMoveInst`, the error will be handled by the error handler where the next move instruction is, that is the second routine call to `my_process`. The raising of the error may be delayed until the program pointer reach the next move instruction.



Tip

To make sure asynchronously raised errors are handled in a routine, make sure the last move instruction ends with a stop point (not corner zone) and does not use `\Conc`.

Example

In this example, asynchronously raised errors can be created in the routine `my_process`. The error handler in `my_process` is made to handle these errors.

A process flow is started by setting the signal *do_myproc* to 1. The signal *di_proc_sup* supervise the process, and an asynchronous error is raised if *di_proc_sup* becomes 1. In this simple example, the error is resolved by setting *do_myproc* to 1 again before resuming the movement.

```
MODULE user_module
  VAR intnum proc_sup_int;
  VAR iodev logfile;

  PROC main()
    ...
    my_process;
```

Continues on next page

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```
    my_process;
    ...
  ERROR
    ...
  ENDPROC

  PROC my_process()
    my_proc_on;
    MoveL p1, v300, z10, tool1;
    write_log;
    MoveL p2, v300, z10, tool1;
    my_proc_off;
  ERROR
    IF ERRNO = ERR_PATH_STOP THEN
      my_proc_on;
      StartMove;
      RETRY;
    ENDIF
  ENDPROC

  PROC write_log()
    Open "HOME:" \File:= "log.txt", logfile \Append;
    Write logfile "my_process executing";
    Close logfile;
  ERROR
    IF ERRNO = ERR_FILEOPEN THEN
      TRYNEXT;
    ENDIF
  UNDO
    Close logfile;
  ENDPROC

  TRAP iprocfail
    my_proc_off;
    ProcerrRecovery \SyncLastMoveInst;
    RETURN;
  ENDTRAP

  PROC my_proc_on()
    SetDO do_myproc, 1;
    CONNECT proc_sup_int WITH iprocfail;
    ISignalDI di_proc_sup, 1, proc_sup_int;
  ENDPROC

  PROC my_proc_off()
    SetDO do_myproc, 0;
    IDelete proc_sup_int;
  ENDPROC
ENDMODULE
```

Continues on next page

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Error when PP is in `write_log`

What will happen if a process error occurs when the robot is on its way to p1, but the program pointer is already in the subroutine `write_log`?

The error is raised in the routine that called the move instruction, which is `my_process`, and is handled by its error handler.

Since the `ProcerrRecovery` instruction, in the example, use the switch `\SyncLastMoveInst`, the error will not be raised until the next move instruction is active. Once the second `MoveL` instruction in `my_process` is active, the error is raised and handled in the error handler in `my_process`.

If `ProcerrRecovery` had used the switch `\SyncOrgMoveInst`, the error would have been raised directly in `my_process`.

Error when execution of `my_process` has finished

What will happen if a process error occurs when the robot is on its way to p2, but the program pointer has already left the routine `my_process`?

The routine call that caused the error (the first `my_process`) has been dropped and its error handler cannot handle the error. Where this error is raised depends on which switch is used when calling `ProcerrRecovery`.

Since the `ProcerrRecovery` instruction, in the example, use the switch `\SyncLastMoveInst`, the error will not be raised until the next move instruction is active. Once a move instruction is active in the second `my_process` routine call, the error is raised and handled in the error handler in `my_process`.

If `ProcerrRecovery` had used the switch `\SyncOrgMoveInst`, the error would have been raised in main. The way `\SyncOrgMoveInst` works is that if the routine call that caused the error (`my_process`) has been dropped, the routine that called that routine (`main`) will raise the error.

Note

If there had been a move instruction between the `my_process` calls in main, and `\SyncLastMoveInst` was used, the error would be handled by the error handler in main. If another routine with move instructions had been called between the `my_process` calls, the error would have been handled in that routine. This shows that when using `\SyncLastMoveInst` you must have some control over which is the next move instruction.

Nostepin move instructions and asynchronously raised errors

When creating a customized nostepin move instruction with a process, it is recommended to use `ProcerrRecovery \SyncLastMoveInst`. This way, all asynchronously raised errors can be handled by the nostepin instruction.

This requires that the user only use this type of move instruction during the entire movement sequence. The movement sequence must begin and end in stop points. Only if two instructions have identical error handlers can they be used in the same movement sequence. This means that one linear move instruction and one circular, using the same process and the same error handler, can be used in the same movement sequence.

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If an error should be raised to the user, use `RaiseToUser \Continue`. After the error has been resolved, the execution can then continue from where the error occurred.

UNDO handler

The execution of a routine can be abruptly ended without running the error handler in that routine. This means that the routine will not clean up after itself.

In the following example, we assume that an asynchronously raised error occurs while the robot is on its way to p1 but the program pointer is at the `Write` instruction in `write_log`. If there was no undo handler, the file logfile would not be closed.

```
PROC main()
  ...
  my_process;
  ...
ERROR
  ...
ENDPROC
PROC my_process()
  MoveL p1, v300, z10, tool1;
  write_log;
  MoveL p2, v300, z10, tool1;
ERROR
  ...
ENDPROC
PROC write_log()
  Open .. logile ..;
  Write logfile;
  Close logfile;
ERROR
  ...
UNDO
  Close logfile;
ENDPROC
```

This problem can be solved by using undo handlers in all routines that can be interrupted by an asynchronously raised error. It is in the nature of asynchronously raised errors that it is difficult to know where the program pointer will be when they occur. Therefore, when using asynchronously raised errors, use undo handlers whenever clean up may be necessary.

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7.5 The instruction SkipWarn

Definition

An error that is handled in an error handler still generates a warning in the event log. If, for some reason, you do not want any warning to be written to the event log, the instruction `SkipWarn` can be used.

Example

In the following example code, a routine tries to write to a file that other robot systems also have access to. If the file is busy, the routine waits 0.1 seconds and tries again. If `SkipWarn` was not used, the log file would write a warning for every attempt, even though these warnings are totally unnecessary. By adding the `SkipWarn` instruction, the operator may not notice that the file was busy at the first attempt.

Note that the maximum number of retries is determined by the parameter *No Of Retry*. To make more than 4 retries, you must configure this parameter.

```
PROC routine1()
  VAR iodev report;
  Open "HOME:" \File:= "FILE1.DOC", report;
  Write report, "No parts from Rob1="\Num:=reg1;
  Close report;
ERROR
  IF ERRNO = ERR_FILEOPEN THEN
    WaitTime 0.1;
    SkipWarn;
    RETRY;
  ENDIF
ENDPROC
```


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7.6 Motion error handling

About motion error handling

The RAPID execution does not have to stop when a collision error occurs (event number *50204 - Motion supervision*). If the system parameter *Collision Error Handler* is defined the execution will enter the RAPID error handler after the retraction and the execution can continue if all conditions for further execution are fulfilled.

This is known as motion error handling.

To separate collision errors from other RAPID errors, the `errno` variable is set to `ERR_COLL_STOP`.

Example

To be able to start the motion after leaving the error handler, a StartMove instruction must be called from the error handler. For MultiMove, all tasks must have a StartMove instruction in the error handler. Even the tasks that has not collided.

```
PROC main()
  MoveJ p10, v200, fine, tool0;
  MoveJ p20, v200, fine, tool0;
ERROR
  TEST ERRNO
  CASE ERR_COLL_STOP:
    StorePath;
    MoveJ p30, v200, fine, tool0;
    RestoPath;
    StartMove;
  ENDTEST
  RETRY;
ENDPROC
```

Functionality of motion error handling

Motion error handling is different compared to normal RAPID error handling since the program pointer can be ahead of the motion pointer. Also, when using procedure calls, the program pointer and the motion pointer are not always in the same procedure when the error is raised.

The following behavior is used in the controller to evaluate where the motion error should be handled:

1. Check if there is an error handler in the procedure where the motion pointer currently is. If so, go to that error handler. If the motion pointer is not in the call stack, then go to number 3.
2. If not 1, move upwards in the call stack from the procedure where the motion pointer is, to see if any of those procedures has an error handler.
3. If not 2, check if there is an error handler in the procedure where the program pointer currently is.
4. If not 3, move upwards in the call stack from the procedure where the program pointer is, to see if any of those procedures has an error handler.
5. If no error handler is found at all, the RAPID execution stops with an error.

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Example 1

In the below example the motion pointer is in a different procedure than the program pointer. If a collision occurs while the program pointer is in `proc3` and the motion pointer is in `proc1`, the system will look for error handlers first in `proc1`, then `main`, then `proc3` and finally `proc2`.

```
MODULE example
  PROC main()
    proc1;
  ERROR
    !Error handling
  ENDPROC
  PROC proc1()
    !Move instructions !Motion pointer
    proc2;
  ERROR
    !Error handling
  ENDPROC
  PROC proc2()
    proc3;
  ERROR
    !Error handling
  ENDPROC
  PROC proc3()
    !Non-move instructions !Program pointer
  ERROR
    !Error handling
  ENDPROC
ENDMODULE
```

Example 2

In the below example the motion pointer is not in the call stack. There is a `\Conc` argument on the move instruction in `Routine2`. The motion pointer is in `Routine2`, but the program pointer hangs on the `WaitTime 10` instruction in `Routine1`.

If a collision occurs on the way to position `p30` then the error handler in `Routine1` will be run although the motion pointer is in `Routine2`.

```
MODULE MainModule
  PROC main()
    MoveJ p10, v1000, z50, tool0;
    Routine1;
  ENDPROC
  PROC Routine1()
    Routine2;
    WaitTime 10; !Program pointer
  ERROR
    TPWrite "Routine1";
  ENDPROC
  PROC Routine2()
    MoveJ\Conc, p20, v10, z50, tool0; !Motion pointer
    MoveJ\Conc, p30, v10, z50, tool0;
  ERROR
```

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```
    TPWrite "Routine2";
    StorePath;
    RestoPath;
    StartMoveRetry;
  ENDPROC
ENDMODULE
```

Example 3

In the below example the instruction RAISE is used in the error handler. RAISE is used to propagate the current error to the error handler of the calling routine. RAISE discards the last active motion instruction so the movement may not be as expected.

```
MODULE example
    PROC main()
      proc1;
    ERROR
      IF ERRNO=ERR_COLL_STOP THEN
      StartMoveRetry;
      ENDIF
    ENDPROC
    PROC proc1()
      !Move instruction
      !Move instruction
    ERROR
      IF ERRNO=ERR_COLL_STOP THEN
      RAISE;
      ENDIF
    ENDPROC
ENDMODULE
```

Limitations

Motion error handling is not active when stepping the program. Any collision that occurs while stepping will stop the program, although an motion error handler is available.

If fine points are used, motion errors can be handled in a predictable way. But if the execution leaves the routine where the motion instruction is that causes the collision, it is no longer possible to run the error handler located in the routine where the motion instruction is. It is therefor not predicable which error handler that will be run, see *Functionality of motion error handling on page 112*.

This is the case when using for example zones, motion instructions with the \Conc argument, or procedure calls. To have a predictable behavior, make sure to end the motion sequence with a fine point.

CAUTION

To have a predictable behavior make sure to end the motion sequence with a fine point when handling collisions using the motion error handler.

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8 Interrupts

Definition

Interrupts are program defined events identified by interrupt numbers. An interrupt occurs as a consequence of an interrupt condition turning true. Unlike errors, the occurrence of an interrupt is not directly related to (synchronous with) a specific code position. The occurrence of an interrupt causes suspension of the normal program execution and the control is passed to a trap routine. Interrupt numbers are allocated and connected (associated) with a trap routine using the connect statement, see *The Connect statement on page 78*. Interrupt conditions are defined and manipulated using predefined routines. A task may define an arbitrary number of interrupts.

Interrupt recognition and response

Even though the system recognizes the occurrence of an interrupt immediately, the response in the form of calling the corresponding trap routine can only take place at specific program positions, namely:

- at the entry of next (after interrupt recognition) statement (of any type).
- after the last statement of a statement list.
- any time during the execution of a waiting routine (for example `WaitTime`).

This means that, after the recognition of an interrupt, the normal program execution always continue until one of these positions are reached. This normally results in a delay of 2-30 ms between interrupt recognition and response, depending on what type of movement is being performed at the time of the interrupt.

Editing interrupts

Interrupt numbers are used to identify interrupts/interrupt conditions. Interrupt numbers are not just "any" numbers. They are "owned" by the system and must be allocated and connected with a trap routine using the connect statement (see *The Connect statement on page 78*) before they may be used to identify interrupts.

For example:

```
VAR intnum full;
...
CONNECT full WITH ftrap;
```

Interrupts are defined and edited using predefined routines. The *definition* of an interrupt specifies an interrupt condition and associates it with an interrupt number.

For example:

```
! define feeder interrupts
ISignalDI sig3, high, full;
```

An interrupt condition must be active to be watched by the system. Normally the definition routine (for example `ISignalDI`) activates the interrupt but that is not always the case. An active interrupt may in turn be deactivated again (and vice versa).

For example:

```
! deactivate empty
```

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Continued

```
ISleep empty;
! activate empty again
IWatch empty;
```

The deletion of an interrupt de-allocates the interrupt number and removes the interrupt condition. It is not necessary to explicitly delete interrupts. Interrupts are automatically deleted when the evaluation of a task is terminated.

For example:

```
! delete empty
IDelete empty;
```

The raising of interrupts may be disabled and enabled. If interrupts are disabled any interrupt that occurs is queued and raised first when interrupts are enabled again. Note that the interrupt queue may contain more than one waiting interrupt. Queued interrupts are raised in fifo order (first in, first out). Interrupts are always disabled during the evaluation of a trap routine, see *Trap routines on page 116*. For example:

```
! enable interrupts
IEnable;
! disable interrupts
IDisable;
```

Trap routines

Trap routines provide a means to respond to interrupts. A trap routine is connected with a particular interrupt number using the connect statement, see *The Connect statement on page 78*. If an interrupt occurs, the control is immediately (see *Interrupt recognition and response on page 115*) transferred to its connected trap routine.

For example:

```
LOCAL VAR intnum empty;
LOCAL VAR intnum full;

PROC main()
...
  ! Connect feeder interrupts
  CONNECT empty WITH ftrap;
  CONNECT full WITH ftrap;
  ! define feeder interrupts
  ISignalDI sig1, high, empty;
  ISignalDI sig3, high, full;
  ...
ENDPROC

TRAP ftrap
  TEST INTNO
  CASE empty:
    open_valve;
  CASE full:
    close_valve;
  ENDTEST
  RETURN;
ENDTRAP
```

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More than one interrupt may be connected with the same trap routine. The predefined (readonly) variable `INTNO` contains the interrupt number and can be used by a trap routine to identify the interrupt. After necessary actions have been taken a trap routine can be terminated using the return statement (see *The Return statement on page 73*) or by reaching the end (endtrap or error) of the trap routine. The execution continues at the point of the interrupt. Note that interrupts are always disabled (see *Editing interrupts on page 115*) during the evaluation of a trap routine.

Since a trap routine can only be called by the system (as a response to an interrupt), any propagation of an error from a trap routine is made to the system error handler, see *Error recovery on page 97*.

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9 Task modules

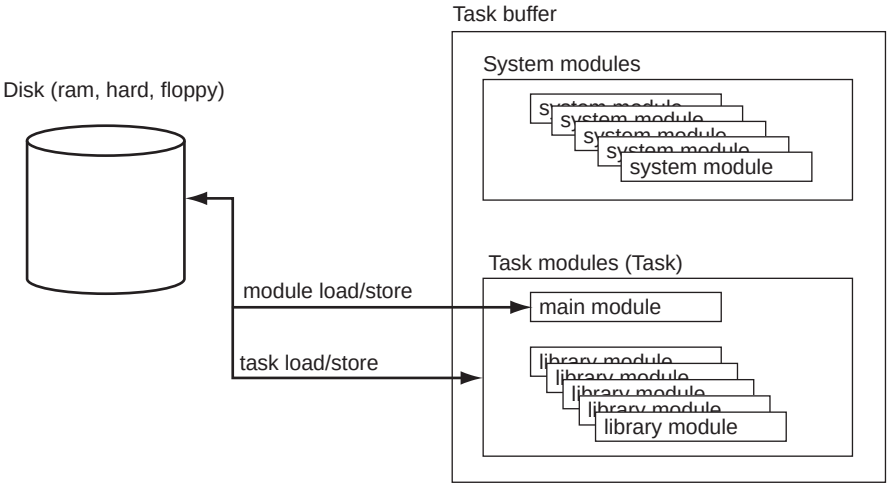
9.1 Introduction to task modules

Definition

A RAPID application is called a *task*. A task is composed of a set of modules. A module contains a set of type definitions, data and routine declarations. The task buffer is used to host modules currently in use (execution, development) on a system. RAPID program code in the task buffer may be loaded/stored from/to file oriented external devices (normally disk files) either as separate modules or as a group of modules – a task.

RAPID distinguishes between task modules and system modules. A task module is considered to be a part of the task/application while a system module is considered to be a part of the *system*. System modules are automatically loaded to the task buffer during system start and are aimed to (pre)define common, system specific data objects (tools, weld data, move data ..), interfaces (printer, logfile ..) etc. System modules are not included when a task is saved on a file. This means that any update made to a system module will have impact on all existing (old) tasks currently in, or later loaded to the task buffer. In any other sense there is no difference between task and system modules; they can have any content.

While small applications usually are contained in a single task module (besides the system module/s), larger applications may have a *main* task module that in turn references routines and/or data contained in one or more other, *library* task modules.



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A *library* module may for example define the interface of a physical or logical object (gripper, feeder, counter etc.) or contain geometry data generated from a CAD system or created online by digitizing (teach in).

One task module contains the entry procedure of the task. Running the task really means that the entry routine is executed. Entry routines cannot have parameters.

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9.2 Module declarations

Definition

A *module declaration* specifies the name, attributes and body of a module. A module name hides any predefined object with the same name. Two different modules may not share the same name. A module and a global module object (type, data object or routine) may not share the same name. Module attributes provide a means to modify some aspects of the systems treatment of a module when it is loaded to the task buffer. The body of a module declaration contains a sequence of data declarations followed by a sequence of routine declarations.

```
<module declaration> ::=
  MODULE <module name> [ <module attribute list> ]
  <type definition list>
  <data declaration list>
  <routine declaration list>
  ENDMODULE
<module name> ::= <identifier>
<module attribute list> ::= '(' <module attribute> { ',' <module
     attribute> } ')'
<module attribute> ::=
  SYSMODULE
  | NOVIEW
  | NOSTEPIN
  | VIEWONLY
  | READONLY
  <routine declaration list> ::= { <routine declaration> }
    <type definition list> ::= { <type definition> }
    <data declaration list> ::= { <data declaration> }
```

Module attributes

The *module attributes* have the following meaning:

Attribute	If specified, the module...
SYSMODULE	is a system module, otherwise a task module
NOVIEW	(it is source code) cannot be viewed (only executed)
NOSTEPIN	cannot be entered during stepwise execution
VIEWONLY	cannot be modified
READONLY	cannot be modified, but the attribute can be removed

An attribute may not be specified more than once. If present, attributes must be specified in table order (see above). The specification of noview excludes nostepin, viewonly, and readonly (and vice versa). The specification of viewonly excludes readonly (and vice versa).

Example

The following three modules could represent a (very simple) task.

```
MODULE prog1(SYSMODULE, VIEWONLY)
  PROC main()
```

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```
    ! init weldlib
    initweld;
    FOR i FROM 1 TO Dim(posearr,1) DO
      slow posearr{i};
    ENDFOR
  ENDPROC

  PROC slow(pose p)
    arcweld p \speed := 25;
  ENDPROC
ENDMODULE

MODULE weldlib
  LOCAL VAR welddata w1 := sysw1;
  ! weldlib init procedure
  PROC initweld()
    ! override speed
    w1.speed := 100;
  ENDPROC

  PROC arcweld(pose position \ num speed | num time)
    ...
  ENDPROC
ENDMODULE

MODULE weldpath ! (CAD) generated module
  CONST pose posearr{768} := [ [[234.7, 1136.7, 10.2], [1, 0, 0,
       0]], ... [[77.2, 68.1, 554.7], [1, 0, 0, 0]] ];
ENDMODULE
```


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9.3 System modules

Definition

System modules are used to (pre)define system specific data objects (tools, weld data, move data ..), interfaces (printer, logfile ..) etc. Normally, system modules are automatically loaded to the task buffer during system start.

For example:

```
MODULE sysun1(SYSMODULE)
  ! Provide predefined variables
  VAR num n1 := 0;
  VAR num n2 := 0;
  VAR num n3 := 0;
  VAR pos p1 := [0, 0, 0];
  VAR pos p2 := [0, 0, 0];
  ...
  ! Define channels - open in init function
  VAR channel printer;
  VAR channel logfile;
  ...
  ! Define standard tools
  PERS pose bmtool := [...
  ! Define basic weld data records
  PERS wdrec wd1 := [ ...
  ! Define basic move data records
  PERS mvrec mv1 := [ ...
  ! Define home position - Sync. Pos. 3
  PERS robtarget home := [ ...
  ! Init procedure
  LOCAL PROC init()
    Open\write, printer, "/dev/lpr";
    Open\write, logfile, "/usr/pm2/log1"... ;
  ENDPROC
ENDMODULE
```

The selection of system module/s is a part of system configuration.

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9.4 Nostepin modules

General

By setting the argument NOSTEPIN on the module, stepwise execution of the RAPID program will not step into the routine. The RAPID code of the routine will not be visible to the user.

Modifying positions in nostepin modules

When stepping the program, the program execution stops before all move instructions, but it is only possible to modify positions that are declared as arguments to the routine. The argument will be highlighted in the program editor and the **ModPos** button becomes active.

Arguments	Behavior
One `robtarget` as argument to the routine	The program will stop when the whole routine is executed. It is then possible to modify the position of the `robtarget`.
Two or more `robtarget` as arguments to the routine	The program will stop before the execution of the second move instruction. It is then possible to modify the position of the first `robtarget`. The program will stop before the execution of the third move instruction. It is then possible to modify the position of the second `robtarget`. Finally, the program will stop when the whole routine is executed. It is then possible to modify the position of the last `robtarget`.

Note

It is not possible to modify positions that are declared inside the nostepin module, nor when using `Offs` and `RelTool` functions on positions that are declared as arguments to the routine.

Example

```
MODULE My_Module(NOSTEPIN)
PROC MoveSquare(robtarget pos1, robtarget pos2, robtarget pos3)
  MoveJ pos1,v500,fine,tool0;
  !Before the next move instruction is run, the execution is stopped
       when stepping
  !Now you can modify the first position pos1
  MoveJ pos2,v500,fine,tool0;
  !Before the next move instruction is run, the execution is stopped
       when stepping
  !Now you can modify the second position pos2
  MoveJ pos3,v500,fine,tool0;
  !The third and last position pos3 can be modified when the whole
       procedure has been run
ENDPROC
ENDMODULE
```


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10 Syntax summary

Summary

Each rule, or group of rules, are prefixed by a reference to the section where the rule is introduced.

Character set on page 19

```
<character> ::= -- ISO 8859-1 (Latin-1)--
<newline> ::= -- newline control character --
<digit> ::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9
<hex digit> ::= <digit> | A | B | C | D | E | F | a | b | c | d |
     e | f
<letter> ::= <upper case letter> | <lower case letter>
<upper case letter> ::=
  A | B | C | D | E | F | G | H | I | J
  | K | L | M | N | O | P | Q | R | S | T
  | U | V | W | X | Y | Z | À | Á | Â | Ã
  | Ä | Å | Æ | Ç | È | É | Ê | Ë | Ì | Í
  | Î | Ï | Ð | Ñ | Ò | Ó | Ô | Õ | Ö | Ø
  | Ù | Ú | Û | Ü | Ý | Þ | ß
<lower case letter> ::=
a | b | c | d | e | f | g | h | i | j
| k | l | m | n | o | p | q | r | s | t
| u | v | w | x | y | z | ß | à | á | â | ã
| ä | å | æ | ç | è | é | ê | ë | ì | í
| î | ï | ð | ñ | ò | ó | ô | õ | ö | ø
| ù | ú | û | ü | ý | þ | ÿ
```

Identifiers on page 21

```
<identifier> ::= <ident> | <ID>
<ident> ::= <letter> {<letter> | <digit> | '_'}
```

Numerical literals on page 23

```
<num literal> ::=
  <integer> [ <exponent> ]
    | <decimal integer>) [<exponent>]
    | <hex integer>
    | <octal integer>
    | <binary integer>
    | <integer> '.' [ <integer> ] [ <exponent> ]
    | [ <integer> ] '.' <integer> [ <exponent> ]
<integer> ::= <digit> {<digit>
<decimal integer> ::= '0' ('D' | 'd') <integer>
<hex integer> ::= '0' ('X' | 'x') <hex digit> {<hex digit>}
<octal integer> ::= '0' ('O' | 'o') <octal digit> {<octal digit>}
<binary integer> ::= '0' ('B' | 'b') <binary digit> {<binary digit>}
<exponent> ::= ('E' | 'e') ['+' | '-'] <integer>
```

Bool literals on page 24

```
<bool literal> ::= TRUE | FALSE
```

Continues on next page

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Continued

String literals on page 25

```
<string literal> ::= '"' { <character> | <character code> } '"'
<character code> ::= '\' <hex digit> <hex digit>
```

Comments on page 28

```
<comment> ::= '!' { <character> | <tab> } <newline>
```

Data types on page 29

```
<type definition> ::=
  [LOCAL] ( <record definition>
  | <alias definition> )
  | <comment>
  | <DN>
<record definition> ::=
  RECORD <identifier>
    <record component list>
  ENDRECORD
<record component list> ::=
  <record component definition>
  | <record component definition> <record component list>
<record component definition> ::=
  <data type> <record component name> ';'
<alias definition> ::=
  ALIAS <data type> <identifier> ';'
<data type> ::= <identifier>
```

Data declarations on page 40

```
<data declaration> ::=
[LOCAL]
  (<variable declaration>
  | <persistent declaration>
  | <constant declaration>)
| TASK
  (<variable declaration>
  | <persistent declaration>)
| <comment>
| <DDN>
```

Variable declarations on page 45

```
<variable declaration> ::=
  VAR <data type> <variable definition> ';'
<variable definition> ::=
  <identifier> [ '{' <dim> { ',' <dim> } '}' ] [ ':=' <constant
       expression> ]
<dim> ::= <constant expression>
```

Persistent declarations on page 46

```
<persistent declaration> ::=
  PERS <data type> <persistent definition> ';'
<persistent definition> ::=
  <identifier> [ '{' <dim> { ',' <dim> } '}' ] [ ':=' <literal
       expression> ]
```

Continues on next page

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Continued

Note

The literal expression may only be omitted for system global persistents.

Constant declarations on page 48

```
<constant declaration> ::=
  CONST <data type> <constant definition> ';'
<constant definition> ::=
  <identifier> [ '{' <dim> { ',' <dim> } '}' ] ':=' <constant
       expression>
<dim> ::= <constant expression>
```

Expressions on page 49

```
<expression> ::=
  <expr>
  | <EXP>
<expr> ::=
  [ NOT ] <logical term> { ( OR | XOR ) <logical term> }
<logical term> ::=
  <relation> { AND <relation> }
<relation> ::=
  <simple expr> [ <relop> <simple expr> ]
<simple expr> ::=
  [ <addop> ] <term> { <addop> <term> }
<term> ::=
  <primary> { <mulop> <primary> }
<primary> ::=
  <literal>
  | <variable>
  | <persistent>
  | <constant>
  | <parameter>
  | <function call>
  | <aggregate>
  | '(' <expr> ')'
<relop> ::= '<' | '<=' | '=' | '>' | '>=' | '<>'
<addop> ::= '+' | '-'
<mulop> ::= '*' | '/' | DIV | MOD
```

Constant expressions on page 51

```
<constant expression> ::= <expression>
```

Literal expressions on page 52

```
<literal expression> ::= <expression>
```

Conditional expressions on page 53

```
<conditional expression> ::= <expression>
```

Literals on page 54

```
<literal> ::=
  <num literal>
  | <string literal>
  | <bool literal>
```

Continues on next page

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Continued

Variables on page 55

```
<variable> ::=
  | <entire variable>
  | <variable element>
  | <variable component>
<entire variable> ::= <ident>
<variable element> ::= <entire variable> '{' <index list> '}'
<index list> ::= <expr> { ',' <expr> }
<variable component> ::= <variable> '.' <component name>
<component name> ::= <ident>
```

Persistents on page 57

```
<persistent> ::=
  <entire persistent>
  | <persistent element>
  | <persistent component>
```

Constants on page 58

```
<constant> ::=
  <entire constant>
  | <constant element>
  | <constant component>
```

Parameters on page 59

```
<parameter> ::=
  <entire parameter>
  | <parameter element>
  | <parameter component>
```

Aggregates on page 60

```
<aggregate> ::= '[' <expr> { ',' <expr> } ']'
```

Function calls on page 61

```
<function call> ::=
  <function> '(' [ <function argument list> ] ')'
<function> ::= <identifier>
<function argument list> ::=
  <first function argument> { <function argument>
<first function argument> ::=
  <required function argument>
  | <optional function argument>
  | <conditional function argument>
<function argument> ::=
  ',' <required function argument>
  | <optional function argument>
  | ',' <optional function argument>
  | <conditional function argument>
  | ',' <conditional function argument>
<required function argument> ::= [ <ident> ':=' ] <expr>
<optional function argument> ::= '\' <ident> [ ':=' <expr> ]
<conditional function argument> ::='\' <ident> '?' <parameter>
```

Continues on next page

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Statements on page 65

```
<statement> ::=
  <simple statement>
  | <compound statement>
  | <label>
  | <comment>
  | <SMT>
<simple statement> ::=
  <assignment statement>
  | <procedure call>
  | <goto statement>
  | <return statement>
  | <raise statement>
  | <exit statement>
  | <retry statement>
  | <trynext statement>
  | <connect statement>
<compound statement> ::=
  <if statement>
  | <compact if statement>
  | <for statement>
  | <while statement>
  | <test statement>
```

Statement lists on page 67

```
<statement list> ::= { <statement> }
```

Label statement on page 68

```
<label> ::= <identifier> ':'
```

Assignment statement on page 69

```
<assignment statement> ::=
  <assignment target> ':=' <expression> ';'
<assignment target> ::=
  <variable>
  | <persistent>
  | <parameter>
  | <VAR>
```

Procedure call on page 70

```
<procedure call> ::=
  <procedure> [ <procedure argument list> ] ';'
<procedure> ::=
  <identifier>
  | '%' <expression> '%'
<procedure argument list> ::=
  <first procedure argument> { <procedure argu¬ment> }
<first procedure argument> ::=
  <required procedure argument>
  | <optional procedure argument>
  | <conditional procedure argument>
  | <ARG>
```

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Continued

```
<procedure argument> ::=
  ',' <required procedure argument>
  | <optional procedure argument>
  | ',' <optional procedure argument>
  | <conditional procedure argument>
  | ',' <conditional procedure argument>
  | ',' <ARG>
<required procedure argument> ::=
  [ <identifier> ':=' ] <expression>
<optional procedure argument> ::=
  '\' <identifier> [ ':=' <expression> ]
<conditional procedure argument> ::=
  '\' <identifier> '?' ( <parameter> | <VAR> )
```

The Goto statement on page 72

```
<goto statement> ::= GOTO <identifier> ';'
```

The Return statement on page 73

```
<return statement> ::= RETURN [ <expression> ] ';'
```

The Raise statement on page 74

```
<raise statement> ::= RAISE [ <error number> ] ';'
<error number> ::= <expression>
```

The Exit statement on page 75

```
<exit statement> ::= EXIT ';'
```

The Retry statement on page 76

```
<retry statement> ::= RETRY ';'
```

The Trynext statement on page 77

```
<trynext statement> ::= TRYNEXT ';'
```

The Connect statement on page 78

```
<connect statement> ::=
  CONNECT <connect target> WITH <trap> ';'
<connect target> ::=
  <variable>
  | <parameter>
  | <VAR>
<trap> ::= <identifier>
```

The IF statement on page 79

```
<if statement> ::=
  IF <conditional expression> THEN
    <statement list>
  { ELSEIF <conditional expression> THEN
    <statement list>
    | <EIT> }
  [ ELSE
    <statement list> ]
  ENDIF
```

The compact IF statement on page 80

```
<compact if statement> ::=
```

Continues on next page

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Continued

```
  IF <conditional expression> ( <simple statement> | <SMT> )
```

The For statement on page 81

```
<for statement> ::=
  FOR <loop variable> FROM <expression> TO <expression> [ STEP
       <expression> ] DO <statement list> ENDFOR
<loop variable> ::= <identifier>
```

The While statement on page 82

```
<while statement> ::=
  WHILE <conditional expression> DO <statement list> ENDWHILE
```

The Test statement on page 83

```
<test statement> ::=
  TEST <expression>
    { CASE <test value> { ',' <test value> } ':'
    <statement list> ) | <CSE> }
    [ DEFAULT ':'<statement list> ]
  ENDTEST
<test value> ::= <constant expression>
```

Routine declarations on page 85

```
<routine declaration> ::=
  [LOCAL] ( <procedure declaration> | <function declaration> |
       <trap declaration> )
  | <comment> | <RDN>
```

Parameter declarations on page 86

```
<parameter list> ::=
  <first parameter declaration> { <next parameter declaration> }
<first parameter declaration> ::=
  <parameter declaration>
  | <optional parameter declaration>
  | <PAR>
<next parameter declaration> ::=
  ',' <parameter declaration>
  | <optional parameter declaration>
  | ',' <optional parameter declaration>
  | ',' <PAR>
<optional parameter declaration> ::=
  '\' ( <parameter declaration> | <ALT> ) { '|' ( <parameter
       declaration> |
  <ALT> ) }
<parameter declaration> ::=
  [ VAR | PERS | INOUT ] <data type> <identifier> [ '{' ( '*' {
       ',' '*' } ) |
  <DIM> '}' ]
  | 'switch' <identifier>
```

Procedure declarations on page 90

```
<procedure declaration> ::=
  PROC <procedure name>
  '(' [ <parameter list> ] ')'
  <data declaration list>
```

Continues on next page

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Continued

```
  <statement list>
  [ BACKWARD <statement list> ]
  [ ERROR [ <error number list> ] <statement list> ]
  [ UNDO <statement list> ]
  ENDPROC
<procedure name> ::= <identifier>
<data declaration list> ::= { <data declaration> }
```

Function declarations on page 91

```
<function declaration> ::=
  FUNC <data type>
  <function name>
  '(' [ <parameter list> ] ')'
  <data declaration list>
  <statement list>
  [ ERROR [ <error number list> ] <statement list> ]
  [ UNDO <statement list> ]
  ENDFUNC
<function name> ::= <identifier>
```

Trap declarations on page 92

```
<trap declaration> ::=
  TRAP <trap name>
  <data declaration list>
  <statement list>
  [ ERROR [ <error number list> ] <statement list> ]
  [ UNDO <statement list> ]
  ENDTRAP
<trap name> ::= <identifier>
<error number list> ::=
  '(' <error number> { ',' <error number>} ')'
<error number> ::=
  <num literal>
  | <entire constant>
  | <entire variable>
  | <entire persistent>
```

Module declarations on page 120

```
<module declaration> ::=
  MODULE <module name> [ <module attriutelist>]
  <type definition list>
  <data declaration list>
  <routine declaration list>
  ENDMODULE
<module name> ::= <identifier>
<module attribute list> ::=
  '(' <module attribute> { ',' <module attribute> } ')'
<module attribute> ::=
  SYSMODULE
  | NOVIEW
  | NOSTEPIN
  | VIEWONLY
```

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Continued

```
  | READONLY
<type definition list> ::= { <type definition> }
<routine declaration list> ::= { <routine declaration> }
```


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11 Built-in routines

General

For more information on the `ref` access mode, see *Function calls on page 61*.

> **Note**
>
> Note that RAPID routines cannot have `REF` parameters.

The marker `anytype` indicates that the argument can have any data type.

> **Note**
>
> Note that `anytype` is just a marker for this property and should not be confused with a "real" data type. Also note that RAPID routines cannot be given `anytype` parameters.

Dim

The `Dim` function is used to get the size of an array (`datobj`). It returns the number of array elements of the specified dimension.

```
FUNC num Dim (REF anytype datobj, num dimno)
```

Legal `dimno` values:

Value	Description
1	Select first array dimension
2	Select second array dimension
3	Select third array dimension

Present

The `Present` function is used to test if the argument (`datobj`) is present, see *Parameter declarations on page 86*. It returns FALSE if `datobj` is a not present optional parameter, TRUE otherwise.

```
FUNC bool Present (REF anytype datobj)
```

Break

The `Break` (breakpoint) procedure causes a temporary stop of program execution. `Break` is used for RAPID program code debugging purposes.

```
PROC Break ()
```

IWatch

The `IWatch` procedure activates the specified interrupt (ino). The interrupt can later be deactivated again using the `ISleep` procedure.

```
PROC IWatch (VAR intnum ino)
```

Continues on next page

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Continued

ISleep

The `ISleep` procedure deactivates the specified interrupt (ino). The interrupt can later be activated again using the `IWatch` procedure.

```
PROC ISleep (VAR intnum ino)
```

IsPers

The `IsPers` function is used to test if a data object (datobj) is (or is an alias for) a persistent

(see *Parameter declarations on page 86*). It returns TRUE in that case, FALSE otherwise.

```
FUNC bool IsPers (INOUT anytype datobj)
```

IsVar

The `IsVar` function is used to test if a data object (datobj) is (or is an alias for) a variable (see *Parameter declarations on page 86*). It returns TRUE in that case, FALSE otherwise.

```
FUNC bool IsVar (INOUT anytype datobj)
```


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12 Built-in data objects

Errors

The following table describes the errors that belongs to the kernel.

For a list of all errors, both kernel errors and RAPID errors, see *Technical reference manual - RAPID Instructions, Functions and Data types*.

Object name	Object type	Data type	Description
ERRNO	variable[i]	errnum	most recent error number
INTNO	variable *i*	intnum	most recent interrupt
ERR_ALRDYCNT	constant	errnum	variable and trap routine already connected
ERR_ARGDUPCND	constant	errnum	duplicated present conditional argument
ERR_ARGNOTPER	constant	errnum	argument is not a persistent reference
ERR_ARGNOTVAR	constant	errnum	argument is not a variable reference
ERR_CALLPROC	constant	errnum	procedure call error (syntax, not procedure) at run time (late binding)
ERR_CNTNOTVAR	constant	errnum	`CONNECT` target is not a variable reference
ERR_DIVZERO	constant	errnum	division by zero
ERR_EXECPHR	constant	errnum	cannot execute placeholder
ERR_FNCNORET	constant	errnum	missing return value
ERR_ILLDIM	constant	errnum	array dimension out of range
ERR_ILLQUAT	constant	errnum	illegal orientation value
ERR_ILLRAISE	constant	errnum	error number in RAISE out of range
ERR_INOISSAFE	constant	errnum	If trying to deactivate a safe interrupt temporarily with `ISleep`.
ERR_INOMAX	constant	errnum	no more interrupt number available
ERR_MAXINTVAL	constant	errnum	integer value too large
ERR_NOTARR	constant	errnum	data object is not an array
ERR_NOTEQDIM	constant	errnum	mixed array dimensions
ERR_NOTINTVAL	constant	errnum	not integer value
ERR_NOTPRES	constant	errnum	parameter not present
ERR_OUTOFBND	constant	errnum	array index out of bounds
ERR_REFUNKDAT	constant	errnum	reference to unknown entire data object
ERR_REFUNKFUN	constant	errnum	reference to unknown function
ERR_REFUNKPRC	constant	errnum	reference to unknown procedure at linking time or at run time (late binding)
ERR_REFUNKTRP	constant	errnum	reference to unknown trap
ERR_STRTOOLNG	constant	errnum	string too long
ERR_UNKINO	constant	errnum	unknown interrupt number

i Read only, can only be updated by the system, not by a RAPID program.

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13 Built-in objects

Definition

There are three groups of *built-in objects*:

- Language kernel reserved objects
- Installed objects
- User installed objects

Language kernel reserved objects are part of the system and cannot be removed (or left out in the configuration). Objects in this group are the instruction `Present`, the variables `intno`, `errno`, and much more. The set of objects in this group is the same for all tasks (multitasking) and installations.

Most of the installed objects are installed at the first system start (or when using the restart mode **Reset RAPID**) by the internal system configuration and cannot be removed (for example the instructions `MoveL`, `MoveJ` ...). Data objects corresponding to I/O signals, mechanical units and cameras are installed according to the user configuration at each system start.

The last group user installed objects are objects that are defined in RAPID modules and installed according to the user configuration at the first system start or when using the restart mode **Reset RAPID**.

The objects could be any RAPID object, that is procedure, function, record, record component, alias, const, var, or pers. Object values of pers and var could be changed, but not the code itself, because of that a modpos of a built in constant declared robtarget is not allowed.

The built-in RAPID code can never be viewed.

Object scope

The scope of object denotes the area in which the object is visible. A built in object is visible at all other levels in the task, if not the same object name is used for another object at a level between the use of the reference and the built-in level.

The following table shows the order of scope levels lookup, for a object referred from different places.

The object is used in a:	Own routine	Own module (local declared)	Global in the program (global declared in one module)	Built-in objects
routine declared in a user or system module	1	2	3	4
data or routine declaration in a user or system module		1	2	3
routine declared in a user installed module	1	2		3

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Continued

The object is used in a:	Own routine	Own module (local declared)	Global in the program (global declared in one module)	Built-in objects
data or routine declaration in a user installed module		1		2
installed object (only for system developers)				1

There are ways to bind a reference in runtime to objects (not functions) outside its scope. For data object see the description of `SetDataSearch` in *Technical reference manual - RAPID Instructions, Functions and Data types*. For procedures use late binding with lookup, described in *Procedure call on page 70*.

The value of a *built-in* data object durability

The init value of a built-in PERS or VAR object is set when the object is installed. It could though be changed from the normal program. The object will always keep its latest value even if the normal program is reset, erased, or replaced. The only way to re-initialize the object is to reset the system by using the restart mode **Reset RAPID** or to change the configuration (then an automatic **Reset RAPID** will be performed).



Note

The value of built in VAR object with a separate value per task, will be reset at PP to Main. `ERRNO` is an example of a built in VAR object with a separate value for each task.



Note

A built-in PERS object is not replacing its init value with its latest as a normal PERS object do.

The way to define user installed objects

The only way to install a user installed object is to define the object in a RAPID module, create an new instance in the system parameter *Task modules* with the file path to that module. The attribute *Storage* must then be set to *Built-in*. (see system parameter, type *Controller* in *Technical reference manual - System parameters*). There are also an attribute for *Task modules* named *TextResource* that is only valid for built-in objects, this makes it possible to use national language or site depended names in the RAPID code for identifiers, without changing the code itself. In the normal case that attribute should not be changed, but for the advanced users see *Text files on page 147*.

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Note

All used references in a built-in module must be known to the system at the time for that module installation.

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14 Intertask objects

Definition

There are two groups of *intertask objects*:

- installed shared object
- system global persistent data object

An installed shared object is configured as shared for all tasks. This make it possible to save memory by reusing RAPID code for more than one task. Its also the only way to share non-value and semi-value data object, see *Built-in data objects on page 137*. The object could be any RAPID object, that is procedure, function, const, var, or pers.

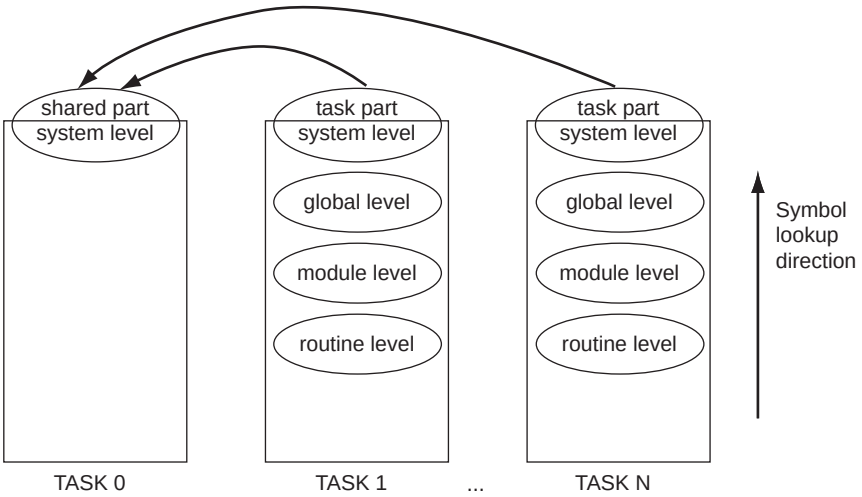
The current value of a system global persistent data object is shared by all tasks where it is declared with the same name and type.

Symbol levels

A symbol in RAPID could be found at different levels, in a routine, in a module (local), in the program of one task (in one module and defined as global) or at the system level. Installed shared objects are on the system level.

The system level is departed into two parts, a shared part and a task part. Objects in the task part are local to that task, but objects in the shared part are global to all task.

The installed shared part is physically existing in task 0 (the shared task), but existing logical in each task.



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The symbol search will start from that position (level) where the object is referred and then, if not found, in nearest level above and so on. See the *Symbol lookup direction* arrow in the preceding figure.

Data object handling

Even if the definition is shared for a data object the value of it could be local in the task. That is the fact for the installed system variables errno, intno, and all stack

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Continued

allocated objects (object defined in a routine). All other data objects share the value with other tasks. This fact will demand a careful manipulation and reading of those values.

If the object has an atomic type (num, bool ...) there is no problem. But if not, make sure that the total object is read/manipulated without any interfering from another task. For example if the object is of a record type and each component is assigned one by one, a reading (between the setting of two record components) from another task will get an inconsistent record.

Also remember that a routine could be called from more than one task at the same time and therefore should be reentrant, that is, use local stack allocated object (parameters and data object declared in the routine).

The way to define installed shared object

The only way to install an installed shared object is to define the object in a RAPID module, create a new instance of *Task/Automatic loading of Modules* in the system parameter with the file path to the module. The attribute shared must be set to *YES*. See system parameter domain *Controller* in *Technical reference manual - System parameters*.

System global persistent data object

The current value of a system global persistent data object (for example, not declared as task or local) is shared by all tasks where it is declared with the same name and type. The object will still exist even if one module where it is declared is removed as long as that module does not contain the last declaration for that object. A persistent object could only be of value type.

A declaration can specify an initial value to a persistent object, but it will only set the initial value of the persistent when the module is installed or loaded for the first time.

Example of usage (several initial values):

Task 1: `PERS tooldata tool1 := [...];`

Task 2: `PERS tooldata tool1 := [...];`

Note that the current value of tool1 will not be updated with the initial value of tool1 in the second loaded module. This is a problem if the initial value differs in the two tasks. This is solved by specifying initial value in one declaration only.

Example of usage (one initial value):

Task 1: `PERS tooldata tool1 := [...];`

task 2: `PERS tooldata tool1;`

After load of the two tasks the current value of tool1 is guaranteed to be equal to the initial value of the declaration in task 1 regardless of the load order of the modules. It is recommended to use this technique for types such as `tooldata`, `wobjdata`, and `loaddata`. Specify initial value along with data declaration in the motiontask and omit initial value in other tasks. It is also possible to specify no initial value at all. Example of usage (no initial value):

Task 1: `PERS num state;`

Task 2: `PERS num state;`

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The current value of state will be initialized like a variable without initial value, in this case state will be equal to zero. This case is useful for intertask communication where the state of the communication should not be saved when the program is saved or at backup.

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15 Text files

Definition

This is a most effective tool that should be used when the demand for the application includes:

- Easily changeable texts, for example help and error texts (the customer should also be able to handle these files).
- Memory saving, text strings in a text file use a smaller amount of memory than RAPID strings.

In a text file you can use ASCII strings, with the help of an off-line editor, and fetch them from the RAPID code. The RAPID code should not be changed in any way even if the result from the execution may look totally different.

Syntax for a text file in .xml format

The application programmer must create one text file for each language to be supported.

The text file is organized as:

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<Resource Language="en" Name="text file">
  <Text Name="1">
    <Value>This is text string 1</Value>
    <Comment>This is a comment</Comment>
  </Text>
  <Text Name="1">
    <Value>This is text string 2</Value>
    <Comment>This is a comment</Comment>
  </Text>
```

Retrieving text during program execution

It is possible to retrieve a text string from the RAPID code. The functions `TextGet` and `TextTabGet` are used for this, see the descriptions of these in *Technical reference manual - RAPID Instructions, Functions and Data types*.

Example of a module: `write_from_file.mod`

```
MODULE write_from_file
VAR num text_res_no;
VAR string text1;

PROC main()
IF TextTabFreeToUse("ACTION_TXRES") THEN
  TextTabInstall "HOME:/text_file.xml";
ENDIF

text_res_no := TextTabGet("ACTION_TXRES");
text1 := TextGet(text_res_no, 2);
TPWrite text1; ! The word "Stop" will be printed.

ENDPROC
```

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Continued

```
ENDMODULE
```

Example of a text file: `text_file.xml`

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<Resource Language="en" Name="text file">
  <Text Name="1">
    <Value>Go</Value>
    <Comment>Start the activity</Comment>
  </Text>
  <Text Name="2">
    <Value>Stop</Value>
    <Comment>Stop the activity</Comment>
  </Text>
  <Text Name="3">
    <Value>Wait</Value>
  </Text>
  <Text Name="4">
    <Value>Call_service_man</Value>
    <Comment>Get help</Comment>
  </Text>
  <Text Name="5">
    <Value>Restart</Value>
    <Comment>Restart the controller</Comment>
  </Text>
</Resource>
```

Loading text files

Loading of the text file into the system can be done with the RAPID instruction `TextTabInstall` and the function `TextTabFreeToUse`.

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16 Storage allocations for RAPID objects

Definition

All RAPID programs stored on PC or controller have ASCII format. At loading of RAPID program from PC/controller memory into the program memory (internal format), the storage of the program needs about four times more memory space.

For memory optimization of RAPID programs, the storage allocation in program memory (internal format in bytes) for some common instructions, data etc. are specified below.

For other instructions or data the storage allocation can be read from the operating message 10040 after loading of a program or program module.

Storage allocation for modules, routines, program flow, and other basic instructions

Instruction or data	Storage in bytes
New empty module: MODULE module1 ... ENDMODULE	1732
New empty procedure without parameters: PROC proc1() ... ENDPROC	224
Procedure call without arguments: proc1;	224
Module numeric variable declaration: VAR num reg1;	156
Numeric assignment: reg1:=1;	44
Compact IF: IF reg1=1 proc1;	124
IF statement: IF reg1=1 THEN proc1; ELSE proc2; ENDIF	184
Waits a given amount of time: WaitTime 1;	88
Comments: ! 0 - 7 chars (for every additional 4 chars)	36 (+4)
Module string constant declaration with 0-80 chars init string value: CONST string string1 := "0-80 characters";	332
Module string variable declaration with 0-80 chars init string value: VAR string string1 := "0-80 characters";	344
Module string variable declaration: VAR string string1;	236
String assignment: string1:= "0-80 characters";	52
Write text on FlexPendant: TPWrite "0-80 characters";	176

Storage allocation for `Move` instructions

Instruction or data	Storage in bytes
Module robtarget constant declaration: `CONST robtarget p1 := [...];`	292
Robot linearly move: `MoveL p1,v1000,z50,tool1;`	244
Robot linearly move: `MoveL *,v1000,z50,tool1;`	312
Robot circular move: `MoveC *,*,v1000,z50,tool1;`	432

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Continued

Storage allocation for I/O instructions

Instruction or data	Storage in bytes
Set digital output: `Set do1;`	88
Set digital output: `SetDO do1,1;`	140
Wait until one digital input is high: `WaitDI di1,1;`	140
Wait until two digital inputs are high: `WaitUntil di1=1 AND di2=1;`	220

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ABB Robotics Sweden AB
S-721 71 VÄSTERÅS, Sweden
Telephone +46 10-732 50 00

ABB Robotics Norway AS
Nordlysvegen 7, N-4340 BRYNE, Norway
Box 265, N-4349 BRYNE, Norway
Telephone: +47 22 87 2000

ABB Robotics (Shanghai) Limited
No. 39, 99 Miaoqiao Road,
Pudong New Area,
Shanghai, 201315, China
Telephone: +86 21 6105 6666

ABB Robotics LLC
1250 Brown Road
Auburn Hills, MI 48326
USA
Telephone: +1 248 391 9000

abb.com/robotics

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