ROBOTICS
MAN AND MACHINE

VAL3 REFERENCE MANUAL

Version 5.3

D28062804A - 02/2006

STÄUBLI

Documentation addenda and errata can be found in the "readme.pdf" document delivered with the controller's CdRom.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

VAL3 is a high-level programming language designed to control **Stäubli** robots in industrial handling and assembly applications.

VAL3 language combines the basic features of a standard real-time high-level computer language with functionalities that are specific to industrial cell robot control:

- robot control tools
- geometrical modelling tools
- input/output control tools

This reference manual explains the essential concepts of robot programming and describes the **VAL3** instructions which fall into the following categories:

- Language elements
- Simple types
- User interface
- Tasks
- Libraries
- Robot control
- Arm position
- Movement control

Each instruction,together with its syntax, is listed in the table of contents for quick reference purposes.

CHAPTER 2

VAL3 LANGUAGE ELEMENTS

VAL3 consists of the following elements:

- applications
- programs
- libraries
- data types
- constants
- variables (global and local datas, parameters)
- tasks

2.1. APPLICATIONS

2.1.1. DEFINITION

A **VAL3** application is a self-contained software package designed for programming robots and inputs/outputs associated with a **CS8** controller.
A **VAL3** application comprises the following elements:

- a set of **programs**: the **VAL3** instructions to be executed
- a set of **global datas**: the application data
- a set of **libraries**: the outside instructions and data used by the application

When an application is running, it also contains:

- a set of **tasks**: the programs being executed

2.1.2. DEFAULT CONTENT

A **VAL3** application always contains the **start()** and **stop()** programs, a **world** frame (**frame** type) and a **flange** tool (**tool** type).
When a **VAL3** application is created, it also contains the instructions and data types that are specific to the arm model.
Further details of these elements can be found in the chapters describing each element type.

2.1.3. START/STOP

VAL3 instructions are not used to control applications: applications can only be loaded, unloaded, started and stopped via the **CS8** user interface of the controller.
When a **VAL3** application is started up, its **start()** program is run.
A **VAL3** application stops automatically when its last task is completed: the **stop()** program is then executed. All the tasks created by libraries, if any remain, are deleted in the reverse order to that in which they were created.
If a **VAL3** application is stopped via the **CS8** user interface, the start task, if it still exists, is immediately destroyed. The **stop()** program is run next, and then any remaining application tasks are deleted in the reverse order to that in which they were created.

2.1.4. APPLICATION PARAMETERS

The following parameters can be used to configure a **VAL3** application:

- unit of length
- size of the execution memory

These parameters cannot be accessed via a **VAL3** instruction and can only be changed via the **CS8** user interface.

2.1.4.1. UNIT OF LENGTH

In **VAL3** applications, the unit of length is either the millimetre or the inch. It is used by the **VAL3** geometrical data types: frame, point, transformation, tool, and trajectory blending.
The unit of length of an application is defined when an application is created, and it cannot be changed subsequently.

2.1.4.2. SIZE OF THE EXECUTION MEMORY

The size of the execution memory of a **VAL3** application is the amount of memory available for each of its tasks, to store data such as the local program variables. By default, it is **5000** bytes.
This level may not be sufficient for applications containing large tables with local variables or recursive algorithms: in this case, it must be increased via the **CS8** user interface.

2.2. PROGRAMS

2.2.1. DEFINITION

A program is a sequence of **VAL3** instructions to be executed.
A program consists of the following elements:

- sequence of **instructions**: the **VAL3** instructions to be executed
- A set of **local variables**: the internal program data
- A set of **parameters**: the data supplied to the program when it is called

Programs are used to group sequences of instructions that can be executed at various points in an application. In addition to saving program time, they also highlight the structure of the applications, facilitate programming and maintenance and improve readability.
The number of instructions in a program is limited only by the amount of memory available in the system.
The number of local variables and parameters is limited only by the size of the execution memory for the application.

2.2.2. RE-ENTRY

The programs are re-entrant; this means that a program can call itself recursively (**call** instruction), or it can be called concurrently by several tasks. Each program call has its own specific variables and parameters.

2.2.3. START() PROGRAM

The **start()** program is the program called when the **VAL3** application is started up. It cannot have any parameters.
Typically, this program includes all the operations required to run the application: initialization of the global datas and the inputs/outputs, starting up the application tasks, etc.
The application does not necessarily terminate at the end of the **start()** program, if other application tasks are still running.
The **start()** program can be called from within a program (**call** instruction) in the same way as any other program.

2.2.4. STOP() PROGRAM

The **stop()** program is the program called when the **VAL3** application stops. It cannot have any parameters.
Typically, this program includes all the operations required to stop the application correctly: resetting the inputs/outputs and stopping the application tasks according to an appropriate sequence, etc.
The **stop()** program can be called from within a program (**call** instruction) in the same way as any other program: calling the **stop()** program does not stop the application.

2.3. DATA TYPES

2.3.1. DEFINITION

A **VAL3** variable or constant type is a characteristic that allows the system to control the applications and programs that can use it.
All the **VAL3** constants and variables have a type. This enables the system to run an initial check when editing a program and hence detect certain programming errors immediately.

2.3.2. SIMPLE TYPES

The **VAL3** language supports the following simple types:

- **bool** type: for Boolean values (true/false)
- **num** type: for numeric values
- **string** type: for character strings
- **dio** type: for on/off inputs/outputs
- **aio** type: for numeric inputs/outputs (analogue or digital)
- **sio** type: for serial ports inputs/outputs and ethernet sockets

2.3.3. STRUCTURED TYPES

Structured types combine typed data, the fields of the structured type. Fields of the structured type can be accessed individually by their name.
The **VAL3** language supports the following structured types:

- **trsf** type: for Cartesian geometrical transformations
- **frame** type: for Cartesian geometrical frames
- **tool** type: for robot mounted tools
- **point** type: for the Cartesian positions of a tool
- **joint** type: for robot revolute positions
- **config** type: for robot configurations
- **mdesc** type: for robot movement parameters

2.4. CONSTANTS

2.4.1. DEFINITION

A constant is a data item that is defined directly in a **VAL3** program without previously being declared. A constant has a type that is determined implicitly by the system.

2.4.2. SIMPLE TYPE CONSTANTS

The precise syntax of a simple type constant is specified in the chapter describing each simple type.

Example

```
bool bBool
num nPi
string sString
bBool = true
nPi = 3.141592653
sString = "this is a string"
```

2.4.3. STRUCTURED TYPE CONSTANTS

The value of a structured type constant is defined by the sequence of values in its fields. The sequence order is specified in the chapter describing each structured type.

Example

```
procedure dummy(trsf t, dio d)
point p
p = {{100, -50, 200, 0, 0, 0}, {sfree, efree, wfree}}
call dummy({a+b, 2* c, 120, limit(c, 0, 90), 0, 0}, io:valve1)
```

2.4.4. CONSTANTS TABLE

A constants table must be initialized entry by entry.

Example

```
joint j[5]
// For 6 axis arms
j[0] = {0, 0, 0, 0, 0, 0}
j[1] = {90, 0, 90, 0, 0, 0}
j[2] = {-90, 0, 90, 0, 0, 0}
j[3] = {90, 0, 0, -90, 0, 0}
j[4] = {-90, 0, 0, -90, 0, 0}
```

2.5. VARIABLES

2.5.1. DEFINITION

A variable is a data item referenced by its name in a program.
A variable is identified by:

- its name: a character string
- its type: one of the **VAL3** types described previously
- its size: for a table, the number of elements it contains
- its scope: the program or programs that can use the variable

A variable name is a string of **1** to **15** characters selected from **"a..zA..Z0..9_"**.
All variables can be used as arrays. Simple variables are size **1**. The **size()** instruction enables the size of a variable to be known.

2.5.2. VARIABLE SCOPE

The scope of a variable can be:

- global: all programs in the application can use the variable, or
- local: the variable can only be accessed in the program in which it is declared

When a global variable and a local variable have the same name, the program in which the local variable is declared will use the local variable and will be unable to access the global variable.
Program parameters are local variables that can only be accessed in the program in which they are declared.

2.5.3. ACCESSING A VARIABLE VALUE

The elements of an array can be accessed by using an index between square brackets **'['** and **']'**. The index must be between **0** and (size-**1**), otherwise an execution error is generated.
If no index is specified, the index **0** is used: **var[0]** is equivalent to **var**.
The fields of structured type variables can be accessed using a **'.'** followed by the field name.

Example

```
num a                  // a is a size 1 num type variable
num b[10]              // b is a size 10 num type variable
trsf t
point p

a = 0                  // Initialization of a simple type variable
a[0] = 0               // Correct: equivalent to a = 0
b[0] = 0               // Initialization of the first element in table b
b = 0                  // Correct: equivalent to b[0] = 0
b[5] = 5               // Initialization of the sixth element in table b
b[5.13] = 7            // Correct: equivalent to b[5] = 7 (only the integer part is used)

b[-1] = 0              //  error: index less than 0
b[10] = 0              //  error: index too high

t = p.trsf             // Initialization of t
p.trsf.x = 100         // Initialization of the x field of the trsf field of the p variable
```

2.5.4. PARAMETER PASSED "BY VALUE"

When a parameter is passed "by value", the system creates a local variable and initializes it with the value of the variable or expression supplied by the calling program.
The variables of the calling program used as "by value" parameters do not change, even if the called program changes the value of the parameter.
A data array cannot be passed by value.

Example:

```
procedure dummy(num x)    // x is passed by value
begin
  x=0
  putln(x)                // displays 0
end

num a
a=10
putln(a)                  // displays 10
call dummy(a)             // displays 0
putln(a)                  // displays 10: a is not modified by dummy()
```

2.5.5. PARAMETER PASSED "BY REFERENCE"

When a parameter is passed "by reference", the program no longer works on a copy of the data item passed by the caller, but on the data item itself, which is simply renamed locally.
The values of the variables of the calling program used as "by reference" parameters change when the called program changes the value of the parameter.
All the components of a table passed by reference can be used or modified. If an array component is passed by reference, that component and all following components can be used and modified. In this case, the parameter is seen as a table that starts with the component passed by the call. The **size()** instruction can be used to determine the effective parameter size.
When a constant or an expression are passed "by reference", the corresponding assigned parameter has no effect: the parameter retains the value of the constant or expression.

Example:

```
procedure dummy(num& x)          // x is passed by reference
begin
  x=0
  putln(x)                       // displays 0
end

procedure element(num& x)
begin
  x[3] = 0
  putln(size(x))
end

num a
num b[10]
a=10
putln(a)                         // displays 10
call dummy(a)                    // displays 0
putln(a)                         // displays 0: a is modified by dummy()
b[2] = 2
b[5] = 5
call element(b[2])               // displays 8, elements 0 and 1 in b are not passed
putln(b[5])                      // displays 0: b[5] is modified by element()
```

2.6. SEQUENCE CONTROL INSTRUCTIONS

Comment //

Syntax
// <string>

Function
A line starting with **« // »** is not evaluated and the evaluation resumes on the next line.

Example
```
// This is an example of a comment
```

call program

Syntax
call program([parameter1][,parameter2])

Function
Runs the specified program with the specified parameters.

Example

```
// Calls the pick() and place() programs for i,j between 1 and 10
for i = 1 to 10
  for j = 1 to 10
    call pick (i, j)
    call place (i, j)
  endFor
endFor
```

return program

Syntax

return

Function

Exits the current program immediately. If this program was called by a **call**, execution resumes after the **call** in the calling program. Otherwise (if the program is the **start()** program or the starting point of a task), the current task is completed.

if control instruction

Syntax

if <bool condition>
** <instructions>**
[else
** <instructions>]**
endIf

Function

When the evaluation of the Boolean **condition** is **(true)**, all the following instructions up to the **else** keyword, if present, or the next **endIf** are evaluated.
When the expression is **(false)**, the instructions evaluated are those between the **else** and **endIf** keywords, if the **else** keyword is present. In all cases, the program then resumes after the **endIf** keyword.

Parameter

bool condition	Boolean expression to be evaluated

Example

```
string s
num a
// s = "a=0" if a=0, else "a = ? "
s = "a = ? "
if a==0
  s = "a=0"
endIf
// s = "a=0" if a=0, else "a <> 0"
s = "a = ? "
if a==0
  s = "a = 0"
else
  s = "a <> 0"
endIf
```

while control instruction

Syntax

while <bool condition>
<instructions>
endWhile

Function

The instructions between **while** and **endWhile** are executed when the Boolean **condition** expression is **(true)**.
If the Boolean **condition** expression is not true at the first evaluation, the instructions between **while** and **endWhile** are not executed.

Parameter

bool condition	Boolean expression to be evaluated

Example

```
dio dLamp
// Causes a signal to flash while the robot is working
dLamp = false
while (isSettled()==false)
  dLamp = !  dLamp              //Inverses the value of the dLamp: true false
  delay(0.5)                    // Waits ½ s
endWhile
dLamp = false
```

do ... until control instruction

Syntax

do
<instructions>
until <bool condition>

Function

The instructions between **do** and **until** are executed until the Boolean **condition** expression is **(true)**.
The instructions between **do** and **until** are executed once if the Boolean **condition** expression is true during its first evaluation.

Parameter

bool condition	Boolean expression to be evaluated

Example

```
num a
// Waits until Enter is pressed
do
  a = get()                     // Waits for a key to be pressed
until (a == 270)                // Tests the Enter key code
```

for control instruction

Syntax

for <num counter> = <num beginning> to <num end> [step <num step>]
<instructions>
endFor

Function

The instructions between **for** and **endFor** are executed until the **counter** exceeds the specified **end** value. The **counter** is initialized by the **beginning** value. If **beginning** exceeds **end**, the instructions between **for** and **endFor** are not executed. At each iteration, the **counter** is incremented by the **step** value, and the instructions between **for** and **endFor** are repeated if the **counter** does not exceed **end**.
If **step** is positive, the **counter** exceeds **end** if it is greater than **end**. If **step** is negative, the **counter** exceeds **end** if it is less than **end**.

Parameter

num counter	**num** type variable used as a counter
num beginning	numerical expression used to initialize the counter
num end	numerical expression used for the loop end test
[num step]	numerical expression used to increment the counter

Example

```
num i
joint jDest
jDest = {0,0,0,0,0,0}
// Rotates axis 1 from 90° to -90° in -10-degree steps
for i = 90 to -90 step -10
  jDest.j1 = i
  movej(jDest, flange, mNomSpeed)
  waitEndMove()
endFor
```

switch control instruction

Syntax

switch <num selection>
case <num case1> [, <num case2>]
** <instructions1-2>**
** break**
[case <num case3> [, <num case4>]
** <instructions3-4>**
** break]**
[default
** <Default Instructions>**
** break]**
endSwitch

Function

Executes the instructions corresponding to the **selection** case specified.
When a non integer value is specified for the **selection** or for a **case**, the nearest integer is used.
If no case corresponds to the **selection** specified, the **Default Instructions**, if present, are executed.
If the same case **case** value occurs several times, only its last occurrence is taken into account.

Parameter

num selection	**num** selection type variable
num case1	test case numerical constant
num case2	test case numerical constant
num case3	test case numerical constant
num case4	test case numerical constant

Example

```
num nMenu
string s
// Tests the menu key pressed
nMenu = get()
switch nMenu
  case 271
    s = "Menu 1"
  break
  case 272
    s= "Menu 2"
  break
  case 273, 274, 275, 276, 277, 278
    s = "Menu 3 to 8"
  break
  default
    s = "this key is not a menu key"
  break
endSwitch
```

CHAPTER 3

SIMPLE TYPES

3.1. INSTRUCTIONS

num **size**(variable)

Syntax
num size(<variable>)

Function
Returns the size of the **variable**.
If the **variable** is a program parameter passed by reference, the size depends on the index specified when calling up the program.

Parameter

variable	variable of any type

Example

```
num nTable[10]
program printSize(num& nParameter)
begin
  putln(size(nParameter))
end
call printSize(nTable)                // displays 10
call printSize(nTable[6])             // displays 4
```

3.2. BOOL TYPE

3.2.1. DEFINITION

bool type values or constants can be:

- **true**: true value
- **false**: false value

When a **bool** type variable is initialized, its default value is **false**.

3.2.2. OPERATORS

In ascending order of priority:

bool <bool& variable> = <bool condition>	Assigns the value of **condition** to the variable **variable** and returns the value of **condition**
bool <bool condition1> or <bool condition2>	Returns the value of the logical OR between **condition1** and **condition2**. **condition2** is only assessed if **condition1** is **false**.
bool <bool condition1> and <bool condition2>	Returns the value of the logical AND between **condition1** and **condition2**. **condition2** is only assessed if **condition1** is **true**.
bool <bool condition1> xor bool <condition2>	Returns the value of the exclusive OR between **condition1** and **condition2**
bool <bool condition1> != <bool condition2>	Tests the equality of the values of **condition1** and **condition2**. Returns **true** if the values are different, and otherwise returns **false**.
bool <bool condition1> == <bool condition2>	Tests the equality of the values of **condition1** and **condition2**. Returns **true** if the values are identical, and otherwise returns **false**.
bool ! <bool condition>	Returns the negation of the value of the **condition**

3.3. NUM TYPE

3.3.1. DEFINITION

The **num** type modelizes a numerical value with about **14** significant digits.
The accuracy of each numerical computation is therefore limited by these **14** significant digits.
This must be taken into account when testing the equality of two numerical values: this must normally be done within a specific level.

Example

```
putln(sel(cos(90)==0,1,-1))                          // displays -1
putln(sel(abs(cos(90))<0.000000000000001,1,-1))      // displays 1
```

The format of numerical type constants is as follows:

```
[-] <digits>[.<digits>]
```

Example

```
1
0.2
-3.141592653
```

The default initialization value of **num** type variables is **0**.

3.3.2. OPERATORS

In ascending order of priority:

num <num& variable> = <num Value>	Assigns **Value** to the variable **variable** and returns **Value**.
bool <num Value1> != <num Value2>	Returns **true** if **Value1** is not equal to **Value2**, otherwise returns **false**.
bool <num Value1> == <num Value2>	Returns **true** if **Value1** is equal to **Value2**, otherwise returns **false**.
bool <num Value1> >= <num Value2>	Returns **true** if **Value1** is greater than or equal to **Value2**, otherwise returns **false**.
bool <num Value1> > <num Value2>	Returns **true** if **Value1** is definitely greater than **Value2**, otherwise returns **false**.
bool <num Value1> <= <num Value2>	Returns **true** if **Value1** is less than or equal to **Value2**, otherwise returns **false**.
bool <num Value1> < <num Value2>	Returns **true** if **Value1** is definitely less than **Value2**, otherwise returns **false**.
num <num Value1> - <num Value2>	Returns the difference between **Value1** and **Value2**.
num <num Value1> + <num Value2>	Returns the sum of **Value1** and **Value2**.
num <num Value1> % <num Value2>	Returns the remainder of the integer division of **Value1** by **Value2**. An execution error is generated if **Value2** is **0**. The sign of the remainder is the same as that of **Value1**.
num <num Value1> / <num Value2>	Returns the quotient of **Value1** by **Value2**. An execution error is generated if **Value2** is **0**.
num <num Value1> * <num Value2>	Returns the product of **Value1** and **Value2**.
num - <num Value>	Returns the inverse of **Value**.

3.3.3. INSTRUCTIONS

num **sin**(num angle)

Syntax

num sin(<num angle>)

Function

Returns the sine of **angle**.

Parameter

num angle	angle in degrees

Example

```
putln(sin(30))                    // displays 0.5
```

num **asin**(num Value)

Syntax

num asin(<num Value>)

Function

Returns the inverse sine of **Value** in degrees. The resulting angle is between **-90** and **+90** degrees.

An execution error is generated if **Value** is greater than **1** or less than **-1**.

Parameter

num Value	Numerical expression

Example

```
putln(asin(0.5))          // displays 30
```

num **cos**(num angle)

Syntax

num cos(<num angle>)

Function

Returns the cosine of **angle**.

Parameter

num angle	angle in degrees

Example

```
putln(cos(60))            // displays 0.5
```

num **acos**(num Value)

Syntax

num acos(<num Value>)

Function

Returns the inverse cosine of **Value**, in degrees. The resulting angle is between **0** and **180** degrees.

An execution error is generated if **Value** is greater than **1** or less than **-1**.

Parameter

num Value	Numerical expression

Example

```
putln(acos(0.5))          // displays 60
```

num **tan**(num angle)

Syntax

num tan(<num angle>)

Function

Returns the tangent of **angle**.

Parameter

num angle	angle in degrees

Example

```
putln(tan(45))          // displays 1.0
```

num **atan**(num Value)

Syntax

num atan(<num Value>)

Function

Returns the inverse tangent of **Value**, in degrees. The resulting angle is between **-90** and **+90** degrees.

Parameter

num Value	Numerical expression

Example

```
putln(atan(1))          // displays 45
```

num **abs**(num Value)

Syntax

num abs(<num Value>)

Function

Returns the absolute value of **Value**.

Parameter

num Value	Numerical expression

Example

```
putln(sel(abs(45)==abs(-45),1,-1))    // displays 1
```

num **sqrt**(num Value)

Syntax

num sqrt(<num Value>)

Function

Returns the square root of **Value**.

An execution error is generated if **Value** is negative.

Parameter

num Value	Numerical expression

Example

```
putln(sqrt(9))          // displays 3
```

num **exp**(num Value)

Syntax

num exp(<num Value>)

Function

Returns the exponential function of **Value**.

An execution error is generated if **Value** is too big.

Parameter

num Value	Numerical expression

Example

```
putln(exp(1))           // displays 2.718282
```

num **ln**(num Value)

Syntax

num ln(<num Value>)

Function

Returns the natural logarithm of **Value**.

An execution error is generated if **Value** is negative or zero.

Parameter

num Value	Numerical expression

Example

```
putln(ln(2.718281828))          // displays 1
```

num **log**(num Value)

Syntax

num log(<num Value>)

Function

Returns the common logarithm of **Value**.

An execution error is generated if **Value** is negative or zero.

Parameter

num Value	Numerical expression

Example

```
putln(log(10))          // displays 1
```

num **roundUp**(num Value)

Syntax

num roundUp(<num Value>)

Function

Returns **Value** rounded up to the nearest integer.

Parameter

num Value	Numerical expression

Example

```
putln(roundUp(7.8))          // Displays 8
putln(roundUp(-7.8))         // Displays -7
```

num **roundDown**(num Value)

Syntax

num roundDown(<num Value>)

Function

Returns **Value** rounded down to the nearest integer.

Parameter

num Value	Numerical expression

Example

```
putln(roundDown(7.8))        // Displays 7
putln(roundDown(-7.8))       // Displays -8
```

num **round**(num Value)

Syntax

num round(<num Value>)

Function

Returns **Value** rounded up or down to the nearest integer.

Parameter

num Value	Numerical expression

Example

```
putln(round(7.8))            // Displays 8
putln(round(-7.8))           // Displays -8
```

num **min**(num x, num y)

Syntax

num min(<num x>, <num y>)

Function

Returns the minimum values of **x** and **y**.

Parameter

num x	Numerical expression
num y	Numerical expression

Example

```
putln(min(-1,10))          // Displays -1
```

num **max**(num x, num y)

Syntax

num max(<num x>, <num y>)

Function

Returns the maximum values of **x** and **y**.

Parameter

num x	Numerical expression
num y	Numerical expression

Example

```
putln(max(-1,10))          // Displays 10
```

num **limit**(num Value, num min, num max)

Syntax

num limit(<num Value>, <num min>, <num max>)

Function

Returns **Value** limited by **min** and **max**.

Parameter

num Value	Numerical expression
num min	Numerical expression
num max	Numerical expression

Example

```
putln(limit(30,-90,90))        // displays 30
putln(limit(100,90,-90))       // displays 90
putln(limit(-100,-90,90))      // displays -90
```

num **sel**(bool condition, num Value1, num Value2)

Syntax

num sel(<bool condition>, <num Value1>, <num Value2>)

Function

Returns **Value1** if **condition** is **true**, otherwise returns **Value2**.

Parameter

bool condition	Boolean expression
num Value1	Numerical expression
num Value2	Numerical expression

Example

```
putln(sel(bFlag,a,b))
```

// is equivalent to

```
if bFlag==true
  putln(a)
else
  putln(b)
endIf
```

3.4. STRING TYPE

3.4.1. DEFINITION

String type variables are used to store texts.
The maximum length of a string is **128** characters.
The characters supported by the **string** type are non-accented editable characters (**ASCII** code between **32** and **126**) except for the character".
string type variables are initialized by default at the value **""** (zero length).

3.4.2. OPERATORS

In ascending order of priority:

string <string& variable> = <string string>	Assigns string to the variable **variable** and returns **string**.
bool <string string1> != <string string2>	Returns **true** if **string1** and **string2** are not identical, otherwise returns **false**.
bool <string string1> == <string string2>	Returns **true** if **string1** and **string2** are identical, otherwise returns **false**.
string <string string1> + <string <string2>	Returns the first **128** characters of **string1** concatenated with **string2**.

3.4.3. INSTRUCTIONS

string **toString**(string format, num Value)

Syntax
string toString(<string format>, <num Value>)

Function
Returns a character string representing **Value** according to the **format** display format.
The format is **"size.precision"**, where **size** is the minimum size of the result (spaces are added at the beginning of the string if necessary), and **precision** is the number of significant digits after the decimal point (the **0** at the end of the string are replaced by spaces). By default, **size** and **precision** equal **0**. The value's integer portion is never shortened, even if its display length exceeds **size**.

Parameter

string format	Character string type expression
num Value	Numerical expression

Example

```
num nPi
nPi = 3.141592654
putln(toString(".4", nPi))          // displays «3.1416»
putln(toString("8", nPi))           // displays «       3»
putln(toString("8.4", nPi))         // displays «  3.1416»
putln(toString("8.4", 2.70001))     // displays «  2.7   »
putln(toString("", nPi))            // displays «3»
putln(toString("1.2", 1234.1234))   // displays «1234.12»
```

See also
string chr(num Ascii Code)
string toNum(string string, num& Value, bool& report)

string **toNum**(string string, num& Value, bool& report)

Syntax

string toNum(<string string>, <num& Value>, bool& report)

Function

Computes the numerical **Value** represented at the beginning of the **string** specified, and returns **string** in which all the characters have been deleted until the next representation of a numerical Value.

If the beginning of the **string** does not represent a numerical value, **report** is set to **false** and **Value** is not modified, otherwise **report** is set to **true**.

Parameter

string string	Character string type expression
num& Value	**num** type variable
bool& report	**bool** type variable

Example

```
num nVal
bool bOk
putln(toNum("10 20 30", nVal, bOk))   // displays «20 30», nVal equals 10, bOk equals true
putln(toNum("a10 20 30", nVal, bOk))  // displays «a10 20 30», nVal is unchanged, bOk equals
                                      false
putln(toNum("10 end", nVal, bOk))     // displays «», nVal equals 10, bOk equals true
buffer = "+90 0.0 -7.6 17.3"
do
  buffer = toNum(buffer, nVal, bOk)
  putln(nVal)                         // displays successively 90, 0, -7.6, 17.3
until (bOk != true)
```

See also

string toString(string format, num Value)

string **chr**(num Ascii Code)

Syntax

string chr(<num Ascii Code>)

Function

Returns the string made up of the **ASCII Value** code character, if it is supported by the **string** type, otherwise returns an empty string.
The following table gives the **ASCII** codes below **128**. The characters in grey boxes are not supported by the **string** type:

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
NUL	SOH	STX	ETX	EOT	ENQ	ACQ	BEL	BS	HT	LF	VT	FF	CR	SO	SI
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
DLE	DC1	DC2	DC3	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS	RS	US
32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
" "	!	"	#"	$	%	&	'	(	)	*	+	,	-	.	/
48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111
`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127
p	q	r	s	t	u	v	w	x	y	z	(	|	)	~	DEL

Parameter

num Value	Expression of **num** type

Example

```
putln(chr(65))          // displays «A»
```

See also

num asc(string text, num position)

num **asc**(string text, num position)

Syntax

num asc(<string string>, <num position>)

Function

Returns the **ASCII** code of the index character **position**.
Returns -1 if **position** is negative or greater than **string**.

Parameter

string string	Character string type expression
num position	Numerical expression

Example

```
putln(asc("A",0))          // displays 65
```

See also

string chr(num Ascii Code)

string **left**(string string, num size)

Syntax

string left(<string string>, <num size>)

Function

Returns the first **size** characters of **string**. If **size** is greater than the length of **string**, the instruction returns **string**.
An execution error is generated if **size** is negative.

Parameter

string string	Character string type expression
num size	Numerical expression

Example

```
putln(left("hello world",5))    // displays «hello»
```

string **right**(string string, num size)

Syntax

string right(<string string>, <num size>)

Function

Returns the last **size** characters of **string**. If the number specified is greater than the length of **string**, the instruction returns **string**.

An execution error is generated if **size** is negative.

Parameter

string string	Character string type expression
num size	Numerical expression

Example

```
putln(right("hello world",5))   // displays «world»
```

string **mid**(string string, num size, num position)

Syntax

string mid(<string string>, <num size>, <num position>)

Function

Returns **size** characters of **string** from the **position** index character, stopping at the end of **string**.

An execution error is generated if **size** or **position** are negative.

Parameter

string string	Character string type expression
num size	Numerical expression
num position	Index in the string (from **0** to **127**)

Example

```
putln(mid(«hello wild world»,4,6))   // displays «wild»
```

string **insert**(string string, string insertion, num position)

Syntax

string insert(<string string>, <string insertion>, <num position>)

Function

Returns **string** in which **insertion** is inserted after the **position** index character. If **position** is greater than the size of **string**, **insertion** is inserted at the end of **string**. The result is truncated to 128 characters.

An execution error is generated if **position** is negative.

Parameter

string string	Character string type expression
string insertion	Character string type expression
num position	Index in the string (from 0 to 127)

Example

```
putln(insert("hello world","wild ",6))   // displays «hello wild world»
```

string **delete**(string string, num size, num position)

Syntax

string delete(<string string>, <num size>, <num position>)

Function

Returns **string** in which **size** have been deleted from the **position** index character. If **position** is greater than the length of **string**, the instruction returns **string**.

An execution error is generated if **size** or **position** are negative.

Parameter

string string	Character string type expression
num size	Numerical expression
num position	Index in the string (from **0** to **127**)

Example

```
string source
source = "hello wild world"
putln(delete(source,5,6))                    // displays «hello world»
putln(source)                                // displays «hello wild world»
```

num **replace**(string string, string replacement, num size, num position)

Syntax

string replace(<string string>, <string replacement>, <num size>, <num position>)

Function

Returns **string** in which **size** characters have been replaced from the **position** index character by **replacement**. If **position** is greater than the length of **string**, the instruction returns **string**.

An execution error is generated if **size** or **position** are negative.

Parameter

string string	Character string type expression
string replacement	Character string type expression
num size	Numerical expression
num position	Index in the string (from **0** to **127**)

Example

```
putln(replace("hello ? world","wild",1,6))   // displays «hello wild world»
```

num **find**(string string1, string string2)

Syntax

num find(<string string1>, <string string2>)

Function

Returns the index (between **0** and **127**) of the first character in the first occurrence of **string2** in **string1**. If **string2** does not appear in **string1**, the instruction returns **-1**.

Parameter

string string1	Character string type expression
string string2	Character string type expression

Example

```
putln(find("hello wild world","wild"))   // displays 6
```

num **len**(string string)

Syntax

num len(<string string>)

Function

Returns the size of **string**.

Parameter

string string	Character string type expression

Example

```
putln(len("hello wild world"))        // displays 16
```

3.5. DIO TYPE

3.5.1. DEFINITION

The **dio** type is used to link a **VAL3** variable to a system on/off input/output.

The inputs/outputs declared in the system can be directly used in a **VAL3** application, without having to be declared in the application as a global or local variable. The **dio** type is therefore used above all to configure a program using an input/output.

All instructions using a **dio** type variable not linked to an input/output declared in the system generate an execution error.

By default, a **dio** type variable is not linked to a system input/output and therefore generates an execution error if used as such in a program.

3.5.2. OPERATORS

In ascending order of priority:

bool <dio output> = <dio input/output>	Assigns the **input/output** status to **output**, and returns the status. An execution error is generated if **output** is not linked to a system output.
bool <dio output> = <bool condition>	Assigns **condition** to the **output** status and returns **condition**. An execution error is generated if **output** is not linked to a system output.
bool <dio input1> != <bool input2>	Returns **true** if **input1** and **input2** do not have the same status, otherwise returns **false**.
bool <dio input> != <bool condition>	Returns **true** if the **input** status is not equal to **condition**, otherwise returns **false**.
bool <dio input> == <bool condition>	Returns **true** if the **input** status is equal to **condition**, otherwise returns **false**.
bool <dio input1> == <dio input2>	Returns **true** if **input1** and **input2** have the same status, otherwise returns **false**.

3.5.3. INSTRUCTIONS

void **dioLink**(dio& variable, dio source)

Syntax

void dioLink(<dio& variable>, <dio source>)

Function

Links **variable** to the input/output to which **source** is linked.

An execution error is generated if **source** is an input/output declared in the system.

Parameter

dio& variable	On/off input/output type variable
dio source	Expression of **dio** type

Example

```
dio dGripper1
dio dGripper2
dioLink(dGripper1, io:valve1)   // links dGripper1 to valve1 system input/output
dioLink(dGripper2, dGripper1)   // links dGripper2 to the dGripper1 input/output, and therefore to valve1
dioLink(dGripper1, io:valve2)   // dGripper2 is now linked to valve2, and dGripper1 is still linked to valve1
```

num **dioGet**(dio dTable)

Syntax

num dioGet(<dio dTable>)

Function

Returns the numerical value from **dTable** of **dio** read as an integer written in binary code, i.e.: **dTable[0]+2 * dTable[1]+4 * dTable[2]+...+2^k * dTable[k]**, where **dTable[i] = 1** if **dTable[i]** is **true**, otherwise **0**.

An execution error is generated if a member of **dTable** is not linked to a system input/output.

Parameter

dio nTable	Expression of **dio** type

Example

```
dio dCode[4]
dCode[0] = false
dCode[1] = true
dCode[2] = false
dCode[3] = true
putln(dioGet(dCode))   // displays 10 = 0 + 2 * 1 + 4 * 0 + 8 * 1
```

See also

num dioSet(dio dTable, num Value)

num **dioSet**(dio dTable, num Value)

Syntax

num dioSet(<dio dTable>, <num Value>)

Function

Assigns the whole part of **Value** in binary code to the outputs in the **dTable**, and returns the value actually assigned, i.e.:

dTable[0]+2 * dTable[1]+4 * dTable[2]+...+2^k * dTable[k], where **dTable[i] = 1** if **dTable[i]** is **true**, otherwise **0**.

An execution error is generated if a member of **dTable** is not linked to a system output.

Parameter

dio dTable	Expression of **dio** type
num Value	Expression of **num** type

Example

```
dio dCode[4]
putln(dioSet(dCode, 10)      // displays 10 = 0 + 2 * 1 + 4 * 0 + 8 * 1
putln(dioSet(dCode, 26)      // displays 10, code is not big enough to encode 26 completely
```

See also

num dioGet(dio dTable)

3.6. AIO TYPE

3.6.1. DEFINITION

The **aio** type is used to link a **VAL3** variable to a system numerical input/output (integer or floating point value).
The inputs/outputs declared in the system can be directly used in a **VAL3** application, without having to be declared in the application as a global or local variable. The **aio** type is therefore used above all to configure a program using an input/output.
All instructions using a **aio** type variable not linked to an input/output declared in the system generate an execution error.
By default, a **aio** type variable is not linked to a system input/output and therefore generates an execution error if used as such in a program.

3.6.2. INSTRUCTIONS

void **aioLink**(aio& variable, aio source)

Syntax
void aioLink(<aio& variable>, <aio source>)

Function
Links **variable** to the input/output to which **source** is linked.
An execution error is generated if **source** is an input/output declared in the system.

Parameter

aio& variable	**aio** type variable
aio source	Expression of **aio** type

Example

```
aio aSensor1
aio aSensor2
aioLink(aSensor1, io:system1)      // links aSensor1 to system1 system input/output
aioLink(aSensor2, aSensor1)        // links aSensor2 to the aSensor1 input/output, and therefore to system1
aioLink(aSensor1, io:system2)      // aSensor2 is now linked to system2, and aSensor1 is still linked to system1
```

num **aioGet**(aio input)

Syntax
num aioGet(<aio input>)

Function
Returns the numerical value of **input**.
An execution error is generated if **input** is not linked to a system input/output.

Parameter

aio & table	Expression of **aio** type

Example

```
aio aSensor
putln(aioGet(aSensor))      // displays the current sensor value
```

See also
num aioSet(aio output, num Value)

num **aioSet**(aio output, num Value)

Syntax

num aioSet(<aio output>, <num Value>)

Function

Assigns **Value** to **output** and returns **Value**.

An execution error is generated if **output** is not linked to a system output.

Parameter

aio& output	Expression of **aio** type
num Value	Expression of **num** type

Example

```
aio aCommand
putln(aioSet(aCommand, -12.3))        // displays -12.3
```

See also

num aioGet(aio input)

3.7. SIO TYPE

3.7.1. DEFINITION

The **sio** type is used to link a **VAL3** variable to a serial port or an Ethernet socket connection. A **sio** input-output is characterized by:

- Parameters specific to the type of communication, defined in the system
- An end of string character, to allow the use of the **string** type
- A communication timeout delay

The serial system inputs-outputs are active at all times. The Ethernet socket connections are activated at the time of the initial reading or writing access by a **VAL3** program. The Ethernet socket connections are deactivated automatically when the **VAL3** application is closed.

The inputs/outputs declared in the system are directly usable in a **VAL3** application, without having to be declared in the application as a global or local variable. The **sio** type is therefore used above all to configure a program using an input/output.

All instructions using a **sio** type variable not linked to an input/output declared in the system generate an execution error.

By default, a **sio** type variable is not linked to a system input/output and therefore generates an execution error if used as such in a program.

Operators

When the communication timeout delay is reached on reading or writing the serial input/output, an execution error is generated.

string <sio output> = <string data item>	Writes successively on **output** the **data item** characters, followed by the end of string character, and returns **data item**.
num <sio output> = <num data item>	Writes on **output** the closest integer to **data item**, modulo **256**, and returns the value actually sent.
num <num data item> = <sio input>	Reads a character on **input** and assigns **data item** with the **ASCII** code for the character.
string <string data item> = <sio input>	Reads on **input** a string of characters and affects **data item** with this string. The characters that are not supported by the **string** type are ignored. The string is completed when the end of string character is read, or when **data item** reaches the maximum size of a **string** (**128** characters). The end of string character is not copied into **data item**.

3.7.2. INSTRUCTIONS

void **sioLink**(sio& variable, sio source)

Syntax

void sioLink(<sio& variable>, <sio source>)

Function

Links **variable** to the serial system input/output to which **source** is linked.

An execution error is generated if **source** is an input/output declared in the system.

Parameter

sio& variable	**sio** type variable
sio source	Expression of **sio** type

Example

```
sio sSensor1
sio sSensor2
sioLink(sSensor1, io: serial1)      // links sSensor1 to serial1 system input/output
sioLink(sSensor2, sSensor1)         // links sSensor2 to the sSensor1 input/output, and therefore to
                                    serial1
sioLink(sSensor2, io: serial1)      // links sSensor2 to serial1, sSensor1 is still linked to
                                    serial1
```

num **clearBuffer**(sio input)

Syntax

num clearBuffer(<sio input>)

Function

Empties the **input** reading buffer and returns the number of characters thus deleted.

For an Ethernet socket connection, **clearBuffer** deactivates (closes) the socket, **clearBuffer** returns **-1** if the socket has already been deactivated.

An execution error is generated if **input** is not connected to a system serial link or Ethernet socket.

num **sioGet**(sio input, num& data)

Syntax

num sioGet(<sio input>,<num& data>)

Function

Reads a table of characters on **input** and returns the number of characters read. The reading sequence stops when the data item table is full or when the input reading buffer is empty.
For an Ethernet socket connection, **sioGet** tries first of all to make a connection if there is no active connection. When the timeout for input communication has been reached, **sioGet** returns **-1**. If the connection is active, but there are no data in the input reader buffer, **sioGet** waits until data are received or until the end of the waiting period has been reached.
An execution error is generated if **input** is not connected to a system serial link or Ethernet socket, or if **data** is not a **VAL3** variable.

num **sioSet**(sio output, num& data)

Syntax

num sioSet(<sio output>,<num& data>)

Function

Writes a table of characters on **output** and returns the number of characters written. Numerical values are converted before transmission into integers between **0** and **255**, taking the nearest integer modulo **256**. For an Ethernet socket connection, **sioSet** tries first of all to make a connection if there is no active connection. When the end of the output communication waiting time has been reached, **sioSet** returns **-1**. The number of characters written can be less than the size of **data** if a communication error is detected. An execution error is generated if **output** is not connected to a system serial link or Ethernet socket.

CHAPTER 4

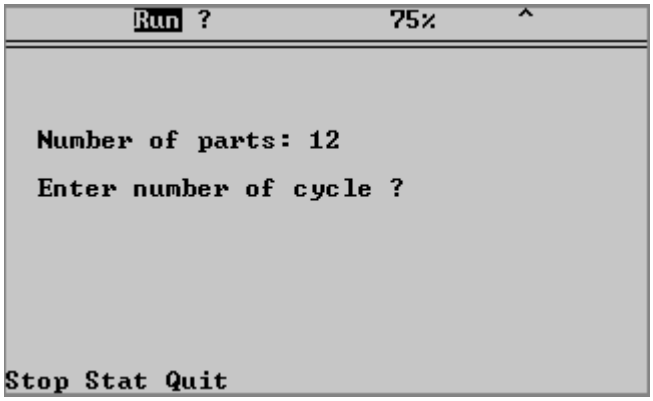
USER INTERFACE

4.1. USER PAGE

In the **VAL3** language, the user interface instructions are used to:

- display messages on a page of the manual control pendant (MCP) reserved for the application
- acquire keystrokes on the **MCP** keyboard

User page



The user page has fourteen (**14**) **40**-column lines. The last line can be used to create menus with the associated key. An additional line is available for a title display.

4.2. INSTRUCTIONS

void **userPage**(), void **userPage**(bool fixed)

Syntax

void userPage ()
void userPage (<bool fixed>)

Function

Displays the user page on the **MCP** screen.
If the parameter **fixed** is **true**, only the user page is accessible for the operator, except for the profile changing page that is accessible via the "Shift User" keyboard shortcut. When this page is displayed, it is possible to stop the application using the "Stop" key if the current user profile authorizes the action.

If the parameter is **false**, the other **CS8** pages become accessible again.

void **gotoxy**(num x, num y)

Syntax

void gotoxy(<num x>, <num y>)

Function

Positions the cursor at the **(x, y)** coordinates on the user page. The coordinates of the top left-hand corner are **(0,0)** and those of the bottom right-hand corner are **(39, 13)**.

The **x** abscissa is taken modulo **40**. The **y** ordinate is taken modulo **14**.

Parameter

num x	Cursor abscissa (**0** to **39**)
num y	Cursor ordinate (**0** to **13**)

See also

void cls()

void **cls**()

Syntax

void cls()

Function

Clears the user page and sets the cursor to **(0,0)**.

See also

void gotoxy(num x, num y)

void **put**() void **putln**()

Syntax

void put(<string string>)
void put(<num Value>)
void putln(<string string>)
void putln(<num Value>)

Function

Displays the specified **string** or **Value** (to **3** decimal places) at the cursor position on the user page. The cursor is then positioned on the character after the last character of the message displayed (**put** instruction), or on the first character of the next line (**putln** instruction).
At the end of a line, the display continues on the following line.
At the end of a page, the user page display moves up one line.

Parameter

string string	Character string type expression
num Value	Numerical expression

See also

void popUpMsg(string string)
void logMsg(string string)
void title(string string)

void **title**(string string)

Syntax

void title(<string string>)

Function

Changes the title of the user page.

The **title()** instruction does not change the current cursor position.

Parameter

string string	Character string type expression

num **get**()

Syntax

num get(<string& string>)
num get(<num& Value>)
num get()

Function

Acquires a string, a number or a control panel key.

string or **Value** are displayed at the current cursor position and can be changed by the user. The entry is terminated by pressing a menu key or the **Return** or **Esc** keys.

The instruction returns the code of the key used to end the entry.

Pressing **Return** or a menu key updates the **string** or **Value** variable. Pressing **Esc** does not change the variable.

If no parameter is passed, the **get()** instruction waits for the operator to press any key and returns the key code. The key that has been pressed is not displayed.

In all cases, the current position of the cursor is unaffected by the **get()** instruction.

Without **Shift**

3	Caps	Space			Move
283	-	32			-
				Ret.	Run
2	Shift	Esc	Help		-
282	-	255	-	270	Stop
	Menu	Tab	Up	Bksp	-
	-	259	261	263	
1	User	Left	Down	Right	
281	-	264	266	268	

With **Shift**

3	Caps	Space			Move
283	-	32			-
				Ret.	Run
2	Shift	Esc	Help		-
282	-	255	-	270	Stop
	Menu	UnTab	PgUp	Bksp	-
	-	260	262	263	
1	User	Home	PgDn	End	
281	-	265	267	269	

Menus (with or without **Shift**):

F1	F2	F3	F4	F5	F6	F7	F8
271	272	273	274	275	276	277	278

For standard keys, the code returned is the **ASCII** code of the corresponding character:

Without **Shift**									
q	w	e	r	t	y	u	i	o	p
113	119	101	114	116	121	117	105	111	112
a	s	d	f	g	h	j	k	l	<
97	115	100	102	103	104	106	107	108	60
z	x	c	v	b	n	m	.	,	=
122	120	99	118	98	110	109	46	44	61

With **Shift**									
7	8	9	+	*	;	(	)	[	]
55	56	57	43	42	59	40	41	91	93
4	5	6	-	/	?	:	!	{	}
52	53	54	45	47	63	58	33	123	125
1	2	3	0	"	%	-	.	,	>
49	50	51	48	34	37	95	46	44	62

With double **Shift**									
Q	W	E	R	T	Y	U	I	O	P
81	87	69	82	84	89	85	73	79	80
A	S	D	F	G	H	J	K	L	}
65	83	68	70	71	72	74	75	76	125
Z	X	C	V	B	N	M	$	\	=
90	88	67	86	66	78	77	36	92	61

Parameter

string& string — **string** type variable

num& Value — **num** type variable

Example

```
num nValue
num nKey
// Waits for Return to be pressed to confirm the entry
do
  nKey = get (nValue)
until (nKey == 270)
```

See also

num getKey()

num **getKey**()

Syntax

num getKey()

Function

Acquires a key stroke from the control panel keyboard. Returns the code of the last key pressed since the last **getKey()** call, or **-1** if no key has been pressed since then.

Unlike the **get()** instruction, **getKey()** returns immediately.

The key pressed is not displayed and the current cursor position stays unchanged.

Example

```
// Displays the system clock until any key is pressed
getKey()                                  // Resets the code of the last key pressed
while (getKey()== -1)
  gotoxy(0,0)
  put(toString(«», clock()* 10))
endWhile
```

See also

num get()

bool isKeyPressed(num code)

bool **isKeyPressed**(num code)

Syntax

bool isKeyPressed(<num code>)

Function

Returns the status of the key specified by its code (see **get()**), **true** if the key is pressed, otherwise **false**.

See also

num getKey()

void **popUpMsg**(string string)

Syntax

void popUpMsg(<string string>)

Function

Displays **string** in a **"popup"** window above the current **MCP** window. This window remains displayed until it is confirmed by clicking on **Ok** in the menu or pressing the **Esc** key.

See also

void userPage(), void userPage(bool fixed)
void put() void putln()

void **logMsg**(string string)

Syntax

void logMsg(<string string>)

Function

Writes **string** in the system history. The message is saved with the current date and time.

See also

void popUpMsg(string string)

string **getProfile**()

Syntax

string getProfile()

Function

Returns the name of the current user profile.

CHAPTER 5

TASKS

5.1. DEFINITION

A task is a program that is running.

An application typically contains an arm movement task, an automaton task, a user interface task, a safety signal monitoring task, communication tasks, etc..

A task is defined by the following elements:

- a name: a task identifier that is unique in the library or application
- a priority, or a period: a task sequencing parameter
- a program: a task entry (and exit) point
- a status: running or stopped
- the next instruction to be executed (and its context)

5.2. RESUMING AFTER AN EXECUTION ERROR

When an instruction causes an execution error, the task is stopped. The **taskStatus()** instruction is used to diagnose the execution error. The task can then be resumed via the **taskResume()** instruction. If the execution error can be corrected, the task can resume from the instruction line where it was stopped. Otherwise, it must be restarted from before or after that instruction line.

Starting and stopping the application

When an application starts, its **start()** program is executed in a task with the name of the application followed by **'~'**, and with priority **10**.

When an application stops, its **stop()** program is executed in a task with the name of the application preceded by **'~'**, priority **10**.

If a **VAL3** application is stopped via the **CS8** user interface, the start task, if it still exists, is immediately destroyed. The stop() program is run next, and then any remaining application tasks are deleted in the reverse order to that in which they were created.

5.3. VISIBILITY

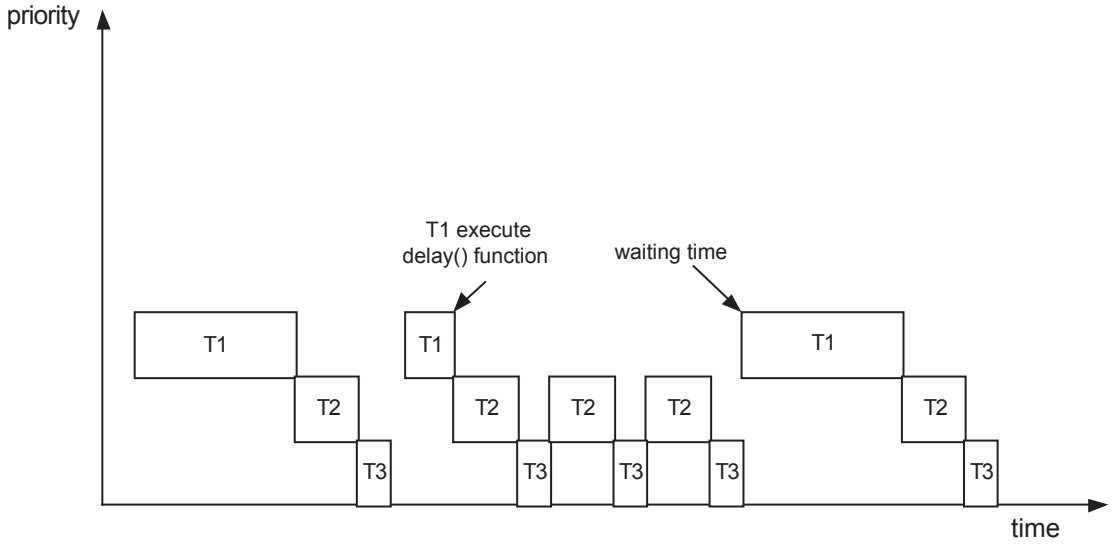
A task is visible only from within the program or library that created it. The instructions taskSuspend(), taskResume(), taskKill() and taskStatus() act on a task created by another library as if the task was not created. Two different libraries may therefore create tasks with the same name.

5.4. SEQUENCING

When several tasks of an application are running, they appear to run concurrently and independently. This is true if the whole application is observed over a sufficiently long period of time (about a second), but not true if its specific behaviour is examined over a short period of time.

In fact, as the system has only one processor, it can only execute one task at a time. Simultaneous execution is simulated by very fast sequencing of the tasks that execute a few instructions in turn before the system moves on to the next task.

Sequencing



VAL3 task sequencing obeys the following rules:

1. The tasks are sequenced in the order in which they were created
2. During each sequence, the system attempts to execute a number of **VAL3** instruction lines corresponding to the priority of the task.
3. When an instruction line cannot be terminated (execution error, waiting for a signal, task stopped, etc.) the system moves on to the next **VAL3** task.
4. When all **VAL3** tasks have been completed, the system keeps some free time for lower priority system tasks (such as network communication, user screen refresh, file access), before a new cycle is started.

S5.3 The maximum delay between two sequential cycles is equal to the duration of the last sequencing cycle; but, most of the time, this delay is null because the system does not need it.

The VAL3 instructions that can cause a task to be sequenced immediately are as follows:

- **watch()** (condition wait timeout)
- **delay()** (timeout)
- **wait()** (condition waiting time)
- **waitEndMove()** (arm stop waiting time)
- **open()** and **close()** (arm stop waiting time followed by timeout)
- **get()** (keystroke waiting time)
- **taskResume()** (waits until the task is ready for restart)
- **taskKill()** (waits for the task to be actually killed)
- **disablePower()** (waits for power to be actually cut off)
- The instructions accessing the contents of the disk (**libLoad, libSave, libDelete, libList**)
- The sio reading/writing instructions (operator =, **sioGet(), sioSet()**)
- **setMutex()** (waits for the Boolean mutex to be false)

S5.3 ## 5.5. SYNCHRONOUS TASKS

The sequence described above is the sequence of normal tasks, called asynchronous tasks, that are scheduled by the system so that they execute as fast as possible. It is sometimes necessary to schedule tasks at regular periods of time, for data acquisition or device control: such tasks are called synchronous tasks.

They are executed in the sequencing cycle by interrupting the asynchronous task between two **VAL3** lines. When the synchronous tasks have finished, the asynchronous task resumes.

The sequencing of the **VAL3** synchronous tasks obeys the following rules:

1. Each synchronous task is sequenced exactly once per period of time specified at the task creation (for instance, once every 4 ms).
2. At each sequence, the system executes up to 3000 **VAL3** instruction lines. It shifts to the next task when an instruction line cannot be completed immediately (runtime error, waiting for a signal, task stopped, ...).
   In practice, a synchronous task is often explicitly ended by using the "delay(0)" instruction to force the sequencing of the next task.
3. The synchronous tasks with same period are sequenced in the order in which they were created.

5.6. OVERRUN

If the execution of a **VAL3** synchronous task takes longer than the specified period, the current cycle ends normally, but the next cycle is cancelled. This overrun error is signalled to the **VAL3** application by setting the Boolean variable specified for this purpose at the task creation to "true". At the beginning of each cycle this Boolean variable thus shows whether the previous sequencing was carried out entirely or not.

5.7. INPUTS / OUTPUTS REFRESH

Inputs are refreshed before both the synchronous tasks and the asynchronous tasks. In the same way, outputs are refreshed after both the synchronous tasks and the asynchronous tasks.

WARNING:
It is not possible to specify which inputs / outputs are used by one task. As a consequence, each refresh is performed on all inputs / outputs.
The refresh of inputs / outputs on Modbus, BIO board, MIO board, CIO board or AS-i bus are not controlled by the VAL3 scheduler. They can be refreshed at any time during the sequencing of a VAL3 task.

5.8. SYNCHRONIZATION

It is sometimes necessary to synchronize several tasks before they are executed.

If the amount of time required to execute each of the tasks is known beforehand, they can be synchronized by simply waiting for a signal generated by the slowest task. However, if it is not known which task is the slowest, it is necessary to use a more complex synchronizing mechanism for which an example of **VAL3** programming is shown below.

Example

```
// synchronization of control for global variables
num n
bool bSynch
n=0                                          // Initialization of the global datas
bSynch=false
program Task1()
begin
  while(true)
    call synchro(n, bSynch, 2)               // Synchronization with task 2
    <instructionsTask1>
  endWhile
end
program Task2()
begin
  while(true)
  call synchro(n, bSynch, 2)                 // Synchronization with task 1
  <instructionsTask2>
  endWhile
end
// Synchronization program for N tasks
program synchro(num& n, bool& bSynch, num N)
begin
  n = n + 1
  wait((n==N) or (bSynch==true))             //  Task synchronization waiting time
  bSynch = true
  n = n - 1
  wait((n==0) or (bSynch == false))          // Task release waiting time
  bSynch = false
end
```

5.9. SHARING RESOURCES

When several tasks use the same system or cell resource (global datas, screen, keyboard, robot, etc.) it is importent to ensure that there is no conflict between them.

A mutual exclusion **('mutex')** mechanism that protects a resource by allowing it to be accessed by only one task at a time can be used for this purpose. An example of mutex programming in **VAL3** is shown below.

Example

```
bool bScreen
bScreen= false                          // Initialization: screen resource is free

program Task1()
begin
  while(true)
    setMutex(bScreen)                   // Screen resource requested
    call fillScreen(1)
    bScreen = false                     // Screen resource released
    delay(0)                            // Proceeds to the next task
  endWhile
end

program Task2()
begin
  while(true)
    setMutex(bScreen)                   // Screen resource requested
    call fillScreen(2)
    bScreen = false                     // Screen resource released
    delay(0)                            // Proceeds to the next task
  endWhile
end

// program to fill the screen with the digit i
program fillScreen(num i)
num x
num y
begin
  i = i % 10
  for x = 0 to 39
    for y = 0 to 13
      gotoxy(x, y)
      put(i);
    endFor
  endFor
end
```

void **taskSuspend**(string name)

Syntax

void taskSuspend(<string name>)

Function

Suspends execution of the **name** task.

If the task is already **STOPPED**, the instruction has no effect.

An execution error is generated if **name** does not correspond to any **VAL3** task, or corresponds to a **VAL3** task created by another library.

Parameter

string name	Character string type expression

See also

void taskResume(string name, num skip)
void taskKill(string name)

void **taskResume**(string name, num skip)

Syntax

void taskResume (<string name>, <num skip>)

Function

Resumes execution of the **name** task on the line located **skip** instruction lines before or after the current line.

If **skip** is negative, the program resumes before the current line. If the task status is not **STOPPED**, the instruction has no effect.

An execution error is generated if **name** does not correspond to a **VAL3** task, corresponds to a **VAL3** task created by another library, or if there is no instruction line at the specified **skip**.

Parameter

string name	Character string type expression
num skip	Numerical expression

See also

void taskSuspend(string name)
void taskKill(string name)

void **taskKill**(string name)

Syntax

void taskKill (<string name>)

Function

Suspends and then deletes the **name** task. When the instruction has been executed, the **name** task is no longer present in the system.

If there is no **name** task, or if the **name** task was created by another library, the instruction has no effect.

Parameter

string name	Character string type expression

See also

void taskSuspend(string name)
void taskCreate string name, num priority, program(...)

void **setMutex**(bool& mutex)

Syntax

void setMutex(<bool& bMutex>)

Function

Wait for the **bMutex** variable to be false, then set it to true.
This function is required to use a Boolean variable as a mutual exclusion mechanism for protecting shared resources (see chapter 5.9).

num **taskStatus**(string name)

Syntax

num taskStatus (<string name>)

Function

Returns the current status of the **name** task, or the task execution error code if the latter is in error condition:

Code	Description
-1	There is no task **name** created by the current library or application
0	No execution error
1	A task is running
10	Invalid numerical calculation (division by zero).
11	Invalid numerical calculation (e.g.**ln(-1)**)
20	Access to a table with an index that is larger than the table size.
21	Access to a table with a negative index.
29	Invalid task name. See **taskCreate()** instruction.
30	The specified name does not correspond to any **VAL3** task.
31	A task with the same name already exists. See **taskCreate** instruction.
32	Only 2 different periods for synchronous tasks are supported. Change scheduling period.
40	Not enough memory space available.
41	Not enough memory space to run the task. See the run memory size.
60	Maximum instruction run time exceeded.
61	Internal **VAL3** interpreter error
70	Invalid instruction parameter. See the corresponding instruction.
80	Uses data or a program from a library not loaded in the memory.
81	Incompatible kinematic: Use of a point/joint/config that is not compatible with the arm kinematic.
90	The task cannot resume from the location specified. See **taskResume()** instruction.
100	The speed specified in the motion descriptor is invalid (negative or too great).
101	The acceleration specified in the motion descriptor is invalid (negative or too great).
102	The deceleration specified in the motion descriptor is invalid (negative or too great).
103	The sideways speed specified in the motion descriptor is invalid (negative or too great).
104	The rotation speed specified in the motion descriptor is invalid (negative or too great).
105	The **reach** parameter specified in the movement descriptor is invalid (negative).
106	The **leave** parameter specified in the movement descriptor is invalid (negative).
122	Attempt to write in a system input.
123	Use of a dio, aio or sio input/output not connected to a system input/output.
124	Attempt to access a protected system input/output
125	Read or write error on a **dio**, **aio** or **sio** (field bus error)
150	Cannot run this movement instruction: a previous movement request could not be completed (point out of reach, singularity, configuration problem, etc.)
153	Movement command not supported
154	Invalid movement instruction: check the movement descriptor.
160	Invalid **flange** tool coordinates
161	Invalid **world** tool coordinates
162	Use of a **point** without a reference frame. See Definition.
163	Use of a frame without a reference frame. See Definition.
164	Use of a tool without reference tool. See Definition.
165	Invalid frame or reference tool (global variable linked to a local variable)
250	No runtime licence for this instruction, or demo licence is over.

Parameter

string name	Character string type expression

See also

void taskResume(string name, num skip)
void taskKill(string name)

void **taskCreate** string name, num priority, program(...)

Syntax

void taskCreate <string name>, <num priority>, program([p1] [,p2])

Function

Creates and starts up the **name** task.
name must contain **1** to **15** characters selected from **"a..zA..Z0..9_"**. There must not be another task with the same name created by the same library.
Execution of **name** begins with a call to **program** using the parameters specified. It is not possible to use a local variable for a parameter passed by reference.
The task ends by default with the last instruction line of **program**, or earlier, if it is deleted explicitly.
priority must be between **1** and **100**. When the task is sequenced, the system executes a number of instruction lines corresponding to the **priority**, or fewer if a blocking instruction is encountered (see the chapter entitled Sequencing).
An execution error is generated if the system does not have enough memory to create the task, if **name** is not valid or already in use in the same library, or if **priority** is not valid.

Parameter

string name	Character string type expression
num priority	Numerical expression
program	Name of an application program
p1	Type of expression specified by the program

Example

```
program display(string& sText)
begin
  putln(sText)
  sText = "stop"
end
string sMessage
program start()

begin
  sMessage = "start"
  taskCreate "t1", 10, display(sMessage)   // displays « start »
  wait(taskStatus("t1") == -1)             // waits for the end of t1
  putln(sMessage)                          // displays "stop"
end
```

See also

void taskSuspend(string name)
void taskKill(string name)
num taskStatus(string name)

S5.3 void **taskCreateSync** string name, num period, bool& overrun, program(...)

Syntax

void taskCreateSync <string name>, <num period>, <bool& overrun>, program(...)

Function

Creates and starts a synchronous task.
The execution of the task starts with the call of the specified program with the specified parameters.
A runtime error is generated if the system does have not enough memory to create the task, or if one or more parameters are invalid.
For a detailed description of synchronous tasks (see chapter 5.5).

Parameter

string name	Name of the task to create. It must contain 1 to 15 characters selected from "_a..zA..Z0..9". There cannot be another task with the same name belonging to the same application or library.
num priority	Period of the task to create (s). The specified value is rounded down to a multiple of 4 ms. Any positive period is supported, but the system supports only two different periods of synchronous tasks at the same time.
bool& overrun	Boolean variable to signal overrun errors. Only global variables are supported, to make sure that the variable is not deleted before the task.
program	Name of the VAL3 program to call when the task is started, with its parameters between parenthesis. It is not possible to use a local variable as parameter if it is passed by reference, to make sure that the variable is not deleted before the task.

Example

```
// Create a supervisor task scheduled every 20 ms
taskCreateSync "supervisor", 0.02, bSupervisor, supervisor()
```

void **wait**(bool condition)

Syntax
void wait(<bool condition>)

Function
Puts the current task on hold until **condition** is **true**.
The task remains **RUNNING** during the waiting time. If **condition** is **true** at the first evaluation, the task in question is executed immediately (the next task is not sequenced).

Parameter

bool condition	Boolean expression

See also
void delay(num seconds)
bool watch(bool condition, num seconds)

void **delay**(num seconds)

Syntax
void delay(<num seconds>)

Function
Puts the current task on hold for **seconds**.
The task remains **RUNNING** during the waiting time. If **seconds** is negative or null, the system sequences the next **VAL3** task immediately.

Parameter

num seconds	Numerical expression

See also
num clock()
bool watch(bool condition, num seconds)

num **clock**()

Syntax

num clock()

Function

Returns the current value of the internal system clock expressed in seconds.

The internal system clock is accurate to within one millisecond. It is initialized at **0** when the controller is started up and is thus unrelated to calendar time.

Example

```
num nStart
nStart=clock()
<instructions>
put("time required for the operation= " )
putln(clock()-nStart)
```

See also

void delay(num seconds)
bool watch(bool condition, num seconds)

bool **watch**(bool condition, num seconds)

Syntax

bool watch (<bool condition>, <num seconds>)

Function

Puts the current task on hold until **condition** is **true** or seconds **seconds** have elapsed.

Returns **true** if the waiting time ends when **condition** is **true**, otherwise returns **false** when the waiting time ends because the time has expired.

The task remains **RUNNING** during the waiting time. If **condition** is **true** at the first evaluation, the same task is evaluated immediately, otherwise the system sequences the other **VAL3** tasks (even if **seconds** is up to and including **0**).

Parameter

bool condition	Boolean expression
num seconds	Numerical expression

Example

```
while (watch (dSensor, 20)) == false
  popUpMsg("Waiting for part")
endWhile
```

See also

void delay(num seconds)
void wait(bool condition)
num clock()

CHAPTER 6

LIBRARIES

6.1. DEFINITION

A **VAL3** library is a software application that can be reused by an application or by other **VAL3** libraries. Like an ordinary application, a **VAL3** library comprises the following components:

- a set of **programs**: the **VAL3** instructions to be executed
- a set of **global datas**: the library data
- a set of **libraries**: the external instructions and data used by the library

When a library is being run, it can also contain:

- a set of **tasks**: The programs that are specific to the library being run

The format used to save the library is the same as that of a **VAL3** application. All applications can be used as a library and all libraries can be used as an application, if the **start()** and **stop()** programs are defined in them.

6.2. INTERFACE

A library's global programs and datas are either public or private. Only global programs and datas that are public are accessible outside the library. Private programs and global datas can only be used by the library programs.
All the public global programs and datas from a library form its interface: a number of different libraries can have the same interface, as long as their public programs and data take the same names.
The tasks created by a library program are always private, i.e. they can only be accessed by that library.

6.3. INTERFACE IDENTIFIER

To use a library, an application needs to first declare an identifier assigned to it, and then request, in a program, that the library be loaded into the memory under that identifier.
The identifier is assigned to the library interface and not to the library itself. Any library presenting the same interface can then be loaded under that identifier. This mechanism can be used, for example, to define a library for every possible part of an application, and then load only the part processed by each cycle.

6.4. CONTENT

A library does not have any required content: it can contain only programs, or only data, or both.

Library content is accessed by writing the identifier's name followed by **':'** in front of the name of the library program or data, for example:

```
part:libLoad("part_7")      // Loads the "part_7" library identified as 'part'
title(part:name)            // Displays as title the content of the name variable of the "part_7" library
call part:init()            // Calls up the init() program for the current part
```

Accessing the content of a library that has not yet been loaded into the memory causes an execution error.

6.5. LOADING AND UNLOADING

When a **VAL3** application is open, all the libraries declared are analysed to build the corresponding interfaces. This step does not load the libraries into the memory.

When a library is loaded, its global datas are initialized and its programs checked to detect any syntax errors.

It is not necessary to unload a library, this is done automatically when the application ends, or when a new library is loaded to replace another one.

When a **VAL3** application is stopped via the **CS8** user interface, the **stop()** program is run first, then all the application tasks, and its libraries, if any are left, are destroyed.

Access path

The **libLoad(), libSave()** and **libDelete()** instructions use a library access path, specified as a character string. An access path comprises an (optional) root, an (optional) path and a library name, in the following format:

root://path/name

The root specifies the file medium: **"Floppy"** for a diskette, **"USB0"** for a device on a **USB** port (stick, floppy driver), **"Disk"** for a version saved on the **CS8**, or the name of an **Ftp** connection defined on the **CS8** for a network access.
By default, the root is **"Disk"** and the path is blank.

Example

```
part:libLoad("part_1")
part:libSave("Floppy://part")
part:libSave("Disk://part_x/part_1")
```

Error codes

The **VAL3** library handling functions never generate execution errors but they send back an error code used to check the instruction result and troubleshoot any problems that may arise.

Code	Description
0	No error
10	The library identifier has not been initialized by **libLoad()**.
11	Cannot load the library: its interface does not correspond to that of the identifier.
12	Cannot load the library: the library contains invalid data or programs.
13	Cannot unload the library: the library contains invalid data or programs.
20	File access error: invalid path root.
21	File access error: invalid path.
22	File access error: invalid name.
30	File reading/writing error.
31	During writing: the path specified already contains a library. During reading: another identifier is already using this library.

6.6. INSTRUCTIONS

num identifier:**libLoad**(string path)

Syntax

num identifier:libLoad(string path)

Function

Initializes the library identifier by loading the library program and data into the memory following the specified **path**.

Returns a **0** after loading, a library loading error code if there are still tasks running that were created by the library, if the library access path is invalid, if the library contains syntax errors or if the library specified does not correspond to the interface declared for the identifier.

See also

num identifier:libSave(), num libSave()

num identifier:**libSave**(), num **libSave()**

Syntax

num identifier:libSave()
num identifier:libSave(string path)

Function

Saves the data and programs assigned to the library's identifier. If **libSave()** is called without an identifier, the application of the library calling is saved. If a parameter is specified, the content is saved via the specified **path**. Otherwise, the content is saved via the path specified on loading.

Returns a **0** if the content has been saved, a library error code if the identifier has not been initialized, if the path is invalid, if a writing error occurs or if the path specified already contains a library.

See also

num libDelete(string path)

num **libDelete**(string path)

Syntax

num libDelete(string path)

Function

Deletes the library located in the specified **path**.

Returns **0** if the specified library does not exist or has been deleted, and a library error code if the identifier has not been initialized, if the path is invalid or if a writing error occurs.

See also

num identifier:libSave(), num libSave()

string identifier:libPath(), string libPath()

string identifier:**libPath**(), string **libPath**()

Syntax
string identifier:libPath()

Function
Sends the access path of the library associated with the identifier, or that of the application or library calling if no identifier is specified.

See also
bool libList(string path, string& contents)

bool **libList**(string path, string& contents)

Syntax
bool libList(string path, string& contents)

Function
Lists the contents of the **path** specified in the **contents** table. Returns **true** if the **contents** table lists the full result, and **false** if the table is too small to hold the full list.
All elements of the **contents** table are first initialized to "" (empty string). After libList() is executed, the end of the list is therefore found by searching the first empty string in the **contents** table.
If **contents** is a global variable, it is automatically incremented as required to enable storage of the full result.

See also
string identifier:libPath(), string libPath()

CHAPTER 7

ROBOT CONTROL

This chapter lists the instructions that allow access to the status of the various parts of the robot.

7.1. INSTRUCTIONS

void **disablePower**()

Syntax

void disablePower()

Function

Cuts off the power supply to the arm and waits until the power supply has actually been cut off.

If the arm is moving, it stops abruptly on its trajectory before the power is switched off.

See also

void enablePower()
bool isPowered()

void **enablePower**()

Syntax

void enablePower()

Function

In remote mode, switches the arm power on.

This instruction does not have any effects in local, manual or test modes, or when the power supply is being switched off.

Example

```
// Switches on the power and waits for the arm power to be switched on
enablePower()
if(watch(isPowered(), 5) == false)
    putln("The power supply cannot be switched on")
endIf
```

See also

void disablePower()
bool isPowered()

bool **isPowered**()

Syntax

bool isPowered()

Function

Returns the power status of the arm:

true: the arm is under power

false: the arm power is switched off, or is being switched on or off

bool **isCalibrated**()

Syntax

bool isCalibrated()

Function

Returns the recovery system status of the robot:

true: all the robot axis are calibrated

false: at least one robot axis is not calibrated

num **workingMode**(), num **workingMode**(num& status)

Syntax

num workingMode (num& status)
num workingMode()

Function

Returns the current working mode of the robot:

Mode	Status	Operating mode	Status
0	**0**	**Invalid or transitional**	-
1	**0**	**Manual**	Programmed movement
	1		Connection movement
	2		Revolute **(Joint)**
	3		Cartesian **(Frame)**
	4		**(Tool)**
	5		To point **(Point)**
	6		Hold
2	**0**	**Test**	Programmed movement **(250 mm/s)**
	1		Connection movement **(250 mm/s)**
	2		Fast programmed movement
	3		Hold
3	**0**	**Local**	**Move** (programmed movement)
	1		**Move** (connection movement)
	2		Hold
4	**0**	**Remote**	**Move** (programmed movement)
	1		**Move** (connection movement)
	2		Hold

Parameter

num& status Numerical type variable.

num **speedScale**()

Syntax

num speedScale()

Function

Returns the current monitor speed.

Example

num nCycle

```
taskCreate "checkSpeed", 5, checkSpeed()

program checkSpeed()
begin
  while true
    if(nCycle < 2)
      if (speedScale()> 10)
        stopMotion()
        putln("For the first cycle the monitor speed must remain at 10%")
        wait(speedScale()<= 10)
        restartMotion()
      endIf
    endIf
  endWhile
end
```

num **esStatus**()

Syntax

num esStatus()

Function

Returns the status of the E-Stop circuit:

Code	Status
0	All the E-Stops are inactive.
1	Waiting for validation after an emergency stop.
2	E-Stop open.

See also

num workingMode(), num workingMode(num& status)

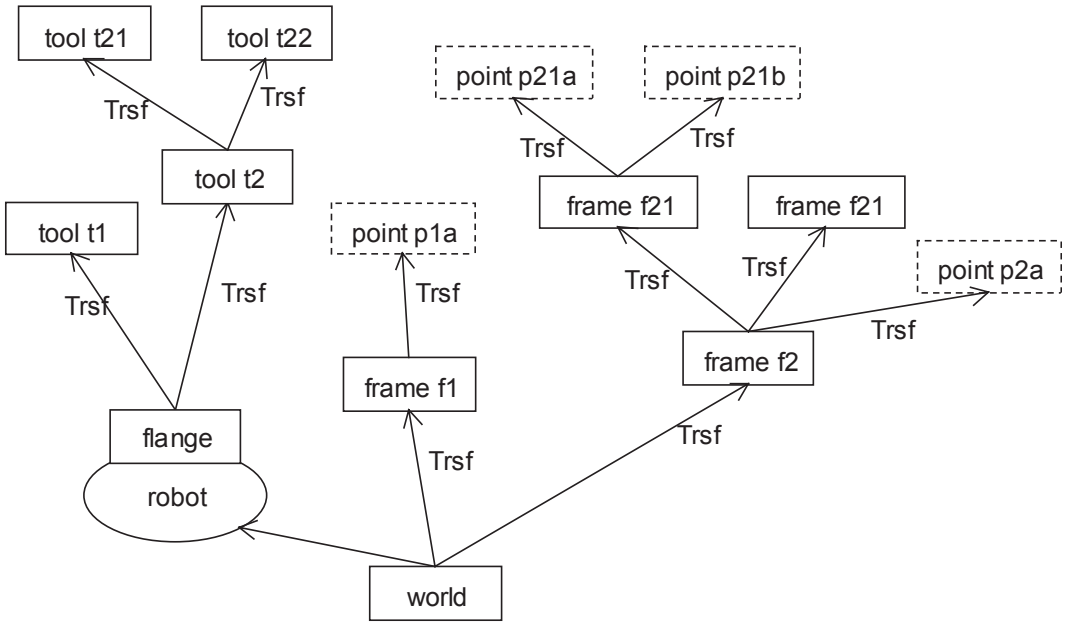
CHAPTER 8

ARM POSITIONS

8.1. INTRODUCTION

This chapter describes the **VAL3** data types used to program the arm positions used in a **VAL3** application.
Two position types are defined in **VAL3**: revolute positions (**joint** type) that give the angular position of each axis, and Cartesian points (**point** type) that give the Cartesian position of the tool at the end of the arm.
The **tool** type describes a tool and its geometry used to position and control the speed of the arm; it describes also how to activate the tool (trigger, delay).
The **frame** type describes a geometrical frame. The use of frames makes geometrical point manipulation much simpler and more intuitive.
The **trsf** type describes a geometrical transformation. It is used implicitly by the **tool**, **point** and **frame** types.
Finally, the **config** type describes the more advanced concept of arm configuration.
The relationships between these various types can be summarized as follows:

Organization chart: frame / point / tool / trsf



8.2. JOINT TYPE

8.2.1. DEFINITION

A revolute point (**joint** type) defines the angular position of each robot axis.
The **joint** type is a structured type, with the following fields, in this order:

num j1	Revolute position of axis **1**
num j2	Revolute position of axis **2**
num j3	Revolute position of axis **3**
num j...	Revolute position of axis **...** (one field for each axis)

These fields are expressed in degrees for the rotary axes, and in millimetres for the linear axes. The origin of each axis is defined by the type of arm used.
By default, each field of a **joint** type variable is initialized at the value **0**.

8.2.2. OPERATORS

In ascending order of priority:

joint <joint& position1> = <joint position2>	Assigns **position2** to the **position1** variable field by field and returns **position2**.
bool <joint position1> != <joint position2>	Returns **true** if a **position1** field is not equal to the corresponding **position2** field, to within the accuracy of the robot, otherwise it returns **false**.
bool <joint position1> == <joint position2>	Returns **true** if each **position1** field is equal to the corresponding **position2** field, to within the accuracy of the robot, otherwise it returns **false**.
bool <joint position1> > <joint position2>	Returns **true** if each **position1** field is greater than the corresponding **position2** field, otherwise it returns **false**.
bool <joint position1> < <joint position2>	Returns **true** if each **position1** field is less than the corresponding **position2** field, otherwise it returns **false**. **Caution: position1 > position2 is not strictly identical to position2 < position1!**
joint <joint position1> - <joint position2>	Returns the difference, field by field, between **position1** and **position2**.
joint <joint position1> + <joint position2>	Returns the sum, field by field, of **position1** and **position2**.

8.2.3. INSTRUCTIONS

joint **abs**(joint jPosition)

Syntax

joint abs(joint jPosition)

Function

Returns the absolute value of a joint **position**, field by field.

Parameter

jPosition	Joint expression

Details

The absolute value of a joint, with the ">" or "<" joint operators, is useful to compute easily a distance between a joint position and a reference position.

Example

```
jReference = {90, 45, 45, 0, 30, 0}
jMaxDistance = {5, 5, 5, 5, 5, 5}
j = herej()
// Checks that all the axis are less than 5 degrees from the reference
if(!(abs(j - jReference) < jMaxDistance))
  popUpMsg("Move closer to the marks")
endIf
```

See also

Operator < (joint)
Operator > (joint)

joint **herej**()

Syntax
joint herej()

Function
Return the current arm joint position.

Details
The returned value is the position sent to the amplifiers by the controller, and not the position read from the axis encoders. The controller joint position is refreshed every 4 ms.

Example
```
// Wait until the arm is near the reference position, with timeout
bStart = watch(abs(herej() - jReference) < jMaxDistance, 60)
if bStart==false
  popUpMsg("Move closer to the start position")
endIf
```

See also
point here(tool tTool, frame fFrame)
bool getLatch(joint& jPosition) (CS8C only)
bool isInRange(joint jPosition)

bool **isInRange**(joint jPosition)

Syntax
bool isInRange(joint jPosition)

Function
Test if a joint position is within the software joint limits of the arm.

Parameter

jPosition	Joint expression to be tested

Details
When the arm is out of the software joint limits (after a maintenance operation), it is not possible to move the arm with a **VAL3** application, only manual moves are possible (with limited move directions).

Example
```
// Check if the current position is within the joint limits
if isInRange(herej())==false
  putln("Please place the arm within its workspace")
endIf
```

See also
joint herej()

S5.3 void **setLatch**(dio input) (CS8C only)

Syntax

void setLatch(dio input)

Function

Enable robot position latch on the next rising edge of the input signal.

Parameter

input	Dio expression defining the digital input to be used for latching

Details

The robot position latching is a hardware feature that is supported only by the fast inputs of the CS8C controller (io:fIn0, io:fIn1).

The detection on the rising edge of the input signal is guaranteed only if the signal remains low during at least 0.2 ms before the rising edge, and high during at least 0.2 ms after the rising edge.

> **CAUTION:**
> **The latch is enabled only after some time (between 0 and 0.2 ms) after the setLatch instruction is executed. You may need to add a delay(0) instruction after setLatch to make sure the latch is effective before the next VAL3 instruction is executed.**

A runtime error is generated is the specified digital input does not support robot position latching.

Example

```
// enable latch on first fast input (CS8C)
setLatch(io:fIn0)
```

See also

bool getLatch(joint& jPosition) (CS8C only)

S5.3 bool **getLatch**(joint& jPosition) (CS8C only)

Syntax
bool getLatch(joint& jPosition)

Function
Read the last latched robot position.

Parameter

jPosition	Joint expression defining the variable to update with the latched position

Details
The function returns true if there is a valid latched position to read. If a latch is pending, or if latching has never been enabled, the function returns false and the position is not updated.
getLatch returns the same latched position until a new latch is enabled with the setLatch instruction.
The arm position is refreshed in the CS8C controller every 0.2 ms; the latched position is the position of the arm between 0 and 0.2 ms after the rising edge of the fast input.l

Example
```
// Wait for a latched position during 5 seconds.
bLatch = watch(getLatch(jPosition)==true, 5)
if bLatch==true
  putln("Successful position latch")
else
  putln("No latch signal was detected")
endif
```

See also
void setLatch(dio input) (CS8C only)
joint herej()

8.3. TRSF TYPE

8.3.1. DEFINITION

A transformation (**trsf** type) defines the position and the orientation of a Cartesian frame relative to another frame.

The **rsf** type is a structured type whose fields are, in this order:

num x	component translating along the **x** axis
num y	component translating along the **y** axis
num z	component translating along the **z** axis
num rx	component rotating about the **x** axis
num ry	component rotating about the **y** axis
num rz	component rotating about the **z** axis

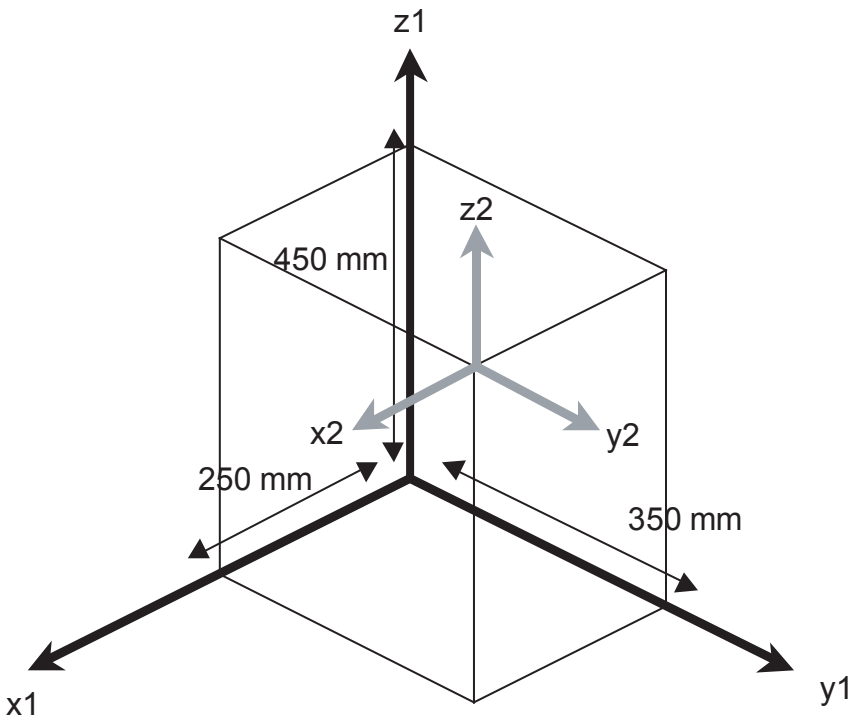
The **x, y** and **z** fields are expressed in the unit of length of the application (millimetre or inch, see the chapter entitled Unit of length). The **rx, ry** and **rz** fields are expressed in degrees.

The **x, y** and **z** coordinates are the Cartesian coordinates of the origin of the frame relative to the reference frame. When **rx, ry** and **rz** are zero, the two frames have the same orientation.

When a **trsf** type variable is initialized, its default value is **{0,0,0,0,0,0}**.

8.3.2. ORIENTATION

Orientation

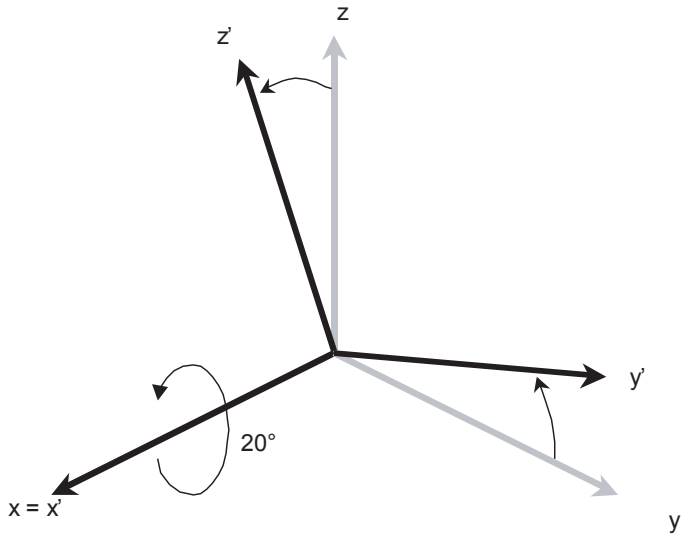


The position of frame **R2** (grey) relative to **R1** (black) is:
x = 250mm, y = 350 mm, z = 450mm, rx = 0°, ry = 0°, rz = 0°

Coordinates **rx, ry** and **rz** correspond to the angles of rotation that must be applied successively about the **x, y** and **z** axis to obtain the orientation of the frame.

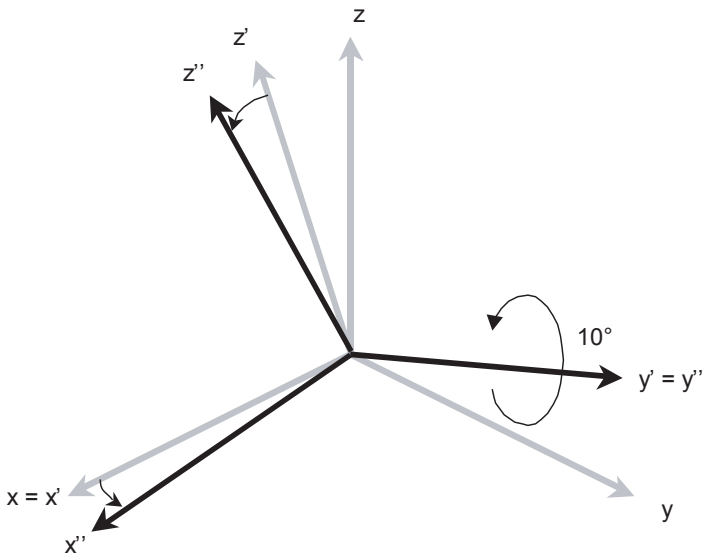
For example, orientation **rx = 20°, ry = 10°, rz = 30°** is obtained as follows. First, the frame **(x,y,z)** is rotated through **20°** about the **x** axis. This gives a new frame **(x',y',z')**. The **x** and **x'** axis coincide.

Frame rotation about the axis: X



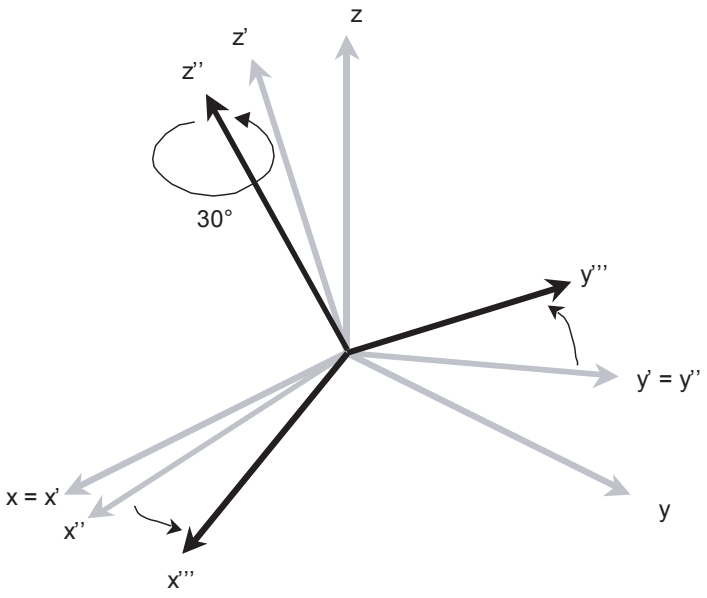
Then the frame is rotated through **20°** about the **y'** axis of the frame obtained at the previous step. This gives a new frame **(x'',y'',z'')**. The **y'** and **y''** axis coincide.

Frame rotation about the axis: Y'



Lastly, the frame is rotated through **20°** about the **z''** axis of the frame obtained at the previous step. The orientation of the new frame obtained **(x''',y''',z''')** is defined by **rx, ry, rz**. The **z''** and **z'''** axis coincide.

Frame rotation about the axis: Z''



The position of frame **R2** (grey) relative to **R1** (black) is:
x = 250mm, y = 350 mm, z = 450mm, rx = 20°, ry = 10°, rz = 30°

The values of **rx, ry** and **rz** are defined modulo **360** degrees. When the system calculates **rx, ry** and **rz**, their values are always between **-180** and **+180** degrees. Several possible values of **rx, ry,** and **rz** still remain: The system ensures that at least two coordinates are between **-90** and **90** degrees (unless **rx** is **+180** and **ry 0**). When **ry** is **90** degrees **(modulo 180)**, the selected value of **rx** is zero.

8.3.3. OPERATORS

In ascending order of priority:

trsf <trsf& position1> = <trsf position2>	Assigns **position2** to the **position1** variable field by field and returns **position2**.
bool <trsf position1> != <trsf position2>	Returns **true** if a **position1** field is not equal to the corresponding **position2** field, otherwise it returns **false**.
bool <trsf position1> == <trsf position2>	Returns **true** if each **position1** field is equal to the corresponding **position2** field, otherwise it returns **false**.
trsf <trsf position1> * **<trsf position2>**	Returns the geometrical composition of the **position1** and **position2** transformations. Caution! Usually, **! position1** * **position2 ! = position2** * **position1!**
trsf ! <trsf position>	Returns the inverse transformation of **position**.

8.3.4. INSTRUCTIONS

num **distance**(trsf position1, trsf position2)

Syntax

num distance(<trsf position1>, <trsf position2>)

Function

Returns the distance between **position1** and **position2**.

> **CAUTION:**
> **To ensure that the distance is valid, position 1 and position 2 must be defined relative to the same reference frame.**

Parameter

trsf position1	Transformation type expression
trsf position2	Transformation type expression

Example

```
// Displays the distance between two points, whatever their reference frames
putln(distance(position(point1, world), position(point2, world)))
```

See also

point appro(point position, trsf transformation)
point compose(point position, frame reference, trsf transformation)
trsf position(point position, frame reference)
num distance(point position1, point position2)

8.4. FRAME TYPE

8.4.1. DEFINITION

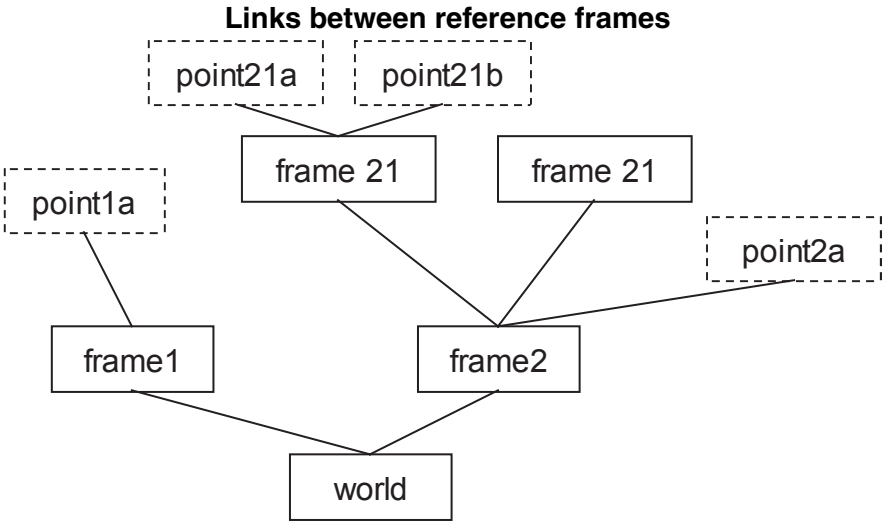
The frame type is used to define the position of reference frames in the cell.

The frame type is a structured type with only one accessible field:

trsf trsf position of the frame in its reference frame

The **reference frame** of a **frame** type variable is defined when it is initialized (via the user interface, or via the **=** operator). The **frame** type **world** reference frame is always defined in a **VAL3** application: a reference frame is linked to the **world** frame, either directly or via other frames.

An execution error is generated during a geometrical calculation if the **world** frame coordinates have been modified.



By default, a **frame** type variable uses **world** as its reference frame.

8.4.2. USE

The use of reference frames in a robotic application is highly recommended for the following purposes:

- **To give a more intuitive view of the application points**
  The cell taught point display is structured according to the hierarchical structure of the frames.
- **To update the position of a set of points quickly**
  When an application point is linked to an object, it is advisable to define a frame for that object and link the **VAL3** points to the frame. If the object is moved, simply reteach the frame to allow all linked points to be corrected at the same time.
- **To reproduce a trajectory in several places in the cell**
  Define the trajectory points relative to a working frame and teach a frame for each position in which the trajectory is to be reproduced. By assigning the value of a taught frame to the working frame, the entire trajectory "moves" to the taught frame.
- **To make it easier to calculate geometrical movements**
  The **compose()** instruction allows geometrical movements expressed in any reference frame to be performed on any point. The **position()** instruction is used to calculate the position of a point in any reference frame.

8.4.3. OPERATORS

In ascending order of priority:

frame <frame& reference1> = <frame reference2>	Assigns the position and the reference frame of **reference2** to the **reference1** variable.
bool <frame reference1> != <frame reference2>	Returns **true** if **reference1** and **reference2** do not have the same reference frame or the same position in their reference frame.
bool <frame reference1> == <frame reference2>	Returns **true** if **reference1** and **reference2** have the same position in the same reference frame.

8.4.4. INSTRUCTIONS

num **setFrame**(point origin, point axisOx, point planeOxy, frame& reference)

Syntax

num setFrame(point origin, point axisOx, point planeOxy, frame& reference)

Function

Calculates the coordinates of **reference** from its **origin**, from an **axisOx** point on the axis **(Ox)**, and a **planeOxy** point on the plane **(Oxy)**.

The **axisOx** point must be on the side of the positive **x** values. The **planeOxy** point must be on the side of the positive **y** values.

The function returns:

0	No error.
-1	The **axisOx** point is too close to the **origin**.
-2	The **planeOxy** point is too close to the axis **(Ox)**.

An execution error is generated if one of the points has no reference frame.

8.5. TOOL TYPE

8.5.1. DEFINITION

The **tool** type is used to define the geometry and action of a tool.

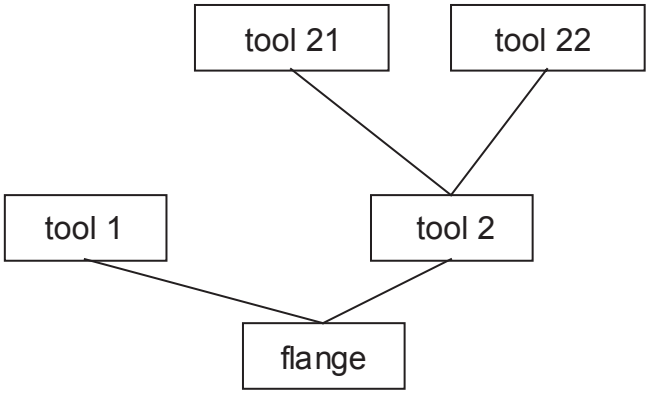
The **tool** type is a stuctured type with the following fields, in this order:

trsf trsf	position of the tool center point (TCP) in its basic tool
dio gripper	Output used to activate the tool
num otime	Time required to open the tool (seconds)
num ctime	Time required to close the tool (seconds)

The **basic tool** of a **tool** type variable is defined when it is initialized (via the user interface, or via the **=** operator). The **flange** basic tool, of **tool** type, is always defined in a **VAL3** application: all tools are linked to the **flange** tool, either directly or via other tools.

An execution error is generated during a geometrical computation if the **flange** tool coordinates have been modified.

Links between tools



By default, the output of a tool is the system **io:valve1** output, the opening and closing times are **0** and the basic tool is **flange**.

8.5.2. USE

The use of tools in a robotic application is highly recommended for the following purposes:

- **To control the speed of movement**
  During manual or programmed movements, the system controls the Cartesian speed at the end of the tool.
- **To reach the same points with different tools**
  Simply select the **VAL3** tool corresponding to the physical tool at the end of the arm.
- **To control tool wear or a tool change**
  To update the arm position, simply update the geometrical coordinates of the tool.

8.5.3. OPERATORS

In ascending order of priority:

tool <tool& tool1> = <tool tool2>	Assigns the position and the basic tool of **tool2** to the **tool1** variable.
bool <tool tool1> != <tool tool2>	Returns **true** if **tool1** and **tool2** do not have the same basic tool, the same position in their basic tool, the same digital output or the same opening and closing times.
bool <tool tool1> == <tool tool2>	Returns **true** if **tool1** and **tool2** have the same position in the same basic tool, and use the same digital output with the same opening and closing times.

void **open**(tool tool)

Syntax

void open (tool tool)

Function

Activates the tool (opening) by setting its digital output to **true**.
Before activating the tool, **open()** waits for the robot to reach the required point by carrying out the equivalent of a **waitEndMove()**. After activation, the system waits for **otime** seconds before executing the next instruction.
This instruction does not make sure that the robot is stabilized in its final position before the tool is activated. When it is necessary to wait for complete stabilization of the movement, the **isSettled()** instruction must be used.
An execution error is generated if the **tool dio** is not defined or is not an output, or if a previously recorded motion command cannot be run.

Parameter

tool tool	Tool type expression

Example

`//` the **`open()`** instruction is equivalent to:

```
waitEndMove()
tTool.gripper=true
delay(tTool.otime)
```

See also

void close(tool tool)
void waitEndMove()

void **close**(tool tool)

Syntax

void close (tool tool)

Function

Activates the tool (closing) by setting its digital output to **false**.
Before activating the tool, **open()** waits for the robot to stop at the point by carrying out the equivalent of a **waitEndMove()**. After activation, the system waits for ctime seconds before executing the next instruction.
This instruction does not make sure that the robot is stabilized in its final position before the tool is activated. When it is necessary to wait for complete stabilization of the movement, the **isSettled()** instruction must be used.
An execution error is generated if the **tool dio** is not defined or is not an output, or if a previously recorded motion command cannot be run.

Parameter

tool tool	Tool type expression

Example

`//` the close instruction is equivalent to:

```
waitEndMove()
tTool.gripper = false
delay(tTool.ctime)
```

See also

Type tool
void open(tool tool)
void waitEndMove()

8.6. POINT TYPE

8.6.1. DEFINITION

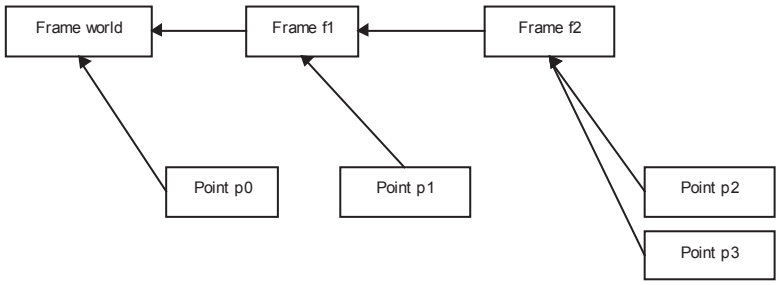
The **point** type is used to define the position and orientation of the robot tool in the cell.

The **point** type is a stuctured type with the following fields, in this order:

trsf trsf	position of the point in its reference frame
config config	arm configuration used to reach the position

The reference frame of a **point** is a **frame** type variable defined when it is initialized (via the user interface, using the **=** operator and the **here()**, **appro()** and **compose()** instructions.

Point definition



An execution error is generated if a **point** type variable with no defined reference frame is used.

> **CAUTION:**
> **By default, a local point type variable has no reference frame. Before it can be used, it must be initialized from another point, or via one of the here(), appro() and compose() instructions.**

8.6.2. OPERATORS

In ascending order of priority:

point <point& point1> = <point point2>	Assigns the position, the configuration and the reference frame of **point2** to the **point1** variable.
bool <point point1> ! = <point point2>	**Returns true if point1 and point2 do not have the same reference frame or the same position in their reference frame.**
bool <point point1> == <point point2>	Returns **true** if **point1** and **point2** have the same position in the same reference frame.

num **distance**(point position1, point position2)

Syntax

num distance(point position1, point position2)

Function

Returns the distance between **position1** and **position2**.

An execution error is generated if **position1** or **position2** do not have a defined reference frame.

Parameter

point position1	Point type expression
point position2	Point type expression

Example

```
// Displays the distance between two points, whatever their reference frames
putln(distance(point1, point2))
```

See also

point appro(point position, trsf transformation)
point compose(point position, frame reference, trsf transformation)
trsf position(point position, frame reference)
num distance(trsf position1, trsf position2)

point **compose**(point position, frame reference, trsf transformation)

Syntax

point compose(point position, frame reference, trsf transformation)

Function

Returns the **position** to which the geometrical transformation **transformation** is applied relative to **reference** frame.

> **CAUTION:**
> **The rotation component of transformation usually modifies not only the orientation of position, but also its Cartesian coordinates (unless position is located at the origin of reference frame).**
> **If we only want transformation to modify the orientation of position, it is necessary to update the result using the Cartesian coordinates of position (see example).**

The reference frame and the configuration of the point returned are those of **position**.

An execution error is generated if **position** has no defined reference frame.

Parameter

point position	Point type expression
frame reference	Reference frame type expression
trsf transformation	Transformation type expression

Example

```
point pResult
// modification of the orientation without modification of position
pResult = compose (position,reference,transformation)
pResult.trsf.x = position.trsf.x
pResult.trsf.y = position.trsf.y
pResult.trsf.z = position.trsf.z
// modification of position without modification of the orientation
transformation.rx = transformation.ry =transformation.rz = 0
pResult = compose (pResult,reference,transformation)
```

See also

Operator trsf <trsf position1> * <trsf position2>
point appro(point position, trsf transformation)

point **appro**(point position, trsf transformation)

Syntax

point appro(point position, trsf transformation)

Function

Returns a point computed by a geometric transformation of an input position. The transformation coordinates are given in the same base as the input position (the base of the input position's reference frame).
The reference frame and the configuration of the returned point are those of the input position.
An execution error is generated if **position** has no defined reference frame.

Parameter

point position	Point type expression
trsf transformation	Transformation type expression

Example

```
// move to 100 mm above the point (z axis)
point p
movej(appro(p,{0,0,-100,0,0,0}), flange, mNomDesc)   // Approach
movel(p, flange, mNomDesc)                           // Go to point
```

See also

Operator trsf <trsf position1> * <trsf position2>
point compose(point position, frame reference, trsf transformation)

point **here**(tool tTool, frame fFrame)

Syntax

point here(tool tool, frame reference)

Function

Returns the current position of the **tool** tool in **reference** frame(the position commanded and not the position measured).

The reference frame of the point returned is **reference**. The configuration of the point returned is the current configuration of the arm.

See also

joint herej()
config config(joint position)
point jointToPoint(tool tool, frame reference, joint position)

point **jointToPoint**(tool tool, frame reference, joint position)

Syntax

point jointToPoint (tool tool, frame reference, joint position)

Function

Returns the position of the **tool** in the **reference** frame when the arm is in the revolute position **position**. The reference frame of the point returned is **reference**. The configuration of the point returned is the configuration of the arm in the revolute **position** position.

Parameter

tool tool	Tool type expression
frame reference	Reference frame type expression
joint position	Revolute position type position

See also

point here(tool tTool, frame fFrame)
bool pointToJoint(tool tool, joint initial, point position,joint& coordinates)

bool **pointToJoint**(tool tool, joint initial, point position,joint& coordinates)

Syntax

bool pointToJoint(tool tool, joint initial, point position, joint& coordinates)

Function

Calculates the revolute **coordinates** corresponding to the specified **position**. Returns **true** if revolute **coordinates** have been found, and returns **false** if no solution has been found.

The revolute position to be located corresponds to the configuration of the **position**. Fields with the value **free** do not determine the configuration. Fields with the value **same** specify the same configuration as **initial**.

For axis that can rotate through more than one full turn, there are several revolute solutions with exactly the same configuration: the solution closest to **initial** is then taken.

No solution is possible if **position** is out of reach (arm too short) or outside the software limits. If **position** specifies a configuration, it may be outside the limits for that configuration, but within the limits for a different configuration.

An execution error is generated if **position** has no defined reference frame.

Parameter

tool tool	Tool type expression
joint initial	Revolute position type position
point position	Point type expression
joint& coordinates	Revolute position type variable

See also

joint herej()
point jointToPoint(tool tool, frame reference, joint position)

trsf **position**(point position, frame reference)

Syntax

trsf position(point position, frame reference)

Function

Returns the coordinates of **position** in **reference** frame.

An execution error is generated if **position** has no reference frame.

Example

```
// Displays the distance between two points, whatever their reference frames
putln(distance(position(point1, world), position(point2, world)))
```

See also

num distance(point position1, point position2)

8.7. CONFIG TYPE

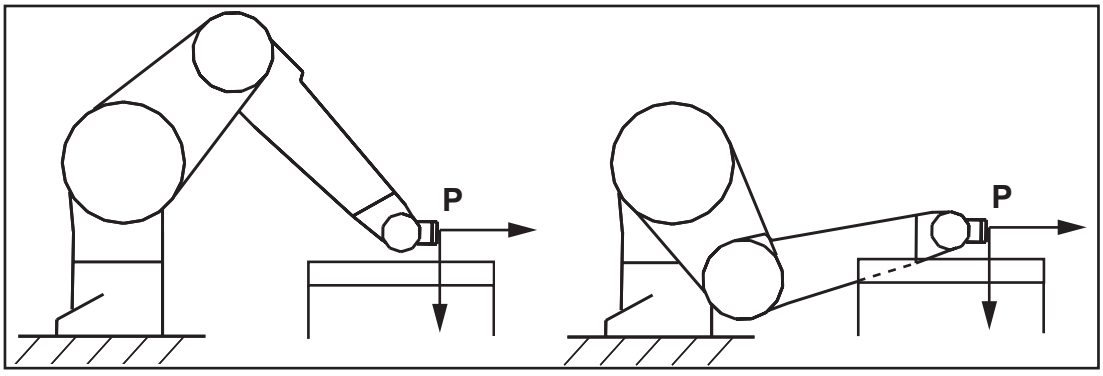
The configuration concept of a Cartesian point is an "advanced" concept that can be skipped the first time you read this document.

8.7.1. INTRODUCTION

There are generally several ways in which a robot can reach a given Cartesian point.

These possibilities are known as "configurations". The figure below illustrates two different configurations:

Two configurations that can be used to reach a given point: P



In some cases, among all the possible configurations, it is important to specify the ones that are valid and the ones that are to be prohibited. To deal with this problem, the **point** type is used to specify the configurations allowed for the robot, via its **config** type field as defined below.

8.7.2. DEFINITION

The **config** type is used to define the configurations authorized for a given Cartesian position.

It depends on the type of arm used.

For a **Stäubli RX/TX** arm, the **config** type is a structured type whose fields are, in that order:

shoulder	shoulder configuration
elbow	elbow configuration
wrist	wrist configuration

For a **Stäubli RS** arm, the **config** type is limited to the **Shoulder** field:

shoulder	shoulder configuration

The **shoulder**, **elbow** and **wrist** fields can have the following values:

shoulder	**righty**	**righty** shoulder configuration imposed
	lefty	**lefty** shoulder configuration imposed
	ssame	Shoulder configuration change not allowed
	sfree	Free shoulder configuration

elbow	**epositive**	**epositive** elbow configuration imposed
	enegative	**enegative** elbow configuration imposed
	esame	Elbow configuration change not allowed
	efree	Free elbow configuration

wrist	**wpositive**	**wpositive** wrist configuration imposed
	wnegative	**wnegative** wrist configuration imposed
	wsame	Wrist configuration change not allowed
	wfree	Free wrist configuration

8.7.3. OPERATORS

In ascending order of priority:

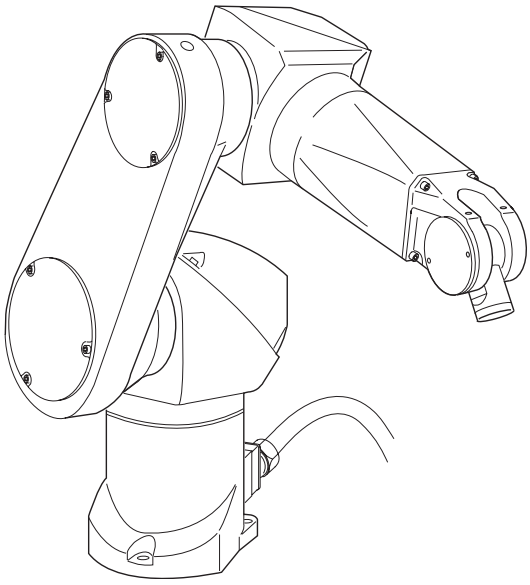
config <config& configuration1> = <config configuration2>	Assigns the **shoulder**, **elbow** and **wrist** fields for **configuration2** to the **configuration1** variable.
bool <config configuration1> != <config configuration2>	Returns **true** if **configuration1** and **configuration2** do not have the same **shoulder**, **elbow** or **wrist** field values.
bool <config configuration1> == <config configuration2>	Returns **true** if **configuration1** and **configuration2** have the same **shoulder**, **elbow** or **wrist** field values.

8.7.4. CONFIGURATION (RX/TX ARM)

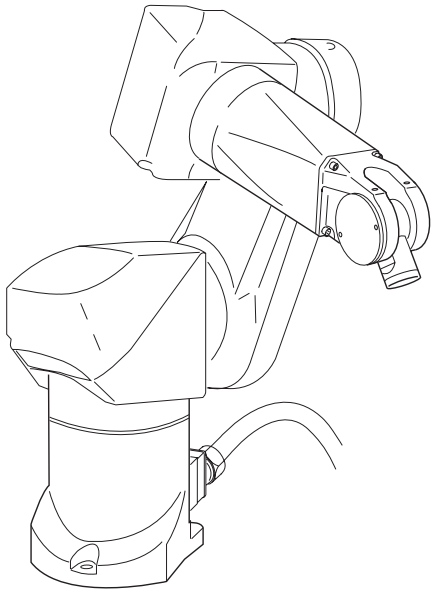
8.7.4.1. SHOULDER CONFIGURATION

To reach a given Cartesian point, the arm of the robot may be to the right or the left of the point: these two configurations are called **righty** and **lefty**.

Configuration: righty



Configuration: lefty

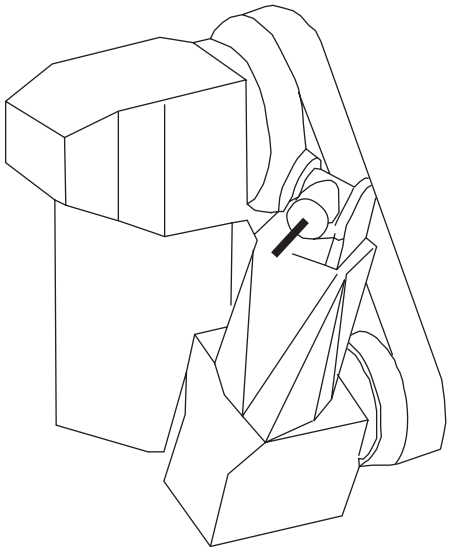


The righty configuration is defined by (d1.sin(j2) + d2.sin(j2+j3) + δ) < 0, and the lefty configuration is defined by (d1.sin(j2) + d2.sin(j2+j3) + δ) >= 0, where d1 is the length of the robot arm, d2 the length of the forearm, and δ the distance between axis 1 and axis 2, in the x direction.

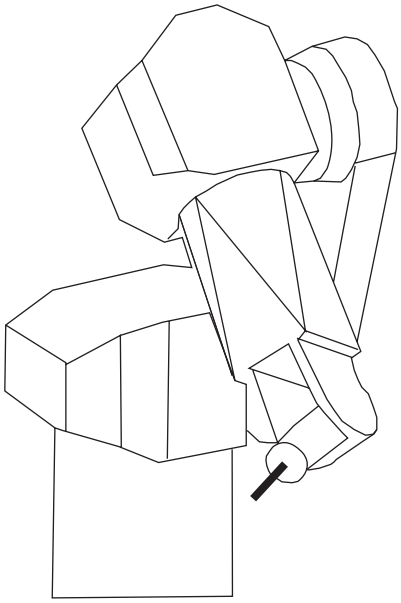
8.7.4.2. ELBOW CONFIGURATION

In addition to the shoulder configuration, there are two robot elbow configurations: the elbow configurations are called **epositive** and **enegative**.

Configuration: enegative



Configuration: epositive



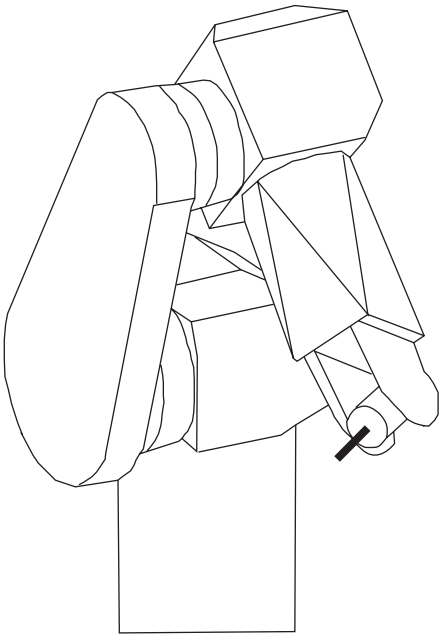
The **epositive** configuration is defined by **j3 >= 0**.

The **enegative** configuration is defined by **j3 < 0**.

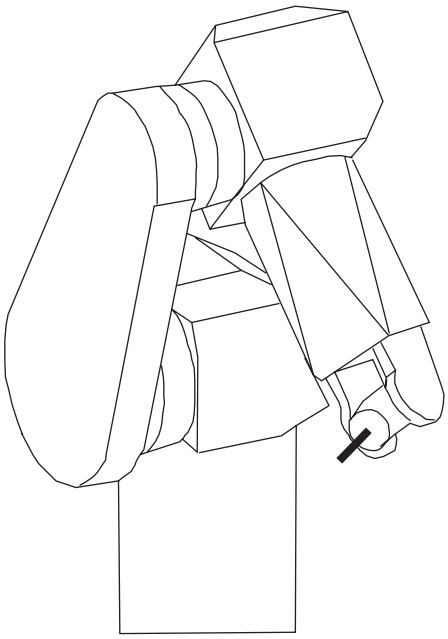
8.7.4.3. WRIST CONFIGURATION

In addition to the shoulder and elbow configurations, there are two robot wrist configurations. The two wrist configurations are called **wpositive** and **wnegative**.

Configuration: wnegative



Configuration: wpositive



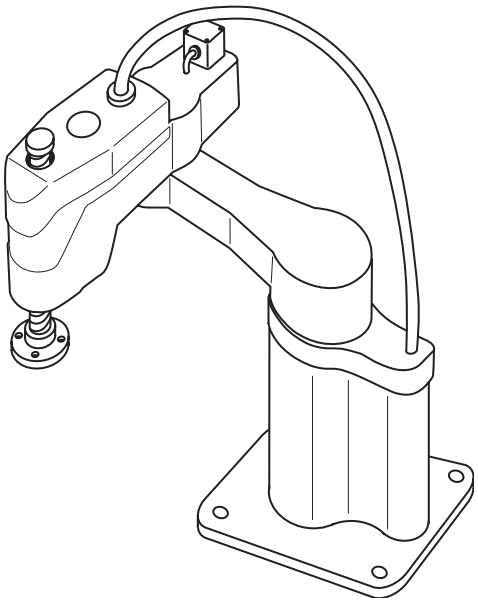
The **wpositive** configuration is defined by **q5 >= 0**.

The **wnegative** configuration is defined by **q5 < 0**.

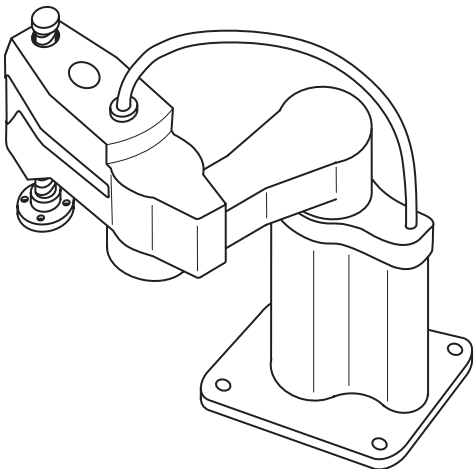
8.7.5. CONFIGURATION (RS ARM)

To reach a given Cartesian point, the arm of the robot may be to the right or the left of the point: these two configurations are called **righty** and **lefty**.

Configuration: righty



Configuration: lefty



The **righty** configuration is defined by **sin(j2) > 0**, and the **lefty** configuration is defined by **sin(j2) ≤ 0**.

8.7.6. INSTRUCTIONS

config **config**(joint position)

Syntax

config config(joint position)

Function

Returns the configuration of the robot for the revolute **position** position.

Parameter

joint position	Revolute position type position

See also

point here(tool tTool, frame fFrame)
joint herej()

CHAPTER 9

MOVEMENT CONTROL

9.1. TRAJECTORY CONTROL

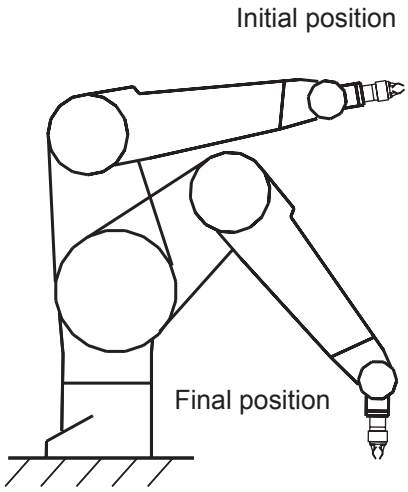
A succession of points is not sufficient to define the trajectory of a robot. It is also necessary to indicate the type of trajectory used between the points (curve or straight line), specify how the trajectories are linked together and define the movement speed parameters. This section therefore presents the point-to-point movements and straight line movements (**movej** and **movel** instructions) and describes how to use the movement descriptor parameters (**mdesc** type).

9.1.1. TYPES OF MOVEMENT: POINT-TO-POINT, STRAIGHT LINE, CIRCLE

The robot's movements are mainly programmed using the **movej, movel** and **movec** instructions. The **movej** instruction can be used to make point-to-point movements, **movel** is used for straight line movements, and **movec** for circular movements.

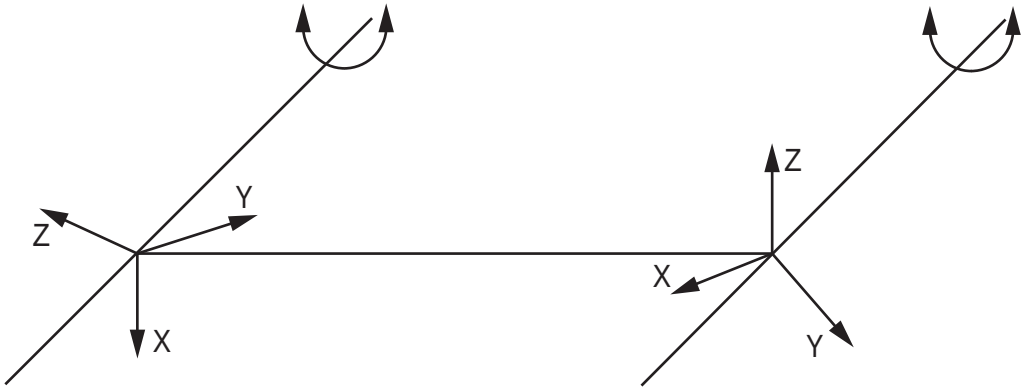
A point-to-point movement is a movement in which only the final destination (Cartesian or revolute point) is important. Between the start point and the end point, the tool center point follows a curve defined by the system to optimize the speed of the movement.

Initial and final positions



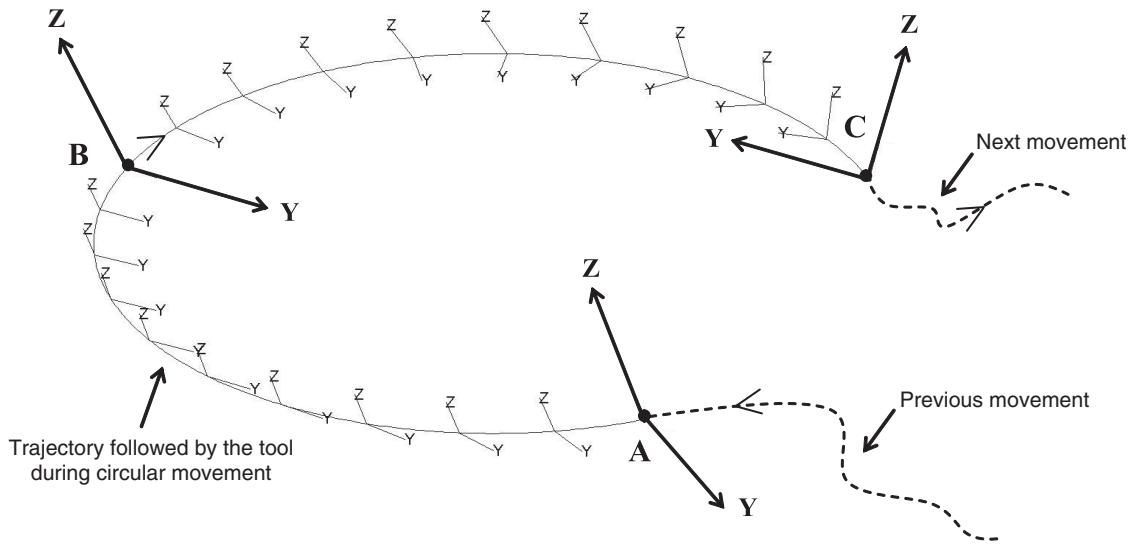
Conversely, in the case of a straight line movement, the tool center point moves along a straight line. The orientation is interpolated in a linear way between the initial and final orientation of the tool.

Straight line movement



In a circular movement, the tool center point moves through an arc defined by **3** points, and the tool orientation is interpolated between the initial orientation, the intermediate orientation, and the final orientation.

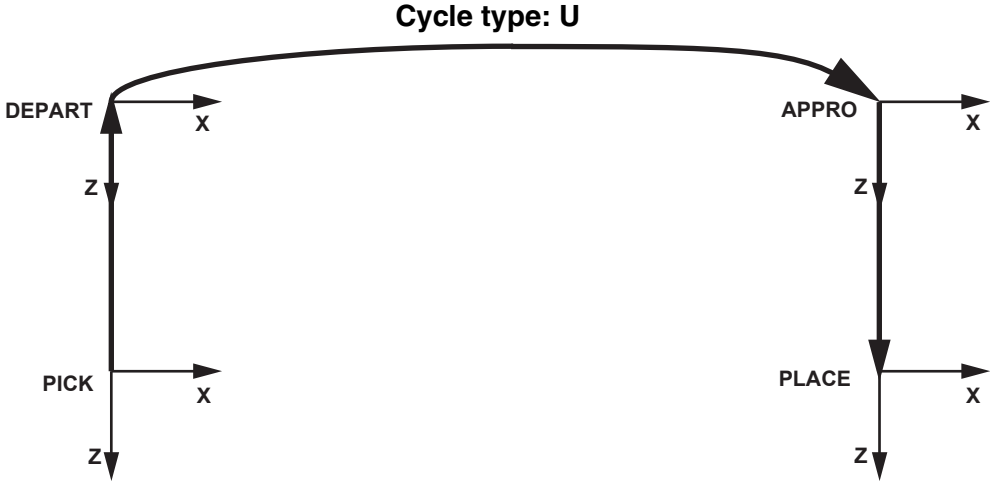
Circular movement



Example:

A typical handling task involves picking up parts at one location and putting them down at another. Let us assume that the parts are to be picked up at the **PICK** point and put down at the **PLACE** point. To go from the **PICK** point to the **PLACE** point, the robot must pass through a disengagement point **DEPART** and an approach point **APPRO**.

Cycle type: U



Let us assume that the robot is initially at the **PICK** point. The program required to execute the movement can be written as follows:

movel(DEPART, tool, mDesc)
movej(APPRO, tool, mDesc)
movel(PLACE, tool, mDesc)

Straight line movements are used for disengagement and approach. However, the main movement is a point-to-point movement, as the geometry of this part of the trajectory does not need to be accurately controlled, because the aim is to move as quickly as possible.

Note:
The geometry of the trajectory does not depend on the speed at which both these types of movement are executed. The robot always passes through the same position. This is particularly important when developing applications. It is possible to start with slow movements and then progressively increase the speed without distorting the trajectory of the robot.

9.1.2. MOVEMENT SEQUENCING

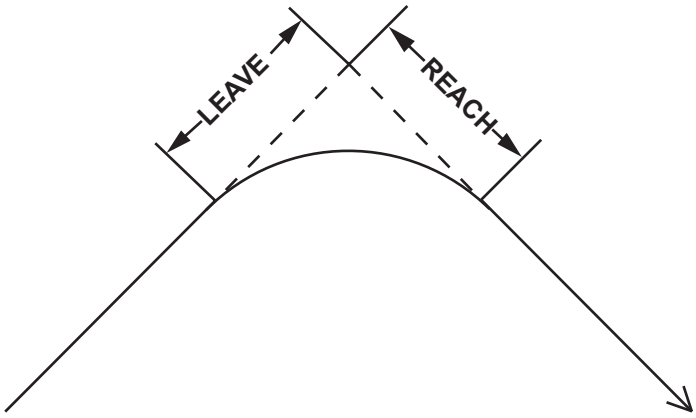
9.1.2.1. BLENDING

Let us now return to the example of the **U** cycle described in the previous chapter. In the absence of any specific movement sequencing control, the robot stops at the **DEPART** and **APPRO** points, as the trajectory is angled at these points. This unnecessarily increases the duration of the operation and there is no need to pass through these precise points.

The duration of the movement can be significantly reduced by "blending" the trajectory in the vicinity of the **DEPART** and **APPRO** points. To do so, we use the **blend** field of the movement descriptor. When this field is set to **off**, the robot stops at each point along the trajectory. However, when the parameter is set to **joint**, the trajectory is blended in the vicinity of each point and the robot no longer stops at the fly-by points.

When the **blend** field has the value **joint**, two other parameters must be specified: **leave** and **reach**. These parameters determine the distance from the arrival point at which the nominal trajectory is left (start of blending) and the distance from the arrival point at which it is rejoined (end of blending).

Definition of the distances: 'leave' / 'reach'

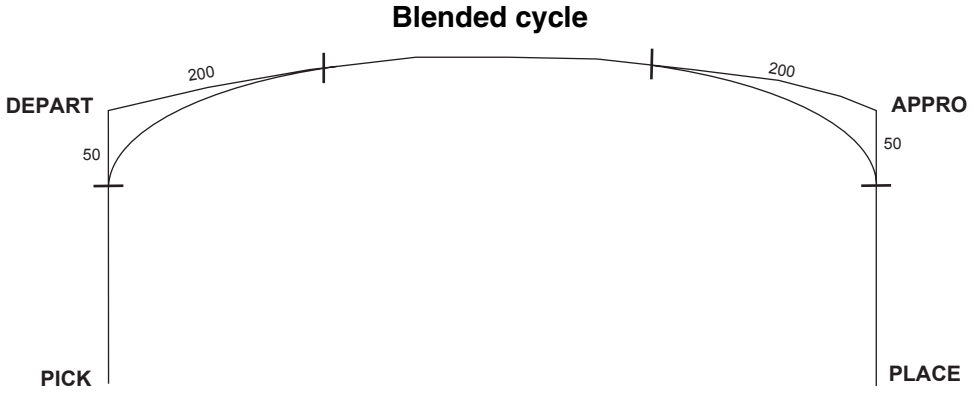


Example:

Let us return to the program described in the section entitled "Types of movement: point-to-point or straight line". The previous movement program can be modified as follows:

```
mDesc.blend = joint
mDesc.leave = 50
mDesc.reach = 200
movel(DEPART, tool, mDesc)
mDesc.leave = 200
mDesc.reach = 50
movej(APPRO, tool, mDesc)
mDesc.blend = OFF
movel(PLACE, tool, mDesc)
```

The following trajectory is obtained:



The robot no longer stops at the **DEPART** and **APPRO** points. The movement is therefore faster. In fact, the larger the **leave** and **reach** distances, the faster the movement.

9.1.2.2. CANCEL BLENDING

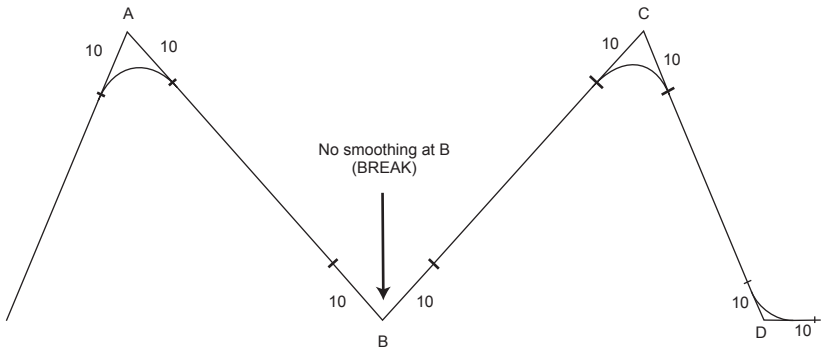
The **waitEndMove()** instruction is used to cancel the effect of blending. The robot then completes the last programmed movement as far as its arrival point, as if the movement descriptor **blend** field were set to **off**.

For example, let us examine the following program:

```
mDesc.blend = joint
mDesc.leave = 10
mDesc.reach = 10
movej(A, tool, mDesc)
movej(B, tool, mDesc)
waitEndMove()
movej(C, tool, mDesc)
movej(D, tool, mDesc)
```

etc.

The trajectory followed by the robot is then as follows:



9.1.3. MOVEMENT RESUMPTION

When the arm power is cut off before the robot has finished its movement, following an emergency stop for example, movement resumption is required when power is restored to the system. If the arm has been moved manually during the stoppage, it may be in a position far from its normal trajectory. It is then necessary for movement resumption to take place without a collision occurring. The **CS8**'s trajectory control function provides the possibility of managing movement resumption using a "connection movement".

When movement resumes, the system ensures that the robot is indeed on its programmed trajectory: if there is any deviation, however slight, it automatically stores a point-to-point command to reach the exact position at which the robot left its trajectory: it is a "connection movement". This movement is made at low speed. It must be validated by the operator, except in automatic mode, in which it can be carried out without human intervention. The **autoConnectMove()** instruction is used to detail behaviour in automatic mode.

The **resetMotion()** instruction is used to cancel the current movement, and possibly to program a connection movement in order to resume a position at low speed and under the operator's control.

9.1.4. PARTICULARITIES OF CARTESIAN MOVEMENTS (STRAIGHT LINE, CIRCLE)

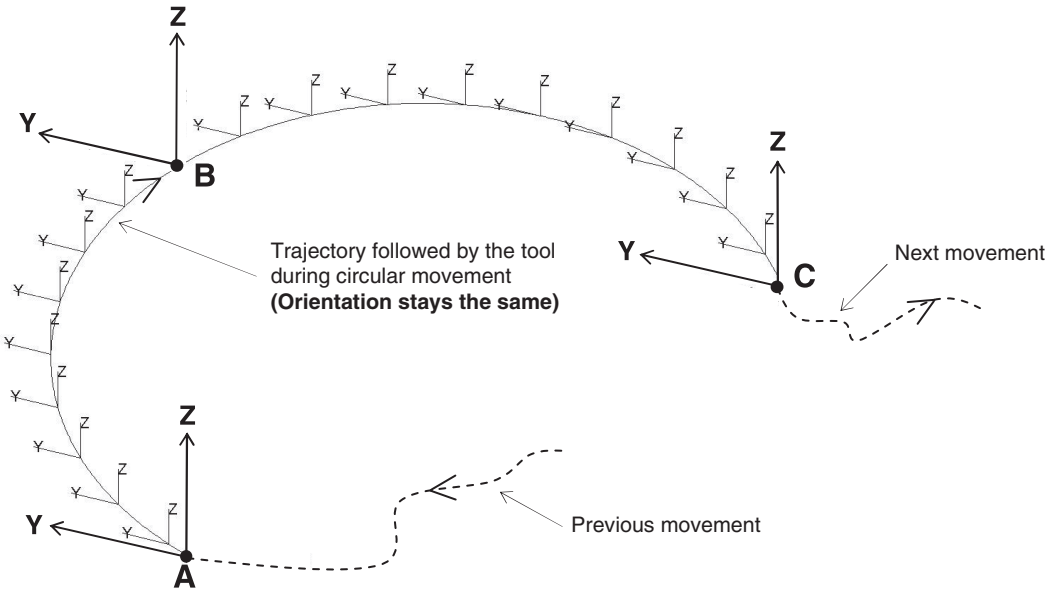
9.1.4.1. INTERPOLATION OF THE ORIENTATION

The trajectory generator of the **CS8** always minimizes the amplitude of tool rotations when moving from one orientation to another.

This makes it possible, as a particular case, to program a constant orientation, in absolute terms, or as compared with the trajectory, on all straight-line or circular movements.

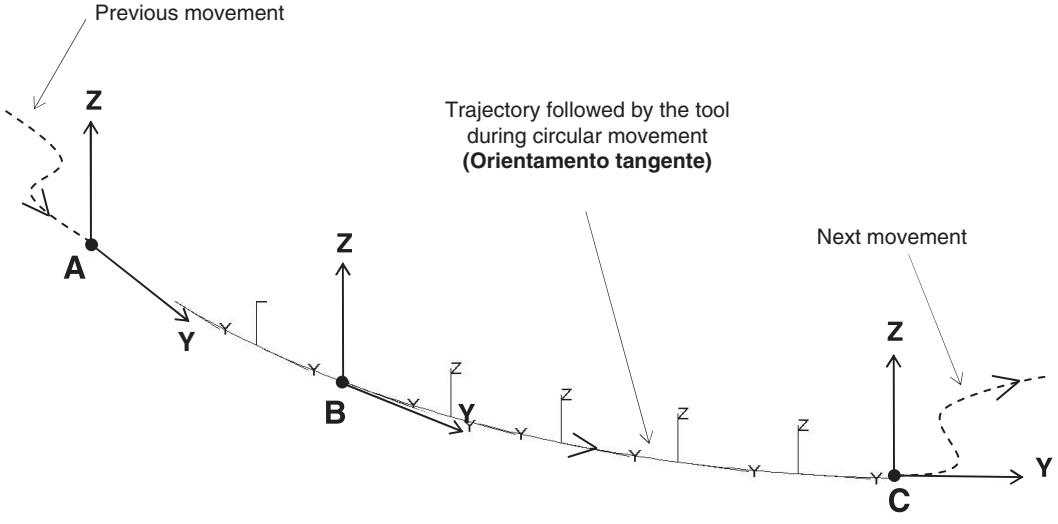
- For a constant orientation, the initial and final positions, and the intermediate position for a circle, must have the same orientation.

Constant orientation in absolute terms



- For a constant orientation as compared with the trajectory (e.g. direction **Y** for the tool marker tangent to the trajectory), the inital and final positions, and the intermediate position for a circle, must have the same orientation as compared with the trajectory.

Constant orientation as compared with the trajectory

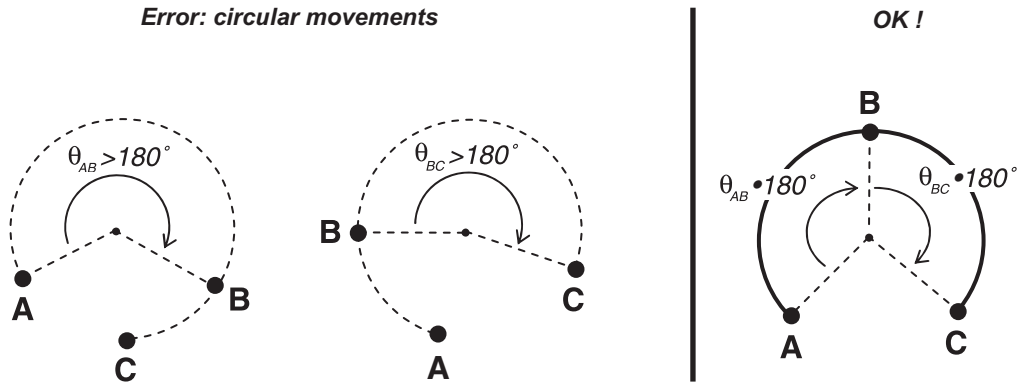


This results in a limitation for circular movements:

If the intermediate point forms an angle of **180°** or more with the initial point or the final point, there are several interpolation solutions for the orientation, and an error is generated.

It is then necessary to modify the position of the intermediate point to remove the ambiguity from the intermediate orientations.

Ambiguity as to the intermediate orientation

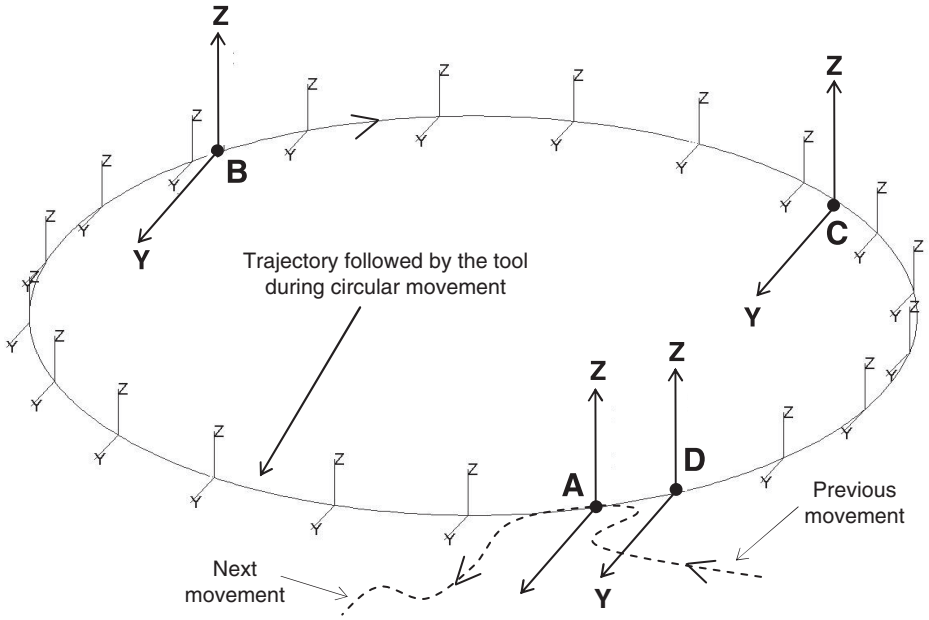


In particular, programming a full circle involves **2 movec** instructions:

movec (B, C, tool, mDesc)

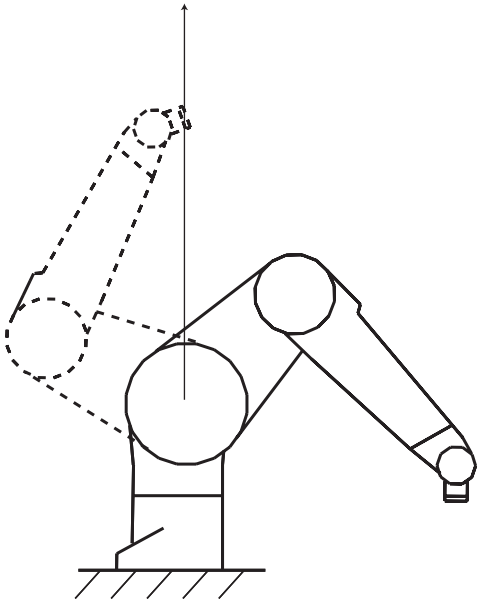
movec (D, A, tool, mDesc)

Full circle



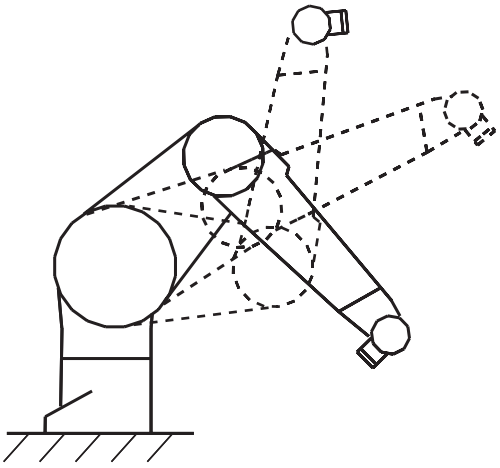
9.1.4.2. CONFIGURATION CHANGE (ARM RX/TX)

Configuration change: righty / lefty



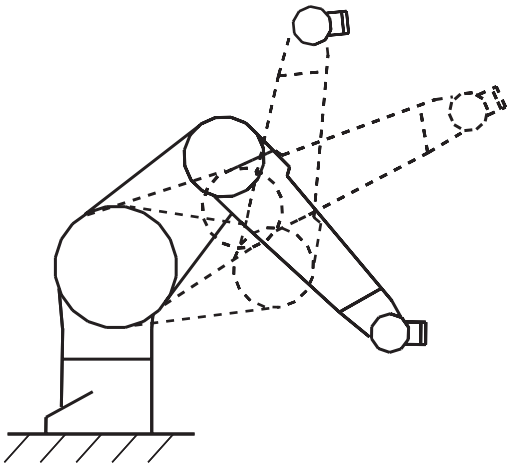
During a change of shoulder configuration, the centre of the robot's wrist has to pass vertically through axis **1** (but not exactly in the case of offset robots).

Positive/negative elbow configuration change



During a change of elbow configuration, the arm has to go through the straight arm position **(q3 = 0°)**.

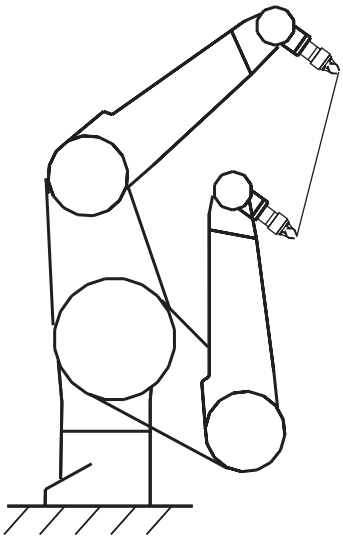
Positive/negative wrist configuration change



During a change of wrist configuration, the arm has to go through the straight wrist position **(q5 = 0°)**.

The robot must therefore pass through specific positions during a configuration change. But we cannot require a straight-line or circular movement to pass through these positions if they are not on the desired trajectory! This means that **we cannot impose a change of configuration during a straight-line or circular movement**.

Elbow configuration change impossible

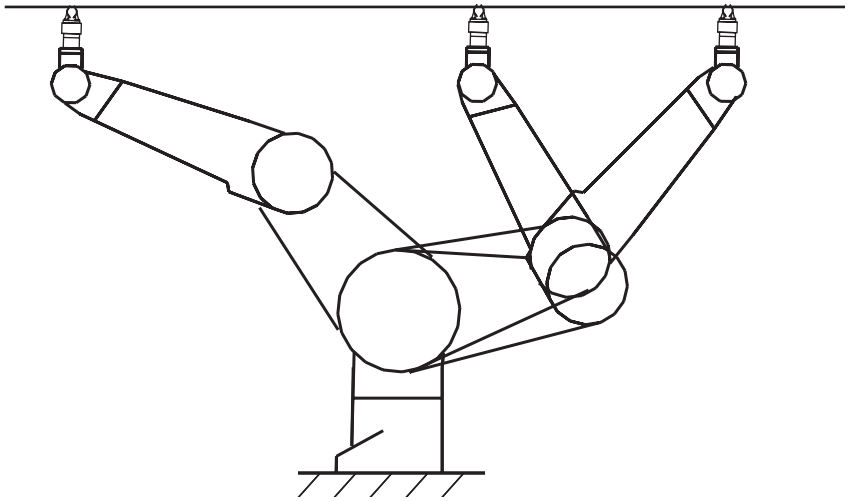


In other words, during a straight-line or circular movement, we can only impose a configuration if it is compatible with the initial position: it is therefore always possible to specify a free configuration, or one that is identical to the initial configuration.

In certain exceptional cases, the straight line or arc does indeed pass through a position in which a change of configuration is possible. In this case,if the configuration has been left free, the system can decide to change the configuration during a straight-line or circular movement.

For a circular movement, the configuration of the intermediate point is not taken into account. The only configurations that count are those of the initial and final positions.

Shoulder configuration change possible



9.1.4.3. SINGULARITIES (ARM RX/TX)

Singularities are an inherent characteristic of all **6**-axis robots. Singularities can be defined as the points at which the robot changes configuration. Certain axis are then aligned: two aligned axes behave as a single axis and the **6**-axis therefore behaves locally as a **5**-axis robot. The end effector is then unable to carry out certain movements. This is not a problem in the case of a point-to-point movement: system-generated movements are still possible. On the other hand, during a straight-line or circular movement, we impose a movement geometry. If the movement is impossible, an error is generated when the robot attempts to move.

9.2. MOVEMENT ANTICIPATION

9.2.1. PRINCIPLE

The system controls the movements of the robot in more or less the same way as a driver drives a car. It adapts the speed of the robot to the geometry of the trajectory. Thus the better the trajectory is known in advance, the better the system can optimize the speed of movement. This explains why the system does not wait for the current robot movement to be completed before taking the instructions for the next movement into account.

Let us consider the following program lines:

```
movej (A, tool, mDesc)
movej (B, tool, mDesc)
movej (C, tool, mDesc)
movej (D, tool, mDesc)
```

Let us suppose that the robot is stationary when the program reaches these lines. When the first instruction is executed, the robot starts to move towards point **A**. The program then immediately proceeds to the second line, well before the robot reaches point **A**.

When the system executes the second line, the robot starts to move towards **A** and the system records the fact that after point **A**, the robot must go to point **B**. The program then continues with the next line: while the robot continues its movement towards **A**, the system records the instruction that after **B**, the robot must proceed to **C**. As the program is executed much faster than the robot actually moves, the robot is probably still moving towards A when the next line is executed. The system thus records the next successive points.

When the robot starts to move towards **A**, it already "knows" that after **A**, it must go successively to **B**, **C** and **D**. If blending has been activated, the system knows that the robot will not stop before point **D**. It can then accelerate faster than if it had to prepare to stop at **B** or **C**.

The fact of executing the instruction lines only records the successive movement commands. The robot then performs them according to its capabilities. The memory in which the movements are stored is large, to allow the system to optimize the trajectory. Nevertheless, it is limited. When it is full, the program stops at the next movement instruction. It resumes when the robot has completed the current movement, thus creating space in the system memory.

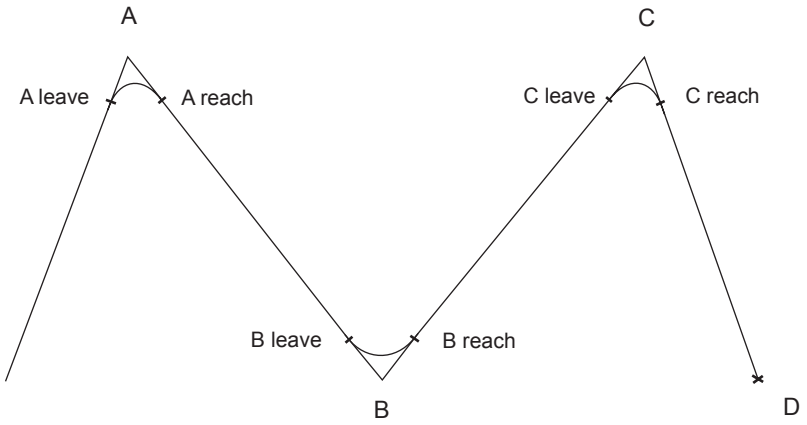
9.2.2. ANTICIPATION AND BLENDING

This section examines in detail what happens when the movements are sequenced. Let us look again at the previous example:

```
movej (A, tool, mDesc)
movej (B, tool, mDesc)
movej (C, tool, mDesc)
movej (D, tool, mDesc)
```

Let us assume that blending is activated in the movement descriptor, **mDesc**. When the first line is executed, the system does not yet know what the next movement will be. Only the movement between the start point and the **Aleave** point is fully determined, as the **Aleave** point is defined by the system from the movement descriptor **leave** data (see the figure below).

Blended cycle



Until the second line is executed, the part of the blending trajectory in the vicinity of point **A** has not been fully determined, as the system has not yet taken the next movement into account. In single-step mode, the robot does not go further than the **Aleave** point. When the next instruction is executed, the blending trajectory in the vicinity of point **A** (between **Aleave** and **Areach**) can be defined, together with the movement as far as point **Bleave**. The robot can then proceed to **Bleave**. In single-step mode, it will not go beyond this point until the user executes the third instruction, and so on.

The advantage of this operating mode is that the robot passes through exactly the same position in single-step mode as in normal program execution mode.

9.2.3. SYNCHRONIZATION

The anticipation mechanism causes desychronization between the **VAL3** instruction lines and the corresponding robot movements: the **VAL3** program is ahead of the robot.

When it is necessary to carry out an action at a given robot position, the program has to wait for the robot to complete its movements: the **waitEndMove()** instruction is used for synchronization purposes.

Thus in the following program:
movej(A, tool, mDesc)
movej(B, tool, mDesc)
waitEndMove()
movej(C, tool, mDesc)
movej(D, tool, mDesc)
etc.
The first two lines are executed when the robot starts to move towards **A**. The program is then blocked at the third line until the robot is stabilized at point **B**. When the robot movement is stabilized at **B**, the program resumes.

The **open()** and **close()** instructions also wait for the robot to comlete its movements before activating the tool.

9.3. SPEED MONITORING

9.3.1. PRINCIPLE

The principle of monitoring the speed along a trajectory is as follows:
The robot moves and accelerates at all times to its maximum capacity, in accordance with the speed and acceleration constraints imposed by the movement command.
The movement commands contain two types of speed constraints defined in a **mdesc** type variable:

1. The revolute speed, acceleration and deceleration constraints
2. The Cartesian speed constraints for the tool center point

Acceleration determines the rate at which the speed increases at the beginning of a trajectory. Conversely, deceleration determines the rate at which the speed decreases at the end of the trajectory. When high acceleration and deceleration values are used, the movements are faster, but jerkier. With low values, the movements take a little longer, but they are smoother.

9.3.2. SIMPLE SETTINGS

When the tool and the object carried by the robot do not need to be handled with special care, Cartesian speed constraints are not necessary. The speed along the trajectory is normally adjusted as follows:

1. Set the Cartesian speed constraints very high, for example to the default values, to ensure that they do not affect the rest of the setting procedure.
2. Initialize the revolute speeds and accelerations using the nominal values **(100%)**.
3. Then adjust the speed along the trajectory using the revolute speed parameter.
4. If the speed is not sufficient, increase the acceleration and deceleration parameters

9.3.3. ADVANCED SETTINGS

To control the Cartesian speed of the tool, for example to execute a trajectory at a constant speed, proceed as follows:

1. Set the Cartesian speed constraints to the values required.
2. Initialize the revolute speeds and accelerations using the nominal values **(100%)**.
3. Then adjust the speed along the trajectory using the Cartesian speed parameter only.
4. If the speed is not sufficient, increase the acceleration and deceleration parameters.
   If you want to brake automatically in sections with pronounced curves, reduce the acceleration and deceleration parameters.

9.3.4. ENVELOPPE ERROR

The nominal values for revolute speed and acceleration are the nominal load values supported by the robot, irrespective of trajectory.

However, the robot can often operate faster: the maximum speeds that can be reached by the robot depend on its load and trajectory. In suitable cases (light load, positive gravitational effect) the robot can exceed its nominal values without any damage being caused.

If the robot is carrying a load that is heavier than its nominal load, or if the revolute speed and acceleration values are too high, the robot cannot always obey its movement command and stops when an enveloppe error occurs. Such errors can be avoided by specifying lower revolute speed and acceleration parameters.

CAUTION:
In the case of straight line movements near a singularity, a small tool movement requires large revolute movements. If the revolute speed is set too high, the robot cannot obey the command and stops when an enveloppe error occurs.

9.4. REAL-TIME MOVEMENT CONTROL

The movement commands previously described in this manual have no immediate effect: when each command is executed, a movement order is stored in the system. The robot then executes the stored movements.

The robot's movements can be controlled instantly, as follows:

- The monitor speed modifies the speed of all the movements. It can only be adjusted via the robot's manual control teach pendant, and not in a **VAL3** application. However, the **speedScale()** instruction allows an application to know the current monitor speed and hence, if necessary, ask the user to reduce it when the cycle resumes, or set it to **100%** during production.
- The **stopMove()** and **restartMove()** instructions are used to stop and restart movement along the trajectory.
- The **resetMotion()** instruction is used to stop the movement in progress and cancel the stored movement commands.

S5.3
- The Alter instruction (option) applies to the path a geometrical transformation (translation, rotation, rotation at the tool centre point) that is immediately effective.

9.5. MDESC TYPE

9.5.1. DEFINITION

The **mdesc** type is used to define the movement parameters (speed, acceleration, blending).

The **mdesc** type is a structured type, with the following fields, in this order:

num accel	Maximum permitted revolute acceleration as a **%** of the nominal acceleration of the robot.
num vel	Maximum permitted revolute speed as a **%** of the nominal speed of the robot.
num decel	Maximum permitted revolute deceleration as a **%** of the nominal deceleration of the robot.
num tvel	Maximum permitted translational speed of the tool center point, in mm/s or inches/s depending on the unit of length of the application.
num rvel	Maximum permitted rotational speed of the tool center point, in degrees per second.
blend **blend**	Blend mode: **off** (no blending), or **joint** (blending).
num leave	In **joint** blend mode, distance between the target point at which blending starts and the next point, in mm or inches, depending on the unit of length of the application.
num reach	In **joint** blend mode, distance between the target point at which blending stops and the next point, in mm or inches, depending on the unit of length of the application.

A detailed explanation of these parameters is given at the beginning of the chapter entitled "Movement control".

By default, an **mdesc** type variable is initialized at **{100,100,100,9999,9999,off,50,50}**.

9.5.2. OPERATORS

In ascending order of priority:

mdesc <mdesc& desc1> = <mdesc desc2>	Assigns each **desc2** field to the field corresponding to the **desc1** variable.
bool <mdesc desc1> != <mdesc desc2>	Returns **true** if the difference between **desc1** and **desc2** is at least one field.
bool <mdesc desc1> == <mdesc desc2>	Returns **true** if **desc1** and **desc2** have the same field values.

9.6. MOVEMENT INSTRUCTIONS

void **movej**(joint joint, tool tool, mdesc desc)

Syntax

void movej(joint joint, tool tool, mdesc desc)
void movej(point point, tool tool, mdesc desc)

Function

Records a command for a revolute movement towards the **point** or **joint** positions, using the **tool** and the **desc** movement parameters.

> **CAUTION:**
> **The system does not wait for the movement to be completed before proceeding to the next VAL3 instruction: several movement commands can be stored in advance. When the system has used up all its available memory and has no room for another command, the instruction waits until the new command can be stored.**

A detailed explanation of the movement parameters is given at the beginning of the chapter entitled "Movement control".

An execution error is generated if **desc** contains invalid values, if **position** is outside the software limits, if **point** cannot be reached, or if a previously saved movement command cannot be run (destination out of reach).

Parameter

tool tool	Tool type expression
mdesc desc	Movement descriptor type expression
joint joint	Joint type expression
point point	Point type expression

See also

void movel(point point, tool tool, mdesc desc)
bool isInRange(joint jPosition)
void waitEndMove()
void movec(Point intermediate, Point target, tool tool, mdesc desc)

void **movel**(point point, tool tool, mdesc desc)

Syntax

void movel(point point, tool tool, mdesc desc)

Function

Records a command for a linear movement towards a **point** position, using the **tool** tool and the **desc** movement parameters.

> **CAUTION:**
> **The system does not wait for the movement to be completed before proceeding to the next VAL3 instruction: several movement commands can be stored in advance. When the system has used up all its available memory and has no room for another command, the instruction waits until the new command can be stored.**

A detailed explanation of the movement parameters is given at the beginning of the chapter entitled "Movement control".

An execution error is generated if **desc** contains invalid values, if **point** cannot be reached, if a straight line movement towards **point** is not possible or if a previously saved movement command cannot be run (destination out of reach).

Parameter

point point	Point type expression.
tool tool	Tool type expression.
mdesc desc	Movement descriptor type expression.

See also

void movej(joint joint, tool tool, mdesc desc)
void waitEndMove()
void movec(Point intermediate, Point target, tool tool, mdesc desc)

void **movec**(Point intermediate, Point target, tool tool, mdesc desc)

Syntax

void movec(Point intermediate, Point target, tool tool, mdesc desc)

Function

Records a command for a circular movement starting from the destination of the previous movement and finishing at **Point target** and passing through the **Point intermediate**.

The tool orientation is interpolated in such a way that it is possible to program a constant orientation in absolute terms, or as compared with the trajectory.

> **CAUTION:**
> **The system does not wait for the movement to be completed before proceeding to the next VAL3 instruction: several movement commands can be stored in advance. When the system has used up all its available memory and has no room for another command, the instruction waits until the new command can be stored.**

A detailed explanation of the various movement parameters and orientation interpolation can be found at the beginning of the "Movement Control" chapter.

An execution error is generated if **desc** has invalid values, if **Point intermediate** (or **Point target**) cannot be reached, if the circular movement is not possible (see the "Movement control - interpolation of orientation" chapter), or if a movement command recorded beforehand cannot be executed (destination out of reach).

Parameter

Point intermediate	Point type expression.
Point target	Point type expression.
tool tool	Tool type expression.
mdesc desc	Movement descriptor type expression.

See also

void movej(joint joint, tool tool, mdesc desc)
void movel(point point, tool tool, mdesc desc)
void waitEndMove()

void **stopMove**()

Syntax

void stopMove()

Function

Stops the arm on the trajectory and suspends authorization of the programmed movement.

> **CAUTION:**
> **This instruction returns immediately: the VAL3 task does not wait for the movement to be completed before proceeding to the next instruction.**

The kinematic parameters used to execute the stop are those used for the current movement.

The movements can only be resumed after a **restartMove()** or **resetMotion()** instruction.

Non-programmed movements (jog interface) are still possible.

Example

```
wait (dSignal==true)          // waits for a signal
stopMove()                    // stops movements along the trajectory
<instructions>
restartMove()                 // restarts movements along the trajectory
```

See also

void restartMove()
void resetMotion(), void resetMotion(joint startingPoint)

void **resetMotion**(), void **resetMotion**(joint startingPoint)

Syntax

void resetMotion()
void resetMotion(joint startingPoint)

Function

Stops the arm on the trajectory and cancels all the stored movement commands.

> **CAUTION:**
> **This instruction returns immediately: the VAL3 task does not wait for the movement to be completed before proceeding to the next instruction.**

The programmed movement authorization is restored if it was suspended by the **stopMove()** instruction.

If the **startingPoint** revolute position is specified, the next movement command can only be run from this position: a connection movement must be performed beforehand to reach the **startingPoint** position.

If no revolute position is specified, the next movement command is run from the arm's current position, wherever it is.

See also

bool isEmpty()
void stopMove()
void autoConnectMove(bool active), bool autoConnectMove()

void **restartMove**()

Syntax

void restartMove()

Function

Restores the programmed movement authorization, and restarts the trajectory interrupted by the **stopMove()** instruction.

If the programmed movement authorization was not interrupted by the **stopMove()** instruction, this intruction has no effect.

See also

void stopMove()
void resetMotion(), void resetMotion(joint startingPoint)

void **waitEndMove**()

Syntax

void waitEndMove()

Function

Cancels the blending of the last movement commmand recorded and waits for the command to be executed.

This instruction does not wait for the robot to be stabilized in its final position, it only waits until the position instructions sent to the variable speed drives correspond to the desired final position. When it is necessary to wait for complete stabilization of the movement, the **isSettled()** instruction must be used.

An execution error is generated if a previously stored movement cannot be run (destination out of reach).

Example

```
waitEndMove()
putln(sel(isEmpty(),1,-1))        // displays 1, no more commands in progress
putln(sel(isSettled(),1,-1))      // May display -1, the robot is not necessarily already stabilized
watch(isSettled(), 1)             // Waits for the robot to stabilize for 1 s maximum
```

See also

bool isSettled()
bool isEmpty()
void stopMove()
void resetMotion(), void resetMotion(joint startingPoint)

bool **isEmpty**()

Syntax
bool isEmpty()

Function
Returns **true** if all the movement commands have been executed, returns **false** if at least one command is still being executed.

Example
```
//  If commands are in progress
if ! isEmpty()
  //Stop the robot and cancel the commands
  resetMotion()
endIf
```

See also
void waitEndMove()
void resetMotion(), void resetMotion(joint startingPoint)

bool **isSettled**()

Syntax
bool isSettled()

Function
Returns **true** if the robot is stopped, and **false** if its position is not yet stabilized.

The position is considered as stabilized if the position error for each joint remains less than 1% of the maximum authorized position, for 50 ms.

See also
bool isEmpty()
void waitEndMove()

void **autoConnectMove**(bool active), bool **autoConnectMove**()

Syntax
void autoConnectMove(bool active)
bool autoConnectMove()

Function
In the remote mode, the connection movement is automatic if the arm is very close to its trajectory (distance less than the maximum authorized drift error). If the arm is too far away from its trajectory, the connection movement is automatic or under manual control depending on the mode defined by the **autoConnectMove** instruction: automatically if **active** is **true**, in manual control mode if **active** is **false**. When called without parameters, **autoConnectMove** returns the current connection movement mode.

By default, the connection movement in remote mode is under manual control.

> **CAUTION:**
> **Under normal conditions of use, the arm stops on its trajectory during an emergency stop. Hence in remote mode, the arm is able to restart automatically whatever the connection movement defined by the autoConnectMove instruction.**

See also
void resetMotion(), void resetMotion(joint startingPoint)

CHAPTER 10

OPTIONS

10.1. COMPLIANT MOVEMENTS WITH FORCE CONTROL

10.1.1. PRINCIPLE

In a standard movement command, the robot moves to reach a requested position at a programmed rate of acceleration and speed. If the arm cannot follow the command, additional force will be requested from the motors in order to attempt to reach the desired position. When the deviation between the position set by the command and the true position is too great, a system error is generated that cuts off power to the robot arm.

The robot is said to be 'compliant' when it accepts certain deviation between the position set by command and the actual position. The **CS8** can be programmed to be trajectory compliant, i.e. to accept a delay or advance in relation to the programmed trajectory, by controlling the force applied by the arm. On the other hand, no deviation in relation to the trajectory is allowed.

In practice, the **CS8**'s compliant movements can allow the arm to follow a trajectory while being pushed or pulled by an outside force, or come into contact with an object, with a check made on the force applied by the arm on the object.

10.1.2. PROGRAMMING

Compliant movements are programmed like standard movements, using the **moveIf()** and **movejf()** instructions, with an additional parameter used to control the force applied by the arm. During the compliant movement, speed and acceleration limits are applied, in the same way as for standard movements, via the movement descriptor. The movement can take place along the trajectory, in either direction.

It is possible to combine compliant movements or combine compliant and standard movements: as soon as the destination position is reached, the robot moves on to the next movement. The **waitEndMove()** instruction is used to wait for the end of a compliant movement.

The **resetMotion()** instruction cancels all programmed movements, whether compliant or not. After **resetMotion()**, the robot is no longer compliant.

The **stopMove()** and **restartMove()** instructions also apply to compliant movements:

The **stopMove()** forces the current movement speed to zero. If it is a compliant movement, it is hence stopped and the robot is no longer compliant until the **restartMove()** instruction is run.

Lastly, the **isCompliant()** instruction is used to ensure that the robot is in compliant mode, for example before allowing any outside force to be applied to the arm.

10.1.3. FORCE CONTROL

When the specified force parameter is null, the arm is passive, i.e. it only moves when actuated by outside forces.

When the force parameter is positive, everything operates as though an outside force were pushing the arm to the position ordered: the arm moves on its own, but it can be held back or accelerated by outside action which is added to the force commanded.

When the force parameter is negative, everything operates as though an outside force were pushing the arm towards its initial position: to move the arm towards the position commanded, it is thus necessary to apply an outside force that is greater than the force commanded.

The force parameter is expressed as a percentage of the arm's nominal load. **100%** means that the arm applies a force towards the position commanded, that is equivalent to the nominal load. In rotation, **100%** corresponds to the nominal torque allowed on the arm.

When the arm's speed or acceleration reach the values specified in the movement descriptor, the robot opposes its full power to resist any attempt to increase its speed or rate of acceleration.

10.1.4. LIMITATIONS

Compliant movements present the following limitations:

- It is not possible to use blending at the start or the end of a compliant movement: the arm is bound to stop at the start and end of every compliant movement.
- When a compliant movement is made, the arm may move back to its starting point, but it cannot move back any further: the arm then stops suddenly at its starting point.
- The force parameter on the arm cannot exceed **1000%**. The precision obtained concerning the force applied is limited by internal friction. It depends mainly on the arm position and the trajectory commanded.
- Long compliant movements require a lot of internal memory capacity. An execution error is generated if the system does not have enough memory to fully process the movement.

10.1.5. INSTRUCTIONS

void **movejf**(joint position, tool tool, mdesc desc, num force)

Syntax

void movejf(joint position, tool tool, mdesc desc, num force)

Function

Records a compliant revolute movement command towards the **position** position using the **tool** tool, the **desc** movement parameters, and a **force** force command.

The **force** force command is expressed as a percentage of the maximum arm force and cannot exceed **±1000%**.

> **CAUTION:**
> **The system does not wait for the movement to be completed before proceeding to the next VAL3 instruction: several movement commands can be stored in advance. When the system has used up all its available memory and has no room for another command, the instruction waits until the new command can be stored.**

A detailed explanation of the various movement parameters is given at the beginning of the section.

An execution error is generated if **desc** or **force** have invalid values, if **position** is outside the software limits, if the previous movement required blending or if a previously recorded movement command cannot be run (destination out of reach).

Parameter

tool tool	Tool type expression.
mdesc desc	Movement descriptor type expression
joint position	Revolute position type position
num force	Numerical type expression

See also

void movelf(point point, tool tool, mdesc desc, num force)
bool isCompliant()

void **movelf**(point point, tool tool, mdesc desc, num force)

Syntax

void movelf(point point, tool tool, mdesc desc, num force)

Function

Records a compliant linear movement command towards the **point** position using the **tool** tool, the **desc** movement parameters and the **force** force command.

The **force** force command is expressed as a percentage of the maximum arm force and cannot exceed **±1000%**.

> **CAUTION:**
> **The system does not wait for the movement to be completed before proceeding to the next VAL3 instruction: several movement commands can be stored in advance. When the system has used up all its available memory and has no room for another command, the instruction waits until the new command can be stored.**

A detailed explanation of the various movement parameters is given at the beginning of the section.

An execution error is generated if **desc** or **force** have invalid values, if **point** cannot be reached, if movement towards **point** is impossible in a straight line, if the previous movement required blending or if a previously recorded movement command cannot be run (destination out of reach).

Parameter

point point	Point type expression.
tool tool	Tool type expression
mdesc desc	Movement descriptor type expression
num force	Numerical type expression

See also

void movejf(joint position, tool tool, mdesc desc, num force)
bool isCompliant()

bool **isCompliant**()

Syntax

bool isCompliant()

Function

Returns **true** if the robot is in compliant mode, otherwise returns **false**.

Example

```
movelf(position, Tool, mDesc, 0)
wait(isCompliant())                // Waits for the robot to actually be in compliant mode
dEjection = true                   // Commands press ejection
waitEndMove()                      // Waits for the end of compliant movement
movej(jDepart, Tool, mDesc)        // Continues with a standard movement
```

See also

void movelf(point point, tool tool, mdesc desc, num force)
void movejf(joint position, tool tool, mdesc desc, num force)

10.2. ALTER: REAL TIME CONTROL ON A PATH

Cartesian Alter

10.2.1. PRINCIPLE

A Cartesian alteration of a path allows apply to the path a geometrical transformation (translation, rotation, rotation at the tool centre point) that is immediately effective.
This feature makes it possible to modify a nominal path using an external sensor, for, for example, track accurately the shape of a part, or operate on a moving part.

10.2.2. PROGRAMMING

The programming consists in defining first the nominal path, then, in real time, specifying a deviation to it.
The nominal path is programmed as for standard moves, with the alterMovel(), alterMovej() and alterMovec() instructions. Several alterable moves may succeed, or some alterable moves may alternate with not alterable moves. We will define the alterable path as the successive alterable move commands between two not alterable move commands.

The alteration itself is programmed with the alter() instruction. Different alter modes are possible depending on the geometrical transformation to apply; the mode is defined with the alterBegin() instruction. The alterEnd() instruction is finally needed to specify how to terminate the altering, either before the nominal move is completed, so that the next non alterable move can be sequenced without stop; either after, so that it remains possible to move the arm with alter while the nominal move is stopped.

The other motion control instructions remains effective in alter mode.

> **CAUTION:**
> **The waitEndMove, open and close instructions wait for the end of the nominal move, not for the end of altered move. VAL3 execution may therefore resume after a waitEndMove even if the arm is still moving because of a changing alter deviation.**

10.2.3. CONSTRAINTS

Synchronisation, desynchronisation: Because the alter command is applied immediately, the change in the alteration must be controlled so that the resulting arm path remains without discontinuity or noise:

- A large change in the alteration can only be applied gradually with a specific approach control.
- The end of the altering requires a null alteration speed, obtained gradually with a specific stop control.

Synchronous command: The controller sends position and velocity commands every 4 ms to the amplifiers. As a consequence, the alter command must be synchronized with this communication period so that the alteration speed remains under control. This is done by using a synchronous **VAL3** task (see Tasks chapter). In the same way, the sensor input may have to be filtered first if the data is noisy or if its sampling period is not synchronized with the controller period.

Smooth sequencing: The first non alterable move following an alterable path can be computed only when alterEnd is executed. As a consequence, if alterEnd is executed too near the end of the alterable move, the arm may slow down or even stop near this point, until the next move is computed.

Moreover, the ability to compute in advance the next move imposes some restrictions on the altered path after alterEnd is executed: It must then keep the same configuration, and make sure all joints remain in the same axis turn. It is then possible that an error is generated during the move that would not occur if alterEnd was not executed in advance.

10.2.4. SAFETY

At any time, the user alteration may be invalid: target out of reach, velocity or acceleration too high. When the system detects such situations, an error is generated and the arm is stopped suddenly at the last valid position. The motion needs to be reset to resume operation.

When the arm motion is disabled during a move (hold mode, stop request or emergency stop), a stop is controlled on the nominal move as for standard moves. After a certain delay, the alter mode is also automatically disabled to guaranty a complete stop of the arm. When the stop condition disappears, the move may resume and the alter mode is automatically enabled again.

10.2.5. LIMITATIONS

A null move (when the move target is on start position) is ignored by the system. As a consequence, you need a not null move to enter the alter mode.

It is not possible to specify the desired configuration for the altered path; the system always uses the same configuration. It is therefore not possible to change the configuration of the arm within an altered path (even with the alterMovej instruction).

10.2.6. INSTRUCTIONS

void **alterMovej**(joint target, tool tcp, mdesc speed)

Syntax

void alterMovej(joint target, tool tcp, mdesc speed)
void alterMovej(point target, tool tcp, mdesc speed)

Function

Register an alterable joint move command (a line in the joint space)

Parameter

target	Point or joint expression defining the end position of the move.
tcp	Tool expression defining the tool centre point used during the move for Cartesian speed control.
speed	mdesc expression defining the speed control and blending parameter for the move.

Details

This instruction behaves exactly as the movej instruction, except that it enables the alter mode for the move. See movej for more details.

void **alterMovel**(point target, tool tcp, mdesc speed)

Syntax
void alterMovel(point target, tool tcp, mdesc speed)

Function
Register an alterable linear move command (a line in the Cartesian space)

Parameter

target	Point expression defining the end position of the move.
tcp	Tool expression defining the tool centre point used during the move for Cartesian speed control. At the end of the move, the tool centre point is at the specified target position.
speed	mdesc expression defining the speed control and blending parameter for the move.

Details
This instruction behaves exactly as the movel instruction, except that it enables the alter mode for the move. See movel for more details.

void **alterMovec**
(point intermediate, point target, tool tcp, mdesc speed)

Syntax
void alterMovec(point intermediate, point target, tool tcp, mdesc speed)

Function
Register an alterable circular move command.

Parameter

Intermediate	Point expression defining an intermediate point on the circle
target	Point expression defining the end position of the move.
tcp	Tool expression defining the tool centre point used during the move for Cartesian speed control. At the end of the move, the tool centre point is at the specified target position.
speed	mdesc expression defining the speed control and blending parameter for the move.

Details
This instruction behaves exactly as the movec instruction, except that it enables the alter mode for the move. See movec for more details.

num **alterBegin**(frame alterReference, mdesc velocity)
num **alterBegin**(tool alterReference, mdesc velocity)

Syntax
num alterBegin(frame alterReference, mdesc velocity)
num alterBegin(tool alterReference, mdesc velocity)

Function
Initialize the alter mode for the alterable path being executed.

Parameter

alterReference	Frame or tool expression defining the reference for the alter deviation.
velocity	mdesc expression defining the safety check parameters for the alter deviation.

Details
The alter mode initiated with alterBegin terminates only with an alterEnd command, or a resetMotion. When the end of an alterable path is reached, the alter mode remains active until alterEnd is executed.

The trsf expression of the alter command defines a transformation of the whole path around alterReference:

- The path is rotated around the centre of the frame or tool using the rotation part of the trsf.
- Then the path is translated by the translation part of the trsf.

The trsf coordinates of the alter command are defined in alterReference base.

When a frame is used as reference, the alterReference is fixed in space (World). This mode must be used when the deviation of the path is known or measured in the Cartesian space (moving part such as conveyor tracking).

When a tool is used as reference, the alterReference is fixed relatively to the tool centre point. This mode must be used when the deviation of the path is known or measured relatively to the tool centre point (for example part shape sensor mounted on the tool).

The motion descriptor is used to define the maximum joint and Cartesian velocity on the altered path (using the fields vel, tvel and rvel of the motion descriptor). An error is generated and the arm is stopped on path if the altered velocity exceeds the specified limits.

The accel and decel fields of the motion descriptor control the stop time when a stop condition occurs (eStop, hold mode, VAL3 stopMove()): The path alteration must be stopped using these deceleration parameters (see alterStopTime).

alterBegin returns a numerical value to indicate the result of the instruction:

1	alterBegin was successfully executed
0	alterBegin is waiting for the start of the alterable move
-1	alterBegin was ignored because the alter mode has already started
-2	alterBegin is refused (alter option is not enabled)
-3	alterBegin was refused because the motion is in error. A resetMotion is required.

See also
num alterEnd()
num alter(trsf alteration)
num alterStopTime()

num **alterEnd()**

Syntax
num alterEnd()

Function
Exit the alter mode and make the current move not alterable any more.

Details
If alterEnd is executed when the end of the alterable path is reached, the next not alterable move (if any) is started immediately.
If alterEnd is executed before the end of the alterable move, the current value of the alter deviation is applied to the rest of the alterable path, until the first next not alterable move. It is not possible to enter the alter mode again on the same alterable path.
The next not alterable move, if any, is computed as soon as alterEnd is executed so that the transition between the alterable path and the next not alterable move is made without stop.

alterEnd returns a numerical value to indicate the result of the instruction:

1	alterEnd was successfully executed
-1	alterEnd was ignored because the alter mode has not yet started
-3	alterEnd was refused because the motion is in error. A resetMotion is required.

See also
num alterBegin(frame alterReference, mdesc velocity)
num alterBegin(tool alterReference, mdesc velocity)

num **alter**(trsf alteration**)**

Syntax
num alter(trsf alteration)

Function
Specify a new alteration of the alterable path.

Parameter

alteration	Trsf expression defining the alteration to apply until the next alter instruction.

Details
The transformation induced by the alteration trsf depends on the alter mode selected by the alterBegin instruction. The alteration coordinates are defined in the frame or tool specified with the alterBegin instruction.

The alteration is applied by the system every 4 ms: When several alter instructions are executed in less that 4 ms, the last one applies. Most often the alter instruction needs to be executed in a synchronous task to force an alteration refresh every 4 ms.

The alteration must be computed carefully so that the resulting arm position and speed commands remain continuous and without noise. A sensor input may need to be filtered adequately to reach the desired quality on the arm path and behaviour.

When the motion is stopped (hold mode, emergency stop, stopMove() instruction), the alteration of the path is locked until all stop conditions are cleared.

When the alteration of the path is invalid (unreachable position, out of speed limits), the arm will stop suddenly at the last valid position and the alter mode is locked in error. A resetMotion is required to resume operation. The velocity limits for the alter move are defined by the alterBegin instruction.

Alter returns a numerical value to indicate the result of the instruction:

1	alter was successfully executed.
0	alter is waiting for the motion to restart (alterStopTime is null).
-1	alter was ignored because the alter mode is not started or already ended.
-2	alter is refused (alter option is not enabled).
-3	alter was refused because the motion is in error. A resetMotion is required.

See also

num alterBegin(frame alterReference, mdesc velocity)
num alterBegin(tool alterReference, mdesc velocity)
void taskCreateSync string name, num period, bool& overrun, program(...)

num **alterStopTime**()

Syntax

num alterStopTime()

Function

Return the remaining time before the alter deviation is locked, when a stop condition occurs.

Details

When a stop condition occurs, the system evaluates the time to stop the arm if the accel and decel parameters of the motion descriptor specified with alterBegin are used. The minimum of this time and the time imposed by the system (typically 0.5s when a eStop occurs) is returned by alterStopTime.

When alterStopTime returns a negative value, there is no pending stop condition. When alterStopTime returns null, the alter command is locked until all stop conditions are reset.

alterStopTime returns null when the alter mode is not enabled.

See also

num alterBegin(frame alterReference, mdesc velocity)
num alterBegin(tool alterReference, mdesc velocity)
num alter(trsf alteration)

CHAPTER 11

APPENDIX

11.1. EXECUTION ERROR CODES

Code	Description
-1	There is no task with the specified name created by this library
0	No execution error
1	A task is running
10	Invalid numerical calculation (division by zero).
11	Invalid numerical calculation (e.g.ln(-1))
20	Access to a table with an index that is larger than the table size.
21	Access to a table with a negative index.
29	Invalid task name. See taskCreate() instruction.
30	The specified name does not correspond to any VAL3 task.
31	A task with the same name already exists. See taskCreate instruction.
32	Only 2 different periods for synchronous tasks are supported. Change scheduling period.
40	Not enough memory space available.
41	Not enough memory space to run the task. See the run memory size.
60	Maximum instruction run time exceeded.
61	Internal VAL3 interpreter error
70	Invalid instruction parameter. See the corresponding instruction.
80	Uses data or a program from a library not loaded in the memory.
81	Incompatible kinematic: Use of a point/joint/config that is not compatible with the arm kinematic.
90	The task cannot resume from the location specified. See taskResume() instruction.
100	The speed specified in the motion descriptor is invalid (negative or too great).
101	The acceleration specified in the motion descriptor is invalid (negative or too great).
102	The deceleration specified in the motion descriptor is invalid (negative or too great).
103	The sideways speed specified in the motion descriptor is invalid (negative or too great).
104	The rotation speed specified in the motion descriptor is invalid (negative or too great).
105	The reach parameter specified in the movement descriptor is invalid (negative).
106	The leave parameter specified in the movement descriptor is invalid (negative).
122	Attempt to write in a system input.
123	Use of a dio, aio or sio input/output not connected to a system input/output.
124	Attempt to access a protected system input/output
125	Read or write error on a dio, aio or sio (field bus error)
150	Cannot run this movement instruction: a previous movement request could not be completed (point out of reach, singularity, configuration problem, etc.)
153	Movement command not supported
154	Invalid movement instruction: check the movement descriptor.
160	Invalid flange tool coordinates
161	Invalid world tool coordinates
162	Use of a point without a reference frame. See Definition.
163	Use of a frame without a reference frame. See Definition.
164	Use of a tool without reference tool. See Definition.
165	Invalid frame or reference tool (global variable linked to a local variable)
250	No runtime licence for this instruction, or demo licence is over.

11.2. CONTROL PANEL KEYBOARD KEY CODES

Without **Shift**

3	Caps	Space		Move
283	-	32		-
2	Shift	Esc	Help	Ret.	Run
282	-	255	-	270	-
	Menu	Tab	Up	Bksp	Stop
	-	259	261	263	-
1	User	Left	Down	Right	
281	-	264	266	268	

With **Shift**

3	Caps	Space		Move
283	-	32		-
2	Shift	Esc	Help	Ret.	Run
282	-	255	-	270	-
	Menu	UnTab	PgUp	Bksp	Stop
	-	260	262	263	-
1	User	Home	PgDn	End	
281	-	265	267	269	

Menus (with or without **Shift**):

F1	F2	F3	F4	F5	F6	F7	F8
271	272	273	274	275	276	277	278

For standard keys, the code returned is the **ASCII** code of the corresponding character:

Without **Shift**									
q	w	e	r	t	y	u	i	o	p
113	119	101	114	116	121	117	105	111	112
a	s	d	f	g	h	j	k	l	<
97	115	100	102	103	104	106	107	108	60
z	x	c	v	b	n	m	.	,	=
122	120	99	118	98	110	109	46	44	61

With **Shift**									
7	8	9	+	*	;	(	)	[	]
55	56	57	43	42	59	40	41	91	93
4	5	6	-	/	?	:	!	{	}
52	53	54	45	47	63	58	33	123	125
1	2	3	0	"	%	-	.	,	>
49	50	51	48	34	37	95	46	44	62

With double **Shift**									
Q	W	E	R	T	Y	U	I	O	P
81	87	69	82	84	89	85	73	79	80
A	S	D	F	G	H	J	K	L	}
65	83	68	70	71	72	74	75	76	125
Z	X	C	V	B	N	M	$	\	=
90	88	67	86	66	78	77	36	92	61

ILLUSTRATION

INDEX

U

V

W