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SERIES Z: LANGUAGES AND GENERAL SOFTWARE ASPECTS FOR TELECOMMUNICATION SYSTEMS

Formal description techniques (FDT) – Testing and Test Control Notation (TTCN)

Testing and Test Control Notation version 3: TTCN-3 core language

ITU-T Recommendation Z.161

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ITU-T Recommendation Z.161

Testing and Test Control Notation version 3: TTCN-3 core language

Summary

ITU-T Recommendation Z.161 defines TTCN-3 (*Testing and Test Control Notation 3*) intended for specification of test suites that are independent of platforms, test methods, protocol layers and protocols. TTCN-3 can be used for specification of all types of reactive system tests over a variety of communication ports. Typical areas of application are protocol testing (including mobile and Internet protocols), service testing (including supplementary services), module testing, testing of CORBA-based platforms and APIs. The specification of test suites for physical layer protocols is outside the scope of this Recommendation.

The core language of TTCN-3 can be expressed in a variety of presentation formats. While this Recommendation defines the core language, ITU-T Recommendation Z.162 defines the tabular format for TTCN (TFT) and ITU-T Recommendation Z.163 defines the graphical format for TTCN (GFT). The specification of these formats is outside the scope of this Recommendation. The core language serves three purposes:

1) as a generalized text-based test language;
2) as a standardized interchange format of TTCN test suites between TTCN tools;
3) as the semantic basis (and where relevant, the syntactical basis) for the various presentation formats.

The core language may be used independently of the presentation formats. However, neither the tabular format nor the graphical format can be used without the core language. Use and implementation of these presentation formats shall be done on the basis of the core language.

Source

ITU-T Recommendation Z.161 was approved on 13 November 2007 by ITU-T Study Group 17 (2005-2008) under the ITU-T Recommendation A.8 procedure.

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ITU-T Recommendation Z.161

Testing and Test Control Notation version 3: TTCN-3 core language

1 Scope

This Recommendation defines the core language of TTCN-3. TTCN-3 can be used for the specification of all types of reactive system tests over a variety of communication ports. Typical areas of application are protocol testing (including mobile and Internet protocols), service testing (including supplementary services), module testing, testing of CORBA based platforms, APIs, etc. TTCN-3 is not restricted to conformance testing and can be used for many other kinds of testing including interoperability, robustness, regression, system and integration testing. The specification of test suites for physical layer protocols is outside the scope of this Recommendation.

TTCN-3 is intended to be used for the specification of test suites which are independent of test methods, layers and protocols. Various presentation formats are defined for TTCN-3 such as a tabular presentation format ([ITU-T Z.162]) and a graphical presentation format ([ITU-T Z.163]). The specification of these formats is outside the scope of this Recommendation.

While the design of TTCN-3 has taken the eventual implementation of TTCN-3 translators and compilers into consideration the means of realization of Executable Test Suites (ETS) from Abstract Test Suites (ATS) is outside the scope of this Recommendation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T T.50]	ITU-T Recommendation T.50 (2002), *International Reference Alphabet (IRA) (Formerly International Alphabet No. 5 or IA5) – Information technology – 7-bit coded character set for information interchange*.
[ITU-T X.290]	ITU-T Recommendation X.290 (1995), *OSI conformance testing methodology and framework for protocol Recommendations for ITU-T applications – General concepts*.
[ITU-T X.292]	ITU-T Recommendation X.292 (2002), *OSI conformance testing methodology and framework for protocol Recommendations for ITU-T applications – The Tree and Tabular Combined Notation (TTCN).*
[ITU-T Z.162]	ITU-T Recommendation Z.162 (2007), *Testing and Test Control Notation version 3: TTCN-3 tabular presentation format*.
[ITU-T Z.163]	ITU-T Recommendation Z.163 (2007), *Testing and Test Control Notation version 3: TTCN-3 graphical presentation format (GFT).*
[ITU-T Z.164]	ITU-T Recommendation Z.164 (2007), *Testing and Test Control Notation version 3: TTCN-3 operational semantics*.
[ITU-T Z.165]	ITU-T Recommendation Z.165 (2007), *Testing and Test Control Notation version 3: TTCN-3 runtime interface (TRI).*

[ITU-T Z.166]	ITU-T Recommendation Z.166 (2007), *Testing and Test Control Notation version 3: TTCN-3 control interface (TCI).*
[ITU-T Z.167]	ITU-T Recommendation Z.167 (2006), *Testing and Test Control Notation version 3: Using ASN.1 with TTCN-3.*
[ITU-T Z.168]	ITU-T Recommendation Z.168 (2007), *Testing and Test Control Notation version 3: TTCN-3 mapping from CORBA IDL.*
[ITU-T Z.170]	ITU-T Recommendation Z.170 (2007), *Testing and Test Control Notation version 3: TTCN-3 documentation comment specification.*
[IEEE 754]	IEEE 754-1985, *IEEE standard for binary floating-point arithmetic.*
[ISO/IEC 6429]	ISO/IEC 6429:1992, *Information technology – Control functions for coded character sets.*
[ISO/IEC 10646]	ISO/IEC 10646:2003, *Information technology – Universal Multiple-Octet Coded Character Set (UCS).*

3 Definitions and abbreviations

3.1 Definitions

For the purposes of this Recommendation, the terms and definitions given in [ITU-T X.290], [ITU-T X.292] and the following apply:

3.1.1 actual parameter: Value, expression, template or name reference (identifier) to be passed as parameter to the invoked entity (function, test case, altstep, etc.) as defined at the place of invoking.

NOTE – The number, order and type of all actual parameters to be passed at a single invocation shall be in line with the list of formal parameters as defined in the invoked entity.

3.1.2 basic types: Set of predefined TTCN-3 types described in clauses 6.1.0 and 6.1.1.

NOTE – Basic types are referenced by their names.

3.1.3 communication port: Abstract mechanism facilitating communication between test components.

NOTE – A communication port is modelled as a FIFO queue in the receiving direction. Ports can be message-based, procedure-based or a mixture of the two.

3.1.4 compatible type: TTCN-3 is not strongly typed but the language does require type compatibility.

NOTE – Variables, constants, templates, etc. have compatible types if conditions in clause 6.3 are met.

3.1.5 data types: Common name for simple basic types, basic string types, structured types, the special data type **`anytype`** and all user-defined types based on them (see Table 3).

3.1.6 defined types (defined TTCN-3 types): Set of all predefined TTCN-3 types (basic types, all structured types, the type **`anytype`**, the address, port and component types and the default type) and all user-defined types declared either in the module or imported from other TTCN-3 modules.

3.1.7 dynamic parameterization: Form of parameterization, in which actual parameters are dependent on run-time events; e.g., the value of the actual parameter is a value received during run-time or depends on a received value by a logical relation.

3.1.8 exception: In cases of procedure-based communication, an exception (if defined) is raised by an answering entity if it cannot answer a remote procedure call with the normal expected response.

3.1.9 formal parameter: Typed name or typed template reference (identifier) not resolved at the time of the definition of an entity (function, test case, altstep, etc.) but at the time of invoking it.

NOTE – Actual values or templates (or their names) to be used at the place of formal parameters are passed from the place of invoking the entity (see also the definition of actual parameter).

3.1.10 global visibility: Attribute of an entity (module parameter, constant, template, etc.) that its identifier can be referenced anywhere within the module where it is defined including all functions, test cases and altsteps defined within the same module and the control part of that module.

3.1.11 implementation conformance statement (ICS): See [ITU-T X.290].

3.1.12 implementation extra information for testing (IXIT): See [ITU-T X.290].

3.1.13 implementation under test (IUT): See [ITU-T X.290].

3.1.14 in parameterization: Kind of parameterization where the value of the actual parameter (the argument) is bound to the formal parameter when the parameterized object is invoked, but the value of the formal parameter is not passed back to the actual parameter when the invoked object completes.

NOTE 1 – The arguments are evaluated before the parameterized object is entered.

NOTE 2 – Only the values of the arguments are passed and changes to the arguments within the invoked object have no effect on the arguments as seen by the invoking object.

3.1.15 inout parameterization: Kind of parameterization where the value of the actual parameter is bound to the formal parameter when the parameterized object is invoked and the value of the formal parameter is passed back to the actual parameter, when the invoked object completes.

NOTE 1 – Inout parameters can be used for functions, altsteps, and test cases only.

NOTE 2 – All changes to the arguments within the invoked object have effect on the arguments as seen by the invoking object.

3.1.16 known types: Set of all TTCN-3 predefined types, types defined in a TTCN-3 module and types imported into that module from other TTCN-3 modules or from non-TTCN-3 modules.

3.1.17 left-hand side (of assignment): Value or template variable identifier or a field name of a structured type value or template variable (including array index if any), which stands left to an assignment symbol (:=).

NOTE – A constant, module parameter, timer, structured type field name or a template header (including template type, name and formal parameter list) standing left of an assignment symbol (:=) in declarations and or a modified template definitions are out of the scope of this definition as not being part of an assignment.

3.1.18 local visibility: Attribute of an entity (constant, variable, etc.) that its identifier can be referenced only within the function, test case or altstep where it is defined.

3.1.19 main test component (MTC): See [ITU-T X.292].

3.1.20 out parameterization: Kind of parameterization where the value of the actual parameter (the argument) is not bound to the formal parameter when the parameterized object is invoked, but the value of the formal parameter is passed back to the actual parameter when the invoked object completes.

NOTE 1 – Out parameters can be used for functions, altsteps, and test cases only.

NOTE 2 – An `out` formal parameter is uninitialized (unbound) when the invoked object is entered.

NOTE 3 – All changes to the arguments within the invoked object have effect on the arguments as seen by the invoking object.

3.1.21 parallel test component (PTC): See [ITU-T X.292].

3.1.22 port parameterization: Ability to pass a port as an actual parameter into a parameterized object via a port parameter.

NOTE – This actual port parameter is added to the specification of that object and may complete it.

3.1.23 right-hand side (of assignment): Expression, template reference or signature parameter identifier which stands right to an assignment symbol (:=).

NOTE – Expressions and template references standing right of an assignment symbol (:=) in constant, module parameter, timer, template or modified template declarations are out of the scope of this definition as not being part of an assignment.

3.1.24 root type: Basic type, structured type, special data type, special configuration type or special default type to which the user-defined TTCN-3 type can be traced back.

3.1.25 static parameterization: Form of parameterization, in which actual parameters are independent of run-time events; i.e., known at compile time or in case of module parameters are known by the start of the test suite execution.

NOTE 1 – A static parameter is to be known from the test suite specification (including imported definitions), or the test system is aware of its value before execution time.

NOTE 2 – All types are known at compile time, i.e., are statically bound.

3.1.26 strong typing: Strict enforcement of type compatibility by type name equivalence with no exceptions.

3.1.27 system under test (SUT): See [ITU-T X.290].

3.1.28 template: TTCN-3 templates are specific data structures for testing; used to either transmit a set of distinct values or to check whether a set of received values matches the template specification.

3.1.29 template parameterization: Ability to pass a template as an actual parameter into a parameterized object via a template parameter.

NOTE 1 – This actual template parameter is added to the specification of that object and may complete it.

NOTE 2 – Values passed to template formal parameters are considered to be in-line templates (see clause 15.4).

3.1.30 test behaviour: (or behaviour) Test case or a function started on a test component when executing an `execute` or a `start` component statement and all functions and altsteps called recursively.

NOTE – During a test case execution, each test component has its own behaviour and hence several test behaviours may run concurrently in the test system (i.e., a test case can be seen as a collection of test behaviours).

3.1.31 test case: See [ITU-T X.290].

3.1.32 test case error: See [ITU-T X.290].

3.1.33 test suite: Set of TTCN-3 modules that contains a completely defined set of test cases, optionally supplemented with one or more TTCN-3 control parts.

3.1.34 test system: See [ITU-T X.290].

3.1.35 test system interface: Test component that provides a mapping of the ports available in the (abstract) TTCN-3 test system to those offered by the SUT.

3.1.36 timer parameterization: Ability to pass a timer as an actual parameter into a parameterized object via a timer parameter.

NOTE – This actual timer parameter is added to the specification of that object and may complete it.

3.1.37 type compatibility: Language feature that allows to use values, expressions or templates of a given type as actual values of another type (e.g., at assignments, as actual parameters at calling a function, referencing a template, etc. or as a return value of a function).

NOTE – Both the type and the current value of the value, expression or template shall be compatible with the other type.

3.1.38 user-defined type: Type that is defined by subtyping of a basic type or declaring a structured type.

NOTE – User-defined types are referenced by their identifiers (names).

3.1.39 value notation: Notation by which an identifier is associated with a given value or range of a particular type.

NOTE – Values may be constants or variables.

3.1.40 value parameterization: Ability to pass a value as an actual parameter into a parameterized object via a value parameter.

NOTE – This actual value parameter is added to the specification of that object and may complete it.

3.2 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

API	Application Programming Interface
ATS	Abstract Test Suite
BMP	Basic Multilingual Plane
BNF	Backus-Nauer Form
CORBA	Common Object Request Broker Architecture
ETS	Executable Test Suite
FIFO	First In First Out
IRV	International Reference Version
TSI	Test System Interface

4 Introduction

TTCN-3 is a flexible and powerful language applicable to the specification of all types of reactive system tests over a variety of communication interfaces. Typical areas of application are protocol testing (including mobile and Internet protocols), service testing (including supplementary services), module testing, testing of CORBA based platforms, API testing, etc. TTCN-3 is not restricted to conformance testing and can be used for many other kinds of testing including interoperability, robustness, regression, system and integration testing.

TTCN-3 includes the following essential characteristics:

- the ability to specify dynamic concurrent testing configurations;
- operations for procedure-based and message-based communication;
- the ability to specify encoding information and other attributes (including user extensibility);
- the ability to specify data and signature templates with powerful matching mechanisms;
- value parameterization;
- the assignment and handling of test verdicts;
- test suite parameterization and test case selection mechanisms;
- combined use of TTCN-3 with other languages;
- well-defined syntax, interchange format and static semantics;

- different presentation formats (e.g., tabular and graphical presentation formats);
- a precise execution algorithm (operational semantics).

NOTE – This is a rewrite of part 1 using the following pattern of concept description. Concepts, principles and mechanisms are explained in (introductory) text at the beginning of a clause. For every concept having concrete syntax, the syntactical structure of that concept is presented afterwards. The syntactical structure follows the conventions for the TTCN-3 syntax description in clause A.1.1 and uses rules of the TTCN-3 BNF given in clause A.1. A semantic description follows the syntactic structure. The restrictions on the concept are listed subsequently. Finally, examples on the usage of the concept are given.

In case of a contradiction between the body of this Recommendation (clauses 5 to 27) and Annex A, Annex A has the priority.

4.1 The core language and presentation formats

The TTCN-3 specification is separated into several parts (see Figure 1).

The first part, defined in this Recommendation, is the core language.

The second part, defined in [ITU-T Z.162], is the tabular presentation format.

The third part, defined in [ITU-T Z.163], is the graphical presentation format.

The fourth part, [ITU-T Z.164], contains the operational semantics of the language.

The fifth part, [ITU-T Z.165], defines the TTCN-3 runtime interface (TRI).

The sixth part, [ITU-T Z.166], defines the TTCN-3 control interfaces (TCI).

The seventh part, [ITU-T Z.167], specifies the use of ASN.1 definitions with TTCN-3.

The eighth part, [ITU-T Z.168], specifies the use of IDL definitions with TTCN-3.

The ninth part, [b-ETSI ES 201 873-9] specifies the use of XML definitions with TTCN-3.

The tenth part, [ITU-T Z.170], defines the documentation of TTCN-3 source code.

The eleventh part, specifies the use of C/C++ definitions with TTCN-3.

The core language serves three purposes:

a) as a generalized text-based test language in its own right;

b) as a standardized interchange format of TTCN-3 test suites between TTCN-3 tools;

c) as the semantic basis (and where relevant, the syntactical basis) for various presentation formats.

The core language may be used independently of the presentation formats. However, neither the tabular format nor the graphical format can be used without the core language. Use and implementation of these presentation formats shall be done on the basis of the core language.

The tabular format and the graphical format are the first in an anticipated set of different presentation formats. These other formats may be standardized presentation formats or they may be proprietary presentation formats defined by TTCN-3 users themselves. These additional formats are not defined in this Recommendation.

TTCN-3 may optionally be used with other type-value notations in which case definitions in other languages may be used as an alternative data type and value syntax. Other parts of the TTCN-3 standard specify use of some other languages with TTCN-3. The support of other languages is not limited to those specified in the Z.160 series of Recommendations but to support languages for which combined use with TTCN-3 is defined, rules given in this Recommendation shall apply.

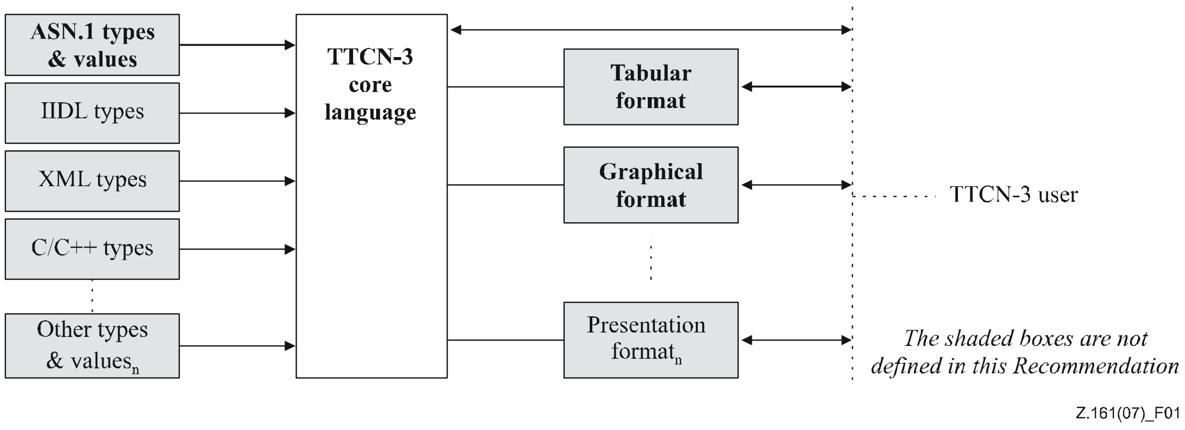


Figure 1 – User's view of the core language and the various presentation formats

The core language is defined by a complete syntax (see Annex A) and operational semantics [ITU-T Z.164]. It contains minimal static semantics (provided in the body of this Recommendation and in Annex A) which do not restrict the use of the language due to some underlying application domain or methodology.

4.2 Unanimity of the specification

The language is specified syntactically and semantically in terms of a textual description in the body of this Recommendation (clauses 5 to 27) and in a formalized way in Annex A. In each case, when the textual description is not exhaustive, the formal description completes it. If the textual and the formal specifications are contradictory, the latter shall take precedence.

4.3 Conformance

For an implementation claiming to conform to this version of the language, all features specified in this Recommendation shall be implemented consistently with the requirements given in this Recommendation and in [ITU-T Z.164].

5 Basic language elements

The top-level unit of TTCN-3 is a module. A module cannot be structured into sub-modules. A module can import definitions from other modules. Modules can have module parameters to allow test suite parameterization.

A module consists of a definitions part and a control part. The definitions part of a module defines test components, communication ports, data types, constants, test data templates, functions, signatures for procedure calls at ports, test cases, etc.

The control part of a module calls the test cases and controls their execution. The control part may also declare (local) variables, etc. Program statements (such as **`if-else`** and **`do-while`**) can be used to specify the selection and execution order of individual test cases. The concept of global variables is not supported in TTCN-3.

TTCN-3 has a number of pre-defined basic data types as well as structured types such as records, sets, unions, enumerated types and arrays.

A special kind of data structure called a template provides parameterization and matching mechanisms for specifying test data to be sent or received over the test ports. The operations on these ports provide both message-based and procedure-based communication capabilities. Procedure calls may be used for testing implementations which are not message based.

Dynamic test behaviour is expressed as test cases. TTCN-3 program statements include powerful behaviour description mechanisms such as alternative reception of communication and timer events, interleaving and default behaviour. Test verdict assignment and logging mechanisms are also supported.

Finally, TTCN-3 language elements may be assigned attributes such as encoding information and display attributes. It is also possible to specify (non-standardized) user-defined attributes.

The TTCN-3 language elements are summarized in Table 1.

Table 1 – Overview of TTCN-3 language elements

Language element	Associated keyword	Specified in module definitions	Specified in module control	Specified in functions/ altsteps/ test cases	Specified in test component type
TTCN-3 module definition	`module`				
Import of definitions from other module	`import`	Yes			
Grouping of definitions	`group`	Yes			
Data type definitions	`type`	Yes			
Communication port definitions	`port`	Yes			
Test component definitions	`component`	Yes			
Signature definitions	`signature`	Yes			
External function/constant definitions	`external`	Yes			
Constant definitions	`const`	Yes	Yes	Yes	Yes
Data/signature template definitions	`template`	Yes	Yes	Yes	Yes
Function definitions	`function`	Yes			
Altstep definitions	`altstep`	Yes			
Test case definitions	`testcase`	Yes			
Value variable declarations	`var`		Yes	Yes	Yes
Template variable declarations	`var template`		Yes	Yes	Yes
Timer declarations	`timer`		Yes	Yes	Yes
NOTE – The notions "definition" and "declaration" of variables, constants, types and other language elements are used interchangeable throughout this Recommendation. The distinction between both notions is useful only for implementation purposes, as it is the case in programming languages like C and C++. On the level of TTCN-3, the notions have equal meaning.					

5.1 Identifiers and keywords

TTCN-3 identifiers are case sensitive. TTCN-3 keywords shall be written in all lowercase letters (see Annex A). TTCN-3 keywords shall neither be used as identifiers of TTCN-3 objects nor as identifiers of objects imported from modules of other languages. The same rules apply to names of predefined TTCN-3 functions (see Annex C).

5.2 Scope rules

TTCN-3 provides seven basic units of scope:

a) module definitions part;

b) control part of a module;

c) component types;

d) functions;

e) altsteps;

f) test cases;

g) "blocks of statements and declarations" within compound statements.

NOTE 1 – Additional scoping rule for groups are given in clause 8.2.2.

NOTE 2 – Additional scoping rule for counters of **`for`** loops are given in clause 19.4.

Each unit of scope consists of (optional) declarations. The scope units: control part of a module, functions, test cases, altsteps and "blocks of statements and declarations" within compound statements may additionally specify some form of behaviour by using the TTCN-3 program statements and operations (see clause 18).

Definitions made in the module definitions part but outside of other scope units are globally visible, i.e., may be used elsewhere in the module, including all functions, test cases and altsteps defined within the module and the control part. Identifiers imported from other modules are also globally visible throughout the importing module.

Definitions made in the module control part have local visibility, i.e., can be used within the control part only.

Definitions made in a test component type may be used only in functions, test cases and altsteps referencing that component type or a consistent test component type (see clause 6.3.3) by a **`runs on`**-clause.

Test cases, altsteps and functions are individual scope units without any hierarchical relation between them, i.e., declarations made at the beginning of their body have local visibility and shall only be used in the given test case, altstep or function (e.g., a declaration made in a test case is not visible in a function called by the test case or in an altstep used by the test case).

Compound statements, e.g., **`if-else`**, **`while`**, **`do-while`**, or **`alt`** statements include "blocks of statements and declarations". They may be used within the control part of a module, test cases, altsteps, functions, or may be embedded in other compound statements, e.g., an **`if-else`** statement that is used within a **`while`** loop.

The "blocks of statements and declarations" of compound statements and embedded compound statements have a hierarchical relation both to the scope unit including the given "block of statements and declarations" and to any embedded "block of statements and declarations". Declarations made within a "block of statements and declarations" have local visibility.

The hierarchy of scope units is shown in Figure 2. Declarations of a scope unit at a higher hierarchical level are visible in all units at lower levels within the same branch of the hierarchy. Declarations of a scope unit in a lower level of hierarchy are not visible to those units at a higher hierarchical level.

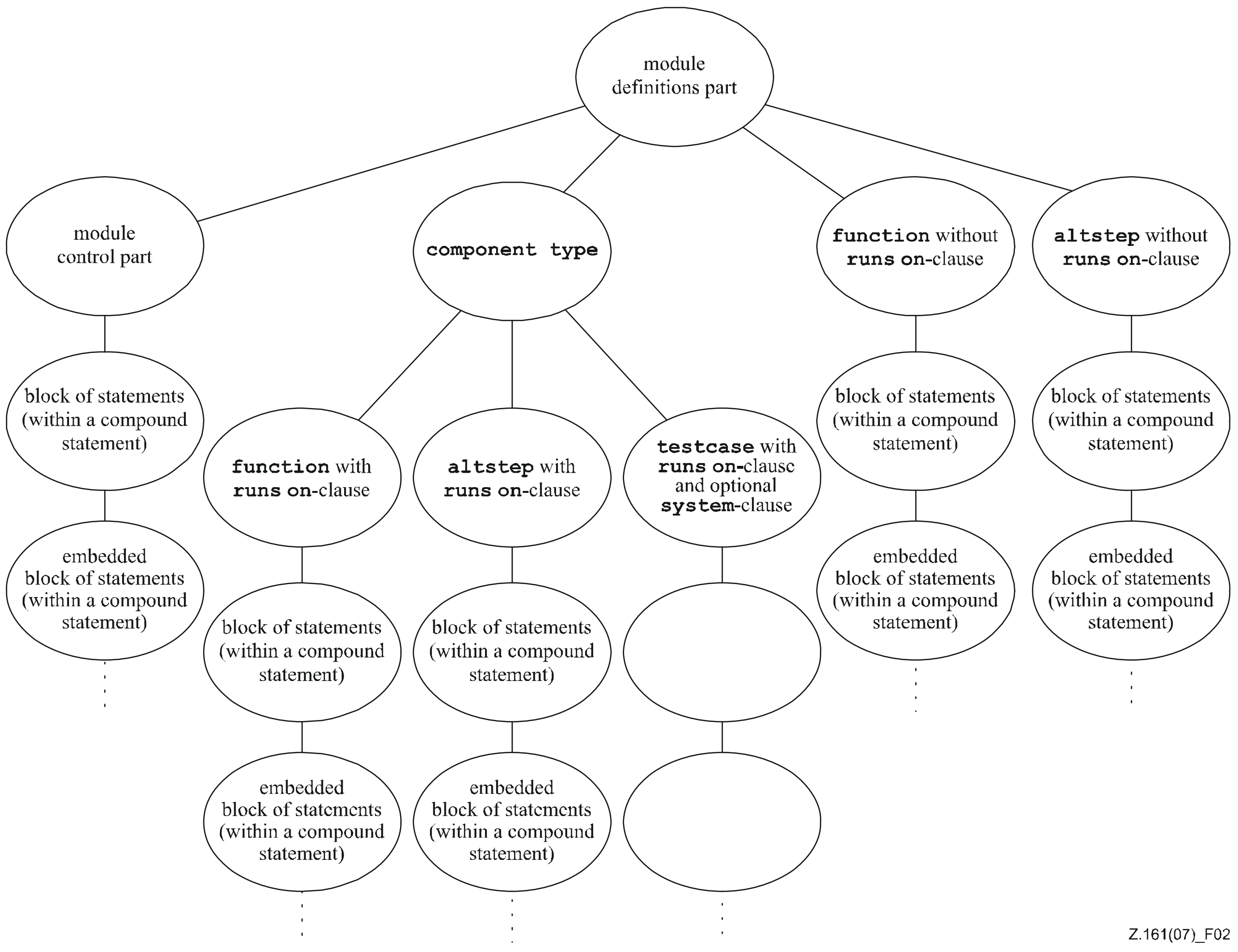

module definitions part
module control part
component type
function without runs on-clause
altstep without runs on-clause
block of statements (within a compound statement)
function with runs on-clause
altstep with runs on-clause
testcase with runs on-clause and optional system-clause
embedded block of statements (within a compound statement)
Z.161(07)_F02

Figure 2 – Hierarchy of scope units

EXAMPLE:

```
module MyModule
{   :
    const integer MyConst := 0; // MyConst is visible to MyBehaviourA and MyBehaviourB
    :
    function MyBehaviourA()
    {   :
        const integer A := 1;   // The constant A is only visible to MyBehaviourA
        :
    }

    function MyBehaviourB()
    {   :
        const integer B := 1;   // The constant B is only visible to MyBehaviourB
        :

    }
}
```

5.2.1 Scope of formal parameters

The scope of formal parameters in a parameterized object (e.g., in a function definition) shall be restricted to the definition in which the parameters appear and to the lower levels of scope in the same scope hierarchy. That is, they follow the scope rules for local definitions (see clause 5.2).

5.2.2 Uniqueness of identifiers

TTCN-3 requires uniqueness of identifiers, i.e., all identifiers in the same scope hierarchy shall be distinctive. This means that a declaration in a lower level of scope shall not reuse the same identifier as a declaration in a higher level of scope in the same branch of the scope hierarchy. Identifiers for fields of structured types, enumeration values and groups do not have to be globally unique, however, in the case of enumeration values the identifiers shall only be reused for enumeration values within other enumerated types. The rules of identifier uniqueness shall also apply to identifiers of formal parameters.

EXAMPLE:

```
module MyModule
{   :
    const integer A := 1;
    :
    function MyBehaviourA()
    {   :
        const integer A := 1; // Is NOT allowed
        :
        if(…)
        {   :
            const boolean A := true; // Is NOT allowed
            :
        }
    }
}

// The following IS allowed as the constants are not declared in the same scope hierarchy
// (assuming there is no declaration of A in module header)
function MyBehaviourA()
{   :
    const integer A := 1;
    :
}

function MyBehaviourB()
{   :
    const integer A := 1;
    :
}
```

5.3 Ordering of language elements

Generally, the order in which declarations can be made is arbitrary. Inside a block of statements and declarations, such as a function body or a branch of an **`if-else`** statement, all declarations (if any), shall be made at the beginning of the block only.

EXAMPLE:

```
// This is a legal mixing of TTCN-3 declarations
  :
var MyVarType MyVar2 := 3;
const integer MyConst:= 1;
if (x > 10)
{
    var integer MyVar1:= 1;
    :
    MyVar1:= MyVar1 + 10;
    :
}

  :
```

Declarations in the module definitions part may be made in any order. However, inside the module control part, test case definitions, functions, and altsteps, all required declarations must be given beforehand. This means in particular, local variables, local timers, and local constants shall never be used before they are declared. The only exception to this rule are labels. Forward references to a label may be used in **`goto`** statements before the label occurs (see clause 19.8).

5.4 Parameterization

TTCN-3 supports value, template, timer and port parameterization. A summary of which language elements can be parameterized and what can be passed to them as parameters is given in Table 2.

Table 2 – Overview of parameterizable TTCN-3 objects

Keyword	Allowed kind of parameterization	Allowed form of parameterization	Allowed types in formal parameter lists
`module`	Value parameterization	Static at start of run-time	all basic types, all user-defined types and **`address`** type.
`type` (see Note)	Value parameterization	Static at compile-time	all basic types, all user-defined types and **`address`** type.
`template`	Value and template parameterization	Dynamic at run-time	all basic types, all user-defined types, **`address`** type and **`template`**.
`function`	Value, template, port and timer parameterization	Dynamic at run-time	all basic types, all user-defined types, **`address`** type, **`component`** type, **`port`** type, **`default`**, **`template`** and **`timer`**.
`altstep`	Value, template, port and timer parameterization	Dynamic at run-time	all basic types, all user-defined types, **`address`** type, **`component`** type, **`port`** type, **`default`**, **`template`** and **`timer`**.
`testcase`	Value, template, port and timer parameterization	Dynamic at run-time	all basic types and of all user-defined types, **`address`** type and **`template`**.
`signature`	Value and template parameterization	Dynamic at run-time	all basic types, all user-defined types and **`address`** type and **`component`** type.
NOTE – Record of, set of, enumerated, port, component and sub-type definitions do not allow parameterization.			

5.4.1 Formal parameters

TTCN-3 modules, structured types, templates, functions, altsteps, testcases and signatures may be defined incompletely, i.e., some entities (variables, templates, ports, timers, etc.) used by the above objects may not be resolved in the definition of the object. These objects are called parameterized objects. Formal entities replacing the unresolved entities in the parameterized object's definition are called formal parameters.

Formal parameters of parameterized templates, functions, altsteps, testcases, signatures and type definitions are defined in formal parameter lists. Formal parameters of modules are defined in module parameter definitions (see clause 8.2.1).

Formal parameters shall be **`in`**, **`inout`** or **`out`** parameters (see definitions in clause 3.1). If not stated otherwise, a formal parameter is an **`in`** parameter. For all these three sorts of parameter passing, the actual parameters can both be read and set (i.e., get new values being assigned) within the parameterized object.

NOTE 1 – Although **`out`** parameters can be read within the parameterized object, they do not inherit the value of their actual parameter; i.e., they should be set before they are read.

NOTE 2 – Although there is no restriction to set formal parameters inside **`type`**s, **`template`**s and **`signature`**s, there is only an indirect way of doing this by passing the formal parameter of, e.g., a template to an **`inout`** formal parameter of a function.

5.4.1.1 Formal parameters of kind value

Values of all basic types, all user-defined types, address type, component type, and default can be passed as value parameters.

Syntactical Structure

```
[ ( in | inout | out ) ] Type ValueParIdentifier
```

Semantic Description

Value formal parameters can be used within the parameterized object the same way as values, for example in expressions.

Value formal parameters may be in, inout or out parameters. The default for value formal parameters is **`in`** parameterization which may optionally be denoted by the keyword **`in`**. Using of inout or out kind of parameterization shall be specified by the keywords **`inout`** or **`out`** respectively.

TTCN-3 supports value parameterization according to the following rules:

- the language element **`module`** allows *static* value parameterization to support test suite parameters, i.e., this parameterization may or may not be resolvable at compile-time but shall be resolved by the commencement of run-time (i.e., *static* at run-time). This means that, at run-time, module parameter values are globally visible but not changeable (see more details in clause 8.2);
- user-defined **`type`** definitions (in particular structured type definitions **`record`** and **`set`**), and the special configuration type **`address`** support *static* value parameterization i.e., this parameterization shall be resolved at compile-time;
- the language elements **`template`**, **`signature`**, **`testcase,`** **`altstep`** and **`function`** support *dynamic* value parameterization (i.e., this parameterization shall be resolved at run-time).

NOTE – Component and default references are also handled as value parameters. In the case of component references, the corresponding component type is the type of the formal parameter. In the case of default references the TTCN-3 type **`default`** is the type of the formal parameter.

Restrictions

a) Language elements which cannot be parameterized are: `const, var, timer, control, record of, set of, enumerated, port, component` and `sub-type definitions, group` and `import.`

b) Formal value parameters of `types`, of `templates,` of `functions` started as test component behaviour (see clause 21.2.2) and of `altsteps` activated as defaults (see clause 20.5.2) shall always be `in` parameters.

c) Restrictions on module parameters are given in clause 8.2.

Examples

EXAMPLE 1: In, out and inout formal parameters.

```
function MyFunction1(in boolean MyReferenceParameter){ … };
// MyReferenceParameter is an in value parameter. The parameter can be read. It can also be set
// within the function, however, the assignment is local to the function only

function MyFunction2(inout boolean MyReferenceParameter){ … };
// MyReferenceParameter is an inout value parameter. The parameter can be read and set
// within the function - the assignment is not local

function MyFunction3(out template boolean MyReferenceParameter){ … };
// MyReferenceParameter is an out value parameter. The parameter can be set within the function,
// the assignment is not local. It can also be read, but only after it has been set.
```

EXAMPLE 2: Reading and setting parameters.

```
type record MyMessage {
  integer f1,
  integer f2
}

template MyMessage t_MyMessage (integer p_int) := {
  f1 := f_mult2 (p_int),
    // parameter p_int is passed on; as the parameter of the called function f_mult2 is
    // defined as an inout parameter, it passes back the changed value for p_int,
  f2 := p_int
}

function f_mult2 (inout integer p_integer) return integer {
  p_integer := 2* p_integer;
    // the value of the formal parameter is changed; this new value is passed back when
    // f_mult2 completes
  return p_integer-1
}

testcase tc_01 () runs on MTC_PT {
...
  P1.send (t_MyMessage(5))
    // the value sent is { f1 := 9 , f2 := 10 }
...
}
```

5.4.1.2 Formal parameters of kind template

Template kind parameters are used to pass templates into parameterizable objects.

Syntactical Structure

```
[ ( in | inout | out ) ] template Type ValueParIdentifier
```

Semantic Description

Templates parameters can be defined for templates, functions, altsteps, and test cases.

To enable a parameterized object to accept templates or matching symbols as actual parameters, the extra keyword **template** shall be added before the type field of the corresponding formal parameter. This makes the parameter a template parameter and in effect extends the allowed actual parameters for the associated type to include the appropriate set of matching attributes (see Annex B) as well as the normal set of values.

Formal template parameters can be used within the parameterized object the same way as templates and template variables.

Formal template parameters may be in, inout or out parameters. The default for formal template parameters is **in** parameterization.

Restrictions

a) Only **function, testcase**, **altstep** and **template** definitions may have formal template parameters.

b) Formal template parameters of **templates**, of **function**s started as test component behaviour (see clause 21.2.2) and of **altstep**s activated as defaults (see clause 20.5.2) shall always be **in** parameters.

Examples

EXAMPLE 1: Template with template parameter.

```
  // The template
  template MyMessageType MyTemplate (template integer MyFormalParam):=
  {   field1 := MyFormalParam,
      field2 := pattern "abc*xyz",
      field3 := true
  }

  // could be used as follows
  pco1.receive(MyTemplate(?));
  // Or as follows
  pco1.receive(MyTemplate(omit)); // provided that field1 is declared in MyMessageType as optional
```

EXAMPLE 2: Function with template parameter.

```
function MyBehaviour(template MyMsgType MyFormalParameter)
runs on MyComponentType
{     :
    pco1.receive(MyFormalParameter);
      :
}
```

5.4.1.3 Formal parameters of kind timer

Functions and altsteps can be parameterized with timers.

Syntactical Structure

```
[ inout ] timer TimerParIdentifier
```

Semantic Description

Timers passed into a parameterized object are known inside the behaviour definition of that object. Timer parameters can be used within the parameterized object like any other timer, i.e., they need not to be declared inside the parameterized object.

Timer parameters shall preserve their current state, i.e., only the timer is made known within the parameterized object. For example, also a started timer continues to run, i.e., it is not stopped implicitly. Thereby, possible timeout events can be handled inside the function or altstep to which the timer is passed.

Formal timer parameters are identified by the keyword **`timer`**.

Restrictions

a) Formal timer parameters shall be inout parameters, which can optionally be indicated by the keyword **`inout`**.

b) Only **`function`** – with the exception of functions started as test component behaviour (see clause 21.2.2) – and **`altstep`** definitions may have formal timer parameters.

Examples

```
// Function definition with a timer in the formal parameter list
function MyBehaviour (timer MyTimer)
{   :
    MyTimer.start;
    :
}

// could be used as follows
function MyBehaviour2 ()
{   :
    timer t;
    MyBehaviour(t);
    :
}
```

5.4.1.4 Formal parameters of kind port

Functions and altsteps can be parameterized with ports.

Syntactical Structure

```
[ inout ] PortTypeIdentifier PortParIdentifier
```

Semantic Description

Ports passed into a parameterized object are known inside the behaviour definition of that object. Port parameters can be used within the parameterized object like any other port, i.e., they need not to be made visible by a **`runs on`** clause.

Ports passed in as parameters shall preserve their current state, only the port is made known within the parameterized object's body. For example, a started port continues to send/receive messages, i.e., it is not stopped implicitly; thereby, possible port events can be handled inside the function or altstep to which the port is passed to.

Formal port parameters are identified by the keyword **`port`**.

Restrictions

a) Formal port parameters shall be inout parameters, which can optionally be indicated by the keyword **`inout`**.

b) Only **`function`** – with the exception of functions started as test component behaviour (see clause 21.2.2) – and **`altstep`** definitions may have formal port parameters.

Examples

```
    // Altstep definition with a port in the formal parameter list
    altstep MyBehaviour (MyPortType MyPort)
    {   :
        [] MyPort.receive { setverdict(fail); stop; }
        :
    }
```

5.4.2 Actual parameters

Values, templates, timers and/or ports can be passed into parameterized TTCN-3 objects as actual parameters.

Syntactical Structure

```
   Expression |            // for value parameter
   TemplateInstance |      // for template parameter
   TimerRef |              // for timer parameter
   Port                    // for port parameter
```

Semantic Description

Actual parameters that are passed by value to **`in`** formal value parameters shall be variables, literal values, module parameters, (external) constants, variables, value returning (external) functions, formal value parameters (of in, inout or out parameterization) of the current scope or expressions composed of the above.

Actual parameters that are passed to **`inout`** or **`out`** formal value parameters shall be variables or formal value parameters (of in, inout or out parameterization).

Actual parameters that are passed to **`in`** formal template parameters shall be literal values, module parameters, (external) constants, variables, value or template returning (external) functions, formal value parameters (of in, inout or out parameterization) of the current scope or expressions composed of the above, as well as templates, template variables or formal template parameters (of in, inout or out parameterization) of the current scope.

Actual parameters that are passed to **`inout`** or **`out`** formal template parameters shall be variables, template variables, formal value or template parameters (of in, inout or out parameterization) of the current scope.

Actual parameters that are passed to formal timer parameters shall be component timers, local timers or formal timer parameters of the current scope.

Actual parameters that are passed to formal port parameters shall be component ports or formal port parameters of the current scope.

Restrictions

a) The number of elements and the order in which they appear in an actual parameter list shall be the same as the number of elements and their order in which they appear in the corresponding formal parameter list. Furthermore, the type of each actual parameter shall be compatible with the type of each corresponding formal parameter.

b) All parameterized entities specified as an actual parameter shall have their own parameters resolved in the top-level actual parameter list.

c) If the formal parameter list of TTCN-3 objects **`function`**, **`testcase`**, **`signature, altstep`** or **`external function`** is empty, then the empty parentheses shall be included both in the declaration and in the invocation of that object. In all other cases the empty parentheses shall be omitted.

d) Restrictions on the use of signature parameters are given in clauses 15.2 and 22.3.

e) Restrictions on parameters passed to altsteps are given in clauses 16.2.1 and 20.5.2.

Examples

EXAMPLE 1: Formal and actual parameter lists have to match.

```
// A function definition with a formal parameter list
function MyFunction(integer FormalPar1, boolean FormalPar2, bitstring FormalPar3) { … }

// A function call with an actual parameter list
MyFunction(123, true,'1100'B);
```

EXAMPLE 2: In parameters.

```
function MyFunction(in template MyTemplateType MyValueParameter){ … };
// MyValueParameter is in parameter, the in keyword is optional

// A function call with an actual parameter
MyFunction(MyGlobalTemplate);
```

EXAMPLE 3: Inout and out parameters.

```
function MyFunction(inout boolean MyReferenceParameter){ … };
// MyReferenceParameter is an inout parameter, the inout keyword is
// mandatory

// A function call with an actual parameter
MyFunction(MyBooleanVariable);
// The actual parameter can be read and set within the function


function MyFunction(out template boolean MyReferenceParameter){ … };
// MyReferenceParameter is an inout parameter, the inout keyword is
// mandatory

// A function call with an actual parameter
MyFunction(MyBooleanVariable);
// The actual parameter is initially unbound, but can be set and read within the function.
```

EXAMPLE 4: Empty parameter lists.

```
// A function definition with an empty parameter list shall be written as
function MyFunction(){ … }

// and shall be called as
MyFunction();


// A record definition with an empty parameter list shall be written as
type record MyRecord { … }
```

```
// and shall be used as
template MyRecord Mytemplate := { … }
```

EXAMPLE 5: Nested parameter lists.

```
// Given the message definition
type record MyMessageType
{
    integer     field1,
    charstring  field2,
    boolean     field3
}

// A message template might be
template MyMessageType MyTemplate(integer MyValue) :=
{
    field1 := MyValue,
    field2 := pattern "abc*xyz",
    field3 := true
}

// A test case parameterized with a template might be
testcase TC001(template MyMessageType RxMsg) runs on PTC1 system TS1 {
    :
    MyPCO.receive(RxMsg);
}

// When the test case is called in the control part and the parameterized template is
// passed as an actual parameter, the template's actual parameters must be provided
control
{   :
    execute( TC001(MyTemplate(7)));
    :
}
```

6 Types and values

TTCN-3 supports a number of predefined basic types. These basic types include ones normally associated with a programming language, such as **`integer`**, **`boolean`** and string types, as well as some TTCN-3 specific ones such as **`verdicttype`**. Structured types such as **`record`** types, **`set`** types and **`enumerated`** types can be constructed from these basic types.

The special data type **`anytype`** is defined as the union of all known data types and the address type within a module.

Special types associated with test configurations such as **`address`**, **`port`** and **`component`** may be used to define the architecture of the test system (see clause 21).

The special type **`default`** may be used for the default handling (see clause 20.5).

The TTCN-3 types are summarized in Table 3.

Table 3 – Overview of TTCN-3 types

Class of type	Keyword	Sub-type
Simple basic types	`integer`	range, list
	`float`	range, list
	`boolean`	list
	`verdicttype`	list
Basic string types	`bitstring`	list, length
	`hexstring`	list, length
	`octetstring`	list, length
	`charstring`	range, list, length, pattern
	`universal charstring`	range, list, length, pattern
Structured types	`record`	list (see Note)
	`record of`	list (see Note), length
	`set`	list (see Note)
	`set of`	list (see Note), length
	`enumerated`	list (see Note)
	`union`	list (see Note)
Special data types	`anytype`	list (see Note)
Special configuration types	`address`	
	`port`	
	`component`	
Special default types	`default`	
NOTE – List subtyping of these types is possible when defining a new constrained type from an already existing parent type but not directly at the declaration of the first parent type.		

6.1 Basic types and values

6.1.0 Simple basic types and values

TTCN-3 supports the following basic types:

a) **`integer`:** a type with distinguished values which are the positive and negative whole numbers, including zero.

   Values of integer type shall be denoted by one or more digits; the first digit shall not be zero unless the value is 0; the value zero shall be represented by a single zero.

b) **`float`:** a type to describe floating-point numbers.

   In general, floating point numbers can be defined as: $<mantissa> \times <base>^{<exponent>}$,

   where *<mantissa>* is a positive or negative integer, *<base>* a positive integer (in most cases 2, 10 or 16) and *<exponent>* a positive or negative integer.

In TTCN-3, the floating-point number value notation is restricted to a base with the value of 10. Floating point values can be expressed by using two forms of value notations:

– the decimal notation with a dot in a sequence of numbers like, 1.23 (which represents 123×10^{-2}), 2.783 (i.e., 2783×10^{-3}) or −123.456789 (which represents $-123\,456\,789 \times 10^{-6}$); or

– by two numbers separated by E where the first number specifies the mantissa and the second specifies the exponent, for example 12.3E4 (which represents 123×10^{3}) or −12.3E-4 (which represents -123×10^{-5}).

NOTE – In contrast to the general definition of float values, the mantissa of the TTCN-3 value notation, beside integers, allows decimal numbers as well.

c) **`boolean`**: a type consisting of two distinguished values.

Values of boolean type shall be denoted by **`true`** and **`false`**.

d) **`verdicttype`**: a type for use with test verdicts consisting of five distinguished values. Values of **`verdicttype`** shall be denoted by **`pass`**, **`fail`**, **`inconc`**, **`none`** and **`error`**.

6.1.1 Basic string types and values

TTCN-3 supports the following basic string types:

NOTE 1 – The general term string or string type in TTCN-3 refers to **`bitstring`**, **`hexstring`**, **`octetstring`**, **`charstring`** and **`universal charstring`**.

a) **`bitstring`**: a type whose distinguished values are the ordered sequences of zero, one, or more bits.

Values of type **`bitstring`** shall be denoted by an arbitrary number (possibly zero) of the bit digits: 0 1, preceded by a single quote (') and followed by the pair of characters 'B.

EXAMPLE 1: `'01101'B.`

b) **`hexstring`**: a type whose distinguished values are the ordered sequences of zero, one, or more hexadecimal digits, each corresponding to an ordered sequence of four bits.

Values of type **`hexstring`** shall be denoted by an arbitrary number (possibly zero) of the hexadecimal digits (uppercase and lowercase letters can equally be used as hex digits):

0 1 2 3 4 5 6 7 8 9 a b c d e f A B C D E F

preceded by a single quote (') and followed by the pair of characters 'H; each hexadecimal digit is used to denote the value of a semi-octet using a hexadecimal representation.

EXAMPLE 2:
```
'AB01D'H
'ab01d'H
'Ab01D'H
```

c) **`octetstring`**: a type whose distinguished values are the ordered sequences of zero or a positive even number of hexadecimal digits (every pair of digits corresponding to an ordered sequence of eight bits).

Values of type **`octetstring`** shall be denoted by an arbitrary, but even, number (possibly zero) of the hexadecimal digits (uppercase and lowercase letters can equally be used as hex digits):

0 1 2 3 4 5 6 7 8 9 a b c d e f A B C D E F

preceded by a single quote (') and followed by the pair of characters `'O`; each hexadecimal digit is used to denote the value of a semi-octet using a hexadecimal representation.

EXAMPLE 3:
```
'FF96'O
'ff96'O
'Ff96'O
```

d) `charstring`: are types whose distinguished values are zero, one, or more characters of the version of [ITU-T T.50] complying with the International Reference Version (IRV) as specified in clause 8.2 of [ITU-T T.50].

NOTE 2 – The International Reference Alphabet (former International Alphabet No. 5 – IA5), described in [ITU-T T.50] is equivalent to the IRV version of ISO/IEC 646.

Values of `charstring` type shall be denoted by an arbitrary number (possibly zero) of characters from the relevant character set, preceded and followed by double quote (") or calculated using the predefined conversion function int2char with the positive integer value of their encoding as argument (see clause C.1).

NOTE 3 – The predefined conversion function is able to return single-character-length values only.

In cases where it is necessary to define strings that include the character double quote (") the character is represented by a pair of double quotes on the same line with no intervening space characters.

EXAMPLE 4: `""abcd""` represents the literal string `"abcd"`.

e) The character string type preceded by the keyword `universal` denotes types whose distinguished values are zero, one, or more characters from [ISO/IEC 10646].

`universal charstring` values can also be denoted by an arbitrary number (possibly zero) of characters from the relevant character set, preceded and followed by double quote ("), calculated using a predefined conversion function (see clause C.2) with the positive integer value of their encoding as argument or by a "quadruple".

NOTE 4 – The predefined conversion function is able to return single-character-length values only.

In cases where it is necessary to define strings that include the character double quote (") the character is represented by a pair of double quotes on the same line with no intervening space characters.

The "quadruple" is only capable of denoting a single character and denotes the character by the decimal values of its group, plane, row and cell according to [ISO/IEC 10646], preceded by the keyword `char` included into a pair of brackets and separated by commas (e.g., `char` (0, 0, 1, 113) denotes the Hungarian character "ű"). In cases where it is necessary to denote the character double quote (") in a string assigned according to the first method (within double quotes), the character is represented by a pair of double quotes on the same line with no intervening space characters. The two methods may be mixed within a single notation for a string value by using the concatenation operator.

EXAMPLE 5: The assignment: "the Braille character" & **char** (0, 0, 40, 48) & "looks like this" represents the literal string: the Braille character ⠰ looks like this.

NOTE 5 – Control characters can be denoted by using the predefined conversion function or the quadruple form.

By default, `universal charstring` shall conform to the UCS-4 coded representation form specified in clause 14.2 of [ISO/IEC 10646].

NOTE 6 – UCS-4 is an encoding format, which represents any UCS character on a fixed, 32 bit-length field.

This default encoding can be overridden using the defined variant attributes (see clause 27.5). The following useful character string types utf8string, bmpstring, utf16string and iso8859string using these attributes are defined in Annex D.

6.1.1.1 Accessing individual string elements

Individual elements in a string type may be accessed using an array-like syntax. Only single elements of the string may be accessed.

Units of length of different string type elements are indicated in Table 4.

Indexing shall begin with the value zero (0).

EXAMPLE:

```
// Given
MyBitString := '11110111'B;
// Then doing
MyBitString[4] := '1'B;
// Results in the bitstring '11111111'B
```

6.1.2 Sub-typing of basic types

User-defined types shall be denoted by the keyword **`type`**. With user-defined types it is possible to create sub-types (such as lists, ranges and length restrictions) on basic types, structured types and anytype according to Table 3.

6.1.2.1 Lists of values

TTCN-3 permits the specification of a list of distinguished values of basic types, structured types and anytype as listed in Table 3. The values in the list shall be of the root type and shall be a true subset of the values defined by the root type. The subtype defined by this list restricts the allowed values of the subtype to those values in the list.

EXAMPLE:

```
type bitstring MyListOfBitStrings ('01'B, '10'B, '11'B);
type float pi (3.1415926);
type charstring MyStringList ("abcd", "rgy", "xyz");
type universal charstring SpecialLetters (char(0, 0, 1, 111), char(0, 0, 1, 112), char(0, 0, 1,
113));
```

6.1.2.2 Ranges

TTCN-3 permits the specification of range constraints for the types **`integer`**, **`charstring`**, **`universal charstring`** and **`float`** (or derivations of these types). For **`integer`** and **`float`**, the subtype defined by the range restricts the allowed values of the subtype to the values in the range including the lower boundary and the upper boundary. In the case of **`charstring`** and **`universal charstring`** types, the range restricts the allowed values for each separate character in the strings. The boundaries shall evaluate to valid character positions according to the coded character set table(s) of the type (e.g., the given position shall not be empty). Empty positions between the lower and the upper boundaries are not considered to be valid values of the specified range.

EXAMPLE 1:

```
type integer MyIntegerRange (0 .. 255);
type float piRange (3.14 .. 3142E-3);
```

EXAMPLE 2:

```
type charstring MyCharString ("a" .. "z");
// Defines a string type of any length with each character within the specified range
type universal charstring MyUCharString1 ("a" .. "z");
// Defines a string type of any length with each character within the range from a to z
// (character codes from 97 to 122), like "abxyz";
// strings containing any other character (including control characters), like
// "abc2" are disallowed.
type universal charstring MyUCharString2 (char(0, 0, 1, 111) .. char(0, 0, 1, 113));
// Defines a string type of any length with each character within the range specified using
// the quadruple notation
```

6.1.2.2.1 Infinite ranges

In order to specify an infinite integer or float range, the keyword **`infinity`** may be used instead of a value indicating that there is no lower or upper boundary. The upper boundary shall be greater than or equal to the lower boundary.

EXAMPLE:

```
type integer MyIntegerRange (-infinity .. -1); // All negative integer numbers
```

NOTE – The 'value' for infinity is implementation dependent. Use of this feature may lead to portability problems.

6.1.2.3 String length restrictions

TTCN-3 permits the specification of length restrictions on string types. The length boundaries are based on different units depending on the string type with which they are used. In all cases, these boundaries shall evaluate to non-negative **`integer`** values (or derived **`integer`** values).

EXAMPLE:

```
type bitstring MyByte length(8);                  // Exactly length 8
type bitstring MyByte length(8 .. 8);             // Exactly length 8
type bitstring MyNibbleToByte length(4 .. 8);     // Minimum length 4, maximum length 8
```

Table 4 specifies the units of length for different string types.

Table 4 – Units of length used in field length specifications

Type	Units of length
`bitstring`	bits
`hexstring`	hexadecimal digits
`octetstring`	octets
`character strings`	characters

For the upper bound the keyword **`infinity`** may also be used to indicate that there is no upper limit for the length. The upper boundary shall be greater than or equal to the lower boundary.

6.1.2.4 Pattern sub-typing of character string types

TTCN-3 allows using character patterns specified in clause B.1.5 to constrain permitted values of **`charstring`** and **`universal charstring`** types. The type constraint shall use the **`pattern`** keyword followed by a character pattern. All values denoted by the pattern shall be a true subset of the type being sub-typed.

NOTE – Pattern sub-typing can be seen as a special form of list constraint, where members of the list are not defined by listing specific character strings but via a mechanism generating elements of the list.

EXAMPLE:

```
type charstring MyString (pattern "abc*xyz");
  // all permitted values of MyString have prefix abc and postfix xyz

type universal charstring MyUString (pattern "*\r\n")
  // all permitted values of MyUString are terminated by CR/LF

type charstring MyString2 (pattern "abc?\q{0,0,1,113}");
  // causes an error because the character denoted by the quadruple {0,0,1,113} is not a
  // legal character of the TTCN-3 charstring type

type MyString MyString3 (pattern "d*xyz");
  // causes an error because the type MyString does not contain a value starting with the
  // character d
```

6.1.2.5 Mixing sub-typing mechanisms

6.1.2.5.1 Mixing patterns, lists and ranges

Within **`integer`** and **`float`** (or derivations of these types) sub-type definitions it is allowed to mix lists and ranges. Overlapping of different constraints is not an error.

EXAMPLE 1:

```
type integer MyIntegerRange (1, 2, 3, 10 .. 20, 99, 100);
```

Within **`charstring`** and **`universal charstring`** sub-type definitions it is not allowed to mix pattern, list or range constraints.

EXAMPLE 2:

```
type charstring MyCharStr0 ("gr", "xyz");
  // contains character strings gr and xyz;

type charstring MyCharStr1 ("a".."z");
  // contains character strings of arbitrary length containing characters a to z.

type charstring MyCharStr2 (pattern "[a-z]#(3,9)");
  // contains character strings of length from 3 to 9 characters containing characters a to z
```

6.1.2.5.2 Using length restriction with other constraints

Within **`bitstring`**, **`hexstring, octetstring`** sub-type definitions lists and length restriction may be mixed in the same sub-type definition.

Within **`charstring`** and **`universal charstring`** sub-type definitions it is allowed to add a length restriction to constraints containing list, range or pattern sub-typing in the same sub-type definition.

When mixed with other constraints the length restriction shall be the last element of the sub-type definition. The length restriction takes effect jointly with other sub-typing mechanisms (i.e., the value set of the type consists of the common subset of the value sets identified by the list, range or pattern sub-typing and the length restriction).

EXAMPLE:

```
type charstring MyCharStr5 ("gr", "xyz") length (1..9);
  // contains the character strings gr and xyz;

type charstring MyCharStr6 ("a".."z") length (3..9);
  // contains character strings of length from 3 to 9 characters and containing characters
  // a to z

type charstring MyCharStr7 (pattern "[a-z]#(3,9)") length (1..9);
  // contains character strings of length from 3 to 9 characters containing characters a to z

type charstring MyCharStr8 (pattern "[a-z]#(3,9)") length (1..8);
  // contains character strings of length from 3 to 8 characters containing characters a to z

type charstring MyCharStr9 (pattern "[a-z]#(1,8)") length (1..9);
  // contains any character strings of length from 1 to 8 characters containing characters
  // a to z

type charstring MyCharStr10 ("gr", "xyz") length (4);
  // contains no value (empty type).
```

6.2 Structured types and values

The **`type`** keyword is also used to specify structured types such as **`record`** types, **`record of`** types, **`set`** types, **`set of`** types, **`enumerated`** types and **`union`** types.

Values of these types may be given using an explicit assignment notation or a short-hand value list notation.

EXAMPLE 1:

```
const MyRecordType MyRecordValue:=                                  //assignment notation
{
    field1 := '11001'B,
    field2 := true,
    field3 := "A string"
}

// Or
const MyRecordType MyRecordValue:= {'11001'B, true, "A string"}      //value list notation
```

When specifying partial values (i.e., setting the value of only a subset of the fields of a structured variable) using the assignment notation only the fields to be assigned values must be specified. Fields not mentioned are implicitly left unspecified. It is also possible to leave fields explicitly unspecified using the not used symbol "-". Using the value list notation all fields in the structure shall be specified either with a value, the not used symbol "-" or the **omit** keyword.

EXAMPLE 2:

```
var MyRecordType MyVariable:=                               //assignment notation
{
    field1 := '11001'B,
    // field2 implicitly unspecified
    field3 := "A string"
}

// Or
var MyRecordType MyVariable:=                               //assignment notation
{
    field1 := '11001'B,
    field2 := -, // field2 explicitly unspecified
    field3 := "A string"
}

// Or
var MyRecordType MyVariable:= {'11001'B, -, "A string"}      //value list notation
```

It is not allowed to mix the two value notations in the same (immediate) context.

EXAMPLE 3:

```
// This is disallowed
const MyRecordType MyRecordValue:= {MyIntegerValue, field2 := true, "A string"}
```

In both the assignment notation and value list notation, optional fields shall be omitted by using the explicit **omit** value for the relevant field. The **omit** keyword shall not be used for mandatory fields. When re-assigning a previously initialized value, using the not used symbol or skipping a field in assignment notation will cause the relevant fields to remain unchanged.

EXAMPLE 4:

```
var MyRecordType MyVariable :=
{
    field1 := '111'B,
    field2 := false,
    field3 := -
}

MyVariable := { '10111'B, -, - };
// after this, MyVariable contains { '10111'B, false /* unchanged */, <undefined> }

MyVariable :=
{
    field2 := true
}
// after this, MyVariable contains { '10111'B, true, <undefined> }

MyVariable :=
{
    field1 := -,
    field2 := false,
    field3 := -
}
// after this, MyVariable contains { '10111'B, false, <undefined> }
```

6.2.1 Record type and values

TTCN-3 supports ordered structured types known as **`record`**. The elements of a **`record`** type may be any of the basic types or user-defined data types (such as other records, sets or arrays). The values of a **`record`** shall be compatible with the types of the **`record`** fields. The element identifiers are local to the **`record`** and shall be unique within the **`record`** (but do not have to be globally unique). A constant that is of **`record`** type shall contain no variables or module parameters as field values, either directly or indirectly.

EXAMPLE 1:

```
    type record MyRecordType
    {
        integer             field1,
        MyOtherRecordType   field2 optional,
        charstring          field3
    }

    type record MyOtherRecordType
    {
        bitstring   field1,
        boolean     field2
    }
```

Records may be defined with no fields (i.e., as empty records).

EXAMPLE 2:

```
    type record MyEmptyRecord { }
```

A **`record`** value is assigned on an individual element basis. The order of field values in the value list notation shall be the same as the order of fields in the related type definition.

EXAMPLE 3:

```
    var integer MyIntegerValue := 1;

    const MyOtherRecordType MyOtherRecordValue:=
    {
        field1 := '11001'B,
        field2 := true
    }

    var MyRecordType MyRecordValue :=
    {
        field1 := MyIntegerValue,
        field2 := MyOtherRecordValue,
        field3 := "A string"
    }
```

The same value is specified with a value list.

EXAMPLE 4:

```
    MyRecordValue:= {MyIntegerValue, {'11001'B, true}, "A string"};
```

6.2.1.1 Referencing fields of a record type

Elements of a **`record`** shall be referenced by the dot notation *`TypeOrValueId.ElementId`*, where *`TypeOrValueId`* resolves to the name of a structured type or variable. ElementId shall resolve to the name of a field in a structured type.

EXAMPLE:

```
MyVar1 := MyRecord1.myElement1;
// If a record is nested within another type then the reference may look like this
MyVar2 := MyRecord1.myElement1.myElement2;
```

6.2.1.2 Optional elements in a record

Optional elements in a `record` shall be specified using the `optional` keyword.

EXAMPLE 1:

```
type record MyMessageType
{
    FieldType1  field1,
    FieldType2  field2  optional,
      :
    FieldTypeN  fieldN
}
```

Optional fields shall be omitted using the omit symbol.

EXAMPLE 2:

```
MyRecordValue:= {MyIntegerValue, omit , "A string"};

// Note that this is not the same as writing,
// MyRecordValue:= {MyIntegerValue, -, "A string"};
// which would mean the value of field2 is unchanged
```

6.2.1.3 Nested type definitions for field types

TTCN-3 supports the definition of types for record fields nested within the `record` definition. Both the definition of new structured types (`record`, `set`, `enumerated`, `set of` and `record of`) and the specification of subtype constraints are possible.

EXAMPLE:

```
    // record type with nested structured type definitions
    type record MyNestedRecordType
    {
        record
        {
            integer nestedField1,
            float   nestedField2
    } outerField1,
    enumerated {
            nestedEnum1,
            nestedEnum2
        } outerField2,
        record of boolean outerField3
}

// record type with nested sub-type definitions
type record MyRecordTypeWithSubtypedFields
{
        integer    field1 (1 .. 100),
        charstring field2 length ( 2 .. 255 )
}
```

6.2.2 Set type and values

TTCN-3 supports unordered structured types known as `set`. Set types and values are similar to records except that the ordering of the `set` fields is not significant.

EXAMPLE:

```
type set MySetType
{
    integer         field1,
    charstring      field2
}
```

The field identifiers are local to the set and shall be unique within the set (but do not have to be globally unique).

The value list notation for setting values shall not be used for values of **`set`** types.

6.2.2.1 Referencing fields of a set type

Elements of a **`set`** shall be referenced by the dot notation (see clause 6.2.1.1).

EXAMPLE:

```
MyVar3 := MySet1.myElement1;
// If a set is nested in another type then the reference may look like this
MyVar4 := MyRecord1.myElement1.myElement2;
// Note, that the set type, of which the field with the identifier 'myElement2' is referenced,
// is embedded in a record type
```

6.2.2.2 Optional elements in a set

Optional elements in a **`set`** shall be specified using the **`optional`** keyword.

6.2.2.3 Nested type definition for field types

TTCN-3 supports the definition of types for set fields nested within the **`set`** definition, similar to the mechanism for record types described in clause 6.2.1.3.

6.2.3 Records and sets of single types

TTCN-3 supports the specification of records and sets whose elements are all of the same type. These are denoted using the keyword **`of`**. These records and sets do not have element identifiers and can be considered similar to an ordered array and an unordered array respectively.

The **`length`** keyword followed by a value or a range within brackets and used between the **`record`** or **`set`** and the **`of`** keywords restricts the allowed lengths of the given **`record of`** or **`set of`** type.

NOTE 1 – A type restriction related to the innermost type is placed after the name of the newly defined type. Note that the innermost type cannot be a **`set of`** or **`record of`**. Type restrictions related to **`record of`** or **`set of`** types are placed between their **`record`**/**`set`** and **`of`** keywords.

EXAMPLE 1:

```
type record length(10) of integer MyRecordOfType; // is a record of exactly 10 integers

type record length(0..10) of integer MyRecordOfType; // is a record of a maximum of 10 integers

type record length(10..infinity) of integer MyRecordOfType; // record of at least 10 integers

type set of boolean MySetOfType; // is an unlimited set of boolean values

type record length(0..10) of charstring StringArray length(12);
// is a record of a maximum of 10 strings each with exactly 12 characters

type record of record of charstring StringArray length(12);
// is a two-dimensional unlimited array of strings each with exactly 12 characters

type set length(5) of set length(6) of charstring StringArray length(12);
// is an unordered two-dimensional array of the size 5*6 of strings each
// with exactly 12 characters
```

The value notation for **record of** and **set of** shall be a value list notation or an indexed notation for an individual element (the same value notation as for arrays, see clause 6.2.7). There is one exception from this general rule: in the case of defining modified templates, when the assignment notation is also allowed to be used (see clause 15.5).

When the value list notation is used, the first value in the list is assigned to the first element, the second list value is assigned to the second element, etc. No empty assignment is allowed (e.g., two commas, the second immediately following the first or only with white space between them). Elements to be left out of the assignment shall be explicitly skipped or omitted in the list.

Indexed value notations can be used on both the right-hand side and left-hand side of assignments. The index of the first element shall be zero and the index value shall not exceed the limitation placed by length subtyping. If the value of the element indicated by the index at the right-hand of an assignment is undefined, this shall cause a semantical or run-time error. If an indexing operator at the left-hand side of an assignment refers to a non-existent element, the value at the right-hand side is assigned to the element and all elements with an index smaller than the actual index and without assigned value are created with an undefined value. Undefined elements are permitted only in transient states (while the value remains invisible). Sending a **record of** value with undefined elements shall cause a dynamic testcase error.

EXAMPLE 2:

```
// Given
type record of integer MyRecordOf;
var integer MyVar;
var MyRecordOf MyRecordVar := { 0, 1, 2, 3, 4 };

MyVar := MyRecordVar[0]; // the first element of the "record of" value (integer 0)
                         // is assigned to MyVar

// Indexed values are permitted on the left-hand side of assignments as well:
MyRecordVar[1] := MyVar; // MyVar is assigned to the second element
                         // value of MyRecordVar is { 0, 0, 2, 3, 4 }

// The assignment
MyRecordVar := { 0, 1, -, 2, omit };
// will change the value of MyRecordVar to { 0, 1, 2 <unchanged>, 2};
// Note, that the 3rd element would be undefined if it had no previous assigned value.

// The assignment
MyRecordVar[6] := 6;

// will change the value of MyRecordVar to { 0, 1, 2 , 2, <undefined>,   <undefined>, 6 };
    // Note the 5th and 6th elements (with indexes 4 and 5) had no assigned value before this
// last assignment and are therefore undefined.
```

NOTE 2 – This makes it possible to copy **record of** values element by element in a for loop. For example, the function below reverses the elements of a **record of** value:

```
function reverse(in MyRecord src) return MyRecord
{
var MyRecord dest;
var integer I;
for(I := 0; I < sizeof(src); I:= I + 1) {
    dest[sizeof(src) - 1 - I] := src[I];
}
return dest;
}
```

Embedded **record of** and **set of** types will result in a data structure similar to multidimensional arrays (see clause 6.2.7).

EXAMPLE 3:

```
// Given
type record of integer MyBasicRecordOfType;
type record of MyBasicRecordOfType  MyRecordOfType;
```

```
// Then, the variable myRecordOfArray will have similar attributes to a two-dimensional array:
var MyRecordOfType myRecordOfArray;
// and reference to a particular element would look like this
// (value of the second element of the third 'MyBasicRecordOfType' construct)
myRecordOfArray [2][1] := 1;
```

6.2.3.1 Nested type definitions

TTCN-3 supports the definition of the aggregated type nested with the **`record of`** or **`set of`** definition. Both the definition of new structured types (**`record`**, **`set`**, **`enumerated`**, **`set of`** and **`record of`**) and the specification of subtype constraints are possible.

EXAMPLE:

```
type record of enumerated { red, green, blue } ColorList;
type record length (10) of record length (10) of integer Matrix;
type set of record { charstring id, charstring val } GenericParameters;
```

6.2.4 Enumerated type and values

TTCN-3 supports **`enumerated`** types. Enumerated types are used to model types that take only a distinct named set of values. Such distinct values are called enumerations. Each enumeration shall have an identifier. Operations on enumerated types shall only use these identifiers and are restricted to assignment, equivalence and ordering operators. Enumeration identifiers shall be unique within the enumerated type (but do not have to be globally unique) and are consequently visible within the context of the given type only. Enumeration identifiers shall only be reused within other structured type definitions and shall not be used for identifiers of local or global visibility at the same or a lower level of the same branch of the scope hierarchy (see scope hierarchy in clause 5.2).

EXAMPLE 1:

```
type enumerated MyFirstEnumType {
    Monday, Tuesday, Wednesday, Thursday, Friday
};

type integer Monday;
// This definition is illegal, as the name of the type has local or global visibility

type enumerated MySecondEnumType {
    Saturday, Sunday, Monday
};
// This definition is legal as it reuses the Monday enumeration identifier within
// a different enumerated type

type record MyRecordType {
    integer         Monday
};
// This definition is legal as it reuses the Monday enumeration identifier within
// a distinct structured type as identifier of a given field of this type

type record MyNewRecordType {
    MyFirstEnumType firstField,
    integer         secondField
};

var MyNewRecordType newRecordValue := { Monday, 0 }
// MyFirstEnumType is implicitly referenced via the firstField element of MyNewRecordType

const integer Monday := 7
// This definition is illegal as it reuses the Monday enumeration identifier for a
// different TTCN-3 object within the same scope unit
```

Each enumeration may optionally have an assigned integer value, which is defined after the name of the enumeration in parenthesis. Each assigned integer number shall be distinct within a single **`enumerated`** type. For each enumeration without an assigned integer value, the system successively associates an integer number in the textual order of the enumerations, starting at the left-hand side, beginning with zero, by step 1 and skipping any number occupied in any of the enumerations with a manually assigned value. These values are only used by the system to allow the use of relational operators.

NOTE 1 – The integer value also may be used by the system to encode/decode enumerated values. This, however is outside of the scope of this Recommendation (with the exception that TTCN-3 allows the association of encoding attributes to TTCN-3 items).

For any instantiation or value reference of an **enumerated** type, the given type shall be implicitly or explicitly referenced.

NOTE 2 – If the enumerated type is an element of a user-defined structured type, the enumerated type is implicitly referenced via the given element (i.e., by the identifier of the element or the position of the value in a value list notation) at value assignment, instantiation, etc.

EXAMPLE 2:

```
// Valid instantiations of MyFirstEnumType and MySecondEnumType would be
var MyFirstEnumType Today := Tuesday;
var MySecondEnumType Tomorrow := Monday;

// But the following statement is illegal because the two enumeration types are not compatible
Today := Tomorrow
```

6.2.5 Unions

TTCN-3 supports the **union** type. The **union** type is a collection of fields, each one identified by an identifier. Only one of the specified fields will ever be present in an actual union value. Union types are useful to model a structure which can take one of a finite number of known types.

EXAMPLE:

```
type union MyUnionType
{
    integer         number,
    charstring      string
};

// A valid instantiation of MyUnionType would be
var MyUnionType age, oneYearOlder;
var integer ageInMonths;

age.number := 34;       // value notation by referencing the field. Note, that this
                        // notation makes the given field to be the chosen one
oneYearOlder := {number := age.number+1};

ageInMonths := age.number * 12;
```

The value list notation for setting values shall not be used for values of **union** types.

6.2.5.1 Referencing fields of a union type

Fields of a **union** type shall be referenced by the dot notation (see clause 6.2.1.1).

EXAMPLE:

```
MyVar5 := MyUnion1.myChoice1;
// If a union type is nested in another type then the reference may look like this
MyVar6 := MyRecord1.myElement1.myChoice2;
// Note, that the union type, of which the field with the identifier 'myChoice2' is referenced,
// is embedded in a record type
```

6.2.5.2 Optionality and union

Optional fields are not allowed for the **union** type, which means that the **optional** keyword shall not be used with **union** types.

6.2.5.3 Nested type definition for field types

TTCN-3 supports the definition of types for union fields nested within the union definition, similar to the mechanism for record types described in clause 6.2.1.3.

6.2.6 The anytype

The special type **`anytype`** is defined as a shorthand for the union of all known data types and the address type in a TTCN-3 module. The definition of the term known types is given in clause 3.1, i.e., the anytype shall comprise all the known data types but not the port, component, and default types. The address type shall be included if it has been explicitly defined within that module.

The fieldnames of the **`anytype`** shall be uniquely identified by the corresponding type names.

NOTE 1 – As a result of this requirement, imported types with clashing names (either with an identifier of a definition in the importing module or with an identifier imported from a third module) cannot be reached via the anytype of the importing module.

EXAMPLE:

```
// A valid usage of anytype would be
var anytype MyVarOne, MyVarTwo;
var integer MyVarThree;

MyVarOne.integer := 34;
MyVarTwo := {integer := MyVarOne.integer + 1};

MyVarThree := MyVarOne.integer * 12;
```

The **`anytype`** is defined locally for each module and (like the other predefined types) cannot be directly imported by another module. However, a user-defined type of the type **`anytype`** can be imported by another module. The effect of this is that all types of that module are imported.

NOTE 2 – The user-defined type of **`anytype`** "contains" all types imported into the module where it is declared. Importing such a user-defined type into a module may cause side effects and hence due caution should be given to such cases.

6.2.7 Arrays

In common with many programming languages, arrays are not considered to be types in TTCN-3. Instead, they may be specified at the point of a variable declaration. Arrays may be declared as single or multi-dimensional. Array dimensions shall be specified using constant expressions, which shall evaluate to a positive **`integer`** value.

EXAMPLE 1:

```
var integer MyArray1[3];    // Instantiates an integer array of 3 elements with the index 0 to 2
var integer MyArray2[2][3]; // Instantiates a two-dimensional integer array of 2 × 3 elements
                               // with indexes from (0,0) to (1,2)
```

Array elements are accessed by means of the index notation (`[]`), which must specify a valid index within the array's range. Individual elements of multi-dimensional arrays can access by repeated use of the index notation. Accessing elements outside the array's range will cause a compile-time or test case error.

EXAMPLE 2:

```
MyArray1[1] := 5;
MyArray2[1][2] := 12;

MyArray1[4] := 12;    // ERROR: index must be between 0 and 2
MyArray2[3][2] := 15; // ERROR: first index must be 0 or 1
```

Array dimensions may also be specified using ranges. In such cases the lower and upper values of the range define the lower and upper index values.

EXAMPLE 3:

```
var integer MyArray3[1 .. 5];   // Instantiates an integer array of 5 elements
                                // with the index 1 to 5
MyArray3[1] := 10; // Lowest index
MyArray3[5] := 50; // Highest index

var integer MyArray4[1 .. 5][2 .. 3 ];  // Instantiates a two-dimensional integer array of
                                        // 5 × 2 elements with indexes from (1,2) to (5,3)
```

The values of array elements shall be compatible with the corresponding variable declaration. Values may be assigned individually by a value list notation or indexed notation or more than one or all at once by a value list notation. When the value list notation is used, the first value of the list is assigned to the first element of the array (the element with index 0), the second value to the second element, etc. Elements to be left out from the assignment shall be explicitly skipped or omitted in the list. For assigning values to multi-dimensional arrays, each dimension that is assigned shall resolve to a set of values enclosed in curly braces. When specifying values for multi-dimensional arrays, the leftmost dimension corresponds to the outermost structure of the value, and the rightmost dimension to the innermost structure. The use of array slices of multi-dimensional arrays, i.e., when the number of indexes of the array value is less than the number of dimensions in the corresponding array definition, is allowed. Indexes of array slices shall correspond to the dimensions of the array definition from left to right (i.e., the first index of the slice corresponds to the first dimension of the definition). Slice indexes shall conform to the related array definition dimensions.

EXAMPLE 4:

```
MyArray1[0]:= 10;
MyArray1[1]:= 20;
MyArray1[3]:= 30;

// or using a value list
MyArray1:= {10, 20, -, 30};

MyArray4:= {{1, 2}, {3, 4}, {5, 6}, {7, 8}, {9, 10}};
    // The array value is completely defined

var integer MyArray5[2][3][4] :=
{
  {
    {1, 2, 3, 4}, // assigns a value to MyArray5 slice [0][0]
    {5, 6, 7, 8}, // assigns a value to MyArray5 slice [0][1]
    {9, 10, 11, 12} // assigns a value to MyArray5 slice [0][2]
  }, // end assignments to MyArray5 slice [0]
  {
    {13, 14, 15, 16}, {17, 18, 19, 20}, {21, 22, 23, 24}
  } // assigns a value to MyArray5 slice [1]
};

MyArray4[2] := {20, 20};
    // yields {{1, 2}, {3, 4}, {20, 20}, {7, 8}, {9, 10}};
MyArray5[1] := { {0, 0, 0, 0}, {0, 0, 0, 0}, {0, 0, 0, 0}};
    // yields {{{1, 2, 3, 4}, {5, 6, 7, 8}, {9, 10, 11, 12}},
    //         {{0, 0, 0, 0}, {0, 0, 0, 0}, {0, 0, 0, 0}}};

MyArray5[0][2] := {3, 3, 3, 3};
    // yields {{{1, 2, 3, 4}, {5, 6, 7, 8}, {3, 3, 3, 3}},
    //         {{0, 0, 0, 0}, {0, 0, 0, 0}, {0, 0, 0, 0}}};

var integer MyArrayInvalid[2][2];
MyArrayInvalid := { 1, 2, 3, 4 }
    // invalid as the dimension of the value notation does not correspond to the dimensions
    // of the definition
MyArrayInvalid[2] := { 1, 2 }
    // invalid as the index of the slice should be 0 or 1
```

NOTE – An alternative way to use multi-dimensional data structures is via employing the record, record of, set or set of types.

EXAMPLE 5:

```
// Given
type record MyRecordType
{
    integer         field1,
    MyOtherStruct   field2,
    charstring      field3
}
// An array of MyRecordType could be
var MyRecordType myRecordArray[10];
// A reference to a particular element would look like this
myRecordArray[1].field1 := 1;
```

6.2.8 Recursive types

Where applicable, TTCN-3 type definitions may be recursive. The user, however, shall ensure that all type recursion is resolvable and that no infinite recursion occurs.

6.3 Type compatibility

Generally, TTCN-3 requires type compatibility of values at assignments, instantiations and comparison.

For the purpose of this clause the actual value to be assigned, passed as parameter, etc., is called value "b". The type of value "b" is called type "B". The type of the formal parameter, which is to obtain the actual value of value "b" is called type "A".

6.3.1 Type compatibility of non-structured types

For variables, constants, templates, etc. of simple basic types and bitsring, hexstring and octetstring types the value "b" is compatible to type "A" if type "B" resolves to the same root type as type "A" (e.g., **`integer`**) and it does not violate subtyping (e.g., ranges, length restrictions) of type "A".

EXAMPLE:

```
// Given
type integer MyInteger(1 .. 10);
:
var integer x;
var MyInteger y;

// Then
y := 5; // is a valid assignment

x := y;
// is a valid assignment, because y has the same root type as x and no subtyping is violated

x := 20; // is a valid assignment
y := x;
// is NOT a valid assignment, because the value of x is out of the range of MyInteger

x := 5; // is a valid assignment
y := x;
// is a valid assignment, because the value of x is now within the range of MyInteger

//Given
type charstring MyChar length (1);
type charstring MySingleChar length (1);
var MyChar myCharacter;
var charstring myCharString;
var MySingleChar mySingleCharString := "B";

//Then
myCharString := mySingleCharString;
//is a valid assignment as charstring restricted to length 1 is compatible with charstring.
myCharacter := mySingleCharString;
//is a valid assignment as two single-character-length charstrings are compatible.

//Given
myCharString := "abcd";

//Then
```

```
myCharacter := myCharString[1];
//is valid as the r.h.s. notation addresses a single element from the string

//Given
var charstring myCharacterArray [5] := {"A", "B", "C", "D", "E"}

//Then
myCharString := myCharacterArray[1];
//is valid and assigns the value "B" to myCharString;
```

For variables, constants, templates, etc. of **`charstring`** type, value 'b' is compatible with a **`universal charstring`** type 'A' unless it violates any type constraint specification (range, list or length) of type "A".

For variables, constants, templates etc. of **`universal charstring`** type, value 'b' is compatible with a **`charstring`** type 'A' if all characters used in value 'b' have their corresponding characters (i.e., the same control or graphical character using the same character code) in the type **`charstring`** and it does not violate any type constraint specification (range, list or length) of type "A".

6.3.2 Type compatibility of structured types

In the case of structured types (except the **`enumerated`** type) a value "b" of type "B" is compatible with type "A", if the effective value structures of type "B" and type "A" are compatible, in which case assignments, instantiations and comparisons are allowed.

6.3.2.1 Type compatibility of enumerated types

Enumerated types are never compatible with other basic or structured types (i.e., for enumerated types strong typing is required).

6.3.2.2 Type compatibility of record and record of types

For **`record`** types the effective value structures are compatible if the number, and optional aspect of the fields in the textual order of definition are identical, the types of each field are compatible and the value of each existing field of the value "b" is compatible with the type of its corresponding field in type "A". The value of each field in the value "b" is assigned to the corresponding field in the value of type "A".

EXAMPLE 1:

```
// Given
type record AType {
    integer     a(0..10)    optional,
    integer     b(0..10)    optional,
    boolean         c
}

type record BType {
    integer         a       optional,
    integer     b(0..10)    optional,
    boolean         c
}

type record CType {     // type with different field names
    integer         d   optional,
    integer         e   optional,
    boolean         f

}

type record DType {     // type with field c optional
    integer         a   optional,
    integer         b   optional,
    boolean         c   optional
}
```

```
type record EType {      // type with an extra field d
    integer         a   optional,
    integer         b   optional,
    boolean         c,
    float           d   optional
}

var AType MyVarA := { -, 1, true};
var BType MyVarB := { omit, 2, true};
var CType MyVarC := { 3, omit, true};
var DType MyVarD := { 4, 4, true};
var EType MyVarE := { 5, 5, true, omit};

// Then

MyVarA := MyVarB;    // is a valid assignment,
                     // value of MyVarA is ( a := <undefined>, b:= 2, c:= true)
MyVarC := MyVarB;    // is a valid assignment
                     // value of MyVarC is ( d := <undefined>, e:= 2, f:= true)
MyVarA := MyVarD;    // is NOT a valid assignment because the optionality of fields does not
                     // match
MyVarA := MyVarE;    // is NOT a valid assignment because the number of fields does not match

MyVarC := { d:= 20 };// actual value of MyVarC is { d:=20, e:=2,f:= true }
MyVarA := MyVarC     // is NOT a valid assignment because field 'd' of MyVarC violates subtyping
                     // of field 'a' of AType
```

For **record of** types and arrays, the effective value structures are compatible if their component types are compatible and value "b" of type "B" does not violate any length subtyping of the **record of** type or dimension of the array of type "A". Values of elements of the value "b" shall be assigned sequentially to the instance of type "A", including undefined elements.

record of types and single-dimension arrays are compatible with **record** types if their effective value structures are compatible and the number of elements of value "b" of the **record of** type "B" or the dimension of array "b" is exactly the same as the number of elements of the **record** type "A". Optionality of the **record** type fields has no importance when determining compatibility, i.e., it does not affect the counting of fields (which means that optional fields shall always be included in the count). Assignment of the element values of the **record of** type or array to the instance of a **record** type shall be in the textual order of the corresponding **record** type definition, including undefined elements. If an element with an undefined value is assigned to an optional element of the **record**, this will cause the optional element to be omitted. An attempt to assign an element with undefined value to a mandatory element of the **record** shall cause an error.

NOTE – If the **record of** type has no length restriction or the length restriction exceeds the number of elements of the compared **record** type and the index of any defined element of the **record of** value is less than or equal to the number of elements of the **record** type minus one, then the compatibility requirement is always fulfilled.

Values of a **record** type can also be assigned to an instance of a **record of** type or a single-dimension array if no length restriction of the **record of** type is violated or the dimension of the array is more than or equal to the number of elements of the **record** type. Optional elements missing in the **record** value shall be assigned as elements with undefined values.

EXAMPLE 2:

```
// Given
type record HType {
    integer a,
    integer b optional,
    integer c
}

type record of integer IType

var HType MyVarH := { 1, omit, 2};
var IType MyVarI;
var integer MyArrayVar[2];
```

```
// Then

MyArrayVar := MyVarH;
// is a valid assignment as type of MyArrayVar and HType are compatible

MyVarI := MyVarH;
// is a valid assignment as the types are compatible and no subtyping is violated

MyVarI := { 3, 4 };
MyVarH := MyVarI;
// is NOT a valid assignment as the mandatory field 'c' of Htype receives no value
```

6.3.2.3 Type compatibility of set and set of types

set types are only type compatible with other **set** types and **set of** types. For **set** types and for **set of** types the same compatibility rules shall apply as to **record** and **record of** types.

NOTE 1 – This implies that though the order of elements at sending and receipt is unknown, when determining type compatibility for **set** types, the textual order of the fields in the type definition is decisive.

NOTE 2 – In **set** values the order of fields may be arbitrary, however this does not effect type compatibility as field names unambiguously identify which fields of the related **set** type correspond to which **set** value fields.

EXAMPLE:

```
// Given
type set FType {
    integer a   optional,
    integer b   optional,
    boolean c
}

type set GType {
    integer d   optional,
    integer e   optional,
    boolean f
}

var FType MyVarF := { a:=1, c:=true };
var GType MyVarG := { f:=true, d:=7};

// Then

MyVarF := MyVarG;   // is a valid assignment as types FType and GType are compatible

MyVarF := MyVarA;   // is NOT a valid assignment as MyVarA is a record type
```

6.3.2.4 Compatibility between sub-structures

The rules defined in this clause for structured types compatibility are also valid for the sub-structure of such types.

EXAMPLE:

```
// Given
type record JType {
    HType   H,
    integer b optional,
    integer c
}

var JType MyVarJ

// If considering the declarations above, then


MyVarJ.H := MyVarH;
// is a valid assignment as the type of field H of JType and HType are compatible

MyVarI := MyVarJ.H;
// is a valid assignment as IType and the type of field H of JType are compatible
```

6.3.3 Type compatibility of component types

Type compatibility of component types has to be considered in two different conditions:

1) Compatibility of a component reference value with a component type (e.g., when passing a component reference as an actual parameter to a function or an altstep or when assigning a component reference value to a variable of different component type): a component reference "b" of component type "B" is compatible with component type "A" if all definitions of "A" have identical definitions in "B".
2) Runs on compatibility: a function or altsteps referring to component type "A" in its runs on clause may be called or started on a component instance of type 'B' if all the definitions of "A" have identical definitions in "B".

Identity of definitions in "A" with definitions of "B" is determined based on the following rules:

a) For port instances, both the type and the identifier shall be identical.
b) For timer instances, identifiers shall be identical and either both shall have identical initial durations or both shall have no initial duration.
c) For variable instances and constant definitions, the identifiers, the types and initialization values shall be identical (in case of variables, this means that either missing in both definitions or be the same).
d) For local template definitions, the identifiers, the types, the formal parameter lists and the assigned template or template field values shall be identical.

6.3.4 Type compatibility of communication operations

The communication operations (see clause 22) **`send`**, **`receive`**, **`trigger`**, **`call`**, **`getcall`**, **`reply`**, **`getreply`** and **`raise`** are exceptions to the weaker rule of type compatibility and require strong typing. The types of values or templates directly used as parameters to these operations must also be explicitly defined in the associated port type definition. Strong typing also applies to storing the received value, address or component reference during a **`receive`** or **`trigger`** operation.

6.3.5 Type conversion

If it is necessary to convert values of one type to values of another type, where the types are not derived from the same root type, then either one of the predefined conversion functions defined in Annex C or a user-defined function shall be used.

EXAMPLE:

```
// To convert an integer value to a hexstring value use the predefined function int2hex
MyHstring := int2hex(123, 4);
```

7 Expressions

TTCN-3 allows the specification of expressions using the operators defined in clause 7.1.

Syntactical Structure

```
SingleExpression |
"{" { ( FieldReference ":=" ( Expression | "-" ) ) [","] } "}" | // compound expression
"{" [ { ( Expression | "-" ) [","] } ] "}"                        // compound expression
```

Semantic Description

Expressions are built from other (simple) expressions. Functions used in expressions shall be value-returning functions. The result of an expression shall be the value of a specific type and the operators used shall be compatible with the type of the operands.

Compound expressions are used for expressions of array, record, record of and set of types.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
    (x + y - increment(z))*3            // single expression
    { a:= 1, b:= true }                 // compound expression, field expression list
    { 1, true }                         // compound expression, value list
```

7.1 Operators

TTCN-3 supports a number of predefined operators that may be used in the terms of TTCN-3 expressions. The predefined operators fall into seven categories:

a) arithmetic operators;

b) string operators;

c) relational operators;

d) logical operators;

e) bitwise operators;

f) shift operators;

g) rotate operators.

These operators are listed in Table 5.

Table 5 – List of TTCN-3 operators

Category	Operator	Symbol or Keyword
Arithmetic operators	addition	+
	subtraction	-
	multiplication	*
	division	/
	modulo	mod
	remainder	rem
String operators	concatenation	&
Relational operators	equal	==
	less than	<
	greater than	>
	not equal	!=
	greater than or equal	>=
	less than or equal	<=
Logical operators	logical not	not
	logical and	and
	logical or	or
	logical xor	xor

Table 5 – List of TTCN-3 operators

Category	Operator	Symbol or Keyword
Bitwise operators	bitwise not	not4b
	bitwise and	and4b
	bitwise or	or4b
	bitwise xor	xor4b
Shift operators	shift left	<<
	shift right	>>
Rotate operators	rotate left	<@
	rotate right	@>

The precedence of these operators is shown in Table 6. Within any row in this table, the listed operators have equal precedence. If more than one operator of equal precedence appears in an expression, the operations are evaluated from left to right. Parentheses may be used to group operands in expressions, in which case a parenthesized expression has the highest precedence for evaluation.

Table 6 – Precedence of operators

Priority	Operator type	Operator
highest		**(…)**
	Unary	+, -
	Binary	*, /, **mod**, **rem**
	Binary	+, -, **&**
	Unary	**not4b**
	Binary	**and4b**
	Binary	**xor4b**
	Binary	**or4b**
	Binary	<<, >>, <@, @>
	Binary	<, >, <=, >=
	Binary	==, !=
	Unary	**not**
	Binary	**and**
	Binary	**xor**
Lowest	Binary	**or**

7.1.1 Arithmetic operators

The arithmetic operators represent the operations of addition, subtraction, multiplication, division, modulo and remainder. Operands of these operators shall be of type `integer` (including derivations of `integer`) or `float` (including derivations of `float`), except for `mod` and `rem` which shall be used with `integer` (including derivations of `integer`) types only.

With `integer` types, the result type of arithmetic operations is `integer`. With `float` types, the result type of arithmetic operations is `float`.

In the case where plus (+) or minus (-) is used as the unary operator, the rules for operands apply as well. The result of using the minus operator is the negative value of the operand if it was positive and vice versa.

The result of performing the division operation (/) on two:

a) **`integer`** values gives the whole **`integer`** part of the value resulting from dividing the first **`integer`** by the second (i.e., fractions are discarded);

b) **`float`** values gives the **`float`** value resulting from dividing the first **`float`** by the second (i.e., fractions are not discarded).

The operators **`rem`** and **`mod`** compute on operands of type **`integer`** and have a result of type **`integer`**. The operations `x` **`rem`** `y` and `x` **`mod`** `y` compute the rest that remains from an integer division of `x` by `y`. Therefore, they are only defined for non-zero operands `y`. For positive `x` and `y`, both `x` **`rem`** `y` and `x` **`mod`** `y` have the same result but for negative arguments they differ.

Formally, **`mod`** and **`rem`** are defined as follows:

```
x rem y = x - y * (x/y)
x mod y = x rem |y|            when    x >= 0
        = 0                    when    x < 0   and x rem |y| = 0
        = |y| + x rem |y|      when    x < 0   and x rem |y| < 0
```

Table 7 illustrates the difference between the **`mod`** and **`rem`** operator:

Table 7 – Effect of mod and rem operator

x	–3	–2	–1	0	1	2	3
x mod 3	0	1	2	0	1	2	0
x rem 3	0	–2	–1	0	1	2	0

7.1.2 String operators

The predefined string operators perform concatenation of values of compatible string types. The operation is a simple concatenation from left to right. No form of arithmetic addition is implied. The result type is the root type of the operands.

EXAMPLE:

```
'1111'B & '0000'B & '1111'B gives '111100001111'B
```

7.1.3 Relational operators

The predefined relational operators represent the relations of equality (`==`), less than (`<`), greater than (`>`), non-equality to (`!=`), greater than or equal to (`>=`) and less than or equal to (`<=`). Operands of equality and non-equality may be of arbitrary but compatible types with the exception of the **`enumerated`** type, in which case operands shall be instances of the same type. All other relational operators shall have only operands of type **`integer`** (including derivatives of **`integer`**), **`float`** (including derivations of **`float`**) or instances of the same **`enumerated`** types. The result type of these operations is **`boolean`**.

Two **`charstring`** or **`universal charstring`** values are equal only, if they have equal lengths and the characters at all positions are the same. For values of **`bitstring, hexstring`** or **`octetstring`** types, the same equality rule applies with the exception, that fractions which shall equal at all positions are bits, hexadecimal digits or pairs of hexadecimal digits accordingly.

Two **`record`** values, **`set`** values, **`record of`** values or **`set of`** values are equal if, and only if, their effective value structures are compatible (see clause 6.3) and the values of all corresponding fields are equal. **`record`** values may also be compared to **`record of`** values and **`set`** values to **`set of`** values. In these cases, the same rule applies as for comparing two **`record`** or **`set`** values.

NOTE – "All fields" means that optional fields not present in the actual value of a **`record`** type shall be taken as an undefined value. Such field can equal only to a missing optional field (also considered to be an undefined value) when compared with a value of another **record** type or to an element with undefined value when compared with a value of a **record of** type. This principle also applies when values of two **set** types or a **set** and a **set of** type are compared.

Two values of **union** types are equal if, and only if, in both values the types of the chosen fields are compatible and the actual values of the chosen fields are equal.

EXAMPLE:

```
// Given
type    set SetA    {
            integer     a1  optional,
            integer     a2  optional,
            integer     a3  optional
            };

type    set SetB    {
            integer     b1  optional,
            integer     b2  optional,
            integer     b3  optional
            };

type    set SetC    {
            integer     c1  optional,
            integer     c2  optional,
            };

type    set of integer  SetOf;

type    union   UniD    {
            integer     d1,
            integer     d2,
            };

type    union   UniE    {
            integer     e1,
            integer     e2,
            };

type    union   UniF    {
            integer     f1,
            integer     f2,
            boolean     f3,
            };

// And
const   SetA    conSetA1    :=  { a1 := 0, a2 := omit, a3 := 2 };
            // Notice that the order of defining values of the fields does not matter
const   SetB    conSetB1    :=  { b1 := 0, b3 := 2, b2 := omit };
const   SetB    conSetB2    :=  { b2 := 0, b3 := 2, b1 := omit };
const   SetC    conSetC1    :=  { c1 := 0, c2 :=2 };
const   SetOf   conSetOf1   :=  { 0, omit, 2 };
const   SetOf   conSetOf2   :=  { 0, 2 };
const   UniD    conUniD1    :=  { d1:= 0 };
const   UniE    conUniE1    :=  { e1:= 0 };
const   UniE    conUniE2;   :=  { e2:= 0 };
const   UniF    conUniF1;   :=  { f1:= 0 };

// Then
conSetA1 == conSetB1;
    // returns true
conSetA1 == conSetB2;
    // returns false, because neither a1 nor a2 are equal to their counterparts
    // ( the corresponding element is not omitted )
conSetA1 == conSetC1;
    // returns false, because the effective value structures of SetA and SetC are not compatible
conSetA1 == conSetOf1;
    // returns true
conSetA1 == conSetOf2;
    // returns false, as the counterpart of the omitted a2 is 2,
    // but the counterpart of a3 is undefined
conSetC1 == conSetOf2;
    // returns true
conUniD1 == conUniE1;
    // returns true
conUniD1 == conUniE2;
```

```
    // returns false, as the chosen field e2 is not the counterpart of the field d1 of UniD1
conUniD1 == conUniF1;
    // returns false, as the effective value structures of UniD1 and UniF are not compatible
```

7.1.4 Logical operators

The predefined **boolean** operators perform the operations of negation, logical **and**, logical **or** and logical **xor**. Their operands shall be of type **boolean**. The result type of logical operations is **boolean**.

The logical **not** is the unary operator that returns the value **true** if its operand was of value **false** and returns the value **false** if the operand was of value **true**.

The logical **and** returns the value **true** if both its operands are **true**; otherwise it returns the value **false**.

The logical **or** returns the value **true** if at least one of its operands is **true**; it returns the value **false** only if both operands are **false**.

The logical **xor** returns the value **true** if one of its operands is **true**; it returns the value **false** if both operands are **false** or if both operands are **true**.

Short circuit evaluation for boolean expressions is used, i.e., the evaluation of operands of logical operators is stopped once the overall result is known: in the case of the **and** operator, if the left argument evaluates to **false**, then the right argument is not evaluated and the whole expression evaluates to **false**. In the case of the **or** operator, if the left argument evaluates to **true**, then the right argument is not evaluated and the whole expression evaluates to **true**.

7.1.5 Bitwise operators

The predefined bitwise operators perform the operations of bitwise **not**, bitwise **and**, bitwise **or** and bitwise **xor**. These operators are known as **not4b**, **and4b**, **or4b** and **xor4b** respectively.

NOTE – To be read as "not for bit", "and for bit", etc.

Their operands shall be of type **bitstring, hexstring** or **octetstring**. In the case of **and4b, or4b** and **xor4b** the operands shall be of compatible types. The result type of the bitwise operators shall be the root type of the operands.

The bitwise **not4b** unary operator inverts the individual bit values of its operand. For each bit in the operanda, 1-bit is set to 0 and a 0-bit is set to 1. That is:

```
not4b '1'B  gives  '0'B
not4b '0'B  gives  '1'B
```

EXAMPLE 1:

```
not4b '1010'B  gives  '0101'B
not4b '1A5'H  gives 'E5A'H
not4b '01A5'O  gives 'FE5A'O
```

The bitwise **and4b** operator accepts two operands of equal length. For each corresponding bit position, the resulting value is a 1 if both bits are set to 1, otherwise the value for the resulting bit is 0. That is:

```
'1'B and4b '1'B  gives  '1'B
'1'B and4b '0'B  gives  '0'B
'0'B and4b '1'B  gives  '0'B
'0'B and4b '0'B  gives  '0'B
```

EXAMPLE 2:

```
'1001'B and4b '0101'B  gives '0001'B
'B'H and4b '5'H  gives  '1'H
'FB'O and4b '15'O  gives  '11'O
```

The bitwise **or4b** operator accepts two operands of equal length. For each corresponding bit position, the resulting value is 0 if both bits are set to 0, otherwise the value for the resulting bit is 1. That is:

```
'1'B or4b '1'B gives  '1'B
'1'B or4b '0'B gives  '1'B
'0'B or4b '1'B gives  '1'B
'0'B or4b '0'B gives  '0'B
```

EXAMPLE 3:

```
'1001'B or4b '0101'B  gives '1101'B
'9'H or4b '5'H gives  'D'H
'A9'O or4b 'F5'O gives  'FD'O
```

The bitwise **xor4b** operator accepts two operands of equal length. For each corresponding bit position, the resulting value is 0 if both bits are set to 0 or if both bits are set to 1, otherwise the value for the resulting bit is 1. That is:

```
'1'B xor4b '1'B gives  '0'B
'0'B xor4b '0'B  gives  '0'B
'0'B xor4b '1'B  gives  '1'B
'1'B xor4b '0'B  gives  '1'B
```

EXAMPLE 4:

```
'1001'B xor4b '0101'B  gives '1100'B
'9'H xor4b '5'H  gives 'C'H
'39'O xor4b '15'O  gives '2C'O
```

7.1.6 Shift operators

The predefined shift operators perform the shift left (`<<`) and shift right (`>>`)operations. Their left-hand operand shall be of type **bitstring**, **hexstring** or **octetstring**. Their right-hand operand shall be of type **integer**. The result type of these operators shall be the same as that of the left operand.

The shift operators behave differently based upon the type of their left-hand operand. If the type of the left-hand operand is:

a) **bitstring** then the shift unit applied is 1 bit;

b) **hexstring** then the shift unit applied is 1 hexadecimal digit;

c) **octetstring** then the shift unit applied is 1 octet.

The shift left (`<<`) operator accepts two operands. It shifts the left-hand operand by the number of shift units to the left as specified by the right-hand operand. Excess shift units (bits, hexadecimal digits or octets) are discarded. For each shift unit shifted to the left, a zero ('0'B, '0'H, or '00'O determined according to the type of the left-hand operand) is inserted from the right-hand side of the left operand.

EXAMPLE 1:

```
'111001'B << 2  gives  '100100'B
'12345'H << 2  gives  '34500'H
'1122334455'O << (1+1)  gives  '3344550000'O
```

The shift right (`>>`) operator accepts two operands. It shifts the left-hand operand by the number of shift units to the right as specified by the right-hand operand. Excess shift units (bits, hexadecimal digits or octets) are discarded. For each shift unit shifted to the right, a zero ('0'B, '0'H, or '00'O determined according to the type of the left-hand operand) is inserted from the left-hand side of the left operand.

EXAMPLE 2:

```
'111001'B >> 2  gives  '001110'B
'12345'H >> 2  gives  '00123'H
'1122334455'O >> (1+1)  gives  '0000112233'O
```

7.1.7 Rotate operators

The predefined rotate operators perform the rotate left (`<@`) and rotate right (`@>`) operators. Their left-hand operand shall be of type **`bitstring`**, **`hexstring`**, **`octetstring`**, **`charstring`** or **`universal charstring`**. Their right-hand operand shall be of type **`integer`**. The result type of these operators shall be the same as that of the left operand.

The rotate operators behave differently based upon the type of their left-hand operand. If the type of the left-hand operand is:

a) **`bitstring`** then the rotate unit applied is 1 bit;

b) **`hexstring`** then the rotate unit applied is 1 hexadecimal digit;

c) **`octetstring`** then the rotate unit applied is 1 octet;

d) **`charstring`** or **`universal charstring`** then the rotate unit applied is one character.

The rotate left (`<@`) operator accepts two operands. It rotates the left-hand operand by the number of shift units to the left as specified by the right-hand operand. Excess shift units (bits, hexadecimal digits, octets, or characters) are re-inserted into the left-hand operand from its right-hand side.

EXAMPLE 1:

```
'101001'B <@ 2  gives  '100110'B
'12345'H <@ 2  gives  '34512'H
'1122334455'O <@ (1+2)  gives  '4455112233'O
"abcdefg" <@ 3  gives "defgabc"
```

The rotate right (`@>`) operator accepts two operands. It rotates the left-hand operand by the number of shift units to the right as specified by the right-hand operand. Excess shift units (bits, hexadecimal digits, octets, or characters) are re-inserted into the left-hand operand from its left-hand side.

EXAMPLE 2:

```
'100001'B @> 2  gives  '011000'B
'12345'H @> 2  gives  '45123'H
'1122334455'O @> (1+2)  gives  '3344551122'O
"abcdefg" @> 3  gives "efgabcd"
```

8 Modules

The principal building blocks of TTCN-3 are modules. For example, a module may define a fully executable test suite or just a library. A module consists of a (optional) definitions part, and a (optional) module control part.

NOTE – The term test suite is synonymous with a complete TTCN-3 module containing test cases and a control part.

8.1 Definition of a module

A module is defined with the keyword **`module`**.

NOTE 1 – The treatment of TTCN-3 modules in files, repositories and alike is outside the scope of this Recommendation.

Syntactical Structure

```
module ModuleIdentifier [ LanguageSpec ] "{"
     [ ModuleDefinitionsPart ]
     [ ModuleControlPart ]
"}"
```

Semantic Description

A TTCN-3 module groups a set of (typically cohesive) TTCN-3 definitions. TTCN-3 modules have an explicit import interface to use definitions from other TTCN-3 or non-TTCN-3 modules. It is not possible to hide definitions in a TTCN-3 module, i.e., all definitions of a TTCN-3 module can be imported by other modules. TTCN-3 modules can be compiled/interpreted separately. They are reusable and parameterizable.

Module names are of the form of a TTCN-3 identifier. In addition, a module specification can carry an optional attribute identified by the **`language`** keyword that identifies the edition of the TTCN-3 language, in which the module is specified. Currently the following language strings are supported: "TTCN-3:2001" for a module specification complying with TTCN-3 edition 1, "TTCN-3:2003" for edition 2, "TTCN-3:2005" for edition 3.

NOTE 2 – The module identifier is the informal text name of the module.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
module MyTestSuite language "TTCN-3:2003"
{ … }
```

8.2 Module definitions part

The module definitions part specifies the top-level definitions of the module and may import identifiers from other modules. Scope rules for declarations made in the module definitions part and imported declarations are given in clause 5.3. Those language elements which may be defined in a TTCN-3 module are listed in Table 1. Every definition can be associated with attributes using the with statement defined in clause 27. The module definitions may be imported by other modules.

Syntactical Structure

```
{
    (
        TypeDef |
        ConstDef |
        TemplateDef |
        ModuleParDef |
        FunctionDef |
        SignatureDef |
        TestcaseDef |
        AltstepDef |
        ImportDef |
        GroupDef |
        ExtFunctionDef |
        ExtConstDef
    ) [ WithStatement ]
    [ ";" ]
}+
```

Semantic Description

Definitions in the module definitions part may be made in any order.

Such definitions, i.e., top level definitions outside of other scope units, are globally visible. They may be used elsewhere in the module. This includes identifiers imported from other modules.

NOTE – Declarations of dynamic language elements such as variables or timers shall only be made in the control part, test cases, functions, altsteps or component types. TTCN-3 does not support the declaration of variables in the module definitions part, i.e., global variables cannot be defined in TTCN-3. However, variables defined in a test component type may be used by all test cases, functions, etc. running on components of that component type and variables defined in the control part provide the ability to keep their values independently of test case execution.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
module MyModule
{   // This module contains definitions only
    :
    const integer MyConstant := 1;
    type record MyMessageType { … }
    :
    function TestStep(){ … }
    :
}
```

8.2.1 Module parameters

Module parameters define a set of values that are supplied by the test environment at run-time.

Syntactical Structure

Single type, single module parameter form:

```
modulepar ModuleParType ModuleParIdentifier [ ":=" ConstantExpression ] ";"
```

Single type, multiple module parameter form:

```
modulepar ModuleParType
     { ModuleParIdentifier [ ":=" ConstantExpression ] "," }
     ModuleParIdentifier [ ":=" ConstantExpression ] ";"
```

Multi-type, multiple module parameter form:

```
modulepar "{"
     { ModuleParType
         { ModuleParIdentifier [ ":=" ConstantExpression ] "," }
         ModuleParIdentifier [ ":=" ConstantExpression ] [ ";" ]
     }
     ModuleParType
         { ModuleParIdentifier [ ":=" ConstantExpression ] "," }
         ModuleParIdentifier [ ":=" ConstantExpression ]
"}"
```

Semantic Description

Module parameters behave as global constants at run-time.

Module parameters allow to customize a TTCN-3 test suite for a specific IUT, test setup or test campaign. Module parameters are declared by specifying the type and listing their identifiers following the keyword **modulepar**.

It is allowed to specify default values for module parameters. This shall be done by an assignment in the module parameter list. A default value can be a literal value only and can merely be assigned at the place of the declaration of the parameter.

If the test system does not provide an actual run-time value for a module parameter, the default value shall be used during test execution, otherwise the actual value provided by the test system.

Module parameters can be imported.

Restrictions

a) During test execution, these values shall be treated as constants.

b) Module parameters shall not be of port type, default type or component type.

c) A module parameter shall only be of type address if the address type is explicitly defined within the associated module.

d) Module parameters shall be declared within the module definitions part only.

e) More than one occurrence of module parameters declaration is allowed but each parameter shall be declared only once (i.e., redefinition of the module parameter is not allowed).

Examples

```
module MyTestSuiteWithParameters
{
    // single type, single module parameter
    modulepar boolean TS_Par0 := true;

    // single type, multiple module parameters
    modulepar integer TS_Par1, TS_Par2 := 1;


    // multiple types, multiple module parameters
    modulepar {
        hexstring TS_Par3;
        bitstring TS_Par4 := '011'B, TS_Par5
    }
}
```

8.2.2 Groups of definitions

In the module definitions part, definitions can be collected in named groups. Grouping is done to aid readability and to add logical structure to the module if required. If necessary, the dot notation shall be used to identify sub-groups within the group hierarchy uniquely, e.g., for the import of a specific sub-group.

Syntactical Structure

```
group GroupIdentifier "{"
    { ModuleDefinition [ ";" ] }
"}"
```

Semantic Description

A group of definitions can be specified wherever a single definition is allowed. Groups may be nested, i.e., groups may contain other groups. This allows the test suite specifier to structure, among other things, collections of test data or functions describing test behaviour.

Groups and nested groups have no scoping. Please note however, attributes given to a group by an associated with statement apply to all elements of a group (see clause 27). Import statements may import groups so that all elements of a group are imported (see clause 8.2.3.3).

Restrictions

Group identifiers across the whole module need not necessarily be unique. However, top-level group identifiers and all group identifiers of subgroups of a single group shall be unique.

Examples

```
module MyModule {
    :
    // A collection of definitions
    group MyGroup {
        const integer MyConst:= 1;
      :
        type record MyMessageType { … };
        group MyGroup1 {    // Sub-group with definitions
```

```
                type record AnotherMessageType { … };
                const boolean MyBoolean := false
            }
        }

        // A group of altsteps
        group MyStepLibrary {
            group MyGroup1 {    // Sub-group with the same name as the sub-group with definitions
                altstep MyStep11() { … }
                altstep MyStep12() { … }
                  :
                altstep MyStep1n() { … }
            }
            group MyGroup2 {
                altstep MyStep21() { … }
                altstep MyStep22() { … }
                :
                altstep MyStep2n() { … }
            }
        }
        :
    }

    // An import statement that imports MyGroup1 within MyStepLibrary
    import from MyModule {
        group MyStepLibrary.MyGroup1
    }
```

8.2.3 Importing from modules

It is possible to reuse definitions specified in different modules using the **`import`** statement. TTCN-3 has no explicit export construct thus, by default, all module definitions in the module definitions part may be imported.

8.2.3.1 General format of import

An import statement can be used anywhere in the module definitions part.

Syntactical Structure

```
import from ModuleId [ recursive ]
    (
        ( all [ except "{" ExceptSpec "}" ] )
        |
        ( "{" ImportSpec "}" )
    )
[ ";" ]
```

Semantic Description

TTCN-3 supports the import of the following definitions: module parameters, user defined types, signatures, constants, external constants, data templates, signature templates, functions, external functions, altsteps and test cases. Each definition has a *name* (defines the identifier of the definition, e.g., a function name), a *specification* (e.g., a type specification or a signature of a function) and in the case of functions, altsteps and test cases an associated *behaviour description*.

EXAMPLE:

```
             Name          Specification                        Behaviour description
function     MyFunction    (inout MyType1 MyPar) return MyType2  {
                           runs on MyCompType                      const MyType3 MyConst := …;
                                                                   : // further behaviour
                                                                 }
```

```
        Specification     Name            Specification
type    record            MyRecordType    {
                                            field1 MyType4,
                                            field2 integer
                                          }
```

```
            Specification   Name          Specification
template    MyType5         MyTemplate    := {
                                            field1 := 1,
                                            field2 := MyConst,  // MyConst is a module constant
                                            field3 := ModulePar // ModulePar is module parameter
                                          }
```

Behaviour descriptions have no effect on the import mechanism, because their internals are considered to be invisible to the importer when the corresponding functions, altsteps or test cases are imported. Thus, they are not considered in the following descriptions.

The specification part of an importable definition contains *local definitions* (e.g., field names of structured type definitions or values of enumerated types) and *referenced definitions* (e.g., references to type definitions, templates, constants or module parameters). For the examples above, this means:

	Name	Local definitions	Referenced definitions
function	MyFunction	MyPar	MyType1, MyType2, MyCompType
type	MyRecordType	field1, field2	MyType4, integer
template	MyTemplate		MyType5, field1, field2, field3, MyConst, ModulePar

NOTE 1 – The local definitions column refers to identifiers only that are newly defined in the importable definition. Values assigned to individual fields of importable definitions, e.g., in template definitions, may also be considered as local definitions, but they are not important for the explanation of the import mechanism.

NOTE 2 – The referenced definitions field1, field2 and field3 of template MyTemplate are the field names of MyType5, i.e., they are referenced via MyType5.

Referenced definitions are also importable definitions, i.e., the source of a referenced definition can again be structured into a name and a specification part and the specification part also contains local and referenced definitions. In other words, an importable definition may be built up recursively from other importable definitions.

The TTCN-3 import mechanism is related to the local and referenced definitions used in the specification part of the importable definitions. Table 8 specifies the possible local and referenced definitions of importable definitions.

Table 8 – Possible local and referenced definitions of importable definitions

Importable definition	Possible local definitions	Possible referenced definitions
Module parameter		Module parameter type
User-defined type (for all)	Parameter names	Parameter type
Enumerated type	Concrete values	
Structured type	Field names, nested type definitions	Field types
Port type		Message types, signatures
Component type	Constant names, variable names, timer names and port names	Constant types, variable types, port types
Signature	Parameter names	Parameter types, return type, types of exceptions
Constant		Constant type
External constant		Constant type
Data Template	Parameter names	Template type, parameter types, constants, module parameters, functions
Signature template		Signature definition, constants, module parameters functions
Function	Parameter names	Parameter types, return type, component type (`runs on`-clause)
External function	Parameter names	Parameter types, return type
Altstep	Parameter names	Parameter types, component type (`runs on`-clause)
Test case	Parameter names	Parameter types, component types (`runs on`-and `system`-clause)

The TTCN-3 import mechanism distinguishes between the *identifier of a referenced definition* and the *information necessary for the usage of a referenced definition* within the imported definition. For the usage, the identifier of a referenced definition is not required and therefore not imported automatically.

If an imported definition has attributes (defined by means of a `with` statement) then the attributes shall also be imported. The mechanism to change attributes of imported definitions is explained in clause 27.1.3.

NOTE 3 – If the module has global attributes they are associated to definitions without these attributes.

The use of `import` on single definitions, groups of definitions, definitions of the same kind, etc. may lead to situations where the *same definition is referred to more than once*. Such cases shall be resolved by the system and definitions shall be imported only once.

NOTE 4 – The mechanisms to resolve such ambiguities, e.g., overwriting and sending warnings to the user, are outside the scope of this Recommendation and should be provided by TTCN-3 tools.

All `import` statements and definitions within import statements are considered to be treated independently one after the other in the order of their appearance.

All TTCN-3 modules shall have their own name space in which all definitions shall be uniquely identified. *Name clashes* may occur due to import, e.g., import from different modules. Name clashes shall be resolved by prefixing the imported definition (which causes the name clash) by the identifier of the module from which it is imported. The prefix and the identifier shall be separated by a dot (.).

In cases where there are no ambiguities the prefixing need not (but may) be present when the imported definitions are used. When the definition is referenced in the same module where it is defined, the module identifier of the module (the current module) also may be used for prefixing the identifier of the definition.

Restrictions

a) An import statement shall only be used in the module definitions part and not be used within a control part, function definition, and alike.

b) Only top-level definitions in the module may be imported. Definitions which occur at a lower scope (e.g., local constants defined in a function) shall not be imported.

c) Only direct importing from the source module of a definition (i.e., the module where the actual definition for the identifier referenced in the **`import`** statement resides) is allowed.

d) A definition is imported together with its name and all local definitions.

NOTE 5 – A local definition, e.g., a field name of a user-defined record type, only has meaning in the context of the definitions in which it is defined, e.g., a field name of a record type can only be used to access a field of the record type and not outside this context.

e) A definition is imported together with all information of referenced definitions that are necessary for the usage of the referenced definition.

NOTE 6 – Import statements are transitive, e.g., if a module A imports a definition from module B that uses a type reference defined in module C, the corresponding information necessary for the usage of that type is automatically imported into module A.

f) Identifiers of referenced definitions are not automatically imported.

NOTE 7 – If the referenced definitions are wished to be used in the importing module, they shall be explicitly imported from its source module.

g) When importing a function, altstep or test case the corresponding behaviour specifications and all definitions used inside the behaviour specifications remain invisible for the importing module.

h) Cyclic imports are forbidden.

i) The use of recursive import (using the keyword **`recursive`**) is deprecated.

Examples

EXAMPLE 1: Selected import examples.

```
module MyModuleA
{   :
    // Scope of the imported definitions is global to MyModuleA
    import from MyModuleB all;  // import of all definitions from MyModuleB
    import from MyModuleC {     // import of selected definitions from MyModuleC
        type MyType1, MyType2;  // import of types MyType1 and MyType2
        template all            // import of all templates
    }
    :
    function MyBehaviourC()
    {
        // import cannot be used here
          :
    }
    :
    control
    {
        // import cannot be used here
        :
    }
}
```

EXAMPLE 2: Use and visibility of imported definitions.

```
module ModuleONE {

    modulepar integer ModPar1 := …;

    type record RecordType_T1 {
        integer Field1_T1,
        :
    }

    type record RecordType_T2 {
        RecordType_T1   Field1_T2,
        :
    }

    const integer MyConst := …;

    template RecordType_T2 Template_T2 (RecordType_T1 TempPar_T2):= { // parameterized template
        Field1_T2 := …,
        :
    }

} // end module ModuleONE


module ModuleTWO {

    import from ModuleONE {
        template Template_T2
    }

    // Only the names Template_T2 and TempPar_T2 will be visible in ModuleTWO. Please note, that
    // the identifier TempPar_T2 can only be used when modifying Template_T2. All information
    // necessary for the usage of Template_T2, e.g., for type checking purposes, are imported
    // for the referenced definitions RecordType_T1, Field1_T2, etc., but their identifiers are
    // not visible in ModuleTWO.
    // This means, e.g., it is not possible to use the constant MyConst or to declare a
    // variable of type RecordType_T1 or RecordType_T2 in ModuleTWO without explicitly importing
    // these types.

    import from ModuleONE {
        modulepar ModPar2
    }

    // The module parameter ModPar2 of ModuleONE is imported from ModuleONE and
    // can be used like an integer constant

} // end module ModuleTWO


module ModuleTHREE {

    import from ModuleONE all;  // imports all definitions from ModuleONE

    type port MyPortType {
        inout RecordType_T2     // Reference to a type defined in ModuleONE
    }

    type component MyCompType {
        var integer MyComponentVar := ModPar2;
                                // Reference to a module parameter of ModuleONE
        :
    }

    function MyFunction () return integer {
        return MyConst          // Reference to a module constant of ModuleONE
    }

    testcase MyTestCase (out RecordType_T2 MyPar) runs on MyCompType {

        :
        MyPort.send(Template_T2); // Sending a template defined in ModuleONE
        :

    }

} // end ModuleTHREE
```

```
module ModuleFOUR {

    import from ModuleTHREE {
        testcase MyTestCase
    }

    // Only the name MyTestCase will be visible and usable in ModuleFOUR.
    // Type information for RecordType_T2 is imported via ModuleTHREE from ModuleONE and
    // Type information for MyCompType is imported from ModuleTHREE. All definitions
    // used in the behaviour part of MyTestCase remain hidden for the user of ModuleFOUR.

} // end ModuleFOUR
```

EXAMPLE 3: Handling of name clashes.

```
module MyModuleA  {
     :
    type bitstring MyTypeA;

    import from SomeModuleC {
        type    MyTypeA,        // Where MyTypeA is of type character string
                MyTypeB         // Where MyTypeB is of type character string
    }
     :
    control {
         :
        var SomeModuleC.MyTypeA MyVar1 := "Test String"; // Prefix must be used
        var MyTypeA MyVar2 := '10110011'B;               // This is the original MyTypeA
         :
        var MyTypeB MyVar3 := "Test String";             // Prefix need not be used …
        var SomeModuleC.MyTypeB MyVar3 := "Test String"; // … but it can be if wished
         :
    }
}
```

NOTE 8 – Definitions with the same name defined in different modules are always assumed to be different, even if the actual definitions in the different modules are identical. For example, importing a type that is already defined locally, even with the same name, would lead to two different types being available in the module.

8.2.3.2 Importing single definitions

Single definitions can be imported by referring to the definition kind and the definition name(s). The import of single definitions can be used in combination with imports of groups (see clause 8.2.3.3) and with imports of definitions of the same kind (see clause 8.2.3.4).

Syntactical Structure

```
import from ModuleId [ recursive ] "{"
     {
         (
             ( type      { TypeDefIdentifier      [ "," ] } ) |
             ( template  { TemplateIdentifier     [ "," ] } ) |
             ( const     { ConstIdentifier        [ "," ] } ) |
             ( testcase  { TestcaseIdentifier     [ "," ] } ) |
             ( altstep   { AltstepIdentifier      [ "," ] } ) |
             ( function  { FunctionIdentifier     [ "," ] } ) |
             ( signature { SignatureIdentifier    [ "," ] } ) |
             ( modulepar { ModuleParIdentifier    [ "," ] } )
         )
         [ ";" ]
     }
"}" [ ";" ]
```

Semantic Description

See clause 8.2.3.

Restrictions

See clause 8.2.3.

Examples

```
    import from MyModuleA {
        type MyType1                        // imports one type definition from MyModuleA only
    }

    import from MyModuleB {
        type MyType2, Mytype3, MyType4;     // imports three types,
        template MyTemplate1;               // imports one template, and
        const MyConst1, MyConst2            // imports two constants
    }
```

8.2.3.3 Importing groups

Groups of definitions may be imported. The import of groups can be used in combination with imports of single definitions (see clause 8.2.3.2) and with imports of definitions of the same kind (see clause 8.2.3.4).

It is allowed to import sub-groups (i.e., a group which is defined within another group) directly, i.e., without the groups in which the sub-group is embedded. If the name of a sub-group that should be imported is identical to the name of another sub-group in the same module (see clause 8.2.2), the dot notation shall be used to identify the sub-group to be imported uniquely.

If some definitions of a group are wished not to be imported, their kinds and identifiers shall be listed in the exception list within a pair of curly brackets following the **except** keyword. The **all** keyword is also allowed to be used in the exception list; this will exclude all definitions of the same kind from the import statement.

Syntactical Structure

```
  import from ModuleId [ recursive ] "{"
       {
           ( group { FullGroupIdentifier [ except "{" ExceptSpec "}" ] [ "," ] } )
           [ ";" ]
       }
  "}" [ ";" ]
```

Semantic Description

The effect of importing a group is identical to an **import** statement that lists all importable definitions (including sub-groups) of this group except of those that are listed in the except specification. See also clause 8.2.3.

It is important to point out, that the except statement does not exclude the definitions listed from being imported in general; all statements importing definitions of the same kind can be seen as a shorthand notation for an equivalent list of identifiers of single definitions. The **except** statement excludes definitions from this single list only.

Restrictions

See clause 8.2.3.

Examples

```
    import from MyModule { group MyGroup } // includes all definitions from MyGroup

    import from MyModule {
        group MyGroup except {
            type MyType3, MyType5;  // excludes the two types from the import statement,
            template all            // excludes all templates defined in MyGroup
                                    // from the import statement
                                    // but imports all other definitions of MyGroup
        }
    }
```

```
import from MyModule {
    group MyGroup
        except { type MyType3 };// imports all types of MyGroup except MyType3
    type MyType3                // imports MyType3 explicitly
}
```

8.2.3.4 Importing definitions of the same kind

The **all** keyword may be used to import all definitions of the same kind of a module. The **all** keyword used with the **constant** keyword identifies all constants as well as all external constants declared in the definitions part of the module the import statement refers to. Similarly the **all** keyword used with the **function** keyword identifies all functions and all external functions defined in the module the import statement denotes.

If some declarations of a kind are wished to be excluded from the given import statement, their identifiers shall be listed following the **except** keyword.

The import of definitions of the same kind can be used in combination with imports of single definitions (see clause 8.2.3.2) and with imports of groups (see clause 8.2.3.3).

Syntactical Structure

```
import from ModuleId [ recursive ] "{"
     {
         (
             ( type      all [ except { TypeDefIdentifier    [ "," ] } ] ) |
             ( template  all [ except { TemplateIdentifier   [ "," ] } ] ) |
             ( const     all [ except { ConstIdentifier      [ "," ] } ] ) |
             ( testcase  all [ except { TestcaseIdentifier   [ "," ] } ] ) |
             ( altstep   all [ except { AltstepIdentifier    [ "," ] } ] ) |
             ( function  all [ except { FunctionIdentifier   [ "," ] } ] ) |
             ( signature all [ except { SignatureIdentifier  [ "," ] } ] ) |
             ( modulepar all [ except { ModuleParIdentifier  [ "," ] } ] )
         )
         [ ";" ]
     }
"}" [ ";" ]
```

Semantic Description

The effect of importing definitions of the same kind is identical to an **import** statement that lists all importable definitions of that kind except of those that are listed in the except specification. See also clause 8.2.3.

Restrictions

See clause 8.2.3.

Examples

```
import from MyModule {
    type all;               // imports all types of MyModule
    template all            // imports all templates of MyModule
}

import from MyModule {
    type all except MyType3, MyType5;   // imports all types except MyType3 and MyType5
    template all                        // imports all templates defined in Mymodule
}
```

8.2.3.5 Importing all definitions of a module

All definitions of a module definitions part may be imported using the **all** keyword next to the module name.

If some declarations are wished not to be imported, their kinds and identifiers shall be listed in the exception list within a pair of curly brackets following the **except** keyword. The **all** keyword is also allowed to be used in the exception list; this will exclude all declarations of the same kind from the import statement.

Syntactical Structure

```
import from ModuleId [ recursive ]
     all
     [
         {
             except "{"
                 ( group      { FullGroupIdentifier    [ "," ] } | all ) |
                 ( type       { TypeDefIdentifier      [ "," ] } | all ) |
                 ( template   { TemplateIdentifier     [ "," ] } | all ) |
                 ( const      { ConstIdentifier        [ "," ] } | all ) |
                 ( testcase   { TestcaseIdentifier     [ "," ] } | all ) |
                 ( altstep    { AltstepIdentifier      [ "," ] } | all ) |
                 ( function   { FunctionIdentifier     [ "," ] } | all ) |
                 ( signature  { SignatureIdentifier    [ "," ] } | all ) |
                 ( modulepar  { ModuleParIdentifier    [ "," ] } | all )
             "}"
             [ ";' ]
         }
     ]
[ ";" ]
```

Semantic Description

The effect of importing all definitions of a module is identical to an **import** statement that lists all importable definitions of that module except of those that are listed in the except specification. See also clause 8.2.3.

Restrictions

a) If all definitions of a module are imported by using the **all** keyword, no other form of import (import of single definitions, import of the same kind, etc.) shall be used for the same import statement.

b) In the set of except statements for an all import, only one except statement per kind of definition (i.e., for a group, type, etc.) is allowed.

Examples

```
import from MyModule all;    // includes all definitions from MyModule

import from MyModule all except {
    type MyType3, MyType5;   // excludes these two types from the import statement and
    template all             // excludes all templates declared in MyModule,
                             // from the import statement
                             // but imports all other definitions of MyModule
}
```

8.2.3.6 Import definitions from other TTCN-3 editions and from non-TTCN-3 modules

In cases when definitions are imported from modules from other TTCN-3 editions or from other sources than TTCN-3 modules, the language specification shall be used to denote the language (may be together with a version number) of the source (e.g., module, package, library or even file) from which definitions are imported. It consists of the **language** keyword and a subsequent textual declaration of the denoted language.

The use of the language specification is optional when importing from a TTCN-3 module of the same edition as the importing module. The following TTCN-3 language identifiers are defined:

– 'TTCN-3:2001' – to be used with modules complying with version 1.1.2 of [b-ETSI 201 873-1].

– 'TTCN-3:2003' – to be used with modules complying with version 2.2.1 of [b-ETSI 201 873-1].

– "TTCN-3:2005' – to be used with modules complying with this Recommendation.

Other language identifiers are defined in the language mapping parts of TTCN-3, i.e., in [ITU-T Z.167], [ITU-T Z.168] and [b-ETSI ES 201 873-9].

When an incompatibility is discovered between the language identification (including implicit identification by omitting the language specification) and the syntax of the module from which definitions are imported, tools shall provide reasonable effort to resolve the conflict.

Syntactical Structure

```
import from ModuleIdentifier [ language FreeText ] … [ ";" ]
```

Semantic Description

TTCN-3 supports the referencing of elements defined in other TTCN-3 editions (*versioned elements*) or other languages (*foreign elements*) from within TTCN-3 modules. Such elements can be used in a TTCN-3 module of a given edition only if they have a TTCN-3 view in that TTCN-3 edition. The term TTCN-3 view can be best explained by considering the case when the definition of a TTCN-3 element is based on another TTCN-3 element, the information content of the referenced element shall be available and is used for the new definition. For example, when a template is defined based on a structured type, the identifiers and types of fields of the base type shall be accessible and are used for the template definition. In a similar way, when a base type is a versioned or foreign element it shall provide the same information content as would be required from a TTCN-3 type declaration. The versioned or foreign element, naturally, may contain more information than required by TTCN-3. The TTCN-3 view of a versioned or foreign element means that part of the information carried by that element, which is necessary to use it in TTCN-3. Obviously, the TTCN-3 view of a versioned or foreign element may be the full set or a subset of the information content of that element but never a superset. There may be versioned or foreign element without a TTCN-3 view (zero TTCN-3 view), i.e., for some reason no TTCN-3 definition in the given edition could be based on them.

To make declarations of versioned or foreign element visible in TTCN-3 modules, their names shall be imported just like definitions in other TTCN-3 modules of the given edition. When imported, only the TTCN-3 view of the versioned or foreign element will be seen from the importing TTCN-3 module. There are two main differences between importing TTCN-3 elements of the same editions and versioned or foreign elements:

- to import from a TTCN-3 module of another edition or from a non-TTCN-3 module the import statement shall contain an appropriate language identifier string;
- only versioned or foreign elements with a TTCN-3 view of a given edition are importable into a TTCN-3 module of that edition.

Importing can be done automatically using the all directive, in which case all importable objects shall automatically be selected by the testing tool, or done manually by listing names of elements to be imported. Naturally, in the second case only importable elements are allowed in the list.

Restrictions

The language specification may only be omitted if the referenced module contains TTCN-3 notation and the TTCN-3 version is known.

Examples

```
import from MyModule language "TTCN-3:2003" {
    type MyType
}
```

NOTE – The import mechanism is designed to allow the reuse of definitions from other TTCN-3 editions or from other language sources. The rules for importing definitions from specifications written in other languages, e.g., SDL packages, may follow the TTCN-3 rules or may have to be defined separately.

8.3 Module control part

The module control part may contain local definitions (i.e., constants or templates), local instances (i.e., variables or timers) and describe the selection, parameterization and execution order (possibly repetitive) of the actual test cases. A test case shall be defined in the module definitions part or imported from another module, and called in the control part.

The control part of a module calls the test cases with actual parameters and controls their execution. Program statements can be used to specify the selection and execution order of the test cases. Definitions made in the module control part have local visibility, i.e., can be used within the control part only.

This is explained in more detail in clause 26.

EXAMPLE:

```
module MyTestSuite
{   // This module contains definitions …
    :
    const integer MyConstant := 1;
    type record MyMessageType { … }
    template MyMessageType MyMessage := { … }
    :
    function MyFunction1() { … }
    function MyFunction2() { … }
    :
    testcase MyTestcase1() runs on MyMTCType { … }
    testcase MyTestcase2() runs on MyMTCType { … }
    :
    // … and a control part so it is executable
    control
    {
        var boolean MyVariable; // local control variable
        :
        execute( MyTestCase1()); // sequential execution of test cases
        execute( MyTestCase2());
        :
    }
}
```

9 Port types, component types and test configurations

TTCN-3 allows the (dynamic) specification of concurrent test configurations (or configuration for short). A configuration consists of a set of inter-connected test components with well-defined communication ports and an explicit test system interface which defines the borders of the test system (see Figure 3).

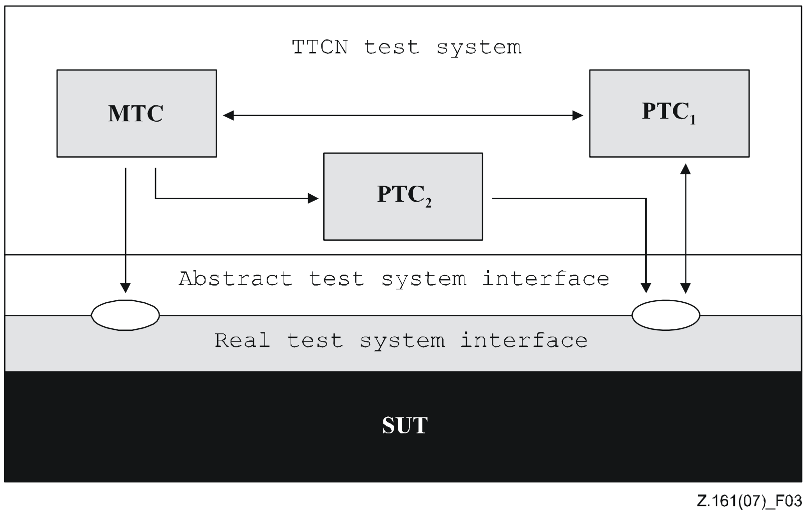


Figure 3 – Conceptual view of a typical TTCN-3 test configuration

Within every configuration there shall be one (and only one) Main Test Component (MTC). Test components that are not MTCs are called parallel test components or PTCs. The MTC shall be created by the system automatically at the start of each test case execution. The behaviour defined in the body of the test case shall execute on this component. During execution of a test case, other components can be created dynamically by the explicit use of the **`create`** operation.

Test case execution shall end when the MTC terminates. All other PTCs are treated equally i.e., there is no explicit hierarchical relationship among them and the termination of a single PTC terminates neither other components nor the MTC. When the MTC terminates, the test system has to stop all PTCs not terminated by the moment when the test case execution is ended.

Communication between test components and between the components and the test system interface is achieved via communication ports (see clause 9.1).

Test component types and port types, denoted by the keywords **`component`** and **`port`**, shall be defined in the module definitions part. The actual configuration of components and the connections between them is achieved by performing **`create`** and **`connect`** operations within the test case behaviour. The component ports are connected to the ports of the test system interface by means of the **`map`** operation (see clause 21.1.1).

9.1 Communication port types

Ports facilitate communication between test components and between test components and the test system interface.

TTCN-3 supports message-based and procedure-based ports. Each port shall be defined as being message-based or procedure-based (or both at the same time). Message-based ports shall be identified by the keyword **`message`** and procedure-based ports shall be identified by the keyword **`procedure`** within the associated port type definition.

Ports are bidirectional. The directions are specified by the keywords **`in`** (for the in direction), **`out`** (for the out direction) and **`inout`** (for both directions). Directions shall be seen from the point of view of the test component owning the port with the exception of the test system interface, where in identifies the direction of message sending or procedure call and out identifies the direction of message receive, get reply or catch exception from the point of view of the test component connected to the test system interface port.

Each port type definition shall have one or more lists indicating the allowed collection of (message) types and/or procedure signatures together with the allowed communication direction.

Whenever a signature (see also clause 14) is defined in the out direction of a procedure-based port, the types of all its inout and out parameters, its return type and its exception types are automatically part of the in direction of this port. Whenever a signature is defined in the in direction for a procedure-based port, the types of all its inout and out parameters, its return type and its exception types are automatically part of the out direction of this port.

It is possible to define a port as allowing both kinds of communication. This is denoted by the keyword `mixed`. This means that the lists for mixed ports will also be mixed and include both signatures and types. No separation is made in the definition. A mixed port in TTCN-3 is defined as a shorthand notation for two ports, i.e., a message-based port and a procedure-based port with the same name. At run-time the distinction between the two ports is made by the communication operations. Operations used to control ports (see clause 22.5), i.e., `start`, `stop` and `clear` shall perform the operation on both queues (in arbitrary order) if called with an identifier of a mixed port.

Syntactical Structure

Message-based port:

```
type port PortTypeIdentifier message "{"
     { ( in | out | inout ) ( all | { MessageType [ "," ] }+ ) ";" }
"}"
```

Procedure-based port:

```
type port PortTypeIdentifier procedure "{"
     { ( in | out | inout ) ( all | { Signature [ "," ] }+ ) ";" }
"}"
```

Mixed port:

```
type port PortTypeIdentifier mixed "{"
     { ( in | out | inout ) ( all | { ( MessageType | Signature ) [ "," ] }+  ";" }
"}"
```

Semantic Description

Test components are connected via their ports, i.e., connections among components and between a component and the test system interface are port-oriented. Each port is modelled as an infinite FIFO queue which stores the incoming messages or procedure calls until they are processed by the component owning that port (see Figure 4).

NOTE 1 – While TTCN-3 ports are infinite in principle in a real test system they may overflow. This should be treated as a test case error (see clause 24.1).

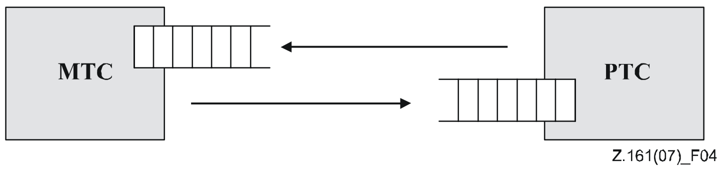


Figure 4 – The TTCN-3 communication port model

TTCN-3 connections are port-to-port and port-to-test system interface connections (see Figure 5). There are no restrictions on the number of connections a component may maintain. One-to-many connections are also allowed (e.g., Figure 5g) or Figure 5h)).

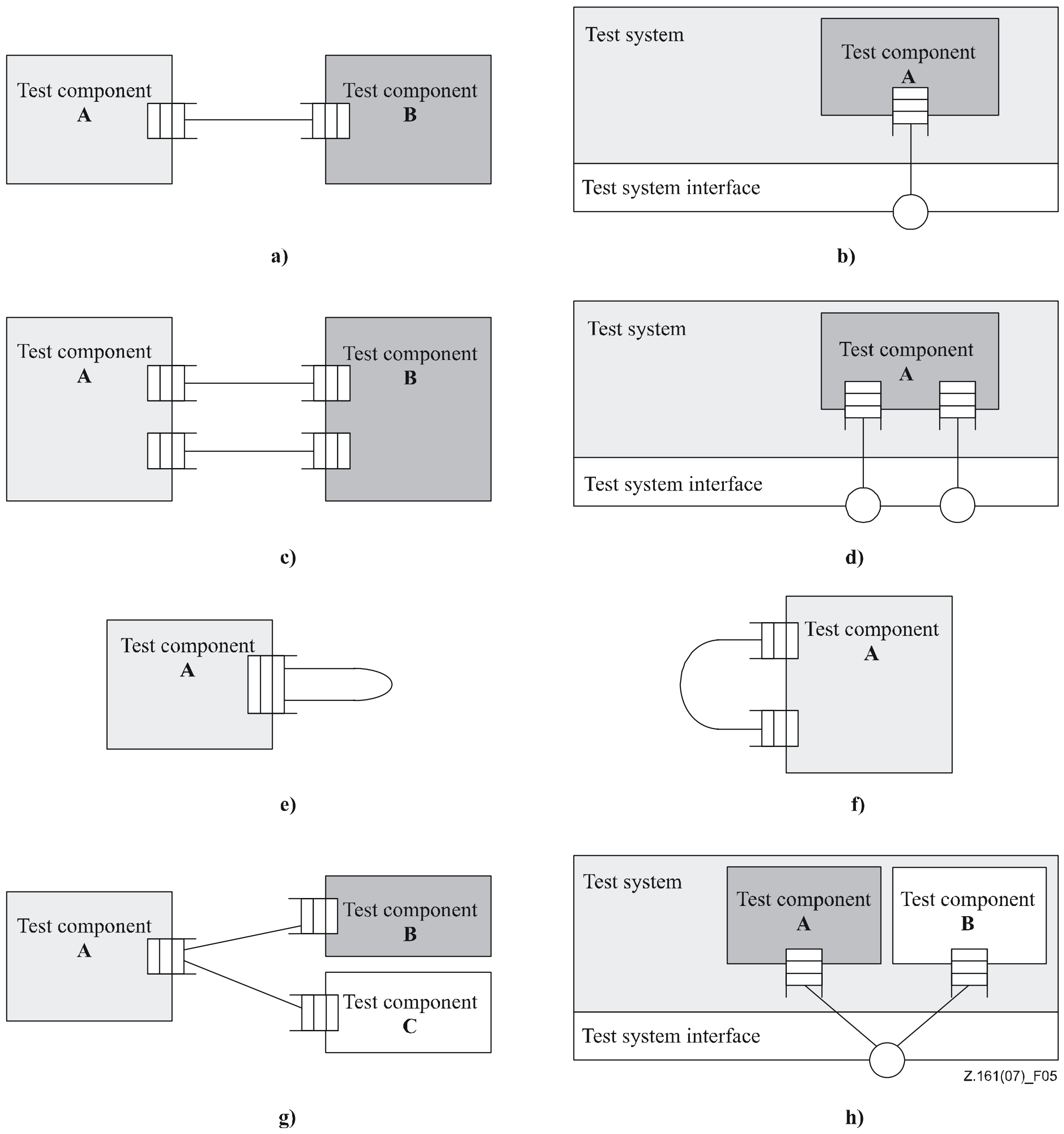


Figure 5 – Allowed connections

Restrictions

a) The following connections are not allowed (see Figure 6):

– A port owned by a component A shall not be connected with two or more ports owned by the same component (Figures 6a) and 6e)).

– A port owned by a component A shall not be connected with two or more ports owned by a component B (see Figure 6c)).

– A port owned by a component A can only have a one-to-one connection with the test system interface. This means, connections as shown in Figures 6b) and 6d) are not allowed.

– Connections within the test system interface are not allowed (see Figure 6f)).

– A port that is connected shall not be mapped and a port that is mapped shall not be connected (see Figure 6g)).

b) Since TTCN-3 allows dynamic configurations and addresses, the restrictions on connections cannot always be checked at compile-time. The checks shall be made at run-time and shall lead to a test case error when failing.

c) The use of the keyword `all` in the direction of a port type definition is deprecated.

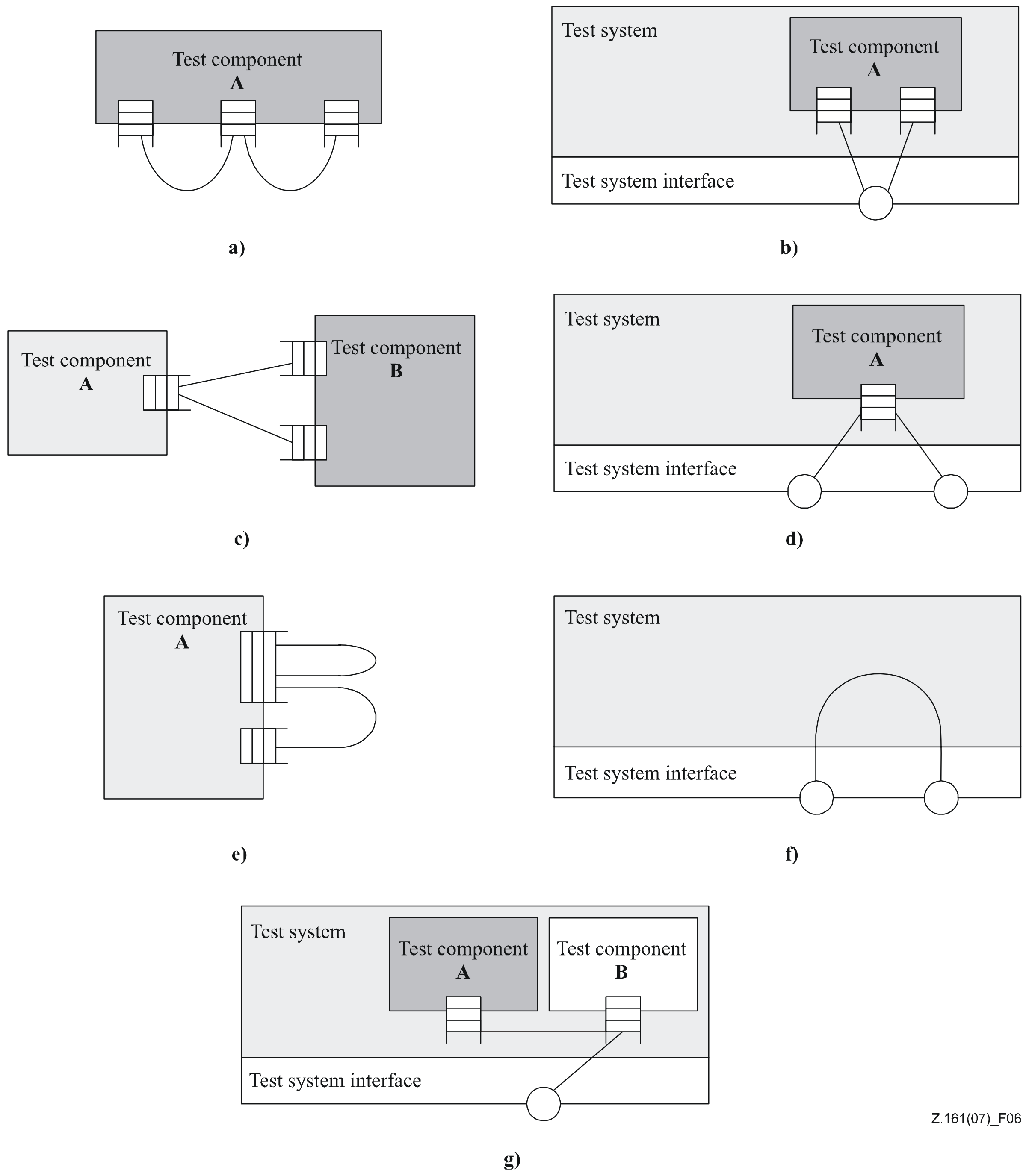


Figure 6 – NOT allowed connections

Examples

EXAMPLE 1: Message-based port

```
// Message-based port which allows types MsgType1 and MsgType2 to be received at, MsgType3 to be
// sent via and any integer value to be sent and received over the port
type port MyMessagePortType message
{
    in      MsgType1, MsgType2;
    out     MsgType3;
```

```
        inout   integer
    }
```

EXAMPLE 2: Procedure-based port

```
    // Procedure-based port which allows the remote call of the procedures Proc1, Proc2 and Proc3.
    // Note that Proc1, Proc2 and Proc3 are defined as signatures
    type port MyProcedurePortType procedure
    {
        out     Proc1, Proc2, Proc3
    }
```

NOTE 2 – The term message is used to mean both messages as defined by templates and actual values resulting from expressions. Thus, the list restricting what may be used on a message-based port is simply a list of type names.

EXAMPLE 3: Mixed port

```
    // Mixed port, defining a message-based and a procedure-based port with the same name. The in,
    // out and inout lists are also mixed: MsgType1, MsgType2, MsgType3 and integer refer to the
    // message-based part of the mixed port and Proc1, Proc2, Proc3, Proc4 and Proc5 refer to the
    // procedure-based port.
    type port MyMixedPortType mixed
    {
        in      MsgType1, MsgType2, Proc1, Proc2;
        out     MsgType3, Proc3, Proc4;
        inout   integer, Proc5;
    }
```

9.2 Component types

The component type defines which ports are associated with a component (see Figure 7). The port names in a component type definition are local to that component type, i.e., another component type may have ports with the same names. Port names in the same component type definition shall all have unique names.

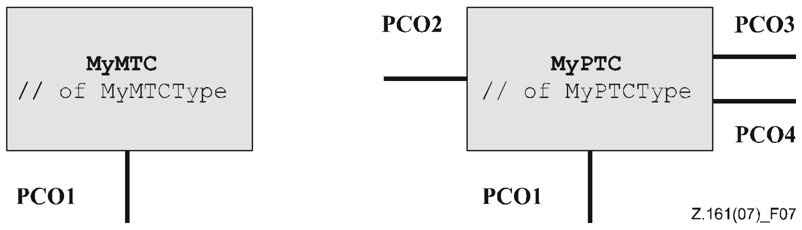


Figure 7 – Typical components

It is also possible to declare constants, variables and timers local to a particular component type. These declarations are visible to all testcases, functions and altsteps that run on an instance of the given component type. This shall be explicitly stated using the **`runs on`** keyword (see clause 16) in the testcase, function or altstep header. Component type definitions are associated with the component instance and follow the scope rules defined in clause 5.2. Each new instance of a component type will thus have its own set of constants, variables and timers as specified in the component type definition (including any initial values, if stated).

NOTE – When used as test system interfaces (see clause 9.4) components cannot make use of any constants, variables and timers declared in the component type.

It is possible to define port, timer and variable arrays in component type definitions.

Syntactical Structure

```
  type component ComponentTypeIdentifier "{"
       { ( PortInstance
       | VarInstance
       | TimerInstance
       | ConstDef ) }
  "}"
```

Semantic Description

Component type definitions specify the creation, declaration and initialization of ports and component constants, variables and timers during the creation of an instance of a component type. These instances can be used as the main test component, as the test system interface or as a parallel test component. Every instance of a component type has its own fresh copy of the port, constant, variable, and timer instances defined in the component type definition.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

EXAMPLE 1: Component type with port instances only

```
    type component MyPTCType
    {
        port MyMessagePortType       PCO1, PCO4;
        port MyProcedurePortType     PCO2;
        port MyAllMesssagesPortType  PCO3
    }
```

EXAMPLE 2: Component type with variable, timer and port instance

```
    type component MyMTCType
    {
        var integer MyLocalInteger;
        timer MyLocalTimer;
        port MyMessagePortType  PCO1
    }
```

EXAMPLE 3: Component type with port instance arrays

```
    type component MyCompType
    {
        port MyMessageInterfaceType PCO[3]
        port MyProcedureInterfaceType PCOm[3][3]
        // Defines a component type which has an array of 3 message ports and a two-dimensional
        // array of 9 procedure ports.
    }
```

9.3 Reuse of component types

It is possible to define component types as the extension of other component types, using the **extends** keyword.

Syntactical Structure

```
  type component ComponentTypeIdentifier extends ComponentTypeIdentifier "{"
       { ( PortInstance
       | VarInstance
       | TimerInstance
       | ConstDef ) }
  "}"
```

Semantic Description

In such a definition, the new type definition is referred to as the *extended type*, and the type definition following the **extends** keyword is referred to as the *parent type*. The effect of this definition is that the extended type will implicitly also contain all definitions from the parent type. It is called the *effective type definition*.

It is allowed to have one component type extending several parent types in one definition, which have to be specified as a comma-separated list of types in the definition. Any of the parent types may also be defined by means of extension. The effective component type definition of the extended type is obtained as the collection of all constant, variable, timer and port definitions contributed by the parent types (determined recursively if a parent type is also defined by means of an extension) and the definitions declared in the extended type directly. The effective component type definition shall be name clash free.

NOTE 1 – It is not considered to be a different declaration and hence causes no error if the same definition is contributed to the extended type by different parent types (via different extension paths).

The semantics of component types with extensions are defined by simply replacing each component type definition by its effective component type definition as a pre-processing step prior to using it.

NOTE 2 – For component type compatibility, this means that a component reference c of type CT1, which extends CT2, is compatible with CT2, and test cases, functions and altsteps specifying CT2 in their **`runs on`** clauses can be executed on c (see clause 6.3.3).

Restrictions

a) When defining component types by extension, there shall be no name clash between the definitions being taken from the parent type and the definitions being added in the extended type, i.e., there shall not be a port, variable, constant or timer identifier that is declared both in the parent type (directly or by means of extension) and the extended type.

b) It is allowed to extend component types that are defined by means of extension, as long as no cyclic chain of definition is created.

Examples

EXAMPLE 1: A component type extension and its effective type definition

```
type component MyMTCType
{
  var integer MyLocalInteger;
  timer MyLocalTimer;
  port MyMessagePortType PCO1
}

type component MyExtendedMTCType extends MyMTCType
{
  var float MyLocalFloat;
  timer MyOtherLocalTimer;
  port MyMessagePortType PCO2;
}

// effectively, the above definition is equivalent to this one:
type component MyExtendedMTCType
{
  /* the definitions from MyMTCType */
  var integer MyLocalInteger;
  timer MyLocalTimer;
  port MyMessagePortType PCO1

  /* the additional definitions */
  var float MyLocalFloat;
  timer MyOtherLocalTimer;
  port MyMessagePortType PCO2;
}
```

EXAMPLE 2: A component type extension chain and forbidden cyclic extensions

```
type component MTCTypeA extends MTCTypeB { /* … */ };
type component MTCTypeB extends MTCTypeC { /* … */ };
type component MTCTypeC extends MTCTypeA { /* … */ };  // ERROR - cyclic extension
type component MTCTypeD extends MTCTypeD { /* … */ };  // ERROR - cyclic extension
```

EXAMPLE 3: Component type extensions with name clashes

```
type component MyExtendedMTCType extends MyMTCType
{
  var integer MyLocalInteger; // ERROR - already defined in MyMTCType (see above)
  var float MyLocalTimer;     // ERROR - timer with that name exists in MyMTCType
  port MyOtherMessagePortType PCO1; // ERROR - port with that name exists in MyMTCType
}

type component MyBaseComponent { timer MyLocalTimer };
type component MyInterimComponent extends MyBaseComponent { timer MyOtherTimer };
type component MyExtendedComponent extends MyInterimComponent
{
  timer MyLocalTimer; // ERROR - already defined in MyInterimComponent via extension
}
```

EXAMPLE 4: Component type extension from several parent types

```
type component MyCompB { timer T };
type component MyCompC { var integer T };
type component MyCompD extends MyCompB, MyCompC {}
  // ERROR - name clash between MyCompB and MyCompC

// MyCompB is defined above
type component MyCompE extends MyCompB {
  var integer MyVar1 := 10;
}

type component MyCompF extends MyCompB {
  var float MyVar2 := 1.0;
}

type component MyCompG extends MyCompB, MyCompE, MyCompF {
  // No name clash.
  // All three parent types of MyCompG have a timer T, either directly or via extension of
  // MyCompB; as all these stem (directly or via extension) from timer T declared in MyCompB,
  // which make this form of collision legal.
  /* additional definitions here */
}
```

9.4 Test system interface

TTCN-3 is used to test implementations. The object being tested is known as the Implementation Under Test or IUT. The IUT may offer direct interfaces for testing or it may be part of system in which case the tested object is known as a System Under Test or SUT. In the minimal case, the IUT and the SUT are equivalent. In this Recommendation, the term SUT is used in a general way to mean either SUT or IUT.

In a real test environment, test cases need to communicate with the SUT. However, the specification of the real physical connection is outside the scope of TTCN-3. Instead, a well-defined (but abstract) test system interface shall be associated with each test case. A test system interface definition is identical to a component definition, i.e., it is a list of all possible communication ports through which the test case is connected to the SUT.

The test system interface statically defines the number and type of the port connections to the SUT during a test run. However, the connections between the test system interface and the TTCN-3 test components are dynamic in nature and may be modified during a test run by using **map** and **unmap** operations (see clause 21.1).

A component type definition is used to define the test system interface because, conceptually, component type definitions and test system interface definitions have the same form (both are collections of ports defining possible connection points).

Syntactical Structure

The same as a component type definition (see clauses 9.2 and 9.3).

Semantic Description

Generally, a component type reference defining the test system interface shall be associated with every test case using more than one test component. The ports of the test system interface shall automatically be instantiated by the system together with the MTC when the test case execution starts.

The operation returning the component reference of the test system interface is **`system`**. This shall be used to address the ports of the test system.

In the case where the MTC is the only component that is instantiated during test execution, a test system interface need not be associated to the test case. In this case, the component type definition associated with the MTC implicitly defines the corresponding test system interface.

Variables, timers and constants declared in component types, which are used as test system interfaces will have no effect.

Restrictions

The same as for component type definitions (see clauses 9.2 and 9.3).

Examples

EXAMPLE 1: Explicit definition of a test system interface

```
type component MyMTCType
{
  var integer MyLocalInteger;
  timer MyLocalTimer;
  port MyMessagePortType PCO1
}

type component MyTestSystemInterface
{
    port MyMessagePortType      PCO1, PCO2;
    port MyProcedurePortType    PCO3
}

// MyTestSystemInterface is the test system interface
testcase MyTestcase1 () runs on MyMTCType system MyTestSystemInterface {
    // establishing the port connections
    map(mtc:PCO1, system:PCO2);
    // the testcase behaviour
    // …
}
```

EXAMPLE 2: Implicit definition of a test system interface

```
// MyMTCType is the test system interface
testcase MyTestcase2 () runs on MyMTCType {
    // map statements are not needed
    // the testcase behaviour
    // …
}
```

9.5 Component references

Component references are unique references to the test components created during the execution of a test case.

Syntactical Structure

```
system | mtc | self | VariableRef | FunctionInstance
```

Semantic Description

A unique component reference is generated by the test system at the time when a component is created. It is the result of a **`create`** operation (see clause 21.2.1). In addition, component references are returned by the predefined operations **`system`** (returns the component reference of the test system interface, which is automatically created when testcase execution is started), **`mtc`** (returns the component reference of the MTC, which is automatically created when testcase execution is started) and **`self`** (returns the component reference of the component in which **`self`** is called).

Component references are used in the configuration operations such as **`connect`**, **`map`** and **`start`** (see clause 21) to set-up test configurations and in the **`from`**, **`to`** and **`sender`** parts of communication operations of ports connected to test components other than the test system interface for addressing purposes (see clause 22 and Figure 5).

In addition, the special value **`null`** is available to indicate an undefined component reference, e.g., for the initialization of variables to handle component references.

The actual data representation of component references shall be resolved externally by the test system. This allows abstract test cases to be specified independently of any real TTCN-3 runtime environment, in other words TTCN-3 does not restrict the implementation of a test system with respect to the handling and identification of test components.

NOTE – A component reference includes component type information. This means, for example, that a variable for handling component references must use the corresponding component type name in its declaration.

The configuration operations (see clause 21) do not work directly on arrays of components. Instead a specific element of the array shall be provided as the parameter to these operations. For components, the effect of an array is achieved by using an array of component references and assigning the relevant array element to the result of the **`create`** operation.

Restrictions

a) The only operations allowed on component references are assignment, equality and non-equality.

b) The variable associated with *VariableRef* (being a component type variable, a component type parameter, etc.) or the return type associated with *FunctionInstance* must be of component type.

Examples

EXAMPLE 1: Component references with component type variables

```
// A component type definition
type component MyCompType {
    port PortTypeOne PCO1;
    port PortTypeTwo PCO2
}

// Declaring one variable for the handling of references to components of type MyCompType
// and creating a component of this type
var MyCompType MyCompInst := MyCompType.create;
```

EXAMPLE 2: Usage of component references in configuration operations

```
// referring to the component created above
connect(self:MyPCO1, MyCompInst:PCO1);
map(MyCompInst:PCO2, system:ExtPCO1);
MyCompInst.start(MyBehavior(self)); // self is passed as a parameter to MyBehavior
```

EXAMPLE 3: Usage of component references in from- and to-clauses

```
MyPCO1.receive from MyCompInst;
  :
MyPCO2.receive(integer:?) -> sender MyCompInst;
  :
MyPCO1.receive(MyTemplate) from MyCompInst;
  :
MyPCO2.send(integer:5) to MyCompInst;
```

EXAMPLE 4: Usage of component references in one-to-many connections

```
// The following example explains the case of a one-to-many connection at a Port PCO1
// where values of type M1 can be received from several components of the different types
// CompType1, CompType2 and CompType3 and where the sender has to be retrieved.
// In this case the following scheme may be used:
  :
var M1 MyMessage, MyResult;
var MyCompType1 MyInst1 := null;
var MyCompType2 MyInst2 := null;
var MyCompType3 MyInst3 := null;
  :
alt {
    [] PCO1.receive(M1:?) from MyInst1 -> value MyMessage sender MyInst1 {}
    [] PCO1.receive(M1:?) from MyInst2 -> value MyMessage sender MyInst2 {}
    [] PCO1.receive(M1:?) from MyInst3 -> value MyMessage sender MyInst3 {}
}
  :
MyResult := MyMessageHandling(MyMessage);   // some result is retrieved from a function
  :
if (MyInst1 != null) {PCO1.send(MyResult) to MyInst1};
if (MyInst2 != null) {PCO1.send(MyResult) to MyInst2};
if (MyInst3 != null) {PCO1.send(MyResult) to MyInst3};
  :
```

EXAMPLE 5: Usage of self

```
var MyComponentType MyAddress;
MyAddress := self; // Store the current component reference
```

EXAMPLE 6: Usage of component arrays

```
// This example shows how to model the effect of creating, connecting and running arrays of
// components using a loop and by storing the created component reference in an array of
// component references.

testcase MyTestCase() runs on MyMtcType system MyTestSystemInterface
{
      :
    var integer i;
    var MyPTCType1  MyPtc[11];
      :
    for (i:= 0; i<=10; i:=i+1)
    {
        MyPtc[i] := MyPTCType1.create;
        connect(self:PtcCoordination, MyPtc[i]:MtcCoordination);
        MyPtc[i].start(MyPtcBehaviour());
    }
      :
}
```

9.6 Addressing entities inside the SUT

A SUT may consist of several entities which can be addressed individually by use of the **address** data type. This is the type to use with port operations in order to address SUT entities.

Syntactical Structure

TemplateInstance

Semantic Description

The actual data representation of **address** is resolved either by an explicit type definition within the test suite or externally by the test system (i.e., the **address** type is left as an open type within the TTCN-3 specification). This allows abstract test cases to be specified independently of any real address mechanism specific to the SUT.

Explicit SUT addresses shall only be generated inside a TTCN-3 module if the type is defined inside the module. If the type is not defined inside the module, explicit SUT addresses shall only be passed in as parameters or be received in message fields or as parameters of remote procedure calls.

In addition, the special value **null** is available to indicate an undefined address, e.g., for the initialization of variables of the address type.

Restrictions

a) *TemplateInstance* shall be of address type and can be an address type value, an address type variable, etc.

b) The address data type shall only be used in the **to**, **from** and **sender** parts of receive and send operations of ports mapped to the test system interface.

EXAMPLE:

```
    // Associates the type integer to the open type address
    type integer address;
      :
    // new address variable initialized with null
    var address MySUTentity := null;
      :
    // receiving an address value and assigning it to variable MySUTentity
    PCO.receive(address:*) -> value MySUTentity;
      :
    // usage of the received address for sending template MyResult
    PCO.send(MyResult) to MySUTentity;
      :
    // usage of the received address for receiving a confirmation template
    PCO.receive(MyConfirmation) from MySUTentity;
```

10 Declaring constants

TTCN-3 constants are static constants.

Syntactical Structure

```
  const Type  { ConstIdentifier [ ArrayDef ] ":=" ConstantExpression [ "," ] }  [ ";" ]
```

Semantic Description

A constant assigns a name to a fixed value. This value is known at compile time. The constant does not change its value during test execution. The value is defined only once, but can be referenced multiple times in a TTCN-3 module.

Restrictions

a) Constants shall not be of port type.

NOTE – The only value that can be assigned to constants of default and component types is the special value **null**.

b) The value of the ConstantExpression assigned to a constant shall be of the same type as the stated type for the constants.

Examples

```
    const integer MyConst1 := 1;
    const boolean MyConst2 := true, MyConst3 := false;
```

10.1 External constants

The assignment of the value to the constant may be done within a TTCN-3 module or it may be done externally. The latter case is an external constant declaration denoted by the keyword **external**.

Syntactical Structure

```
  external const Type  { ConstIdentifier [ ArrayDef ] ":=" ConstantExpression [ "," ] }  [ ";" ]
```

Semantic Description

The value of an external constant is provided at compile time from the environment.

The mapping of the type to the external representation of an external constant and the mechanism of how the value of an external constant is passed into a module are outside the scope of this Recommendation.

Restrictions

a) An external constant may have an arbitrary type except of port type, default type, or component type.

b) The type has to be known in the TTCN-3 module i.e., shall be a root type or a user-defined type defined in the module, or imported from another module.

Examples

```
external const integer MyExternalConst; // external constant declaration
```

11 Declaring variables

TTCN-3 variables are statically typed variables. Variables are either value variables to store values or template variables to store templates.

Variables can be of simple basic types, basic string types, structured types, special data types (including subtypes derived from these types) as well as address, component or default types.

Variables can be declared and used in the module control part, test cases, functions and altsteps. Additionally, variables can be declared in component type definitions. These variables can be used in test cases, altsteps and functions which are running on a given component type.

11.1 Value variables

A TTCN-3 value variable stores values. It is declared by the `var` keyword followed by a type identifier and a variable identifier. An initial value can be assigned at variable declaration.

It may be used at the right hand side as well as at the left hand side of assignments, in expressions, following the `return` keyword in bodies of functions with a return clause in their headers and may be passed to both value and template-type formal parameters.

Syntactical Structure

```
var Type VarIdentifier [ ArrayDef ] ":=" Expression
        { [ "," ] VarIdentifier [ ArrayDef ] ":=" Expression } [ ";" ]
```

Semantic Description

A value variable associates a name with the location of a value. A value variable may change its value during test execution several times. A value can be assigned several times to a value variable. The value variable can be referenced multiple times in a TTCN-3 module.

Restrictions

a) *Expression* shall be of type *Type*.

b) Value variables shall store values only.

c) Value variables shall not be declared or used in a module definitions part (i.e., global variables are not supported in TTCN-3).

d) Use of uninitialized or not completely initialized value variables at other places than the left hand side of assignments or as actual parameters passed to out formal parameters shall cause an error.

Examples

```
var integer MyVar0;
var integer MyVar1 := 1;
var boolean MyVar2 := true, MyVar3 := false;
```

11.2 Template variables

A TTCN-3 template variable stores templates. They are declared by the **`var template`** keyword followed by a type identifier and a variable identifier. An initial content can be assigned at declaration. In excess to value variables, template variables may also store matching mechanisms (see clause 15.7).

Template variables may be used on the right hand side as well as on the left hand side of assignments, following the **`return`** keyword in bodies of functions defining a template-type return value in their headers and may be passed as actual parameters to template-type formal parameters. It is also allowed to assign a template instance to a template variable or a template variable field.

Syntactical Structure

```
var template Type VarIdentifier [ ArrayDef ] ":=" TemplateBody
                 { [ "," ] VarIdentifier [ ArrayDef ] ":=" TemplateBody } [ ";" ]
```

Semantic Description

A template variable associates a name with the location of a template or a value (as every value is also a template).

A template variable may change its template during test execution several times. A template or value can be assigned several times to a template variable. The template variable can be referenced multiple times in a TTCN-3 module.

Restrictions

a) Template variables shall not be declared or used in a module definitions part (i.e., global variables are not supported in TTCN-3).

b) When used on the right hand side of assignments, template variables shall not be operands of TTCN-3 operators (see clause 7.1) and the variable on the left hand side shall be a template variable too.

NOTE 1 – While it is not allowed to directly apply TTCN-3 operations to template variables, it is allowed to use the dot notation and the index notation to inspect and modify template variable fields. Rules to apply when these notations attempt to reach fields beyond a matching mechanism are given in clause 15.6.

c) Use of uninitialized or not completely initialized template variables at other places than the left hand side of assignments or as actual parameters passed to out formal parameters shall cause an error.

NOTE 2 – Template variables, similarly to global and local templates, shall be fully specified in order to be used in sending and receiving operations.

Examples

```
var template integer MyVarTemp1 := ?;
var template MyRecord MyVarTemp2 := { field1 := true, field2 := * },
                      MyVarTemp3 := { field1 := ?, field2 := MyVarTemp1 };
```

12 Declaring timers

TTCN-3 provides a timer mechanism. Timers can be declared and used in the module control part, test cases, functions and altsteps. Additionally, timers can be declared in component type definitions. These timers can be used in test cases, functions and altsteps which are running on the given component type.

A timer declaration may have an optional default duration value assigned to it. The timer shall be started with this value if no other value is specified. The timer value shall be a non-negative **`float`** value (i.e., greater than or equal to 0.0) where the base unit is seconds.

In addition to single timer instances, timer arrays can also be declared. Default duration(s) of the elements of a timer array shall be assigned using a value array. Default duration(s) assignment shall use the array value notation as specified in clause 6.2.7. If the default duration assignment is wished to be skipped for some element(s) of the timer array, it shall explicitly be declared by using the not used symbol ("-").

Syntactical Structure

```
timer { TimerIdentifier [ ArrayDef ] ":=" TimerValue [ "," ] } [ ";" ]
```

Semantic Description

Timers are local to components. A component can start and stop a timer, check if a timer is running, read the elapsed time of a running timer and process timeout events after timer expiration. The timer value is interpreted with a base unit of seconds.

NOTE – Visibility of timer names follow the scoping rules given in clause 5. For example, the name of a timer defined locally in a function can be seen within that function only, though the timer is started on the component instance; on returning from that function the specific timer cannot be stopped directly, but only indirectly by an **`all timer.stop`** statement. Also, its timeout cannot be checked directly, but only indirectly by an **`any timer.timeout`** statement.

Restrictions

a) In case of a single timer, the default duration value should resolve to a float value.

b) In case of a timer array, it should resolve to an array of float values of the same size as the size of the timer array.

Examples

EXAMPLE 1: Single timer

```
timer MyTimer1 := 5E-3;
               // declaration of the timer MyTimer1 with the default value of 5 ms

timer MyTimer2; // declaration of MyTimer2 without a default timer value i.e., a value has
               // to be assigned when the timer is started
```

EXAMPLE 2: Timer array

```
timer t_Mytimer1[5] := { 1.0, 2.0, 3.0, 4.0, 5.0 }
               // all elements of the timer array get a default duration.

timer t_Mytimer2[5] := { 1.0, -, 3.0, 4.0, 5.0 }
               // the second timer (t_Mytimer2[1]) is left without a default duration.
```

13 Declaring messages

One of the key elements of TTCN-3 is the ability to send and receive simple or complex messages over message-based ports defined by the test configuration (see clause 9 and clause 21). These messages may be those explicitly concerned with testing the SUT or with the internal coordination and control messages specific to the relevant test configuration.

Messages are instances of types declared in the in/out/inout clauses of message port type definition.

Any type can be declared as type of a message in a message port type definition, i.e., values of any basic or structured type (see clauses 6 and 7) can be sent or received. Received messages can also be declared as a combination of value and matching mechanisms (see clause 15.5). Instances of messages can be declared by global, local or in-line templates (see clause 15) or being constructed and passed via variables or template variables (see clause 11) and parameters or template parameters (see clause 5.4).

Syntactical Structure

See syntactical structure of types (see clause 6).

Semantic Description

See semantic description of types (see clause 6).

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
    // a structured, ordered message with two fields
    type record ARecord { integer i, float f }
```

14 Declaring procedure signatures

Procedure signatures (or signatures for short) are needed for procedure-based communication. Procedure-based communication may be used for the communication within the test system, i.e., among test components, or for the communication between the test system and the SUT. In the latter case, a procedure may either be invoked in the SUT (i.e., the test system performs the call) or invoked in the test system (i.e., the SUT performs the call).

Syntactical Structure

```
   signature SignatureIdentifier
   "(" { [ in | inout | out ] Type ValueParIdentifier [ ","] } ")"
   [ ( return Type ) | noblock ]
   [ exception "(" ExceptionTypeList ")" ]
```

Semantic Description

For all used procedures, i.e., procedures used for the communication among test components, procedures called from the SUT and procedures called from the test system, a procedure **`signature`** shall be defined in the TTCN-3 module.

TTCN-3 supports *blocking* and *non-blocking* procedure-based communication. By default, signature definitions without the **`noblock`** keyword are assumed to be used for blocking procedure-based communication.

Signature definitions may have parameters. Within a **`signature`** definition, the parameter list may include parameter identifiers, parameter types and their direction, i.e., **`in`**, **`out`** or **`inout`**. The directions **`inout`** and **`out`** indicate that these parameters are used to retrieve information from the remote procedure. Note that the direction of the parameters is as seen by the *called* party rather than the *calling* party.

A remote procedure may return a value after its termination. The type of the return value shall be specified by means of a **`return`** clause in the corresponding signature definition.

Exceptions that may be raised by remote procedures are represented in TTCN-3 as values of a specific type. Therefore, templates and matching mechanisms can be used to specify or check return values of remote procedures.

NOTE – The conversion of exceptions generated by or sent to the SUT into the corresponding TTCN-3 type or SUT representation is tool- and system-specific and therefore beyond the scope of this Recommendation.

The exceptions are defined in the form of an exception list included in the **`signature`** definition. This list defines all the possible different types associated with the set of possible exceptions (the meaning of exceptions themselves will usually only be distinguished by specific values of these types).

Restrictions

a) Signature definitions for non-blocking communication shall use the `noblock` keyword, shall only have `in` parameters and shall have no return value but may raise exceptions.

Examples

```
signature MyRemoteProcOne ();           // MyRemoteProcOne will be used for blocking
                                        // procedure-based communication. It has neither
                                        // parameters nor a return value.

signature MyRemoteProcTwo () noblock;   // MyRemoteProcTwo will be used for non-blocking
                                        // procedure-based communication. It has neither
                                        // parameters nor a return value.

signature MyRemoteProcThree (in integer Par1, out float Par2, inout integer Par3);
// MyRemoteProcThree will be used for blocking procedure-based communication. The procedure
// has three parameters: Par1 an in parameter of type integer, Par2 an out parameter of
// type float and Par3 an inout parameter of type integer.

signature MyRemoteProcFour (in integer Par1) return integer;
// MyRemoteProcFour will be used for blocking procedure-based communication. The procedure
// has the in parameter Par1 of type integer and returns a value of type integer after its
// termination

signature MyRemoteProcFive (inout float Par1) return integer
        exception (ExceptionType1, ExceptionType2);
// MyRemoteProcFive will be used for blocking procedure-based communication. It returns a
// float value in the inout parameter Par1 and an integer value, or may raise exceptions of
// type ExceptionType1 or ExceptionType2

signature MyRemoteProcSix (in integer Par1) noblock
        exception (integer, float);
// MyRemoteProcSix will be used for non-blocking procedure-based communication. In case of
// an unsuccessful termination, MyRemoteProcSix raises exceptions of type integer or float.
```

15 Declaring templates

Templates are used to either transmit a set of distinct values or to test whether a set of received values matches the template specification. Templates can be defined globally or locally.

Templates provide the following possibilities:

a) they are a way to organize and to reuse test data, including a simple form of inheritance;

b) they can be parameterized;

c) they allow matching mechanisms;

d) they can be used with either message-based or procedure-based communications.

Within a template values, ranges and matching attributes can be specified and then used in both message-based and procedure-based communications. Templates may be specified for any TTCN-3 type or procedure signature. The type-based templates are used for message-based communications and the signature templates are used in procedure-based communications.

A modified template declaration (see clause 15.5) specifies only the fields to be changed from the base template, i.e., it is a partial specification.

15.1 Declaring message templates

Instances of messages with actual values may be specified using templates. A template can be thought of as being a set of instructions to build a message for sending or to match a received message.

Syntactical Structure

See syntactical structure of global and local templates (see clause 15.3) and of in-line templates (see clause 15.4).

Semantic Description

A template used in a **`send`** operation defines a complete set of field values comprising the message to be transmitted over a port.

NOTE – For sending templates, omitting an optional field is considered to be a value notation rather than a matching mechanism.

A template used in a **`receive`**, **`trigger`** or **`check`** operation defines a data template against which an incoming message is to be matched. Matching mechanisms, as defined in Annex B, may be used in receive templates. No binding of the incoming values to the template shall occur.

Restrictions

At the time of a **`send`** operation, the used template shall be fully defined i.e., all fields shall resolve to actual values and no matching mechanisms shall be used in the template fields, neither directly nor indirectly.

Examples

EXAMPLE 1: Template for sending messages

```
// Given the message definition
type record MyMessageType
{
    integer     field1  optional,
    charstring  field2,
    boolean     field3
}

// a message template could be
template MyMessageType MyTemplate:=
{
    field1 := omit,
    field2 := "My string",
    field3 := true
}

// and a corresponding send operation could be
MyPCO.send(MyTemplate);
```

EXAMPLE 2: Template for receiving messages

```
// Given the message definition
type record MyMessageType
{
    integer     field1  optional,
    charstring  field2,
    boolean     field3
}

// a message template might be
template MyMessageType MyTemplate:=
{
    field1 := ?,
    field2 := pattern "abc*xyz",
    field3 := true
}

// and a corresponding receive operation could be
MyPCO.receive(MyTemplate);
```

EXAMPLE 3: Template for receiving messages

```
// When used in a receiving operation this template will match any integer value
template integer Mytemplate := ?;

// This template will match only the integer values 1, 2 or 3
template integer Mytemplate := (1, 2, 3);
```

15.2 Declaring signature templates

Instances of procedure parameter lists with actual values may be specified using templates. Templates may be defined for any procedure by referencing the associated signature definition.

Syntactical Structure

See syntactical structure of global and local templates (see clause 15.3) and of in-line templates (see clause 15.4).

Semantic Description

A signature template defines the values and matching mechanisms of the procedure parameters only, but not the return value. The values or matching mechanisms for a return have to be defined within the reply (see clause 22.3.3) or getreply operation (see clause 22.3.4).

A template used in a **`call`** or **`reply`** operation defines a complete set of field values for all **`in`** and **`inout`** parameters. At the time of the **`call`** operation, all **`in`** and **`inout`** parameters in the template shall resolve to actual values, no matching mechanisms shall be used in these fields, either directly or indirectly. Any template specification for **`out`** parameters is simply ignored, therefore it is allowed to specify matching mechanisms for these fields, or to omit them (see Annex B).

A template used in a **`getcall`** operation defines a data template against which the incoming parameter fields are matched. Matching mechanisms, as defined in Annex B, may be used in any templates used by this operation. No binding of incoming values to the template shall occur. Any **`out`** parameters shall be ignored in the matching process.

Restrictions

a) At the time of a **`call`**, **`reply`** and **`raise`** operation, the used template shall be fully defined, i.e., all **`in`**/**`inout`** parameters in a **`call`**, all **`out`**/**`inout`** parameters in a **`reply`** or **`raise`** operation shall resolve to actual values and no matching mechanisms shall be used for these parameters, neither directly nor indirectly.

b) The NotUsedSymbol shall only be used in signature templates for parameters which are not relevant and in modified template declarations and modified in-line templates to indicate no change for the specified field or element.

Examples

EXAMPLE 1: Templates for invoking and accepting procedures

```
// signature definition for a remote procedure
signature RemoteProc(in integer Par1, out integer Par2, inout integer Par3) return integer;

// example templates associated to defined procedure signature
template RemoteProc Template1:=
{
    Par1 := 1,
    Par2 := 2,
    Par3 := 3
}
```

```
template RemoteProc Template2:=
{
    Par1 := 1,
    Par2 := ?,
    Par3 := 3
}

template RemoteProc Template3:=
{
    Par1 := 1,
    Par2 := ?,
    Par3 := ?
}
```

EXAMPLE 2: In-line templates for invoking procedures

```
// Given example 1 in this clause

// Valid invocation since all in and inout parameters have a distinct value
MyPCO.call(RemoteProc:Template1);

// Valid invocation since all in and inout parameters have a distinct value
MyPCO.call(RemoteProc:Template2);

// Invalid invocation because the inout parameter Par3 has a matching attribute not a value
MyPCO.call(RemoteProc:Template3);

// Templates never return values. In the case of Par2 and Par3 the values returned by the
// call operation must be retrieved using an assignment clause at the end of the call statement
```

EXAMPLE 3: In-line templates for accepting procedure invocations

```
// Given example 1 in this clause

// Valid getcall, it will match if Par1 == 1 and Par3 == 3
MyPCO.getcall(RemoteProc:Template1);

// Valid getcall, it will match if Par1 == 1 and Par3 == 3
MyPCO.getcall(RemoteProc:Template2);

// Valid getcall, it will match on Par1 == 1 and Any value of Par3
MyPCO.getcall(RemoteProc:Template3);
```

15.3 Global and local templates

TTCN-3 allows defining global templates and local templates.

Syntactical Structure

```
template Type TemplateIdentifier  ["(" TemplateFormalParList ")"]
[ modifies TemplateRef ] ":=" TemplateBody
```

Semantic Description

Global templates can be defined in the module definitions part. Local templates can be defined in testcases, functions, altsteps or statement blocks. Both global and local templates scoping rules specified in clause 5 apply.

Both global and local templates can be parameterized. The actual parameters of a template can include values and templates. The rules for formal and actual parameter lists shall be followed as defined in clause 5.2.

At the time of their use (e.g., in communication operations **send**, **receive**, **call**, **getcall,** etc.), it is allowed to change template fields by in-line modified templates, to pass in values via value parameters as well as to pass in templates via template parameters. The effects of these changes on the values of the template fields do not persist in the template subsequent to the corresponding communication event.

Restrictions

a) Templates may be specified for any TTCN-3 type defined in Table 3 except for **`port`** and **`default`** types and for any procedure signature.

b) The dot notation such as *MyTemplateId.FieldId* shall not be used to set or retrieve values in templates in communication events. The "->" symbol shall be used for this purpose (see clause 23).

c) Restrictions on referencing elements of templates or template fields are described in clause 15.6.

d) There exist a number of restrictions on the functions used in expressions when specifying templates or template fields; these are specified in clause 16.1.4.

Examples

```
// The template
template MyMessageType MyTemplate (integer MyFormalParam):=
{
    field1 := MyFormalParam,
    field2 := pattern "abc*xyz",
    field3 := true
}

// could be used as follows
pco1.send(MyTemplate(123));
```

15.4 In-line templates

Templates can be specified directly at the place they are used. Such templates are called in-line templates.

Syntactical Structure

```
[ Type ":" ] [ modifies TemplateRefWithParList ":=" ] TemplateBody
```

NOTE 1 – An in-line template is an argument of a communication operation or an actual parameter of a testcase, function or altstep call, i.e., it is always placed within parenthesis and potentially separated with a comma.

Semantic Description

In-line templates can be defined directly at the place of its use.

In-line templates do not have names, therefore they cannot be referenced or reused. The lifetime of in-line templates is the TTCN-3 statement (an assignment, a testcase/function/alstep invocation, a return from a function, a communication operation), where they are defined.

Restrictions

a) Templates may be specified for any TTCN-3 type defined in Table 3 and for any procedure signature except for **`port`** and **`default`** types.

b) The type field may only be omitted when the type is implicitly unambiguous.

NOTE 2 – For literal in-line templates, the following types may be omitted: **`integer`**, **`float`**, **`boolean`**, **`bitstring`**, **`hexstring`**, **`octetstring`**.

NOTE 3 – Types of constants, parameters and variables of the actual scope are always unambiguous and can hence always be omitted.

c) In-line templates containing matching mechanisms (see clause 15.7) can only be defined in arguments of receiving communication operations (i.e., **`receive`**, **`trigger`**, **`check`**, **`getcall`**, **`getreply`** and **`catch`**), in arguments of the **`match`** and **`select case`** operations, in actual template parameters, at the right hand side of assignments (when there is a template variable at the left hand side of the assignment) and in return statements of template returning functions. In-line templates not containing matching mechanisms can be defined wherever values are allowed.

d) When used in communication operations, the type of the in-line template shall be in the port list over which the template is sent or received. In the case where there is an ambiguity between the listed type and the type of the value provided (e.g., through sub-typing) then the type name of the in-line template shall be included in the communication operation.

e) There exist a number of restrictions on the functions used in expressions when specifying templates or template fields; these are specified in clause 16.1.4.

Examples

```
MyPCO.receive(charstring:"abcxyz");
```

15.5 Modified templates

Normally, a template specifies a set of base or default values or matching symbols for each and every field defined in the appropriate type or signature definition. In cases where small changes are needed to specify a new template, it is possible to specify a modified template. A modified template specifies modifications to particular fields of the original template, either directly or indirectly. As well as creating explicitly named modified templates, TTCN-3 allows the definition of in-line modified templates.

Syntactical Structure

Global or local modified template:

```
template Type TemplateIdentifier  ["(" TemplateFormalParList ")"]
modifies TemplateRef ":=" TemplateBody
```

In-line modified template:

```
[ Type ":" ] modifies TemplateRefWithParList ":=" TemplateBody
```

Semantic Description

The `modifies` keyword denotes the parent template from which the new, or modified template shall be derived. This parent template may be either an original template or a modified template.

The modifications occur in a linked fashion eventually tracing back to the original template. If a template field and its corresponding value or matching symbol is specified in the modified template, then the specified value or matching symbol replaces the one specified in the parent template. If a template field and its corresponding value or matching symbol is not specified in the modified template, then the value or matching symbol in the parent template shall be used. When the field to be modified is nested within a template field which is a structured field itself, no other field of the structured field is changed apart from the explicitly denoted one(s).

When individual values of a modified template or a modified template field of `record of` type wished to be changed, and only in these cases, the value assignment notation may also be used, where the left hand side of the assignment is the index of the element to be altered.

Restrictions

a) A modified template shall not refer to itself, either directly or indirectly, i.e., recursive derivation is not allowed.

b) If a base template has a formal parameter list, the following rules apply to all modified templates derived from that base template, whether or not they are derived in one or several modification steps:

   1) the derived template shall not omit parameters defined at any of the modification steps between the base template and the actual modified template;

2) a derived template can have additional (appended) parameters if wished;

3) the formal parameter list shall follow the template name for every modified template.

c) Restrictions on referencing elements of templates or template fields are described in clause 15.6.

Examples

EXAMPLE 1:

```
// Given
type record MyRecordType
{
    integer field,
    charstring field2,
    boolean field3
}
template MyRecordType MyTemplate1 :=
{
    field1 := 123,
    field2 := "A string",
    field3 := true
}
// then writing
template MyRecordType MyTemplate2 modifies MyTemplate1 :=
{
    field1 := omit,                // field1 is optional but present in MyTemplate1
    field2 := "A modified string"
                                   // field3 is unchanged
}
// is the same as writing
template MyRecordType MyTemplate2 :=
{
    field1 := omit,
    field2 := "A modified string",
    field3 := true
}
```

EXAMPLE 2: Modified record of template

```
template MyRecordOfType MyBaseTemplate := { 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 };
template MyRecordOfType MyModifTemplate modifies MyBaseTemplate := { [2] := 3, [3] := 2 };
// MyModifTemplate shall match the sequence of values { 0, 1, 3, 2, 4, 5, 6, 7, 8, 9 }
```

EXAMPLE 3: Modified in-line template

```
// Given
template MyMessageType Setup :=
{   field1 := 75,
    field2 := "abc",
    field3 := true
}

// Could be used to define an in-line modified template of Setup
pco1.send (modifies Setup := {field1:= 76});
```

EXAMPLE 4: Modified parameterized template

```
// Given
template MyRecordType MyTemplate1(integer MyPar):=
{
    field1 := MyPar,
    field2 := "A string",
    field3 := true
}

// then a modification could be
    template MyRecordType MyTemplate2(integer MyPar) modifies MyTemplate1 :=
{   // field1 is parameterized in Template1 and remains also parameterized in Template2
    field2 := "A modified string",
}
```

15.6 Referencing elements of templates or template fields

This clause defines rules and restrictions when referencing elements of templates or template fields.

15.6.1 Referencing individual string elements

It is not allowed to reference individual string elements inside templates or template fields. Instead, the substr function (see clause C.3) should be used.

EXAMPLE:

```
var template charstring t_Char1 := "MYCHAR";
var template charstring t_Char2;

t_Char2 := t_Char1[1];
// shall cause an error as referencing individual string elements is not allowed
```

15.6.2 Referencing `record` and `set` fields

Both templates and template variables allow referencing sub-fields inside a template definition using the dot notation. However, the referenced field may be a subfield of a structured field to which a matching mechanism is assigned. This clause provides rules for such cases.

a) *Omit, AnyValueOrNone, value lists and complemented lists*: referencing a subfield within a structured field to which Omit, AnyValueOrNone, a value list or a complemented list is assigned, shall cause an error.

EXAMPLE 1:

```
type record R1 {
    integer f1 optional,
    R2      f2 optional
}
type record R2 {
    integer g1,
    R2      g2 optional
}

:
var template R1 t_R1 := {
    f1 := 5,
    f2 := omit
}
var template R2 t_R2 := t_R1.f2.g2;
    // causes an error as omit is assigned to t_R1.f2
t_R1.f2 := *;
t_R2 := t_R1.f2.g2;
    // causes an error as * is assigned to t_R1.f2

t_R1 := ({f1:=omit, f2:={g1:=0, g2:=omit}},{f1:=5, f2:={g1:=1, g2:={g1:=2, g2:=omit}}});

t_R2 := t_R1.f2;
t_R2 := t_R1.f2.g2;
t_R2 := t_R1.f2.g2.g2;
    // all these assignments cause an error as a value list is assigned to t_R1

t_R1 :=
    complement({f1:=omit, f2:={g1:=0, g2:=omit}},{f1:=5, f2:={g1:=1, g2:={g1:=2, g2:=omit}}});

t_R2 := t_R1.f2;
t_R2 := t_R1.f2.g2;
t_R2 := t_R1.f2.g2.g2;
    // all these assignments cause errors as a complemented list is assigned to t_R1
```

b) *AnyValue*: when referencing a subfield within a structured field to which AnyValue is assigned, at the right hand side of an assignment, AnyValue shall be returned for mandatory subfields and AnyValueOrNone shall be returned for optional subfields. When referencing a subfield within a structured field to which AnyValue is assigned, at the left hand side of an assignment, the structured field has to be expanded recursively up to the depth of the referenced subfield. During this expansion an AnyValue shall be assigned to mandatory subfields and AnyValueOrNone shall be assigned to optional subfields. After this expansion the value or matching mechanism at the right hand side of the assignment shall be assigned to the referenced subfield.

EXAMPLE 2:

```
t_R1 := {f1:=0, f2:=?}
t_R2 := t_R1.f2.g2;
    // after the assignment t_R2 will be {g1:=?, g2:=*}
t_R1.f2.g2.g2 := ({g1:=1, g2:=omit},{g1:=2, g2:=omit});
    // first the field t_R1.f2 has hypothetically been expanded to {g1:=?,g2:={g1:=?,g2:=*}}
    // thus after the assignment t_R1 will be:
    //   {f1:=0, f2:={g1:=?,g2:={g1:=?,g2:=({g1:=1, g2:=omit},{g1:=2, g2:=omit})}}}
```

c) *Ifpresent attribute*: referencing a subfield within a structured field to which the ifpresent attribute is attached, shall cause an error (irrespective of the value or the matching mechanism to which `ifpresent` is appended).

15.6.3 Referencing `record of` and `set of` elements

Both templates and template variables allow referencing elements of a `record of` or `set of` template or field using the index notation. However, a matching mechanism may be assigned to the template or field within which the element is referenced. This clause provides rules on handling such cases.

a) *Omit, AnyValueOrNone, value lists, complemented lists, subset and superset*: referencing an element within a record of or set of field to which Omit, AnyValueOrNone with or without a length attribute, a value list, a complemented list, a subset or a superset is assigned, shall cause an error.

EXAMPLE 1:

```
type record of integer RoI;
type record of RoI RoRoI;

:
var template RoI t_RoI;
var template RoRoI t_RoRoI;
var template integer t_Int;
:
t_RoRoI := ({},{0},{0,0},{0,0,0});
t_RoI := t_RoRoI[0];
    // shall cause an error as value list is assigned to t_RoRoI;
```

b) *AnyValue*: when referencing an element of a `record of` or `set of` template or field to which AnyValue is assigned (without a length attribute), at the right hand side of an assignment, AnyValue shall be returned. If a length attribute is attached to AnyValue, the index of the reference shall not violate the length attribute. When referencing an element within a `record of` or `set of` template or field to which AnyValue is assigned (without a length attribute), at the left hand side of an assignment, the value or matching mechanism at the right hand side of the assignment shall be assigned to the referenced element, AnyElement shall be assigned to all elements before the referenced one (if any) and a single AnyElementsOrNone shall be added at the end. When a length attribute is attached to AnyValue, the attribute shall be conveyed to the new template or field transparently. The index shall not violate type restrictions in any of the above cases.

EXAMPLE 2:

```
type record of integer RoI;
type record of RoI RoRoI;
```

```
:
var template RoI t_RoI;
var template RoRoI t_RoRoI;
var template integer t_Int;
:
t_RoI := ?;
t_Int := t_RoI[5];
    // after the assignment t_Int will be AnyValue(?);

t_RoRoI := ?;
t_RoI := t_RoRoI[5];
    // after the assignment t_RoI will be AnyValue(?);
t_Int := t_RoRoI[5].[3];
    // after the assignment t_Int will be AnyValue(?);

t_RoI := ? length (2..5);
t_Int := t_RoI[3];
    // after the assignment t_Int will be AnyValue(?);
t_Int := t_RoI[5];
    // shall cause an error as the referenced index is outside the length attribute
    // (note that index 5 would refer to the 6th element);

t_RoRoI[2] := {0,0};
    // after the assignment t_RoRoI will be {?,?,{0,0},*};
t_RoRoI[4] := {1,1};
    // after the assignment t_RoRoI will be {?,?,{0,0},?,{1,1},*};
t_RoI[0] := -5;
    // after the assignment t_RoI will be {-5,*}length(2..5);
t_RoI := ? length (2..5);
t_RoI[1] := 1;
    // after the assignment t_RoI will be {?,1,*}length(2..5);
t_RoI[3] := ?
    // after the assignment t_RoI will be {?,1,?,?,*}length(2..5);
t_RoI[5] := 5
    // after the assignment t_RoI will be {?,1,?,?,?,5,*}length(2..5); note that t_RoI
    // becomes an empty set but that shall cause no error;
```

c) *Permutation*: when referencing an element of a **`record of`** template or field, which is located inside a permutation (based on its index), this shall cause an error. Indexes of elements sheltered by a permutation shall be determined based on the number of permutation elements. AnyValueOrNone as a permutation element causes that the permutation shelters all record of element indexes.

EXAMPLE 3:

```
t_RoI := {permutation(0,1,3,?),2,?}
t_Int := t_RoI[5];
    // after the assignment t_Int will be AnyValue(?)

t_RoI := {permutation(0,1,3,?),2,*}
t_Int := t_RoI[5];
    // after the assignment t_Int will be * (AnyValueOrNone)
t_Int := t_RoI[2];
    // causes error as the third element (with index 2) is inside permutation

t_RoI := {permutation(0,1,3,*),2,?}
t_Int := t_RoI[5];
    // causes error as the permutation contains AnyValueOrNone(*) that is able to
    // cover any record of indexes
```

d) *Ifpresent attribute*: referencing an element within a **`record of`** or **`set of`** field to which the **`ifpresent`** attribute is attached, shall cause an error (irrespective of the value or the matching mechanism to which **`ifpresent`** is appended).

15.7 Template matching mechanisms

Generally, matching mechanisms are used to replace values of single template fields or to replace even the entire contents of a template. Matching mechanisms may also be used in-line (see clause 15.4).

Matching mechanisms are arranged in four groups:

- specific values;
- special symbols that can be used *instead* of values;
- special symbols that can be used *inside* values;
- special symbols which describe *attributes* of values.

Some of the mechanisms may be used in combination.

The supported matching mechanisms and their associated symbols (if any) and the scope of their application are shown in Table 9. The left-hand column of this table lists all the TTCN-3 types to which these matching mechanisms apply. A full description of each matching mechanism can be found in Annex B.

Table 9 – TTCN-3 matching mechanisms

Used with values of	**Value**		**Instead of values**								**Inside values**			**Attributes**	
	Specific value	Omit value	Complemented list	Value list	Any value (?)	Any value or none (*)	Range	Superset	Subtype	Pattern	Any element (?)	Any elements or none (*)	Permutation	Length restriction	If present
`boolean`	Yes	Yes	Yes	Yes	Yes	Yes[1]									Yes[2]
`integer`	Yes	Yes	Yes	Yes	Yes	Yes[1]	Yes								Yes[2]
`float`	Yes	Yes	Yes	Yes	Yes	Yes[1]	Yes								Yes[2]
`bitstring`	Yes	Yes	Yes	Yes	Yes	Yes[1]					Yes	Yes		Yes	Yes[2]
`octetstring`	Yes	Yes	Yes	Yes	Yes	Yes[1]					Yes	Yes		Yes	Yes[2]
`hexstring`	Yes	Yes	Yes	Yes	Yes	Yes[1]					Yes	Yes		Yes	Yes[2]
`character strings`	Yes	Yes	Yes	Yes	Yes	Yes[1]	Yes			Yes	Yes	Yes		Yes	Yes[2]
`record`	Yes	Yes	Yes	Yes	Yes	Yes[1]									Yes[2]
`record of`	Yes	Yes	Yes	Yes	Yes	Yes[1]					Yes	Yes	Yes	Yes	Yes[2]
`array`	Yes	Yes	Yes	Yes	Yes	Yes[1]					Yes	Yes		Yes	Yes[2]
`set`	Yes	Yes	Yes	Yes	Yes	Yes[1]									Yes[2]
`set of`	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes		Yes	Yes		Yes	Yes[2]
`enumerated`	Yes	Yes	Yes	Yes	Yes	Yes[1]									Yes[2]
`union`	Yes	Yes	Yes	Yes	Yes	Yes[1]									Yes[2]
`anytype`	Yes	Yes	Yes	Yes	Yes	Yes[1]									Yes[2]

NOTE 1 – When used, shall be applied to optional fields of record and set types only (without restriction on the type of that field).

NOTE 2 – When used, shall be applied to record and set fields only (without restriction on the type of that field).

15.7.1 Specific values

Specific values are the basic matching mechanisms of TTCN-3 templates. Specific values in templates are expressions which do not contain any matching mechanisms.

Syntactical Structure

```
SingleExpression |
omit
```

Semantic Description

The matching mechanisms for specific values are:

- an expression that evaluates to a specific value;
- **omit**: value is omitted.

For further details please refer to Annex B.

Restrictions

See the restrictions given in Table 9 and in Annex B.

Examples

```
 MyPCO.receive(charstring:"abcxyz");
 MyPCO.receive('AAAA'O);
```

15.7.2 Special symbols that can be used instead of values

These matching mechanisms can be used to characterize a set of values.

Syntactical Structure

```
"(" { ConstantExpression [","] } ")" |
complement "(" { ConstantExpression [","] } ")" |
"?" |
"*" |
"(" ( ConstantExpression | -infinity ) ".." ( ConstantExpression | infinity ) ")" |
superset "(" { ConstantExpression [","] } ")" |
subset "(" { ConstantExpression [","] } ")" |
pattern Cstring
```

Semantic Description

The matching mechanisms for special symbols that can be used *instead* of values are:

- **(…)**: a list of values;
- **complement (…)**: complement of a list of values;
- **?**: wildcard for any value;
- *****: wildcard for any value or no value at all (i.e., an omitted value);
- (*lowerBound* **..** *upperBound*): a range of integer or float values between and including the lower- and upper-bounds;
- **superset**: at least all of the elements listed, i.e., possibly more;
- **subset**: at most the elements listed, i.e., possibly less;
- **pattern**: a charstring or universal charstring that matches this format.

For further details please refer to Annex B.

Restrictions

See the restrictions given in Table 9 and in Annex B.

Examples

```
 MyPCO.receive (integer:complement(1, 2, 3));
```

15.7.3 Special symbols that can be used inside values

These matching mechanisms allow to characterize value sets by varying values inside.

Syntactical Structure

```
…"?"… |
…"*"… |
…permutation "(" { ( TemplateBody | "?" | "*" )[","] } ")"…
```

Semantic Description

The matching mechanisms for special symbols that can be used *inside* values are:

- **?**: wildcard for any single element in a string, array, **record of** or **set of**;
- *****: wildcard for any number of consecutive elements in a string, array, **record of** or **set of**, or no element at all (i.e., an omitted element);
- **permutation**: all of the elements listed but in an arbitrary order (note, that ? and * are also allowed as elements of the permutation list).

For further details please refer to Annex B.

Restrictions

See the restrictions given in Table 9 and in Annex B.

Examples

```
template bitstring b := '10???'B;       // where each "?" may either be 0 or 1
type record of integer RI;
template RI ri := {1, ?, 3}             // where ? may be any integer value
```

15.7.4 Special symbols which describe attributes of values

These matching mechanisms define properties of values.

Syntactical Structure

```
length "(" ConstantExpression [ ".." ( ConstantExpression | infinity ) ] ")" [ ifpresent ] |
ifpresent
```

Semantic Description

The matching mechanisms which describe *attributes* of values are:

- **length**: restrictions for string length of string types and the number of elements for **record of**, **set of** and arrays;
- **ifpresent**: for matching of optional field values (if not omitted).

For further details please refer to Annex B.

Restrictions

See the restrictions given in Table 9 and in Annex B.

Examples

```
type record R {
    record of integer ri optional
}
template R r:=
{
    ri := * length (1 .. 6) ifpresent   // any value containing 1, 2, 3, 4,
                                        // 5 or 6 provided it is present
}
```

15.8 Match Operation

The **match** operation allows to compare a value with a template.

Syntactical Structure

```
match "(" Expression "," TemplateInstance ")"
```

Semantic Description

The **match** operation returns a boolean value. If the types of the template and the value are not compatible (see clause 6.3) the operation returns false. If the types are compatible the return value of the operation indicates whether the value matches the specified template.

Restrictions

a) The type of the value returned by the *Expression* must be the same as the *TemplateInstance* type.

b) Each field of the template shall resolve to a specific value.

Examples

```
template integer LessThan10 := (-infinity..9);
:
MyPort.receive(integer:?) -> value RxValue;
if( match( RxValue, LessThan10)) { … }
// true if the actual value of Rxvalue is less than 10 and false otherwise
:
```

15.9 Valueof Operation

The **valueof** operation allows to return the value specified within a template. The returned value can be assigned to a variable, may be used in expressions, as an actual value parameter, etc.

Syntactical Structure

```
valueof "(" TemplateInstance")"
```

Semantic Description

The **valueof** operation returns the value of a template instance.

Restrictions

Each field of the template shall resolve to a specific value.

Examples

```
type record ExampleType
{
    integer field1,
    boolean field2
}

template ExampleType SetupTemplate :=
{
    field1 := 1,
    field2 := true
}

:
var ExampleType RxValue := valueof(SetupTemplate);
```

16 Functions, altsteps and testcases

In TTCN-3, functions, altsteps and testcases are used to specify and structure test behaviour, define default behaviour and to structure computation in a module, etc. as described in the following clauses.

16.1 Functions

Functions are used in TTCN-3 to express test behaviour, to organize test execution or to structure computation in a module, for example, to calculate a single value, to initialize a set of variables or to check some condition.

Syntactical Structure

```
function FunctionIdentifier
"(" [ { ( FormalValuePar | FormalTimerPar | FormalTemplatePar | FormalPortPar ) [","] } ] ")"
[ runs on ComponentType ]
[ return [ template ] Type ]
StatementBlock
```

Semantic Description

Functions are portions of TTCN-3 behaviour, which perform a specific task and are relatively independent of the remaining behaviour.

Functions may return a value or a template. Value return is denoted by the `return` keyword followed by a type identifier. Template return is denoted by the `return template` keywords followed by a type identifier. The keyword `return`, when used in the body of the function with a value return defined in its header, shall always be followed by an expression representing the return value. The type of the return value shall be compatible with the return type. The keyword `return`, when used in the body of the function with a template return defined in its header, shall always be followed by an expression or a template instance representing the return template. The type of the return template shall be compatible with the return template type. The return statement in the body of the function causes the function to terminate and to return the return value to the location of the call of the function.

The behaviour of a function can be defined by using statements and operations described in clauses 18 to 26. If a function uses variables, constants, timers and ports that are declared in a component type definition, the component type shall be referenced using the `runs on` keywords in the function header. The one exception to this rule is if all the necessary component-wide information is passed in the function as parameters.

Functions may be parameterized.

Restrictions

a) A function without `runs on` clause shall never invoke a function or altstep or activate an altstep as default with a `runs on` clause locally.

b) Functions started by using the `start` test component operation shall always have a `runs on` clause (see clause 21.2.2) and are considered to be invoked in the component to be started, i.e., not locally. However, the `start` test component operation may be invoked in functions without a `runs on` clause.

NOTE 1 – The restrictions concerning the `runs on` clause are only related to functions and altsteps and not to test cases.

c) Functions used in the control part of a TTCN-3 module shall have no `runs on` clause.

NOTE 2 – Nevertheless, functions used in the control part are allowed to execute test cases.

d) The rules for formal parameter lists shall be followed as defined in clause 5.4.

Examples

EXAMPLE 1: Function with return

```
// Definition of MyFunction which has no parameters
function MyFunction() return integer
{

    return 7;   // returns the integer value 7 when the function terminates
}
```

EXAMPLE 2: Function with template return

```
// Definition of functions which may return matching symbols or templates
function MyFunction2() return template integer
{
:
    return ?;   // returns the matching mechanism AnyValue
}
function MyFunction3() return template octetstring
{
:
    return 'FF??FF'O;   // returns an octetstring with AnyValue inside it
}
```

EXAMPLE 3: Function with **`runs on`** clause

```
function MyFunction3() runs on MyPTCType {
                    lo          // MyFunction3 does not return a value, but
    var integer MyVar := 5;     // does make use of the port operation
    PCO1.send(MyVar);           // send and therefore requires a runs on
                                // clause to resolve the port identifiers
}                               // by referencing a component type
```

EXAMPLE 4: Parameterized function

```
function MyFunction2(inout integer MyPar1) {
                            // MyFunction2 does not return a value
    MyPar1 := 10 * MyPar1;  // but changes the value of MyPar1 which
}                           // is passed in by reference
```

16.1.1 Invoking functions

A function is invoked by referring to its name and providing the actual list of parameters.

Syntactical Structure

```
FunctionRef "(" [ { ( TimerRef | TemplateInstance | Port | ComponentRef ) [","] } ] ")"
```

Semantic Description

A function invocation results in the execution of the statement block of the invoked function. The invoked function is performed by the test component invoking it. Actual parameters are passed into the statement block. If the function returns (upon termination and potentially with a return value), the test component continues its behaviour right after the function invocation.

Restrictions

a) Functions that do not return values shall be invoked directly. Functions that return values may be invoked directly or inside expressions.

b) The rules for actual parameter lists shall be followed as defined in clause 5.4.

c) Special restrictions apply to functions bound to test components using the **`start`** test component operation. These restrictions are described in clause 21.2.2.

d) When invoking a function, the compatibility to the test component type of the invoking test component as described in clause 6.3.3 need to be fulfilled.

e) Restrictions on invoking functions from specific places are described in clause 16.1.4.

Examples

```
MyVar := MyFunction4(); // The value returned by MyFunction4 is assigned to MyVar.
                        // The types of the returned value and MyVar have to be compatible

MyFunction2(MyVar2);    // MyFunction2 does not return a value and is called with the
                        // actual parameter MyVar2, which may be passed in by reference

MyVar3 := MyFunction6(4) + MyFunction7(MyVar3); // Functions used in expressions
```

16.1.2 Predefined functions

TTCN-3 contains a number of predefined (built-in) functions that need not be declared before use. These are summarized in Table 10.

Table 10 – List of TTCN-3 predefined functions

Category	Function	Keyword
Conversion functions	Convert **integer** value to **charstring** value	**int2char**
	Convert **integer** value to **universal charstring** value	**int2unichar**
	Convert **integer** value to **bitstring** value	**int2bit**
	Convert **integer** value to **hexstring** value	**int2hex**
	Convert **integer** value to **octetstring** value	**int2oct**
	Convert **integer** value to **charstring** value	**int2str**
	Convert **integer** value to **float** value	**int2float**
	Convert **float** value to **integer** value	**float2int**
	Convert **charstring** value to **integer** value	**char2int**
	Convert **charstring** value to **octetstring** value	**char2oct**
	Convert **universal charstring** value to **integer** value	**unichar2int**
	Convert **bitstring** value to **integer** value	**bit2int**
	Convert **bitstring** value to **hexstring** value	**bit2hex**
	Convert **bitstring** value to **octetstring** value	**bit2oct**
	Convert **bitstring** value to **charstring** value	**bit2str**
	Convert **hexstring** value to **integer** value	**hex2int**
	Convert **hexstring** value to **bitstring** value	**hex2bit**
	Convert **hexstring** value to **octetstring** value	**hex2oct**
	Convert **hexstring** value to **charstring** value	**hex2str**
	Convert **octetstring** value to **integer** value	**oct2int**
	Convert **octetstring** value to **bitstring** value	**oct2bit**
	Convert **octetstring** value to **hexstring** value	**oct2hex**
	Convert **octetstring** value to **charstring** value	**oct2str**
	Convert **octetstring** value to **charstring** value, version II	**oct2char**
	Convert **charstring** value to **integer** value	**str2int**
	Convert **charstring** value to **octetstring** value	**str2oct**
	Convert **charstring** value to **float** value	**str2float**
Length/size functions	Return the length of a value of any string type	**lengthof**
	Return the number of elements in a **record, record of, template**, **set**, **set of** or **array**	**sizeof**
	Return the number of elements in a structured type	**sizeoftype**
Presence/choice functions	Determine if an optional field in a **record, record of, template**, **set** or **set of** is present	**ispresent**
	Determine which choice has been made in a **union** type	**ischosen**

Table 10 – List of TTCN-3 predefined functions

Category	Function	Keyword
String handling functions	Returns part of the input string matching the specified pattern description	`regexp`
	Returns the specified portion of the input string	`substr`
	Replaces a substring of a string with or inserts the input string into a string	`replace`
Other functions	Generate a random float number	`rnd`

Syntactical Structure

```
int2char "(" SingleExpression ")" |
int2unichar "(" SingleExpression ")" |
int2bit "(" SingleExpression "," SingleExpression ")" |
int2hex "(" SingleExpression "," SingleExpression ")" |
int2oct "(" SingleExpression "," SingleExpression ")" |
int2str "(" SingleExpression ")" |
int2float "(" SingleExpression ")" |
float2int "(" SingleExpression ")" |
char2int "(" SingleExpression ")" |
char2oct "(" SingleExpression ")" |
unichar2int "(" SingleExpression ")" |
bit2int "(" SingleExpression ")" |
bit2hex "(" SingleExpression ")" |
bit2oct "(" SingleExpression ")" |
bit2str "(" SingleExpression ")" |
hex2int "(" SingleExpression ")" |
hex2bit "(" SingleExpression ")" |
hex2oct "(" SingleExpression ")" |
hex2str "(" SingleExpression ")" |
oct2int "(" SingleExpression ")" |
oct2bit "(" SingleExpression ")" |
oct2hex "(" SingleExpression ")" |
oct2str "(" SingleExpression ")" |
oct2char "(" SingleExpression ")" |
str2int "(" SingleExpression ")" |
str2oct "(" SingleExpression ")" |
str2float "(" SingleExpression ")" |
lengthof "(" SingleExpression ")" |
sizeof "(" Expression ")" |
sizeoftype "(" Expression ")" |
ispresent "(" Expression ")" |
ischosen "(" Expression ")" |
regexp "(" SingleExpression "," SingleExpression "," SingleExpression ")" |
substr "(" SingleExpression "," SingleExpression "," SingleExpression ")" |
replace "(" SingleExpression "," SingleExpression "," SingleExpression "," SingleExpression ")" |
rnd "(" [ SingleExpression ] ")"
```

Semantic Description

The description of predefined functions is given in Annex C.

Restrictions

1) When a predefined function is invoked:
   a) the number of the actual parameters shall be the same as the number of the formal parameters; and
   b) each actual parameter shall evaluate to an element of its corresponding formal parameter's type; and
   c) all variables appearing in the actual parameter list shall be bound.
2) Restrictions on invoking functions from specific places are described in clause 16.1.4.

Examples

```
    var hexstring h:= bit2hex ('111010111'B);
    var octetstring o:= substr ('01AB23CD'O, 1, 2);
```

16.1.3 External functions

A function may be defined within a module or be declared as being defined externally (i.e., **`external`**).

Syntactical Structure

```
  external function ExtFunctionIdentifier
  "(" [ { ( FormalValuePar | FormalTimerPar | FormalTemplatePar | FormalPortPar ) [","] } ] ")"
  [ return Type ]
```

Semantic Description

For an external function only the function interface has to be provided in the TTCN-3 module. The realization of the external function is outside the scope of this Recommendation.

Restrictions

a) External functions are not allowed to contain port, timer or default handling operations.

b) External functions are not allowed to return templates.

c) Restrictions on invoking functions from specific places are described in clause 16.1.4.

Examples

```
    external function MyFunction4() return integer; // External function without parameters
                                                    // which returns an integer value

    external function InitTestDevices();    // An external function which only has an
                                            // effect outside the TTCN-3 module
```

16.1.4 Invoking functions from specific places

Value returning functions can be called during communication operations (in templates, template fields or in-line templates) or during snapshot evaluation (in Boolean guards of alt statements or altsteps (see clause 20.2)) and in initialization of altstep local definitions (see clause 16.2). To avoid side effects that cause changing the state of the component or the actual snapshot and to prevent different results of subsequent evaluations on an unchanged snapshot, the following operations shall not be used in functions called in the cases specified above:

a) All component operations, i.e., **`create`**, **`start`** (component), **`stop`** (component), **`kill`**, **`running`** (component), **`alive`**, **`done`** and **`killed`** (see Notes 1, 3, 4 and 6).

b) All port operations, i.e., **`start`** (port), **`stop`** (port), **`halt`**, **`clear`**, **`send`**, **`receive`**, **`trigger`**, **`call`**, **`getcall`**, **`reply`**, **`getreply`**, **`raise`**, **`catch`**, **`check`**, **`connect`**, **`map`** (see Notes 1, 2, 3 and 6).

c) The **`action`** operation (see Notes 2 and 6).

d) All timer operations, i.e., **`start`** (timer), **`stop`** (timer), **`running`** (timer), **`read`**, **`timeout`** (see Notes 4 and 6).

e) Calling external functions (see Notes 4 and 6).

f) Calling the **`rnd`** predefined function (see Notes 4 and 6).

g) Changing of component variables, i.e., using component variables on the right-hand side of assignments, and in the instantiation of **`out`** and **`inout`** parameters (see Notes 4 and 6).

h) Calling the **`setverdict`** operation (see Notes 4 and 6).

i) Activation and deactivation of defaults, i.e., the **`activate`** and **`deactivate`** statements (see Notes 5 and 6).

j) Calling functions with **out** or **inout** parameters (see Notes 7 and 8).

NOTE 1 – The execution of the operations **start**, **stop**, **done**, **killed**, **halt**, **clear**, **receive**, **trigger**, **getcall**, **getreply**, **catch** and **check** can cause changes to the current snapshot.

NOTE 2 – The operations **send**, **call**, **reply**, **raise**, and **action** shall be avoided for readability purposes, i.e., all communication shall be made explicit and not as a side-effect of another communication operation or the evaluation of a snapshot.

NOTE 3 – The operations **map**, **unmap**, **connect**, **disconnect**, **create** shall be avoided for readability purposes, i.e., all configuration operations shall be made explicit, and not as a side-effect of a communication operation or the evaluation of a snapshot.

NOTE 4 – Calling of external functions, **rnd**, **running**, **alive**, **read**, **setverdict**, and writing to component variables shall be avoided because it may lead to different results of subsequent evaluations of the same snapshot, thus, e.g., rendering deadlock detection impossible.

NOTE 5 – The operations **activate** and **deactivate** shall be avoided because they modify the set of defaults that is considered during the evaluation of the current snapshot.

NOTE 6 – Restrictions except the limitation on the use of **out** or **inout** parameterization shall apply recursively, i.e., it is disallowed to use them directly, or via an arbitrary long chain of function invocations.

NOTE 7 – The restriction of calling functions with **out** or **inout** parameters does not apply recursively, i.e., calling functions that themselves call functions with **out** or **inout** parameters is legal.

NOTE 8 – Using **out** or **inout** parameters shall be avoided because it may also lead to different results of subsequent evaluations of the same snapshot.

16.2 Altsteps

TTCN-3 uses altsteps to specify default behaviour or to structure the alternatives of an **alt** statement.

Syntactical Structure

```
altstep AltstepIdentifier
"(" [ { ( FormalValuePar | FormalTimerPar | FormalTemplatePar | FormalPortPar ) [","] } ] ")"
[ runs on ComponentType ]
"{"
     { ( VarInstance | TimerInstance | ConstDef | TemplateDef ) [";"] }
     AltGuardList
"}"
```

Semantic Description

Altsteps are scope units similar to functions. The altstep body defines an optional set of local definitions and a set of alternatives, the so-called *top alternatives*, that form the altstep body. The syntax rules of the top alternatives are identical to the syntax rules of the alternatives of **alt** statements.

The behaviour of an altstep can be defined by using the program statements and operations summarized in clause 18. Altsteps may invoke functions and altsteps or activate altsteps as defaults.

Altsteps may be parameterized as defined in clause 5.4.

Restrictions

a) The local definitions of an altstep shall be defined before the set of alternatives.

b) The initialization of local definitions by calling value returning functions may have side effects. To avoid side effects that cause an inconsistency between the actual snapshot and the state of the component, and to prevent different results of subsequent evaluations on an unchanged snapshot, restrictions given in clause 16.1.4 shall apply to the initialization of local definitions.

c) If an altstep includes port operations or uses component variables, constants or timers the associated component type shall be referenced using the **runs on** keywords in the altstep header. The one exception to this rule is if all ports, variables, constants and timers used within the altstep are passed in as parameters.

d) An altstep without a **runs on** clause shall never invoke a function or altstep or activate an altstep as default with a **runs on** clause locally.

e) An altstep that is activated as a default shall only have **in** value or template parameters, port parameters, and timer parameters. An altstep that is only invoked as an alternative in an **alt** statement or as stand-alone statement in a TTCN-3 behaviour description may have **in**, **out** and **inout** parameters. The rules for formal parameter lists shall be followed as defined in clause 5.4.

Examples

EXAMPLE 1: Parameterized altstep with runs on clause

```
// Given
type component MyComponentType {
    var integer MyIntVar := 0;
    timer MyTimer;
    port MyPortTypeOne PCO1, PCO2;
    port MyPortTypeTwo PCO3;
}

// Altstep definition using PCO1, PCO2, MyIntVar and MyTimer of MyComponentType
altstep AltSet_A(in integer MyPar1) runs on MyComponentType {
    [] PCO1.receive(MyTemplate(MyPar1, MyIntVar) {
        setverdict(inconc);
       }
    [] PCO2.receive {
           repeat
       }
    [] MyTimer.timeout {
        setverdict(fail);
           stop
       }
}
```

EXAMPLE 2: Altstep with local definitions

```
altstep AnotherAltStep(in integer MyPar1) runs on MyComponentType {
    var integer MyLocalVar := MyFunction();        // local variable
    const float MyFloat := 3.41;                   // local constant
    [] PCO1.receive(MyTemplate(MyPar1, MyLocalVar) {
        setverdict(inconc);
       }
    [] PCO2.receive {
           repeat
       }
}
```

16.2.1 Invoking altsteps

The invocation of an altstep is always related to an **alt** statement. The invocation may be done either implicitly by the default mechanism (see clause 20.5.1) or explicitly by a direct call within an **alt** statement (see clause 20.2).

Syntactical Structure

```
AltstepRef "(" [ { ( TimerRef | TemplateInstance | Port | ComponentRef ) [","] } ] ")"
```

Semantic Description

The invocation of an altstep causes no new snapshot and the evaluation of the top alternatives of an altstep is done by using the actual snapshot of the **alt** statement from which the altstep was called.

NOTE – A new snapshot within an altstep will of course be taken, if within a selected top alternative a new `alt` statement is specified and entered.

For an implicit invocation of an altstep by means of the default mechanism, the altstep shall be activated as a default by means of an `activate` statement before the place of the invocation is reached.

An explicit call of an altstep within an `alt` statement looks syntactically like a function invocation as an alternative. When an altstep is called explicitly within an `alt` statement, the next alternative to be checked is the first alternative of the `altstep`. The alternatives of the `altstep` are checked and executed the same way as alternatives of an `alt` statement (see clause 20.1) with the exception that no new snapshot is taken when entering the `altstep`. An unsuccessful termination of the altstep (i.e., all top alternatives of the `altstep` have been checked and no matching branch is found) causes the evaluation of the next alternative or invocation of the default mechanism (if the explicit call is the last alternative of the `alt` statement). A successful termination may cause either the termination of the test component, i.e., the altstep ends with a `stop` statement, or a new snapshot and re-evaluation of the `alt` statement, i.e., the altstep ends with `repeat` (see clause 20.2) or a continuation immediately after the `alt` statement, i.e., the selected top alternative of the altstep ends without explicit `repeat` or `stop`.

An `altstep` can also be called as a stand-alone statement in a TTCN-3 behaviour description. In this case, the call of the `altstep` can be interpreted as shorthand for an `alt` statement with only one alternative describing the explicit call of the `altstep`.

Restrictions

a) When invoking an altstep, the compatibility of the test component type of the invoking test component and of the altstep `runs on` clause (as described in clause 6.3.3) need to be fulfilled.

b) Further restrictions on invoking altsteps in the `activate` statement are given in clause 20.5.2.

Examples

EXAMPLE 1: Implicit invocation of an altstep via a default activation

```
 :
var default MyDefVarTwo := activate(MySecondAltStep()); // Activation of an altstep as default
 :
```

EXAMPLE 2: Explicit invocation of an altstep within an alt statement

```
 :
alt {
    [] PCO3.receive {
        …
       }
    [] AnotherAltStep();    // explicit call of altstep AnotherAltStep as an alternative
                            // of an alt statement
    [] MyTimer.timeout {}
}
```

EXAMPLE 3: Explicit, standalone invocation of an altstep

```
// The statement
AnotherAltStep(); // AnotherAltStep is assumed to be a correctly defined altstep

//is a shorthand for

alt {
    [] AnotherAltStep();
}
```

16.3 Test cases

A test case is a complete and independent specification of the actions required to achieve a specific test purpose. It typically starts in a stable testing state and ends in a stable testing state. It may involve one or more consecutive or concurrent connections to the SUT. The test case should be complete in the sense that it is sufficient to enable a test verdict to be assigned unambiguously to each potentially observable test outcome (i.e., sequence of test events). The test case should be independent in the sense that it should be possible to execute the derived executable test case in isolation from other such test cases.

In TTCN-3, test cases are a special kind of function. Test cases define the behaviours, which have to be executed to check whether the SUT passes a test or not. This behaviour is performed by the MTC which is automatically created when a test case is being executed.

Syntactical Structure

```
testcase TestcaseIdentifier
"(" [ { ( FormalValuePar | FormalTemplatePar) [","] } ] ")"
runs on ComponentType
[ system ComponentType ]
StatementBlock
```

Semantic Description

A test case is considered to be a self-contained and complete specification that checks a test purpose. The result of a test case execution is a test verdict.

A test case header has two parts:

a) *interface part (mandatory)*: denoted by the keyword **runs on** which references the required component type for the MTC and makes the associated port names visible within the MTC behaviour; and

b) *test system part (optional)*: denoted by the keyword **system** which references the component type which defines the required ports for the test system interface. The test system part shall only be omitted if, during test execution, only the MTC is instantiated. In this case, the MTC type defines the test system interface ports implicitly.

The behaviour of a test case can be defined by using the program statements and operations described in clause 18.

Test cases may be parameterized as described in clause 5.4. Test cases can be executed in the control part of a module (see clause 26).

Restrictions

a) The rules for formal parameter lists shall be followed as defined in clause 5.4.

b) Test cases may only be invoked with an execute statement in a module control part as defined in clause 26.

Examples

```
testcase MyTestCaseOne()
runs on MyMtcType1              // defines the type of the MTC
system MyTestSystemType         // makes the port names of the TSI visible to
                                       the MTC
{
      :     // The behaviour defined here executes on the mtc when the test
                  case is invoked
}

// or, a test case where only the MTC is instantiated
testcase MyTestCaseTwo() runs on MyMtcType2
{
      :     // The behaviour defined here executes on the mtc when the test case is invoked
}
```

17 Void

18 Overview of program statements and operations

The fundamental program elements of test cases, functions, altsteps and the control part of TTCN-3 modules are expressions, basic program statements such as assignments, loop constructs, etc., behavioural statements such as sequential behaviour, alternative behaviour, interleaving, defaults, etc., and operations such as **`send`**, **`receive`**, **`create`**, etc.

Statements can be either single statements (which do not include other program statements) or compound statements (which may include other statements and blocks of statements and declarations).

Statements shall be executed in the order of their appearance, i.e., sequentially, as illustrated in Figure 8.

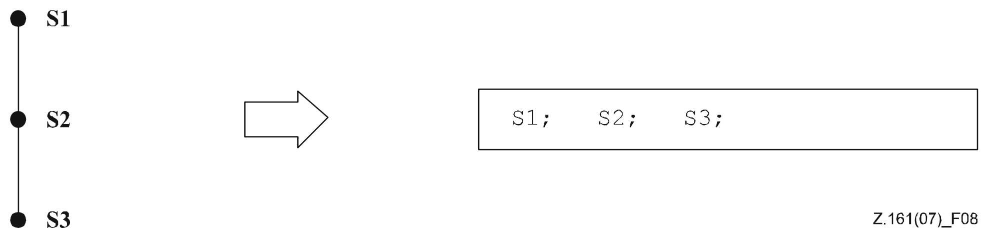


Figure 8 – Illustration of sequential behaviour

The individual statements in the sequence shall be separated by the delimiter ";".

Examples

```
    MyPort.send(Mymessage); MyTimer.start; log("Done!");
```

The specification of an empty block of statements and declarations, i.e., {}, may be found in compound statements, e.g., a branch in an **`alt`** statement, and implies that no actions are taken.

Table 11 gives an overview of the TTCN-3 expressions, statements and operations and restrictions on their usage.

Table 11 – Overview of TTCN-3 expressions, statements and operations

Statement	**Associated keyword or symbol**	**Can be used in module control**	**Can be used in functions, test cases and altsteps**	**Can be used in functions called from templates, Boolean guards, or from initialization of altstep local definitions**
Expressions	(…)	Yes	Yes	Yes
Basic program statements				
Assignments	**`:=`**	Yes	Yes	Yes (see Note 3)
If-else	**`if (…) {…} else {…}`**	Yes	Yes	Yes

Table 11 – Overview of TTCN-3 expressions, statements and operations

Statement	Associated keyword or symbol	Can be used in module control	Can be used in functions, test cases and altsteps	Can be used in functions called from templates, Boolean guards, or from initialization of altstep local definitions
Select case	`select case (…) { case (…) {…} case else {…}}`	Yes	Yes	Yes
For loop	`for (…) {…}`	Yes	Yes	Yes
While loop	`while (…) {…}`	Yes	Yes	Yes
Do while loop	`do {…} while (…)`	Yes	Yes	Yes
Label and Goto	`label / goto`	Yes	Yes	Yes
Stop execution	`stop`	Yes	Yes	
Returning control	`return`		Yes (see Note 4)	Yes
Logging	`log`	Yes	Yes	Yes
Statements and operations for alternative behaviours				
Alternative behaviour	`alt {…}`	Yes (see Note 1)	Yes	
Re-evaluation of alternative behaviour	`repeat`	Yes (see Note 1)	Yes	
Interleaved behaviour	`interleave {…}`	Yes (see Note 1)	Yes	
Activate a default	`activate`	Yes (see Note 1)	Yes	
Deactivate a default	`deactivate`	Yes (see Note 1)	Yes	
Configuration operations				
Create parallel test component	`create`		Yes	
Connect component port to component port	`connect`		Yes	
Disconnect two component ports	`disconnect`		Yes	
Map port to test interface	`map`		Yes	
Unmap port from test system interface	`unmap`		Yes	
Get MTC component reference value	`mtc`		Yes	Yes
Get test system interface component reference value	`system`		Yes	Yes

Table 11 – Overview of TTCN-3 expressions, statements and operations

Statement	Associated keyword or symbol	Can be used in module control	Can be used in functions, test cases and altsteps	Can be used in functions called from templates, Boolean guards, or from initialization of altstep local definitions
Get own component reference value	`self`		Yes	Yes
Start execution of test component behaviour	`start`		Yes	
Stop execution of test component behaviour	`stop`		Yes	
Remove a test component from the system	`kill`		Yes	
Check termination of a PTC behaviour	`running`		Yes	
Check if a PTC exists in the test system	`alive`		Yes	
Wait for termination of a PTC behaviour	`done`		Yes	
Wait a PTC cease to exist	`killed`		Yes	
Communication operations				
Send message	`send`		Yes	
Invoke procedure call	`call`		Yes	
Reply to procedure call from remote entity	`reply`		Yes	
Raise exception (to an accepted call)	`raise`		Yes	
Receive message	`receive`		Yes	
Trigger on message	`trigger`		Yes	
Accept procedure call from remote entity	`getcall`		Yes	
Handle response from a previous call	`getreply`		Yes	
Catch exception (from called entity)	`catch`		Yes	
Check (current) message/call received	`check`		Yes	
Clear port queue	`clear`		Yes	
Clear queue and enable sending & receiving at a port	`start`		Yes	

Table 11 – Overview of TTCN-3 expressions, statements and operations

Statement	Associated keyword or symbol	Can be used in module control	Can be used in functions, test cases and altsteps	Can be used in functions called from templates, Boolean guards, or from initialization of altstep local definitions
Disable sending and disallow receiving operations to match at a port	`stop`		Yes	
Disable sending and disallow receiving operations to match new messages/calls	`halt`		Yes	
Timer operations				
Start timer	`start`	Yes	Yes	
Stop timer	`stop`	Yes	Yes	
Read elapsed time	`read`	Yes	Yes	
Check if timer running	`running`	Yes	Yes	
Timeout event	`timeout`	Yes	Yes	
Verdict operations				
Set local verdict	`setverdict`		Yes	
Get local verdict	`getverdict`		Yes	Yes
External actions				
Stimulate an (SUT) action externally	`action`	Yes	Yes	
Execution of test cases				
Execute test case	`execute`	Yes	Yes (see Note 2)	
NOTE 1 – Can be used to control timer operations only. NOTE 2 – Can only be used in functions and altsteps that are used in module control. NOTE 3 – Changing of component variables is disallowed. NOTE 4 – Can be used in functions and altsteps but not in test cases.				

19 Basic program statements

The basic program statements presented in Table 12 can be used in the control part of a module and in TTCN-3 functions, altsteps and test cases.

Table 12 – Overview of TTCN-3 basic program statements

Basic program statements	
Statement	**Associated keyword or symbol**
Assignments	`:=`
If-else	`if (…) {…} else {…}`
Select case	`select case (…) { case (…) {…} case else {…}}`
For loop	`for (…) {…}`
.While loop	`while (…) {…}`
Do while loop	`do {…} while (…)`
Label and Goto	`label / goto`
Stop execution	`stop`
Returning control	`return`
Logging	`log`

19.1 Assignments

Values may be assigned to variables. This is indicated by the symbol ":=".

Syntactical Structure

```
VariableRef ":=" ( Expression | TemplateBody )
```

Semantic Description

During execution of an assignment the right-hand side of the assignment shall evaluate to a value or template. The effect of an assignment is to bind the variable to the value of the expression or to a template. The expression shall contain no unbound variables. All assignments occur in the order in which they appear, that is left to right processing.

Restrictions

a) The right-hand side of an assignment shall evaluate to a value or template, which is type compatible with the variable at the left-hand side of the assignment.

b) When the right-hand side of the assignment evaluates to a template (global or local template, in-line template or template variable), the variable at the left hand side shall be a template variable.

Examples

```
MyVariable := (x + y - increment(z))*3;
```

19.2 The If-else statement

The **`if-else`** statement, also known as the conditional statement, is used to denote branching in the control flow.

Syntactical Structure

```
if "(" BooleanExpression ")" StatementBlock
{ else if "(" BooleanExpression ")" StatementBlock }
[ else StatementBlock]
```

NOTE – **`else if`** "(" *BooleanExpression* ")" *StatementBlock* [**else** *StatementBlock*] is a shorthand notation for **`else`** "{" **`if`** "(" *BooleanExpression* ")" *StatementBlock* [**else** *StatementBlock*] "}".

Semantic Description

The branching of the control flow is decided upon the value of the Boolean expressions – the condition. A statement block – and only one – will be executed, if its condition evaluates to true. The optional else specifies a statement block that will be executed if all the "if" and "else if" conditions before are false.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
if (date == "1.1.2005") { return ( fail ); }

if (MyVar < 10) { MyVar := MyVar * 10; log ("MyVar < 10"); }
else { MyVar := MyVar/5; }
```

19.3 The Select Case statement

The **`select case`** statement is an alternative syntactic form of the **`if-else`** statement.

Syntactical Structure

```
select "(" SingleExpression ")" "{"
          { case "(" { SingleExpression [","] } ")" StatementBlock }
          [ case else StatementBlock ]
"}"
```

Semantic Description

The **`select case`** statement is an alternative to using **`if`** .. **`else if`** .. **`else`** statements when comparing a value to one or several other values. The statement contains a header part and zero or more branches. Never more than one of the branches is executed.

In the header part of the **`select case`** statement an expression shall be given. Each branch starts with the **`case`** keyword followed by a list of templateInstance (a list branch, which may also contain a single element) or the **`else`** keyword (an else branch) and a block of statements.

All templateInstance in all list branches shall be of a type compatible with the type of the expression in the header. A list branch is selected and the block of statements of the selected branch is executed only, if any of the templateInstance matches the value of the expression in the header of the statement. On executing the block of statements of the selected branch (i.e., not jumping out by a goto statement), execution continues with the statement following the select case statement.

The block of statements of an else branch is always executed if no other branch textually preceding the else branch has been selected.

Branches are evaluated in their textual order. If none of the templateInstances matches the value of the expression in the header and the statement contains no else branch, execution continues without executing any of the **`select case`** branches.

Restrictions

The **`select`** *SingleExpression* and the **`case`** *SingleExpression*"s shall be type compatible.

Examples

```
select (MyModulePar)  // where MyModulePar is of charstring type
{
      case ("firstValue")
            {
             log ("The first branch is selected");
            }
      case (MyCharVar, MyCharConst)
            {
             log ("The second branch is selected");
            }
      case else
            {
             log ("The value of the module parameter MyModulePar is selected");
            }
}

// the above select statement is equivalent to the following if statement
if (match(MyModulePar, "firstValue")
            {
             log ("The first branch is selected");
            }
else if     (match(MyModulePar, MyCharVar) or match(MyModulePar, MyCharConst))
            {
             log ("The second branch is selected");
            }
else
            {
             log ("The value of the module parameter MyModulePar is selected");
            }
```

19.4 The For statement

The **for** statement defines a counter loop.

Syntactical Structure

```
for "(" ( VarInstance | Assignment ) ";" BooleanExpression ";" Assignment
")"
    StatementBlock
```

Semantic Description

The **for** statement contains two assignments and a **boolean** expression. The first assignment is necessary to initialize the index (or counter) variable of the loop. The **boolean** expression terminates the loop and the second assignment is used to manipulate the index variable.

The value of the index variable is increased, decreased or manipulated in such a manner that after a certain number of execution loops a termination criteria is reached.

The termination criterion of the loop shall be expressed by a **boolean** expression. It is checked at the beginning of each new loop iteration. If it evaluates to **true**, the execution continues with the block of statements in the **for** statement, if it evaluates to **false**, the execution continues with the statement which immediately follows the **for** loop.

The index variable of a **for** loop can be declared before being used in the **for** statement or can be declared and initialized in the **for** statement header. If the index variable is declared and initialized in the **for** statement header, the scope of the index variable is limited to the loop body, i.e., it is only visible inside the loop body.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
var integer j;                          // Declaration of integer variable j
```

```
for (j:=1; j<=10; j:= j+1) { … }          // Usage of variable j as index
                                          variable of the for loop

for (var float i:=1.0; i<7.9; i:= i*1.35) { … }      // Index variable i is
                                                     declared and initialized
                                                     // in the for loop header.
                                                     Variable i only is
                                                     // visible in the loop
                                                     body.
```

19.5 The While statement

A **while** statement defines a loop that is executed as long as the loop condition holds.

Syntactical Structure

```
while "(" BooleanExpression ")" StatementBlock
```

Semantic Description

The loop condition shall be checked at the beginning of each new loop iteration. If the loop condition does not hold, then the loop is exited and execution shall continue with the statement, which immediately follows the **while** loop.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
while (j<10){ … }
```

19.6 The Do-while statement

A **do-while** statement defines a loop that is executed up until the loop condition does not hold.

Syntactical Structure

```
do StatementBlock while "(" BooleanExpression ")"
```

Semantic Description

The **do-while** loop is identical to a **while** loop with the exception that the loop condition shall be checked at the *end* of each loop iteration. This means when using a **do-while** loop the behaviour is executed at least once before the loop condition is evaluated for the first time.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
do { … } while (j<10);
```

19.7 The Label statement

The **label** statement allows the specification of labels in test cases, functions, altsteps and the control part of a module.

Syntactical Structure

```
label LabelIdentifier
```

Semantic Description

A **label** marks a statement. The label is used by the **goto** statement (see clause 19.8) to transfer control to a labelled statement.

Restrictions

a) A **`label`** statement can be used freely like other TTCN-3 behavioural program statements according to the syntax rules defined in Annex A. It can be used before or after a TTCN-3 statement but not as the first statement of an alternative or top alternative in an **`alt`** statement, **`interleave`** statement or **`altstep`**.

b) Labels used following the **`label`** keyword shall be unique among all labels defined in the same test case, function, altstep or control part.

Examples

```
label MyLabel;                              // Defines the label MyLabel

// The labels L1, L2 and L3 are defined in the following TTCN-3 code fragment
 :
label L1;                                   // Definition of label L1
alt{
[]    PCO1.receive(MySig1)
      {     label L2;                       // Definition of label L2
            PCO1.send(MySig2);
            PCO1.receive(MySig3)
      }
[]    PCO2.receive(MySig4)
      {     PCO2.send(MySig5);
            PCO2.send(MySig6);
            label L3;                       // Definition of label L3
            PCO2.receive(MySig7);
      }
}
 :
```

19.8 The Goto statement

A **`goto`** statement performs a jump to a **`label.`**

Syntactical Structure

```
goto LabelIdentifier
```

Semantic Description

The **`goto`** statement can be used in functions, test cases, altsteps and the control part of a TTCN-3 module to transfer control to a labelled statement.

The **`goto`** statement provides the possibility to jump freely, i.e., forwards and backwards, within a sequence of statements, to jump out of a single compound statement (e.g., a **`while`** loop) and to jump over several levels out of nested compound statements (e.g., nested alternatives).

Restrictions

a) It is not allowed to jump out of or into functions, test cases, altsteps and the control part of a TTCN-3 module.

b) It is not allowed to jump into a sequence of statements defined in a compound statement (i.e., **`alt`** statement, **`while`** loop, **`for`** loop, **`if-else`** statement, **`do-while`** loop and the **`interleave`** statement).

c) It is not allowed to use the **`goto`** statement within an **`interleave`** statement.

Examples

```
// The following TTCN-3 code fragment includes
:
label L1;                                   // … the definition of label L1,
MyVar := 2 * MyVar;
if (MyVar < 2000) { goto L1; }          // … a jump backward to L1,
MyVar2 := Myfunction(MyVar);
if (MyVar2 > MyVar) { goto L2; }    // … a jump forward to L2,
      PCO1.send(MyVar);
      PCO1.receive -> value MyVar2;
      label L2;                                     // … the definition of label L2,
      PCO2.send(integer: 21);
      alt {
        [] PCO1.receive { }
        [] PCO2.receive(integer: 67) {
                label L3;                           // … the definition of label L3,
                PCO2.send(MyVar);
                alt {
                  [] PCO1.receive { }
                  [] PCO2.receive(integer: 90) {
                          PCO2.send(integer: 33);
                          PCO2.receive(integer: 13);
                          goto L4;                  // … a jump forward out of two nested alt
statements,
                     }
                  [] PCO2.receive(MyError) {
                          goto L3;                  // … a jump backward out of the current alt
statement,
                     }
                  [] any port.receive {
                          goto L2;                  // … a jump backward out of two nested alt
statements,
                     }
                }
           }
        [] any port.receive {
                goto L2;                            // … and a long jump backward out of an alt
statement.
           }
      }
      label L4;
      :
```

19.9 The Stop execution statement

The **stop** statement terminates execution of test components, a test case or a test control.

Syntactical Structure

```
      Stop
```

Semantic Description

The **stop** statement terminates execution in different ways depending on the context in which it is used. When used in the control part of a module or in a function used by the control part of a module, it terminates the execution of the module control part. When used in a test case, altstep or function that are executed on a test component, it terminates the relevant test component.

NOTE – The semantics of a **stop** statement that terminates a test component is identical to the stop component operation **self.stop** (see clause 21.2.3).

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
      module MyModule {
             :    // Module definitions
            testcase MyTestCase() runs on MyMTCType system MySystemType{
                  var MyPTCType ptc:= MyPTCType.create;     // PTC creation
                  ptc.start(MyFunction());                   // start PTC execution
                   :                // test case behaviour continued
                  stop        // stops the MTC, all PTCs and the whole test case
            }
            function MyFunction() runs on MyPTCType {
                   :
                  stop        // stops the PTC only, the test case continues
            }
```

```
		control {
			:	// test execution
			stop  // stops the test campaign
		} // end control
	} // end module
```

19.10 The Return statement

The `return` statement terminates execution of functions or altsteps.

Syntactical Structure

```
	return [ Expression ]
```

Semantic Description

The `return` statement terminates execution of a function or altstep and returns control to the point from which the function or altstep was called. When used in functions, a `return` statement may be optionally associated with a return value.

NOTE – The `return` statement, when used in altsteps has the same effect as if the end of the block of statements and declarations of the chosen alternative has been reached, e.g., when the altstep is called from an `alt` statement, the execution continues with the first statement following the `alt` statement.

Restrictions

The `return` statement should not be used in the statement block of a testcase.

Examples

```
	function MyFunction() return boolean {
		 :
		if (date == "1.1.2005") {
			return false; // execution stops on the 1.1.2000 and returns the boolean false
		}
		 :
		return true;	// true is returned
	}

	function MyBehaviour() return verdicttype {
		 :
		if (MyFunction()) {
			setverdict(pass); // use of MyFunction in an if statement
		}
		else {
			setverdict(inconc);
		}
		 :
		return getverdict; // explicit return of the verdict
	}
```

19.11 The Log statement

The `log` statement provides the means to write logging information to some logging device. The information that can be logged is summarized in Table 13.

Table 13 – TTCN-3 language elements that can be logged

Used in a log statement	What is logged	Comment
module parameter identifier	actual value	
literal value	value	This includes also free text.
data constant identifier	actual value	
external constant identifier	actual value	
template instance	actual template or field values and matching symbols	
data type variable identifier	actual value or "UNITIALIZED"	See Notes 3 and 4.
`self`, **`mtc`**, **`system`** or component type variable identifier	actual value and if assigned the component instance name or "UNITIALIZED"	On logging actual values see Notes 2 to 4. Actual component states shall be logged according to Note 5.
running operation (component or timer)	return value	**`true`** or **`false`**. In case of component or timer arrays, array element specification shall be included.
alive operation (component)	return value	**`true`** or **`false`**. In case of arrays, array element specifications shall be included.
port instance	actual state	Port states shall be logged according to Note 6.
default type variable identifier	actual state or 'UNITIALIZED'	Default states shall be logged according to Note 7. See also Notes 2 to 4.
timer name	actual state	Timer states shall be logged according to Note 8.
read operation	return value	See clause 23.4.
predefined functions	return value	See Annex C.
function instance	return value	Only functions with return clause are allowed.
external function instance	return value	Only external functions with return clause are allowed.

Table 13 – TTCN-3 language elements that can be logged

Used in a log statement	What is logged	Comment
formal parameter identifier	See comment column	Logging of actual parameters shall follow rules specified for the language elements they are substituting. In case of value parameters the actual parameter value, in case of template-type parameters the actual template or field values and matching symbols, in case of component type parameters the actual component reference, etc. shall be logged. For timer parameters also the use of the read operation and for component type and timer parameters the use of the running operation are allowed.
NOTE 1 – Actual value/actual template is the value/template at the moment of the execution of the log statement. NOTE 2 – The type of the logged value is tool dependent. NOTE 3 – In case of array identifiers without array element specification, actual values and for component references names of all array elements shall be logged. NOTE 4 – The string "UNITIALIZED" shall be logged only if the log item is unbound (uninitialized). NOTE 5 – Component states that can be logged are: Inactive, Running, Stopped and Killed (for further details see Annex E). NOTE 6 – Port states that can be logged are: Started and Stopped (for further details see Annex E). NOTE 7 – Default states that can be logged are: Activated and Deactivated. NOTE 8 – Timer states that can be logged are: Inactive, Running and Expired (for further details see Annex E).		

Syntactical Structure

```
    log "(" { ( FreeText | TemplateInstance ) [","] } ")"
```

Semantic Description

The **log** statement provides the means to write one or more log items to some logging device associated with the test control or the test component in which the statement is used. Items to be logged shall be identified by a comma-separated list in the argument of the log statement. Log items may be individual language elements specified in Table 13 or expressions composed of such log items.

It is strongly recommended that the execution of the log statement has no effect on the test behaviour. In particular, functions used in a log statement should neither explicitly nor implicitly change component variable values, port or timer status, and should not change the value of any of its inout or out parameters.

NOTE – It is outside the scope of this Recommendation to define complex logging and trace capabilities which may be tool dependent.

Restrictions

Functions used in log statements should not use directly or indirectly statements other than `if…else`, `for`, `while`, `do…while`, `label`, `goto`, `return`, `mtc`, `system`, `self`, `running` (PTC or timer), `read` and `getverdict`.

Examples

```
var integer myVar:= 1;
log("Line 248 in PTC_A: ", myVar, " (actual value of myVar)");
// The string "Line 248 in PTC_A: 1 (actual value of myVar)" is written to some log device
// of the test system
```

20 Statement and operations for alternative behaviours

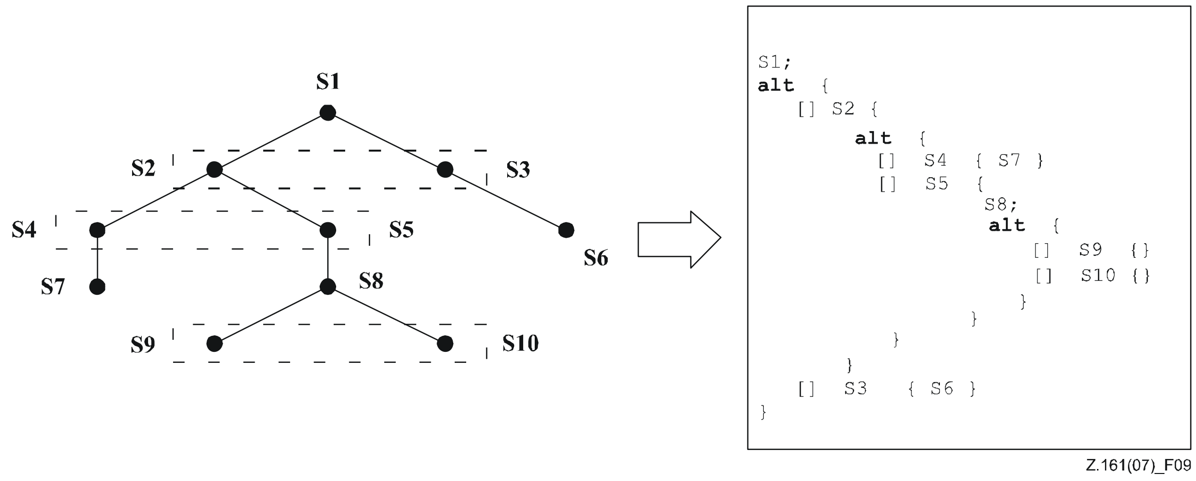
Test behaviour cannot only be expressed sequentially, but also as a set of alternatives or combinations of both. An interleaving operator allows the specification of interleaved sequences or alternatives. Table 14 summarizes the statements and operations for alternative behaviours.

Table 14 – Overview of TTCN-3 statements and operations for alternative behaviours

Statement/operation	Associated keyword or symbol
Alternative behaviour	`alt { … }`
Re-evaluation of alt statements	`repeat`
Interleaved behaviour	`interleave { … }`
Activate a default	`activate`
Deactivate a default	`deactivate`

20.1 The snapshot mechanism

A more complex form of behaviour is where sequences of statements are expressed as sets of possible alternatives to form a tree of execution paths, as illustrated in Figure 9.



```
S1;
alt {
   [] S2 {
        alt {
          [] S4  { S7 }
          [] S5  {
                  S8;
                  alt {
                       [] S9 {}
                       [] S10 {}
                      }
                 }
            }
        }
   [] S3   { S6 }
}
```

Figure 9 – Illustration of alternative behaviour

This is done with the `alt` statement.

When entering an `alt` statement, a snapshot is taken. A snapshot is considered to be a partial state of a test component that includes all information necessary to evaluate the Boolean conditions that guard alternative branches, all relevant stopped test components, all relevant timeout events and the top messages, calls, replies and exceptions in the relevant incoming port queues. Any test component, timer and port which is referenced in at least one alternative in the `alt` statement, or in a top alternative of an altstep that is invoked as an alternative in the `alt` statement or activated as default is considered to be relevant. A detailed description of the snapshot semantics is given in the operational semantics of TTCN-3 (part 4 of the TTCN-3 standard [ITU-T Z.164]).

NOTE 1 – Snapshots are only a conceptual means for describing the behaviour of the `alt` statement. The concrete algorithms for the snapshot handling can be found in part 4 of the TTCN-3 standard [ITU-T Z.164].

NOTE 2 – The TTCN-3 semantics assumes that taking a snapshot is instantaneous, i.e., has no duration. In a real implementation, taking a snapshot may take some time and race conditions may occur. The handling of such race conditions is outside the scope of this Recommendation.

20.2 The Alt statement

The **alt** statement expresses sets of possible alternatives that form a tree of possible execution paths.

Syntactical Structure

```
alt "{"
          {
      "[" [ BooleanExpression ] "]"
                 ( ( TimeoutStatement |
              ReceiveStatement |
              TriggerStatement |
              GetCallStatement |
              CatchStatement |
              CheckStatement |
              GetReplyStatement |
              DoneStatement |
              KilledStatement ) StatementBlock ) |
                ( AltstepInstance [ StatementBlock ] )
          }
          [ "[" else "]" StatementBlock ]
"}"
```

Semantic Description

The `alt` statement denotes branching of test behaviour due to the reception and handling of communication and/or timer events and/or the termination of parallel test components, i.e., it is related to the use of the TTCN-3 operations **`receive`**, **`trigger`**, **`getcall`**, **`getreply`**, **`catch`**, **`check`**, **`timeout`**, **`done`** and **`killed`**. The `alt` statement denotes a set of possible events that are to be matched against a particular snapshot.

Execution of alternative behaviour

When entering an `alt` statement, a snapshot is taken.

The alternative branches in the `alt` statement and the top alternatives of invoked altsteps and altsteps that are activated as defaults are processed in the order of their appearance. If several defaults are active, the reverse order of their activation determines the evaluation order of the top alternatives in the defaults. The alternative branches in active defaults are reached by the default mechanism described in clause 20.5.

The individual alternative branches are either branches that may be guarded by a Boolean expression or else-branches, i.e., alternative branches starting with `[else]`.

Else-branches are always chosen and executed when they are reached (see below).

Branches that may be guarded by a Boolean expression either invoke an altstep (*altstep-branch*), or start with a **`done`** operation (*done-branch*), a **`killed`** operation (*killed-branch*), **`timeout`** operation (*timeout-branch*) or a receiving operation (*receiving-branch*), i.e., **`receive`**, **`trigger`**, **`getcall`**, **`getreply`**, **`catch`** or a **`check`** operation. The evaluation of the Boolean guards shall be based on the snapshot. The Boolean guard is considered to be *fulfilled* if no Boolean guard is defined, or if the Boolean guard evaluates to **`true`**. The branches are processed and executed in the following manner.

An *altstep-branch* is selected if the Boolean guard is fulfilled. The selection of an *altstep-branch* causes the invocation of the referenced altstep, i.e., the altstep is invoked and the evaluation of the snapshot continues within the altstep.

A *done-branch* is selected if the Boolean guard is fulfilled and if the specified test component is in the list of stopped components of the snapshot. The selection causes the execution of the statement block following the **`done`** operation. The **`done`** operation itself has no further effect.

A *killed-branch* is selected if the Boolean guard is fulfilled and if the specified test component is in the list of killed components of the snapshot. The selection causes the execution of the statement block following the **`killed`** operation. The **`killed`** operation itself has no further effect.

A *timeout-branch* is selected if the Boolean guard is fulfilled and if the specified timeout event is in the timeout-list of the snapshot. The selection causes execution of the specified **`timeout`** operation, i.e., removal of the timeout event from the timeout list, and the execution of the statement block following the **`timeout`** operation.

A *receiving-branch* is selected if the Boolean guard is fulfilled and if the matching criteria of receiving operation is fulfilled by one of the messages, calls, replies or exceptions in the snapshot. The selection causes execution of the receiving operation, i.e., removal of the matching message, call, reply or exception from the port queue, maybe an assignment of the received information to a variable and the execution of the statement block following the receiving operation. In the case of the **`trigger`** operation the top message of the queue is also removed if the Boolean guard is fulfilled but the matching criteria is not. In this case the statement block of the given alternative is not executed.

NOTE 1 – The TTCN-3 semantics describe the evaluation of a snapshot as a series of indivisible actions of a test component. The semantics do not assume that the evaluation of a snapshot has no duration. During the evaluation of a snapshot, test components may stop, timers may timeout and new messages, calls, replies or exceptions may enter the port queues of the component. However, these events do not change the actual snapshot and thus, are not considered for the snapshot evaluation.

If none of the alternative branches in the **`alt`** statement and top alternatives in the invoked altsteps and active defaults can be selected and executed, the **`alt`** statement shall be executed again, i.e., a new snapshot is taken and the evaluation of the alternative branches is repeated with the new snapshot. This repetitive procedure shall continue until either an alternative branch is selected and executed, or the test case is stopped by another component or by the test system (e.g., because the MTC is stopped) or with a dynamic error.

The test case shall stop and indicate a dynamic error if a test component is completely blocked. This means none of the alternatives can be chosen, no relevant test component is running, no relevant timer is running and all relevant ports contain at least one message, call, reply or exception that do not match.

NOTE 2 – The repetitive procedure of taking a complete snapshot and re-evaluate all alternatives is only a conceptual means for describing the semantics of the **`alt`** statement. The concrete algorithm that implements this semantics is outside the scope of this Recommendation.

Selecting/deselecting an alternative

If necessary, it is possible to enable/disable an alternative by means of a Boolean expression placed between the ("[…]") brackets of the alternative.

Else branch in alternatives

Any branch in an **`alt`** statement can be defined as an else branch by including the **`else`** keyword between the opening and closing brackets at the beginning of the alternative. The statement block of the else branch is always executed if no other alternative textually preceding the else branch has proceeded.

Default mechanism

It should be noted that the default mechanism (see clause 20.5) is always invoked at the end of all alternatives. If an **`else`** branch is defined, the default mechanism will never be called, i.e., active defaults will never be entered.

NOTE 3 – It is also possible to use **`else`** in altsteps.

NOTE 4 – It is allowed to use a **`repeat`** statement within an **`else`** branch.

NOTE 5 – It is allowed to define more than one else branch in an alt statement or in an altstep, however always only the first else branch is executed.

Re-evaluation of alt statements

The re-evaluation of an **`alt`** statement can be specified by using a **`repeat`** statement (see clause 20.3).

Invocation of altsteps as alternatives

TTCN-3 allows the invocation of altsteps as alternatives in **`alt`** statements (see clause 16.2.1).

Restrictions

a) The open and close square brackets ("[…]") shall be present at the start of each alternative, even if they are empty. This not only aids readability but also is necessary to syntactically distinguish one alternative from another.

b) The evaluation of a Boolean expression guarding an alternative may have side effects. To avoid side effects that cause an inconsistency between the actual snapshot and the state of the component, the same restrictions as the restrictions for the initialization of local definitions within altsteps shall apply (clause 16.2).

c) The else branch shall not contain any of the actions allowed in branches guarded by a boolean expression (i.e., an **`altstep`** call or a **`done`**, a **`killed`**, a **`timeout`** or a receiving operation).

d) An **`alt`** statement used within the module control part shall only contain the **`timeout`** statements.

Examples

EXAMPLE 1: Nested alternatives

```
alt {
    [] MyPort.receive (MyMessage) {
        setverdict (pass);
        MyTimer.start;
        alt {
            [] MyPort.receive (MySecondMessage) {
                MyTimer.stop;
                setverdict (pass);
            }
            [] MyTimer.timeout {
                MyPort.send (MyRepeat);
                MyTimer.start;
```

```
                            alt {
                                  [] MyPort.receive (MySecondMessage) {
                                        MyTimer.stop;
                                        setverdict (pass)
                                  }
                                  [] MyTimer.timeout { setverdict (inconc) }
                                  [] MyPort.receive { setverdict (fail) }
                            }
                      }
                      [] MyPort.receive { setverdict (fail) }
                }
          }
          [] MyTimer.timeout { setverdict (inconc) }
          [] MyPort.receive { setverdict (fail) }
    }
```

EXAMPLE 2: Alt statement with guards

```
    alt {
      [x>1] L2.receive {                            // Boolean guard/expression
                setverdict(pass);
         }
      [x<=1] L2.receive {                           // Boolean guard/expression
                setverdict(inconc);
         }
    }
```

EXAMPLE 3: Alt statement with else branch

```
    // Use of alternative with Boolean expressions (or guard) and else branch
    alt {
      :
      [else] {                                // else branch
                MyErrorHandling();
                setverdict(fail);
                stop;
         }
    }
```

EXAMPLE 4: Re-evaluation with repeat

```
    alt {
      [] PCO3.receive {
                count := count + 1;
                repeat                              // usage of repeat
         }
      [] T1.timeout { }
      [] any port.receive {
                setverdict(fail);
                stop;
         }
    }
```

EXAMPLE 5: Alt statement with explicitly invoked altstep

```
    alt {
      [] PCO3.receive { }
      [] AnotherAltStep();  // explicit call of altstep AnotherAltStep as alternative
                                  // of an alt statement
      [] MyTimer.timeout { }
    }
```

20.3 The Repeat statement

The **repeat** statement is used for a re-evaluation of an **alt** statement.

Syntactical Structure

```
    repeat
```

Semantic Description

The **repeat** statement, when used in the block of statements and declarations of alternatives of **alt** statements, causes the re-evaluation of the **alt** statement, i.e., a new snapshot is taken and the alternatives of the **alt** statement are evaluated in the order of their specification.

When used in blocks of statements and declarations of the response and exception handling parts of blocking procedure calls, the repeat statement causes the re-evaluation of the response and exception handling part of the call (see clause 22.3.1).

If a **repeat** statement is used in a top alternative in an altstep definition, it causes a new snapshot and the re-evaluation of the **alt** statement from which the altstep has been called. The call of the altstep may either be done implicitly by the default mechanism (see clause 20.5.1) or explicitly in the **alt** statement (see clause 20.2).

Restrictions

The **repeat** statement should only be used within **alt** statements, **call** statements or altsteps.

Examples

EXAMPLE 1: Usage of repeat in an alt statement

```
alt {
  [] PCO3.receive {
          count := count + 1;
          repeat                             // usage of repeat
     }
  [] T1.timeout { }
  [] any port.receive {
          setverdict(fail);
          stop;
     }
}
```

EXAMPLE 2: Usage of repeat in an altstep

```
altstep AnotherAltStep() runs on MyComponentType {
      [] PCO1.receive{
           setverdict(inconc);
           repeat                            // usage of repeat
         }
      [] PCO2.receive {}
}
```

20.4 The Interleave statement

The **interleave** statement allows to specify the interleaved occurrence and handling of receiving events including **done**, **killed**, **timeout**, **receive**, **trigger**, **getcall**, **getreply**, **catch** and **check**.

Syntactical Structure

```
interleave "{"
      { "[]" ( TimeoutStatement |
        ReceiveStatement |
        TriggerStatement |
        GetCallStatement |
        CatchStatement |
        CheckStatement |
        GetReplyStatement |
        DoneStatement |
        KilledStatement ) StatementBlock
      }
"}"
```

Semantic Description

The **interleave** statement allows to specify the interleaved occurrence and handling of the statements **done**, **killed**, **timeout**, **receive**, **trigger**, **getcall**, **getreply**, **catch** and **check**.

Interleaved behaviour can always be replaced by an equivalent set of nested alternatives. The procedures for this replacement and the operational semantics of interleaving are described in part 4 of the TTCN-3 standard ([ITU-T Z.164]).

The rules for the evaluation of an interleaving statement are the following:

a) whenever a reception statement is executed, the following non-reception statements are subsequently executed until the next reception statement is reached or the interleaved sequence ends;

   NOTE – Reception statements are TTCN-3 statements which may occur in sets of alternatives, i.e., **receive**, **check**, **trigger**, **getcall**, **getreply**, **catch**, **done**, **killed** and **timeout**. Non-reception statements denote all other non-control-transfer statements which can be used within the **interleave** statement.

b) the evaluation then continues by taking the next snapshot.

The operational semantics of interleaving are fully defined in part 4 of the TTCN-3 standard ([ITU-T Z.164]).

Restrictions

a) Control transfer statements **for**, **while**, **do-while**, **goto**, **activate**, **deactivate**, **stop**, **repeat**, **return**, direct call of altsteps as alternatives and (direct and indirect) calls of user-defined functions, which include communication operations, shall not be used in **interleave** statements.

b) In addition, it is not allowed to guard branches of an **interleave** statement with Boolean expressions (i.e., the '[ ]' shall always be empty). It is also not allowed to specify **else** branches in interleaved behaviour.

Examples

```
// The following TTCN-3 code fragment
interleave {
[]    PCO1.receive(MySig1)
      {     PCO1.send(MySig2);
            PCO1.receive(MySig3);
      }
[]    PCO2.receive(MySig4)
      {     PCO2.send(MySig5);
            PCO2.send(MySig6);
            PCO2.receive(MySig7);
      }
}

// is a shorthand for
alt {
[]    PCO1.receive(MySig1)
      {     PCO1.send(MySig2);
            alt {
            []    PCO1.receive(MySig3)
                  {     PCO2.receive(MySig4);
                        PCO2.send(MySig5);
                        PCO2.send(MySig6);
                        PCO2.receive(MySig7)
                  }
            []    PCO2.receive(MySig4)
                  {     PCO2.send(MySig5);
                        PCO2.send(MySig6);
                        alt {
                        []    PCO1.receive(MySig3) {
                                    PCO2.receive(MySig7); }
                        []    PCO2.receive(MySig7) {
                                    PCO1.receive(MySig3); }
                        }
                  }
            }
      }
[]    PCO2.receive(MySig4)
      {     PCO2.send(MySig5);
            PCO2.send(MySig6);
```

```
                alt {
                []      PCO1.receive(MySig1)
                        {       PCO1.send(MySig2);
                                alt {
                                []      PCO1.receive(MySig3)
                                        {       PCO2.receive(MySig7);
                                        }
                                []      PCO2.receive(MySig7)
                                        {       PCO1.receive(MySig3);
                                        }
                                }
                        }
                []      PCO2.receive(MySig7)
                        {       PCO1.receive(MySig1);
                                PCO1.send(MySig2);
                                PCO1.receive(MySig3);
                        }
                }
        }
}
```

20.5 Default Handling

TTCN-3 allows the activation of altsteps (see clause 16.2) as defaults. For each test component the defaults, i.e., activated altsteps, are stored as an ordered list. The defaults are listed in the reversed order of their activation i.e., the last activated default is the first element in the list of active defaults. The TTCN-3 operations **activate** (see clause 20.5.2) and **deactivate** (see clause 20.5.3) operate on the list of defaults. An **activate** puts a new default as the first element into the list and a **deactivate** removes a default from the list. A default in the default list can be identified by means of default reference that is generated as a result of the corresponding **activate** operation.

20.5.1 The default mechanism

The default mechanism is evoked at the end of each **alt** statement, if due to the actual snapshot none of the specified alternatives could be executed. An evoked default mechanism invokes the first altstep in the list of defaults, i.e., the last activated default, and waits for the result of its termination. The termination can be successful or unsuccessful. Unsuccessful means that none of the top alternatives of the **altstep** (see clause 16.2) defining the default behaviour could be selected, successful means that one of the top alternatives of the default has been selected and executed.

In the case of an unsuccessful termination, the default mechanism invokes the next default in the list. If the last default in the list has terminated unsuccessfully, the default mechanism will return to the place in the **alt** statement in which it has been invoked, i.e., at the end of the **alt** statement, and indicate an unsuccessful default execution. An unsuccessful default execution will also be indicated if the list of defaults is empty.

An unsuccessful default execution may cause a new snapshot or a dynamic error if the test component is blocked (see clause 20.1).

In the case of a successful termination, the default may either stop the test component by means of a **stop** statement, or the main control flow of the test component will continue immediately after the **alt** statement from which the default mechanism was called or the test component will take new snapshot and re-evaluate the **alt** statement. The latter has to be specified by means of a **repeat** statement (see clause 20.3). If the selected top alternative of the default ends without a **repeat** statement, the control flow of the test component will continue immediately after the **alt** statement.

NOTE – TTCN-3 does not restrict the implementation of the default mechanism. It may, for example, be implemented in form of a process that is implicitly called at the end of each **alt** statement or in form of a separate thread that is only responsible for the default handling. The only requirement is that defaults are called in the reverse order of their activation when the default mechanism has been invoked.

20.5.1.1 Default references

Default references are unique references to activated defaults. Such a unique default reference is generated by a test component when an altstep is activated as a default, i.e., a default reference is the result of an `activate` operation (see clause 20.5.2).

Default references have the special and predefined type `default`. Variables of type `default` can be used to handle activated defaults in test components. The special value `null` is available to indicate an undefined default reference, e.g., for the initialization of variables to handle default references.

Default references are used in `deactivate` operations (see clause 20.5.3) in order to identify the default to be deactivated.

The actual data representation of the `default` type shall be resolved externally by the test system. This allows abstract test cases to be specified independently of any real TTCN-3 runtime environment, in other words TTCN-3 does not restrict the implementation of a test system with respect to the handling and identification of defaults.

20.5.2 The Activate operation

The `activate` operation is used to activate altsteps as defaults.

Syntactical Structure

```
activate "("
      AltstepRef "(" [ { ( TimerRef | TemplateInstance | Port | ComponentRef ) [","] } ] ")"
")"
```

Semantic Description

An `activate` operation will put the referenced altstep as the first element into the list of defaults and return a default reference. The default reference is a unique identifier for the default and may be used in a `deactivate` operation for the deactivation of the default.

The effect of an `activate` operation is local to the test component in which it is called. This means, a test component cannot activate a default in another test component.

The `activate` operation can be called without saving the returned default reference. This form is useful in test cases which do not require explicit deactivation of the activated default, i.e., deactivation of a default is done implicitly at MTC termination.

The actual parameters of a parameterized altstep (see clause 16.2.1) that should be activated as a default, shall be provided in the corresponding `activate` statement. This means the actual parameters are bound to the default at the time of its activation (and not e.g., at the time of its invocation by the default mechanism).

Restrictions

a) All timer instances in the actual parameter list shall be declared as component type local timers (see clause 9.2).

b) An altstep that is activated as a default shall only have `in` parameters, port parameters, or timer parameters.

Examples

EXAMPLE 1: Activation where the default reference is kept

```
// Declaration of a variable for the handling of defaults
var default MyDefaultVar := null;
 :
// Declaration of a default reference variable and activation of an altstep  as default
var default MyDefVarTwo := activate(MySecondAltStep());
 :
// Activation of altstep MyAltStep as a default
MyDefaultVar := activate(MyAltStep()); // MyAltStep is activated as default
```

```
  :
// Usage of MyDefaultVar for the deactivation of default MyDefAltStep
deactivate(MyDefaultVar);
```

EXAMPLE 2: Simple activation

```
// Activation of an altstep as a default, without assignment of default reference
activate(MyCommonDefault());
```

EXAMPLE 3: Activation of a parameterized altstep

```
altstep MyAltStep2 ( integer    par_value1, MyType par_value2,
                     MyPortType par_port,   timer  par_timer )
{
  :
}
function MyFunc () runs on MyCompType
{ :
var default MyDefaultVar := null;

MyDefaultVar := activate(MyAltStep2(5, myVar, myCompPort, myCompTimer));
      // MyAltStep2 is activated as default with the actual parameters 5 and
      // the value of myVar. A change of myVar before a call of MyAltStep2 by
      // the default mechanism will not change the actual parameters of the call.
  :
}
```

20.5.3 The Deactivate operation

The **`deactivate`** operation is used to deactivate defaults, i.e., previously activated altsteps.

Syntactical Structure

```
deactivate [ "(" VariableRef | FunctionInstance ")" ]
```

Semantic Description

A **`deactivate`** operation will remove the referenced default from the list of defaults.

The effect of a **`deactivate`** operation is local to the test component in which it is called. This means, a test component cannot deactivate a default in another test component.

A **`deactivate`** operation without parameter deactivates all defaults of a test component.

Calling a **`deactivate`** operation with the special value **`null`** has no effect. Calling a **`deactivate`** operation with an undefined default reference, e.g., an old reference to a default that has already been deactivated or an uninitialized default reference variable, shall cause a runtime error.

Restrictions

The variable associated with *VariableRef* (being a component type variable, a component type parameter, etc.) or the return type associated with *FunctionInstance* must be of default type.

Examples

```
var default MyDefaultVar := null;
var default MyDefVarTwo := activate(MySecondAltStep());
var default MyDefVarThree := activate(MyThirdAltStep());
  :
MyDefaultVar := activate(MyAltStep());
  :
deactivate(MyDefaultVar); // deactivates MyAltStep
  :
deactivate; // deactivates all other defaults, i.e., in this case MySecondAltStep
                  // and MyThirdAltStep
```

21 Configuration operations

Configuration operations are used to set up and control test components. They are summarized in Table 15. These operations shall only be used in TTCN-3 test cases, functions and altsteps (i.e., not in the module control part).

Table 15 – Overview of TTCN-3 configuration operations

Operation	Explanation	Syntax examples
Connection operations		
`connect`	Connects the port of one test component to the port of another test component	`connect(ptc1:p1, ptc2:p2);`
`disconnect`	Disconnects two or more connected ports	`disconnect(ptc1:p1, ptc2:p2);`
`map`	Maps the port of one test component to the port of the test system interface	`map(ptc1:q, system:sutPort1);`
`unmap`	Unmaps two or more mapped ports	`unmap(ptc1:q, system:sutPort1);`
Test component operations		
`create`	Creation of a normal or alive test component, the distinction between normal and alive test components is made during creation (MTC behaves as a normal test component)	Non-alive test components: `var PTCType c := PTCType.create;` Alive test components: `var PTCType c := PTCType.create alive;`
`start`	Starting test behaviour on a test component, starting a behaviour does not affect the status of component variables, timers or ports	`c.start(PTCBehaviour());`
`stop`	Stopping test behaviour on a test component	`c.stop;`
`kill`	Causes a test component to cease to exist	`c.kill;`
`alive`	Returns true if the test component has been created and is ready to execute or is executing already a behaviour; otherwise returns false	`if (c.alive) …`
`running`	Returns true as long as the test component is executing a behaviour; otherwise returns false	`if (c.running) …`
`done`	Checks whether the function running on a test component has terminated	`c.done;`
`killed`	Checks whether a test component has ceased to exist	`c.killed { … }`

Table 15 – Overview of TTCN-3 configuration operations

Operation	Explanation	Syntax examples
Reference operations		
`mtc`	Gets the reference to the MTC	`connect(mtc:p, ptc:p);`
`system`	Gets the reference to the test system interface	`map(c:p, system:sutPort);`
`self`	Gets the reference to the test component that executes this operation	`self.stop;`

21.1 Connection operations

The ports of a test component can be connected to other components or to the ports of the test system interface (see Figure 10). In the case of connections between two test components, the **`connect`** operation shall be used. When connecting a test component to a test system interface the **`map`** operation shall be used. The **`connect`** operation directly connects one port to another with the **`in`** side connected to the **`out`** side and vice versa. The **`map`** operation on the other hand can be seen purely as a name translation defining how communications streams should be referenced.

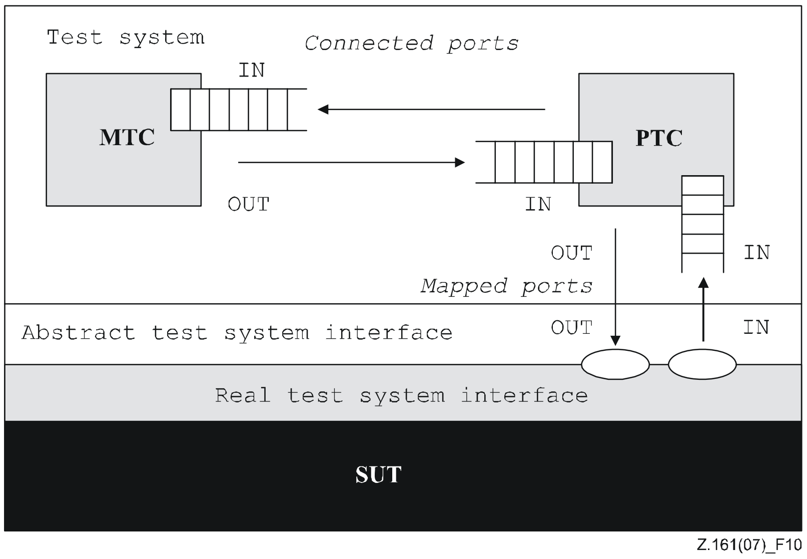


Figure 10 – Illustration of the connect and map operations

21.1.1 The Connect and map operations

The **`connect`** operation and the **`map`** operation are used to setup connections to the SUT or between test components.

Syntactical Structure

```
connect "(" ComponentRef ":" Port "," ComponentRef ":" Port ")"
map "(" ComponentRef ":" Port "," ComponentRef ":" Port ")"
```

Semantic Description

With both the **`connect`** and **`map`** operations, the ports to be connected are identified by the component references of the components to be connected and the names of the ports to be connected.

The operation **`mtc`** identifies the MTC, the operation **`system`** identifies the test system interface and the operation **`self`** identifies the test component in which **`self`** has been called (see clause 9.5). All these operations can be used for identifying and connecting ports.

Both the **`connect`** and **`map`** operations can be called from any behaviour definition except for the control part of a module. However, before either operation is called, the components to be connected shall have been created and their component references shall be known together with the names of the relevant ports.

Both the **`map`** and **`connect`** operations allow the connection of a port to more than one other port. It is not allowed to connect to a mapped port or to map to a connected port.

Restrictions

a) For both the **`connect`** and **`map`** operations, only consistent connections are allowed.

   Assuming the following:

   – ports PORT1 and PORT2 are the ports to be connected;

   – inlist-PORT1 defines the messages or procedures of the in-direction of PORT1;

   – outlist-PORT1 defines the messages or procedures of the out-direction of PORT1;

   – inlist-PORT2 defines the messages or procedures of the in-direction of PORT2; and

   – outlist-PORT2 defines the messages or procedures of the out-direction of PORT2.

b) The **`connect`** operation is allowed if and only if:

   outlist-PORT1 $\subseteq$ inlist-PORT2 and outlist-PORT2 $\subseteq$ inlist-PORT1.

c) The **`map`** operation (assuming PORT2 is the test system interface port) is allowed if and only if:

   outlist-PORT1 $\subseteq$ outlist-PORT2 *and* inlist-PORT2 $\subseteq$ inlist-PORT1.

d) In all other cases, the operations shall not be allowed.

e) Since TTCN-3 allows dynamic configurations and addresses, not all of these consistency checks can be made statically at compile-time. All checks, which could not be made at compile-time, shall be made at run-time and shall lead to a test case error when failing.

f) In addition, the restrictions on allowed and disallowed connections described in clause 9.1 apply.

Examples

```
// It is assumed that the ports Port1, Port2, Port3 and PCO1 are properly defined and declared
// in the corresponding port type and component type definitions
  :
var MyComponentType  MyNewPTC;
MyNewPTC := MyComponentType.create;
  :
connect(MyNewPTC:Port1, mtc:Port3);
map(MyNewPTC:Port2, system:PCO1);
  :
// In this example, a new component of type MyComponentType is created and its reference
// stored in variable MyNewPTC. Afterwards in the connect operation, Port1 of this new
// component is connected with Port3 of the MTC. By means of the map operation, Port2 of the
// new component is then connected to port PCO1 of the test system interface
```

21.1.2 The Disconnect and unmap operations

The **`disconnect`** and **`unmap`** operations are the opposite operations of **`connect`** and **`map`**.

Syntactical Structure

```
disconnect [ ( "(" ComponentRef ":" Port "," ComponentRef ":" Port ")" ) |
             ( "(" PortRef ")" ) |
             ( "(" ComponentRef ":" all port ")" ) |
             ( "(" all component ":" all port ")" ) ]
```

Semantic Description

The **`disconnect`** and **`unmap`** operations perform the disconnection (of previously connected) ports of test components and the unmapping of (previously mapped) ports of test components and ports in the test system interface.

Both the **`disconnect`** and **`unmap`** operations can be called from any component if the relevant component references together with the names of the relevant ports are known. A **`disconnect`** or **`unmap`** operation has only an effect if the connection or mapping to be removed has been created beforehand.

To ease **`disconnect`** and **`unmap`** operations related to all connections and mappings of a component or a port, it is allowed to use **`disconnect`** and **`unmap`** operations with one argument only. This one argument specifies one side of the connections to be disconnected or unmapped. The **`all port`** keyword can be used to denote all ports of a component.

The usage of a **`disconnect`** or **`unmap`** operation without any parameters is a shorthand form for using the operation with the parameter **`self:all port`**. It disconnects or unmaps all ports of the component that calls the operation.

The **`all component`** keyword shall only be used in combination with the **`all port`** keyword, i.e., **`all component:all port`**, and shall only be used by the MTC. Furthermore, the **`all component:all port`** argument shall be used as the one and only argument of a **`disconnect`** or **`unmap`** operation and it allows to release all connections and mappings of the test configuration.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

EXAMPLE 1: Disconnect/unmap for specific connections

```
connect(MyNewComponent:Port1, mtc:Port3);
map(MyNewComponent:Port2, system:PCO1);
  :
disconnect(MyNewComponent:Port1, mtc:Port3);    // disconnect previously made connection
unmap(MyNewComponent:Port2, system:PCO1);       // unmap previously made mapping
```

EXAMPLE 2: Disconnect/unmap for a component

```
disconnect(MyNewComponent:Port1);               // disconnects all connections of Port1, which
                                                // is owned by component MyNewComponent.
unmap(MyNewComponent:all port);                 // unmaps all ports of component MyNewComponent
```

EXAMPLE 3: Disconnect/unmap for "self"

```
disconnect;                                     // is a shorthand form for …
disconnect(self:all port);                      // which disconnects all ports of the component
                                                // that called the operation
  :
unmap;                                          // is a shorthand form for …
unmap(self:all port);                           // which unmaps all ports of the component
                                                // that called the operation
```

EXAMPLE 4: Disconnect/unmap for "all component"

```
disconnect(all component:all port);             // the MTC disconnects all ports of all
                                                // components in the test configuration.
  :
unmap(all component:all port);                  // the MTC unmaps all ports of all
                                                // components in the test configuration.
```

21.2 Test component operations

Test component operations are used to create, start, stop and kill test components. They can also be used to check if test components are alive, running, done or killed.

21.2.1 The Create operation

The **`create`** operation is used to create test components.

Syntactical Structure

```
ComponentType "." create [ "(" Expression ")" ] [ alive ]
```

Semantic Description

The MTC is the only test component, which is automatically created when a test case starts. All other test components (the PTCs) shall be created explicitly during test execution by **`create`** operations. A component is created with its full set of ports of which the input queues are empty and with its full set of constants, variables and timers. Furthermore, if a port is defined to be of the type **`in`** or **`inout`** it shall be in a listening state ready to receive traffic over the connection.

All component variables and timers are reset to their initial value (if any) and all component constants are reset to their assigned values when the component is explicitly or implicitly created.

Two types of PTCs are distinguished: a PTC that can execute a behaviour function only once and a PTC that is kept alive after termination of a behaviour function and can be therefore reused to execute another function. The latter is created using the additional **`alive`** keyword. An alive-type PTC must be destroyed explicitly using the **`kill`** operation (see clause 21.2.4), whereas a non-alive PTC is destroyed implicitly after its behaviour function terminates. Termination of a test case, i.e., the MTC, terminates all PTCs that still exist, if any.

Since all test components and ports are implicitly destroyed at the termination of each test case, each test case shall completely create its required configuration of components and connections when it is invoked.

The **`create`** operation shall return the unique component reference of the newly created instance. The unique reference to the component will typically be stored in a variable (see clause 9.5) and can be used for connecting instances and for communication purposes such as sending and receiving.

Optionally, a name can be associated with the newly created component instance. The test system shall associate the names 'MTC' to the MTC and 'SYSTEM' to the test system interface automatically at creation. Associated component names are not required to be unique.

NOTE – The component instance name is used for logging purposes (see clause 19.11) only and shall not be used to refer to the component instance (the component reference shall be used for this purpose) and has no effect on matching.

Components can be created at any point in a behaviour definition providing full flexibility with regard to dynamic configurations (i.e., any component can create any other PTC). The visibility of component references shall follow the same scope rules as that of variables and, in order to reference components outside their scope of creation, the component reference shall be passed as a parameter or as a field in a message.

Restrictions

The name given by *Expression* shall be a charstring value and, when assigned, it shall appear as the argument of the **`create`** function.

Examples

```
// This example declares variables of type MyComponentType, which is used to store the
// references of newly created component instances of type MyComponentType which is the
// result of the create operations. An associated name is allocated to some of the created
// component instances.
```

```
  :
var MyComponentType MyNewComponent;
var MyComponentType MyNewestComponent;
var MyComponentType MyAliveComponent;
var MyComponentType MyAnotherAliveComponent;
  :
MyNewComponent := MyComponentType.create;
MyNewestComponent := MyComponentType.create("Newest");
MyAliveComponent := MyComponentType.create alive;
MyAnotherAliveComponent := MyComponentType.create("Another Alive") alive;
```

21.2.2 The Start test component operation

The start operation is used to associate a test behaviour to a test component, which is then being executed by that test component.

Syntactical Structure

```
( VariableRef | FunctionInstance ) "." start "(" FunctionInstance ")"
```

Semantic Description

Once a PTC has been created and connected, behaviour has to be bound to this PTC and the execution of its behaviour has to be started. This is done by using the **`start`** operation (as PTC creation does not start execution of the component behaviour). The reason for the distinction between **`create`** and **`start`** is to allow connection operations to be done before actually running the test component.

The **`start`** operation shall bind the required behaviour to the test component. This behaviour is defined by reference to an already defined function.

An alive-type PTC may perform several behaviour functions in sequential order. Starting a second behaviour function on a non-alive PTC or starting a function on a PTC that is still running results in a test case error. If a function is started on an alive-type PTC after termination of a previous function, it uses variable values, timers, ports, and the local verdict as they were left after termination of the previous function. In particular, if a timer was started in the previous function, the subsequent function should be enabled to handle a possible timeout event.

Restrictions

a) The variable associated with *VariableRef* (being a component type variable, a component type parameter, etc.) or the return type associated with *FunctionInstance* must be of component type.

b) The following restrictions apply to a function invoked in a **`start`** test component operation:

- If this function has parameters they shall only be **`in`** parameters, i.e., parameters by value.
- This function shall have a **`runs on`** definition referencing a component type that is compatible with the newly created component (see clause 6.3.3).
- Ports and timers shall not be passed into this function.

NOTE – As **`in`** and **`inout`** ports start listening when the component is created, at the moment, when they start execution there may be messages in the incoming queues of such ports already waiting to be processed.

Examples

```
function MyFirstBehaviour() runs on MyComponentType { … }
function MySecondBehaviour() runs on MyComponentType { … }
:
var MyComponentType MyNewPTC;
var MyComponentType MyAlivePTC;
:
MyNewPTC := MyComponentType.create;           // Creation of a new non-alive test component.
MyAlivePTC := MyComponentType.create alive;   // Creation of a new alive-type test component
:
```

```
MyNewPTC.start(MyFirstBehaviour());        // Start of the non-alive component.
MyNewPTC.done;                                        // Wait for termination
MyNewPTC.start(MySecondBehaviour());           // Test case error
:
MyAlivePTC.start(MyFirstBehaviour());          // Start of the alive-type component
MyAlivePTC.done;                                     // Wait for termination
MyAlivePTC.start(MySecondBehaviour());         // Start of the next function on the same
                                               // component
```

21.2.3 The Stop test behaviour operation

The stop test behaviour operation is used to stop the execution of a test component by itself or by another test component.

Syntactical Structure

```
stop |
( ( VariableRef | FunctionInstance | mtc | self ) "." stop ) |
( all component "." stop )
```

Semantic Description

By using the **stop** test component statement a test component can stop the execution of its own currently running test behaviour or the execution of the test behaviour running on another test component. If a component does not stop its own behaviour, but the behaviour running on another test component in the test system, the component to be stopped has to be identified by using its component reference. A component can stop its own behaviour by using a simple **stop** execution statement (see clause 19.9) or by addressing itself in the **stop** operation, e.g., by using the **self** operation.

NOTE 1 – While the **create**, **start**, **running**, **done** and **killed** operations can be used for PTC(s) only, the **stop** operation can also be applied to the MTC.

Stopping a test component is the explicit form of terminating the execution of the currently running behaviour. A test component behaviour terminates also by completing its execution upon reaching the end of the testcase or function that is started on this component or by an explicit **return** statement. This termination is also called implicit stop. The implicit stop has the same effects as an explicit stop, i.e., the global verdict is updated with the local verdict of the stopped test component (see clause 24).

If the stopped test component is the MTC, resources of all existing PTCs shall be released, the PTCs shall be removed from the test system and the test case shall terminate (see clause 26.1).

Stopping a non-alive-type test component (implicitly or explicitly) shall destroy it and all resources associated with the test component shall be released.

Stopping an alive-type component shall stop the currently running behaviour only but the component continues to exist and can execute new behaviour (started on it using the **start** operation). The component shall be left in a consistent state after stopping its behaviour.

NOTE 2 – For example, if the behaviour of an alive-type component is stopped during assigning a new value to an already bound variable, the variable shall remain bound after the component is stopped (with the old or the new value). Similarly, if the component is stopped during re-starting an already running timer, the timer shall be left in the running state after termination of the behaviour.

The rules for the termination of test cases and the calculation of the final test verdict are described in clause 24.

The **all** keyword can be used by the MTC only in order to stop all running PTCs but the MTC itself.

NOTE 3 – A PTC can stop the test case execution by stopping the MTC.

NOTE 4 – The concrete mechanism for stopping PTCs is outside the scope of this Recommendation.

Restrictions

The variable associated with *VariableRef* (being a component type variable, a component type parameter, etc.) or the return type associated with *FunctionInstance* must be of component type.

Examples

EXAMPLE 1: Stopping another test component and a test component by itself

```
var MyComponentType MyComp := MyComponentType.create;// A new test component is created
MyComp.start(CompBehaviour());                        // The new component is started
:
if (date == "1.1.2005") {
      MyComp.stop;                            // The component "MyComp" is stopped
}

:
if (a < b ) {
       :
      self.stop;        // The test component that is currently executing stops its own
                        // behaviour
}
:
stop             // The test component stops its own behaviour
```

EXAMPLE 2: Stopping all PTCs by the MTC

```
all component.stop           // The MTC stops all PTCs of the test case but not itself.
```

21.2.4 The Kill test component operation

The **kill** test component operation is used to destroy a test component by itself or by another test component. Kill and stop on a non-alive component have the same results, while they differ for alive components: stopping an alive components stops the test behaviour only, the test component continues to exist. Killing a test component destroys the test component.

Syntactical Structure

```
kill |
( ( VariableRef | FunctionInstance | mtc | self ) "." kill ) |
( all component "." kill )
```

Semantic Description

The **kill** operation applied on a test component stops the execution of the currently running behaviour – if any – of that component and frees all resources associated to it (including all port connections of the killed component) and removes the component from the test system. The **kill** operation can be applied on the current test component itself by a simple **kill** statement or by addressing itself using the **self** operation in conjunction with the **kill** operation. The **kill** operation can also be applied to another test component. In this case the component to be killed shall be addressed using its component reference. If the **kill** operation is applied on the MTC, e.g., **mtc.kill**, it terminates the test case.

The **all** keyword can be used by the MTC only in order to stop and kill all running PTCs but the MTC itself.

Restrictions

The variable associated with *VariableRef* (being a component type variable, a component type parameter, etc.) or the return type associated with *FunctionInstance* must be of component type.

Examples

EXAMPLE 1: Killing another test component and a test component by itself

```
var PTCType MyAliveComp := PTCType.create alive;      // Create an alive-type test component
MyAliveComp.start(MyFirstBehaviour());                 // The new component is started
MyAliveComp.done;                                              // Wait for termination
MyAliveComp.start(MySecondBehavior());              // Start the component a 2nd time
MyAliveComp.done;                                           // Wait for termination
MyAliveComp.kill;                                           // Free its resources
```

EXAMPLE 2: Killing all PTCs by the MTC

```
all component.kill;          // The MTC stops all (alive-type and normal) PTCs of the test
                             // case first and frees their resources.
```

21.2.5 The Alive operation

The **alive** operation is a Boolean operation that checks whether a test component has been created and is ready to execute or is executing already a behaviour function.

Syntactical Structure

```
( VariableRef |
FunctionInstance |
any component |
all component ) "." alive
```

Semantic Description

Applied on a normal test component, the **alive** operation returns true if the component is inactive or running a function and false otherwise. Applied on an alive-type test component, the operation returns true if the component is inactive, running or stopped. It returns false if the component has been killed.

The **alive** operation can be used similar to the **running** operation on PTCs only (see clause 21.2.6). In particular, in combination with the **all** keyword it returns true if all (alive-type or normal) PTCs are alive.

The **alive** operation used in combination with the **any** keyword returns true if at least one PTC is alive.

Restrictions

The variable associated with *VariableRef* (being a component type variable, a component type parameter, etc.) or the return type associated with *FunctionInstance* must be of component type.

Examples

```
PTC1.done;                                  // Waits for termination of the component
if (PTC1.alive) {                           // If the component is still alive …
      PTC1.start(AnotherFunction());        // … execute another function on it.
}
```

21.2.6 The Running operation

The **running** operation is a Boolean operation that checks whether a test component is executing already a behaviour function.

Syntactical Structure

```
( VariableRef |
FunctionInstance |
any component |
all component ) "." running
```

Semantic Description

The **running** operation allows behaviour executing on a test component to ascertain whether behaviour running on a different test component has completed. The **running** operation can be used for PTCs only. The running operation returns **true** for PTCs that have been started but not yet terminated or stopped. It returns **false** otherwise. The **running** operation is considered to be a **boolean** expression and, thus, returns a **boolean** value to indicate whether the specified test component (or all test components) has terminated. In contrast to the **done** operation, the **running** operation can be used freely in **boolean** expressions.

When the **all** keyword is used with the **running** operation, it will return **true** if all PTCs started but not stopped explicitly by another component are executing their behaviour. Otherwise it returns **false**.

When the **any** keyword is used with the **running** operation, it will return **true** if at least one PTC is executing its behaviour. Otherwise it returns **false**.

Restrictions

The variable associated with *VariableRef* (being a component type variable, a component type parameter, etc.) or the return type associated with *FunctionInstance* must be of component type.

Examples

```
if (PTC1.running)                          // usage of running in an if statement
{
     // do something!
}

while (all component.running != true) {  // usage of running in a loop condition
     MySpecialFunction()
}
```

21.2.7 The Done operation

The **done** operation allows behaviour executing on a test component to ascertain whether the behaviour running on a different test component has completed.

Syntactical Structure

```
( VariableRef |
FunctionInstance |
any component |
all component ) "." done
```

Semantic Description

The **done** operation shall be used in the same manner as a receiving operation or a **timeout** operation. This means it shall not be used in a **boolean** expression, but it can be used to determine an alternative in an **alt** statement or as stand-alone statement in a behaviour description. In the latter case a **done** operation is considered to be a shorthand for an **alt** statement with only one alternative, i.e., it has blocking semantics, and therefore provides the ability of passive waiting for the termination of test components.

When the done operation is applied to a PTC, it matches only if the behaviour of that PTC has been stopped (implicitly or explicitly) or the PTC has been killed. Otherwise, the match is unsuccessful.

When the **all** keyword is used with the **done** operation, it matches if no one PTC is executing its behaviour. It also matches if no PTC has been created.

When the **any** keyword is used with the **done** operation, it matches if at least the behaviour of one PTC has been stopped or killed. Otherwise, the match is unsuccessful.

NOTE – Stopping the behaviour of a non-alive component also results in removing that component from the test system, while stopping an alive-type component leaves the component alive in the test system. In both cases the **done** operation matches.

Restrictions

a) The **done** operation can be used for PTCs only.

b) The variable associated with *VariableRef* (being a component type variable, a component type parameter, etc.) or the return type associated with *FunctionInstance* must be of component type.

Examples

```
      // Use of done in alternatives
      alt {
            []    MyPTC.done {
                        setverdict(pass)
                  }

            []    any port.receive {
                        repeat
                  }
      }

      var MyComp c := MyComp.create alive;
      c.start(MyPTCBehaviour());
      :
      c.done;
            // matches as soon as the function MyPTCBehaviour (or function/altstep called by it)
stops
      c.done;
            // matches the end of MyPTCBehaviour (or function/altstep called by it) too
      if(c.running) {c.done}
            // done here matches the end of the next behaviour only

      // the following done as stand-alone statement:
      all component.done;

      // has the following meaning:
      alt {
            []    all component.done {}
      }
      // and thus, blocks the execution until all parallel test components have terminated
```

21.2.8 The Killed operation

The **killed** operation allows to ascertain whether a different test component is alive or has been removed from the test system.

Syntactical Structure

```
      ( VariableRef |
      FunctionInstance |
      any component |
      all component ) "." killed
```

Semantic Description

The **killed** operation shall be used in the same manner as receiving operations. This means it shall not be used in **boolean** expressions, but it can be used to determine an alternative in an **alt** statement or as a stand-alone statement in a behaviour description. In the latter case a **killed** operation is considered to be a shorthand for an **alt** statement with only one alternative, i.e., it has blocking semantics, and therefore provides the ability of passive waiting for the termination of test components.

NOTE – When checking normal test components a killed operation matches if it stopped (implicitly or explicitly) the execution of its behaviour or has been **killed** explicitly, i.e., the operation is equivalent to the **done** operation (see clause 21.2.7). When checking alive-type test components, however, the **killed** operation matches only if the component has been killed using the **kill** operation. Otherwise the **killed** operation is unsuccessful.

When the **all** keyword is used with the **killed** operation, it matches if all PTCs of the test case have ceased to exist. It also matches if no PTC has been created.

When the **any** keyword is used with the **killed** operation, it matches if at least one PTC ceased to exist. Otherwise, the match is unsuccessful.

Restrictions

The `killed` operation can be used for PTCs only.

Examples

```
var MyPTCType ptc := MyPTCType.create alive;    // create an alive-type test component
timer T(10.0);                                  // create a timer
T.start;                                        // start the timer
ptc.start(MyTestBehavior());                    // start executing a function on the PTC
alt {
[] ptc.killed {                                 // if the PTC was killed during execution …
      T.stop;                                   // … stop the timer and …
      setverdict(inconc);                       // … set the verdict to 'inconclusive'
   }
[] ptc.done {                                   // if the PTC terminated regularly …
      T.stop;                                   // … stop the timer and …
      ptc.start(AnotherFunction());             // … start another function on the PTC
   }
[] T.timeout {                                  // if the timeout occurs before the PTC stopped
      ptc.kill;                                 // … kill the PTC and …
      setverdict(fail);                         // … set the verdict to 'fail'
   }
}
```

21.2.9 Summary of the use of any and all with components

The keywords `any` and `all` may be used with configuration operations as indicated in Table 16.

Table 16 – Any and All with components

Operation	Allowed		Example	Comment
	`any` (see Note)	`all` (see Note)		
`create`	▨	▨	▨	▨
`start`	▨	▨	▨	▨

`running`	Yes but from MTC only	Yes but from MTC only	`any component.running;`
			`all component.running;`
				Is there any PTC performing test behaviour?
				Are all PTCs performing test behaviour?

`alive`	Yes but from MTC only	Yes but from MTC only	`any component.alive;`
			`all component.alive;`
				Is there any alive PTC?
				Are all PTCs alive?

`done`	Yes but from MTC only	Yes but from MTC only	`any component.done;`
			`all component.done;`
				Is there any PTC that completed execution?
				Did all PTCs complete their execution?

`killed`	Yes but from MTC only	Yes but from MTC only	`any component.killed;`
			`all component.killed;`
				Is there any PTC that ceased to exist?
				Did all PTCs cease to exist?

`stop`	▨	Yes but from MTC only	`all component.stop;`	Stop the behaviour on all PTCs.
`kill`	▨	Yes but from MTC only	`all component.kill;`	Kill all PTCs, i.e., they cease to exist.
NOTE – `any` and `all` refer to PTCs only, i.e., the MTC is not considered.				

22 Communication operations

TTCN-3 supports *message-based* and *procedure-based unicast*, *multicast* and *broadcast* communication. Furthermore, TTCN-3 allows to examine the top element of incoming port queues and to control the access to ports by means of *controlling operations*. The communication operations and restrictions on their usage are summarized in Table 17.

Table 17 – Overview of TTCN-3 communication operations

Communication operation	Keyword	Can be used at message-based ports	Can be used at procedure-based ports
Message-based communication			
Send message	`send`	Yes	▨
Receive message	`receive`	Yes	▨
Trigger on message	`trigger`	Yes	▨
Procedure-based communication			
Invoke procedure call	`call`	▨	Yes
Accept procedure call from remote entity	`getcall`	▨	Yes
Reply to procedure call from remote entity	`reply`	▨	Yes
Raise exception (to an accepted call)	`raise`	▨	Yes
Handle response from a previous call	`getreply`	▨	Yes
Catch exception (from called entity)	`catch`	▨	Yes
Examine top element of incoming port queues			
Check msg/call/exception/reply received	`check`	Yes	Yes
Controlling operations			
Clear port queue	`clear`	Yes	Yes
Clear queue and enable sending and receiving at a port	`start`	Yes	Yes
Disable sending and disallow receiving operations to match at a port	`stop`	Yes	Yes
Disable sending and disallow receiving operations to match new messages/calls	`halt`	Yes	Yes

22.1 The communication mechanisms

This clause explains the principles of TTCN-3 communication for message-based communication (see clause 22.1.1), for procedure-based communication (see clause 22.1.2), for unicast, multicast, and broadcast communication (see clause 22.1.3), as well as the general format of sending and receiving operations (see clause 22.1.4).

22.1.1 Principles of message-based communication

Message-based communication is communication based on an asynchronous message exchange. Message-based communication is non-blocking on the **`send`** operation, as illustrated in Figure 11, where processing in the SENDER continues immediately after the **`send`** operation occurs. The RECEIVER is blocked on the **`receive`** operation until it processes the received message.

In addition to the **receive** operation, TTCN-3 provides a **trigger** operation that filters messages with certain matching criteria from a stream of received messages on a given incoming port. Messages at the top of the queue that do not fulfil the matching criteria are removed from the port without any further action.

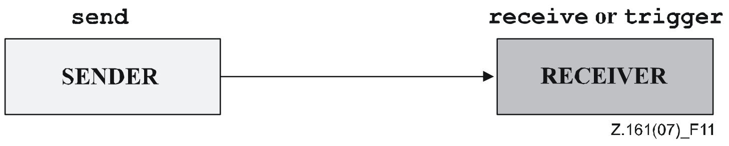


Figure 11 – Illustration of the asynchronous send and receive

22.1.2 Principles of procedure-based communication

The principle of procedure-based communication is to call procedures in remote entities. TTCN-3 supports *blocking* and *non-blocking* procedure-based communication. Blocking procedure-based communication is blocking on the calling and the called side, whereas non-blocking procedure-based communication is only blocking on the called side. Signatures of procedures that are used for non-blocking procedure-based communication shall be specified according to the rules in clause 13.

The communication scheme of blocking procedure-based communication is shown in Figure 12. The CALLER calls a remote procedure in the CALLEE by using the **call** operation. The CALLEE accepts the call by means of a **getcall** operation and reacts by either using a **reply** operation to answer the call or by raising (**raise** operation) an exception. The CALLER handles the reply or exception by using **getreply** or **catch** operations. In Figure 12, the blocking of CALLER and CALLEE is indicated by means of dashed lines.

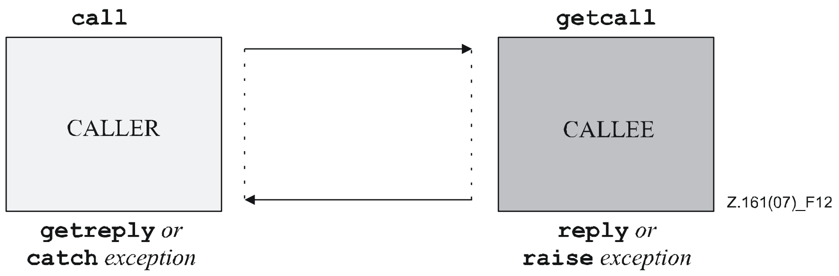


Figure 12 – Illustration of blocking procedure-based communication

The communication scheme of non-blocking procedure-based communication is shown in Figure 13. The CALLER calls a remote procedure in the CALLEE by using the **call** operation and continues its execution, i.e., does not wait for a reply or exception. The CALLEE accepts the call by means of a **getcall** operation and executes the requested procedure. If the execution is not successful, the CALLEE may raise an exception to inform the CALLER. The CALLER may handle the exception by using a **catch** operation in an **alt** statement. In Figure 13, the blocking of the CALLEE until the end of the call handling and possible raise of an exception is indicated by means of a dashed line.

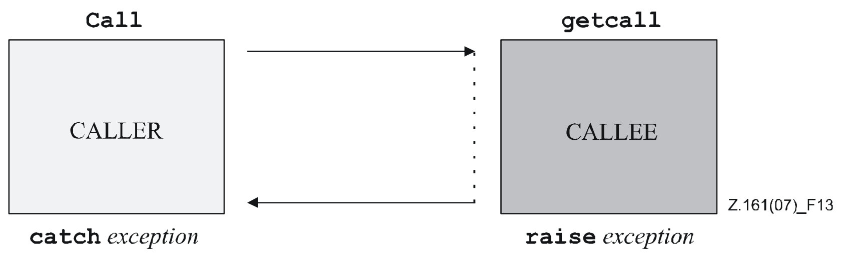


Figure 13 – Illustration of non-blocking procedure-based communication

22.1.3 Principles of unicast, multicast and broadcast communication

TTCN-3 supports unicast, multicast and broadcast communication:

- Unicast communication means one sender to one receiver.
- Multicast communication is from one sender to a list of receivers.
- Broadcast communication is from one sender to all receivers (being connected or mapped to the sender).

The terms unicast, multicast and broadcast communication are related to port communication. This means, it is only possible to address one, several or all test components that are connected to the specified port. Unicast, multicast and broadcast can also be used for mapped ports. In this case, one, several or all entities within the SUT can be reached via the specified mapped port.

22.1.4 General format of communication operations

Operations such as `send` and `call` are used for the exchange of information among test components and between an SUT and test components. For explaining the general format of these operations, they can be structured into two groups:

a) a test component sends a message (`send` operation), calls a procedure (`call` operation), or replies to an accepted call (`reply` operation) or raises an exception (`raise` operation). These actions are collectively referred to as *sending operations*;

b) a component receives a message (`receive` operation), awaits a message (`trigger` operation), accepts a procedure call (`getcall` operation), receives a reply for a previously called procedure (`getreply` operation) or catches an exception (`catch` operation). These actions are collectively referred to as *receiving operations*.

22.1.4.1 General format of the sending operations

Sending operations consist of a *send* part and, in the case of a blocking procedure-based `call` operation, a *response* and *exception handling* part.

The send part:

- specifies the port at which the specified operation shall take place;
- defines the message or procedure call to be transmitted;
- gives an (optional) address part that uniquely identifies one or more communication partners to which a message, call, reply or exception shall be sent.

The port name, operation name and value shall be present in all sending operations. The address part (denoted by the `to` keyword) is optional and need only be specified in cases of one-to-many connections where:

- unicast communication is used and one receiving entity shall be explicitly identified;
- multicast communication is used and a set of receiving entities has to be explicitly identified;

• broadcast communication is used and all entities connected to the specified port have to be addressed.

EXAMPLE 1:

Send part			(Optional) response and exception
Port and operation	**Value part**	**(Optional) address part**	**handling part**
`MyP1.send`	`(MyVariable + YourVariable - 2)`	`to MyPartner;`	

Response and exception handling is only needed in cases of procedure-based communication. The response and exception handling part of the **`call`** operation is optional and is required for cases where the called procedure returns a value or has **`out`** or **`inout`** parameters whose values are needed within the calling component and for cases where the called procedure may raise exceptions which need to be handled by the calling component.

The response and exception handling part of the call operation makes use of **`getreply`** and **`catch`** operations to provide the required functionality.

EXAMPLE 2:

Send part			(Optional) response and exception handling part
Port and operation	**Value part**	**(Optional) address part**	
`MyP1.call`	`(MyProc:{MyVar1})`		`{ [] MyP1.getreply(MyProc:{MyVar2}) {} [] MyP1.catch(MyProc, ExceptionOne) {} }`

22.1.4.2 General format of the receiving operations

A receiving operation consists of a *receive* part and an (optional) *assignment* part.

The receive part:

a) specifies the port at which the operation shall take place;

b) defines a matching part which specifies the acceptable input which will match the statement;

c) gives an (optional) address expression that uniquely identifies the communication partner (in case of one-to-many connections).

The port name, operation name and value part of all receiving operations shall be present. The identification of the communication partner (denoted by the **`from`** keyword) is optional and need only be specified in cases of one-to-many connections where the receiving entity needs to be explicitly identified.

The assignment part in a receiving operation is optional. For message-based ports, it is used when it is required to store received messages. In the case of procedure-based ports, it is used for storing the **`in`** and **`inout`** parameters of an accepted call, for storing the return value or for storing exceptions. For the assignment part, strong typing is required, e.g., the variable used for storing a message shall have the same type as the incoming message.

In addition, the assignment part may also be used to assign the **`sender`** address of a message, exception, **`reply`** or **`call`** to a variable. This is useful for one-to-many connections where, for example, the same message or call can be received from different components, but the message, reply or exception must be sent back to the original sending component.

EXAMPLE:

Receive part				(Optional) assignment part		
Port and operation	**Matching part**	**(Optional) address expression**		**(Optional) value assignment**	**(Optional) parameter value assignment**	**(Optional) sender value assignment**
`MyP1.getreply`	`(AProc:{?} value )`		`->`		`param (V1)`	`Sender APeer`

Receive part				(Optional) assignment part		
Port and operation	**Matching part**	**(Optional) address expression**		**(Optional) value assignment**	**(Optional) parameter value assignment**	**(Optional) sender value assignment**
`MyP2.receive`	`(MyTemplate (5,7))`	`From APeer`	`->`	`Value MyVar`		

22.2 Message-based communication

The operations for message-based communication via asynchronous ports are summarized in Table 18.

Table 18 – Overview of TTCN-3 message-based communication

Communication operation	Keyword
Send message	**`send`**
Receive message	**`receive`**
Trigger on message	**`trigger`**
Check message received	**`check`**

22.2.1 The Send operation

The **`send`** operation is used to place a message on an outgoing message port.

Syntactical Structure

```
Port "." send "(" TemplateInstance ")"
[ to ( AddressRef | AddressRefList | all component ) ]
```

Semantic Description

The **`send`** operation places a message on an outgoing message port. The message may be specified by referencing a defined template or can be defined as an in-line template.

Sending unicast, multicast or broadcast

Unicast, multicast and broadcast communication can be determined by the optional **`to`** clause in the **`send`** operation. A **`to`** clause can be omitted in case of a one-to-one connection where unicast communication is used and the message receiver is uniquely determined by the test system structure.

Unicast communication is specified, if the `to` clause addresses one communication partner only. Multicast communication is used, if the `to` clause includes a list of communication partners. Broadcast is defined by using the `to` clause with **`all component`** keyword.

Restrictions

a) The TemplateInstance (and all parts of it) shall have a specific value i.e., the use of matching mechanisms such as *AnyValue* is not allowed.

b) When defining the message in-line, the optional type part shall be used if there is ambiguity of the type of the message being sent.

c) The **`send`** operation shall only be used on message-based (or mixed) ports and the type of the template to be sent shall be in the list of outgoing types of the port type definition.

d) A `to` clause shall be present in case of one-to-many connections.

e) *AddressRef* should not contain matching mechanisms and must be of address or component type.

Examples

EXAMPLE 1: Simple send (receiver is determined from the test configuration)

```
MyPort.send(MyTemplate(5,MyVar));  // Sends the template MyTemplate with the actual
                                   // parameters 5 and MyVar via MyPort.

MyPort.send(5);                    // Sends the integer value 5 (which is an in-line template)
```

EXAMPLE 2: Sending with explicit to clause

```
MyPort.send(charstring:"My string") to MyPartner;
                                         // Sends the string "My string" to a component with a
                                         // component reference stored in variable MyPartner

MyPCO.send(MyVariable + YourVariable - 2) to MyPartner;
                              // Sends the result of the arithmetic expression to MyPartner.

MyPCO2.send(MyTemplate) to (MyPeerOne, MyPeerTwo);
                              // Specifies a multicast communication, where the value of
                              // MyTemplate is sent to the two component references stored
                              // in the variables MyPeerOne and MyPeerTwo.

MyPCO3.send(MyTemplate) to all component;
                              // Broadcast communication: the value of Mytemplate is sent to
                              // all components which can be addressed via this port. If
                              // MyPCO3 is a mapped port, the components may reside inside
                              // the SUT.
```

22.2.2 The Receive operation

The **`receive`** operation is used to receive a message from an incoming message port queue.

Syntactical Structure

```
( Port | any port ) "." receive
[ "(" TemplateInstance ")" ]
[ from AddressRef ]
[ "->" [ value VariableRef ]
       [ sender VariableRef ] ]
```

Semantic Description

The **`receive`** operation is used to receive a message from an incoming message port queue. The message may be specified by referencing a defined template or can be defined as an in-line template.

The **`receive`** operation removes the top message from the associated incoming port queue if, and only if, that top message satisfies all the matching criteria associated with the **`receive`** operation.

If the match is not successful, the top message shall not be removed from the port queue i.e., if the **receive** operation is used as an alternative of an **alt** statement and it is not successful, the execution of the test case shall continue with the next alternative of the **alt** statement.

Matching criteria

The matching criteria are related to the type and value of the message to be received. The type and value of the message to be received are determined by the argument of the **receive** operation, i.e., may either be derived from the defined template or be specified in-line. An optional type field in the matching criteria to the **receive** operation shall be used to avoid any ambiguity of the type of the value being received.

NOTE 1 – Encoding attributes also participate in matching in an implicit way, by preventing the decoder to produce an abstract value from the received message encoded in a different way than specified by the attributes.

Receiving from a specific sender

In the case of one-to-many connections the **receive** operation may be restricted to a certain communication partner. This restriction shall be denoted using the **from** keyword.

Storing the received message

If the match is successful, the value removed from the port queue can be retrieved and stored in a variable. This is denoted by the symbol '->' and the keyword **value**.

Storing the sender

It is also possible to retrieve and store the component reference or address of the sender of a message. This is denoted by the keyword **sender**.

NOTE 2 – When the message is received on a connected port, only the component reference is stored in the following **sender** keyword, but the test system shall internally store the component name too, if any (to be used in logging).

Receive any message

A **receive** operation with no argument list for the type and value matching criteria of the message to be received shall remove the message on the top of the incoming port queue (if any) if all other matching criteria are fulfilled.

Receive on any port

To **receive** a message on any port, use the **any port** keywords.

Stand-alone receive

The **receive** operation can be used as a stand-alone statement in a behaviour description. In this latter case, the **receive** operation is considered to be shorthand for an **alt** statement with only one alternative, i.e., it has blocking semantics, and therefore provides the ability of waiting for the next message matching the specified template or value on that queue.

Restrictions

a) When defining the message in-line, the optional type part shall be present whenever the type of the message being received is ambiguous.

b) The **receive** operation shall only be used on message-based (or mixed) ports and the type of the value to be received shall be included in the list of incoming types of the port type definition.

c) No binding of the incoming values to the terms of the expression or to the template shall occur.

d) A message received by *receive any message* shall not be assigned to a variable, i.e., the **value** clause shall not be present.

Examples

EXAMPLE 1: Basic receive

```
      MyPort.receive(MyTemplate(5, MyVar));     // Matches a message that fulfils the conditions
                                                // defined by template MyTemplate at port MyPort.

      MyPort.receive(A<B);    // Matches a Boolean value that depends on the outcome of A<B

      MyPort.receive(integer:MyVar);      // Matches an integer value with the value of MyVar
                                          // at port MyPort

      MyPort.receive(MyVar);              // Is an alternative to the previous example
```

EXAMPLE 2: Receiving from a sender, storing the message or the sender

```
      MyPort.receive(charstring:"Hello")from MyPeer; // Matches charstring "Hello" from MyPeer

      MyPort.receive(MyType:?) -> value MyVar; // The value of the received message is
                                                // assigned to MyVar.

      MyPort.receive(A<B) -> sender MyPeer;           // The address of the sender is assigned to
MyPeer

      MyPort.receive(MyTemplate:{5, MyVarOne}) -> value MyVarTwo sender MyPeer;
      // The received message value is stored in MyVarTwo and the sender address is stored in
MyPeer.
```

EXAMPLE 3: Receive any message

```
      MyPort.receive;                     // Removes the top value from MyPort.

      MyPort.receive from MyPeer;         // Removes the top message from MyPort if its sender is
                                                         MyPeer

      MyPort.receive -> sender MySenderVar;     // Removes the top message from MyPort and assigns
                                                          // the sender address to MySenderVar
```

EXAMPLE 4: Receive on any port

```
      any port.receive(MyMessage);
```

22.2.3 The Trigger operation

The **trigger** operation is used to await a specific message on an incoming port queue.

Syntactical Structure

```
     ( Port | any port ) "." trigger
     [ "(" TemplateInstance ")" ]
     [ from AddressRef ]
     [ "->" value VariableRef ]
     [ sender VariableRef ]
```

Semantic Description

The **trigger** operation removes the top message from the associated incoming port queue. If that top message meets the matching criteria, the **trigger** operation behaves in the same manner as a **receive** operation. If that top message does not fulfil the matching criteria, it shall be removed from the queue without any further action.

The **trigger** operation requires the port name, matching criteria for type and value, an optional **from** restriction (i.e., selection of communication partner) and an optional assignment of the matching message and sender component to variables.

Matching criteria

The matching criteria as defined in clause 22.2.2 apply also to the **`trigger`** operation.

Trigger on any message

A **`trigger`** operation with no argument list shall trigger on the receipt of any message. Thus, its meaning is identical to the meaning of receive any message.

Trigger on any port

To **`trigger`** on a message at any port, use the **`any port`** keywords.

Stand-alone trigger

The **`trigger`** operation can be used as a stand-alone statement in a behaviour description. In this latter case, the **`trigger`** operation is considered to be shorthand for an **`alt`** statement with two alternatives (one alternative expecting the message and another alternative consuming all other messages and repeating the alt statement, see [ITU-T Z.164]), i.e., it has blocking semantics, and therefore provides the ability of waiting for the next message matching the specified template or value on that queue.

Restrictions

a) The **`trigger`** operation shall only be used on message-based (or mixed) ports and the type of the value to be received shall be included in the list of incoming types of the port type definition.

b) A message received by *TriggerOnAnyMessage* shall not be assigned to a variable.

Examples

EXAMPLE 1: Basic trigger

```
MyPort.trigger(MyType:?);
// Specifies that the operation will trigger on the reception of the first message observed of
// the type MyType with an arbitrary value at port MyPort.
```

EXAMPLE 2: Trigger from a sender and with storing message or sender

```
MyPort.trigger(MyType:?) from MyPartner;
// Triggers on the reception of the first message of type MyType at port MyPort
// received from MyPartner.

MyPort.trigger(MyType:?) from MyPartner -> value MyRecMessage;
// This example is almost identical to the previous example. In addition, the message which
// triggers i.e., all matching criteria are met, is stored in the variable MyRecMessage.

MyPort.trigger(MyType:?) -> sender MyPartner;
// This example is almost identical to the first example. In addition, the reference of the
// sender component will be retrieved and stored in variable MyPartner.

MyPort.trigger(integer:?) -> value MyVar sender MyPartner;
// Trigger on the reception of an arbitrary integer value which afterwards is stored in
// variable MyVar. The reference of the sender component will be stored in variable MyPartner.
```

EXAMPLE 3: Trigger on any message

```
MyPort.trigger;

MyPort.trigger from MyPartner;

MyPort.trigger -> sender MySenderVar;
```

EXAMPLE 4: Trigger on any port

```
any port.trigger
```

22.3 Procedure-based communication

The operations for procedure-based communication via synchronous ports are summarized in Table 19.

Table 19 – Overview of procedure-based communication

Communication operation	Keyword
Invoke procedure call	`call`
Accept procedure call from remote entity	`getcall`
Reply to procedure call from remote entity	`reply`
Raise exception (to an accepted call)	`raise`
Handle response from a previous call	`getreply`
Catch exception (from called entity)	`catch`
Check call/exception/reply received	`check`

22.3.1 The Call operation

The **`call`** operation specifies the call of a remote operation on another test component or within the SUT.

Syntactical Structure

```
port "." call "(" TemplateInstance [ "," CallTimerValue ] ")"
 [ to ( AddressRef | AddressRefList | all component ) ]
```

Semantic Description

The **`call`** operation is used to specify that a test component calls a procedure in the SUT or in another test component.

The information to be transmitted in the send part of the **`call`** operation is a signature that may either be defined in the form of a signature template or be defined in-line.

Handling responses and exceptions to a call

In case of non-blocking procedure-based communication the handling of exceptions to **`call`** operations is done by using **`catch`** (see clause 22.3.6) operations as alternatives in **`alt`** statements.

If the **`nowait`** option is used, the handling of responses or exceptions to **`call`** operations is done by using **`getreply`** (see clause 22.3.4) and **`catch`** (see clause 22.3.6) operations as alternatives in **`alt`** statements.

In case of blocking procedure-based communication, the handling of responses or exceptions to a call is done in the response and exception handling part of the **`call`** operation by means of **`getreply`** (see clause 22.3.4) and **`catch`** (see clause 22.3.6) operations.

The response and exception handling part of a **`call`** operation looks similar to the body of an **`alt`** statement. It defines a set of alternatives, describing the possible responses and exceptions to the call.

If necessary, it is possible to enable/disable an alternative by means of a **`boolean`** expression placed between the '[ ]' brackets of the alternative.

The response and exception handling part of a call operation is executed like an **`alt`** statement without any active default. This means a corresponding snapshot includes all information necessary to evaluate the (optional) Boolean guards, may include the top element (if any) of the port over which the procedure has been called and may include a timeout exception generated by the (optional) timer that supervises the call.

Handling timeout exceptions to a call

The `call` operation may optionally include a timeout. This is defined as an explicit value or constant of `float` type and defines the length of time after the `call` operation has started that a `timeout` exception shall be generated by the test system. If no timeout value part is present in the `call` operation, no `timeout` exception shall be generated.

Nowait calls of blocking procedures

Using the keyword `nowait` instead of a timeout exception value in a `call` operation allows calling a procedure to continue without waiting either for a response or an exception raised by the called procedure or a timeout exception.

If the `nowait` keyword is used, a possible response or exception of the called procedure has to be removed from the port queue by using a `getreply` or a `catch` operation in a subsequent `alt` statement.

Calling blocking procedures without return value, out parameters, inout parameters and exceptions

A blocking procedure may have no return values, no `out` and `inout` parameters and may raise no exception. The `call` operation for such a procedure shall also have a response and exception handling part to handle the blocking in a uniform manner.

Calling non-blocking procedures

A non-blocking procedure has no `out` and `inout` parameters, no return value and the non-blocking property is indicated in the corresponding signature definition by means of a `noblock` keyword.

Possible exceptions raised by non-blocking procedures have to be removed from the port queue by using `catch` operations in subsequent `alt` or `interleave` statements.

Unicast, multicast and broadcast calls of procedures

Like for the `send` operation, TTCN-3 also supports unicast, multicast and broadcast calls of procedures. This can be done in the same manner as described in clause 22.2.1, i.e., the argument of the `to` clause of a `call` operation is for unicast calls the address of one receiving entity (or can be omitted in case of one-to-one connections), for multicast calls a list of addresses of a set of receivers and for broadcast calls the `all component` keyword. In case of one-to-one connections, the `to` clause may be omitted, because the receiving entity is uniquely identified by the system structure.

The handling of responses and exceptions for a blocking or non-blocking unicast `call` operation has been explained in this clause under "Handling timeout exceptions to a call". A multicast or broadcast `call` operation may cause several responses and exceptions from different communication partners.

In case of a multicast or broadcast `call` operation of a non-blocking procedure, all exceptions which may be raised from the different communication partners can be handled in subsequent `catch`, `alt` or `interleave` statements.

In case of a multicast or broadcast `call` operation of a blocking procedure, two options exist. Either, only one response or exception is handled in the response and exception handling part of the `call` operation. Then, further responses and exceptions can be handled in subsequent `alt` or `interleave` statements. Or, several responses or exceptions are handled by the use of repeat statements in one or more of the block of statements and declarations of the response and exception handling part of the call operation: the execution of a repeat statement causes the re-evaluation of the call body.

NOTE – In the second case, the user needs to handle the number of repetitions.

Restrictions

a) `call` operation shall only be used on procedure-based (or mixed) ports. The type definition of the port at which the call operation takes place shall include the procedure name in its `out` or `inout` list i.e., it must be allowed to call this procedure at this port.

b) All `in` and `inout` parameters of the signature shall have a specific value i.e., the use of matching mechanisms such as *AnyValue* is not allowed.

c) Only `out` parameters may be omitted or specified with a matching attribute.

d) The signature arguments of the `call` operation are not used to retrieve variable names for `out` and `inout` parameters. The actual assignment of the procedure return value and `out` and `inout` parameter values to variables shall explicitly be made in the response and exception handling part of the `call` operation by means of `getreply` and `catch` operations. This allows the use of signature templates in `call` operations in the same manner as templates can be used for types.

e) A `to` clause shall be present in case of one-to-many connections.

f) *AddressRef* should not contain matching mechanisms and must be of address or component type.

g) *CallTimerValue* must be of type float.

h) The selection of the alternatives to a call shall only be based on `getreply` and `catch` operations for the called procedure. Unqualified `getreply` and `catch` operations shall only treat replies from and exceptions raised by the called procedure. The use of `else` branches and the invocation of altsteps is not allowed.

i) The evaluation of the Boolean expressions guarding the alternatives in the response and exception handling part may have side effects. In order to avoid unexpected side effects, the same rules as for the Boolean guards in `alt` statements shall be applied (see clause 20.2).

j) The call operation for a blocking procedure without return value, out parameters, inout parameters and exceptions shall also have a response and exception handling part to handle the blocking in a uniform manner.

k) In case of a multicast or broadcast `call` operation of a blocking procedure, where the `nowait` keyword is used, all responses and exceptions have to be handled in subsequent `alt` or `interleave` statements.

l) The `call` operation for a non-blocking procedure shall have no response and exception handling part, shall raise no timeout exception and shall not use the `nowait` keyword.

Examples

EXAMPLE 1: Blocking call with getreply

```
// Given …
signature MyProc (out integer MyPar1, inout boolean MyPar2);
  :
// a call of MyProc
MyPort.call(MyProc:{ -, MyVar2}) {        // in-line signature template for the call of MyProc
      [] MyPort.getreply(MyProc:{?, ?}) { }
}

// … and another call of MyProc
MyPort.call(MyProcTemplate) {             // using signature template for the call of MyProc
      [] MyPort.getreply(MyProc:{?, ?}) { }
}

MyPort.call(MyProcTemplate) to MyPeer {               // calling MyProc at MyPeer
      [] MyPort.getreply(MyProc:{?, ?}) { }
}
```

EXAMPLE 2: Blocking call with getreply and catch

```
// Given
signature MyProc3 (out integer MyPar1, inout boolean MyPar2) return MyResultType
     exception (ExceptionTypeOne, ExceptionTypeTwo);
 :

// Call of MyProc3
MyPort.call(MyProc3:{ -, true }) to MyPartner {

  [] MyPort.getreply(MyProc3:{?, ?}) -> value MyResult param (MyPar1Var,MyPar2Var) { }

  [] MyPort.catch(MyProc3, MyExceptionOne) {
          setverdict(fail);
          stop;
     }
  [] MyPort.catch(MyProc3, ExceptionTypeTwo : ?) {
          setverdict(inconc);
     }
  [MyCondition] MyPort.catch(MyProc3, MyExceptionThree) { }
}
```

EXAMPLE 3: Blocking call with timeout exception

```
MyPort.call(MyProc:{5,MyVar}, 20E-3) {

  [] MyPort.getreply(MyProc:{?, ?}) { }

  [] MyPort.catch(timeout) {                    // timeout exception after 20 ms
          setverdict(fail);
          stop;
     }
}
```

EXAMPLE 4: Nowait call

```
MyPort.call(MyProc:{5, MyVar}, nowait);         // The calling test component will continue
                                                // its execution without waiting for the
                                                // termination of MyProc
```

EXAMPLE 5: Blocking call without return value, out parameters, inout parameters and exceptions

```
// Given …
signature MyBlockingProc (in integer MyPar1, in boolean MyPar2);
 :
// a call of MyBlockingProc
MyPort.call(MyBlockingProc:{ 7, false }) {
  [] MyPort.getreply( MyBlockingProc:{ -, - } ) { }
}
```

EXAMPLE 6: Broadcast call

```
var boolean first:= true;
MyPort.call(MyProc:{5,MyVar}, 20E-3) to all component {       // Broadcast call of MyProc
     // Handles the response from MyPeerOne
     [first] MyPort.getreply(MyProc:{?, ?}) from MyPeerOne {
          if (first) { first := false; repeat; }
          :
     }
     // Handles the response from MyPeerTwo
     [first] MyPort.getreply(MyProc:{?, ?}) from MyPeerTwo {
          if (first) { first := false; repeat; }
          :
     }
     [] MyPort.catch(timeout) {                      // timeout exception after 20 ms
          setverdict(fail);
          stop;
     }
}

alt {
  [] MyPort.getreply(MyProc:{?, ?}) {           // Handles all other responses to the broadcast
call
          repeat
  }
}
```

EXAMPLE 7: Multicast call

```
MyPort.call(MyProc:{5,MyVar}) to (MyPeer1, MyPeer2) nowait;  // Multicast call of MyProc

interleave {
  [] MyPort.getreply(MyProc:{?, ?}) from MyPeer1 { } // Handles the response of MyPeer1
  [] MyPort.getreply(MyProc:{?, ?}) from MyPeer2 { } // Handles the response of MyPeer2
}
```

22.3.2 The Getcall operation

The **getcall** operation is used to accept calls.

Syntactical Structure

```
( Port | any port ) "." getcall
[ "(" TemplateInstance ")" ]
[ from AddressRef ]
[ "->" [ param "(" { ( VariableRef ":=" ParameterIdentifier ) "," } |
                  { ( VariableRef | NotUsedSymbol ) "," }
               ")" ]
      [ sender VariableRef ] ]
```

Semantic Description

The **getcall** operation is used to specify that a test component accepts a call from the SUT, or another test component.

The **getcall** operation shall remove the top call from the incoming port queue, if and only if, the matching criteria associated to the **getcall** operation are fulfilled. These matching criteria are related to the signature of the call to be processed and the communication partner. The matching criteria for the signature may either be specified in-line or be derived from a signature template.

The assignment of **in** and **inout** parameter values to variables shall be made in the assignment part of the **getcall** operation. This allows the use of signature templates in **getcall** operations in the same manner as templates are used for types.

A **getcall** operation may be restricted to a certain communication partner in case of one-to-many connections. This restriction shall be denoted by using the **from** keyword.

The (optional) assignment part of the **getcall** operation comprises the assignment of **in** and **inout** parameter values to variables and the retrieval of the address of the calling component. The keyword **param** is used to retrieve the parameter values of a call.

The keyword **sender** is used when it is required to retrieve the address of the sender (e.g., for addressing a **reply** or exception to the calling party in a one-to-many configuration).

Accepting any call

A **getcall** operation with no argument list for the signature matching criteria will remove the call on the top of the incoming port queue (if any) if all other matching criteria are fulfilled.

Getcall on any port

getcall on any port is denoted by the **any** keyword.

Restrictions

a) The **getcall** operation shall only be used on procedure-based (or mixed) ports and the signature of the procedure call to be accepted shall be included in the list of allowed incoming procedures of the port type definition.

b) The signature argument of the **getcall** operation shall not be used to pass in variable names for **in** and **inout** parameters.

c) The *ParameterIdentifier*s must be from the corresponding signature definition.

d) The value assignment part shall not be used with the **getcall** operation.

e) Parameters of calls accepted by *accepting any call* shall not be assigned to a variable, i.e., the **param** clause shall not be present.

Examples

EXAMPLE 1: Basic getcall

```
      MyPort.getcall(MyProc: MyProcTemplate(5, MyVar));    // accepts a call of MyProc at MyPort

      MyPort.getcall(MyProc:{5, MyVar}) from MyPeer; // accepts a call of MyProc at MyPort from
MyPeer
```

EXAMPLE 2: Getcall with matching and assignments of parameter values to variables

```
      MyPort.getcall(MyProc:{?, ?}) from MyPartner -> param (MyPar1Var, MyPar2Var);
      // The in or inout parameter values of MyProc are assigned to MyPar1Var and MyPar2Var.

      MyPort.getcall(MyProc:{5, MyVar}) -> sender MySenderVar;
      // Accepts a call of MyProc at MyPort with the in or inout parameters 5 and MyVar.
      // The address of the calling party is retrieved and stored in MySenderVar.

      // The following getcall examples show the possibilities to use matching attributes
      // and omit optional parts, which may be of no importance for the test specification.

      MyPort.getcall(MyProc:{5, MyVar}) -> param(MyVar1, MyVar2) sender MySenderVar;

      MyPort.getcall(MyProc:{5, ?}) -> param(MyVar1, MyVar2);

      MyPort.getcall(MyProc:{?, MyVar}) -> param( - , MyVar2);
      // The value of the first inout parameter is not important or not used

      // The following examples shall explain the possibilities to assign in and inout parameter
      // values to variables. The following signature is assumed for the procedure to be called:

      signature MyProc2(in integer A, integer B, integer C, out integer D, inout integer E);

      MyPort.getcall(MyProc2:{?, ?, 3, - , ?}) -> param (MyVarA, MyVarB, - , -, MyVarE);
      // The parameters A, B, and E are assigned to the variables MyVarA, MyVarB, and
      // MyVarE. The out parameter D needs not to be considered.

      MyPort.getcall(MyProc2:{?, ?, 3, -, ?}) -> param (MyVarA:= A, MyVarB:= B, MyVarE:= E);
      // Alternative notation for the value assignment of in and inout parameter to variables. Note,
      // the names in the assignment list refer to the names used in the signature of MyProc2

      MyPort.getcall(MyProc2:{1, 2, 3, -, *}) -> param (MyVarE:= E);
      // Only the inout parameter value is needed for the further test case execution
```

EXAMPLE 3: Accepting any call

```
      MyPort.getcall;                    // Removes the top call from MyPort.

      MyPort.getcall from MyPartner;     // Removes a call from MyPartner from port MyPort

      MyPort.getcall -> sender MySenderVar;    // Removes a call from MyPort and retrieves
                                                    // the address of the calling entity
```

EXAMPLE 4: Getcall on any port

```
      any port.getcall(MyProc)
```

22.3.3 The Reply operation

The **reply** operation is used to reply to a call.

Syntactical Structure

```
      Port "." reply "(" TemplateInstance [ value Expression ] ")"
      [ to ( AddressRef | AddressRefList | all component ) ]
```

Semantic Description

The **`reply`** operation is used to reply to a previously accepted call according to the procedure signature.

NOTE – The relation between an accepted call and a **`reply`** operation cannot always be checked statically. For testing it is allowed to specify a **`reply`** operation without an associated **`getcall`** operation.

The value part of the **`reply`** operation consists of a signature reference with an associated actual parameter list and (optional) return value. The signature may either be defined in the form of a signature template or it may be defined in-line.

Responses to one or more **`call`** operations may be sent to one, several or all peer entities connected to the addressed port. This can be specified in the same manner as described in clause 22.2.1. This means, the argument of the **`to`** clause of a **`reply`** operation is for unicast responses the address of one receiving entity, for multicast responses a list of addresses of a set of receivers and for broadcast responses the **`all component`** keywords.

In case of one-to-one connections, the **`to`** clause may be omitted, because the receiving entity is uniquely identified by the system structure.

A return value shall be explicitly stated with the **`value`** keyword.

Restrictions

a) A **`reply`** operation shall only be used at a procedure-based (or mixed) port. The type definition of the port shall include the name of the procedure to which the **`reply`** operation belongs.

b) All **`out`** and **`inout`** parameters of the signature shall have a specific value i.e., the use of matching mechanisms such as *AnyValue* is not allowed.

c) A **`to`** clause shall be present in case of one-to-many connections.

d) *AddressRef* should not contain matching mechanisms and must be of address or component type.

e) If a value is to be returned to the calling party, this shall be explicitly stated using the **`value`** keyword.

Examples

```
MyPort.reply(MyProc2:{ - ,5});                // Replies to an accepted call of MyProc2.

MyPort.reply(MyProc2:{ - ,5}) to MyPeer; // Replies to an accepted call of MyProc2 from MyPeer

MyPort.reply(MyProc2:{ - ,5}) to (MyPeer1, MyPeer2); // Multicast reply to MyPeer1 and MyPeer2

MyPort.reply(MyProc2:{ - ,5}) to all component;// Broadcast reply to all entities connected
                                               // to MyPort

MyPort.reply(MyProc3:{5,MyVar} value 20);// Replies to an accepted call of MyProc3.
```

22.3.4 The Getreply operation

The **`getreply`** operation is used to handle replies from a previously called procedure.

Syntactical Structure

```
( Port | any port ) "." getreply
[ "(" TemplateInstance [ value TemplateInstance ]")" ]
[ from AddressRef ]
[ "->" [ value VariableRef ]
       [ param "(" { ( VariableRef ":=" ParameterIdentifier ) "," } |
                   { ( VariableRef | NotUsedSymbol ) "," }
               ")" ]
       [ sender VariableRef ] ]
```

Semantic Description

The **getreply** operation is used to handle replies from a previously called procedure.

The **getreply** operation shall remove the top reply from the incoming port queue, if and only if, the matching criteria associated to the **getreply** operation are fulfilled. These matching criteria are related to the signature of the procedure to be processed and the communication partner. The matching criteria for the signature may either be specified in-line or be derived from a signature template.

Matching against a received return value can be specified by using the **value** keyword.

A **getreply** operation may be restricted to a certain communication partner in case of one-to-many connections. This restriction shall be denoted by using the **from** keyword.

The assignment of **out** and **inout** parameter values to variables shall be made in the assignment part of the **getreply** operation. This allows the use of signature templates in **getreply** operations in the same manner as templates are used for types.

The (optional) assignment part of the **getreply** operation comprises the assignment of **out** and **inout** parameter values to variables and the retrieval of the address of the sender of the reply. The keyword **value** is used to retrieve return values and the keyword **param** is used to retrieve the parameter values of a reply. The keyword **sender** is used when it is required to retrieve the address of the sender.

Get any reply

A **getreply** operation with no argument list for the signature matching criteria shall remove the reply message on the top of the incoming port queue (if any) if all other matching criteria are fulfilled.

If *GetAnyReply* is used in the response and exception handling part of a **call** operation, it shall only treat replies from the procedure invoked by the **call** operation.

Get a reply on any port

To get a reply on any port, use the **any port** keywords.

Restrictions

a) A **getreply** operation shall only be used at a procedure-based (or mixed) port. The type definition of the port shall include the name of the procedure to which the **getreply** operation belongs.

b) The signature argument of the **getreply** operation shall not be used to pass in variable names for **out** and **inout** parameters.

c) Parameters or return values of responses accepted by *get any reply* shall not be assigned to a variable, i.e., the **param** and **value** clauses shall not be present.

Examples

EXAMPLE 1: Basic getreply

```
MyPort.getreply(MyProc:{5, ?} value 20); // Accepts a reply of MyProc with two out or
                                          // inout parameters and a return value of 20

MyPort.getreply(MyProc2:{ - , 5}) from MyPeer; // Accepts a reply of MyProc2 from MyPeer
```

EXAMPLE 2: Getreply with storing inout/out parameters and return values in variables

```
MyPort.getreply(MyProc1:{?, ?} value ?) -> value MyRetValue param(MyPar1,MyPar2);
// The returned value is assigned to variable MyRetValue and the value
// of the two out or inout parameters are assigned to the variables MyPar1 and MyPar2.
```

```
      MyPort.getreply(MyProc1:{?, ?} value ?) -> value MyRetValue param( - , MyPar2) sender
MySender;
      // The value of the first parameter is not considered for the further test execution and
      // the address of the sender component is retrieved and stored in the variable MySender.

      // The following examples describe some possibilities to assign out and inout parameter values
      // to variables. The following signature is assumed for the procedure which has been called

      signature MyProc2(in integer A, integer B, integer C, out integer D, inout integer E);

      MyPort.getreply(ATemplate) -> param( - , - , - , MyVarOut1, MyVarInout1);

      MyPort.getreply(ATemplate) -> param(MyVarOut1:=D, MyVarOut2:=E);

      MyPort.getreply(MyProc2:{ - , - , - , 3, ?}) -> param(MyVarInout1:=E);
```

EXAMPLE 3: Get any reply

```
      MyPort.getreply;                   // Removes the top reply from MyPort.

      MyPort.getreply from MyPeer;  // Removes the top reply received from MyPeer from MyPort.

      MyPort.getreply -> sender MySenderVar;    // Removes the top reply from MyPort and retrieves
                                                // the address of the sender entity
```

EXAMPLE 4: Get a reply on any port

```
      any port.getreply(Myproc)
```

22.3.5 The Raise operation

Exceptions are raised with the **raise** operation.

Syntactical Structure

```
      Port "." raise "(" Signature "," TemplateInstance ")"
      [ to ( AddressRef | AddressRefList | all component ) ]
```

Semantic Description

The **raise** operation is used to raise an exception.

NOTE – The relation between an accepted call and a **raise** operation cannot always be checked statically. For testing it is allowed to specify a **raise** operation without an associated **getcall** operation.

The value part of the **raise** operation consists of the signature reference followed by the exception value.

Exceptions are specified as types. Therefore, the exception value may either be derived from a template or be the value resulting from an expression (which of course can be an explicit value). The optional type field in the value specification to the **raise** operation shall be used in cases where it is necessary to avoid any ambiguity of the type of the value being sent.

Exceptions to one or more **call** operations may be sent to one, several or all peer entities connected to the addressed port. This can be specified in the same manner as described in clause 22.2.1. This means, the argument of the **to** clause of a **raise** operation is for unicast exceptions the address of one receiving entity, for multicast exceptions a list of addresses of a set of receivers and for broadcast exceptions the **all component** keywords.

In case of one-to-one connections, the **to** clause may be omitted, because the receiving entity is uniquely identified by the system structure.

Restrictions

a) An exception shall only be raised at a procedure-based (or mixed) port. An exception is a reaction to an accepted procedure call the result of which leads to an exceptional event.

b) The type of the exception shall be specified in the signature of the called procedure. The type definition of the port shall include in its list of accepted procedure calls the name of the procedure to which the exception belongs.

c) A **to** clause shall be present in case of one-to-many connections.

d) *AddressRef* should not contain matching mechanisms and must be of address or component type.

Examples

```
MyPort.raise(MySignature, MyVariable + YourVariable - 2);
// Raises an exception with a value which is the result of the arithmetic expression
// at MyPort

MyPort.raise(MyProc, integer:5}); // Raises an exception with the integer value 5 for MyProc

MyPort.raise(MySignature, "My string") to MyPartner;
// Raises an exception with the value "My string" at MyPort for MySignature and
// send it to MyPartner

MyPort.raise(MySignature, "My string") to (MyPartnerOne, MyPartnerTwo);
// Raises an exception with the value "My string" at MyPort and sends it to MyPartnerOne and
// MyPartnerTwo (i.e., multicast communication)

MyPort.raise(MySignature, "My string") to all component;
// Raises an exception with the value "My string" at MyPort for MySignature and sends it
// to all entities connected to MyPort (i.e., broadcast communication)
```

22.3.6 The Catch operation

The **catch** operation is used to catch exceptions.

Syntactical Structure

```
( Port | any port ) "." catch
[ "(" ( Signature "," TemplateInstance ) | TimeoutKeyword ")" ]
[ from AddressRef ]
[ "->" [ value VariableRef ]
       [ sender VariableRef ] ]
```

Semantic Description

The **catch** operation is used to catch exceptions raised by a test component or the SUT as a reaction to a procedure call. Exceptions are specified as types and thus, can be treated like messages, e.g., templates can be used to distinguish between different values of the same exception type.

The **catch** operation removes the top exception from the associated incoming port queue if, and only if, that top exception satisfies all the matching criteria associated with the **catch** operation.

A **catch** operation may be restricted to a certain communication partner in case of one-to-many connections. This restriction shall be denoted by using the **from** keyword.

The (optional) assignment part of the **catch** operation comprises the assignment of the exception value and the retrieval of the address of the calling component. The keyword **value** is used to retrieve the value of an exception and the keyword **sender** is used when it is required to retrieve the address of the sender.

The **catch** operation may be part of the response and exception handling part of a **call** operation or be used to determine an alternative in an **alt** statement. If the **catch** operation is used in the accepting part of a **call** operation, the information about port name and signature reference to indicate the procedure that raised the exception is redundant, because this information follows from the **call** operation. However, for readability reasons (e.g., in case of complex **call** statements) this information shall be repeated.

The Timeout exception

There is one special **timeout** exception that can be caught by the **catch** operation. The **timeout** exception is an emergency exit for cases where a called procedure neither replies nor raises an exception within a predetermined time (see clause 22.3.1).

Catch any exception

A **catch** operation with no argument list allows any valid exception to be caught. The most general case is without using the **from** keyword. *CatchAnyException* will also catch the **timeout** exception.

Catch on any port

To **catch** an exception on any port use the **any** keyword.

Restrictions

a) The **catch** operation shall only be used at procedure-based (or mixed) ports. The type of the caught exception shall be specified in the signature of the procedure that raised the exception.

b) No binding of the incoming values to the terms of the expression or to the template shall occur. The assignment of the exception values to variables shall be made in the assignment part of the **catch** operation.

c) Catching **timeout** exceptions shall be restricted to the exception handling part of a call. No further matching criteria (including a **from** part) and no assignment part is allowed for a **catch** operation that handles a **timeout** exception.

d) Exception values accepted by *catch any exception* shall not be assigned to a variable, i.e., the **value** clause shall not be present.

e) If *CatchAnyException* is used in the response and exception handling part of a **call** operation, it shall only treat exceptions raised by the procedure invoked by the **call** operation.

Examples

EXAMPLE 1: Basic catch

```
MyPort.catch(MyProc, integer: MyVar);     // Catches an integer exception of value
                                          // MyVar raised by MyProc at port MyPort.

MyPort.catch(MyProc, MyVar);              // Is an alternative to the previous example.

MyPort.catch(MyProc, A<B);                      // Catches a boolean exception

MyPort.catch(MyProc, MyType:{5, MyVar}); // In-line template definition of an exception value.

MyPort.catch(MyProc, charstring:"Hello")from MyPeer; // Catches "Hello" exception from MyPeer
```

EXAMPLE 2: Catch with storing value and/or sender in variables

```
MyPort.catch(MyProc, MyType:?) from MyPartner -> value MyVar;
// Catches an exception from MyPartner and assigns its value to MyVar.

MyPort.catch(MyProc, MyTemplate(5)) -> value MyVarTwo sender MyPeer;
// Catches an exception, assigns its value to MyVarTwo and retrieves the
// address of the sender.
```

EXAMPLE 3: The Timeout exception

```
MyPort.call(MyProc:{5,MyVar}, 20E-3) {
  [] MyPort.getreply(MyProc:{?, ?}) { }
  [] MyPort.catch(timeout) {                    // timeout exception after 20 ms
          setverdict(fail);
          stop;
```

```
        }
    }
```

EXAMPLE 4: Catch any exception

```
    MyPort.catch;

    MyPort.catch from MyPartner;

    MyPort.catch -> sender MySenderVar;
```

EXAMPLE 5: Catch on any port

```
    any port.catch;
```

22.4 The Check operation

The **check** operation allows to read the top element of a message-based or procedure-based *incoming* port queue.

Syntactical Structure

```
    ( Port | any port ) "." check
    [ "("
            ( PortReceiveOp | PortGetCallOp | PortGetReplyOp | PortCatchOp ) |
            ( [ from AddressRef ] [ "->" value VariableRef ][ sender VariableRef ] )
    ")" ]
```

Semantic Description

The **check** operation is a generic operation that allows read access to the top element of message-based and procedure-based *incoming* port queues without removing the top element from the queue. The **check** operation has to handle values of a certain type at message-based ports and to distinguish between calls to be accepted, exceptions to be caught and replies from previous calls at procedure-based ports.

The receiving operations **receive**, **getcall**, **getreply** and **catch** together with their matching and assignment parts, are used by the **check** operation to define the condition that has to be checked and to extract the value or values of its parameters, if required.

It is the *top* element of an incoming port queue that shall be checked (it is not possible to look *into* the queue). If the queue is empty the **check** operation fails. If the queue is not empty, a copy of the top element is taken and the receiving operation specified in the **check** operation is performed on the copy. The **check** operation fails if the receiving operation fails i.e., the matching criteria are not fulfilled. In this case the *copy* of the top element of the queue is discarded and test execution continues in the normal manner, i.e., the next statement or alternative to the check operation is evaluated. The **check** operation is successful if the receiving operation is successful.

Check any operation

A **check** operation with no argument list allows checking whether something waits for processing in an incoming port queue. The **check** any operation allows to distinguish between different senders (in case of one-to-many connections) by using a **from** clause and to retrieve the sender by using a shorthand assignment part with a **sender** clause. In case of mixed ports, the **check** any operation checks both the message-based and the procedure-based input queues of the mixed port. If the **check** any operation matches on both input queues of the mixed port, information related to the procedure-based queue shall be given priority, i.e., returned as result of the **check** any operation. For example, if the message-based and the procedure-based input queues of a mixed port are not empty and sender information should be retrieved by a **check** any operation, the sender of the call, reply or exception in the procedure-based input queue shall be returned.

NOTE 1 – Information related to the message-based input queue of a mixed port can be retrieved easily by using the **`check`** operation in combination with a **`receive`** any operation, e.g., `MyPort.`**`check`**`(`**`receive`**`) ->` **`sender`** `Mysender`.

Check on any port

To **`check`** on any port, use the **`any port`** keywords. In case of a **`check`** on any port operation without argument, input queues of mixed ports shall be checked as specified above for checking any operation.

Restrictions

Using the **`check`** operation in a wrong manner, e.g., check for an exception at a message-based port shall cause a test case error.

NOTE 2 – In most cases the correct usage of the check operation can be checked statically, i.e., before/during compilation.

Examples

EXAMPLE 1: Basic check

```
MyPort1.check(receive(5));    // Checks for an integer message of value 5.

MyPort2.check(getcall(MyProc:{5, MyVar}) from MyPartner);
// Checks for a call of MyProc at port MyPort2 from MyPartner

MyPort2.check(getreply(MyProc:{5, MyVar} value 20));
// Checks for a reply from procedure MyProc at MyPort2 where the returned value is 20 and
// the values of the two out or inout parameters are 5 and the value of MyVar.

MyPort2.check(catch(MyProc, MyTemplate(5, MyVar)));

MyPort2.check(getreply(MyProc1:{?, MyVar} value *) -> value MyReturnValue param(MyPar1,-));

MyPort.check(getcall(MyProc:{5, MyVar}) from MyPartner -> param (MyPar1Var, MyPar2Var));

MyPort.check(getcall(MyProc:{5, MyVar}) -> sender MySenderVar);
```

EXAMPLE 2: Check any operation

```
MyPort.check;

MyPort.check(from MyPartner);

MyPort.check(-> sender MySenderVar);
```

EXAMPLE 3: Check on any port

```
any port.check;
```

22.5 Controlling communication ports

TTCN-3 operations for controlling message-based, procedure-based and mixed ports are presented in Table 20.

Table 20 – Overview of TTCN-3 port operations

Port operations	
Statement	**Associated keyword or symbol**
Clear port	**clear**
Start port	**start**
Stop port	**stop**
Halt port	**halt**

22.5.1 The Clear port operation

The **clear** port operation empties incoming port queues.

Syntactical Structure

```
( Port | ( all port ) ) "." clear
```

Semantic Description

The **clear** operation removes the contents of the *incoming* queue of the specified port or of all ports of the test component performing the **clear** operation.

If a port queue is already empty then this operation shall have no action on that port.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
MyPort.clear;     // clears port MyPort
```

22.5.2 The Start port operation

The **start** operation enables sending and receiving operations on the port(s).

Syntactical Structure

```
( Port | ( all port ) ) "." start
```

Semantic Description

If a port is defined as allowing receiving operations such as **receive**, **getcall**, etc., the **start** operation clears the incoming queue of the named port and starts listening for traffic over the port. If the port is defined to allow sending operations then the operations such as **send**, **call**, **raise**, etc., are also allowed to be performed at that port.

By default, all ports of a component shall be started implicitly when a component is created. The start port operation will cause unstopped ports to be restarted by removing all messages waiting in the incoming queue.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
MyPort.start;     // starts MyPort
```

22.5.3 The Stop port operation

The **stop** operation disables sending and disallow receiving operations to match at the port(s).

Syntactical Structure

```
( Port | ( all port ) ) "." stop
```

Semantic Description

If a port is defined as allowing receiving operations such as **`receive`** and **`getcall`,** the **`stop`** operation causes listening at the named port to cease. If the port is defined to allow sending operations then **`stop`** port disallows the operations such as **`send`**, **`call`**, **`raise`**, etc., to be performed.

NOTE – To cease listening at the port means that all receiving operations defined before the stop operation shall be completely performed before the working of the port is suspended.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
MyPort.receive (MyTemplate1) -> value RecPDU;
                                    // the received value is decoded, matched against
                                  // MyTemplate1 and the matching value is stored
                             // in the variable RecPDU
MyPort.stop;                 // No receiving operation defined following the stop
                             // operation is executed (unless the port is restarted
                             // by a subsequent start operation)
MyPort.receive (MyTemplate2);       // This operation does not match and will block (assuming
                                                      // that no default is activated)
```

22.5.4 The Halt port operation

The **`halt`** operation is comparable to the **`stop`** operation, but allows entries being already in the queue to be processed with receiving operations.

Syntactical Structure

```
( Port | ( all port ) ) "." halt
```

Semantic Description

If a port allows receiving operations such as **`receive`**, **`trigger`** and **`getcall`,** the **`halt`** operation disallows receiving operations to succeed for messages and procedure call elements that enter the port queue after performing the **`halt`** operation at that port. Messages and procedure call elements that were already in the queue before the **`halt`** operation can still be processed with receiving operations. If the port allows sending operations then **`halt`** port immediately disallows sending operations such as **`send`**, **`call`**, **`raise`**, etc. to be performed. Subsequent halt operations have no effect on the state of the port or its queue.

NOTE 1 – The port **`halt`** operation virtually puts a marker after the last entry in the queue received when the operation is performed. Entries ahead of the marker can be processed normally. After all entries in the queue ahead of the marker have been processed, the state of the port is equivalent to the stopped state.

NOTE 2 – If a port **`stop`** operation is performed on a halted port before all entries in the queue ahead of the marker have been processed, further receive operations are disallowed immediately (i.e., the marker is virtually moved to the top of the queue).

NOTE 3 – A port **`start`** operation on a halted port clears all entries in the queue irrespectively if they arrived before or after performing the port **`halt`** operation. It also removes the marker.

NOTE 4 – A port **`clear`** operation on a halted port clears all entries in the queue irrespectively if they arrived before or after performing the port **`halt`** operation. It also virtually puts the marker at the top of the queue.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
MyPort.halt;                        // No sending allowed on MyPort from this moment on;
                                    // processing of messages in the queue still possible.
```

```
MyPort.receive (MyTemplate1);       // If a message was already in the queue before the halt
                                    // operation and it matches MyTemplate1, it is processed;
                                    // otherwise the receive operation blocks.
```

22.6 Use of any and all with ports

The keywords **`any`** and **`all`** may be used with configuration and communication operations as indicated in Table 21.

Table 21 – Any and All with ports

Operation	Allowed		Example
	any	all	
`receive, trigger, getcall, getreply, catch, check`	yes		**`any port.receive`**
`connect / map`			
`start, stop, clear, halt`		yes	**`all port.start`**

23 Timer operations

TTCN-3 supports a number of timer operations as given in Table 22. These operations may be used in test cases, functions, altsteps and module control.

Table 22 – Overview of TTCN-3 timer operations

Timer operations	
Statement	**Associated keyword or symbol**
Start timer	**`start`**
Stop timer	**`stop`**
Read elapsed time	**`read`**
Check if timer running	**`running`**
Timeout event	**`timeout`**

23.1 The timer mechanism

It is assumed that each TTCN-3 scope unit in which timers are declared, maintains its own *running-timers list* and *timeout-list*, i.e., a list of all timers that is actually running and a list of all timers that have timed out. The timeout-lists are part of the snapshots that are taken when a test case is executed. A timeout-list is updated if a timer in the scope unit is started, is stopped, times out or a **`timeout`** operation is executed.

NOTE 1 – The running-timers list and the timeout-list are only conceptual lists and do not restrict the implementation of timers. Other data structures like a set, where the access to timeout events is not restricted by, e.g., the order in which the timeout events have happened, may also be used.

NOTE 2 – It is assumed that for each test component a special running-timers list and timeout-list exist that handle timer start/stop and timeout events of timers declared in the corresponding component type definition.

When a timer expires (conceptually immediately before a snapshot processing of a set of alternative events), a timeout event is placed in the timeout list of the scope unit in which the timer has been declared. The timer becomes immediately inactive. Only one entry for any particular timer may appear in the timeout list of the scope unit in which the timer has been declared at any one time.

All running timers shall automatically be cancelled when the component is explicitly or implicitly stopped.

23.2 The Start timer operation

The **start** timer operation is used to indicate that a timer should start running.

Syntactical Structure

```
( ( TimerIdentifier | TimerParIdentifier ) { "[" SingleExpression "]" } )
"." start [ "(" TimerValue ")" ]
```

Semantic Description

When a timer is started, its name is added to the list of running timers (for the given scope unit).

The optional timer value parameter shall be used if no default duration is given, or if it is desired to override the default value specified in the timer declaration. When a timer duration is overridden, the new value applies only to the current instance of the timer, any later **start** operations for this timer, which do not specify a duration, shall use the default duration.

Starting a timer with the timer value 0.0 means that the timer times out immediately. Starting a timer with a negative timer value, e.g., the timer value is the result of an expression, or without a specified timer value shall cause a runtime error.

The timer clock runs from the float value zero (0.0) up to maximum stated by the duration parameter.

The **start** operation may be applied to a running timer, in which case the timer is stopped and re-started. Any entry in a timeout-list for this timer shall be removed from the timeout-list.

Restrictions

Timer value shall be a non-negative **float** number (i.e., greater or equal 0.0).

Examples

```
MyTimer1.start;              // MyTimer1 is started with the default duration
MyTimer2.start(20E-3);  // MyTimer2 is started with a duration of 20 ms

// Elements of timer arrays may also be started in a loop, for example
timer t_Mytimer [5];
var float v_timerValues [5];

for (var integer i := 0; i<=4; i:=i+1)
  { v_timerValues [i] := 1.0 }

for (var integer i := 0; i<=4; i:=i+1)
  {t_Mytimer [i].start ( v_timerValues [i])}
```

23.3 The Stop timer operation

The **stop** operation is used to stop a running timer.

Syntactical Structure

```
 ( ( ( TimerIdentifier | TimerParIdentifier ) { "[" SingleExpression "]" } ) |
      all timer )
"." stop
```

Semantic Description

A **stop** operation removes a running timer from the list of running timers. A stopped timer becomes inactive and its elapsed time is set to the float value zero (0.0).

Stopping an inactive timer is a valid operation, although it does not have any effect. Stopping an expired timer causes the entry for this timer in the timeout-list to be removed. The **all** keyword may be used to stop all timers that are visible in the scope unit in which the **stop** operation has been called.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
      MyTimer1.stop;          // stops MyTimer1
      all timer.stop;         // stops all running timers
```

23.4 The Read timer operation

The **read** operation is used to retrieve the time that has elapsed since the specified timer was started.

Syntactical Structure

```
      ( ( TimerIdentifier | TimerParIdentifier ) { "[" SingleExpression "]" } )
      "." read
```

Semantic Description

The **read** operation returns the time that has elapsed since the specified timer was started. The returned value shall be of type **float**.

Applying the **read** operation on an inactive timer, i.e., on a timer not listed on the running-timer list, will return the float value zero (0.0).

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
      var float Myvar;
      MyVar := MyTimer1.read; // assign to MyVar the time that has elapsed since MyTimer1 was
started
```

23.5 The Running timer operation

The **running** timer operation is used to check whether a timer is in the running-timer list.

Syntactical Structure

```
      ( ( ( TimerIdentifier | TimerParIdentifier ) { "[" SingleExpression "]" } ) |
      all timer )
      "." running
```

Semantic Description

The **running** timer operation is used to check whether a timer is listed on the running-timer list of the given scope unit or not (i.e., that it has been started and has neither timed out nor been stopped). The operation returns the value **true** if the timer is listed on the list, **false** otherwise.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
      if (MyTimer1.running) { … }
```

23.6 The Timeout operation

The **timeout** operation allows to check the expiration of timers.

Syntactical Structure

```
      ( ( ( TimerIdentifier | TimerParIdentifier ) { "[" SingleExpression "]" } ) |
      any timer )
      "." running
```

Semantic Description

The **`timeout`** operation allows to check the expiration of a specific timer, or of an arbitrary timer, in the scope unit of a test component or module control in which the **`timeout`** operation has been called.

When a **`timeout`** operation is processed, if a timer name is indicated, the timeout-list is searched according to the TTCN-3 scope rules. If there is a timeout event matching the timer name, that event is removed from the timeout-list, and the **`timeout`** operation succeeds.

The **`timeout`** can be used to determine an alternative in an **`alt`** statement or as stand-alone statement in a behaviour description. In the latter case, a **`timeout`** operation is considered to be shorthand for an **`alt`** statement with only one alternative, i.e., it has blocking semantics, and therefore provides the ability of passive waiting for the timeout of timer(s).

The **`any`** keyword used with the **`timeout`** operation (rather than an explicitly named timer) succeeds if the timeout-list is not empty.

Restrictions

The **`timeout`** shall not be used in a **`boolean`** expression.

Examples

EXAMPLE 1: Timeout of a specific timer

```
MyTimer1.timeout; // checks for the timeout of the previously started timer MyTimer1
```

EXAMPLE 2: Timeout of an arbitrary timer

```
any timer.timeout; // checks for the timeout of any previously started timer
```

23.7 Summary of use of any and all with timers

The keywords **`any`** and **`all`** may be used with timer operations as indicated in Table 23.

Table 23 – Any and All with Timers

Operation	Allowed		Example
	any	**all**	
`start`			
`stop`		yes	**`all timer.stop`**
`read`			
`running`	yes		**`if (any timer.running) {…}`**
`timeout`	yes		**`any timer.timeout`**

24 Test verdict operations

Verdict operations given in Table 24 allow to set and retrieve verdicts. These operations shall only be used in test cases, altsteps and functions.

Table 24 – Overview of TTCN-3 test verdict operations

Test verdict operations	
Statement	**Associated keyword or symbol**
Set local verdict	`setverdict`
Get local verdict	`getverdict`

24.1 The Verdict mechanism

Each test component of the active configuration shall maintain its own local verdict. The local verdict is an object which is created for each test component at the time of its creation. It is used to track the individual verdict in each test component (i.e., in the MTC and in each and every PTC).

Additionally, there is a global test case verdict instantiated and handled by the test system that is updated when each test component (i.e., the MTC and each and every PTC) terminates execution (see Figure 14). This verdict is not accessible to the **getverdict** and **setverdict** operations. The value of this verdict shall be returned by the test case when it terminates execution. If the returned verdict is not explicitly saved in the control part (e.g., assigned to a variable) then it is lost.

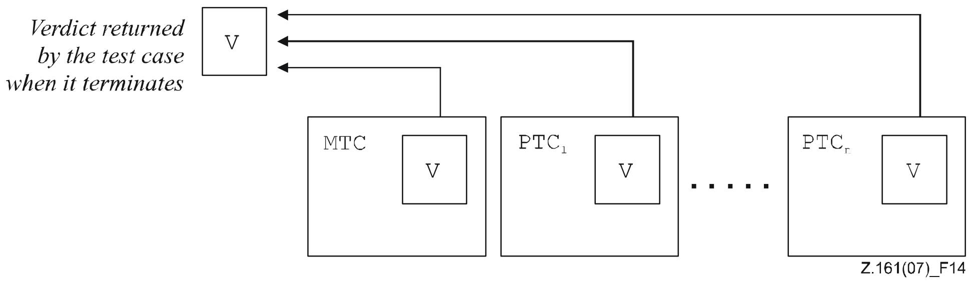


Figure 14 – Illustration of the relationship between verdicts

NOTE 1 – TTCN-3 does not specify the actual mechanisms that perform the updating of the local and test case verdicts. These mechanisms are implementation dependent.

The verdict can have five different values: **pass**, **fail**, **inconc**, **none** and **error**, i.e., the distinguished values of the **verdicttype** (see clause 6.1).

NOTE 2 – **inconc** means an inconclusive verdict.

When a test component is instantiated, its local verdict object is created and set to the value **none**.

When changing the value of the local verdict (i.e., using the **setverdict** operation) the effect of this change shall follow the overwriting rules listed in Table 25. The test case verdict is implicitly updated on the termination of a test component. The effect of this implicit operation shall also follow the overwriting rules listed in Table 25.

Table 25 – Overwriting rules for the verdict

Current value of verdict	New verdict assignment value			
	`pass`	`inconc`	`fail`	`none`
`none`	`pass`	`inconc`	`fail`	`none`
`pass`	`pass`	`inconc`	`fail`	`pass`
`inconc`	`inconc`	`inconc`	`fail`	`inconc`
`fail`	`fail`	`fail`	`fail`	`fail`

The **`error`** verdict is special in that it is set by the test system to indicate that a test case (i.e., run-time) error has occurred. It shall not be set by the **`setverdict`** operation and will not be returned by the **`getverdict`** operation. No other verdict value can override an **`error`** verdict. This means that an **`error`** verdict can only be a result of an **`execute`** test case operation.

24.2 The Setverdict operation

The local verdict is set with the **`setverdict`** operation.

Syntactical Structure

```
setverdict "(" SingleExpression ")"
```

Semantic Description

The value of the local verdict is changed with the **`setverdict`** operation. The effect of this change shall follow the overwriting rules listed in Table 25.

Restrictions

a) The **`setverdict`** operation shall only be used with the values **`pass`**, **`fail`**, **`inconc`** and **`none`**. It shall not be used to assign the value **error**, this is set by the test system only to indicate run-time errors.

b) *SingleExpression* shall resolve to a value of type **verdict**.

Examples

```
setverdict(pass); // the local verdict is set to pass
:
setverdict(fail); // until this line is executed, which will result in the value
                  // of the local verdict being overwritten to fail
                  // When the ptc terminates the test case verdict is set to fail
```

24.3 The Getverdict operation

The value of the local verdict may be retrieved using the **`getverdict`** operation.

Syntactical Structure

```
getverdict
```

Semantic Description

The **`getverdict`** operation returns the actual value of the local verdict.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
MyResult := getverdict; // Where MyResult is a variable of type verdicttype
```

25 External actions

In some testing situations, some interface(s) to the SUT may be missing or unknown *a priori* (e.g., management interface) but it may be necessary that the SUT is stimulated to carry out certain actions (e.g., send a message to the test system). Also certain actions may be required from the test executing personnel (e.g., to change the environmental conditions of testing like the temperature, voltage of the power feeding, etc.).

The required action may be described as a string expression, i.e., the use of literal strings, string typed variables and parameters, etc. and any concatenation thereof are allowed.

Syntactical Structure

```
action "(" { ( FreeText | Expression ) ["&"] } ")"
```

Semantic Description

External actions can be used in test cases, functions, altsteps and module control.

There is no specification of what is done to or by the SUT to trigger this action, only an informal description of the required action itself.

Restrictions

Expression shall have the base type charstring or universal charstring.

Examples

```
var charstring myString:= " now."
action("Send MyTemplate on lower PCO" & myString);   // Informal description of the
                                                      // external action
```

26 Module control

Test cases are defined in the module definitions part while the module control part manages their execution. The statements and operations that can be used in the module control are summarized in Table 26.

Table 26 – Overview of TTCN-3 statements and operations in module control

Statement	Associated keyword or symbol
Assignments	`:=`
If-else	`if (…) {…} else {…}`
Select case	`select case (…) { case (…) {…} case else {…}}`
For loop	`for (…) {…}`
While loop	`while (…) {…}`
Do while loop	`do {…} while (…)`
Label and Goto	`label / goto`
Stop execution	`stop`
Logging	`log`
Alternative behaviour (see Note)	`alt {…}`
Re-evaluation of alternative behaviour (see Note)	`repeat`
Interleaved behaviour (see Note)	`interleave {…}`
Activate a default (see Note)	`activate`
Deactivate a default (see Note)	`deactivate`
Start timer	`start`

Table 26 – Overview of TTCN-3 statements and operations in module control

Statement	Associated keyword or symbol
Stop timer	**stop**
Read elapsed time	**read**
Check if timer running	**running**
Timeout event	**timeout**
Stimulate an (SUT) action externally	**action**
Execute test case	**execute**
NOTE – Can be used to control timer operations only.	

26.1 The Execute statement

Test cases are executed with an **execute** statement in the module control.

Syntactical Structure

```
execute "(" TestcaseRef "(" [ { TemplateInstance [","] } ] ")"
          [ "," TimerValue ] ")"
```

Semantic Description

In the module control part the **execute** statement is used to start test cases (see clause 26.2). The result of an executed test case is always a value of type **verdicttype**. Every test case shall contain one and only one MTC the type of which is referenced in the header of the test case definition. The behaviour defined in the test case body is the behaviour of the MTC.

When a test case is invoked the MTC is created, the ports of the MTC and the test system interface are instantiated and the behaviour specified in the test case definition is started on the MTC. All these actions shall be performed implicitly i.e., without explicit **create** and **start** operations.

Test case start

A test case is called using an **execute** statement. As the result of the execution of a test case, a test case verdict of either **none**, **pass**, **inconc**, **fail** or **error** shall be returned and may be assigned to a variable for further processing.

Optionally, the **execute** statement allows supervision of a test case by means of a timer duration.

Test case parameterization and configuration

All variables (if any) defined in the control part of a module shall be passed into the test case by parameterization if they are to be used in the behaviour definition of that test case, i.e., TTCN-3 does not support global variables of any kind.

At the start of each test case, the test configuration shall be reset. This means that all components and ports conducted by **create**, **connect,** etc. operations in a previous test case were destroyed when that test case was stopped (hence are not "visible" to the new test case).

Test case termination

A test case terminates with the termination of the MTC. On termination of the MTC (explicitly or implicitly), all running parallel test components shall be removed by the test system.

NOTE 1 – The concrete mechanism for stopping all PTCs is tool specific and therefore outside the scope of this Recommendation.

The final verdict of a test case is calculated based on the final local verdicts of the different test components according to the rules defined in clause 24. The actual local verdict of a test component becomes its final local verdict when the test component terminates itself or is stopped by itself, another test component or by the test system.

NOTE 2 – To avoid race conditions for the calculation of test verdicts due to the delayed stopping of PTCs, the MTC should ensure that all PTCs have stopped (by means of the **done** or **killed** statement) before it stops itself.

Test case timer

Timer may be used to supervise the execution of a test case. This may be done using an explicit timeout in the **execute** statement. If the test case does not end within this duration, the result of the test case execution shall be an error verdict and the test system shall terminate the test case. The timer used for test case supervision is a system timer and need not be declared or started.

Restrictions

a) *TimerValue* shall be of base type **float**.

b) When the corresponding formal parameter is not of template type, *TemplateInstance* shall resolve to an *Expression*.

c) The execute statement shall not be called from within an existing executing testcase or function chain called from a test case, i.e., test cases can only be executed from the control part or from functions directly called from the control part.

Examples

EXAMPLE 1: Test case execution without keeping the test case verdict

```
execute(MyTestCase1());                        // executes MyTestCase1, without storing the
                                               // returned test verdict and without time
                                               // supervision
```

EXAMPLE 2: Test case execution with keeping the test case verdict

```
MyVerdict := execute(MyTestCase2());           // executes MyTestCase2 and stores the
                                               // resulting verdict in variable MyVerdict
```

EXAMPLE 3: Test case timer

```
  MyVerdict := execute(MyTestCase3(),5E-3);   // executes MyTestCase3 and stores the resulting
                                             // verdict in variable MyVerdict. If the test case
                                             // does not terminate within 5 ms, MyVerdict will
                                             // get the value 'error'
    MyReturnVal := execute (MyTestCase(), 7E-3);
    // Where the return verdict will be error if MyTestCase does not complete execution
    // within 7 ms
```

26.2 The Control part

The control part defines, in which order, sequence, loop, under which preconditions, and with which parameters test cases are to be executed.

Syntactical Structure

```
control "{"
      { ( ConstDef |
          TemplateDef |
          VarInstance |
          TimerInstance |
          TimerStatements |
          BasicStatements |
          BehaviourStatements |
          SUTStatements |
          stop ) [";"] }
"}"
[ WithStatement ] [";"]
```

Semantic Description

Sequence of test cases

Program statements specify such things like the order in which test cases are to be executed or the number of times a test case should run.

If no programming statements are used then, by default, the test cases are executed in the sequential order in which they appear in the module control.

NOTE – This does not preclude the possibility that certain tools may wish to override this default ordering to allow a user or tool to select a different execution order.

Timer operations may also be used explicitly to control test case execution.

Selection/deselection of test cases

The selection and deselection of test cases can also be used to control the execution of test cases.

There are different ways in TTCN-3 to select and deselect test cases. For example, boolean expressions may be used to select and deselect which test cases are to be executed. This includes, of course, the use of functions that return a `boolean` value.

Another way to execute test cases as a group is to collect them in a function and execute that function from the module control.

As a test case returns a single value of type `verdicttype`, it is also possible to control the order of test case execution depending on the outcome of a test case. The use of the TTCN-3 `verdicttype` is another way to select test cases.

Restrictions

a) Configuration statements such as connect and map (with the exception of stop execution, which is allowed), communication statements such as send and receive and verdict statements such as setverdict shall not be used in the control part.

b) Statements for alternative behaviours shall only be used to control timer behaviours.

c) The restrictions on the use of statements in the control part are given in Table 11.

Examples

EXAMPLE 1: Test case execution in a loop

```
module MyTestSuite () {
        :
      control {
              :
            // Do this test 10 times
            count:=0;
            while (count < 10)
            {     execute (MySimpleTestCase1());
                  count := count+1;
            }
      }
}
```

EXAMPLE 2: Test case execution controlled by a timer and a counter

```
// Example of the use of the running timer operation
while (T1.running or x<10)    // Where T1 is a previously started timer
{     execute(MyTestCase());
      x := x+1;
}

// Example of the use of the start and timeout operations

timer T1 := 1.0;
  :
execute(MyTestCase1());
T1.start;
```

```
T1.timeout; // Pause before executing the next test case
execute(MyTestCase2());
```

EXAMPLE 3: Selection/deselection of test cases with Boolean expressions

```
module MyTestSuite () {
      :
      control {
            :
            if (MySelectionExpression1()) {
                  execute(MySimpleTestCase1());
                  execute(MySimpleTestCase2());
                  execute(MySimpleTestCase3());
            }
            if (MySelectionExpression2()) {
                  execute(MySimpleTestCase4());
                  execute(MySimpleTestCase5());
                  execute(MySimpleTestCase6());
            }
             :
      }
}
```

EXAMPLE 4: Selection/deselection of test cases with functions

```
function MyTestCaseGroup1()
{     execute(MySimpleTestCase1());
      execute(MySimpleTestCase2());
      execute(MySimpleTestCase3());
}
function MyTestCaseGroup2()
{     execute(MySimpleTestCase4());
      execute(MySimpleTestCase5());
      execute(MySimpleTestCase6());
}
 :
control
{     if (MySelectionExpression1()) { MyTestCaseGroup1(); }
      if (MySelectionExpression2()) { MyTestCaseGroup2(); }
       :
}
```

EXAMPLE 5: Selection/deselection of test cases based on test case verdicts

```
if ( execute (MySimpleTestCase()) == pass )
  { execute (MyGoOnTestCase()) }
else
  { execute (MyErrorRecoveryTestCase()) };
```

27 Specifying attributes

TTCN-3 uses attributes to give special characterization/meaning to language elements such as specific presentation format, specific encoding and encoding variants, and user-defined properties.

27.1 The Attribute mechanism

Attributes can be associated with TTCN-3 language elements by means of the `with` statement.

27.1.1 Scope of attributes

A `with` statement may associate attributes to a single language element. It is also possible to associate attributes to a number of language elements by, e.g., listing fields of a structured type in an attribute statement associated with a single type definition or associating a `with` statement to the surrounding scope unit or `group` of language elements.

EXAMPLE:

```
// MyPDU1 will be displayed as PDU
type record MyPDU1 { … } with { display "PDU"}
```

```
// MyPDU2 will be displayed as PDU with the application specific extension attribute MyRule
type record MyPDU2 { … }
with
{
      display "PDU";
      extension "MyRule"
}

// The following group definition …
group MyPDUs {
      type record MyPDU3 { … }
      type record MyPDU4 { … }
}
with {display "PDU"}    // All types of group MyPDUs will be displayed as PDU

// is identical to
group MyPDUs {
      type record MyPDU3 { … } with { display "PDU"}
      type record MyPDU4 { … } with { display "PDU"}
}
```

27.1.2 Overwriting rules for attributes

An attribute definition in a lower scope unit will override a general attribute definition in a higher scope. Additional overwriting rules for variant attributes are defined in clause 27.1.2.1.

EXAMPLE 1:

```
type record MyRecordA
{
      :
} with { encode "RuleA" }

// In the following, MyRecordA is encoded according to RuleA and not according to RuleB
type record MyRecordB
{
       :
      field MyRecordA
} with { encode "RuleB" }
```

A **with** statement that is placed inside the scope of another **with** statement shall override the outermost **with**. This shall also apply to the use of the **with** statement with groups. Care should be taken when the overwriting scheme is used in combination with references to single definitions. The general rule is that attributes shall be assigned and overwritten according to the order of their occurrence.

```
// Example of the use of the overwriting scheme of the with statement
group MyPDUs
{
      type record MyPDU1 { … }
      type record MyPDU2 { … }
      group MySpecialPDUs
      {
            type record MyPDU3 { … }
            type record MyPDU4 { … }
      }
      with {extension "MySpecialRule"}    // MyPDU3 and MyPDU4 will have the application
                                          // specific extension attribute MySpecialRule
}
with
{
      display "PDU";          // All types of group MyPDUs will be displayed as PDU and
      extension "MyRule";     // (if not overwritten) have the extension attribute MyRule
}

// is identical to …
group MyPDUs
{
      type record MyPDU1 { … } with {display "PDU"; extension "MyRule" }
      type record MyPDU2 { … } with {display "PDU"; extension "MyRule" }
      group MySpecialPDUs {
            type record MyPDU3 { … } with {display "PDU"; extension "MySpecialRule" }
```

```
                type record MyPDU4 { … } with {display "PDU"; extension "MySpecialRule" }
          }
    }
```

An attribute definition in a lower scope can be overwritten in a higher scope by using the **override** directive.

EXAMPLE 2:

```
    type record MyRecordA
    {
           :
    } with { encode "RuleA" }

    // In the following, MyRecordA is encoded according to RuleB
    type record MyRecordB
    {
           :
          fieldA      MyRecordA
    } with { encode override "RuleB" }
```

The **override** directive forces all contained types at all lower scopes to be forced to the specified attribute.

27.1.2.1 Additional overwriting rules for variant attributes

A **variant** attribute is always related to an **encode** attribute. Whereas a variant of an encoding may change, an encoding shall not change without overwriting all current variant attributes. Therefore, for variant attributes the following overwriting rules apply:

- a **variant** attribute overwrites a current **variant** attribute according to the rules defined in clause 27.1.2;
- an **encoding** attribute, which overwrites a current **encoding** attribute according to the rules defined in clause 27.1.2, also overwrites a corresponding current **variant** attribute, i.e., no new **variant** attribute is provided, but the current **variant** attribute becomes inactive;
- an **encoding** attribute, which changes a current **encoding** attribute of an imported language element according to the rules defined in clause 27.1.3, also changes a corresponding current **variant** attribute, i.e., no new **variant** attribute is provided, but the current **variant** attribute becomes inactive.

EXAMPLE:

```
    module MyVariantEncodingModule {
          :
          type charstring MyCharString; // Normally encoded according to "Encoding 1"
          :
          group MyVariantsOne {
                :
                type record MyPDUone
                {
                      Integer field1,   // field1 will be encoded according to "Encoding 2" only.
                                        // "Encoding 2" overwrites "Encoding 1" and variant
                                        // "Variant 1"
                      Mytype field3     // field3 will be encoded according to "Encoding 1" with
                                        // variant "Variant 1".
                }
                with { encoding (field1) "Encoding 2" }
                :
          }
          with { variant "Variant 1" }

          group MyVariantsTwo
          {     :
                type record MyPDUtwo
                {
                      Integer field1,   // field1 will be encoded according to "Encoding 3"
                                        // using encoding variant "Variant 3"
                      Mytype field3     // field3 will be encoded according to "Encoding 3"
```

```
                                  // using encoding variant "Variant 2"
              }
              with { variant (field1) "Variant 3" }
              :
          }
          with { encode "Encoding 3"; variant "Variant 2"}

      }
      with { encode "Encoding 1" }
```

27.1.3 Changing attributes of imported language elements

In general, a language element is imported together with its attributes. In some cases these attributes may have to be changed when importing the language element, e.g., a type may be displayed in one module as ASP, then it is imported by another module where it should be displayed as PDU. For such cases it is allowed to change attributes on the **import** statement.

EXAMPLE:

```
      import from MyModule {
          type MyType
      }
      with { display "ASP" }        // MyType will be displayed as ASP

      import from MyModule {
          group MyGroup
      }
      with {
          display "PDU";          // By default all types will be displayed as PDU
          extension "MyRule"
      }
```

27.2 The With statement

The **with** statement is used to associate attributes to TTCN-3 language elements (and sets thereof).

Syntactical Structure

```
      with  "{"
        { ( encode | variant | display | extension )
          [ override ]
          ["(" DefinitionRef | FieldReference | AllRef ")"]
          FreeText [";"] }
      "}"
```

Semantic Description

There are four kinds of attributes that can be associated to language elements:

a) **display**: allows the specification of display attributes related to specific presentation formats;

b) **encode**: allows references to specific encoding rules;

c) **variant**: allows references to specific encoding variants;

d) **extension**: allows the specification of user-defined attributes.

The syntax for the argument of the **with** statement (i.e., the actual attributes) is defined as a free text string.

Restrictions

DefinitionRef and *FieldReference* must refer to a definition or field respectively which is within the module, group or definition to which the **with** statement is associated.

Examples

```
      type record MyService {
          integer i,
          float f
      }
```

```
with { display "ServiceCall" }          // MyRecord will be displayed as a ServiceCall
```

27.3 Display attributes

Display attributes allow the specification of display attributes related to specific presentation formats.

Syntactical Structure

```
display
```

Semantic Description

All TTCN-3 language elements can have **`display`** attributes to specify how particular language elements should be displayed in, for example, a tabular format.

Special attribute strings related to the display attributes for the tabular (conformance) presentation format can be found in [ITU-T Z.162].

Special attribute strings related to the display attributes for the graphical presentation format can be found in [ITU-T Z.163].

Other **`display`** attributes may be defined by the user.

NOTE – Because user-defined attributes are not standardized, the interpretation of these attributes may differ between tools or even may not be supported.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
type record MyService {
      integer i,
      float f
}
with { display "ServiceCall" }          // MyRecord will be displayed as a ServiceCall
```

27.4 Encoding attributes

In TTCN-3, general or particular encoding rules can be specified by using **`encode`** and **`variant`** attributes. Encoding attributes allow references to specific encoding rules.

Syntactical Structure

```
encode
```

Semantic Description

Encoding rules define how a particular value, template, etc. shall be encoded and transmitted over a communication **`port`** and how received signals shall be decoded. TTCN-3 does not have a default encoding mechanism. This means that encoding rules or encoding directives are defined in some external manner to TTCN-3.

The **`encode`** attribute allows the association of some referenced encoding rule or encoding directive to be made to a TTCN-3 definition.

The manner in which the actual encoding rules are defined (e.g., prose, functions, etc.) is outside the scope of this Recommendation. If no specific rules are referenced, then encoding shall be a matter for individual implementation.

In most cases, encoding attributes will be used in a hierarchical manner. The top-level is the entire module, the next level is a group and the lowest is an individual type or definition:

a) **`module`**: encoding applies to all types defined in the module, including TTCN-3 types (built-in types);

b) `group`: encoding applies to a group of user-defined type definitions;

c) `type or definition`: encoding applies to a single user-defined type or definition;

d) `field`: encoding applies to a field in a `record` or `set` type or `template`.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
module MyFirstmodule
{     :
      import from MySecondModule {
            type MyRecord
      }
      with { encode "MyRule 1" } // Instances of MyRecord will be encoded according to
                                 // MyRule 1

      :
      type charstring MyType; // Normally encoded according to the 'Global encoding rule'
      :
      group MyRecords
      {     :
            type record MyPDU1
            {
                  integer     field1,           // field1 will be encoded according to "Rule 3"
                  boolean     field2,           // field2 will be encoded according to "Rule 3"
                  Mytype      field3            // field3 will be encoded according to "Rule 2"
            }
            with { encode (field1, field2) "Rule 3" }
            :
      }
      with { encode "Rule 2" }

}
with { encode "Global encoding rule" }
```

27.5 Variant attributes

In TTCN-3, general or particular encoding rules can be specified by using `encode` and `variant` attributes. Variant attributes allow references to specific encoding variants.

Syntactical Structure

`variant`

Semantic Description

To specify a refinement of the currently specified encoding scheme instead of its replacement, the `variant` attribute shall be used. The variant attributes are different from other attributes, because they are closely related to encode attributes. Therefore, for variant attributes, additional overwriting rules apply (see clause 27.1.2.1).

Special variant strings

The following strings are the predefined (standardized) `variant` attributes for simple basic types (see clause D.2.1):

a) "`8 bit`" and "`unsigned 8 bit`" mean, when applied to integer and enumerated types, that the integer value or the integer numbers associated with enumerations shall be handled as it was represented on 8 bits (single byte) within the system.

b) "`16 bit`" and "`unsigned 16 bit`" mean, when applied to integer and enumerated types, that the integer value or the integer numbers associated with enumerations shall be handled as it was represented on 16 bits (two bytes) within the system.

c) "`32 bit`" and "`unsigned 32 bit`" mean, when applied to integer and enumerated types, that the integer value or the integer numbers associated with enumerations shall be handled as it was represented on 32 bits (four bytes) within the system.

d) "`64 bit`" and "`unsigned 64 bit`" mean, when applied to integer and enumerated types, that the integer value or the integer numbers associated with enumerations shall be handled as it was represented on 64 bits (eight bytes) within the system.

e) `IEEE754 float","IEEE754 double", "IEEE754 extended float"` and `"IEEE754 extended double"` mean, when applied to a float type, that the value shall be encoded and decoded according to [IEEE 754] (see Annex D).

The following strings are the predefined (standardized) **`variant`** attributes for **`charstring`** and **`universal charstring`** (see clause D.2.2):

a) "`UTF-8`" means, when applied to the universal charstring type, that each character of the value shall be individually encoded and decoded according to the UCS Transformation Format 8 (UTF-8) as defined in Annex R of [ISO/IEC 10646].

b) "`UCS-2`" means, when applied to the universal charstring type, that each character of the value shall be individually encoded and decoded according to the UCS-2 coded representation form (see clause 14.1 of [ISO/IEC 10646]).

c) "`UTF-16`" means, when applied to the universal charstring type, that each character of the value shall be individually encoded and decoded according to the UCS Transformation Format 16 (UTF-16) as defined in Annex Q of [ISO/IEC 10646].

d) "`8 bit`" means, when applied to charstring and universal charstring types, that each character of the value shall be individually encoded and decoded according to the coded representation as specified in [b-ISO/IEC 8859-1] (an 8-bit coding).

The following string is the predefined (standardized) **`variant`** attribute for structured types (see clause D.2.3):

a) "`IDL:fixed FORMAL/01-12-01 v.2.6`" means, when applied to a record type, that the value shall be handled as an IDL fixed point decimal value (see Annex D).

These variant attributes can be used in combination with the more general encode attributes specified at a higher level. For example a **`universal charstring`** specified with the **`variant`** attribute "UTF-8" within a module which itself has a global encoding attribute "BER:1997" (see clause 12.2 of [ITU-T Z.167]) will cause each character of the values within the string to first be encoded following the UTF-8 rules and then this UTF-8 value will be encoded following the more global BER rules.

Invalid encodings

If it is desired to specify invalid encoding rules then these shall be specified in a referenceable source external to the module in the same way that valid encoding rules are referenced.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

EXAMPLE:

```
module MyTTCNmodule1
{      :
       type charstring MyType; // Normally encoded according to the "Global encoding rule"
       :
       group MyRecords
       {      :
              type record MyPDU1
              {
                  integer     field1,           // field1 will be encoded according to "Rule 2"
                                                // using encoding variant "length form 3"
                  Mytype      field3            // field3 will be encoded according to "Rule 2"
                                                // using any possible length encoding format
            }
            with { variant (field1) "length form 3" }
            :
      }
      with { encode "Rule 2" }

}
with { encode "Global encoding rule" }
```

27.6 Extension attributes

Extension attributes can be used for proprietary extensions to TTCN-3.

Syntactical Structure

```
extension
```

Semantic Description

All TTCN-3 language elements can have **`extension`** attributes specified by the user.

NOTE – Because user-defined attributes are not standardized the interpretation of these attributes between tools supplied by different vendors may differ or even not be supported.

Restrictions

No specific restrictions in addition to the general static rules of TTCN-3 given in clause 5.

Examples

```
testcase MyTestcase() runs on MTCType {
:
}
with { extension "Test Purpose: This test case is used to check …" }
```

Annex A

BNF and static semantics

(This annex forms an integral part of this Recommendation)

A.1 TTCN-3 BNF

This annex defines the syntax of TTCN-3 using extended BNF (henceforth just called BNF).

A.1.1 Conventions for the syntax description

Table A.1 defines the metanotation used to specify the extended BNF grammar for TTCN-3.

Table A.1 – The syntactic metanotation

::=	is defined to be
abc xyz	abc followed by xyz
|	alternative
[abc]	0 or 1 instances of abc
{abc}	0 or more instances of abc
{abc}+	1 or more instances of abc
(...)	textual grouping
Abc	the non-terminal symbol abc
"abc"	a terminal symbol abc

A.1.2 Statement terminator symbols

In general, all TTCN-3 language constructs (i.e., definitions, declarations, statements and operations) are terminated with a semi-colon (;). The semi-colon is optional if the language construct ends with a right-hand curly brace (}) or the following symbol is a right-hand curly brace (}), i.e., the language construct is the last statement in a block of statements, operations and declarations.

A.1.3 Identifiers

TTCN-3 identifiers are case sensitive and may only contain lowercase letters (a-z), uppercase letters (A-Z) and numeric digits (0-9). Use of the underscore (_) symbol is also allowed. An identifier shall begin with a letter (i.e., not a number and not an underscore).

A.1.4 Comments

Comments written in free text may appear anywhere in a TTCN-3 specification.

Block comments shall be opened by the symbol pair /* and closed by the symbol pair */.

EXAMPLE 1:
```
    /* This is a block comment
    spread over two lines */
```

Block comments shall not be nested.
```
    /* This is not /* a legal */ comment */
```

Line comments shall be opened by the symbol pair // and closed by a <*newline*>.

EXAMPLE 2:
```
      // This is a line comment
      // spread over two lines
```

Line comments may follow TTCN-3 program statements but they shall not be embedded in a statement.

EXAMPLE 3:
```
    // The following is not legal
    const // This is MyConst integer MyConst := 1;

    // The following is legal
    const integer MyConst := 1; // This is MyConst
```

A.1.5 TTCN-3 terminals

TTCN-3 terminal symbols and reserved words are listed in Tables A.2 and A.3.

Table A.2 – List of TTCN-3 special terminal symbols

Begin/end block symbols	`{` `}`
Begin/end list symbols	`(` `)`
Alternative symbols	`[` `]`
To symbol (in a range)	`..`

Line comments and Block comments	`/*` `*/`
	`//`

Line/statement terminator symbol	`;`
Arithmetic operator symbols	`+` `/` `-`
String concatenation operator symbol	`&`

Equivalence operator symbols	`!=` `==` `>=`
	`<=`

String enclosure symbols	`"` `'`
Wildcard/matching symbols	`?` `*`
Assignment symbol	`:=`
Communication operation assignment	`->`
Bitstring, hexstring and octetstring values	`B` `H` `O`
Float exponent	`E`

The predefined function identifiers defined in Table 10 and described in Annex C shall also be treated as reserved words.

Table A.3 – List of TTCN-3 terminals which are reserved words

action	fail	noblock	select
activate	false	none	self
address	float	not	send
alive	for	not4b	sender
all	from	nowait	set
alt	function	null	setverdict
altstep			signature
and	getverdict	octetstring	start
and4b	getcall	of	stop
any	getreply	omit	subset
anytype	goto	on	superset
	group	optional	system
bitstring		or	
boolean	hexstring	or4b	template
		out	testcase
case	if	override	timeout
call	ifpresent		timer
catch	import	param	to
char	in	pass	trigger
charstring	inconc	pattern	true
check	infinity	port	type
clear	inout	procedure	
complement	integer		union
component	interleave	raise	universal
connect		read	unmap
const	kill	receive	
control	killed	record	value
create			valueof
	label	rem	var
deactivate	language	repeat	variant
default	length	reply	verdicttype
disconnect	log	return	
display		running	while
do	map	runs	with
done	match		
	message		xor
else	mixed		xor4b
encode	mod		
enumerated	modifies		
error	module		
except	modulepar		
exception	mtc		
execute			
extends			
extension			
external			

The TTCN-3 terminals listed in Table A.3 shall not be used as identifiers in a TTCN-3 module. These terminals shall be written in all lowercase letters.

A.1.6 TTCN-3 syntax BNF productions

A.1.6.0 TTCN-3 module

```
1. TTCN3Module ::= TTCN3ModuleKeyword TTCN3ModuleId
                   "{"
                   [ModuleDefinitionsPart]
                   [ModuleControlPart]
                   "}"
                   [WithStatement] [SemiColon]
```

A.1.6 TTCN-3 syntax BNF productions

A.1.6.0 TTCN-3 module

```
1. TTCN3Module ::= TTCN3ModuleKeyword TTCN3ModuleId
                   "{"
                   [ModuleDefinitionsPart]
                   [ModuleControlPart]
                   "}"
                   [WithStatement] [SemiColon]
2. TTCN3ModuleKeyword ::= "module"
3. TTCN3ModuleId ::= ModuleId
4. ModuleId ::= GlobalModuleId [LanguageSpec]
5. GlobalModuleId ::= ModuleIdentifier
6. ModuleIdentifier ::= Identifier
7. LanguageSpec ::= LanguageKeyword FreeText
8. LanguageKeyword ::= "language"
```

A.1.6.1 Module definitions part

A.1.6.1.0 General

```
9. ModuleDefinitionsPart ::= ModuleDefinitionsList
10. ModuleDefinitionsList ::= {ModuleDefinition [SemiColon]}+
11. ModuleDefinition ::= (TypeDef |
                          ConstDef |
                          TemplateDef |
                          ModuleParDef |
                          FunctionDef |
                          SignatureDef |
                          TestcaseDef |
                          AltstepDef |
                          ImportDef |
                          GroupDef |
                          ExtFunctionDef |
                          ExtConstDef) [WithStatement]
```

A.1.6.1.1 Typedef definitions

```
12. TypeDef ::= TypeDefKeyword TypeDefBody
13. TypeDefBody ::= StructuredTypeDef | SubTypeDef
14. TypeDefKeyword ::= "type"
15. StructuredTypeDef ::= RecordDef |
                          UnionDef |
                          SetDef |
                          RecordOfDef |
                          SetOfDef |
                          EnumDef |
                          PortDef |
                          ComponentDef
16. RecordDef ::= RecordKeyword StructDefBody
17. RecordKeyword ::= "record"
18. StructDefBody ::= (StructTypeIdentifier [StructDefFormalParList] | AddressKeyword)
                      "{" [StructFieldDef {"," StructFieldDef}] "}"
19. StructTypeIdentifier ::= Identifier
20. StructDefFormalParList ::= "(" StructDefFormalPar {"," StructDefFormalPar} ")"
21. StructDefFormalPar ::=  FormalValuePar
22. StructFieldDef ::= (Type | NestedTypeDef) StructFieldIdentifier [ArrayDef] [SubTypeSpec]
                       [OptionalKeyword]
23. NestedTypeDef ::= NestedRecordDef |
                      NestedUnionDef |
                      NestedSetDef |
                      NestedRecordOfDef |
                      NestedSetOfDef |
                      NestedEnumDef
24. NestedRecordDef ::= RecordKeyword "{" [StructFieldDef {"," StructFieldDef}] "}"
25. NestedUnionDef ::= UnionKeyword "{" UnionFieldDef {"," UnionFieldDef} "}"
26. NestedSetDef ::= SetKeyword "{" [StructFieldDef {"," StructFieldDef}] "}"
27. NestedRecordOfDef ::= RecordKeyword [StringLength] OfKeyword (Type | NestedTypeDef)
28. NestedSetOfDef ::= SetKeyword [StringLength] OfKeyword (Type | NestedTypeDef)
29. NestedEnumDef ::= EnumKeyword "{" EnumerationList "}"
30. StructFieldIdentifier ::= Identifier
31. OptionalKeyword ::= "optional"
32. UnionDef ::= UnionKeyword UnionDefBody
33. UnionKeyword ::= "union"
34. UnionDefBody ::= (StructTypeIdentifier [StructDefFormalParList] | AddressKeyword)
                     "{" UnionFieldDef {"," UnionFieldDef} "}"
35. UnionFieldDef ::= (Type | NestedTypeDef) StructFieldIdentifier [ArrayDef] [SubTypeSpec]
36. SetDef ::= SetKeyword StructDefBody
```

```
37. SetKeyword ::= "set"
38. RecordOfDef ::= RecordKeyword [StringLength] OfKeyword StructOfDefBody
39. OfKeyword ::= "of"
40. StructOfDefBody ::= (Type | NestedTypeDef) (StructTypeIdentifier | AddressKeyword) [SubTypeSpec]
41. SetOfDef ::= SetKeyword [StringLength] OfKeyword StructOfDefBody
42. EnumDef ::= EnumKeyword (EnumTypeIdentifier | AddressKeyword)
            "{" EnumerationList "}"
43. EnumKeyword ::= "enumerated"
44. EnumTypeIdentifier ::= Identifier
45. EnumerationList ::= Enumeration {"," Enumeration}
46. Enumeration ::= EnumerationIdentifier ["("[Minus] Number ")"]
47. EnumerationIdentifier ::= Identifier
48. SubTypeDef ::= Type (SubTypeIdentifier | AddressKeyword)  [ArrayDef] [SubTypeSpec]
49. SubTypeIdentifier ::= Identifier
50. SubTypeSpec ::= AllowedValues [StringLength] | StringLength
/* STATIC SEMANTICS - AllowedValues shall be of the same type as the field being subtyped */
51. AllowedValues ::= "(" (ValueOrRange {"," ValueOrRange}) | CharStringMatch ")"
52. ValueOrRange ::= RangeDef | ConstantExpression
/* STATIC SEMANTICS - RangeDef production shall only be used with integer, charstring, universal
charstring or float based types */
/* STATIC SEMANTICS - When subtyping charstring or universal charstring range and values shall not
be mixed in the same SubTypeSpec */
53. RangeDef ::= LowerBound ".." UpperBound
54. StringLength ::= LengthKeyword "(" SingleConstExpression [".." UpperBound] ")"
/* STATIC SEMANTICS - StringLength shall only be used with String types or to limit set of and
record of. SingleConstExpression and UpperBound shall evaluate to non-negative integer values (in
case of UpperBound including infinity) */
55. LengthKeyword ::= "length"
56. PortType ::= [GlobalModuleId Dot] PortTypeIdentifier
57. PortDef ::= PortKeyword PortDefBody
58. PortDefBody ::= PortTypeIdentifier PortDefAttribs
59. PortKeyword ::= "port"
60. PortTypeIdentifier ::= Identifier
61. PortDefAttribs ::= MessageAttribs | ProcedureAttribs | MixedAttribs
62. MessageAttribs ::= MessageKeyword
                   "{" {MessageList [SemiColon]}+ "}"
63. MessageList ::= Direction AllOrTypeList
64. Direction ::= InParKeyword | OutParKeyword | InOutParKeyword
65. MessageKeyword ::= "message"
66. AllOrTypeList ::= AllKeyword | TypeList
/* NOTE: The use of AllKeyword in port definitions is deprecated */
67. AllKeyword ::= "all"
68. TypeList ::= Type {"," Type}
69. ProcedureAttribs ::= ProcedureKeyword
                     "{" {ProcedureList  [SemiColon]}+ "}"
70. ProcedureKeyword ::= "procedure"
71. ProcedureList ::= Direction AllOrSignatureList
72. AllOrSignatureList ::= AllKeyword | SignatureList
73. SignatureList ::= Signature {"," Signature}
74. MixedAttribs ::= MixedKeyword
                 "{" {MixedList [SemiColon]}+ "}"
75. MixedKeyword ::= "mixed"
76. MixedList ::= Direction ProcOrTypeList
77. ProcOrTypeList ::= AllKeyword | (ProcOrType {"," ProcOrType})
78. ProcOrType ::= Signature | Type
79. ComponentDef ::= ComponentKeyword ComponentTypeIdentifier
                 [ExtendsKeyword ComponentType {"," ComponentType}]
                 "{" [ComponentDefList] "}"
80. ComponentKeyword ::= "component"
81. ExtendsKeyword ::= "extends"
82. ComponentType ::= [GlobalModuleId Dot] ComponentTypeIdentifier
83. ComponentTypeIdentifier ::= Identifier
84. ComponentDefList ::= {ComponentElementDef [SemiColon]}
85. ComponentElementDef ::= PortInstance | VarInstance | TimerInstance | ConstDef
86. PortInstance ::= PortKeyword PortType PortElement {"," PortElement}
87. PortElement ::= PortIdentifier [ArrayDef]
88. PortIdentifier ::= Identifier
```

A.1.6.1.2 Constant definitions

```
89. ConstDef ::= ConstKeyword Type ConstList
90. ConstList ::= SingleConstDef  {"," SingleConstDef}
91. SingleConstDef ::= ConstIdentifier [ArrayDef] AssignmentChar ConstantExpression
92. ConstKeyword ::= "const"
93. ConstIdentifier ::= Identifier
```

A.1.6.1.3 Template definitions

```
94. TemplateDef ::= TemplateKeyword BaseTemplate  [DerivedDef] AssignmentChar TemplateBody
95. BaseTemplate ::= (Type | Signature) TemplateIdentifier  ["(" TemplateFormalParList ")"]
96. TemplateKeyword ::= "template"
97. TemplateIdentifier ::= Identifier
98. DerivedDef ::= ModifiesKeyword TemplateRef
99. ModifiesKeyword ::= "modifies"
100. TemplateFormalParList ::= TemplateFormalPar {"," TemplateFormalPar}
101. TemplateFormalPar ::= FormalValuePar | FormalTemplatePar
/* STATIC SEMANTICS - FormalValuePar shall resolve to an in parameter */
102. TemplateBody ::= (SimpleSpec | FieldSpecList | ArrayValueOrAttrib) | [ExtraMatchingAttributes]
/* STATIC SEMANTICS - Within TeplateBody the ArrayValueOrAttrib can be used for array, record,
record of and set of types. */
103. SimpleSpec ::= SingleValueOrAttrib
104. FieldSpecList ::= "{"[FieldSpec {"," FieldSpec}] "}"
105. FieldSpec ::= FieldReference AssignmentChar TemplateBody
106. FieldReference ::= StructFieldRef | ArrayOrBitRef | ParRef
/* STATIC SEMANTICS - Within FieldReference ArrayOrBitRef can be used for record of and set of
templates/template fields in modified templates only*/
107. StructFieldRef ::= StructFieldIdentifier| PredefinedType | TypeReference
/* STATIC SEMANTICS - PredefinedType and TypeReference shall be used for anytype value notation
only. PredefinedType shall not be AnyTypeKeyword.*/
108. ParRef ::= SignatureParIdentifier
/* STATIC SEMANTICS - SignatureParIdentifier shall be a formal parameter identifier from the
associated signature definition */
109. SignatureParIdentifier ::= ValueParIdentifier
110. ArrayOrBitRef ::= "[" FieldOrBitNumber "]"
/* STATIC SEMANTICS - ArrayRef shall be optionally used for array types and TTCN-3 record of and set
of. The same notation can be used for a Bit reference inside a TTCN-3 charstring, universal
charstring, bitstring, octetstring and hexstring type */
111. FieldOrBitNumber ::= SingleExpression
/* STATIC SEMANTICS - SingleExpression will resolve to a value of integer type */
112. SingleValueOrAttrib ::= MatchingSymbol |
                            SingleExpression |
                            TemplateRefWithParList
/* STATIC SEMANTIC - VariableIdentifier (accessed via singleExpression) may only be used in in-line
template definitions to reference variables in the current scope */
113. ArrayValueOrAttrib ::= "{" ArrayElementSpecList "}"
114. ArrayElementSpecList ::= ArrayElementSpec {"," ArrayElementSpec}
115. ArrayElementSpec ::= NotUsedSymbol | PermutationMatch | TemplateBody
116. NotUsedSymbol ::= Dash
117. MatchingSymbol ::= Complement |
                       AnyValue |
                       AnyOrOmit |
                       ValueOrAttribList |
                       Range |
                       BitStringMatch |
                       HexStringMatch |
                       OctetStringMatch |
                       CharStringMatch |
                       SubsetMatch |
                       SupersetMatch
118. ExtraMatchingAttributes ::= LengthMatch | IfPresentMatch | LengthMatch  IfPresentMatch
119. BitStringMatch ::= "'" {BinOrMatch} "'" "B"
120. BinOrMatch ::= Bin | AnyValue | AnyOrOmit
121. HexStringMatch ::= "'" {HexOrMatch} "'" "H"
122. HexOrMatch ::= Hex | AnyValue | AnyOrOmit
123. OctetStringMatch ::= "'" {OctOrMatch} "'" "O"
124. OctOrMatch ::= Oct | AnyValue | AnyOrOmit
125. CharStringMatch ::= PatternKeyword Cstring
126. PatternKeyword ::= "pattern"
127. Complement ::= ComplementKeyword ValueList
128. ComplementKeyword ::= "complement"
129. ValueList ::= "(" ConstantExpression {"," ConstantExpression} ")"
130. SubsetMatch ::= SubsetKeyword ValueList
131. SubsetKeyword ::= "subset"
132. SupersetMatch ::= SupersetKeyword ValueList
133. SupersetKeyword ::= "superset"
134. PermutationMatch ::= PermutationKeyword PermutationList
135. PermutationKeyword ::= "permutation"
136. PermutationList ::= "(" TemplateBody { "," TemplateBody } ")"
/* STATIC SEMANTICS: Restrictions on the content of TemplateBody are given in clause B.1.3.3 */
137. AnyValue ::= "?"
138. AnyOrOmit ::= "*"
139. ValueOrAttribList ::= "(" TemplateBody {"," TemplateBody}+ ")"
140. LengthMatch ::= StringLength
141. IfPresentMatch ::= IfPresentKeyword
142. IfPresentKeyword ::= "ifpresent"
143. Range ::= "(" LowerBound ".." UpperBound ")"
```

```
144. LowerBound ::= SingleConstExpression | Minus InfinityKeyword
145. UpperBound ::= SingleConstExpression | InfinityKeyword
/* STATIC SEMANTICS - LowerBound and UpperBound shall evaluate to types integer, charstring,
universal charstring or float. In case LowerBound or UpperBound evaluates to types charstring or
universal charstring, only SingleConstExpression may be present and the string length shall be 1*/
146. InfinityKeyword ::= "infinity"
147. TemplateInstance ::= InLineTemplate
148. TemplateRefWithParList ::= [GlobalModuleId Dot] TemplateIdentifier [TemplateActualParList] |
                                  TemplateParIdentifier
149. TemplateRef ::= [GlobalModuleId Dot] TemplateIdentifier | TemplateParIdentifier
150. InLineTemplate ::= [(Type | Signature) Colon] [DerivedRefWithParList AssignmentChar]
                          TemplateBody
151. DerivedRefWithParList ::= ModifiesKeyword TemplateRefWithParList
152. TemplateActualParList ::= "(" TemplateActualPar {"," TemplateActualPar} ")"
153. TemplateActualPar ::= TemplateInstance
/* STATIC SEMANTICS - When the corresponding formal parameter is not of template type the
TemplateInstance production shall resolve to one or more SingleExpressions */
154. TemplateOps ::= MatchOp | ValueofOp
155. MatchOp ::= MatchKeyword "(" Expression "," TemplateInstance")"
156. MatchKeyword ::= "match"
157. ValueofOp ::= ValueofKeyword "(" TemplateInstance")"
158. ValueofKeyword ::= "valueof"
```

A.1.6.1.4 Function definitions

```
159. FunctionDef ::= FunctionKeyword FunctionIdentifier
                     "("[FunctionFormalParList] ")" [RunsOnSpec] [ReturnType]
                     StatementBlock
160. FunctionKeyword ::= "function"
161. FunctionIdentifier ::= Identifier
162. FunctionFormalParList ::= FunctionFormalPar {"," FunctionFormalPar}
163. FunctionFormalPar ::= FormalValuePar |
                           FormalTimerPar |
                           FormalTemplatePar |
                           FormalPortPar
164. ReturnType ::= ReturnKeyword [TemplateKeyword] Type
165. ReturnKeyword ::= "return"
166. RunsOnSpec ::= RunsKeyword OnKeyword ComponentType
167. RunsKeyword ::= "runs"
168. OnKeyword ::= "on"
169. MTCKeyword ::= "mtc"
170. StatementBlock ::= "{" [FunctionStatementOrDefList] "}"
171. FunctionStatementOrDefList ::= {FunctionStatementOrDef [SemiColon]}+
172. FunctionStatementOrDef ::= FunctionLocalDef |
                                FunctionLocalInst |
                                FunctionStatement
173. FunctionLocalInst ::= VarInstance | TimerInstance
174. FunctionLocalDef ::= ConstDef | TemplateDef
175. FunctionStatement ::= ConfigurationStatements |
                           TimerStatements |
                           CommunicationStatements |
                           BasicStatements |
                           BehaviourStatements |
                           VerdictStatements |
                           SUTStatements
176. FunctionInstance ::= FunctionRef "(" [FunctionActualParList] ")"
177. FunctionRef ::= [GlobalModuleId Dot] (FunctionIdentifier | ExtFunctionIdentifier ) |
                     PreDefFunctionIdentifier
178. PreDefFunctionIdentifier ::= Identifier
/* STATIC SEMANTICS - The Identifier shall be one of the pre-defined TTCN-3 Function Identifiers
from Annex C of [b-ES 201 873-1] */
179. FunctionActualParList ::= FunctionActualPar {"," FunctionActualPar}
180. FunctionActualPar ::= TimerRef |
                           TemplateInstance |
                           Port |
                           ComponentRef
/* STATIC SEMANTICS - When the corresponding formal parameter is not of template type the
TemplateInstance production shall resolve to one or more SingleExpressions i.e. equivalent to the
Expression production */
```

A.1.6.1.5 Signature definitions

```
181. SignatureDef ::= SignatureKeyword SignatureIdentifier
                      "("[SignatureFormalParList] ")" [ReturnType | NoBlockKeyword]
                      [ExceptionSpec]
182. SignatureKeyword ::= "signature"
183. SignatureIdentifier ::= Identifier
184. SignatureFormalParList ::= SignatureFormalPar {"," SignatureFormalPar}
185. SignatureFormalPar ::=     FormalValuePar
```

```
186. ExceptionSpec ::= ExceptionKeyword "(" ExceptionTypeList ")"
187. ExceptionKeyword ::= "exception"
188. ExceptionTypeList ::= Type {"," Type}
189. NoBlockKeyword ::= "noblock"
190. Signature ::= [GlobalModuleId Dot] SignatureIdentifier
```

A.1.6.1.6 Testcase definitions

```
191. TestcaseDef ::= TestcaseKeyword TestcaseIdentifier
                     "("[TestcaseFormalParList] ")" ConfigSpec
                     StatementBlock
192. TestcaseKeyword ::= "testcase"
193. TestcaseIdentifier ::= Identifier
194. TestcaseFormalParList ::= TestcaseFormalPar {"," TestcaseFormalPar}
195. TestcaseFormalPar ::= FormalValuePar |
                           FormalTemplatePar
196. ConfigSpec ::= RunsOnSpec [SystemSpec]
197. SystemSpec ::= SystemKeyword ComponentType
198. SystemKeyword ::= "system"
199. TestcaseInstance ::= ExecuteKeyword "(" TestcaseRef "(" [TestcaseActualParList] ")"
                          ["," TimerValue] ")"
200. ExecuteKeyword ::= "execute"
201. TestcaseRef ::= [GlobalModuleId Dot] TestcaseIdentifier
202. TestcaseActualParList ::= TestcaseActualPar {"," TestcaseActualPar}
203. TestcaseActualPar ::= TemplateInstance
/* STATIC SEMANTICS - When the corresponding formal parameter is not of template type the
TemplateInstance production shall resolve to one or more SingleExpressions i.e. equivalent to the
Expression production */
```

A.1.6.1.7 Altstep definitions

```
204. AltstepDef ::= AltstepKeyword AltstepIdentifier
                    "("[AltstepFormalParList] ")" [RunsOnSpec]
                    "{" AltstepLocalDefList AltGuardList "}"
205. AltstepKeyword ::= "altstep"
206. AltstepIdentifier ::= Identifier
207. AltstepFormalParList ::= FunctionFormalParList
208. AltstepLocalDefList ::= {AltstepLocalDef [SemiColon]}
209. AltstepLocalDef ::= VarInstance | TimerInstance | ConstDef | TemplateDef
210. AltstepInstance ::= AltstepRef "(" [FunctionActualParList] ")"
211. AltstepRef ::= [GlobalModuleId Dot] AltstepIdentifier
```

A.1.6.1.8 Import definitions

```
212. ImportDef ::= ImportKeyword ImportFromSpec (AllWithExcepts | ("{" ImportSpec "}"))
213. ImportKeyword ::= "import"
214. AllWithExcepts ::= AllKeyword [ExceptsDef]
215. ExceptsDef ::= ExceptKeyword "{" ExceptSpec "}"
216. ExceptKeyword ::= "except"
217. ExceptSpec ::= {ExceptElement [SemiColon]}
218. ExceptElement ::= ExceptGroupSpec |
                       ExceptTypeDefSpec |
                       ExceptTemplateSpec |
                       ExceptConstSpec |
                       ExceptTestcaseSpec |
                       ExceptAltstepSpec |
                       ExceptFunctionSpec |
                       ExceptSignatureSpec |
                       ExceptModuleParSpec
219. ExceptGroupSpec ::= GroupKeyword (ExceptGroupRefList | AllKeyword)
220. ExceptTypeDefSpec ::= TypeDefKeyword (TypeRefList | AllKeyword)
221. ExceptTemplateSpec ::= TemplateKeyword (TemplateRefList | AllKeyword)
222. ExceptConstSpec ::= ConstKeyword (ConstRefList | AllKeyword)
223. ExceptTestcaseSpec ::= TestcaseKeyword (TestcaseRefList | AllKeyword)
224. ExceptAltstepSpec ::= AltstepKeyword (AltstepRefList | AllKeyword)
225. ExceptFunctionSpec ::= FunctionKeyword (FunctionRefList | AllKeyword)
226. ExceptSignatureSpec ::= SignatureKeyword  (SignatureRefList | AllKeyword)
227. ExceptModuleParSpec ::= ModuleParKeyword  (ModuleParRefList | AllKeyword)
228. ImportSpec ::= {ImportElement [SemiColon]}
229. ImportElement ::= ImportGroupSpec |
                       ImportTypeDefSpec |
                       ImportTemplateSpec |
                       ImportConstSpec |
                       ImportTestcaseSpec |
                       ImportAltstepSpec |
                       ImportFunctionSpec |
                       ImportSignatureSpec |
                       ImportModuleParSpec
230. ImportFromSpec ::= FromKeyword ModuleId [RecursiveKeyword]
```

```
231. RecursiveKeyword ::= "recursive"
232. ImportGroupSpec ::= GroupKeyword (GroupRefListWithExcept | AllGroupsWithExcept)
233. GroupRefList ::= FullGroupIdentifier {"," FullGroupIdentifier}
234. GroupRefListWithExcept ::= FullGroupIdentifierWithExcept {"," FullGroupIdentifierWithExcept}
235. AllGroupsWithExcept ::= AllKeyword [ExceptKeyword GroupRefList]
236. FullGroupIdentifier ::= GroupIdentifier {Dot GroupIdentifier}
237. FullGroupIdentifierWithExcept ::= FullGroupIdentifier [ExceptsDef]
238. ExceptGroupRefList ::= ExceptFullGroupIdentifier {"," ExceptFullGroupIdentifier}
239. ExceptFullGroupIdentifier ::= FullGroupIdentifier
240. ImportTypeDefSpec ::= TypeDefKeyword (TypeRefList | AllTypesWithExcept)
241. TypeRefList ::= TypeDefIdentifier {"," TypeDefIdentifier}
242. AllTypesWithExcept ::= AllKeyword [ExceptKeyword TypeRefList]
243. TypeDefIdentifier ::= StructTypeIdentifier |
                           EnumTypeIdentifier |
                           PortTypeIdentifier |
                           ComponentTypeIdentifier |
                           SubTypeIdentifier
244. ImportTemplateSpec ::= TemplateKeyword (TemplateRefList | AllTemplsWithExcept)
245. TemplateRefList ::= TemplateIdentifier {"," TemplateIdentifier}
246. AllTemplsWithExcept ::= AllKeyword [ExceptKeyword TemplateRefList]
247. ImportConstSpec ::= ConstKeyword (ConstRefList | AllConstsWithExcept)
248. ConstRefList ::= ConstIdentifier {"," ConstIdentifier}
249. AllConstsWithExcept ::= AllKeyword [ExceptKeyword ConstRefList]
250. ImportAltstepSpec ::= AltstepKeyword (AltstepRefList | AllAltstepsWithExcept)
251. AltstepRefList ::= AltstepIdentifier {"," AltstepIdentifier}
252. AllAltstepsWithExcept ::= AllKeyword [ExceptKeyword AltstepRefList]
253. ImportTestcaseSpec ::= TestcaseKeyword (TestcaseRefList | AllTestcasesWithExcept)
254. TestcaseRefList ::= TestcaseIdentifier {"," TestcaseIdentifier}
255. AllTestcasesWithExcept ::= AllKeyword [ExceptKeyword TestcaseRefList]
256. ImportFunctionSpec ::= FunctionKeyword (FunctionRefList | AllFunctionsWithExcept)
257. FunctionRefList ::= FunctionIdentifier {"," FunctionIdentifier}
258. AllFunctionsWithExcept ::= AllKeyword [ExceptKeyword FunctionRefList]
259. ImportSignatureSpec ::= SignatureKeyword  (SignatureRefList | AllSignaturesWithExcept)
260. SignatureRefList ::= SignatureIdentifier {"," SignatureIdentifier}
261. AllSignaturesWithExcept ::= AllKeyword [ExceptKeyword SignatureRefList]
262. ImportModuleParSpec ::= ModuleParKeyword  (ModuleParRefList | AllModuleParWithExcept)
263. ModuleParRefList ::= ModuleParIdentifier {"," ModuleParIdentifier}
264. AllModuleParWithExcept ::= AllKeyword [ExceptKeyword ModuleParRefList]
```

A.1.6.1.9 Group definitions

```
265. GroupDef ::= GroupKeyword GroupIdentifier
                  "{" [ModuleDefinitionsPart] "}"
266. GroupKeyword ::= "group"
267. GroupIdentifier ::= Identifier
```

A.1.6.1.10 External function definitions

```
268. ExtFunctionDef ::= ExtKeyword FunctionKeyword ExtFunctionIdentifier
                        "("[FunctionFormalParList] ")" [ReturnType]
269. ExtKeyword ::= "external"
270. ExtFunctionIdentifier ::= Identifier
```

A.1.6.1.11 External constant definitions

```
271. ExtConstDef ::= ExtKeyword ConstKeyword Type ExtConstIdentifierList
272. ExtConstIdentifierList ::= ExtConstIdentifier { "," ExtConstIdentifier }
273. ExtConstIdentifier ::= Identifier
```

A.1.6.1.12 Module parameter definitions

```
274. ModuleParDef ::= ModuleParKeyword ( ModulePar | ("{" MultitypedModuleParList "}"))
275. ModuleParKeyword ::= "modulepar"
276. MultitypedModuleParList ::= { ModulePar [SemiColon] }
277. ModulePar ::= ModuleParType ModuleParList
278. ModuleParType ::= Type
279. ModuleParList ::= ModuleParIdentifier [AssignmentChar ConstantExpression]
                     {","ModuleParIdentifier [AssignmentChar ConstantExpression]}
280. ModuleParIdentifier ::= Identifier
```

A.1.6.2 Control part

A.1.6.2.0 General

```
281. ModuleControlPart ::= ControlKeyword
                           "{" ModuleControlBody "}"
                           [WithStatement] [SemiColon]
```

```
282. ControlKeyword ::= "control"
283. ModuleControlBody ::= [ControlStatementOrDefList]
284. ControlStatementOrDefList ::= {ControlStatementOrDef [SemiColon]}+
285. ControlStatementOrDef ::= FunctionLocalDef |
                               FunctionLocalInst |
                               ControlStatement
286. ControlStatement ::= TimerStatements |
                          BasicStatements |
                          BehaviourStatements |
                          SUTStatements |
                          StopKeyword
```

A.1.6.2.1 Variable instantiation

```
287. VarInstance ::= VarKeyword ((Type VarList) | (TemplateKeyword Type TempVarList))
288. VarList ::= SingleVarInstance {"," SingleVarInstance}
289. SingleVarInstance ::= VarIdentifier [ArrayDef] [AssignmentChar VarInitialValue]
290. VarInitialValue ::= Expression
291. VarKeyword ::= "var"
292. VarIdentifier ::= Identifier
293. TempVarList ::= SingleTempVarInstance {"," SingleTempVarInstance}
294. SingleTempVarInstance ::= VarIdentifier [ArrayDef] [AssignmentChar TempVarInitialValue]
295. TempVarInitialValue ::= TemplateBody
296. VariableRef ::= (VarIdentifier | ValueParIdentifier) [ExtendedFieldReference]
```

A.1.6.2.2 Timer instantiation

```
297. TimerInstance ::= TimerKeyword TimerList
298. TimerList ::= SingleTimerInstance{"," SingleTimerInstance}
299. SingleTimerInstance ::= TimerIdentifier [ArrayDef] [AssignmentChar TimerValue]
300. TimerKeyword ::= "timer"
301. TimerIdentifier ::= Identifier
302. TimerValue ::= Expression
303. TimerRef ::= (TimerIdentifier | TimerParIdentifier) {ArrayOrBitRef}
```

A.1.6.2.3 Component operations

```
304. ConfigurationStatements ::= ConnectStatement |
                                 MapStatement |
                                 DisconnectStatement |
                                 UnmapStatement |
                                 DoneStatement |
                                 KilledStatement |
                                 StartTCStatement |
                                 StopTCStatement |
                                 KillTCStatement
305. ConfigurationOps ::= CreateOp | SelfOp | SystemOp | MTCOp | RunningOp | AliveOp
306. CreateOp ::= ComponentType Dot CreateKeyword ["(" SingleExpression ")"] [AliveKeyword]
307. SystemOp ::= SystemKeyword
308. SelfOp ::= "self"
309. MTCOp ::= MTCKeyword
310. DoneStatement ::= ComponentId Dot DoneKeyword
311. KilledStatement ::= ComponentId Dot KilledKeyword
312. ComponentId ::= ComponentOrDefaultReference | (AnyKeyword | AllKeyword) ComponentKeyword
313. DoneKeyword ::= "done"
314. KilledKeyword ::= "killed"
315. RunningOp ::= ComponentId Dot RunningKeyword
316. RunningKeyword ::= "running"
317. AliveOp ::= ComponentId Dot AliveKeyword
318. CreateKeyword ::= "create"
319. AliveKeyword ::= "alive"
320. ConnectStatement ::= ConnectKeyword SingleConnectionSpec
321. ConnectKeyword ::= "connect"
322. SingleConnectionSpec ::= "(" PortRef "," PortRef ")"
323. PortRef ::= ComponentRef Colon Port
324. ComponentRef ::= ComponentOrDefaultReference | SystemOp | SelfOp | MTCOp
325. DisconnectStatement ::= DisconnectKeyword [SingleOrMultiConnectionSpec]
326. SingleOrMultiConnectionSpec ::= SingleConnectionSpec |
                                     AllConnectionsSpec |
                                     AllPortsSpec |
                                     AllCompsAllPortsSpec
327. AllConnectionsSpec ::= "(" PortRef ")"
328. AllPortsSpec ::= "(" ComponentRef ":" AllKeyword PortKeyword ")"
329. AllCompsAllPortsSpec ::= "(" AllKeyword ComponentKeyword ":" AllKeyword PortKeyword ")"
330. DisconnectKeyword ::= "disconnect"
331. MapStatement ::= MapKeyword SingleConnectionSpec
332. MapKeyword ::= "map"
333. UnmapStatement ::= UnmapKeyword [SingleOrMultiConnectionSpec]
334. UnmapKeyword ::= "unmap"
```

```
335. StartTCStatement ::= ComponentOrDefaultReference Dot StartKeyword "(" FunctionInstance ")"
336. StartKeyword ::= "start"
337. StopTCStatement ::= StopKeyword | (ComponentReferenceOrLiteral Dot StopKeyword) |
                        (AllKeyword ComponentKeyword Dot StopKeyword)
338. ComponentReferenceOrLiteral ::= ComponentOrDefaultReference | MTCOp | SelfOp
339. KillTCStatement ::= KillKeyword | (ComponentReferenceOrLiteral Dot KillKeyword) |
                        (AllKeyword ComponentKeyword Dot KillKeyword)
340. ComponentOrDefaultReference ::= VariableRef | FunctionInstance
341. KillKeyword ::= "kill"
```

A.1.6.2.4 Port operations

```
342. Port ::= (PortIdentifier | PortParIdentifier) {ArrayOrBitRef}
343. CommunicationStatements ::= SendStatement |
                                 CallStatement |
                                 ReplyStatement |
                                 RaiseStatement |
                                 ReceiveStatement |
                                 TriggerStatement |
                                 GetCallStatement |
                                 GetReplyStatement |
                                 CatchStatement |
                                 CheckStatement |
                                 ClearStatement |
                                 StartStatement |
                                 StopStatement
344. SendStatement ::= Port Dot PortSendOp
345. PortSendOp ::= SendOpKeyword "(" SendParameter ")" [ToClause]
346. SendOpKeyword ::= "send"
347. SendParameter ::= TemplateInstance
348. ToClause ::= ToKeyword ( AddressRef |
                 AddressRefList |
                 AllKeyword ComponentKeyword )
349. AddressRefList ::= "(" AddressRef {"," AddressRef} ")"
350. ToKeyword ::= "to"
351. AddressRef ::= TemplateInstance
352. CallStatement ::= Port Dot PortCallOp  [PortCallBody]
353. PortCallOp ::= CallOpKeyword "(" CallParameters ")" [ToClause]
354. CallOpKeyword ::= "call"
355. CallParameters ::= TemplateInstance ["," CallTimerValue]
356. CallTimerValue ::= TimerValue | NowaitKeyword
357. NowaitKeyword ::= "nowait"
358. PortCallBody ::= "{" CallBodyStatementList "}"
359. CallBodyStatementList ::= {CallBodyStatement [SemiColon]}+
360. CallBodyStatement ::= CallBodyGuard  StatementBlock
361. CallBodyGuard ::= AltGuardChar CallBodyOps
362. CallBodyOps ::= GetReplyStatement | CatchStatement
363. ReplyStatement ::= Port Dot PortReplyOp
364. PortReplyOp ::= ReplyKeyword "(" TemplateInstance [ReplyValue]")" [ToClause]
365. ReplyKeyword ::= "reply"
366. ReplyValue ::= ValueKeyword Expression
367. RaiseStatement ::= Port Dot PortRaiseOp
368. PortRaiseOp ::= RaiseKeyword "(" Signature "," TemplateInstance ")" [ToClause]
369. RaiseKeyword ::= "raise"
370. ReceiveStatement ::= PortOrAny Dot PortReceiveOp
371. PortOrAny ::= Port | AnyKeyword PortKeyword
372. PortReceiveOp ::= ReceiveOpKeyword ["(" ReceiveParameter ")"] [FromClause] [PortRedirect]
373. ReceiveOpKeyword ::= "receive"
374. ReceiveParameter ::= TemplateInstance
375. FromClause ::= FromKeyword AddressRef
376. FromKeyword ::= "from"
377. PortRedirect ::= PortRedirectSymbol (ValueSpec [SenderSpec] | SenderSpec)
378. PortRedirectSymbol ::= "->"
379. ValueSpec ::= ValueKeyword VariableRef
380. ValueKeyword ::= "value"
381. SenderSpec ::= SenderKeyword VariableRef
382. SenderKeyword ::= "sender"
383. TriggerStatement ::= PortOrAny Dot PortTriggerOp
384. PortTriggerOp ::= TriggerOpKeyword ["(" ReceiveParameter ")"] [FromClause] [PortRedirect]
385. TriggerOpKeyword ::= "trigger"
386. GetCallStatement ::= PortOrAny  Dot PortGetCallOp
387. PortGetCallOp ::= GetCallOpKeyword ["(" ReceiveParameter ")"] [FromClause]
                      [PortRedirectWithParam]
388. GetCallOpKeyword ::= "getcall"
389. PortRedirectWithParam ::= PortRedirectSymbol RedirectWithParamSpec
390. RedirectWithParamSpec ::= ParamSpec [SenderSpec] |
                              SenderSpec
391. ParamSpec ::= ParamKeyword ParamAssignmentList
392. ParamKeyword ::= "param"
```

```
393. ParamAssignmentList ::= "(" (AssignmentList | VariableList) ")"
394. AssignmentList ::= VariableAssignment {"," VariableAssignment}
395. VariableAssignment ::= VariableRef AssignmentChar ParameterIdentifier
396. ParameterIdentifier ::= ValueParIdentifier
397. VariableList ::= VariableEntry  {"," VariableEntry}
398. VariableEntry ::= VariableRef | NotUsedSymbol
399. GetReplyStatement ::= PortOrAny Dot PortGetReplyOp
400. PortGetReplyOp ::= GetReplyOpKeyword ["(" ReceiveParameter [ValueMatchSpec] ")"]
                        [FromClause] [PortRedirectWithValueAndParam]
401. PortRedirectWithValueAndParam ::= PortRedirectSymbol RedirectWithValueAndParamSpec
402. RedirectWithValueAndParamSpec ::= ValueSpec [ParamSpec] [SenderSpec] |
                                      RedirectWithParamSpec
403. GetReplyOpKeyword ::= "getreply"
404. ValueMatchSpec ::= ValueKeyword TemplateInstance
405. CheckStatement ::= PortOrAny Dot PortCheckOp
406. PortCheckOp ::= CheckOpKeyword ["(" CheckParameter ")"]
407. CheckOpKeyword ::= "check"
408. CheckParameter ::= CheckPortOpsPresent | FromClausePresent | RedirectPresent
409. FromClausePresent ::= FromClause [PortRedirectSymbol SenderSpec]
410. RedirectPresent ::= PortRedirectSymbol SenderSpec
411. CheckPortOpsPresent ::= PortReceiveOp | PortGetCallOp | PortGetReplyOp | PortCatchOp
412. CatchStatement ::= PortOrAny Dot PortCatchOp
413. PortCatchOp ::= CatchOpKeyword ["("CatchOpParameter ")"] [FromClause] [PortRedirect]
414. CatchOpKeyword ::= "catch"
415. CatchOpParameter ::= Signature "," TemplateInstance | TimeoutKeyword
416. ClearStatement ::= PortOrAll Dot PortClearOp
417. PortOrAll ::= Port | AllKeyword PortKeyword
418. PortClearOp ::= ClearOpKeyword
419. ClearOpKeyword ::= "clear"
420. StartStatement ::= PortOrAll Dot PortStartOp
421. PortStartOp ::= StartKeyword
422. StopStatement ::= PortOrAll Dot PortStopOp
423. PortStopOp ::= StopKeyword
424. StopKeyword ::= "stop"
425. AnyKeyword ::= "any"
```

A.1.6.2.5 Timer operations

```
426. TimerStatements ::= StartTimerStatement | StopTimerStatement | TimeoutStatement
427. TimerOps ::= ReadTimerOp | RunningTimerOp
428. StartTimerStatement ::= TimerRef Dot StartKeyword ["(" TimerValue ")"]
429. StopTimerStatement ::= TimerRefOrAll Dot StopKeyword
430. TimerRefOrAll ::= TimerRef | AllKeyword TimerKeyword
431. ReadTimerOp ::= TimerRef Dot ReadKeyword
432. ReadKeyword ::= "read"
433. RunningTimerOp ::= TimerRefOrAny  Dot RunningKeyword
434. TimeoutStatement ::= TimerRefOrAny  Dot TimeoutKeyword
435. TimerRefOrAny ::= TimerRef | AnyKeyword TimerKeyword
436. TimeoutKeyword ::= "timeout"
```

A.1.6.3 Type

```
437. Type ::= PredefinedType | ReferencedType
438. PredefinedType ::= BitStringKeyword |
                        BooleanKeyword |
                        CharStringKeyword |
                        UniversalCharString |
                        IntegerKeyword |
                        OctetStringKeyword |
                        HexStringKeyword |
                        VerdictTypeKeyword |
                        FloatKeyword |
                        AddressKeyword |
                        DefaultKeyword |
                        AnyTypeKeyword
439. BitStringKeyword ::= "bitstring"
440. BooleanKeyword ::= "boolean"
441. IntegerKeyword ::= "integer"
442. OctetStringKeyword ::= "octetstring"
443. HexStringKeyword ::= "hexstring"
444. VerdictTypeKeyword ::= "verdicttype"
445. FloatKeyword ::= "float"
446. AddressKeyword ::= "address"
447. DefaultKeyword ::= "default"
448. AnyTypeKeyword ::= "anytype"
449. CharStringKeyword ::= "charstring"
450. UniversalCharString ::= UniversalKeyword CharStringKeyword
451. UniversalKeyword ::= "universal"
452. ReferencedType ::= [GlobalModuleId Dot] TypeReference [ExtendedFieldReference]
```

```
453. TypeReference ::= StructTypeIdentifier[TypeActualParList] |
                       EnumTypeIdentifier |
                       SubTypeIdentifier |
                       ComponentTypeIdentifier
454. TypeActualParList ::= "(" TypeActualPar {"," TypeActualPar} ")"
455. TypeActualPar ::= ConstantExpression
456. ArrayDef ::= {"[" ArrayBounds [".." ArrayBounds] "]"}+
457. ArrayBounds ::= SingleConstExpression
/* STATIC SEMANTICS - ArrayBounds will resolve to a non negative value of integer type */
```

A.1.6.4 Value

```
458. Value ::= PredefinedValue | ReferencedValue
459. PredefinedValue ::= BitStringValue |
                         BooleanValue |
                         CharStringValue |
                         IntegerValue |
                         OctetStringValue |
                         HexStringValue |
                         VerdictTypeValue |
                         EnumeratedValue |
                         FloatValue |
                         AddressValue |
                         OmitValue
460. BitStringValue ::= Bstring
461. BooleanValue ::= "true" | "false"
462. IntegerValue ::= Number
463. OctetStringValue ::= Ostring
464. HexStringValue ::= Hstring
465. VerdictTypeValue ::= "pass" | "fail" | "inconc" | "none" | "error"
466. EnumeratedValue ::= EnumerationIdentifier
467. CharStringValue ::= Cstring | Quadruple
468. Quadruple ::= CharKeyword "(" Group "," Plane "," Row "," Cell ")"
469. CharKeyword ::= "char"
470. Group ::= Number
471. Plane ::= Number
472. Row ::= Number
473. Cell ::= Number
474. FloatValue ::= FloatDotNotation | FloatENotation
475. FloatDotNotation ::= Number Dot DecimalNumber
476. FloatENotation ::= Number [Dot DecimalNumber] Exponential [Minus] Number
477. Exponential ::= "E"
478. ReferencedValue ::= ValueReference [ExtendedFieldReference]
479. ValueReference ::= [GlobalModuleId Dot] (ConstIdentifier | ExtConstIdentifier |
                       ModuleParIdentifier ) |
                       ValueParIdentifier |
                       VarIdentifier
480. Number ::= (NonZeroNum {Num}) | "0"
481. NonZeroNum ::= "1" | "2" | "3" | "4" | "5" | "6" | "7" | "8" | "9"
482. DecimalNumber ::= {Num}+
483. Num ::= "0" | NonZeroNum
484. Bstring ::= "'" {Bin} "'" "B"
485. Bin ::= "0" | "1"
486. Hstring ::= "'" {Hex} "'" "H"
487. Hex ::= Num | "A" | "B" | "C" | "D" | "E" | "F"| "a" | "b" | "c" | "d" | "e" | "f"
488. Ostring ::= "'" {Oct} "'" "O"
489. Oct ::= Hex Hex
490. Cstring ::= """ {Char} """
491. Char ::= /* REFERENCE - A character defined by the relevant CharacterString type. For
charstring a character from the character set defined in [ITU-T T.50]. For universal charstring a
character from any character set defined in [ISO/IEC 10646] */
492. Identifier ::= Alpha{AlphaNum | Underscore}
493. Alpha ::= UpperAlpha | LowerAlpha
494. AlphaNum ::= Alpha | Num
495. UpperAlpha ::= "A" | "B" | "C" | "D" | "E" | "F" | "G" | "H" | "I" | "J" | "K" | "L" | "M" |
"N" | "O" | "P" | "Q" | "R" | "S" | "T" | "U" | "V" | "W" | "X" | "Y" | "Z"
496. LowerAlpha ::= "a" | "b" | "c" | "d" | "e" | "f" | "g" | "h" | "i" | "j" | "k" | "l" | "m" |
"n" | "o" | "p" | "q" | "r" | "s" | "t" | "u" | "v" | "w" | "x" | "y" | "z"
497. ExtendedAlphaNum ::= /* REFERENCE - A graphical character from the BASIC LATIN or from the
LATIN-1 SUPPLEMENT character sets defined in [ISO/IEC 10646] (characters from char (0,0,0,32) to
char (0,0,0,126), from char (0,0,0,161) to char (0,0,0,172) and from char (0,0,0,174) to char
(0,0,0,255) */
498. FreeText ::= """ {ExtendedAlphaNum} """
499. AddressValue ::= "null"
500. OmitValue ::= OmitKeyword
501. OmitKeyword ::= "omit"
```

A.1.6.5 Parameterization

```
502. InParKeyword ::= "in"
503. OutParKeyword ::= "out"
504. InOutParKeyword ::= "inout"
505. FormalValuePar ::= [(InParKeyword | InOutParKeyword | OutParKeyword)] Type ValueParIdentifier
506. ValueParIdentifier ::= Identifier
507. FormalPortPar ::= [InOutParKeyword] PortTypeIdentifier PortParIdentifier
508. PortParIdentifier ::= Identifier
509. FormalTimerPar ::= [InOutParKeyword] TimerKeyword TimerParIdentifier
510. TimerParIdentifier ::= Identifier
511. FormalTemplatePar ::= [(InParKeyword | OutParKeyword | InOutParKeyword )]
                           TemplateKeyword Type TemplateParIdentifier
512. TemplateParIdentifier ::= Identifier
```

A.1.6.6 With statement

```
513. WithStatement ::= WithKeyword WithAttribList
514. WithKeyword ::= "with"
515. WithAttribList ::= "{" MultiWithAttrib "}"
516. MultiWithAttrib ::= {SingleWithAttrib [SemiColon]}
517. SingleWithAttrib ::= AttribKeyword  [OverrideKeyword] [AttribQualifier] AttribSpec
518. AttribKeyword ::= EncodeKeyword |
                       VariantKeyword |
                       DisplayKeyword |
                       ExtensionKeyword
519. EncodeKeyword ::= "encode"
520. VariantKeyword ::= "variant"
521. DisplayKeyword ::= "display"
522. ExtensionKeyword ::= "extension"
523. OverrideKeyword ::= "override"
524. AttribQualifier ::= "(" DefOrFieldRefList ")"
525. DefOrFieldRefList ::= DefOrFieldRef {"," DefOrFieldRef}
526. DefOrFieldRef ::= DefinitionRef | FieldReference | AllRef
527. DefinitionRef ::= StructTypeIdentifier |
                       EnumTypeIdentifier |
                       PortTypeIdentifier |
                       ComponentTypeIdentifier |
                       SubTypeIdentifier |
                       ConstIdentifier |
                       TemplateIdentifier |
                       AltstepIdentifier |
                       TestcaseIdentifier |
                       FunctionIdentifier |
                       SignatureIdentifier |
                       VarIdentifier |
                       TimerIdentifier |
                       PortIdentifier |
                       ModuleParIdentifier |
                       FullGroupIdentifier
528. AllRef ::= ( GroupKeyword AllKeyword [ExceptKeyword "{" GroupRefList "}"]) |
                ( TypeDefKeyword AllKeyword [ExceptKeyword "{" TypeRefList "}"]) |
                ( TemplateKeyword AllKeyword [ExceptKeyword "{" TemplateRefList "}"]) |
                ( ConstKeyword AllKeyword [ExceptKeyword "{" ConstRefList "}"]) |
                ( AltstepKeyword AllKeyword [ExceptKeyword "{" AltstepRefList "}"]) |
                ( TestcaseKeyword AllKeyword [ExceptKeyword "{" TestcaseRefList "}"]) |
                ( FunctionKeyword AllKeyword [ExceptKeyword "{" FunctionRefList "}"]) |
                ( SignatureKeyword AllKeyword [ExceptKeyword "{" SignatureRefList "}"]) |
                ( ModuleParKeyword AllKeyword [ExceptKeyword "{" ModuleParRefList "}"])
529. AttribSpec ::= FreeText
```

A.1.6.7 Behaviour statements

```
530. BehaviourStatements ::= TestcaseInstance |
                             FunctionInstance |
                             ReturnStatement |
                             AltConstruct |
                             InterleavedConstruct |
                             LabelStatement |
                             GotoStatement |
                             RepeatStatement |
                             DeactivateStatement |
                             AltstepInstance |
                             ActivateOp
531. VerdictStatements ::= SetLocalVerdict
532. VerdictOps ::= GetLocalVerdict
533. SetLocalVerdict ::= SetVerdictKeyword "(" SingleExpression ")"
534. SetVerdictKeyword ::= "setverdict"
535. GetLocalVerdict ::= "getverdict"
536. SUTStatements ::= ActionKeyword "(" [ActionText ] {StringOp ActionText} ")"
```

```
537. ActionKeyword ::= "action"
538. ActionText ::= FreeText | Expression
539. ReturnStatement ::= ReturnKeyword  [Expression]
540. AltConstruct ::= AltKeyword "{" AltGuardList "}"
541. AltKeyword ::= "alt"
542. AltGuardList ::= {GuardStatement | ElseStatement [SemiColon]}
543. GuardStatement ::= AltGuardChar (AltstepInstance [StatementBlock] | GuardOp StatementBlock)
544. ElseStatement ::= "["ElseKeyword "]" StatementBlock
545. AltGuardChar ::= "[" [BooleanExpression] "]"
546. GuardOp ::= TimeoutStatement |
                ReceiveStatement |
                TriggerStatement |
                GetCallStatement |
                CatchStatement |
                CheckStatement |
                GetReplyStatement |
                DoneStatement |
                KilledStatement
547. InterleavedConstruct ::= InterleavedKeyword "{" InterleavedGuardList "}"
548. InterleavedKeyword ::= "interleave"
549. InterleavedGuardList ::= {InterleavedGuardElement [SemiColon]}+
550. InterleavedGuardElement ::= InterleavedGuard InterleavedAction
551. InterleavedGuard ::= "[" "]" GuardOp
552. InterleavedAction ::= StatementBlock
553. LabelStatement ::= LabelKeyword LabelIdentifier
554. LabelKeyword ::= "label"
555. LabelIdentifier ::= Identifier
556. GotoStatement ::= GotoKeyword LabelIdentifier
557. GotoKeyword ::= "goto"
558. RepeatStatement ::= "repeat"
559. ActivateOp ::= ActivateKeyword "(" AltstepInstance ")"
560. ActivateKeyword ::= "activate"
561. DeactivateStatement ::= DeactivateKeyword ["(" ComponentOrDefaultReference ")"]
562. DeactivateKeyword ::= "deactivate"
```

A.1.6.8 Basic statements

```
563. BasicStatements ::= Assignment | LogStatement | LoopConstruct | ConditionalConstruct |
                         SelectCaseConstruct
564. Expression ::= SingleExpression | CompoundExpression
565. CompoundExpression ::= FieldExpressionList | ArrayExpression
/* STATIC SEMANTICS - Within CompoundExpression the ArrayExpression can be used for Arrays, record,
record of and set of types. */
566. FieldExpressionList ::= "{" FieldExpressionSpec {"," FieldExpressionSpec} "}"
567. FieldExpressionSpec ::= FieldReference AssignmentChar NotUsedOrExpression
568. ArrayExpression ::= "{" [ArrayElementExpressionList] "}"
569. ArrayElementExpressionList ::= NotUsedOrExpression  {"," NotUsedOrExpression}
570. NotUsedOrExpression ::= Expression | NotUsedSymbol
571. ConstantExpression ::= SingleConstExpression | CompoundConstExpression
572. SingleConstExpression ::= SingleExpression
/* STATIC SEMANTICS - SingleConstExpression shall not contain Variables or Module parameters and
shall resolve to a constant Value at compile time */
573. BooleanExpression ::= SingleExpression
/* STATIC SEMANTICS - BooleanExpression shall resolve to a Value of type Boolean */
574. CompoundConstExpression ::= FieldConstExpressionList | ArrayConstExpression
/* STATIC SEMANTICS - Within CompoundConstExpression the ArrayConstExpression can be used for
arrays, record, record of and set of types. */
575. FieldConstExpressionList ::= "{" FieldConstExpressionSpec {"," FieldConstExpressionSpec} "}"
576. FieldConstExpressionSpec ::= FieldReference AssignmentChar ConstantExpression
577. ArrayConstExpression ::= "{" [ArrayElementConstExpressionList] "}"
578. ArrayElementConstExpressionList ::= ConstantExpression {"," ConstantExpression}
579. Assignment ::= VariableRef AssignmentChar (Expression | TemplateBody)
/* STATIC SEMANTICS - The Expression on the right hand side of Assignment shall evaluate to an
explicit value of a type compatible with the type of the left hand side for value variables and
shall evaluate to an explicit value, template (literal or a template instance) or a matching
mechanism compatible with the type of the left hand side for template variables. */
580. SingleExpression ::= XorExpression { "or" XorExpression }
/* STATIC SEMANTICS - If more than one XorExpression exists, then the XorExpressions shall evaluate
to specific values of compatible types */
581. XorExpression ::= AndExpression { "xor" AndExpression }
/* STATIC SEMANTICS - If more than one AndExpression exists, then the AndExpressions shall evaluate
to specific values of compatible types */
582. AndExpression ::= NotExpression { "and" NotExpression }
/* STATIC SEMANTICS - If more than one NotExpression exists, then the NotExpressions shall evaluate
to specific values of compatible types */
583. NotExpression ::= [ "not" ] EqualExpression
/* STATIC SEMANTICS - Operands of the not operator shall be of type boolean or derivatives of type
Boolean. */
584. EqualExpression ::= RelExpression { EqualOp RelExpression }
```

```
/* STATIC SEMANTICS - If more than one RelExpression exists, then the RelExpressions shall evaluate
to specific values of compatible types */
585. RelExpression ::= ShiftExpression [ RelOp ShiftExpression ]
/* STATIC SEMANTICS - If both ShiftExpressions exist, then each ShiftExpression shall evaluate to a
specific integer, Enumerated or float Value or derivatives of these types */
586. ShiftExpression ::= BitOrExpression { ShiftOp BitOrExpression }
/* STATIC SEMANTICS - Each Result shall resolve to a specific Value. If more than one Result exists
the right-hand operand shall be of type integer or derivatives and if the shift op is "<<" or ">>"
then the left-hand operand shall resolve to either bitstring, hexstring or octetstring type or
derivatives of these types. If the shift op is "<@" or "@>" then the left-hand operand shall be of
type bitstring, hexstring, charstring or universal charstring or derivatives of these types */
587. BitOrExpression ::= BitXorExpression { "or4b" BitXorExpression }
/* STATIC SEMANTICS - If more than one BitXorExpression exists, then the BitXorExpressions shall
evaluate to specific values of compatible types */
588. BitXorExpression ::= BitAndExpression { "xor4b" BitAndExpression }
/* STATIC SEMANTICS - If more than one BitAndExpression exists, then the BitAndExpressions shall
evaluate to specific values of compatible types */
589. BitAndExpression ::= BitNotExpression { "and4b" BitNotExpression }
/* STATIC SEMANTICS - If more than one BitNotExpression exists, then the BitNotExpressions shall
evaluate to specific values of compatible types */
590. BitNotExpression ::= [ "not4b" ] AddExpression
/* STATIC SEMANTICS - If the not4b operator exists, the operand shall be of type bitstring,
octetstring or hexstring or derivatives of these types. */
591. AddExpression ::= MulExpression { AddOp MulExpression }
/* STATIC SEMANTICS - Each MulExpression shall resolve to a specific Value. If more than one
MulExpression exists and the AddOp resolves to StringOp then the MulExpressions shall resolve to
same type which shall be of bitstring, hexstring, octetstring, charstring or universal charstring or
derivatives of these types. If more than one MulExpression exists and the AddOp does not resolve to
StringOp then the MulExpression shall both resolve to type integer or float or derivatives of these
types.*/
592. MulExpression ::= UnaryExpression { MultiplyOp UnaryExpression }
/* STATIC SEMANTICS - Each UnaryExpression shall resolve to a specific Value. If more than one
UnaryExpression exists then the UnaryExpressions shall resolve to type integer or float or
derivatives of these types. */
593. UnaryExpression ::= [ UnaryOp ] Primary
/* STATIC SEMANTICS - Primary shall resolve to a specific Value of type integer or float or
derivatives of these types.*/
594. Primary ::= OpCall | Value | "(" SingleExpression ")"
595. ExtendedFieldReference ::= {(Dot ( StructFieldIdentifier | TypeDefIdentifier))
                                | ArrayOrBitRef }+
/* STATIC SEMANTIC - The TypeDefIdentifier shall be used only if the type of the VarInstance or
ReferencedValue in which the ExtendedFieldReference is used is anytype.*/
596. OpCall ::= ConfigurationOps |
                VerdictOps |
                TimerOps |
                TestcaseInstance |
                FunctionInstance |
                TemplateOps |
                ActivateOp
597. AddOp ::= "+" | "-" | StringOp
/* STATIC SEMANTICS - Operands of the "+" or "-" operators shall be of type integer or float or
derivations of integer or float (i.e. subrange) */
598. MultiplyOp ::= "*" | "/" | "mod" | "rem"
/* STATIC SEMANTICS - Operands of the "*", "/", rem or mod operators shall be of type integer or
float or derivations of integer or float (i.e. subrange). */
599. UnaryOp ::= "+" | "-"
/* STATIC SEMANTICS - Operands of the "+" or "-" operators shall be of type integer or float or
derivations of integer or float (i.e. subrange). */
600. RelOp ::= "<" | ">" | ">=" | "<="
/* STATIC SEMANTICS - the precedence of the operators is defined in Table 6 */
601. EqualOp ::= "==" | "!="
602. StringOp ::= "&"
/* STATIC SEMANTICS - Operands of the string operator shall be bitstring, hexstring, octetstring or
character string */
603. ShiftOp ::= "<<" | ">>" | "<@" | "@>"
604. LogStatement ::= LogKeyword "(" LogItem { "," LogItem } ")"
605. LogKeyword ::= "log"
606. LogItem ::= FreeText | TemplateInstance
607. LoopConstruct ::= ForStatement |
                       WhileStatement |
                       DoWhileStatement
608. ForStatement ::= ForKeyword "(" Initial SemiColon Final SemiColon Step ")"
                      StatementBlock
609. ForKeyword ::= "for"
610. Initial ::= VarInstance | Assignment
611. Final ::= BooleanExpression
612. Step ::= Assignment
613. WhileStatement ::= WhileKeyword "(" BooleanExpression ")"
                        StatementBlock
614. WhileKeyword ::= "while"
```

```
615. DoWhileStatement ::= DoKeyword StatementBlock
                          WhileKeyword "(" BooleanExpression ")"
616. DoKeyword ::= "do"
617. ConditionalConstruct ::= IfKeyword "(" BooleanExpression ")"
                              StatementBlock
                              {ElseIfClause}[ElseClause]
618. IfKeyword ::= "if"
619. ElseIfClause ::= ElseKeyword  IfKeyword "(" BooleanExpression ")"  StatementBlock
620. ElseKeyword ::= "else"
621. ElseClause ::= ElseKeyword  StatementBlock
622. SelectCaseConstruct ::= SelectKeyword "(" SingleExpression ")" SelectCaseBody
623. SelectKeyword ::= "select"
624. SelectCaseBody ::= "{" { SelectCase }+ "}"
625. SelectCase ::= CaseKeyword ( "(" TemplateInstance {"," TemplateInstance } ")" | ElseKeyword )
                    StatementBlock
626. CaseKeyword ::= "case"
```

A.1.6.9 Miscellaneous productions

```
627. Dot ::= "."
628. Dash ::= "-"
629. Minus ::= Dash
630. SemiColon ::= ";"
631. Colon ::= ":"
632. Underscore ::= "_"
633. AssignmentChar ::= ":="
```

Annex B

Matching incoming values

(This annex forms an integral part of this Recommendation)

B.1 Template matching mechanisms

This annex specifies the matching mechanisms that may be used in TTCN-3 templates (and only in templates).

B.1.1 Matching specific values

Specific values are the basic matching mechanism of TTCN-3 templates. Specific values in templates are expressions which do not contain any matching mechanisms or wildcards. Unless otherwise specified, a template field matches the corresponding incoming field value if, and only if, the incoming field value has exactly the same value as the value to which the expression in the template evaluates.

EXAMPLE:

```
// Given the message type definition
type record MyMessageType
{
    integer     field1,
    charstring  field2,
    boolean     field3 optional,
    integer[4]  field4
}

// A message template using specific values could be
template MyMessageType MyTemplate:=
{
    field1 := 3+2,          // specific value of integer type
    field2 := "My string",  // specific value of charstring type
    field3 := true,         // specific value of boolean type
    field4 := {1,2,3}       // specific value of integer array
}
```

B.1.1.1 Omitting values

The keyword **`omit`** denotes that an optional template field shall be absent. It can be used on values of all types, provided that the template field is optional.

EXAMPLE:

```
template Mymessage MyTemplate:=
{   :
    :
    field3 := omit,     // omit this field
    :
}
```

B.1.2 Matching mechanisms instead of values

The following matching mechanisms may be used in place of explicit values.

B.1.2.1 Value list

Value lists specify lists of acceptable incoming values. It can be used on values of all types. A template field that uses a value list matches the corresponding incoming field if, and only if, the incoming field value matches any one of the values in the value list. Each value in the value list shall be of the type declared for the template field in which this mechanism is used.

EXAMPLE:

```
template Mymessage MyTemplate:=
{
    field1 := (2,4,6),                  // list of integer values
    field2 := ("String1", "String2"),   // list of charstring values
    :
    :
}
```

B.1.2.2 Complemented value list

The keyword `complement` denotes a list of values that will not be accepted as incoming values (i.e., it is the complement of a value list). It can be used on all values of all types.

Each value in the list shall be of the type declared for the template field in which the complement is used. A template field that uses complement matches the corresponding incoming field if and only if the incoming field does not match any of the values listed in the value list. The value list may be a single value, of course.

EXAMPLE:

```
template Mymessage MyTemplate:=
{
    complement (1,3,5), // list of unacceptable integer values
    :
    field3 not(true)        // will match false
    :
}
```

B.1.2.3 Any value

The matching symbol "?" (*AnyValue*) is used to indicate that any valid incoming value is acceptable. It can be used on values of all types. A template field that uses the any value mechanism matches the corresponding incoming field if, and only if, the incoming field evaluates to a single element of the specified type.

EXAMPLE:

```
template Mymessage MyTemplate:=
{
    field1 := ?,    // will match any integer
    field2 := ?,    // will match any non-empty charstring value
    field3 := ?,    // will match true or false
    field4 := ?     // will match any sequence of integers
}
```

B.1.2.4 Any value or none

The matching symbol "*" (*AnyValueOrNone*) is used to indicate that any valid incoming value, including omission of that value, is acceptable. It can be used on values of all types, provided that the template field is declared as optional.

A template field that uses this symbol matches the corresponding incoming field if, and only if, either the incoming field evaluates to any element of the specified type, or if the incoming field is absent.

EXAMPLE:

```
template Mymessage MyTemplate:=
{   :
    field3 := *,    // will match true or false or omitted field
    :
}
```

B.1.2.5 Value range

Ranges indicate a bounded range of acceptable values. When used for values of **`integer`** or **`float`** types (and integer or float sub-types). A boundary value shall be either:

a) infinity or -infinity;

b) an expression that evaluates to a specific integer or float value.

The lower boundary shall be put on the left side of the range, the upper boundary at the right side. The lower boundary shall be less than the upper boundary. A template field that uses a range matches the corresponding incoming field if, and only if, the incoming field value is equal to one of the values in the range.

When used in templates or template fields of **`charstring`** or **`universal charstring`** types, the boundaries shall evaluate to valid character positions according to the coded character set table(s) of the type (e.g., the given position shall not be empty). Empty positions between the lower and the upper boundaries are not considered to be valid values of the specified range.

EXAMPLE:

```
template Mymessage MyTemplate:=
{
    field1 := (1 .. 6), // range of integer type
    :
    :
    :
}
// other entries for field1 might be (-infinity to 8) or (12 to infinity)
```

B.1.2.6 SuperSet

SuperSet is an operation for matching that shall be used only on values of **`set of`** types. SuperSet is denoted by the keyword **`superset`**. A field that uses SuperSet matches the corresponding incoming field if, and only if, the incoming field contains at least all of the elements defined within the SuperSet, and may contain more. The argument of SuperSet shall be of the type declared for the field in which the SuperSet mechanism is used.

EXAMPLE:

```
type set of integer MySetOfType;

template MySetOfType MyTemplate1 := superset ( 1, 2, 3 );
// any sequence of integers matches which contains at least one occurrence of the numbers
// 1, 2 and 3 in any order and positions
```

B.1.2.7 SubSet

SubSet is an operation for matching that can be used only on values of **`set of`** types. SubSet is denoted by the keyword **`subset`**.

A field that uses SubSet matches the corresponding incoming field if, and only if, the incoming field contains only elements defined within the SubSet, and may contain less. The argument of SubSet shall be of the type declared for the field in which the SubSet mechanism is used.

EXAMPLE:

```
template MySetOfType MyTemplate1:= subset ( 1, 2, 3 );
// any sequence of integers matches which contains zero or one occurrence of the numbers
// 1, 2 and 3 in any order and positions
```

B.1.3 Matching mechanisms inside values

The following matching mechanisms may be used inside explicit values of strings, records, records of, sets, sets of and arrays.

B.1.3.1 Any element

The matching symbol "?" (*AnyElement*) is used to indicate that it replaces single elements of a string (except character strings), a **`record of`**, a **`set of`** or an array. It shall be used only within values of string types, **`record of`** types, **`set of`** types and arrays.

EXAMPLE:

```
template Mymessage MyTemplate:=
{   :
    field2 := "abcxyz",
    field3 := '10???'B,      // where each "?" may either be 0 or 1
    field4 := {1, ?, 3} // where ? may be any integer value
}
```

NOTE – The "?" in `field4` can be interpreted as *AnyValue* as an integer value, or *AnyElement* inside a **`record of`**, **`set of`** or array. Since both interpretations lead to the same match, no problem arises.

B.1.3.1.1 Using single character wildcards

If it is required to express the "?" wildcard in character strings, it shall be done using character patterns (see clause B.1.5). For example: "abcdxyz", "abccxyz" "abcxxyz", etc. will all match **`pattern`** "abc?xyz". However, "abcxyz", "abcdefxyz", etc. will not.

B.1.3.2 Any number of elements or no element

The matching symbol "*" (*AnyElementsOrNone*) is used to indicate that it replaces none or any number of consecutive elements of a string (except character strings), a **`record of`**, a **`set of`** or an array. The "*" symbol matches the longest sequence of elements possible, according to the pattern as specified by the symbols surrounding the "*".

EXAMPLE:

```
template Mymessage MyTemplate:=
{   :
    field2 := "abcxyz",
    field3 := '10*11'B,      //  where "*" may be any sequence of bits (possibly empty)
    field4 := {*, 2, 3}      // where "*" may be any number of integer values or omitted
}

var charstring MyStrings[4];
MyPCO.receive(MyStrings:{"abyz", *, "abc" });
```

If a "*" appears at the highest level inside a string, a **`record of`**, **`set of`** or array, it shall be interpreted as *AnyElementsOrNone*.

NOTE – This rule prevents the otherwise possible interpretation of "*" as *AnyValueOrNone* that replaces an element inside a string, **`record of`**, **`set of`** or array.

B.1.3.2.1 Using multiple character wildcards

If it is required to expressed the "*" wildcard in character strings, it shall be done using character patterns (see clause B.1.5). For example: "abcxyz", "abcdefxyz" "abcabcxyz", etc. will all match **`pattern`** "abc*xyz".

B.1.3.3 Permutation

Permutation is an operation for matching that shall be used only on values of **`record of`** types. Permutation is denoted by the keyword **`permutation`**. Expressions and *AnyElement* and *AnyElementsOrNone* are allowed as permutation elements. Each element listed in the permutation shall be of the type replicated by the **`record of`** type.

Permutation in place of a single element means that any series of elements is acceptable provided it contains the same elements as the value list in the permutation, though possibly in a different order.

If both permutation and *AnyElementsOrNone* are used inside a value, they shall be evaluated jointly.

AnyElementsOrNone used inside permutation replaces none or any number of elements within the segment of the record of value matched by permutation. *AnyElementsOrNone* used inside a permutation shall be evaluated last (when all other elements of the permutation list have matched an element in the evaluated list already).

NOTE 1 – *AnyElementsOrNone* used inside permutation has a different effect as *AnyElementsOrNone* used in conjunction with permutation as in the latter *AnyElementsOrNone* replaces consecutive elements only. For example, {**permutation**(1,2,*)} is equivalent to ({*,1,*,2,*},{*,2,*,1,*}), while {**permutation**(1,2),*} is equivalent to ({1,2},{2,1},*).

NOTE 2 – When *AnyElementsOrNone* is used in conjunction with permutation a length attribute may be applied to *AnyElementsOrNone* to restrict the number of elements matched by *AnyElementsOrNone* (see also clause B.1.4.1). On the contrary, no length attribute shall be added to *AnyElementsOrNone* used inside a permutation (but can be applied to the whole permutation instead).

EXAMPLE:

```
type record of integer MySequenceOfType;

template MySequenceOfType MyTemplate1 := { permutation ( 1, 2, 3 ), 5 };
// matches any of the following sequences of 4 integers: 1,2,3,5; 1,3,2,5; 2,1,3,5;
// 2,3,1,5; 3,1,2,5; or 3,2,1,5

template MySequenceOfType MyTemplate2 := { permutation ( 1, 2, ? ), 5 };
// matches any sequence of 4 integers that ends with 5 and contains 1 and 2 at least once in
// other positions

template MySequenceOfType MyTemplate3 := { permutation ( 1, 2, 3 ), * };
// matches any sequence of integers starting with 1,2,3; 1,3,2; 2,1,3; 2,3,1; 3,1,2 or 3,2,1

template MySequenceOfType MyTemplate4 := { *, permutation ( 1, 2, 3 )};
// matches any sequence of integers ending with 1,2,3; 1,3,2; 2,1,3; 2,3,1; 3,1,2 or 3,2,1

template MySequenceOfType MyTemplate5 := { *, permutation ( 1, 2, 3 ),* };
// matches any sequence of integers containing any of the following substrings at any position:
// 1,2,3; 1,3,2; 2,1,3; 2,3,1; 3,1,2 or 3,2,1

template MySequenceOfType MyTemplate6 := { permutation ( 1, 2, * ), 5 };
// matches any sequence of integers that ends with 5 and containing 1 and 2 at least once in
// other positions

template MySequenceOfType MyTemplate7 := { permutation ( 1, 2, 3 ), * length (0..5)};
// matches any sequence of three to eight integers starting with 1,2,3; 1,3,2; 2,1,3; 2,3,1;
// 3,1,2 or 3,2,1

template MySequenceOfType MyTemplate9 := { permutation ( 1, 2, *) length (3..5), 5 };
// matches any sequence of four to six integers that ends with 5 and contains 1 and 2 at least
// once in other position
```

B.1.4 Matching attributes of values

The following attributes may be associated with matching mechanisms.

B.1.4.1 Length restrictions

The length restriction attribute is used to restrict the length of string values and the number of elements in a **set of, record of** or array structure. It shall be used only as an attribute of the following mechanisms: *AnyValue*, *AnyValueOrNone*, *AnyElement* and *AnyElementsOrNone* (but not inside permutation), permutation, superset and subset. It can also be used in conjunction with the complement matching mechanism and with the **ifpresent** attribute. The syntax for **length** can be found in clauses 6.1.2.3 and 6.2.3.

NOTE – When both the complement and the length restriction matching mechanisms are used for a template or template field, restrictions implied by them shall apply to the template or template field independently.

The units of length are to be interpreted according to Table 4 in the case of string values. For **`set of`**, **`record of`** types and arrays the unit of length is the replicated type. The boundaries shall be denoted by expressions which resolve to specific non-negative **`integer`** values. Alternatively, the keyword **`infinity`** can be used as a value for the upper boundary in order to indicate that there is no upper limit of length.

The length specifications for the template shall not conflict with the length for restrictions (if any) of the corresponding type. A template field that uses length as an attribute of a symbol matches the corresponding incoming field if, and only if, the incoming field matches both the symbol and its associated attribute. The length attribute matches if the length of the incoming field is greater than or equal to the specified lower bound and less than or equal to the upper bound. In the case of a single length value the length attribute matches only if the length of the received field is exactly the specified value.

It is allowed to use a length restriction in conjunction with the special value **`omit`**, however in this case the length attribute has no effect (i.e., with **`omit`** it is redundant). With *AnyValueOrNone* and **`ifpresent`** it places a restriction on the incoming value, if any.

EXAMPLE:

```
template Mymessage MyTemplate:=
{
    field1 := complement ({4,5},{1,4,8,9}) length (1 .. 6), // any value containing 1, 2, 3, 4,
    // 5 or 6 elements is accepted provided it is not {4,5} or {1,4,8,9}
    field2 := "ab*ab" length(13) // max length of the AnyElementsOrNone string is 9 characters
    :
}
```

B.1.4.2 The IfPresent indicator

The **`ifpresent`** indicates that a match may be made if an optional field is present (i.e., not omitted). This attribute may be used with all the matching mechanisms, provided the type is declared as optional.

A template field that uses **`ifpresent`** matches the corresponding incoming field if, and only if, the incoming field matches according to the associated matching mechanism, or if the incoming field is absent.

EXAMPLE:

```
template Mymessage:MyTemplate:=
{   :
    field2 := "abcd" ifpresent, // matches "abcd" if not omitted
    :
    :
}
```

NOTE – *AnyValueOrNone* has exactly the same meaning as **`? ifpresent`**.

B.1.5 Matching character pattern

Character patterns can be used in templates to define the format of a required character string to be received. Character patterns can be used to match **`charstring`** and **`universal charstring`** values. In addition to literal characters, character patterns allow the use of meta-characters (e.g., ? and * within a character pattern means matching any character and any number of any character respectively).

EXAMPLE 1:

```
template charstring MyTemplate:= pattern "ab??xyz*0";
```

This template would match any character string that consists of the characters "ab", followed by any two characters, followed by the characters "xyz", followed by any number of any characters (including any number of "0"-s) before the closing character "0".

If it is required to interpret any metacharacter literally it should be preceded with the metacharacter "\".

EXAMPLE 2:

```
template charstring MyTemplate:= pattern "ab?\?xyz*";
```

This template would match any character string which consists of the characters "ab", followed by any character, followed by the characters "?xyz", followed by any number of any characters.

The list of metacharacters for TTCN-3 patterns is shown in Table B.1. Metacharacters shall not contain whitespaces except a whitespace preceded by a newline character before or inside a set expression.

Table B.1 – List of TTCN-3 pattern metacharacters

Metacharacter	Description
?	Match any character (see Notes 1 and 2)
*	Match any character zero or more times; shall match the longest possible number of characters (see example 1 above) (see Notes 1 and 2)
\	Cause the following metacharacter to be interpreted as a literal (see Note 3). When preceding a character without defined metacharacter meaning "\" and the character together match the character following the "\" (see Note 4)
[ ]	Match any character within the specified set, see clause B.1.5.1 for more details
-	Has a metacharacter meaning inside a pair of square brackets ("[" and "]") only, except the first and last positions within the bracket. Allows to specify a range of characters; see clause B.1.5.1 for more details
^	Has a metacharacter meaning as the first character following the opening square bracket inside a pair of square brackets ("[" and "]") only and cause to match any character complementing the set of characters following this metacharacter; see clause B.1.5.1 for more details
\q{group,plane,row,cell}	Match the Universal character specified by the quadruple
{reference}	Insert the referenced user defined string and interpret it as a regular expression. See clause B.1.5.2 for more details
\N{reference}	Match any character within the set of characters, where the set is defined by the referenced definition; see clause B.1.5.4 for more details
\d	Match any numerical digit (equivalent to [0-9])
\w	Match any alphanumeric character (equivalent to [0-9a-zA-Z])
\t	Match the C0 control character HT(9) (see [ISO/IEC 6429])
\n	Match any of the following C0 control characters: LF(10), VT(11), FF(12), CR(13) (see [ISO/IEC 6429]) (jointly called newline characters)
\r	Match the C0 control character CR (see [ISO/IEC 6429])
\s	Match any one of the following C0 control characters: HT(9), LF(10), VT(11), FF(12), CR(13), SP(32) (see [ISO/IEC 6429], [ITU-T T.50]) (jointly called white-space characters)

Table B.1 – List of TTCN-3 pattern metacharacters

Metacharacter	Description
`\b`	Match a word boundary (any graphical character except SP or DEL is preceded or followed by any of the whitespace or newline characters)
\"	Match the double quote character
""	Match the double quote character
|	Used to denote two alternative expressions
( )	Used to group an expression
#(n, m)	Match the preceding expression at least n times but no more than m times (postfix). See clause B.1.5.3 for more details
#n	Match the previous expression exactly n times (where n is a single digit) (postfix); the same as #(n)
+	Match the preceding expression one or several times (postfix); the same as #(1,)

NOTE 1 – Metacharacters ? and * are able to match any characters of the character set of the root type of the template or template field in which they are used (i.e., not considering type constraints applied). However, it shall not be forgotten, that receiving operations require type checking of the received message before attempting to match it. Therefore, received values not complying with the subtype specification of the template or template field are never provided for matching.

NOTE 2 – In some other languages/notations ? and * have different meanings as metacharacters. However, in TTCN these characters are traditionally used for matching in the sense as specified in this table.

NOTE 3 – Consequently the backslash character can be matched by a pair of backslash characters without space between them (\\), e.g., the pattern "\\d" will match the string "\d"; opening or closing square brackets can be matched by "\[" and "\]" respectively, etc.

NOTE 4 – Such use of the metacharacter "\" is deprecated as further metacharacters can be defined later.

B.1.5.1 Set expression

A list of characters enclosed by a pair of "[" and "]" matches any single character in that list. The set expression is delimited by the "[" "]" symbols. In addition to character literals, it is possible to specify character ranges using the hyphen "-" as separator. The range consists of the character immediately before the separator, the character immediately after it and all characters with a character code between the codes of the two bordering characters. A hyphen character "-" inside the list but without preceding or following character loses its special meaning.

The set expression can also be negated by placing the caret "^" character as the first character after the opening square bracket. Negation takes precedence over character ranges. Therefore, a hyphen "-" immediately following a negating caret "^" shall be processed as a literal character.

An empty list and an empty negated list are not allowed. Therefore, a closing square bracket "]" immediately following an opening square bracket "[" or a caret following the opening square bracket "[" and immediately followed by a closing square bracket "]" shall be processed as literal characters.

All metacharacters, except those listed below, lose their special meaning inside the list:

- "]" not at the first position and not immediately following a "^" at the first position;
- "-" not at the first or last positions in the list;

- "^" at the first position in the list except when immediately followed by a closing square bracket;
- "\", "\d", "\t", "\w", "\r", "\n", "\s" and "\b";
- "\q{group,plane,row,cell}";
- "\N{reference}".

NOTE 1 – Embedded lists are not allowed (for example in pattern "[ab[r-z]]" the second "[" denotes a literal "[", the first "]" closes the list and the second "]" causes an error as no related opening bracket in the pattern).

NOTE 2 – To include a literal caret character "^", place it anywhere except in the first position or precede it with a backslash. To include a literal hyphen "-", place it first or last in the list, or precede it with a backslash. To include a literal closing square bracket "]", place it first or precede it with a backslash. If the first character in the list is the caret "^", then the characters "-" and "]" also match themselves when they immediately follow that caret.

EXAMPLE:

```
template charstring RegExp1:= pattern "[a-z]";  // this will match any character from a to z

template charstring RegExp2:= pattern "[^a-z]";  // this will match any character except a to z

template charstring RegExp3:= pattern "[AC-E][0-9][0-9][0-9]YKE";

// RegExp3 will match a string which starts with the letter A or a letter between
// C and E (but not e.g., B) then has three digits and the letters YKE
```

B.1.5.2 Reference expression

In addition to direct string values, it is also possible within the pattern to use references to existing templates, constants, variables or module parameters. The reference is enclosed within the "{" "}" characters and reference shall resolve to one of the character string types. Contents of the referenced templates, constants or variables shall be handled as a regular expression. Each expression shall be dereferenced only once.

EXAMPLE 1:

```
const charstring MyString:= "ab?";

template charstring MyTemplate:= pattern "{MyString}";
```

This template would match any character string that consists of the characters "ab", followed by any character. In effect any character string following the `pattern` keyword either explicitly or by reference will be interpreted following the rules defined in this clause.

```
template universal charstring MyTemplate1:= pattern "{MyString}de\q{1, 1, 13, 7}";
```

This template would match any character string which consists of the characters "ab", followed by any character, followed by the characters "de", followed by the character in [ISO/IEC 10646] with group=1, plane=1, row=13 and cell=7.

If a reference expression refers to a template, constant or variable which contains one or more reference expressions, then the references in the referred template, constant or variable shall recursively be dereferenced before inserting their contents into the referring pattern.

EXAMPLE 2:

```
const charstring MyConst2 := pattern "ab";
template charstring RegExp1 := pattern "{MyConst2}";
   // matches the string "ab"
template charstring RegExp2 := pattern "{RegExp1}{RegExp1}";
   // matches the string "abab"
template charstring RegExp3 := pattern "c{RegExp2}d";
   // matches the string "cababd"

template charstring RegExp4 := pattern "{Reg";
template charstring RegExp5 := pattern "Exp1}";
template charstring RegExp6 := pattern "{RegExp4}{RegExp5}";
   // matches the string "{RegExp1}" only (i.e., shall not be handled as a reference expression
        // to the template RegExp1)
```

B.1.5.3 Match expression n times

To specify that the preceding expression should be matched a number of times, one of the following syntaxes shall be used: "#(n, m)", "#(n,)", "#(, m)", "#(n)", "#n" or "+".. The form "#(n, m)" specifies that the preceding expression must be matched at least n times but not more than m times. The metacharacter postfix "#(n,)" specifies that the preceding expression must be matched at least n times while "#(, m)" indicates that the preceding expression shall be matched not more than m times. Metacharacters (postfixes) "#(n)" and "#n" specify that the preceding expression must be matched exactly n times (they are equivalent to "#(n, n)"). In the form "#n" n shall be a single digit. The metacharacter postfix "+" denotes that the preceding expression must be matched at least 1 time (equivalent to "#(1,)").

EXAMPLE:

```
template charstring RegExp4:= pattern "[a-z]#(9, 11)";  // match at least 9 but no more than 11
                                                         // characters from a to z
template charstring RegExp5a:= pattern "[a-z]#(9)";     // match exactly 9
                                                         // characters from a to z
template charstring RegExp5b:= pattern "[a-z]#9";       // match exactly 9
                                                         // characters from a to z
template charstring RegExp6:= pattern "[a-z]#(9, )";    // match at least 9
                                                         // characters from a to z
template charstring RegExp7:= pattern "[a-z]#(, 11)";   // match no more than 11
                                                         // characters from a to z
template charstring RegExp8:= pattern "[a-z]+";         // match at least 1
                                                         // character from a to z,
```

B.1.5.4 Match a referenced character set

A notation of the form **"\N{**reference**}"**, where reference is denoting a one-character-length template, constant, variable or module parameter, matches the character in the referenced value or template.

Referencing a template, constant, variable or module parameter that is not of length 1 shall cause an error.

A notation of the form **"\N{**typereference**}"**, where "typereference" is a reference to a **charstring** or **universal charstring** type, matches any character of the character set denoted by the referenced type.

NOTE 1 – Cases when the referenced set of characters is not a true subset of values allowed by the type definition of the template or template field for which the character pattern is used, shall not be treated as an error (but e.g., matching can never occur if the two sets do not overlap).

NOTE 2 – \N{**charstring**} is equivalent to ? when the latter is applied to a template or template field of **charstring** type and \N{**universal charstring**} is equivalent to ? when the latter is applied to a template or template field of **universal charstring** type (but causes an error if applied to a template or template field of **charstring** type).

EXAMPLE:

```
type charstring MyCharRange ("a".."z");
type charstring MyCharList ("a", "z");
const MyCharRange myCharR := "r";

template charstring myTempPatt1 := pattern "\N { myCharR }";
// myTempPatt1 shall match the string "r" only

template charstring myTempPatt2 := pattern "\N { MyCharRange }";
// myTempPatt2 shall match any string containing a single character from a to z

template MyCharRange myTempPatt3 := pattern "\N { MyCharList }";
// myTempPatt3 and shall match strings "a" and "r" only

template MyCharList myTempPatt4 := pattern "\N { MyCharRange }";
// myTempPatt4 shall match strings "a" and "r" only
```

B.1.5.5 Type compatibility rules for patterns

For the purpose of referenced patterns (see clause B.1.5.2) and referenced character sets (see clause B.1.5.3) specific type compatibility rules apply: a referenced type, template, constant, variable or module parameter of the type `charstring` can always be used in the pattern specification of a template or template field of `universal charstring` type; a referenced type, template or value of the type `universal charstring` can be used in the pattern specification of a template or template field of `charstring` type if all characters used in the referenced template or value and the character set allowed by the referenced type has their corresponding characters in the `charstring` type (see definition of corresponding characters in clause 6.3.1).

Annex C

Pre-defined TTCN-3 functions

(This annex forms an integral part of this Recommendation)

This annex defines the TTCN-3 predefined functions.

C.0 General exception handling procedures

Error situations (e.g., input parameter is out of the allowed range, input parameter is of a wrong type, input value contains improper character, etc.) for which no explicit exception-handling rule is defined in the relevant clauses of this annex shall cause a TTCN-3 compile-time or run-time error. Which error situation causes compile-time and which one run-time error is a tool implementation option.

C.1 Integer to character

```
int2char(integer value) return charstring
```

This function converts an **integer** value in the range of 0 to 127 (8-bit encoding) into a single-character-length **charstring** value. The integer value describes the 8-bit encoding of the character.

C.2 Integer to universal character

```
int2unichar(integer value) return universal charstring
```

This function converts an **integer** value in the range of 0 to 2 147 483 647 (32-bit encoding) into a single-character-length **universal charstring** value. The integer value describes the 32-bit encoding of the character.

C.3 Integer to bitstring

```
int2bit(in integer value, in integer length) return bitstring
```

This function converts a single **integer** value to a single **bitstring** value. The resulting string is `length` bits long.

For the purposes of this conversion, a **bitstring** shall be interpreted as a positive base 2 **integer** value. The rightmost bit is least significant, the leftmost bit is the most significant. The bits 0 and 1 represent the decimal values 0 and 1 respectively. If the conversion yields a value with fewer bits than specified in the `length` parameter, then the **bitstring** shall be padded on the left with zeros.

C.4 Integer to hexstring

```
int2hex(in integer value, in integer length) return hexstring
```

This function converts a single **integer** value to a single **hexstring** value. The resulting string is `length` hexadecimal digits long.

For the purposes of this conversion, a **hexstring** shall be interpreted as a positive base 16 **integer** value. The rightmost hexadecimal digit is least significant, the leftmost hexadecimal digit is the most significant. The hexadecimal digits 0 to F represent the decimal values 0 to 15 respectively. If the conversion yields a value with fewer hexadecimal digits than specified in the `length` parameter, then the **hexstring** shall be padded on the left with zeros.

C.5 Integer to octetstring

```
int2oct(in integer value, in integer length) return octetstring
```

This function converts a single **integer** value to a single **octetstring** value. The resulting string is `length` octets long.

For the purposes of this conversion, an **octetstring** shall be interpreted as a positive base 16 **integer** value. The rightmost hexadecimal digit is least significant, the leftmost hexadecimal digit is the most significant. The number of hexadecimal digits provided shall be multiples of 2 since one octet is composed of two hexadecimal digits. The hexadecimal digits 0 to F represent the decimal values 0 to 15 respectively. If the conversion yields a value with fewer hexadecimal digits than specified in the `length` parameter, then the **hexstring** shall be padded on the left with zeros.

C.6 Integer to charstring

```
int2str(integer value) return charstring
```

This function converts the integer value into its string equivalent (the base of the return string is always decimal).

EXAMPLE:

```
int2str(66)      // will return the charstring value "66"

int2str(-66)     // will return the charstring value "-66"

int2str(0)       // will return the charstring value "0"
```

C.7 Integer to float

```
int2float (integer value) return float
```

This function converts an **integer** value into a **float** value.

EXAMPLE:

```
int2float(4) = 4.0
```

C.8 Float to integer

```
float2int (float value) return integer
```

This function converts a **float** value into an **integer** value by removing the fractional part of the argument and returning the resulting **integer**.

EXAMPLE:

```
float2int(3.12345E2) = float2int(312.345) = 312
```

C.9 Character to integer

```
char2int(charstring value) return integer
```

This function converts a single-character-length **charstring** value into an integer value in the range of 0 to 127. The integer value describes the 8-bit encoding of the character.

C.10 Character string to octetstring

```
char2oct (charstring invalue) return octetstring
```

This function converts a **charstring** `invalue` to an **octetstring**. Each octet of the **octetstring** will contain the [ITU-T T.50] codes (according to the IRV) of the appropriate characters of `invalue`.

EXAMPLE:

```
char2oct ("Tinky-Winky") = '54696E6B792D57696E6B79'O
```

C.11 Universal character to integer

```
unichar2int(universal charstring value) return integer
```

This function converts a single-character-length **universal charstring** value into an integer value in the range of 0 to 2 147 483 647. The integer value describes the 32-bit encoding of the character.

C.12 Bitstring to integer

```
bit2int(bitstring value) return integer
```

This function converts a single **bitstring** value to a single **integer** value.

For the purposes of this conversion, a **bitstring** shall be interpreted as a positive base 2 **integer** value. The rightmost bit is least significant, the leftmost bit is the most significant. The bits 0 and 1 represent the decimal values 0 and 1 respectively.

C.13 Bitstring to hexstring

```
bit2hex (bitstring value) return hexstring
```

This function converts a single **bitstring** value to a single **hexstring**. The resulting **hexstring** represents the same value as the **bitstring**.

For the purpose of this conversion, a **bitstring** shall be converted into a **hexstring**, where the **bitstring** is divided into groups of four bits beginning with the rightmost bit. Each group of four bits is converted into a hex digit as follows:

'0000'B → '0'H, '0001'B → '1'H, '0010'B → '2'H, '0011'B → '3'H, '0100'B → '4'H, '0101'B → '5'H, '0110'B → '6'H, '0111'B → '7'H, '1000'B → '8'H, '1001'B → '9'H, '1010'B → 'A'H, '1011'B → 'B'H, '1100'B → 'C'H, '1101'B → 'D'H, '1110'B → 'E'H, and '1111'B → 'F'H.

When the leftmost group of bits does contain less than 4 bits, this group is filled with '0'B from the left until it contains exactly 4 bits and is converted afterwards. The consecutive order of hex digits in the resulting hexstring is the same as the order of groups of 4 bits in the bitstring.

EXAMPLE:

```
bit2hex ('111010111'B)= '1D7'H
```

C.14 Bitstring to octetstring

```
bit2oct (bitstring value) return octetstring
```

This function converts a single **bitstring** value to a single **octetstring**. The resulting **octetstring** represents the same value as the **bitstring**.

For the conversion the following holds: bit2oct(value)=hex2oct(bit2hex(value)).

EXAMPLE:

```
bit2oct ('111010111'B)= '01D7'O
```

C.15 Bitstring to charstring

```
bit2str (bitstring value) return charstring
```

This function converts a single **`bitstring`** value to a single **`charstring`**. The resulting **`charstring`** has the same length as the **`bitstring`** and contains only the characters '0' and '1'.

For the purpose of this conversion, a **`bitstring`** should be converted into a **`charstring`**. Each bit of the **`bitstring`** is converted into a character '0' or '1' depending on the value 0 or 1 of the bit. The consecutive order of characters in the resulting **`charstring`** is the same as the order of bits in the **`bitstring`**.

EXAMPLE:

```
bit2str ('1110101'B) will return "1110101"
```

C.16 Hexstring to integer

```
hex2int(hexstring value) return integer
```

This function converts a single **`hexstring`** value to a single **`integer`** value.

For the purposes of this conversion, a **`hexstring`** shall be interpreted as a positive base 16 **`integer`** value. The rightmost hexadecimal digit is least significant, the leftmost hexadecimal digit is the most significant. The hexadecimal digits 0 to F represent the decimal values 0 to 15 respectively.

C.17 Hexstring to bitstring

```
hex2bit (hexstring value) return bitstring
```

This function converts a single **`hexstring`** value to a single **`bitstring`**. The resulting **`bitstring`** represents the same value as the **`hexstring`**.

For the purpose of this conversion, a **`hexstring`** shall be converted into a **`bitstring`**, where the hex digits of the **`hexstring`** are converted in groups of bits as follows:

'0'H → '0000'B, '1'H → '0001'B, '2'H → '0010'B, '3'H → '0011'B, '4'H → '0100'B, '5'H → '0101'B, '6'H → '0110'B, '7'H → '0111'B, '8'H → '1000'B, '9'H → '1001'B, 'A'H → '1010'B, 'B'H → '1011'B, 'C'H → '1100'B, 'D'H → '1101'B, 'E'H → '1110'B, and 'F'H → '1111'B.

The consecutive order of the groups of 4 bits in the resulting **`bitstring`** is the same as the order of hex digits in the **`hexstring`**.

EXAMPLE:

```
hex2bit ('1D7'H)= '000111010111'B
```

C.18 Hexstring to octetstring

```
hex2oct (hexstring value) return octetstring
```

This function converts a single **`hexstring`** value to a single **`octetstring`**. The resulting **`octetstring`** represents the same value as the **`hexstring`**.

For the purpose of this conversion, a **`hexstring`** shall be converted into a **`octetstring`**, where the **`octetstring`** contains the same sequence of hex digits as the **`hexstring`** when the length of the **`hexstring`** modulo 2 is 0. Otherwise, the resulting **`octetstring`** contains 0 as leftmost hex digit followed by the same sequence of hex digits as in the **`hexstring`**.

EXAMPLE:

```
hex2oct ('1D7'H)= '01D7'O
```

C.19 Hexstring to charstring

```
hex2str (hexstring value) return charstring
```

This function converts a single **hexstring** value to a single **charstring**. The resulting **charstring** has the same length as the **hexstring** and contains only the characters '0' to '9' and 'A' to 'F'.

For the purpose of this conversion, a **hexstring** should be converted into a **charstring**. Each hex digit of the **hexstring** is converted into a character '0' to '9' and 'A' to 'F' depending on the value 0 to 9 or A to F of the hex digit. The consecutive order of characters in the resulting **charstring** is the same as the order of digits in the **hexstring**.

EXAMPLE:

```
hex2str ('AB801'H) will return "AB801"
```

C.20 Octetstring to integer

```
oct2int(octetstring value) return integer
```

This function converts a single **octetstring** value to a single **integer** value.

For the purposes of this conversion, an **octetstring** shall be interpreted as a positive base 16 **integer** value. The rightmost hexadecimal digit is least significant, the leftmost hexadecimal digit is the most significant. The number of hexadecimal digits provided shall be multiples of 2 since one octet is composed of two hexadecimal digits. The hexadecimal digits 0 to F represent the decimal values 0 to 15 respectively.

C.21 Octetstring to bitstring

```
oct2bit (octetstring value) return bitstring
```

This function converts a single **octetstring** value to a single **bitstring**. The resulting **bitstring** represents the same value as the **octetstring**.

For the conversion the following holds: oct2bit(value)=hex2bit(oct2hex(value)).

EXAMPLE:

```
oct2bit ('01D7'O)='0000000111010111'B
```

C.22 Octetstring to hexstring

```
oct2hex (octetstring value) return hexstring
```

This function converts a single **octetstring** value to a single **hexstring**. The resulting **hexstring** represents the same value as the **octetstring**.

For the purpose of this conversion, an **octetstring** shall be converted into a **hexstring** containing the same sequence of hex digits as the **octetstring**.

EXAMPLE:

```
oct2hex ('1D74'O)= '1D74'H
```

C.23 Octetstring to character string

```
oct2str (octetstring invalue) return charstring
```

This function converts an **octetstring** invalue to a **charstring** representing the string equivalent of the input value. The resulting **charstring** shall have the same length as the incoming **octetstring**.

For the purpose of this conversion each hex digit of invalue is converted into a character '0', '1', '2', '3', '4', '5', '6', '7', '8', '9', 'A', 'B', 'C', 'D', 'E' or 'F' echoing the value of the hex digit. The consecutive order of characters in the resulting **charstring** is the same as the order of hex digits in the **octetstring**.

EXAMPLE:

```
oct2str ('4469707379'O) = "4469707379"
```

C.24 Octetstring to character string, version II

```
oct2char (octetstring invalue) return charstring
```

This function converts an **octetstring** invalue to a **charstring**. The input parameter invalue shall not contain octet values higher than 7F. The resulting **charstring** shall have the same length as the input **octetstring**. The octets are interpreted as [ITU-T T.50] codes (according to the IRV) and the resulting characters are appended to the returned value.

EXAMPLE:

```
oct2char ('4469707379'O) = "Dipsy"
```

NOTE – The character string returned may contain non-graphical characters, which cannot be presented between the double quotes.

C.25 Charstring to integer

```
str2int(charstring value) return integer
```

This function converts a **charstring** representing an **integer** value to the equivalent **integer**.

EXAMPLE:

```
str2int("66")   // will return the integer value 66

str2int("-66")  // will return the integer value -66

str2int("abc")  // will generate compiler or testcase error

str2int("0")    // will return the integer value 0
```

C.26 Character string to octetstring

```
str2oct (charstring invalue) return octetstring
```

This function converts a string of the type **charstring** to an **octetstring**. The string invalue shall contain even number characters and each shall be one of the '0', '1', '2', '3', '4', '5', '6', '7', '8', '9', 'a', 'b', 'c', 'd', 'e' 'f', 'A', 'B', 'C', 'D', 'E' or 'F' graphical characters only. The resulting **octetstring** will have the same length as the incoming **charstring**.

EXAMPLE:

```
str2oct ("54696E6B792D57696E6B79") = '54696E6B792D57696E6B79'O
```

C.27 Character string to float

```
str2float (charstring value) return float
```

This function converts a **charstring** comprising a floating-point number into a **float** value. The format of the number in the **charstring** shall follow rules in clause 6.1.0 with the following exceptions:

leading zeros are allowed,

leading '+' sign before positive values is allowed,

'-0.0' is allowed.

EXAMPLE:

```
str2float("12345.6") //  is the same as str2float("123.456E+02")
```

C.28 Length of string type

```
lengthof(any_string_type value) return integer
```

This function returns the length of a value that is of type **bitstring**, **hexstring**, **octetstring**, or any character string. The units of length for each string type are defined in Table 4.

The length of an **universal charstring** shall be calculated by counting each combining character and hangul syllable character (including fillers) on its own (see [ISO/IEC 10646], clauses 23 and 24).

EXAMPLE:

```
lengthof('010'B) // returns 3

lengthof('F3'H) // returns 2

lengthof('F2'O) // returns 1

lengthof (universal charstring : "Length_of_Example") // returns 17
```

C.29 Number of elements in a structured value

```
sizeof(any_type value) return integer
```

This function returns the actual number of elements of a module parameter, constant, variable or **template** of a **record**, **record of**, **set**, **set of** type or array (see Note). In the case of **record of** and **set of** values, templates or arrays, the actual value to be returned is the sequential number of the last defined element (index of that element plus 1).

NOTE – Only elements of the TTCN-3 object, which is the parameter of the function are calculated; i.e., no elements of nested types/values are taken into account at determining the return value.

EXAMPLE:

```
// Given
type record MyPDU
    {   boolean field1  optional,
        integer field2
    };

template MyPDU  MyTemplate
    { field1  omit,
      field2    5
    };

var integer numElements;

// then

numElements := sizeof(MyTemplate);  // returns 1
```

```
// Given
 type record length(0..10) of integer MyList;
 var MyList MyRecordVar;
 MyRecordVar := { 0, 1, omit, 2, omit };


 // then
 numElements := sizeof(MyRecordVar);
 // returns 4 without respect to the fact, that the element MyRecordVar[2] is undefined
```

C.30 Number of elements in a structured type

```
sizeoftype(any_type value) return integer
```

This function returns the declared number of elements of a module parameter, constant, variable or `template` of a `record of` or `set of` type or array (see Note). This function shall be applied to values of types with length restriction. The actual number to be returned is the sequential number of the last element without respect to whether its value is defined or not (i.e., the upper length index of the type definition on which the parameter of the function is based on plus 1).

NOTE – Only elements of the TTCN-3 object, which is the parameter of the function are calculated; i.e., no elements of nested types/values are taken into account at determining the return value.

EXAMPLE:

```
// Given
type record of integer MyPDU1;
type set length(1..8) of integer MyPDU2;
type record length(10) of integer MyPDU3;

var MyPDU1 MyRecordOfVar1;
var MyPDU2 MyRecordOfVar2;
var MyPDU3 MyRecordOfVar3;

var integer numElements;

// then
numElements := sizeoftype(MyRecordOfVar1);  // returns error as MyPDU1 is not constrained
numElements := sizeoftype(MyRecordOfVar2);  // returns 8
numElements := sizeoftype(MyRecordOfVar3);  // returns 10
```

C.31 The IsPresent function

```
ispresent(any_type value) return boolean
```

This function is allowed for `record` and `set` types only and returns the value `true` if and only if the value of the referenced field is present in the actual instance of the referenced data object. The argument to `ispresent` shall be a reference to a field of a `record` or `set` type.

```
// Given
type record MyRecord
    {   boolean field1 optional,
        integer field2
    }
// and given that MyPDU is a template of MyRecord type
// and received_PDU is also of MyRecord type
// then
MyPort.receive(MyPDU) -> value received_PDU
ispresent(received_PDU.field1)
// returns true if field1 in the actual instance of MyPDU is present
```

C.32 The IsChosen function

```
ischosen(any_type value) return boolean
```

This function returns the value `true` if and only if the data object reference specifies the variant of the `union` type that is actually selected for a given data object.

EXAMPLE:

```
// Given
type union MyUnion
    {   PDU_type1   p1,
        PDU_type2   p2,
        PDU_type    p3
    }

// and given that MyPDU is a template of MyUnion type
// and received_PDU is also of MyUnion type
// then
MyPort.receive(MyPDU) -> value received_PDU
ischosen(received_PDU.p2)
// returns true if the actual instance of MyPDU carries a PDU of the type PDU_type2
```

C.33 The Regexp function

```
    regexp (any_character_string_type instr, any_character_string_type expression, integer groupno)
return  any_character_string_type
```

This function returns the substring of the input character string `instr`, which is the content of n-th group matching to the `expression`. In input string `instr` may be of any character string type. The type of the character string returned is the root type of `instr`. The expression is a character pattern as described in clause B.1.5. The number of the group to be returned is specified by `groupno`, which shall be a positive integer. Group numbers are assigned by the order of occurrences of the opening bracket of a group and counted starting from 0 by step 1. If no substring fulfilling all conditions (i.e., pattern and group number) is found within the input string, an empty string is returned.

EXAMPLE:

```
// Given
var charstring mypattern2 := "
var charstring  myinput := "      date: 2001-10-20 ;  msgno: 17; exp  "
var charstring mypattern := "[ /t]#(,)date:[ \d\-]#(,);[ /t]#(,)msgno: (\d#(1,3)); (exp)#(0,1)"

// Then the expression
var charstring mystring := regexp(myinput, mypattern,1)
//will return the value "17".
```

C.34 The Substring function

```
substr (any_string_type value, in integer index, in integer returncount) return
input_string_type
```

This function returns a substring from a value that is of type **`bitstring`**, **`hexstring`**, **`octetstring`**, or any character string. The type of the substring is the root type of the input value. The starting point of substring to return is defined by the second in parameter (index). Indexing starts from zero. The third input parameter defines the length of the substring to be returned. The units of length are as defined in Table 4.

EXAMPLE:

```
substr ('00100110'B, 3, 4)      // returns '0011'B

substr ('ABCDEF'H, 2, 3)        // returns 'CDE'H

substr ('01AB23CD'O, 1, 2)      // returns 'AB23'O

substr ("My name is JJ", 11, 2) // returns "JJ"
```

C.35 The Replace function

```
replace (in any_string_type str, in integer ind, in integer len, in any_string_type repl)
return any_string_type
```

This function replaces the substring of value **`str`** at index **`ind`** of length **`len`** with the string value **`repl`** and returns the resulting string. **`str`** shall not be modified. If **`len`** is **`0`** the string **`repl`** is inserted. If **`ind`** is **`0`**, **`repl`** is inserted at the beginning of **`str`**. If **`ind`** is **`lengthof(str)`**, **`repl`** is inserted at the end of **`str`**. **`str`** and **`repl`** shall be of the same string type and shall have as base type **`bitstring`**, **`hexstring`**, **`octetstring`**, or any character string. The returned string is of the same type as **`str`** and **`repl`**. Note that indexing in strings starts from zero.

The following error cases will lead to an error at compile or runtime:

- **`str`** or **`repl`** are not of string type;
- **`str`** and **`repl`** are of different type;
- **`ind`** is less than **`0`** or greater than **`lengthof(str)`**;
- **`len`** is less than **`0`** or greater than **`lengthof(str)`**;
- **`ind+len`** is greater than **`lengthof(str)`**.

EXAMPLE:

```
replace ('00000110'B, 1, 3, '111'B)     // returns '01110110'B

replace ('ABCDEF'H, 0, 2, '123'H)       // returns '123CDEF'H

replace ('01AB23CD'O, 2, 1, 'FF96'O)    // returns '01ABFF96CD'O

replace ("My name is JJ", 11, 1, "xx")  // returns "My name is xxJ"

replace ("My name is JJ", 11, 0, "xx")  // returns "My name is xxJJ"

replace ("My name is JJ", 2, 2, "x")    // returns "Myxame is JJ"

replace ("My name is JJ", 12, 2, "xx")  // produces test case error

replace ("My name is JJ", 13, 2, "xx")  // produces test case error

replace ("My name is JJ", 13, 0, "xx")  // returns "My name is JJxx"
```

C.36 The random number generator function

```
rnd ([float seed]) return float
```

The **`rnd`** function returns a (pseudo) random number less than 1 but greater than or equal to 0. The random number generator is initialized by means of an optional seed value. Afterwards, if no new seed is provided, the last generated number will be used as seed for the next random number. Without a previous initialization a value calculated from the system time will be used as seed value when **`rnd`** is used the first time.

NOTE – Each time the **`rnd`** function is initialized with the same seed value, it shall repeat the same sequence of random numbers.

To produce a random integers in a given range, the following formula can be used:

```
float2int(int2float(upperbound - lowerbound +1)*rnd()) + lowerbound
// Here, upperbound and lowerbound denote highest and lowest number in range.
```

Annex D

Library of useful types

(This annex is informative)

D.1 Limitations

Names of types added to this library should be unique within the whole language and within the library (i.e., should not be one of the names defined in Annex C). Names defined in this library should not be used by TTCN-3 users as identifiers of other definitions than given in this annex.

NOTE – Therefore type definitions given in this annex may be repeated in TTCN-3 modules but no type distinct from the one specified in this annex can be defined with one of the identifiers used in this annex.

D.2 Useful TTCN-3 types

D.2.1 Useful simple basic types

D.2.1.0 Signed and unsigned single byte integers

These types support integer values of the range from –128 to 127 for the signed type and from 0 to 255 for the unsigned type. The value notation for these types is the same as the value notation for the integer type. Values of these types shall be encoded and decoded as they were represented on a single byte within the system independently from the actual representation form used.

NOTE – Encoding of values of these types may be the same or may differ from each other and from the encoding of the integer type (the root type of these useful types) depending on the actual encoding rules used. Details of encoding rules are out of the scope of this Recommendation.

Type definitions for these types are:

```
type integer    byte            (-128 .. 127)   with { variant "8 bit" };

type integer    unsignedbyte    (0 .. 255)      with { variant "unsigned 8 bit" };
```

D.2.1.1 Signed and unsigned short integers

These types support integer values of the range from –32 768 to 32 767 for the signed type and from 0 to 65 535 for the unsigned type. The value notation for these types is the same as the value notation for the integer type. Values of these types shall be encoded and decoded as they were represented on two bytes within the system independently from the actual representation form used.

NOTE – Encoding of values of these types may be the same or may differ from each other and from the encoding of the integer type (the root type of these useful types) depending on the actual encoding rules used. Details of encoding rules are out of the scope of this Recommendation.

Type definitions for these types are:

```
type integer    short           (-32768 .. 32767)   with { variant "16 bit" };

type integer    unsignedshort   (0 .. 65535)        with { variant "unsigned 16 bit" };
```

D.2.1.2 Signed and unsigned long integers

These types support integer values of the range from –2 147 483 648 to 2 147 483 647 for the signed type and from 0 to 4 294 967 295 for the unsigned type. The value notation for these types is the same as the value notation for the integer type. Values of these types shall be encoded and decoded as they were represented on four bytes within the system independently from the actual representation form used.

NOTE – Encoding of values of these types may be the same or may differ from each other and from the encoding of the integer type (the root type of these useful types) depending on the actual encoding rules used. Details of encoding rules are out of the scope of this Recommendation.

Type definitions for these types are:

```
type integer    long    (-2147483648 .. 2147483647)
                with { variant "32 bit" };

type integer    unsignedlong    (0 .. 4294967295)
                with { variant "unsigned 32 bit" };
```

D.2.1.3 Signed and unsigned longlong integers

These types support integer values of the range from –9 223 372 036 854 775 808 to 9 223 372 036 854 775 807 for the signed type and from 0 to 18 446 744 073 709 551 615 for the unsigned type. The value notation for these types is the same as the value notation for the integer type. Values of these types shall be encoded and decoded as they were represented on eight bytes within the system independently from the actual representation form used.

NOTE – Encoding of values of these types may be the same or may differ from each other and from the encoding of the integer type (the root type of these useful types) depending on the actual encoding rules used. Details of encoding rules are out of the scope of this Recommendation.

Type definitions for these types are:

```
type integer    longlong    (-9223372036854775808 .. 9223372036854775807)
                with { variant "64 bit" };

type integer    unsignedlonglong    (0 .. 18446744073709551615)
                with { variant "unsigned 64 bit" };
```

D.2.1.4 IEEE 754 floats

These types support the ANSI/IEEE Standard 754 [IEEE 754] for binary floating-point arithmetic. The type IEEE 754 float supports floating-point numbers with base 10, exponent of size 8, mantissa of size 23 and a sign bit. The type IEEE 754 double supports floating-point numbers with base 10, exponent of size 11, mantissa of size 52 and a sign bit. The type IEEE 754 `extfloat` supports floating-point numbers with base 10, minimal exponent of size 11, minimal mantissa of size 32 and a sign bit. The type IEEE 754 `extdouble` supports floating-point numbers with base 10, minimal exponent of size 15, minimal mantissa of size 64 and a sign bit.

Values of these types shall be encoded and decoded according to the IEEE 754 definitions. The value notation for these types are the same as the value notation for the float type (base 10).

NOTE – Precise encoding of values of this type depends on the actual encoding rules used. Details of encoding rules are out of the scope of this Recommendation.

Type definitions for these types are:

```
type    float   IEEE754float        with { variant "IEEE754 float" };

type    float   IEEE754double       with { variant "IEEE754 double" };

type    float   IEEE754extfloat     with { variant "IEEE754 extended float" };

type    float   IEEE754extdouble    with { variant "IEEE754 extended double" };
```

D.2.2 Useful character string types

D.2.2.0 UTF-8 character string "utf8string"

This type supports the whole character set of the TTCN-3 type **`universal charstring`** (see paragraph d) of clause 6.1.1). Its distinguished values are zero, one, or more characters from this set. Values of this type shall entirely (e.g., each character of the value individually) be encoded and decoded according to the UCS Transformation Format 8 (UTF-8) as defined in Annex R of [ISO/IEC 10646]. The value notation for this type is the same as the value notation for the **universal charstring** type.

The type definition for this type is:

```
type universal charstring utf8string with { variant "UTF-8" };
```

D.2.2.1 BMP character string "bmpstring"

This type supports the Basic Multilingual Plane (BMP) character set of [ISO/IEC 10646]. The BMP represents all characters of plane 00 of group 00 of the Universal Multiple-octet coded Character Set. Its distinguished values are zero, one, or more characters from the BMP. Values of this type shall entirely (e.g., each character of the value individually) be encoded and decoded according to the UCS-2 coded representation form (see clause 14.1 of [ISO/IEC 10646]). The value notation for this type is the same as the value notation for the **universal charstring** type.

NOTE – The type "bmpstring" supports a subset of the TTCN-3 type **universal charstring**.

The type definition for this type is:

```
type universal charstring bmpstring ( char ( 0,0,0,0 ) .. char ( 0,0,255,255) )
                                    with { variant "UCS-2" };
```

D.2.2.2 UTF-16 character string "utf16string"

This type supports all characters of planes 00 to 16 of group 00 of the Universal Multiple-octet coded Character Set (see [ISO/IEC 10646]). Its distinguished values are zero, one, or more characters from this set. Values of this type shall entirely (e.g., each character of the value individually) be encoded and decoded according to the UCS Transformation Format 16 (UTF-16) as defined in Annex Q of [ISO/IEC 10646]. The value notation for this type is the same as the value notation for the **universal charstring** type.

NOTE – The type "utf16string" supports a subset of the TTCN-3 type **universal charstring.**

The type definition for this type is:

```
type universal charstring utf16string   ( char ( 0,0,0,0 ) .. char ( 0,16,255,255) )
                                        with { variant "UTF-16" };
```

D.2.2.3 ISO/IEC 8859 character string "iso8859string"

This type supports all characters in all alphabets defined in the multiparty standard ISO/IEC 8859. Its distinguished values are zero, one, or more characters from the ISO/IEC 8859 character set. Values of this type shall entirely (e.g., each character of the value individually) be encoded and decoded according to the coded representation as specified in ISO/IEC 8859 (an 8-bit coding). The value notation for this type is the same as the value notation for the **universal charstring** type.

NOTE 1 – The type "iso8859string" supports a subset of the TTCN-3 type **universal charstring.**

NOTE 2 – In each ISO/IEC 8859 alphabet the lower part of the character set table (positions 02/00 to 07/14) is compatible with the [ITU-T T.50] character set. Hence all extra language specific characters are defined for the upper part of the character table only (positions 10/00 to 15/15). As the "iso8859string" type is defined as a subset of the TTCN-3 type universal charstring, any coded character representation of any ISO/IEC 8859 alphabets can be mapped into an equivalent character (a character with the same coded representation when encoded on 8 bits) from the Basic Latin or Latin-1 Supplement character tables of [ISO/IEC 10646].

The type definition for this type is:

```
type universal charstring iso8859string ( char ( 0,0,0,0 ) .. char ( 0,0,0,255) )
                                        with { variant "8 bit" };
```

D.2.3 Useful structured types

D.2.3.0 Fixed-point decimal literal

This type supports the use of fixed-point decimal literal as defined in the IDL Syntax and Semantics version 2.6 (see [b-OMG]). It is specified by an integer part, a decimal point and a fraction part. The integer and fraction parts both consist of a sequence of decimal (base 10) digits. The number of digits is stored in "digits" and the size of the fraction part is given in "scale". The digits themselves are stored in "value_". Value notation for this type is the same as the value notation for the record type. Values of this type shall be encoded and decoded as IDL fixed point decimal values.

NOTE – Precise encoding of values of this type depends on the actual encoding rules used. Details of encoding rules are out of the scope of this Recommendation.

The type definition for this type is:

```
type record IDLfixed {
                        unsignedshort   digits,
                        short   scale,
                        charstring  value_
                    }
                    with { variant "IDL:fixed FORMAL/01-12-01 v.2.6" };
```

D.2.4 Useful atomic string types

D.2.4.1 Single ISO 646 character type

A type whose distinguished values are single characters of the version of [ITU-T T.50] complying to the International Reference Version (IRV) as specified in clause 8.2 of [ITU-T T.50] (see also Note 1 to clause 6.1.1).

The type definition for this type is:

```
type charstring char length (1);
```

NOTE 1 – The name of this useful type is the same as the TTCN-3 keyword used to denote **universal charstring** values in the quadruple form. In general, it is disallowed to use TTCN-3 keywords as identifiers. The "char" useful type is a solitary exception and allowed only for backward compatibility with previous versions of the TTCN-3 standard.

NOTE 2 – The special string "8 bit" defined in clause 27.5 may be used with this type to specify a given encoding for its values. Also, other properties of the base type can be changed by using attribute mechanisms.

D.2.4.2 Single universal character type

A type whose distinguished values are single characters from [ISO/IEC 10646].

The type definition for this type is:

```
type universal charstring uchar length (1);
```

NOTE – Special strings defined in clause 27.5 except "8 bit" may be used with this type to specify a given encoding for its values. Also, other properties of the base type can be changed by using attribute mechanisms.

D.2.4.3 Single bit type

A type whose distinguished values are single binary digits.

The type definition for this type is:

```
type bitstring bit length (1);
```

D.2.4.4 Single hex type

A type whose distinguished values are single hexadecimal digits.

The type definition for this type is:

```
    type hexstring hex length (1);
```

D.2.4.5 Single octet type

A type whose distinguished values are pairs of hexadecimal digits.

The type definition for this type is:

```
    type octetstring octet length (1);
```

Annex E

Operations on TTCN-3 active objects

(This annex is informative)

This annex describes in a short form the semantics of operations on active objects in TTCN-3 being test components, timers and ports. This dynamic behaviour is written in the form of state machines with:

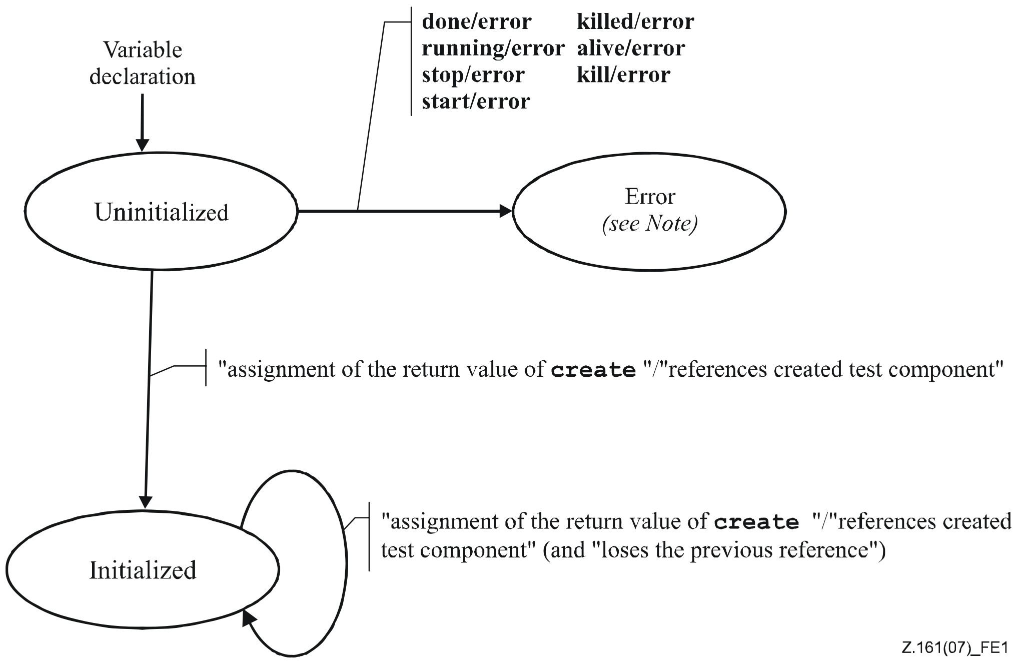
- the states being named and identified as nodes;
- the initial state being identified by an incoming arrow;
- transitions between states connecting two states (not necessarily different states) and identified as arrows;
- transitions being marked with the enabling condition for that transition (i.e., operation or statement calls) and the resulting condition (for example a test case error), both are separated by '/':
  - operation and statement calls are the TTCN-3 operations and statements applicable to the object (written in bold);
  - error as a resulting condition means testcase error (written in bold);
  - null as a resulting condition means that except for a possible state change, no other results apply (written in bold);
  - match/no match refers to the matching result of a transition (written in bold);
  - concrete values are boolean or float results (written in bold italics);
  - all other resulting conditions are textually described (written in standard font);
- notes are used to explain further details of the state machine.

For further details, please refer to the operational semantics of TTCN-3 [ITU-T Z.164]. In case of any contradiction between this annex and the operational semantics of TTCN-3 [ITU-T Z.164] the latter takes precedence.

E.1 Test components

E.1.1 Test component references

Variables of test component types, the **`self`** and **`mtc`** operations are used to reference test components. The **`start`**, **`stop`**, **`done`** and **`running`** operations are not directly applied on test components but on component references. The test system shall decide if the operation requested shall effect the component object itself or other action is appropriate (e.g., an error occurs when the reference of a stopped PTC is used in a component start operation). The **`create`** operation used to create PTCs returns a unique reference to the created PTC, which is typically bound to a test component variable. The behaviour related to test component variables themselves is shown in Figure E.1.



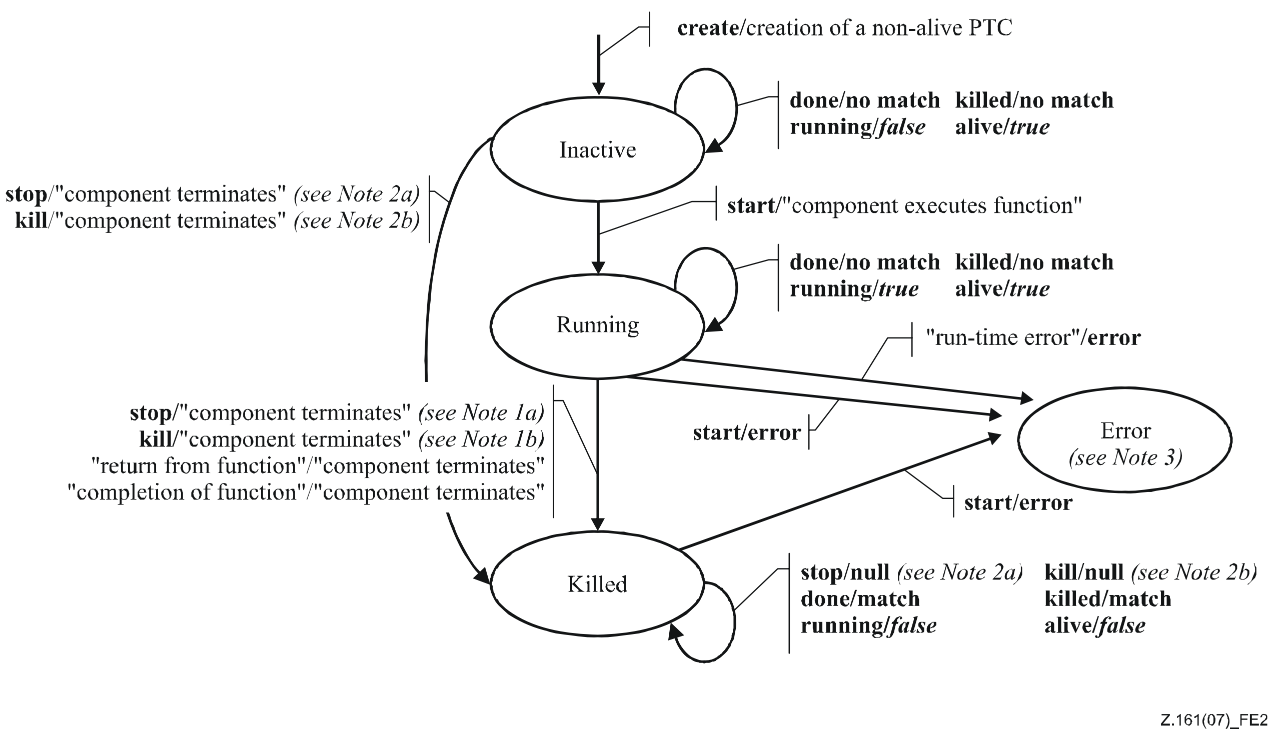
Variable declaration
done/error
running/error
stop/error
start/error
killed/error
alive/error
kill/error
Uninitialized
Error
(see Note)
"assignment of the return value of create "/"references created test component"
Initialized
"assignment of the return value of create "/"references created test component" (and "loses the previous reference")
Z.161(07)_FE1

NOTE – Whenever a test component enters its error state, the error verdict is assigned to its local verdict, the test case terminates and the overall test case result will be an error.

Figure E.1 – Handling of test component references

E.1.2 Dynamic behaviour of PTCs

PTCs can be of non-alive type or alive-type. Non-alive type PTCs can be in Inactive, Running and Killed states. Their dynamic behaviour is shown in Figure E.2.


create/creation of a non-alive PTC
Inactive
done/no match killed/no match
running/false alive/true
stop/"component terminates" (see Note 2a)
kill/"component terminates" (see Note 2b)
start/"component executes function"
Running
done/no match killed/no match
running/true alive/true
"run-time error"/error
stop/"component terminates" (see Note 1a)
kill/"component terminates" (see Note 1b)
"return from function"/"component terminates"
"completion of function"/"component terminates"
start/error
Error
(see Note 3)
start/error
Killed
stop/null (see Note 2a) kill/null (see Note 2b)
done/match killed/match
running/false alive/false
Z.161(07)_FE2

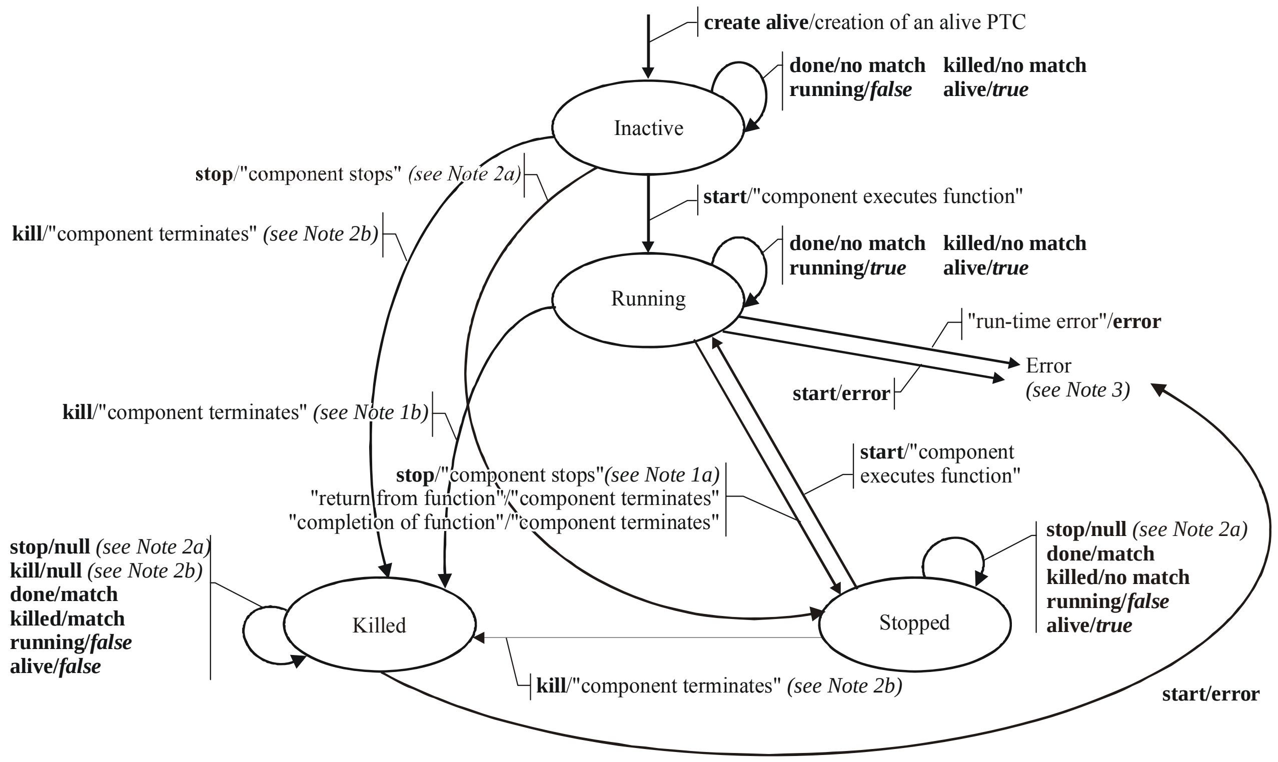
NOTE 1 – a) Stop can be either a stop, self.stop or a stop from another test component.
b) Kill can be either a kill, self.kill, a kill from another test component or a kill from the test system (in error cases).

NOTE 2 – a) Stop can be from another test component only.
b) Kill can be from another test component or from the test system (in error cases) only.

NOTE 3 – Whenever a test component enters its error state, the error verdict is assigned to its local verdict, the test case terminates and the overall test case result will be an error.

Figure E.2 – Dynamic behaviour of non-alive type PTCs

Alive-type PTCs can be in Inactive, Running, Stopped and Killed states. Their dynamic behaviour is shown in Figure E.3.



create alive/creation of an alive PTC
done/no match killed/no match
running/false alive/true
Inactive
stop/"component stops" (see Note 2a)
kill/"component terminates" (see Note 2b)
start/"component executes function"
done/no match killed/no match
running/true alive/true
Running
"run-time error"/error
Error
(see Note 3)
start/error
kill/"component terminates" (see Note 1b)
start/"component executes function"
stop/"component stops"(see Note 1a)
"return from function"/"component terminates"
"completion of function"/"component terminates"
stop/null (see Note 2a)
kill/null (see Note 2b)
done/match
killed/match
running/false
alive/false
Killed
Stopped
stop/null (see Note 2a)
done/match
killed/no match
running/false
alive/true
kill/"component terminates" (see Note 2b)
start/error

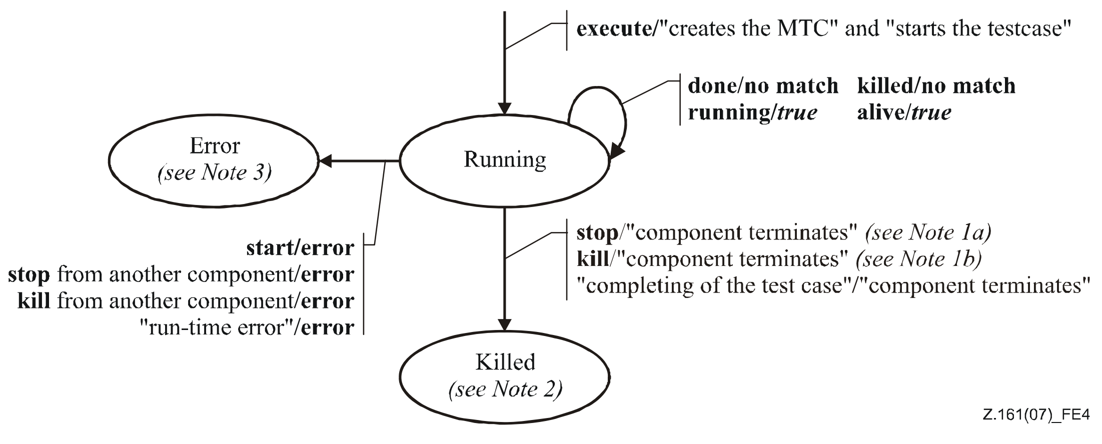
NOTE 1 – a) Stop can be either a stop, self.stop or a stop from another test component.
b) Kill can be either a kill, self.kill, a kill from another test component or a kill from the test system (in error cases).
NOTE 2 – a) Stop can be from another test component only.
b) Kill can be from another test component or from the test system (in error cases) only.
NOTE 3 – Whenever a test component enters its error state, the error verdict is assigned to its local verdict, the test case terminates and the overall test case result will be an error.

Z.161(07)_F.E3

Figure E.3 – Dynamic behaviour of alive-type PTCs

E.1.3 Dynamic behaviour of the MTC

The MTC can be in Running or Killed state. The dynamic behaviour of the MTC is shown in Figure E.4.



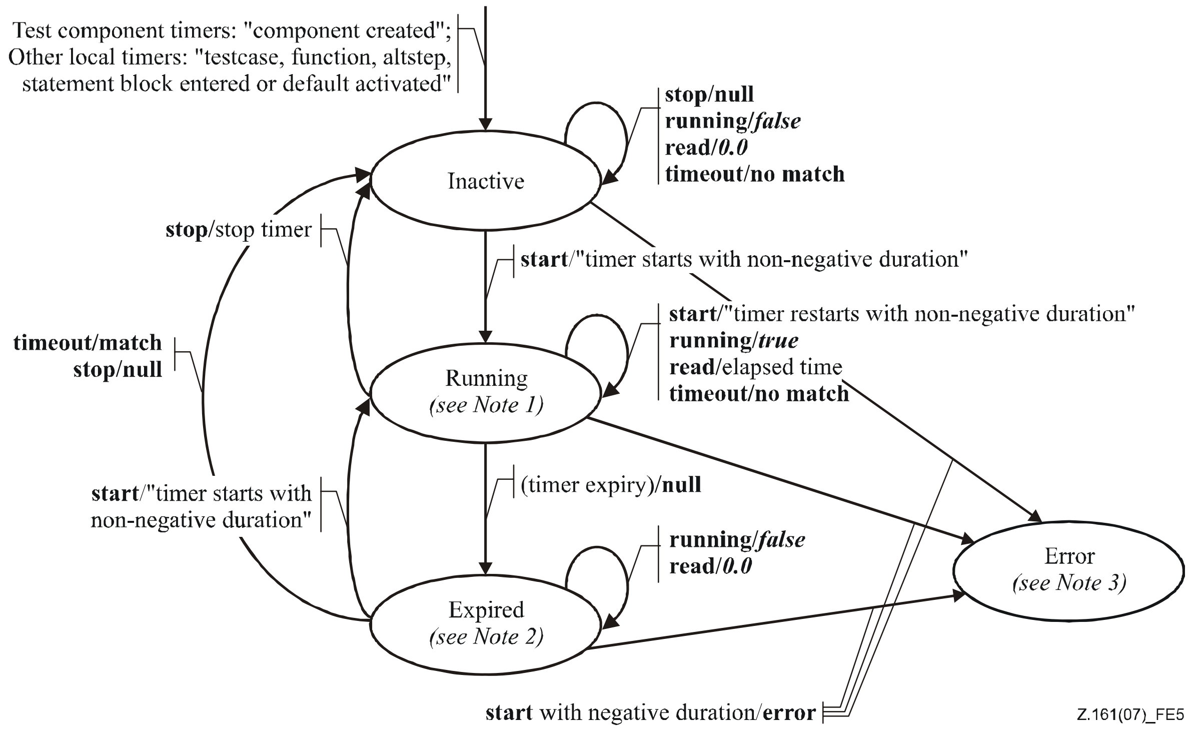
execute/"creates the MTC" and "starts the testcase"
done/no match killed/no match
running/true alive/true
Error
(see Note 3)
Running
start/error
stop from another component/error
kill from another component/error
"run-time error"/error
stop/"component terminates" (see Note 1a)
kill/"component terminates" (see Note 1b)
"completing of the test case"/"component terminates"
Killed
(see Note 2)
Z.161(07)_FE4

NOTE 1 – a) Stop can be either a stop, self.stop, a stop from another test component.
b) Kill can be either a kill, self.kill, a kill from another test component or a kill from the test system (in error cases).
NOTE 2 – All remaining PTCs shall be killed as well and the testcase terminates.
NOTE 3 – Whenever the MTC enters its error state, the error verdict is assigned to its local verdict, the test case terminates and the overall test case result will be an error.

Figure E.4 – Dynamic behaviour of the MTC

E.2 Timers

Timers can be in Inactive, Running or Expired state. The dynamic behaviour of a timer is shown in Figure E.5.



Test component timers: "component created";
Other local timers: "testcase, function, altstep, statement block entered or default activated"
stop/null
running/*false*
read/*0.0*
timeout/no match
Inactive
stop/stop timer
start/"timer starts with non-negative duration"
start/"timer restarts with non-negative duration"
running/*true*
read/elapsed time
timeout/no match
timeout/match
stop/null
Running
(see Note 1)
(timer expiry)/null
start/"timer starts with non-negative duration"
running/*false*
read/*0.0*
Error
(see Note 3)
Expired
(see Note 2)
start with negative duration/error
Z.161(07)_FE5

NOTE 1 – For any scope unit, all timers in that scope being in Running state constitute the running-timer list.
NOTE 2 – For any scope unit, all timers in that scope being in Expired state constitute the timeout-list.
NOTE 3 – Whenever a timer enters its error state, the test component it belongs to enters also its error state, assigns a local error verdict, the test case terminates and the overall test case result will be an error.

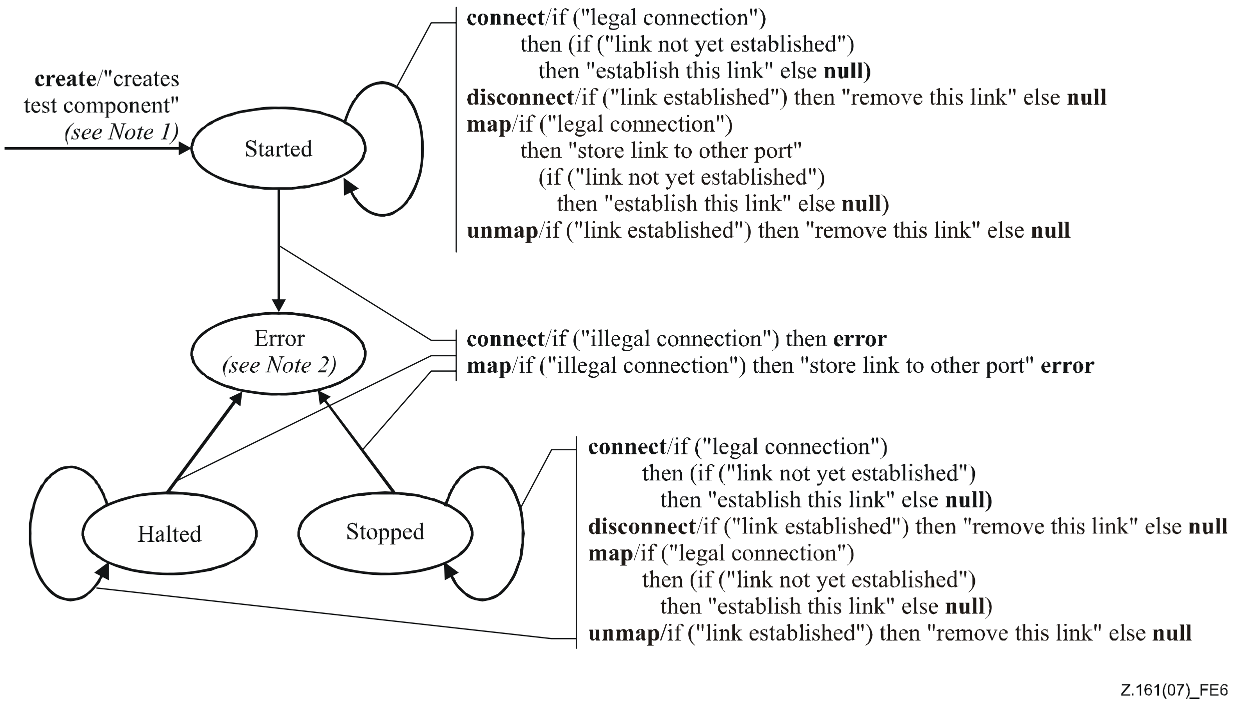
Figure E.5 – Dynamic behaviour of timers

E.3 Ports

Ports can be in Started or Stopped state. As their behaviour is rather complex, the state machine has been split into a state machine giving the dynamic behaviour of configuration operations (i.e., connect, disconnect, map and unmap), of port controlling operations (i.e., start, stop, and clear) and of communication operations (i.e., send, receive, call, getcall, raise, catch, reply, getreply, and check). As trigger is a shorthand for an alt together with receive, it is not considered here.

E.3.1 Configuration operations

The port configuration operations (i.e., connect, disconnect, map, and unmap) are indifferent to the state of the port. They show the behaviour shown in Figure E.6.


create/"creates test component" *(see Note 1)*
Started
Error *(see Note 2)*
Halted
Stopped
connect/if ("legal connection") then (if ("link not yet established") then "establish this link" else **null)**
disconnect/if ("link established") then "remove this link" else **null**
map/if ("legal connection") then "store link to other port" (if ("link not yet established") then "establish this link" else **null**)
unmap/if ("link established") then "remove this link" else **null**
connect/if ("illegal connection") then **error**
map/if ("illegal connection") then "store link to other port" **error**
connect/if ("legal connection") then (if ("link not yet established") then "establish this link" else **null)**
disconnect/if ("link established") then "remove this link" else **null**
map/if ("legal connection") then (if ("link not yet established") then "establish this link" else **null**)
unmap/if ("link established") then "remove this link" else **null**
Z.161(07)_FE6

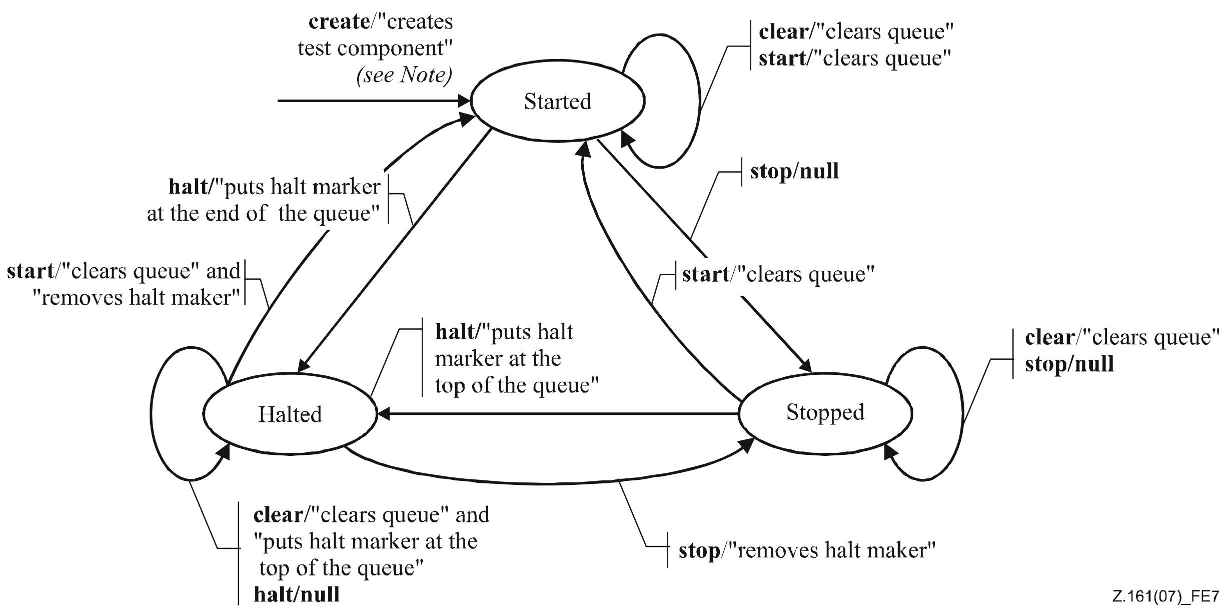
NOTE 1 – When creating a PTC, the ports of that PTC are created and started; when creating the MTC, the ports of the MTC and the ports of the TSI are created and started.
NOTE 2 – Whenever a port enters its error state, the test component it belongs to enters also its error state, assigns a local error verdict, the test case terminates and the overall test case result will be an error.

Figure E.6 – Dynamic behaviour of ports: port configuration operations

The transitions do not change the main state of the port, i.e., the port remains in the Started or Stopped state.

E.3.2 Port controlling operations

The results of port controlling operations are shown in Figure E.7.

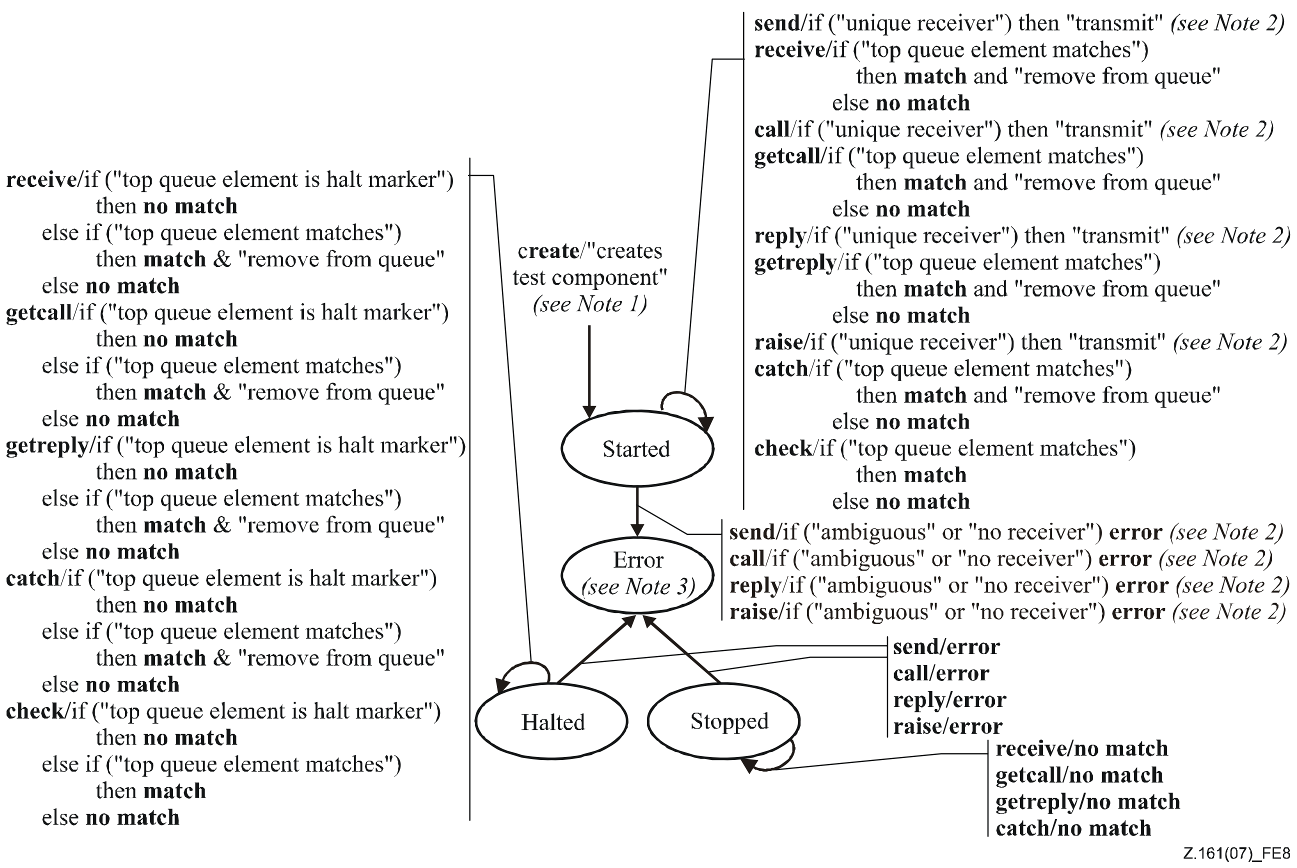

create/"creates test component" (see Note)
Started
clear/"clears queue"
start/"clears queue"
stop/null
halt/"puts halt marker at the end of the queue"
start/"clears queue" and "removes halt maker"
start/"clears queue"
halt/"puts halt marker at the top of the queue"
clear/"clears queue"
stop/null
Halted
Stopped
clear/"clears queue" and "puts halt marker at the top of the queue"
halt/null
stop/"removes halt maker"
Z.161(07)_FE7

NOTE – When creating a PTC, the ports of that PTC are created and started; when creating the MTC, the ports of the MTC and the ports of the TSI are created and started.

Figure E.7 – Dynamic behaviour of ports: port controlling operations

E.3.3 Communication operations

The results of the communication operations send, receive, call, getcall, raise, catch, reply, getreply, check are shown in Figure E.8.


send/if ("unique receiver") then "transmit" (see Note 2)
receive/if ("top queue element matches") then match and "remove from queue" else no match
call/if ("unique receiver") then "transmit" (see Note 2)
getcall/if ("top queue element matches") then match and "remove from queue" else no match
reply/if ("unique receiver") then "transmit" (see Note 2)
getreply/if ("top queue element matches") then match and "remove from queue" else no match
raise/if ("unique receiver") then "transmit" (see Note 2)
catch/if ("top queue element matches") then match and "remove from queue" else no match
check/if ("top queue element matches") then match else no match
receive/if ("top queue element is halt marker") then no match else if ("top queue element matches") then match & "remove from queue" else no match
getcall/if ("top queue element is halt marker") then no match else if ("top queue element matches") then match & "remove from queue" else no match
getreply/if ("top queue element is halt marker") then no match else if ("top queue element matches") then match & "remove from queue" else no match
catch/if ("top queue element is halt marker") then no match else if ("top queue element matches") then match & "remove from queue" else no match
check/if ("top queue element is halt marker") then no match else if ("top queue element matches") then match else no match
create/"creates test component" (see Note 1)
Started
Error (see Note 3)
Halted
Stopped
send/if ("ambiguous" or "no receiver") error (see Note 2)
call/if ("ambiguous" or "no receiver") error (see Note 2)
reply/if ("ambiguous" or "no receiver") error (see Note 2)
raise/if ("ambiguous" or "no receiver") error (see Note 2)
send/error
call/error
reply/error
raise/error
receive/no match
getcall/no match
getreply/no match
catch/no match
Z.161(07)_FE8

NOTE 1 – When creating a PTC, the ports of that PTC are created and started; when creating a MTC, the ports of the MTC and the ports of the TSI are created and started.
NOTE 2 – A unique receiver exists if there is only one link for this port or if the to address expression references a test component whose port is linked to this port (a terminated test component is not a legal receiver).
NOTE 3 – Whenever a port enters its error state, the test component it belongs to enters also its error state, assigns a local error verdict, the test case terminates and the overall test case result will be an error.
NOTE 4 – As trigger is a shorthand for an alt together with receive, it is not considered here.

Figure E.8 – Dynamic behaviour of ports: communication operations

Annex F

Deprecated language features

(This annex is informative)

F.1 Group style definition of module parameters

The previous version of this Recommendation required to use a group-like syntax shown in the example below to declare module parameters. The module parameter syntax has been unified with constant and variable declaration syntax in this version but group-like syntax is not fully removed to leave a time period for tool providers and users to change from the old syntax to the new one. The group-like syntax of module parameter declarations is planned to be fully removed in the next published edition of this Recommendation.

EXAMPLE (superfluous syntax):

```
module MyModuleWithParameters
{
    modulepar { integer TS_Par0, TS_Par1 := 0;
                boolean TS_Par2 := true
            "};
    modulepar { hexstring TS_Par3 };
}
```

F.2 Recursive import

The previous version of this Recommendation allowed to import named definitions implicitly, via importing other definitions of the same module using them in a recursive mode. This feature is deprecated in this edition of this Recommendation and is planned to be fully removed in the next published edition.

F.3 Using `all` in port type definitions

The previous edition of this Recommendation allowed to use the **`all`** keyword in port type definitions instead of an explicit list of types and signatures allowed via the given port. This feature is deprecated in this edition of this Recommendation and is planned to be fully removed in the next published edition.

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[b-ETSI 201 873-1] ETSI ES 201 873-1 V2.2.1 (2003), *Methods for Testing and Specification (MTS); The Testing and Test Control Notation version 3; Part 1: TTCN-3 Core Language*.

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[b-ISO/IEC 8859-1] ISO/IEC 8859-1:1998, *Information technology – 8-bit single-byte coded graphic character sets – Part 1: Latin alphabet No. 1*.

[b-OMG] Object Management Group (OMG): *The Common Object Request Broker: Architecture and Specification – IDL Syntax and Semantics*. Version 2.6, FORMAL/01-12-01, December 2001.

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