TTCN-3 COURSE

PRESENTATION MATERIAL

TEST COMPETENCE CENTER
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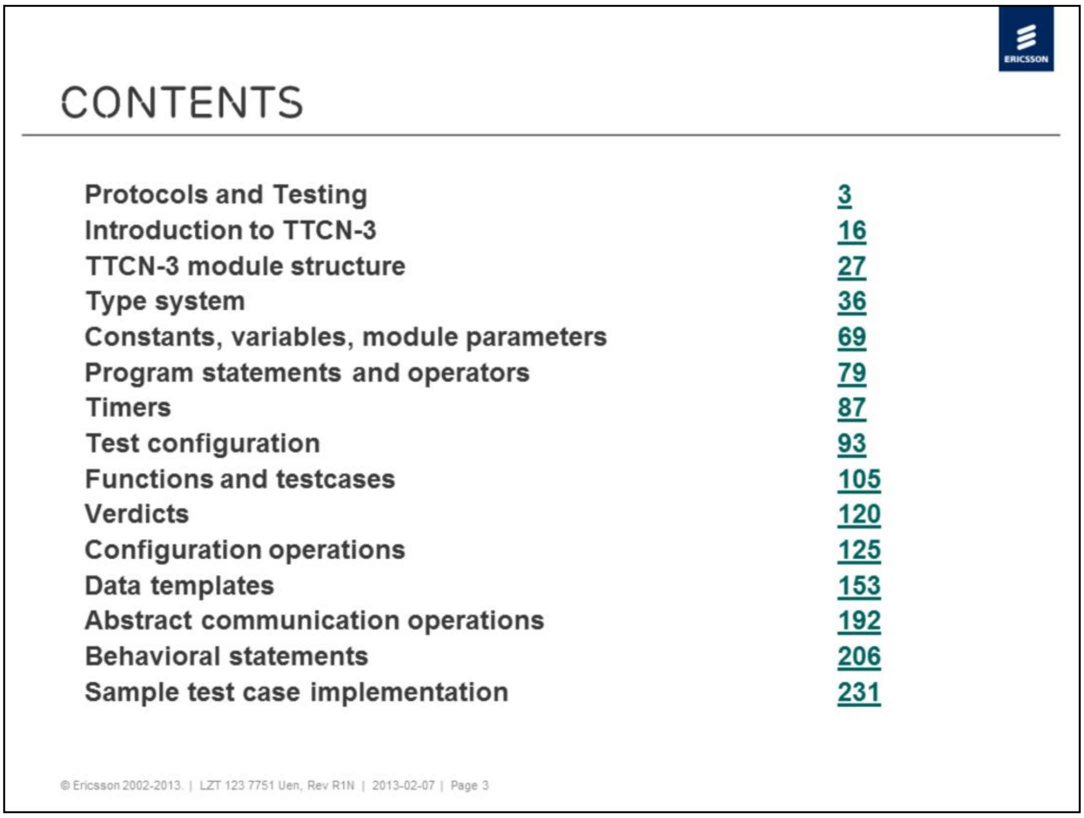

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I. PROTOCOLS AND TESTING

WHAT IS "PROTOCOL"?
DEFINITIONS
PROTOCOL VERIFICATION, TESTING AND VALIDATION

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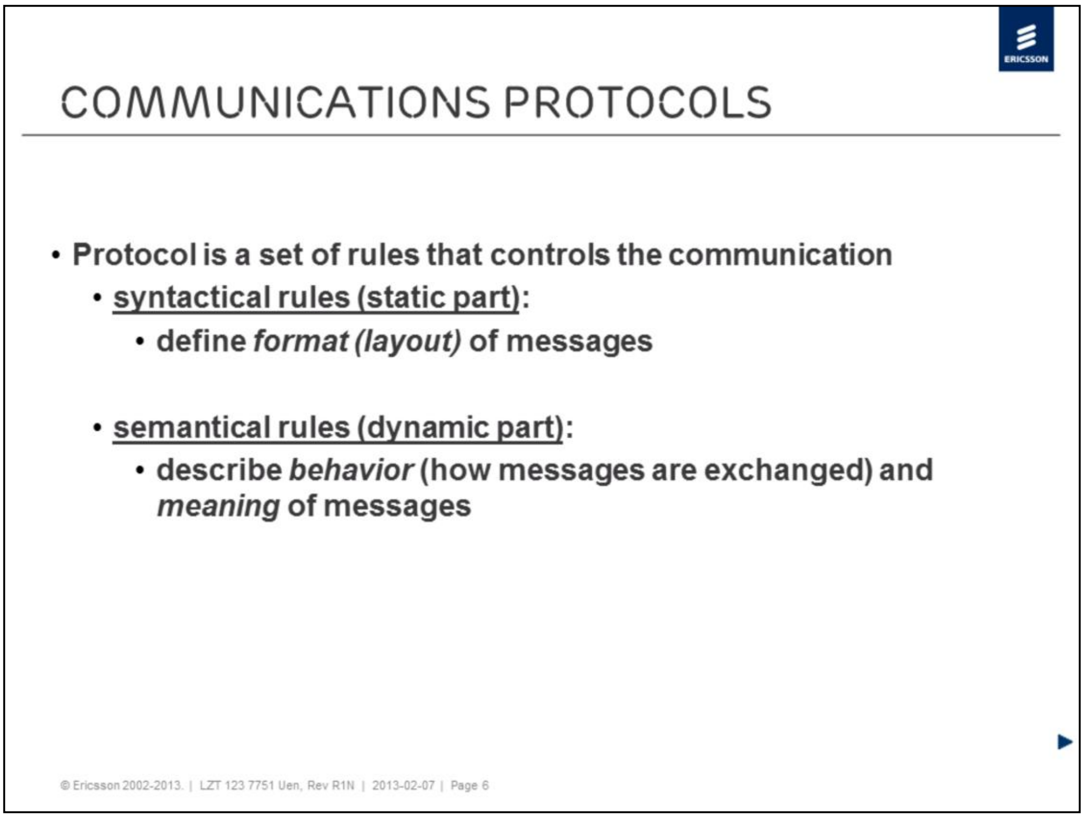
PROTOCOL



COMMUNICATIONS PROTOCOLS

- Protocol is a set of rules that controls the communication
  - syntactical rules (static part):
    - define *format (layout)* of messages
  - semantical rules (dynamic part):
    - describe *behavior* (how messages are exchanged) and *meaning* of messages

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A protocol is a set of rules that controls the communication between entities in different systems.

Protocols define format (syntax), order of messages sent and received among network entities, as well as actions taken on message transmission or reception (behaviour).

Behaviour of the protocols can be defined using natural language (e.g. English) or some formal description technique. Examples for the latter: SDL, Estelle and Lotos. They are compilable specification languages. None of them has outweighed the others.

•ASN.1 Abstract Syntax Notation One (ITU-T X.680-X.699)

•TTCN-3 Testing and Test Control Notation version 3 (ETSI ES 201 873)

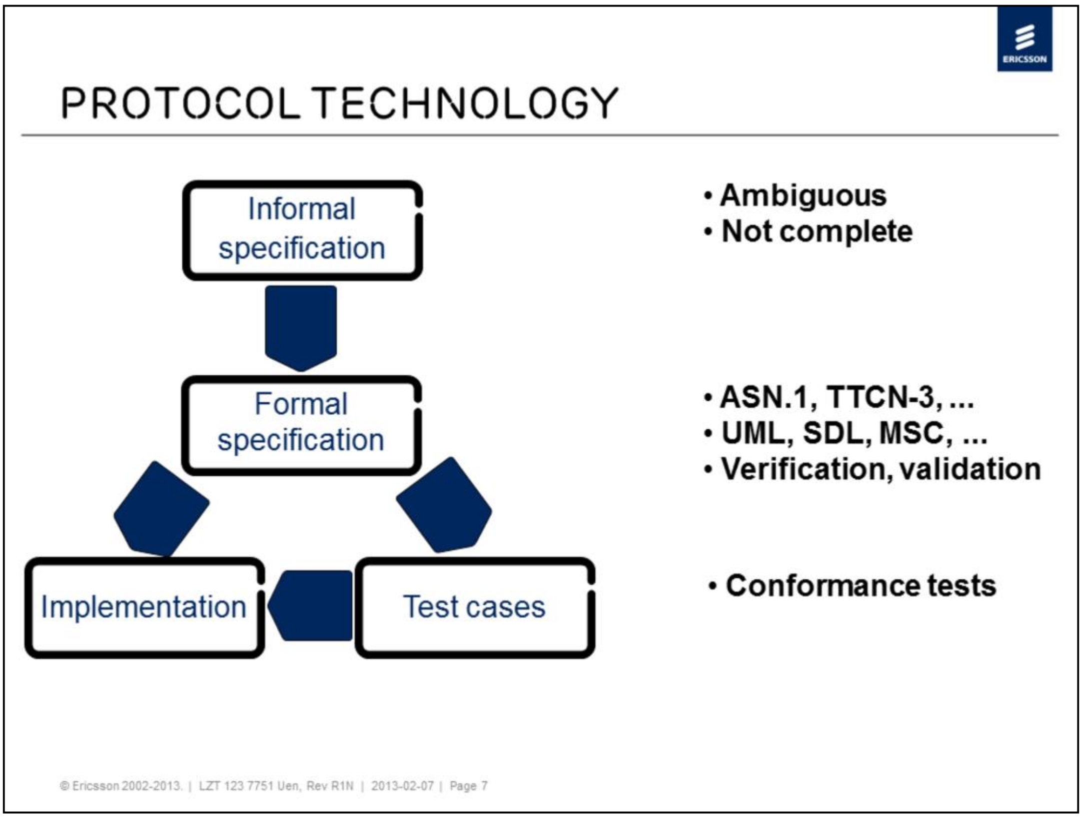
•UML Unified Modeling Language (http://www.omg.org/uml/, ITU-T Z.109 [SDL combined with UML])

•SDL: Specification & Description Language. (ITU-T Z.100-Z.109) Most popular in the industry.

•MSC Message Sequence Charts (ITU-T Z.120-Z.129)

•LOTOS: Language of Temporal Ordering Specifications (ISO8807) is widely used in the academic world. LOTOS is based on communicating processes.

•Estelle (ISO9074) is based on extended finite automata.



PROTOCOL TECHNOLOGY

Informal specification

Formal specification

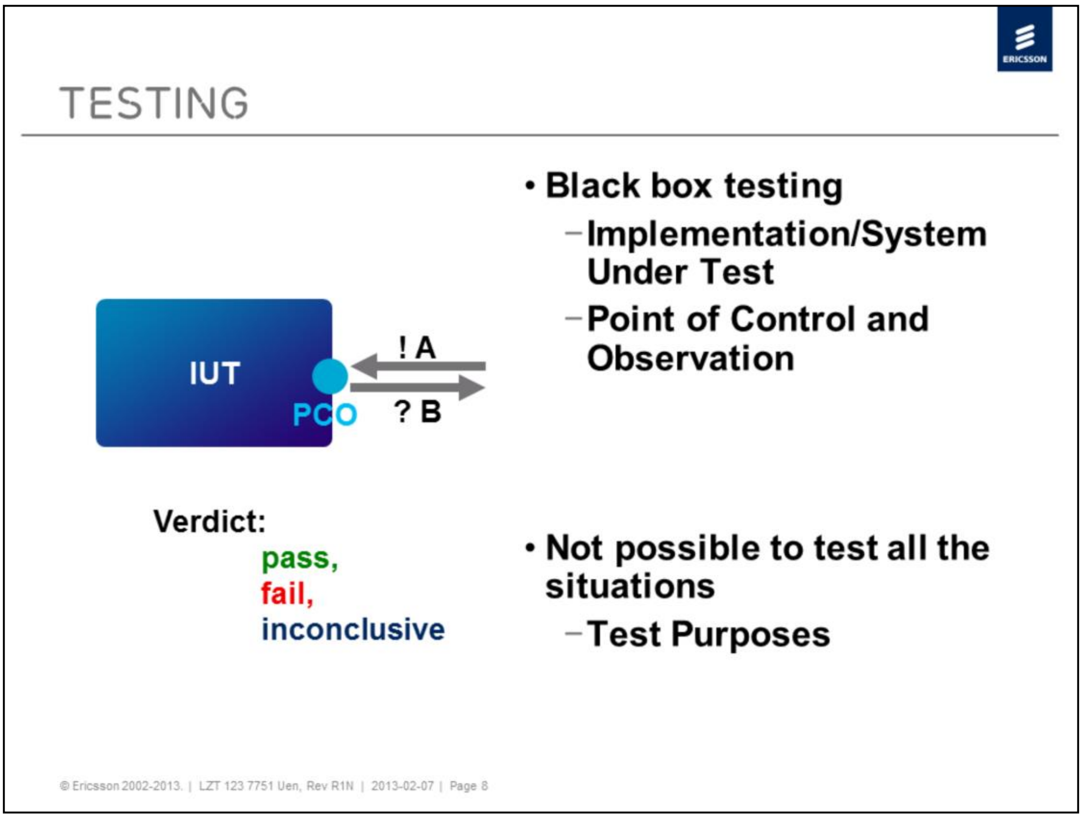
Implementation

Test cases

- Ambiguous
- Not complete

- ASN.1, TTCN-3, ...
- UML, SDL, MSC, ...
- Verification, validation

- Conformance tests

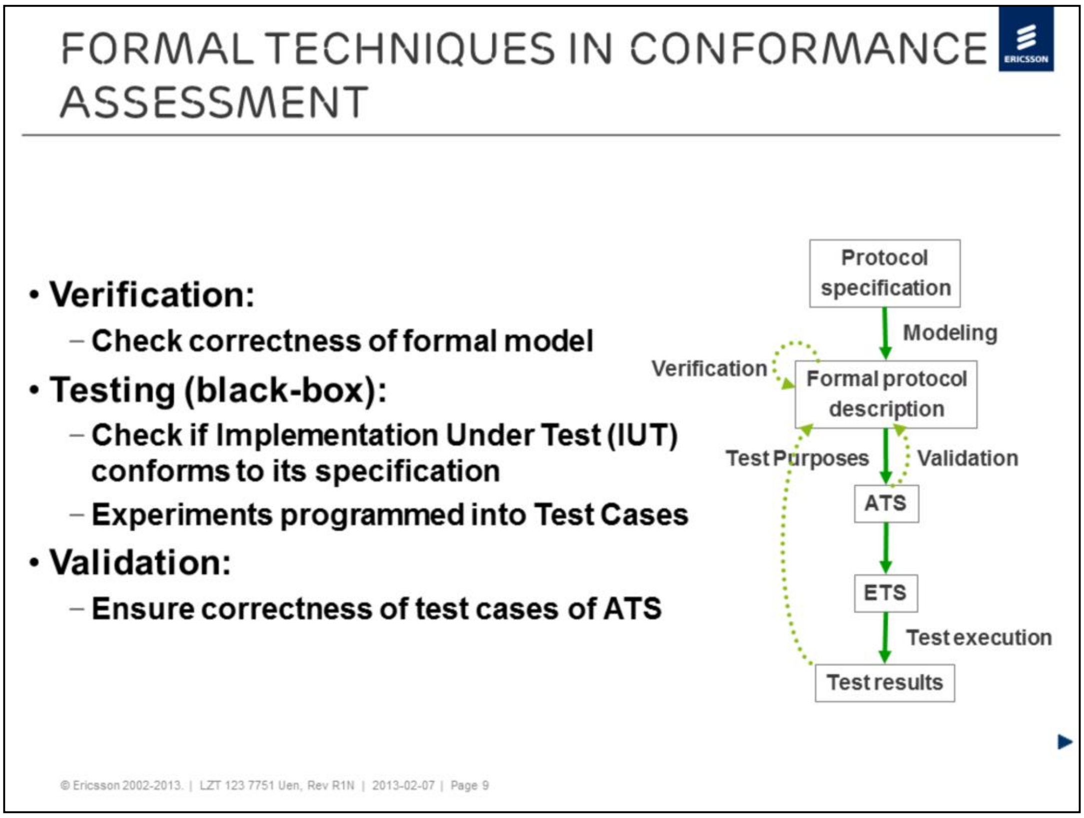


TESTING

- Black box testing
  - Implementation/System Under Test
  - Point of Control and Observation

Verdict:
pass,
fail,
inconclusive

- Not possible to test all the situations
  - Test Purposes



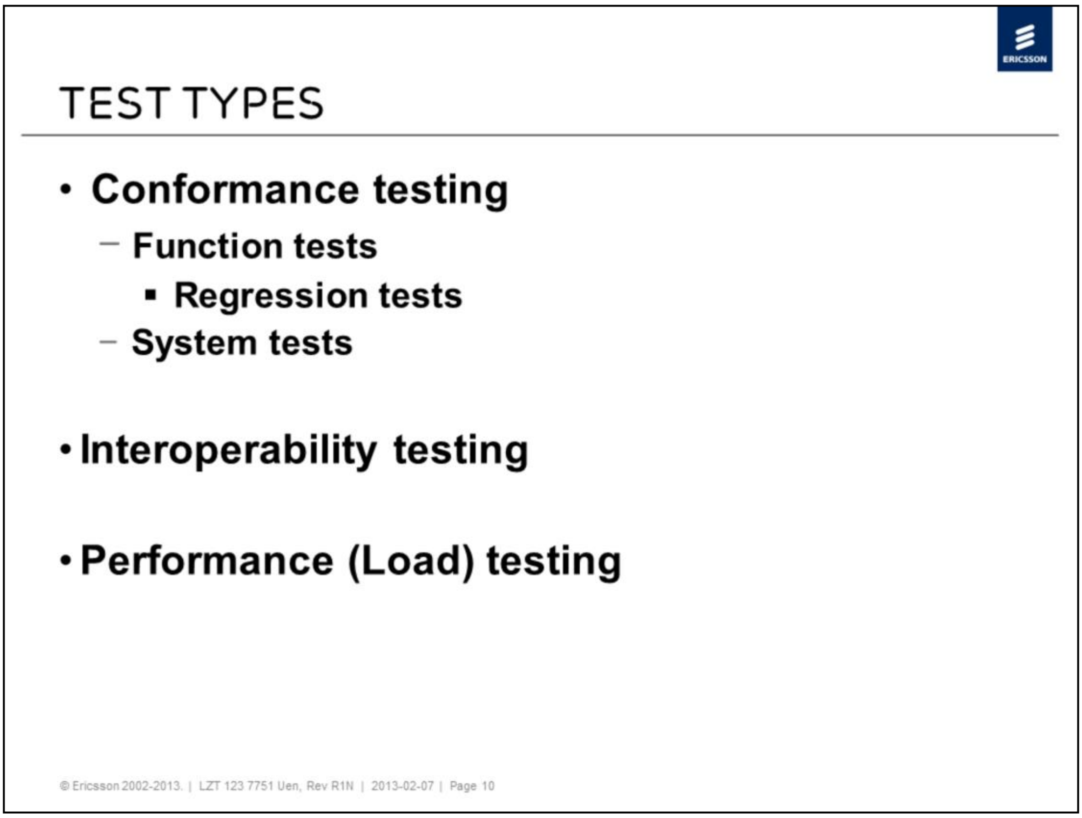
FORMAL TECHNIQUES IN CONFORMANCE ASSESSMENT

- **Verification:**
  - **Check correctness of formal model**
- **Testing (black-box):**
  - **Check if Implementation Under Test (IUT) conforms to its specification**
  - **Experiments programmed into Test Cases**
- **Validation:**
  - **Ensure correctness of test cases of ATS**

ATS: Abstract Test Suite, a collection of Abstract Test Cases.

ETS: Executable Test Suite, a set of Executable Test Cases.

IUT: Implementation Under Test

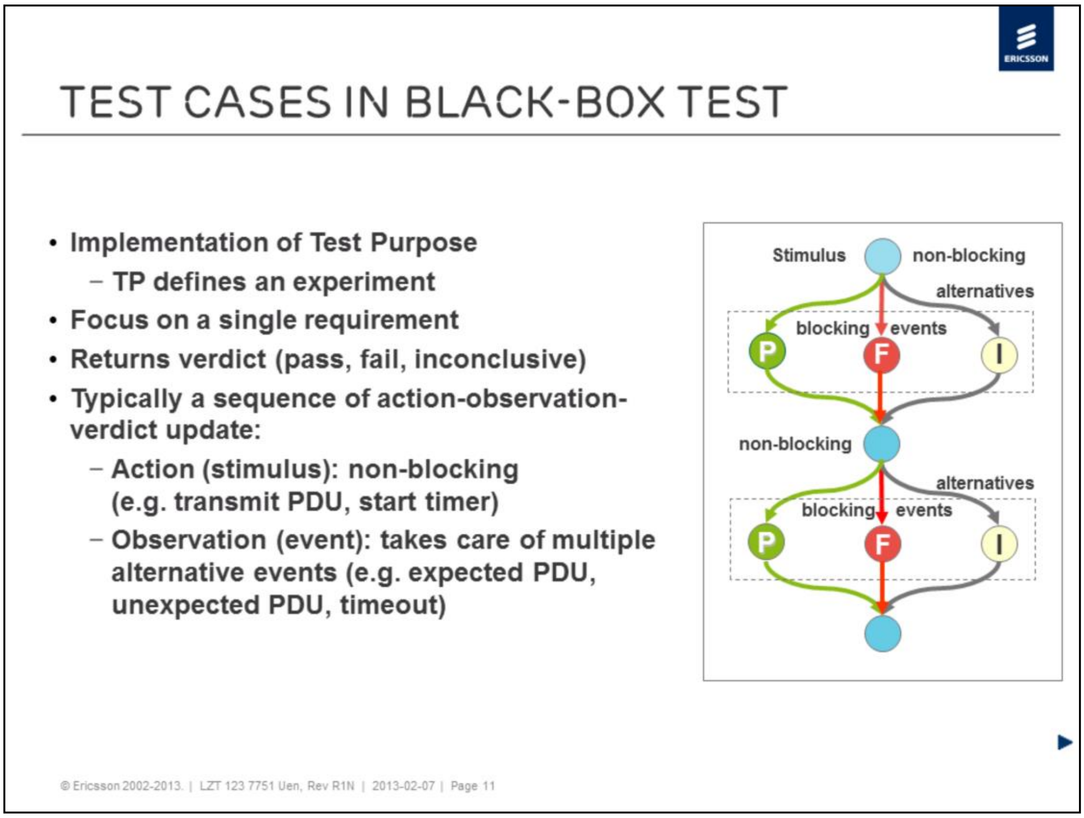


TEST TYPES

- Conformance testing
  - Function tests
    - Regression tests
  - System tests

- Interoperability testing

- Performance (Load) testing



TEST CASES IN BLACK-BOX TEST

- Implementation of Test Purpose
  - TP defines an experiment
- Focus on a single requirement
- Returns verdict (pass, fail, inconclusive)
- Typically a sequence of action-observation-verdict update:
  - Action (stimulus): non-blocking (e.g. transmit PDU, start timer)
  - Observation (event): takes care of multiple alternative events (e.g. expected PDU, unexpected PDU, timeout)

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Black-box testing means that the internal structure of the tested software product is not known: the only way to test it is to send a message ("stimulus") to the system and to analyse the received response. The latter is compared to the due response determined beforehand using the reference specification. If the comparison ("pattern matching") between the real and the expected response fails, the test case is considered as "failed" otherwise "passed".

The test script language must have means to match the expected and the received messages even if the message elements arrive in different order, or some of them (the optional ones) are missing. Usually, there are more than one possible responses; all of them must be accepted.

Once the match is determined, the next stimulus is constructed taking into consideration the data having received in the response, and so on.

The test script language must be prepared to determine that the expected response is not received within the specified time frame: it must handle timing ("temporal") requirements.

3.3.118 test purpose: A prose description of a well defined objective of testing, focusing on a single conformance requirement or a set of related conformance requirements as specified in the appropriate OSI specification (e.g. verifying the support of a specific value of a specific parameter).

3.3.3 abstract test case: A complete and independent specification of the actions required to achieve a specific test purpose, defined at the level of abstraction of a particular Abstract Test Method, starting in a stable testing state and ending in a stable testing state. This specification may involve one or more consecutive or concurrent connections.

Note 1: The specification 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).

Note 2: The specification 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 (i.e. the specification should always include the possibility of starting and finishing in the “idle” state).

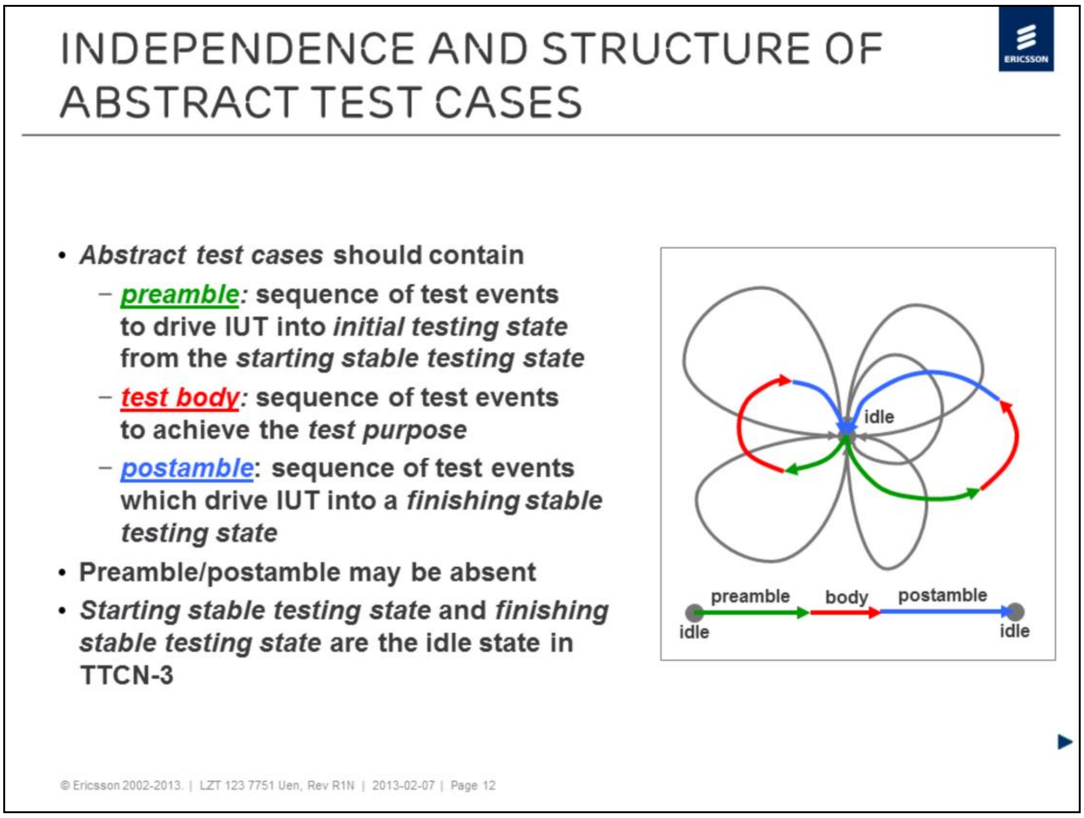
3.3.31 executable test case: A realization of an abstract test case.

3.3.107 test case: An abstract or executable test case.

Abbreviations

IUT: Implementation Under Test

SUT: System Under Test



INDEPENDENCE AND STRUCTURE OF ABSTRACT TEST CASES

- *Abstract test cases* should contain
  - *preamble*: sequence of test events to drive IUT into *initial testing state* from the *starting stable testing state*
  - *test body*: sequence of test events to achieve the *test purpose*
  - *postamble*: sequence of test events which drive IUT into a *finishing stable testing state*
- Preamble/postamble may be absent
- *Starting stable testing state* and *finishing stable testing state* are the idle state in TTCN-3

3.3.121 testing state: A state encountered during testing, comprising the combination of the states of the SUT, the test system, the protocols for which control and observation is specified in the ATS, and, if relevant, the state of the underlying service.

3.3.93 stable testing state: A testing state which can be maintained, without prescribed Lower Tester behaviour, sufficiently long to span the gap between one test case and the next in a test campaign.

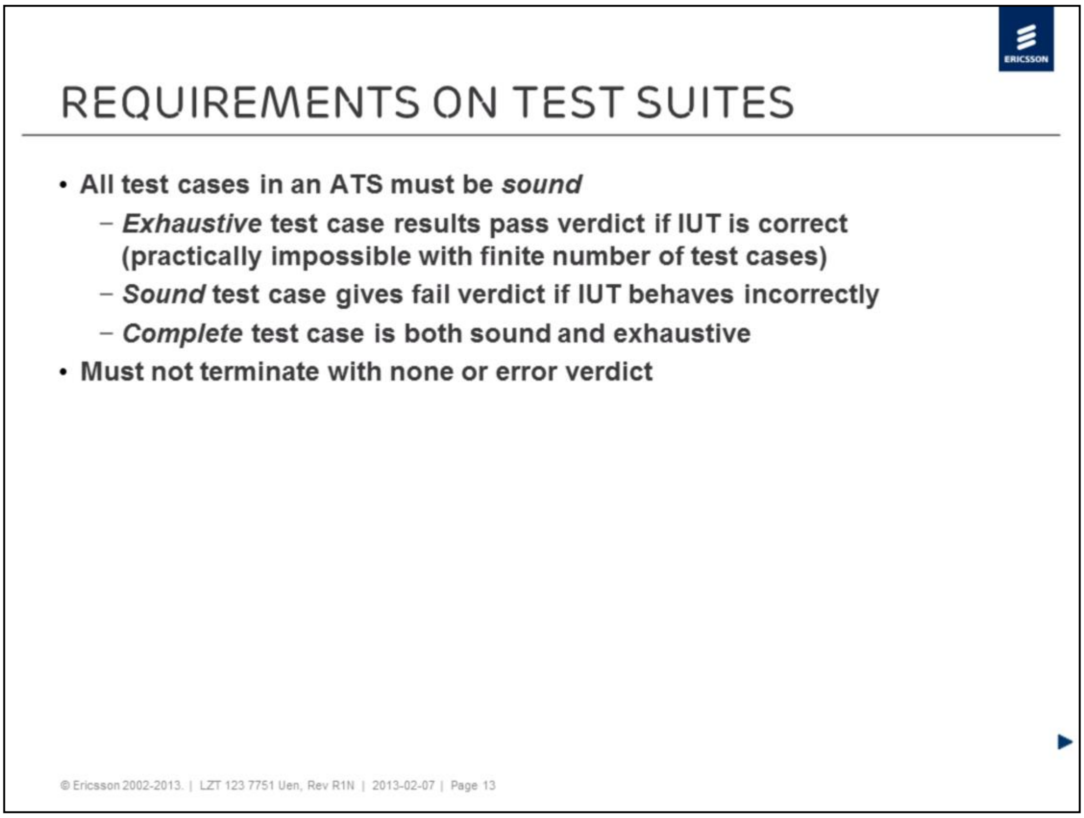
3.3.47 initial testing state: The testing state in which a test body starts.

3.3.110 test event: An indivisible unit of test specification at the level of abstraction of the specification (e.g. sending or receiving a single PDU).

3.3.117 (test) preamble: The sequences of test events from the starting stable testing state of the test case up to the initial testing state from which the test body will start.

3.3.105 test body: The sequences of test events that achieve the test purpose.

3.3.116 (test) postamble: The sequences of test events from the end of the test body up to the finishing stable testing state(s) for the test case.



REQUIREMENTS ON TEST SUITES

- **All test cases in an ATS must be *sound***
  - ***Exhaustive* test case results pass verdict if IUT is correct (practically impossible with finite number of test cases)**
  - ***Sound* test case gives fail verdict if IUT behaves incorrectly**
  - ***Complete* test case is both sound and exhaustive**
- **Must not terminate with none or error verdict**

ATS is exhaustive if all test cases are exhaustive (all passing implementations are compliant)

ATS is sound if all test cases are sound (all implementations that do not pass are not compliant)

ATS is complete if all test cases are both sound and exhaustive

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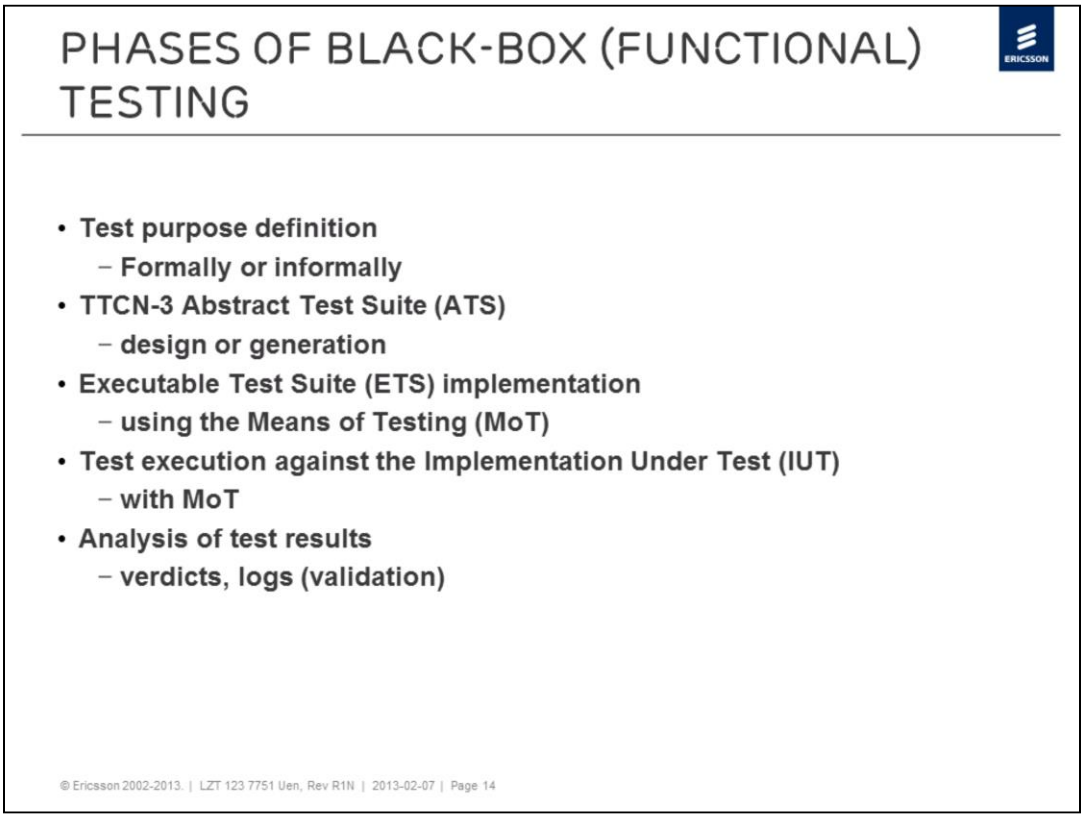
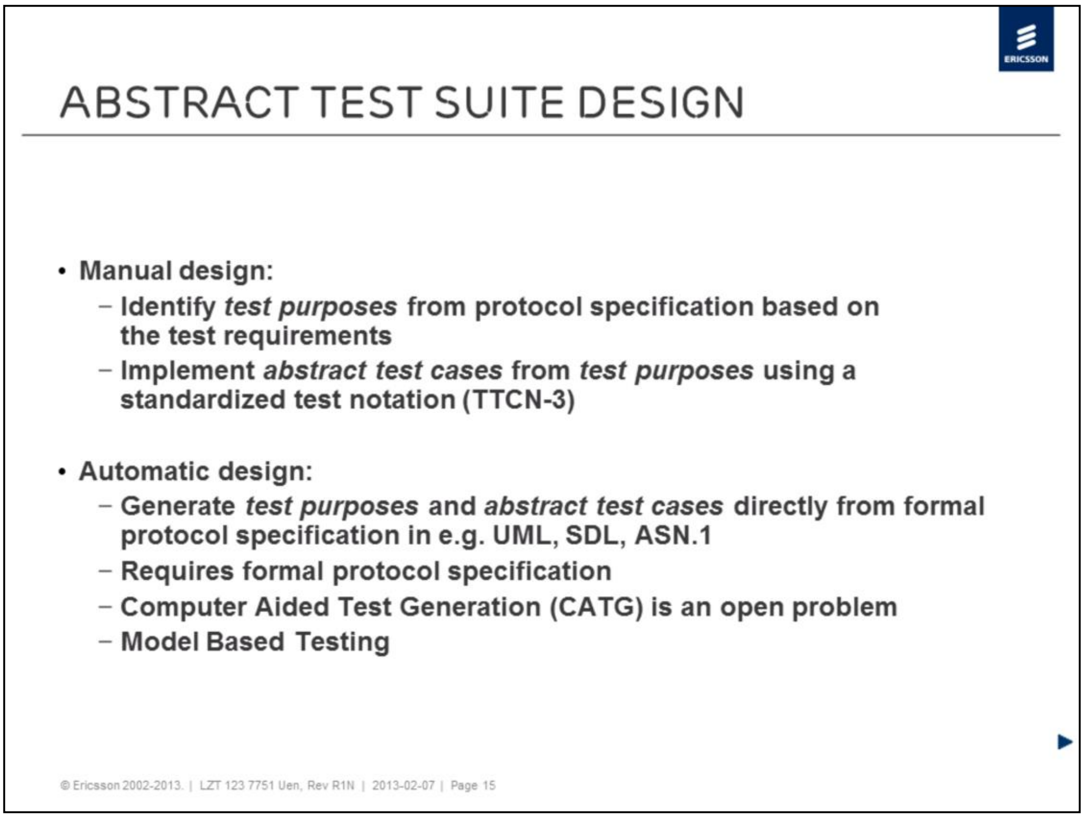


PHASES OF BLACK-BOX (FUNCTIONAL) TESTING

- Test purpose definition
  - Formally or informally
- TTCN-3 Abstract Test Suite (ATS)
  - design or generation
- Executable Test Suite (ETS) implementation
  - using the Means of Testing (MoT)
- Test execution against the Implementation Under Test (IUT)
  - with MoT
- Analysis of test results
  - verdicts, logs (validation)

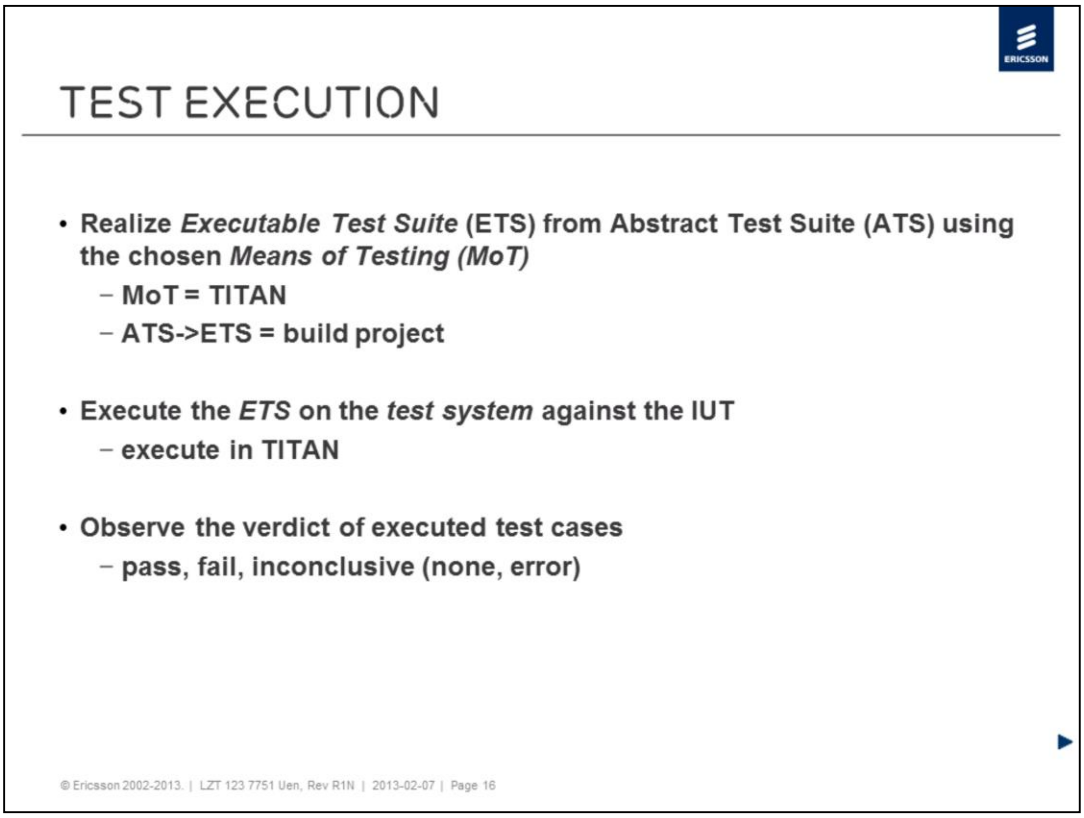


ABSTRACT TEST SUITE DESIGN

- **Manual design:**
  - **Identify *test purposes* from protocol specification based on the test requirements**
  - **Implement *abstract test cases* from *test purposes* using a standardized test notation (TTCN-3)**
- **Automatic design:**
  - **Generate *test purposes* and *abstract test cases* directly from formal protocol specification in e.g. UML, SDL, ASN.1**
  - **Requires formal protocol specification**
  - **Computer Aided Test Generation (CATG) is an open problem**
  - **Model Based Testing**

Once the protocol specification is formalised, it is theoretically possible to generate executable test cases automatically. However, this procedure, called Computer Aided Test Generation (CATG) is only being developed.

Otherwise, one needs to design abstract test cases manually. Manual test suite design starts with the formulation of test purposes from protocol specification. Test purposes are implemented in test cases.



TEST EXECUTION

- Realize *Executable Test Suite* (ETS) from Abstract Test Suite (ATS) using the chosen *Means of Testing (MoT)*
  - MoT = TITAN
  - ATS->ETS = build project
- Execute the *ETS* on the *test system* against the IUT
  - execute in TITAN
- Observe the verdict of executed test cases
  - pass, fail, inconclusive (none, error)

The test system is the link between “abstract” and “executable”. It derives executable test cases from abstract test cases and executable test suites (ETSs) from abstract test suites (ATSs). The test system and any additional equipment and procedures that may be required for the execution of test cases together are called the Means of Testing.

II. INTRODUCTION TO TTCN-3

HISTORY OF TTCN
TTCN-2 TO TTCN-3 MIGRATION
TTCN-3 CAPABILITIES, APPLICATION AREAS
PRESENTATION FORMATS
STANDARD DOCUMENTS

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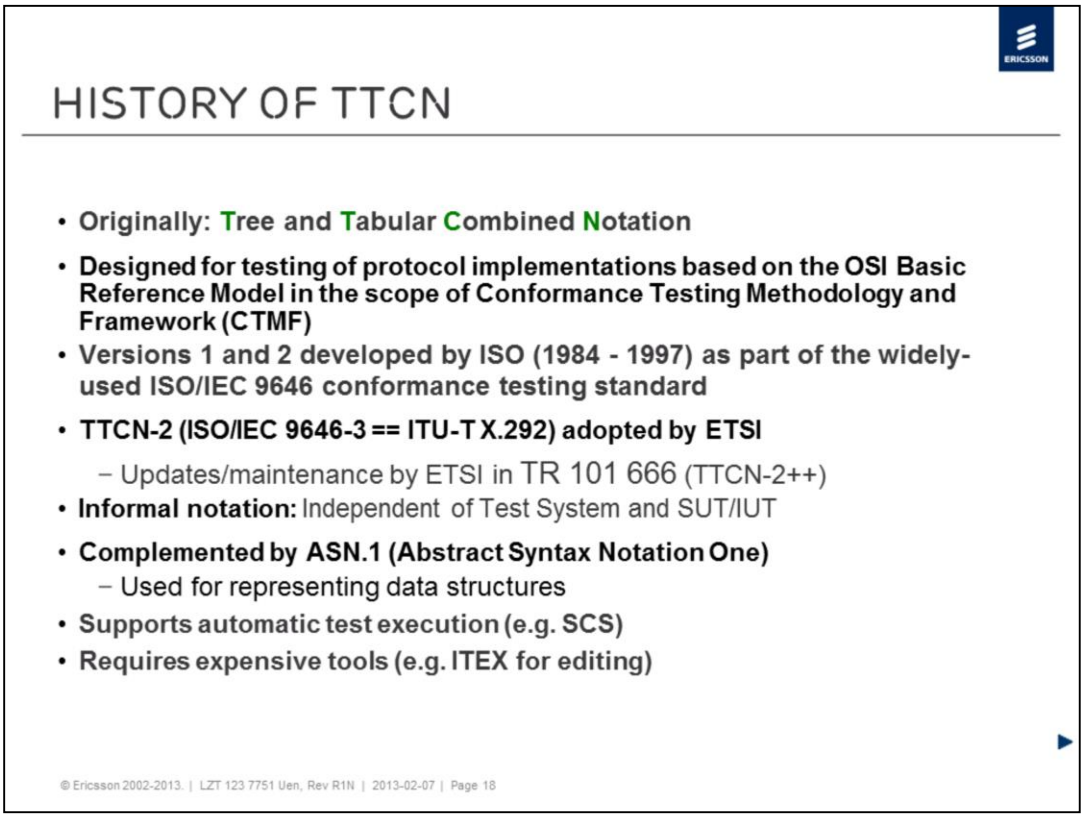


HISTORY OF TTCN

- Originally: **T**ree and **T**abular **C**ombined **N**otation
- **Designed for testing of protocol implementations based on the OSI Basic Reference Model in the scope of Conformance Testing Methodology and Framework (CTMF)**
- Versions 1 and 2 developed by ISO (1984 - 1997) as part of the widely-used ISO/IEC 9646 conformance testing standard
- **TTCN-2 (ISO/IEC 9646-3 == ITU-T X.292) adopted by ETSI**
  - Updates/maintenance by ETSI in TR 101 666 (TTCN-2++)
- **Informal notation:** Independent of Test System and SUT/IUT
- **Complemented by ASN.1 (Abstract Syntax Notation One)**
  - Used for representing data structures
- Supports automatic test execution (e.g. SCS)
- Requires expensive tools (e.g. ITEX for editing)

Test notation is used to describe abstract test cases. The test notation can be an informal notation (without formally defined semantics) or a Formal Description Technique (FDT). TTCN-2 is an informal notation with clearly defined, but not formally defined semantics.a

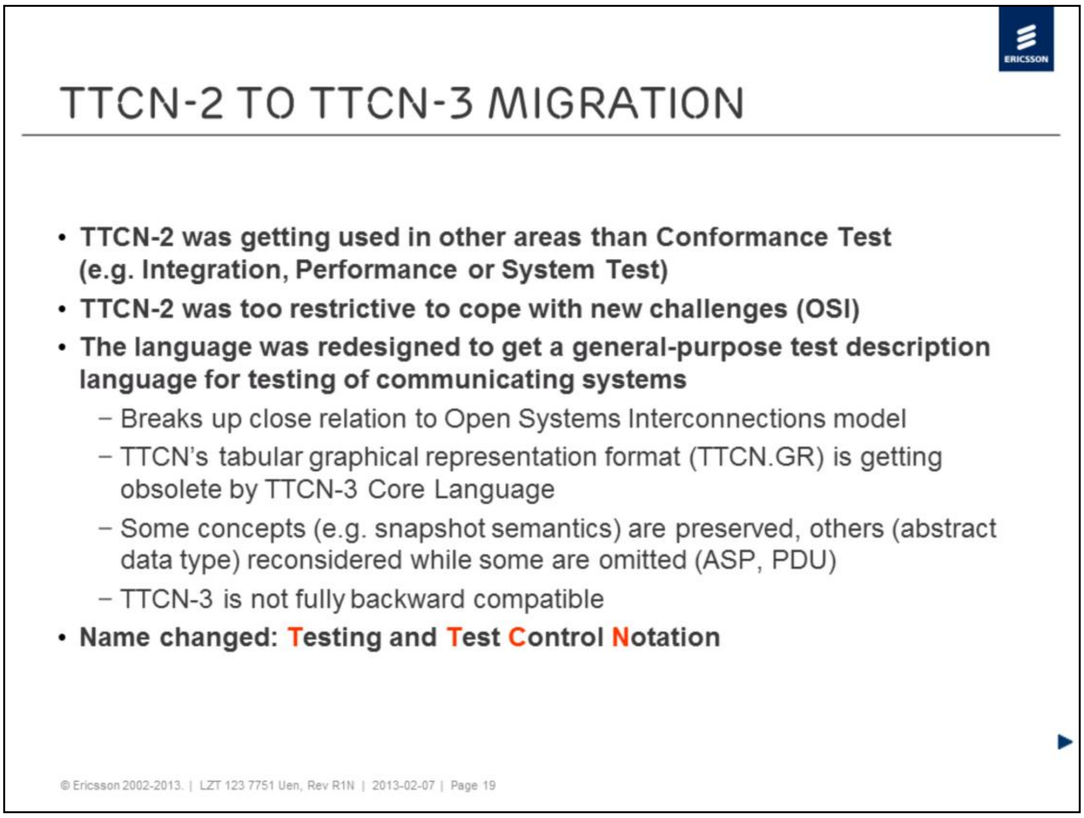
The International Organization for Standardization (ISO*) has **standardised** first two versions of TTCN. The very same standard has been adopted as ITU-T and ETSI standard. Data structure definitions written in ASN.1 can be imported to TTCN-2.

TTCN-2 **test cases** can be **edited** using special software, e.g. ITEX. Executable test cases are produced and **run** with help of e.g. SCS.

Abbreviations:

ETSI	
IEC	International Engineering Consortium
ITU-T	International
SCS	System Certification System (Ericsson's TTCN test case execution platform)
ITEX	Interactive TTCN Editor and eXecutor (from the Swedish firm Telelogic)

* Because "International Organization for Standardization" would have different abbreviations in different languages ("IOS" in English, "OIN" in French for *Organisation internationale de normalisation*), it was decided at the outset to use a word derived from the Greek isos, meaning "equal". Therefore, whatever the country, whatever the language, the short form of the organization's name is always ISO.



TTCN-2 TO TTCN-3 MIGRATION

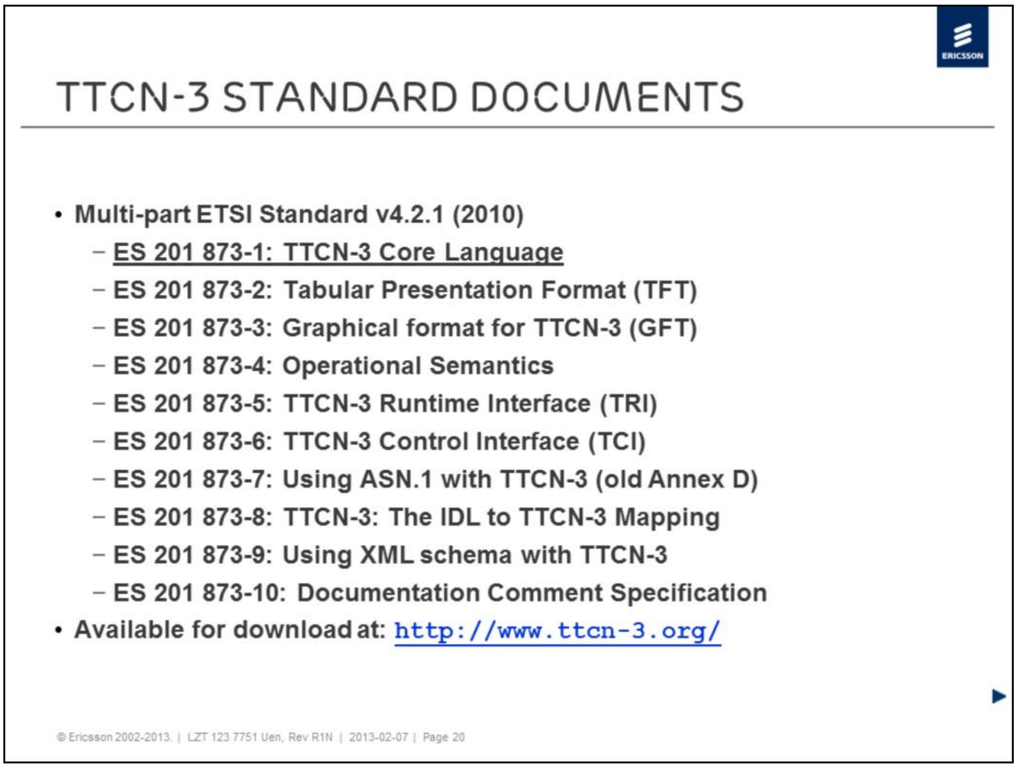
- **TTCN-2 was getting used in other areas than Conformance Test (e.g. Integration, Performance or System Test)**
- **TTCN-2 was too restrictive to cope with new challenges (OSI)**
- **The language was redesigned to get a general-purpose test description language for testing of communicating systems**
  - Breaks up close relation to Open Systems Interconnections model
  - TTCN's tabular graphical representation format (TTCN.GR) is getting obsolete by TTCN-3 Core Language
  - Some concepts (e.g. snapshot semantics) are preserved, others (abstract data type) reconsidered while some are omitted (ASP, PDU)
  - TTCN-3 is not fully backward compatible
- **Name changed: Testing and Test Control Notation**

Language development was being done in the following framework:
ETSI MTS/STFs 133, 156, 213, 253

TTCN-3 can be used for protocol testing (for mobile and Internet protocols), supplementary service testing, module testing, the testing of CORBA-based platforms, the testing of Application Programming Interfaces (APIs) and many more applications. The language is not restricted to conformance testing, but can be used for interoperability, robustness, regression, system, and integration testing.

The syntax of TTCN-3 is new, but the language has retained (and improved upon) much of the well proven capabilities of its predecessors. Its main features include:

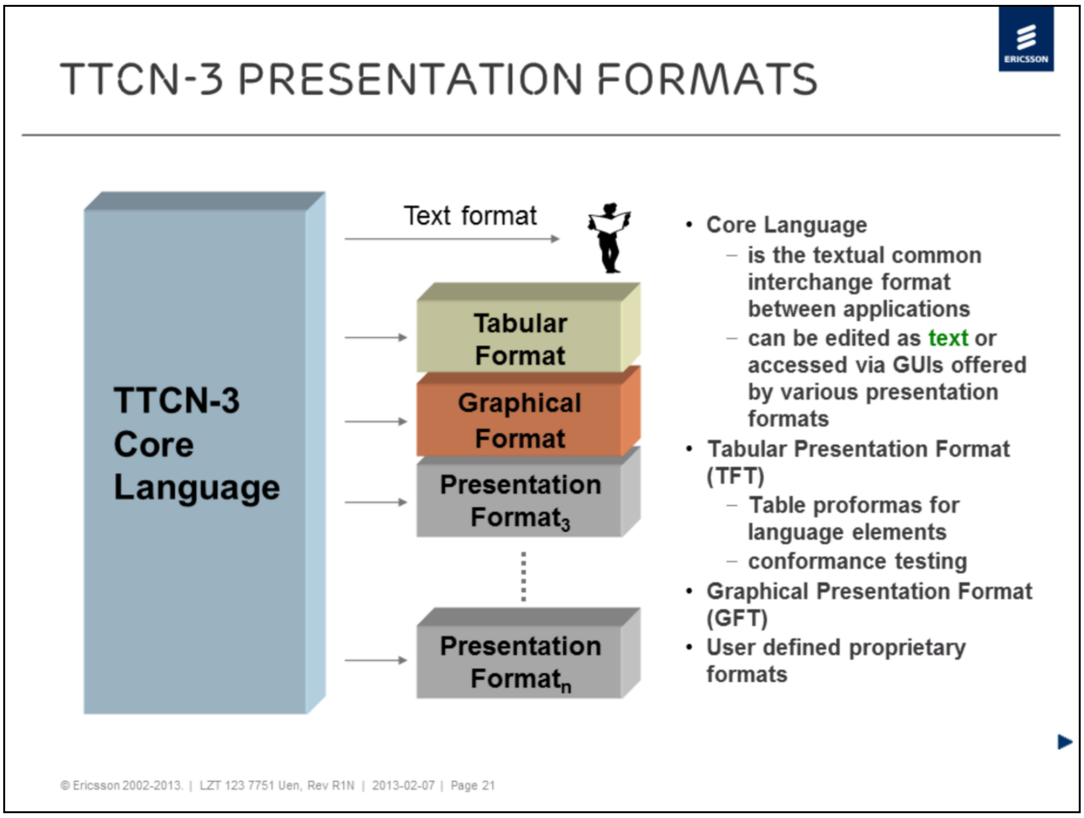
•Dynamic, concurrent testing configurations
•Synchronous and asynchronous communication mechanisms
•Encoding information and other attributes (including user extensibility)
•Data and signature templates with powerful matching mechanisms
•Type and value parameterization
•Assignment and handling of test verdicts
•Test suite parameterization and test case selection mechanisms
•Combined use of TTCN-3 with ASN.1
•Well defined syntax, interchange format and static semantics
•Optional presentation formats (eg. tabular conformance presentation format, MSC (Message Sequence Chart) format)
•Precise execution algorithm (operational semantics)
•Execution and control of test cases



TTCN-3 STANDARD DOCUMENTS

- Multi-part ETSI Standard v4.2.1 (2010)
  - ES 201 873-1: TTCN-3 Core Language
  - ES 201 873-2: Tabular Presentation Format (TFT)
  - ES 201 873-3: Graphical format for TTCN-3 (GFT)
  - ES 201 873-4: Operational Semantics
  - ES 201 873-5: TTCN-3 Runtime Interface (TRI)
  - ES 201 873-6: TTCN-3 Control Interface (TCI)
  - ES 201 873-7: Using ASN.1 with TTCN-3 (old Annex D)
  - ES 201 873-8: TTCN-3: The IDL to TTCN-3 Mapping
  - ES 201 873-9: Using XML schema with TTCN-3
  - ES 201 873-10: Documentation Comment Specification
- Available for download at: `http://www.ttcn-3.org/`

The latest ETSI TTCN-3 Core Language standard edition dates from 2005. The exact URL is http://ttcn.ericsson.se/standardization/downloads.shtml#ttcnv3.



TTCN-3 PRESENTATION FORMATS

- Core Language
  - is the textual common interchange format between applications
  - can be edited as text or accessed via GUIs offered by various presentation formats
- Tabular Presentation Format (TFT)
  - Table proformas for language elements
  - conformance testing
- Graphical Presentation Format (GFT)
- User defined proprietary formats

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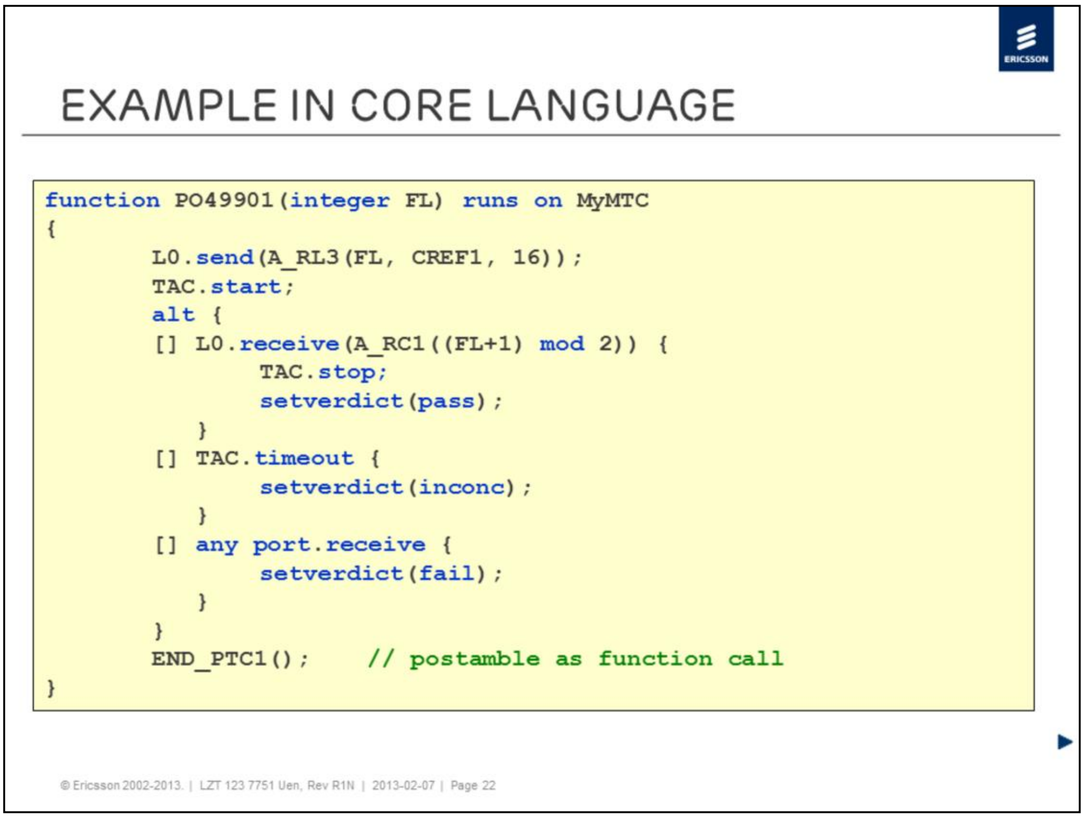
The **Core Language** has a textual format, that, as opposed to the mp format of the TTCN-2 language, can be read by humans.

Tabular format was originally meant to facilitate the migration from TTCN-2 to TTCN-3. It is sparingly used nowadays.

In the graphical format (similarly to MSC) it is not possible to define types, templates etc.

User Defined Formats are open to anyone.

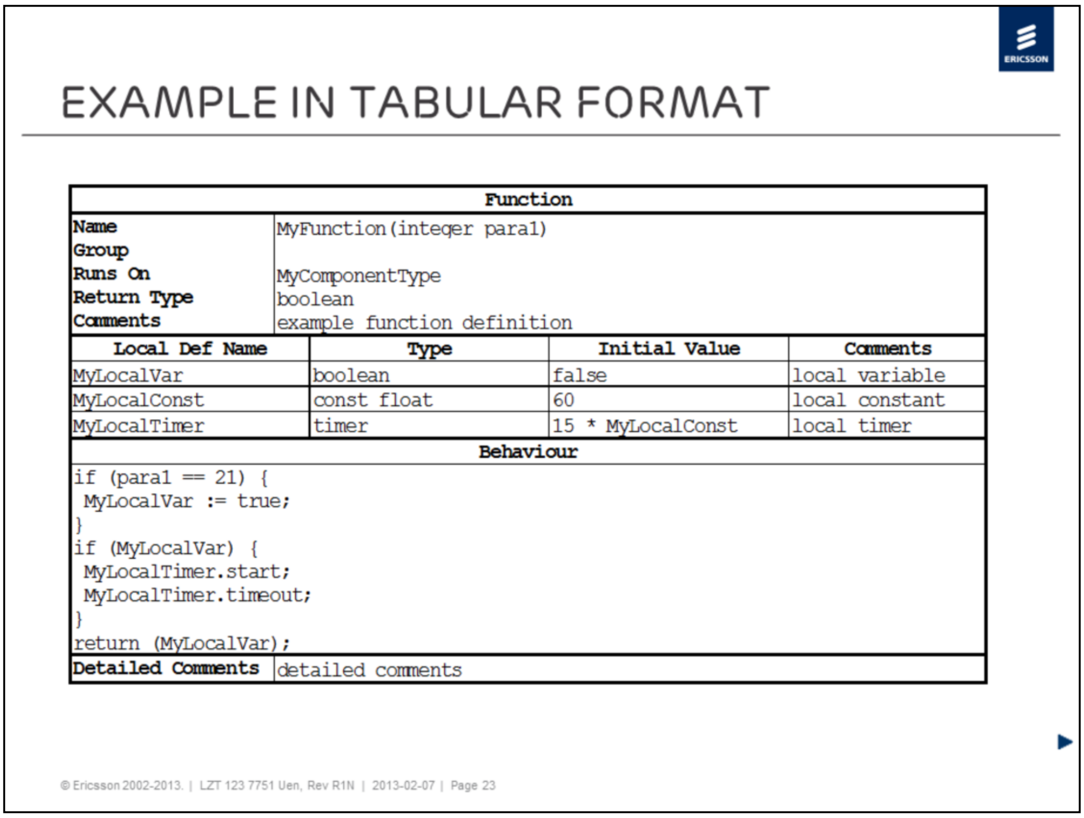


EXAMPLE IN CORE LANGUAGE

```
function PO49901(integer FL) runs on MyMTC
{
        L0.send(A_RL3(FL, CREF1, 16));
        TAC.start;
        alt {
        [] L0.receive(A_RC1((FL+1) mod 2)) {
                TAC.stop;
                setverdict(pass);
           }
        [] TAC.timeout {
                setverdict(inconc);
           }
        [] any port.receive {
                setverdict(fail);
           }
        }
        END_PTC1();    // postamble as function call
}
```

Core Language is the basic language. White space or new line characters are not taken into consideration; it makes it similar to a programming language. Different TTCN-3 applications use it for data interchange.

You should not strive to understand the example, rather get a look and feel of it. It looks like any ordinary programming language.



EXAMPLE IN TABULAR FORMAT

Function

Name	MyFunction(integer para1)
Group	
Runs On	MyComponentType
Return Type	boolean
Comments	example function definition

Local Def Name	Type	Initial Value	Comments
MyLocalVar	boolean	false	local variable
MyLocalConst	const float	60	local constant
MyLocalTimer	timer	15 * MyLocalConst	local timer

Behaviour

```
if (para1 == 21) {
 MyLocalVar := true;
}
if (MyLocalVar) {
 MyLocalTimer.start;
 MyLocalTimer.timeout;
}
return (MyLocalVar);
```

Detailed Comments	detailed comments

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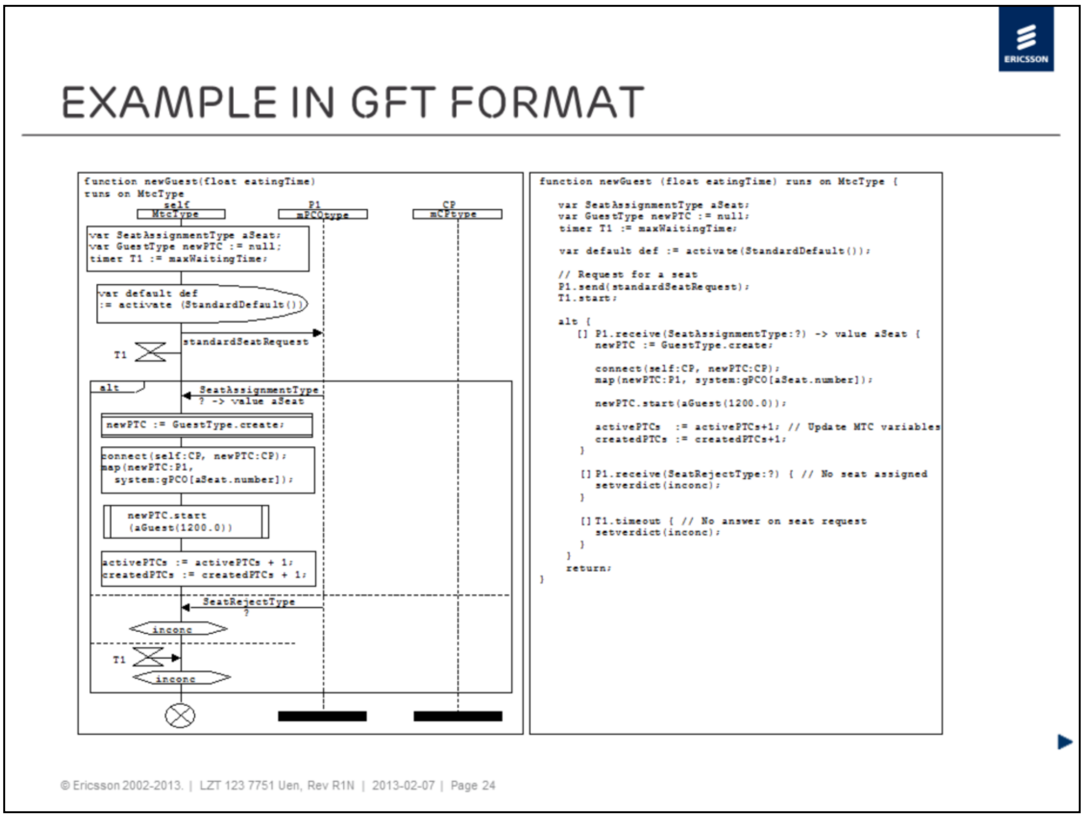
Tabular Presentation Format resembles the most the TTCN-2 format, it is specified mainly for compatibility reasons. Editing is done in strictly specified tables, but data is saved in Core Language.

The example shows the same extract in Tabular Format: we can fill in the name of the test case, any comments, the type of the variables. The behaviour is specified as text in the next raw.



EXAMPLE IN GFT FORMAT

```
function newGuest (float eatingTime) runs on MtcType {

   var SeatAssignmentType aSeat;
   var GuestType newPTC := null;
   timer T1 := maxWaitingTime;

   var default def := activate(StandardDefault());

   // Request for a seat
   P1.send(standardSeatRequest);
   T1.start;

   alt {
      [] P1.receive(SeatAssignmentType:?) -> value aSeat {
         newPTC := GuestType.create;

         connect(self:CP, newPTC:CP);
         map(newPTC:P1, system:gPCO[aSeat.number]);

         newPTC.start(aGuest(1200.0));

         activePTCs  := activePTCs+1; // Update MTC variables
         createdPTCs := createdPTCs+1;
      }

      [] P1.receive(SeatRejectType:?) { // No seat assigned
         setverdict(inconc);
      }

      [] T1.timeout { // No answer on seat request
         setverdict(inconc);
      }
    }
    return;
}
```

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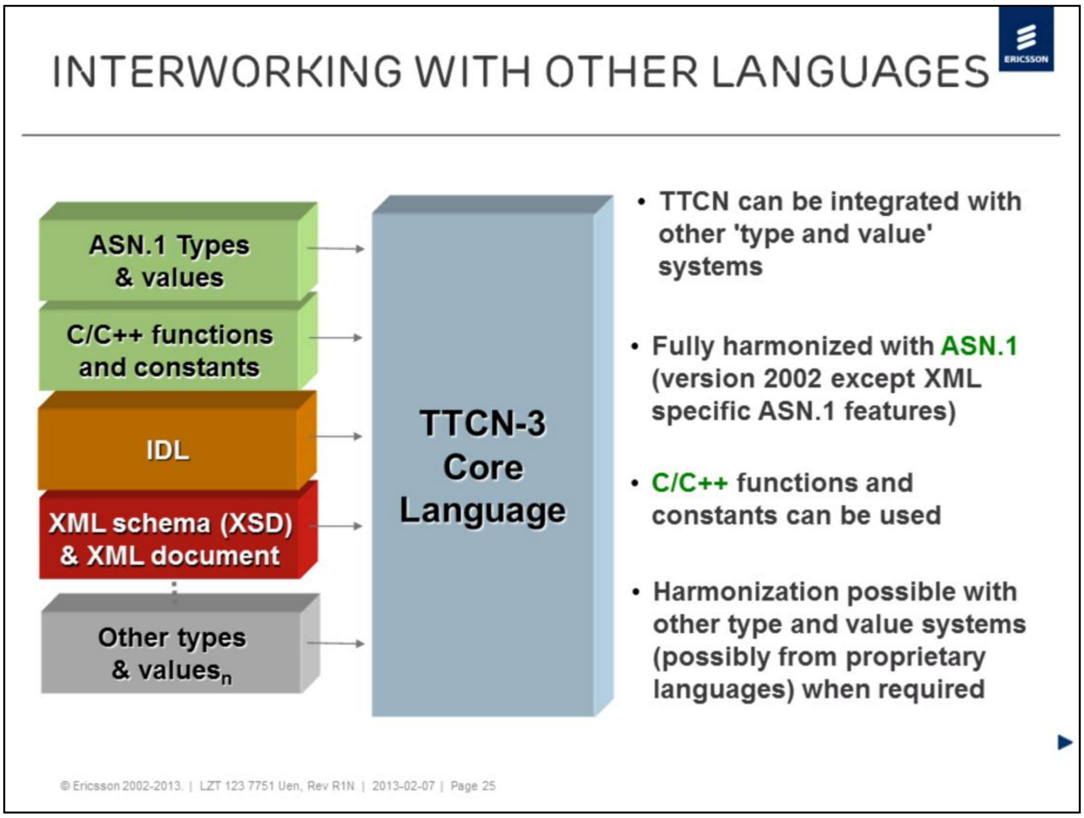
Graphical Presentation Format reminds the Test Sequence Chart or MSC. The messages sent and received are represented by arrows; there are additional special symbols for dynamic behaviour, cycles, decisions. For the time being, no editing program handling this format is known to us, however, there are programs capable of displaying Core Language programs in Graphical Format.

The perpendicular lines symbolize the components or, more precisely, the ports of the components. The horizontal arrows represent the messages sent and received. Boxes of various shape are representing the diverse operations coded in the Core Language.



INTERWORKING WITH OTHER LANGUAGES

- TTCN can be integrated with other 'type and value' systems
- Fully harmonized with ASN.1 (version 2002 except XML specific ASN.1 features)
- C/C++ functions and constants can be used
- Harmonization possible with other type and value systems (possibly from proprietary languages) when required

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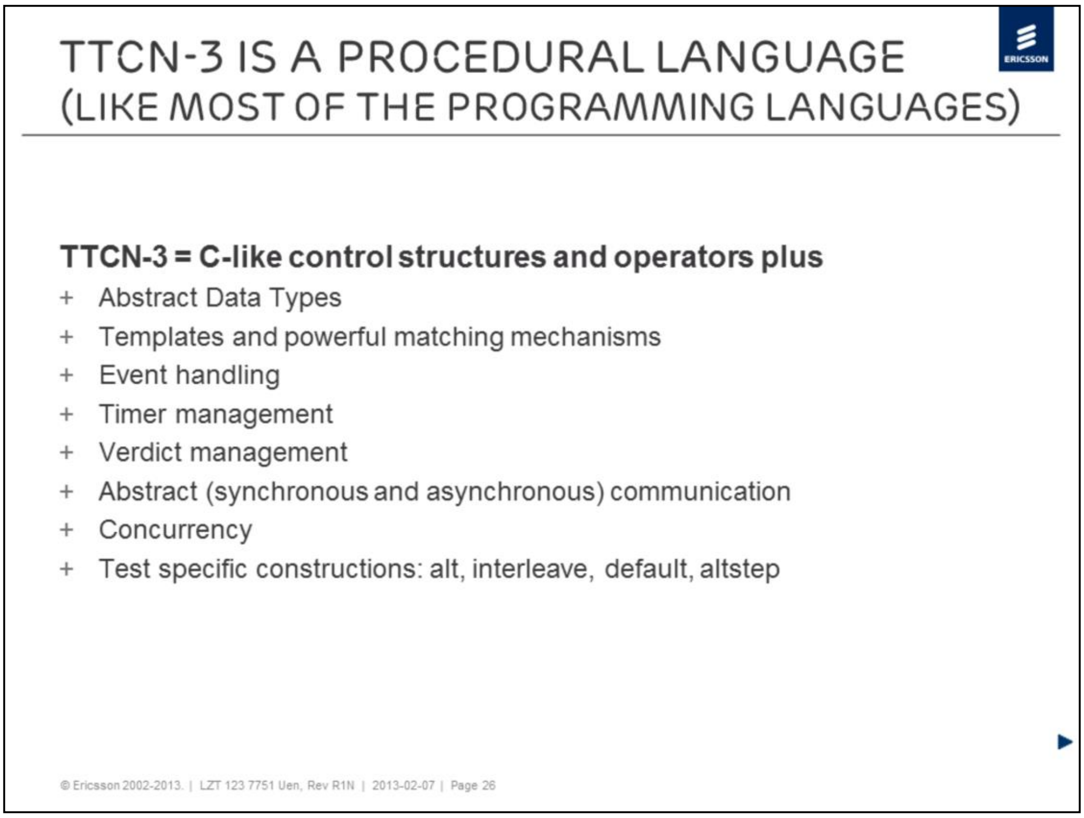
The most important language TTCN-3 can interwork with is ASN.1. TTCN-3 has been designed from the beginning to ensure that definitions written in ASN.1 can be imported into test suites without the need for any modifications. With other words, when a protocol is specified in ASN.1 there is no need to rephrase it. Likewise, information in other format can be reused, e.g. functions written in C++ can be called from within the TTCN-3 module. It is planned to harmonize TTCN-3 with XML (eXtended Markup Language) and IDL (Interface Definition Language), but it can be harmonized with other 'type & value' system.



TTCN-3 IS A PROCEDURAL LANGUAGE (LIKE MOST OF THE PROGRAMMING LANGUAGES)

TTCN-3 = C-like control structures and operators plus

- \+ Abstract Data Types
- \+ Templates and powerful matching mechanisms
- \+ Event handling
- \+ Timer management
- \+ Verdict management
- \+ Abstract (synchronous and asynchronous) communication
- \+ Concurrency
- \+ Test specific constructions: alt, interleave, default, altstep

TTCN-3 is a procedural language,
i.e., using the concept of the unit and scope. Unit corresponds to TTCN-3 modules, which are built of procedures (functions). Scope is the viewing range of a definition. There are seven scoping units in TTCN-3; they are dealt with later.

Abstract Data Types
Data can be specified independently from its coding and physical representation.

Templates
When sending a message, templates make possible to parameterise the message. When receiving a message, parameters or wildcards in templates render possible to accept or reject ('to match') a group of possible messages.

Event handling
While executing the program, we can wait for different events. The incidental arrival of these independent events influences the further program execution. Events are among others: reception of a message, completion of a test component, timer expiration.

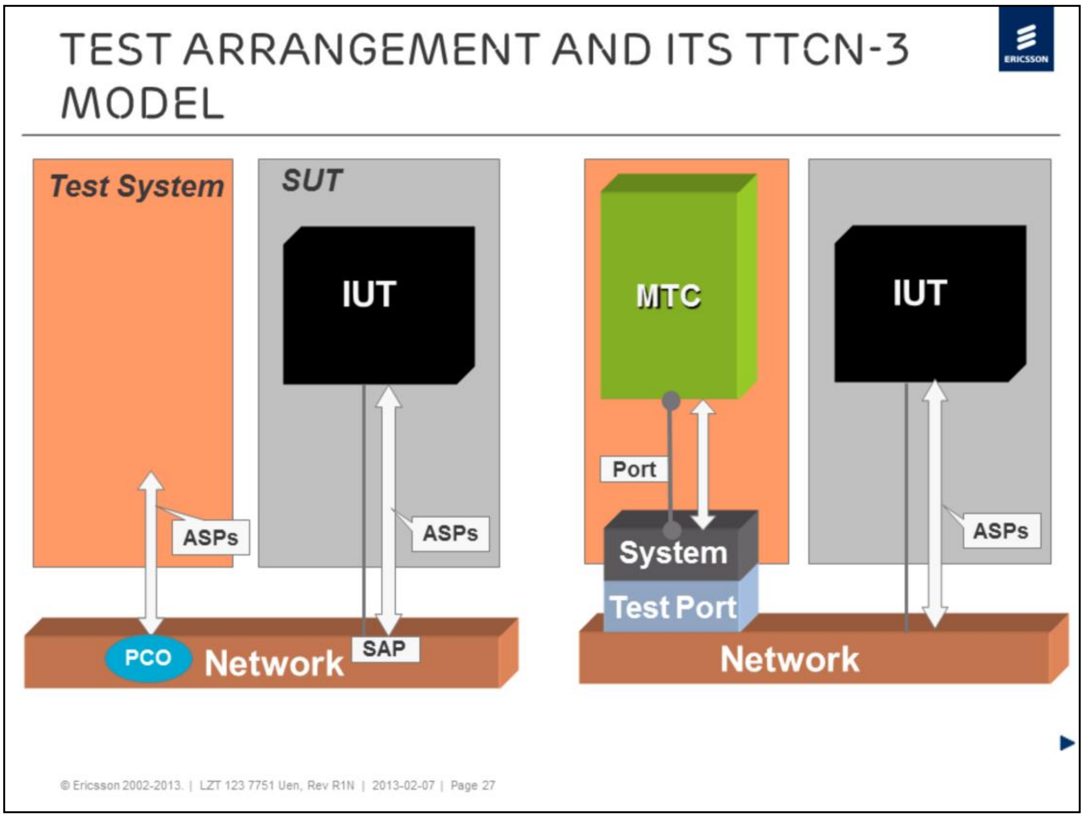
Timer management
Timers can be started, stopped. The actual value of a timer can be read as well whether a given timer is running. The expiration of a timer can be checked.

Verdict management
Test verdict can be pass, fail, inconclusive, none or error. The final verdict is determined with regard to the outcome of each test step.

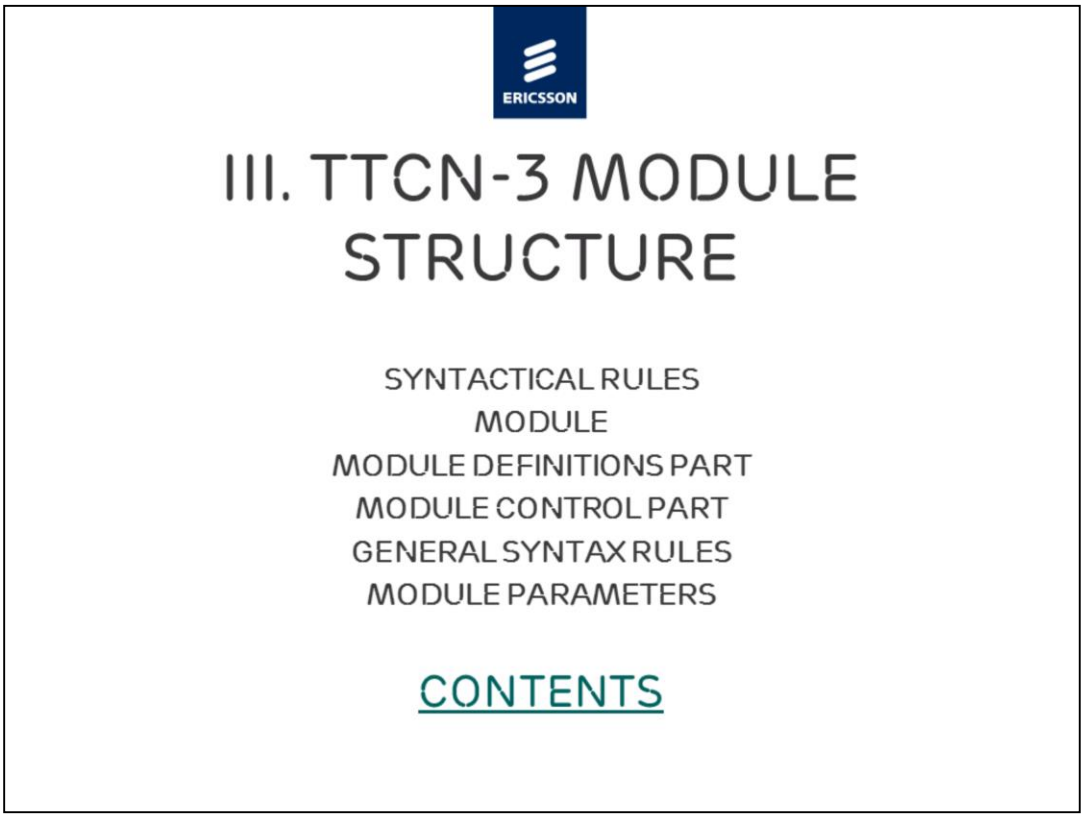
Abstract communication
Between the test executor system and the implementation under test there are two different communication possibilities. Message based communication is asynchronous while procedure based communication is synchronous. There is communication also between components.

Concurrency
Parallel test components (PTCs) are working concurrently, they can be created and destroyed.

Test specific constructions: alt, interleave, default, altstep
…are used to specify message reception behavior



TEST ARRANGEMENT AND ITS TTCN-3 MODEL



III. TTCN-3 MODULE STRUCTURE

SYNTACTICAL RULES
MODULE
MODULE DEFINITIONS PART
MODULE CONTROL PART
GENERAL SYNTAX RULES
MODULE PARAMETERS

CONTENTS

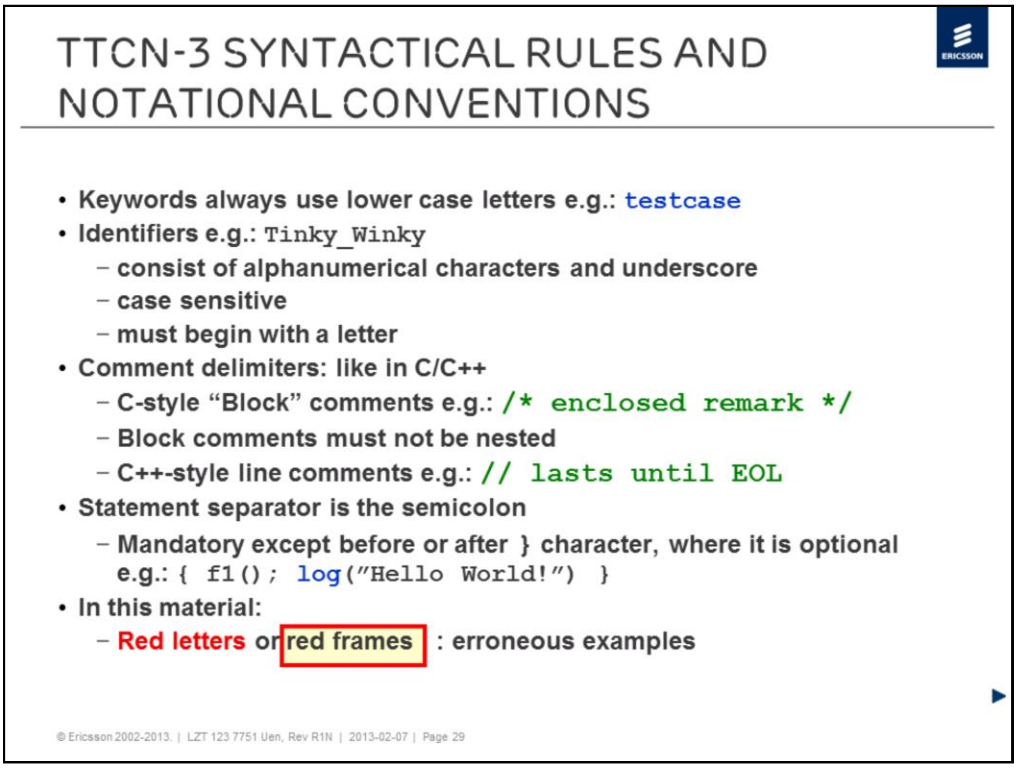
The principal building blocks of TTCN-3 are **module**s.

The **module definitions part** specifies the top-level definitions of the module and may import identifiers from other modules. TTCN-3 does not support the definition of variables in the module definitions part. This means that global variables cannot be defined in TTCN-3.

The **module control part** may contain local definitions and describes the execution order of the actual test cases. A test case shall be defined in the module definitions part and called in the control part.

General syntax rules describe the file format, capitalisation, delimiters, identifiers etc.

The **module parameter list** defines a set of values that are supplied by the test environment at run-time. During test execution these values shall be treated as constants. Module parameters shall be defined within the module definition part only.



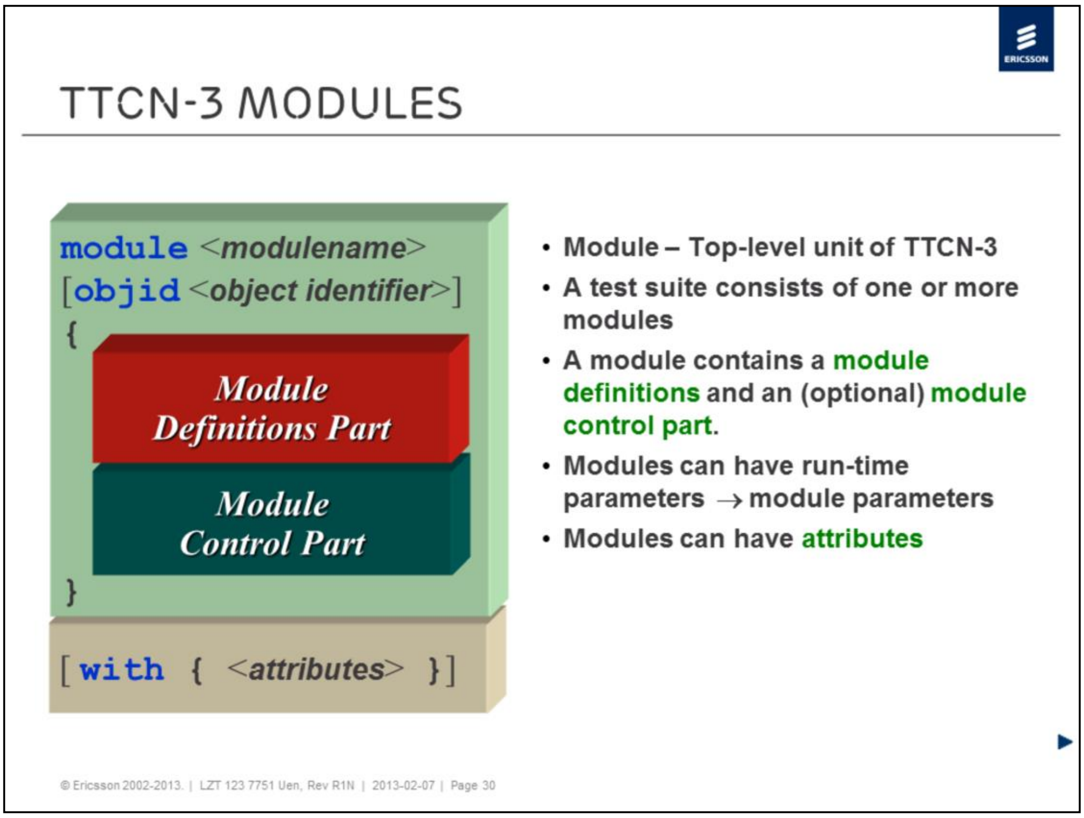
TTCN-3 SYNTACTICAL RULES AND NOTATIONAL CONVENTIONS

- Keywords always use lower case letters e.g.: `testcase`
- Identifiers e.g.: `Tinky_Winky`
  - consist of alphanumerical characters and underscore
  - case sensitive
  - must begin with a letter
- Comment delimiters: like in C/C++
  - C-style “Block” comments e.g.: `/* enclosed remark */`
  - Block comments must not be nested
  - C++-style line comments e.g.: `// lasts until EOL`
- Statement separator is the semicolon
  - Mandatory except before or after } character, where it is optional e.g.: `{ f1(); log(”Hello World!”) }`
- In this material:
  - Red letters or red frames : erroneous examples

Keywords are listed in table A.3 of the ETSI standard 201 873-1. These words must not be used as identifiers.

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.

Comments written in free text may appear anywhere in a TTCN-3 specification.



TTCN-3 MODULES

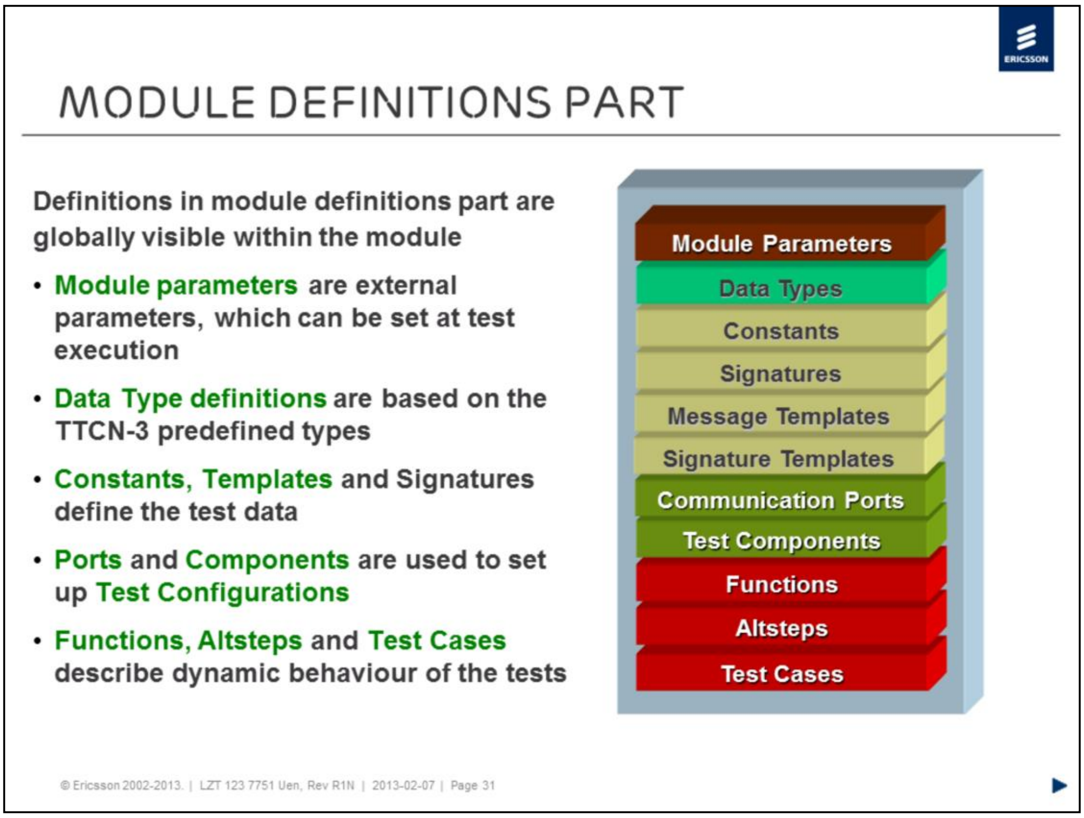
```
module <modulename>
[objid <object identifier>]
{
    Module
    Definitions Part

    Module
    Control Part
}
[with { <attributes> }]
```

- Module – Top-level unit of TTCN-3
- A test suite consists of one or more modules
- A module contains a module definitions and an (optional) module control part.
- Modules can have run-time parameters → module parameters
- Modules can have attributes

A test suite consists of one ore more modules. There is no hierarchy between modules. Modules are written as free text files: line breaks or paragraph marks may be used without restrictions. A module consists of a (optional) definitions part, and a (optional) module control part. Usually, the definitions part is longer, the control part only states the execution order of the test cases. Module parameters are supplied to the module at run-time and are considered constant during test execution. Module attributes give additional information, like coding rules or the size of a table.

The beginning of a module is indicated in the header by the keyword "module" followed by the module name (here:modulename). Thereafter between curly brackets appears the definitions part followed by the control part. Module attributes (here: the encoding rule valid for the whole module) may be given after the closing curly bracket of the module. Attributes are introduced by the keyword "with" whereas the attributes themselves are listed between curly brackets.



MODULE DEFINITIONS PART

Definitions in module definitions part are globally visible within the module

- Module parameters are external parameters, which can be set at test execution
- Data Type definitions are based on the TTCN-3 predefined types
- Constants, Templates and Signatures define the test data
- Ports and Components are used to set up Test Configurations
- Functions, Altsteps and Test Cases describe dynamic behaviour of the tests

Module Parameters
Data Types
Constants
Signatures
Message Templates
Signature Templates
Communication Ports
Test Components
Functions
Altsteps
Test Cases

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Module Parameters are supplied by the test environment at run-time and are treated as constants during test execution.

Data Types : a common name for simple basic types, basic string types, structured types, the special data type and all user defined types based on them.

Procedure **Signatures** (or signatures for short) are needed for procedure-based communication.

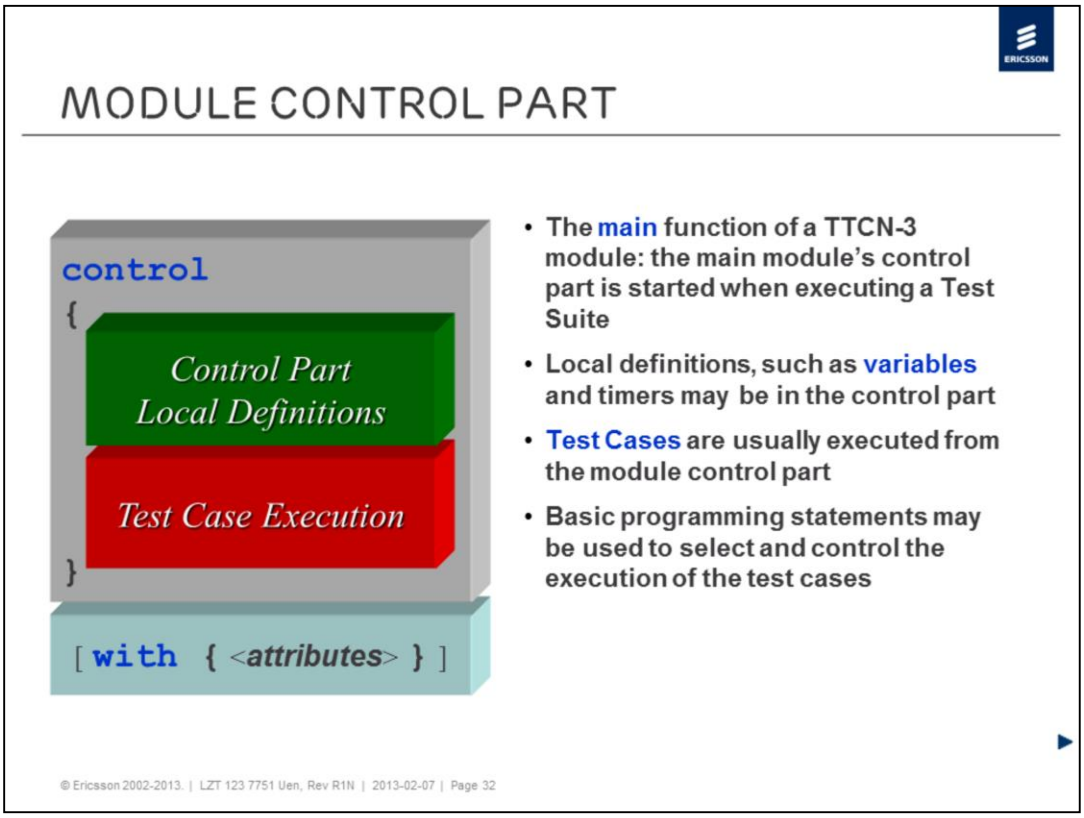
Templates are used to either transmit a set of distinct values or to test whether a set of received values matches the template specification. A template can be thought of as being a set of instructions to build a message for sending or to match a received message. **Message Templates** are used over message based ports, whereas **Signature Templates** are used over procedure based ports.

Test components are connected via their **Communication Ports**. Each port is modelled as an infinite FIFO queue which stores the incoming messages or procedure calls until they are processed.

Test Components are the owner of the ports. Each test component has a unique reference created during the execution of a test case.

Altsteps are special **functions** used to specify and structure test behaviour.

Test Cases are functions running on MTC and returning the result of the test ("verdict").



MODULE CONTROL PART

control

{

Control Part
Local Definitions

Test Case Execution

}

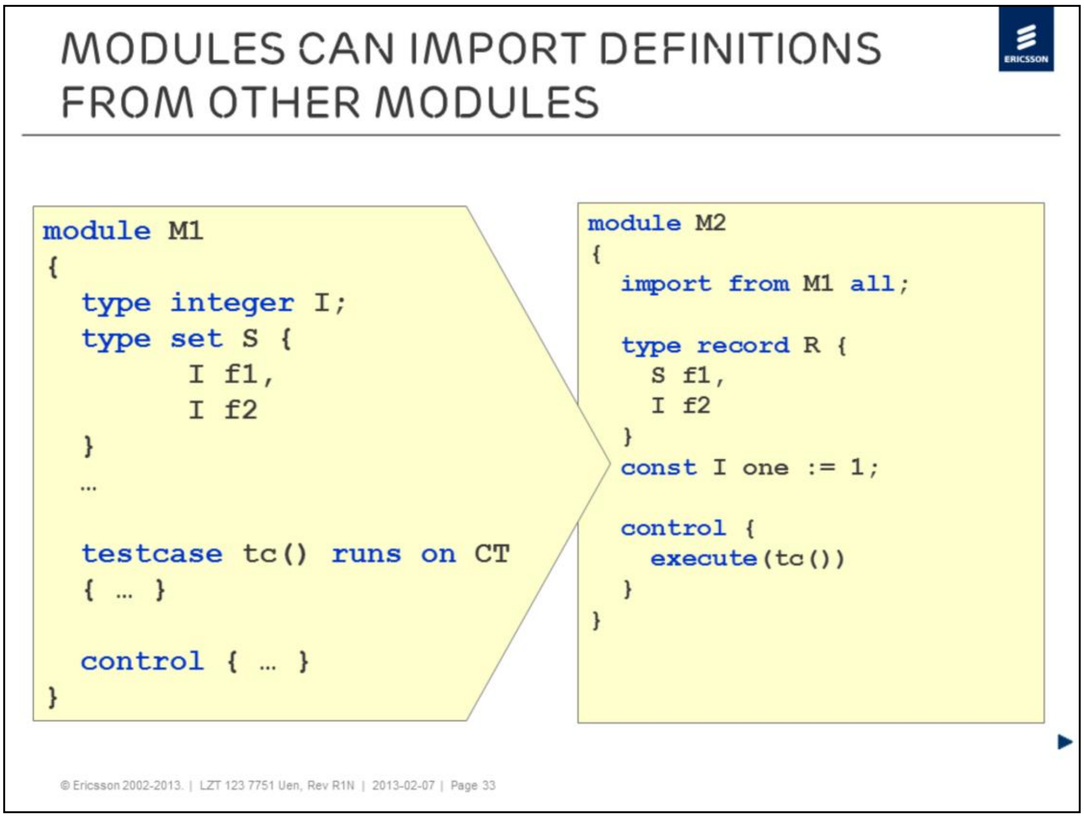
[**with** { <*attributes*> }]

- The main function of a TTCN-3 module: the main module's control part is started when executing a Test Suite
- Local definitions, such as variables and timers may be in the control part
- Test Cases are usually executed from the module control part
- Basic programming statements may be used to select and control the execution of the test cases

The module control part manages the execution of the test cases.

In the module control part the **execute** statement is used to start test cases. Program statements may be used in the control part of a module to specify such things as the order in which the test cases are to be executed or the number of times a test case may be run. Variables, timers etc. (if any) defined in the control part of a module are only locally visible, i.e., they shall be passed into the test case by parameterization when required.

As the result of the execution of a test case a test case verdict of either **none**, **pass**, **inconclusive**, **fail** or **error** shall be returned.



MODULES CAN IMPORT DEFINITIONS FROM OTHER MODULES

```
module M1
{
  type integer I;
  type set S {
         I f1,
         I f2
  }
  …

  testcase tc() runs on CT
  { … }

  control { … }
}
```

```
module M2
{
  import from M1 all;

  type record R {
    S f1,
    I f2
  }
  const I one := 1;

  control {
    execute(tc())
  }
}
```

Modules can import definitions from any module. Identifiers imported from other modules are globally visible throughout the importing module. It is possible to import to various extent:

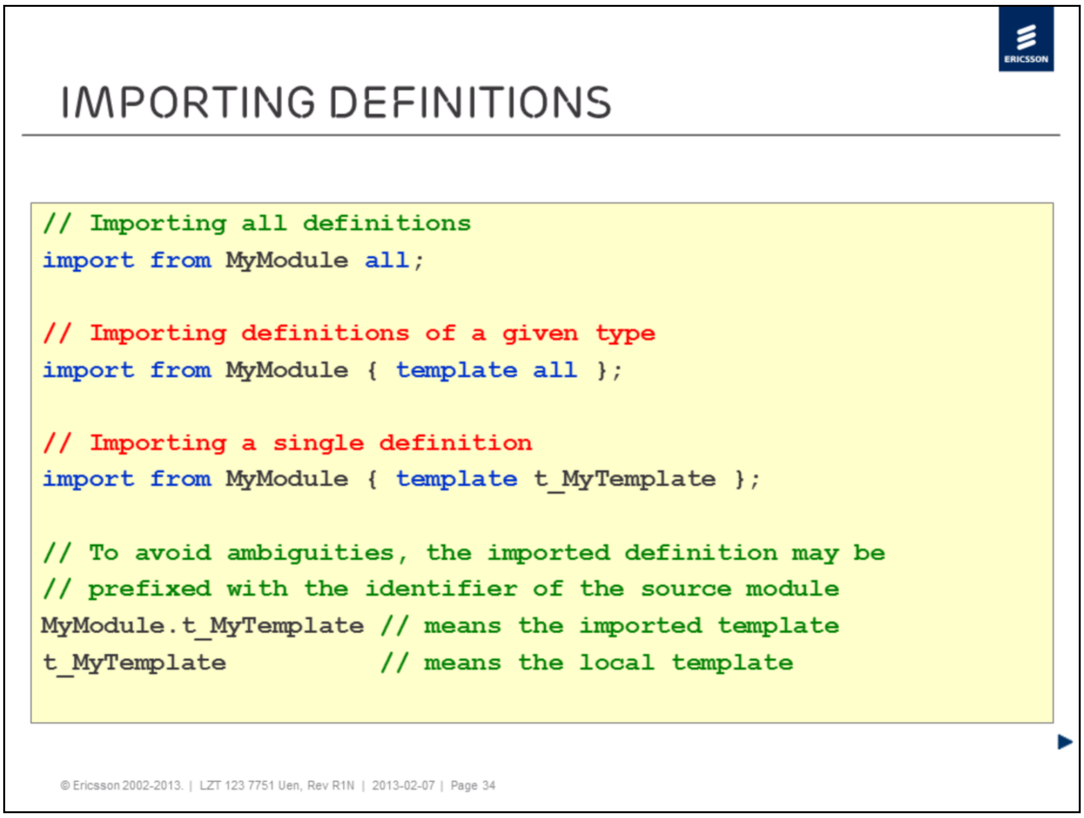
•single definitions;

•groups of definitions;

•all templates, functions and types;

•all definitions.

The default import mechanism imports referenced definitions without their identifier. A recursively imported definition, in turn, is imported together with all referenced definitions, i.e. the identifier of all referenced definitions becomes visible and usable in the importing module.



IMPORTING DEFINITIONS

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

// Importing definitions of a given type
import from MyModule { template all };

// Importing a single definition
import from MyModule { template t_MyTemplate };

// To avoid ambiguities, the imported definition may be
// prefixed with the identifier of the source module
MyModule.t_MyTemplate // means the imported template
t_MyTemplate          // means the local template
```

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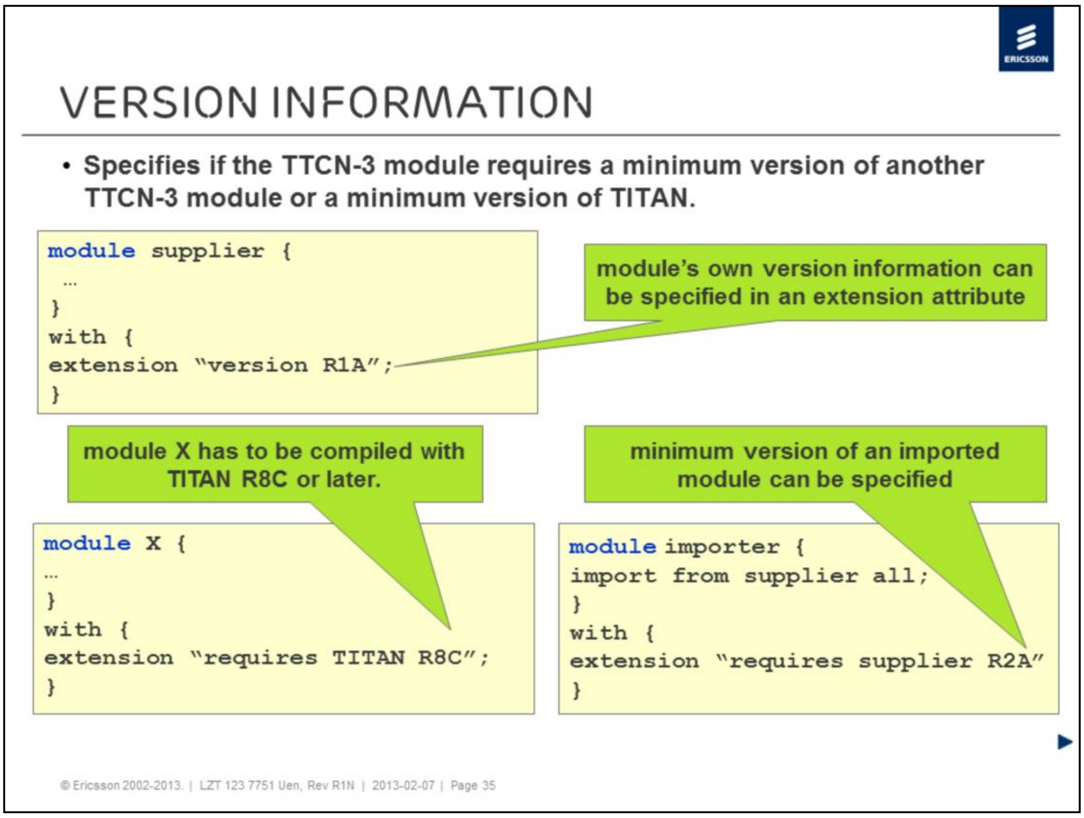
It is possible to re-use definitions specified in different modules using the **import** statement. An import statement can be used anywhere in the module definitions part. It shall not be used in the control part.

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.

The rules of importing are depicted in the chapter 7.5 of ETSI standard ES 201 873-1.

Legend: the import options preceded by comments in red are not implemented in the TITAN environment.



VERSION INFORMATION

- Specifies if the TTCN-3 module requires a minimum version of another TTCN-3 module or a minimum version of TITAN.

```
module supplier {
 …
}
with {
extension "version R1A";
}
```

module's own version information can be specified in an extension attribute

module X has to be compiled with TITAN R8C or later.

minimum version of an imported module can be specified

```
module X {
…
}
with {
extension "requires TITAN R8C";
}
```

```
module importer {
import from supplier all;
}
with {
extension "requires supplier R2A"
}
```

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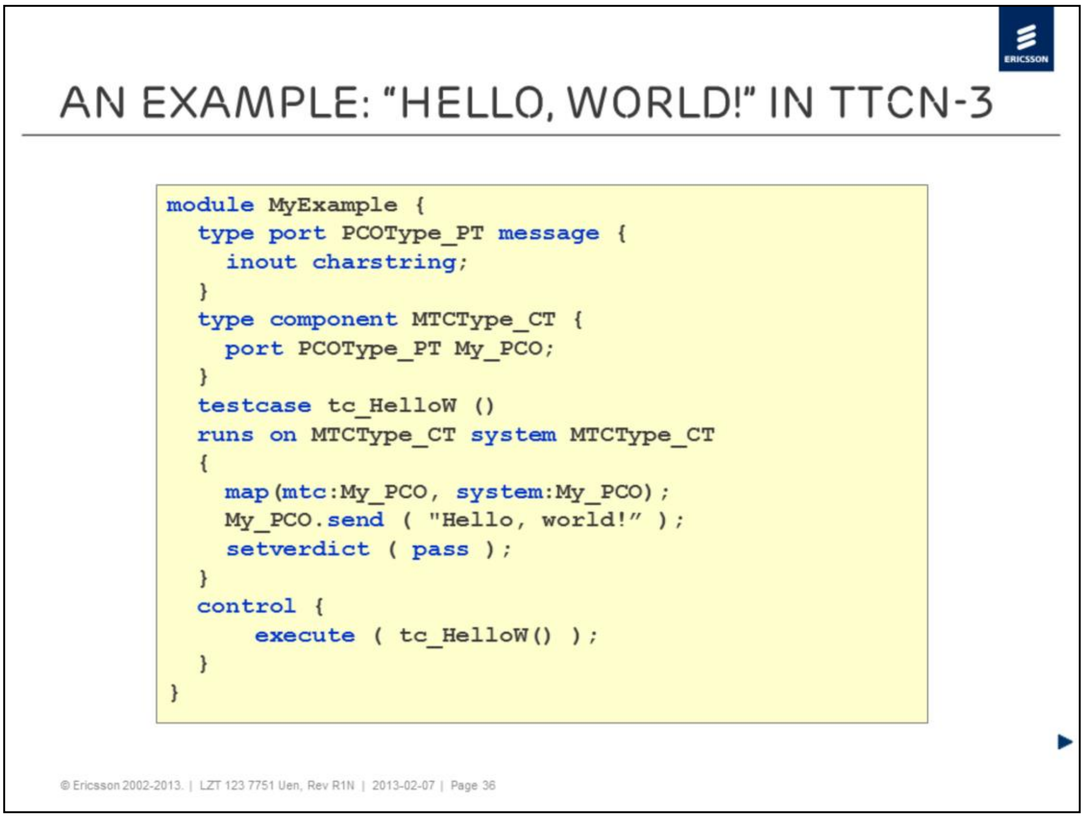


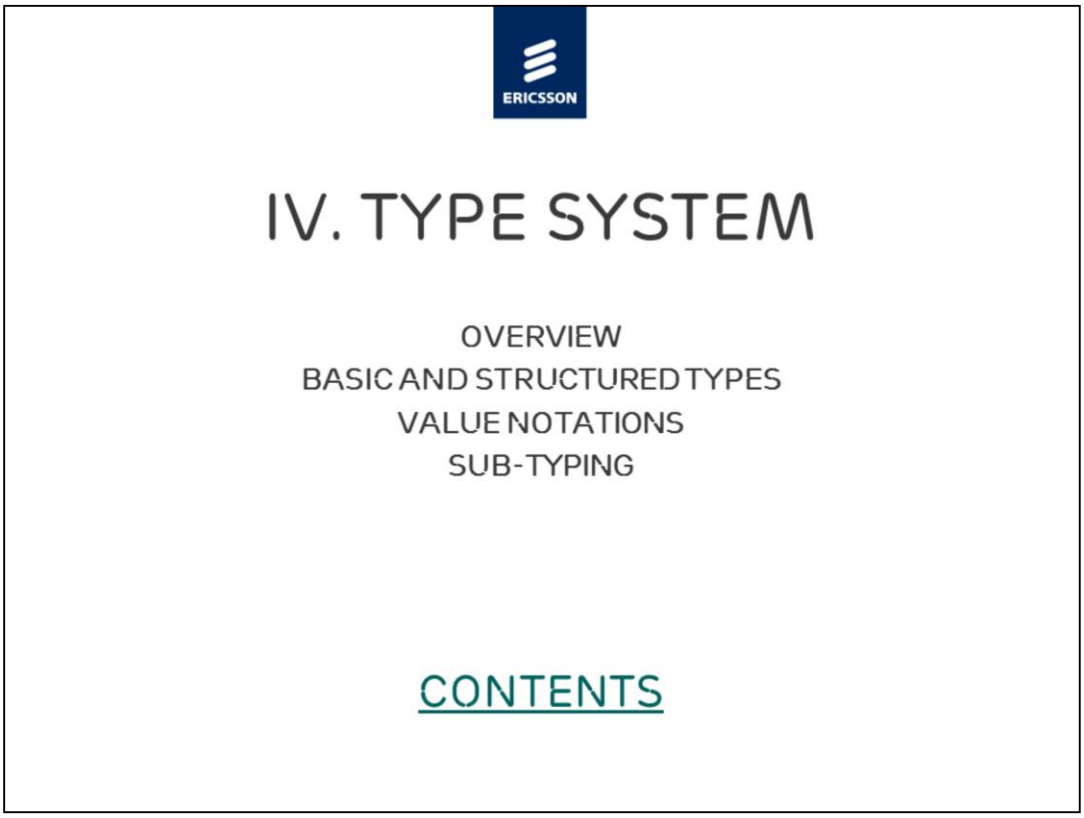
AN EXAMPLE: “HELLO, WORLD!” IN TTCN-3

```
module MyExample {
  type port PCOType_PT message {
    inout charstring;
  }
  type component MTCType_CT {
    port PCOType_PT My_PCO;
  }
  testcase tc_HelloW ()
  runs on MTCType_CT system MTCType_CT
  {
    map(mtc:My_PCO, system:My_PCO);
    My_PCO.send ( "Hello, world!” );
    setverdict ( pass );
  }
  control {
      execute ( tc_HelloW() );
  }
}
```

This classical example illustrates how many definitions should be made to complete a module.

The main point is the testcase called **HelloW**. The message is sent over the port **My_PCO** defined previously.

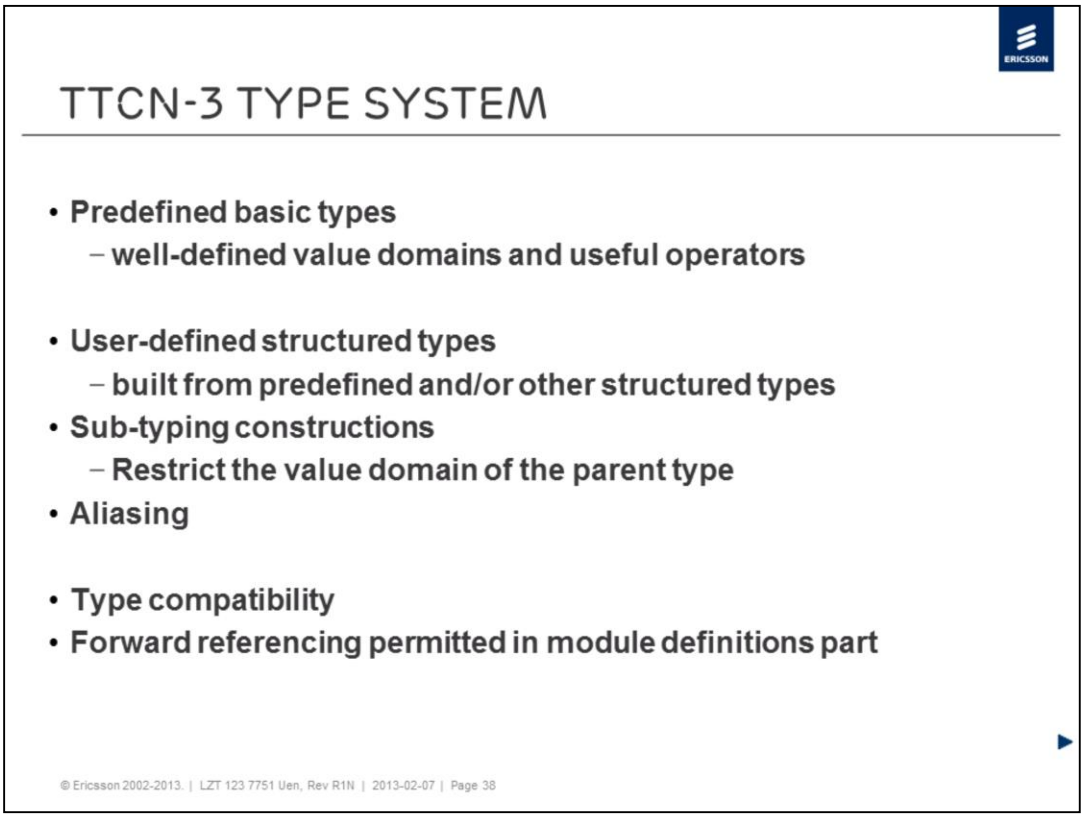
The port, component, testcase definition form the module definitions part followed by the module control part.



IV. TYPE SYSTEM

OVERVIEW
BASIC AND STRUCTURED TYPES
VALUE NOTATIONS
SUB-TYPING

CONTENTS



TTCN-3 TYPE SYSTEM

- **Predefined basic types**
  - **well-defined value domains and useful operators**
- **User-defined structured types**
  - **built from predefined and/or other structured types**
- **Sub-typing constructions**
  - **Restrict the value domain of the parent type**
- **Aliasing**
- **Type compatibility**
- **Forward referencing permitted in module definitions part**

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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 objid and verdicttype. Structured types such as record types, set types and enumerated types can be constructed from these basic types.

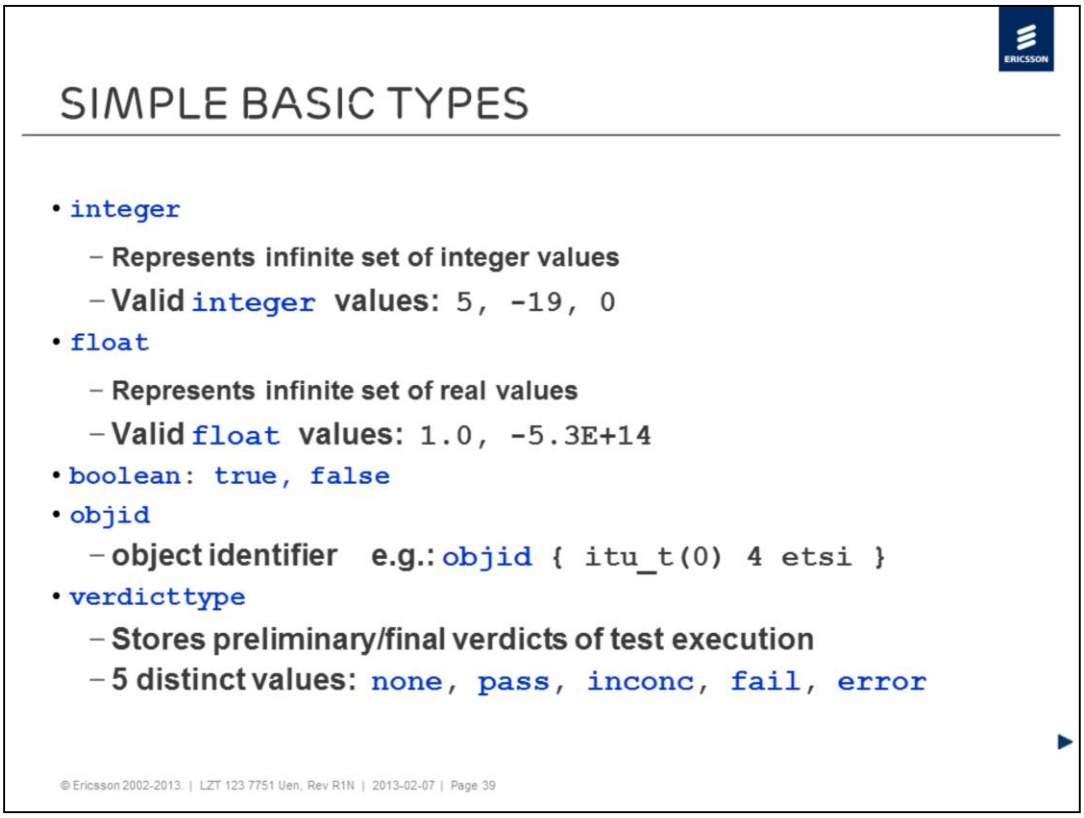
User-defined type is defined by subtyping of a basic type, defining a structured type or constraining the anytype to a single type by the dot notation.

Definitions in the module definitions part may be made in any order but **forward references** should be avoided for readability reasons.

Sub-types are user-defined types formed from simple basic and basic string types using lists, ranges and length restrictions.

Parameterisation: all user-defined type definitions support static value parameterization (i.e. this parameterization shall be resolved at compile-time); template, signature, testcase, altstep and function support dynamic value parameterization (i.e. this parameterization shall be resolvable at run-time).

Type compatibility: TTCN-3 is **not strongly typed.** For non-structured variables, constants, templates etc. the value "b" is compatible to type "A" if type "B" resolves to the same root type as type "A" and it does not violate subtyping (e.g. ranges, length restrictions) of type "A". In the case of structured types (except the enumerated type, that is never compatible with other basic or structured types) a value "b" of type "B" is compatible with type "A", if the effective value structures of type "B" and type "A" are compatible. The communication operations are exceptions to the weaker rule of type compatibility and require strong typing.



SIMPLE BASIC TYPES

- `integer`
  - Represents infinite set of integer values
  - Valid `integer` values: `5, -19, 0`
- `float`
  - Represents infinite set of real values
  - Valid `float` values: `1.0, -5.3E+14`
- `boolean: true, false`
- `objid`
  - object identifier e.g.: `objid { itu_t(0) 4 etsi }`
- `verdicttype`
  - Stores preliminary/final verdicts of test execution
  - 5 distinct values: `none, pass, inconc, fail, error`

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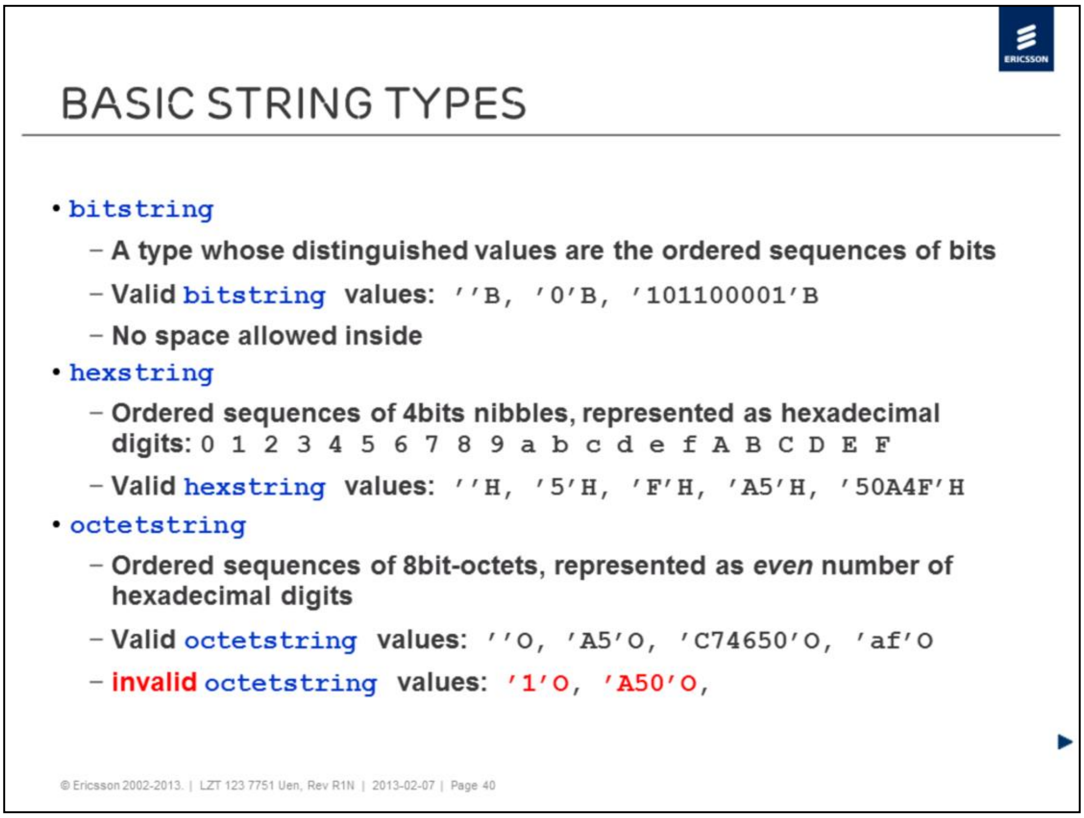
Integer: a type with distinguished values which are the positive and negative whole numbers, including zero.

Float: a type to describe floating-point numbers. Floating point numbers are represented in TTCN-3 as: <mantissa> × <10>$^{\text{<exponent>.}}$

Boolean: a type consisting of two distinguished values: true, false.

Objid: a type whose distinguished values are the set of all object identifiers conforming to clause 6.2 of ITU-T Recommendation X.660.

Verdicttype: a type for use with test verdicts consisting of 5 distinguished values.



BASIC STRING TYPES

- `bitstring`
  - A type whose distinguished values are the ordered sequences of bits
  - Valid `bitstring` values: `’’B, ’0’B, ’101100001’B`
  - No space allowed inside
- `hexstring`
  - Ordered sequences of 4bits nibbles, represented as hexadecimal digits: `0 1 2 3 4 5 6 7 8 9 a b c d e f A B C D E F`
  - Valid `hexstring` values: `’’H, ’5’H, ’F’H, ’A5’H, ’50A4F’H`
- `octetstring`
  - Ordered sequences of 8bit-octets, represented as *even* number of hexadecimal digits
  - Valid `octetstring` values: `’’O, ’A5’O, ’C74650’O, ’af’O`
  - invalid `octetstring` values: `’1’O, ’A50’O,`

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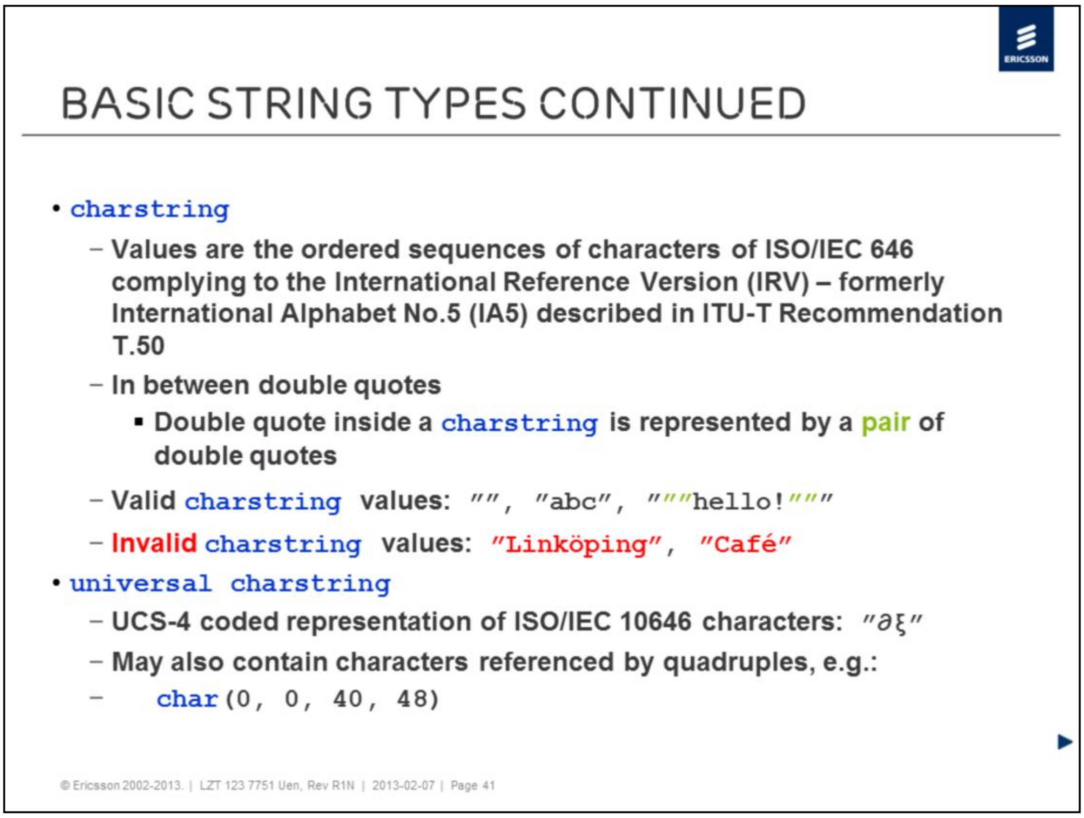
Bitstring: a type whose distinguished values are the ordered sequences of zero, one, or more bits.

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.

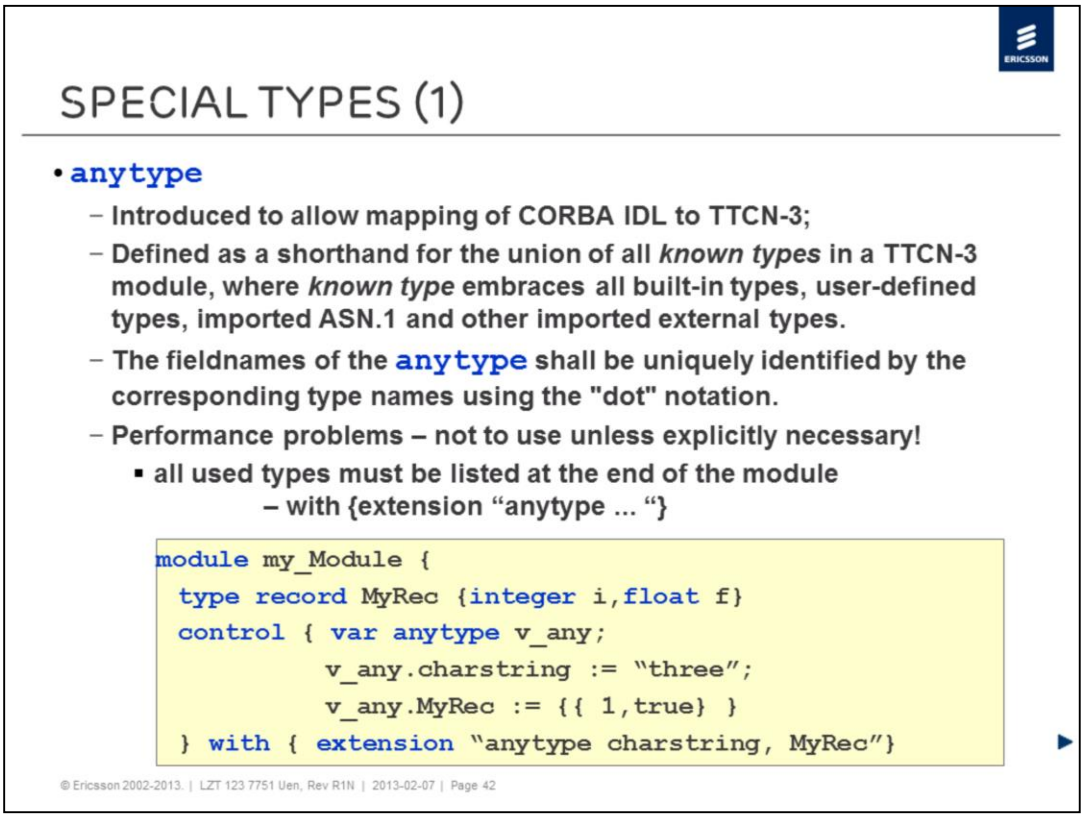
Octetstring: a type whose distinguished values are the ordered sequences of zero or a positive even number of hexadecimal digits (every pair of digits corresponding to an ordered sequence of eight bits).



BASIC STRING TYPES CONTINUED

- `charstring`
  - Values are the ordered sequences of characters of ISO/IEC 646 complying to the International Reference Version (IRV) – formerly International Alphabet No.5 (IA5) described in ITU-T Recommendation T.50
  - In between double quotes
    - Double quote inside a `charstring` is represented by a pair of double quotes
  - Valid `charstring` values: `""`, `"abc"`, `"""hello!"""`
  - Invalid `charstring` values: `"Linköping"`, `"Café"`
- `universal charstring`
  - UCS-4 coded representation of ISO/IEC 10646 characters: "∂ξ"
  - May also contain characters referenced by quadruples, e.g.:
  - `char(0, 0, 40, 48)`

`Universal charstring:` The "quadruple" is capable to denote a single character and denotes the character by the decimal values of its group, plane, row and cell according to ISO/IEC 10646.



SPECIAL TYPES (1)

- **anytype**
  - Introduced to allow mapping of CORBA IDL to TTCN-3;
  - Defined as a shorthand for the union of all *known types* in a TTCN-3 module, where *known type* embraces all built-in types, user-defined types, imported ASN.1 and other imported external types.
  - The fieldnames of the **anytype** shall be uniquely identified by the corresponding type names using the "dot" notation.
  - Performance problems – not to use unless explicitly necessary!
    - all used types must be listed at the end of the module – with {extension "anytype … "}

```
module my_Module {
  type record MyRec {integer i,float f}
  control { var anytype v_any;
            v_any.charstring := "three";
            v_any.MyRec := {{ 1,true} }
  } with { extension "anytype charstring, MyRec"}
```

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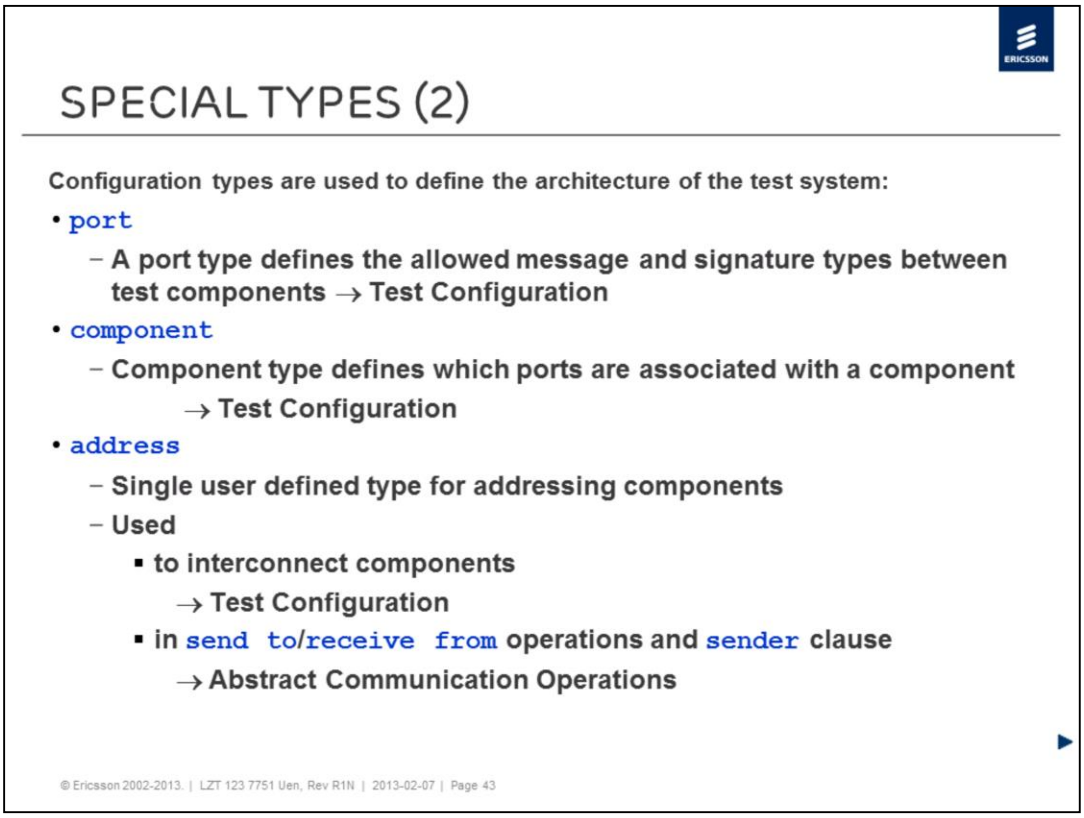
CORBA	Common Object Request Broker Architecture
IDL	Interface Description Language

The specification of CORBA IDL can be read by following the Uniform Resource Locator: http://www.omg.org/technology/documents/idl2x_spec_catalog.htm

```
module my_Module {
type integer money;
type record MyRec {
integer i,
float f
}
control {
var anytype v_any;
v_any.integer := 3;
// ischosen(v_any.integer) == true
v_any.charstring := "three";
}
}
with {
extension "anytype integer, charstring" // adds two fields
extension "anytype MyRec" // adds a third field
extension "anytype money" // adds the money type
}
```



SPECIAL TYPES (2)

Configuration types are used to define the architecture of the test system:

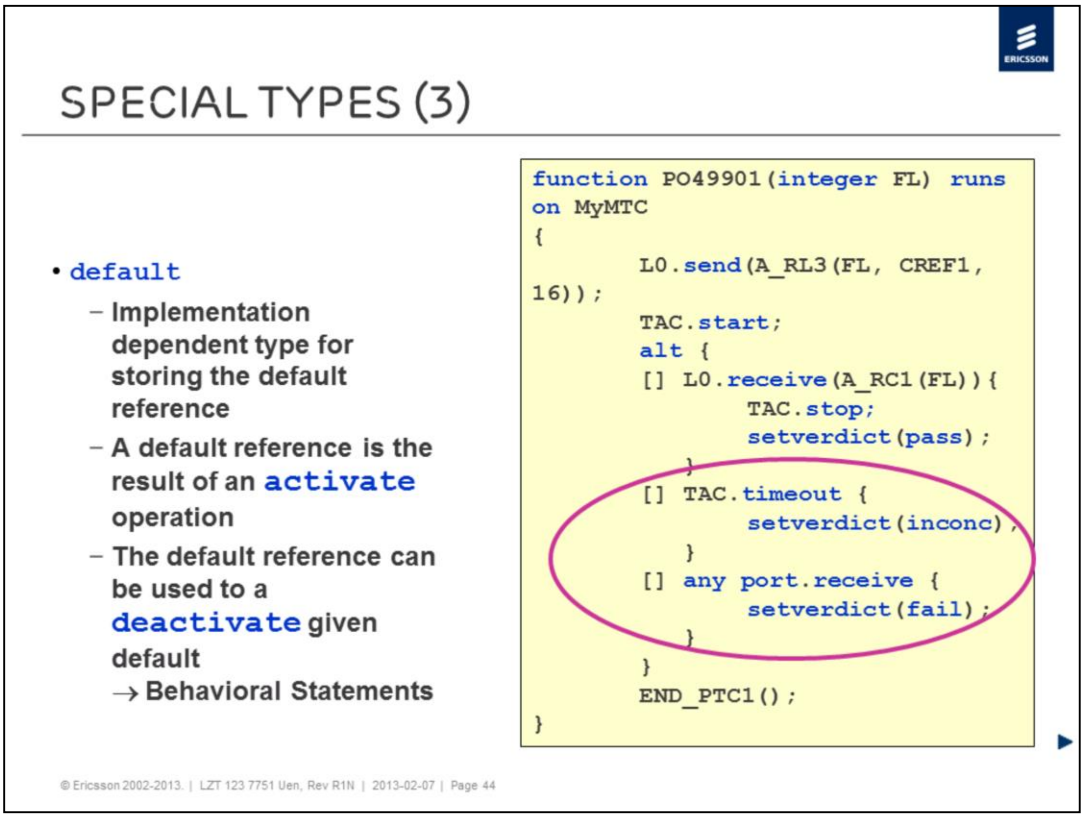
- `port`
  - A port type defines the allowed message and signature types between test components → Test Configuration
- `component`
  - Component type defines which ports are associated with a component → Test Configuration
- `address`
  - Single user defined type for addressing components
  - Used
    - to interconnect components → Test Configuration
    - in `send to`/`receive from` operations and `sender` clause → Abstract Communication Operations

Address shall only be used in receive and send operations of ports mapped to test system interface. Only one definition of type address may exist in a test suite.

SUT: System Under Test

Each **port** type definition shall have list(s) indicating the allowed collection of message types and/or procedures together with the allowed communication direction.

Component definitions shall be made in the module definitions part. It is possible to define constants, variables and timers local to a particular component.

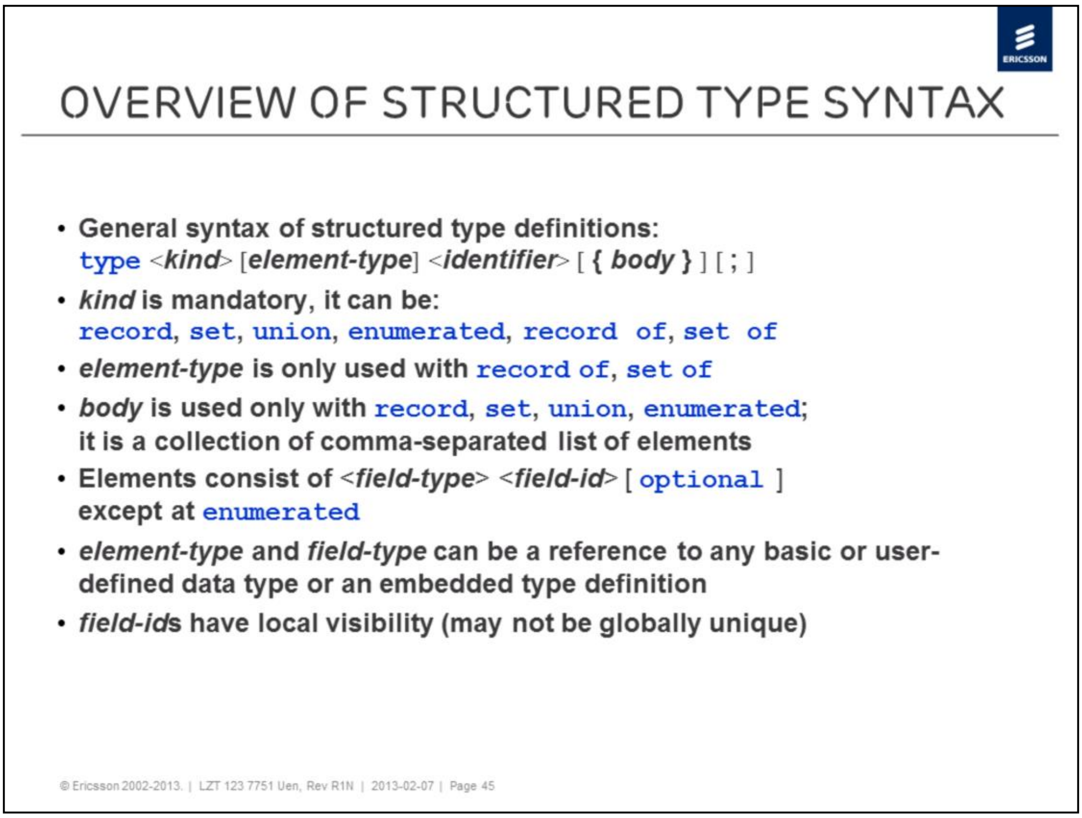


SPECIAL TYPES (3)

- `default`
  - Implementation dependent type for storing the default reference
  - A default reference is the result of an `activate` operation
  - The default reference can be used to a `deactivate` given default → Behavioral Statements

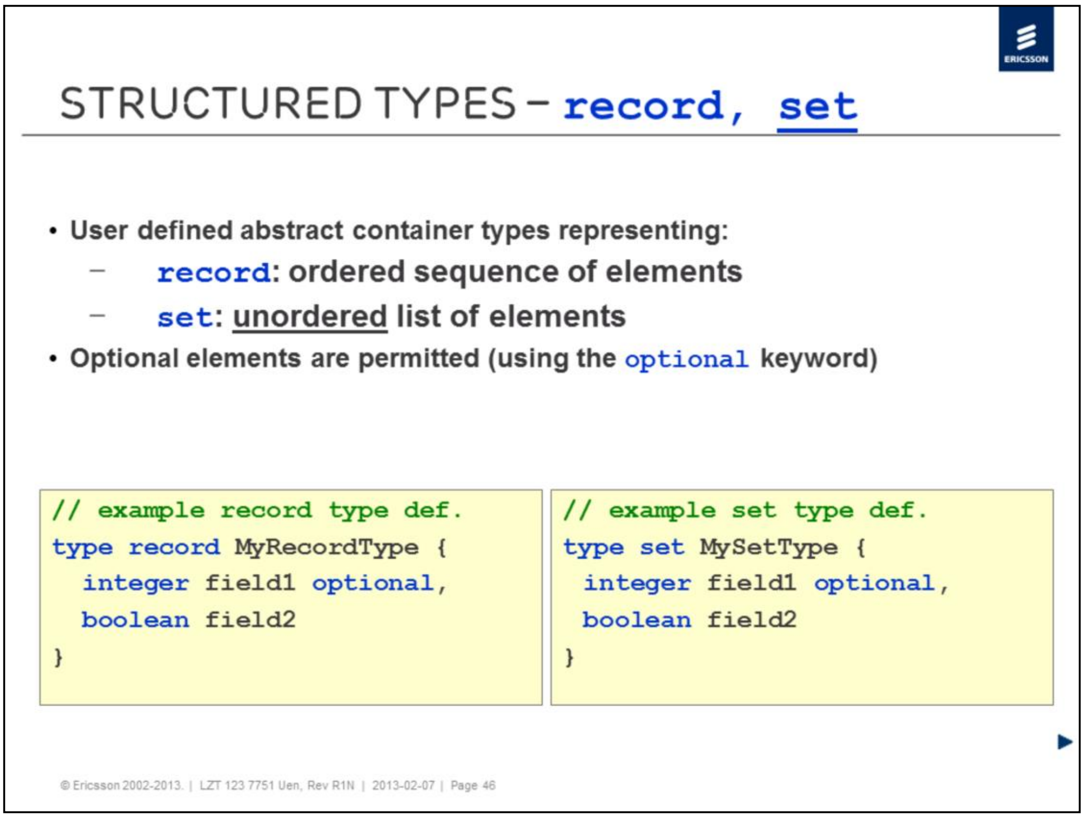
```
function PO49901(integer FL) runs
on MyMTC
{
        L0.send(A_RL3(FL, CREF1,
16));
        TAC.start;
        alt {
        [] L0.receive(A_RC1(FL)){
                TAC.stop;
                setverdict(pass);
            }
        [] TAC.timeout {
                setverdict(inconc);
            }
        [] any port.receive {
                setverdict(fail);
            }
        }
        END_PTC1();
}
```

Received messages are usually examined in an alt statement. When no branch of the alt matches the received message, the previously activated default(s) are examined. It is possible to have several defaults activated at same time and deactivate them one by one.



OVERVIEW OF STRUCTURED TYPE SYNTAX

- **General syntax of structured type definitions:**
  `type` <***kind***> [***element-type***] <***identifier***> [**{** ***body*** **}**] [;]
- ***kind*** **is mandatory, it can be:**
  `record`, `set`, `union`, `enumerated`, `record of`, `set of`
- ***element-type*** **is only used with** `record of`, `set of`
- ***body*** **is used only with** `record`, `set`, `union`, `enumerated`**;**
  it is a collection of comma-separated list of elements
- **Elements consist of** <***field-type***> <***field-id***> [`optional`]
  except at `enumerated`
- ***element-type*** **and** ***field-type*** **can be a reference to any basic or user-defined data type or an embedded type definition**
- ***field-id*****s have local visibility (may not be globally unique)**



STRUCTURED TYPES – `record`, `set`

- User defined abstract container types representing:
  - `record`: ordered sequence of elements
  - `set`: unordered list of elements
- Optional elements are permitted (using the `optional` keyword)

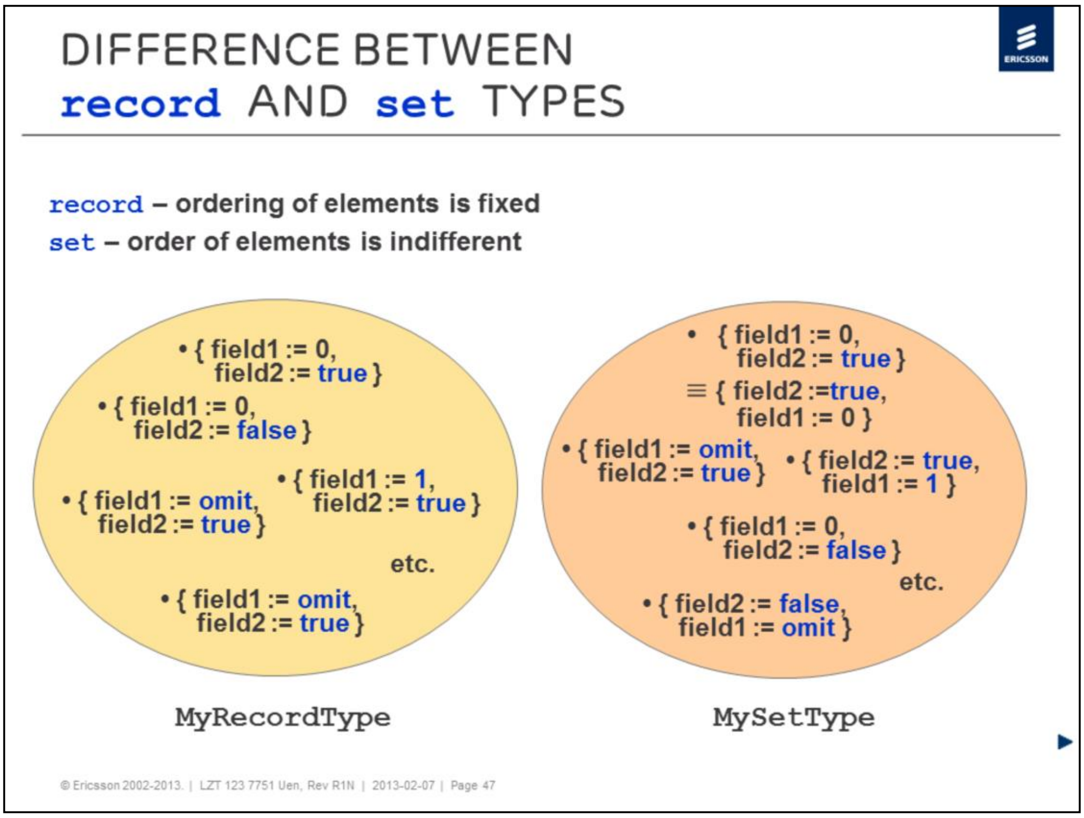
```
// example record type def.
type record MyRecordType {
  integer field1 optional,
  boolean field2
}
```

```
// example set type def.
type set MySetType {
 integer field1 optional,
 boolean field2
}
```

In the above example, "type" of the elements is integer or boolean, their "identifier" is field1 or field2. The same identifiers may be used in both record and set, because it is not mandatory to use globally unique names.

Optional elements may or may not be present when assigning value to the constructs.

A record or a set may be an element of another record or set.



DIFFERENCE BETWEEN `record` AND `set` TYPES

`record` – ordering of elements is fixed

`set` – order of elements is indifferent

MyRecordType

- { field1 := 0, field2 := true }
- { field1 := 0, field2 := false }
- { field1 := omit, field2 := true }
- { field1 := 1, field2 := true }
- { field1 := omit, field2 := true }

etc.

MySetType

- { field1 := 0, field2 := true }

≡ { field2 :=true, field1 := 0 }

- { field1 := omit, field2 := true }
- { field2 := true, field1 := 1 }
- { field1 := 0, field2 := false }
- { field2 := false, field1 := omit }

etc.

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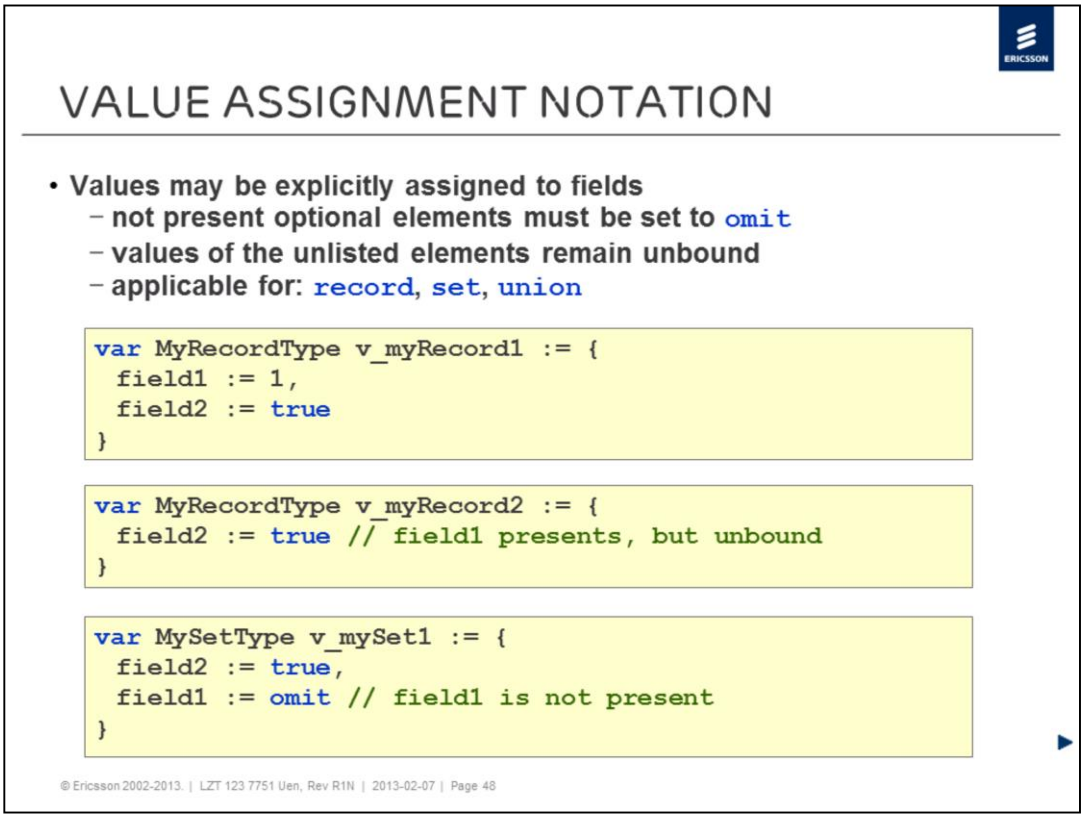
The main difference between **record** and **set** is the following: elements of a record must be referenced in the same order as defined, whereas elements of a set may be referenced in arbitrary order. In other words, the ordering of the **set** fields is not significant.



VALUE ASSIGNMENT NOTATION

- Values may be explicitly assigned to fields
  - not present optional elements must be set to `omit`
  - values of the unlisted elements remain unbound
  - applicable for: `record`, `set`, `union`

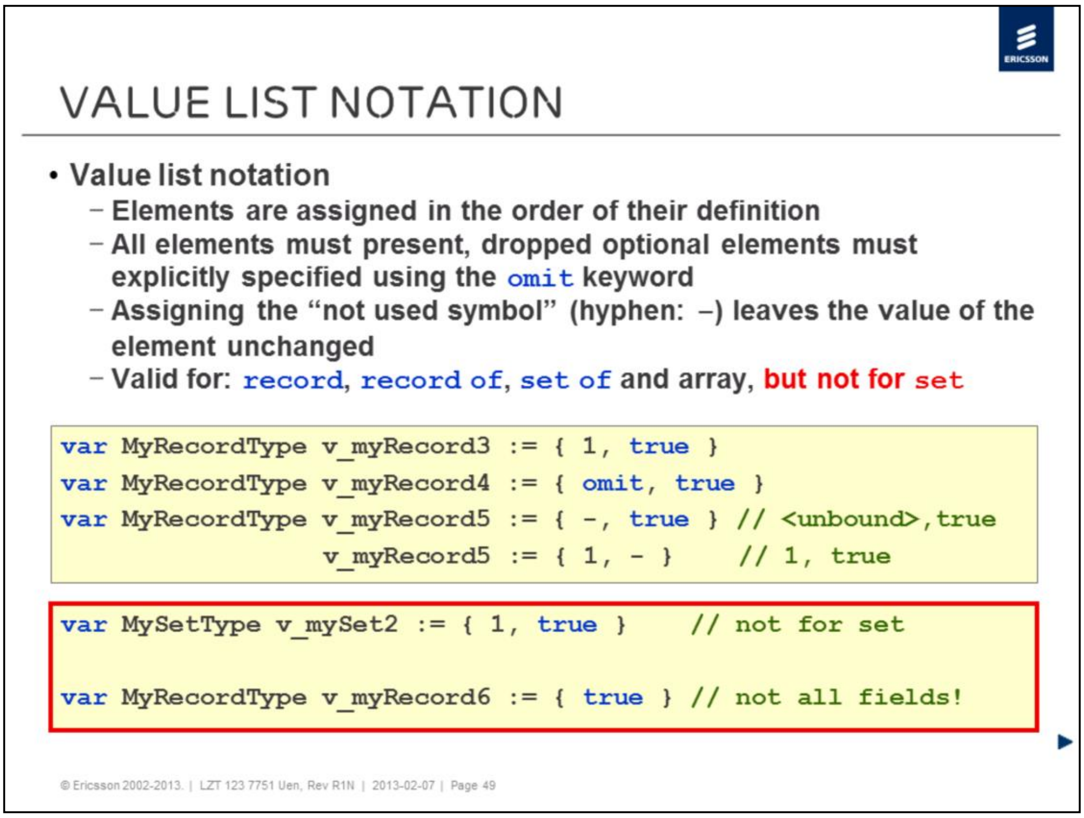
```
var MyRecordType v_myRecord1 := {
  field1 := 1,
  field2 := true
}
```

```
var MyRecordType v_myRecord2 := {
  field2 := true // field1 presents, but unbound
}
```

```
var MySetType v_mySet1 := {
  field2 := true,
  field1 := omit // field1 is not present
}
```

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

Assignment notation: in the curly brackets following the name of the record or set, the element identifier must be present to designate which element is the value is assigned to. It is important to know that every identifier of the record or set must be listed. Omitted optional elements must be given the value "omit" otherwise its value remains undetermined (unbound), resulting in run-time error.



VALUE LIST NOTATION

- Value list notation
  - Elements are assigned in the order of their definition
  - All elements must present, dropped optional elements must explicitly specified using the `omit` keyword
  - Assigning the “not used symbol” (hyphen: –) leaves the value of the element unchanged
  - Valid for: `record`, `record of`, `set of` and array, **but not for** `set`

```
var MyRecordType v_myRecord3 := { 1, true }
var MyRecordType v_myRecord4 := { omit, true }
var MyRecordType v_myRecord5 := { -, true } // <unbound>,true
                 v_myRecord5 := { 1, - }    // 1, true
```

```
var MySetType v_mySet2 := { 1, true }    // not for set

var MyRecordType v_myRecord6 := { true } // not all fields!
```

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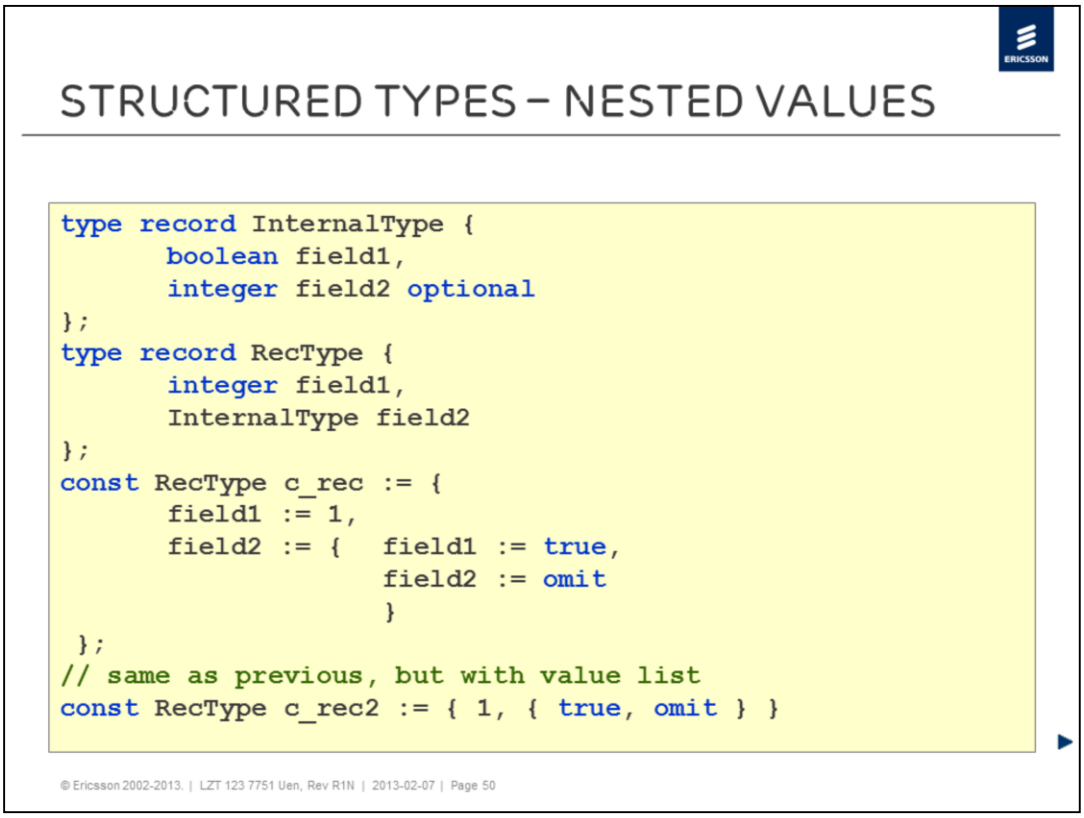
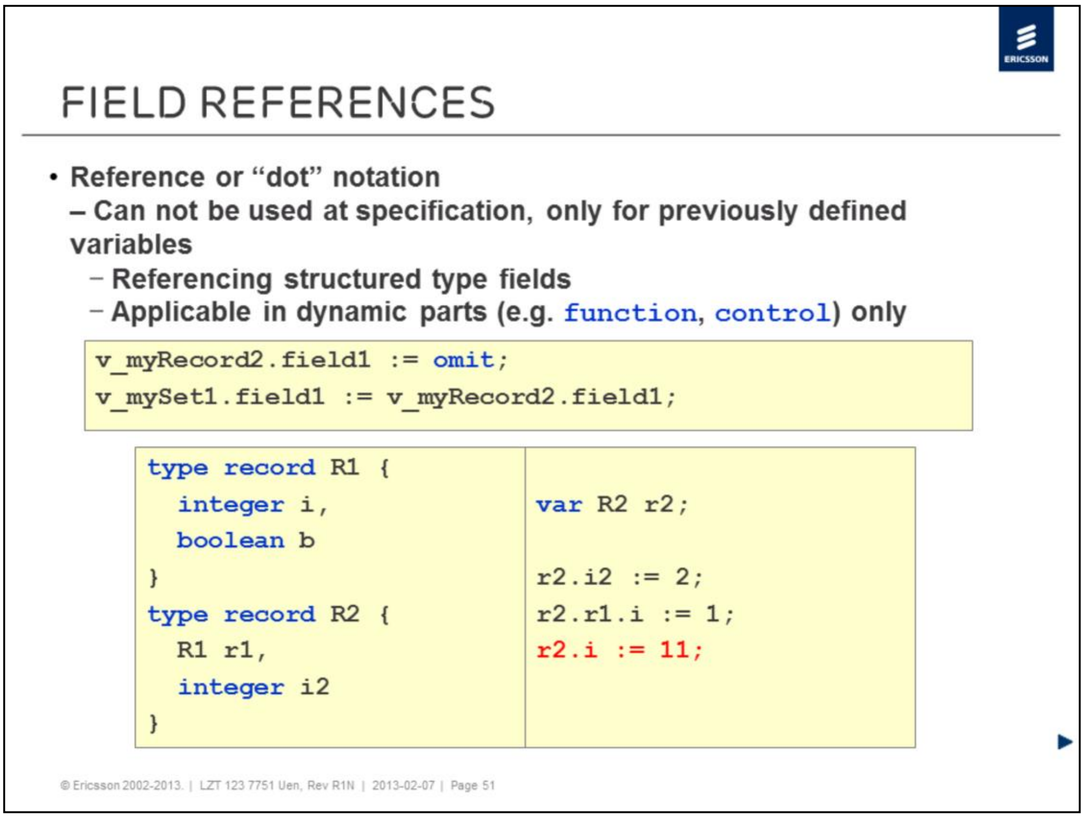
Value-list notation: in the curly brackets following the name of the record, values of the elements are listed one by one. Every identifier of the record must be listed. Omitted optional elements must be given the value "omit" otherwise its value remains undetermined (unbound), resulting in run-time error. In contrast to value assignment notation, all elements must appear inside the initializer. Application of the hyphen (-) leaves the corresponding field unchanged. Attention! Such a field is unbound unless it has been given a value earlier. It is not allowed to mix value-list notation and assignment notation in the same context! The not-used symbol is only valid in value-list notation.



STRUCTURED TYPES – NESTED VALUES

```
type record InternalType {
       boolean field1,
       integer field2 optional
};
type record RecType {
       integer field1,
       InternalType field2
};
const RecType c_rec := {
       field1 := 1,
       field2 := {   field1 := true,
                     field2 := omit
                     }
 };
// same as previous, but with value list
const RecType c_rec2 := { 1, { true, omit } }
```



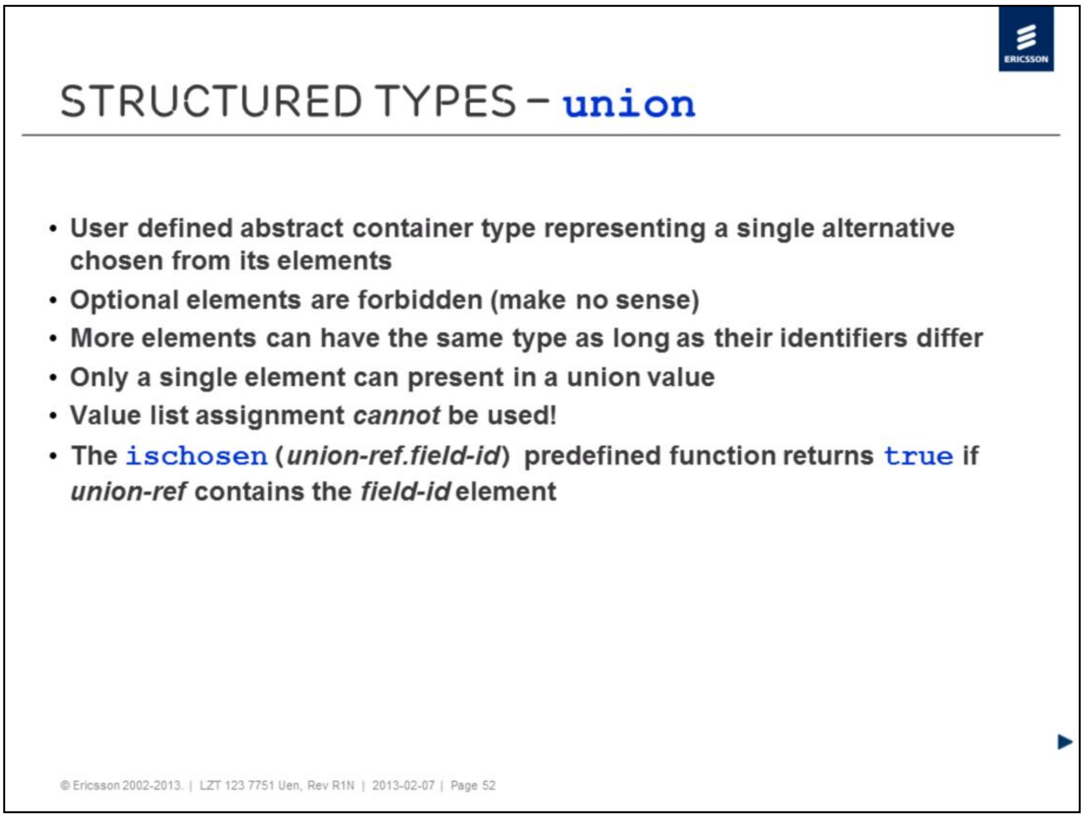
FIELD REFERENCES

- Reference or “dot” notation
  – Can not be used at specification, only for previously defined variables
    - Referencing structured type fields
    - Applicable in dynamic parts (e.g. `function`, `control`) only

```
v_myRecord2.field1 := omit;
v_mySet1.field1 := v_myRecord2.field1;
```

```
type record R1 {
  integer i,
  boolean b
}
type record R2 {
  R1 r1,
  integer i2
}
```

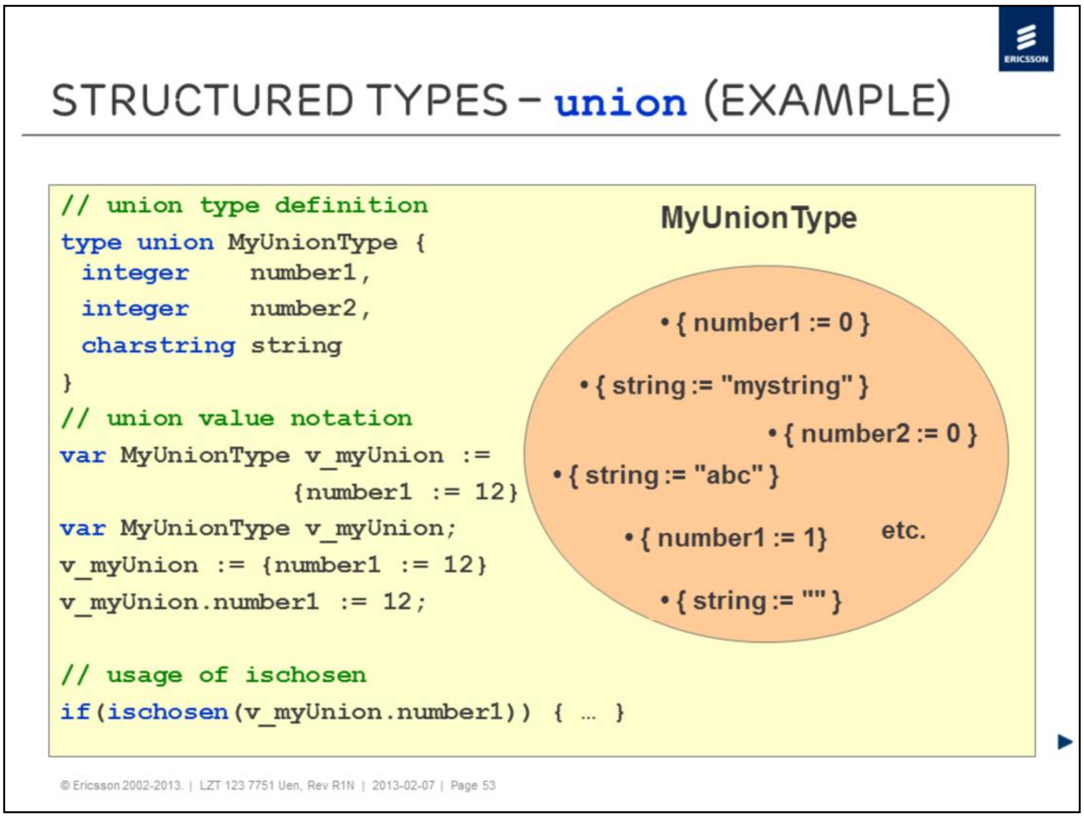
```

var R2 r2;

r2.i2 := 2;
r2.r1.i := 1;
r2.i := 11;
```



STRUCTURED TYPES – `union`

- User defined abstract container type representing a single alternative chosen from its elements
- Optional elements are forbidden (make no sense)
- More elements can have the same type as long as their identifiers differ
- Only a single element can present in a union value
- Value list assignment *cannot* be used!
- The `ischosen` (*union-ref.field-id*) predefined function returns `true` if *union-ref* contains the *field-id* element

Union type is useful to model a structure which can take one of a finite number of known types.



STRUCTURED TYPES – union (EXAMPLE)

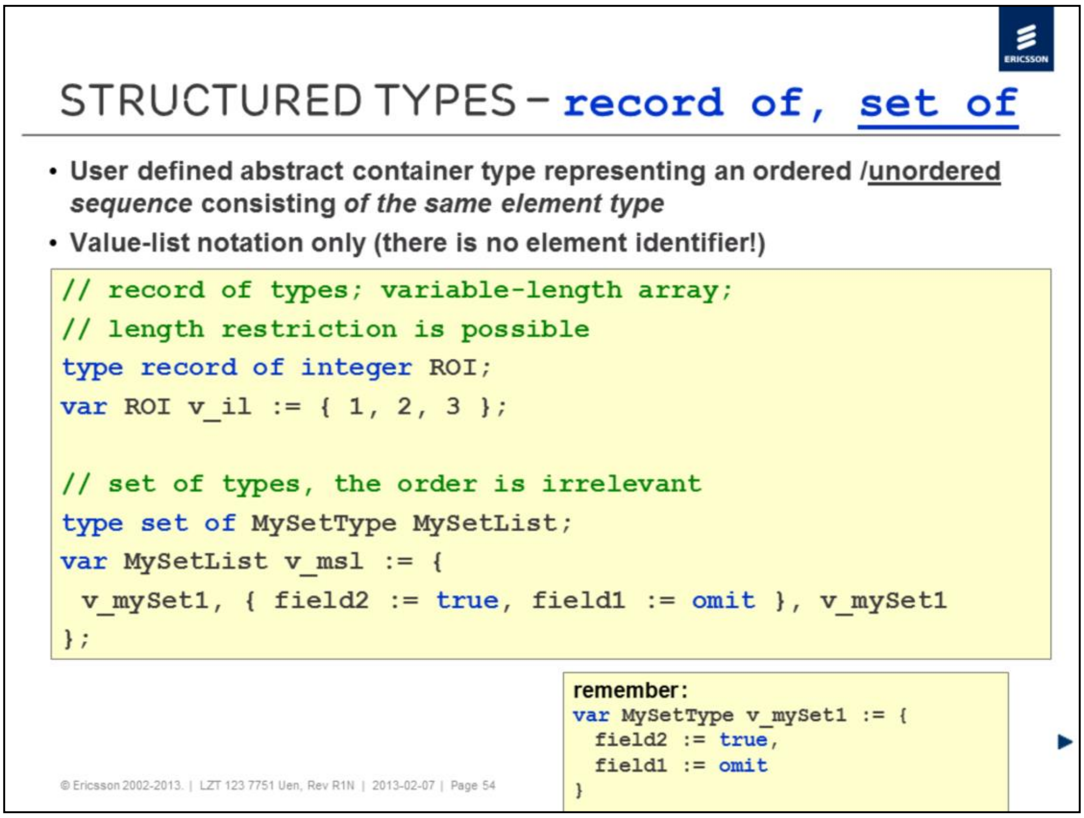
```
// union type definition
type union MyUnionType {
  integer    number1,
  integer    number2,
  charstring string
}
// union value notation
var MyUnionType v_myUnion :=
                     {number1 := 12}
var MyUnionType v_myUnion;
v_myUnion := {number1 := 12}
v_myUnion.number1 := 12;

// usage of ischosen
if(ischosen(v_myUnion.number1)) { … }
```

MyUnionType

- { number1 := 0 }
- { string := "mystring" }
- { number2 := 0 }
- { string := "abc" }
- { number1 := 1}
- { string := "" }

etc.

For the **union** type, assignment notation and dot notation may be used. (First, respective second row in the example on the middle of the slide.) Value-list notation (listing of element values without their identifiers) must not be used.



STRUCTURED TYPES – `record of`, `set of`

- User defined abstract container type representing an ordered /unordered *sequence* consisting *of the same element type*
- Value-list notation only (there is no element identifier!)

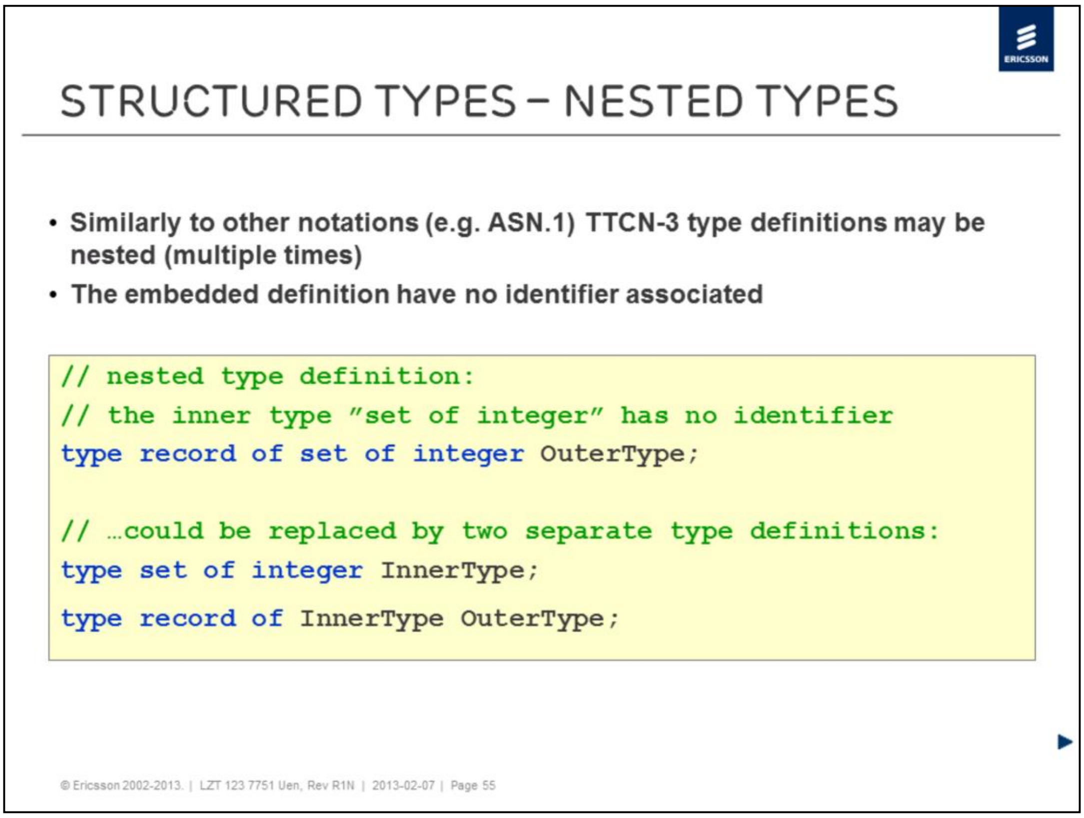
```
// record of types; variable-length array;
// length restriction is possible
type record of integer ROI;
var ROI v_il := { 1, 2, 3 };

// set of types, the order is irrelevant
type set of MySetType MySetList;
var MySetList v_msl := {
  v_mySet1, { field2 := true, field1 := omit }, v_mySet1
};
```

remember:

```
var MySetType v_mySet1 := {
  field2 := true,
  field1 := omit
}
```

The only difference between **record of** and **set of** appears when comparing them. Two **records of** are only equal when they contain the equal elements in the same order. Two **sets of** are equal if there is exactly one pair for each element.

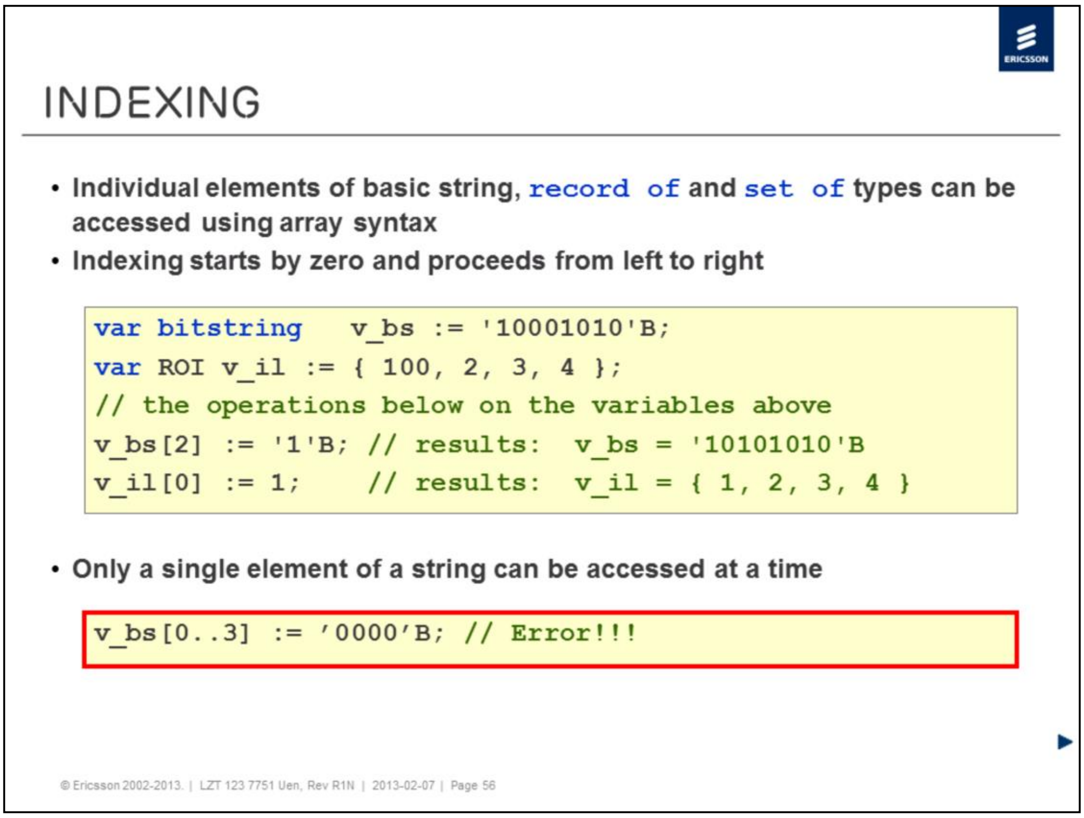
These records and sets can be considered similar to an ordered array and an unordered array respectively.



STRUCTURED TYPES – NESTED TYPES

- Similarly to other notations (e.g. ASN.1) TTCN-3 type definitions may be nested (multiple times)
- The embedded definition have no identifier associated

```
// nested type definition:
// the inner type ”set of integer” has no identifier
type record of set of integer OuterType;

// …could be replaced by two separate type definitions:
type set of integer InnerType;
type record of InnerType OuterType;
```



INDEXING

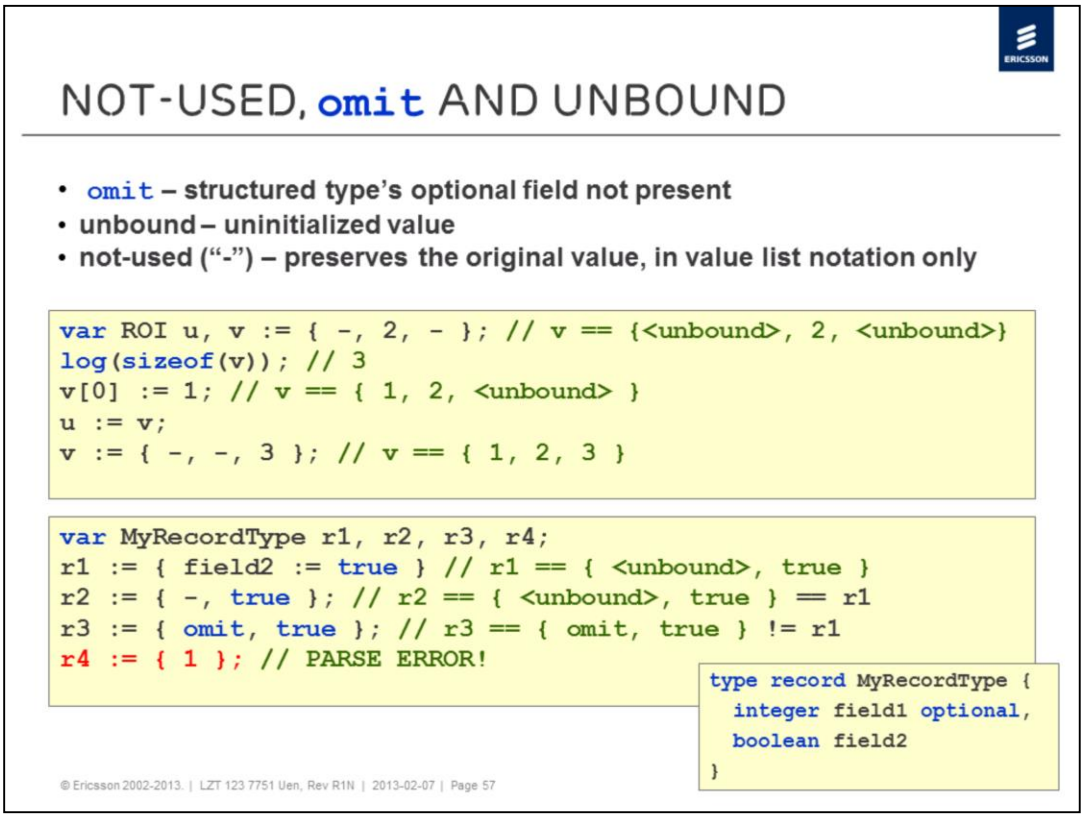
- Individual elements of basic string, `record of` and `set of` types can be accessed using array syntax
- Indexing starts by zero and proceeds from left to right

```
var bitstring   v_bs := '10001010'B;
var ROI v_il := { 100, 2, 3, 4 };
// the operations below on the variables above
v_bs[2] := '1'B; // results:  v_bs = '10101010'B
v_il[0] := 1;    // results:  v_il = { 1, 2, 3, 4 }
```

- Only a single element of a string can be accessed at a time

```
v_bs[0..3] := ’0000’B; // Error!!!
```

When indexing a string type element, index corresponds to different units of length in function of the string type. A bitstring is indexed by bits, a hexstring by hexadecimal digits, an octetstring by octets and finally a character string by characters.



NOT-USED, omit AND UNBOUND

- `omit` – structured type's optional field not present
- unbound – uninitialized value
- not-used ("-") – preserves the original value, in value list notation only

```
var ROI u, v := { -, 2, - }; // v == {<unbound>, 2, <unbound>}
log(sizeof(v)); // 3
v[0] := 1; // v == { 1, 2, <unbound> }
u := v;
v := { -, -, 3 }; // v == { 1, 2, 3 }
```

```
var MyRecordType r1, r2, r3, r4;
r1 := { field2 := true } // r1 == { <unbound>, true }
r2 := { -, true }; // r2 == { <unbound>, true } == r1
r3 := { omit, true }; // r3 == { omit, true } != r1
r4 := { 1 }; // PARSE ERROR!
```

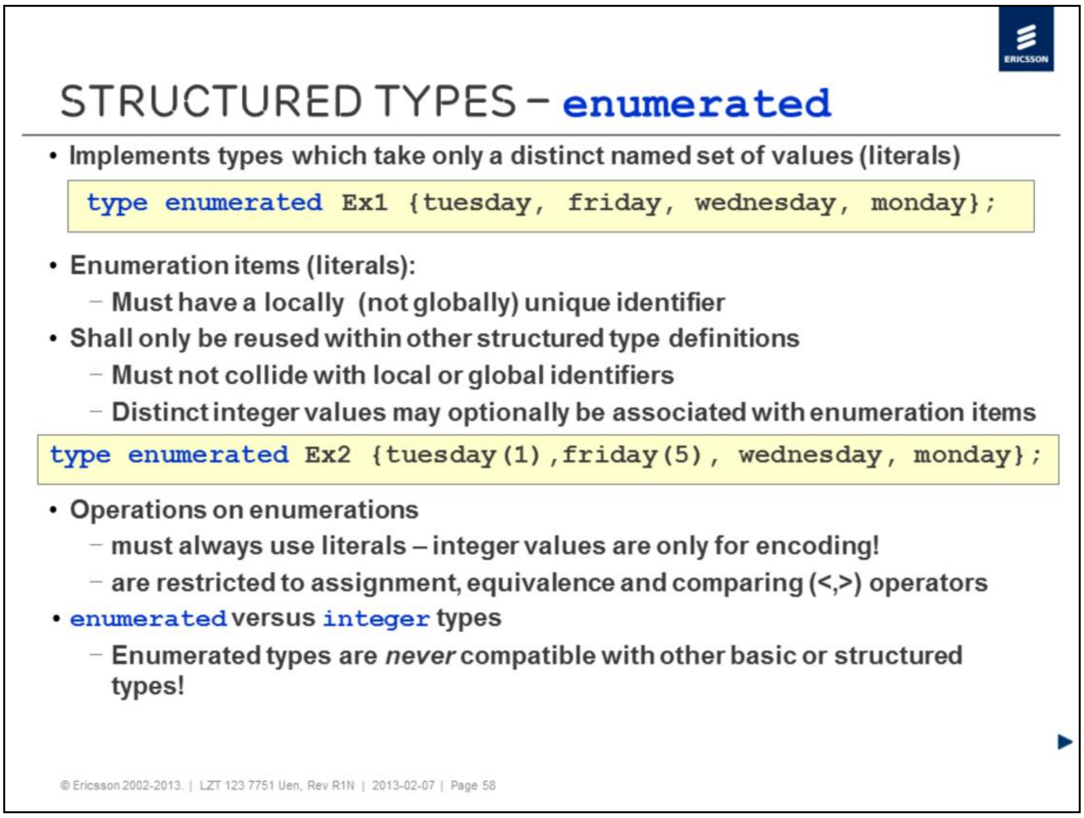
```
type record MyRecordType {
  integer field1 optional,
  boolean field2
}
```

NOTE1: The comments at the assignment examples of r2 and r3 might be misleading:

an unbound value *never* can be a right-hand-side value, not even for relational operators! It causes a run time error!

NOTE2: Just for convenience: the typedefs. from one of the earlier slides:

```
// example record type def.
type record MyRecordType {
  integer field1 optional,
  boolean field2
}
// example set type def.
type set MySetType {
                    integer field1 optional,
                    boolean field2
}
```



STRUCTURED TYPES – `enumerated`

- Implements types which take only a distinct named set of values (literals)

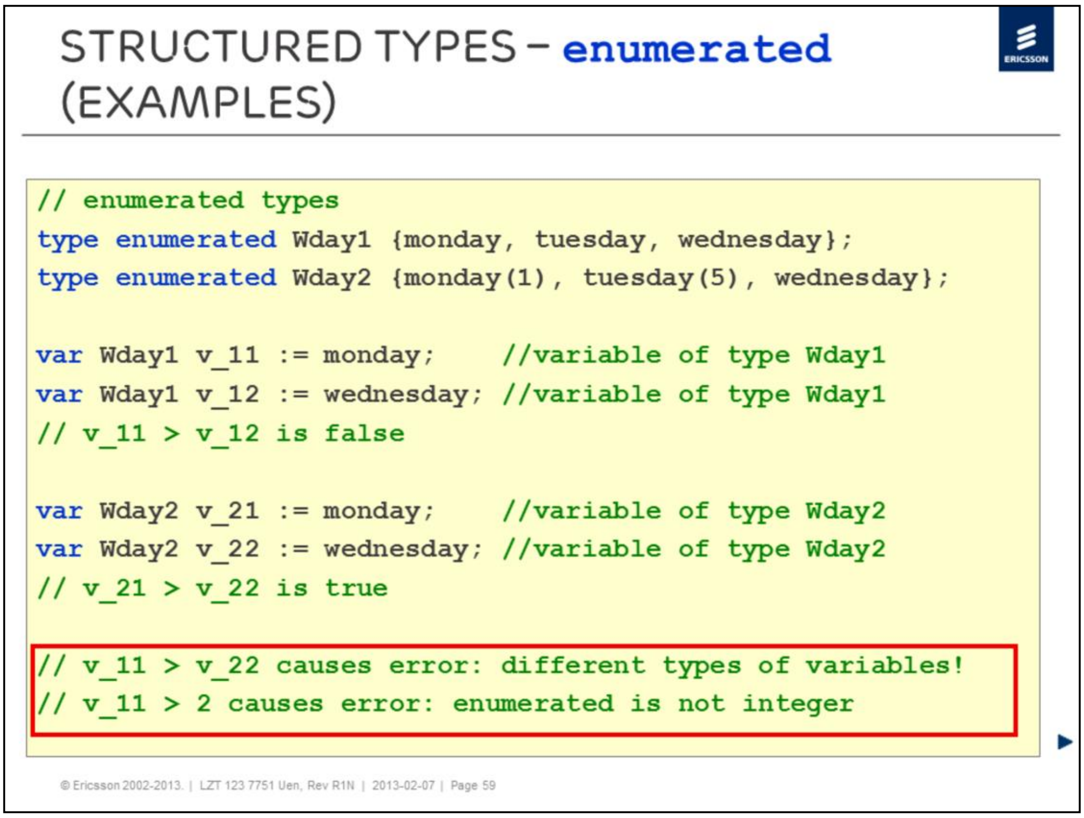
```
type enumerated Ex1 {tuesday, friday, wednesday, monday};
```

- Enumeration items (literals):
  - Must have a locally (not globally) unique identifier
- Shall only be reused within other structured type definitions
  - Must not collide with local or global identifiers
  - Distinct integer values may optionally be associated with enumeration items

```
type enumerated Ex2 {tuesday(1),friday(5), wednesday, monday};
```

- Operations on enumerations
  - must always use literals – integer values are only for encoding!
  - are restricted to assignment, equivalence and comparing (<,>) operators
- `enumerated` versus `integer` types
  - Enumerated types are *never* compatible with other basic or structured types!

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.

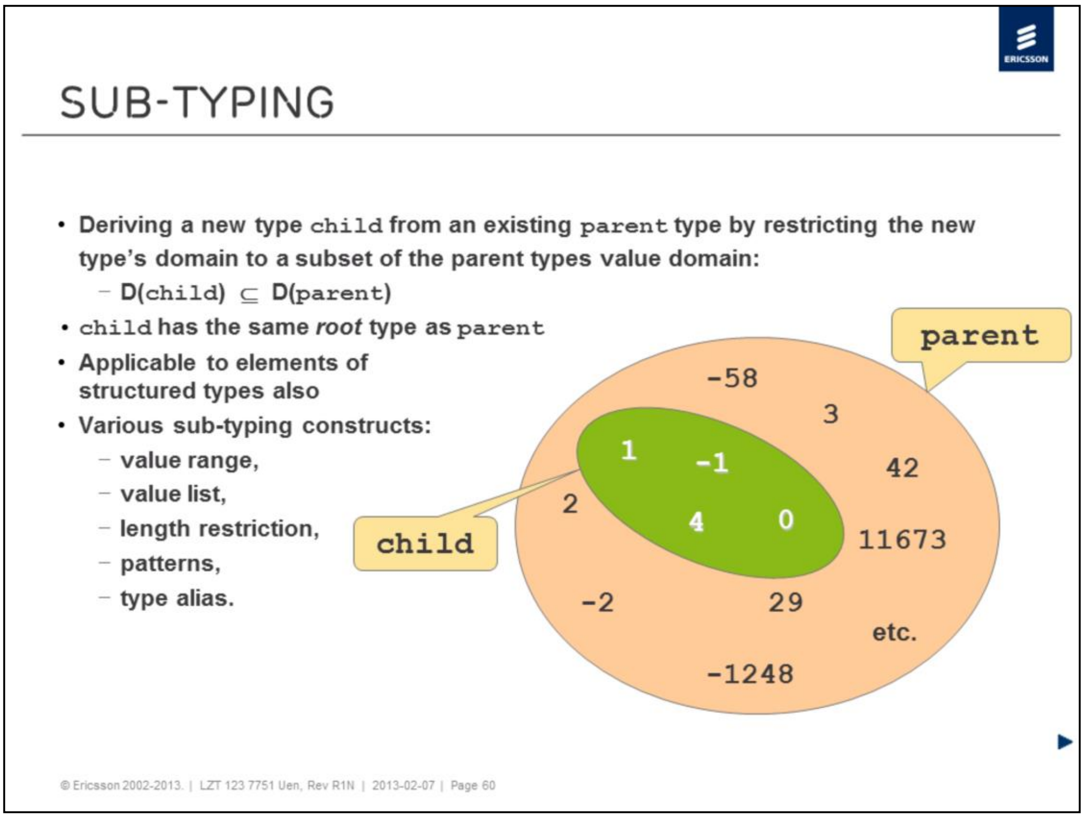


STRUCTURED TYPES – enumerated (EXAMPLES)

```
// enumerated types
type enumerated Wday1 {monday, tuesday, wednesday};
type enumerated Wday2 {monday(1), tuesday(5), wednesday};

var Wday1 v_11 := monday;    //variable of type Wday1
var Wday1 v_12 := wednesday; //variable of type Wday1
// v_11 > v_12 is false

var Wday2 v_21 := monday;    //variable of type Wday2
var Wday2 v_22 := wednesday; //variable of type Wday2
// v_21 > v_22 is true

// v_11 > v_22 causes error: different types of variables!
// v_11 > 2 causes error: enumerated is not integer
```

Although the TTCN-3 standard does not require it, it is a good practice to begin user-defined type names with uppercase letters and to use lowercase letters as the first letter of element, variable and constant names. That's why weekdays are written in small letters violating English orthography.

Comparison is only possible between two elements of the same enumeration type.

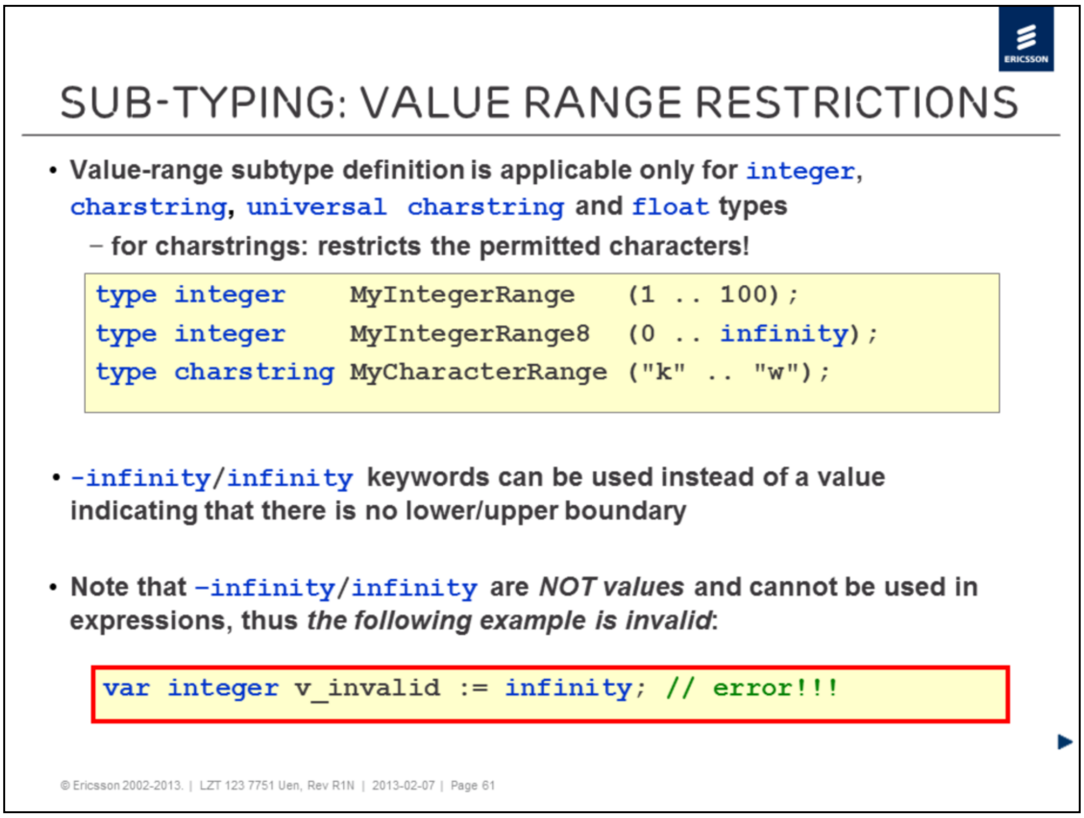


SUB-TYPING

- Deriving a new type `child` from an existing `parent` type by restricting the new type's domain to a subset of the parent types value domain:
  - D(`child`) ⊆ D(`parent`)
- `child` has the same *root* type as `parent`
- Applicable to elements of structured types also
- Various sub-typing constructs:
  - value range,
  - value list,
  - length restriction,
  - patterns,
  - type alias.

One way to create user-defined types is sub-typing a basic type. (The two other ways already discussed are defining a structured type or constraining the anytype to a single type by the dot notation.) By sub-typing the value set of the original type is restricted to certain values. In case of string types also the length of the string can be restricted. Mathematically spoken, the set D(New) is the proper subset of set D(basic) and has the same type as the original basic type.

universal charstring / charstring types can be sub-typed with patterns (not supported in TITAN yet, as of v1.6.pl3 (R6D))



SUB-TYPING: VALUE RANGE RESTRICTIONS

- Value-range subtype definition is applicable only for `integer`, `charstring`, `universal charstring` and `float` types
  - for charstrings: restricts the permitted characters!

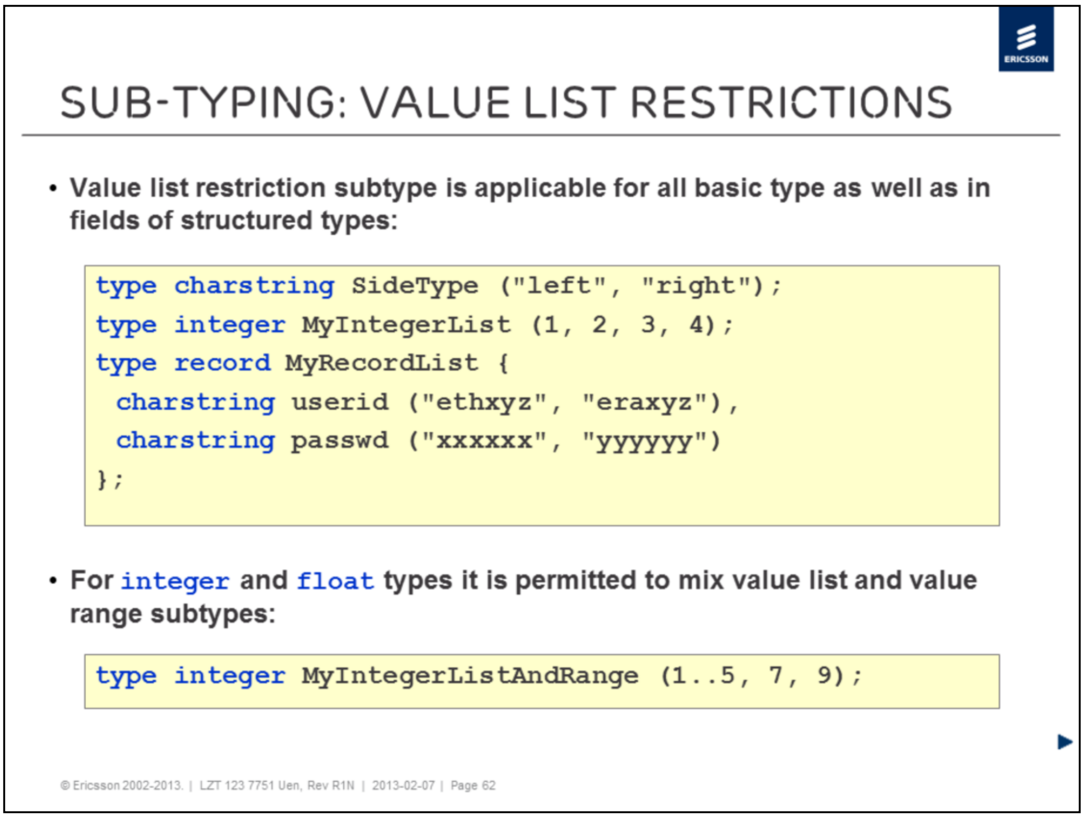
```
type integer    MyIntegerRange    (1 .. 100);
type integer    MyIntegerRange8   (0 .. infinity);
type charstring MyCharacterRange ("k" .. "w");
```

- `-infinity`/`infinity` keywords can be used instead of a value indicating that there is no lower/upper boundary
- Note that `-infinity`/`infinity` are *NOT values* and cannot be used in expressions, thus *the following example is invalid*:

```
var integer v_invalid := infinity; // error!!!
```

TTCN-3 permits the specification of a range of values of type integer, charstring, universal charstring and float. The lower boundary and the upper boundary are included in the range of permitted values. In the case of **charstring** and **universal charstring** types, the boundaries mean character positions according to the coding rules of the respective character set.

The keyword infinity may be used in order to specify an infinite integer or float range.



SUB-TYPING: VALUE LIST RESTRICTIONS

- Value list restriction subtype is applicable for all basic type as well as in fields of structured types:

```
type charstring SideType ("left", "right");
type integer MyIntegerList (1, 2, 3, 4);
type record MyRecordList {
  charstring userid ("ethxyz", "eraxyz"),
  charstring passwd ("xxxxxx", "yyyyyy")
};
```

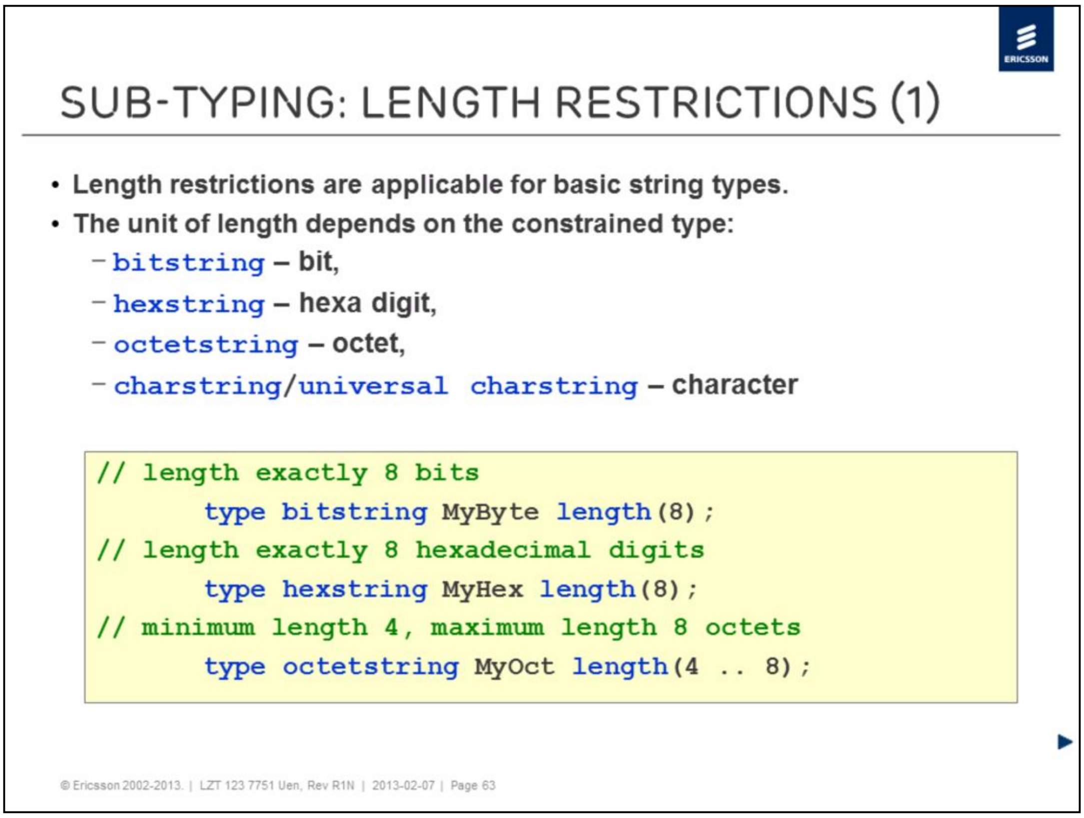
- For `integer` and `float` types it is permitted to mix value list and value range subtypes:

```
type integer MyIntegerListAndRange (1..5, 7, 9);
```

The subtype defined by this list enumerated in parentheses restricts the allowed values of the subtype to those values in the list. 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.

For values of type integer, charstring, universal charstring and float it is possible to mix lists and ranges. Within charstring and universal charstring subtype definitions, lists and ranges shall not be mixed in the same subtype definition. For values of type bitstring, hexstring, octetstring it is possible to mix lists and length restrcitions.

Note: in sub-typing we use parenthesizes around the value list, while in value-notation we use curly braces around the value lists



SUB-TYPING: LENGTH RESTRICTIONS (1)

- Length restrictions are applicable for basic string types.
- The unit of length depends on the constrained type:
  - `bitstring` – bit,
  - `hexstring` – hexa digit,
  - `octetstring` – octet,
  - `charstring/universal charstring` – character

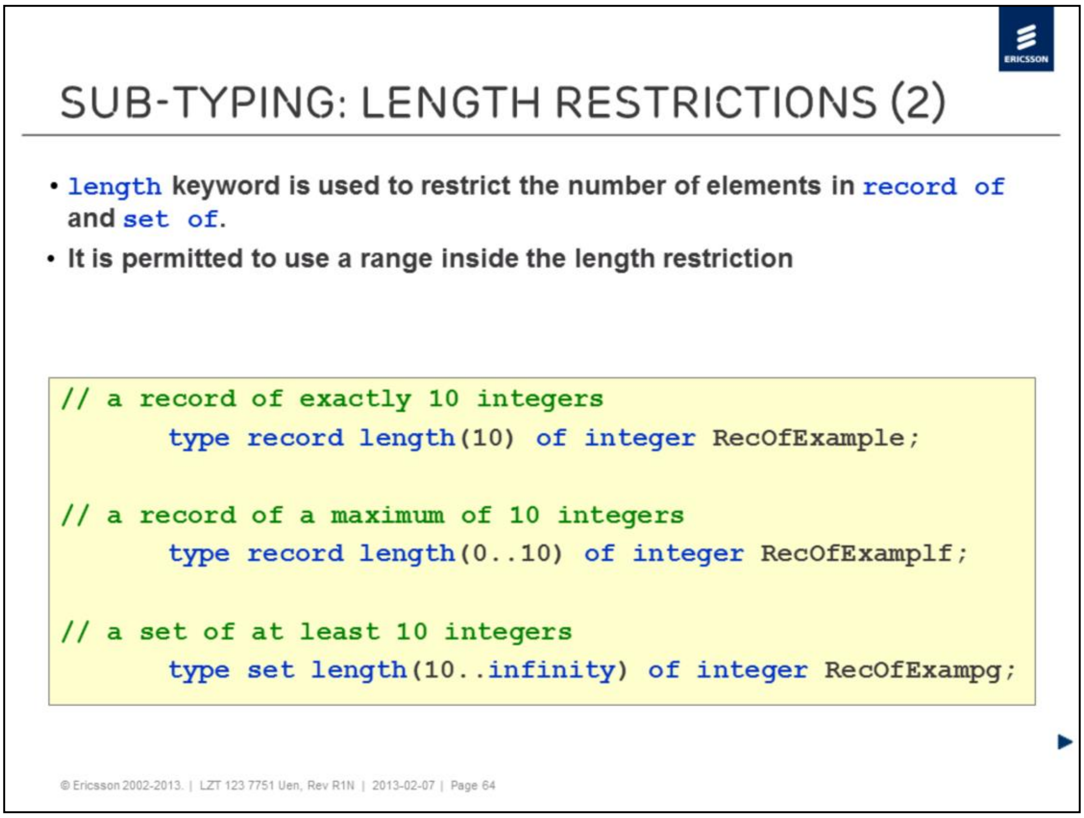
```
// length exactly 8 bits
        type bitstring MyByte length(8);
// length exactly 8 hexadecimal digits
        type hexstring MyHex length(8);
// minimum length 4, maximum length 8 octets
        type octetstring MyOct length(4 .. 8);
```

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. The lower boundary and the upper boundary are included in the range of permitted values.

Length restriction can only be either a concrete number or a range. Other (e.g. value list) not allowed

```
type octetstring MyOct length(4 .. 8, 11);
type octetstring MyOct length(4 , 8);
```

Both wrong

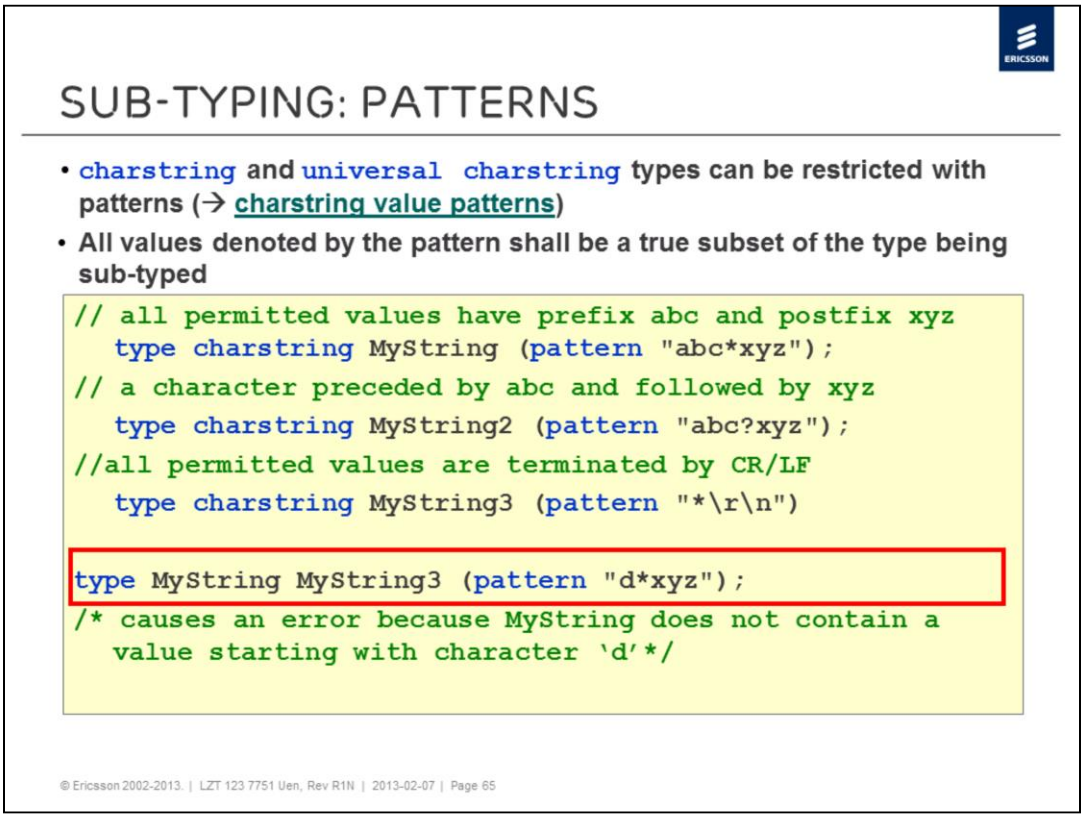


SUB-TYPING: LENGTH RESTRICTIONS (2)

- `length` keyword is used to restrict the number of elements in `record of` and `set of`.
- It is permitted to use a range inside the length restriction

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

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

// a set of at least 10 integers
       type set length(10..infinity) of integer RecOfExampg;
```

According to table 3 in chapter 6.0 of ETSI ES 201 873-1 V2.2.1 length restriction of the structured types record of and set of is considered as sub-typing. Chapter 6.2.0, on the other hand, only allows sub-typing of on simple basic and basic string types.



SUB-TYPING: PATTERNS

- charstring and universal charstring types can be restricted with patterns (→ charstring value patterns)
- All values denoted by the pattern shall be a true subset of the type being sub-typed

```
// all permitted values have prefix abc and postfix xyz
   type charstring MyString (pattern "abc*xyz");
// a character preceded by abc and followed by xyz
   type charstring MyString2 (pattern "abc?xyz");
//all permitted values are terminated by CR/LF
   type charstring MyString3 (pattern "*\r\n")

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

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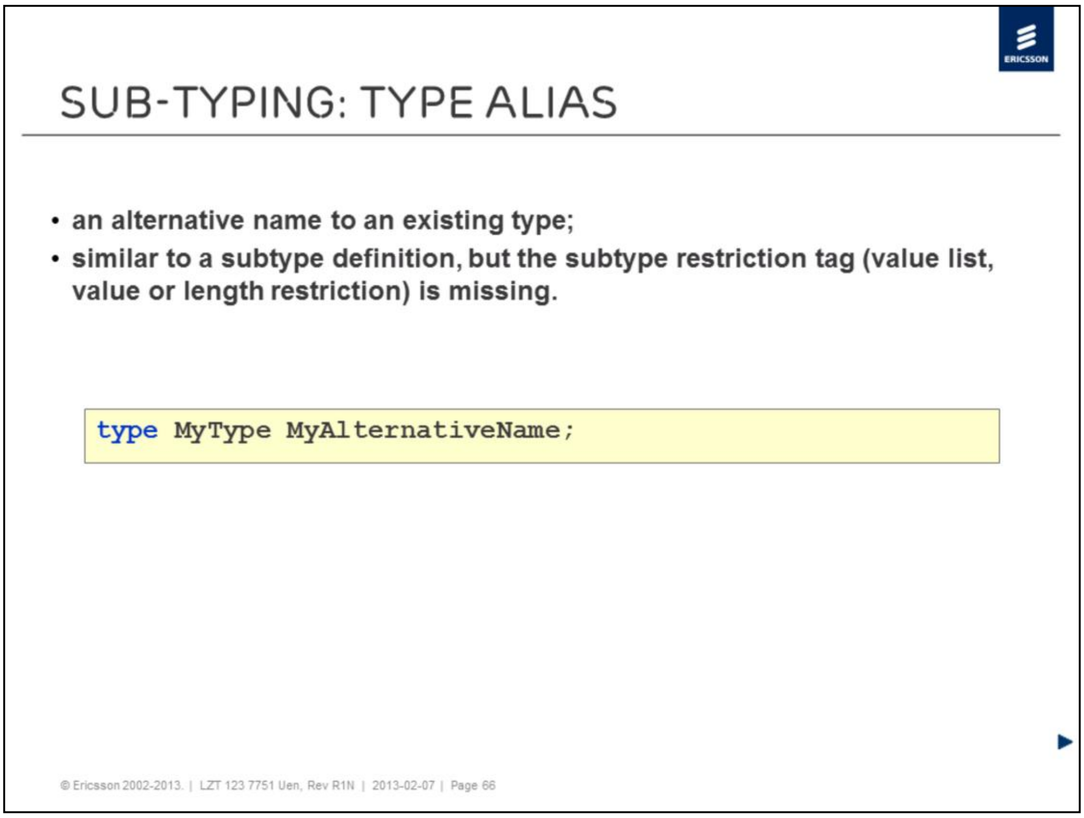
```
type charstring MyString2 (pattern "abc?\q{0,0,1,113}");
/* causes an error because a universal char {0,0,1,113} is not allowed in the
charstring type */

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

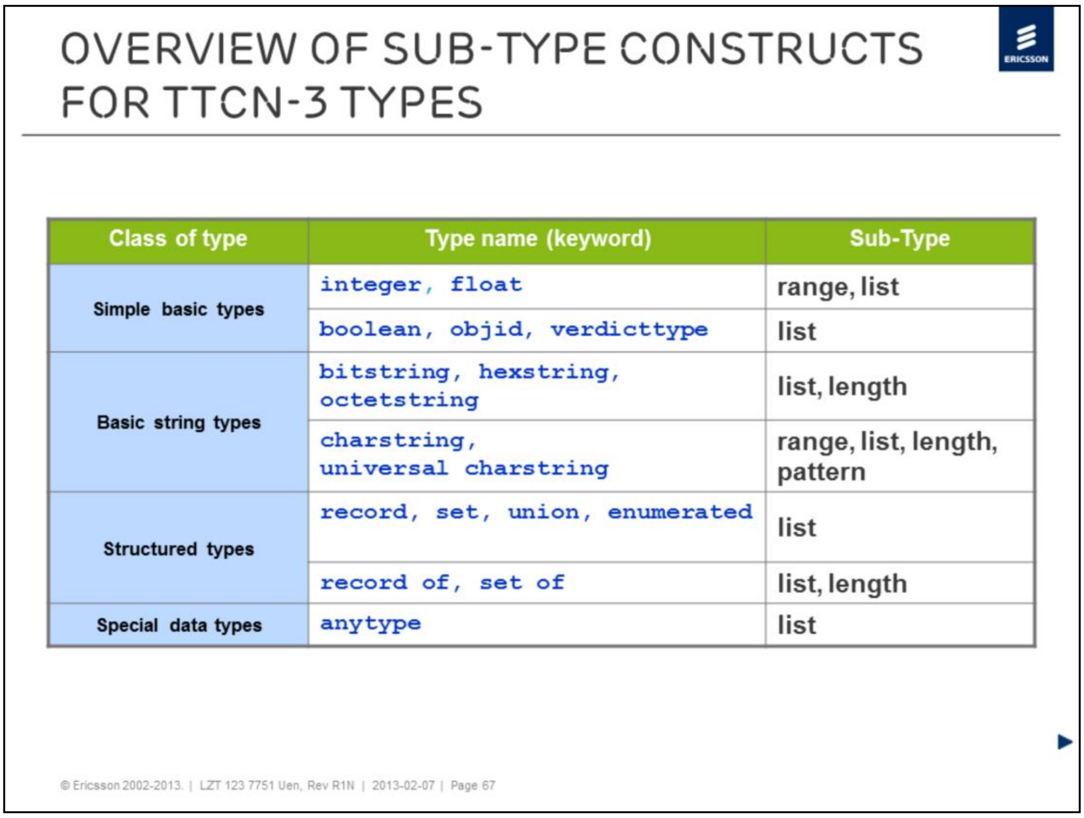


SUB-TYPING: TYPE ALIAS

- an alternative name to an existing type;
- similar to a subtype definition, but the subtype restriction tag (value list, value or length restriction) is missing.

```
type MyType MyAlternativeName;
```

Type aliasing is defined in TTCN-3 BNF only, but it is implemented in TITAN.



OVERVIEW OF SUB-TYPE CONSTRUCTS FOR TTCN-3 TYPES

Class of type	Type name (keyword)	Sub-Type
Simple basic types	`integer, float`	range, list
	`boolean, objid, verdicttype`	list
Basic string types	`bitstring, hexstring, octetstring`	list, length
	`charstring, universal charstring`	range, list, length, pattern
Structured types	`record, set, union, enumerated`	list
	`record of, set of`	list, length
Special data types	`anytype`	list

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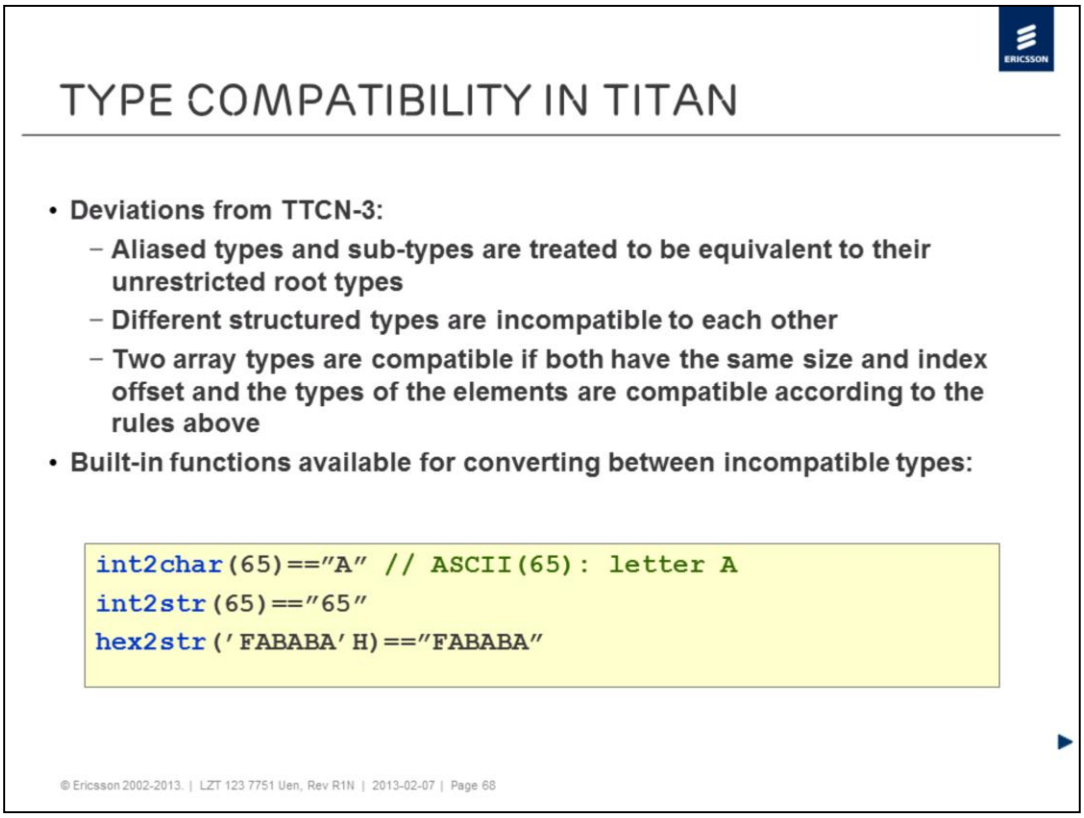
NOTE:

List subtyping of the types “record”, “record of”, “set”, “set of”, “union”, “enumerated”, “anytype” are possible when defining a new constrained type from an already existing parent type but not directly at the declaration of the first parent type.



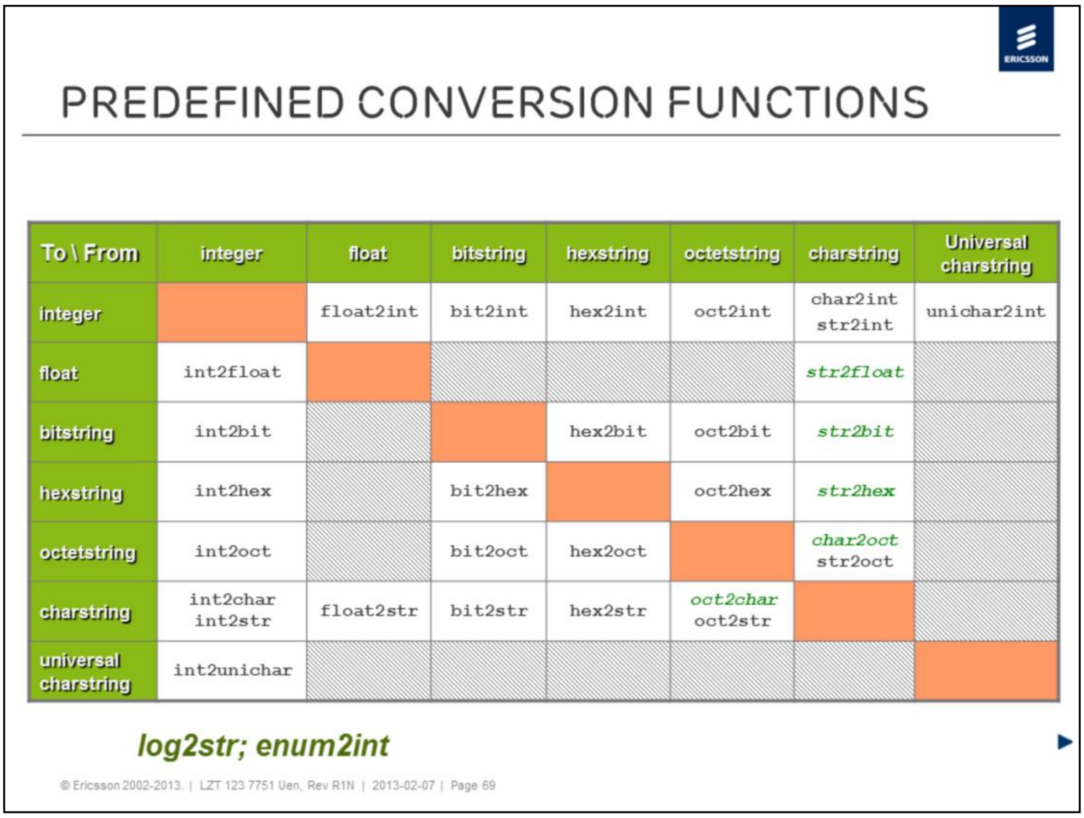
TYPE COMPATIBILITY IN TITAN

- Deviations from TTCN-3:
  - Aliased types and sub-types are treated to be equivalent to their unrestricted root types
  - Different structured types are incompatible to each other
  - Two array types are compatible if both have the same size and index offset and the types of the elements are compatible according to the rules above
- Built-in functions available for converting between incompatible types:

```
int2char(65)==”A” // ASCII(65): letter A
int2str(65)==”65”
hex2str(’FABABA’H)==”FABABA”
```

Type compatibility is a language feature, which allows to use values 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)

An example for type compatibility of structured types is given in chapter 6.7.2 of ETSI ES 201 873-1.



PREDEFINED CONVERSION FUNCTIONS

To \ From	integer	float	bitstring	hexstring	octetstring	charstring	Universal charstring
integer	🟧	float2int	bit2int	hex2int	oct2int	char2int str2int	unichar2int
float	int2float	🟧	▨	▨	▨	*str2float*	▨
bitstring	int2bit	▨	🟧	hex2bit	oct2bit	*str2bit*	▨
hexstring	int2hex	▨	bit2hex	🟧	oct2hex	*str2hex*	▨
octetstring	int2oct	▨	bit2oct	hex2oct	🟧	*char2oct* str2oct	▨
charstring	int2char int2str	float2str	bit2str	hex2str	*oct2char* oct2str	🟧	▨
universal charstring	int2unichar	▨	▨	▨	▨	▨	🟧

log2str; enum2int

Conversion functions span the gap between different simple variable types.

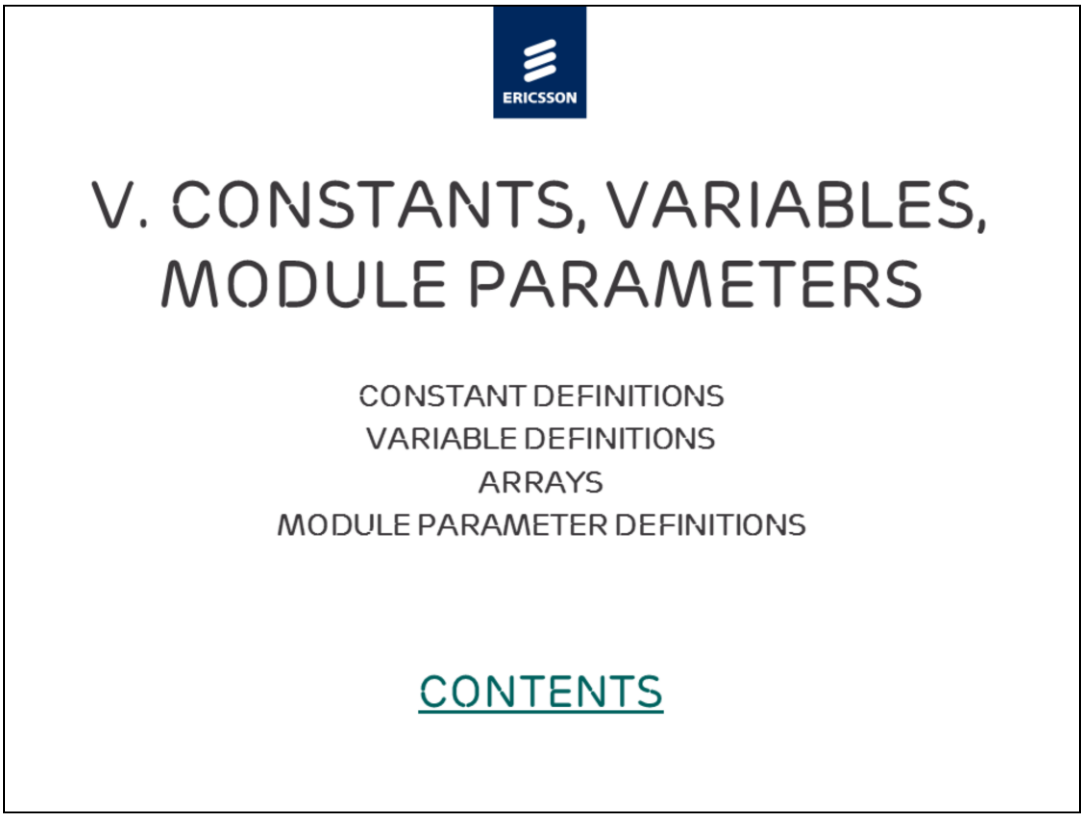
A function at the intersection of a given column and a row has an in parameter indicated in the column header and returns the value type indicated in the row header.

The detailed description of predefined functions is given in annex C of the ETSI standard ES 201 873-1.

Green letters indicate TITAN extensions, not included in the standard.

Difference between functions with 'str' and 'char' in their names is explained with the following examples:

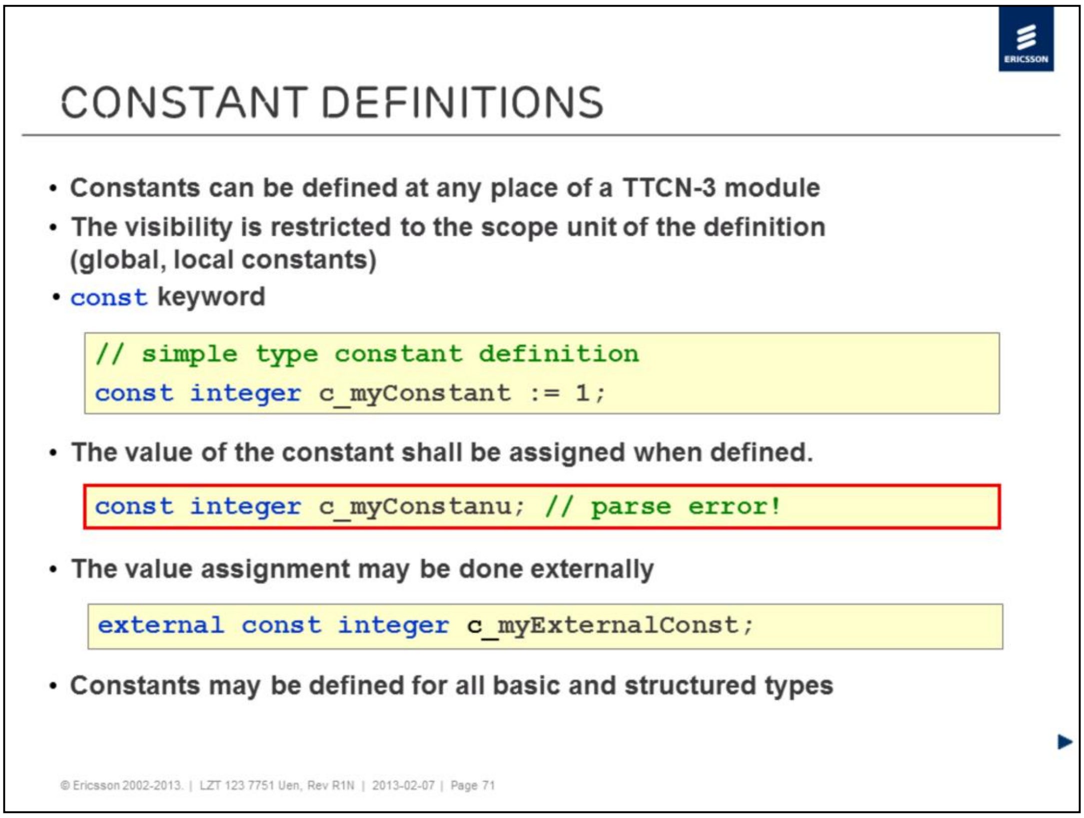
int2char (66) = "B", int2str (66) = "66".



V. CONSTANTS, VARIABLES, MODULE PARAMETERS

CONSTANT DEFINITIONS
VARIABLE DEFINITIONS
ARRAYS
MODULE PARAMETER DEFINITIONS

CONTENTS



CONSTANT DEFINITIONS

- Constants can be defined at any place of a TTCN-3 module
- The visibility is restricted to the scope unit of the definition (global, local constants)
- `const` keyword

```
// simple type constant definition
const integer c_myConstant := 1;
```

- The value of the constant shall be assigned when defined.

```
const integer c_myConstanu; // parse error!
```

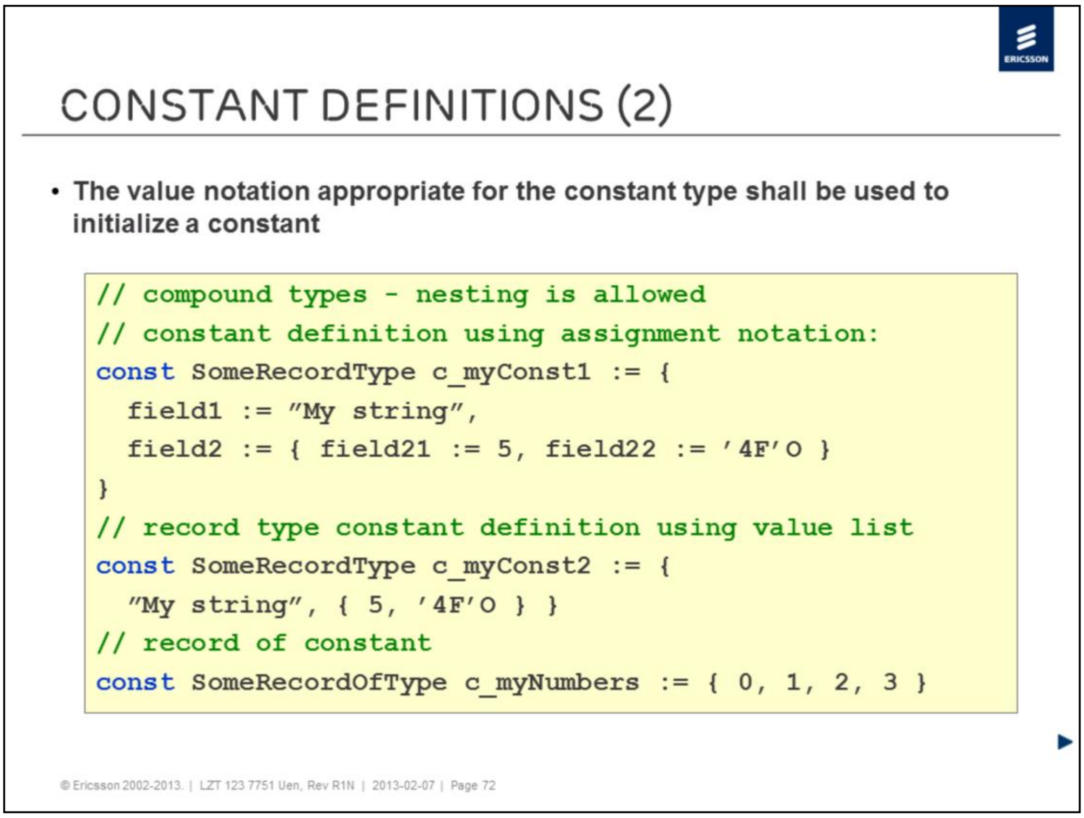
- The value assignment may be done externally

```
external const integer c_myExternalConst;
```

- Constants may be defined for all basic and structured types

Constants defined in module definitions part are globally (= anywhere in the module) visible. Those defined in the module control part, test cases, functions and altsteps are only locally (=within the same scope unit) visible. The ones defined in component type definitions are visible in functions, test cases and altsteps referencing that component type by a runs on-clause.

No forward referencing allowed in constant definitions except in module definition part.

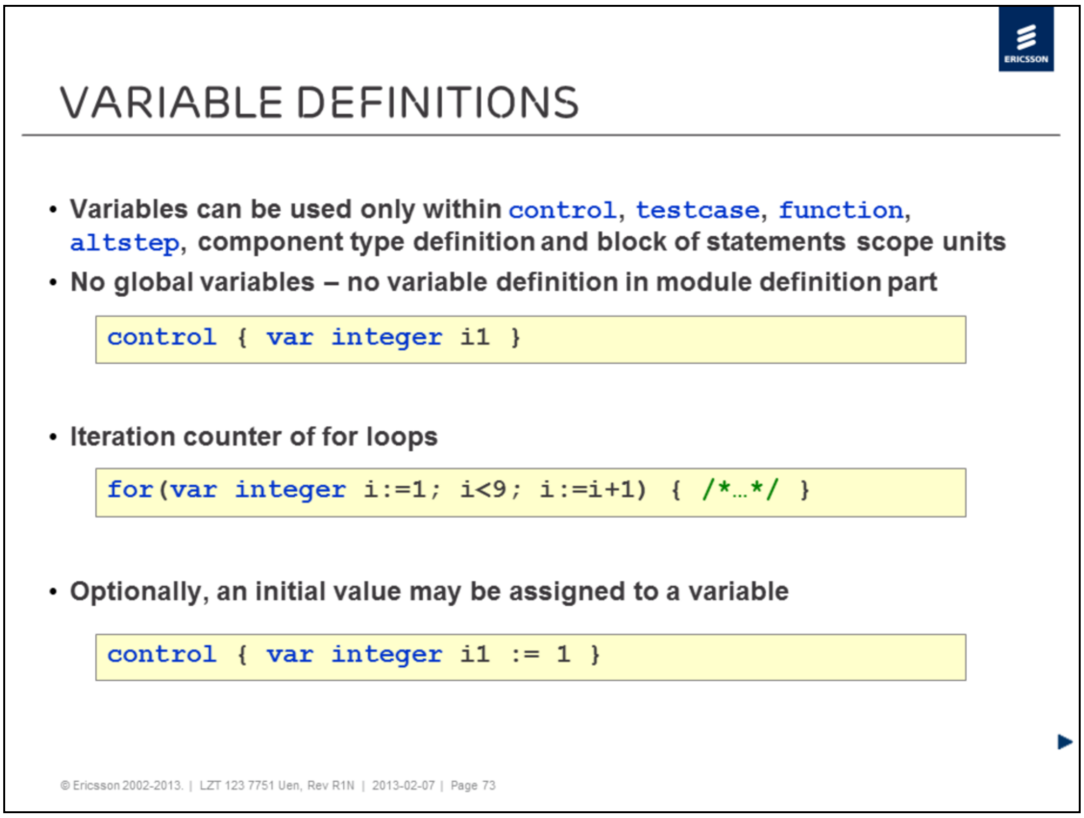


CONSTANT DEFINITIONS (2)

- **The value notation appropriate for the constant type shall be used to initialize a constant**

```
// compound types - nesting is allowed
// constant definition using assignment notation:
const SomeRecordType c_myConst1 := {
  field1 := ”My string”,
  field2 := { field21 := 5, field22 := ’4F’O }
}
// record type constant definition using value list
const SomeRecordType c_myConst2 := {
  ”My string”, { 5, ’4F’O } }
// record of constant
const SomeRecordOfType c_myNumbers := { 0, 1, 2, 3 }
```

Both assignment notation and the short-hand value list notation may be used when assigning value to a constant.



VARIABLE DEFINITIONS

- Variables can be used only within `control`, `testcase`, `function`, `altstep`, component type definition and block of statements scope units
- No global variables – no variable definition in module definition part

```
control { var integer i1 }
```

- Iteration counter of for loops

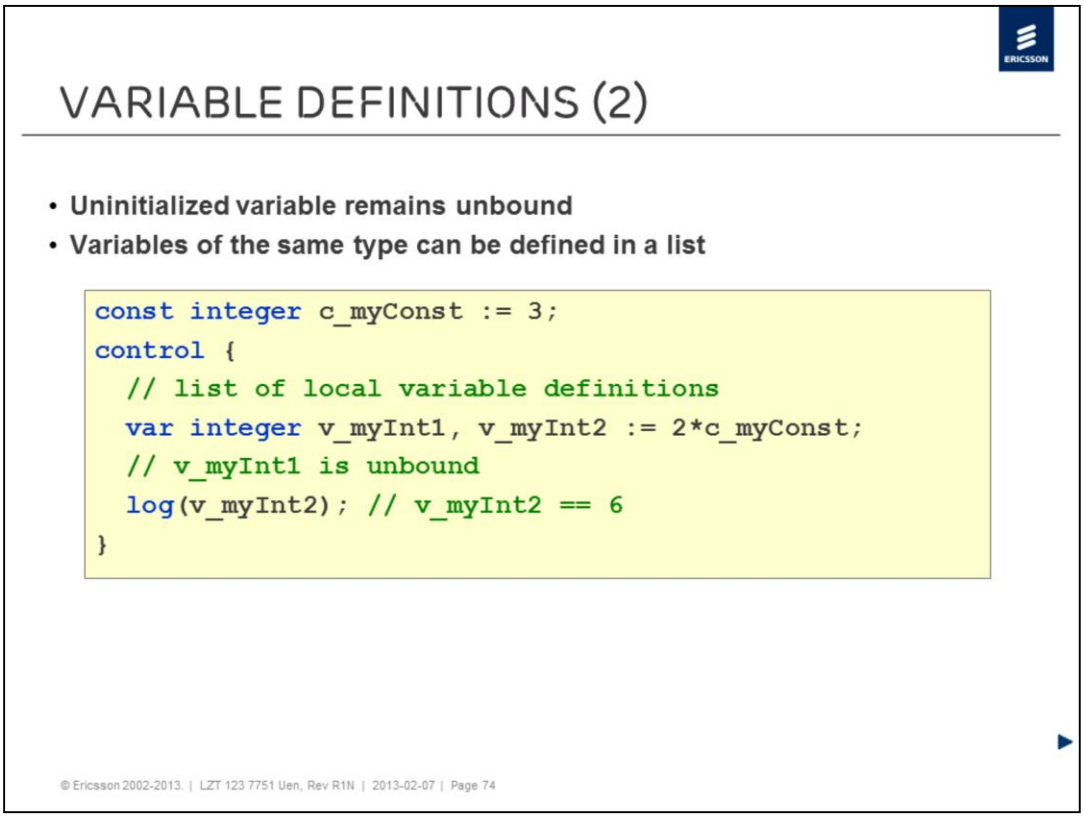
```
for(var integer i:=1; i<9; i:=i+1) { /*…*/ }
```

- Optionally, an initial value may be assigned to a variable

```
control { var integer i1 := 1 }
```

Variables defined in the module control part, test cases, functions and altsteps are only locally (=within the same scope unit) visible. The ones defined in component type definitions are visible in functions, test cases and altsteps referencing that component type by a runs on-clause. An initial value may be assigned to the variable.

The naming convention (ETH/R-04:000010 Uen rev. A) generally requires that the variable names should be prefixed by ‘v’. However, the prefix may be omitted for non-protocol related variables like loop counters, for loop control variables, variables used in calculations etc.



VARIABLE DEFINITIONS (2)

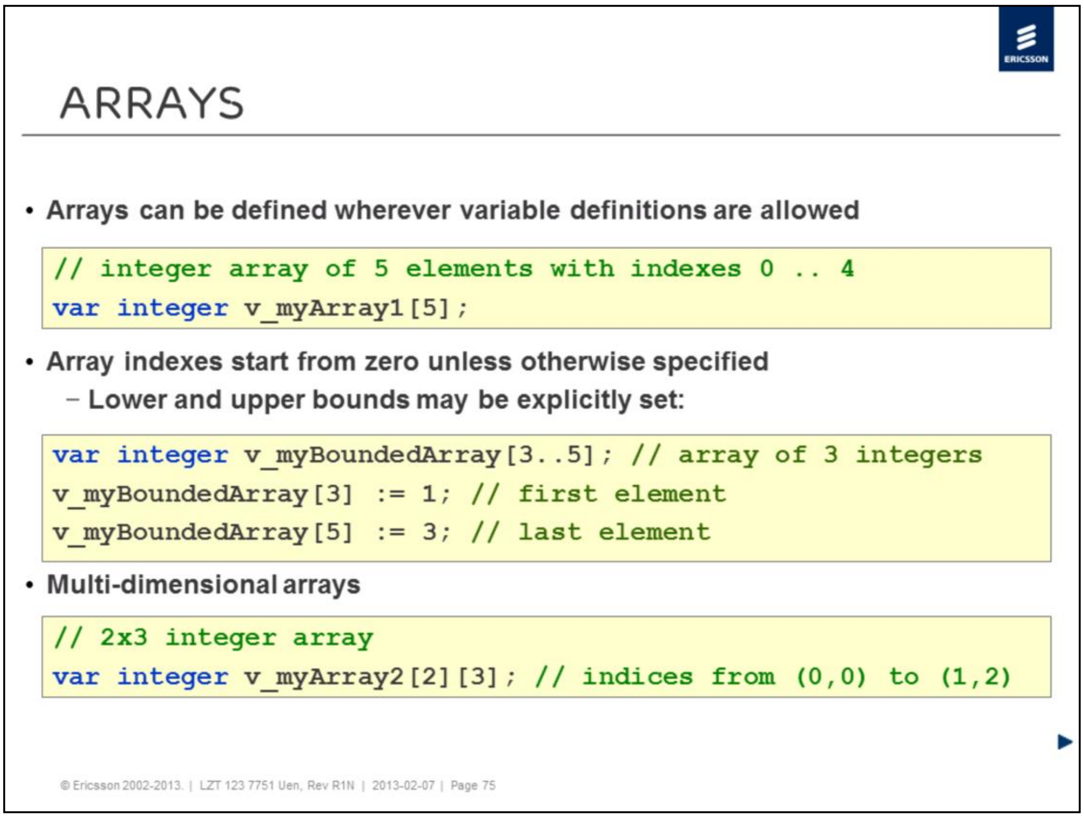
- Uninitialized variable remains unbound
- Variables of the same type can be defined in a list

```
const integer c_myConst := 3;
control {
  // list of local variable definitions
  var integer v_myInt1, v_myInt2 := 2*c_myConst;
  // v_myInt1 is unbound
  log(v_myInt2); // v_myInt2 == 6
}
```

Forward references shall never be made inside the module control part, test case definitions, functions and altsteps. This means forward references to local variables, local timers and local constants shall never occur.

Although initial value assignment is optional, a variable defined must receive a value assigned somewhere in the program, otherwise a reference to it results in run-time error (reference to an unbound value).

In the last example, v_myInt1 remains unbound, while v_myInt2 has the value 2*c_myConst=6.



ARRAYS

- Arrays can be defined wherever variable definitions are allowed

```
// integer array of 5 elements with indexes 0 .. 4
var integer v_myArray1[5];
```

- Array indexes start from zero unless otherwise specified
  - Lower and upper bounds may be explicitly set:

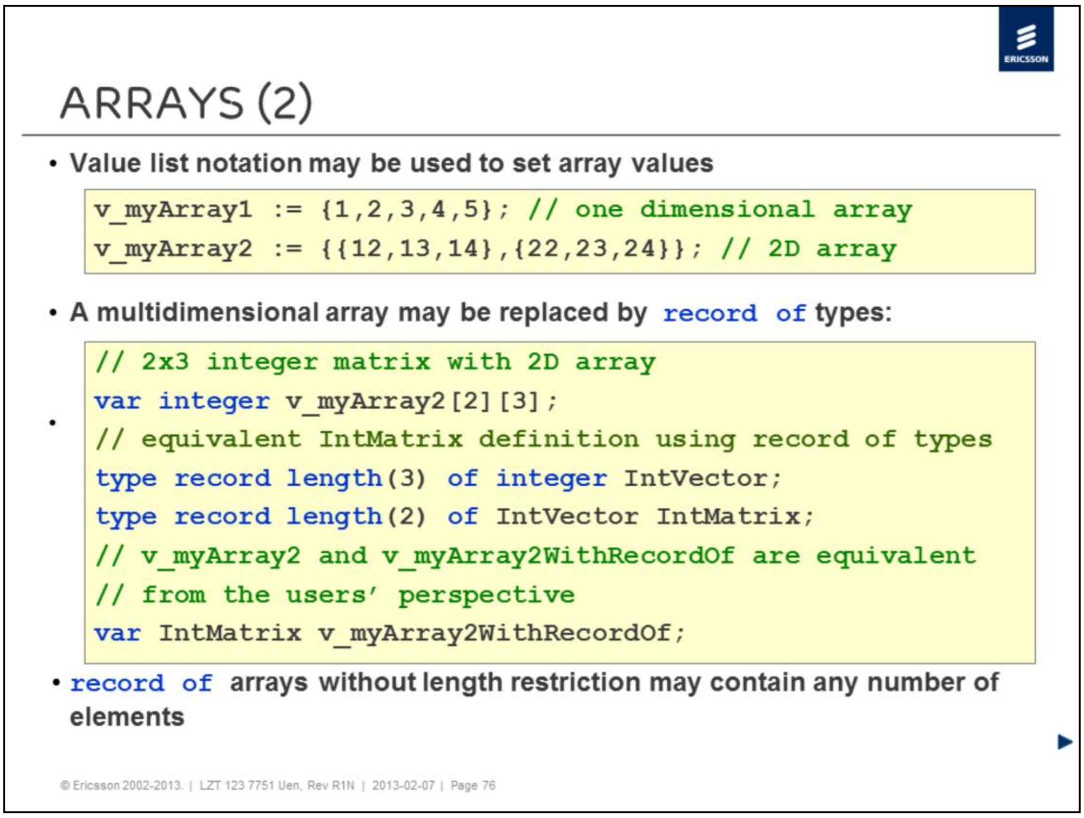
```
var integer v_myBoundedArray[3..5]; // array of 3 integers
v_myBoundedArray[3] := 1; // first element
v_myBoundedArray[5] := 3; // last element
```

- Multi-dimensional arrays

```
// 2x3 integer array
var integer v_myArray2[2][3]; // indices from (0,0) to (1,2)
```

It is important to realize that a single figure in brackets specifies the number of elements (=array dimension). When a range is given, however, the two figures give the lower respective the upper index value.

In the first case, the maximum index value is one less then the figure indicated in the brackets; in the latter case, the maximum index value equals to the last figure indicated in brackets.



ARRAYS (2)

- Value list notation may be used to set array values

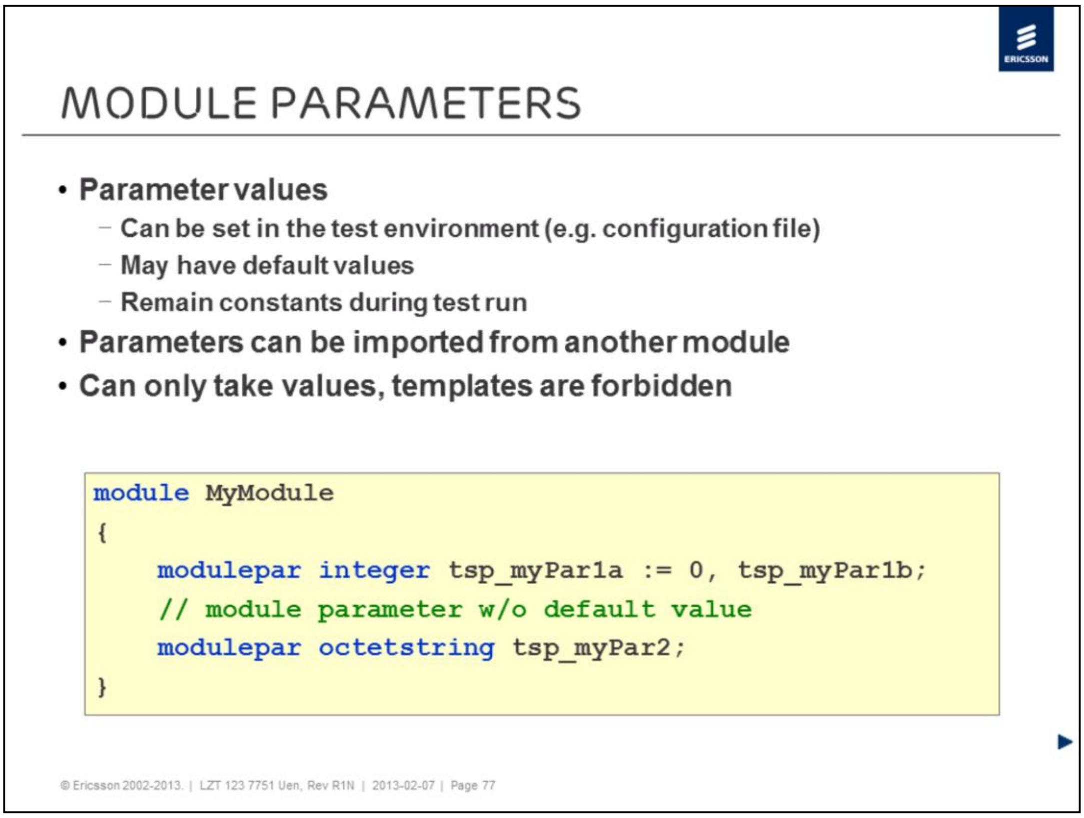
```
v_myArray1 := {1,2,3,4,5}; // one dimensional array
v_myArray2 := {{12,13,14},{22,23,24}}; // 2D array
```

- A multidimensional array may be replaced by `record of` types:

```
// 2x3 integer matrix with 2D array
var integer v_myArray2[2][3];
// equivalent IntMatrix definition using record of types
type record length(3) of integer IntVector;
type record length(2) of IntVector IntMatrix;
// v_myArray2 and v_myArray2WithRecordOf are equivalent
// from the users’ perspective
var IntMatrix v_myArray2WithRecordOf;
```

- `record of` arrays without length restriction may contain any number of elements

A multidimensional array may be replaced by nested record of types. The number of record of types equals to the number of indices of the array. The length of the individual records correspond to the value of the array indices.



MODULE PARAMETERS

- Parameter values
  - Can be set in the test environment (e.g. configuration file)
  - May have default values
  - Remain constants during test run
- Parameters can be imported from another module
- Can only take values, templates are forbidden

```
module MyModule
{
    modulepar integer tsp_myPar1a := 0, tsp_myPar1b;
    // module parameter w/o default value
    modulepar octetstring tsp_myPar2;
}
```

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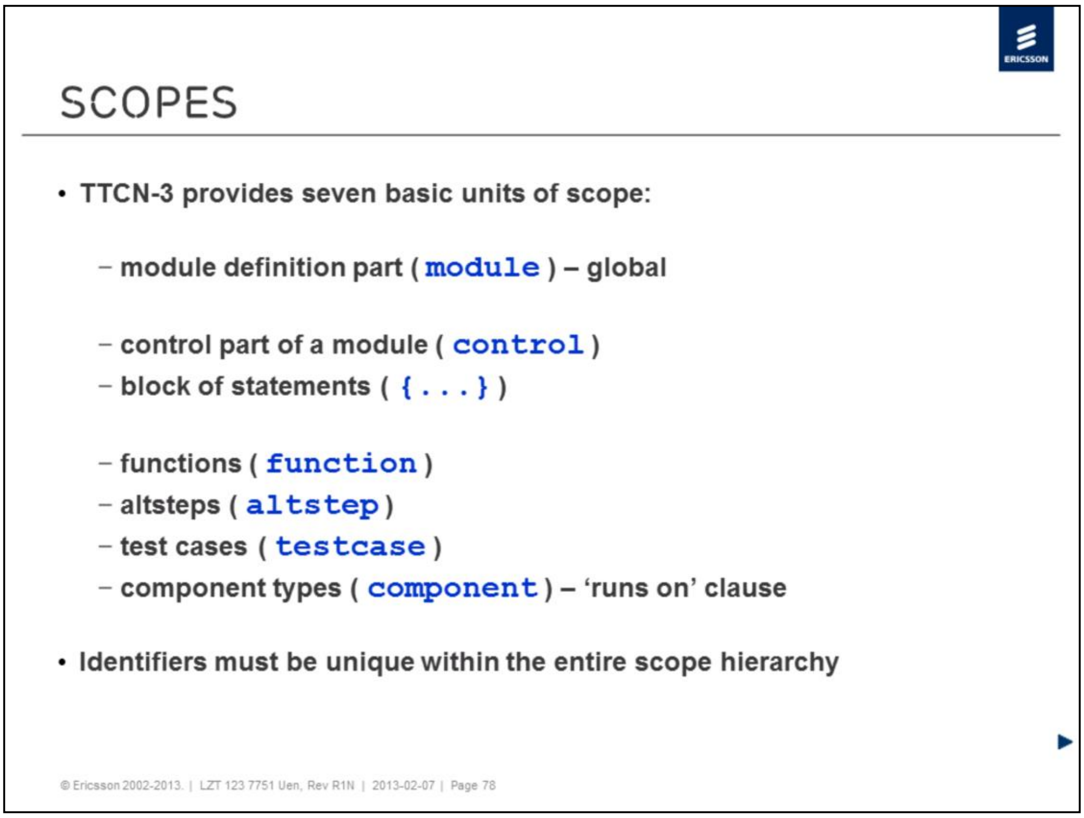
The module parameter list defines a set of values that are supplied by the test environment at run-time. During test execution these values shall be treated as constants. Module parameters are defined by listing their identifiers and types following the keyword **modulepar**. Module parameters shall be defined within the module definition part only. Redefinition of module parameters is not allowed.

It is allowed to specify default values for module parameters.



SCOPES

- TTCN-3 provides seven basic units of scope:
  - module definition part (`module`) – global
  - control part of a module (`control`)
  - block of statements (`{...}`)
  - functions (`function`)
  - altsteps (`altstep`)
  - test cases (`testcase`)
  - component types (`component`) – ‘runs on’ clause
- Identifiers must be unique within the entire scope hierarchy

The **scope unit** is the region of the TTCN-3 source within which (constant, timer, variable, etc.) definitions may have effect, within which multiple definitions of the same name are prohibited, and outside of which definitions inside the unit do not have effect.

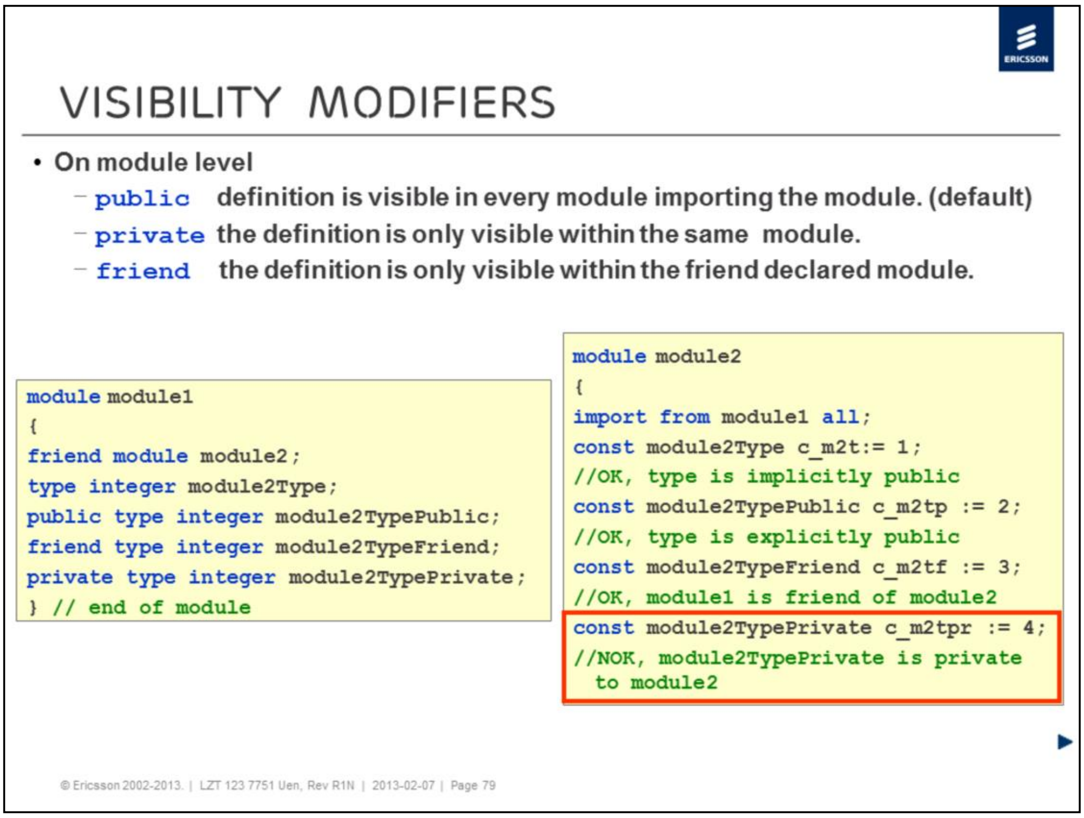
Definitions made in the **module definition part** but outside of other scope units are globally visible in the module. So are imported identifiers.

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 by a runs on-clause.

Functions, altsteps and **test cases** are individual scope units without any hierarchical relation between them, i.e. definitions made at the beginning of their body have local visibility.

Definitions within **block of statements** (e.g. for, if-else, while, do-while, alt, interleave**)** have local visibility within the statement concerned.



VISIBILITY MODIFIERS

- On module level
  - `public` definition is visible in every module importing the module. (default)
  - `private` the definition is only visible within the same module.
  - `friend` the definition is only visible within the friend declared module.

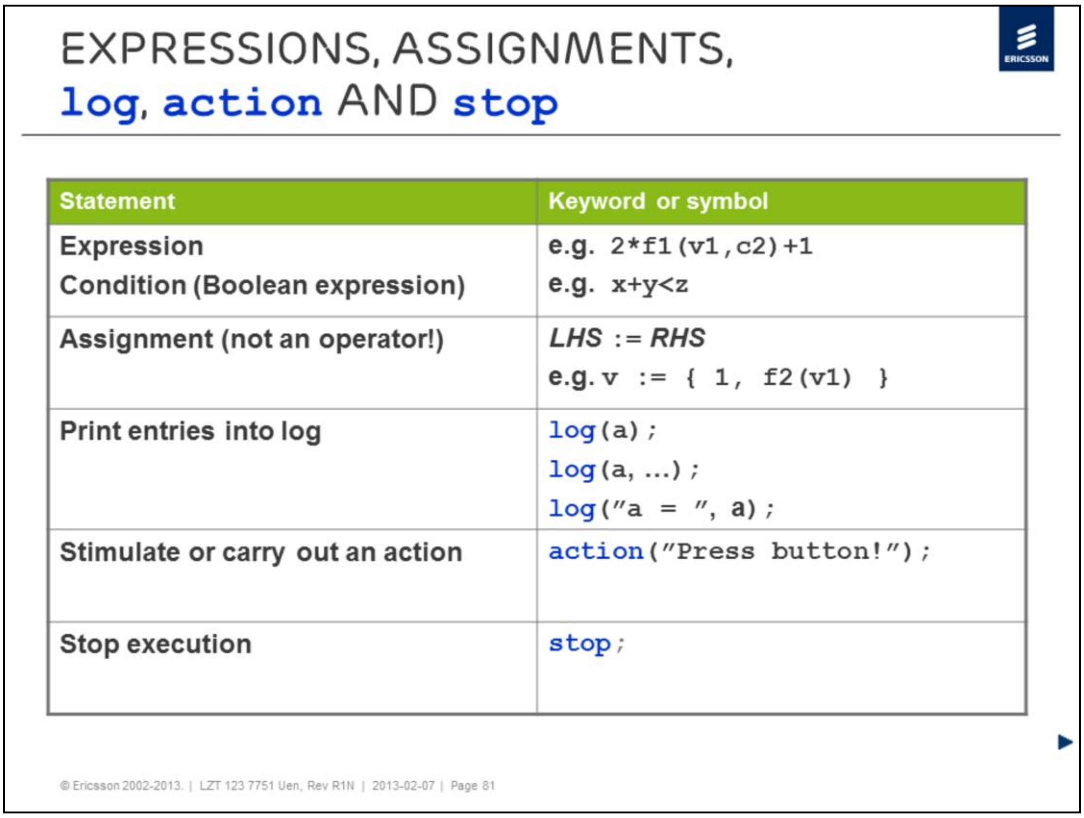
```
module module1
{
friend module module2;
type integer module2Type;
public type integer module2TypePublic;
friend type integer module2TypeFriend;
private type integer module2TypePrivate;
} // end of module
```

```
module module2
{
import from module1 all;
const module2Type c_m2t:= 1;
//OK, type is implicitly public
const module2TypePublic c_m2tp := 2;
//OK, type is explicitly public
const module2TypeFriend c_m2tf := 3;
//OK, module1 is friend of module2
const module2TypePrivate c_m2tpr := 4;
//NOK, module2TypePrivate is private
  to module2
```

VI. PROGRAM STATEMENTS AND OPERATORS

EXPRESSIONS
ASSIGNMENTS
PROGRAM CONTROL STATEMENTS
OPERATORS
EXAMPLE

CONTENTS



EXPRESSIONS, ASSIGNMENTS, `log`, `action` AND `stop`

Statement	Keyword or symbol
Expression Condition (Boolean expression)	e.g. `2*f1(v1,c2)+1` e.g. `x+y<z`
Assignment (not an operator!)	*LHS* := *RHS* e.g. `v := { 1, f2(v1) }`

Print entries into log	`log(a);`
	`log(a, ...);`
	`log(”a = ”, a);`

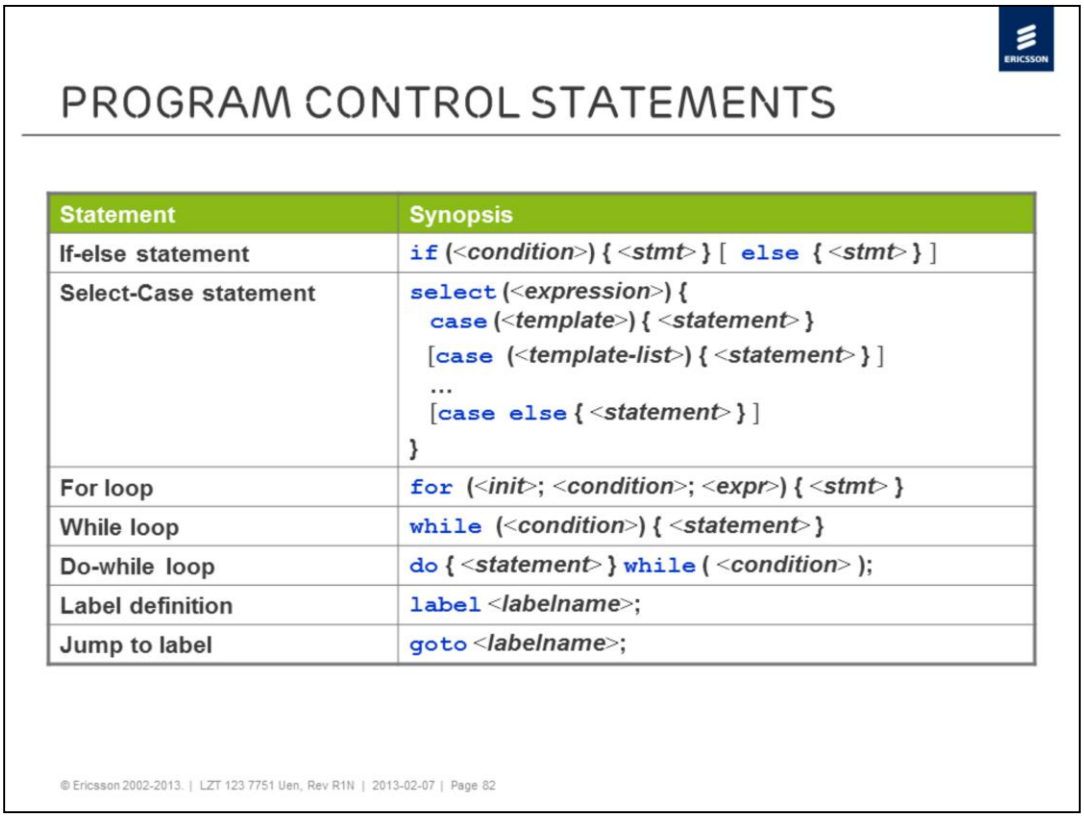
Stimulate or carry out an action	`action(”Press button!”);`
Stop execution	`stop;`

Basic program statements can be used in the module control part, functions, altsteps and test cases.

Expressions are specified using the operators shown on the following two slides.

An **assignment** binds the variable on the left side to the value of the expression on the right side.

Logging enables to write a string or a variable value to a log file in an implementation dependent manner.



PROGRAM CONTROL STATEMENTS

Statement	Synopsis
If-else statement	`if (<condition>) { <stmt> } [ else { <stmt> } ]`

Select-Case statement	`select (<expression>) {`
	`case (<template>) { <statement> }`
	`[case (<template-list>) { <statement> } ]`
	`…`
	`[case else { <statement> } ]`
	`}`

For loop	`for (<init>; <condition>; <expr>) { <stmt> }`
While loop	`while (<condition>) { <statement> }`
Do-while loop	`do { <statement> } while ( <condition> );`
Label definition	`label <labelname>;`
Jump to label	`goto <labelname>;`

An **if-else** statement is used to denote branching in the program execution based on a Boolean expression (condition).

The **select-case** statement permits branching based on the calculated value of an expression. The statement block of the first branch containing a matching template inside its **case** is executed. The statement block of the **case else** is run when none of the cases match.

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.

The **for** statement defines a counter **loop**. The first statement (init) is used to initialize the counter variable. If the Boolean expression (cond) is true, the loop terminates. The second assignment (expr) is used to manipulate (increase or decrease) the index variable.

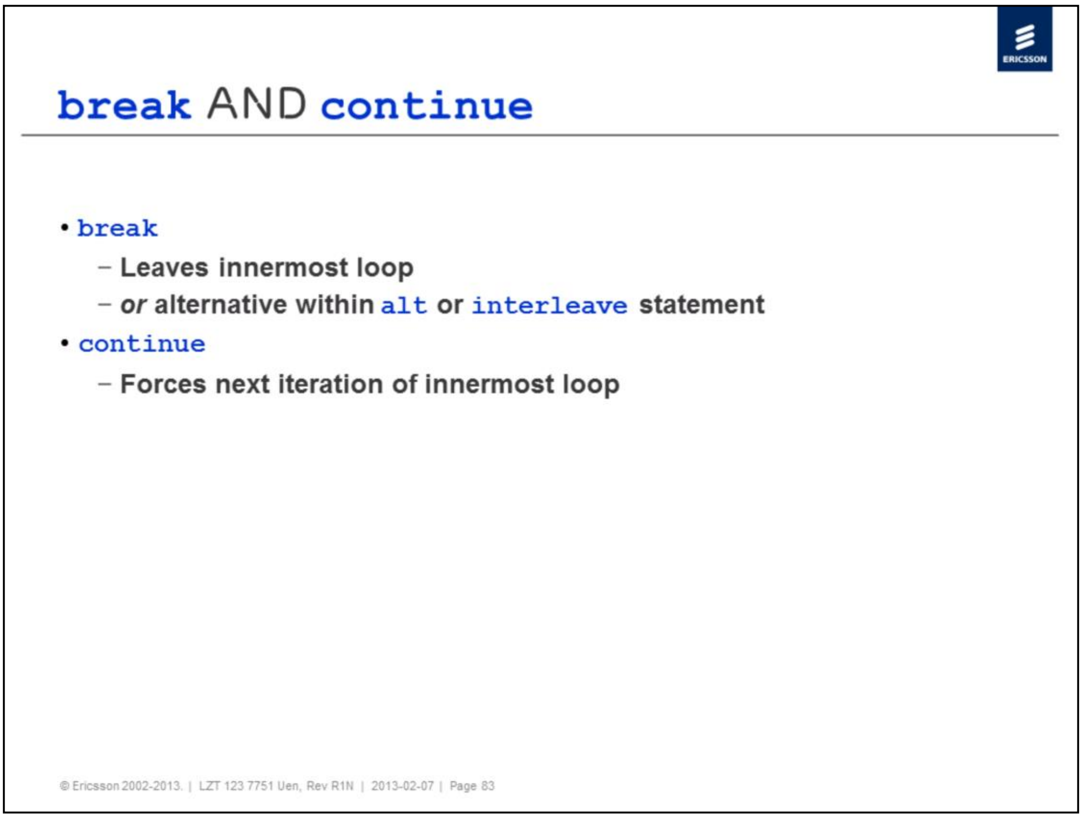
A **while loop** is executed as long as the loop condition holds.

The **do while loop** is identical to a <u>while</u> loop with the exception that the loop condition shall be checked at the *end* of each loop iteration. This means that the instruction is executed at least once.

Label definition allows the specification of labels (a specific place in the program code).

Jump to a label performs a jump to a previously defined label.

Used in the control part of a module, the **stop** statement terminates the **execution** of the module control part. When used in a test case, altstep or function with <u>runs on</u> clause, it terminates the relevant test component.



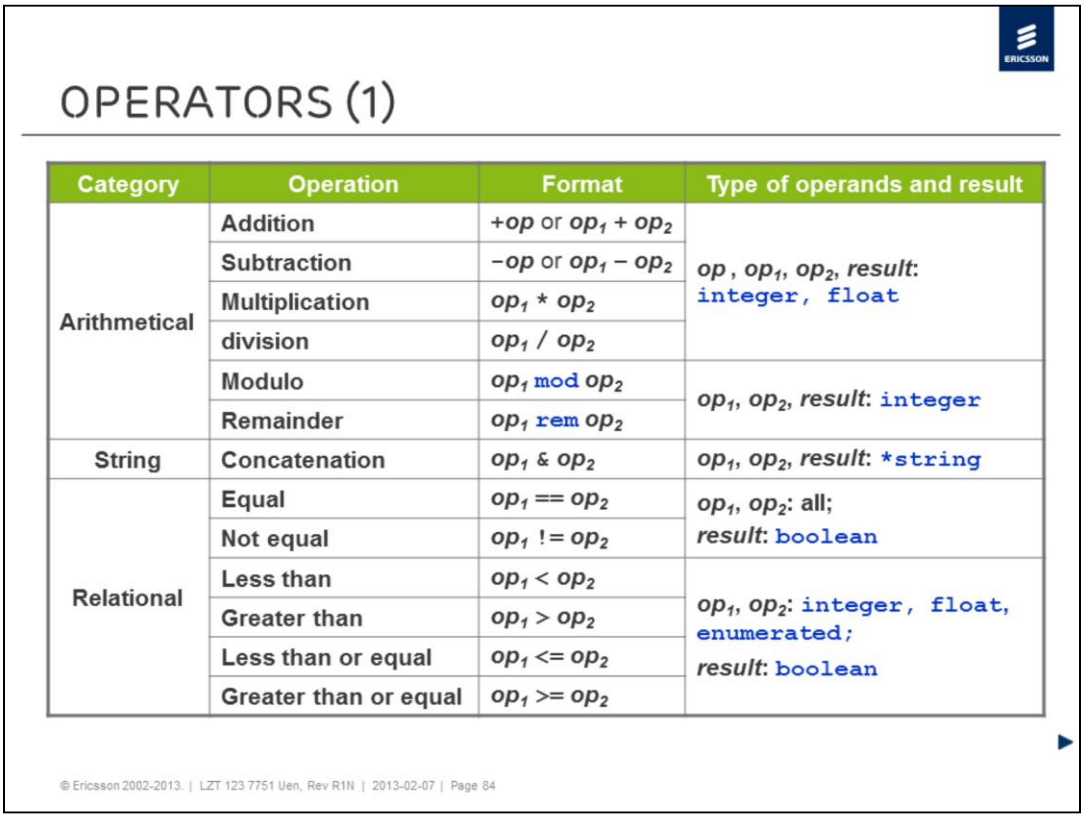
`break` AND `continue`

- `break`
  - Leaves innermost loop
  - *or* alternative within `alt` or `interleave` statement
- `continue`
  - Forces next iteration of innermost loop

- `continue`

  Forces next iteration of innermost loop

  Not for taking new snapshot in `alt` or `interleave` statement -> `repeat`



OPERATORS (1)

Category	Operation	Format	Type of operands and result
Arithmetical	Addition	$+op$ or $op_1 + op_2$	op, op_1, op_2, *result*: `integer, float`
	Subtraction	$-op$ or $op_1 - op_2$	
	Multiplication	$op_1 * op_2$	
	division	op_1 / op_2	
	Modulo	op_1 `mod` op_2	op_1, op_2, *result*: `integer`
	Remainder	op_1 `rem` op_2	
String	Concatenation	op_1 & op_2	op_1, op_2, *result*: `*string`
Relational	Equal	$op_1 == op_2$	op_1, op_2: all; *result*: `boolean`
	Not equal	$op_1 != op_2$	
	Less than	$op_1 < op_2$	op_1, op_2: `integer, float, enumerated;` *result*: `boolean`
	Greater than	$op_1 > op_2$	
	Less than or equal	$op_1 <= op_2$	
	Greater than or equal	$op_1 >= op_2$	

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Operands of arithmetic operators shall be of type integer or float, except for **mod** and **rem** which shall be used with integer types only. The result is of the same type as the operands, operands must not have different types. Both mod and rem have the same result for positive arguments but they differ for negative ones. See Table 7 in 7.1.1 in ETSI ES 201 873-1 V4.4.1 (2012-04).

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

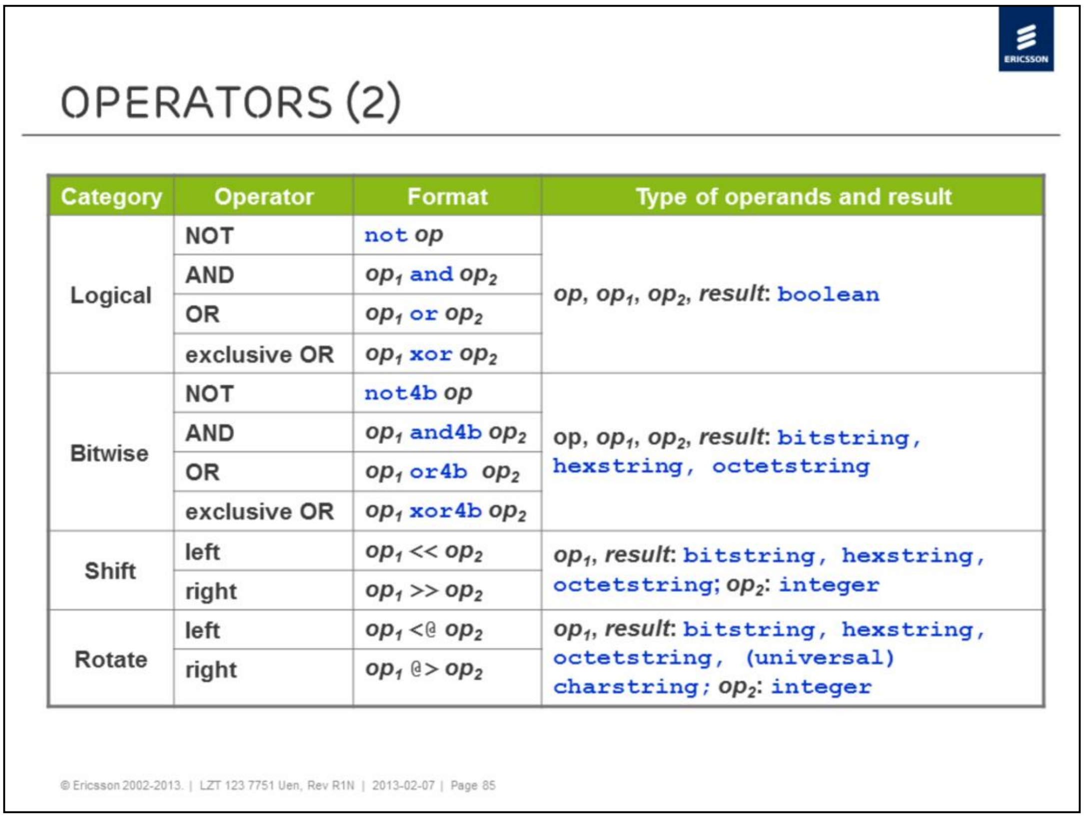
= |y| + x rem |y| when x < 0 and x rem |y| < 0 ETSI

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

Concatenation is performed from left to right on compatible string types. The result type is the root type of the operands.

The relational operators **equal** and **not equal** may be applied on all compatible types. All other relational operators shall have only operands of type integer**,** float or instances of the same enumerated types. The result type of these operations is boolean.



OPERATORS (2)

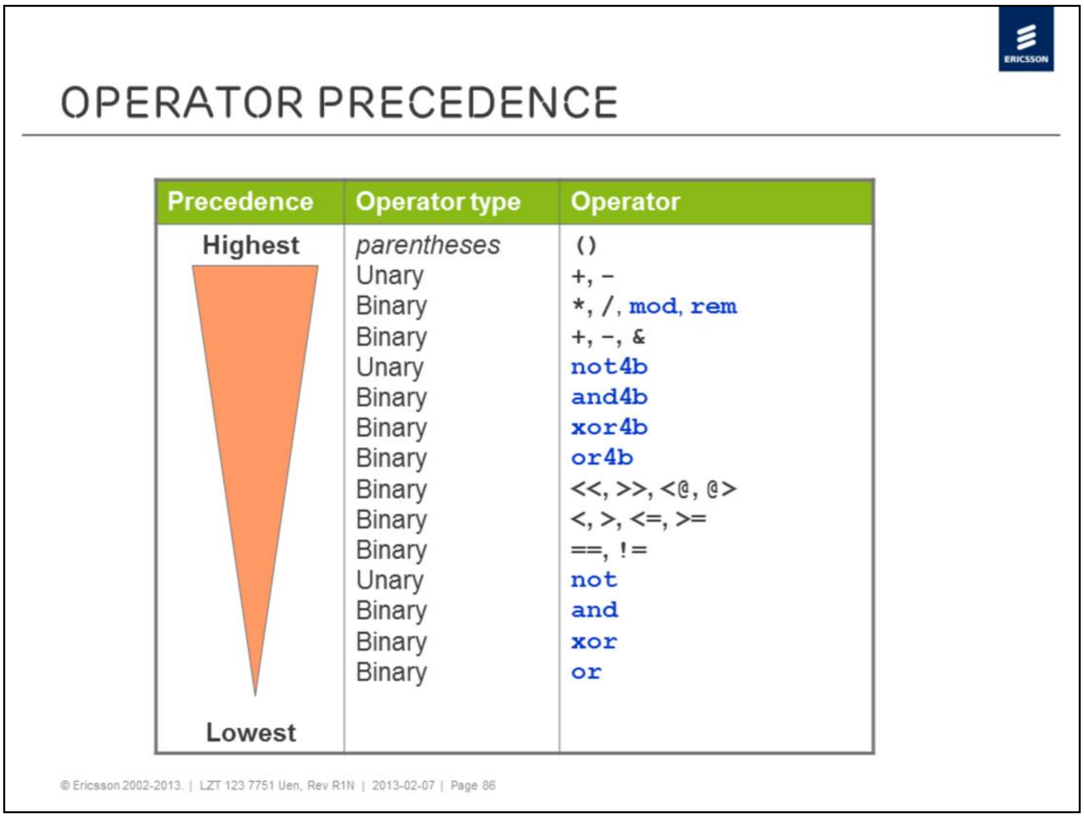
Category	Operator	Format	Type of operands and result
Logical	NOT	`not` *op*	*op*, op_1, op_2, *result*: `boolean`
	AND	op_1 `and` op_2	
	OR	op_1 `or` op_2	
	exclusive OR	op_1 `xor` op_2	
Bitwise	NOT	`not4b` *op*	*op*, op_1, op_2, *result*: `bitstring, hexstring, octetstring`
	AND	op_1 `and4b` op_2	
	OR	op_1 `or4b` op_2	
	exclusive OR	op_1 `xor4b` op_2	
Shift	left	$op_1 << op_2$	op_1, *result*: `bitstring, hexstring, octetstring`; op_2: `integer`
	right	$op_1 >> op_2$	
Rotate	left	op_1 <@ op_2	op_1, *result*: `bitstring, hexstring, octetstring, (universal) charstring`; op_2: `integer`
	right	op_1 @> op_2	

The operands and the result of **logical** operations shall be of type boolean.

The **bitwise** operators perform the operations of bitwise not, bitwise and, bitwise or and bitwise xor. The unary operator **not4b** inverts the individual bit values of its operand. The operands shall be of type bitstring**,** hexstring or octetstring. The result type shall be the root type of the operands.

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 and its value of e.g. 1 means a shift of one bit, one hexadecimal digit and one octet, respectively, according to the three possible left-hand operand types. The result type shall be the same as that of the left operand.

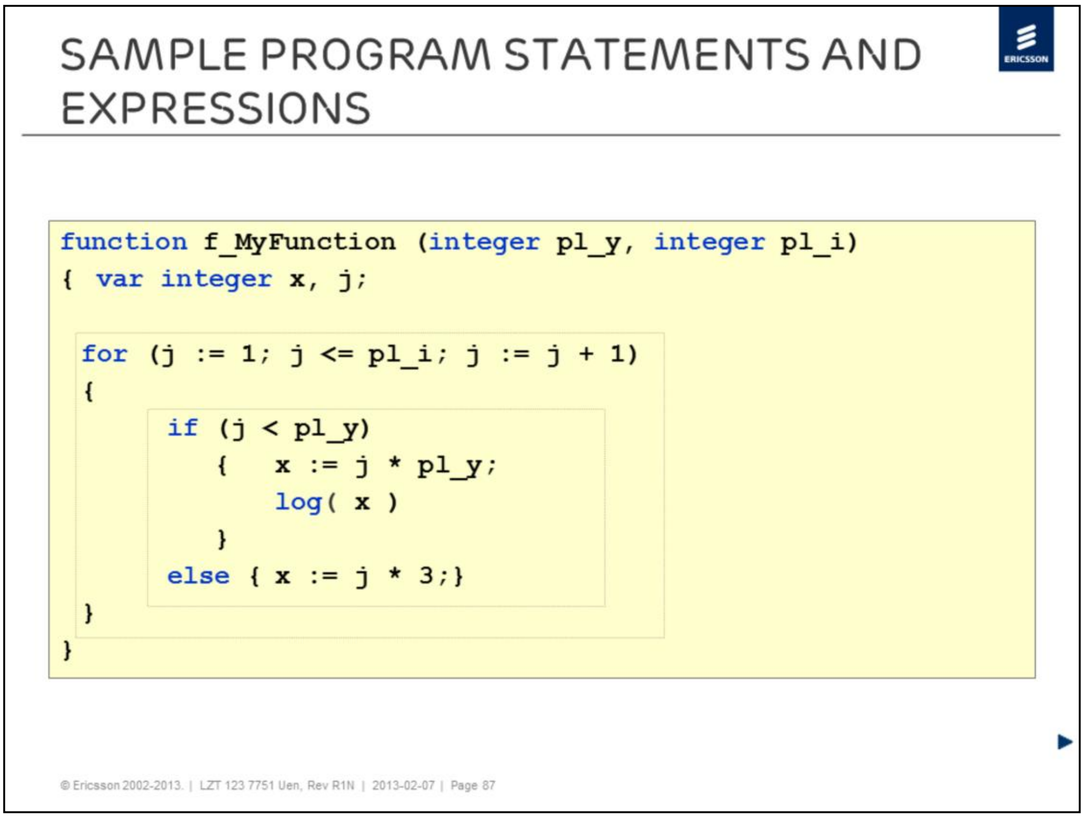
Rotate operators perform the rotate left and rotate right operations. Their left-hand operand shall be of type bitstring**,** hexstring, octetstring, charstring or universal charstring**.** Their right-hand operand shall be of type integer and its value of e.g. 1 means a rotate of one bit, one hexadecimal digit, one octet and one character, respectively, according to the possible left-hand operand types. The result type shall be the same as that of the left operand.



OPERATOR PRECEDENCE

Precedence	Operator type	Operator
Highest	*parentheses*	`()`
	Unary	`+, -`
	Binary	`*, /, mod, rem`
	Binary	`+, −, &`
	Unary	`not4b`
	Binary	`and4b`
	Binary	`xor4b`
	Binary	`or4b`
	Binary	`<<, >>, <@, @>`
	Binary	`<, >, <=, >=`
	Binary	`==, !=`
	Unary	`not`
	Binary	`and`
	Binary	`xor`
	Binary	`or`
Lowest		

Note: The assignment symbol **:=** , structure field symbol . , function calling ( ),indexing [ ] are not operators!



SAMPLE PROGRAM STATEMENTS AND EXPRESSIONS

```
function f_MyFunction (integer pl_y, integer pl_i)
{  var integer x, j;

 for (j := 1; j <= pl_i; j := j + 1)
 {
        if (j < pl_y)
           {   x := j * pl_y;
               log( x )
           }
        else { x := j * 3;}
 }
}
```

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Is the value of j is less than pl_y, then x will get the value of j multiplied by the parameter pl_y, otherwise it will have the value of three times j. The value x will only be converted to a character string and logged when the flag equals true.

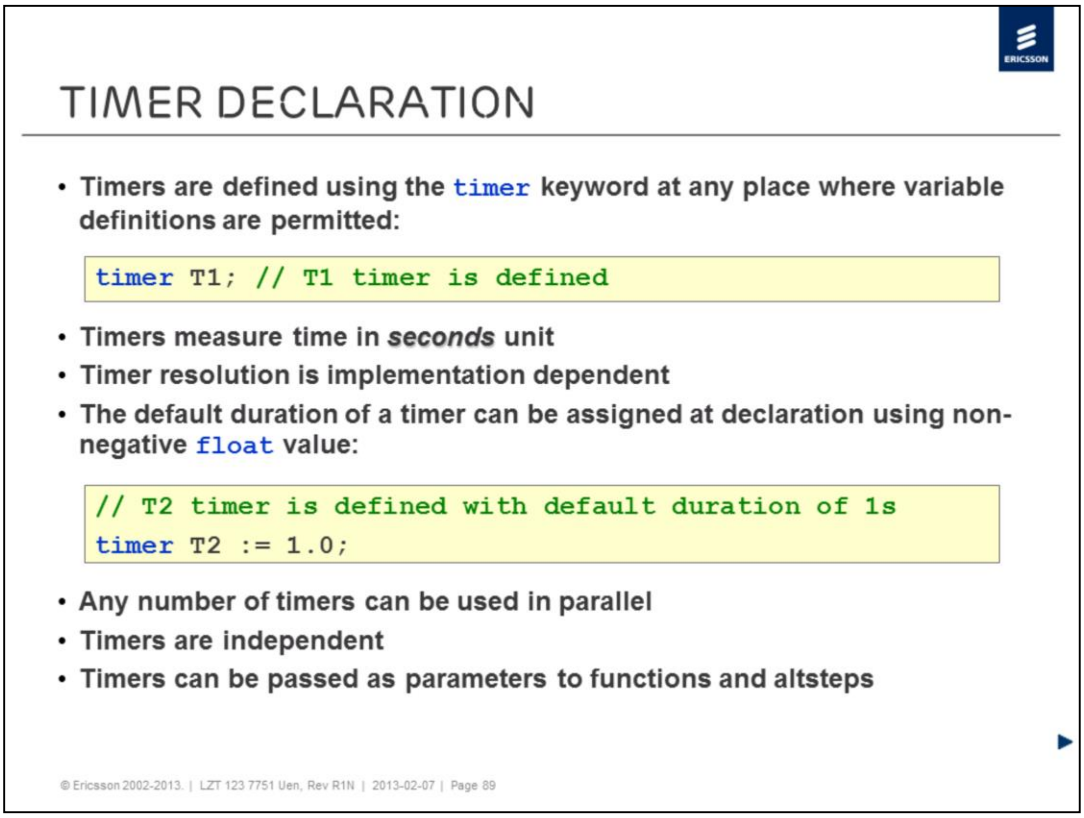
The procedure described above will be executed in a for loop. The number of executions is controlled by the value of the parameter pl_i.

The whole process is called in a function (f_MyFunction). The function has two parameters: pl_y sets the multiplication factor of j, while pl_i controls how many times the calculation is repeated.

VII. TIMERS

TIMER DECLARATIONS
TIMER OPERATIONS

CONTENTS



TIMER DECLARATION

- Timers are defined using the `timer` keyword at any place where variable definitions are permitted:

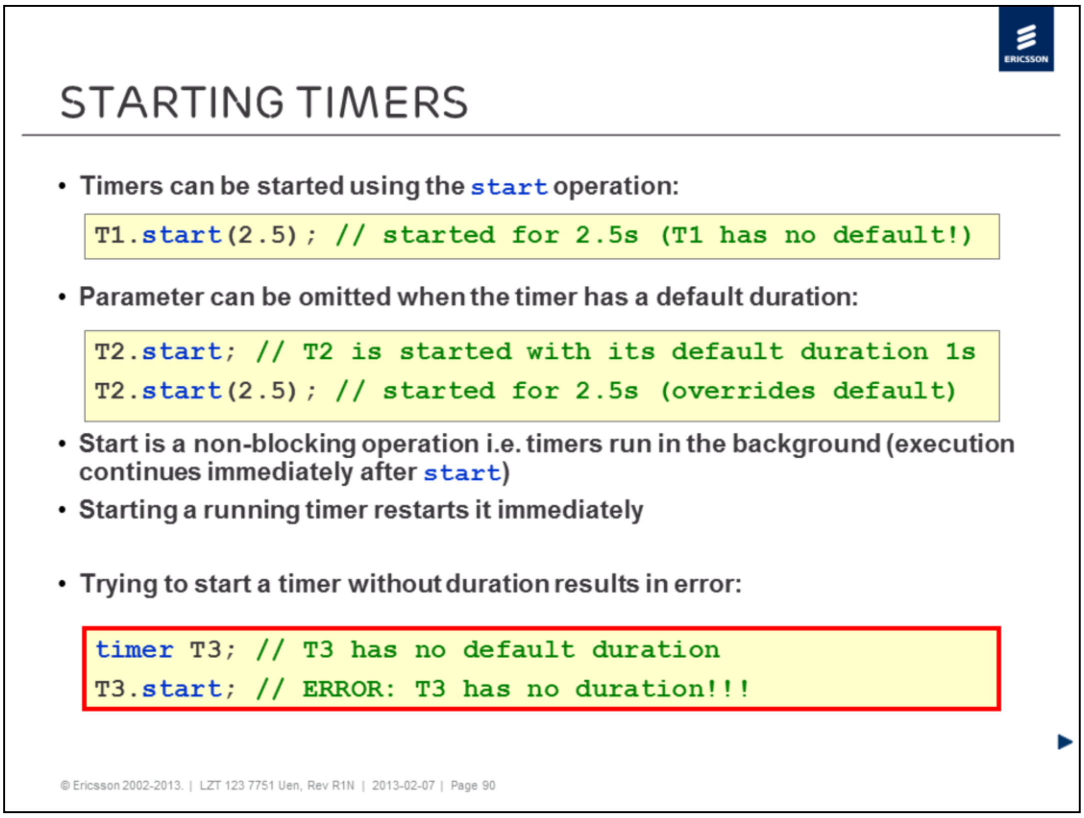
```
timer T1; // T1 timer is defined
```

- Timers measure time in ***seconds*** unit
- Timer resolution is implementation dependent
- The default duration of a timer can be assigned at declaration using non-negative `float` value:

```
// T2 timer is defined with default duration of 1s
timer T2 := 1.0;
```

- Any number of timers can be used in parallel
- Timers are independent
- Timers can be passed as parameters to functions and altsteps

Timers can be defined and used in the module control part, test cases, functions and altsteps. Additionally, timers can be defined in component type definitions. These timers can be used in test cases, functions and altsteps which are running on the given component type.



STARTING TIMERS

- Timers can be started using the `start` operation:

```
T1.start(2.5); // started for 2.5s (T1 has no default!)
```

- Parameter can be omitted when the timer has a default duration:

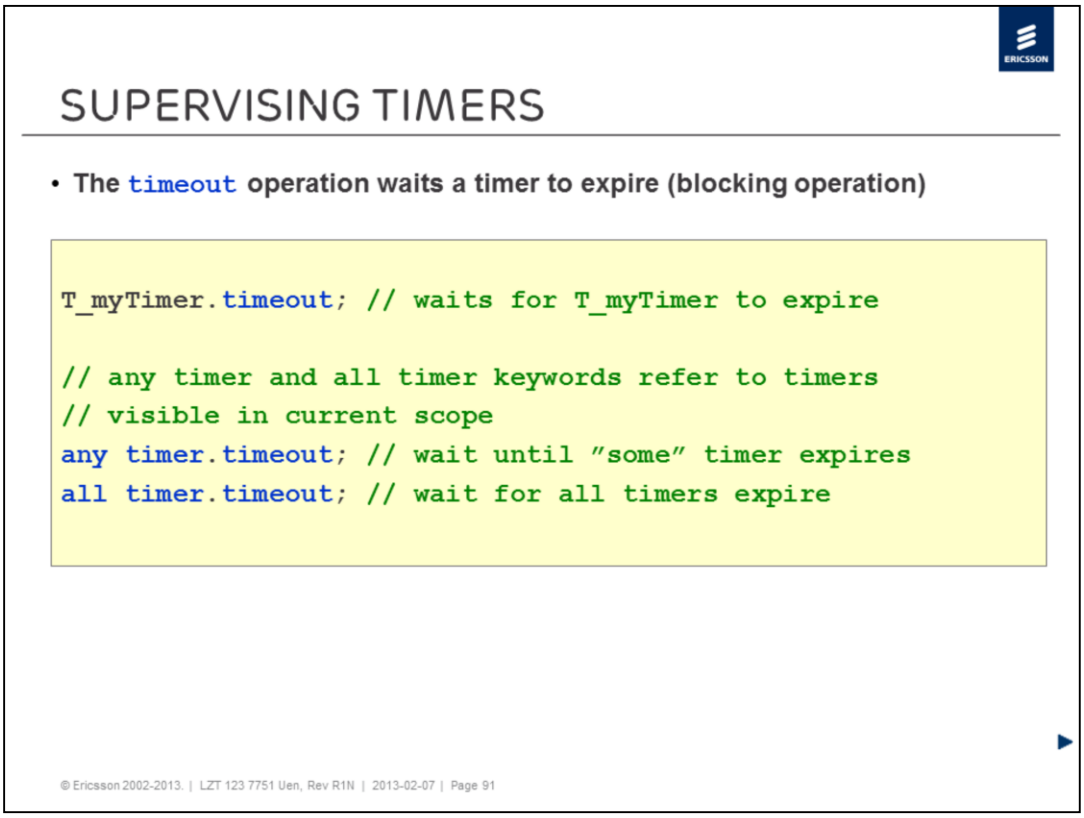
```
T2.start; // T2 is started with its default duration 1s
T2.start(2.5); // started for 2.5s (overrides default)
```

- Start is a non-blocking operation i.e. timers run in the background (execution continues immediately after `start`)
- Starting a running timer restarts it immediately
- Trying to start a timer without duration results in error:

```
timer T3; // T3 has no default duration
T3.start; // ERROR: T3 has no duration!!!
```

When starting a timer, 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 definition. When a timer duration is overridden, the new value applies only to the current instance of the timer, any subsequent start operation for this timer, which do not specify a duration, shall use the default duration.

The start operation may be applied to a running timer, in which case the timer is stopped and re-started.



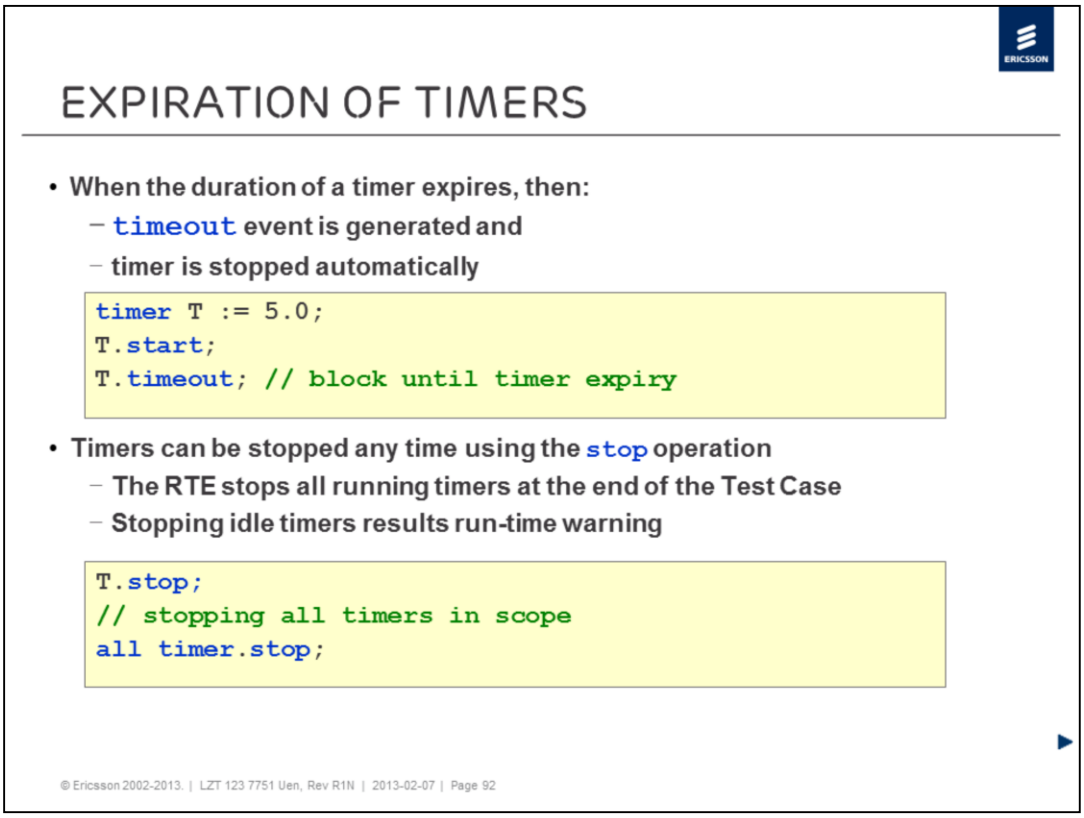
SUPERVISING TIMERS

- The `timeout` operation waits a timer to expire (blocking operation)

```
T_myTimer.timeout; // waits for T_myTimer to expire

// any timer and all timer keywords refer to timers
// visible in current scope
any timer.timeout; // wait until ”some” timer expires
all timer.timeout; // wait for all timers expire
```

The **timeout** operation allows to check expiration of a timer, or of all timers, in a scope unit in which the timeout operation has been called. The **timeout** shall not be used in a boolean expression, but it can be used to determine an alternative in an alt statement



EXPIRATION OF TIMERS

- When the duration of a timer expires, then:
  - `timeout` event is generated and
  - timer is stopped automatically

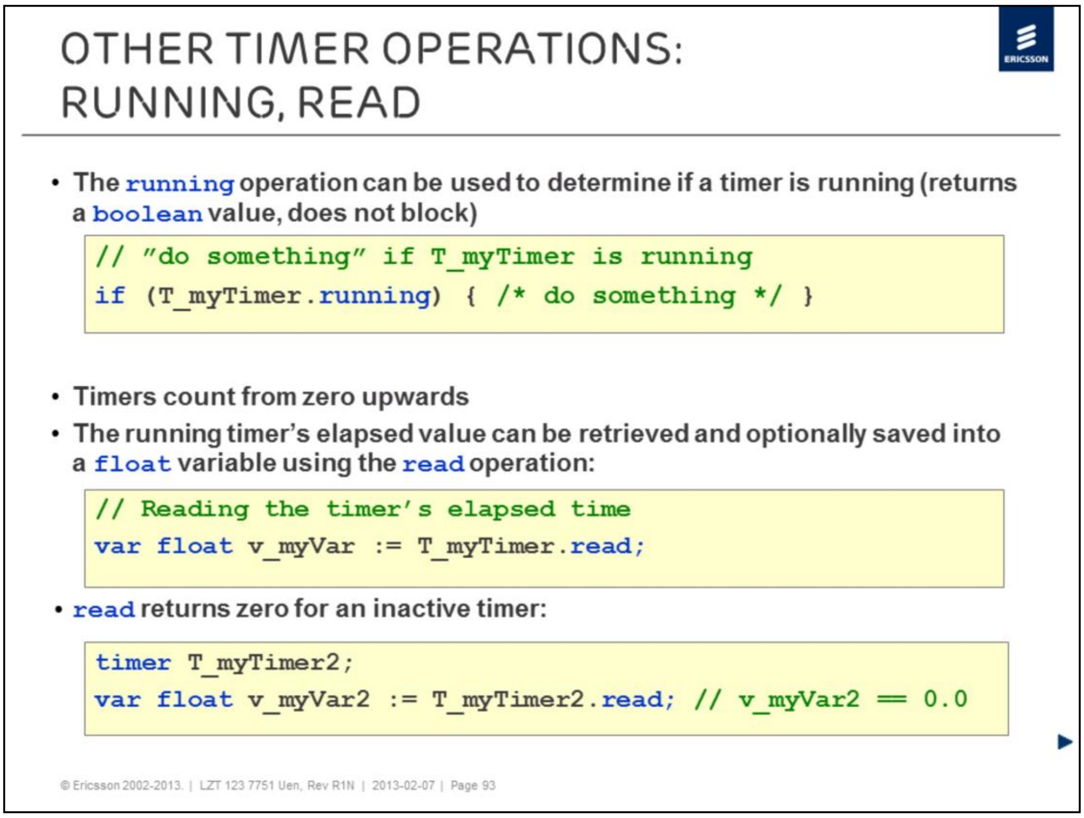
```
timer T := 5.0;
T.start;
T.timeout; // block until timer expiry
```

- Timers can be stopped any time using the `stop` operation
  - The RTE stops all running timers at the end of the Test Case
  - Stopping idle timers results run-time warning

```
T.stop;
// stopping all timers in scope
all timer.stop;
```

The **stop** operation is used to stop a running timer. The elapsed time of a stopped timer is set to the float value zero (0.0). An already stopped timer may be stopped again, although it does not have any effect.

RTE: Run Time Environment



OTHER TIMER OPERATIONS: RUNNING, READ

- The `running` operation can be used to determine if a timer is running (returns a `boolean` value, does not block)

```
// "do something" if T_myTimer is running
if (T_myTimer.running) { /* do something */ }
```

- Timers count from zero upwards
- The running timer's elapsed value can be retrieved and optionally saved into a `float` variable using the `read` operation:

```
// Reading the timer's elapsed time
var float v_myVar := T_myTimer.read;
```

- `read` returns zero for an inactive timer:

```
timer T_myTimer2;
var float v_myVar2 := T_myTimer2.read; // v_myVar2 == 0.0
```

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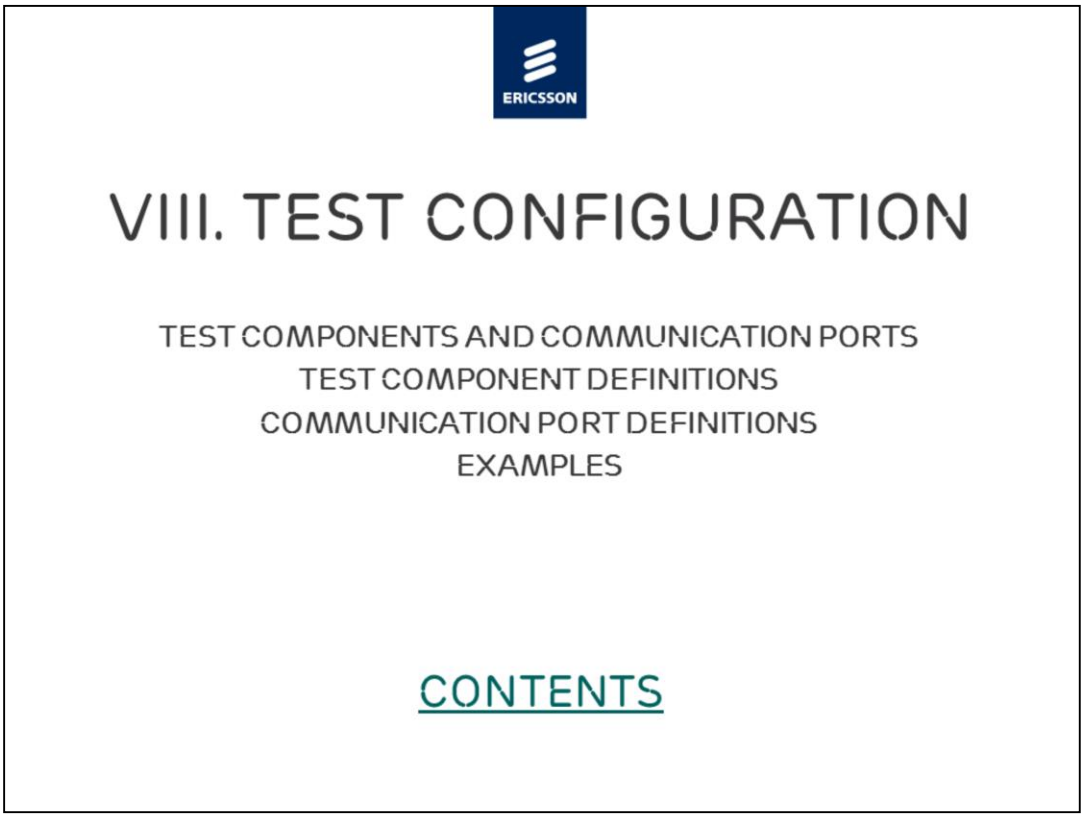
The **running** timer operation is used to check whether a timer has been started and has neither timed out nor been stopped.

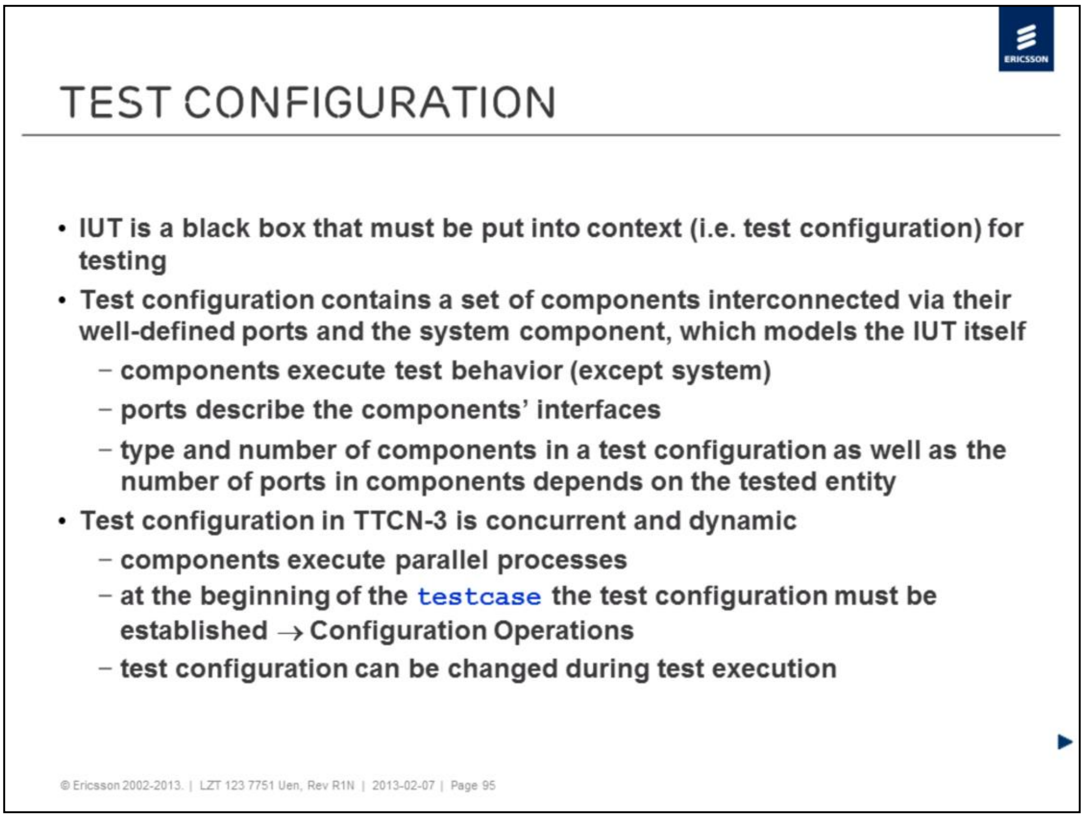
The **read** operation is used to retrieve the time that has elapsed since the specified timer was started. The operation returns a value of type float. Applying the read operation on an inactive timer will return the value zero.



VIII. TEST CONFIGURATION

TEST COMPONENTS AND COMMUNICATION PORTS
TEST COMPONENT DEFINITIONS
COMMUNICATION PORT DEFINITIONS
EXAMPLES

CONTENTS

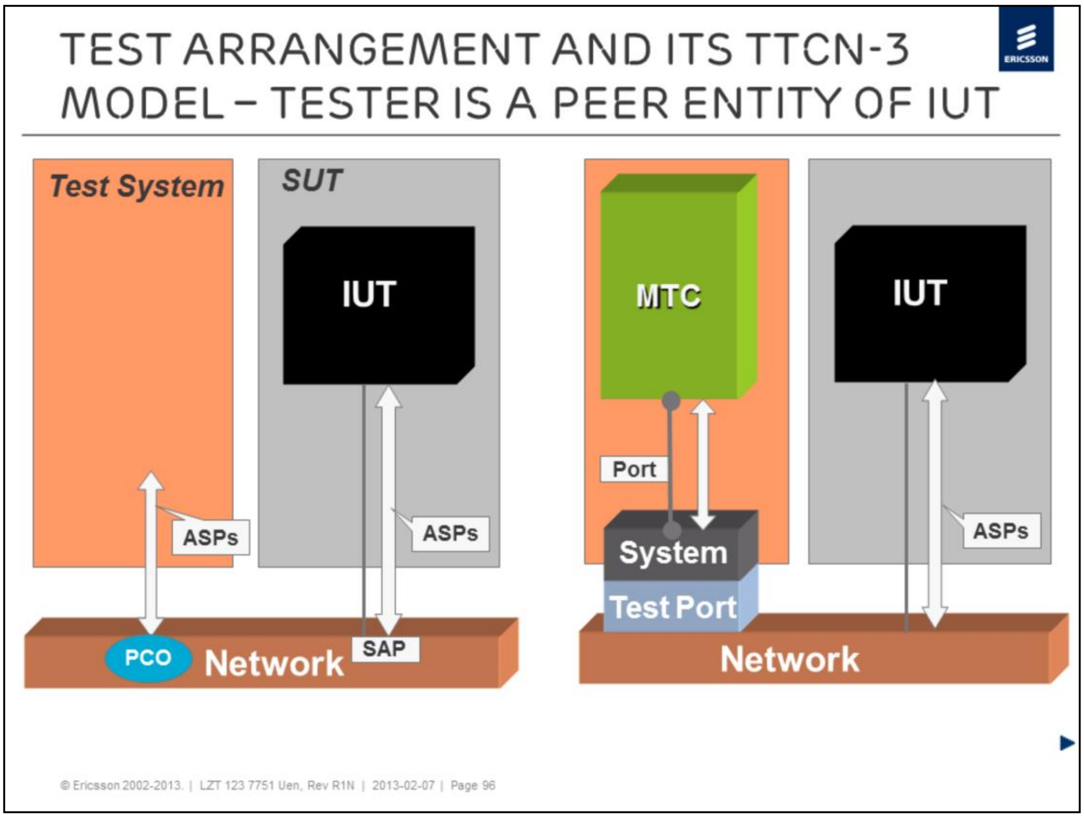


TEST CONFIGURATION

- IUT is a black box that must be put into context (i.e. test configuration) for testing
- Test configuration contains a set of components interconnected via their well-defined ports and the system component, which models the IUT itself
  - components execute test behavior (except system)
  - ports describe the components' interfaces
  - type and number of components in a test configuration as well as the number of ports in components depends on the tested entity
- Test configuration in TTCN-3 is concurrent and dynamic
  - components execute parallel processes
  - at the beginning of the `testcase` the test configuration must be established → Configuration Operations
  - test configuration can be changed during test execution

The abstract test configuration consists of **component**s. The components are interconnected by means of **port**s. In the course of the test, the components themselves may emerge and disappear, their interconnection vary, in other words, the test configuration is dynamic.

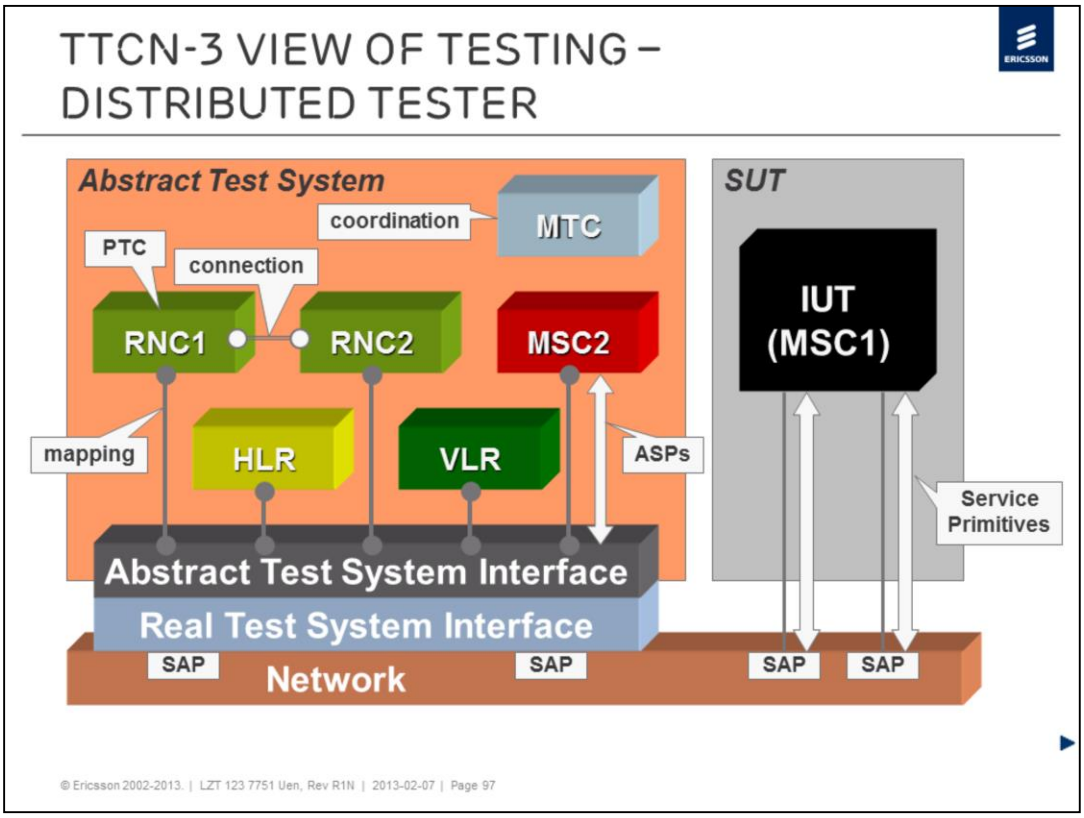
The tested implementation (IUT, Implementation Under Test) is considered a black box, i.e., its internal structure is hidden from the tester. A special test component, called the test system interface (or System for short) interfaces the ports of the real world to the abstract world of components.



TEST ARRANGEMENT AND ITS TTCN-3 MODEL – TESTER IS A PEER ENTITY OF IUT

In most of the cases Tester behaves as a peer entity of the IUT/SUT

Main Test Component (mtc)
System Component (system)
mtc and system are of the same type



TTCN-3 VIEW OF TESTING – DISTRIBUTED TESTER

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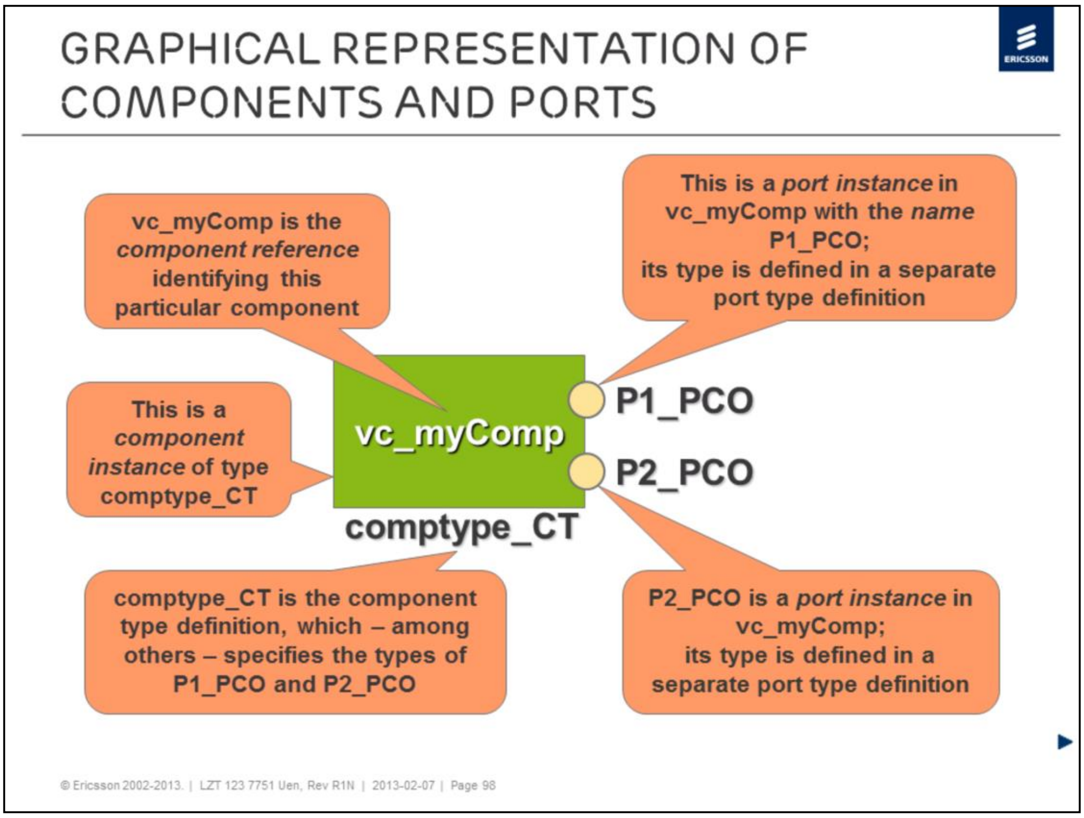
The Implementation Under Test (IUT) is usually located inside the System Under Test (SUT). The test system is connected to the SUT through a Network. The connection points between the IUT and the Network respective between the test system and the network are called Service Access Points (SAPs).

Communication between the Abstract Test System Interface (mapping the Real Test System Interface to the abstract world) and the Test Components is carried in Abstract Service Primitives (ASPs). ASP is an implementation-independent description of an interaction between the test system and the SUT. ASPs are usually described in the specification of the tested protocol.

Communication within the test system (between the components) runs through associated ports. The association between components (on the slide: Parallel Test Components [PTCs] and the Main Test Component [MTC]) is called connection and is set up using the connect keyword. The association between components and the Abstract Test System Interface is called mapping and is set up using the map keyword.



GRAPHICAL REPRESENTATION OF COMPONENTS AND PORTS

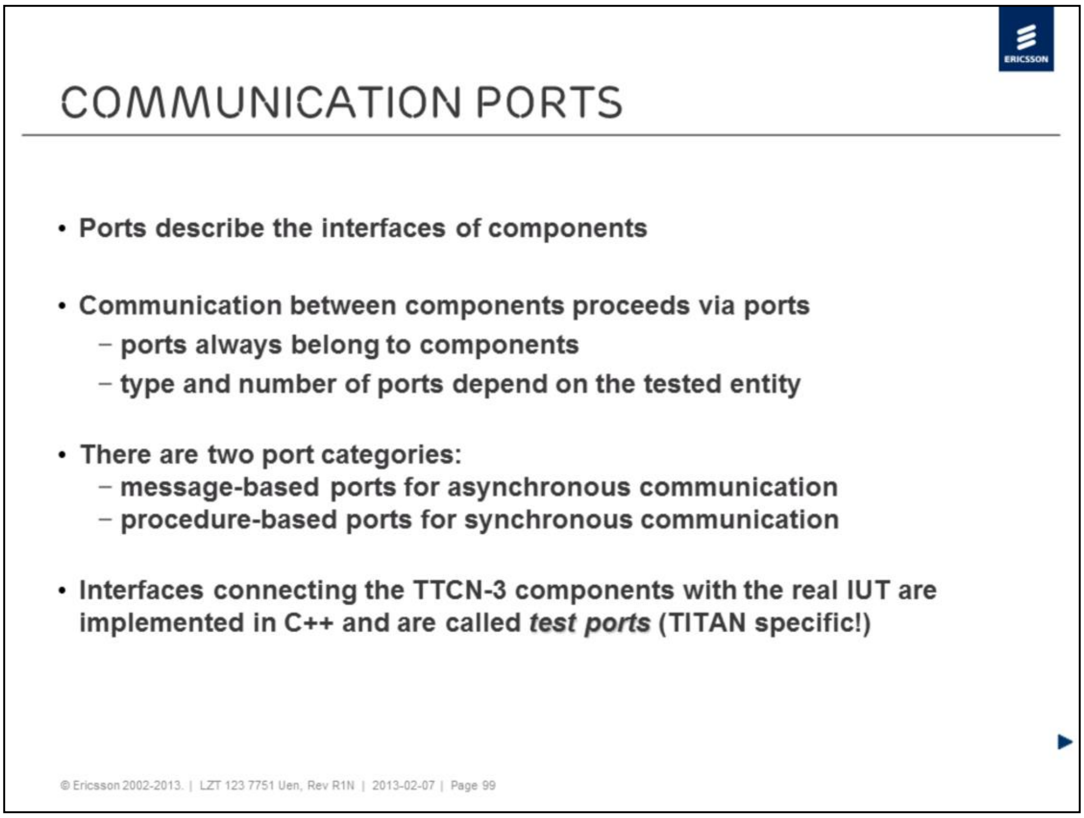
vc_myComp is the *component reference* identifying this particular component

This is a *port instance* in vc_myComp with the *name* P1_PCO; its type is defined in a separate port type definition

This is a *component instance* of type comptype_CT

comptype_CT is the component type definition, which – among others – specifies the types of P1_PCO and P2_PCO

P2_PCO is a *port instance* in vc_myComp; its type is defined in a separate port type definition



COMMUNICATION PORTS

- **Ports describe the interfaces of components**
- **Communication between components proceeds via ports**
  - **ports always belong to components**
  - **type and number of ports depend on the tested entity**
- **There are two port categories:**
  - **message-based ports for asynchronous communication**
  - **procedure-based ports for synchronous communication**
- **Interfaces connecting the TTCN-3 components with the real IUT are implemented in C++ and are called *test ports* (TITAN specific!)**

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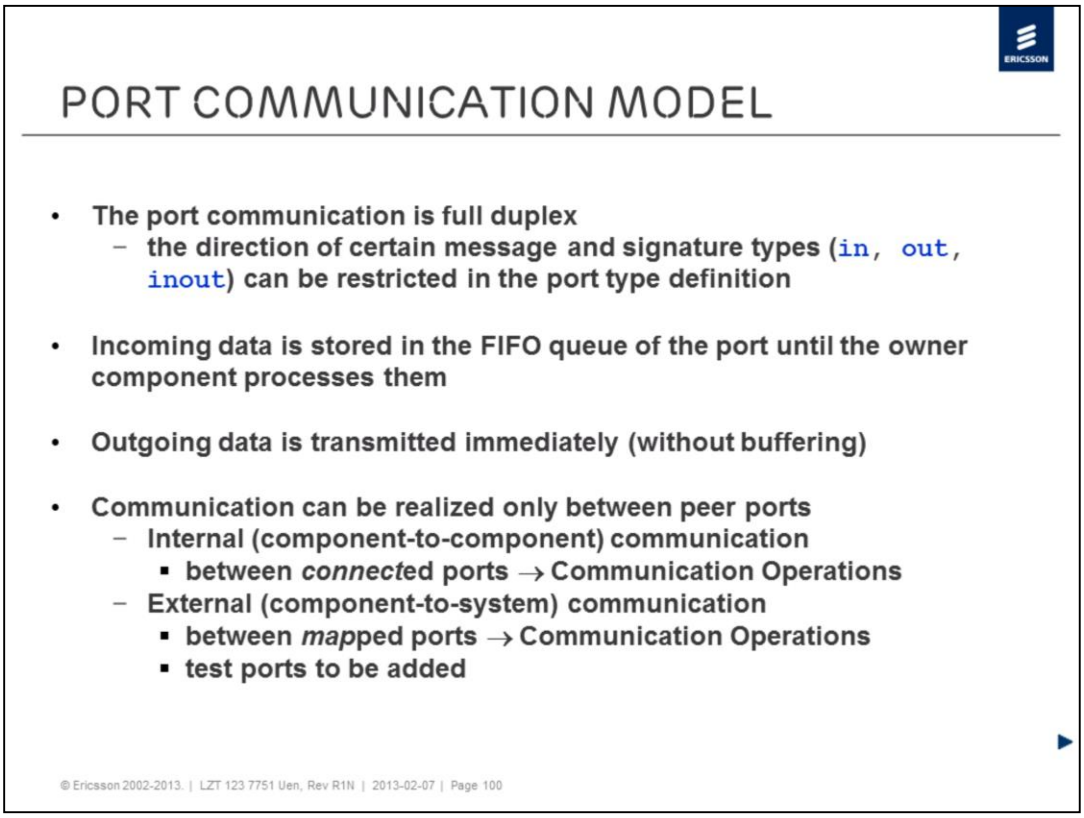
The components are interconnected via test ports. TTCN-3 defines the port communication model through which messages are exchanged (message based ports) or procedures are called (procedure based ports). The interconnection is called mapping between System and components and connecting between components.



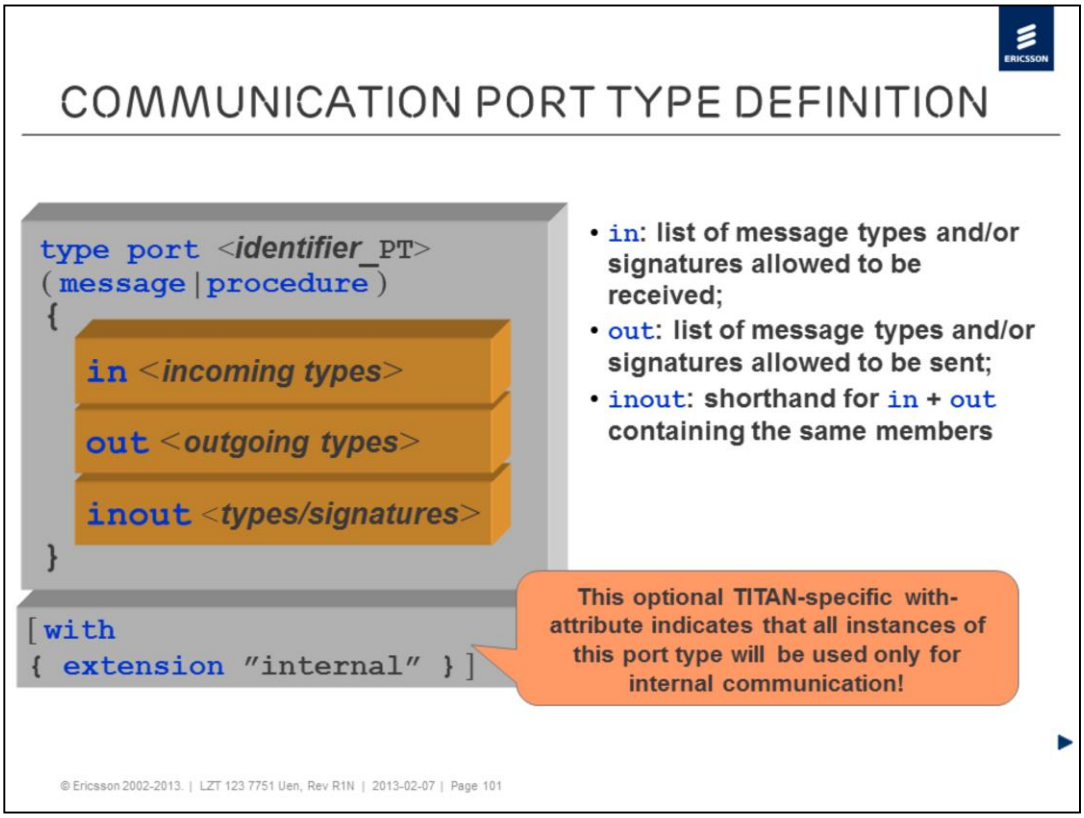
PORT COMMUNICATION MODEL

- The port communication is full duplex
  - the direction of certain message and signature types (`in`, `out`, `inout`) can be restricted in the port type definition
- Incoming data is stored in the FIFO queue of the port until the owner component processes them
- Outgoing data is transmitted immediately (without buffering)
- Communication can be realized only between peer ports
  - Internal (component-to-component) communication
    - between *connect*ed ports → Communication Operations
  - External (component-to-system) communication
    - between *map*ped ports → Communication Operations
    - test ports to be added

Information (messages, procedure calls or both) are exchanged between associated **communication ports** of the components. Internal (component-to-component) communication happens between *connect*ed ports whereas external (component-to-system) communication happens between *map*ped ports.

Ports are bidirectional, but have a list enumerating the allowed messages together with their direction (in, out, inout).

The infinite FIFO queue stores the incoming messages or procedure calls until they are processed by the component owning that port. A queue overflow (in a real implementation a queue is never infinite) is treated as a test case error.



COMMUNICATION PORT TYPE DEFINITION

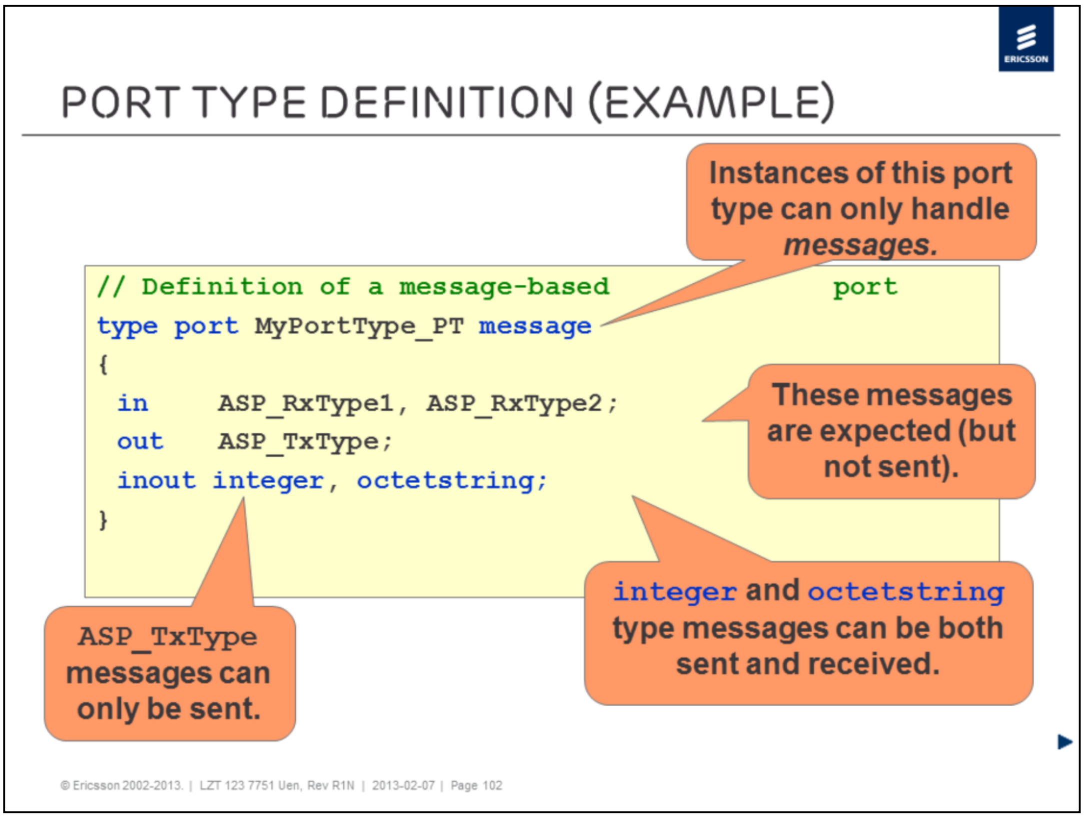
```
type port <identifier_PT>
(message|procedure)
{
    in <incoming types>
    out <outgoing types>
    inout <types/signatures>
}
[with
{ extension ”internal” }]
```

- `in`: list of message types and/or signatures allowed to be received;
- `out`: list of message types and/or signatures allowed to be sent;
- `inout`: shorthand for `in` + `out` containing the same members

This optional TITAN-specific with-attribute indicates that all instances of this port type will be used only for internal communication!

When defining a message based **port type**, the messages allowed to pass that port must be listed together with their direction. When defining a procedure based **port type**, the procedure signatures allowed must be listed. A mixed port a shorthand notation for two ports, i.e. a message-based port and a procedure-based port with the same name.

The attributes defined with the keyword with may define e.g. the coding rules used for the messages passing the port. Such a rule may be for example whether the most os the less significant bit should be sent first through the port.



PORT TYPE DEFINITION (EXAMPLE)

```
// Definition of a message-based port
type port MyPortType_PT message
{
  in     ASP_RxType1, ASP_RxType2;
  out    ASP_TxType;
  inout integer, octetstring;
}
```

Instances of this port type can only handle *messages*.

These messages are expected (but not sent).

`ASP_TxType` messages can only be sent.

`integer` and `octetstring` type messages can be both sent and received.

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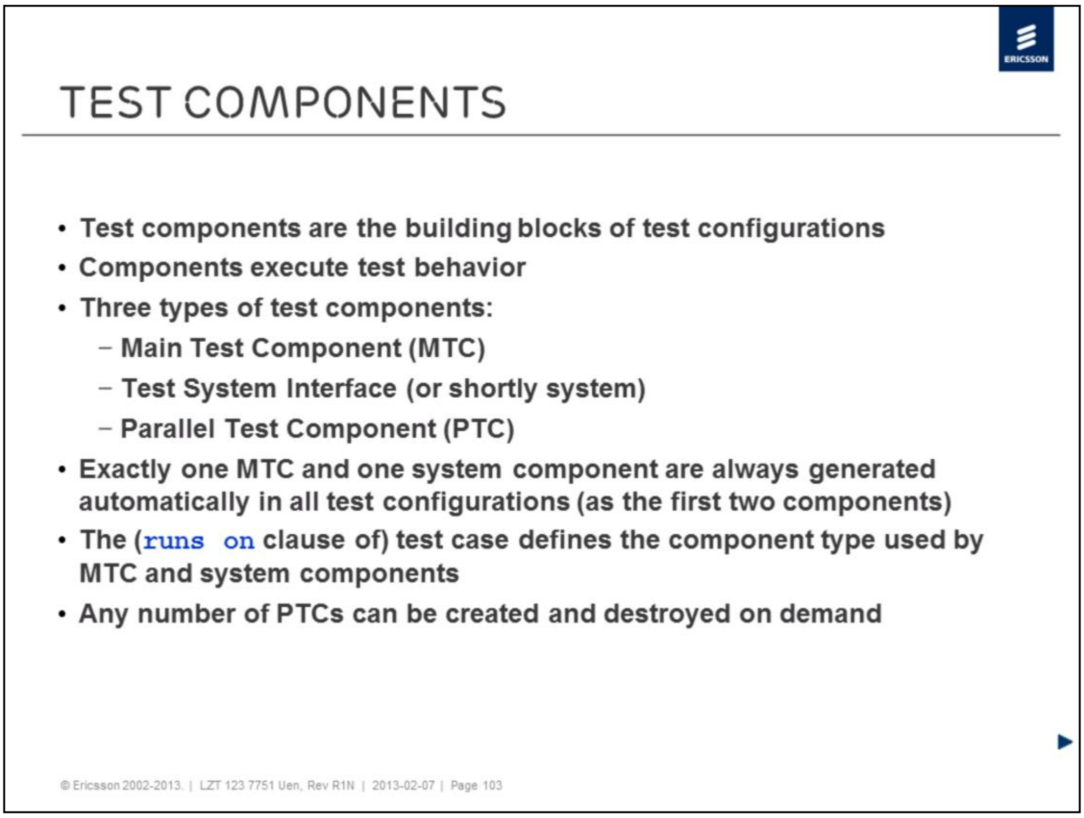
A message based port is defined by enumerating the allowed message types together with their direction.



TEST COMPONENTS

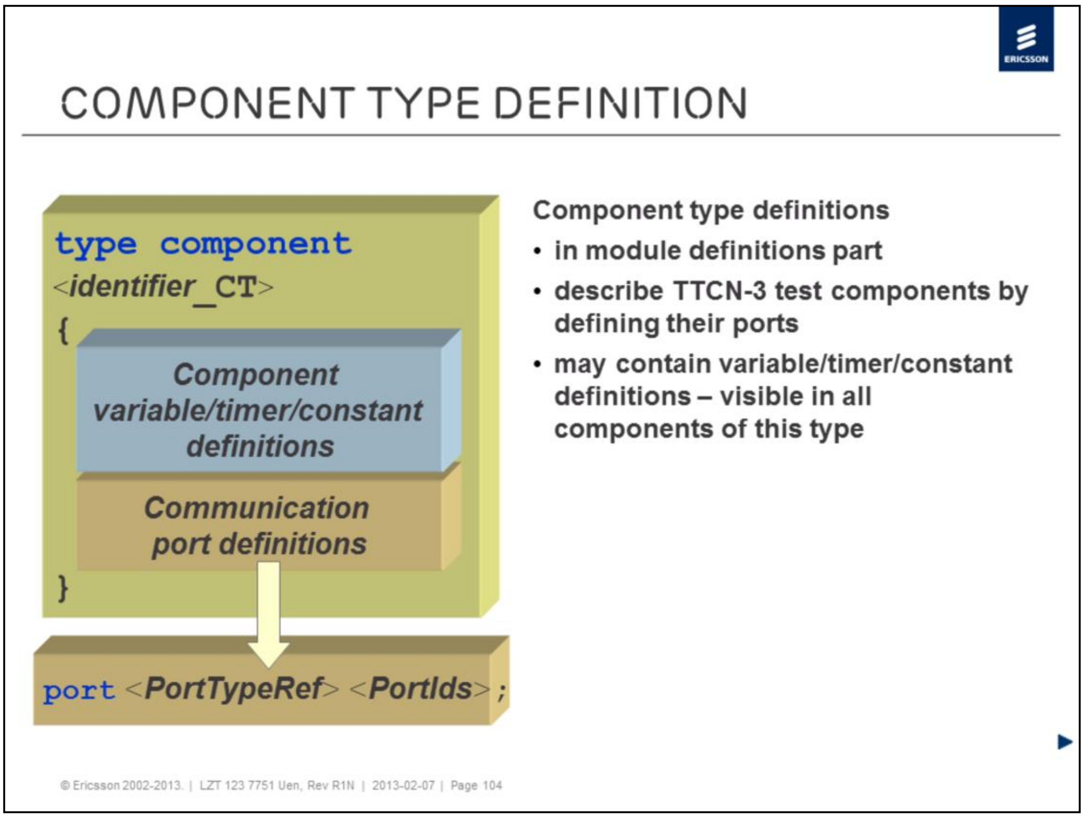
- Test components are the building blocks of test configurations
- Components execute test behavior
- Three types of test components:
  - Main Test Component (MTC)
  - Test System Interface (or shortly system)
  - Parallel Test Component (PTC)
- Exactly one MTC and one system component are always generated automatically in all test configurations (as the first two components)
- The (`runs on` clause of) test case defines the component type used by MTC and system components
- Any number of PTCs can be created and destroyed on demand

The abstract test configuration consists of **component**s. The components are interconnected by means of **port**s. In the course of the test, the components themselves may emerge and disappear, their interconnection vary, in other words, the test configuration is dynamic.

Within every test configuration there shall be one (and only one) main test component (MTC) created automatically at the start of each test case execution.

Parallel test components (PTCs) can dynamically be created during execution of a test case by the explicit use of the <u>create</u> operation.

The tested implementation (IUT, Implementation Under Test) is considered a black box, i.e., its internal structure is hidden from the tester. A special test component, called the test system interface (or System for short) interfaces the ports of the real world to the abstract world of components.



COMPONENT TYPE DEFINITION

```
type component
<identifier_CT>
{
    Component variable/timer/constant definitions
    Communication port definitions
}
port <PortTypeRef> <PortIds> ;
```

Component type definitions

- in module definitions part
- describe TTCN-3 test components by defining their ports
- may contain variable/timer/constant definitions – visible in all components of this type

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A test configuration consists of a set of inter-connected test components with well-defined communication ports.

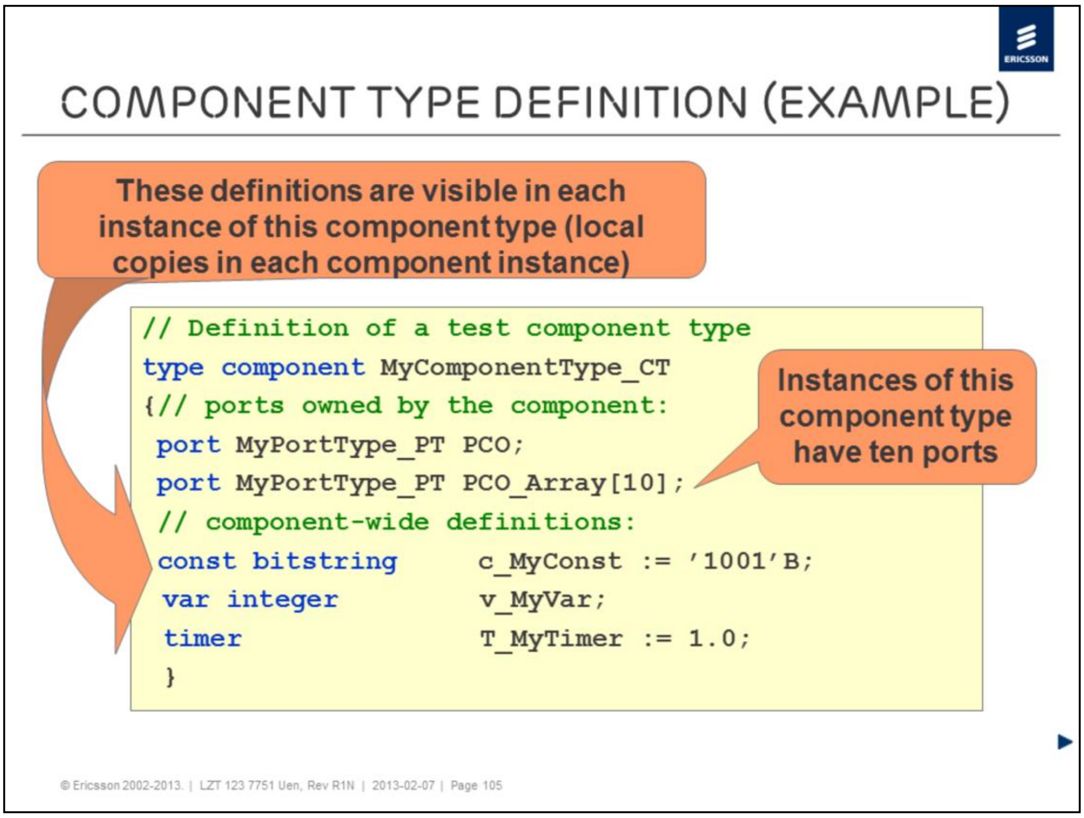
Test **component type** definitions shall be made in the module definitions part. The actual configuration of components is achieved by performing create operations within the test case behavior.

The component type defines which ports are associated with a component. The port names in a component definition are local to that component i.e. another component may have ports with the same names.

It is possible to define constants, variables and timers local to a particular component.

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

It does not make sense to define timers, variables or constants in the system component as the latter serves as an image of the physical world.



COMPONENT TYPE DEFINITION (EXAMPLE)

These definitions are visible in each instance of this component type (local copies in each component instance)

```
// Definition of a test component type
type component MyComponentType_CT
{// ports owned by the component:
 port MyPortType_PT PCO;
 port MyPortType_PT PCO_Array[10];
 // component-wide definitions:
 const bitstring      c_MyConst := ’1001’B;
  var integer          v_MyVar;
  timer                T_MyTimer := 1.0;
  }
```

Instances of this component type have ten ports

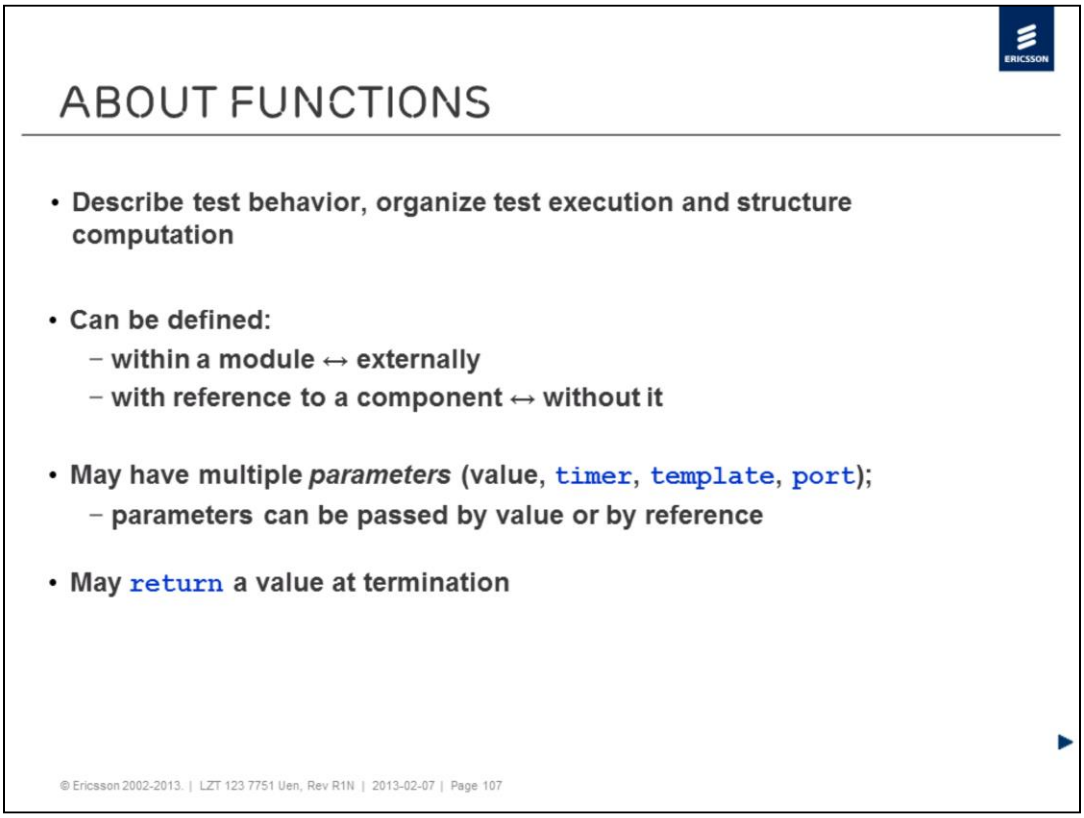
The component type MyComponentType_CT owns a port called PCO and a port array PCO_Array containing 10 ports of type MyPortType_PT.

In each component instance of this type local copies of the ports, the variable (v_MyVar) and the timer (T_MyTimer) are generated, and the constant (c_MyConst) will be visible.

IX. FUNCTIONS AND TESTCASES

OVERVIEW OF FUNCTIONS
FUNCTION DEFINITIONS
PARAMETERIZATION
PREDEFINED FUNCTIONS
TESTCASE DEFINITIONS
VERDICT HANDLING
CONTROLLING TEST CASE EXECUTION

CONTENTS



ABOUT FUNCTIONS

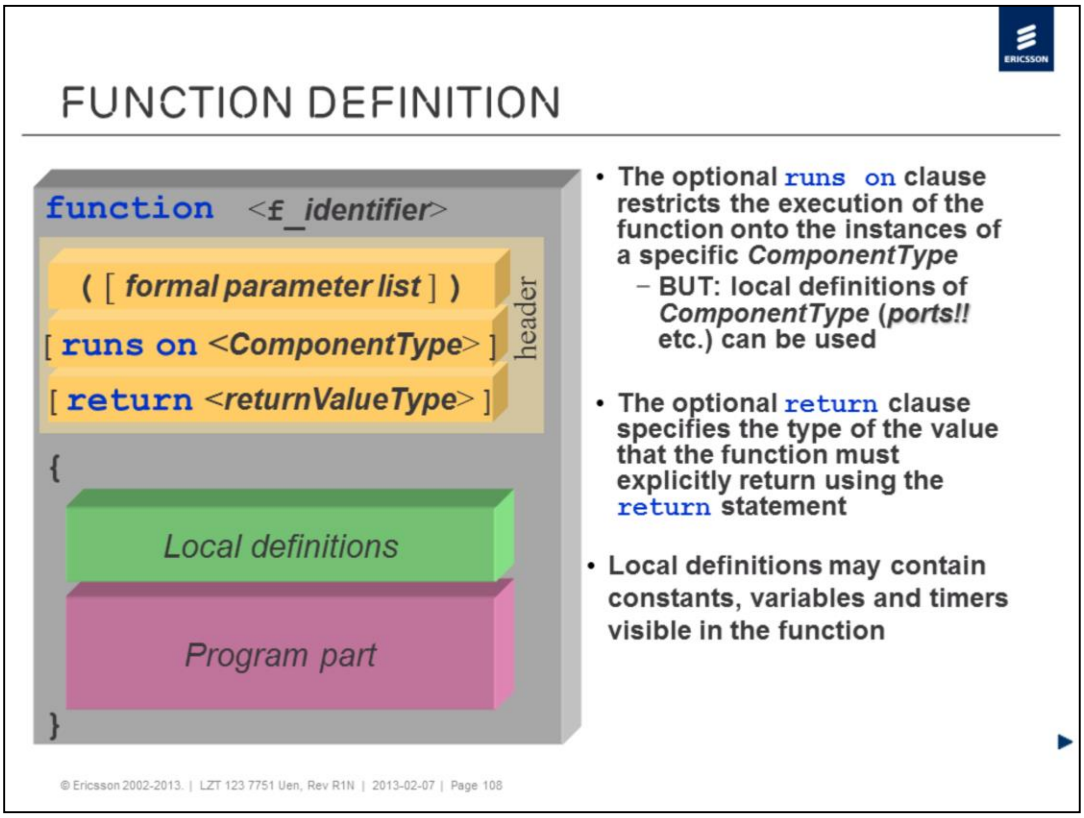
- **Describe test behavior, organize test execution and structure computation**
- **Can be defined:**
  - **within a module ↔ externally**
  - **with reference to a component ↔ without it**
- **May have multiple *parameters* (value, `timer`, `template`, `port`);**
  - **parameters can be passed by value or by reference**
- **May `return` a value at termination**

In TTCN-3, functions are used to specify and probe behavior and to structure computation in a module.

Usually, a function is defined in TTCN-3 (using the keyword function) but may be defined as an external function (using the keyword external) implemented in one or more C++ source files.

A function must be defined with reference to a component (“runs on”) if the function uses variables, constants, timers and ports that are defined in a component type definition.

Parameter passing mechanism (by value or by reference) can be chosen for each parameter separately. Parameters passed by value are read-only parameters. Those passed by reference may even be altered by the function.



FUNCTION DEFINITION

function <f_identifier>
([*formal parameter list*])
[runs on <*ComponentType*>]
[return <*returnValueType*>]
header
{
Local definitions
Program part
}

- The optional runs on clause restricts the execution of the function onto the instances of a specific *ComponentType*
  - BUT: local definitions of *ComponentType* (*ports!!* etc.) can be used
- The optional return clause specifies the type of the value that the function must explicitly return using the return statement
- Local definitions may contain constants, variables and timers visible in the function

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The function **header**:

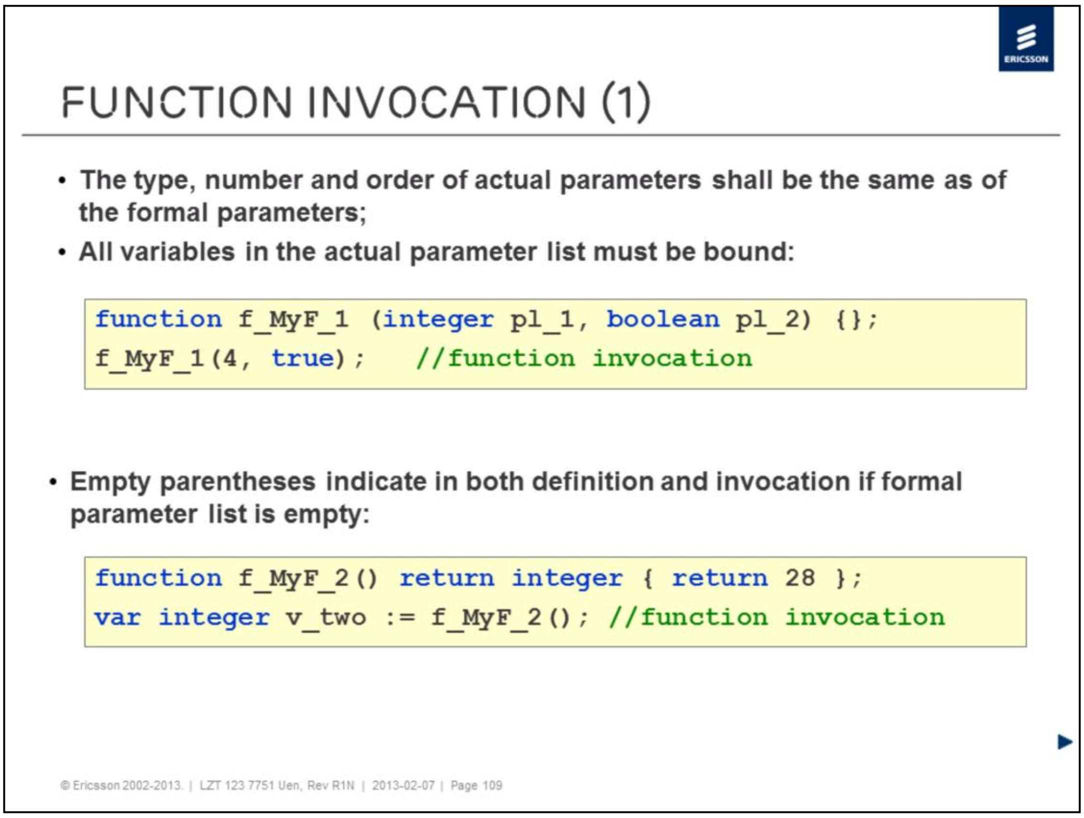
•contains the list of formal parameters of the function. When no parameters are used, empty brackets must be written;

•the usually optional **runs on** clause must be present if the function uses variables, constants, timers and ports that are defined in a component type definition;

•the keyword **return** is only used if the function returns a parameter. A function can only return a single value of a given type.

The **local definitions** are optional. When present, the constants, variables and timers defined here are only visible within the function.

The keyword <u>return</u> must conclude the program part. It must be followed by an expression resulting in the same type as defined in the header when the **return** keyword was used in the header. Notice that the bold and underscored “return” keyword has two different meanings!



FUNCTION INVOCATION (1)

- **The type, number and order of actual parameters shall be the same as of the formal parameters;**
- **All variables in the actual parameter list must be bound:**

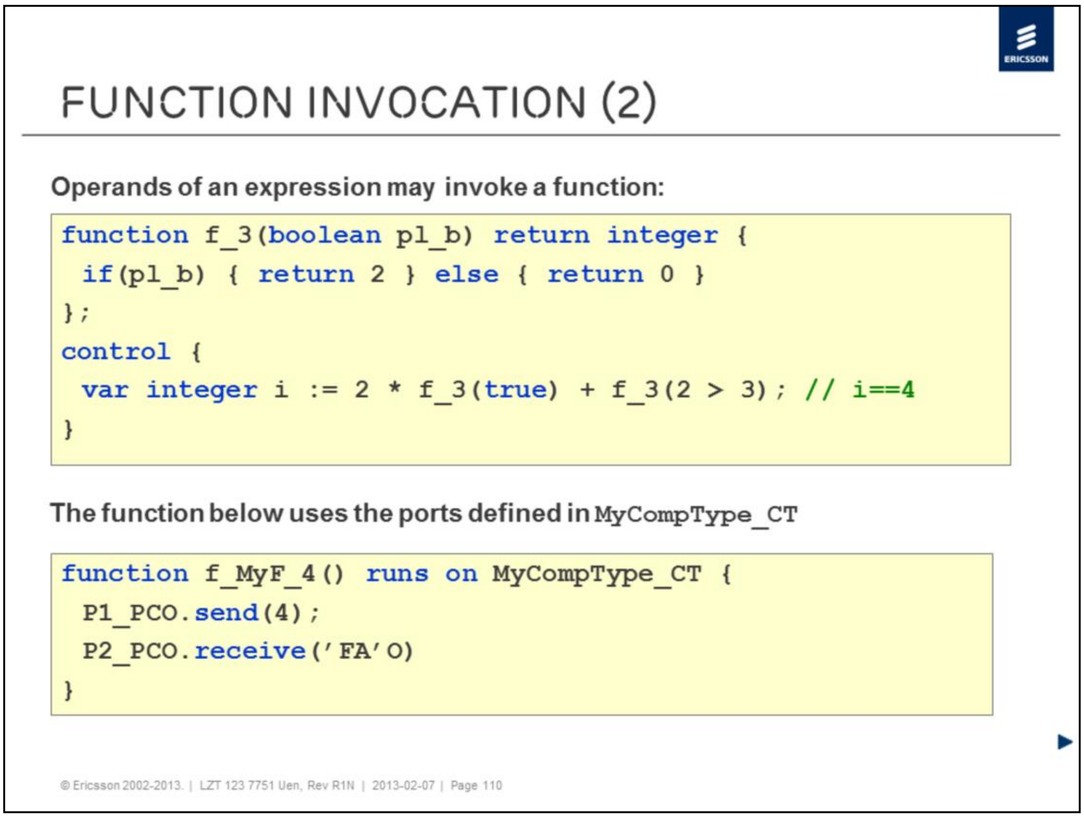
```
function f_MyF_1 (integer pl_1, boolean pl_2) {};
f_MyF_1(4, true);   //function invocation
```

- **Empty parentheses indicate in both definition and invocation if formal parameter list is empty:**

```
function f_MyF_2() return integer { return 28 };
var integer v_two := f_MyF_2(); //function invocation
```

The formal parameters of the function f_MyF_1 are **pl_1** and **pl_2**. Their types are integer and boolean, respectively. When invoking the function, the actual parameter list contains the parameters of the corresponding type in the same order as defined.
By the way: the program part of the function defined is empty, in other words, the function does not do anything.

The formal parameter list of the function f_MyF_2 is empty thus it is invoked with two brackets after the function name standing for an empty parameter list. The program always return the integer value 28 (see the code between the curly brackets). The returned values is of integer type (cf. the function definition) and that’s why it can be assigned to the variable v_two, the latter being of the same type.



FUNCTION INVOCATION (2)

Operands of an expression may invoke a function:

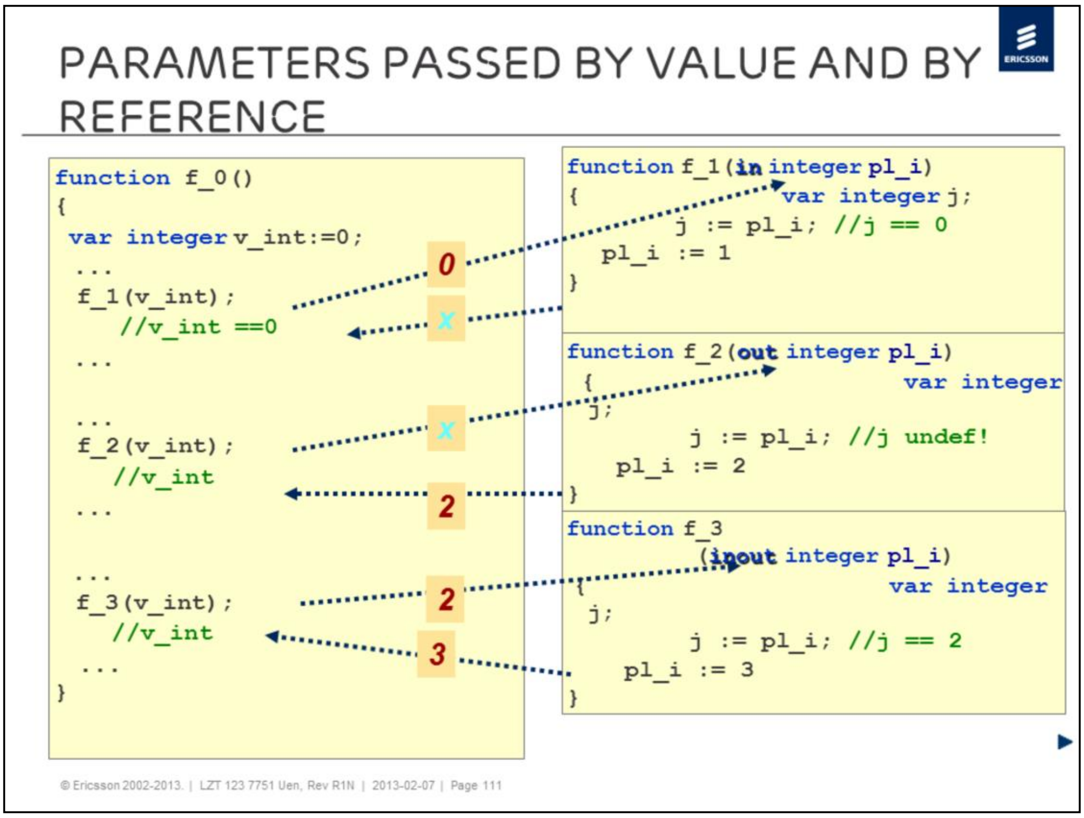
```
function f_3(boolean pl_b) return integer {
  if(pl_b) { return 2 } else { return 0 }
};
control {
  var integer i := 2 * f_3(true) + f_3(2 > 3); // i==4
}
```

The function below uses the ports defined in `MyCompType_CT`

```
function f_MyF_4() runs on MyCompType_CT {
  P1_PCO.send(4);
  P2_PCO.receive(’FA’O)
}
```

Functions with a return value may be invoked in expressions. On the slide above, the function f_3 returns the value 2 if the parameter is true, otherwise the value returned will be 0.
The first summand has the value of two times two, the second summand equals zero, thus, the variable **i** results in four.

The function f_4 is defined with reference to a component (MyCompType_CT) because it makes use of the ports having been defined in that component.



PARAMETERS PASSED BY VALUE AND BY REFERENCE

```
function f_0()
{
 var integer v_int:=0;
  ...
  f_1(v_int);
     //v_int ==0
  ...

  ...
  f_2(v_int);
    //v_int
  ...

  ...
  f_3(v_int);
    //v_int
   ...
}
```

```
function f_1(in integer pl_i)
{                              var integer j;
                        j := pl_i; //j == 0
    pl_i := 1
}
```

```
function f_2(out integer pl_i)
 {                                      var integer
  j;
               j := pl_i; //j undef!
     pl_i := 2
}
```

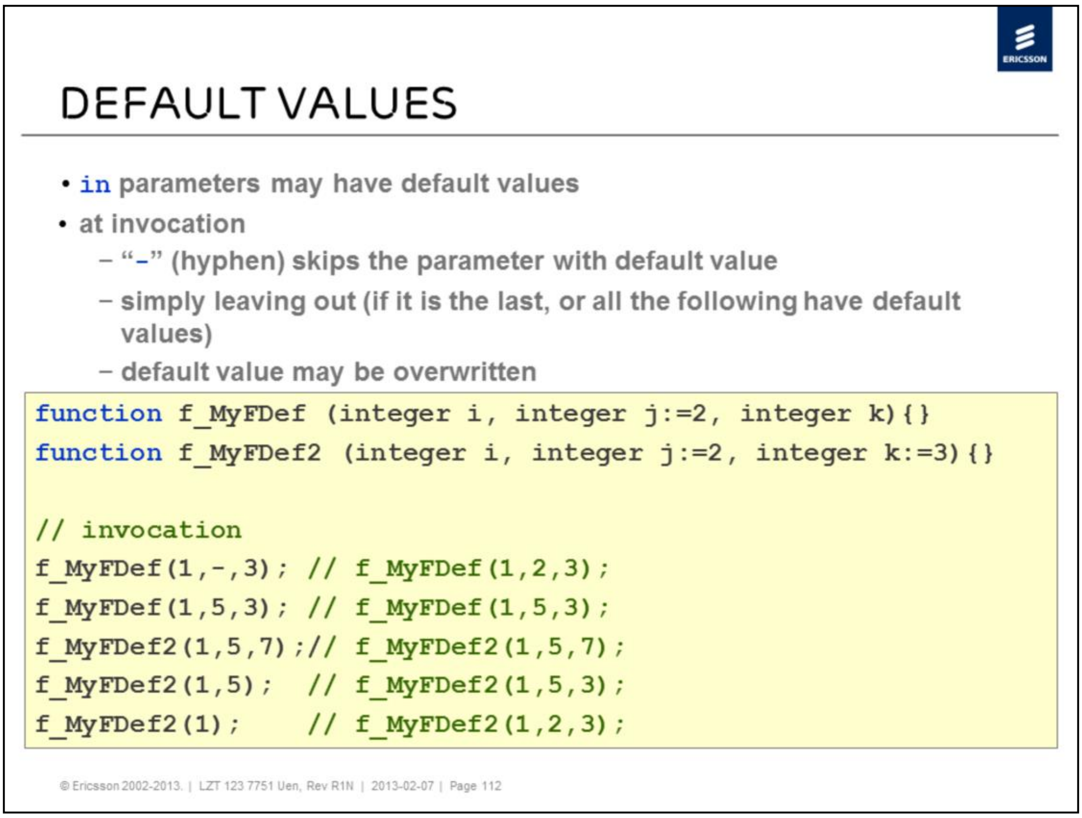
```
function f_3
           (inout integer pl_i)
 {                                     var integer
  j;
               j := pl_i; //j == 2
     pl_i := 3
}
```

By default, parameters are passed by value (optionally denoted by the keyword in). To pass parameters by reference, the keywords out or inout shall be used.

In parameters may only be read inside the parameterized function, i.e., the parameter is only allowed on the right-hand side of an assignment.

Out parameters may only be written inside the parameterized function, i.e., the parameter is only allowed on the left-hand side of an assignment.

Inout parameters may only be both read and written inside the parameterized function, i.e., the parameter is only allowed on the both sides of an assignment.

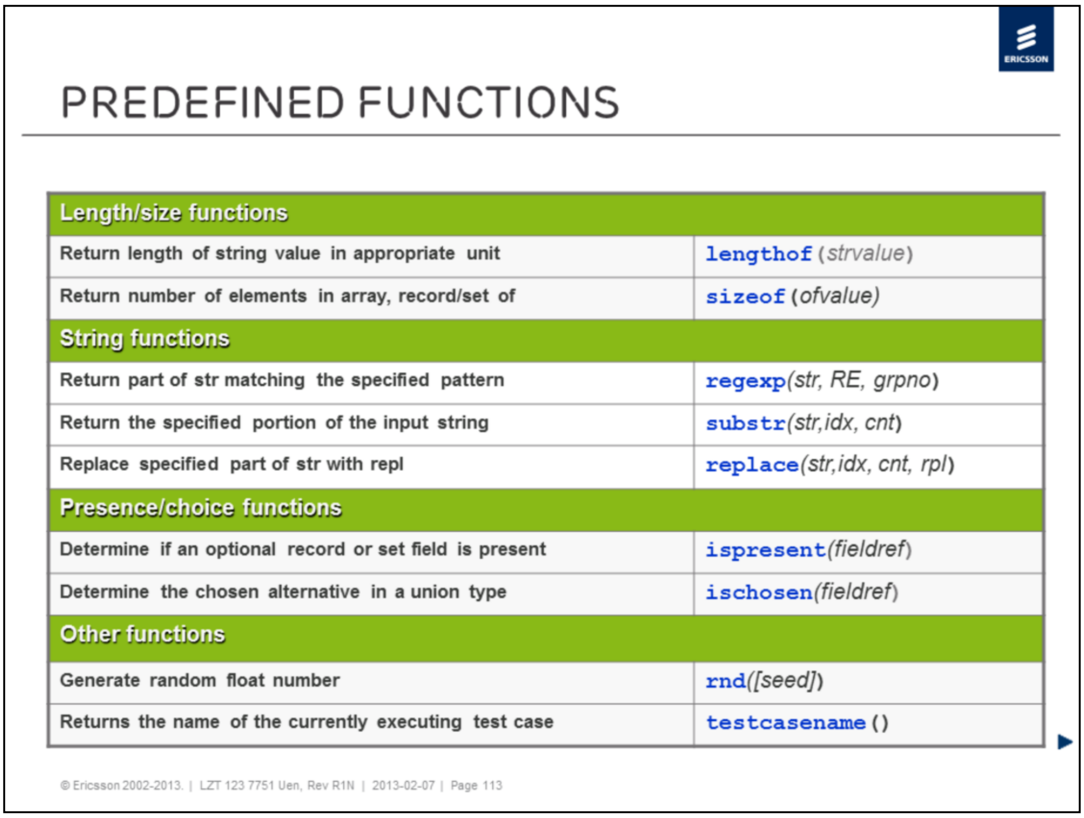


DEFAULT VALUES

- `in` parameters may have default values
- at invocation
  - “`-`” (hyphen) skips the parameter with default value
  - simply leaving out (if it is the last, or all the following have default values)
  - default value may be overwritten

```
function f_MyFDef  (integer i, integer j:=2, integer k){}
function f_MyFDef2  (integer i, integer j:=2, integer k:=3){}

// invocation
f_MyFDef(1,-,3); // f_MyFDef(1,2,3);
f_MyFDef(1,5,3); // f_MyFDef(1,5,3);
f_MyFDef2(1,5,7);// f_MyFDef2(1,5,7);
f_MyFDef2(1,5);  // f_MyFDef2(1,5,3);
f_MyFDef2(1);    // f_MyFDef2(1,2,3);
```



PREDEFINED FUNCTIONS

Length/size functions	
Return length of string value in appropriate unit	`lengthof` (*strvalue*)
Return number of elements in array, record/set of	`sizeof` (*ofvalue)*
String functions	
Return part of str matching the specified pattern	`regexp`(*str, RE, grpno*)
Return the specified portion of the input string	`substr`(*str,idx, cnt*)
Replace specified part of str with repl	`replace`(*str,idx, cnt, rpl*)
Presence/choice functions	
Determine if an optional record or set field is present	`ispresent`(*fieldref*)
Determine the chosen alternative in a union type	`ischosen`(*fieldref*)
Other functions	
Generate random float number	`rnd`(*[seed]*)
Returns the name of the currently executing test case	`testcasename` ()

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The functions **lengthof** resp. **sizeof** give the length of a string respective the number of elements in the referenced constructed type.

The functions **regexp** and **substr** return a specific part of the referenced string.

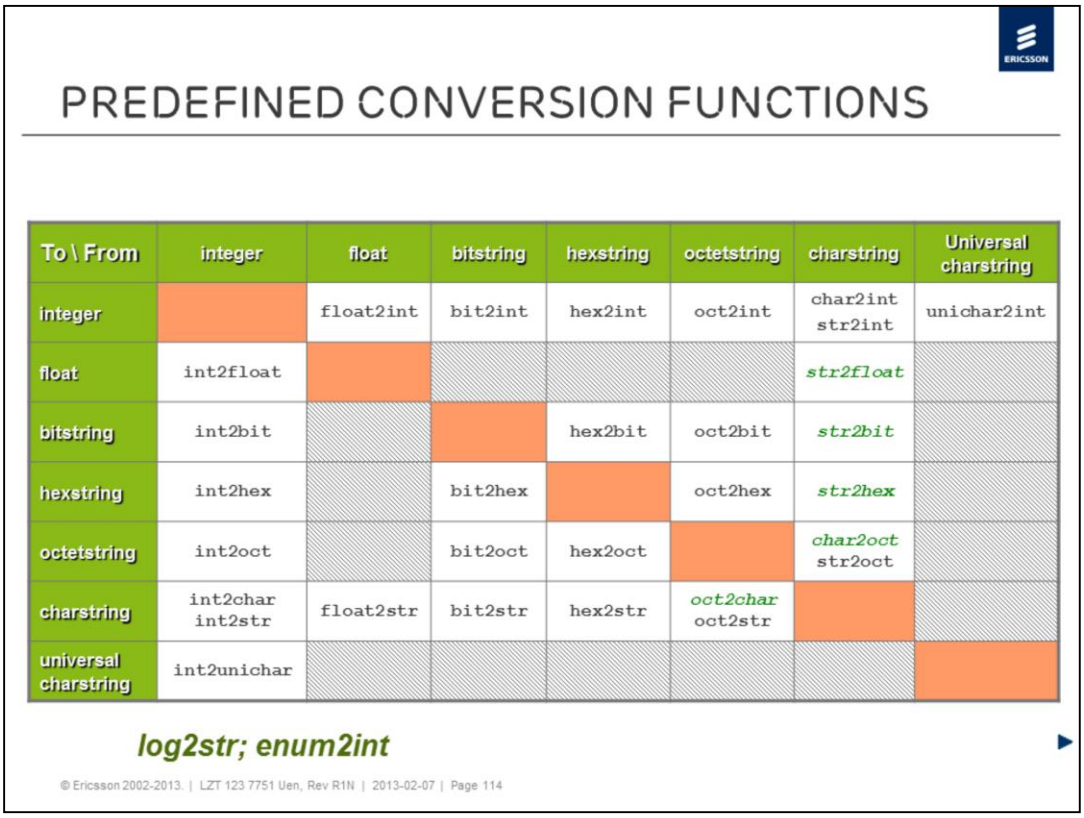
The function **ischosen** returns the Boolean value true if the element given in the parameter is selected in the union. The parameter contains the the reference to the union element in dot notation format.

The function **ispresent** returns the Boolean value true if the optional field given in the parameter is present in the record or set. The parameter contains the the reference to the record or set field in dot notation format.

The **rnd** function returns a pseudorandom float number r where $1 > r \geq 0$. The function may optionally be initialized by a seed value. The same seed value results in the same sequence of pseudorandom numbers.

The **testcasename** function returns the unqualified name of the actually executing test case.

The detailed description of predefined functions is given in annex C of the ETSI standard ES 201 873-1.



PREDEFINED CONVERSION FUNCTIONS

To \ From	integer	float	bitstring	hexstring	octetstring	charstring	Universal charstring
integer		float2int	bit2int	hex2int	oct2int	char2int str2int	unichar2int
float	int2float		▨	▨	▨	*str2float*	▨
bitstring	int2bit	▨		hex2bit	oct2bit	*str2bit*	▨
hexstring	int2hex	▨	bit2hex		oct2hex	*str2hex*	▨
octetstring	int2oct	▨	bit2oct	hex2oct		*char2oct* str2oct	▨
charstring	int2char int2str	float2str	bit2str	hex2str	*oct2char* oct2str		▨
universal charstring	int2unichar	▨	▨	▨	▨	▨	

log2str; enum2int

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Conversion functions span the gap between different simple variable types.

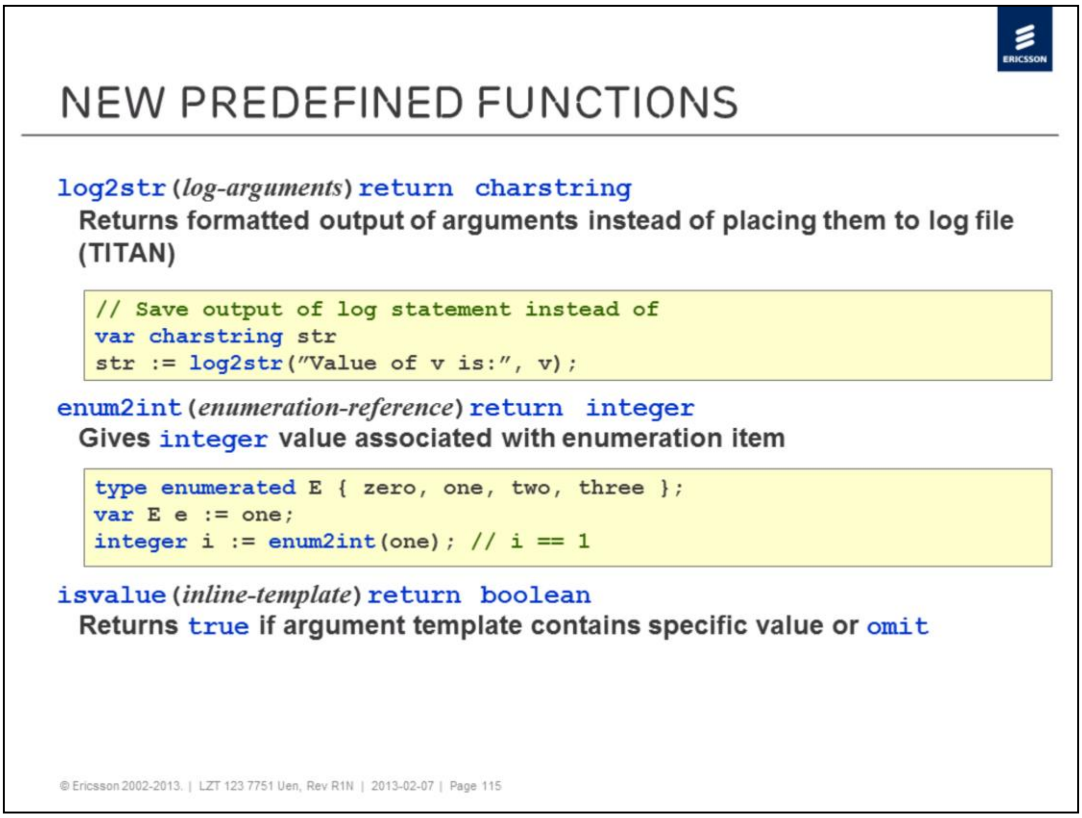
A function at the intersection of a given column and a row has an in parameter indicated in the column header and returns the value type indicated in the row header.

The detailed description of predefined functions is given in annex C of the ETSI standard ES 201 873-1.

Green letters indicate TITAN extensions, not included in the standard.

Difference between functions with 'str' and 'char' in their names is explained with the following examples:

int2char (66) = "B", int2str (66) = "66".



NEW PREDEFINED FUNCTIONS

`log2str` (*log-arguments*) `return charstring`

Returns formatted output of arguments instead of placing them to log file (TITAN)

```
// Save output of log statement instead of
var charstring str
str := log2str(”Value of v is:”, v);
```

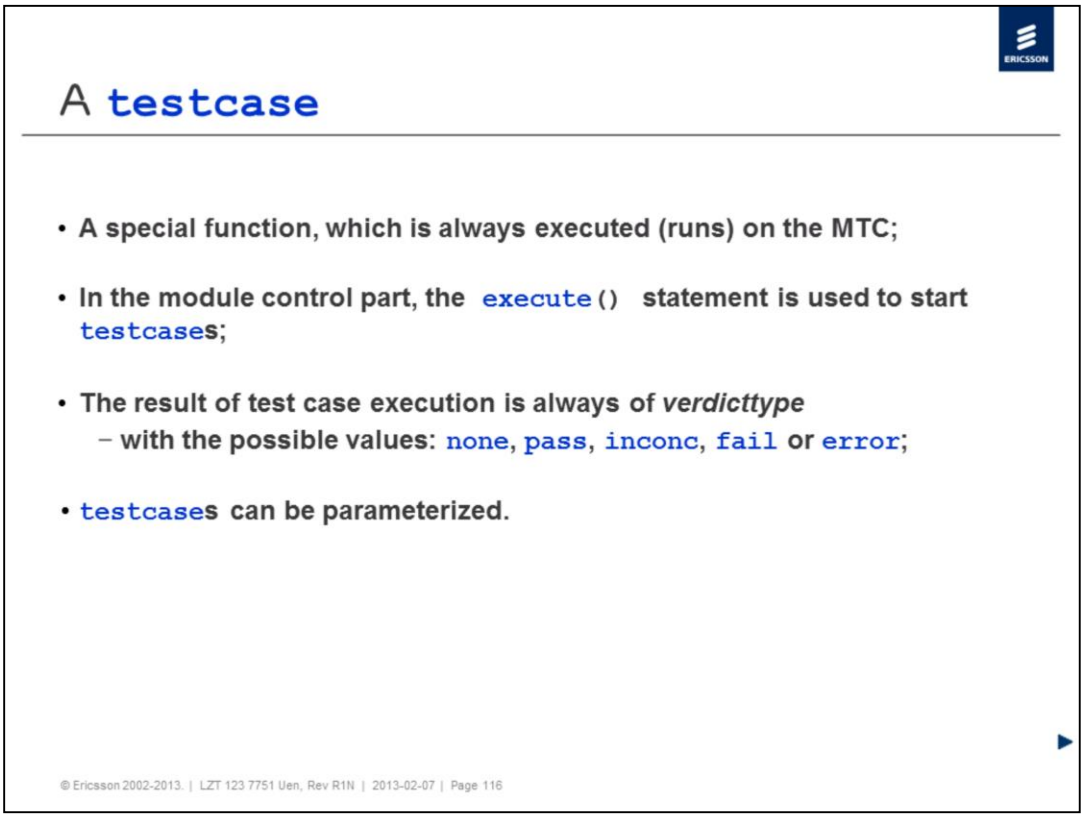
`enum2int` (*enumeration-reference*) `return integer`

Gives `integer` value associated with enumeration item

```
type enumerated E { zero, one, two, three };
var E e := one;
integer i := enum2int(one); // i == 1
```

`isvalue` (*inline-template*) `return boolean`

Returns `true` if argument template contains specific value or `omit`



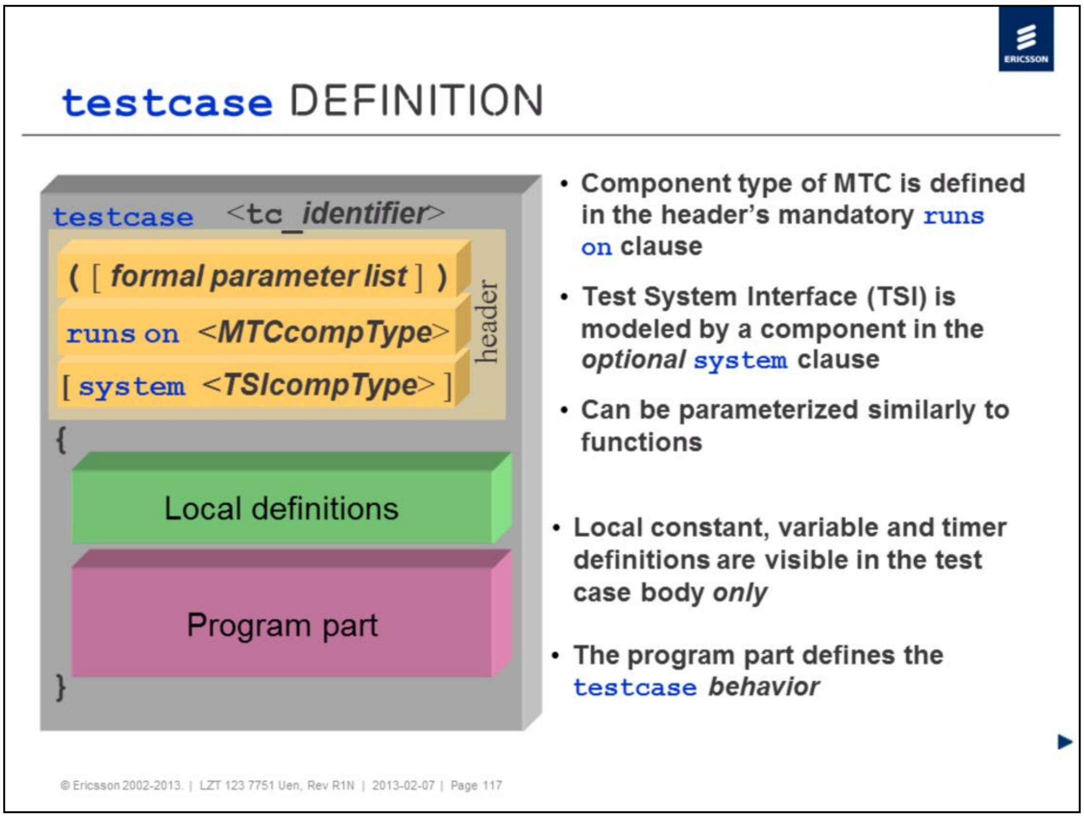
A `testcase`

- A special function, which is always executed (runs) on the MTC;
- In the module control part, the `execute()` statement is used to start `testcase`s;
- The result of test case execution is always of *verdicttype*
  - with the possible values: `none`, `pass`, `inconc`, `fail` or `error`;
- `testcase`s can be parameterized.

The Main Test Component (MTC) and Test System Interface (TSI or System for short) are implicitly instantiated (created) when the test case is started. TSI may be omitted if only the MTC is instantiated during test execution. In this case, MTC type defines the TSI ports implicitly.

A testcase has no return clause, must not use the return statement. Instead, the result of the test case execution is done in a verdict type variable. This internal verdict variable is associated with each component instance and the MTC determines the final verdict based on the verdicts returned by the Parallel Test Components and the Main Test Component.

TC can be started directly from control part, or from a function running on the control part (i.e., MTC is not yet created) using the execute() statement.



testcase DEFINITION

testcase <tc_identifier>
([*formal parameter list*])
runs on <*MTCcompType*>
[system <*TSIcompType*>]
{
Local definitions
Program part
}

- Component type of MTC is defined in the header's mandatory `runs on` clause
- Test System Interface (TSI) is modeled by a component in the *optional* `system` clause
- Can be parameterized similarly to functions
- Local constant, variable and timer definitions are visible in the test case body *only*
- The program part defines the `testcase` *behavior*

The testcase **header**:

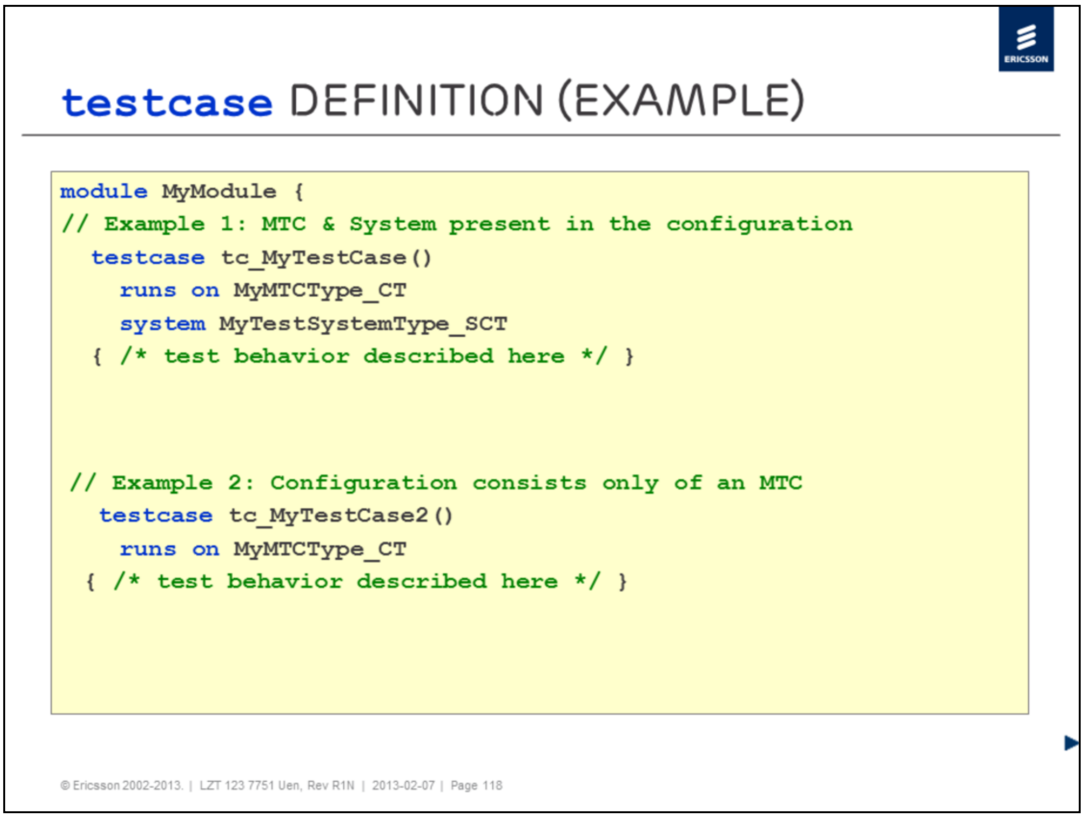
•contains the list of formal parameters of the test case. When no parameters are used, empty brackets must be written;

•the mandatory **runs on** clause specifies the Main Test Component which the test case is running on. This makes the test ports visible to the MTC;

•the keyword **system** is only used if a distinct Test System Interface (TSI) is used. Otherwise, MTC type defines the TSI ports implicitly.

•the **local definitions** are optional. When present, the constants, variables and timers defined here are only visible within the test case.

•the program part (test case body) defines the behavior of the Main Test Component (MTC)



testcase DEFINITION (EXAMPLE)

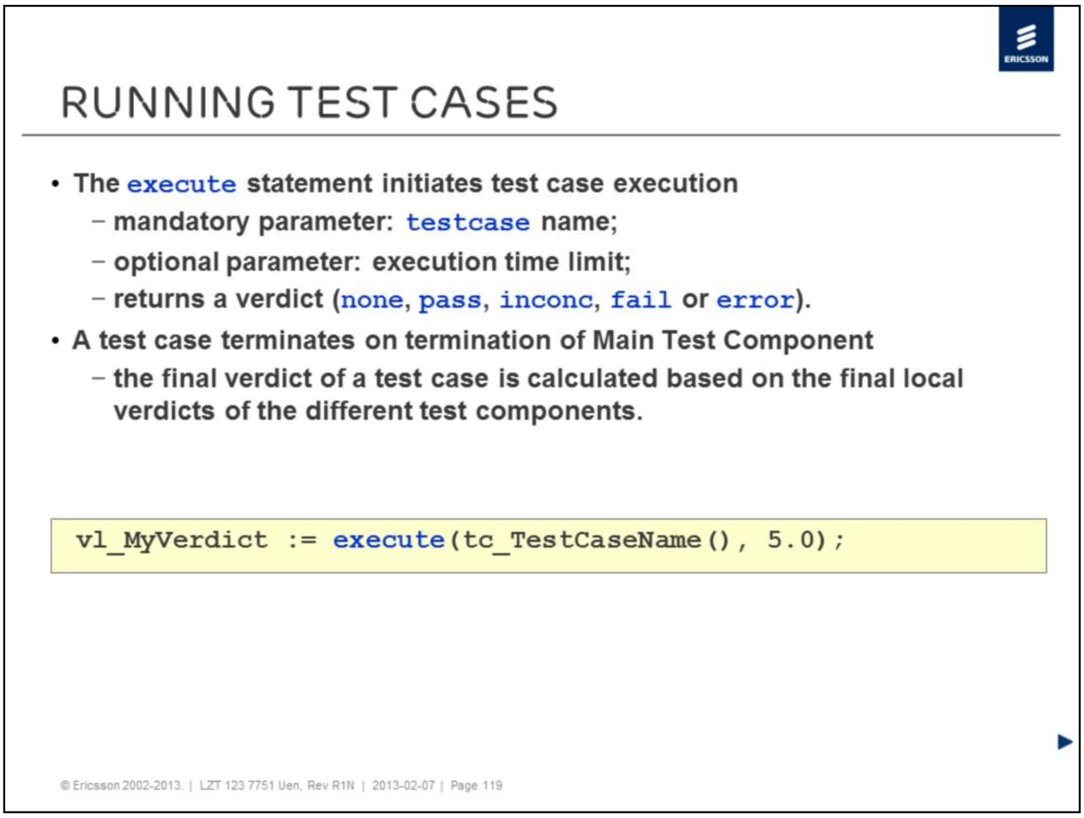
```
module MyModule {
// Example 1: MTC & System present in the configuration
  testcase tc_MyTestCase()
    runs on MyMTCType_CT
    system MyTestSystemType_SCT
  { /* test behavior described here */ }



 // Example 2: Configuration consists only of an MTC
   testcase tc_MyTestCase2()
     runs on MyMTCType_CT
  { /* test behavior described here */ }
```

The first example shows a configuration where both the Main Test Component (here: MyMTCType_CT) and the Test System Interface (here: MyTestSystemType_SCT) are present.

The second example shows a configuration where only the Main Test Component is present.



RUNNING TEST CASES

- The `execute` statement initiates test case execution
  - mandatory parameter: `testcase` name;
  - optional parameter: execution time limit;
  - returns a verdict (`none`, `pass`, `inconc`, `fail` or `error`).
- A test case terminates on termination of Main Test Component
  - the final verdict of a test case is calculated based on the final local verdicts of the different test components.

```
vl_MyVerdict := execute(tc_TestCaseName(), 5.0);
```

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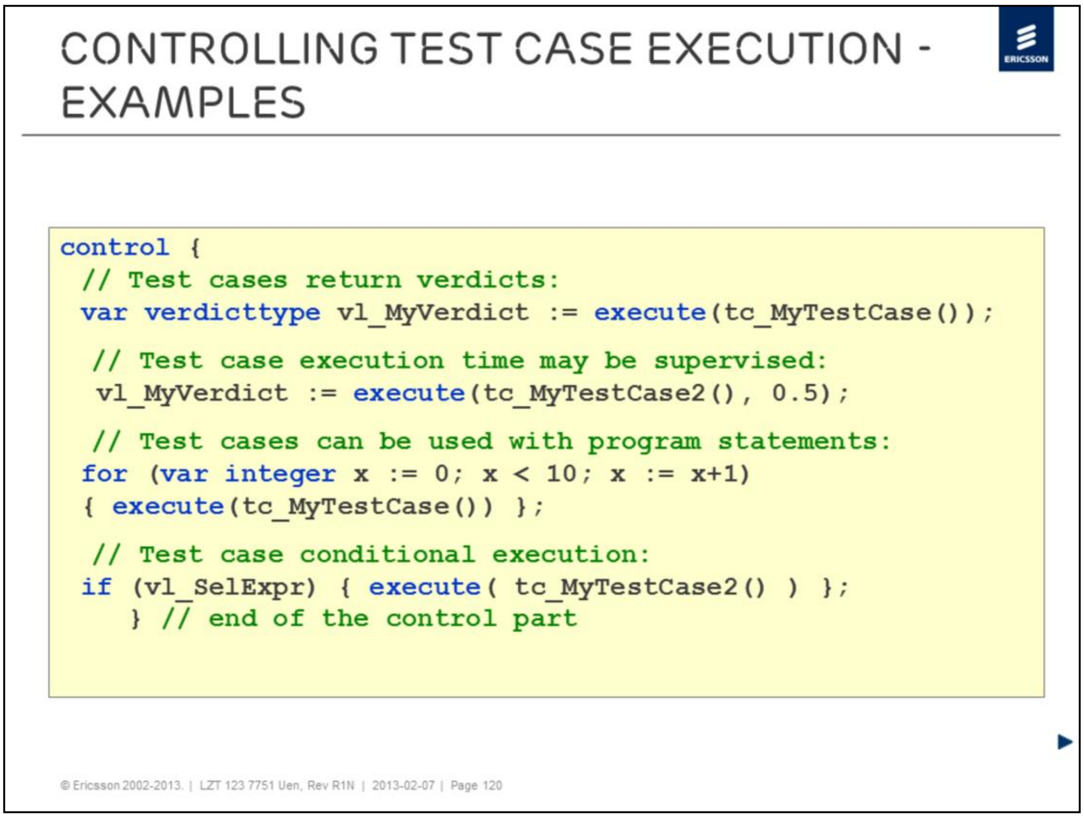
Timer may be used to supervise the execution of a test case. This may be done using an explicit timeout in the

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.



CONTROLLING TEST CASE EXECUTION - EXAMPLES

```
control {
  // Test cases return verdicts:
  var verdicttype vl_MyVerdict := execute(tc_MyTestCase());
   // Test case execution time may be supervised:
   vl_MyVerdict := execute(tc_MyTestCase2(), 0.5);
   // Test cases can be used with program statements:
  for (var integer x := 0; x < 10; x := x+1)
  { execute(tc_MyTestCase()) };
   // Test case conditional execution:
  if (vl_SelExpr) { execute( tc_MyTestCase2() ) };
      } // end of the control part
```

The module control part describes the execution order of the actual test cases.

The instruction after the first comment executes the test case (tc_MyTestCase) and stores the resulting verdict in a variable (vl_MyVerdict).

The next instruction shows how to put an optional time limit (here: 0.5 second) on the test case execution time. When the time limit expires without a returned verdict, the final verdict is set to "error" and the test components are stopped.

The third program statement executes the test case (tc_MyTestCase) ten times.

In the last example the test case (tc_MyTestCase) is only executed when the variable vl_SelExpr has the value true.

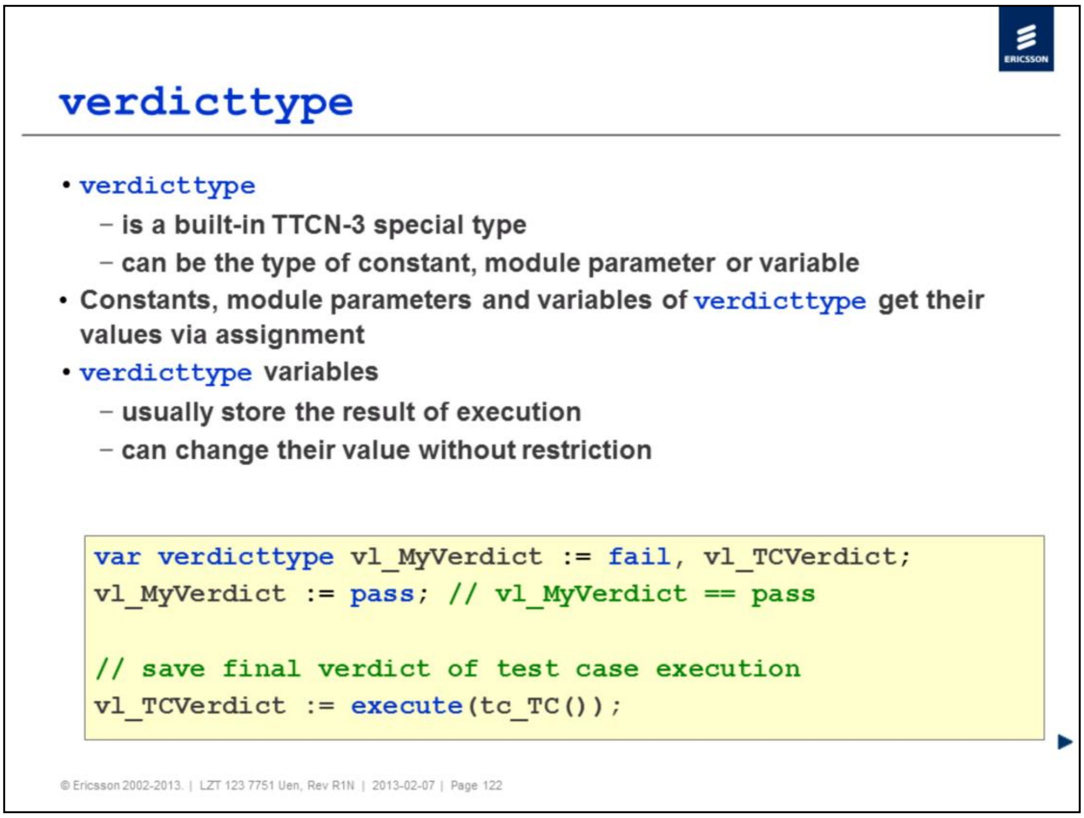
X. VERDICTS

`verdicttype` VS. BUILT-IN VERDICT

OPERATIONS FOR BUILT-IN VERDICT MANAGEMENT

VERDICT OVERWRITING LOGIC

CONTENTS



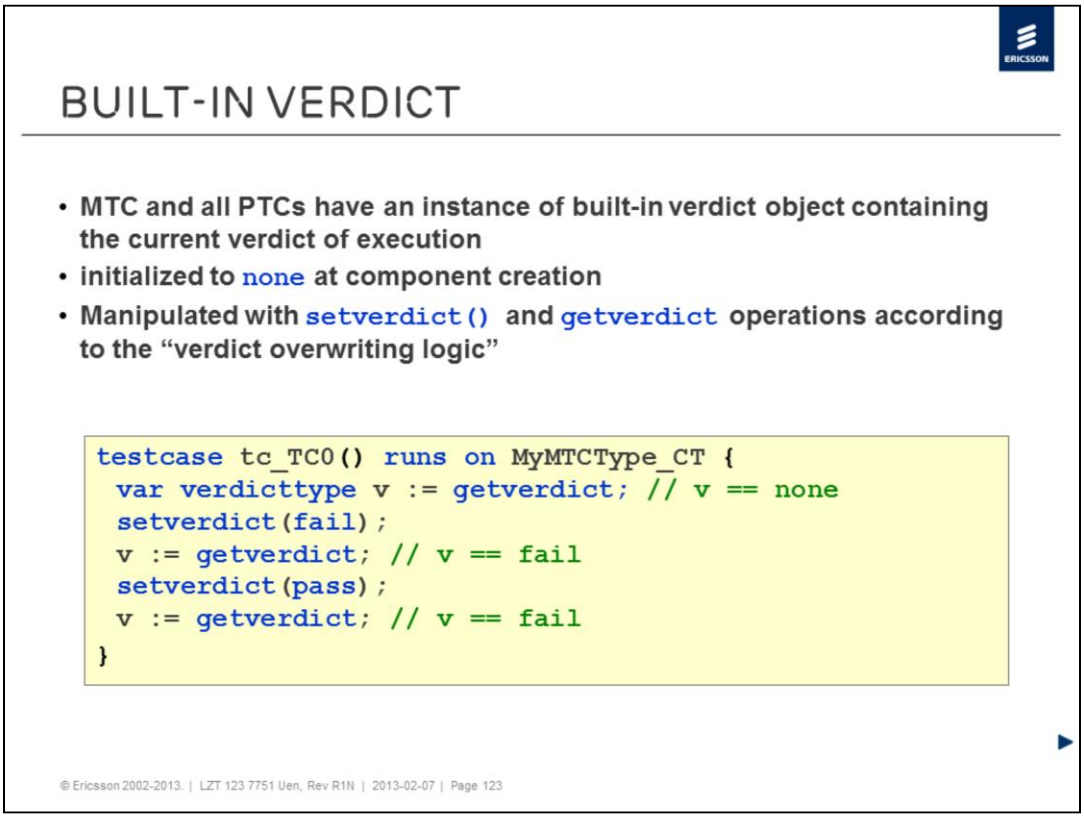
verdicttype

- `verdicttype`
  - is a built-in TTCN-3 special type
  - can be the type of constant, module parameter or variable
- Constants, module parameters and variables of `verdicttype` get their values via assignment
- `verdicttype` variables
  - usually store the result of execution
  - can change their value without restriction

```
var verdicttype vl_MyVerdict := fail, vl_TCVerdict;
vl_MyVerdict := pass; // vl_MyVerdict == pass

// save final verdict of test case execution
vl_TCVerdict := execute(tc_TC());
```

Local variables of type verdicttype can be used to store verdicts. The value of such a variable can be manipulated using common assignments. Assigning a different value to a verdicttype variable always overwrites the existing value.



BUILT-IN VERDICT

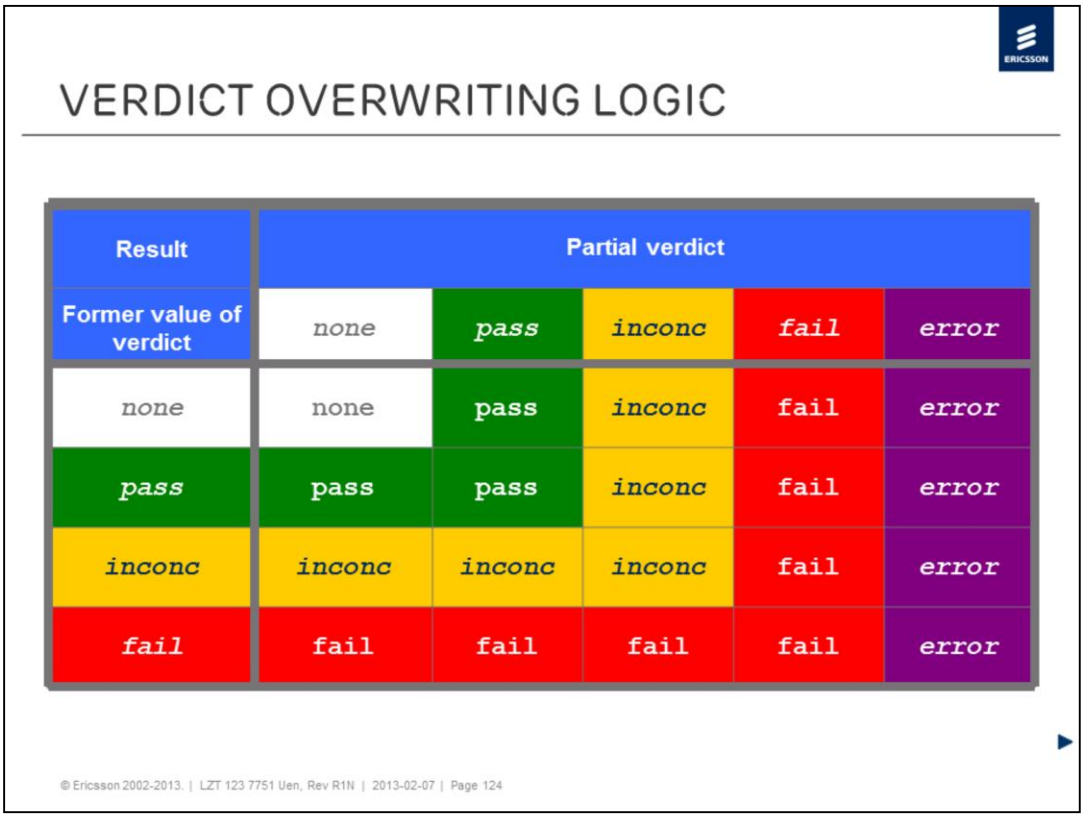
- MTC and all PTCs have an instance of built-in verdict object containing the current verdict of execution
- initialized to `none` at component creation
- Manipulated with `setverdict()` and `getverdict` operations according to the “verdict overwriting logic”

```
testcase tc_TC0() runs on MyMTCType_CT {
 var verdicttype v := getverdict; // v == none
 setverdict(fail);
 v := getverdict; // v == fail
 setverdict(pass);
 v := getverdict; // v == fail
}
```

MTC and PTCs each have a built-in or local verdict. The test case author can alter local verdict during test case execution in each component using the following operations.

The **setverdict** operation is used to set local verdict in test cases, altsteps and functions. The operation may be applied several times in a component resulting in a final local verdict determined according the rules shown on the next slide. "Local" means local to a component.

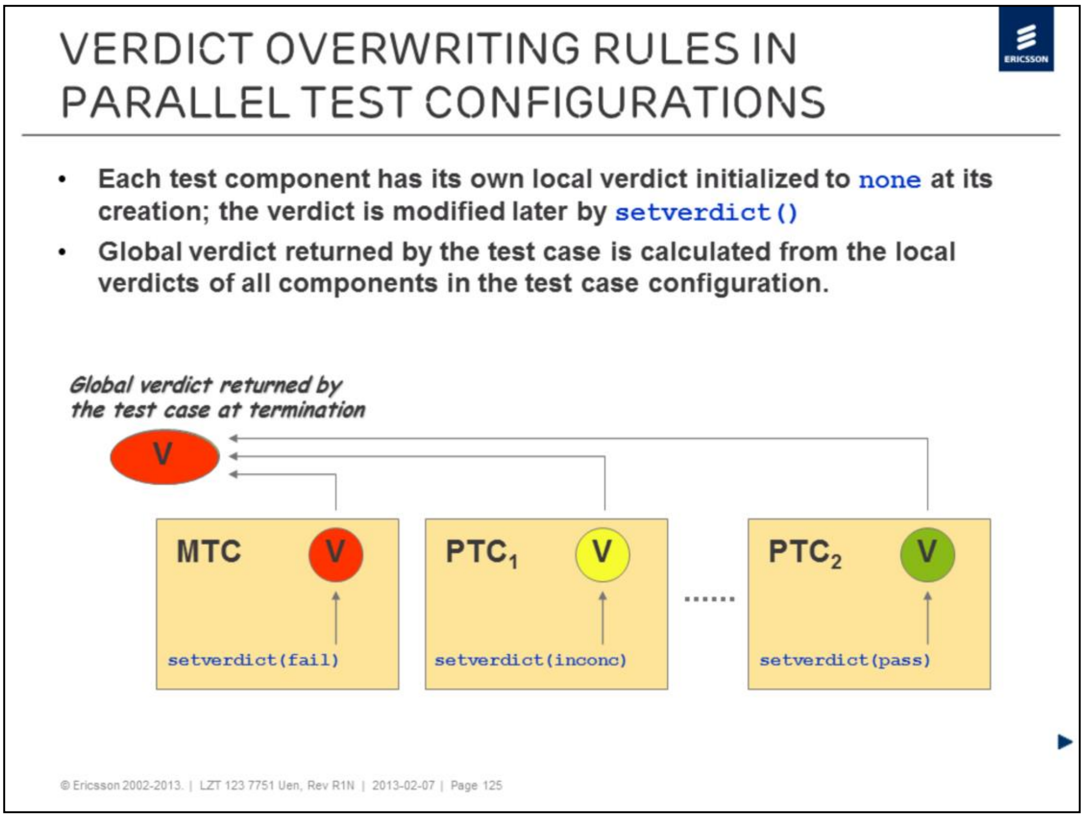
The **getverdict** operation returns current value of the built-in verdict of the component.



VERDICT OVERWRITING LOGIC

Result	Partial verdict				
Former value of verdict	*none*	*pass*	*inconc*	*fail*	*error*
none	none	pass	*inconc*	fail	*error*
pass	pass	pass	*inconc*	fail	*error*
inconc	*inconc*	*inconc*	*inconc*	fail	*error*
fail	fail	fail	fail	fail	*error*

The **verdict overwriting logic** determines the resulting verdict in function of the former verdict every time the operation setverdict is applied in a module. The verdict only can change for the worse, i.e., the following sequence alone is possible: none > pass > inconc > fail > error.



VERDICT OVERWRITING RULES IN PARALLEL TEST CONFIGURATIONS

- Each test component has its own local verdict initialized to `none` at its creation; the verdict is modified later by `setverdict()`
- Global verdict returned by the test case is calculated from the local verdicts of all components in the test case configuration.

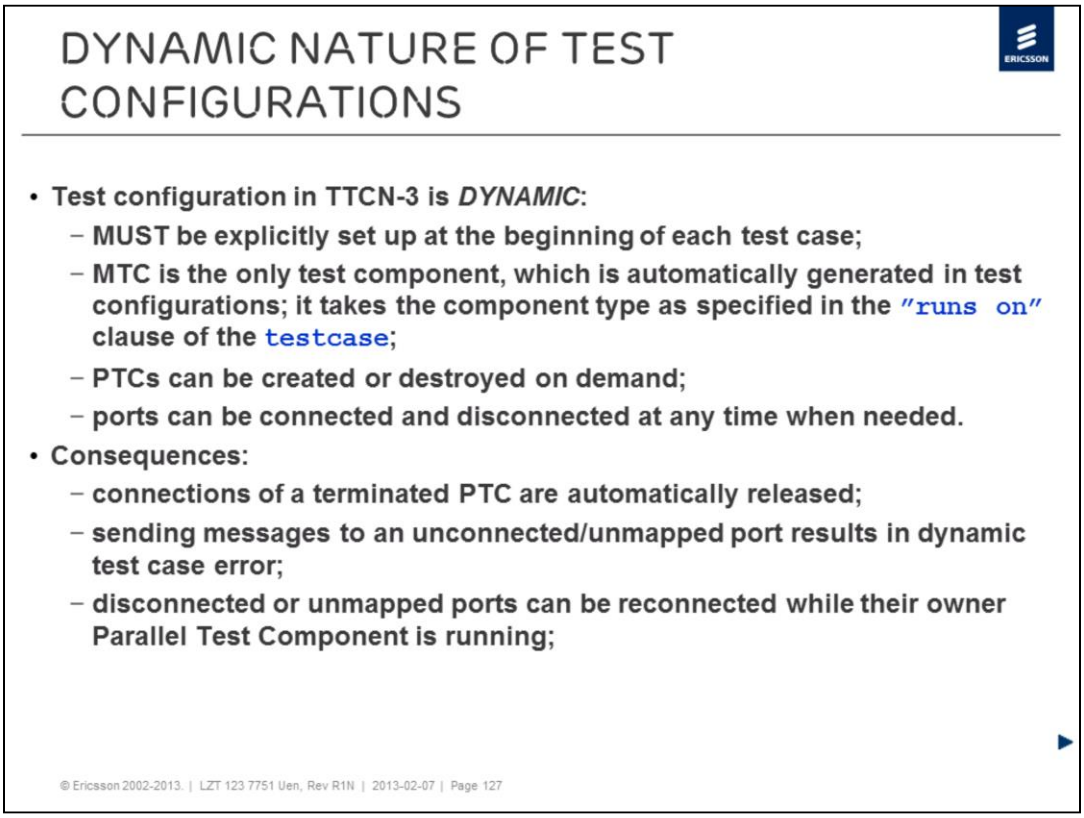
Global verdict returned by the test case at termination

Test case (global) verdict is computed based on the local verdicts of involved test components. The execute statement returns the global verdict following the test case termination.

XI. CONFIGURATION OPERATIONS

CREATING AND STARTING OF COMPONENTS
ADDRESSING AND SUPERVISING COMPONENTS
CONNECTING AND MAPPING OF COMPONENTS
PORT CONTROL OPERATIONS
EXAMPLE

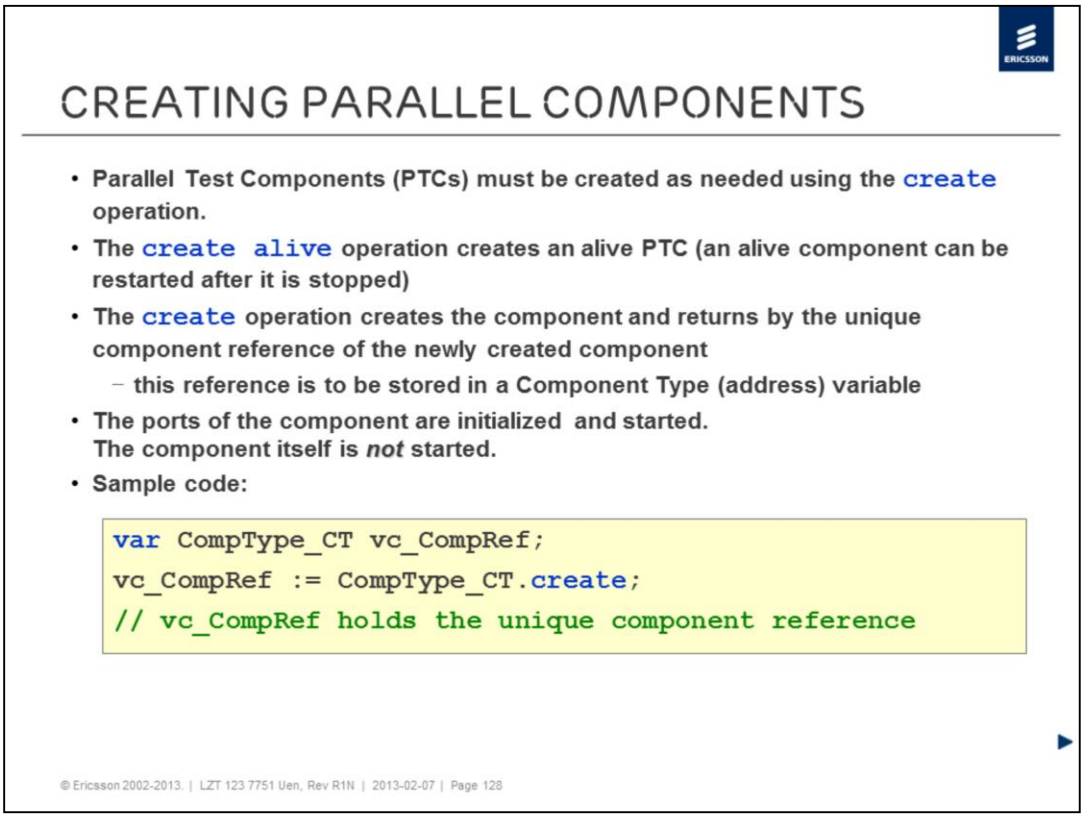
CONTENTS



DYNAMIC NATURE OF TEST CONFIGURATIONS

- Test configuration in TTCN-3 is *DYNAMIC*:
  - MUST be explicitly set up at the beginning of each test case;
  - MTC is the only test component, which is automatically generated in test configurations; it takes the component type as specified in the `"runs on"` clause of the `testcase`;
  - PTCs can be created or destroyed on demand;
  - ports can be connected and disconnected at any time when needed.
- Consequences:
  - connections of a terminated PTC are automatically released;
  - sending messages to an unconnected/unmapped port results in dynamic test case error;
  - disconnected or unmapped ports can be reconnected while their owner Parallel Test Component is running;

Dynamic nature of test configurations means that parallel test components may be created and destroyed as needed. The same is valid for the connections between components.



CREATING PARALLEL COMPONENTS

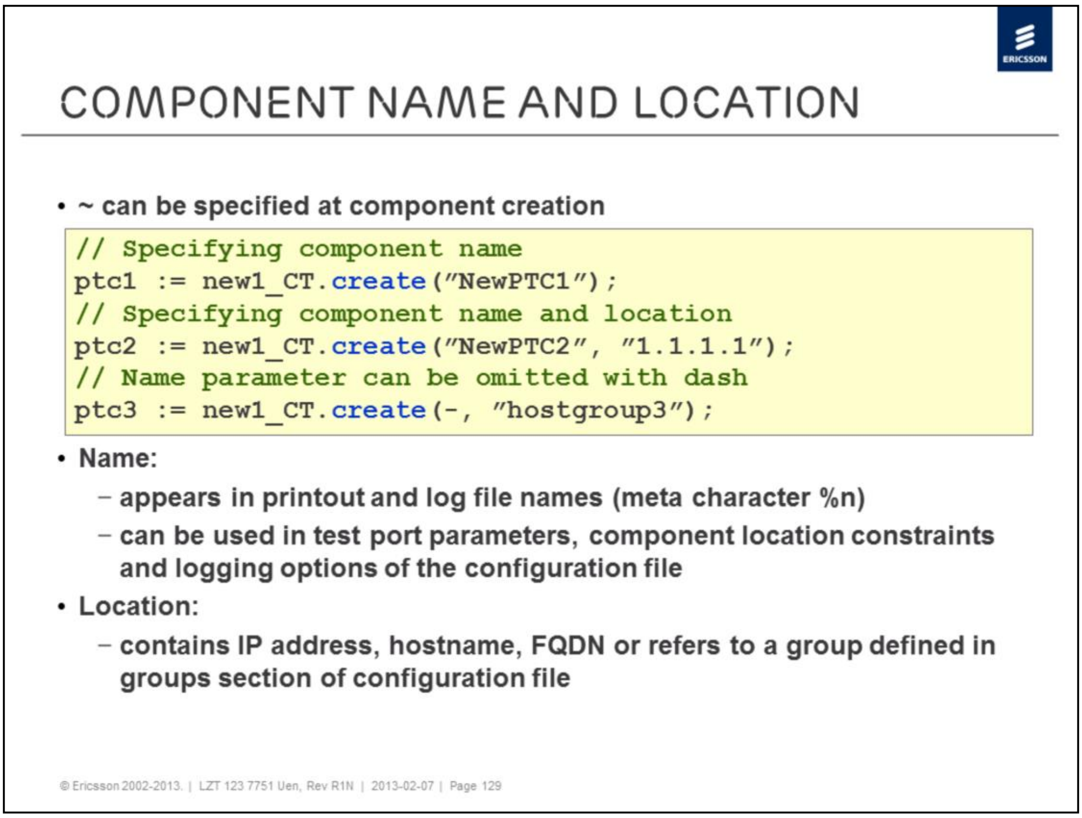
- Parallel Test Components (PTCs) must be created as needed using the `create` operation.
- The `create alive` operation creates an alive PTC (an alive component can be restarted after it is stopped)
- The `create` operation creates the component and returns by the unique component reference of the newly created component
  - this reference is to be stored in a Component Type (address) variable
- The ports of the component are initialized and started.
  The component itself is *not* started.
- Sample code:

```
var CompType_CT vc_CompRef;
vc_CompRef := CompType_CT.create;
// vc_CompRef holds the unique component reference
```

Ports and components are used to set up test configurations. Components are the owner of the ports. Test components are working concurrently, they can be created and destroyed.

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 at any point in a behavior description by any other (running) component using the **create** operation. A component is created with its full set of ports and empty input queues. All component variables and timers are reset to their initial value (if any) and all component constants are reset to their assigned values.

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 and can be used for connecting instances and for communication purposes such as sending and receiving. Variables holding component references shall be of a a previously defined component type (and not one of the built-in component type).



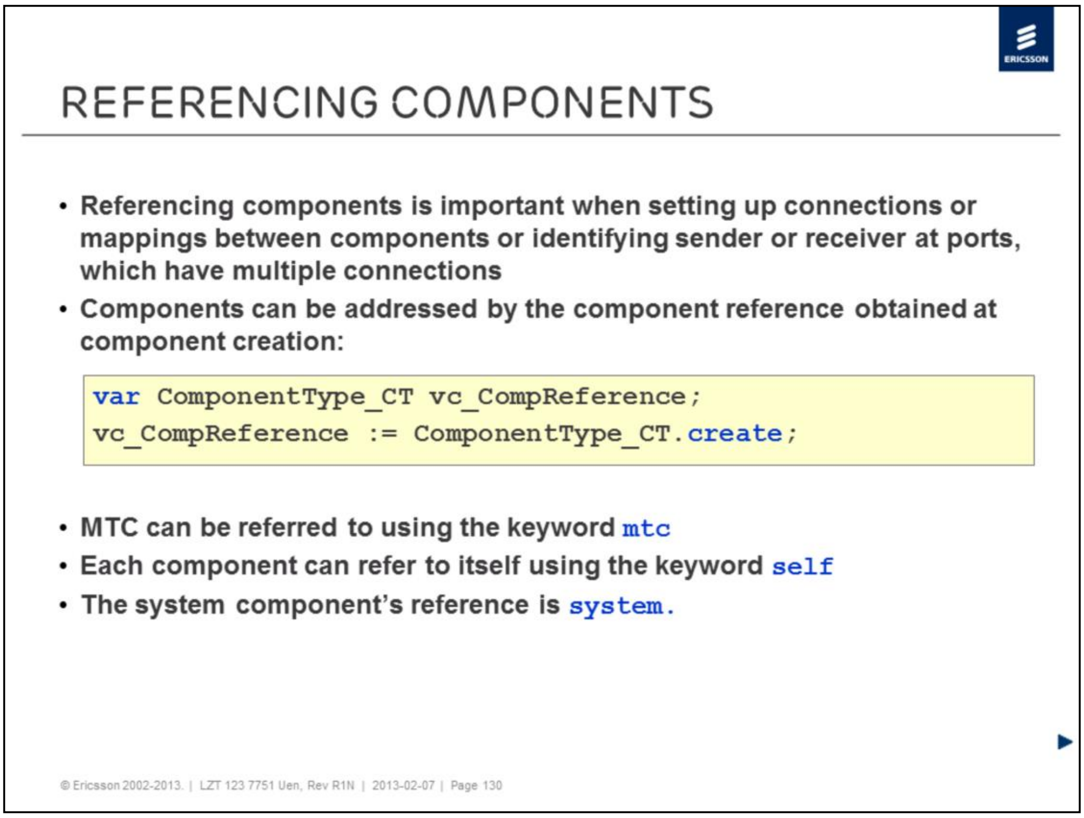
COMPONENT NAME AND LOCATION

- ~ can be specified at component creation

```
// Specifying component name
ptc1 := new1_CT.create(”NewPTC1”);
// Specifying component name and location
ptc2 := new1_CT.create(”NewPTC2”, ”1.1.1.1”);
// Name parameter can be omitted with dash
ptc3 := new1_CT.create(-, ”hostgroup3”);
```

- Name:
  - appears in printout and log file names (meta character %n)
  - can be used in test port parameters, component location constraints and logging options of the configuration file
- Location:
  - contains IP address, hostname, FQDN or refers to a group defined in groups section of configuration file

Fully Qualified Domain Name (**FQDN**)



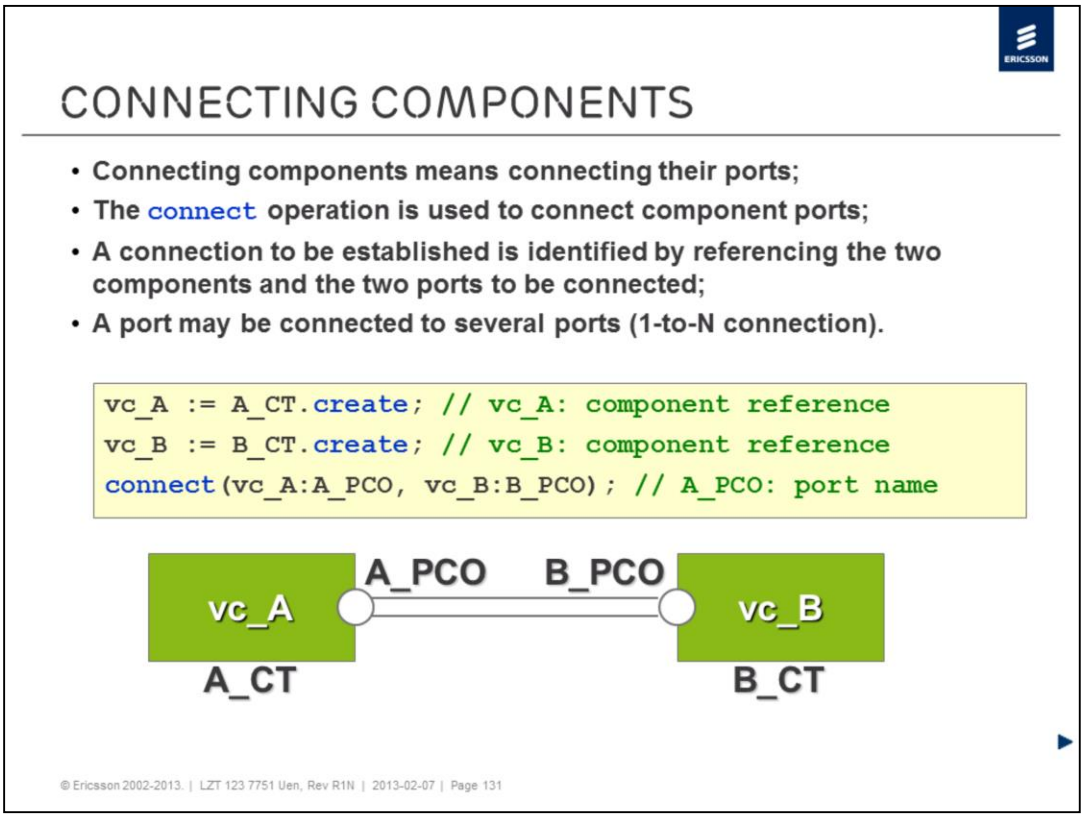
REFERENCING COMPONENTS

- **Referencing components is important when setting up connections or mappings between components or identifying sender or receiver at ports, which have multiple connections**
- **Components can be addressed by the component reference obtained at component creation:**

```
var ComponentType_CT vc_CompReference;
vc_CompReference := ComponentType_CT.create;
```

- **MTC can be referred to using the keyword** `mtc`
- **Each component can refer to itself using the keyword** `self`
- **The system component's reference is** `system`.

When defining a variable to store a component reference, care must be taken to use the same component type as has the component to be created.



CONNECTING COMPONENTS

- Connecting components means connecting their ports;
- The `connect` operation is used to connect component ports;
- A connection to be established is identified by referencing the two components and the two ports to be connected;
- A port may be connected to several ports (1-to-N connection).

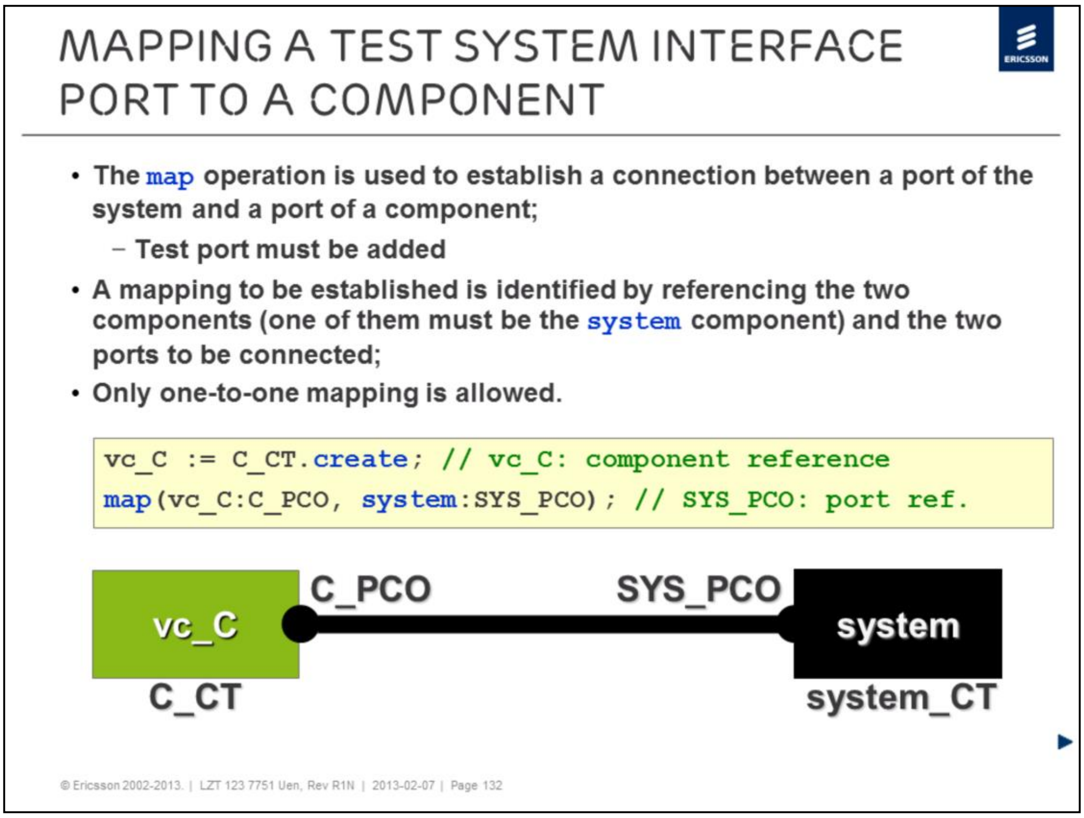
```
vc_A := A_CT.create; // vc_A: component reference
vc_B := B_CT.create; // vc_B: component reference
connect(vc_A:A_PCO, vc_B:B_PCO); // A_PCO: port name
```

A connection can forward messages, procedure calls or both depending on the operation type of the involved ports. The direction of the message flow (in: incoming, out: outgoing, inout: both ways) can be limited at port definition.

The **connect** operation can only connect consistent ports of test components. It means that on outgoing port may only be connected to an incoming port and vice versa. Another condition is that the messages defined for both ports must match, i.e., the incoming port must be able to receive all outgoing messages from the connected port. A connection can be set up between a pair of running ports at any time.

Limitations: A port owned by component A shall not be connected with two or more ports owned by A or component B. If a port has more than 1 connections then all outgoing messages must be explicitly addressed.

Connections between two test components can be manipulated by a 3rd component as well.



MAPPING A TEST SYSTEM INTERFACE PORT TO A COMPONENT

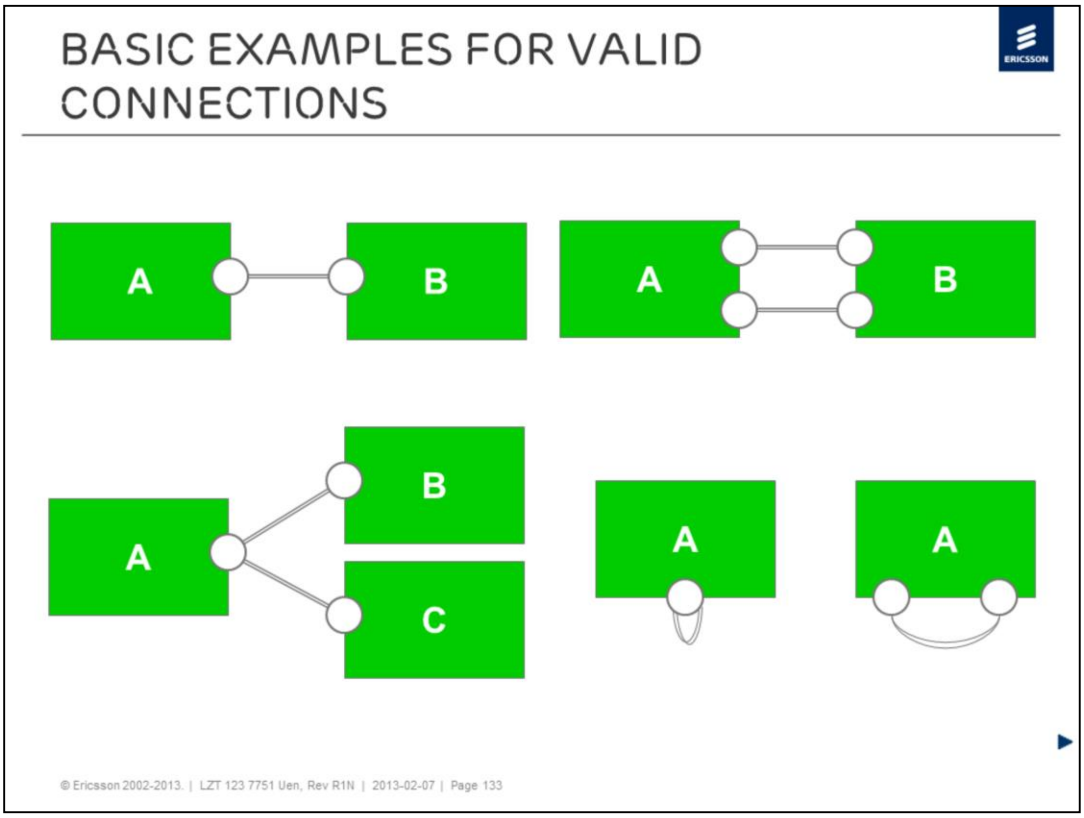
- The `map` operation is used to establish a connection between a port of the system and a port of a component;
  - Test port must be added
- A mapping to be established is identified by referencing the two components (one of them must be the `system` component) and the two ports to be connected;
- Only one-to-one mapping is allowed.

```
vc_C := C_CT.create; // vc_C: component reference
map(vc_C:C_PCO, system:SYS_PCO); // SYS_PCO: port ref.
```

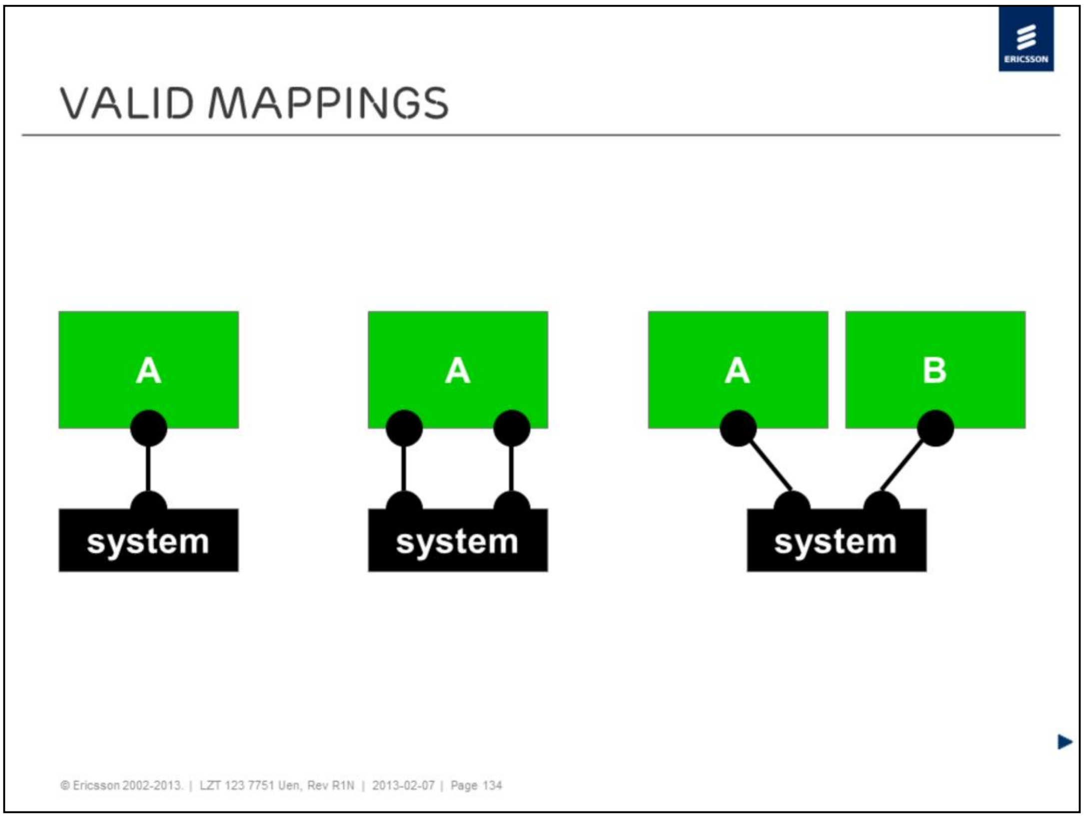
Mappings carry data between Test System and the Implementation (or System) Under Test (IUT/SUT).

Mappings and connections are equivalent from the abstract communication’s point of view. It is not allowed, however, to connect to a mapped port or to map to a connected port.

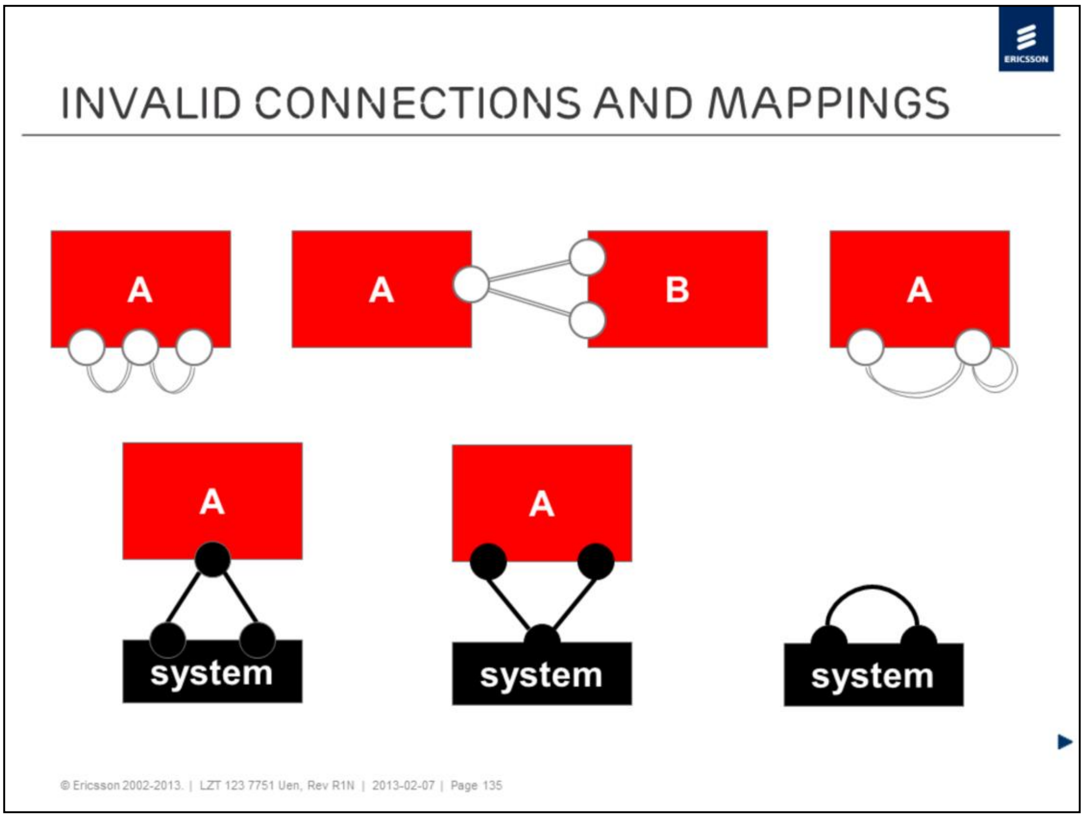
Connections ("loop back") within the test system interface are not allowed.



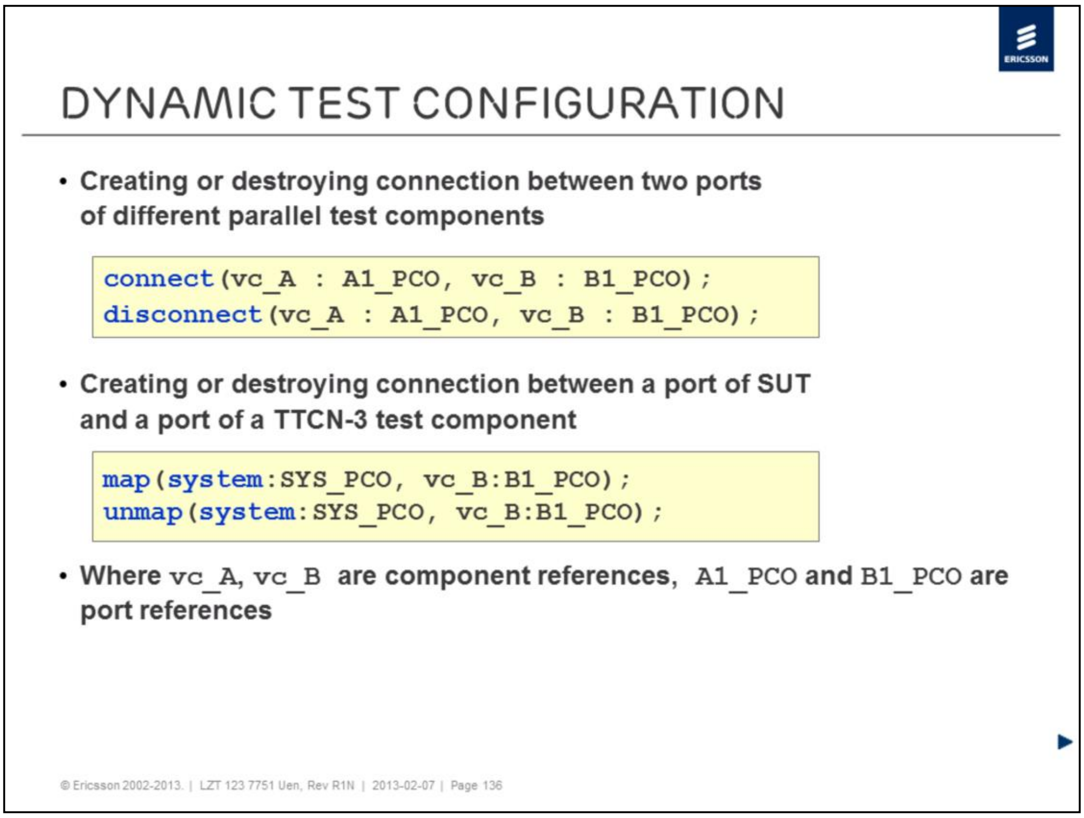
BASIC EXAMPLES FOR VALID CONNECTIONS



VALID MAPPINGS



INVALID CONNECTIONS AND MAPPINGS



DYNAMIC TEST CONFIGURATION

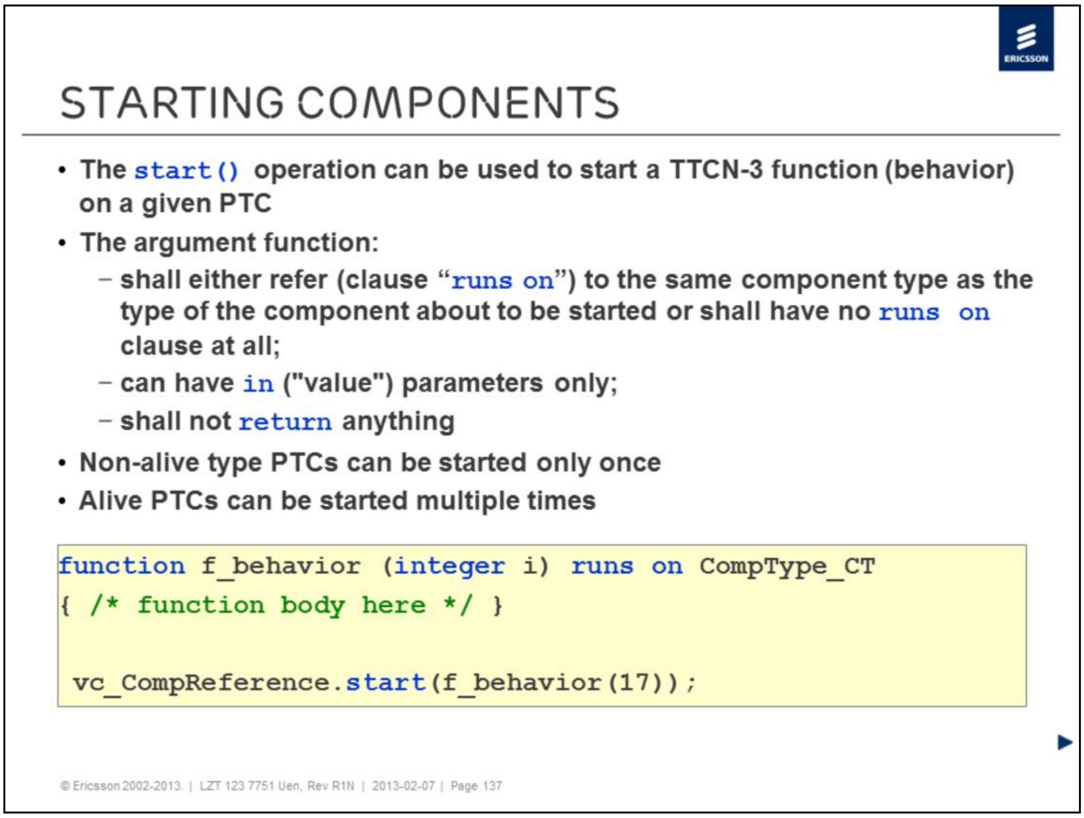
- **Creating or destroying connection between two ports of different parallel test components**

```
connect(vc_A : A1_PCO, vc_B : B1_PCO);
disconnect(vc_A : A1_PCO, vc_B : B1_PCO);
```

- **Creating or destroying connection between a port of SUT and a port of a TTCN-3 test component**

```
map(system:SYS_PCO, vc_B:B1_PCO);
unmap(system:SYS_PCO, vc_B:B1_PCO);
```

- **Where** `vc_A`, `vc_B` **are component references,** `A1_PCO` **and** `B1_PCO` **are port references**



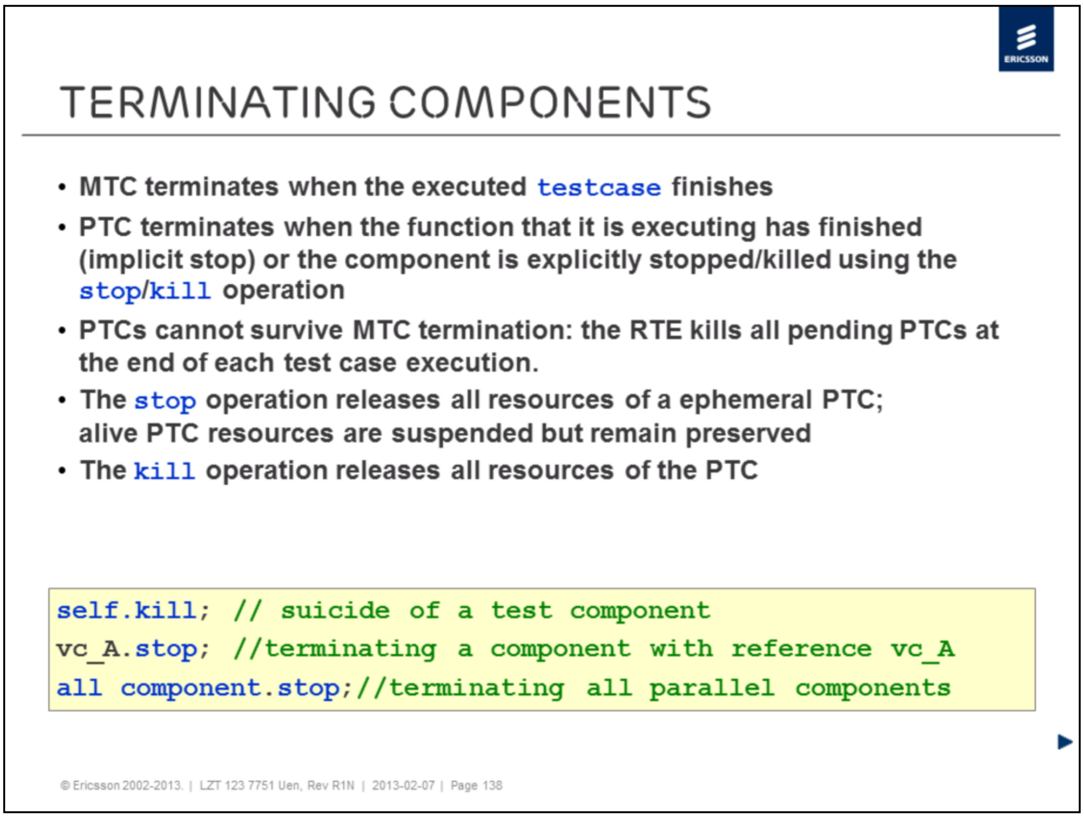
STARTING COMPONENTS

- The `start()` operation can be used to start a TTCN-3 function (behavior) on a given PTC
- The argument function:
  - shall either refer (clause “`runs on`”) to the same component type as the type of the component about to be started or shall have no `runs on` clause at all;
  - can have `in` ("value") parameters only;
  - shall not `return` anything
- Non-alive type PTCs can be started only once
- Alive PTCs can be started multiple times

```
function f_behavior (integer i) runs on CompType_CT
{ /* function body here */ }

 vc_CompReference.start(f_behavior(17));
```

Once a component has been created and connected, the execution of its behavior has to be started. This is done by using the **start** operation. Every component can only be started once. The function start() is non-blocking, execution continues immediately.



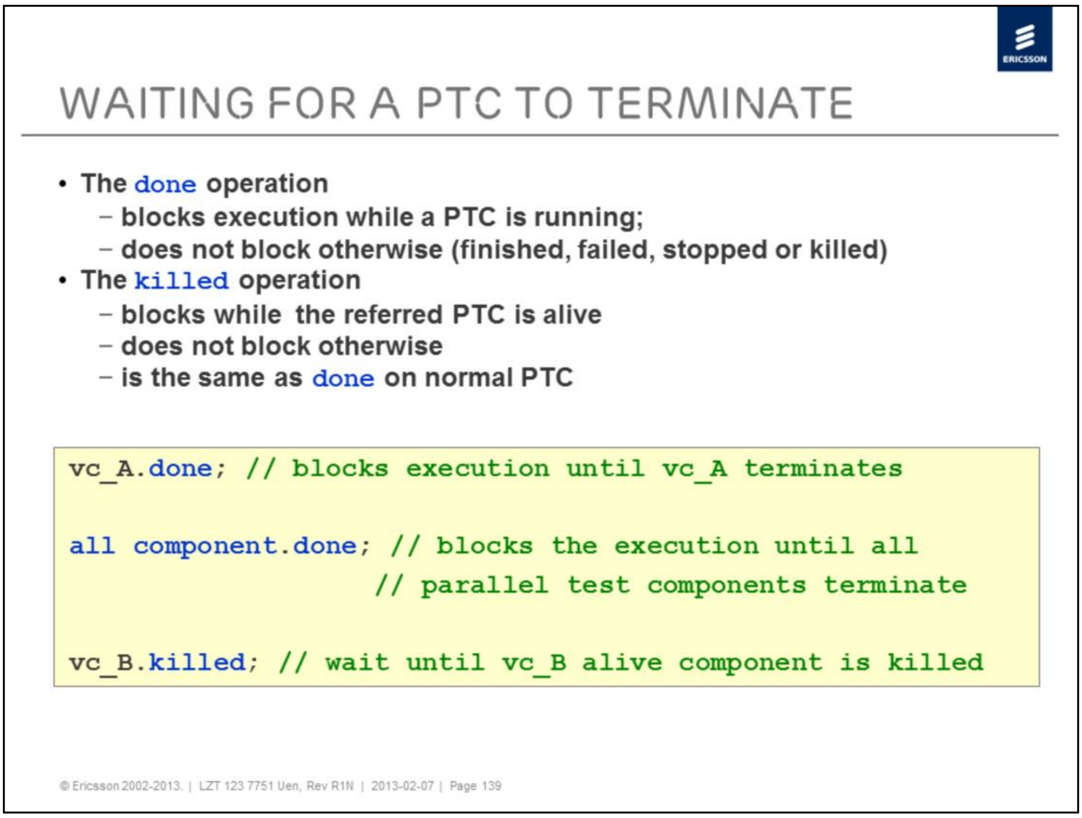
TERMINATING COMPONENTS

- MTC terminates when the executed `testcase` finishes
- PTC terminates when the function that it is executing has finished (implicit stop) or the component is explicitly stopped/killed using the `stop`/`kill` operation
- PTCs cannot survive MTC termination: the RTE kills all pending PTCs at the end of each test case execution.
- The `stop` operation releases all resources of a ephemeral PTC; alive PTC resources are suspended but remain preserved
- The `kill` operation releases all resources of the PTC

```
self.kill; // suicide of a test component
vc_A.stop; //terminating a component with reference vc_A
all component.stop;//terminating all parallel components
```

Using the all component keyword, all (parallel) components may only be stopped from the Main Test Component (MTC).

stop ≠ self.stop



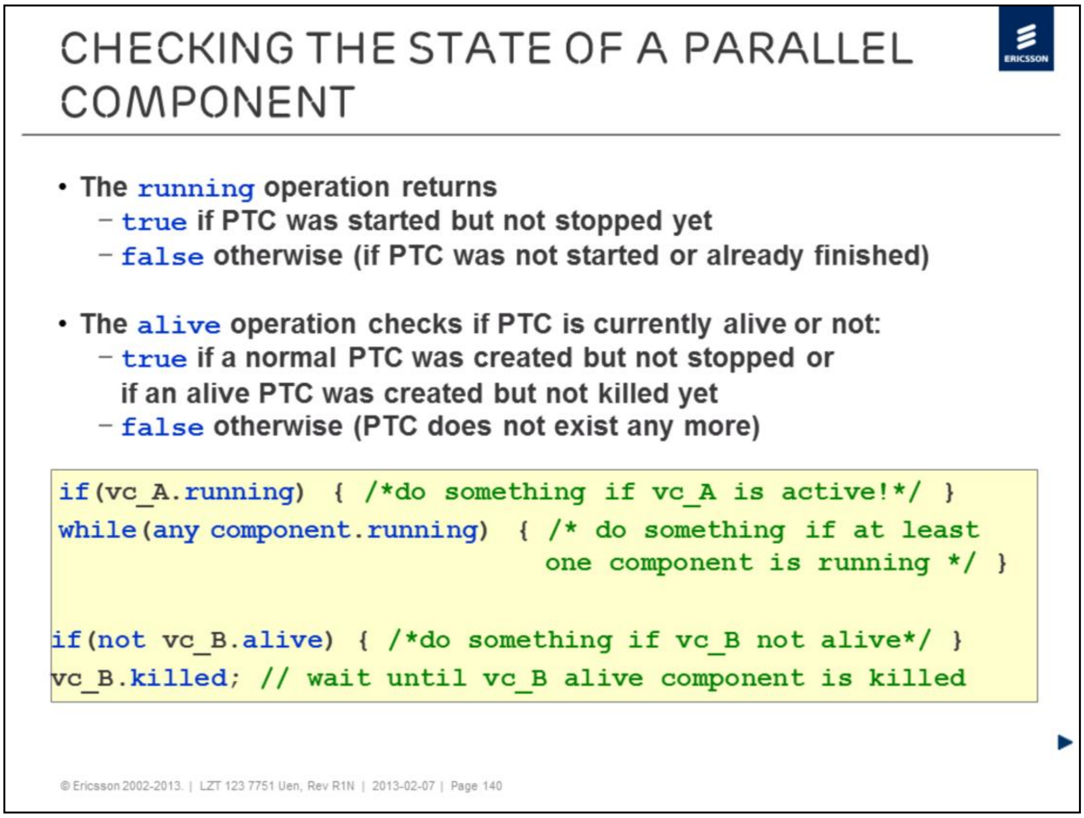
WAITING FOR A PTC TO TERMINATE

- The `done` operation
  - blocks execution while a PTC is running;
  - does not block otherwise (finished, failed, stopped or killed)
- The `killed` operation
  - blocks while the referred PTC is alive
  - does not block otherwise
  - is the same as `done` on normal PTC

```
vc_A.done; // blocks execution until vc_A terminates

all component.done; // blocks the execution until all
                    // parallel test components terminate

vc_B.killed; // wait until vc_B alive component is killed
```



CHECKING THE STATE OF A PARALLEL COMPONENT

- The `running` operation returns
  - `true` if PTC was started but not stopped yet
  - `false` otherwise (if PTC was not started or already finished)
- The `alive` operation checks if PTC is currently alive or not:
  - `true` if a normal PTC was created but not stopped or if an alive PTC was created but not killed yet
  - `false` otherwise (PTC does not exist any more)

```
if(vc_A.running)  { /*do something if vc_A is active!*/ }
while(any component.running)  { /* do something if at least
                                   one component is running */ }

if(not vc_B.alive)  { /*do something if vc_B not alive*/ }
vc_B.killed; // wait until vc_B alive component is killed
```

The **running** operation returns a Boolean value depending on the active or passive state of the referenced component. The **done** operation blocks the execution until the referenced component has terminated when used as a stand-alone statement. (It can also be used as an alternative in an alt statement.)

Components can be in following states:

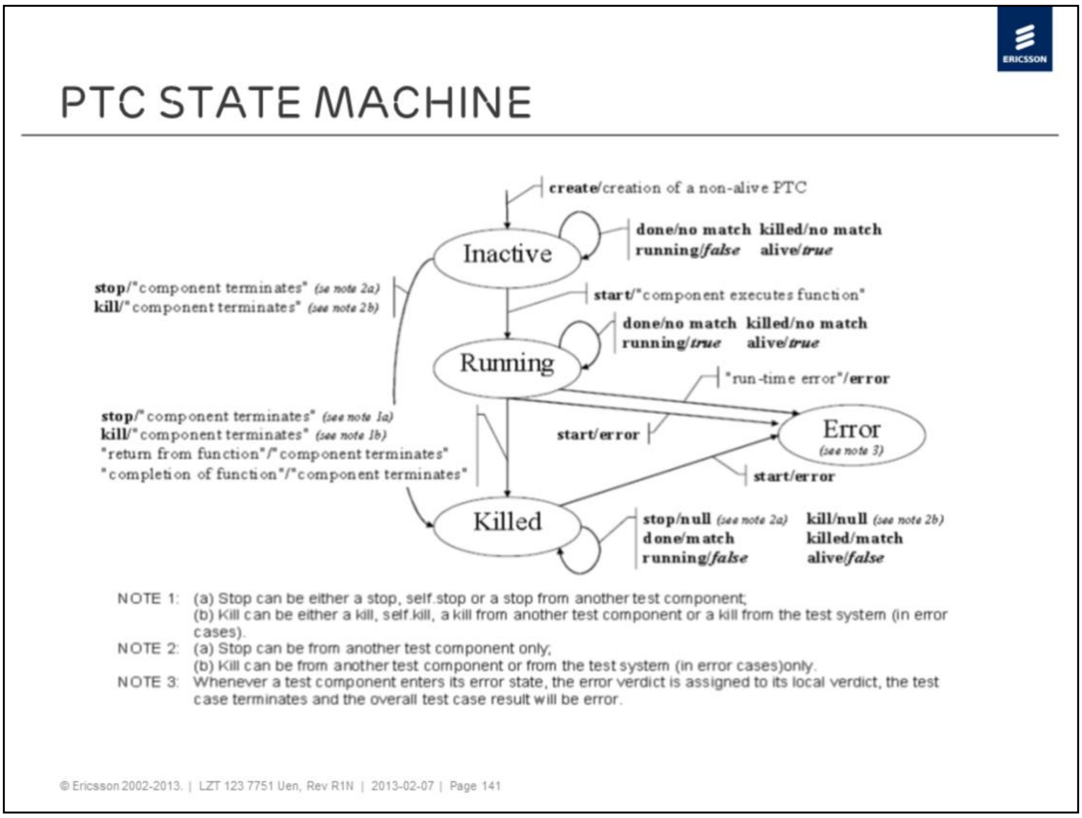
- non-existing or not created (running == error, done == error)
- created but not yet started (running == false, done blocks execution)
- started and running (running == true, done blocks execution)
- finished execution or stopped or a test case error occurred (running == false, done does not block)

When the all component keyword is used instead of a component reference in the **running** operation (allowed only in the Main Test Component [MTC]), it will return true if all PTCs started but not stopped explicitly by another component are executing their behavior.

When the any component keyword is used instead of a component reference in the running operation (allowed only in the MTC), it will return true if at least one PTC is executing its behavior.

When the all component keyword is used instead of a component reference in the **done** operation (allowed only in the MTC), execution continues if no one PTC is executing its behavior or if no PTC has been created or started.

When the any component keyword is used instead of a component reference in the **done** operation (allowed only in the MTC), execution continues if at least one PTC has terminated or stopped.

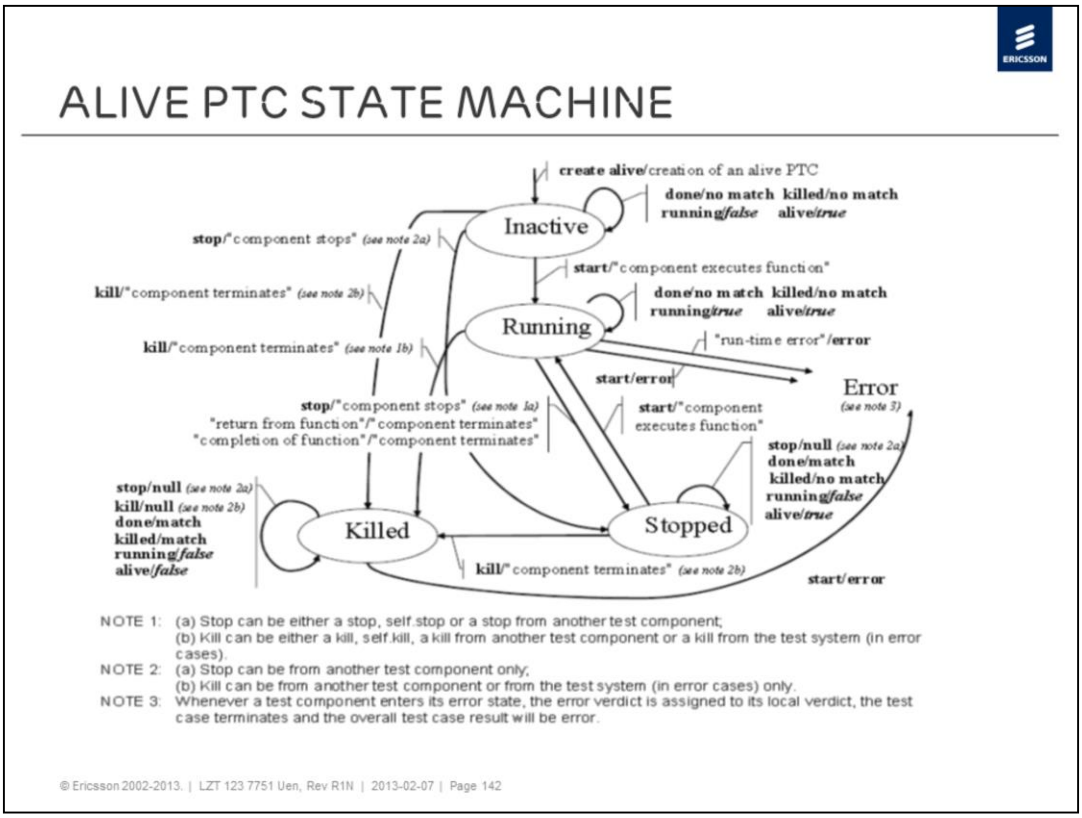


PTC STATE MACHINE

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 error.

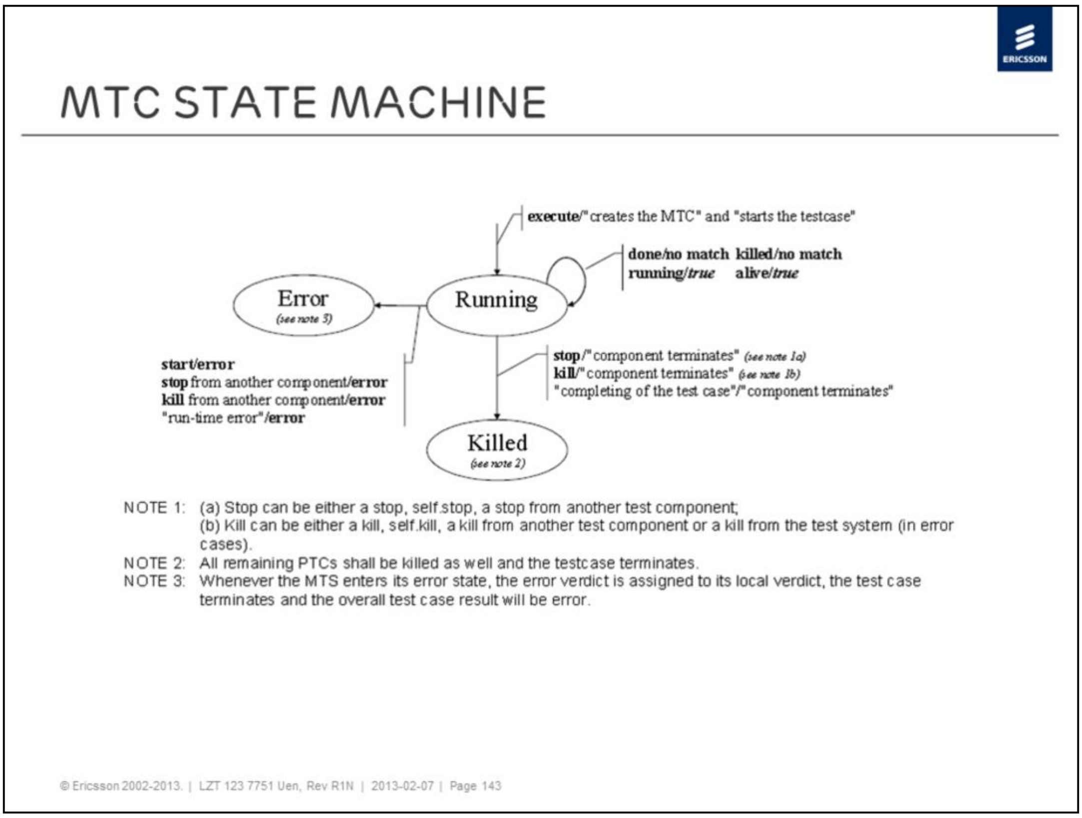


ALIVE PTC STATE MACHINE

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 error.

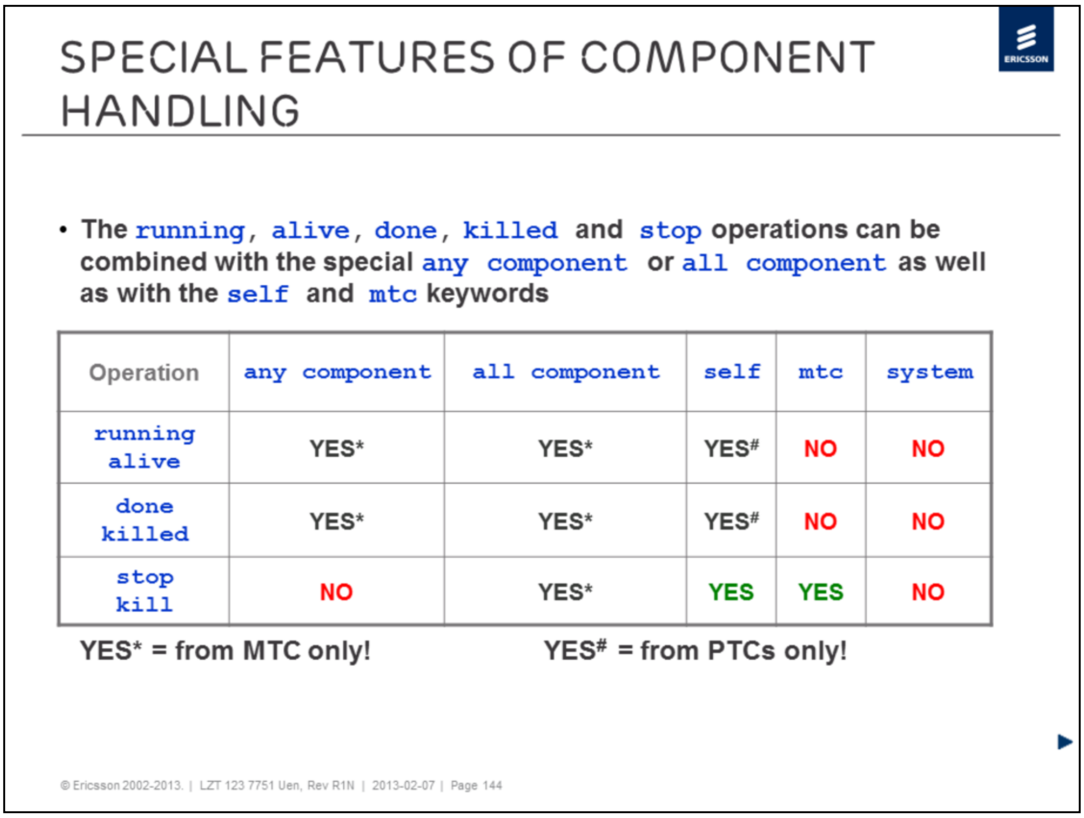


MTC STATE MACHINE

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 MTS 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 error.

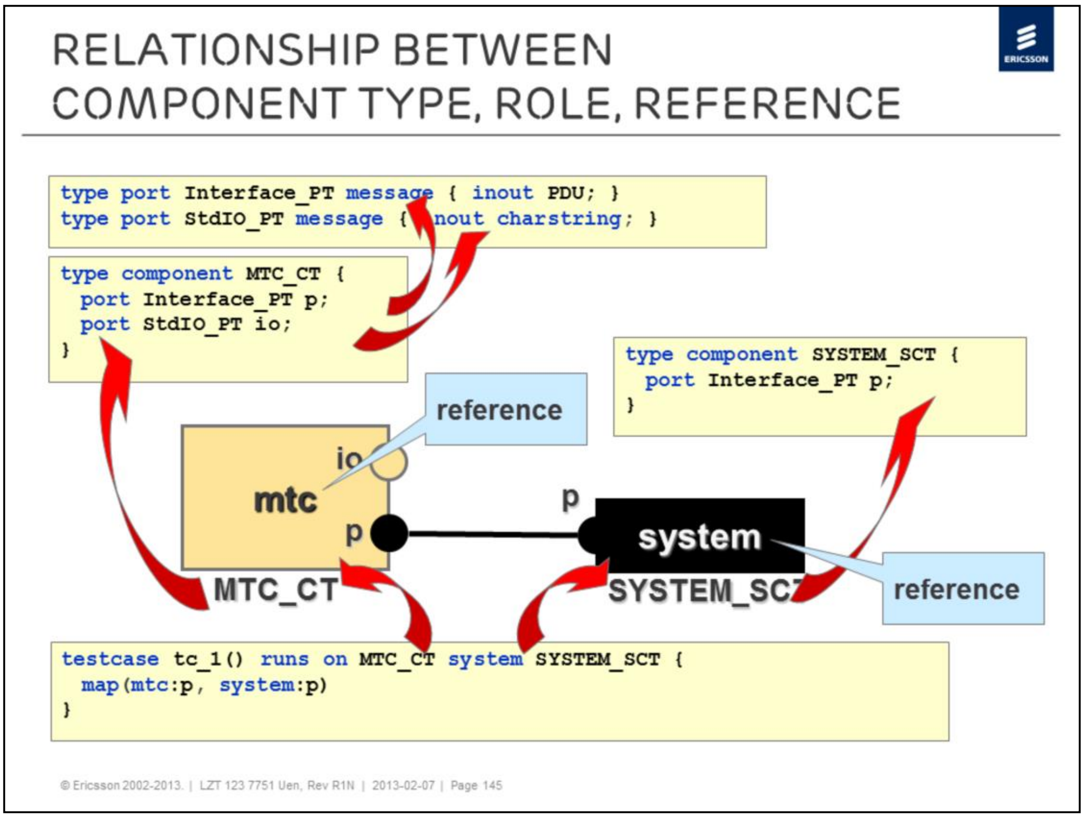


SPECIAL FEATURES OF COMPONENT HANDLING

- The `running`, `alive`, `done`, `killed` and `stop` operations can be combined with the special `any component` or `all component` as well as with the `self` and `mtc` keywords

Operation	`any component`	`all component`	`self`	`mtc`	`system`
`running` `alive`	YES*	YES*	YES#	NO	NO
`done` `killed`	YES*	YES*	YES#	NO	NO
`stop` `kill`	NO	YES*	YES	YES	NO

YES* = from MTC only! YES# = from PTCs only!



RELATIONSHIP BETWEEN COMPONENT TYPE, ROLE, REFERENCE

```
type port Interface_PT message { inout PDU; }
type port StdIO_PT message { inout charstring; }
```

```
type component MTC_CT {
  port Interface_PT p;
  port StdIO_PT io;
}
```

```
type component SYSTEM_SCT {
  port Interface_PT p;
}
```

```
testcase tc_1() runs on MTC_CT system SYSTEM_SCT {
  map(mtc:p, system:p)
}
```

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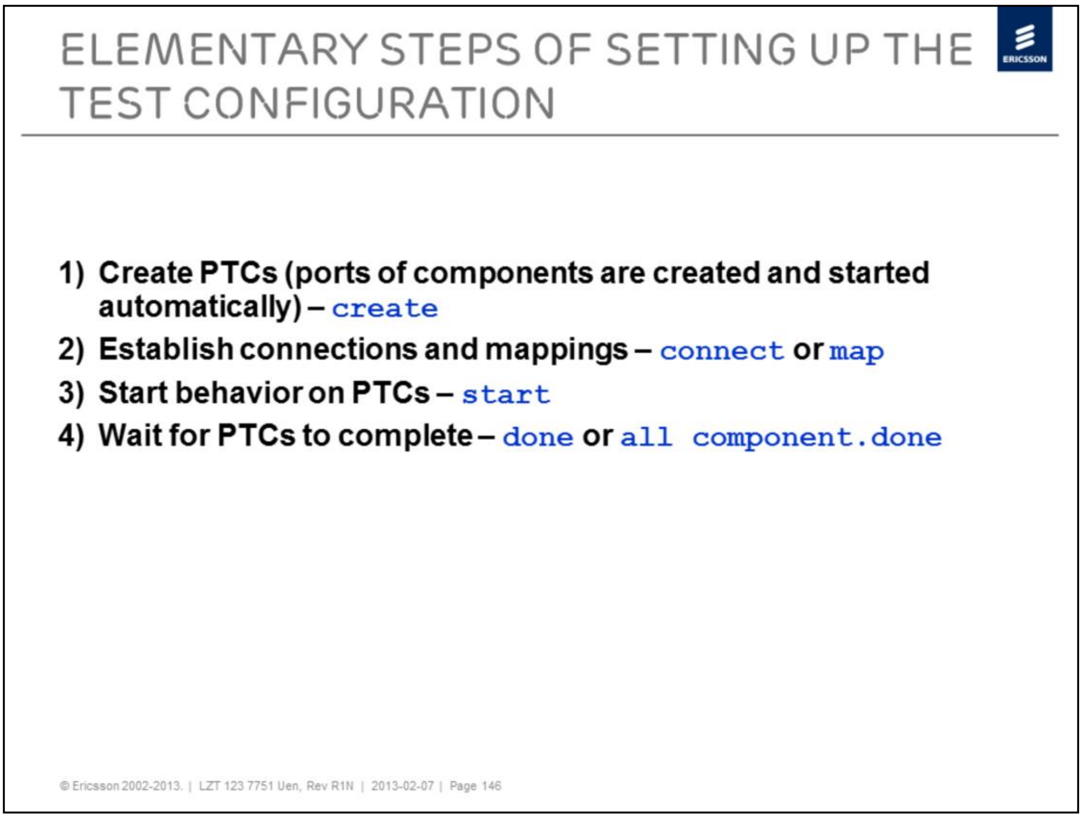
The mtc and system components are automatically created in the beginning of test case execution and destroyed when the test execution finishes. The test case itself is executed on the mtc. The system component does not run any behavior as it acts as a logical model of the IUT.

The runs on clause of the executed test case determines the component type of the mtc, while the system clause specifies the component type used for system.

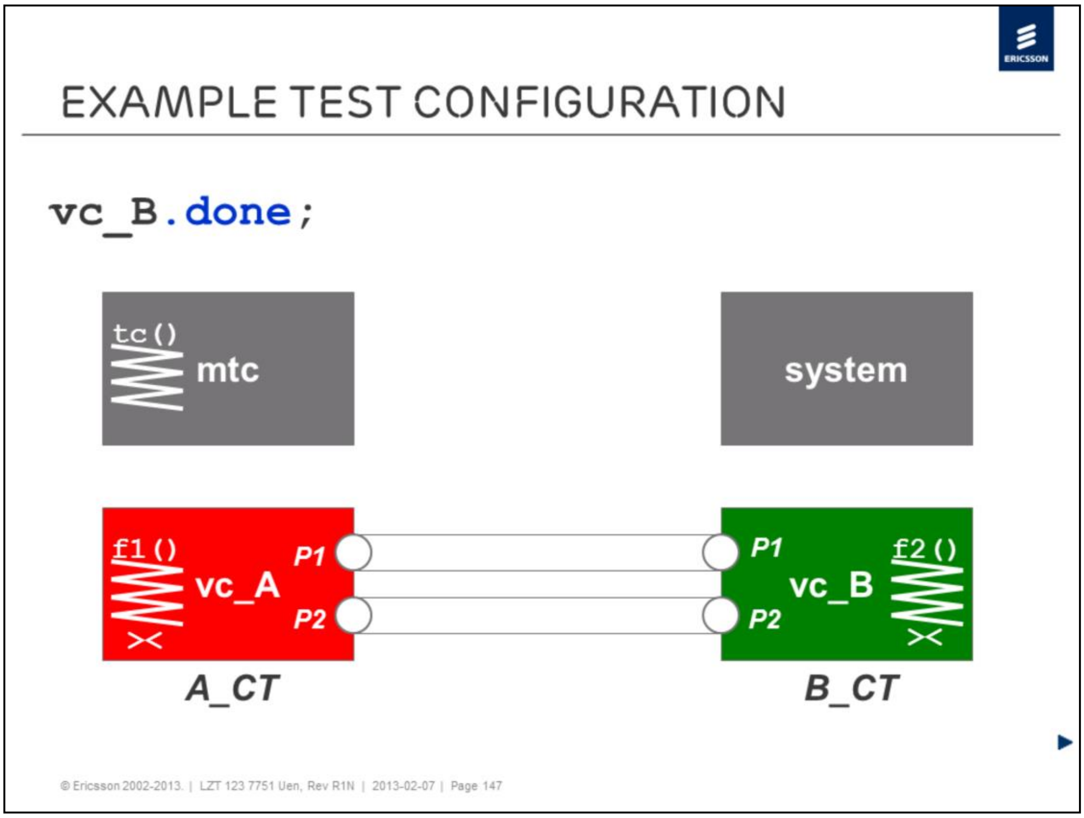
The component type definition enlists the resources of a particular type component, e.g. how many and what kind of interfaces the component has.

The port type definition declares operation mode of the interface (message=asynchronous, procedure=synchronous) and enlists the type of messages (or signatures at a procedural port), which can traverse the port.



ELEMENTARY STEPS OF SETTING UP THE TEST CONFIGURATION

1) **Create PTCs (ports of components are created and started automatically) –** `create`
2) **Establish connections and mappings –** `connect` **or** `map`
3) **Start behavior on PTCs –** `start`
4) **Wait for PTCs to complete –** `done` **or** `all component.done`



EXAMPLE TEST CONFIGURATION

```
vc_B.done;
```

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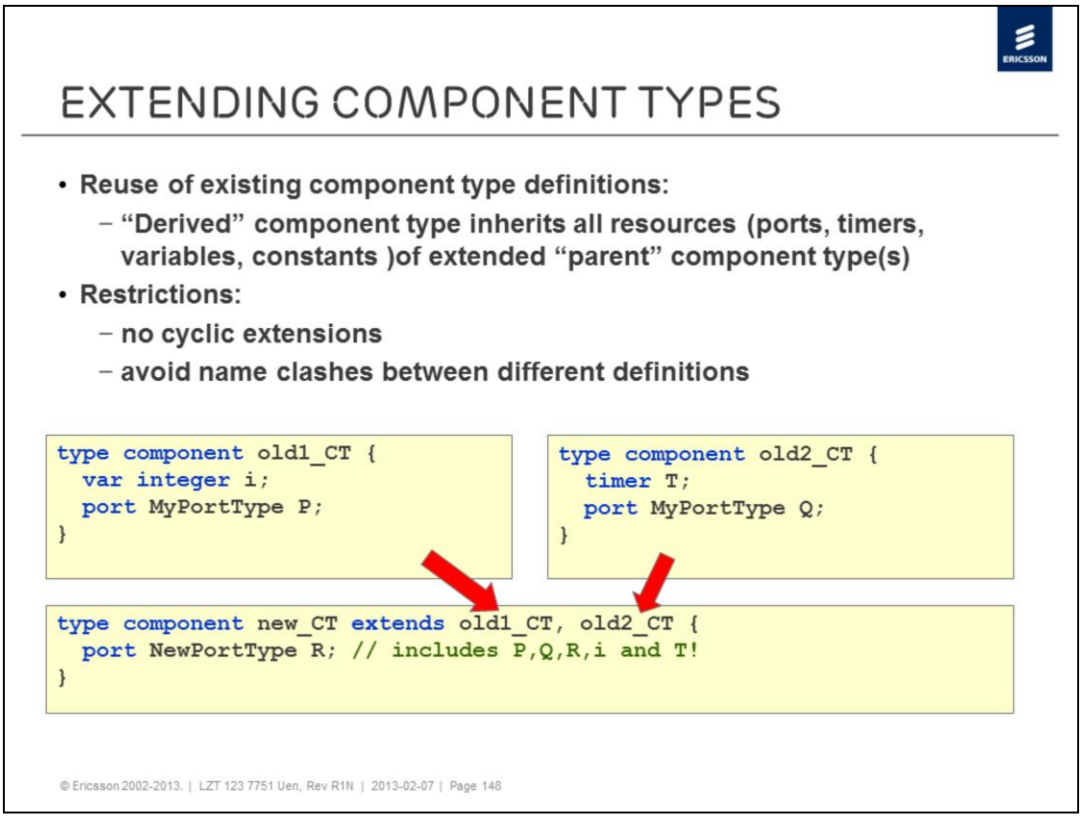
Elementary steps of setting up the test configuration:

1) Create PTCs (ports of components are created and started automatically)
2) Establish connections and mappings
3) Start behavior on PTCs remotely
4) Wait for PTCs to complete



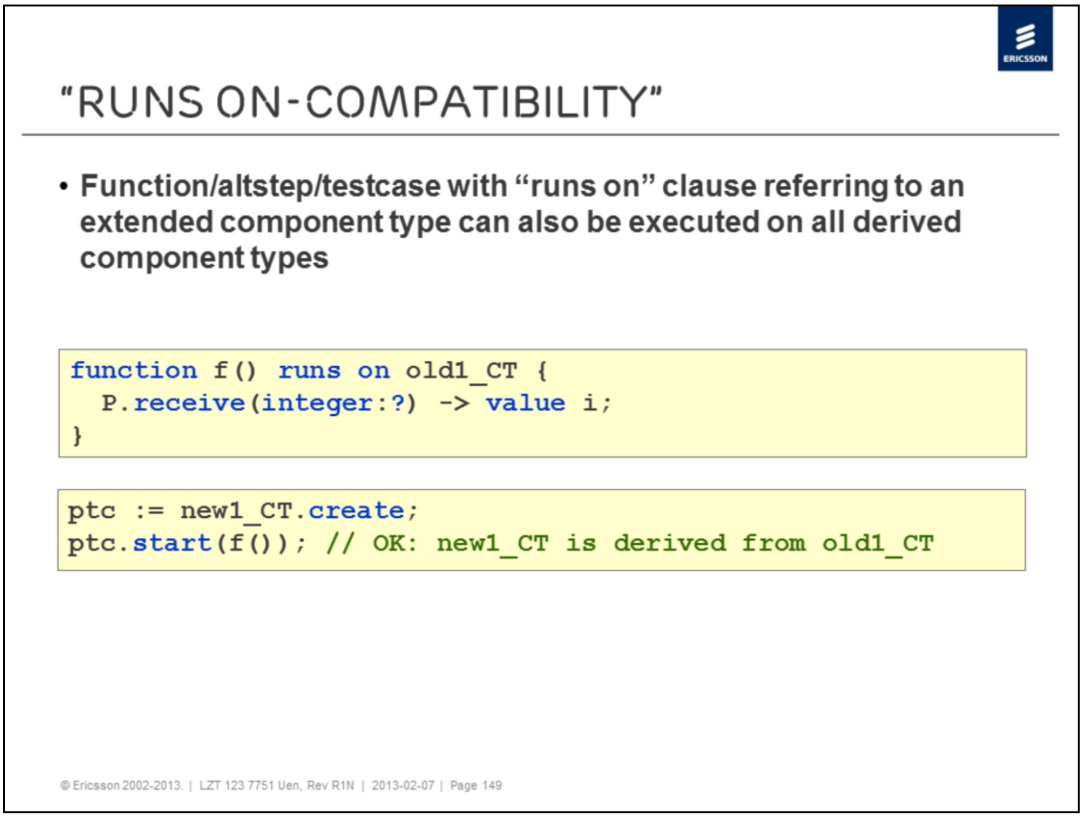
EXTENDING COMPONENT TYPES

- **Reuse of existing component type definitions:**
  - **“Derived” component type inherits all resources (ports, timers, variables, constants)of extended “parent” component type(s)**
- **Restrictions:**
  - **no cyclic extensions**
  - **avoid name clashes between different definitions**

```
type component old1_CT {
  var integer i;
  port MyPortType P;
}
```

```
type component old2_CT {
  timer T;
  port MyPortType Q;
}
```

```
type component new_CT extends old1_CT, old2_CT {
  port NewPortType R; // includes P,Q,R,i and T!
}
```

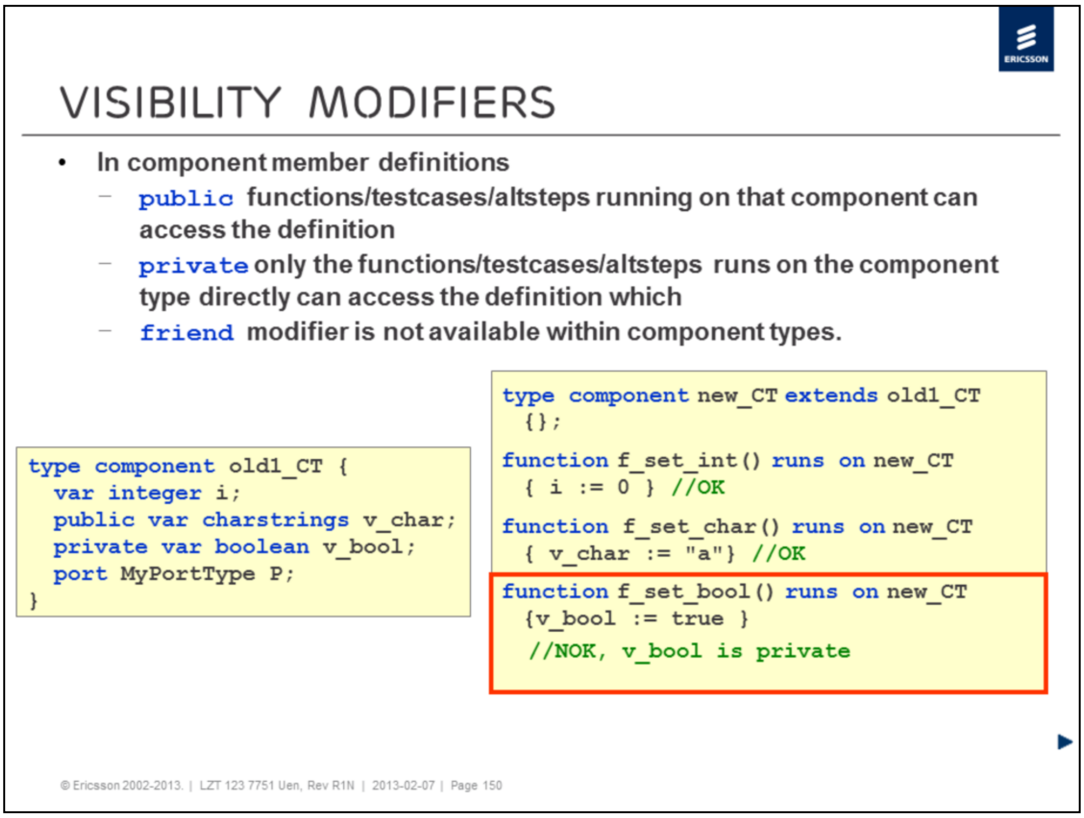


“RUNS ON-COMPATIBILITY”

- Function/altstep/testcase with “runs on” clause referring to an extended component type can also be executed on all derived component types

```
function f() runs on old1_CT {
  P.receive(integer:?) -> value i;
}
```

```
ptc := new1_CT.create;
ptc.start(f()); // OK: new1_CT is derived from old1_CT
```



VISIBILITY MODIFIERS

- In component member definitions
  - `public` functions/testcases/altsteps running on that component can access the definition
  - `private` only the functions/testcases/altsteps runs on the component type directly can access the definition which
  - `friend` modifier is not available within component types.

```
type component old1_CT {
  var integer i;
  public var charstrings v_char;
  private var boolean v_bool;
  port MyPortType P;
}
```

```
type component new_CT extends old1_CT
  {};
function f_set_int() runs on new_CT
  { i := 0 } //OK
function f_set_char() runs on new_CT
  { v_char := "a"} //OK
function f_set_bool() runs on new_CT
  {v_bool := true }
  //NOK, v_bool is private
```

The **scope unit** is the region of the TTCN-3 source within which (constant, timer, variable, etc.) definitions may have effect, within which multiple definitions of the same name are prohibited, and outside of which definitions inside the unit do not have effect.

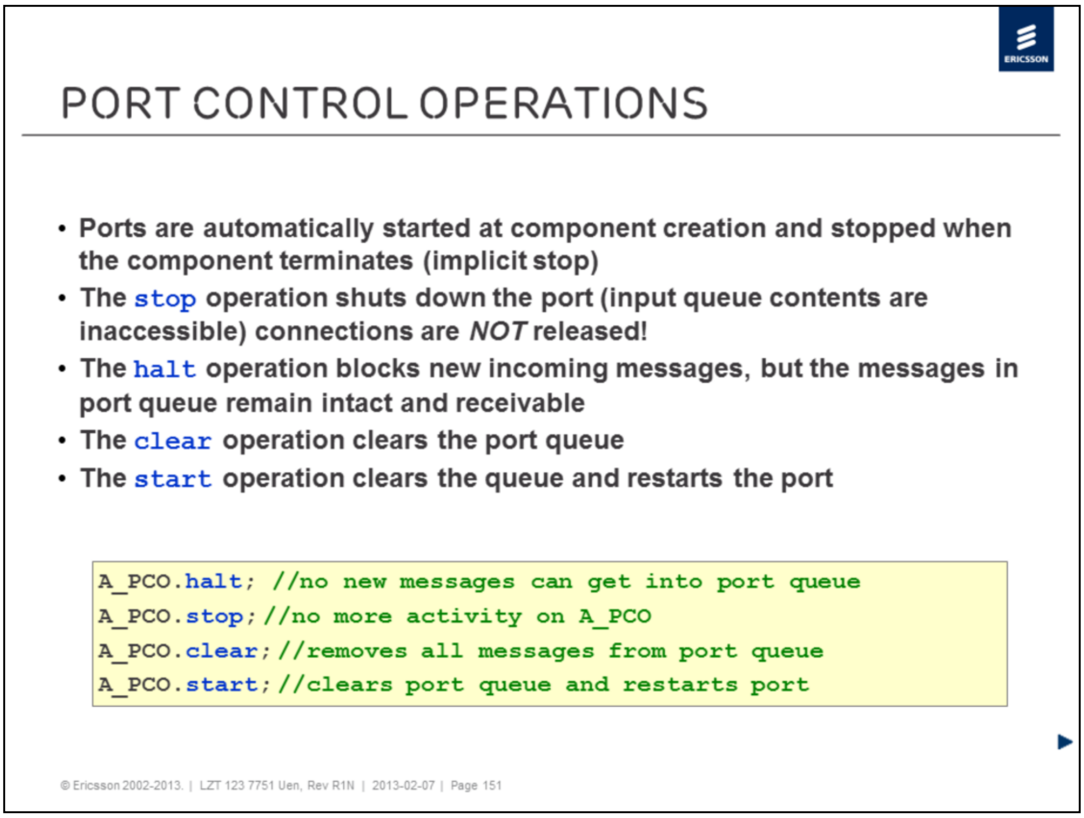
Definitions made in the **module definition part** but outside of other scope units are globally visible in the module. So are imported identifiers.

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 by a runs on-clause.

Functions, altsteps and **test cases** are individual scope units without any hierarchical relation between them, i.e. definitions made at the beginning of their body have local visibility.

Definitions within **block of statements** (e.g. for, if-else, while, do-while, alt, interleave**)** have local visibility within the statement concerned.



PORT CONTROL OPERATIONS

- **Ports are automatically started at component creation and stopped when the component terminates (implicit stop)**
- **The `stop` operation shuts down the port (input queue contents are inaccessible) connections are *NOT* released!**
- **The `halt` operation blocks new incoming messages, but the messages in port queue remain intact and receivable**
- **The `clear` operation clears the port queue**
- **The `start` operation clears the queue and restarts the port**

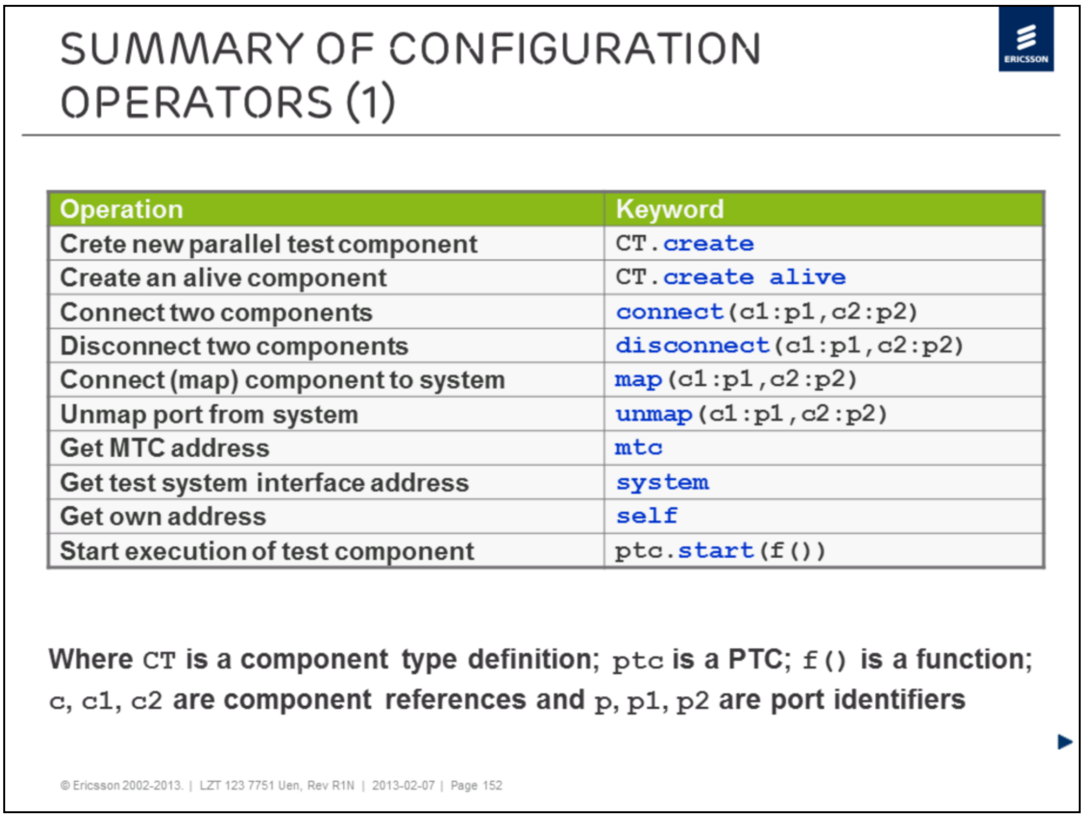
```
A_PCO.halt; //no new messages can get into port queue
A_PCO.stop; //no more activity on A_PCO
A_PCO.clear; //removes all messages from port queue
A_PCO.start; //clears port queue and restarts port
```

Ports are already running when the component is started. All ports are automatically stopped by the run-time environment when their owner component has finished execution.

None of the above operations affect connections and mapping of ports.

Receiving operations block on stopped ports until the port is restarted (provided no defaults are active).

The contents of port queue can still be matched and read on halted ports.

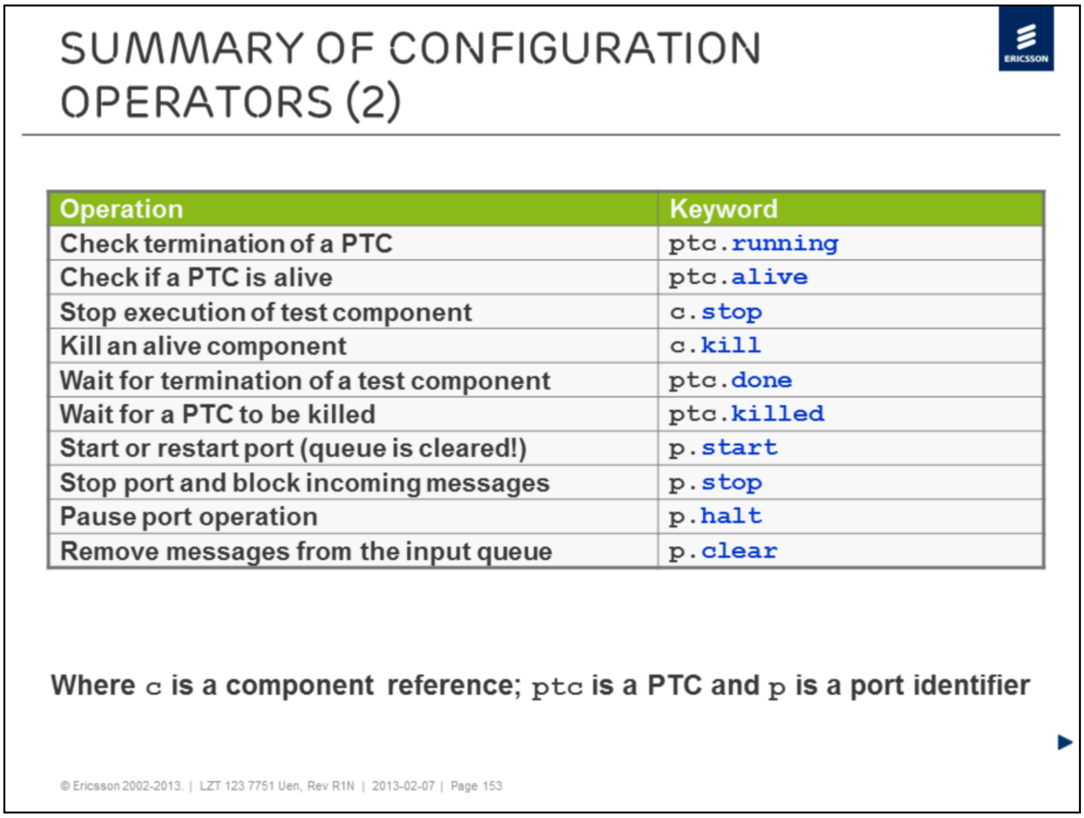


SUMMARY OF CONFIGURATION OPERATORS (1)

Operation	Keyword
Crete new parallel test component	`CT.create`
Create an alive component	`CT.create alive`
Connect two components	`connect(c1:p1,c2:p2)`
Disconnect two components	`disconnect(c1:p1,c2:p2)`
Connect (map) component to system	`map(c1:p1,c2:p2)`
Unmap port from system	`unmap(c1:p1,c2:p2)`
Get MTC address	`mtc`
Get test system interface address	`system`
Get own address	`self`
Start execution of test component	`ptc.start(f())`

Where `CT` is a component type definition; `ptc` is a PTC; `f()` is a function; `c`, `c1`, `c2` are component references and `p`, `p1`, `p2` are port identifiers

Configuration operations are used to set up and control test components. These operations shall only be used in test cases, functions and altsteps (i.e. not in the module control part).



SUMMARY OF CONFIGURATION OPERATORS (2)

Operation	Keyword
Check termination of a PTC	`ptc.running`
Check if a PTC is alive	`ptc.alive`
Stop execution of test component	`c.stop`
Kill an alive component	`c.kill`
Wait for termination of a test component	`ptc.done`
Wait for a PTC to be killed	`ptc.killed`
Start or restart port (queue is cleared!)	`p.start`
Stop port and block incoming messages	`p.stop`
Pause port operation	`p.halt`
Remove messages from the input queue	`p.clear`

Where `c` is a component reference; `ptc` is a PTC and `p` is a port identifier

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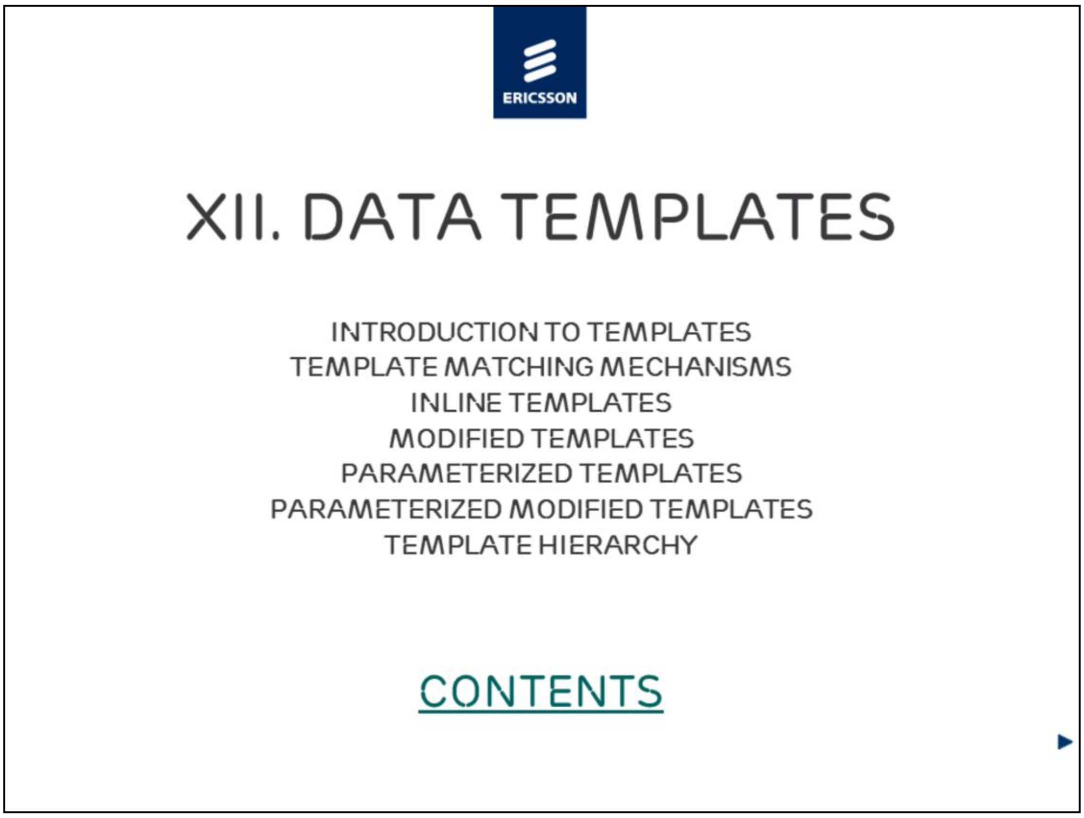
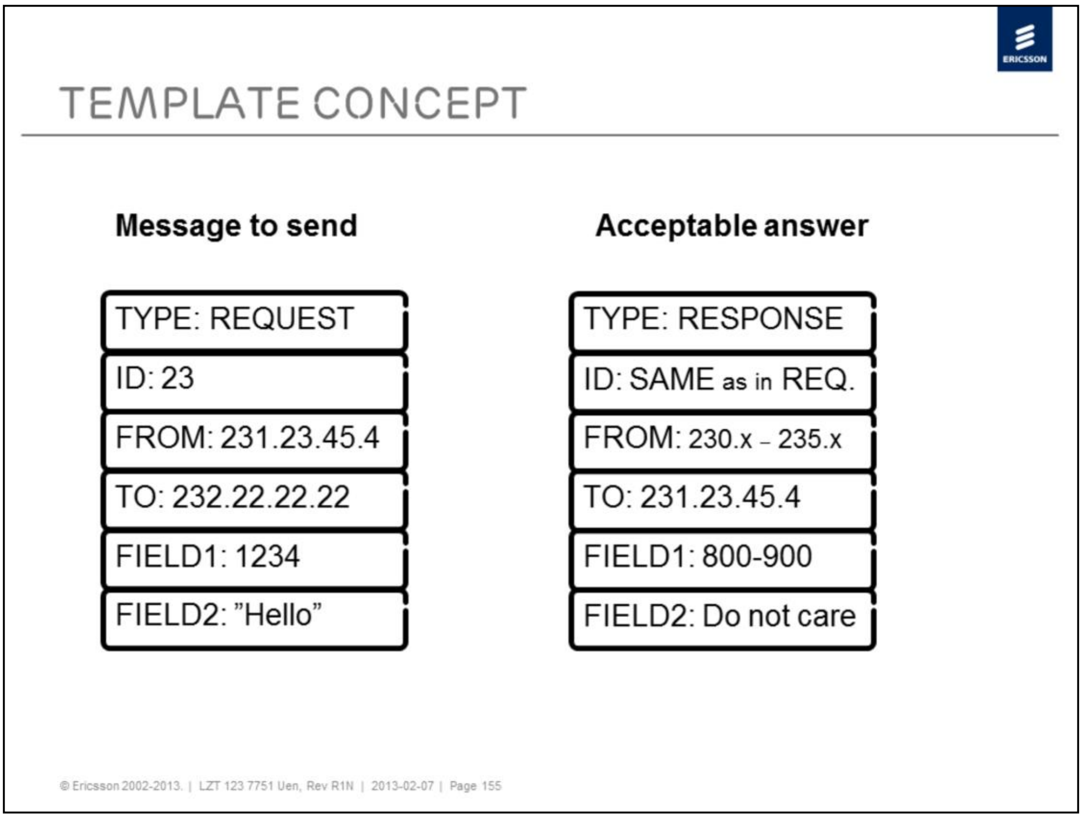
Configuration operations are used to set up and control test components. These operations shall only be used in test cases, functions and altsteps (i.e. not in the module control part).



XII. DATA TEMPLATES

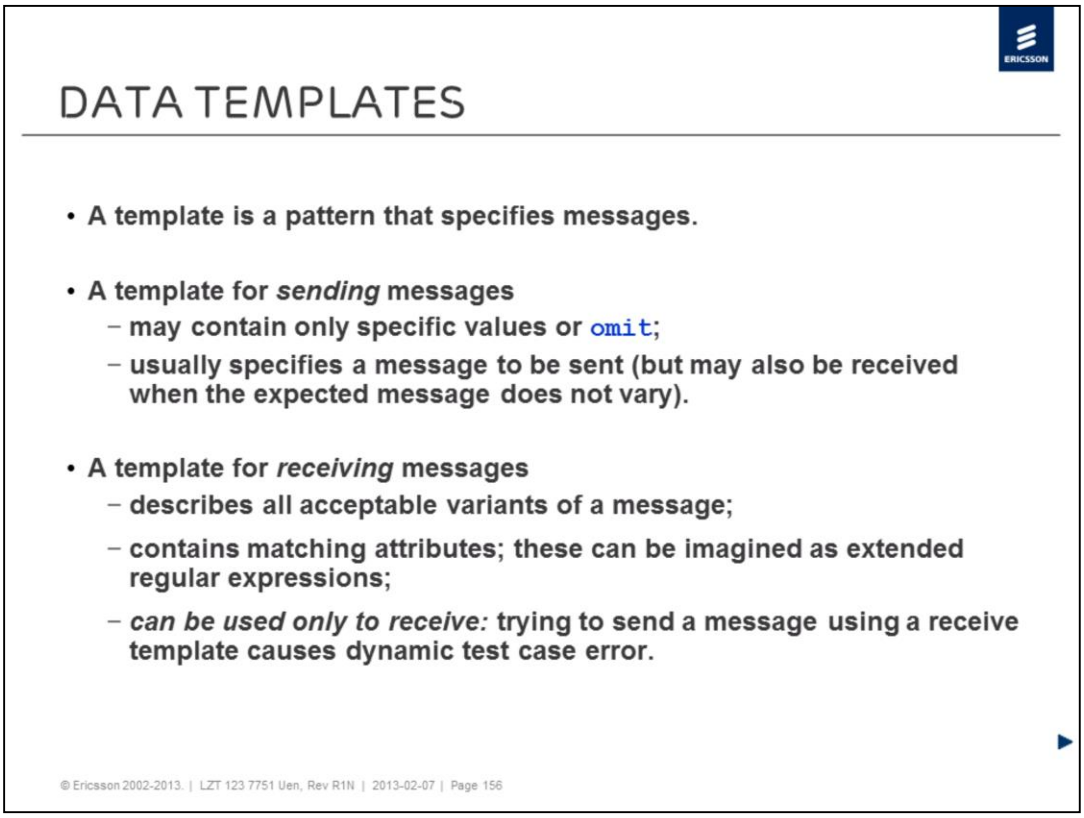
INTRODUCTION TO TEMPLATES
TEMPLATE MATCHING MECHANISMS
INLINE TEMPLATES
MODIFIED TEMPLATES
PARAMETERIZED TEMPLATES
PARAMETERIZED MODIFIED TEMPLATES
TEMPLATE HIERARCHY

CONTENTS



TEMPLATE CONCEPT

Message to send	**Acceptable answer**
TYPE: REQUEST	TYPE: RESPONSE
ID: 23	ID: SAME as in REQ.
FROM: 231.23.45.4	FROM: 230.x – 235.x
TO: 232.22.22.22	TO: 231.23.45.4
FIELD1: 1234	FIELD1: 800-900
FIELD2: ”Hello”	FIELD2: Do not care



DATA TEMPLATES

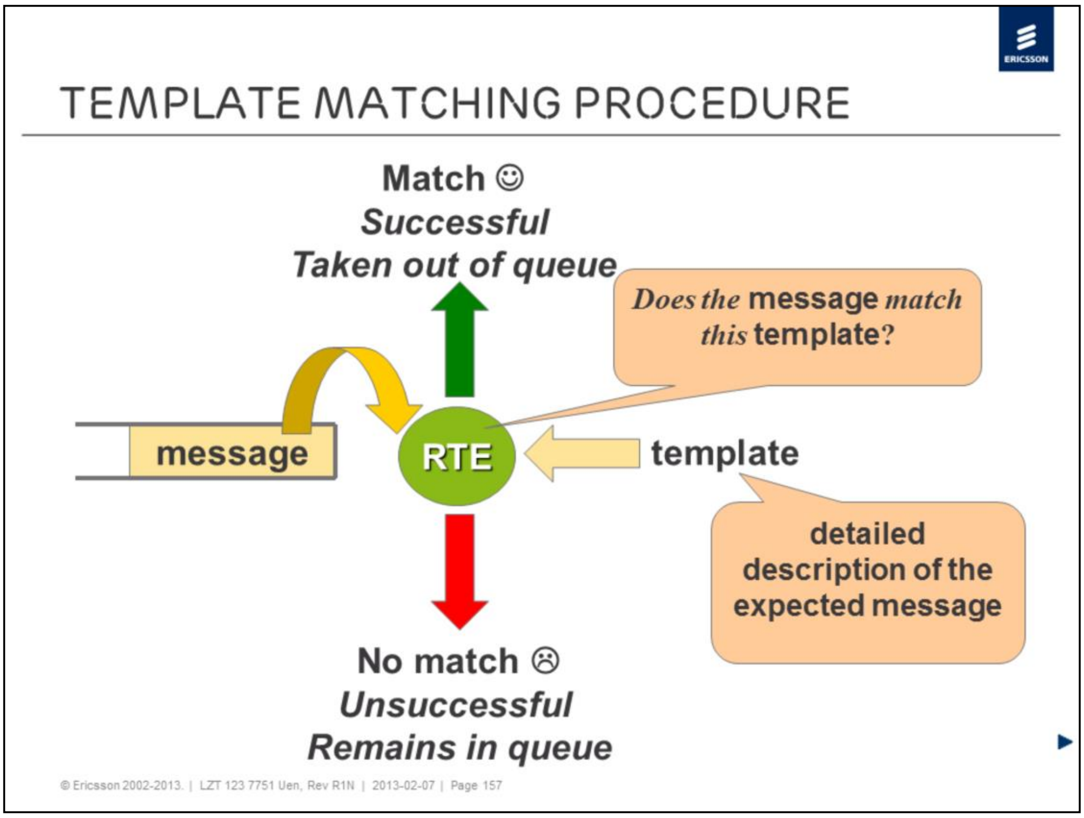
- **A template is a pattern that specifies messages.**
- **A template for *sending* messages**
  - **may contain only specific values or `omit`;**
  - **usually specifies a message to be sent (but may also be received when the expected message does not vary).**
- **A template for *receiving* messages**
  - **describes all acceptable variants of a message;**
  - **contains matching attributes; these can be imagined as extended regular expressions;**
  - ***can be used only to receive:* trying to send a message using a receive template causes dynamic test case error.**

Template: something that establishes or serves as a pattern.

Templates are used either to test whether a set of received values matches the template specification or to transmit a set of distinct values.

Templates used to receive messages have the advantage that all valid message variants may be described in a single template. When a message arrives, the program can decide whether it is a valid one or not. This procedure is called matching.

Templates used to send messages are advantageous because they can be parameterized, thus, reused. All fields of these templates must have a determined value at the point when a message is sent using them. These templates may be used to receive messages as well, but only when all fields of the expected message are fixed and known beforehand.



TEMPLATE MATCHING PROCEDURE

Match ☺
Successful
Taken out of queue

Does the **message** *match this* **template***?*

message

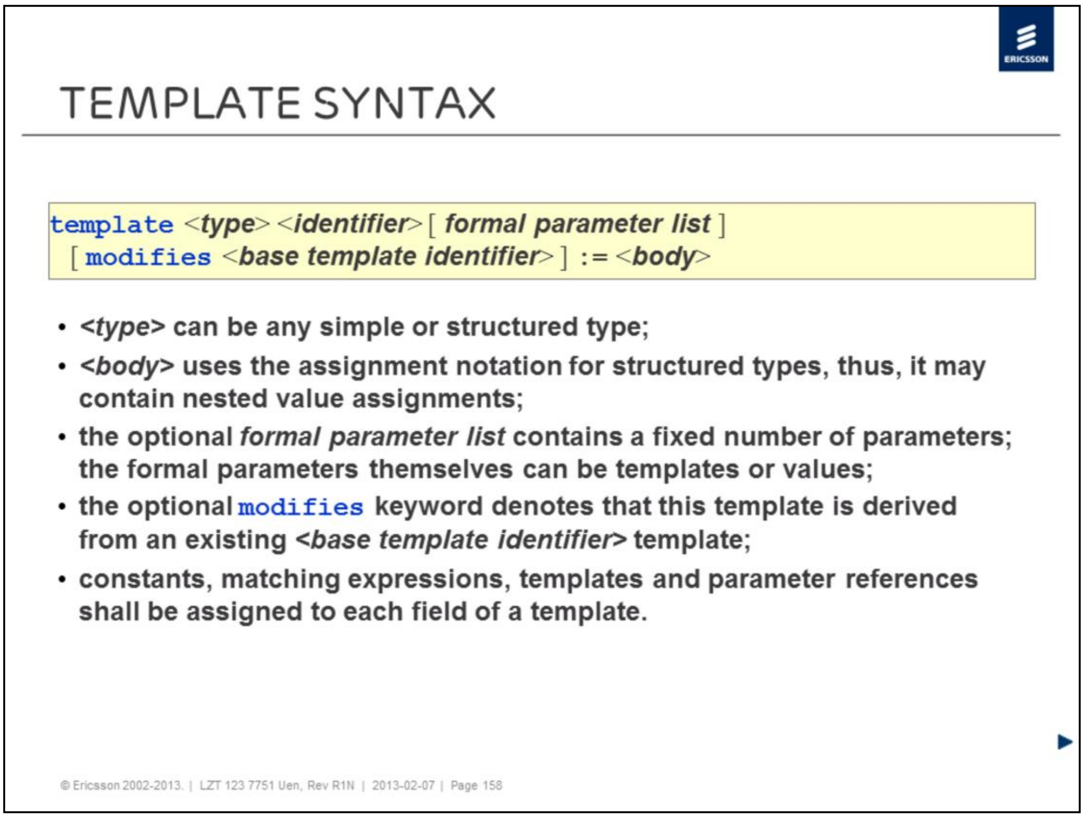
RTE

template

detailed description of the expected message

No match ☹
Unsuccessful
Remains in queue

The runtime environment (RTE) compares the received message with the predefined template describing all valid message variants. When the message is one of the valid messages (it fits into the template), the match is successful.



TEMPLATE SYNTAX

```
template <type> <identifier> [ formal parameter list ]
  [ modifies <base template identifier> ] := <body>
```

- ***<type>*** **can be any simple or structured type;**
- ***<body>*** **uses the assignment notation for structured types, thus, it may contain nested value assignments;**
- **the optional *formal parameter list* contains a fixed number of parameters; the formal parameters themselves can be templates or values;**
- **the optional `modifies` keyword denotes that this template is derived from an existing *<base template identifier>* template;**
- **constants, matching expressions, templates and parameter references shall be assigned to each field of a template.**

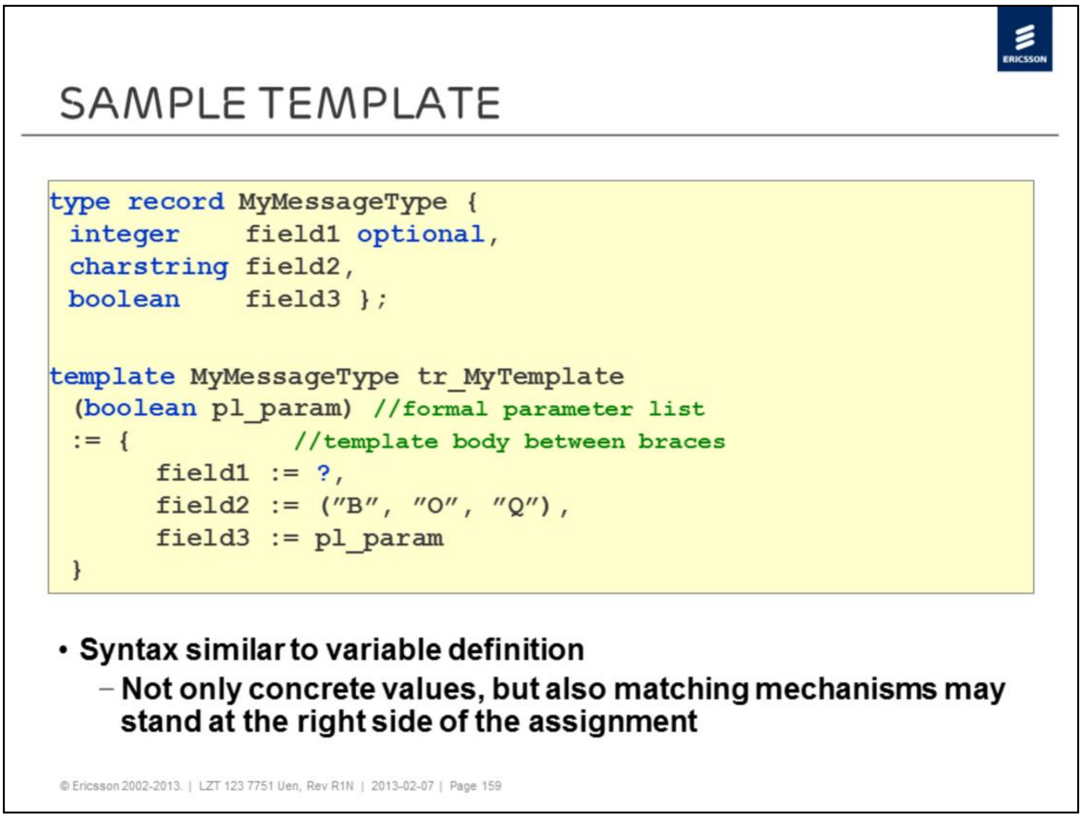
Type determines the structure of the template, i.e., its fields.

Identifier is the name of the template. It is used when we want to refer to the template.

The formal parameter list provides the list of the parameters of the template. These optional parameters are used to alter the template at every invocation.

The keyword modifies denotes derived template where only some of the fields of the original template are changed. Both templates have the same fields.

The template body lists the permitted values for all fields.



SAMPLE TEMPLATE

```
type record MyMessageType {
 integer    field1 optional,
 charstring field2,
 boolean    field3 };

template MyMessageType tr_MyTemplate
 (boolean pl_param) //formal parameter list
 := {            //template body between braces
       field1 := ?,
       field2 := (”B”, ”O”, ”Q”),
       field3 := pl_param
 }
```

- **Syntax similar to variable definition**
  - **Not only concrete values, but also matching mechanisms may stand at the right side of the assignment**

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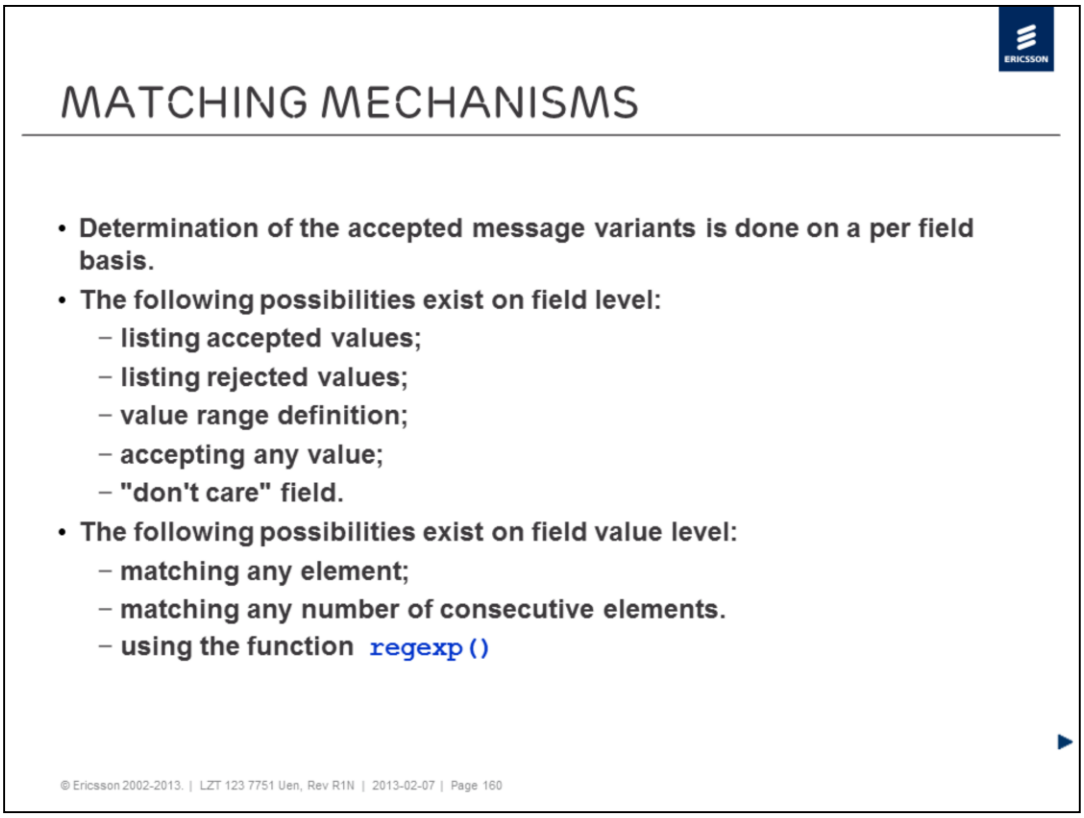
First, we define a record (MyMessageType) containing three fields, the first one being optional.

The type of the template will be the one just defined. The template we'll define is called tr_MyTemplate. In the template name prefix, 't' stands for 'template' and 'r' for receiving.

The template accepts the following messages: the first field must be present, but its content is don't care. The second field may have the value B, O or Q. The value of the last field must be in function of the parameter pl_param either true or false.

The template can be used for receiving only, because it contains an undefined field (the first one).

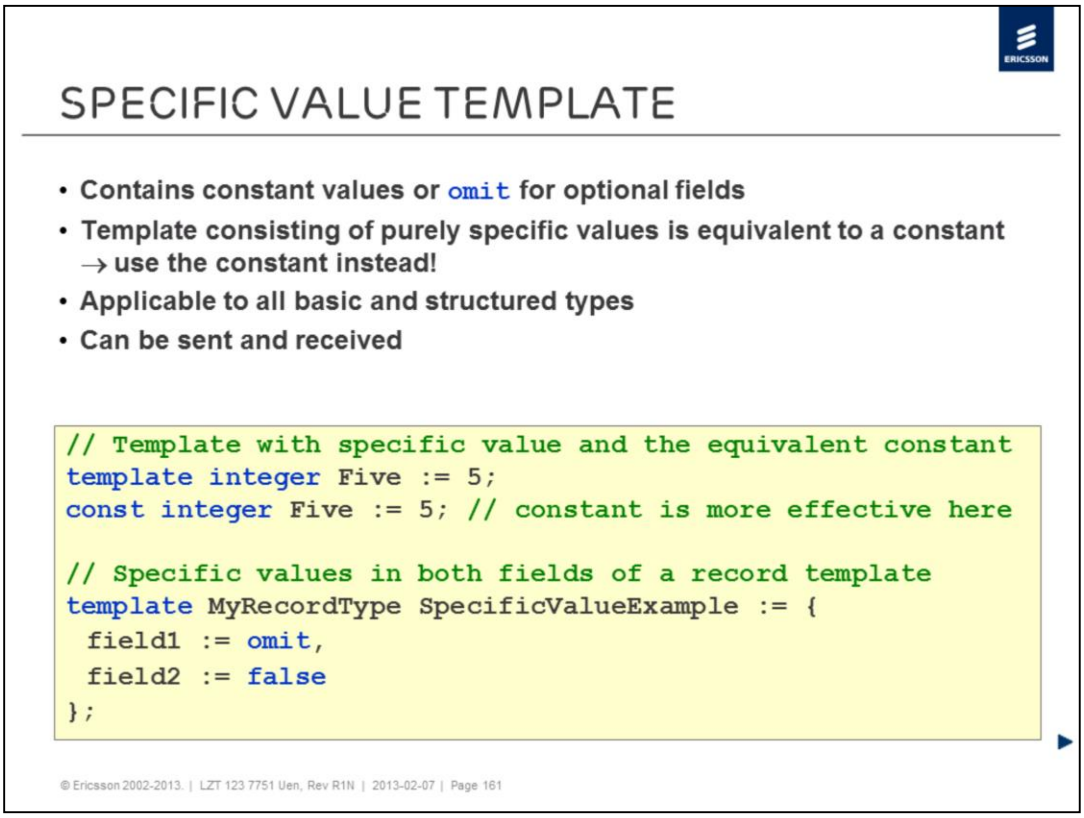


MATCHING MECHANISMS

- Determination of the accepted message variants is done on a per field basis.
- The following possibilities exist on field level:
  - listing accepted values;
  - listing rejected values;
  - value range definition;
  - accepting any value;
  - "don't care" field.
- The following possibilities exist on field value level:
  - matching any element;
  - matching any number of consecutive elements.
  - using the function `regexp()`

Matching checks whether the received message fits in the set of accepted messages. The check is done for each field of the template independently. A message is accepted ("matches") when all fields contain accepted values.

The matching mechanisms are depicted in the annex B.1 of ETSI ES 201 873-1.

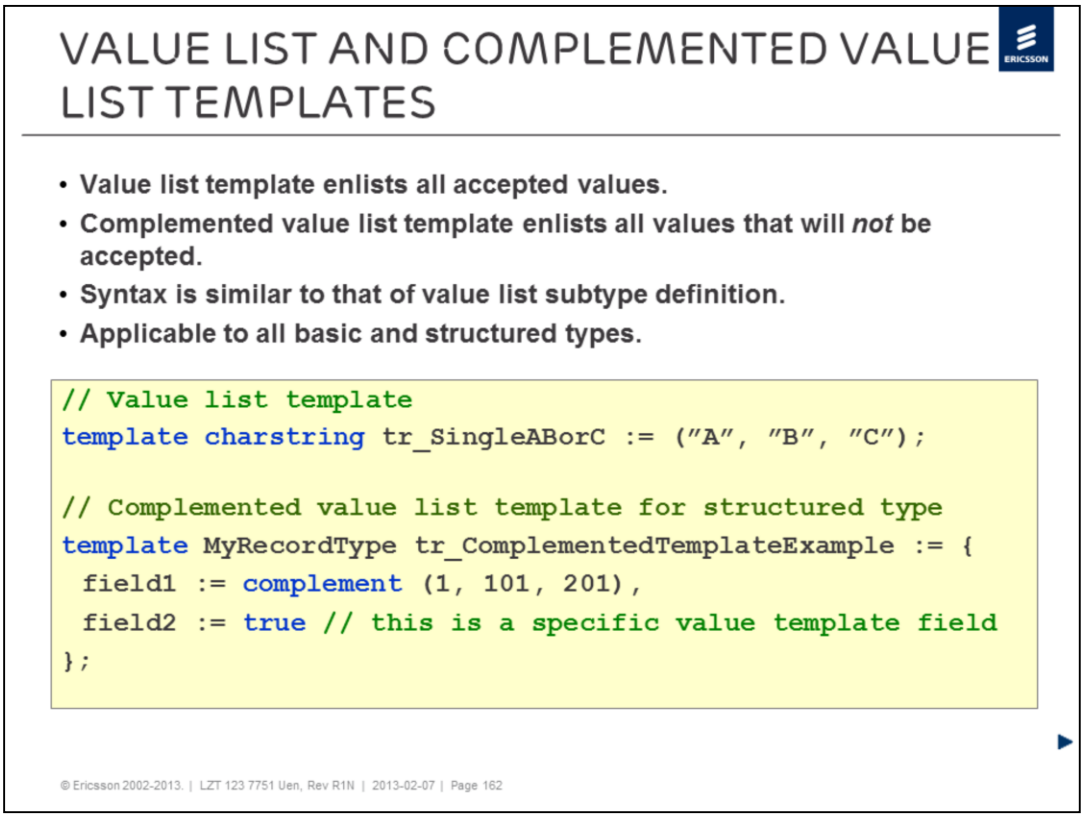


SPECIFIC VALUE TEMPLATE

- Contains constant values or `omit` for optional fields
- Template consisting of purely specific values is equivalent to a constant → use the constant instead!
- Applicable to all basic and structured types
- Can be sent and received

```
// Template with specific value and the equivalent constant
template integer Five := 5;
const integer Five := 5; // constant is more effective here

// Specific values in both fields of a record template
template MyRecordType SpecificValueExample := {
 field1 := omit,
 field2 := false
};
```



VALUE LIST AND COMPLEMENTED VALUE LIST TEMPLATES

- Value list template enlists all accepted values.
- Complemented value list template enlists all values that will *not* be accepted.
- Syntax is similar to that of value list subtype definition.
- Applicable to all basic and structured types.

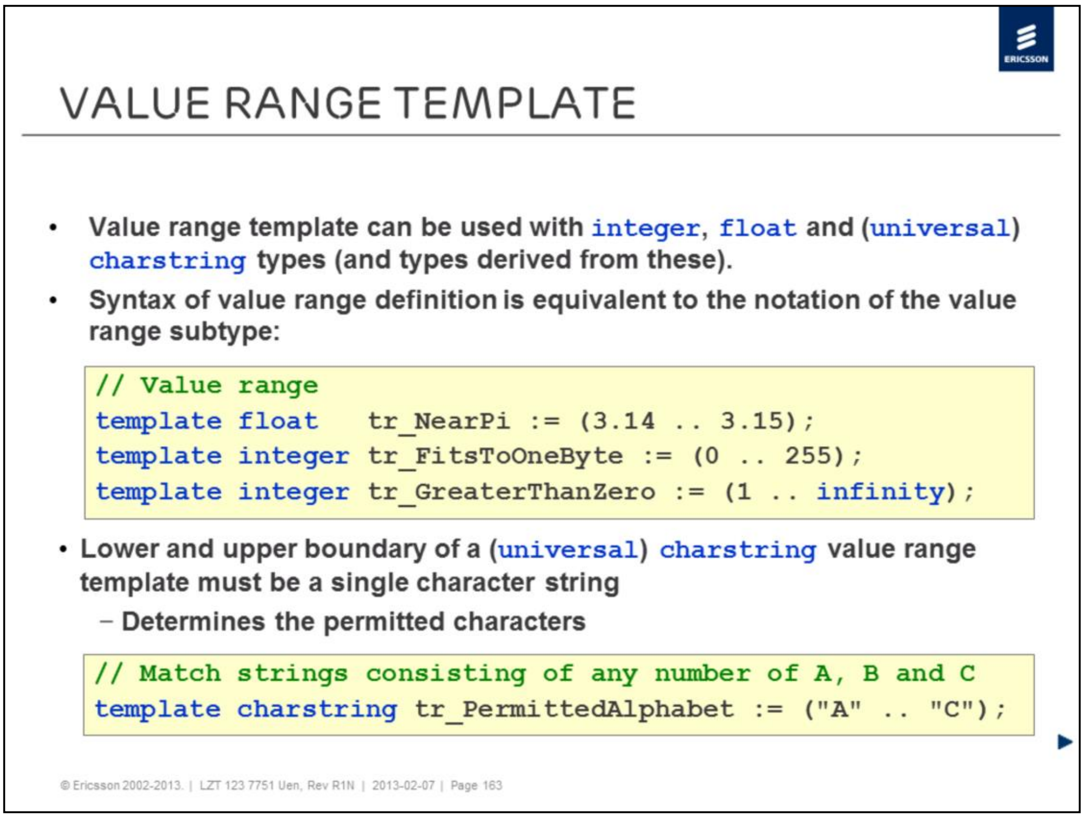
```
// Value list template
template charstring tr_SingleABorC := (”A”, ”B”, ”C”);

// Complemented value list template for structured type
template MyRecordType tr_ComplementedTemplateExample := {
 field1 := complement (1, 101, 201),
 field2 := true // this is a specific value template field
};
```

The simplest template lists all discrete message values that will be accepted.

Complemented values list lists the values which will not be accepted.

Both lists refer to *fields* of the template, i.e., both notations may be mixed in different fields of the same template.



VALUE RANGE TEMPLATE

- Value range template can be used with `integer`, `float` and (`universal`) `charstring` types (and types derived from these).
- Syntax of value range definition is equivalent to the notation of the value range subtype:

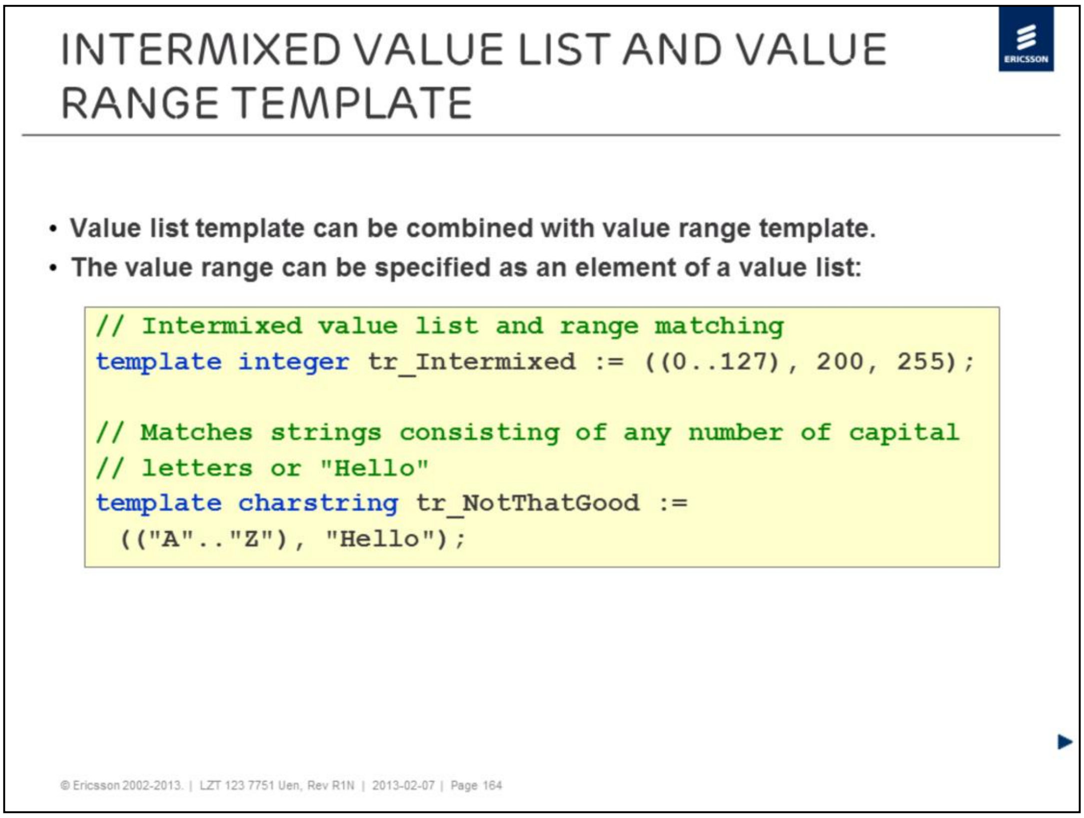
```
// Value range
template float   tr_NearPi := (3.14 .. 3.15);
template integer tr_FitsToOneByte := (0 .. 255);
template integer tr_GreaterThanZero := (1 .. infinity);
```

- Lower and upper boundary of a (`universal`) `charstring` value range template must be a single character string
  - Determines the permitted characters

```
// Match strings consisting of any number of A, B and C
template charstring tr_PermittedAlphabet := ("A" .. "C");
```

Range indicates the upper and the lower boundaries of acceptable values. An expression evaluating to a specific integer or float value can be used when setting the boundaries.

The lower boundary (written after the left parenthesis) must be less than the upper boundary (written before the right parenthesis).



INTERMIXED VALUE LIST AND VALUE RANGE TEMPLATE

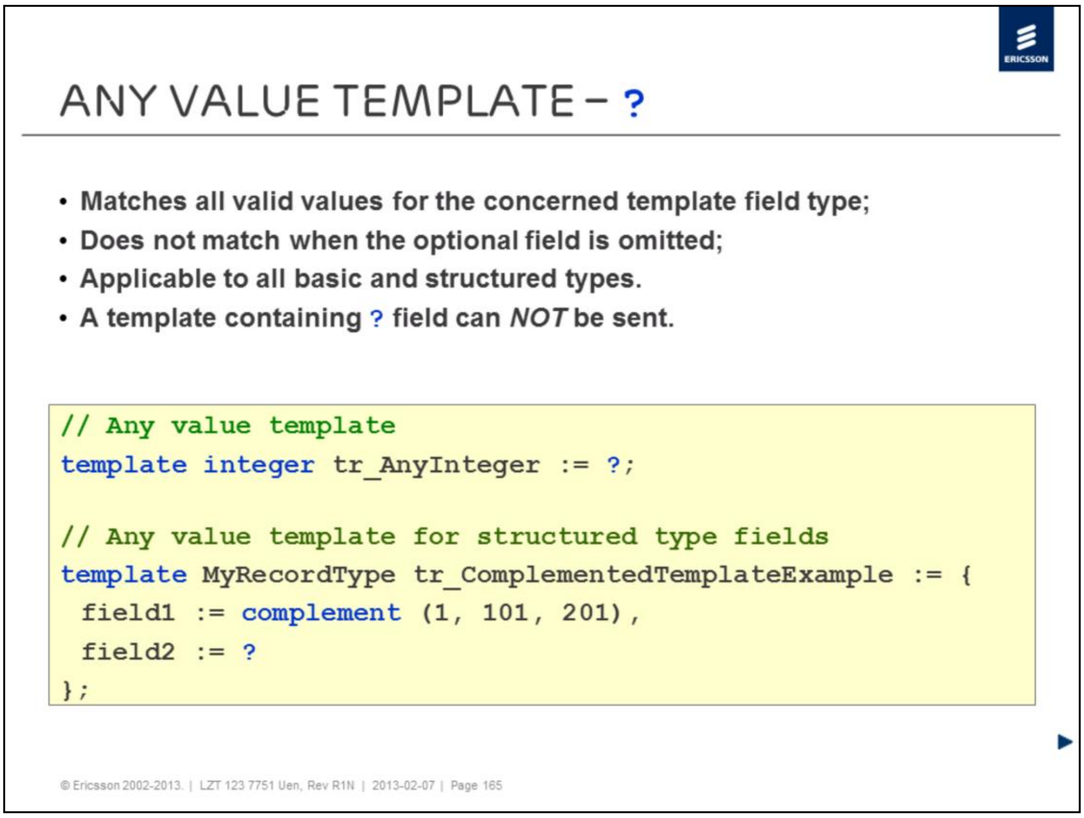
- Value list template can be combined with value range template.
- The value range can be specified as an element of a value list:

```
// Intermixed value list and range matching
template integer tr_Intermixed := ((0..127), 200, 255);

// Matches strings consisting of any number of capital
// letters or "Hello"
template charstring tr_NotThatGood :=
  (("A".."Z"), "Hello");
```

Note: The syntax differs from the intermixed value list and value range subtype construction’s notation:

type integer Intermixed (0..127,255);



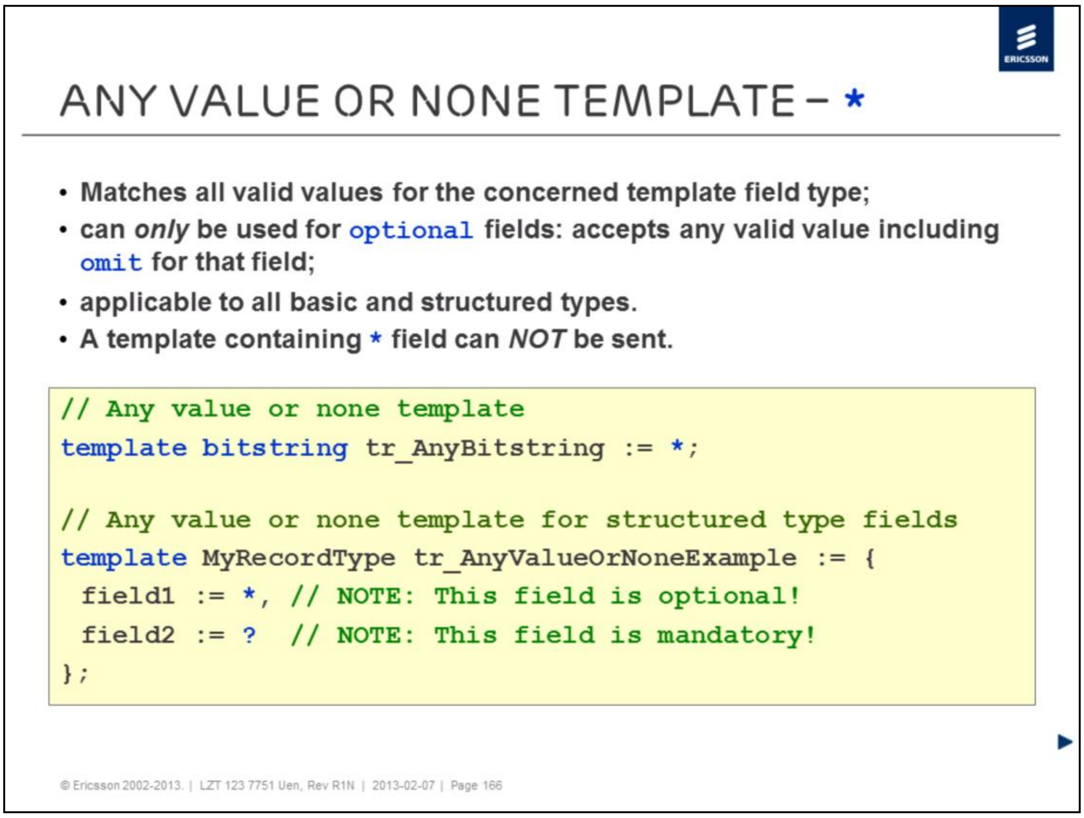
ANY VALUE TEMPLATE – ?

- Matches all valid values for the concerned template field type;
- Does not match when the optional field is omitted;
- Applicable to all basic and structured types.
- A template containing ? field can *NOT* be sent.

```
// Any value template
template integer tr_AnyInteger := ?;

// Any value template for structured type fields
template MyRecordType tr_ComplementedTemplateExample := {
  field1 := complement (1, 101, 201),
  field2 := ?
};
```

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.



ANY VALUE OR NONE TEMPLATE – *

- Matches all valid values for the concerned template field type;
- can *only* be used for `optional` fields: accepts any valid value including `omit` for that field;
- applicable to all basic and structured types.
- A template containing `*` field can *NOT* be sent.

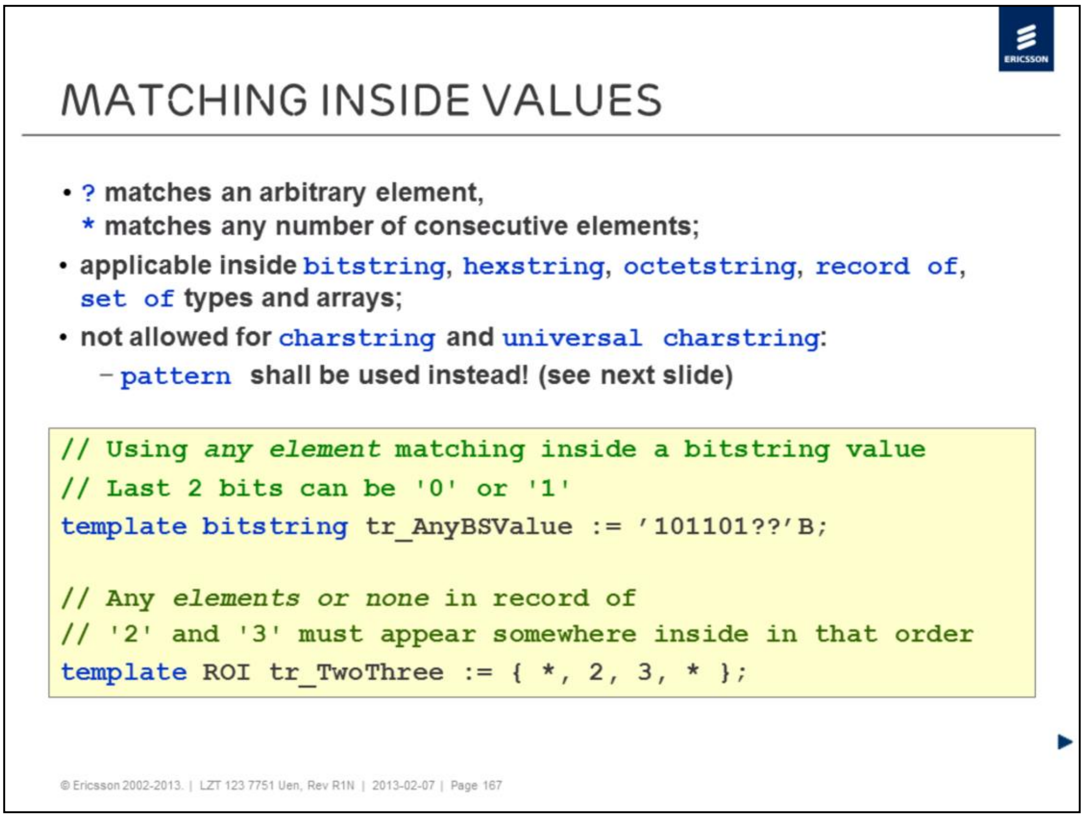
```
// Any value or none template
template bitstring tr_AnyBitstring := *;

// Any value or none template for structured type fields
template MyRecordType tr_AnyValueOrNoneExample := {
  field1 := *, // NOTE: This field is optional!
  field2 := ?  // NOTE: This field is mandatory!
};
```

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 defined 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.

Note: The template tr_AnyBitstring can only be used as an optional field of another template.



MATCHING INSIDE VALUES

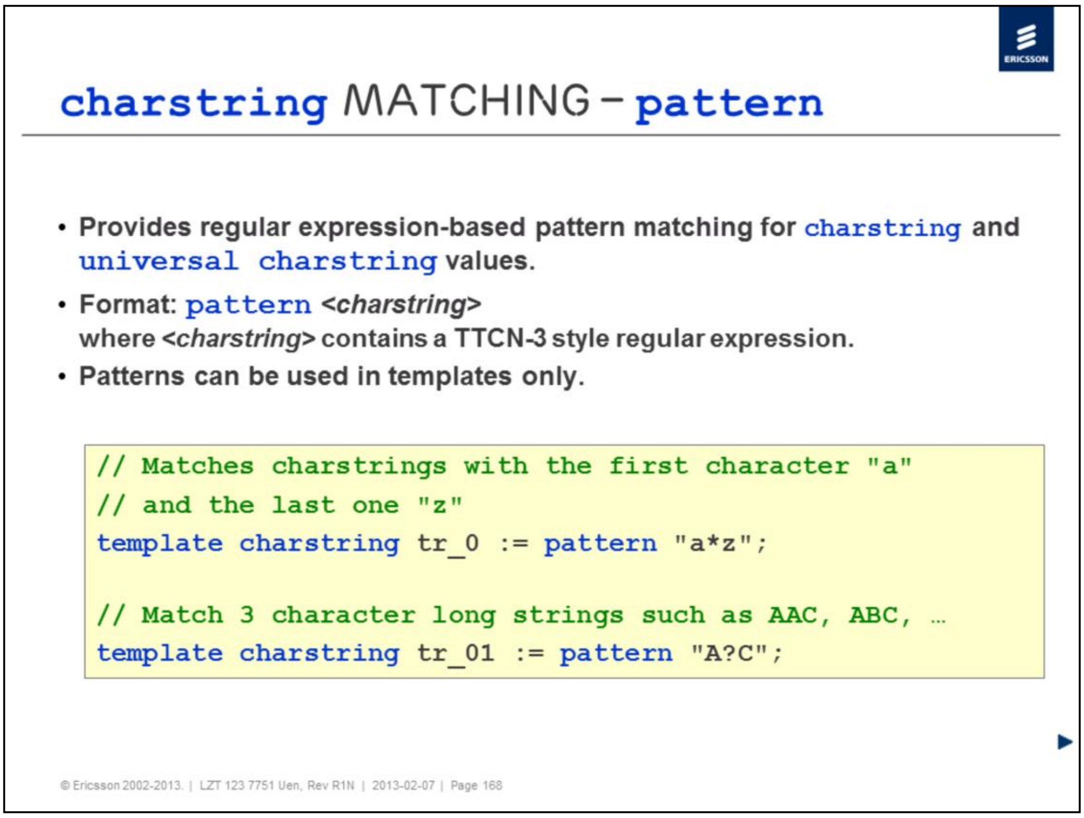
- `?` matches an arbitrary element,
  `*` matches any number of consecutive elements;
- applicable inside `bitstring`, `hexstring`, `octetstring`, `record of`, `set of` types and arrays;
- not allowed for `charstring` and `universal charstring`:
  - `pattern` shall be used instead! (see next slide)

```
// Using any element matching inside a bitstring value
// Last 2 bits can be '0' or '1'
template bitstring tr_AnyBSValue := ’101101??’B;

// Any elements or none in record of
// '2' and '3' must appear somewhere inside in that order
template ROI tr_TwoThree := { *, 2, 3, * };
```

The matching symbol "?" 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.

The matching symbol "*" 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 "*".



`charstring` MATCHING – `pattern`

- Provides regular expression-based pattern matching for `charstring` and `universal charstring` values.
- Format: `pattern` <*charstring*>
  where <*charstring*> contains a TTCN-3 style regular expression.
- Patterns can be used in templates only.

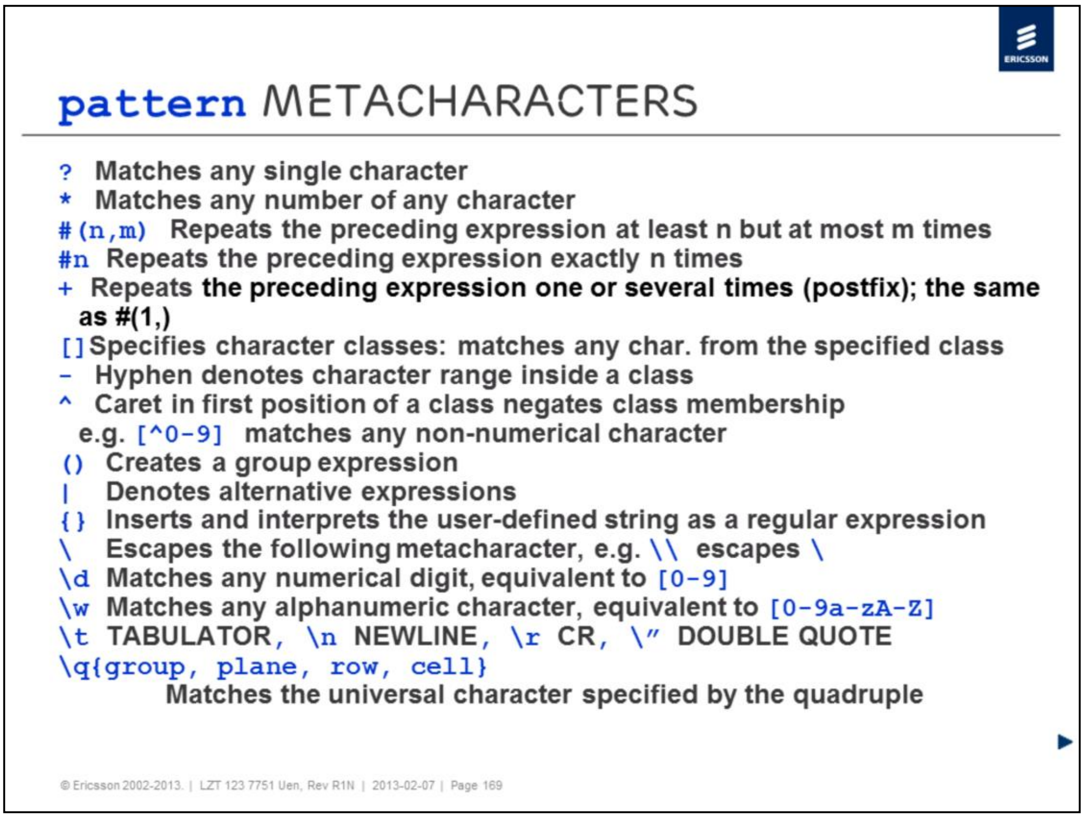
```
// Matches charstrings with the first character "a"
// and the last one "z"
template charstring tr_0 := pattern "a*z";

// Match 3 character long strings such as AAC, ABC, …
template charstring tr_01 := pattern "A?C";
```

Character patterns can be used in templates to define the format of a required character string to be received.

TTCN-3 pattern expressions have little common with standard regular expressions!

Note: pattern matching for universal charstring is not implemented in TITAN yet!



`pattern` METACHARACTERS

`?`	Matches any single character
`*`	Matches any number of any character
`#(n,m)`	Repeats the preceding expression at least n but at most m times
`#n`	Repeats the preceding expression exactly n times
`+`	Repeats **the preceding expression one or several times (postfix); the same as #(1,)**
`[]`	Specifies character classes: matches any char. from the specified class
`-`	Hyphen denotes character range inside a class
`^`	Caret in first position of a class negates class membership e.g. `[^0-9]` matches any non-numerical character
`()`	Creates a group expression
`|`	Denotes alternative expressions
`{}`	Inserts and interprets the user-defined string as a regular expression
`\`	Escapes the following metacharacter, e.g. `\\` escapes `\`
`\d`	Matches any numerical digit, equivalent to `[0-9]`
`\w`	Matches any alphanumeric character, equivalent to `[0-9a-zA-Z]`
`\t`	TABULATOR, `\n` NEWLINE, `\r` CR, `\"` DOUBLE QUOTE
`\q{group, plane, row, cell}`	Matches the universal character specified by the quadruple

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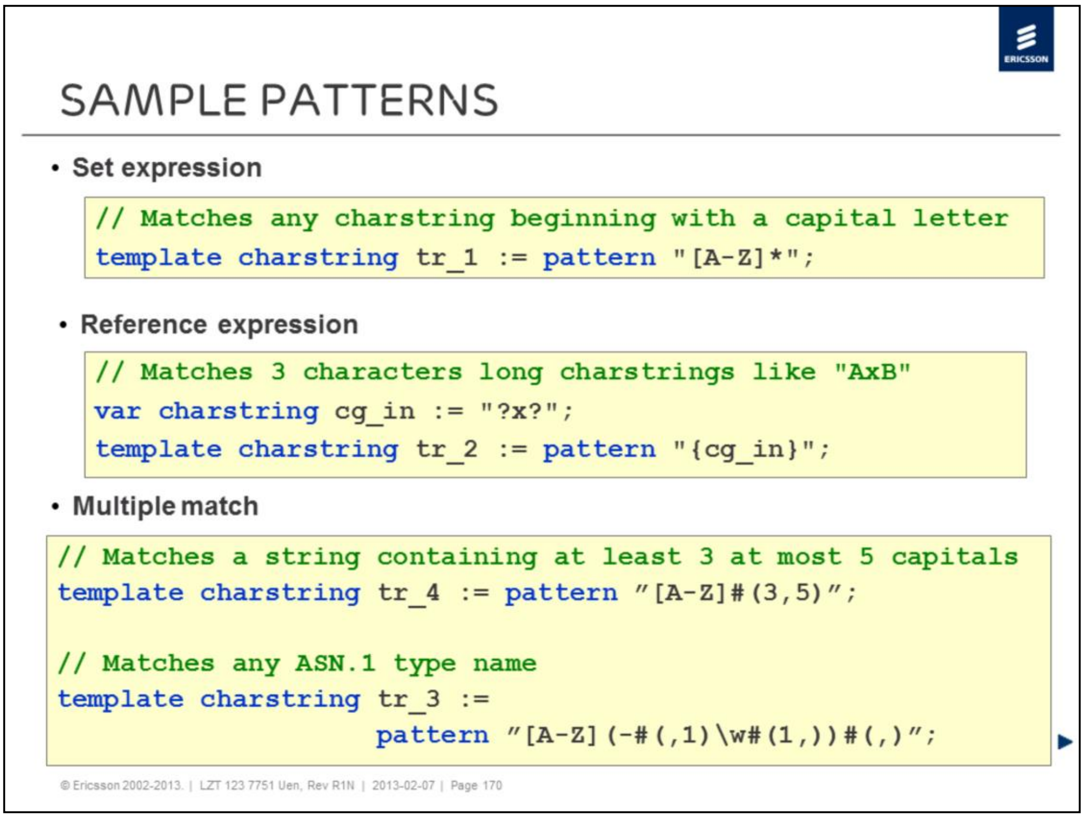
In addition to literal characters, character patterns allow the use of meta-characters. If it is required to interpret any metacharacter literally it should be preceded with the metacharacter '\'.

“-” means a range, if before and after there is no space!

inside [ ] char set may be defined e.g. [a f t] --- a or f or t

[a d -] a or d or – (- can be only at the LAST position!)



SAMPLE PATTERNS

- **Set expression**

```
// Matches any charstring beginning with a capital letter
template charstring tr_1 := pattern "[A-Z]*";
```

- **Reference expression**

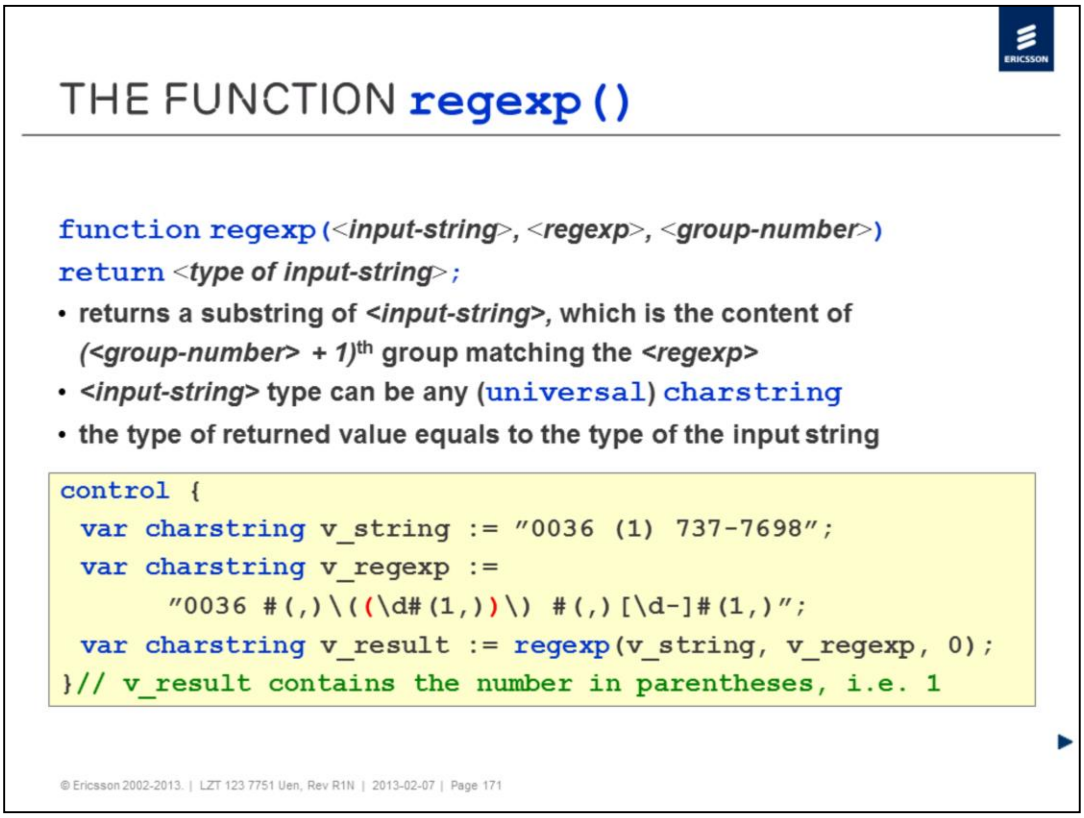
```
// Matches 3 characters long charstrings like "AxB"
var charstring cg_in := "?x?";
template charstring tr_2 := pattern "{cg_in}";
```

- **Multiple match**

```
// Matches a string containing at least 3 at most 5 capitals
template charstring tr_4 := pattern ”[A-Z]#(3,5)”;

// Matches any ASN.1 type name
template charstring tr_3 :=
                         pattern ”[A-Z](-#(,1)\w#(1,))#(,)”;
```

The pattern used in template tr_3 explained: it begins with a capital letter, followed by (zero or more hyphen and at least one letter or number) and the section inside the parentheses may be repeated several times.



THE FUNCTION `regexp()`

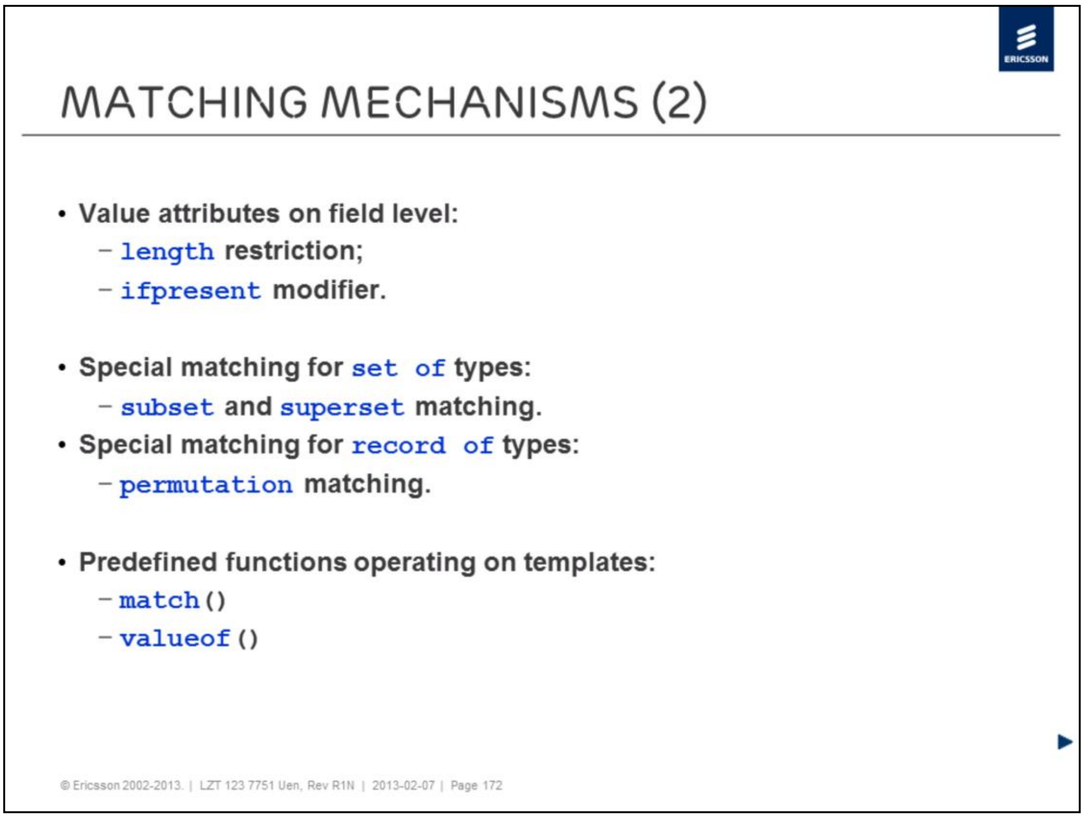
`function regexp(`*<input-string>*, *<regexp>*, *<group-number>*`)`
`return` *<type of input-string>*`;`

- **returns a substring of *<input-string>*, which is the content of (*<group-number>* + 1)th group matching the *<regexp>***
- ***<input-string>* type can be any (`universal`) `charstring`**
- **the type of returned value equals to the type of the input string**

```
control {
 var charstring v_string := ”0036 (1) 737-7698”;
 var charstring v_regexp :=
       ”0036 #(,)\((\d#(1,))\) #(,)[\d-]#(1,)”;
 var charstring v_result := regexp(v_string, v_regexp, 0);
}// v_result contains the number in parentheses, i.e. 1
```

The function is used to extract a substring from the input string (on the slide: v_string). It is used mainly with textual protocols.

The substring to be extracted is the one matching the regular expression (on the slide: v_regexp). The last argument of the function (on the slide: 0) denotes the cardinal number of the group in the regexp, 0 being the first match. A group is enclosed in parentheses, where the first parenthesis must not be preceded by a '#' or a '\'.

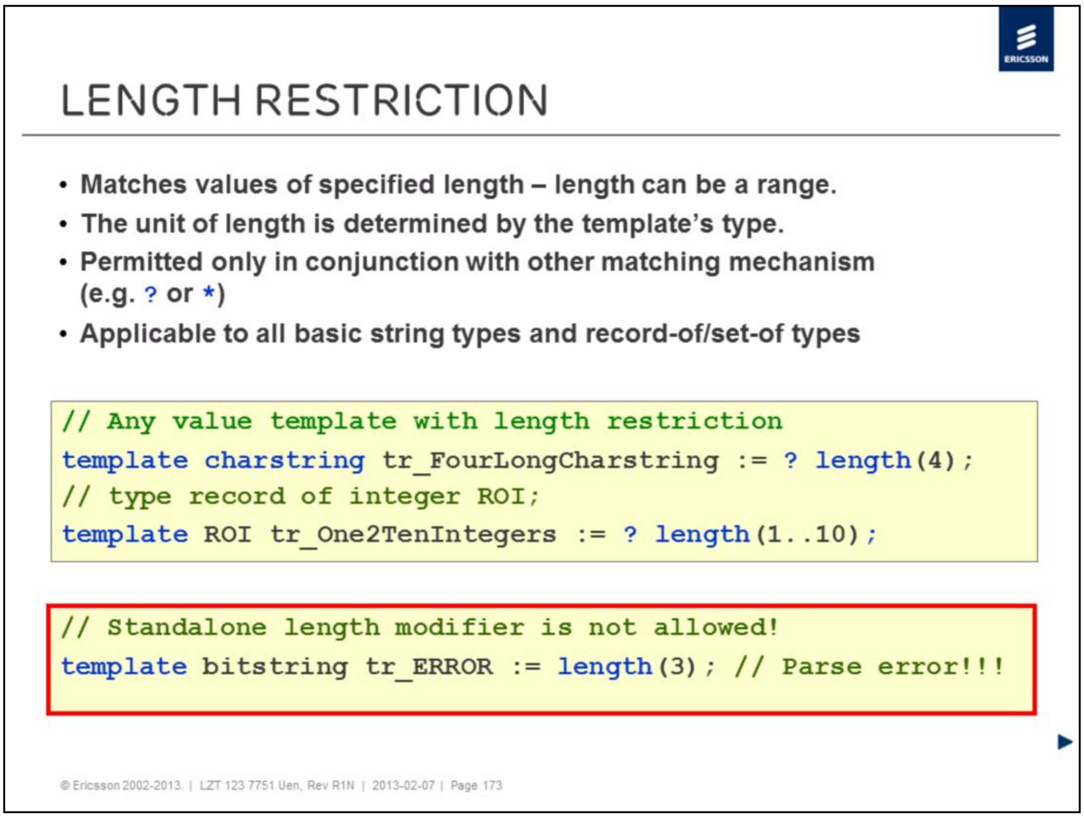


MATCHING MECHANISMS (2)

- **Value attributes on field level:**
  - `length` **restriction;**
  - `ifpresent` **modifier.**

- **Special matching for** `set of` **types:**
  - `subset` **and** `superset` **matching.**
- **Special matching for** `record of` **types:**
  - `permutation` **matching.**

- **Predefined functions operating on templates:**
  - `match()`
  - `valueof()`



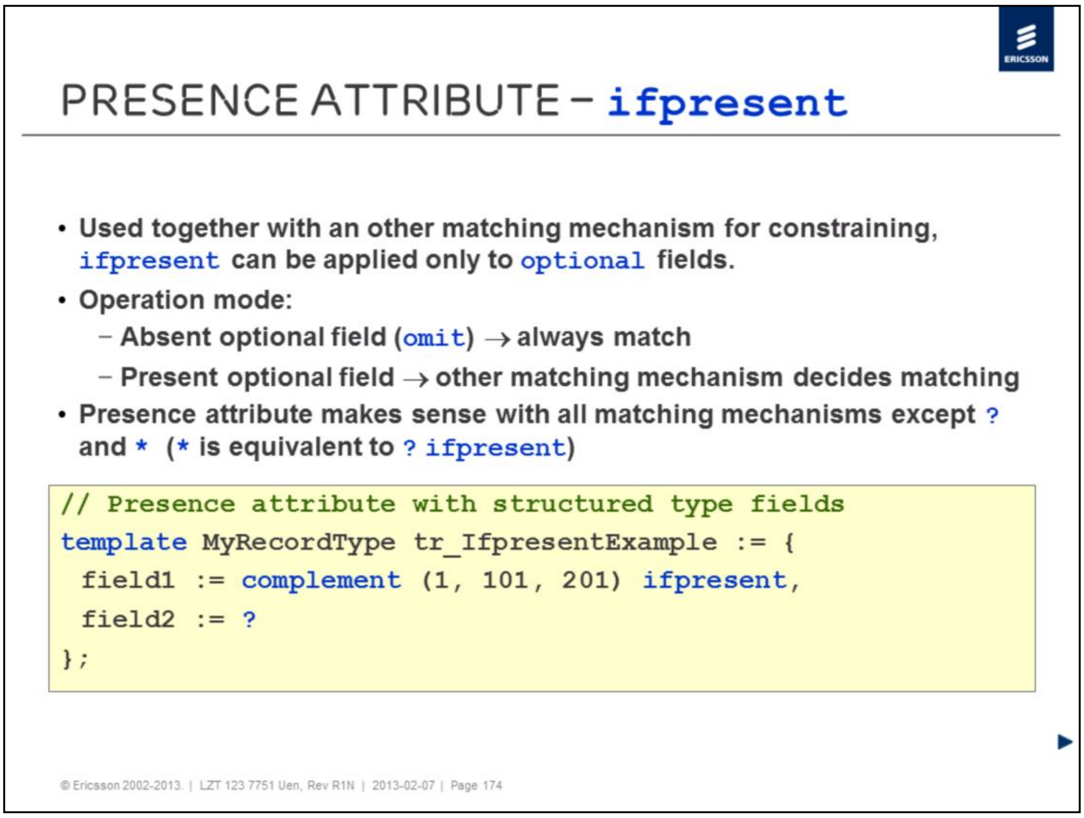
LENGTH RESTRICTION

- Matches values of specified length – length can be a range.
- The unit of length is determined by the template's type.
- Permitted only in conjunction with other matching mechanism (e.g. ? or *)
- Applicable to all basic string types and record-of/set-of types

```
// Any value template with length restriction
template charstring tr_FourLongCharstring := ? length(4);
// type record of integer ROI;
template ROI tr_One2TenIntegers := ? length(1..10);
```

```
// Standalone length modifier is not allowed!
template bitstring tr_ERROR := length(3); // Parse error!!!
```

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.



PRESENCE ATTRIBUTE – `ifpresent`

- **Used together with an other matching mechanism for constraining, `ifpresent` can be applied only to `optional` fields.**
- **Operation mode:**
  - **Absent optional field (`omit`) → always match**
  - **Present optional field → other matching mechanism decides matching**
- **Presence attribute makes sense with all matching mechanisms except `?` and `*` (`*` is equivalent to `? ifpresent`)**

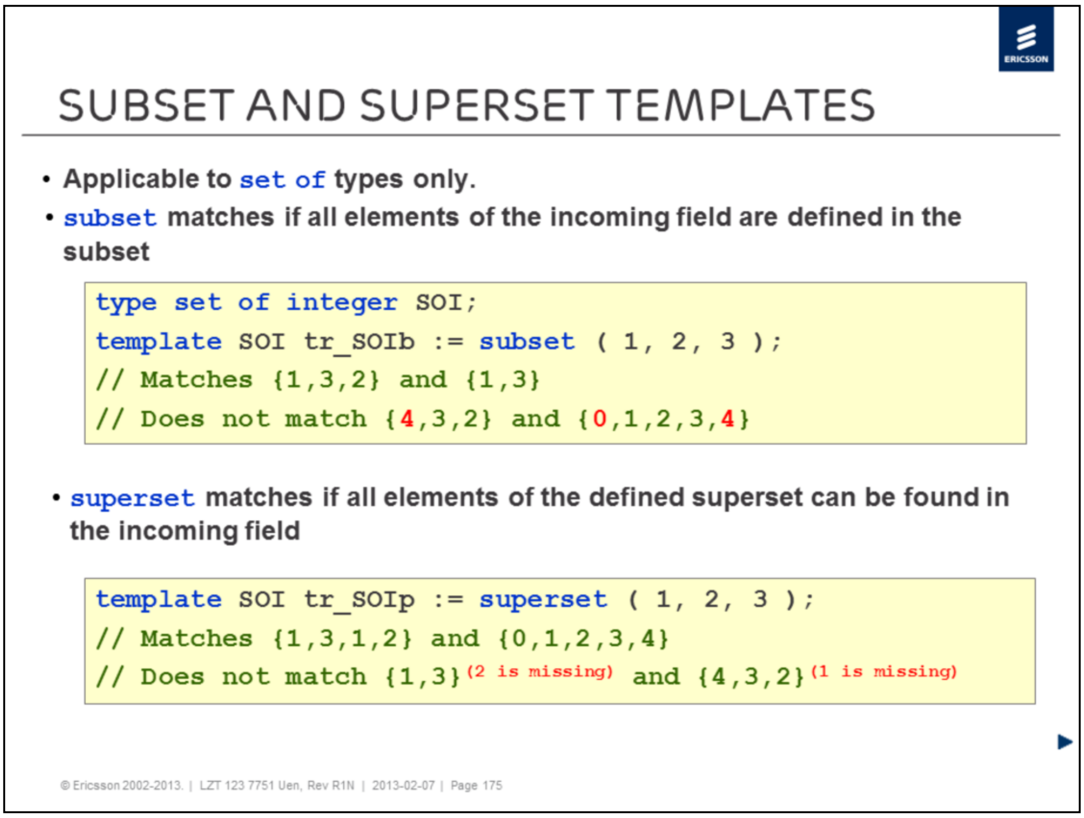
```
// Presence attribute with structured type fields
template MyRecordType tr_IfpresentExample := {
 field1 := complement (1, 101, 201) ifpresent,
 field2 := ?
};
```

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.

Not to be confused with the predefined function ispresent() which checks whether an optional field is present in the actual instance of the referenced data object.



SUBSET AND SUPERSET TEMPLATES

- Applicable to `set of` types only.
- `subset` matches if all elements of the incoming field are defined in the subset

```
type set of integer SOI;
template SOI tr_SOIb := subset ( 1, 2, 3 );
// Matches {1,3,2} and {1,3}
// Does not match {4,3,2} and {0,1,2,3,4}
```

- `superset` matches if all elements of the defined superset can be found in the incoming field

```
template SOI tr_SOIp := superset ( 1, 2, 3 );
// Matches {1,3,1,2} and {0,1,2,3,4}
// Does not match {1,3}(2 is missing) and {4,3,2}(1 is missing)
```

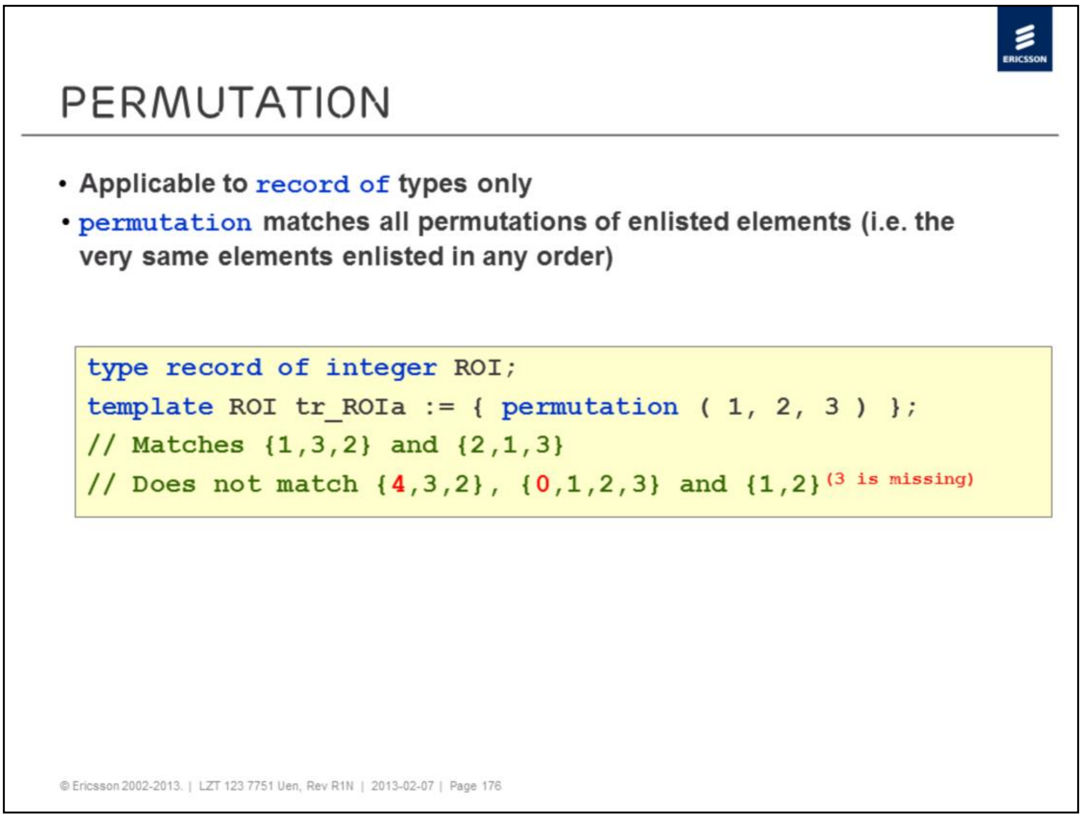
A field that uses SubSet matches the corresponding incoming field if, and only if, the incoming field contains only elements defined within the SubSet, and may contain less.

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.

$\forall$value $\in$ set of : value $\subseteq$ subset: For all value in set of such that value is a subset of subset.

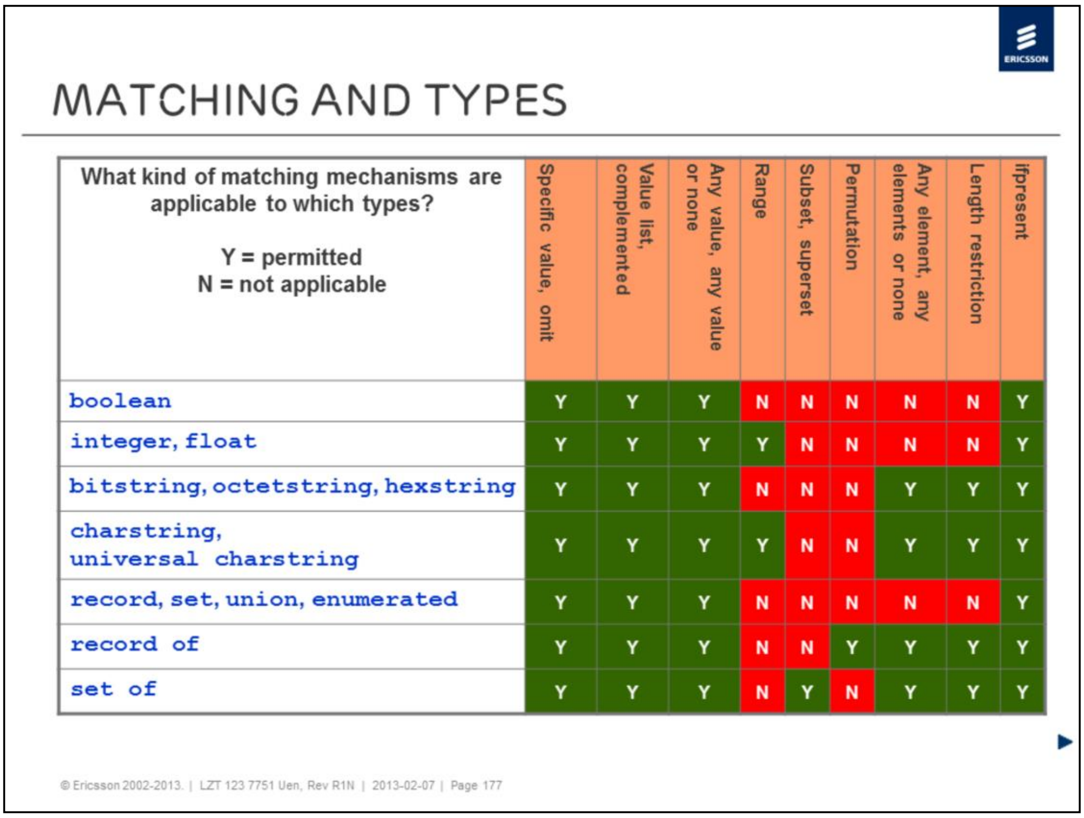
In the superset example, the group {4,3,2} does not match because '1' is missing. The excess '4' would not hinder the match.



PERMUTATION

- Applicable to `record of` types only
- `permutation` matches all permutations of enlisted elements (i.e. the very same elements enlisted in any order)

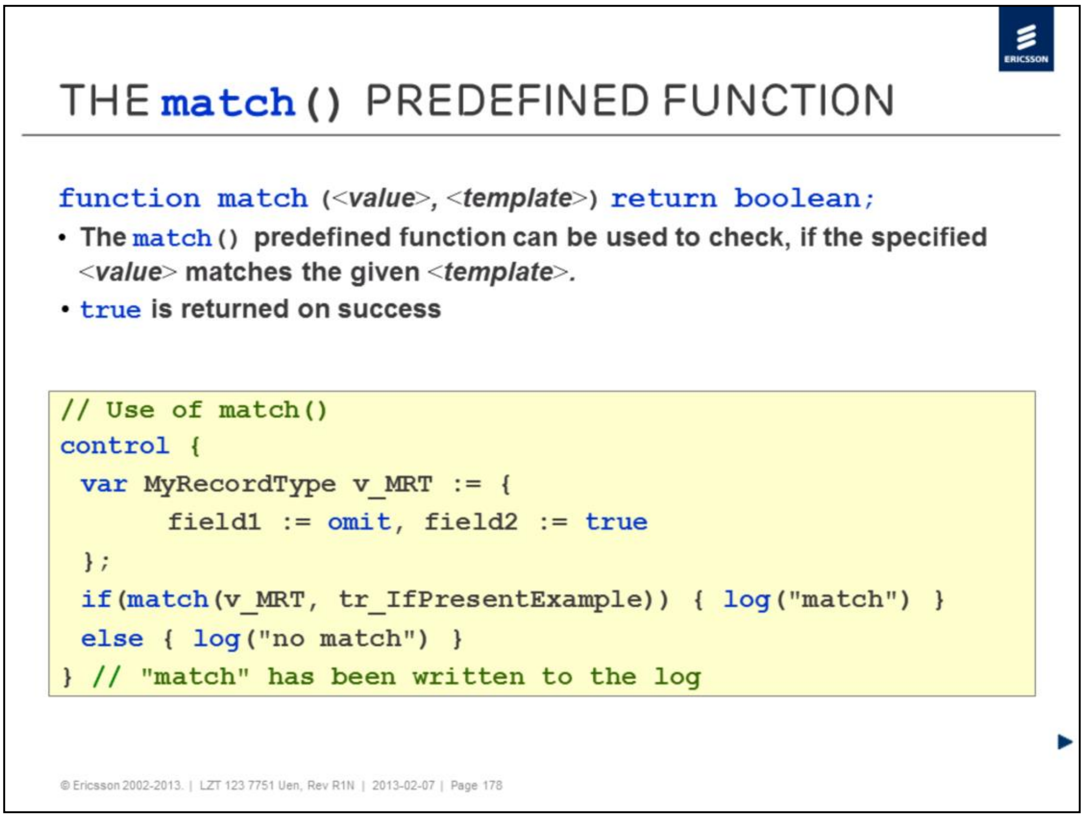
```
type record of integer ROI;
template ROI tr_ROIa := { permutation ( 1, 2, 3 ) };
// Matches {1,3,2} and {2,1,3}
// Does not match {4,3,2}, {0,1,2,3} and {1,2}(3 is missing)
```



MATCHING AND TYPES

What kind of matching mechanisms are applicable to which types? Y = permitted N = not applicable	Specific value, omit	Value list, complemented	Any value, any value or none	Range	Subset, superset	Permutation	Any element, any elements or none	Length restriction	ifpresent
`boolean`	Y	Y	Y	N	N	N	N	N	Y
`integer, float`	Y	Y	Y	Y	N	N	N	N	Y
`bitstring, octetstring, hexstring`	Y	Y	Y	N	N	N	Y	Y	Y
`charstring, universal charstring`	Y	Y	Y	Y	N	N	Y	Y	Y
`record, set, union, enumerated`	Y	Y	Y	N	N	N	N	N	Y
`record of`	Y	Y	Y	N	N	Y	Y	Y	Y
`set of`	Y	Y	Y	N	Y	N	Y	Y	Y

Specific value template, mentioned in the first column, 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. Thus, it cannot be regarded as a veritable matching mechanism, as it only accepts a fixed value.



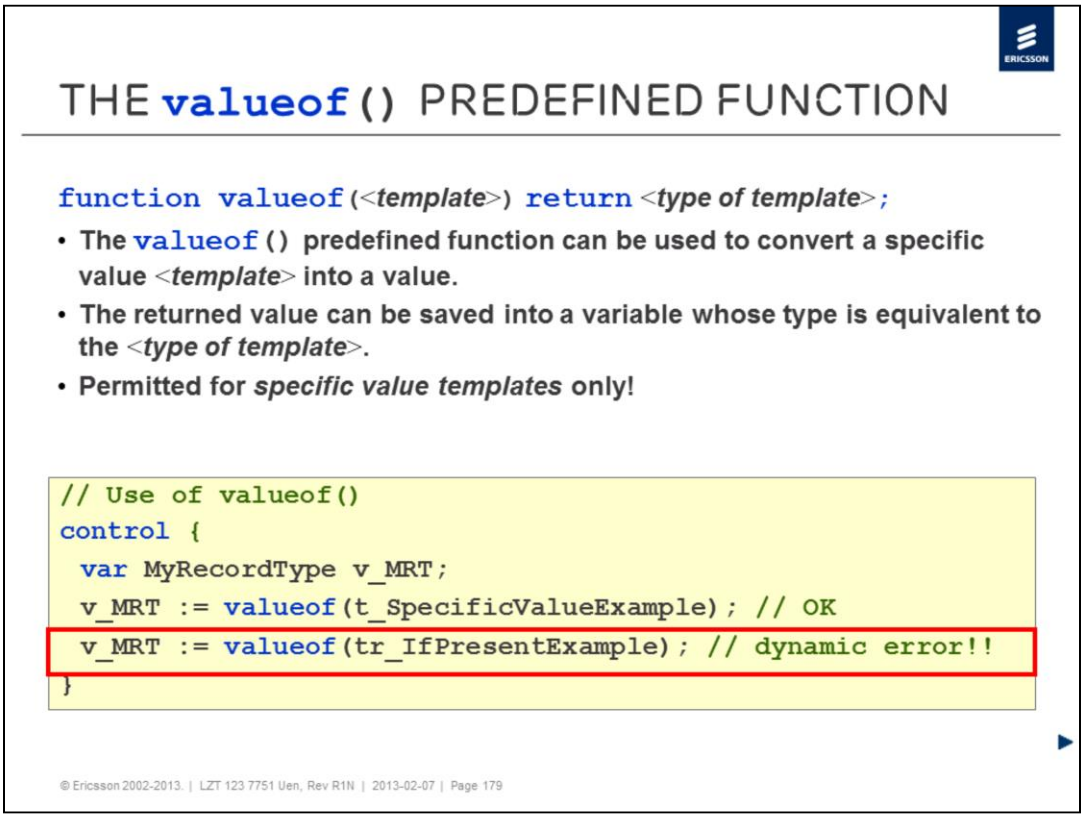
THE `match()` PREDEFINED FUNCTION

`function match (<value>, <template>) return boolean;`

- The `match()` predefined function can be used to check, if the specified <*value*> matches the given <*template*>.
- `true` is returned on success

```
// Use of match()
control {
 var MyRecordType v_MRT := {
       field1 := omit, field2 := true
 };
 if(match(v_MRT, tr_IfPresentExample)) { log("match") }
 else { log("no match") }
} // "match" has been written to the log
```

The function can be interpreted as an extended 'equality' operation. It compares the value of a variable with a template and returns 'true' if the template matches the value of the variable as it is the case in the example on the slide.



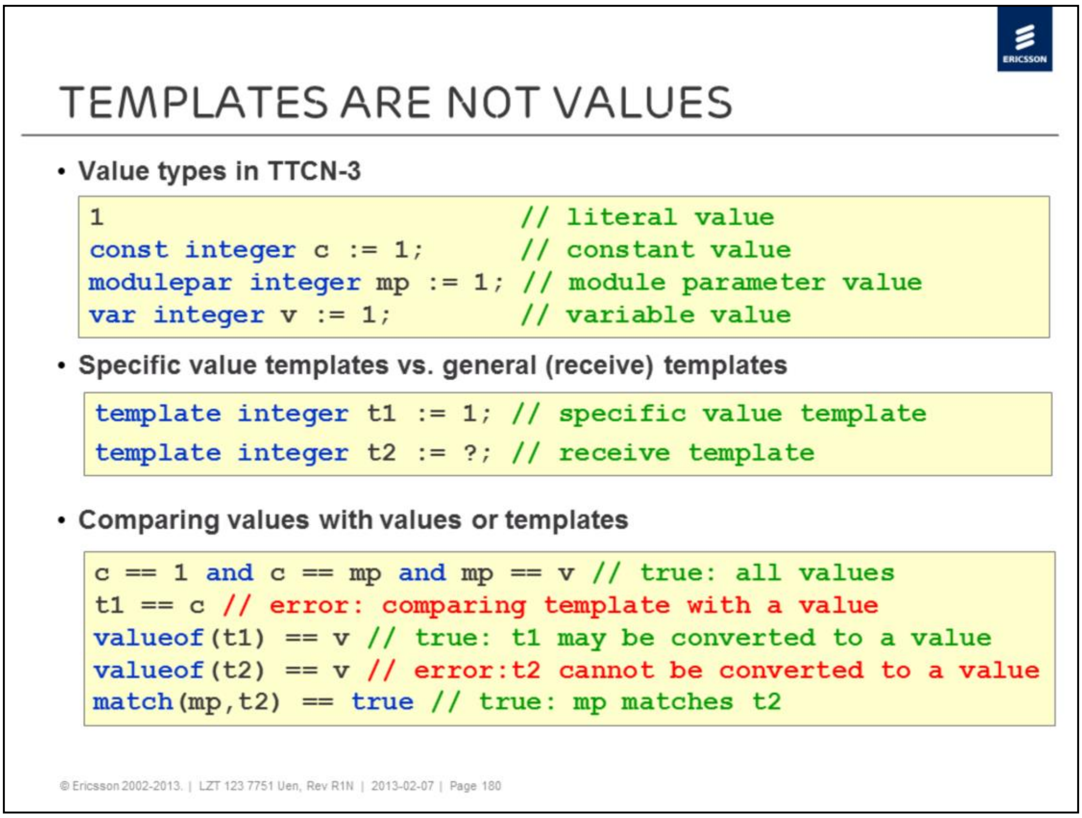
THE `valueof()` PREDEFINED FUNCTION

`function valueof(`<*template*>`) return` <*type of template*>`;`

- **The `valueof()` predefined function can be used to convert a specific value <*template*> into a value.**
- **The returned value can be saved into a variable whose type is equivalent to the <*type of template*>.**
- **Permitted for *specific value templates* only!**

```
// Use of valueof()
control {
 var MyRecordType v_MRT;
 v_MRT := valueof(t_SpecificValueExample); // OK
 v_MRT := valueof(tr_IfPresentExample); // dynamic error!!
}
```

Specific values template means that each field of the template shall resolve to a single value.



TEMPLATES ARE NOT VALUES

- **Value types in TTCN-3**

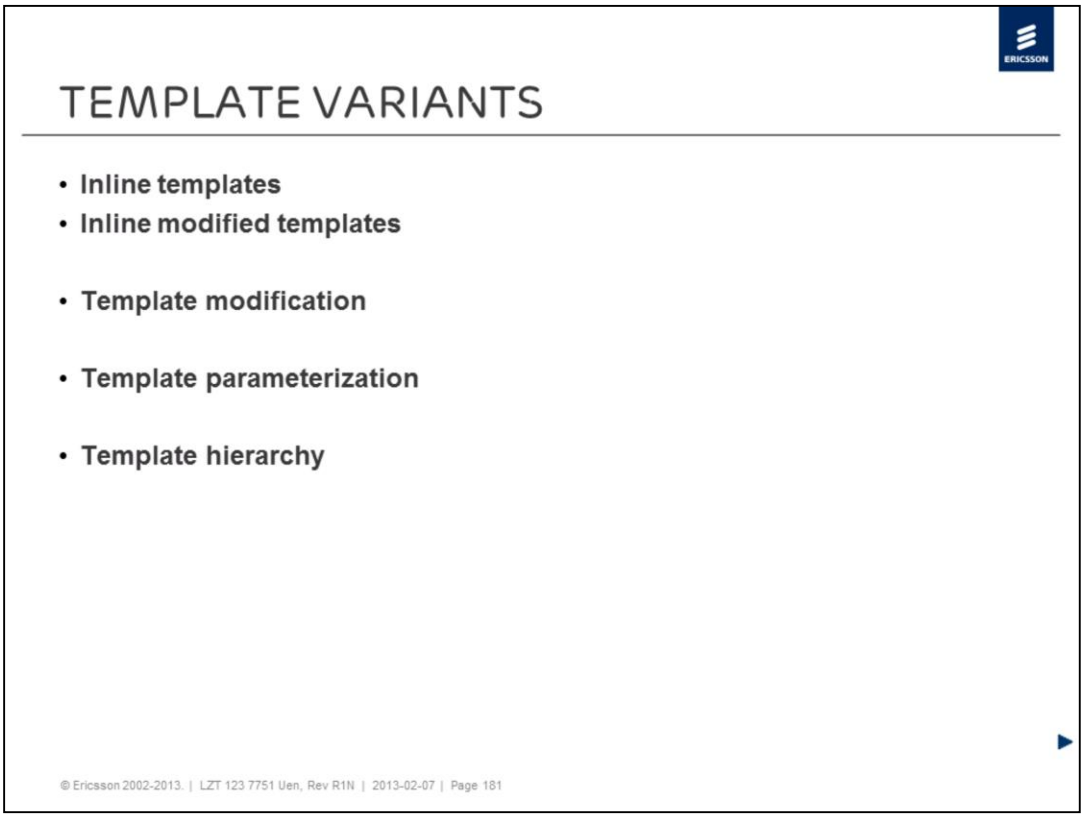
```
1                          // literal value
const integer c := 1;      // constant value
modulepar integer mp := 1; // module parameter value
var integer v := 1;        // variable value
```

- **Specific value templates vs. general (receive) templates**

```
template integer t1 := 1; // specific value template
template integer t2 := ?; // receive template
```

- **Comparing values with values or templates**

```
c == 1 and c == mp and mp == v // true: all values
t1 == c // error: comparing template with a value
valueof(t1) == v // true: t1 may be converted to a value
valueof(t2) == v // error:t2 cannot be converted to a value
match(mp,t2) == true // true: mp matches t2
```



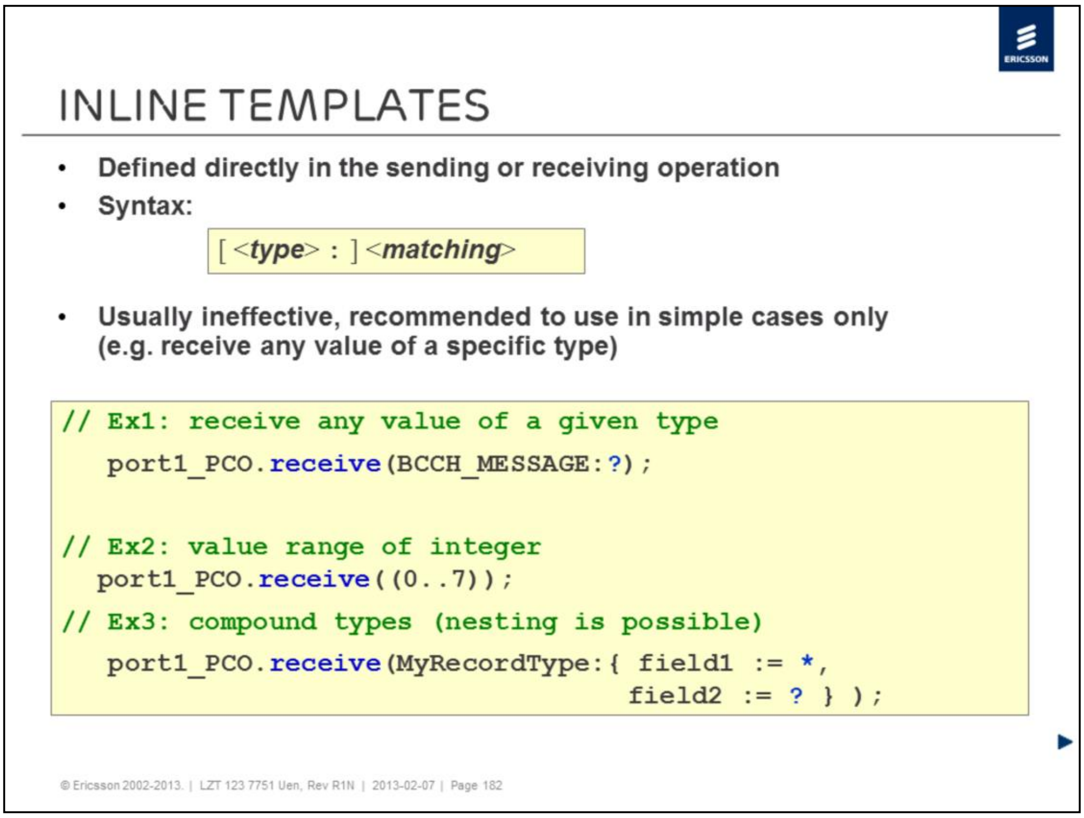
TEMPLATE VARIANTS

- Inline templates
- Inline modified templates

- Template modification

- Template parameterization

- Template hierarchy



INLINE TEMPLATES

- **Defined directly in the sending or receiving operation**
- **Syntax:**

  [<***type***> :] <***matching***>

- **Usually ineffective, recommended to use in simple cases only (e.g. receive any value of a specific type)**

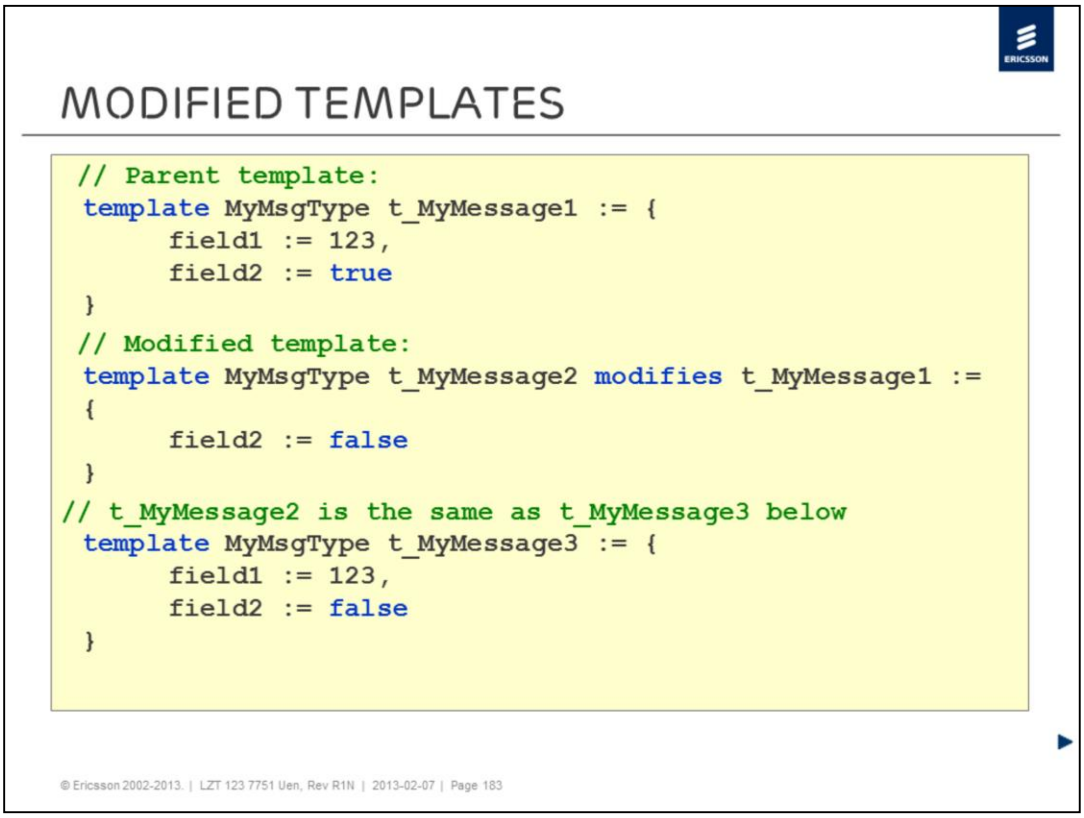
```
// Ex1: receive any value of a given type
   port1_PCO.receive(BCCH_MESSAGE:?);


// Ex2: value range of integer
  port1_PCO.receive((0..7));
// Ex3: compound types (nesting is possible)
   port1_PCO.receive(MyRecordType:{ field1 := *,
                                    field2 := ? } );
```

Inline templates do not have identifiers and are valid for that single operation. Inline templates must not have parameters.

The type identifier may be omitted when the value unambiguously identifies the type, see Ex2 on the slide.

The typical use is depicted in Ex1. It is used mainly for value redirect and sender redirect.



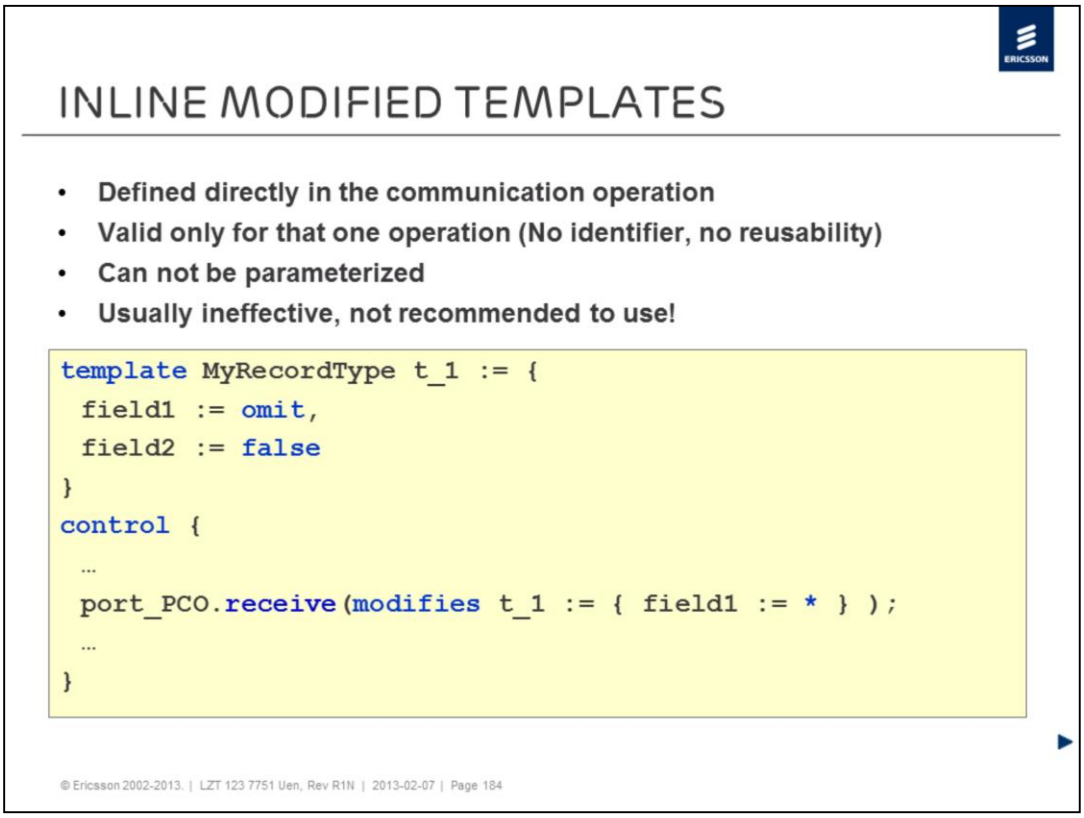
MODIFIED TEMPLATES

```
 // Parent template:
  template MyMsgType t_MyMessage1 := {
        field1 := 123,
        field2 := true
  }
 // Modified template:
  template MyMsgType t_MyMessage2 modifies t_MyMessage1 :=
  {
        field2 := false
  }
// t_MyMessage2 is the same as t_MyMessage3 below
  template MyMsgType t_MyMessage3 := {
        field1 := 123,
        field2 := false
  }
```

Instead of specifying a new template, it is possible to modify an existing template when only a few fields change.

The modifies keyword denotes the parent template from which the new, or modified template shall be derived.

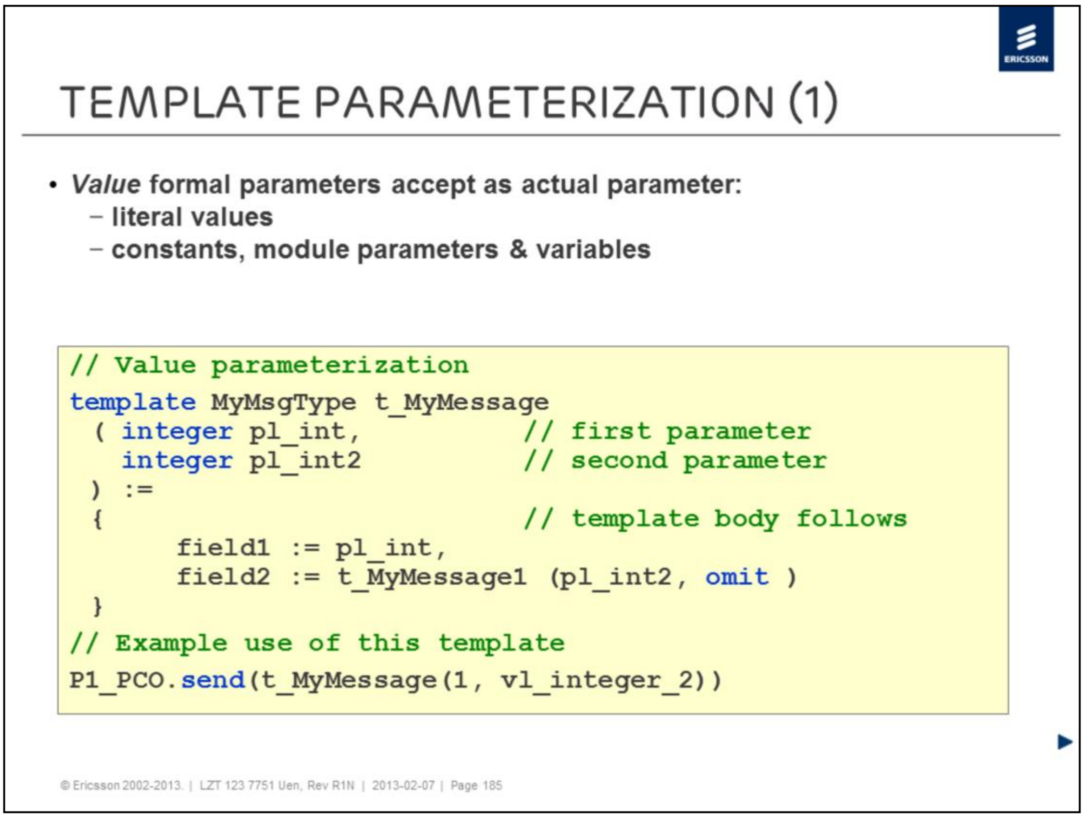
This parent template may be either an original template or a modified template.



INLINE MODIFIED TEMPLATES

- Defined directly in the communication operation
- Valid only for that one operation (No identifier, no reusability)
- Can not be parameterized
- Usually ineffective, not recommended to use!

```
template MyRecordType t_1 := {
 field1 := omit,
 field2 := false
}
control {
 …
 port_PCO.receive(modifies t_1 := { field1 := * } );
 …
}
```



TEMPLATE PARAMETERIZATION (1)

- *Value* formal parameters accept as actual parameter:
  - literal values
  - constants, module parameters & variables

```
// Value parameterization
template MyMsgType t_MyMessage
  ( integer pl_int,             // first parameter
    integer pl_int2             // second parameter
  ) :=
  {                             // template body follows
        field1 := pl_int,
        field2 := t_MyMessage1 (pl_int2, omit )
  }
// Example use of this template
P1_PCO.send(t_MyMessage(1, vl_integer_2))
```

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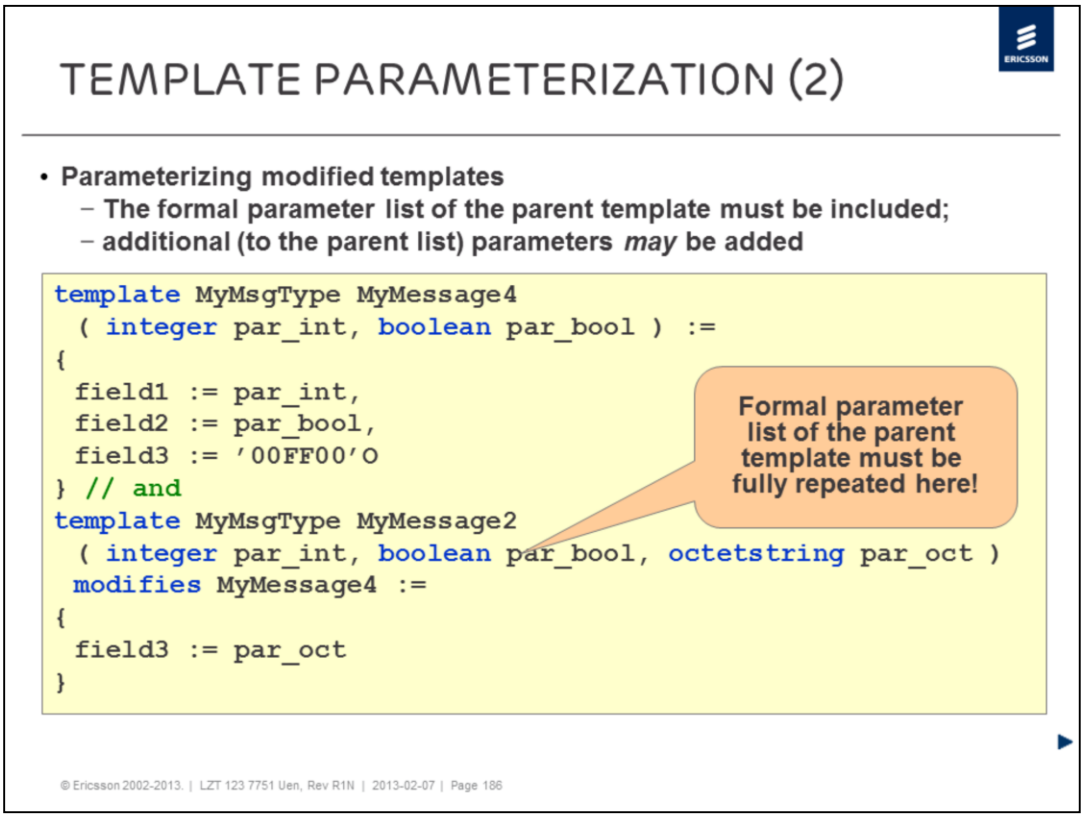
Templates for both sending and receiving operations can be parameterized. On the slide, the first one is appearing. This slide shows the use of value parameters.

The message sent on P1_PCO will have the following structure:

the 1st field is integer, its value equals to 1;
the 2nd field is structured (MyMsgType) and has two subfields:

its 1st subfield is integer, its value is determined by the variable vl_integer_2;
its 2nd subfield is not present.



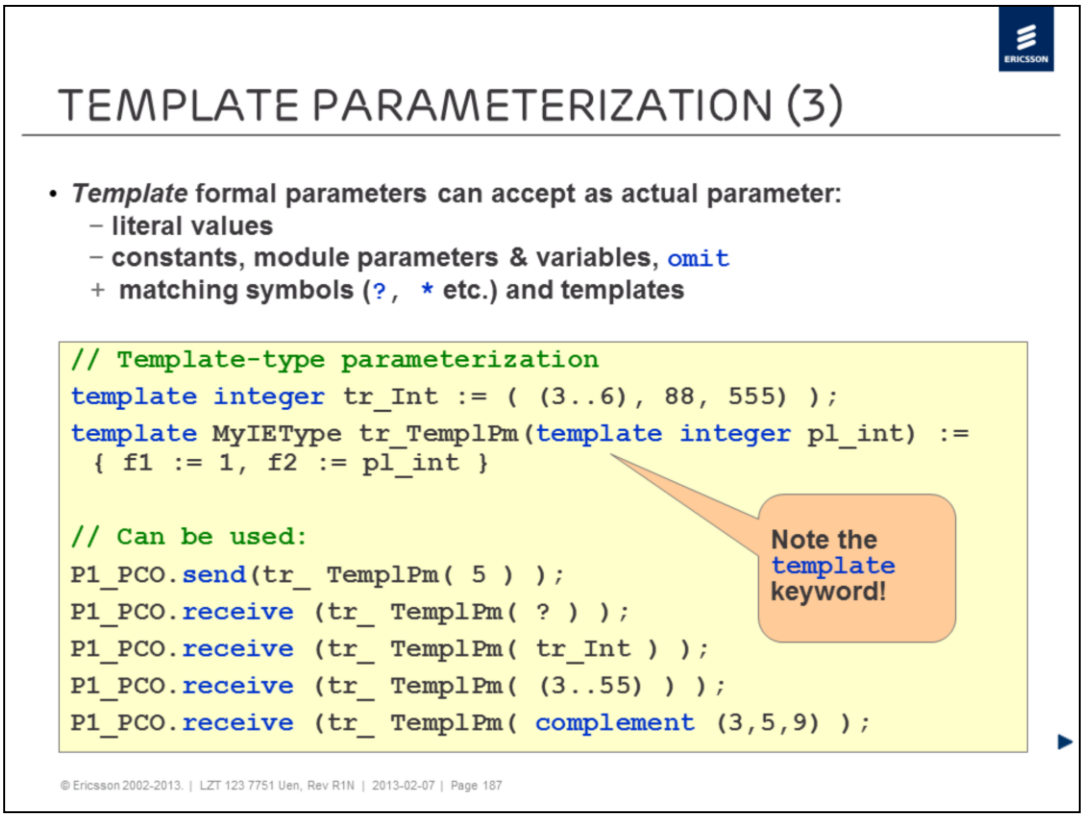
TEMPLATE PARAMETERIZATION (2)

- **Parameterizing modified templates**
  - **The formal parameter list of the parent template must be included;**
  - **additional (to the parent list) parameters *may* be added**

```
template MyMsgType MyMessage4
  ( integer par_int, boolean par_bool ) :=
{
  field1 := par_int,
  field2 := par_bool,
  field3 := ’00FF00’O
} // and
template MyMsgType MyMessage2
  ( integer par_int, boolean par_bool, octetstring par_oct )
  modifies MyMessage4 :=
{
  field3 := par_oct
}
```

Formal parameter list of the parent template must be fully repeated here!

It is not allowed to modify a field, which is parameterized in the parent template. Thus, in the example on the slide field1 and filed2 cannot be modified while field3 can.



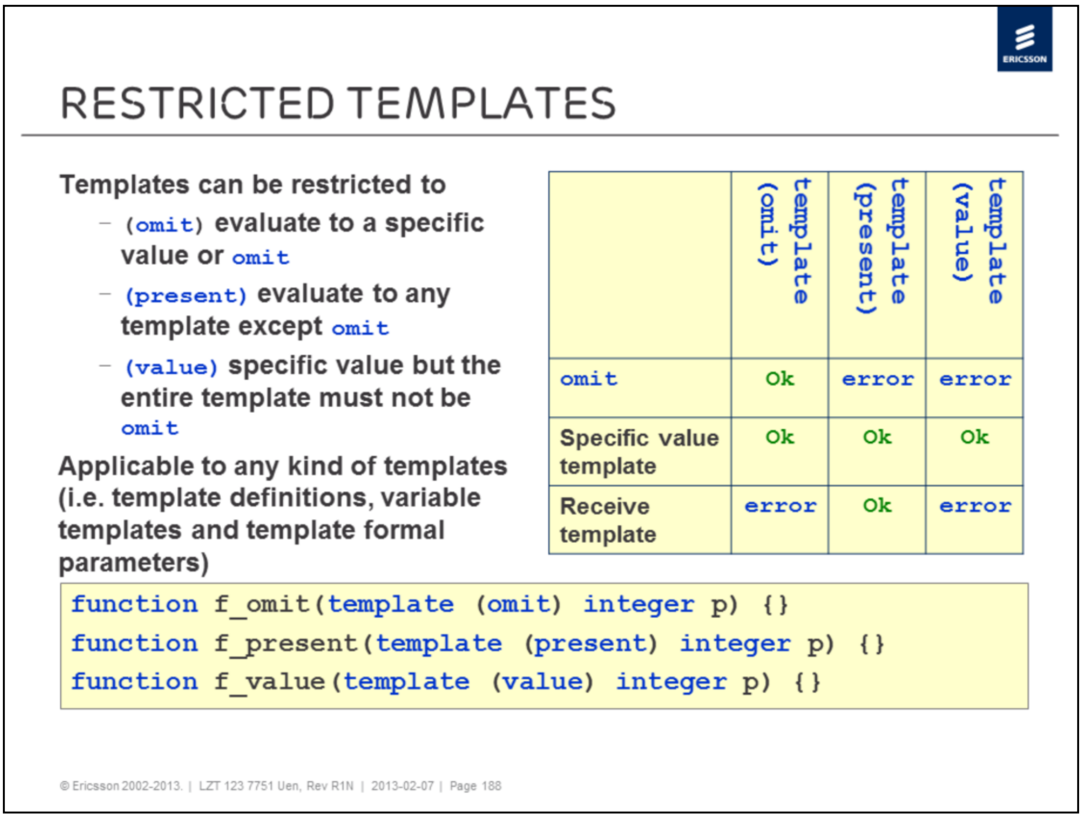
TEMPLATE PARAMETERIZATION (3)

- *Template* formal parameters can accept as actual parameter:
  - literal values
  - constants, module parameters & variables, `omit`
  - \+ matching symbols (`?`, `*` etc.) and templates

```
// Template-type parameterization
template integer tr_Int := ( (3..6), 88, 555) );
template MyIEType tr_TemplPm(template integer pl_int) :=
  { f1 := 1, f2 := pl_int }

// Can be used:
P1_PCO.send(tr_ TemplPm( 5 ) );
P1_PCO.receive (tr_ TemplPm( ? ) );
P1_PCO.receive (tr_ TemplPm( tr_Int ) );
P1_PCO.receive (tr_ TemplPm( (3..55) ) );
P1_PCO.receive (tr_ TemplPm( complement (3,5,9) );
```

Note the `template` keyword!



RESTRICTED TEMPLATES

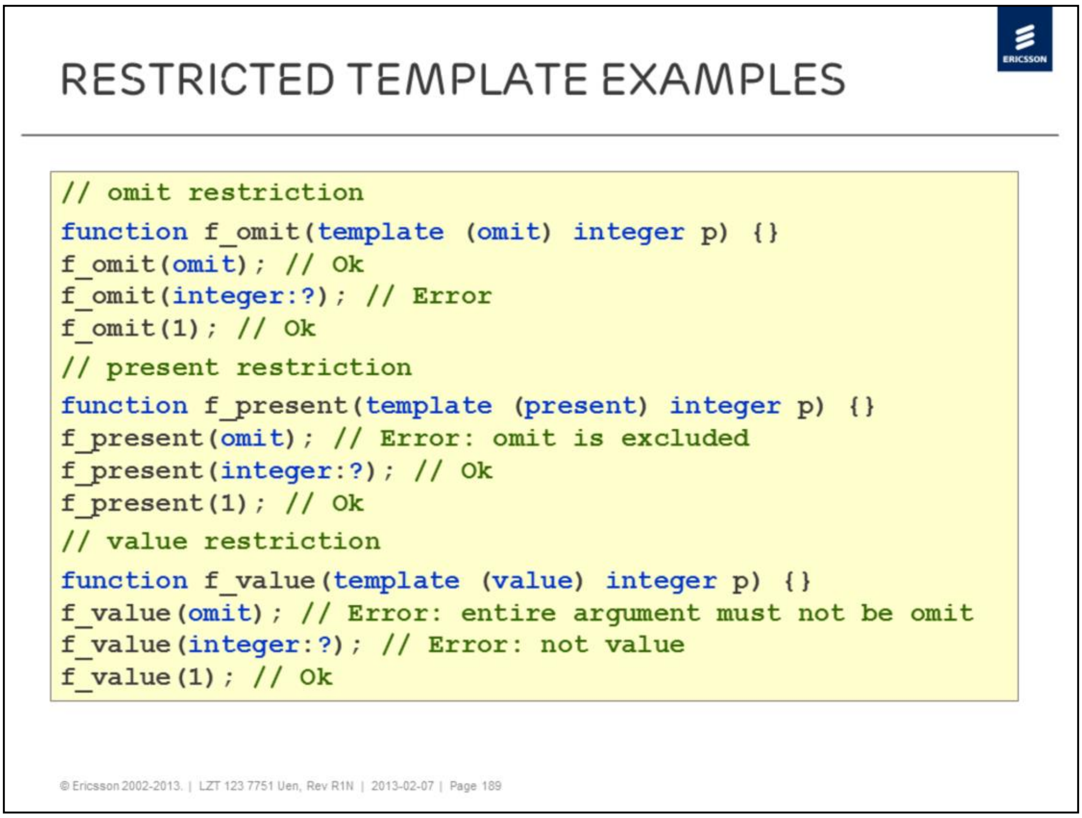
Templates can be restricted to

- `(omit)` evaluate to a specific value or `omit`
- `(present)` evaluate to any template except `omit`
- `(value)` specific value but the entire template must not be `omit`

Applicable to any kind of templates (i.e. template definitions, variable templates and template formal parameters)

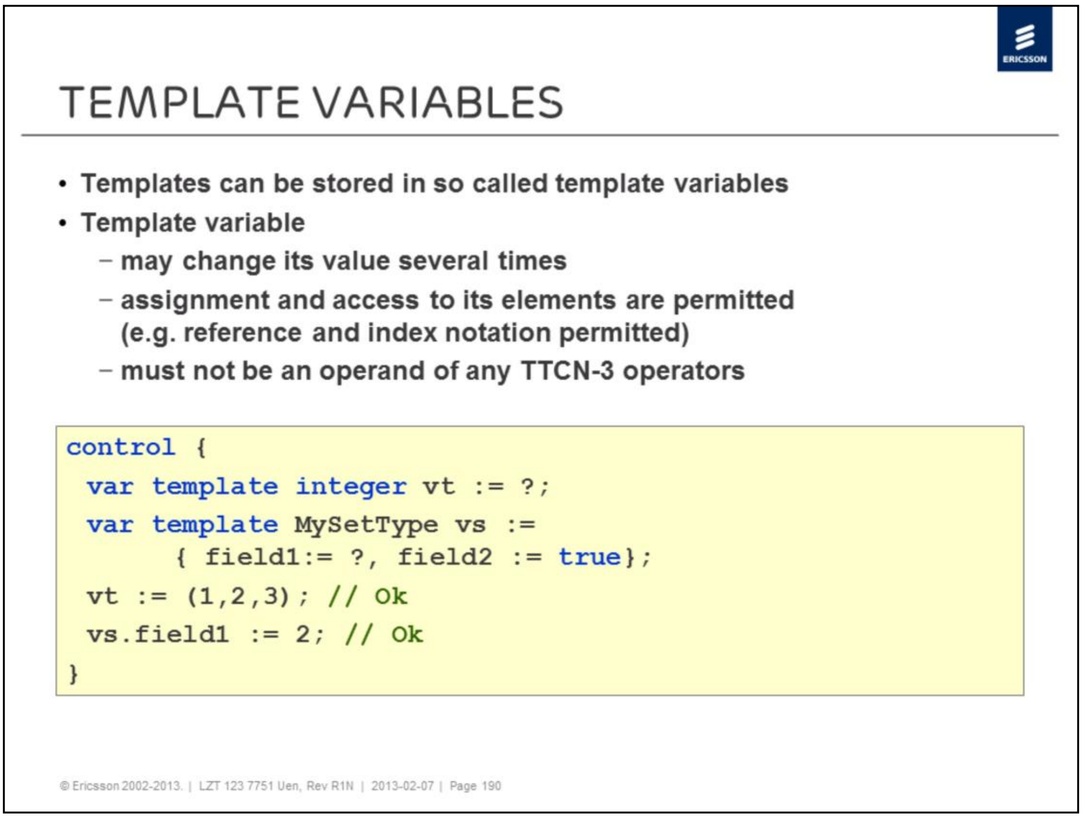
	`template (omit)`	`template (present)`	`template (value)`
`omit`	Ok	error	error
Specific value template	Ok	Ok	Ok
Receive template	error	Ok	error

```
function f_omit(template (omit) integer p) {}
function f_present(template (present) integer p) {}
function f_value(template (value) integer p) {}
```



RESTRICTED TEMPLATE EXAMPLES

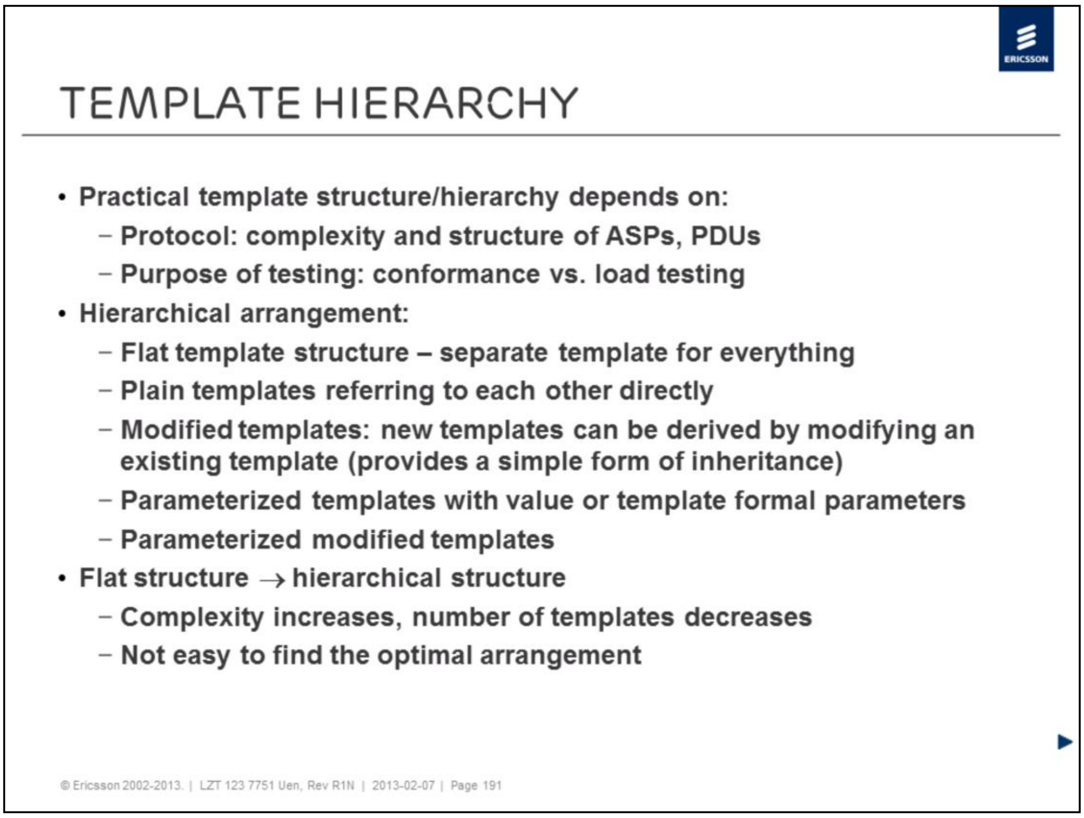
```
// omit restriction
function f_omit(template (omit) integer p) {}
f_omit(omit); // Ok
f_omit(integer:?); // Error
f_omit(1); // Ok
// present restriction
function f_present(template (present) integer p) {}
f_present(omit); // Error: omit is excluded
f_present(integer:?); // Ok
f_present(1); // Ok
// value restriction
function f_value(template (value) integer p) {}
f_value(omit); // Error: entire argument must not be omit
f_value(integer:?); // Error: not value
f_value(1); // Ok
```



TEMPLATE VARIABLES

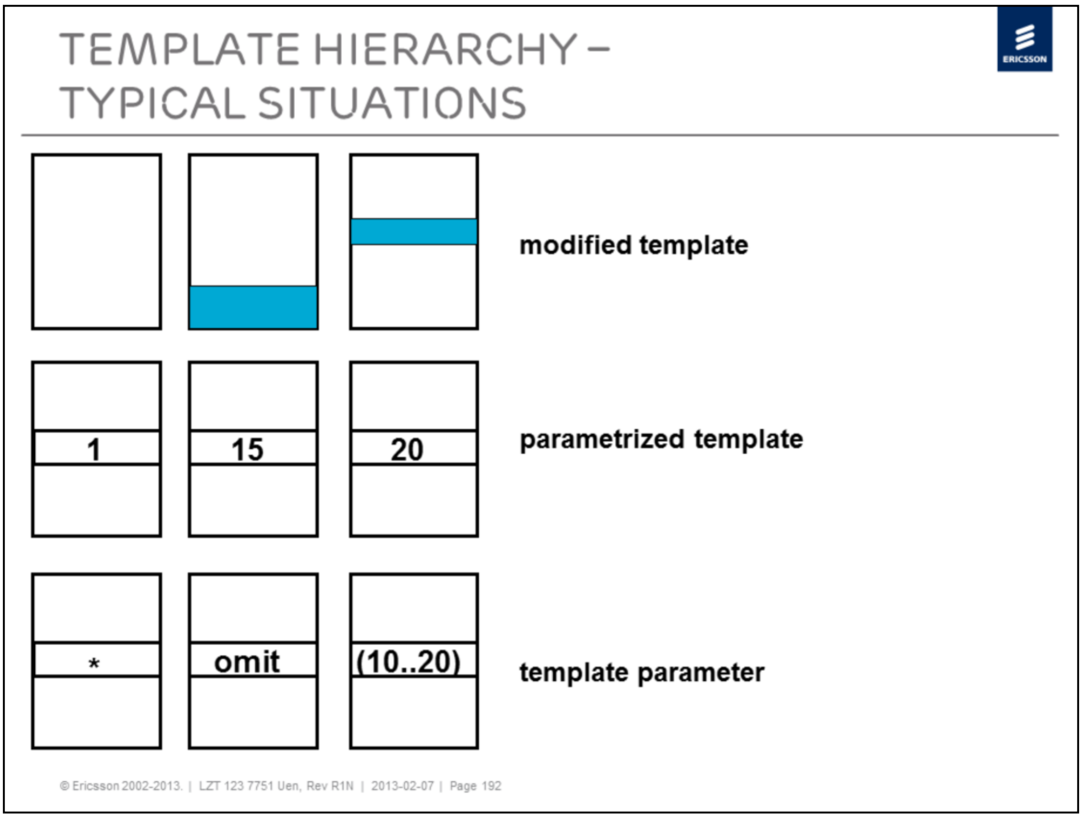
- Templates can be stored in so called template variables
- Template variable
  - may change its value several times
  - assignment and access to its elements are permitted (e.g. reference and index notation permitted)
  - must not be an operand of any TTCN-3 operators

```
control {
 var template integer vt := ?;
 var template MySetType vs :=
       { field1:= ?, field2 := true};
 vt := (1,2,3); // Ok
 vs.field1 := 2; // Ok
}
```



TEMPLATE HIERARCHY

- Practical template structure/hierarchy depends on:
  - Protocol: complexity and structure of ASPs, PDUs
  - Purpose of testing: conformance vs. load testing
- Hierarchical arrangement:
  - Flat template structure – separate template for everything
  - Plain templates referring to each other directly
  - Modified templates: new templates can be derived by modifying an existing template (provides a simple form of inheritance)
  - Parameterized templates with value or template formal parameters
  - Parameterized modified templates
- Flat structure → hierarchical structure
  - Complexity increases, number of templates decreases
  - Not easy to find the optimal arrangement



TEMPLATE HIERARCHY – TYPICAL SITUATIONS

modified template

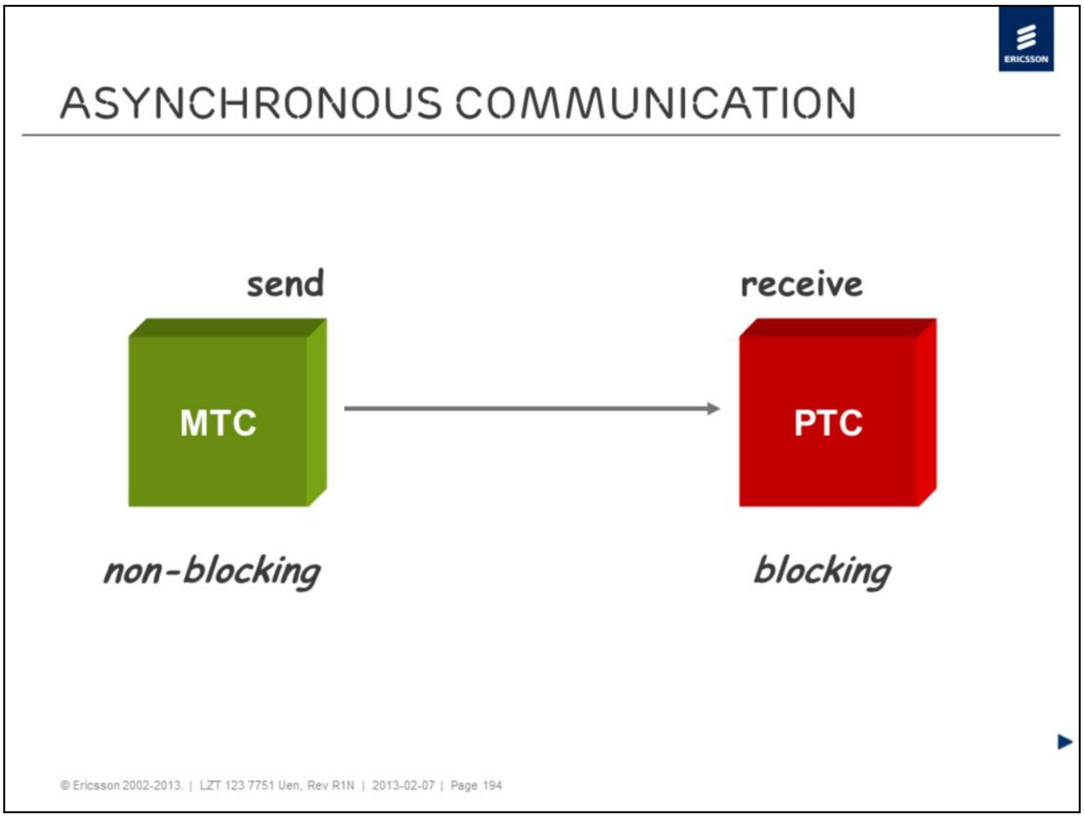
parametrized template

template parameter

XIII. ABSTRACT COMMUNICATION OPERATIONS

ASYNCHRONOUS COMMUNICATION
SEND, RECEIVE, CHECK AND TRIGGER OPERATIONS
PORT CONTROL OPERATIONS (START, STOP, CLEAR)
VALUE AND SENDER REDIRECTS
SEND TO AND RECEIVE FROM OPERATIONS
SYNCHRONOUS COMMUNICATION

CONTENTS



ASYNCHRONOUS COMMUNICATION

send

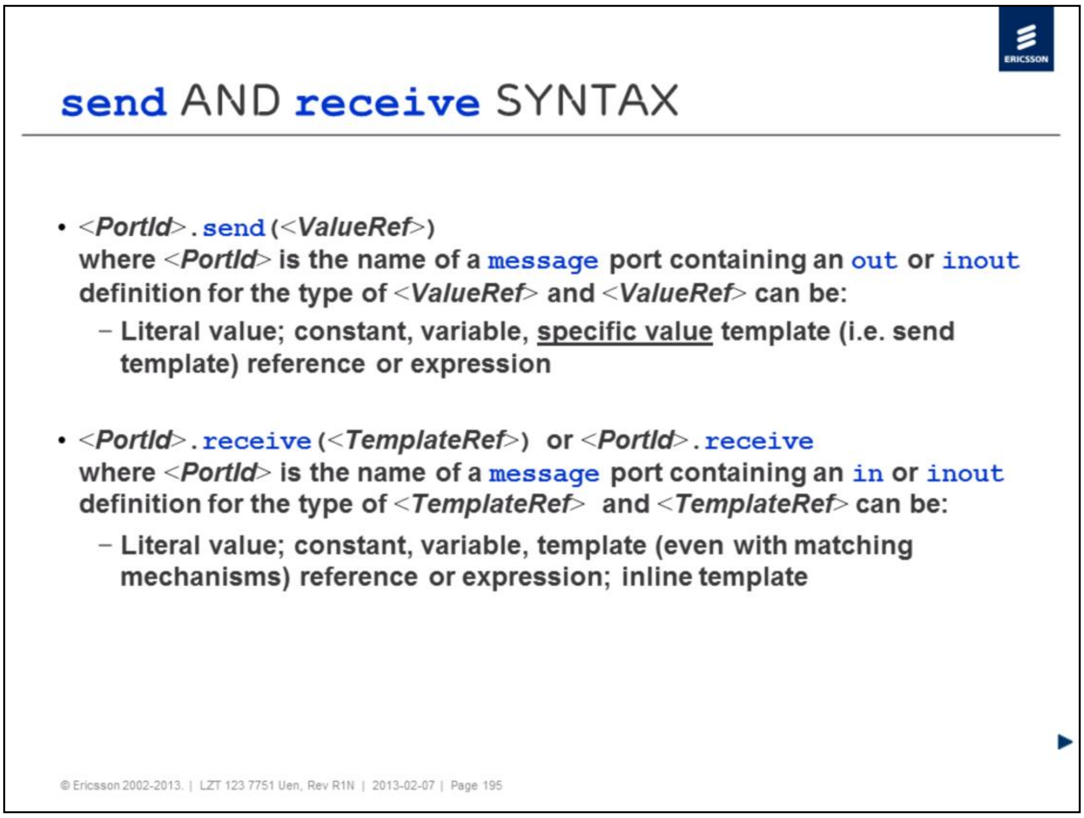
MTC

receive

PTC

non-blocking

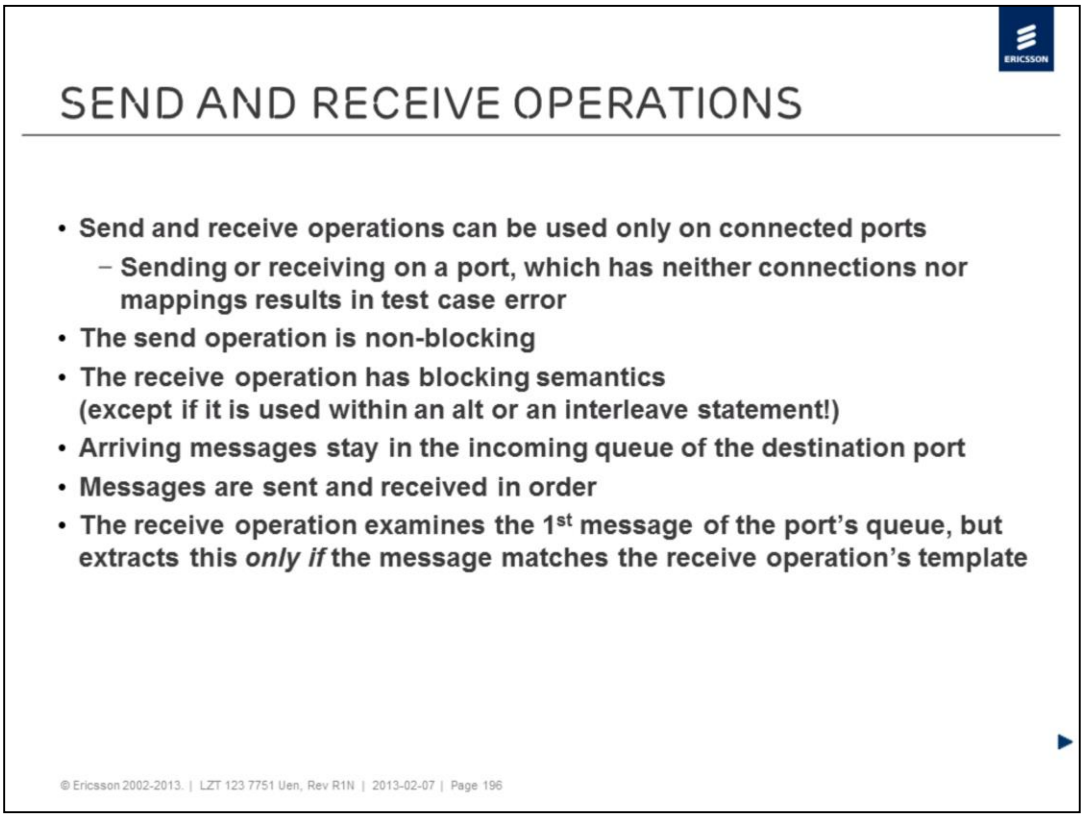
blocking



`send` AND `receive` SYNTAX

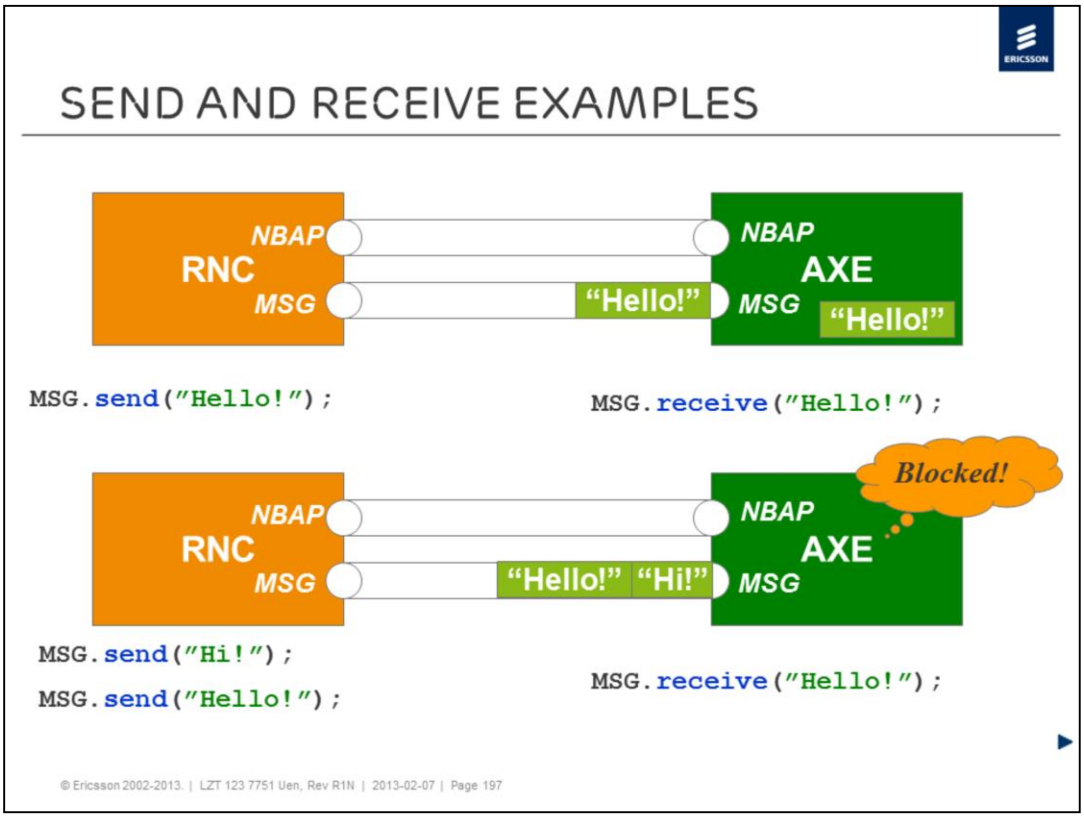
- <*PortId*>`.send(`<*ValueRef*>`)`
  where <*PortId*> is the name of a `message` port containing an `out` or `inout` definition for the type of <*ValueRef*> and <*ValueRef*> can be:
  - Literal value; constant, variable, specific value template (i.e. send template) reference or expression

- <*PortId*>`.receive(`<*TemplateRef*>`)` or <*PortId*>`.receive`
  where <*PortId*> is the name of a `message` port containing an `in` or `inout` definition for the type of <*TemplateRef*> and <*TemplateRef*> can be:
  - Literal value; constant, variable, template (even with matching mechanisms) reference or expression; inline template



SEND AND RECEIVE OPERATIONS

- Send and receive operations can be used only on connected ports
  - Sending or receiving on a port, which has neither connections nor mappings results in test case error
- The send operation is non-blocking
- The receive operation has blocking semantics (except if it is used within an alt or an interleave statement!)
- Arriving messages stay in the incoming queue of the destination port
- Messages are sent and received in order
- The receive operation examines the 1st message of the port's queue, but extracts this *only if* the message matches the receive operation's template



SEND AND RECEIVE EXAMPLES

```
MSG.send(”Hello!”);
```

```
MSG.receive(”Hello!”);
```

```
MSG.send(”Hi!”);
MSG.send(”Hello!”);
```

```
MSG.receive(”Hello!”);
```

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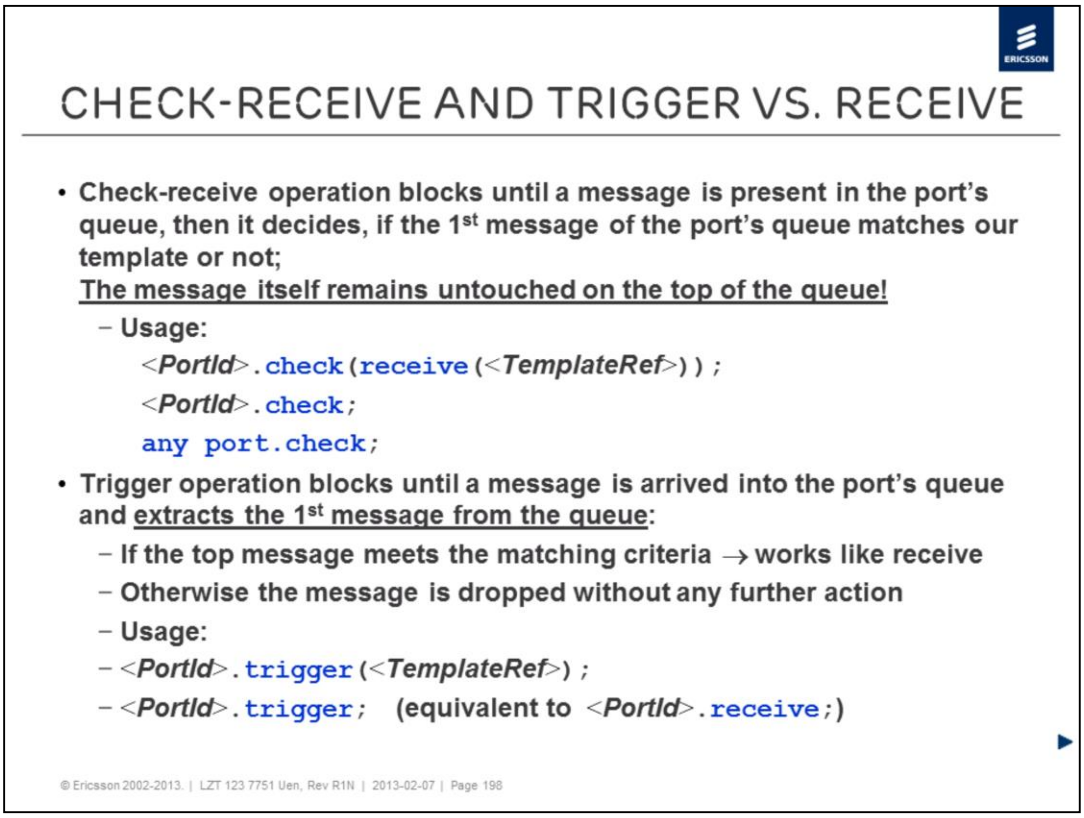
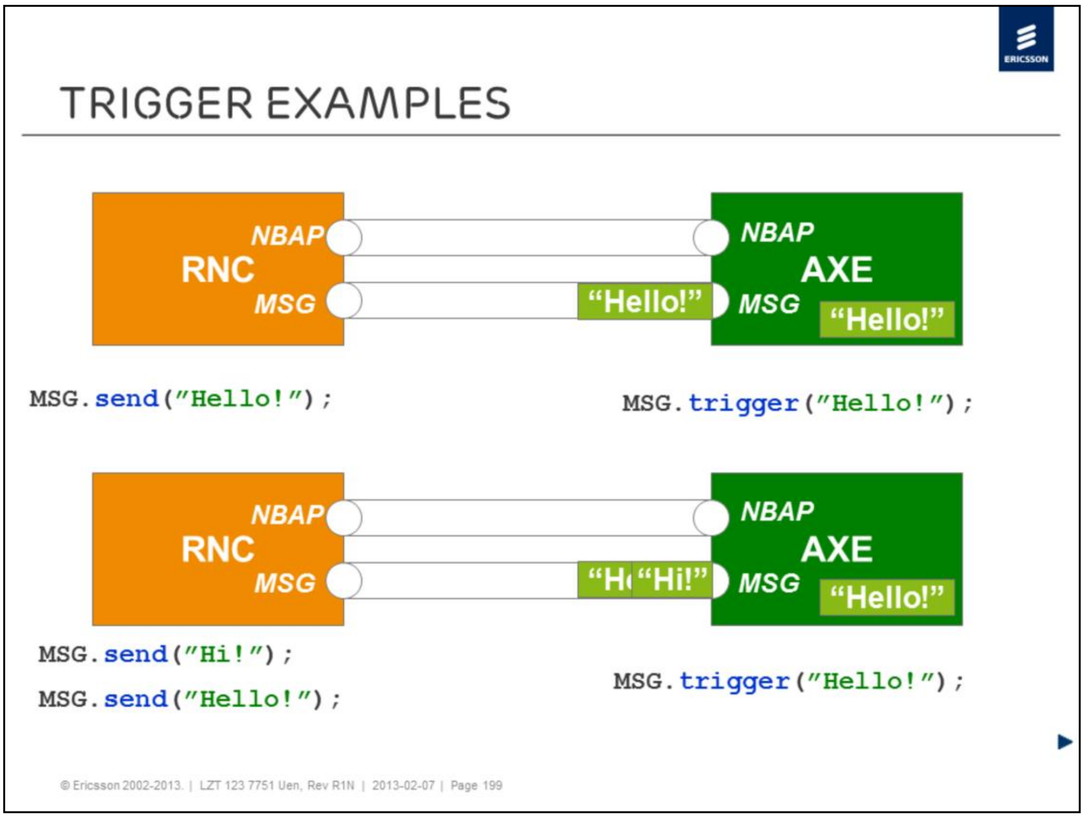


CHECK-RECEIVE AND TRIGGER VS. RECEIVE

- Check-receive operation blocks until a message is present in the port's queue, then it decides, if the 1st message of the port's queue matches our template or not;
  <u>The message itself remains untouched on the top of the queue!</u>
  - Usage:
    - `<PortId>.check(receive(<TemplateRef>));`
    - `<PortId>.check;`
    - `any port.check;`
- Trigger operation blocks until a message is arrived into the port's queue and <u>extracts the 1st message from the queue</u>:
  - If the top message meets the matching criteria → works like receive
  - Otherwise the message is dropped without any further action
  - Usage:
  - `<PortId>.trigger(<TemplateRef>);`
  - `<PortId>.trigger;` (equivalent to `<PortId>.receive;`)

`<PortId>.check;` checks if there is anything waiting in the queue



TRIGGER EXAMPLES

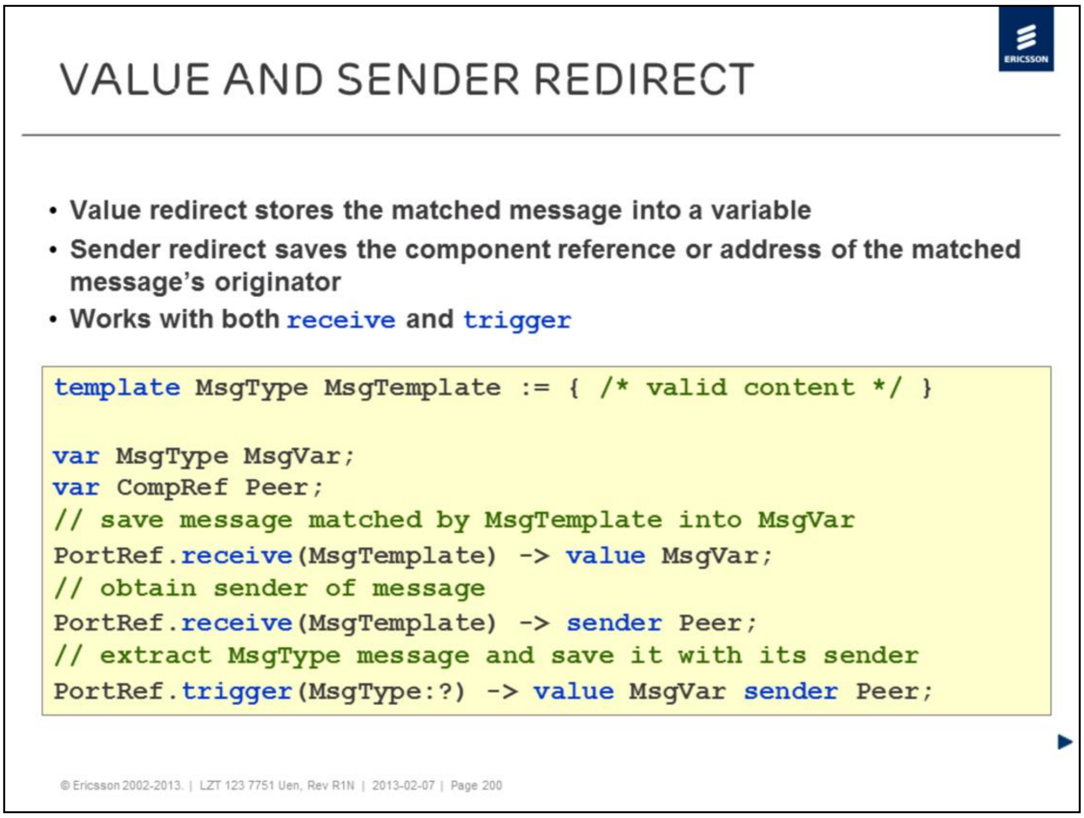
`MSG.send(”Hello!”);`

`MSG.trigger(”Hello!”);`

`MSG.send(”Hi!”);`

`MSG.send(”Hello!”);`

`MSG.trigger(”Hello!”);`

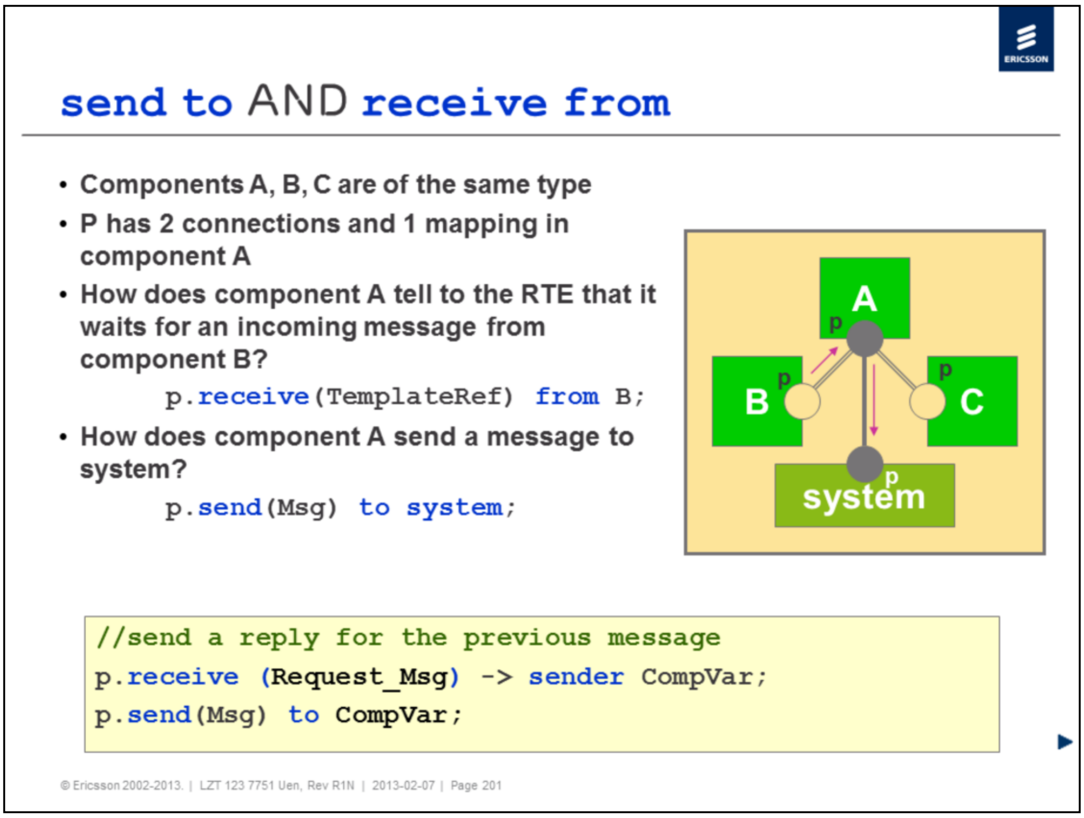


VALUE AND SENDER REDIRECT

- Value redirect stores the matched message into a variable
- Sender redirect saves the component reference or address of the matched message’s originator
- Works with both `receive` and `trigger`

```
template MsgType MsgTemplate := { /* valid content */ }

var MsgType MsgVar;
var CompRef Peer;
// save message matched by MsgTemplate into MsgVar
PortRef.receive(MsgTemplate) -> value MsgVar;
// obtain sender of message
PortRef.receive(MsgTemplate) -> sender Peer;
// extract MsgType message and save it with its sender
PortRef.trigger(MsgType:?) -> value MsgVar sender Peer;
```

```
// obtain sender of message in queue w/o removing it
PortRef.check(receive(MsgTemplate) -> sender Peer);
```



`send to` AND `receive from`

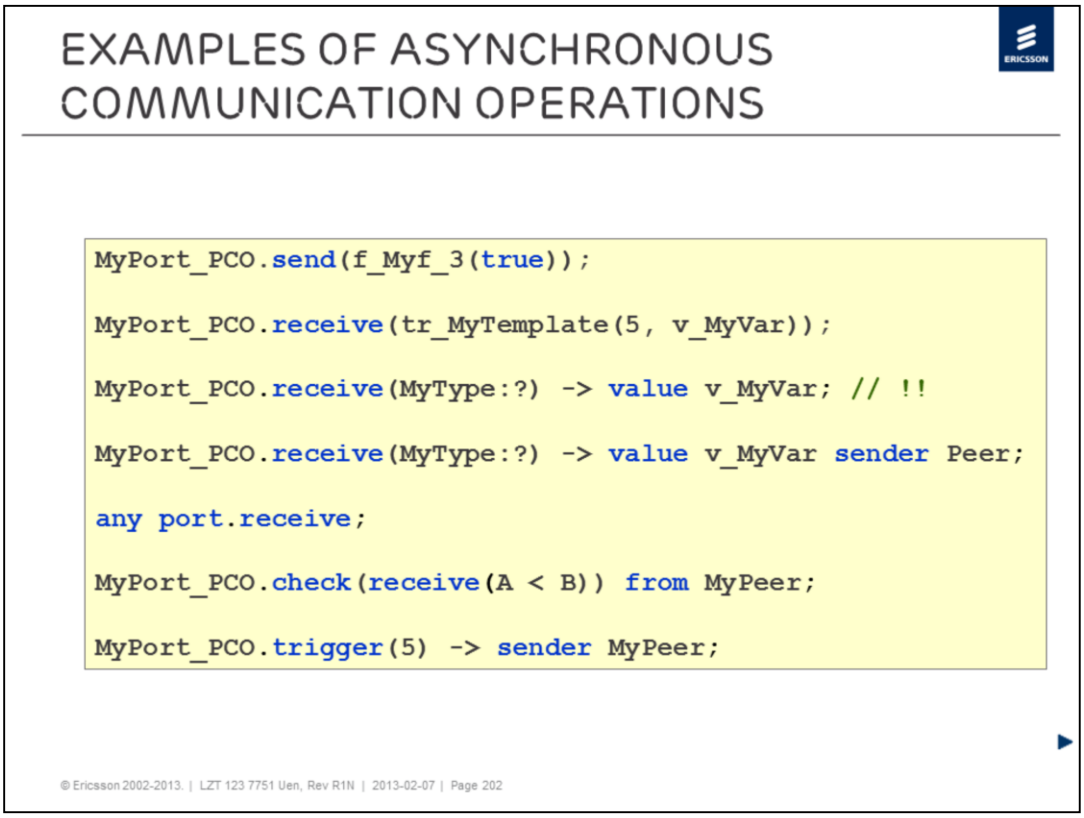
- Components A, B, C are of the same type
- P has 2 connections and 1 mapping in component A
- How does component A tell to the RTE that it waits for an incoming message from component B?

```
p.receive(TemplateRef) from B;
```

- How does component A send a message to system?

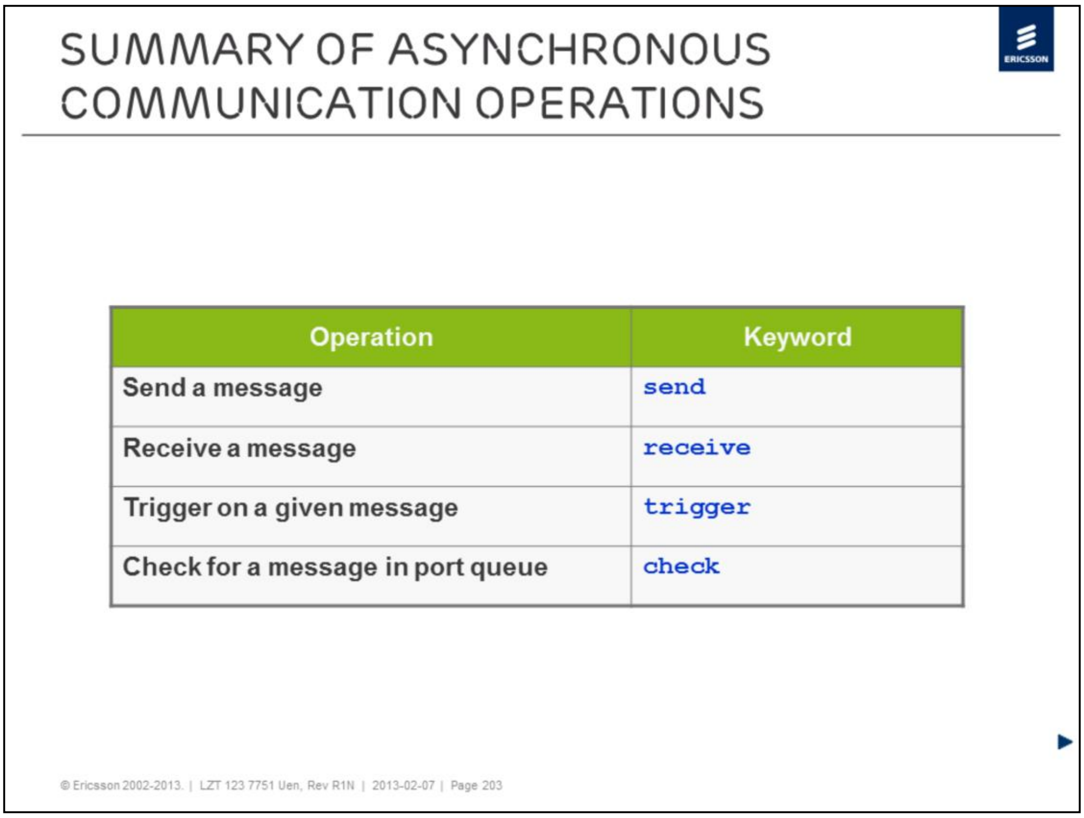
```
p.send(Msg) to system;
```

```
//send a reply for the previous message
p.receive (Request_Msg) -> sender CompVar;
p.send(Msg) to CompVar;
```



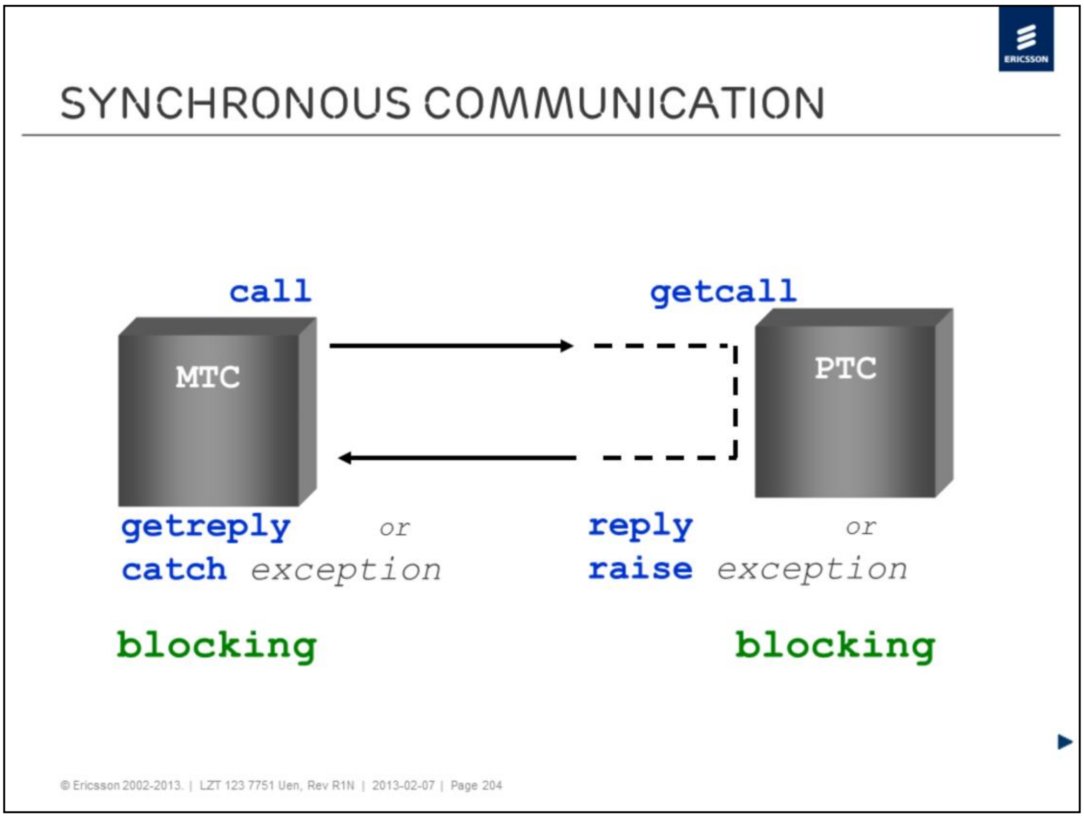
EXAMPLES OF ASYNCHRONOUS COMMUNICATION OPERATIONS

```
MyPort_PCO.send(f_Myf_3(true));

MyPort_PCO.receive(tr_MyTemplate(5, v_MyVar));

MyPort_PCO.receive(MyType:?) -> value v_MyVar; // !!

MyPort_PCO.receive(MyType:?) -> value v_MyVar sender Peer;

any port.receive;

MyPort_PCO.check(receive(A < B)) from MyPeer;

MyPort_PCO.trigger(5) -> sender MyPeer;
```



SUMMARY OF ASYNCHRONOUS COMMUNICATION OPERATIONS

Operation	Keyword
Send a message	`send`
Receive a message	`receive`
Trigger on a given message	`trigger`
Check for a message in port queue	`check`



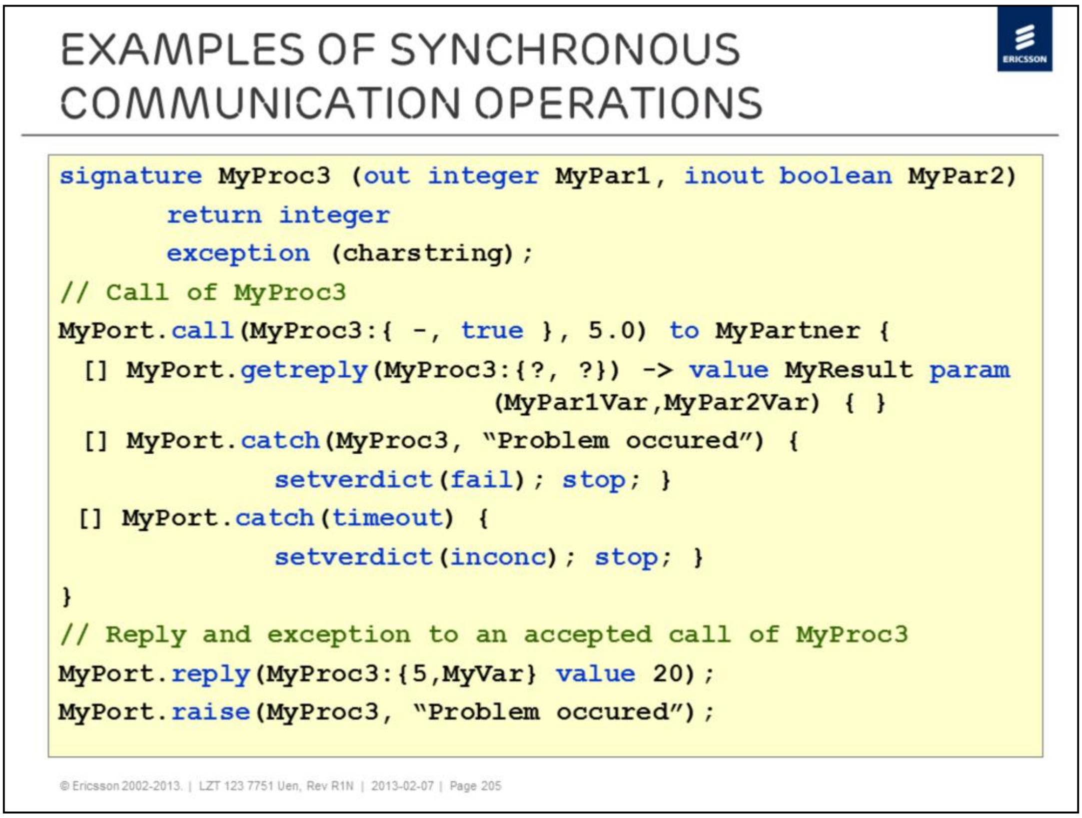
SYNCHRONOUS COMMUNICATION

getreply *or*
catch *exception*

reply *or*
raise *exception*

blocking

blocking



EXAMPLES OF SYNCHRONOUS COMMUNICATION OPERATIONS

```
signature MyProc3 (out integer MyPar1, inout boolean MyPar2)
       return integer
       exception (charstring);
// Call of MyProc3
MyPort.call(MyProc3:{ -, true }, 5.0) to MyPartner {
  [] MyPort.getreply(MyProc3:{?, ?}) -> value MyResult param
                              (MyPar1Var,MyPar2Var) { }
  [] MyPort.catch(MyProc3, "Problem occured") {
              setverdict(fail); stop; }
 [] MyPort.catch(timeout) {
              setverdict(inconc); stop; }
}
// Reply and exception to an accepted call of MyProc3
MyPort.reply(MyProc3:{5,MyVar} value 20);
MyPort.raise(MyProc3, "Problem occured");
```

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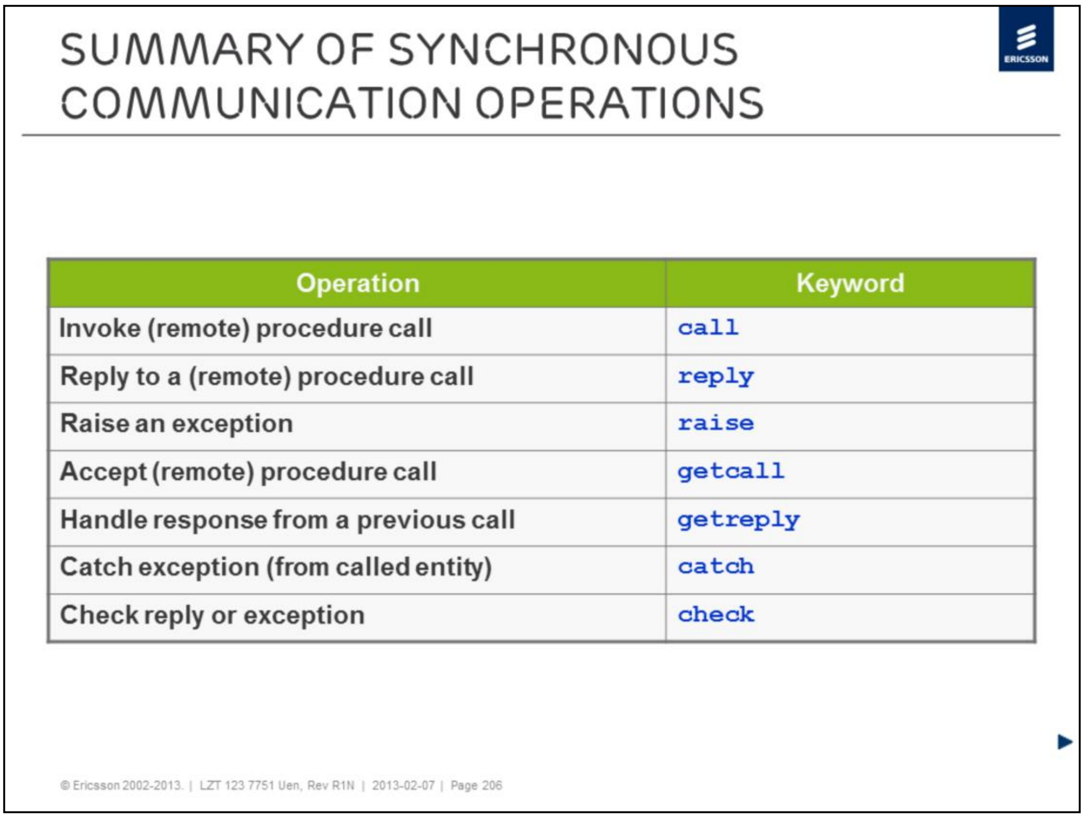
```
signature MyProc3 (out integer MyPar1, inout boolean MyPar2)  //
signature definition
                        return integer
                        exception (charstring);
// Call of MyProc3
MyPort.call(MyProc3:{ -, true }, 5.0) to MyPartner {
//5.0 – guarding timer, after expiration timeout exception generated
// after call, return value (getreply) and exception (catch) MUST be
handled
            [] MyPort.getreply(MyProc3:{?, ?}) -> value MyResult
// return value is stored in MyResult
                                                param
(MyPar1Var,MyPar2Var) { }
 // values of the out/inout parameters stored in MyPar1Var,MyPar2Var
            [] MyPort.catch(MyProc3, "Problem occured") {
 // catch user defined exception
                                    setverdict(fail); stop; }
            [] MyPort.catch(timeout) {
//catch timeout exception (5.0s in this concrete case)
                                    setverdict(inconc); stop; }
}
// Reply and exception to an accepted call of MyProc3
MyPort.reply(MyProc3:{5,MyVar} value 20);  // reply
MyPort.raise(MyProc3, "Problem occured");  // exception
```



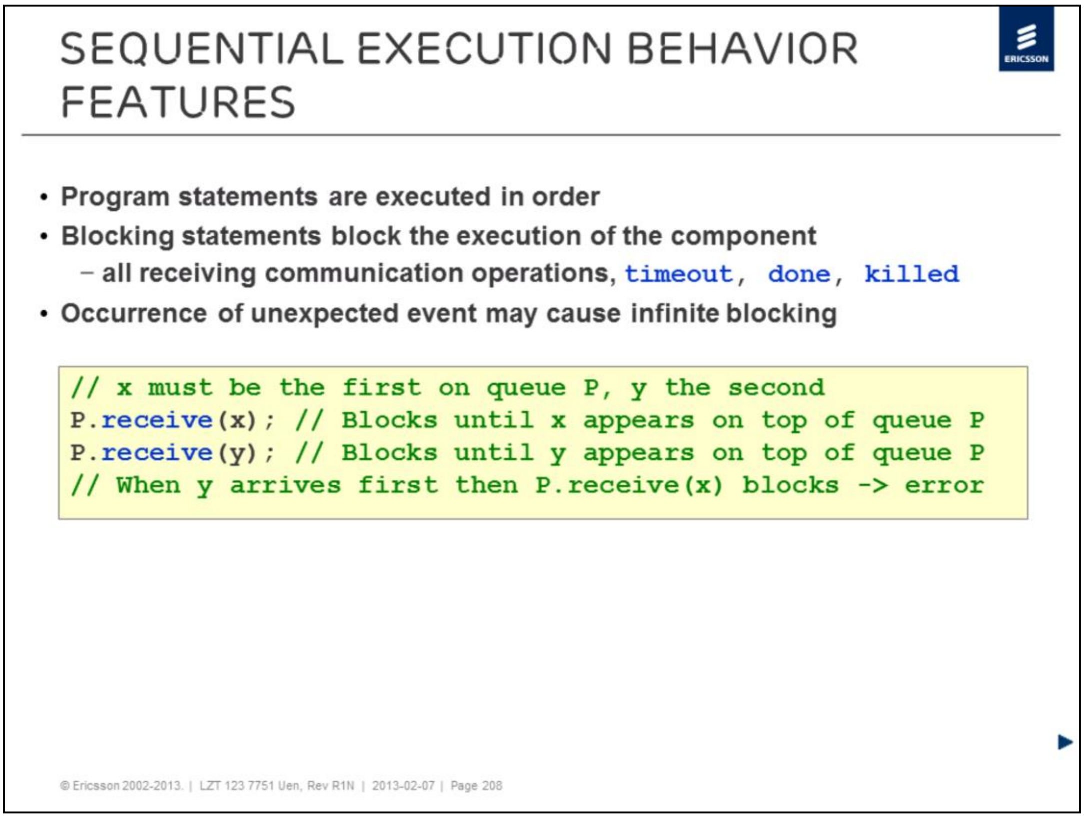
SUMMARY OF SYNCHRONOUS COMMUNICATION OPERATIONS

Operation	Keyword
Invoke (remote) procedure call	`call`
Reply to a (remote) procedure call	`reply`
Raise an exception	`raise`
Accept (remote) procedure call	`getcall`
Handle response from a previous call	`getreply`
Catch exception (from called entity)	`catch`
Check reply or exception	`check`

XIV. BEHAVIORAL STATEMENTS

SEQUENTIAL BEHAVIOR
ALTERNATIVE BEHAVIOR
ALT STATEMENT, SNAPSHOT SEMANTICS
GUARD EXPRESSIONS, ELSE GUARD
ALTSTEPS
DEFAULTS
INTERLEAVE STATEMENT

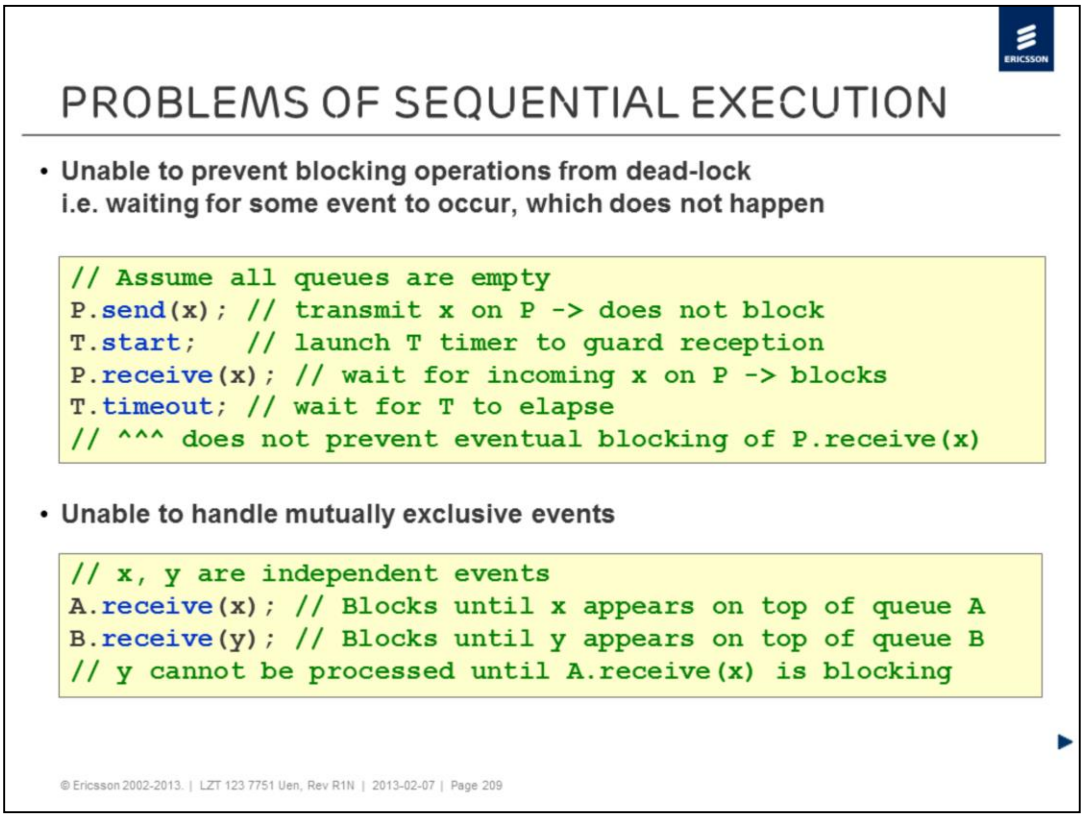
CONTENTS



SEQUENTIAL EXECUTION BEHAVIOR FEATURES

- Program statements are executed in order
- Blocking statements block the execution of the component
  - all receiving communication operations, `timeout`, `done`, `killed`
- Occurrence of unexpected event may cause infinite blocking

```
// x must be the first on queue P, y the second
P.receive(x); // Blocks until x appears on top of queue P
P.receive(y); // Blocks until y appears on top of queue P
// When y arrives first then P.receive(x) blocks -> error
```



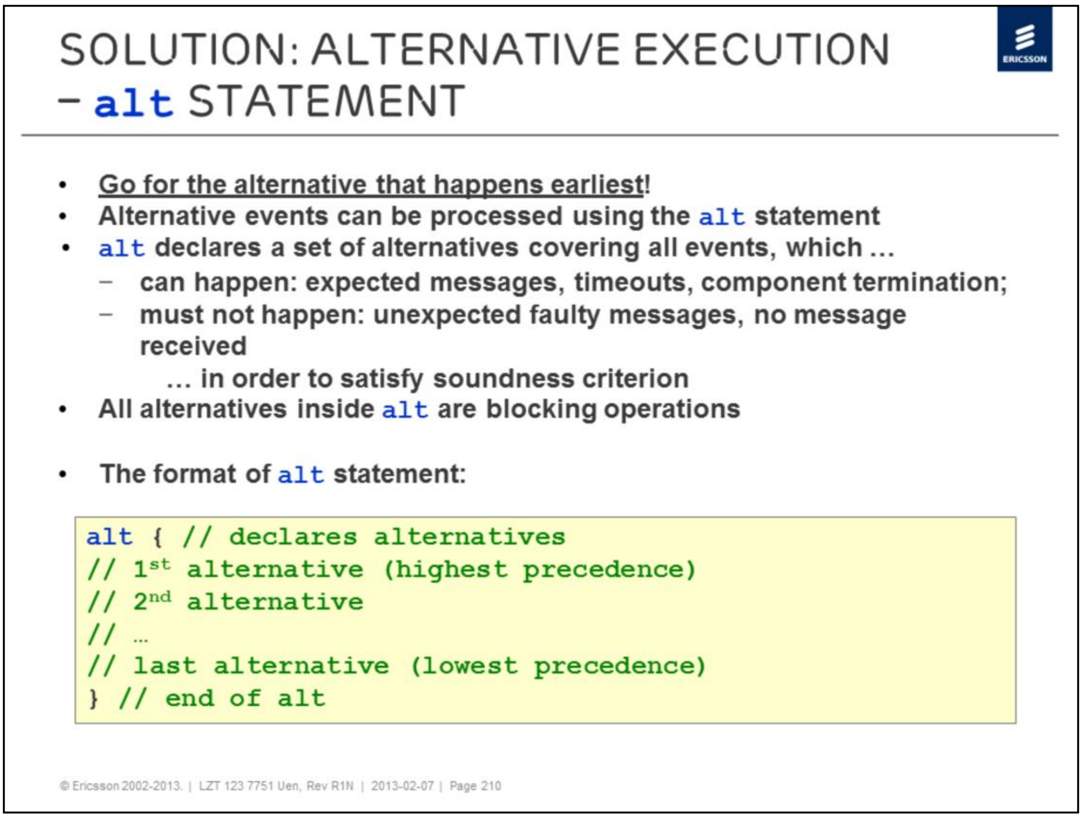
PROBLEMS OF SEQUENTIAL EXECUTION

- Unable to prevent blocking operations from dead-lock
  i.e. waiting for some event to occur, which does not happen

```
// Assume all queues are empty
P.send(x); // transmit x on P -> does not block
T.start;   // launch T timer to guard reception
P.receive(x); // wait for incoming x on P -> blocks
T.timeout; // wait for T to elapse
// ^^^ does not prevent eventual blocking of P.receive(x)
```

- Unable to handle mutually exclusive events

```
// x, y are independent events
A.receive(x); // Blocks until x appears on top of queue A
B.receive(y); // Blocks until y appears on top of queue B
// y cannot be processed until A.receive(x) is blocking
```



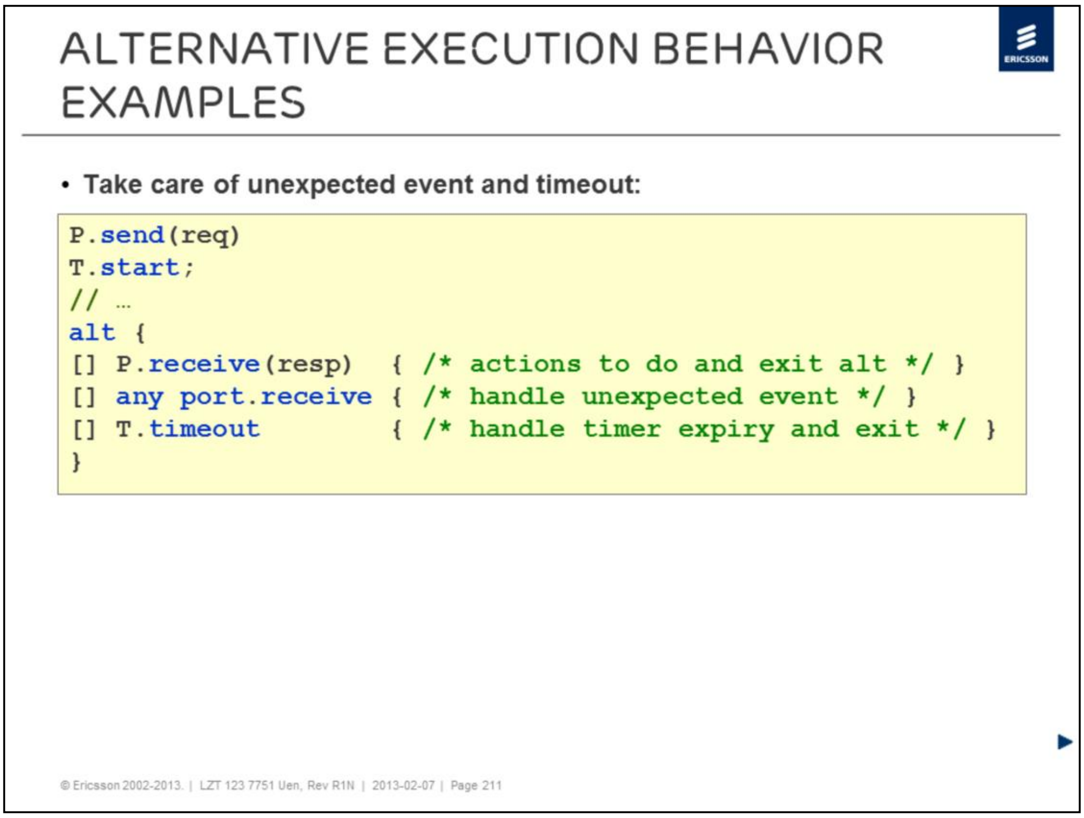
SOLUTION: ALTERNATIVE EXECUTION – `alt` STATEMENT

- <u>Go for the alternative that happens earliest</u>!
- Alternative events can be processed using the `alt` statement
- `alt` declares a set of alternatives covering all events, which …
  - can happen: expected messages, timeouts, component termination;
  - must not happen: unexpected faulty messages, no message received

    … in order to satisfy soundness criterion
- All alternatives inside `alt` are blocking operations

- The format of `alt` statement:

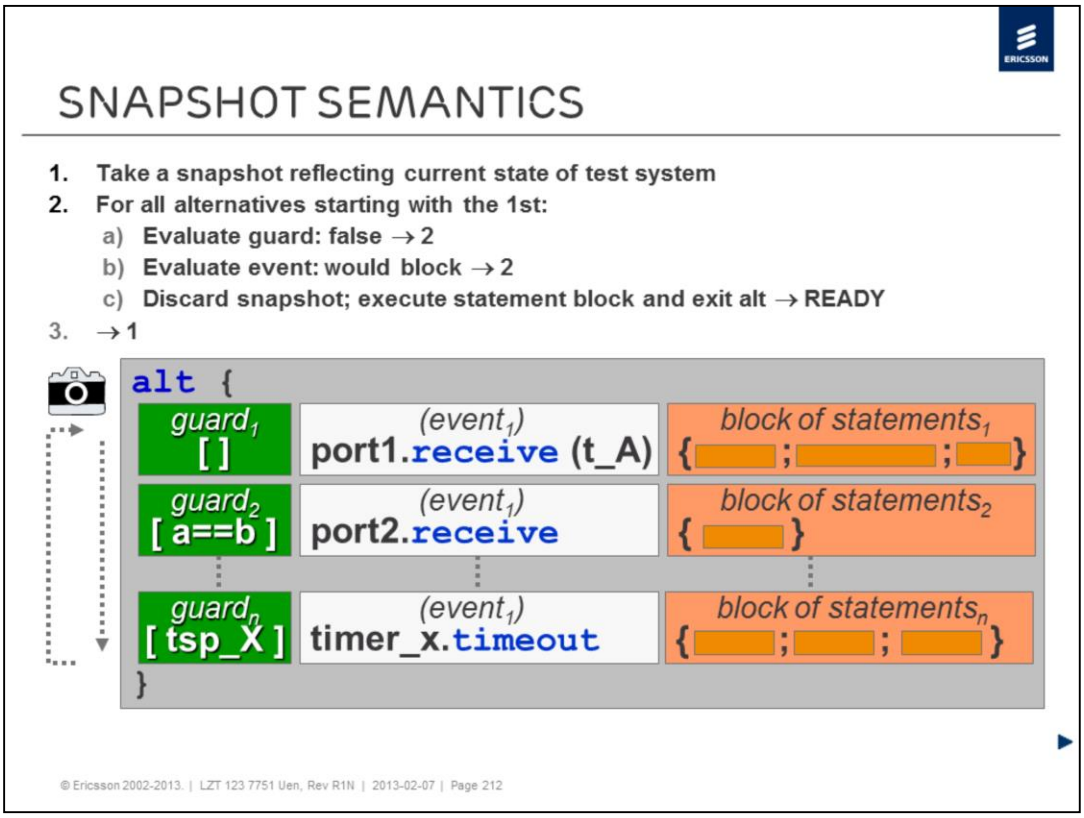
```
alt { // declares alternatives
// 1st alternative (highest precedence)
// 2nd alternative
// …
// last alternative (lowest precedence)
} // end of alt
```



ALTERNATIVE EXECUTION BEHAVIOR EXAMPLES

- **Take care of unexpected event and timeout:**

```
P.send(req)
T.start;
// …
alt {
[] P.receive(resp)   { /* actions to do and exit alt */ }
[] any port.receive { /* handle unexpected event */ }
[] T.timeout         { /* handle timer expiry and exit */ }
}
```



SNAPSHOT SEMANTICS

1. **Take a snapshot reflecting current state of test system**
2. **For all alternatives starting with the 1st:**
   a) **Evaluate guard: false → 2**
   b) **Evaluate event: would block → 2**
   c) **Discard snapshot; execute statement block and exit alt → READY**
3. **→ 1**

alt {

guard$_1$ **[ ]**	*(event$_1$)* **port1.receive (t_A)**	*block of statements$_1$* **{ ; ; }**
guard$_2$ **[a==b]**	*(event$_1$)* **port2.receive**	*block of statements$_2$* **{ }**
guard$_n$ **[tsp_X]**	*(event$_1$)* **timer_x.timeout**	*block of statements$_n$* **{ ; ; }**

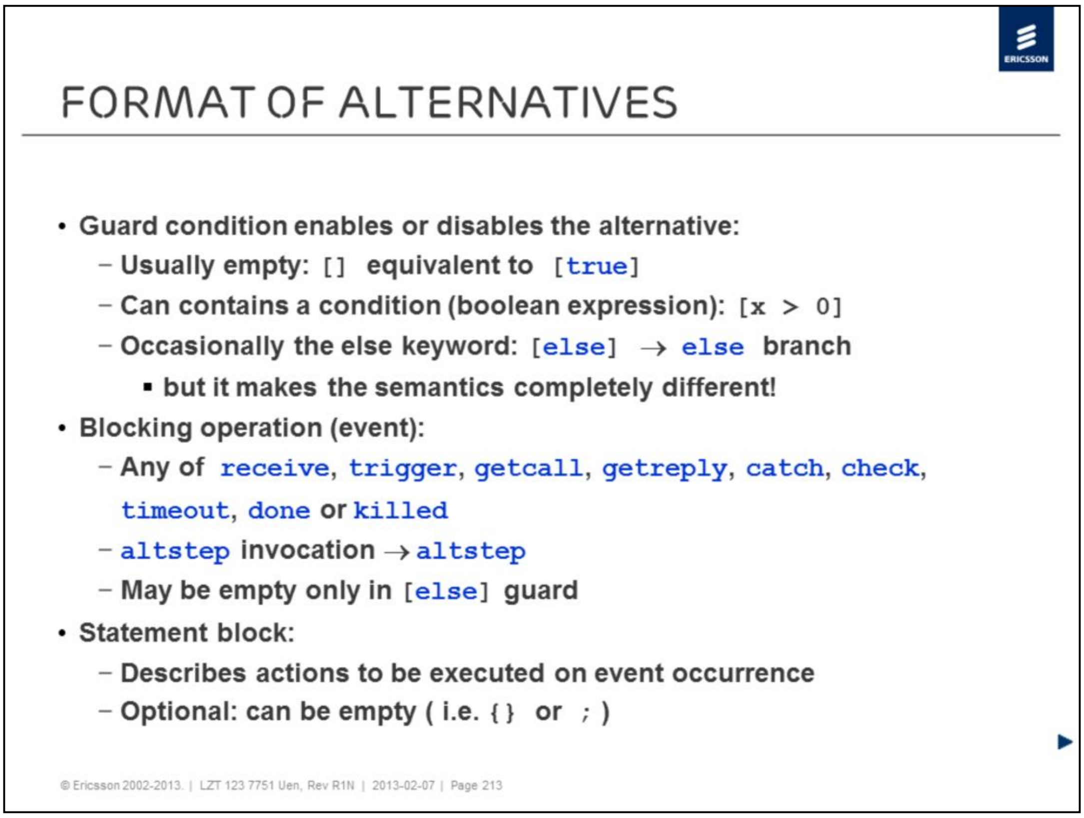
}

The execution of alt starts with taking a “snapshot”. The snapshot represent the current state of the test system including timers, port queues, components, etc. The alternatives enlisted within the alt statement are evaluated on the contents of the snapshot.

When none of the alternatives are successful, the run-time environment takes a new snapshot and the execution resumes with the first alternative.

The execution proceeds until a single successful alternative is found or when the run-time environment can determine that no alternative can ever be successful. In the former case the statement block of the successful alternative is executed. Then, the next statement following the alt is executed. In the latter case the execution terminates with dynamic test case error.

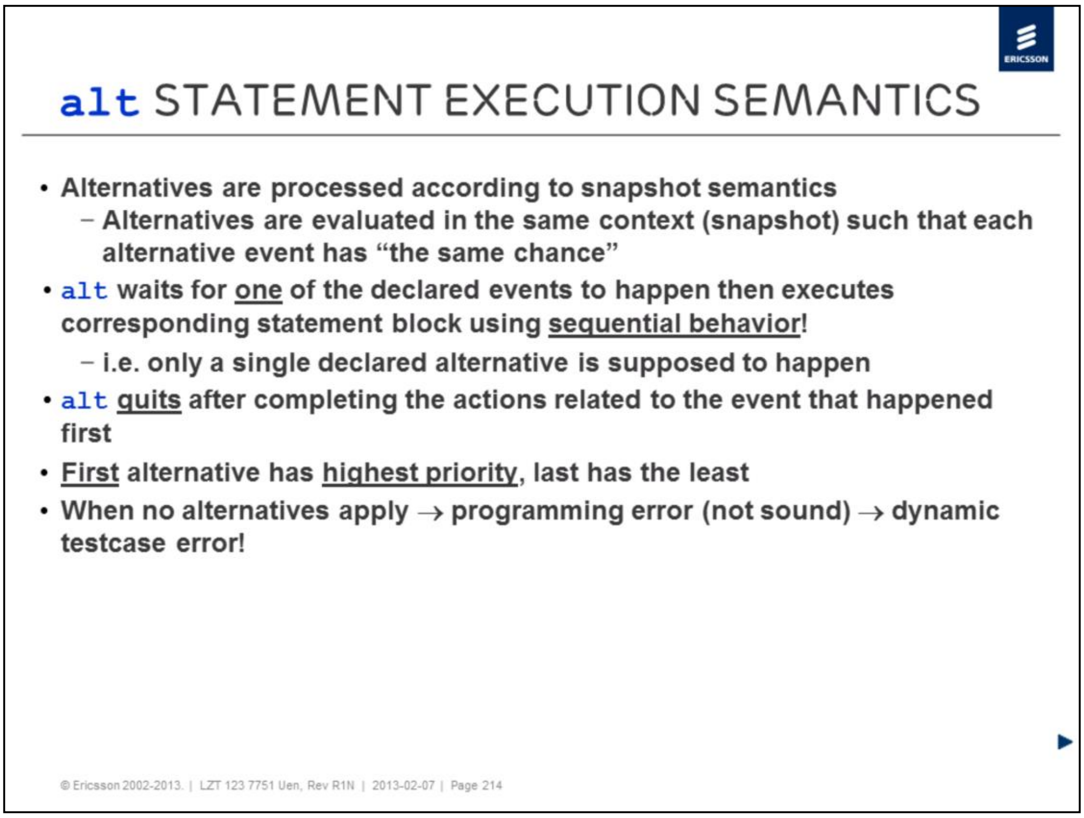
The snapshot is only valid until the execution gets to the statement block! That is why the alt statement can be nested.



FORMAT OF ALTERNATIVES

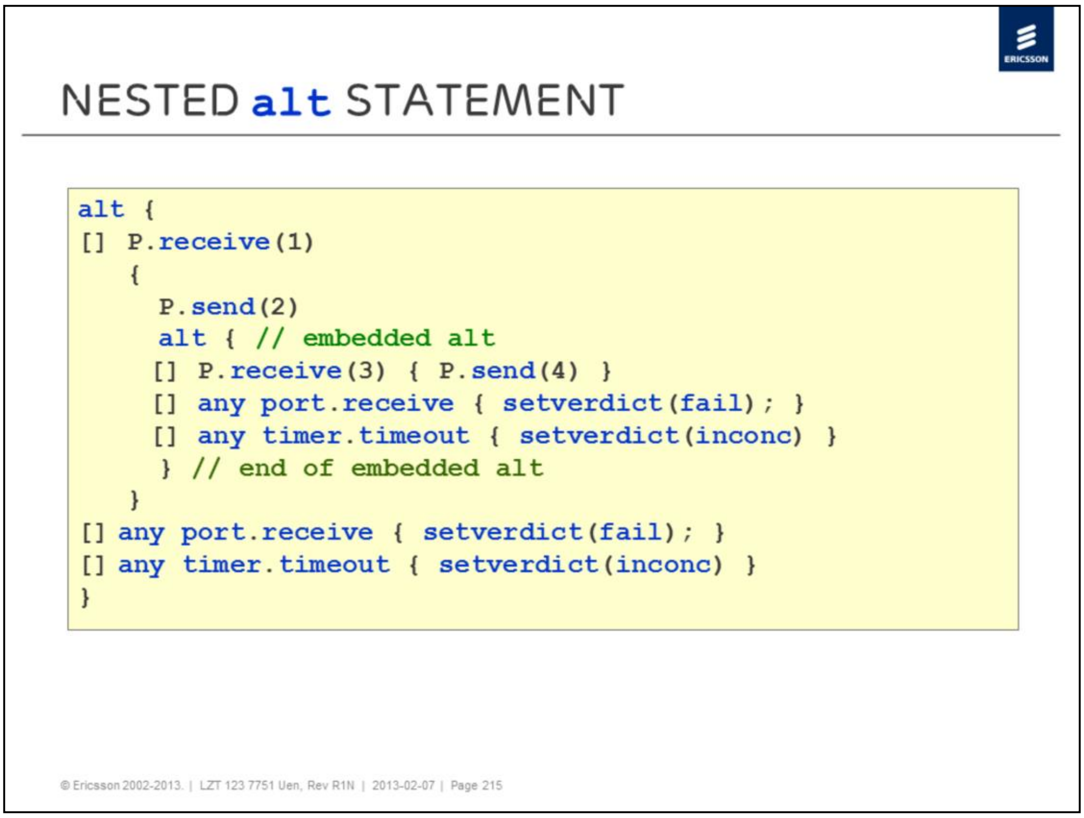
- **Guard condition enables or disables the alternative:**
  - Usually empty: `[]` equivalent to `[true]`
  - Can contains a condition (boolean expression): `[x > 0]`
  - Occasionally the else keyword: `[else]` → `else` branch
    - but it makes the semantics completely different!
- **Blocking operation (event):**
  - Any of `receive`, `trigger`, `getcall`, `getreply`, `catch`, `check`, `timeout`, `done` or `killed`
  - `altstep` invocation → `altstep`
  - May be empty only in `[else]` guard
- **Statement block:**
  - Describes actions to be executed on event occurrence
  - Optional: can be empty (i.e. `{}` or `;`)

The alt statement consists of alternatives. Alternatives normally consist of guard, event and statement block. The event used in alt can only be a receiving (or blocking) event. The semantics of these blocking statements change when used within the alt statement!



`alt` STATEMENT EXECUTION SEMANTICS

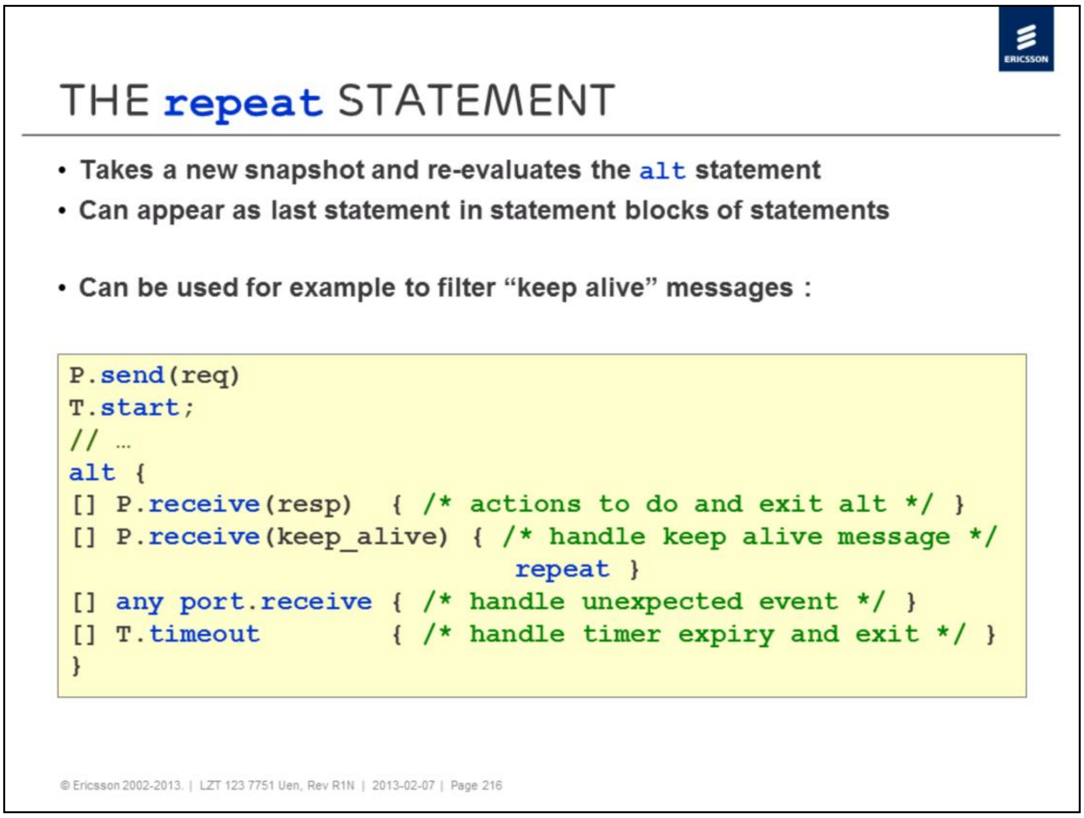
- Alternatives are processed according to snapshot semantics
  - Alternatives are evaluated in the same context (snapshot) such that each alternative event has “the same chance”
- `alt` waits for one of the declared events to happen then executes corresponding statement block using sequential behavior!
  - i.e. only a single declared alternative is supposed to happen
- `alt` quits after completing the actions related to the event that happened first
- First alternative has highest priority, last has the least
- When no alternatives apply → programming error (not sound) → dynamic testcase error!



NESTED alt STATEMENT

```
alt {
[] P.receive(1)
   {
     P.send(2)
     alt { // embedded alt
    [] P.receive(3) { P.send(4) }
    [] any port.receive { setverdict(fail); }
    [] any timer.timeout { setverdict(inconc) }
     } // end of embedded alt
   }
[] any port.receive { setverdict(fail); }
[] any timer.timeout { setverdict(inconc) }
}
```

The repeat keyword can appear only as the last statement within statements blocks of alt statements. Then, istead of jumping to the next statement following the alt, the execution is continued from the beginning of the alt with a new snapshot.



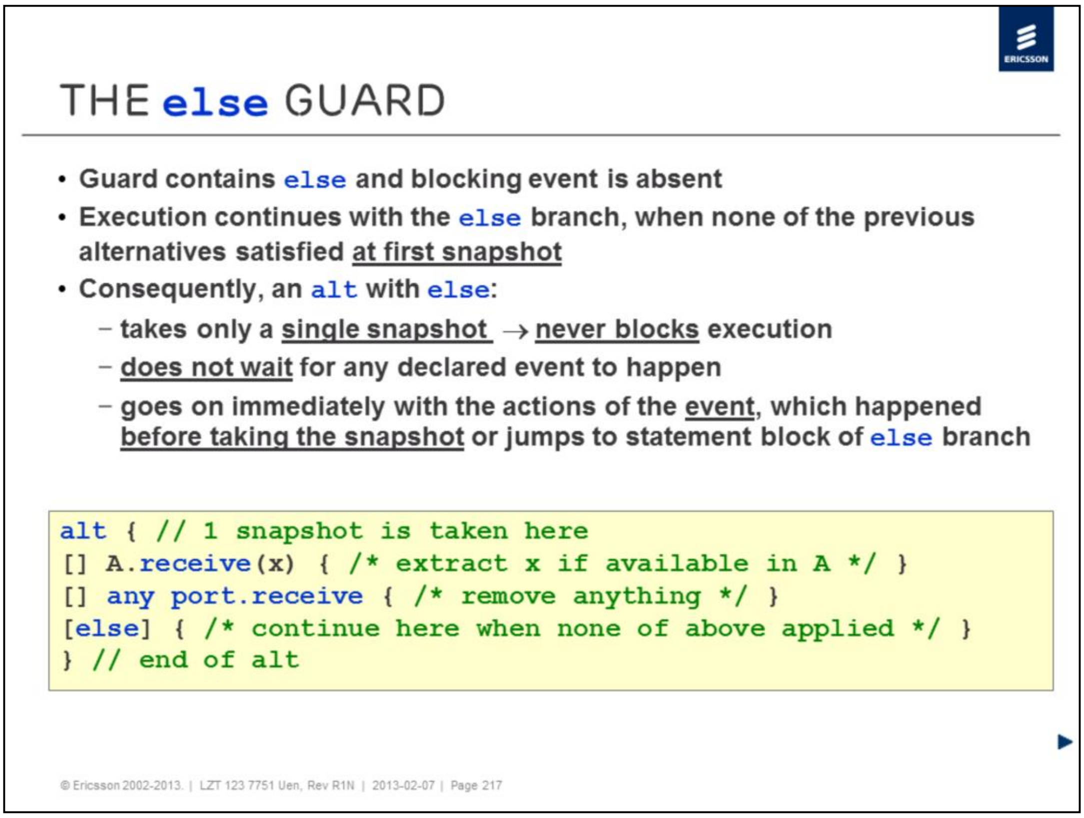
THE repeat STATEMENT

- Takes a new snapshot and re-evaluates the `alt` statement
- Can appear as last statement in statement blocks of statements

- Can be used for example to filter “keep alive” messages :

```
P.send(req)
T.start;
// …
alt {
[] P.receive(resp)   { /* actions to do and exit alt */ }
[] P.receive(keep_alive) { /* handle keep alive message */
                           repeat }
[] any port.receive { /* handle unexpected event */ }
[] T.timeout        { /* handle timer expiry and exit */ }
}
```

The repeat keyword can appear only as the last statement within statements blocks of alt statements. Then, istead of jumping to the next statement following the alt, the execution is continued from the beginning of the alt with a new snapshot.



THE `else` GUARD

- Guard contains `else` and blocking event is absent
- Execution continues with the `else` branch, when none of the previous alternatives satisfied at first snapshot
- Consequently, an `alt` with `else`:
  - takes only a single snapshot → never blocks execution
  - does not wait for any declared event to happen
  - goes on immediately with the actions of the event, which happened before taking the snapshot or jumps to statement block of `else` branch

```
alt { // 1 snapshot is taken here
[] A.receive(x) { /* extract x if available in A */ }
[] any port.receive { /* remove anything */ }
[else] { /* continue here when none of above applied */ }
} // end of alt
```

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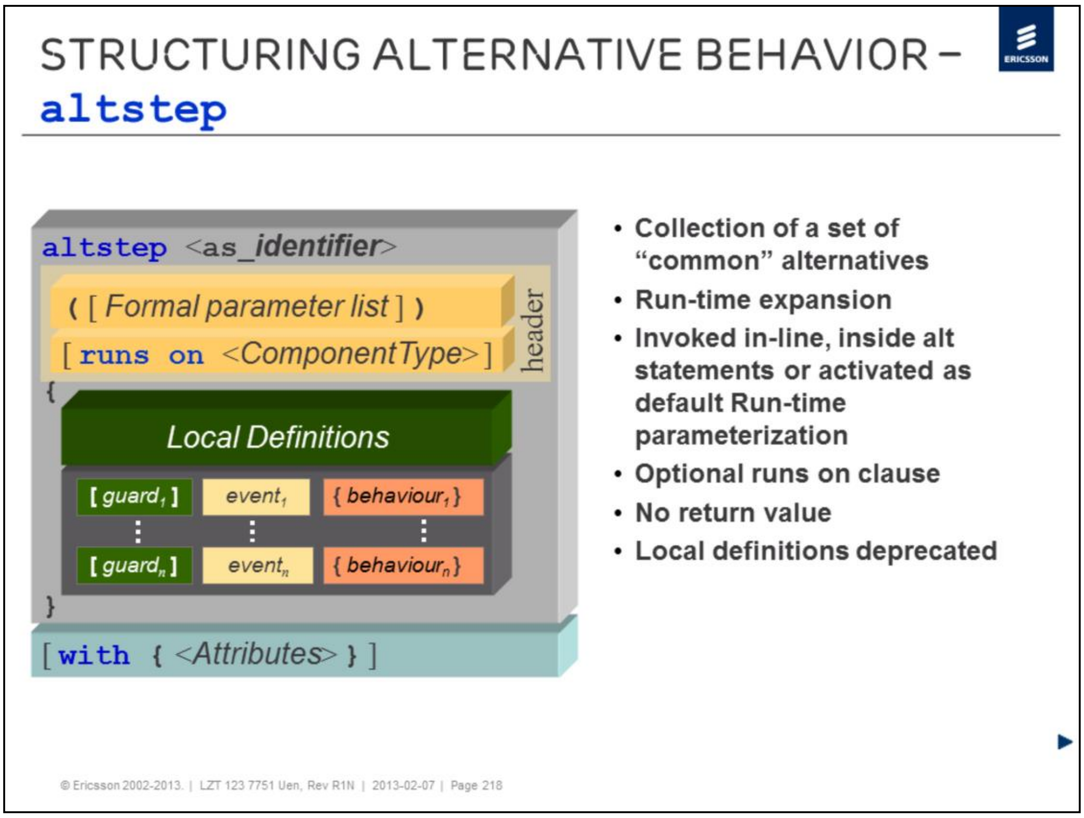
The else guard does not have an accompanying event because it is always successful.



STRUCTURING ALTERNATIVE BEHAVIOR – `altstep`

`altstep` <as_*identifier*>

([*Formal parameter list*])

[`runs on` <*ComponentType*>]

header

{

Local Definitions

[*guard*$_1$] *event*$_1$ { *behaviour*$_1$ }

⋮ ⋮ ⋮

[*guard*$_n$] *event*$_n$ { *behaviour*$_n$ }

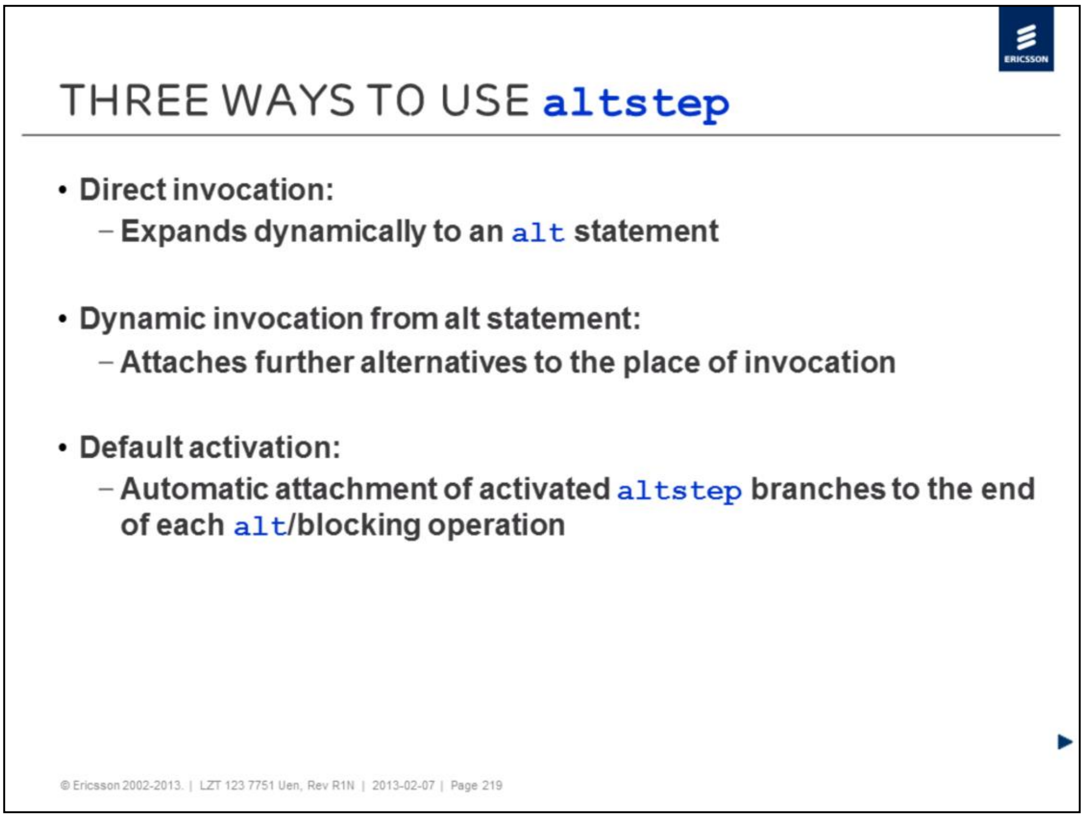
}

[`with` { <*Attributes*> }]

- **Collection of a set of "common" alternatives**
- **Run-time expansion**
- **Invoked in-line, inside alt statements or activated as default Run-time parameterization**
- **Optional runs on clause**
- **No return value**
- **Local definitions deprecated**

Local definitions within altsteps are deprecated. When initializing a local variable with a function having side-effect (I.e. doing something else in addition to initializing the variable) then this side-effect may be executed multiple times. Consequently, variables should be initialized with constant only!

Side-effect is for instance the sending of a message. In the above situation we could not know how many times this message is sent!



THREE WAYS TO USE `altstep`

- **Direct invocation:**
  - **Expands dynamically to an `alt` statement**
- **Dynamic invocation from alt statement:**
  - **Attaches further alternatives to the place of invocation**
- **Default activation:**
  - **Automatic attachment of activated `altstep` branches to the end of each `alt`/blocking operation**

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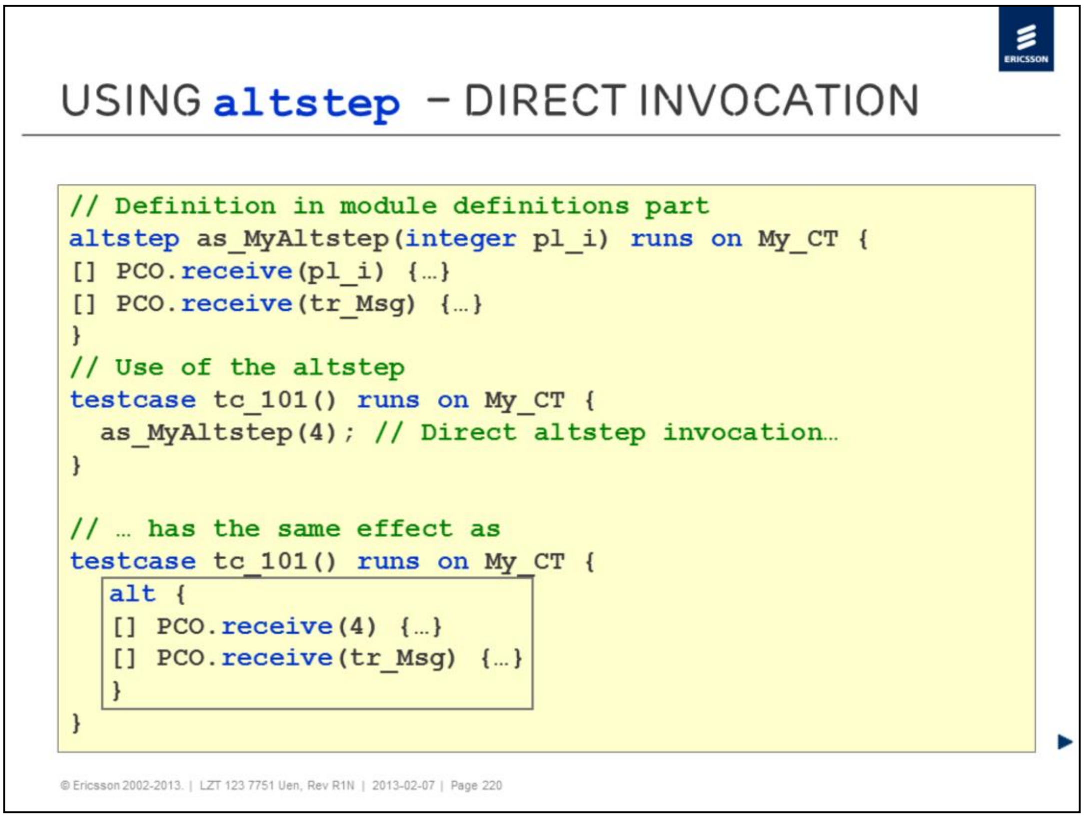
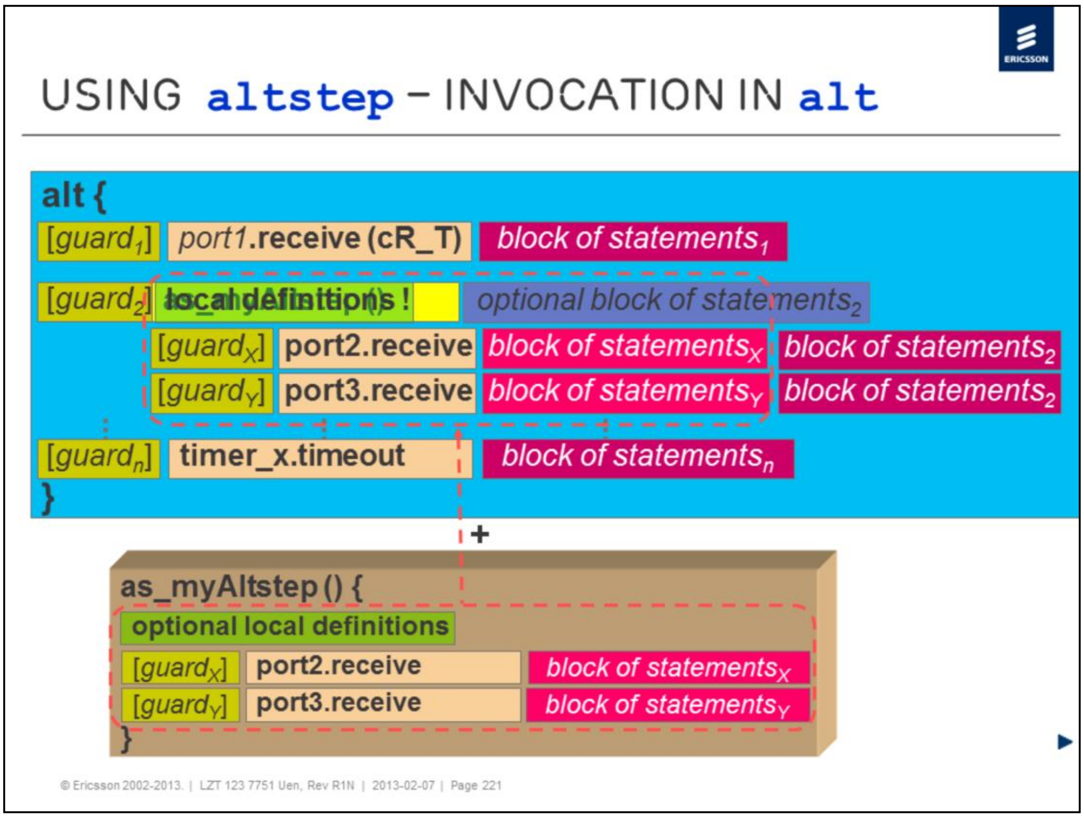


USING `altstep` – DIRECT INVOCATION

```
// Definition in module definitions part
altstep as_MyAltstep(integer pl_i) runs on My_CT {
[] PCO.receive(pl_i) {…}
[] PCO.receive(tr_Msg) {…}
}
// Use of the altstep
testcase tc_101() runs on My_CT {
  as_MyAltstep(4); // Direct altstep invocation…
}

// … has the same effect as
testcase tc_101() runs on My_CT {
   alt {
   [] PCO.receive(4) {…}
   [] PCO.receive(tr_Msg) {…}
   }
}
```



USING `altstep` – INVOCATION IN `alt`

alt {

[*guard*$_1$] *port1*.**receive (cR_T)** *block of statements*$_1$

[*guard*$_2$] **local definitions** **as_myAltstep() !** *optional block of statements*$_2$

[*guard*$_X$] **port2.receive** *block of statements*$_X$ *block of statements*$_2$

[*guard*$_Y$] **port3.receive** *block of statements*$_Y$ *block of statements*$_2$

[*guard*$_n$] **timer_x.timeout** *block of statements*$_n$

}

+

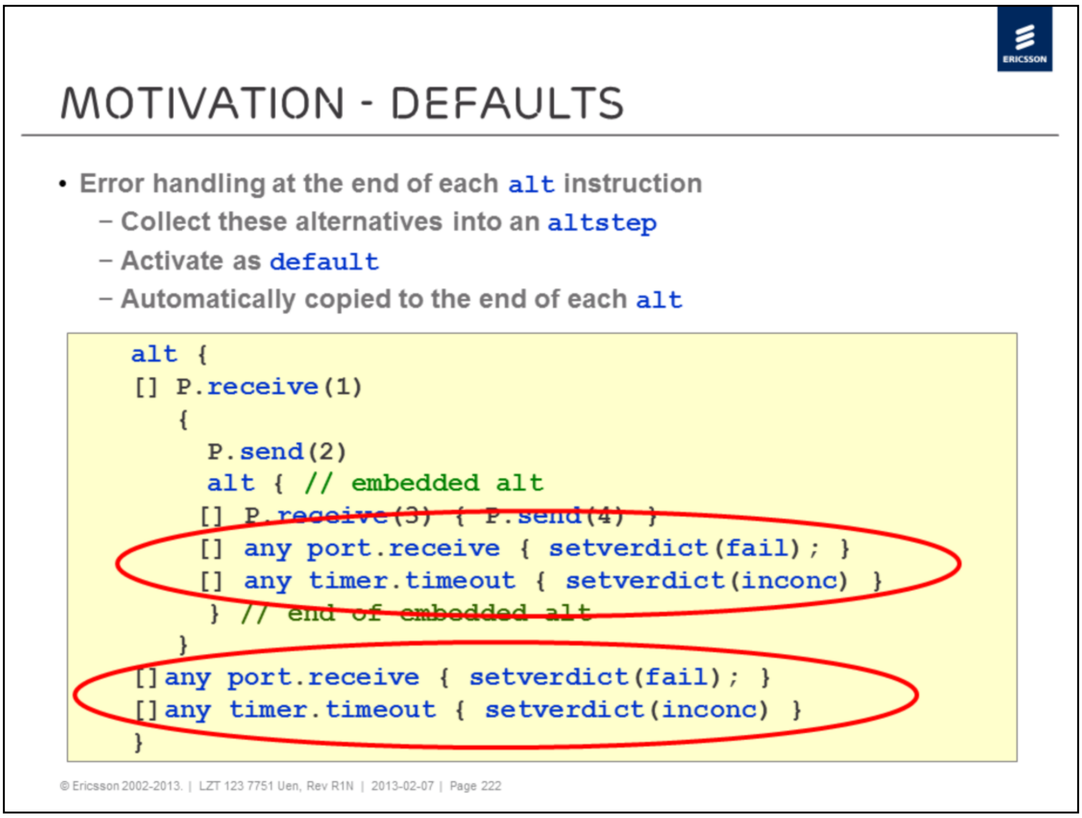
as_myAltstep () {

optional local definitions

[*guard*$_X$] **port2.receive** *block of statements*$_X$

[*guard*$_Y$] **port3.receive** *block of statements*$_Y$

}



MOTIVATION - DEFAULTS

- Error handling at the end of each `alt` instruction
  - Collect these alternatives into an `altstep`
  - Activate as `default`
  - Automatically copied to the end of each `alt`

```
  alt {
  [] P.receive(1)
     {
       P.send(2)
       alt { // embedded alt
      [] P.receive(3) { P.send(4) }
      [] any port.receive { setverdict(fail); }
      [] any timer.timeout { setverdict(inconc) }
       } // end of embedded alt
     }
  []any port.receive { setverdict(fail); }
  []any timer.timeout { setverdict(inconc) }
  }
```

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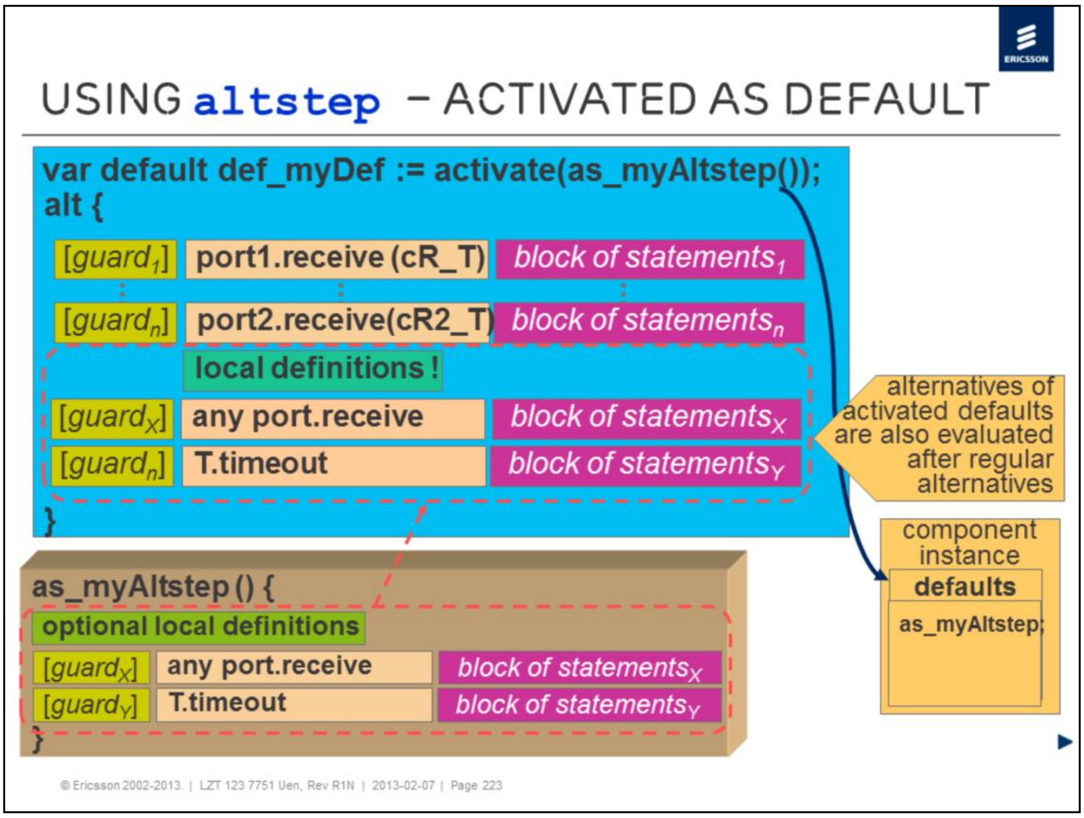

USING `altstep` – ACTIVATED AS DEFAULT

var default def_myDef := activate(as_myAltstep());
alt {

[*guard*$_1$] **port1.receive (cR_T)** *block of statements*$_1$

[*guard*$_n$] **port2.receive(cR2_T)** *block of statements*$_n$

local definitions !

[*guard*$_X$] **any port.receive** *block of statements*$_X$

[*guard*$_n$] **T.timeout** *block of statements*$_Y$

}

as_myAltstep () {

optional local definitions

[*guard*$_X$] **any port.receive** *block of statements*$_X$

[*guard*$_Y$] **T.timeout** *block of statements*$_Y$

}

alternatives of activated defaults are also evaluated after regular alternatives

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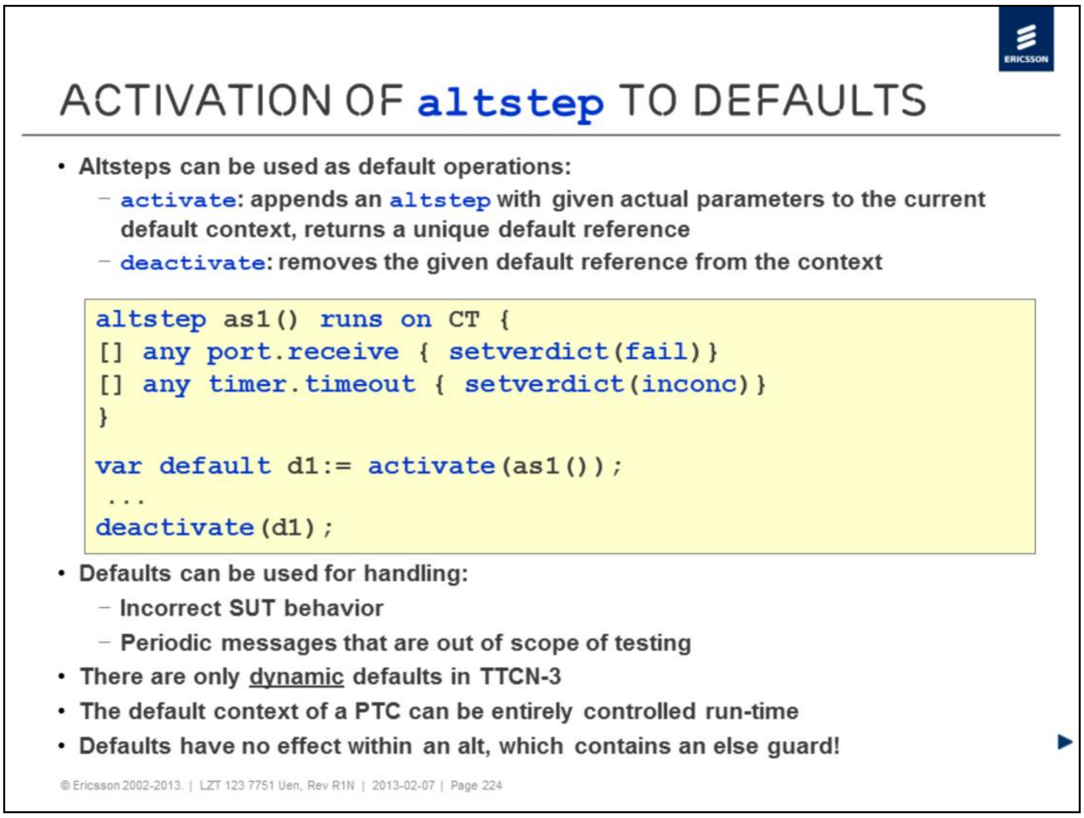


ACTIVATION OF `altstep` TO DEFAULTS

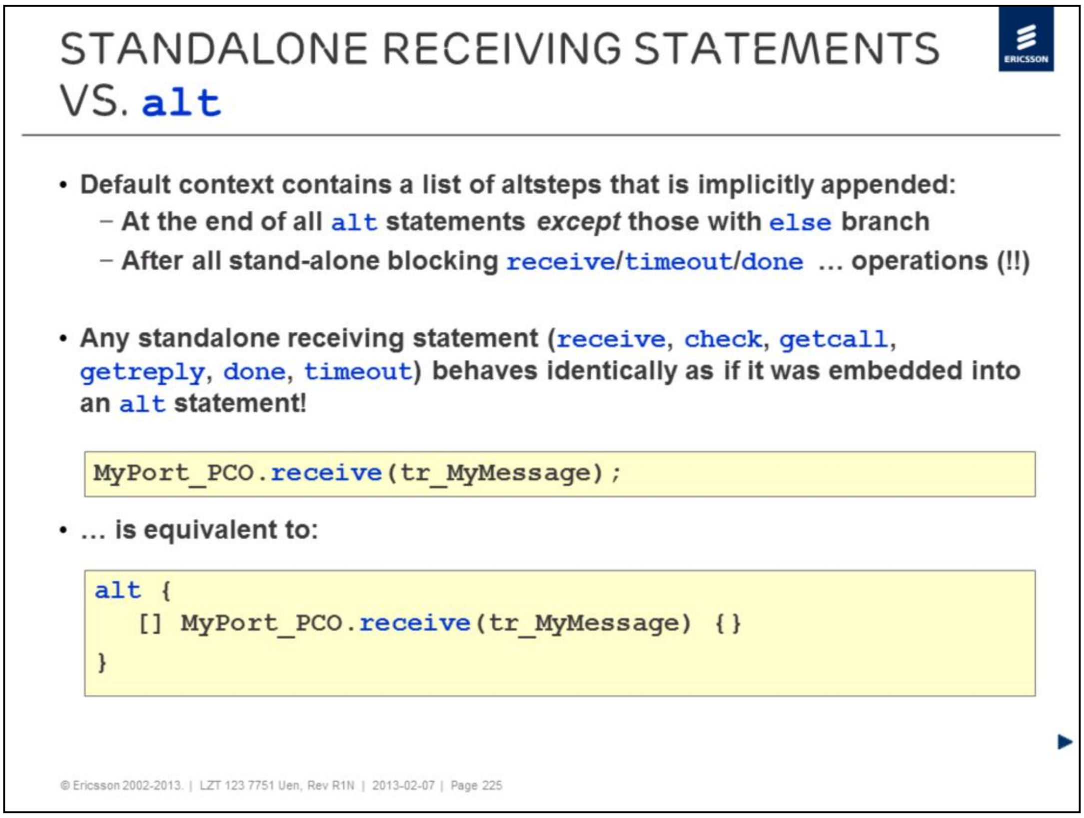
- Altsteps can be used as default operations:
  - `activate`: appends an `altstep` with given actual parameters to the current default context, returns a unique default reference
  - `deactivate`: removes the given default reference from the context

```
altstep as1() runs on CT {
[] any port.receive { setverdict(fail)}
[] any timer.timeout { setverdict(inconc)}
}

var default d1:= activate(as1());
 ...
deactivate(d1);
```

- Defaults can be used for handling:
  - Incorrect SUT behavior
  - Periodic messages that are out of scope of testing
- There are only <u>dynamic</u> defaults in TTCN-3
- The default context of a PTC can be entirely controlled run-time
- Defaults have no effect within an alt, which contains an else guard!

Defaults have no effect within an alt, which contains an else guard!



STANDALONE RECEIVING STATEMENTS VS. `alt`

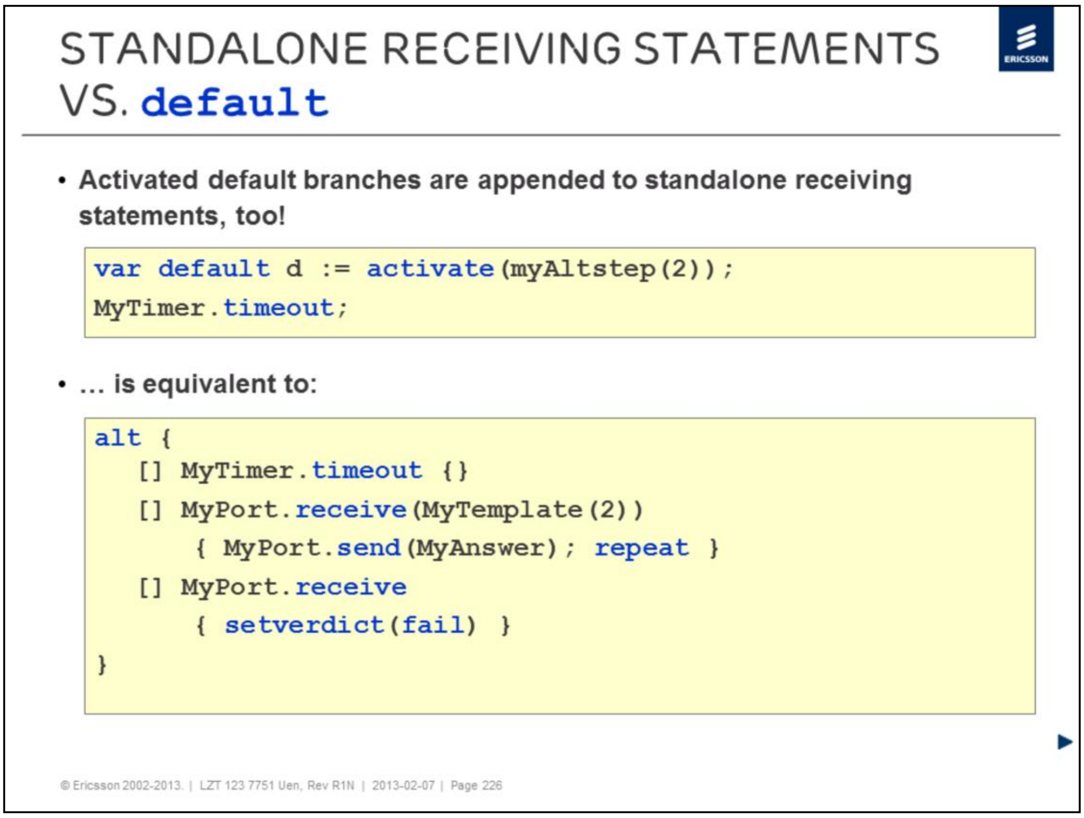
- **Default context contains a list of altsteps that is implicitly appended:**
  - **At the end of all `alt` statements *except* those with `else` branch**
  - **After all stand-alone blocking `receive`/`timeout`/`done` … operations (!!)**

- **Any standalone receiving statement (`receive`, `check`, `getcall`, `getreply`, `done`, `timeout`) behaves identically as if it was embedded into an `alt` statement!**

```
MyPort_PCO.receive(tr_MyMessage);
```

- **… is equivalent to:**

```
alt {
   [] MyPort_PCO.receive(tr_MyMessage) {}
}
```



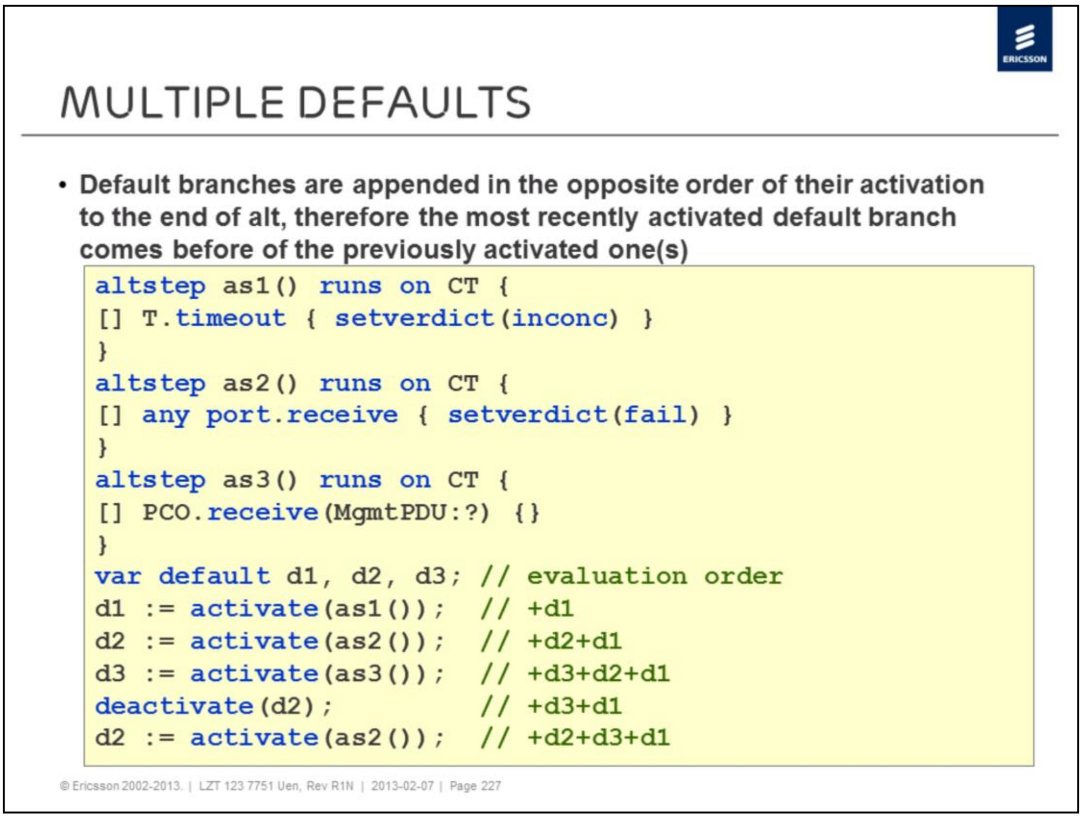
STANDALONE RECEIVING STATEMENTS VS. `default`

- Activated default branches are appended to standalone receiving statements, too!

```
var default d := activate(myAltstep(2));
MyTimer.timeout;
```

- … is equivalent to:

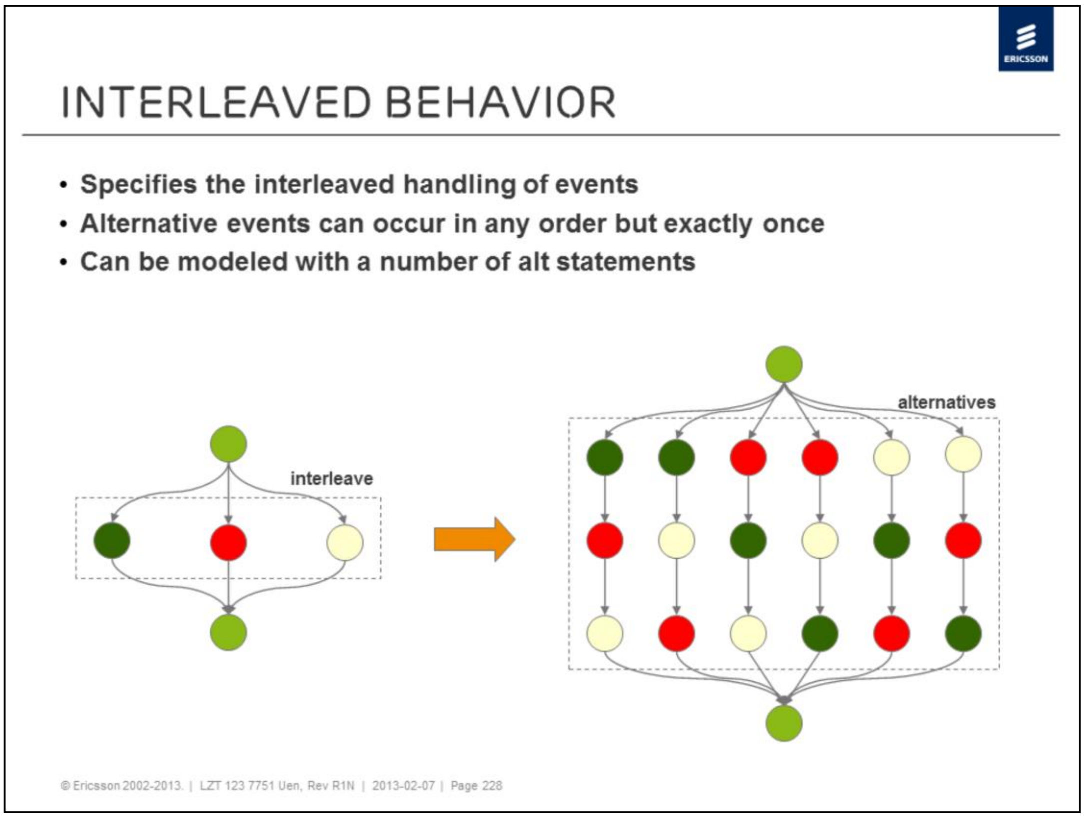
```
alt {
   [] MyTimer.timeout {}
   [] MyPort.receive(MyTemplate(2))
       { MyPort.send(MyAnswer); repeat }
   [] MyPort.receive
       { setverdict(fail) }
}
```



MULTIPLE DEFAULTS

- Default branches are appended in the opposite order of their activation to the end of alt, therefore the most recently activated default branch comes before of the previously activated one(s)

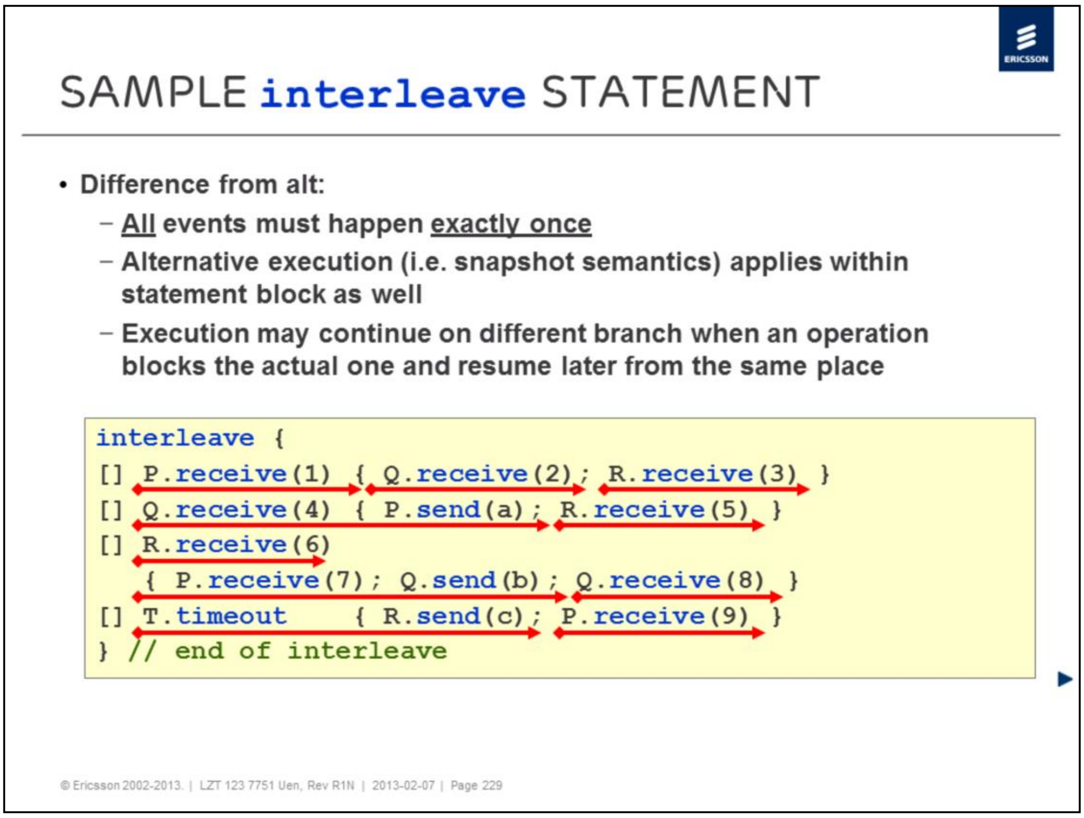
```
altstep as1() runs on CT {
[] T.timeout { setverdict(inconc) }
}
altstep as2() runs on CT {
[] any port.receive { setverdict(fail) }
}
altstep as3() runs on CT {
[] PCO.receive(MgmtPDU:?) {}
}
var default d1, d2, d3; // evaluation order
d1 := activate(as1());  // +d1
d2 := activate(as2());  // +d2+d1
d3 := activate(as3());  // +d3+d2+d1
deactivate(d2);         // +d3+d1
d2 := activate(as2());  // +d2+d3+d1
```



INTERLEAVED BEHAVIOR

- Specifies the interleaved handling of events
- Alternative events can occur in any order but exactly once
- Can be modeled with a number of alt statements

The number of alt statements used for modeling a single interleave statement grows exponentially with the number of blocking operations used within the interleave statement.

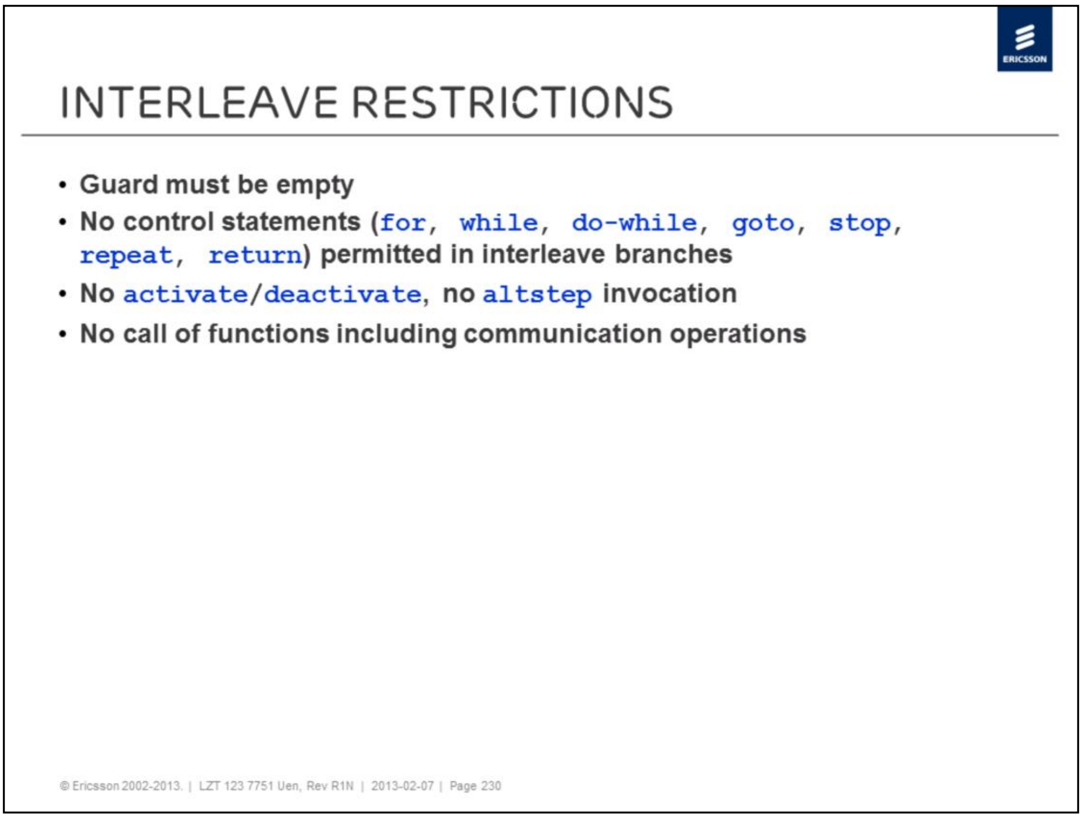


SAMPLE `interleave` STATEMENT

- Difference from alt:
  - All events must happen exactly once
  - Alternative execution (i.e. snapshot semantics) applies within statement block as well
  - Execution may continue on different branch when an operation blocks the actual one and resume later from the same place

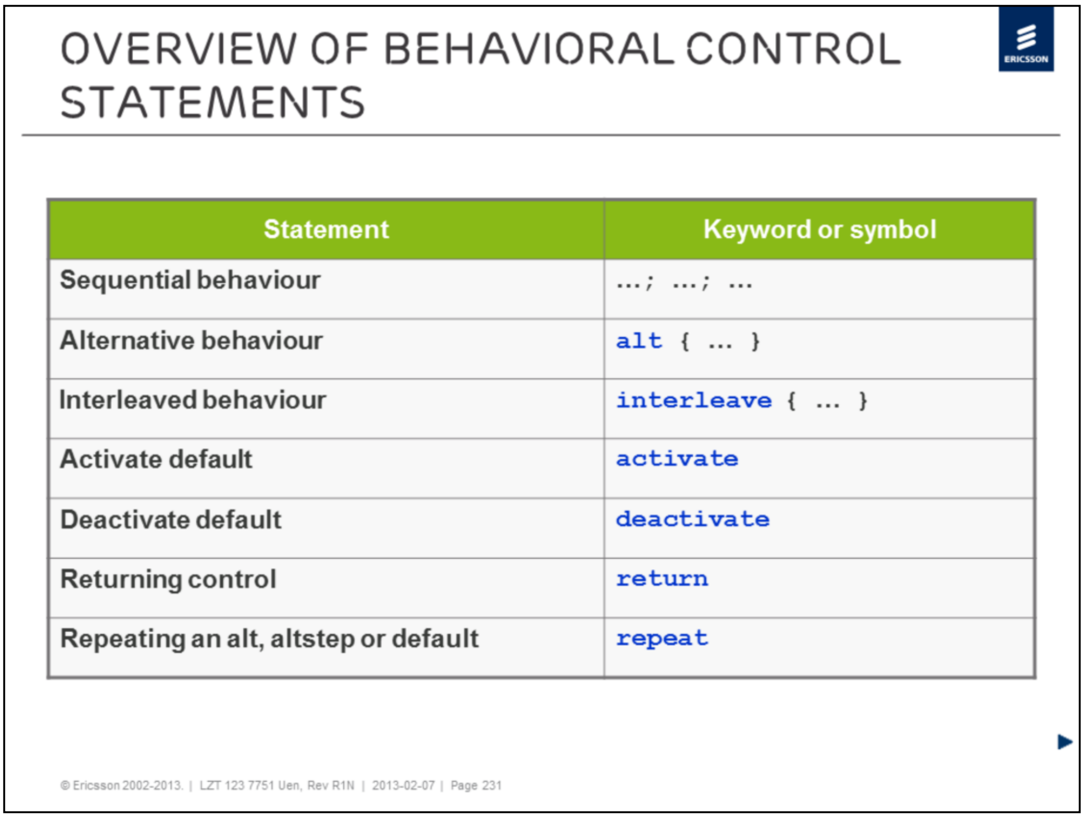
```
interleave {
[] P.receive(1)  { Q.receive(2); R.receive(3) }
[] Q.receive(4)  { P.send(a); R.receive(5) }
[] R.receive(6)
   { P.receive(7); Q.send(b); Q.receive(8) }
[] T.timeout     { R.send(c); P.receive(9) }
} // end of interleave
```

Execution segments are shown with arrows. Alternative segments are evaluated using snapshot semantics and executed interleaved.



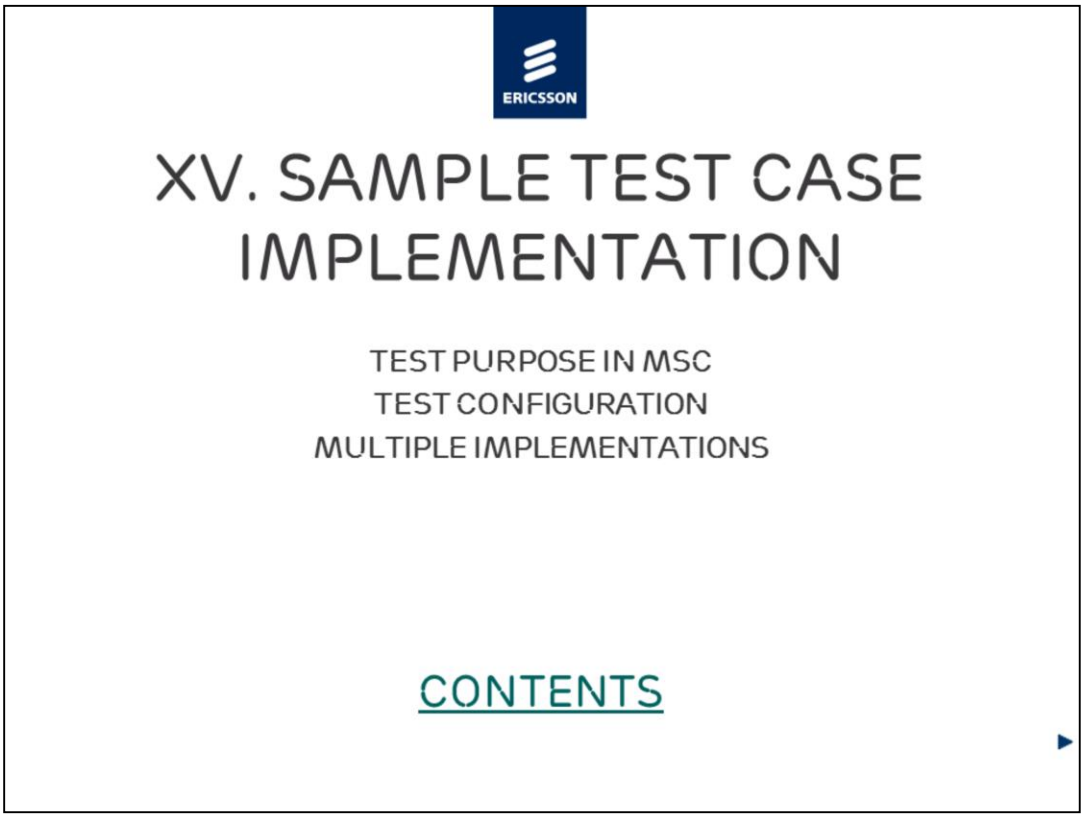
INTERLEAVE RESTRICTIONS

- Guard must be empty
- No control statements (`for`, `while`, `do-while`, `goto`, `stop`, `repeat`, `return`) permitted in interleave branches
- No `activate`/`deactivate`, no `altstep` invocation
- No call of functions including communication operations



OVERVIEW OF BEHAVIORAL CONTROL STATEMENTS

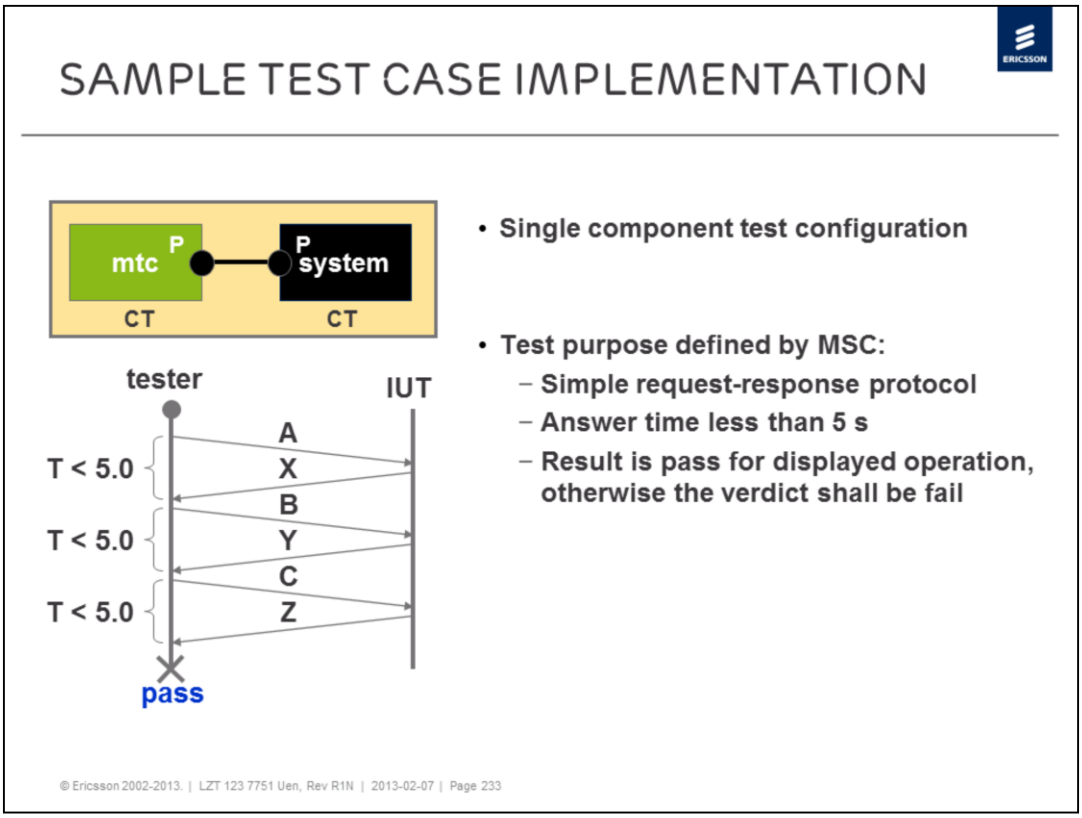
Statement	Keyword or symbol
Sequential behaviour	`…; …; …`
Alternative behaviour	`alt { … }`
Interleaved behaviour	`interleave { … }`
Activate default	`activate`
Deactivate default	`deactivate`
Returning control	`return`
Repeating an alt, altstep or default	`repeat`



XV. SAMPLE TEST CASE IMPLEMENTATION

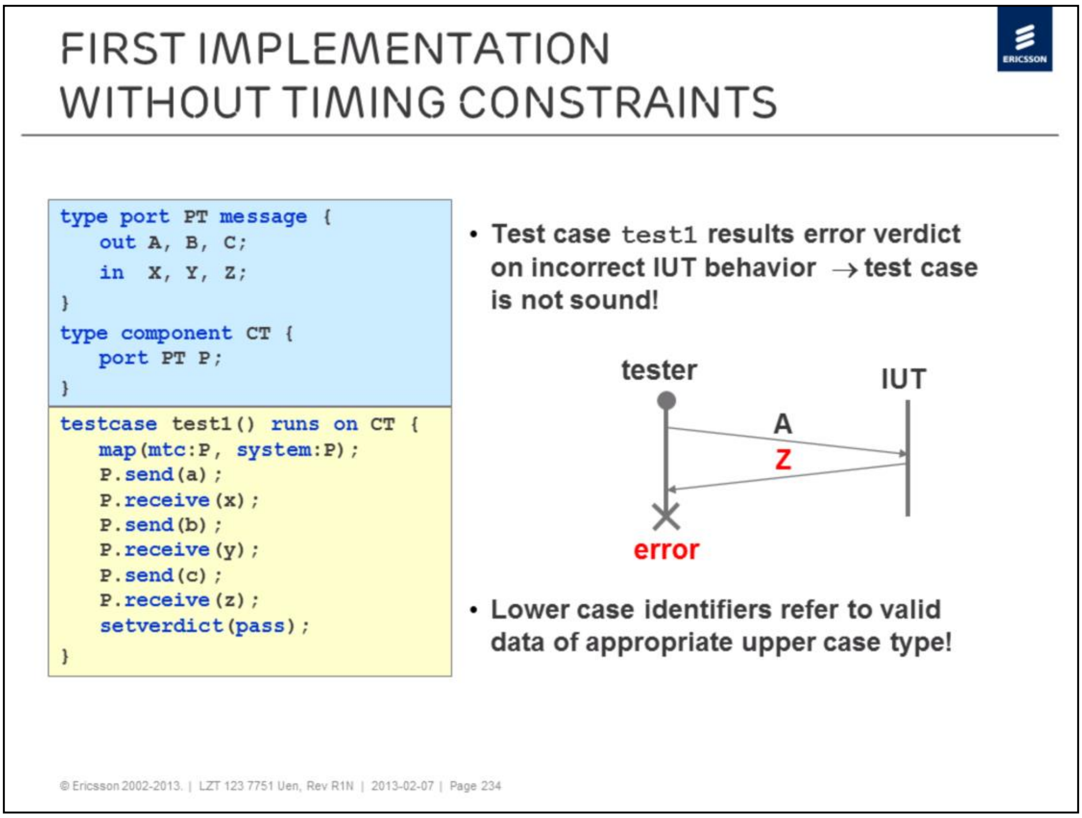
TEST PURPOSE IN MSC
TEST CONFIGURATION
MULTIPLE IMPLEMENTATIONS

CONTENTS



SAMPLE TEST CASE IMPLEMENTATION

- Single component test configuration
- Test purpose defined by MSC:
  - Simple request-response protocol
  - Answer time less than 5 s
  - Result is pass for displayed operation, otherwise the verdict shall be fail

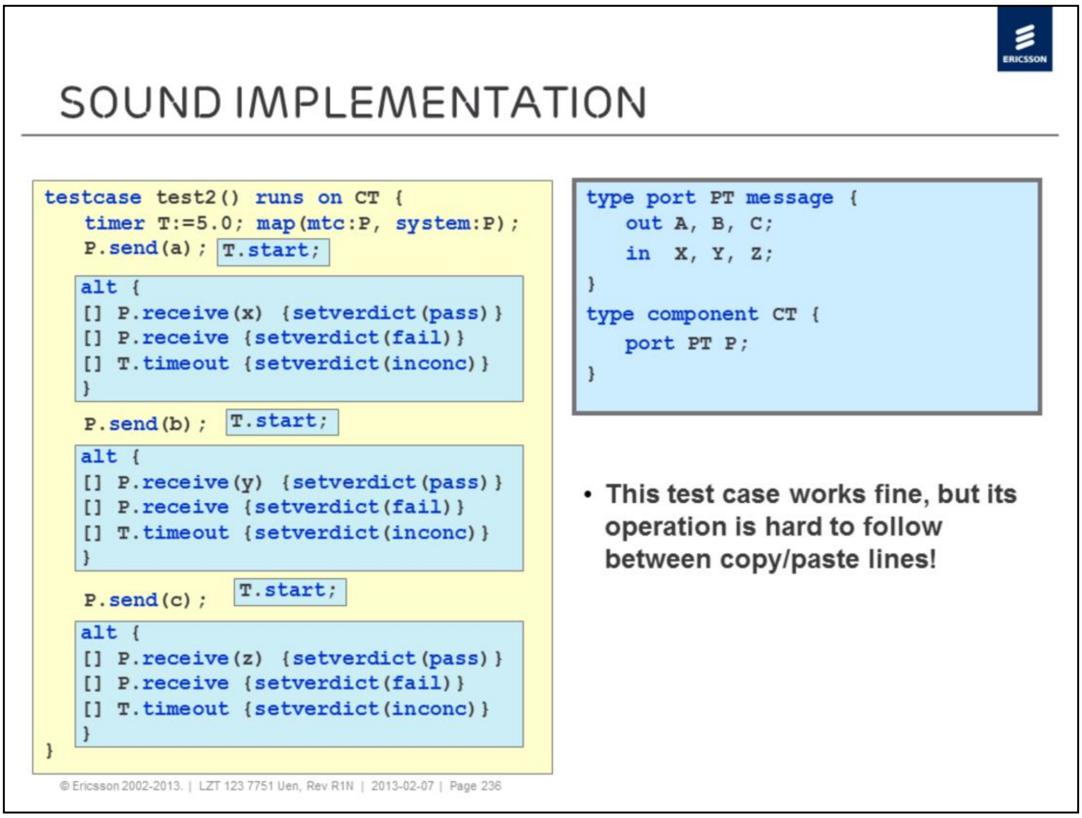


FIRST IMPLEMENTATION WITHOUT TIMING CONSTRAINTS

```
type port PT message {
   out A, B, C;
   in  X, Y, Z;
}
type component CT {
   port PT P;
}
testcase test1() runs on CT {
   map(mtc:P, system:P);
   P.send(a);
   P.receive(x);
   P.send(b);
   P.receive(y);
   P.send(c);
   P.receive(z);
   setverdict(pass);
}
```

- Test case `test1` results error verdict on incorrect IUT behavior → test case is not sound!

- Lower case identifiers refer to valid data of appropriate upper case type!

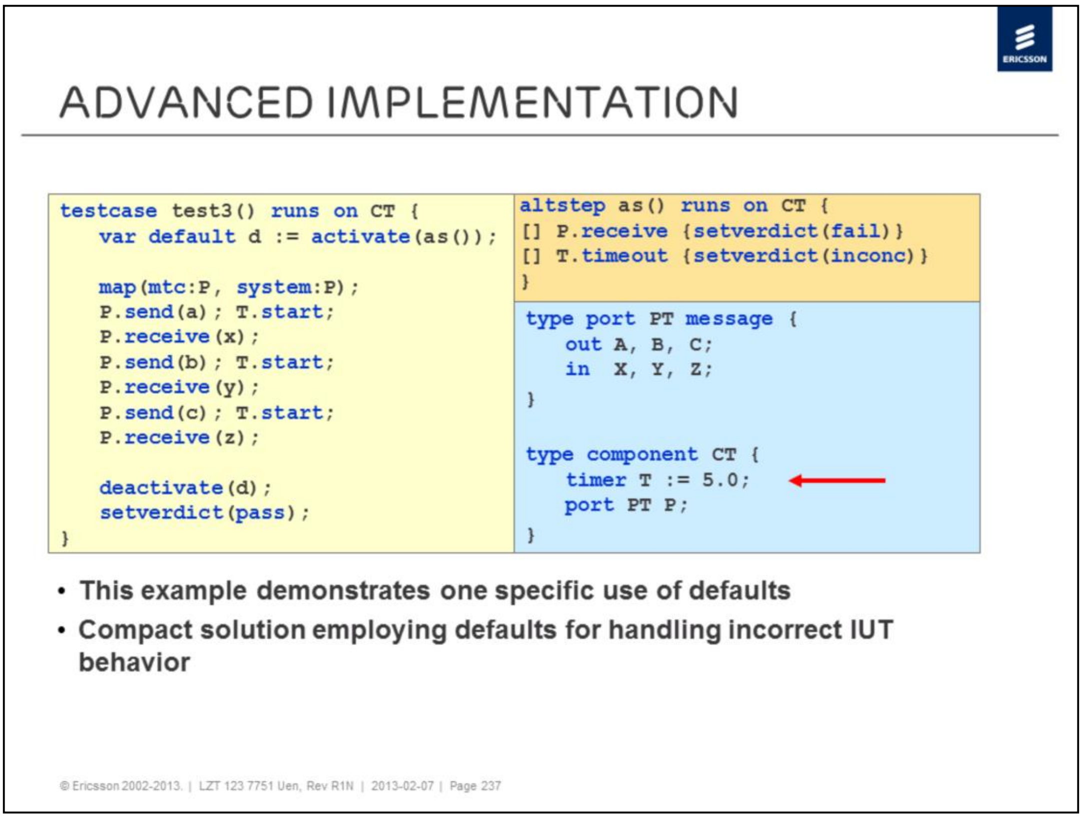


SOUND IMPLEMENTATION

```
testcase test2() runs on CT {
    timer T:=5.0; map(mtc:P, system:P);
    P.send(a); T.start;
   alt {
   [] P.receive(x)  {setverdict(pass)}
   [] P.receive {setverdict(fail)}
   [] T.timeout {setverdict(inconc)}
   }
    P.send(b);  T.start;
   alt {
   [] P.receive(y)  {setverdict(pass)}
   [] P.receive {setverdict(fail)}
   [] T.timeout {setverdict(inconc)}
   }
    P.send(c);  T.start;
   alt {
   [] P.receive(z)  {setverdict(pass)}
   [] P.receive {setverdict(fail)}
   [] T.timeout {setverdict(inconc)}
   }
}
```

```
type port PT message {
    out A, B, C;
    in  X, Y, Z;
}
type component CT {
    port PT P;
}
```

- This test case works fine, but its operation is hard to follow between copy/paste lines!



ADVANCED IMPLEMENTATION

```
testcase test3() runs on CT {
   var default d := activate(as());

   map(mtc:P, system:P);
   P.send(a); T.start;
   P.receive(x);
   P.send(b); T.start;
   P.receive(y);
   P.send(c); T.start;
   P.receive(z);

   deactivate(d);
   setverdict(pass);
}
```

```
altstep as() runs on CT {
[] P.receive {setverdict(fail)}
[] T.timeout {setverdict(inconc)}
}
```

```
type port PT message {
   out A, B, C;
   in  X, Y, Z;
}

type component CT {
   timer T := 5.0;
   port PT P;
}
```

- This example demonstrates one specific use of defaults
- Compact solution employing defaults for handling incorrect IUT behavior

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