

**Technical Paper**

**PLCopen Promotional Committee Training**

As part of the

**Software Construction Guidelines initiative**

Sub Committee

**Coding Guidelines**

**PLCopen Document, Version 1.0, Official Release**

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### **Coding Guidelines**

It summarises the results of the PLCopen workgroup Software Construction Guidelines Task Force Coding Guidelines, containing contributions of all its members.

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<b>Version</b>	<b>Date</b>	<b>Change/ comment</b>
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V 0.3	July 1, 2015	As a result of the webmeeting and last feedback in
V 0.99	July 23, 2015	Version to be published to the open community as Release for Comments till Oct. 23, 2015
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V 0.99B	Jan. 20, 2016	As result of the final feedback and editorial issues
V 1.0	April 20, 2016	Official published version

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## **1. Introduction**

Although there are coding guidelines for many programming languages, these are nearly non-existent for the important area of industrial control, e.g. IEC 61131-3 and its PLCopen extensions.

Nevertheless, the software in the industrial environments becomes more and more important, the software projects become larger, and the costs of errors increase. Software nowadays absorbs half of the initial project costs and between 40 and 80% deals with maintenance over the life cycle costs of the software.

In order to deal with the complexity of larger programs one needs modern software development processes supporting a structured approach. Also, we need to increase the efficiency in coding via re-use of pre-defined functionalities and to help to better understand the program over the life cycle.

With the above message PLCopen invited interested parties to join the working group of Software Construction Guidelines. The kick-off meeting resulted in several working groups for the different areas of interest, including their working packages (targets):

- Coding Guidelines
- Software quality issues and software consistency
- Creating PLCopen compliant Function Blocks
- Structuring and decomposition via SFC (do's & don'ts)
- Guidance for documentation in software programs
- Library usage
- Software development process

The key topic of the new PLCopen Software Construction Guidelines working group is the definition of Rules, Coding Patterns and Guidance and how to use them in Industrial Automation. These rules will be published as technical documents, as well as possibly on websites and software tools, and marketed by PLCopen.

The results of the working group should be based on the IEC 61131-3 1<sup>st</sup> and 2<sup>nd</sup> edition standard but should be easily extensible to the 3<sup>rd</sup> edition which was released in February 2013.

The aim of the subgroup Coding Guidelines is to define a set of rules and to provide a PLCopen proposal how these rules can be used. Nowadays large automation companies have their own rules but many mid-size companies or IEC 61131-3 beginners are very interested in using PLCopen guidelines. Such guidelines will have a great impact in expanding IEC 61131-3 further in the world.

The rules will be very useful to train users and can be a good basis for universities to help them teach IEC 61131-3 programming more efficiently.

## **2. How-to use this document**

The IEC 61131-3 standardizes programming languages and techniques, a major step forward in the PLC technology. These languages and techniques can contribute to the quality of the controller application. However IEC 61131-3 does not describe how a programmer can increase the quality of the application program. The IEC 61131-8 gives some guidance, but does not extend to the need of software quality. This technical paper fills in this gap.

This document is designed for PLC programmers who want to increase the product quality of their application program. It's not about process quality; this is the subject of other technical papers. This document consists of a set of rules that a programmer can use during coding and code reviews. Therefore, the technical paper contains no design rules. The set is certainly not complete, but significant enough to give the product quality a boost. The programmer or its organization can add or remove rules from the set.

The working group recommends the programmers take the following steps:

1. List the quality needs of the stakeholders and the maturity of the organization. Bring the quality in line with the organization.
2. Analyze the type of application.
3. Add other available rules to the set of rules from the technical paper.
4. Tailor the set of rules for the application based on the information from the previous steps, create a sub-set of rules.
5. Use the sub-set of rules when coding or reviewing the PLC program.

Ad 1.

The purpose of this technical paper is to increase the quality of software. This requires an organization with certain abilities or maturity, see for instance the Capability Maturity Model for software.

Ad 2.

The IEC 61131-3 standard specifies different languages, but if any are not used, then those language's rules can be ignored.

Ad 3.

Besides this document, there are other sources that describe quality rules. Think of company standards or general standards. Larger companies have already gained experiences and these experiences recorded in their own standard. Research the available rules. There are also overall software quality standards, such as McCall, etc. These standards are generally not directly applicable to PLC programs, hence this technical paper.

Ad 4.

Once the programmer has collected all the rules, then a selection can be made to create a sub-set of rules that will be applicable to the application. Of course, the sub-set may be the full set of rules.

## ***2.1. Methodology used to build this document***

The rules listed here are the combination of common rules used in computer science, rules developed by companies that are part of the working group and rules created by the workgroup based on their experience of PLC development. The documents used here are:

- IEC61131-3
- Misra-C
- JSF++
- Codesys on-line help

See 2.4 References for more details.

A first list has been issued in a spreadsheet, each rule on a row. The row number is the current identifier used in this document. Then for each row a page on a working wiki was created on which the workgroup was working during one year and a half.

The content of this document is the concatenation of all those individual rules which have been discussed during the working sessions.

The rules are written with the 3<sup>rd</sup> edition of the IEC 61131-3 standard in mind. Many rules can be equally applied to other editions or even outside the IEC 61131-3 scope.

The working group wants to get feedbacks from users about this initiative. In the future, the content of this document is subject to evolution both by rewriting some rules, giving more meaningful examples or adding some new rules. So feel free to contact info <at> PLCopen.org for giving your feedback.

## **2.2. Document structure**

The rules defined in this document have been classified in the following categories:

- Naming: how to name the PLC program elements. Some constraints for the naming and proposal for naming schemes;
- Comment rules: rules about the best way to comment your code so it is easy to read, understand and maintain;
- Coding practice: this section contains rules that are related to coding;
- Language: rules specific to one of the IEC61131 languages;
- Vendor Specific IEC61131 Extension: some rules specific to extensions of the IEC 61131 standard which are not available on all PLC vendors.

To enhance clarity, the chapters are initially organized in order of priorities, highest first. Each paragraph starts with 1. Later additions, irrespective of priorities, are done at the end.

Identifiers per rule contain a prefix for easy reference. The abbreviations are CP for Coding Practice; N for Naming, C for Comment, L for Language, and E for Extension. Each chapter starts with rule 1, like CP1. Future additions are done at the end.

An annex at the end of this document presents other ways to view the rules, based on priority.

### 2.3. Rules description format

Each rule in the document uses the same template. This section describes the different fields and gives the different possible values. A rules description looks like the following example:

<p><b>Identifier:</b> rule XX</p> <p><b>Importance:</b> high</p> <p><b>Targeted languages:</b> All</p> <p><b>References:</b></p> <ul style="list-style-type: none"> <li>• Misra-C_2004 rule 3.5</li> </ul> <p><b>Description:</b> When referencing user defined...</p> <p><b>Guideline:</b> Access to a member by offset ...</p> <p><b>Reasoning:</b> Referencing by offset is difficult to read, understand ...</p> <p><b>Exceptions:</b> None</p> <p><b>Example:</b></p> <p><i>Don't:</i></p> <pre>STRUCT example   X : DINT; ...  Do: instance.Z[1] := 'E';</pre> <p><b>Comments:</b> none</p>
---

- **Identifier:** Required - used to refer to a given rule easily. The current identifier has no semantic, it is just a number.
- **Importance:** Required - high, medium, low – this shows the interpretation of the group of the effect it has on the quality of the application software (high, medium or low)
- **Targeted language:** Required - some rules are only valid for some languages of the IEC61131. Either it is all languages, or the languages where the rule can be applied are listed.
- **References:** Required - when rules was found or inspired by a third party document, the reference is given in this field
- **Description:** Required - this is a longer description of the rule to get clear context
- **Guidelines:** Required - this is a help for the developer to explain how to work around the rule violation.
- **Reasoning:** Required - this gives reasons why this rule is a good idea.

- **Exceptions:** Optional - sometimes it is possible not to follow a rule for good reasons in a given case. This field lists the good reasons not to follow the rule.
- **Example:** Optional - the goal of the example is to help understand the reasoning of the rule and the guidelines to work around the violation with an explanatory example.
  - Don't – the don't part of the example uses red color to highlight bad coding practice
  - Do – the Do part of the example uses green color.
- **Comments:** Optional - this field is used to complete the rule description. It may be used to link with other rules or other subjects which may be out of the scope of this document.

Only fields Exceptions, Example and Comments are optional.

## 2.4. References

The following standards and committees are referenced from this site.

### **IEC 61131-3**

NAME: IEC 6-1131-3 edition 2 and 3

TITLE: Programmable controllers - Part 3: Programming languages

LOCATION: International Electrotechnical Commission

WEBSITE: <http://www.iec.ch/index.htm>

### **IEC 61131-8**

NAME: IEC 6-1131-8 edition 1 (and in future edition 3)

TITLE: Programmable controllers - Part 8: Guidelines for the application and implementation of programming languages

LOCATION: International Electrotechnical Commission

WEBSITE: <http://www.iec.ch/index.htm>

### **JSF++ coding standard**

NAME: JSF++ coding standard

TITLE: JSF Air Vehicle - C++ Coding Standards (Revision C)

DOCUMENT: 2RDU00001 Rev C. December 2005

WEBSITE: [http://www.jsf.mil/downloads/down\\_documentation.htm](http://www.jsf.mil/downloads/down_documentation.htm)

### **MISRA-C**

NAME: Motor Industry Software Reliability Association C

TITLE: Guidelines for the Use of the C Language in Vehicle Based Software

EDITION: 2005

WEBSITE: <http://www.misra.org.uk/>

### **Codesys On-line help**

EDITION: 2015

Website: <http://store.codesys.com/codesys-static-analysis.html>

### 3. Naming Rules

#### 3.1. *Additional rules for Variables only*

##### 3.1.1. Avoid physical addresses

**Identifier:** Rule N1

**Importance:** High

**Targeted languages:** Ladder, Structured Text, Sequential Function Chart, Function Block Diagram

**References:**

- IEC 61131-3 6.5.5
- IEC 61131-8 3.11.2

**Description:** Use of hardcoded, system dependent physical addresses shall be avoided

**Guideline:** Using physical addresses in programs is forbidden - always define a Variable.

**Reasoning:** Using physical addresses makes code less portable. To use a program on a different manufacturer, or even a different instance on the same manufacturer requires it to be edited. It also makes programs less readable as without a symbol table for reference it can be difficult to know what each address is used for. Later system changes are also more error prone as some access to the physical addresses may be skipped or overlooked.

**Exceptions:** In some communication protocols a physical addressing is needed to assign variables to a physical location for the order in the communication structure.

**Example, use case:** none

**Comments:** It is recommended that the VAR\_ACCESS method always be used when accessing variables in remote programmable controllers because it is then possible to use meaningful names for variables. There is always the likelihood that I/O physical addresses will be changed if the remote programmable controller program is modified. It may be convenient to fix VAR\_ACCESS names for a number of different programmable controller programs.



### 3.1.2. Define type prefixes for Variables (if used)

**Identifier:** Rule N2

**Importance:** Low

**Targeted languages:** All

**References:**

- Wikipedia [Hungarian Notation](#)

**Description:** You can define any scheme used to prefix name variables. These prefixes can include variable attributes like:

- Data Type (Boolean, Numeric, String etc)
- Scope (global, local, parameter)
- Control (input, output)
- System variable
- Zone (e.g. infeed, part 1, part 2, outfeed etc)

**Guideline:** If you use prefixes, document your notation. One option is to use Hungarian Notation for distinguishing data types. Choose one or many notation(s) in the examples below and use it consistently.

Warning, the same prefix may be used in different notations. In this case, you should use compound prefixes.

**Reasoning:** Using the variable's name to also communicate other attributes can improve readability and help reduce programming mistakes. For example, knowing the size of the datatype or whether signed or unsigned can be important in the selection of instructions. Knowing a variable is Global can suggest external influence, or caution about undesirable side effects when writing. Writing to an "Input" signal by mistake will have no effect, and is not always shown as an error, for example if intermediate variables are mapped.

Also as programs get bigger and bigger, there is a tendency to group related variables (for example InfeedSpeed, InfeedAlarm, InfeedStatus). This grouping fails if groups are used inconsistently (for example Infeed\_Speed, In\_Feed\_Alarm, ifStatus, inFault etc) so the common 'zone' names could be defined. This is especially true for large, multi-developer teams.

However, adding too many prefixes can create complexity and long variable names. The most useful (and most commonly used) is a prefix for the data type.

**Exceptions:** Attributes can be omitted if the Programming Support Environment clearly shows them by other means, for instance by hovering over it.

**Example, use case:**

Examples of a Hungarian Notation implementation coupled to the datatypes as defined in the 3rd edition of the IEC 61131-3 are:

<i>Data Type</i>	<i>Prefix</i>
BOOL	x
SINT	si
INT	i

DINT	di
LINT	li
USINT	usi
UINT	ui
UDINT	udi
ULINT	uli
REAL	r
LREAL	lr
TIME	tim
LTIME	ltim
DATE	dt
LDATE	ldt
TIME_OF_DAY / TOD	tod
LTIME_OF_DAY / TOD	ltod
DATE_AND_TIME / DT	dt
LDATE_AND_TIME / DT	ldt
STRING	str
WSTRING	wstr
CHAR	c
WCHAR	wc
BYTE	by
WORD	w
DWORD	dw
LWORD	lw

PLCopen Safety (as last character of the prefix)

All SAFE Datatypes prefix end with:	s
-------------------------------------	---

Example: SAFEBOOL prefix is: xs

Note: safety related tools will already differentiate between safe and non-safe datatypes, like with a color. So the usage of this character may not be necessary.

Cf. Table 11 of the 3rd edition of IEC 61131-3.

ENUM	e
NAMED	e
SUBRANGE	sb
ARRAY	a
STRUCT	st
Type STRUCT	ts
Reference	ref
FUNCTION BLOCK	fb
PROGRAM	prg
CLASS	cls

Note: ENUM and NAMED are proposed to use the same prefix.

For arrays, the datatypes does not have to be included.

As alternative, all user derived datatypes can be shown with one prefix: udt, no matter if it is an ENUM, NAMED or any other.

#### Examples of Scope prefix

<i>Scope</i>	<i>Prefix</i>
Global scope	g
Local scope	l
POU Parameter	p
Temporary Variable	tmp

#### Examples of Control prefix

<i>Control</i>	<i>Prefix</i>
Input (read only)	i
Output (read/write)	o

**Comments:** none

## **3.2. Tasks, Programs, Functions Blocks, Functions, Variables, UDTs and namespaces**

### **3.2.1. Define the names to avoid**

**Identifier:** Rule N3

**Importance:** High

**Targeted languages:** All

**References:**

- IEC 61131-3 6.1.3
- MISRA-C\_2004 20.1

**Description:** You shall define the words to avoid in object names

**Guideline:**

- IEC data types and standard library object names must be avoided
- IEC Structured Text keywords must be avoided
- Reserved words (for your platform) must be avoided
- Avoid uncommon abbreviations (or specify them clearly)
- Avoid meaningless names like: Info, Data, Temp, Str, Buf.

**Reasoning:** In many cases the keywords and reserved words must be avoided as they create build / compiler errors. Even in cases where it is permitted by the compiler (e.g. due to scope) it should be avoided as it can cause confusion and poor maintainability. If you intend your code to be portable across different platforms then you should avoid the Reserved Words from ALL platforms. Truncating words and Three Letter Abbreviations can be misleading and confusing. If necessary, define a list of acceptable abbreviations (like Max, Min, Temp, IP, OP etc) and abbreviations common to your industry.

**Exceptions:**

**Example, use case:**

**Comments:** None

Keywords / reserved word list of IEC 61131-3 Ed.3 starting with a letter:

ABS	END_IF	LEFT	REF_TO	UINT
ABSTRACT	END_INTERFACE	LEN	REPEAT	ULINT
ACOS	END_METHOD	LIMIT	REPLACE	UNTIL
ACTION	END_NAMESPACE	LINT	RESOURCE	USING
ADD	END_PROGRAM	LN	RETAIN	USINT
AND	END_REPEAT	LOG	RETURN	VAR
ARRAY	END_RESOURCE	LREAL	RIGHT	VAR_ACCESS
ASIN	END_STEP	LT	ROL	VAR_CONFIG
AT	END_STRUCT	LTIME	ROR	VAR_EXTERNAL
ATAN	END_TRANSITION	LTIME_OF_DAY	RS	VAR_GLOBAL
ATAN2	END_TYPE	LTOD	SEL	VAR_IN_OUT
BOOL	END_VAR	LWORD	SHL	VAR_INPUT
BY	END_WHILE	MAX	SHR	VAR_OUTPUT
BYTE	EQ	METHOD	SIN	VAR_TEMP
CASE	EXIT	MID	SINGLE	WCHAR
CHAR	EXP	MIN	SINT	WHILE
CLASS	EXPT	MOD	SQRT	WITH
CONCAT	EXTENDS	MOVE	SR	WORD
CONFIGURATION	F_EDGE	MUL	STEP	WSTRING
CONSTANT	F_TRIG	MUX	STRING	XOR
CONTINUE	FALSE	NAMESPACE	STRING#	
COS	FINAL	NE	STRUCT	
CTD	FIND	NON_RETAIN	SUB	
CTU	FOR	NOT	SUPER	
CTUD	FROM	NULL	T	
DATE	FUNCTION	OF	TAN	
DATE_AND_TIME	FUNCTION_BLOCK	ON	TASK	
DELETE	GE	OR	THEN	
DINT	GT	OVERLAP	THIS	
DIV	IF	OVERRIDE	THIS	
DO	IMPLEMENTS	PRIORITY	TIME	
DT	INITIAL_STEP	PRIVATE	TIME_OF_DAY	
DWORD	INSERT	PROGRAM	TO	
ELSE	INT	PROTECTED	TOD	
ELSIF	INTERFACE	PUBLIC	TOF	
END_ACTION	INTERNAL	R_EDGE	TON	
END_CASE	INTERVAL	R_TRIG	TP	
END_CLASS	LD	READ_ONLY	TRANSITION	
END_CONFIGURATION	LDATE	READ_WRITE	TRUE	
END_FOR	LDATE_AND_TIME	REAL	TRUNC	
END_FUNCTION	LDT	REF	TYPE	
END_FUNCTION_BLOCK	LE		UDINT	

### 3.2.2. Define the use of case (capitals)

**Identifier:** Rule N4

**Importance:** High

**Targeted languages:** Ladder, Structured Text, Sequential Function Chart, Function Block Diagram

**References:**

- IEC 6-1131-3 6.1.2
- MISRA-C\_2004 1.4
- GNU 5.4
- Java section 9
- Wikipedia CamelCase

**Description:** The use of capital letters in object names shall be clear and consistent across the project. Options are (not limited to):

- alllowercase
- underscore\_separated (also known as lower\_snake\_case)
- lowerCamelCase
- UpperCamelCase (also known as PascalForm)
- ALLUPPERCASE or CAPITALIZED
- UPPER\_SNAKE\_CASE
- OTHER\_style

**Guideline:**

Use the same capitalization for every object instance, even if the tool/compiler doesn't mandate it. The following guidelines are proposed:

- Use UPPER\_SNAKE\_CASE for CONSTANTS and user defined datatypes and keywords (like BOOL, FOR, TYPE and END\_TYPE).
- Use UpperCamelCase for all other multi-word items

**Reasoning:** Case is not always significant to the tool or compiler but for readability purpose it should be consistent. Since in the IEC 61131-3 standard all identifiers are case insensitive it does not affect the portability.

CamelCase keeps long names readable while being shorter and quicker to type than using underscores. Use "UPPER\_SNAKE\_CASE" format to separate capitalized words with underscores like used for keywords. These guidelines are also similar to external standards likely to be used for third party code or libraries.

**Exceptions:** When using prefixes for Variables (see Rule 14) the UpperCamelCase changes to lowerCamelCase.

**Example, use case:**

*Don't:*

```
STARTMOTOR();    //Don't use all capitals as it confuses with constants.  
startmotor();    //Don't use the same case as it is difficult to read
```

*Do:*

```
StartMotor(); //UpperCamelCase makes it quick to read
```

*Don't:*

**Declaration of a structured data type (IEC 61131-3 6.4.4.6.1 Structured data type)**

```
TYPE
    ANALOG_SIGNAL_RANGE:
        (BIPOLAR_10V,
         UNIPOLAR_10V);
    ANALOG_DATA: INT (-4095 .. 4095);
    ANALOG_CHANNEL_CONFIGURATION:
        STRUCT
            RANGE: ANALOG_SIGNAL_RANGE;
            MIN_SCALE: ANALOG_DATA;
            MAX_SCALE: ANALOG_DATA;
        END_STRUCT;
END_TYPE
```

*Do:*

```
TYPE
    ANALOG_SIGNAL_RANGE:
        (Bipolar10Volt,
         Unipolar10Volt);
    ANALOG_DATA: INT (-4095 ... 4095);
    ANALOG_CHANNEL_CONFIGURATION:
        STRUCT
            Range: ANALOG_SIGNAL_RANGE;
            MinScale: ANALOG_DATA;
            MaxScale: ANALOG_DATA;
        END_STRUCT;
END_TYPE
```

*Do:*

### **Naming example from PLCopen Motion Control**

Over the years the suite of Motion Control specifications was defined within PLCopen. Consistency in the naming conventions was realized after 2010.

**Function Blocks:** Prefix MC\_, and capitalize first letter of each word, and no hyphenation between words. Example: MC\_MoveAbsolute

**Enum elements:** prefix to name is mc, and each word starts with a capital letter. So mcNameName2. Example mcPositive, mcBlendingLow.

**Data types and Structures:** Prefix MC\_ (except AXIS\_REF), capitalized and underscore between groups of words. Example: AXIS\_REF; MC\_BUFFER\_MODE, MC\_TP\_REF, MC\_INPUT\_REF.

**Inputs and outputs:** No prefix. Each word start with a capital letter. No hyphen between words.  
Examples: Busy, CommandAborted, Master, BufferMode

**Comments:** None



### 3.2.3. Local names shall not shadow global names

**Identifier:** Rule N5

**Importance:** High

**Targeted languages:** All

**References:**

- IEC 61131-3 6.9.1
- MISRA-C\_2004
- JSF++ 135

**Description:** The elements Tasks, Programs, Functions Blocks, Functions, Variables and UDTs shall not re-use the same global name, especially not within the same scope/namespace. A local element shall not shadow the global elements. (With shadowing, a local element has the same name as a global element; however the local scope cannot access the global element)

**Guideline:** Do not use identical names for any tasks programs, functions and function blocks, variables, user defined types, and name spaces. Using prefixes to name your programming elements may help (see rule N2 3.1.2 Define type prefixes for Variables (if used)).

**Reasoning:** Using the same name for different objects would make code difficult to read. Even if compilation is possible, errors in readability can introduce program mistakes. Also such code cannot be guaranteed portability either. Even within different namespaces such confusion is best avoided.

**Exceptions:** none

**Example:**

*Don't:*

```
VAR_GLOBAL
    MyCalculation: REAL;    // Global Variable Declaration
END_VAR
FUNCTION_BLOCK MyFirstCalculation // Global Type Declaration
VAR
    MyCalculation: REAL;    // Local variable declaration
                            // any access in the FB accesses this variable
END_VAR
MyCalculation := 1.1;      // scope is within this FB
...
END_FUNCTION_BLOCK

FUNCTION_BLOCK MySimilarCalculation // 1) Declared in the global namespace.
    VAR_EXTERNAL
        MyCalculation : REAL;
    END_VAR
MyCalculation := 1.1;      // same line of code but different access:
                            // to the global variable defined at start
END_FUNCTION_BLOCK
```

*Do:* Use a different name for the global variable

```
VAR_GLOBAL
  GlobalCalculationResult: REAL;    // Global Variable Declaration
END_VAR
.....
```

**Comments:** none

### 3.2.4. Define an acceptable name length

**Identifier:** Rule N6

**Importance:** Medium

**Targeted languages:** Ladder, Structured Text, Sequential Function Chart, Function Block Diagram

**References:**

- IEC61131-3 6.1.2
- JSF++ AV Rule 46
- MISRA Rule 5.1
- GNU 5.4
- Java Section 9

**Description:** All named elements should have a mnemonics of an acceptable length. This relates to Tasks, POUs, Functions and Function Blocks and Variables.

**Guideline:**

- Min. length proposal: 8 characters, or 3 characters for local names.
- Max. length proposal: 25 characters
- On the average: keep the maximum to 15 characters
- Don't use abbreviations, unless required to shorten the name and the abbreviations are expected to be well known.
- Avoid names that are very similar or different only in case. For example, avoid using the names like variable and variables.

**Reasoning:** When all elements have a mnemonic in a given length range, maintenance is easier and it is easier to understand content. The minimum size is used to ensure that mnemonic are meaningful. Maximum length is used to ensure that a reader will be able to differentiate quickly two elements and some Programming Support Environment truncate the longest names.

**Exceptions:** It is not required for some elements of limited scope (e.g. Internal Variables):

- loop indexes: as their usage is limited to a given loop and it is common usage to use very short name
- structure members: the structure member name is always used with the instance name so it may be meaningful even when being short.

**Example, use case**

*Don't:*

```
FUNCTION Go : BOOL; ...  
// too short
```

```
FUNCTION aaa: INT; ...  
// meaningless name
```

```
FUNCTION ReadAndScaleTheTemperatureInput: REAL; ... //Too long
```

*Do:*

```
FUNCTION StartFeeding: BOOL;      // Name explains function
FUNCTION ReadTemperature: REAL; // Name explains function
```

*Don't:*

```
VAR
    Go : BOOL; // too short
    aaa: INT;  // meaningless name
    MaximumTemperatureForTheThermocoupleInput: REAL; //Too long
END_VAR;
```

*Do:*

```
VAR
    i: INT; // FOR loop counters and indexes only
    MaxTCTemperature: REAL; // Only use clear abbreviations (TC ==
Thermocouple)
END_VAR;
```

**Comments:** None

### 3.2.5. Define naming rules for namespaces

**Identifier:** Rule N7

**Importance:** Medium

**Targeted languages:** All

**References:**

- IEC61131-3, 6.9

**Description:** Naming rule for namespace and declaration rule for new namespace should be clarified.

**Guideline:**

- Each namespace should be written in casing manner called "UpperCamelCase".
- On declaring POU's and data types, at least one namespace should be declared in the global namespace. No elements except standard types of IEC 61131-3 should be declared directly in the global namespace.
- The first level namespace just below global namespace should be started with the word which represents the organization/company who is responsible for the specification of the content of the namespaces below it.
- Regarding sub-namespaces below the namespace of company/organization, each company/organization should define its own semantic naming rule. Such sub-namespace names may consist of sub-committee name, functional category, product name, etc...

**Reasoning:**

- Standard functions/function blocks of IEC 61131-3 are in the global namespace whose name is empty. The global namespace is applied for each namespace without USING directive by default. Thus declaring elements directly in the global namespace increases the risk of conflict when a short name used in any namespace shadows the same name in another namespace.
- POU/data type library may be distributed across vendors/organizations. In order to avoid naming conflict, non-standard POU's/data types need to be declared in the namespace whose name is as unique as possible according to the name of vendors/organizations.

**Exceptions:** This rule can be only followed in Programming Support Environment that supports namespace feature. Applications or library which are to be used only within the specific organization where naming can be fully controlled.

**Example, use case:**

*Don't:* Types declared directly in the global namespace

```
FUNCTION_BLOCK MyCalculation // 1) Declared in the global namespace.
...
END_FUNCTION_BLOCK

NAMESPACE SomeCompany.XseriesCPU
    FUNCTION_BLOCK MyCalculation // 2) The same name is used also.
    ...
END_FUNCTION_BLOCK
```

```
PROGRAM MainProgram
  VAR MyCal : MyCalculation;
  // Usage of short type name above becomes ambiguous.
  // Need to write "SomeCompany.XseriesCPU.MyCalcuration" for 2).
  // No means to explicitly refer to 1).
END_PROGRAM
END_NAMESPACE
```

*Do:* Nothing is directly declared in the global namespace. All namespaces start with organization name.

```
NAMESPACE SomeCompany.XseriesCPU
  USING PLCopen.Motion;
  USING PLCopen.Safety;

PROGRAM MainProgram
  USING OMAC.OPW.PackML3;
  ...
END_PROGRAM

PROGRAM CommProgram
  USING IEC_61131_5;
  ...
END_PROGRAM
END_NAMESPACE
```

**Comments:** None

### 3.2.6. Define the acceptable character set

**Identifier:** Rule N8

**Importance:** Medium

**Targeted languages:** All

**References:**

- IEC61131-3 6.1.2
- JSF++ AV Rule 9
- MISRA Rule 3.2

**Description:** The character set should be explicitly defined.

**Guideline:** The mnemonics should use a subset from the character set:

- Identifiers should not start with a digit character
- Only alphanumeric and underscore characters should be used in mnemonics. Accents should not be used.
- Identifiers should use characters from ASCII 7 bits.

**Reasoning:** Using special characters may generate some problems of portability to future Programming Support Environment version and/or to other platforms. It also reduces the readability in an international context. Finally, the restriction to only alphanumerical characters ensures a better distinction between variable names.

**Exceptions:** Comments can use character sets from the native languages. Also if the scope of usage of the program is known (like China) then the usage of the national character set can be applied to identifiers.

**Examples:**

*Don't:*

```
départ := true; // .... Lines of code
depart := false; //Using the special character 'é', leads to a
confusion between mnemonics.
```

*Do:*

```
Depart := True; // No accent in the variable name
// Autorise le départ du wagonnet // Accent in the
comment-
```

**Comments:** None

### 3.2.7. Different element types should not bear the same name

**Identifier:** Rule N9

**Importance:** Medium

**Targeted languages:** All

**References:**

- IEC 6-1131-3 6.9.1
- MISRA-C\_2004
- JSF++ 135

**Description:** The elements types Tasks, Programs, Functions Blocks, Functions, Variables and User Defined Types should not share the same name in the same scope.

**Guideline:** Do not use identical names for any tasks programs, functions and function blocks, variables, UDTs and name spaces.

**Reasoning:** Using the same name for different object types would make code difficult to read. Even if compilation is possible, errors in readability can introduce program mistakes.

**Exceptions:** none

**Example:**

*Don't:*

```
VAR_GLOBAL
    MyCalculation: REAL;    // Global Variable Declaration
END_VAR

FUNCTION_BLOCK MyCalculation // Global Type Declaration with same name
VAR_IN_OUT
    MyCalculation : REAL;    // Input variable declaration
                            // any access in the FB accesses this variable
END_VAR

MyCalculation := 1.1;      // scope is also external to this FB
...
END_FUNCTION_BLOCK

PROGRAM MyCalculation      // Declared in the global namespace.
    VAR
        MyCalculation : MyCalculation;
    END_VAR
    ...                    // Note: it is not possible to access the global variable
                            // from here due to shadowing
END_PROGRAM
```

**Comments:** none



### 3.2.8. Define name prefixes for user defined types

**Identifier:** Rule N10

**Importance:** Low

**Targeted languages:** All

**References:** none

**Description:** You can define any scheme used to prefix names for user defined types. These prefixes can include attributes like:

- Type (Function, Function Block, Structure, Array, etc.)
- Domain (e.g. MC for Motion Control, SF for Safety, etc)

**Guideline:** If you use prefixes, document your notation. Choose one or many notation(s) in the examples below and use it consistently.

The proposal is to use capitals for the prefixes for user defined type names.

Warning, the same prefix may be used in different notations. In this case, you should use compound prefixes.

**Reasoning:** Using the type name to also communicate other attributes can improve readability and help reduce programming mistakes.

**Exceptions:** Attributes can be omitted if the Programming Support Environment clearly shows them by other means, for instance by hovering over it.

**Example, use case:**

Cf. Table 11 of the 3rd edition of IEC 61131-3.

ENUM	E
NAMED	E
SUBRANGE	SB
ARRAY	A
STRUCT	ST
Reference	REF
FUNCTION	FU
FUNCTION BLOCK	FB
PROGRAM	PRG
CLASS	CLS
INTERFACE	I

Note: ENUM and NAMED are proposed to use the same prefix.

For arrays, the datatypes does not have to be included.

As alternative, all user derived datatypes can be shown with one prefix: UDT, no matter if it is an ENUM, NAMED or any other.

**Comments:** none

## **4. Comment Rules**

This chapter is related to commenting the program and the application so that it is easier to read, understand and modify. The following guidelines are good practices about writing good comments.

#### 4.1. Comments shall describe the intention of the code

**Identifier:** Rule C1

**Importance:** High

**Targeted languages:** All

**References:**

- JSF++ 130

**Description:** All code shall be explained by a comment, although that doesn't necessarily mean 1 line of comment per code. Comments shall describe the intention of the code.

**Guideline:** Review code to ensure it is explained by a comment, either:

- At the end of the code line
- Separate comment, immediately prior to the code
- Block comment and the start of a sub section of code (e.g. whole IF THEN ELSE block)
- Function/Function Block comment, if the code is small enough to be wholly explained by the comment
- Program comment, if the code is small enough to be wholly explained by the comment

**Reasoning:** Good programming practice dictates that well written code with well-chosen variable names should be self-documenting. Commenting every rung or line is therefore not always necessary, unless it is complex or potentially ambiguous.

You can divide comments into five categories (McConnell 1993, p. 463):

1. *Repeat of the code,*
2. *Explanation of the code,*
3. *Marker in the code,*
4. *Summary of the code*
5. *Description of the code's intent.*

What are good comments? Comments that describe the intentions of the programmer. Where do you draw the line? The boundary is at the transition from Intention (what, or function) to Extension (how, program code). The Extension (Program Code) is coded in a formal language, such as IL, ST, LD, FBD or SFC and the Intention is written in an informal language, such as English or Chinese. One of the qualities of an informal language is that it is likely to inconsistent interpretations. Furthermore programmers are not always informal language experts. So one merely describes the intentions in the shape of block comments (Marker or Summary) or routine commentary. In exceptional cases, a programmer may explain a program part.

For example it may be clear to comment several statements in each branch of a conditional IF-THEN statement with a single comment. If the branches are small, and the logic clear enough then it may be clear with a single comment prior to the whole conditional block. You can even argue that code in a small Program/Function/Function Block can be explained by a single comment. All the code should be explained by a comment at some scope. The comments should describe the intention of the code.

However there should be no code that performs tasks other than those that the comments state.

**Exceptions:** Any use of 'magic numbers' or physical addresses should always be commented

## Example:

Don't:	Do:
<p>Code blocks with no comments:</p> <pre> IF IsValid(TCInput) THEN     Temperature := TCInput *                   TCScale + TCOffset; ELSE     TCBadQuality := TRUE; END_IF; </pre> <p>Comments that add no value over the code:</p> <pre> IF IsValid(TCInput) THEN     // TCInput is valid     Temperature := TCInput *                   TCScale + TCOffset; ELSE     // TCInput is not valid     CBadQuality := TRUE; END_IF; </pre>	<p>Branch comments should add value:</p> <pre> IF IsValid(TCInput) THEN     // Scaling of the     //Temperature     Temperature := TCInput *                   TCScale + TCOffset; ELSE     // Some error reading the     // temperature value     TCBadQuality := TRUE; END_IF; </pre> <p>Whole block explained well by a single comment:</p> <pre> // Check for a new maximum // temperature reading MaxReading := nReadings[0]; FOR index:=1 TO 10 DO     IF nReadings[Index] &gt; MaxReading     THEN         MaxReading := nReadings[Index];     END_IF; END_FOR; </pre>

**Comments:** None

## 4.2. *All elements shall be commented*

**Identifier:** Rule C2

**Importance:** High

**Targeted languages:** Ladder, Structured Text, Sequential Function Chart, Function Block Diagram

**References:**

- JSF++ 132, 134

**Description:** All POU (Program, Function Block and Function), Task, User-Defined Types, Resource and Variable elements shall be explained by a comment.

**Guideline:** Include clear comments for all elements, including Tasks, Programs, Function Blocks, Functions, User Defined Types, Variables and Resources.

**Reasoning:** Clear comments communicate the intention of each element, and aid readability and improve understanding of the program.

**Exceptions:** None

**Example:** None

**Comments:** None

### 4.3. *Avoid nested comments*

**Identifier:** Rule C3

**Importance:** Low

**Targeted languages:** All

**References:**

- MISRA-C\_2004 section 2.3

**Description:** Nesting of multiline comments must be avoided

**Guideline:** In the released versions of programs there should be no nested comments, even if it's possible during development and debug phases.

**Reasoning:** Editing of nested comments is a common source of accidentally mismatching comment delimiters and unintentionally commenting out code. This editing error can be missed by the compiler if valid code can still be compiled.

As a general principle Code in comment should not be used for version control or configuration management purposes; proper tools should be used for that.

**Exceptions:** None

**Example:**

*Don't:*

```
(* Any comment with the end marker has been forgotten
Critical_section_that_must_be_executed_which_is_found_in_the
comment());

(* <- The start marker comment is commented because the end marker
of the previous comment has been forgotten *)
```

**Comments:** None

#### 4.4. *Comments may not include code*

**Identifier:** Rule C4

**Importance:** Low

**Targeted languages:** Structured Text

**References:**

- MISRA-c\_2004 2.4
- JSF++ 127

**Description:** Valid code statements may not be commented out and left in programs

**Guideline:** In the released versions of programs there should be no code in comments, even if it's possible during development and debug phases.

**Reasoning:** Editing multi-line Comments is a common source of accidentally commenting out code. This editing error can be missed by the compiler if valid code can still be compiled. Equally, code that is not required and is commented out can easily be accidentally reinstated.

While commenting out a few lines of code is commonplace in the debugging and commissioning phase it should not be used for released software: if the code is not used it should be deleted, or if it needs to be disabled another construct should be used e.g. removing Program from a Task or a "IF 0 THEN" construct.

As a general principle Code in comments should not be used for version control or configuration management purposes; proper tools should be used for that.

**Exceptions:** None

**Example:** None

**Comments:** None



## 4.5. Use single line comments

**Identifier:** Rule C5

**Importance:** Low

**Targeted languages:** Structured Text

**References:**

- IEC 6-1131-3 6.1.5
- MISRA-c\_2004 2.2

**Description:** Define the type of Comment definition character to be used

**Guideline:** Use single line comments, i.e. //

**Reasoning:** Although multiple commenting styles are available, for consistency and portability you should define which style to use. Multi-line comments can be problematic and be the cause of accidental commenting in or out of code depending on the way the workbench manages the nested comment. Also not all Programming Support Environment support IEC 3rd Edition. Commenting out some code containing only '/' style comments avoids the errors of nested comments.

**Exceptions:** During testing and debugging phases, multi-line comments can be used to exclude portion of codes. Single line comments with // should not be used for this purpose.

**Example:**

*Don't:*

```
(* Multiline comments can be dangerous because matching close
comment can be deleted by accident.

b:=a;          // commented out code can be activated by accident

// or active code after this block accidentally commented out.

*)

(* (* NESTED COMMENTS *) *)
```

*Do:*

```
<statement>;    // End of line comment

// Block Comment
// <the following block...>
// <...>
<statement>;
```

**Comments:** For existing code with (\*, one can use the /\* to exclude portions of code to differentiate, if the system allows this.

#### 4.6. *Define comments language*

**Identifier:** Rule C6

**Importance:** Low

**Targeted languages:** Ladder, Structured Text, Sequential Function Chart, Function Block Diagram

**References:** None

**Description:** You may define which spoken language your comments may be written in. This applies to code comments in both ST and Ladder, plus any other comments like Variable comments, Project comments, Task comments, source control comments etc.

**Guideline:** Use English only for all comments

**Reasoning:** Understanding and maintaining the comments improves readability, reduces mistakes and therefore development costs. For all developers, current and future, to understand the comments, a common language should be chosen. This includes teams with members of international members and also multi-site teams. Any common language is sufficient, but English is the most widely spoken language internationally.

It may be desirable to have the comments duplicated in more than 1 language, especially where the languages are completely different alphabets e.g. English and Chinese. This can be done manually although some tools already have facilities to do this. You should still consider which language is mandatory, and ensure your code review process checks for untranslated comments.

**Exceptions:** None

**Example:** None

**Comments:** None

## 5. Coding Practice

### 5.1. *Access to a member shall be by name*

**Identifier:** Rule CP1

**Importance:** High

**Targeted languages:** All

**References:**

- Misra-C\_2004 rule 3.5

**Description:** When referencing user defined types like structures in the code, the references shall be done using the member name and not using an offset between the beginning of the structure and the position of the member in memory.

**Guideline:** Access to a member by offset should be avoided.

**Reasoning:** Referencing by offset is difficult to read, understand and maintain. If for some reason one another member is inserted before, then all offsets of the following members have to be recalculated. Moreover it relies on memory implementation (like big endian vs. little endian) and especially, the offset of a given structure depends on the PLC type: the alignment rules are not always the same.

**Exceptions:** None

**Example:**

*Don't:*

```
STRUCT EXAMPLE_STRUCT
  X : DINT
  Y : BOOL;
  Z : STRING[40];
END_STRUCT;

VAR
instance : EXAMPLE_STRUCT AT %MW500;
END_VAR

// Write the first character of Z:
%MW504 := 'E';
```

*Do:*

```
instance.Z[1] := 'E';
```

**Comments:** none

## 5.2. All code shall be used in the application

**Identifier:** Rule CP2

**Importance:** High

**Targeted languages:** All

**References:**

- Codesys SA0001, SA0031
- Itris Automation Square I3
- Misra C 14.1
- JSF++ Rule 186

**Description:** Dead code is not allowed

**Guideline:** All parts of the application code should be reachable under certain conditions so that they are not dead code.

**Reasoning:** Dead code affects the readability and maintainability of the program and can be a symptom of a functional problem. Different kinds of dead code exists:

- Unreferenced functions :
  - re-use of an already existing application to create a new application slightly different
  - developer mistake forgetting to call part of the application during development
  - part of the code used in a specific environment : testing, simulation of missing hardware
- Code not reachable unconditionally - techniques used by developer to bypass part of the code :
  - due to unconditional go to followed by code without called label
  - condition always false or true

**Exceptions:** A dead code with a nice comment delimiting and explaining correctly the reason why the code was bypassed may be used. In such case, the code section should be small enough so that a developer sees as evidence that it is dead code.

**Example:**

*Do:*

```
...  
//  
// The following section handles the optional device FOO.  
// It is bypassed for application THIS_PARTICULAR_APPLICATION  
because  
// this device is not loaded for this application  
IF FALSE THEN  
    // unreachable code  
    ...  
END_IF;
```

```
// End of bypassed section for THIS_PARTICULAR_APPLICATION
```

**Comments:** none

### 5.3. *All variables shall be initialized before being used*

**Identifier:** Rule CP3

**Importance:** High

**Targeted languages:** All

**References:**

- IEC 61131-3 3rd Ed. section 6.5.1 and 6.5.6
- IEC 6-1131-8 Section 3.1.1
- JSF++ - rule 142

**Description:** A variable shall be initialized before being read by another part of the code, whatever the cycle: cold start, warm start, first cycle, normal cycle.

**Guideline:**

- According to IEC 61131-3 all variables have default initial values. If the programming system does not support this feature (for example for ARRAYS), the user has to initialize the variables explicitly in the user program.
- Using an initialization at the variable declaration is good but the behavior may be different depending if it is a cold start or a warm one
- Using code to explicitly initialize variable is a maintainable and readable way
- When creating User Defined Types specify a good Default Initial Value. Any variables created of this type will not need to be explicitly defined.

**Reasoning:** Reading uninitialized variables in your code gives undetermined behavior to the code.

**Exceptions:**

- If the PLC initializes explicitly variables to 0, and if this variable should be initialized to 0, it is not required to explicitly initialize the variables to zero. However this can affect portability of the code.
- Variables that have RETAIN attribute will automatically have their values initialized to their retained upon power reset.
- Variables that are linked to physical inputs do not need to be initialized.

**Example:**

*Do:*

```
PROGRAM Initialization
VAR
    NumOfRetries: INT:= 3;           // direct initialisation
    Enable: BOOL:= TRUE;           // direct initialisation
    ConfTimerPreselection : TIME := T#5s;

    StateLastPosition : INT;
    SpeedAverage : REAL;
END_VAR;

    StateLastPosition := 50;
    SpeedAverage := 0.0;
```

...

```
END_PROGRAM
```

IEC 61131-3 also allows the user to specify default initial values for user-defined types. For instance, consider a type declared by:

```
TYPE TempLimit : REAL:= 250.0; END_TYPE
```

Any declared variable of this new type TempLimit is initialized with the default value of 250.0 instead of 0.0 as would be the normal case for all REAL data. Thus, in the following declaration, the variable BoilerMaxTemperature is initialized to 250.0, while the variable PipeMaxTemperature is initialized to 0.0. If the value of zero is not a reasonable maximum temperature for the pipeline, its correct value has to be set before the first usage of the variable. Forgetting this will cause problems. In the present example, the maximum temperature for the boiler is initialized with a proper default initial value. There is no need for a set-up before the first usage, which greatly simplifies a programmable controller program and increases software reliability.

```
VAR_GLOBAL
```

```
    BoilerMaxTemperature: TempLimit;
    PipeMaxTemperature: REAL;
```

```
END_VAR
```

**Comments:** More examples of defining default initial values for user-defined types:

- Initialization of enumerated data types, e.g.:

```
TYPE ANALOG_SIGNAL_RANGE :
    (BIPOLAR_10V, (* -10 to +10 VDC *)
     UNIPOLAR_10V, (* 0 to +10 VDC *)
     UNIPOLAR_1_5V, (* + 1 to + 5 VDC *)
     UNIPOLAR_0_5V, (* 0 to + 5 VDC *)
     UNIPOLAR_4_20_MA, (* + 4 to +20 mADC *)
     UNIPOLAR_0_20_MA (* 0 to +20 mADC *)
    ) := UNIPOLAR_1_5V ;
END_TYPE
```

- Initialization of subrange data types, e.g.:

```
TYPE ANALOG_DATA : INT (-4095..4095) := 0 ; END_TYPE
```

- Initialization of array data types, e.g.:

```
TYPE ANALOG_16_INPUT_DATA :
    ARRAY [1..16] OF ANALOG_DATA := [8(-4095), 8(4095)] ;
END_TYPE
```

- Initialization of structured data type elements, e.g.:

```
TYPE ANALOG_CHANNEL_CONFIGURATION :
    STRUCT
        RANGE : ANALOG_SIGNAL_RANGE ;
        MIN_SCALE : ANALOG_DATA := -4095 ;
        MAX_SCALE : ANALOG_DATA := 4095 ;
    END_STRUCT
END_TYPE
```



```

        END_STRUCT ;
    END_TYPE

```

- Initialization of derived structured data types, e.g.:

```

TYPE ANALOG_CHANNEL_CONFIG :
    ANALOG_CHANNEL_CONFIGURATION
        := (MIN_SCALE := 0, MAX_SCALE := 4000);
END_TYPE

```

IEC 61131-3 provides following three layered initialization feature.

User should explicitly specify initial values by these embedded initialization feature, or user's application program.

### 1) Default initial value for user-defined type

User can specify own default initial values for user-defined types.

If no initial value is specified for the user-defined type, default initial value is succeeded from its base elementary data type. Default initial value for elementary data types have been specified in IEC 61131-3 (See Table 10).

As for examples, see above.

### 2) Initial value assignment to internal variables (instance) in POU type declaration

If no initial value is specified to the variable, default initial value of the data type is applied.

- Initialization of elementary data type variable
- Initialization of user-defined data type variable
- Initialization of array type variable
- Initialization of structured data type variable
- Initialization of FUNCTION\_BLOCK type variable (Only input/output and PUBLIC variables can be initialized)
- Initialization of CLASS type variable (Only PUBLIC variables can be initialized)

As for example, please see feature tables of IEC 61131-3 Ed.3.

All of Table 14, No.2 of Table 41, No.2 of 49

### 3) Instance specific initial value or location assignment with VAR\_CONFIG construct in CONFIGURATION

(See No.11a, 11b of Table 62 of IEC 61131-3)

This initial value declaration overwrites 1) and 2) above.

```

CONFIGURATION Cell_1
    VAR_GLOBAL
        Gvar1 : INT:= 5;
        Gvar2 : INT:= 0;

```

```
END_VAR

RESOURCE Station1 ON ProcessorType201
    TASK FastPeriodic ( INTERVAL := t#1ms, PRIORITY:=2)
    TASK SlowPeriodic ( INTERVAL := t#15ms, PRIORITY:=4)
    PROGRAM ProgInst1 WITH FastPeriodic
        : MyProgramA (Input1 := GVar1, Output1 => Gvar2)
    PROGRAM ProgInst2 WITH SlowPeriodic
        : MyProgramA (Input1 := GVar2, Output1 => Gvar1)
END_RESOURCE

RESOURCE Station2 ON ProcessorType201
    TASK FastPeriodic ( INTERVAL := t#1ms, PRIORITY:=2)
    PROGRAM ProgInst1 WITH FastPeriodic : MyProgramB
END_RESOURCE

// Instance specific initialization or location assignment
VAR_CONFIG
    Station1.ProgInst1.COUNT : INT:= 1;
    Station1.ProgInst2.TIME1 : TON:= (PT:= T#2.5s);
    // initialization of function block instance
    Station2.ProgInst1.FbInst1.FbInst2.FbInst3.Count : INT:= 100;
    Station2.ProgInst1.FbInst1.C2 AT %QB25 : BYTE;// I/O assignment
END_VAR
END_CONFIGURATION
```

#### 5.4. Direct addressing should not overlap

**Identifier:** Rule CP4

**Importance:** High

**Targeted languages:** All

**References:**

- Itrix Coding Standard - S8
- Codesys SA0028
- Misra-C 18.2, 18.3

**Description:** When assigning a memory location to an object, developer shall take care that the memory is not already assigned for another usage.

**Guideline:**

Overlap of variables addresses should be avoided

**Reasoning:** As most of PLC program are designed with a data flow from inputs to outputs, re-using the same memory location for different purpose may not be detected during program testing and commissioning. May be the first variable is written and the read during the first program's part and the second variable at the same location is also written and the read during another part of the program. Unfortunately some sparse condition may occur where one of the two variables won't be written and then the read will access the wrong variable value. It will be a problem very difficult to cope with.

**Exceptions:** STRUCT OVERLAP types are designed to overlap. On some platforms bit addressable and value addressable types are designed to overlap.

**Example:**

*Don't:* in the following example, two variables overlap at %MW451. Most of the time, everything goes well because of program data flow, the memory cell is firstly used by temp, and then by level. By when VeryRareCondition is true, level is not written and then the level value used in the test is in fact part of temp variable.

```
// Wrong example
Temperature : INT AT %MW451;
... else where in the database definition
Level: REAL AT %MW450;

Temperature := %IW56;
IF Temperature > 56 THEN
    StartFans;
END_IF;

// The second part of the code related to the other variable
IF NOT VeryRarecondition THEN
    Level := %IW34;
END_IF;
IF Level < LevelThreshold THEN
    // In the case of VeryRareCondition, the CriticalFunction will be
```

```
    // called with a wrong level value as it is a temperature.  
    DoCriticalFunction(Level);  
END_IF;  
  
// Right example  
Temperature : INT AT %MW444;  
... else where in the database definition  
Level: REAL AT %MW450;  
    // the direct addresses do not overlap  
Temperature := %IW56;  
IF Temperature > 56 THEN  
    StartFans;  
END_IF;
```

**Comments:** None

### 5.5. Applications shall be well designed

**Identifier:** Rule CP5

**Importance:** High

**Targeted languages:** Ladder, Structured Text, Sequential Function Chart, Function Block Diagram

**References:**

- IEC 61131-8 Section 3.3

**Description:** All applications shall be well designed, ideally before development phase is started. The design principles shall include object oriented principles like modularization and encapsulation.

**Guideline:**

- Applications must be well designed
- Make use of Arrays (where supported) to aggregate related variables of the same data type
- Make use of Structures (where supported) to aggregate related variables of different data types
- Make use of Classes where supported or Functions and Function Blocks to reduce complexity of large areas into smaller parts
- Make use of Classes where supported, or Functions and Function Blocks to reuse common code
- Make use of PRIVATE variables in Classes where supported, or Function Block internal variables to encapsulate data
- Design separate programs to use the best language for the job: Ladder, Structured Text, Sequential Function Chart or Function Block Diagram (where supported)

**Reasoning:** Well-designed applications reduce the total cost of development by making a project objective clearly understandable, and communicating the plan to avoid mistakes, redevelopment, and bugs found at the testing and maintenance stages. Modularizing the design allows each small part to be considered, designed, and even successfully programmed in isolation. The qualities of Classes and Function Blocks are related to object oriented programming (OOP). The function block type is similar to a class, which defines the data structure and computational method within the body of the function block. Individual objects are represented by the private data areas of the individual function block instances. This data can only be modified from outside the function block body in a controlled manner. This enforces the software engineering principles of encapsulation and information hiding, a key element of OOP.

**Exceptions:** none

**Example:** none

**Comments:** none

## 5.6. *Avoid external variables in functions, function blocks and classes*

**Identifier:** Rule CP6

**Importance:** High

**Targeted languages:** All

**References:**

- JSF++ AV Rule 207
- IEC61131-3 - 2.5.1

**Description:** The use of external variables referencing global variables in functions, function blocks and classes shall be avoided. This means do not use VAR\_EXTERNAL inside the definition of a function or function block.

**Guideline:**

Functions, Function Blocks and Classes should not use external variables.

A good alternative to using external references to global variables can be to extend the parameter list, and pass the variables needed for access.

**Reasoning:**

Good design principles allow Function, Function Blocks and Class POU's to be easily reused. The inner workings are sometimes unknown to the user, and even unexposed. Using any external reference detracts from or prevents reusing the POU. For example if a function accesses 10 external references, then when you copy the function to a new project you must also copy the accompanying global variable definitions including the code affecting these variables.

Function Blocks and Classes also have 'instances' with their own data. Directly using external references can make it impossible to have multiple instances.

Encapsulation of data can minimize integration testing and remove functional testing for pre-tested POU's as the known behavior cannot really change. However using data in external references means the functionality now depends on that external data so requires full retesting to ensure no issues have been introduced.

Also, using external references increases the chance of different POU's performing multiple writes to the same variable. This is related to rule CP26 "**A global variable may be written only by one POU**" and rule CP15 "**Read a variable written by another task only once per cycle**" so avoiding externals can also avoid these accidental uses, which can be very difficult to find and debug.

In addition, the code gets more complex, and the need for using an external variable can be a signal that the program is not coherent and refactoring is necessary.

Finally, such a practice can introduce side-effects, like a function returning different results with the same inputs, which makes it hard to verify correct operation. There should be a very good and well documented reason for any such usage of external data.

**Exceptions:** Accessing system-defined variables or VAR\_GLOBAL CONSTANT may require the use of external references

**Example:***Don't:*

```
FUNCTION CommandMotor
VAR_INPUT
    Enable : BOOL;
    Default: BOOL;
END_VAR;
VAR_OUTPUT
    Command : BOOL;
END_VAR;
VAR_EXTERNAL
    ModeAuto : BOOL;
END_VAR;

    Command := Enable AND NOT Default AND ModeAuto;
END_FUNCTION;
```

*Do:*

```
FUNCTION CommandMotor
VAR_INPUT
    Enable : BOOL;
    Default: BOOL;
    ModeAuto : BOOL; //Here the variable is passed as a parameter
END_VAR;
VAR_OUTPUT
    Command : BOOL;
END_VAR;
    Command := Enable AND NOT Default AND ModeAuto;
END_FUNCTION;
```

**Comments:** This rule also applies to PROGRAM POU's when the programming systems support this. PROGRAM is a reusable POU type which can have input/output/in/out parameters. See Table 47 No.2, Table 62 No.89 of IEC 61131-3.

### 5.7. Error information shall be tested

**Identifier:** Rule CP7

**Importance:** High

**Targeted languages:** All

**References:**

- Misra C 16.10
- JSF++ Rule 115

**Description:** When available, error information returned by a function shall be tested and error condition shall be properly handled.

**Guideline:** After a call to a function returning error information, the returned error information should be tested and eventually the behavior of the process should be changed in case of error.

**Reasoning:** an undetected error can have bad consequences on the continuation of the process. A detected and handled error shows as well that the developer has understood the consequences of errors in the called routine. Without such error handling, either developer forgot an error case or consequences of this error have no real impact.

**Exceptions:** None

**Example:**

*Don't:*

```

+-----+
| Instance |
Cond -|En   Eno |-
Eff1 -|P1   Out |- Result
Eff2 -|P2 xError |-
      -|P2 iError |-
      |           |
+-----+

+-----+
|   ADD   |
|-----| En  Eno |-
Result -| i1  Out |- CriticalThreshold
10000  -| i2      |
+-----+

```

In this case the result is used directly without checking the error information and then the CriticalThreshold is changed even if there was an error raised by Instance call.



Do:

```

+-----+
| Instance |
Cond -|En    Eno  |-
Eff1 -|P1    Out  |- Result
Eff2 -|P2 xError |- xError
      -|P2 iError |- iError
      |          |
+-----+

```

```

+-----+
| xError |   ADD  |
|---| |---| En  Eno  |-
| Result -| i1  Out  |- CriticalThreshold
      10000 -| i2    |
+-----+

```

In this case, the error information generated by the Instance call is effectively used and then the CriticalThreshold is not changed.

**Comments:** None.

## 5.8. Floating point comparison shall not be equality or inequality

**Identifier:** Rule CP8

**Importance:** High

**Targeted languages:** All

**References:**

- Codesys SA0054
- Misra C 13.3
- JSF++ Rule 202

**Description:** Using equality or inequality operators to detect threshold with floating point variable is prohibited.

**Guideline:** comparison between floating point variables must use only the following operators: strict less than (<), less than or equal (<=), strict greater than (>), greater than or equal (>=).

**Reasoning:** The equality operator requires a strict equality between operands. When using floating point number, this equality is almost never and the inequality is almost always.

**Exceptions:** Compare to 0.0

**Example:**

Many numbers cannot be represented exactly in floating point notation: - number 0.1 is represented by a binary value that corresponds to decimal 0.100000001490116119384765625 in 24bits single precision.

Moreover, when using floating point numbers, mathematical operations might produce rounding errors (for example, small differences between large numbers).

*Don't:*

```
IF TEMP - OLD_Temp = 0.1 THEN
    // execution of this branch is sensitive to rounding errors
    . . . .
END_IF;
```

*Do:*

```
IF TEMP - OLD_TEMP < 0.1 THEN
    // executed code
END_IF;
```

or

```
IF REAL_TO_INT((TEMP - OLD_TEMP) * 100) = 10 THEN
    // executed code
END_IF;
```

**Comments:** None

### 5.9. Time and physical measures comparison shall not be equality or inequality

**Identifier:** Rule CP28

**Importance:** High

**Targeted languages:** All

**References:** None

**Description:** Using equality or inequality operators to detect threshold with time information or physical measure even in Integer format is prohibited.

**Guideline:** Comparison between time information or physical measures must use only the following operators: strict less than (<), less than or equal (<=), strict greater than (>), greater than or equal (>=).

**Reasoning:** The equality operator requires a strict equality between operands. When using time information or physical measure, this equality may not be met and the inequality is almost always met.

**Exceptions:** None

**Example:**

*Don't:*

```
IF Distance - InitialPosition = 12 THEN
    // execution of this branch is sensitive to missing measured
    // values
    ....
END_IF;

IF T5.Et = T#10s then
    // Stop the process
END_IF;
```

*Do:*

```
IF Distance - InitialPosition - 12 < ERROR_MARGIN THEN
    // executed code
END_IF;
```

or

```
IF T5.Et - T#10s < T#100MS THEN
    // executed code
END_IF;
```

**Comments:** None

### 5.10. Limit the complexity of POU code

**Identifier:** Rule CP9

**Importance:** High

**Targeted languages:** All

**References:**

**Description:** There are different possibilities to measure the complexity of code. It is still very common, just to count the lines of code per POU, or the number of statements per POU. Other metrics like McCabe-metric, Elshof-metric, and Prater-metric can be found in the literature. Every metric has advantages and disadvantages; therefore we do not propose one single metric or a set of metrics.

Some of the metrics are only applicable for textual languages (McCabe, Prater), whereas other metrics are applicable for any kind of code (Elshof).

It is recommended to measure the complexity of code and to set upper limits for the complexity.

**Guideline:** If the code of a POU exceeds some complexity level, the code should be split up into several POU's.

**Reasoning:** Complex code is difficult to maintain and a source of errors.

**Exceptions:** None

**Example:**

*Don't:*

The following Function block CHARCURVE has

- Number of Statements 18
- McCabe complexity of 12
- Prater complexity of 3,89
- Halstead complexity of 44,9
- Elshof complexity of 0,14 (the lower the number, the more complex is the function).

```
FUNCTION_BLOCK CHARCURVE
VAR_INPUT
    IN: INT;
    N: BYTE;
END_VAR
VAR_IN_OUT
    P: ARRAY[0..10] OF POINT;
END_VAR
VAR_OUTPUT
    OUT: INT;
    ERR: BYTE;
END_VAR
VAR
```

```

    I:INT;
END_VAR
IF N > 1 AND N < 12 THEN
    ERR:=0;
    IF IN<P[0].X THEN
        ERR:=2;
        OUT:=DINT_TO_INT(P[0].Y);
    ELSIF IN>P[N-1].X THEN
        ERR:=2;
        OUT:=DINT_TO_INT(P[N-1].Y);
    ELSE
        FOR I:=1 TO N-1 DO
            IF P[I-1].X>=P[I].X THEN
                ERR:=1;
                EXIT;
            END_IF;
            IF IN<=P[I].X THEN
                EXIT;
            END_IF
        END_FOR;
        IF ERR=0 THEN
            OUT:=DINT_TO_INT(P[I].Y-(P[I].X-IN)*(P[I].Y-P[I-1].Y)/(P[I].X-P[I-1].X));
        ELSE
            OUT:=0;
        END_IF;
    END_IF
ELSE
    ERR:=4;
END_IF;

```

*Do:*

The changed function block with one (private) help method CalculateOut is far less complex:

- Number of Statements 12
- McCabe complexity of 8
- Prater complexity of 2,25
- Halstead complexity of 19,9
- Elshof complexity of 0,32

```

OUT:=0;
ERR:=0;
iIndexFound := -1;
FOR I := 1 TO N-1 DO
    IF iIndexFound < 0 AND ERR = 0 THEN
        IF P[I-1].X >= P[I].X THEN

```

```
        ERR := 1;
    ELSIF IN <= P[I].X THEN
        iIndexFound := i;
    END_IF
END_IF
END_FOR;
IF ERR = 0 THEN
    OUT := CalculateOut (P[iIndexFound], P[iIndexFound -1]);
ELSE
    OUT := 0;
END_IF;
```

**Comments:**

Literature references:

- Thomas J. McCabe: "A Complexity Measure" in: IEEE Transactions on Software Engineering, Vol 2, 1976.
- Prater, R. E.: "An axiomatic theory of software complexity metrics", in Computer Journal, Vol. 27, 1984
- Halstead, M.: "Elements of Software Science", Elsevier North-Holland, Amsterdam, 1977
- Elshof, J.: "An Analysis of Commercial PL/I Programs", IEEE Transactions on Software Engineering, Vol. 2, 1976

### 5.11. Avoid multiple writes from multiple tasks

**Identifier:** Rule CP10

**Importance:** High

**Targeted languages:** All

**References:**

- Itris Automation Square S2
- Codesys SA0006

**Description:** Any writing to a variable from multiple tasks shall be avoided. A variable shall be written in one task only.

**Guideline:** When sharing variables among tasks you must avoid writing to a variable from more than one task. When using communication variables between two tasks, it is important to decide which task writes which variables so that a given variable is not written from the two different tasks.

**Reasoning:** The task exception is triggered by some timing constraints and relative priorities of the running tasks. On systems that implement multitasking in a 'preemptive' nature, or true parallel processing, one task may be interrupted by a higher priority task. In such a case, concurrent writing access to the same variable leads to non-deterministic behavior. The non-deterministic behavior has two consequences:

- Information loss
- Data inconsistency

**Exceptions:**

- Carefully design and peer review your code with skilled engineers to ensure non-deterministic behavior cannot occur
- With a centralized error monitoring system every task is allowed to set the error flag, but no one should reset the flag.
- Use vendor specific functions, like mutex or semaphore, to manage multiple write operations on the shared resource

## Example:

### Don't:

Imagine any simple case where a programmer has created a 'LoopCounter' Global Variable for general use throughout their Main program. Now imagine a second developer has copied and pasted a block to a priority program, that happens to run in a different task:

<pre>VAR_GLOBAL   LoopCounter; END_VAR</pre>	
<pre>Main Program: ... FOR LoopCounter := 0 TO 10 DO   IF ValveWarning[LoopCounter] == TRUE THEN     ProcessWarning := TRUE;   END_IF; END FOR;</pre>	<pre>Priority Program: ... MaxReading := Reading[0]; FOR LoopCounter := 1 TO 100 DO   IF Reading[LoopCounter] &gt; MaxReading THEN     MaxReading := Reading[LoopCounter];   END_IF; END FOR;</pre>

During execution of the main program, while inside the FOR loop the Priority Program may start to execute at any time (while the LoopCounter may be any value from 0 to 10). At the end of the Priority Program the global variable "LoopCounter" is left with the value of 100 when execution returns to the Main Program but the FOR loop now ends at the next iteration without completing the rest of the iterations. There is also potential for the code to execute now on the wrong element or even worse attempt access data beyond the bounds of the array.

### Do:

In the above example, we can solve the problem by avoiding the multiple writes to LoopCounter by creating 2 program variables with local scope. For clarity these should be defined with different names.

**Comments:** For more information about synchronizing the execution of tasks see *Manage synchronization among tasks* (Rule CP11), page 64.



## 5.12. Manage synchronization among tasks

**Identifier:** Rule CP11

**Importance:** High

**Targeted languages:** All

**References:**

**Description:** Where tasks share data they shall be managed to avoid synchronization issues.

**Guideline:**

- Avoid interaction between tasks  
or
- Use vendor-specific feature to manage synchronization among tasks

In the case that synchronized data passing is necessary among PROGRAMs which can be assigned with different TASKs, following have to be done.

1) The PROGRAM should access to the global variables via

A) VAR\_EXTERNAL, or

B) VAR\_IN\_OUT and assignment declaration to/from global variables  
in PROGRAM instance declaration in RESOURCE declaration.

2) In addition, some vendor-specific system-defined function or function block should be used which controls system's task scheduling and make specified code block be executed exclusively among other tasks.

**Reasoning:**

Considering multitasking behavior with synchronization is intrinsically difficult even if the PLC vendors support some feature for it. Pseudo parallel processing by cyclic execution of synchronized process is the key feature of PLC architecture which can overcome undetermined timing-dependent behavior of asynchronous multitasking control system. Thus basically data passing among PROGRAMs which need synchronization is better to be avoided.

If such synchronization is necessary from logic point of view, some code blocks within the body have to be exclusively executed among tasks. As IEC 61131-3 does not specify such a feature as standard, each vendor provides their own specific feature like tryLock(), Lock() of C++ / C# / Java.

**Exceptions:** Some vendors may provide completely different inter-task synchronization feature.

**Example:**

In the example below the 2 programs running in different tasks.

*Do:*

```
// This is an example where:  
// 1) A) VAR_EXTERNAL and  
// 2) Vendor specific system-defined function "Lock()", "Unlock()" are used.
```

```
//Acquisition function called with the high frequency task
```

```
PROGRAM Fast_Acquisition
  VAR_EXTERNAL
    ClearSubTotalCount : BOOL; // This is actually used as input
    SubTotalCount : INT; // This is actually used as output
  END_VAR
  VAR_INPUT
    SignalInput : BOOL; // input signal to count rising-edge
  END_VAR
  VAR
    Old_ClearSubTotalCount : BOOL := FALSE;
  END_VAR

  //---- Beginning of the Body ----
  Vendor.Lock(LockResId := 0); // Start of atomic process for exclusive
execution
    IF ClearSubTotalCount AND NOT Old_ClearSubTotalCount THEN
      SubTotalCount := 0 ;
    END_IF;
    Old_ClearSubTotalCount := ClearSubTotalCount;
    ClearSubTotalCount := FALSE;

    IF SignalInput AND NOT Old_SignalInput THEN
      SubTotalCount := SubTotalCount + 1 ;
    END_IF;
    Old_SignalInput := SignalInput ;

  Vendor.Unlock(LockResId := 0); // End of atomic process for exclusive
execution
END_PROGRAM

// Acquisition with main task (100ms)
PROGRAM Main_Acquisition
  VAR_EXTERNAL
    SubTotalCount : INT; // This is used as input actually.
    ClearSubTotalCount : BOOL; // This is used as output actually.
  END_VAR
  VAR
    GrandTotalCount : INT;
  END_VAR
```

```
//----- Beggingin of the Body -----  
Vendor.Lock(LockResId := 0); // Start of atomic process for exclusive  
execution  
    GrandTotalCount := GrandTotalCount + SubTotalCount;  
    ClearSubTotalCount := TRUE;  
Vendor.Unlock(LockResId := 0); // End of atomic process for exclusive  
execution  
END_PROGRAM  
  
CONFIGURATION CELL_1  
    VAR_GLOBAL  
        SubTotalCount : INT;  
        ClearSubTotalCount: BOOL;  
    END_VAR  
    RESOURCE STATION_1 ON PROCESSOR_TYPE_1  
        TASK SLOW_1 (INTERVAL := t#200ms, PRIORITY := 2) ;  
        TASK FAST_1 (INTERVAL := t#10ms, PRIORITY := 1) ;  
        PROGRAM MainAquisitionInst WITH SLOW_1 : Main_Acquisition();  
        PROGRAM FastAcquisitionInst WITH FAST_1 : Fast_Acquisition(SignalInput  
:= %I1.1);  
    END_RESOURCE  
END_CONFIGURATION
```

### Comments:

This rule is only for PLC system of "Preemptive scheduling" implementation (See IEC 61131-3, Table 63, No.5b).

Some vendor provides similar system-defined functions.

It may be possible to avoid the need for synchronization. In the case that multiple PROGRAM instances all need to exchange data synchronously from the logic point of view, such PROGRAMs should be changed into FUNCTION\_BLOCK and one PROGRAM should be added instead to call the FUNCTION\_BLOCK instances synchronously.

As using vendor-specific "lock" feature temporarily blocks switching execution to the task with higher priority. It can make periodic task not to be in time for the specified period.

### 5.13. *Physical outputs shall be written once per PLC cycle*

**Identifier:** Rule CP12

**Importance:** High

**Targeted languages:** All

**References:**

- Codesys SA0004
- Itris Automation Square S4

**Description:** The physical outputs shall be written only once per PLC cycle.

**Guideline:** The physical output elaboration shall be done in one line of code or one rung.

**Reasoning:** 1. Undeterministic behavior when outputs are written more than once per PLC cycle. 2. Maintainability – it is difficult when a physical output elaboration is spread along the application. It is a good practice to prepare all variables participating to physical output elaboration and then at the end of the cycle, calculate and write the value for the physical outputs.

**Exceptions:** Clear and explicit requirements, like specific security architecture may overcome this rule. Sometimes it is necessary to write the output from more than one location, but then it should be done with caution.

**Example:** None

**Comments:** None

### 5.14. POU's shall not call themselves directly or indirectly

**Identifier:** Rule CP13

**Importance:** High

**Targeted languages:** All

**References:**

- Misra C 16.2
- JSF++ Rule 119
- IEC 61131-8 Section 3.5.4

**Description:** Recursion shall not be used in an application

**Guideline:** A recursive algorithm should be replaced by an iterative algorithm.

**Reasoning:** Recursive algorithms normally consume stack space for each call so deep recursion can cause system failure, even if unplanned. Support for recursive calls of POU is vendor-specific so using it also makes the program less portable

**Exceptions:** None

**Example:**

Don't:

The following function is using recursion to calculate the value of factorial (the factorial of N is the product of N<sup>th</sup> first

```
FUNCTION Factorial : INT
VAR_INPUT
  X : INT;
END_VAR
IF X > 1 THEN
  Factoriale := Factorial(X - 1) * X;
ELSE
  Factorial := X;
END_IF;
END_FUNCTION;
```

Do:

In this implementation, the recursion was removed and replaced by an iteration using FOR

```
FUNCTION Factorial : INT
VAR_INPUT
  X : INT;
END_VAR
VAR_LOCAL
  Acc : INT;
END_VAR
  FOR I IN 1..X DO
    Acc := Acc * X;
  END_FOR;
  Factorial := Acc;
END_FUNCTION;
```

**Comments:** None

### ***5.15. POU's shall have a single point of exit***

**Identifier:** Rule CP14

**Importance:** High

**Targeted languages:** All

**References:**

- Codesys SA0090
- Itris Automation Square I6
- Misra C 14.7
- JSF++ Rule 113
- IEC 61508-7 C.2.9

**Description:** RETURN instruction shall be avoided to exit from POU's. RETURN instruction shall be used only to explicitly return the value of a function.

**Guideline:** POU structure should be changed to avoid the usage of RETURN instruction before the end of the code. If programming language is Structured Text, conditional instructions should be used for the other languages, use a label at the end of the POU and use JUMP instruction to jump to this last label.

**Reasoning:** Testability, Readability and maintainability are good reasons to do that. In case of debugging, it is possible to add some code just before returning the POU and we got this information in all cases.

**Exceptions:** None

**Example:** None

**Comments:** None

### 5.16. Read a variable written by another task only once per cycle

**Identifier:** Rule CP15

**Importance:** High

**Targeted languages:** All

**References:** None

**Description:** In one task, multiple reading of a variable written by another task shall be avoided. The other task is able to be executed at any time between the two readings and so the two read values may be different. The program may behave in a non-deterministic way.

**Guideline:** To avoid this situation, in a task that reads a variable written to in another task, that variable should be copied into a local variable which is then exclusively used. This will ensure that the value won't unexpectedly change and so make program execution more predictable.

This copy could be done automatically by a programming support environment supporting the following features from IEC 61131-3,

Table 47, No.2a "Declaration of inputs of a program"

Table 47, No.2b "Declaration of outputs of a program "

Table 62, No.8b "Connection of GLOBAL variables to PROGRAM inputs"

Table 62, No.9b "Connection of PROGRAM outputs to GLOBAL variables"

When the declaration of program POU input/output variables, the global variables are copied to the input variables of the program before execution, and output variables are copied to the global variables after the execution. The value of input variables is never overwritten during the execution of the program in that cycle. Also output variables are never reflected to the global variables until the cycle execution of the program finishes.

**Reasoning:** In a program successive reading of a variable declared externally should be consistent. However, in the case of a variable written to by another task, this other task can be executed between two reads due to task switching.

Before running the process, the PLC is sampling the process inputs by copying the input values at a given time into an image memory. This is for the same reason: having constant input during a process execution.

**Exceptions:** None

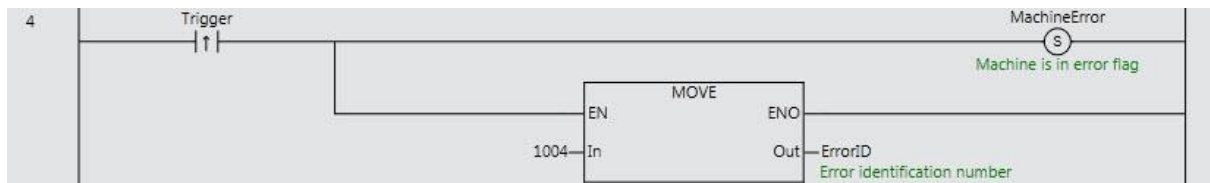
**Example:**

*Don't:*

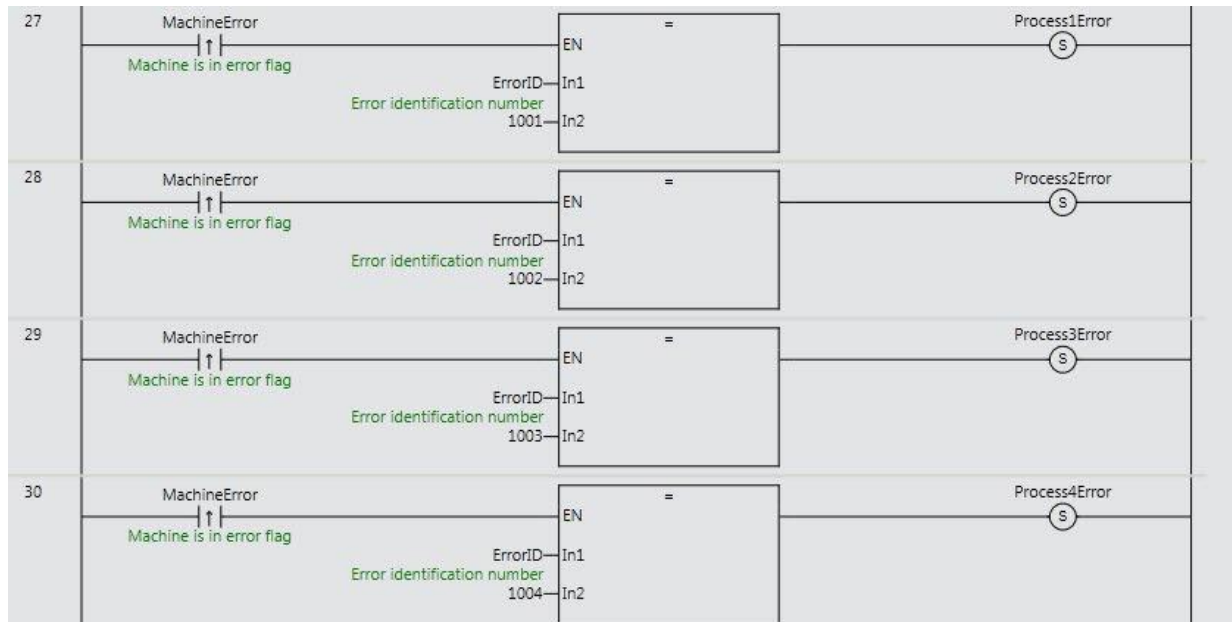
In this example every time an error flag is raised, an error code is also raised to identify which part of the process is in error. The MachineError flag is generated from a high priority task that can preempt the main program at every time.



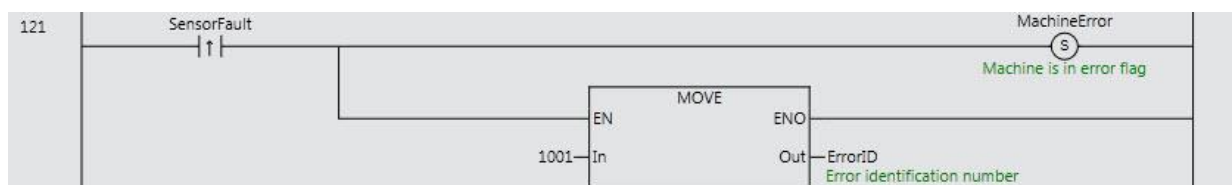
## Main Program:



.....



## Priority Program:



If execution of the main program is interrupted after rung 27, but before rung 30, the Priority Program may start to execute overwriting global variable "ErrorID". When execution returns to the Main Program the remaining rungs are evaluated, with the possibility that none of the "ProcessnError" bits are set.

This is a situation the developer of Main Program will not have realistically catered for.

*Do:*

The solution consists in reading MachineError and ErrorId only once and copying their value in a variable image. Then it ensures that ProcessnError will be consistent. The case where no ProcessnError is flagged when MachineError is flagged is not possible anymore.

If the Programming Support Environment allows it, the input/output of the POU program should be explicitly declared. Then the system takes care of this copy automatically.

**Comments:** None

### 5.17. Tasks shall only call program POU's and not Function Blocks

**Identifier:** Rule CP16

**Importance:** High

**Targeted languages:** Ladder, Structured Text, Sequential Function Chart, Function Block Diagram

**References:**

- IEC 61131-8 Sections 3.5.4 and 3.12.6
- IEC 61131-3 Section 2.7.2

**Description:** IEC Tasks shall not be configured to call Functions or Function Blocks directly. They shall only be configured to call program POU's.

**Guideline:** Tasks shall call program POU's only. Direct association of tasks to such function blocks should be avoided.

**Reasoning:** This is recommended to avoid ambiguity in determining the execution control of indirectly referenced function block instances. The association of tasks with function block instances and its effects on data concurrency are described in 2.7.2 of IEC 61131-3. The programmer should be aware of the fact that use of this feature may produce data consistency errors during program run time. The guidelines provided by the IEC 61131-3 implementer should be consulted to determine the mechanisms provided to assure data consistency. Since these mechanisms are implementation dependent, programs using this feature may not be portable between different IEC 61131-3 compliant systems

**Exceptions:** None

**Example:**

*Don't:* (example from Figure 20 of IEC61131-3. FB1 and FB2 should not be assigned directly to TASKs)

```
RESOURCE STATION_1 ON PROCESSOR_TYPE_1
  VAR_GLOBAL z1: BYTE; END_VAR
  TASK SLOW_1 (INTERVAL := t#20ms, PRIORITY := 2) ;
  TASK FAST_1 (INTERVAL := t#10ms, PRIORITY := 1) ;
  PROGRAM P1 WITH SLOW_1 :
    F(x1 := %IX1.1) ;
  PROGRAM P2 : G(OUT1 => w,
    FB1 WITH SLOW_1,
    FB2 WITH FAST_1) ;
END_RESOURCE
```

**Comments:** None

### 5.18. Usage of parameters shall match their declaration mode

**Identifier:** Rule CP17

**Importance:** High

**Targeted languages:** All

**References:**

- Codesys SA0009
- Itris Automation square E2
- IEC 61131-8 Section 3.2.2

**Description:** The parameters declared as input shall be read, the parameters declared as output shall be written and the parameters declared as in/out shall be read and written.

**Guideline:** The mode of a parameter (input, output or input/output) should reflect the usage of the parameter in the corresponding POU. The following rules apply:

- Each input parameter should be read at least once in the POU code
- Each input parameter should not be written in the POU code
- Each output parameter should be written at least once in the POU code
- Each input/output parameter should be either read or written in the POU code

**Reasoning:** Not using the parameters declared in the POU interface is a loss of time for the developers and for the machine performance. Using the parameter in the wrong way may lead to side effects when the Programming Support Environment doesn't limit the usage.

**Exceptions:** None

**Example, use case:**

**Comments:**

It is illegal to attempt to pass an output from a Function to an In-Out parameter of a Function Block:

<pre>                 ACC1       +----+   +-----+ X1---  *       ACCUM   X2---     --- A-----A ---ACC       +----+             X3----- X                         +-----+           </pre>	<p>ILLEGAL USAGE: In-out A is not a variable or function block name</p>
---	---

It is illegal use to attempt to pass a literal to an In-out parameter:

<pre>          ACC1         +-----+            ACCUM    2.0--- A-----A ---2.0                              --- X                +-----+</pre>	<p>ILLEGAL USAGE: In-out A is not a variable or function block name</p>
---	---

### 5.19. Use of global variables shall be limited

**Identifier:** Rule CP18

**Importance:** High

**Targeted languages:** Ladder, Structured Text, Sequential Function Chart, Function Block Diagram

**References:**

- Misra C 8.7
- JSF++ AV Rule 207
- Codesys SA0121

**Description:** A global variable is required to exchange data with an entity outside the program or in another task. It is good practice to declare local variables whenever it is possible.

**Guideline:**

The use of global variables should be limited in preference for local variables. In the following case, the use of global variable is justified:

- Exchanging data among PROGRAM instances whether in the same TASK or in different TASKS
- Exchanging data with the System: accessing system-defined variable to use execution environment specific feature, such as CurrentTime, ErrorStatus, etc.
- Exchanging data with external devices (physical I/O, communication variables,..)

**Reasoning:**

Usage of global variables within a POU impairs its ability to be reused. In some development environments the use of an EXTERNAL declaration is not required, which serves to hide the dependency of a POU on external data. This rule improves the testability, maintainability, reusability of applications.

**Exceptions:** System-defined variables are the only authorized global variables, but there is no need to declare them.

**Example:**

*Don't:*

```
RESOURCE Station1 ON ProcesserTypeA
```

```
VAR_GLOBAL
```

```
    MainProgDone: BOOL := TRUE;
```

```
    InitDone: BOOL := FALSE;
```

```
    InitError: BOOL := FALS;
```

```
    CurrentTime : TIME;
```

```
    CPUErrorStatus : ErrorStats;
```

```
END_VAR
```

```
TASK FastTask (INTERVAL := t#1ms, PRIORITY := 1);
TASK SlowTask (INTERVAL := t#10ms, PRIORITY := 15);
PROGRAM ProgInst1 WITH FastTask : Program1;
PROGRAM ProgInst2 WITH FastTask : Program2;
PROGRAM ProgInst3 WITH SlowTask : Program3;
PROGRAM ProgComm WITH SlowTask : CommProg;
END_RESOURCE
```

## Note:

In this "Don't" example, each PROGRAM does not declare input/output variables and accesses global variables via external variables. To know the data flow among PROGRAM instances, the logic of each PROGRAM body need to be examined.

## Do:

```
RESOURCE Station1 ON ProcessorTypeA
  VAR_GLOBAL
    //-- 1) Variables for inter-PROGRAM communication
    MainProgDone: BOOL := TRUE;
    InitDone: BOOL := FALSE;
    InitError: BOOL := FALSE;
    //-- 2) System-defined variables to be accessed via VAR_EXTERNAL
    CurrentTime : TIME;
    CPUErrStatus : ErrorStats;
    //-- 3) Variables exchanged between tasks
    HighSpeedCounter : DINT;
    //-- 4) I/O and communication variables
    HSPulse : BOOL AS %I4.5;
  END_VAR
  TASK FastTask (INTERVAL := t#1ms, PRIORITY := 1);
  TASK SlowTask (INTERVAL := t#10ms, PRIORITY := 15);
  PROGRAM ProgInst1 WITH FastTask
    : Program1 (Execute := MainProgDone,
      HighSpeedCounter := HighSpeedCounter,
      Done => InitDone,
```

```

        Error => InitError); //Global variable assignment

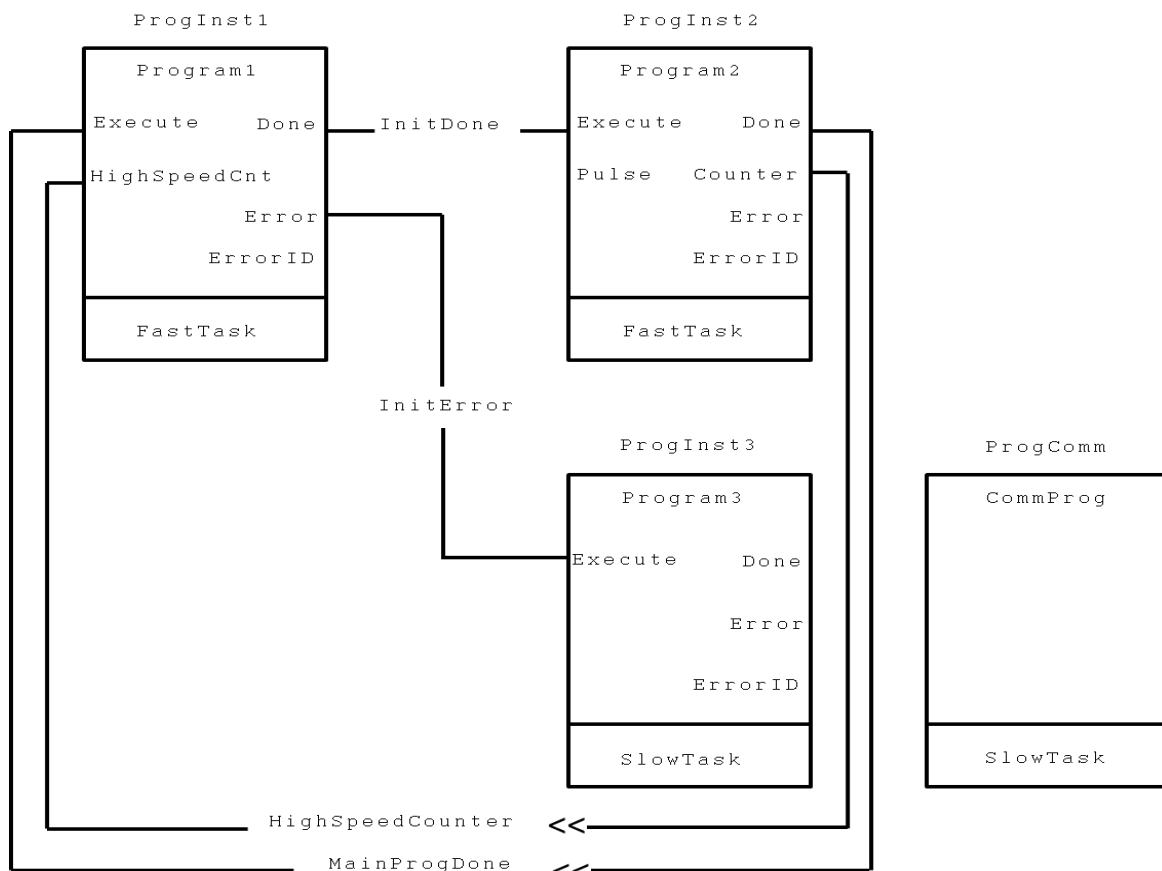
PROGRAM ProgInst2 WITH FastTask
    : Program2(Execute := InitDone,
              Pulse := HSPulse,
              Counter => HighSpeedCounter,
              Done => MainProgDone); // Global variables
                                     // assignment

PROGRAM ProgInst3 WITH SlowTask
    : Program3(Execute := InitError); // Global variables
                                     // assignment

PROGRAM ProgComm WITH SlowTask : CommProg;
END_RESOURCE
    
```

**Note:**

Program instance declaration above explicitly represents data flow among PROGRAM instances shown below. (This diagram is NOT a formal graphical representation of IEC 61131-3)



## **Comments:**

The rules below also relate to the usage of global variables:

1. Rule 5.27 A global variable may be written only by one PROGRAM
2. Rule 5.11 Avoid multiple writes from multiple tasks.



### 5.20. Usage of Jump and Return should be avoided

**Identifier:** Rule CP19

**Importance:** Medium

**Targeted languages:** Ladder, Function Block Diagram

**References:**

- Misra C 14.5
- JSF++ Rules 189, 190

**Description:** The branching instructions Jump and Return should be avoided in Ladder and Function Block Diagram. This also includes any implementation specific branching instructions.

**Guideline:**

- Unconditional branching instructions Jump and Return shall not be used
- Conditional branching shall not jump backwards

**Reasoning:** Maintaining and debugging code containing sequence breaking instructions like Jump and Return is harder. Jumping over code to disable it leaves the dead code liable to future execution if the jump is accidentally removed. Jumping backwards can cause irregular scan times, and even cause tight loops that affect the main control function. The construct of EN/ENO can be used for conditional execution in LD and FBD.

**Exceptions:** Small jumps backwards are sometimes necessary to implement loops or iterations. Extreme caution must be used to ensure that infinite loops cannot occur. It is recommended to switch to Structured Text for these conditional transitions and use IF..THEN..ELSE, CASE, FOR..WHILE.., REPEAT..UNTIL.

**Example:**

<i>Don't:</i>	<i>Do:</i>
<pre> +-----&gt;&gt;LABELA     a       b           c       d     +---   ---   ---+---( )---( )---+                 e                                 +---( )-----+ LABELA:               This code is 'commented out' by skipping over, but still reserves program space and can too easily be accidently reinstated, without compile error, if the rung with the Jump is accidently deleted. </pre>	<p>Release code should have all unneeded code deleted and removed.</p>
<pre>     flg         </pre>	<pre>     flg       w           x         +--- / ---   -----+---(S)---+ </pre>

<pre> +---   -----&gt;&gt;J26     w           x     +---   -----+------(S)---+   J26:     flg +--- / -----&gt;&gt;J27     y           z     +---   -----+------(S)---+   J27:   </pre>	<pre>       flg   y           z     +---   -----   ------(S)---+     Conditional code can be controlled with Boolean logic IF NOT flg AND w THEN     z := TRUE; ELSIF flg AND y THEN     x := TRUE; END_IF; Conditional code can better be expressed in ST, especially more complex and nested structures </pre>
<pre>             +-----+ +-----  MOVE -----     0  --     -- ctr                               +-----+ LOOP1:             +-----+ +-----  MOVE -----   y[ctr] --     -- x[ctr]                               +-----+             +-----+ +-----  Add  -----+   ctr --     -- ctr     1  -                  +-----+             +-----+ </pre>	<pre> FOR ctr := 0 to 10 DO     x[ctr] := y[ctr]; END_FOR; </pre>

<pre>+-----  &lt;=  -----&gt;&gt;LOOP1   ctr --         10  -              +-----+</pre>	
--	--

**Comments:** none

### 5.21. *Function block instances should be called only once*

**Identifier:** Rule CP20

**Importance:** Medium

**Targeted languages:** All

**References:**

- IEC 61131-8 Sections 3.3.3 and 3.7
- Itris Automation Square I6

**Description:** Each instance of a function block should be called only once per PLC cycle.

**Guideline:** For each variable instantiating a function block, the function block code should be called no more than once per PLC cycle. The call may be conditional.

**Reasoning:** With a single invocation rule there is typically one place, and only one place, where the input variable of a function block will be assigned a value (unless IEC feature "Separate assignment of input" is employed), which increases the reliability and maintainability of the software.

- Development by copy, paste and modify is error prone, especially with code involving function blocks where it is possible to forget to change the instance, resulting in problems that may be hard to diagnose.
- Moreover depending on function block architecture, calling the same function block twice may change the global behavior. In general, it may be possible to invoke a single instance of a function block several times ("multiple assignment") within a POU. However, depending on the programmable controller implementation, this possibility may be restricted to a single invocation of each function block instance within a POU. A POU that uses multiple invocations of a single function block instance may be non-portable to such implementations.

A Function Block that does access any physical I/O should be called only one time within a PLC cycle.

A simple guideline would be to call a function block instance only once in the same PLC cycle. Although in practice there can be reasons to call a function blocks more than once in the same cycle (see exceptions hereunder). Check the documentation of the function block if this is possible.

**Exceptions:** There can be many cases where it is actually wise, efficient or necessary to invoke the same instance multiple times. This can be acceptable for the experienced developer with sufficient code review and program analysis. Examples of some exceptions are:

- A Counter FB that could be counting up many cases during the same PLC cycle.
- As function blocks only have one body, it is possible to simulate different methods using an additional parameter. In this case the same instance of a function block could be called once per simulated 'method' in a PLC cycle
- When using the non-formal invocation it is common to omit any unrequired parameters. It is likely to invoke the instance in multiple places with different parameter lists and these multiple invocations might occur in the same PLC cycle. Care should be taken that the formal invocation of a function block has been used at least once, or that initial parameter values are meaningful

- Motion Function Blocks instances are sometimes called multiple times per PLC scan, for example when Blending between steps or using "BufferMode" to stack up consecutive commands.

**Example:**

*Don't:* calling twice a raising edge function block: the second call doesn't see any more the rising edge it-self.

```
FUNCTION_BLOCK Rising_Edge
```

```
VAR_INPUT
```

```
  S : BOOL;
```

```
END_VAR;
```

```
VAR
```

```
  Old_State : BOOL;
```

```
END_VAR;
```

```
Old_State := Old_State XOR S;
```

```
END_FUNCTION_BLOCK;
```

```
VAR
```

```
  InputDetectionForDashboardButtonA: Rising_Edge;
```

```
  InputDetectionForDashboardButtonB: Rising_Edge;
```

```
END VAR;
```

```
InputDetectionForDashboardButtonA(InputFilterA);
```

```
...
```

```
// The second call of the same FB
```

```
InputDetectionForDashboardButtonA(InputFilterB);
```

```
// Information about the rising edge found previously is lost here
```

```
// In fact this is a COPY/PASTE error: the parameters were changed
```

```
// but not the instance.
```

**Comments:** None

## 5.22. Use VAR\_TEMP for temporary variable declaration

**Identifier:** Rule CP21

**Importance:** Medium

**Targeted languages:** All languages

**References:**

- IEC61131-3 (ed3) 6.5.2.1
- IEC61131-3 (ed3) 7.3.3.4.2

**Description:**

The standard says:

- VAR  
The variables declared in the VAR ... END\_VAR section persist from one call of the program or function block instance to another.  
Within functions the variables declared in this section do not persist from one call of the function to another.
- VAR\_TEMP  
Within program organization units, variables can be declared in a VAR\_TEMP...END\_VAR section.  
For functions and methods, the keywords VAR and VAR\_TEMP are equivalent.  
These variables are allocated and initialized with a type specific default value at each call, and do not persist between calls.

**Guideline:** Use the VAR\_TEMP construct to declare temporary variables, for example in FOR loop control. For FBs use VAR\_TEMP. Temporary variables are created and initialized upon each invocation of the FB, and cannot be accessed outside of the body.

**Reasoning:** For Functions and Methods VAR and VAR\_TEMP are the same but not for Function Blocks. Therefore it is always better to use VAR\_TEMP for temporary variables.

**Exceptions:** none

**Example:**

*Don't:*

```
// In the above example
VAR
    values: ARRAY[1..10] OF REAL;
    index: INT;
END_VAR
```

*Do:*

```
FUNCTION_BLOCK Lifo
VAR_OUTPUT
    currentValue: REAL;
END_VAR
```

```
VAR_INPUT
    newValue: REAL;
END_VAR
VAR
    values: ARRAY[1..10] OF REAL;
END_VAR
VAR_TEMP
    index: INT;
END_VAR
    currentValue := values[ 1 ];
    FOR index := 1 TO 10 DO
        values[ i ] := values[ i + 1 ];
    END_FOR
    values[ 10 ] := newValue;
END_FUNCTION_BLOCK
```

### 5.23. *Select Appropriate Data Type*

**Identifier:** Rule CP22

**Importance:** Medium

**Targeted languages:** Ladder, Structured Text, Sequential Function Chart, Function Block Diagram

**References:**

- IEC 61131-8 Section 3.1

**Description:** The data type selected for a variable should be appropriate to the data it is intended to store. It should be appropriate to the range of values and operations to be performed on the variable.

**Guideline:** Choose the correct data type appropriate to the range of values and operations to be performed.

- Use the smallest length necessary to store the range of values
- Do not use signed data types for unsigned data
- Use enumerations where possible
- Use subranges where appropriate
- Group collected data of same type into arrays
- Group collected data of different types into structures
- Do not use the same datatype throughout the program, just to prevent the need for explicit conversions. Use the appropriate ones

**Reasoning:**

- A correctly data typed variable helps describe its function, making its use somewhat self-explanatory
- "Strongly typed" code, where data type conversions must be explicitly made helps avoid coding mistakes and oversights where some conversion behavior may not be as assumed, and may be missed by commissioning and testing phases
- Compilers are able to use the data type to check assignments and instructions use, to ensure operations are as the developer expects
- Smaller data types typically use less memory, so allow for more variables or larger programs
- Using unsigned data types where appropriate prevents any negative value being assigned accidentally, and having to write code, and test the code, to deal with these eventualities.
- The use of enumerated and subrange types make a program even more readable and can contribute to program reliability by helping to avoid the use of unintended values of variables as well as by explicitly expressing the intended semantics of the values of enumerated variables

**Exceptions:** When sharing data with third party devices the data type may be externally mandated as a sub-optimal data type.

**Example:**

- If a variable can only hold the values 0 or 1, and is only to be operated on by Boolean operations, then the elementary type BOOL should be chosen;



- If a programmable controller program has to count something and the counts are expected to be in the range from 0 to 1000, a variable of type SINT or USINT cannot be used, since their value ranges only extend from -128 to +127 for SINT and from 0 to 255 for USINT. A reasonable data type for this purpose would be UINT. This has a sufficient value range and the usage of an unsigned integer type also makes it clear that negative values are not expected
- Any code that uses a CASE statement should strongly consider if the expression variable should be an enumerated type, testing against the semantic value rather than numeric value
- An enumerated data type restricts the values of variables of the type to a user-defined set of identifiers. As an example consider

```
TYPE Color : ( Red, Yellow, Green );
END_TYPE
...
VAR_GLOBAL brickColor : Color; END_VAR
```

Here a new type Color is defined. It may only have three values - Red, Green, or Yellow. IEC 61131-3 does not define numerical values to which these enumerated values may correspond. There also is no conversion function to and from enumerated types to integral types. The values only have to be distinct and reproducible. An assignment of a value to the variable brickColor is possible only if one of the defined color values is used. All other values are flagged as errors

Another enumerated data types example:

```
TYPE ANALOG_SIGNAL_TYPE : (SINGLE_ENDED, DIFFERENTIAL) ;
END_TYPE
```

Even though there are only 2 values, using enumeration make the code easier to read and also extend.

- Subrange data types can limit the range of permissible values, e.g.:

```
TYPE ANALOG_DATA : INT (-4095..4095) ; END_TYPE
```

- Array data types group data of the same data type, e.g.:

```
TYPE ANALOG_16_INPUT_DATA : ARRAY [1..16] OF ANALOG_DATA ;
END_TYPE
```

- Structured data types group data of the different data types e.g.:

```
TYPE
    ANALOG_CHANNEL_CONFIGURATION :
        STRUCT
            RANGE : ANALOG_SIGNAL_RANGE ;
            MIN_SCALE : ANALOG_DATA ;
            MAX_SCALE : ANALOG_DATA ;
        END_STRUCT ;
    ANALOG_16_INPUT_CONFIGURATION :
        STRUCT
            SIGNAL_TYPE : ANALOG_SIGNAL_TYPE ;
            FILTER_PARAMETER : SINT (0..99) ;
            CHANNEL : ARRAY [1..16] OF
ANALOG_CHANNEL_CONFIGURATION ;
        END_STRUCT ;
END_TYPE
```

**Comments:** None

### 5.24. Define maximum number of input/output/in-out variables of a POU

**Identifier:** Rule CP23

**Importance:** Medium

**Targeted languages:** all

**References:**

- JSF++ - AV Rule 110

**Description:** Define a maximum number of input/output/in-out variables of a POU. The number of input variables, output variables, and in-out variables should be within a limited set by your organization.

**Guideline:** A limit can be around 10.

If more input/output/in-out variables are necessary, consider to reduce the number of pins (input/output/in-out variables) of POUs by the following method.

1. Introduce UDTs (user-defined structured data type) to group some input/output/in-out variables.
2. If some input/in-out variables are a kind of configuration parameter which does not need to be changed on every cyclic call of the FB,
  - A) Change them into internal variables, and give them necessary initial values by using VAR\_CONFIG struct.
  - or
  - B) Change them into internal variables with PUBLIC or INTERNAL access specifier, and give them necessary value before calling the FB.

Note: internal variable with access specifier is a newly added feature of IEC 61131-3 Ed.3.

**Reasoning:** Using FB with too many pins breaks readability.

**Exceptions:**

- POUs which are to be used only in ST language.
- POUs which are to be used only in the vendor-specific PSE which supports some feature to hide specified pins of specified POU in graphical language editor.

**Example:**

*Don't:* **Function block with too many pins**

```
(* Graphical representation of FB declaration *)
+-----+
|      MyFunctionBlock      |
DINT--|Cfg_Param1--Cfg_Param1|--DINT
DWORD--|Cfg_Param2--Cfg_Param2|--DWORD
BOOL--|Cfg_Param3--Cfg_Param3|--BOOL
INT--|Cfg_Param4--Cfg_Param4|--INT
STRING[32]--|Cfg_Param5--Cfg_Param5|--STRING[32]
BOOL--|Cfg_Param6      Output1|--BOOL
DINT--|Cfg_Param7      Output2|--BOOL
BOOL--|Cfg_Param8      Output3|--BOOL
BOOL--|Cfg_Param9      Output4|--BOOL
BOOL--|Enable          Output5|--BOOL
INT--|Input2           Output6|--DINT
INT--|Input3           Output7|--BOOL
BOOL--|Input4          Output8|--BOOL
BOOL--|Input5          Output9|--BOOL
INT--|Input6           Output10|--BOOL
BOOL--|Input7          Output11|--BOOL
BOOL--|Input8          Output12|--DINT
INT--|Input9           Output12|--BOOL
BOOL--|Input10         Output14|--BOOL
BOOL--|Input11         Output15|--BOOL
INT--|Input12          Output16|--BOOL
BOOL--|Input13         Output17|--BOOL
BOOL--|Input14         Output18|--DINT
INT--|Input15          Error|--BOOL
BOOL--|Input16         ErrorID|--DWORD
BOOL--|Input17         |
INT--|Input18         |
+-----+
```

*Do:*

```
(* Graphical representation of FB declaration *)
+-----+
|      MyFunctionBlock      |
BOOL--|Enable          CylinderOut1|--DT_CylinderOut
INT--|Input2           CylinderOut2|--DT_CylinderOut
INT--|Input3           CylinderOut3|--DT_CylinderOut
ARRAY[1..5] OF DT_EncoderInput--|EncoderInputs      Error|--BOOL
|                               |                     ErrorID|--DWORD
+-----+
```

```
(* Textual declaration of FB *)
FUNCTION_BLOCK MyFunctionBlock
VAR_INPUT
    Enable : BOOL;
```

```

        Input2 : INT;
        Input3 : INT;
        EncoderInputs : ARRAY[1..5] OF DT_EncoderInput
    END_VAR
    VAR_OUTPUT
        CylinderOut1 : DT_CylinderOut;
        CylinderOut2 : DT_CylinderOut;
        CylinderOut3 : DT_CylinderOut;
        Error : BOOL;
        ErrorID : DWORD;
    VAR PUBLIC
        ConfigParams : DT_MyFBConfiguration //Static configuration
parameter.
        // This variable is not shown as pin but can be written
        // separately before calling the FB instance.
    END_VAR
END_FUNCTION_BLOCK
TYPE
    DT_MyFBConfiguration : STRUCT
        Param1 : DINT;
        Param2 : DWORD ;
        Param3 : BOOL;
        Param4 : INT;
        Param5 : STRING[32];
        Param6 : BOOL;
        Param7 : DINT;
        Param8 : BOOL;
        Param9 : BOOL;
    END_STRUCT
    DT_EncoderInput : STRUCT
        IsReverse : BOOL := FALSE;
        Reset : BOOL := FALSE;
        Count : INT := 0;
    END_STRUCT
    DT_CylinderOut : STRUCT
        Solenoid1 : BOOL;
        Solenoid2 : BOOL;
        Solenoid3 : BOOL;
        Solenoid4 : BOOL;
        PilotLamp : BOOL;
        DumpParam : DINT;
    END_STRUCT
END_TYPE

```

**Comments:** none

### 5.25. *Do not declare variables that are not used*

**Identifier:** Rule CP24

**Importance:** Medium

**Targeted languages:** All

**References:**

- Codesys SA0011, SA0033
- Itris Automation Square S7

**Description:** Each declared variable should be used in the code

**Guideline:** All declared variable in an application should be read or written elsewhere in the code.

**Reasoning:** When development starts from an pre-existing project, removing unused declarations is not always the priority, so unused variables may be part of the final application. Such an application may be more difficult to understand and maintain, and will also lose some performance from a memory point of view.

**Exceptions:** Variables explicitly identified as spare variables can be defined. In such a case a variable identified as a spare should not be used elsewhere in the code. Those variables are used for keeping spare memory free for future usage and for allowing on line modifications (impossible to declare while the program is running, so variables are declared in advance).

**Example:** None

**Comments:** None

### 5.26. Data types conversion should be explicit

**Identifier:** Rule CP25

**Importance:** Medium

**Targeted languages:** All

**References:**

- Codesys SA0019
- Misra C 10.3
- IEC 61131-3 section 6.6.1.6 and Table 11

**Description:** Data types conversion should be done explicitly by the developer and not added by the compiler

**Guideline:** When writing code that converts between types, the developers shall use explicit casts and not rely on the compiler's type inference capabilities.

**Reasoning:** The data type conversions are responsible for loss of range, loss of precision or loss of signedness. The compiler doesn't care about the loss occurring when doing the conversion between two data types. The conversion shall be explicitly done by the developer so that the correct questions get their answers.

It is good practice to keep as long as possible the initial data type format and convert it to something else before sending the information outside the code: SCADA formatting, other equipment communication.

**Exceptions:** Implicit datatype conversions can be used when there is no loss of value or precision (see table 11 of IEC 61131-3 3<sup>rd</sup> edition)

**Example:**

*Don't:*

```
VAR
```

```
  I : INT := 10;
```

```
  J : REAL := 0.55;
```

```
END_VAR;
```

```
I := I * J;
```

```
// If it compiles (compiler not compliant to IEC61131 Ed.3rd)
```

```
// Result can be either 0 or 5 depending on the way the compiler
```

```
// is interfering types
```

*Do either:*

```
I := I * REAL_TO_INT(J);
```

*or:*

```
I := REAL_TO_INT(INT_TO_REAL(I) * J);
```

Note that the result can differ between the 2 cases. Also if there is no explicit typecast the user does not know which solution is chosen by the compiler.

**Comments:** None



### **5.27. A global variable may be written only by one PROGRAM**

**Identifier:** Rule CP26

**Importance:** Low

**Targeted languages:** All

**References:**

- Itris Automation Square : S2

**Description:** A global variable may be written only by one PROGRAM

**Guideline:** When a global variable is assigned, this assignment should be in one PROGRAM only. Each PROGRAM is in charge of assigning some of the global application variables.

**Reasoning:** The data flow is easier to understand and read and so the debug and the maintenance are more efficient.

**Exceptions:** None

**Example:** None

**Comments:** None

## 5.28. Avoid deprecated features

**Identifier:** Rule CP27

**Importance:** Low

**Targeted languages:** Ladder, Structured Text, Sequential Function Chart, Function Block Diagram

**References:**

- IEC 61131-8 Section 3.12
- IEC 61131-3 3<sup>rd</sup> edition

**Description:** Avoid writing code using deprecated or obsolete Data Types, Functions, Function Blocks, System variables etc. Also you may avoid using programming practices which are replaced by improved methods.

**Guideline:** Avoid all deprecated and obsolete functions and practices, including:

- BCD Data types and instructions
- IEC 61131-3 Second Edition the standard Functions and Function Blocks that have been superseded by IEC 61131-3 Third Edition
- Use of JUMP instruction, where conditional statements are implemented
- Use of multiple Function Blocks processing the same data, where Classes with multiple Methods are provided
- Unnecessary use of global variables. Instead use Local variables and encapsulate data, where possible. In particular, the writing of global variables from more than one program location should be avoided. It is recommended that global variables should be used (if at all) only for supplying values of “global” interest to other program organization units.
- The direct association of tasks with function block instances

**Reasoning:** The effects of programming technique on software quality should be considered when choosing among the options made available in IEC 61131-3. The latest programming practices to achieve higher software quality are recommended. Also features that are currently deprecated are likely to become obsolete in future versions and not be supported, which can force unplanned rewriting. Excessive use of global variables contradicts the principles of encapsulation and hiding discussed in IEC 61131-8 section 2.4.2.1 and can greatly reduce software reliability, maintainability and reusability.

**Exceptions:**

- When connecting to legacy devices which *only* support the deprecated features.
- When using third party libraries or code that makes use of deprecated features.

**Examples:** In IEC61131-3 Ed.3rd, the following features are marked as deprecated and should not be used anymore:

- Octal literals 8#377
- Use of directly represented variables in the body of POU's and methods.
- Standard function "TRUNC"
- Indicator-variable of Action Block of SFC
- Instruction list (IL)

**Comments:** None

## 6. Languages

### 6.1. *Define indentation*

**Identifier:** Rule L1

**Importance:** Low

**Targeted languages:** Structured Text, Instruction List, textual variable declaration

**References:**

- JSF++ 44

**Description:** You may define your use of indentation, and use consistently throughout the project.

**Guideline:** Use 4 spaces for indentation level.

**Reasoning:** Indenting code aids readability, particularly for conditional and loop statements. Small indents (e.g. 1-2 spaces) are not always clear. Large indents (e.g. 8 spaces) can mean that nested statements create code too wide for the screen.

**Exceptions:** none

**Example, use case:**

*Don't:* the nested IF instruction should be at the same indentation than Sort call:

```
IF sizeListToSort < 0 THEN
    Sort (numberElements := sizeListToSort,
        direction := 2,
        idEse := idEse,
        Ese := Ese,
        status => statusTemp);

        IF NOT statusTemp THEN // Indentation is not correct here
            status := statusTemp;
        END_IF;
END_IF;
```

*Do:*

```
// Initialisation
IF Dem_froid OR Rep_chaud OR Prem_cycle THEN
    Cmd_vanne_replissage.Temps_ma := 15;
    Cmd_vanne_vidange.Temps_ma := 15;

    Local := true;
ELSE
    // Grafcet
    init_graph := false;
END_IF;
```

**Comments:** See also 6.6.7 *Define use of tabs*, page 120.

## 6.2. Function Block Diagram FBD

### 6.2.1. Avoid assignments of intermediate results within networks

**Identifier:** Rule L2

**Importance:** Medium

**Targeted languages:** Function Block Diagram

**References:** None

**Description:** Avoid assignments of intermediate results within networks

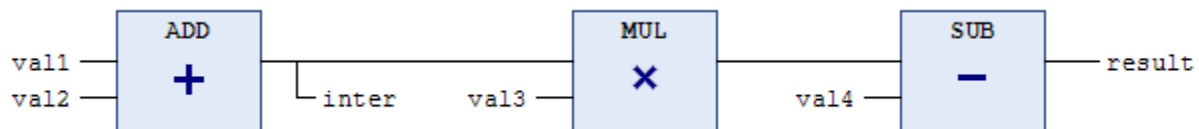
**Guideline:** In Function Block Diagram networks one should avoid the assignment of variables between blocks.

**Reasoning:** Side effects in the networks are difficult to see if this construct is used.

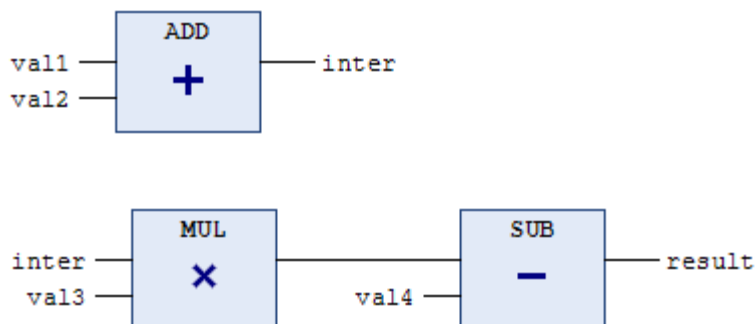
**Exceptions:** None

Example:

Don't



Do:



**Comments:** None

### 6.2.2. Define maximum complexity of single network

**Identifier:** Rule L3

**Importance:** Medium

**Targeted languages:** Function Block Diagram

**References:** None

**Description:** Define the maximum complexity permissible for a network, for example by limiting the number of elements

**Guideline:** Function Block Diagram networks should be kept to a maximum of 32 elements (Functions, Function Blocks) per network.

**Reasoning:** Complex algorithms reduce readability and increase the likelihood of misunderstanding and mistakes. When a diagram grows, it cannot be shown on a single screen (although dependent on screen size and zoom factor). Large diagrams containing too many elements suggest a need to split into more diagrams or sub diagrams, each with a distinct action.

**Exceptions:** None

**Example:** None

**Comments:** None

### 6.3. Ladder (LD)

#### 6.3.1. A coil should not be followed by a contact

**Identifier:** Rule L5

**Importance:** Medium

**Targeted languages:** Ladder

**References:**

- MISRA C: 13.4

**Description:** A coil should not be followed by a contact.

**Guideline:** Instead of directly using a coil one should insert a second rung. See the ‘Do’ example below.

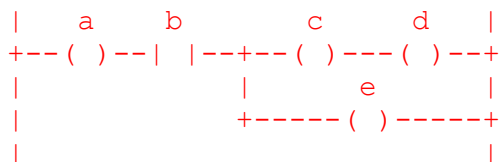
**Reasoning:** Readability

**Exceptions:** None

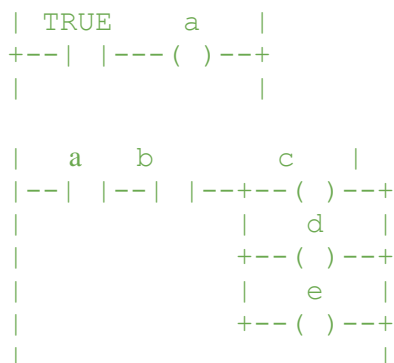
**Example:**

*Don't:* IEC 61131-3 section 8.2.5 shows a contact after a coil: "in the rung shown below, the values of the Boolean output a is always TRUE, while the value of outputs c,d and e upon completion of an evaluation of the rung is equal to the value of the input b."

**Problem:** the assignment of 'a' by the coil is unexpected here, and can be overseen.



*Do:* Use an extra network for the assignment to variable 'a'.



**Comments:** None

### 6.3.2. Define maximum rung complexity

**Identifier:** Rule L6

**Importance:** Medium

**Targeted languages:** Ladder

**References:** none

**Description:** Define the maximum complexity permissible for a rung, for example by limiting the number of ladder elements

**Guideline:** Ladder rungs should be kept to a maximum of 32 ladder elements (contacts, coils, Functions, Function Blocks) per rung.

**Reasoning:** Complex algorithms reduce readability and increase the likelihood of misunderstanding and mistakes. When the program grows, the rung cannot be shown on a single screen (although dependent on screen size and zoom factor). Large rungs may contain many sequential elements, or many parallel elements, or often both. When the rung is too large it should be split into more rungs or Functions/Function Blocks, each with a distinct action.

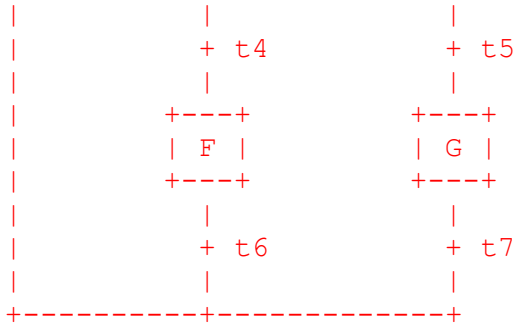
**Exceptions:** None

**Example:** None

**Comments:** None







**Comments:** None

### 6.4.2. Do not program an SFC action block in SFC

**Identifier:** Rule L8

**Importance:** Medium

**Targeted languages:** Sequential Function Chart

**References:**

- [Link to SFC subgroup](#)

**Description:** When adding actions to an SFC state, it is possible to select the action programming language. Don't choose the SFC language to program such an action.

**Guideline:** Use only ST, FBD or LD in an action block. If you need to have a state diagram in SFC inside your action block, encapsulate this state machine in a separate FB which is then called in the action block itself.

**Reasoning:** Programming an action block detail in SFC (sometimes called “nested SFC”) can become complex and difficult to look through. The lower/inner SFC execution behavior is not specified by the IEC61131-3 standard. Then depending on programming software, it may not be executed in every task cycle but only when its related action in the higher/outer SFC is active. Therefore it is difficult or impossible in the lower/inner SFC to react.

**Exceptions:** none

**Example:** none

**Comments:** Most PLC programming software doesn't allow developer to select the SFC language to implement an SFC action. This feature was supported in the 2nd edition of the IEC 61131-3 standard, however it is removed in the 3rd edition.

### 6.4.3. Define maximum complexity

**Identifier:** Rule L9

**Importance:** Medium

**Targeted languages:** Sequential Function Chart

**References:** None

**Description:** Define the maximum complexity permissible for a diagram, for example by limiting the number of elements to 32.

**Guideline:** Sequential Function Charts should be kept to a user defined maximum steps per chart.

**Reasoning:** Complex algorithms reduce readability, and increase likelihood of misunderstanding and mistakes. There also comes a time when the whole chart cannot be shown on a single screen (although dependent on screen size and zoom factor). Large charts containing too many elements should be split into 2 or more sub-charts, each with a distinct action.

**Exceptions:** None

**Example:** None

**Comments:** None

## 6.5. Structured Text (ST)

### 6.5.1. Define General formatting rules

**Identifier:** Rule L4

**Importance:** Low

**Targeted languages:** Structured Text

**References:** none

**Description:** Define general formatting rules and use them coherently in the program.

**Guideline:**

Section A:

- Put a single space character around infix operators (like + and \*) and assignment except when used in formal parameter lists.
- For non-keyword unary operators put no space between operand and operator but put a space on the other side.
- No space after opening '(' or before closing parenthesis ')'
- One space before '(' and one after ')' in expressions
- No space before '(' and after ')' in calls
- No space before semi-colon ';'.
- No space before colon ':'. One space after
- No white-space characters at the end of a line.
- Always place a space after a comma ',' that does not end a line.
- In an array there is no space before and after the brackets []

Section B:

- When multiple parameters are put on multiple lines they should start in the same column.
- When line length is not exceeded put THEN/DO etc. on the same line as IF/WHILE
- When an expression needs to be put on multiple lines start the following lines with the operator.

Section C:

- Use AND and not '&'
- Use TRUE and FALSE not 0 and 1 for Boolean values.

**Reasoning:** Coherent formatting makes it easier to read a program. There is no OR equivalence to “&” for AND. In the first edition of the standard keywords where in upper-case

**Exceptions:** None

**Example:**

*Don't:*

```
if pump.temperature>=90&pump.running
then
    pump.speedmode:= slow ;
```

```
end_if ;
```

*Do:*

```
IF (Pump.Temperature >= 90) AND Pump.Running THEN  
    Pump.SpeedMode := SLOW;  
END_IF;
```

**Comments:** None

### 6.5.2. Usage of Continue and Exit instruction should be avoided

**Identifier:** Rule L10

**Importance:** Medium

**Targeted languages:** Structured Text

**References:**

- Misra C 14.5
- JSF++ Rules 189, 190

**Description:** Execution branching instructions CONTINUE and EXIT should not be used in Structured Text. This also includes any implementation specific instructions like GOTO or JUMP

**Guideline:** Most execution branching instructions can be replaced with structured instruction like conditional instructions (IF THEN ELSE or CASE) or loop instructions (WHILE, FOR, REPEAT).

**Reasoning:** Maintaining and debugging code containing sequence breaking instructions like CONTINUE and EXIT is more difficult to understand. Replacing those instructions with more structured instructions makes the code more readable and maintainable.

**Exceptions:** There are instances where the use of EXIT can enhance clarity and/or performance, though these are rare and so caution should always be exercised in their use. In FOR loops it can be necessary to use additional exit conditions. For CONTINUE this can be applicable to avoid deeply nested IF statements.

**Examples:**

Rather than using CONTINUE within a loop to skip code execution, use a conditional block to execute it only when needed, for example:

<i>Don't:</i>	<i>Do:</i>
<pre> // Count number of elements in error Count:= 0; FOR index:= 1 TO 20 DO     IF NOT bError[index] THEN         // Not in error so skip to next element         CONTINUE;     END_IF;     Count:= Count + 1; END_FOR; </pre>	<pre> // Count number of elements in error Count:= 0; FOR index:= 1 TO 20 DO     IF bError[index] THEN         // Another element in error         Count:= Count + 1;     END_IF; END_FOR; </pre>

FOR loops using EXIT can iterate less times than expected. Rewrite the loop to expect an early exit:

<i>Don't:</i>	<i>Do:</i>
<pre> J:= 101; FOR index := 1 TO 100 DO     IF WORDS[index] = 'KEY' THEN         J:= index;         EXIT;     END_IF; END_FOR; </pre>	<pre> index:= 1; WHILE index &lt;= 100 AND WORDS[index] &lt;&gt; 'KEY' DO     index:= index+1; END_WHILE; J:=index; </pre>

### 6.5.3. Define the maximum line length

**Identifier:** Rule L11

**Importance:** Medium

**Targeted languages:** Structured Text

**References:**

- JSF++ 41

**Description:** You should define the maximum line length

**Guideline:** Use a maximum line length for ST of 80 characters

**Reasoning:** Although some tools and compilers can support very long line lengths, it proves very difficult to read. It either requires lots of panning and scrolling (which loses the context and indentation level) or zooming, which can make the text too small to read. Also, any deep nesting is an indication to break down the design of your code using other POU's.

For maximum portability and readability, define your maximum line length as a value no greater than 80.

**Exceptions:**

*Don't:*

```
translatePwr (power := maxEse, powerFactor := 10.0, mode := mode,  
const := const, clusterVoltage := clusterVoltage, current =>  
maxCurrentEse);
```

*Do:*

```
translatePwr (power := maxEse,  
powerFactor := 10.0,  
mode := mode,  
const := const,  
clusterVoltage := clusterVoltage,  
current => maxCurrentEse);
```

**Example, use case:** None

**Comments:** None



#### 6.5.4. Loop variables should not be modified inside a FOR loop

**Identifier:** Rule L12

**Importance:** Medium

**Targeted languages:** ST

**References:**

- IEC61131-3 (ed3) 7.3.3.4.2
- JSF++ AV Rule 188
- MISRA Rule 13.6
- CoDeSYS SA0072: Invalid use of counter variable

**Description:** The standard states "The control variable, initial value, and final value should be expressions of the same integer type and shall not be altered by any of the repeated statements."

**Guideline:** Modifying loop variables inside a FOR loop is forbidden

**Reasoning:** The FOR statement is used if the number of iterations can be determined in advance; otherwise, the WHILE or REPEAT constructs are used. Modifying during execution can cause unexpected behavior, including infinite loops, and can be difficult to debug and maintain.

**Exceptions:** None

**Example:**

*Don't:*

```
// This loop is not fine
j:= 11;
FOR i := 0 TO 10 BY 2 DO
    IF WORDS[i] = 'Key' THEN
        j := i ;
        i := 10; // The loop variable should not be written here
    END_IF;
END_FOR;
```

*Do:*

```
// This loop is fine
i:= 0;
WHILE i <= 10 AND WORDS[i] <> 'KEY' DO
    i := i + 2;
END_WHILE;
j := i;
```

**Comments:** After the execution of the loop the value of the control variable is implementation specific.

### 6.5.5. FOR loop variable usage should not be used outside the FOR loop

**Identifier:** Rule L13

**Importance:** Medium

**Targeted languages:** ST

**References:**

- IEC61131-3 (ed3) 7.3.3.4.2
- JSF++ Av Rule 136

**Description:** The IEC 61131-3 standard states: "The value of the control variable after completion of the FOR loop is Implementer specific."

**Guideline:** Don't use the control variable outside the FOR loop, otherwise, the WHILE or REPEAT constructs can be used.

**Reasoning:** Since the value of the control variable outside the loop is implementation depended using it would make the code non portable.

**Exceptions:** None

**Example:**

*Don't:*

```
FOR i := 0 TO 100 BY 2 DO
    IF Words[ i ] = 'Key' THEN
        EXIT;
    END_IF;
END_FOR;

IF i <= 100 THEN      // value of i is not defined here
    Words[i + 1] := value;
END_IF;
```

*Do:*

```
// This loop is fine
KeyAtIndex := 101;
FOR i := 0 TO 100 BY 2 DO
    IF Words[i] = 'Key' THEN
        KeyAtIndex := i;
    END_IF;
END_FOR;

IF KeyAtIndex <= 100 THEN
    Words[KeyAtIndex + 1] := Value;
```

```
END_IF;
```

Alternatively, a WHILE loop can be used:

```
i := 0;  
WHILE i <= 100 AND WORDS[i] <> 'KEY' DO  
    i := i + 2;  
END_WHILE;  
IF i <= 100 THEN  
    Words[i + 1] := Value;  
END_IF;
```

**Comments:** None

## 6.5.6. Passing parameters should be clear

**Identifier:** Rule L14

**Importance:** Medium

**Targeted languages:** Structured Text

**References:**

- IEC 61131-3 Section 2.5.1.1
- IEC 61131-8 Section 3.2.3
- IEC 61508 C.2.9
- JSF++ 58

**Description:** Passing parameters in ST to Functions and Function Block invocations and method calls should be clear: which parameters are which, and whether they are input or output.

**Guideline:**

- For "Standard" IEC Functions and Function Blocks use the non-formal invocation type
- For User Defined Functions and Function Blocks use the IEC formal invocation type to name each argument, and use := and => operators to highlight input or output usage and sort into Inputs, Outputs and In-Out parameters
- When parameters have to be omitted or the quantity of parameters is large then use the formal invocation type with each parameter written on a separate line. Each line should have a comment describing the *argument* and its usage (not to be confused with the generic parameter comment in the FB definition).

**Reasoning:** Using meaningful parameter names makes the code unambiguous. Using the := and => operators also forces developers to consider which variable they expect to get overwritten. However to avoid long lines, and aid readability multiple lines are sometimes needed.

All the Standard IEC Functions (like Numerical and Arithmetic Functions) should be portable and recognizable, so IEC 61131 Section 2.5.1.1 recommends the non-formal invocation type is used.

**Exceptions:** None

**Example:**

*Don't:*

```
// Avoid the non-formal invocation type for custom FBs and long
invocations
A := MyFunction(Bee, 5);
MC_Home(Axis:=var0, Execute:=var1, Done=>var2, Busy=>var3,
CommandAborted=>var4, Error=>var5, ErrorID=>var6);
```

*Do:*

```
// Use formal argument list: MyFunction will not modify Bee
A := MyFunction(In:=Bee, Max:=5);

MC_Home(Axis:=ShuttleAxis,           // Home the shuttle axis
        Execute:=DoHome,             // at the timing DoHome
        Done=>HomeDone,               // shuttle at home position
```

```
Busy=>ShuttleMoving,           // shuttle is currently homing  
CommandAborted=>HomeAborted,  // shuttle homing aborted  
Error=>HomeError,             // error during operation  
ErrorID=>HomeErrorID);       // error code if error flag set
```

**Comments:** None

### 6.5.7. Use parenthesis to explicitly express operation precedence

**Identifier:** Rule L15

**Importance:** Medium

**Targeted languages:** Structured Text

**References:**

- Misra C 12.1
- JSF++ Rule 213

**Description:** When using operators with a similar precedence, use parenthesis to disambiguate.

**Guideline:** In a structured text expression using operators AND/OR/= or +/-, use parenthesis to specify explicitly the order of evaluation.

**Reasoning:** The precedence of operators may change between implementations. When a developer looks at an ambiguous expression, time may be lost due to assumptions about precedence.

**Exceptions:** None

**Example:**

*Don't:*

```
IF A AND B OR C AND D THEN
    ...
END_IF;
```

*Do:*

```
IF (A AND B) OR (C AND D) THEN
    ...
END_IF;
```

or

```
IF A AND (B OR C) AND D THEN
    ...
END_IF;
```

**Comments:** None

### 6.5.8. Define the use of tabs

**Identifier:** Rule L16

**Importance:** Low

**Targeted languages:** Structured Text

**References:**

- JSF++ 43

**Description:** You may define your use of tab characters and use consistently throughout the project.

**Guideline:** Use of tab character (ASCII code 9) should be avoided, and Programming Support Environment set to replace tabs with spaces

**Reasoning:** The visual interpretation of a tab character varies wildly. It can be interpreted as 8 spaces, or 4 spaces, or undefined spaces until the next tab stop. Therefore for maximum portability, it is recommended to not use tab characters.

Usage of tabs should be done consistently throughout the code and consistently with the Programming Support Environment behavior.

**Exceptions:** None

**Example, use case:** None

**Comments:** Depending on the Programming Support Environment, this may not be the same as using the tab Key on the keyboard. If possible, you should define the Programming Support Environment to replace use spaces for the tab key.



### 6.5.9. Each IF instruction should have an ELSE clause

**Identifier:** Rule L17

**Importance:** Low, High in critical software

**Targeted languages:** Structured Text

**References:**

- Codesys SA0075
- Itris Automation Square S12
- Misra C 14.10
- JSF++ Rule 192

**Description:** For every IF instruction in the code, an ELSE clause should be present.

**Guideline:** For each IF instruction in the structured text, the developer should add an ELSE clause to ensure that all cases are managed.

**Reasoning:** It is defensive programming. The developer should always take into account what will happen if the condition is False. This rule should be a requirement for safety critical software.

**Exceptions:** Development of non-safety critical software

**Example, use case:**

*Don't:*

```
IF some_condition THEN
  // some code
  ...
END_IF;
```

*Do:*

```
IF some_condition THEN
  // some code
  ...
ELSE
  // Nothing needs to happen in this case ! (Deliberate choice)
;
END_IF;
```

**Comments:** None

## 7. Vendor Specific IEC 61131-3 Extensions

### 7.1. *Dynamic memory allocation shall not be used*

**Identifier:** Rule E1

**Importance:** High

**Targeted languages:** All

**References:**

- =>Misra C 20.4

**Description:** The application shall not rely on dynamic allocation feature supplied by a PLC nor implement its own memory allocation mechanism.

**Guideline:** Dynamic allocation is forbidden.

**Reasoning:** Dynamic memory allocation has undefined, undocumented, implementation defined behavior. It may lead to memory leaks, data inconsistency, memory exhaustion, non-deterministic behavior.

**Exceptions:** None

**Example:** None

**Comments:** None

## 7.2. *Pointer arithmetic shall not be used*

**Identifier:** Rule E2

**Importance:** High

**Targeted languages:** ST, IL

**References:**

- IEC61131-3: not allowed:  
no "pointers" defined in 2nd and 3rd edition of IEC 61131-3,  
in 3rd edition "reference" defined, only with comparison with NULL and assignment  
operations, see Table 12)
- MISRA C 17,1

**Description:** The only allowed operators for manipulating pointers are equality and inequality. Developer shall not use pointer arithmetic to calculate a position in a memory to access further data.

**Guideline:** Should be limited and used only for array access

**Reasoning:** Pointer arithmetic is implementation dependent and understanding such code requires a thorough understanding of PLC's internals. This practice was only acceptable due to the lack of high level abstractions like structure, function blocks and arrays, but now these are available, they should be used instead of pointer arithmetic. Moreover, as mentioned in rule N1, developers should not use physical addresses for manipulating data.

**Exceptions:** None

**Example:** None

**Comments:** None

### 7.3. *Some comparator instructions shall not be used for pointer or reference manipulation*

**Identifier:** Rule E3

**Importance:** High

**Targeted languages:** All

**References:**

- Codesys SA0061
- Misra-C 17.3

**Description:** <=, >=, < and > operators shall not be used on pointers or references. Only equality and differences operators are allowed. If the order is required, then developer shall use an explicit array so that the relative positioning of variables is known.

**Guideline:** Pointer equality and inequality are allowed - all other comparison operators are forbidden

**Reasoning:** This rule is related to others rules relative to variable mapping in memory. The test relies on knowledge of memory organization of the PLC. It is either undocumented or susceptible to change and it is difficult to maintain.

**Exceptions:** None

**Example:**

*Don't:*

```
// Wrong example
VAR
  x: POINTER;
  y: POINTER;
END_VAR
...
IF X^ < Y^ AND X < Y THEN  -- the comparison X and Y is not allowed
  TEMP := X^;
  X^ := Y^;
  Y^ := TEMP;
END_IF;
```

*Do:*

```
// Good example - the usage of array is more explicit and relies
// on wide used arrays
VAR
  Values : ARRAY [1..50] OF INT;
```

```
    IndexX : INT;  
    IndexY : INT;  
END_VAR  
IF Values[IndexX] < Values[IndexY] AND IndexX < IndexY THEN  
    TEMP := Values[IndexX];  
    Values[IndexX] := Values[IndexY];  
    Values[IndexY] := Temp;  
END_IF;
```

**Comments:** None

## 8. Annex 1 – overview of the rules via their priorities

<i>Priority</i>	<i>Rule #</i>	<i>Chapter</i>	<i>Name</i>	<i>Page</i>
High	N1	3.1.1.	Avoid physical addresses	16
High	N3	3.2.1.	Define the names to avoid	20
High	N4	3.2.2.	Define the use of case (capitals)	22
High	N5	3.2.3.	Local names shall not shadow global names	25
High	C1	4.1.	Comments shall describe the intention of the code	36
High	C2	4.2.	All elements shall be commented	38
High	CP1	5.1.	Access to a member shall be by name	44
High	CP2	5.2.	All code shall be used in the application	45
High	CP3	5.3.	All variables shall be initialized before being used	47
High	CP4	5.4.	Direct addressing should not overlap	51
High	CP5	5.5.	Applications shall be well designed	53
High	CP6	5.6.	Avoid external variables in functions, function blocks and classes	54
High	CP7	5.7.	Error information shall be tested	56
High	CP8	5.8.	Floating point comparison shall not be equality or inequality	58
High	CP28	5.9	Time and physical measures comparison shall not be equality or inequality	59
High	CP9	5.10.	Limit the complexity of POU-code	60
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High	CP12	5.13.	Physical outputs shall be written once per PLC cycle	68
High	CP13	5.14.	POUs shall not call themselves directly or indirectly	69
High	CP14	5.15.	POUs shall have a single point of exit	71
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Medium	CP23	5.24.	Define maximum number of input/output/in-out variables of a POU	91
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Medium	CP25	5.26.	Data types conversion shall be explicit	95
Medium	L2	6.2.1.	Avoid assignments of intermediate results within networks	100
Medium	L3	6.2.2.	Define maximum complexity of single network	101
Medium	L5	6.4.1.	A coil should not be followed by a contact	102
Medium	L6	6.4.2.	Define maximum rung complexity	103
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