TYPE EXAMINATION CERTIFICATE

46 24 03

PLUS+1 Development tools, version 9.1.X

Issued to

Danfoss Power Solutions AB,

Teknikgatan 1, SE-34334 ÄLMHULT, Sweden

Product name and description

The PLUS+1 development tools, version 9.1.X are support tools used for code generation, where high level graphical symbols are transferred to source code and in addition supports the assembling, linking and downloading of the source code to the hardware and reading/writing of information from/to the hardware. The PLUS+1 Development tools, version 9.1.X, consists of two main parts, namely:

- GUIDE tool, that handles the translation of graphical symbols to executable code
- Service Tool, that handles the download of executable code to the hardware and reading/writing of information from/to the hardware

Certification

The product described above fulfils the requirements placed on support tools for use in the development of application software according to the standard IEC 61508:2010 Functional safety of electrical/electronic/programmable electronic safety-related systems, Part 1 and 3 within the following limitations:

- IEC 61508 tool requirements for GUIDE version 9.1 are fulfilled for graphic code, GUIDE C-code, Structured Text, Function Block Diagram, Ladder Logic Diagram code, Instruction lists, Sequential function chart but not for externally developed C-code
- IEC 61508 tool requirements for Service Tool version 9.1 are fulfilled as long as it is not used as a software on-line support tool as defined by IEC 61508

The certification is based on a functional safety assessment according to IEC 61508:2010 described in RISE report 7P06848:A supplemented with a separate evaluation of the PLUS+1 Development tools described in RISE report 7P06848:B and the user documentation in the currently valid revision. The external C-compilers that are fully verified to be used with PLUS+1 GUIDE 9.1 are listed in RISE reports 7P06848:B and 7P06848:C.

Marking

Each sample that conforms in all respects with the original item certified may display the text "Type-examined by SP". In addition, manuals and marking shall also show the number of the standard, the reached SIL (Safety Integrity Level) of the item, the number of this certificate and the serial number or equivalent of the item.

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Validity

This certificate is valid until not later than 2021-06-27.

Miscellaneous

Other terms and conditions are set out in RISE certification rules for type-examination, SPCR 123.

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REPORT

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PLUS+1 9.1 Safety Evaluation Overview

Test object

The test object is PLUS+1 tools GUIDE version 9.1 and Service Tool version 9.1 developed by Danfoss Power Solutions AB.

Summary

The conclusion is that Danfoss PLUS+1 tools GUIDE version 9.1 and Service Tool version 9.1 is certified according to IEC 61508:2010 [1] under certain conditions.

RISE Research Institutes of Sweden AB
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Summary

This document is public and focusses on the Danfoss Power Solutions AB PLUS+1 tools from a safety perspective according to IEC 61508:2010 [1]. This document is an extract of "RISE report PLUS+1 9.1 Evaluation, 7P06848:B, 2018-02-13" and is intended for users and as initial information when considering Danfoss Power Solutions AB PLUS+1 tools [2].

The PLUS+1 Development tools are two, namely:

- GUIDE tool, that handles the translation of graphic symbols to executable code [3].
- Service Tool, that handles the download of the executable code to hardware [4].

These are certified according to IEC 61508:2010, but under certain conditions.

Commission

This document is public and gives an overview of the Danfoss Power Solutions AB PLUS+1 tools from a safety perspective according to IEC 61508:2010. The document is assumed to match PLUS+1 version 9.1.X (where X is an integer ≥ 1), however there could be coming versions that may have effects on this document. Check with Danfoss if uncertainties.

The purpose is to give an overview of the possible quality of a product developed using the PLUS+1 environment. In this document a product is a safety function or a part of a safety function according to IEC 61508:2010.

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Test object

Introduction

The test object is the pair of tools GUIDE and Service Tool both of version 9.1, which are defined by the referenced documents as given below.

The test object was delivered to RISE Electronics 2017-09-19.

Terminology

Term	Description
CCP	Compiled Code Package used for making it possible to merge external C-code, “Function Block Diagram”, “Ladder Logic Diagram”, “Structured Text”, “Instruction List” and “Sequential Function Chart” code with graphic code.
Danfoss	Danfoss Power Solutions AB. Danfoss is here considered as a development environment provider not as a safety function provider.
Danfoss graphic language	The Danfoss language including graphic symbols and connections between them.
FBD	“Function Block Diagram” programming language defined in IEC61131-3 Second edition 2003-01, Programmable controllers – Part 3:Programming languages
Function Block	Application independent function created using graphic symbols. License may be needed.
GUIDE C-code	Programming language C supported by GUIDE
HWD file	Hardware Description file
IEC 61131 language	One of “Function Block Diagram”, “Ladder Logic Diagram”, “Structured Text”, “Instruction List” or “Sequential Function Chart” as defined in IEC 61131-3 Second edition 2003-01, Programmable controllers – Part 3:Programming languages
IEC 61508	IEC 61508:2010 part 1-7
IL	“Instruction List” programming language defined in IEC61131-3 Second edition 2003-01, Programmable controllers – Part 3:Programming languages
LD	“Ladder Logic Diagram” programming language defined in IEC61131-3 Second edition 2003-01, Programmable controllers – Part 3:Programming languages
LHX file	Downloadable protected file
NV memory	Non Volatile memory
P1D file	Diagnostic file to be used with the Service Tool to connect to the system
POU	Program Organization Unit, used for IEC 61131 languages defined in IEC 61131-3 Second edition 2003-01, Programmable controllers – Part 3:Programming languages
SFC	“Sequential Function Chart” programming language defined in IEC61131-3 Second edition 2003-01, Programmable controllers – Part 3:Programming languages
SIL application	An application according to IEC 61508 SIL i.e. a safety critical application (safety function or part of it).
ST	“Structured Text” programming language defined in IEC61131-3 Second edition 2003-01, Programmable controllers – Part 3:Programming languages

Performance and result

General

Evaluation was carried out by Johan Hedberg and Ted Strandberg, RISE Electronics, during the period from December 2017 to February 2018.

Results apply to the test object only.

PLUS+1 Overview

The Danfoss Power Solutions AB PLUS+1 tools are used to create applications, typically for controlling heavy, powerful, and mobile off-road equipment such as tractors, cranes, and harvesters.

The PLUS+1 tools consists of GUIDE which is a graphical programming environment and Service tool which is a tool for downloading applications or parameters to a controller.

The PLUS+1 development environment is shown in the figure below.

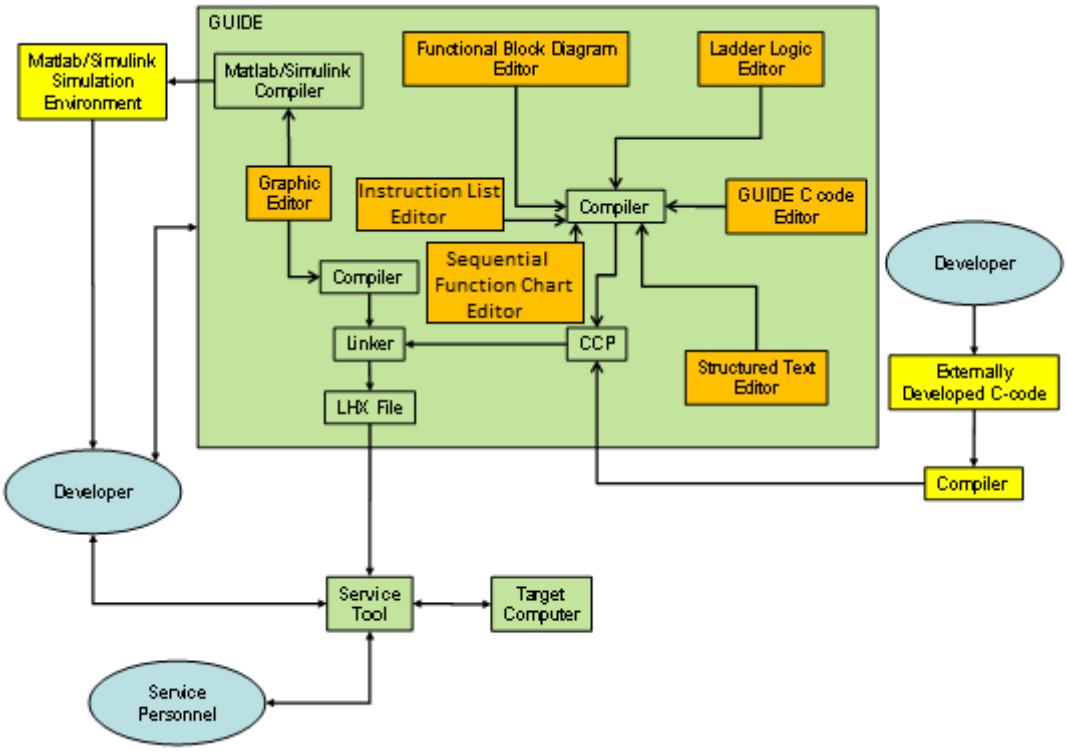

Figure 1: Plus+1 development environment.

GUIDE supports the Danfoss graphic language, GUIDE C-code, FBD, LD, IL, ST and SFC [3]. Each can be edited, connected and compiled in the GUIDE environment. The purpose of including all the languages is primarily for making it easy to include already written code. However, there could be cases where adaptation is needed in order to incorporate code into GUIDE. As shown in the figure the same compiler is used for the application languages. The compiler takes the source code and generates C-code which is packed into CCP and linked. Separate application editor is used for each of the languages.

A call is always made from the graphic GUIDE component to subroutine defined using the different languages. Since IEC 61508 considers a single programming language at a time, each of the languages is handled separately, compiled separately and then linked together.

It is possible to simulate behaviour using Matlab/Simulink and by loading S-Functions created from graphic code. Thus the original is always the graphic code.

It is also possible for a developer to handle externally developed C-code and to create a CCP to be linked with other code. However, in this case the responsibility is completely up to the developer. Also, the compiler used to create a CCP needs to match the compiler defined by the HWD file in the project where it is used. This has to be checked manually i.e. without tool support.

Tools

Classification

In IEC 61508, tools are classified as T1, T2 or T3. T1 concerns e.g. administrative tools, T2 concerns test tools while T3 concerns tools that could affect the behaviour at runtime. The following is a possible classification of Danfoss tools:

1. Software off-line support tool, T2 (Service Tool). Service Tool in combination with P1D file can be used as a test tool during application development.
2. Software off-line support tool, T3 (GUIDE). GUIDE is a compiler/translator and used as a development tool during application development. Test Tool and debugger are included.
3. Software on-line support tool - Not affecting behaviour (Service Tool and P1D file). Even though not explicitly stated in IEC 61508 this case could be seen as matching T2. It is up to the developer to guarantee that the behaviour is not affected when using Service Tool and P1D file at runtime (this is set up in the application). For example, Service Tool changing CAN ID or sending CAN messages in general must, if allowed, be guaranteed not affecting behaviour.
4. Software on-line support tool - Software element according to IEC 61508 (Service Tool). In this case the Service Tool and P1D file combination can affect behaviour at runtime (decided by the application) and is thus considered a part of the safety function (like any other Software Element). This case is complicated since much effort is necessary and Danfoss details are needed.

Compatibility and suitability of other tools used together with Danfoss tools is up to the application developer. Danfoss is responsible for GUIDE and Service Tool working together.

GUIDE

There are several internal checks e.g. detection of corrupt file. An error, by definition, stops the creation of an executable.

For a SIL application all included application parts are treated as SIL. Everything is compiled from graphics to linkable objects files since the directive COMPILE SIL2 is used. Thus there is no mixture of parts with different SILs. The following conditions apply for fulfilling COMPILE SIL2:

- A market released and certified according to IEC 61508 version of PLUS+1 GUIDE (there are built-in checks if this is the case).

- A released version of an HWD that is certified according to IEC 61508. Such HWD tells the PLUS+1 GUIDE if it supports the “COMPILE SIL2”.
- Manual acknowledge via dialogues.

In the HWD file a flag is set indicating support of SIL application. COMPILE SIL2 enforce Strict Mode for GUIDE C-code, FBD, LD, ST, IL and SFC.

A specific Test Tool is included making it possible to verify a complete page including sub-pages and CAN messages, module calls and calls to GUIDE C-code, FBD, LD, IL, ST and SFC.

Graphic code can be compiled to S-Functions which can be verified by executing them in the Matlab/Simulink environment. Thus GUIDE addresses additional tools (T2 tool according to IEC 61508) available for verification and thus improving quality.

Service Tool

As described above the Service Tool in combination with P1D file gives different roles. Especially important is to be aware of the roles at runtime. For not affecting behaviour at runtime an analysis has to be made concerning the application handling this situation.

To download a “Compile SIL2” application the following conditions apply:

- A market released and certified according to IEC 61508 version of Service Tool (there are built-in checks if this is the case).
- Only a SIL version of Service Tool can be used for SIL application.

The Service Tool reads back a checksum of the downloaded data, calculated by the boot loader of the hardware after the download is completed. Service Tool blocks download if error is detected.

Service Tool can handle different nodes in a CAN network e.g. it is possible to set parameters via CAN (if a valid P1D file is available and the application allows parameter setting).

A USB/CAN gateway makes it possible to connect external tools via USB interface in order to get access to CAN bus used for communication between target computers.

Safety measure examples

Parameters

Parameters can be used for supporting variants and allowing different behaviour. Special care is needed in order to not create inconsistent sets of parameters.

In order to claim conformance to IEC 61508:2010 for an application that is based on this certificate, the application software needs to ensure that the PLUS+1 Service Tool program cannot affect the application’s run-time behaviour. This can be done by using the S**erviceTool.DisableWrite** and **ServiceTool.DisableDownload** signals.

To claim the PLUS+1 Service Tool program as an off-line service tool, the developer has to verify that the application software prevents the PLUS+1 Service Tool program from affecting the application’s runtime behaviour.

Protection from unauthorized use

The means for protection against unauthorized use are licenses, passwords and application controlled access to the application at runtime.

A lock between target computer and P1D file is needed in order to ensure that only the intended P1D file can be used to access the target computer. This locking is supported by the Service Tool by the use of Tool Key. The target computer using Tool Key demands Tool Key from the Service Tool in order to enable access to target computer. The Service Tool receives the Tool Key from a locked P1D file where the Tool Key is embedded and thus provide the lock between P1D file and target computer.

Protection from unauthorized use can also be determined by the access levels. There are 10 different access levels (0-9) where 9 has the least access rights, and 0 has the most rights.

License is checked at start of GUIDE, Service Tool for verifying. License can also be used for Function Blocks and can be decided for each Function Block individually. The data of the license file is both encrypted and a checksum is added.

Since user identity is stored for several actions it is possible to trace responsible person.

SIL application

For the scope of this report the following applies for a SIL application:

- In the HWD file a flag is set indicating support of SIL application.
- Activity Log is included.
- Only a SIL version of Service Tool can be used for SIL application.

A SIL flag is set in the LHX file if all conditions are fulfilled for a SIL application i.e.

- SIL version of HWD file. Connection is made to specific hardware since information in system file specifies hardware with specific part number.
- SIL version of GUIDE
- COMPILE SIL2 has been used
- Manual acknowledge via dialogues. Application developer user identity is included in LHX file.

If conditions are fulfilled, the COMPILE SIL2 button will be visible in the menu bar and compile of the safety classified application possible.

Programming languages

Graphic code

The graphic code has the following advantages:

- Non-programmers can understand and create programs
- Clear separation of application and infrastructure/hardware.
- Exhaustive test of graphic symbols is possible since there is a limited number of possible code blocks (one per graphic symbol). This makes it also possible to fully verify an external C-compiler with respect to the code generated by the graphic symbols.

The following C-compilers are fully verified to be used with PLUS+1 GUIDE 9.1.

Compiler	**Flags**	**PLUS+1 GUIDE naming**
GNU ARM Embedded Toolchain 4.7-2013-q2	-c -fno-inline-small-functions -mthumb -mcpu=cortex-m3 -O2 -fwrapv -fsigned-char -mlittle-endian -Wall -Wno-main	ARM v4.7-2013q2
Sourcery G++ ARM EABI 2006q1-3	-g -c -mcpu=arm7tdmi-s -w -O2	arm-elf v410
Sourcery G++ Lite ARM EABI Sourcery G++ Lite 2009q3-68	-c -fno-inline-small-functions -mthumb -mcpu=cortex-m3 -O1 -fsigned-char -mlittle-endian -Wall -Wno-main	Sourcery G++ Lite arm-2009q3-68
Texas Instruments C2000 Code Generation Tools v5.2.5	-pm -o3 -q -g -pdv -pden -pdw -pdse225 -d"LARGE_MODEL" -ml -v28 -pdf -me	TI v525
Texas Instruments C2000 Code Generation Tools v6.4.9	-pm -o3 -q -g -pdv -pden -pdw -pdse225 -d"LARGE_MODEL" -ml -v28 -pdf -me	TI v649

Each application has a top level graphic page. A page may consist of modules, sub-pages and symbols. At each cycle, the execution takes place as a strict sequence from left to right.

The application can check its own safety level (SIL or not SIL). It shall be used for stopping the whole SIL application if not all conditions for SIL are fulfilled.

If the result of a calculation made by a symbol is outside the range of the output type, the output value is undefined. If capped symbols are used the output value is limited to the range of the output type and an overflow output is set active. In any case no warning or error is given. Thus special care is needed.

Before application is started the first time, outputs are set to predefined values. Special care is then needed in order to not create a dangerous situation at start up. This is up to the application to handle.

IEC 61131 languages

Each IEC 61131 language has its own definition of strict mode (language subset). Each of the IEC 61131 languages have their own coding guideline which is defined in the PLC Open Coding Guidelines [5].

An IEC 61131 language subroutine can generate different types of errors. Checks are made automatically (by GUIDE at compile time and by runtime support at runtime).

In case deadline is passed when executing IEC 61131 language code the error is propagated back to first called IEC 61131 language subroutine and then to the graphic code where it is handled in the normal way.

C (externally developed)

Since the Danfoss handling of externally developed C-code does not fulfil all requirements in IEC 61508 it means that externally developed C-code shall not be used within SIL applications unless the application developer is able to prove that the implementation fulfils the requirements of IEC 61508.

Danfoss does not take any responsibility for including externally generated C-code, this is completely up to the application developer to handle. No guidance is given by Danfoss.

GUIDE C-code

Strict mode is supported for GUIDE C-code, following the coding guideline for GUIDE C-code [6].

In case deadline is passed when executing GUIDE C-code the error is propagated back to first called GUIDE C-code subroutine and then to the graphic code where it is handled in the normal way.

References

[1] IEC 61508:2010, parts 1-7

[2] PLUS+1 9.1 Evaluation, 7P06848:B, 2018-02-13

[3] PLUS+1 GUIDE User Manual, 10100824 · Rev 1503 April 2017

[4] PLUS+1 GUIDE Service Tool User Manual, L1307770 • Rev 0401 March 2017

[5] PLCopen Coding Guidelines 2016-04-21
http://www.plcopen.org/pages/pc2_training/index.htm

[6] MISRA C:2012 Coding Guidelines
https://www.misra.org.uk/Buyonline/tabid/58/Default.aspx