IEC 61508 Functional Safety Assessment

Project:
Rosemount 3051S 4-20mA HART Pressure Transmitter
Software Revision 7.0 and Above

Company:
Rosemount Inc.
(an Emerson Process Management company)
Chanhassen, MN
USA

Contract No.: Q13/04-008
Report No.: ROS 06/12-18 R001
Version V2, Revision R1, September 5, 2014
Ted Stewart

Management Summary

This report summarizes the results of the functional safety assessment according to IEC 61508 carried out on the:

- Rosemount 3051S 4-20mA HART Pressure Transmitter: Coplanar Differential & Coplanar Gage
- Rosemount 3051S 4-20mA HART Pressure Transmitter: Coplanar Absolute, In-line Gage, and In-Line Absolute

The functional safety assessment performed by *exida* consisted of the following activities:

- *exida* assessed the development process used by Rosemount Inc. through an audit and creation of a detailed assessment against the requirements of IEC 61508.
- *exida* reviewed and assessed a detailed Failure Modes, Effects, and Diagnostic Analysis (FMEDA) of the devices to document the hardware architecture and failure behavior.
- *exida* reviewed field failure data to ensure that the FMEDA analysis was complete.
- *exida* reviewed the manufacturing quality system in use at Rosemount Inc.

The functional safety assessment was performed to the requirements of IEC 61508: ed2, 2010, SIL 3. A full IEC 61508 Safety Case was prepared using the *exida* SafetyCase tool as the primary audit tool. Hardware process requirements and all associated documentation were reviewed. Environmental test reports were reviewed. Also the user documentation (safety manual) was reviewed.

The results of the Functional Safety Assessment can be summarized by the following statements:

The Rosemount 3051S 4-20mA HART Pressure Transmitter was found to meet the Systematic Capability requirements of IEC 61508 for up to SC 3 (SIL 3 Capable).

The Rosemount 3051S was found to meet the Random Capability requirements for a Type B device of SIL 2@HFT=0, SIL 3@HFT=1 (Route 1_H for models where the SFF ≥ 90% and all models Route 2_H).

The manufacturer will be entitled to use the Functional Safety Logo.

Table of Contents

1 Purpose and Scope

This document shall describe the results of the IEC 61508 functional safety assessment of the Rosemount 3051S 4-20mA HART Pressure Transmitter by *exida* according to the requirements of IEC 61508: ed2, 2010.

The results of this provides the safety instrumentation engineer with the required failure data as per IEC 61508 / IEC 61511 and confidence that sufficient attention has been given to systematic failures during the development process of the device.

2 Project management

2.1 *exida*

exida is one of the world's leading accredited Certification Bodies and knowledge companies specializing in automation system safety and availability with over 300 years of cumulative experience in functional safety. Founded by several of the world's top reliability and safety experts from assessment organizations and manufacturers, *exida* is a global company with offices around the world. *exida* offers training, coaching, project oriented system consulting services, safety lifecycle engineering tools, detailed product assurance, cyber-security and functional safety certification, and a collection of on-line safety and reliability resources. *exida* maintains the largest process equipment database of failure rates and failure modes with over 60 billion unit operating hours.

2.2 Roles of the parties involved

Rosemount Inc.	Manufacturer of the Rosemount 3051S
exida	Performed the IEC 61508 Functional Safety Assessment

Rosemount Inc. contracted *exida* with the IEC 61508 Functional Safety Assessment of the above mentioned devices.

2.3 Standards / Literature used

The services delivered by *exida* were performed based on the following standards / literature.

[N1]	IEC 61508 (Parts 1 - 7): ed. 2, 2010	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems

2.4 Reference documents

2.4.1 Documentation provided by Rosemount Inc.

[D1]	DOP 415	Product Design and Development Process
[D2]	DOP 440	Engineering Change Order
[D3]	EDP 400-500	Peer Review Procedure
[D4]	EDP 400-300	Configuration and Change Management Procedure
[D6]	Functional_Safety_Requirements_Specification.doc	Functional Safety Requirements Specification for the Rosemount 3051S
[D7]	D9900093	Rosemount 3051S System Requirements Document
[D10]	00809-0100-4801	Product Safety Manual for 3051S
[D11]	Safety Impact Analysis 3051S.doc	Safety Impact Analysis for Rosemount 3051S
[D12]	SIS_SM_Project _Plan.doc	Project Plan for Rosemount 3051S
[D13]	Safety_Validation	Safety Validation Test Plan for Rosemount 3051S

	_Test_Plan.doc	
[D14]	Safety_Validation _Test_Report_ROM7.doc	Safety Validation Test Report for the Rosemount 3051S
[D20]	fsrs_cons_log_sis_super module.xls	Inspection Report – Rosemount 3051S Functional Safety Requirements Specification
[D21]	Project Plan Review Log.xls	Inspection Report – Rosemount 3051S Inspection Plan
[D23]	sis_module_lint _output.txt	Output from PC LINT
[D24]	Rom7 _code_review _log.xls	Code Review Inspection Report
[D25]	Sis_supermodule _design_review _log.xls	Design Review Inspection Report
[D26]	SIS_SuperModule _Integration _Test.doc	Rosemount 3051S Integration Test Specification and Report
[D27]	SM_SIS_Action _Items.doc	Rosemount 3051S Action Item List
[D28]	svtp_cons_log_sis _supermodule.xls	Inspection Report for Safety Validation Test Plan

2.4.2 Documentation generated by *exida*

[R1]	Rosemount Change Audit.xls	Details of assessment (internal document)
[R2]	ROS 05/05-05 R001, FMEDA, V2R2 9/11/2014	Rosemount 3051S FMEDA Report
[R3]	ROS 03/11-07 R001, V1R1, 1/16/2004	Rosemount 3051S Proven in Use Assessment
[R4]	Coplanar II 3051S – with proof test coverage.xls	Detailed FMEDA for Rosemount 3051S Coplanar Board

3 Product Description

The Rosemount 3051S 4-20mA HART Pressure Transmitter, Software Revisions 7.0 and Above, is a two-wire 4 – 20 mA smart device used in multiple industries for both control and safety applications.

The FMEDA has been performed for four different configurations of the 3051S Pressure Transmitter, i.e. Coplanar, In-Line, Level, and Flow configurations. The Rosemount 3051S Pressure Transmitter series include the following measurement configurations:

- Rosemount 3051S 4-20mA HART Pressure Transmitter: Differential and Gage Coplanar

  Capacitance technology is utilized for differential Coplanar measurements.
- Rosemount 3051S 4-20mA HART Pressure Transmitter: Coplanar Absolute, In-line Gage and In-line Absolute

  Piezoresistive sensor technology is used for the absolute Coplanar and In-line measurements.
- Rosemount 3051S 4-20mA HART Level Transmitter

  A Rosemount 3051S Pressure Transmitter is available as a Level assembly. The Rosemount 3051S Level transmitter can be used to measure level on virtually any liquid level vessel. Rosemount 3051S transmitters and seal systems are designed to offer a flexible solution to meet the performance, reliability, and installation needs of nearly any level measurement application.
- Rosemount 3051S 4-20mA HART Flowmeter

  A Rosemount 3051S Pressure Transmitter can be combined with primary elements to offer fully assembled flowmeters. The direct mount flowmeter capability eliminates troublesome impulse lines associated with traditional installations. With multiple primary element technologies available, Rosemount 3051S flowmeters offer a flexible solution to meet the performance, reliability, and installation needs of nearly any flow measurement application. The flowmeters covered for this assessment are based on the Rosemount 1195, 405, and 485 primary elements. Excluded from the assessment are models with Flo-Tap, remote mount, or temperature input options.

The Rosemount 3051S 4-20mA HART Pressure Transmitter is classified as a Type B[1] device according to IEC 61508, having a hardware fault tolerance of 0.

The Rosemount 3051S 4-20mA HART Pressure Transmitter can be connected to the process using an impulse line, depending on the application the clogging of the impulse line needs to be accounted for, see section 5.1 of the FMEDA report [R2].

[1] Type B element: “Complex” element (using micro controllers or programmable logic); for details see 7.4.4.1.3 of IEC 61508-2, ed2, 2010.

4 IEC 61508 Functional Safety Assessment

The IEC 61508 Functional Safety Assessment was performed based on the information received from Rosemount Inc. and is documented in this report.

4.1 Methodology

The full functional safety assessment includes an assessment of all fault avoidance and fault control measures during hardware and software development and demonstrates full compliance with IEC 61508 to the end-user. The assessment considers all requirements of IEC 61508. Any requirements that have been deemed not applicable have been marked as such in the full Safety Case report, e.g. software development requirements for a product with no software.

As part of the IEC 61508 functional safety assessment the following aspects have been reviewed:

- Development process, including:
    - Functional Safety Management, including training and competence recording, FSM planning, and configuration management
    - Specification process, techniques and documentation
    - Design process, techniques and documentation, including tools used
    - Validation activities, including development test procedures, test plans and reports, production test procedures and documentation
    - Verification activities and documentation
    - Modification process and documentation
    - Installation, operation, and maintenance requirements, including user documentation
- Product design
    - Hardware architecture and failure behavior, documented in a FMEDA
    - Software architecture and failure behavior, documented in safety integrity requirement specification

The review of the development procedures is described in section 5.1. The review of the product design is described in section 5.2.

4.2 Assessment level

The Rosemount 3051S 4-20mA HART Pressure Transmitter has been assessed per IEC 61508 to the following levels:

- Systematic Integrity (SIL 3 capability) as the development procedures were assessed as suitable for use in applications with a maximum Safety Integrity Level of 3 (SIL 3) according to IEC 61508.
- Architecture Constraint limitations of SIL 2 for a single device and SIL 3 for multiple devices in safety redundant configurations with a Hardware Fault Tolerance of 1.

5 Results of the IEC 61508 Functional Safety Assessment

exida assessed the development process used by Rosemount Inc. during the product development against the objectives of IEC 61508 parts 1, 2, and 3, see [N1]. The development of the Rosemount 3051S 4-20mA HART Pressure Transmitter was done using this development process. The Safety Case was updated with project specific design documents.

5.1 Lifecycle Activities and Fault Avoidance Measures

Rosemount Inc. has an IEC 61508 compliant development process as defined in [D1]. The process defines a safety lifecycle which meets the requirements for a safety lifecycle as documented in IEC 61508. Throughout all phases of this lifecycle, fault avoidance measures are included. Such measures include design reviews, FMEDA, code reviews, unit testing, integration testing, fault injection testing, etc.

This functional safety assessment investigated the compliance with IEC 61508 of the processes, procedures and techniques as implemented for the Rosemount 3051S 4-20mA HART Pressure Transmitter development. The investigation was executed using subsets of the IEC 61508 requirements tailored to the SIL 3 work scope of the development team. The result of the assessment can be summarized by the following observations:

The audited Rosemount Inc. development process complies with the relevant managerial requirements of IEC 61508 SIL 3.

5.1.1 Functional Safety Management

FSM Planning

The functional safety management of any Rosemount Inc. Safety Instrumented Systems Product development is governed by [D1]. This process requires that Rosemount Inc. create a project plan [D12] which is specific for each development project. The Project Plan defines all of the tasks that must be done to ensure functional safety as well as the person(s) responsible for each task. These processes and the procedures referenced herein fulfill the requirements of IEC 61508 with respect to functional safety management.

Version Control

All documents are under version control as required by [D4].

Training, Competency recording

Competency is ensured by the creation of a competency and training matrix for the project. The matrix lists all of those on the project who are working on any of the phases of the safety lifecycle. Specific competencies for each person are listed on the matrix which is reviewed by the project manager. Any deficiencies are then addressed by updating the matrix with required training for the project.

5.1.2 Safety Requirements Specification and Architecture Design

As defined in [D1] a safety requirements specification (SRS) is created for all products that must meet IEC 61508 requirements. For the Rosemount 3051S 4-20mA HART Pressure Transmitter, the safety integrity requirements specification (SIRS) [D6] contains a system overview, safety assumptions, and safety requirements sections. During the assessment, *exida* reviewed the content of the specification for completeness per the requirements of IEC 61508: ed2, 2010.

Requirements are tracked throughout the development process by the creation of a series of traceability matrices which are included in the following documents: [D6] and [D13]. The system requirements are broken down into derived hardware and software requirements which include specific safety requirements. Traceability matrices show how the system safety requirements map to the hardware and software requirements, to hardware and software architecture, to software and hardware detailed design, and to validation tests.

Requirements from **IEC 61508-2, Table B.1** that have been met by Rosemount Inc. include project management, documentation, structured specification, inspection of the specification, and checklists.

Requirements from **IEC 61508-3, Table A.1** that have been met by Rosemount Inc. include backward traceability between the safety requirements and the perceived safety needs.

5.1.3 Hardware Design

Hardware design, including both electrical and mechanical design, is done according to [D1]. The hardware design process includes creating a hardware architecture specification, a peer review of this specification, creating a detailed design, a peer review of the detailed design, component selection, detailed drawings and schematics, a Failure Modes, Effects and Diagnostic Analysis (FMEDA), electrical unit testing, fault injection testing, and hardware verification tests.

Requirements from **IEC 61508-2, Table B.2** that have been met by Rosemount Inc. include observance of guidelines and standards, project management, documentation, structured design, modularization, use of well-tried components, checklists, semi-formal methods, computer aided design tools, simulation, and inspection of the specification. This meets the requirements of SIL 3.

5.1.4 Software (Firmware) Design

Software (firmware) design is done according to [D1]. The software design process includes software architecture design and peer review, detailed design and peer review, critical code reviews, static source code analysis and unit test.

Requirements from **IEC 61508-3, Table A.2** that have been met by Rosemount Inc. include fault detection, error detecting codes, failure assertion programming, diverse monitor techniques, stateless software design, retry fault recovery mechanisms, graceful degradation, forward and backward traceability between the software safety requirements specification and software architecture, semi-formal methods, event-driven, with guaranteed maximum response time, static resource allocation, and static synchronization of access to shared resources.

Requirements from **IEC 61508-3, Table A.3** that have been met by Rosemount Inc. include suitable programming language, strongly typed programming language, language subset, and increased confidence from use for the tools and translators.

Requirements from **IEC 61508-3, Table A.4** that have been met by Rosemount Inc. include semi-formal methods, computer aided design tools, defensive programming, modular approach, design and coding standards, structured programming, forward traceability between the software safety requirements specification and software design. This meets the requirements of SIL 3.

5.1.5 Validation

Validation Testing is done via a set of documented tests. The validation tests are traceable to the Safety Requirements Specification [D6] in the validation test plan [D13]. The traceability matrices show that all safety requirements have been validated by one or more tests. In addition to standard Test Specification Documents, third party testing is included as part of the validation testing. All non-conformities are documented in a change request and procedures are in place for corrective actions to be taken when tests fail as documented in [D1].

Requirements from IEC **61508-2, Table B.5** that have been met by Rosemount Inc. include functional testing, functional testing under environmental conditions, interference surge immunity testing, fault insertion testing, project management, documentation, static analysis, dynamic analysis, and failure analysis, expanded functional testing and black-box testing.

Requirements from IEC **61508-3, Table A.7** that have been met by Rosemount Inc. include process simulation, functional and black box testing, and forward and backward traceability between the software safety requirements specification and the software safety validation plan. This meets SIL 3.

5.1.6 Verification

Verification activities are built into the standard development process as defined in [D1]. Verification activities include the following: Fault Injection Testing, static source code analysis, module testing, integration testing, FMEDA, peer reviews and both hardware and software unit testing. In addition, safety verification checklists are filled out for each phase of the safety lifecycle. This meets the requirements of IEC 61508 SIL 3.

Requirements from **IEC 61508-2, Table B.3** that have been met by Rosemount Inc. include functional testing, project management, documentation, and black-box testing.

Requirements from **IEC 61508-3, Table A.5** that have been met by Rosemount Inc. include dynamic analysis and testing, data recording and analysis, functional and black box testing, performance testing, interface testing, and test management and automation tools.

Requirements from **IEC 61508-3, Table A.6** that have been met by Rosemount Inc. include functional and black box testing, performance testing, and forward traceability between the system and software design requirements for hardware/software integration and the hardware/software integration test specifications

Requirements from **IEC 61508-3, Table A.9** that have been met include static analysis, dynamic analysis and testing, forward traceability between the software design specification and the software verification plan.

This meets the requirements of SIL 3.

5.1.7 Modifications

Modifications are done per the Rosemount Inc.'s change management process as documented in [D2] and [D4]. Impact analyses are performed for all changes once the product is released for integration testing. The results of the impact analysis are used in determining whether to approve the change. The standard development process as defined in [D1] is then followed to make the change. The handling of hazardous field incidents and customer notifications is governed by DOP 1440. This procedure includes identification of the problem, analysis of the problem, identification of the solution, and communication of the solution to the field. This meets the requirements of IEC 61508 SIL 3.

Requirements from **IEC 61508-3, Table A.8** that have been met by the Rosemount Inc. modification process include impact analysis, reverify changed software modules, reverify affected software modules, revalidate complete system or regression validation, software configuration management, data recording and analysis, and forward and backward traceability between the software safety requirements specification and the software modification plan (including reverification and revalidation)

5.1.8 User documentation

Rosemount Inc. created a safety manual for the Rosemount 3051S 4-20mA HART Pressure Transmitter [D10] which addresses all relevant operation and maintenance requirements from IEC 61508. This safety manual was assessed by *exida*. The final version is considered to be in compliance with the requirements of IEC 61508.

Requirements from IEC **61508-2, Table B.4** that have been met by Rosemount Inc. include operation and maintenance instructions, maintenance friendliness, project management, documentation, and limited operation possibilities.

This meets the requirements for SIL 3.

5.2 Hardware Assessment

To evaluate the hardware design of the Rosemount 3051S 4-20mA HART Pressure Transmitter, a Failure Modes, Effects, and Diagnostic Analysis was performed by *exida* for each component in the system. The FMEDA was verified using Fault Injection Testing as part of the development, and as part of the IEC 61508 assessment.

A Failure Modes and Effects Analysis (FMEA) is a systematic way to identify and evaluate the effects of different component failure modes, to determine what could eliminate or reduce the chance of failure, and to document the system in consideration. An FMEDA (Failure Mode Effect and Diagnostic Analysis) is an FMEA extension. It combines standard FMEA techniques with extension to identify online diagnostics techniques and the failure modes relevant to safety instrumented system design.

Failure rates are listed in the FMEDA reports for each important failure category. Refer to the FMEDA [R2] for a complete listing of the assumptions used and the resulting failure rates.

The FMEDA results must be considered in combination with PFD_{AVG} and architectural constraints of other devices of a Safety Instrumented Function (SIF) in order to determine suitability for a specific Safety Integrity Level (SIL). The Safety Manual states that the application engineer should calculate the PFD_{AVG} for each defined safety instrumented function (SIF) to verify the design of that SIF.

The FMEDA analysis shows that most of the reviewed 3051 models have a Safe Failure Fraction > 90% (assuming that the logic solver is programmed to detect over-scale and under-scale currents) and therefore those models meet Route 1_H hardware architectural constraints for up to SIL 2 as a single device and SIL 3 with Hardware Fault Tolerance of 1.

The failure rate data used for this analysis meets the *exida* criteria for Route 2_H and the diagnostic coverage is ≥60%. Therefore all of the reviewed 3051 models meet the Route 2_H hardware architectural constraints for up to SIL 2 as a single device when the listed failure rates are used.

If the Rosemount 3051S 4-20mA HART Pressure Transmitter is one part of an element the architectural constraints should be determined for the entire sensor element

The architectural constraint type for the Rosemount 3051S 4-20mA HART Pressure Transmitter Series is B. The required SIL determine the level of hardware fault tolerance that is required per requirements of IEC 61508 or IEC 61511. The SIS designer is responsible for meeting other requirements of applicable standards for any given SIL as well.

The analysis shows that design of the Rosemount 3051S Pressure Transmitter meets the hardware requirements of IEC 61508, SIL 2 @HFT=0 and SIL 3 @ HFT=1.

6 Terms and Definitions

Fault tolerance	Ability of a functional unit to continue to perform a required function in the presence of faults or errors (IEC 61508-4, 3.6.3).
FIT	Failure In Time ($1x10^{-9}$ failures per hour)
FMEDA	Failure Mode Effect and Diagnostic Analysis
HFT	Hardware Fault Tolerance
Low demand mode	Mode, where the demand interval for operation made on a safety-related system is greater than twice the proof test interval.
PFD_{AVG}	Average Probability of Failure on Demand
Random Capability	The SIL limit imposed by the Architectural Constraints for each element.
SFF	Safe Failure Fraction summarizes the fraction of failures, which lead to a safe state and the fraction of failures which will be detected by diagnostic measures and lead to a defined safety action.
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
SIS	Safety Instrumented System – Implementation of one or more Safety Instrumented Functions. A SIS is composed of any combination of sensor(s), logic solver(s), and final element(s).
Systematic Capability	Measure of the confidence that the systematic safety integrity of an element meets the requirements of the specified SIL.
Type B element	“Complex” element (using complex components such as micro controllers or programmable logic); for details see 7.4.4.1.3 of IEC 61508-2

7 Status of the Document

7.1 Liability

exida prepares reports based on methods advocated in International standards. Failure rates are obtained from a collection of industrial databases. *exida* accepts no liability whatsoever for the use of these numbers or for the correctness of the standards on which the general calculation methods are based.

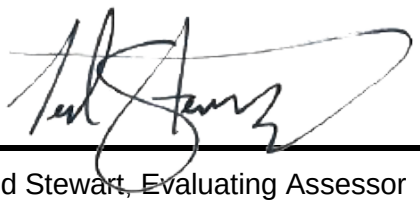
7.2 Releases

Version:	V2
Revision:	R1
Version History:	V2, R1: updated to IEC 61508 2010 standard and incorporated route $2_{H;}$ TES; 9/5/14
	V1, R2: updated from Q06-12-18, incorporated new template, and updated to incorporate Rosemount feedback/comments for cert; Rosemount decided no route 2H at this time; Ted Stewart; May 2, 2013
	V1, R1: Released to Emerson, December 22, 2006
Authors:	Michael Medoff, John Yozallinas
Review:	V0, R1: William M. Goble; December 22, 2006
Release status:	RELEASED

7.3 Future Enhancements

At request of client.

7.4 Release Signatures



Ted Stewart, Evaluating Assessor

William Goble, Certifying Assessor