



GUIDANCE NOTES ON

RESPONSE TIME ANALYSIS FOR PROGRAMMABLE ELECTRONIC ALARM SYSTEMS

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ABS Plaza
16855 Northchase Drive
Houston, TX 77060 USA**

Foreword

The response time analysis of programmable electronic alerts and indicators onboard marine and offshore structures helps to demonstrate how real-time alarm deadlines are satisfied under worst-case operational conditions. The ABS requirements for Response Time Analysis of alarms generated by Category III systems (defined in the ABS Rules and IACS UR E22), offer digital design clarification that the paramount situational awareness function of any standalone programmable electronic alarm or any integrated alarm within the Alarm and Monitoring System remains intact, regardless of any additional computational or network load introduced from sensory elements provided in excess of those required by the ABS Rules and statutory regulations.

ABS defines deadlines for response time analysis of alerts and indicators within its Rules so as to effectively harmonize class requirements with national and international standards (e.g., IEEE 45.2) on real-time systems deterministic behavior.

However, considering further the complexity of processors and communication protocols used to implement a real-time, programmable electronic alarm system, as well as the ever increasing utilization of such systems by additional or retrofitted sensory elements, ABS has developed a proposed methodology to further support Response Time Analysis efforts. The proposed methodology described in these Guidance Notes utilizes block diagrams for programmable electronic alarms system architectural modeling. The proposed methodology also introduces the concept of the response time table and offers applicable equations for calculating the Worst Case Response Time. These concepts aim to introduce both an optional unified terminology and a generalized methodology for Response Time Analysis efforts, targeting similar quality and consistency of engineering review submittals subject to ABS requirements for Response Time Analysis of alarms generated by Category III systems.

Alternative calculations and methods used to estimate the Worst-case Response Time (WCRT) of programmable electronic alarm systems can be reviewed and evaluated on an individual basis.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of these Guidance Notes is the most current.

These Guidance Notes become effective on the first day of the month of publication.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.

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SECTION 1 General

1 Application

These Guidance Notes can be of relevance to any Category III system (defined in the ABS Rules and IACS Unified Requirement E22), with real-time performance requirements for its alerts and indicators on board ABS Classed vessels, as required by ABS Rules and statutory regulations.

1.1 Audience

These Guidance Notes are intended for use by Programmable Electronic System suppliers, vendors and system integrators.

1.2 Purpose

With the increasing complexity and utilization of Programmable Electronic Alarm Systems, ABS developed a proposed methodology to further support response time analysis of alarms generated by Category III systems.

The objectives of these Guidance Notes is to utilize block diagrams for programmable electronic alarms system architectural modeling, identify the critical elements of the design by means of a response time table and to suggest applicable equations for calculating the Worst Case Response Time. The aim of these Guidance Notes is to introduce both an optional common terminology and a generalized methodology for Response Time Analysis (RTA) efforts, targeting similar quality and consistency of engineering submittal to demonstrate meeting ABS Rules requirements for Response Time Analysis.

It is also the purpose of these Guidance Notes to further clarify the proposed methodology by means of example RTA calculations.

Alternative calculations and methods used to estimate the Worst-case Response Time (WCRT) of programmable electronic alarm systems can be reviewed and evaluated on an individual basis.

2 Scope

These Guidance Notes, provide recommended methods for documenting both the real-time scheduling and the medium access control (MAC) protocols latency of processors and networks, respectively, in order to demonstrate that the expected response time of the design is achieved under worst-case operational conditions.

It is further within the scope of this document to discuss methods for showing that the software execution times of the system under design assessment, are always lower or equal to their specified deadlines under worst-case conditions during a fault-free, normal operation.

3 Background

Alerts and indicators required by ABS Rules and conditionally by statutory requirements are critical to safety and form part of a vessel's safety systems. Their proper functioning within the required timeframe are also critical to safety and need to be verified when the systems are new, throughout their full lifecycle and in particular following modifications that increase network load or modify its real-time response.

In addition to those alerts and indicators required by classification regulations, the Code on Alerts and Indicators, 2009 provides the type, location and priority for those alerts and indicators which may be required by the International Convention for the Safety of Life at Sea, 1974 (1974 SOLAS Convention), as amended; associated codes (BCH, Diving, FSS, Gas Carrier, 2000 HSC, IBC, IGC, IMDG, LSA, 2009 MODU, and Nuclear Merchant Ship Codes); the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78), as amended; the Principles of Safe Manning; the Guidelines for Inert Gas Systems (IGS); the Standards for Vapour Emission Control Systems (VEC); the Performance Standards for a Bridge Navigational Watch Alarm System (BNWAS); and the Revised Performance Standards for Integrated Navigation Systems (INS), according to IMO Resolution A.1021(26).

Although relevant international standards on Programmable Electronic Systems explicitly require a response time assessment for operator's control commands (e.g., IEC 60092-504:2016/10.4.9), the response time requirements of Alerts and Indicators (e.g., IEC 60092-504:2016/9.3.3.6, MSC 87/26/Add.1 Annex 21/13.1.2.1) and their necessary assessment are not explicitly stated. Also, continuous advancements in data acquisition, software and network technologies allow additional monitoring channels to be integrated with the programmable electronic alarm systems, in excess of those required by both the statutory and the classification regulation, resulting in increased situation awareness. As a result, several IACS members including ABS, state requirements for response time assessment of critical alarms in their Rules to better promote and verify the dependability of programmable electronic alarm system designs.

The importance of response time assessment of critical alarms becomes even more apparent considering the required automatic safety functions onboard. In several programmable electronic alarm system designs, especially if they are part of an Integrated Automation System, a variable number of monitoring channels have additional functionalities that satisfy the requirements in 4-9-2/9.5.2(a) of the *ABS Rules for Building and Classing Marine Vessels (Marine Vessel Rules)*, "Threshold Warning for Safety System Activations". Consequently, the lower the real-time deadline for reaching the remote control station(s) and the bridge, the greater the time for situation assessment by the crew, manual override and intervention. Lower real-time deadlines of both alarms and safety output signals are even more important for those monitored processes where the manual intervention is not an option, as it can result in total failure of the engine and/or propulsion equipment within a short time, for example, in the case of over speed.

However, lowering the real-time deadline of any alarm signal, below the two seconds requirement included in 4-9-3/5.1.7 of the *Marine Vessel Rules*, requires response time analysis historical trends and independent benchmarking. Such design documentation that calculates the response times of current programmable electronic alarm system designs is not an easy task to complete as trends in Commercial Off-The-Shelf (COTS) hardware and software products run contrary to the drive toward response time predictability. The level of detail for the Response Time Analysis is therefore very important and is addressed herein.

4 General Definitions and Nomenclature

The following definitions and nomenclature are used in these Guidance Notes.

4.1 Definitions

Programmable Electronic System (PES): A system based on one or more programmable electronic devices, connected to (and including) input devices (e.g., sensors) and/or output devices/final elements (e.g., actuators), for the purposes of control, protection or monitoring. The term "PES" includes all elements in the system, including power supplies, extending from sensors or other input devices, via data highways or other communicating paths, to the actuators, or other output devices, associated software, peripherals and interfaces.

Worst-case Execution Time (WCET): The WCET of a computational task is the maximum length of time the task could take to execute on a specific hardware platform.

PES Worst-case Response Time (WCRT): The maximum time taken from the input to the sensor (or input device), to the output device (final element) completing its required action. This time period includes the time taken for the Programmable Electronic System to carry out any software processing under WCET and communicate with the sensors and final elements.

Task Deadline: The instant of time by which an output signal of the system (or component) is required to be produced.

Message Deadline: The instant of time by which an output network signal of the system (or component) is required to be delivered.

Medium Access Control (MAC): Controlling when data is sent and when a delay is necessary to avoid congestion and collisions, especially for topologies with a collision domain (bus, ring, mesh, point-to-multipoint topologies).

Network Load: The fractional load relative to full network capacity.

4.2 Abbreviations

FMEA:	Failure Mode and Effect Analysis
ETA:	Event Tree Analysis
FTA:	Fault Tree Analysis
HMI:	Human Machine Interface
IODM:	Input Output Direct Memory
CPU:	Central Processing Unit
UTP:	Unshielded Twisted Pair

4.3 Lowercase Symbols

d :	Cable distance between the Programmable Device and the HMI,
s :	Wave propagation speed, approximately 2×10^8 m/sec for both the UTP cable and the fiber optic cable.

4.4 Uppercase Symbols

R :	Worst-Case Response Time
D_{SD} :	State Detection Delay
D_P :	Processing Delay
$E(I_i)$:	Worst-case reception time of Input i .
$E(X_i)$:	Worst-case execution time of Processing Task i .
$E(O_i)$:	The worst-case transmission time of Output i .
D_{PR} :	Propagation Delay
D_{RT} :	Retransmission Delay
N :	Number of bits per frame
RT :	Rate of transmission (e.g., 10 Mbps, 100 Mbps, 1 Gbps)
D_{QL} :	Average latency due to queuing
$D_{RT}(\text{max})$:	Store and forward latency of a full-size (1526 bytes) packet.

4.5 List of Applicable Rules, Regulations and International Standards

ABS Rules for Building and Classing Marine Vessels

ABS Rules for Building and Classing Offshore Support Vessels

ABS Rules for Building and Classing Mobile Offshore Units

ABS Rules for Building and Classing High Speed Craft

ABS Rules for Building and Classing High Speed Naval Craft

IMO Resolution A.1021(26)

IMO Resolution MSC.302(87)

IACS UR E22: On Board Use and Application of Computer based systems

IEC 61508: Functional safety of electrical/electronic/programmable electronic safety-related systems

IEC 61511: Functional safety – Safety instrumented systems for the process industry sector

IEC 60092-504: Electrical installations in ships – Part 504: Special features – Control and instrumentation.

ISO 17894:2005: Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications

IEC 61069-1:2016: Industrial-process measurement, control and automation – Evaluation of system properties for the purpose of system assessment

IEEE Standard 45.2: IEEE Recommended Practice for Electrical Installations on Shipboard – Controls and Automation