

Industrial communication networks - High availability  
automation networks - Part 3: Parallel Redundancy  
Protocol (PRP) and High-availability Seamless  
Redundancy (HSR)

## EESTI STANDARDI EESSÕNA

## NATIONAL FOREWORD

See Eesti standard EVS-EN IEC 62439-3:2022 sisaldab Euroopa standardi EN IEC 62439-3:2022 ingliskeelset teksti.	This Estonian standard EVS-EN IEC 62439-3:2022 consists of the English text of the European standard EN IEC 62439-3:2022.
Standard on jõustunud sellekohase teate avaldamisega EVS Teatajas	This standard has been endorsed with a notification published in the official bulletin of the Estonian Centre for Standardisation and Accreditation.
Euroopa standardimisorganisatsioonid on teinud Euroopa standardi rahvuslikele liikmetele kättesaadavaks 11.02.2022.	Date of Availability of the European standard is 11.02.2022.
Standard on kättesaadav Eesti Standardimis- ja Akrediteerimiskeskusest.	The standard is available from the Estonian Centre for Standardisation and Accreditation.

Tagasisidet standardi sisu kohta on võimalik edastada, kasutades EVS-i veebilehel asuvat tagasiside vormi või saates e-kirja meiliaadressile [standardiosakond@evs.ee](mailto:standardiosakond@evs.ee).

ICS 25.040.40, 35.100.05

**Standardite reprodutseerimise ja levitamise õigus kuulub Eesti Standardimis- ja Akrediteerimiskeskusele**

Andmete paljundamine, taastekitamine, kopeerimine, salvestamine elektroonsesse süsteemi või edastamine ükskõik millises vormis või millisel teel ilma Eesti Standardimis- ja Akrediteerimiskeskuse kirjaliku loata on keelatud.

Kui Teil on küsimusi standardite autoriõiguse kaitse kohta, võtke palun ühendust Eesti Standardimis- ja Akrediteerimiskeskusega: Koduleht [www.evs.ee](http://www.evs.ee); telefon 605 5050; e-post [info@evs.ee](mailto:info@evs.ee)

**The right to reproduce and distribute standards belongs to the Estonian Centre for Standardisation and Accreditation**

No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, without a written permission from the Estonian Centre for Standardisation and Accreditation.

If you have any questions about standards copyright protection, please contact the Estonian Centre for Standardisation and Accreditation: Homepage [www.evs.ee](http://www.evs.ee); phone +372 605 5050; e-mail [info@evs.ee](mailto:info@evs.ee)

## English Version

**Industrial communication networks - High availability automation  
networks - Part 3: Parallel Redundancy Protocol (PRP) and  
High-availability Seamless Redundancy (HSR)  
(IEC 62439-3:2021)**

Réseaux de communication industriels - Réseaux de haute  
disponibilité pour l'automatisation - Partie 3: Protocole de  
redondance en parallèle (PRP) et redondance transparente  
de haute disponibilité (HSR)  
(IEC 62439-3:2021)

Industrielle Kommunikationsnetze - Hochverfügbare  
Automatisierungsnetze - Teil 3: Parallelredundanz-Protokoll  
(PRP) und nahtloser Hochverfügbarkeits-Ring (HSR)  
(IEC 62439-3:2021)

This European Standard was approved by CENELEC on 2022-01-19. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.



European Committee for Electrotechnical Standardization  
Comité Européen de Normalisation Electrotechnique  
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

## European foreword

The text of document 65C/1120/FDIS, future edition 4 of IEC 62439-3, prepared by SC 65C "Industrial networks" of IEC/TC 65 "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 62439-3:2022.

The following dates are fixed:

- latest date by which the document has to be implemented at national (dop) 2022-10-19 level by publication of an identical national standard or by endorsement
- latest date by which the national standards conflicting with the (dow) 2025-01-19 document have to be withdrawn

This document supersedes EN IEC 62439-3:2018 and all of its amendments and corrigenda (if any).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

Any feedback and questions on this document should be directed to the users' national committee. A complete listing of these bodies can be found on the CENELEC website.

## Endorsement notice

The text of the International Standard IEC 62439-3:2021 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 61784-1	NOTE	Harmonized as EN IEC 61784-1
IEC 61784-2	NOTE	Harmonized as EN IEC 61784-2
IEC 61850 (series)	NOTE	Harmonized as EN 61850 (series)
IEC 61850-8-1	NOTE	Harmonized as EN 61850-8-1
IEC 61850-9-2	NOTE	Harmonized as EN 61850-9-2
IEC 62439-2	NOTE	Harmonized as EN 62439-2
IEC 62439-3:2016	NOTE	Harmonized as EN IEC 62439-3:2018 (not modified)
IEC 62439-4	NOTE	Harmonized as EN 62439-4
IEC 62439-6	NOTE	Harmonized as EN 62439-6
IEC 62439-7	NOTE	Harmonized as EN 62439-7

## Annex ZA (normative)

### Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: [www.cenelec.eu](http://www.cenelec.eu).

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60050-192	-	International Electrotechnical Vocabulary (IEV) - Part 192: Dependability	-	-
IEC 61588	2021	Precision Clock Synchronization Protocol for Networked Measurement and Control Systems	-	-
IEC/TR 61850-90-4	2020	Communication networks and systems for power utility automation - Part 90-4: Network engineering guidelines	-	-
IEC 62439-1	-	Industrial communication networks - High availability automation networks - Part 1: General concepts and calculation methods	EN 62439-1	-
ISO/IEC/IEEE 8802-3	2021	Telecommunications and exchange between information technology systems - Requirements for local and metropolitan area networks - Part 3: Standard for Ethernet	-	-
IEC/IEEE 61850-9-3	2016	Communication networks and systems for power utility automation - Part 9-3: Precision time protocol profile for power utility automation	-	-
IEEE 802.1Q	2018	IEEE Standard for Local and metropolitan area networks – Bridges and Bridged Network	-	-
IETF RFC 768	-	User Datagram Protocol (UDP) [online]. August 1980.	-	-
IETF RFC 791	-	Internet Protocol (IP) [online]. September 1981.	-	-
IETF RFC 792	-	Internet Control Message Protocol [online]. September 1981.	-	-

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IETF RFC 793	-	Transmission Control Protocol [online]. September 1981.	-	-
IETF RFC 826	-	Ethernet Address Resolution Protocol [online]. November 1982.	-	-
IETF RFC 2578	-	Structure of Management Information Version 2 (SMIv2) [online]. April 1999.	-	-
IETF RFC 3418	-	Structure of Management Information Version 2 (SMIv2) [online]. December 2002.	-	-

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE



**Industrial communication networks – High availability automation networks –  
Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless  
Redundancy (HSR)**

**Réseaux de communication industriels – Réseaux de haute disponibilité pour  
l'automatisation –**

**Partie 3: Protocole de redondance en parallèle (PRP) et redondance transparente  
de haute disponibilité (HSR)**



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2021 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

#### IEC publications search - [webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

#### IEC Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [sales@iec.ch](mailto:sales@iec.ch).

#### IEC online collection - [oc.iec.ch](http://oc.iec.ch)

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 18 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

### A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

### A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

#### Recherche de publications IEC -

[webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

#### Service Clients - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: [sales@iec.ch](mailto:sales@iec.ch).

#### IEC online collection - [oc.iec.ch](http://oc.iec.ch)

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 000 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.



# INTERNATIONAL STANDARD

## NORME INTERNATIONALE



**Industrial communication networks – High availability automation networks –  
Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless  
Redundancy (HSR)**

**Réseaux de communication industriels – Réseaux de haute disponibilité pour  
l'automatisation –  
Partie 3: Protocole de redondance en parallèle (PRP) et redondance  
transparente de haute disponibilité (HSR)**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

ICS 25.040.40; 35.100.05

ISBN 978-2-8322-1059-5

**Warning! Make sure that you obtained this publication from an authorized distributor.  
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

# CONTENTS

FOREWORD.....	10
INTRODUCTION.....	13
0.1 General.....	13
0.2 Patent declaration.....	13
1 Scope.....	15
1.1 General.....	15
1.2 Code component distribution.....	15
2 Normative references .....	16
3 Terms, definitions, abbreviated terms, and conventions.....	17
3.1 Terms and definitions.....	17
3.2 Abbreviated terms.....	19
3.3 Conventions.....	20
4 Parallel Redundancy Protocol (PRP) .....	20
4.1 PRP principle of operation .....	20
4.1.1 PRP network topology .....	20
4.1.2 PRP LANs with linear or bus topology.....	22
4.1.3 PRP LANs with ring topology .....	22
4.1.4 DANP node structure .....	23
4.1.5 PRP attachment of singly attached nodes.....	24
4.1.6 Compatibility between singly and doubly attached nodes.....	25
4.1.7 Network management .....	25
4.1.8 Implication on application .....	25
4.1.9 Transition to a single-thread network.....	26
4.1.10 Duplicate handling .....	26
4.1.11 Network supervision .....	31
4.1.12 Redundancy management interface.....	31
4.2 PRP protocol specifications .....	32
4.2.1 Installation, configuration and repair guidelines .....	32
4.2.2 Unicast MAC addresses.....	32
4.2.3 Multicast MAC addresses .....	32
4.2.4 IP addresses .....	33
4.2.5 Node specifications .....	33
4.2.6 Duplicate Accept mode (testing only).....	33
4.2.7 Duplicate Discard mode.....	34
4.3 PRP_Supervision frame .....	38
4.3.1 PRP_Supervision frame format.....	38
4.3.2 PRP_Supervision frame contents.....	40
4.3.3 PRP_Supervision frame for RedBox .....	41
4.3.4 Bridging node (deprecated) .....	41
4.4 Constants .....	42
4.5 PRP layer management entity (LME) .....	42
5 High-availability Seamless Redundancy (HSR) .....	42
5.1 HSR objectives .....	42
5.2 HSR principle of operation .....	43
5.2.1 Basic operation with a ring topology .....	43
5.2.2 HSR connection to other networks .....	45

5.2.3	DANH node structure .....	57
5.2.4	RedBox structure .....	58
5.3	HSR protocol specifications .....	59
5.3.1	HSR layout .....	59
5.3.2	HSR operation .....	59
5.3.3	DANH sending from its link layer interface .....	61
5.3.4	DANH receiving from an HSR port .....	62
5.3.5	DANH forwarding rules .....	62
5.3.6	HSR Class of Service .....	64
5.3.7	HSR clock synchronization .....	64
5.3.8	Deterministic transmission delay and jitter .....	64
5.4	HSR RedBox specifications .....	64
5.4.1	RedBox properties .....	64
5.4.2	RedBox receiving from port C (interlink) .....	65
5.4.3	RedBox receiving from port A or port B (HSR ring) .....	67
5.4.4	RedBox receiving from its link layer interface (local) .....	69
5.4.5	Redbox ProxyNodeTable handling .....	69
5.4.6	RedBox CoS .....	69
5.4.7	RedBox clock synchronization .....	69
5.4.8	RedBox medium access .....	69
5.5	QuadBox specification .....	70
5.6	Duplicate Discard method .....	70
5.7	Frame format for HSR .....	70
5.7.1	Frame format for all frames .....	70
5.7.2	HSR_Supervision frame .....	71
5.8	HSR constants .....	74
5.9	HSR layer management entity (LME) .....	75
6	Protocol Implementation Conformance Statement (PICS) .....	77
7	PRP/HSR Management Information Base (MIB) .....	79
Annex A	(normative) Synchronization of clocks over redundant paths .....	94
A.1	Overview .....	94
A.2	PRP mapping to PTP .....	94
A.2.1	Particular operation of PRP for PTP messages .....	94
A.2.2	Scenarios and device roles .....	96
A.2.3	Attachment to redundant LANs by a BC .....	98
A.2.4	Attachment to redundant LANs by doubly attached clocks .....	98
A.2.5	Specifications of DANP as DAC .....	102
A.2.6	PRP-SAN RedBoxes for PTP .....	103
A.3	HSR Mapping to PTP .....	123
A.3.1	HSR messages and other messages .....	123
A.3.2	HSR operation with PTP messages .....	123
A.3.3	HSR with redundant master clocks .....	125
A.3.4	HSR timing diagram for PTP messages .....	126
A.3.5	HSR nodes specifications .....	127
A.4	HSR RedBoxes for PTP .....	129
A.4.1	HSR-SAN RedBox .....	129
A.4.2	HSR-PRP RedBox connection by BC .....	130
A.4.3	HSR-PRP RedBox connection by TC .....	132
A.4.4	HSR to HSR connection by QuadBoxes .....	134

A.5	Doubly attached clock specification.....	135
A.5.1	State machine .....	135
A.5.2	Supervision of the port.....	138
A.5.3	BMCA for paired ports .....	139
A.5.4	Selection of the port state .....	140
A.6	PTP datasets for high availability .....	140
A.6.1	General .....	140
A.6.2	Data types .....	140
A.6.3	Datasets for OC or BC .....	141
A.6.4	Datasets for TCs.....	149
Annex B (normative)	PTP profile for Power Utility Automation (PUP) – Redundant clock attachment.....	150
B.1	Application domain.....	150
B.2	PTP profile specification .....	150
B.3	Specifications .....	150
B.4	Redundant clock attachment .....	150
Annex C (normative)	PTP industry profiles for high-availability automation networks .....	151
C.1	Application domain.....	151
C.2	PTP profile specification .....	151
C.3	Clock types .....	152
C.4	Protocol specification common.....	152
C.4.1	Base protocol .....	152
C.4.2	Version control .....	152
C.4.3	Time scale .....	153
C.4.4	BMCA.....	153
C.4.5	Time correction mechanism .....	153
C.4.6	Management.....	153
C.4.7	1 PPS support .....	153
C.4.8	Leap second transition.....	153
C.4.9	Use of port number .....	153
C.4.10	Time distribution security .....	154
C.5	Protocol specification for L3E2E industry profile .....	154
C.5.1	Base protocol .....	154
C.5.2	Multicast address.....	154
C.5.3	Delay calculation mechanism.....	154
C.5.4	Sync message padding.....	154
C.6	Protocol specification for L2P2P industry profile .....	155
C.6.1	Base protocol .....	155
C.6.2	Delay measurement mechanism .....	155
C.6.3	Consideration of media converters.....	155
C.7	Common timing requirements for L2P2P and L3E2E .....	155
C.7.1	Measurement conditions .....	155
C.7.2	Network time inaccuracy .....	155
C.7.3	Response to time step changes .....	156
C.7.4	Requirements for GCs .....	156
C.7.5	Requirements for TCs.....	158
C.7.6	Requirements for BCs.....	158
C.8	Requirements for media converters.....	161
C.9	Requirements for links .....	161

C.10	Network engineering .....	161
C.11	Default settings .....	162
C.12	Handling of doubly attached clocks .....	163
C.13	Protocol Implementation Conformance Statement (PICS) for PTP .....	164
C.13.1	PICS conventions .....	164
C.13.2	PICS for PTP .....	164
C.14	Recommendations for time representation .....	166
C.14.1	Usage of flags in TimePropertyDS .....	166
C.14.2	UTC leap second transition .....	167
C.14.3	ALTERNATE_TIME_OFFSET_INDICATOR_TLV .....	168
Annex D (informative)	Precision Time Protocol tutorial for the PTP Industrial profile .....	172
D.1	Objective .....	172
D.2	Precision and accuracy .....	172
D.3	PTP clock types .....	173
D.4	PTP main options .....	175
D.5	Layer 2 and layer 3 communication .....	176
D.6	1-step and 2-step correction .....	176
D.6.1	Time correction in TCs .....	176
D.6.2	2-step to 1-step translation .....	177
D.7	End-to-End link delay measurement .....	179
D.7.1	General method .....	179
D.7.2	End-to-end link delay measurement with 1-step clock correction .....	179
D.7.3	End-to-end link delay measurement with 2-step clock correction .....	180
D.7.4	End-to-end link delay calculation by Delay_Req – Delay_Resp .....	181
D.7.5	Consideration of media converters in end-to-end delay calculation .....	181
D.8	Peer-to-peer link delay calculation .....	182
D.8.1	Peer-to-peer link delay calculation with 1-step correction .....	182
D.8.2	Peer-to-peer link delay calculation with 2-step correction .....	183
D.8.3	Consideration of media converters in peer delay calculation .....	184
Annex E (normative)	Management Information base for singly and doubly attached clocks .....	186
Annex F (normative)	Conformance testing for PRP and HSR and handling of redundancy in PIP and PUP .....	214
F.1	General .....	214
F.2	PRP conformance test .....	214
F.2.1	PRP test set-up .....	214
F.2.2	PRP test components .....	215
F.2.3	Test for documentation and labelling .....	215
F.2.4	Test for (unicast) IP addresses .....	216
F.2.5	Test for configuration .....	216
F.2.6	Test of DANP .....	217
F.2.7	Test of PRP Redboxes .....	221
F.2.8	Test for Management .....	223
F.2.9	Test of DANP or RedBox for processing of PTP frames .....	225
F.3	HSR conformance test .....	230
F.3.1	HSR test set-up .....	230
F.3.2	HSR test components .....	231
F.3.3	Test for HSR documentation and labelling .....	231
F.3.4	Test of DANH or RedBox for IP addresses .....	232

F.3.5	Test of DANH for configuration .....	232
F.3.6	Test of DANH .....	233
F.3.7	Test of HSR RedBoxes .....	237
F.3.8	Test of DANH or RedBox for receive/transmit counters .....	239
F.3.9	Test of DANH or RedBox for processing of PTP frames in L2P2P .....	240
Bibliography	.....	244
Figure 1	– PRP example of general duplicated network .....	21
Figure 2	– PRP example of duplicated network in bus topology .....	22
Figure 3	– PRP example of redundant ring with SANs and DANPs .....	23
Figure 4	– PRP with two DANPs communicating .....	24
Figure 5	– PRP RedBox, transition from single to double LAN .....	26
Figure 6	– PRP frame closed by an RCT .....	27
Figure 7	– PRP VLAN-tagged frame closed by an RCT .....	28
Figure 8	– PRP padded frame closed by an RCT .....	28
Figure 9	– Duplicate Discard algorithm boundaries .....	30
Figure 10	– HSR example of ring traffic for multicast frames .....	43
Figure 11	– HSR example of ring traffic for unicast frames .....	44
Figure 12	– HSR example of coupling two redundant PRP LANs to a ring (unicast) .....	47
Figure 13	– HSR example of coupling from a ring node to PRP LANs (multicast) .....	49
Figure 14	– HSR example of coupling from a ring to two PRP LANs (multicast) .....	50
Figure 15	– HSR example of coupling three rings to one PRP LAN .....	51
Figure 16	– HSR example of peer coupling of two rings .....	52
Figure 17	– HSR example of connected rings .....	53
Figure 18	– HSR example of meshed topology .....	54
Figure 19	– HSR example of topology using two independent networks .....	55
Figure 20	– HSR example of coupling an RSTP LAN to HSR by two bridges .....	56
Figure 21	– HSR structure of a DANH .....	57
Figure 22	– HSR structure of a RedBox .....	58
Figure 23	– HSR frame without a VLAN tag .....	70
Figure 24	– HSR frame with VLAN tag .....	71
Figure 25	– HSR node with management counters .....	76
Figure 26	– HSR RedBox with management counters .....	77
Figure A.1	– Connection of a DAC master to a DAC slave over PRP .....	95
Figure A.2	– Elements of PRP time distribution networks .....	97
Figure A.3	– Doubly Attached Clock as BC (OC3A is best master) .....	98
Figure A.4	– Doubly Attached Clocks OC1 and OC2 .....	100
Figure A.5	– Doubly attached clocks when OC1 has the same identity on both LANs .....	102
Figure A.6	– PRP RedBox as TWBCs .....	104
Figure A.7	– RedBox DABC clock model .....	105
Figure A.8	– PRP RedBoxes as DABC with E2E – message flow .....	107
Figure A.9	– PRP RedBoxes as DABC with E2E – timing .....	108
Figure A.10	– PRP RedBoxes as DABC with P2P on PRP – message flow .....	109
Figure A.11	– PRP RedBoxes as DABC with P2P on PRP – timing .....	110

Figure A.12 – PRP-SAN RedBox as SLTC with E2E – message flow .....	112
Figure A.13 – PRP RedBox as SLTC with E2E – timing .....	114
Figure A.14 – PRP RedBox as SLTC with P2P – message flow.....	115
Figure A.15 – PRP RedBox as SLTC with P2P – timing diagram .....	116
Figure A.16 – PRP RedBox as DATC with E2E – message flow .....	119
Figure A.17 – PRP RedBox as DATC with E2E – timing .....	120
Figure A.18 – PRP RedBox as DATC with P2P – message flow .....	121
Figure A.19 – PRP RedBox as DATC with P2P – timing .....	122
Figure A.20 – HSR with two GCs (GC1 is grandmaster, GC2 is back-up) .....	125
Figure A.21 – PTP messages sent and received by an HSR node (1-step).....	126
Figure A.22 – PTP messages sent and received by an HSR node (2-step).....	127
Figure A.23 – Attachment of a GC to an HSR ring through a RedBox as TC and BC .....	129
Figure A.24 – PRP to HSR coupling by BCs.....	131
Figure A.25 – PRP to HSR coupling by DATC and SLTC .....	133
Figure A.26 – HSR coupling to two PRP and one HSR network.....	134
Figure A.27 – Port states including transitions for redundant operation .....	136
Figure A.28 – BMCA for redundant masters .....	139
Figure C.1 – Response to a time step .....	156
Figure C.2 – States of a BC .....	159
Figure D.1 – Time error as a probability distribution function.....	172
Figure D.2 – PTP principle with GC, TC and OC .....	174
Figure D.3 – PTP elements .....	175
Figure D.4 – Delays and time-stamping logic in TCs .....	176
Figure D.5 – 1-step and 2-step correction of a Sync message (peer-to-peer) .....	177
Figure D.6 – Translation from 2-step to 1-step correction in TCs.....	178
Figure D.7 – Translation from 2-step to 1-step correction – message view .....	179
Figure D.8 – End-to-end link delay measurement with 1-step correction .....	180
Figure D.9 – End-to-end delay measurement with 2-step correction .....	181
Figure D.10 – Peer-to-peer link delay measurement with 1-step correction .....	182
Figure D.11 – Peer-to-peer link delay measurement with 2-step correction .....	183
Figure D.12 – Peer delay measurement and Sync message delay with media converter .....	185
Figure F.1 – Test set-up for PRP .....	215
Figure F.2 – Test set-up for PRP and PTP with L2P2P .....	225
Figure F.3 – Test set-up for HSR (without PTP) .....	231
Figure F.4 – Test set-up for HSR with L2P2P.....	240
Table 1 – Duplicate discard cases .....	30
Table 2 – Monitoring data set.....	34
Table 3 – NodesTable attributes .....	35
Table 4 – PRP_Supervision frame with no VLAN tag.....	39
Table 5 – PRP_Supervision frame with (optional) VLAN tag.....	40
Table 6 – PRP_Supervision frame contents .....	41
Table 7 – PRP_Supervision TLV for Redbox .....	41

Table 8 – PRP constants .....	42
Table 9 – HSR_Supervision frame with no VLAN tag .....	72
Table 10 – HSR_Supervision frame with optional VLAN tag .....	73
Table 11 – HSR Constants.....	75
Table 12 – PICS .....	78
Table A.1 – States .....	137
Table A.2 – Transitions .....	138
Table A.3 – Variables .....	138
Table C.1 – ClockClass.....	157
Table C.2 – PTP attributes.....	163
Table C.3 – PICS for clocks .....	164
Table C.4 – Transitions with an inserted leap second (UTC binary and C37.118).....	168
Table C.5 – Transitions with a removed leap second (UTC binary and C37.118).....	168
Table C.6 – ATOI transition to Pacific Summer Time (spring).....	170
Table C.7 – ATOI transitions to Pacific Standard Time (autumn).....	170
Table C.8 – Transitions with an inserted leap second in Pacific Standard Time.....	171
Table C.9 – Transitions with a removed leap second in Pacific Standard Time.....	171
Table F.1 – Test for PRP documentation and labelling .....	216
Table F.2 – Test for (unicast) IP addresses.....	216
Table F.3 – Test for PRP configuration (Table 8) .....	217
Table F.4 – Test for PRP supervision frames (Table 4 and Table 5).....	217
Table F.5 – Test for PRP tagging (4.1.10.2, 4.2.7.3) .....	219
Table F.6 – Test of a DANP without a NodesTable.....	220
Table F.7 – Test of a DANP with a NodesTable .....	220
Table F.8 – Test for discard over different ports.....	221
Table F.9 – Test for PRP supervision frames (Table 4 and Table 5).....	222
Table F.10 – Test of RedBox for ProxyNodeTable.....	222
Table F.11 – Test of RedBox for forwarding .....	223
Table F.12 – Test for DANP receive/transmit counters .....	224
Table F.13 – Test procedure for processing of PTP frames .....	227
Table F.14 – Test for processing of PTP frames .....	228
Table F.15 – Test for processing of PTP frames .....	229
Table F.16 – Test procedure for processing of PTP frames .....	230
Table F.17 – Test for HSR documentation.....	232
Table F.18 – Test for IP addresses .....	232
Table F.19 – Test procedure for HSR configuration (Table 11).....	233
Table F.20 – Test for HSR supervision frames (Table 9 and Table 10).....	234
Table F.21 – Test for HSR tagging .....	235
Table F.22 – Test of DANH for HSR Mode H multicast.....	236
Table F.23 – Test of DANH for HSR Mode H unicast.....	236
Table F.24 – Test of DANH for other modes than Mode H.....	237
Table F.25 – Test of RedBox for HSR supervision frames (Table 9 and Table 10).....	237
Table F.26 – Test of RedBox for ProxyNodeTable.....	238



Table F.27 – Test of RedBox for Mode H Unicast.....	238
Table F.28 – Test of DANH or RedBox for receive/transmit counters .....	239
Table F.29 – Test for processing of PTP frames (slave).....	241
Table F.30 – Test for processing of PTP frames (master) .....	242

This document is a preview generated by EVS

# INTERNATIONAL ELECTROTECHNICAL COMMISSION

## INDUSTRIAL COMMUNICATION NETWORKS – HIGH AVAILABILITY AUTOMATION NETWORKS –

### Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR)

#### FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 62439-3 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2016. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) References to Precision Time Protocol (PTP) IEC 61588:2021 replace references to IEC 61588:2009, unless the previous version is explicitly referenced (Clause 2);
- b) References to IEC 61850-90-4:2020 replace references to IEC 61850-90-4:2013 with corresponding changes in the Logical Nodes (Clause 2);

- c) Terms and abbreviations are aligned with the next edition of IEC/IEEE 61850-9-3 (currently under preparation) (Clause 3);
- d) RSTP support in HSR is specified (5.2.2.10);
- e) RedBoxes and QuadBoxes specifications are extended to TCs (5.5);
- f) Network management (MIB) for PRP and HSR is available as a "Code Component", machine-readable separate document (Clause 7);
- g) PTP over PRP specifies a unified operation of DATC and SLTC RedBoxes (A.2.6.4);
- h) PTP over HSR specifies the operation of RedBoxes for TCs (A.4.3);
- i) PTP datasets are aligned with IEC 61588:2021 (Clause A.6);
- j) PTP industry profile is extended:
  - Sync messages padding to support media converters (C.5.4);
  - ClockClass definition aligned with IEC 61588:2021 option a) (C.7.4.3);
  - TC operation over different domains (C.7.5.3);
  - BCs behaviour in holdover and recovery (C.7.6.2);
  - PICS entries renamed and extended (C.13.2);
  - Flags semantics in TimePropertyDS actualized (C.14.1);
  - UTC events handling during a leap second specified (C.14.2);
  - UTC leap second time representation aligned with IEEE C37.118.2 (C.14.2.2);
  - Daylight saving time and leap second events recommended in the ALTERNATE\_TIME\_OFFSET\_INDICATOR TLV (C.14.3.2);
- k) Tutorial extended to explain the media converter issue (D.8.3);
- l) PTP network management MIB (Annex E) is available as a "Code Component", machine-readable separate document and considers IEC 61588:2021 objects;
- m) Conformance testing for PRP, HSR and the doubly attached PTP clocks (Annex F) has been added.
- n) Interoperability issues with previous editions of this International Standard are mentioned in a note at the end of the corresponding clause.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
65C/1120/FDIS	65C/1139/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at [www.iec.ch/members\\_experts/refdocs](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/standardsdev/publications](http://www.iec.ch/standardsdev/publications).

This International Standard is to be read in conjunction with IEC 62439-1.

A list of all parts in the IEC 62439 series, published under the general title *Industrial communication networks – High availability automation networks*, can be found on the IEC website.

This IEC standard includes Code Components, i.e., components that are intended to be directly processed by a computer. Such content is any text found between the markers <CODE BEGINS> and <CODE ENDS>, or otherwise is clearly labeled in this standard as a Code Component.

The purchase of this IEC standard carries a copyright license for the purchaser to sell software containing Code Components from this standard directly to end users and to end users via distributors, subject to IEC software licensing conditions, which can be found at: <http://www.iec.ch/CCv1>.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under [webstore.iec.ch](http://webstore.iec.ch) in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

**IMPORTANT – The "colour inside" logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.**

## INTRODUCTION

### 0.1 General

This document belongs to the IEC 62439 series “*Industrial communication networks – High availability automation networks*”. It was developed jointly with IEC TC57 WG10 as the redundancy method for demanding substation automation networks operating on layer 2 networks, in accordance with IEC 61850-8-1 and IEC 61850-9-2, and extended to encompass the needs of CPF 2 of IEC 61784-1 and IEC 61784-2 for layer 3 networks.

This document specifies two related redundancy protocols that, in the event of failure of any network element, provide seamless switchover with zero recovery time:

- PRP (Parallel Redundancy Protocol), which allows attaching nodes to two separate networks while allowing attachment of nodes to one network only; and
- HSR (High-availability Seamless Redundancy), which allows threading two-port nodes in a ring or multi-port nodes in a meshed network.

This document applies the seamless redundancy principle to clocks compliant with the Precision Time Protocol (PTP).

This document specifies a PTP Industry profile (PIP) that offers the performance needed to achieve sub-microsecond time accuracy. This profile can be applied to any industrial communication network based on Ethernet. Two variants of PIP are specified:

- L3E2E (Layer 3, end-to-end) for clocks operating on layer 3 networks with end-to-end path delay measurement such as CP 2/2 of IEC 61784-1 and IEC 61784-2; and
- L2P2P (Layer 2, peer-to-peer) for clocks operating on layer 2 with peer-to-peer link delay measurement (P2P).

Based on L2P2P, IEC TC57 WG10 and the IEEE PSRC jointly specified the Power Utility Profile (PUP) and copied it to IEC/IEEE 61850-9-3. IEC and IEEE agreed to keep the contents of this document and IEC/IEEE 61850-9-3 aligned, under the umbrella of the Dual Logo Maintenance Team (DLMT) hosted by IEEE PSCC P20.

The specifications of PRP and HSR present no backward compatibility issues as the changes are compatible extensions of the protocol. The minor version of these protocols is kept at value “1”.

The specifications of the clock profile PIP are based on IEC 61588:2021, which presents some differences compared with IEC 61588:2009. The minorVersionPTP has been increased to 1.

This document includes guidelines for conformance testing, applicable to PRP, HSR and to the PIP and PUP clock synchronization profiles.

### 0.2 Patent declaration

The International Electrotechnical Commission (IEC) draws attention to the fact that it is claimed that compliance with this standard may involve the use of a patent. IEC takes no position concerning the evidence, validity, and scope of this patent right.

The holder of this patent right has assured IEC that s/he is willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with IEC. Information may be obtained from the patent database available at <http://patents.iec.ch>.

Attention is drawn to the possibility that some of the elements of this standard may be the subject of patent rights other than those in the patent database. IEC shall not be held responsible for identifying any or all such patent rights.

This document is a preview generated by EVS

## **INDUSTRIAL COMMUNICATION NETWORKS – HIGH AVAILABILITY AUTOMATION NETWORKS –**

### **Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR)**

## **1 Scope**

### **1.1 General**

The IEC 62439 series is applicable to high-availability automation networks based on the Ethernet technology.

This document:

- specifies PRP and HSR as two related redundancy protocols designed to provide seamless recovery in case of single failure of an inter-bridge link or bridge in the network, which are based on the same scheme: parallel transmission of duplicated information;
- specifies the operation of the precision time protocol (PTP) in networks that implement the two redundancy protocols (Annex A);
- specifies PTP profiles with performance suitable for power utility automation (Annex B) and industrial automation (Annex C);
- includes for better understanding a tutorial (Annex D) on the PTP features effectively used in high-availability automation networks;
- includes a management information base for PTP (Annex E);
- defines a conformance test suite for the above protocols (Annex F).

### **1.2 Code component distribution**

This document is associated with Code components. Each Code Component is a ZIP package containing at least the electronic representation of the Code Component itself and a file describing the content of the package (IECManifest.xml).

The IECManifest contains different sections giving information on:

- the copyright notice;
- the identification of the code component;
- the publication related to the code component;
- the list of the electronic files which compose the code component;
- an optional list of history files to track changes during the evolution process of the code component.

The Code Components associated with this IEC standard are a set of SNMP MIBs. The Code Component IEC-62439-3-MIB.mib is a file containing the MIBs for PRP/HSR and PTP\_SNMP. It is available in a full version, which contains the MIBs defined in this document with the documentation associated and access is restricted to purchaser of this document.

The Code Components are freely accessible on the IEC website for download at: [https://www.iec.ch/sc65c/supportingdocuments/IEC\\_62439-3.MIB.{VersionStateInfo}.full.zip](https://www.iec.ch/sc65c/supportingdocuments/IEC_62439-3.MIB.{VersionStateInfo}.full.zip) but the usage remains under the licensing conditions.