

EIA STANDARD

ANSI/EIA-61078-2018 Approved: January 17, 2018

Reality Block Diagrams

EIA-61078

(IEC 61078:2016, IDT)

January 2018



Electronic Components Industry Association

NOTICE

EIA Engineering Standards and Publications are designed to serve the public interest through eliminating misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for his particular need. Existence of such Standards and Publications shall not in any respect preclude any member or nonmember of ECIA from manufacturing or selling products not conforming to such Standards and Publications, nor shall the existence of such Standards and Publications preclude their voluntary use by those other than ECIA members, whether the standard is to be used either domestically or internationally.

Standards and Publications are adopted by ECIA in accordance with the American National Standards Institute (ANSI) patent policy. By such action, ECIA does not assume any liability to any patent owner, nor does it assume any obligation whatever to parties adopting the Standard or Publication.

This EIA Standard is identical (IDT) with the International Standard IEC Publication 61078:2016 Edition 3: *Reliability Block Diagrams*.

This document is the EIA Standard EIA-61078-2018 Edition 1: *Reliability Block Diagrams*.

The text, figures and tables of IEC 61078:2018 are used in this Standard with the consent of the IEC and the American National Standards Institute (ANSI). The IEC copyrighted material has been reproduced with permission from ANSI. The IEC Foreword and Introduction are not part of the requirements of this standard but are included for information purposes only.

This Standard does not purport to address all safety problems associated with its use or all applicable regulatory requirements. It is the responsibility of the user of this Standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations before its use.

(From Standards Proposal No. 5398, formulated under the cognizance of the Committee for Dependability Standards.

Published by

©Electronic Components Industry Association 2018
Engineering Department
2214 Rock Hill Road, Suite 265
Herndon, VA 20170

PLEASE! DON'T VIOLATE THE LAW!

This document is copyrighted by the ECIA and may not be reproduced without permission.

Organizations may obtain permission to reproduce a limited number of copies through entering into a license agreement. For information, contact:

IHS Markit
15 Inverness Way East
Englewood, CO 80112-5704 or call
USA and Canada (1-877-413-5186), International (303-397-7956)

CONTENTS

F(OREWO)RD	Vİİ
IN	TRODU	JCTION	ix
1		De	
2		native references	
3		ns and definitions	
4	•	bols and abbreviated terms	
5		minary considerations, main assumptions, and limitations	
	5.1	General considerations	
	5.2	Pre-requisite/main assumptions	
	5.3	Limitations	
6	Estab	blishment of system success/failed states	14
	6.1	General considerations	14
	6.2	Detailed considerations	14
	6.2.1	System operation	14
	6.2.2	2 Environmental conditions	15
	6.2.3	, ,	
7	Elem	nentary models	15
	7.1	Developing the model	15
	7.2	Series structures	15
	7.3	Parallel structures	
	7.4	Mix of series and parallel structures	
	7.5	Other structures	17
	7.5.1		
	7.5.2		
	7.5.3		
	7.6	Large RBDs and use of transfer gates	
8	Quali	itative analysis: minimal tie sets and minimal cut sets	
	8.1	Electrical analogy	20
	8.2	Series-parallel representation with minimal success path and cut sets	22
	8.3	Qualitative analysis from minimal cut sets	
9	Quan	ntitative analysis: blocks with constant probability of failure/success	23
	9.1	Series structures	23
	9.2	Parallel structures	24
	9.3	Mix of series and parallel structures	24
	9.4	m/n architectures (identical items)	
10) Quan	ntitative analysis: blocks with time dependent probabilities of failure/success	25
	10.1	General	25
	10.2	Non-repaired blocks	26
	10.2.	.1 General	26
	10.2.	.2 Simple non-repaired block	26
	10.2.	.3 Non-repaired composite blocks	26
	10.2.	.4 RBDs with non-repaired blocks	27
	10.3	Repaired blocks	27
	10.3.	.1 Availability calculations	27
	10.3.	.2 Average availability calculations	29

	10.3.	.3 Reliability calculations	31
	10.3.	.4 Frequency calculations	33
11	Boole	ean techniques for quantitative analysis of large models	33
	11.1	General	33
	11.2	Method of RBD reduction	33
	11.3	Use of total probability theorem	34
	11.4	Use of Boolean truth tables	35
	11.5	Use of Karnaugh maps	37
	11.6	Use of the Shannon decomposition and binary decision diagrams	38
	11.7	Use of Sylvester-Poincaré formula	39
	11.8	Examples of RBD application	41
	11.8.	.1 Models with repeated blocks	41
	11.8.	, , , , , , , , , , , , , , , , , , , ,	
12	Exter	nsion of reliability block diagram techniques	44
	12.1	Non-coherent reliability block diagrams	44
	12.2	Dynamic reliability block diagrams	46
	12.2.	.1 General	46
	12.2.		
	12.2.	3 Systemic dynamic interactions	48
	12.2.	4 Graphical representations of dynamic interactions	49
	12.2.		
Anr	nex A ((informative) Summary of formulae	53
Anr	nex B ((informative) Boolean algebra methods	57
	B.1	Introductory remarks	57
	B.2	Notation	57
	B.3	Tie sets (success paths) and cut sets (failure paths) analysis	58
	B.3.1	Notion of cut and tie sets	58
	B.3.2	Series-parallel representation using minimal tie and cut sets	59
	B.3.3	B Identification of minimal cuts and tie sets	60
	B.4	Principles of calculations	61
	B.4.1	Series structures	61
	B.4.2		
	B.4.3	Mix of series and parallel structures	63
	B.4.4	(
	B.5	Use of Sylvester Poincaré formula for large RBDs and repeated blocks	
	B.5.1		
	B.5.2		
	B.5.3	•	
	B.6	Method for disjointing Boolean expressions	
	B.6.1	9 9	
	B.6.2		
	B.6.3	, 31	
	B.6.4	, , , , , , , , , , , , , , , , , , , ,	
	B.6.5		
	B.7	Binary decision diagrams	
	B.7.1		
	B.7.2	•	
	B.7.3	B Probabilistic calculations with BDDs	76

B.7.4	Key remarks about the use of BDDs	77
Annex C (informative) Time dependent probabilities and RBD driven Markov	
	, , , , , , , , , , , , , , , , , , , ,	78
C.1	General	78
C.2	Principle for calculation of time dependent availabilities	78
	Non-repaired blocks	
C.3.1	General	79
C.3.2	Simple non-repaired blocks	79
C.3.3	·	
C.4	RBD driven Markov processes	
	Average and asymptotic (steady state) availability calculations	
	Frequency calculations	
	Reliability calculations	
	informative) Importance factors	
,	General	
	Vesely-Fussell importance factor	
	Birnbaum importance factor or marginal importance factor	
	Lambert importance factor or critical importance factor	
	Diagnostic importance factor	
	Risk achievement worth	
	Risk reduction worth	
	Differential importance measure	
	Remarks about importance factors	
	nformative) RBD driven Petri nets	
•	·	
	General	
	Example of sub-PN to be used within RBD driven PN models	
	Evaluation of the DRBD state	
	Availability, reliability, frequency and MTTF calculations	
,	nformative) Numerical examples and curves	
	General	
	Typical series RBD structure	
F.2.1	Non-repaired blocks	
F.2.2	•	
	Typical parallel RBD structure	
F.3.1	Non-repaired blocks	
F.3.2	Repaired blocks	
	Complex RBD structures	
F.4.1	Non series-parallel RBD structure	
F.4.2	Convergence to asymptotic values versus MTTR	
F.4.3	System with periodically tested components	
	Dynamic RBD example	
F.5.1	Comparison between analytical and Monte Carlo simulation results	
F.5.2	Dynamic RBD example	
Bibliograp	hy	105
Figure 1 –	Shannon decomposition of a simple Boolean expression and resulting BDD	8
Figure 2 –	Series reliability block diagram	15
-	Parallal reliability block diagram	16

Figure 4 – Parallel structure made of duplicated series sub-RBD	16
Figure 5 – Series structure made of parallel reliability block diagram	17
Figure 6 – General series-parallel reliability block diagram	17
Figure 7 – Another type of general series-parallel reliability block diagram	17
Figure 8 – 2 out of 3 redundancy	18
Figure 9 – 3 out of 4 redundancy	18
Figure 10 - Diagram not easily represented by series/parallel arrangement of blocks	18
Figure 11 – Example of RBD implementing dependent blocks	19
Figure 12 – Example of a composite block	19
Figure 13 – Use of transfer gates and sub-RBDs	19
Figure 14 – Analogy between a block and an electrical switch	20
Figure 15 – Analogy with an electrical circuit	20
Figure 16 – Example of minimal success path (tie set)	21
Figure 17 - Example of minimal failure path (cut set)	21
Figure 18 - Equivalent RBDs with minimal success paths	22
Figure 19 – Equivalent RBDs with minimal cut sets	22
Figure 20 – Link between a basic series structure and probability calculations	23
Figure 21 – Link between a parallel structure and probability calculations	24
Figure 22 – "Availability" Markov graph for a simple repaired block	28
Figure 23 – Standby redundancy	28
Figure 24 – Typical availability of a periodically tested block	29
Figure 25 – Example of RBD reaching a steady state	30
Figure 26 – Example of RBD with recurring phases	31
Figure 27 - RBD and equivalent Markov graph for reliability calculations	
Figure 28 – Illustrating grouping of blocks before reduction	34
Figure 29 – Reduced reliability block diagrams	34
Figure 30 - Representation of Figure 10 when item A has failed	35
Figure 31 – Representation of Figure 10 when item A is working	35
Figure 32 - RBD representing three redundant items	35
Figure 33 – Shannon decomposition equivalent to Table 5	39
Figure 34 – Binary decision diagram equivalent to Table 5	39
Figure 35 – RBD using an arrow to help define system success	41
Figure 36 – Alternative representation of Figure 35 using repeated blocks and success paths	41
Figure 37 – Other alternative representation of Figure 35 using repeated blocks and minimal cut sets	41
Figure 38 – Shannon decomposition related to Figure 35	43
Figure 39 – 2-out-of-5 non-identical items	
Figure 40 – Direct and inverted block	44
Figure 41 - Example of electrical circuit with a commutator A	44
Figure 42 - Electrical circuit: failure paths	
Figure 43 – Example RBD with blocks with inverted states	
Figure 44 – BDD equivalent to Figure 43	46

Figure 45 – Symbol for external elements	47
Figure 46 - Dynamic interaction between a CCF and RBDs' blocks	49
Figure 47 – Various ways to indicate dynamic interaction between blocks	49
Figure 48 - Dynamic interaction between a single repair team and RBDs' blocks	50
Figure 49 - Implementation of a PAND gate	50
Figure 50 - Equivalent finite-state automaton and example of chronogram for a PAND gate	.51
Figure 51 – Implementation of a SEQ gate	51
Figure 52 - Equivalent finite-state automaton and example of chronogram for a SEQ gate	51
Figure B.1 – Examples of minimal tie sets (success paths)	58
Figure B.2 – Examples of non-minimal tie sets (non minimal success paths)	58
Figure B.3 – Examples of minimal cut sets	59
Figure B.4 – Examples of non-minimal cut sets	59
Figure B.5 – Example of RBD with tie and cut sets of various order	60
Figure B.6 – Reminder of the RBD in Figure 35	72
Figure B.7 – Shannon decomposition of the Boolean function represented by Figure B.6	72
Figure B.8 – Identification of the parts which do not matter	73
Figure B.9 – Simplification of the Shannon decomposition	73
Figure B.10 – Binary decision diagram related to the RBD in Figure B.6	74
Figure B.11 – Obtaining success paths (tie sets) from an RBD	74
Figure B.12 – Obtaining failure paths (cut sets) from an RBD	75
Figure B.13 – Finding cut and tie sets from BDDs	75
Figure B.14 – Probabilistic calculations from a BDD	76
Figure B.15 – Calculation of conditional probabilities using BDDs	77
Figure C.1 – Principle of time dependent availability calculations	78
Figure C.2 – Principle of RBD driven Markov processes	81
Figure C.3 – Typical availability of RBD with quickly repaired failures	81
Figure C.4 – Example of simple multi-phase Markov process	82
Figure C.5 – Typical availability of RBD with periodically tested failures	82
Figure E.1 – Example of a sub-PN modelling a DRBD block	90
Figure E.2 – Example of a sub-PN modelling a common cause failure	91
Figure E.3 – Example of DRBD based on RBD driven PN	91
Figure E.4 – Logical calculation of classical RBD structures	92
Figure E.5 – Example of logical calculation for an n/m gate	92
Figure E.6 – Example of sub-PN modelling a PAND gate with 2 inputs	92
Figure E.7 – Example of the inhibition of the failure of a block	93
Figure E.8 – Sub-PN for availability, reliability and frequency calculations	94
Figure F.1 – Availability/reliability of a typical non-repaired series structure	95
Figure F.2 – Failure rate and failure frequency related to Figure F.1	96
Figure F.3 – Equivalence of a non-repaired series structure to a single block	96
Figure F.4 – Availability/reliability of a typical repaired series structure	96
Figure F.5 – Failure rate and failure frequency related to Figure F.4	97
Figure F.6 – Availability/reliability of a typical non-repaired parallel structure	97
Figure F.7 – Failure rate and failure frequency related to Figure F.6	

Figure F.8 – Availability/reliability of a typical repaired parallel structure	98
Figure F.9 – Vesely failure rate and failure frequency related to Figure F.8	99
Figure F.10 – Example 1 from 7.5.2	99
Figure F.11 – Failure rate and failure frequency related to Figure F.10	100
Figure F.12 – Impact of the MTTR on the convergence quickness	100
Figure F.13 – System with periodically tested blocks	101
Figure F.14 – Failure rate and failure frequency related to Figure F.13	102
Figure F.15 – Analytical versus Monte Carlo simulation results	102
Figure F.16 – Impact of CCF and limited number of repair teams	103
Figure F.17 – Markov graphs modelling the impact of the number of repair teams	104
Figure F.18 – Approximation for two redundant blocks	104
Table 1 – Acronyms used in IEC 61078	
Table 2 – Symbols used in IEC 61078	9
Table 3 – Graphical representation of RBDs: Boolean structures	11
Table 4 - Graphical representation of RBDs: non-Boolean structures/DRBD	12
Table 5 – Application of truth table to the example of Figure 32	36
Table 6 - Karnaugh map related to Figure 10 when A is in up state	37
Table 7 – Karnaugh map related to Figure 10 when A is in down state	37
Table 8 – Karnaugh map related to Figure 35	42
Table A.1 – Example of equations for calculating the probability of success of basic configurations	53
Table F.1 - Impact of functional dependencies	103

INTERNATIONAL ELECTROTECHNICAL COMMISSION

RELIABILITY BLOCK DIAGRAMS

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 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.

International Standard IEC 61078 has been prepared by IEC technical committee 56: Dependability.

This third edition cancels and replaces the second edition published in 2006. This edition constitutes a technical revision.

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

- a) the structure of the document has been entirely reconsidered, the title modified and the content extended and improved to provide more information about availability, reliability and failure frequency calculations;
- b) Clause 3 has been extended and clauses have been introduced to describe the electrical analogy, the "non-coherent" RBDs and the "dynamic" RBDs;
- c) Annex B about Boolean algebra methods has been extended;
- d) Annex C (Calculations of time dependent probabilities), Annex D (Importance factors), Annex E (RBD driven Petri net models) and Annex F (Numerical examples and curves) have been introduced.