



Developing high-quality software is tough. ECLAIR is designed to help development, QA, and safety teams reach their quality goals.

Coverage of EN 50128

1 Introduction to EN 50128:2011

EN 50128:2011, “Railway applications — Communication, signalling and processing systems — Software for railway control and protection systems,” is part of a group of related international functional-safety standards for the railway industry issued by CENELEC (the *European Committee for Electrotechnical Standardization*) [3].¹ It is a European standard adapting the IEC 61508 series of standards [4] to the development of safety-related software for railway applications, and concerns both track-side and train-side equipment.

The first edition of EN 50128 was published in 2001 and withdrawn in April 2014 after a three-year transition period. The second edition, published in 2011, completely supersedes the previous version. Noteworthy changes introduced in EN 50128:2011 include:

- the addition of requirements on software management, deployment and maintenance;
- the addition of a new clause on support tools, defining what is commonly called *tool qualification*;
- the updating of tables in Annex A.

EN 50128 approach to risk management is based on the determination of the *Safety Integrity Level* (SIL) for each safety function assigned to each subsystem. There are five SILs: 0, 1, 2, 3 and 4, with 0 being the lowest safety integrity level and 4 being the highest. SIL 4 represents likely potential for severely life-threatening or fatal injury in the event of a malfunction and requires the highest level of assurance that the dependent safety goals are sufficient and have been achieved. EN 50128, based on the SIL, specifies whether techniques and measures are *recommended*, *highly recommended*, or even *mandatory*. For instance, static analysis is highly recommended at all SILs from 1 to 4.

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¹The other standards in the group are EN 50126-1:1999 “Railway applications — The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) — Part 1: Basic requirements and generic process” and EN 50129:2003 “Railway applications — Communication, signalling and processing systems — Safety related electronic systems for signalling.”

1.1 Role of ECLAIR in Ensuring Compliance with EN 50128:2011

The ECLAIR Software Verification Platform can be used to comply with several of the techniques and measures required by EN 50128:2011 [3]. In addition, the [ECLAIR Fusa Pack](#) greatly simplifies obtaining all the confidence-building evidence that is required to make a solid argument justifying the use of ECLAIR in safety-related projects.

2 ECLAIR Coverage of EN 50128:2011 Techniques and Measures

EN 50128:2011 applies to all safety-related software used in railway control and protection systems, including application programming, operating systems, support tools, and firmware. For such software, it specifies requirements for safety lifecycle phases and activities that shall be applied during design and development. These requirements include the application of measures and techniques for the avoidance of and the control of faults and failures in the software. Techniques and measures are detailed in tables contained in Annex A, which is normative. Annex D, which is informative, contains a bibliography of techniques and measures that is referenced in the entries of the tables of Annex A.

The degree of recommendation to use each technique and measure depends on the SIL, and is symbolically encoded as follows:

M indicates that the method is *Mandatory* for the identified SIL;

HR indicates that the method is *Highly Recommended* for the identified SIL;

R indicates that the method is *Recommended* for the identified SIL;

– indicates that the method has no recommendation for or against its usage for the identified SIL;

NR indicates that the method is positively *Not Recommended* for the identified SIL.

If a highly-recommended technique or measure is not used, then the rationale for using alternative techniques must be detailed in the *Software Quality Assurance Plan* (or in a document referenced therein), unless an approved combination of techniques given in the corresponding table is used. In any case, the selected combination of techniques and measures must be justified, and each selected technique and measure must be demonstrated to have been applied correctly [3, Clause 4].

The following tables have been obtained by extending the corresponding tables in EN 50128:2011 Annex A with a column indicating where ECLAIR, suitably instantiated with the appropriate package, can be used to ensure compliance or to facilitate the achievement of compliance. Note that, in the sequel, every reference to MISRA C:2012 should be interpreted as referring to [5] as amended by [6, 7, 8], whereas MISRA C++ is [9]. As ECLAIR provides direct support for MISRA guidelines as well as guidelines from other coding standards, a reference for a guideline should be taken as a reference to the corresponding *ECLAIR service* as described in the *ECLAIR User's Manual*. For example, “MISRA C:2012 Directive 3.1” corresponds to the ECLAIR service `MC3R1.D3.1` and “BARR-C:2018 Rule 4.1.a” corresponds to the ECLAIR service `NC3.4.1.a`. For ECLAIR services that do not correspond to published coding standards, the service name is given in teletype font: for example, `B.PROJORG` is the name of an ECLAIR service that supports automatically enforcing software architectural constraints. A complete definition of all ECLAIR services is contained in the *ECLAIR User's Manual* and, where applicable, in the corresponding coding standard documentation referenced therein.

2.1 MISRA C:2012

MISRA C:2012 Revision 1 [5], with Amendments 2 [6] and 3 [7], and Technical Corrigendum 2 [8], is the software development C subset developed by MISRA that is a de facto standard for safety-, life-, security-, and mission-critical embedded applications in many industries, including aerospace, railway,

medical, telecommunications and others. MISRA C:2012, which allows coding MISRA-compliant applications in subsets of C90, C99, C11 and C18, is supported by the ECLAIR package called “MC3”.

2.2 MISRA C++:2008

MISRA C++:2008 [9] is the software development C++ subset developed by MISRA for the motor industry, which is now a de facto standard for safety-, life-, and mission-critical embedded applications also in many other industries. It is currently undergoing a quite deep revision: the structure is being made similar to that in MISRA C:2012, support is being added for C++17, and (some of) the AUTOSAR guidelines are being merged. MISRA C++:2008 is supported by the ECLAIR package called “MP1”.

2.3 BARR-C:2018

The *Barr Group’s Embedded C Coding Standard*, BARR-C:2018 [2], is, for coding standards used by the embedded system industry, second only in popularity to MISRA C. BARR-C:2018 guidelines include 64 guidelines dealing with language subsetting and project management as well as 79 guidelines concerning programming style. For projects in which a MISRA compliance requirement is not (yet) present, the adoption of BARR-C:2018 is a major improvement with respect to the situation where no coding standards and no static analysis are used. The adoption of the stylistic subset of BARR-C:2018 (79 out of 143 rules) can be part of complying with the MISRA requirement that a consistent programming style is adopted and systematically used as part of the software development process. Moreover, complying with BARR-C:2018, besides avoiding many dangerous bugs, entails compliance with a non-negligible subset of MISRA C:2012 [1]. ECLAIR support for BARR-C:2018 has no equals on the market: it is included in all ECLAIR packages, including the affordable package “B”.

Table A.1 — Lifecycle Issues and Documentation

DOCUMENTATION	SIL					ECLAIR
	0	1	2	3	4	
Software requirements						
6. Software Requirements Specification	HR	HR	HR	HR	HR	√ ^a
7. Overall Software Test Specification	HR	HR	HR	HR	HR	√ ^a
8. Software Requirements Verification Report	HR	HR	HR	HR	HR	–
Architecture and design						
9. Software Architecture Specification	HR	HR	HR	HR	HR	√ ^{a,b}
10. Software Design Specification	HR	HR	HR	HR	HR	√ ^a
11. Software Interface Specification	HR	HR	HR	HR	HR	√ ^{a,b}
12. Software Integration Test Specification	HR	HR	HR	HR	HR	√ ^a
13. Software/Hardware Integration Test Specification	HR	HR	HR	HR	HR	–
14. Software Architecture and Design Verification Report	HR	HR	HR	HR	HR	–
46. Software Assessment Report	R	HR	HR	HR	HR	–

^a ECLAIR service B.REQMAN allows ensuring that all code is forward and backward traceable to documented requirements, including safety requirements. B.REQMAN also allows tracing code to the tests and back. The integrated requirements management tool makes ECLAIR a cost-effective, complete solution for requirements-based development and testing.

^b ECLAIR service B.PROJORG allows the formal specification and systematic checking of software architectural constraints, e.g., to enforce constraints about layering and to prevent bypassing of software interfaces.

Table A.3 — Software Architecture

TECHNIQUE/MEASURE	SIL					ECLAIR
	0	1	2	3	4	
1. Defensive Programming	-	HR	HR	HR	HR	√ ^a
2. Fault Detection & Diagnosis	-	R	R	HR	HR	√ ^b
17. Information Hiding	-	-	-	-	-	√ ^c
18. Information Encapsulation	R	HR	HR	HR	HR	√ ^c
19. Fully Defined Interface	HR	HR	HR	M	M	√ ^d
20. Formal Methods	-	R	R	HR	HR	—
21. Modelling	R	R	R	HR	HR	√ ^e
22. Structured Methodology	R	HR	R	HR	HR	√ ^e
23. Modelling supported by computer aided design and specification tools	R	R	R	HR	HR	√ ^e

^a The MISRA C/C++ guidelines promote the use of several defensive programming techniques. E.g., for MISRA C:2012, Directives 4.1, 4.7, 4.11 and 4.14, Rules 2.1–2.7, 14.2, 15.7, 16.4, and 17.7.

^b The MISRA C/C++ guidelines require systematic checking of error information returned by functions. Guidance is also provided on how to perform some of these checks. E.g., for MISRA C:2012, Dir 4.7, Rules 22.8, 22.9, and 22.10.

^c The MISRA C/C++ guidelines promote the use of information hiding and encapsulation. E.g., for MISRA C:2012, Directives 4.3 and 4.8 and Rules 8.7 and 8.9. In addition ECLAIR's B.PROJORG service can be used to enforce strict encapsulation constraints.

^d The MISRA C/C++ guidelines promote the full definition of interfaces. E.g., for MISRA C:2012, Rules 8.2 and 8.3 prescribe the use of prototype form and the use of consistent names for function declarations; Rule 17.3 forbids implicit declarations; Directive 4.14 requires data verification; BARR-C:2018 Rule 2.2.h recommends commenting modules and functions with explicit specification of pre-conditions and post-conditions with Doxygen; such comment blocks are automatically checked by ECLAIR for consistency.

^e ECLAIR service B.PROJORG allows the formal specification and systematic checking of software architectural constraints, e.g., to enforce constraints about layering and to prevent bypassing of software interfaces. B.PROJORG is instrumental in proving independence among different software components, which is essential when the software consists of components of different software safety integrity levels and treating them as belonging to the highest of these levels is inadvisable (see [4], Clause 7.3.4.9).

Table A.4 — Software Design and Implementation

	TECHNIQUE/MEASURE	SIL					ECLAIR
		0	1	2	3	4	
1.	Formal Methods	-	R	R	HR	HR	—
2.	Modelling	R	HR	HR	HR	HR	—
3.	Structured methodology	R	HR	HR	HR	HR	—
4.	Modular Approach	HR	M	M	M	M	√ ^a
5.	Components	HR	HR	HR	HR	HR	√ ^b
6.	Design and Coding Standards	HR	HR	HR	M	M	√ ^c
7.	Analysable Programs	HR	HR	HR	HR	HR	√ ^d
8.	Strongly Typed Programming Language	R	HR	HR	HR	HR	√ ^e

continued

Table A.4 — Software Design and Implementation

	TECHNIQUE/MEASURE	SIL					ECLAIR
		0	1	2	3	4	
9.	Structured Programming	R	HR	HR	HR	HR	√ ^f
10.	Programming Language	R	HR	HR	HR	HR	√ ^g
11.	Language Subset	-	-	-	HR	HR	√ ^h
12.	Object Oriented Programming	R	R	R	R	R	√ ⁱ
13.	Procedural programming	R	HR	HR	HR	HR	√ ^j
14.	Metaprogramming	R	R	R	R	R	—

^a ECLAIR offers numerous services to enforce modularization in the design and coding phase of a software project. With reference to item D.38 (Modular Approach) in Annex D of [3]: connections between modules/components can be limited and strictly defined using `B.PROJORG`; cohesion in one module/component can be constrained to be high using ECLAIR specific metric `B.STFCO_UNIT`; modules/components and subprograms can be constrained to be small by enforcing upper bounds on `HIS` and other metrics related to size and complexity; MISRA C:2012 Rule 15.5 and MISRA C++:2008 Rule 6–6–5 require subprograms to have a single entry and a single exit only; the MISRA C/C++ guidelines promote the full definition of interfaces as outlined in note (d) to Table A.3; the MISRA C/C++ guidelines include prescriptions against the use of unnecessary global variables, e.g., for MISRA C:2012, Rules 8.7 and 8.9; the specific ECLAIR service `B.GLOBALVAR` allows fine control of acceptable global variables. BARR-C:2018 Rule 2.2.h recommends commenting modules and functions with explicit specification of pre-conditions and post-conditions with Doxygen; such comment blocks are automatically checked by ECLAIR for consistency; limitations on the number of parameters of a function/method can be automatically enforced by imposing upper bounds on the `HIS.PARAM` metric.

^b See Table A.20.

^c See Table A.12.

^d The MISRA C/C++ and BARR-C:2018 coding standards can be used to ensure that programs are relatively easy to reason about and to analyze statically. In particular, they limit the use of non-structured programming constructs, language extensions and assembly code; they promote the reduction of the scope of identifiers, the use of simple branching and loop decision, the use of simplified loop and switch constructs. In addition, `HIS` and other metrics provided by ECLAIR allow imposing upper bounds on the size and complexity of components as well as on the number of possible paths through them.

^e MISRA C/C++ enforce strong typing on the respective languages. E.g., for MISRA C:2012, Rules 10.1–10.8, 11.1–11.9, and 14.4.

^f The MISRA C/C++ guidelines include limits on the use of non-structured control-flow constructs. E.g., for MISRA C:2012, Rules 14.3, 15.1–15.4, and 21.4. A threshold on metric `HIS.GOTO` allows limiting the use of `goto`.

^g Excluding ADA and the obsolete programming languages in EN 50128 Table A.15, C and C++ are the ones with the longest history of application in the development of critical systems. Moreover, it can be argued that the MISRA C and MISRA C++ subsets are as safe as other languages marked as highly recommended in that table. MISRA C and MISRA C++ satisfy the requirements of D.54 (Suitable Programming languages) in Annex D of [3].

^h MISRA C/C++ and BARR-C:2018 define language subsets where the potential of committing possibly dangerous mistakes is reduced.

ⁱ MISRA C++ is an object oriented programming language. Service `B.PROJORG` can support an object oriented programming style also in C, by restricting access to “private” data and functions.

^j (All subsets of) C and C++ are procedural programming languages.

Table A.12 — Coding Standards

TECHNIQUE/MEASURE	SIL					ECLAIR
	0	1	2	3	4	
1. Coding Standard	HR	HR	HR	M	M	√ ^a
2. Coding Style Guide	HR	HR	HR	HR	HR	√ ^b
3. No Dynamic Objects	-	R	R	HR	HR	√ ^c
4. No Dynamic Variables	-	R	R	HR	HR	√ ^c
5. Limited Use of Pointers	-	R	R	R	R	√ ^d
6. Limited Use of Recursion	-	R	R	HR	HR	√ ^e
7. No Unconditional Jumps	-	HR	HR	HR	HR	√ ^f
8. Limited size and complexity of Functions, Subroutines and Methods	HR	HR	HR	HR	HR	√ ^g
9. Entry/Exit Point strategy for Functions, Subroutines and Methods	R	HR	HR	HR	HR	√ ^h
9. Limited number of subroutine parameters	R	R	R	R	R	√ ⁱ
10. Limited use of Global Variables	HR	HR	HR	M	M	√ ^j

^a The MISRA C/C++ and BARR-C:2018 coding standards define language subsets where the potential of committing possibly dangerous mistakes is reduced.

^b More than half of the guidelines in BARR-C:2018 [2] concern coding style [1]. MISRA C:2012 Rules 7.3 and 16.5 are also stylistic.

^c The MISRA C/C++ guidelines include prescriptions limiting the use of dynamic memory allocation. E.g., for MISRA C:2012, Directive 4.12 and Rules 18.7, 21.3, 22.1 and 22.2.

^d The MISRA C/C++ guidelines include rules restricting the use of pointers. E.g., for MISRA C:2012, Rules 8.13, 11.1–11.8, and 18.1–18.5. The specific ECLAIR services `B.PTRDECL` and `B.PTRUSE` allow fine control of pointers' use.

^e MISRA C Rule 17.2 and MISRA C++ Rule 7-5-4 forbid recursion. A threshold on metric `HIS.ap_cg_cycle` also allows ruling out recursion.

^f The MISRA C/C++ guidelines include limits on the use of non-structured control-flow constructs as well as other unconditional jumps. E.g., for MISRA C:2012, Rules 14.3, 15.1–15.4, and 21.4. A threshold on metric `HIS.GOTO` allows limiting the use of `goto`.

^g `HIS` and other metrics are related to the size and complexity of software components. ECLAIR allows associating thresholds to each metric.

^h MISRA C:2012 Rule 15.5 and MISRA C++:2008 Rule 6–6–5 require subprograms to have a single entry and a single exit only. An upper threshold on metric `HIS.RETURN` allows for a more flexible approach.

ⁱ Limitations on the number of parameters of a function/method can be automatically enforced by imposing upper bounds on the `HIS.PARAM` metric.

^j The MISRA C/C++ guidelines include prescriptions against the use of unnecessary global variables, e.g., for MISRA C:2012, Rules 8.7 and 8.9; the specific ECLAIR service `B.GLOBALVAR` allows fine control of acceptable global variables.

Table A.19 — Static Analysis

TECHNIQUE/MEASURE	SIL					ECLAIR
	0	1	2	3	4	
1. Boundary Value Analysis	-	R	R	HR	HR	–
2. Checklists	-	R	R	R	R	–
3. Control Flow Analysis	-	HR	HR	HR	HR	√ ^a
4. Data Flow Analysis	-	HR	HR	HR	HR	√ ^b
5. Error Guessing	-	R	R	R	R	–
6. Walkthroughs/Design Reviews	HR	HR	HR	HR	HR	√ ^c

^a ECLAIR builds accurate control flow graphs to reason on (feasible and unfeasible) execution paths.

^b ECLAIR performs a number of data flow analyses to reason about, e.g., pointers, values and dead stores.

^c Compliance to the MISRA C/C++ and the BARR-C:2018 guidelines greatly increases code readability and understandability, thereby facilitating verification activities by walk-through, pair-programming and inspection.

Table A.20 — Components

TECHNIQUE/MEASURE	SIL					ECLAIR
	0	1	2	3	4	
1. Information Hiding ¹	-	-	-	-	-	√ ^a
2. Information Encapsulation	R	HR	HR	HR	HR	√ ^a
3. Parameter Number Limit	R	R	R	R	R	√ ^b
4. Fully Defined Interface	R	HR	HR	M	M	√ ^c

^a The MISRA C/C++ guidelines promote the use of information hiding and encapsulation. E.g., for MISRA C:2012, Directives 4.3 and 4.8 and Rules 8.7 and 8.9. In addition ECLAIR’s `B.PROJORG` service can be used to enforce strict encapsulation constraints.

^b Limitations on the number of parameters of a function/method can be automatically enforced by imposing upper bounds on the `HIS.PARAM` metric.

^c The MISRA C/C++ guidelines promote the full definition of interfaces. E.g., for MISRA C:2012, Rules 8.2 and 8.3 prescribe the use of prototype form and the use of consistent names for function declarations; Rule 17.3 forbids implicit declarations; Directive 4.14 requires data verification; BARR-C:2018 Rule 2.2.h recommends commenting modules and functions with explicit specification of pre-conditions and post-conditions with Doxygen; such comment blocks are automatically checked by ECLAIR for consistency.

¹ Note 1 in EN 50128 Table A.20 says that “Information Hiding and encapsulation are only highly recommended if there is no general strategy for data access.”

3 ECLAIR Qualification in Compliance with EN 50128

The ECLAIR functionality described above is qualifiable in compliance with EN 50128: ECLAIR is a class T2 tool and meets all the requirements set forth in EN 50128:2011 for such tools [3, Clause 6.7.4]. TÜV SÜD audited BUGSENG software development and quality assurance processes for ECLAIR, as well as the internal validation activities performed by BUGSENG on each ECLAIR release. At the end of its assessment, TÜV SÜD awarded BUGSENG the “Software Tool for Safety Related Development” Certificate no. Z10 116151 0001 Rev. 00, attesting that the ECLAIR Software Verification Platform is suitable to be used in safety-related development projects according to EN 50128:2011 for any SIL.



4 The Bigger Picture

ECLAIR is very flexible and highly configurable: it supports all sorts of software development workflows and environments.

ECLAIR is fit for use in mission- and safety-critical software projects: it has been designed from the outset to exclude configuration errors that would undermine the significance of the obtained results.

ECLAIR is developed in a rigorous way and carefully checked with extensive internal test suites (tens of thousands of test cases) and industry-standard validation suites.

ECLAIR is based on solid scientific research results and on the best practices of software development.

ECLAIR’s unique features and BUGSENG’s strong commitment to the customer, allow for a smooth transition to ECLAIR from any other tool.

BUGSENG’s quality system has been certified by TÜV Italia (TÜV SÜD Group) to comply with the requirements of UNI EN ISO 9001:2015 for the “Design, development, maintenance and support of tools for software verification and validation” (IAF 33).

BUGSENG is an **Arm’s Functional Safety Partner**, and is thus recognized as a partner who can reliably support their customers with industry leading functional safety products and services.

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