

IEEE Recommended Practice for Functional Testing of a Communications-Based Train Control (CBTC) System

IEEE Vehicular Technology Society

Sponsored by the
Rail Transportation Standards Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1474.4™-2011

16 September 2011

IEEE Recommended Practice for Functional Testing of a Communications-Based Train Control (CBTC) System

Sponsor

Rail Transportation Standards Committee
of the
IEEE Vehicular Technology Society

Approved 16 June 2011
IEEE-SA Standards Board

Approved 18 July 2012
American National Standards Institute

Abstract: A preferred approach for functional testing of a communications-based train control (CBTC) system, based on the CBTC system design and functional allocations as defined in IEEE Std 1474.3™-2008, is established in this recommended practice.

Keywords: automation, communication, IEEE 1474.4, signaling, testing, train control

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2011 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 16 September 2011. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by the Institute of Electrical and Electronics Engineers, Incorporated.

PDF: ISBN 978-0-7381-6667-4 STD97118
Print: ISBN 978-0-7381-6668-1 STDPD97118

IEEE prohibits discrimination, harassment and bullying. For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>. No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

Use of an IEEE Standard is wholly voluntary. The IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other IEEE Standard document.

The IEEE does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. IEEE Standards documents are supplied “**AS IS.**”

The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation, or every ten years for stabilization. When a document is more than five years old and has not been reaffirmed, or more than ten years old and has not been stabilized, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

In publishing and making this document available, the IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other IEEE Standards document, should rely upon his or her independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration. A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered the official position of IEEE or any of its committees and shall not be considered to be, nor be relied upon as, a formal interpretation of the IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Recommendations to change the status of a stabilized standard should include a rationale as to why a revision or withdrawal is required. Comments and recommendations on standards, and requests for interpretations should be addressed to:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854-4141
USA

Authorization to photocopy portions of any individual standard for internal or personal use is granted by The Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Introduction

This introduction is not part of IEEE Std 1474.4-2011, IEEE Recommended Practice for Functional Testing of a Communications-Based Train Control (CBTC) System.

The characteristics of a communications-based train control (CBTC) system are very different from that of a more conventional track circuit-based signaling/train control system and these characteristics can have a fundamental impact on the approach to system testing and verification. CBTC field test requirements in particular can be significantly more onerous in a resignaling application than signaling for a new line, primarily because of the need to maintain revenue operations during the migration to the new CBTC system, which in turn results in track access limitations.

Against this background, this document provides a recommended practice for the functional testing of CBTC systems, from factory tests through test track tests to field tests, with a goal of maximizing the effectiveness and efficiency of the test procedures at each stage. This recommended practice considers CBTC performance and functional requirements as defined in IEEE Std 1474.1TM-2004 and the CBTC recommended system design and functional allocations as defined in IEEE Std 1474.3TM-2008.^a

Notice to users

Laws and regulations

Users of these documents should consult all applicable laws and regulations. Compliance with the provisions of this standard does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

This document is copyrighted by the IEEE. It is made available for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making this document available for use and adoption by public authorities and private users, the IEEE does not waive any rights in copyright to this document.

^a Information on references can be found in Clause 2.

Updating of IEEE documents

Users of IEEE standards should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect. In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE Standards Association web site at <http://ieeexplore.ieee.org/xpl/standards.jsp>, or contact the IEEE at the address listed previously.

For more information about the IEEE Standards Association or the IEEE standards development process, visit the IEEE-SA web site at <http://standards.ieee.org>.

Errata

Errata, if any, for this and all other standards can be accessed at the following URL: <http://standards.ieee.org/reading/ieee/updates/errata/index.html>. Users are encouraged to check this URL for errata periodically.

Interpretations

Current interpretations can be accessed at the following URL: <http://standards.ieee.org/reading/ieee/interp/index.html>.

Patents

Attention is called to the possibility that implementation of this recommended practice may require use of subject matter covered by patent rights. By publication of this recommended practice, no position is taken with respect to the existence or validity of any patent rights in connection therewith. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this recommended practice are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this recommended practice was submitted to the IEEE-SA Standards Board for approval, the Communications-Based Train Control Working Group had the following membership:

Alan Rumsey, *Chair*
Norman May, *Vice Chair*

Frederick Childs
Michael Crispo
Stephane Dubois
Tom Eichorn
Nicolas Estivals
Steve Farrell
Nabil Ghaly

Harvey Glickenstein
Kenneth Karg
Andrei Kukushkin
John LaForce
Bob MacDonald
Dave Male

Lou Sanders
George Simon
Jeffrey Smith
Carl Thompson
David Thurston
Robert Walsh
Firth Whitwam

The following members of the individual balloting committee voted on this recommended practice. Balloters may have voted for approval, disapproval, or abstention.

Ronald Birkelbach
Stephane Bois
William Byrd
Frederick Childs
Keith Chow
Timothy Cramond
Michael Crispo
Douglas Dorr
Jeff Eilenberg
Christian Girard
Harvey Glickenstein
David Gregson
Randall Groves

James R. Hoelscher
Werner Hoelzl
Ronald W. Hotchkiss
Paul Jamieson
Andrew Jones
Kenneth Karg
Piotr Karocki
Walter Keevil
Thomas Kurihara
Norman May
Daniel McFadden
Michael S. Newman
William Petit
D. Phelps

Edward Rowe
Alan Rumsey
Bartien Sayogo
Gil Shultz
Alexander Sinyak
Jeffrey Sisson
James Smith
David Thurston
Gary Touryan
John Vergis
Robert Walsh
Stephen Webb
Jian Yu

When the IEEE-SA Standards Board approved this recommended practice on 16 June 2011, it had the following membership:

Richard H. Hulett, *Chair*
John Kulick, *Vice Chair*
Robert M. Grow, *Past Chair*
Judith Gorman, *Secretary*

Masayuki Ariyoshi
William Bartley
Ted Burse
Clint Chaplin
Wael Diab
Jean-Philippe Faure
Alexander Gelman
Paul Houzé

Jim Hughes
Joseph L. Koepfinger*
David J. Law
Thomas Lee
Hung Ling
Oleg Logvinov
Ted Olsen

Gary Robinson
Jon Walter Rosdahl
Sam Sciacca
Mike Seavey
Curtis Siller
Phil Winston
Howard L. Wolfman
Don Wright

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Satish K. Aggarwal, *NRC Representative*
Richard DeBlasio, *DOE Representative*
Michael Janezic, *NIST Representative*

Lisa Perry
IEEE Standards Program Manager, Document Development

Michael D. Kipness
IEEE Standards Program Manager, Technical Program Development

Contents

1. Overview	1
1.1 Scope	1
1.2 Purpose	1
1.3 General	1
1.4 Application	2
2. Normative references.....	2
3. Definitions, acronyms, and abbreviations	2
3.1 Definitions	2
3.2 Acronyms and abbreviations	2
4. CBTC characteristics and applications.....	3
4.1 CBTC characteristics.....	3
4.2 CBTC applications	4
5. Overall test process.....	4
5.1 General	4
5.2 Functional test prerequisites	6
5.3 Database verification	7
6. Factory functional tests.....	8
6.1 Factory integrated system test facility	8
6.2 Factory test plan.....	10
7. CBTC test track functional tests	22
7.1 CBTC test track	22
7.2 CBTC test track test plan.....	23
8. Field functional tests.....	28
8.1 Field test plan	28
9. Summary	32

IEEE Recommended Practice for Functional Testing of a Communications-Based Train Control (CBTC) System

IMPORTANT NOTICE: *This standard is not intended to ensure safety, security, health, or environmental protection. Implementers of the standard are responsible for determining appropriate safety, security, environmental, and health practices or regulatory requirements.*

This IEEE document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

1. Overview

1.1 Scope

This recommended practice establishes a preferred approach for functional testing of a communications-based train control (CBTC) system.

1.2 Purpose

The purpose of this recommended practice is to define a preferred sequence and extent of off-site and on-site functional testing for CBTC systems with the objective of maximizing test efficiency and effectiveness.

1.3 General

This recommended practice establishes a preferred approach for functional testing of a CBTC system. Clause 1 describes the scope and purpose of this recommended practice. Clause 2 lists normative references that are useful in applying this recommended practice. Clause 3 provides definitions that are either not

found in other IEEE standards or have been modified for use with this recommended practice. Clause 1 describes the basic characteristics of CBTC systems and typical applications. Clause 5 provides an overview of the overall test process. Clause 6 provides recommended practices for factory tests, and Clause 7 provides recommended practices for test track tests. Clause 8 provides recommended practices for field tests.

1.4 Application

The extent to which this recommended practice would be applicable to a specific CBTC installation/project should be determined by the authority having jurisdiction.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 1474.1TM-2004 (Reaff 2009), IEEE Standard for Communications-Based Train Control (CBTC) Performance and Functional Requirements.^{1, 2}

IEEE Std 1474.3TM-2008, IEEE Recommended Practice for Communications-Based Train Control (CBTC) System Design and Functional Allocations.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

The IEEE Standards Dictionary: Glossary of Terms & Definitions should be consulted for terms not defined herein.³ See also IEEE Std 1474.1-2004 for other CBTC-related definitions.⁴

3.2 Acronyms and abbreviations

ATO	automatic train operation
ATP	automatic train protection
ATS	automatic train supervision
CBTC	communications-based train control

¹ IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854-4141, USA (<http://standards.ieee.org>).

² The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronic Engineers, Inc.

³ *The IEEE Standards Dictionary: Glossary of Terms & Definitions* is available at <http://shop.ieee.org/>.

⁴ Information on references can be found in Clause 2.

4. CBTC characteristics and applications

4.1 CBTC characteristics

The primary characteristics of a CBTC system, as defined in IEEE Std 1474.1-2004, include the following:

- a) High-resolution train location determination, independent of track circuits
- b) Continuous, high capacity, bidirectional train-to-wayside data communications
- c) Train-borne and wayside processors performing vital functions

The influence of these primary characteristics on the functional test process is summarized as follows.

4.1.1 Train location determination, independent of track circuits

With train location determination independent of fixed-block track circuits, alternative control strategies become possible (where movement authority limits are not constrained by physical fixed-block track circuit boundaries) that should be reflected in the CBTC functional test process. Certain test practices for fixed-block, track circuit-based signaling systems may no longer be applicable or practicable, and alternative test procedures are necessary to reflect the specific principles of operation of CBTC systems.

4.1.2 Bidirectional train-to-wayside data communications

The performance and availability of a geographically continuous train-to-wayside and wayside-to-train data communications network is critical to CBTC operations. Hence, as an element of the system level functional testing, the network performance and availability (including network stability, data-link bandwidth, and message latency) should be verified, supported by analysis, as necessary, of worse-case conditions that cannot be easily duplicated in the factory or in the field.

4.1.3 Train-borne and wayside vital processors

The distributed CBTC wayside and train-borne vital processors that process the train status and control data and provide continuous automatic train protection (ATP), automatic train operation (ATO), and automatic train supervision (ATS) functions are typically highly integrated. As a consequence, the final functional testing can only be performed at a systems level with all major CBTC subsystems operational and with multiple vehicles operating. CBTC systems also typically include significant levels of equipment redundancy to achieve the high system availability required. The need to verify the overall stability of such a distributed computer system and the need to verify switchover capabilities between redundant sets of wayside and/or train-borne CBTC equipment also should be reflected in the functional test process.

CBTC systems—typical of other advanced technology systems—are software/database driven. In such complex software-based systems it is important to understand that whereas the majority of software development often occurs prior to field testing, the software development process does not end until the system is verified to be operating correctly in the field. Multiple software releases are also typically required in a given application (specifically for complex cut-overs in a resignaling application) resulting in a need for a defined level of regression testing following each software update.

4.1.4 Application-specific requirements

The correctness of application-specific data (i.e., infrastructure data, such as curves, grades, station locations, etc., and train-specific data, such as braking rates and response times, etc.) and that this data has been correctly implemented within the system databases, should also be verified as an element of the functional test process.

When resignaling with a CBTC system, application-specific external (legacy) equipment interfaces, application-specific operating modes, and application-specific functional requirements are common. This can result in application-specific designs that should be reflected in the application-specific functional test process. To exploit the operational capabilities of CBTC systems, the design of a CBTC system is often integrated with the design of other fixed operating elements of a rapid transit system such as traction power systems, tunnel and station ventilation systems, passenger information and security systems, and backbone communications networks, for example. In addition, the designs of the onboard train location/speed measurement subsystems are also often application-specific due to vehicle-specific interfaces. As such, the performance of these application-specific designs should be verified through the functional test process.

4.2 CBTC applications

The CBTC functional test process for resignaling applications can be significantly more onerous than signaling new lines, primarily because of the need to maintain revenue operations and the integrity of the existing signaling system during the migration to the new CBTC system, which in turn results in track access limitations and the need to support mixed modes of operation. In addition, the specific signaling/train control system being replaced is typically different from one application to another.

NOTE—For the purposes of this recommended practice, and for consistency with IEEE Std 1474.3-2008, the CBTC system is assumed to interface with an external separate interlocking subsystem, which is more common for resignaling applications. As a consequence, this recommended practice does not include testing of interlocking functions, but does include the testing of functional interfaces between CBTC and external interlockings.⁵

5. Overall test process

5.1 General

This recommended practice addresses system-level functional testing only, as an integral element of the overall test process, to verify in the factory, on a CBTC test track, and in the field that the CBTC system functional requirements have been satisfied, as highlighted in Figure 1.

This recommended practice does not address unit testing at a module level, subsystem tests, hardware qualification tests, hardware post-installation check-out testing, and data communications coverage testing, which are all necessary prerequisites to system-level functional testing. Trial operations, reliability/availability/maintainability demonstrations and other customer-specific final acceptance testing are also not included.

If a function/sub-function has been previously verified in one application, it may not be necessary to retest the function/sub-function in a subsequent application, based on consideration of any differences in hardware, software, system databases, and operating environment.

⁵ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.