

IEEE Standard for Advanced Audio and Video Coding

IEEE Computer Society

Sponsored by the
Standards Activities Board

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

IEEE Std 1857™-2013

4 June 2013

IEEE Standard for Advanced Audio and Video Coding

Sponsor

**Standards Activities Board
of the
IEEE Computer Society**

Approved 6 March 2013

IEEE-SA Standards Board

Abstract: In this standard, a set of tools for efficient video coding is defined, including directional intra prediction, variable block size inter prediction and context adaptive binary arithmetic coding, and the corresponding decoding procedure. The target applications and services include but not limited TV over Internet, user-generated multimedia content, IP-based video conference, IP-based surveillance, and other video/audio enabled services and applications such as digital television broadcasting, digital storage media, and communication.

Keywords: block, coefficients, decoding, encoding, entropy coding, field, frame, IEEE 1857™, image, Internet Protocol television (IPTV), inter prediction, intra prediction, macroblock, picture, quantization, slice, transform

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

Copyright © 2013 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 4 June 2013. 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 978-0-7381-8283-4 STD98168
Print: ISBN 978-0-7381-8284-1 STDPD98168

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.

Notice and Disclaimer of Liability Concerning the Use of IEEE Documents: IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. 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 IEEE administers the process and establishes rules to promote fairness in the consensus development process, 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. 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 any IEEE Standard document.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, 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 in its standards 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 ten years. When a document is more than ten years old and has not undergone a revision process, 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 its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own 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.

Translations: The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official Statements: 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 position of 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 of IEEE.

Comments on Standards: Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important to ensure that any responses to comments and questions also receive 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 comments or questions except in those cases where the matter has previously been addressed. Any person who would like to participate in evaluating comments or revisions to an IEEE standard is welcome to join the relevant IEEE working group at <http://standards.ieee.org/develop/wg/>.

Comments on standards should be submitted to the following address:

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

Photocopies: 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.

Notice to users

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document 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.

Updating of IEEE documents

Users of IEEE Standards documents 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-SA Website at <http://standards.ieee.org/index.html> or contact the IEEE at the address listed previously. For more information about the IEEE Standards Association or the IEEE standards development process, visit IEEE-SA Website at <http://standards.ieee.org/index.html>.

Errata

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

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at <http://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. 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 standard 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 IEEE standard was completed, the Audio Video Coding Working Group had the following membership:

Wen Gao, *Chair*
Cliff Reader, *Vice Chair*

Xiaopeng Fan	Yan Lu	Lu Yu
Yun He	Siwei Ma	Zihua Zeng
Tiejun Huang	Qiang Wang	Li Zhang
Xiangyang Ji	Ronggang Wang	Xianguo Zhang
Guoping Li	Zhenyu Wang	Haiwu Zhao
Fan Liang	Feng Wu	Jianhua Zheng
Jian Lou	Lianhuan Xiong	Xiaozhen Zheng

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

Oscar Au	Alex Kot	Yonghong Tian
Jianfei Cai	Gwo Lee	John Vergis
Juan Carreon	Houqiang Li	David Virette
Jianwen Chen	Jia Li	Dong Wang
Xilin Chen	Jinghua Li	Lichun Wang
Keith Chow	Weiping Li	Ronggang Wang
Sharon Chuang	Fan Liang	Ruiping Wang
Giovanni Cordara	Weisi Lin	Shaofan Wang
Ray Davis	Jiaying Liu	Shuhui Wang
Wenpeng Ding	William Lumpkins	Xushu Wang
Weibei Dou	Chong Luo	Forrest Wright
P. Eastman	Greg Luri	Feng Wu
Andrew Fieldsend	Siwei Ma	Xiaolin Wu
Wen Gao	Wei Ma	Jun Xin
Matthew Goldman	Luntian Mou	Hongkai Xiong
Randall Groves	Michael S. Newman	Ruiqin Xiong
Zongming Guo	Charles Ngethe	Zhiwei Xiong
Yun He	Xingde Pan	Xiaokang Yang
Werner Hoelzl	Xiulian Peng	Hongxun Yao
Ruimin Hu	Ulrich Pohl	Baocai Yin
Yongli Hu	Honggang Qi	Haoping Yu
Qingming Huang	Lei Qin	Li Yu
Tiejun Huang	Lai-Yun Qing	Lu Yu
Longshe Huo	Cliff Reader	Junsong Yuan
Noriyuki Ikeuchi	Benjamin Rolfe	Oren Yuen
Akio Iso	Bartien Sayogo	Chen-Xiong Zhang
Euee Seon Jang	Guangming Shi	Chunjie Zhang
Junzhong Ji	Yunhui Shi	Li Zhang
Xiangyang Ji	Haiyan Shu	Xinggong Zhang
Huizhu Jia	Walter Struppler	Yong Zhang
Feng Jiang	Li Su	Zhebin Zhang
Ming Jiang	Hui-Fang Sun	Debin Zhao
Shuqiang Jiang	Jiande Sun	Xiaozhen Zheng
Tingting Jiang	Jun Sun	Daidi Zhong
Hui Jin	Yanfeng Sun	Huan Zhou
Piotr Karocki		Wenwu Zhu

When the IEEE-SA Standards Board approved this standard on 6 March 2013, it had the following membership:

John Kulick, *Chair*
David J. Law, *Vice Chair*
Richard H. Hulett, *Past Chair*
Konstantinos Karachalios, *Secretary*

Masayuki Ariyoshi
Peter Balma
Farooq Bari
Ted Burse
Wael William Diab
Stephen Dukes
Jean-Philippe Faure
Alexander Gelman

Mark Halpin
Gary Hoffman
Paul Houzé
Jim Hughes
Michael Janezic
Joseph L. Koepfinger*
Oleg Logvinov

Ron Petersen
Gary Robinson
Jon Walter Rosdahl
Adrian Stephens
Peter Sutherland
Yatin Trivedi
Phil Winston
Yu Yuan

*Member Emeritus

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

Richard DeBlasio, *DOE Representative*
Michael Janezic, *NIST Representative*

Julie Alessi
IEEE Standards Program Manager, Document Development

Malia Zaman
IEEE Standards Program Manager, Technical Program Development

Introduction

This introduction is not part of IEEE Std 1857-2013, IEEE Standard for Advanced Audio and Video Coding.

This standard provides regular high-quality and efficient coding tool sets for compression, decompression, and packaging of video data to save storage space or bandwidth for transmission over the Internet.

Contents

1. Overview	1
1.1 Scope	1
1.2 Purpose	1
1.3 Applications.....	2
1.4 Profiles and levels.....	2
1.5 Overview of the design characteristics	2
1.6 Predictive coding	2
1.7 Picture partitioned into macroblocks and smaller partitions.....	3
1.8 Transform and quantization.....	3
2. Normative references.....	3
3. Definitions, acronyms, and abbreviations	3
3.1 Definitions	3
3.2 Acronyms and abbreviations	7
4. Operators and mathematical functions	8
4.1 Description	8
4.2 Arithmetic operators	8
4.3 Logical operators	8
4.4 Relational operators	8
4.5 Bit-wise operators.....	9
4.6 Assignment operators	9
4.7 Mathematical functions	10
4.8 Structure relation	10
5. Description method of bitstream syntax, parsing process, and decoding process	11
5.1 Description style.....	11
5.2 Functions	12
5.3 Descriptors.....	13
5.4 Reserved, forbidden, and marker.....	14
6. Structure of coded bitstream.....	14
6.1 Sequence.....	15
6.2 Picture.....	15
6.3 Slices.....	19
6.4 Macroblock.....	22
6.5 8×8 Block	22
6.6 4×4 Block	23
7. Bitstream syntax and semantics.....	24
7.1 Syntax description	24
7.2 Semantics description	35
8. Parsing process	57
8.1 kth-order Exp-Golomb codes	57
8.2 $ue(v)$, $se(v)$, $me(v)$, and $me4(v)$	57
8.3 $ce(v)$ and $ce4(v)$	60
8.4 $ae(v)$	63

9. Decoding process.....	76
9.1 High-level syntax structures	76
9.2 Picture header decoding.....	76
9.3 Slice decoding.....	79
9.4 Macroblock decoding	80
9.5 Block decoding	104
9.6 Quantization coefficients prediction	109
9.7 Inverse quantization.....	112
9.8 Inverse transform.....	114
9.9 Intra prediction	116
9.10 Inter prediction	122
9.11 Reconstruction.....	135
9.12 Loop filter.....	136
 Annex A (normative) Start code emulation.....	 141
 Annex B (normative) Profiles and levels.....	 142
 Annex C (normative) Bitstream buffer verifier	 149
 Annex D (normative) Variable-length code tables	 155

IEEE Standard for Advanced Audio and Video Coding

IMPORTANT NOTICE: IEEE Standards documents are not intended to ensure safety, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

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 standard defines a set of tools for efficient video coding and the corresponding decoding procedure, including intraprediction, interprediction, transform, quantization, and entropy coding.

1.2 Purpose

This standard provides efficient coding tool sets for compression, decompression, and packaging of the video data to save the storage space and the bandwidth for transmission over the Internet.

The target applications and services include but are not limited to Internet Protocol television (IPTV), IP-based video conference, IP-based surveillance, user-generated multimedia content, and other video/audio-enabled services and applications such as digital television broadcasting, digital storage media, and communication.