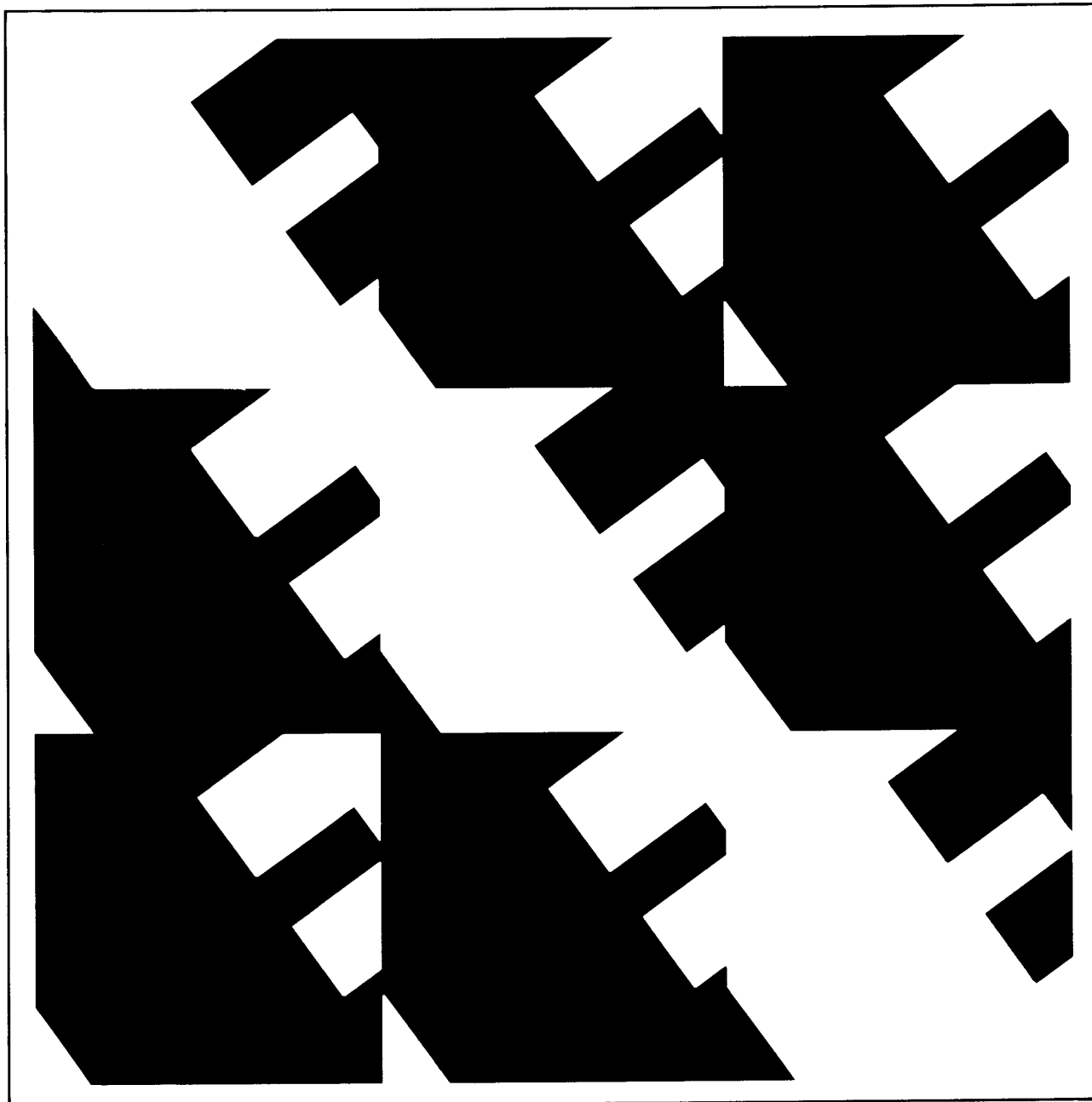


IEEE Standard Definitions of Primary Ferroelectric Terms



ANSI/IEEE Std 180-1986



Published by The Institute of Electrical and Electronics Engineers, Inc. 345 East 47th Street, New York, NY 10017, USA

June 2, 1986

SH10553



Documents

Document Sharing Hub

Authorized licensed use limited to: Tsinghua University. Downloaded on February 25, 2026 at 00:35:08 UTC from IEEE Xplore. Restrictions apply.

An American National Standard
**IEEE Standard Definitions of
Primary Ferroelectric Terms**

Sponsor

**Group on Sonics and Ultrasonics of the
IEEE Ultrasonics, Ferroelectrics and
Frequency Control Society**

Approved June 13, 1985

IEEE Standards Board

Approved November 5, 1985

American National Standards Institute

© Copyright 1986 by

**The Institute of Electrical and Electronics Engineers, Inc
345 East 47th Street, New York, NY 10017, USA**

*No part of this publication may be reproduced in any form,
in an electronic retrieval system or otherwise,
without the prior permission of the publisher.*

IEEE Standards documents are developed within the Technical Committees of the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Board. Members of the committees serve voluntarily and without compensation. They are not necessarily members of the Institute. The standards developed within IEEE represent a consensus of the broad expertise on the subject within the Institute as well as those activities outside of IEEE which have expressed an interest in participating in the development of the standard.

Use of an IEEE Standard is wholly voluntary. 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 once every five years for revision or reaffirmation. When a document is more than five years old, and has not been reaffirmed, 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.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of member affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments.

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 all 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 technical committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE Standards Board
345 East 47th Street
New York, NY 10017
USA

Foreword

(This Foreword is not a part of ANSI/IEEE Std 180-1986, IEEE Standard Definitions of Primary Ferroelectric Terms.)

Compared to some of the older areas of specialization found within the IEEE organization, ferroelectrics is a relatively new field. The first standard covering the definitions of ferroelectric terms was IEEE Std 180-1962 (R1971), prepared by Subcommittee 14.1 on Ferroelectric Crystals under the chairmanship of J. H. Armstrong and approved in 1962 as an IRE standard. IEEE Std 180-1962 continued in force until the publication of the present standard, which replaces it.

During the 20 years that have elapsed since the publication of the original standard, the field of ferroelectrics has enlarged substantially. New materials have been developed, new technical terms have come into use, and even new concepts have arisen. Consequently, there is a genuine need for a new standard, and the present document represents the efforts of the IEEE Committee on Ferroelectrics to meet this need.

The major emphasis in this standard is on the definition of terms. When particular terms are related to experimental measurements, the basic measuring techniques are briefly described. However, the discussions of measuring techniques are given with the intention of being recommended practices or guides rather than mandatory requirements.

Within the IEEE family of standards, there appear to be three standards that are closely related to this one: ANSI/IEEE Std 176-1978, IEEE Standard on Piezoelectricity; IEEE Std 319-1971, IEEE Standard on Magnetostrictive Materials: Piezomagnetic Nomenclature; and ANSI/IEEE Std 268-1982, American National Standard Metric Practice. The preparation of this standard was carried out with an awareness of the existence of the three related standards and an intention to keep the usage of symbols and terminology as mutually consistent as possible.

At the time of preparation of the final draft of this standard, the membership of the Ferroelectrics Subcommittee on Standards was as follows:

A. H. Meitzler, *Chairman*

J. P. Dougherty
C. E. Land

S. T. Liu
M. A. Marcus

Earlier draft versions of this standard benefited from substantial contributions by L. E. Cross, J. P. Dougherty, S. K. Kurtz, C. E. Land, and C. F. Pulvari; these five specialists in ferroelectricity deserve a large share of the credit for the existence of this standard. Other members of the parent Committee on Ferroelectrics who made notable contributions to the discussion and development of this standard include the following:

J. T. Cutchen
A. M. Glass
G. H. Haertling
R. L. Holman

W. N. Lawless
I. Lefkowitz*
R. C. Pohanka
W. A. Smith

*deceased

G. W. Taylor

The Committee on Ferroelectrics is a standing committee of the IEEE Sonics and Ultrasonics Group.

The following persons were on the balloting committee that approved this document for submission to the IEEE Standards Board:

Norman Berg
Phillip Bloomfield
Gerald Burns
C. Fred Clark
L. Eric Cross
J. T. Cutchen
J. P. Dougherty
Errol P. EerNisse
Lynn E. Garn
Robert Gerson

A. M. Glass
G. H. Haertling
R. L. Holman
S. K. Kurtz
C. E. Land
W. N. Lawless
S. T. Liu
M. A. Marcus
A. H. Meitzler
Robert E. Newnham

David A. Payne
R. C. Pohanka
C. F. Pulvari
V. Hugo Schmidt
W. A. Smith
Donald M. Smyth
Robert C. Sundahl, Jr.
George W. Taylor
Harry F. Tiersten
Van Wood

When the IEEE Standards Board approved this standard on June 13, 1985, it had the following membership:

John E. May, *Chairman*

Sava I. Sherr, *Secretary*

John P. Riganati, *Vice Chairman*

James H. Beall
Fletcher J. Buckley
Rene Castenschiold
Edward Chelotti
Edward J. Cohen
Paul G. Cummings
Donald C. Fleckenstein

Jay Forster
Daniel L. Goldberg
Kenneth D. Hendrix
Irvin N. Howell
Jack Kinn
Joseph L. Koepfinger*
Irving Kolodny
R. F. Lawrence

Lawrence V. McCall
Donald T. Michael*
Frank L. Rose
Clifford O. Swanson
J. Richard Weger
W. B. Wilkens
Charles J. Wylie

*Member emeritus

Contents

SECTION	PAGE
1. Introduction and References	7
1.1 Introduction	7
1.1.1 Discussion of Ferroic Materials	7
1.1.2 Hierarchy Among Piezoelectric, Pyroelectric, and Ferroelectric Materials	7
1.1.2.1. Polar Axis	7
1.1.2.2. Pyroelectric Effect	8
1.1.3 Symbols and Units	8
1.2 References.....	9
2. Ferroelectric Materials: Definitions and Measuring Techniques	9
2.1 Ferroelectric Materials	9
2.2 Polarization	9
2.2.1 Permittivity.....	9
2.2.2 Spontaneous Polarization	9
2.2.3 Measurement of Spontaneous Polarization	10
2.2.4 Depolarization Fields	12
2.3 Ferroelectric Domains	12
2.3.1 Remanent Polarization	12
2.3.2 Poling and Switching	13
2.3.3 Coercive Field	14
2.3.4 Differential Permittivity	14
2.4 Phase Transitions	14
2.4.1 Ferroelectric Curie Point, T_C	15
2.4.2 Proper Ferroelectric	15
2.4.3 Improper Ferroelectric	15
2.4.4 Order Parameter.....	15
2.4.5 Paraelectric Phase	15
2.4.6 Curie-Weiss Temperature.....	16
2.4.7 Order of the Phase Transition	16
2.4.8 Prototype Phase	17
2.4.9 Types of Phase Transitions.....	17
2.4.10 Diffuse Ferroelectrics	17
3. Antiferroelectric Materials	17
4. Ferroelectric Ceramics and Ferroelectric Polymers: Definitions and Measuring Techniques	18
4.1 Ferroelectric Ceramics	18
4.2 Ferroelectric Polymers	18
4.3 Poling and Switching	19
4.4 Ferroelectric Glass-Ceramics	19
5. Ferroelastic Materials: Definitions	19
5.1 Ferroelastic Crystals	19
5.2 Spontaneous Strain	19
5.3 Ferroelastic Domains and Switching	19
5.4 Praelastic Phase	20
6. Coexistence of Ferroic Properties.....	20
7. Bibliography	20

FIGURES	PAGE
Fig 1 Polar Prototype Phase, Tetragonal (4mm)	10
Fig 2 Ferroelectric Phase in the Monoclinic Symmetry (m), Which Was Derived from the Tetragonal Prototype Phase	10
Fig 3 Demonstration of How the Change in a Pyroelectric Vector Can Be in a Direction Different from That of the Spontaneous Polarization Vector	11
Fig 4 Charge Integration Methods for Measuring Spontaneous Polarization	11
Fig 5 Sawyer and Tower Circuit for Observing Hysteresis Loops of Ferroelectric Materials	12
Fig 6 Polarization, Capacitive, and Resistive Contributions to the Hysteresis Loop for a Sinusoidal Drive Voltage Applied to the Circuit of Fig 5	13
Fig 7 Spontaneous Polarization versus Electric Field Hysteresis Loop	14
Fig 8 Variation of Switching Current Transient with Field ($E_1 > E_2 > E_3 > E_4$)	14
Fig 9 Plot of $1/\kappa$ versus T , Demonstrating Curie-Weiss Behavior	16
Fig 10 Polarization-Electric Field Characteristic for an Antiferroelectric Material	18
 TABLES	 PAGE
Table 1 List of Symbols and Units	8
Table 2 Relationship Between Ideal Single-Crystal Polarization P_s and Expected Ceramic Polarization $\bar{P}$	19