



BSI Standards Publication

Superconductivity

Part 22-2: Normal state resistance and critical current measurement — High- T_c Josephson junction

National foreword

This British Standard is the UK implementation of EN IEC 61788-22-2:2021. It is identical to IEC 61788-22-2:2021.

The UK participation in its preparation was entrusted to Technical Committee L/-/90, Super Conductivity.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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(IEC 61788-22-2:2021)

Supraconductivité - Partie 22-2: Mesure de la résistance à
l'état normal et du courant critique - Jonction Josephson à
 T_C élevée
(IEC 61788-22-2:2021)

Supraleitfähigkeit - Teil 22-2: Messung des
Normalleitungswiderstands und des kritischen Stroms -
HTS Josephson Kontakt
(IEC 61788-22-2:2021)

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Comité Européen de Normalisation Electrotechnique
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European foreword

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Annex ZA

(normative)

Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 61788-22-1	-	Superconductivity - Part 22-1: Superconducting electronic devices - Generic specification for sensors and detectors	EN 61788-22-1	-
IEC 60050-815	2015	International Electrotechnical Vocabulary - Part 815: Superconductivity	-	-
IEC 60617	-	Graphical symbols for diagrams	-	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SUPERCONDUCTIVITY –

Part 22-2: Normal state resistance and critical current measurement – High- T_c Josephson junction

FOREWORD

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The text of this International Standard is based on the following documents:

FDIS	Report on voting
90/484/FDIS	90/486/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 61788 series, published under the general title *Superconductivity*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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- withdrawn,
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- amended.

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INTRODUCTION

IEC 61788-22 (all parts) is a series of International Standards on superconductor electronic devices. Superconductivity offers various possibilities of realizing sensors and detectors for a variety of measurands. Several types of superconductor sensors and detectors have been developed, using such features as superconducting energy gaps, sharp normal-superconducting transition, nonlinear current-voltage characteristics, superconducting coherent states and quantization of magnetic flux. Superconductors are influenced by interaction with electromagnetic fields, photons, ions, etc. The superconductor sensors and detectors have extremely high performance in resolution, time response and sensitivity, which cannot be realized by any other sensors and detectors.

IEC 61788-22-1 lists various types of superconductor sensors and detectors. A key element of some sensors and detectors is Josephson junction. The superconductor material types used for Josephson junctions are divided into two categories: low- T_c superconductor (LTS) and high- T_c superconductor (HTS). This document (IEC 61788-22-2) defines a measurement method of normal state resistance (R_n) and intrinsic critical current (I_{ci}) of HTS Josephson junctions, which are used for magnetic measurement with superconductor quantum interference device (SQUID), detection of millimetre to terahertz band radiation and other applications.

The measurement method covered in this document is intended to give an appropriate and agreeable technical base for those engineers working in the field of superconductor technology. Although the mechanism of high- T_c superconductivity is under investigation, the occurrence of the Josephson effect in such weak link structures as bicrystal, step-edge and ramp edge is reliable, and characteristic parameters for conventional LTS Josephson junctions are valid also for HTS Josephson junctions. The important parameters of HTS Josephson junctions for designing superconductor devices are normal state resistance (R_n) and critical current (I_c), which are combined as $I_c R_n$ product that is obtained experimentally. At this moment, most HTS Josephson junctions exhibit a non-hysteretic characteristic voltage-current ($U-I$) curve, which is typical for superconductor/normal-conductor/superconductor (SNS) junctions. On $U-I$ curves, two types of distortions are often observed: noise-rounding and self-heating effects. Especially, maximum current values without voltage drop on the $U-I$ curves are often considerably reduced because of the noise-rounding effect, and therefore it is difficult to estimate an intrinsic critical current value. This document provides a method to obtain intrinsic values by selecting a data set range to eliminate the distortions and by fitting a model function even when two effects are present.

The critical current obtained by this standard method is therefore called intrinsic critical current with the variable symbol of I_{ci} , eliminating the noise-rounding effect on $U-I$ curves. On the other hand, the normal state resistance is insensitive to the noise rounding and it is possible to avoid the self-heating effect, so that the variable symbol R_n is used. The $I_{ci} R_n$ product is more essential for designing superconductor devices than the $I_c R_n$ product. I_{ci} values estimated by this document are usually higher than experimental I_c values.

Practical application of this document to HTS Josephson junctions is shown in Annex A. The estimation method in this document is applied to SNS-type LTS Josephson junctions to check universality in Annex B.

SUPERCONDUCTIVITY –

Part 22-2: Normal state resistance and critical current measurement – High- T_c Josephson junction

1 Scope

This part of IEC 61788 is applicable to high- T_c Josephson junctions. It specifies terms, definitions, symbols and the measurement and estimation method for normal state resistance (R_n) and intrinsic critical current (I_{ci}), based on a combination of selecting a data set from measured U - I curves with a geometric mean criterion and fitting a hyperbolic function to that data set.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61788-22-1, *Superconductivity – Part 22-1: Superconducting electronic devices – Generic specification for sensors and detectors*

IEC 60617, *Graphical symbols for diagrams*: available at <http://std.iec.ch/iec60617>

IEC 60050-815:2015, *International Electrotechnical Vocabulary – Part 815: Superconductivity*: (available at <http://www.electropedia.org/>)

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

U - I characteristic curve

V - I characteristic curve

I - V characteristic curve

data set of voltage drop between two superconductors of a Josephson junction and current applied to the junction

3.2 normal state resistance

R_n

normal resistance

resistance between two superconductors forming a Josephson junction in a normal-conducting state

Note 1 to entry: In a Josephson bridge junction, a normal state resistance is also defined as the resistance at a bias current that suppresses superconductivity well above critical current, when the self-heating effect is negligible.

Note 2 to entry: In a Josephson tunnel junction, a normal state resistance is also defined as the tunnelling resistance at a bias voltage well above $2\Delta/e$, where Δ is the energy gap and e is the elementary electric charge, when the self-heating effect is negligible.

3.3 intrinsic critical current

I_{ci}

maximum direct current that can be applied to a Josephson junction without causing a voltage drop across the junction in the absence of noise-rounding on a $U-I$ characteristic curve

Note 1 to entry: Critical current (I_c) is the maximum direct current value that can be applied to a Josephson junction experimentally so that it can be regarded as flowing without resistance (IEC 61788-22-1).

Note 2 to entry: The method described in this document estimates I_{ci} , the value of which is usually higher than I_c .

3.4 geometric mean

square root of the product of dU/dI and U/I obtained from a $U-I$ characteristic curve

3.5 noise-rounding effect

effect of noise on a $U-I$ characteristic curve

Note 1 to entry: The $U-I$ curve shape near I_{ci} is rounded from an ideal shape by the noise-rounding effect. Because of this, an I_c value is lower than the I_{ci} value.

3.6 self-heating effect

effect of power dissipation due to transport current applied to a Josephson junction on a $U-I$ characteristic curve

Note 1 to entry: The current generates heat, and a $U-I$ curve shape in a high current region well above I_{ci} deviates upward above a straight line corresponding to R_n .

4 Symbols

U voltage drop across two superconductors connected by a weak link

NOTE " V " can also be used.

I current flowing through two superconductors connected by a weak link

R_n normal state resistance

I_c experimental critical current

I_{ci} intrinsic critical current estimated by this document

$u_{A,R}$ type A standard uncertainty of R_n

$u_{A,I}$ type A standard uncertainty of I_{ci}

$u_{B,R}$ type B standard uncertainty of R_n