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Edition 5.0 2018-04
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INTERNATIONAL STANDARD

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Sound system equipment – Part 3: Amplifiers

IEC 60268-3:2018-04 RLV(en)

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Sound system equipment –
Part 3: Amplifiers

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SOUND SYSTEM EQUIPMENT –

Part 3: Amplifiers

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International Standard IEC 60268-3 has been prepared by IEC technical committee 100: Audio, video and multimedia systems and equipment.

This fifth edition cancels and replaces the fourth edition published in 2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) rated condition of digital input is newly specified;
b) tolerance of rated power supply is changed;
c) maximum effective output power is appended to output characteristics list;
d) "Terms, definitions and rated values" clause is complemented.

The text of this standard is based on the following documents:

CDV	Report on voting
100/2960/CDV	100/3069/RVC

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

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60268 series, published under the general title *Sound system equipment*, can be found on the IEC website.

This part of IEC 60268 shall be used in conjunction with IEC 60268-1:1985 and IEC 60268-2:1987.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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SOUND SYSTEM EQUIPMENT –

Part 3: Amplifiers

1 Scope

This part of IEC 60268 applies to analogue amplifiers, and the analogue parts of analogue/digital amplifiers, which form part of a sound system for professional or household applications. It specifies the characteristics that should be included in specifications of amplifiers and the corresponding methods of measurement.

NOTE The methods of measurement for digital amplifiers and similar equipment are given in IEC 61606 [1][1].

In general, the specified methods of measurement are those which are seen to be most directly related to the characteristics. This does not exclude the use of other methods that give equivalent results.

In general, the methods are based on the simplest measuring equipment which can provide useful results. This does not exclude the use of more complex equipment that can give higher accuracy and/or allow automatic measurement and recording of results.

Rated conditions and standard measuring conditions are specified in order to allow measurements to be reliably repeated.

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 60065:~~2001~~ 2014, *Audio, video and similar electronic apparatus – Safety requirements*
~~Amendment 1:2005~~
~~Amendment 2:2010~~

IEC 60268-1:1985, *Sound system equipment – Part 1: General*
IEC 60268-1:1985/AMD1:1988
IEC 60268-1:1985/AMD2:1988

IEC 60268-2:1987, *Sound system equipment – Part 2: Explanation of general terms and calculation methods*
Amendment 1:1991

IEC 60417:2002, *Graphical symbols for use on equipment*
~~*Available from: http://www.graphical-symbols.info/equipment*~~ *– 12-month subscription to regularly updated online database comprising all graphical symbols published in IEC 60417*

IEC 60958:2016 (all parts), *Series, Digital audio interface*

[1] Numbers in square brackets refer to the Bibliography.

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IEC 61000-4-13:2002, *Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests*
IEC 61000-4-13:2002/AMD1:2009
IEC 61000-4-13:2002/AMD2:2015

IEC 61000-4-17:1999, *Electromagnetic Compatibility (EMC) – Part 4-17: Testing and measurement techniques – Ripple on d.c. input power port immunity test*
IEC 61000-4-17:1999/AMD1:2001
IEC 61000-4-17:1999/AMD2:2008

IEC 61000-4-29:2000, *Electromagnetic Compatibility (EMC) – Part 4-29: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations on d.c. input power ports immunity tests*

IEC 61606-1:2009, *Audio and audiovisual equipment – Digital audio parts – Basic measurement methods of audio characteristics – Part 1: General*

IEC 61883-6:2014, *Consumer audio/video equipment – Digital interface – Part 6: Audio and music data transmission protocol*

~~IEC 61938:1996, *Audio, video and audiovisual systems – Interconnections and matching values – Preferred matching values of analogue signals*~~

IEC 61938:2013, *Multimedia systems – Guide to the recommended characteristics of analogue interfaces to achieve interoperability*

3 Terms, definitions and rated values

3.1 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

3.1.1
class A
class of operation in which the current in each active device supplying the load current is greater than zero throughout each cycle of the signal for all values of load current up to, and including, the value determined by the rated output power or voltage and the rated load impedance

3.1.2
class B
class of operation in which the current in each active device supplying the load current is equal to zero for exactly one-half of each cycle of load current

Note 1 to entry: In common usage, the term Class B is extended to the case where current flows for slightly more than one half-cycle.

Note 2 to entry: Classes G and H are modifications of class B with improved efficiency.

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3.1.3
class AB
class of operation in which the current in at least one of the active devices supplying the load current is zero for some part of each cycle of load current for some range of values of load current not exceeding the value defined by the rated output power or voltage and the rated load impedance

Note 1 to entry: At sufficiently low signal levels, a Class AB amplifier usually operates in Class A.

3.1.4
class D
class of operation in which all active power devices are switched between fully on and fully off at a rate faster than the highest frequency of interest, and where the wanted signal is encoded in the switching pattern

Note 1 to entry: Other classes of operation have been commercialized but no formal definitions of such classes have been submitted for standardization.

3.2 Rated values

A full explanation of the term "rated" is given in IEC 60268-2.

The rated conditions for amplifiers are:

– rated power supply voltage;
– rated source impedance;
– rated source e.m.f.;
– rated load impedance;
– rated total harmonic distortion, or rated (distortion-limited) output voltage or power;
– rated mechanical and climatic conditions.

NOTE 1 Total harmonic distortion and (distortion-limited) output voltage or power are interdependent. Both cannot be taken as rated conditions simultaneously because normally a given sample amplifier produces less than rated total harmonic distortion at rated output voltage or power.

NOTE 2 If the power supply frequency is critical, it is also a rated condition.

To obtain the correct conditions for measurements, the values for the above-mentioned rated conditions shall be taken from the manufacturer's specification. These values themselves are not subject to measurement but they constitute the basis for measuring the other characteristics.

Methods of measurement for these other characteristics are given in this document and the manufacturer is either required or permitted to state 'rated values' for these characteristics in the specification of the equipment. These include

– rated voltage gain;
– rated distortion limited output voltage or power (when not adopted as a rated condition);
– rated signal-to-noise ratio;
– rated equivalent noise source e.m.f.

4 Conditions

4.1 Rated conditions and standard measuring conditions

4.1.1 Overview

For convenience in specifying how amplifiers shall be set up for measurement, sets of conditions are specified in this document, under the titles of "Rated conditions" and "Standard measuring conditions".

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4.1.2 Rated conditions

4.1.2.1 Analogue input

An amplifier, considered as a four-terminal network with regard to a specified pair of input terminals and a specified pair of output terminals, shall be understood to be working under rated conditions when the following conditions are fulfilled:

a) the amplifier is connected to its rated power supply;

b) the source e.m.f. is connected in series with the rated source impedance to the input terminals;

NOTE 1 Multi-channel amplifiers can be specified with any number of channels driven, or all channels. See Annex B. The input signal can be applied simultaneously to all inputs of similar channels.

c) the output terminals are terminated with the rated load impedance;

NOTE 2 For the measurement of Class D amplifiers, the low pass filter can be connected between the analyser and the rated load impedance. The low pass filter (analogue) is given in IEC 61606-1 (see Figure 3).

d) the terminals which are not used during the measurement are terminated, if necessary, as specified by the manufacturer;

e) the source e.m.f. is a sinusoidal voltage equal to the rated source e.m.f. at an appropriate frequency. Unless there is a special reason to the contrary, this frequency shall be the standard reference frequency of 1 000 Hz according to IEC 60268-1.

   Such a reason could be that the standard reference frequency is outside or near the limit of the effective frequency range of the amplifier;

f) the volume control, if any, is set to such a position that the rated distortion-limited output voltage appears at the output terminals;

g) the tone controls, if any, are set to a specified position to give the specified frequency response, generally the flat frequency response;

h) the balance control(s), if any, is (are) set to the mechanical central position;

i) the rated mechanical and climatic conditions according to IEC 60268-1 are complied with.

Figure 1 shows block diagrams of amplifiers with some rated conditions stated.

Amplifiers for which the rated distortion-limited output power exceeds the rated temperature-limited output power are likely to be subject to overheating when operated under rated conditions for an extended period of time. For these amplifiers, rated conditions shall be maintained for no longer than can be tolerated by the amplifier.

4.1.2.2 Digital input

The amplifier and measuring instrument is connected as shown in Figure 2. The input signal is a digital audio signal and the output signal is an analogue signal. All the digital specifications are described in IEC 61606-1. The digital interface can be according to IEC 60958 or IEC 61883-6, or other interfaces having the same specification as in 3.1 of IEC 61606-1. The source e.m.f. for digital input is the signal level of the digital sine signal generator specified in 4.6.2 of IEC 61606-1:2009:

a) the amplifier is connected to its rated power supply;

b) input signal is adjusted to:

   – frequency: 997 Hz;

   – signal level: full-scale level.

NOTE 1 Multi-channel amplifiers can be specified with any number of channels driven, or all channels. See Annex B. The input signal can be applied simultaneously to all inputs of similar channels.

NOTE 2 The standard reference frequency of 997 Hz is according to 4.3 of IEC 61606-1:2009.

c) the output terminals are terminated with the rated load impedance;

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NOTE 3 For the measurement of Class D amplifiers, the low pass filter can be connected between the analyser and the rated load impedance. The low pass filter (analogue) is given in IEC 61606-1 (see Figure 2).

d) the terminals that are not used during the measurement are terminated, if necessary, as specified by the manufacturer;

e) the volume control, if any, is set to such a position that the rated distortion-limited output voltage appears at the output terminals;

f) the tone controls, if any, are set to a specified position to give the specified frequency response, generally the flat frequency response;

g) the balance control(s), if any, is (are) set to the mechanical central position;

h) the rated mechanical and climatic conditions according to IEC 60268-1 are complied with.

Amplifiers for which the rated distortion-limited output power exceeds the rated temperature-limited output power are likely to be subject to overheating when operated under rated conditions for an extended period of time. For these amplifiers, rated conditions shall be maintained for no longer than can be tolerated by the amplifier.

4.1.3 Standard measuring conditions

These are obtained by bringing the amplifier under rated conditions (see 4.1.2) and then reducing the source e.m.f. to a level of −10 dB referred to the rated source e.m.f.

4.2 Other conditions

If supplementary data of the amplifier are presented, applying to other than the rated or standard measuring conditions, for example at different frequencies or at different settings of controls, then the conditions shall be fully defined in the presentation. These conditions shall, if possible, be chosen according to the recommendations made in the relevant clauses of this document.

The procedures for supplementary measurements may be derived from the measurement procedures given for the standard conditions. If special precautions are necessary to ensure accuracy, these shall be indicated together with the measurement procedure involved.

5 Classes of operation

~~Class A: in which the current in each active device supplying the load current is greater than zero throughout each cycle of the signal for all values of load current up to and including the value determined by the rated output power or voltage and the rated load impedance.~~

~~Class B: in which the current in each active device supplying the load current is equal to zero for exactly one-half of each cycle of load current.~~

~~NOTE 1 In common usage, the term Class B is extended to the case where current flows for slightly more than one half-cycle.~~

~~NOTE 2 Classes G and H are modifications of class B with improved efficiency.~~

~~Class AB: in which the current in at least one of the active devices supplying the load current is zero for some part of each cycle of load current for some range of values of load current not exceeding the value defined by the rated output power or voltage and the rated load impedance.~~

~~NOTE 3 At sufficiently low signal levels, a Class AB amplifier usually operates in Class A.~~

~~Class D: in which all active power devices are switched between fully on and fully off at a rate faster than the highest frequency of interest, and where the wanted signal is encoded in the switching pattern.~~

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~~NOTE 4 Other classes of operation have been commercialized but no formal definitions of such classes have been submitted for standardization.~~

Amplifier classes are classified according to the operation of an amplifying stage. These classes are defined as Class A, Class B, Class AB and Class D; detailed definitions are given in 3.1.

6 Interchangeable parts

For type measurements, interchangeable parts shall have characteristics as close as is reasonably practicable to the mean characteristics specified for these parts.

For measurements on a particular sample, the interchangeable parts supplied with that amplifier shall be used.

7 Automatic controls

The amplifier may contain automatic control circuits such as limiters, compressors, expanders and electronic fader circuits. These circuits make certain characteristics of the amplifier dependent either on a signal passing through the amplifier itself or on an external control signal. When measuring the characteristics of such an amplifier, the automatic control circuits shall be disabled, except when measuring their characteristics.

8 Power supply

Measurements shall be made with the amplifier connected to rated power supply. Care shall be taken to maintain the power supply voltage at the rated value during the measurement. ~~If the manufacturer claims power supply voltage tolerances exceeding ±10 %, then the characteristics to be specified shall also be stated for the upper and lower limits of these tolerances.~~ The tolerance of the supply voltages should be ± 1 % or less. A tolerance of up to ± 10 % may be allowed if the results of the measurements are not noticeably affected.

Additional measurements may be made at the upper and lower limits claimed as tolerable for the power supply voltage, the power supply frequency and the a.c. power supply harmonics or the d.c. power supply ripple.

WARNING – The power supply voltage tolerances specified by the manufacturer shall not be exceeded.

9 Position of the volume controls

If a characteristic is measured at only one position of the volume control, the control shall be at the position corresponding to rated conditions (see 4.1.2), unless a maximum or minimum position of the control is inherent in the characteristic to be measured.

If the characteristic is to be measured for several settings of the volume control, then the position for rated conditions shall be included, other preferred settings being maximum, and −3 dB, −6 dB, −10 dB, −20 dB and −40 dB with respect to the setting for rated conditions.

Volume controls belonging to channels not being measured shall, if possible, be put in the minimum position, unless otherwise stated.

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10 Pre-conditioning for measurements

Before beginning measurements on an amplifier, it shall be operated under approximately standard measuring conditions for a period of 1 h, or as specified by the manufacturer.

Before operating the amplifier the manufacturer's instructions concerning initial operation should be studied.

The amplifier is then brought under standard measuring conditions (see 4.1.3). Due to internal heating, the output voltage may subsequently vary with time. Unless excessive, this effect is ignored during the pre-conditioning period. When the pre-conditioning period is over, the amplifier shall be brought under rated conditions or standard measuring conditions, as required.

11 Series of measurements

If a series of measurements is made, the amplifier should preferably be maintained under standard measuring conditions in the periods between measurements.

If the amplifier has to be put out of operation for an extended period between measurements, then pre-conditioning according to Clause 10 shall be repeated before each set of measurements, unless this can be shown to be unnecessary.

12 Variable consumption apparatus

Sound system equipment shall be considered as variable consumption apparatus if it contains one or more power amplifiers operating in the Class AB, B, or D modes, in which the d.c. power supply for the output stages is either electronically regulated by means of series control elements or is not regulated.

NOTE 1 Variable consumption apparatus is defined in IEC 60065:1976 [2] as "apparatus in which the power consumption can vary by more than 15 % due to changes in load impedances of the output circuit or in signal parameters", but no definition appears in later editions.

NOTE 2 Where the d.c. supply is regulated by shunt control elements, the power consumption is usually, if not always, substantially constant. The apparatus, however, behaves in some respects as a variable consumption apparatus, and, in particular, the text of 15.7.4.1 still applies.

All the measurements contained in this document may be performed on variable consumption apparatus, in most cases with no special problems. However, certain problems may occur in the measurement of hum and rated distortion-limited output power, and some additional measurements are valuable in assessing the performance of such apparatus (see the note of 15.6.3.1 and item c) of 15.14.3).

13 Marking

Principles for marking the terminals and controls are given in IEC 60268-1.

Marking may concern:

– personal safety and prevention of spread of fire, in the sense of IEC 60065;
– safety in case of faulty connections;
– indications relating to normal operation, according to IEC 60417.

[2] IEC 60065:1976, *Safety requirements for mains operated electronic and related apparatus for household and similar general use*

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Marking can neither prevent incorrect operation nor provide complete operating instructions. It therefore has to be considered in conjunction with adequate means for preventing dangerous or faulty operation, and with the directions for use included in the user's instructions. Care should be taken that marking is unambiguous and as clearly understandable as possible.

Terminals for the interconnection of equipment, which are inaccessible without the use of a tool when the equipment has been installed, shall be clearly and unambiguously identified with respect to the manufacturer's instructions for installation. It may be assumed that these instructions are to be read by adequately skilled personnel.

14 Operating environment

Measurements, especially those including temperature measurements, shall be carried out with the amplifier mounted in a situation similar to that in which it is to be used. Restrictions on mounting and special ventilation requirements shall be stated by the manufacturer and form part of the rated conditions (see 4.1.2). See also IEC 60065 or other appropriate IEC safety standard.

15 Characteristics to be specified, and their methods of measurement

15.1 Power supply characteristics

15.1.1 Characteristics to be specified

The following information shall (except where indicated as optional) be stated by the manufacturer in the locations indicated, for each pair of terminals to be connected to the power supply and for each position of the power supply voltage selector, if any:

a) the type of power supply (d.c. or a.c.); on the equipment and in the specification;

b) the rated power supply voltage (this is a rated condition, see 4.1.2); on the equipment and in the specification;

c) the power supply frequency or range of frequencies (this may be a rated condition, see 4.1.2); on the equipment and in the specification;

d) the power drawn, under rated conditions, expressed in watts; on the equipment and in the specification;

e) for variable consumption apparatus (see Clause 12), the power drawn from the power supply may optionally be expressed as a function of output voltage or power from zero to the rated value, with specified load impedances, including the rated load impedance. This characteristic is particularly of value for equipment which may be operated from batteries. It may be presented as a graph.

If, in items d) or e) above, the apparent power drawn is significantly greater than the true power, the apparent power should be stated in addition.

15.1.2 Method of measurement

The amplifier is brought under rated conditions. The power drawn from the power supply is measured in watts by means of a wattmeter:

a) with rated source e.m.f., see 15.5.3;

b) with the source e.m.f. according to standard measuring conditions;

c) for variable consumption apparatus, at various values of output voltage or power from zero to the rated value.

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15.2 Tolerance of (long-term) power supply voltage variations

15.2.1 Characteristic to be specified

The tolerance of power supply voltage variation, such that, for any power supply voltage within the stated limits:

a) the upper limit of working voltage is not exceeded for any condition of normal operation; this applies particularly to such components as semiconductor devices and electrolytic capacitors;

b) the tolerances of the heater voltage of electronic tubes used in the amplifier are not exceeded;

c) the maximum permissible temperature is not exceeded in any component when the amplifier works under standard measuring conditions – except as regards power supply voltage – for an extended period of time;

d) neither output nor gain is subject to excessive variations;

e) the signal-to-hum ratio is not reduced by more than 3 dB with respect to the rated value.

Amplifiers designed to take their power supply from the mains are generally not subject to power supply variations exceeding ± 10 %. Such variations do not generally require a special design of amplifier.

Amplifiers designed to take their power supply from batteries or small converters may be subject to larger variations of power supply voltage, which may be due to changing load, the temperature of batteries or the gradual decrease of battery voltage during life or discharge.

The rated value shall be stated by the manufacturer in the specification. If the manufacturer states that the amplifier tolerates power supply voltage variations not exceeding ± 10 %, then compliance with requirements a), b) and c) is considered to be within the scope of normal amplifier design. Compliance with requirements d) and e) shall be checked.

If the manufacturer states that the amplifier will tolerate power supply voltage variations exceeding ± 10 %, the specification shall give details of any special means for compensating such variations and the proper working of these means shall be checked if possible. Compliance with requirements a) to e) shall be checked.

15.2.2 Methods of measurement

15.2.2.1 Temperature

The amplifier is brought under standard measuring conditions.

a) If a rated temperature-limited output power is given, the source e.m.f. shall be adjusted so that this value of output power is obtained.

b) The power supply voltage is adjusted to the upper limit stated by the manufacturer and the source e.m.f. readjusted, if necessary, to restore the output power to the value specified in item a).

c) The amplifier shall be capable of working continuously under these conditions for at least 4 h without any component exceeding the maximum permissible temperature.

15.2.2.2 Variations of output and gain

The amplifier is brought under rated conditions, the total harmonic distortion being measured by the method given in 15.12.3.2.

a) The source e.m.f. E_s and the output voltage U_2 are measured.

b) The power supply voltage is varied step by step over the range specified by the manufacturer. For each value of the power supply voltage chosen, the source e.m.f. E_s is

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readjusted to obtain the initial total harmonic distortion, and the source e.m.f. E_s' and the output voltage U_2' are measured.

NOTE Over the range of permitted supply voltage, both E_s' and U_2' are usually substantially proportional to the power supply voltage, where no voltage regulation is provided.

15.2.2.3 Hum

The amplifier is brought under standard measuring conditions and the source e.m.f then reduced to zero.

a) The signal-to-hum ratio is measured as indicated in 15.14.

b) The power supply voltage is varied step by step over the range specified by the manufacturer. For each value of the power supply voltage chosen, the hum voltage at the output is measured and the signal-to-hum ratio computed. It is expressed as the ratio in decibels of the rated output voltage to the measured hum voltage.

15.3 Tolerance of power supply frequency variations

15.3.1 Characteristics to be specified

The tolerance of power supply frequency variation, such that, for any power supply frequency within the stated limits:

a) the maximum permissible temperature is not exceeded in any component when the amplifier is under standard measuring conditions – except as regards power supply frequency – for at least 4 h;

b) the output voltage and the total harmonic distortion of the amplifier are not subject to significant variations;

c) the signal-to-hum ratio is not reduced by more than 3 dB with respect to the rated value.

The manufacturer shall state the rated value in the specification.

Compliance with requirement a) is considered to be within the scope of normal amplifier design.

NOTE Increase in temperature of components might occur, particularly in the power supply portion, at the lower end of the power supply frequency range.

15.3.2 Methods of measurement

15.3.2.1 Variations of output voltage and total harmonic distortion

The amplifier is brought under rated conditions, the total harmonic distortion being measured by the method given in 15.12.4.2.

a) The source e.m.f. E_s and the output voltage U_2 are measured.

b) The power supply frequency is varied step by step over the range specified by the manufacturer. For each value of the power supply frequency chosen, the output voltage U_2' and the total harmonic distortion are measured.

c) Neither the voltage U_2' nor the total harmonic distortion shall be subject to significant variations within the specified power supply frequency range.

15.3.2.2 Hum

The method of measurement is as given in 15.2.2.3, except that the power supply frequency is varied instead of the power supply voltage.

NOTE The worst signal-to-hum ratio is generally found at the lower limit of power supply frequency.

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15.4 Tolerance of power supply harmonics and ripple

15.4.1 Characteristics to be specified

The following characteristics should be specified.

a) The tolerance of power supply harmonics, such that, within the stated tolerance range
   1) the variations of the rectified power supply voltage due to changes in the peak-to-r.m.s. ratio of power supply voltage do not exceed the variation due to the permissible power supply voltage variations specified according to 15.2.1;
   2) the signal-to-hum ratio is not reduced by more than 3 dB with respect to the rated value.

Requirement 1) implies that the tolerance of a.c. power supply harmonics does not exceed the smallest tolerance, either positive or negative, specified for the power supply voltage according to 15.2.1.

b) The tolerance of ripple on the d.c. power supply, such that, within the stated tolerance range
   1) the variations of the power supply voltage do not exceed the variation due to the permissible power supply voltage variations specified according to 15.2.1;
   2) the signal-to-noise ratio is not reduced by more than 3 dB with respect to the rated value.

The manufacturer may optionally state these tolerance ranges in the specification.

15.4.2 Methods of measurement

The methods of measurement are specified in other IEC standards:

a) Power supply harmonics

   See IEC 61000-4-13.

b) Ripple

   See IEC 61000-4-17.

c) Voltage dips, short interruptions and voltage variations

   See IEC 61000-4-29.

15.5 Input characteristics

15.5.1 Rated source impedance, characteristic to be specified

The internal impedance, stated by the manufacturer in the specification, of the source supplying the signal to the amplifier.

Unless otherwise specified, the rated source impedance is assumed to be a constant pure resistance.

NOTE The manufacturer can also give the range of source impedances which is considered tolerable in practice.

If the rated source impedance is not stated by the manufacturer, the appropriate impedance specified in IEC 61938 shall be used.

15.5.2 Input impedance

15.5.2.1 Characteristics to be specified

The internal impedance measured between the input terminals:

a) under standard measuring conditions; the rated value shall be stated in the specification;

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b) at other signal frequencies; this may optionally be stated in the specification, except where the variation with frequency may be important (such as for inputs for magnetic tape heads or pick-ups for analogue disc records), in which case sufficient additional data shall be given.

15.5.2.2 Methods of measurement

15.5.2.2.1 General

In the methods given in 15.5.2.2.2 and 15.5.2.2.3 the modulus of the input impedance is measured. If more information is required (such as the values of the components of an equivalent circuit representing the input impedance over a range of frequencies) then one of the methods given in 15.5.2.2.4 or 15.5.2.2.5 may be used.

15.5.2.2.2 Balanced input

The amplifier is brought under standard measuring conditions, using a source free from earth (or chassis), as shown in Figure 4 a).

a) The input voltage U_1 is measured by means of a voltmeter with balanced input, whose input impedance is high compared with the input impedance of the amplifier.

b) The amplifier is then substituted by a calibrated variable resistor, which is adjusted so that the voltmeter again reads U_1. The value of the variable resistor is then equal to the modulus of the input impedance of the amplifier at the standard reference frequency.

c) The measurement may be repeated at other signal frequencies, preferably standard one-third octave band centre frequencies (see IEC 60268-1).

If the input impedance of the amplifier is high compared with the rated source resistance, it is difficult to determine precisely the setting of the variable resistor which gives a voltmeter reading equal to U_1. In other words, the sensitivity of the method of measurement is low. This effect can be overcome by increasing the source impedance for this measurement, to a value of 10 or more times the rated source impedance.

The input impedance of the voltmeter also affects the sensitivity of the measurement. It should therefore be high compared with the parallel combination of the source impedance used for the measurement and the input impedance of the amplifier.

The position of the volume control may affect the input impedance. If so, the measurements should be repeated at different positions of the control and the positions reported with the results. The source e.m.f. should be adjusted to maintain the output voltage at 10 dB below the rated value, unless this would require the overload source e.m.f. to be exceeded.

15.5.2.2.3 Unbalanced input

The amplifier is brought under standard measuring conditions, the common input terminal being connected to earth (see Figure 4 b).

a) The input voltage U_1 is measured by means of a voltmeter, the input impedance of which is high compared with that of the amplifier.

b) The amplifier is then substituted by a calibrated variable resistor, which is adjusted so that the voltmeter again reads U_1. The value of the variable resistor is then equal to the modulus of the input impedance of the amplifier at the standard reference frequency.

c) The measurement may be repeated at other signal frequencies, preferably standard one-third octave band centre frequencies (see IEC 60268-1).

15.5.2.2.4 Measurement of input impedance using a bridge

The amplifier is brought under standard measuring conditions.

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a) The signal source is then replaced by the 'unknown' terminals of a suitable audio-frequency bridge. It is essential to ensure that the amplifier is not overloaded by the signal from the bridge.

NOTE 1 A suitable bridge has means for adjusting the voltage across the 'unknown' terminals (usually by adjusting the input voltage to the bridge network).

NOTE 2 For a balanced input, a high-quality unity-ratio transformer can be included between the bridge and the input terminals of the amplifier, or a battery-operated bridge could be used.

b) The bridge controls are adjusted to achieve balance, and the input impedance is then read from the controls.

15.5.2.2.5 Measurement of input impedance using two values of source resistance

The amplifier is brought under standard measuring conditions.

a) The gain-limited effective frequency range is then measured (see 15.11.2).
b) The measurement is repeated with a known value of source resistance, at least 10 times the rated input impedance, the source e.m.f. being increased to restore the output voltage to 10 dB below the rated value. The new value of source e.m.f. is noted.
c) The input impedance at any frequency can be calculated, using simple circuit theory, from the ratios of the source e.m.f.s and the ratios of the gains measured in steps a) and b), if the ratio of the gains is sufficiently large to give the required accuracy.

Approximate values can be calculated from the limit frequencies of the gain-limited effective frequency range determined in step b).

NOTE 1 At high frequencies, the input impedance can usually be represented quite accurately by the parallel combination of a resistor and a capacitor. At low frequencies, the input impedance might behave as a parallel combination of a resistor and an inductor or as a series combination of a resistor and a capacitor.

NOTE 2 This method involves assumptions that the input impedance is not influenced by the value of source resistance and that the resistive component of the input impedance is substantially independent of frequency. In some cases, one or both of these assumptions might not be justified.

15.5.3 Rated source e.m.f., characteristic to be specified

The e.m.f. stated by the manufacturer in the specification, which, when connected to the input terminals in series with the rated source impedance, gives rated distortion-limited output voltage across the rated load impedance at a specified, appropriate setting of the controls.

15.5.4 Minimum source e.m.f. for rated distortion-limited output voltage

15.5.4.1 Characteristic to be specified

The e.m.f. which, when connected to the input terminals in series with the rated source impedance, gives rated distortion-limited output voltage across the rated load impedance with the volume control(s), if any, set for maximum gain and the tone control(s), if any, set as specified for rated conditions.

If a volume control is provided, the rated source e.m.f. should obviously be equal to or greater than the minimum source e.m.f. for rated output voltage. If there is no volume control, the rated source e.m.f. is equal to the rated value of minimum source e.m.f. for rated output voltage.

The manufacturer may optionally state the rated value in the specification.

15.5.4.2 Method of measurement

The amplifier is brought under rated conditions.

a) The output voltage U_2 is measured.

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b) The volume control is adjusted for maximum gain and the source e.m.f. is readjusted to restore the initial output voltage.

c) The minimum source e.m.f. E_s is then measured.

15.6 Output characteristics

15.6.1 Rated load impedance, characteristic to be specified

The impedance, stated by the manufacturer in the specification and preferably marked on the equipment, to which the output terminals shall be connected for measuring purposes.

Unless otherwise specified by the manufacturer, the rated load impedance shall be assumed to be a constant pure resistance.

More than one value of rated impedance may be specified. The corresponding values of output voltage or power and rated total harmonic distortion shall be specified with each rated value of load impedance. They may be presented in a table, as in the following example:

Rated load impedance Ω	**Rated output power** W	**Rated THD** %
16 8 4	10 20 40	0,2 0,2 0,25

A range of values may be specified, provided the above data is given for the highest and lowest values of rated impedance, as follows:

Rated load impedance Ω	**Rated output power** W	**Rated THD** %
16 Any intermediate value 4	10 – 40	0,2 – 0,25

The amplifier shall meet the relevant electrical safety requirements (normally those specified in IEC 60065) for each value of rated load impedance.

15.6.2 Output source impedance

15.6.2.1 Characteristic to be specified

The internal impedance measured between the output terminals under specified conditions. The manufacturer shall state the rated value in the specification.

15.6.2.2 Method of measurement

The amplifier is brought under standard measuring conditions. Then the source e.m.f. is reduced to zero and the rated load impedance is disconnected.

a) A sinusoidal current source of internal impedance at least 10 times the expected value of the output source impedance is connected, in series with an ammeter, to the output terminals of the amplifier. A voltmeter is also connected to the output terminals. The current is then adjusted to the value which would flow through the output terminals under standard measuring conditions.

b) The value of this current may be calculated as the current which would produce a voltage level of −10 dB referred to the rated (distortion-limited) output voltage across the rated load impedance.

c) The voltage across the output terminals U_2 is then measured.

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d) The measurement may be repeated at other signal frequencies.

e) The output source impedance is then calculated according to the following formula:

$$|Z| = U_2/I_2$$

NOTE 1 The current source can consist of an audio power amplifier with a suitable resistor in series with its output terminals. The amplifier is supplied with a sinusoidal signal from an oscillator. The ammeter can consist of a low-value resistor (for example 0,1 Ω) in series with the output terminals of the current source, the voltage across the resistor being measured with a sensitive voltmeter.

NOTE 2 The output source impedance of an amplifier is in general not a pure resistance, but for many purposes it is sufficient to measure the modulus as given above.

15.6.3 Output voltage and power (distortion-limited)

15.6.3.1 Characteristics to be specified

The following characteristics shall be specified:

a) Distortion-limited output voltage. The r.m.s. voltage, measured across the rated load-impedance, at which rated total harmonic distortion is produced.

b) Distortion-limited output power. The power produced in the rated load impedance by the distortion-limited output voltage:

$$P_2 = U_2^2/R_2$$

where

P_2 is the distortion-limited output power;

U_2 is the distortion-limited output voltage;

R_2 is the rated load impedance.

c) Distortion-limited output voltage with complex (that is, partially or wholly reactive) load impedance. The voltage, measured across a stated complex load impedance, at which rated total harmonic distortion, or another stated value of total harmonic distortion, is produced.

The stated complex load impedance shall be chosen having regard to the actual load impedance likely to be presented to the amplifier when in use.

A typical loudspeaker or a network simulating the impedance of a typical loudspeaker may be used, but due to the wide variations in actual load impedance that occur in practice, no preferred values can be given.

These characteristics may be expressed directly in volts or watts respectively, or may be expressed in decibels, preferably referred to 1 V or 1 W; the reference level shall be stated.

If the characteristic is specified at a single frequency, that frequency shall be the standard reference frequency (see 4.1.2).

Rated values for some or all of the above characteristics shall be stated by the manufacturer in the specification, and preferably marked on the equipment, for each rated value of load impedance.

Where no confusion can arise between these characteristics and those specified according to 15.7.2, the words "distortion-limited" may be omitted, but it is preferable to retain them.

NOTE If the d.c. supply to the amplifier output stage is not stabilized the supply voltage decreases as the source e.m.f. is increased. Some amplifiers are designed and set up in such a way that under continuous signal conditions the output waveform is unsymmetrically limited due to this decrease in supply voltage. When amplifying speech

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and music signals, the decrease in supply voltage might be much less, so that symmetrical limiting occurs, with consequent reduction in even-harmonic distortion.

15.6.3.2 Method of measurement

The amplifier is brought under rated conditions, using the appropriate load impedance and a suitable harmonic distortion measuring device connected at the output terminals (see 15.12).

a) The amplifier is operated under these conditions during a period exceeding 60 s. Then the source e.m.f. is readjusted, if necessary, so that rated total harmonic distortion is produced.

b) The output voltage U_2 is measured; this voltage is stated as the (distortion-limited) output voltage. The (distortion-limited) output power is calculated according to the formula in 15.6.3.1 b).

c) For multi-channel amplifiers measured by one channel driven independently, the number of operated channel conditions should be stated by the manufacturer in the specification. The measurements may, in addition, be repeated with only one channel driven. For multi-channel amplifiers operated by several channels simultaneously, the measurements shall be made on each channel in turn, while all other channels continue to operate under rated conditions. Small changes in output voltage and/or distortion of these other channels due to temperature effects during the measuring period shall be neglected.

d) The measurements may be repeated at other frequencies and for other rated values of load impedance and with complex load impedance (see also 15.11.3.1 and 15.12.4.1). The measurements may also be repeated for other values of total harmonic distortion such as those specified in other IEC standards. The measurements may, in addition, be repeated with only one channel driven.

e) The (distortion-limited) output voltage or power shall be stated for each channel separately, together with the signal frequency, the rated total harmonic distortion and the appropriate rated load impedance.

NOTE Multi-channel amplifiers can be specified with any number of channels driven, or all channels. See Annex B.

15.6.4 Maximum effective output power (distortion-limited at 10 %)

15.6.4.1 Characteristics to be specified

The following characteristics shall be specified:

a) The r.m.s. voltage, measured across the rated load-impedance, at which the total harmonic distortion at 10 % is produced.

b) Maximum effective output power. The power produced in the rated load impedance by the distortion-limited at 10 % output voltage:

$$P_2 = U_2^2/R_2$$

where

P_2 is the maximum effective output power;

U_2 is the total harmonic distortion at 10 % output voltage;

R_2 is the rated load impedance.

c) Distortion-limited at 10 % output voltage with complex (that is, partially or wholly reactive) load impedance. The voltage, measured across a stated complex load impedance, at which total harmonic distortion at 10 %, is produced.

The stated complex load impedance shall be chosen having regard to the actual load impedance likely to be presented to the amplifier when in use.

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A typical loudspeaker or a network simulating the impedance of a typical loudspeaker may be used, but due to the wide variations in actual load impedance that occur in practice, no preferred values can be given.

These characteristics are expressed directly in watts.

If the characteristic is specified at a single frequency, that frequency shall be the standard reference frequency (see 4.1.2).

The values of maximum effective output power shall be shown it by maximum effective output power (MEOP)

NOTE Maximum effective output power is not same as “rated output power”, “distortion-limited” and “short-term maximum output voltage and power”, the values need to be clarified by this measurement method. i.e. P =100 W (MEOP)

15.6.4.2 Method of measurement

The amplifier is brought under rated conditions, using the appropriate load impedance and a suitable harmonic distortion measuring device connected at the output terminals (see 15.12).

a) The amplifier is brought under the total harmonic distortion at 10 % output voltage after cool down. The amplifier is operated under these conditions during a measurable period. Then the source e.m.f. is readjusted, if necessary, so that the total harmonic distortion at 10 % is produced.

b) The output voltage U_2 is measured; this voltage is stated as the output voltage of the total harmonic distortion at 10 %. The total harmonic distortion at 10 % output power is calculated according to the formula in 15.6.3.1 b).

c) For multi-channel amplifiers measured by one channel driven independently, the number of operated channel conditions should be stated by the manufacturer in the specification. The measurements may, in addition, be repeated with only one channel driven. For multi-channel amplifiers operated by several channels simultaneously, the measurements shall be made on each channel in turn, while all other channels continue to operate under rated conditions. Small changes in output voltage and/or distortion of these other channels due to temperature effects during the measuring period shall be neglected.

d) In case of stereo amplifiers, the 2-channel amplifiers shall drive both channels at the same time. Maximum effective output power of stereo amplifiers shall be shown the values by 2 channels driven.

e) The measurements may be repeated at other frequencies and for other rated values of load impedance and with complex load impedance (see also 15.11.3.1 and 15.12.4.1). The measurements may also be repeated for other values of total harmonic distortion such as those specified in other IEC standards. The measurements may, in addition, be repeated with only one channel driven.

f) The power shall be stated for each channel separately, together with the signal frequency, the total harmonic distortion at 10% and the appropriate rated load impedance.

g) In case of the maximum total harmonic distortion under the 10 %, the maximum effective output power may use the maximum total harmonic distortion on the amplifier.

NOTE 1 Multi-channel amplifiers can be specified with any number of channels driven, or all channels. See Annex B.

NOTE 2 Maximum effective output power (distortion-limited at 10 %) is specified by JEITA CP-1301A [2].

15.6.5 Regulation

15.6.5.1 Characteristic to be specified

The increase in output voltage, expressed as a percentage, or as a regulation level in decibels, when, under standard measuring conditions, the rated load impedance is disconnected, the source e.m.f. remaining constant.

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The manufacturer may optionally state the rated value in the specification.

15.6.5.2 Method of measurement

The amplifier is brought under standard measuring conditions.

a) The output voltage U_2 is measured.

b) The load is disconnected, the source e.m.f. remaining constant, and the output voltage U_2' is measured.

c) The regulation is:

$$\frac{U_2' - U_2}{U_2} \times 100\ \%$$

The regulation level is 20 lg (U_2'/U_2)

NOTE The regulation and output source impedance might or might not be interrelated, depending on the design of the power supply circuit.

15.6.6 Overload restoring time

15.6.6.1 Characteristic to be specified

The time interval (which occurs after the amplifier working under standard measuring conditions is overloaded by a certain amount for a specified period) between the moment when the input voltage is restored to its original value and the moment when the output voltage has again reached its original value within specified limits (see Figure 5).

The manufacturer may optionally state the rated value in the specification.

15.6.6.2 Method of measurement

a) The amplifier is brought under standard measuring conditions.

b) The source e.m.f. is increased by 20 dB during a time interval of less than one-quarter period of the input signal and kept at this value for approximately 1 s.

c) The source e.m.f. is then reduced to its initial value during a time interval of less than one-quarter period of the input signal.

d) The time that passes before both the positive and the negative output peak voltages have reached their final value, within 1 dB unless otherwise specified, is measured by means of a suitable calibrated oscilloscope.

15.7 Limiting characteristics

15.7.1 Overload source e.m.f.

15.7.1.1 Characteristic to be specified

The maximum source e.m.f. for which an amplifier, connected as for rated conditions and with an appropriate setting of the volume control, can deliver an output voltage 10 dB below the rated distortion-limited output voltage without exceeding the rated total harmonic distortion.

The manufacturer shall state the rated value in the specification.

15.7.1.2 Method of measurement

The amplifier is brought under rated conditions.

a) A distortion meter is connected at the output terminals.

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b) The volume control is adjusted to obtain an output voltage U_2 of −10 dB referred to the rated output voltage.

c) The volume control is adjusted to successive positions for lower gain, increasing the source e.m.f. to restore the initial output voltage U_2, until rated total harmonic distortion is obtained.

d) The source e.m.f. E_s is measured.

15.7.2 Short-term maximum output voltage and power

NOTE See also the related clauses in IEC 60268-5 [3] and IEC 61938.

15.7.2.1 Characteristic to be specified

The maximum voltage or the corresponding power which the amplifier is capable of producing across, or dissipating in the rated load resistance (regardless of non-linearity) 1 s after the application of a specified short tone-burst signal. Each channel is operated independently.

It is recommended that the manufacturer state the rated value in the specification.

IMPORTANT

It is fundamental to the concept of this characteristic that, for all samples of a given amplifier, the measured value of short-term maximum output voltage or power shall not exceed the value stated by the manufacturer.

15.7.2.2 Method of measurement

The amplifier is brought under rated conditions with a true r.m.s.-responding level recorder connected to the output terminals.

a) The source e.m.f. is then applied to the amplifier under test in the form of a sinusoidal tone burst of 1 s duration and the output voltage U_2 of the amplifier at the time 1 s from the start of the pulse is measured from the level recorder chart. The frequency of the tone burst shall be 1 kHz unless otherwise stated.

NOTE A 1 s burst of the noise signal simulating normal programme material (see IEC 60268-1) can be used if more convenient.

b) The source e.m.f. is then increased until the measured output voltage U_2 reaches the maximum.

c) The value U_2 is then the short-term maximum output voltage and U_2^2/R_2 is the short-term maximum output power where R_2 is the rated load impedance.

d) If the test is repeated, the repetition period of the signal pulses shall be 60 s or greater.

15.7.2.3 Values of load impedance to be used for the test

If the manufacturer states a range of rated load impedances the tests shall be carried out with the value of load impedance giving the highest value of short-term maximum output power, or short-term maximum output voltage. If the manufacturer does not state a rated short-term output voltage, the value shall be measured with a load impedance of 16 Ω, for household equipment and the like, rated in terms of the voltage or power delivered to a specified load impedance or range of load impedances.

If the manufacturer specifies the amplifier in terms of the power delivered at a specified output voltage, (such as 100 V or 70 V, for 'voltage line operation'), the short-term maximum output voltage shall be measured with no load.

15.7.3 Long-term maximum output voltage and power

NOTE See also the related clauses in IEC 60268-5 [3] and IEC 61938.

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15.7.3.1 Characteristic to be specified

The maximum voltage or the corresponding power which the amplifier is capable of producing across, or dissipating in the rated load resistance 1 min after the application of a noise input signal simulating normal programme material (see IEC 60268-1). One channel is driven at a time.

It is recommended that the manufacturer state the rated value in the specification.

IMPORTANT

It is fundamental to the concept of this characteristic that for all samples of a given amplifier the measured value of long-term maximum output voltage or power shall not exceed the value stated by the manufacturer.

15.7.3.2 Method of measurement

The amplifier is brought under rated conditions with a true r.m.s. voltmeter connected to the output terminals of the apparatus.

a) The signal source is replaced by a source of the simulated programme signal (see IEC 60268-1) whose e.m.f. is at least 10 times the rated source e.m.f. of the amplifier.

b) The output voltage U_2 is measured 1 min after the application of the signal.

c) The value U_2 is then the long-term maximum output voltage and U_2^2/R_2 is the long-term maximum output power where R_2 is the rated load impedance.

d) The signal should be applied for a period no longer than that required for the test.

15.7.3.3 Value of load impedance to be used for the test

If the manufacturer states a range of rated load impedances the tests shall be carried out with the value of load impedance giving the highest value of long-term maximum output power, or long-term maximum output voltage. If the manufacturer does not state a rated long-term output voltage, the value shall be measured with a load impedance of 16 Ω, for household equipment and the like, rated in terms of the voltage or power delivered to a specified load impedance or range of load impedances.

If the manufacturer specifies the amplifier in terms of the power delivered at a specified output voltage, (such as 100 V or 70 V, for 'voltage line operation'), the long-term maximum output voltage shall be measured with no load.

15.7.3.4 Protective devices

Protective devices within the amplifier may operate during the test, for example due to high temperature. If a non-self-resetting device operates, the value of output voltage or output power measured immediately before the operation of the device shall be taken as the result.

If an automatic resetting device operates, the highest output voltage or output power measured after the device has reset once shall be taken as the result.

15.7.4 Temperature-limited output power

15.7.4.1 Characteristic to be specified

The output power which the amplifier is capable of supplying continuously, at a specified ambient temperature, without exceeding the maximum permissible temperature in any component.

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When the amplifier is specified for different methods of mounting, for example, in enclosures or in racks, the corresponding rated temperature-limited output powers shall be stated by the manufacturer.

The rated temperature-limited output power may be less than the rated distortion-limited output power, because in Class AB, B, or D amplifiers, the active devices operating in these modes reach their maximum temperatures at output powers considerably less than the rated output power, and the temperature maxima of several devices may be reached at different output powers. Furthermore, where the d.c. supply to a stage is not stabilized, it is possible for temperature maxima of different values to occur at two values of output power.

Amplifiers for which this is the case are satisfactory for amplifying normal speech and music signals because of the amplitude/time characteristics of these signals (see 15.12.3.1, Note 1).

15.7.4.2 Method of measurement

Provisional tests at different output powers shall be made to determine the components which are likely to reach their limiting temperature. Appropriate thermometers are mounted on the components selected according to these provisional tests.

a) The amplifier, mounted in a specified way, is then brought under standard measuring conditions except that the power supply voltage is adjusted to the upper limit of tolerance of the rated power supply voltage for which the amplifier is set (see 15.2). The ambient temperature shall be measured.

b) The source e.m.f. is adjusted in steps to increase the output voltage U_2, waiting after each step until the thermometer readings have become practically constant. This procedure is maintained until at a certain output voltage U_2' one of the components reaches its limit temperature.

c) The temperature limited output power is $U_2'^2/R_2$, where R_2 is the rated load impedance.

The amplifier shall have worked continuously for at least 4 h under the conditions specified before final temperature readings are made.

The manufacturer may optionally state the rated value in the specification.

15.8 Characteristics of protection circuits

15.8.1 General

Protection circuits in amplifiers may be classified as follows:

a) protection against excessive load current, or potentially damaging combinations of load voltage and current;

b) protection against the presence of d.c. voltage between the load terminals (d.c. offset protection);

c) protection against potentially damaging input signals (for example, excessive amplitude at high frequencies).

Protection of types a) and c) are mainly intended to protect the components of the amplifier. Protection of type b) may protect amplifier components, but is also intended to protect components in the load, such as loudspeaker voice-coils, which can be damaged by direct current (a situation which has been reported to give rise to safety hazards). The design of the d.c. protection circuit usually involves a compromise between sensitivity and speed of response. This is because the circuit should not respond to large-amplitude low-frequency signals, but should respond to a relatively small d.c. voltage. This is achieved by low-pass filtering, and the greater the attenuation of signal frequencies that this filter provides, the more sensitive the protection circuit can be made, but the slower it responds. The amplifier designer may choose a compromise which does not respond at all to a d.c. offset voltage which is small with respect to the d.c. supply voltage(s) of the amplifier circuit. However, such

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an offset voltage may produce a d.c. load current which impairs the performance of the loudspeakers used with the amplifier, and may result in damage to them. A different compromise may result in a protection circuit which does not respond quickly enough to prevent damage to the components of the load. For the above reasons, the characteristics of d.c. offset protection circuits should be included in amplifier specifications. At present, no methods of measurement of these characteristics are known that can be made without access to the internal circuits of the amplifier. Subclause 15.8.3 therefore gives methods which should be used only by the manufacturer, and consequently the names of the characteristics include the word 'rated'.

15.8.2 Protection against potentially damaging combinations of output voltage and current

15.8.2.1 Characteristic to be specified

The output current/output voltage characteristic of the amplifier, measured using the test signal and method described in 15.8.2.2 and 15.8.2.3 and presented graphically, with output voltage as abscissa and output current as ordinate.

If the amplifier does not incorporate protection circuits of the relevant type, the application of the test described below can cause damage.

The manufacturer is recommended to present these data in the specification.

15.8.2.2 Test signal and load network

The test signal consists of a sinusoidal signal whose frequency is 20 Hz, to which is added positive and negative pulses of 50 μs duration and 500 Hz repetition rate. The amplitude of the 20 Hz signal is chosen to drive the amplifier to its voltage clipping limits, while the amplitude of the pulses takes the amplifier alternately into its current-overload limits. A circuit for generating the test signal is given in the bibliography [4].

NOTE For amplifiers having a restricted effective frequency range, other suitable test frequencies can be chosen and stated with the results.

The load network, for amplifiers designed to feed low-impedance loudspeakers, consists of a 40 μF capacitor, in series with a 1 Ω resistor. For other amplifiers, the values may be scaled. The 40 μF capacitor limits the current due to the 20 Hz signal to a low value, whereas for the short pulses the effective load impedance is of the order of 1 Ω, and a high output current is produced.

Using this signal and load network, the measurement may be made without causing excessive dissipation in the amplifier. The dissipation in the 1 Ω resistor is much lower than the rated output power of the amplifier, because of the value of the output current duty cycle.

15.8.2.3 Method of measurement

a) The amplifier is brought under standard measuring conditions and the test circuit configuration is then changed to that shown in Figure 6a.

b) Adjust the oscilloscope sensitivities to 20 V/div for X-deflection and 5 V/div (equivalent to 5 A/div since the voltage is developed across a 1 Ω resistor) for Y-deflection (or other stated values if necessary).

c) With zero signal input, adjust the spot on the oscilloscope screen to the centre of the graticule.

d) Apply the 20 Hz signal and increase the input e.m.f. until the output voltage shows significant clipping.

e) Apply the pulse signal in addition, for as short a time as is necessary to record the display (for example, photographically). The input e.m.f. shall be adjusted so that hard current-limiting occurs, as shown by the display.

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f) Adjust the bright-up delay control for a clear display and record the display.

15.8.2.4 Presentation of results

The results are presented graphically, using scales of 20 V/div for the abscissa and 5 A/div for the ordinate. Other stated scales may be used if necessary. An example is given in Figure 6b.

NOTE Presentation as line-drawing might be preferable to direct reproduction of a photograph.

15.8.3 Characteristics of d.c. offset protection circuits

NOTE These characteristics do not apply to amplifiers with only capacitive coupling to the load terminals.

15.8.3.1 Characteristics to be specified

The following characteristics should be specified:

a) rated maximum offset voltage at the load terminals, stated by the manufacturer in the specification, that does not operate the protection circuit;

b) rated response time of the protection circuit, optionally stated by the manufacturer in the specification, to an offset voltage of 30 % of the highest d.c. supply voltage (see item d) of 15.8.3.2.1) of the amplifier output stage;

c) rated maximum residual d.c. voltage, optionally stated by the manufacturer in the specification, across the load terminals when the protection circuit is operating, or

d) rated maximum percentage of the rated output power, optionally stated by the manufacturer in the specification, represented by the rated maximum residual d.c. voltage.

If the values are different, depending on the presence or absence of a signal, or of different polarities of offset voltage, the higher value, and the corresponding signal condition and/or polarity of the offset voltage, shall be stated.

15.8.3.2 Methods of measurement

15.8.3.2.1 Methods of measurement for amplifiers which continuously sense the d.c. offset condition

The procedure is as follows:

a) The amplifier is brought under standard measuring conditions, and the input signal frequency is then changed to 20 Hz. A d.c. oscilloscope and a d.c. voltmeter are connected to the load terminals.

b) The d.c. balance of the amplifier is then slowly changed, by a suitable method which depends on the detailed design of the circuit and cannot be standardized, and the maximum reading on the d.c. voltmeter, before the protection circuit operates, is noted. This is the maximum offset voltage that does not operate the protection circuit.

c) The balance of the amplifier is then changed further in the same direction, so that the protection circuit operates. The maximum reading on the d.c. voltmeter, as the balance is changed towards maximum imbalance, is noted. This is the maximum residual d.c. voltage across the load terminals when the protection circuit is operating.

d) The d.c. balance of the amplifier is then restored to normal, and the source e.m.f. reduced to zero. By means of a suitable d.c. supply and switch, a d.c. voltage is applied to the internal circuits of the amplifier, which would produce, in the absence of the protection circuit, a d.c offset voltage at the load terminals of 30 % of the d.c. supply voltage of the output stage of the amplifier. If there is more than one supply voltage, the highest shall be chosen unless there is a reason for this choice not to be correct. By observation of the oscilloscope display, the time for the output voltage to fall to 110 % of its steady-state value after the application of the offset, or 1 V, whichever is greater, is measured. This is the response time of the protection circuit to an offset of 30 % of the d.c. supply voltage.

e) Items b) and c) are repeated with the input source e.m.f. reduced to zero.

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All the measurements are then repeated with d.c. offsets of the opposite polarity.

15.8.3.2.2 Methods of measurement for amplifiers which intermittently sense the d.c. offset condition

The same procedure as in 15.8.3.2.1 is followed, except that the test described in items a) to c) is only carried out with the input source e.m.f. set at zero. The measurements in items b) and c) shall be made after the protection circuit has operated several times, for example, after 60 s. A calibrated storage oscilloscope or equivalent is useful for observing the variation of the offset voltage and measuring its values.

In order to investigate fully the operation of the protection circuit, it may be necessary to carry out further tests, simulating component failures. The nature of the necessary tests may be decided by examining the circuit diagram of the amplifier.

15.9 Sustaining-time for rated (distortion-limited) output voltage or power

15.9.1 General

Clipping level is the level, expressed in decibels referred to a stated reference, of the output signal of an amplifier, above which the total harmonic distortion rises rapidly. Normally, the peaks of the waveform of a sinusoidal signal, displayed on an oscilloscope, become visibly clipped at this level.

The amplitude/time characteristics of speech and music signals are such that if an amplifier is operated with an uncompressed speech or music signal input, whose level is adjusted so that the output signal is just clipped on peaks, but not sufficiently to cause serious impairment of subjective sound quality, the average output signal level is approximately 10 dB below the clipping level. For the amplification of uncompressed speech and music signals therefore, there is no need for the amplifier to be able to reproduce signals at clipping level for more than a few tens of milliseconds.

However, sound system amplifiers may be called upon to reproduce tone signals and compressed speech and music signals. While, in a well-designed system, these signals should not greatly increase the time for which the amplifier may have to reproduce signals at clipping level (because this would involve loss of sound quality and increased heat-dissipation in loudspeakers), some increase is bound to occur, and high-level signals may occur by accident, for example, if a microphone is dropped. The amplifier also has to produce high-level signals during measurements according to this document (see 15.6.3, 15.7.2 and 15.7.3), and the time-period is specified in some of these subclauses. These measurements have to be carried out in order to produce a properly complete specification for the amplifier.

Another consideration is that the relationship between clipping level and the level of the rated (distortion-limited) output power or voltage varies very greatly from one type of amplifier to another, because the rated output power or voltage is decided by the manufacturer, taking many factors into account. See Table 1.

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Table 1 – Different rated total harmonic distortion and rated distortion-limited output power specifications for the same amplifier

Rated output power W	Rated total harmonic distortion %	Clipping level minus rated output level dB
100	10	−0,97
80	2	0,0
60	0,05	1,25
NOTE It is assumed in the above that 2 % total harmonic distortion corresponds to the clipping level; the exact value does not change the reasoning.		

It should be noted that the above three specifications relate to the same amplifier. The rated output voltage or power is thus NOT a reliable guide to the true output capabilities of an amplifier, which is why additional characteristics have been standardized in 15.7.2 and 15.7.3.

A further consideration is that operation for an extended period at an output level near the clipping level is likely to result in overheating; the heating effect is much less with speech and music signals, and results in the concept of temperature-limited output power (see 15.7.4). It should be noted that, for most amplifier designs, it is the power supply components, not the output stage devices, which overheat under high output power conditions. Protection against over-heating may be provided

– by automatic means which attenuate the input signal, thus allowing the amplifier to continue working more or less normally, or
– by automatic means which disconnect the load, thus preventing the amplifier from working normally but allowing it to continue to work normally when the high-level output is no longer demanded, or
– by the operation of fuses or cut-outs, which require an operator to replace or reset.

In applications such as sound systems for emergency purposes, it is essential that the amplifier continues to work normally under all possible conditions. It is therefore justified, in such cases, to require the time for which the amplifier can produce high-level output signals to be specified. It is not essential for this time to be specified if the amplifier is required for the normal reproduction of speech and music signals, especially in the context of household high-fidelity systems, where, in a properly designed and adjusted system, the amplifier should not be driven near, or into, clipping even for brief periods.

15.9.2 Characteristic to be specified

The time for which the amplifier can produce rated distortion-limited output voltage or power.

The rated value shall be stated by the manufacturer in the specification.

15.9.3 Method of measurement

WARNING: Some amplifiers may be seriously damaged by this test.

a) The method described in 15.6.3.2 is used, the amplifier being operated under rated conditions for a measured period of time, ending when the rated distortion-limited output power or voltage can no longer be achieved at the rated total harmonic distortion, or for 60 min, whichever is less.
b) Care shall be taken that the conditions of ventilation and any other means of cooling during the test are similar to those which occur when the amplifier is in normal use.
c) The results shall be expressed as the time, measured as in item a) above, in seconds or minutes, as appropriate, or as 'greater than 60 min', if that is the case.

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15.10 Gain

15.10.1 Voltage gain and e.m.f. gain

The manufacturer may use one of the following two methods for stating the rated value of gain in the specification, either as a direct ratio or in decibels.

a) The voltage gain, being the ratio of the output voltage U_2 to the input voltage U_1 under standard measuring conditions.

b) The e.m.f. gain, being the ratio of the output voltage U_2 to the source e.m.f. E_s under standard measuring conditions.

NOTE In item b), the difference between the voltage at the input terminals and the e.m.f. of the source is taken into account.

15.10.2 Maximum e.m.f. gain

15.10.2.1 Characteristic to be specified

The e.m.f. gain measured with the volume control set at the position for maximum gain and the source e.m.f. being set so as to restore the output voltage for standard measuring conditions.

The manufacturer may optionally state the rated value in the specification.

15.10.2.2 Method of measurement

The amplifier is brought under standard measuring conditions.

a) The volume control is readjusted to the position for maximum gain and the source e.m.f. decreased to restore the initial output voltage for standard measuring conditions.

b) The output voltage U_2 is measured.

c) The source e.m.f. E_s is measured.

d) The maximum e.m.f. gain is expressed, either as a ratio U_2/E_1 or in decibels 20 lg U_2/E_1.

15.10.3 Attenuation characteristic of the volume control

15.10.3.1 Characteristic to be specified

The attenuation of the volume control, expressed in decibels, as a function of the mechanical position of the control (for example, angle of rotation from a specified position). The characteristic may be expressed graphically.

It should be taken into account that the attenuation characteristic may be a function of frequency, either intentionally, as in a 'loudness control' (physiologically-compensated gain control) or otherwise. If there is more than one volume control, the characteristic of each control should be specified.

NOTE Where ganged volume controls are used to control the gains of more than one channel together, the gain differences between channels are functions of the volume control position, and such gain differences are often an important characteristic which can also be specified by the manufacturer.

The manufacturer may optionally present these data in the specification.

15.10.3.2 Method of measurement

The amplifier is brought under standard measuring conditions, except that the volume control is set to the position of maximum gain.

a) The output voltage U_2 is measured.

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b) The volume control is then adjusted in successive steps; after each step, the position of the volume control is noted and the output voltage U_2' measured.

c) The ratio of the output voltage at maximum gain U_2 to the output voltage measured at each step U_2' is, expressed in decibels, 20 lg (U_2/U_2').

d) These ratios are presented as a tabulation or graphically as a function of the position of the volume control.

e) This measurement may be repeated at other frequencies (see note).

For large attenuations, care should be taken to ensure that noise and hum do not affect the results. To prevent this, the source e.m.f. may be increased by a known amount, and an allowance made in the results. Care should be taken not to exceed the overload source e.m.f.

NOTE The results obtained in item e) of this method can also be used to present graphs of gain-frequency response at various settings of the volume control or 'loudness control'.

15.10.4 Attenuation characteristic of balance controls for multi-channel equipment

15.10.4.1 Characteristic to be specified

The attenuation of the balance control, expressed in decibels, as a function of the mechanical position of the control (for example, angle of rotation from a given datum).

The manufacturer may optionally present these data in the specification.

15.10.4.2 Method of measurement

The amplifier is brought under standard measuring conditions, with the balance control adjusted to produce maximum gain in the channel first to be measured, the source e.m.f. being applied only to this channel. It may be necessary to reduce the source e.m.f. to prevent the rated output voltage or power being exceeded.

a) The output voltage U_2 is measured.

b) The balance control is then adjusted in successive steps; after each step, the position of the balance control is noted and the output voltage U_2' measured.

c) The ratio of the output voltage at maximum gain U_2 to the output voltage measured at each step U_2' is, expressed in decibels, 20 lg (U_2/U_2').

d) These ratios are presented graphically as a function of position of the balance control.

e) The measurement is repeated for other channel(s) controlled by the balance control being measured.

f) The measurement may be repeated at other frequencies.

NOTE It is usual to plot the characteristic of all channels controlled by the same balance control on the same graph.

15.11 Response

15.11.1 Gain-frequency response

15.11.1.1 Characteristic to be specified

Variation, as a function of frequency, of the e.m.f. gain (ratio of the output voltage to the source e.m.f.), expressed in decibels, relative to its value at a specified reference frequency (normally the standard reference frequency).

It is recommended that the manufacturer state the rated value in the specification.

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15.11.1.2 Method of measurement

The amplifier is brought under standard measuring conditions, with the source at the specified frequency.

a) The source e.m.f. E_s and the output voltage U_2 are measured.

b) The frequency of the source is varied continuously or step by step, maintaining the source e.m.f. constant. The output voltage U_2' is measured at each frequency.

c) The ratio of the output voltage at each frequency of the source to the output voltage at the specified reference frequency is, expressed in decibels, 20 lg (U_2'/U_2).

d) These ratios are presented graphically as a function of frequency.

15.11.1.3 Equalizing amplifiers

The frequency response of an equalizing amplifier with specified equalizing characteristics shall be measured by the method described in 15.11.1.2, adjusting the source e.m.f. at each frequency in accordance with the inverse of the specified equalizing characteristic.

The source impedance shall represent the impedance of the transducer for which the equalizing amplifier is intended, over the effective frequency range. This impedance shall be stated with the results (if possible in the form of an equivalent circuit).

NOTE IEC 60098 [5] specifies a relationship between the recorded velocity on a disk record and the output voltage of the amplifier. Unless otherwise specified, it is usual to compare the response of the amplifier itself with this specified relationship (thus assuming a transducer having an ideal frequency response).

If the response of an equalizing amplifier is designed to compensate deficiencies in the frequency characteristic of a particular transducer, this should be stated by the manufacturer.

15.11.2 Gain-limited effective frequency range

15.11.2.1 Characteristic to be specified

The frequency range within which the deviations from the required frequency response under standard measuring conditions do not exceed stated limits.

The manufacturer is recommended to state the rated value in the specification.

15.11.2.2 Method of measurement

The effective frequency range is obtained from the graph prepared according to 15.11.1, under standard measuring conditions.

15.11.3 Distortion-limited effective frequency range

15.11.3.1 Characteristic to be specified

The frequency range within which the output power or voltage obtained at rated total harmonic distortion exceeds a specified fraction of the rated value.

Unless otherwise stated, the specified fraction shall be one-half in terms of power, or −3 dB when expressed in decibels.

It is recommended that the manufacturer state the rated value in the specification.

NOTE The deprecated term "power bandwidth" is often used for this characteristic.

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15.11.3.2 Method of measurement

The distortion-limited effective frequency range may be determined from the distortion-frequency curves prepared according to 15.12.4.1.

15.11.4 Phase-frequency response

15.11.4.1 Characteristic to be specified

The phase difference between the output voltage and the source e.m.f. as a function of frequency, under standard measuring conditions for stated positions of the controls, if any.

The manufacturer may optionally present these data in the specification.

Instead of the phase-frequency response, the time delay may be given as a function of frequency.

15.11.4.2 Method of measurement

The amplifier is brought under standard measuring conditions.

a) A phase difference meter is connected to the source and the output terminals, proper account being taken of the marking of the terminals.
b) The frequency of the source is varied continuously or step by step, the phase difference being measured at each frequency.
c) The phase difference $\Delta\varphi$ is expressed as a function of frequency, or as a time difference τ in microseconds, and presented as a graph:

$$\tau = (\Delta\varphi/360f) \times 10^6$$

with $\Delta\varphi$ expressed in degrees (°).

NOTE For equalizing amplifiers, see 15.11.1.3.

15.12 Amplitude non-linearity

15.12.1 General

A general explanation of amplitude non-linearity can be found in IEC 60268-2.

15.12.2 Rated total harmonic distortion, characteristic to be specified

The value of total harmonic distortion stated by the manufacturer in the specification or specified in an IEC standard, above which the performance of the amplifier is considered unacceptable for the intended purpose.

NOTE Published research on distortion perception by the human ear suggests that the limiting value of distortion for most purposes is in the order of 1 %. The overload restoring time is also significant; see 15.6.6.

15.12.3 Total harmonic distortion under standard measuring conditions

15.12.3.1 Characteristic to be specified

The total harmonic distortion, when the amplifier is working under standard measuring conditions.

It is strongly recommended that the manufacturer state the rated value in the specification, for the reasons given below.

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NOTE 1 In a properly designed system, the amplifier operates for most of the time with its output voltage in the order of 10 dB below the rated distortion-limited output voltage, due to the amplitude probability distribution of speech and music signals (hence the choice of 'standard measuring conditions').

NOTE 2 This characteristic is a good measure of the distortion performance of the amplifier, provided that the distortion does not rise at lower output voltages due to cross-over distortion. In contrast, the rated total harmonic distortion is a somewhat arbitrarily chosen limiting value.

15.12.3.2 Method of measurement

a) The amplifier is brought under standard measuring conditions and the output voltage U_2 is measured.

   The level of total harmonic distortion of the source of signals shall be at least 10 dB below the lowest level of distortion to be measured.

   NOTE For greatest accuracy of measurement of the voltages, a true r.m.s. meter is best, but for a total harmonic distortion of less than 10 %, the error of an average-responding meter scaled to read r.m.s. values of a sinusoidal signal is small.

b) A filter, selectively attenuating the input signal frequency to a level 10 dB below that of the distortion components, or a high-pass filter with similar attenuation at the input signal frequency and low known pass-band attenuation at the harmonic frequencies, is connected at the output terminals.

c) The output voltage U_2' (due to distortion) is measured and, if necessary, corrected for the pass-band attenuation of the filter.

d) The source e.m.f. is reduced to zero and the output voltage U_2'' is measured. Unless this voltage is less than one-third of U_2', the measurement is being affected by noise and the results shall be discarded. In this case, the more time-consuming but robust measurement of the harmonic distortion of the nth order (see 15.12.5) shall be used.

e) The total harmonic distortion under standard measuring conditions can be determined by the formulae:

$$d_{\text{tot}} = (U_2'/U_2) \times 100\ \%$$

   as a percentage, or:

$$L_{d,\text{tot}} = 20\ \lg\ (U_2'/U_2)$$

   in decibels (dB).

15.12.4 Total harmonic distortion as a function of amplitude and frequency

15.12.4.1 Characteristic to be specified

The total harmonic distortion, determined for different frequencies and output voltages.

NOTE 1 If the total harmonic distortion is measured at a frequency high enough for significant components of the harmonic spectrum (see last paragraph of this 15.12.4.1) to be above the upper limit of the gain-limited effective frequency range (see 15.11.2), the measured value of total harmonic distortion is very likely (depending on the design of the amplifier) to be misleadingly low. The higher the order of the highest significant harmonic, the lower the fundamental frequency at which this effect becomes important.

Care is necessary to ensure that the frequencies of significant distortion components do not fall above the upper frequency limit of the analyser.

NOTE 2 For example, if the upper limit of the gain-limited effective frequency range is 30 kHz, and the highest significant harmonic is the fifth, the highest fundamental frequency for which a value of total harmonic distortion is valid is (30/5) kHz, that is, 6 kHz. If the highest significant harmonic were the third, however, values of total harmonic distortion could be stated for frequencies up to (30/3) kHz, that is, 10 kHz.

The manufacturer may optionally present these data in the specification.

Some amplifiers produce a spectrum of harmonics including small but measurable harmonics of high orders. The highest frequency component of this spectrum, the amplitude of which is significant, may in general be taken as the highest harmonic whose r.m.s. value (see 15.12.5)

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exceeds one-third of the total harmonic distortion at the same fundamental frequency. In some cases a different criterion may be necessary, in which case it shall be stated.

15.12.4.2 Method of measurement

The procedure is as follows:

a) The total harmonic distortion is determined as given in 15.12.3.2.

b) The measurements are then repeated at least at three other frequencies up to the limit indicated in the notes of 15.12.4.1 and at other values of output voltage U_2 up to and beyond the rated distortion-limited output voltage.

   To ensure the accuracy of each measurement, it is essential to observe the precaution in item a), and repeat the test according to item d), of 15.12.3.2.

c) The results of the test are presented graphically.

15.12.5 Harmonic distortion of the *n*th order under standard measuring conditions

15.12.5.1 Characteristic to be specified

The harmonic distortion under standard measuring conditions due to the component of the output signal of harmonic order n.

It is recommended that the manufacturer state rated values for this characteristic, at least for values of n from 2 to 5, in the specification.

15.12.5.2 Method of measurement

The amplifier is brought under standard measuring conditions and the output voltage U_2 is measured.

a) A band-pass filter passing only the harmonic frequency to be measured is connected to the output terminals. The attenuation of the filter at the input signal frequency shall be at least 10 dB greater than the ratio of the output voltage U_2 to the smallest harmonic voltage to be measured.

b) The level of the nth order harmonic distortion in the source of signals shall be at least 10 dB below the lowest level of distortion to be measured. As an alternative to measuring each harmonic frequency in turn using bandpass filters or a wave analyser, a spectrum analyser may be used to measure the amplitudes of several distortion components and the fundamental simultaneously.

c) The output voltage $U_{2,n}'$ of the filter is measured and corrected if necessary for the pass-band attenuation of the filter. Due to the narrow measuring bandwidth a true r.m.s. meter is not essential for the measurement of $U_{2,n}'$

d) The source e.m.f. is reduced to zero and the output voltage measured. Unless this voltage is less than one-third of the voltage $U_{2,n}'$, the measurement is being affected by noise or spurious signals and the results shall be discarded.

e) The harmonic distortion of the nth order can be determined by the formulae:

$$d_n = (U_{2,n}'/U_2) \times 100\ \%$$

   as a percentage, or:

$$L_{d,n} = 20 \lg (d_n/100)$$

   in decibels (dB).

Documents
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