BS EN 60268-3:2013

BSI Standards Publication

Sound system equipment

Part 3: Amplifiers

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National foreword

This British Standard is the UK implementation of EN 60268-3:2013. It is identical to IEC 60268-3:2013. It supersedes BS EN 60268-3:2001 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EPL/100, Audio, video and multimedia systems and equipment.

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

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English version

Sound system equipment -
Part 3: Amplifiers
(IEC 60268-3:2013)

Equipements pour systèmes électroacoustiques -
Partie 3: amplificateurs
(CEI 60268-3:2013)

Elektroakustische Geräte -
Teil 3: Verstärker
(IEC 60268-3:2013)

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Foreword

The text of document 100/2010A/CDV, future edition 4 of IEC 60268-3, prepared by IEC/TC 100 "Audio, video and multimedia systems and equipment" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60268-3:2013.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2014-02-28
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2016-05-28

This document supersedes EN 60268-3:2000.

EN 60268-3:2013 includes the following significant technical changes with respect to EN 60268-3:2000:

– rated condition of multi-channel amplifier is expanded;

– arrangement for the D-class amplifier is added;

– method of measurement for output power (distortion-limited) is expanded;

– Annex B is newly added.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 60268-3:2013 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60268-5:2003	NOTE	Harmonised as EN 60268-5:2003 (not modified).
IEC 61606 series	NOTE	Harmonised in EN 61606 series.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60065 (mod) + corr. August + A1 (mod) + A2 (mod)	2001 2002 2005 2010	Audio, video and similar electronic apparatus - Safety requirements	EN 60065 + corr. August + A1 + A2 + A11 + A12	2002 2007 2006 2010 2008 2011
IEC 60268-1 + A1 + A2	1985 1988 1988	Sound system equipment - Part 1: General	HD 483.1 S2	1989
IEC 60268-2 + A1	1987 1991	Sound system equipment - Part 2: Explanation of general terms and calculation methods	HD 483.2 S2	1993
IEC 60417	Data-base	Graphical symbols for use on equipment	-	-
IEC 61000-4-13 + A1	2002 2009	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	EN 61000-4-13 + A1	2002 2009
IEC 61000-4-17 + A1 + A2	1999 2001 2008	Electromagnetic compatibility (EMC) - Part 4-17: Testing and measurement techniques - Ripple on d.c. input power port immunity test	EN 61000-4-17 + A1 + A2	1999 2004 2009
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 port immunity tests	EN 61000-4-29	2000
IEC 61938	1996	Audio, video and audiovisual systems - Interconnections and matching values - Preferred matching values of analogue signals	EN 61938 + corr. February	1997 1997

CONTENTS

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 which 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 [4][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 which 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 which 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, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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, *Audio, video and similar electronic apparatus – Safety requirements*
Amendment 1:2005
Amendment 2:2010

IEC 60268-1:1985, *Sound system equipment – Part 1: General*
Amendment 1:1988
Amendment 2:1988

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

IEC 60417, *Graphical symbols for use on equipment.* Available from: http://www.graphical-symbols.info/equipment

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*
Amendment 1:2009

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

IEC 61000-4-17:1999, *Electromagnetic Compatibility (EMC) – Part 4-17: Testing and measurement techniques – Ripple on d.c. input power port immunity test*
Amendment 1:2001
Amendment 2:2008

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

3 Conditions

3.1 Rated conditions and standard measuring conditions

3.1.1 Overview

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

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 standard 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.

3.1.2 Rated conditions

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 2).

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.

3.1.3 Standard measuring conditions

These are obtained by bringing the amplifier under rated conditions (see 3.1.2) and then reducing the source e.m.f. to a level of –10 dB referred to the rated source e.m.f.

3.2 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 standard.

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.

4 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.

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

5 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.

6 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.

7 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.

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.

8 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 3.1.2), 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.

9 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 3.1.3). 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.

10 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 9 shall be repeated before each set of measurements, unless this can be shown to be unnecessary.

11 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 more than 15 % due to changes in load impedances of the output circuit or in signal parameters', but no definition appears in the fifth (1985) or sixth (1998) 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 14.7.4.1 still applies.

All the measurements contained in this standard 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 14.6.3.1 and item c) of 14.14.3).

12 Marking

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

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

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.

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.

13 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 3.1.2). See also IEC 60065 or other appropriate IEC safety standard.

14 Characteristics to be specified, and their methods of measurement

14.1 Power supply characteristics

14.1.1 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 3.1.2); on the equipment and in the specification;
c) the power supply frequency or range of frequencies (this may be a rated condition, see 3.1.2); 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 11), 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.

14.1.2 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 14.5.3;
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.

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

14.2.1 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.

14.2.2 Methods of measurement

14.2.2.1 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.

14.2.2.2 Variations of output and gain

The amplifier is brought under rated conditions, the total harmonic distortion being measured by the method given in 14.12.3.2.

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 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.

14.2.2.3 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 14.14.
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.

14.3 Tolerance of power supply frequency variations

14.3.1 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.

14.3.2 Methods of measurement

14.3.2.1 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 14.12.4.2.

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.

14.3.2.2 Hum

The method of measurement is as given in 14.2.2.3, 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.

14.4 Tolerance of power supply harmonics and ripple

14.4.1 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 14.2.1;
   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 14.2.1.

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 14.2.1;
   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.

14.4.2 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.

14.5 Input characteristics

14.5.1 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.

14.5.2 Input impedance

14.5.2.1 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;

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.

14.5.2.2 Methods of measurement

14.5.2.2.1 General

In the methods given in 14.5.2.2.2 and 14.5.2.2.3 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 14.5.2.2.4 or 14.5.2.2.5 may be used.

14.5.2.2.2 Balanced input

The amplifier is brought under standard measuring conditions, using a source free from earth (or chassis), as shown in Figure 3 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.

14.5.2.2.3 Unbalanced input

The amplifier is brought under standard measuring conditions, the common input terminal being connected to earth (see Figure 3 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).

14.5.2.2.4 Measurement of input impedance using a bridge

The amplifier is brought under standard measuring conditions.

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.

14.5.2.2.5 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 14.11.2).
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.

14.5.3 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.

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

14.5.4.1 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.

14.5.4.2 Method of measurement

The amplifier is brought under rated conditions.

a) The output voltage U_2 is measured.

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.

14.6 Output characteristics

14.6.1 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.

14.6.2 Output source impedance

14.6.2.1 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.

14.6.2.2 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.

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.

14.6.3 Output voltage and power (distortion-limited)

14.6.3.1 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 3.1.2).

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

14.6.3.2 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 14.12).

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 14.6.3.1 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 14.11.3.1 and 14.12.4.1). 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.

14.6.4 Regulation

14.6.4.1 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.

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

14.6.4.2 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.

14.6.5 Overload restoring time

14.6.5.1 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 4).

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

14.6.5.2 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.

14.7 Limiting characteristics

14.7.1 Overload source e.m.f.

14.7.1.1 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.

14.7.1.2 Method of measurement

The amplifier is brought under rated conditions.

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

14.7.2 Short-term maximum output voltage and power

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

14.7.2.1 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.

14.7.2.2 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.

14.7.2.3 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.

14.7.3 Long-term maximum output voltage and power

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

14.7.3.1 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.

14.7.3.2 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.

14.7.3.3 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.

14.7.3.4 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.

14.7.4 Temperature-limited output power

14.7.4.1 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.

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 14.12.3.1, Note 1).

14.7.4.2 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 14.2). 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.

14.8 Characteristics of protection circuits

14.8.1 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 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 14.8.3 therefore gives methods which should be used only by the manufacturer, and consequently the names of the characteristics include the word 'rated'.

14.8.2 Protection against potentially damaging combinations of output voltage and current

14.8.2.1 Characteristic to be specified

The output current/output voltage characteristic of the amplifier, measured using the test signal and method described in 14.8.2.2 and 14.8.2.3 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.

14.8.2.2 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 [1].

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.

14.8.2.3 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 5a.
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.
f) Adjust the bright-up delay control for a clear display and record the display.

14.8.2.4 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 5b.

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

14.8.3 Characteristics of d.c. offset protection circuits

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

14.8.3.1 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 14.8.3.2.1) 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.

14.8.3.2 Methods of measurement

14.8.3.2.1 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.

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

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

The same procedure as in 14.8.3.2.1 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.

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

14.9.1 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 standard (see 14.6.3, 14.7.2 and 14.7.3), 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.

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 14.7.2 and 14.7.3.

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 14.7.4). 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.

14.9.2 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.

14.9.3 Method of measurement

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

a) The method described in 14.6.3.2 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.

14.10 Gain

14.10.1 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.

14.10.2 Maximum e.m.f. gain

14.10.2.1 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.

14.10.2.2 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.

14.10.3 Attenuation characteristic of the volume control

14.10.3.1 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.

14.10.3.2 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.
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'.

14.10.4 Attenuation characteristic of balance controls for multi-channel equipment

14.10.4.1 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.

14.10.4.2 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.

14.11 Response

14.11.1 Gain-frequency response

14.11.1.1 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.

14.11.1.2 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.

14.11.1.3 Equalizing amplifiers

The frequency response of an equalizing amplifier with specified equalizing characteristics shall be measured by the method described in 14.11.1.2, 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 [2] 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.

14.11.2 Gain-limited effective frequency range

14.11.2.1 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.

14.11.2.2 Method of measurement

The effective frequency range is obtained from the graph prepared according to 14.11.1, under standard measuring conditions.

14.11.3 Distortion-limited effective frequency range

14.11.3.1 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.

14.11.3.2 Method of measurement

The distortion-limited effective frequency range may be determined from the distortion-frequency curves prepared according to 14.12.4.1.

14.11.4 Phase-frequency response

14.11.4.1 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.

14.11.4.2 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 14.11.1.3.

14.12 Amplitude non-linearity

14.12.1 General

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

14.12.2 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 14.6.5.

14.12.3 Total harmonic distortion under standard measuring conditions

14.12.3.1 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.

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.

14.12.3.2 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 *n*th order (see 14.12.5) 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).

14.12.4 Total harmonic distortion as a function of amplitude and frequency

14.12.4.1 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 14.12.4.1) to be above the upper limit of the gain-limited effective frequency range (see 14.11.2), 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 14.12.5) 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.

14.12.4.2 Method of measurement

The procedure is as follows:

a) The total harmonic distortion is determined as given in 14.12.3.2.
b) The measurements are then repeated at least at three other frequencies up to the limit indicated in the notes of 14.12.4.1 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 14.12.3.2.
c) The results of the test are presented graphically.

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

14.12.5.1 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.

14.12.5.2 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 *n*th 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 *n*th 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).

14.12.6 Harmonic distortion of the *n*th order as a function of amplitude and frequency

14.12.6.1 Characteristic to be specified

The total harmonic distortion of the *n*th order under standard measuring conditions (see 14.12.5), determined for different frequencies and output voltages.

The manufacturer may optionally present these data in the specification.

NOTE 1 This method is preferred when noise affects the wide-band method given in 14.12.4.

NOTE 2 See last paragraph of14.12.4.1.

14.12.6.2 Method of measurement

The procedure is as follows:

a) The harmonic distortion of the *n*th order is determined as given in 14.12.5.2.
b) The measurements are then repeated, at least at three other frequencies up to the limit indicated in the notes of 14.12.4.1, at other values of output voltage U_2 up to and beyond the rated distortion-limited output voltage and at other values of harmonic order.
c) To ensure the accuracy of each measurement it is essential to repeat the test according to item d) of 14.12.5.2.
d) The total harmonic distortion under the given conditions can be determined by the formulae:

$$d_{\text{tot}} = \frac{\left[\sum_{n=2}^{\infty} U'^{2}_{2,n}\right]^{1/2}}{U_2} \times 100\ \%$$

as a percentage, or:

$$L_{d,\text{tot}} = 20 \lg (d_{\text{tot}}/100)$$

in decibels (dB).
e) The results of the test are presented graphically.

14.12.7 Modulation distortion of the *n*th order (where *n* = 2 or *n* = 3)

14.12.7.1 Characteristics to be specified

The following characteristics should be specified:

a) Modulation distortion of the second order

When f_1 and f_2 are the frequencies of two sinusoidal input signals of specified amplitude ratio, the second-order modulation distortion is given by the ratio of the arithmetic sum of the output voltages at frequencies $f_2 + f_1$ and $f_2 – f_1$ to the output voltage at frequency f_2.
b) Modulation distortion of the third order

When f_1 and f_2 are the frequencies of two sinusoidal input signals of specified amplitude ratio, the third-order modulation distortion is given by the ratio of the arithmetic sum of the output voltages at frequencies $f_2 + 2f_1$ and $f_2 – 2f_1$ to the output voltage at frequency f_2.

Unless a spectrum analyser is used, making it possible to make an immediate identification of the various components of the output voltage, f_1 and f_2 should be chosen as follows: $f_2 – 2f_1$ should preferably be higher in frequency than the highest significant harmonic of f_1; if the highest significant harmonic is the fifth, then f_1 should not exceed $f_2/8$.

It is desirable to choose f_1 to be between 0,5 octave and 1,5 octaves above the lower limit of the effective frequency range and f_2 to be between 0,5 octave to 1,5 octaves below the upper limit of that range.

If the amplifier to be measured includes equalization, the amplitude ratio shall be adjusted to the specified value, preferably 4:1, at a point (usually either the input or output of the amplifier) where, when the amplifier is in use, the spectral distribution of the signal is normal. For example, an equalizing amplifier for a magnetic pick-up cartridge for analogue disk records has a normal signal spectrum at its output, whereas a recording amplifier for a magnetic tape recorder has a normal signal spectrum at its input.

It is recommended that the manufacturer present these data in the specification.

14.12.7.2 Method of measurement

The amplifier is brought under standard measuring conditions.

a) It is then connected to two sources with frequencies f_1 and f_2, each via a switch and a series resistor of at least 10 times the rated source impedance of the amplifier to a shunt resistor connected in parallel with the input terminals of the amplifier (see Figure 6). The combined value of this shunt resistor in parallel with the series resistors shall be equal to the rated source impedance of the amplifier.
b) Each source is connected in turn by means of the switch. The source e.m.f. at the frequency f_1 is adjusted to produce an output voltage $U_{2,f1}$ of 12 dB below the rated output voltage and the source e.m.f. at f_2, for an amplitude ratio of 4:1, to produce an output voltage $U_{2,\mathrm{f}2}$ 24 dB below the rated output voltage.
c) Both sources are then connected simultaneously and a band-pass filter passing the appropriate measuring frequency: $f_2 + f_1$, $f_2 - f_1$, $f_2 + 2f_1$ or $f_2 - 2f_1$ connected between the output load resistor and the voltmeter. The attenuation of the band-pass filters at other frequencies shall be sufficient to preserve the accuracy of the measurement.
d) The selectively measured output voltage ($U_{2,f2+f1}'$, etc.) is measured and corrected for the pass-band attenuation of the filter and the measurements repeated for the other distortion components, if required.
e) The measurement may be repeated for other values of input voltages, keeping the amplitude ratio at 4:1.
f) Noise and spurious signal voltages shall not exceed one-third of the voltage of the component being measured. This can be checked by reducing the source e.m.f. to zero.
g) The modulation distortion of the second order can be determined by the formula:

$$d_{m,2} = \frac{U'_{2,f2+f1} + U'_{2,f2-f1}}{U_2} \times 100\ \%$$

as a percentage of the output voltage at frequency f_2. Alternatively,

$$d_{m',2} = 5\, d_{m,2}$$

as a percentage of the reference output voltage, if the amplitude ratio is 4:1.

h) The modulation distortion of the third order can be determined by the formula:

$$d_{m,3} = \frac{U'_{2,f2+2f1} + U'_{2,f2-2f1}}{U_2} \times 100\ \%$$

as a percentage of the output voltage at frequency f_2. Alternatively,

$$d_{m',3} = 5\, d_{m,3}$$

as a percentage of the reference output voltage, if the amplitude ratio is 4:1.

The results of the measurement should be presented graphically, as functions of frequency and reference output voltage, or as single figures, preferably for standard measuring conditions.

Due to the presence of two incoherent signals in the amplifier, the peak-to-peak signal amplitude is equal (apart from effects due to non-linearity) to the sum of the peak-to-peak signal amplitudes of the two sinusoidal signals.

The reference output voltage for expressing the results is therefore chosen to be equal to the sum of the output voltages due to the sinusoidal components.

For an amplitude ratio of 4:1 the reference output voltage is

$$U_{2,\text{ref}} = U_{2,f2} + U_{2,f1} = 5\,U_{2,f2}$$

14.12.8 Difference-frequency distortion of the *n*th order (where *n* = 2 or *n* = 3)

14.12.8.1 Characteristic to be specified

The following characteristics should be specified:

a) Difference frequency distortion of the second order

   When f_1 and f_2 are the frequencies of two equal amplitude sinusoidal signals, separated by a specified frequency difference, the difference-frequency distortion of the second order is given by the ratio of the output voltage $U_{2,f2-f1}'$ at frequency $f_2 - f_1$ to the reference voltage $U_{2,\text{ref}}$, which is equal to twice the output voltage $U_{2,f2}$.

b) Difference frequency distortion of the third order

   With signals as under item a), the difference-frequency distortion of the third-order is given by the ratio of the arithmetic sum of the output voltages at frequencies $2f_2 - f_1$ and $2f_1 - f_2$ to the reference voltage $U_{2,\text{ref}}$ which is equal to twice the output voltage $U_{2,f2}$.

   It is recommended that the manufacturer present these data in the specification.

14.12.8.2 Method of measurement

The amplifier is brought under standard measuring conditions.

a) It is then connected to two sources with frequencies f_1 and f_2 each via a switch and a series resistor of at least 10 times the rated source impedance of the amplifier to a shunt resistor connected in parallel with the input terminals of the amplifier (see Figure 6). The combined value of this shunt resistor in parallel with the series resistors shall be equal to the rated source impedance of the amplifier.

   NOTE 1 The series and shunt resistors are intended to prevent intermodulation in the signal sources. Other, equally effective methods can be used.

b) The source frequencies f_1 and f_2 are adjusted to have a frequency difference of 80 Hz, unless there is a good reason to choose otherwise.

c) Each source is connected in turn by means of the switch and the source e.m.f.s of each source adjusted to produce an output voltage $U_{2,f1}$ or $U_{2,f2}$ respectively of 16 dB below the rated output voltage (one-half of the voltage under standard measuring conditions).

d) Both sources are connected simultaneously and a band-pass filter passing the appropriate measuring frequency, $f_2 - f_1$, $2f_1 - f_2$ or $2f_2 - f_1$ connected to the output terminals. The attenuation of the band-pass filter at other frequencies shall be sufficient to preserve the accuracy of the measurement.

e) The output voltage due to the relevant component of distortion is measured and corrected for the pass-band attenuation of the filter. The measurements are repeated for the other distortion components, if required.

   NOTE 2 A spectrum analyser can be used to measure all the components simultaneously.

f) Noise and spurious signal voltages shall not exceed one-third of the voltage of the component being measured. This can be checked by reducing the source e.m.f.s to zero.

g) The difference frequency distortion of the second order can be determined by the formula:

$$d_{d,2} = \frac{U'_{2,f2\text{-}f1}}{U_{2,\text{ref}}} \times 100\ \%$$

The difference frequency distortion of the third order can be determined by the formula:

$$d_{d,3} = \frac{U'_{2,2f2\text{-}f1} + U'_{2,2f1\text{-}f2}}{U_{2,\text{ref}}} \times 100\ \%$$

h) The measurements may be repeated for other values of source e.m.f. and other values of mean measuring frequency f_m. Care should be taken with measurements at low frequencies that the band-pass filter referred to in item d) has sufficient selectivity to discriminate between the second and one of the third-order components which are close together in frequency.

i) Due to the presence of two incoherent signals in the amplifier, the peak-to-peak signal amplitude is twice that of either signal alone. The reference output voltage $U_{2,\text{ref}}$ is therefore chosen as twice that measured at f_2, so $U_{2,\text{ref}} = 2U_{2,f2}$.

j) The results of the measurement should be presented graphically, as functions of frequency and reference output voltage, or as single figures, preferably for standard measuring conditions.

k) In this method of measurement it has been assumed that the required frequency response is flat. When measuring frequency-dependent circuits, for example pre-amplifiers employing equalization, an appropriate counter-equalization at the input shall be used to create quasi-normal test signal spectral distribution within the amplifier under test and at its output.

   In that case, the amplitude ratio shall be adjusted to the specified value, preferably 1:1, at a point (usually the input or the output of the amplifier) where, when the amplifier is in use, the spectral distribution of the signal is normal. For example, an equalizing amplifier for a magnetic pick-up cartridge for analogue disk records has a normal signal spectrum at its output whereas a recording amplifier for a magnetic tape recorder has a normal signal spectrum at its input.

14.12.9 Dynamic intermodulation distortion (DIM)

14.12.9.1 Characteristics to be specified

The modulation distortion arising when a particular input signal is used. The input signal is the sum of a sinusoidal signal of frequency f_s and a low-pass filtered square wave of fundamental frequency f_q, where f_q is less than both f_s and the filter cut-off frequency f_c. The peak-to-peak amplitude ratio of the square wave signal to the sinusoidal signal is 4:1 and the dynamic intermodulation distortion is then determined by the ratio of the r.m.s. sum of the output voltages at the frequencies specified in Table 2 to the amplitude of the output voltage at the frequency f_s.

The manufacturer may optionally present these data in the specification.

Table 2 – Distortion components due to dynamic intermodulation distortion falling in the frequency range up to 20 kHz

Intermodulation components		Frequency
Frequency	Symbol for output voltage	kHz
$5f_q - f_s$	U_5	0,75
$f_s - 4f_q$	U_4	2,40
$6f_q - f_s$	U_6	3,90
$f_s - 3f_q$	U_3	5,55
$7f_q - f_s$	U_7	7,05
$f_s - 2f_q$	U_2	8,70
$8f_q - f_s$	U_8	10,20
$f_s - f_q$	U_1	11,85
$9f_q - f_s$	U_9	13,35

14.12.9.2 Method of measurement

The amplifier is brought under standard measuring conditions.

a) It is then connected to two sources, one of sinusoidal voltage and one of square-wave voltage, each via a switch and a series resistor of at least 10 times the rated source impedance of the amplifier to a shunt resistor, connected in parallel with the input terminals of the amplifier (see Figure 6). The combined value of this shunt resistor in parallel with the series resistors shall be equal to the rated source impedance of the amplifier.

   The square-wave source shall be provided with a single-pole low-pass filter with a cut-off frequency f_c of 30 kHz or 100 kHz (see Note 1).

   NOTE 1 The frequency f_c is normally 30 kHz, but a frequency of 100 kHz will increase the sensitivity of the method.

   The even harmonic content of the square-wave signal should not exceed 1 % of the value of the fundamental.

b) The sinusoidal source is adjusted to a frequency f_s = 15 kHz, the square-wave source to a frequency f_q = 3,15 kHz and the input peak-to-peak voltage ratio of these signals to 1:4 respectively. A typical spectrum of this signal as obtained in practice is given in Figure 7.

   In this method of measurement it has been assumed that the required frequency response is flat. When measuring frequency-dependent circuits, for example pre-amplifiers employing equalization, an appropriate counter-equalization at the input shall be used to create quasi-normal test signal spectral distribution within the amplifier under test and at its output. In that case, the amplitude ratio shall be adjusted to the specified value, preferably 4:1, at a point (usually the input or the output of the amplifier) where, when the amplifier is in use, the spectral distribution of the signal is normal. For example, an equalizing amplifier for a magnetic pick-up cartridge for disk records has a normal signal spectrum at its output whereas a recording amplifier for a magnetic tape recorder has a normal signal spectrum at its input.

   NOTE 2 The peak-to-peak voltage ratio 1:4 is equivalent to

   – the ratio 1:5,66 between r.m.s. amplitudes,

   – the ratio 1:11,3 between the r.m.s. value of the sinusoid and the peak-to-peak value of the square wave.

   Measuring instruments specifically intended to perform this measurement c use a square wave, the frequency of which is up to 1 % higher than 3,15 kHz.

c) With both sources connected the input source e.m.f.s are then increased until the peak-to-peak input voltage corresponds to the peak-to-peak value of the rated distortion-limited output voltage.

d) A selective voltmeter or a spectrum analyser is connected to the output terminals. The amplitudes of the sinusoidal signal U_s and of the intermodulation components U_1, U_2, ... U_i having frequencies $mf_s \pm nf_q$ (m and n being integers) are measured; the relevant distortion components are given in Table 2.

   The meter shall attenuate by at least 80 dB the frequencies which are more than 750 Hz away from the frequency of the component being measured.

   NOTE 3 Output spectrum components other than those specified above (such as any component of frequency $2nf_q$) are not taken into account.

e) The levels of other residual components, including hum and noise, shall not exceed –10 dB with respect to the component to be measured; this can be checked by reducing the source e.m.f.s to zero.

f) The dynamic intermodulation distortion can be determined by the formulae:

$$d_{\mathrm{DIM}} = \frac{\left(\Sigma_{i=1}^{9} U_i'^{2}\right)^{1/2}}{U_2} \times 100\ \%$$

   as a percentage, or: $L_{d,\mathrm{DIM}} = 20 \lg d_{\mathrm{DIM}}$

   in decibels (dB).

g) Further information on the dynamic performance of the amplifier may be determined from additional measurements for a number of output voltages in the range between zero and rated output voltage.

h) The results of the test are presented either as a table or graphically. The value of f_c shall be stated. The reference output voltage to which measurements are referred is measured by replacing the test signal by a sine wave with the same peak-to-peak voltage and a frequency of 3,15 kHz.

14.12.10 Total difference frequency distortion

14.12.10.1 Characteristic to be specified

When f_1 and f_2 are frequencies of two sinusoidal input signals, where $f_1 = 2f_0$, $f_2 = 3f_0 - \delta$, δ being the frequency offset, the distortion is given by the ratio of the r.m.s. sum of the output voltages $U_{2,f2-f1}'$ and $U_{2,f1-f2}'$ of the in-band second-order and third-order intermodulation products at the frequencies $f_0 - \delta$ and $f_0 + \delta$ to a reference output voltage, equal to the arithmetical sum of the output voltages $U_{2,f1}$ and $U_{2,f2}$ at the frequencies f_1 and f_2.

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

14.12.10.2 Method of measurement

The amplifier is brought under standard measuring conditions.

a) It is then connected to two sinusoidal sources, each via a switch and a series resistor of at least 10 times the rated source impedance of the amplifier to a shunt resistor, connected in parallel with the input terminals of the amplifier (see Figure 6). The combined value of the shunt resistor in parallel with the series resistors shall be equal to the rated source impedance of the amplifier. Connection or disconnection of one source shall have a negligible effect on the level of signal delivered to the amplifier input from the other source.

b) The source frequencies are adjusted to frequencies f_1 and f_2 (see 14.12.10.1). Unless there is a good reason to the contrary, f_1 = 8 kHz, f_2 = 11,95 kHz. In this case $f_2 - f_1 = f_0 - \delta$ = 3 950 Hz and $2f_1 - f_2 = f_0 + \delta$ = 4 050 Hz.

   In this method of measurement it has been assumed that the required frequency response is flat. When measuring frequency-dependent circuits, for example pre-amplifiers employing equalization, an appropriate counter-equalization at the input shall be used to create quasi-normal test signal spectral distribution within the amplifier under test and at its output. In that case, the amplitude ratio shall be adjusted to the specified value, preferably 1:1, at a point (usually the input or the output of the amplifier) where, when the amplifier is in use, the spectral distribution of the signal is normal. For example, an equalizing amplifier for a magnetic pick-up cartridge for disk records has a normal signal spectrum at its output whereas a recording amplifier for a magnetic tape recorder has a normal signal spectrum at its input.

c) Each source is connected in turn by means of the switch and the source e.m.f.s of each source adjusted to produce an output voltage U_2 of 16 dB below the rated output voltage (one-half of the voltage under standard measuring conditions).

d) Both sources are connected simultaneously and a band-pass or low-pass filter, passing the frequencies $f_0 \pm \delta$, normally being 4 kHz ± 50 Hz connected to the output terminals. The attenuation of the filter at other frequencies shall be sufficient to preserve the accuracy of the measurement.

e) The output voltages $U_{2,f2-f1}'$ and $U_{2,2f1-f2}'$ are measured and corrected for the pass-band attenuation of the filter. A wave or spectrum analyser, or a selective voltmeter, may be used to measure all the output components; the manner in which the measurement is made is determined by the resolution bandwidth of the measuring equipment. Where the bandwidth is less than 2δ, the individual distortion-component voltages $U_{2,f2-f1}'$ and $U_{2,2f1-f2}'$ at frequencies $f_0 \pm \delta$ are measured separately and summed in an r.m.s. manner. Where the bandwidth is greater than 2δ, the two components can be measured together using an r.m.s.-responding indicator. The use of an average-responding indicator might give an error of up to 1 dB, while a peak-responding indicator might give an error of up to 3 dB.

f) Noise and spurious signal voltages at the filter output shall not exceed one-third of the output voltage measured with the intermodulation components present. This can be checked by disconnecting each source in turn.

g) The total difference frequency distortion can be determined by the formulae:

$$d_{\text{TDFD}} = \frac{(U'^2_{2,f2-f1} + U'^2_{2,2f1-f2})^{1/2}}{U_{2,f1} + U_{2,f2}} \times 100\ \%$$

as a percentage, or:

$$L_{d,\text{TDFD}} = 20\ \lg\left(\frac{d_{\text{TDFD}}}{100}\right)$$

in decibels (dB).

h) Further information on the performance of the amplifier may be determined from additional measurements for a number of output voltages in the range between zero and rated output voltage and for a number of stated frequencies (see 14.12.10.1). The frequency f_2 may be made as high as practicable within the gain-limited effective frequency range, but not exceeding 20 kHz, whichever is less.

i) The results of the tests are presented graphically or as values for specified frequencies and output voltages. The reference output to which measurements are referred is a sine wave with the same peak-to-peak voltage as the measured output voltage and a frequency f_0. The frequencies f_1 and f_2 used for the measurement shall be stated.

14.12.11 Weighted total harmonic distortion

The characteristics given in 14.12.3, 14.12.4, 14.12.5 and 14.12.6 may also be measured and presented as weighted values by including a weighting network complying with Appendix A of IEC 60268-1:1985 between the amplifier output terminals and the distortion measuring instrument. Allowance shall be made for the insertion loss of the weighting network at the input signal frequency. See also Amendment 1 to IEC 60268-2:1987.

Because of the shape of the response of the weighting network, the measurements are valid only for input signal frequencies between 31,5 Hz and 400 Hz.

Rated total harmonic distortion (see 14.12.2) may also be presented as a weighted value.

In the presentation of results, it shall be made clear that a weighted value is being reported.

NOTE Weighted total harmonic distortion measurements are useful when the harmonic distortion consists of many harmonics, all of similar low level relative to the total output voltage, such as are caused by crossover distortion. In such a case, the results of weighted measurements correlate, better than those of unweighted measurements, with subjective assessments of quality of reproduction (listening tests). Except in the above case, unweighted measurements are preferred.

14.13 Noise

14.13.1 Characteristic to be specified

The following characteristics are suitable for inclusion in specifications:

a) Signal-to-noise ratio

The ratio, expressed in decibels, of the rated output voltage to the wide-band, or a weighted sum of the output voltages or the octave/third-octave band output voltages produced by the different noise components, the amplifier being brought under rated conditions and the source e.m.f. being then reduced to zero. The weighting curve and the characteristics of the measuring instruments shall be as specified in IEC 60268-1.

Information about noise, excluding hum and the other spurious signal components, may be given, where relevant. When this is done, it shall be explicitly stated.

If it is justified to use a reference output voltage other than the rated output voltage, the level of decibels of this reference voltage with respect to the rated voltage (0 dB) shall be stated when reporting the results.

b) Noise output voltage

The output voltage of an amplifier which is due to noise generated both within the amplifier and within its rated source resistance. This voltage is measured at the output of the appropriate filter or weighting network according to IEC 60268-1.

NOTE 1 For many purposes, it is the value of this noise output voltage which is significant rather than its ratio to the rated distortion-limited output voltage.

Also, the specification of noise output voltage (instead of signal-to-noise ratio) avoids conceptual difficulties which arise when the noise performance is to be specified under measuring conditions where rated distortion-limited output voltage cannot be obtained.

c) Residual noise output voltage

The noise output voltage as defined in b) above but with the volume control set to its minimum position.

d) Equivalent noise source e.m.f.

The e.m.f. of a source giving a sinusoidal signal of a specified frequency which will produce an output voltage equal to the noise output voltage produced by the amplifier.

NOTE 2 The frequency of the equivalent source is preferably the standard reference frequency of 1 000 Hz.

The manufacturer shall state rated values for one or more of these characteristics in the specification.

14.13.2 Method of measurement

The amplifier is brought under rated conditions.

a) The source e.m.f. is then reduced to zero.
b) Noise measuring equipment for wide-band (unweighted), weighted or octave/third-octave band measurement is connected to the output terminals (see IEC 60268-1).
c) The noise output voltage U_2' is then measured at each required setting of the controls, or under such required measuring conditions (for example, reduced or increased power supply voltage), as required.
d) The noise output voltage U_2' may be stated directly.
e) The signal-to-noise ratio may be expressed as

$$20\lg\frac{U_{2,\mathrm{ref}}}{U_2'}$$

where $U_{2,\mathrm{ref}}$ is a stated reference voltage, for example rated distortion-limited output voltage.

f) The settings of all relevant controls and the measuring conditions shall be clearly stated with the results.

g) The equivalent noise source e.m.f. may be calculated from the measurements of noise output voltage and of gain (see 14.10.2):

$$E_{\mathrm{in}} = \frac{U_2'}{A}$$

where

E_{in} is the equivalent noise source e.m.f.;

U_2' is the noise output voltage;

A is the e.m.f. gain, measured under the same conditions.

14.14 Hum

14.14.1 General

Interference at the power supply frequency and its harmonics is termed hum. The subjective effects of hum depend very much on the waveform and spectral content so that good correlation is not usually achieved between simple measurements and subjective evaluations, particularly since the characteristics of the loudspeakers used strongly influence the subjective results.

In variable consumption apparatus the hum output voltage is likely to be a function of the signal level, so that a special method of measurement is required.

14.14.2 Characteristics to be specified

The following characteristics are suitable for inclusion in specifications:

a) Hum output voltage: the output voltage due to interference at the power supply frequency and its harmonics, when the amplifier is operating under specified conditions.

b) Signal-to-hum ratio: the ratio of rated distortion-limited output voltage to hum output voltage, the amplifier being under rated conditions but with the source e.m.f. reduced to zero.

c) Equivalent hum source e.m.f: the source e.m.f. at the specified frequency which would produce an output voltage equal to the measured hum output voltage if applied to the input of the amplifier operating otherwise under the same conditions.

d) Residual hum output voltage: The hum output voltage measured with the gain control(s) set to minimum position.

NOTE It is illogical to refer this voltage to rated output voltage and calculate a "residual signal-to-hum ratio" since with the gain control(s) at minimum, rated output voltage cannot be achieved.

It is recommended that the manufacturer state rated values for one or more of these characteristics.

14.14.3 Method of measurement

The amplifier is brought under rated conditions.

a) The conditions are then readjusted to those under which the measurement is to be made.

b) A band-pass filter is connected at the output terminals to pass the hum frequency component to be measured.

c) If the variation of hum output with signal output is to be measured for a variable consumption apparatus, a source at a frequency which is high compared with the power supply frequency, 5 kHz for example, is connected and the source e.m.f. adjusted to produce the required signal output voltage (for example, as for standard measuring conditions).

d) The output voltage from the filter is measured, and corrected if necessary for the pass-band attenuation of the filter.

e) The measurement is repeated at other hum frequencies.

f) The hum output voltages may be presented as a spectrum, or added to produce a total hum voltage:

$$U_{\mathrm{HT}} = (\Sigma U_H^2)^{1/2}$$

The signal-to-hum ratio may be calculated as described in item b) of 14.14.2. The equivalent hum source e.m.f. may be calculated as described in item c) of 14.14.2, using the e.m.f. gain calculated from the results of the measurement described in 14.5.4.

g) For variable consumption apparatus the measurements may be repeated with other values of output voltage, and the results presented graphically.

h) A spectrum analyser may be used to measure all the hum voltage components simultaneously.

i) The measurements may be repeated with the gain control(s) set at minimum gain position to determine the residual hum output voltage.

14.15 Balanced inputs and outputs

14.15.1 Balance of the input

14.15.1.1 General

General information on the purpose and characteristics of balanced interfaces is given in Annex A. The balance of an input port may be influenced by inequality of the internal impedances from the input terminals to the reference point and/or failure of the circuit to reject common-mode signals adequately. Through mode conversion, the balance may also be influenced by inequality of the internal impedances to reference potential of each limb of the source supplying the balanced input.

14.15.1.2 Characteristic to be specified

The combination of unbalancing effects shall be expressed as the common-mode rejection ratio (CMRR), measurements being made by the method of 14.15.1.3. This ratio should preferably be stated in decibels.

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

14.15.1.3 Method of measurement

The procedure is as follows:

a) The equipment, connected in the test circuit shown in Figure 8 (based on Figure 3 of IEC 60268-2:1987), is brought under standard measuring conditions with switches S1 and S2 in position 1. The generator shall have a balanced floating output circuit with a rated source resistance R_s not greater in value than the rated source impedance of the equipment under test. The two resistors R shall be 10 Ω ± 1 %, or of closer tolerance.

NOTE Table 10 of IEC 61938:1996 recommends a value of R_s of 50 Ω or less.

b) The input voltage U_1 is measured using a high-impedance earth-free measuring instrument.

c) The output voltage U_2 is measured using an appropriate instrument.

d) The switch S1 is then set to position 2, leaving switch S2 in position 1. The source e.m.f. is then increased to U_1', so that the output voltage U_2' is either equal to U_2 or at least sufficiently high to avoid errors due to hum and noise.

e) The values of U_1' and U_2' are measured using the same instruments as before. While measuring U_2', temporarily note the value with switch S_2 in position 1 and then set it to position 2. The higher of the two values of U_2' is noted as the value for use in the next step.

f) The common-mode rejection ratio, CMRR, is calculated in decibels:

$$20 \lg (U_1'U_2/U_1U_2')$$

To maintain accuracy, it is essential to use electrostatic screens and earth connections as shown in Figure 8, and to shield the components from air currents which could cause differential temperature changes.

The value of rated source resistance R_s used for measurement shall be stated with the measurement data. If no value of R_s is given by the manufacturer, a value of 50 Ω shall be used unless otherwise stated.

g) The measurement is repeated for a number of frequencies, adequately covering the effective frequency range of the equipment. At least three measurements, one at a low frequency such as 80 Hz, one at the standard reference frequency and one at a higher frequency, such as 10 kHz, are recommended. The measurement may also be repeated with other values of source e.m.f.

h) The results are given either in a table or graphically, presenting the CMRR as the ordinate (decibels on a linear scale) and the frequency as the abscissa (log scale).

14.15.2 Overload (distortion-limited) peak-to-peak common-mode input voltage

14.15.2.1 Characteristic to be specified

The peak-to-peak value of common-mode input voltage at which the distortion of the output signal waveform begins to increase rapidly as the input voltage is increased.

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

14.15.2.2 Method of measurement

The procedure is as follows:

a) The procedure given in 14.15.1.3 is followed as far as step e), with an oscilloscope connected to the output of the equipment under test, so that the signal waveform can be observed. The voltage U_1' is then increased until the waveform begins to show rapidly increasing distortion as the voltage is increased. The value of U_1' is then noted.

NOTE A conventional measurement of the increase in distortion is not usable, because the distortion of the output signal is likely to vary in a complex manner with input signal level.

b) If no rapid increase in distortion is observed with U_1' equal to 24 V (r.m.s.), no greater input voltage need be applied.

c) The measured value of U_1' is expressed as a peak-to-peak value, by multiplying by $2\sqrt{2}$ (2,828) to convert from an r.m.s. to a peak-to-peak value. If the condition given in b) above applies, the result may be reported as 'greater than 68 V'.

14.15.3 Balance of the output

14.15.3.1 General

General information on the purpose and characteristics of balanced interfaces is given in Annex A. The balance of an output port may be influenced by one or more of the following effects:

a) Inequality of the internal impedances from the output terminals to the reference point. This effect is particularly significant if the input to which the output is connected also has unequal internal impedances to the reference point.
b) Inequality of the e.m.f.s at the output terminals with respect to the reference point. This effect is considered in terms of a common-mode signal superimposed on the wanted balanced signal by mode conversion.
c) Internal impedance of the source of unbalance. This is considered as the source impedance associated with the common-mode signal described in b).
d) Phase-shift differences in the signal chains to each output terminal.

14.15.3.2 Characteristics to be specified

The following characteristics are suitable for inclusion in specifications:

a) The internal impedance balance, expressed as the inverse ratio of the differential output voltage caused by injecting a common-mode signal into the output, to the e.m.f. of the common mode signal, measured by the method given in 14.15.3.3.
b) The symmetry of the output voltages, expressed as the inverse ratio of the common-mode voltage produced by mode-conversion, to the differential output voltage producing it, measured by the method given in 14.15.3.4.

   NOTE This includes effects due to differential phase-shift.

It is recommended that the manufacturer state the rated values in decibels in the specification.

14.15.3.3 Method of measurement of internal impedance balance

The procedure is as follows:

a) The equipment is connected in the test circuit shown in Figure 9. The resistors R shall be 3 300 Ω ± 1 %, or of closer tolerance, and the potentiometer R_T shall be 500 Ω ± 10 %, or of closer tolerance. The input voltage V shall be 7,75 V (20 dBu), unless otherwise stated. In some cases, it may not be necessary to terminate the input of the equipment under test with its rated source impedance R_s.
b) The switch S is set first to position 1 and R_T is adjusted to minimize the measured voltage U_2, then S is set to position 2 and R_T readjusted so that the same value of U_2 is measured in both positions of the switch S.
c) The internal impedance balance is expressed as the ratio in decibels of V to U_2:

$$20 \lg (V/U_2)$$

d) The measurement is repeated for a number of frequencies, adequately covering the effective frequency range of the equipment. At least three measurements, one at a low frequency such as 80 Hz, one at the standard reference frequency and one at a higher frequency, such as 10 kHz, are recommended. The measurement may also be repeated with other values of input voltage.
e) The results are given either in a table or graphically, presenting the ratio as ordinate (decibels on a linear scale) and the frequency as abscissa (logarithmic scale).

14.15.3.4 Method of measurement of voltage symmetry

The procedure is as follows:

a) The equipment, connected in the test circuit of Figure 10 (based on Figure 4 of IEC 60268-2:1987), is brought under standard measuring conditions with S in position 1. The two resistors $R_L/2$ shall each be equal to half the rated load resistance, minus the resistance of the potentiometer R_T. Unless otherwise stated, the value R_m shall be 600 Ω.
b) The output voltage U_2 is measured using a high-impedance earth-free measuring instrument. The common-mode voltage U_2' is measured using an appropriate instrument.

c) The trimming potentiometer R_t is adjusted so that the same (minimum) value of U_2' is produced in both positions of the switch S.

d) The ratio of differential signal to common-mode signal is calculated in decibels as:

$$20 \lg (U_2/U_2')$$

e) The measurement is repeated for a number of frequencies, adequately covering the effective frequency range of the equipment. At least three measurements, one at a low frequency such as 80 Hz, one at the standard reference frequency and one at a higher frequency, such as 10 kHz, are recommended. The measurement may also be repeated with other values of source e.m.f.

f) The results are given either in a table or graphically, presenting the ratio as ordinate (decibels on a linear scale) and the frequency as abscissa (logarithmic scale).

14.16 Cross-talk and separation in multi-channel amplifiers

14.16.1 Characteristics to be specified

Cross-talk attenuation is expressed in decibels as:

$$20 \lg \frac{U_{A,A}}{U_{B,A}}$$

where

$U_{A,A}$ is the rated output voltage of channel A;

$U_{B,A}$ is the output voltage of channel B due to the rated input voltage applied to channel A.

Separation is expressed in decibels as:

$$20 \lg \frac{U_{A,A}}{U_{A,B}}$$

where $U_{A,B}$ is the output voltage of channel A due to the rated input voltage applied to channel B.

It is recommended that the manufacturer specify rated values of some or all of these characteristics in the specification.

14.16.2 Method of measurement

Two channels A and B are brought under rated conditions.

a) The output voltages $U_{A,A}$ of channel A and $U_{B,B}$ of channel B are measured.

b) The input voltage to channel A is reduced to zero and the output voltage $U_{A,B}$ is measured. This measurement may be either

   1) wide band, or

   2) selective at the measuring frequency, or

   3) selective at the harmonics of the measuring frequency.

c) For the wide-band measurement, an r.m.s. voltmeter and wide-band filter according to IEC 60268-1 shall be used. To improve the signal-to-noise ratio of the wide-band measurement, the input source e.m.f. may be increased. Care should be taken that this does not result in overloading anywhere in the active channel and that the overload source e.m.f. is not exceeded. The value of source e.m.f. used should be noted with the results.

d) The input voltage to channel A is restored and that of channel B reduced to zero. The output voltage $U_{B,A}$ is measured as above.

e) From these measurements, the required ratios can be calculated.

The cross-talk attenuation in decibels from channel A into channel B is:

$$20\lg\frac{U_{A,A}}{U_{B,A}}$$

The cross-talk attenuation in decibels from channel B into channel A is:

$$20\lg\frac{U_{B,B}}{U_{A,B}}$$

The separation in decibels of channel A from channel B is:

$$20\ \lg\frac{U_{A,A}}{U_{A,B}}$$

The separation in decibels of channel B from channel A is:

$$20\lg\frac{U_{B,B}}{U_{B,A}}$$

NOTE 1 The term 'separation' is normally used only in the case of pairs of channels carrying related signals for stereophony. Separation and cross-talk attenuation are equivalent only if $U_{A,A} = U_{B,B}$.

NOTE 2 The term 'channel', in this context, includes both a simple signal path from a single input to a single output, and a branched path which might have more than one input and/or more than one output. Consequently, this method of measurement can be used to determine the cross-talk attenuation between any input and any output (including a low-level output for recording) which is not part of the same signal path (usually known as an 'unrelated output').

The method of measurement of the unwanted signal (wide-band, selective, or selective at harmonic frequencies) shall be stated.

The wide-band measurements may be referred to as 'Total cross-talk attenuation' or 'Total separation'.

The selective measurements may be referred to as 'Linear cross-talk attenuation' or 'Linear separation'.

The measurements made selectively at harmonic frequencies may be referred to as 'Non-linear cross-talk attenuation' or 'Non-linear separation', and the harmonic components may be combined as the square root of the sum of the squared amplitudes to obtain 'single-figure' results.

f) The measurements may be repeated at other frequencies, at other output voltages and for other channels. The results may be tabulated or expressed graphically.

14.17 Gain and phase differences between channels in multi-channel amplifiers

14.17.1 Gain difference

14.17.1.1 Characteristic to be specified

The difference in gain between a pair of channels for stated positions of the controls, if any, as a function of frequency.

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

14.17.1.2 Method of measurement

Both channels are brought under standard measuring conditions, the source being the same for both.

a) Volume, balance and tone controls, if any, are set to corresponding stated positions for both channels. If there is a device for gain trimming, this should be properly adjusted.

b) The frequency of the source is varied continuously or step by step, maintaining the source e.m.f. constant and measuring the output voltages $U_{A,A}$ and $U_{B,B}$ of both channels at each frequency.

c) The ratio of the output voltages $U_{A,A}$ and $U_{B,B}$ is expressed in decibels as a function of frequency.

d) The measurement is repeated for a number of corresponding positions of the volume, balance and tone controls, one of the positions being that for rated conditions. When there is a device for gain trimming, this should not be changed from the position adjusted under item b) above.

e) The results are given as a series of graphs, each labelled with the positions of the controls, presenting the ratio of the output voltages as the ordinate and the frequency as the abscissa.

14.17.2 Phase difference

14.17.2.1 Characteristic to be specified

The difference in phase response between a pair of channels for stated positions of the controls, if any, as a function of frequency.

The manufacturer may optionally present these data in the specification.

14.17.2.2 Method of measurement

Both channels are brought under standard measuring conditions, the source being the same for both.

a) Volume, balance and tone controls, if any, are set to corresponding stated positions for both channels. If there is a device for gain trimming, this should be properly adjusted.

b) A phase difference meter is connected to the output terminals of both channels taking proper account of terminal marking.

c) The frequency of the source is varied, the phase difference being measured at each frequency.

d) The phase difference $\Delta\varphi$ between the two channels is expressed as a function of frequency either in radians or in degrees or as a time difference, as specified in 14.11.4.

e) The measurement is repeated for a number of corresponding positions of the volume, balance and tone controls, one of the positions being that for rated conditions. When there is a device for gain trimming, this should not be changed from the position adjusted under item a) above.

f) The results are presented as a series of graphs, each labelled with the positions of the controls, presenting the phase difference as the ordinate and the frequency as the abscissa.

14.18 Dimensions and mass, characteristics to be specified

The manufacturer shall state these values in the specification.

a) The overall and mounting dimensions;

b) The net mass.

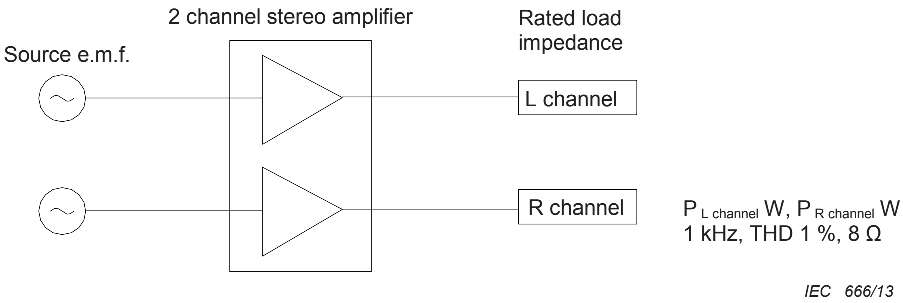

Figure 1a – Rated condition of 2 channel stereo amplifier (see 3.1.2)

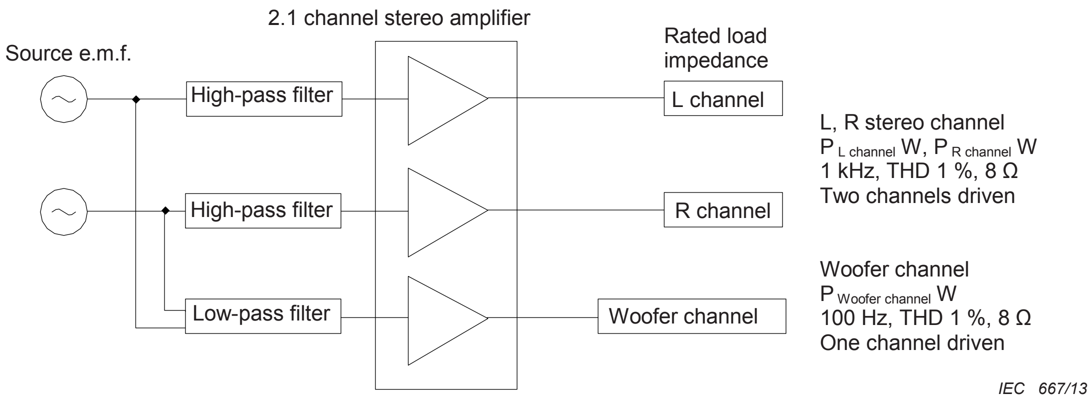

Figure 1b – Rated condition of 2.1 channel amplifiers (see 3.1.2)

Figure 1 – Example block diagram for multi-channel amplifier

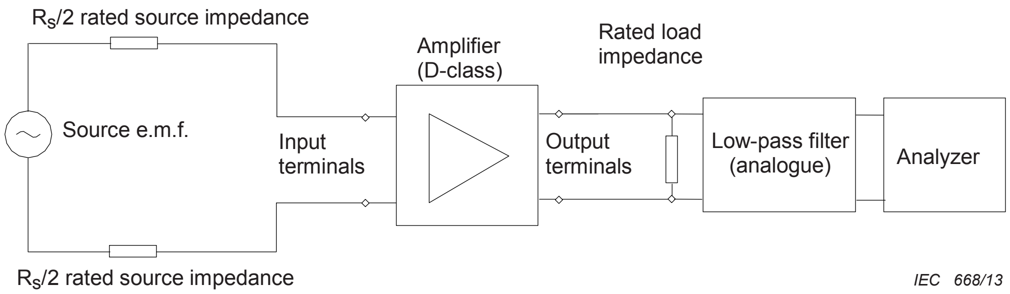

Figure 2a – Arrangements for the Class D amplifier – balanced input, floating (see 3.1.2)

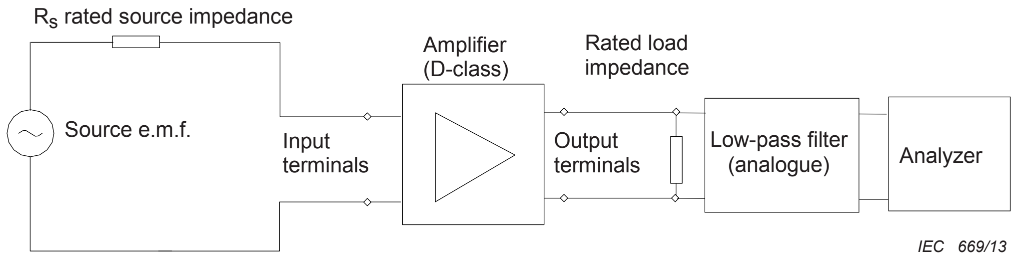

Figure 2b – Arrangements for the Class D amplifier – unbalanced input (see 3.1.2)

Figure 2 – Arrangements for the Class D amplifier

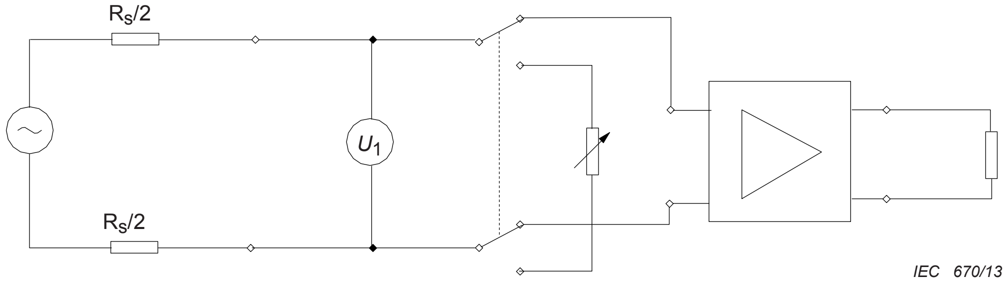

Figure 3a – Arrangements for measuring input impedance – balanced input, floating (see 14.5.2.2.2)

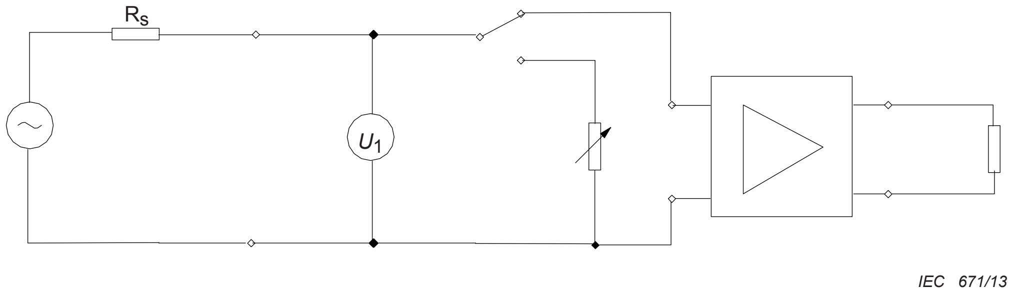

Figure 3b – Arrangements for measuring input impedance – unbalanced input (see 14.5.2.2.3)

Figure 3 – Arrangements for measuring input impedance

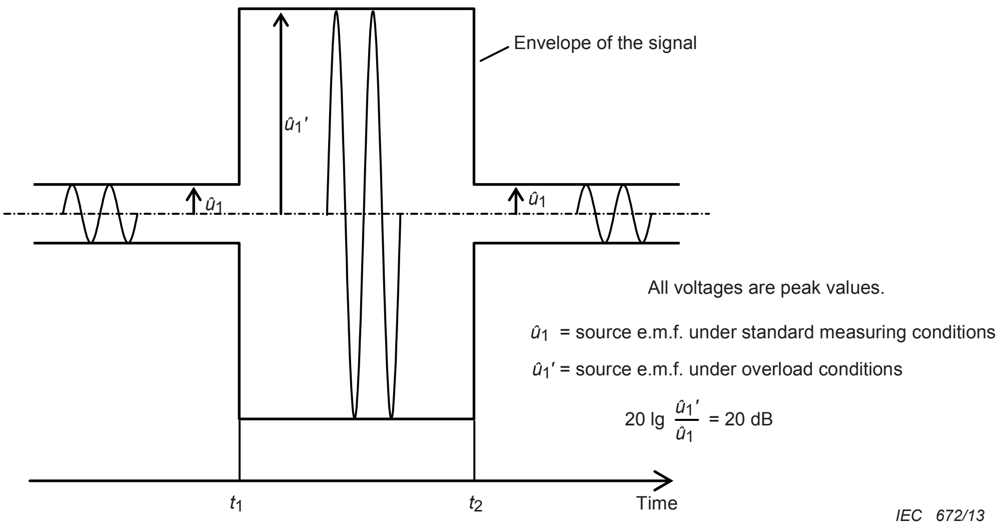

Figure 4a – Oscillogram of the source e.m.f. for measuring overload restoring time (see 14.6.5)

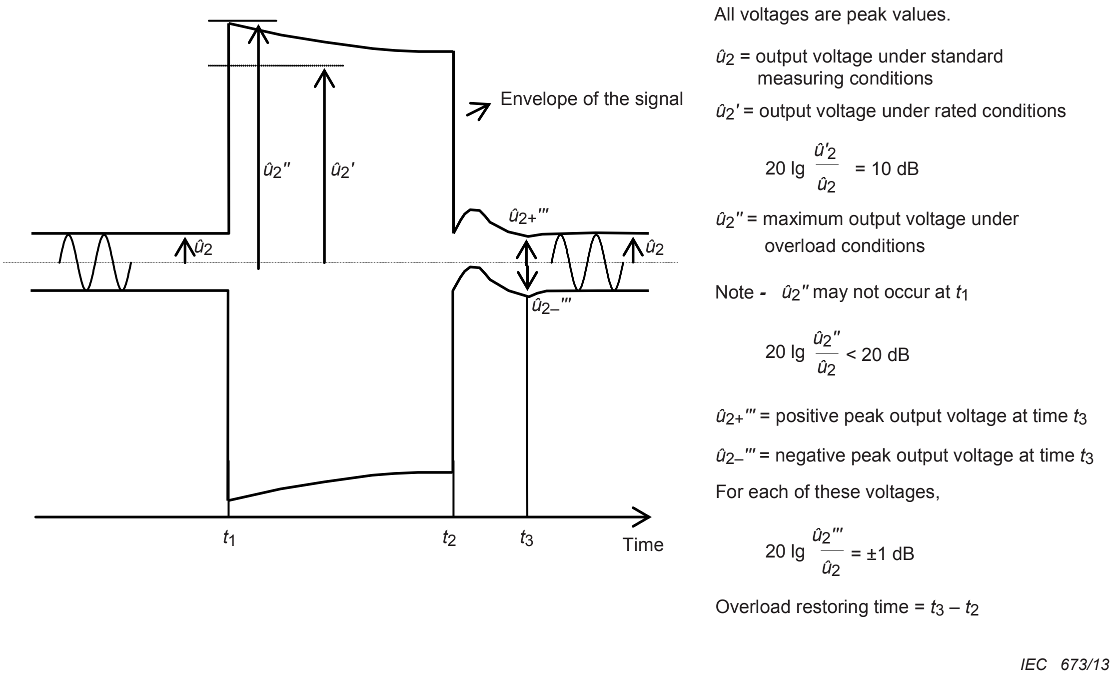

Figure 4b – Oscillogram of the output voltage when measuring overload restoring time (see 14.6.5)

Figure 4 – Oscillogram when measuring overload restoring time

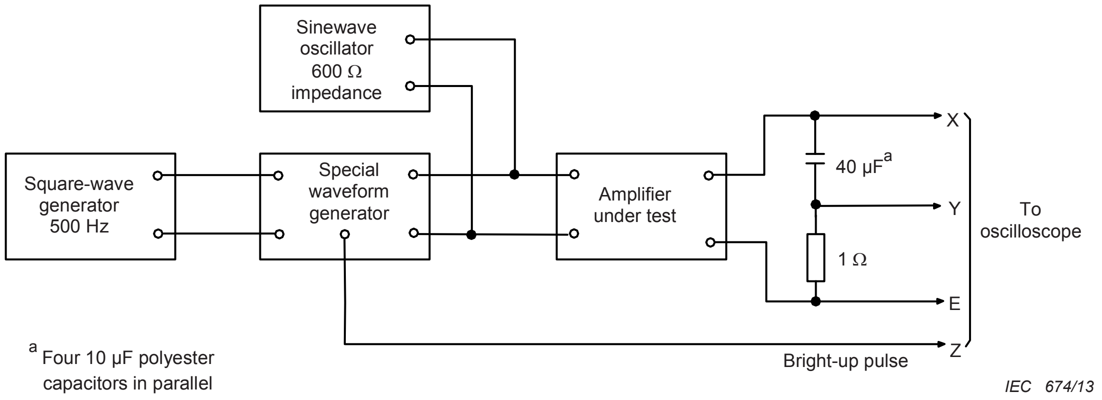

Figure 5a – Configuration of the measuring circuit (see 14.8.2.3 and reference [1] in the bibliography)

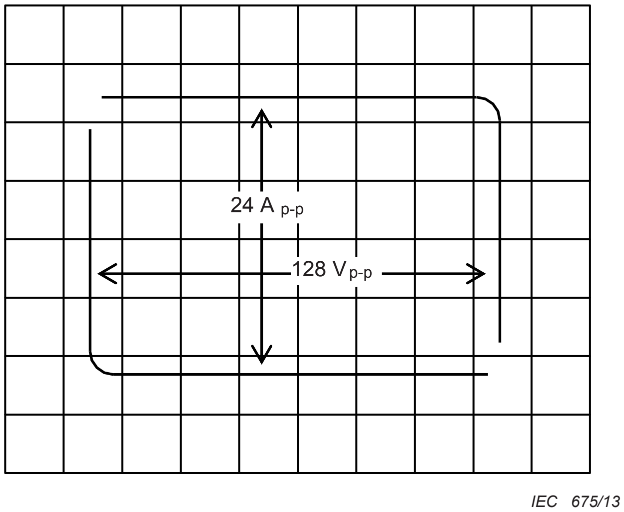

Figure 5b – Typical display of output current and voltage (see 14.8.2.4)

Figure 5 – Protection against potentially damaging combinations of output voltage and current

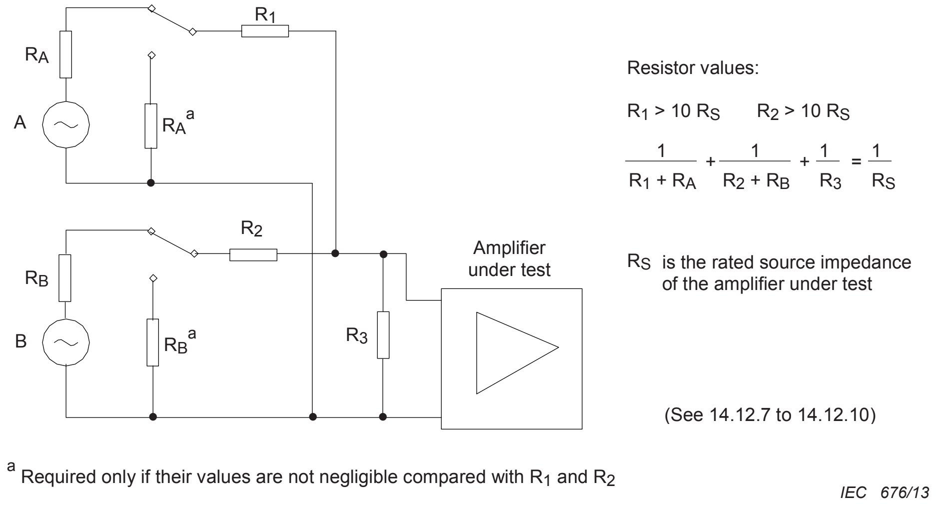

Figure 6 – Arrangement for combining two input signals

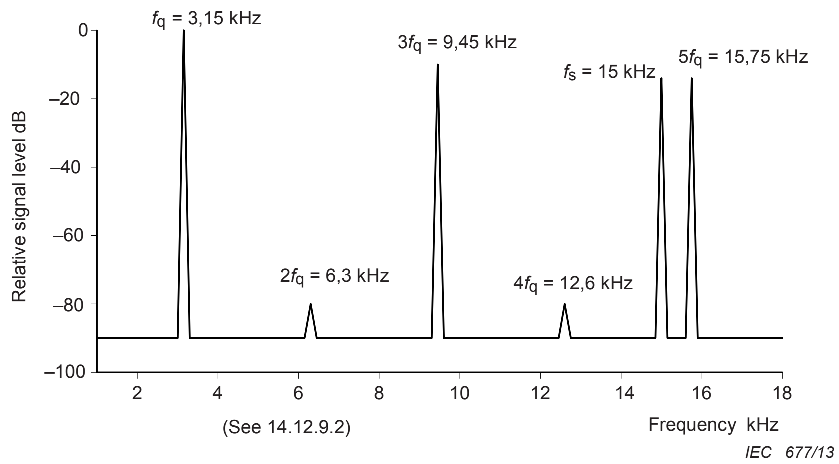

Figure 7 – Frequency spectrum below 30 kHz of the signal for measuring dynamic intermodulation distortion

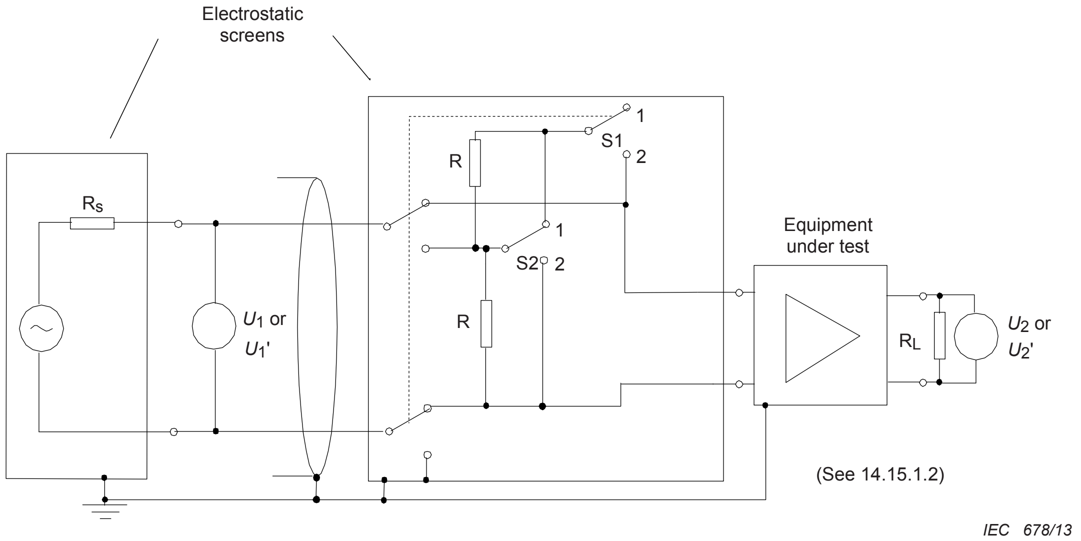

Figure 8 – Arrangement for measuring the balance of a balanced input

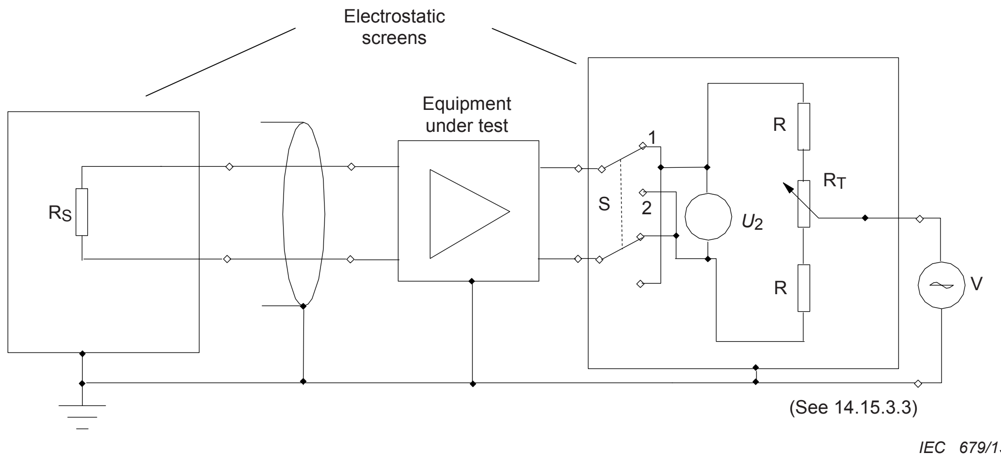

Figure 9 – Arrangement for measuring the internal impedance balance of a balanced output

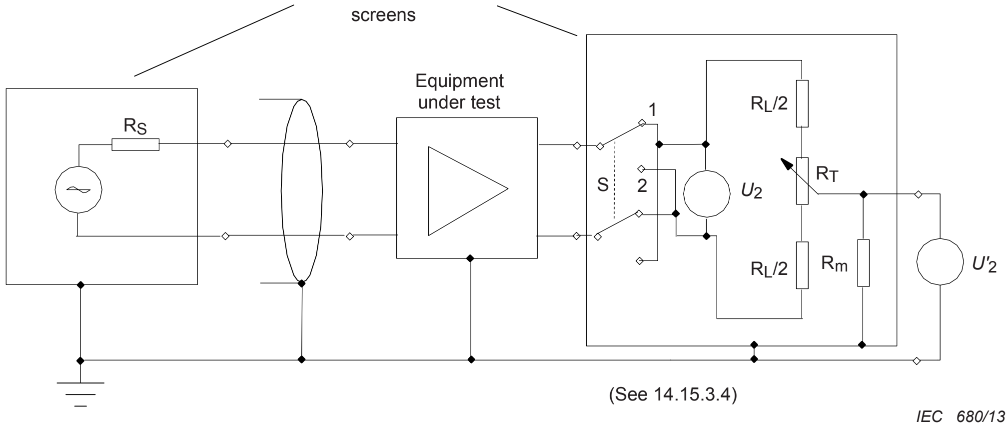

Figure 10 – Arrangement for measuring the voltage symmetry of a balanced output

Annex A
(informative)

Balanced interfaces

The purpose of a balanced interface is to transfer a desired signal as a differential voltage on two signal lines. An ideal balanced line receiver responds only to the differential voltage at its inputs, and does not respond to identical, or common-mode, voltages applied to its inputs. If undesired noise or an interfering signal appears identically on both lines, i.e. no portion is converted to a differential voltage, the noise or interference can be completely rejected by the line receiver. A balanced interface system consists of a line driver, line (normally a screened, balanced cable), and a line receiver, whose common-mode impedances effectively form a bridge. Conversion of noise or interfering signals occurs only when the bridge is not balanced. Therefore, only the common-mode impedance balance of the driver, line, and receiver play a role in noise or interference rejection. This noise or interference rejection property is independent of the presence of a desired differential signal. Therefore, it can make no difference whether the *desired* signal exists entirely on one line, as a greater voltage on one line than the other, or as equal voltages on both of them.

Symmetry of the desired signal has advantages, but they concern headroom (distortion-limited output voltage and overload source e.m.f.) and crosstalk, not noise or interference rejection. For constant power supply rail voltages at the driving end, symmetrical drive obviously increases maximum output by a factor of approximately 2. Symmetrical drive of the signal conductors of a screened cable significantly reduces crosstalk, which can be either capacitively coupled (through imperfect cable screening) or inductively coupled (from unwanted currents flowing in the cable screen). If the screen is earthed at any point other than the driving end, these signal currents flowing in the screen can cause additional crosstalk by flowing in unforeseen paths in the system.

Annex B
(informative)

Specification of a multi-channel amplifier

B.1 General

Unless the specification relates to the operating condition in which all channels are driven, the manufacturer should state the operating condition (see 14.6.3.2).

B.2 Example specification of a 5.1 channel amplifier

Figure B.1 shows a block diagram for a 5.1 channel surround amplifier.

Stereo mode

Front L/R channel: $P_{\text{Front L channel}}$ W, $P_{\text{Front R channel}}$ W

1 kHz, THD 1 %, 8 Ω

Surround mode

Front L; $P_{\text{Front L channel}}$ W / 1 kHz, THD 1 %, 8 Ω

Front R; $P_{\text{Front R channel}}$ W / 1 kHz, THD 1 %, 8 Ω

Centre; (Centre channel) W / 1 kHz, THD 1 %, 8 Ω

Surround L; $P_{\text{Surround L channel}}$ W / 1 kHz, THD 1 %, 8 Ω

Surround R; $P_{\text{Surround R channel}}$ W / 1 kHz, THD 1 %, 8 Ω

Woofer; $P_{\text{Woofer channel}}$ W / 100 Hz, THD 1 %, 8 Ω

One channel driven

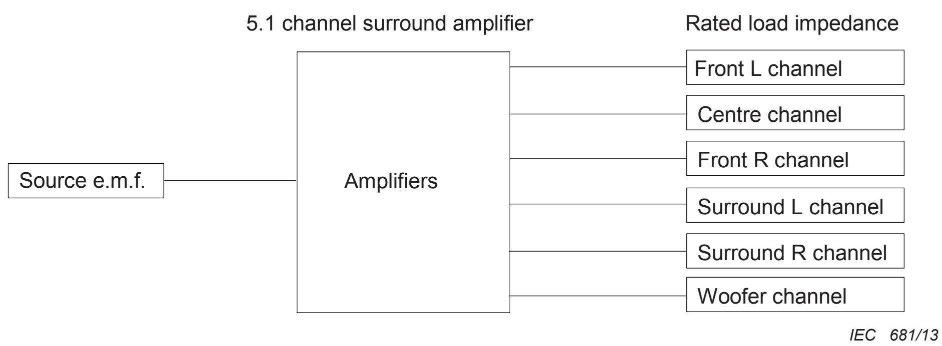

Figure B.1 – Block diagram for a 5.1 channel surround amplifier

B.3 Example specification of a 5 channel amplifier

Figure B.2 shows a block diagram for a 5 channel surround amplifier.

Front L; $P_{\text{Front L channel}}$ W

Front R; $P_{\text{Front R channel}}$ W

Centre; $P_{\text{Centre channel}}$ W

Surround L; $P_{\text{Surround L channel}}$ W

Surround R; $P_{\text{Surround R channel}}$ W

1 kHz, THD 1 %, 8 Ω

All channels driven

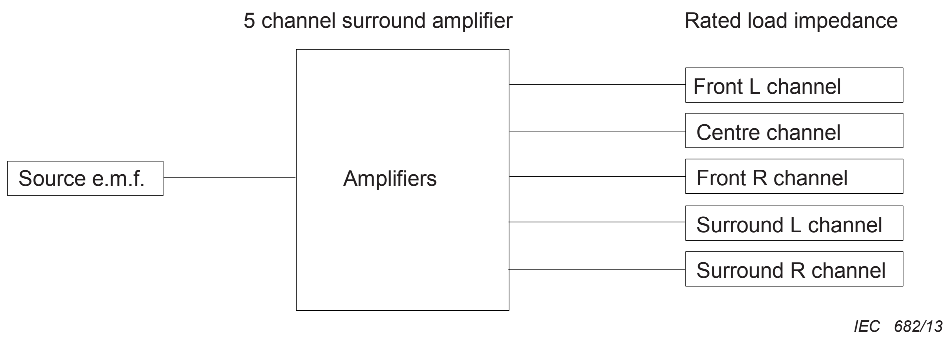

Figure B.2 – Block diagram for a 5 channel surround amplifier

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[2] IEC 60098:1987, *Analogue audio disk records and reproducing equipment*

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