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# INTERNATIONAL STANDARD

## Audio and audiovisual equipment – Digital audio parts – Basic measurement methods of audio characteristics – Part 3: Professional use



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# AUDIO AND AUDIOVISUAL EQUIPMENT – DIGITAL AUDIO PARTS – BASIC MEASUREMENT METHODS OF AUDIO CHARACTERISTICS –

## Part 3: Professional use

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International Standard IEC 61606-3 has been prepared by IEC technical committee 100:Audio, video and multimedia systems and equipment.

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

| FDIS | Report on voting |
|---|---|
| 100/1428/FDIS | 100/1453/RVD |

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

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

A list of all parts of the IEC 61606 series, under the general title *Audio and audiovisual equipment – Digital audio parts – Basic measurement methods of audio characteristics*, can be found on the IEC website.

This International Standard is to be used in conjunction with IEC 61606-1.

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

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- withdrawn,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

A bilingual version of this publication may be issued at a later date.

# AUDIO AND AUDIOVISUAL EQUIPMENT – DIGITAL AUDIO PARTS – BASIC MEASUREMENT METHODS OF AUDIO CHARACTERISTICS –

## Part 3: Professional use

## 1 Scope

This part of IEC 61606 is applicable to the basic measurement methods of audio equipment for professional use.

The definitions, measuring conditions and methods common to both consumer and professional equipment are described in the IEC 61606-1.

This standard contains details of definitions and measuring conditions and methods applicable to professional equipment which differ from those described in IEC 61606-1.

This standard excludes consideration of

- measurement of low-quality audio devices,
- measurement of low-bit-rate audio devices (‘sub-band’ or ‘perceptual’ coding devices),
- measurement of devices which significantly modify time or frequency characteristics of the signal, such as pitch shifters or reverberators,
- measurement of signals from analogue input to analogue output, beyond the most general,
- EMC and safety related testing.

## 2 Normative references

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

IEC 60268-1, *Sound system equipment – Part 1: General*

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

IEC 60958-1, *Digital audio interface – Part 1: General*

IEC 61260, *Electroacoustics – Octave-band and fractional-octave-band filters*

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

AES11-2003, *AES Recommended Practice for Digital Audio Engineering – Synchronization of digital audio equipment in studio operations*

# 3 Terms and definitions

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

**3.1**
**aliasing components**
see definition in IEC 61606-1

**3.2**
**analogue full-scale input and output amplitude**
when applied to an analogue input of the EUT, it produces digital full-scale amplitude within the EUT; conversely, the analogue output full-scale amplitude is that which is produced at an analogue output from the EUT by a digital full-scale amplitude within the EUT

NOTE 1 Sometimes the range of an analogue input or output path may be less than that corresponding to digital full-scale amplitude. For this reason, analogue full-scale input and output amplitudes are usually inferred by driving the converters at a lower amplitude (see 6.3.1.1 and 6.3.2.1).

NOTE 2 The ideal values of these amplitudes cannot be defined within the standard since they are different for different EUTs, and may be modally variable for a single EUT.

NOTE 3 Where these values are unknown for an EUT at the outset of testing, they should generally be established first (using the methods described in 6.3.1.1 and 6.3.2.1 since it may subsequently be necessary, for example, to drive an analogue input at –60 $dB_{FS}$ or to measure an amplitude at an analogue output in $dB_{FS}$ relative to a digital stimulus.

**3.3**
**coding format**
a numerical convention used to represent digital audio data at the inputs or outputs of the EUT

NOTE This standard is primarily intended to be applied to EUTs which transact digital audio signals expressed as a stream of LPCM (Linear Pulse Code Modulation) samples; that is, a stream of binary words, directly representing the amplitudes of successive audio samples quantised at the sampling frequency, and rendered as binary 2's complement numbers. Positive analogue voltages correspond to positive digital sample values (that is, 2's complement numbers whose most-significant bit (MSB) is zero). Many of the methods described in the standard are applicable to other coding formats.

**3.4**
**decibels full-scale**
**$dB_{FS}$**
the r.m.s. amplitude of a sinusoid described in 3.10 is defined as 0 $dB_{FS}$, where the amplitude of any signal can be defined in $dB_{FS}$ as 20 times the common logarithm of the ratio of the r.m.s. amplitude of the signal to that of the signal defined in 3.10

NOTE Analogue amplitudes at the input or output of an EUT can be expressed in $dB_{FS}$ by referring to the analogue full-scale input or output amplitudes as defined in 3.2.

**3.5**
**digital audio interface**
a physical medium upon which digital audio data are transferred into or out of the EUT

NOTE Digital audio interfaces may include packaged media (such as in the case of a CD player) or radio-frequency (RF) carriers (such as in the case of a set-top-box) as well as conventional copper or optical digital interconnections.

**3.6**
**digital audio signal**
see definition in IEC 61606-1

**3.7**
**digital zero**
see definition in IEC 61606-1

**3.8**
**equipment under test**
**EUT**
see definition in IEC 61606-1

NOTE In structuring an equipment or installation specification, it is important to consider the way in which the different elements of the equipment might best be segmented for the purposes of the specification or measurement. A basic D/A converter, for example, would represent a simple EUT with 'General characteristics', 'Digital input characteristics' and 'Analogue output characteristics'. But consider a large studio mixing console, which may have many different functional blocks, and many different inputs and outputs of different types and in different domains. Such a mixing console example might be considered as a collection of different elements; for example, 'analogue line inputs', 'analogue mic inputs', 'AES3 inputs', 'channel equalizers', 'mix bus processors' etc. Typically, different measurement criteria are applicable to each different element, and different performance levels might be specified. In such a case each element or subsystem should, where possible, be considered as a discrete 'EUT' and should be specified and measured individually. In addition, typical signal paths through the entire equipment may also be specified, and their performance criteria stated as a single EUT.

**3.9**
**folding frequency**
half the sampling frequency of the EUT

NOTE 1 Signals above this frequency applied to the EUT are subject to aliasing.

NOTE 2 Complex EUTs may have an input folding frequency and an output folding frequency which are different. In such cases, where input or output is unspecified, the folding frequency shall refer to the lower frequency.

**3.10**
**full-scale amplitude**
**FS**
amplitude of a 997 Hz sinusoid whose peak positive sample just reaches positive digital full-scale (in 2's-complement a binary value of 0111…1111 to make up the word length) and whose peak negative sample just reaches a value one away from negative digital full-scale (1000…0001 to make up the word length) leaving the maximum negative code (1000…0000) unused

**3.11**
**high and low interference frequencies**
moderately high and low signal frequencies of 15 kHz and 60 Hz respectively at which certain interference effects may be quoted if a graphical report is not required

**3.12**
**in-band amplitude**
an amplitude measurement incorporating a standard low-pass filter so as to exclude out-of-band components above the upper band-edge frequency

**3.13**
**in-band frequency range**
see definition in IEC 61606-1

**3.14**
**input word length**
the maximum audio word length which can be applied to a digital input of the EUT at its present settings, for which the least significant bit is not ignored

**3.15**
**interface jitter**
timing errors in the transitions of a digital audio carrier or reference sync, owing to cabling effects or jitter in the clock of the sourcing equipment

**3.16**
**jitter susceptibility**
the effect on EUT performance as a result of sampling jitter caused by interface jitter on the incoming reference sync

**3.17**
**maximal measuring amplitude**
a signal amplitude of –1 $dB_{FS}$, close to (but below) full scale amplitude, which is applied to the EUT in certain of the described methods

NOTE This definition can apply to either a digital or an analogue signal (see 3.4).

**3.18**
**normal load impedance**
required differential input impedance of the analogue measuring equipment defined as 100 kΩ or more, in parallel with not more than 500 pF in this standard

**3.19**
**normal measuring amplitude**
a signal amplitude of −20 $dB_{FS}$, representative of a typical operating amplitude, which is applied to the EUT in certain of the described methods

NOTE This definition can apply to either a digital or an analogue signal (see 3.4).

**3.20**
**normal measuring frequency**
a signal frequency of 997 Hz, representative of a typical mid-range frequency, which is applied to the EUT in certain of the described methods

**3.21**
**normal source impedance**
required differential output impedance of the analogue measuring equipment defined as 50 Ω or less for a balanced output and 25 Ω or less for an unbalanced output in this standard

**3.22**
**out-of-band amplitude**
amplitude measurement incorporating a standard out-of-band filter so as to exclude in-band components below the upper band-edge frequency

**3.23**
**out-of-band frequency range**
frequency range from the folding frequency to 192 kHz (or some other stated maximum)

NOTE Signals applied to the EUT input in this frequency range are subject to aliasing.

**3.24**
**output word length**
number of significant bits transmitted by a digital output of the EUT at its present settings, of which none is continuously zero

**3.25**
**residual amplitude**
an amplitude measurement incorporating a standard band-reject filter to suppress the effects of an unwanted frequency, usually the stimulus frequency

**3.26**
**sampling frequency**
$f_s$
the rate at which audio samples are processed within the EUT

NOTE Complex EUTs may have an input sampling frequency and an output sampling frequency which are different. In such cases, where input or output is unspecified, the sampling frequency shall refer to the lower frequency.

**3.27**
**sampling jitter**
timing errors in the sampling instants applied by an A/D converter, D/A converter or asynchronous sample-rate converter which lead to phase modulation of the converted audio signal

**3.28**
**selective amplitude**
amplitude measurement incorporating a standard band-pass filter to suppress the effects of spurious components and wideband noise

**3.29**
**standard third-octave frequencies**
set of measurement frequencies set at one-third-octave intervals, as defined in IEC 61260, where these frequencies are preferred whenever third-octave analysis is specified

**3.30**
**upper band-edge frequency**
see definition in IEC 61606-1

## 4 Rated values

For a full explanation of these terms, see IEC 60268-2. The followings are rated conditions for digital audio equipment. They should be specified by the manufacturer.

- rated supply voltage
- rated supply frequency
- rated pre-emphasis and de-emphasis characteristics
- rated digital input word length
- rated sampling frequencies

## 5 Measuring conditions

### 5.1 Environmental conditions

Where environmental conditions for EUT operation are specified by the manufacturer, measurements will be assumed to be valid over the entire range, and shall be so verified. In the absence of an environmental specification, tests will be performed at a temperature of 25 ˚C ± 10 ˚C, relative humidity of 60 % ± 15 % and air pressure of 96 kPa ± 10 kPa.

### 5.2 Power supply

Power-line (mains) voltage shall be set within 2 % of the nominal value listed on the panel of the device being tested. If a range of values is given, the specifications are assumed to be valid over the entire range and may be so verified.

Power-line (mains) frequency shall be set within 1 % of the nominal value listed on the panel of the device being tested. If a range of values is given, the specifications are assumed to be valid over the entire range and shall be so verified.

For dc-powered devices the dc supply voltage shall have a peak-to-peak ripple content of less than 0,5 % of the nominal supply voltage.

### 5.3 Test signal frequencies

The test signal frequencies defined in IEC 61606-1 are not especially applicable in the professional context. Although these frequencies are referenced where possible, in general this standard specifies directly such frequencies as may be required.

### 5.4 Standard settings

All controls of the EUT shall be set to the reference positions specified by the manufacturer, or to their normal operating positions or to those specified in IEC 61606-1 where none is specified.

### 5.5 Preconditioning

The EUT shall be preconditioned as described in IEC 61606-1.

### 5.6 Measuring instruments

#### 5.6.1 General

All measuring instruments specified in this standard shall comply with the instrument specifications in 4.6 of IEC 61606-1 except for variations and additions to their specifications as detailed in this document.

In general, equivalent analogue and digital instruments should behave identically except where detailed.

Digital instruments shall be able to generate and analyze data in whatever digital audio interface format(s) are supported by the EUT.

Analogue instrument outputs should present the normal source impedance as defined in 3.21; analogue instrument inputs should present the normal load impedance as defined in 3.18.

#### 5.6.2 Signal generator

##### 5.6.2.1 Generator modes

The methods described in this Clause require a variety of generator modes, which are detailed below. These are most easily realised using a multi-function generator.

The different generator modes are indicated for each method by a generator block symbol as shown in Figure 1.

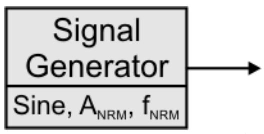



**Figure 1 – Signal generator**

The lower section of the symbol describes the mode of the generator: its function, amplitude and frequency settings. Abbreviations are as follows:

Amplitude:

- NRM Normal measuring amplitude
- MAX Maximal measuring amplitude

- SWP Swept amplitude; the method is repeated at each of a defined series of test amplitudes
- ADJ Manually adjusted amplitude

Frequency:

- NRM Normal measuring frequency
- UBE Upper band-edge frequency
- SWP Swept frequency

Other settings, as required in various modes, are described in the accompanying text.

If synchronous multi-tone analysis is to be performed, the signal generator shall additionally have wavetable generation capabilities as described in A.1.

#### 5.6.2.2 Dither

Unless otherwise stated, all stimuli which are used to drive the EUT in the digital domain shall be dithered with triangular probability-density function (TPDF) white dither at the appropriate amplitude as determined by the input word length of the EUT.

NOTE This type of dithering precisely linearizes the quantization noise of the test stimuli to finite word lengths. It is achieved by adding a dither signal to the test stimulus signal prior to its truncation to the input word length of the EUT. The correct dither signal is a random or pseudo-random sequence having a triangular probability density function (TPDF), no DC offset, and a peak-to-peak amplitude of two least-significant bits of the EUT input word length. The amplitude is constant per unit bandwidth (white) up to at least the upper band-edge frequency. TPDF is achieved by adding pairs of uniformly-distributed random or pseudo-random numbers to form each dither sample; the generating sequence should be long in duration and maximally random, and the extraction points of the number pairs should be well separated in order to minimize correlation.

#### 5.6.2.3 Accuracy

Signal generators used for measurements in this standard shall provide control over frequency with an accuracy of at least ±0,05 %. For analogue signal generators, the frequency may be measured with a frequency counter and adjusted to be within the required accuracy. The frequency adjustment resolution shall be adequate to produce the frequencies specified for each test.

Analogue stimuli shall be generated with an amplitude accuracy of at least ± (0,2 dB + 3 μV) at the normal measuring frequency, and ±(0,3 dB + 3 μV) from 20 Hz to the upper band-edge frequency. Digital stimuli shall be generated with an amplitude accuracy of ±(0,01 dB + 0,5 LSB).

### 5.6.3 Signal analyzer

#### 5.6.3.1 Analyzer modes

The methods described in this Clause require a variety of analyzer modes which are detailed below. These are most easily realised using a multi-function analyzer. However, individual filters, meters etc. may be used if required. All amplitude measurements specified in this standard shall be made with true root-mean-square (r.m.s.) responding meters. Filters are described in 5.6.3.2.

A wideband amplitude meter, as shown in Figure 2, is a simple r.m.s. amplitude meter with no pre-metering filters.


**Figure 2 – Wideband amplitude**

An in-band amplitude meter, as shown in Figure 3, incorporates the low-pass filter as described in 5.6.3.2.1.

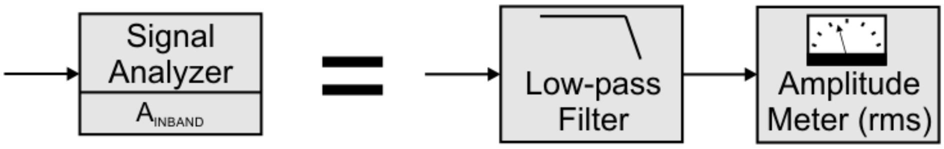



**Figure 3 – In-band amplitude**

An out-of-band amplitude meter, as shown in Figure 4, incorporates the high-pass filter as described in 5.6.3.2.2.

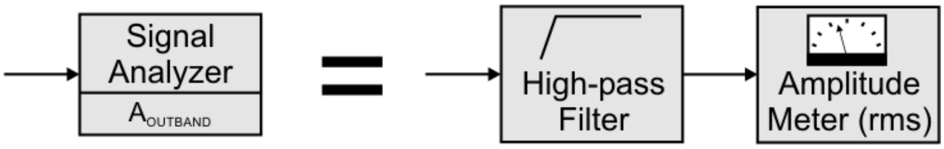



**Figure 4 – Out-of-band amplitude**

A selective amplitude meter, as shown in Figure 5, incorporates the band-pass filter as described in 5.6.3.2.3 to measure the amplitude of a single frequency component. Unless otherwise stated, the band-pass filter is auto-tuned to the generator frequency.

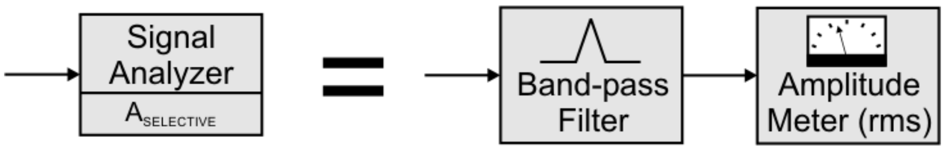



**Figure 5 – Selective amplitude**

A residual amplitude meter, as shown in Figure 6, incorporates the band-reject filter as described in 5.6.3.2.6 to exclude the effects of a single frequency component, usually the stimulus frequency. Unless otherwise stated, the band-reject filter is auto-tuned to the predominant input frequency.

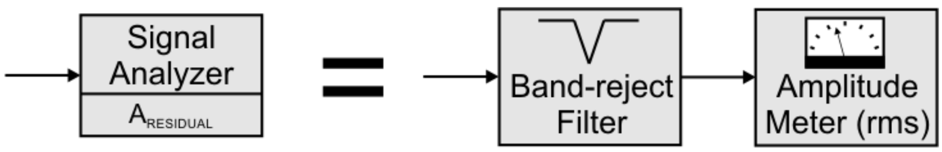



**Figure 6 – Residual amplitude**

A weighted amplitude meter, as shown in Figure 7, incorporates the weighting filter as described in 5.6.3.2.9.

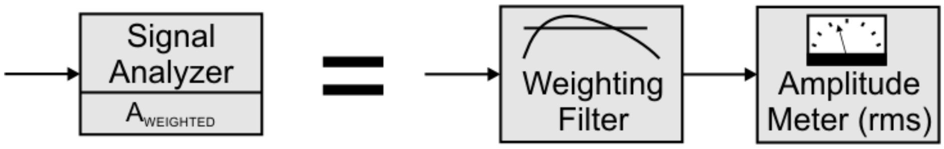



**Figure 7 – Weighted amplitude**

Where methods require variations on the analyzer modes described, these are detailed in the accompanying text.

Some analyzer modes require the use of more than one cascaded filter (for example it is sometimes necessary to exclude out-of-band components from residual measurements); in these cases, the analyzer block symbol is designated with both filters (for example $A_{\mathrm{INBAND\ RESIDUAL}}$).

NOTE If synchronous multi-tone analysis is to be performed, a signal analyzer with additional FFT analysis and computation capabilities is required, as described in Annex A.

#### 5.6.3.2 Filters

##### 5.6.3.2.1 Low-pass filter (in-band filter)

Defined in IEC 61606-1.

##### 5.6.3.2.2 High-pass filter (out-of-band filter)

Defined in IEC 61606-1, except as dictated by the revised out-of-band frequency range or the sampling frequency.

##### 5.6.3.2.3 Band-pass filter

Unless otherwise specified, band-pass filters shall conform to class II or class III response limits as outlined in IEC 61260. This provides at least 30 dB of attenuation of signals one octave away from the filter centre frequency and 60 dB, three octaves away. Such band-pass filters shall be used where third-octave analysis is described (at the standard third-octave frequencies), and for all selective amplitude measurements, except where a more selective filter is specified.

##### 5.6.3.2.4 Narrow band-pass filter

Defined in IEC 61606-1.

##### 5.6.3.2.5 Window-width band-pass filter

A band-pass filter realised in the frequency domain, having an extremely narrow unity-gain pass-band defined by the sampling frequency, Fast Fourier Transform (FFT) record length and window function, and extreme attenuation outside that band. The width of the pass-band is the minimum number of bins required to effectively pass the selected frequency, since the energy at that frequency is dispersed into a number of adjacent bins dependent on the chosen window function.

##### 5.6.3.2.6 Band-reject filter

The band-reject filter used by default for residual and Distortion-and-noise measurements shall have a $Q$ of at least 1 and not more than 5, except where a greater selectivity is specified.

The band-reject filter may be substituted in residual measurements by sharper (more selective) band-reject filters, as described below, in certain circumstances.

#### 5.6.3.2.7 Narrow band-reject filter

A band-reject filter with a *Q* of between 5 and 10.

#### 5.6.3.2.8 Window-width band-reject filter

A band-reject filter realised in the frequency domain, having an extremely narrow stop-band defined by the sampling frequency, FFT record length and window function, providing extreme attenuation, and unity gain outside that band. The width of the stop-band is the minimum number of bins required to effectively exclude the selected frequency, since the energy at that frequency is dispersed into a number of adjacent bins dependent on the chosen window function.

#### 5.6.3.2.9 Weighting filter

The weighting filter for all weighted noise measurements shall conform to IEC 60268-1 except for overall gain. The filter unity-gain frequency shall be 2 kHz. Relative amplitude measurements, such as signal-to-noise ratio, performed using this recommended standard weighting filter, shall be abbreviated “dB CCIR-RMS”. Absolute amplitude measurements performed using this recommended filter shall be denoted by the appropriate quantity abbreviation followed by “CCIR-RMS”; for example, $dB_{FS}$ shall be “$dB_{FS}$ CCIR-RMS” If a standard weighting filter differing from this recommendation is used for a measurement according to this standard, the filter network – and gain if appropriate – shall be specified.

NOTE The 2 kHz reference in this standard is equivalent to inserting an attenuation of 5,629 dB at all frequencies when compared with the reference frequency of 1 kHz specified in IEC 60268-1.

### 5.6.3.3 Absolute and relative amplitude measurements

Absolute amplitude results shall be stated directly in r.m.s. units, for example $dB_{FS}$ for digital signals and $dB_u$ or $V_{rms}$ for analogue signals.

Amplitude results may also be stated relative to a reference amplitude, as a ratio in decibels or percent. Self-relative results should be stated relative to the measured analyzer input amplitude for the same channel (prior to any filters), for example in the ‘Distortion-and-noise’ method. Channel-relative results shall be stated relative to the analyzer input amplitude of a reference channel, for example in the cross-talk method.

Multi-function analyzers are generally capable of performing relative measurements directly. Otherwise, the reference amplitude shall be measured in addition to the desired measurement, and the relative result computed manually.

### 5.6.3.4 Accuracy

Unless otherwise specified, equipment used for measurements in this standard shall have an accuracy in the parameter being measured of at least three times better than the specification being verified.

All amplitude meters used for measurements in this standard shall be true root-mean-square (r.m.s.) responding devices with a minimum required accuracy of 0,25 dB (in-band or selective measurements) or 1,0 dB (residual measurements) over the range from 20 Hz to the upper band-edge frequency. This accuracy shall be maintained for a signal having a crest factor of 5 or less. RMS. calibrated average or peak-responding devices shall not be used.

Analogue analysis shall apply an additional allowed tolerance of ±3 µV, and digital analysis shall apply an additional allowed tolerance of ±0,5 LSB.

All amplitude meters used for measurements in this standard shall integrate the signal for a minimum of 25 ms to ensure an adequate number of codes are exercised in the EUT. For low detected signal frequencies the required time shall be increased to ensure that at least one full cycle of the signal shall be measured.

# 6 Measurement methods

## 6.1 Overview

The measurement methods described in ‘General characteristics’ below shall apply to all EUTs irrespective of their input and output types. In addition, the methods described in ‘analogue input characteristics’, ‘analogue output characteristics’, ‘digital input characteristics’ and ‘digital output characteristics’ shall be applied as dictated by the input and output domains of the particular EUT.

If the EUT provides two or more channels, the measurements should be repeated for every channel.

In many cases it will be appropriate to repeat certain measurements for various operating conditions or control settings; for example, sampling frequency. In such cases, the applied conditions and settings shall be clearly stated in conjunction with each measurement.

Unless specifically stated, the EUT shall be configured with the standard settings as described in 5.4. Wherever different settings are employed, these shall be clearly stated.

## 6.2 General characteristics

### 6.2.1 Linear response

#### 6.2.1.1 Amplitude related

##### 6.2.1.1.1 Gain

Aim: This test measures the ratio of output amplitude to input amplitude under standard settings.

Using the method shown in Figure 8, the EUT shall be driven with a sinusoidal stimulus at the normal measuring amplitude and frequency. The selective amplitude at the output of the EUT shall be measured, and expressed relative to the normal measuring amplitude, in dB.

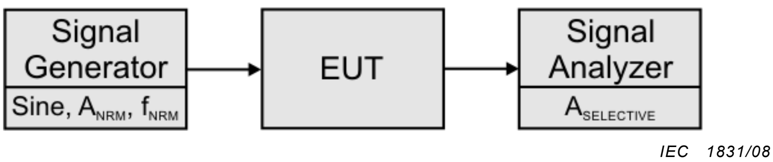



**Figure 8 – Gain method**

NOTE This characteristic applies generally to EUTs with analogue input and analogue output, or with digital input and digital output. For cross-domain gain characteristics, refer to 6.3.1.1 and 6.3.2.1).

##### 6.2.1.1.2 Gain stability

Aim: This test measures the variation of gain over time.

Using the method shown in Figure 8, the EUT shall be driven with a sinusoidal stimulus at the normal measuring amplitude and frequency. The selective amplitude at the output of the EUT shall be measured for a period of at least 1,0 h immediately following preconditioning as described in 5.5. The gain stability shall be defined as the ratio of the highest to the lowest amplitude recorded during the period, expressed in dB.

#### 6.2.1.1.3 Gain difference between channels and tracking error

Aim: This test measures the matching of gain between channels.

Where possible, each channel of the EUT shall be simultaneously driven with a sinusoidal stimulus at the normal measuring amplitude and frequency using the method shown in Figure 8. The selective amplitude at the output of each EUT channel shall be recorded. The inter-channel gain matching shall be defined as the ratio of the highest to the lowest channel amplitude recorded, expressed in dB.

Where a ganged gain control affects all of the EUT channels, the tracking error shall be defined as the highest inter-channel gain matching result which occurs at any point on the control. If only a part of the control's range is to be measured, then that part shall be defined. The test shall be applied without the signal being clipped within the EUT; it may therefore be necessary to specify a lower stimulus amplitude if the range of the gain control demands it.

#### 6.2.1.1.4 Frequency response

Aim: This test measures the variation of gain with frequency.

Using the method shown in Figure 9, the frequency response may be measured by applying a sinusoidal stimulus at the normal measuring amplitude to the input of the EUT, and measuring the amplitude at the EUT's output for a range of different stimulus frequencies. The amplitude measurement should preferably be selective, to prevent the result from being influenced by the presence of significant noise or spurious components.


*IEC 1832/08*

**Figure 9 – Frequency response method**

The measurement frequencies can be freely chosen to suit the particular EUT, sampling frequency etc., but should preferably be logarithmically spaced. It is suggested that the frequencies be chosen in accordance with the appropriate Table in IEC 61606-1. In any case, the frequency range shall include 10 Hz and the upper band-edge frequency.

The response should be presented as a graph with frequency on the X axis (preferably rendered logarithmically) and the recorded amplitude at each frequency, expressed relative to the recorded amplitude at the normal measuring frequency (or the nearest available frequency thereto), in dB, on the Y axis.

Alternatively, if a graph is not provided, the frequency response may be quoted by expressing the largest and smallest recorded amplitudes relative to the amplitude recorded at the normal measuring frequency, in dB, for example: "+0,1/−3,0 dB from 10 Hz to 20 kHz with respect to 997 Hz".

#### 6.2.1.1.5 Maximum input amplitude

Aim: This test measures the input amplitude corresponding to the EUT's maximum signal handling capability under standard settings.

Maximum input amplitude shall be measured as shown in Figure 10 by driving the input of the EUT with a sinusoidal stimulus of adjustable frequency and amplitude. Both the amplitude and the residual amplitude of the output of the EUT shall be monitored whilst the generator amplitude is adjusted to the highest that can be accommodated before either a 0,3 dB gain reduction or –40 dB (1 %) 'distortion-and-noise' occurs. The corresponding generated amplitude shall then be recorded. Digital domain amplitudes shall be expressed in $dB_{FS}$, analogue domain amplitudes should be expressed in $dB_u$ but may be expressed in $V_{rms}$.

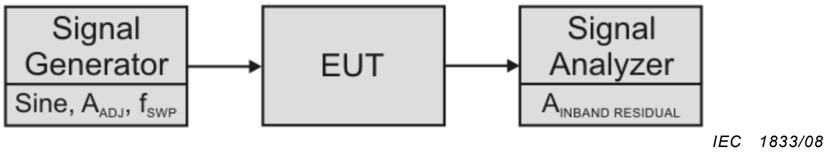



**Figure 10 – Maximum input and output amplitude method**

When measuring maximum input amplitude, any gain controls should be set so that the onset of input saturation occurs at the highest possible input amplitude, and to ensure that output saturation does not occur.

Maximum input amplitude should be measured at a range of frequencies. The measurement frequencies can be freely chosen to suit the particular EUT and sampling frequency, for example, but should be logarithmically spaced no more than one octave apart. In any case, the frequency range should include 10 Hz and the upper band-edge frequency. The results should be presented as a graph with frequency on the X axis (preferably rendered logarithmically) and the maximum input amplitude expressed in the appropriate amplitude unit on the Y axis.

If the maximum input amplitude is only characterised at a single frequency, the normal measuring frequency shall be used.

When de-emphasis filters are incorporated in the EUT input, measurement results should be reported separately with each available de-emphasis filter, as well as without de-emphasis.

NOTE Maximum input amplitude measurements are most often applied to analogue inputs, and are sometimes measured against frequency since such dependence in A/D converter devices is not uncommon. However, this method is included in the ‘general characteristics’ because it may be relevant in other cases, for example when characterising digital signal paths with non-flat frequency response or with imperfect gain structure.

#### 6.2.1.1.6 Maximum output amplitude

Aim: This test measures the output amplitude corresponding to the EUT’s maximum signal handling capability under standard settings.

Maximum output amplitude shall be measured using the same methods as shown in Figure 10 in 6.2.1.1.5, driving the input of the EUT with a sinusoidal stimulus of adjustable frequency and amplitude. Both the amplitude and the residual amplitude of the output of the EUT shall be monitored whilst the generator amplitude is adjusted to the highest that can be accommodated before either a 0,3 dB gain reduction or –40 dB (1 %) ‘distortion-and-noise’ occurs. The corresponding output amplitude shall then be recorded. Digital domain amplitudes shall be expressed in $dB_{FS}$, analogue domain amplitudes should be expressed in $dB_u$ but may be expressed in $V_{rms}$.

When measuring maximum output amplitude, any gain controls should be set so as to maximise output amplitude and to ensure that input saturation does not occur.

Maximum output amplitude should be measured at a range of frequencies. The measurement frequencies can be freely chosen to suit the particular EUT and sampling frequency, for example, but should be logarithmically spaced no more than one octave apart. In any case, the frequency range should include 10 Hz and the upper band-edge frequency. The results should be presented as a graph with frequency on the X axis (preferably rendered logarithmically) and the maximum output amplitude expressed in the appropriate amplitude unit on the Y axis.

If the maximum output amplitude is only characterised at a single frequency, the normal measuring frequency shall be used.

When emphasis filters are incorporated in the EUT output, measurement results should be reported separately with each available emphasis filter, as well as without emphasis.

NOTE Maximum output amplitude measurements are most often applied to analogue outputs, and are sometimes measured against frequency since such dependence in D/A converter devices is not uncommon. However, this method is included in the 'general characteristics' because it may be relevant in other cases, for example when characterising digital signal paths with non-flat frequency response or with imperfect gain structure.

#### 6.2.1.1.7 Polarity

Aim: This test measures whether or not the EUT inverts the polarity of signals passing through it.

The input of the EUT should be driven with a tone burst comprising periods of sinusoidal stimulus at the normal measuring amplitude and frequency, interspersed with periods of silence. The sinusoid shall be gated on and off at positive-going zero crossings, and shall be on for five cycles and off for a period approximately equivalent to 20 cycles. The output of the EUT shall be examined using a digital signal monitor or an analogue signal monitor (for example, an oscilloscope) to determine whether the EUT is either 'non-inverting' or 'inverting'.

Alternatively, polarity may be measured with any asymmetrical signal, and can be checked manually or using an automated device that can sense the polarity of the asymmetry.

### 6.2.1.2 Time related

#### 6.2.1.2.1 Phase response

Aim: This test measures the difference in phase delay between the measured frequency, and a component at the normal measuring frequency, when passing through the EUT.

The phase delays of frequencies passed through the EUT should be compared by direct means, such as using FFTs of pseudo-random sequences, impulses or multi-tones, and the deviation from linear phase recorded in degrees. The FFT technique provides result bins equally spaced from DC to the folding frequency. The peak amplitude of any stimulus should be equal to the peak amplitude of a sinusoid at the normal measuring amplitude.

Alternatively, the phase response of an EUT that processes signals in real time and allows simultaneous access to the input and output terminals may be measured using comparative techniques such as sine-wave display. The phase shift produced by any time delay through the EUT shall be subtracted before recording the results.

The phase response shall be presented as a graph with frequency on the X axis (preferably rendered logarithmically) and the phase, expressed relative to the recorded phase at the normal measuring frequency, in degrees, on the Y axis.

NOTE 1 When using impulses, it may be necessary to average the results of several measurements to obtain the required measurement accuracy.

NOTE 2 When emphasis filters are incorporated in the EUT, measurement results should be reported separately with and without emphasis.

#### 6.2.1.2.2 Group delay

Group delay relative to the normal measuring frequency may be computed (if required) from the phase response of the EUT measured in 6.2.1.2.1 by dividing the phase angle difference at each frequency by 360° and multiplying the result by the period of that frequency. Group delay should be presented in similar graphical form to the phase response, but with the relative time on the Y axis.

#### 6.2.1.2.3 Inter-channel phase response

Aim: This test measures the variation of phase response between channels.

Inter-channel phase response shall be measured by applying a sinusoidal stimulus of variable frequency at the normal measuring amplitude to all channel inputs of the EUT. One channel shall be selected as the reference and so specified. The phase differences between every other channel and the reference channel shall be reported in degrees as a function of stimulus frequency, which is varied from 10 Hz to the upper band-edge frequency in octave steps. If the r.m.s. sum of the non-harmonic and spurious components in each output signal does not exceed 1 % of the test signal amplitude, the phase difference may be measured based on the zero crossings of the two output sinusoids.

The inter-channel phase response should be presented as a graph, with separate traces for each channel except the reference, with frequency on the X axis (preferably rendered logarithmically) and the inter-channel phase difference, in degrees, on the Y axis.

The graph may be replaced by specification of the maximum phase difference over the frequency range from 10 Hz to the upper band-edge frequency, for example: "+1,0/−1,5° from 10 Hz to 20 kHz".

#### 6.2.1.2.4 Delay through EUT

Aim: This test measures the absolute delay experienced by a signal passing through the EUT.

One of three methods – identified as A, B and C below – may be used to measure delay through the EUT.

a) An impulse test signal shall be passed through the EUT. The input and output signals shall be displayed together on a time-calibrated analogue or digital waveform monitor, and the delay time read directly from the display.
b) A low-frequency sinusoid shall be passed through the EUT. The delay through the EUT shall be measured by connecting a conventional time-domain phase meter between the EUT's input and output which derives a phase difference based on the zero crossings of the input and output sinusoids. The resulting phase measurement at the frequency of the sinusoid may then be computed as time.
c) A random or pseudorandom noise stimulus shall be passed through the EUT. The output signal is cross-correlated with the signal at the EUT's input to obtain a measurement of delay. The time value corresponding to the peak in the correlation function shall be reported as the delay through the EUT.

The peak amplitude of the stimulus in each case shall be equal to the peak amplitude of a sinusoid at the normal measuring amplitude. When measuring a dual-channel device, each channel should be measured separately. This is because some equipment processes samples from the two channels alternately; however, this characteristic is also shown by inter-channel phase measurements.

When delay measurements are made on signals that pass through both the analogue and digital domains, the timing reference point corresponding to the timing of the digital audio data shall be specified. For digital signals compliant with IEC 60958-1, the timing reference point shall be the first transition of the frame containing each sample (the start of the X or Z preamble preceding the sample data). This standard gives both samples in the frame of the same time reference.

If a separate synchronization reference can be used, then a second delay measurement should be made with the timing reference point defined with respect to a point in the reference with a defined timing relationship to the digital audio signal. For a reference specified to AES11, the reference is approximately co-timed with the digital audio and measurements shall be made with respect to the timing reference point in the reference signal closest to the timing reference point in the digital audio data.

### 6.2.2 Amplitude non-linearity

#### 6.2.2.1 Distortion and noise

Aim: This test measures the sum of all distortion components and noise added to a signal passing through the EUT.

The input of the EUT shall be driven with a sinusoidal stimulus of maximal measuring amplitude at the normal measuring frequency. Both the amplitude and the in-band residual amplitude at the EUT output shall be measured. See Figure 11.


IEC 1834/08

**Figure 11 – Distortion-and-noise method**

The 'distortion and noise' shall be the in-band residual amplitude expressed relative to the total amplitude in decibels. 'Distortion and noise' may be quoted in units of percent (%).

NOTE 1 This measurement is also referred to as THD+N. Whilst strictly a misnomer (since it includes non-harmonic distortion), 'total harmonic distortion and noise', or 'THD+N', is the common nomenclature for the most widely used method of transfer function non-linearity measurement.

NOTE 2 Percentage units are not preferred since they may produce unwieldy results with modern professional equipment.

#### 6.2.2.2 Distortion and noise versus frequency

Aim: This test measures the variation of the distortion-and-noise measurement with frequency.

A series of distortion-and-noise results shall be recorded using a range of stimulus frequencies, as shown in Figure 12. The measurement frequencies can be freely chosen to suit the particular EUT, sampling frequency for example, but should be logarithmically spaced. Octave-spaced frequencies from 20 Hz to the upper band-edge frequency are preferred.


IEC 1835/08

**Figure 12 – Distortion and noise versus frequency method**

The results shall be presented as a graph with stimulus frequency (preferably rendered logarithmically) on the X axis and 'distortion and noise' in decibels on the Y axis.

NOTE 1 This measurement is also referred to as 'THD+N versus frequency'.

NOTE 2 For stimulus frequencies above half the upper band-edge frequency, no harmonics fall into the measurement band. However, it is common to plot 'distortion and noise versus frequency' for stimuli right up to the upper band-edge frequency.

#### 6.2.2.3 Distortion and noise versus amplitude

Aim: This test measures the variation of the distortion-and-noise measurement with amplitude.

A series of distortion-and-noise results shall be recorded using a range of stimulus amplitudes, as shown in Figure 13. The stimulus amplitude should be varied from 0 $dB_{FS}$ to –80 $dB_{FS}$ in steps no larger than 10 dB.


**Figure 13 – Distortion and noise versus amplitude method**

The results shall be presented as a graph with stimulus amplitude (preferably rendered in logarithmic units) on the X axis and 'distortion and noise' in decibels on the Y axis.

NOTE This measurement is also referred to as 'THD+N versus amplitude'.

#### 6.2.2.4 Individual harmonic distortion

Aim: This test measures the amplitude of individual harmonic distortion components.

This shall be done by driving the input of the EUT with a sinusoidal stimulus of maximal measuring amplitude at the normal measuring frequency, as shown in Figure 14. An FFT combined with a window-width band-pass filter shall then be used to measure the amplitude of each individual harmonic of the normal measuring frequency at the EUT output.


**Figure 14 – Individual harmonic distortion method**

The amplitudes of such individual harmonics shall be expressed either relative to the amplitude of the stimulus frequency measured at the EUT output, in decibels, or absolutely in $dB_{FS}$.

EXAMPLE: 2nd harmonic distortion: ≤135 dB

NOTE It is usual to measure harmonics using the FFT technique described, because the high band-pass filter selectivity required to prevent masking of the result by leakage of the stimulus frequency is not generally attained by time-domain analysers; nor are they usually capable of simultaneously eliminating the stimulus with a narrow band-reject filter.

#### 6.2.2.5 Total harmonic distortion

Aim: This test measures the harmonic distortion components collectively (but excluding non-harmonic and noise contribution).

This shall be done by driving the input of the EUT with a sinusoidal stimulus of maximal measuring amplitude at the normal measuring frequency, as shown in Figure 15. An FFT combined with a window-width band-pass filter shall then used to measure the amplitude of each individual harmonic of the normal measuring frequency at the EUT output.


**Figure 15 – Total harmonic distortion method**

The r.m.s. summation of all the harmonics below the upper band edge frequency; that is, the ‘total harmonic distortion’, shall be expressed either relative to the amplitude of the stimulus frequency measured at the EUT output, in dB, or absolutely in $dB_{FS}$. An example would be “total harmonic distortion: ≤120 dB”.

NOTE It is usual to measure harmonics using the FFT technique described, because the high band-pass filter selectivity required to prevent masking of the result by leakage of the stimulus frequency is not generally attained by time-domain analysers; nor are they usually capable of simultaneously eliminating the stimulus with a narrow band-reject filter.

#### 6.2.2.6 Non-harmonic distortion

Aim: This test measures the amplitude of the largest spurious signal – that is, non-harmonic distortion component – produced at the output of the EUT, may be measured.

The input of the EUT shall be driven with a sinusoidal stimulus of maximal measuring amplitude at the normal measuring frequency, as shown in Figure 16. An FFT combined with a window-width band-pass filter shall then be used to measure the amplitude of the largest individual frequency component observed in the FFT below the upper band-edge frequency, excluding the stimulus frequency and its harmonics.


**Figure 16 – Largest spurious signal method**

The amplitude of the largest spurious signal may be expressed either relative to the amplitude of the stimulus frequency measured at the EUT output, in decibels, or absolutely in $dB_{FS}$.

NOTE 1 The justification in quoting the largest spurious signal, whether it be caused by interference, aliasing, sampling jitter or signal modulation, is that whilst uniform noise and harmonic components are benign to the ear, non-harmonic frequencies are not.

NOTE 2 It is usual to measure spurious signals using the FFT technique described, because the high band-pass filter selectivity required to prevent masking of the result by leakage of the stimulus frequency is not generally attained by time-domain analysers; nor are they usually capable of simultaneously eliminating the stimulus with a narrow band-reject filter.

#### 6.2.2.7 Intermodulation distortion, close tone

Aim: This test measures the distortion produced in the rendition of a high frequency stimulus by the EUT owing to the simultaneous presence of another high frequency component.

Close tone intermodulation distortion shall be measured by applying a ‘twin-tone’ stimulus comprising two summed sinusoids to the EUT input, with one tone at the upper band-edge frequency and the other 2 kHz below that frequency. The amplitudes shall be set to a 1:1 amplitude ratio, the peak amplitude being adjusted to equal the peak amplitude of a sinusoid at the maximal measuring amplitude. Selective amplitude measurements of the EUT output shall be made at the second- and third-order difference frequencies, using either narrow or window-width band-pass filters. See Figure 17. Their r.m.s. amplitude shall be reported in decibels relative to the output amplitude of the lower-frequency tone.


**Figure 17 – Intermodulation method**

Alternatively, close tone intermodulation may be quoted in units of percent (%).

NOTE 1 This method is commonly known as the "CCIF" method, and is referred to as "difference-frequency distortion" in IEC 60268-2 and IEC 60268-3.

NOTE 2 Presenting intermodulation distortion as a percentage is not preferred since the low figures expected of modern professional equipment may produce unwieldy results.

NOTE 3 The difference frequencies should be extracted with band-pass filters much more selective than the standard band-pass filter if the main stimulus frequencies are to be adequately excluded. By preference, an FFT analysis with window-width band-pass filters should be used.

#### 6.2.2.8 Intermodulation distortion, spread tone

Aim: This test measures the distortion produced in the rendition of a high frequency stimulus by the EUT owing to the simultaneous presence of a low frequency component.

The EUT input shall be driven with the sum of a pair of sinusoids at 41 Hz and 7 993 Hz. The amplitude of the high frequency tone shall be set to 0,25 times the amplitude of the low frequency tone. The peak amplitude of the signal shall be adjusted to equal the peak amplitude of an equivalent sinusoid at the maximal measuring amplitude. Selective amplitude measurements of the EUT output shall be made at the modulation sideband frequencies adjacent to the 7 993 Hz tone, using either narrow or window-width band-pass filters (or by a demodulation method). Their r.m.s. sum shall be reported in decibels relative to the output amplitude of the 7 993 Hz tone. See Figure 18.


**Figure 18 – Intermodulation method**

Alternatively, spread tone intermodulation distortion may be quoted in units of percent (%).

NOTE 1 This method is commonly known as the "SMPTE/DIN" method, and is referred to as "modulation distortion" in IEC 60268-2 and IEC 60268-3.

NOTE 2 Presenting intermodulation distortion as a percentage is not preferred since the low figures expected of modern professional equipment may produce unwieldy results.

NOTE 3 The sideband frequencies may be extracted either by amplitude-demodulation, or by using band-pass filters much more selective than the standard band-pass filter, if the main stimulus frequencies are to be adequately excluded. By preference, an FFT analysis with window-width band-pass filters is recommended.

#### 6.2.2.9 Amplitude-dependent gain (linearity)

Aim: This test measures any change in the gain of the EUT with signal amplitude.

Amplitude-dependent gain shall be measured by applying a sinusoidal stimulus at the normal measuring amplitude and frequency to the EUT, as shown in Figure 19. A selective amplitude measurement shall be made of the EUT output, with the band-pass filter tuned to the stimulus frequency. Starting with a stimulus amplitude of –5 $dB_{FS}$, the ratio of the measured output amplitude to the input amplitude shall be recorded as the gain of the EUT, expressed in decibels. The stimulus amplitude shall be progressively reduced in steps no greater than 5 dB, and the gain recorded at each step, until the selective output amplitude is within 5 dB of the selective amplitude of the idle-channel noise, measured using the same band-pass filter.


**Figure 19 – Amplitude-dependent gain method**

The results shall be presented as a graph with stimulus amplitude in $dB_{FS}$ on the X axis and EUT gain in decibels on the Y axis.

If a scalar measurement is reported, it shall be the worst-case deviation at any amplitude from the gain at the first measurement. However, this is not preferred since the final stimulus amplitude can be indeterminate and the highest gain deviations are generally measured at the lowest amplitudes.

NOTE When measuring EUTs subject to high levels of noise or other artefacts, improved results may be obtained by using a band-pass filter with a narrower bandwidth than that of the standard band-pass filter.

### 6.2.2.10 Intrinsic signal modulation products

Aim: This test measures the inherent amplitude modulation of a stimulus by the EUT.

The EUT input should be driven with a −5 $dB_{FS}$ sinusoidal stimulus at 0,499 9 times the upper band-edge frequency, as shown in Figure 20. The EUT's output signal shall be full-wave rectified and a set of selective amplitude measurements of the resulting signal shall be made with a band-pass filter tuned to each standard third-octave frequency between 50 Hz and 500 Hz.

NOTE This measurement may be performed with most commercial IM distortion analyzers used in conjunction with a third-octave band analyser.


**Figure 20 – Intrinsic signal modulation products method**

Alternatively, if FFT analysis is available, the selective measurements may be made at difference frequencies ranging from 50 Hz to 500 Hz from the stimulus frequency, without the need for demodulating rectification.

The results shall be presented as a graph with selective frequency (preferably rendered logarithmically) on the X axis and the modulation amplitude, expressed relative to the output amplitude of the stimulus frequency, in decibels on the Y axis.

### 6.2.2.11 Low-amplitude noise modulation

Aim: This test measures the modulation of residual noise in the EUT as a consequence of varying signal level. This may be the consequence of unequal quantization levels in an A/D or D/A converter, or of poor linearity in a digital device owing to ineffectual dithering.

The EUT input shall be driven with a 41 Hz sinusoidal stimulus at –40 $dB_{FS}$ as shown in Figure 21. The 41 Hz tone shall be removed from the EUT output with a band-reject filter, and a set of selective amplitude measurements of the remaining noise shall be made with a band-pass filter tuned to each standard third-octave frequency between 200 Hz and the upper band-edge frequency.

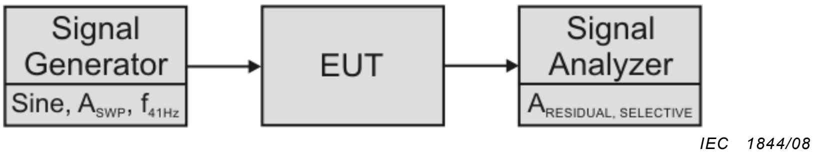



**Figure 21 – Low-amplitude noise modulation method**

The stimulus amplitude shall then be reduced progressively, in 10 dB steps, recording a set of third-octave spaced selective amplitudes at each stimulus amplitude, until the selective amplitude of the stimulus measured at the EUT output is below the idle-channel noise.

The low-amplitude noise modulation at each filter frequency shall be the ratio of the highest to the lowest recorded noise amplitude at that frequency, expressed in decibels.

The results should be presented as a graph with selective frequency (preferably rendered logarithmically) on the X axis and the respective noise modulation ratios in decibels on the Y axis.

Alternatively, the greatest computed ratio, irrespective of frequency, may be quoted as a scalar result.

### 6.2.3 Noise

#### 6.2.3.1 Idle-channel noise

Aim: This test measures weighted noise with zero signal applied to the EUT input.

The idle-channel noise shall be the in-band amplitude measured at the EUT output, after the application of the weighting filter, read in $dB_{FS}$ and expressed in "$dB_{FS}$ CCIR-RMS". If the EUT input is analogue, it shall be terminated with the normal source impedance; if digital, it shall be driven with digital zero. See Figure 22.

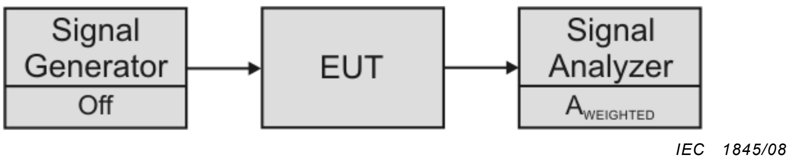



**Figure 22 – Idle-channel noise method**

#### 6.2.3.2 Idle-channel noise spectrum

Aim: This test measures the spectral distribution of the EUT's idle-channel noise.

The idle-channel noise spectrum shall comprise a set of selective amplitude measurements of the EUT output, with the input idle-channel conditions as specified in 6.2.3.1 but WITHOUT the weighting filter. The selective measurements shall be made with the band-pass filter tuned to the standard third-octave frequencies, not exceeding the upper band-edge frequency. See Figure 23.


IEC 1846/08

**Figure 23 – Idle-channel noise spectrum method**

The results shall be presented as a graph with selective frequency (preferably rendered logarithmically) on the X axis and selective noise amplitude in $dB_{FS}$ on the Y axis.

NOTE The idle-channel noise spectrum may be rapidly computed by FFT analysis of the EUT output under idle-channel conditions.

#### 6.2.3.3 Dynamic range

Aim: This test measures the ratio of full-scale amplitude to the noise amplitude produced by the EUT in the presence of a small signal.

The EUT shall be driven with a sinusoidal stimulus at the normal measuring frequency, of amplitude –60 $dB_{FS}$ as shown in Figure 24. The in-band residual amplitude of the EUT output shall be measured after the application of the weighting filter.


IEC 1847/08

**Figure 24 – Dynamic range method**

The dynamic range, expressed in “dB CCIR-RMS”, shall be derived by reciprocation of the measured amplitude; that is, negation of the measurement expressed in $dB_{FS}$. For example, a weighted residual amplitude measurement of 110 $dB_{FS}$ simply corresponds to a dynamic range of 110 dB CCIR-RMS.

NOTE The noise amplitude in the presence of signal may differ from the idle-channel noise amplitude owing to non-linearity of the EUT, or in cases where the EUT responds specifically to a digital zero input.

#### 6.2.3.4 Out-of-band noise ratio

Aim: This test measures the extent of spurious components produced by the EUT at frequencies above the audio band under idle-channel conditions.

The out-of-band noise ratio shall be measured at the output of the EUT, with zero signal applied to the EUT input, as shown in Figure 25. If the EUT input is analogue, it shall be terminated with the normal source impedance; if digital, it shall be driven with digital zero.


IEC 1848/08

**Figure 25 – Out-of-band noise ratio method**

The amplitude of all components above the upper band-edge frequency shall be measured using the out-of-band filter, and expressed in $dB_{FS}$.

NOTE This method is primarily intended to be applied to EUTs with analogue outputs. However, it is included among the ‘General methods’ since it can be usefully applied to EUTs with high sampling frequencies where quantization noise is shaped into the region between the upper band-edge frequency and the folding frequency.

### 6.2.4 Interference products

#### 6.2.4.1 General

The following characteristics generally apply to EUTs with analogue inputs or outputs, but are included in the ‘General methods’ since they are not precisely or necessarily input or output characteristics.

#### 6.2.4.2 Channel separation

Aim: This test measures the linear leakage of signal from one channel of a multi-channel EUT into another channel.

One EUT channel input shall be driven with a sinusoidal stimulus of variable frequency at the maximal measuring amplitude. The other channel inputs shall be terminated with the normal source impedance (if analogue) or driven with digital zero (if digital). Refer to Figure 26.


**Figure 26 – Channel separation method**

The stimulus frequency shall be swept from 10 Hz to the upper band-edge frequency in steps no greater than one octave. At each frequency, the channel separation shall be measured as the selective output amplitude at each of the un-driven channels, relative to the output amplitude of the driven channel, in decibels. The process shall be repeated with each channel in turn being the driven channel, and the highest amplitude result at each frequency retained for each channel output.

The results should be presented as a graph with frequency (preferably rendered logarithmically) on the X axis and worst-case separation at that frequency for any channel pair in decibels on the Y axis. Alternatively, the result may be quoted as the worst separation for any pair of channels at the high and low interference frequencies.

#### 6.2.4.3 Inter-source cross-talk

Aim: This test measures the linear leakage of signal from any unselected input channels of the EUT to any output channel of the EUT, for example in the case of a router or multi-input preamplifier.

All EUT channel inputs of the unselected source shall be driven with a sinusoidal stimulus of variable frequency at the maximal measuring amplitude. The channel inputs of the selected source shall be terminated with the normal source impedance (if analogue) or driven with digital zero (if digital). Refer to Figure 26.

The stimulus frequency shall be swept from 10 Hz to the upper band-edge frequency in steps no greater than one octave. At each frequency, the selective output amplitude at each of the channel outputs shall be measured relative to the output amplitude if the hostile source were selected, in decibels.

The results should be presented as a graph with frequency (preferably rendered logarithmically) on the X axis and cross-talk of the worst-affected channel at that frequency in decibels on the Y axis. Alternatively, a single result may be quoted as the worst cross-talk into any channel at the high and low interference frequencies.

The process may be repeated for all representative combinations of selected and unselected sources. In this case, each graph point, or single result, should reflect the performance of the worst-case source pair.

#### 6.2.4.4 Input-to-output leakage

Aim: This test measures the linear leakage of signal from all input channels of the EUT to any channel of the EUT output. This measurement is only relevant for an EUT capable of outputting a signal uncorrelated to that at its input (for example, when a tape recorder operates in its playback mode) or to an EUT whose outputs can be muted.

All EUT channel inputs of all selectable sources shall be driven with a sinusoidal stimulus of variable frequency at the maximal measuring amplitude. The EUT shall be placed in a mode that sends a digital zero signal (either dithered or not) to all outputs. Refer to Figure 26.

The stimulus frequency shall be swept from 10 Hz to the upper band-edge frequency in steps no greater than one octave. At each frequency, the selective output amplitude at each of the channel outputs shall be measured relative to the nominal output amplitude if the stimulus had been enabled to that output, in decibels.

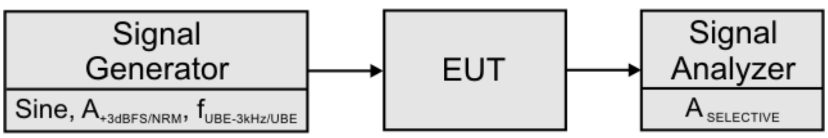
The results shall be presented as a graph with frequency (preferably rendered logarithmically) on the X axis and leakage to the worst-affected output in decibels on the Y axis. Alternatively, a single result may be quoted as the worst leakage into any channel at the high and low interference frequencies.

NOTE This measurement is also known as ‘feed through’.

#### 6.2.4.5 Non-linear cross-talk

Aim: This test measures the non-linear interaction of signals in the channels of a multi-channel EUT. Since the method involves overdriving of the analogue circuits of the EUT it can only be applied to EUTs with analogue inputs.

Non-linear cross-talk at high frequencies shall be measured by applying a signal to all inputs of the EUT using the method shown in Figure 27. The channel being measured shall be driven at the normal measuring amplitude with a sinusoidal stimulus at the upper band-edge frequency. The other channels shall be connected together and driven at +3 $dB_{FS}$ with a sinusoidal stimulus 3 kHz below that of the measured channel.




IEC 1850/08

**Figure 27 – Non-linear cross-talk method**

The ratio of the amplitude of the second-order difference frequency component at 3 kHz in the measured channel to the signal amplitude in the measured channel shall be expressed in decibels.

The ratio of the amplitude of the third-order intermodulation component at 6 kHz below the upper band-edge frequency to the signal amplitude in the measured channel shall be expressed in decibels.

These measurements shall be repeated for each of the channels of the EUT. The measured values shall be reported separately as even- and odd-order non-linear cross-talk respectively for each channel, or the worst even- and odd-order results among the channels shall be reported.

Non-linear cross-talk at low frequencies shall be measured by applying a signal to all inputs of the EUT. The channel being measured shall be driven at the normal measuring amplitude with a sinusoidal stimulus at half the upper band-edge frequency. The other channels shall be connected together and driven at +3 $dB_{FS}$ with a sinusoidal stimulus at 40 Hz. The ratio of the r.m.s. sum of the amplitudes of the modulation sidebands introduced onto the signal in the measured channel to the signal amplitude in the measured channel shall be expressed in dB. The measurement shall be repeated for each of the channels of the EUT. The worst measured value of all the channels shall be reported.

#### 6.2.4.6 Power-line (mains) related products

Aim: This test measures the components of the EUT noise caused by the power supplied to the EUT.

The channel inputs of the EUT shall be terminated with the normal source impedance (if analogue) or driven with dithered digital zero (if digital). With all EUT controls set to their normal positions, a selective measurement of the EUT output shall be made at the power-line frequency. The measurement shall be repeated at the second through fifth harmonics, and the r.m.s. summation of the six measurements computed. This shall be expressed relative to the output for full-scale amplitude, in $dB_{FS}$. The method is shown in Figure 28.

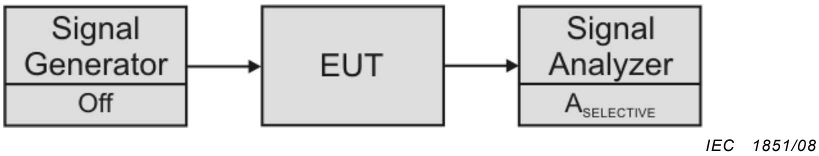



**Figure 28 – Power-line (mains) related products method**

NOTE 1 Only components harmonically related to the power-line frequency are included as power-line interference. Any artefacts due to a high-frequency-switching type power supply in the EUT are classified as spurious components elsewhere.

NOTE 2 For good quality equipment with low power-line interference, the selective measurements are likely to be dominated by noise. It is therefore preferred to use the narrowest band-pass filter available. Alternatively, a single FFT analysis of the EUT output can compute the sum of all six components with a selectivity limited only by the record length and selected window function.

### 6.2.5 Sampling effects

#### 6.2.5.1 Suppression of aliasing components

Aim: This test measures the spurious translation by the EUT of input frequencies beyond the folding frequency to output frequencies below the folding frequency.

The suppression of aliasing components shall be measured by driving the EUT input with a sinusoidal stimulus at the normal measuring amplitude. If the EUT input is analogue, the stimulus shall be swept from a stated maximum (ideally four times the sampling frequency) to the folding frequency in steps not exceeding one third of an octave. If the EUT input is digital, the stimulus shall be swept from the input folding frequency to the output folding frequency. See Figure 29.

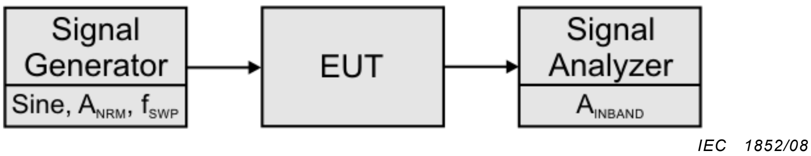



**Figure 29 – Suppression of the aliasing components method**

For each stimulus frequency, an in-band amplitude measurement shall be recorded at the EUT output. This shall be expressed relative to the stimulus amplitude, in dB. The results shall be presented as a graph with frequency (preferably rendered logarithmically) on the X axis and the relative amplitude of measured aliasing components in decibels on the Y axis. Alternatively, the result may simply be reported as the highest recorded result across the frequency range.

For an EUT with analogue inputs and outputs, a narrow band-reject filter at the stimulus frequency may be applied to the EUT output in order to suppress input to output leakage.

NOTE 1 This method is primarily intended to be applied to EUTs with analogue inputs. However, it is included among the general methods since aliasing can occur in any signal-processing element which involves down-sampling. Thus the method should also be applied to EUTs with digital inputs where the input sampling frequency may exceed the output sampling frequency.

NOTE 2 The sampling frequency of analogue ports of EUTs for which it is not already known may be determined by monitoring the frequency of the output alias component.

### 6.2.5.2 Suppression of imaging components

Aim: This test measures the total amplitude of out-of-band components produced by the EUT, measured in the presence of an in-band stimulus.

The EUT shall be driven with a sinusoidal stimulus at the maximal measuring amplitude which is swept in frequency from 10 Hz to one-half the upper band-edge frequency or 10 kHz, whichever is the lower, in steps not exceeding one third of an octave. For each stimulus frequency, the stimulus shall be removed from the EUT output with the band-reject filter, and the amplitude of all components above the upper band-edge frequency shall be measured using the out-of-band filter, and expressed relative to the stimulus amplitude in decibels. See Figure 30.


IEC 1853/08

**Figure 30 – Suppression of imaging components method**

The results shall be presented as a graph with frequency (preferably rendered logarithmically) on the X axis and the relative amplitude of measured imaging components in decibels on the Y axis. Alternatively, the result may simply be reported as the highest recorded result across the frequency range.

NOTE 1 The measurement is identical to that for out-of-band spurious components, but with the addition of the stimulus and a band-reject filter to remove the stimulus at the EUT output.

NOTE 2 This method is primarily intended to be applied to EUTs with analogue outputs. However, it is included among the general methods since imaging can occur in any signal-processing element which involves up-sampling. Thus the method should also be applied to EUTs with digital outputs where the output sampling frequency may exceed the input sampling frequency.

NOTE 3 The sampling frequency of analogue ports of EUTs for which it is not already known may be determined by monitoring the frequency of the output image component.

### 6.2.5.3 Sampling jitter susceptibility

Aim: This test measures 'sampling jitter', or phase modulation, in the EUT caused by imperfect filtering of interface jitter from the reference sync.

The EUT input shall be driven with a sinusoidal stimulus of maximal measuring amplitude at half the upper band-edge frequency as shown in Figure 31. The reference sync input shall be driven with a signal whose phase is jittered with a sinusoidal jitter signal whose frequency is swept from 80 Hz to half the upper band-edge frequency in octave steps. The jitter amplitude shall be set at the high frequency jitter tolerance limit of the reference sync format used. If no limit is stated, a peak-to-peak value of 40 ns or $1/(512 \cdot f_s)$ (whichever is the least), shall be used.


**Figure 31 – Sampling jitter susceptibility method**

The in-band residual amplitude of the EUT output relative to the stimulus shall be measured using as narrow a band-reject filter as possible, preferably a window-width band-reject filter. If no narrow band-reject filter is available, a standard band-reject filter may be used but will render the method insensitive to low-frequency jitter. The results shall be presented as a graph with jitter frequency (preferably rendered logarithmically) on the X axis and the relative residual amplitude in decibels on the Y axis.

The measurement may be repeated for other input signal frequencies, for example 1/192 times the sampling frequency (which may identify anomalous low-frequency behaviour) or 997 Hz (which may maximise interaction with data codes).

NOTE 1 This is most usually encountered in EUTs with analogue inputs or outputs, where sampling jitter occurs at the point of A/D or D/A conversion. However, this method is included in the 'general methods' because sampling jitter can occur in any device where jitter in a reference sync can cause modulation of the audio signal passing through the EUT, for example in asynchronous sample-rate converters (ASRCs).

NOTE 2 It is important that the active reference sync of the EUT be correctly identified. For EUTs with analogue inputs, a dedicated reference sync input is usually used, whereas for EUTs with digital inputs, the reference sync is typically the digital audio input itself. However, there are frequent exceptions to this and it is important that all sources of reference sync are characterised since they may behave differently. This method is not applicable to assessing 'intrinsic' jitter from internal reference syncs, since it is not capable of isolating which products at the EUT output result from sampling jitter.

### 6.3 Input/output characteristics

#### 6.3.1 Analogue input characteristics

##### 6.3.1.1 Analogue full-scale input amplitude

Aim: This test measures the analogue input amplitude required to reach digital clipping under standard settings. This characteristic is sometimes termed: "line-up", "digital/analogue line-up" or "D/A line-up".

For EUTs where the output is accessible in the digital domain, the analogue full-scale input amplitude shall be 20 dB (that is, 10 times) greater than the amplitude of a sinusoidal stimulus at the normal measuring frequency which, when applied to the input, causes a digital output amplitude of 20 $dB_{FS}$. See Figure 32.


**Figure 32 – Analogue full-scale input amplitude method**

For EUTs where the output is not accessible in the digital domain, the analogue full-scale input amplitude shall be 0,5 dB below the highest amplitude of a sinusoidal stimulus at the normal measuring frequency that may be applied to the input of the EUT before introducing

−40 dB (1 %) 'Distortion and noise', or 0,3 dB gain reduction at the EUT output, whichever occurs first.

The analogue full-scale input amplitude should be expressed in dBu; it may alternatively be expressed in $V_{rms}$

All controls of the EUT shall be set to the standard settings, or to their normal operating position where none is specified. Other gain controls in the EUT shall be adjusted to minimize the potential for overload in the EUT output circuitry.

#### 6.3.1.2 Overload behaviour

Aim: This test identifies non-linear behaviour in A/D converters at the point of overload, especially a condition commonly called 'rollover' or 'wrap round'.

The overload characteristics of an analogue EUT input shall be measured by applying a +3 $dB_{FS}$ sinusoidal stimulus at the normal measuring frequency. The 'distortion and noise' of the output signal shall be measured and recorded in decibels. The measurement shall then be repeated at –3 $dB_{FS}$. The reported value shall be the second measurement subtracted from the first measurement, expressed in decibels. See Figure 33.

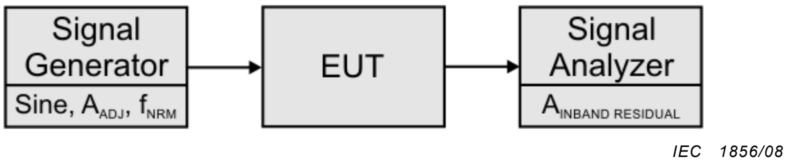



**Figure 33 – Overload behaviour method**

If desired, the measurement may be repeated at other frequencies to examine the frequency dependence of the overload behaviour.

#### 6.3.1.3 Common-mode rejection ratio (CMRR)

Aim: This test measures the extent to which a common-mode stimulus is rejected by a balanced analogue input.

An analogue, balanced EUT input's common mode rejection ratio (CMRR) shall be measured by driving the both limbs of the input with the same sinusoidal stimulus, at the normal measuring amplitude, with respect to the input's signal ground pin. Each limb is driven through the normal source impedance. See Figure 34. The CMRR shall be computed as the ratio, in decibel, of the output-referred amplitude of (each limb of) the stimulus to the selective amplitude measured with the limbs driven in common. The CMRR shall be measured at a range of frequencies from 20 Hz to the upper band-edge frequency not more than one octave apart.

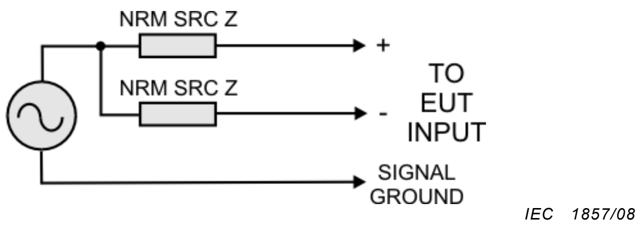



**Figure 34 – Common-mode rejection ratio method**

The results should be presented as a graph with frequency (preferably rendered logarithmically) on the X axis and CMRR in decibels on the Y axis. Alternatively, individual results at the upper and lower standard interference frequencies may be quoted.

A more stringent characteristic may be measured by repeating the measurement set with asymmetric source impedances. One limb should be fed from the normal source impedance whilst the other is fed through 600 Ω.

NOTE 1 A CMRR test mode is usually available in analogue signal generators, wherein the inverted signal output is substituted behind its source impedance for the non-inverted output, thus driving identical rather than the normal phase-opposed signals at the signal generator's balanced output limbs.

NOTE 2 For a more rigorous method of CMRR measurement, refer to IEC 60268-3.

### 6.3.2 Analogue output characteristics

#### 6.3.2.1 Analogue full-scale output amplitude

Aim: This test measures the analogue output amplitude resulting from digital full-scale amplitude under standard settings. This characteristic is sometimes termed: "line-up", "digital/analogue line-up" or "D/A line-up".

All controls of the EUT shall be set to the standard settings, or to their normal operating position where none is specified. Other gain controls in the EUT shall be adjusted to minimize the potential for overload in the EUT input circuitry.

For EUTs where the input is accessible in the digital domain, the analogue full-scale output amplitude shall be 20 dB (that is, 10 times) greater than the amplitude measured at the EUT output when the EUT input shall be driven by a −20 $dB_{FS}$ sinusoidal stimulus at the normal measuring frequency. See Figure 35.

For EUTs where the input is not accessible in the digital domain, the analogue full-scale output amplitude shall be 0,5 dB below the amplitude measured at the EUT output when the EUT input is driven by a sinusoidal stimulus at the normal measuring frequency whose amplitude has been gradually increased until either –40 dB (1 %) 'distortion and noise', or 0,3 dB gain reduction has occurred at the EUT output.


IEC 1858/08

**Figure 35 – Analogue full-scale output amplitude method**

The analogue full-scale output amplitude shall be expressed in $dB_u$ or, optionally, in $V_{rms}$.

#### 6.3.2.2 Output balance

Aim: This test measures the symmetry of a balanced analogue output.

The symmetry of a balanced analogue output of an EUT is characterised by driving the input of the EUT with a sinusoidal stimulus of variable frequency at the normal measuring amplitude. The non-inverting and inverting limbs of the EUT output shall be terminated with a 600 Ω impedance, comprising two 300 Ω elements whose common point is terminated to the ground pin of the EUT output with a further 600 Ω across which the imbalance amplitude is measured selectively. See Figure 36. The output balance shall be the ratio of the differential output amplitude of the EUT to the imbalance amplitude, expressed in dB, and shall be measured at a range of frequencies between 20 Hz and the upper band-edge frequency, separated by not more than one octave.

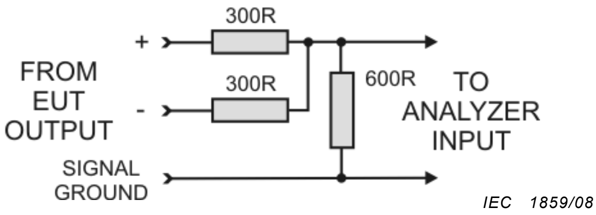



**Figure 36 – Output balance method**

The results should be presented as a graph with frequency (preferably rendered logarithmically) on the X axis and output balance in decibels on the Y axis. Alternatively, individual results at the upper and lower standard interference frequencies may be quoted.

NOTE 1 The 300 Ω resistors should be closely matched in order to measure the output balance accurately. Matching to 0,01 % is preferred, although matching to within 0,1 % is adequate for most equipment. When measuring an EUT which cannot drive a 600 Ω differential load, the three resistors may be scaled up accordingly.

NOTE 2 For a more rigorous method of output balance measurement, refer to IEC 60268-3.

### 6.3.3 Digital input characteristics

#### 6.3.3.1 General

The interface standard to which all digital inputs conform shall be stated, including any applicable grade or level of conformance. Any dedicated reference sync inputs should be included.

Appropriate methods for testing the conformance of the EUT are beyond the scope of this document and should be established with reference to the relevant standard. In general, methods should be applied to establish the input's handling of both audio and non-audio data, and its susceptibility to relevant carrier quality parameters, including sampling frequency accuracy and jitter.

#### 6.3.3.2 Input word length

Aim: This test determines the number of active audio bits which are accepted by the EUT's digital inputs, as defined in 3.14.

Note that the input word length is important because it defines the generator dither amplitude used in performing other measurements involving that EUT input. The input word length may be specified by the manufacturer or (if not specified) may be inferred by the following methods:

In EUTs where a unity-gain path is available from the digital input under test to a digital output with greater or equal word length, the input word length may be established by performing a dynamic range measurement of that path with the generator word length initially set to 12 bits. The generator word length is then increased by one bit at a time, and the change in dynamic range measurement noted. The input word length is that where increasing the generator output word length by one bit results in an increase in dynamic range of less than 3 dB.

In other circumstances, input word length can be established by stimulating the input with a sequence of samples with all bits set to zero except for one bit, which follows the sequence 1,1,0,0. When the changing bit is within the input word length, a selective amplitude measurement at one quarter the sample rate ($f_s/4$) at the EUT output can detect the activity of the bit. With the changing bit below the input word length, no change in measured amplitude can be detected from an input of digital zero.

### 6.3.4 Digital output characteristics

#### 6.3.4.1 General

The interface standards to which all of the digital outputs of the EUT conform shall be stated, including any applicable grade or level of conformance. Any dedicated reference sync outputs should be included.

Appropriate methods for testing the conformance of the EUT are beyond the scope of this document and should be established with reference to the relevant standards. In general, methods should be applied to establish the generation of both audio and non-audio data at the outputs, and their relevant carrier quality parameters. For dedicated reference sync outputs, intrinsic jitter and jitter transfer characteristics should also be included.

#### 6.3.4.2 Output word length

Aim: This test determines the number of active audio bits which are transmitted from the EUT's outputs, as defined in 3.24.

The output word length is determined by observing the bit activity on the digital output, using equipment suitable to the interface standard specified. The output word length is the number of most-significant bits which are not transmitted continuously as logic zero.

NOTE 1 If the output word length is adjustable, the output word length used for each measurement should be stated. It may be appropriate to specify certain measurements at a variety of word lengths.

NOTE 2 The output word length is not per se an indication of audio quality, since the contents of the lower-order bits is not implied nor assessed by a bit activity measurement.

# Annex A
(normative)

# Alternative measurement methods

## A.1 General

This standard draws mainly on traditional methods using simple sinusoidal stimuli and basic selective and residual measurements. These techniques evolved because they allowed simple implementation of analogue test equipment. However, they are slow to perform, with each method needing to be carried out sequentially. Even repeated measurements aided by automatic sweeps are sequential and slow.

Modern test equipment allows the use of complex stimuli and sophisticated FFT analysis at low cost. These techniques can enable many properties of the EUT to be characterised by its response to a single stimulus. Thus can an EUT be characterised much more quickly than is possible through traditional means alone. More thorough characterisation is also possible than can be derived from simple sinusoidal stimuli.

## A.2 Synchronous multi-tone analysis

### A.2.1 General

Multi-tone analysis involves stimulating the EUT with many frequencies at once, and analysing its output with FFT-based methods. This allows many measurements to be derived simultaneously, over many channels if required.

A special case of multi-tone analysis requires that the generation and analysis sampling frequencies be identical to within very fine tolerance. In that case, the stimulus can be arranged such that subsequent FFT analysis may be performed without 'windowing' and that each stimulus tone will occupy only one bin of the resulting FFT. This is known as 'synchronous multi-tone analysis', and it has many useful properties. The following subclause describes a set of methods based on synchronous multi-tone analysis.

Synchronous multi-tone analysis can be applied to EUTs with analogue or digital inputs and outputs, so long as the sampling rates of the test equipment's signal generator and signal analyzer can be synchronous. This is inherent in most digital-to-digital EUTs, and can usually be easily arranged in cross-domain EUTs by synchronising the analogue generator or analyzer to the sampling frequency of the EUT. For digital-to-digital EUTs where the input and output have different or unlocked sampling frequencies (such as sample-rate converters) synchronous multi-tone analysis cannot be applied unless the signal analyzer is capable of re-sampling its input signal to closely match the sampling frequency of the signal generator.

For all methods described below, unless specifically stated, the EUT is configured with the standard settings as described in 5.4. Wherever different settings are employed, these should be clearly stated.

### A.2.2 Stimulus

The EUT shall be driven with a stimulus derived from a wavetable of length 2n samples, containing a summation of many sinusoids spread across the in-band frequency range, with all tones executing an even number of precise periods within the wavetable.

The number of tones, frequencies and amplitudes of the tone set, as well as the record length (2n) shall be specified. By default, 12 logarithmically-spaced tones, each of amplitude −20 $dB_{FS}$, contained within a record length of 16 384 samples should be used. For a sampling frequency of 48 kHz, and an upper band-edge frequency of 20 kHz, the adjusted frequencies are given in Table A.1, below.

**Table A.1 – Stimulus wavetables**

| Tone number | Adjusted frequency A (Hz) | Adjusted frequency B (Hz) |
|---|---|---|
| 1 | 23,44 | 29,30 |
| 2 | 41,02 | 46,88 |
| 3 | 70,31 | 76,27 |
| 4 | 134,77 | 140,63 |
| 5 | 246,09 | 251,95 |
| 6 | 462,89 | 468,75 |
| 7 | 867,19 | 873,05 |
| 8 | 1 623,05 | 1 628,91 |
| 9 | 3 041,02 | 3 046,88 |
| 10 | 5 695,31 | 5 701,17 |
| 11 | 16 675,78 | 10 681,64 |
| 12 | 20 003,91 | 20 009,77 |
| NOTE Two alternative sets of adjusted frequencies are available to allow cross-talk measurement between channels, as described below. If cross-talk is not measured, only one set of adjusted frequencies need to be used. | | |

The tone nearest to 997 Hz (tone number 7 in the example above) shall be the normal measuring frequency where required.

It may be possible to use the same sample set at different sampling frequencies, since the in-band region usually scales with sampling frequency.

### A.2.3 Analysis

#### A.2.3.1 General

The output of the EUT shall be analyzed by accumulating 2n samples and performing a windowless FFT of the accumulated samples. The resulting data set allows immediate computation of many EUT characteristics, defined below.

#### A.2.3.2 Multi-tone gain (MTG)

Multi-tone gain shall be calculated as the ratio of the amplitude of the recovered normal measuring frequency tone to the transmitted amplitude, expressed in dB.

#### A.2.3.3 Multi-tone inter-channel gain balance (MTB)

Multi-tone inter-channel gain balance shall be calculated as the ratio of the amplitude of recovered normal measuring frequency tones between two measured channels, expressed in dB. Where more than two channels are measured, the multi-tone inter-channel gain balance shall be the ratio of the largest to the smallest amplitude measured.

#### A.2.3.4 Multi-tone frequency response (MTF)

Multi-tone frequency response shall be calculated by computing the ratio of each recovered tone amplitude to the recovered amplitude at the normal measuring frequency, in dB.

The result shall be plotted as a graph joining the points resulting from each tone's ratio, with frequency on the X axis and gain on the Y axis. The X axis should be linear if linearly-spaced tones have been specified, logarithmic in the case of logarithmically-spaced tones.

#### A.2.3.5 Multi-channel phase response (MTP)

The phase of each recovered tone shall be calculated as the arctangent of the ratio of the imaginary to the real component of the complex FFT result. The phase at each tone frequency shall be normalised with respect to the phase computed for the recovered normal measuring frequency.

The result shall be plotted as a graph joining the points resulting from each tone's normalized phase, with frequency on the X axis and phase on the Y axis. The X axis should be linear if linearly-spaced tones have been specified, logarithmic in the case of logarithmically-spaced tones.

#### A.2.3.6 Multi-tone distortion (MTD)

NOTE It is generally not practical to differentiate between harmonic distortion and intermodulation products using multi-tone analysis. For this reason, the total distortion is usually calculated.

Multi-tone distortion shall be calculated as the r.m.s. sum of those even-numbered bins of the FFT not containing stimulus tones. The result may be expressed in absolute units ($dB_{FS}$ or V rms) or may be conventionally expressed relative to the amplitude of the recovered normal measuring frequency tone, in decibels or percent (%). Note that the relative result is significantly affected by the number of tones applied.

A weighted or band-limited result can be obtained by multiplying the FFT bins by an envelope of the desired weighting response prior to summation.

A graphical rendition of multi-tone distortion against frequency can be plotted by tracing the amplitudes of the distortion bins or by summing those bins in, for example, third-octave bands.

#### A.2.3.7 Multi-tone noise (MTN)

Multi-tone noise shall be calculated as twice the r.m.s. sum of the odd bins of the FFT. The doubling is necessary to include noise inferred to be present in the even bins.

A weighted or band-limited result can be obtained by multiplying the FFT bins by an envelope of the desired weighting response prior to summation.

A graphical rendition of the noise spectrum can be plotted by tracing the amplitudes of the noise bins or by summing those bins in, for example, third-octave bands.

#### A.2.3.8 Multi-tone distortion+noise (MTD+N)

Multi-tone distortion+noise shall be calculated as the r.m.s. sum of all the bins of the FFT not containing tones. The result may be expressed in absolute units ($dB_{FS}$ or $V_{rms}$) or may be conventionally expressed relative to the amplitude of the recovered normal measuring frequency tone, in decibels or percent (%). Note that the relative result is significantly affected by the number of tones applied.

A weighted or band-limited result can be obtained by multiplying the FFT bins by an envelope of the desired weighting response prior to summation.

A graphical rendition of the multi-tone distortion+noise spectrum can be plotted by tracing the amplitudes of the non-tone bins or by summing those bins in, for example, third-octave bands.

#### A.2.3.9 Multi-tone inter-channel cross-talk (MTX)

For measurement of multi-tone inter-channel cross-talk, the channels to be measured shall be driven with different frequencies, using both the A and the B sets of adjusted frequencies in the table above.

The multi-tone inter-channel cross-talk can then be calculated at any frequency by computing the ratio of the recovered un-driven bin amplitude in one channel to the amplitude of the hostile bin in the other channel; the cross-talk is expressed in dB. Note that the A > B and B > A cross-talk can be computed separately.

A graphical rendition of the cross-talk response against frequency can be plotted.

# Bibliography

The following documents contain information that is useful in understanding this standard.

IEC 60268-3, *Sound system equipment – Part 3: Amplifiers*

IEC 60748-4-3, *Semiconductor devices – Integrated circuits – Part 4-3: Interface integrated circuits – Dynamic criteria for analogue-digital converters (ADC)*

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

AES3-2003, *AES standard for digital audio engineering – Serial transmission format for two channel linearly represented digital audio data*

AES5-2003, *AES recommended practice for professional digital audio – Preferred sampling frequencies for applications employing pulse-code modulation*

SMPTE RP104, *Cross-Modulation Tests for Variable-Area Photographic Audio Tracks*

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