STANDARDS AND INFORMATION DOCUMENTS

AES3-4-2009
(Rev. AES3-2003)

STANDARDS

AES standard for digital audio — Digital input-output interfacing — Serial transmission format for two-channel linearly represented digital audio data Part 4: Physical and electrical

(Multi-part revision of AES3-2003, incorporating Amendments 5 & 6)

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AES3-4-2009

AES standard for digital audio — Digital input-output interfacing — Serial transmission format for two-channel linearly-represented digital audio data — Part 4: Physical and electrical

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Abstract

AES3 provides for the serial digital transmission of two channels of periodically sampled and uniformly quantized audio signals on various media.

This Part specifies the physical signals that convey the bit stream specified in Part 3. The current version covers electrical signals on twisted-pair and co-axial cables. Other media, including fibre optic, are under consideration.

Contents

Foreword

This foreword is not part of the *AES3-4-2009, AES standard for digital audio — Digital input-output interfacing — Serial transmission format for two-channel linearly represented digital audio data Part 4: Physical and electrical.*

AES3 has been under constant review since the standard was first issued in 1985, and the present edition reflects the collective experience and opinions of many users, manufacturers, and organizations familiar with equipment or systems employing AES3.

This document was adapted by R. Caine from the 2003 edition as amended by Amendments 5 and 6 and from AES-3id-2001, and its technical content is believed to be identical to the relevant parts of those versions. Other members of the writing group that developed this document in draft included: C. Travis, C. Langen, H. Jahne, J. Grant, J. Woodgate, M. Natter, M. Poimboeuf, R. Cabot, S. Heinzmann, M. Werwein, and M. Yonge.

J. Grant, chair
SC-02-02 Working Group on Digital Input-Output Interfacing
May 2009

Note on normative language

In AES standards documents, sentences containing the word “shall” are requirements for compliance with the document. Sentences containing the verb “should” are strong suggestions (recommendations). Sentences giving permission use the verb “may”. Sentences expressing a possibility use the verb “can”.

AES standard for digital audio — Digital input-output interfacing — Serial transmission format for two-channel linearly-represented digital audio data — Part 4: Physical and electrical

1 Scope

These four documents specify an interface for the serial digital transmission of two channels of periodically sampled and linearly represented digital audio data from one transmitter to one receiver. This Part 4 document specifies the physical and electrical parameters for different media.

The transport format defined in Part 3 is intended for use with shielded twisted-pair cable of conventional design over distances of up to 100 m without transmission equalization or any special equalization at the receiver and at frame rates of up to 50 kHz. Longer cable lengths and higher frame rates may be used, but with a rapidly increasing requirement for care in cable selection and possible receiver equalization or the use of active repeaters, or both. Provision is made in this standard for adapting the balanced terminals to use 75 Ohm coaxial cable, and transmission by fibre-optic cable is under consideration.

The document does not cover connection to any common carrier equipment.

In this interface specification, mention is made of an interface for consumer use. The two interfaces are not identical.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this document. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this document are encouraged to investigate the possibility of applying the most recent editions of the indicated standards.

ISO/IEC 11801 *Information technology – Generic cabling for customer premises*, International Organization for Standardization and International Electrotechnical Commission, Geneva, Switzerland.

IEC 60169-8 *Radio frequency connectors Part 8 RF coaxial connectors diameter of outer conductor 6.5mm with bayonet lock – characteristic impedance of 50 Ohms* (Type BNC)

IEC 60268-12, *Sound system equipment, Part 12: Application of connectors for broadcast and similar use*, International Electrotechnical Commission, Geneva, Switzerland.

IEC 60603-7, *Connectors for frequencies below 3 MHz for use with printed boards - Part 7: Detailed specification for connectors, 8-way, including fixed and free connectors with common features*, multi-part, International Electrotechnical Commission, Geneva, Switzerland.

IEC 60958-3, *Digital audio interface - Part 3: Consumer applications*, International Electrotechnical Commission, Geneva, Switzerland.

3 Definitions and abbreviations

3.1
unit interval
UI
shortest nominal time interval in the coding scheme

NOTE There are 128 UI in a sample frame. See annex B.

3.2
interface jitter
deviation in timing of interface data transitions (zero crossings) when measured with respect to an ideal clock

3.3
intrinsic jitter
output interface jitter of a device that is either free-running or synchronized to a jitter-free reference

3.4
jitter gain
ratio, expressed in decibels, of the amplitude of jitter at the synchronization input of a device to the resultant jitter at the output of the device

NOTE This definition excludes the effect of intrinsic jitter.

3.5
frame rate
frequency at which frames are transmitted.

4 Common features

All interfaces shall be subject to the common jitter requirements in 5. Other parameters shall comply with the transmission type specified.

The interface should use the balanced transmission format specified in Annex C. The interface may use one of the alternative transmission formats specified in subsequent annexes.

5 Jitter

5.1 Output interface jitter

5.1.1 General

Jitter at the output of a device shall be measured as the sum of the jitter intrinsic to the device and jitter being passed through from the timing reference of the device.

5.1.2 Intrinsic jitter

The peak value of the intrinsic jitter at the output of the interface, measured at all the transition zero crossings shall be less than 0,025 UI when measured with the intrinsic-jitter measurement filter.

NOTE 1 This jitter may be strongly asymmetric in character and the deviation from the ideal timing should meet the specification in either direction.

NOTE 2 This requirement applies both when the equipment is locked to an effectively jitter-free timing reference, which may be a modulated digital audio signal, and when the equipment is free-running.

NOTE 3 The intrinsic-jitter measurement-filter characteristic is shown in figure 1. It shows a minimum-phase high-pass filter with 3 dB attenuation at 700 Hz, a first order roll-off to 70 Hz and with a pass-band gain of unity.

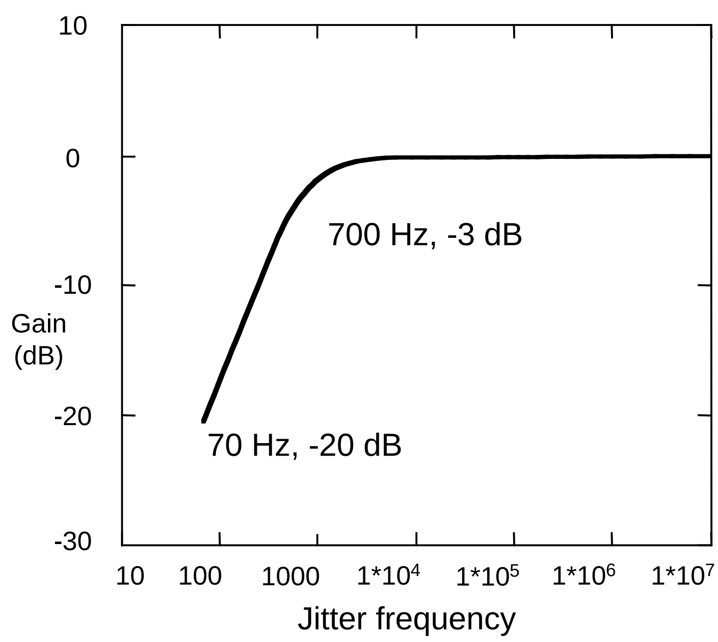


Figure 1 — Intrinsic-jitter measurement-filter characteristic

5.1.3 Jitter gain

The sinusoidal jitter gain from any timing reference input to the signal output shall be less than 2 dB at all frequencies.

NOTE If jitter attenuation is provided and it is such that the sinusoidal jitter gain falls below the jitter transfer function mask of figure 2 then the equipment specification should state that the equipment jitter attenuation is within this specification. The mask imposes no additional limit on low-frequency jitter gain. The limit starts at the input-jitter frequency of 500 Hz where it is 0 dB, and falls to –6 dB at and above 1 kHz.

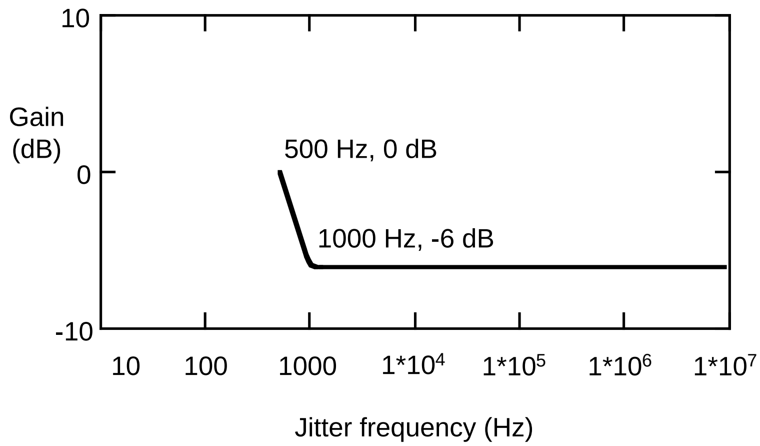


Figure 2 — Jitter transfer-function mask

5.2 Receiver jitter tolerance

An interface data receiver should correctly decode an incoming data stream with any sinusoidal jitter defined by the jitter tolerance template of figure 3.

NOTE The template requires a jitter tolerance of 0,25 UI peak-to-peak at high frequencies, increasing with the inverse of frequency below 8 kHz to level off at 10 UI peak-to-peak below 200 Hz.

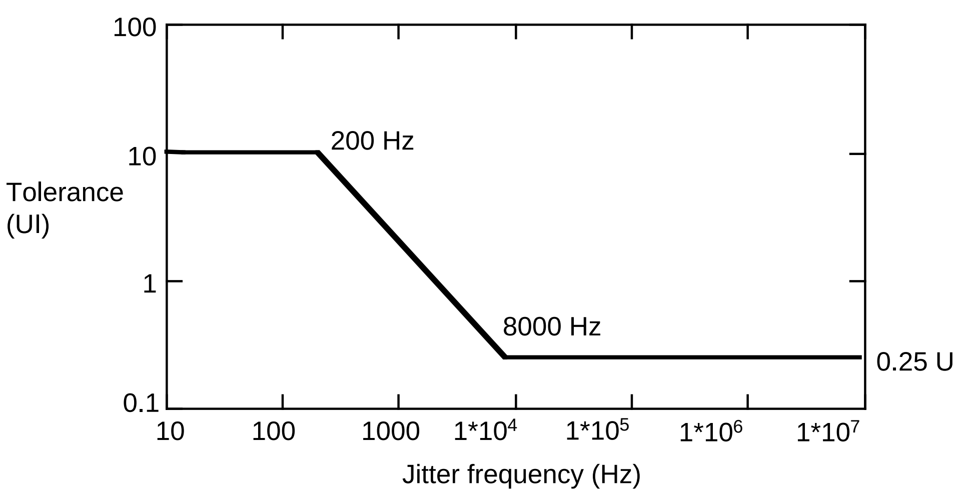


Figure 3 — Jitter tolerance template

Annex A (informative) Informative references

ITU-T V.11, *Electrical characteristics for balanced double-current interchange circuits operating at data signalling rates up to 10 Mbit/s*, International Telecommunication Union, Geneva, Switzerland.

AES5, *AES recommended practice for professional digital audio — Preferred sampling frequencies for applications employing pulse-code modulation*, Audio Engineering Society, New York, NY, USA.

AES10, *AES Recommended Practice for Digital Audio Engineering—Serial Multi-channel Audio Digital Interface (MADI)*, Audio Engineering Society, New York, NY., USA.

AES26, *AES recommended practice for professional audio - Conservation of the polarity of audio signals*, Audio Engineering Society, New York, NY, USA.

AES-2id, *AES information document for digital audio engineering - Guidelines for the use of the AES3 interface*, Audio Engineering Society, New York, NY, USA.

AES preprint 3783, 96th AES Convention, Amsterdam, February 1994, *Twisted-pair cables for AES/EBU Digital Audio Signals,* D. G. Kirby, BBC R & DD, (later published in J. Audio Eng. Soc. Vol. 43, No. 3, 1995 March, pp. 137-146).

IEC 60958-1, *Digital audio interface - Part 1: General*, International Electrotechnical Commission, Geneva, Switzerland.

IEC 60958-4, *Digital audio interface - Part 4: Professional applications*, International Electrotechnical Commission, Geneva, Switzerland.

ITU-R BS.647, *A digital audio interface for broadcasting studios*, International Telecommunication Union, Geneva, Switzerland.

SMPTE 297M, *Serial Digital fiber Transmission System for ANSI/SMPTE 259M Signals,* Society of Motion Picture and Television engineers, White Plains, NY., USA

SMPTE 276M, *Transmission of AES/EBU Digital Audio Signals Over Coaxial Cable*, Society of Motion Picture and Television engineers, White Plains, NY., USA

Annex B (informative) Symbol rates and UI

Demands on the performance of the interface are determined by the frame rate, which is in turn determined by the audio sampling frequency. AES5 recommends a set of sampling frequencies referred to a basic rate of 48 kHz with options to use 44,1 kHz or 32 kHz. These basic rates may be scaled by certain multiples to achieve higher or lower sampling frequencies.

The following tables illustrate how the symbol rate at the interface, and the UI, change with different sampling-frequency multiples.

Table B.1 - Symbol rate (MHz) vs sampling frequency

	Sampling Frequency (F_s) kHz		
Multiple	**32**	**44,1**	**48**
0,25	1,024	1,411 2	1,536
0,5	2,048	2,822 4	3,072
1	4,096	5,644 8	6,144
2	8,192	11,289 6	12,288
4	16,384	22,579 2	24,576
8	32,768	45,158 4	49,152

Table B.2 - UI (ns) vs sampling frequency

	Sampling Frequency (F_s) kHz		
Multiple	**32**	**44,1**	**48**
0,25	976,56	708,62	651,04
0,5	488,28	354,31	325,52
1	244,14	177,15	162,76
2	122,07	88,58	81,38
4	61,04	44,29	40,69
8	30,52	22,14	20,35

NOTE As the sampling frequency is increased, the demand on jitter performance will also increase. For example: a sampling frequency of 8 * 48 kHz (384 kHz) will require an intrinsic jitter of 0,025 * 20,35 ns, or 0,51 ns (see 5.1.2)

Annex C (normative) Balanced transmission

C.1 General Characteristics

C.1.1 Configuration

A circuit conforming to the general configuration shown in figure C.1 may be used.

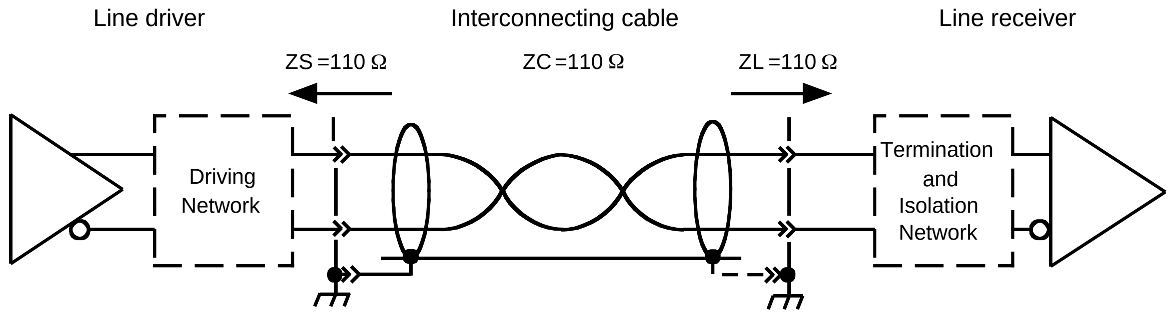


Figure C.1 – Simplified example of the configuration of the circuit (balanced)

NOTE The electrical parameters of the interface are based on those defined in ITU-T recommendation V.11 which allow transmission of balanced-voltage digital signals over cables up to a few hundred meters in length.

C.1.2 Equalisation

Equalization may be used at the receiver.

There shall be no equalization before transmission.

The frequency range used to qualify the interface electrical parameters is dependent on the maximum data rate supported. The upper frequency is 128 times the maximum frame rate (about 6 MHz for 48 kHz).

C.1.3 Cable

The interconnecting cable shall be balanced with a nominal characteristic impedance of 110 Ω at frequencies from 100 kHz to 128 times the maximum frame rate.

The cable shall be one of the following types:

- Shielded (screened) cable
- unshielded (unscreened) twisted pair (UTP) structured wiring (Category 5 or better, see ISO/IEC 11801). see note 5.
- Shielded (screened) twisted pair (STP) structured wiring (see ISO/IEC 11801).

The same cable type shall be used throughout any single interface connection, including patch leads.

NOTE 1 Holding closer tolerances for the characteristic impedance of the cable, and for the driving and terminating impedances, can increase the cable lengths for reliable transmission and for higher data rates.

NOTE 2 Closer tolerances for the balance of the driving impedance, the terminating impedance, and for the cable itself can reduce both electromagnetic susceptibility and emissions.

NOTE 3 Using cable having lower loss at higher frequencies can improve the reliability of transmission for greater distances and higher data rates.

NOTE 4 Care should be taken in design of the interface to provide adequate balance on the twisted pair within the Category 5 cable. Using RJ45 connectors, conventionally wired, current practice favours the use of pins 4 and 5 for AES3 signals (separating them from ATM signals on the same cable, for example). Pins 3 and 6 are the preferred second pair. For full protection, the interface may have to withstand power voltages specified to support network equipment, and the use of transformers and blocking capacitors on the AES3 interface is strongly recommended.

NOTE 5 UTP cable has been shown to offer transmission up to 400 metres overall unequalised, or 800 metres equalised, at 48 kHz frame rate. (See AES preprint 3783)

C.2 Line driver characteristics

C.2.1 Output impedance

The line driver shall have a balanced output with an internal impedance of 110 Ω with a tolerance of 20 %, at frequencies from 0,1 MHz to 128 times the maximum frame rate when measured at the output terminals.

C.2.2 Signal amplitude

The signal amplitude shall lie between 2 V and 7 V peak-to-peak, when measured across a 110-Ω resistor connected to the output terminals, without any interconnecting cable present.

NOTE a typical value is 4 V ± 10 %.

C.2.3 Balance

Any common-mode component at the output terminals shall be more than 30 dB below the signal at frequencies from d.c. to 128 times the maximum frame rate when terminated in a floating load of 110 Ω

C.2.4 Rise and fall times

The rise and fall times, determined between the 10 % and 90 % amplitude points, shall be between 0,03 UI and 0.18 UI when measured across a 110-Ω resistor connected to the output terminals, without any interconnecting cable present.

NOTE 1 The minimum and maximum rise and fall times for a frame rate of 48 kHz are 5 ns and 30 ns respectively.

NOTE 2 Operation toward the lower limit of 5 ns may improve the received-signal eye pattern, but may increase electromagnetic radiation at the transmitter. Care should be taken to meet local regulations regarding electromagnetic compatibility (EMC).

C.3 Line receiver characteristics

C.3.1 Terminating impedance

The receiver shall present an essentially resistive impedance of 110 Ω with a tolerance of 20 % to the interconnecting cable over the frequency band from 0,1 MHz to 128 times the maximum frame rate when measured across the input terminals. The application of more than one receiver to any one line might create transmission errors due to the resulting impedance mismatch.

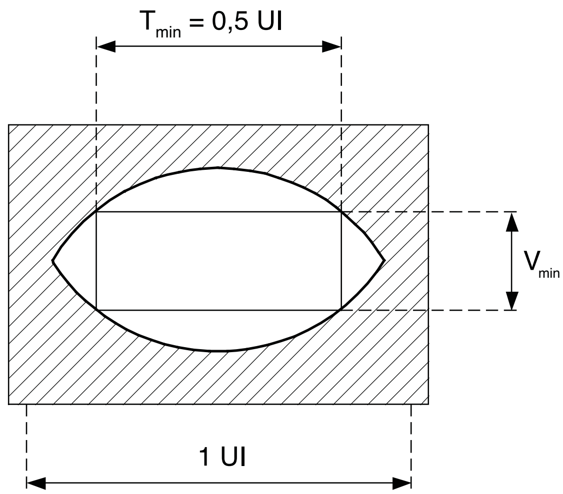
C.3.2 Maximum input signals

The receiver shall correctly interpret the data when connected directly to a line driver working between the extreme voltage limits specified in C.2.2.

NOTE The AES3-1985 specification for line driver signal amplitude was 10 V peak to peak maximum.

C.3.3 Minimum input signals

The receiver shall correctly sense the data when a random input signal produces the eye diagram characterized by a V_{min} of 200 mV and T_{min} of 0,5 UI. See figure C.2.



T_{min}: 0,5 UI
V_{min}: 200 mV

Figure C.2 — Eye diagram, balanced receiver

C.3.4 Receiver equalization

Equalization may be applied in the receiver to enable an interconnecting cable longer than 100 m to be used. A suggested frequency equalization characteristic for operation at frame rates of 48 kHz is shown in figure C.3. The receiver shall meet the requirements specified in C.3.2 and C.3.3.

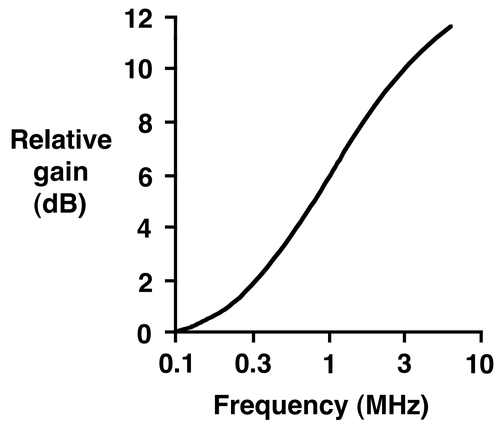


Figure C.3 — Suggested equalizing characteristic for a receiver operating at 48 kHz frame rate

C.3.5 Common-mode rejection

There shall be no data errors introduced by the presence of a common-mode signal of up to 7 V peak at frequencies from DC to 20 kHz.

C.4 Connector

C.4.1 XLR connector

The standard connector for both outputs and inputs shall be the circular latching three-pin connector described in IEC 60268-12. Note: this type of connector is usually called XLR, or XLR-3.

An output connector fixed on an item of equipment shall use male pins with a female shell. The corresponding cable connector shall thus have female pins with a male shell.

An input connector fixed on an item of equipment shall use female pins with a male shell. The corresponding cable connector shall thus have male pins with a female shell. The pin usage shall be:

Pin 1	Cable shield or signal earth
Pin 2	Signal
Pin 3	Signal

NOTE The channel coding means that the relative polarity of pins 2 and 3 is not important. See Part 3, clause 6. However it is recommended that relative polarity is preserved for these signal paths. See AES26.

C.4.2 8-way modular connector

Where Category 5 structured cabling is used, the 8-way modular connector specified in IEC 60603-7 (sometimes called "RJ45") is required. While the interface is by definition insensitive to polarity, for the purposes of constructing adaptors, XLR Pin 2 should be connected to RJ45 Pin 5 (or other odd-numbered pin), XLR Pin 3 should be connected to RJ45 Pin 4 (or even-numbered pin), consistent with using one of the four twisted pairs.

Equipment manufacturers should clearly label digital audio inputs and outputs as such, including the terms digital audio input or digital audio output as appropriate.

In such cases where panel space is limited and the function of the connector might be confused with an analog signal connector, the abbreviation DI or DO should be used to designate digital audio inputs and outputs, respectively.

Annex D (normative) Coaxial transmission

The parameters set in this section apply to circuits where balanced equipment is adapted to coaxial cable. Other standards call for more stringent figures where conventional video equipment is used for AES3 signals (SMPTE 276M) or less stringent figures where consumer equipment is connected over short distances using screened audio cable (IEC 60958-3). Techniques for adapters are described in AES-2id.

D.1 Line driver characteristics

D.1.1 General

No equalization before transmission shall be permitted.

> NOTE The specification for the line driver (also known as a generator or transmitter) is totally different from the balanced AES3 electrical specification and is based on unbalanced coaxial-cable transmission consistent with conventional professional analog-video practice.

D.1.2 Output impedance

The line driver shall have an unbalanced output circuit having a source impedance of 75 Ω and a return loss better than 15 dB over the frequency band from 0,1 MHz to 128 x frame rate (6,0 MHz in the case of 48 kHz).

D.1.3 Signal characteristics

The output signal characteristic shall be as shown in figure D.1 and table D.1 when measured across a resistor connected to the output terminals. The resistor shall have a value of 75 Ω with a relative tolerance of ± 1 %.

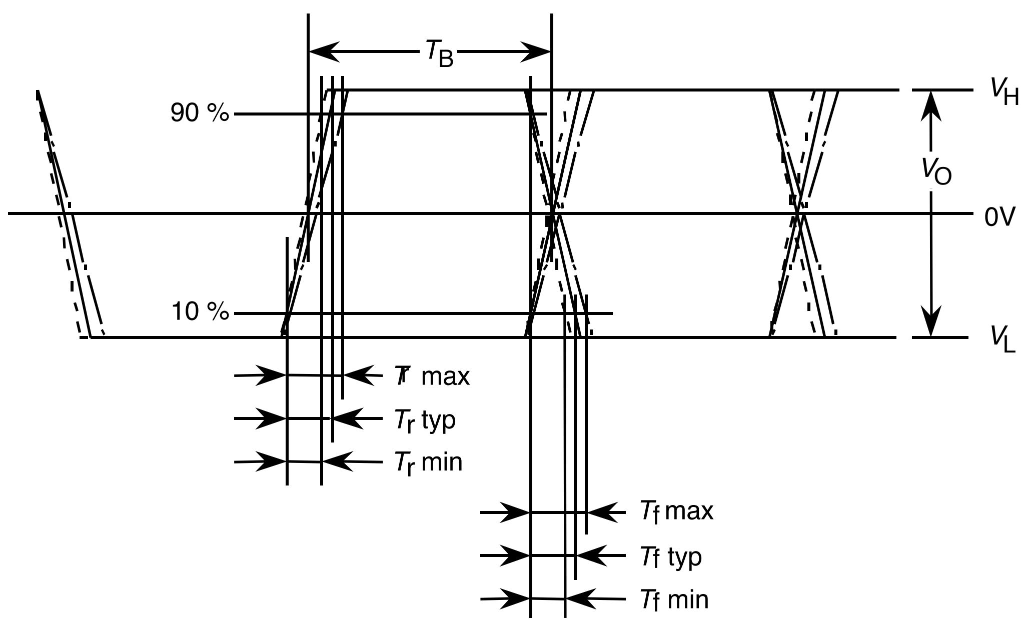


Figure D.1 — Output signal waveform

Table D.1 — Output signal characteristics

Parameter	Symbol	Minimum	Typical	Maximum	Unit
Output voltage	$V_O = V_H - V_L$	0,8	1,0	1,2	V
D.c. offset	$\lvert V_H + V_L \rvert$	–	–	<50	mV
Rise time	T_r	0,185 (30 ns)	0,225 (37 ns)	0,27 (44 ns)	UI see note 6
Fall time	T_f	0,185 (30 ns)	0,225 (37 ns)	0,27 (44 ns)	UI see note 6
Bit width	T_B	–	1 (163 ns)	–	UI notes 1, 6

NOTE 1 Equal to 1/(128 x frame rate)

NOTE 2 The output voltage is similar to typical analog video signals.

NOTE 3 Less DC offset provides a better result for long transmission.

NOTE 4 The minimum value of the rise and fall times is chosen to restrict the bandwidth of the output signal. When this digital audio signal is fed to a conventional analog video distribution amplifier (VDA), this specification prevents unnecessary phase distortion of the signal caused by limited bandwidth of the analog VDA High frame rates imply high video bandwidths free of phase distortion. Operation toward the lower limit may improve the received-signal eye pattern, but may increase EMC at the transmitter. Care should be taken to meet local regulations regarding EMC.

NOTE 5 The maximum value of the rise and fall times is chosen with consideration given to the desirability of long-distance (1000 m) transmission.

NOTE 6 Figures in (brackets) represent time values where the frame rate is 48 kHz.

D.2 Coaxial cable characteristics

The interconnecting cable shall be coaxial and have a characteristic impedance of 75 Ω ± 3 Ω over the frequency band from 0,1 MHz to 128 x frame rate (6,0 MHz in the case of 48 kHz). See AES-2id-2006 for a discussion of design principles. It should be well screened.

D.3 Line receiver characteristics

D.3.1 General

Equalization may be used at the receiver

NOTE The recovered signal integrity is determined by the signal condition at the end of the terminated cable and the receiver characteristics. Receiver characteristics such as threshold level, hysteresis level, input sensitivity, and so on, depend on the application. The application is defined in part by transmission distance, specific cable used, required noise margin, and performance of the downstream clock-recovery circuitry. If the intention is to preserve the integrity of the signal under various circumstances such that it be identical in all cases, then the requirement for the optimum receiver will differ in each case. Thus, this document establishes only the minimum requirements, rather than specifying the characteristic of every receiver.

D.3.2 Terminating impedance

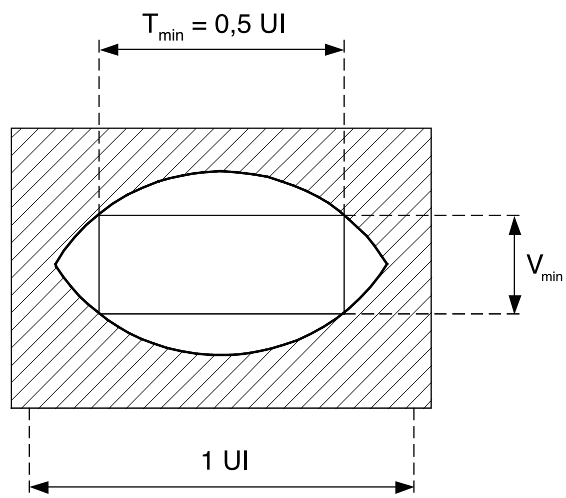
The terminating impedance shall be a resistive impedance, at the cable connector, of 75 Ω with return loss of 15 dB or more over the frequency band from 0,1 to 128 x frame rate (6,0 MHz in the case of 48 kHz).

D.3.3 Maximum input signals

The receiver shall correctly interpret the data when connected directly to a line driver working between the extreme voltage limits specified in D.1.3.

D.3.4 Minimum input signals

The receiver shall correctly interpret the data when a random signal at the input connector produces the eye diagram characterized by a V_{min} of 320 mV and a T_{min} of 0,5 UI, (see figure D.2).

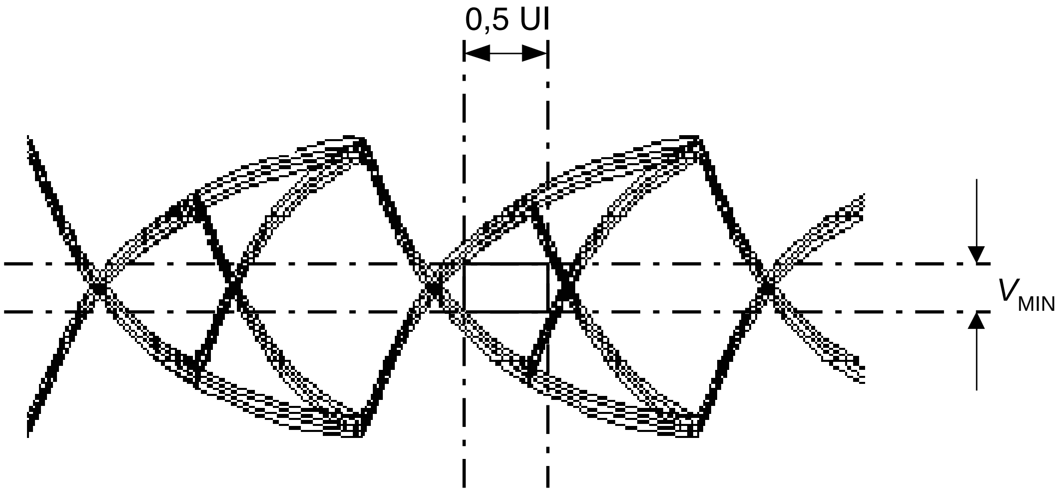


T_{min}: 0,5 UI
V_{min}: 320 mV

Figure D.2 — Eye diagram, coaxial receiver

NOTE 1 This specification is equivalent to one for minimum signal at the terminated BNC connector at the receiving end of the coaxial cable. It is written to maintain compatibility with existing equipment conforming to annex C when a resistive pad or transformer impedance-converter, adapting a BNC (75 Ω) connector to the type of XLR connector described in annex C (110 Ω), is used to connect the unbalanced coaxial cable to the balanced AES3 input. See AES-2id-2006 for examples.

NOTE 2 For transmissions beyond 1000 m, experiments have found the necessity to use a receiver of high sensitivity that can reliably operate with an input signal eye diagram characterized by a V_{min} of 30 mV as shown in figure D.3. See AES-2id-2006 for examples.



V_{MIN} = 30 mV

Figure D.3 — Eye pattern for long-distance transmission

D.4 Connector

The connector shall have mechanical characteristics conforming to type BNC as described in IEC 60169-8, but may feature an impedance of 75 Ω.

Annex E (informative) Optical transmission

E.1 Short haul

The use of plastic optical fibre for short distances (<10 m) is under consideration

E.2 Medium haul

The use of graded index (multimode) optical fibre for medium distances (10 m to 2 km) is under consideration

E.3 Long haul

The use of single-mode (mono-mode) optical fibre for long distances (>1 km) is under consideration