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DIGITAL SYSTEMS AND NETWORKS

Digital terminal equipments – Coding of analogue signals
by pulse code modulation

Transmission performance characteristics of pulse code modulation channels

ITU-T Recommendation G.712

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ITU-T Recommendation G.712

Transmission performance characteristics of pulse code modulation channels

Summary

This Recommendation deals with the transmission performance characteristics of PCM channels of digital transmission equipment. Requirements to be met between 4-wire and 2-wire analogue ports are given as well as requirements for analogue-to-digital and digital-to-analogue connections. The parameters and values specified in this Recommendation apply to the use of PCM equipment connected to analogue trunks or to analogue and digital exchanges.

Source

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

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ITU-T Recommendation G.712¹

Transmission performance characteristics of pulse code modulation channels

0 Scope

This Recommendation deals with the transmission performance characteristics of PCM channels transmitted via digital transmission equipment. Requirements to be met between 4-wire and 2-wire analogue ports are given as well as requirements for analogue-to-digital and digital-to-analogue connections.

1 General

Performance characteristics which follow should be met between voice-frequency ports or between the voice-frequency and digital ports of PCM channels coded in accordance with ITU-T Rec. G.711.

Equipment which meets the analogue-to-analogue requirements, but not the analogue-to-digital requirements, may only be used as permanently connected pairs of equipment.

The parameters and values specified in this Recommendation apply to the use of PCM equipment connected to analogue trunks or to analogue and digital exchanges. When PCM equipment is connected directly to analogue subscriber lines, different values for some of the parameters may be required. ITU-T Rec. Q.552 contains those values. The requirements in this Recommendation may also be applied if the PCM equipment is directly connected to an analogue local exchange that is virtually transparent with regard to the impedances connected to its ports and the subscriber lines are short (e.g. less than 500 metres).

Line current is not normally to be expected at the ports of the PCM equipment. If "line current" is nevertheless present, as is the case when signalling takes place on the two wires, any noise it contributes should meet requirements at the appropriate interface as described in the Q.550-series of Recommendations. The limits should be met when any signalling function is in the normal speaking condition, but excluding any dynamic signalling conditions, e.g. metering.

1.1 Measurement considerations

When a nominal reference frequency of 1020 Hz is indicated (e.g. measurement of attenuation/frequency distortion and adjustment of relative levels), the actual frequency should be 1020 Hz, +2 Hz, -7 Hz in accordance with ITU-T Rec. O.6.

In the following subclauses, the concepts of a "standard digital generator" and "a standard digital analyser" should be assumed and these are defined as follows.

A **standard digital generator** is a hypothetical device which is absolutely ideal, i.e. a perfect analogue-to-digital converter preceded by an ideal low pass filter (assumed to have no attenuation/frequency distortion and no group delay distortion), and which may be simulated by a digital processor.

A **standard digital analyser** is a hypothetical device which is absolutely ideal, i.e. a perfect digital-to-analogue converter followed by an ideal low pass filter (assumed to have no attenuation/frequency distortion and no group delay distortion), and which may be simulated by a digital processor.

¹ This Recommendation replaces ITU-T Recs. G.712, G.713, G.714 and G.715 of the CCITT *Blue Book* Volume III, Fascicle III.4.

ITU-T Rec. O.133 contains information about test equipment based on these concepts. Account should be taken of the measurement accuracy provided by test equipment designed in accordance with that Recommendation.

A PCM quiet signal is defined to be an idle character signal corresponding to decoder output value number 0 for μ -law or decoder output value number 1 for A-law with the sign bit in a fixed state.

The following specifications are based on ideal measuring equipment. Therefore, they do not include any margin for measurement errors.

1.2 Port definitions

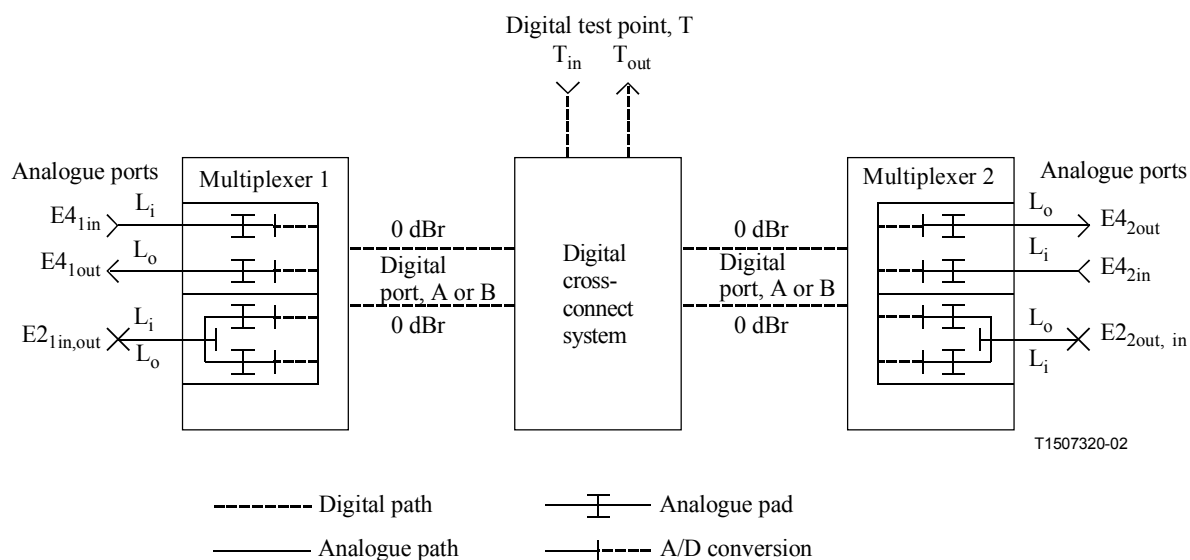
The term "port" in this Recommendation is defined as a functional unit (e.g. a connector) of the PCM equipment through which signals can enter or leave the unit under test. The measurements are made at the equipment, and the requirements do not include an allowance for wiring to a distribution frame.

Figure 1 shows two elements of PCM equipment connected via a digital cross-connect (DXC) system. Each element of PCM equipment is shown to have a 4-wire analogue voice-frequency port, E4, and a 2-wire analogue voice-frequency port, E2. Each of the PCM elements is connected to the DXC by digital ports A or B (ports A and B are defined in 1.1/Q.551), which consists of transparent 64 kbit/s PCM channels within a higher order digital signal conforming to applicable Recommendations. The DXC implements transparent 64 kbit/s cross connections between its own A or B ports, or to the digital test point, T. The T point consists of a 64 kbit/s channel within a digital signal suitable for connection to the standard digital generator and analyser. Since the connections provided by the DXC are 64 kbit/s transparent, the paths within the DXC are assumed not to affect the recommended transmission performance characteristics except for absolute delay. The test points T are defined for specification purposes. They may not physically exist in a DXC but may be accessed via the DXC network.

Unless stated otherwise, measurements between two-wire ports ($E2_{1in}$ to $E2_{2out}$ connections) should be made with the 4-wire loop opened in such a way that the impedances presented to the 4-wire port of the 2-wire/4-wire terminating unit are representative of those that will occur in normal operation. This condition may be achieved by interrupting the digital signal in the opposite direction to the direction of measurement and injecting a PCM quiet signal into the appropriate channel. It should be noted that the opening of the 4-wire loop is considered necessary to determine the intrinsic performance of the equipment. In normal operation, where the loop is not opened, the impact on overall performance of the terminating impedances connected to the 2-wire ports needs to be taken into account.

Figure 1 is similar to Figure 1/Q.551, which identifies interfaces, transmission levels designations and test points at a digital exchange.

The performance characteristics between ports were previously specified in CCITT *Blue Book*, Volume III, Fascicle III.4, as shown in the Table 1.



NOTE – Numbers 1 or 2 in the subscript indicate multiplexers 1 or 2.

Figure 1/G.712 – PCM equipment and test ports

Table 1/G.712 – Equivalence between previous ITU-T Recommendations and channels specified in this Recommendation

Channel	Previous ITU-T Recommendation
4-wire analogue to 4-wire analogue ($E4_1$ to $E4_2$ channels)	G.712
2-wire analogue to 2-wire analogue ($E2_1$ to $E2_2$ channels)	G.713
4-wire analogue-to-digital ($E4$ to A or B for a primary multiplexer)	G.714
2-wire analogue-to-digital ($E2$ to A or B for a primary multiplexer)	G.715

1.3 Abbreviations

This Recommendation uses the following abbreviations:

DXC	Digital Cross-Connect
FDM	Frequency Division Multiplex
FEXT	Far-End crosstalk
NEXT	Near-End crosstalk
PCM	Pulse Code Modulation
SL	Stability Loss
TBRL	Terminal Balance Return Loss

2 Relative levels at analogue ports

2.1 Relative levels at 4-wire ports ($E4$)

When attenuation pads are set to zero loss, L_o at $E4_{2out}$ and L_i at $E4_{1in}$ must have one of the following two series of nominal values: Maximum $L_o = +4$ dBr and minimum $L_i = -14$ dBr; or maximum $L_o = +7$ dBr and minimum $L_i = -16$ dBr. See 11/G.232.

2.2 Relative levels at 2-wire ports (E2)

Due to differences in network transmission plans and equipment utilization, network operators have differing requirements for the range of relative levels to be provided. The following ranges would encompass the requirements of a large number of network operators:

- input level (L_i) at encoding side 0 to -5 dBr in 0.5 dB steps;
- output level (L_o) at decoding side -2 to -7.5 dBr in 0.5 dB steps.

It is recognized that it is not necessarily appropriate for a specifically designed piece of equipment to be capable of operating over the entire range.

NOTE – The requirements in this clause are different from the requirements in 2.1.3/Q.552.

3 Adjustment of actual relative levels

3.1 Adjustment of the decoding side (T_{in} to E_{out})

The gain of the decoding side should be adjusted by connecting T_{in} to a standard digital generator and applying a 1020 Hz sinusoidal test signal at a level of 0 dBm0. The adjustment should result in an output level of $0 \text{ dBm0} \pm 0.3 \text{ dB}$ for 4-wire ports (T_{in} to E_{4out}) or an output level of $0 \text{ dBm0} \pm 0.4 \text{ dB}$ for 2-wire ports (T_{in} to E_{2out}) and should be made under typical conditions of power supply voltage, humidity and temperature.

3.2 Adjustment of the encoding side (E_{in} to T_{out})

The gain of the encoding side should be adjusted by connecting T_{out} to a standard digital analyser and applying a 1020 Hz test signal at a level of 0 dBm0 to E_{in} . The adjustment should result in an output level of $0 \text{ dBm0} \pm 0.3 \text{ dB}$ for 4-wire ports (E_{4in} to T_{out}) or an output level of $0 \text{ dBm0} \pm 0.4 \text{ dB}$ for 2-wire ports (E_{2in} to T_{out}) and should be made under typical conditions of power supply voltage, humidity and temperature.

3.3 Load capacity (overload point)

The load capacity of the encoding side may be checked by applying a 1020 Hz sinusoidal test signal at E_{in} . The level of this signal should be initially well below the maximum value of T_{out} ($=T_{outmax}$), and should then be slowly increased. The input level should be measured at which the first occurrence of the character signal corresponding to the extreme quantizing interval for both positive and negative values is observed. T_{outmax} is taken as being 0.3 dB greater than the measured input level.

This method allows T_{outmax} to be checked for both positive and negative amplitudes, and the values thus obtained should be within 0.4 dB of the theoretical load capacity (i.e. +3.14 dBm0 for the A-law or +3.17 dBm0 for the μ -law).

4 Short- and long-term variation of loss with time

When a 1020 Hz sinusoidal test signal at a level of -10 dBm0 (preferred value; however, a level of 0 dBm0 may be used) is applied to any voice-frequency input, the level measured at the corresponding output should not vary by more than the limits shown in Table 2 during any 10-minute interval of typical operation, nor by more than the limits shown during any one year under the permitted variations in the power supply voltage and temperature.

Table 2/G.712 – Requirements for short- and long-term variation of level with time

Channels	Maximum permitted variation (dB)		
	10-minute interval	One-year interval	
4-wire to 4-wire (E_{4in} to E_{4out})	± 0.2	± 0.5	
2-wire to 2-wire (E_{2in} to E_{2out})	± 0.2	± 0.6	
4-wire to digital (E_{4in} to T_{out})	± 0.1	± 0.3	
Digital to 4-wire (T_{in} to E_{4out})	± 0.1	± 0.3	(Note)
2-wire to digital (E_{2in} to T_{out})	± 0.1	± 0.3	
Digital to 2-wire (T_{in} to E_{2out})	± 0.1	± 0.3	(Note)
NOTE – The 0 dBm0 sequence of Tables 5/G.711 or 6/G.711 may be used.			

5 Nominal impedance and return loss of analogue ports

5.1 Nominal impedance

The nominal impedance at the 4-wire analogue input and output ports, E_{4in} and E_{4out} , should be 600 Ω , balanced.

For 2-wire analogue ports, E_2 , no single value of impedance is recommended. The following values can be found in practice:

- 600 Ω resistive, balanced;
- 900 Ω resistive, balanced;
- 600 Ω + 2.16 μ F, balanced;
- 900 Ω + 2.16 μ F, balanced.
- 750 Ω //150 nF + 270 Ω

NOTE 1 – Some examples of complex impedances used in connection with subscriber lines can be found in Table 1/Q.552.

NOTE 2 – Measurements at ports with complex impedances shall follow the definitions and conventions given in Annex A/G.100.

5.2 Return loss

The return loss, against the nominal impedance, should meet the return loss requirements shown in Table 3 over the frequency range 300 Hz to 3400 Hz.

Table 3/G.712 – Return loss requirements for E4 and E2 ports

Analogue port	Return loss (dB)		Notes
	300 Hz to 600 Hz	600 Hz to 3400 Hz	
4-wire, E4	> 20	> 20	1
2-wire, E2	> 12	> 15	2
NOTE 1 – The return loss limit should be met when the adjusting pads are set to 0 dB (see Figure 5/G.232).			
NOTE 2 – Reflections due to impedance mismatches at 2-wire/4-wire ports may cause severe sidetone and echo problems in the network. Network operators need to adopt a suitable impedance strategy, including tolerances, to ensure an adequate transmission quality. (For further information, see clause 5/G.121.)			

6 Impedance unbalance about earth

The longitudinal conversion loss parameters referred to below are defined in ITU-T Rec. O.9, which also gives some information about the requirements of test circuits (see Note 1 of Table 4). The value of Z in the driving test circuit should be within $\pm 20\%$ of the values shown in Tables 4 and 5. The termination at the other port shall be the nominal impedance.

6.1 Longitudinal conversion loss

The longitudinal conversion loss (see 4.1/O.9) should not be less than the limits in Table 4.

Table 4/G.712 – Longitudinal conversion loss requirements for E4 and E2 ports

Port	Z (Ω)	Longitudinal conversion loss (dB)			Notes
		300 Hz to 600 Hz	600 Hz to 2400 Hz	2400 Hz to 3400 Hz	
4-wire, E4 _{in}	600	> 46	> 46	> 41	1, 2
4-wire, E4 _{out}	600	> 46	> 46	> 41	1, 2
2-wire, E2	600	> 40	> 46	> 41	1, 2, 3, 4
2-wire, E2	750	> 40	> 46	> 41	1, 2, 3, 4
NOTE 1 – Attention is drawn to clause 5/O.9, which shows the equivalence between a number of different test driving circuits and also includes information concerning the inherent balance requirements of the test bridge.					
NOTE 2 – Attention is drawn to the fact that these values represent minimum requirements. The magnitude of potential longitudinal signal voltages depends, for example, on system use, the system environment, the location of hybrid transformers and attenuators, and may therefore vary for different network operators. Some network operators have found it necessary to specify higher values for longitudinal conversion loss and longitudinal conversion transfer loss to ensure that transverse voltages caused by possible longitudinal signal voltages are sufficiently small.					
NOTE 3 – For frequencies below 300 Hz, in particular at 50 Hz or 60 Hz, overall rejection of longitudinal interference can be achieved by a combination of good longitudinal balancing and high pass filtering (see 10.2).					
NOTE 4 – The measurements should be made selectively.					