BS EN IEC 61280-2-8:2021

BSI Standards Publication

Fibre optic communication subsystem test procedures

Part 2-8: Digital systems — Determination of low BER using Q-factor measurements

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National foreword

This British Standard is the UK implementation of EN IEC 61280-2-8:2021. It is identical to IEC 61280-2-8:2021. It supersedes BS EN 61280-2-8:2003, which will be withdrawn on 5 November 2021.

The UK participation in its preparation was entrusted to Technical Committee GEL/86/3, Fibre optic systems and active devices.

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English Version

Fibre optic communication subsystem test procedures - Part 2-8: Digital systems - Determination of low BER using Q-factor measurements (IEC 61280-2-8:2021)

Procédures d'essai des sous-systèmes de télécommunications fibroniques - Partie 2-8: Systèmes numériques - Détermination de faibles valeurs de BER en utilisant des mesures du facteur Q (IEC 61280-2-8:2021)

Prüfverfahren für Lichtwellenleiter-Kommunikationsuntersysteme - Teil 2-8: Digitale Systeme - Bestimmung von geringen Bitfehlerraten (BER) mit Hilfe von Q-Faktor Messungen (IEC 61280-2-8:2021)

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European foreword

The text of document 86C/1708/FDIS, future edition 2 of IEC 61280-2-8, prepared by SC 86C "Fibre optic systems and active devices" of IEC/TC 86 "Fibre optics" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61280-2-8:2021.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2022-01-06
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2024-04-06

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IEC 61281-1	NOTE	Harmonized as EN IEC 61281-1

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Full document details: BS EN IEC 61280-2-8:2021

CONTENTS

FOREWORD 4
1 Scope 6
2 Normative references 6
3 Terms, definitions, and abbreviated terms 6
3.1 Terms and definitions 6
3.2 Abbreviated terms 7
4 Measurement of low bit-error ratios 7
4.1 General considerations 7
4.2 Background to Q-factor 8
5 Variable decision threshold method 10
5.1 Overview 10
5.2 Apparatus 13
5.3 Sampling and specimens 13
5.4 Procedure 13
5.5 Calculations and interpretation of results 15
5.5.1 Sets of data 15
5.5.2 Convert BER using inverse error function 16
5.5.3 Linear regression 17
5.5.4 Standard deviation and mean 18
5.5.5 Optimum decision threshold 18
5.5.6 BER optimum decision threshold 18
5.5.7 BER non-optimum decision threshold 19
5.5.8 Error bound 19
5.6 Test documentation 19
5.7 Specification information 19
6 Variable optical threshold method 19
6.1 Overview 19
6.2 Apparatus 20
6.3 Items under test 20
6.4 Procedure for basic optical link 20
6.5 Procedure for self-contained system 21
6.6 Evaluation of results 22
Annex A (normative) Calculation of error bound in the value of Q 24
Annex B (informative) Sinusoidal interference method 26
B.1 Overview 26
B.2 Apparatus 26
B.3 Sampling and specimens 26
B.4 Procedure 27
B.4.1 Optical sinusoidal interference method 27
B.4.2 Electrical sinusoidal interference method 28
B.5 Calculations and interpretation of results 29
B.5.1 Mathematical analysis 29
B.5.2 Extrapolation 29
B.5.3 Expected results 30
B.6 Documentation 31

AVA Documents
Document Sharing Hub

Full document details: BS EN IEC 61280-2-8:2021

B.7 Specification information 31
Bibliography 32

Figure 1 – Sample eye diagram showing patterning effects 9
Figure 2 – More accurate measurement technique using a DSO that samples noise statistics between eye centres 10
Figure 3 – Bit error ratio as a function of decision threshold level 11
Figure 4 – Plot of Q-factor as a function of threshold voltage 12
Figure 5 – Set-up for the variable decision threshold method 14
Figure 6 – Set-up of initial threshold level (approximately at the centre of the eye) 14
Figure 7 – Effect of optical bias 20
Figure 8 – Set-up for optical link or device test 21
Figure 9 – Set-up for system test 21
Figure 10 – Extrapolation of log BER as a function of bias 23
Figure B.1 – Set-up for the sinusoidal interference method by optical injection 27
Figure B.2 – Set-up for the sinusoidal interference method by electrical injection 29
Figure B.3 – BER result from the sinusoidal interference method (data points and extrapolated line) 30
Figure B.4 – BER versus optical power for three methods 31

Table 1 – Mean time for the accumulation of 15 errors as a function of BER and bit rate 7
Table 2 – BER as a function of threshold voltage 16
Table 3 – f_i as a function of D_i 17
Table 4 – Values of linear regression constants 18
Table 5 – Mean and standard deviation 18
Table 6 – Example of optical bias test 22
Table B.1 – Results for sinusoidal injection 28

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Document Sharing Hub
Full document details: BS EN IEC 61280-2-8:2021

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FIBRE OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 2-8: Digital systems – Determination of low BER using Q-factor measurements

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IEC 61280-2-8 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics. It is an International Standard.

This second edition cancels and replaces the first edition published in 2003. This edition constitutes a technical revision.

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

a) correction of errors in Formula (8) in 5.5.2 and in a related formula in 5.5.3;
b) correction of errors in the references to clauses, subclauses, figures, procedures, and in the Bibliography;
c) alignment of the terms and definitions in 3.1 with those in IEC 61281-1.

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The text of this International Standard is based on the following documents:

FDIS	Report on voting
86C/1708/FDIS	86C/1711/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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FIBRE OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 2-8: Digital systems – Determination of low BER using Q-factor measurements

1 Scope

This part of IEC 61280 specifies two main methods for the determination of low BER values by making accelerated measurements. These include the variable decision threshold method (Clause 5) and the variable optical threshold method (Clause 6). In addition, a third method, the sinusoidal interference method, is described in Annex B.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
amplified spontaneous emission
ASE
optical power associated to spontaneously emitted photon amplified by an active medium in an optical amplifier

3.1.2
bit error ratio
BER
P_e
number of errored bits divided by the total number of bits, over some stipulated period of time

3.1.3
intersymbol interference
ISI
overlap of adjacent pulses as caused by the limited bandwidth characteristics of the optical devices in a fibre optic link

3.1.4
Q-factor
Q
ratio of the difference between the mean voltage of the 1 and 0 rails, to the sum of their standard deviation values

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3.2 Abbreviated terms

AC	alternating current
CW	continuous wave (normally referring to a sinusoidal wave form)
DC	direct current
DSO	digital sampling oscilloscope
DUT	device under test
PRBS	pseudo-random binary sequence
SNR	signal-to-noise ratio

4 Measurement of low bit-error ratios

4.1 General considerations

Fibre optic communication systems and subsystems are inherently capable of providing exceptionally good error performance, even at very high bit rates. The mean bit error ratio (BER) may typically lie in the region 10^{-12} to 10^{-20}, depending on the nature of the system. While this type of performance is well in excess of practical performance requirements for digital signals, it gives the advantage of concatenating many links over long distances without the need to employ error correction techniques.

The measurement of such low error ratios presents special problems in terms of the time taken to measure a sufficiently large number of errors to obtain a statistically significant result. Table 1 presents the mean time required to accumulate 15 errors. This number of errors can be regarded as statistically significant, offering a confidence level of 75 % with a variability of 50 %.

Table 1 – Mean time for the accumulation of 15 errors as a function of BER and bit rate

Bit rate	Mean times for the accumulation of 15 errors										
	BER										
	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	10^{-14}	10^{-15}
1,0 Mbit/s	150 ms	1,5 s	15 s	2,5 min	25 min	4,2 h	1,7d	17 d	170 d	4,7 years	47 years
2,0 Mbit/s	75 ms	750 ms	7,5 s	75 s	750 s	2,1 h	21 h	8,8 d	88 d	2,4 years	24 years
10 Mbit/s	15 ms	150 ms	1,5 s	15 s	2,5 min	25 min	4,2 h	1,7 d	17 d	170 d	4,7 years
50 Mbit/s	3,0 ms	30 ms	300 ms	3,0 s	30 s	5,0 min	50 min	8,3 h	3,5 d	35 d	350 d
100 Mbit/s	1,5 ms	15 ms	150 ms	1,5 s	15 s	2,5 min	25 min	4,2 h	1,7 d	17 d	170 d
500 Mbit/s	300 µs	3 ms	30 ms	300 ms	3,0 s	30 s	5,0 min	50 min	8,3 h	3,5 d	35 d
1,0 Gbit/s	150 µs	1,5 ms	15 ms	150 ms	1,5 s	15 s	2,5 min	25 min	4,2 h	1,7 d	17 d
10 Gbit/s	15 µs	150 µs	1,5 ms	15 ms	150 ms	1,5 s	15 s	2,5 min	25 min	4,2 h	1,7 d
40 Gbit/s	3,8 µs	38 µs	380 µs	3,8 ms	38 ms	380 ms	3,8 s	38 s	6,3 min	63 min	10,4 h
100 Gbit/s	1,5 µs	15 µs	150 µs	1,5 ms	15ms	150 ms	1,5 s	15 s	2,5 min	25 min	4,2 h

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The times given in Table 1 show that the direct measurement of the low BER values expected from fibre optic systems is not practical during installation and maintenance operations. One way of overcoming this difficulty is to artificially impair the signal-to-noise ratio at the receiver in a controlled manner, thus significantly increasing the BER and reducing the measurement time. The error performance is measured for various levels of impairment, and the results are then extrapolated to a level of zero impairment using computational or graphical methods according to theoretical or empirical regression algorithms.

The difficulty presented by the use of any regression technique for the determination of the error performance is that the theoretical BER value is related to the level of impairment via the inverse complementary error function (erfc). This means that very small changes in the impairment lead to very large changes in BER; for example, in the region of a BER value of 10^{-15}, a change of approximately 1 dB in the level of impairment results in a change of three orders of magnitude in the BER. A further difficulty is that a method based on extrapolation is unlikely to reveal a levelling off of the BER at only about 3 orders of magnitude below the lowest measured value.

It should also be noted that, in the case of digitally regenerated sections, the results obtained apply only to the regenerated section whose receiver is under test. Errors generated in upstream regenerated sections may generate an error plateau which may have to be taken into account in the error performance evaluation of the regenerator section under test.

As noted above, two main methods for the determination of low BER values by making accelerated measurements are described. These are the variable decision threshold method (Clause 5) and the variable optical threshold method (Clause 6). In addition, a third method, the sinusoidal interference method, is described in Annex B.

It should be noted that these methods are applicable to the determination of the error performance in respect of amplitude-based impairments. Jitter may also affect the error performance of a system, and its effect requires other methods of determination. If the error performance is dominated by jitter impairments, the amplitude-based methods described in this document will lead to BER values which are lower than the actual value.

The variable decision threshold method is the procedure which can most accurately measure the Q-factor and the BER for optical systems with unknown or unpredictable noise statistics. A key limitation, however, to the use of the variable threshold method to measure Q-factor and BER is the need to have access to the receiver electronics in order to manipulate the decision threshold. For systems where such access is not available, it may be useful to utilize the alternative variable optical threshold method. Both methods are capable of being automated in respect of measurement and computation of the results

4.2 Background to Q-factor

The Q-factor is the signal-to-noise ratio (SNR) at the decision circuit and is typically expressed as [1][1]:

$$Q = \frac{\mu_1 - \mu_0}{\sigma_1 + \sigma_0} \tag{1}$$

where

μ_1 and μ_0 are the mean voltage levels of the "1" and "0" rails, respectively;

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

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