IEC 62496-2

Edition 1.0 2017-05

INTERNATIONAL STANDARD

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**Optical circuit boards – Basic test and measurement procedures –
Part 2: General guidance for definition of measurement conditions for optical characteristics of optical circuit boards**

**Cartes à circuits optiques – Méthodes fondamentales d'essais et de mesures –
Partie 2: Recommandations générales pour la définition des conditions de mesure des caractéristiques optiques des cartes à circuits optiques**

IEC 62496-2:2017-05(en-fr)

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OPTICAL CIRCUIT BOARDS – BASIC TEST AND MEASUREMENT PROCEDURES –

Part 2: General guidance for definition of measurement conditions for optical characteristics of optical circuit boards

FOREWORD

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International Standard IEC 62496-2 has been prepared by IEC technical committee 86: Fibre optics.

This bilingual version (2018-01) corresponds to the monolingual English version, published in 2017-05.

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

CDV	Report on voting
86/509/CDV	86/515/RVC

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

The French version of this standard has not been voted upon.

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

A list of all parts in the IEC 62496 series, published under the general title *Optical circuit boards – Basic test and measurement procedures*, can be found on the IEC website.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

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

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- withdrawn,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

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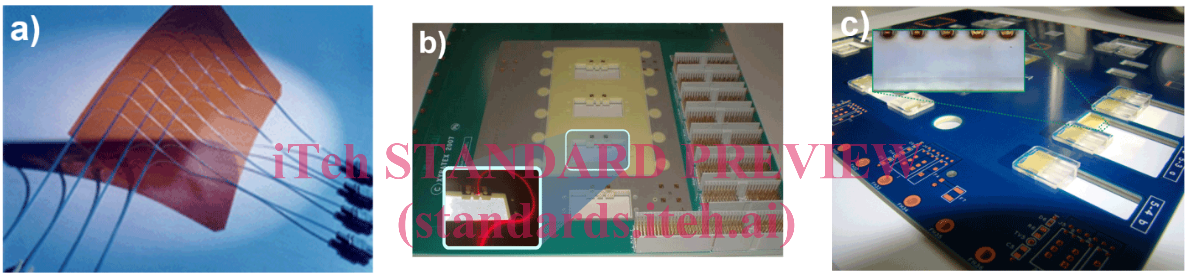
INTRODUCTION

Bandwidth densities in modern data communication systems are driven by interconnect speeds and scalable input/output (I/O) and will continue to increase over the coming years, thereby severely impacting cost and performance in future data communication systems, bringing increased demands in terms of signal integrity and power consumption.

The projected increase in capacity, processing power and bandwidth density in future information communication systems will need to be addressed by the migration of embedded optical interconnects into system enclosures. In particular, this would necessitate the deployment of optical circuit board technologies on some or all key system cards, such as the backplane, motherboard and peripheral circuit boards.

Many varieties of optical circuit board technology exist today, which differ strongly from each other in terms of their intrinsic waveguide technology. As shown in Figure 1, these varieties include, but are not limited to: a) fibre-optic laminate, b) polymer waveguides and c) planar glass waveguides. Annex A provides a detailed overview of the state of the art of such optical interconnect technologies.



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a) Fibre-optic laminate **b) Polymer waveguides** **c) Planar glass waveguides**

Figure 1 – Optical circuit board varieties

One important prerequisite to the commercial adoption of optical circuit boards is a reliable test and measurement definition system that is agnostic to the type of waveguide system under test and, therefore, can be applied to different optical circuit board technologies as well as being adaptable to future variants. A serious and common problem with the measurement of optical waveguide systems has been lack of proper definition of the measurement conditions for a given test regime, and consequently strong inconsistencies ensue in the results of measurements by different parties on the same test sample. To date, no methodology has been established to ensure that test and measurement conditions for such optical waveguide systems are properly identified.

This document specifies a method of capturing sufficient information about the measurement conditions for a given optical circuit board to ensure consistency of measurement results within an acceptable margin.

Given the substantial variety in properties and requirements for different optical circuit board types, some test environments and conditions are more appropriate than others for a given optical circuit board. It is, therefore, crucial that this measurement identification standard encompass a comprehensive range of test and measurement scenarios for all known types of optical circuit boards and their waveguide systems, while also being sufficiently adaptable and extendable to accommodate future waveguide technologies. In addition, a degree of customisation is possible to account for arbitrary test parameters.

OPTICAL CIRCUIT BOARDS – BASIC TEST AND MEASUREMENT PROCEDURES –

Part 2: General guidance for definition of measurement conditions for optical characteristics of optical circuit boards

1 Scope

This part of IEC 62496 specifies a method of defining the conditions for measurements of optical characteristics of optical circuit boards. The method comprises the use of code reference look-up tables to identify different critical aspects of the measurement environment. The values extracted from the tables are used to construct a measurement identification code, which, in itself, captures sufficient information about the measurement conditions, so as to ensure consistency of independently measured results within an acceptable margin. Recommended measurement conditions are specified to minimise further variation in independently measured results.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 61300-1, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 1: General and guidance*

IEC 61300-3-53, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-53: Examinations and measurements – Encircled angular flux (EAF) measurement method based on two-dimensional far field data from step index multimode waveguide (including fibre)*

IEC 62614, *Fibre optics – Launch condition requirements for measuring multimode attenuation*

IEC 62496-2-1:2011, *Optical circuit boards – Part 2-1: Measurements – Optical attenuation and isolation*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62496-2-1 and the following 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
optical channel measurement identification code
MIC
numerical code used to capture sufficient information about the measurement conditions on a waveguide under test in an optical circuit board, such as to ensure independent repeatability of the measurement and consistency of measured results on an identical sample

3.2
optical channel under test
optical circuit board channel subjected to test and measurement regime

3.3
parabolic profile parameter
parameter which describes the refractive index profile of waveguide according to the following equation

$$n(r) = \begin{cases} n_1\sqrt{1-2\Delta\left(\frac{r}{a}\right)^g} & r < a \\ n_1\sqrt{1-2\Delta} & r > a \end{cases}$$

where

g is the parabolic profile parameter;

a is the core radius;

r is the radial distance from core centre;

n_1 is the refractive index at r = 0;

Δ is given by the relation $\Delta = (n_1^2 - n_2^2)/2n_1^2$, where n_1 again is the refractive index at r = 0, i.e. at the axis, and n_2 is the refractive index at the outer edge of the core, i.e. at $r = a$

3.4
launch conduit
structure or mechanism which guides light from the measurement test source to the input facet of the optical channel under test

Note 1 to entry: Examples include optical fibres, optical waveguides or optical trains.

3.5
capturing conduit
structure or mechanism which guides light from the output facet of the optical channel under test to a measurement device

3.6
top input axis of channel under test
axis defined by the tester within the plane of the input facet used as a reference, against which the polarisation axis of the launch conduit can be defined

3.7
top output axis of channel under test
axis defined by the tester within the plane of the output facet used as a reference, against which the polarisation axis of the capturing conduit can be defined

3.8
polarisation maintaining optical fibre
single-mode optical fibre in which linearly polarized light, if properly launched into the fibre, maintains a linear polarisation during propagation, exiting the fibre in a specific linear

polarisation state with little or no cross-coupling of optical power between the two polarisation modes

Note 1 to entry: Such fibre is used in special applications where preserving polarisation is essential and is characterised by a fast axis and a slow axis.

3.9
refractive index matching material
compliant or fixed material with a refractive index equal to the refractive index of the core of the channel under test at the measurement wavelength and measurement conditions, which, unless otherwise stated, is the standard atmospheric conditions as according to IEC 61300-1

3.10
refractive index damping material
compliant or fixed material with a refractive index within 0,05 of the refractive index of the core of the channel under test at the measurement wavelength and measurement conditions, which, unless otherwise stated, is the standard atmospheric conditions as according to IEC 61300-1

4 Measurement definition system for optical circuit boards

4.1 General

A reliable test and measurement definition system for optical interconnect is a crucial prerequisite for future commercial adoption of optical circuit board technology.

Independent repeatability of waveguide measurements is still very difficult to achieve due to the lack of clarity on how measurement conditions are specified.

Therefore, such a definition system shall capture sufficient information about the measurement conditions to ensure that the results of measurement on an identical test sample by independent parties will be consistent within an acceptable margin of error.

Given the large number of measurement parameter permutations possible, the amount of information required to describe sufficiently the measurement conditions is prohibitive. It would be impractical for testers to provide a full textual description for each type of measurement, especially in situations where optical circuit boards are subjected to a variety of different measurement regimes, for instance, as part of a comprehensive quality assurance regime in a commercial optical circuit board foundry.

IEC 62496-2-1 provides details on various types of measurements that can be carried out on optical circuit boards.

4.2 Measurement definition system requirements

4.2.1 Accuracy

The measurement definition system shall capture sufficient information to ensure variability in independently measured results within an acceptable margin.

4.2.2 Accountability

The measurement definition system shall force testers to be accountable to provide sufficient information about the measurement conditions. The system shall therefore comprise a formalised framework to capture the required amount of information about the measurement conditions.

4.2.3 Efficiency

The measurement definition system shall allow the entirety of the measurement condition information to be abbreviated into an optical channel measurement identification code (MIC) such that it can be contained within no more than one line of text.

4.2.4 Convenience

The measurement identification code should be easy to construct and deconstruct using the references look-up tables in this document.

4.2.5 Independent

The measurement definition system shall be independent of the type of optical circuit board under test in order to accommodate different varieties of optical interconnect. To this end, the type of optical channel under test will not be included in the information to be specified; it will be treated as a "black box" bounded by the input facet and output facet of the optical channel under test.

4.2.6 Scalable

The measurement definition system shall be scalable to accommodate new measurement conditions appropriate to existing or as yet unknown optical interconnect types. To this end, the system will have placeholders to allow easy addition of new information in future.

4.2.7 Customised requirements

Where the parameters of a measurement condition are not explicitly provided in the corresponding look-up tables, the MIC shall be extendable to accommodate user-defined parameters.

4.2.8 Prioritised structure

The measurement definition system shall give preference to measurement configurations that are

- accessible, favouring the use of available and affordable equipment,
- viable, favouring measurements which can be easily carried out by most organisations without the requirement for specialised or restricted equipment or expertise, and
- useful, favouring measurement of optical channel characteristics, which are most common and relevant to its deployment and operation, for example insertion loss.

4.3 Measurement definition criteria

4.3.1 General

The measurement definition system shall provide information on the following five critical aspects of the measurement environment:

- source characteristics (4.3.2);
- launch conditions (4.3.3);
- input coupling conditions (4.3.4);
- output coupling conditions (4.3.5);
- capturing conditions (4.3.6).

4.3.2 Source characteristics

4.3.2.1 General

Typical sources for common measurements on optical circuit board channels include LEDs, laser diodes and white light sources, while less common sources include amplified spontaneous emission devices. In order to accommodate a comprehensive range of available source types and characteristics, the measurement identification system will define most sources in terms of permutations of key properties including wavelength and spectral width. Source optical power or modal profile need not be specified as only the optical power, and modal profile at the launch facet need be specified as part of the launch conditions. Table 1 in IEC 62496-2-1:2011 provides a list of recommended source characteristics.

4.3.2.2 Modulated sources

According to this document, the source amplitude and phase is considered un-modulated. Optical modulation is a large and complex area with many possible permutations of modulation type, duty cycle and data characteristics. Modulation schemes include standard on-off keying (OOK) and multi-level modulation schemes such as phase amplitude modulation (PAM), in-phase and quaternary (IQ) modulation schemes such as quadrature phase shift keying (QPSK), multi-level quadrature amplitude modulation (nQAM), multi-pulse modulation schemes, and discrete multi-tone (DMT). Data characteristics would include pseudo random binary sequence (PRBS) data with various correlation lengths, as well as test data associated with real data transmission protocols. Modulation will not be included in the measurement definition system described in this document. In the event of a modulated source, the modulation characteristics shall be stated explicitly.

4.3.2.3 Wavelength division multiplexed sources

According to this document, the source is considered to be centred on a single wavelength with varying spectral widths, or white, which is consistent with the use of common commercial sources including laser diodes, LEDs or amplified spontaneous emission devices. It may be desirable to characterise the performance of the channel under test with wavelength division multiplexed (WDM) light in which multiple wavelengths are superposed onto the launch conduit in accordance with various WDM schemes. For example, the coarse wavelength division multiplexing (CWDM) scheme allows on the order of ten signals to be encoded onto separate wavelengths. The dense wavelength division multiplexing (DWDM) scheme allows on the order of hundreds of signals to be encoded onto separate, more closely spaced, wavelengths.

WDM sources are not included in this document, as the possible permutations would be prohibitively complex. In the event of a wavelength division multiplexed source, the wavelength division multiplexing characteristics shall be explicitly stated. Preferably, if convenient, each wavelength-encoded channel can be uniquely specified using the measurement identification system outlined in this document.

4.3.3 Launch conditions

4.3.3.1 General

Launch conditions have the greatest effect on variability of measurement results on optical circuit board channels. It is, therefore, crucial that these be sufficiently defined.

Launch conditions shall include the following information that determines how light propagates through the optical channel under test and, therefore, determines the independent reproducibility of the measurement:

a) launch facet size and shape, which is typically defined by the core of the launch conduit – for a standard fibre, it would be sufficient to specify the fibre type;
b) total optical power amplitude at the launch facet;

c) spatial (near-field) and angular (far-field) optical power distribution of light at the launch facet. The launch conditions for multimode fibres should preferably comply with encircled flux (EF) requirements defined in IEC 61300-1 or encircled angular flux (EAF) requirements defined in IEC 61300-3-53. Such launch conditions can be reliably achieved by deploying appropriate mode filtering equipment around or in-line with the launch conduit. The launch conditions for single-mode fibres should comply with IEC 61300-1.

4.3.3.2 Recommended launch conditions

Table 1 defines key recommended launch profiles, including underfilled profiles, various mode filtered multimode profiles and overfilled profiles, as well as recommendations on how to reproduce some of these modal profiles.

Table 1 – Recommended modal launch profiles

Designation	Modal distribution at launch facet	Recommended measurement setup to achieve modal distribution
Single-mode launch		
L1	***UF*** Underfilled launch complies with single-mode launch requirements in IEC 61300-1.	Preferably, optical isolator between source and OS1 launch fibre 2 m long OS1 single-mode fibre (SMF) provides a single-mode launch profile.
Multimode launch		
L2 [a)]	***EF/EMD*** Complies with EF requirements in IEC 61300-1.	The source is passed into a 5 m graded index multimode fibre (GI-MMF), which is wrapped 20 times around a 38 mm diameter mandrel. The output of the mandrel is then passed through a mode controller/filter producing a mode filtered optical intensity profile, which complies with EF requirement of IEC 61280-4-1. This is then used as the input to a 5 m GI-MMF, which is wrapped 20 times around a 38 mm diameter mandrel to produce a mode-stripped optical intensity profile at the GI-MMF launch facet.
L3 [a)]	***EF*** Complies with EF requirements in IEC 61300-1.	5 m graded index multimode fibre (GI-MMF) is passed through a mode controller/filter producing a mode filtered optical intensity profile at the GI-MMF launch facet, which complies with EF requirement of IEC 61280-4-1.
L4 [a)]	***EMD*** Equilibrium modal distribution	5 m 50 µm graded index OM3 multimode fibre (GI-MMF) is wrapped 20 times around a 38 mm diameter mandrel to produce a mode-stripped optical intensity profile at the GI-MMF launch facet.
L5 [a)]	***OF*** Overfilled distribution – uniform near-field optical intensity distribution	5 m 105 µm step index multimode fibre (SI-MMF) is wrapped 20 times around a 38 mm diameter mandrel to create a mode-scrambled, overfilled optical intensity profile at the SI-MMF launch facet.
L6 [a]	***VOF/EAF*** Very overfilled distribution Complies with EAF requirements in IEC 61300-3-53.	5 m 200µm core step-index fibre (SI-MMF) is passed through a mode controller producing a mode filtered optical intensity profile at the launch facet, which complies with the EAF requirement of IEC 61300-3-53.
[a)] Bend insensitive fibre is not recommended for MM or SM test leads.		

4.3.3.3 Recommended single-mode fibre launch measurement setup

The recommended measurement setup for single-mode fibre launch conditions is shown in Figure 2. A single-mode optical source should be connected with a single-mode optical fibre, first through a single-mode optical isolator to shield the source from unwanted back-reflections occurring at different interfaces further on down the test link, especially the interface between the launch facet and the input facet of the channel under test. The output from the optical isolator should then be connected through a variable single-mode optical attenuator. This will allow the tester to adjust the optical power at the launch facet to match the required optical power as defined in the measurement identification code. This can alternatively be achieved by using a power tuneable source.

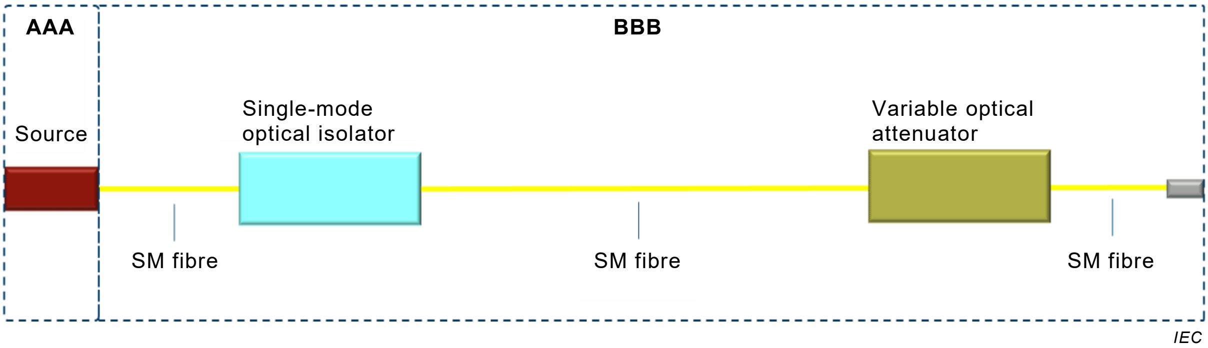

Figure 2 – Recommended test setup for single-mode fibre launch conditions

4.3.3.4 Recommended multimode fibre launch measurement setup

A single-mode or multimode optical source should be connected with a single-mode or multimode optical fibre, first through a single-mode or multimode optical isolator to shield the source from unwanted back-reflections occurring at different interfaces further on in the test link, especially the interface between the launch facet and the input facet of the channel under test. If the source is a coherent source, it will be important to use a speckle filter to average out the effects of speckle at the launch facet. One device can be an electromechanical shaker applied after the source but before the variable optical attenuator. If using such a device, it is important that the fibre be completely mechanically decoupled from the launch facet, so the device should be applied between the source and the variable optical attenuator. The photodetector used to measure the received light would need to be configured to record average values over an appropriate time period, rather than immediate values. The output from the optical isolator should then be connected with single-mode or multimode fibre to the input of a variable single-mode or multimode optical attenuator. This will allow the tester to adjust the optical power at the launch facet to match the required optical power as defined in the measurement identification code. Alternatively, this can be achieved by using a power tuneable source. Then the output of the variable optical attenuator will be connected with multimode fibre to the input of a modal conditioning or filtering system, the output of which will be connected with multimode fibre to the launch facet. The purpose of the modal conditioning or filtering system is to ensure that the modal profile of the launch facet is defined according to L2, L3, L4, L5 or L6 in Table 1. Figure 3 shows the recommended test setup.

L2 is the preferred launch condition, in which a modal profile is generated, which complies with the restricted launch EF requirements of IEC 61300-1, and this in turn is injected into a GI-MMF fibre mandrel to produce a normalised output.

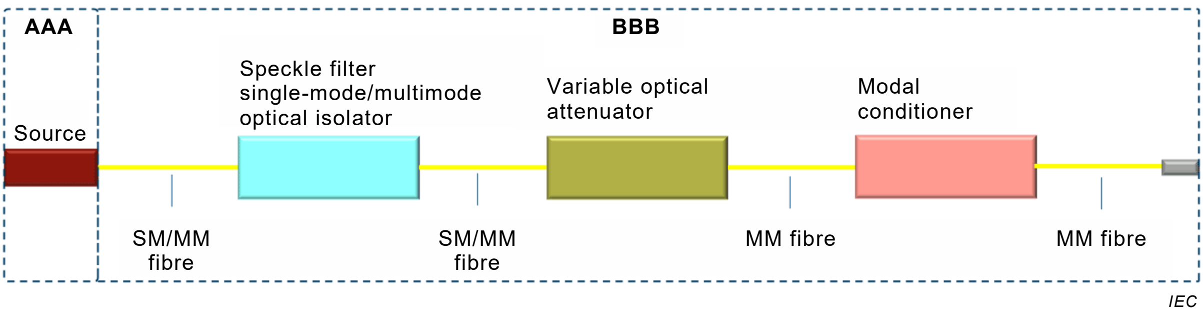

Figure 3 – Recommended test setup for multimode fibre launch conditions