BS EN 60876-1:2014

BSI Standards Publication

Fibre optic interconnecting devices and passive components — Fibre optic spatial switches

Part 1: Generic specification

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National foreword

This British Standard is the UK implementation of EN 60876-1:2014. It is identical to IEC 60876-1:2014. It supersedes BS EN 60876-1:2012 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee GEL/86, Fibre optics, to Subcommittee GEL/86/2, Fibre optic interconnecting devices and passive components.

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 86B/3713/CDV, future edition 5 of IEC 60876-1, prepared by SC 86B “Fibre optic interconnecting devices and passive components” of IEC/TC 86 “Fibre optics” was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60876-1:2014.

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)	2015-06-26
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This document supersedes EN 60876-1:2012

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Endorsement notice

The text of the International Standard IEC 60876-1:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60410	NOTE	Harmonised as EN 60410
IEC 60869-1	NOTE	Harmonised as EN 60869-1
IEC 61073-1	NOTE	Harmonised as EN 61073-1

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60027	Series	Letter symbols to be used in electrical technology	EN 60027	Series
IEC 60050-731	-	International Electrotechnical Vocabulary (IEV) Chapter 731: Optical fibre communication	-	-
IEC 60617	Series	Standard data element types with associated classification scheme for electric components	-	Series
IEC 60695-11-5	-	Fire hazard testing Part 11-5: Test flames - Needle-flame test method - Apparatus, confirmatory test arrangement and guidance	EN 60695-11-5	-
IEC 60825-1	-	Safety of laser products Part 1: Equipment classification and requirements	EN 60825-1	-
IEC 61300	Series	Fibre optic interconnecting devices and passive components - Basic test and measurement procedures	EN 61300	Series
IEC/TR 61930	-	Fibre optic graphical symbology	-	-
IEC 62047-1	-	Semiconductor devices - Micro-electromechanical devices Part 1: Terms and definitions	EN 62047-1	-
ISO 129-1	-	Technical drawings - Indication of dimensions and tolerances Part 1: General principles	-	-
ISO 286-1	-	Geometrical product specifications (GPS) - ISO code system for tolerances on linear sizes Part 1: Basis of tolerances, deviations and fits	EN ISO 286-1	-
ISO 1101	-	Geometrical product specifications (GPS) - Geometrical tolerancing - Tolerances of form, orientation, location and run-out	EN ISO 1101	-
ISO 8601	-	Data elements and interchange formats - Information interchange - Representation of dates and times	-	-

CONTENTS

FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS – IBRE OPTIC SPATIAL SWITCHES –

Part 1: Generic specification

1 Scope

This part of IEC 60876 applies to fibre optic switches possessing all of the following general features:

- they are passive in that they contain no optoelectronic or other transducing elements;
- they have one or more ports for the transmission of optical power and two or more states in which power may be routed or blocked between these ports;
- the ports are optical fibres or fibre optic connectors.

2 Normative references

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

IEC 60027 (all parts), *Letter symbols to be used in electrical technology*

IEC 60050-731, *International Electrotechnical Vocabulary – Chapter 731: Optical fibre communication*

IEC 60617 (all parts), *Graphical symbols for diagrams* (available at <http://std.iec.ch/iec60617>)

IEC 60695-11-5, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 61300 (all parts), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures*

IEC TR 61930, *Fibre optic graphical symbology*

IEC 62047-1, *Semiconductor devices – Micro-electromechanical devices – Part 1: Terms and definitions*

ISO 129-1, *Technical drawings – Indication of dimensions and tolerances – Part 1: General principles*

ISO 286-1, *Geometrical product specifications (GPS) – ISO code system for tolerances on linear sizes – Part 1: Basis of tolerances, deviations and fits*

ISO 1101, *Geometrical product specifications (GPS) – Geometrical tolerancing – Tolerances of form, orientation, location and run-out*

ISO 8601, *Data elements and interchange formats – Information interchange – Representation of dates and times*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-731, together with the following, apply.

3.1 Basic terms and definitions

3.1.1
port
optical fibre or fibre optic connector attached to a passive component for the entry and/or exit of optical power

3.1.2
transfer matrix
optical properties of a fibre optic switch can be defined in a $n \times n$ matrix of coefficients (n is the number of ports)

Note 1 to entry: The T matrix represents the on-state paths (worst-case transmission) and the T° matrix represents the off-state paths (worst-case isolation).

3.1.3
transfer coefficient
element t_{ij} or $t°_{ij}$ of the transfer matrix

Note 1 to entry: Each transfer coefficient t_{ij} is the worst-case (minimum) fraction of power transferred from port i to port j for any state with path ij switched on. Each coefficient $t°_{ij}$ is the worst-case (maximum) fraction of power transferred from port i to port j for any state with path ij switched off.

3.1.4
logarithmic transfer matrix

$$a_{ij} = -10 \log_{10} t_{ij}$$

where

a_{ij} is the optical power reduction in decibels out of port j with unit power into port i, i.e.

t_{ij} is the transfer coefficient

Note 1 to entry: Similarly, for the off state, $a°_{ij} = -10 \log_{10} t°_{ij}$.

3.1.5
switch state
particular optical configuration of a switch, whereby optical power is transmitted or blocked between specific ports in a predetermined manner

3.1.6
actuation mechanism
physical means (mechanical, electrical, acoustic, optical, etc.) by which a switch is designed to change between states

3.1.7
actuation energy
input energy required to place a switch in a specific state

3.1.8
blocking
inability to establish a connection from a free input port to a free output port due to the existence of some other established connection

Note 1 to entry: Blocking and various degrees of non-blocking operation functionalities are of various types:

"Strict-sense non-blocking" refers to a switch matrix in which it is always possible to establish a connection between any free input port and any free output port, irrespective of previously established connections.

"Wide-sense non-blocking" refers to a matrix in which it is always possible to establish a desired connection provided that some systematic procedure is followed in setting up connections. Some multistage switching architectures fall into this category.

"Rearrangeably non-blocking" refers to a switch matrix in which any free input port can be connected to any free output port provided that other established connections are unconnected and then reconnected as part of making the new connection.

3.1.9
normally on
condition where a port pair is in a conducting state when there is no actuation energy applied for a non-latching switch

3.1.10
normally off
condition where a port pair is in an isolated state when there is no actuation energy applied for a non-latching switch

3.2 Component definitions

3.2.1
optical switch
passive component processing one or more ports which selectively transmits, redirects or blocks optical power in an optical fibre transmission line

3.2.2
latching switch
switch that maintains its last state and specified performance level when the actuation energy which initiated the change is removed

3.2.3
non-latching switch
switch that reverts to a home state or undefined state when the actuation energy which initiated a change is removed

3.2.4
magneto-optic effect switch
MO switch
optical switch which uses the magneto-optic effect (phenomenon of polarization state change in transmitted light and reflected light due to a magnetic field)

Note 1 to entry: Annex A shows an example of magnet-optic effect swich technologies.

3.2.5
mechanical switch
optical switch which realises the switching function by driving of the movable part

Note 1 to entry: Annex B shows an example of mechanical swich technologies.

3.2.6
micro-electromechanical system switch
MEMS switch
optical switch using MEMS technology, as defined in IEC 62047-1

Note 1 to entry: Annex C shows example of micro-mechanical system swich technologies.

3.2.7
thermo-optic effect switch
TO switch
optical switch which uses the thermo-optic effect (phenomenon of refractive index change caused by temperature variation)

Note 1 to entry: Annex D shows an example of thermo-optic effect swich technologies.

3.3 Performance parameter definitions

3.3.1
operating wavelength
λ
nominal wavelength at which a passive component is designed to operate with the specified performance

3.3.2
insertion loss
element a_{ij} (where $i \neq j$) of the logarithmic transfer matrix

Note 1 to entry: It is the reduction in optical power between an input and output port of a passive component expressed in decibels and is defined as follows:

$$a_{ij} = -10 \log_{10} (P_j/P_i)$$

where

P_i is the optical power launched into the input port, and

P_j is the optical power received from the output port.

Note 2 to entry: The insertion loss values depend on the state of the switch.

3.3.3
return loss
element a_{ij} (where $i = j$) of the logarithmic transfer matrix

Note 1 to entry: It is the fraction of input power that is returned from a port of a passive component and is defined as follows:

$$RL_i = -10 \log_{10} (P_{refl}/P_i)$$

where

P_i is the optical power launched into a port, and

P_{refl} is the optical power received back from the same port.

Note 2 to entry: The return loss values depend on the state of the switch.

3.3.4
crosstalk
ratio of the output power of the isolated input port to the output power of the conducting input port for an output port

3.3.5
latency time

3.3.5.1
latency time
t_l

<switching from isolated state to conducting state> elapsed time for the output power of a specified output port to reach 10 % of its steady-state value from the time the actuation energy is applied, when switching from an isolated state to conducting state, normally-off for a non-latching switch, or a latching switch

SEE: Figure 1.

3.3.5.2
latency time
t_l'
<switching from conducting state to isolated state, normally-off for a non-latching switch> elapsed time for the output power of a specified output port to reach 90 % of its steady-state value from the time the actuation energy is removed. when switching from a conducting state to isolated state, normally-off for a non-latching switch

SEE: Figure 1.

3.3.5.3
latency time
t_l'
<switching from conducting state to isolated state, for a latching switch> elapsed time when the output power of a specified output port reaches 90 % of its steady-state value from the time the actuation energy is applied, when switching from a conducting state to isolated state, for a latching switch

SEE: Figure 1.

Note 1 to entry: See Annex E.

3.3.6
rise time
elapsed time when the output power of the specified output port rises from 10 % of the steady-state value to 90 % of the steady-state value

3.3.7
fall time
elapsed time when the output power of the specified output port falls from 90 % of the steady-state value to 10 % of the steady-state value

3.3.8
bounce time

3.3.8.1
bounce time
t_b
<switching from isolated state to conducting state> elapsed time when the output power of a specified output port maintains between 90 % and 110 % of its steady-state value from the first time the output power of a specified output port reaches to 90 % of its steady-state value

SEE: Figure 1.

3.3.8.2
bounce time
t_b'
<switching from conducting state to isolated state> elapsed time when the output power of a specified output port maintains between 0 % and 10 % of its steady-state value from the first time the output power of a specified output port reaches 10 % of its steady-state value

SEE: Figure 1.

3.3.9
switching time

3.3.9.1
switching time
t_s
<switching from isolated state to conducting state> switching time is defined as follows:

$$t_s = t_l + t_r + t_b$$

where

t_l is the latency time;

t_r is the rise time;

t_b is the bounce time.

3.3.9.2
switching time
t_s'
<switching from conducting state to isolated state> switching time is defined as follows:

$$t_s' = t_l' + t_f + t_b'$$

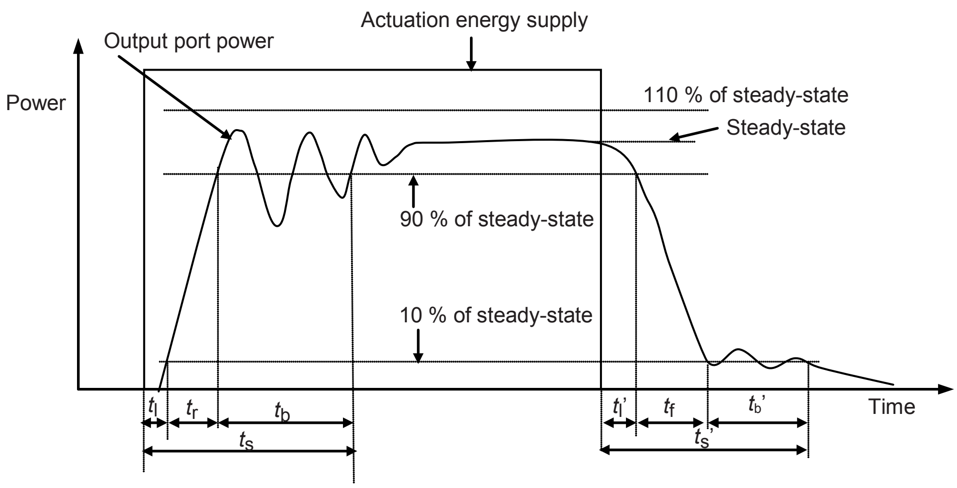
where

t_l' is the latency time;

t_f is the fall time;

t_b' is the bounce time.

3.3.10
switching time matrix
matrix of coefficients in which each coefficient S_{ij} is the longest switching time to turn path ij on or off from any initial state



t_s, t_s' switching time
t_l, t_l' latency time
t_r rise time
t_f fall time
t_b, t_b' bounce time

IEC

Figure 1a – Non-latching switch, normally off

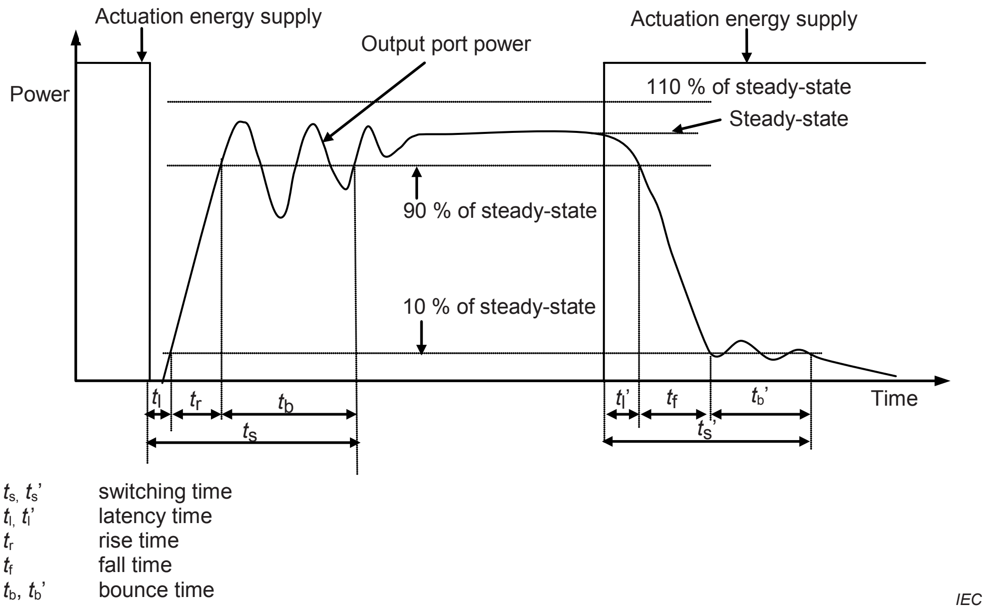


Figure 1b – Non-latching switch, normally on

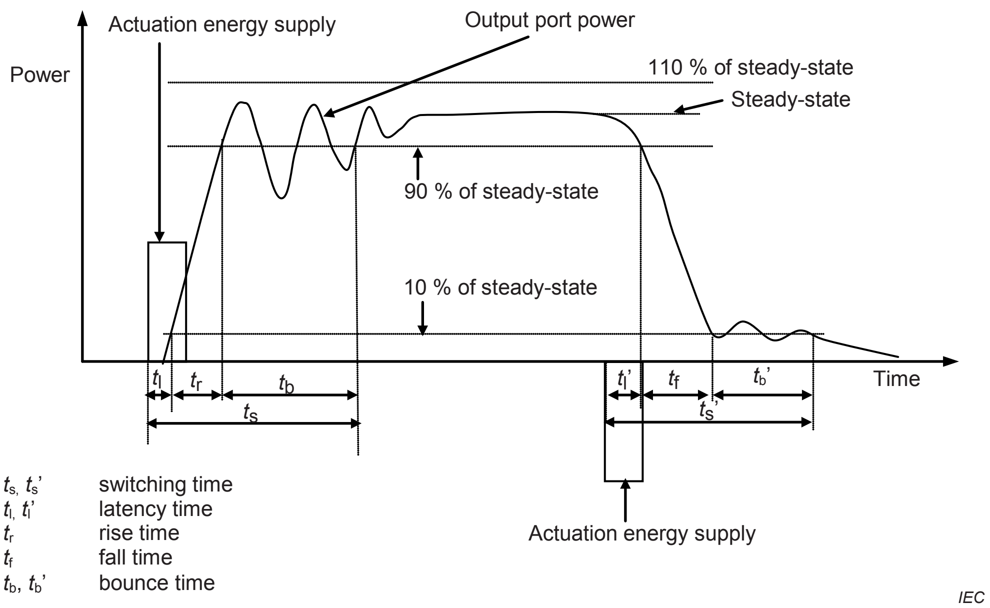


Figure 1c – Latching switch

Figure 1 – Representation of latency time, rise time, fall time, bounce time and switching time

Note 1 to entry: If, for any reason, the steady-state power of the isolated state is not zero, all the power levels leading to the definitions of latency time, rise time, fall time, bounce time and, thus, of switching time, should be normalized, subtracting from them the steady-state power of the isolated state, before applying such definitions.

4 Requirements

4.1 Classification

4.1.1 General

Fibre optic spatial switches shall be classified based on the following:

– type;
– style;
– variant;
– assessment level;
– normative reference extensions.

Table 1 is an example of a switch classification.

Table 1 – Example of a typical switch classification

Type:	1×2 mechanical switch
Style:	– Configuration B – IEC type A1 a fibre – F-SMA connector
Variants:	Means of mounting
Assessment level:	A
Normative reference extensions:	………………………….

4.1.2 Type

4.1.2.1 General

Switches are divided into types by their actuation mechanism, latching and topology (optical switching function).

There are multiple actuation mechanisms of switches. The following is a non-exhaustive list of examples of current technologies used in the industry:

– magneto-optic effect (MO);
– mechanical;
– micro-electromechanical system (MEMS);
– thermo-optic effect (TO).

Switches are divided into two types based on the latching function as follows:

– latching switch;
– non-latching switch.

There are an essentially infinite number of possible topologies. Each topology is illustrated by a schematic diagram and defined by a unique transfer matrix.

The following device topologies include only those which are in common use within the industry at present. The schematic diagrams which follow do not necessarily correspond to the physical layout of the switch and its ports.

The examples given in 4.1.2.2 to 4.1.2.4 apply to unidirectional switches only, where $t_{ij} \neq t_{ji}$. For bi-directional switches, $t_{ij} = t_{ji}$ in each transfer matrix below.

4.1.2.2 Single-pole, single-throw switch

Figure 2 shows a single-pole, single-throw switch.

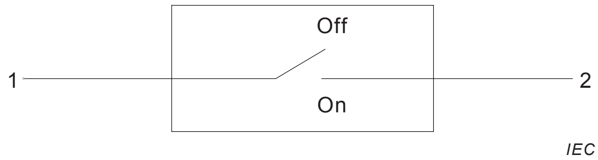


Figure 2 – Single-pole, single-throw switch

This switch has one input port and one output port. Figure 3 shows the transfer matrix describing the device.

$$T = \begin{bmatrix} t_{11} & t_{21} \\ t_{12} & t_{22} \end{bmatrix}$$

IEC

Figure 3 – Transfer matrix for one input port and one output port

Ideally, t_{12} is 1 and the other coefficients are 0 when the switch is on. When the switch is off, all coefficients are 0.

4.1.2.3 Single-pole, *N*-throw switch

Figure 4 shows a single-pole, *N*-throw switch.

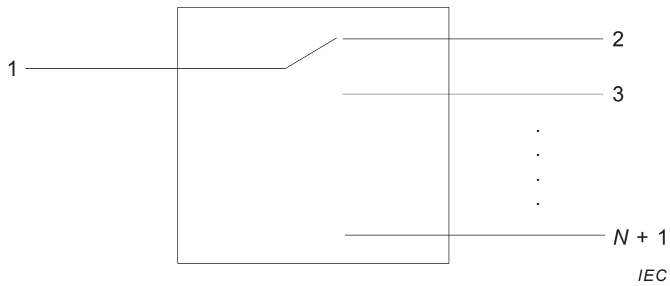


Figure 4 – Single-pole, throw switch

This switch has one input port and *N* output ports. Figure 5 shows the transfer matrix describing the device.

$$T = \begin{bmatrix} t_{11} & t_{12} & \cdot & \cdot & \cdot & t_{1N+1} \\ t_{21} & & & & & \\ \cdot & & & & & \\ \cdot & & & t_{ij} & & \cdot \\ \cdot & & & & & \\ t_{N+11} & \cdot & & & & t_{N+1N+1} \end{bmatrix}$$

IEC

Figure 5 – Transfer matrix for one input port and *N* output ports

Ideally, in the first position of the switch, t_{12} is 1 and the other coefficients are 0. In the generic *i*-th position of the switch, the $t_{1\ i+1}$ transfer coefficient is 1 and the others are 0.

4.1.2.4 *N*-port matrix switch

Figure 6 shows an *N*-port matrix switch.

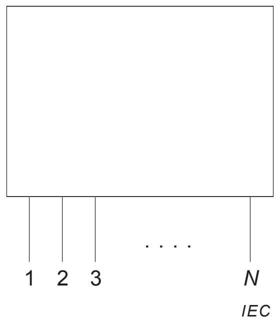


Figure 6 – *N*-port matrix switch

This switch has *N* ports. Figure 7 shows the transfer matrix describing the device.

$$T = \begin{bmatrix} t_{11} & t_{12} & \cdot & \cdot & \cdot & t_{1N} \\ t_{21} & & & & & \\ \cdot & & & & & \\ \cdot & & & t_{ij} & & \cdot \\ \cdot & & & & & \\ t_{N11} & \cdot & & & & t_{NN} \end{bmatrix}$$

IEC

Figure 7 – Transfer matrix for *N*-ports switch

A 2×2 matrix switch is a particular case with two input and two output ports.

In one type, it is possible to have four positions with the transfer coefficients t_{14} and t_{23} always zero while t_{13} and t_{24} have the values indicated in Table 2. Figure 8 shows a four-port switch without crossover.

Table 2 – Transfer matrix of a four-port switch without crossover

Transfer coefficient	State			
	1	2	3	4
t_{13}	1	0	1	0
t_{24}	1	1	0	0

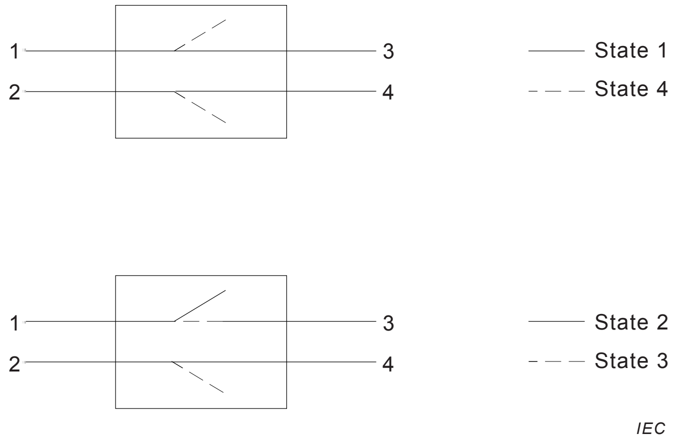


Figure 8 – Four-port switch without crossover

In another type, a four-port crossover switch or by-pass switch is described. This switch has two input and two output ports. The transfer coefficients are indicated in Table 3. Figure 9 shows a four-port switch with crossover.

Table 3 – Transfer matrix of a four-port switch with crossover

Transfer coefficient	State	
	1	2
t_{13}	1	0
t_{24}	1	0
t_{14}	0	1
t_{23}	0	1

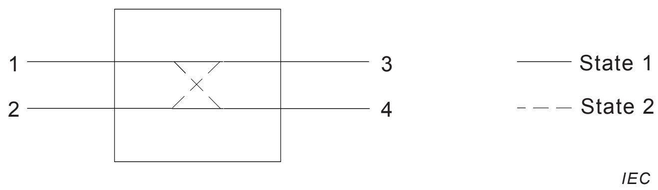


Figure 9 – Four-port switch with crossover

4.1.3 Style

Switches may be classified into styles based upon fibre type, connector type, cable type, housing shape and dimensions and configuration.

The configuration of the switch ports is classified as shown below.

Figure 10 shows configuration A, device containing integral fibre optic pigtails without connectors.

Figure 10 – Configuration A, a device containing integral fibre optic pigtails without connectors

Figure 11 shows configuration B, a device containing integral fibre optic pigtails, with a connector on each pigtail.

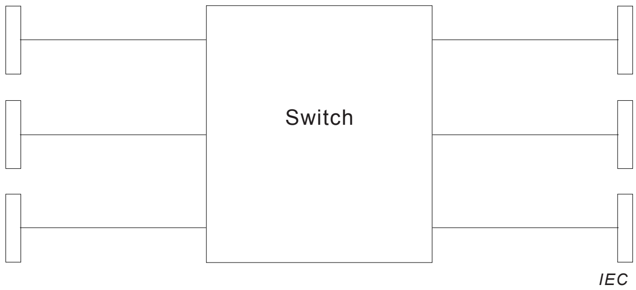


Figure 11 – Configuration B, a device containing integral fibre optic pigtails, with a connector on each pigtail

Figure 12 shows configuration C, a device containing a fibre optic connector as an integral part of the device housing.

Figure 12 – Configuration C, a device containing a fibre optic connector as an integral part of the device housing

Configuration D is a device containing some combination of the interfacing features of the preceding configurations.

4.1.4 Variant

The switch variant identifies those features which encompass structurally similar components.

Examples of features which define a variant include, but are not limited to the following:

– orientation of ports on housing;
– means for mounting.

4.1.5 Normative reference extension

Normative reference extensions are used to identify integrated independent standards specifications or other reference documents into blank detail specifications.

Unless specified exception is noted, additional requirements imposed by an extension are mandatory. Usage is primarily intended to merge associated components to form hybrid devices, or integrated functional application requirements that are dependent on technical expertise other than fibre optics.

Published reference documents produced by the ITU, consistent with the scope statements of the relevant IEC specification series may be used as extensions. Published documents produced by other regional standardization bodies such as ANSI, CENELEC, JIS, etc., may be referenced in a bibliography attached to the generic specification.

Some spatial switch configurations require special qualification provisions which shall not be imposed universally. This accommodates individual component design configurations, specialized field tooling or specific application processes. In this case, requirements are necessary to assure repeatable performance or adequate safety and provide additional guidance for complete product specification and they shall be defined in the relevant specification. These extensions are mandatory whenever they are used to prepare, assemble or install a spatial switch either for field application usage or preparation of qualification test specimens. The relevant specification shall clarify all stipulations. However, design and style-dependent extensions shall not be imposed universally.

In the event of conflicting requirements, precedence, in descending order, shall be the generic specification over mandatory extension, over blank detail, over detail specification, over application-specific extension.

Examples of requirements for normative extensions are as follows:

- Some commercial or residential building applications may require direct reference to specific safety codes and regulations or incorporate other specific material flammability or toxicity requirements for specialized locations.
- Specialized field tooling may require an extension to implement specific ocular safety, electrical shock, burn hazard avoidance requirements, or require isolation procedures to prevent potential ignition of combustible gases.

4.2 Documentation

4.2.1 Symbols

Graphical and letter symbols shall, whenever possible, be taken from the IEC 60027 series, the IEC 60617 series and from IEC TR 61930.

4.2.2 Specification system

4.2.2.1 General

This specification is part of the IEC specification system. Subsidiary specifications shall consist of blank detail specifications and detail specifications. This system is shown in Table 4. There are no sectional specifications for switches.

Table 4 – IEC specification structure

Specification level	Examples of information to be included	Applicable to
Basics	Assessment system rules Inspection rules Optical measurement methods Environmental test methods Sampling plans Identification rules Marking standards Dimensional standards Terminology Symbol standards Preferred number series SI units	Two or more component families or sub-families
Generic	Specific terminology Specific symbols Specific units Preferred values Marking Quality assessment procedures Selection of tests Qualification approval procedures Capability approval procedures	Component family
Blank detail	Quality conformance test schedule Inspection requirements Information common to a number of types	Groups of types having a common test schedule
Detail	Individual values Specific information Completed quality conformance test schedules	Individual type

4.2.2.2 Blank detail specification

Blank detail specifications are not, by themselves, a specification level. They are associated with the generic specification.

Each blank detail specification shall contain:

– the minimum mandatory test schedules and performance requirements;
– one or more assessment levels;
– the preferred format for stating the required information in the detail specification;
– in case of hybrid components, including connectors, add appropriate entry fields to show the reference normative document, document title and issue date.

4.2.2.3 Detail specification

A specific switch is described by a corresponding detail specification, which is prepared by filling in the blanks of the blank detail specification. Within the constraints imposed by this generic specification, the blank detail specification may be filled in by any national committee of the IEC, thereby defining a particular switch design as an official IEC standard.

Detail specifications shall specify the following, as applicable:

– type (see 4.1.2);
– style (see 4.1.3);
– variant(s) (see 4.1.4);
– assessment level (see 4.1.5);
– part identification number for each variant (see 4.7.2);
– drawings and dimensions required (see 4.2.3);
– quality assessment test schedules (see 4.1.5);
– performance requirements (see 4.6).

4.2.3 Drawings

4.2.3.1 General

The drawings and dimensions given in detail specifications shall not restrict themselves to details of construction, nor shall they be used as manufacturing drawings.

4.2.3.2 Projection system

Either first-angle or third-angle projection shall be used for the drawings in documents covered by this specification. All drawings within a document shall use the same projection system and the drawings shall state which system is used.

4.2.3.3 Dimensional system

All dimensions shall be given in accordance with ISO 129-1, ISO 286-1 and ISO 1101.

The metric system shall be used in all specifications.

Dimensions shall not contain more than five significant digits.

When units are converted, a note shall be added in each detail specification.

4.2.4 Test and measurement

4.2.4.1 Test and measurement procedures

The test and measurement procedures for optical, mechanical and environmental characteristics of switches to be used shall be defined and selected preferably from the IEC 61300 series.

The size measurement method to be used shall be specified in the detail specification for dimensions which are specified within a total tolerance zone of 0,01 mm or less.

4.2.4.2 Reference components

Reference components for measurement purposes, if required, shall be specified in the detail specification.

4.2.4.3 Gauges

Gauges, if required, shall be specified in the detail specification.

4.2.5 Test reports

Test reports shall be prepared for each test conducted as required by a detail specification. These reports shall be included in the qualification report and in the periodic inspection report.

The reports shall at least contain the following information:

- title of test and date;
- specimen description including the variant identification number (see 4.7.2);
- test equipment used and date of latest calibration;
- all applicable test details;
- all measurement values and observations;
- sufficiently detailed documentation to provide traceable information for failure analysis.
- Instructions for use

Instructions for use, when required, shall be given by the manufacturer and shall include:

- assembly and connection instructions;
- cleaning method;
- safety aspects;
- additional information, as necessary.

4.3 Standardization system

4.3.1 Interface standards

Interface standards provide both manufacturer and user with all the information they require to make or use products conforming to the physical features of that standard interface. Interface standards fully define and dimension the features essential for the mating and unmating of optical fibre connectors and other components. They also serve to position the optical datum target, where defined, relative to other reference datum.

Interface standards ensure that connectors and adapters that comply with the standard will fit together. The standards may also contain tolerance grades for ferrules and alignment devices. Tolerance grades are used to provide different levels of alignment precision.

The interface dimensions may also be used to design other components that will mate with the connectors. For example, an active device mount can be designed using the adapter interface dimensions. The use of these dimensions, combined with those of a standard plug, provides the designer with the assurance that the standard plugs will fit into the optical device mount. They also provide the location of the optical datum target of the plug.

Standard interface dimensions do not, by themselves, guarantee optical performance. They only guarantee connector mating at a specified fit. Optical performance is currently guaranteed via the manufacturing specification. Products from the same or different manufacturing specifications using the same standard interface will always fit together. Guaranteed performance can be given by any single manufacturer only for products delivered to the same manufacturing specification. However, it can be reasonably expected that some level of performance will be obtained by mating products from different manufacturing specifications, although the level of performance cannot be expected to be any better than that of the lowest specified performance.

4.3.2 Performance standards

Performance standards contain a series of tests and measurements (which may or may not be grouped into a specified schedule depending on the requirements of that standard) with clearly defined conditions, severities and pass/fail criteria. The tests are intended to be run on a one-off basis to prove any product's ability to satisfy the performance standards requirement. Each performance standard has a different set of tests, and/or severities (and/or groupings) which represents the requirements of a market sector, user group or system location.

A product that has been shown to meet all the requirements of a performance standard can be declared as complying with a performance standard but should then be controlled by a quality assurance/quality conformance programme.

It is possible to define a key point of the test and measurements standards for their application (particularly with regard to insertion loss and return loss) in conjunction with the interface standards of inter-product compatibility. Conformance to this standard will be ensured for each individual product.

4.3.3 Reliability standards

Reliability standards are intended to ensure that a component can meet performance specifications under stated conditions for a stated time period.

For each type of component, the following shall be identified (and appear in the standard):

- failure modes (observable, general mechanical or optical effects of failure);
- failure mechanisms (general causes of failure, common to several components);
- failure effects (detailed causes of failure, specific to the component).

These are all related to environmental and material aspects.

Initially, just after component manufacture, there is an infant mortality phase during which many components would fail if they were deployed in the field. To avoid early field failure, all components shall be subjected to a screening process in the factory, involving environmental stresses that may be mechanical, thermal, or humidity-related. This is to induce known failure mechanisms in a controlled environmental situation to occur earlier than would normally be seen in the unscreened population. For those components that survive (and are then sold), there is a reduced failure rate since these mechanisms have been eliminated.

Screening is an optional part of the manufacturing process, rather than a test method. It will not affect the useful life of a component, defined as the period during which it performs according to specifications. Eventually, other failure mechanisms appear and the failure rate increases beyond some defined threshold. At this point, the useful life ends, the wear-out stage begins and the component has to be replaced.

At the beginning of useful life, performance testing on a sample population of components may be applied by the supplier, by the manufacturer or by a third party. This is to ensure that the component meets performance specifications over the range of intended environments at this initial time. Reliability testing, on the other hand, is applied to ensure that the component meets performance specifications for at least a specified minimum useful lifetime or specified maximum failure rate. These tests are usually carried out by utilizing performance testing, but with increased duration and severity to accelerate the failure mechanisms.

A reliability theory relates component reliability testing to component parameters and to lifetime or failure rate under testing. The theory then extrapolates these to lifetime or failure rate under less stressful service conditions. The reliability specifications include values of the component parameters needed to ensure the specified minimum lifetime or maximum failure rate in service.

4.3.4 Interlinking

Standards currently under preparation are given in Figure 13. A large number of the test and measurement standards as well as the quality assurance qualification approval standards, from the IECQ (IEC Quality Assessment System for Electronic Components), exist already and have done so for many years. As previously mentioned, alternative methods of quality assurance/quality conformance are being developed under the headings "capability approval" and "technology approval" (for further details see IEC Guide 102).

The matrix given in Table 5 demonstrates some of the other options available for product standardization with regard to interface, performance and reliability standards, once all these three standards are in place.

Product A is fully IEC standardized, having a standard interface and meeting defined performance standards and reliability standards.

Product B is a product with a proprietary interface but which meets a defined IEC performance standard and reliability standard.

Product C is a product which complies with an IEC standard interface but does not meet the requirements of either an IEC performance standard or reliability standard.

Product D is a product which complies with both an IEC standard interface and performance standard but does not meet any reliability requirements.

Obviously, the matrix is more complex than shown, since there will be a number of interface, performance and reliability standards which will be cross-related. In addition, the products may all be subject to a quality assurance programme that could be under IEC qualification approval, capability approval, technology approval (as Table 4 attempts to demonstrate), or even under a national or company quality assurance system.

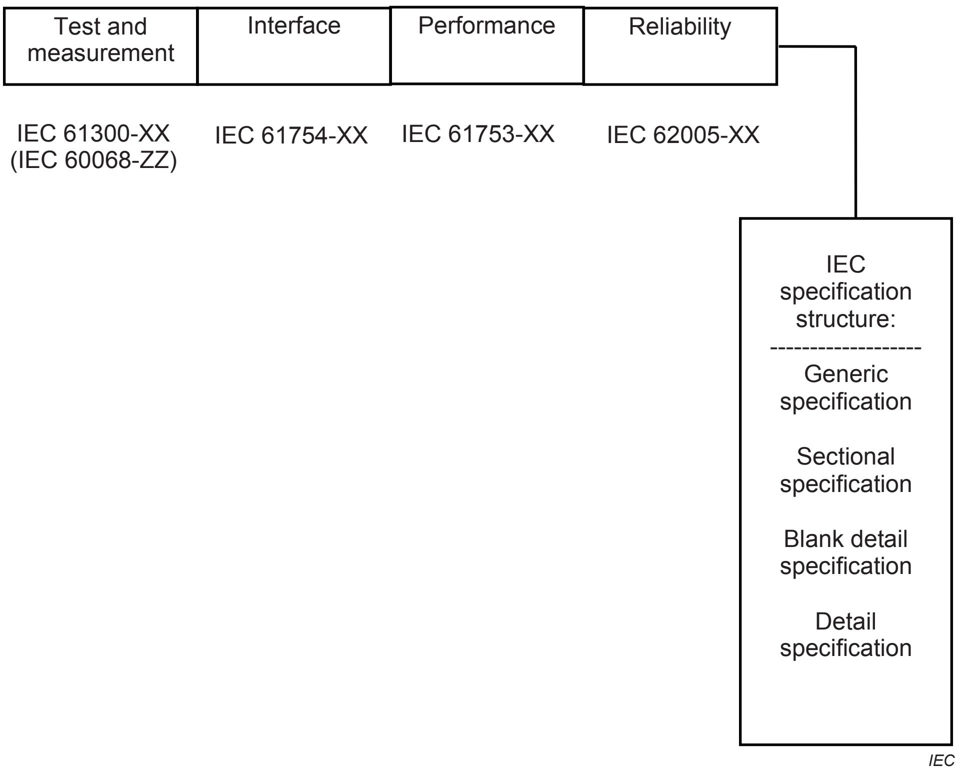


Figure 13 – Standards

Table 5 – Standards interlink matrix

	Interface standard	Performance standard	Reliability standard
Product A	Yes	Yes	Yes
Product B	No	Yes	Yes
Product C	Yes	No	No
Product D	Yes	Yes	No

4.4 Design and construction

4.4.1 Materials

4.4.1.1 Corrosion resistance

All materials used in the construction of switches shall be corrosion resistant or suitably finished to meet the requirements of the relevant specification.

4.4.1.2 Non-flammable materials

When non-flammable materials are required, the requirement shall be specified in the specification and reference made to IEC 60695-11-5.

4.4.2 Workmanship

Components and associated hardware shall be manufactured to a uniform quality and shall be free of sharp edges, burrs or other defects that would affect the life, service ability or appearance. Particular attention shall be given to neatness and thoroughness of marking, plating, soldering, bonding, etc.

4.5 Quality

Switches shall be controlled by the quality assessment procedures. The test and measurement procedures of the IEC 61300 series shall be used, as applicable, for quality assessment.

4.6 Performance

Switches shall meet the performance requirements specified in the relevant specification.

4.7 Identification and marking

4.7.1 General

Components, associated hardware and shipping packages shall be permanently and legibly identified and marked when required by the detail specification.

4.7.2 Variant identification number

Each variant in a detail specification shall be assigned a variant identification number. The number shall consist of the number assigned to the detail specification followed by a four-digit dash number and a letter designating the assessment level. The first digit of the dash number shall be sequentially assigned to each component type covered by the detail specification. The last three digits shall be sequentially assigned to each variant of the component.

4.7.3 Component marking

Component marking, if required, shall be specified in the detail specification. The preferred order of marking is as follows:

a) port identification;
b) manufacturer's part number (including serial number, if applicable);
c) manufacturer's identification mark or logo;
d) manufacturing date;
e) variant identification number;
f) any additional marking required by the detail specification.

If space does not allow for all the required marking on the component, each unit shall be individually packaged with a data sheet containing all of the required information which is not marked.

4.7.4 Package marking

Package marking, if required, shall be specified in the detail specification. The preferred order of marking is as follows:

a) manufacturer's identification mark or logo;
b) manufacturer's part numbers;
c) manufacturing date codes (year/week; see ISO 8601);
d) variant identification number(s) (see 4.7.2);
e) assessment level;
f) type designations (see 4.1.2);
g) any additional marking required by the detail specification.

When applicable, individual unit packages (within the sealed package) shall be marked with the reference number of the certified record of released lots, the manufacturer's factory identity code and the component identification.

4.8 Packaging

Packages shall include instructions for use when required by the specification.

4.9 Storage conditions

Where short-term degradable materials such as adhesives are supplied with the package, the manufacturer shall mark these with the expiry date (year and week numbers, see ISO 8601) together with any requirements or precautions concerning safety hazards or environmental conditions for storage.

4.10 Safety

Optical switches, when used on an optical fibre transmission system and/or equipment, may emit potentially hazardous radiation from an uncapped or unterminated output port or fibre end.

Manufacturers of optical switches shall make available sufficient information to alert system designers and users about the potential hazard and shall indicate the required precautions and working practices.

In addition, each detail specification shall include the following.

WARNING

Care should be taken when handling small diameter fibre to prevent puncturing the skin, especially in the eye area. Direct viewing of the end of an optical fibre, or an optical fibre connector when it is propagating energy, is not recommended unless prior assurance has been obtained as to the safety energy output level.

Reference shall be made to IEC 60825-1, the relevant standard on safety.

Annex A
(informative)

Example of magneto-optic effect (MO) switch technologies

Figure A.1 shows an example of a 1 × 2 switch based on the magneto-optic effect. The switch consists of a Faraday rotator, a polarization separator/combiner (birefringent crystal), a half-wave plate and an electric magnet. The incident light from the input port is separated into two cross-polarizations by the polarization separator (birefringent crystal 1). Two cross-polarizations are paralleled by the Faraday rotator and the half-wave plate. In the electro magnetic field H1, the two parallel polarization from the input port is recombined by the half-wave plate, Faraday rotator and the polarization combiner (birefringent crystal 2), then it exits from the output port 1. In the reverse electromagnetic field H2, the two parallel polarizations from the input port is shifted by the middle birefringent crystal, due to the changed polarization direction by reverse Faraday rotator, then it exits from the output port 2. Switching is achieved by reversing the direction of the electromagnetic field of a non-machine.

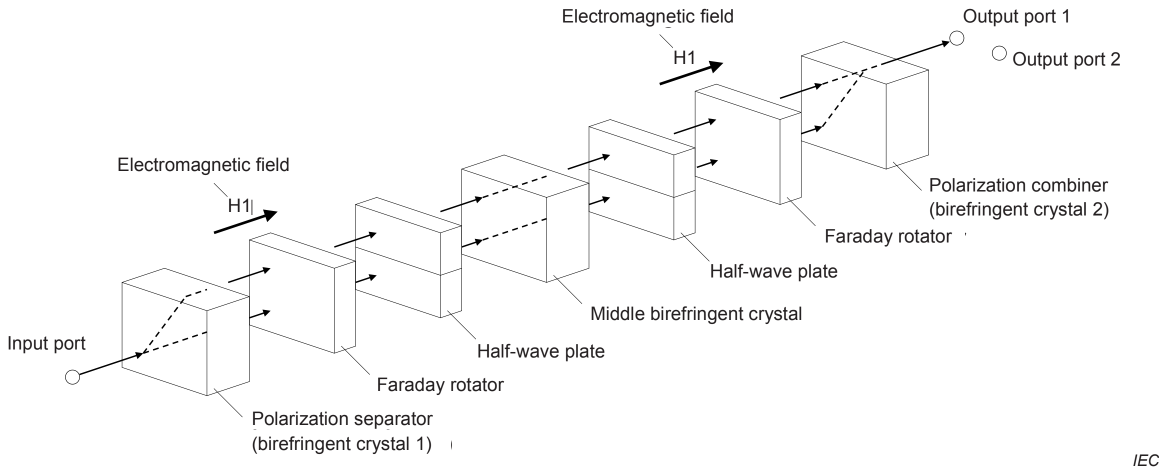


Figure A.1a – Input port to output port 1

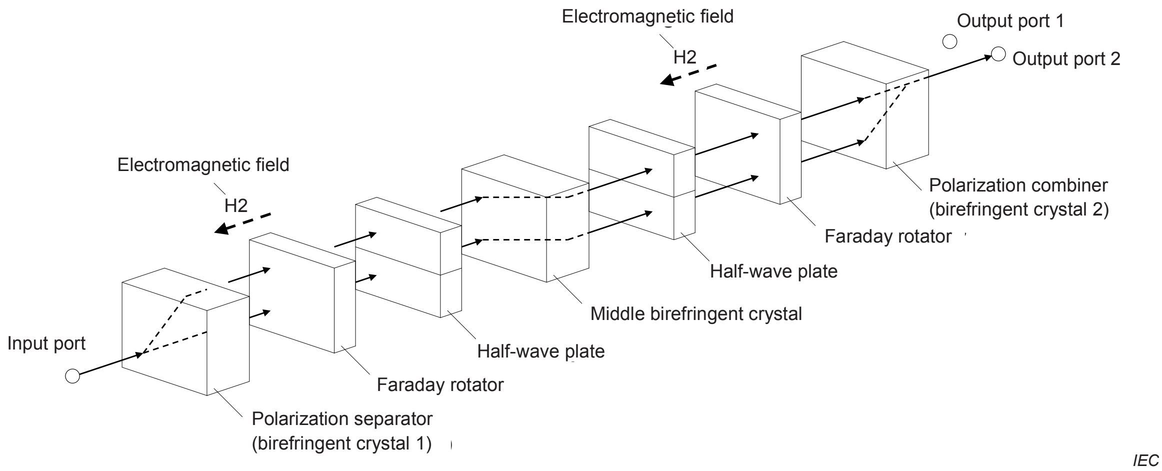


Figure A.1b – Input port to output port 2

Figure A.1 – Example of 1×2 MO switch

Annex B
(informative)

Example of mechanical switch technologies

Figures B.1 and B.2 show examples of 1×2 mechanical switches.

Figure B.1 shows a mirror driving type mechanical switch. There is a movable mirror between two gradient index lenses (GRIN lenses). The light from input port becomes a beam in the GRIN lens and it is reflected by the movable mirror when the mirror is set between the GRIN lenses. The reflected light is focused at the end of another fibre for output port 1. Then the movable mirror is removed from the middle of the GRIN lenses, the beam goes into another GRIN lens. The light is focused at the end of the GRIN lens where the output port 2 is attached. Switching is achieved by taking the mirror in and out.

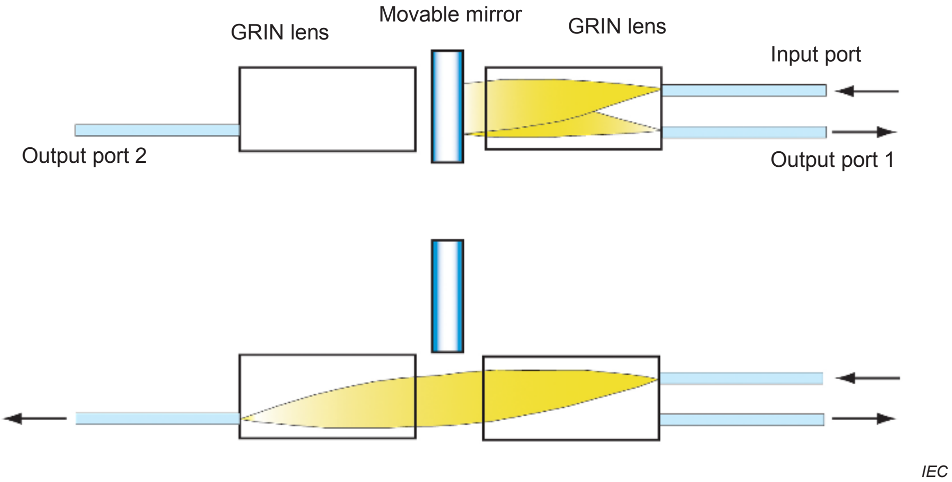


Figure B.1 – Example of mechanical switch (mirror driving type)

Figure B.2 shows a fibre driving type mechanical switch. There is one movable fibre for the input port with a magnetic pipe near the end and two fixed fibres for the output ports. The movable fibre is set to one magnet due to magnetic poles of the pipe and the fibre end is aligned to one of the fixed fibres. When electric current is applied to the solenoidal coil and the magnetic poles of the pipe are reversed, the movable fibre is set to another magnet and the fibre end is connected to another fixed fibre. After the current is stopped, the fibre connection will be maintained because of the magnetic attraction force so that the switch can work as a latching switch.

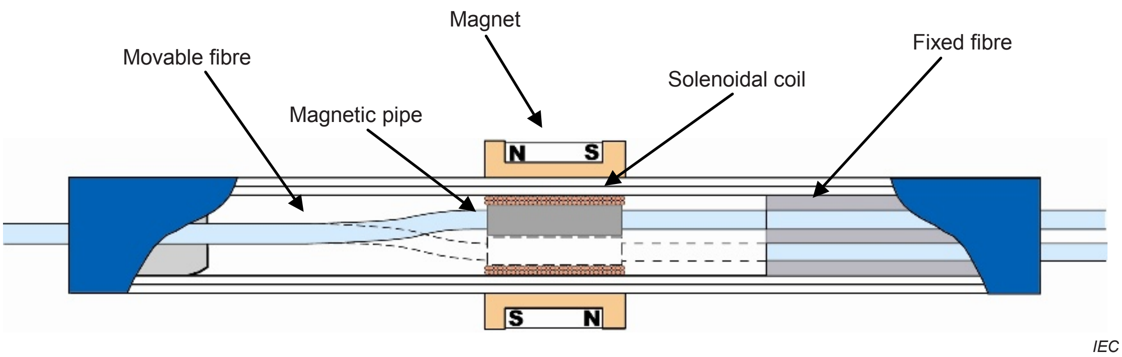


Figure B.2 – Example of mechanical switch (fibre driving type)

Annex C
(informative)

Example of micro-electromechanical system (MEMS) switch technologies

Figure C.1 shows an example of an *N*x*N* MEMS switch.

The MEMS switch has two-axes MEMS mirror arrays and optical fibre collimator arrays. The light from the input port becomes collimated light by the collimator array. The collimated light is reflected by the first MEMS mirror array to go to a mirror in the second MEMS mirror array. By controlling the tilt angle of the mirror in the first MEMS mirror array, the light is connected to any mirror in the second MEMS mirror array. Then the light is reflected by the second mirror and goes into an output port fibre through the collimator array. Connection between any input port and any output port is achieved by controlling the tilt angle of each mirror, thus the $N \times N$ switch function is realised.

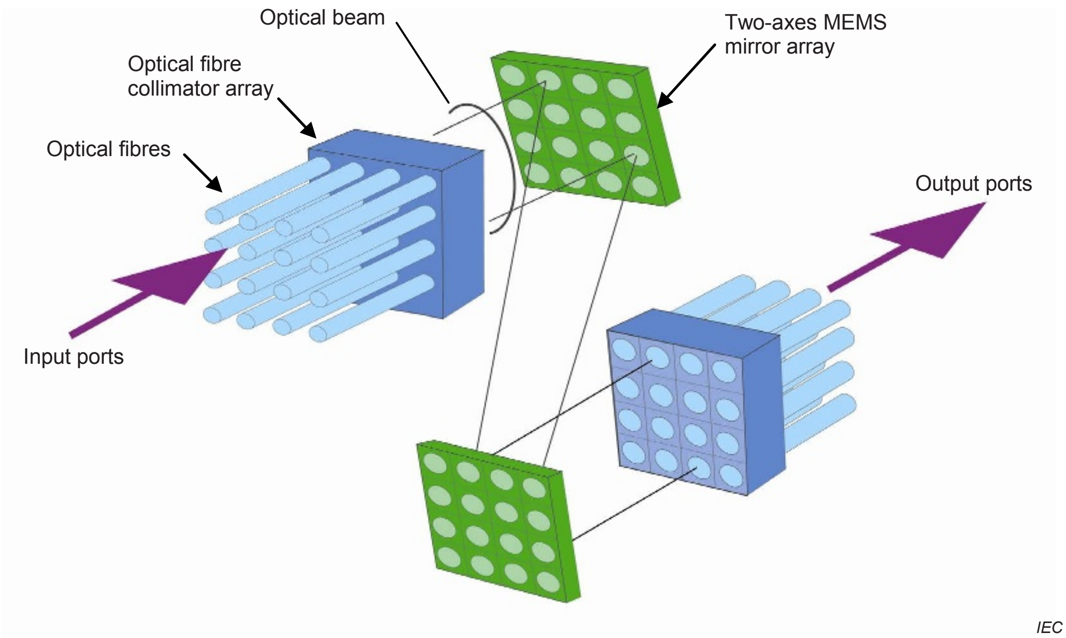


Figure C.1 – Example of MEMS switch

Annex D
(informative)

Example of thermo-optic effect (TO) technologies

Figure D.1 shows an example of 2×2 TO switch by planar lightwave circuit (PLC).

The 2×2 PLC switch element is a silica-based waveguide type Mach-Zehnder interferometer (MZI). The switch consists of two 2×2 couplers and two waveguide arms between the couplers. The arm waveguides are equipped with thin film heater on their cladding. Figure A.5 shows the top and cross-sectional views of the switch configuration, respectively.

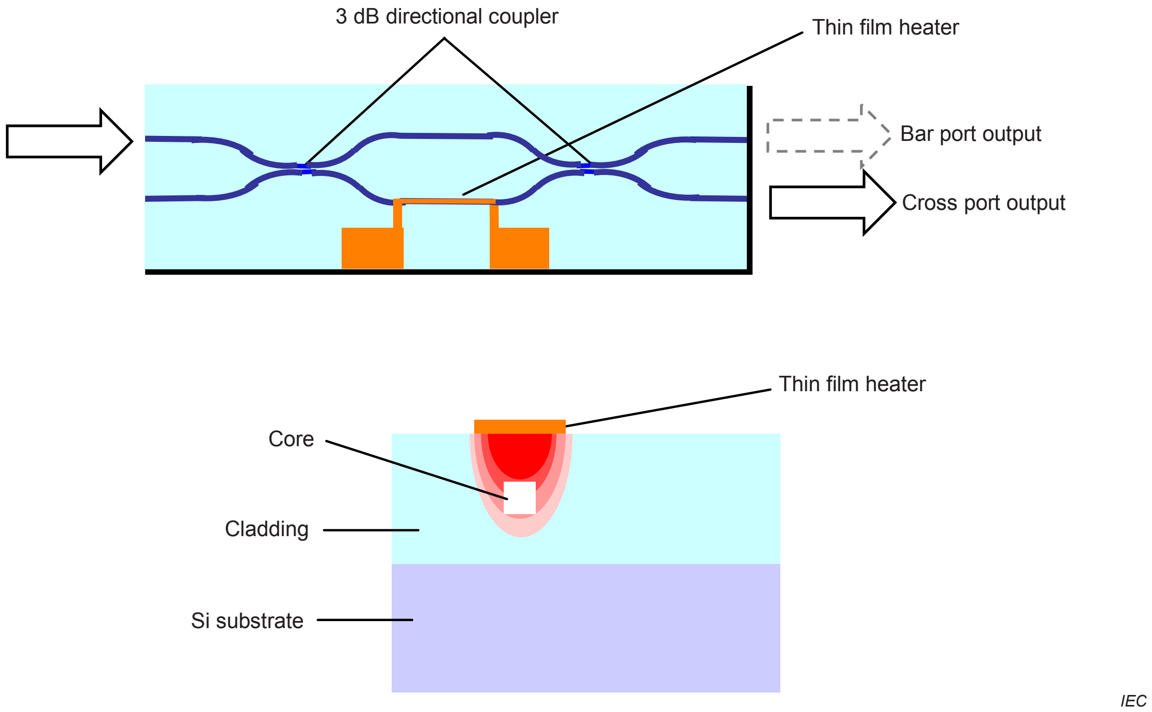


Figure D.1 – Example of TO switch

When there is no heating power, the input light is guided to the cross port. By varying the refractive index of one waveguide arm using the thermo-optic effect, the optical path length difference can be changed by half a wavelength. In this case, the input light is switched to the bar port.

Figure D.2 shows the relationship between the output lights and optical path length difference. Figure D.3 gives an example of switching responses.

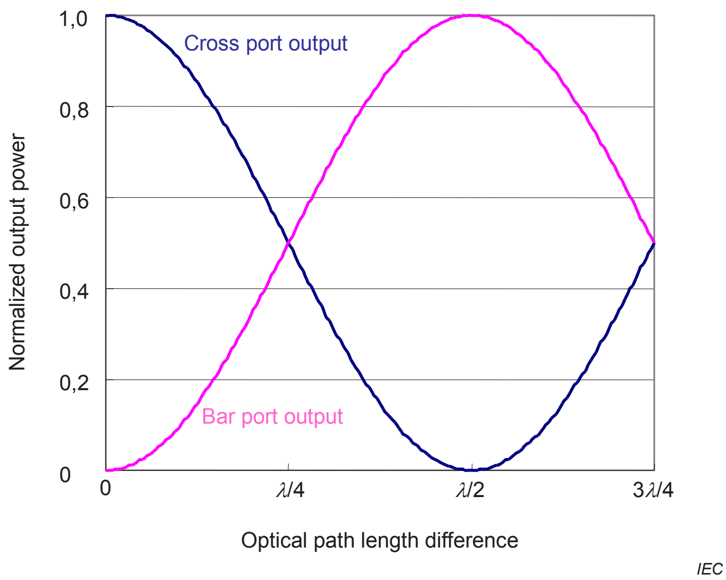


Figure D.2 – Output power of TO switch

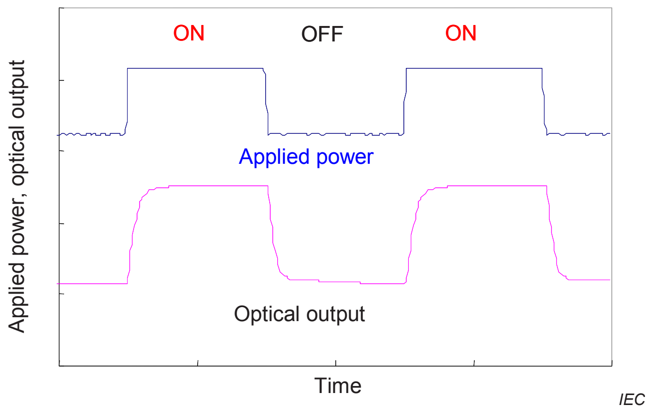


Figure D.3 – Example of switching response of TO switch

Many types of large scale switches can be made by integrating the 2 × 2 switch elements. Figure D.4 gives an example of 1 × *N* and *N* × *N* switch configurations.

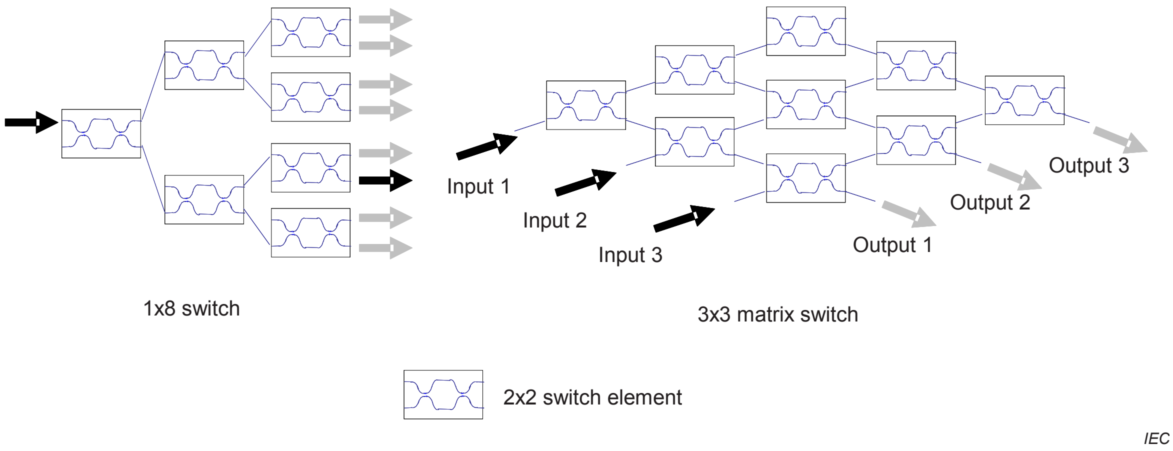


Figure D.4 – 1 × *N* and *N* × *N* examples of TO switch

Annex E
(informative)

Summary of definitions on switching time

Table E.1 – Summary of definitions of latency time

Condition	Type of switches	From	To
Isolating to connecting	Latching and non-latching normally off	Actuation energy on	Reaching 10 % of optical power at stabilized state of connecting condition
	Non-latching normally on	Actuation energy off	
Connecting to isolating	Latching and non-latching normally off	Actuation energy off	Reaching 90 % of optical power at stabilized state of connecting condition
	Non-latching normally on	Actuation energy off	

Table E.2 – Summary of the definitions of rise time

Condition	Type of switches	From	To
Isolating to connecting	Latching, Non-latching normally off Non-latching normally on	Reaching 10 % of optical power at stabilized state of connecting condition	Reaching 90 % of optical power at stabilized state of connecting condition

Table E.3 – Summary of the definitions of fall time

Condition	Type of switches	From	To
Connecting to Isolating	Latching, Non-latching normally off Non-latching normally on	Reaching 90 % of optical power at stabilized state of connecting condition	Reaching 10 % of optical power at stabilized state of connecting condition

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IEC Guide 102, *Electronic components – Specification structures for quality assessment (Qualification approval and capability approval)*

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