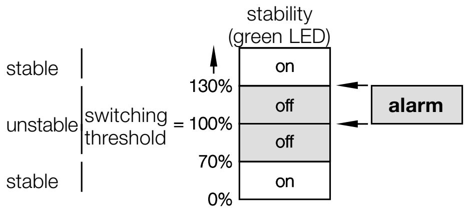
Wire colors
designation
per DIN IEC 60757

BN	brown
BK	black
BU	blue
OG	orange
WH	white
RD	red
GY	gray

The **alarm output ...**
(for series BOS 15, BOS 18 teach-in, BOS 25, BOS 65, BOS 74)

... in the receiver (PNP open collector – 30 mA). The receiver is equipped with an alarm output. It acts as a warning signal when the function is affected by contamination or mechanical maladjustment.
The alarm output is activated when the receive signal is present in the alarm range for a defined length of time.



Series BOS 18M with teach-in and BOS 65K represent a complete family, including diffuse and retroreflective models, equipped with an alarm output.

Analog output

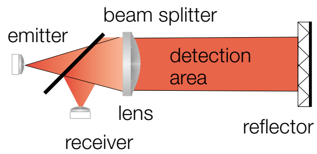
A sensor with an analog output does not switch at a particular target distance. These devices have an analog output with an distance-dependent output signal. The output voltage corresponds to the object location within the sensing range.
These systems operate on the same principle as sensors with background suppression. They generate a linear output signal within a certain range (measuring range).

Turn-off delay ...

... is the time which the sensor requires for actuation when the target object leaves the sensing zone, at a transmission efficiency factor of 0.5.

Auto-collimation

Emitter and receiver use a common lense. The emitter light passes through the beam splitter and the lens to the reflector. The reflector bounces the emitter light back to the lens. This gives retroreflective sensors having auto-collimation a small, round beam profile.
And there is another benefit: no dead area for sensing and for the reflector, better small parts detection, and the switching characteristic is independent of the approach direction.



Dark-on ●
per DIN 44030

Light receiver	Amplifier	Consumer
non-illuminated	conducting	switched on
illuminated	non conducting	switched off

Turn-on delay ...

... is the response time a sensor needs if the target object enters the sensing zone, with the transmission efficiency at a factor of 2.

Thru-beam

Thru-beam sensors consists of separate emitter and receiver units which must be aligned on opposite sides of the sensing path.
A target interrupts the light beam and causes the receiver to switch regardless of the surface characteristics. Thru-beam versions are best in unfavorable conditions (e.g. dust, moisture, oil).
Ranges of up to 50 m can be achieved.

Color sensing

Sensors for color recognition detect objects based on their color. The sensor is calibrated so that it recognizes objects having a certain color. Objects with different colors do not generate a switching signal.

Fiber optics

Optical conductors are made of glass or plastic with a diameter of as little as 50 µm and bunched in bundles of several hundred individual fibers to form so-called fiber optics. The fiber ends are ground and polished to meet the quality criteria of the optical industry. The individual fibers have an extremely thin, permanently adhering lubricant coating which reduces friction with the outer jacket and between the fibers, so that fiber breaks are virtually unheard of even under constant bending. The transmission properties are guaranteed over a longer period of time.
The ends of the bundles are potted with the connection sleeve and the jacket. Balluff fiber optics thus have an IP 67 rating (IP 65 for metal jacket). Moisture and aggressive media cannot hurt either the fibers or the slide coating, so the optical properties remain unaffected. This design distributes axial pull forces evenly over all the fibers and protects the individual fibers from excessive pull loads.

Polyurethane jacket

– Temperature T = +85 °C
– excellent chemical resistance
– flexible
– no embrittlement from oils and cooling emulsions.

Corrugated metal tube, silicon jacketed

– Temperature T = +150 °C
– meets food grade standards
– highly flexible
– tread-resistant
– can be sterilized.

Metal jacket

– Temperature T = +250 °C
– resistant to hot chips
– flexible
– tread-resistant.

Focusing

To achieve a smaller light spot, the light beam from the emitter is focused using lenses. Focusing and the resulting light spot allow the switch to better detect small parts and details.
Focusing is often used with retroreflective sensors as well as with diffuse sensors in conjunction with background suppression.

Ambient light ...

... is the portion of light which impinges on the receiver, but does not originate from the emitter.

Slot sensor

Slot sensors are thru-beam designs in which the emitter and receiver are arranged opposing in a U-shaped housing. The fixed housing makes alignment and the electrical connection easier. Different ranges are available by selecting different housing configurations. Slot openings of between 5 and 120 mm in various step sizes are available. The built-in potentiometer and diaphragms allow you to adjust the slot sensors easily for detecting parts down to a diameter of 0.5 mm.

Gray scale shift

Gray scale shift is the switching distance difference when calibrating using different object reflectivities. The sensor is calibrated for a distance using a Kodak gray card having 90 % reflection. A Kodak gray card having 18 % reflection is used and the resulting distance measured. The difference between these two switchpoints in % is referred to as the gray scale shift. The smaller the gray scale shift the less color-dependent the sensor will be.

Light-on O
per DIN 44030

Light receiver	Amplifier	Consumer
illuminated	conducting	switched on
non-illuminated	not conducting	switched off

Background suppression (HGA)

HGA allows objects within a certain switching distance to be detected without being affected by a reflecting background and virtually independent of object reflectivity (color or surface texture).
HGA is realized by allowing the beam cones of the emitter and receiver to intersect. This results in a division of the field of view into an active area and the background. In addition, by dividing the receiver into at least two adjacent areas (e. g. by using a dual diode or a PSD element) and by means of a geometric arrangement (triangulation), the actual position of the object within the sensing range can be determined. These two design features alow the object to be reliably distinguished from the background. Diffuse sensors with HGA are characterized by low gray scale shift and hysteresis.

Hysteresis H ...

...is the distance between the switchpoints for a target approaching and then receding from an optoswitch.

Kodak gray card

The "standard target" for optoelectronic sensors is the Kodak gray card. This is a cardboard sheet whose surface has a defined degree of reflectivity. The side with 90 % reflection is used for determining the range of diffuse sensors, and the side with 18 % for determining the gray scale shift.

Correction factors (for diffuse types)

For objects with varying reflection characteristics, the range can be determined by using the correction factors shown. See the adjacent table.

Factor	Object, surface
1	paper, white, matte 200 g/m²
1.2...1.6	metal, shiny
1.2...1.8	aluminum, black anodized
1	styrofoam, white
0.6	cotton fabric, white
0.5	PVC, gray
0.4	wood, rough
0.3	cardboard, black, shiny
0.1	cardboard, black, mat

Short circuit protection

The output leads can be connected to the wrong potential without destroying the sensor. Together with their polarity reversal protection, these sensors are completely protected against miswiring.

Lasers, laser protection class

The purpose of laser protection classes is to protect persons from laser radiation by specifying limit values. Based on this the lasers used are classified according to a scale which references the degree of hazard.
The calculations used for the classification and the resulting limit values are described in EN 60825-1/94. The grouping is based on a combination of output power and wavelength, taking into account duration of the emission, number of pulses and angle opening.

Balluff sensors operate in the following laser protection classes:

Class 1: harmless, no protective measures necessary
Class 2: low power, eyelid reflex is sufficient protection.

For devices in Class 1 and 2 the eye protects itself from looking too long into the beam through the eyelid reflex. Appropriate warning labels must be affixed to the device and in some cases to the machine in which the laser is used. No other mechanical or optical protection measures are required. When using devices from class 1 and 2, no person responsible for laser protection needs to be present.

Light as a sensor medium ...

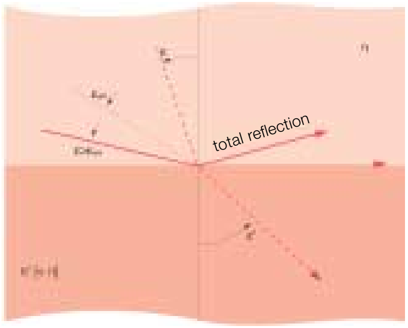
...is used in numerous areas of technology and in everyday life in controlling applications. Generally a change in the light intensity in an optical beam (between emitter and receiver) caused by a target object is evaluated. Depending on the properties of this object and the characteristics of the optical beam, the light beam is either interrupted or reflected, or even scattered. Pulsed infrared LED's are normally used as the emitter, and phototransistors as the receiver. The output signal is for the most part independent of the ambient light conditions, since visible light can be easily filtered out. In critical sensing applications, diffuse sensors or thru-beam systems with red light LED's are used, since the light beam and the sensing point can be visually seen and more easily adjusted.
Balluff offers three sensor types for the various application requirements: diffuse, retroreflective, and thru-beam sensors.

Light refraction

Light beams experience a change in direction at the surfaces of two optical media with differing optical density (e. g. glass/air), i. e. they are refracted.
The degree of refraction is dependent on the quotients of the optical densities **n** of both media and on the angle of incidence ε to the optical axis.

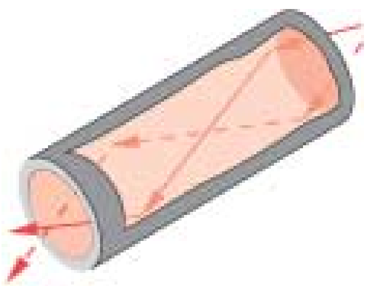
$$\sin \varepsilon' = \frac{n}{n'} \sin \varepsilon$$

If a light beam travels from a dense medium **n** into a thinner one **n'**, its course there will show a greater angle **ε'**. Above $\varepsilon_{crit.}$ (critical angle, at which the deflected beam runs parallel to the boundary layer), however, it re-enters the medium with density **n**, i. e. here there is total reflection.



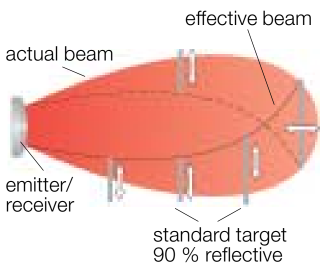
Light transmission by total reflection

Without the above described total reflection at boundary layers, fiber optics of today's quality would not be attainable. They consist of a cylindrical, light-conducting core and a surrounding thin-wall jacket. The optical density of the core is greater than that of the jacket. A light beam is always totally reflected at the junction between core and jacket, and can therefore never leave the core in a radial direction. Theoretically the light is not weakened by these reflections; however, contamination and small defects both in the core material as well as the boundary layer do cause losses (attenuation) and effectively limit the conductor length over which reliable information can be propagated.



Diffuse

Diffuse types have the emitter and receiver integrated into a single housing. Orientation to the target is not critical.
A target object (e. g. a standard target which is 90 % reflective) bounces a part of the light from its surface back to the receiver. Once the standard target enters the effective beam (see illustration), a change in the output switching state occurs.
The sensing range depends upon size, shape, color and surface characteristics of the reflecting target object. Using a Kodak gray card with 90 % reflectivity (like white paper), ranges up to 2 m can be obtained.



Max. **humidity ...** ... is 35...85 % (non-condensing).

Luminescence

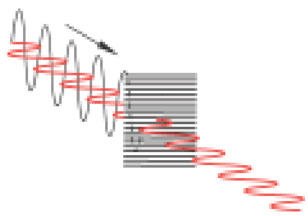
To sense invisible marks on objects, so-called luminescent materials (contained in special chalks, inks, paints etc.) are used which can only be made visible under ultraviolet (UV) light. The fluorescent materials convert the invisible UV light (short wavelength, here 380 nm) into visible light (between blue 450 nm and dark red 780 nm). This effect is called photoluminescence.
The visible light can then be detected as usual by the receiver component of the sensor.

Polarizing filters
When do you need them?

A part of the emitter light in retroreflective systems is reflected directly back to the receiver from target objects with shiny surfaces, e. g. stainless steel, aluminum or tinplate. Simple retroreflective systems can thus not reliably distinguish reflected "object light" from "reflector light". False switching can therefore not be ruled out. Balluff retroreflective sensors are available with **polarization filters,** which together with a **Balluff reflector,** which is an **"optically active" prism mirror,** provide a selective barrier against the reflected "object light" while still allowing the "reflector light" to pass freely.

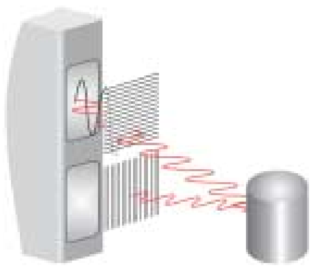
How do they work?

Light consists of a number of "single beams", all of which oscillate sinusoidally around their propagation axes. Their polarization planes are however independent of each other and can assume any angle orientation (see figure). When they meet a polarizing filter (fine grid lines), only the beams oscillating parallel to the grid plane are allowed to pass, and those oscillating at right angles to the grid are cancelled out. Of all the other polarization planes, only the portion which consists of parallel components is allowed to pass.



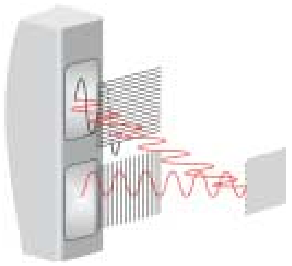
... for blocking reflected light

Behind the filter, the light only oscillates parallel to the polarization plane. For this light, an additional 90° rotated polarizing filter becomes an impassable barrier.
With a 90° rotated polarizing filter in front of both the emitter and receiver of a retroreflective system, you can therefore prevent reflected light from a reflecting target object from false triggering the signal of the photoreceiver.



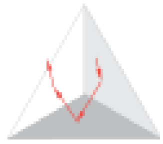
... for reliable detection of reflecting target objects

On the other hand, the light reflected from the triple mirror, with its polarization plane rotated by 90° as described above, is allowed to pass unhindered by this filter. The receiver of a retroreflective system is thereby fully shielded even when a reflecting target object enters the beam, so that the object is still reliably detected.



Reflectors
optically active triple mirrors

The two-dimensional principle of retroreflection described above can be carried over to a spatial system with three mirrors which are oriented at right angles to each other (one corner of a cube standing on its point). A light beam entering this system is totally reflected by all three surfaces and exits parallel to the infalling beam.
Triple mirrors are said to be **"optically active"**, because they also rotate the polarization level of the reflected light beam by 90°. This characteristic is needed – together with a **polarization filter** (see page **2.0.**20) – to provide reliable detection of reflecting objects using retroreflective sensor systems.



Six triple-mirrors are combined into a hexagon and arranged in honeycomb fashion. Their orientation with respect to the light beam is then totally uncritical.

These are generally made of plastics with high optical density, injected as sheets or pressed into flexible tape.

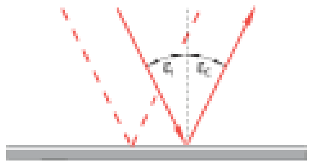
Reflection
What is it?

Light beams propagate in free space in a straight line. Upon striking an object, they are reflected back. Depending on the surface composition of the object, one of three types of reflection occurs: total reflection, retroreflection, and diffuse reflection.

Total reflection ...

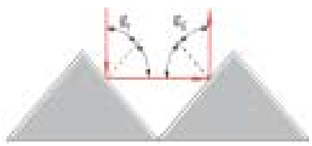
... occurs with a highly shiny (reflecting) surface. The angle of incidence is thereby the same as the angle of reflection ($\varepsilon_I = \varepsilon_E$).

The reflection losses are in the ideal case negligible.



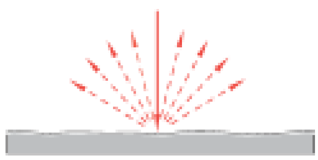
Retroreflection ...

... is caused by two mirrors at vertical angles to each other. The double reflection causes a light beam to be bounced back in the same direction. The angle of incidence can thus be altered in a relatively wide range.



Diffuse reflection ...

... occurs with an uneven and rough surface. It can be demonstrated with a variety of poorly reflecting and variously oriented miniature mirrors.
Infalling light is widely "scattered" from such a surface. The reflection losses are higher the darker and more matte finished the surface is.



Retroreflective

Retroreflective types have the emitter and receiver integrated into a single housing. A reflector on the opposite side of the beam bounces the emitter's light back to the receiver. A target object interrupts the reflected light beam and causes a change in the output signal.

With reflective surfaces it is recommended that the light reflected from the object be filtered out using a polarizing filter in front of the receiver, in order to prevent any possible spurious signals.

Ranges up to 8 m can be obtained.

2.0

Switching distance

Switching distance s ... ... is the distance between the standard target and the "active surface" of the light sensor for causing a signal change (per EN 60947-5-2).

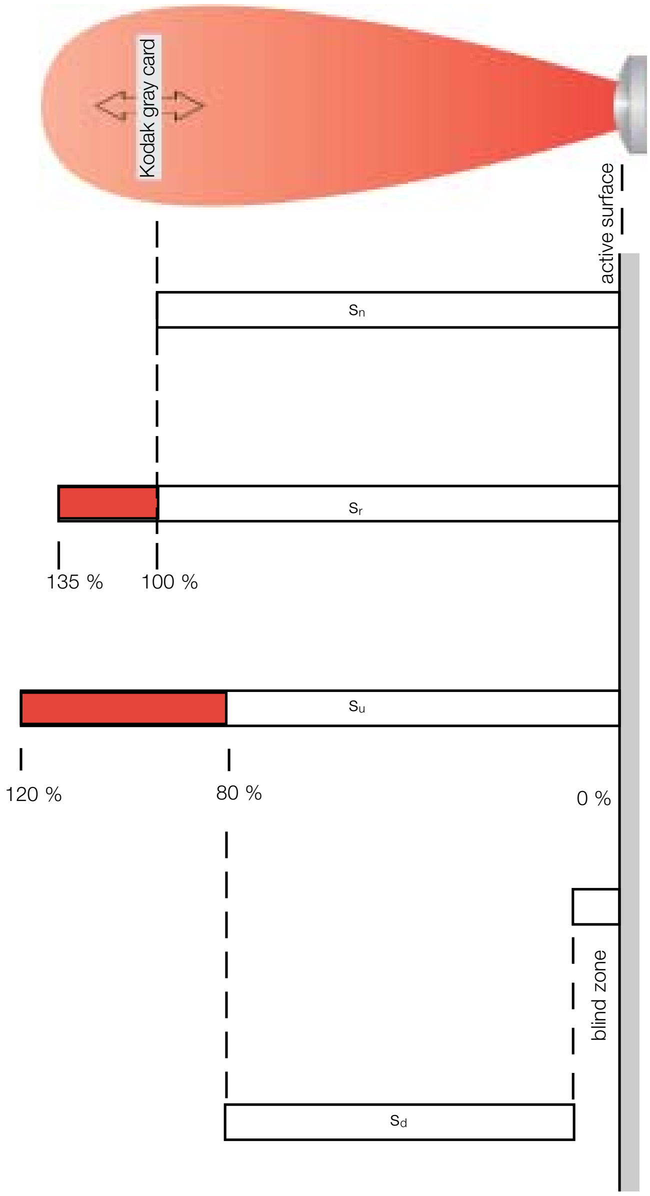
Nominal range s_n ... ... is a switching distance parameter which ignores manufacturing tolerances, random variance, and external influences like temperature and voltage.

Actual range s_r ... ... is the switching distance at rated voltage U_e taking into account manufacturing tolerances at rated ambient temperature (T = +23 °C ±0.5).

Useful switching distance s_u ... ... is the permissible switching distance within specified voltage and temperature ranges ($0.80\ s_n \leq s_u \leq 1.20\ s_n$).

Blind zone ... ... is the area between the "active surface" and minimum switching distance, within which an object cannot be detected.

Detection range s_d ... ... is the area within which the switching distance of an opto switch can be set using a standard target.



Emitter light

Optical sensors generally use the following emitter components:

Redlight-LED
Visible light, good as an alignment aid and for sensor adjustment.

Infrared-LED (IR)
Invisible beam with high energy.

Redlight laser
Visible light whose physical properties make it ideal for small parts detection and long ranges.

Teach-in

Sensor settings on teach-in sensors do not have to be made using a potentiometer or slide switches; everything is controlled with the push of a button. The microcontroller integrated into teach-in sensors allows the entire setup sequence to be controlled by pressing the button. The use of defined calibration steps also means that the sensor cannot be calibrated for an unreliable zone. The microcontroller also assumes control of the contamination indicator and the contamination output. A variety of Balluff teach-in sensors also provide the option of remote operation, whereby the teach-in calibration process is initiated "externally" through a cable line.

Technical data, general

	Diffuse					Background suppression			Retroreflective			Thru-beam			
Nominal sensing distance s_n	100 mm	200 mm	400 mm	1 m	2 m	120 mm	250 mm	1.1 m	2 m	4 m	8 m	5 m	8 m	16 m	50 m
Effective sensing distance (in % of s_n)	125	125	125	135	150	135	135	135	150	150	150	150	150	150	150
Switching hysteresis (in %)	≤ 20	≤ 20	≤ 25	≤ 15	≤ 15	≤ 1	≤ 1	≤ 1	≤ 10	≤ 10	≤ 10	≤ 15	≤ 15	≤ 15	≤ 15
∅ of the response beam at $s_n/2$ typ. (mm)	20	25	150	300	300	6	10	25	50	100	150				
∅ of the active area (mm)												8	12	12	20

Temperature drift ...

... is the switchpoint shift with changing temperature in % of s_r.

The **test input ...**
(for series BOS 15, BOS 25, BOS 36, BOS 65, BOS 74)

... for the emitter interrupts the light pulses from the emitter and allows the function of emitter and receiver to be checked. When using Test+, Test– must be at 0 V, when using Test–, Test+ must be at 10...30 V.

The receiver output must switch each time when a voltage of 10...30 V DC (Test+) or 0 V (Test–) is present on the test input. Contamination or maladjustment on the optical axis causes the emitter signal to reach the receiver only weakly, if at all.

Therefore the output will not switch even though the test input is activated. The test function provides a remote check of the thru-beam type and serves as a preventive measure.

Transmission ...

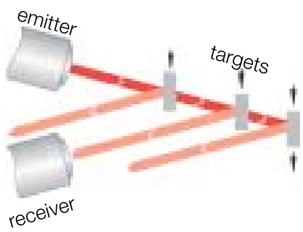
... is a measure of the lights transmission ability of a medium.

It is defined as the ratio of:
– passed to
– entering light (in %).

Diffuse transmission is the term which is used when the light is partially or completely diffused.

In **triangulation ...**

... the light cones of a thru-beam system intersect each other at a narrow angle. A target object will only be registered in the area **where the cones overlap.** The emitter light which is reflected or diffused from objects outside this limited zone cannot be registered by the photo-receiver. This fact can be used to advantage in the triangulation method to sense relatively small distance changes (e. g. grooves, shaft recesses). Color and shape of the object have very little effect on the registration.



Ambient operating temperature ...

... is the temperature range within which reliable operation of the opto switch is guaranteed.
Balluff standard:
$-15\ °C \leq T_a \leq +55\ °C$

Polarity reversal protection

The supply voltage leads can be reversed without destroying the sensor. In combination with the short circuit protection, these sensors are completely protected against miswiring.

Contamination ...
(influence on the sensing range)

... reduces the indicated sensing range of sensors and fiber optics as compared with "pure air", because the dirt and dust particles:

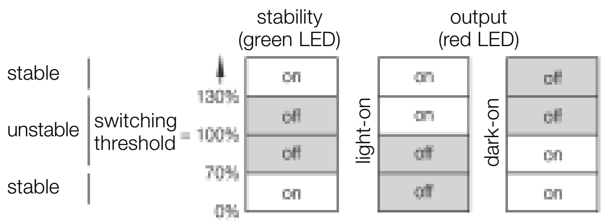
– accumulate on the lenses and affect their transparency, and
– absorb and diffuse the light in the incoming beam.

An oil-free source of compressed air can be used to prevent dirt and contamination effects due to impure air.

The **contamination indicator (green) ...**
(for series BOS 15, BOS 18 (some), BOS 25, BOS 44, BOS 65, BOS 74)

... illuminates in the "safe" range, where the input energy is at least 30 % over or under the "threshold energy".
The "threshold energy" at which a signal change is effected, is defined as 100 %. The "safe" range is therefore reached when

- the input signal is at **130 %** or more of the threshold energy
- the input signal is at **70 %** or less than the threshold energy.



Contamination scale

pure air	ideal conditions
trace contamination	relatively clean air in indoor rooms
slight contamination	tool and storage rooms
moderate contamination	dusty and vaporous environment switching distance reduced by a factor of $s = 0.5\ s_u$
high contamination	heavy precipitations, swirling flakes and chips optosensor function may fail
worst contamination	coal dust precipitating on the lens optosensor function may fail

Resistance

to mechanical impact per EN 60068-2-27

Pulse shape: half-sine
Peak acceleration:
$300 \frac{m}{s^2}$ ($30\ g_n$)
Pulse duration: 11 ms

3 shocks per main axis and direction, for a total of 18 shocks

to continuous shock per EN 60068-2-29

Pulse shape: half-sine
Peak acceleration:
$1000 \frac{m}{s^2}$ ($100\ g_n$)
Pulse duration: 2 ms

4000 shocks per main axis and direction, i. e. 24.000 shocks in total

to mechanical vibration per EN 600068-2-6

Frequency range:
10...2000 Hz
Amplitude: 1 mm
(peak-to-peak) to to 122 Hz
$30\ g_n$ above 122 Hz

Duration: 20 for each position and direction