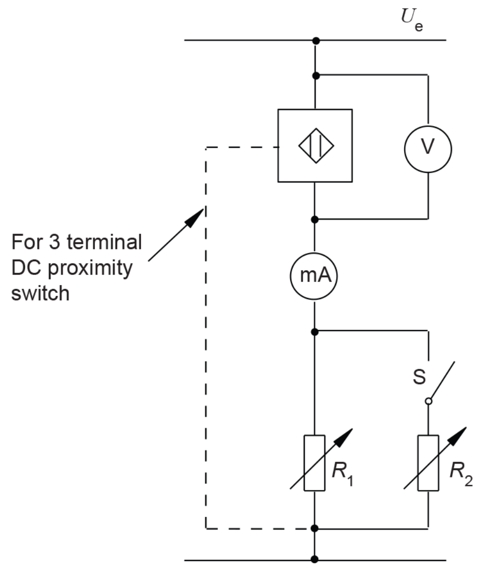


Key

R_1, R_2	resistive load
V	high impedance voltmeter (≥ 0,2 MΩ/V)
mA	milliammeter
S	switch

NOTE All meters are RMS for alternating current, mean for direct current.

Figure 9 – Test circuit for the verification of minimum operational current OFF-state current, voltage drop and independent action (see 9.3.3.2.2, 9.3.3.2.3, 9.3.3.2.4 and 9.3.3.2.5)

The target is placed in a position such that the switching element is in the ON-state.

With supply voltage U_e and the switch S being open, the load R_1 is adjusted to obtain the current I_m. The measured value shall not exceed the value specified in 8.2.1.10.

The switching element shall not change state during the test.

9.3.3.2.3 OFF-state current (I_r)

With the circuit in Figure 9 and the switch S closed, the load R_2 is adjusted to obtain the rated operational current I_e when the supply voltage is the highest U_e. The target is then moved in a position such that the switching element is in the OFF-state.

The (I_r) current shall be measured with supply voltage U_e + 10 % or with the maximum value of the supply voltage U_B where it is specified as a range. The (I_r) current shall not exceed the value specified in 8.2.1.11.

9.3.3.2.4 Independent action

Independent action shall be checked at maximum and minimum operating load currents at both maximum and minimum rated operating voltages. Resistive loads of appropriate value shall be used for each of the four tests.

These tests shall be carried out by moving the target from a position where the switching element is in the OFF-state to a position where the switching element is in the ON-state and observing the output on an oscilloscope. The switching element function shall be substantially independent from the velocity of the target and the output shall switch between the ON and the OFF-states without oscillating or holding at any intermediate level.

9.3.3.2.5 Voltage drop (U_d)

The voltage drop is measured across the active outputs of the proximity switch when the switching element is in the ON-state and carrying the rated operational current (I_e) at 23 °C ± 5 °C ambient temperature and at the lowest rated frequency. This measurement is performed with the circuit in Figure 9 and the switch S closed. The load R_2 is adjusted to obtain the rated operational current (I_e) with the supply voltage U_e. The voltage drop U_d is measured:

- at U_e + 10 % and U_e – 15 %,
- or $U_{e\ max}$ + 10 % and $U_{e\ min}$ – 15 %,
- or $U_{B\ max}$ and $U_{B\ min}$.

The measured voltage drop shall not exceed the values specified in 8.2.1.13.

9.3.3.3 Temperature-rise

The proximity switch, installed in free air, is supplied with its rated operational voltage (U_e) (or the highest operational voltage of its voltage range), and connected to a load corresponding to its rated operational current (I_e) until the thermal equilibrium is reached.

The temperature-rise, measured on the terminals when applicable, and on any point of the enclosure shall not exceed the values according to 8.2.2.

The length of conductor connected to each terminal shall be $2^{+0,1}_{0}$ m.

9.3.3.4 Dielectric properties

9.3.3.4.1 General

The test for verifying dielectric properties shall be made in accordance with 9.3.3.4.2, 9.3.3.4.3, 9.3.3.4.4 and 9.3.3.4.5 of this document.

For class II proximity switches insulated by encapsulation, see Annex B.

9.3.3.4.2 Application of the test voltage

This test is to be carried out as near as possible to actual in-service conditions e.g. with conductors attached. The external surface of all insulating parts likely to be touched in-service shall be covered by a metal foil in mutual contact with these parts. The proximity switch shall be capable of withstanding the test voltage applied for 1 min for a type test, and 1 s for routine test with the following conditions:

- between live parts of the switching element and parts of the proximity switch intended to be earthed;
- between live parts of the switching element and surfaces of the proximity switch likely to be touched in service, conducting or made conducting by metal foil;
- between live parts belonging to electrically separated switching elements, if any.

9.3.3.4.3 Value of the test voltage

A sinusoidal voltage of power frequency is applied according to 9.3.3.4.2.

The test voltages are given in Table 12.

Table 12 – Test voltages

Rated insulation voltage		Dielectric test voltage [a]
DC (V)	AC (V)	AC (RMS) (V)
75	50	500
150	125	1 250
300	250	1 500

[a] The defined test voltages are specified for basic insulation.

The values of Table 12 are deemed to cover the ability to withstand temporary overvoltages according to overvoltage category I.

9.3.3.4.4 Results to be obtained

There shall be no unintentional disruptive discharge during the test.

NOTE 1 Exception is an intentional disruptive discharge designed for the purpose, e.g. transient overvoltage suppressing means.

NOTE 2 The term "disruptive discharge" relates to a phenomenon associated with the failure of insulation under electrical stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or nearly to zero.

NOTE 3 The term "sparkover" is used when a disruptive discharge occurs in a gaseous or liquid dielectric.

NOTE 4 The term "flashover" is used when a disruptive discharge occurs over the surface of a dielectric in a gaseous or liquid medium.

NOTE 5 The term "puncture" is used when a disruptive discharge occurs through a solid dielectric.

A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength; in a liquid or gaseous dielectric, the loss may be only temporary.

9.3.3.4.5 Impulse withstand voltage test

The test is performed according to 7.2.3 of IEC 60947-1:2007, IEC 6094-1:2007/AMD1:2010 and IEC 60947-1:2007/AMD2:2014 and 8.2.3.2 of this document with the following additional requirement:

- the proximity device is not powered during the test;
- the impulse test shall be applied:
  a) between all terminals connected together and earth;
  b) between terminals intended to be connected to the power supply;
  c) between each output terminal and each terminal intended to be connected to the power supply.
- three positive and three negative pulses shall be applied between each two points at intervals of not less than 5 s.

NOTE The impulse withstand voltage test is designed as a type test.

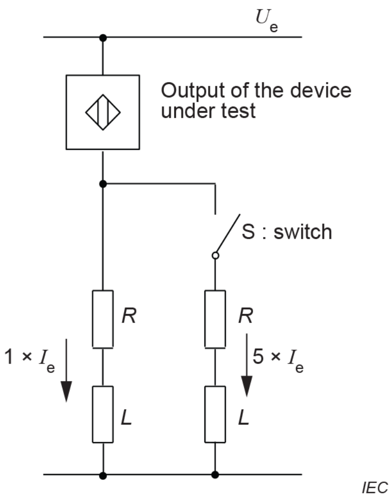
9.3.3.5 Making and breaking capacities

9.3.3.5.1 General

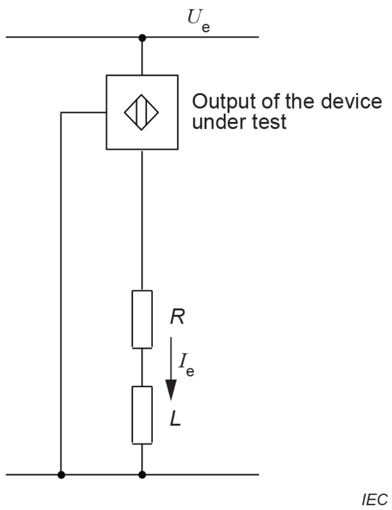
Tests for verification of making and breaking capacities shall be made according to the general test requirements stated in 9.3.2.1.

9.3.3.5.2 Test circuits

The load impedance shall be placed on the load side of the device as shown in Figure 10a) and Figure 10b). The circuit voltage with the test current flowing shall not be less than U_e.



a) **2 AC terminals or 2 DC terminals**



b) **3 DC terminals**

Figure 10 – Test circuit for the verification of making and breaking capability (see 9.3.3.5)

9.3.3.5.3 Making and breaking capacities under normal conditions

The load circuit shall be adjusted to give the values shown in Table 7.

9.3.3.5.4 Making and breaking capacities under abnormal conditions

The load circuit shall be adjusted to give the values shown in Table 8.

9.3.3.5.5 Results to be obtained

After the test, the effective operating distance of the proximity switch shall be measured and remain within the limits given in 8.2.1.3.2.

9.3.4 Performance under short-circuit current conditions

9.3.4.1 Test circuit and test procedure

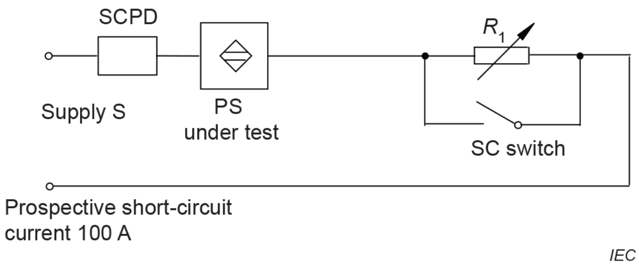
The proximity switch "PS" in new condition shall be mounted as in service, in free air, and connected to the test circuit with the same size wire as used in service, see Figure 11a) and Figure 11b).

In case of different type of outputs, e.g. current sinking outputs (NPN) or optical isolated outputs or combinations, the test setups have to be adapted accordingly.

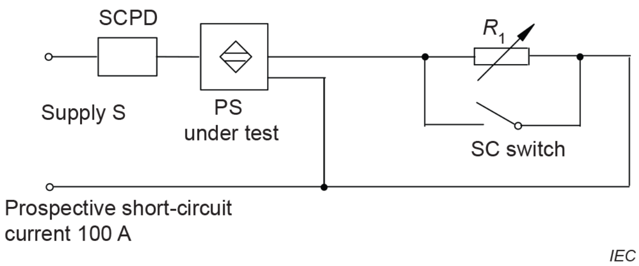
The short-circuit protective device "SCPD" shall be of the type and rating specified by the manufacturer. This "SCPD" shall be omitted if the proximity switch is integrally protected against short circuits.

The target is placed in a position such that the switching element is in the ON-state, R_1 is selected so that the current flowing through the proximity switch is equal to its rated operational current. The supply S shall be adjusted to 100 A prospective short-circuit current. The "SC" switch connected in parallel with load R_1 is fitted to initiate the short circuit. The open circuit voltage shall be 1,1 times the rated operational voltage or the maximum value of the voltage range.

The test shall be performed three times by randomly closing the "SC" switch. The test current is maintained until the SCPD or the internal short-circuit protection in the proximity switch has operated. The interval between each of the three tests shall be not less than 3 min. The actual time between tests shall be stated in the test report. After each test, the "SCPD" shall be replaced or reset.



a) 2 AC terminals or 2 DC terminals



b) 3 DC terminals

Figure 11 – Short-circuit testing (see 9.3.4.2)

9.3.4.2 Results to be obtained

After the test, the effective operating distance of the proximity switch shall be measured and remain within the limits given in 8.2.1.3.2 and shall pass a dielectric test performed in accordance with 9.3.3.4.

9.4 Testing of operating distances

9.4.1 Inductive, capacitive, non-mechanical magnetic and ultrasonic proximity switches

9.4.1.1 Test conditions

A proximity switch in new condition is mounted according to the relevant annex and the target is moved at a slow speed (but not faster than 1 mm/s at the point of switching), towards and away from the sensing face of the proximity switch in an axial direction. The operating distances are measured as shown in Figure 1, Figure 2 and Figure 3.

9.4.1.2 Effective operating distance (s_r)

The effective operating distance is measured at the rated voltage or at any voltage within the voltage range and at 23 °C ± 5 °C ambient air temperature. The measured value shall be within the limits given in 8.2.1.3.2.

9.4.1.3 Differential travel (*H*)

The differential travel is defined as a percentage of the effective operating distance (s_r). The measurement is made at the ambient temperature of 23 °C ± 5 °C at rated supply voltage. The target shall be moved towards the proximity switch within the (s_r) range and then be moved away from the proximity switch. The measured value shall be according to 8.2.1.5.

9.4.1.4 Usable operating distance (s_u)

Usable operating distance is measured over the –25 °C to +70 °C ambient temperature range with the supply voltage at 85 % and 110 % of its rated value. The target shall be moved towards the proximity switch. The measured value shall be within the limits given in 8.2.1.3.3.

9.4.1.5 Repeatability (*R*)

The repeatability of the effective operating distance (s_r) is measured over an 8 h period with an enclosure temperature within 23 °C ± 5 °C and with supply voltage U_e ± 5 % or at any voltage ±5 % within the rated operational voltage range. The target shall be moved towards the proximity switch. The period between any two consecutive measurements shall be 1 h or less. The measured value shall be within the limits given in 8.2.1.4.

9.4.2 Photoelectric proximity switches

9.4.2.1 Test conditions

This test is performed at rated voltage or at any voltage within the voltage range with new photoelectric proximity switches, except when specified as verification after another test (see 9.3.1), in clean air conditions, at any ambient temperature between 23 °C ± 5 °C at an ambient light value of 5 000 lx obtained as per 9.4.2.3, 9.4.2.4, 9.4.2.5, 9.4.2.6.

9.4.2.2 Source for ambient light

A light source with a colour temperature between 3 000 K and 3 200 K shall be used.

9.4.2.3 Type T

The emitter is installed near the stated operating range and moved not faster than 1 mm/s in an axial direction, towards the receiver. The operating range is measured with ambient light value of 5 000 lx (±1 000 lx tolerance).

The light source is positioned at an angle of 5° ± 1° to the reference axis and is aimed at the receiver (see Figure 12a), Type T).

9.4.2.4 Type R

The reflector is installed on the reference axis near the stated operating range r_o.

The device is moved, not faster than 1 mm/s in an axial direction towards the reflector. The operating range is measured with ambient light value of 5 000 lx (±1 000 lx tolerance).

The light source is positioned at an angle of 5° ± 1° to the reference axis and is aimed at the photoelectric proximity switch (see Figure 12b), Type R).

9.4.2.5 Type D

a) For sensing ranges not exceeding 400 mm:

The target (see 9.3.2.1.4) is installed on the reference axis near the stated sensing range s_d;

The light source is positioned at an angle of 15° ± 1° to the reference axis and is aimed at the target (see Figure 12d), Type D);

The device is moved, not faster than 1 mm/s in an axial direction, towards the target and the sensing range is measured with ambient light value of 5 000 lx (±1 000 lx tolerance).

b) For sensing ranges above 400 mm:

The target is installed on the reference axis near the stated sensing range s_d;

The light source is positioned at an angle of 15° ± 1° to the reference axis and is aimed at the device (see Figure 12c), Type D);

The target is moved, not faster than 1 mm/s in an axial direction, towards the device and the sensing range is measured with ambient light value of 5 000 lx (±1 000 lx tolerance).

9.4.2.6 Type D with background suppression

a) For sensing ranges not exceeding 400 mm:

The light source is positioned at an angle of 15° ± 1° to the reference axis and is aimed at the paper target (see Figure 12d), Type D) with the following conditions:

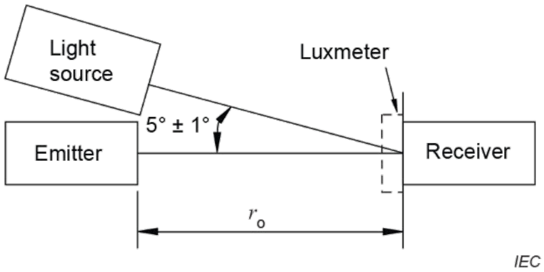
b) For sensing ranges above 400 mm:

The light source is positioned at an angle of 15° ± 1° to the reference axis and is aimed at the device (see Figure 12c), Type D);

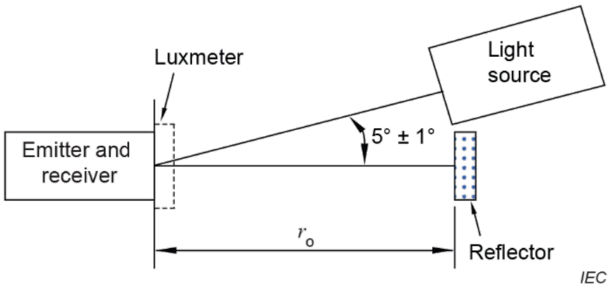
For both ranges a) and b), the sensing range s_d is measured successively with white and black paper target (see 9.3.2.1.4). The paper target is installed on the reference axis near the stated sensing range s_d. The device is moved at moderate speed (not faster than 1 mm/s at the point of switching) in an axial direction, towards the paper target and the sensing range is measured with ambient light value of 5 000 lx (±1 000 lx tolerance).

9.4.2.7 Results to be obtained

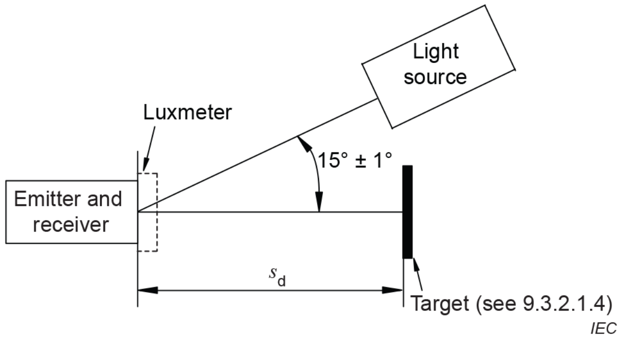
The results of the test for operating range and sensing range shall comply with the values stated by the manufacturer (see 8.2.1.3.5 and 8.2.1.3.6).



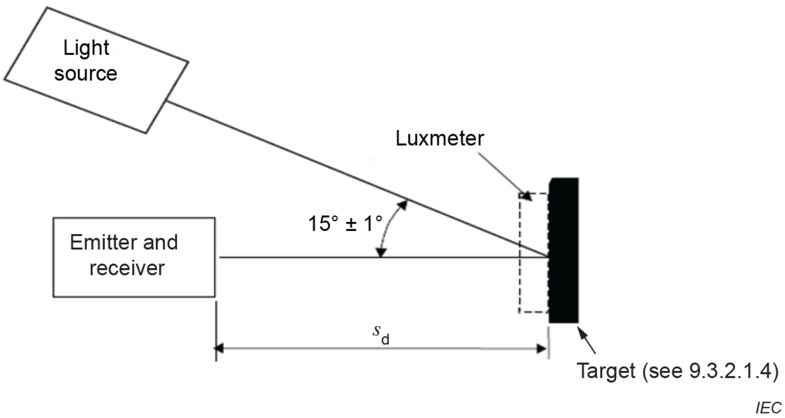
a) Type T, emitter and receiver



b) Type R, emitter-receiver and reflector



c) Type D (and Type D with background suppression) light-source aimed to emitter-receiver



d) Type D (and Type D with background suppression) light-source aimed to target

Figure 12 – Testing of the sensing range (see 9.4.2)

9.4.2.8 Determination of the excess gain values and in case of Type D with background suppression sensing range displacement

a) Type D

The standard target is positioned at the stated sensing distance. The reduction of luminance which is necessary to deactivate the proximity switch is determined with neutral density filters. The excess gain can then be calculated. During the test sequence the element under test (EUT) shall not be adjusted.

b) Type D with background suppression

The standard target is positioned at the stated sensing distance. The reduction of luminance which is necessary to deactivate the proximity switch is determined by moving the target.

The sensing range displacement can then be calculated. During the test sequence the element under test (EUT) shall not be adjusted.

To determine the value of the sensing range displacement, the following steps shall be performed:

– set white target to desired sensing range and adjust/teach the proximity switch to the white target;
– slowly move the white target (not faster than 1 mm/s) away from the EUT (equipment under test) until it is switching off;
– measure the distance W_off between the white target and EUT;
– change target to black and slowly move the target toward the EUT until it is switching on;
– measure the distance B_on between the black target and EUT;
– calculate the sensing range displacement according to Equation (1).

$$\text{Sensing\_range\_displacement} = \frac{\text{W\_off-B\_on}}{\text{B\_on}} \tag{1}$$

W_off → White target, 90 % reflectivity

B_on → Black target, 6 % reflectivity

c) Types R and T

The emitter or the reflector is positioned at the stated operating range. The reduction of luminance which is necessary to activate the proximity switch is determined with neutral density filters. The excess gain is then calculated.

EXAMPLE To determine the distance at which an excess gain of 2 is achieved, a 50 % neutral density filter can be used for Type T, and a 70 % neutral density filter can be used for Types R and, D. The filter shall be as close as possible to the sensing face. In the case of Type D with background suppression, the target shall be adjusted to achieve a sensing range displacement of 0,5 or less.

The neutral density filter measurement technique is the preferred method. Other techniques leading to similar results may be used and shall then be stated by the manufacturer.

NOTE Care is taken to avoid erroneous results due to reflections from the filter.

9.5 Testing for the frequency of operating cycles

9.5.1 General

When the proximity switch frequency of operating cycles exceeds the limit of the measuring method described, the manufacturer shall state the method of measurement.

9.5.2 Method for measuring the frequency of operating cycles

a) Inductive, capacitive and non-mechanical magnetic proximity switches

As shown in Figure 13, the targets are fixed on the front (method 1, Figure 13a)) or sides (method 2, Figure 13b)) of teeth on a rotating disc, the spaces between the teeth being 2*a*, in such a manner that they can pass in front of the sensing face of the proximity switch at a distance equal to half of the rated operating distance.

Each target shall have the same dimensions as those specified in 9.3.2.1. The output signal of the proximity switch is measured with the speed of rotation of the disc increasing from 0.

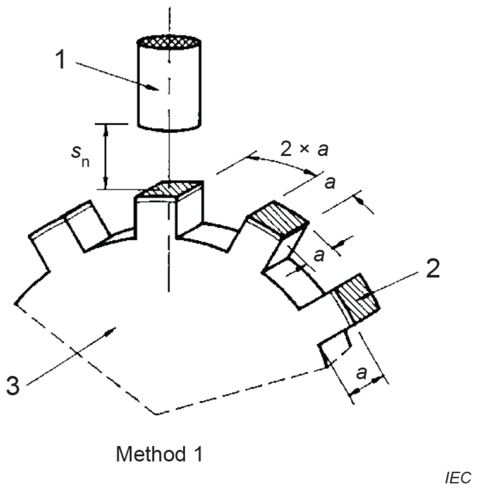
The targets of the rotating disc shall be connected to earth when capacitive proximity switches are tested.

An illustration of the output signal of proximity switches is given in Figure 15.

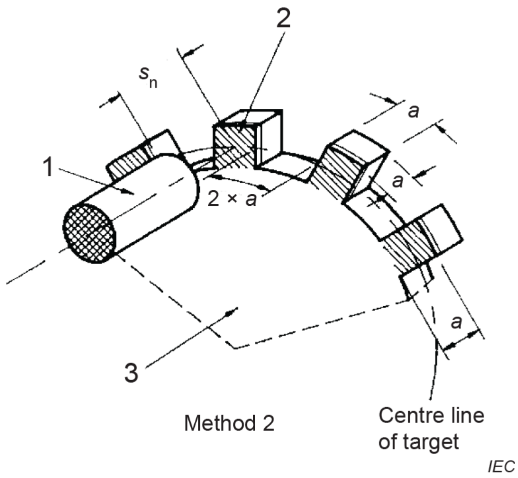
With the speed increasing, the durations t_1 and t_2 decrease.

For direct current proximity switches, the rated value of the frequency of operating cycle is obtained when t_1 or t_2 correspond to 50 µs, or when the characteristics of the output signal, in the "ON" or "OFF" states, reaches the values specified in the relevant annexes.

For alternating current proximity switches, the rated value of the frequency of operating cycle is obtained when either t_1 or t_2 corresponds to one-half period of the supply frequency (f_b).



a) **Method 1 (fixed on front)**



b) **Method 2 (fixed on side)**

Key

1 proximity switch

2 target

3 disc in non-magnetic and non-conducting material

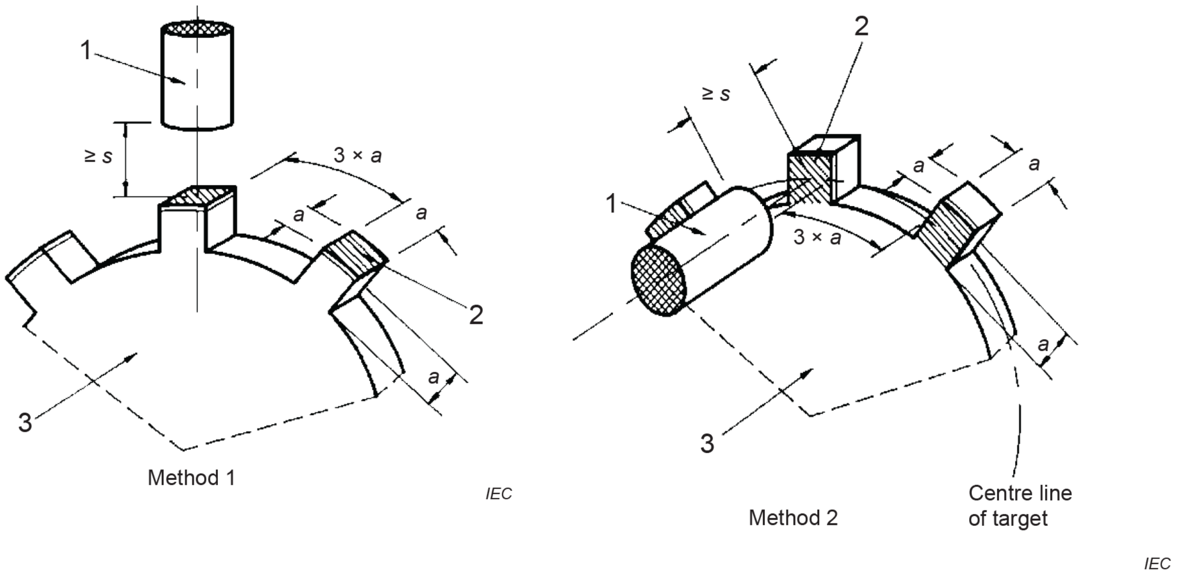
NOTE To avoid angular influence from one target to another, the disc is constructed to include at least 10 targets, if the rated operating distance (s_n) is less than 10 mm, or 6 targets for higher operating distances.

Figure 13 – Methods for measuring the frequency of operating cycle of inductive, capacitive and non-mechanical magnetic proximity switches (if applicable)

b) Ultrasonic proximity switch

As shown in Figure 14, the targets are fixed on the front (method 1, Figure 14a)) or sides (method 2, Figure 14b)) of teeth on a rotating disc.

The spaces between the teeth being 3*a* in such a manner that they can pass in front of the sensing face at the minimum operating distance and the proximity switch shall be adjusted to this operating distance.



a) Method 1 (fixed on front) **b) Method 2 (fixed on side)**

Key

1 proximity switch

2 target

3 disc in non-magnetic and non-conducting material

NOTE 1 To avoid angular influence from one target to another, the disc is constructed to include at least 10 targets.

NOTE 2 Method 2 is only applicable to narrow-beam angled proximity switches.

Figure 14 – Methods for measuring the frequency of operating cycles *(f)*, ultrasonic proximity switch

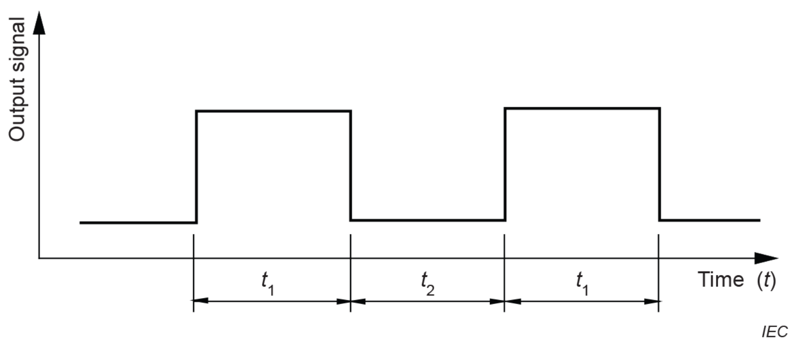


Figure 15 – Output signal of direct current proximity switch during the measurement of frequency of operating cycles *(f)*

The frequency of operating cycle *f* is determined from the following formula: