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Semiconductor devices – Micro-electromechanical devices –
Part 33: MEMS piezoresistive pressure-sensitive device

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SEMICONDUCTOR DEVICES –
MICRO-ELECTROMECHANICAL DEVICES –

Part 33: MEMS piezoresistive pressure-sensitive device

FOREWORD

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International Standard IEC 62047-33 has been prepared by subcommittee 47F: Micro-electromechanical systems, of IEC technical committee 47: Semiconductor devices.

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

FDIS	Report on voting
47F/327FDIS	47F/332/RVD

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

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

A list of all parts in the IEC 62047 series, published under the general title *Semiconductor devices – Micro-electromechanical devices*, can be found on the IEC website.

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

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- withdrawn,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

A bilingual version of this publication may be issued at a later date.

SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 33: MEMS piezoresistive pressure-sensitive device

1 Scope

This part of IEC 62047 defines terms, definitions, essential ratings and characteristics, as well as test methods applicable to MEMS piezoresistive pressure-sensitive device. This document applies to piezoresistive pressure-sensitive devices for automotive, medical treatment, electronic products.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-1, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-10, *Environmental testing – Part 2-10: Tests – Test J and guidance: Mould growth*

IEC 60747-14-3, *Semiconductor devices – Part 14-3: Semiconductor sensors – Pressure sensors*

IEC 60749-2, *Semiconductor devices-Mechanical and climatic test methods – Part 2: Low air pressure*

IEC 60749-6, *Semiconductor devices-Mechanical and climatic test methods – Part 6: Storage at high temperature*

IEC 60749-10, *Semiconductor devices – Mechanical and climatic tests methods – Part 10: Mechanical shock*

IEC 60749-12, *Semiconductor devices – Mechanical and climatic tests methods – Part 12: Vibration, variable frequency*

IEC 60749-13, *Semiconductor devices – Mechanical and climatic test methods – Part 13: Salt atmosphere*

IEC 60749-24, *Semiconductor devices – Mechanical and climatic test methods – Part 24: Accelerated moisture resistance-Unbiased HAST*

IEC 60749-25, *Semiconductor devices – Mechanical and climatic test methods – Part 25: Temperature cycling*

IEC 60749-36, *Semiconductor devices – Mechanical and climatic tests methods – Part 36: Acceleration, steady state*

IEC TR 61000-4-1, *Electromagnetic compatibility (EMC) – Part 4-1:Testing and measurement techniques – Overview of the IEC 61000-4 series*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60747-14-3 and the following apply.

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

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

3.1
MEMS piezoresistive pressure-sensitive device
device that transforms pressure signal into electric signal due to piezoresistive effect, usually including cavity-membrane structure on silicon substrate and Wheatstone bridge in the membrane fabricated by MEMS technology

Key

1 membrane

2 sensitive resistance

3 silicon

4 cavity

Figure 1 – Structure schematic diagram of the device

3.2
frequency response
ratio variation of output to measurand depending on frequency

Note 1 to entry: The frequency response should be based on the given frequency range.

3.3
resonant frequency
frequency at which the device responds with the maximum output amplitude

3.4
ringing frequency
frequency of free oscillations in the transducer output resulting from a step change in measurand

3.5
damping ratio
ratio of the practical damping coefficient to the critical damping coefficient

3.6
rise time
length of time required for the output of the device to rise from 10 % to 90 % of its final steady value when excited by a step change in measurand

3.7
overshoot
amount of output measured beyond the final steady output value in response to a step change in the measurand

4 Essential ratings and characteristics

4.1 Ratings (Limiting values)

The following items should be described in the specification, unless otherwise stated in the relevant procurement specifications. Stresses over these limits can be one of the causes of permanent damage to the devices:

a) power supply voltage;
b) storage temperature;
c) mechanical shock;
d) acceleration;
e) vibration.

4.2 Recommended operating conditions

The following items should be described in the specification, unless otherwise stated in the relevant procurement specifications.

a) power supply voltage;
b) operating temperature.

4.3 Characteristics

Characteristics of the pressure-sensitive devices are listed as shown in Table 1.

Table 1 – Characteristics of the device

Parameter	Mandatory	Optional	Value			Symbol	Test method
			Min	Type	Max		
Input resistance		×		×		R_i	See 5.1
Output resistance		×		×		R_o	See 5.2
Leakage current	×		×		×	I_L	See 5.3
Breakdown voltage		×	×		×	U_b	See 5.4
Isolation voltage		×	×		×	U_s	See 5.5
Output under normal pressure		×	×		×	Y_c	See 5.6.2
Zero output	×		×		×	Y_0	See 5.6.3
Output symmetry		×			×	P_d	See 5.6.4
Full-span output	×			×		$Y^{F \cdot S}$	See 5.6.5
Nonlinearity	×			×		ξ_L	See 5.6.6
Pressure hysteresis	×			×		ξ_H	See 5.6.7
Repeatability	×				×	ξ_R	See 5.6.8
Accuracy	×				×	ξ	See 5.6.9
Sensitivity	×			×		b	See 5.6.10
Zero drift	×				×	D_0	See 5.6.11
Zero long-term stability		×			×	r_z	See 5.7.2

Parameter	Mandatory	Optional	Value			Symbol	Test method
			Min	Type	Max		
Sensitivity long-term stability		×			×	r_s	See 5.7.3
Thermal zero drift	×				×	α	See 5.8.2
Thermal sensitivity drift	×				×	β	See 5.8.3
Thermal zero output hysteresis		×			×	α_H	See 5.8.4
Thermal sensitivity hysteresis		×			×	β_H	See 5.8.5
Temperature hysteresis		×			×	σ	See 5.8.6
Zero static pressure deviation		×			×	p_0	See 5.9.1.2
Full-span output static pressure deviation		×			×	$p_{F\cdot S}$	See 5.9.1.3
Overload	×				×	O_l	See 5.10
Frequency response	×		×		×	F_r	See 5.11.2
Ringing frequency		×		×		w_d	See 5.11.3
Damping ratio		×		×		ζ	See 5.11.4
Rise time		×		×		T_r	See 5.11.5
Resonant frequency	×			×		w_x	See 5.11.6
Overshoot		×			×	O_s	See 5.11.7

5 Test methods

5.1 Input resistance

Measure the resistance value of power supply terminals with the output terminals of device staying open circuited.

5.2 Output resistance

Measure the resistance value of output terminals of device with the power supply terminals staying short circuited.

5.3 Leakage current

5.3.1 P-N junction isolation type sensitive device

Connect the P-N junction isolation type sensitive device according to Figure 2. There are P-N junctions between the sensitive resistance and the silicon substrate. Measure the voltage V of the standard resistance R under the condition of specified bias voltage and no light. Calculate the leakage current according to Formula (1):

$$I_l = \frac{V}{R} \tag{1}$$

where

I_l is the leakage current;

V is the voltage of the standard resistance;

R is the value of the standard resistance.

Choose the bias voltage form the following: 10 V DC, 15 V DC, 20 V DC, 25 V DC, 30 V DC, 35 V DC, 40 V DC.

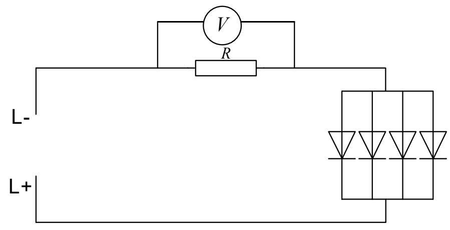
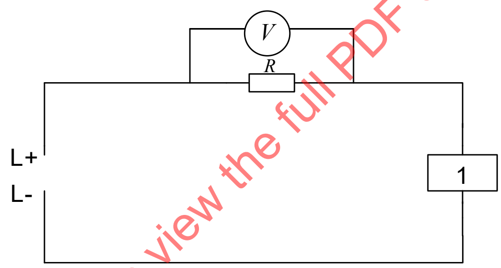


Figure 2 – Test connection graph for P-N junction isolation type sensitive device

5.3.2 Insulating medium type sensitive device

Connect it according to Figure 3. There is an insulating medium between sensitive resistance and silicon substrate. Measure the voltage V of the standard resistance R under the condition of the specified bias voltage and no light. Calculate the leakage current according to Formula (1).



Key

1 insulating medium

Figure 3 – Test connection graph for insulating medium type sensitive device

5.4 Breakdown voltage

Measure the inverse voltage between sensitive resistance and the silicon substrate under the specified test current. Choose the test current form the following: 2 μA, 5 μA, 10 μA, 20 μA, 50 μA.

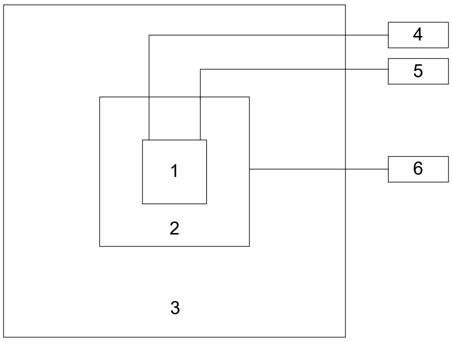
5.5 Isolation voltage

Measure the voltage between sensitive resistance and the silicon substrate under the specified test current. Choose the test current form the following: 1 μA, 2 μA, 5 μA, 10 μA.

5.6 Static performances

5.6.1 Test method

The test system is shown in Figure 4. Turn on the pressure source and control the pressure to be stable at the full-scale pressure for at least 1 minute and then at the zero-scale pressure for at least 1 minute on the condition of 5.2. Recycle this process for 3 times.



Key

1 pressure-sensitive device

2 pressure chamber

3 temperature cabinet

4 power supply

5 data acquisition equipment

6 pressure control system

Figure 4 – Test system

The test points of the device shall be no less than 6 in full range, including full-scale pressure and the zero-scale pressure.

This test shall start from the zero-scale pressure and approach the full-scale pressure (i.e. forward stroke) by increasing load steadily in accordance with the provision. For each testing pressure point, when the pressure is stable, read the output values of the devices on the wafer. Then start from the full-scale pressure and approach the zero-scale pressure (i.e. backward stroke) by decreasing the load steadily in accordance with the provision.

There are m test points in the full-scale pressure range and n cycle tests. Then there are n test data at each point in forward and backward stroke respectively. Calculate the average value of each test point in the forward/backward stroke and the overall average value of each test pressure point in the forward and backward stroke.

The average value during forward stroke of the i^{th} test point $\overline{Y_{\text{U}i}}$,

$$\overline{Y_{\text{U}i}} = \frac{1}{n}\sum_{j=1}^{n} Y_{\text{U}ij} \tag{2}$$

The average value during backward stroke of the i^{th} test point $\overline{Y_{\text{D}i}}$,

$$\overline{Y_{\text{D}i}} = \frac{1}{n}\sum_{j=1}^{n} Y_{\text{D}ij} \tag{3}$$

The overall average value of the forward and backward stroke of the i^{th} test point $\overline{Y_i}$,

$$\overline{Y_i} = \frac{1}{2}\left(\overline{Y_{\text{U}i}} + \overline{Y_{\text{D}i}}\right) \tag{4}$$

where

Y_{Uij} is the output value of the i^{th} test point in the j^{th} forward stroke (i = 1,2,3, …m, j = 1,2,3, …n);

Y_{Dij} is the output value of the i^{th} test point in the j^{th} backward stroke (i = 1,2,3, …m, j = 1,2,3, …n);

n is the number of cycle test.

The working characteristic formula of the device is given as

$$Y = a + bX \tag{5}$$

The intercept a and slope b (i.e. sensitivity) is fitted using least squares method

$$a = \frac{\sum_{i=1}^{m} X_i^2 * \sum_{i=1}^{m} \overline{Y_i} - \sum_{i=1}^{m} X_i * \sum_{i=1}^{m} X_i \overline{Y_i}}{m\sum_{i=1}^{m} X_i^2 - (\sum_{i=1}^{m} X_i)^2} \tag{6}$$

$$b = \frac{m\sum_{i=1}^{m} X_i \overline{Y_i} - \sum_{i=1}^{m} X_i * \sum_{i=1}^{m} \overline{Y_i}}{m\sum_{i=1}^{m} X_i^2 - (\sum_{i=1}^{m} X_i)^2} \tag{7}$$

where

X_i is the pressure value of the i^{th} test point (i=1, 2, 3, …m);

$\overline{Y_i}$ is the overall average value of the i^{th} test point in the forward and backward stroke;

m is the number of test points.

5.6.2 Output under normal pressure

Connect the testing cavity with atmosphere to measure the voltage output of the device and correct the value to standard reference atmosphere pressure (101,3 kPa). Calculate the voltage output under normal pressure with the following equation.

$$Y_c = Y + b(P_c - X) \tag{8}$$

where

Y_c is the voltage output corrected to standard reference atmosphere pressure (101,3 kPa);

Y is the voltage output under the practical atmosphere pressure;

P_c is the standard reference atmosphere pressure(101,3 kPa);

X is the actual atmosphere pressure in the test.

5.6.3 Zero output

For absolute pressure-sensitive device, measure the output of the device under the input pressure within 10 Pa. For differential pressure device, measure the output with both high and low pressure terminals connected to the atmosphere.

5.6.4 Output symmetry

Measure the full-span output of the device in the high pressure terminal and the low pressure terminal respectively or positive pressure section and negative pressure section of the device. Calculate the output symmetry under normal pressure with the following equation.

$$P_d = \frac{Y_{F\cdot S}(h) - Y_{F\cdot S}(l)}{Y_{F\cdot S}(h)} \times 100\% \quad (9)$$

where

P_d is output symmetry;

$Y_{F\cdot S}(h)$ is the full-span output of the device in the high pressure terminal;

$Y_{F\cdot S}(l)$ is the full-span output of the device in the low pressure terminal.

5.6.5 Full-span output

The full-span output value of the device is the absolute difference between the outputs of full-scale pressure and zero-scale pressure in measure range, based on the calculated value of theoretical working characteristic formula. The full-span output value $Y_{F\cdot S}$ is given as

$$Y_{F\cdot S} = b \times (X_H - X_L) \quad (10)$$

where

b is the slope of theoretical working characteristic formula, i.e. sensitivity;

X_H, X_L are the full-scale pressure and zero-scale pressure value in measure range, respectively.

5.6.6 Nonlinearity

Nonlinearity describes the deviation extent between the measure curve and a specific straight line. The nonlinearity ξ_L is given as

$$\xi_L = \frac{\left|\overline{Y_i} - Y_i\right|_{max}}{Y_{F\cdot S}} \times 100\% \quad (11)$$

where

$\overline{Y_i}$ is the overall average value of the forward and backward stroke of the i^{th} test point given by Formula (4);

Y_i is the value calculated by Formula (5);

$Y_{F\cdot S}$ is the full-span output value given by Formula (10).

5.6.7 Pressure hysteresis

Hysteresis is the maximum difference between the outputs of the same testing point when increasing and decreasing pressure within the range. The hysteresis ξ_H is given as

$$\xi_H = \frac{\left|\overline{Y_{Ui}} - \overline{Y_{Di}}\right|_{max}}{Y_{F\cdot S}} \times 100\% \quad (12)$$

where

$\overline{Y_{Ui}}$ is the average value of the i^{th} test point during forward stroke, given by Formula (2);

$\overline{Y_{Di}}$ is the average value of the i^{th} test point during backward stroke, given by Formula (3);

$Y_{F\cdot S}$ is the full-span output value given by Formula (10).

5.6.8 Repeatability

Repeatability is defined to describe the consistency of many testing results for the same measurand under all the following circumstances:

a) same testing method;
b) same tester;
c) same testing devices;
d) same location;
e) same working/testing condition;
f) repeated testing within a short period.

The repeatability ξ_R is derived from Formulae (13) to (16). Use the Bessel formula to calculate standard deviation of each testing point in forward/ backward stroke.

The standard deviation of the i^{th} test point in forward stroke S_{Ui} is

$$S_{Ui} = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}(Y_{Uij} - \overline{Y_{Ui}})^2} \tag{13}$$

The standard deviation of the i^{th} test point in backward stroke S_{Di} is given as

$$S_{Di} = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}(Y_{Dij} - \overline{Y_{Di}})^2} \tag{14}$$

The standard deviation S of the device among the full testing range is given as

$$S = \sqrt{\frac{1}{2m}(\sum_{j=1}^{m} S_{Ui}^2 + \sum_{j=1}^{m} S_{Di}^2)} \tag{15}$$

The repeatability ξ_R is given as

$$\xi_R = \frac{\lambda S}{Y_{F\cdot S}} \times 100\% \tag{16}$$

where

Y_{Uij} is the output value of the i^{th} test point in j^{th} forward stroke (i=1,2,3, …m, j=1,2,3, …n);

Y_{Dij} is the output value of the i^{th} test point in j^{th} backward stroke (i=1,2,3, …m, j=1,2,3, …n);

$\overline{Y_{Ui}}$ is the average value of the i^{th} test point during all forward strokes;

$\overline{Y_{\mathrm{D}i}}$ is the average value of the i^{th} test point during all backward strokes;

n is the number of cycle test;

m is the number of test points;

λ is the coverage factor, which should be given by the method presented in 6.3 of ISO/IEC Guide 98-3:2008.

5.6.9 Accuracy

Accuracy is defined to describe the consistency between testing result and (conventional) true value of the device. In addition, the accuracy is determined by systematic error range and random error range, which is derived from Formulae (16) to (19).

Systematic error during forward stroke $(\Delta Y)_{\mathrm{U}i}$,

$$(\Delta Y)_{\mathrm{U}i} = \left|\overline{Y_{\mathrm{U}i}} - Y\right|_{\max} \tag{17}$$

Systematic error during backward stroke $(\Delta Y)_{\mathrm{D}i}$,

$$(\Delta Y)_{\mathrm{D}i} = \left|\overline{Y_{\mathrm{D}i}} - Y\right|_{\max} \tag{18}$$

where

Y is the value calculated by Formula (5).

Define U_1 to be the larger one between $(\Delta Y)_{\mathrm{U}i}$ and $(\Delta Y)_{\mathrm{D}i}$. And the random error range of sensitive device U_2 is given as

$$U_2 = \pm 3S \tag{19}$$

The accuracy of the device is given as

$$\xi = \pm \frac{|U_1| + |U_2|}{Y_{\mathrm{F \cdot S}}} \times 100\% \tag{20}$$

5.6.10 Sensitivity

The slope b given by Formula (7) is defined as sensitivity.

5.6.11 Zero drift

Read and record the zero output value of sensitive device every 20 min for at least 2 h following the test method in 5.6.3. And the zero drift D_0 is given as

$$D_0 = \frac{|Y_{\max} - Y_{\min}|}{Y_{\mathrm{F \cdot S}}} \times 100\% \tag{21}$$

where

$Y_{\max}$ is the maximum value of zero output;

$Y_{\min}$ is the minimum value of zero output.

5.7 Stability

5.7.1 Test method

The power supply of the device should be turned on for 4 h or more every month. The device should be calibrated for 3 cycles or more.

5.7.2 Zero long-term stability

Zero long-term stability should be the ratio of the maximum difference of zero output to the full-span output during the stability test period. And the zero long-term stability is given as Formula (22).

$$r_z = \frac{|\Delta Y_0|_{max}}{Y_{F \cdot S}} \times 100\% \tag{22}$$

where

$|\Delta Y_0|_{max}$ is the maximum difference of zero output during the stability test period;

$Y_{F \cdot S}$ is the full-span output.

5.7.3 Sensitivity long-term stability

Sensitivity long-term stability should be the ratio of the maximum difference of full-span output to the full-span output during the stability test period. And the sensitivity long-term stability is given as Formula (23).

$$r_s = \frac{|\Delta Y_{F \cdot S}|_{max}}{Y_{F \cdot S}} \times 100\% \tag{23}$$

where

$|\Delta Y_{F \cdot S}|_{max}$ is the maximum difference of full-span output during the stability test period;

$Y_{F \cdot S}$ is the full-span output.

5.8 Temperature influence

5.8.1 Test method

Perform the test cycle for three times sequentially under room temperature, the upper limit of operating temperature, the lower limit of working temperature, and then back to the same room temperature. Maintain each temperature for 1 h and test zero output, as well as full-span output of the devices.

Measure the output of the device in the same pressure and at different temperature. The test points of the device shall be no less than 6 in operating temperature range, including room temperature, the upper limit of working temperature, the lower limit of working temperature. This test shall start from the lowest temperature of the range and approach the highest temperature by increasing load steadily in accordance with the provision. For each testing point, when the temperature is stable, read the output values of the device. Then start from the highest temperature and approach the lowest temperature by decreasing the load steadily in accordance with the provision.

The performance index shall be calculated in accordance with 5.11.2 to 5.11.6.

5.8.2 Thermal zero drift

Thermal zero drift α is given as

$$\alpha = \frac{Y_0(t_2) - Y_0(t_1)}{Y_{F\cdot S}(t_1)(t_2 - t_1)} \times 100\%\text{F}\cdot\text{S}/℃ \tag{24}$$

where

t_1 is room temperature;

t_2 is the upper or lower limit of working temperature;

$Y_0(t_1)$ is zero output under room temperature;

$Y_0(t_2)$ is zero output under the upper or lower limit of operating temperature;

$Y_{F\cdot S}(t_1)$ is full- span output under the room temperature for the first time.

5.8.3 Thermal sensitivity drift

The thermal sensitivity drift β is given as

$$\beta = \frac{Y_{F\cdot S}(t_2) - Y_{F\cdot S}(t_1)}{Y_{F\cdot S}(t_1)(t_2 - t_1)} \times 100\%\text{F}\cdot\text{S}/℃ \tag{25}$$

where

t_1 is room temperature;

t_2 is the upper or lower limit of operating temperature;

$Y_{F\cdot S}(t_1)$ is full-span output under the room temperature;

$Y_{F\cdot S}(t_2)$ is full-span output under the upper or lower limit of operating temperature.

5.8.4 Thermal zero output hysteresis

The thermal zero output hysteresis α_H is given as

$$\alpha_H = \frac{Y_0(t_3) - Y_0(t_1)}{Y_{F\cdot S}(t_1)} \times 100\%\text{F}\cdot\text{S} \tag{26}$$

where

$Y_0(t_1)$ is zero output under room temperature before the thermal cycles;

$Y_0(t_3)$ is zero output under the same room temperature after thermal cycles;

$Y_{F\cdot S}(t_1)$ is full-span output under the room temperature before the thermal cycles.

5.8.5 Thermal sensitivity hysteresis

The thermal sensitivity hysteresis β_H is given as

$$\beta_H = \frac{Y_{F\cdot S}(t_3) - Y_{F\cdot S}(t_1)}{Y_{F\cdot S}(t_1)} \times 100\%\text{F}\cdot\text{S} \tag{27}$$

where

$Y_{F\cdot S}(t_1)$ is full-span output under room temperature before thermal cycles;

$Y_{F\cdot S}(t_3)$ is full-span output under room temperature after thermal cycles.

5.8.6 Temperature hysteresis

Temperature hysteresis is the maximum difference between the outputs of the same testing point when increasing and decreasing temperature within the range. The temperature hysteresis σ is given as

$$\sigma = \frac{|Y_{si} - Y_{ri}|_{\max}}{Y_{F \cdot S}} \times 100\% \tag{28}$$

where

Y_{si}、Y_{ri} are the outputs of the i^{th} test point when increasing and decreasing temperature respectively;

$Y_{F \cdot S}$ is the full-span output value given by Formula (10).

5.9 Static pressure influence

5.9.1 Two way static pressure

5.9.1.1 Maximum static pressure

The high and low pressure terminals should be connected to the maximum static pressure for 5 min. Then measure the zero output 10 min after unloading the pressure.

5.9.1.2 Zero static pressure deviation

Zero static pressure deviation is the percentage based on the change in zero output of the device between loaded the static pressure and unloaded the static pressure divided by full-span output. For differential pressure device, measure the output with both high and low pressure terminals connected to the atmosphere. The high and low pressure terminals should be connected to the zero static pressure for 5 min, then measure the output. The zero static pressure deviation is given as

$$p_0 = \frac{Y_0(p) - Y_0}{Y_{F \cdot S}} \times 100\% \tag{29}$$

where

p_0 is zero static pressure deviation;

$Y_0(p)$ is zero output of the device loaded the static pressure deviation;

Y_0 is zero output of the device loaded the atmosphere;

$Y_{F \cdot S}$ is the full-span output.

5.9.1.3 Full-span output static pressure deviation

The full-span output static pressure deviation is the percentage based on the change in full-span output of the device between the loaded static pressure and the unloaded static pressure divided by the full-span output of static performance. Measure the difference between the output under the zero-scale pressure and the output under the full-scale pressure in the range. The difference is the full-span output. The high and low pressure terminals should be connected to the maximum static pressure for 5 min. Then the high pressure terminal should be connected to the full-scale pressure and the zero-scale pressure respectively, and measure the difference of the output. The full-span output static pressure deviation is given as Formula (30).

The high and low pressure terminals should be connected to 50 % of the maximum static pressure for 5 min. Then the high pressure terminal should be connected to the full-scale pressure and the zero-scale pressure respectively, and measure the difference of the output. The full-span output static pressure deviation of the device loaded 50 % of the maximum static pressure is given as Formula (30).

The maximum value of the full-span output static pressure deviation above is the full-span output static pressure deviation.

$$p_{\mathrm{F\cdot S}} = \frac{Y_{\mathrm{F\cdot S}}(p) - Y_{\mathrm{F\cdot S}}(0)}{Y_{\mathrm{F\cdot S}}} \times 100\% \qquad (30)$$

where

$p_{\mathrm{F\cdot S}}$ is the full-span output static pressure deviation;

$Y_{\mathrm{F\cdot S}}(p)$ is the full-span output of the device loaded the 100% or 50% of the maximum static pressure;

$Y_{\mathrm{F\cdot S}}(0)$ is the full-span output of the device loaded the atmosphere;

$Y_{\mathrm{F\cdot S}}$ is the full-span output of the static performance.

5.9.2 Unidirectional static pressure

The high pressure terminal should be connected to the positive static pressure for 5 min. Then measure the zero output 10 min after unloading the pressure.

The high pressure terminal should be connected to the negative static pressure for 5 min. Then measure the zero output 10 min after unloading the pressure.

5.10 Overload

Load the overload pressure for 3 min. Then measure the zero output 10 min after unloading the pressure.

5.11 Dynamic performance

5.11.1 Test method

Test the dynamic performance according to one of the following methods.

a) transient excitation method

Connect the device with shock tube or fast opening valve. Generate the negative step pressure signal by blast film generator for the negative device. The rise time of the step pressure should be less than 1/3 of the rise time for the device.

When the excitation device generates the step signal, record the response wave form by transient recorder. Then analyse the wave form and get the dynamic performance parameter.

b) sinusoidal excitation method

Test the frequency response of the device for 100 MPa peak dynamic pressure and less than a few thousand Hertz frequency by the sinusoidal pressure generator. If the resonance frequency of the device is in the frequency range of sinusoidal pressure generator, the resonance frequency and the damping ratio should be tested.

The standard transducer is mounted to sinusoidal pressure generator. The dynamic performance for the standard transducer should be superior by 2 times in comparison with it of the device.

5.11.2 Frequency response

The amplitude-frequency response curve of the device will be acquired by the transient excitation method or the sinusoidal excitation method. The frequency range needed will be read by the amplitude-frequency response curve.

5.11.3 Ringing frequency

The output should be tested when the measurand shall be step variable, see Figure 5. Ringing frequency is given as

$$w_{\mathrm{d}} = \frac{2\pi N}{t} \tag{31}$$

where

t is the time of N oscillation wave.

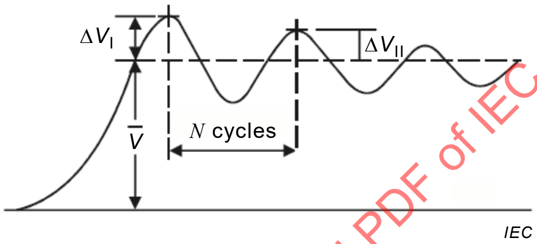


Figure 5 – The output wave

5.11.4 Damping ratio

a) The amplitude-frequency response curve should be got by sinusoidal excitation method. The damping ratio is given as

$$\zeta = \left(\frac{1-\sqrt{1-1/A_{\mathrm{r}}^{2}}}{2}\right)^{\frac{1}{2}} \tag{32}$$

where

A_{r} is the amplification factor (the ratio of the output amplitude to the input amplitude) of a resonance on the amplitude-frequency response curve.

b) The output wave of the device should be got by transient excitation method, as shown in Figure 5.

$$\zeta = \left[1+\left\{\frac{2.728}{\log_{10}\left(\frac{\Delta V_1}{\Delta V_2}\right)}\right\}^{2}\right]^{-1/2} \tag{33}$$

where

ΔV_1 and ΔV_2 are the peak incremental voltages above the average value $\bar{V}$ at the beginning and end of N = 1 cycle.