DYNAMIC MECHANICS
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dm2 application sheet

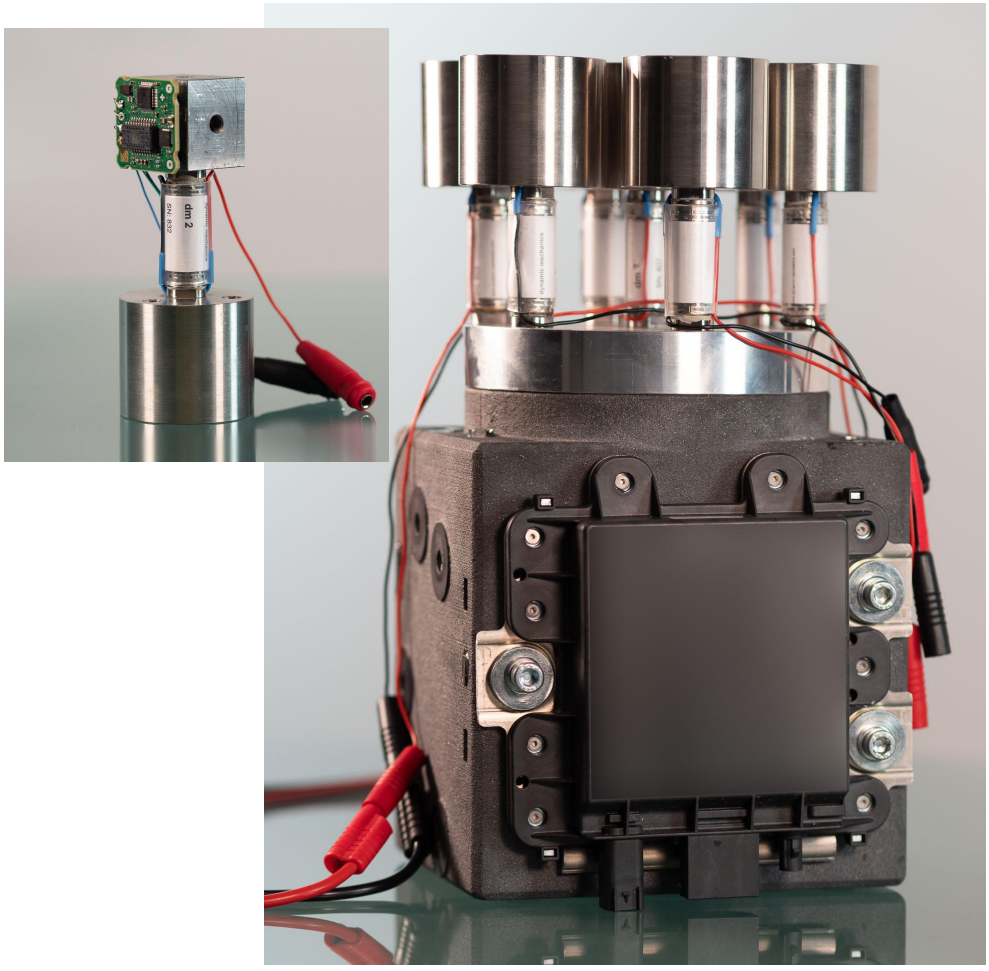

Table of content

1 Introduction

dm 2 is specially designed for the demands of high frequency vibration testing. The vibration exciter makes use of the piezoelectric effect. Due to the unique modular design different exciter setups are possible. So one can use the basic exciter in **different mechanical configurations (e.g. parallel / serial)** to adjust the exciter performance to the testing demand.

2 Theory of operation

Piezoelectric modal exciters consist of three main components: actuator, reaction mass and DUT with fixture (payload). This setup is analogue to a Two-Mass-Oscillator with its natural resonant frequency (schematic see Figure 1, example see Figure 3).

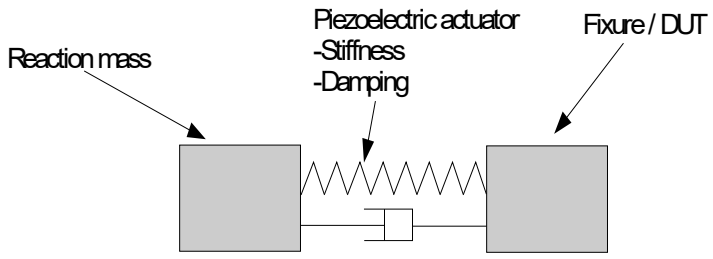

Figure 1: Schematic of a piezoelectric modal exciter

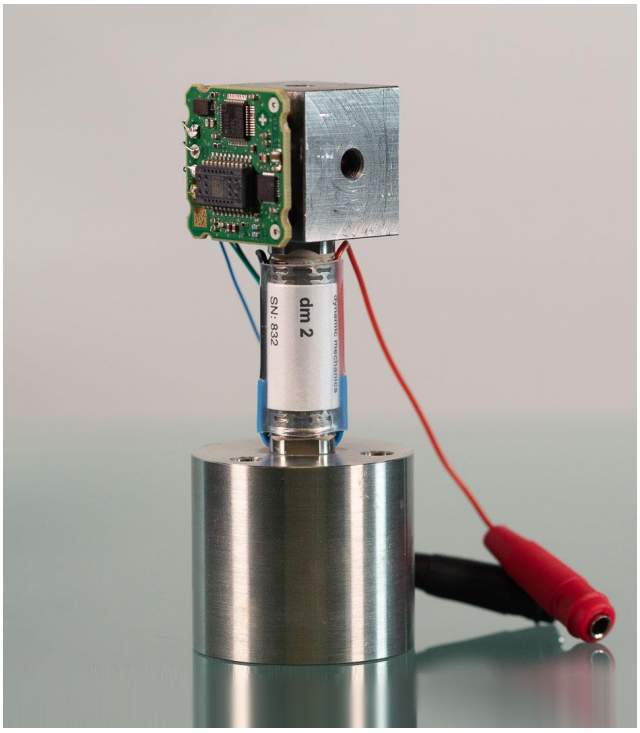

Figure 2: Example of a piezoelectric modal exciter

The transfer function of this kind of drives looks typically as shown in Figure 3.

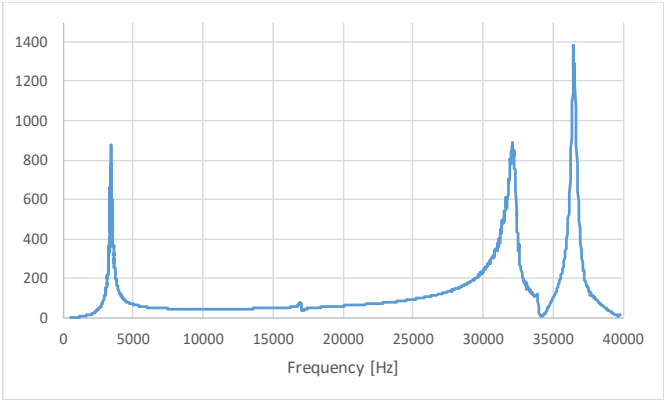

Figure 3: Transfer function of piezoelectric modal exciter [m/s² / Drive Voltage]

The lower resonance frequency (in the example approx. 3 kHz) is created by the resonance of the two-mass-oscillator. This frequency can be estimated by the following equation.

$$\omega_0 = \sqrt{c \frac{(m_{reactionmass} + m_{DUT})}{(m_{reactionsmass} \cdot m_{DUT})}}$$

Below this frequency the performance of the exciter is limited by the maximum stroke, above this frequency by the maximum force. By choosing the corresponding mass / stiffness relation one can influence the resonant frequency of the system.

The higher resonances (in the example approx. 33 kHz and 37 kHz) are caused by modal frequencies of reaction mass or fixure / DUT. In Figure 4 the modal frequency of a reaction mass is shown.

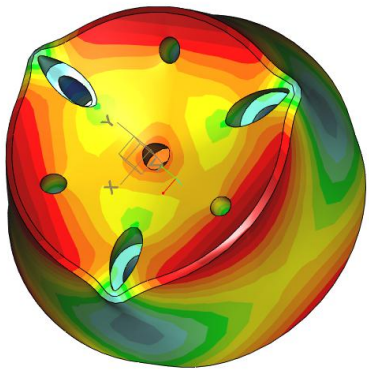

Figure 4: Modal frequency of reaction mass at 37 kHz

By choosing size and material of the corresponding masses the upper frequency limit of the piezoelectric modal exciter can be influenced.

3 Basic technical Data

dm2 bases on a piezoelectric actuator (Figure 5) with the following technical data

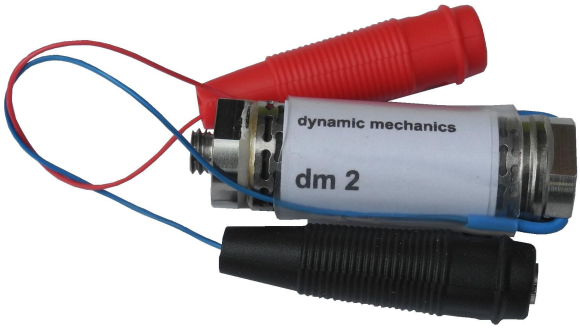

Figure 5: dm2 - bare actuator

- Maximum force: 100 N / 400 N (contineous / intermittend)
- Lower frequency: typical 2 kHz ... 8 kHz (depending on reaction mass and fixure / DUT)
- Upper frequency: typical 40 kHz (free of resonances)
- Working temperature: -40 °C ... 120 °C
- Mechanical Interfaces: M6 x 1 thread / stud

4 Application examples

4.1 Modal excitation

Dynamic gear wheel analysis

Task:

- Reducing the high frequency sound emissions of gear wheel
- Investigation of modal properties of gear wheels using Laser Vibrometry
- state of the art impact hammers not suitable > 10 kHz (poor coherency)
- usage of **dm2** brings strong improvement

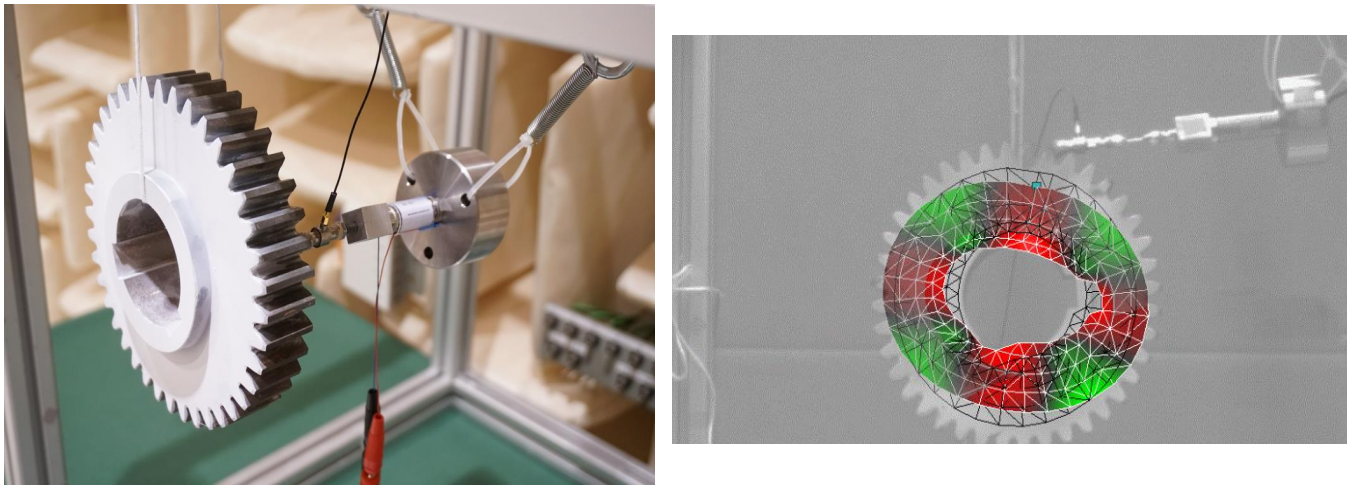

Figure 6: Excitation of gear wheel with dm2 – laser scanning vibrometry

Technical Data

- Frequency range: 1 kHz ... 30 kHz
- Excitation: sine chirp
- Force: 100 N

Modal analysis of a car Body

Task:

- investigation of mounting conditions for automotive IMU sensor
- broad band vibration excitation with dm2

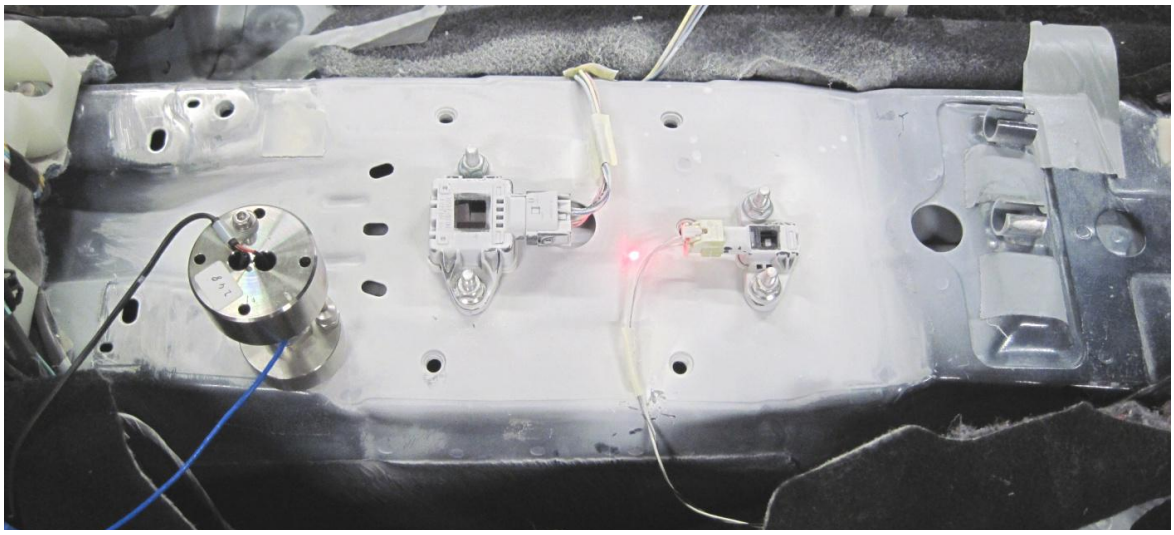

Figure 7: Excitation of a car body

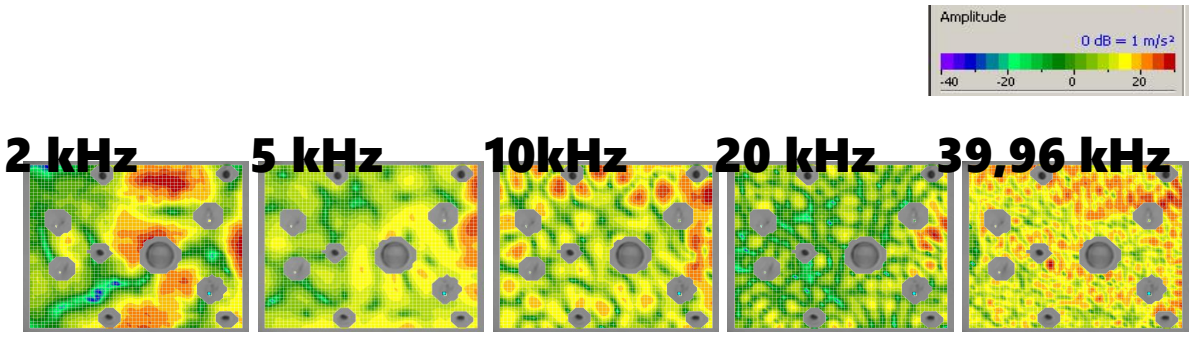

Figure 8: Results of Laser scanning vibrometry

Technical Data

- Frequency range: 2 kHz ... 30 kHz
- Excitation: Noise
- Force: 100 N

4.2 Vibration Excitation

Single actuator

Task:

- Test of vibration resistance / sensitivity in **high frequency** range with **high g-level** in **extended temperature range**
- typical DUT: MEMS Sensors (automotive / consumer), switches, connectors, ...
- in plane / out of plane tests

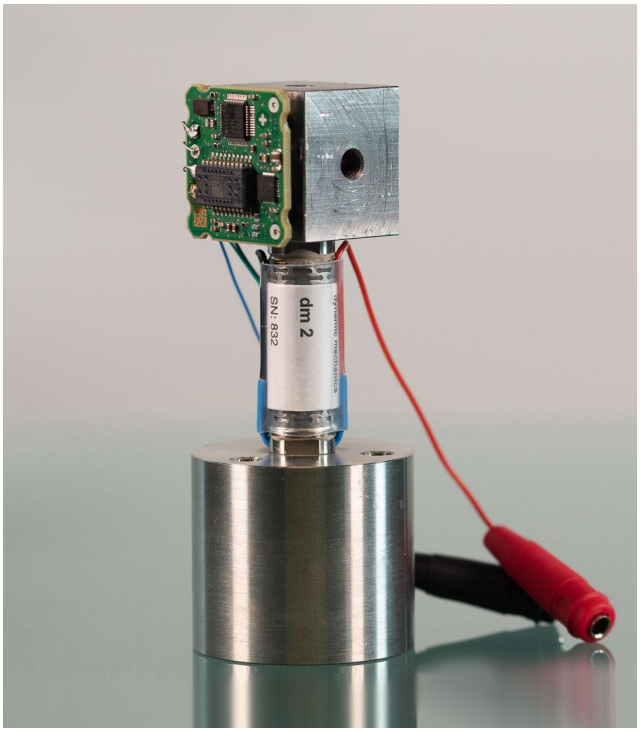

Figure 9: Single actuator test with dm2

Figure 10: dm2 in temperature chamber

Technical Data

- Frequency range: 2 kHz ... 40 kHz (depending on reaction mass and fixture / DUT)
- Maximum force: 100 N / 400 N (continuous / intermittend)
- Maximum acceleration: 1000 m/s² (100 Gramm fixture / DUT mass, continuous operation)
- Working temperature: -40 °C ... 120 °C

Parallel actuator

Task:

- Test of **big DUT** in **high frequency** range with **high g-level** in **extended temperature range**
- Test of **high number of small DUT** in **high frequency range** with **high g-level** in **extended temperature range**
- In plane / out of plane tests

Solution:

- **parallel usage of dm2**
- Design of DUT fixture using FEM / high performance materials (e.g. ceramics)
- calculation of necessary number of actuators

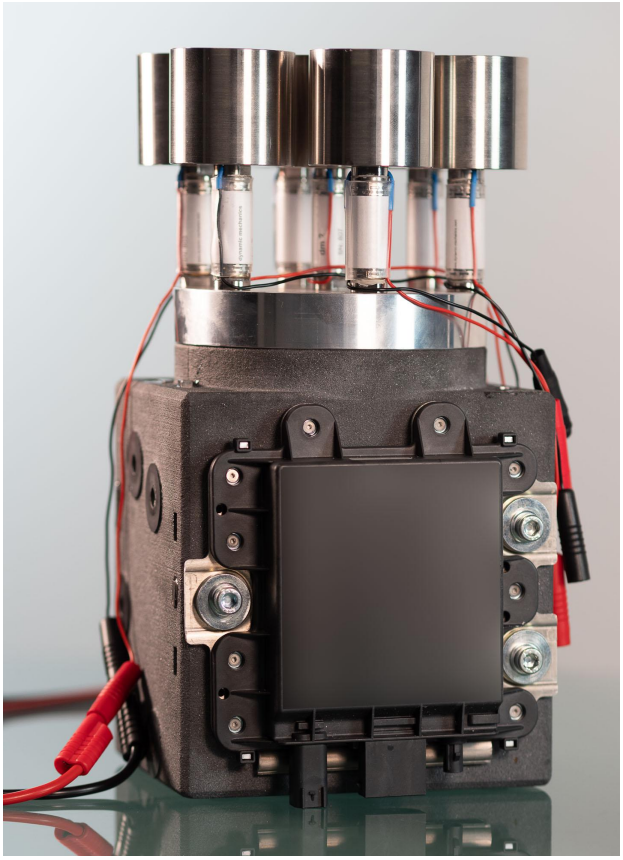

Figure 11: Automotive ECU Test - 7 pcs. of dm2 on a ceramic fixture

Technical Data

- Fixture: 150 x 150 x 150 mm, 3D printed ceramics, 6 kg
- In Plane / Out of plane excitation of DUT
- Frequency range: 1 kHz ... 30 kHz
- Maximum force: 700 N (continuous)
- Maximum acceleration: 140 m/s² pk

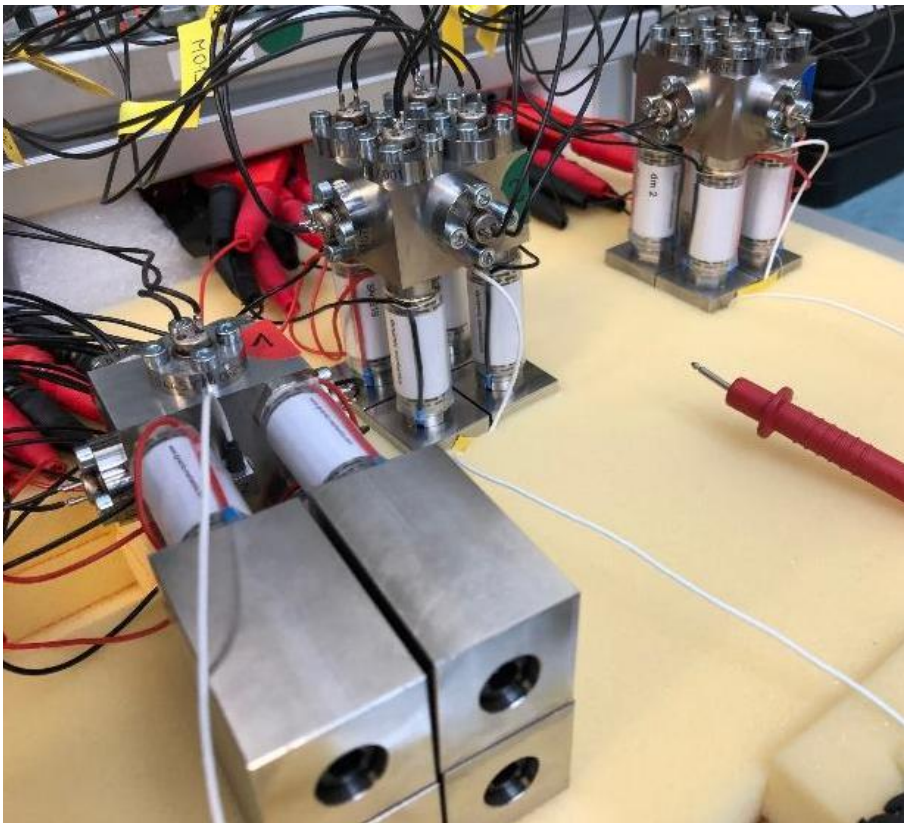

Figure 12: Endurance testing of electrical connectors – 4 pcs. of dm2 /courtesy: Robert Bosch GmbH/

Technical Data

- Fixture: 40 x 40 x 40 mm, steel, 500 Gramms
- In Plane / Out of plane excitation of DUT
- Frequency range: 4 kHz ... 40 kHz
- Maximum force: 400 N (continuous)
- Maximum acceleration: 800 m/s²

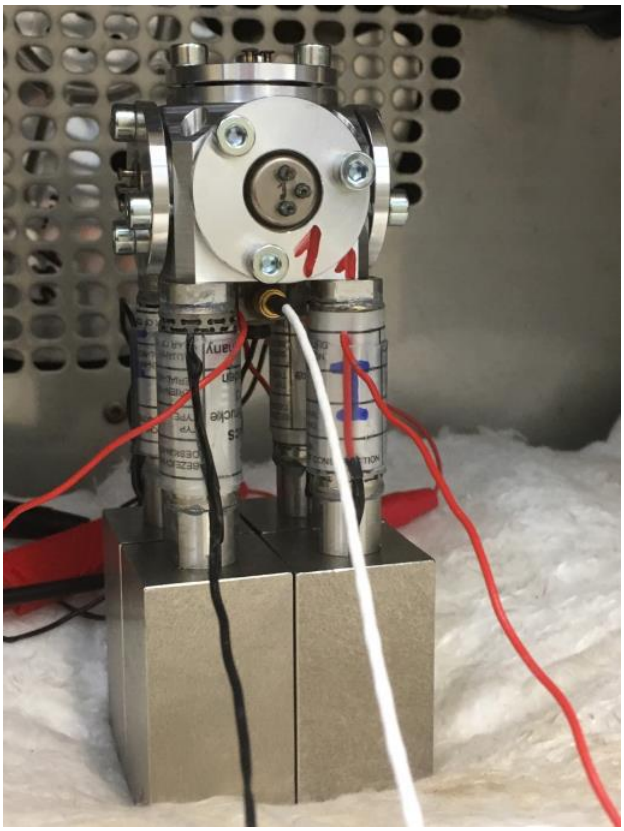

Figure 13: Endurance testing of automotive sensor with high g-level and high temperature 4 pcs. of dm2 /courtesy: Robert Bosch GmbH/

Test conditions:

- acceleration level: **3000 m/s²** using the resonance frequency of the two-mass-oscillator
- temperature: **> 100 °C**
- test time: **> 1000 h**

General technical Data

- Fixture: aluminium, total mass: 250 Gramms
- In Plane / Out of plane excitation of DUT
- Frequency range: 5 kHz ... 40 kHz
- Maximum force: 400 N (continuous)
- Acceleration: 1600 m/s²

Multi Axis Testing

Task:

- 3D excitation in high frequency range with high g-level

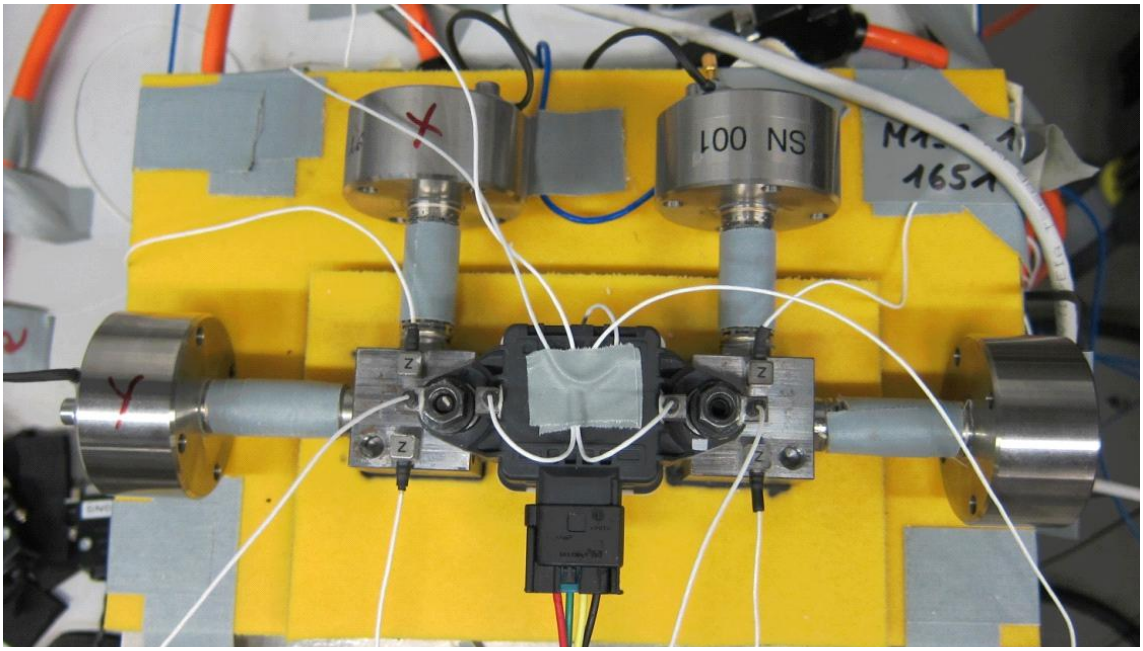

Figure 14: 3D Excitation of IMU Sensor – 6 pcs. of dm2 /courtesy: Robert Bosch GmbH/

Technical Data

- Fixture: 20 x 20 x 20 mm, steel, 200 Gramms
- 3 actuators / fixture
- simultaneous / sequential stimulation of DUT possible
- Frequency range: 4 kHz ... 40 kHz
- Maximum force: 100 N / 400 N (continuous / intermittend)
- Maximum acceleration: 500 m/s² / 2000 m/s² (continuous / intermittend)