Keysight Technologies
Improving the Test Efficiency of MEMS Capacitive Sensors Using the E4980A Precision LCR Meter

Application Note
Introduction

- Exceptional accuracy and repeatability
- DC bias function up to 40 V (Option 001)
- High-speed measurement, scanner interface (Option 301)

This application brief describes the features of the Keysight Technologies, Inc. E4980A and how it can dramatically improve the test efficiency of MEMS capacitive sensors.
Keysight E4980A Precision LCR Meter

The Keysight E4980A Precision LCR Meter with extremely high accuracy and speed is an ideal tool for research and development, as well as manufacturing test.

MEMS Capacitive Sensor

For a MEMS sensor such as a pressure sensor or accelerometer sensor, one of the major methods to detect mechanical displacement is one that detects the capacitance change caused by mechanical displacement (Figure 2). A capacitor is micro-fabricated on the substrate and displacement of the capacitor electrodes is detected as capacitance change.

High-Accuracy Measurement of Sensor Capacitance

The capacitance of a MEMS capacitive sensor needs to be measured in precise sub-femto farad resolution because the capacitance change of the actuator is very small as its position changes very slightly. Therefore, capacitance measurement requires an instrument with very high measurement accuracy and repeatability.

The Keysight E4980A Precision LCR Meter has the ability to measure capacitance with atto-farad order repeatability (σ<1 fF). This instrument is the ideal tool for testing MEMS capacitive sensors. Also the E4980A can test the capacitance without being affected by any resonances of the MEMS structures, as the frequency range up to 2 MHz is far enough away from the resonant frequency (generally up to 10s of kHz) of the mechanical structure such as a movable electrode (see Figure 3).

![Figure 2. Principle operation of a MEMS capacitive sensor](image)

![Figure 3. Superb repeatability of the E4980A](image)
Efficient Evaluation Method Without Physical Stimulus Test

MEMS capacitive sensors detect physical quantities such as pressure and acceleration. Generally, testing MEMS sensors by inducing physical stimulus such as pressure is ideal but leads to test efficiencies. Replacing physical stimulus test with electrical test in the manufacturing process can improve the test throughput.

For a capacitive sensor, applying DC voltage to the capacitor generates an electrostatic force between the electrodes, which changes the distance between the electrodes (capacitance). Measuring capacitance with the DC voltage sweep is faster than the physical stimulus test. This can improve the manufacturing test efficiency once the relationship between physical quantities such as pressure and acceleration and the DC voltage applied are known in advance by:

- modeling the device
- sampling devices and evaluating capacitance versus physical quantity and capacitance versus applied voltage for the same device (See Figure 4)

Figure 5 shows an example of capacitive sensor characteristics.

NOTE: This method is available for displacement of up to approximately 1/3 of the distance between electrodes when no signal is input.

The Keysight E4980A Precision LCR Meter (with Option 001) applies up to 40-V DC bias voltage with high accuracy and performs DC sweep measurement up to 201 points, which is very effective for improving throughput.
High-Speed Measurement Maximizes Manufacturing Test Throughput

Throughput is always a major issue in the manufacturing test process. The Keysight E4980A Precision LCR Meter achieves a measurement speed that is five times as fast as the legacy Keysight 4284A, which improves test productivity in both design and manufacturing. In addition, the 128-channel scanner interface option (Figure 6) maximizes the test throughput without sacrificing the measurement accuracy. The instrument has all compensated data up to 128 channels so it can quickly get the corrected measured data inside the instrument. This also dramatically improves the total throughput because users do not need to take the extra time of transferring measured data and corrected data back and forth between an external controller and the instrument.

Summary

The Keysight E4980A Precision LCR Meter, which provides high accuracy and repeatability as well as high-speed measurements, is the ideal measurement instrument for testing and evaluating MEMS capacitive sensors. With up to 40-V DC bias (Option 001) and the 128-channel scanner interface (Option 301), test productivity in design and manufacturing can be improved.

For more information, please refer to the following literature and websites:
- Keysight E4980A Brochure (P/N 5989-4235EN)
- Keysight E4980A Data Sheet (P/N 5989-4435EN)
- Keysight Technologies Impedance Measurement Handbook (P/N 5950-3000)
- MEMS/NEMS Device Measurement Solution: www.keysight.com/find/mems
- Keysight E4980A Precision LCR Meter: www.keysight.com/find/e4980a
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