

## Improving Test Efficiency of MEMS Electrostatic Actuators Using the Agilent E4980A Precision LCR Meter

- Application Note
- ▶ Highly accurate and repeatable measurements
  - ▶ DC bias function up to 40 V (Option 001)
  - ▶ High-speed measurement, scanner interface (Option 301)



Figure 1. Agilent E4980A Precision LCR Meter

## Introduction

This application brief describes how the Agilent E4980A can greatly improve the test efficiency of MEMS electrostatic actuators.

## Agilent E4980A Precision LCR Meter

The Agilent E4980A Precision LCR Meter, with exceptional accuracy and speed, is the ideal tool for research and development, as well as manufacturing test.

## MEMS Electrostatic Actuator

The electrostatic actuator is one of the major actuators used for MEMS devices such as DLPs and optical switches. Electrostatic force created by applied voltage to the electrodes moves the movable part. It is possible to drive the movable part by creating the capacitor on the substrate by micromachining and applying voltage to the capacitor's electrodes. For the shape of electrodes, comb electrodes are popular as well as parallel-plate electrodes and the principle of operation is common for both electrodes.

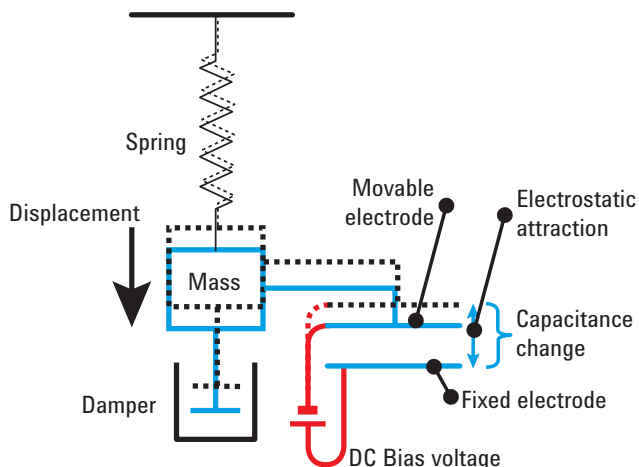


Figure 2. Principle operation of a MEMS capacitance sensor

## Highly Accurate Actuator Capacitance Measurements

The capacitor of the MEMS electrostatic actuator is a micro-fabricated device. The capacitance needs to be measured as precise as 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 Agilent E4980A Precision LCR Meter has the ability to measure capacitance with atto-farad order repeatability ( $\sigma < 1$  fF). This instrument is the ideal tool for testing MEMS capacitive sensors. Also, the Agilent 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 frequencies (generally up to 10s of kHz) of the mechanical structures such as movable electrodes.

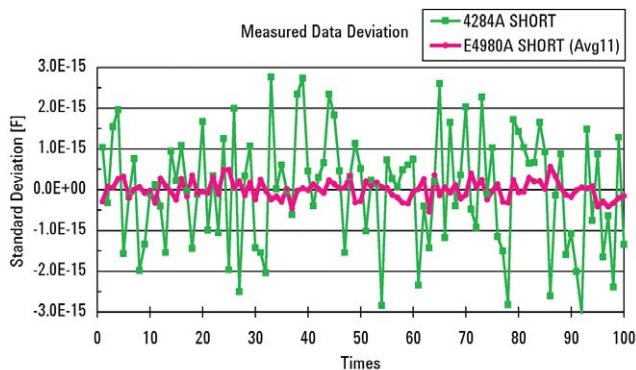


Figure 3. Superb repeatability of the Agilent E4980A

## Efficient Evaluation Method Without Physical Stimulus Test

The input to the MEMS electrostatic actuator is an electric signal, while output from the actuator is a mechanical displacement. In the manufacturing test environment, direct measurement of the mechanical displacement of MEMS actuators is ideal but leads to a reduction in test efficiency. Replacing the direct mechanical displacement measurement with an electrical test method can improve the test throughput because the electrical test can generally be performed faster and simpler than the mechanical displacement test.

In the case of electrostatic actuators, the capacitance between electrodes changes depending on mechanical displacement. Measuring capacitance by sweeping DC voltage gives you an alternative characteristic of mechanical displacement to applied voltage (Figure 4). This method improves throughput. In the design phase, relating the mechanical displacement measurement data to the capacitance measurement data gives more insights such as failure mode analysis.

The Agilent E4980A Precision LCR Meter (with Option 001) applies up to 40-V DC bias voltage with high accuracy without using external DC sources, and performs sweep measurements of impedance for up to 201 points, which is very effective for improving throughput.

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

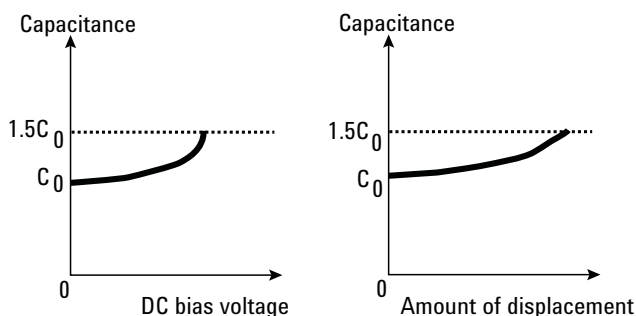


Figure 4. DC bias characteristic test as an alternative test method of the capacitive sensors

## High-Speed Measurements Maximize Manufacturing Test Throughput

Throughput is always a major issue in the manufacturing test environment. The Agilent E4980A Precision LCR Meter achieves a measurement speed that is five times as fast as the legacy Agilent 4284A, which improves test productivity in both design and manufacturing. In addition, the 128-channel scanner interface option (Figure 5) maximizes test throughput without sacrificing measurement accuracy. The instrument has compensated data up to 128 channels so that it can quickly obtain the corrected measured data inside the instrument. This also dramatically improves the total throughput because users will not need to take extra time transferring measured data and corrected data back and forth between an external controller and the instrument.



Figure 5. Agilent E4980A scanner interface

## Summary

The Agilent E4980A Precision LCR Meter, which provides highly accurate, repeatable, and high-speed measurements, is the ideal measurement instrument for testing MEMS electrostatic actuators. Using the DC bias function (Option 001) and 128-channel scanner interface (Option 301) together can improve test productivity in both design and manufacturing.

For more information, please refer to the following literature and websites:

- ▶ Agilent E4980A Brochure (P/N 5989-4235EN)
- ▶ Agilent E4980A Data Sheet (P/N 5989-4435EN)
- ▶ Agilent Technologies Impedance Measurement Handbook (P/N 5950-3000)
- ▶ MEMS/NEMS Device Measurement Solution: [www.agilent.com/find/mems](http://www.agilent.com/find/mems)
- ▶ Agilent E4980A Precision LCR Meter: [www.agilent.com/find/e4980a](http://www.agilent.com/find/e4980a)

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