

Electrostatic Actuation

An Overview of Hysitron's Patented Transducer

Hysitron nanomechanical testing instruments are unique in their ability to measure nanomechanical properties quantitatively with a patented* three-plate capacitive transducer. This technology has proven to provide the most versatile nanomechanical characterization equipment available. Force is applied electrostatically and displacement is measured capacitively by utilizing the unique design and operation of the three-plate capacitive transducer. This low current design allows Hysitron's instruments to realize industry-leading stability and sensitivity.

Unique Design

The three plate capacitive transducer is unique in its operation and exclusive to Hysitron's instruments. It works by applying AC signals 180° out of phase with each other to the top and bottom plate of the three-plate capacitive sensor. The AC signals are picked up by the center (floating) plate and the sum of the signals corresponds to a displacement of the plate. To apply a load, a DC voltage offset is applied to the lower plate of the transducer that electrostatically attracts the center (floating) plate downward.

Transducer Calibration

The force-displacement transducer is pre-calibrated using a series of traceable weights and laser interferometry. These tools can determine the effective spring constant, displacement sensitivity, load sensitivity and initial electrostatic actuation parameters. Prior to testing, an "air indent"

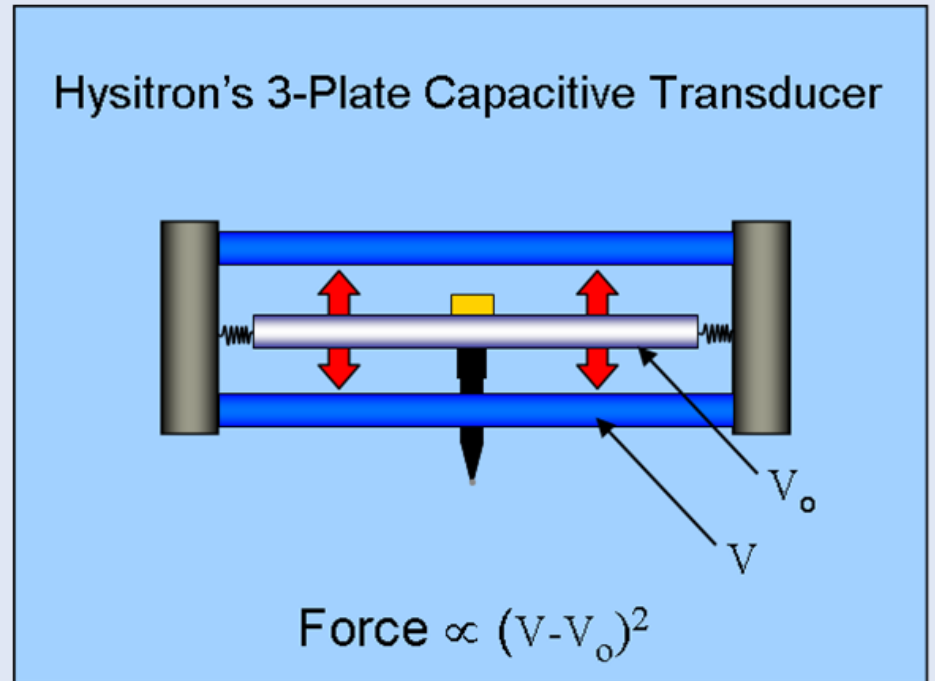


Figure 1. Schematic of Hysitron's patented 3-plate capacitive transducer. Electrostatic actuation of the nanoindenter probe is realized by applying a known voltage between the movable center plate and the fixed lower outer plate of the force actuator sensor.

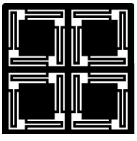
to self-calibrate the transducer is run. This refines the electrostatic force constant and the electrode gap to ensure the transducer is accurately calibrated.

Thermal Drift

Thermal drift can be a significant challenge to obtaining repeatable and meaningful data when testing at the nanoscale. Sources of drift, particularly thermal drift, must be minimized for successful test results. Thermal drift can be caused by changes in the ambient conditions, but these changes are typically dealt with by means of appropriate environmental buffering, such as the custom designed enclosures in the TI series.

However, sources of thermal drift caused by the instrument itself cannot be buffered from the instrument. Therefore, testing must be done in a manner that generates minimal change in the thermal state of the instrument.

Actuation of any component of the system requires energy, which, in turn, produces heat. For this reason, actuation techniques that require minimal energy must be chosen to minimize the amount of resultant heating. Two of the most common methods of actuation for devices that require high precision are electrostatic and electromagnetic. Each of these methods offers certain advantages based on the application.



Electrostatic vs. Electromagnetic

Electromagnetic actuation typically offers greater forces with larger displacements than electrostatic actuation. However, electrostatic actuation is able to provide more than sufficient force and displacement range for nanoindentation. Other factors to consider are the voltages and currents required for actuation. Electromagnetic actuation has low voltage requirements but demands large amounts of current, which creates large amount of resistive heating. In contrast, electrostatic actuation utilizes larger voltages but requires very little current. Electrostatic actuation inherently creates less heat and generates less thermal drift than electromagnetic actuation. This is particularly crucial due to the fact that this thermal drift is highly nonlinear due to continuously changing applied currents or forces, which makes it virtually impossible to correct the displacements accurately for thermal drift. It is clear that for nanoindentation, electrostatic actuation is superior to electromagnetic actuation and will provide greater thermal stability during the actuation process. For this reason, Hysitron relies on its three-plate capacitive transducer to provide electrostatic actuation for realization of each of its nanomechanical testing techniques.

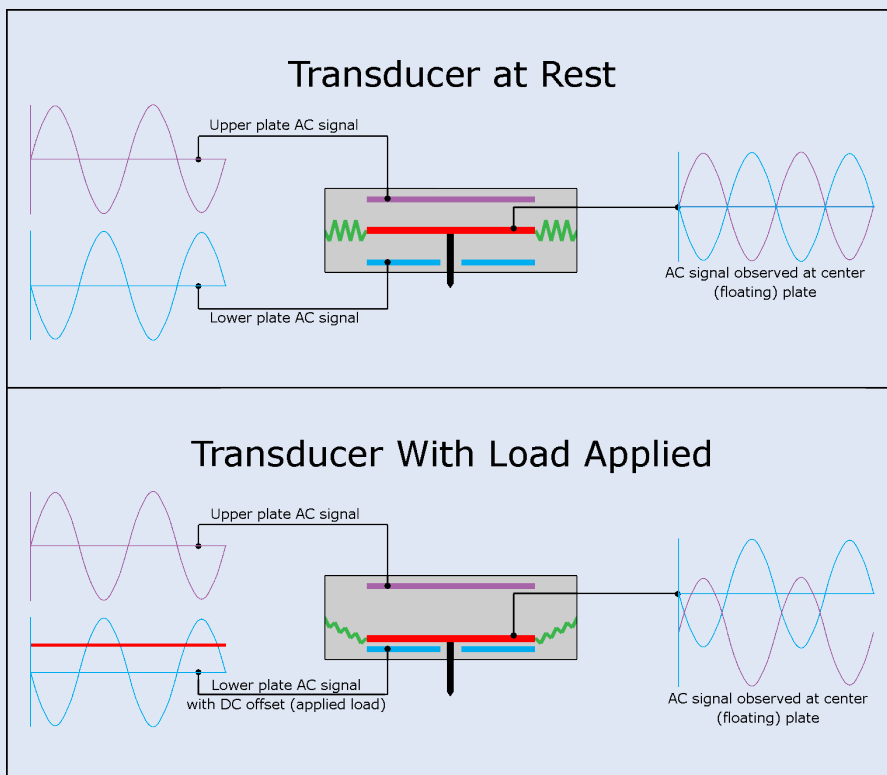


Figure 2. Explanation of Hysitron's patented 3-plate capacitive transducer operation for accurate force application.

*Covered under US patents: 5,553,486; 5,576,483; 5,661,235; 5,869,751; 6,026,677.

HIGHLIGHTS

- Unique capacitive transducer design provides the most reliable, reproducible results with the lowest available noise floor specifications
- All transducers are pre-calibrated with traceable external weights and laser interferometry
- Advanced and software automated nanoindentation probe calibration procedure
- Low thermal drift due to electrostatic actuation
- Unique ability of transducer to scan surface and create *in-situ* SPM image in addition to nanoindentation testing

SPECIFICATIONS

- Displacement resolution: <0.02nm
- Displacement noise floor: <0.2nm
- Maximum normal load: ~10mN
- Maximum indentation depth: >5 μ m
- Load resolution: <1nN
- Load noise floor: \leq 30nN
- Maximum load rate: >50mN/s

(Specifications stated are for Hysitron transducer tested with *performech*TM controller.)