Architecture of the pMEMS Matrix Board

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Summary

- The pMEMS Matrix Board is a platform to evaluate the operation, yield, uniformity and performance of piezoMEMS designs after fabrication.
- The Matrix Board will test DIP packages or connect to any fixture having BNC connectors such as probe stations, thermal chambers, or signal multiplexers.
- Six external signals connected to a bank of twelve relays are routed dynamically by Vision to pins of the sample package during test execution.
- Two Tasks in the Vision Library allow the user to configure the Matrix Board for use.

Summary

- The Matrix Board is divided into four sections:

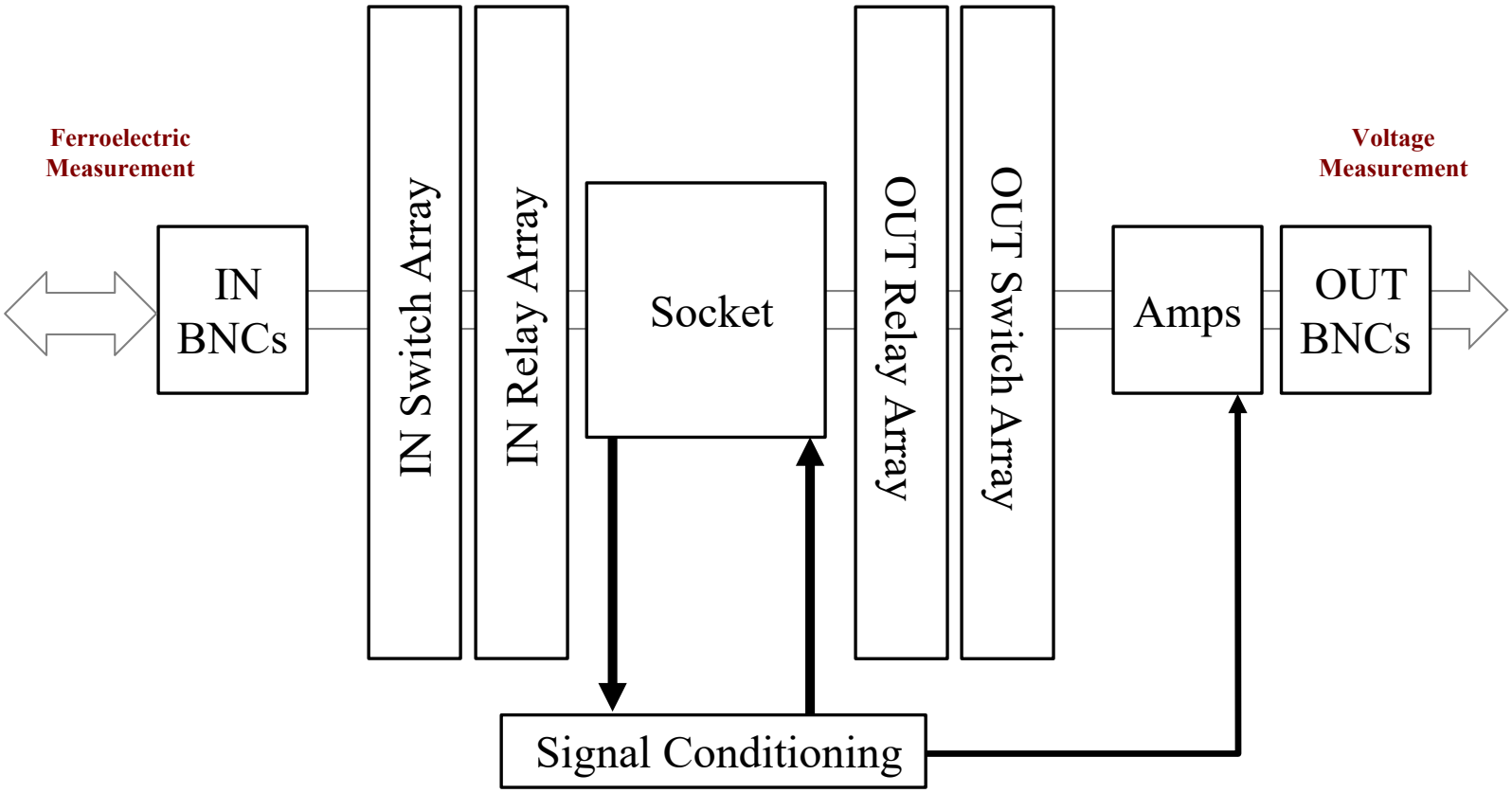
1) **IN**: BNC connectors, a switch array and six relays connect ferroelectric or piezoelectric capacitors on the pMEMS die to a Radiant pMEMS tester for characterization and poling.

2) **OUT**: Six relays and a switch array connect outputs from the pMEMS die to amplifiers driving cables to the SENSOR analog voltage inputs and/or the Frequency Counter of Radiant's pMEMS tester.

3) **FEEDBACK**: Two amplifier-driven paths with isolation relays will condition the sensed signal from a pMEMS pin for feedback to another pMEMS pin.

4) **Support Circuitry**: An array of solder holes plus a connector to the parallel Digital I/O port or I^2C port of the Radiant pMEMS tester supports installation of circuitry or a microprocessor that can independently operate the pMEMS under test.

Test Flow Diagram



- The board divides in half logically. The left connects to ferroelectric measurement channels. The right to voltage measurement channels.

Theory of Operation

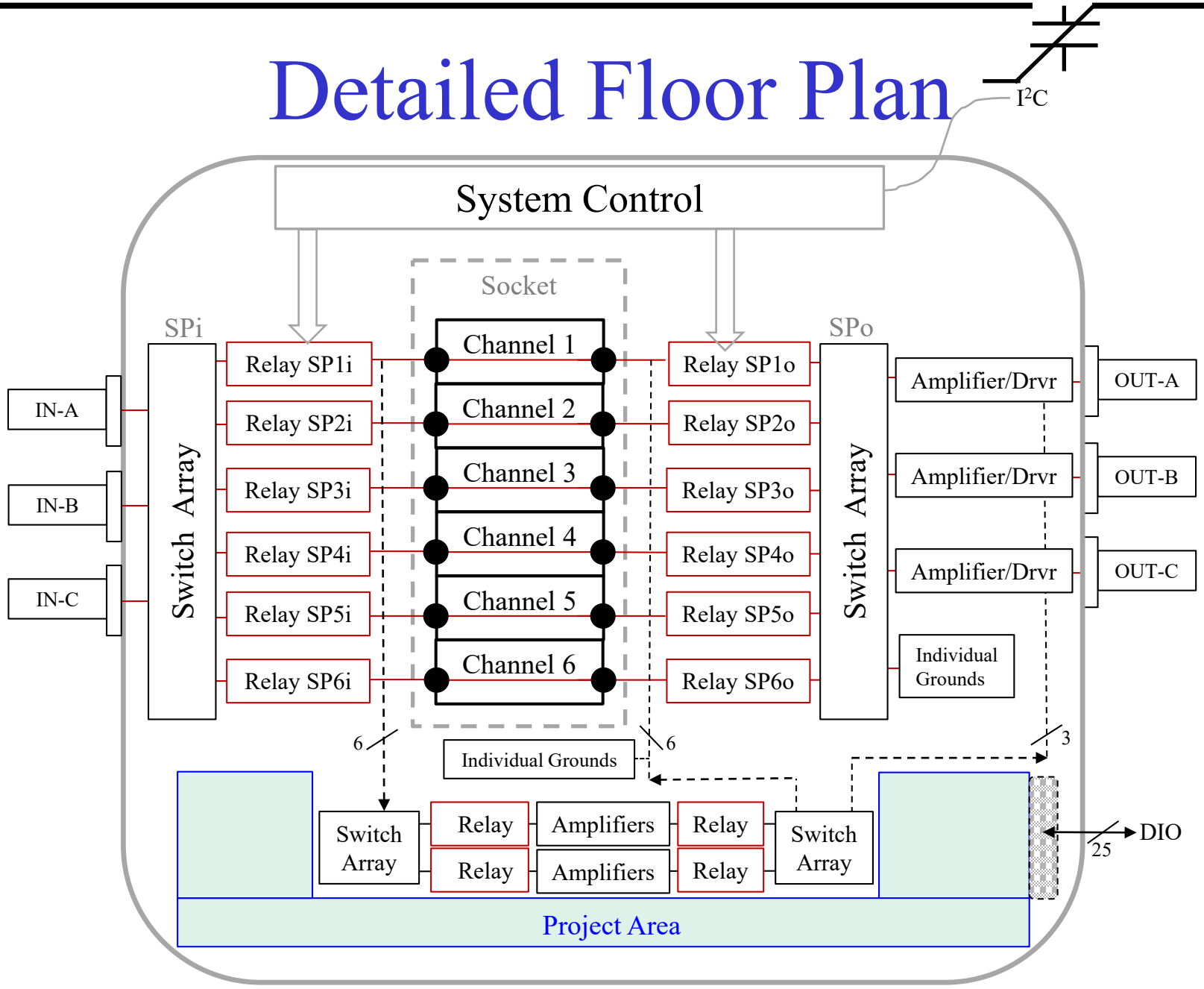
- The Matrix Board signal flow is from ***left-to-right***. (Except that signals may move back to tester RETURN?)
- On the **left side** of the board:
  1. **Three BNCs** (IN-A, IN-B, and IN-C) accept signals expected to go directly **to** or **from** any pin on the sample package. For instance, DRIVE and RETURN connect here for hysteresis measurements.
  2. **Manual DIP switches** connected to each BNC determine which IN signal connects to the input of which IN relay on the **SPi bus**. (Serial Peripheral Interface.)
     a) Manual switches ***cannot be changed*** during execution of a Test definition.
  3. The operator selects **IN Relays** to be opened and closed ***during*** Test Definition execution to connect pins on the package under test to **IN BNC** signals through the **SPin bus** and **switch array**.
     a) Relays can be turned on and off any number of times during a Test Definition using **the pMEMS Matrix Board Relays Task** from the Vision Library.

Theory of Operation

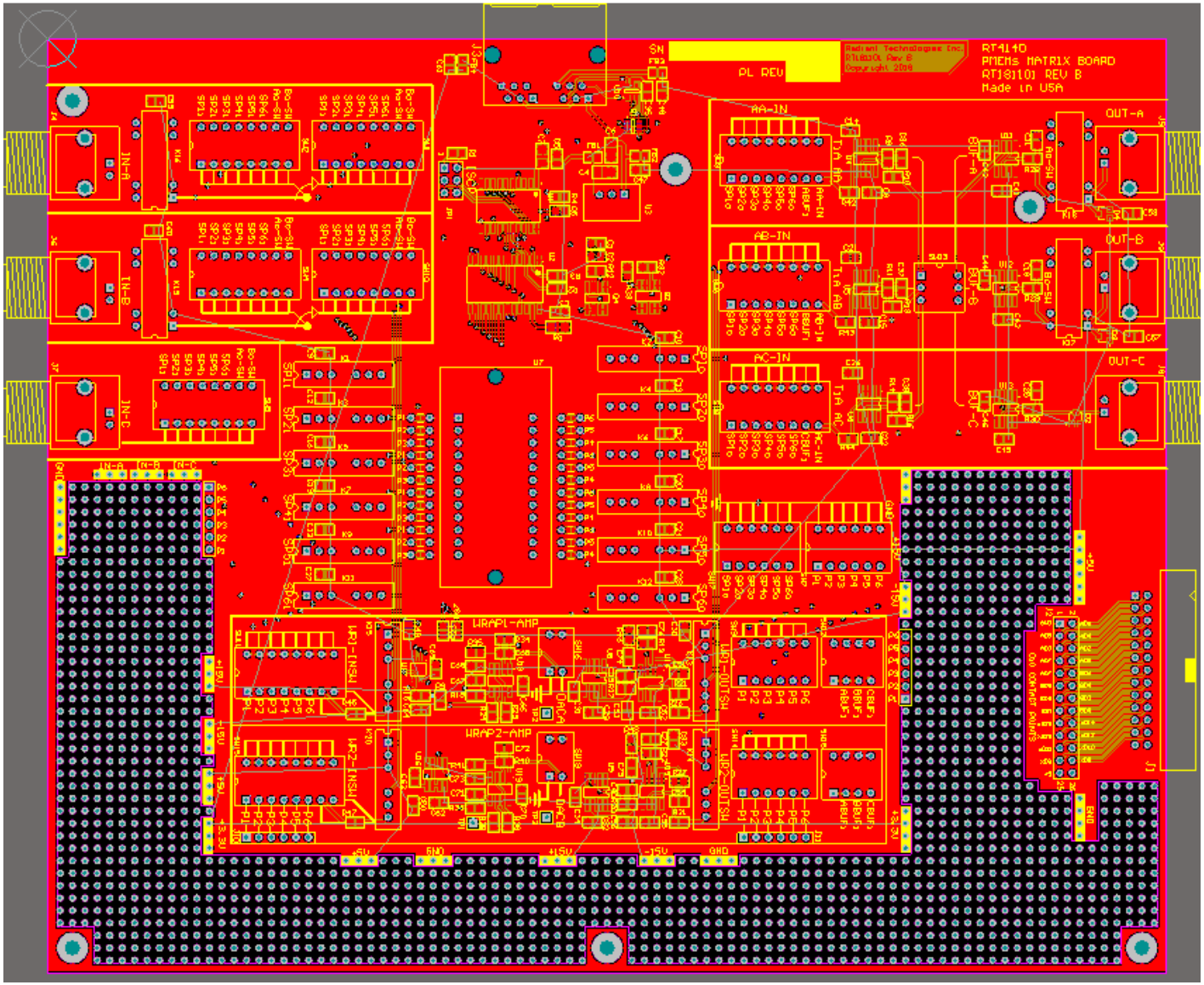
- On the **right** side of the board:
  1. Six **Out Relays** connect the pins of the sample to the **SPout** bus during Test Definition execution.
  2. Manual **DIP switches** connect the **SPout bus** to the inputs of the **OUT amplifiers** to send selected signals through the **OUT BNCs** (OUT-A, OUT-B, and OUT-C) to external test equipment.
     a) Manual switches cannot be changed during execution of a Test definition.

- At the **bottom** of the board sit the **Feedback Path Amplifiers**:
  1. Manual **DIP switches** connect the inputs of the **Feedback Input Relays** to selected pins of the sample under test. Only one input is allowed per feedback path.
  2. Manual **DIP switches** on the output of each **Feedback Output Relay** connect that relay to the **SPout bus** and/or **Cable Drivers**.
  3. The **Feedback Input** and **Output Relays** are controlled dynamically during Test Definition execution.

Detailed Floor Plan



Matrix Board PCB



Vision Tasks

- Two Tasks control the Matrix Board in Vision:
  1. The pMEMS Matrix Map Task
  2. The pMEMS Matrix Relay Task

- The Map Task is a passive Task that *records* the settings of all manual DIP switches on the board as well as the names of the signals and sample pins.
  1. Each Matrix Map may be saved as a file to be recalled by the Relay Task. (How will the Relay Task use this file?)
  2. Each Map file ensures that the switch settings on the Matrix Board for a particular sample are saved *in the Vision DataSet* for future reference.

- The Relay Task is an active task inserted into Test Definitions to close and open individual relays on the Matrix Board during test execution.

Summary

- The pMEMS matrix Board is quite complex but allows the device under test to be evaluated in multiple ways.

1) Configure the switches.

2) Fill in the Map.

3) Set the Relays.

4) Insert the device to test.

5) Test.

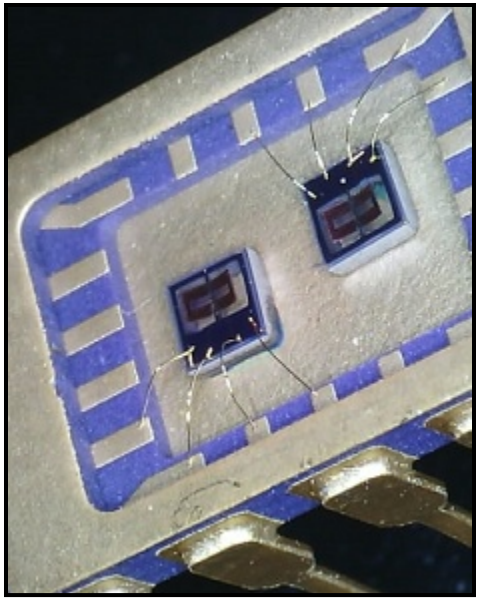
Configuration Procedure

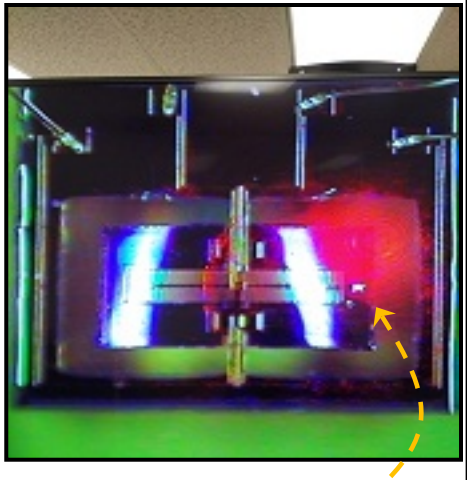
- **Determine** all tests to be executed.
- **Establish external connections** to be made to IN-A, IN-B, IN-C and OUT-A, OUT-B, and OUT-C for all tests.
- **Set the Switches** to route signals to the relay banks.
- **Open** the **pMEMS Matrix Map Task**.
  1) Enter the names of each pin of the sample
  2) Enter the signal names attached to the IN and OUT BNCs
  3) Enter the Switch settings
  4) Save the Matrix Map.
- **Insert the pMEMS Matrix Relay Task** at the appropriate points in the test.
  1) Recall the desired Matrix Map for that sample. When loaded, the names of the pins will appear on the sample diagram and the names of the external signals will appear on the inputs to the relay banks as determined by the Switch settings in the recalled Map.
  2) When relays are set to be closed by the Task, the appropriate signal name will appear at the assigned pin of the sample.
  3) Remember to open all relays at the end of each Test Definition.
- **Load the sample** and **run** the targeted tests.

Measuring Piezoelectrics

- The enclosure of the pMEMS Matrix Board is sized to fit under the Polytec NLV laser doppler vibrometer (LDV).
  1. A port through the top cover of the enclosure is positioned directly over the ZIF socket to allow the laser to see the entire area of the device under test.
  2. The enclosure will mount on an X:Y:Tip:Tilt table beneath the laser to position the laser split and align it back into its sensor.
- The NLV can measure displacements down to 0.2 Ångstroms and up to millimeters when connected to a Radiant Premier II, Multiferroic II or pMEMS tester.
- The NLV is fully compatible with Radiant's Vision operating system.
- With the NLV connected to the tester SENSOR ports while the tester operates the sample on the pMEMS Matrix Board, the direct and converse piezoelectric response of the devices under test will be captured simultaneously with the electrical measurements of the sample.

Measuring with LDV

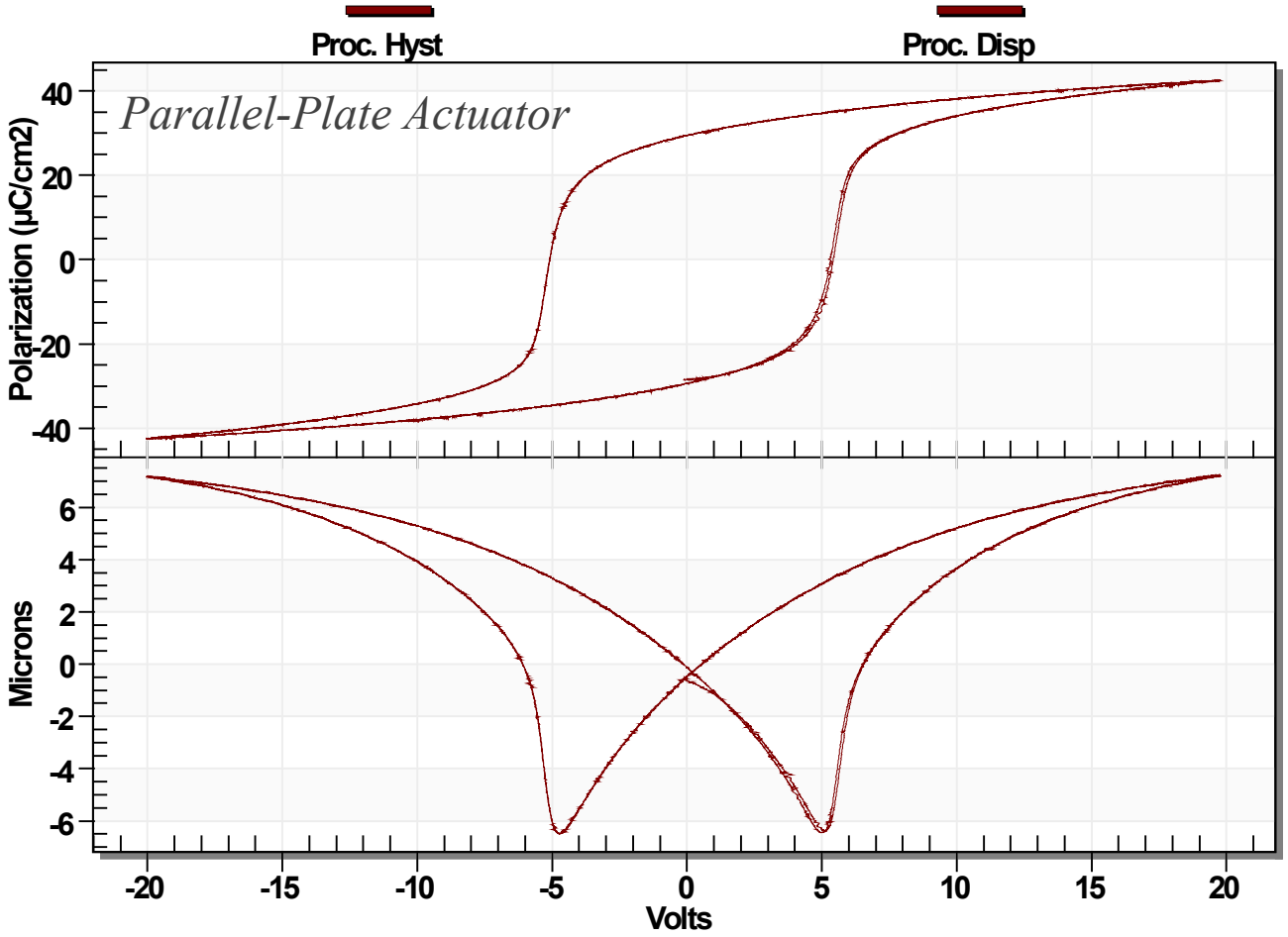




LDV laser

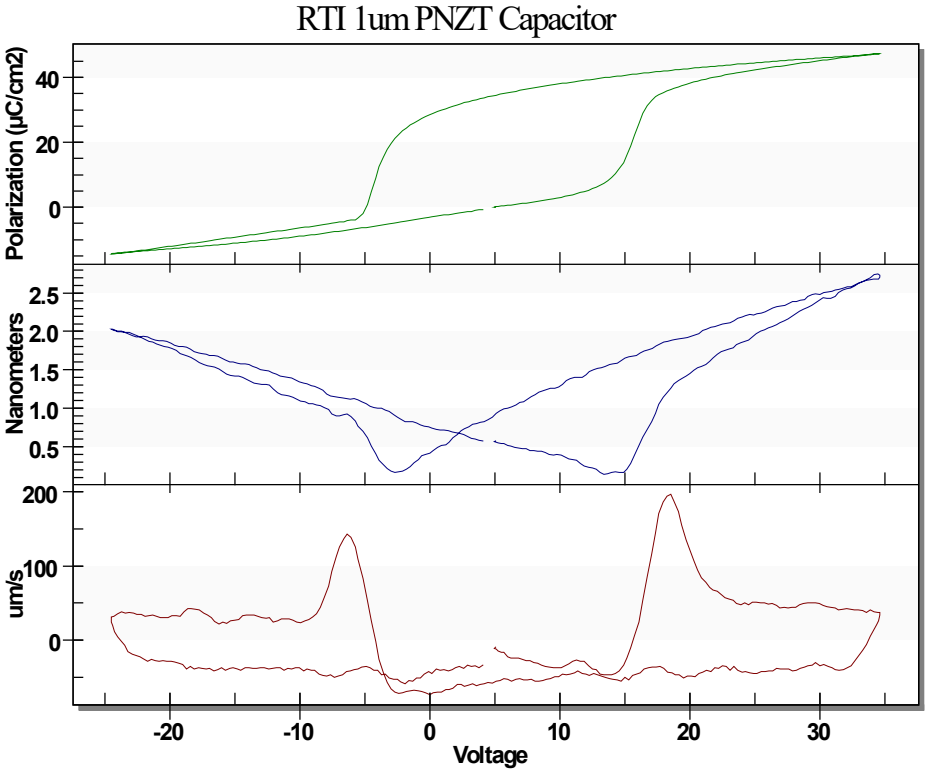
- Measuring piezoelectric “wings” with an LDV.
- *This experiment in 2017 lead to the development of the Matrix Board.*

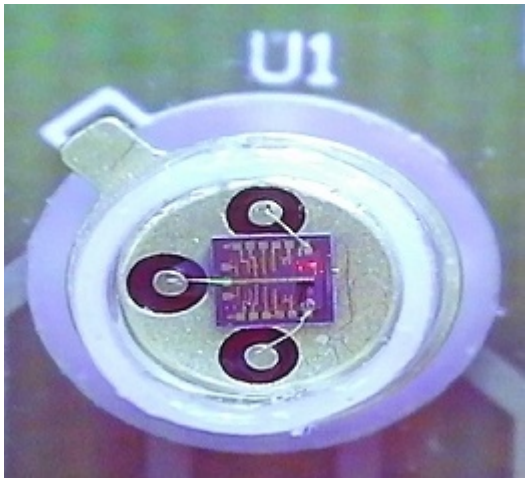
Motion of the Wings



- Double butterfly loop of wing on previous page driven by parallel-plate capacitors at 1 Hz/20 V with 32,000 points.

Angstrom Resolution

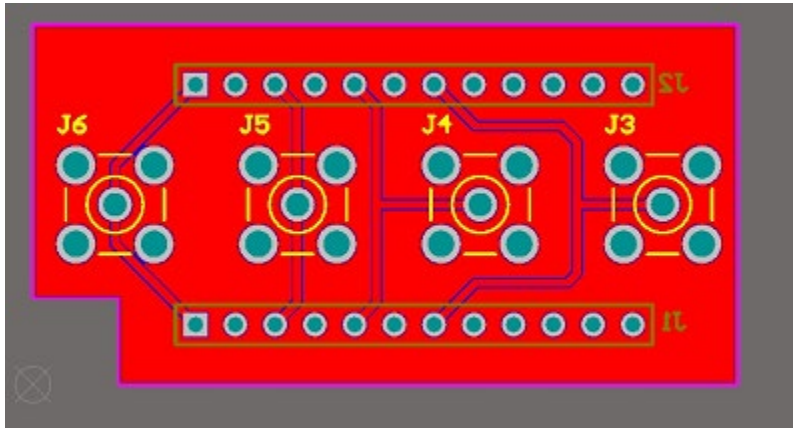




- 20 Å butterfly motion of the top surface of a 1 µm-thick parallel-plate PNZT capacitor clamped to the substrate surface.
- The pMEMS Matrix Board mounted beneath the Polytec NLV laser vibrometer is a powerful tool for measuring complex piezoMEMS.

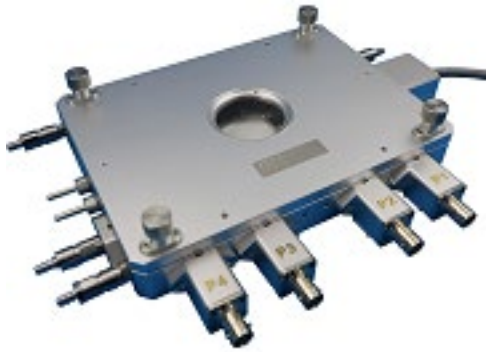
Using Cables

- The ZIF socket on the pMEMS Matrix Board will hold 300 mil to 600 mil DIP packages or printed circuit boards having headers positioned to fit DIP footprints.
- A special daughter board provided by Radiant for the Matrix Board locks into the ZIF socket and holds four SMA connectors.
- Using SMA-to-BNC cables, the daughter board allows the Matrix Board to test devices on a probe station, in a thermal chamber or in arrays controlled by multiplexers.

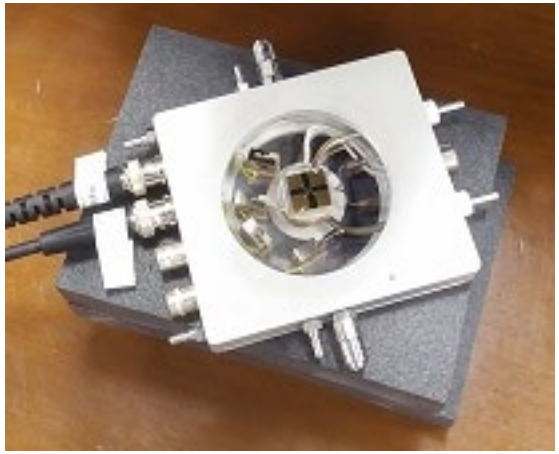


Testing at Temperature

- Using the pMEMS SMA Daughter Board, four test channels of the Matrix Board may be connected to small thermal chambers from Instec and Linkam.



Instec HCP621G-PM

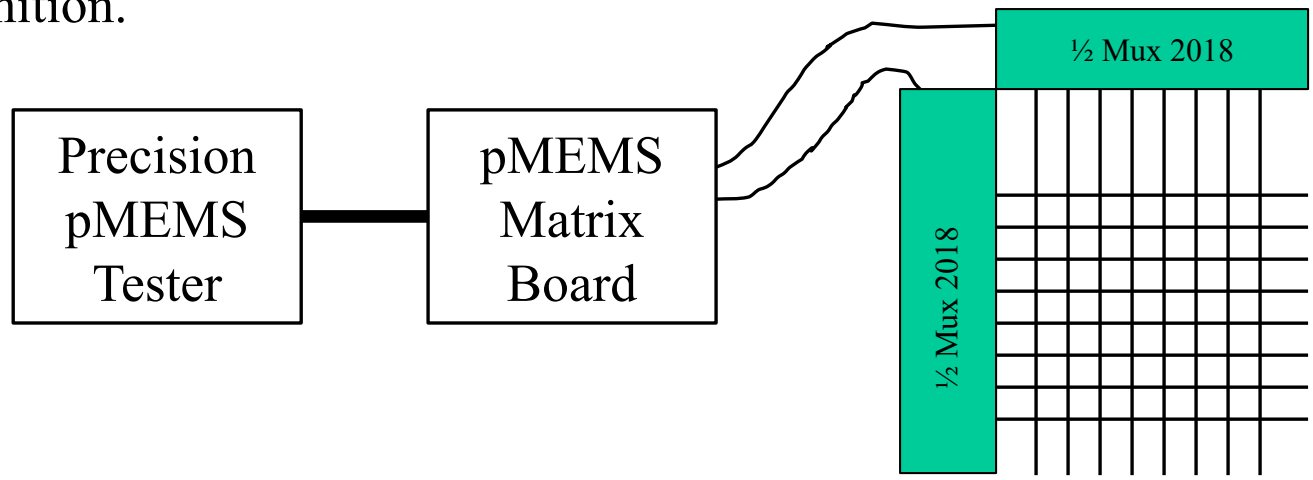


Linkam HFS600E-P

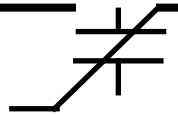
- These chambers sit on a table top but will take the sample from -190° C up to 600° C. They have connections for four electrical signals between the tester through the Matrix board to the sample inside the chamber.
- The chambers interface with the NLV laser & are fully controllable by Vision.

Adding Multiplexers

- Radiant Technologies offers the Precision Multiplexer 2018 controlled from within Vision.
- The multiplexer has two independent 1x8 multiplexers.
- Vision will control up to three multiplexers at a time. (No actual limit.)
- Connecting two SMA-to-BNC cables from the pMEMS Matrix Board to the Multiplexer 2018 allows full testing of cross-point arrays up to 8x8. Two Mux 2018s will scan 16x16 arrays in a Vision Test Definition.



Testing Transistors



- The Precision pMEMS Tester is a fully-functional analog ferroelectric tester with additional channels to test semiconductor devices made with PVDF or ferroelectric ceramic gates.
- In addition to a Frequency Counter, Parallel DIO channel, I^2C comm channel and an LCR, the pMEMS Tester hosts two asynchronous 16-bit voltage sources (V1 & V2) and one asynchronous 16-bit ADC.
- The connections from the tester to a FET or a diode are:
  1. DRIVE = Gate
  2. RETURN= Source
  3. V2 = Drain
  4. V1 = Substrate bias
- Connected to the Matrix Board, the pMEMS transistor test signals easily switch between Curve Trace and I_{ds} vs V_{gs} test configurations for multiple transistors on a single die.

Conclusion

- Radiant ferroelectric and piezoelectric test instruments have proven themselves accurate and versatile for characterizing individual non-linear capacitors.
- Multiple non-linear capacitors are now being fabricated on membranes, cantilevers and beams of piezoMEMS systems-on-chip. SOCs require complex test sequences.
- Radiant's pMEMS Matrix Board is a unique accessory containing manual switches, Vision-controlled relays and on-board amplifiers to interface a packaged pMEMS SOC with a Radiant tester for functional system testing.
- The Matrix Board will also connect to unpackaged SOCs on probe stations, thermal chambers, multiplexers and laser interferometers