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MEMS Ohmic Latching Relay

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Sandia National Laboratories

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Presentation Outline

- Comparison with COTS latching relays
- Design and fabrication
- Shock testing
- Radiation testing
- Frequency performance
- Contact metallurgy

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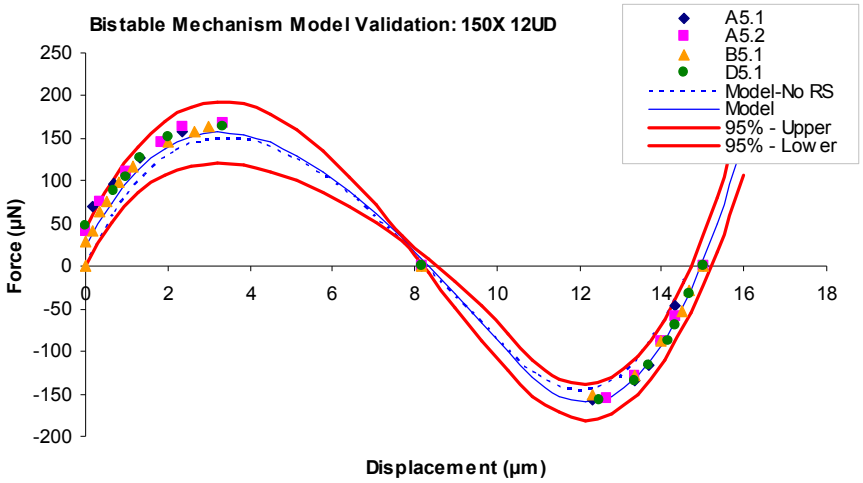
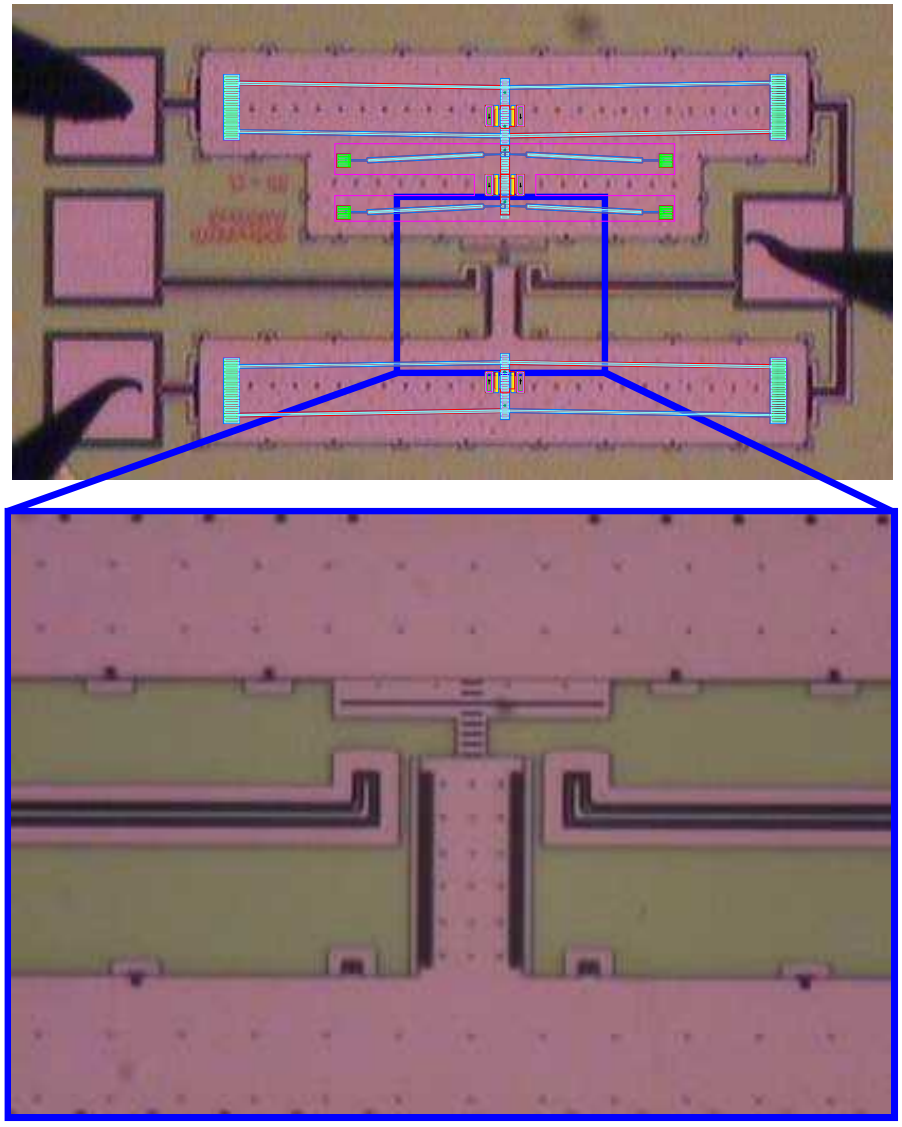
Comparison versus COTS parts

- **Pro's of MEMS relay**
  - Custom layout (multiple pole, multiple throw)
  - Low energy consumption (~150 mW switch power for ~0.25 ms)
  - Smaller total volume
  - Smaller electrical length at high frequency
  - Shock and radiation hard
  - No chatter and fast switching (<0.5 ms)
  - Longer life demonstrated on several parts

- **Con's**
  - Not available for $6.50 each in orders of 1M parts
  - Resistance/power handling of metal contact – practical below 20 mA at this time (can be engineered to be larger)
  - Currently, resistance through switch is greater than 5Ω

Latching Relay Design

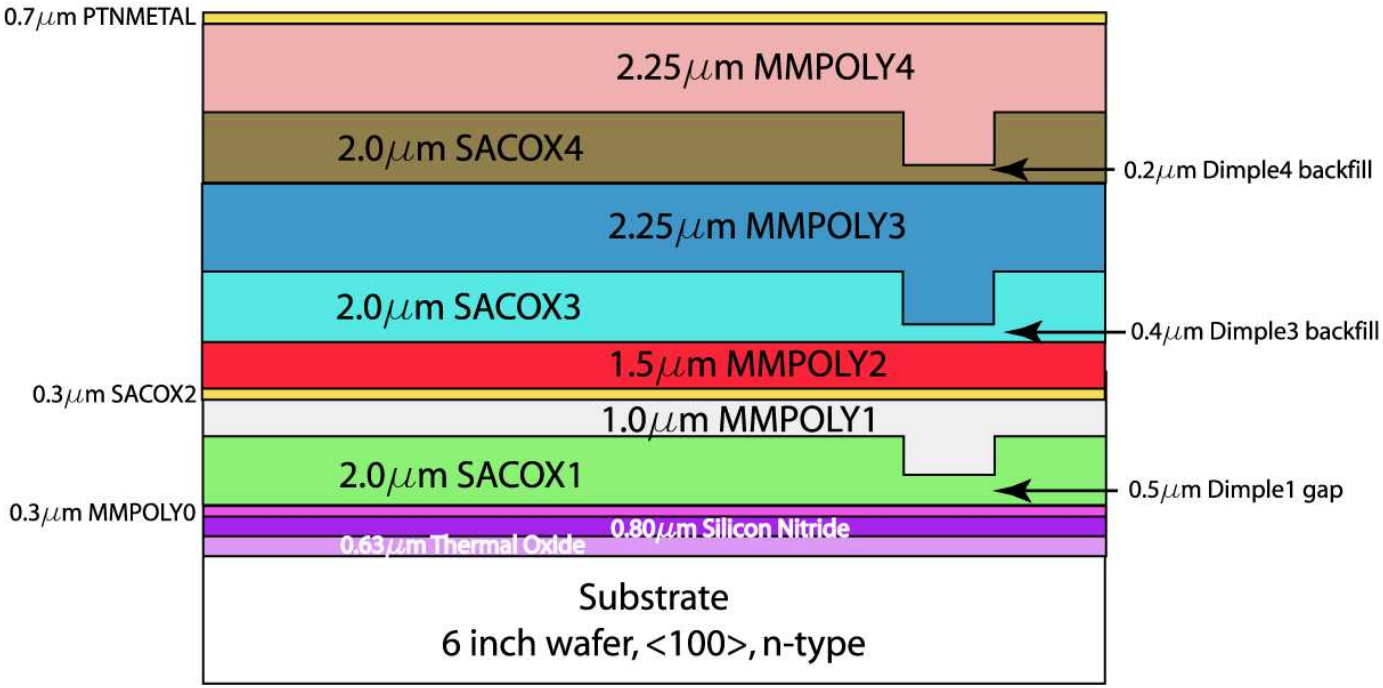


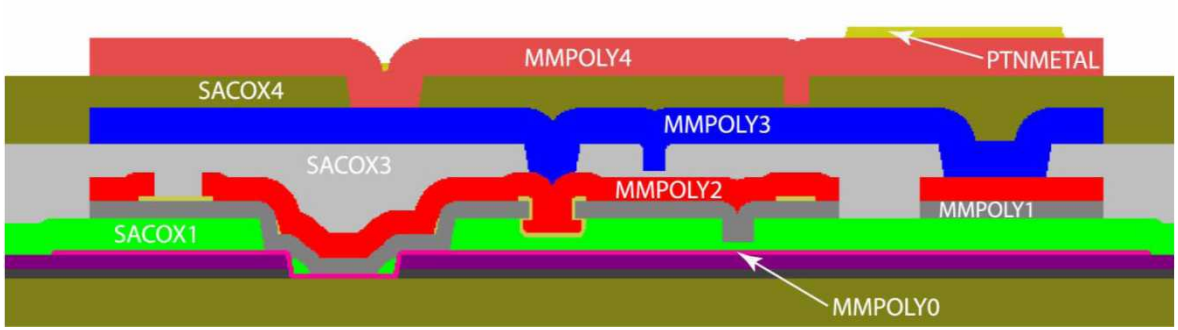


- 2 stable equilibrium positions
- 1 unstable equilibrium position
- Can design mechanism for unique response curves

Latching Relay Fabrication

SUMMiT™





http://www.MEMS.Sandia.gov/

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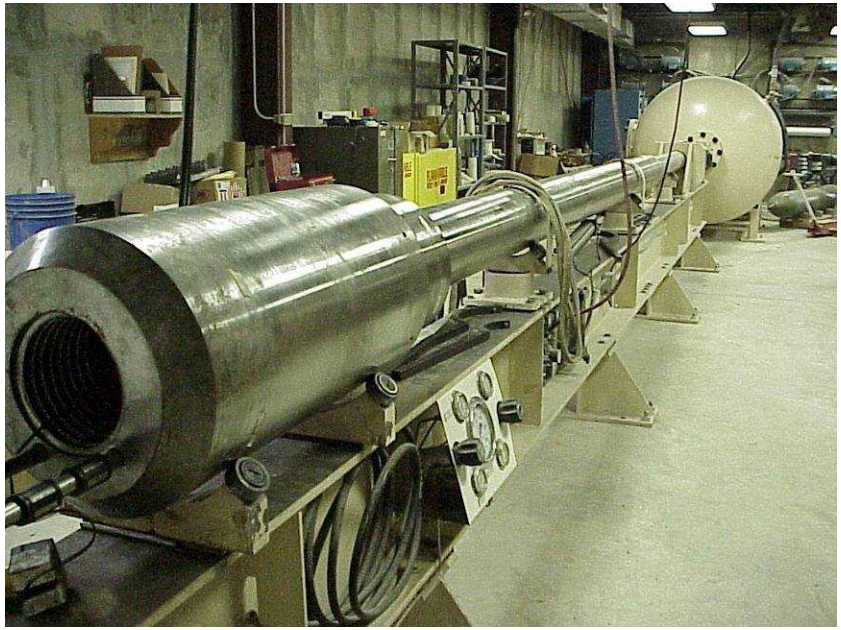
Penetrator Gun and Target

- Performed at the Waterways Experiment Station in Vicksburg, MS (Army Corps of Engineers)



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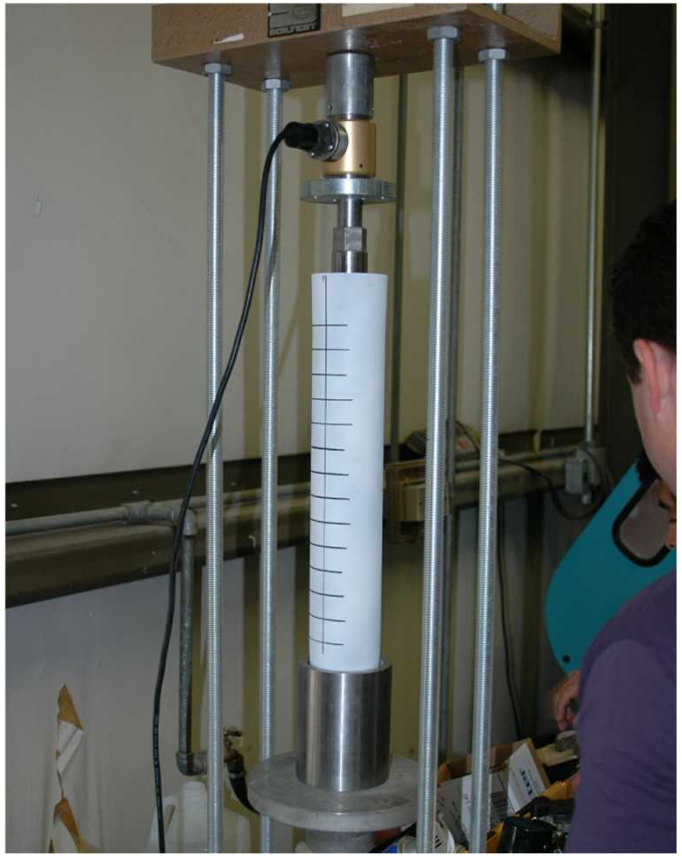
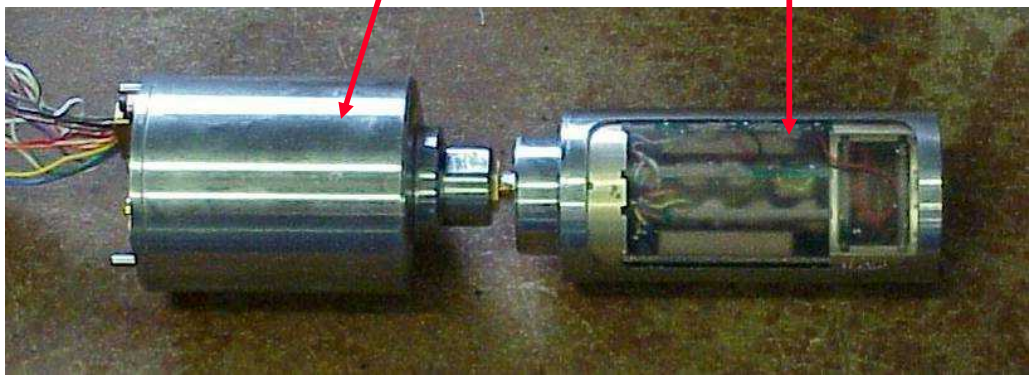
Penetrator Test Setup



- Penetrator
  - 22” long, 3” diameter
  - 13.7 lbs.

- Housing mates to MDES and assembles in penetrator
- MDES unit:
  - Power
  - Ground
  - Analog/digital inputs
  - Records analog/digital outputs



Tony Mittas – Org. 2621, 2005

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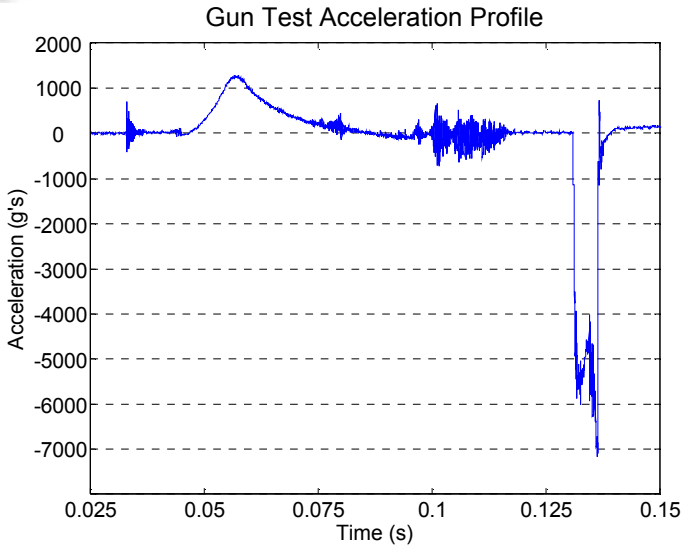
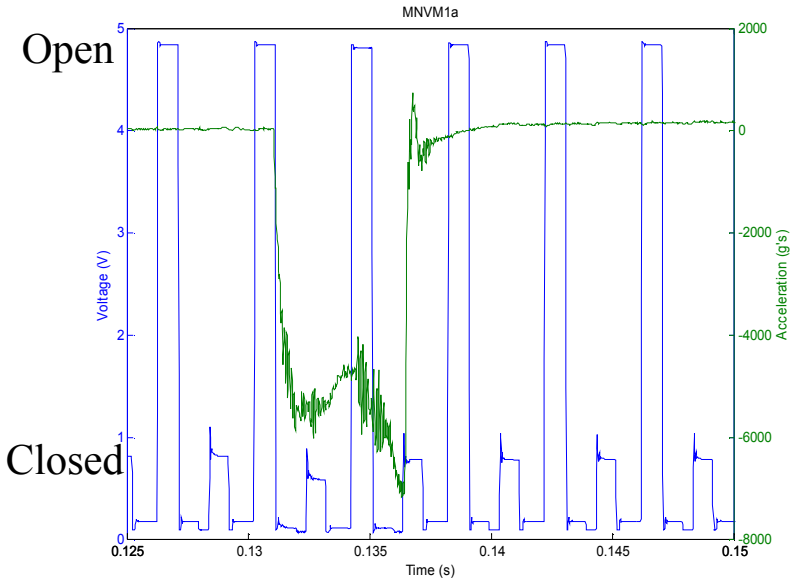
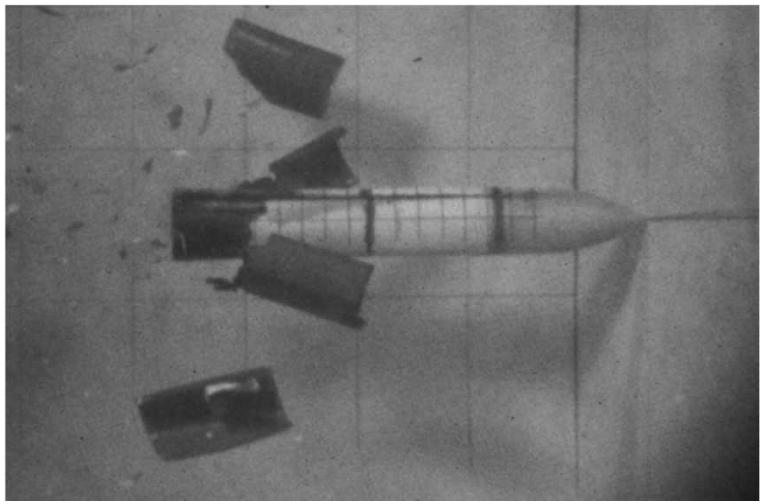
Penetrator Test Results



Duration:
> 5.5 ms
Ave. accel.:
~5500 g's
Max. accel.:
> 7200 g's





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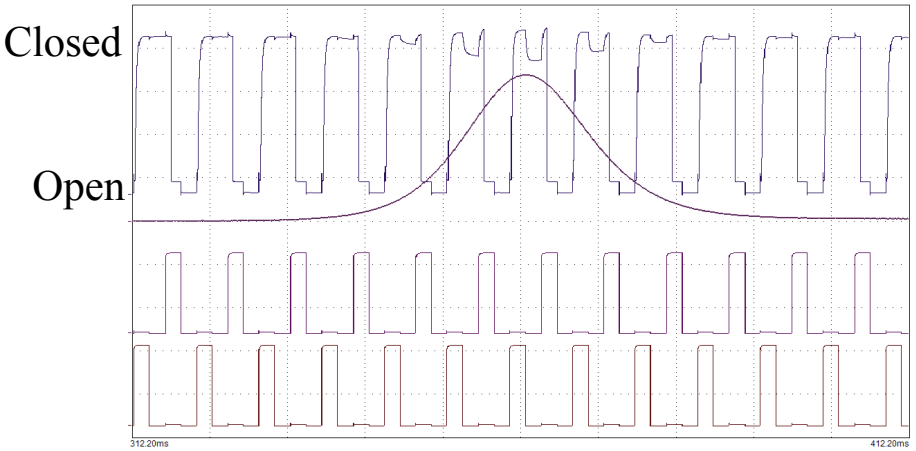
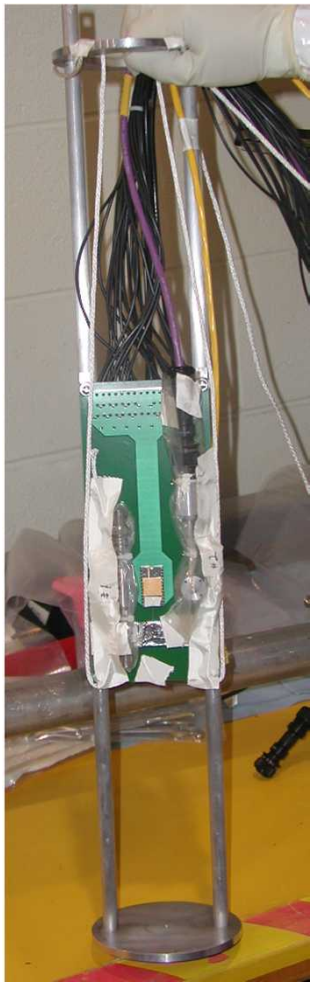
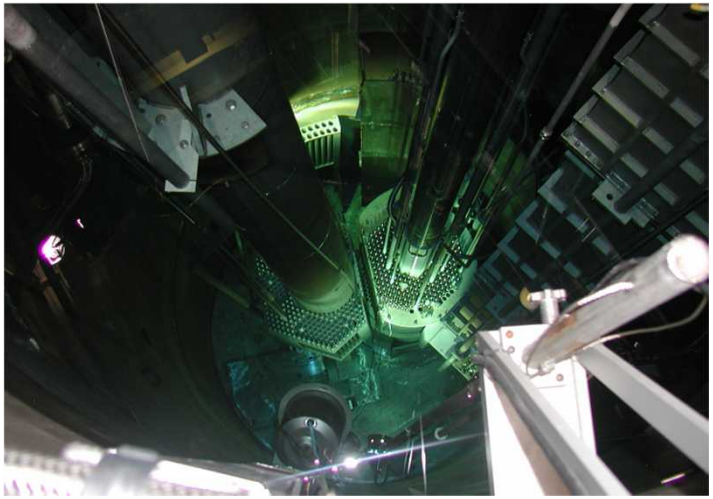
ACRR Radiation Testing

- **Operated through**
  - **16.5 Mrad(Si) total dose at steady-state**
  - **100 Mrad(Si)/s peak dose rate from pulse**
  - **$1x10^{16}$ n/cm^2 max fluence**







Mike Luker – Org. 1384, 2007

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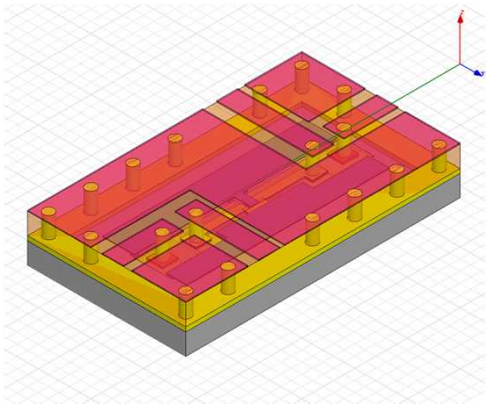
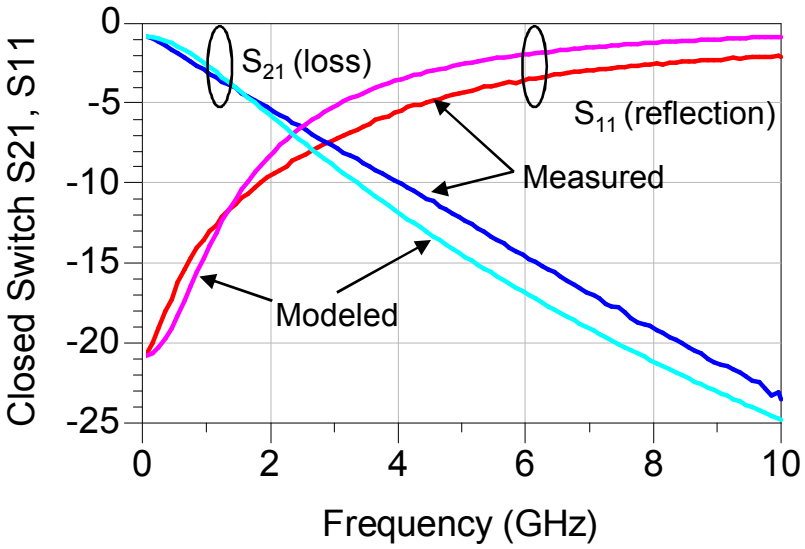
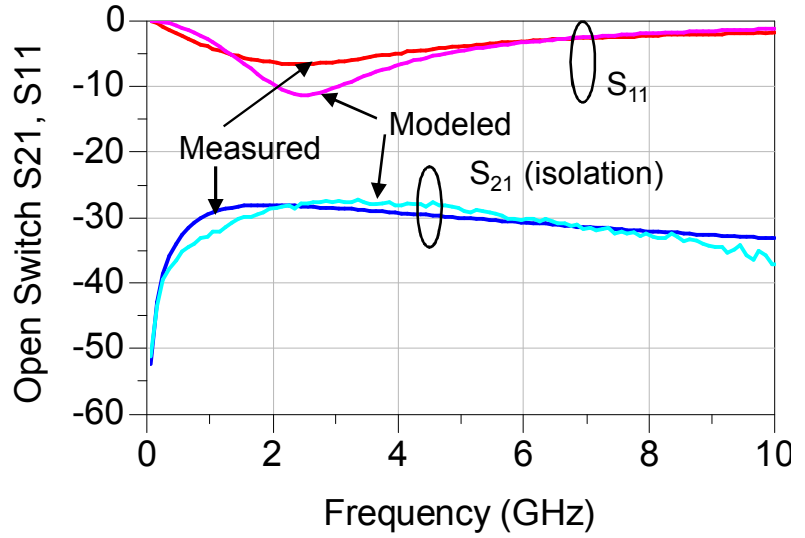
RF Measurements

- Gold-contact SPST tested using RF probes
  - –Using old DC design
  - –Wirebonds ~2 mm long (~2 nH)
- SPST switch has 3 dB insertion loss and 32 dB isolation at 1 GHz
  - –Substrate capacitance is major contributor to insertion loss and off-state resonance
  - –Simple redesign of trace would greatly improve performance

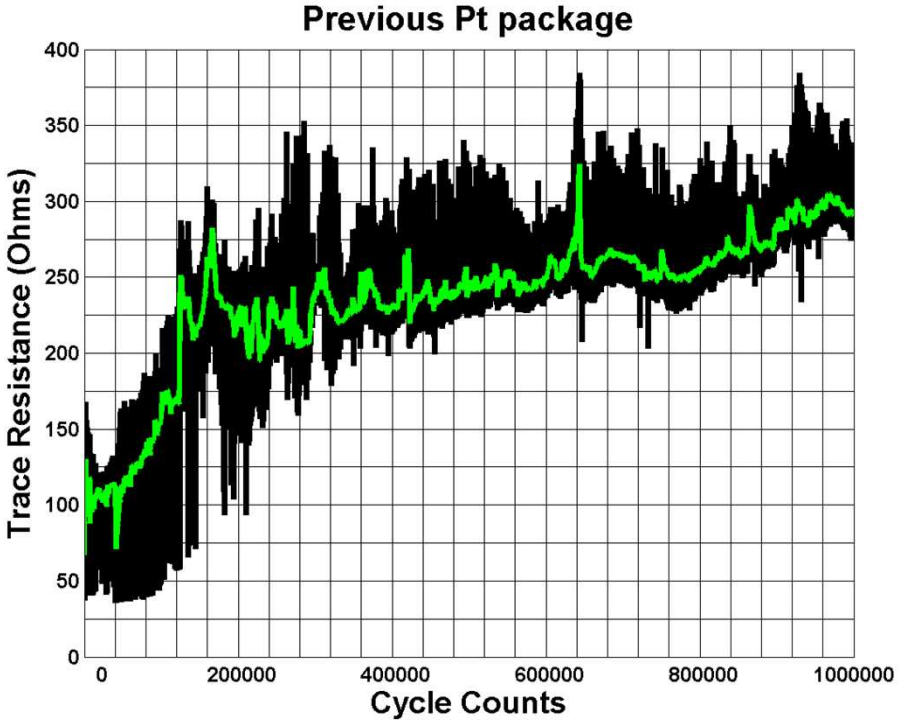


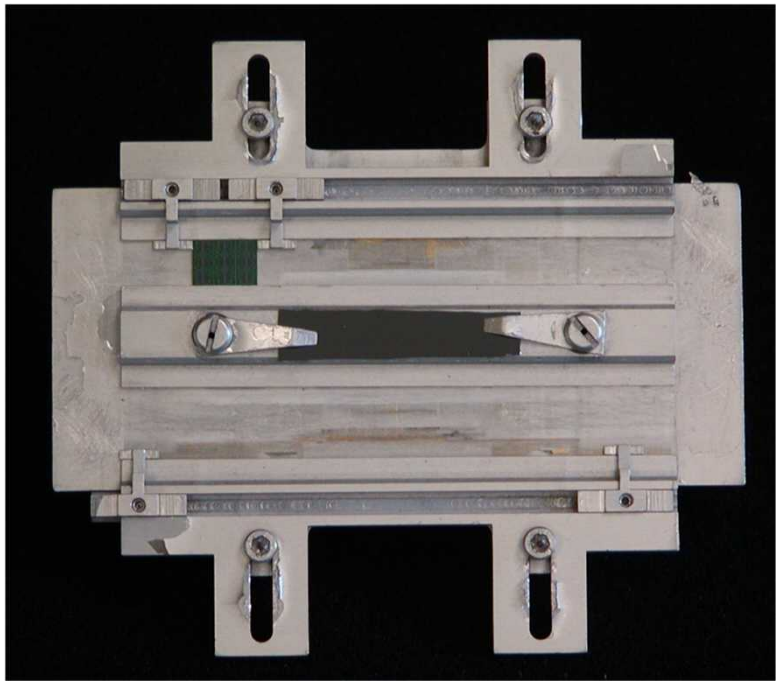




Contact Metallization

- Au selected as initial contact metal – too sticky
- Platinum selected as candidate (harder material)
- Contact is reliable but resistance is high and increases dramatically with cycle count.





Pt Contact, O2 Plasma cleaned,
Hermetic package in N2 atmosphere

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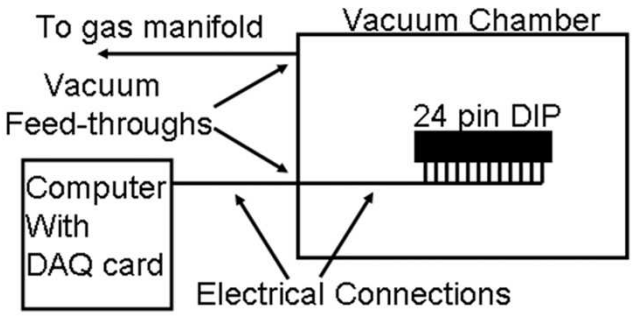
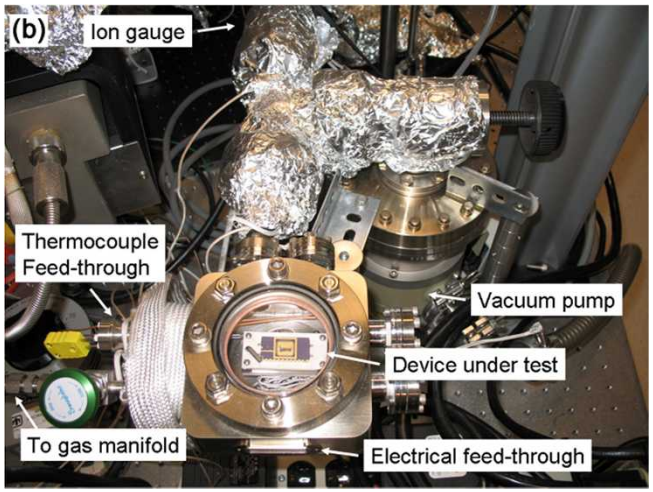
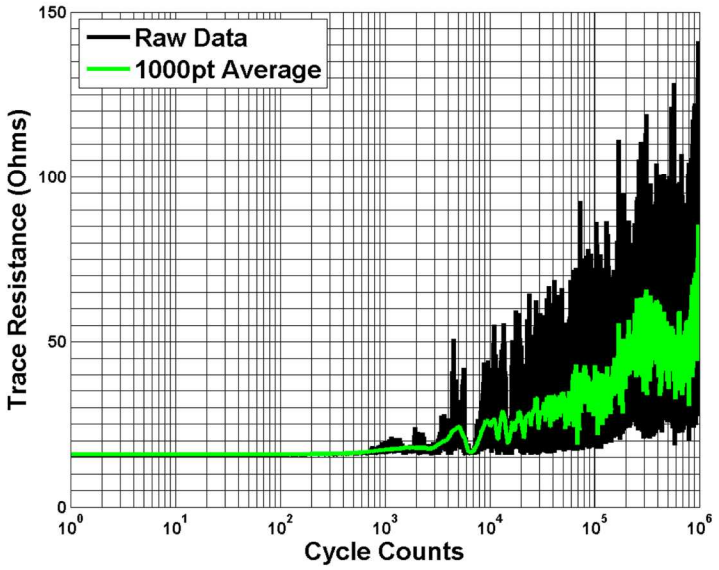
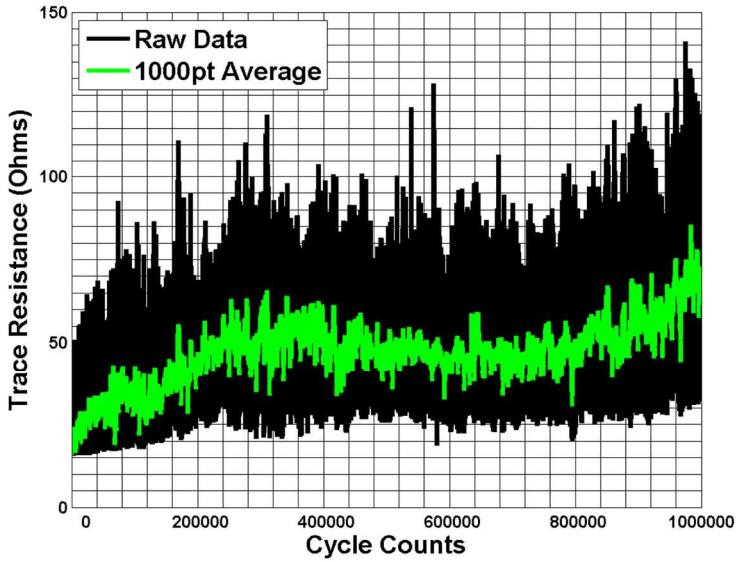
Clean Environment









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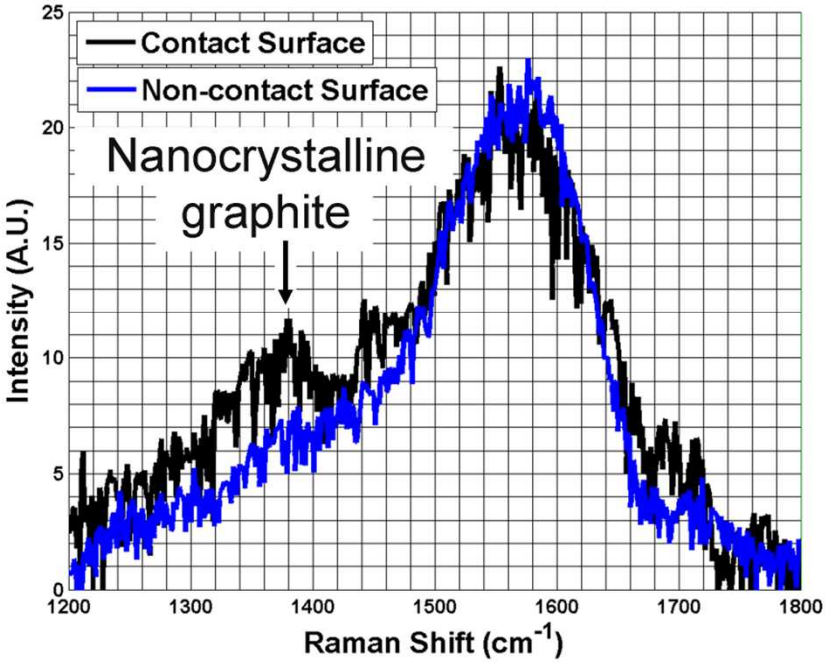
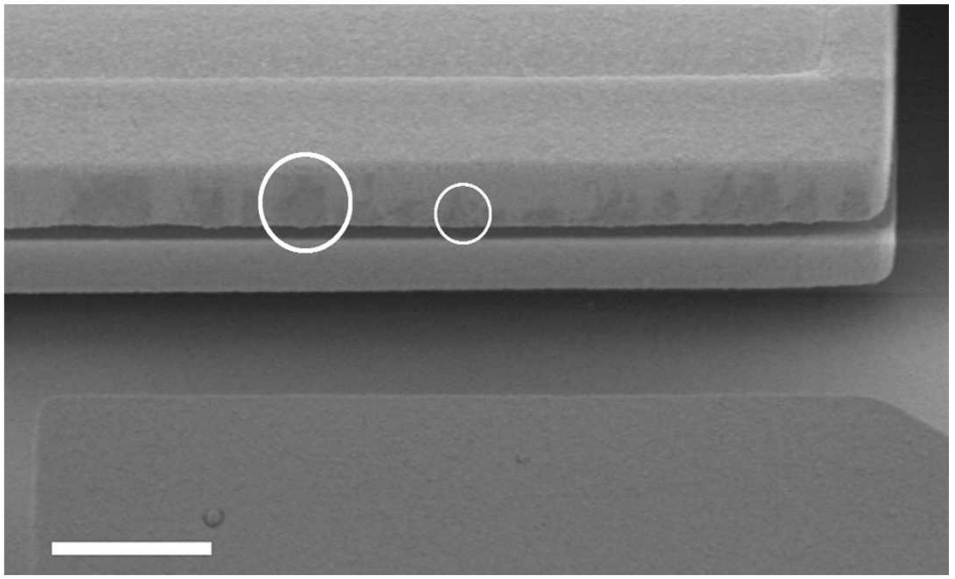
Contact Contamination

- Inspected contact surfaces with SEM
- Used Raman spectroscopy to analyze surfaces
- Build-up is present under mechanical cycling only and is not due to hot or cold switching





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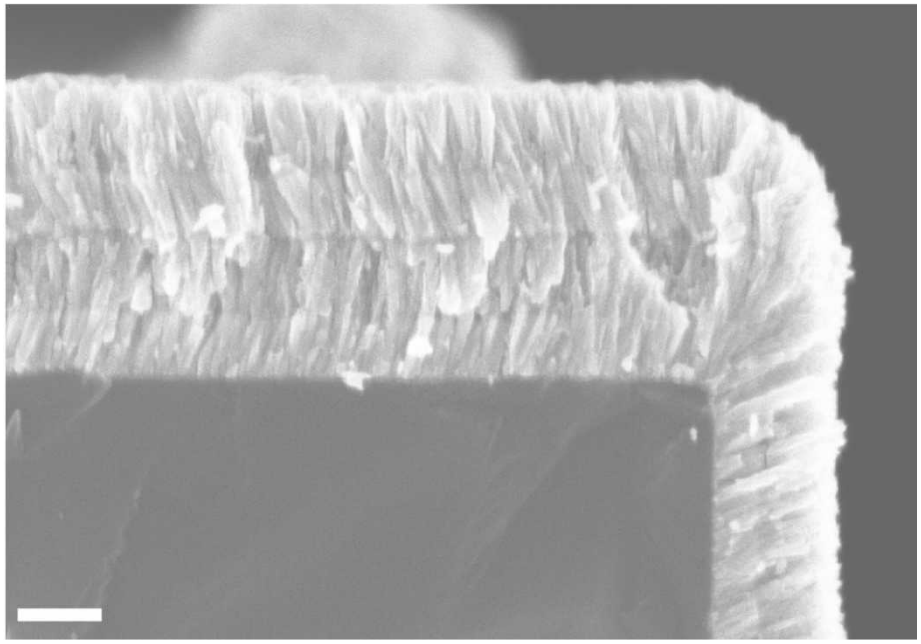
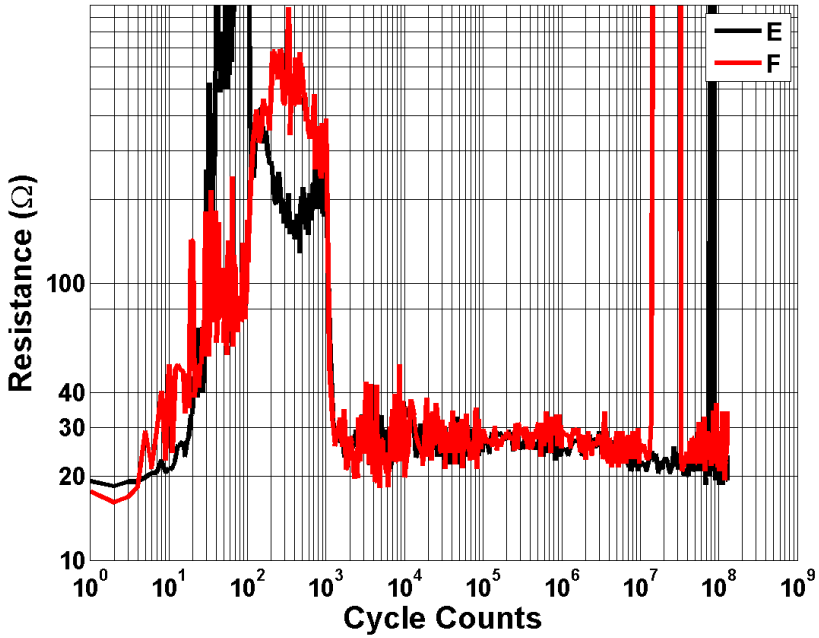
Ruthenium Oxide Metallization

- Literature suggests that transition metal oxides prevent accumulation of friction polymer (Rh_2O_3, RuO_2, IrO_2, ReO_3)
- Proven in commercial reed relays (low force, high cycle count macro-scale relays)
- Ruthenium Oxide selected as candidate metal.





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Summary

- Overall, MEMS latching relays are TRL 4
- TRL limited to 4 by contact metallurgy
- Radiation and shock testing increased TRL to ~6
- Designing relays for larger bandwidth
- Can custom design to multiple pole and throw
- Can be integrated with other components to provide new or improved functionality over existing COTS parts
- Tunable antennas ???
- Switching COM bands in multi-RF front ends ???

Acknowledgments

- The Microelectronics Development Laboratory and Microfabrication Laboratory staff at Sandia National Laboratories
- Gary Patrizi and Frank Austin for metal deposition
- This work was supported by a Laboratory Directed Research and Development Project at Sandia National Laboratories
- Sandia is a multiprogram laboratory operated by Sandia Corp., a Lockheed Martin Co., for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

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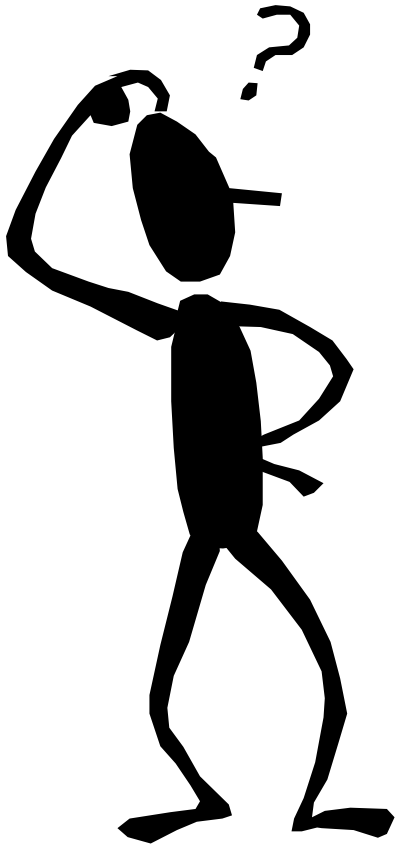
Questions



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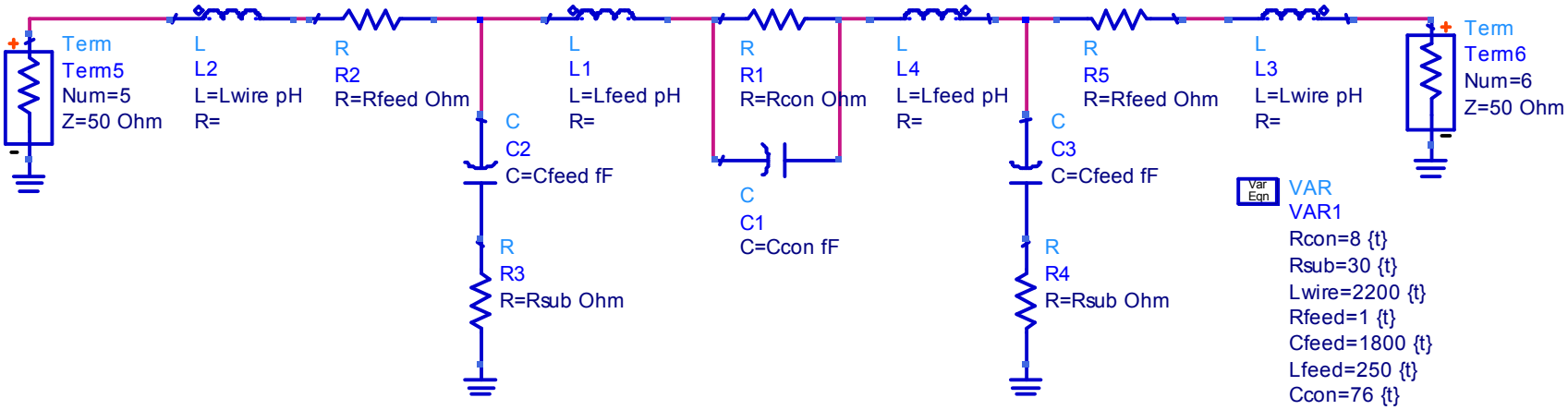
Extra slides

RF Measurements



Equivalent circuit model for latching relay

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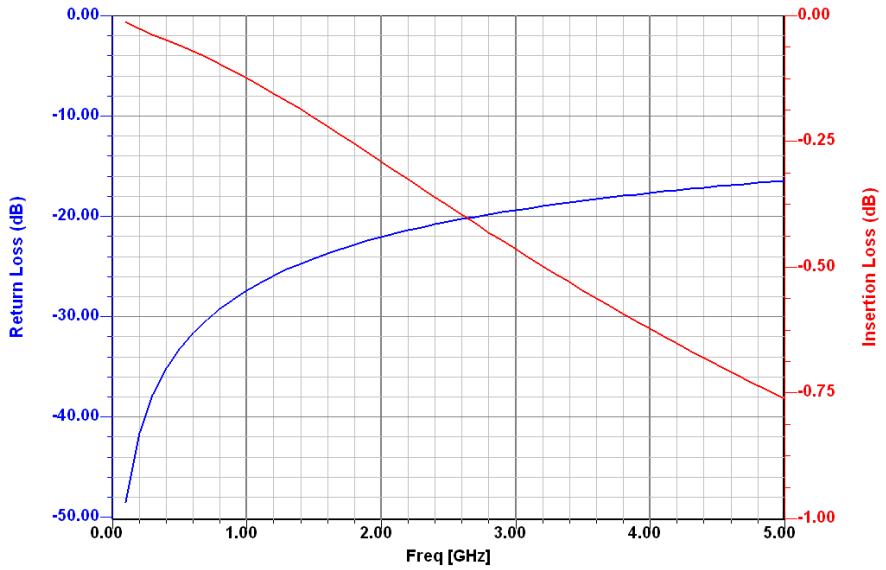
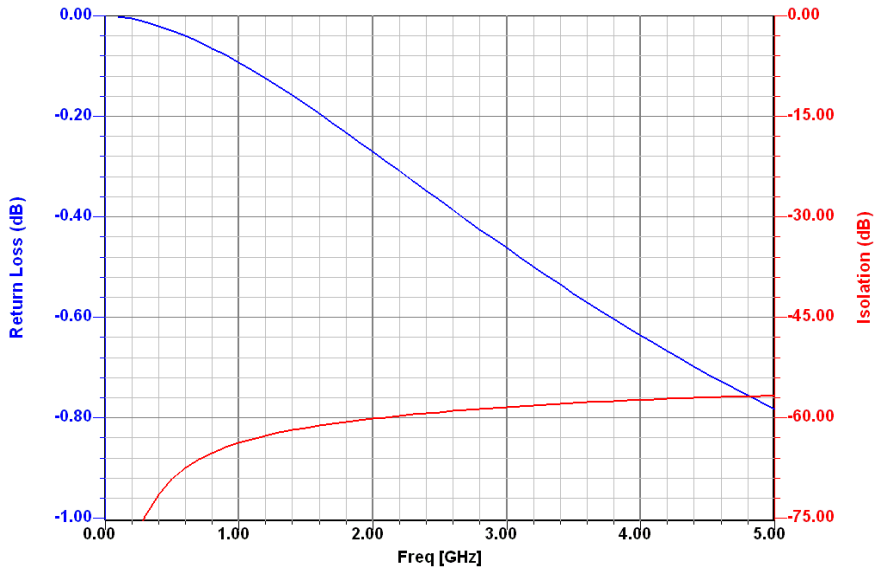
RF Measurements



Relay Closed



Relay Open

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