Micromachined Switches and Relays

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Outline

• Motivation
  – Relays: for low frequency signals
  – Switches: for low and high frequency signals
• Embodiment of micro switches and relays
  – Electrostatic actuation
  – Electromagnetic actuation
  – Thermal bimetallic actuation
Conventional Electromagnetic Relay
Macro Relay

Spring keeps the 'normally closed' contacts closed when coil is NOT energized.

When the coil is energized, the movable contacts will be pulled in and allow current to flow through the other set of contacts.

The green line indicates the path in which current would be allowed to flow when the relay coil is NOT energized.

Relay coil

Relay coil contacts
P-I-N diode

- Advantage for RF switching
  - Constant capacitance
  - High power handling capacity
  - High speed
    - $W/2v_s$
    - $v_s$ being the saturation velocity of minority carriers in the intrinsic region
Motivation for Micro Mechanical Switches

- High degree of integration with IC
- Increased on/off impedance ratio
- Reduced power consumption
Shortcomings of Conventional Relays and Switches

• Performance
  – High loss at on-state
  – High leakage at off state
    • Especially important for phase array phase shifters
  – Response speed slow
• Volume, weight and power consumption
Requirement of Military Radars

Reduce aerodynamic drag associated traditional dish radar
Increase response speed of weapon deployment and foe detection
Planar configuration for realizing low radar cross-section.
Electronics Scanning and Phase-Array Radar

- Increased data rates
- Instantaneous beam positioning
- Elimination of mechanical errors
- Multi-mode/Multi-target capability

- Refer to attached paper by Elliot Brown
2D Arrayed Phase Array Radar
Micro Switch Phase Delay (Coarse)

- Schematic diagram of time-delay phase shifter in which $N$ different binary loops are connected in series to provide $2^N$ possible delays.
- Following delays are possible for $N=3$
  - $3\lambda/24$, 6, 9, 14, 15, 18, 21, 24.
Electrostatic Actuation Switch

- Simple configuration
- Easy to control
- May require voltage outside of the IC power supply range
  - I.e. greater than 5 V.
Types of Waveguides

Micro strip waveguide

Co-planar wave guide
Electrostatic Simulation Results
Photos of Switch at On and Off Positions

ON

OFF
Electroplated Ni Switch
Electromagnetic Micro Relay

- High force, stable contact
- Possibility of achieving latching
- Low voltage, compatible with IC

- Current driving, power hungry.
Electromagnetic Active Micro Relay

Integrated Micro Relay

Permalloy beam

Copper coil
First Variable Reluctance Actuator

Deflection: 5 μm to 10 μm

Coil Current: 20 mA to 500 mA

Closing Force: 10 μN to 1 mN
Fabrication Process
Fabrication Process (continued)
• http://www.memsindustrygroup.org/instat02.htm
• http://www.memagazine.org/backissues/jan01/features/reraces/reraces.html
Electromagnetic Latching Switch

- Invented by Arizona State University Professor J. Shen
- Basis for MicroLab, a start up backed by 4.5 Million funding.
  - http://www.microlab.net/paperBody.html
Two Stable Positions

[Diagram showing two stable positions with North (N) and South (S) poles indicated.]
Chang’s Secret Sauce to Get Tech-Rich

• A “brilliant” idea
  – best ideas are always simple ideas!
  – Don’t fool yourself.
  – Career wise, always place your self in a good position to generate a good idea.
    • A faculty member, a research group leader, a department head
• Turn it into an iron-locked patent
  – uniqueness + good lawyers
  – why? Prevent others from competing
• Find good investment
  – All dollars are not created equal.
Thermal Actuator

- Thermal Actuator offers unique control modes

- Thermal actuation requires high power, so latch is required at steady state.