Position Sensing for Every Pneumatic Cylinder

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Introduction to Sensor Embedded Actuator

- **Basic Principle**
  - Resistance variation corresponding to piston position
  - Capacitively coupled AC signal pickup
  - Sensing capability inherent to the cylinder

- **Implementation**
  - Resistive film applied to exterior of cylinder tube
  - Alternating voltage penetrates insulation and reaches piston
  - Two alternatives for leading the signal out
  - Signal is processed by standard LVDT signal conditioner

- **Advantages**
  - Performance similar to LVDTs
  - Non-contact sensing
  - Reduced cost
  - Space savings

- **Applications**
  - Industrial manufacturing and control, robotics, etc.

Pneumatic Actuator Can Replace Hydraulic Actuator

**Pneumatic Actuators In Comparison to Hydraulic Actuators**

- **Advantages of Pneumatics**
  - Faster response
  - Compliance (depends on application)
  - Clean working media
  - Low sensitive to leakage

- **Disadvantages of Pneumatics**
  - Poor controllability (speed and displacement control)
  - Compliance (depends on application)

**Solutions**

- **Higher Frequency PWM control (~1000Hz)**
- **Displacement Sensor**
  - Accurate displacement control
  - Smooth pressure control
  - Wide range of speed control (0.9 ~ 1513 mm/s)

- **Bi-port Pressure Control**
  - Compliance is controllable

**Digital Clay**

- **Composition**
  - Micro miniature actuator-sensor arrays
  - Fluid power system
  - Control system

**Application Example**

- **3D human-machine haptic interface**
  - Tangible 3D shape/surface
  - Computer controlled
  - Haptic/semi-haptic style
  - Can be digitally edited/ transferred

Future work

- **Ubiquitous sensor embedded actuator**
  - Sensor in every actuator
  - Power via energy harvesting
  - Sensing via wireless transmission

Digital Clay

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**Sensing Performance**

- **Non-Linearly (< 0.5%)**
- **Non-Repeatability (<0.01%)**
- **Longevity (> 2 million cycles)**

**Signal Out**

- Cushion
- Coaxial Cable
- Piston
- Resistive Film
- Tube
- Cushion
- Seal
- Cylinder Rod

**Encoder**

- Pressure Sensors
- Displacement Signal

**Digital Clay**

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