

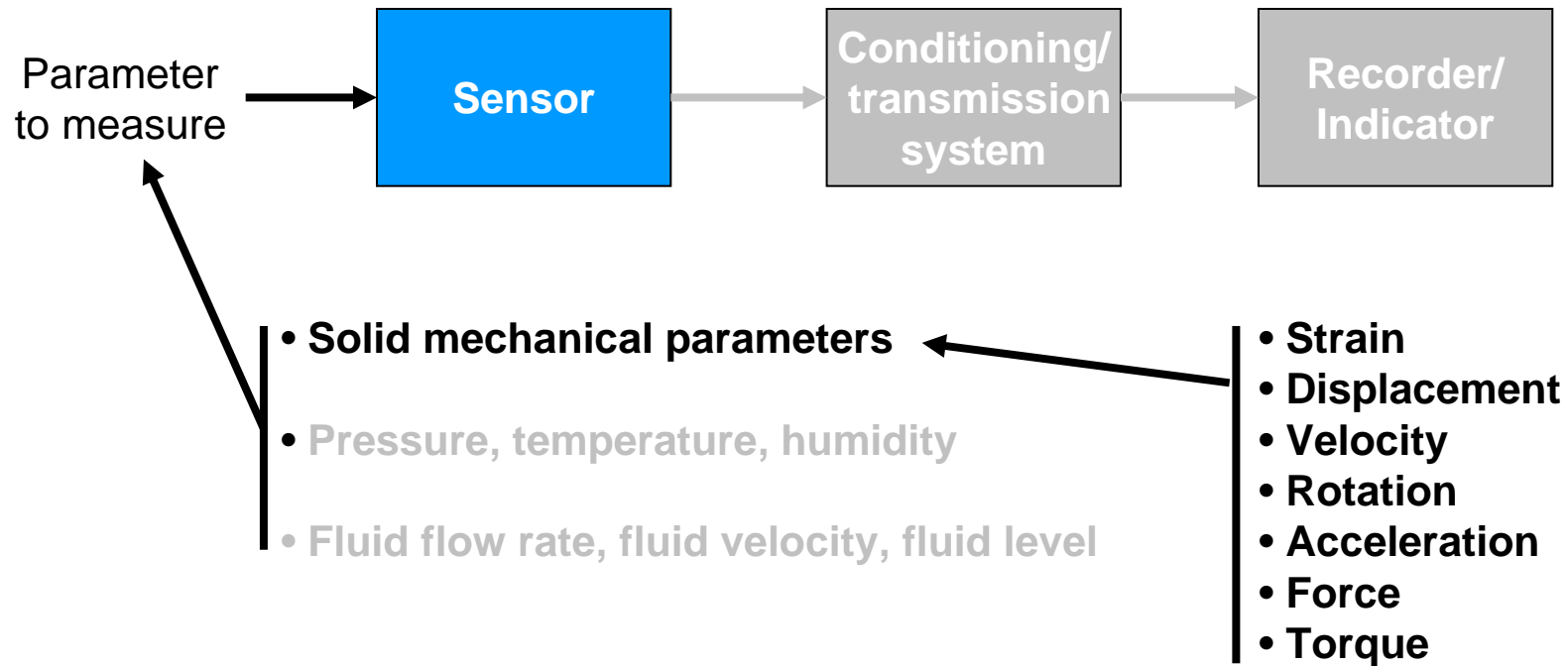
# Design IV

## E232 Spring 07

Class 17

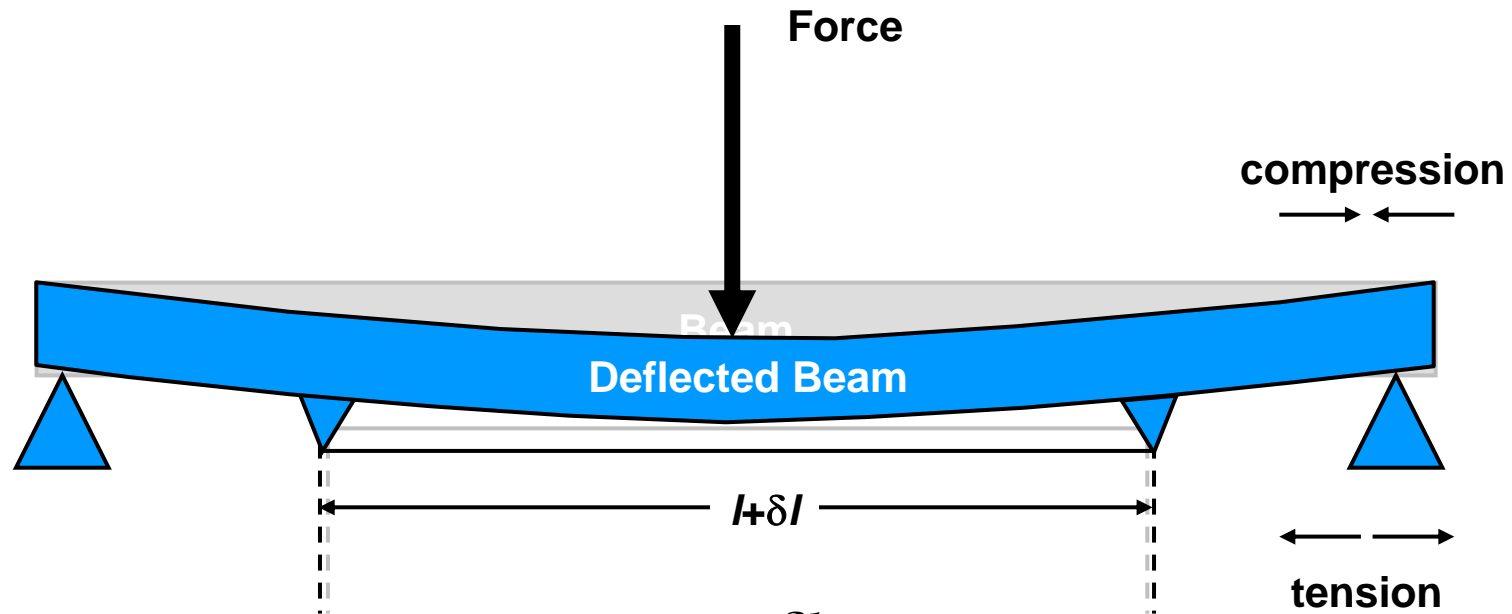
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# Measurement Systems



# Strain Measurement

- Under load, the beam deforms and places the bottom edge of the beam in tension

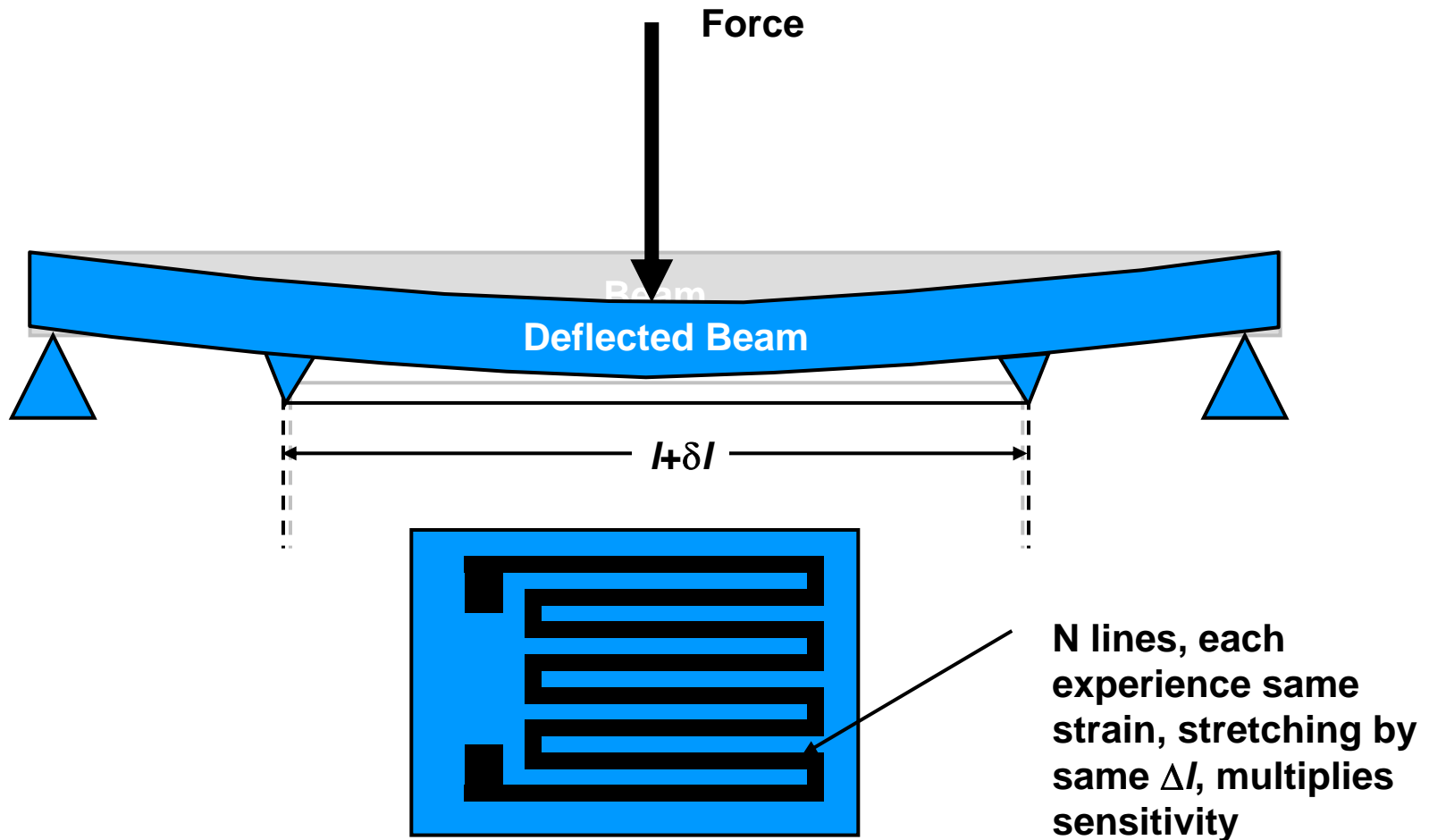


**Strain:**  $\varepsilon = \frac{\delta l}{l}$

**Stress:**  $\sigma = E\varepsilon$

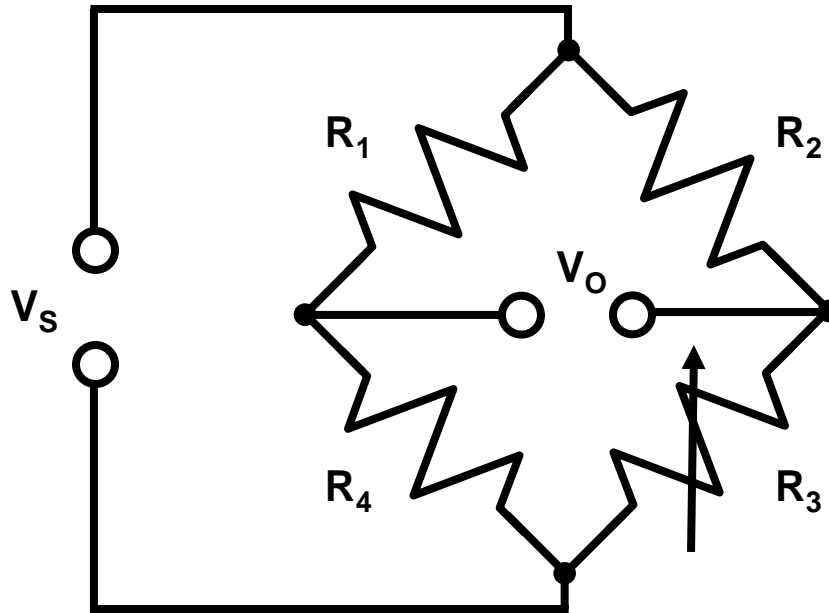
# Strain Measurement

- Alternative: foil strain gauges



# Magnitude of Stress Resistance Measurements

- How can you expect to measure a change in resistance that is much less than 3 ppm? A Whetstone Bridge:



- $R_3$  is the strain gauge

- $R_1+R_4$  as well as  $R_2+R_3$  create voltage dividers. If:

$$\frac{R_1}{R_4} = \frac{R_2}{R_3}$$

- the bridge is balanced and  $V_o = 0$

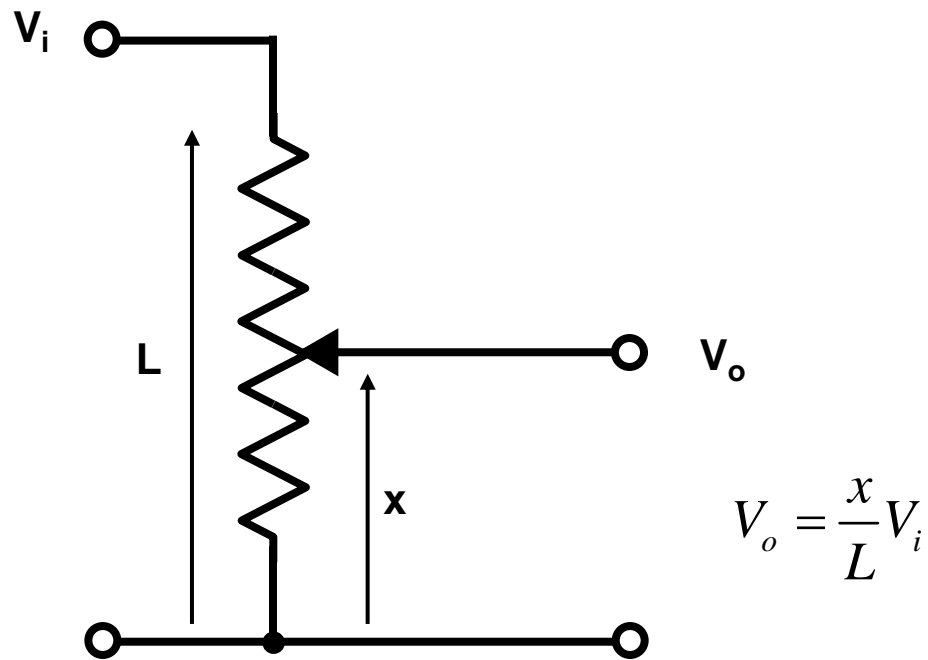
- Any change in  $R_3$  unbalances the bridge, generating a non-zero  $V_o$

# Today's topics

- Measurement sensors
  - Strain
  - **Displacement**
  - Velocity
  - **Rotation**
  - Acceleration
  - Force
  - Torque

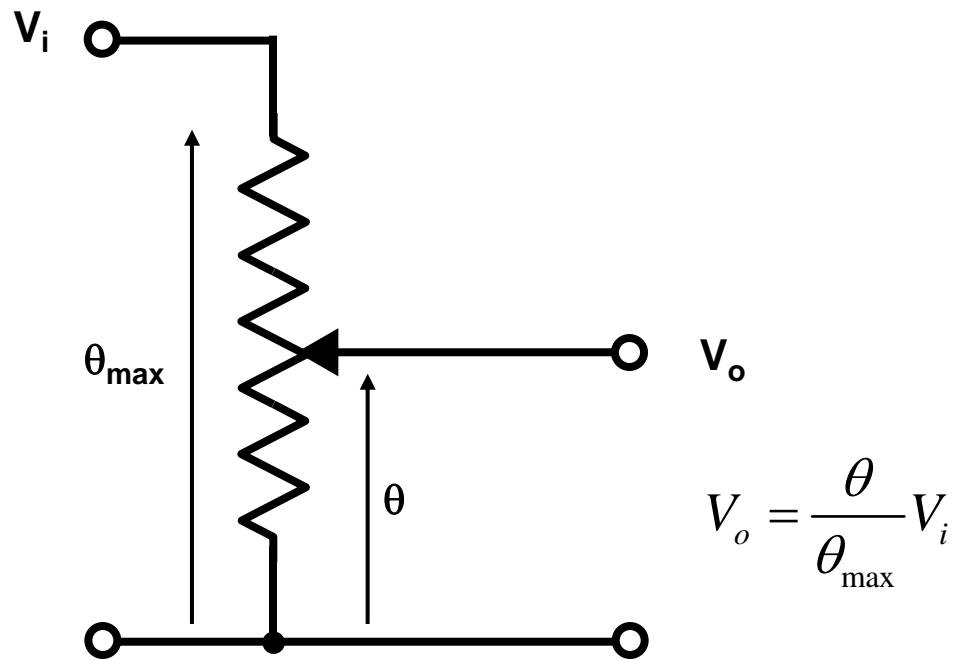
# Displacement Sensors

- Linear potentiometer



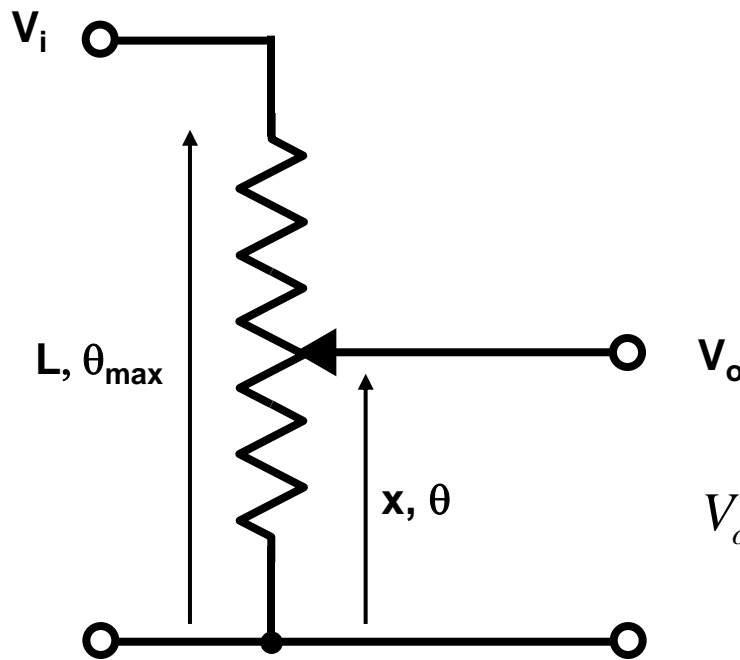
# Displacement Sensors

- Rotating potentiometer



# Displacement Sensors

- Potentiometer



## Issues:

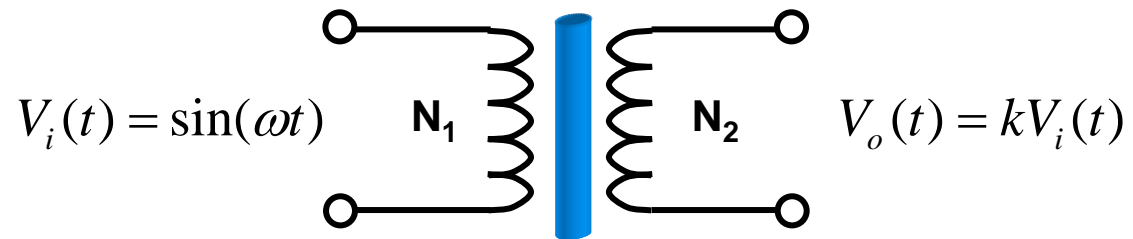
- Noise
- Linearity
- Resolution
- Measurement range
- Lifetime
- Discrete steps

$$V_o = \frac{\theta}{\theta_{\max}} V_i$$

$$V_o = \frac{x}{L} V_i$$

# Displacement Sensors

- Transformer

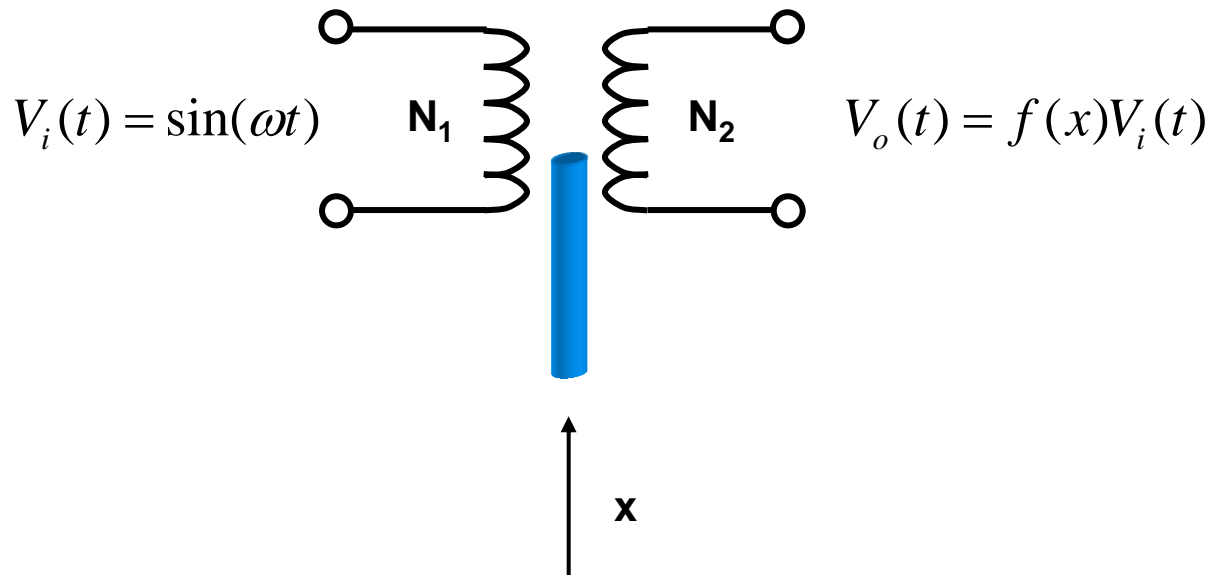


# Displacement Sensors

- Transformer

## Issues:

- Linearity
- Measurement range

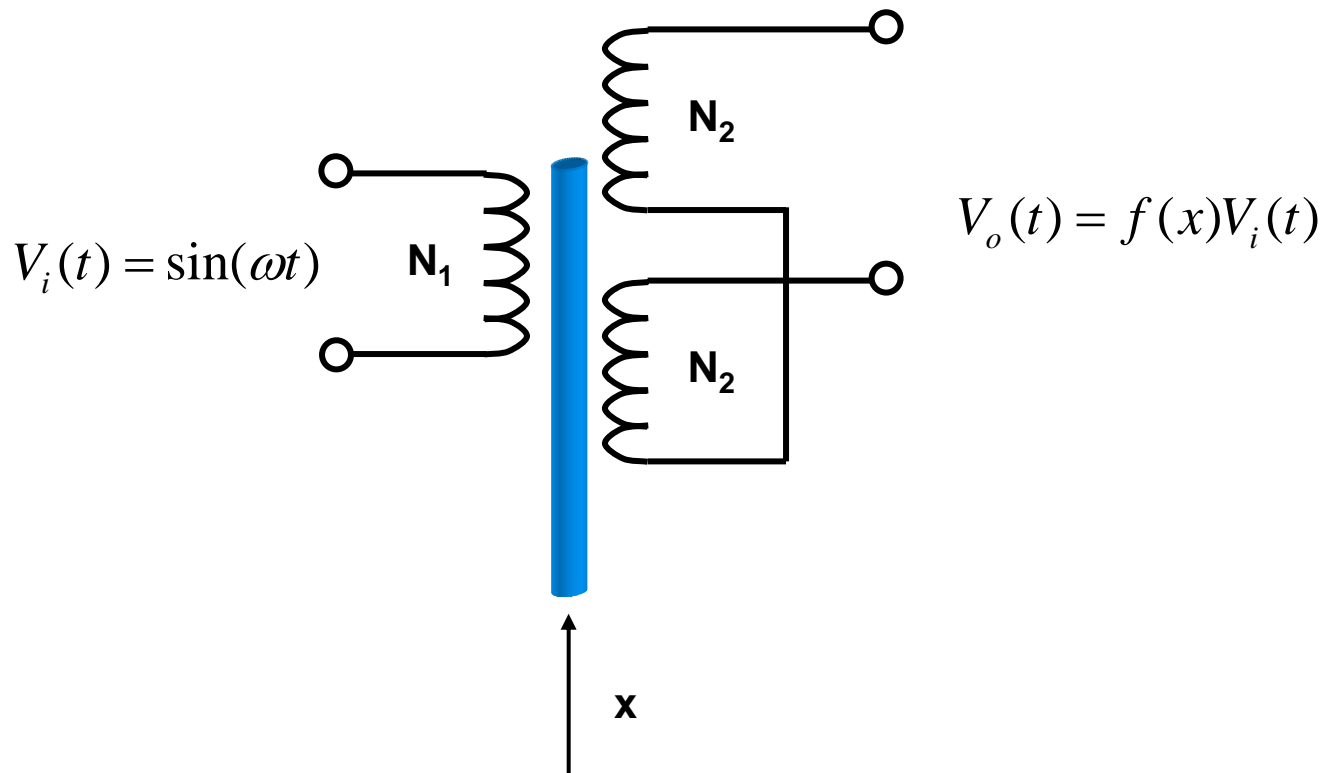


# Displacement Sensors

- Differential Transformer

**Issues:**

- Measurement range

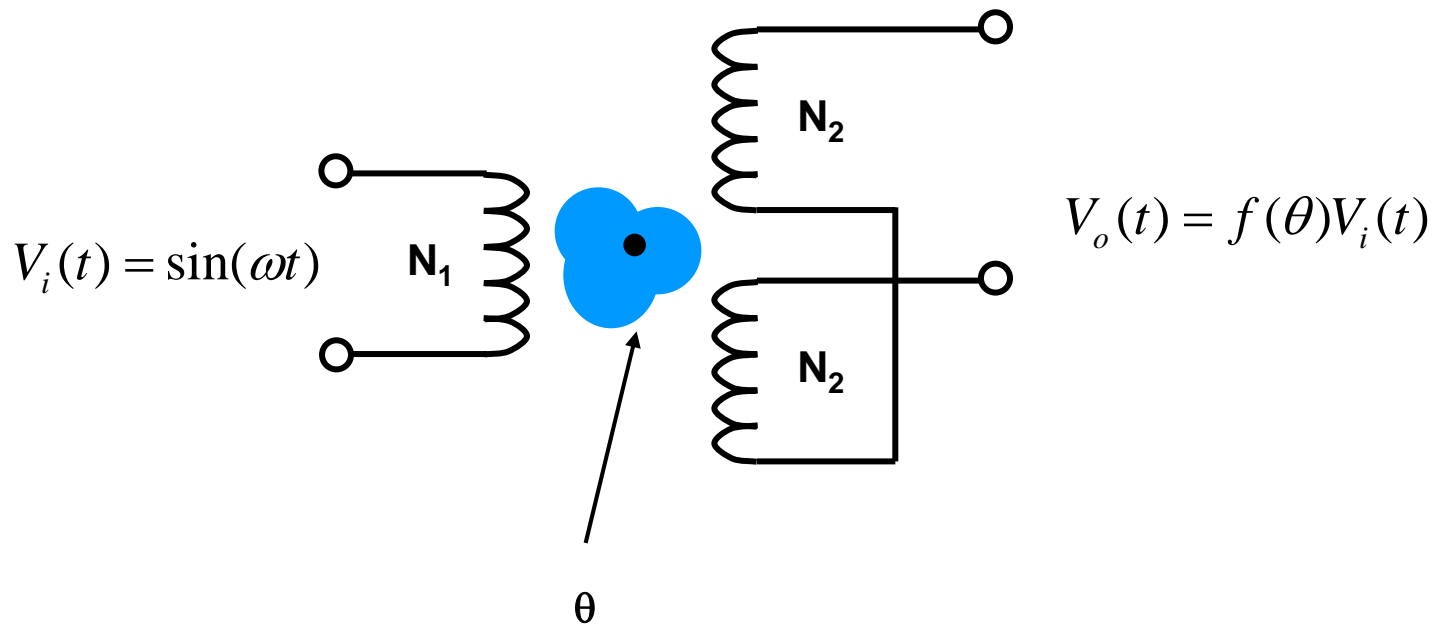


# Rotation/Displacement Sensors

- Rotational Differential Transformer

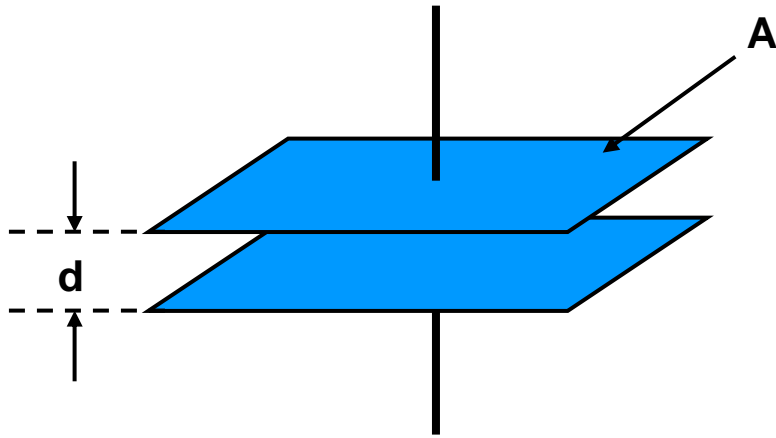
## Issues:

- Resolution
- Linearity



# Displacement Sensors

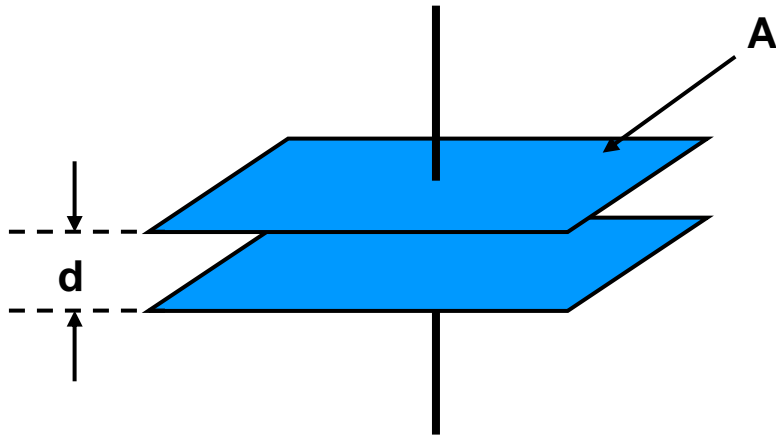
- Capacitive sensor



$$C = K \epsilon_0 \frac{A}{d}$$

# Displacement Sensors

- Capacitive sensor



**Change overlap:**

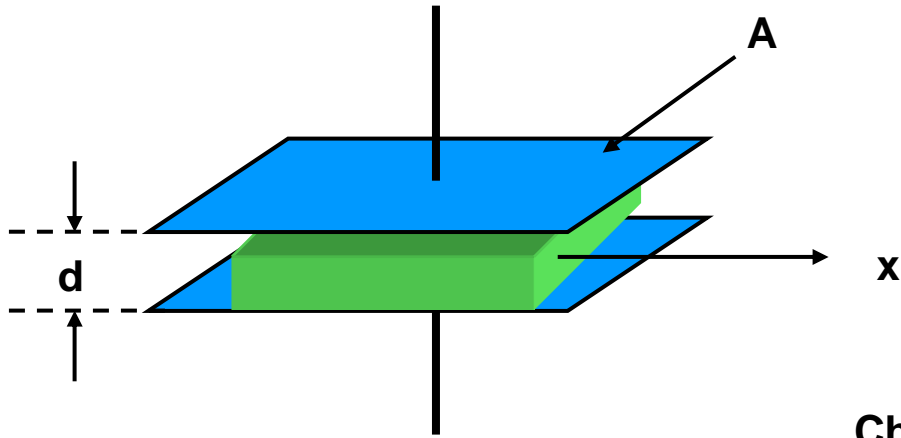
$$C = K \epsilon_0 \frac{A(x)}{d}$$

**Change spacing:**

$$C = K \epsilon_0 \frac{A}{d(x)}$$

# Displacement Sensors

- Capacitive sensor



**Change overlap:**

$$C = K \epsilon_0 \frac{A(x)}{d}$$

**Change spacing:**

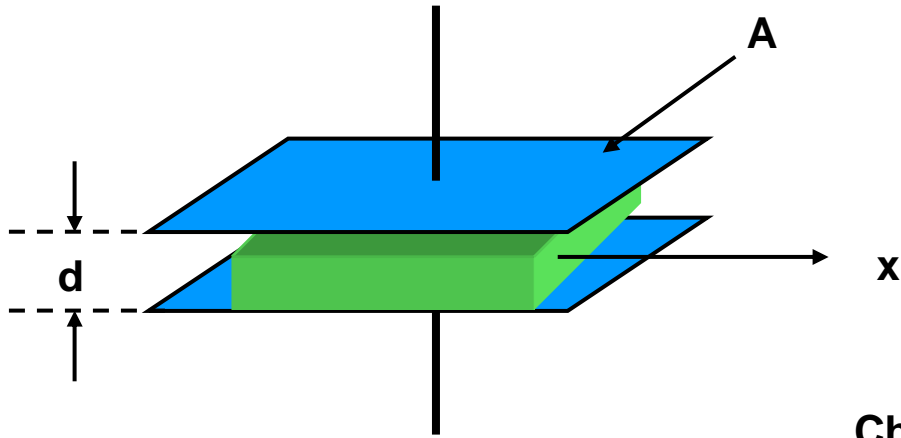
$$C = K \epsilon_0 \frac{A}{d(x)}$$

**Change dielectric overlap:**

$$C = K(x) \epsilon_0 \frac{A}{d}$$

# Displacement Sensors

- Capacitive sensor



**Change overlap:**

$$C = K \epsilon_0 \frac{A(x)}{d}$$

**Change spacing:**

$$C = K \epsilon_0 \frac{A}{d(x)}$$

**Issues:**

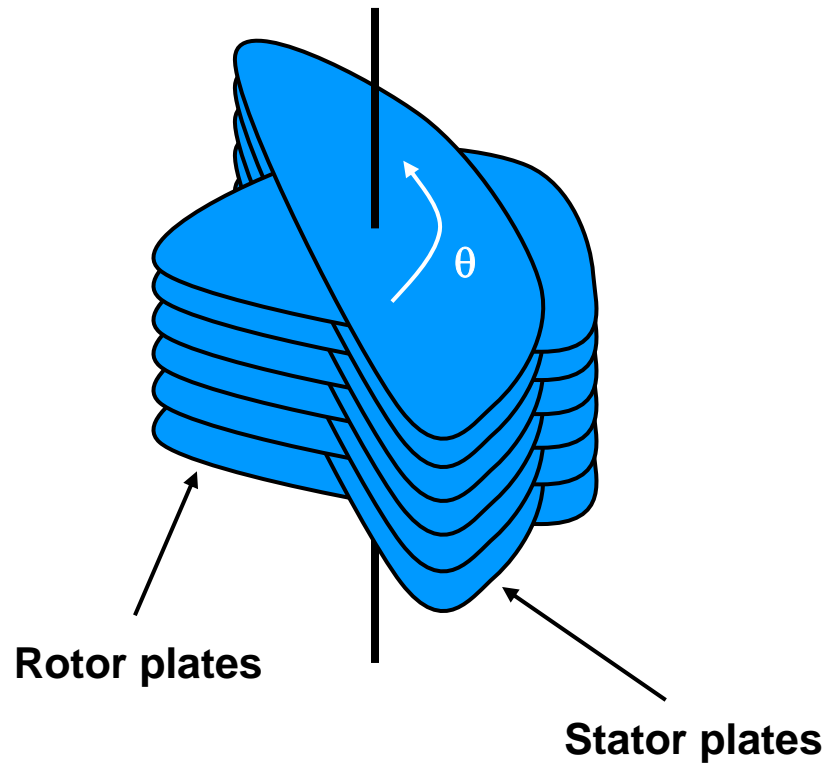
- Measurement range

**Change dielectric overlap:**

$$C = K(x) \epsilon_0 \frac{A}{d}$$

# Rotation/Displacement Sensors

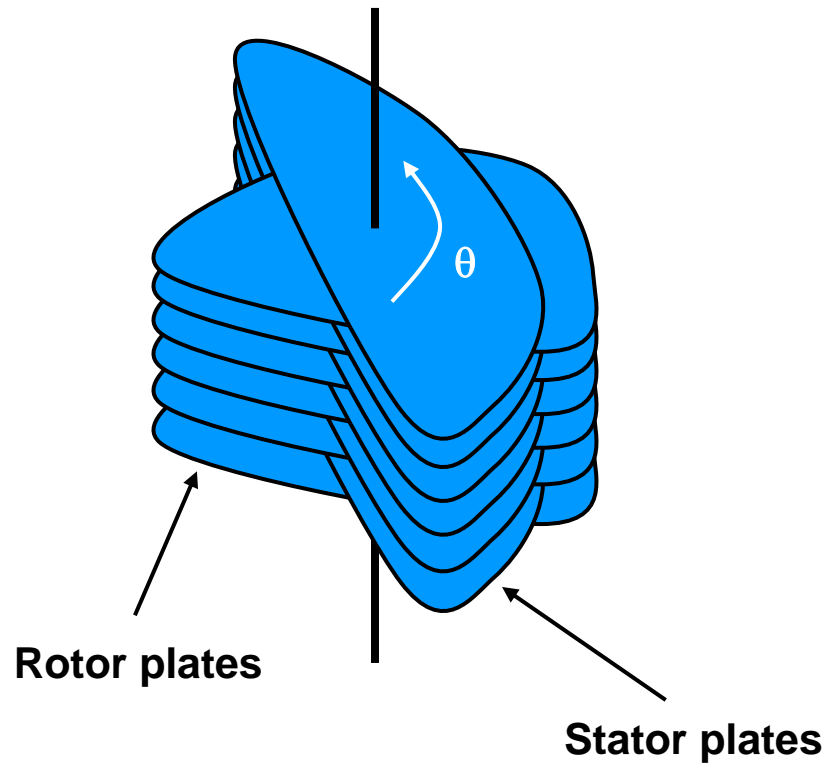
- Rotary capacitor



$$C = K \epsilon_0 \frac{A(\theta)}{d}$$

# Rotation/Displacement Sensors

- Rotary capacitor



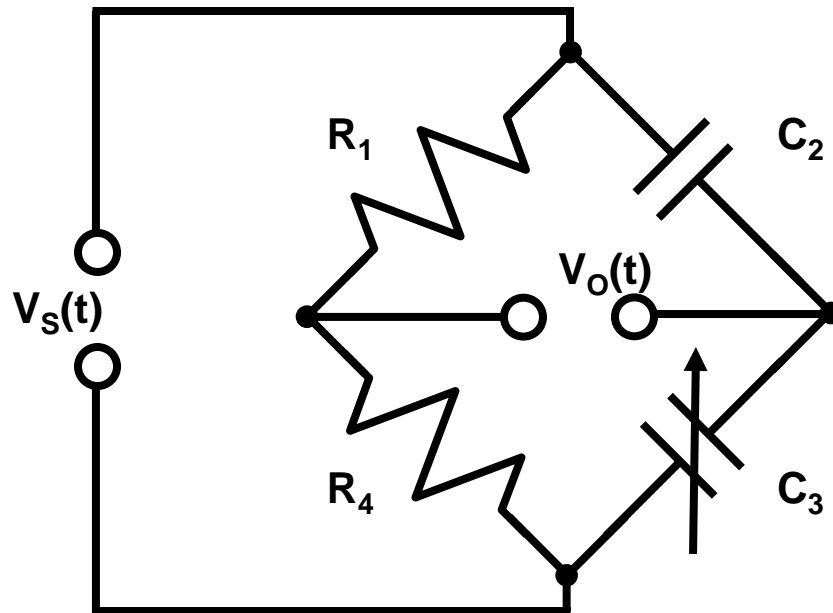
$$C = K \varepsilon_0 \frac{A(\theta)}{d}$$

## Issues:

- Measurement range
- Linearity

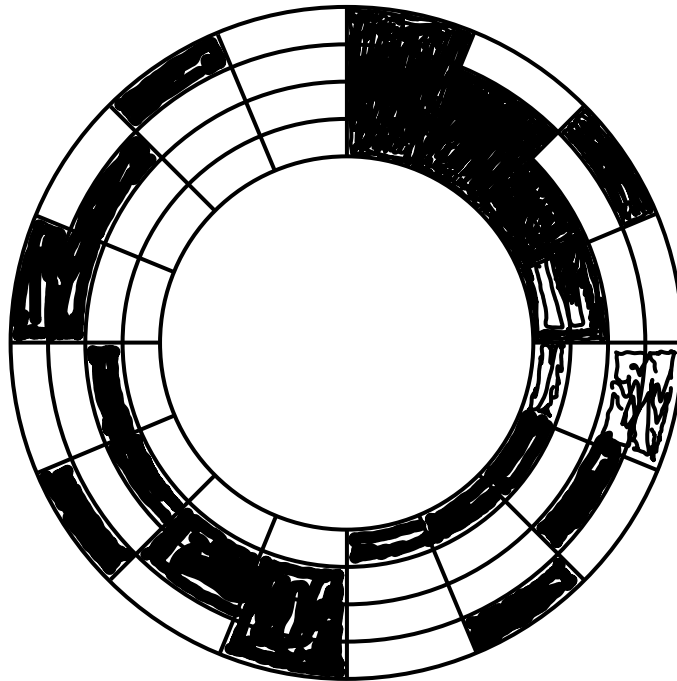
# Displacement Sensors

- Using capacitive sensors



# Rotation Sensors

- Digital angular encoder

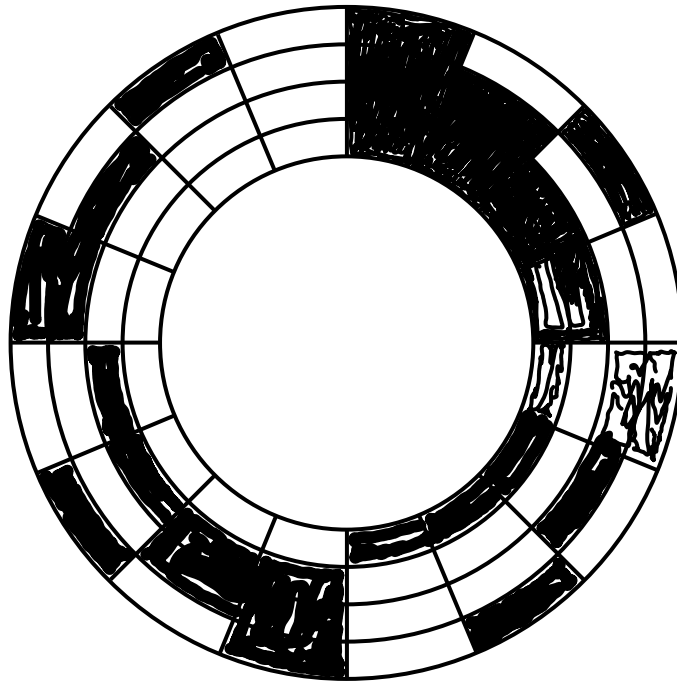


**Binary encoding of angle  
e.g., 4-bit encoder**

0000  
0001  
0010  
0011  
0100  
0101  
0110  
0111  
1000  
1001  
1010  
1011  
1100  
1101  
1110  
1111

# Rotation Sensors

- Digital angular encoder



**Binary encoding of angle  
e.g., 4-bit encoder**

0000  
0001  
0010  
0011  
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0110  
0111  
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1001  
1010  
1011  
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1101  
1110  
1111

**Issues:**

- Quantization

# Next time

- More measurement sensors