1 Formula

Strain Gauge:

- Δl:length
- Δa: cross sectional area
- Poisson Ratio: $v = -\frac{e_T}{e_L}$

$$strainguage : G = \frac{\frac{\Delta R}{R}}{e}$$

$$strain : e = \frac{\Delta L}{L}$$

$$\Rightarrow \frac{\Delta R}{R} = G \cdot e$$

$$R_{new} = R_{origin}(1 + G \cdot e)$$

- Quater Bridge:$V = out = \frac{1}{4} V_s \cdot G \cdot e$
- Half Bridge:$V = out = \frac{1}{2} V_s \cdot G \cdot e$
- Full Bridge:$V = out = \frac{1}{1} V_s \cdot G \cdot e$

Gauge Factor

$$G.e = \frac{\Delta R}{R}$$

$$\frac{\Delta R}{R} = \frac{\Delta \rho}{\rho} + (1 + 2k)\frac{\Delta L}{L} = G.e$$

RTD(Resistance Temperature Device)

$$R_T = R_0(1 + a_1 T + a_2 T^2 + \cdots + a_n T^n)$$

$$\epsilon(T) = R(T) - R(ideal)$$

Thermistor(Semiconductors)

$$R = R_0 e^{\frac{1}{\beta}(\frac{1}{T} - \frac{1}{T_0})}$$

Displacement Measurement

- Resistive Potentiometer:$\frac{V_0}{V_S} = \frac{R_{AC}}{R_{AB}} = AC/AB$
- Differential Capacitive transducer:

1. Three plate in parallel and move middle one: $V_0 = -V_S \frac{\Delta x}{2d}$(Middle plate move to the right C2). Details in LECTURE 6.
2. Overlap area changing: $V_0 = -V_S \frac{\Delta A}{2A}$(Increase overlap)

Hamming Code

$$2^r = n + 1$$

$$r = 3.322 log_2^n$$

Accelerometer
Steady-state sensitivity

$$S_0 = \frac{Steady\ state\ voltage}{acceleration}$$

Unit: $\frac{V}{g}$

First-order System

$$x(t) = x(\infty) + (x(0) - x(\infty))e^{-\frac{t}{\tau}}$$

Hamming Distance Between A and B

$$A \oplus B$$

2 Definition

- **Sensors**: Detect physical variables and give measurable electrical output.
- **Measurand**: The physical quantity being measured.
- **Transducer**: Device which converts one energy to another.
- **Accuracy**:How close the output reading of the instrument is to the correct value. typically: $\pm 1\%$ of all scale.
- **Precision**: Describes an instruments degree of freedom from random errors
- **Resolution**: Smallest increment of measurand (increment).
- **Sensitivity**: Sensitivity if a measure of change in output of an instrument for a change in measurement input variable.
- **Rosulution**: Resolution is smallest increment of measurand, which can be measured by instruments.
- **Nonlinearity**: Nonlinearity is defined as maximum deviation of any of output readings from the approximate transfer function.
- **Hysteresis**: Hysteresis is the deviation of sensor's output at a specified point of input signal, when the input signal is approached from opposite direction, it is expressed as maximum hysteresis.
- **MEMS**: Micro-Electro-Mechanical Systems. Micro-components integrated on a single chip, which allows the micro-system to control the system.

3 Devices

Inductive transducers (LECTURE 7)

- Linear Variable Differential Transfoemer(LVDT)
- Rotray Variable Differential Transfoemer(RVDT)

Optical Transducers (LECTURE 7)

- Incremental: When moving to next sector, only 1 bit changes
- absolute: Each sector increments by 1

Key points:The advantages and disadvantages for each

4 Tao Lu

4.1 Transient Response Analysis

1. Find the point with proper $\frac{\omega}{\omega_n}$ and ζ
2. Read $\frac{S}{S_0}$ from the graph
3. Convert from dB, then find S
4. $V = S \times a$, where a is acceleration
5. $V_{p-p} = 2 \times V$

4.2 Thermalcouple

1. Denote the voltage with reference temperature T_1 is V_1
2. Find voltage at reference temperature V_2
3. The voltage with reference temperature 0 is $V = V_1 + V_2$
4. Find the temperature.

4.3 RTD(end point linearity)

1. Write down $R_T = R_0(1 + a_1T + a_2T^2 + \cdots + a_nT^n)$
2. Find R at T_{max}
3. Calculate the slope $\frac{T_{max}-T_{min}}{R_{max}-R_{min}}$
4. The slope is sensitivity.
5. $\epsilon(T) = R(T) - R(ideal)$
6. $\frac{d\epsilon(T)}{dT}$, find T_0
7. Find $\epsilon(T_0)$
8. $\epsilon(\%FSD) = \frac{\epsilon(T_0)}{R_{Max}-R_{Min}}$

4.4 Strain Gauge

- **Temperature Compensator**: Does not measure strain, use cross axis.
- **Amplifier**: $Gain = \frac{R_{Right}}{R_Left}$

4.5 Resistive Potentiometer

- **Error**: Caused by the resistance of potentiometer, or resistance of wires.

4.6 Fuel Tank

Capacitance change when dielectric constant changes. The reading is not affected by the movement because the capacitors are connected in parallel, the total C does not change.

4.7 Parity Check

1.

4.8 Accelerometer

Advantages of Servo Accelerometers

- Electronically control damping and spring coefficient, easy to get desired characteristics
- Low Hysteresis.

4.9 Noise Elimination

- **Capacitive**:
  1. Differential Amplifier
  2. Connect the inner conductor to outer conductor which is grounded
- **Electromagnatic**:
  1. Twist the conductors(cancel induced voltage).
  2. Physical seperation.
- **Ground Loops**:
  1. Remove one of the ground paths, thus converting the system to a single point ground.
  2. Isolate one of the ground paths with an isolation transformer, common mode choke, optical coupler, balanced circuitry, or frequency selective grounding.

4.10 Relative Error

1. Find the variable X.
2. Find the error may occur ΔX
3. Relative error is given by $\frac{\Delta X}{X}$

4.11 Phase Dector

1. Find $V_0 = V_S(\frac{C_1}{C_1+C_2} - \frac{1}{2})$
2. Write C as $\epsilon_r\epsilon_0\frac{A}{d}$, and substitute into the function.
3. Replace d with $d \pm \Delta X$
4. The phase indicates the direction