

May 14, 2016

## 1 Formula

### Strain Gauge:

- $\Delta l$ : length
- $\Delta a$ : cross sectional area
- Poisson Ratio:  $\nu = -\frac{e_T}{e_L}$

$$\text{strain} : G = \frac{\frac{\Delta R}{R}}{e}$$

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

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

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

- Quarter 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

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

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

Both side divided by  $e$ ,  $G = 1 + 2k + \frac{\Delta \rho}{\rho} \frac{1}{e}$ , which is larger than unity.

### RTD(Resistance Temperature Device)

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

$$\epsilon(T) = R(T) - R(\text{ideal})$$

### 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

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

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 instrument's degree of freedom from random errors
- **Resolution:** Smallest increment of measurand (increment).
- **Sensitivity:** Sensitivity is a measure of change in output of an instrument for a change in measurement input variable.
- **Resolution:** 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 Transducer (LVDT)
- Rotary Variable Differential Transducer (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  $\zeta$
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  $R_T = R_0(1 + a_1T + a_2T^2 + \dots + a_nT^n)$
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
- **Electromagnetic:**
  1. Twist the conductors(cancel induced voltage).
  2. Physical separation.
- **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  $\Delta X$
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