10/8/22

2

18EC0133T. Sensors & Transducers

Unit.1

Sensors & Transducers

used in industries

Sensors: Converts physical qty to some other electrical qty.

Transducers: One form of energy to another

SYLLABUS

1. Introduction to sensors/transducers, principles.
2. Classification based on different criteria
3. Characterstics of measurement systems
4. Static characterstics (accuracy, precesion, resolution, sensitivity)
5. Dynamic characterstics

MCQ
X area,
10M

6. Electrical parameters
7. Electrical & Mechanical Characterization
8. Thermal, Optical characterstics
9. Errors and its classification

10. Selection of transducers
11. Intro. to mechanical sensors
12. Resistive potentiometer
13. Strain Guage
14. RTB
15. Thermistor

Theory portion

Definition:

1. Transducer

A device that converts energy from one form to an another form

2. Sensor

It is a type of transducer which converts a physical parameter to an electrical output. Eg: Microphone

3. Physical Quantity:

Temperature, pressure, force, motion, displacement, humidity etc...

4. Electrical Quantity

Change in resistance, Inductance, Capacitance

STATIC CHARACTERSTICS

A set of criteria which do not vary with time

↳ Accuracy

↳ precision

↳ resolution

↳ sensitivity

(i) Accuracy

The accuracy of an instrument is a measure how closely measured value of the instrument is to the true value

(ii) Precesion

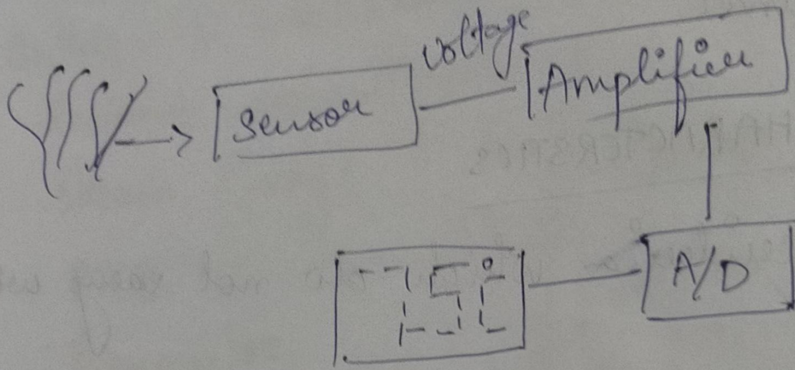
It is defined as capablity of an instrument to show the same reading when used each time

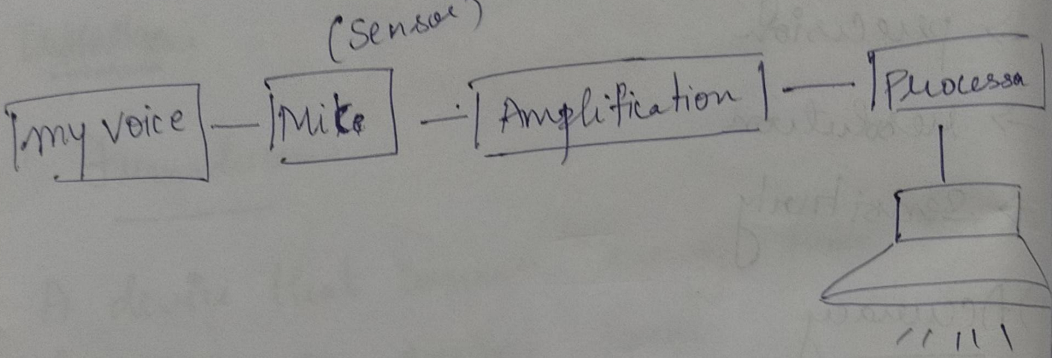
[Reproducablity of an instrument]

↓

repeatablity

16/8/22





I STATIC CHARACTERSTICS

→ A set of criteria which does not vary with time is called static characterstics

* Accuracy
* Precesion
* Resolution
* Sensitivity

Accuracy

The accuracy of an instrument is a measure of how close the measured value of the instrument is to the true value.

$$\boxed{\text{Percentage of accuracy} = \frac{\text{True value} + \text{Measured value}}{\text{True value}} \times 100}$$

Precision

Precision is defined as capability of an instrument ~~shun used~~ to show the same reading everytime. (Reproducibility of the instrument)

Sensitivity

It is defined as the ratio of change in output towards the change in input at a steady state condition

$\boxed{Q \rightarrow \text{quantity}}$

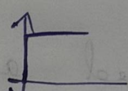
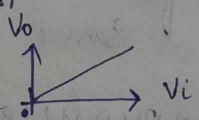
$$\text{Sensitivity (K)} = \frac{\Delta Q_o}{\Delta Q_i}$$

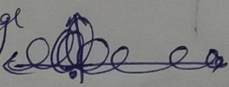
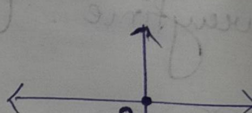
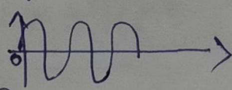
Resolution

It is the smallest change in the measured quantity that will produce a dedictable change in instrument reading

II. Dynamic Characterstics

A set of criteria which varies with time is called dynamic characterstics

* Step change 
* Linear change/Ramp 

* Impulse change  
* Sinusoidal change 
* Speed of response
* Fidelity
* Lag
* Dynamic Error

(i) Speed of response

It gives the information about how fast the system reacts to the changes in input

(ii) Fidelity (without error how a system will output)

It is defined as the degree to which an instrument indicates the changes in the measured variable without dynamic error

(iii) Lag : delay in the response of the system

(iv) Dynamic error : difference b/w true value of the variable to be measured changing with time and the value indicated by the measurement system assuming zero error.

Classification of transducers

Based on

i) Transduction principle
- using physical / chemical effect

ii) Primary input quantity
→ pressure
→ temperature
→ humidity .... etc

iii) Material & Technology
↓
Sensors
- Image sensor
  → CMOS
- Motion detector
  → IR, ultrasonic
- Biosensor electrical
- Acceleration MEMS

iv) Application
- industrial type
- non-industrial type
  - automobile
  - Consumer products
  - aircraft
  - Medical products

v) property

20/8

Errors

- Gross errors
  - due to human mistake
  - avoid by
    1) Careful reading
    2) Repeat reading
- Systematic errors
  - Environmental error
  - Instrumental error
    1) due to inherent short coming of ~~dest~~ instrument
    2) Misuse of instrument
    3) Loading effect
  - Observational error
    - parallax
    - Inaccurate estimation
    - Incorrect conversion
- Random error
  - any disturbance

Types of error appeared in Sensors 4 Transducer

Ty
→ Gross error
→ Systematic error
→ Random error

231

10M :- Selection of Transducers

1) Operating principle
2) Sensitivity
3) Operating range
4) Accuracy
5) Cross Sensitivity
6) Transient & frequency response
7) loading effect
8) Environment compatiblity
9) Usage and readiness
10) electrical aspects
11) Stability & ~~sea~~ reliablity

3/8/22

Characterization

↳ (how to test the transducer
↓
electrical, mechanical,
$\underbrace{\text{optical}}_{\text{diff. aspects}}$)

Characterization of the sensor can be done in many ways depending upon type of sensors.

Specifically they are

(i) electrical
(II) Mechanical
(III) Optical
(IV) Thermal
(V) Chemical
(VI) Biological and so on

Electrical Characterization

(i) Impedance, voltage, current
(II) Breakdown voltage & fields
(III) Leakage current

(IV) noise

(V) Cross talk

Impedence : Coupling circuit

↓

Ratio of voltage & current

$\frac{\text{O/P imp}}{\text{I/P imp}}$ ~~will~~ should be high for voltage sensitive sensor

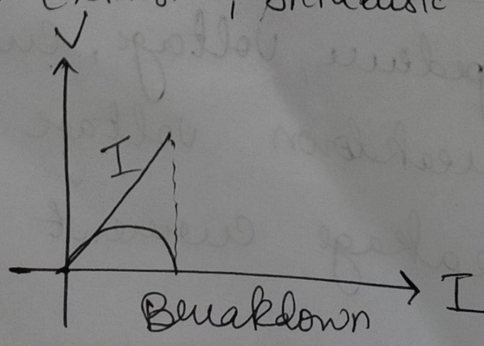
$\frac{\text{O/P imp}}{\text{I/P imp}}$ ~~will~~ should be low for current sensitive sensor

Checkuphealth

→ sudden, avalanche

→ extensic, Intrinsic

} Breakdown, voltage & field



Mechanical & thermal characterization

- Reliablity & integrity

⇓

by means of testing

⇓

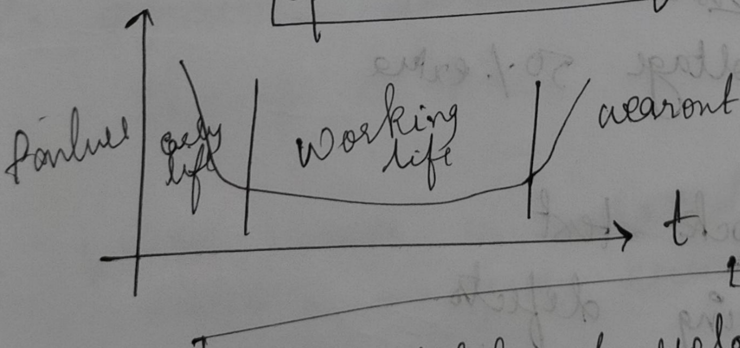
failure analysis

(1) catastropic early life failure (during manufacturing itself it may fail)

(2) short term drift (within very short term, it many get fail)

(3) long term drift & failure (due to ageing / used the longterm failure)

$\boxed{\text{probability of failure} = f(x)}$



$\boxed{\text{probability of relaiablity} = R(x) = 1 - f(x)}$

$= \int f(t).dt.$

※ Explain characterization of procedures

10M / 12M

1) High temperature burn in

↳ H.T over a stipulated period

125°C

2) High temperature storage bake

backed at a high temperature

↳ contamination

↳ Metallization problem

3) Electrical Overstress

Over voltage 50% extra

4) Thermal Shock test

packaging defects

65° - 125°C

10 seconds → repeated

5) Mechanical shock test

dropping 3 to 10m

Optical characterisation

absorption co-efficient
refractive index
reflectivity

MCQ

1. Change in output of sensor with change in input → Sensitivity

2. dynamic describes the performance with change in time

3. Which error is related to human error → gross error

4. Fidelity is static characteristics - False

5. Sudden change in voltage / current - breakdown

6. Large value upto 50% in excess are applied over different intervals of time is called <u>electrical overstress</u>.

~~7. Probablity fn is~~

7. Reablity fn is gn by <u>1 - f(x)</u>

Sensors and transducers

Mechanical ~~Sensors~~ Sensors

Input quality - Mechanical parameter

Motion
Displacement
Speed
Velocity
pressure flow & Flow
acceleration
Torque

→ Sensor ↓ Output

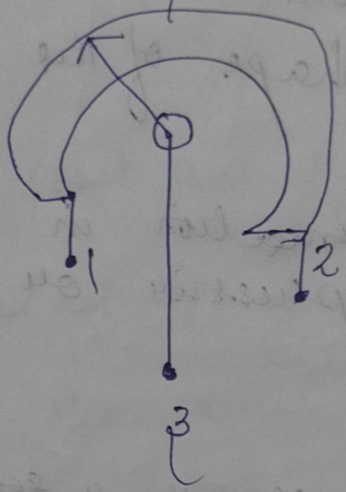
Electrical
Magnetic
Optical
Thermal etc

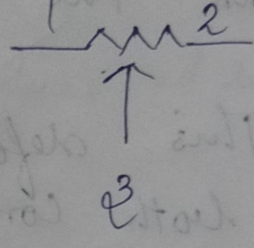
electromechanical
(or)
mechanoelectrical

→ processing & display

Resistive potentiometer

1) Linear potentiometer
2) Variable potentiometer





$$\Delta V = \frac{V}{n}$$

$$\Delta V_m = V_p\left[\frac{1}{n-1} - \frac{1}{n}\right]$$

$$\Delta V - \Delta V_m = \frac{V}{n} - V_p\left[\frac{1}{n-1} - \frac{1}{n}\right]$$

Strain Gauge X (Class test)

$$\text{Gauge factor } (G) = \left\{\frac{\Delta R/R}{\Delta L/L}\right\} \rightarrow \text{Strain}$$

When an external force is applied on an object (force, pressure, tension, weight) due to which there is a deformation (change in in the shape of the object

This deformation in the shape is both compressive or tensile is called strain

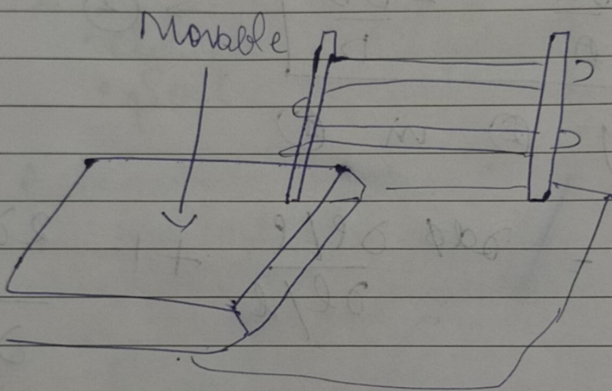
A strain gauage is a ~~sen~~ sensor whose resistance varying with applied force by measuring the change in resistance of an object. the amount of induced stress can be calculated.

Type of strain guage

1) Wire strain type — Unbounded resistance wire strain guage
— bounded resistance wire strain guage

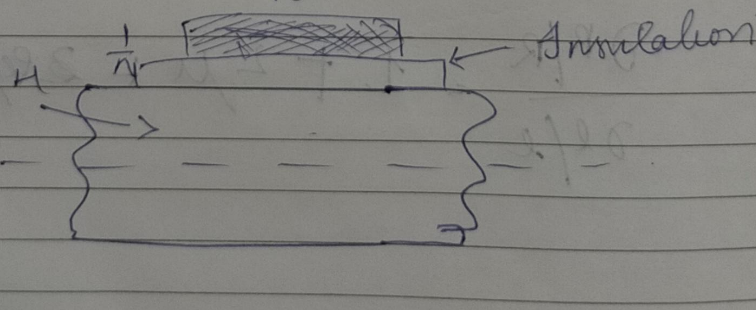
2) Semiconductor gauge type

Unbounded strain guage



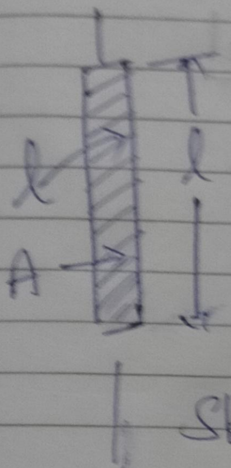
Bounded type ..

Strain : $E_m \frac{H}{h+H}$



Depending upon the implementation, the resistance guage can be classified as

(i) Unbounded metal wire
(ii) bounded metal wire
(iii) Bonded metal foil
(iv) Thin metal film by vacuum
v) " " " by spatter



$R = \frac{\rho l}{A}$ ρ – resistivity
l – length of wire
A – Area of crossection of wire

Strain Gauge

Calculation of gauge factor

$$R = \frac{\rho l}{A}$$

$$\log R = \log \rho + \log l - \log A.$$

$$\frac{\partial R}{R} = \frac{\partial \rho}{\rho} + \frac{\partial l}{l} - \frac{\partial A}{A}$$

divide $\partial l/l$ completely

$$\frac{\partial R/R}{\partial l/l} = \frac{\partial \rho/\rho}{\partial l/l} + 1 - \frac{\partial A/A}{\partial l/l}$$

$A = \frac{\pi D^2}{}$ $\partial A = \frac{\pi 2D\, \partial D}{}$

$$\partial A = \frac{\pi}{4}(2D)\,\partial D$$

$\div A$

$$\frac{\partial A}{A} = \frac{\cancel{\pi/4}(2\cancel{D})\,\partial D}{\cancel{\pi/4}\,D^2}$$

$$\boxed{\frac{\partial A}{A} = 2\frac{\partial D}{D}} \rightarrow (2)$$

Apply (2) in (1)

$$\frac{\partial R/R}{\partial l/l} = \frac{\partial \rho/\rho}{\partial l/l} + 1 - \frac{2\,\partial D/D}{\partial l/l}$$

Let poisson ratio $\mu = -\frac{\partial D/D}{\partial l/l}$

$$\frac{\partial R/R}{\partial l/l} = 1 + 2\mu + \frac{\partial \rho/\rho}{\partial l/l}$$

RTD (Resistance Temperature Detector)

? The value of resistance changes with change in temperature

$$R_T = R_0 (1 + \alpha T)$$

↳ Temperature co-efficient of resistance

→ +ve temperature co efficient

PTC - Temp ↑ R ↑

NTC - Temp ↑ R ↓

↓

-ve temperature co-efficient

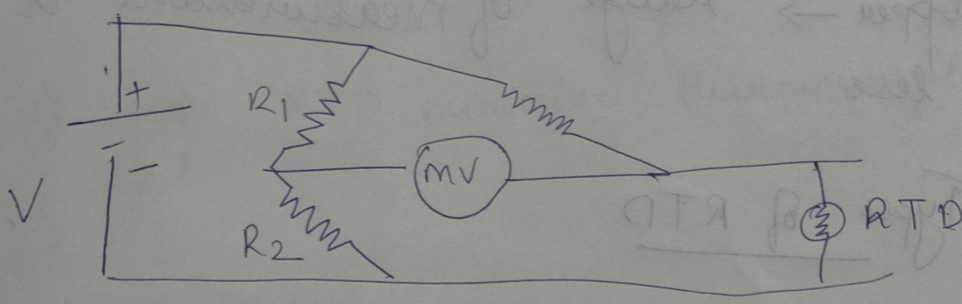
Mostly platinum

Others are copper, initial

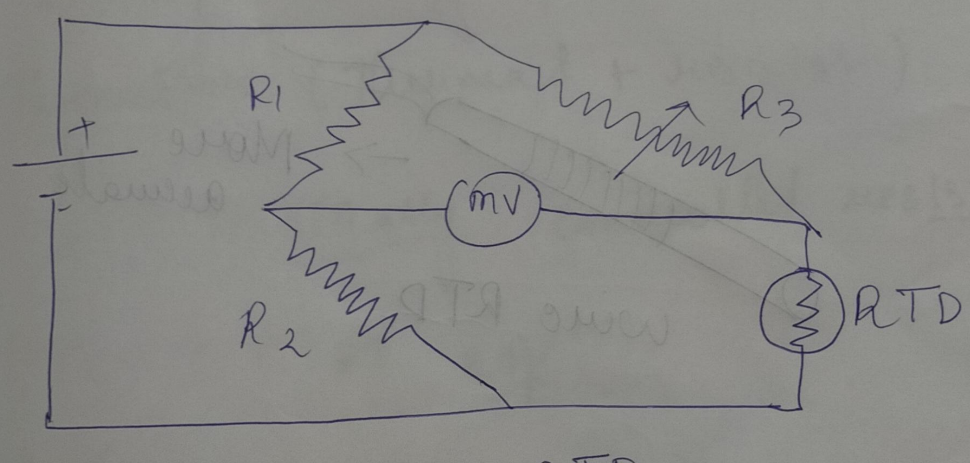
Eg

Used in Industries to monitor temperature of steam flowing in a pipeline

* RTD insearted in epipeline
* PT100 ⇒ 0°c → 100 Ω
  1°c → 200 Ω



cheap, simple, but lower accuracy.



Maleuials used in R.T.D:

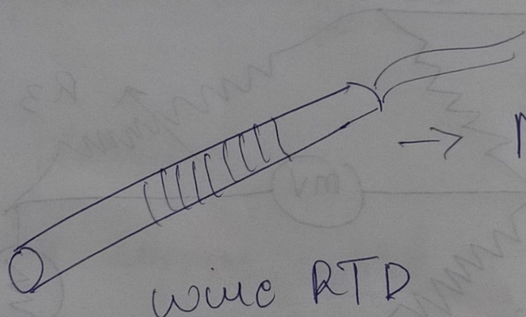
platinum → most common type RTD
→ Excellent corruission resistance
→ " longteum stability

Nickel → less expensive
→ good corrosion replacement
→ less accuracy

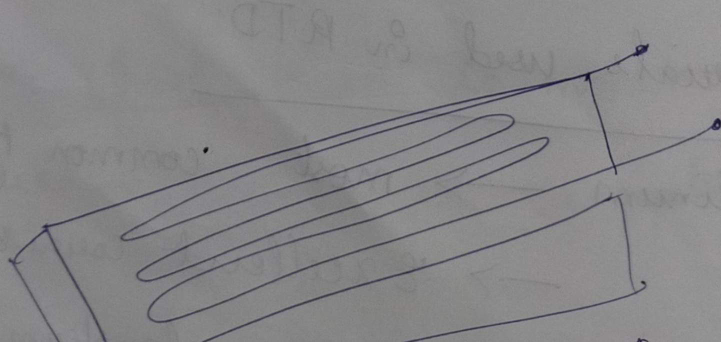
Copper → range of measurement is less

Types of RTD

1) Wire type RTD
2) Film type RTD



wire RTD



Thin film
→ less accurate
→ less expensive

Advantages of RTD

1) Good sensitivity

2) Linear over wide operating range

3) Copper RTD minimize thermocouple effect

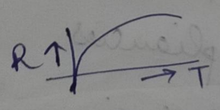
Disadvantage

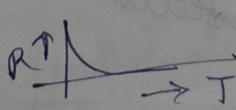
1) Bulky in size & fragile

2) Self heating problem

Thermistor (Thermal + resistor)

THERMally controlled resISTOR

PTC: T ↑ R ↑ 

NTC: T ↑ R ↓ 

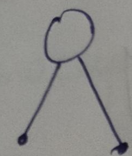
~~diff types of thermish shape~~

~~1) DISC Type~~

~~2) Bead "~~

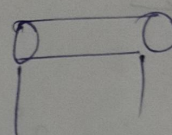
~~(3) Rod Type~~

different type of

1) DISC Type  → ~~[illegible]~~ greater power dissipation capacitor

2) Beed Type – very smallest (0.15mm diameter)

mostly used in industry

3) Rod Type -  - high power handling capacity

applications

1) digital thermometers
2) automative applications
3) Household appliancies
4) circuit protection

Thermistor

low cost

more accuracy

Thermistors are more accurate, cheaper and faster response than RTD.

Only demerit of thermistor is narrow operating temperature range, which is wider for RTD

Advantages

1) compact, ~~it~~ inexpensive

2) good stability.

3) sensitivity

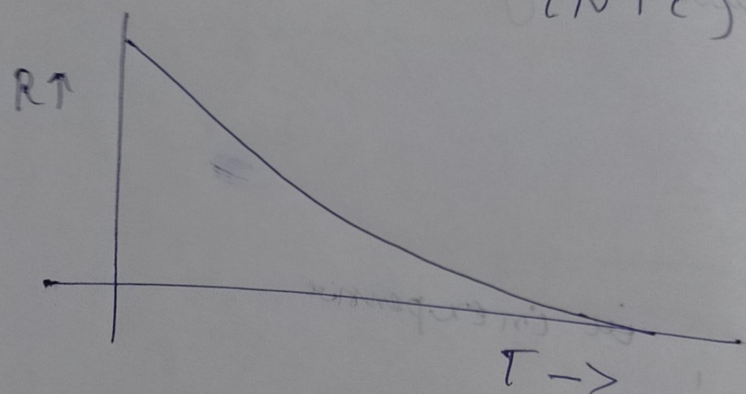
4) Faster response.

does not get affected due to electric and magnetic fields

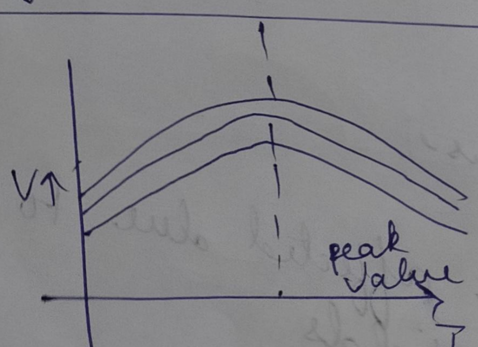
Characteristics of thermistor

1) resistance - temperature characteristics
2) Voltage - Current "
3) Current - time "

I Resistance - temperature charac (NTC)



II Voltage current charac.

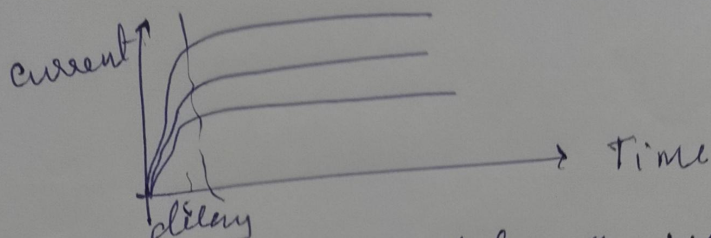


I↑ V↑ after peak V↓, I↑

Reason: Initially I is small, it's not produce a change in temp. So voltage drop↑

After peak value, I↑, R↓, V↓,

Current-time charac



V↓, delay ↑, V↑ delay ↓