Self generating / natural — no need for power supply

need a power supply

Passive and active sensors

Like Thermocouple

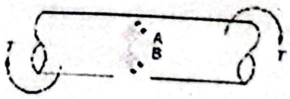
- Passive or self-generating
  - Directly generate an electrical signal in response to an external stimuli without the need for an external power supply
    - Output signal power comes from the stimulus
  - Examples (examples)
    - Thermocouple
    - Piezoelectric sensors
- Active or modulating
  - These sensors require external power supply or an excitation signal for their operation
    - Output signal power comes from the power supply
  - Examples
    - Thermistors (with Temp.)
    - Chemo-resistors

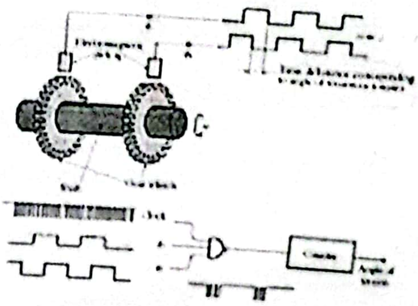
LDR → active sensor. needs power. (with light)

continuous — discrete.

Analog and digital sensors

- Analog sensors
  - Provide a signal that is continuous in both its magnitude and temporal or spatial content
    - Most of the physical measurands are analog in nature
  - Examples: Temperature, displacement, light intensity
- Digital sensors
  - Their output takes the form of discretesteps or states
  - Digital signals are more repeatable, reliable and easier to transmit
  - Examples: Shaft encoder, contact switch



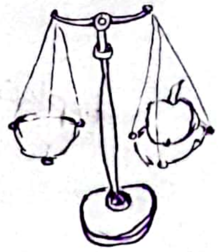


Deflection → الاعتيادي / الاكترونى
Null mode → الاخر

Operational modes

- Deflection mode → الالكتروني فكرة الميزان
  - The sensor or instrument generates a response that is a deflection or a deviation from the initial condition of the instrument
  - The deflection is proportional to the measurand of interest
- Null mode → الميزان العادي.
  - The sensor or instrument exerts an influence on the measured system so as to oppose the effect of the measurand
    - The influence and measurand are balanced (typically through feedback) until they are equal but opposite in value, yielding a null measurement

Benifts & desBenfits.
- Null mode instrumentation can produce very accurate measurements, but are not as fast as deflection instruments
  - → used in Widstond briged.



اجهزة

Mechanical measurands

- Displacement
  - Resistive sensors
  - Capacitive sensors
  - Inductive sensors
- Force and acceleration
  - Strain gauges ⟹ has a R GF = $\frac{\Delta R / R}{\Delta L / L}$ → المقاومة
  - Cantilever beam-based sensors

العرض

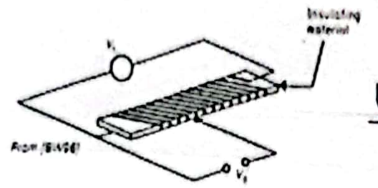
↳ Stress

أسهل مثال يعتمد على التغير في المقاومة

$$V_o = \frac{X - X_{min}}{X_{max} - X_{min}} V_o$$

Resistive displacement sensors

- A resistance with a movable contact (a potentiometer) may be used to measure linear or rotational displacements
  - A known voltage is applied to the resistor ends
  - The contact is attached to the moving object of interest
  - The output voltage at the contact is proportional to the displacement
- Notes
  - restrictions:
  - Non-linearities as a result of loading effects
  - Resolution due to limited number of turns per unit distance
  - Contact wear as a result of frictions



$$V_o = V_s \frac{X - X_{min}}{X_{max} - X_{min}}$$

العلاقة بين الـ Position الـ input والـ Voltage

$$V_o = V_s \frac{X - X_{min}}{X_{max} - X_{min}}$$

بـ نقدر اقيس الـ displacment

$$C = \frac{\varepsilon \varepsilon_0 A}{d}$$

$$C = \frac{2\pi \varepsilon \varepsilon h}{\ln(r_2/r_1)}$$

Capacitive Sensors

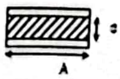
Capacitive displacement sensors

أنواع المكثف للقياس

- The capacitance of a parallel plate capacitor is

$$C = \frac{\varepsilon_0 \varepsilon_R \text{ Area of plate}}{\text{distance}}$$

$$C = \frac{\varepsilon_0 \varepsilon_R A}{d}$$



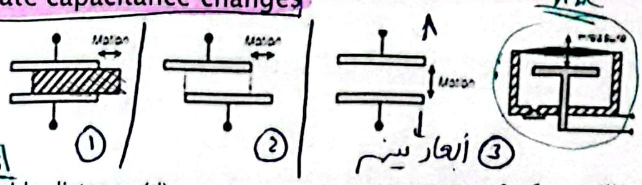
→ [non-Linear relationship]

  - d is the separation between the plates, A is the area of the plates, ε0 is the permittivity of air and εr is the relative permitivity of the dielectric → نقدر نتحكم في C عن طريق اللعب في ε_R

How to Find Cap of the cylinderical

$$C = \frac{2\pi h \varepsilon_0 \varepsilon_R}{\ln(r_2/r_1)}$$

- A moving object is attached to the dielectric or the plates to generate capacitance changes



أبعاد بينهم

(١) هوضع الـ core متحرك بناءً على الـ motion بتتغير قيمة الـ C، ومنها نقدر اعمل استنتاج للحركة

(٢) الطريقة الثانية اعمل overlap تغير Area

(٣) الطريقة الثالثة اغير الـ d

- Notes
  - Variable distance (d) sensors operate over a range of a few millimeters
  - Cross-sensitivity to temperature and humidity (specially if the dielectric is air)
  - Capacitive sensors are also commonly used to measure pressure
    - "Condenser" microphones measure changes in air pressure of incoming sound waves

Example on Capacitive Sensors

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why touch screen uses just finger? finger is capacitive

سرعة ثانية لقياس المسافة

Inductive displacement sensors

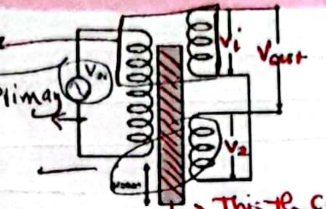
- Linear Variable Differential Transformer (LVDT)
  - Motion of a magnetic core changes the mutual inductance of two secondary coils relative to a primary coil

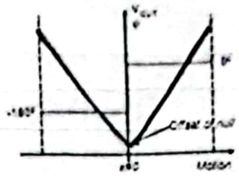
Screen needs capacitor sensor

AC Signal ← sensor one

Primary

Secondary Two





Linear علاقة Vout مع distance ←

→ This the core change coupling of secondary 1 & 2

- Primary coil voltage: $V_s\sin(\omega t)$
- Secondary coil induced emf: $V1=k1\sin(\omega t+\varphi)$ and $V2=k2\sin(\omega t+\varphi)$
  - k1 and k2 depend on the amount of coupling between the primary and the
  - secondary coils, which is proportional to the position of the coil
    - When the coil is in the central position, $k1=k2 \Rightarrow VOUT=V1-V2=0$ → #1
    - When the coil is is displaced x units, $k1 \neq k2 \Rightarrow VOUT=(k1-k2)\sin(\omega t+\varphi)$ → #2
    - Positive or negative displacements are determined from the phase of VOUT

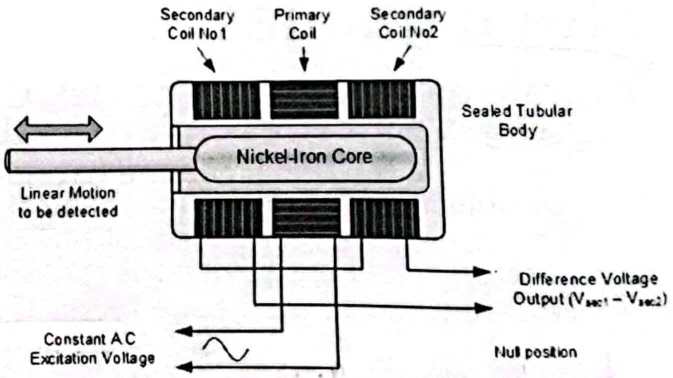
https://www.elprocus.com/lvdt-working-principle-construction-types-applications-advantages-and-disadvantages/
https://www.fierceelectronics.com/components/modern-lvdts-new-applications-air-ground-and-sea

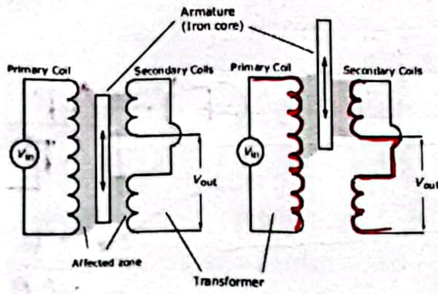
Aseel Deek

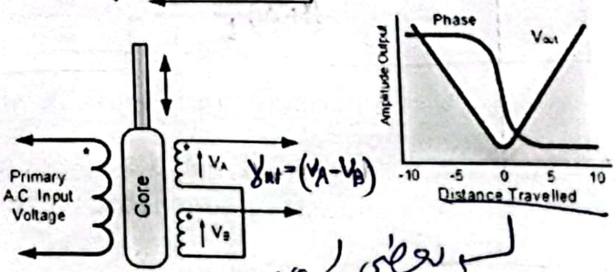
she is Cute. I Like her. hehehe.

← بيكون جوا Transformer شو اختصار تحويل من الكهرباء وحولها من AC لـ dc

حتى لا يتحرق الجهاز [magnatic effect]







Long live Time ← بتكون resistive مافي احتكاك ←

بيعطي destiance, مع direction [بيعطينا او بالسالب او موجب]

output voltage

Engineer A

Inductive displacement sensors (cont)

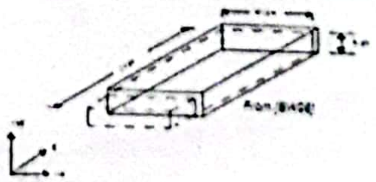
- LVDT Characteristics
  - Typical LVDTs run at 5V, 2kHz
  - LVDTs can measure from mm down to μm
  - Due to small variations in the windings, a small residual voltage appears at the output when the coil is in the central position
- Advantages of the LVDT over other displacement sensors
  - No mechanical wear ensures a long life
  - Complete electrical isolation
  - DC versions with integrated oscillators are available

Strain gauges

- Strain gauges are devices whose resistance changes with stress (piezo-resistive effect)
  - Strain is a fractional change ($\Delta L/L$) in the dimensions of an object as a result of mechanical stress (force/area)
  - The resistance R of a strip of material of length L, cross-section A and resistivity ρ is $R=\rho L/A$
  - Differentiating, the gauge factor G becomes

$$\frac{\Delta R}{R}=\frac{\Delta L}{L}-\frac{\Delta A}{A}+\frac{\Delta \rho}{\rho}=(1+2\nu)\frac{\Delta L}{L}+\frac{\Delta \rho}{\rho}\Rightarrow G=\frac{\Delta R/R}{\Delta L/L}=\underbrace{(1+2\nu)}_{\text{GEOMETRIC EFFECT}}+\underbrace{\frac{\Delta \rho}{\rho \Delta L}}_{\text{PIEZO-RESISTIVE EFFECT}}$$

- Where ν is the Poisson's ratio (ν≅0.3), which determines the strain in directions normal to L
  - In metal foil gauges, the geometric term dominates (G≅2)
  - In semiconductor gauges, the piezo-resistive term dominates (G≅100)



Pizo Resistive :- matiral بتغير قيمتها عالتغير ال

زي السليكون d لقوة او stresses

$$R = \frac{\rho \cdot l}{A P \alpha}$$

change $\frac{\Delta \rho}{\rho}$ = strains

لا الممنوع كل ~~الجولد~~ القطع بنفس المادة عشان اذى الي اي اعمل Integrated ~~circuits~~ bord ابنه كل القطع على نفس القطعه

$$GF = \frac{\Delta R / R}{\Delta L / L}$$

معناها change بال resistance

⇒ semi cond. تبعت ال GF عيبه ال رح تكون بالعادة كبيرة لانه في $\frac{\Delta R}{R}$ واشياء. اما في ال metical ما فيها $\frac{\Delta \rho}{\rho}$ اعلى اشي 1.6

$$GF = \frac{\Delta R / R}{\Delta L / L} \qquad Strain = \Delta L / L$$

Strain = 160 mm/m = 0.16

For $GF_{meg} = \frac{\Delta R / R}{\Delta L / L} \Rightarrow \frac{\Delta R}{R} = GF_{meg} (\Delta L / L)$

$$\frac{\Delta R}{~~120~~} = 2.13 (160) \times 10^{-3}$$

$$\boxed{\Delta R = 40.896}$$

For $GF_{semic} = \frac{\Delta R / 120}{~~160~~\ 0.16} \neq -162$

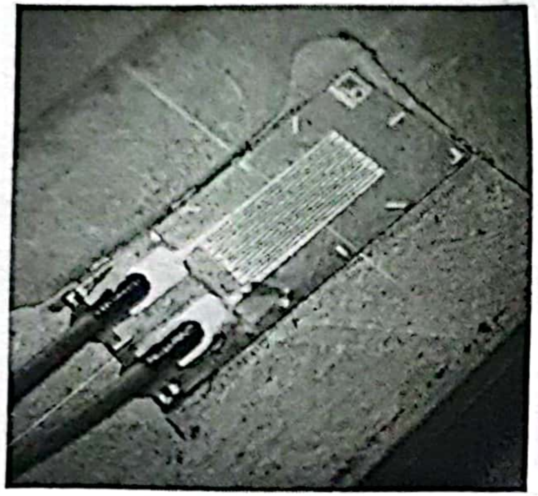
~~2.13~~

$$\boxed{\Delta R = 3091.2}$$

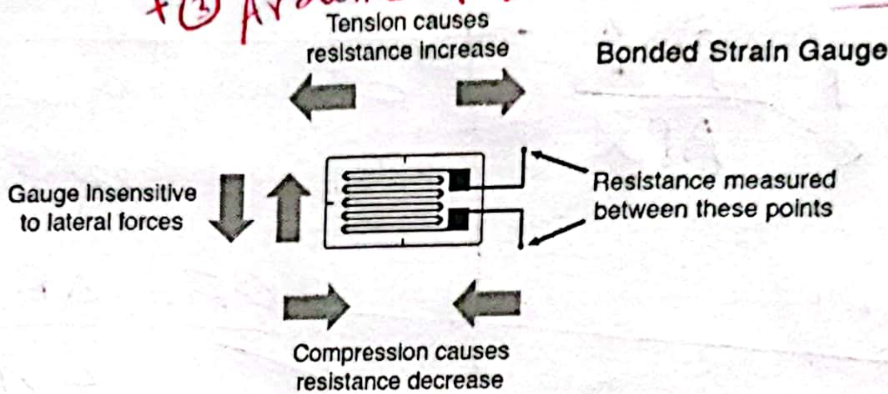
+ ① LoadCell
② Load ~~cell~~ ← ميزان الكتروني ←
conditioning circuit → Bridge + Amplification

How Strain Gauges Work?

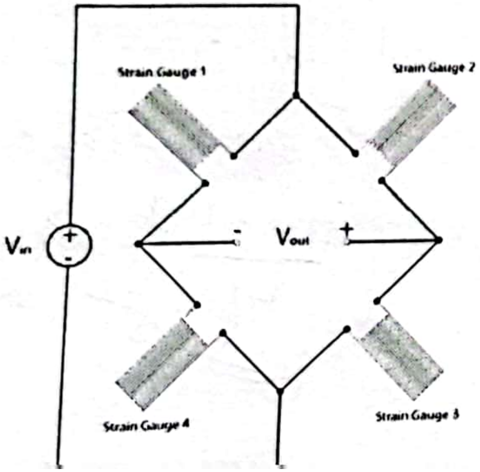
+ ③ Arduino + LCD → ميزان

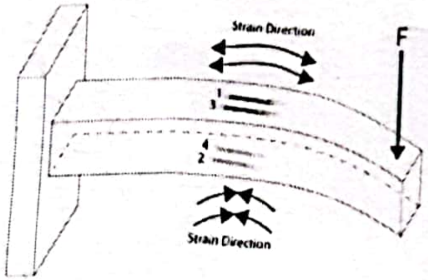


Bonded Strain Gauge



https://www.youtube.com/watch?v=LRd3W_p8PJ4



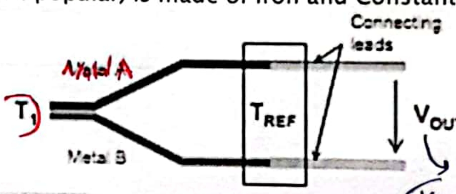


→ هاظ نفسه الي فرجانا اياه الدكتور، خشبة إلى فوقها لصق.

Find $T_{J}(13)$ … $T(13) = T_{(0)}(13) - T_{(0)}(3)$

Thermoelectric sensors

- The Seebeck effect
  - When a pair of dissimilar metals are joined at one end, and there is a temperature difference between the joined ends and the open ends, thermal emfis generated, which can be measured in the open ends
- The Peltier effect
  - When a current passes through the junction of two different conductors, heat can be either absorbed or released depending on the direction of current flow
- Thermocouples
  - Based on the Seebeck effect
  - Open ends must be kept at a constant reference temperature TREF
  - A number of standard TCs are used
    - These are denominated with different letter codes: T, J, K, S, R…
      - i..e, type J (the most popular) is made of Iron and Constantan (Cu/Ni alloy: 57/43)



$V_{\Delta} = (\alpha_A - \alpha_B)(T_1 - T_2)$

$\Delta V = (\alpha_A - \alpha_B)(T_A - T_B)$

Positive ↔ negative will produce very large ΔV

Thermocouples

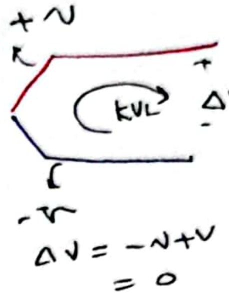
- Based on the Seebeck effect
- When any conductor is subjected to a thermal gradient, it will generate a voltage
- The magnitude of the effect depends on the metal in use

$T_J(20)(80) = T_J(0)(80) - T_J(0)(20)$

20 C° → my reference

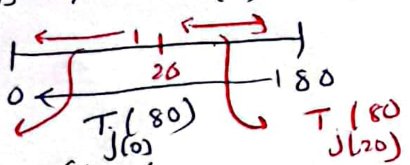
& The table is $T_J(0)(T_X)$

- To measure the generated voltage we need to connect another conductor
- This conductor also experiences the Seebeck effect and its voltage tends to oppose the original
- So the conductor used to measure the voltage must be different — the meaning of it.
- A small difference voltage can be made available by use of dissimilar metals
- Difference increases with temperature, and can typically be between 1 and 70 μV/°C



* if my table is refrence to (0) & i want refren from (20) (80)

Then First



$T_{j(0)}(80)$ ← من الجدول

Answer

$$T_{j(20)}(80) = T_{j(0)}(80) - T_{j(0)}(20)$$

- Thermocouples measure the temperature difference between two points and not the absolute temperature
- The **relationship** between the temperature difference and the output voltage of a thermocouple is nonlinear and is approximated by polynomial:

ΔT & ΔV is not linear.

- $$\Delta T = \sum_{n=0}^{N} a_n v^n.$$ → #1

I apperar

To achieve accurate measurements the equation is usually implemented in a digital controller or stored in a look-up table

https://srdata.nist.gov/its90/download/download.html

https://www.ti.com/lit/an/sbaa274/sbaa274.pdf?ts=1602672527665&ref_url=https%253A%252F%252Fwww.google.com%252F

Advantages and Disadvantages

- They are simple, rugged, need no batteries, measure over very wide temperature ranges
- The main limitation is accuracy; System errors of less than 1°C can be difficult to achieve

Applications

- Thermocouples are most suitable for measuring over a large temperature range, up to 1800 °C
- These are widely used in the steel industry, heating appliances, manufacturing of electrical equipments like switch gears etc

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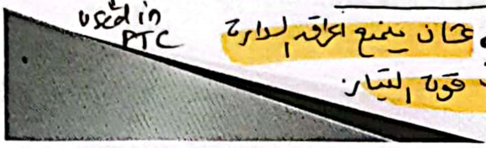
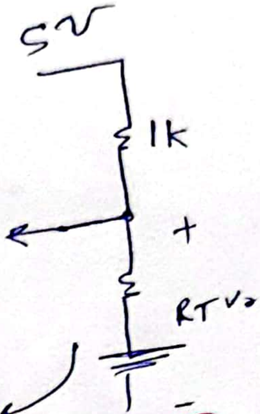
Thermistor (Thermo resistor)

- A thermistor is a type of resistor with resistance varying according to its temperature. The resistance is measured by passing a small, measured direct current through it and measuring the voltage drop produced.
- There are basically two broad types
  1. NTC-Negative Temperature Coefficient: used mostly in temperature sensing
  2. PTC-Positive Temperature Coefficient: used mostly in electric current control.



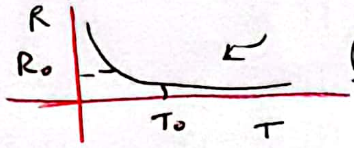


$$V_o = \frac{R_T}{R_T + 1K} \times 5V$$

Type

- A NTC thermistor is one in which the zero-power resistance decreases with an increase in temperature

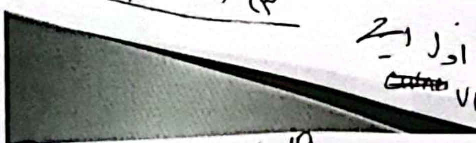
$$R_T = R_0 \exp\left[B\left(\frac{1}{T} - \frac{1}{T_0}\right)\right]$$

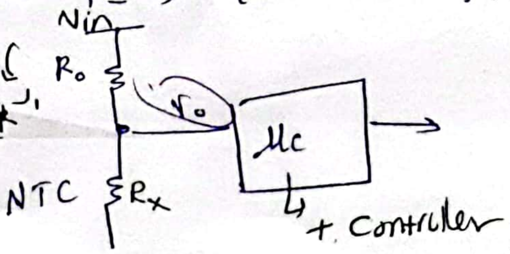


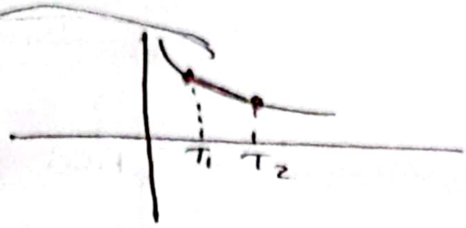
Thermistors ("thermally sensitive resistor")

- The material is a semiconductor
  - A composite of a ceramic and a metallic oxide (Mn, Co, Cu or Fe)

- A PTC thermistor is one in which the zero-power resistance increases with an increase in temperature







- Assuming, as a first-order approximation, that the relationship between resistance and temperature is linear, then:

$$\Delta R = k\Delta T$$ one way of linearization.

where

- ΔR = change in resistance
- ΔT = change in temperature
- k = first-order temperature coefficient of resistance
- For PTC k is positive while negative for NTC

Advantages and Disadvantages

- Thermistors, since they can be very small, are used inside many other devices as temperature sensing and correction devices
- Thermistors typically work over a relatively small temperature range, compared to other temperature sensors, and can be very accurate and precise within that range

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Applications

- PTC thermistors can be used as current-limiting devices for circuit protection, as replacements for fuses. Current through the device causes a small amount of resistive heating. This creates a self-reinforcing effect that drives the resistance upwards
- PTC thermistors can be used as heating elements in small temperature-controlled ovens. As the temperature rises, resistance increases, decreasing the current and the heating, resulting in a steady state
- NTC thermistors are used as resistance thermometers in low-temperature measurements of the order of 10 K.
- NTC thermistors can be used as inrush-current limiting devices in power supply circuits. They present a higher resistance initially which prevents large currents from flowing at turn-on, and then heat up and become much lower resistance to allow higher current flow during normal operation.
- NTC thermistors are regularly used in automotive applications.
- Thermistors are also commonly used in modern digital thermostats and to monitor the temperature of battery packs while charging.

RTD Resistance Temperature Detectors (RTDs)

- Resistance Temperature Detectors (RTD), as the name implies, are sensors used to measure temperature by correlating the resistance of the RTD element with temperature
- As they are almost invariably made of platinum, they are often called **platinum resistance thermometers** (**PRTs**)

- Based on materials whose resistance changes in accordance with temperature
  - Resistance Temperature Detectors (RTDs)
    - The material is a metal
      - Platinum, Nickel, Copper are typically used
  - Positive temperature coefficients

$$R_T = R_0[1+\alpha_1 T + \alpha_2 T^2 + \cdots \alpha_n T^n +] \cong R_0[1+\alpha_1 T]$$

$\Rightarrow R_T = R_0 [1+\alpha T]$

$R(T) = R(T_0)\,[1+\alpha(T-T_0)]$

$y - y_0 = m(x - x_0)$

Construction

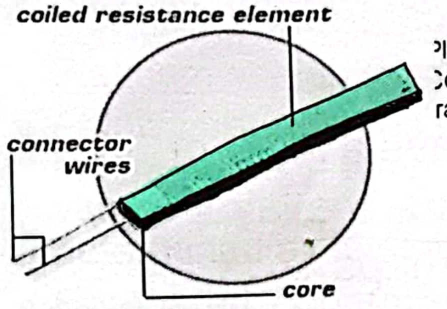
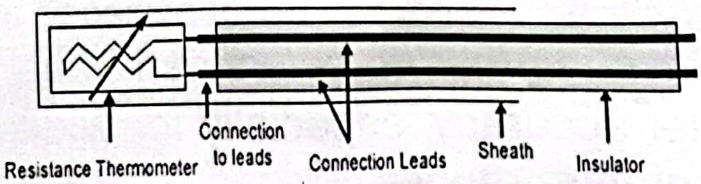


Image obtained from www.omega.com

Common Resistance Materials for RTDs:
Platinum (most popular and accurate) Nickel
Copper Tungsten
(rare)



Semiconductor Thermometer Devices

TMP35, TMP36 → IC + vcc + ground
بطول منها الـ Vout.

- Semiconductor thermometers are usually produced in the form of ICs, Integrated Circuits with very high linearity.
- These devices have temperature measurement ranges that are small compared to thermocouples and RTD, but, they can be quite accurate and inexpensive and very easy to interface with other electronics for display and control.

كنا زمان نحصل الـ Temprature sensors على أساس انهم مواد تتأثر بالحرارة [Thermocouples, RTD, Thermistors

أما الـ IC عالداخل عملت فرق كبير → new evalution

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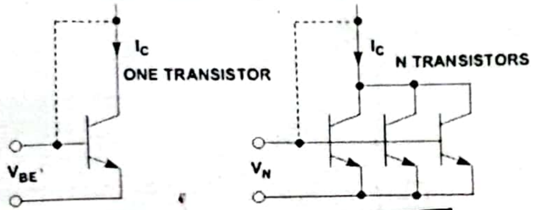
Integrates Temperature Sensor

If we take N transistors identical to the first and allow the total current Ic to be shared equally among them, we find that the new base-emitter voltage is given by the equation

$$V_N = \frac{kT}{q}\ln\left(\frac{I_c}{N \cdot I_s}\right)$$

BASIC RELATIONSHIPS FOR SEMICONDUCTOR TEMPERATURE SENSORS



#1 ← $V_{BE} = \frac{kT}{q}\ln\left(\frac{I_C}{I_S}\right)$ $V_N = \frac{kT}{q}\ln\left(\frac{I_C}{N \cdot I_S}\right)$ → N : عدد Transistors.

$\Delta V_{BE} = V_{BE} - V_N = \frac{kT}{q}\ln(N)$

$\frac{kT}{q}\ln\left(\frac{I_c}{I_s}\right) - \frac{kT}{q}\ln\left(\frac{I_c}{NI_s}\right)$

$\left[\Delta V_{BE} = \frac{kT}{q}\ln(N)\right]$ $\frac{kT}{q}\left(\ln\left(\frac{I_c}{I_s}\right) - \ln\left(\frac{I_c}{NI_s}\right)\right) \Rightarrow \frac{kT}{q}\ln(N)$

Neither of these circuits is of much use by itself because of the strongly temperature dependent current I_s, but if we have equal currents in one BJT and N similar BJTs then the expression for the difference between the two base-emitter voltages is proportional to absolute temperature and does not contain I_s.

$$\Delta V_{BE} = V_{BE} - V_N = \frac{kT}{q}\ln\left(\frac{I_c}{I_s}\right) - \frac{kT}{q}\ln\left(\frac{I_c}{N \cdot I_s}\right)$$

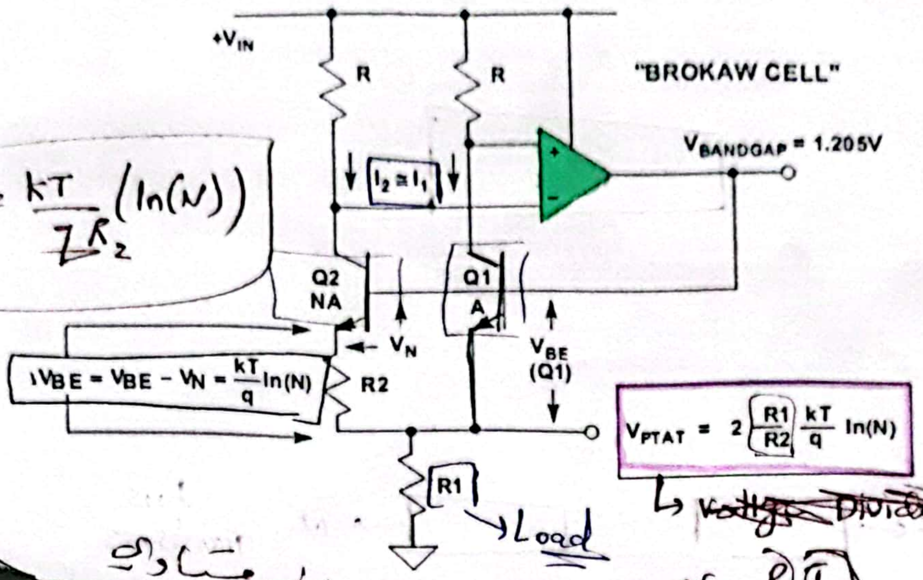
$$\Delta V_{BE} = V_{BE} - V_N = \frac{kT}{q}\left[\ln\left(\frac{I_c}{I_s}\right) - \ln\left(\frac{I_c}{N \cdot I_s}\right)\right]$$

$$\Delta V_{BE} = V_{BE} - V_N = \frac{kT}{q}\ln\left[\frac{\left(\frac{I_c}{I_s}\right)}{\left(\frac{I_c}{N \cdot I_s}\right)}\right] = \frac{kT}{q}\ln(N)$$

$\frac{kT}{q}\ln(N)$

Thermocouples	RTD	Thermistor	Integrated Circuits
-270 → 1800°	-250 — 900°C (very high accuracy)	-100 — 440°C	-55 — 150°C

CLASSIC BANDGAP TEMPERATURE SENSOR



$I_2 = \frac{kT}{qR_2}(\ln(N))$

Voltage Divider Rule

$V = R_1 I$

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$2\frac{R_1}{R_2}\left(\frac{kT}{I}\ln(n)\right)$

$V_{PTAT} = 2\frac{R_1}{R_2}\frac{kT}{q}\ln(N)$

The voltage DVBE = V BE − V N appears across resistor R2.
The emitter current in Q2 is therefore DV BE /R2. The op amp's servo loop and the resistors, R, force the same current to flow through Q1. The Q1 and Q2 currents are equal and are summed and flow into resistor R1. The corresponding voltage developed across R1 is proportional to absolute temperature (PTAT) and given by:

$$V_{PTAT} = \frac{2R1(V_{BE} - V_N)}{R2} = 2\frac{R1}{R2}\frac{kT}{q}\ln(N).$$

The bandgap cell reference voltage, $V_{BANDGAP}$, appears at the base of Q1 and is the sum of $V_{BE}(Q1)$ and V_{PTAT}. $V_{BE}(Q1)$ is complementary to absolute temperature (CTAT), and summing it with V_{PTAT} causes the bandgap voltage to be constant with respect to temperature (assuming proper choice of R1/R2 ratio and N to make the bandgap voltage equal to 1.205V). This circuit is the basic band-gap temperature sensor, and is widely used in semiconductor temperature sensors.

piezo resistive → False
piezo electric → True

$V_o = \frac{R_T}{R_T + \cdot}$

$V = RI$

10 → 4
7.5 → x

$x = \frac{4 \times 7.5}{10} \Rightarrow 3$

10 → 100mm
7.5 → x

$x = \frac{7.5 \times 100mm}{10}$

0.075 ⇒ 7.5×10^{-9}