تقدم لجنة ElCoM الاكاديمية

تلخيص لمختبر:

تحكم و مجسات

جزيل الشكر للطالبة:

سارة آبو سارة

Transducers & Control Lab. Summary [mid]

Exp1 Proximity Sensors "Switches"

Theoretical Part:

* الفرق بين ال "Sensors" وال "switches" ←

Sensors ≡ transducer that has a function of producing a variation of motion, light, sound, heat and magnetic which became later the voltage & current.
used to detect, measure, and to know magnitude.
There are many types of sensors in an electronic circuit, such like (light sensor, pressure sensor, temperature sensor, ...)
most of them are dealing with analog applications.

Switches ≡ Component or device used to connect or disconnect the power supply, dealing with digital applications (on/off)

* Mechanical Sensors: مشكلتهم انه مع الوقت والاستهلاك بيتعرضوا لل (mechanical wear) وبحاجوا للصيانة الدورية ، وهاي الأمور بتجعل من ال (mechanical sensors) غير مناسبة للاستخدام في بعض التطبيقات.

* proximity sensors بيشتغلوا ع مبدأ القرب وما في داعي يكون في contact بينهم وبين ال (object) ، لذلك بكفي ان يكون هنالك [Field Range] لعمل السنسور detection [وهذا يختلف من سنسور لآخر]

Proximity sensor types → digital sensors (switches فبعتبرهم)
بيشتغلوا ع مبدأ في object ضمن ال [field range] ولا لا ؟
On/Off
Yes/No

→

Proximity Sensors "Switches" advantages → "Operate electronically" that

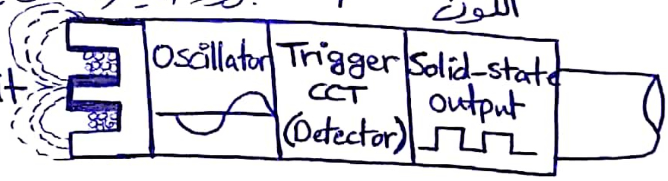
* مهم هادا الموضوع *

1- Precise and automatic sensing of geometric positions
2- No contact between sensor and workpiece is usually required
3- Fast switching characteristics due to the electronically output signals generation, no error pulses created.
4- Wear_resistant function because there isn't any moving part in it.
5- Unlimited no. of switching cycles.
6- Suitable versions available for use in hazardous conditions (e.g. areas with explosion hazard) → يوجد منها اصدارات تتناسب مع الظروف الخطرة المحيطة
المناطق اللي يكون فيها خطر الانفجار
[Safety]

Proximity Switches types →

[1] Inductive :

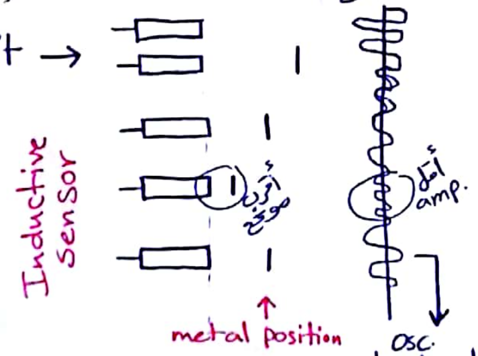
- Incorporates an electromagnetic coil used to detect the presence of a conductive metal object. (أو أي مادة موصلة تسمح بمرور التيار الكهربائي) / بغض النظر عن اللون
- Consists of → coil
  → oscillator
  → trigger circuit
  → output



مبدأ عمله

- designed to generate an electromagnetic field.
- When a metal object enters this field, surface currents (eddy) are induced in the metal object. They drain energy from the electromagnetic field (causes a load on the sensor) resulting in a loss of energy in the oscillator circuit, and consequently, a reduction in the amplitude of oscillation. بسبب الطاقة اللي استهلكتها الـ eddy currents من المجال الكهرومغناطيسي
(بيستنزفوا / بيستهلكوا) eddy
the trigger circuit detects this change and generates a signal to switch the output ON or OFF. رح تحس بالتغير اللي صار في الـ osc. الـ اللي هي solid state output
- When the object leaves the electromagnetic field, regenerates and the sensor returns to its original state.

- Response of it →

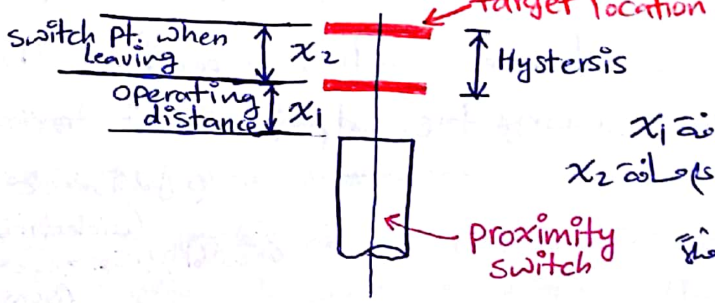


→ ملاحظ من الـ (oscillator signal)
انه كلما اقترب الـ metal من الـ (sensor) تقل الـ [Oscillator amplitude]
والعكس صحيح ..

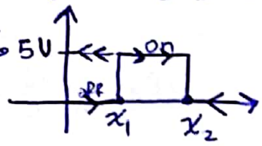
- Hysteresis phenomena ≡ the difference between its (operate) and (release) points that is needed to prevent chattering (turning on and off rapidly)

* مهم هادا الموضوع *

[مهمّ لمسافات قليلة]



* ما رح يضوي الا عم مسافة x_1
* وما رح يطفي الا لأبعد عن مسافة x_2



- Inductive proximity switch advantages :
  1. No moving parts, so no mechanical wear.
  2. Not color dependent.
  3. Less surface dependent.

- Inductive proximity switch disadvantages :
  1. Sensing metal objects only.
  2. Shorting operating range.
  3. Affected by strong electromagnetic field.

---

2 Capacitive :

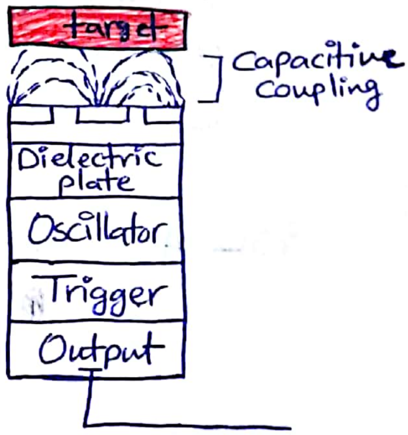
- Non contact technology, suitable for detecting → metals
  → non metals (Paper, glass, liquid, cloth, ...)

"لأي مادة"

Because of its characteristics and cost relative to the inductive proximity switch. ⇐ يتناسب تعامله مع المواد غير المعدنية أكثر *

* ومن المواد المعدنية، نفضّل استخدام الـ (Inductive Sensor) أكثر
لأنه ⇐ ① reliable
② more affordable technology

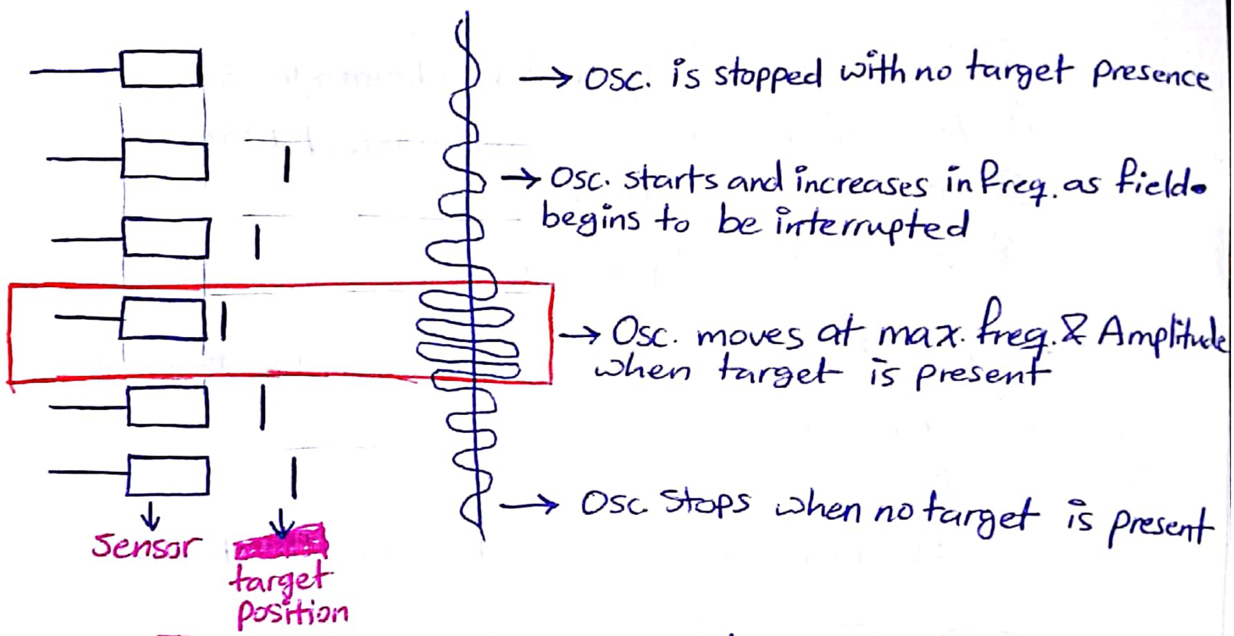
- Consist of → Capacitive probe or plate
  → Oscillator
  → Signal level detector (Trigger)
  → Output switching device



- When power is applied to the sensor, an electrostatic field is generated, that reacts to changes in capacitance caused by the presence of a target. As the target approaches, Capacitive Coupling develops between the target & the capacitive probe. When the capacitance reaches a specified threshold, the oscillator is activated, triggering the output circuit to switch states on/off.

الي تتناسب مع التغير الكامل ع (dielectric)
الي متغير مع اقتراب المادة من الـ (sensor)

- Response of it →



* مثلاً من الشكل انو مع اقتراب الـ (object) لـ [Capacitive switch]
يزداد كلاً من Freq. ← amplitude ←
بعكس الـ "Inductive" لأنو الـ osc. بشتغل مع اقتراب المادة من الـ (sensor)..

- Capacitive proximity switch advantages :

1. detects metal & non metal, liquids and solids.
2. Solid state, long-life
3. Many mounting configurations
4. Can "see through" certain materials.

- Capacitive proximity switch disadvantages :

1. Short Sensing distance (< 2.5 cm)
2. Very sensetive to environmental factors
3. Control of what comes close to the sensor is necessary, because not at all selective for its target.

- Application example → level detection through a barrier

مثلاً [$\varepsilon_{water} > \varepsilon_{plastic}$] → this gives the sensor the ability to "see through" the plastic & detect the level water.

Magnetic :

- Non contact proximity devices utilize → inductance
  → Hall Effect Principles
  → Variable Reluctance
  or → Magneto Resistive technology
- Characterized by the possibility of large switching distances and availability with small dimensions.
- They detect magnetic objects (usually permanent magnets), which are used to trigger the switching process. « المواد المغناطيسية »
- their operating principle is based on the use of "reed contacts", which are thin plates hermetically sealed in a glass bulb with inert gas. So, when the magnetic field is present, it forces the thin plates to touch each other causing an electrical contact فبصير في (trigger) عندها ..

مبدأ العمل

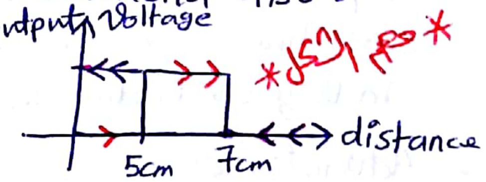
مربوط بإحكام وغير متأثر بالظروف الخارجية

بيكون عبارة عن صفيحتين (reed contacts) موضوعين في مكان مُفرغ من الهواء وبينهم فراغ مصنوعين من مواد حساسة للمجال المغناطيسي ، بحيث في حال وجوده بصير بين الصفيحتين contact لما يلمسوا بعض بصير عندي (trigger)

- advantages :
  1. Contacts are well protected from (dust, oxidization, Corrosion, :) due to the → hermetic glass bulb → Inert gas
  2. long contact lifes due to special surface treatment
  3. Maintenance free
  4. Easy Operation & small size.

- It suffers from the hysteresis phenomena also.

الفكرة إنه بعد ال 5cm ←
5 cm مسافة معينة معتارها لما يصل detection بتكون
ولما يصل release بتكون عند مسافة أكبر شوي بين ال 5cm وال 7cm (وهو معروفة بينهم)



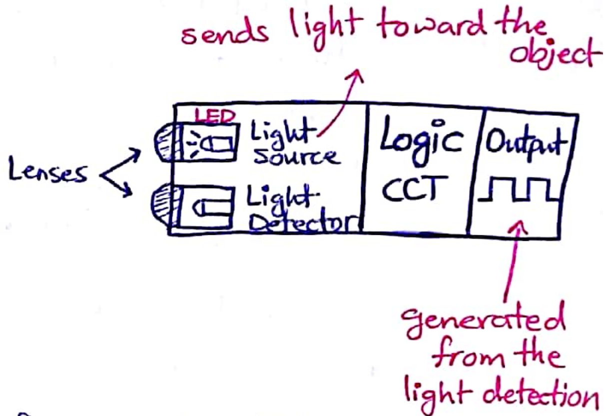
- Application example → in the elevators (لتحديد المصعد عند أي طابق وصل ..)

4 Optical :
"Photoelectric"

- the difference between → Light Sensor, to measure Light Int...
  → Optical Sensor, ... "Beam of light"

- It operates by sensing a change in the amount of light received by a photo detector.
  This change in light allows the sensor to detect ① the presence or absence of the object, ② it's size, ③ shape, ④ reflectivity, ⑤ opacity, ⑥ translucence, ⑦ or color.

- Consists of → Light Source
  → Light detector
  → Lenses
  → Logic Circuit
  → Output

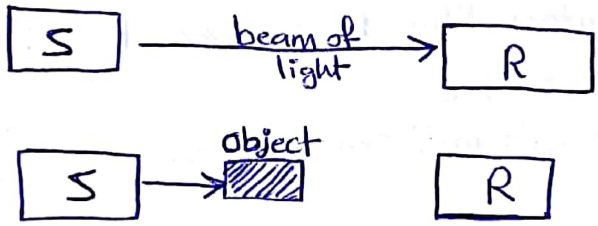


- Can be used in applications requiring sensing distances for [$x < 2.5$ cm] or [$x > 1000$ m]

- Optical Sensor types :

a. Transmitted Beam (through beam) →

S : transmitter
R : Receiver

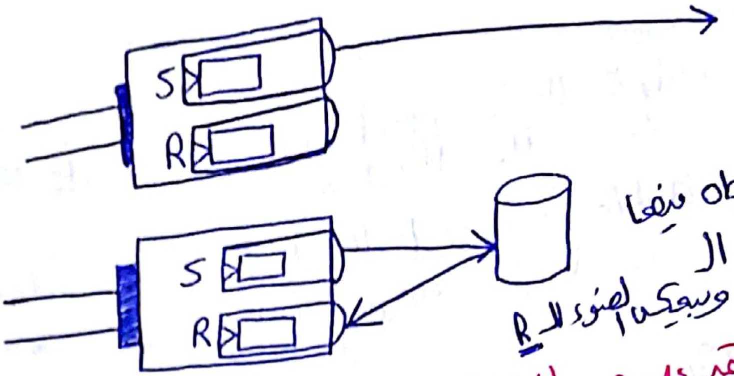


* ملاحظة من الشكل إنه في (Beam of light) بين ال (R) وال (S) حين لما يجي (object) بيقطعه فيعمله (trigger)

- It provides the longest sensing distances and the highest level of operating margin, hence it's the best sensing mode for operating in very dust, dirt industrial environments. (الأفضل)

- Advantages :
  ① the most reliable for accurate parts counting, due to their well-defined effective beam
  ② Eliminates the variable of surface reflectivity or color.
  ③ Offers lower maintenance cost, because of their ability to sense through (dirt, dust, oil, mist), so it allows for the most reliable performance before cleaning is required.

C. Diffuse →



...oreflective عكس الـ

الـ object بيعمل عمل الـ reflector نفسها ويعكس الضوء للـ R

optical types

* هاد النوع ما بيعتمد ع وجود (Light) ، بل يعتمد ع انعكاس الضوء من الجسم نفسه في حال تواجد
وهذا يتم بدرجات حسب لون الجسم ← ازا كان أسود (ويمتص أغلب الأشعة الساقطة عليه من الـ S
← ازا ماكان أسود (غير معتم) (ما رح يمتص الضوء) ويعكسه

- diffuse sensors can detect the object nature (ناعم/خشن) and its color

- Advantages :
① used in applications where the sensor-to-object distance is from a few inches to a few feet, and when neither transmitted beam nor reflective is practical
② used in applications that require sensetivity to differences in surface reflectivity & monitoring of surface conditions that relate to those differences in reflectively are important.

- Disadvantages :
① Reflectivity, because the sensor response depends on the surface reflectivity of the object to be sensed.
② Shiny objects that aren't at a perpendicular angle maybe difficult to detect
③ Less sensing distance for small objects. (small reflective area)
④ Most of them are less tolerant to the contamination around them and lose their margin very rapidly as dirt and moisture accumulates on their lenses.

الترتيب من حيث الأفضل : →

transmitted beam > RetroReflective > Diffuse

← أفضل

– Hysteresis Phenomena :

also appears in optical sensors, the high hysteresis in most optical sensors is useful for detecting large opaque objects in both types
- → retroreflective
- → through-Beam

مثلاً. لما يكون عنا belt بيضل يهتز أو أشياء معينة م تعمل disturbance فبهالحالة ما بدي يصير أي (detection process) أو ممكن عشان أحمي النظام ككل...

* مهم هاد الموضوع *

∴ بما أنّ كلاً من ← Capacitive / Optical مخصّصين لكل أنواع الـ objects

كيف بدنا نميّز بينهم ؟

ج: من خلال الفرق بال (Operating Range)

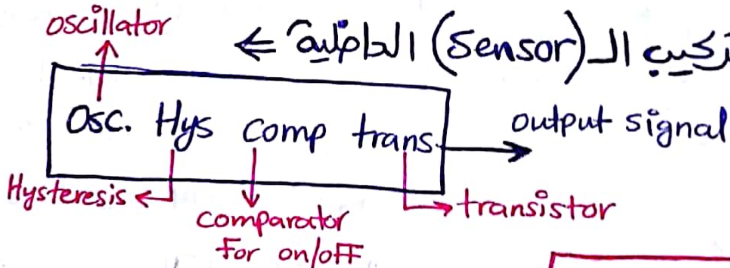
Optical ← لأقل من 2.5 cm ولأكثر من 100 m

Capacitive ← لأقل من 2.5 cm فقط

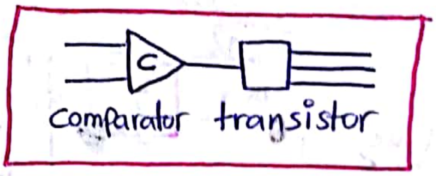
General Notes →

* مهم الـ(standard object) بيبيّن بالـ datasheet، فإذا كان الجسم اللي عندي بيختلف عن الـ[standard] فأكيد الـ(response) مختلف وبحتاج الـ sensor وقت أكثر ليعمل detection

* كيفية تركيب الـ(sensor) الداخلية ⇐

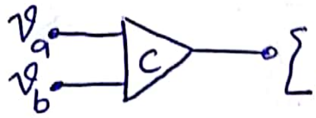


* transistor types
  - → NPN (sink)
  - → PNP (source)



* Comparator operating principle

بيقارن بين (2 analog voltages) مع تثبيت قيمة وحدة بينهم بسميها (trigger voltage) or (V_{ref})



$$\begin{cases} 1, & v_a > v_b \\ 0, & v_a < v_b \end{cases}$$

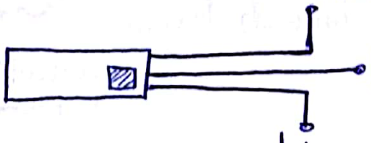
v_b → v_{ref}

Practical Part :

Part one

- Lab sensors contains LED to indicate the presence / absence of the object

3 wire Sensors →

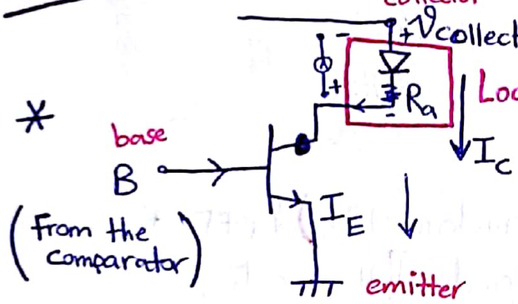


PNP نوع

شبكنا السلك البني بال 12V والسلك الأزرق على ال GND لتشغيل ال sensor وقربنا المواد بأنواعها عليه لما كان يضوي الليد ، قدرنا نتعرف ع نوع ال sensor (من حيث المواد الي عم يعملها detection)

Part two

Sensor Output Circuit type Determination (PNP/NPN) →



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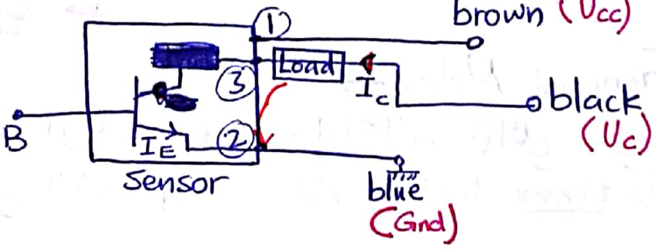


NPN / sink

بدل توصيل اللود مع السورس

تتغير قيمة الفولتية (V_{out}) لما مايكون في object عند ما يصير في object ← من قيمة صغيرة لصفر

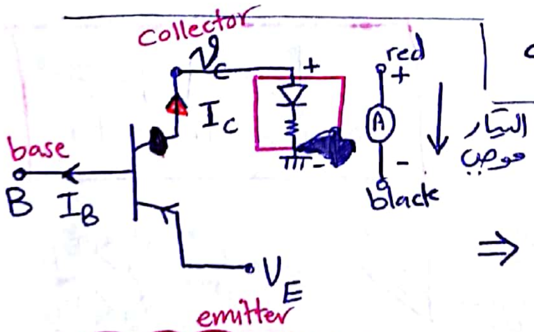
V_{on} (with object) ≈ Ø

V_{off} (without object) = Ø V

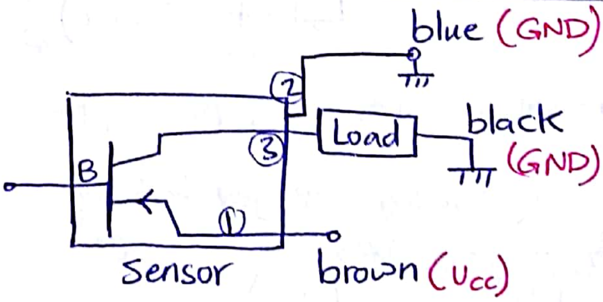
[بتقل الفولتية NPN]

Black → A → Red
Red + , Black −

التيار بيكون سالب



⇒



PNP / Source

بدل توصيل اللود مع الجراوند

تتغير قيمة (V_{out}) من [redacted] صفر لقيمة كبيرة ←

V_{on} (with object) ≈ Ø

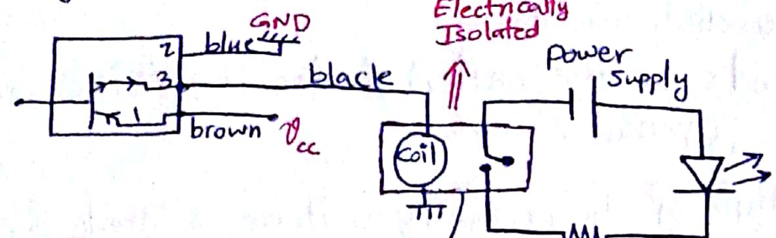
V_{off} (without object) > Ø V

[بتزيد الفولتية PNP]

V_{out} from the sensor = 12 − (2) = 10 V

بطرح من ال V_c مقدار ال drop voltage الي بالداتا شيت

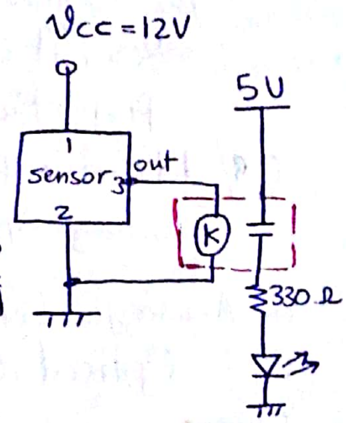
Relay coil and contact →



بينعي مادة مغناطيسية بتجذب ال contact لما يمر تيار بال (coil) وتتشكل فيه مجال مغناطيسي

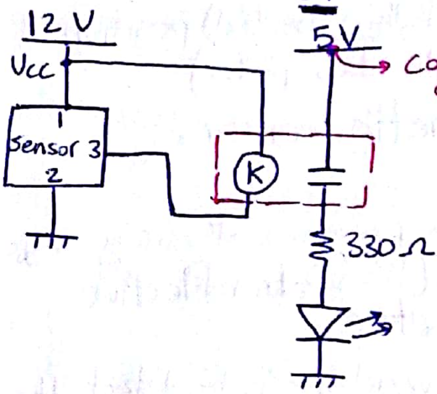
PNP [10-30V]

source / PNP
اللود مشبوك مع الجراوند



→ to make isolation between high and low current or voltage

or



→ common pin on relay

→ NPN / sink
اللود مشبوك مع السورس

ال connection مهم جداً

Part three

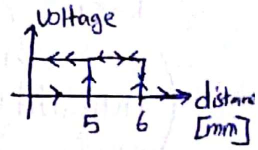
بعد ما نكون حددنا من خلال فرق الفولتية نوع ال (output CCT) منوصل احدى الشكلين الموجودين في الأعلى وبعد ذلك

Q: Measure and record the turn on/off distance?

turn on distance ——→ متى ضوى ال LED 5 mm

turn off distance ——→ متى طفى ال LED 6 mm

[on < off]



بتحريك ال (object) بعيداً عن ال sensor شوي شوي ..

Discussion and Analysis: "From the manual"

Q1/ Which sensor has the max. sensing distance? which one has the min. sensing distance?

max. → Optical
min. → ~~magnetic~~ Capacitive

Q2/ What is the most desirable for sensor to have a large or small sensing distance?

It depends on the application itself.

Q3/ Is the switching on distance the same as the switching off distance? If no, explain the phenomena causing this, which sensor has the largest difference?

No, Hysteresis → (الشرح عام)

optical

Q4/ Does the type of the material approaching the sensor affect the switching on distance?

Yes, it depends on the material density, size, and other properties. „Optical غالباً„

Q5/ determine the type of the proximity switches suitable for each of the following application, and why?

a. A conveyer belt is to detect the presence of milk cartoons.

Optical, Capacitive / Level: Capacitive

b. The rear (fully retracted) position of a pneumatic cylinedar (a magnet is attached to the cylinedars piston)

Magnetic Sensors [min. sensing distance] ← موضوع 2

c. Detect the presence of shiny objects regardless their materials.

Optical (بطلب → Retroreflective) | optical ← لو المسافة كبيرة

Capacitive

d. A milling machine is to detect the presence of iron plates only.

Inductive, because iron plates are metallic objects (non magnetic)

or optical

except / Capacitive cuz it sensing everything & I want just the metallic parts of it.

e. Detect the presence of wooden boxes in a high humidity enviroment.

Optical

← مش الCapacitive فقط لأنه يتأثر بال (high humidity environment)

#

Exp2 Thermal Sensors (RTD) ✓

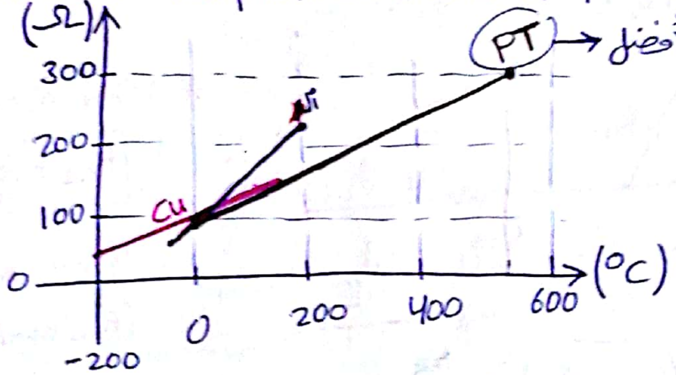
retical

RTD ≡ Resistance Temperature Detector ↗ ΔR عبارة عن (Sensor output) ال

- Temperature Sensor that according to the variation of the temp., it will change the resistance of a conductor.
  So, we can calculate the resistance from present temp. value.

- The most common resistance materials for RTD's are:
  1. Metals → have a low temp. coefficient of resistance
     high stability
     wide temp. detection range
  2. Platinum → most popular and accurate (PT-100) ← الي منستخدمه بالـلاب
  3. Copper
  4. Nickel

- The resistance vs. temperature curves of platinum, copper and nickel:



$$R(T) = R_o[1+\alpha\,\Delta T]$$ → First Order

R_o ≡ resistance at 0°C ($R_o = 100\,\Omega$ for PT-RTD)

$\Delta T \equiv T - T_o$

α ≡ Temp. Coefficient of resistance / تعبير عن ال sensitivity

$\alpha = 0.00392/°C$ for (PT-RTD)
(always +ve)

Generally, RTD's are considered [Linear Devices].

ولا (range) تبعه نتاز نوعاً ما..

– Resistive sensors usually require circuitry that conv[ert] their resistance changes to voltage changes [Wheatstone Bridge]

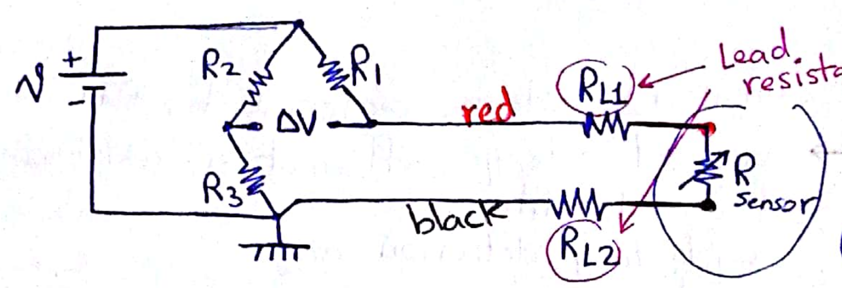
بحيث تتغير ΔV تبعه ال WB بناءاً ع التغير الحاصل ع مقاومة السنسور ..

← يمكن برفع ال "Sensetivity"

– RTD is a wire wound element with internal configuration

(Series) ال ... أي ...

[1] Two wire RTD's →



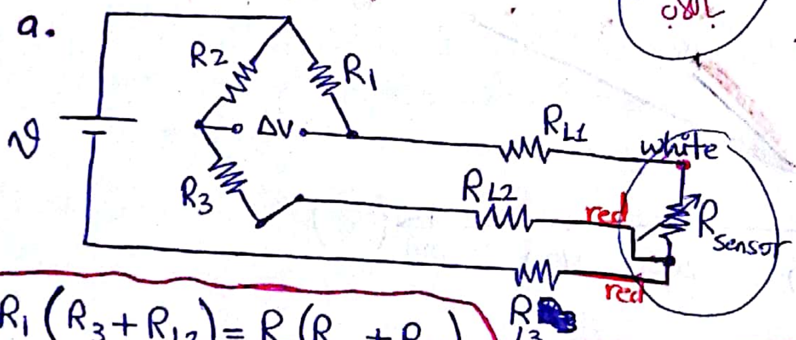
أي (R_L) بينها متوصلين معها "error" بسبب ال Losses الناتجة عنها ..

- advantage → Low Cost
- disadvantage → Losses due to Lead resistances which affect it's precision
- Application → where the [resistance changes of leads < resistive changes of the RTD]

* نادرة الاستخدام بسبب ⇐ high error from Lead wire resistance

[2] 3 wire RTD's → [الأشهر] اللي استخدمناها باللاب

a.



$$R_1(R_3+R_{L2}) = R_2(R_{sensor}+R_{L1})$$

* when $R_1 = R_2$ (at balance) :-

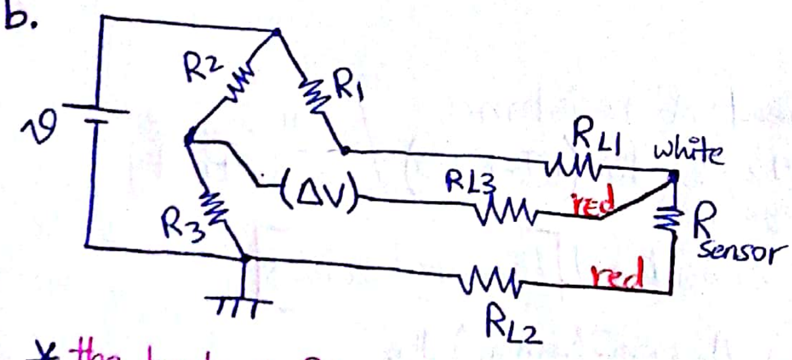
$$R_{L1} + R_{sensor} = R_{L2} + R_3$$

* when $R_{L1} = R_{L2}$:-

ال effect تبع ال ($R_{L1}/R_{L2}/R_{L3}$) neglected when [$R_3 = R_{sensor}$]

← بهاي الحالة رح يزيد ال error وما تخلصنا منه كثير بعمل voltage drop متغير مع ال (R_{eq}) للسيركت لأنه داخلة مع ال supply

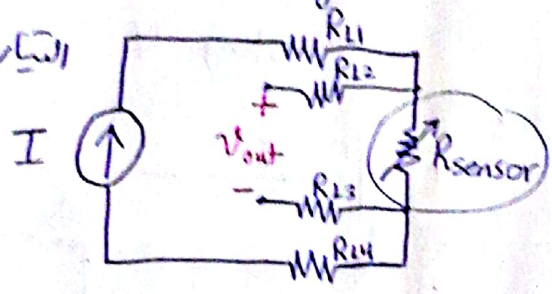
b.



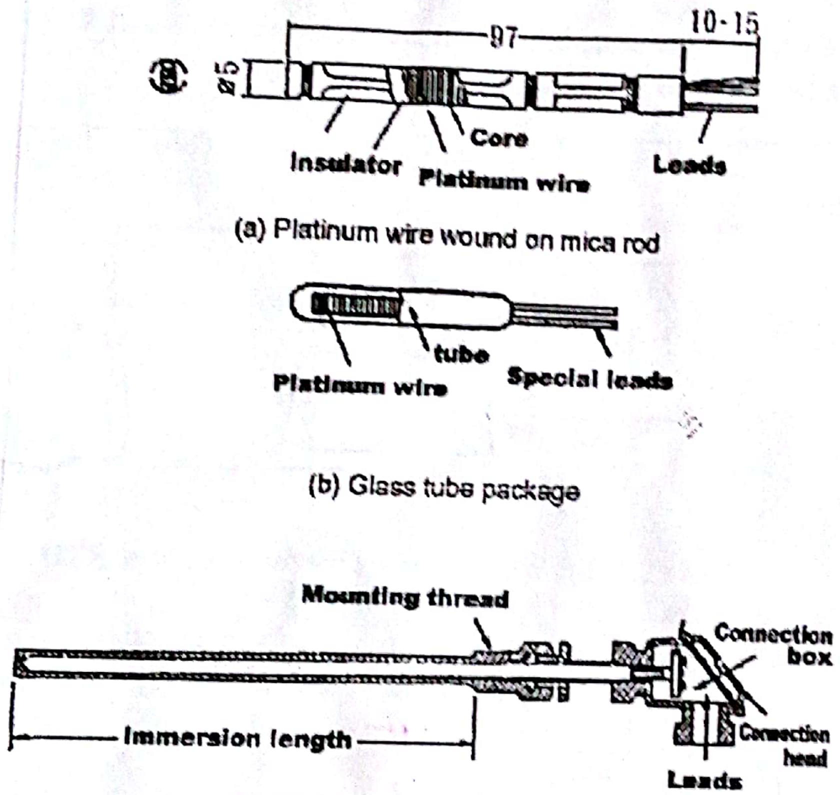
* ال R_{sensor} داخلة مع ال (measurement device)

* the best configuration because it'll eliminate the effect of R_{L3} that's connected to high impedance device ... (فكأنها مش موجودة ...)

3] 4 wire RTD's → used for laboratory applications where accuracy & precision are important
higher in cost than 2 and 3 wire RTD's ..



ما عطيناه حقه bridge لأنه ميكون في 2 parallel resistors بيعطي تأثيره 3 wire RTD بالأخير

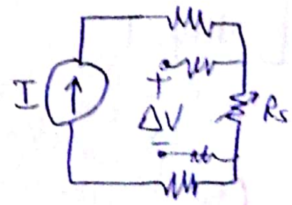


(a) Platinum wire wound on mica rod

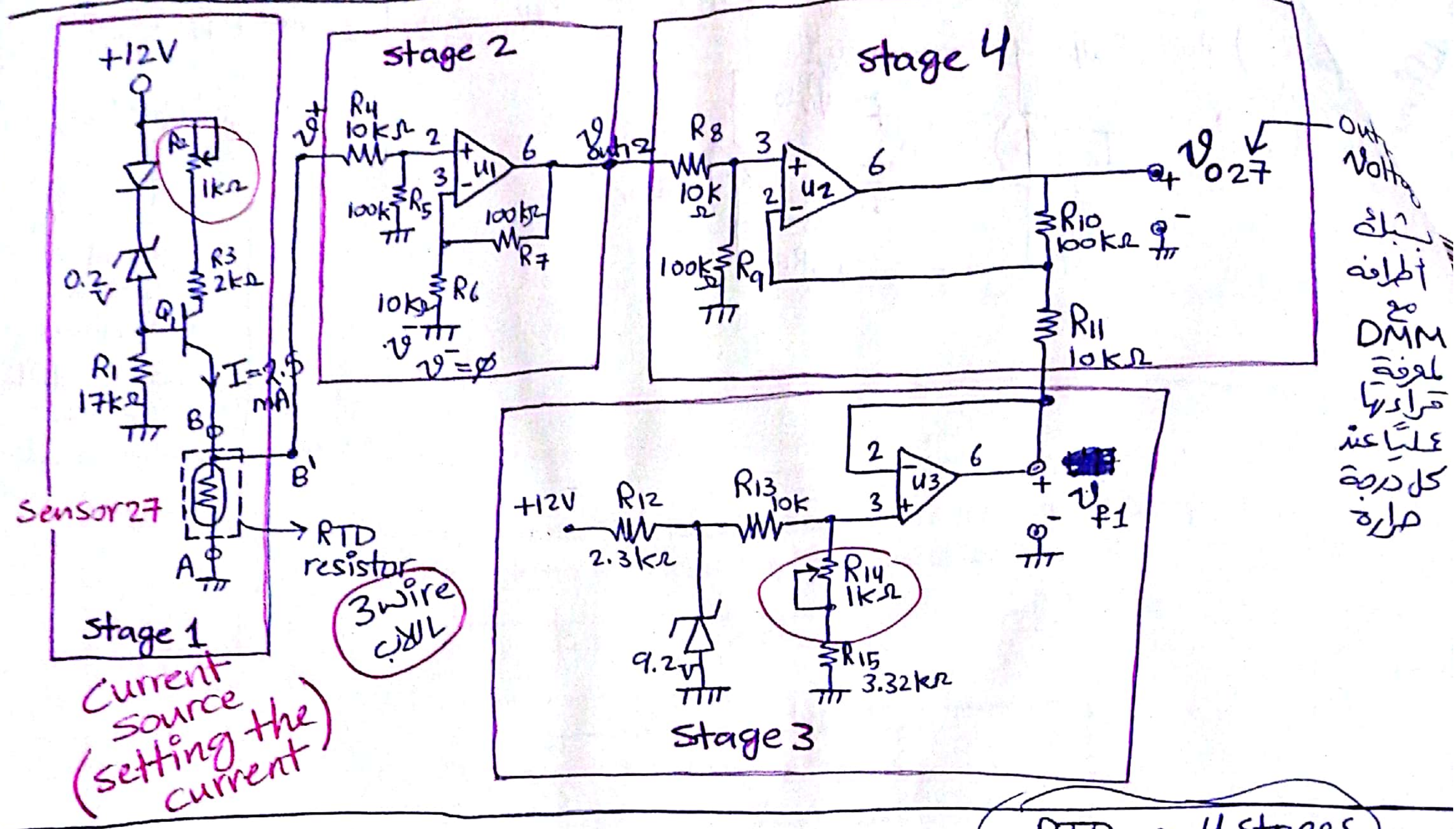
(b) Glass tube package

(c) Stainless-steel protection tube

Figure 2.7: PT 100 construction



Practical Part → [using Sensor module 12]



RTD → 4 stages

1. Without the presence of the sensor:
   a. set the value of current to 2.5 mA → by adjusting R2 (stage 1) at 2.5 mA
   b. Set the value of voltage to 2.58 V → setting the output voltage at v_{f1} to 2.58 V by adjusting R_{14} (Stage 3)

2. Inserting the sensor, and find:

Temp	72	65	60	55	50	45
v_{out}	6.87	6.1	5.8	5.3	4.62	4.11
→ theo (v_{out})	6.2	5.57	5.08	4.59		

(A) أحمر
(B) أبيض
(B') أبيض

* How to find theoretical value of the output voltage? (v_{o27})

$I = 2.5\ mA$

$V = 2.58\ V$

* $R = R_o[1+\alpha\Delta T]$

at $T = 72°C$ → $R = 100[1+0.00392(72-0)] = 128.22\ \Omega$

Stage 2: $v_{out,2} = \frac{R_2}{R_1}(v^+ - 0) = \frac{100}{10}[v^+ - 0]$ → $v_{out,2} = 10 * 0.321 = 3.21\ V$

كل مرة تتغير درجة الحرارة تتغير قيمة المقاومة وبالتالي تتغير معها v_2^+ / $v^+ = IR = 2.5(10^{-3})(128.22)$

$v^+ = 0.32056\ V$

Stage 4: $v_{o27} = \frac{R_2}{R_1}(v^+ - v^-) = 10(v_{out,2} - v_{f1}) = 10(3.21 - 2.58)$

$= 6.2\ V$

* Calculate the Percentage error for one sample?

$$\% \text{Error} = \frac{R_{sensor}(\text{calcu.}) - R_{sensor}(\text{meas.})}{R_{sensor}(\text{calcu.})} * 100\%$$

$R_{sensor}(\text{meas.})$ ← by the ohmeter

• $R_{sensor}(\text{calcu.}) = R_o[1 + \alpha \Delta T]$

* According to the transduction circuit before, determine the relationship between V_{027} and T?

$V_1 = IR$

$= I * 100[1 + 0.00392 T]$

stage 2 / $V_2 = 10(V_1 - \phi) = 10 * 100 * 2.5(10^{-3})[1 + 0.00392 T]$

$V_{out,2} = 2.5[1 + 0.00392 T]$

$V_{027} = 10[2.5[1 + 0.00392 T] - 2.58]$

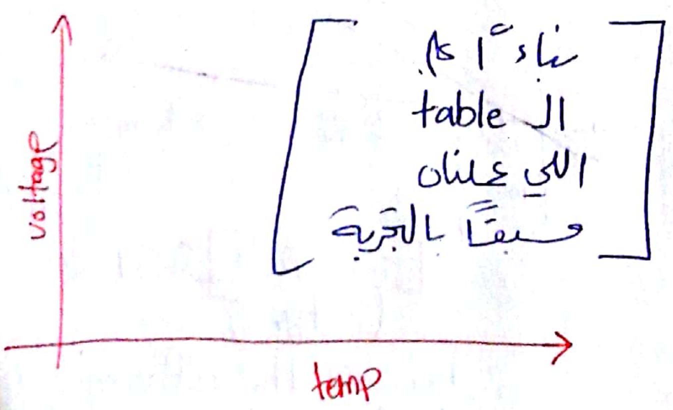
$V_{027} = (25 + 0.1 T) - 25.8$

$V_{027} = 0.098 T - 0.8$

---

* Plot a voltage vs. temperature characteristic curve 8o

(عموماً)



$R = 128.22[1 + 0.00392(72 - 65)]$

$=$

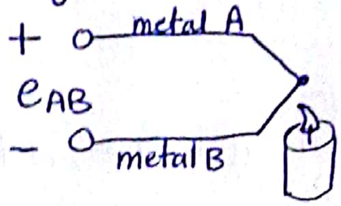
Exp 3 / Thermal Sensors (Thermocouples)

أسرع سنسور حراري — الـ output هو ΔV

* For

Theoretical Part

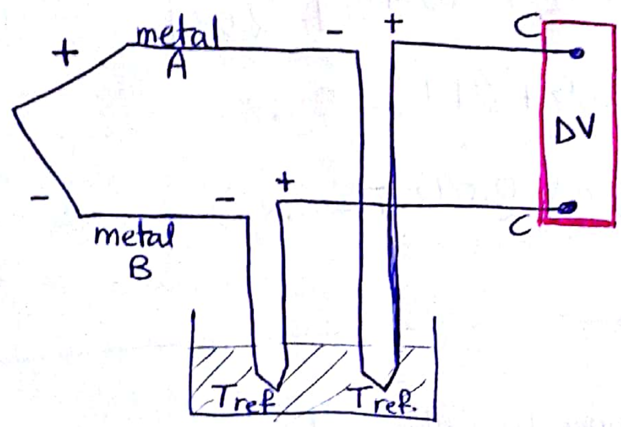
- It's a junction formed from two different metals.
- TC gives a voltage to be induced as output from the temp. difference



الفولتية اللي بتطلع متكون بال [mV]
بتعتمد على ← نوع الـ metals
← ΔT

- advantages →
  - inexpensive
  - reliable
  - rugged
  - can be used over a wide temp. range

- Thermocouple Circuit →



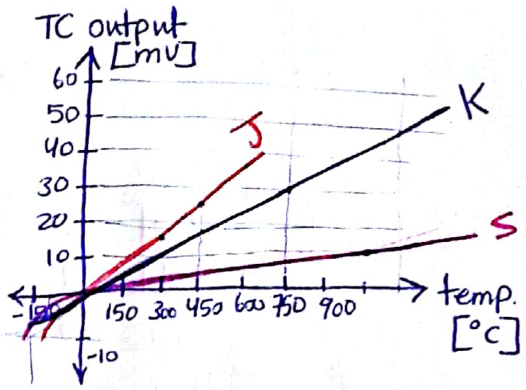
* when ΔV = Ø
Tm = Tref

$\Delta V \propto \Delta T$

$\Delta V \propto (T_m - T_{ref})$

[C : بتعمل cancel لأي ΔV زايدة]

- Thermocouple types →
  the most common (K/S/J)



(مهم)

non Linear exactly but at small ranges it's almost linear ..

(J, K) → high slope
high sensetivity than

(S) → Low slope
Low sensetivity

J > K > S

⇐ الأكثر [Sensetivity] هو (J type)
because the difference in output for the same difference in input is Larger than K and S types ..

$$Sensetivity = \frac{\Delta V_{out}}{\Delta T}$$

ΔV_{out} ← التفرق في الـ (output)

ΔT ← التفرق في الـ (input)

thermocouple table → نستعين بالجداول بحيث أنّ الفولتية اللي نطلعها حتكون بوحدة [mV] ويمكن أحتاج لعمل interpolation

* For $T_{ref} = 0°C$ → direct reading

بس ممكن يعطينا الفولتية ويطلب Tm فبندوّر بهاي الحالة ع range القيم اللي بتنحصر فيها قيمة الفولتية المعطاة في السؤال ، وبعمل Interpolation

$v_1 = \dots \rightarrow T_m = \dots$

$v = V \rightarrow T_m = ?$

$v_2 = \dots \rightarrow T_m = \dots$

* For $T_{ref} \neq 0°C$ → مثلاً

$$V_{J30}(-90°C) = V_{J0}(-90°C) - V_{J0}(30°C)$$

new ref. → $J30$

الفولتية عند الـ new Ref. → $V_{J0}(30°C)$ → Correction Factor

Ex:

Table 3.1: K-type TC table at $Tref$ =0oC (voltage is in mV).

	0	5	10	15	20	25	30	35	40	45
−150	−4.81	−4.92	−5.03	−5.14	−5.24	−5.34	−5.43	−5.52	−5.60	−5.68
−100	−3.49	−3.64	−3.78	−3.92	−4.06	−4.19	−4.32	−4.45	−4.58	−4.70
−50	−1.86	−2.03	−2.20	−2.37	−2.54	−2.71	−2.87	−3.03	−3.19	−3.34
−0	0.00	−0.19	−0.39	−0.58	−0.77	−0.95	−1.14	−1.32	−1.50	−1.68
+0	0.00	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.61	1.81
50	2.02	2.23	2.43	2.64	2.85	3.05	3.26	3.47	3.68	3.89
100	4.10	4.31	4.51	4.72	4.92	5.13	5.33	5.53	5.73	5.93
150	6.13	6.33	6.53	6.73	6.93	7.13	7.33	7.53	7.73	7.93
200	8.13	8.33	8.54	8.74	8.94	9.14	9.34	9.54	9.75	9.95
250	10.16	10.36	10.57	10.77	10.98	11.18	11.39	11.59	11.80	12.01
300	12.21	12.42	12.63	12.83	13.04	13.25	13.46	13.67	13.88	14.09
350	14.29	14.50	14.71	14.92	15.13	15.34	15.55	15.76	15.98	16.19
400	16.40	16.61	16.82	17.03	17.24	17.46	17.67	17.88	18.09	18.30
450	18.51	18.73	18.94	19.15	19.36	19.58	19.79	20.01	20.22	20.43
500	20.65	20.86	21.07	21.28	21.50	21.71	21.92	22.14	22.35	22.56
550	22.78	22.99	23.20	23.42	23.63	23.84	24.06	24.27	24.49	24.70
600	24.91	25.12	25.34	25.55	25.76	25.98	26.19	26.40	26.61	26.82
650	27.03	27.24	27.45	27.66	27.87	28.08	28.29	28.50	28.72	28.93
700	29.14	29.35	29.56	29.77	29.97	30.18	30.39	30.60	30.81	31.02
750	31.23	31.44	31.65	31.85	32.06	32.27	32.48	32.68	32.89	33.09
800	33.30	33.50	33.71	33.91	34.12	34.32	34.53	34.73	34.93	35.14
850	35.34	35.54	35.75	35.95	36.15	36.35	36.55	36.76	39.96	37.16
900	37.36	37.56	37.76	37.96	38.16	38.36	38.56	38.76	38.95	39.15
950	39.35	39.55	39.75	39.94	40.14	40.34	40.53	40.73	40.92	41.12
1000	41.31	41.51	41.70	41.90	42.09	42.29	42.48	42.67	42.87	43.06
1050	43.25	43.44	43.63	43.83	44.02	44.21	44.40	44.59	44.78	44.97
1100	45.16	45.35	45.54	45.73	45.92	46.11	46.29	46.48	46.67	46.85
1150	47.04	47.23	47.41	47.60	47.78	47.97	48.15	48.34	48.52	48.70
1200	48.89	49.07	49.25	49.43	49.62	49.80	49.98	50.16	50.34	50.52
1250	50.69	50.87	51.05	51.23	51.41	51.58	51.76	51.94	52.11	52.29
1300	52.46	52.64	52.81	52.99	53.16	53.34	53.51	53.68	53.85	54.03
1350	54.20	54.37	54.54	54.71	54.88					

اللي ع الأطراف Tm For $T_{ref} = 0°C$

V_{TC}

from K-type TC table :

1] V_{TC} when $T_m = 1220°C$, $T_{ref} = 0°C$ → $V_{TC} = 49.62\ mV$

2] V_{TC} when $T_m = 977°C$, $T_{ref} = 0°C$ → V_{TC} ⇒ Interpolation

$T_1 = 975 \rightarrow V_{TC1} = 40.34\ mV$

$T_m = 977 \rightarrow V_{TC} = ??$

$T_2 = 980 \rightarrow V_{TC2} = 40.53\ mV$

$$\frac{980-975}{977-975} = \frac{40.53-40.34}{V_{TC}-40.34} \rightarrow V_{TC} = 40.416\ mV$$

3] V_{TC} when $T_m = 350°C$, $T_{ref} = 10°C$

$$V_{K10}(350°) = V_{K0}(350°C) - V_{K0}(10°C)$$

$$= 14.29\ mV - 0.4\ mV = 13.89\ mV$$

4] T_m when $V_{TC} = 34.12\ mV$, $T_{ref} = 0°C$?

$T_m = 820°C$

5] T_m when $V_{TC} = 35\ mV$, $T_{ref} = 0°C$?

$T_{m1} = 840°C \rightarrow V_{TC_1} = 34.93$

$T_m = ? \rightarrow V_{TC} = 35$

$T_{m2} = 845 \rightarrow V_{TC_2} = 35.14$

$$\frac{35.14-34.93}{35-34.93} = \frac{845-840}{T_m-840} \rightarrow T_m = 841.67°C$$

6] T_m when $V_{TC} = 35\ mV$ and $T_{ref} = 20°C$?

$$V_m = V_{KO}(T_m) - V_{KO}(20°C)$$

$$V_m = V_{KO}(T_m) - 0.8 \rightarrow 35\ mV = V_{KO}(T_m) - 0.8$$

$$35.8 = V_{KO}(T_m)$$

[illegible]

$T_1 = 840°C \rightarrow V = 34.93$

$T_m = ?? \rightarrow V = 35.8$

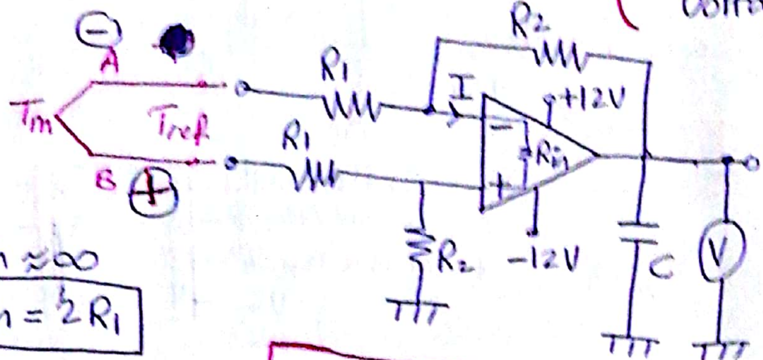
$T_2 = 845 \rightarrow V = 35.14$

$$\frac{5}{T_m - 840} = \frac{0.21}{0.87}$$

$T_m = 860.7°C$

Signal Conditioning →

بتتاج الـ [differential Op-Amp] لإنه هو بيضبط الـ output من الـ TC
والي هو (differential voltage) ← 2wire ويأعطي gain مناسب



لو عكسنا الـ polarity الـ العكس بصير الـ output سالب

$R_{in} \approx \infty$

$R_{in} = 2R_1$

I الملاحظة في الـ Op-Amp بسبب الـ (offset current) واذا كان إلها قيمة فهو بيعمل Loading ع الدائرة اللي قبلها..

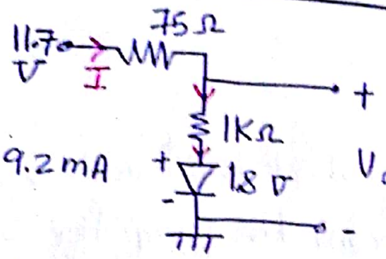
$$V_{out} = \underbrace{\left(\frac{R_2}{R_1}\right)}_{gain}\left(V(T_m) - V(T_{ref})\right)$$

منقسم $\frac{V_{out}}{gain}$ بتعطي بالـ (mV) ومنجمعها $V|_{T_{ref}}$ لنوجد $V|_{T_m}$ ومن بعدها منطلع الحرارة

C : for regulation and storing the data.

theoretically ← بيكون في فرق بينها وبين الـ expirement values بسبب الاختلافات ← اختلاف مهم

Q1: Find I →



$$I = \frac{11.7 - 1.8}{1075\,\Omega} = 9.2\,mA$$

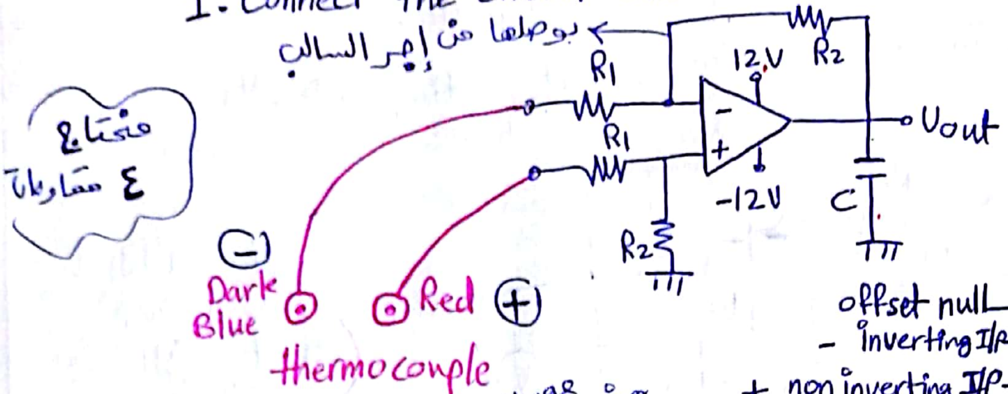
$$V_{out} = (9.2)(1) + 1.8\,V = 11\,V$$

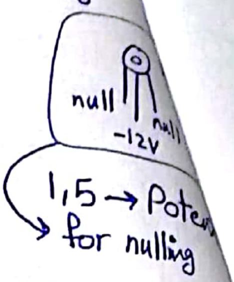
Q2: this signal conditioning (differential Op-Amp) isn't suitable for driving a motor?

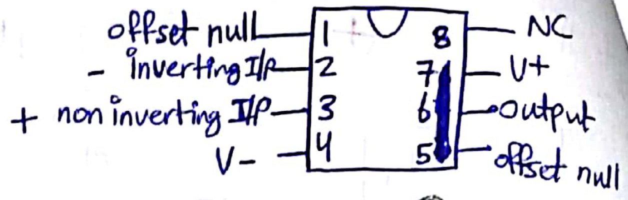
→ because the motor stage needs high current, so there is no matching between Op-Amp & motor stages.

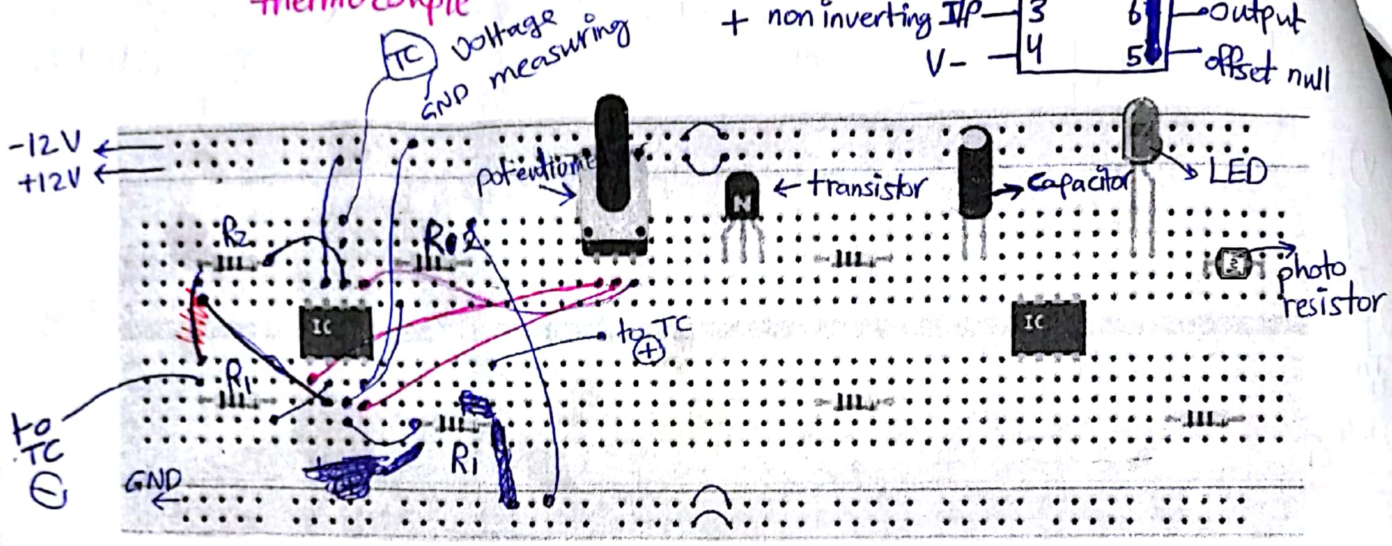
Practical Part

1. Connect the circuit shown below, without the TC ?









2- Without potentiometer /TC , short the inverting & the non-inverting terminals. Measure Vout from the amplifier ___0.5 V___ [Ø ΔV_{in}]

حل ال potentiometer / offset voltage

منشان ع نفس النود

3- Adding the potentiometer & adjust it until you get Ø Vout.

[وخليه مثل ما هو ما بشيله]

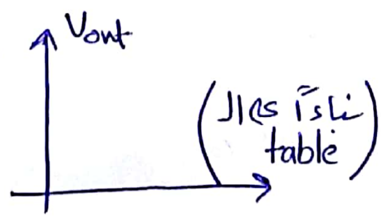
4- Insert TC

Temp	70	65	....
V_{out}			

For offset null
↓
الهدف من ال potentiometer

* theoretical output voltage (V_{out}) $= \frac{R_2}{R_1}\left(V|_{T_m} - V|_{T_{ref}}\right)$

5- Plot Vout vs. temp. ?



6- What are the error sources in this expirement ?

موجودة

① reading from thermometer

② room temp. doesn't exactly equal with Tref

Exp 4 Thermal Sensors (Thermistors) ∝

بيشبه ال RTD لأنه بتغير الحرارة ، بتغير المقاومة ΔR (بتكون ΔR ، كبيرة أكثر من ال RTD)

Sensor Output → ΔR

Non Linear Device

- Thermistor's widely used as →
  - inrush current limiter
  - temperature sensor (NTC)
  - Self_resetting overcurrent protectors
  - Self regulating heating elements.

- Thermistor differ from RTD's :

① material → thermistor / ceramic or Polymer ، RTD / metals Ni Cu PT

② temp. response → thermistor / Limited temp. range (-90 _ 130°C) ، RTD / Larger temp. ranges

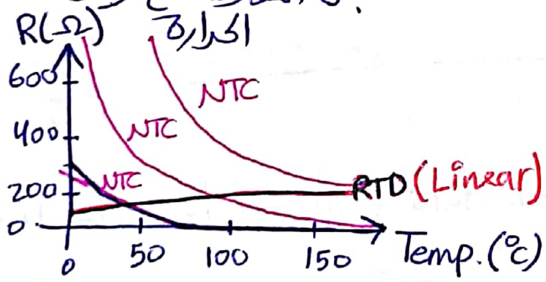
- Thermistors can be classified into 2 types ، depending on the behaviour of resistance with change in temp :-

1] NTC "Negative Temp. Coefficient" ← الأشهر

↓ تقل المقاومة مع زيادة الحرارة

2] PTC "Positive Temp. Coefficient"

↓ تزداد المقاومة مع زيادة الحرارة



Highly non Linear relationship بين الحرارة وقيمة المقاومة

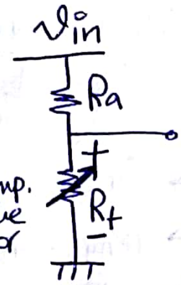
High Sensetivity

Good Range

"thermal runaway"

Problem of the thermistor is → Self Heating Phenomen[a]

[thermistor in a voltage Divider CCT]



لما يمر تيار بالمقاومة ال thermistor
(it'll generate heat) رح يحمى
وبالتالي رح ترتفع درجة حرارة
ال thermistor عن الدرجة
المحيطة فيه. وتقل مقاومته ويزيد التيار
وترتفع حرارته أكثر مع ذلك

so, this electrical heating may introduce a significant error if a correction isn't made.

which is ↓

the current flow → $I = \frac{V_{in}}{R_t + R_a}$

- Correction: dissipating factor "Constant Value" [mW/°C] ← تكون بالداتا شيت

$$P_{diss} = I^2R \quad mW/°C$$

[كلما زادت الحرارة تقل المقاومة
فبناءً ع الحرارة بحسب المقاومة
بحيث التيار]

1 mW → 1°C

I^2R W → ??

فرضًا طلعت الحرارة 27°C المقاومة بتقل
عن اللي كانت 25°C

← المشكلة هاي مابتوقف إلا اذا ←
if the voltage is Low enough or the Ra & Rt are large enough

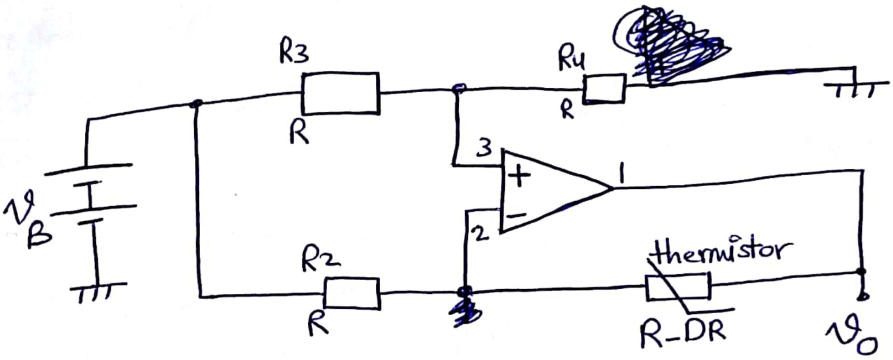
Applications for NTC :

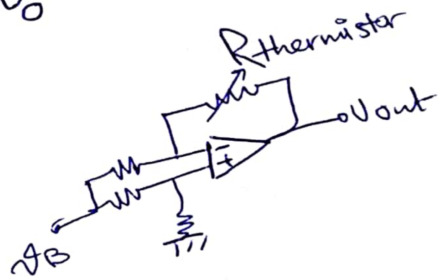
① used in modern digital thermostats & to monitor the battery packs while charging

② in automotive applications to monitor things like Coolant or oil temp. inside the engine, and provide data to the ECU & to the dashboard.

③ Used in the hot ends of 3D printers by monitoring the heat produced and allow the printer's control circuitry to keep a constant temp. for melting the plastic filament

Conditioning Circuit → Bridge / Op-Amps
But these circuits differs in its sensetivity & Linearity





[Op-Amp bridge CCT
thermistor
SC]

About dissipation constant :

Ex If the D.C. of a thermistor assembly had been determined as 3 mW/°C in a stirred oil bath, and it was desired to measure the oil bath to an absolute temp. accuracy of ±0.1 °C, the max. power that should be developed in the thermistor by measuring current is 0.15 mW. This is to keep the self-heat factor to 50% or less of the measurement accuracy?

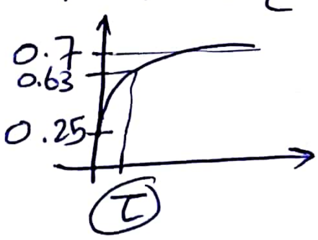
$$3\,mW/^\circ C \times 0.1\,^\circ C \times 50\% = 0.15\,mW$$

$$P = IV = I^2R$$

---

thermal sensors → [بتختلف عن بعض حسب ال (Response) متى بوصل لل steady state]

TC أخر واحد بأقل زمن ← steady state



تحليل بال TC

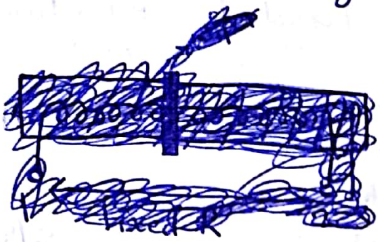
Exp 5 Displacement Sensors (VLT) ✗

VLT ≡ Variable Length Transducer → (sensor output → resistance)
"Potentiometric Sensor"

Theoretical Part:

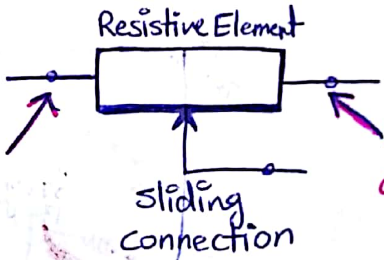
- Linear device involves the action of displacement in moving the wiper of a potentiometer, then converts (Linear or angular) motion into (ΔR) that maybe converted directly to Voltage / current.

the position of this sliding contact maybe varied by pushing or pulling the threaded connecting rod.



{ من خلال حركة wiper
يمين وشمال، متغير المقاومة
بين 2 و 3
(كل ما حركته بتزيد R) }

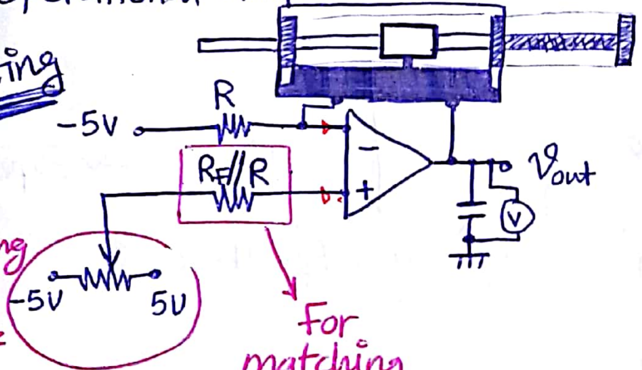
- Disadvantages:
  1. Mechanical wear
  2. High electronic noise
  3. Limited operating range (small)



Practical Part:

For an Operational amplifier circuit with resistive feedback

S.C ال VLT → Inverting



For nulling
زي كان بالاول لما
عملناها ووصّلنا GND
بدلها لأننا عنا
ال thermocouple
أكثر ..

→ For matching purposes between + & - amplifier ends to get the same current...

$$V_{out} = -V_{in}\frac{R_F}{R}$$

$$V_{out} = -(-5)\frac{R_f}{R}$$

$$\therefore\; V_{out} = 5\,\frac{R_f}{R}$$

بالامتحان بعتبر
السلك
اللي
بالنص
هو
المتغير
↓
الفكرة
انه
ال
wiper
مع أي
سلك
مربوط
من اللي
طالعين من
ال (sensor) ..

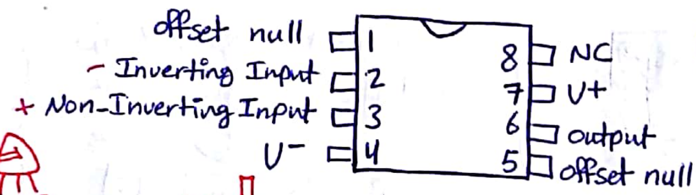
1.) Measure the max. resistance of the sensor (between fixed ends)

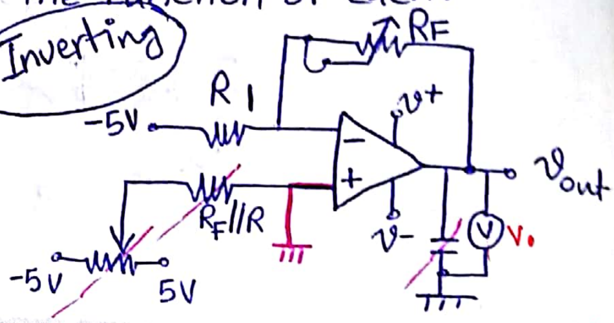
$R_{max} = \dots \rightarrow$ between ① & ③ from the LVT

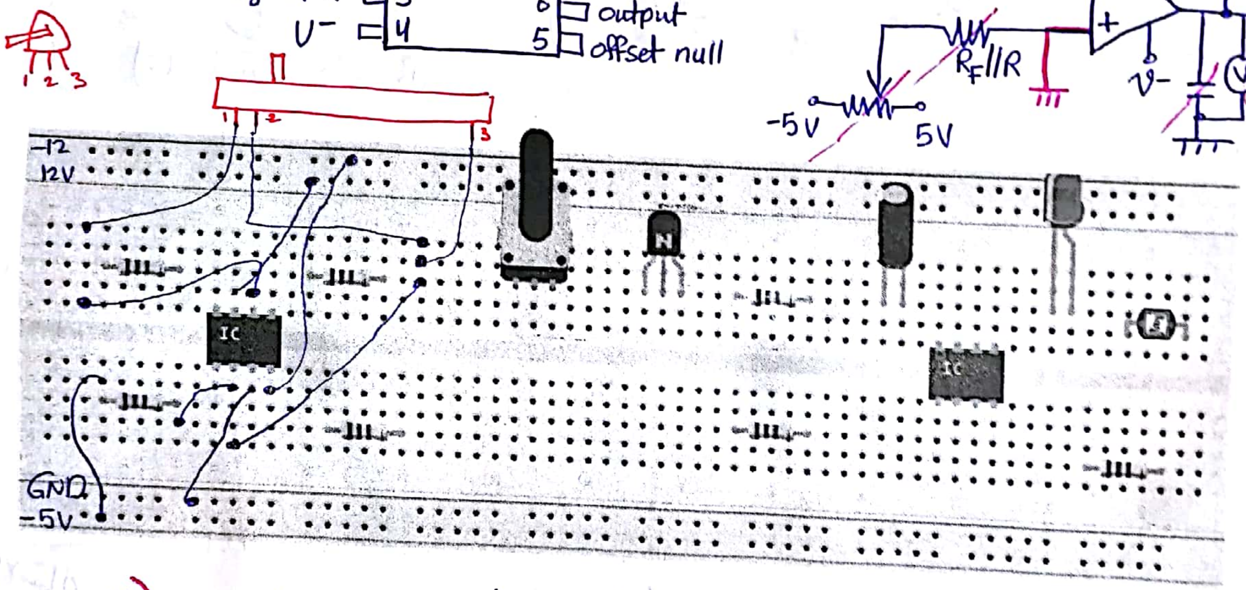
$L_{max} = \dots \rightarrow$ من طرف لطرف

QUIZ: وعأساس القيم الي بتطلع بتسعهم ع بعض وبحدد ال resolution [kΩ/cm]

2.) Connect the circuit below, without the nulling potentiometer, the resistor at the non-inverting terminal or the output Capacitor, but understand the function of each.







3.)

distance (cm)	0	0.42	1.9
Output Voltage	ØV	1.2V	5.5V
	$R_F = 0\Omega$	$R_F = 2.4\,k\Omega$	$R_F = 11\,k\Omega$

→ Experimentally

theoretically:

For $R_1 = 10k\Omega$ because (input voltage + gain) that resulting Vout don't exceed Lmax

$* \; V_{out} = V_{in} \frac{-R_F}{R}$

$= 5 \; \frac{2.4\,k\Omega}{10\,k\Omega}$

$= 1.20\,V$

L = 0.42 → R_f?
Lmax → Rmax

$\frac{0.42 * R_{max}}{R * L_{max}}$

$R_f = $

*بعرف ال (Length)
بعوض ال R_F
بعوضها بال Resolution [kΩ/cm]

4.) How can you Calculate the Output resistance of the sensor based on the V_{out} you obtained? [expirementally]

$$\left[V_{out} = 5\,\frac{R_F}{10k}\ ?\right]$$

لكن (theoretically) ميكون معنا R_F منطلعه بواسطة الطريقة (النسبة وتناسب) ولعبنا أوجد V_{out}

* to find Vout → بوجد R_F عند الـلاالة الطاولة (النسبة وتناسب مع الـ Rs)

5.) What are the advantages of having the sensor in the feedback of the amplifier?

→ to get Linear relationship between Vout and the resistance

لأنه ميكون في تغيير بالمقام اذا كان موصلك

hence, we can find the resolution for it.

6.) What are the design criteria when selecting the value of R_1?

① for not reaching the saturation mode (Losing the sensetivity because of high gains)

② depending on the input Voltage

7.) Plot the calculated resistor values against position?

[موجود كثير]

8.) What's the output of this sensor in this case (Voltage / current / resistance)?

بغض النظر عن الـ conditioning circuit

9.) Does the temp. affect the obtained results? Explain.

Yes, because any sensor resistance $\left[R = \frac{\rho L}{A}\right]$

10.) What are the possible sources of error that affect the expirement results?

[موجود]

Scanned by CamScanner

Exp 6 Displacement Sensors (Strain Gauge)

- Sensor whose electrical resistance varies in proportion to the amount of strain in the element being deformed.

Tension / compression ⇐ [حسب نوع الفورس الي سبّبت ال deformation الحاصل]

Compression → decreasing R, due to decrease in (Length) and increase in (Area)

Tension → increasing R, due to increase in (Length) and decrease in (Area)

- Sensor for measuring ΔR according to the deflection caused by the external force.

$$R = \frac{\rho L}{A}$$ → conductor resistance

- A fundamental parameter of the strain gauge is its sensetivity to strain, known as (gauge factor) ⇒ the ratio of fractional change in electrical resistance to the fractional change in length (strain)

$$GF = \frac{\Delta R / R}{\Delta L / L}$$: بتغير حسب نوع المادة

الي بدي أعرفه ← ΔL

- Strain gauge has been in use for many types of sensors :
  ① Pressure Sensors ② Load cells ③ Torque Sensors ④ Position Sensors

- Applications
  → in mechanical engineering research to measure the stresses generated by machinery
  → Aircraft Component Testing
  → ...

Sensetive interfacing CCT's ⇐ لذلك قليل جدًا S.G التغيير الناتج عن ال * must be used to detect these changes

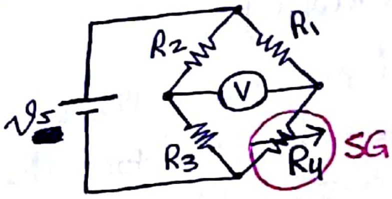
[Wheatstone Bridge]

- موقع ال SG كتير مهم إنه يكون ع ال (sensetive direction)

Interfacing with WB :

($R_1 = R_2 = R_3 = R_4 = R_o$)

① quarter → (one active SG)



$R_4 = R_o + \Delta R$

$$\Delta V = V_s \left[\frac{R_o}{2R_o} - \frac{R_o \pm \Delta R}{2R_o \pm \Delta R} \right]$$

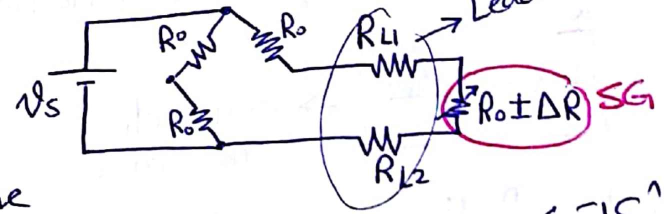
$$\Delta V = V_s \left[\frac{1}{2} - \frac{R_o \pm \Delta R}{2R_o \pm \Delta R} \right]$$

Highly Non Linear

$+\Delta R$: Tension
$-\Delta R$: Compression

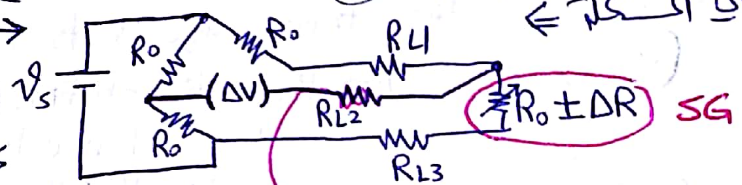
* Leads effect on measurements :

بسبب مقاومات الأسلاك الغير معتبرة



[R_{L1}, R_{L2}, S.G] → series

to reduce the error resulting from the Lead resistors →

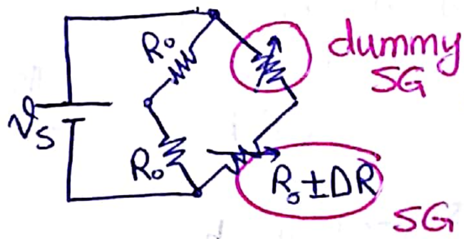


← كده حلك الـ

error sources
① temperature
② Lead resistors

This wire carries practically no wire (due to voltmeter's high internal resistance)

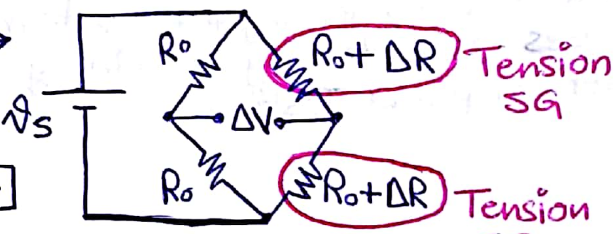
→ to reduce the error resulting from the temperature, a "dummy" SG in place of R_1 is used.



dummy SG / خلّي الـ Insensetive direction لتتأثر بحرارة فقط

② Half → (two active SG)

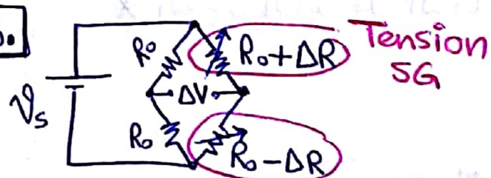
a.



$$\Delta V = V_s \left[\frac{1}{2} - \frac{R_o + \Delta R}{2R_o + 2\Delta R} \right]$$

highly non Linear

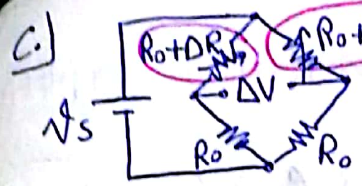
b.



$$\Delta V = V_s \left[\frac{1}{2} - \frac{R_o - \Delta R}{2R_o} \right]$$

✓ Linear + more sensetivity

c.

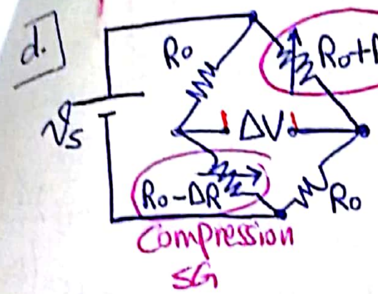


ولو عملنا Tension / comp. لنفس الشكل
لكن مضاعف sens. ← non Linear

$$\Delta V = V_s\left[\frac{R_o}{2R_o+(\Delta R)} - \frac{R_o}{2R_o+(\Delta R)}\right]$$

highly non Linear

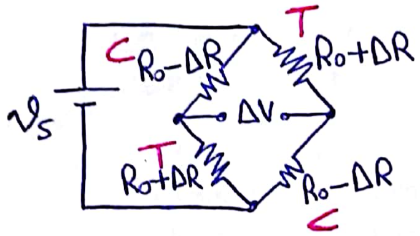
d.



$$\Delta V = V_s\left[\frac{R_o+\Delta R}{2R_o+(\Delta R)} - \frac{R_o}{2R_o+(\Delta R)}\right]$$

Highly non Linear

③ Full Bridge (اللي تستوزن بالللاب) →



* ال sensetivity صارت ٤ أضعاف
وأكيد صارت Linear

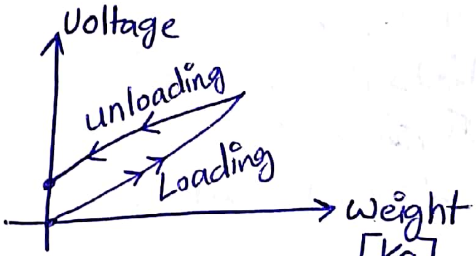
$$\Delta V = V_s\left[\frac{\Delta R}{R_o}\right]$$

ولو عكسنا T C
C T

$$\Delta V = -V_s\left[\frac{\Delta R}{R_o}\right]$$ صغير

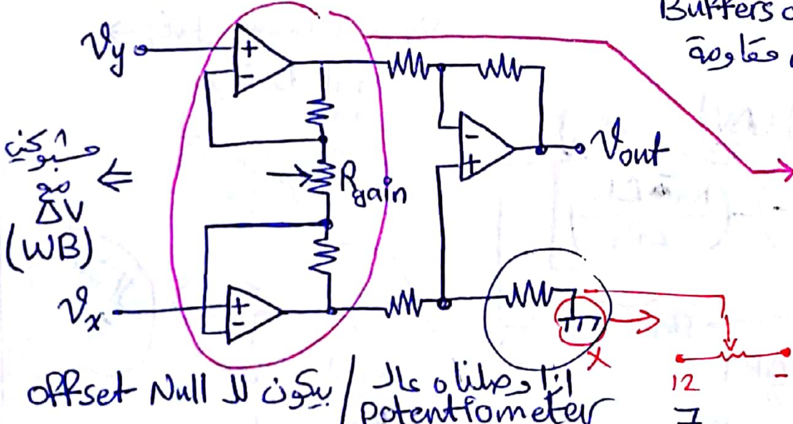
- Strain Gauge → 2wire
  → 3wire

- Hysteresis in SG :



ما أنا بحمل Loading
تتقل المادة من حالة
إلى حالة أخرى فلهيك
لما بدي أعمل
(unloading)
كي ترجع لوضعها الطبيعي بحاجة لوقت لهالشي
فنصير مشكلة ال (Hysteresis) لما بحمل unloading مباشرة

Instrumentation Amplifier →



بتميز عن ال differential اللي معاه Buffers
إنه بنكن تتحكم بال gain من خلال مقاومة
R_{24} / R_{gain} بالمختبر

→ For impedence matching to solve the loading effect problem by setting (R_{gain})

عبارة عن 2 non inverting

$$V_{out} = V_{in}\left(1+\frac{R_2}{R_1}\right)$$

offset Null لل بيكون / إذا وصلناه على potentiometer

* The relationship of the instrumentation amplifier to its input voltages →

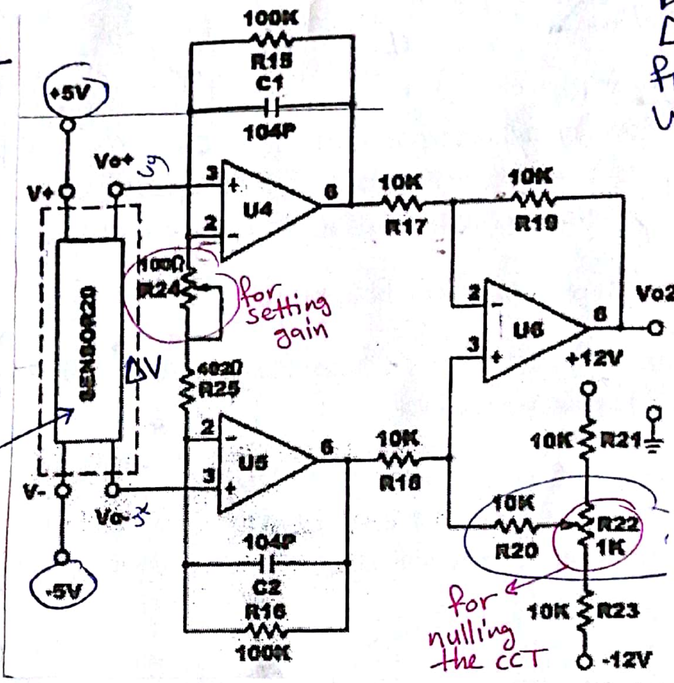
حفظ

$$\left[V_{out} = \left(1+\frac{2R}{R_{gain}}\right)\left(\frac{R_2}{R_1}\right)(V_2 - V_1) \right]$$!

$(V_2 - V_1) \rightarrow \Delta V$ from WB $(5-(-5))\left(\frac{R_0+\Delta R}{2R_0} - \dots\right)$

$= 10\left(\frac{\Delta R}{R_0}\right)$

Practical Part



SG transducer module ←

output الـ من الـ (bridge) Full Bridge الي استخدمناه بالمختبر

1- Null the circuit using (R_{22})

2- Set the amplifier gain using Potentiometer R24

3- Insert the sensor (beam عبارة عن)

مفير محط أوزان عطرفها أفضل

لأنه صيعطي مومنت أكثر

ومراقب قراءة الفولتية

4- Measure R24 you used to set the gain

$(R_{24} = 400.5\ \Omega)$

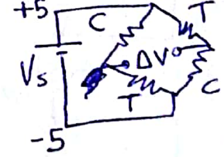
*Do you think that the load position on the beam affects the measurements Explain!

→ Yes, because it will give more moment [more deflection]

لما يكون كم طرف الـ beam "edge"

5- Calculate the theoretical expected output voltage of the Bridge $V_{o20}/\Delta R$?

V_{o20} always (+ve) → Full Bridge



$$\rightarrow V_{out} = \left(1+\frac{2R}{R_{gain}}\right)\left(\frac{R_2}{R_1}\right)(\Delta V)$$

$$\left[\Delta V = (5-(-5))\left[\left(\frac{R_0+\Delta R}{2R_0}\right) - \left(\frac{R_0 - \Delta R}{2R_0}\right)\right] = 10 * \frac{\Delta R}{R_0} \right]$$

gain = 150 مهم

$$\therefore V_{out} = \left[\left(1+\frac{2R}{R_{gain}}\right)\left(\frac{R_2}{R_1}\right)\right]\left(10\,\frac{\Delta R}{R_0}\right)$$

quiz ممكن تعطينا قيمة gain / R_0

سؤال مهم

9- Plot the voltage vs. weight curve of the system using data

10- Do you think that the load position on the beam affects the measurements. Explain?

→ Yes, because it'll give more moment "more deflection"

Exp7 Encoders → Electro_mechanical device converts (angular position or motion) (أو) to digital or analog

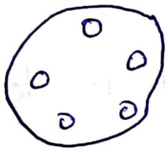
Optical digital sensor, compatible with arduino, PIC

High continuosly Range

الانكودر عبارة عن جهاز يعتمد على الـ Beam of Light
يعني بالـ (optical) مثلاً اذا
كانت الـ "beam of Light"
نافذة ما بيعمل شي
واذا انقطع الضو بيعطي
pulse أو بيعطي (trigger)

a.) Incremental (relative) → to measure [speed or position]

no. of pulses = no. of holes



5 holes
5 pulses

output الـ
من
Know the motion of the shaft
الي بقدر أعرف منها
speed, distance, position

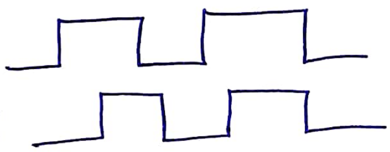
resolution = 5 pulse/rev

$\frac{360^\circ}{5} = 72^\circ$ → كل 72° بيعطي pulse

[من سلبياته: لازم أعرف من وين بيلش]

* 8 wires in it according to the no. of phases

لتحديد اتجاه دوران الانكودر



→ phase A Lead Phase B (CW)

but if phase B Lead phase A (CCW)

phase Z → to know how much does the encoder rotate (full rotation)

لأعرف كم لفة كاملة لفها الانكودر؟

A A' → Phase A
B B' → 〃 B
Z Z' → 〃 Z
GND VCC → power supply

→ 8 wires
incremental Encoder
max. no.

*three channel, provides a "zero signal" for each revolution, giving a fixed point of reference.

Ex: res = 100 pulse/rev → position = 360° ✓

for 50 pulse/rev → position = 180°

$$\text{Speed} = \frac{\text{Position} * \frac{\pi}{180}}{\text{time}}$$

$$\text{position} = \frac{360^\circ}{\text{Resolution [pulse/rev]}}$$

b. Absolute Encoder → يطلع منه أسلاك حسب : $[V_{cc}$ / GND / #of bits$]$

- Just to measure the (precise) position — ال output منه

- Resolution depends on the no. of → bits
  → tracks

  (مع ترتيب ال holes فيه)

$$Res = 2^{n}$$

n → عدد ال bits

ما بقدر أعمل كم لفة كاملة لفها الانكودر من هالنوع ، لهيك بستخدم ال (multiterm Encoder) بحيث كل ٥ لفات للأول ، بلف الانكودر الثاني مرة !

$$Res_{total} = 2^{n} * 2^{m} = 2^{n+m}$$

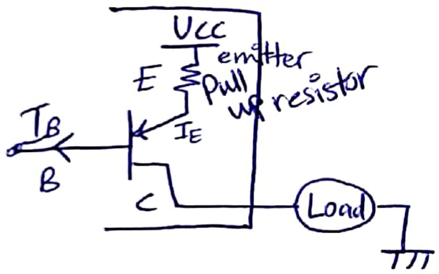
*لو كان عنا 2 bits → #of wires = 4

---

* Output Configuration (CCT) :

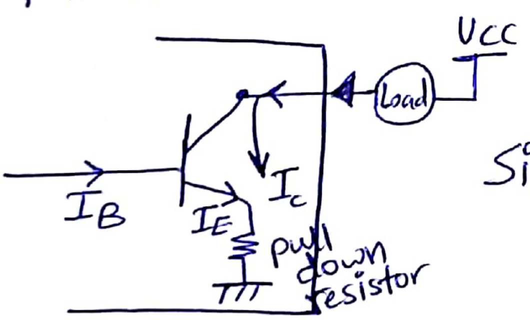
* الانكودر الموجود في اللاب
  - 2 phase / Inc. → 6 wires
  - 6 bit / Abs. → 8 wires

1] Line Driver →



source / PNP

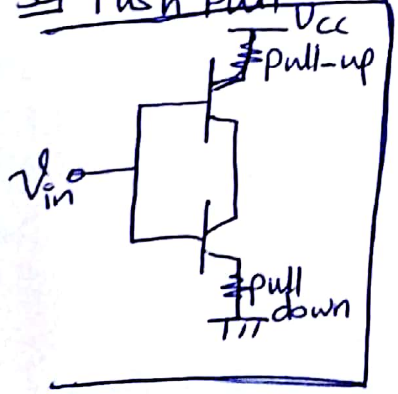
2] Open Collector



Sink / NPN

Encoders use an LED (Light source)
phototransistors or photodiodes (Receivers)

3] Push Pull



Quiz | If the no. of pulses measured at phase A are 500 pulses & the encoder is fitted on tire (50cm) diameter. Calculate the displacement of the tire (Circle Circumference = $2\pi r$)

$$\text{revolution} = \frac{500 \text{ pulses}}{200} = 2.5$$

200 ← Resolution
من الراسم

$$2.5 \text{ rev} * 2\pi * \frac{0.5}{2} = 1.25\pi \text{ m}$$

* advantages →

① No mechanical parts in contact.

② Non-magnetic product

③ Compact size

[digital & optical technology]

* disadvantages →

① Susceptible to dirt, oil, ...

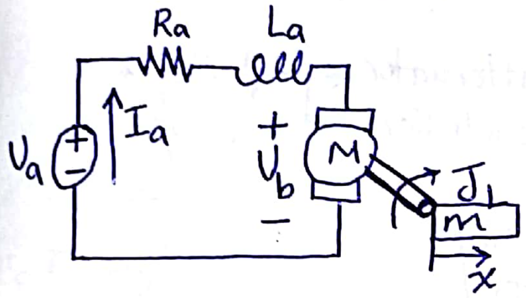
② Direct Light source inference.

Calculate

Exp(8) Servo motor system
"Servo motor kit units".

Theoretical Part →

DC motors are used extensively in many control applications. Therefore, it's necessary to establish mathematical models for DC motors. The transfer function of a DC motor can be approximated by a first order model with unknown constants. These constants can be identified experimentally.



$\mathcal{V}_a \rightarrow I_a \rightarrow T \rightarrow \omega \rightarrow \theta \rightarrow x$

$$\sum T = J\ddot{\theta} + b\dot{\theta} \quad , \quad T_{in} = K_m I_a$$

$$K_m I_a = J\ddot{\theta} + b\dot{\theta}$$

$$\mathcal{V}_a - \mathcal{V}_b = R_a I_a + L_a \frac{dI_a}{dt}$$

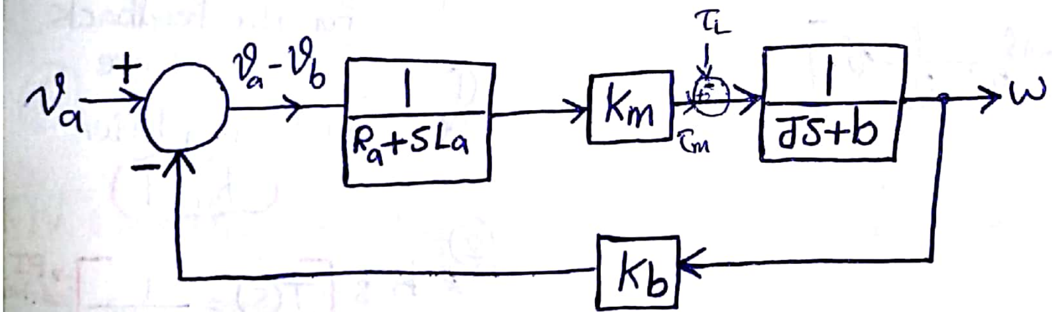
$$\mathcal{V}_a - K_b\dot{\theta} = R_a I_a + L_a \frac{dI_a}{dt}$$

$$I_a(s) = \frac{V_a(s) - K_b s\theta(s)}{R_a + sL_a}$$

$$K_m \left[\frac{V_a(s) - K_b s\theta(s)}{R_a + sL_a}\right] = \theta(s)\left[Js^2 + bs\right]$$

$$\frac{K_m \mathcal{V}_a(s)}{R_a + sL_a} = \theta(s)\left[\frac{K_m K_b s}{R_a + sL_a} + \frac{(R_a + sL_a)(Js^2 + bs)}{R_a + sL_a}\right]$$

$$\frac{\theta(s)}{\mathcal{V}_a(s)} = \frac{K_m}{(R_a + sL_a)(Js^2 + bs) + sK_m K_b}$$



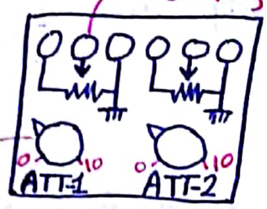
إذا اعتبرنا $L_a = \emptyset$
هيطلع عندي بالنهاية
First Order Sys

1

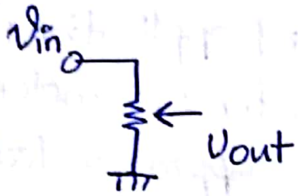
Servo Motor kit Units

① attenuator →

يمثل ال output من ال attenuator



موقع ال GND إله علاقة بمكان بداية مؤشر ال (selector) ⇐



$V_{out} \leq V_{in}$ → open CCT كأني علة

For attenuator = 10 ← [$0 \leq$ gain ≤ 1] ⇐ يحتوي على 2potentiometers (10 kΩ) ، كل واحد منهم بيزود

→ for atten. = ∅

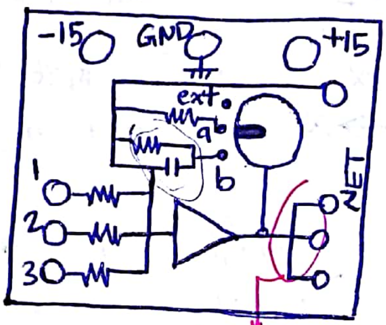
depending on the position of its knob

يزيد التخفيض يعني تقلل ال gain

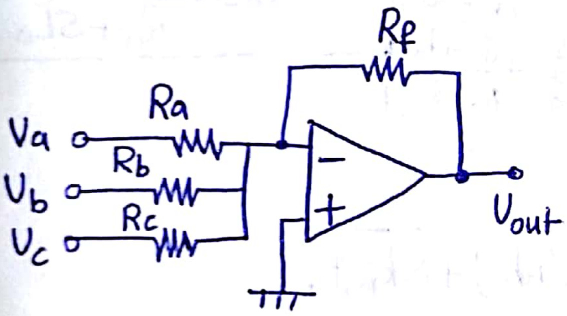
* تستخدم → as an attenuator
→ as a controller

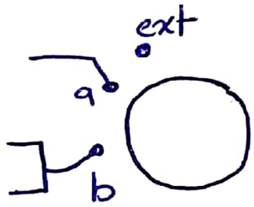
---

② Summing amp. →



but still there's one output for multi using.





$$V_{out} = -R_f \left[\frac{1}{R_a} V_a + \frac{1}{R_b} V_b + \frac{1}{R_c} V_c \right]$$

[3 options] for the feedback impedence

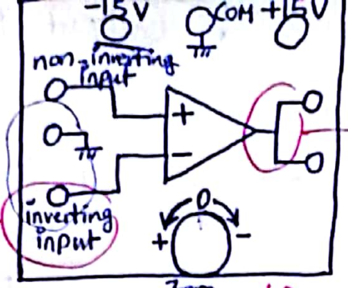
① * a : amplifier $K_a = 1$

② * b : $\left[T(s) = \frac{1}{s+1} \right]$ → PI controller

③ * the feedback depending on an external circuit

---

pre-amp →



→ still one output

منستخدم هاد فقط في المختبر لنتخلص من السالب ← inverting input

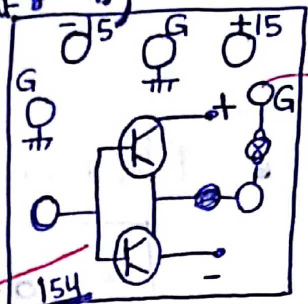
نقيس بالفولتميتر عبين ما نصير (-15V)

قبل ما أشغل بوصله على الصفر وأشغل بعين اربع بتكه بالدارة عادي

(inverting) Gnd input و براقب ال output مع تحريك ال speed knob

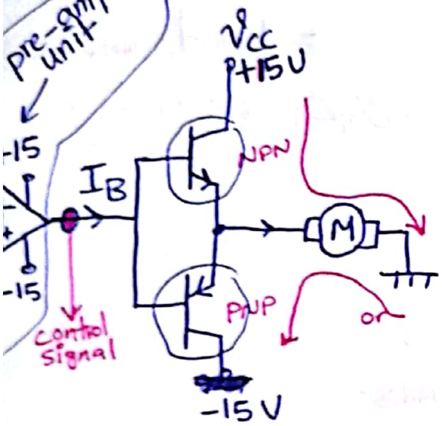
← gain بيعطي
كبير وبعكس الاشارة
السالبة عن طريق
استخدام ال Inverting Input

(4) Motor driver amp. →



→ with respect to GND

push pull configuration



* الدرايفر بالنظام موقعه بيكون ↓

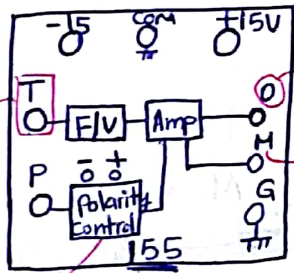
* الهدف منه — transistor, for current amplification
for control the direction of rotation

الدرايفرهو اللي فيها ال [push pull]

(5) Motor unit (tacho+gearbox+motor) →

F/V : frequency to Voltage

2inputs / 2outputs



For speed magnitude / جاي من ال tachometer والطرف الثاني إلى GND

→ voltage magnitude / direction الحركة

→ meter display

for the direction of rotation

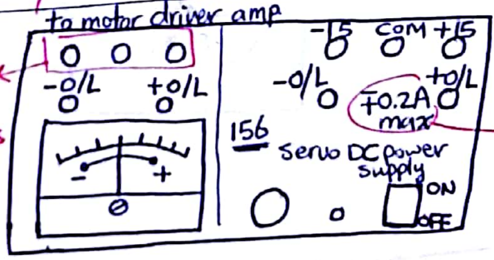
ازا استخدمت ال tachometer
لازم استخدم هاي ال unit

Quiz : ازا شبكت شي ال (P) يعني ذلك ← unidirectional control / ازا شبكتها -15/15 كبيله انه بدور باتجاه ثابت

* ازا ام شبكتها م تعتبر unidirectional

* لكن ازا ام توصلها مع ال pre-amp. output
بيكون bidirectional
ما بيكون ثابت

(6) DC Power supply →

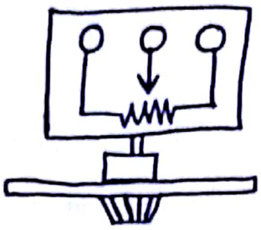


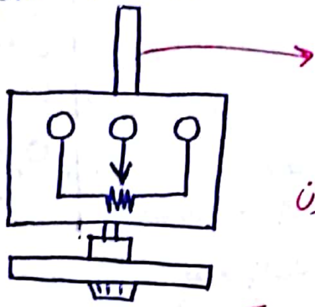
gives high currents

→ for the small units before

ما بصير أوصلها مع ال
الـ units السابقة لأنها ما
بتقدر تسحب تيارات عالية كان
تحترق ..

⑦ Input potentiometer ، Output Potentiometer





[لأعرف ال position تبعه]

"بستخدمه ك Sensor"

* ممكن أستبدل ال attenuator فيه

* بستخدم ← for position control

انا استخدمه ك ([redacted])
input
"Set point"

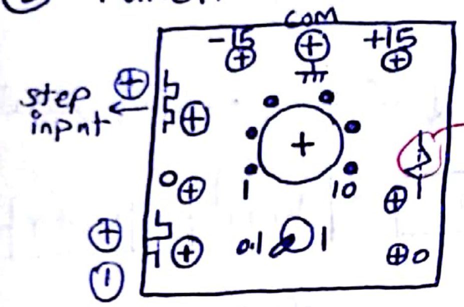
---

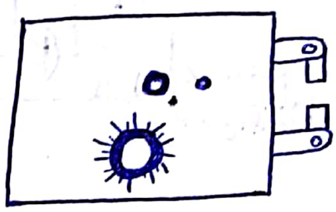
⑧ Function Generator ، Electro-magnetic Brake

"mechanical"

≡ Load (disturbance)

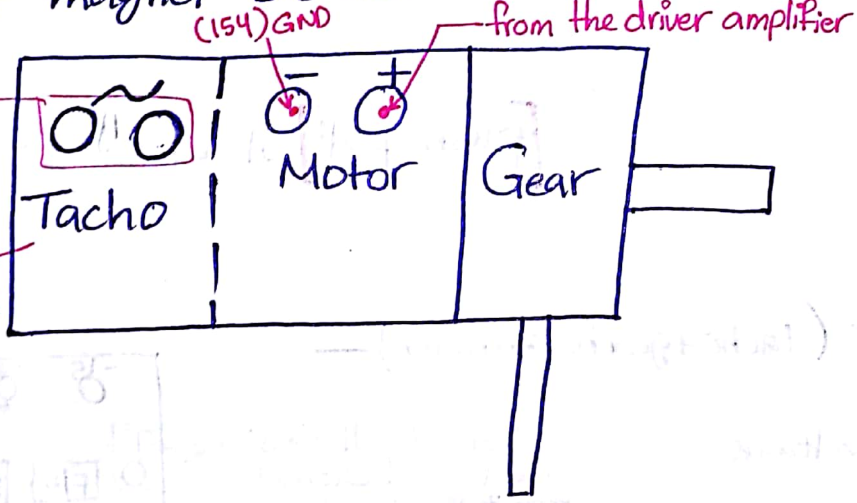
ما إله دخل بالنظام الكهربائي تبعنا





---

⑨ Permanent magnet DC motor →



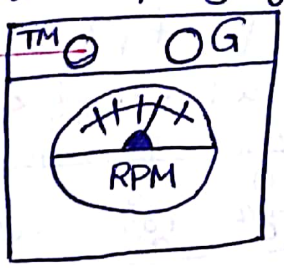
وصلة منع لل GND لتشغيل -ve feedback والثانية

F/U — T

(155)

ولو عكسنا القطبية هون منشغل على +ve feedback بدلاً من ال -ve اللي بدنا ايها

⑩ Meter unit [redacted], Just for displaying the speed →



مع M بشبكها بالموتور (motor unit)

Exp(9) 1^{st} and 2^{nd} Order System/ Servo

Theoretical Part →

Control systems are inherently dynamic, because of that, their performances are usually described in terms of transient response and the steady state response. The transient response disappears with time, while the steady state response exists for along time after the initiation of an input signal.

① Dynamic Response of first order control systems →

$$T(s) = \frac{k}{\tau s + 1}$$

" اللي بدي أوجدهم k, τ "

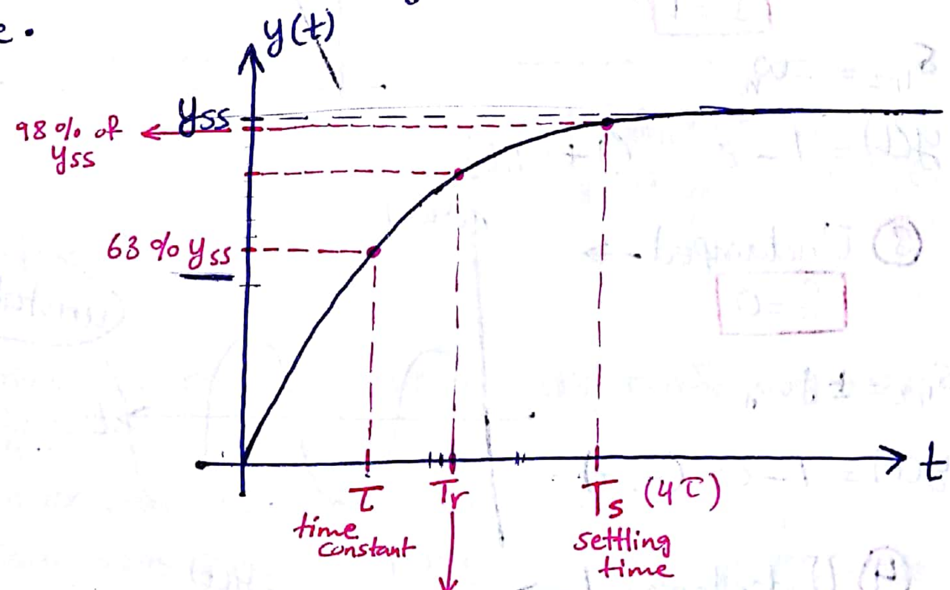
the output as afunction of time for aunit step input is :

$$y(t) = k\left(1 - e^{-t/\tau}\right)$$

* k (system gain) ≡ dc value (steady state value of the output $y(t)$) for aunit step input ($R_{ss}=1$)

$$k = \frac{y_{ss}}{R_{ss}}$$

* τ (time constant) ≡ time value when the system reaches 63% of its steady state value.



* T_s (settling time) $= 4\tau$
  0.98 y_{ss}

$T_s(0.95\, y_{ss}) = 3\tau$

/ بيساوي الزمن اللي تستقر فيه النظام تبعي ..

② Dynamic Response of second order control system →

$$\left[T(s) = \frac{k\,\omega_n^2}{s^2 + (2\zeta\omega_n)s + \omega_n^2} \right] \quad , \quad \boxed{K = \frac{y_{ss}}{R_{ss}}}$$

كلما زادت قيمتها قلت الـ oscillation في النظام

$$S_{1,2} = -\zeta\omega_n \pm \omega_n\sqrt{\zeta^2 - 1}$$

احمي تربيع مرتين

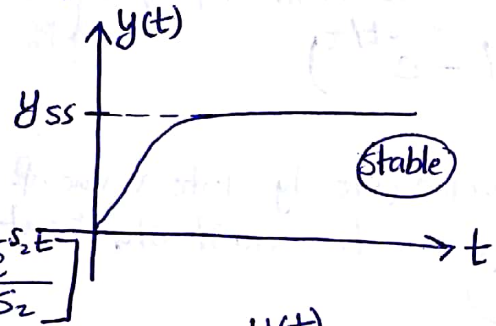
- Complex (OSC. في) — $\zeta < 1$ → stable / unstable
- Real (No OSC.) — $\zeta > 1$ → stable

2^{nd} order System Responses :

① Overdamped →

$\boxed{\zeta > 1}$

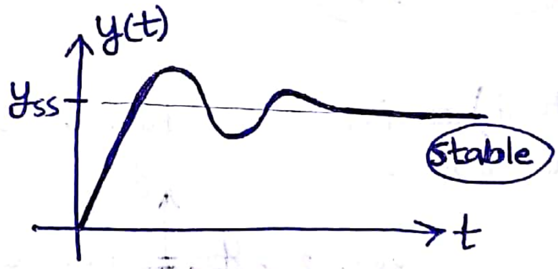
- $S_{1,2} = -\zeta\omega_n \pm \omega_n\sqrt{\zeta^2-1}$
- $y(t) = 1 + \frac{\omega_n}{2\sqrt{\zeta-1}}\left[\frac{e^{-S_1 t}}{S_1} - \frac{e^{-S_2 t}}{S_2}\right]$



② Critically damped →

$\boxed{\zeta = 1}$

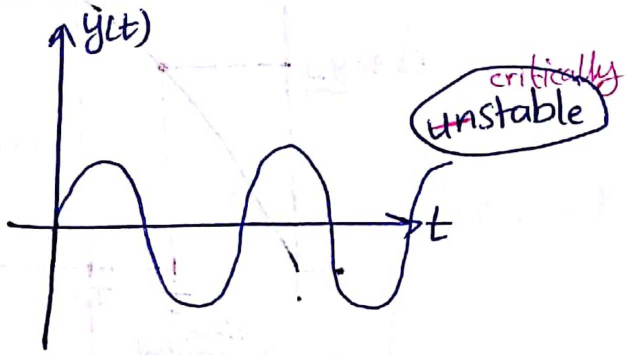
- $S_{1,2} = -\omega_n$
- $y(t) = 1 - e^{-\omega_n t}(1 + \omega_n t)$



③ Undamped →

$\boxed{\zeta = 0}$

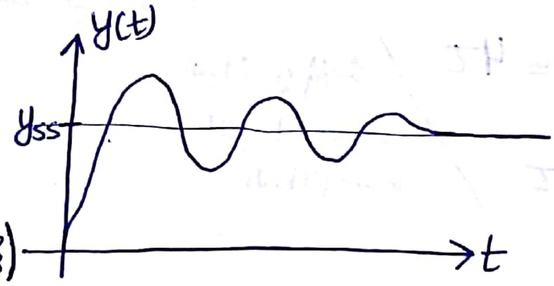
- $S_{1,2} = \pm j\omega_n$
- $y(t) = 1 - \cos(\omega_n t)$

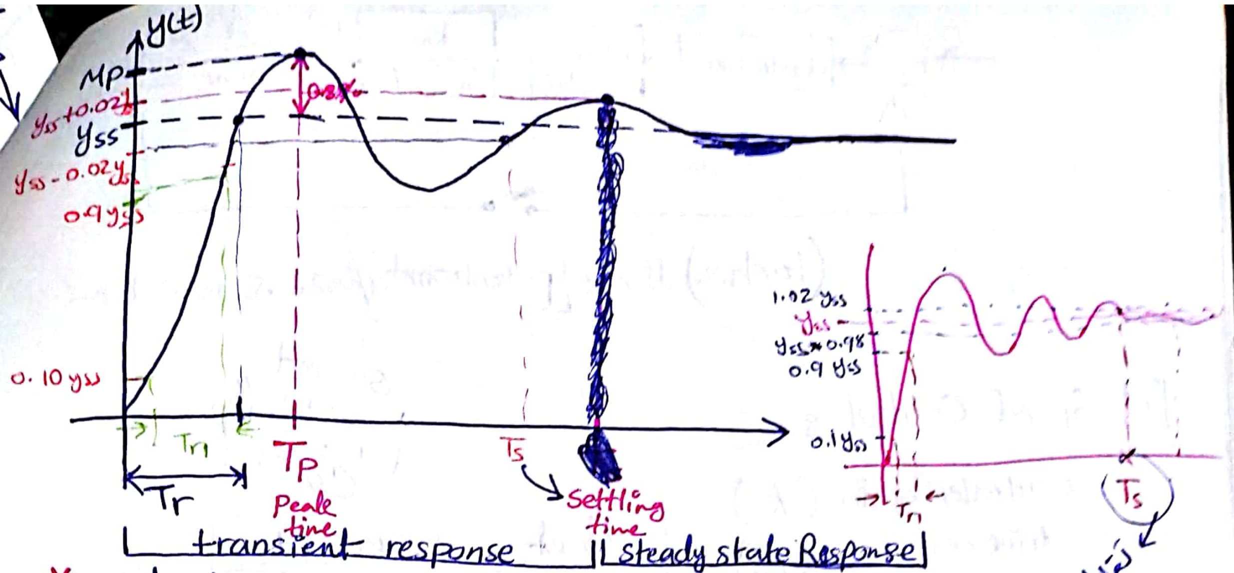


④ Underdamped →

$\boxed{0 < \zeta < 1}$

- $S_{1,2} = -\zeta\omega_n \pm \omega_n\sqrt{\zeta^2-1}$
- $y(t) = 1 - \frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}}\sin\left(\omega_n\sqrt{1-\zeta^2}\,t + \cos^{-1}\zeta\right)$





underdamped Second Order System Response

نقاطع 0.98yss أو 1.02yss ع المنحنى
نأخذ الحسب الي بقطع أول شي

- $T_P = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$
- $T_s = \frac{4}{\zeta\omega_n}$ (2% Criteria)
- $M_P\% = \frac{y(T_P) - y_{ss}}{y_{ss}} * 100\%$
- $O.S\% = 100\, e^{-\pi\zeta/\sqrt{1-\zeta^2}}$

{ ازا طلبوا الـ O.S% وما عطين قيمة ؟ بوجد الـ(Mp%) وبساويها بعلاقة الـ(O.S%) وبطلّع ؟ }

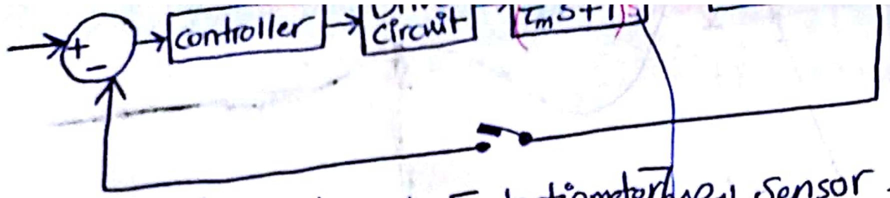
The Servomotor system in the previous experiment behaves as a first Order system when controlled in its speed form, and as a second order system when controlled in its position control form.

[Speed control] → the motor can be controlled at both open & closed Loop configurations.

Position control → the motor can be controlled only at closed loop configurations because it'll be unstable at its open loop.

Open loop	vs.	Closed Loop
Higher gain		Less gain
lower speed		higher in speed

→



← الـ sensor بيصير [potentiometer] بدل الـ (tacho.)

"Second Order" For Position Control

[1] Speed Control :

Controller gain (K_c)
drive CCT gain (K_d)
Sensor gain (K_s)
motor gain (K_m)

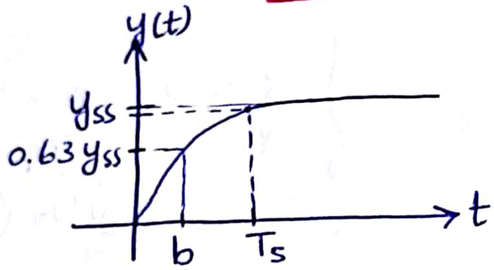
$$\left[\frac{V_{out}}{V_{in}} = \frac{K_m K_s K_d K_c}{\tau_m S + 1}\right] \text{ "open Loop form"}$$

First Order

$$\left[\frac{V_{out}}{V_{in}} = \frac{K_m K_s K_d K_c}{\tau_m S + [1 + K_m K_s K_d K_c]}\right] \text{ "Closed Loop form"}$$

(أسرع في الاستجابة)

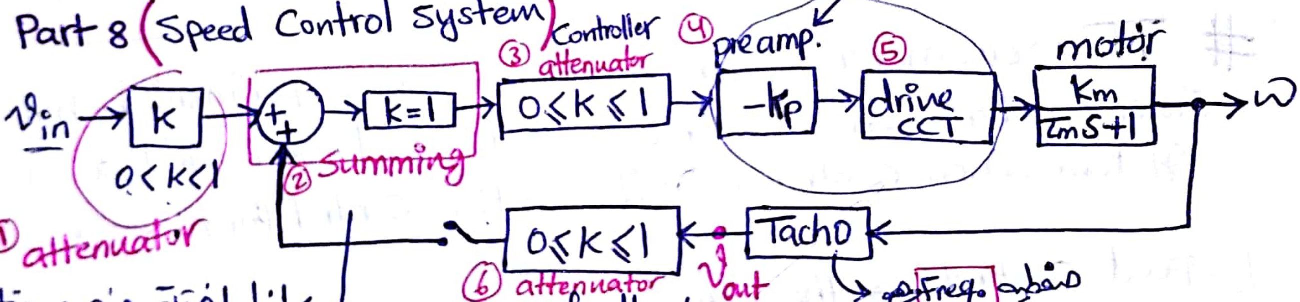
ما منقدر نحوّل الـ response position/speed للـ بالـلاب لكن منقدر نعرض شي تستجيب اللي هو الـ (V_{out}) حيث تتناسب مع الـ TF



$$T(s) = \frac{A}{bs+1}$$

$A \rightarrow y_{ss}$, $b \rightarrow \tau$

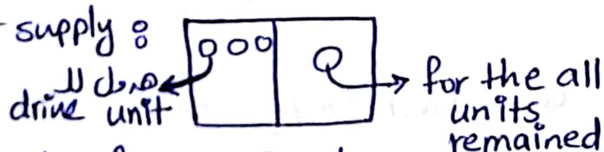
Practical Part 8 (Speed Control system)



ازا افترضنا فيه options أخرى يمكن أعتبره (controller)

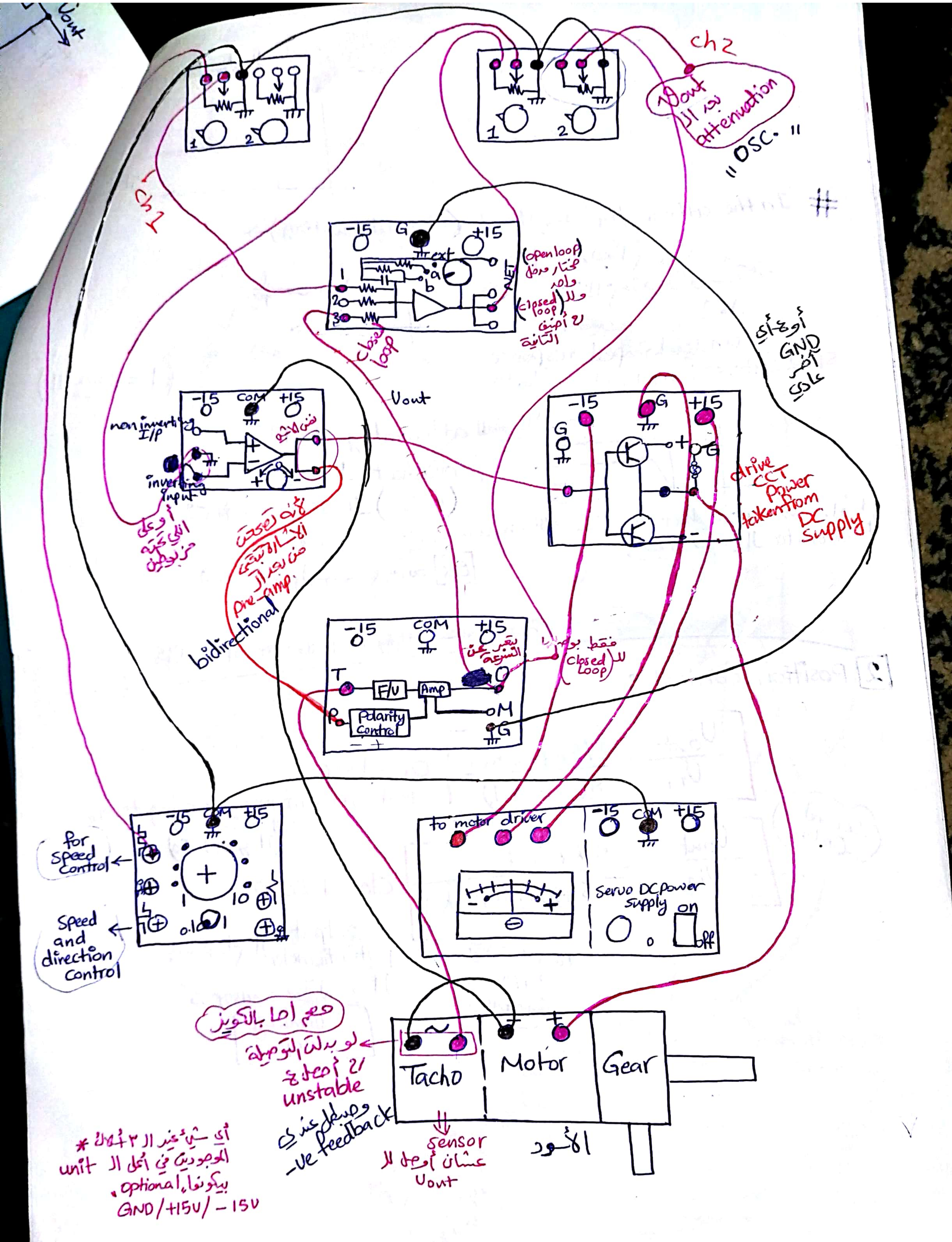
منظومة هو Freq. يحوله لـ voltage "Sensor"

* we needs 2 attenuator units / لأنه الواحد فيه تنين atten.
* In this part, we don't need the potentiometer units
* meter unit for displaying the speed / ما بعني بمرحلة كان موجود عالـ (Block Diagram)
* we need DC power supply :



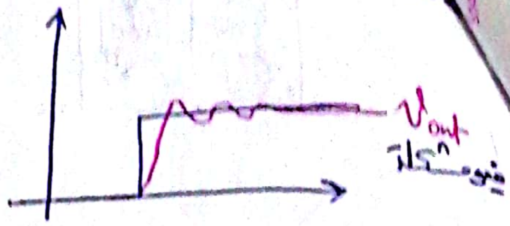
+ Function generator for the input Voltage ([illegible] unit step input) → ازا أخذت freq. كثير بطيئة في حال افترضنا الـ (square wave) رح تبين معي إنها [unit step input] #

أو ممكن أجيب الـ (DC power supply) بوديه ع (voltage divider) حيث بطلع [Variable DC input voltage]



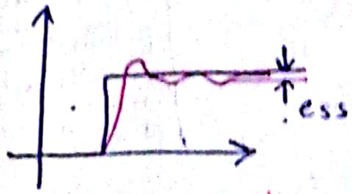
ch2
Vout بعد ال attenuation
"OSC."
ch1
-15
G
+15
ext
a
b
1
20
30
NET
(open loop) مختار مدخل واحد
(closed loop) وللـ ع أمنين التانية
closed loop
Vout
أو ع أي GND آخر عادي
COM
non inverting I/P
inverting input
نفس الشيء
أو على اللي تحته مربوطين
لأنه تصحيح الإشارة يتم من بعد ال pre-amp.
bidirectional
drive CCT Power taken from DC supply
T
F/V
Amp
P
Polarity Control
M
يعبر عن السرعة
فقط بوصلها للـ (closed loop)
for speed control
speed and direction control
0.1
10
to motor driver
Servo DC power supply
on
off
معمول ابا بالكويز
لو بدلت التوصيلة ح أوصل ع unstable
وهيطلع عندي -ve feedback
Tacho
Motor
Gear
sensor عشان أوصل لل Vout
الأسود
* أي شيء غير ال ٣ أطراف الموجودين في أول ال unit بيكونوا optional، GND/+15V/-15V

لما بدينا نعرض على الـ OSC.



In the attenuator feedback (w/o attenuating) →

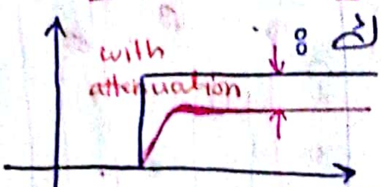
e_{ss} (قليل جداً)
والنظام منيح لكن مشكلة
انو صار على شكل
underdamped response



at 0 attenuation (الـ gain = 1 كبير)

Speed control ≡ [first order sys.] مع انه

← فبعد ما عملنا attenuating للسيغنال :



بيقل الـ overshoot
(noise) الـ فقيمته الأساسية هي بيتخفف
الي جاية على الـ measurement والي سببت الـ overshoot والحاصل في الأصل
وليس بسبب الـ tachometer

لكن سلبيته الوحيدة ⇐ بيزيد [e_{ss}]

∴ كلما زدنا الـ gain (قللنا الـ attenuator value) ← بيقل e_{ss}

---

[2] Position control :

$$\left[\frac{V_{out}}{V_{in}} = \frac{K_c K_d K_m K_s}{S(\tau_m S+1)}\right]$$

Open Loop
But, it's unstable "missing term"
غير قابلة للاستقرار
(it goes to ∞)

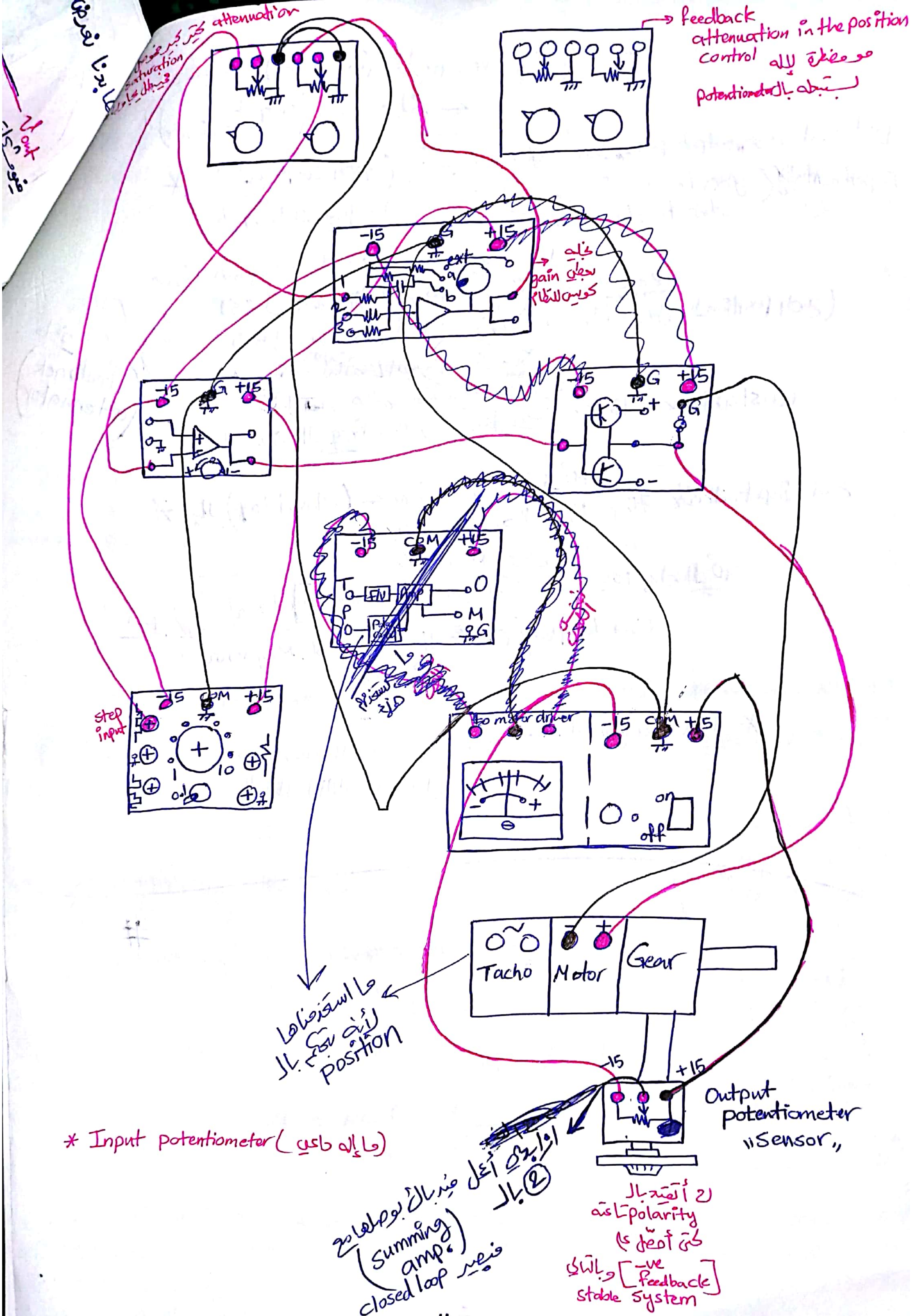
Second Order

$$\left[\frac{V_{out}}{V_{in}} = \frac{K_c K_d K_m K_s}{\tau_m S^2 + S + K_c K_d K_m K_s}\right]$$

Closed Loop

↙ no missing term
stable

باستخدام الـ output potentiometer
كـ sensor بوضعه مع الـ
[summing amp.]



* Input potentiometer (ما إله داعي)

لما نكبس على (on state) بالـ (DC Power Supply)
الـ (output potentiometer) بيلش يتحرك ←

* بالـ (Open Loop sys.) [يعني السلك اللي بيعض الـ "output Pot." مو موصلة مع اشي
طول ما السيغنال جايته بتحرك (ما بصير صون goes to ∞ experimentally)
due to the saturation

مبدئيًا هو سرعته بطيئة لأني عاطيه فولتية قليلة
لكن لو أضفت الـ (input attenuator) أعلى عالـ zero
حيتحرك بشكل أسرع (ما رح يعرف انه وصل عالـ position الصح)
شكله مثلًا لما نعرضه عالـ OSC.
بضل يكرر حالها وتشبه حالات معينة
ولو زودنا الـ freq صار يشتغل ويطفي وهكذا ← unstable

* بالـ (Closed Loop) ← بيمشي ويوقف عند الـ 70°
يعني برجع عند الـ 170° ثم 70° لأنه الـ input ثابت
فالزاوية اللي صرجع عليها ثابتة
ولو عليت [attenuation] صار يوقف عند الـ 100° بدل الـ 70°
Overdamped / Critically damped Response "أرج"
شكله

feedback / attenuator ما في

* Underdamped → مفضل عليه لما يصير يدور حوالين
النقطة (الزاوية) فيعمل oscillation

Scanned by CamScanner

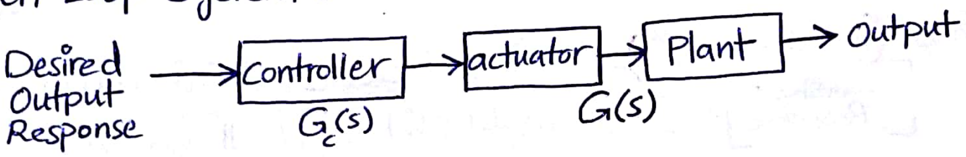
Exp (9) Characteristics of Open Loop and Closed Loop System

[Theor]etical Part ⇒

[Con]trol system performances are usually described in terms of :

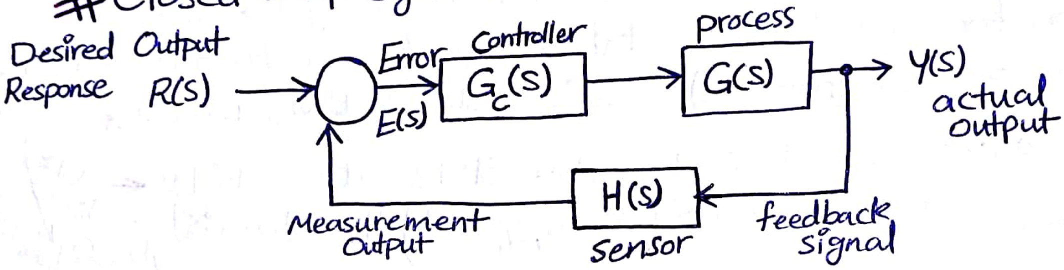
- [T]ransient Response → it's the response that disappears with time.
- Steady-State Response → it's the response that exists for along time after the initiation of an input.

Open Loop System :



*without a feedback

Closed Loop System :



- Control system behaviour is judged by several characteristics such as :

[1] Accuracy → determined by observing the error in the system, the most desired system, which is having a zero error.

$$E(s) = R(s) - Y(s)\,H(s)$$

(Less Error ↓ more accurate system)

for unity feedback : $H(s)=1$

$$E(s) = R(s) - Y(s)$$

- then, for the closed loop system above : $[H(s)=1]$

$$E(s) = R(s) - \left(\frac{G_c(s)\,G(s)}{1+G_c(s)G(s)}\,R(s)\right)$$

$$= R(s)\left[1 - \frac{G_c(s)\,G(s)}{1+G_c(s)G(s)}\right]$$

$$E(s) = R(s)\left[\frac{1}{1+G_c(s)G(s)}\right]$$

بإمكاني ازا تحكمت بقيمة G_c أقلل من قيمة ال E(s)

*error (-ve) : output > Input ($Y(s)$ > $R(s)$)

*error (+ve) : output < input ($Y(s)$ < $R(s)$)

• ما بتفرق الإشارة هاي عند تحديد ال "accuracy"

* the steady state error of the system → $e_{ss} = \lim_{s\to 0} s\,E(s)$, " $e_{ss} = \lim_{t\to\infty} e(t)$ "

- for the open Loop system above:

$$E(s) = R(s) - Y(s)$$
$$= R(s) - R(s)G_c(s)G(s)$$
$$= R(s)[1 - G_c(s)G(s)]$$

→ شو ما عطيت إله قيمة ما عم يأثر في error $E(s)$

: Closed loop better than the open loop in accuracy, because I can reduce the error (controlling it) by choose a large gain of $G_c(s)$

← ما بقدر من خلال الـ e_{ss} أعرف أحدد الـ (transfer function) كونها بتم فقط بالـ [Steady state Response]

وعند تحديد الـ (TF) لا أحتاج لمعلومات معينة في الـ [Transient Response]

---

[2] Sensetivity → It's the ratio of the change in the system transfer function for a small incremental change to a certain parameter. in the process

* أديه بتأثر النظام في حال حدوث تغيير على (parameter) معين موجود فيه *

← كلما كانت قليلة كلما كان أفضل للنظام من ناحية "control" عمليًا فقط عالكنترولر

لكن فقط في الـ (measurement side) كلما كانت الـ sensetivity أعلى كلما كان أفضل ..

$$S_G^T = \frac{\partial T}{\partial G} \cdot \frac{G}{T}$$

// theoretically → معي الـ transfer function والـ $G(s)$ نطبق على العلاقة الموجودة لكن عمليًا مختلف طريقة الحل ..

Ex

- For Open Loop system →

$$T = G_c(s)G(s)$$

$$S_{G_c(s)}^T = \left(\frac{\partial T}{\partial G_c(s)}\right) \cdot \frac{G_c(s)}{T}$$

⇐ لو بدي أطلع مدى تأثر بالنظام في حال حدوث أي تغيير على $G_c(s)$

$$= G(s) \cdot \frac{G_c(s)}{G_c(s)G(s)}$$

$$S_{G_c(s)}^T = 1$$ → High Sensetivity (100 %)

هاد بيعني انه النظام بتأثر بشكل كبير بنسبة 100 % لأي تغيير يحدث في النظام.

For Closed Loop System →

$$T = \frac{G_c(s)\,G(s)}{1+G_c(s)G(s)H(s)} \quad [\text{assume } H(s)=1]$$

$$S^{T}_{G_c(s)} = \frac{\partial T}{\partial G_c(s)} \cdot \frac{G_c(s)}{T}$$

$$= \frac{(1+G_c(s)G(s))(G(s)) - (G_c(s)G(s))(G(s))}{(1+G_c(s)G(s))^{2}} * \frac{G_c(s)[1+G_c(s)G(s)]}{G_c(s)G(s)}$$

$$= \frac{G(s) + G_c(s)G^2(s) - G_c(s)G^2(s)}{1+G_c(s)G(s)} * \frac{1}{G(s)}$$

$$= \frac{G(s)}{1+G_c(s)G(s)} * \frac{1}{G(s)}$$

$$0 < \boxed{S^{T}_{G_c(s)} = \frac{1}{1+G_c(s)G(s)}} < 1$$

وأيضاً هنا من خلال التحكم بال (controller gain) بقدر أقلل من ال [system sensetivity] بزيادة ال [$G_c(s)$ gain] ...

---

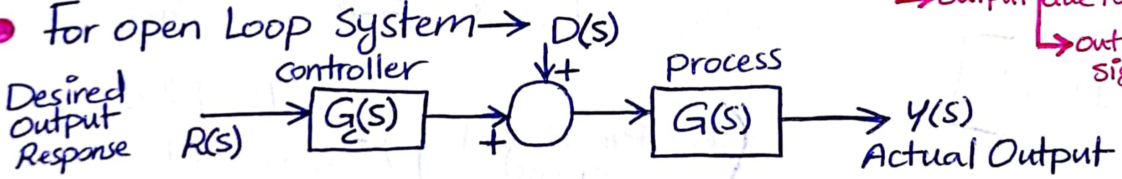
3 Disturbance Rejection →

It's an external signal that i don't want to deal with it (I want to reject it)

$$Y(s) = Y_R(s) + Y_D(s)$$

- $Y_R(s)$ → output due to the input signal ...
- $Y_D(s)$ → output due to the disturbance signal ...

- For open Loop System →



$$Y(s) = G_c(s)G(s)R(s) + G(s)D(s)$$

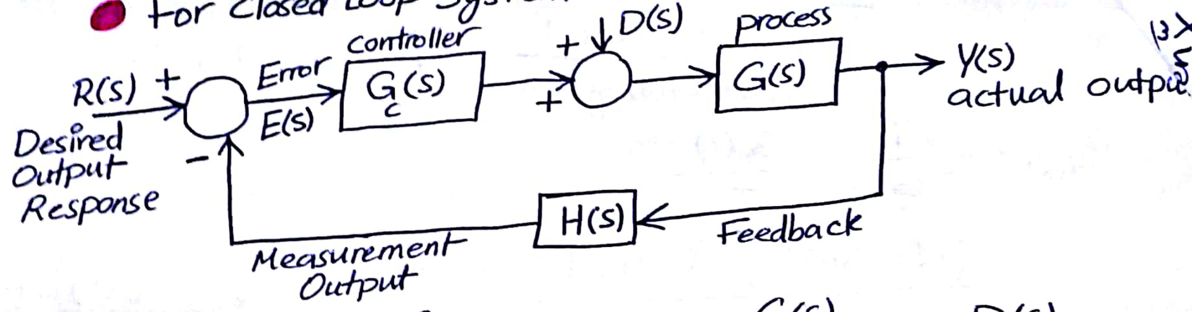
* لو بدي أحسب ال (error) ← عندما $R(s) = \emptyset$

$$E(s) = R(s) - Y(s)$$
$$= \emptyset - Y(s)$$
$$= -G(s)\,D(s)$$

↳ Nothing will reduce/remove the error resulting from the disturbance signal in the open loop system.

→

● For Closed Loop System →



$$Y(s) = \frac{G_c(s)\,G(s)}{1+G_c(s)G(s)\,H(s)^{\to 1}}R(s) + \frac{G(s)}{1+G_c(s)G(s)\,H(s)^{\to 1}}D(s)$$

$E(s) = R(s) - Y(s)$

$= \emptyset - Y(s)$

$= \frac{-\,G(s)}{1+G_c(s)G(s)}D(s)$

* لو بدي أحسب الـ error ⇐ عندما $R(s) = \emptyset$

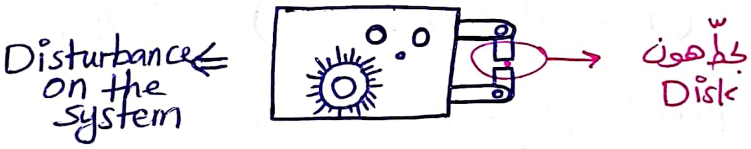
من خلال رفع قيمة الـ $[G_c(s)]$ أقدر أقلل من نسبة الـ "error" اللي جاي من الـ D(s)

∴ Closed Loop better than the Open Loop in rejection the disturbance signal ..

ما بدرسها على الـ (position controlled) لأنها رح تعطيني unstable في حالة الـ "Open Loop"

Practical Part ⇒ [Speed Controlled Servomotor]

In this experiment, we use the electro-magnetic brake as a load on the motor :



[حمِل اللود بتعتمد على السرعة] (as a function of speed) بتغير بين الـ [0-100] تزداد مع ازدياد السرعة

* لما أحط عليه كهربا ، الـ (disk) الموجودة في الفتحة بتسمح للمجال المغناطيسي المتولد انه يعمل "induction" ، فبمشي eddy currents بالـ disk يمشّي الـ Φ فبعمل damping للـ (motor Φ) فبصير كـ Load على الموتور ⇐ Braking

" الموتور رح يبطئ سرعته فاللود سالب"

$$\Rightarrow Y_D(s) = Y(s) - Y_R(s) \Leftarrow$$

$$Y_R(s) > Y(s)$$

→ Y(s) actual outp

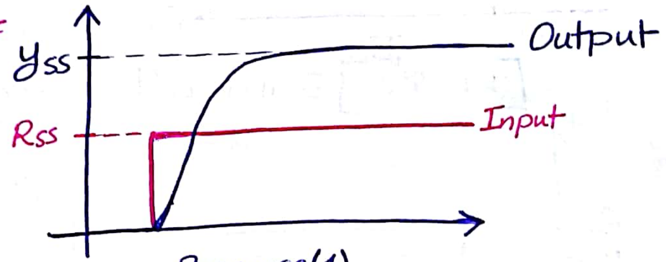
Ess Observation Practically ⇒

← على نفس التوصيلة في التجربة السابقة والـ Block Diagram :

practically / عند عرض الـ response ع ما نقدر نعرف من خلاله مباشرة انا انا موصل closed ولا open
فبنستطيع نعرف توصيلتي حسب اللي فايتة ع الـ summing Amp. انا فايتة ٢ ← closed
open ← ١

لو فصلت السلك اللي جاي من الـ feedback attenuator ع الـ summing
ع نلاحظ انه النظام صار open loop وصوت الموتور ارتفع

Open Loop Response



Response(1)

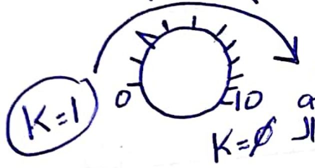
① مبدئيًا بقدر أحسب منه الـ gain تبع الـ transfer function

system gain ← $\left[K = \frac{y_{ss}}{R_{ss}}\right]$

② بقدر أحدد الـ ess أيضًا ⇐ $e_{ss} = R_{ss} - y_{ss}$

صطلع بهالحالة (-ve) بما انه [open Loop]

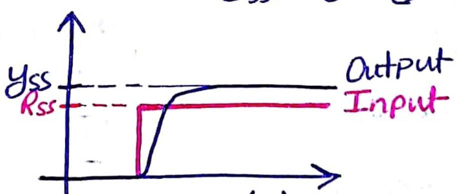
* مركز على الـ [attenuator controller] بما انه "open loop" ← $0 \leqslant K \leqslant 1$



كلما زدت الـ attenuating بكون قللت الـ Gain تبع الكنترولر $K=\phi$

ع نلاحظ انا اذا علينا الـ attenuator هاد بدلاً من 2 اللي أعطتني الـ (response 1) أعلاه
حطيتها على 4 ⇐ ع تقل الـ ess

زدت الـ attenuator controller gain (خففته أكثر) ⇒
خففته لـ 4 بدلاً من 2



Response(2)

مش شي صحيح تحديد

⇐ تغير الـ gain غيرلي الـ open loop بالـ output
لأنه بعّد عن الـ Original Output
اللي بدي أوصله .. والـ open loop مابيعمل tracking أصلاً مجموع لمكان غير محدد / مرغوب بالأساس
وليس لأنه أفضل من الـ closed loop ..

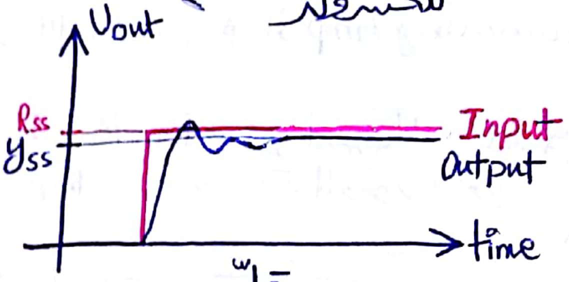
وكلما عملت attenuating أكثر ضلاحظ مدى اقتراب الـ output من الـ Input
وهالحكي بالنسبة للـ "open Loop sys" موضح لأنه فنكون بقدناش الـ desired O/P
وما بقدر أعمم انه بالـ open Loop زيادة الـ G_c هتقلل الـ (ess) لأنه منشوف لبعدين
انه ممكن يصير العكس [بزيادة G_c هتزيد ess] ..

→

Closed Loop Response

لمّا بجمّع مكان ال (Feedback attenuator) ع ال (Summing Amp.)

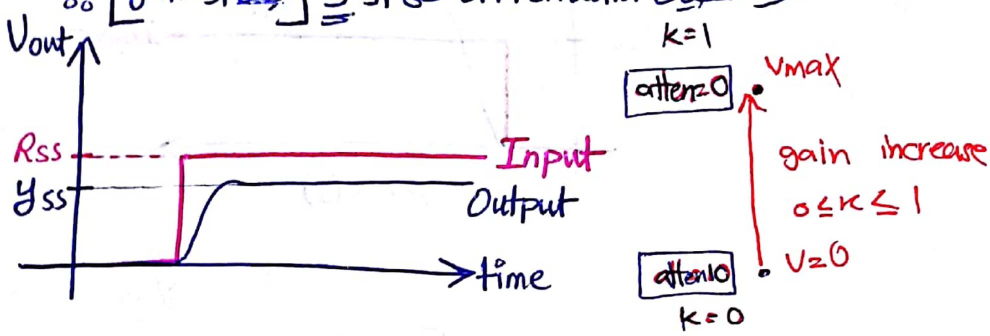
with Ø attenuation للكنترولر



المفروض يكون شكل ال Output "first Order" ليس هو طالع Second بسبب ال (Feedback noise)

⇑

لو حطيت ال attenuator على ال 5 [قلّل ال gain] :



ما تأثر كثير مقارنة مع ال Open loop ← اللي لما خفضت ال gain تأثر ال output فيه بشكل كثير كبير وهاد يعتبر شي منيح بالنسبة لل "Closed loop" [عدم تأثره الكبير]

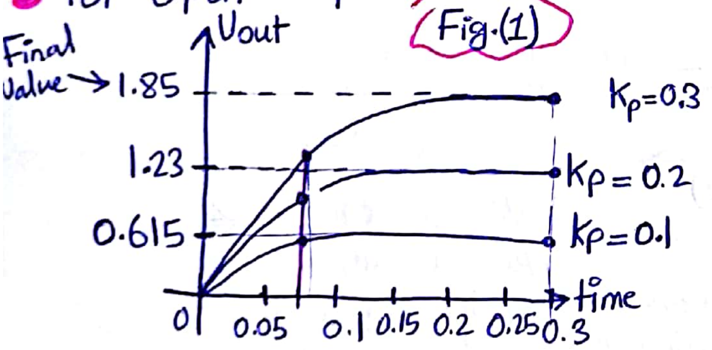
: كلما زدت قيمة ال attenuator (خفّضت ال gain تبع الكنترولر) كلما زاد ال (ess)

---

2 Sensetivity Calculation from the system Response →

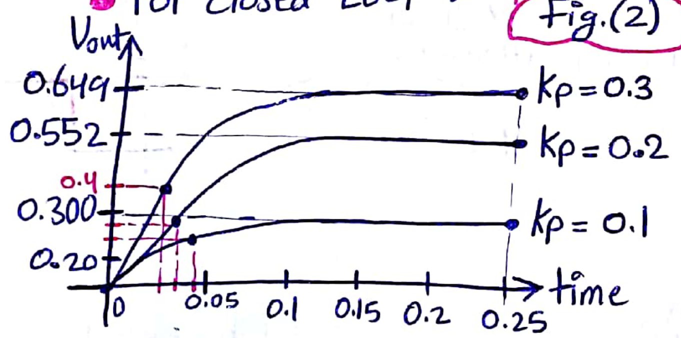
- For Open Loop :

Fig.(1)



- For closed Loop :

Fig.(2)



$$S_G^T = \frac{\partial T}{\partial G} * \frac{G}{T}$$

[المشتقة عبارة عن : slope]

$$= \frac{\Delta T}{T} * \frac{G}{\Delta G}$$

(where, $T = \frac{y_{ss}}{R_{ss}}$, $G \equiv gain\ (K_p)$)

if ($R_{ss}=1$) : → $T = \frac{1.85}{1}$ ⇒ $\left[\frac{\frac{1.85}{1} - \frac{1.23}{1}}{\frac{1.23}{1}}\right]$

لازم نحط صيغة ال transfer func. كاملة :

$$T = \frac{y_{ss}}{R_{ss}}$$

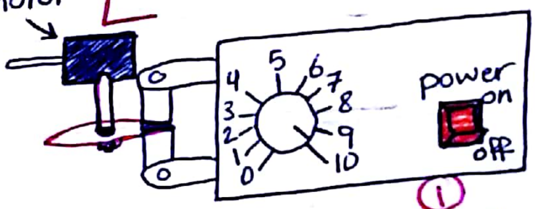
$$S_G^T = \frac{1.85-1.23}{1.23} * \frac{0.2}{0.3-0.2} \simeq 1 \quad \#$$

$$S_G^T = \frac{0.649-0.552}{0.552} * \frac{0.2}{0.3-0.2} = 0.35$$

F) Disturbance Rejection → من خلال الـ [Electro-magnetic Brake]

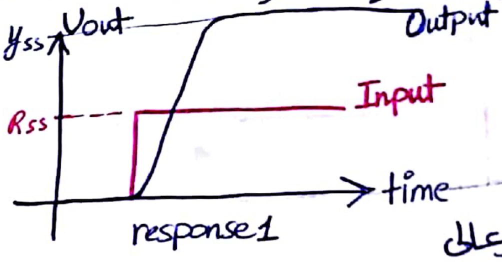
at the Open Loop

motor



⇐ لو كنت حاطيته على الـ Ø (1) [ما في عندي ⇐ disturbance]
والـ gain عالي تبع الـ [Controller attenuator] → خففت لعند الـ 9 (0.1)

NO Load

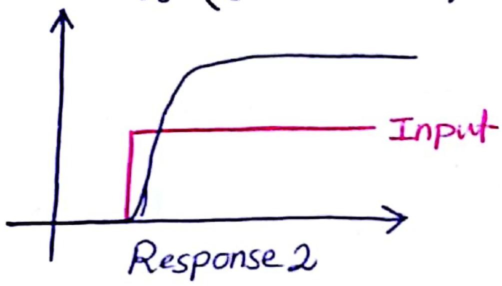


عامل Saturation بسبب ← الـ input كثير عالي
↳ أو الكنترولر كثير عالي فخلّى الـ output كثير عالي

عند الـ (1) الـ gain 0.9

[الـ Openloop ما بنعزز عليه]

⇐ لو حطيت الـ attenuator على 2 (قلّت الـ gain) :



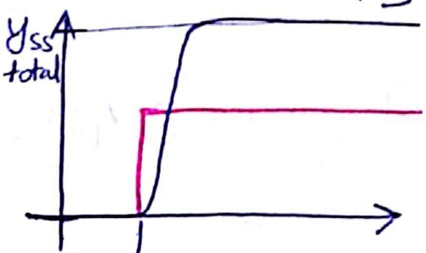
قلّ الـ ess !

⇐ لو حطيت اللود على 5 مثلاً (2) [صار عندي لود ⇐ disturbance]

(مع اللود)

$$y_{ss}\Big|_{total} - y_{ss}\Big|_{R(s)} = y_{ss}\Big|_{D(s)}$$

⇐



فرقت معنا 1V نسبة كبيرة !

[وضل الـ attenuator controller على 2]

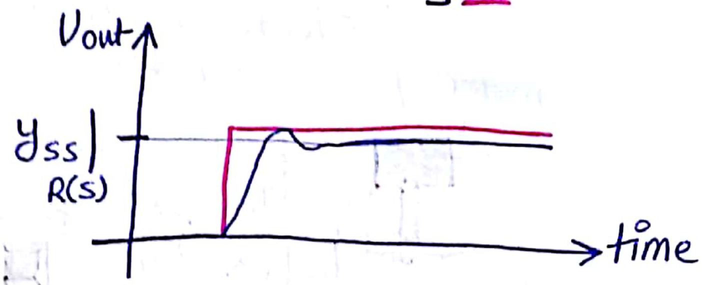
لو حطيتو على 10 صعب نشوف هاي الرسمة أعلاه

هنا الرسمة اللي حصلنا عليها بالـ open loop (بدون اللود) (بدون disturbance)

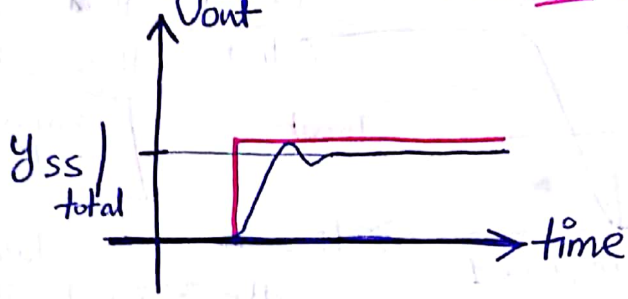
الـ response هاي تمثل الـ [total form]

Closed Loop Response

① لو رجعت اللود على الـ Ø [No disturbance]



② عطينا اللود على 10 [صار عندي لود ← disturbance]

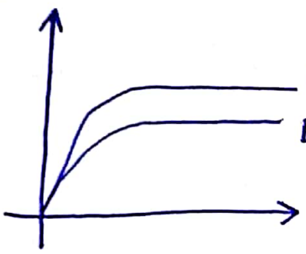


⇐ ما في تغيير كبير حاصل بين لما ما كان في لود ولما عطينا Full Load

هاد دليل ع إنه الـ Closed Loop ← immune for the disturbance

الفرق 0.05 V

نسبة قليلة



$$Y_{ss}\big|_{total} = Y_{ss}\big|_{R(s)} + Y_{ss}\big|_{D(s)}$$

$Y_{ss}|_{total}$ ↓ at D=1; $Y_{ss}|_{R(s)}$ ↓ at D=0; $Y_{ss}|_{D(s)}$ ↓ at D=1

* منحسب الـ $Y_d(s)$ ك ratio مع الـ input للمقارنة