AEC session 32.1 18/4/22

Introduction to Feedback: General Feedback system

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Today's lecture

- Introduction to feedback
- General feedback System
- "Closed-loop" Transfer Function

- Feedback has been around since ages – human have been around. as long as

Simple exercise:- (Eg of negative f/b)
- Close your eyes and try to touch your finger tips
- I can't, why?
- Becoz, we have broken a f/b loop consisting of our eyes that monitors the movement of our fingers to make sure that the finger tip touch.
- The notion of having a loop that regulates & monitors movements & actions is very powerful.

• Examples of Negative feedback :

• Our Eyes

Pupil shrinks when we go to a bright room.

• The eye is smart enough to adjust the size of the pupil to make sure that the amount of light that enters our eye & hits the retina in the back is controlled.

That's a -ve f/b system.

• Our Ears:

Ear

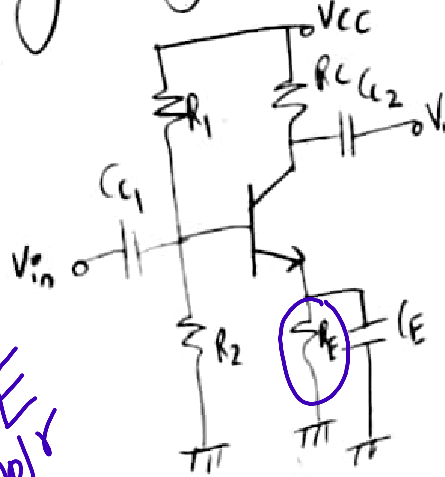
• If you go to a concert that has very loud music, & we stay there for 1 or 2 hours & then when you leave the concert & you go to a quiet area : You feel like your ears are a little deaf / you are little hard of hearing. Why?

~ If music is so loud, our ear has a mechanism to adjust the threshold of hearing (so that loud music does not damage our ear), so when you leave the concert, that mechanism is still keeping the threshold at that point, so you feel a little hard of hearing & it takes some time for the ear to go back to where it was.

That's a -ve f/b system:- That tries to adjust the volume (level of sound) that enters your ear. -ve f/b → Stabilizing

• Why negative feedback? ---- used in ckts? (what am I trying to achieve?)

eg ①



CE ampl'r

Poorly controlled gain

$A_v = -g_m R_C$

$A_v = -150$ (with C_E)

vtg gain is not that accurate

$A_v = -4$ (w/o C_E)

Av can vary:

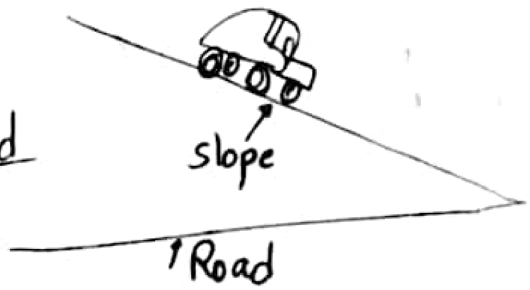
Resistor: whether discrete or in a chip has some variability
~ from Temperature it changes
~ from sample to sample it changes

• If an applicat^n requires a gain of $A_v = -4.00$ to such precision.

• There is no way, that this $\boxed{A_v = -g_m R_C}$ gain will give us that amount of accuracy.

-ve f/b → Reduces gain but makes it more stable

eg ②



Poorly controlled speed

• (car going down the road.)

• If we just let the car go by itself, the speed of car will keep ↑sing, there is no way to control the speed.

(The slope want's to accelerate the car) - ie speed keeps ↑sing.

• Without feedback, we have "untamed" and "poorly-controlled" circuits and systems.

• So, without any f/b present, we have no control over the car.

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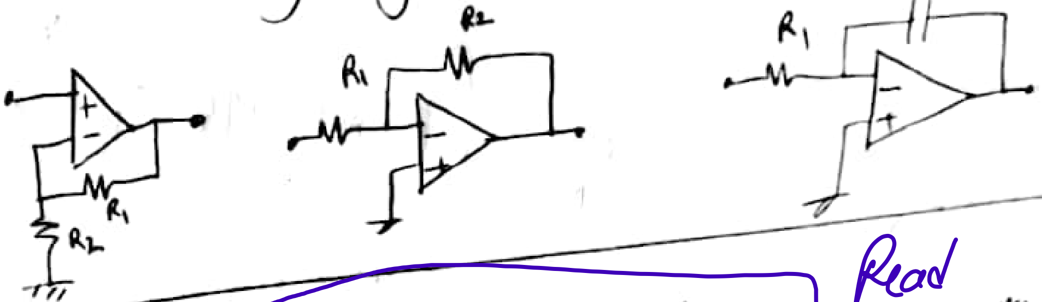
Purpose of negative feedback is to in eg ① tidely controlled of gain (A_v) and in eg ② is to make sure that the speed of the car achieves some amount that you want (under control).

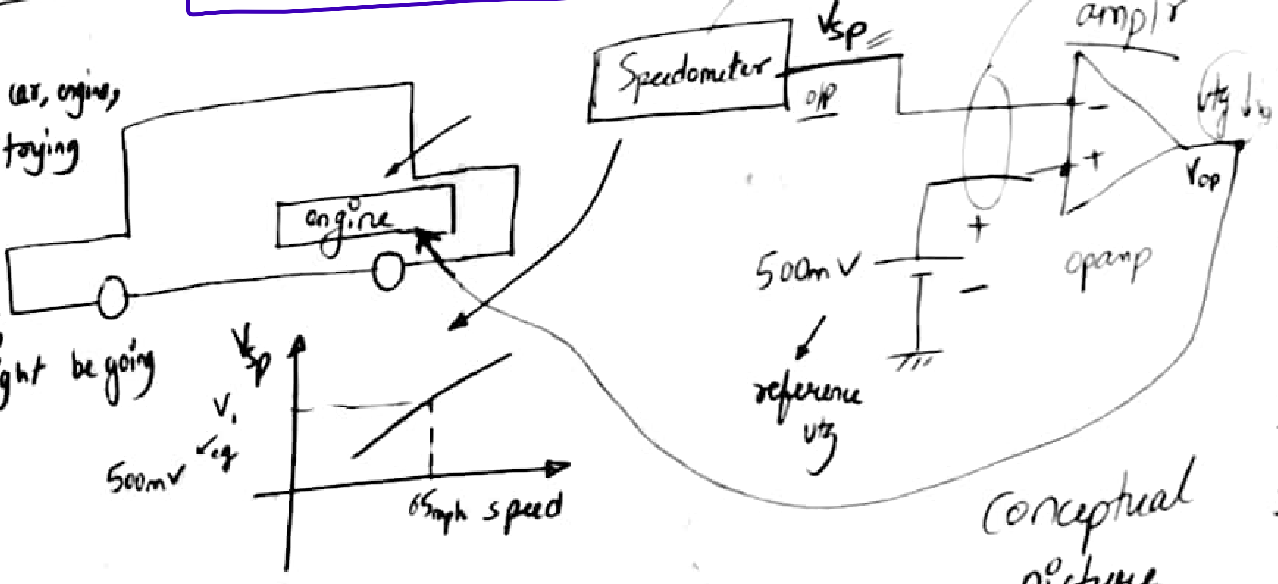
- We will be seeing negative feedback in <u>LICD:</u>



- Let's build a $\boxed{\text{cruise control system:-}}$

Read

- loop consisting of the car, engine, Speedometer, ampl^r → trying to make sure that the speed of car is relatively constant, even though we might be going upslope or down the slope.



→ faster the car goes, higher is V_{sp}

→ Car want to speed up → i.e beyond 65 mph ; <u>V_{sp} ↑ses beyond 500mV</u> $(V^-) > (V^+)$ → <u>V_{op} goes down.</u> → engine slows down → car goes more slowly

Conversely, upper slope, car want to go slowly, ↓ $(V^-) < (V^+)$ → V_{op} ↑ → engine faster → back to 65mph

→ This is an example of a negative f/b system.

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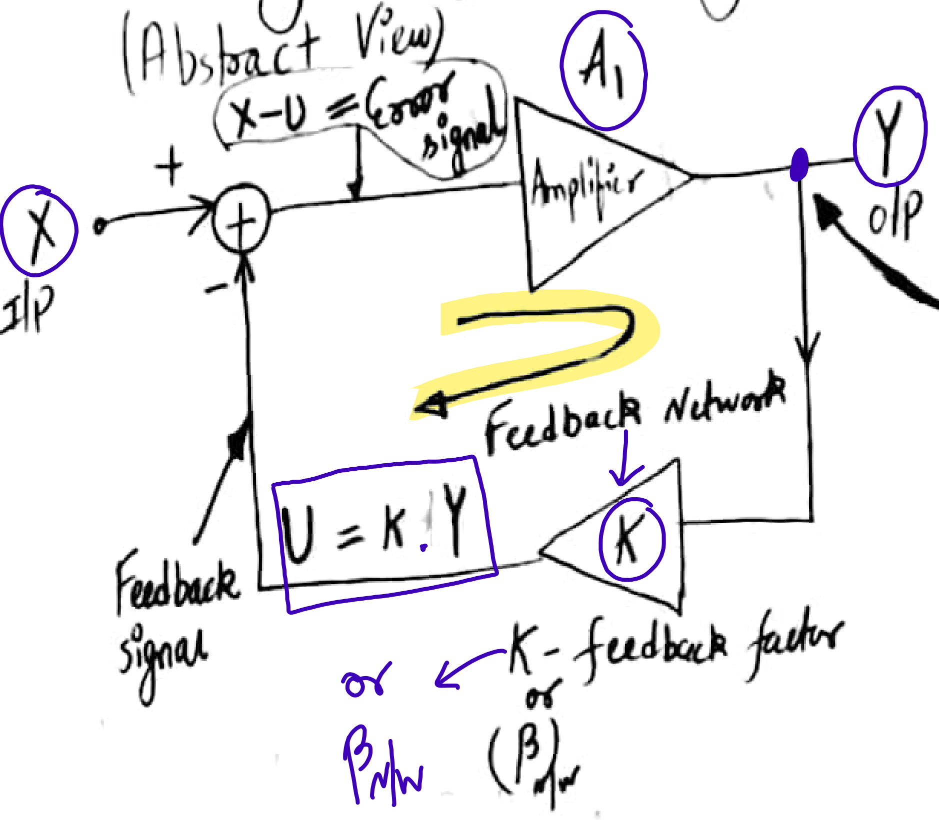
General negative Feedback system :

(Abstract View)



4 components

1. A_1 : Feed forward system (Ampl^r) (eg Car engine)
2. Sensing Mechanism (Speedometer)
3. Feedback network (just a wire)
4. Subtractor (opamp) (Comparing X & U)

Notes: (Have clear understanding of the points below)

1. Negative Feedback (f/b sig is subtracted from I/p)
2. Direction of signal flow (↩)
3. Error signal = X − U must be minimized. How and why?
4. Open loop system (No feedback) $K = 0$

Closed-loop System (with feedback) $K \neq 0$

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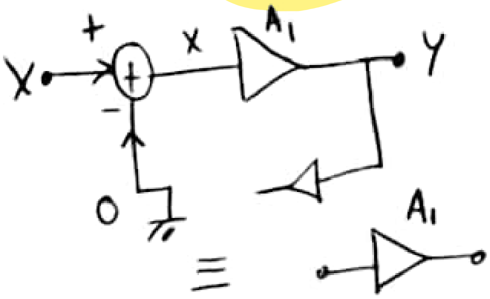

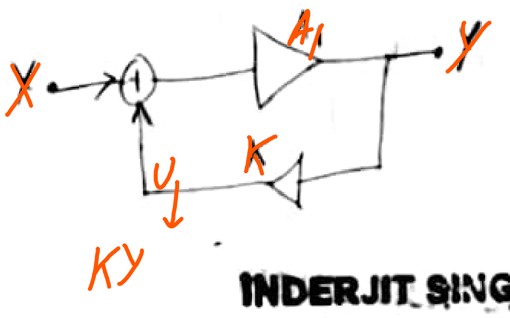

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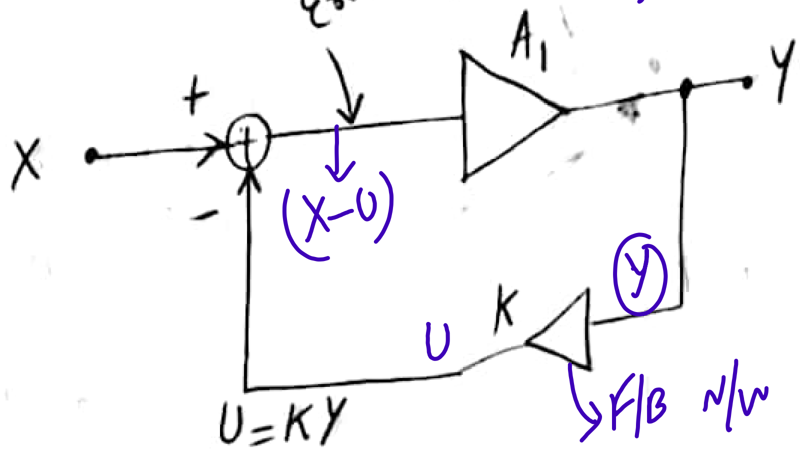
Transfer function of closed-loop System :-

Error signal

$$Y = A_1(X-U) = A_1(X-KY)$$



$$\frac{Y}{X} = ?$$

$$\left(\frac{Y}{X}\right) = ?$$

→ Error Signal $= X - U = X - KY$

→ $Y = A_1(X - KY) = A_1X - A_1KY$

$$\boxed{\frac{Y}{X} = \frac{A_1}{1+KA_1}}$$

→ Memorize this eq^n for the rest of your life

→ This eq^n tells us so much about negative feedback

We will examine this eq^n from many different perspectives

A_1 – open-loop gain

$\frac{A_1}{1+KA_1}$ – closed loop gain

→ A_1 : open-loop gain

→ $\left[\frac{A_1}{1+KA_1}\right]$: closed-loop gain

→ $K, A_1 > 0$ (K & A_1 are positive)

⇒ Closed-loop gain < open-loop gain

Why do we reduce the gain ? 07

How do we implement the subtractor ?

What is the purpose of the feedback network ?

Quiz: Determine the error signal in terms of the i/p X ?

$U = KY$

$$\text{Error signal} = X - U = X - KY = X - K\left(\frac{A_1}{1 + KA_1}\right)X$$

$$\boxed{\text{Error sig} = \frac{X}{1 + KA_1}}$$

$1 + KA_1 \uparrow$

$KA_1 \uparrow\uparrow$

$K \rightarrow \beta$ N/W

$A_1 \rightarrow$ Amplr gain.

- To minimize this error ⇒ we have to maximize KA_1
- This quantity "KA_1" play a profound role in the performance of this overall system.

Observation: If the error is minimized, $(X-U)$ becomes small ⇒ $\boxed{X = U}$

⇒ Feedback signal is a good replica/copy of the input.

$X - U \rightarrow 0$

$\boxed{X = U}$

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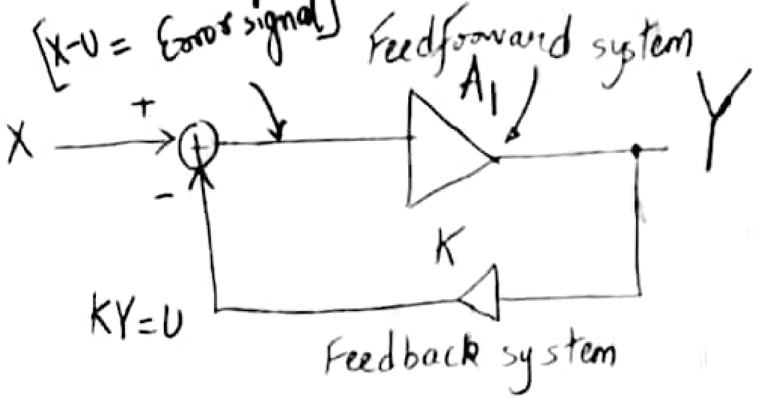
Review : (Story so far)

[X-U = Error signal]



$$\frac{Y}{X} = \frac{A_1}{1+KA_1}$$

A_1 → Open-loop gain

$\frac{A_1}{1+KA_1}$ → Closed-loop gain

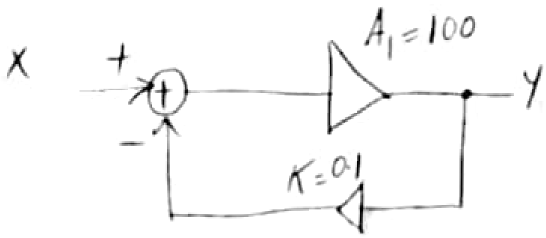
$$\text{Error} = \frac{X}{1+KA_1}$$

If error is small; $\underline{U \approx X}$

Golden Rule:

- In a well-designed negative-feedback system, the feedback signal U is a good copy (replica) of the input signal X.

Example:-



$$\frac{Y}{X} = \frac{\overset{100}{A_1}}{1+\underset{0.1}{K}\underset{100}{A_1}} \approx \frac{100}{1+10} \approx \frac{100}{11}$$

$$\frac{Y}{X} \approx \underline{9.09}$$

Example: What happens if A_1 drops to 50 in the previous example? ($100 \rightarrow 50$)

$A_1 \approx 50$

$$\frac{Y}{X} = \frac{50}{1+5} \approx \frac{50}{6} \approx \underline{8.33}$$

$\frac{Y}{X} \rightarrow \underline{\underline{8.33}}$

Stability

100 → 9.09

↓ ↓

50 → 8.33

↓ ↓

10

• Even though the open-loop gain changed by a factor ~~of 2~~, 02
the closed-loop gain changed by only <u>10%</u>

↳ <u>Most important result:-</u>
↳ Significant change in A_1 leads to a ~~minor~~ <u>change</u> in closed-loop gain. $\left(\frac{A_1}{1+KA_1}\right)$

$KA_1 >> 1$

<u>Observation:</u> If $KA_1 >> 1$, ⇒

$$\boxed{\frac{Y}{X} \approx \frac{1}{K}}$$

⇒ Closed-loop gain is relatively <u>independent</u> of <u>open-loop gain</u>.

$$\frac{Y}{X} = \frac{A_1}{1+KA_1}$$

$$\frac{Y}{X} = \frac{1}{K}$$

$$\frac{1}{\frac{1}{KA_1}+1}$$

0

⇒ We should try to maximize <u>KA_1</u>.

<u>Observation:</u> K is usually chosen ≤ 1

$$\boxed{\frac{Y}{X} \approx \frac{1}{K}}$$

• <u>Loop gain:</u> KA_1 : in a well-designed negative feedback system, the loop gain >> 1.
⇒ Closed-loop gain ≈ $\frac{1}{K}$

$$\boxed{KA_1 \to \text{loop gain}}$$

<u>Important Property:</u> If $KA_1 >> 1$ ⇒

$$\frac{Y}{X} \approx \frac{1}{K} \text{ and relatively indep. of } A_1$$

• Summary of feedback concepts:-

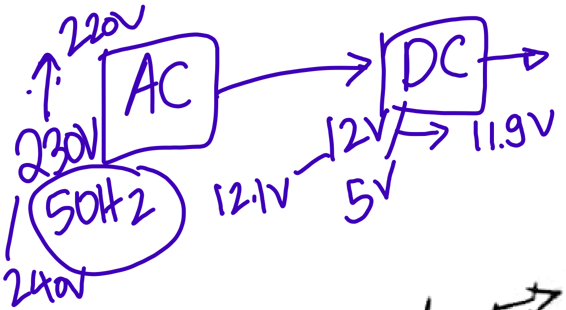
(1) We sacrifice the open-loop gain to benefit from negative feedback.

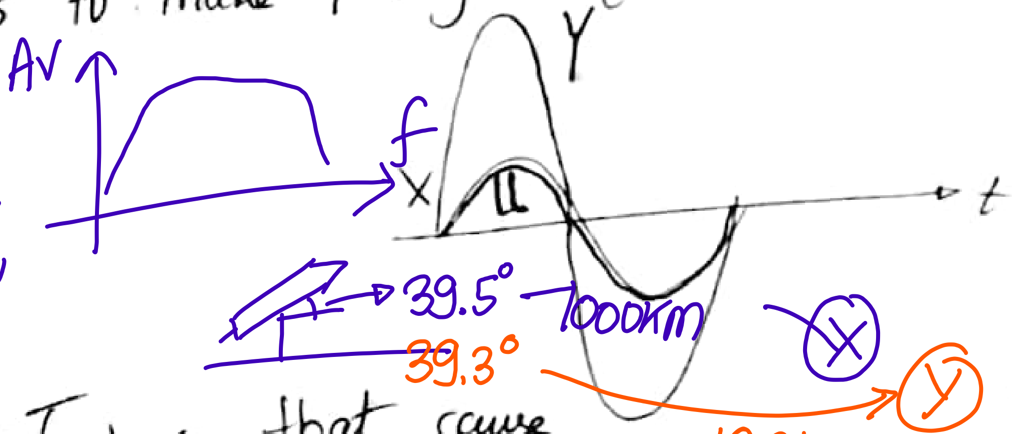
(2) The feedback signal is a good copy (replica) of the input signal.

$U = KY$

(3) $Y = \frac{U}{K}$ is a good copy of X but with a scaling factor. eg if $K = 0.1$, $Y \approx 10X$

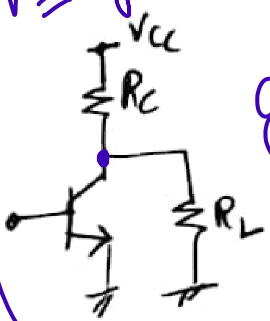
⇒ The loop wants to make Y a good (scaled) copy of X.



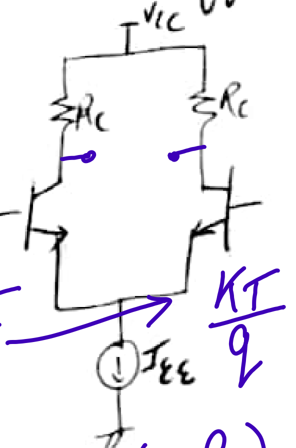


(4) If $KA_1 >> 1$ ⇒ Factors that cause A_1 to vary have less effect on the closed-loop gain.

$A_V = -g_m(R_C || R_L)$



$g_m = \frac{I_C}{V_T}$ $\frac{KT}{q}$



$A_d = (g_m R_C)$

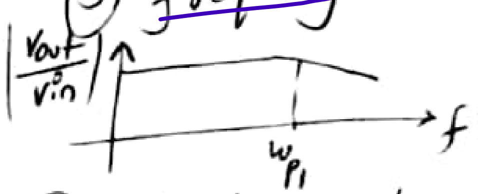
open-loop gain

Factors that cause A_1 to vary:

(1) Temperature ✓

(2) Supply voltage ✓

(3) Frequency



(4) load impedance ($\sim R_L$)