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Analysis of physiological system

- System is any collection of communicating parts an performing some specific function.
- Every system is sensitive to some signals coming from its environment which are called input signals.
- System performs some processes on the input and produce a response which is called output.

İnput $\rightarrow$ system $\rightarrow$ output

a(t) y(t)

Technical system

İnput $\rightarrow$ amplifier $\rightarrow$ output

Gain: output/input

Teknik sistemlerde kazanç, girişin sistem üzerindeki performansını belirler. Kazanç, çıkışın girişe oranıdır. Girişe bir sinyal verilmedikçe çıkıştan sinyal alınmaz.

Physiological systems

In physiological systems sistemin girişine sinyal uygulanmasa da çıkıştan bir sinyal ölçülebilir. Böylece kazanç, verilen giriş nedeni ile çıkıştaki değişim olarak tanımlanabilir.

Gain:G: change in the output/change in the input

- Function of physiological system anlayabilmek için girişe bir uyaran vererek çıkıştaki cevabı ölçmeliyiz.

- İn System analysis girişin seçimi
  - Chose an aduquate input signal
  - Chose the wave form of the input
  - Set the amplitude of the input

I. Uyaranın tipi fizyolojik sisteme ve planlanan işlere uygun olmalı

Example, Basınç reseptörüne basınç değişimleri şeklinde bir uyaran

II. Wave form of the input

- Impulse
- Step function
- Triangular function
- Square wave
- Sinus wave

III. Amplitude of the input

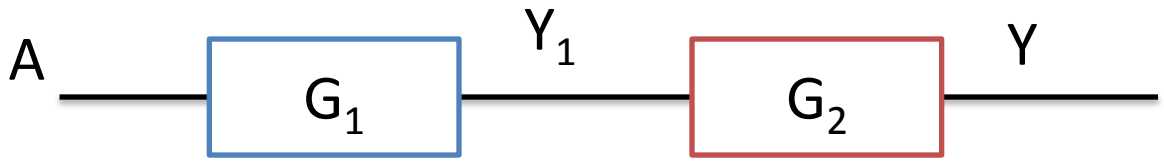
for linear system

for non-linear sistem (physiological systems)

- When analyzing a non-linear systems:
  - Amplitude of the input signal should be small
  - Small amplitude input is superimposed on a mean value.
  - Gain value thus obtain is valid only for that mean value. Never can be used for any other means values
  - In order to obtain gain values for a wide range of the inputs the input signal is superimposed on different mean value

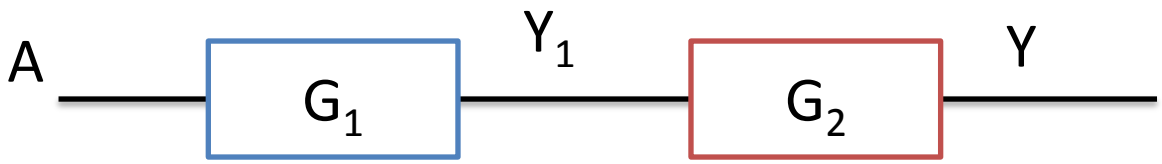
Complex system

- Birinci sytmenin çıkışı, ikinci sytmenin girişine bağlanır.



Y_1: output of the 1st system
Y: output of the 2nd system
G_1: gain of the 1st system
G_2: gain of the 2nd system
A: actual or referance system

$G_1=Y_1/A$
$G_2=Y/Y_1$
$G_2=Y/G_1.A$

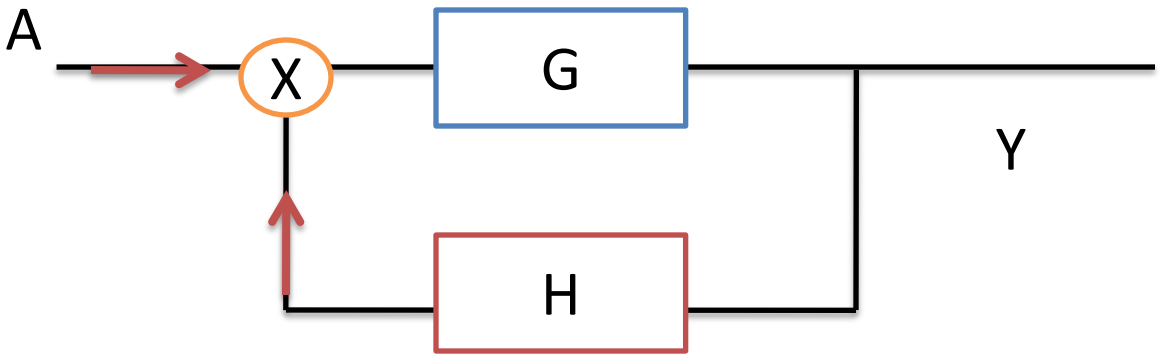


- Bütün sistemlerin toplam kazancı, her sistemin kazancının birbiriyle çarpımına eşittir.

  Overall gain, $G=Y/A=G_1.G_2$

Positive feedback systems

- Phsiological system are complex system. There is also a feedback system between them.
- In this lecture the gain we will talk about is the static gain.



G: gain of the 1st system

H: gain of the 2nd system

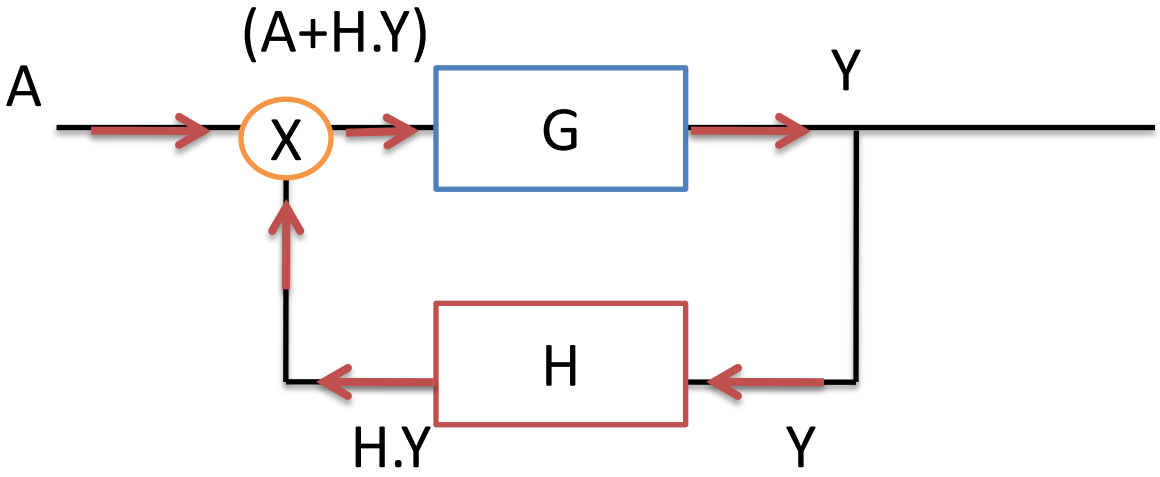
Y: output

A: actual or referance system

G=Y/A

K=Y/A closed loop gain

- Since the out put is connected to the input through the 2^{nd} system, we called it as feed back system.
- İkinci sistemin çıkışı geri besleme ile girişe ilave edilir.
- Out of the 2^{nd} sytem is $H \times Y$.



G=Y/A

K=Y/A closed loop gain

Since the two signal A, H $\times$ Y is added we called it as positive feedback system.

$Y = G \times A$

$Y = G \times (A + H.Y)$

$Y = GA + GHY$

$Y - GHY = GA$

$Y(1 - GH) = GA$

$Y = GA/(1 - GH)$

$Y/A = G/(1 - GH)$ $Y/A = K = G/(1 - GH)$ close loop gain

so close loop gain K= G/(1-GH)

- If the break the H system so it is not connected any more the gain will be equal to GH and this gain is called open loop gain.

- This type of systems aim to change the output in the direction of the input whatever the input is.

Close loop gain K= G/(1-GH)

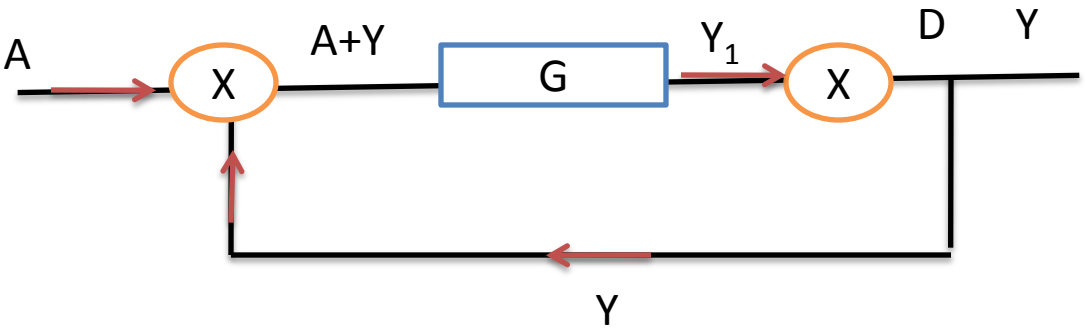
If open loop gain is 1-GH close loop gain goes to the infinity.

In this case the system become unstable.

But if the open loop gain is lower than one we will approach to constant value.

System is stable

- Example: hemorrhage: blood bleeding



D: disturbing signal, perturbation

- By an accident we many have hemorrhage (blood lose). This lose is shown by disturbing (D) or perturbution signal.

- Lets calculate output any gain

$Y = Y_1 + D$

$Y_1 = G(A+Y)$

$Y = GA+GY+D$

$Y-GY=GA+D$

$Y(1-G)=GA+D$

$Y=[GA/(1-G)]+[D/1-G]$

$K = G/(1-G)$ closed loop gain

G=open loop gain

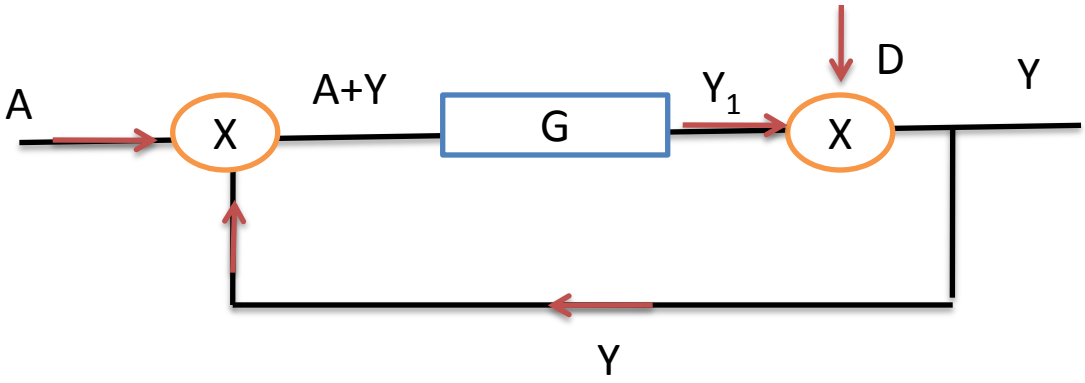
D/1-G: contribution of the disturbing signal to the output

GA/(1-G): contribution of the input to the output

- If an initial increase cause further increase positive feedback
- If an initial decrease cause further decrease positive feedback system.

- Due to this blood losing decrease in cardiac output.
- Decrease in systemic pressure decrease in blood flow.
- Decrease in cardiac nutrition decrease in cardiac contraction.

- Output has two componants
- GA/1-G: contribution of input to out put
- D/1-G: contribution of D to out put
- Y/A always the close loop gain
- Open loop gain depends on the amount of lose in blood (lose in blood increases, open loop gain increases).



$Y = Y_1 + D$

$Y_1 = G(A+Y)$

$Y = [GA/(1-G)] + [D/1-G]$

D/1-G: contribution of the disturbing signal to the output

GA/(1-G): contribution of the input to the output

$G \cong 1$ ise $1/1-G \cong \propto$ and $K \cong \propto$

Out put due to (D) will be present into the input and than will enter the circulation and each time multiplied by G.

t	Output due to the D	Output due to the A (input)
O	D	AG
dt	DG	AG^2
2dt	DG^2	AG^3
…	……	……
Total:	$D+DG+DG^2+…$	$AG+AG^2+AG^3+…$
Total:	$=D(1+G+G^2+…)$	$=AG(1+G+G^2+…)$
Total:	D/(1-G)	AG/(1-G)

If G =1 so we will go to infinity which mean death.

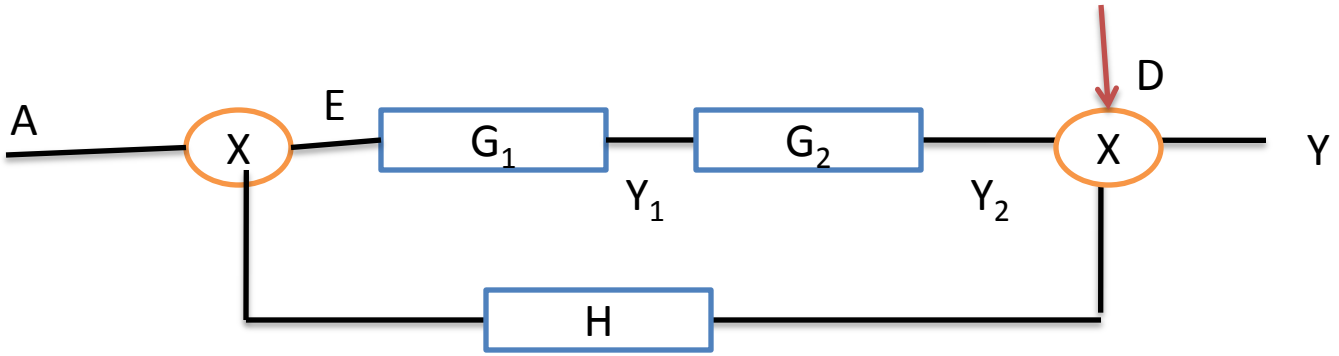
- Kontrol sistemleri 2 grupta incelenir:
  - Açık döngü
  - kapalı döngü
- Açık döngü kontrol sistemlerinde sistemin girişi çıkışından etkilenmez.
- Kapalı döngü kontrol sistemlerinde sistemin çıkış cevabının bir kısmı sistemin girişine katılır.

- Açık döngü sitemlere örnek olarak, karotid sinüsteki sinir lifi uçları sinus içideki kan basıncının etkisiyle gerilerek dedektörün çıkışında implusları toplamı olarak gözlenir. Sinus içindeki basıncın artması veya azalmasına bağlı olarak sinus sinir liflerinden elde edilen sinir impulsları da artar veya azalır.

- Kapalı döngü sistemleri 2 ye ayrılır.
- (-) feed back close loop
- (+) Feed back close loop

Negative feedback system

- This type of systems work as a control system.
- A: referance signal
- E: error signal
- D: disturbing signal



- K= Y/A closed loop gain
- G_1G_2H open loop gain
- $Y=Y_2+D$
- $Y=G_2Y_1+D$
- $Y=G_1G_2(A-HY)+D$
- $Y=(G_1G_2/HG_1G_2H)A+D/HG_1G_2H$

- $K=Y/A=G_1G_2/1+G_1G_2H$ Closed loop gain
- $DY= D/(1+G_1G_2H)$ contribution of the disturbing signal to the output.
- G_1G_2H open loop gain
- To minimize the effect at the disturbing signal to output (G_1G_2H) must be high.

- Açık sistemlerde bozucu etki nedeni ile çıkışta meydana gelen değişim D olmaktadır.
- $\Delta Y_{open} = D$
- $\Delta Y_{close} = D/1+G_1G_2H$
- $\Delta Y_{open} / \Delta Y_{close} = 1/1+G_1G_2H$
  - That ratio is called sensitivity of the system or minification factor.
  - This information give us how the system controls output

Example: air condition

- We wish to have 20^{o}C (reference signal A)
- H sensor system sense and compare the room temperature to (A).
- If we got 18 ^{o}C to compare we substractc (A-18)
- So 18 ^{o}C is less than 20 ^{o}C this will appear as an error signal (E)

- Controlling system make processes and we got output Y1
- Controlled system heat the room to become equal to (A)
- In this case controlled system works under the effect of controlling system
- When temperature is 20 ^{o}C, error will be zero so controlling system stop.

- If room ısolated the temperature will remains $20^{o}C$ but we know that there is an leakages dur to windows and doors, so air flow will effect the room temperature and this indicate by disturbing signal (D)

- Lets find open and close loop gain
- K=Y/A closed loop gain
- G_1G_2H open loop gain
- In this system we wish to have constant output whatever the input is.
- In technical system we could control the effect of D very well but not as well in physiological system.

- In open lop system (H system is not connected) distrubing signal will directly appear in the output. Therefore the change is equal to D
- But in closed system the change is equal to this ratio $D/(1+G_1G_2H)$
- $\Delta Y_{open}=D$
- $\Delta Y_{close}= D/(1+G_1G_2H)$
- $\Delta Y_{open}/ \Delta Y_{close}= 1/(1+G_1G_2H)$

- $\Delta Y_{open} / \Delta Y_{close} = 1/(1+G_1G_2H)$

- Example

Controlling of blood glucose level by negative feed back system.

We have person with 70 mgglucose/100ml blood

We have change by 30mg/100cc

İt is the change in the output of open loop system.

After time passing glucose level will decrease assume that after 30min. It become 75 mg/100cc

- Close loop gain: 75-70=5 mg
- Open loop gain=30mg
- So system sensitivity become
- $5/30=1/1+\underbrace{G_1G_2H}_{\text{Open loop gain}}$

- In human blood body volume 5litre. We inject 1200mg glucose and normal blood glucose level is 85 mg/100ml. But the last is 89mg/100ml, find the open loop gain.
- ΔY_{close}=89-85=4mg/100cc
- ΔY_{open}=1200/5000=0.24mg=24mg/100ml
- $\Delta Y_{open}/\Delta Y_{close}= 1/(1+G_1G_2H)$
- $4/24= 1/(1+G_1G_2H)$
- $1+G_1G_2H=5$

- Which is/are correct for feed back mechanisime?

✓I. In negative feedback one or odd numbers negative gain must be.

_II. In positive feed back when input decrease the output is increasing directly.

✓III. To have a stable positive feed back open loop gain is ≤ 1.

- What would be the sensitivity of a negative feedback if the open loop gain is 4?
- Sensitivity: $1/\ 1+G_1G_2H$
  - $= 1/1+4$
  - $=1/5$