TI DSP, MCU 및 Xilinx Zynq FPGA 프로그래밍 전문가 과정

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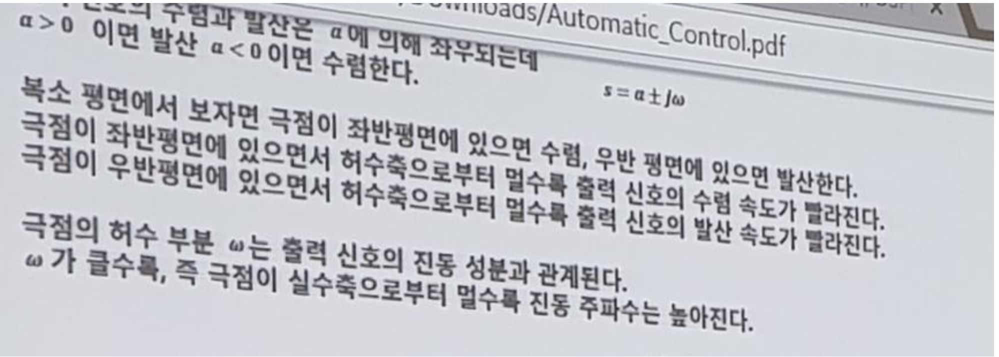
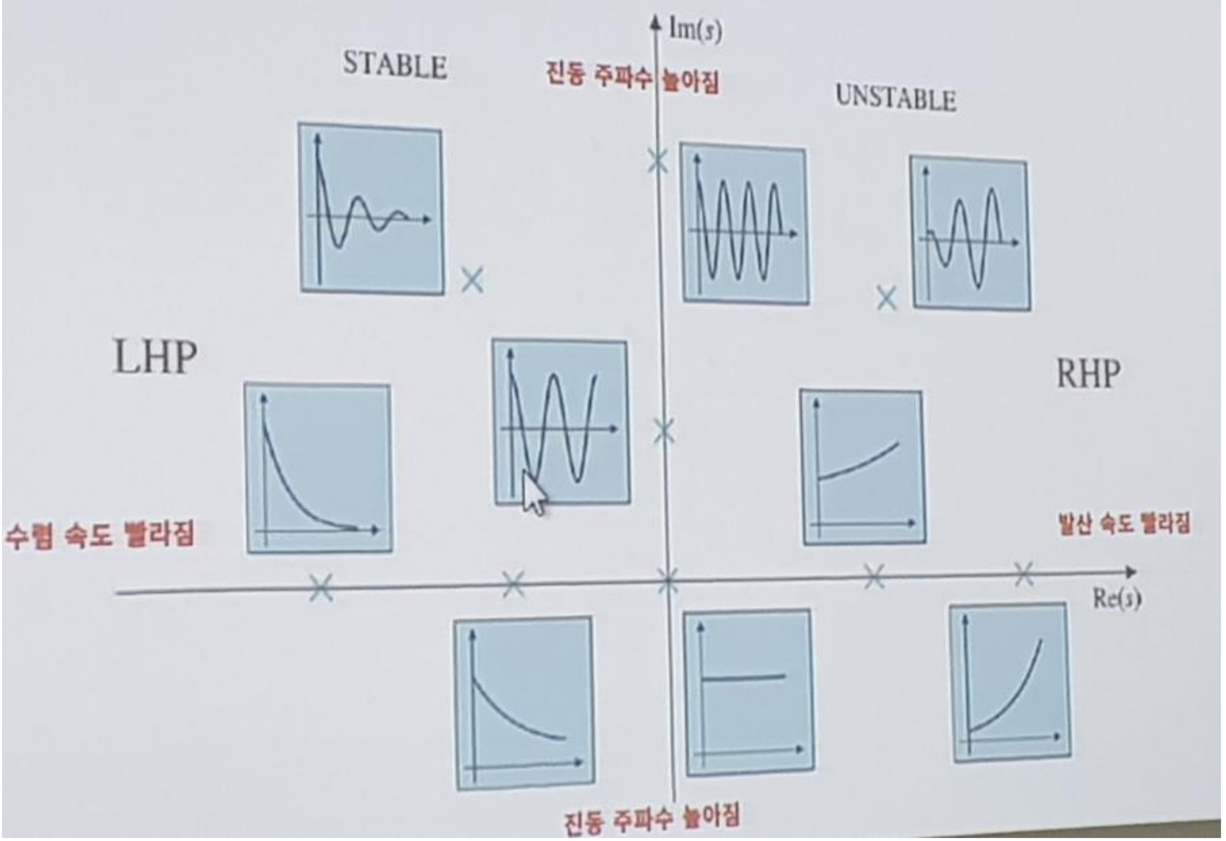
목차

제어공학

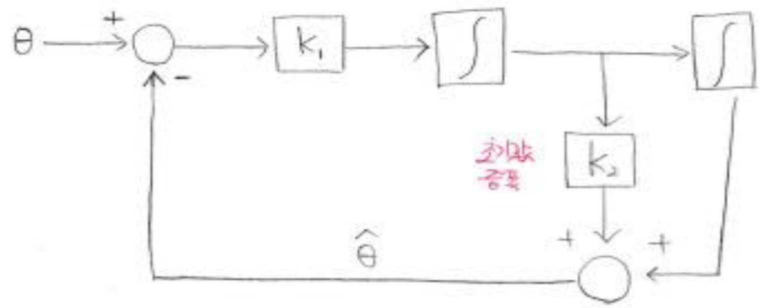
1) 제어의 안정성


Automatic_Control.pdf
수렴과 발산은 α에 의해 좌우되는데
α > 0 이면 발산 α < 0 이면 수렴한다.
s = α ± jω
복소 평면에서 보자면 극점이 좌반평면에 있으면 수렴, 우반 평면에 있으면 발산한다.
극점이 좌반평면에 있으면서 허수축으로부터 멀수록 출력 신호의 수렴 속도가 빨라진다.
극점이 우반평면에 있으면서 허수축으로부터 멀수록 출력 신호의 발산 속도가 빨라진다.
극점의 허수 부분 ω는 출력 신호의 진동 성분과 관계된다.
ω가 클수록, 즉 극점이 실수축으로부터 멀수록 진동 주파수는 높아진다.


Im(s)
STABLE
진동 주파수 높아짐
UNSTABLE
LHP
RHP
수렴 속도 빨라짐
발산 속도 빨라짐
Re(s)
진동 주파수 높아짐

2) Block Diagram

○ 제어공학 – Block Diagram



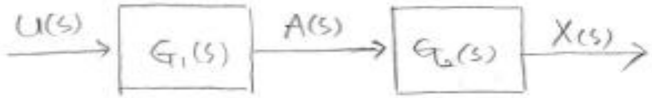
$$\hat{\theta} = k_2 \int_0^t k_1(\theta(\tau) - \hat{\theta}(\tau) d\tau) + \int_0^t \int_0^\tau k_1(\theta(\tau) - \hat{\theta}(\tau)) d\tau d\tau$$

$$\hat{\theta} = \frac{k_2 k_1}{s}(\theta(s) - \hat{\theta}(s)) + \frac{k_1}{s^2}(\theta(s) - \hat{\theta}(s))$$

$$\therefore \frac{\hat{\theta}}{\theta} = H(s) = \frac{k_1(1 + k_2 s)}{s^2 + k_1 k_2 s + k_1}$$

○ 전달함수

①



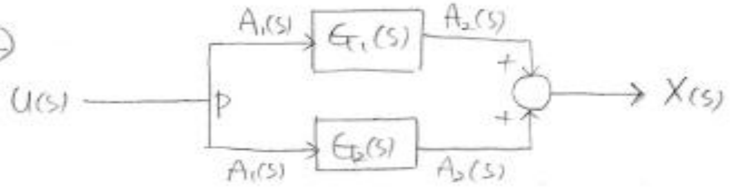
$$X(s) = A(s) \cdot G_2(s)$$

$$A(s) = U(s)\, G_1(s)$$

$$X(s) = G_1(s)\, G_2(s)\, U(s)$$

$$\therefore G(s) = \frac{X(s)}{U(s)} = G_1(s)\, G_2(s)$$

②



$$A_1(s) = U(s)$$

$$A_2(s) = A_1(s) G_1(s)$$

$$A_3(s) = A_1(s) G_2(s)$$

$$X(s) = A_2(s) + A_3(s)$$

$$X(s) = U(s)(G_1(s) + G_2(s))$$

$$\therefore G(s) = \frac{X(s)}{U(s)} = G_1(s) + G_2(s)$$

3) 2차 시스템의 Block Diagram

○ 2차 시스템

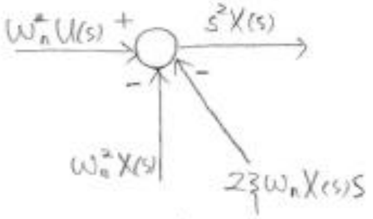
$$\ddot{x}(t)+2\zeta\omega_n\dot{x}(t)+\omega_n^2x(t)=\omega_n^2u(t)$$

초기값: $x(0)=\dot{x}(0)=0$

라플라스 변환

$$X(s)s^2+2\underbrace{\zeta}_{\text{제동비}}\omega_n\underbrace{X(s)}_{\text{출력}}s+\underbrace{\omega_n^2}_{\text{고유주파수}}X(s)=\omega_n^2\underbrace{U(s)}_{\text{입력}}$$

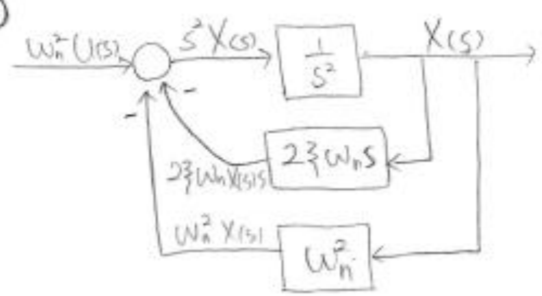
$$\omega_n^2U(s)-2\zeta\omega_nX(s)s-\omega_n^2X(s)=X(s)\cdot s^2$$



⇓

블록다이어그램

①



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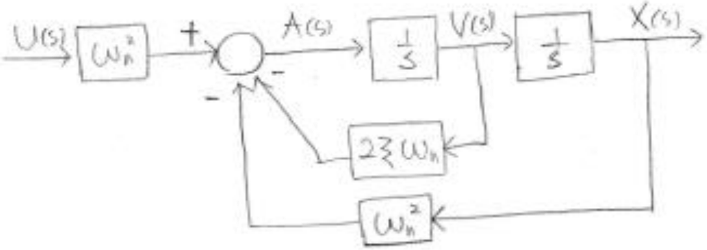

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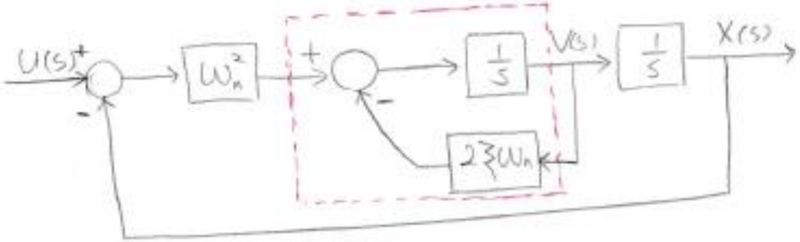
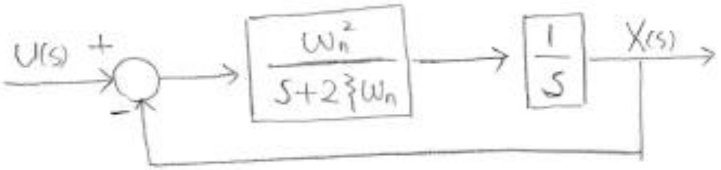


$$\frac{G(s)}{1+G(s)H(s)}=\frac{\frac{1}{s}}{1+\frac{2\zeta\omega_n}{s}}=\frac{1}{s+2\zeta\omega_n}$$

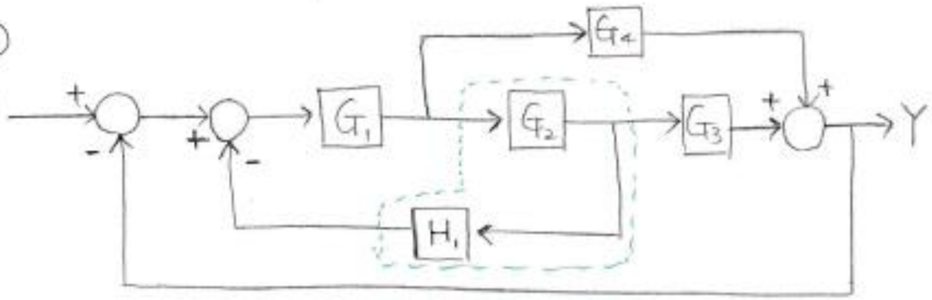
④



4) Block의 전달함수

○ Block의 전달함수

①



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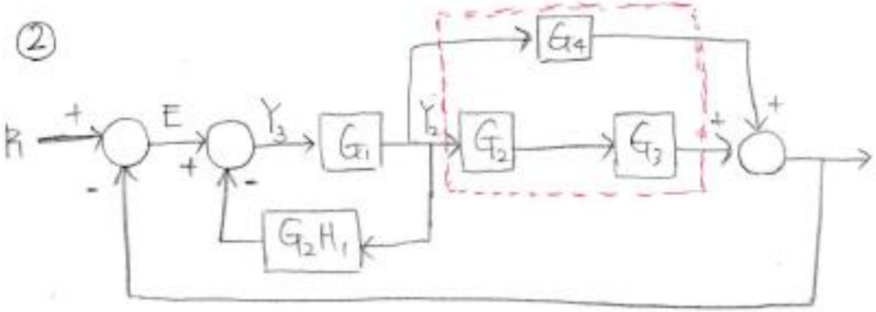

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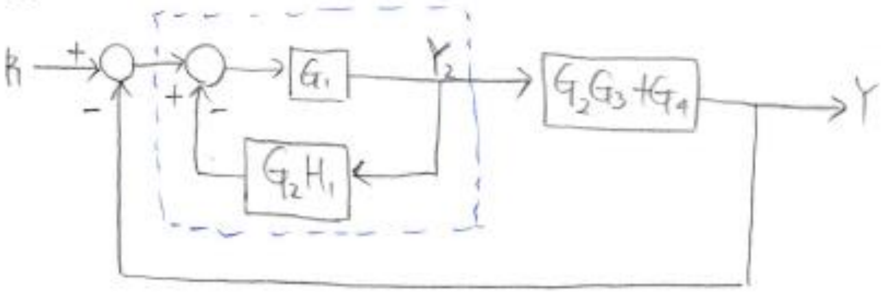

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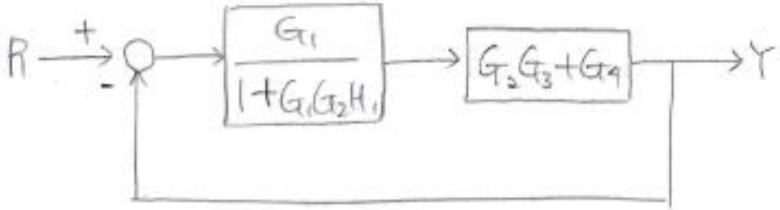
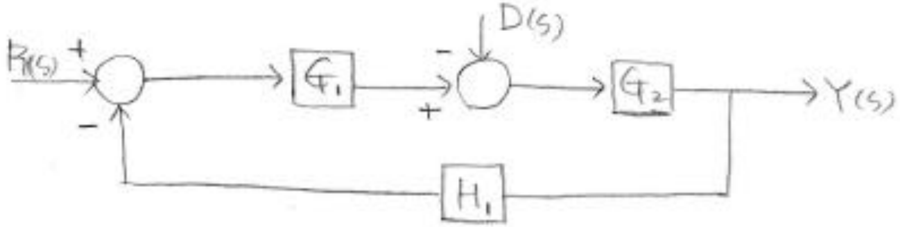


$$\therefore G(s) = \frac{\dfrac{G_1G_2G_3+G_1G_4}{1+G_1G_2H_1}}{1+\dfrac{G_1G_2G_3+G_1G_4}{1+G_1G_2H_1}}$$

$$= \frac{G_1G_2G_3+G_1G_4}{1+G_1G_2H_1+G_1G_2G_3+G_1G_4}$$

5) 외란(입력 다수)의 Block Diagram

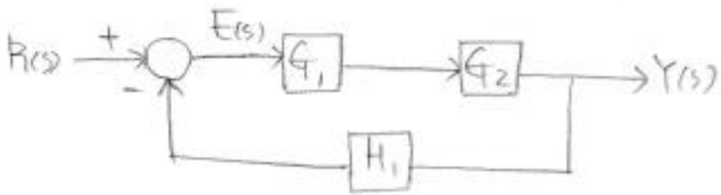
○ 외란(입력 다수)의 블록 다이어그램



$$Y_{total} = Y_R\Big|_{D=0} + Y_D\Big|_{R=0}$$

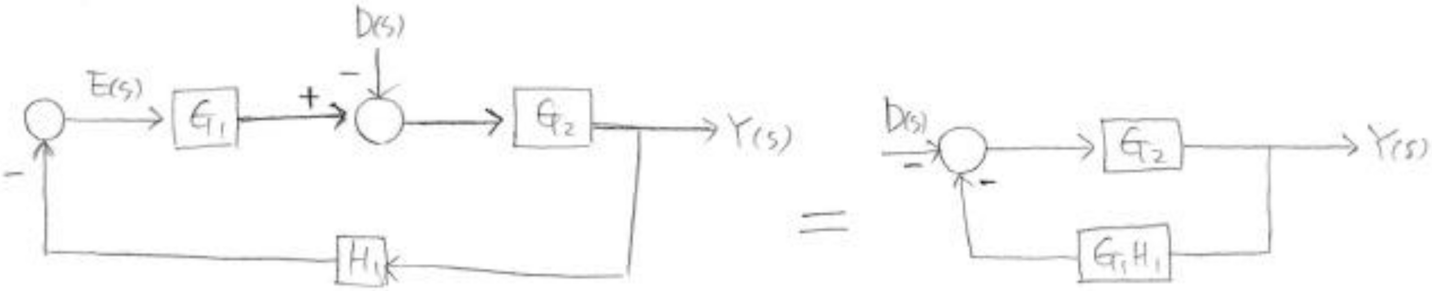
① $D(s)=0$

$$\frac{Y(s)}{R(s)} = \frac{G_1(s)G_2(s)}{1+G_1(s)G_2(s)H_1(s)}$$



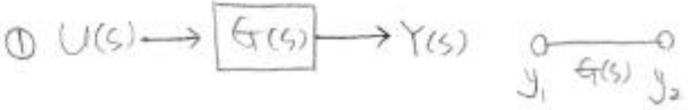
② $R(s)=0$

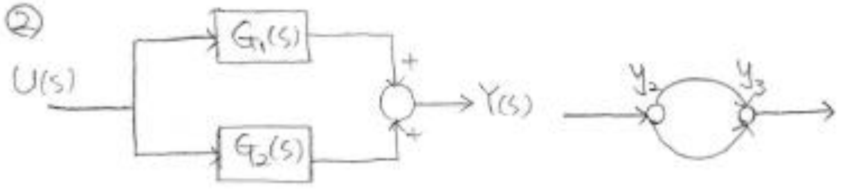
$$\frac{Y(s)}{D(s)} = \frac{-G_2(s)}{1+G_1(s)G_2(s)H_1(s)}$$

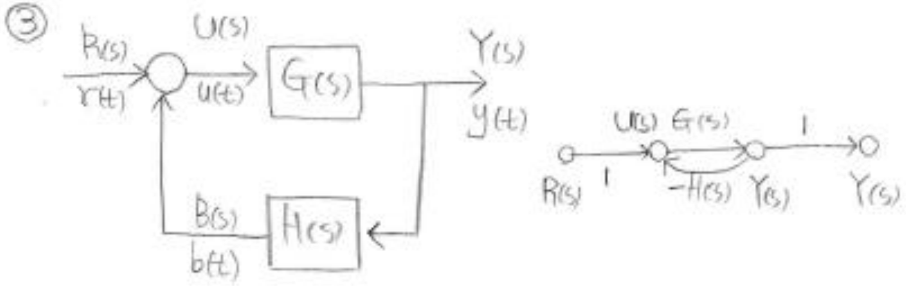


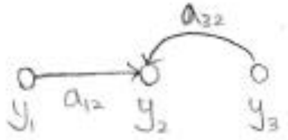
6) Signal Flow Graph

○ Signal Flow Graph

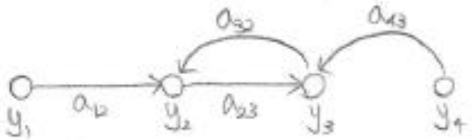






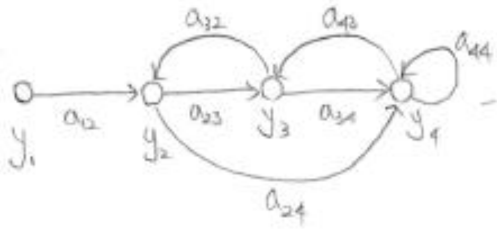


$y_2 = a_{12}y_1 + a_{32}y_3$



$y_2 = a_{12}y_1 + a_{32}y_3$

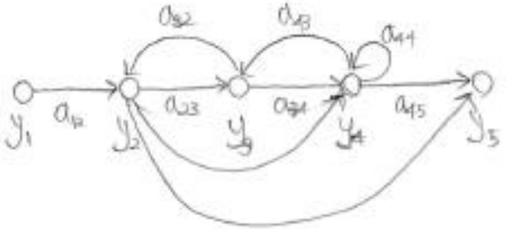
$y_3 = a_{23}y_2 + a_{43}y_4$



$y_2 = a_{12}y_1 + a_{32}y_3$

$y_3 = a_{23}y_2 + a_{43}y_4$

$y_4 = a_{24}y_2 + a_{34}y_3 + a_{44}y_4$



$y_2 = a_{12}y_1 + a_{32}y_3$

$y_3 = a_{23}y_2 + a_{43}y_4$

$y_4 = a_{23}y_2 + a_{34}y_3 + a_{44}y_4$

$y_5 = a_{25}y_2 + a_{45}y_4$

7) SFG 기반 전달함수 구하기

o SFG 기반 전달함수 구하기

$$M = \frac{y_{out}}{y_{in}} = \sum_{k=1}^{N} \frac{M_k \Delta_k}{\Delta}$$

y_{in} = 입력변수

y_{out} = 출력변수

M = 입력과 출력 변수 사이의 이득

N = 입력과 출력사이의 전방경로 개수

M_k = 입력과 출력 변수 사이에 k번째 전방경로의 이득

$$\Delta = 1 - \sum_i L_{i1} + \sum_j L_{j2} - \sum_k L_{k3} + \cdots$$

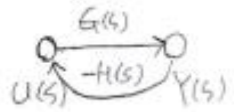
Δ는 1-(각각의 모든 루프이득의 합)+(두 개의 비접촉루프의 가능한 모든 조합의 이득의 곱의 합) - (세 개의 비접촉루프 〃) + (네 개 ···

L_{mr} = r개의 비접촉루프의 가능한 m번째 ($m=i,j,k$) 조합의 이득곱

Δ_k = k번째 전방경로와 접촉하지 않는 Signal Flow Graph에 대한 Δ

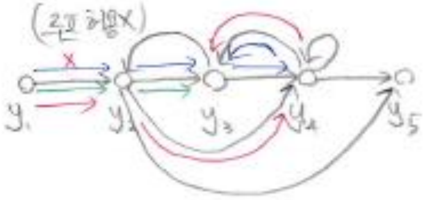
o 용어 정의

경로 :



같은 구간을 여러 번 거쳐도 무방

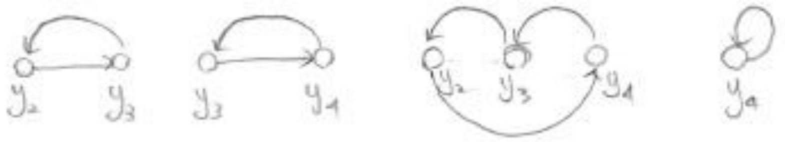
전방경로 :



$y_1 \rightarrow y_3$까지 가는 방법은 빨간선과 초록선 뿐임.

경로이득 : $y_1 \rightarrow y_2 \rightarrow y_3 \rightarrow y_4$ 의 경우 $a_{12} * a_{23} * a_{34}$

루프 : 시작과 끝이 같은 것.

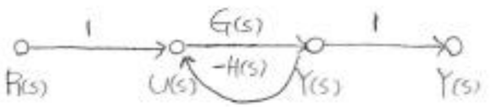


비접촉 루프 : Signal Flow Graph의 두 부분이 공통의 마디를 공유하지 않으면 비접촉이다.

8) SFG 예제

○ SFG 예제

①



$M_1 = G(s)$

$L_{11} = -G(s)H(s)$

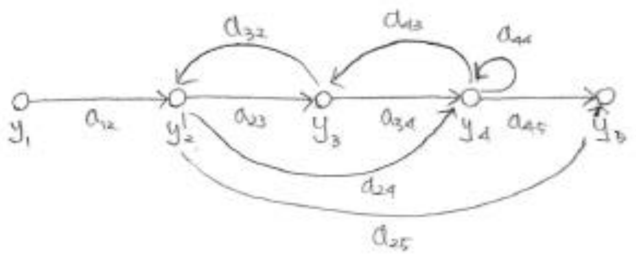
$\Delta_1 = 1$ (Δ_k = k번째 전방경로와 접촉하지 않는 SFG에 대한 Δ)

$\Delta = 1 - L_{11}$ $\left(\Delta = 1 - \sum_i L_{i1} + \sum_j L_{j2} - \sum_k L_{k3} + \cdots\right)$

$$\therefore M = \frac{y_{out}}{y_{in}} = \sum_{k=1}^{N} \frac{M_k \Delta_k}{\Delta} = \frac{M_1 \Delta_1}{\Delta} = \frac{G(s)}{1+G(s)H(s)}$$

$$\therefore M = \frac{y_2}{y_1} = \sum_{k=1}^{N} \frac{M_k \Delta_k}{\Delta} = \frac{M_1 \Delta_1}{\Delta} = \frac{a_{12}(1 - a_{34}a_{43} - a_{44})}{1 - (a_{23}a_{32} + a_{34}a_{43} + \cdots)}$$

②



◦ 전방경로 이득

$y_1 \to y_2 \to y_3 \to y_4 \to y_5$ $\quad M_1 = a_{12}a_{23}a_{34}a_{45}$

$y_1 \to y_2 \to y_5$ $\quad M_2 = a_{12}a_{25}$

$y_1 \to y_2 \to y_4 \to y_5$ $\quad M_3 = a_{12}a_{24}a_{45}$

· Loop 이득 (L_{mr} : r개의 비접촉루프의 m번째 조합)

○ $L_{11} = a_{23}a_{32}$ $\quad L_{21} = a_{34}a_{43}$ $\quad L_{31} = a_{24}a_{32}a_{43}$ $\quad L_{41} = a_{44}$

○ $L_{12} = a_{23}a_{32}a_{44}$

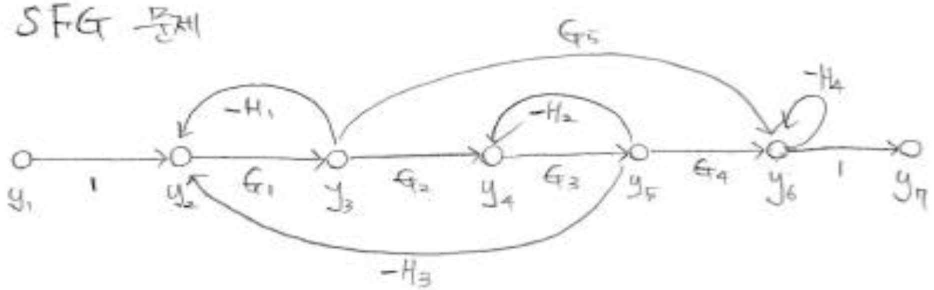
$\Delta_1 = \Delta_3 = 1$, $\Delta_2 = 1 - a_{34}a_{43} - a_{44}$ ($y_2 \to y_3 \to y_2$, $y_4 \to y_4$)

$\Delta = 1 - (L_{11} + L_{21} + L_{31} + L_{41}) + L_{21} = 1 - (a_{23}a_{32} + a_{34}a_{43} + a_{24}a_{32}a_{43} + a_{44}) + a_{23}a_{32}a_{44}$

$$\therefore M = \frac{y_5}{y_1} = \sum_{k=1}^{N} \frac{M_k \Delta_k}{\Delta} = \frac{a_{12}a_{23}a_{34}a_{45} + a_{12}a_{25}(1 - a_{34}a_{43} - a_{44}) + a_{12}a_{24}a_{45}}{1 - (a_{23}a_{32} + a_{34}a_{43} + a_{24}a_{32}a_{43} + a_{44}) + a_{23}a_{32}a_{44}}$$

9) SFG 문제

○ SFG 문제



1) 전방경로이득

$y_1 \to y_2 \to y_3 \to y_4 \to y_5 \to y_6 \to y_7$ $\quad M_1 = G_1G_2G_3G_4$

$y_1 \to y_2 \to y_3 \to y_6 \to y_7$ $\quad M_2 = G_1G_5$

2) Loop 이득

$L_{11} = -G_1H_1$, $L_{21} = -G_3H_2$, $L_{31} = -H_4$, $L_{41} = -G_1G_2G_3H_3$

3) 비접촉루프

$L_{12} = (-G_1H_1)(-G_3H_2) = G_1H_1G_3H_2$, $L_{22} = G_1H_1H_4$, $L_{32} = G_3H_2H_4$, $L_{42} = G_1G_2G_3H_3H_4$ (2개 조합)

$L_{31} = -G_1H_1G_3H_2H_4$

$\Delta = 1 - (L_{11} + L_{21} + L_{31} + L_{41}) + (L_{12} + L_{22} + L_{32} + L_{42}) - (L_{31})$

$= 1 + G_1H_1 + G_3H_2 + H_4 + G_1G_2G_3H_3 + G_1H_1G_3H_2 + G_1H_1H_4 + G_3H_2H_4 + G_1H_1G_3H_2H_4$

4) 결과

$\therefore M = \dfrac{y_2}{y_1} = \dfrac{M_1\Delta_1}{\Delta} = \dfrac{1-(L_{21}+L_{31}+L_{32})}{\Delta}$

$= \dfrac{1+G_3H_2+H_4+G_3H_2H_4}{\Delta}$

$\therefore \dfrac{y_4}{y_1} = \dfrac{M_1\Delta_1}{\Delta} = \dfrac{G_1G_2\{1-(L_{31})\}}{\Delta} = \dfrac{G_1G_2(1+H_4)}{\Delta}$

$\therefore \dfrac{y_6}{y_1} = \dfrac{M_1\Delta_1}{\Delta} + \dfrac{M_2\Delta_2}{\Delta}$, $\quad \Delta_1 = 1$, $\Delta_2 = 1 + G_3H_2$

$= \dfrac{G_1G_2G_3G_4 + G_1G_5(1+G_3H_2)}{\Delta}$