Spring 2020

控制系統
Control Systems

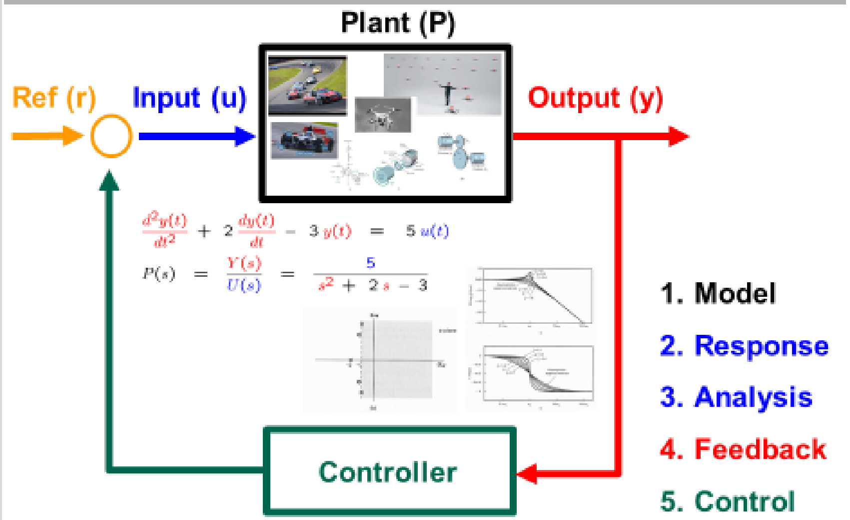
Unit 32
System Modeling Diagrams

Feng-Li Lian & Ming-Li Chiang

NTU-EE & NTUT-AT

Jan20 – Jun20

Plant, Input, Output, Action, Goal



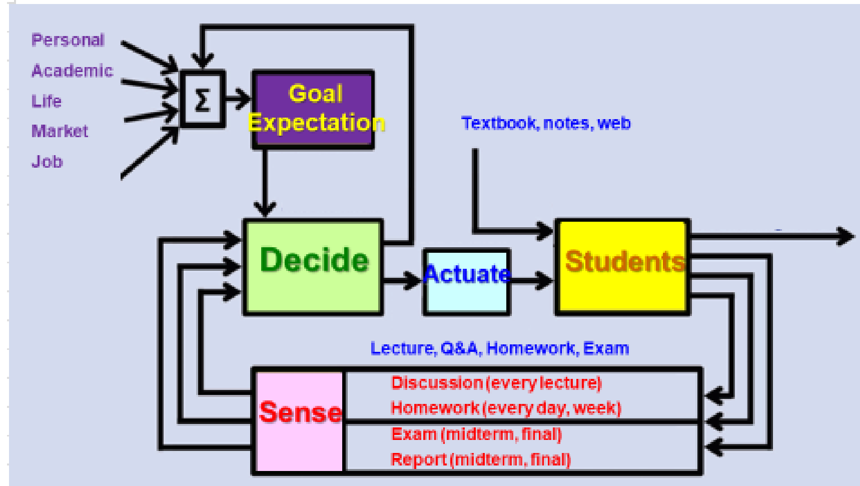
$$\frac{d^2y(t)}{dt^2} + 2\frac{dy(t)}{dt} - 3\,y(t) = 5\,u(t)$$

$$P(s) = \frac{Y(s)}{U(s)} = \frac{5}{s^2 + 2s - 3}$$

$$\frac{d^2y(t)}{dt^2} + 4\frac{dy(t)}{dt} + 3\,y(t) = 3\,r(t)$$

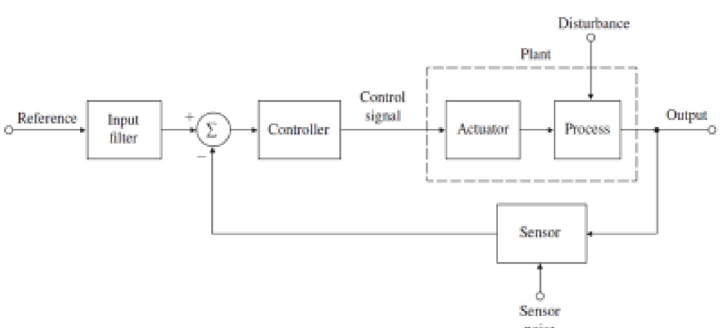
$$G(s) = \frac{Y(s)}{R(s)} = \frac{3}{s^2 + 4s + 3}$$

Feedback and Control in Teaching and Learning



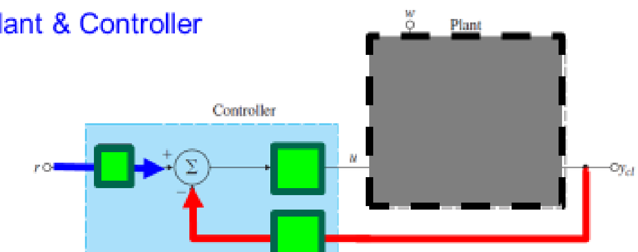
Source : IEEE CSM 2013

Key Terminologies in Feedback and Control



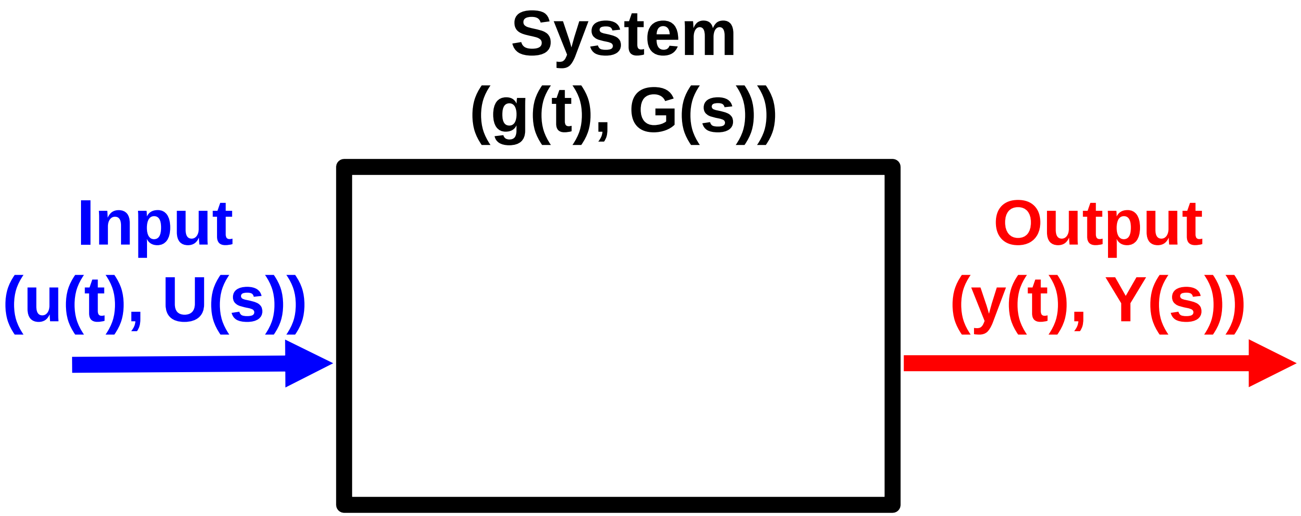
Motivating Example: Cruse Control of An Automobile

- Plant & Controller



r = 65 w	error Open	% error Open	% error Closed (Feedback)	% error Feedback+Feedforward
0	0	0	0.99%	0%
1	5	7.69%	0.99 + 0.07.62%	0.0762%
2	10	15.38%	0.99 + 0.1523%	0.1523%

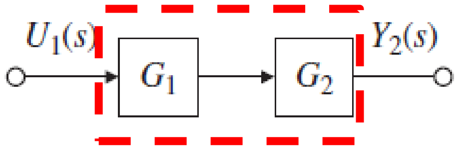
- Elementary Block Diagram:
  A System and its Input and Output



Plant, Processor, Sensor, Actuator, Controller, Filter, Maker, etc.

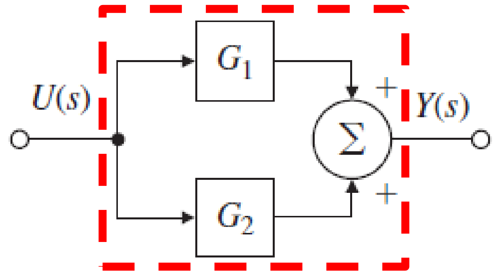
The Block Diagram

- Elementary block diagrams: (a) series; (b) parallel; (c) feedback



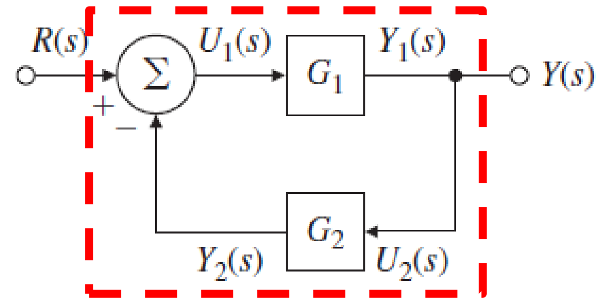
$$\frac{Y_2(s)}{U_1(s)} = G_2 G_1$$

(a)



$$\frac{Y(s)}{U(s)} = G_2 + G_1$$

(b)



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

(c)

$$Y_1(s) = G_1(s)\, U_1(s)$$

$$Y_2(s) = G_2(s)\, Y_1(s)$$

$$= G_2(s)\, G_1(s)\, U_1(s)$$

$$Y_1(s) = G_1(s)\, U(s)$$

$$Y_2(s) = G_2(s)\, U(s)$$

$$Y(s) = Y_1(s) + Y_2(s)$$

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

$$U_1(s) = R(s) - Y_2(s)$$

$$Y_2(s) = G_2(s)\, U_2(s)$$

$$U_2(s) = Y_1(s)$$

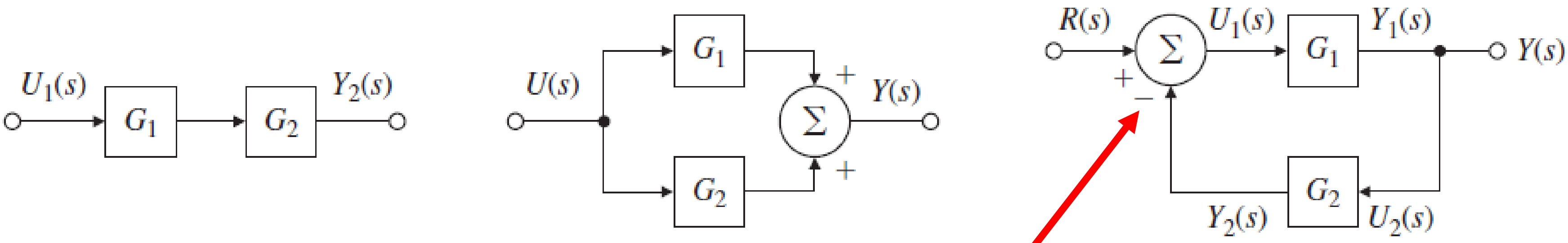
$$Y_1(s) = G_1(s)\, U_1(s)$$

$$= G_1\, (R - Y_2)$$

$$= G_1\, R - G_1\, G_2\, U_2$$

$$= G_1\, R - G_1\, G_2\, Y_1$$

- Elementary block diagrams: (a) series; (b) parallel; (c) feedback



$$\frac{Y_2(s)}{U_1(s)} = G_2 G_1$$

(a)

$$\frac{Y(s)}{U(s)} = G_2 + G_1$$

(b)

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

(c)

- The gain of a single-loop negative feedback system is given by

  the forward gain divided by the sum of 1 plus the loop gain.

- Negative Feedback

$$\frac{Y}{R} = \frac{G_1}{1 + G_2\,G_1}$$

- Positive Feedback

$$\frac{Y}{R} = \frac{G_1}{1 - G_2\,G_1}$$

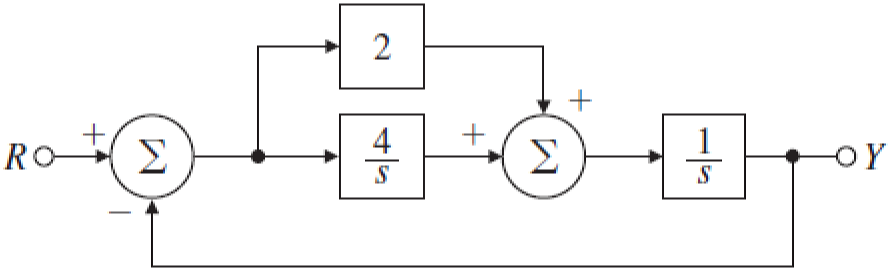
- Unity Feedback System

$$G_2 = 1$$

The Block Diagram

- Block-Diagram Algebra: (a) moving a pickoff point; (b) moving a summer; (c) conversion to unity feedback

Example 3.22: Transfer Function from a Simple Block Diagram



(a)

$$Y = \frac{1}{s} U$$

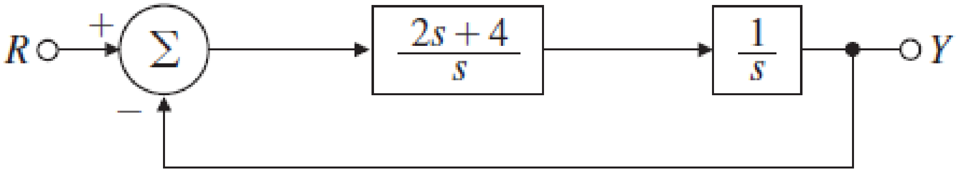
$$U = (\frac{4}{s} + 2) E$$

$$E = R - Y$$

$$Y = \frac{1}{s} (\frac{4}{s} + 2)(R - Y)$$

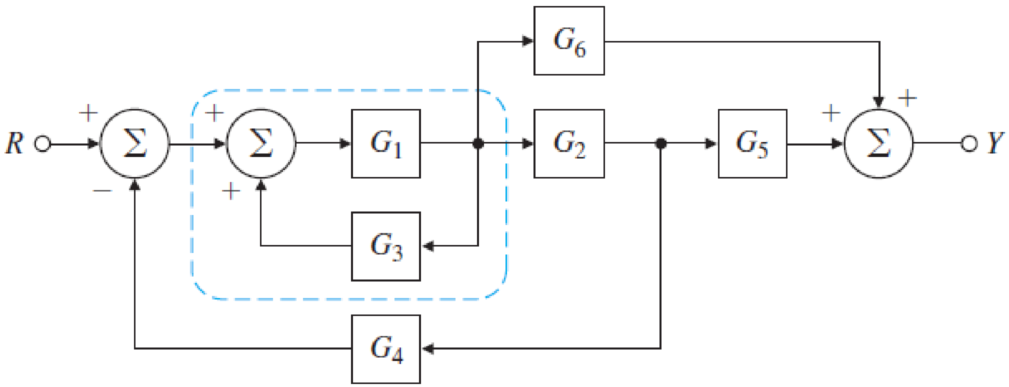
$$\frac{Y}{R} = \frac{\frac{2s+4}{s^2}}{1 + \frac{2s+4}{s^2}}$$

$$= \frac{2s+4}{s^2 + 2s + 4}$$



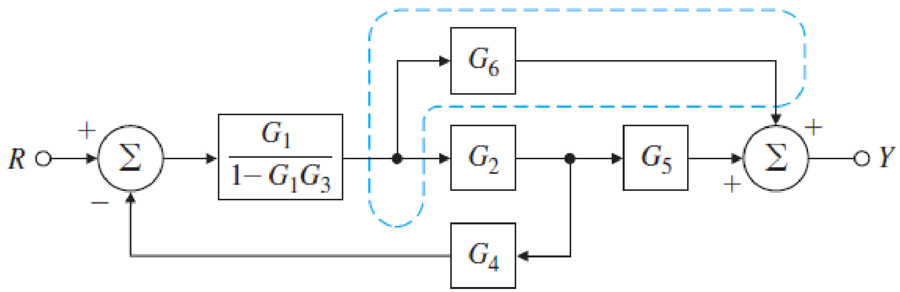
(b)

Example 3.23: Transfer Function from the Block Diagram

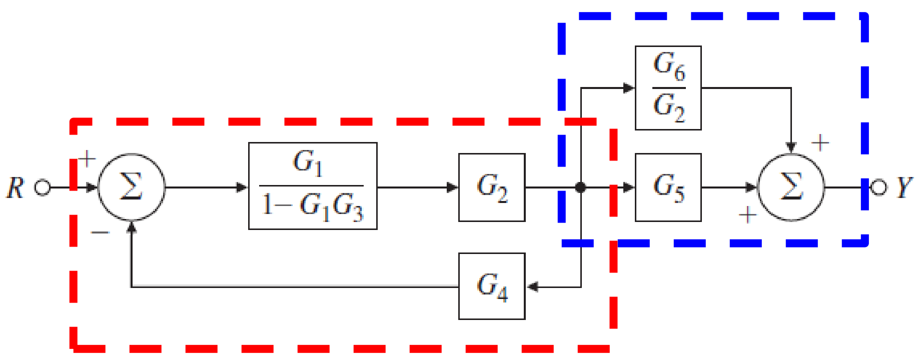


(a)

$$\Rightarrow \frac{G_1}{1 - G_1 G_3}$$



(b)

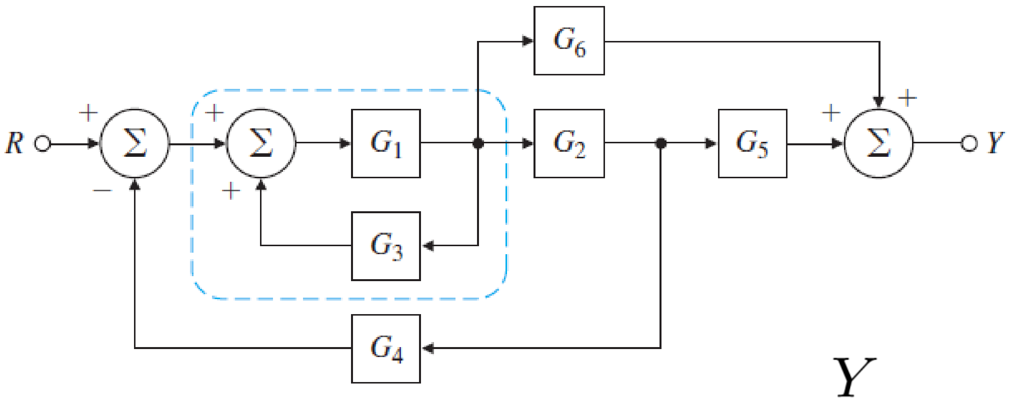


(c)

$$\Rightarrow (G_5 + \frac{G_6}{G_2})$$

$$\Rightarrow \frac{\frac{G_1}{1-G_1G_3} G_2}{1 + \frac{G_1}{1-G_1G_3} G_2 G_4}$$

▪ Example 3.23: Transfer Function from the Block Diagram



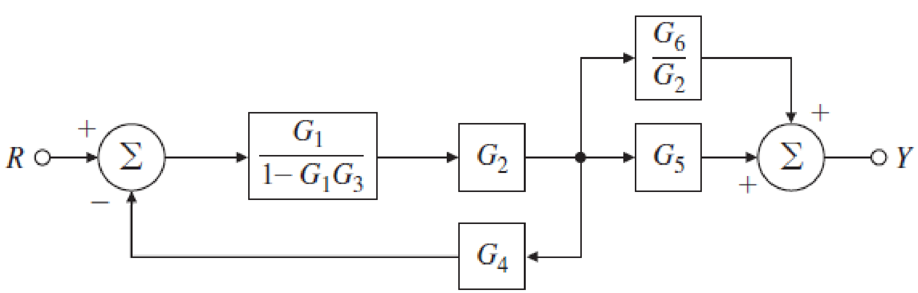
(a)

$$\Rightarrow \frac{G_1}{1 - G_1G_3}$$

$$\frac{Y}{R} = \frac{\frac{G_1}{1-G_1G_3}G_2}{1 + \frac{G_1}{1-G_1G_3}G_2G_4}\left(G_5 + \frac{G_6}{G_2}\right)$$

$$= \frac{G_1G_2G_5 + G_1G_6}{1 - G_1G_3 + G_1G_2G_4}$$

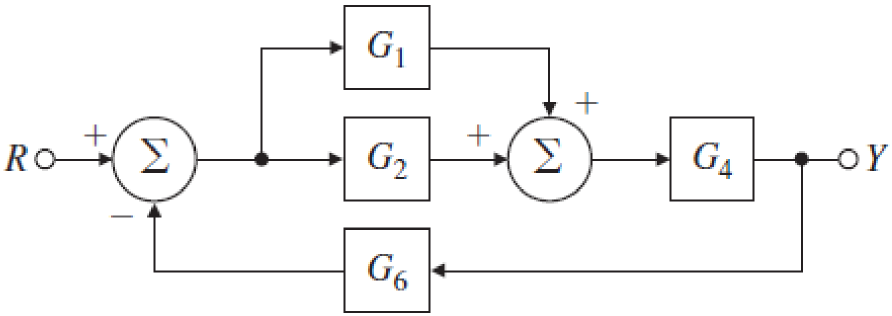
$$\Rightarrow \left(G_5 + \frac{G_6}{G_2}\right)$$



(c)

$$\Rightarrow \frac{\frac{G_1}{1-G_1G_3}G_2}{1 + \frac{G_1}{1-G_1G_3}G_2G_4}$$

Example 3.24: Using Matlab




```
s = tf( 's' )

sysG1 = 2;
sysG2 = 4/s;
sysG3 = parallel( sysG1, sysG2 );
sysG4 = 1/s;
sysG5 = series( sysG3, sysG4 );
sysG6 = 1;

sysCL = feedback( sysG5, sysG6, -1 )
```

```
>> sysCL

sysCL =

2 s + 4
-------------
s^2 + 2 s + 4

Contnuous-time transfer function.
```