

Fall 2022 (111-1)

控制系統  
Control Systems

Unit 3B  
System Modeling Diagrams

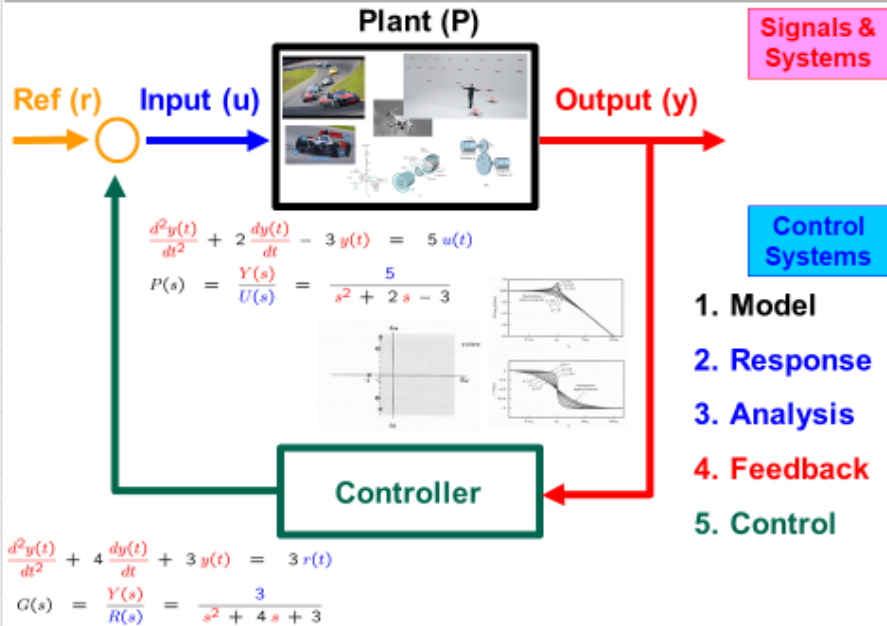
Feng-Li Lian

NTU-EE

Sep 2022 – Dec 2022

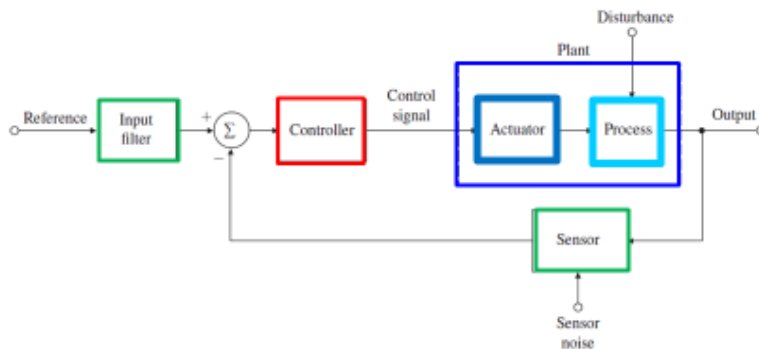
## Plant, Input, Output, Action, Goal

CS1B-IntroFC - 11  
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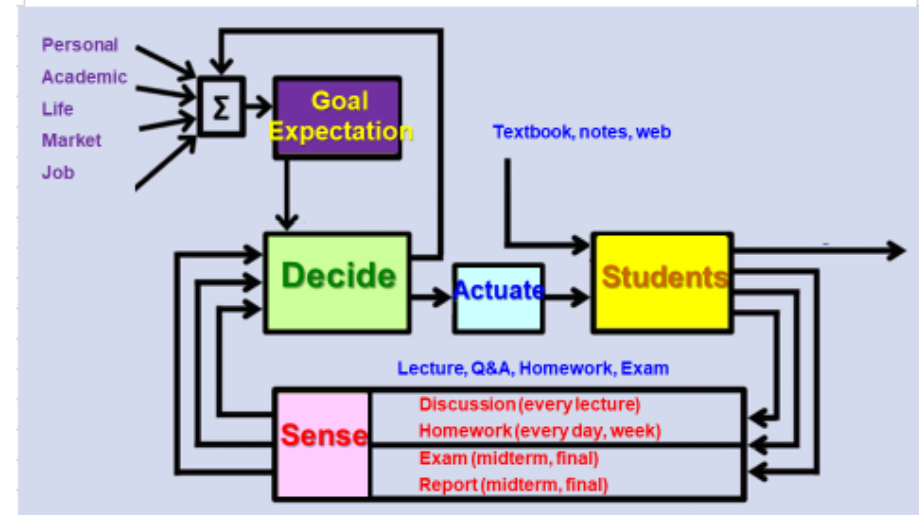
## Key Terminologies in Feedback and Control

CS1B-IntroFC - 29  
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## Feedback and Control in Teaching and Learning

CS1B-IntroFC - 15  
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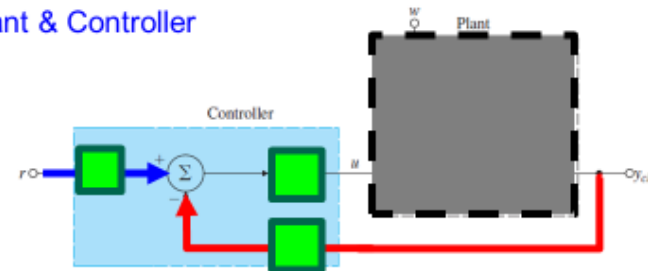


Source : IEEE CSM 2013

## Motivating Example: Cruise Control of An Automobile

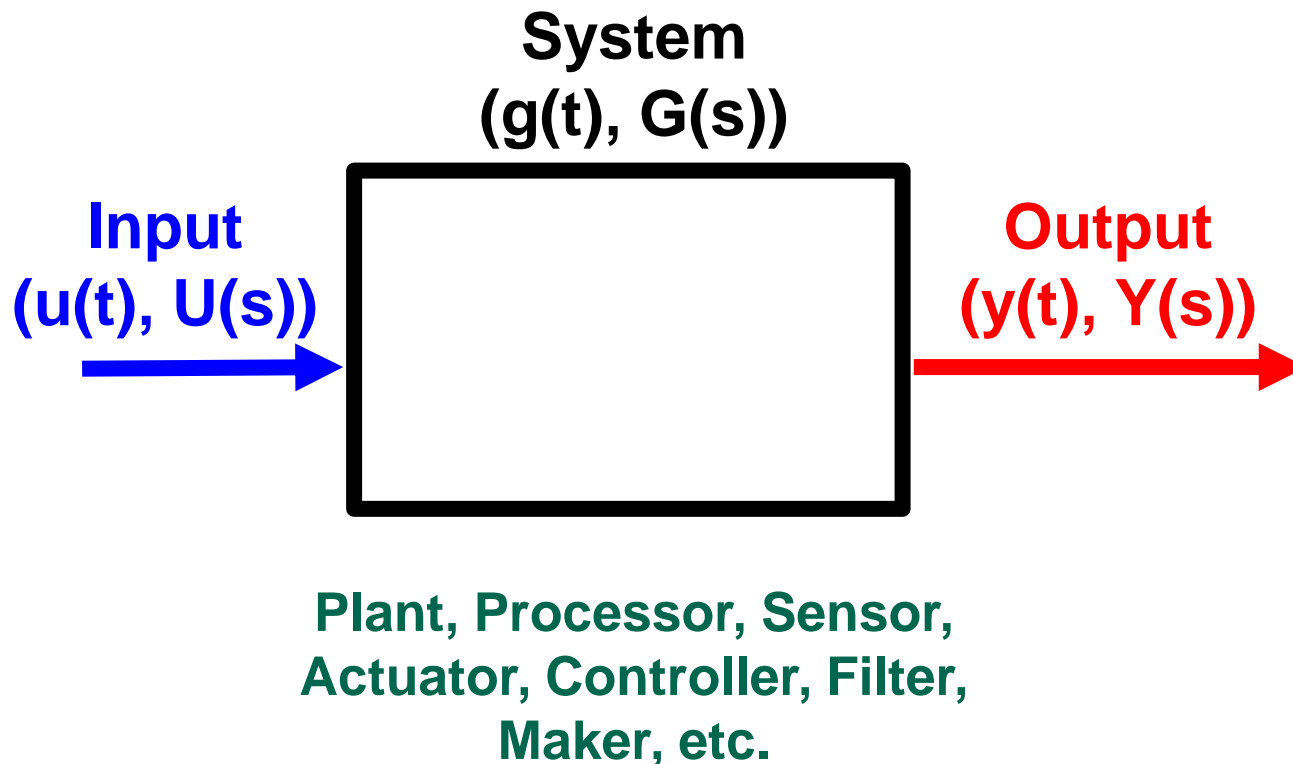
CS1D-Example - 10  
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### Plant & Controller

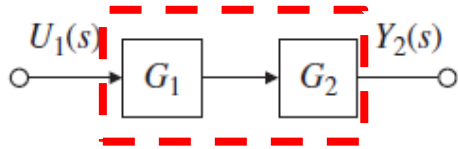


r = 65 w	error Open	error Open %	% error Feedback + Feedforward C=10	% error Closed (Feedback) C=1	% error Closed (Feedback) C=10	% error Closed (Feedback) C=100
0	0	0	0 %	9.090 %	0.990 %	0.099 %
1	5	7.69 %	0.0762 %	9.790 %	1.066 %	0.107 %
2	10	15.38 %	0.1523 %	10.489 %	1.142 %	0.115 %

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

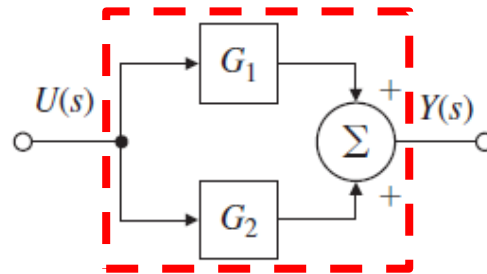


- Elementary block diagrams: (a) series; (b) parallel; (c) feedback



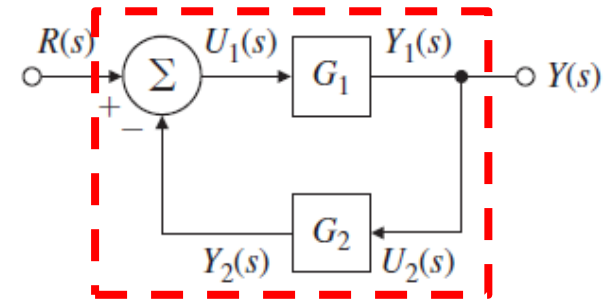
$$\frac{Y_2(s)}{U_1(s)} = G_2 G_1$$

(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)

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

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

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

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

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

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

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

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

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

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

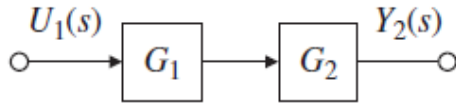
$$Y_1(s) = G_1(s) U_1(s)$$

$$= G_1 (R - Y_2)$$

$$= G_1 R - G_1 G_2 U_2$$

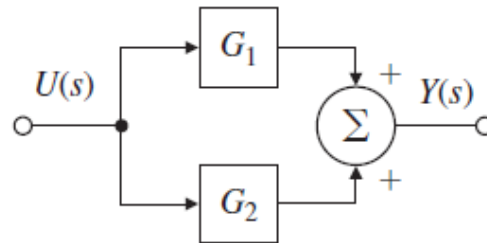
$$= G_1 R - G_1 G_2 Y_1$$

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



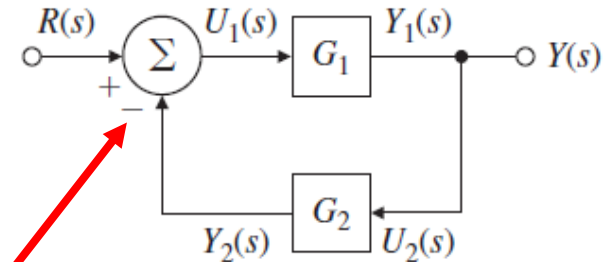
$$\frac{Y_2(s)}{U_1(s)} = G_2 G_1$$

(a)



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

(b)



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

(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**.

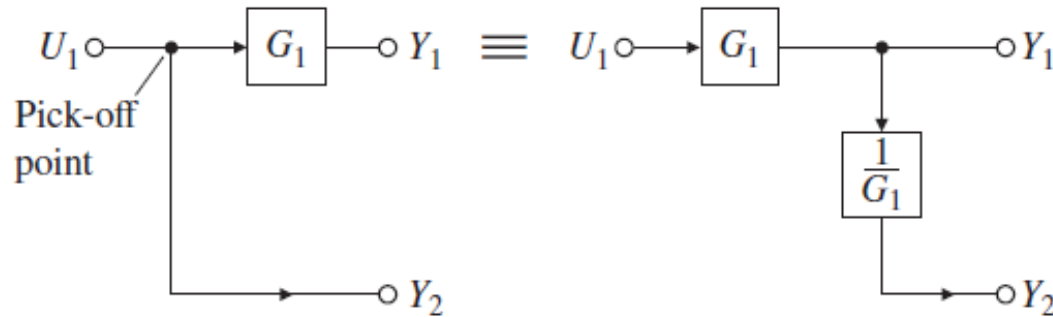
- Negative Feedback**
- Positive Feedback**
- Unity Feedback System**

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

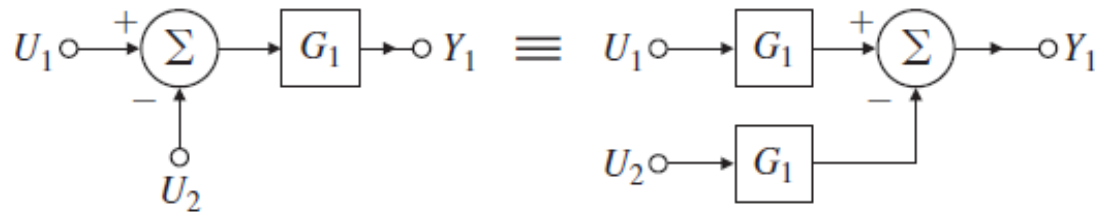
$$\frac{Y}{R} = \frac{G_1}{1 - G_2 G_1}$$

$$G_2 = 1$$

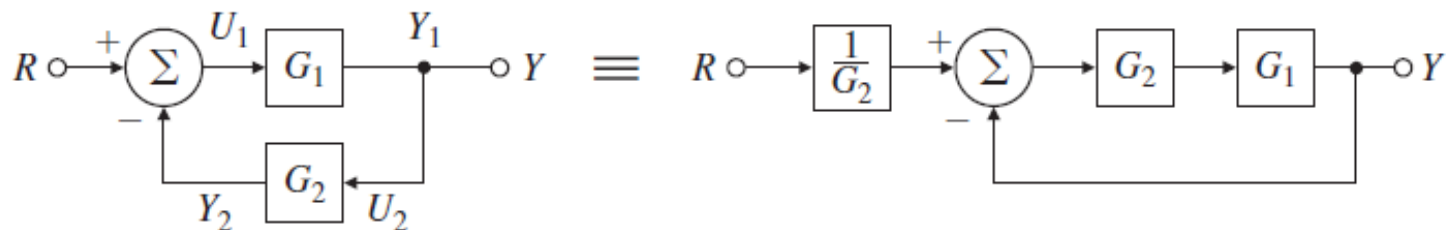
- Block-Diagram Algebra: (a) moving a pickoff point;  
(b) moving a summer; (c) conversion to unity feedback



(a)

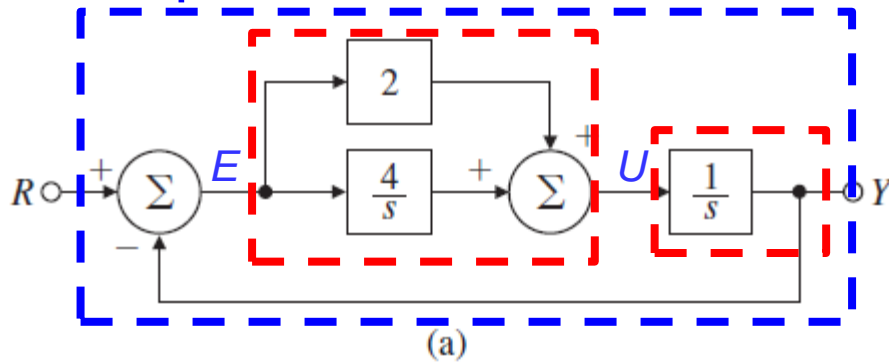


(b)



(c)

## Example 3.22: Transfer Function from a Simple Block Diagram



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

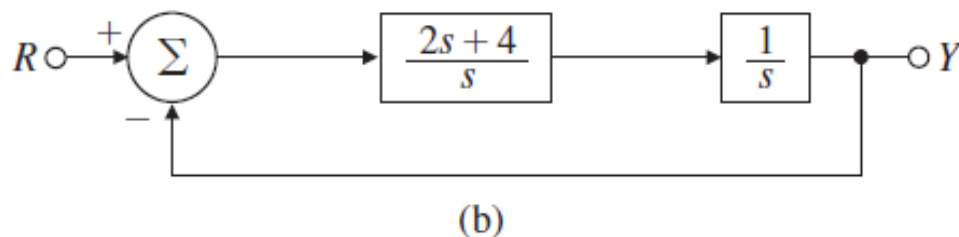
$$U = \left(\frac{4}{s} + 2\right)E$$

$$E = R - Y$$

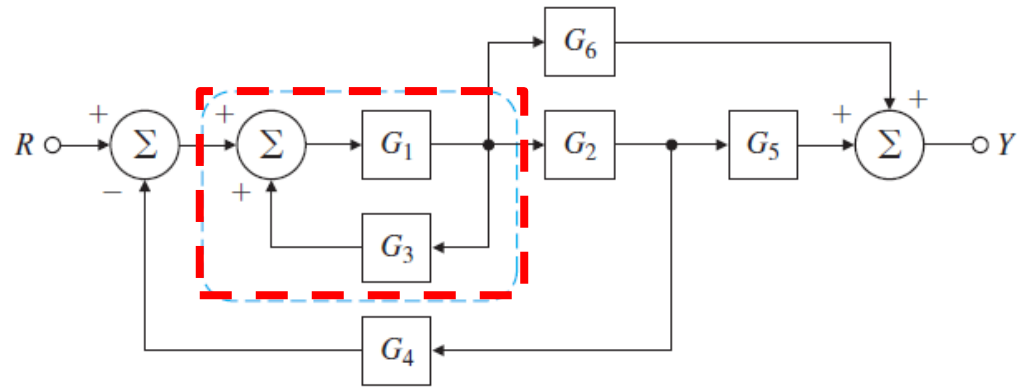
$$Y = \frac{1}{s} \left(\frac{4}{s} + 2\right)(R - Y)$$

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

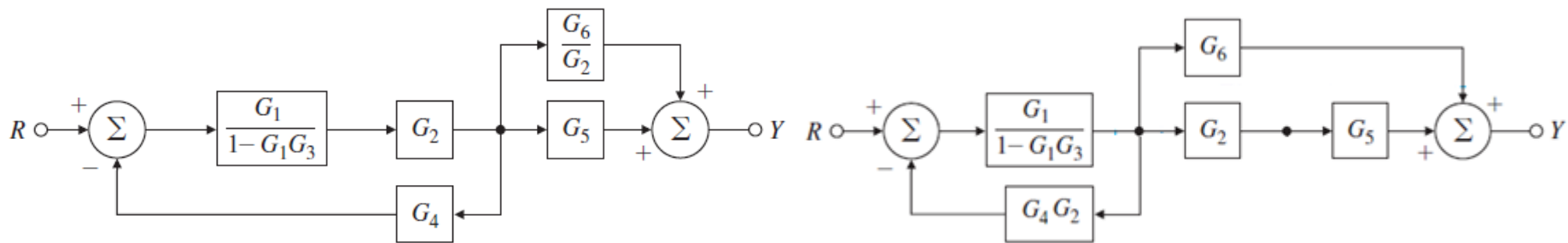
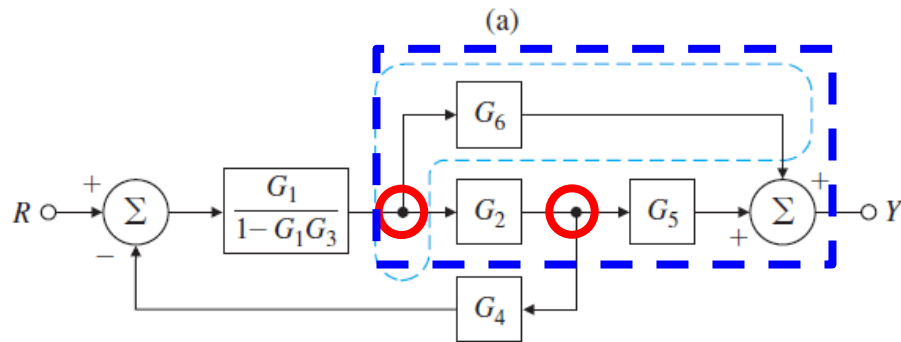
$$= \frac{2s + 4}{s^2 + 2s + 4}$$



## Example 3.23: Transfer Function from the Block Diagram



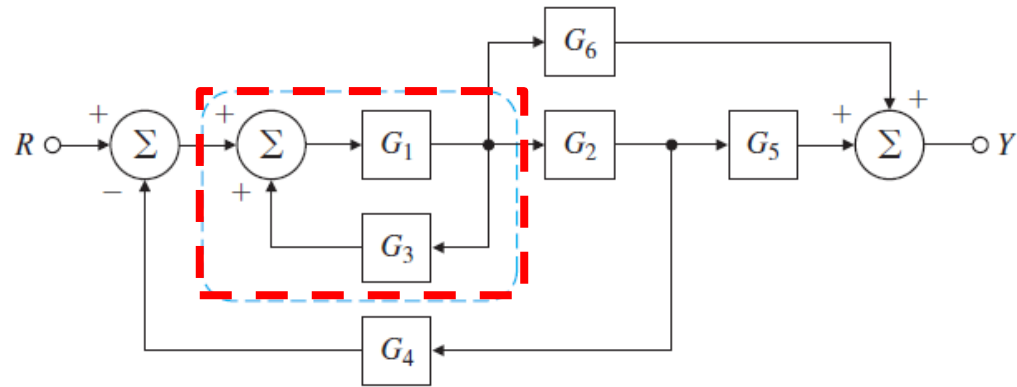
$$\Rightarrow \frac{G_1}{1 - G_1 G_3}$$



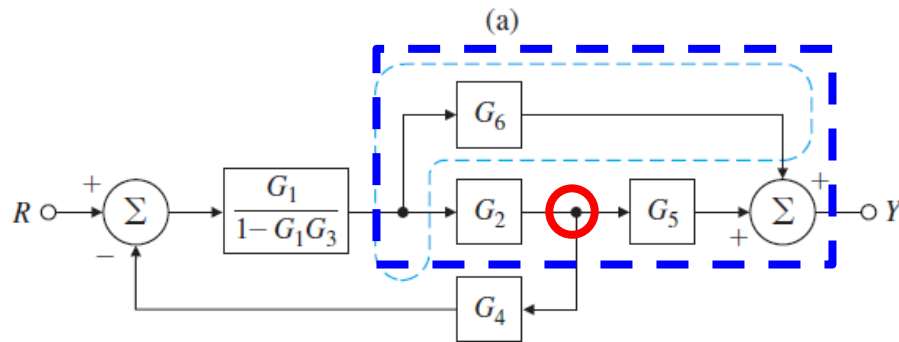
(c)



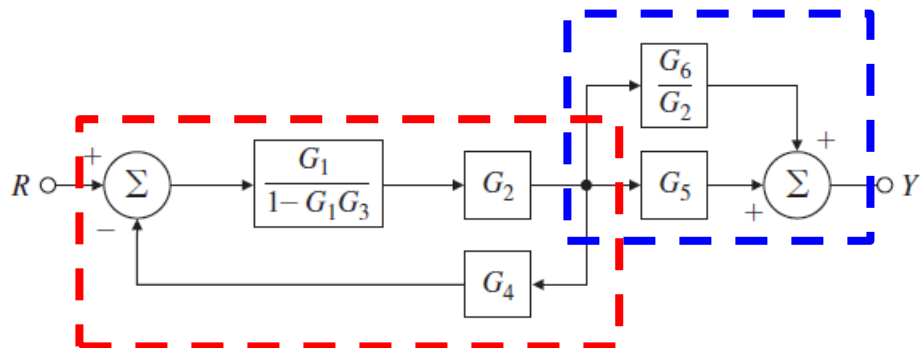
## Example 3.23: Transfer Function from the Block Diagram



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



(b)

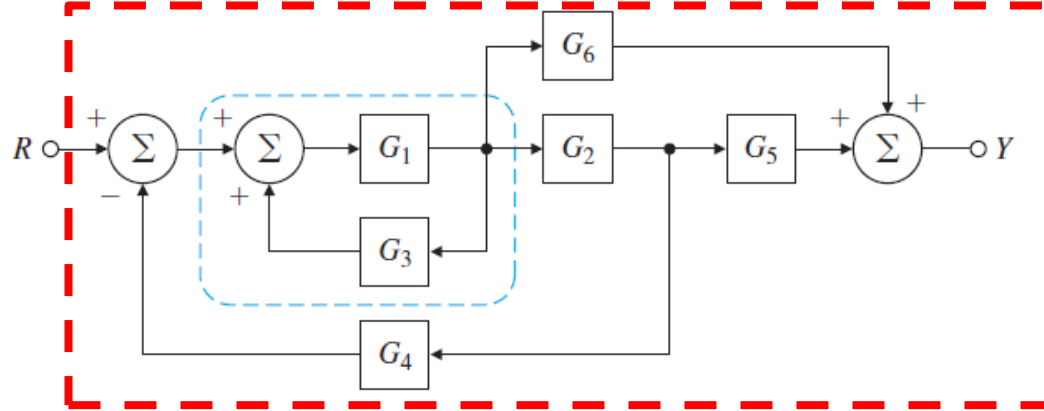


(c)

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

$$\Rightarrow \frac{\frac{G_1}{1 - G_1 G_3} G_2}{1 + \frac{G_1}{1 - G_1 G_3} G_2 G_4}$$

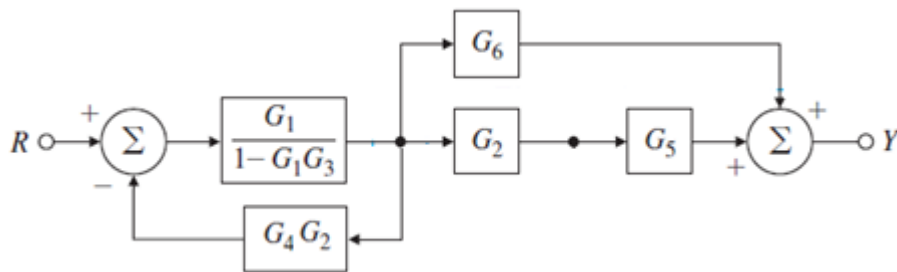
## Example 3.23: Transfer Function from the Block Diagram



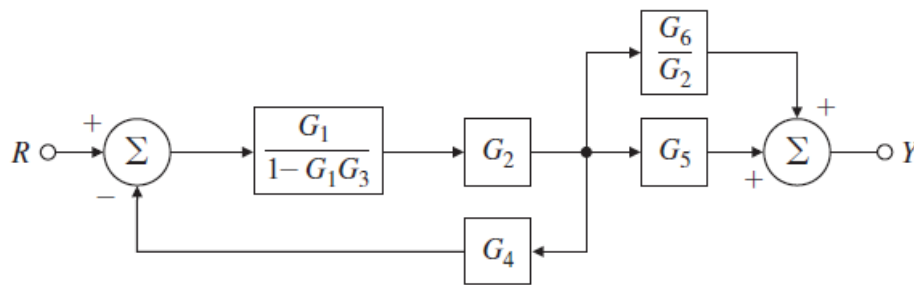
(a)

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

$$\frac{Y}{R} = \frac{\frac{G_1}{1 - G_1 G_3} G_2}{1 + \frac{G_1}{1 - G_1 G_3} G_2 G_4} \left( G_5 + \frac{G_6}{G_2} \right)$$



$$= \frac{G_1 G_2 G_5 + G_1 G_6}{1 - G_1 G_3 + G_1 G_2 G_4}$$

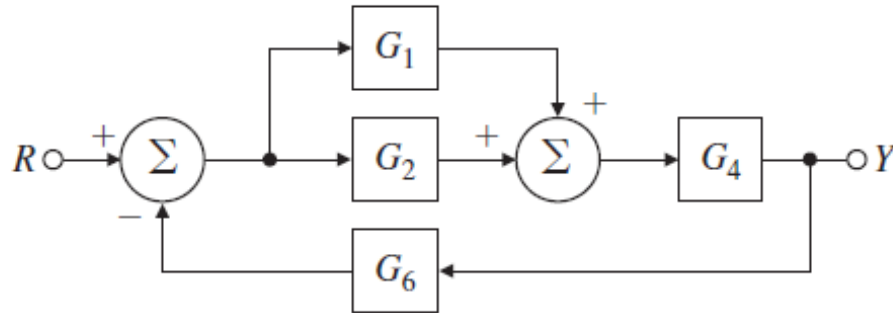


(c)

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

$$\Rightarrow \frac{\frac{G_1}{1 - G_1 G_3} G_2}{1 + \frac{G_1}{1 - G_1 G_3} G_2 G_4}$$

## 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
```

Continuous-time transfer function.