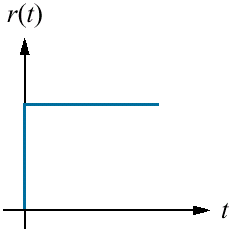
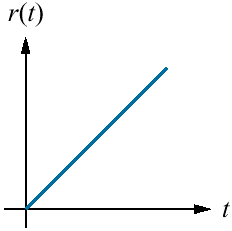
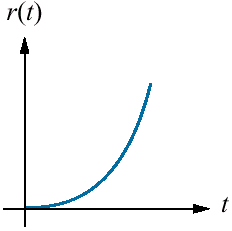


# Capítulo 7

## Erros de Estado Estacionário

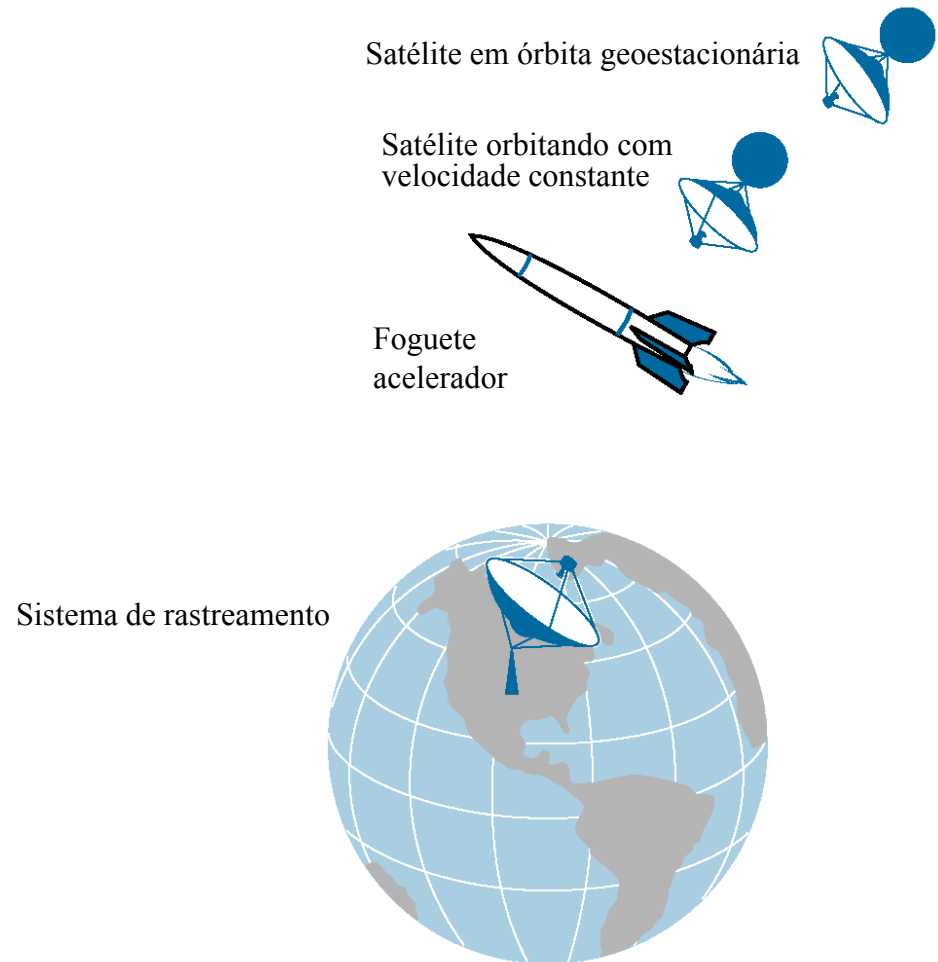
# Tabela 7.1

## Formas de onda dos sinais de teste para o cálculo dos erros de estado estacionário em sistemas de controle de posição

Forma de onda	Nome	Interpretação física	Função do tempo	Transformada de Laplace
	Degrau	Posição constante	1	$\frac{1}{s}$
	Rampa	Velocidade constante	$t$	$\frac{1}{s^2}$
	Parábola	Aceleração constante	$\frac{1}{2}t^2$	$\frac{1}{s^3}$

## Fig. 7.1

As entradas de teste para análise e projeto de erro de estado estacionário variam com o tipo de alvo

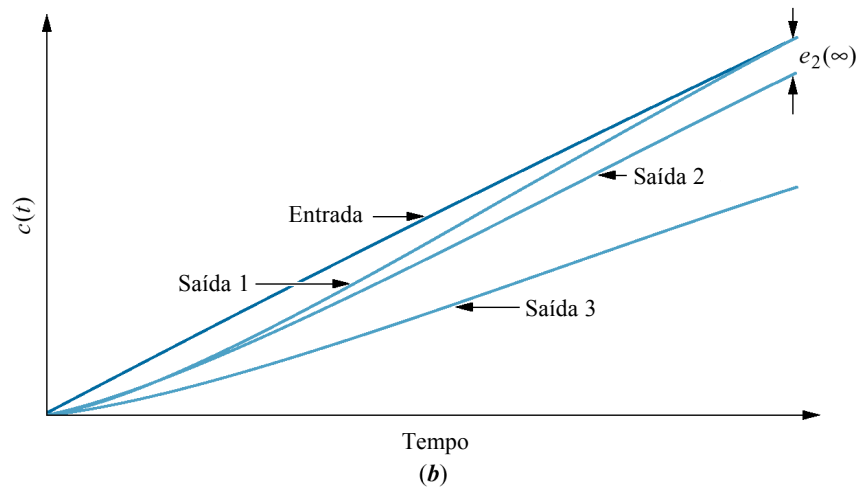
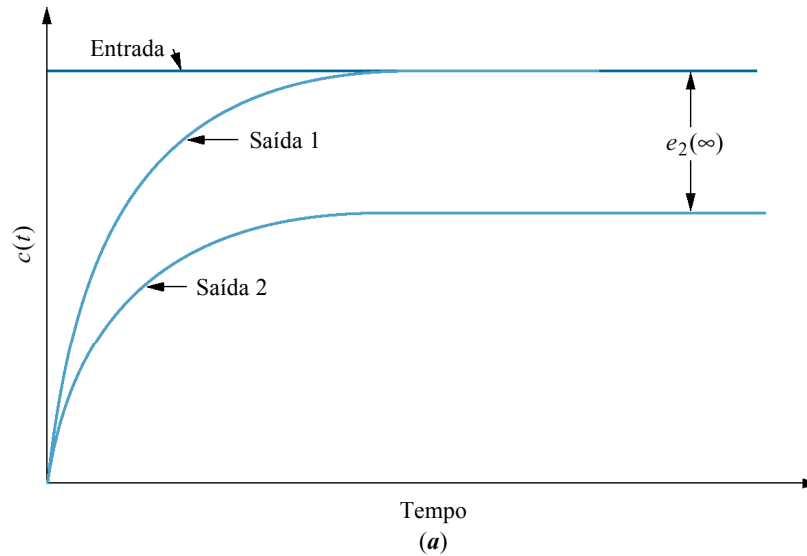


# Fig. 7.2

Erro de estado estacionário:

**a.** entrada em degrau;

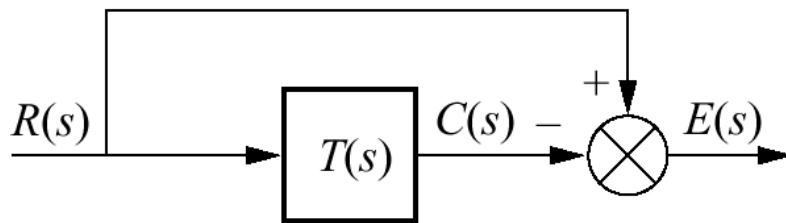
**b.** entrada em rampa



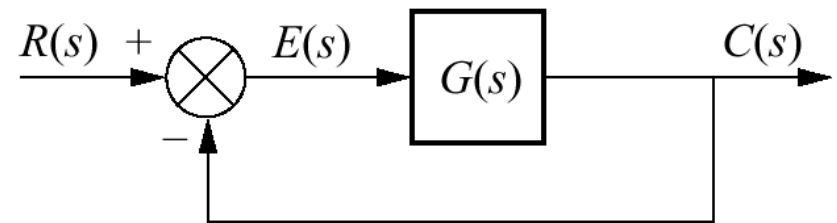
# Fig. 7.3

Erro de sistema de controle a malha fechada:

- a. representação geral;
- b. representação para sistemas com retroação unitária



(a)



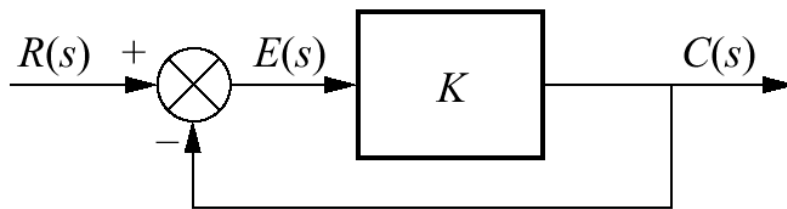
(b)

## Fig. 7.4

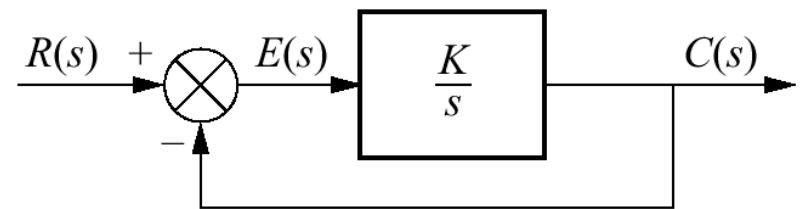
Sistemas com:

a. erro de estado estacionário finito para uma entrada em degrau;

b. erro de estado estacionário nulo para uma entrada em degrau



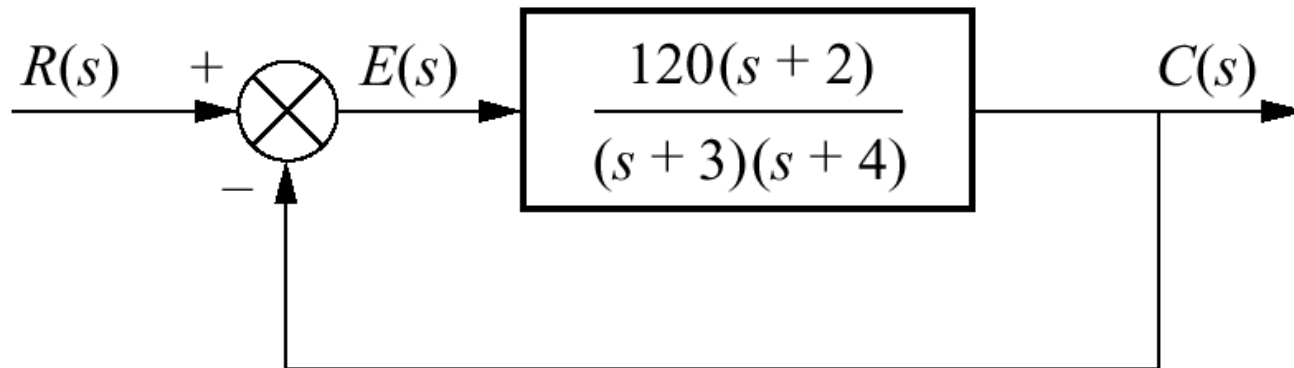
(a)



(b)

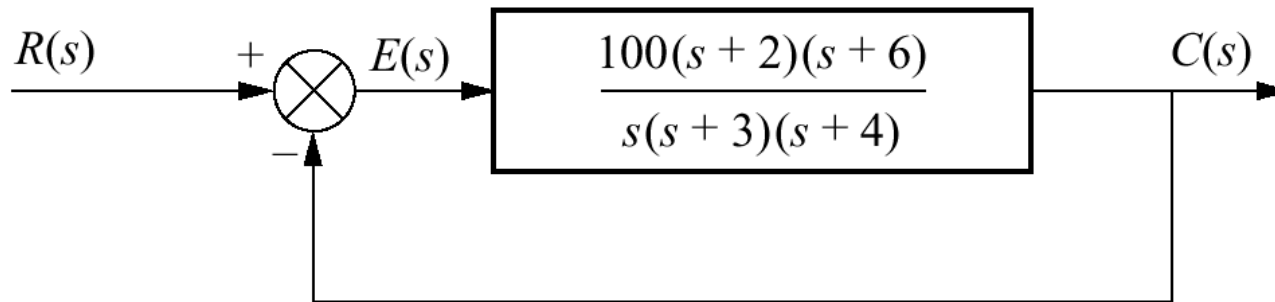
**Fig. 7.5**

Sistema de controle com retroação para o Exemplo 7.2



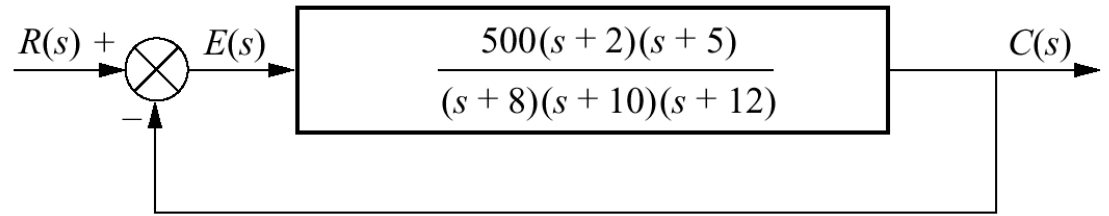
## Fig. 7.6

Sistema de controle com retroação para o Exemplo 7.3

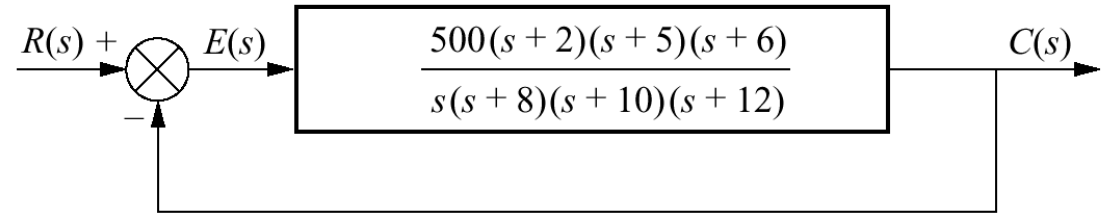




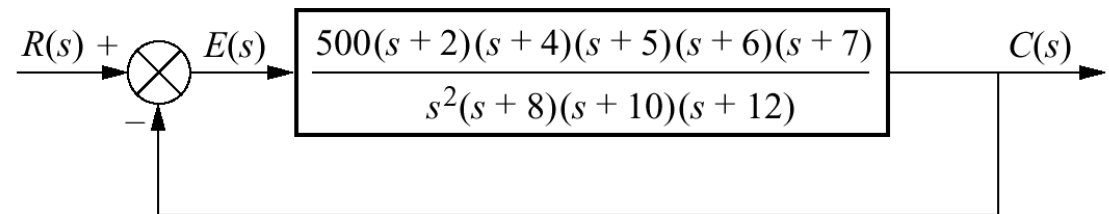
**Fig. 7.7**  
 Sistemas de controle com retroação para o Exemplo 7.4



(a)



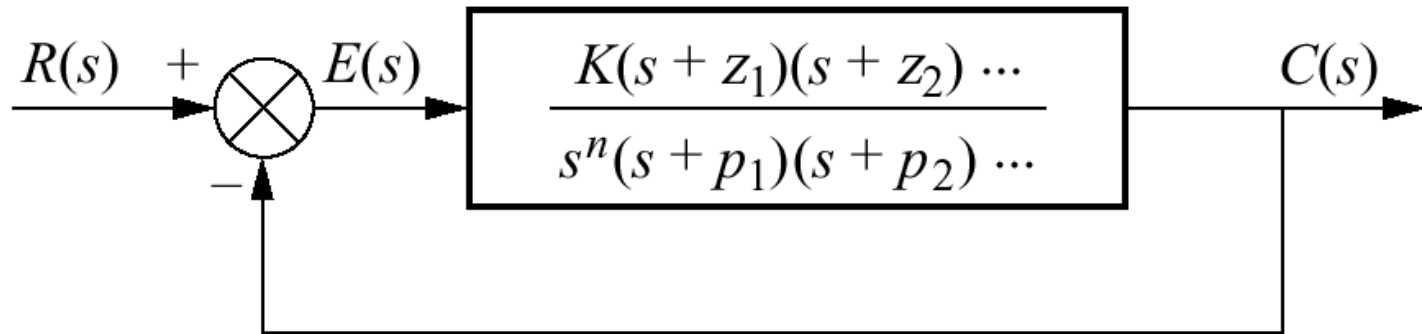
(b)



(c)

**Fig. 7.8**

Sistema de controle com retroação para definição do tipo de sistema



# Tabela 7.2

Relações entre entrada, tipo de sistema, constante de erro estático e erro de estado estacionário

Entrada	Expressão do erro estacionário	Tipo 0		Tipo 1		Tipo 2	
		Constante de erro estacionário	Erro	Constante de erro estacionário	Erro	Constante de erro estacionário	Erro
Degrau, $u(t)$	$\frac{1}{1 + K_p}$	$K_p =$ Constante	$\frac{1}{1 + K_p}$	$K_p = \infty$	0	$K_p = \infty$	0
Rampa, $tu(t)$	$\frac{1}{K_v}$	$K_v = 0$	$\infty$	$K_v =$ Constante	$\frac{1}{K_v}$	$K_v = \infty$	0
Parábola, $\frac{1}{2}t^2u(t)$	$\frac{1}{K_a}$	$K_a = 0$	$\infty$	$K_a = 0$	$\infty$	$K_a =$ Constante	$\frac{1}{K_a}$

## Fig. 7.9

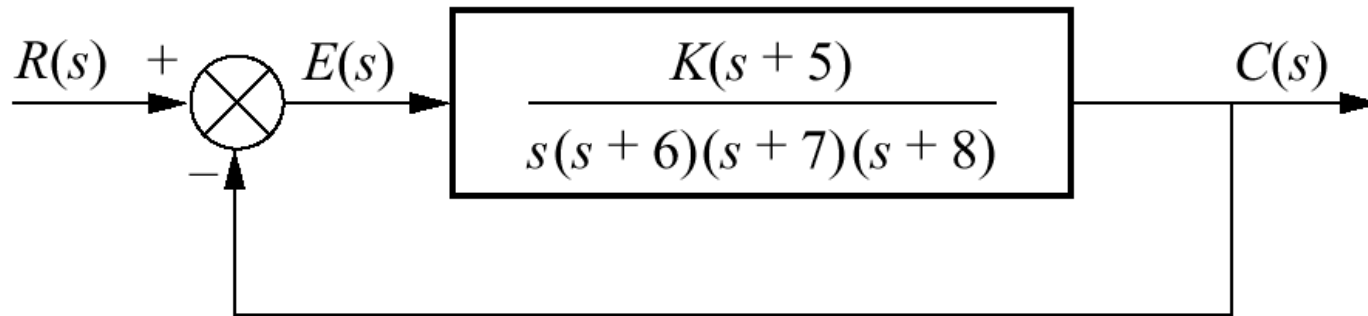
Robô usado na fabricação de memórias de acesso aleatório (RAMs) em semicondutor semelhantes às utilizadas nos computadores pessoais. O erro de estado estacionário constitui uma consideração importante no projeto de robôs para linhas de montagem.



© Westlight/ Charles O'Rear.

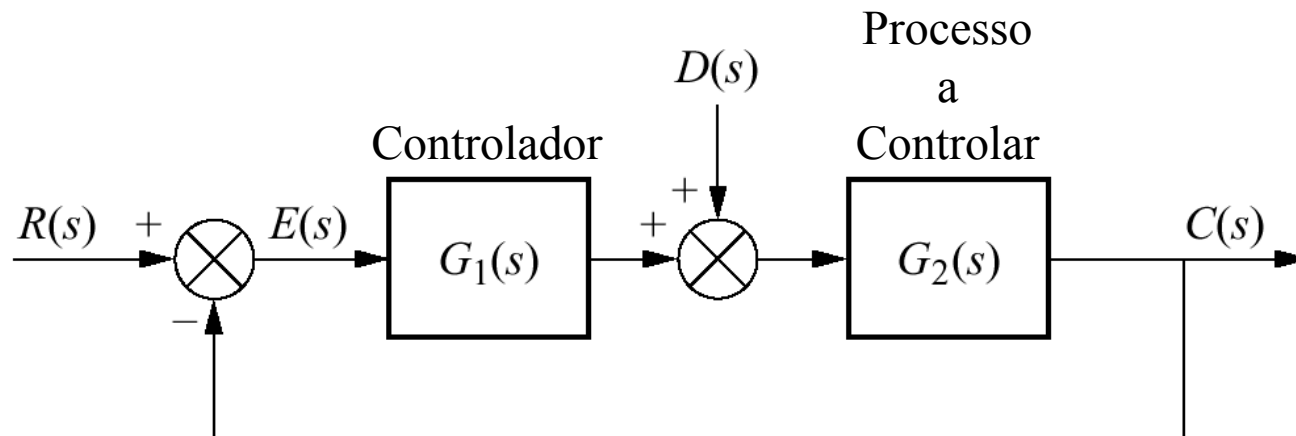
**Fig. 7.10**

Sistema de controle com retroação para o Exemplo 7.6



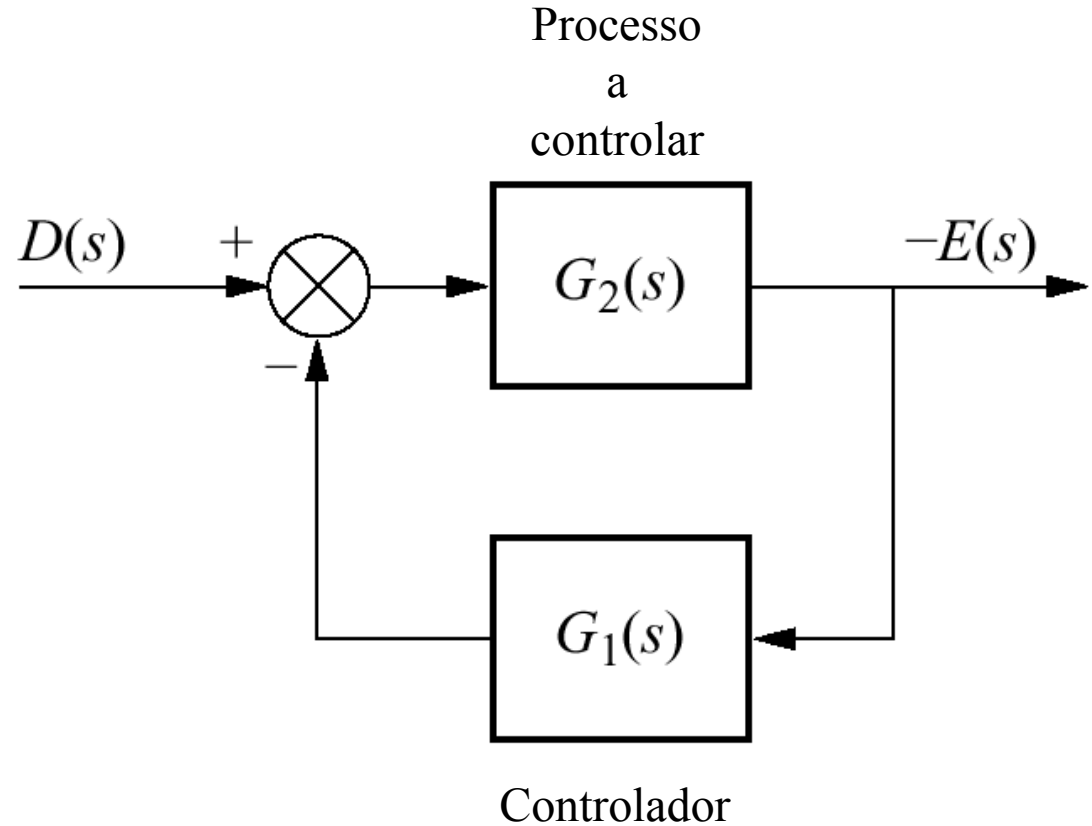
# Fig. 7.11

## Sistema de controle com retroação com perturbação



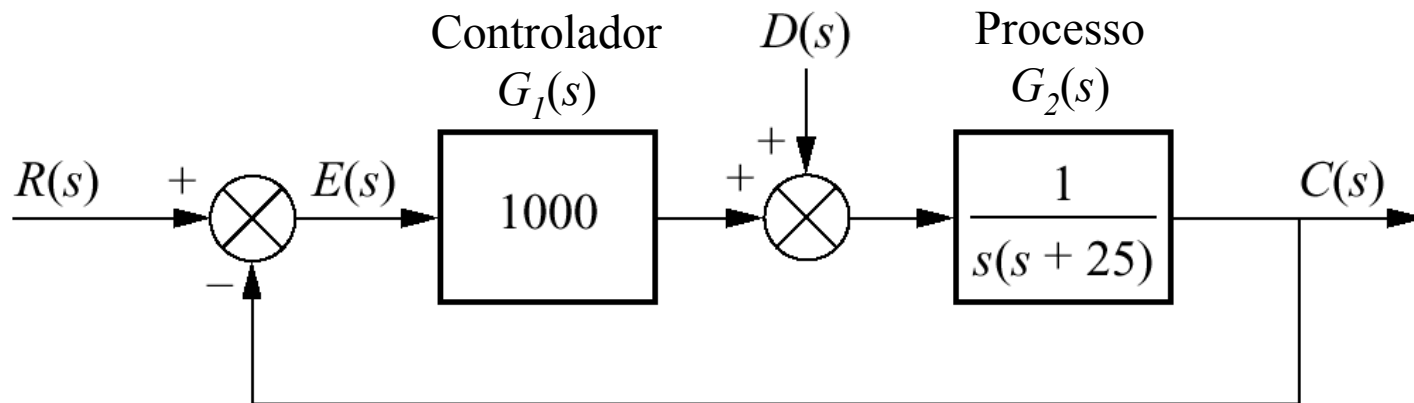
**Fig. 7.12**

Sistema da Fig. 7.11 rearrumado para mostrar a perturbação como entrada e o erro como saída, com  $R(s) = 0$



# Fig. 7.13

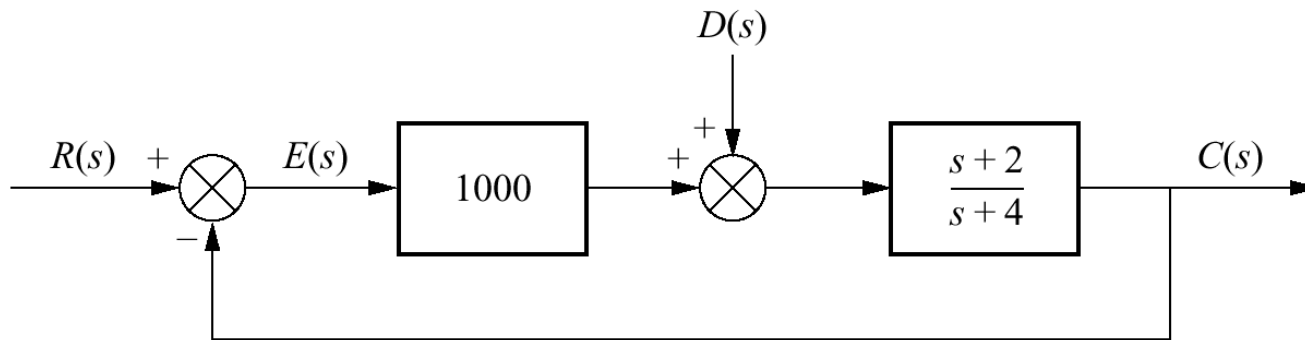
Sistema de controle com retroação para o Exemplo 7.7





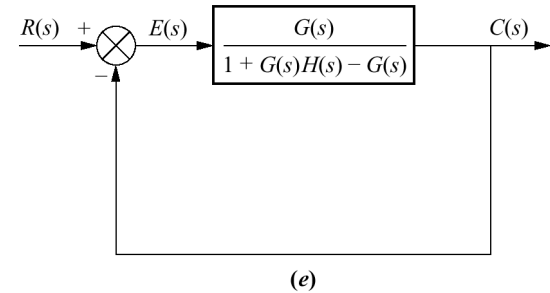
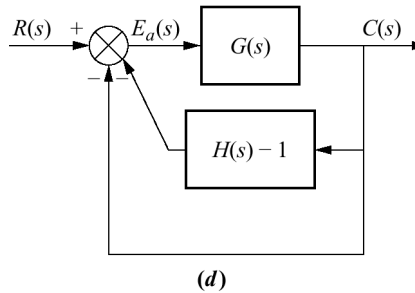
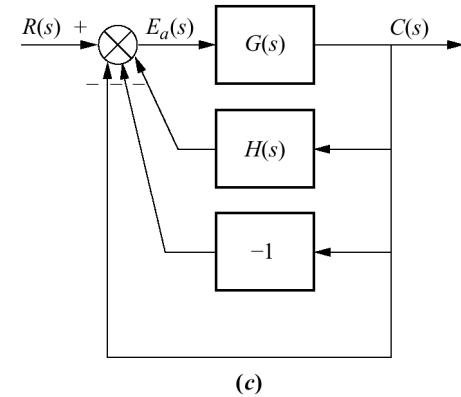
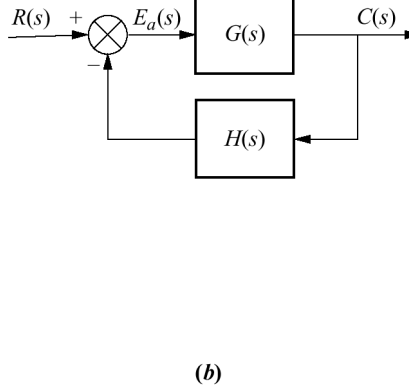
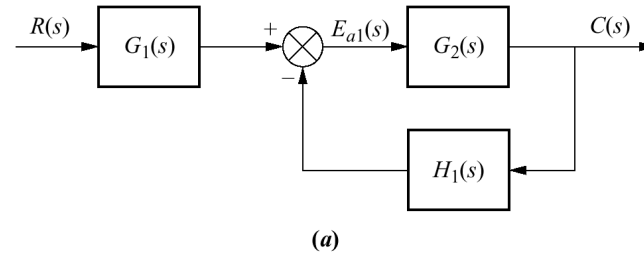
# Fig. 7.14

## Sistema para o Exercício de Avaliação 7.4



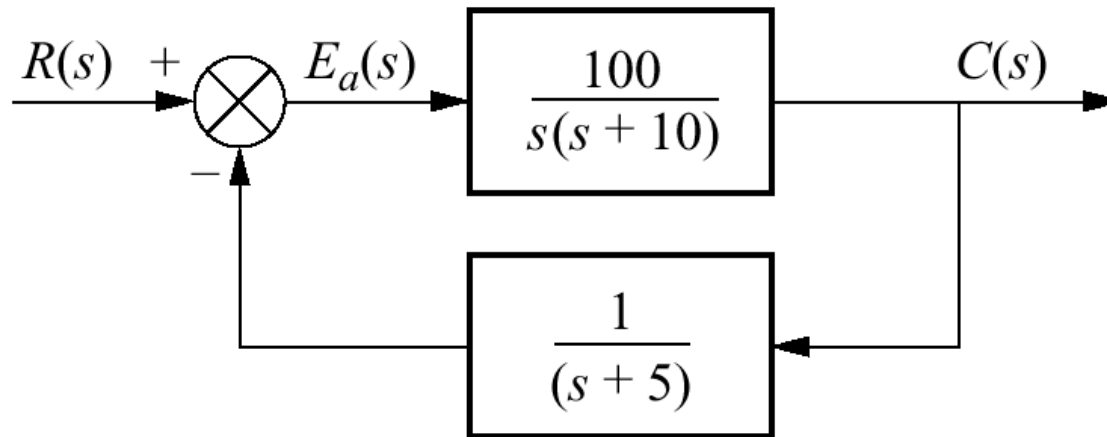
# Fig. 7.15

Formando um sistema com retroação unitária equivalente a partir de um sistema geral com retroação não-unitária



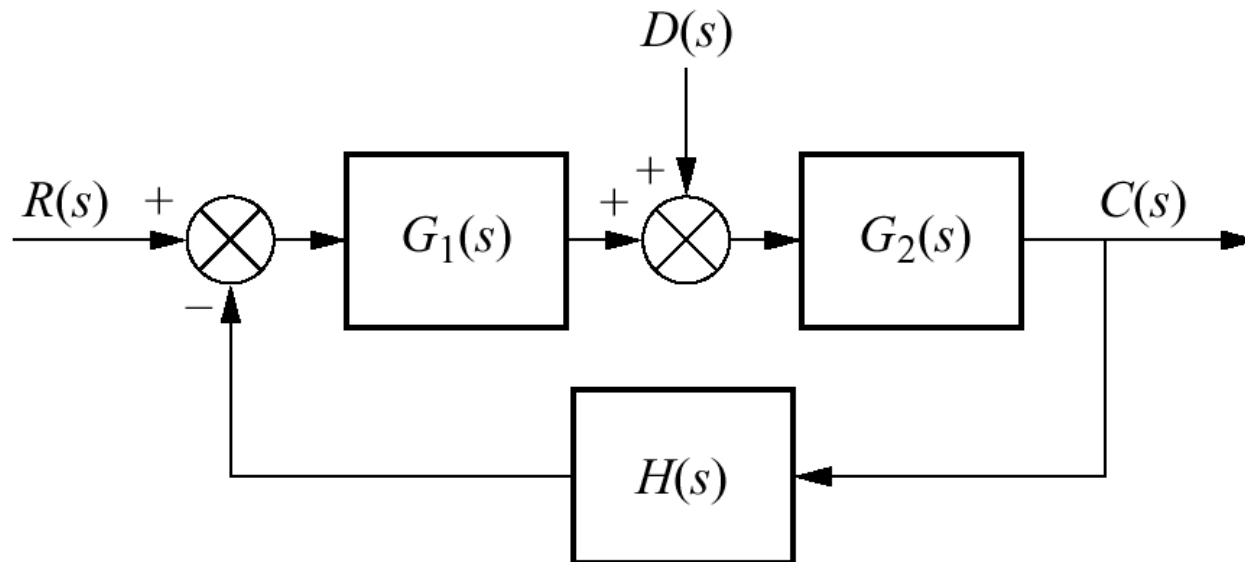
## Fig. 7.16

Sistema de controle com retroação não-unitária para o Exemplo 7.8



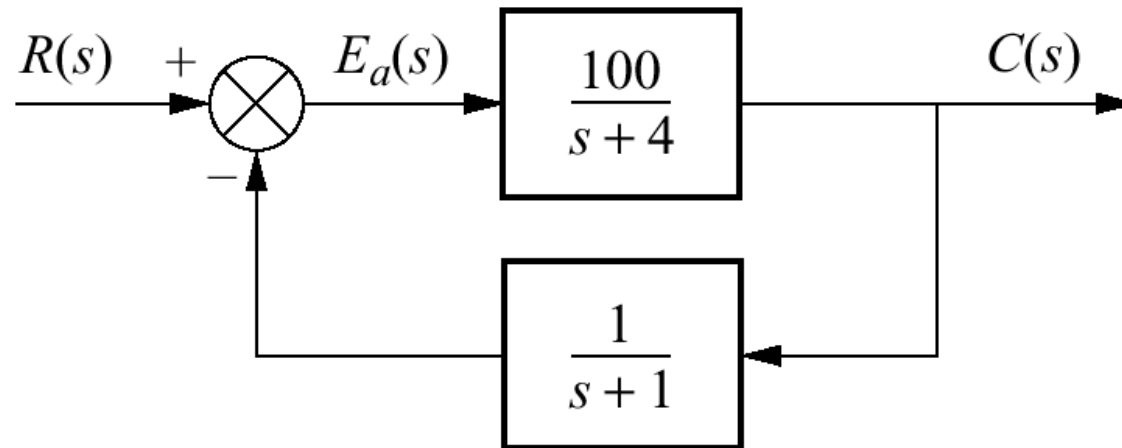
**Fig. 7.17**

Sistema de controle com retroação não-unitária com perturbação



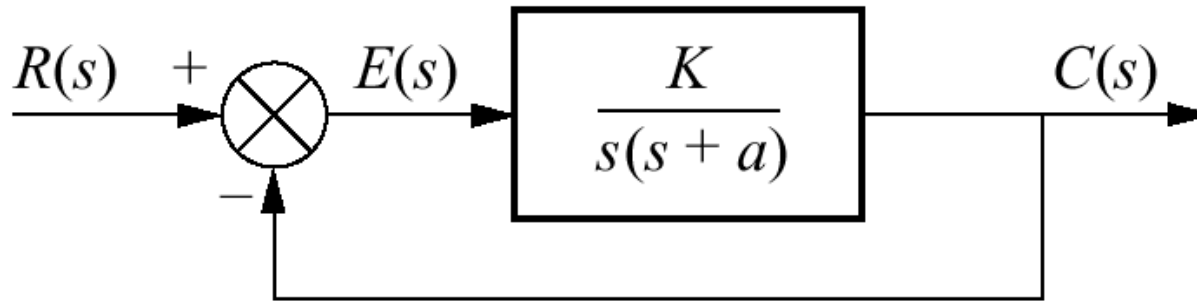
## Fig. 7.18

Sistema com retroação não-unitária para o Exercício de Avaliação 7.5



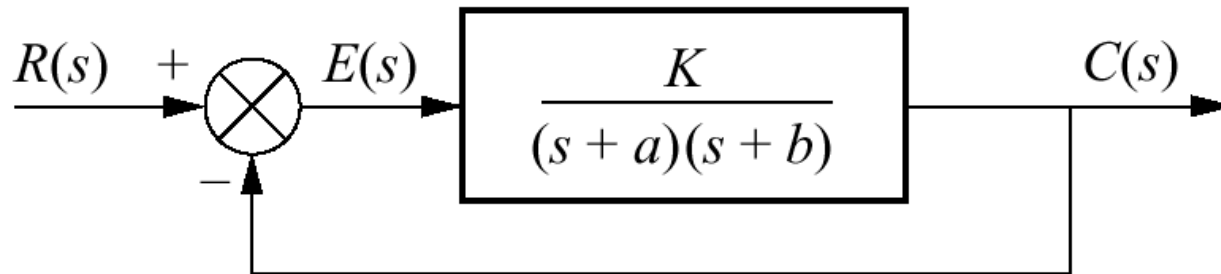
## Fig. 7.19

Sistema de controle com retroação não-unitária para os Exemplos 7.10 e 7.11



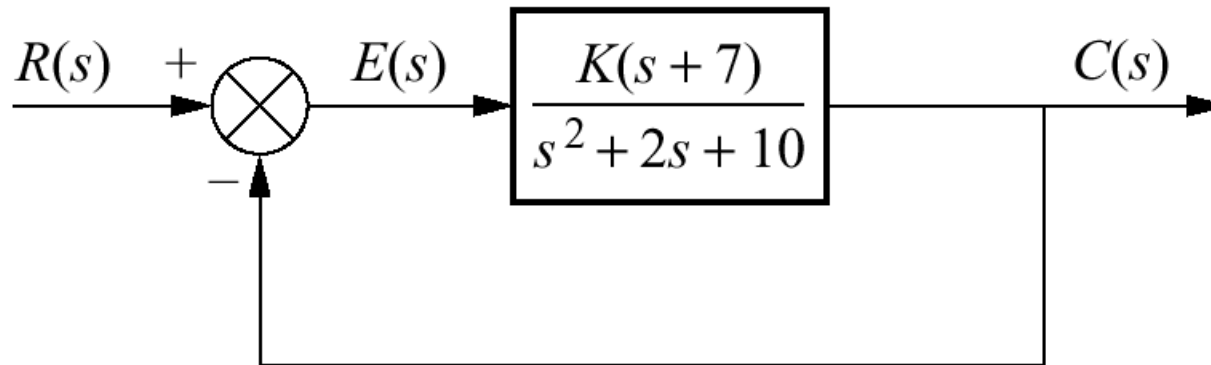
**Fig. 7.20**

Sistema de controle com retroação não-unitária para o Exemplo 7.12



# Fig. 7.21

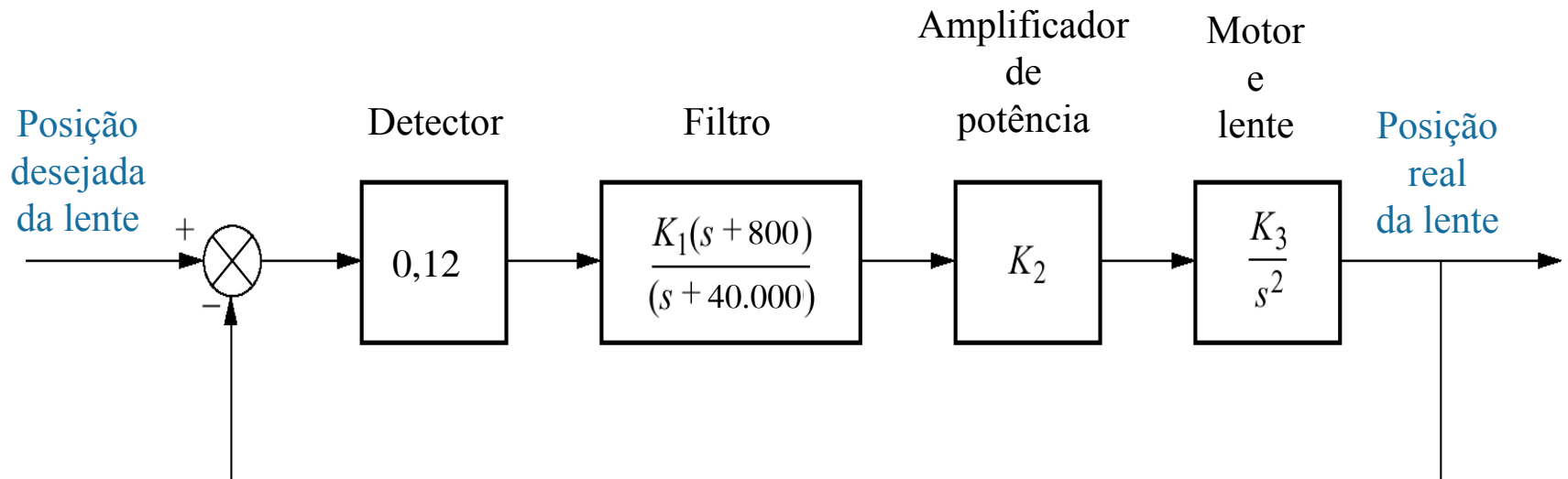
Sistema para o  
Exercício de  
Avaliação 7.6



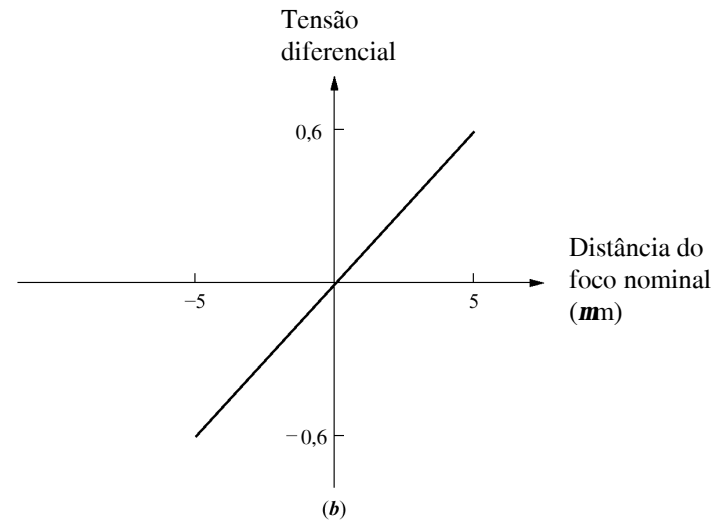
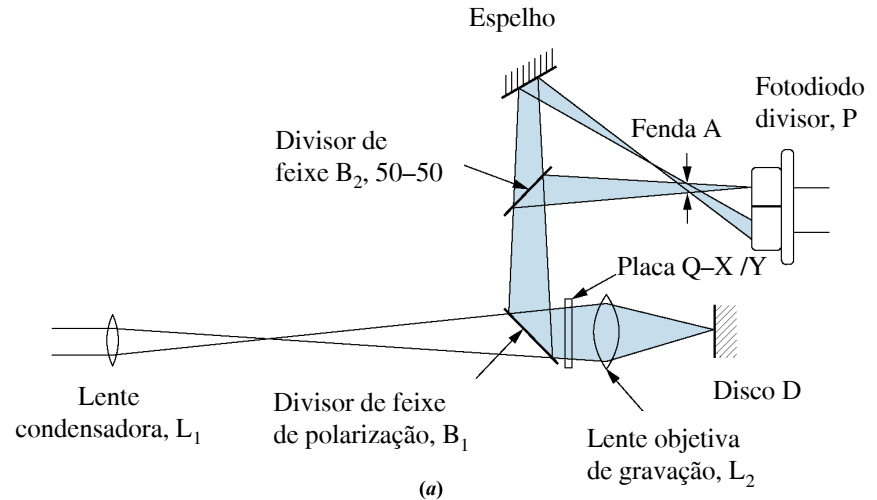


# Fig. 7.22

Gravação de videodisco a laser:  
sistema de controle de foco do  
feixe de gravação



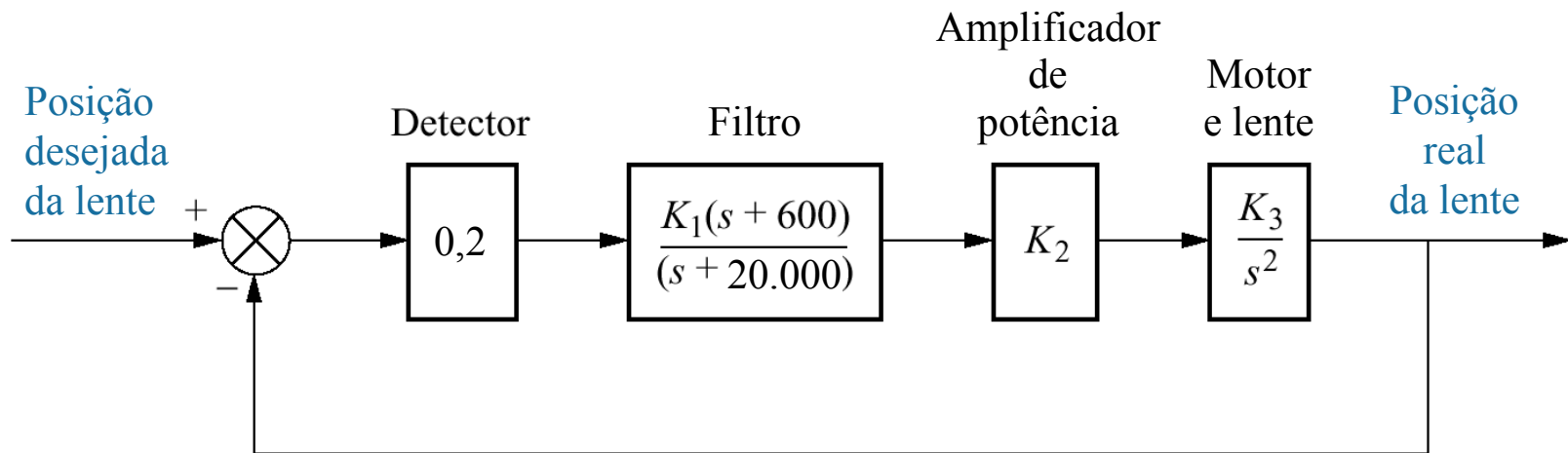
**Fig. 7.23**  
 Gravação de videodisco a laser:  
**a.** óptica do detector de foco;  
**b.** função de transferência linearizada para o detector de foco

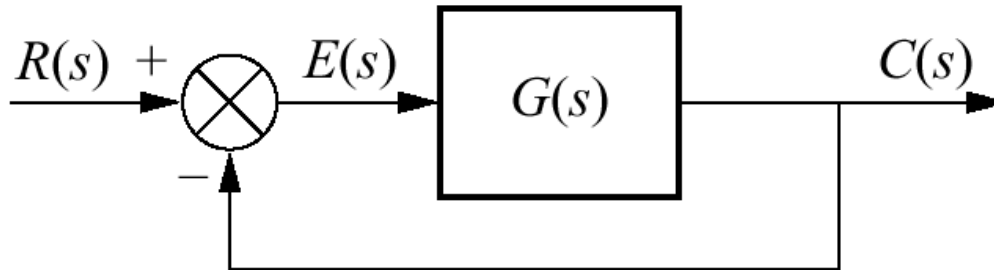


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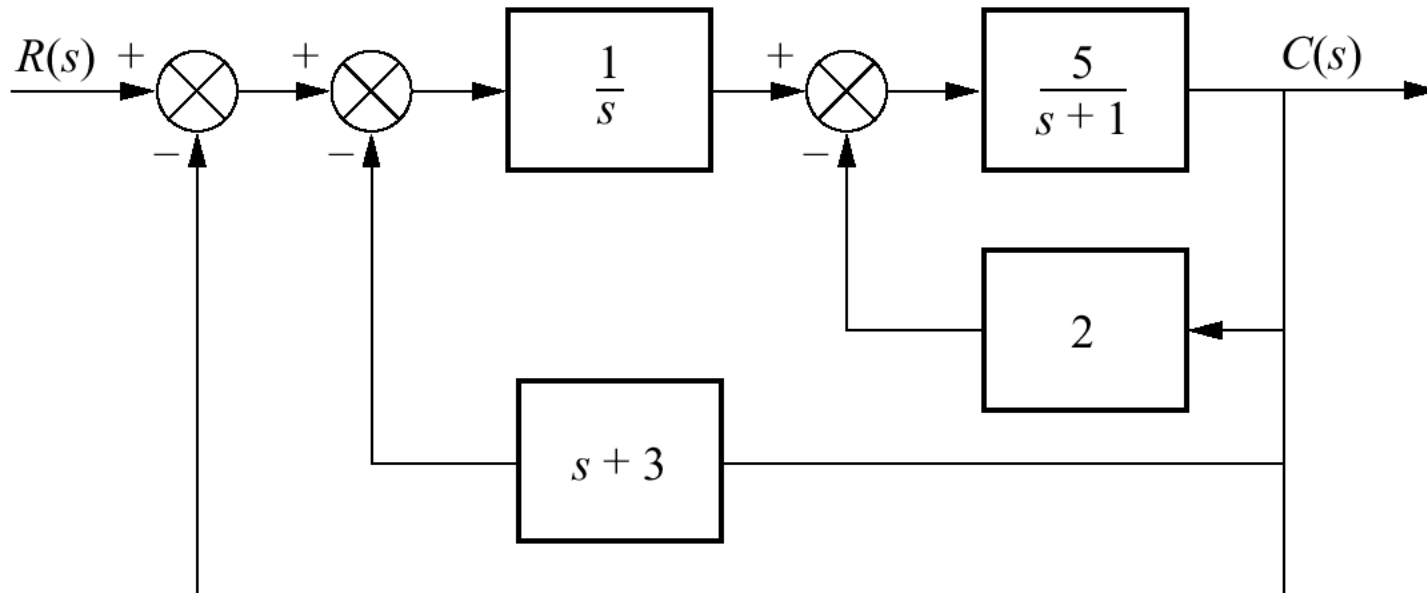
## Fig. 7.24

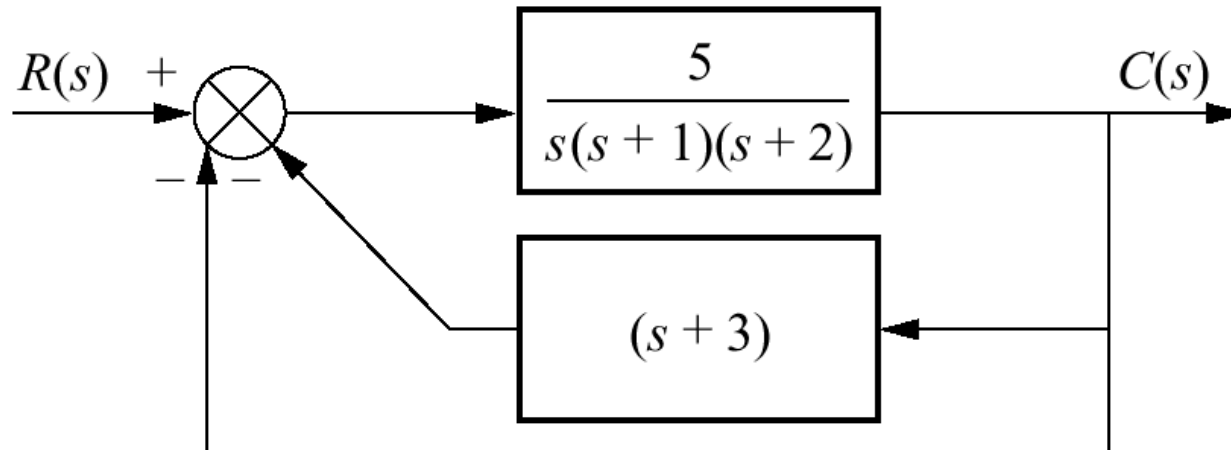
### Sistema de foco de gravação em videodisco a laser



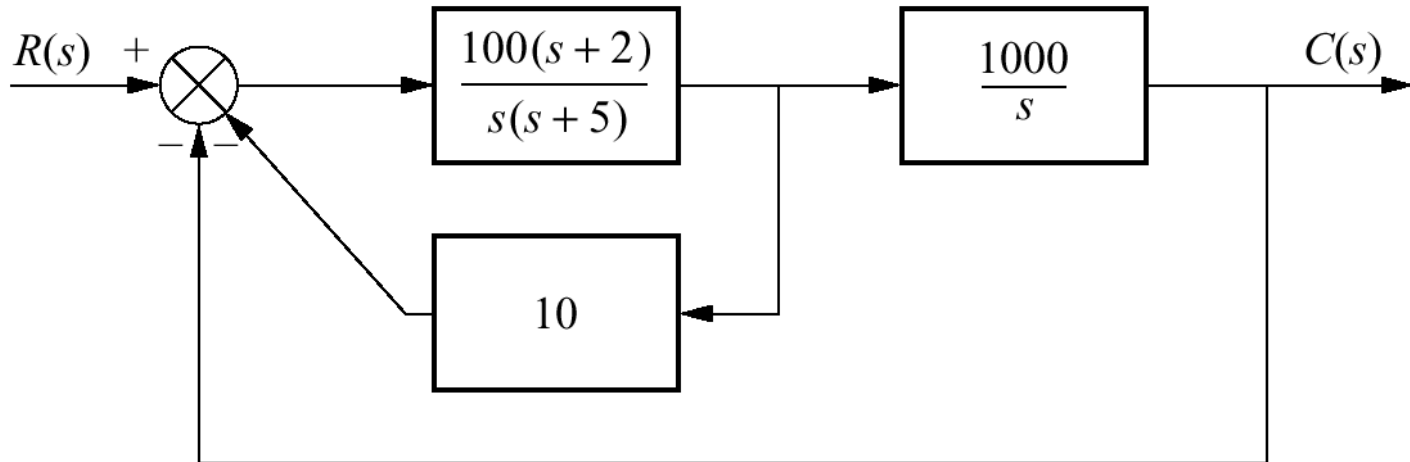
**Fig. P7.1**

**Fig. P7.2**



**Fig. P7.3**

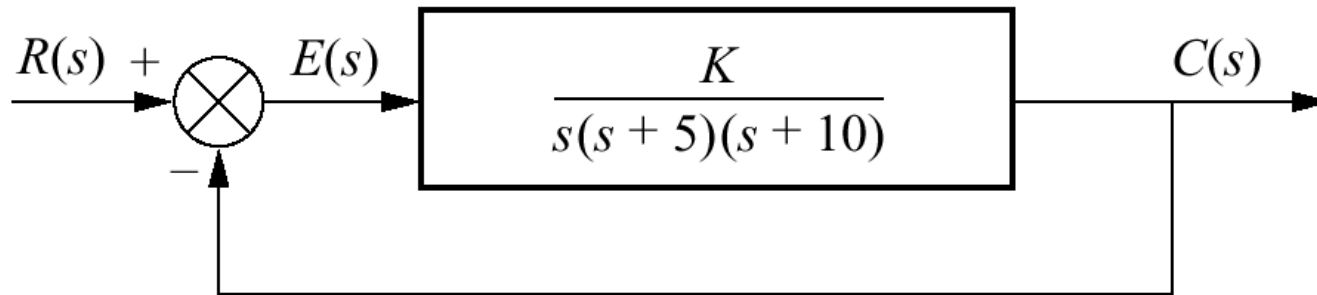
**Fig. P7.4**



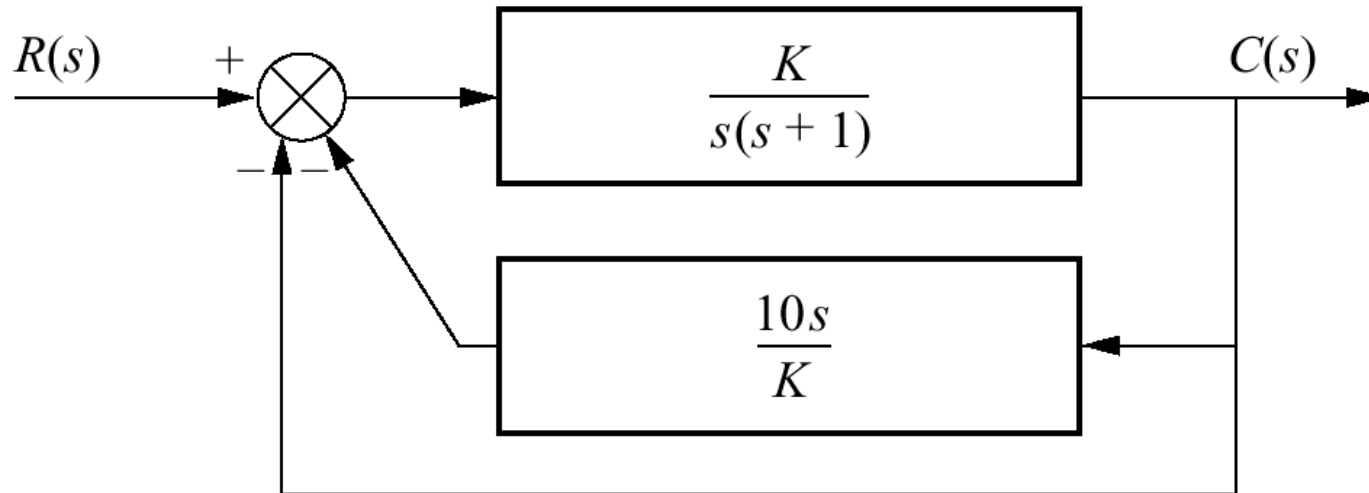
**Tabela P7.1**

		Tipo		
		0	1	2
Entrada	Degrau			
	Rampa			
	Parábola			

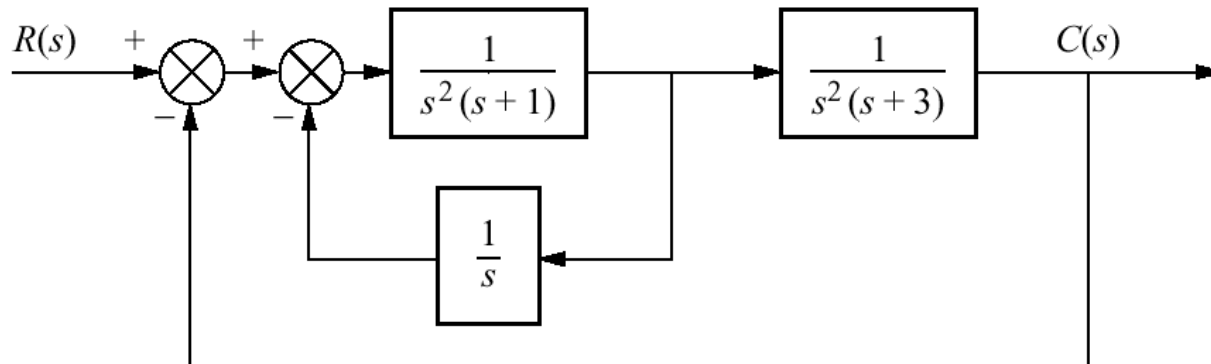


**Fig. P7.5**

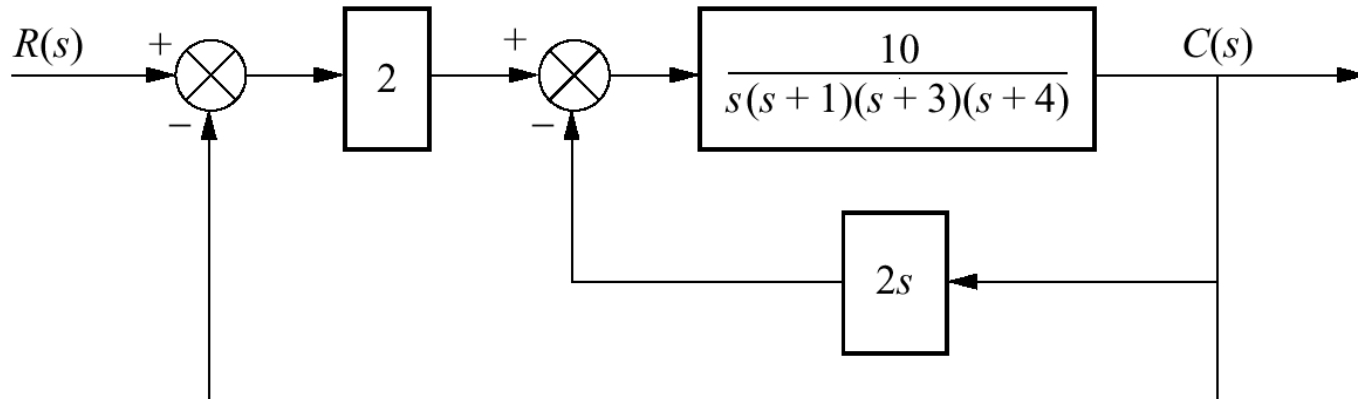
**Fig. P7.6**



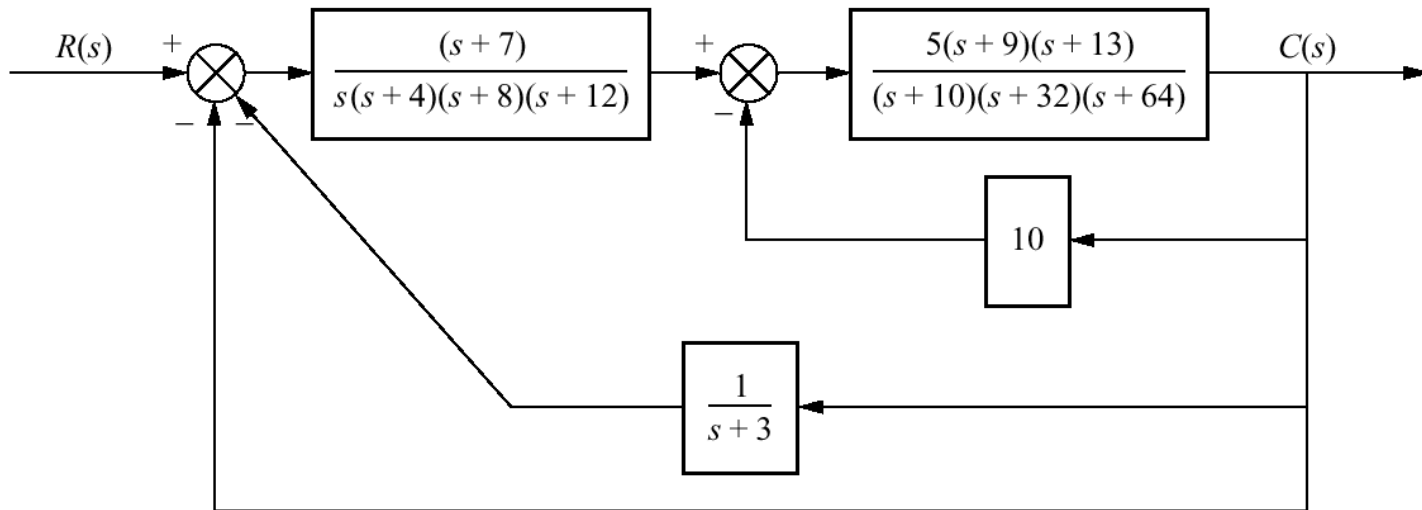
**Fig. P7.7**



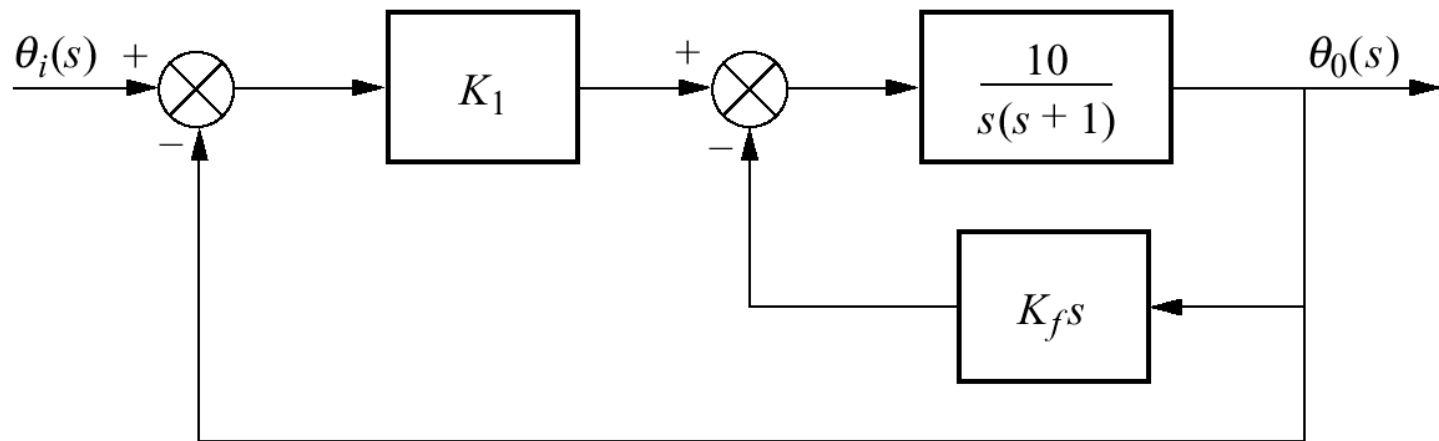
**Fig. P7.8**



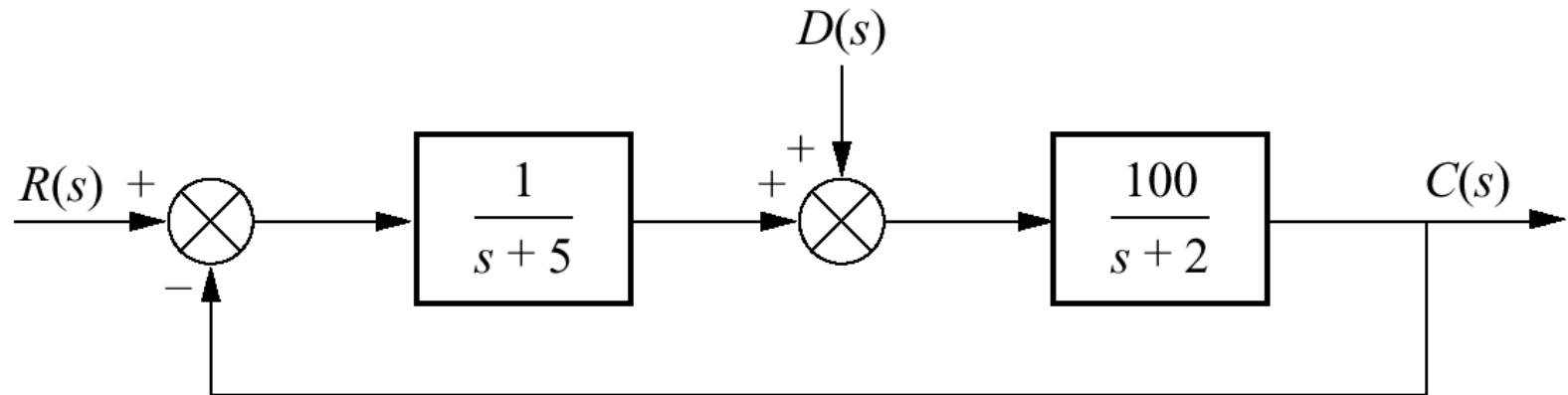
**Fig. P7.9**



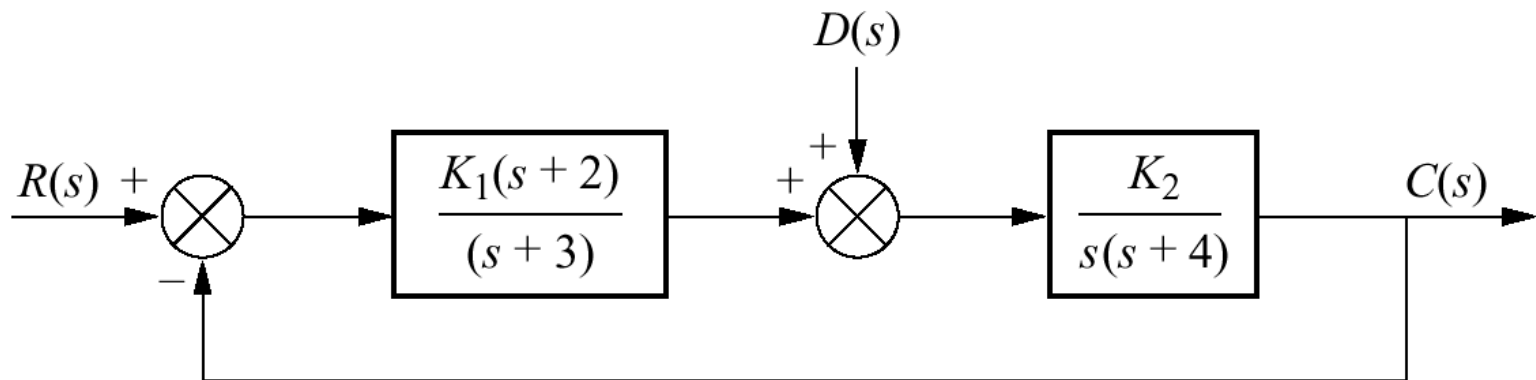
**Fig. P7.10**



**Fig. P7.11**

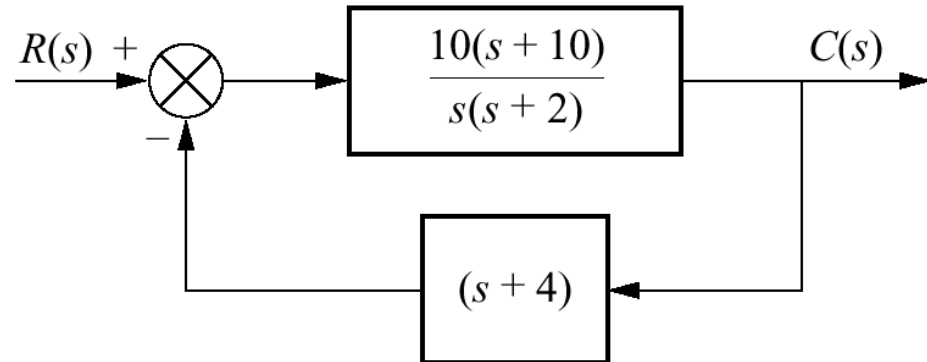


**Fig. P7.12**

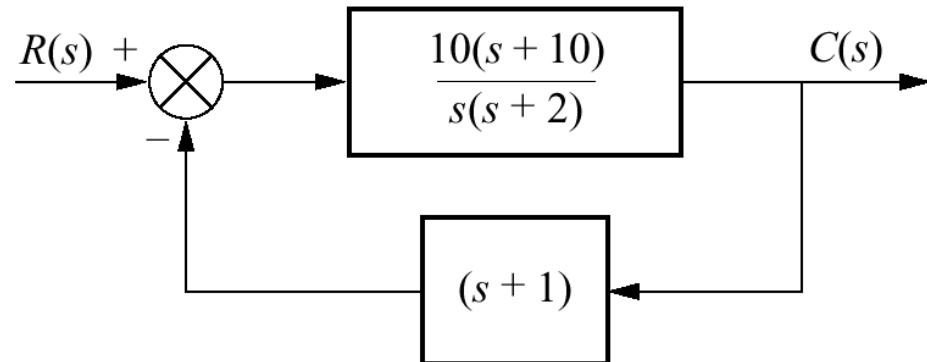




**Fig. P7.13**  
 Sistemas de controle com retroação não-unitária

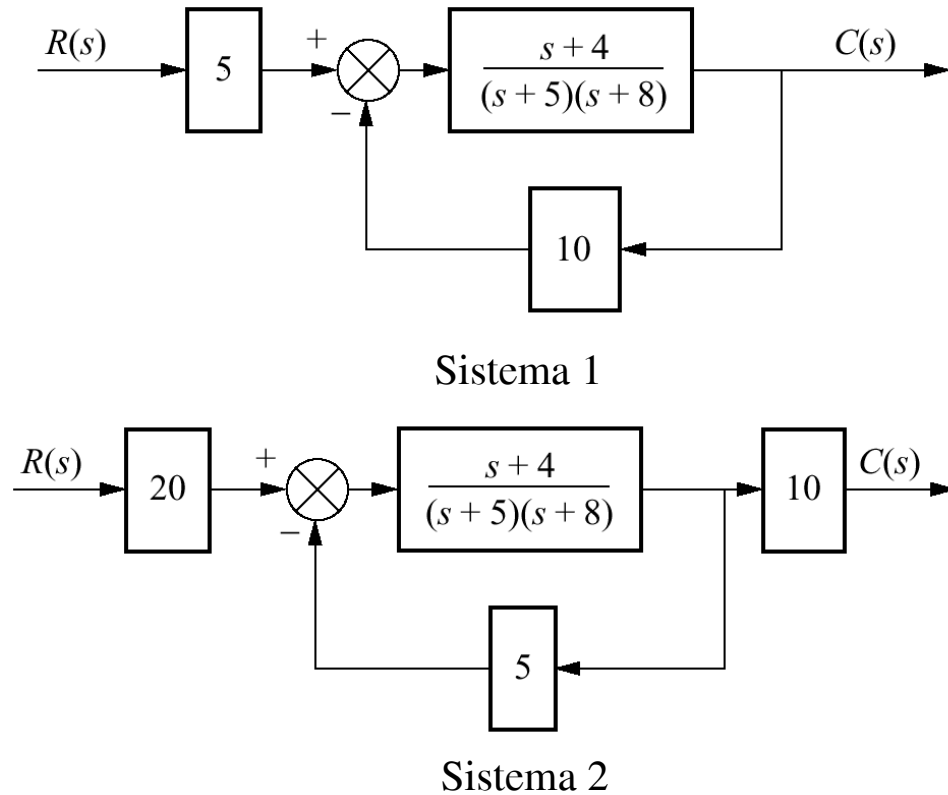


Sistema 1

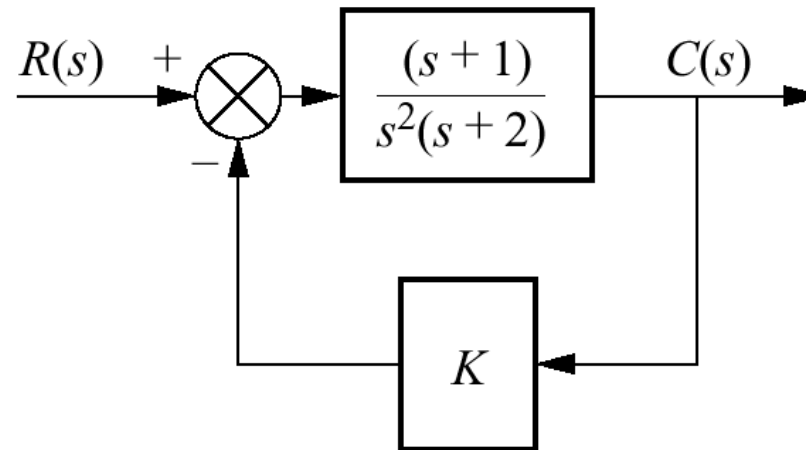


Sistema 2

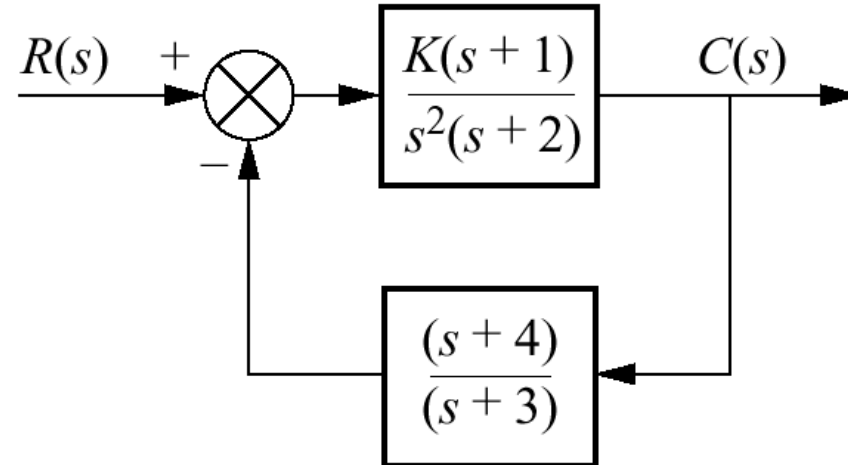
# Fig. P7.14

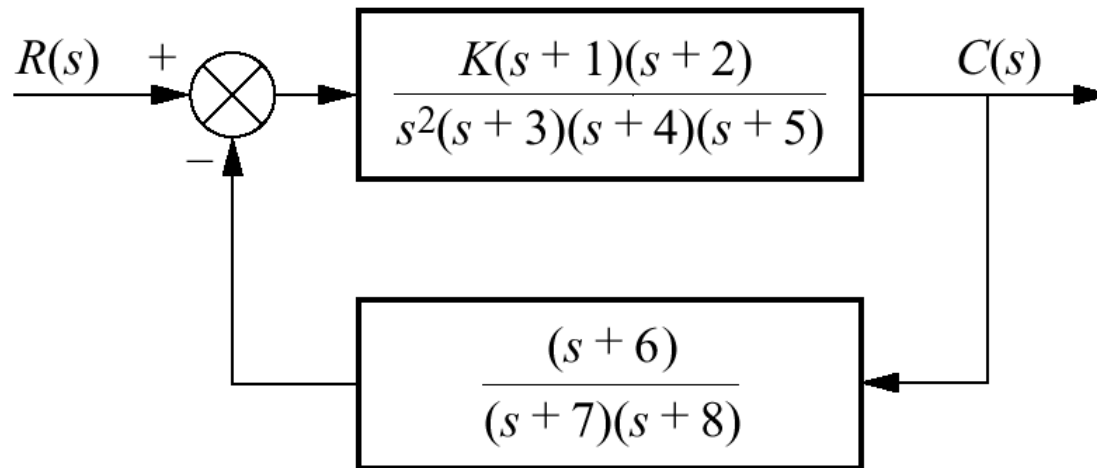


**Fig. P7.15**



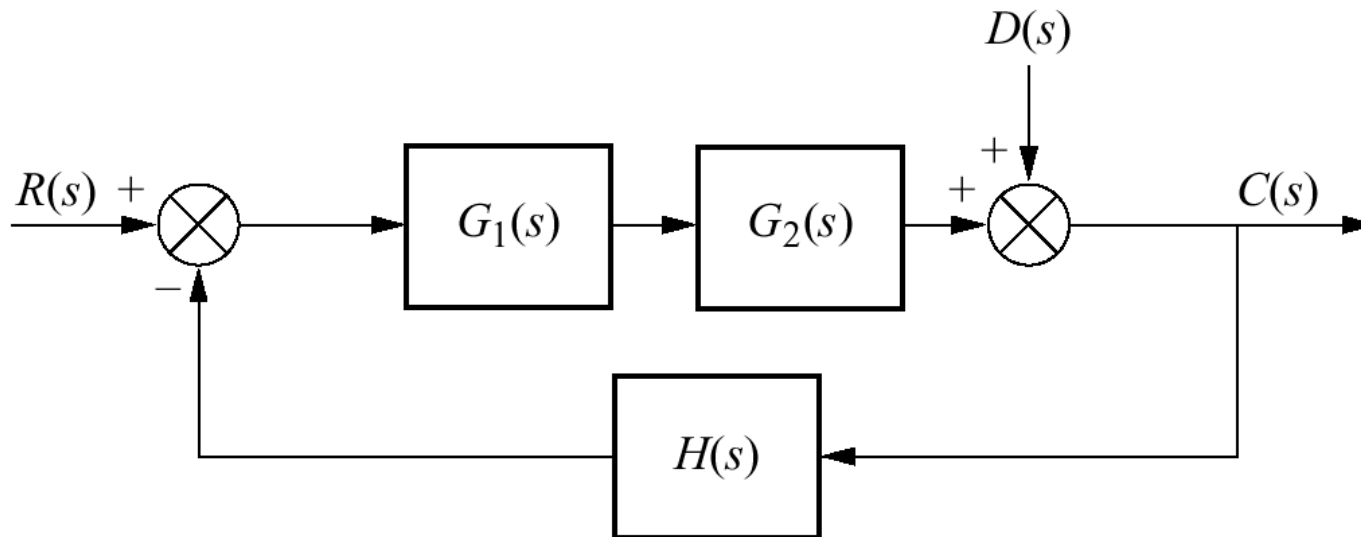
**Fig. P7.16**

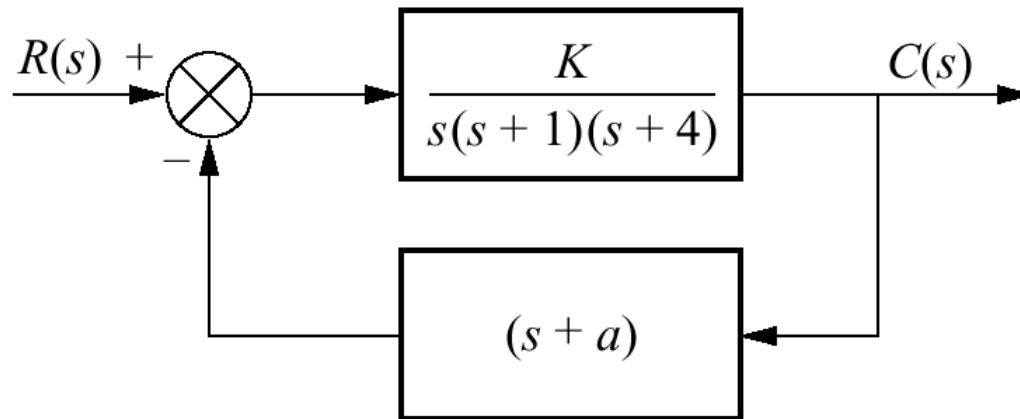


**Fig. P7.17**

# Fig. P7.18

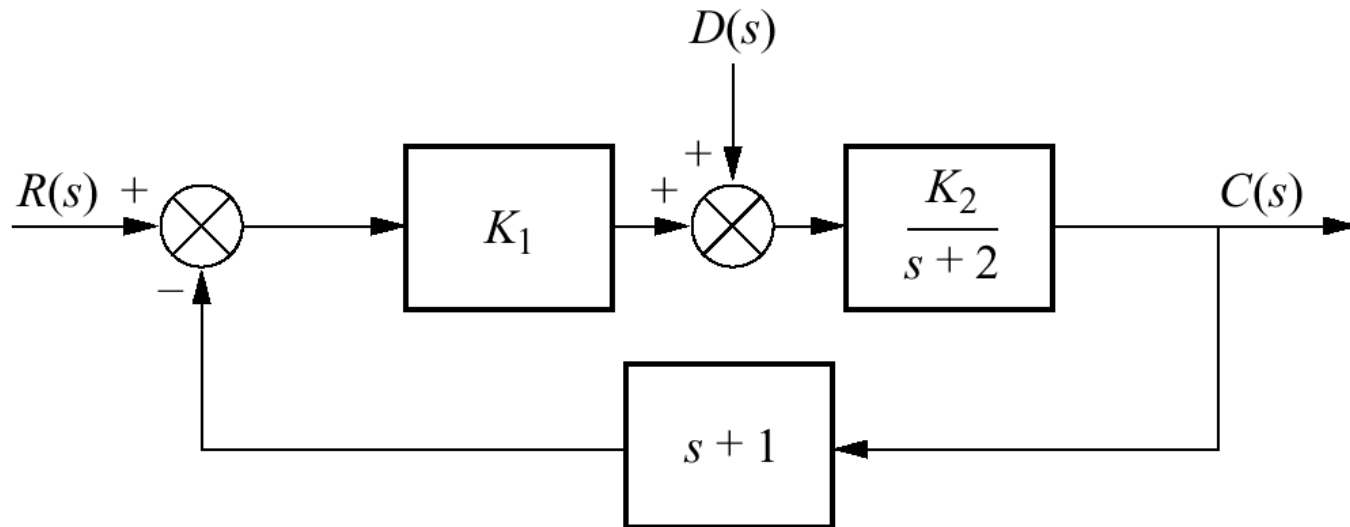
Sistema com entrada e perturbação



**Fig. P7.19**

# Fig. P7.20

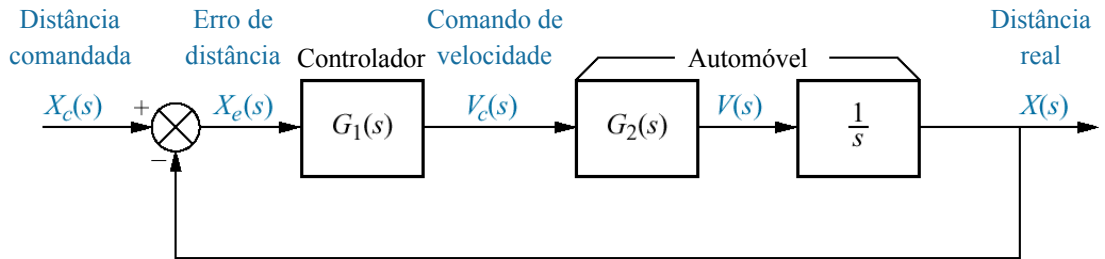
Sistema com entrada e perturbação



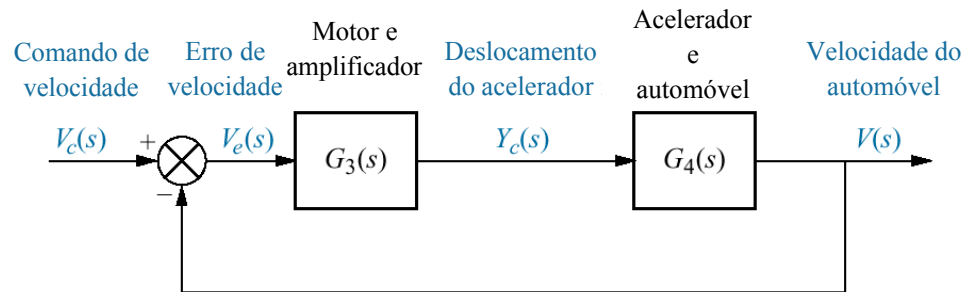


# Fig. P7.21

Sistema de direção de um automóvel  
**a.** sistema de controle de deslocamento;  
**b.** malha de controle de velocidade



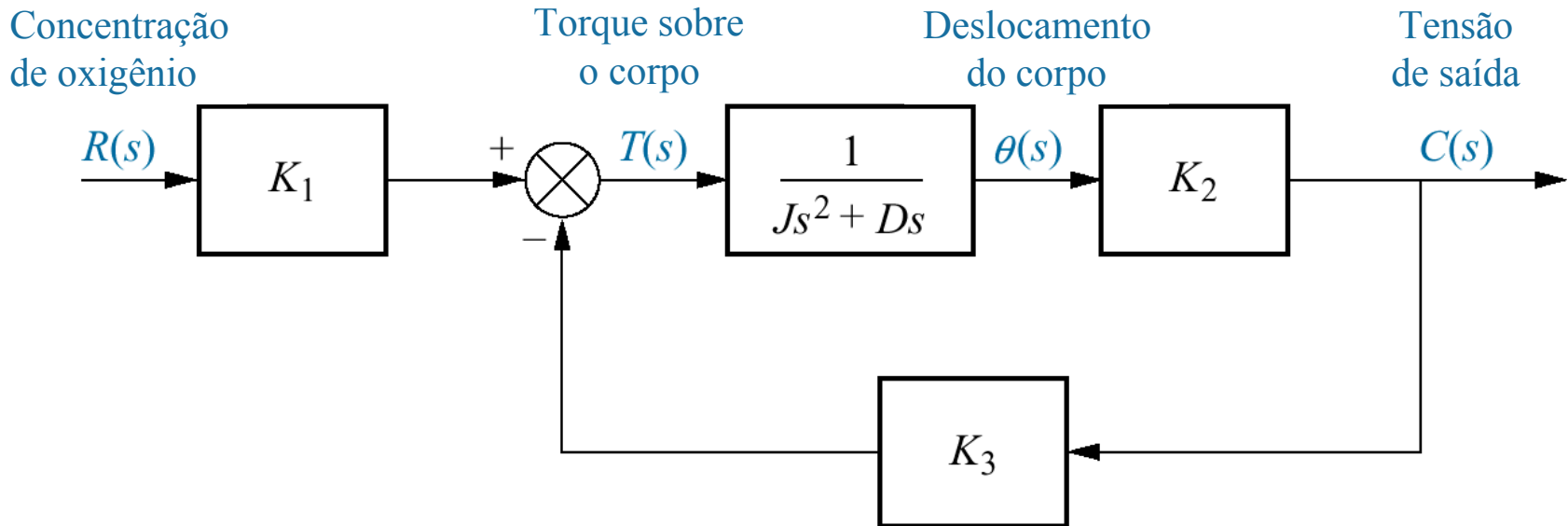
(a)



(b)

## Fig. P7.22

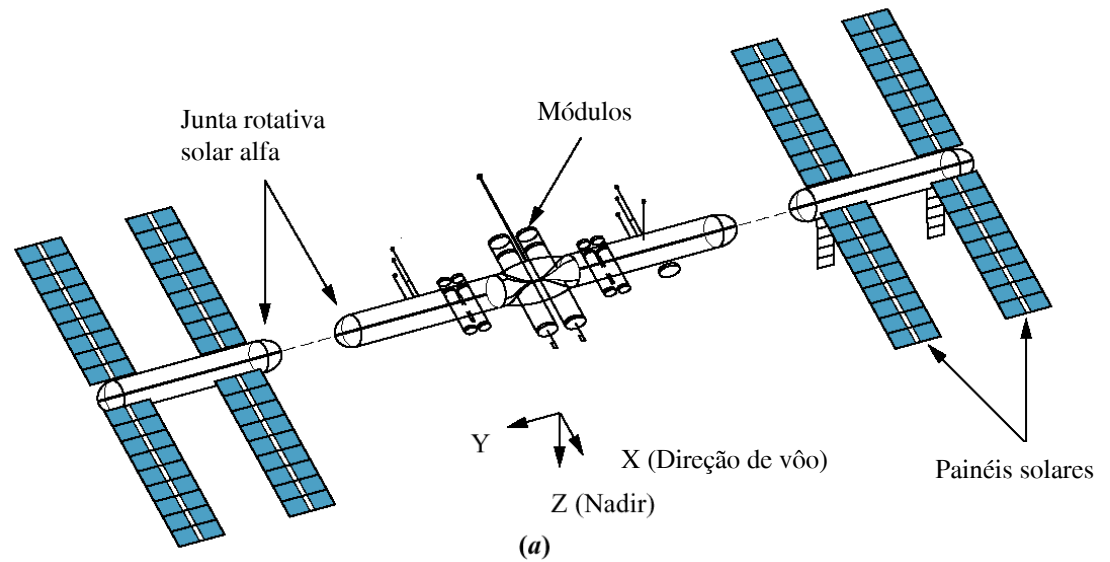
Diagrama de blocos de um analisador paramagnético de oxigênio



# Fig. P7.23

Estação espacial  
Freedom:

a. configuração  
(A figura continua)



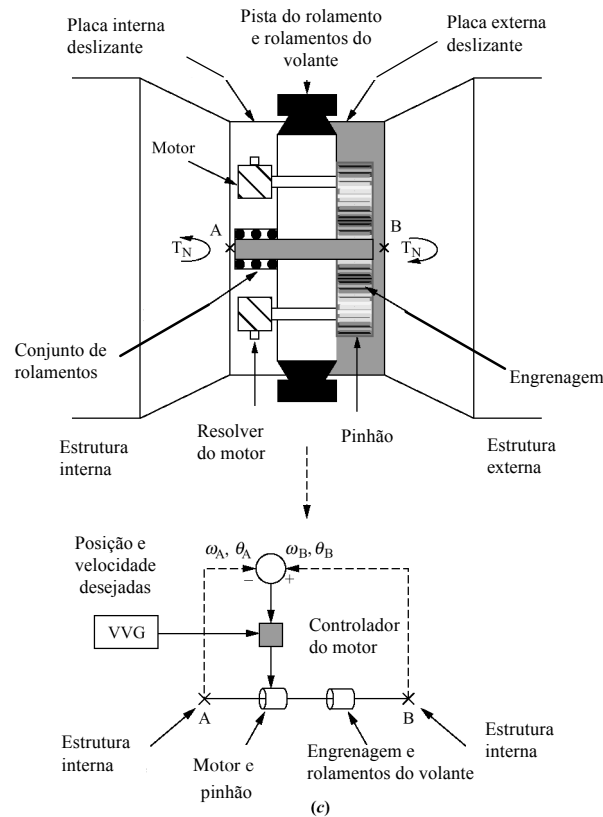
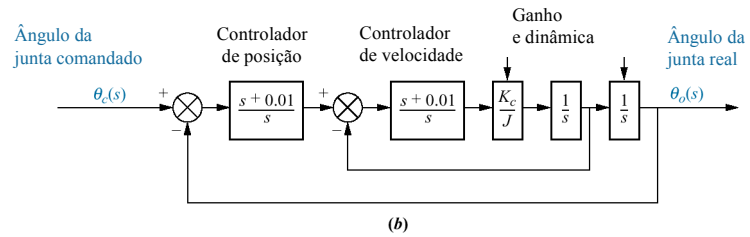
© 1992 AIAA.

# Fig. P7.23

(continuação)

b. diagrama de blocos simplificado;

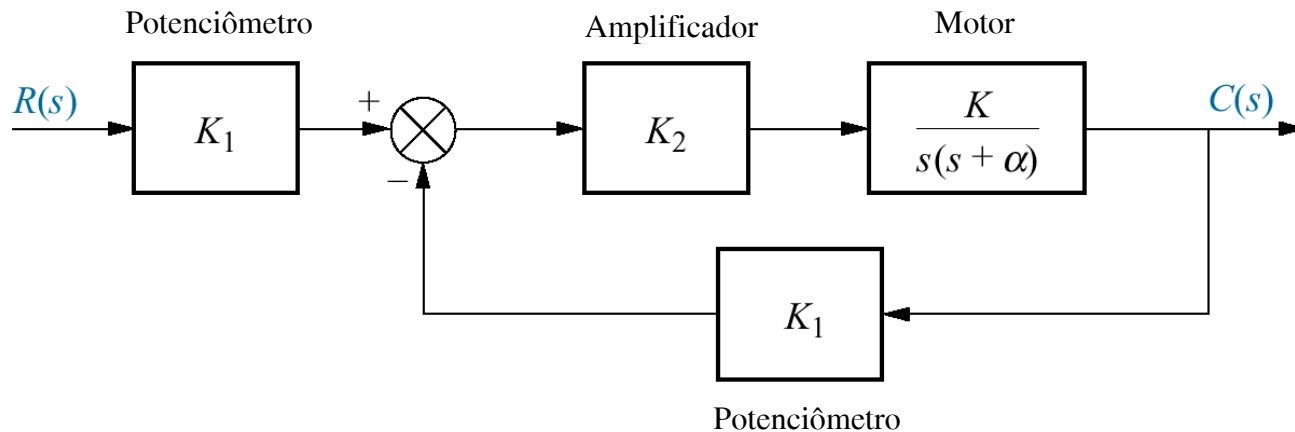
c. cadeia de acionamento da junta alfa e sistema de controle



© 1992 AIAA.

# Fig. P7.24

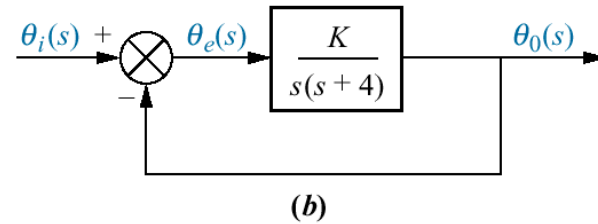
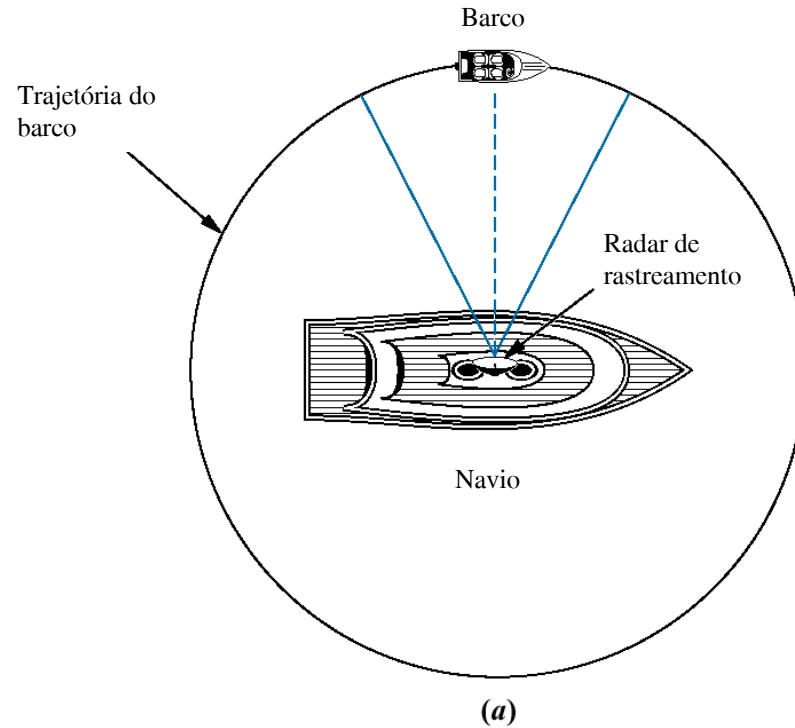
## Sistema de controle de posição



# Fig. P7.25

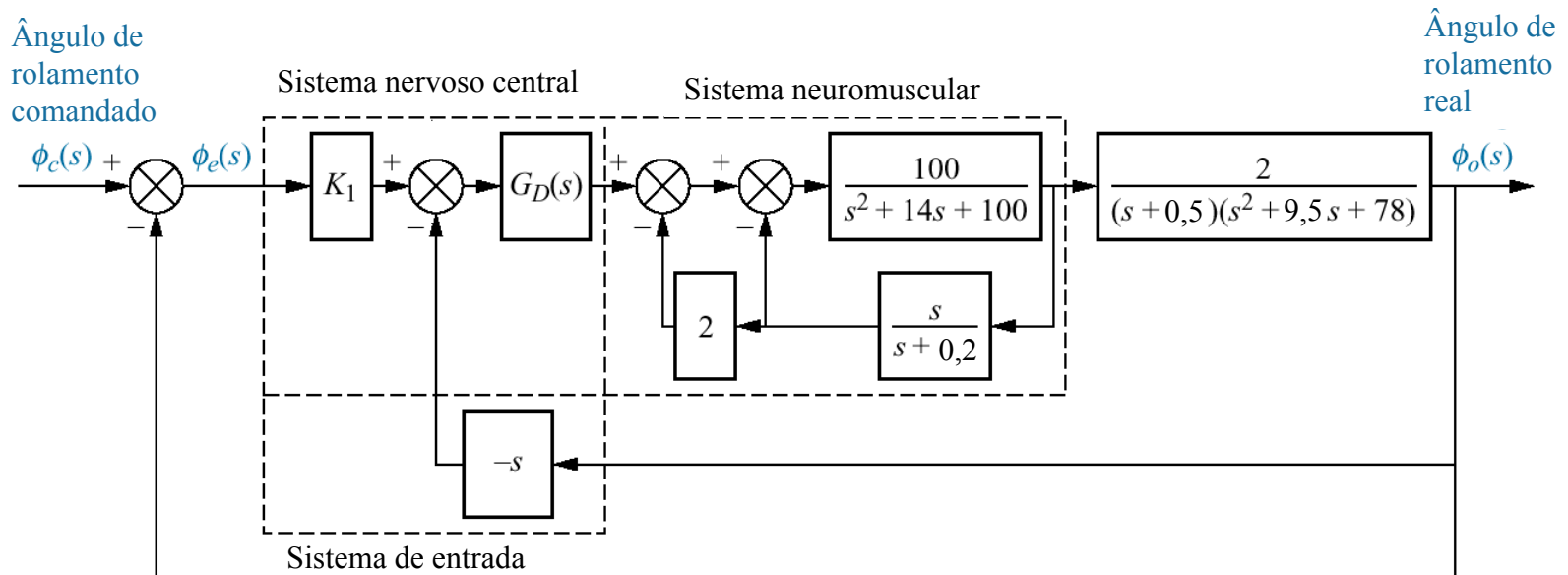
Barco rastreado pelo radar do navio

- a. arranjo físico;
- b. diagrama de blocos do sistema de rastreamento



# Fig. P7.26

Diagrama de blocos simplificado de um piloto na malha de controle (© 1992 AIAA)



# Fig. P7.27

a. Malha de controle mecânico de força de movimento com contato

(© 1996 IEEE);

b. diagrama de blocos (© 1996 IEEE)

