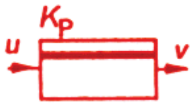
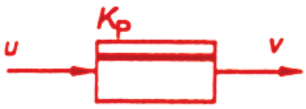
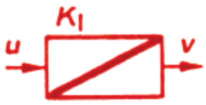
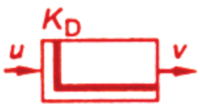
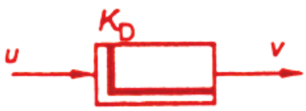
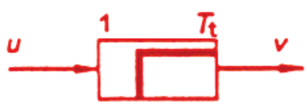
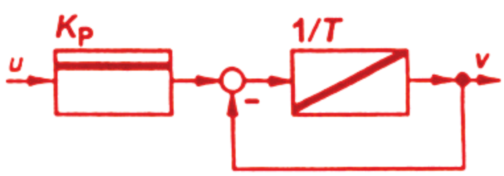
U'14 Ingeniería de control

Elementos primitivos de transferencia
Elemento de retraso de primer orden

Identificador Símb. en el diagrama de ctrol.	Ecuación en el dominio del tiempo	Ejemplos de estructura
P 	$v = K_P \cdot u$	 Elemento proporcional
I 	$v = K_I \int u\,dt$ $= K_I \int_0^t u\,dt + v(0)$ $\dot{v} = K_I \cdot u$	 Elemento integral
D 	$v = K_D \cdot \dot{u}$ $\int v\,dt = K_D \cdot u$	 Elemento derivativo
T_t 	$v(t) = u(t - T_t)$	 Elemento de tiempo muerto
$P - T_1$ 	$v + T\,\dot{v} = K_P \cdot u$	 Elemento $P-T_1$

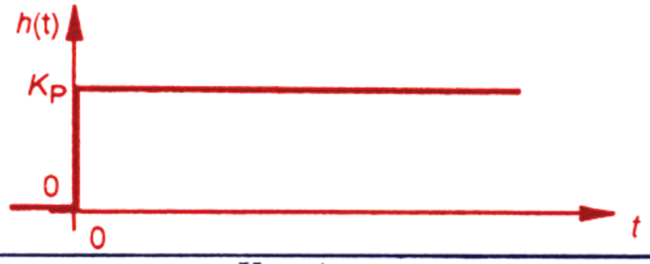
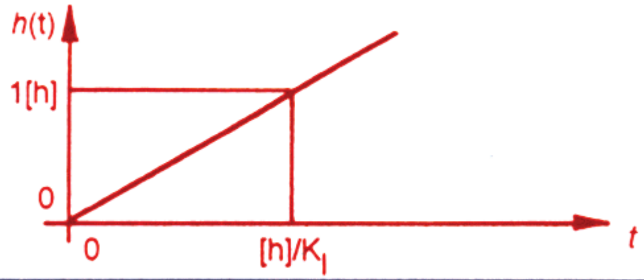
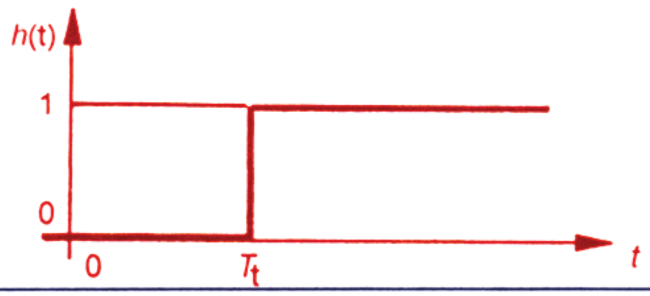
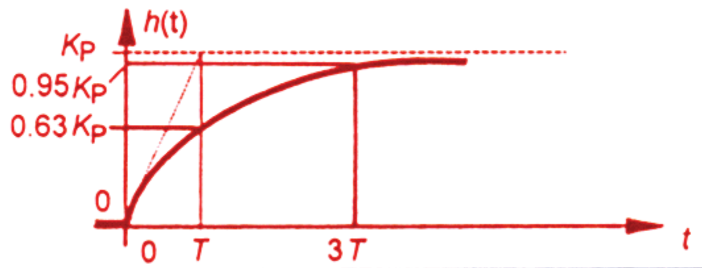
Ver la explicación de los símbolos en U'35

u'36 a u'43

Ingeniería de control

Elementos primitivos de transferencia
Elemento de retraso de primer orden

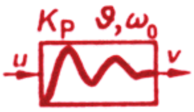
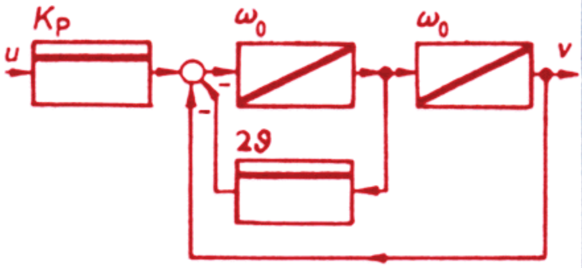
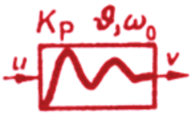
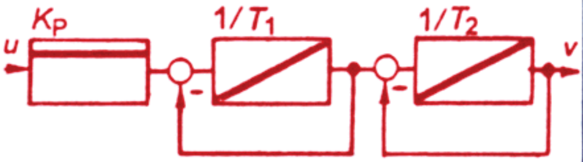
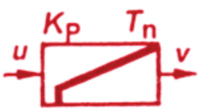
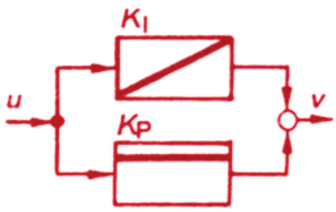
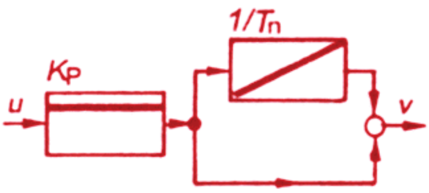
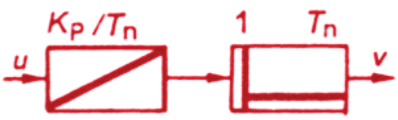
u′44 a u′53

Función de transferencia $F(s)$ =	Respuesta escalón unitario, ecuación $h(t)$ = / diagrama
K_P	K_P 
$K_I \dfrac{1}{s}$ ([h] = Unidad de h)	$K_I \cdot t$ 
$K_D \cdot s$	$K_D \cdot \delta(t)$ 
$e^{-T_t s}$	0 para $t < T_t$; 1 para $t > T_t$ 
$\dfrac{K_P}{1 + T \cdot s}$	$K_P\,(1 - e^{-t/T})$ 

Ver la explicación de los símbolos en U′35

U'15 Ingeniería de control

Elemento de retraso de segundo orden
Elemento PI de combinación en paralelo

Identificador / Símb. en el diagrama de ctrol.	Ecuación en el dominio del tiempo		Ejemplos de estructura
P – T_2 	$v + 2\frac{\vartheta}{\omega_0}\dot{v} + (\frac{1}{\omega_0})^2\ddot{v} =$ $= K_P \cdot u$	$\vartheta < 1$	
P – T_2 		$\vartheta > 1$	 
PI 	$v = K_I \int u \, dt + K_P \cdot u$ $= K_P \left(\frac{1}{T_n}\int u \, dt + u\right)$ donde $T_n = K_P / K_I$		  

u'54 a u'58

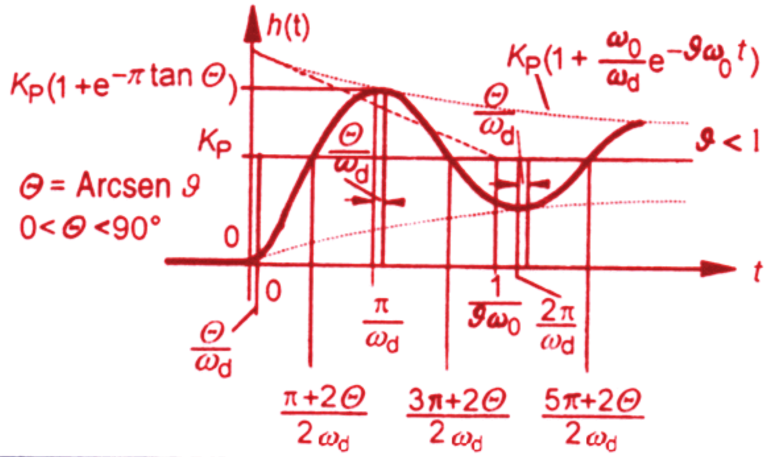
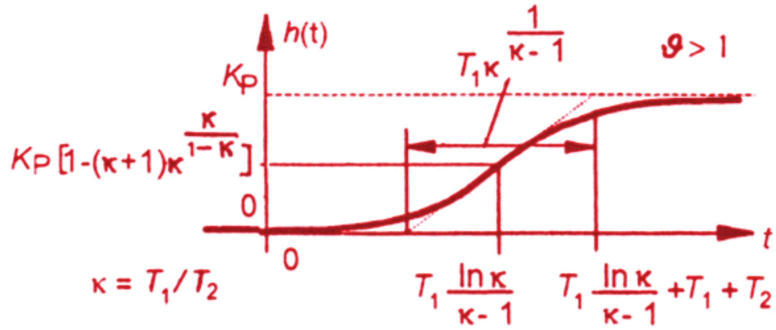
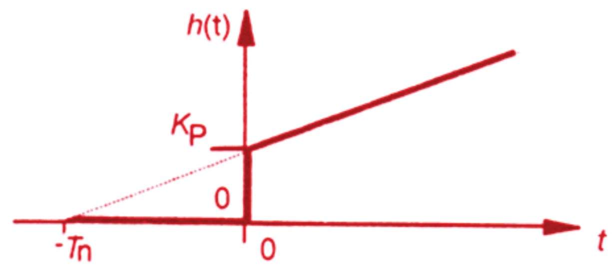
Ver la explicación de los símbolos en U'35

Ingeniería de control

Elemento de retraso de segundo orden
Elemento PI de combinación en paralelo

U'15

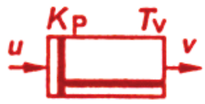
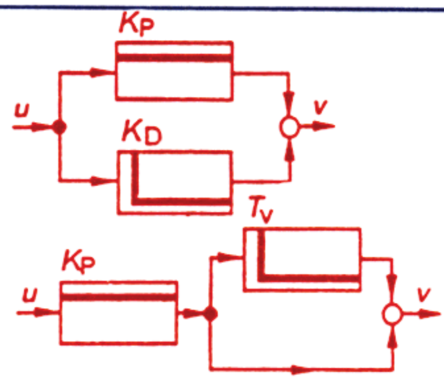
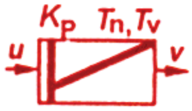
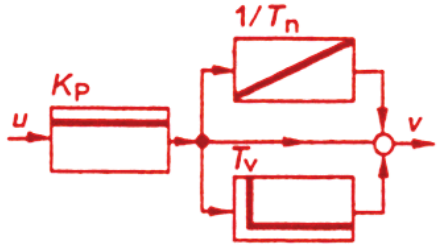
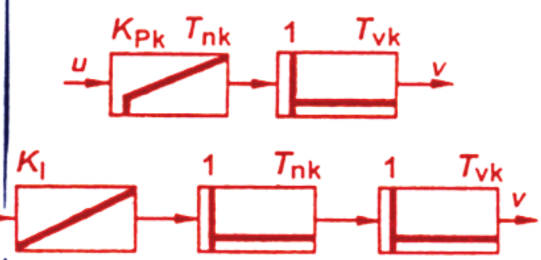
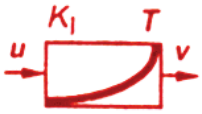
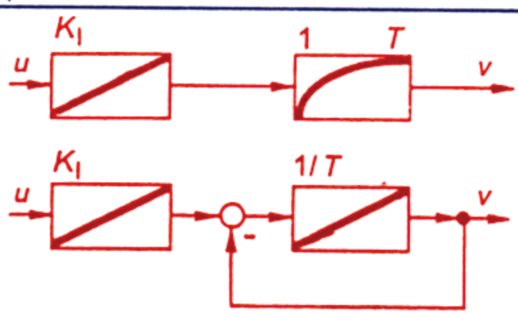
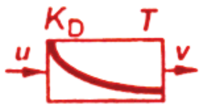
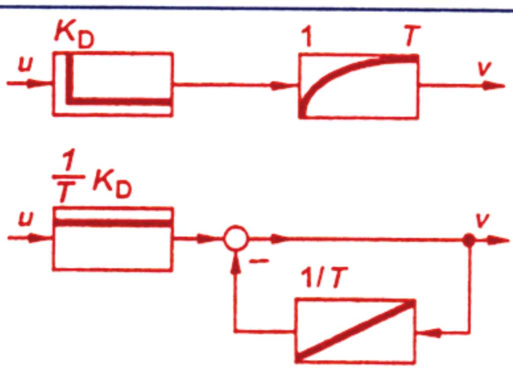
u'59 a u'68

Función de transferencia $F(s)$ =	Respuesta escalón unitario, ecuación $h(t)$ = / diagrama
$$\frac{K_P}{1+2\frac{\vartheta}{\omega_0}s+\left(\frac{1}{\omega_0}\right)^2\cdot s^2}$$ $0<\vartheta<\infty$	$K_P\left[1-\frac{\omega_0}{\omega_d}e^{-\vartheta\omega_0 t}\cdot\cos(\omega_d t-\Theta)\right];\ \omega_d=\omega_0\sqrt{1-\vartheta^2}$ Θ = Arcsen ϑ $0<\Theta<90°$ 
$$\frac{K_P}{(1+T_1 s)(1+T_2 s)}$$ $T_{1,2}=\frac{1}{\omega_0}(\vartheta\pm\sqrt{\vartheta^2-1})$ $\vartheta>1$	$K_P\left[1-\frac{1}{T_1-T_2}\left(T_1 e^{-\frac{t}{T_1}}-T_2 e^{-\frac{t}{T_2}}\right)\right]$ 
$K_I\frac{1}{s}+K_P$ $K_P\left[\frac{1}{T_n\cdot s}+1\right]$ $\frac{K_P}{T_n\cdot s}(1+T_n\cdot s)$	$K_I t+K_P=K_P\left(1+\frac{t}{T_n}\right)$ 

Ver la explicación de los símbolos en U'35

U'16 Ingeniería de control

Elementos PD, PID de combinación en paralelo
Elementos I-T_1 y D-T_1 de combinación en serie

Identificador / Símb. en el diagrama de ctrol.	Ecuación en el dominio del tiempo	Ejemplos de estructura
PD 	$v = K_P \cdot u + K_D \cdot \dot{u}$ $= K_P (u + T_v \cdot \dot{u})$ $T_v = \dfrac{K_D}{K_P}$	
PID 	$v = K_I \int u\,dt + K_P \cdot u + K_D \cdot \dot{u}$ $= K_P \left[\dfrac{1}{T_n} \int u\,dt + u + T_v \cdot \dot{u}\right]$ $T_n = \dfrac{K_P}{K_I}$; $T_v = \dfrac{K_D}{K_P}$	 $T_n \geq 4T_v$ 
I – T_1 	$v + T\,\dot{v} = K_I \int u\,dt$	
D – T_1 	$v + T\,\dot{v} = K_D \cdot \dot{u}$	

Ver la explicación de los símbolos en U'35

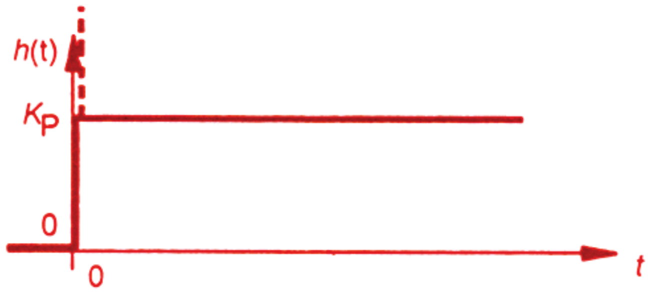
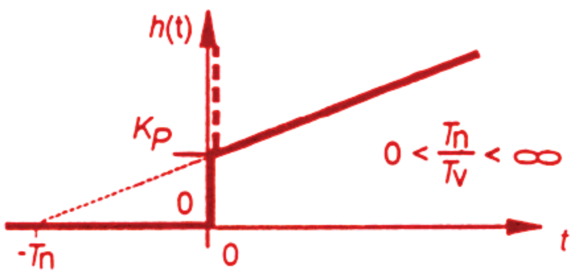
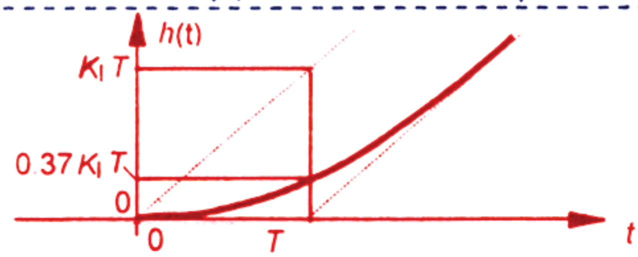
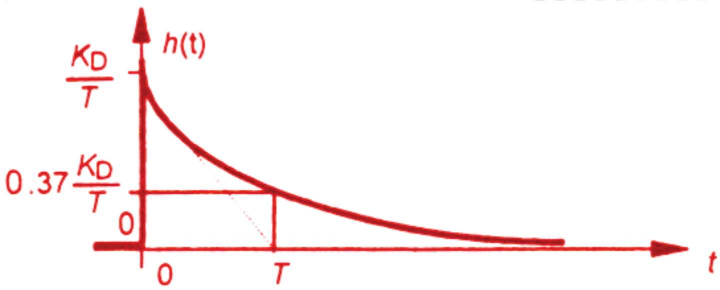
u'69 a u'76

Ingeniería de control

Elementos PD, PID de combinación en paralelo
Elementos I-T_1 y D-T_1 de combinación en serie

U'16

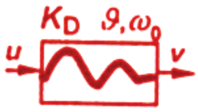
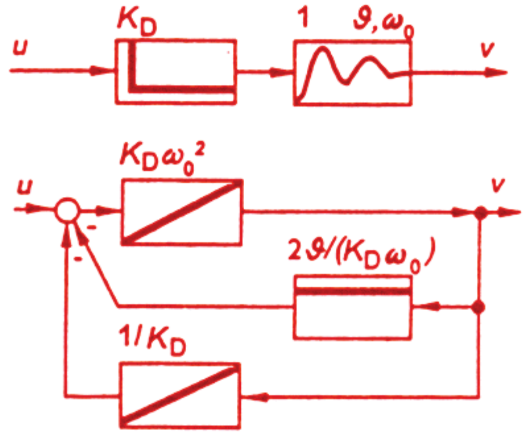
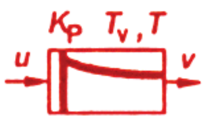
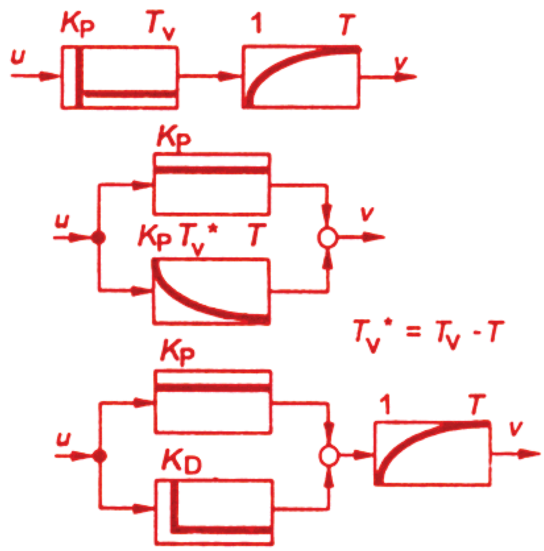
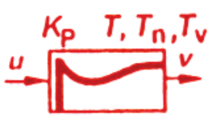
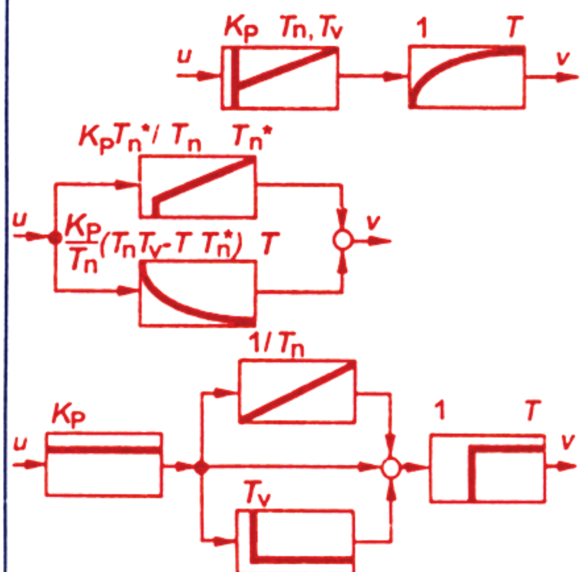
u'77 a u'93

Función de transferencia $F(s)$ =	Respuesta escalón unitario, ecuación $h(t)$ = diagrama
$K_P + K_D \cdot s$ $K_P\,(1 + T_v \cdot s)$	$K_P + K_D\,\delta(t)$ 
$K_I \frac{1}{s} + K_P + K_D \cdot s$ $K_P \left[\frac{1}{T_n \cdot s} + 1 + T_v \cdot s\right]$ $0 < \frac{T_n}{T_v} < \infty$ $K_{Pk}\,(\frac{1}{T_{nk} \cdot s} + 1)\,(1 + T_{vk} \cdot s)$ $\frac{K_I}{s}\,(1 + T_{nk} \cdot s)\,(1 + T_{vk} \cdot s)$ $T_{nk} = \frac{1}{2} T_n \left(1 + \sqrt{1 - 4\,T_v / T_n}\right)$ $T_{vk} = \frac{1}{2} T_n \left(1 - \sqrt{1 - 4\,T_v / T_n}\right)$ $K_{Pk} = K_I \cdot T_{nk}$	$K_I\,t + K_P + K_D\,\delta(t) = K_P \left[\frac{t}{T_n} + 1 + T_v\,\delta(t)\right]$ para $0 < \frac{T_n}{T_v} < \infty$; $K_I \left[t + T_{nk} + T_{vk} + T_{nk} \cdot T_{vk}\,\delta(t)\right]$ 
$\frac{K_I}{s\,(1 + T \cdot s)}$	$K_I\,(t - T + T \cdot e^{-t/T})$ 
$\frac{K_D \cdot s}{1 + T \cdot s}$	$K_D\,(1/T)\,e^{-t/T}$ 

Ver la explicación de los símbolos en U'35

U′17 Ingeniería de control

Elemento de combinación en serie
Elementos (PD)-T1 y (PID)-T1 de combinación en grupo

Identificador Símb. en el diagrama de ctrol.	Ecuación en el dominio del tiempo	Ejemplos de estructura
D-T_2 	$v + 2\frac{\vartheta}{\omega_0}\dot v + \left(\frac{1}{\omega_0}\right)^2 \ddot v =$ $= K_D \cdot \dot u$	
(PD)-T_1 	$v + T\dot v = K_P \cdot u + K_D \dot u$ $= K_P \left[u + T_v \cdot \dot u\right]$ $T_v = \frac{K_D}{K_P}$	
(PID)-T_1 	$v + T\dot v = K_I \int u\,dt +$ $+ K_P \cdot u + K_D \cdot \dot u$ $= K_P \left[\frac{1}{T_n}\int u\,dt + \right.$ $\left. + u + T_v \cdot \dot u\right]$ $T_v = \frac{K_D}{K_P}$	

u′94 a u′102

Ver la explicación de los símbolos en U′35

Ingeniería de control

Elemento de combinación en serie
Elementos (PD)-T1 y (PID)-T1 de combinación en grupo

U'17

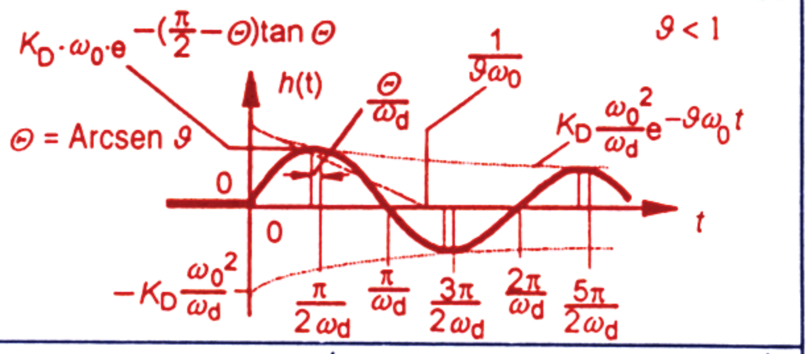
u'103 a u'117

<table>
<tr><th>Función de transferencia $F(s)$ =</th><th>Respuesta escalón unitario, ecuación $h(t)$ =
diagrama</th></tr>
<tr><td>

$$\frac{K_D \cdot s}{1 + 2\frac{\vartheta}{\omega_o} s + \left(\frac{1}{\omega_o}\right)^2 s^2}$$

</td><td>

$$K_D \frac{\omega_o^2}{\omega_d} \cdot e^{-\vartheta \omega_o t} \cdot \text{sen}\, \omega_d t \; ; \quad \omega_d = \omega_o \sqrt{1 - \vartheta^2}$$



</td></tr>
<tr><td>

$$\frac{K_P + K_D \cdot s}{1 + T \cdot s}$$

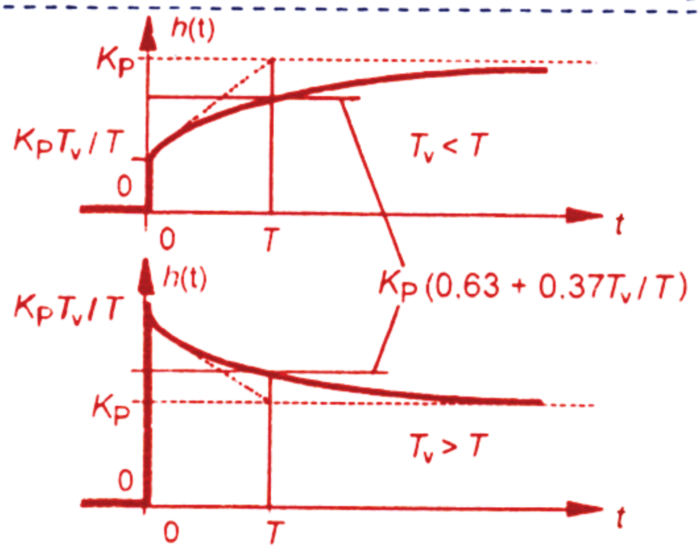
$$= K_P \frac{1 + T_v \cdot s}{1 + T \cdot s}$$

$$= K_P + K_P \frac{(T_v - T) \cdot s}{1 + T \cdot s}$$

$$T_v - T = T_v^*$$

</td><td>

$$K_P + \left[\frac{K_D}{T} - K_P\right] e^{-\frac{t}{T}} = K_P \left[1 + \left(\frac{T_v}{T} - 1\right) e^{-\frac{t}{T}}\right]$$



</td></tr>
<tr><td>

$$\frac{K_I / s + K_P + K_D \cdot s}{1 + T \cdot s}$$

$$= K_P \frac{1/(T_n \cdot s) + 1 + T_v \cdot s}{1 + T \cdot s}$$

$$= K_P \left[\frac{1}{T_n \cdot s} + \frac{T_n^*}{T_n} + \frac{T_n T_v - T T_n^*}{T_n (1 + T \cdot s)} s\right]$$

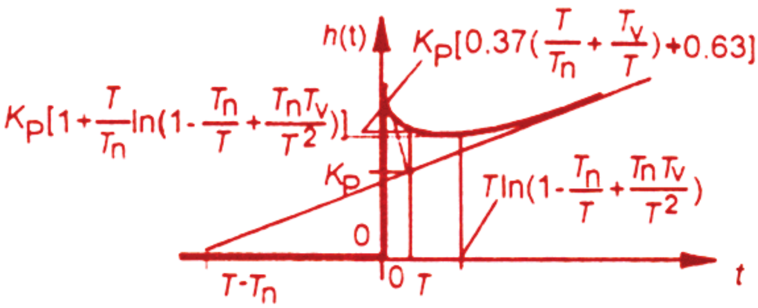
$$T_n = K_P / K_I ; \quad T_v = K_D / K_P$$

$$T_n^* = T_n - T$$

</td><td>

$$K_P - K_I T + K_I t + \left[K_I T - K_P + K_D \frac{1}{T}\right] e^{-\frac{t}{T}}$$

$$= K_P \left[1 - \frac{T}{T_n} + \frac{t}{T_n} + \left(\frac{T}{T_n} - 1 + \frac{T_v}{T}\right) e^{-\frac{t}{T}}\right]$$



</td></tr>
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Ver la explicación de los símbolos en U'35