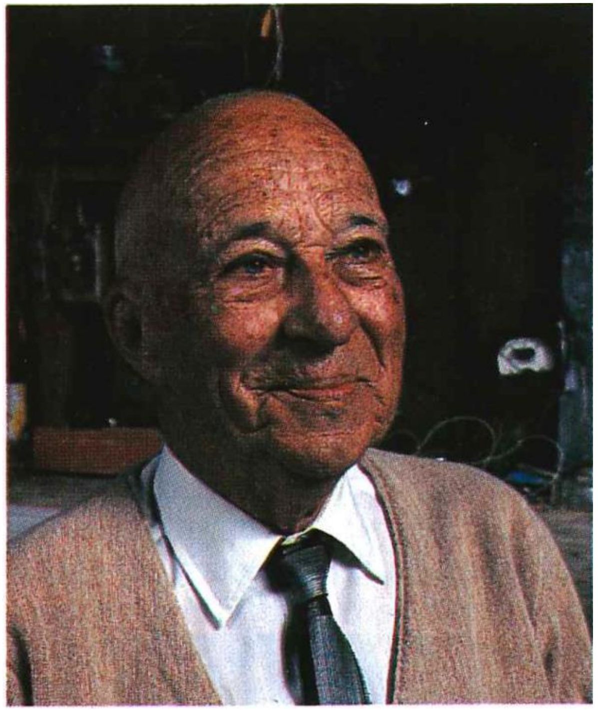
INTRODUCCIÓN A SISTEMAS DE CONTROL

ALEJANDRO S. GHERSIN

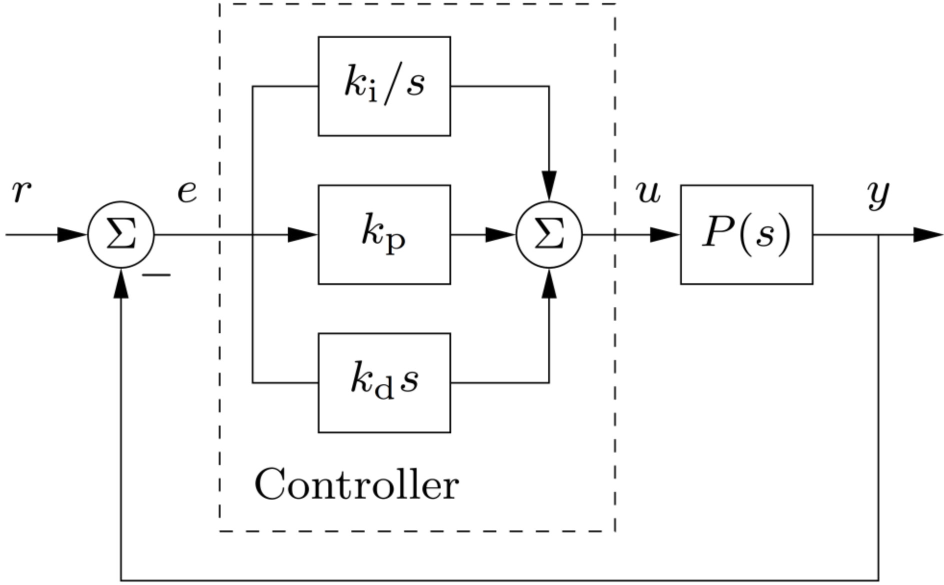
SÍNTESIS DE CONTROL PID

CONTROL PID

John G. Ziegler & Nathaniel B. Nichols



PID IDEAL



Expresión del PID en el tiempo y frecuencia

$$u = k_p e + k_i \int_0^t e(\tau)\, d\tau + k_d \frac{de}{dt} = k_p \left(e + \frac{1}{T_i} \int_0^t e(\tau)\, d\tau + T_d \frac{de}{dt} \right)$$

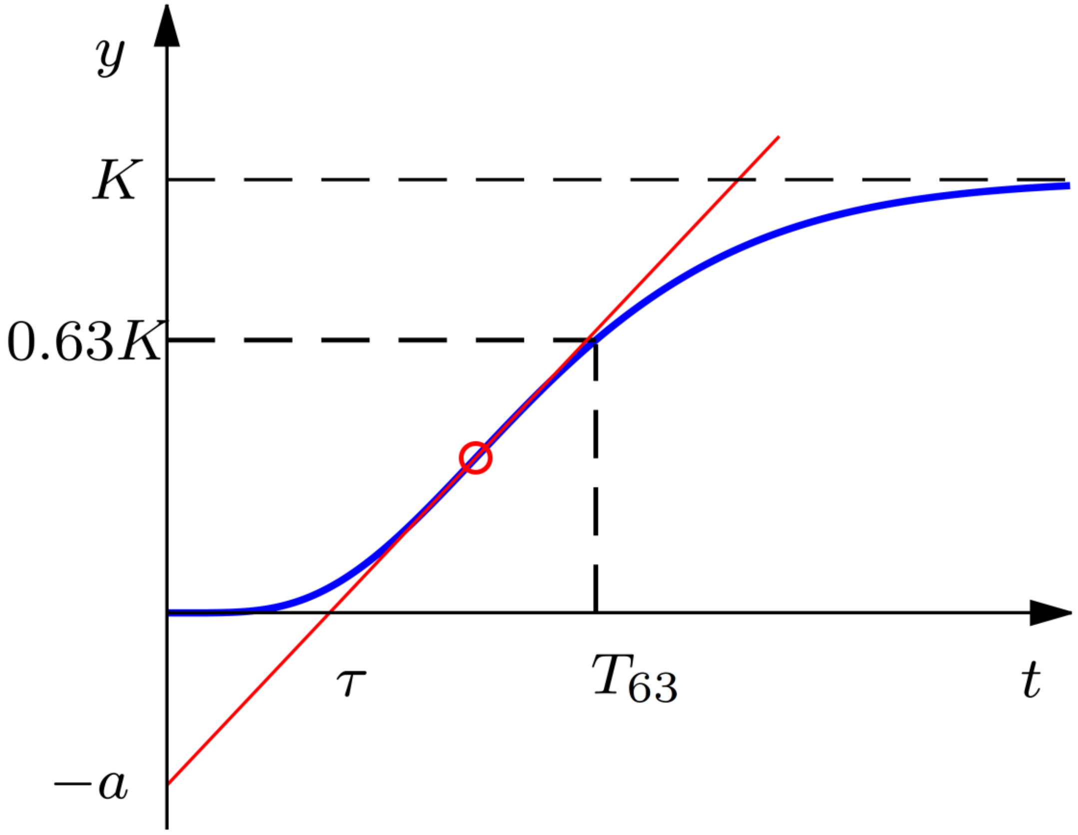
$$C(s) = k_p + \frac{k_i}{s} + k_d s$$

PD REINTERPRETADO

El control PD se puede pensar como un acción de control que se genera de manera proporcional al error que se predice en base al error actual y su derivada:

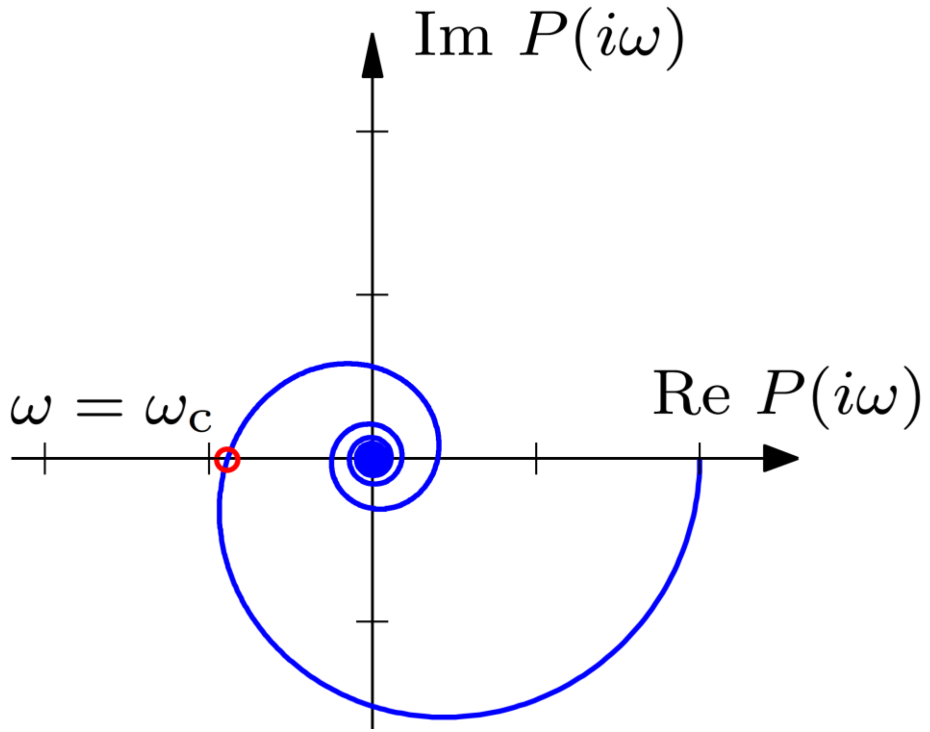
$$u = k_{\mathrm{p}} e + k_{\mathrm{d}} \frac{de}{dt} = k_{\mathrm{p}} \left(e + T_{\mathrm{d}} \frac{de}{dt} \right) =: k_{\mathrm{p}} e_{\mathrm{p}}$$

MÉTODO Z-N DE SINTONÍA EN EL TIEMPO



Type	k_p	T_i	T_d
P	$1/a$		
PI	$0.9/a$	$\tau/0.3$	
PID	$1.2/a$	$\tau/0.5$	0.5τ

MÉTODO Z-N DE SINTONÍA EN LA FRECUENCIA



Type	k_p	T_i	T_d
P	$0.5k_c$		
PI	$0.45k_c$	$T_c/1.2$	
PID	$0.6k_c$	$T_c/2$	$T_c/8$

SINTONÍA P.I. PARA PLANTAS F.O.T.D.

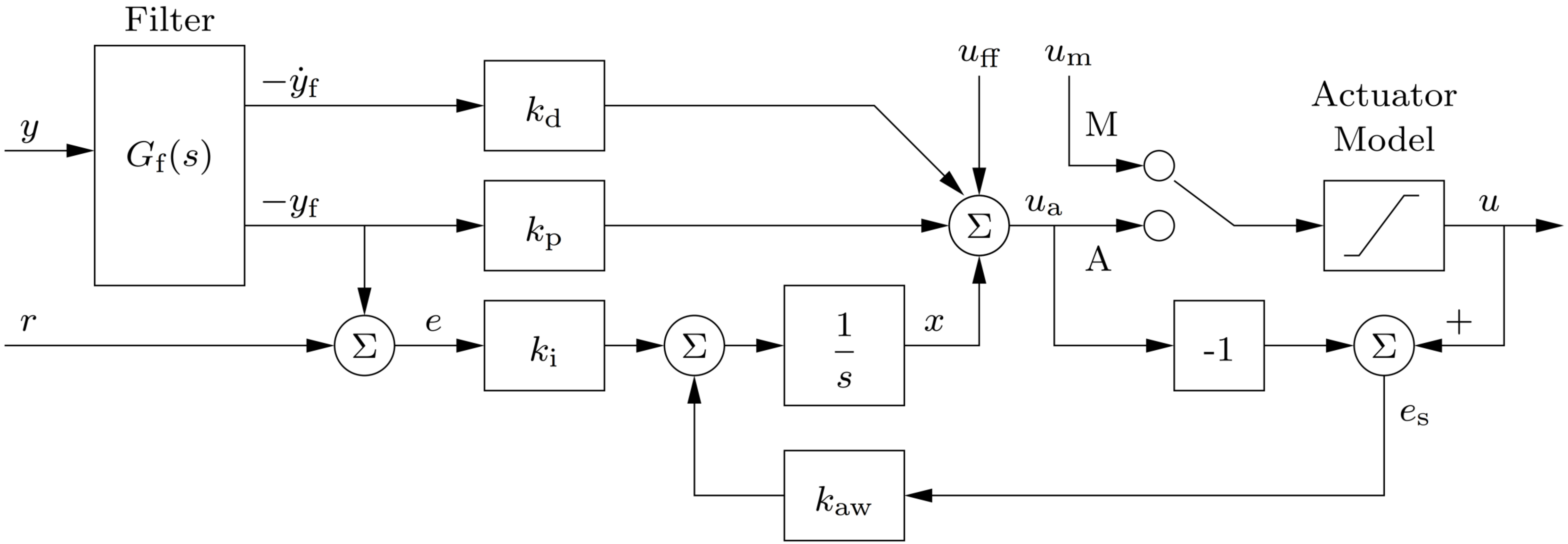
$$P(s) = \frac{K}{1+sT}e^{-\tau s} \qquad \tau_{\mathrm{n}} = \frac{\tau}{T+\tau}$$

$$k_{\mathrm{p}} = \frac{0.15\tau + 0.35T}{K\tau} \quad \left(\frac{0.9T}{K\tau}\right), \qquad k_{\mathrm{i}} = \frac{0.46\tau + 0.02T}{K\tau^2} \quad \left(\frac{0.27T}{K\tau^2}\right),$$

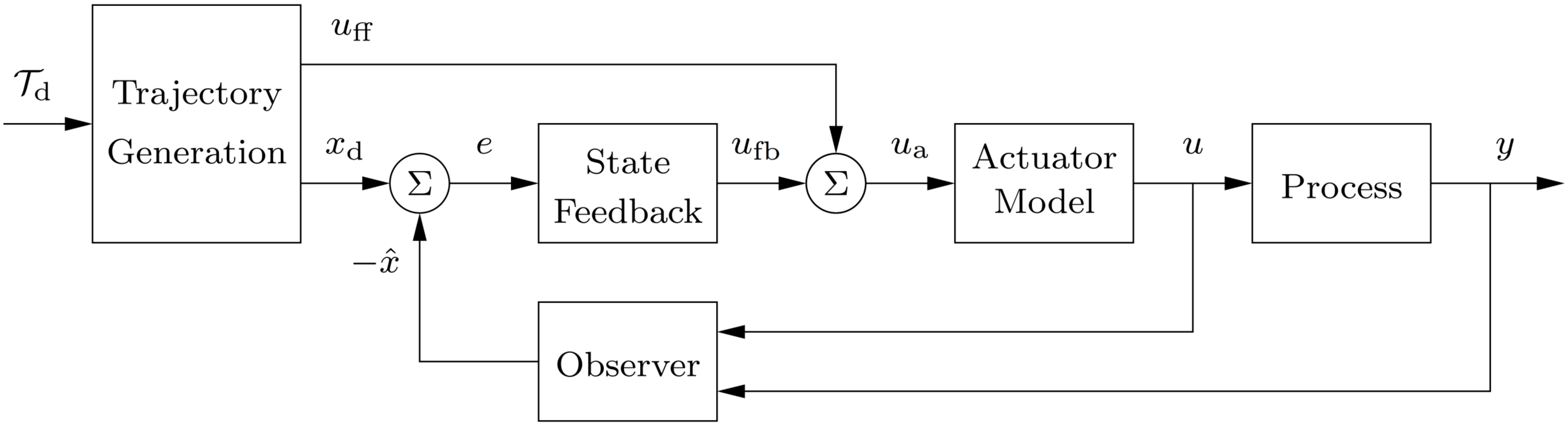
$$k_{\mathrm{p}} = 0.16k_{\mathrm{c}} \quad \left(0.45k_{\mathrm{c}}\right), \qquad k_{\mathrm{i}} = \frac{0.16k_{\mathrm{c}} + 0.72/K}{T_{\mathrm{c}}} \quad \left(\frac{0.54k_{\mathrm{c}}}{T_{\mathrm{c}}}\right)$$

K. J. Åström and T. Hägglund. *Advanced PID Control.* ISA—The Instrumentation, Systems, and Automation Society, Research Triangle Park, NC, 2006.

RESET ANTIWINDUP

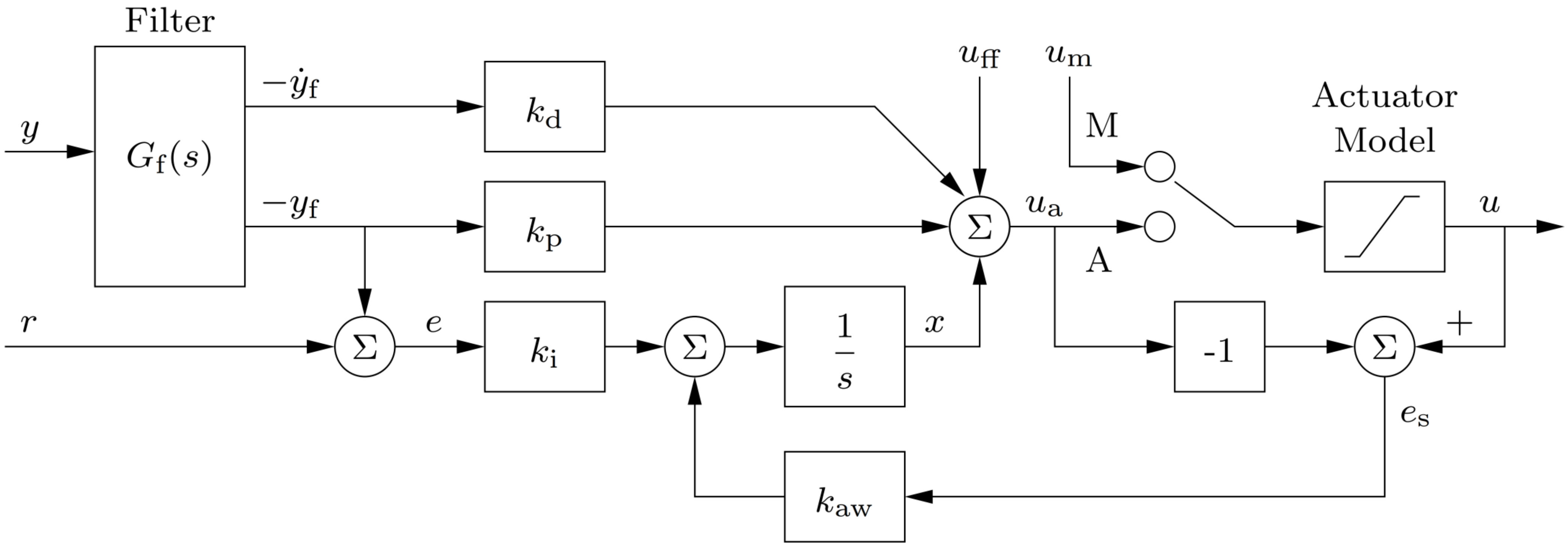


STATE SPACE ANTIWINDUP



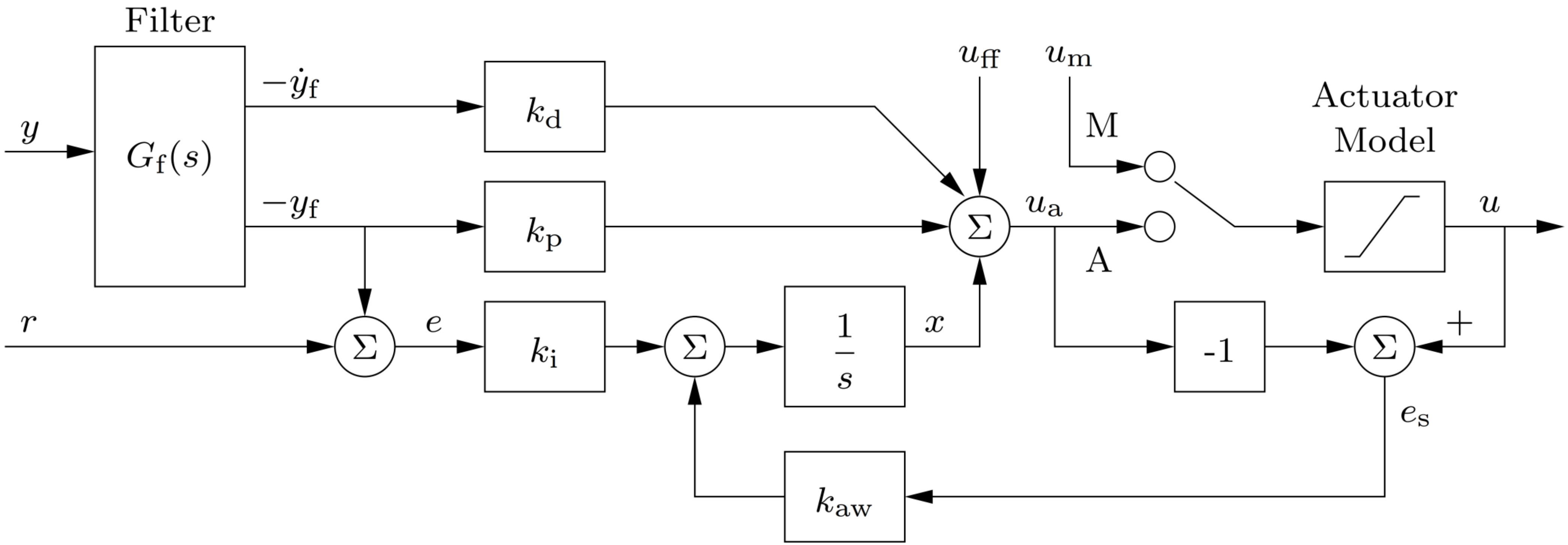
REGULARIZACIÓN CON PASABAJOS DE 2NDO ORDEN

$$C(s) = k_{\mathrm{p}} \left(1 + \frac{1}{sT_{\mathrm{i}}} + sT_{\mathrm{d}} \right) \frac{1}{1 + sT_{\mathrm{f}} + (sT_{\mathrm{f}})^2/2}$$



SETPOINT WEIGHTING

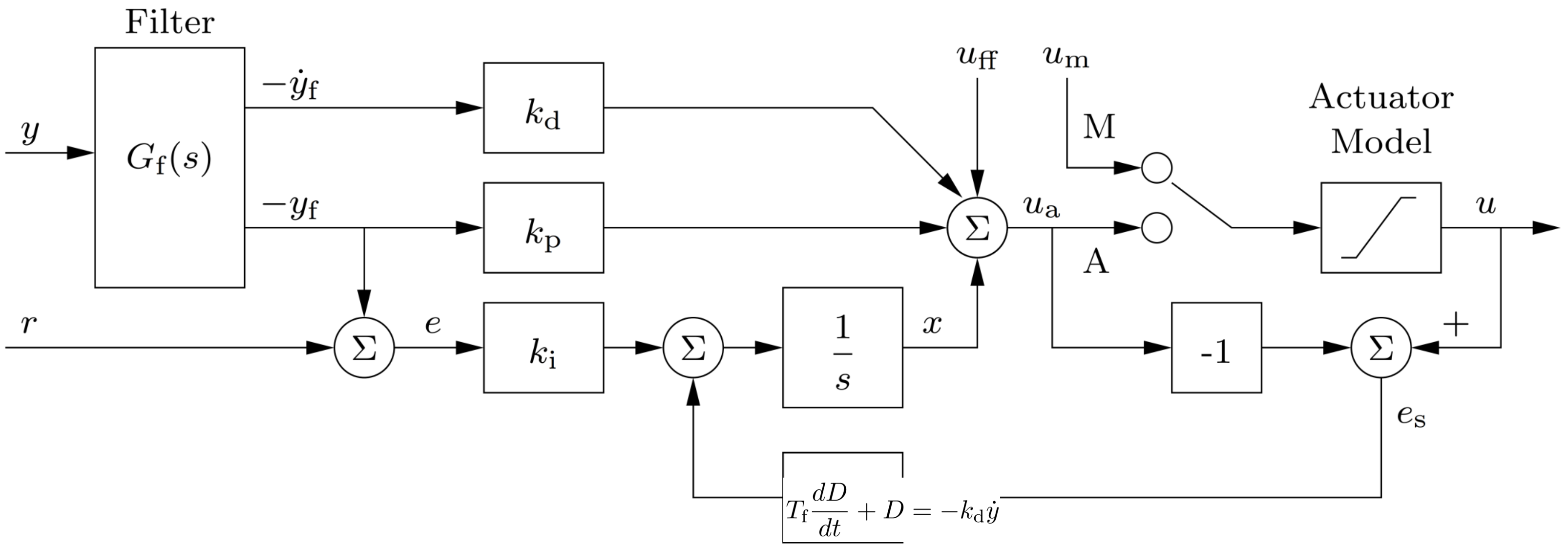
$$u = k_\mathrm{p}\big(\beta r - y\big) + k_\mathrm{i}\int_0^t \big(r(\tau) - y(\tau)\big)\,d\tau + k_\mathrm{d}\left(\gamma\frac{dr}{dt} - \frac{dy}{dt}\right)$$



IMPLEMENTACIÓN DIGITAL

1. Wait for clock interrupt
2. Read input from sensor
3. Compute control output
4. Send output to the actuator
5. Update controller state
6. Repeat

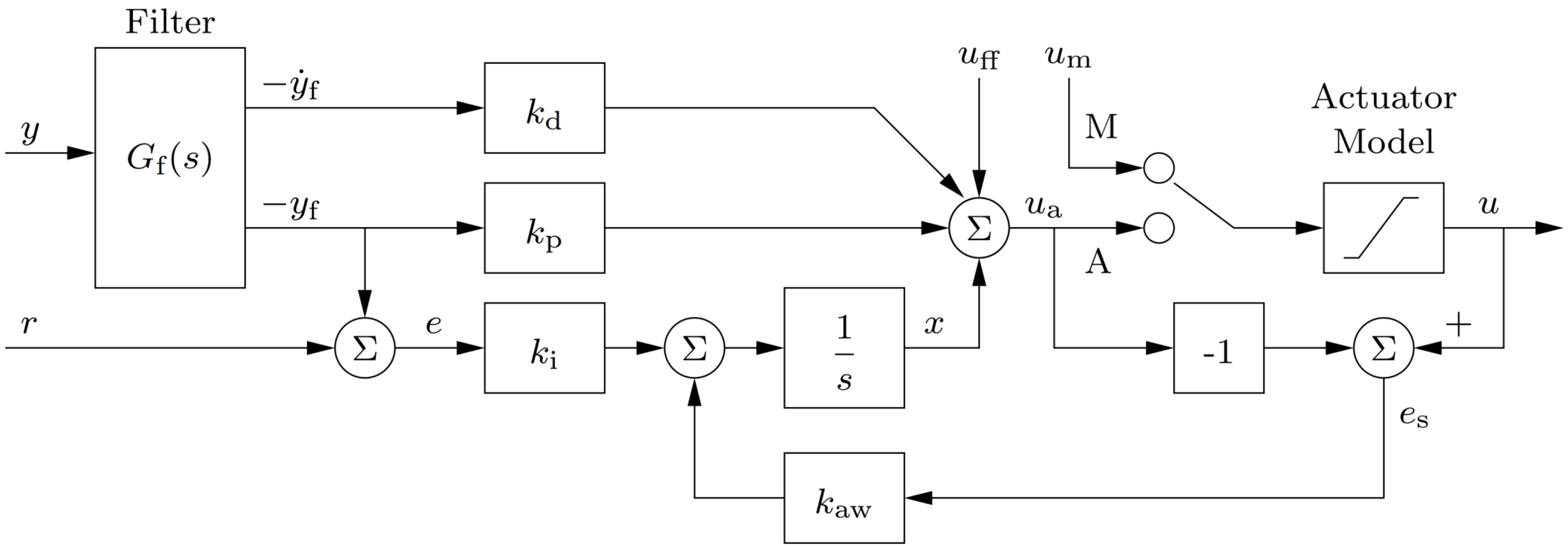
IMPLEMENTACIÓN DIGITAL



$$P = k_p(\beta r - y)$$

$$P(t_k) = k_p\big(\beta r(t_k) - y(t_k)\big)$$

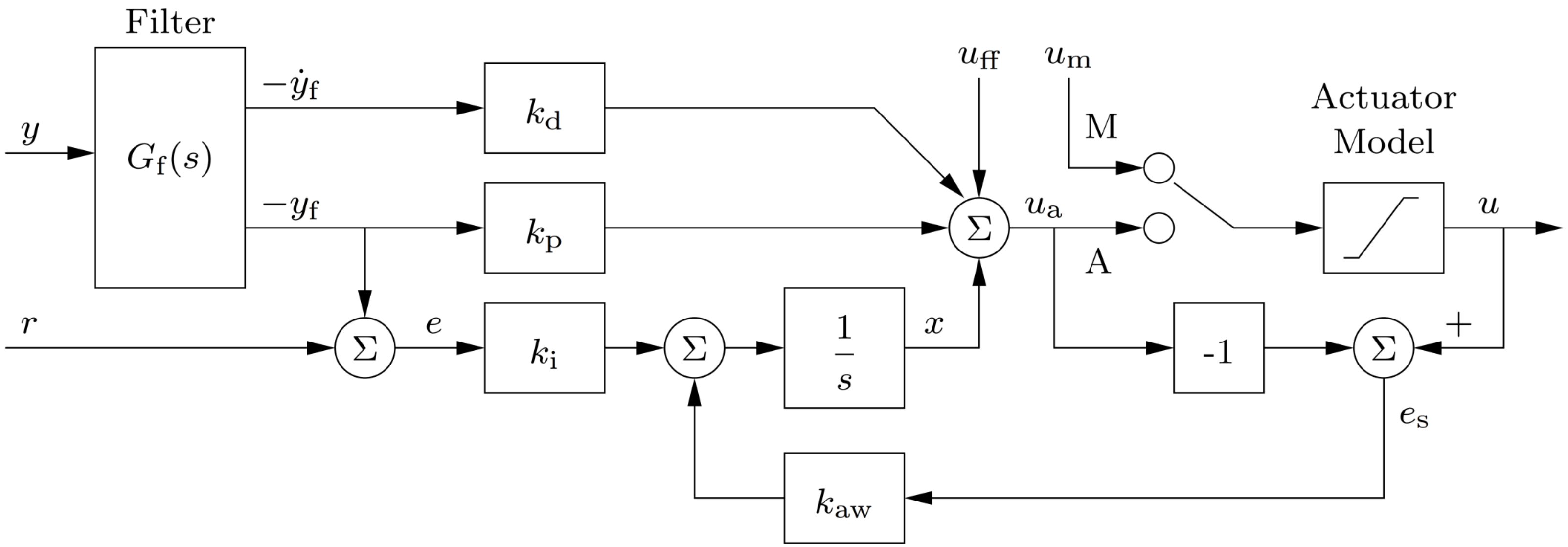
IMPLEMENTACIÓN DIGITAL



$$T_f \frac{dD}{dt} + D = -k_d \dot{y}$$

$$I(t_{k+1}) = I(t_k) + k_i h\, e(t_k) + \frac{h}{T_{aw}}\big(\mathrm{sat}(u_a) - u_a\big)$$

IMPLEMENTACIÓN DIGITAL



$$T_\mathrm{f}\frac{dD}{dt} + D = -k_\mathrm{d}\dot{y}$$

$$T_\mathrm{f}\frac{D(t_k) - D(t_{k-1})}{h} + D(t_k) = -k_\mathrm{d}\,\frac{y(t_k) - y(t_{k-1})}{h}$$

$$D(t_k) = \frac{T_\mathrm{f}}{T_\mathrm{f} + h}\,D(t_{k-1}) - \frac{k_\mathrm{d}}{T_\mathrm{f} + h}\,(y(t_k) - y(t_{k-1}))$$