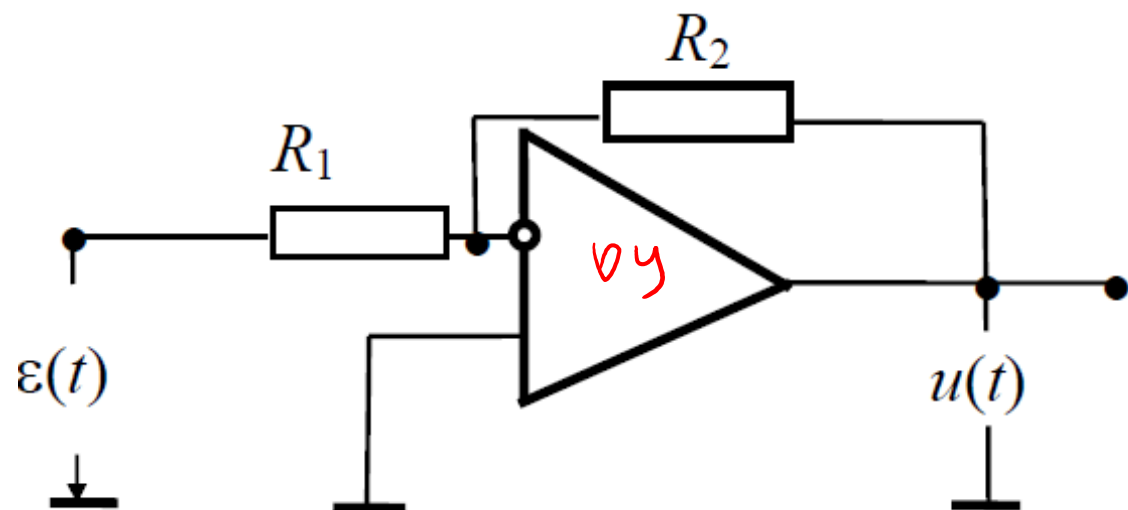


Регуляторы

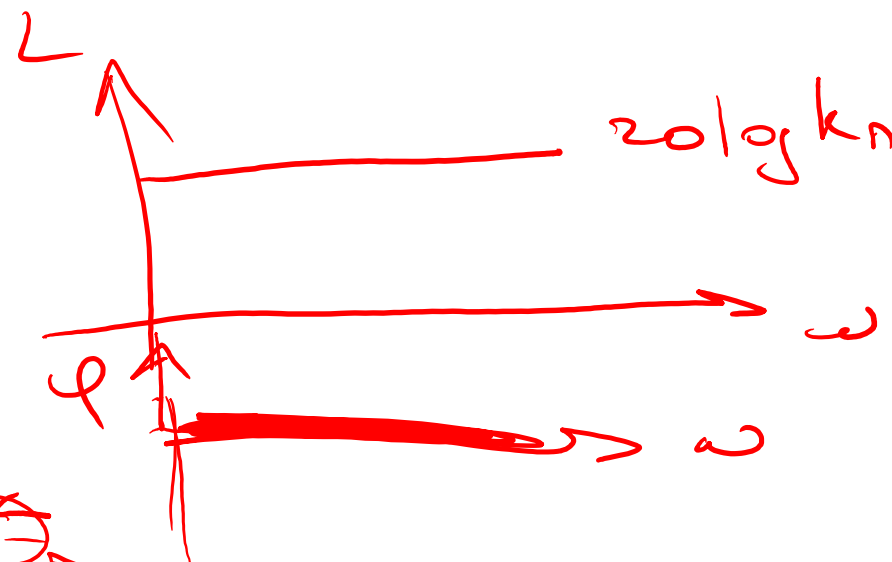
П-регулятор

уст. ност.

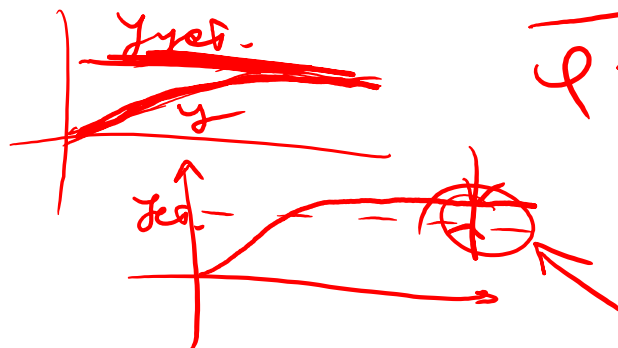


$$k_n = \frac{u_y}{\varepsilon} = \frac{R_2}{R_1}$$

$$W(p) = \frac{u(p)}{\varepsilon(p)} = k_n$$



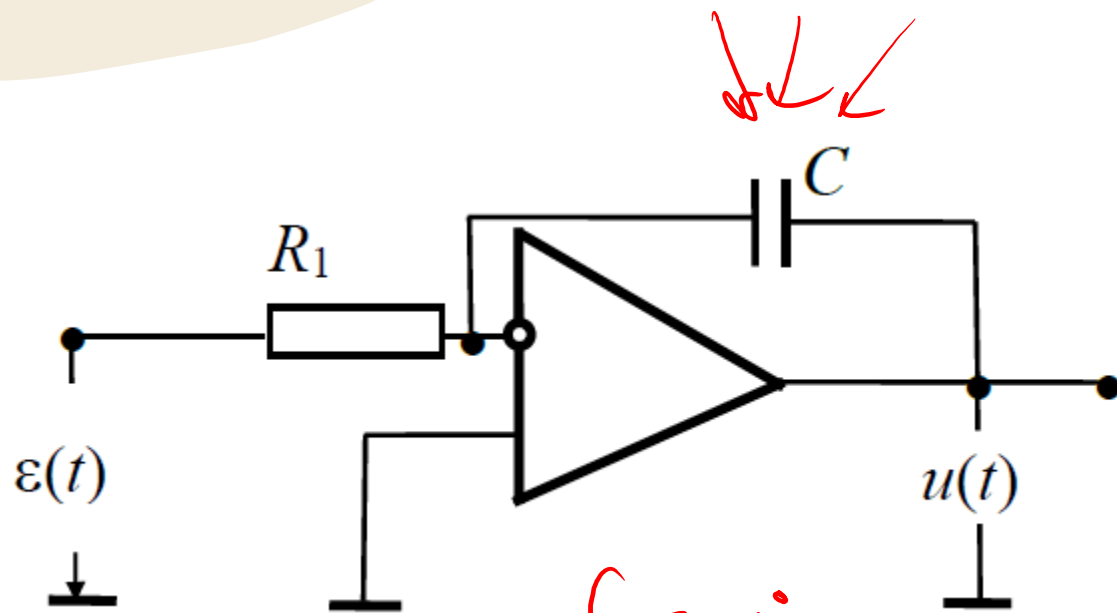
ε ↑





П-регулятор

И-регулятор



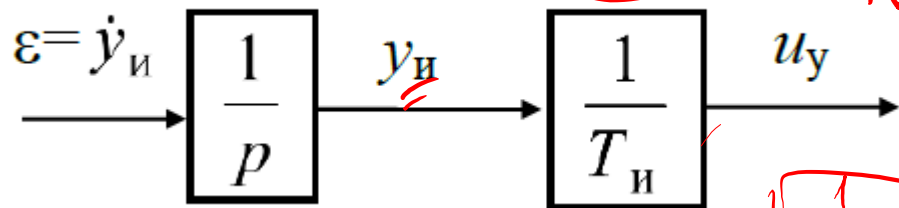
$$\frac{du_y}{dt} = k_u \epsilon(t)$$

$$u(t) = k_u \int \epsilon(t) dt$$

$$k_u = \frac{1}{T_u}$$

$$T_u = R_1 C$$

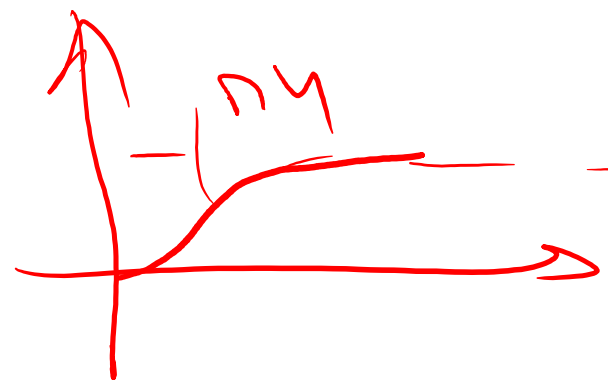
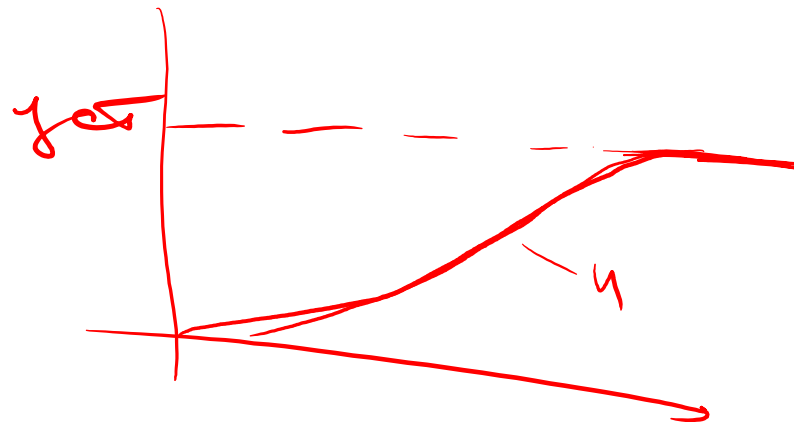
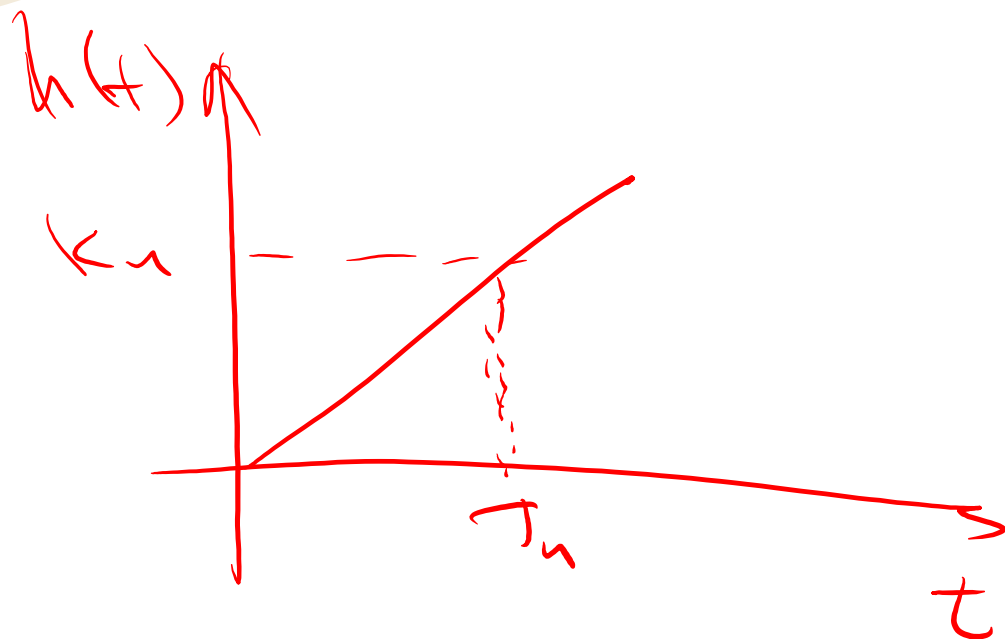
$$\begin{cases} \epsilon = \dot{y}_u \\ u_y = \frac{y_u}{T_u} \end{cases}$$



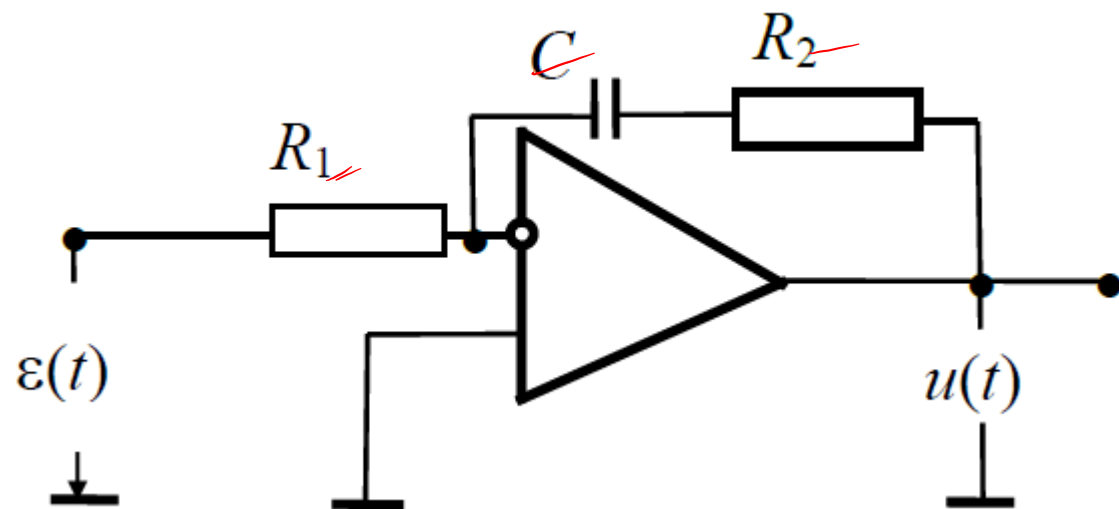
$$W_u(p) = \frac{u(p)}{\epsilon(p)} = \frac{1}{T_u p}$$



И-регулятор



ПИ-регулятор



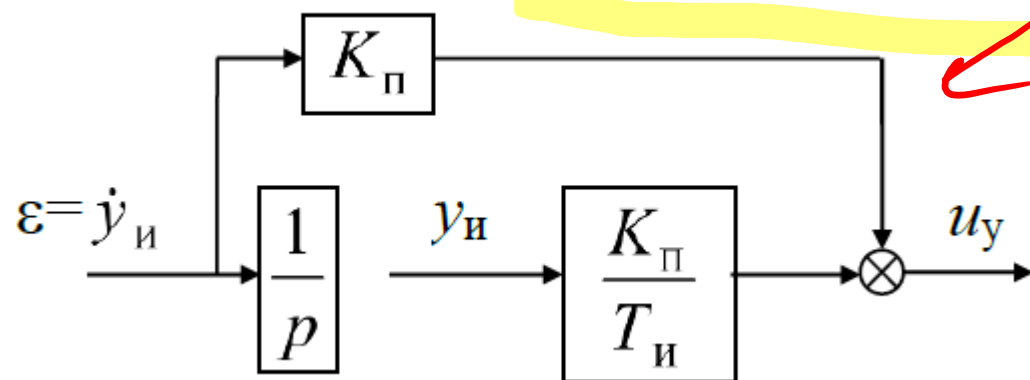
$$T_u = R_2 C$$

$$K_u = \frac{R_2}{R_1}$$

$$u(t) = K_u \varepsilon(t) + K_u \int_0^t \varepsilon(\tau) d\tau$$

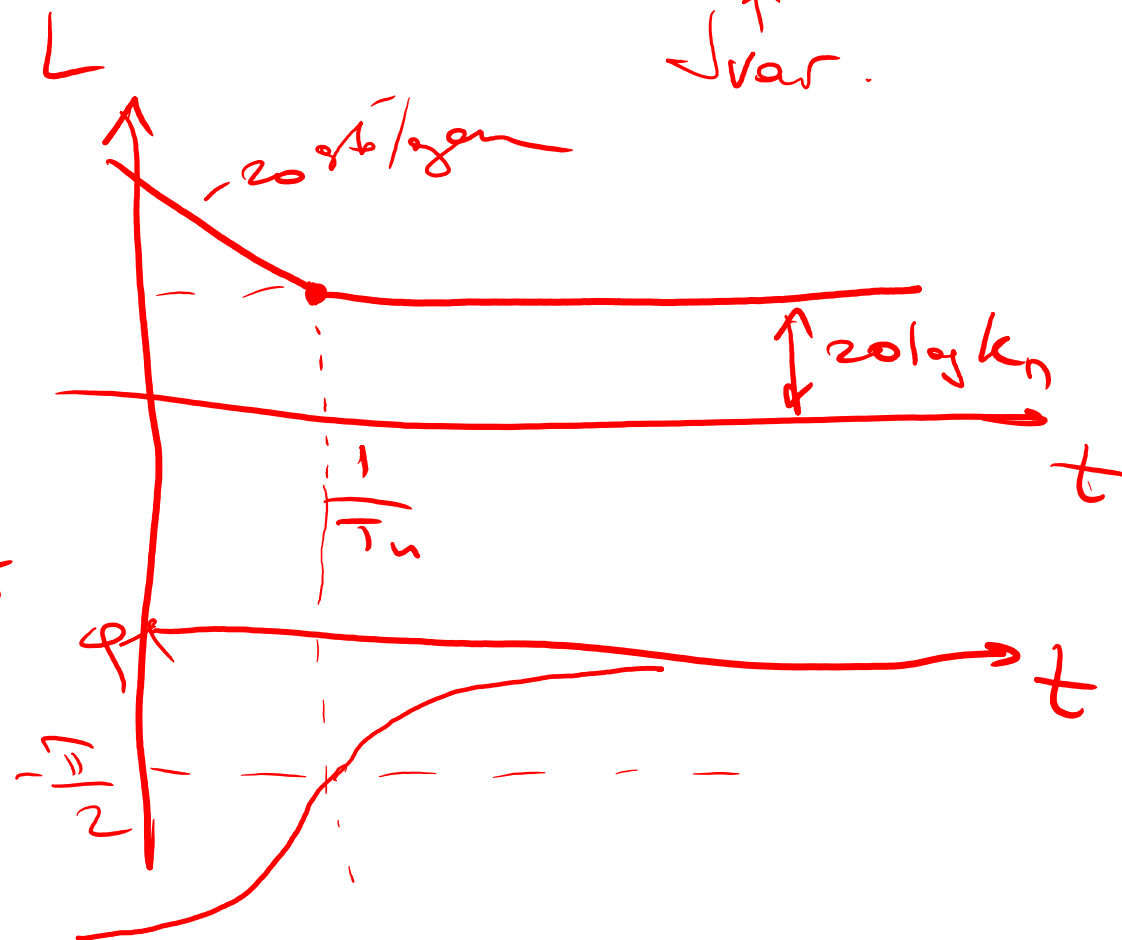
$$u(t) = K_u \left(\varepsilon(t) + \frac{1}{T_u} \int_0^t \varepsilon(\tau) d\tau \right)$$

$$W_{nu}(p) = \frac{K_u (T_u p + 1)}{T_u p}$$



80%

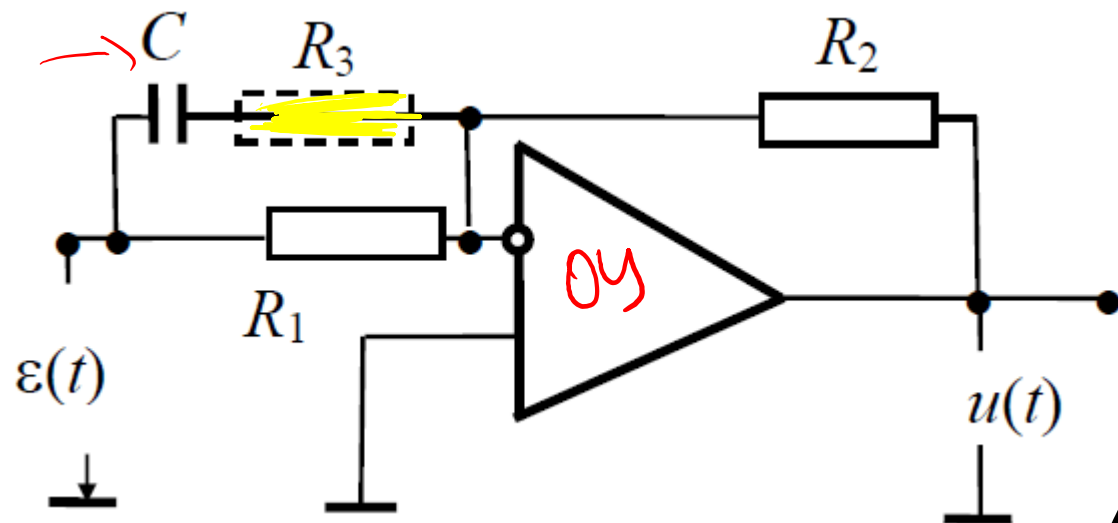
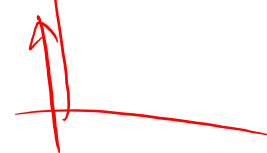
ПИ-регулятор



ПД-регулятор

$$\frac{du}{dt}$$

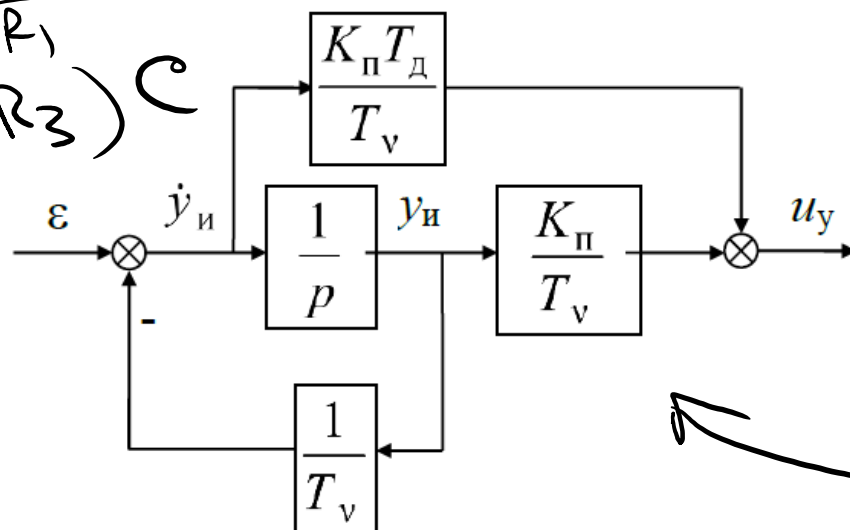
X



$$k_n = \frac{R_2}{R_1}$$

$$T_D = (R_1 + R_3)C$$

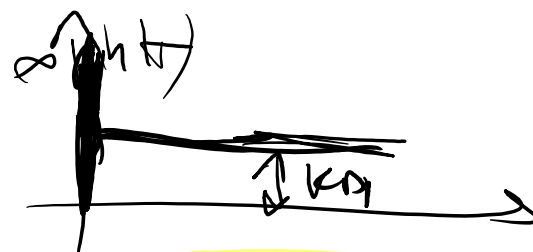
$$T_v = R_3C$$



$$u(t) = k_n \varepsilon(t) + k_n \frac{d\varepsilon(t)}{dt}$$

$$W_{PD}(p) = k_n + k_n p = k_n (T_D p + 1)$$

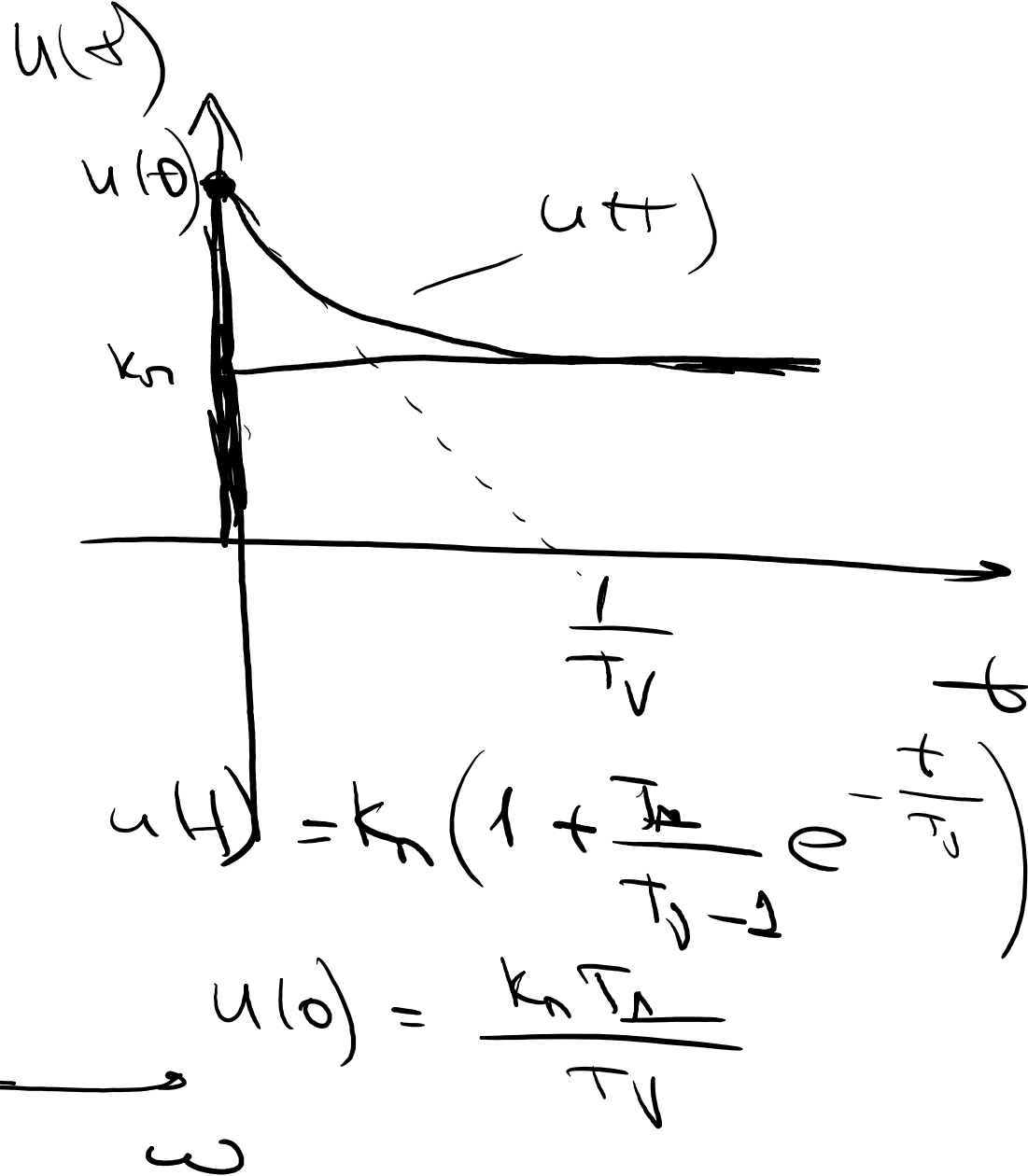
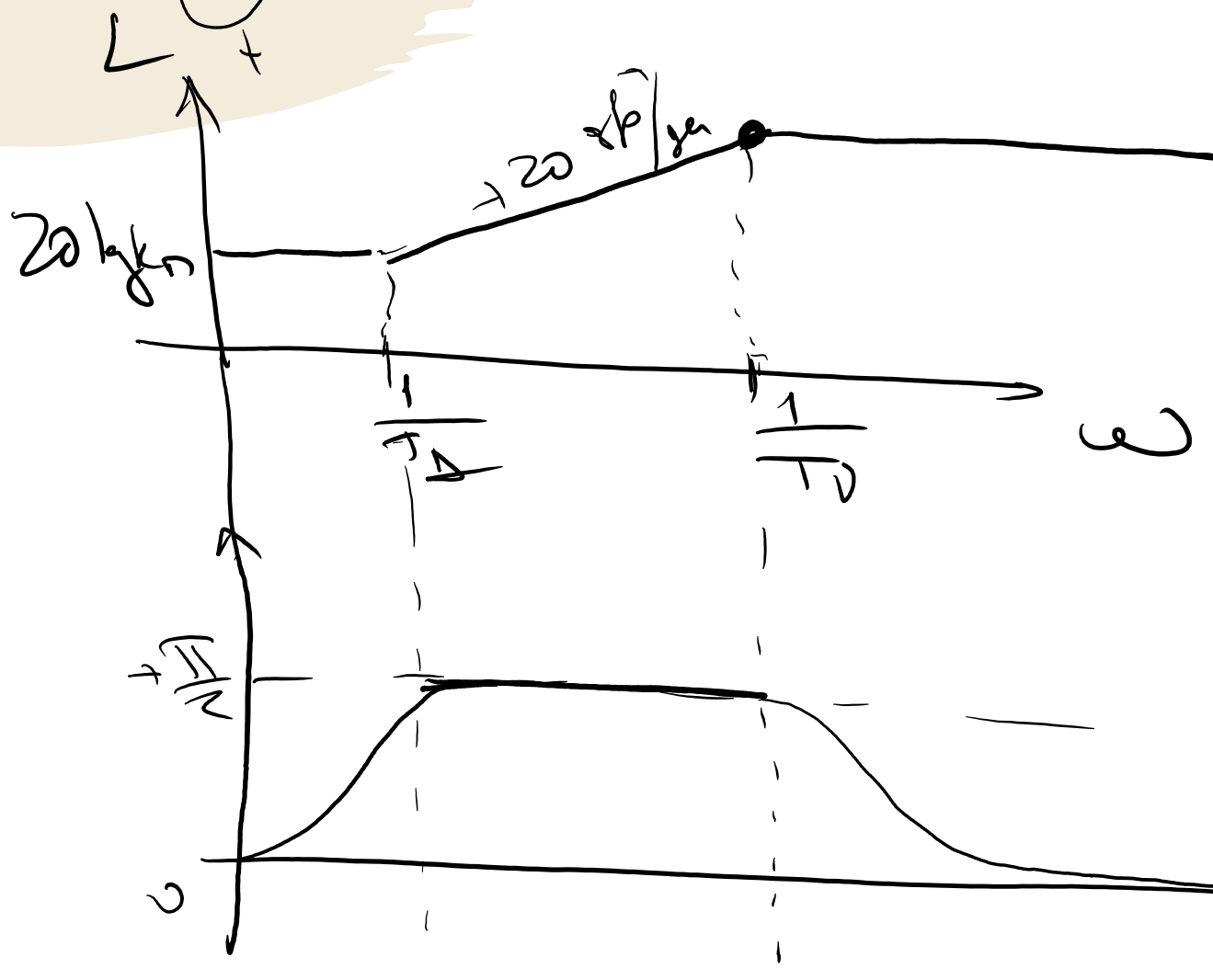
$$h(t) = k_n (1 + \delta(t))$$



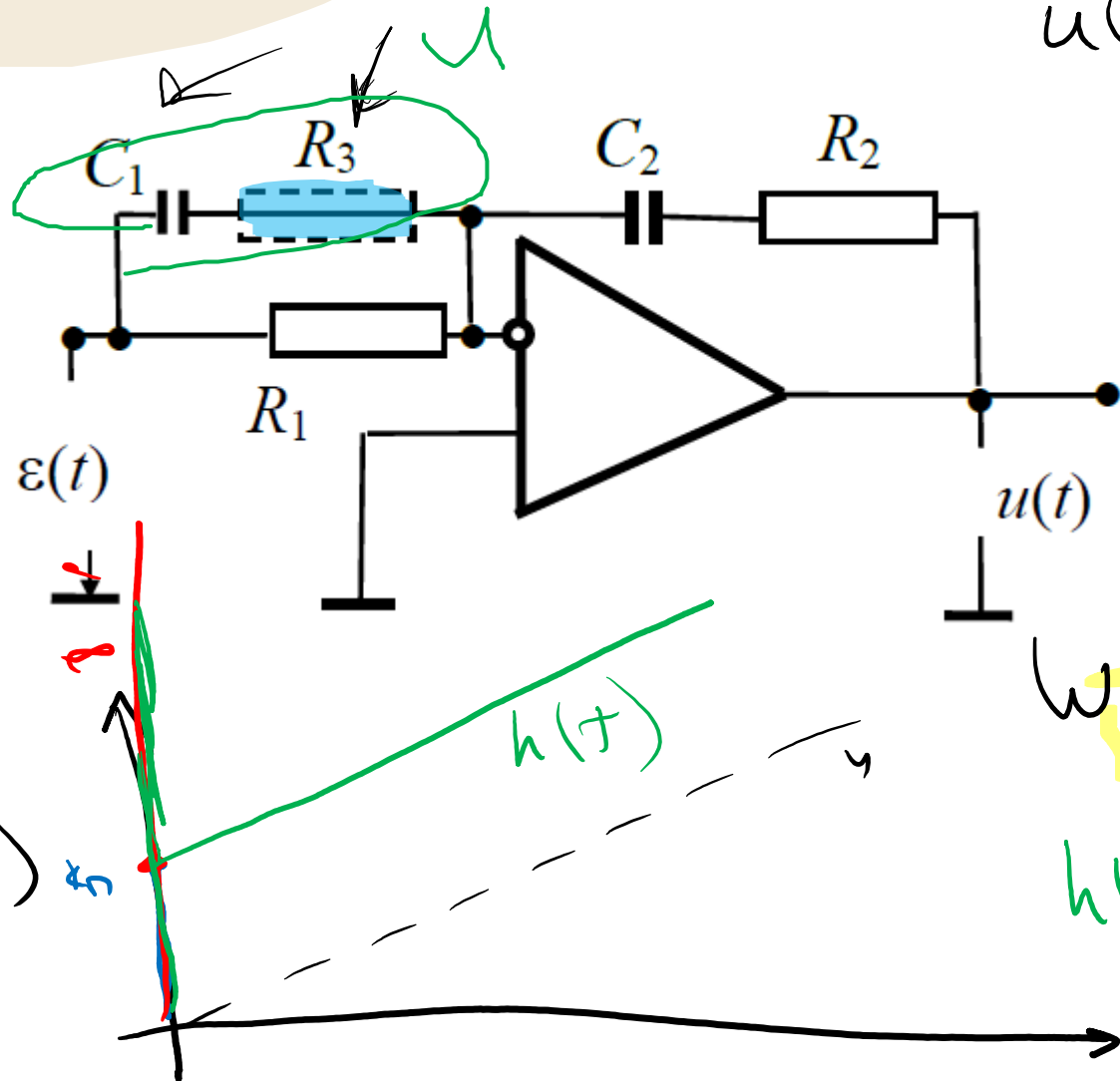
$$W_{PD}(p) = \frac{k_n (T_D p + 1)}{(T_v p + 1)}$$

ПД-регулятор

u



ПИД-регулятор



$$u(t) = k_1 \varepsilon(t) + k_2 \int \varepsilon(t) dt + k_3 \frac{d\varepsilon(t)}{dt}$$

$$u(t) = k_n \left(\varepsilon(t) + \frac{1}{T_n} \int \varepsilon(t) dt + T_n \frac{d\varepsilon(t)}{dt} \right)$$

$$W(p) = k_n \frac{(T_D T_n p^2 + T_n p + 1)}{T_n p}$$

$T_D > T_n$

$$W(p) = k_n (T_n p + 1) (T_D p + 1)$$

$$h(t) = k_n \left(1 + T_D \delta(t) + \frac{t}{T_n} \right)$$

ПИД-регулятор

$$k_n = \frac{R_2}{R_1}$$

$$T_u = R_2 C_2$$

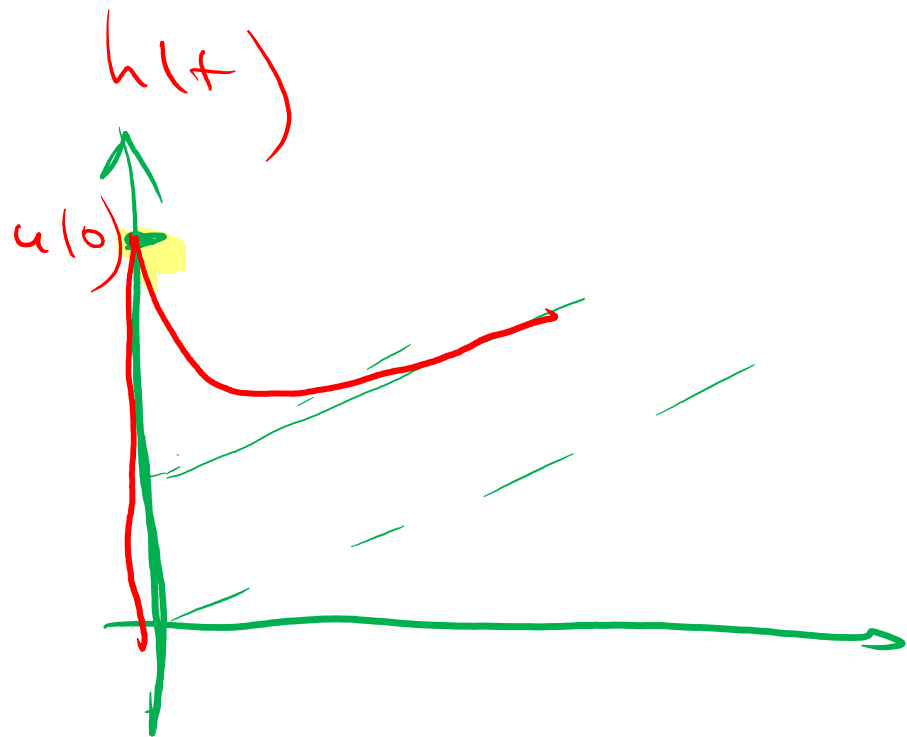
$$T_D = R_1 C_1$$

$$k_n = \frac{R_2}{R_1}$$

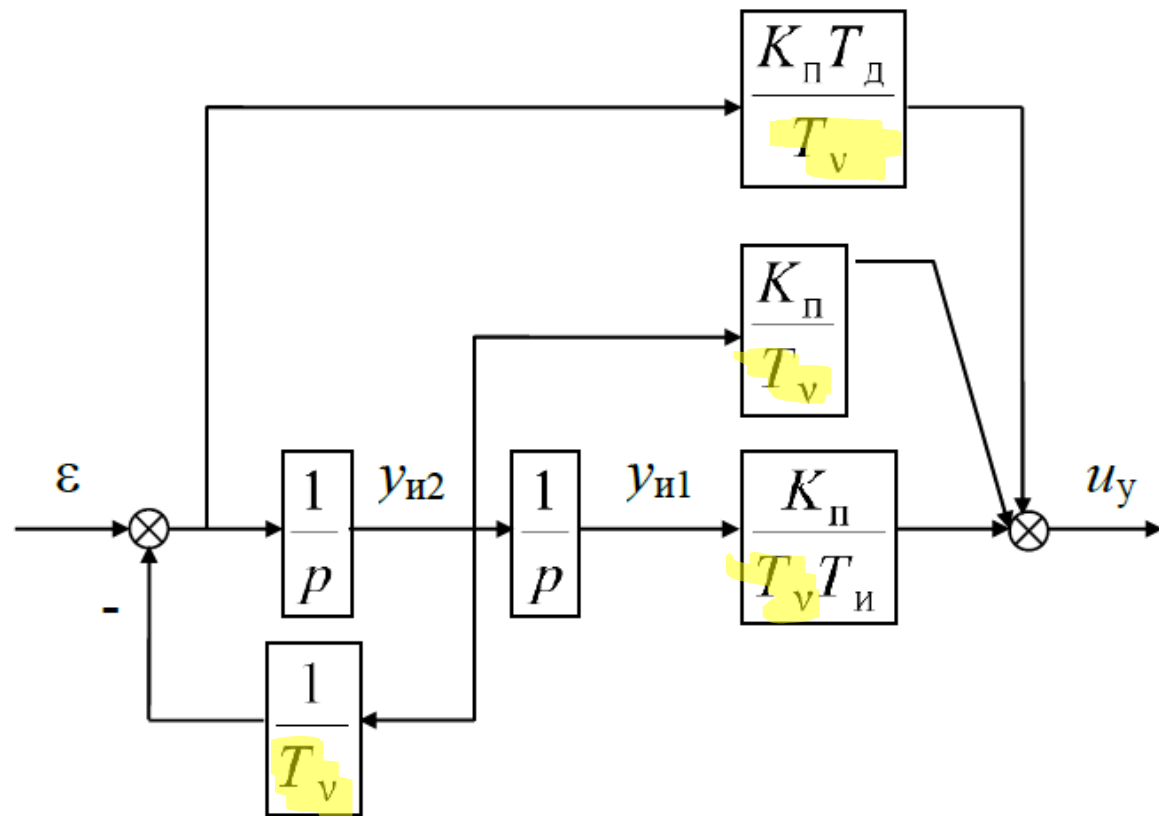
$$T_u = R_2 C_2$$

$$T_D = R_3 C_1$$

$$T_D = (R_3 + R_1) C_1$$



ПИД-регулятор



$$W(\phi) = K_p \frac{T_i T_d p^2 + T_i p + 1}{T_i p (T_v p + 1)}$$

Handwritten note: $W(\phi) = K_p \frac{T_i T_d p^2 + T_i p + 1}{T_i p (T_v p + 1)}$

