$\dot{x} = ax + bu$ $\quad a \in \mathbb{R}$

$b \in \mathbb{R}^+$

cieľ $x \to 0$

$u = ?$

$u = kx$ test:

$\dot{x} = ax + b(kx)$

$\dot{x} = \underbrace{(a + bk^*)}_{a_m} x$

existuje $a + bk^* = a_m$

hľadať ? (priame AR)

k^*

$\dot{x} = ax + bu + bk^*x - bk^*x$

$\dot{x} = \boxed{a_m x} + bkx - bk^*x$

$\dot{x} = a_m x + b\tilde{k}x$ $\quad \tilde{k} = k - k^*$ $\quad k(t)$

$\dot{\tilde{k}} = \dot{k}$

$x \to 0$

$\tilde{k} \to 0$ $\quad \tilde{k}(t)$

$\dot{\tilde{k}}$ - ?

$\dot{x} = \ldots$

$\dot{\tilde{k}} = \ldots ?$

V stabil $\quad$ eqv. $\to 0$

$V = \frac{1}{2}x^2(t) + \frac{1}{2}\tilde{k}^2(t)|b|$

$\Rightarrow \dot{V} = x\,\dot{x} + \tilde{k}\,\dot{\tilde{k}}|b|$

$x(a_m x + b\tilde{k}x) + \tilde{k}\,\dot{\tilde{k}}|b|$

$\dot{V} = a_m x^2 + b\tilde{k}x^2 + \tilde{k}\,\dot{\tilde{k}}|b|$

$a_m < 0$ $\quad \overset{!}{=} 0$

$\dot{V} = a_n x^2$

$x \to 0$

$\tilde{k}$ je ohraničené

$b\tilde{k}x^2 + \tilde{k}\dot{\tilde{k}} \cancel{/b} = 0$

$|b|\tilde{k}\dot{\tilde{k}} = -b\tilde{k}x^2$

$b = \text{sign}(b)|b|$

$\dot{\tilde{k}} = -bx^2 = -\text{sign}(b)x^2$

$\dot{\tilde{k}} = -\text{sign}(b)x^2$

$\boxed{\text{cieľ} \quad x \to x_m}$

$\dot{x}_m = a_m x_m + b_m r$

$u = kx + \ell r$

$\dot{x} = ax + b(kx + \ell r)$

$\dot{x} = \underbrace{(a+bk)}_{a_m}x + \underbrace{b\ell}_{b_m} r$

hľadanie

$\to$ kritérium ?

„$e \to 0$" $\quad e = x - x_m$

$\dot{e} = ?$

$\dot{x} - \dot{x}_m$

$\dot{e} = ax + bu - a_n x_n - b_n r +$ $+$ „$k^* \ell^*$"

$\to \boxed{\dot{e} = \ldots}$

$\dot{\tilde{k}} = \ldots ?$

$\dot{\tilde{\ell}} = \ldots ?$

$\dot{e} = ax + bu + b(k^*x + \ell^*r - k^*x - \ell^*r) - a_n x_m - b_n r$

$\dot{e} = a_m e + b(\tilde{k}x + \tilde{\ell}r)$

$\dot{\tilde{k}} = \ldots$

$\dot{\tilde{\ell}} = \ldots$

$V = \frac{1}{2}e^2 + \frac{1}{2}\tilde{k}^2 + \frac{1}{2}\tilde{\ell}^2$

$\dot{V} = ? \leq 0$

$\dot{V} = \frac{1}{2}2e\dot{e} + \frac{1}{2}2\tilde{k}\dot{\tilde{k}} + \frac{1}{2}2\tilde{\ell}\dot{\tilde{\ell}}$

$\dot{V} = e(a_m e + b(\tilde{k}x + \tilde{\ell}r)) + \tilde{k}\dot{\tilde{k}} + \tilde{\ell}\dot{\tilde{\ell}}$

$\dot{V} = a_n e^2 + eb\tilde{k}x + eb\tilde{\ell}r + \tilde{k}\dot{\tilde{k}} + \tilde{\ell}\dot{\tilde{\ell}}$

$eb\tilde{k}x + \tilde{k}\dot{\tilde{k}} = 0$

$eb\tilde{\ell}r + \tilde{\ell}\dot{\tilde{\ell}} = 0$

$\dot{\tilde{k}} = -bex$

$\dot{\tilde{\ell}} = -ber$

$\dot{\tilde{k}} = -ebx = -\text{sign}(b)ex$

$\dot{\tilde{\ell}} = -ebr$

$\dot{x} = ax + bu$

grad ! $\boxed{RM ?}$ $\dot{x}_m = a_m x_m + b_m r$

$\boxed{e = x - x_m}$

$x = \frac{b}{s-a} u$ $x_m = \frac{b_m}{s-a_m} r$ $\frac{x_m}{r}$

$u = kx + \ell r$

$x = \frac{b(kx+\ell r)}{s-a} = \frac{bk}{(s-a)} x + \frac{b\ell}{(s-a)} r$

$\frac{x}{r} = ?$

$\frac{(s-a) - bk}{(s-a)} x = \frac{b\ell}{(s-a)} r$

$\frac{x}{r} = \frac{b\ell^*}{(s-(a+bk^*))} \overset{?}{=} \frac{b_m}{s-a_m}$

$\frac{\partial e}{\partial k} = ?$

$\dot{k} = ? \quad = -\alpha_1 e \frac{\partial e}{\partial k}$

$\dot{\ell} = ? \quad = -\alpha_2 e \frac{\partial e}{\partial \ell}$

$e = x - x_m$

$e = b\ell(s-(a+bk))^{-1} r - x_m$

$\frac{\partial e}{\partial k} = b\ell(-1)(s-(a+bk))^{-2}(-b) r$

$= b(s-(a+bk))^{-1} \underbrace{b\ell(s-(a+bk))^{-1} r}_{x}$

$\frac{\partial e}{\partial k} = \frac{b}{s-(a+bk)} x$

$b \longrightarrow \mathrm{sign}(b)$

$\frac{\partial e}{\partial \ell} = b(\quad)^{-1} r$

$\approx \mathrm{sign}(b)(s-a_m)^{-1} r$

$\dot{\ell} = -\alpha_2 e \left(\frac{\mathrm{sign}(b)}{(s-a_m)} r \right)$

$$b \longrightarrow \mathrm{sign}(b)$$

$$(s - a_n)$$

$$\dot{k} = -\alpha_1 e \left(\frac{\mathrm{sign}(b)}{s - a_n} x \right)$$