



Лагранжиан:

$$(M+m)\ddot{x} - mL\ddot{\varphi}\cos\varphi + mL\dot{\varphi}^2\sin\varphi = F$$

$$L\ddot{\varphi} - g\sin\varphi = \ddot{x}\cos\varphi$$

$$\varphi \approx 5^\circ$$

$$\varphi \approx 0 \Rightarrow \dot{\varphi} \approx 0, \cos\varphi \approx 1, \sin\varphi \approx \varphi$$

$$\ddot{x} = -g\varphi \quad \ddot{x} - \text{ли. уск. центра колеса}$$

$$\varepsilon = -gR\varphi$$

$\varepsilon$  - уг. уск.  $R$  - радиус колеса.

ДПТ:

$$J \cdot \varepsilon = k_1 \cdot \dot{\varphi} - M_H$$

$$U = k_2 \cdot \omega + \bar{I} \cdot Rg\varphi$$

$$U = (J \cdot R/k_1) \cdot \varepsilon \quad \varepsilon = -gR\varphi$$

$$U = - \left( J \frac{R}{k_1} \right) \cdot g \cdot R \cdot \varphi$$

$$U = - k_{g\varphi} \cdot \varphi$$

...

Uth speed 0...255  $\Rightarrow$  0...7.2B

max  $\varphi = 5^\circ$   $u_{max} = 7.2 \Rightarrow k_{gb} \approx 30$

speed  $< 100 \Rightarrow \epsilon = 0$

speed = 100...255

np4  $\varphi = 0$  speed = 100

np4  $\varphi = 5^\circ$  speed = 255

speed =  $k_{gb} \cdot \varphi + 100$   $\varphi > 0$

speed =  $k_{gb} \cdot \varphi - 100$   $\varphi < 0$

$k_{gb} = 30$

PID =  $k_p \cdot \varphi + k_i \cdot \int \varphi dt + k_d \cdot d\varphi/dt$

Speed =  $k_{gb} \cdot (k_p \cdot \varphi + k_i \cdot \int \varphi dt + k_g \cdot \frac{d\varphi}{dt}) / 100$