Exercises for lectures
10 - Feedforward

Martin Hromčík
Automatické řízení 2013

19-3-17

Oscillating system

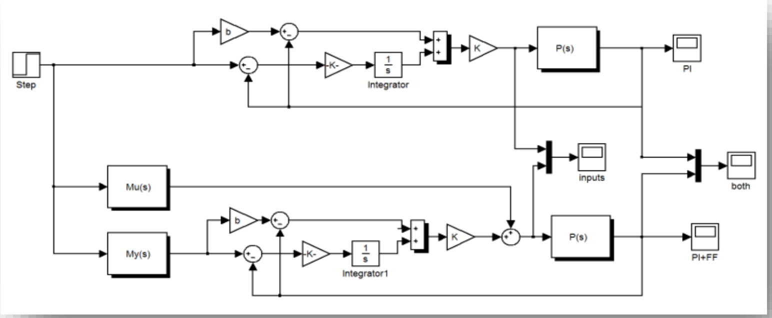
AH_5_9_FFforOscilatory.mdl

- For oscillating system transfer function

$$G(s)=\frac{9}{(s+1)(s^2+0.1s+9)}$$

- And reasonable tuned PI controller

$$K=-0.167, T_i=-0.210$$

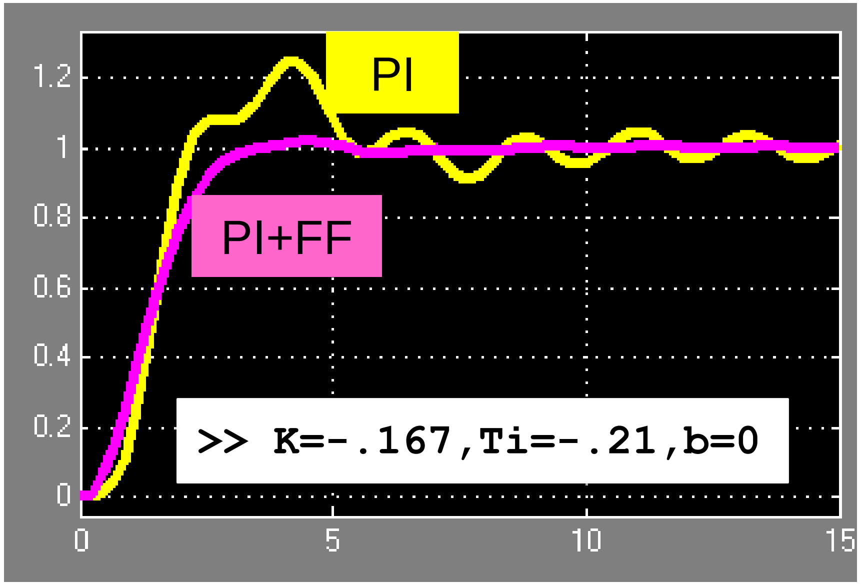


- We achieve significant improvement with

$$M_y(s)=\frac{9}{(s+1)(s^2+6s+9)}$$

- Which leads to

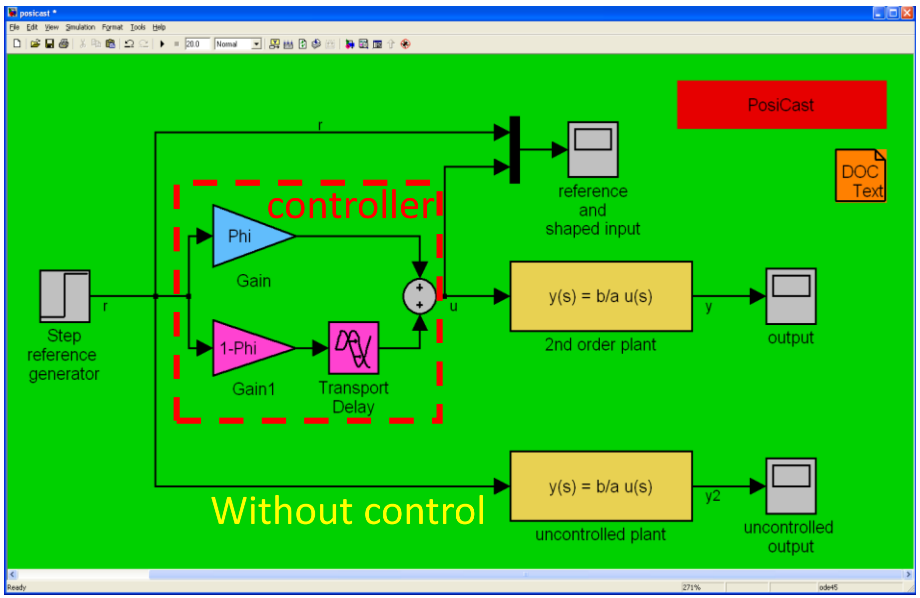
$$M_u(s)=\frac{s^2+0.1s+9}{s^2+6s+9}$$

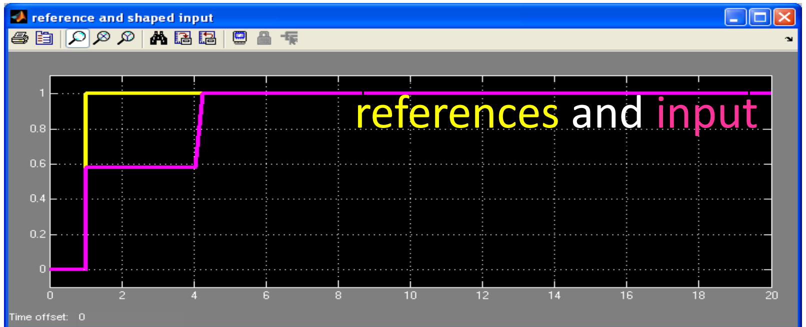


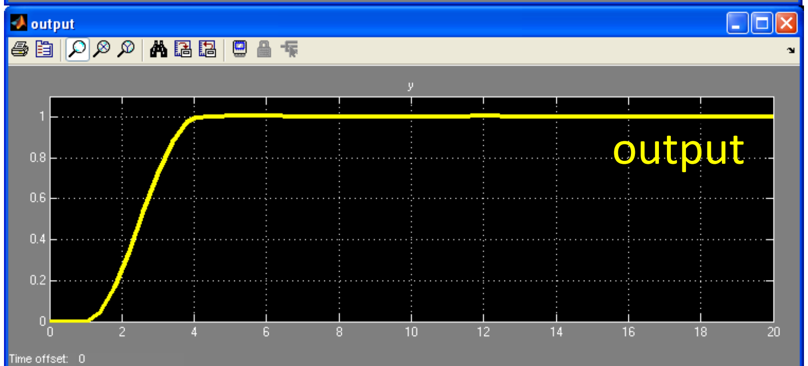
Posicast - simulation

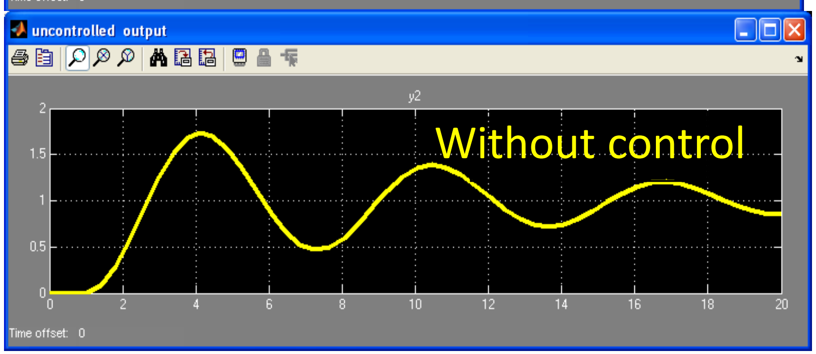
- Simulink: **`posicast.mdl`** with values $\omega_n = 1\,\text{rad/s}, \zeta = 0.1$

```
>> omegan=1,zeta=0.1, ...
   a=s^2+2*omegan*zeta*s+omegan^2,...
   b=omegan^2
omegan = 1 , zeta = 0.1000
a =  1 + 0.2s + s^2
b =  1
>> n=1;
>> tau=n*pi/omegan/(sqrt(1-dzeta^2)),...
   Phi=1/(1+exp(-tau*zeta*omegan))
tau = 3.1574, Phi = 0.5783
```



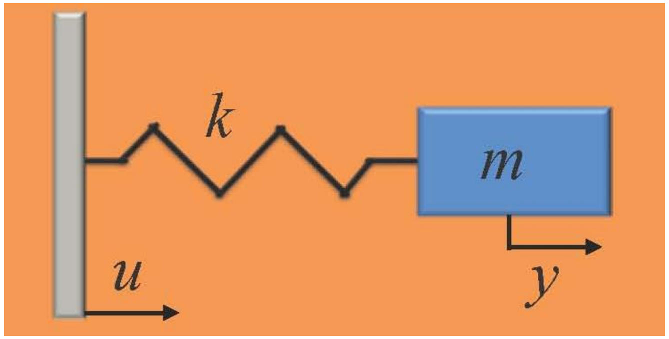






Posicast for mass spring system

- It is similar for mass spring system

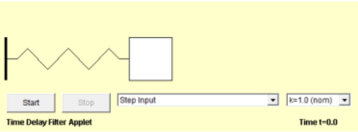


- Same equation without damping

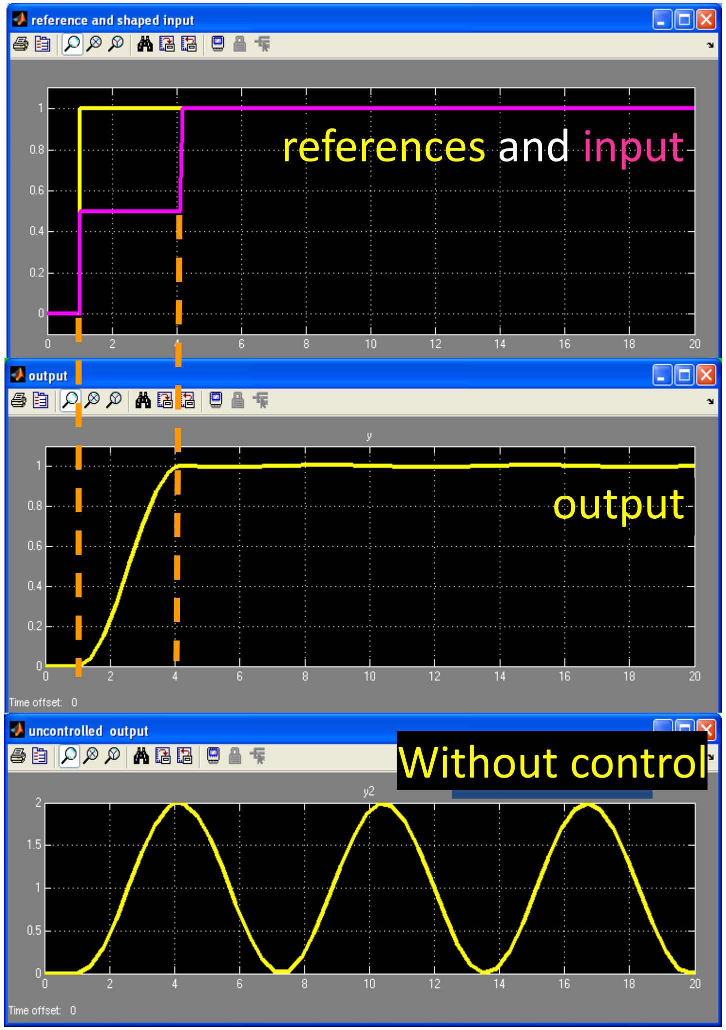
$$\omega_n = 1\,\mathrm{rad/s}, \zeta = 0$$

$$\tau = \pi, \Phi = 0.5$$

- Animation (M. Münchhof , TU Darmstadt) http://www.muenchhof.net/introinputshaping.html



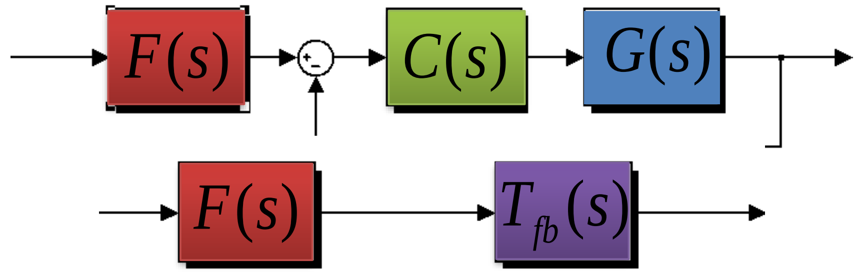
$$\tau = 3.1574,\ \Phi = 0.5783$$



Prefilter and zero reduction

- For systém with transfer function $G(s)=\frac{1}{s}$ and $T_{s2\%}$ = 0,5s a *OS 4%*
  PI controller design

$$C(s)=16+\frac{128}{s}=\frac{16(s+8)}{s}$$

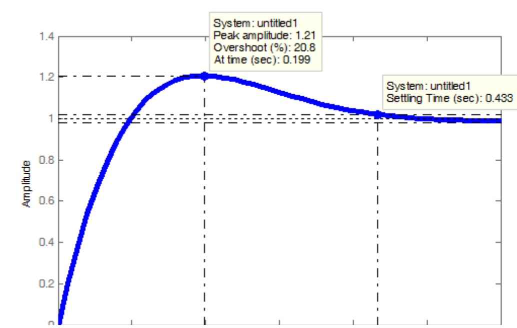


- Ensuring CL characteristic polynomial

$$c(s)=s^2+16s+128$$

- But the closed loop transfer function

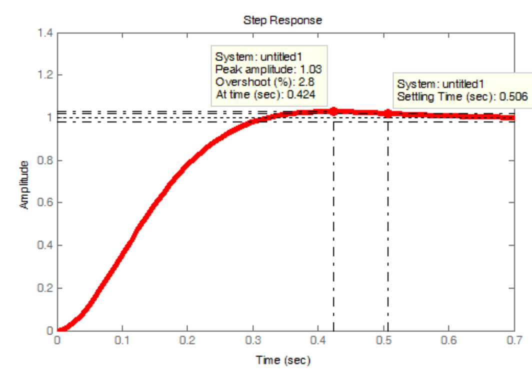
$$T_{fb}(s)=\frac{16(s+8)}{s^2+16s+128}$$



- It has unsuitable step response.
- By using prefilter
  The transfer function is $F(s)=\frac{8}{s+8}$

$$T_{fb}(s)=\frac{128}{s^2+16s+128}$$

with better response



Transport aircraft vibration supression

- The aim is to reduce vibration – fuselage deflection – of a flexible aircraft caused by aggressive maneuvering.
- Robustness requirements (number of passangers, altitude, speed, …)

- Transfer function (normalized) from the elevator to pitching speed

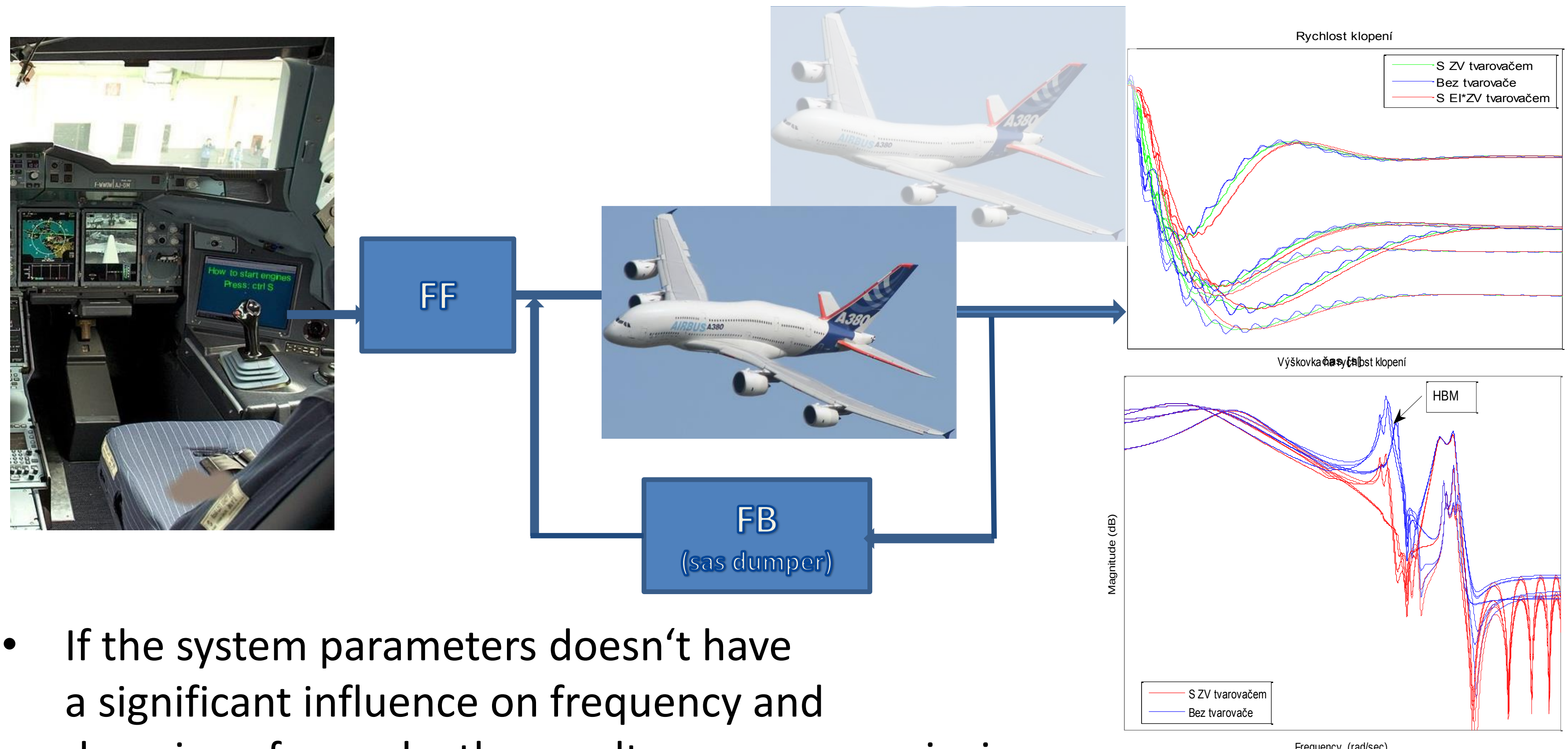
$$\frac{(s+1.7)(s+79)(s+400)(s+22)(s+15)(s+2.85)(s+0.83)(s+0.0774)(s\hat{}2 + 0.27s + 77.51)(s\hat{}2 + 0.3692s + 408.7)(s\hat{}2 + 1.16s + 722.6)(s\hat{}2 + 0.6158s + 9.4)(s\hat{}2 + 0.9224s + 12)(s\hat{}2 + 1.078s + 1}{(s+45.04)(s+253)(s+11.38)(s+22)(s-0.2908)(s+0.08)(s\hat{}2 + s + 2.)(s\hat{}2 + 3s + 7.919)(s\hat{}2 + 0.756s + 78.8)(s\hat{}2 + 0.\check{r}s + 409.4)(s\hat{}2 + 13s + 73.2)(s\hat{}2 + 0.2s + 988.9)(s\hat{}2 + 0.934s + 13)(s\hat{}2 + 1 s + 14)}$$

It contains HBM (hull bending mode) on frequency 8.87 rad/s with damping 0.042

Transport aircraft vibration supression

- Using “signal shaper” (e.g. PosiCast) tuned to HBM mode:

```
>> s = tf('s');
>> IS = 0.43 + 0.57 * ss(exp(-s*0.31));
```



- If the system parameters doesn‘t have a significant influence on frequency and damping of a mode, the results are very convincing.

Manipulator with flexible load

- Rotating servomechanism - positional feedback for arm setpoint tracking.
- The feedback controller is designed as a fast system (by RL, frequency methods, ...)
- Flexible modes are excited by load flicking.

Manipulator with flexible load

- Signal shaper to reference:

Charakteristické vlastnosti ramene

- Vlastní frekvence ω_n= 15.9 rad/s
- Tlumení $\xi = 0.2$

```
tau = pi/wn/sqrt(1-a^2);
phi = 1/(1+exp(-pi*a/sqrt(1-a^2)));
phi=1-0.35
tau=0.1973
s=zpk('s')
ZV=phi+(1-phi)*ss(exp(-s*tau))
```

- It ensure „unexciting“ of a flexible modes and the response is reasonably fast.