Nested Velocity Feedback Control

Dr Richard Mitchell, Cybernetics Intelligence Group
School of Systems Engineering, University of Reading
R.J.Mitchell@reading.ac.uk

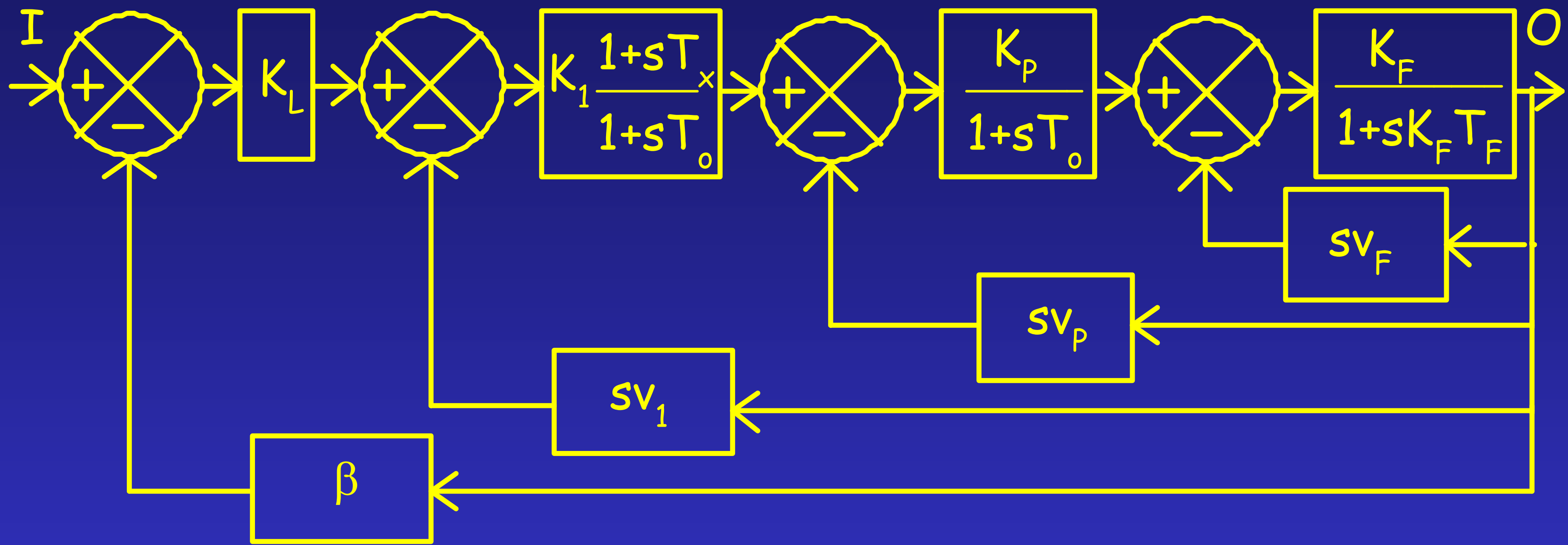
Good Feedback Systems have high loop gain over the appropriate bandwidth. This is limited to maximum available feedback (MAF) in single loop systems

Here explore having multiple loops – specifically with local velocity feedback – inspired by Cherry Amp

Also, (borrowed from MAF) how to increase bandwidth

Resultant systems comparable with PID control, but more tolerant to changes in the plant under control

Cherry Amplifier



Two output lags with local velocity feedback (lvf)

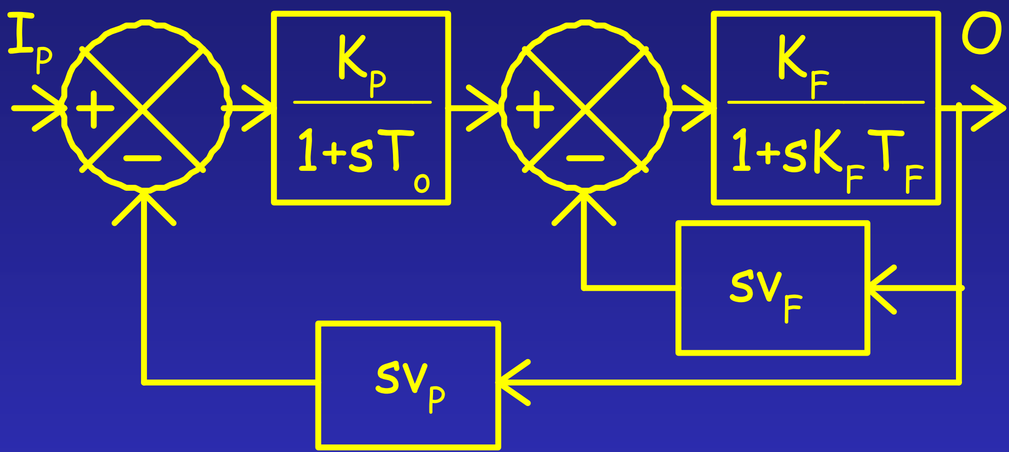
Preceded by a lead-lag with lvf … could have n lead-lags

Each increases loop gain; designed so system ~ 2nd order

Overall gain set by β in feedback path

Cherry Amplifier - Why Use LVF?

Just consider exponential lags with local velocity feedback



The velocity feedback in effect moves the time constants of the lags, which can also be done by series lead-lags

However, Cherry shows VF gives better sensitivity re changes in the lag constants

Also, better if only v_p term is used

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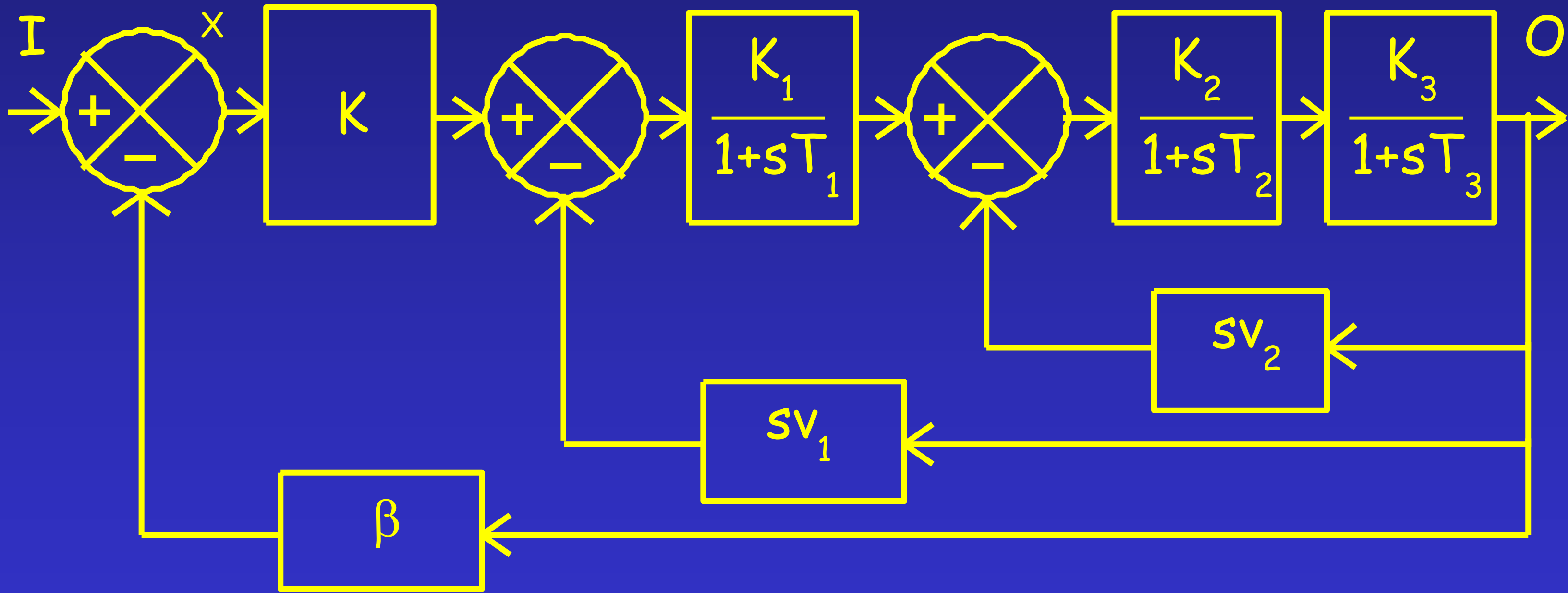
Velocity Feedback for Control

Cherry Amp: keep add stages from scratch til meet spec.
For control, need to add controller to a 'plant'
Let's see how to use LVF … for say power amp + motor



As will show, v terms set to give freq response, linear K to meet Phase Margin spec; β usually unity for control

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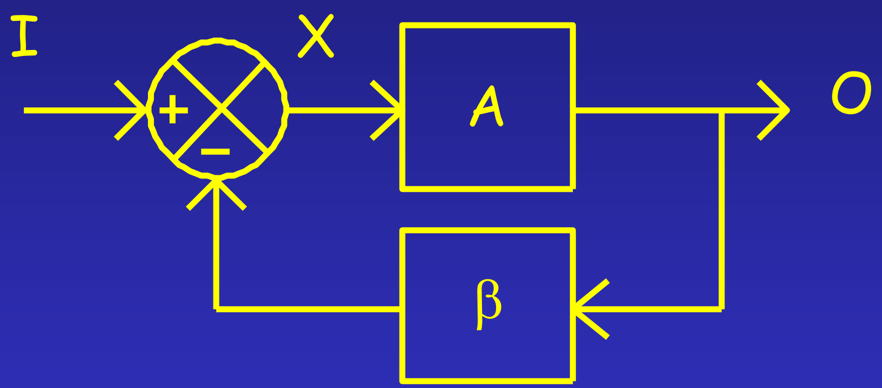
Analysis

Need to analyse – want transfer function of forward path

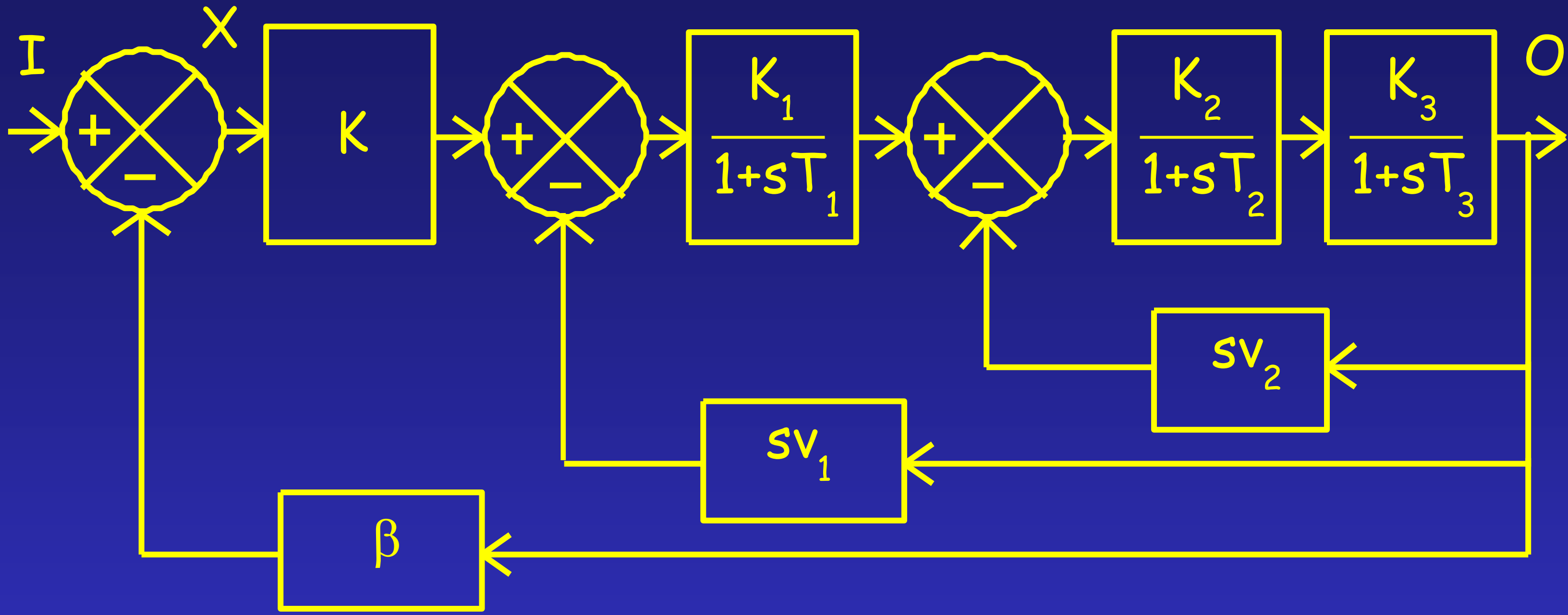
Easiest to use ‘inverse transfer functions’



$$\frac{I}{O} = \text{Feedback} + \frac{1}{\text{Forward}}$$

$$\frac{I}{O} = \beta + {}^{1}\!/\!_{A} = \frac{\beta A + 1}{A}$$

Hence



$$\frac{X}{O} = \frac{K}{1} * \left(sv_1 + \frac{1+sT_1}{K_1} * \left(sv_2 + \frac{1+sT_2}{K_2}\frac{1+sT_3}{K_3} \right) \right)$$

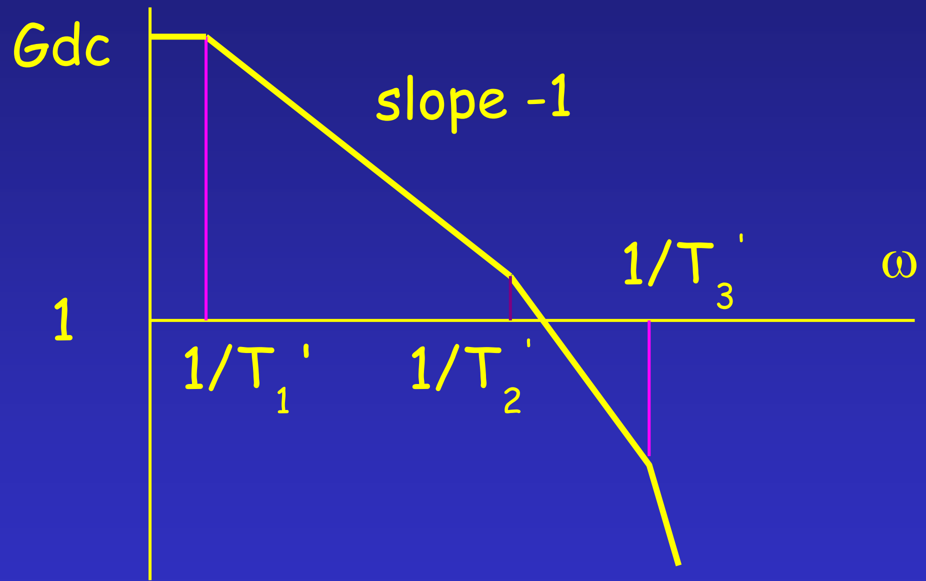
So

$$\frac{O}{X} = \frac{KK_1K_2K_3}{(1+sT_1)(1+sT_2)(1+sT_3)+s(v_1K_1+v_2K_2K_3)+s^2v_2K_2K_3T_1}$$

Strategy

Can then choose v's st $\frac{O}{X} = \frac{KK_1K_2K_3}{(1+sT_1^{'})(1+sT_2^{'})(1+sT_3^{'})}$

Designer specifies T'_ns



From paper: Tpk to step for 45^o PM is $0.826\pi T_2'$

So set estimate of T_2'

T_3' chosen to be factor of 30 (say) below this

T_1' then set as product of T_n = that of T'_n (s^3 terms)

v's found easily (from equating other coefficients)

K then calculated to meet PM spec:

eg for 45^o PM, K set so unity gain at $1/T_2'$

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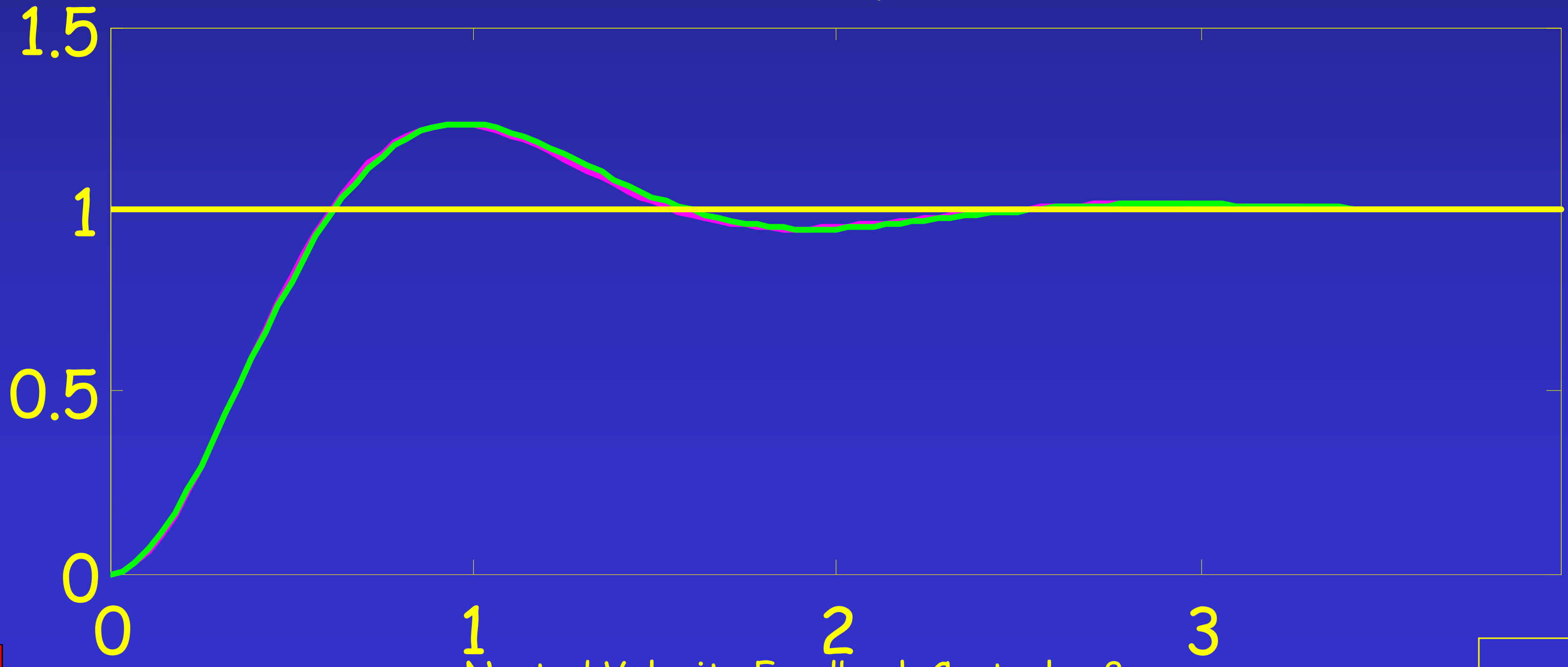
Example – Power Amp + Motor

$$\frac{15}{(1+s/3)} * \frac{3}{(1+s2)(1+s5)}$$

So as to give comparison, a PID controller was designed, using MZN for 45^{o} PM, Step Peak was 1.23 at 0.97s

Vel FB design for same PM and peak (after an iteration)

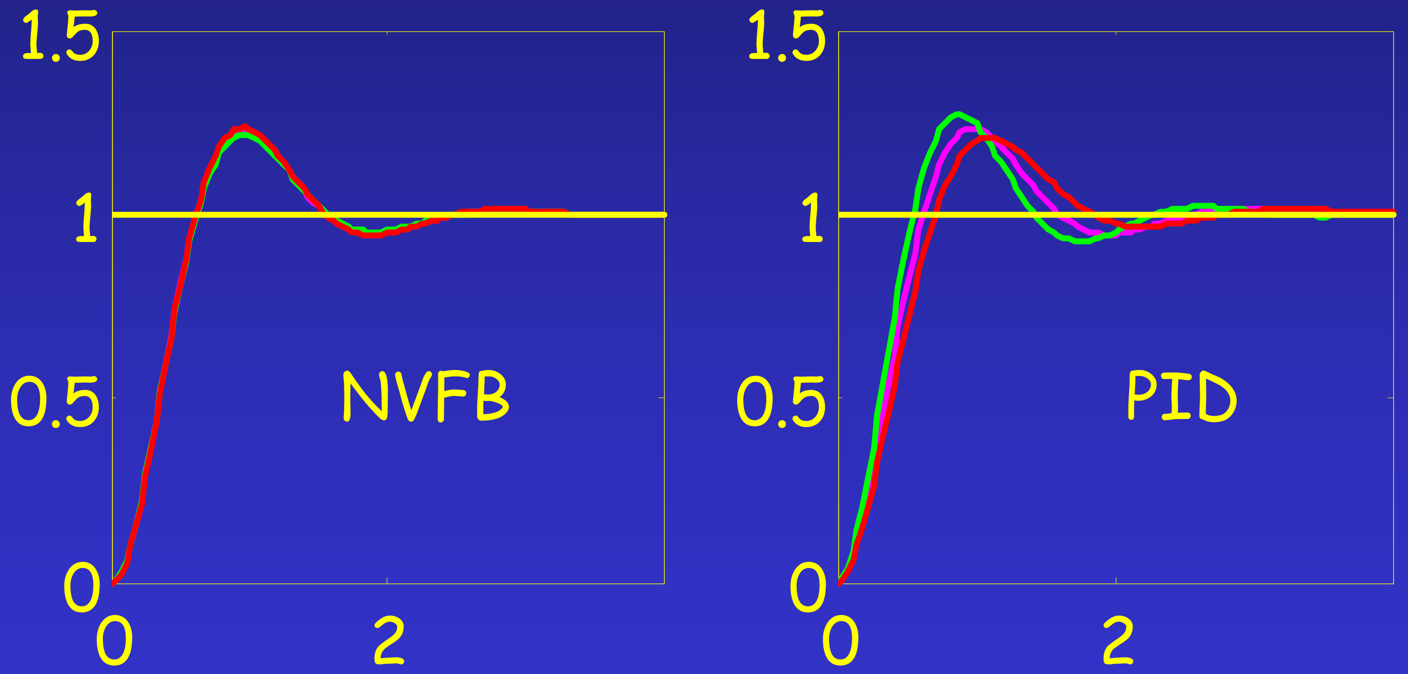


Responses almost identical

So adv of nested velocity feedback?

Its aim is reduced sensitivity to changes in plant.

So see what happens if K_3 and T_3 each change by 20%



Little effect re NVFB, but PID system changes much

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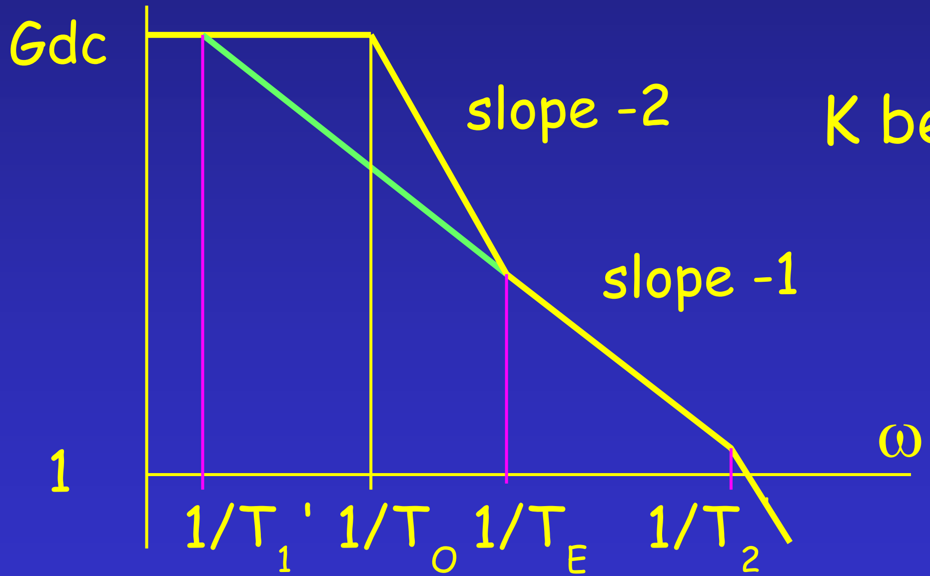
Improving Bandwidth

First corner freq is quite low, so bandwidth low

To increase, borrow from Maximum Available Feedback (where double bandwidth by incr slope of gain at low f)



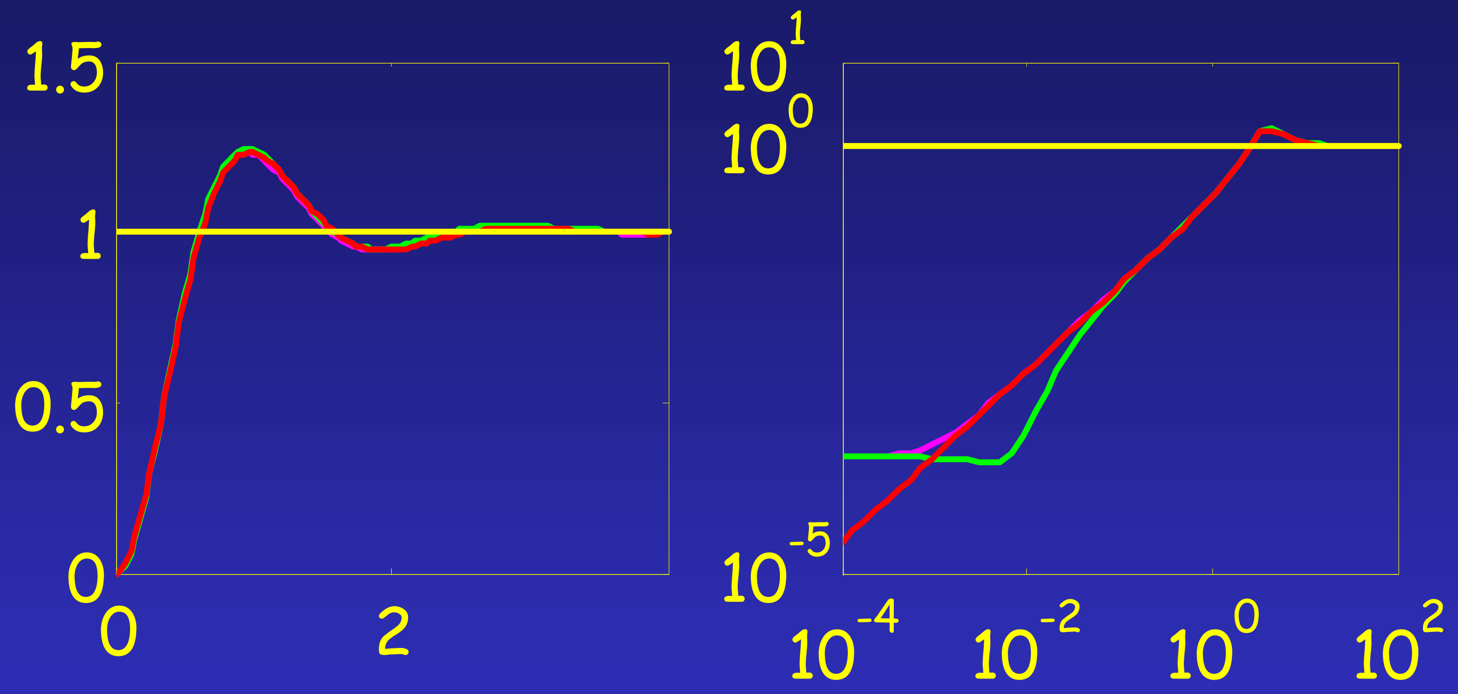
K becomes series compensator:

$$K\frac{(1+sT_e)(1+sT_1')}{s^2T_o^2+sT_o+1}$$

Bandwidth is $1/T_O$

Propose $\frac{T_E}{T_1'} = 2\frac{T_2'}{T_E}$ or $T_E = \sqrt{2T_1'T_2'}$ so $T_O = \sqrt{T_E T_1'}$

Step and Closed Loop Dist Freq Resp



Responses of PID, NVFB, NVFB + more bandwidth

Clearly, element not affected Step significantly

Re Disturbance, has improved range where D rejected

Conclusion

Nested velocity feedback has been proposed as a means of designing some third order systems.

These designs have been compared against the common PID controller, and have been shown to be much more robust as regards changes in the gain and time constant of the devices under control.

Method extended to increase the system bandwidth.

Further work is planned to investigate higher order systems and ones where the device under control also has a pure integrator.

