Examination of the new CERN PS transverse damper performance for beam injection

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Activity initiated by Alfred Blas

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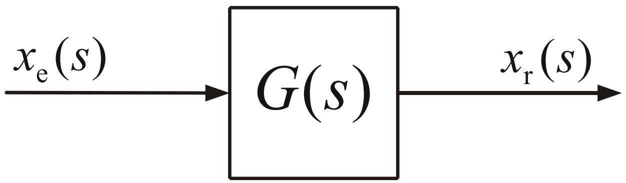
Recall: The working principle of a transverse feedback

Driven harmonic oscillator differential equation, Laplace transform and transfer function:

$$\frac{1}{q_0^2}\frac{d^2}{dl^2}x_r(l)+\frac{2D}{q_0}\frac{d}{dl}x_r(l)+x_r(l)=K_p x_e(l) \quad \Rightarrow \quad \int_0^\infty dl\, e^{-sl}\ldots \quad \Rightarrow \quad G(s)=\frac{x_r(s)}{x_e(s)}=\frac{K_p}{1+\frac{2D}{q_0}s+\frac{1}{q_0^2}s^2}$$

Block diagram, representing the transfer function:



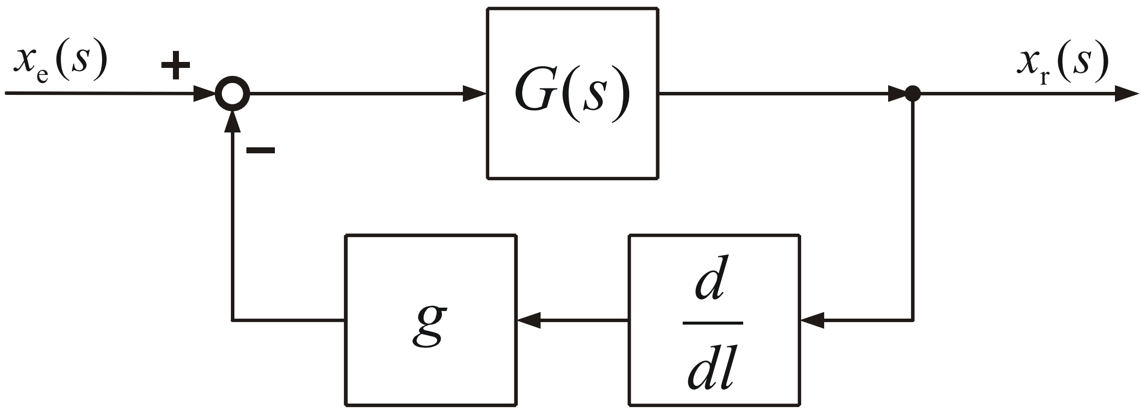
Introducing additional damping

Additional damping term in the differential equation:

$$\frac{1}{q_0^2}\frac{d^2}{dl^2}x_r(l)+\frac{2\left(D+D_{\mathrm{fb}}\right)}{q_0}\frac{d}{dl}x_r(l)+x_r(l)=K_p x_e(l)$$

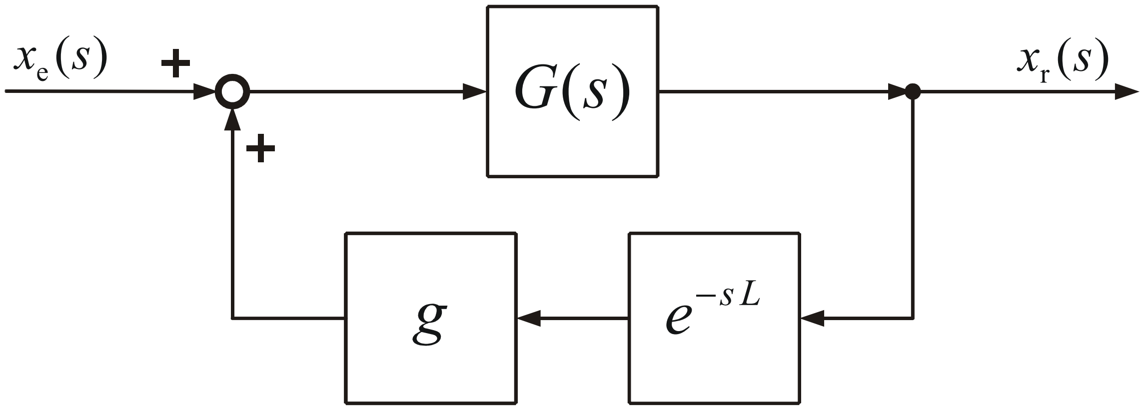
$$\Rightarrow \qquad \frac{1}{q_0^2}\frac{d^2}{dl^2}x_r(l)+\frac{2\,D}{q_0}\frac{d}{dl}x_r(l)+x_r(l)=K_p\left(x_e(l)-\frac{2\,D_{\mathrm{fb}}}{K_p\,q_0}\frac{d}{dl}x_r(l)\right)$$

Hence, feeding back the derivative of the response signal leads to additional damping:



Replacement of the derivative by a time delay

Determining the derivative requires several samples per oscillation. This is not possible for transverse beam oscillations. Therefore, the derivative signal is approximated by a time delayed signal, shifting the response signal by –π/2 in phase:



Consequence:

Such feedback loops are sensitive to the signal propagation times through the feedback path.

There is no problem, as long we have a constant signal propagation time for all frequencies.

The signal propagation time through a circuit is determined by derivative of the phase response.

Nothing is ideal – the actual status of the new CPS damper

- the new amplifier does not cover the frequency of the lowest betatron line

Questions form Alfred

- is the frequency response of the new amplifier sufficient?
- can we in principle operate without damping of the lowest betatron line?

First answers / advice

- according to the actual available frequency response data the amplifier is not sufficient – the loop would become unstable
  - ⇒ the phase response has to be re-measured
- damping without lowest betatron line is in principle possible
  - ⇒ the beam blow up of the first four bunches at the injection of the second two has to be studied, see work form EB and FZ!

Connection of transverse CPS damper with collective effects

- sample frequency of the damper ≈ 73 MHz (14 ns)
- bunch length at injection 180 ns

  ⇒ the damper is sampling each bunch 13 times!
- pick-up signals scale with beam intensity

  ⇒ the head and the tail of the bunch is less damped by the damper as compared to the core
- the head and tail and the core are mixed within the timescale of the synchrotron oscillations

  ⇒ the transverse damper and the incoherent collective beam dynamics interact!

Intuitively I would expect that one may learn a lot by studying this interaction in more detail by simulations and MDs because one is in principle able to influence well-aimed one side (the damper).

The practical result could be an improvement of the algorithms in the damper and an increase of the performance e.g. less blow-up.