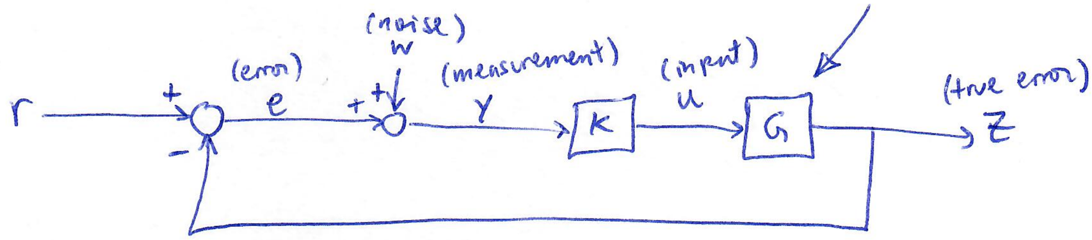
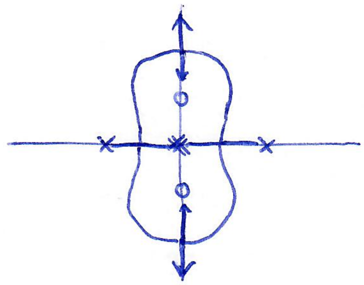
Balancing a stick (diagrams).

$$G = \frac{(1 - L_0/\eta L)s^2 - \omega_n^2}{s^2(s^2 - \omega_n^2)}$$

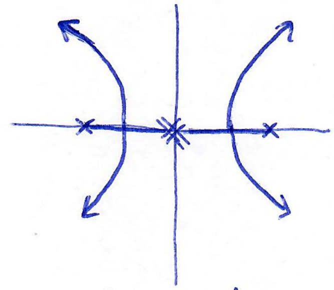
block diagram:



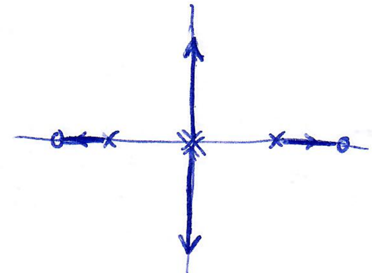
root locus:



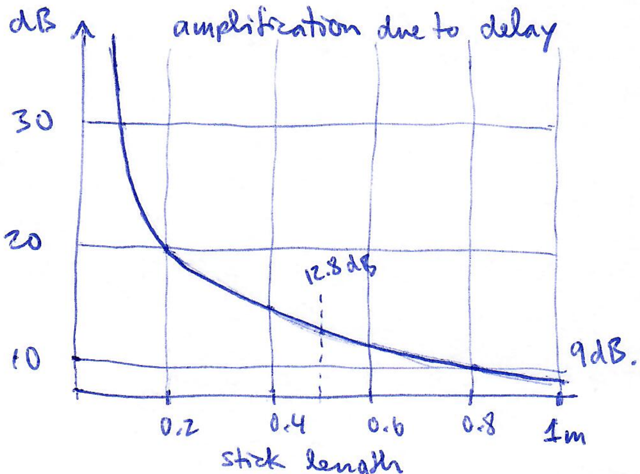
$L_0 > \eta L$
(easiest case)
imaginary zeros



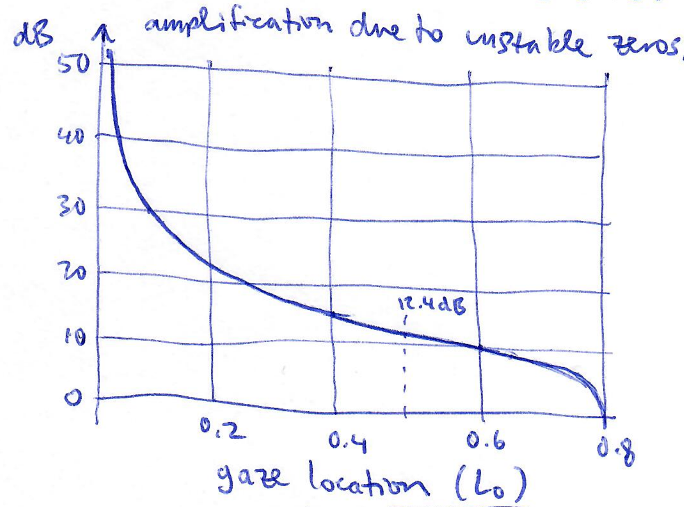
$L_0 = \eta L$
(harder)
no zeros



$L_0 < \eta L$
(hardest)
unstable zero.

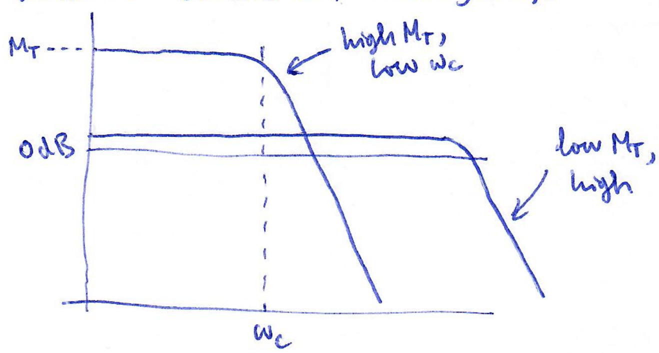


$M_T \geq e^{\omega_n \tau} = \exp\left(\sqrt{\frac{g}{\eta L}}\,\tau\right)$. $(\tau \approx 300\text{ms})$



$M_T \geq \text{gain} = \left|\frac{1 + \sqrt{1 - L_0/\eta L}}{1 - \sqrt{1 - L_0/\eta L}}\right|$

$|T(j\omega)|$ (closed loop Bode gain).



★ we want low ω_c (low bandwidth) to reject as much noise as possible.

★ we want low M_T, so amplified frequencies have as little amplification as possible.

But $\omega_c(M_T - 1) \geq \omega_n$, so we can't have both! and $\omega_n = \sqrt{\frac{g}{\eta L}}$ so this also gets harder as L gets larger.