ME 327: Design and Control of Haptic Systems
Spring 2020

Interactive Session 10: Kinesthetic haptic devices: Stability

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Questions from prerecorded video?

effect of time delay

review stability in the context of the s-plane

common second-order system: $m\ddot{x} + b\dot{x} + kx = f$

take the Laplace transform of both sides:

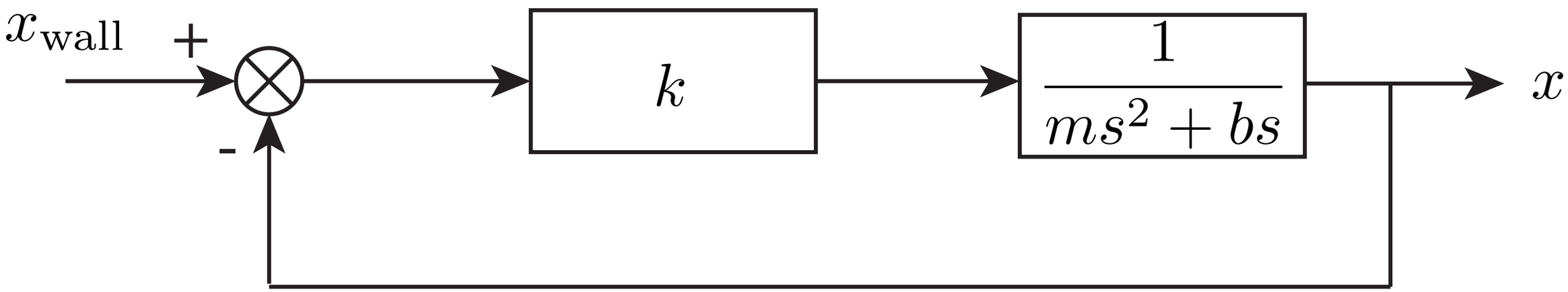
$$\mathcal{L}[m\ddot{x} + b\dot{x} + kx] = \mathcal{L}[f]$$

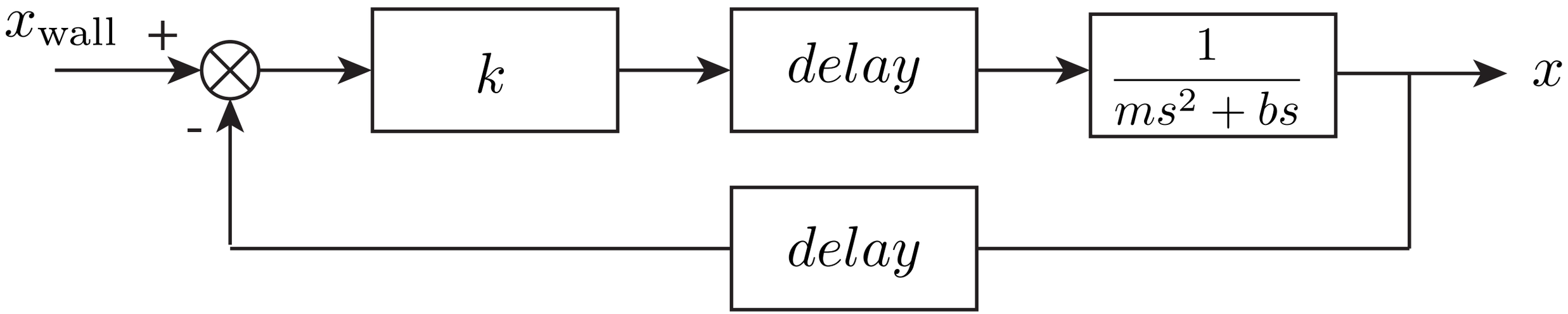
$$ms^2X(s) + bsX(s) + kX(s) = F(s)$$

$$(ms^2 + bs + k)X(s) = F(s)$$

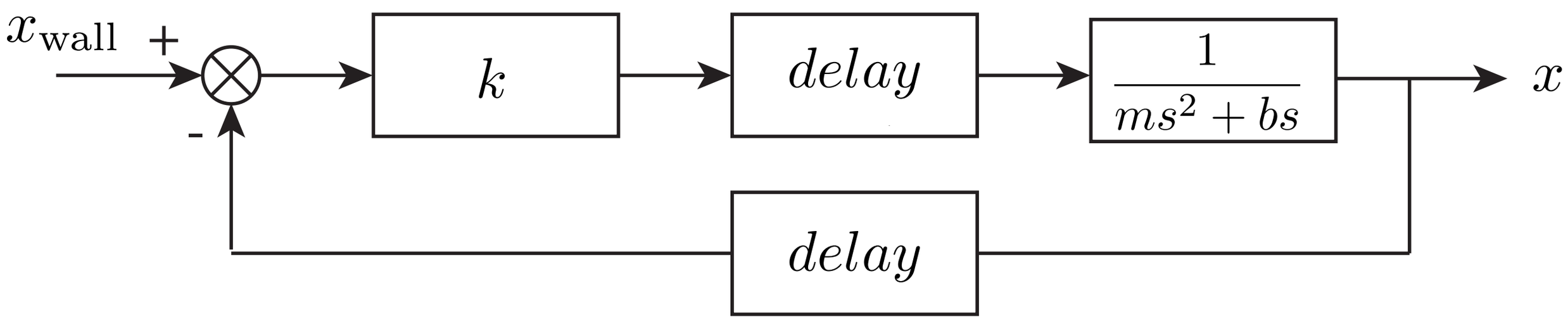
transfer function/characteristic equation: $\dfrac{F(s)}{X(s)} = ms^2 + bs + k$

Time Delay





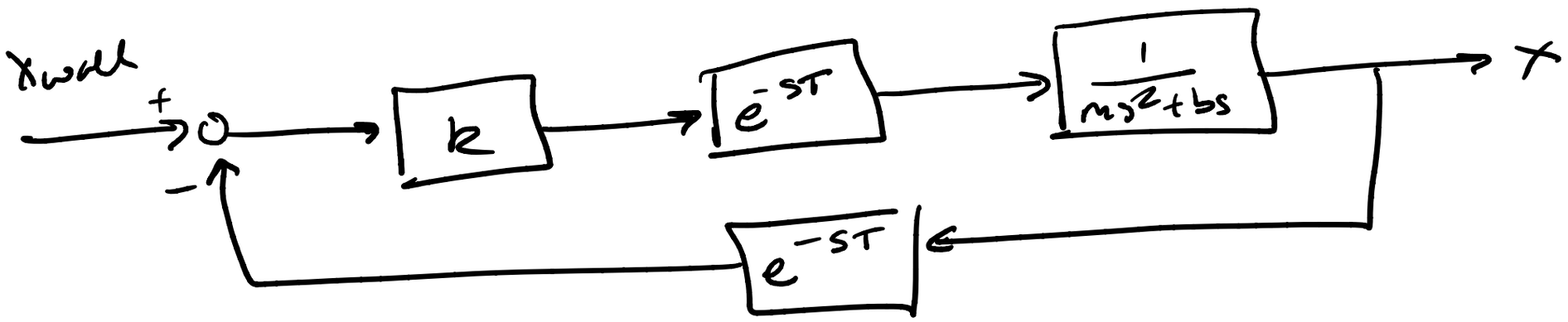
Padé approximation



$$delay = e^{-sT} \qquad e^{-sT} \approx \frac{1-\left(\frac{sT}{2}\right)}{1+\left(\frac{sT}{2}\right)}$$

This adds a left half plane pole and a right half plane zero!

In breakout groups: Discuss/calculate how time delay affects the maximum stable stiffness of a virtual wall



$$X = \frac{ke^{-sT}}{ms^2+bs}\left(x_{wall} - e^{-sT}x\right)$$

$$x\left(1+e^{-sT}\frac{ke^{-sT}}{ms^2+bs}\right) = \frac{ke^{-sT}}{ms^2+bs}x_{wall}$$

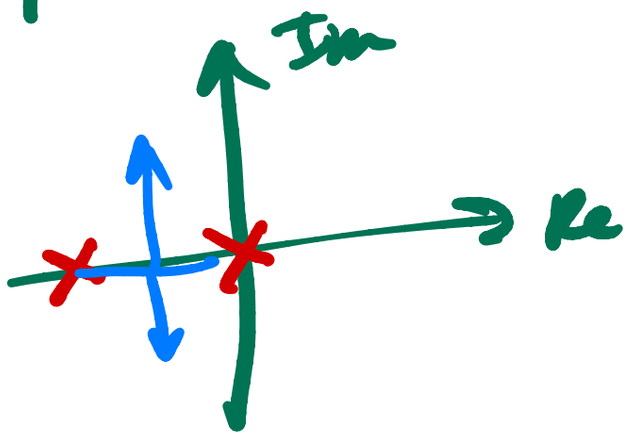
$$\frac{X}{x_{wall}} = \frac{ke^{-sT}\left(\frac{1}{ms^2+bs}\right)}{1+e^{-sT}ke^{-sT}\left(\frac{1}{ms^2+bs}\right)}$$

e^{-2sT}

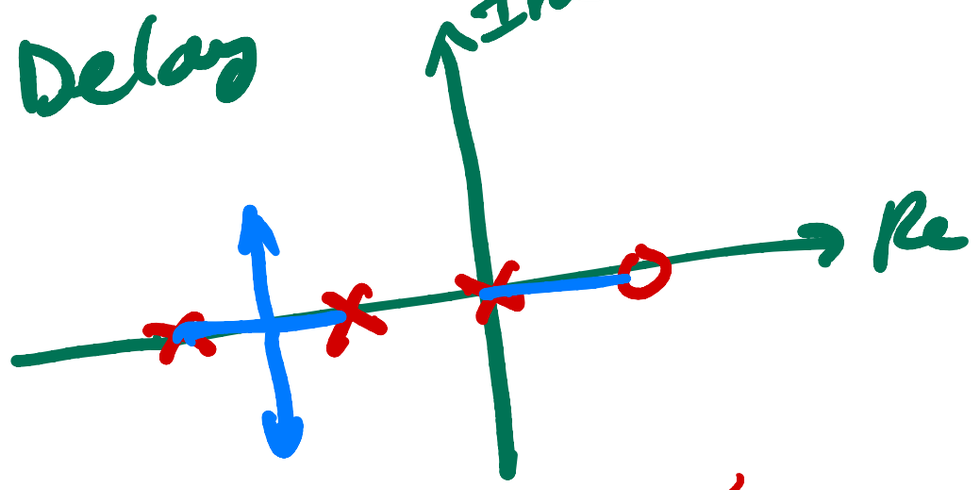
← Char. eqn.

$$1 + \frac{K}{ms^2 + bs} \cdot \underbrace{\frac{1 - Ts}{1 + Ts}}_{(e^{-2sT})} = 0$$

No delay

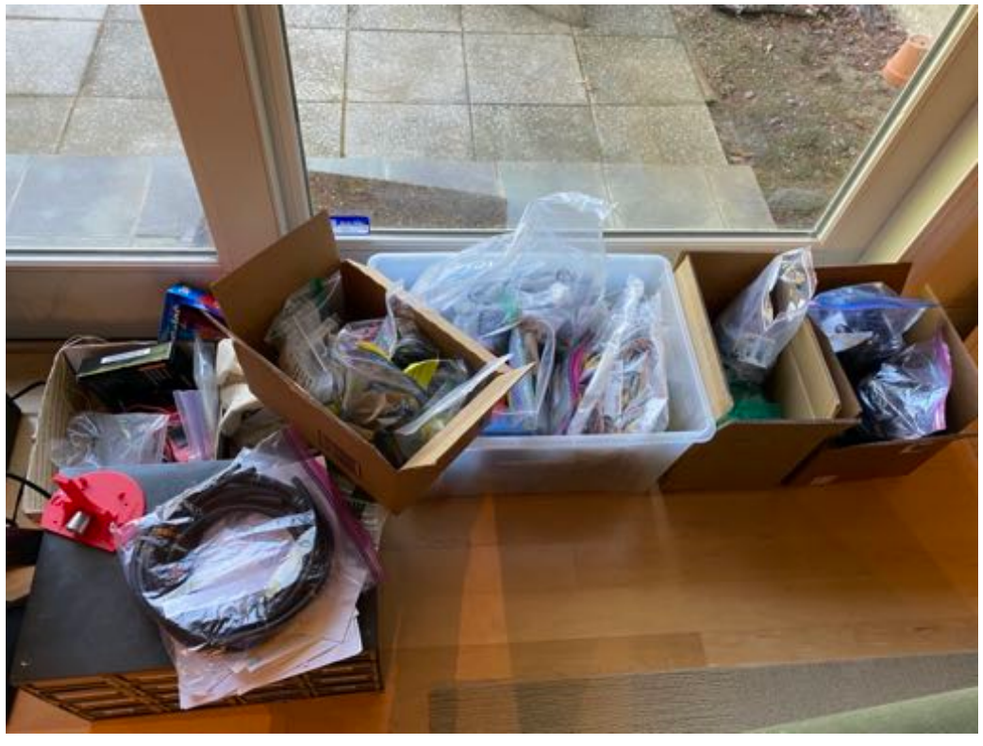


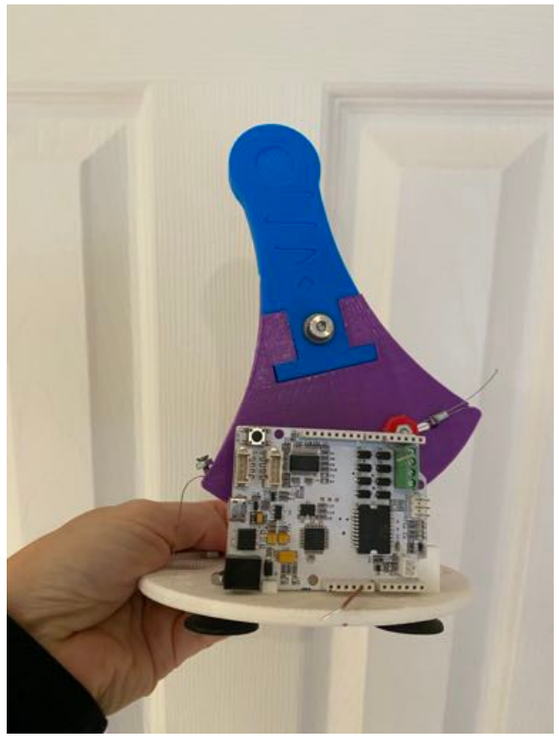
Delay



Corrected from lecture!
(I was using the higher-order approx. which gave complex time delays → this version uses the real poles & zeros from the time delay given above)

HAPKITS!!





Fill out address form TODAY
(see announcement on Canvas)

Reminders:

Assignment 4 due today
Look for Assignment 5 posted later today

Quiz will be discussed later — there are still a couple students who need to take it

Office Hours/Q&A with Allison until 10 am.
Question queue (see tab with today's date):
https://tinyurl.com/HapticsAllison

