Ball and Plate System: Simulation and Design

Poster 312
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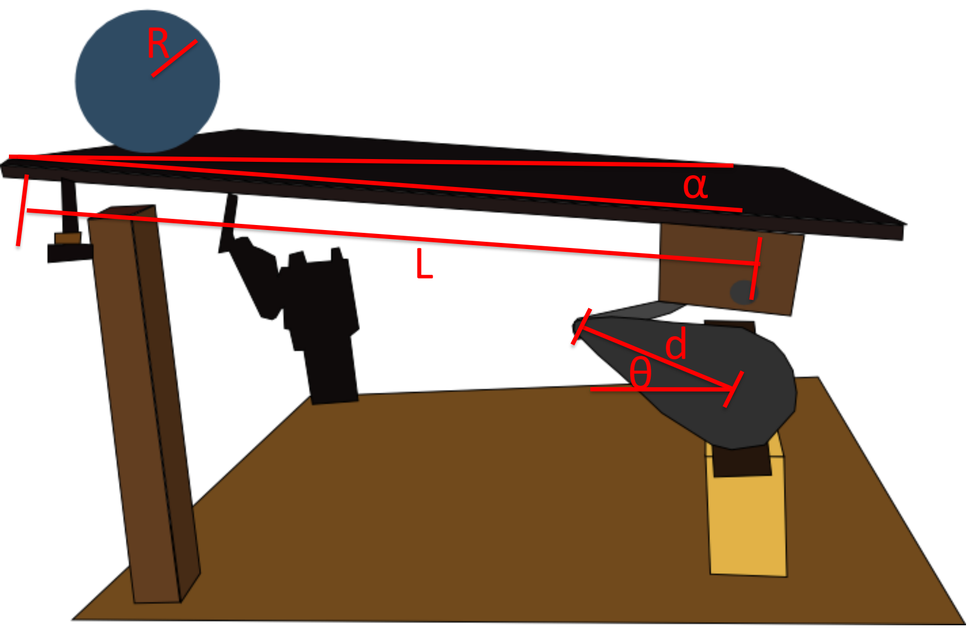
Goal: Design a system which balances a ball on a plate with minimal transient response and the ability to reject noise

The Plant



Approximations

$$\frac{d}{L}\theta = \alpha$$

$$\cos\theta = \theta$$

$$\sin\theta = \theta$$

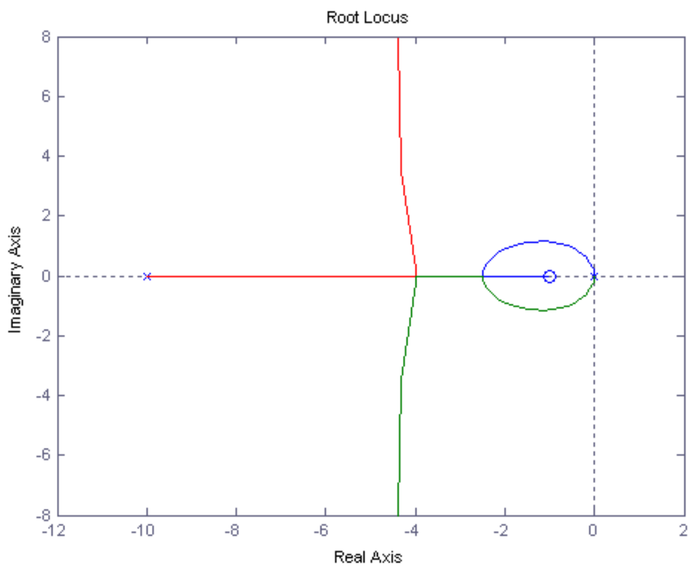
Transfer Function

$$\left(\frac{j}{r^2} + m\right)\ddot{x} = -mg\alpha$$

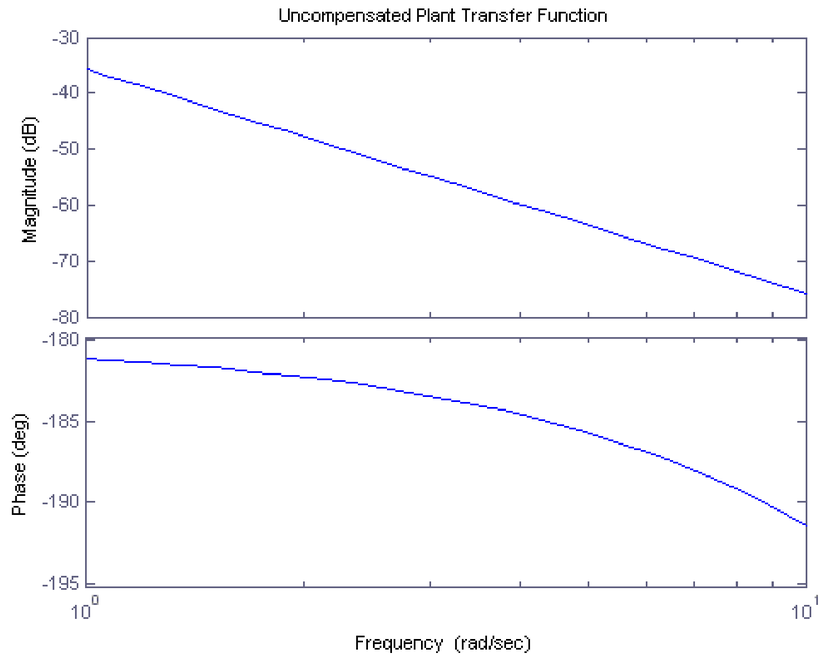
$$\frac{X(s)}{\theta(s)} = \frac{-mgd}{s^2 L\left(\frac{j}{r^2} + m\right)} = \frac{K_{plant}}{s^2}$$

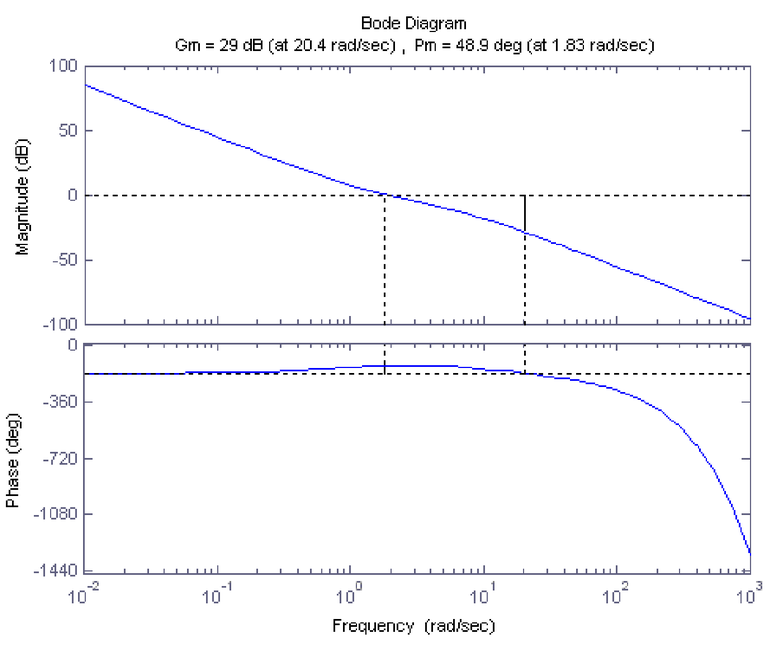
Lead Compensation

$$K\frac{\alpha\tau s + 1}{\tau s + 1} = 100\frac{10s + 1}{s + 1}$$



Bode of Compensated and Uncompensated Systems





Compensated Loop Transfer Function $L(s) = 1.6\frac{10s + 1}{s^2(s + 1)}$

Verification

Goals Met

- Successfully balanced ball on plate
- Transient lasts under 10 seconds
- Successfully rejects noise

Model Accuracy

- All values used within an order of magnitude of simulation values

Sources of Error

- Image tracking
- Saturation
- Discrete angle positions
- Bending of the plate
- Model of servos