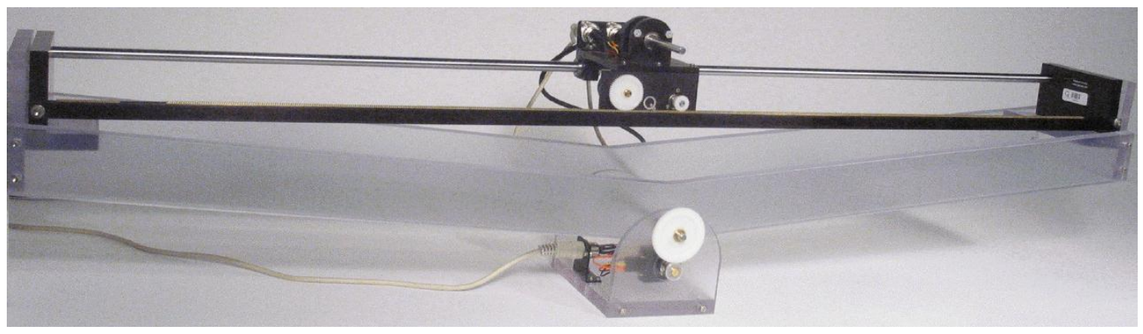
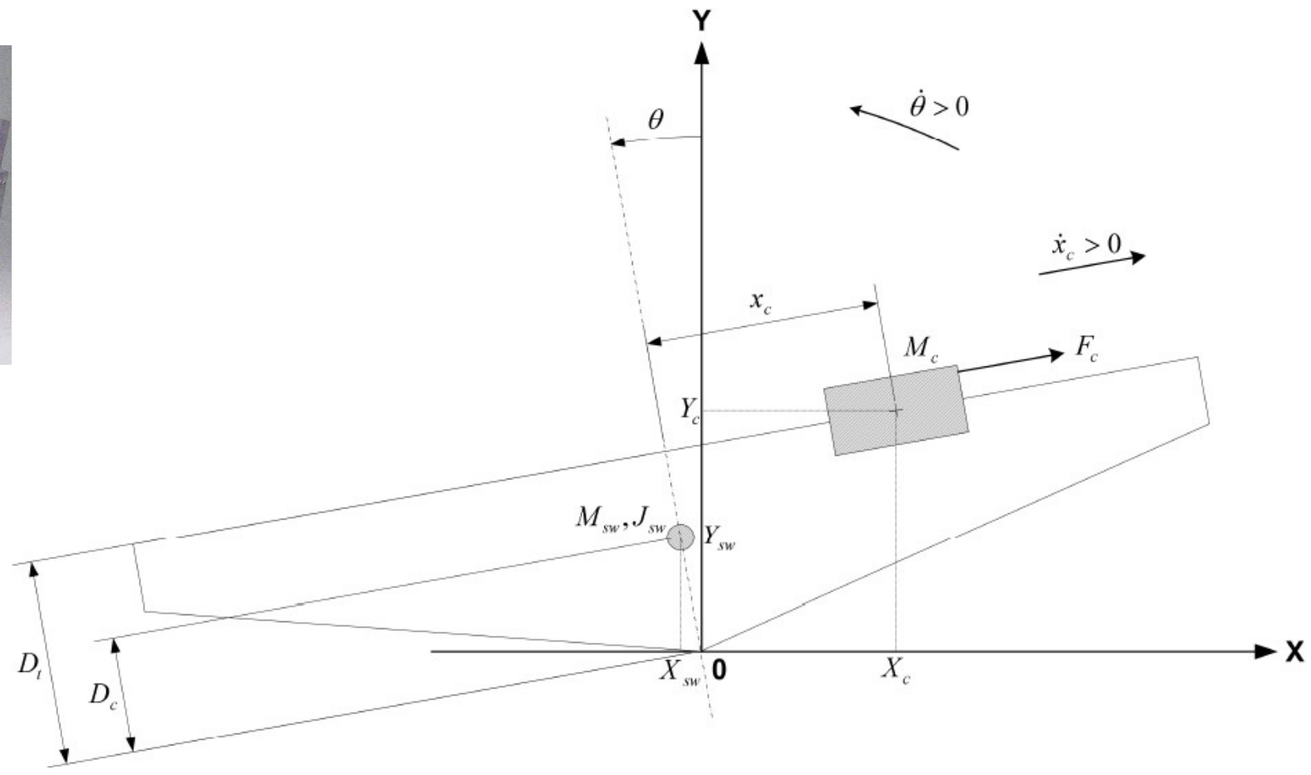
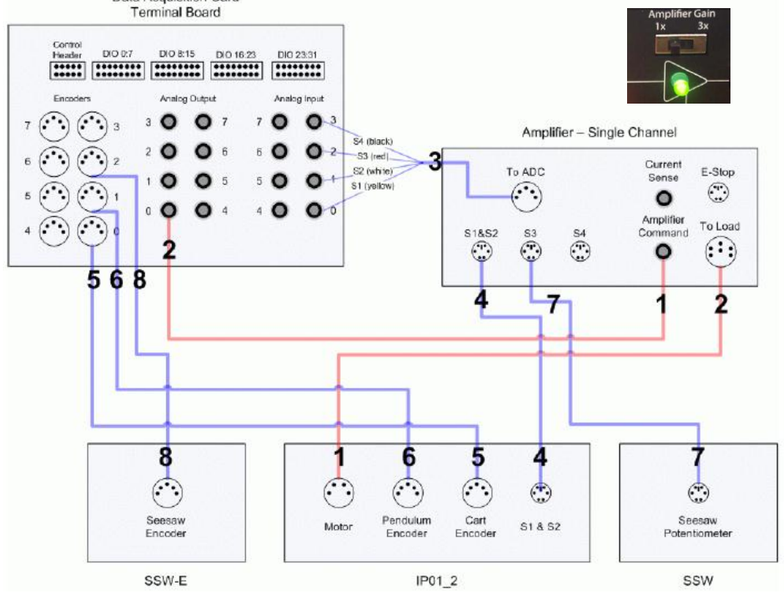
Seesaw

The Quanser Seesaw is an instrumented, fulcrum supported linear arm on which a rail mounted motorized cart device moves to balance the seesaw.





Wiring schematics



Requirements

Seesaw angular position: $e_{ss\ \theta}^{6^\circ\ step} = 0$ $t_{s\ \theta}^{5\%} \le 4.5$

Cart position: $t_{s\ x_c}^{5\%} \le 2.5$

$\min V_m$

System dynamics

$$\ddot{x}_c = (M_c^2 x_c^3 \dot{\theta}^2 + (F_c M_c - g M_c^2 \sin\theta - B_{eq}\dot{x}_c M_c))x_c^2 - (2M_c^2 D_t \dot{x}_c \dot{\theta} - (M_c^2 D_t^2 + M_c J_{sw})\ddot{\theta}^2 + M_c^2 D_t g \cos\theta)x_c$$
$$-(M_c D_t^2 B_{eq} + B_{eq} J_{sw})\dot{x}_c - M_c D_t B_{sw}\dot{\theta} + (F_c - g M_c \sin\theta)J_{sw} + M_c D_t^2 F_c + M_c D_t g M_{sw} D_c \sin\theta) / (M_c^2 x_c^2 + J_{sw} M_c)$$

$$\ddot{\theta} = \frac{(D_t M_c \dot{\theta}^2 - 2M_c \dot{x}_c \dot{\theta} - g M_c \cos\theta)x_c + D_t F_c - D_t B_{eq}\dot{x}_c + g M_{sw} D_c \sin\theta - B_{sw}\dot{\theta}}{M_c \dot{x}_c + J_{sw}}$$

$$\ddot{x}_c = -\frac{M_c D_t g}{J_{sw}} x_c + \left(-g + \frac{D_t g M_{sw} D_c}{J_{sw}}\right)\theta - \left(\frac{D_t^2 B_{eq}}{J_{sw}} + \frac{B_{eq}}{M_c}\right)\dot{x}_c - \frac{D_t B_{sw}}{J_{sw}}\dot{\theta} + \frac{F_c}{M_c} + \frac{D_t^2 F_c}{J_{sw}}$$

$$\ddot{\theta} = -\frac{g M_c}{J_{sw}} x_c + \frac{g M_{sw} D_c}{J_{sw}}\theta - \frac{D_t B_{eq}}{J_{sw}}\dot{x}_c - \frac{B_{sw}}{J_{sw}}\dot{\theta} + \frac{D_t F_c}{J_{sw}}$$

$$\mathbf{x} = [x_c \quad \theta \quad \dot{x}_c \quad \dot{\theta} \quad \int \theta dt]^T$$

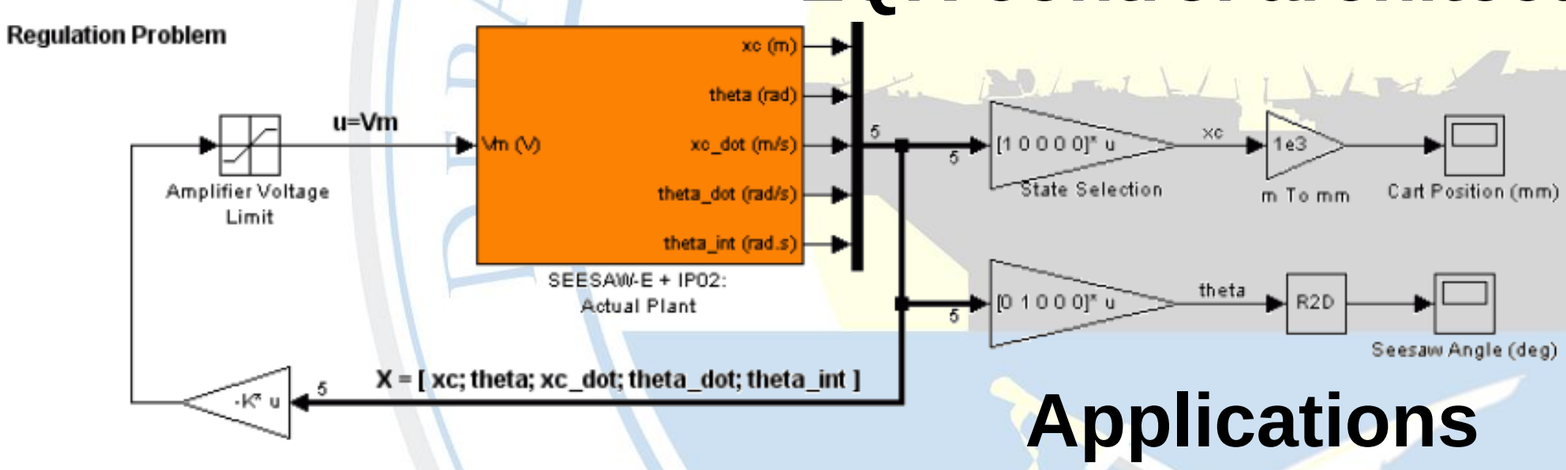
$$A = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ -1.77 & -9.17 & -21.6 & 0 & 0 \\ -14.16 & 5.19 & -3.81 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{bmatrix}, \quad B = \begin{bmatrix} 0 \\ 0 \\ 3.10 \\ 0.55 \\ 0 \end{bmatrix}$$

LQR controller design

$$\dot{\mathbf{x}} = A\mathbf{x} + Bu \qquad J = \int_0^\infty (\mathbf{x}^T Q \mathbf{x} + uRu)dt$$

$$A^T P + PA - PBR^{-1}B^T P + Q = 0 \qquad K = R^{-1}B^T P \qquad u = -K\mathbf{x}$$

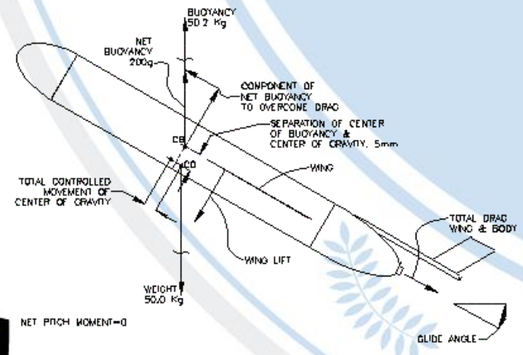
LQR control architecture

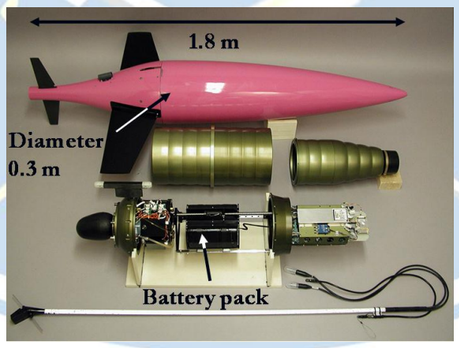


$$Q = diag([100, 5000, 0, 0, 2000]) \qquad R = 0.05$$

$$K = [180.80, -224.35, 16.67, -67.00, -63.25]$$

Applications





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