Design of control systems

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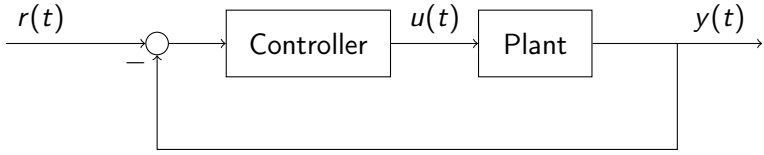
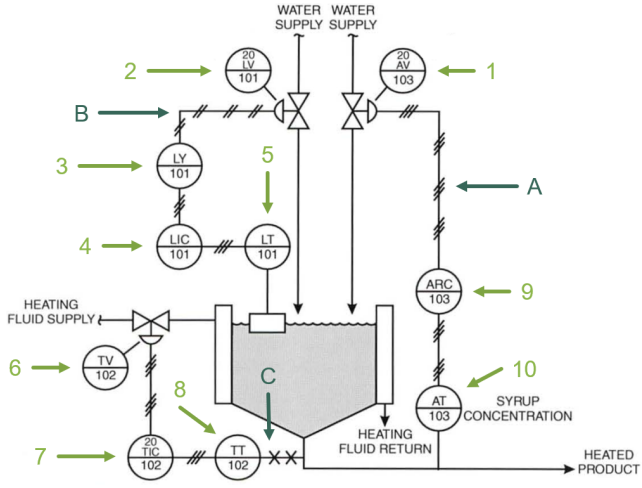
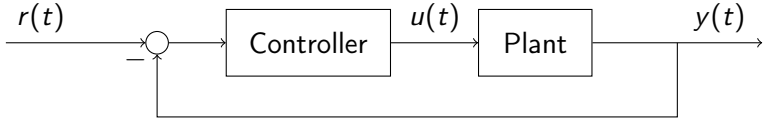
Feedback control



Feedback control systems are ubiquitous

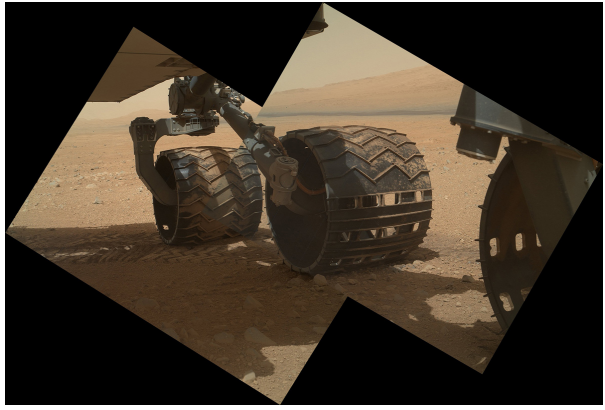


Feedback control systems



Controller design: Determine a feedback controller such that the controlled system performs according to given performance specifications.

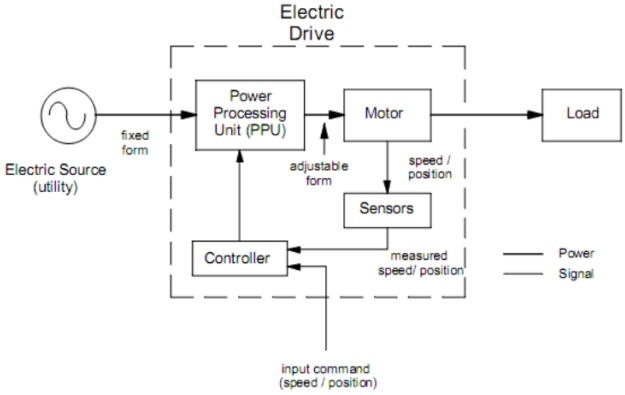
The problem situation



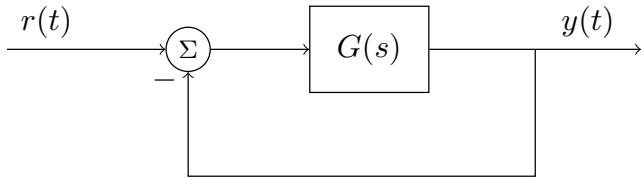
- Mass 900 kg
- Six wheels, each with an electric motor
- Front- and rear-wheel steering
- Rocker-bogie suspension system

The problem situation

The problem situation



Block diagram algebra



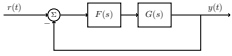
Transfer function from $r(t)$ to $y(t)$:

$$\frac{Y(s)}{R(s)} = \frac{G(s)}{1 + G(s)}$$

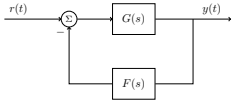
Block diagram algebra

Activity Pair the block-diagram with the correct closed-loop transfer function!

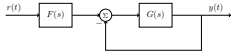
A



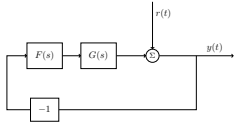
B



C



D



I

$$\frac{Y(s)}{R(s)} = \frac{G(s)F(s)}{1+G(s)}$$

II

$$\frac{Y(s)}{R(s)} = \frac{G(s)}{1+G(s)F(s)}$$

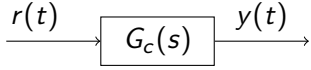
III

$$\frac{Y(s)}{R(s)} = \frac{1}{1+G(s)F(s)}$$

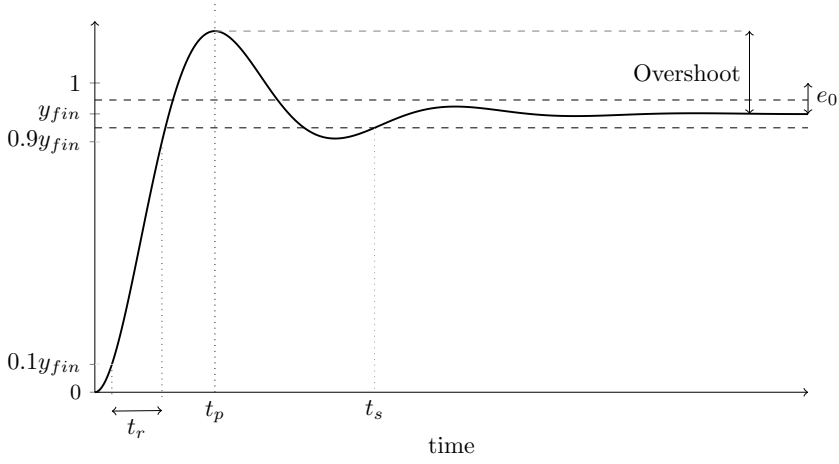
IV

$$\frac{Y(s)}{R(s)} = \frac{G(s)F(s)}{1+G(s)F(s)}$$

Performance requirements



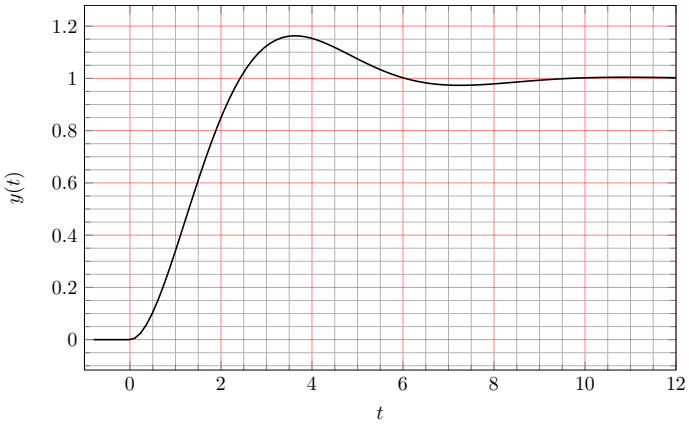
Performance requirements - time domain



Performance requirements - time domain

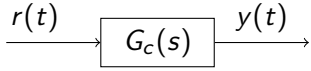
Activity Does the system satisfy the requirements?

Rise time < 1.5s
Overshoot $< 18\%$



Performance requirements - frequency domain

Response of LTI systems to sinusoids

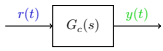


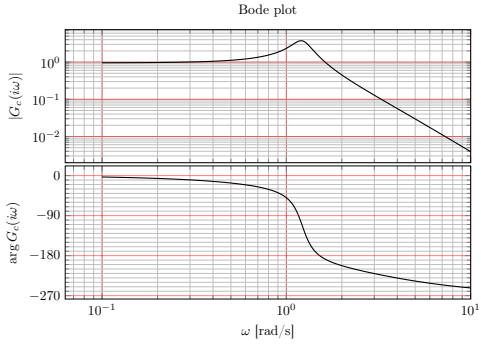
Let $r(t) = \sin \omega_1 t$. Then, after transients have died out,

$$y(t) = |G_c(i\omega_1)| \sin\left(\omega_1 t + \arg G_c(i\omega_1)\right).$$

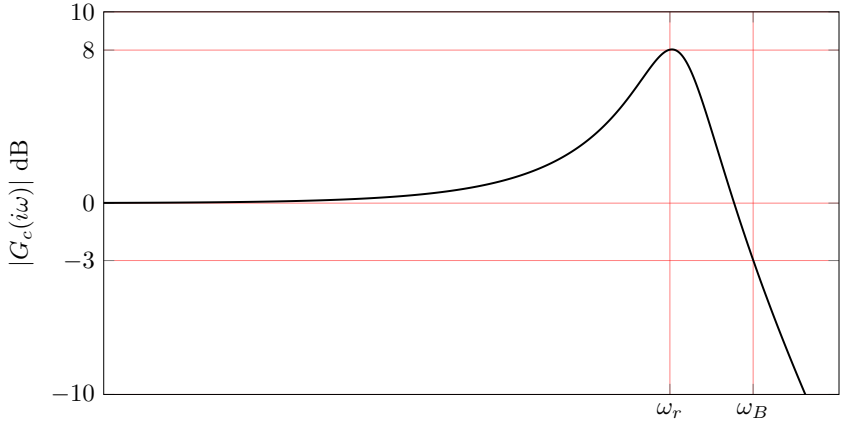
The Bode diagram shows the frequency properties of a dynamical system

$$y(t) = \underbrace{|G_c(i\omega_1)|}_{\text{amplification}} \sin\left(\omega_1 t + \underbrace{\arg G_c(i\omega_1)}_{\text{phase shift}}\right)$$

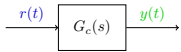


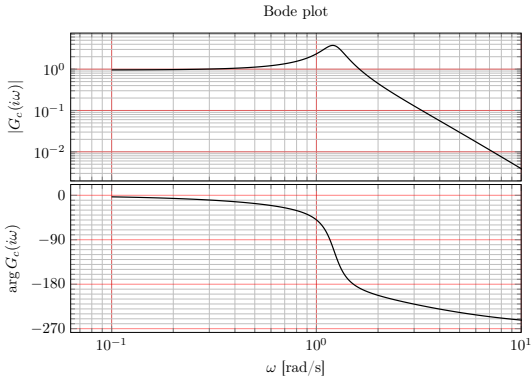


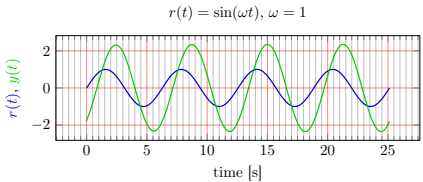
Performance requirements - frequency domain

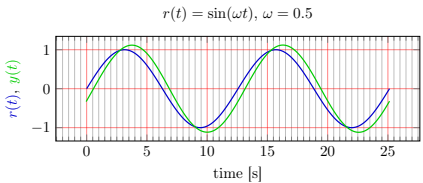


Performance requirements - frequency domain

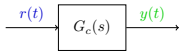


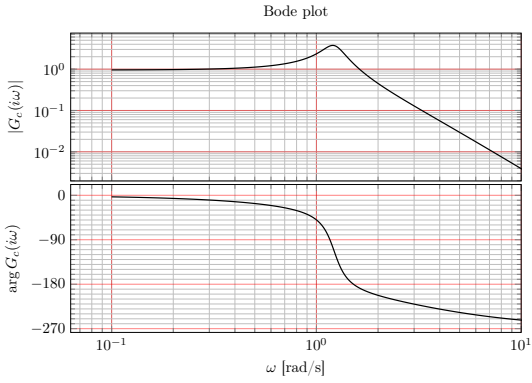


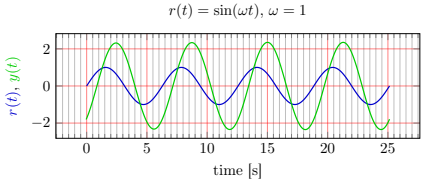


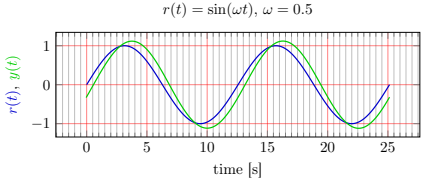


Performance requirements - frequency domain



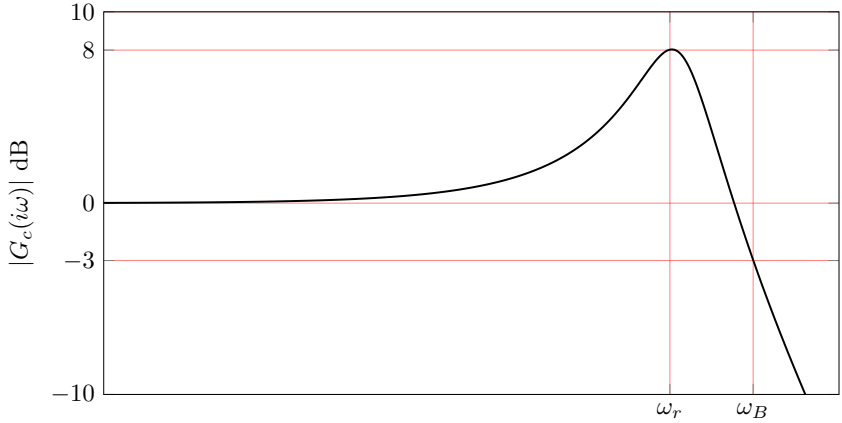






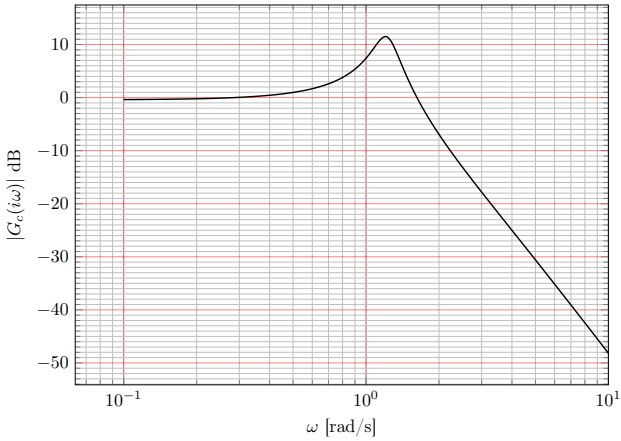
Activity What is the gain and phase shift at $\omega = 2$ rad/s?

Performance requirements - frequency domain



Performance requirements - frequency domain

Activity Does the system satisfy the requirements?



Bandwidth	>3 rad/s
Resonance peak	<9dB