Sensors with Feedback Correction

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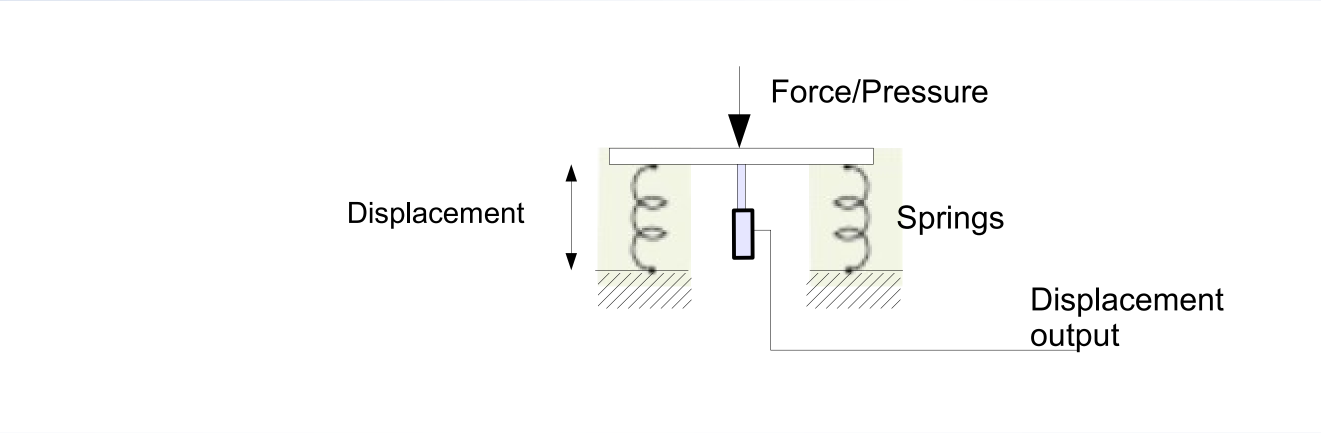
Lecture - Outline

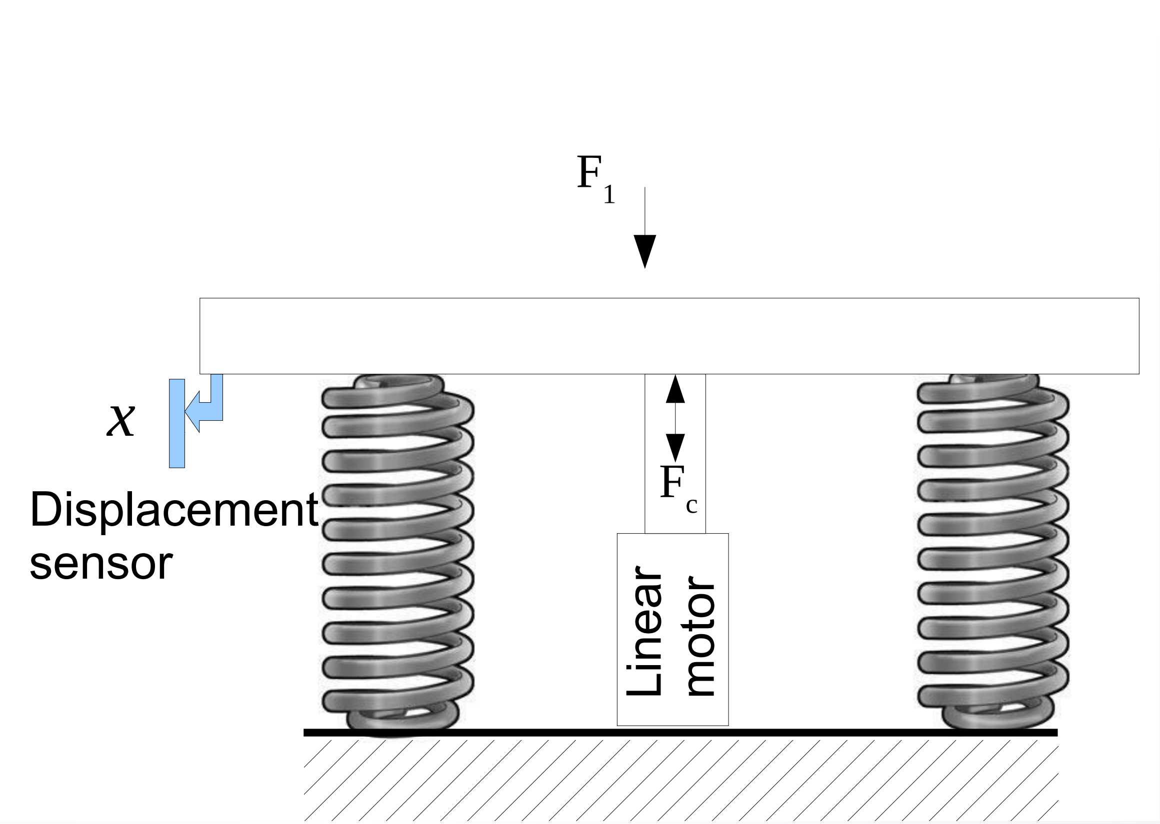
- Force and Pressure Transducers as Second Order Systems
- Force Actuators
- Force Balance with Feedback

Force and Pressure measurement



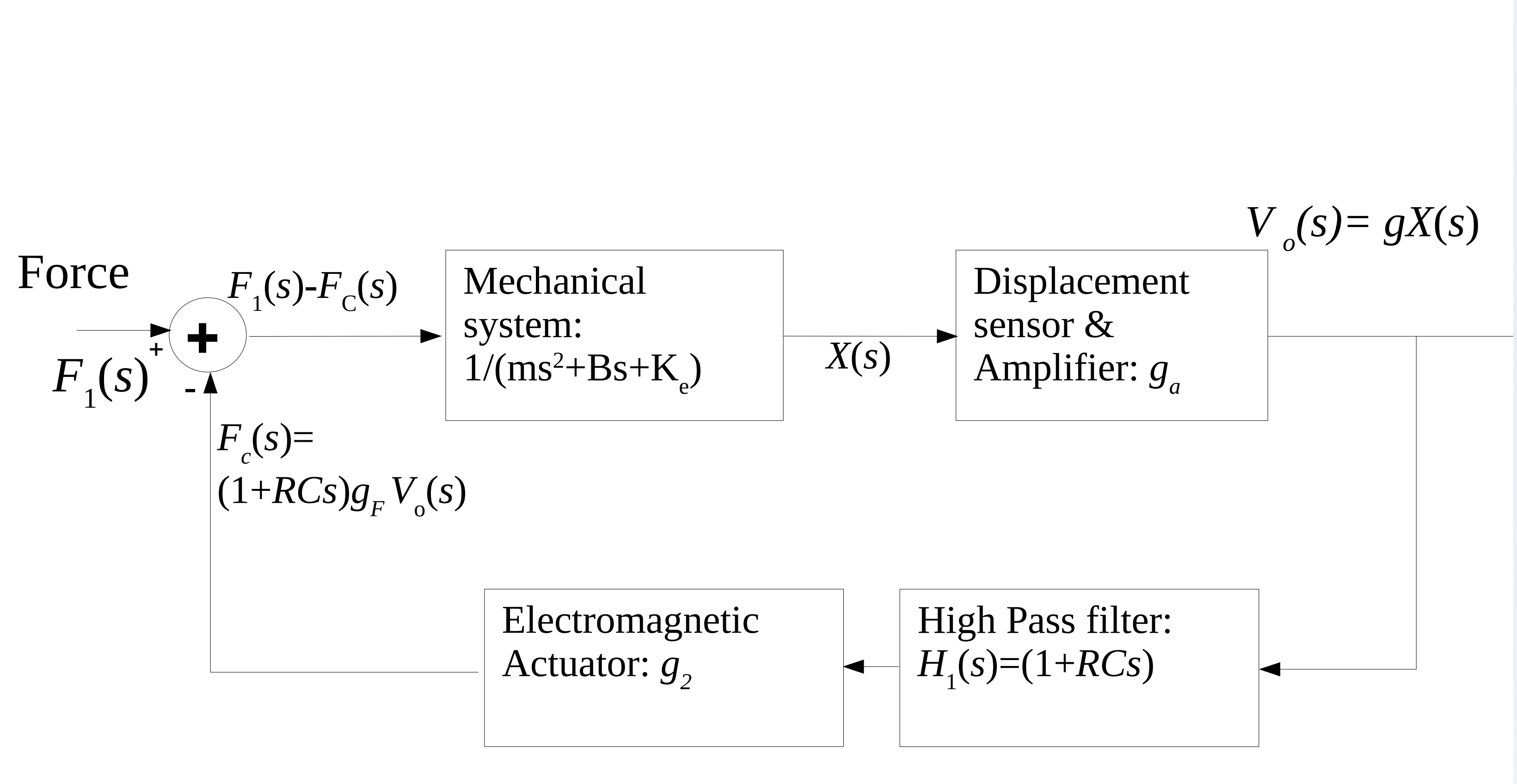
$$F_1(s)=[ms^2+K_B s+K_e]X(s)$$

Add actuator to force/pressure transducer



$$F_2(s) = F_1(s) - F_c(s)$$

Feedback compensation for force sensor



Overall Transfer Function

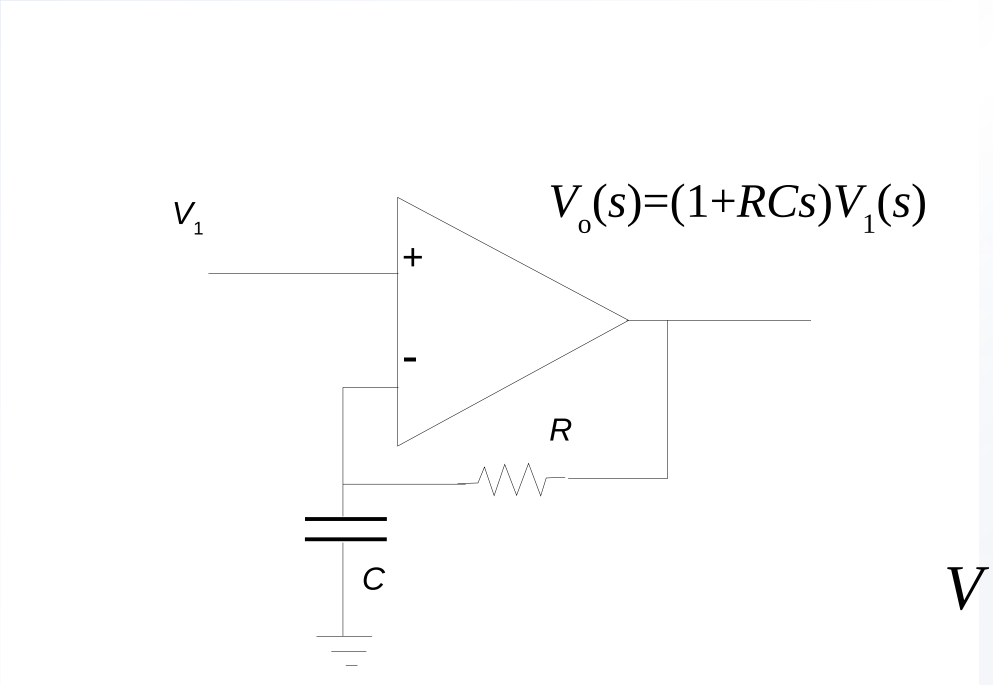
$$F_2(s) = F_1(s) - F_c(s) = [ms^2 + Bs + K]X(s)$$

$$V_o(s) = g_a X(s)$$

$$F_c(s) = V_o(s) g_2 [1 + RCs]$$

$$\frac{V_o(s)}{F_1(s)} = \frac{g_a}{ms^2 + (B + g_a g_2 RC)s + (K + g_a g_2)}$$

Opamp circuit for Proportional+Differentiator



$$V_2(s) = V_1(s)[1 + RCs]$$

$$V_2(t) = V_1(t) + RC\frac{d}{dt}V_1(t)$$

Standard form for second order system

$$H(s) = \frac{A}{\frac{s^2}{\omega_c^2} + \frac{2\zeta}{\omega_c}s + 1}$$

Why closed loop?

- Open-loop case

$$\frac{V_o(s)}{F_1(s)} = \frac{g_a}{ms^2 + Bs + K}$$

$$A = \frac{K_g}{K_e}$$

$$\omega_c = \sqrt{\frac{K}{m}}$$

$$\zeta = \frac{B}{\sqrt{4Km}}$$

- Closed-loop case

$$\frac{V_o(s)}{F_1(s)} = \frac{g_a}{ms^2 + (B + g_a g_2 RC)s + (K + g_a g_2)}$$

$$A = \frac{g_a}{K + g_a g_2}$$

$$\omega_c = \sqrt{\frac{K + g_a g_2}{m}}$$

$$\zeta = \frac{B + g_a g_2 RC}{\sqrt{4m(K + g_a g_2)}}$$

Force Actuators - Electromagnetic actuator

- EMF in a coil

$$V = -N \frac{d\phi}{dt}$$

- EMF in a moving conductor

$$V = -B v l$$

- Force on a conductor

$$F = B\ I\ l$$

- Magnetomotive force

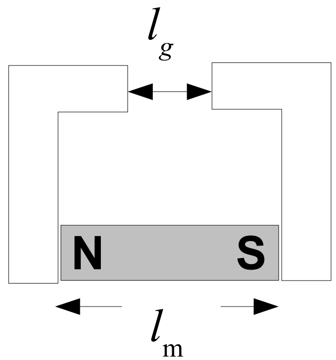
$$M = N\ I$$

Magnetic Circuit equivalent

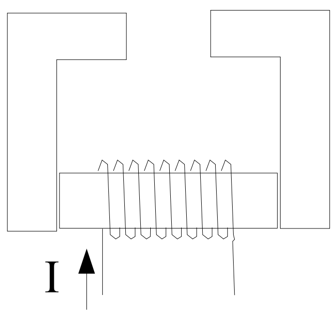
Analogy between electric circuits and magnetic circuits

Electrical quantity			Magnetic quantity		
Name	Symbol	Unit	Name	Symbol	Unit
Electromotive force	V	V, (volts)	Magnetomotive force	M	Amp-turns
Electric field	$E = V/l$	V/m	Magnetic field intensity	$H = M/l$	Amp-turns/m
Current density	$J = I/A$	Amp/m^2	Magnetic flux density	B	Weber/m^2
Current	I	Amp	Magnetic flux	$\Phi = B.A$	Weber
Resistance	$R = V/I$ $\boxed{R = \rho \frac{l}{A}}$	Ω=Ohm =Volt/Amp	Reluctance	$R = M/\Phi$ 1. $\boxed{R = \frac{1}{\mu}\frac{l}{A}}$ 2. $\boxed{R = \frac{H_c l_m}{B_r A_m}}$	Amp-turns/Weber

Magnetic circuits

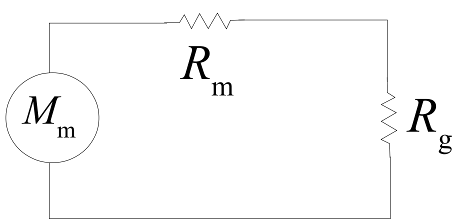


$$R_g = \frac{1}{\mu_o}\frac{l_g}{A_g}$$



$$R_m = \frac{M_m}{\phi} = \frac{H_c l_m}{B_m A_m}$$

$$R_m = \frac{M_m}{\phi} = \frac{N I}{B_m A_m}$$



$$\phi = \frac{M_m}{R_m + R_g} \cdot R_g$$

Voice coil - actuator