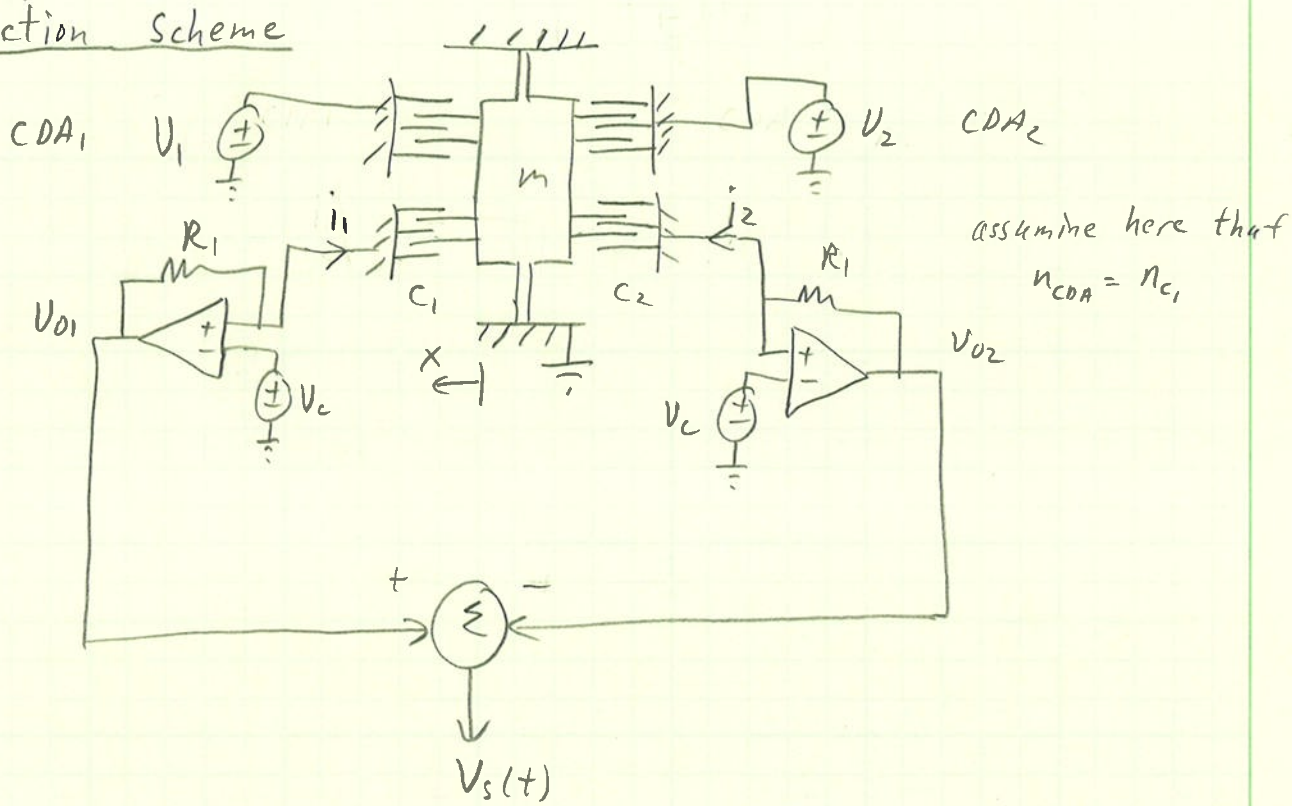
Detection Scheme



op amp circuit is a TIA → transimpedance amplifier

$$V_{01} = V_c + i_1 R_1 \text{ and } V_{02} = V_c + i_2 R_1$$

C_1 and C_2 → CDA style variable capacitors with V_c applied across each one → $F_{net} = 0$

$$C_1 = \frac{n\varepsilon_0\varepsilon_r b(x_0 + x)}{d_0} = \alpha(x_0 + x), \quad x = X_0 \sin(\omega_n t)$$

$$C_2 = \frac{n\varepsilon_0\varepsilon_r b(x_0 - x)}{d_0} = \alpha(x_0 - x)$$

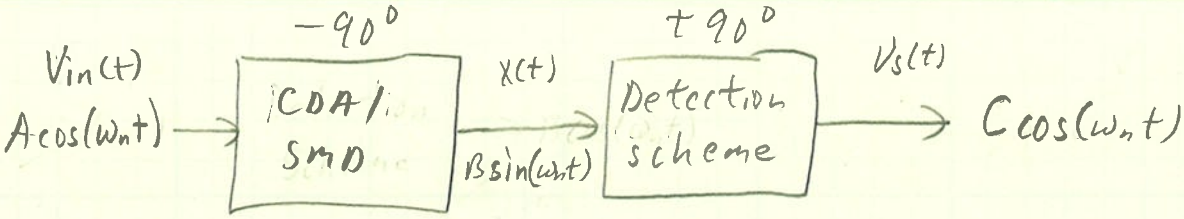
$$i_1 = \frac{dQ_1}{dt} = V_c\frac{dC_1}{dt} = V_c\alpha X_0\omega_n\cos(\omega_n t)$$ → $Q = CV \rightarrow \frac{dQ}{dt} = i = \dot{C}V + \dot{V}C^{\nearrow 0}$

$$V_{01} = V_c + V_c R_1 \alpha X_0 \omega_n \cos(\omega_n t)$$

$$i_2 = \frac{dQ_2}{dt} = V_c\frac{dC_2}{dt} = -V_c\alpha X_0\omega_n\cos(\omega_n t)$$

$$V_{02} = V_c - V_c R_1 \alpha X_0 \omega_n \cos(\omega_n t)$$

$$V_s(t) = V_{01} - V_{02} = 2V_c R_1 \alpha X_0 \omega_0 \cos(\omega_n t)$$ → $x(t) \propto \sin(\omega t)$, $V_s(t) \propto \cos(\omega t)$ — leads by 90^0

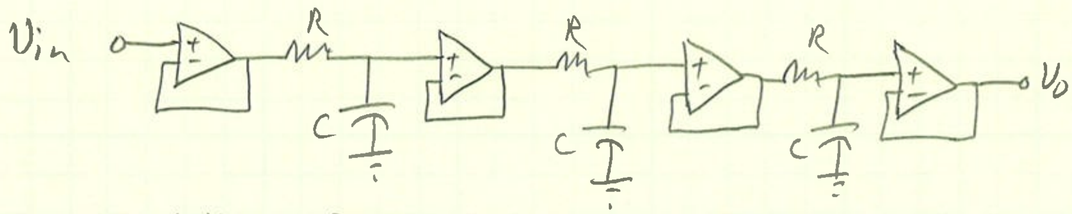


$\therefore \theta_{Det} = 90^\circ$

$\theta_{mech} + \theta_{Det} = -90^\circ + 90^\circ = 0^\circ$

$\therefore \theta_{Delay} = -180^\circ$

$\therefore$ use 3 RC phase lag circuits where each one produces -60°



$$\frac{V_0}{V_{in}}(s) = \left(\frac{1/RC}{s + 1/RC}\right)^3$$

→ select R & C to be close to expected ω_n for -180°

→ since mechanical system is high Q and other phase delays exist in the real system, f_{osc} will "track" changes in ω_n

Gain stages

"$-A$" → inverts for negative feedback

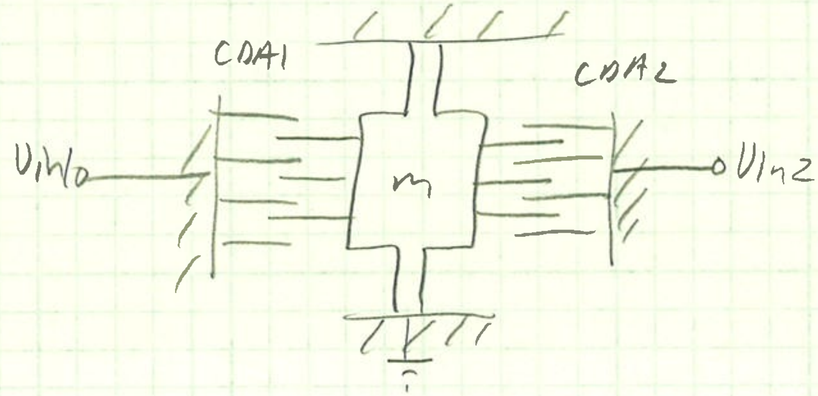
→ provide $V_B + V_0\cos(\omega_n t)$ to CDA_1 and $V_B - V_0\cos(\omega_n t)$ to CDA_2

AGC → automatic gain control adjusts loop gain to be 1 at ω_n {where $\angle AB = -180^\circ$} for a desired mechanical motion amplitude {X_0}

→ X_0 too big → AGC decreases gain

X_0 too small → AGC increases gain

Another Technique for Measuring Displacement

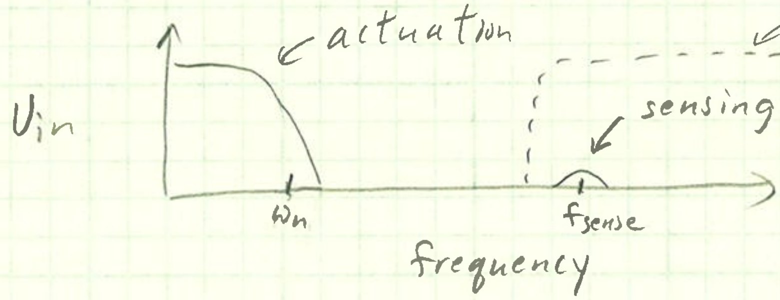


Mechanical system is low frequency and CDA's are
~high voltage devices

∴ Let Vin1/Vin2 have low freq, high V signal for actuation and high freq (100-200kHz) low votage signal for displacement measurement

∴ Do not need separate actuation and sensing structures → higher force/lower voltage with bigger actuator

→ electronics is more complicated



HPF and mix with f_{sense} then LPF to obtain DC signal proportional to instantaneous displacement

↳ $X_m \sin(\omega_n t)$