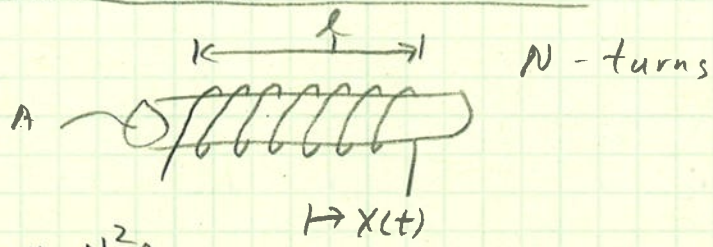
1. Inductive Sensors Continued

Given:



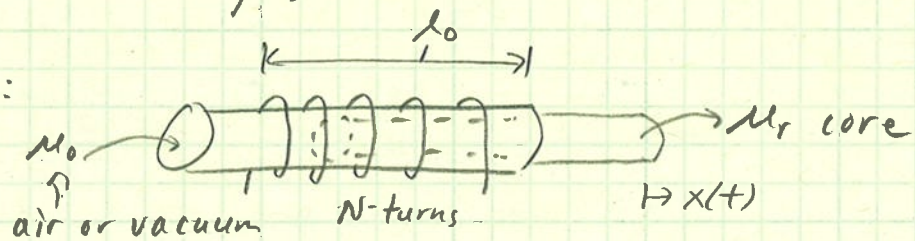
$$L = \frac{\mu_0 \mu_r N^2 A}{L}$$

→ if the turns are consistently ordered so that N/L is a constant : $N/L = G$

→ then $L = \mu_0 \mu_r N G A$

a. Movable high μ_r core

Given:



let $0 \le x \le N$

$\therefore L = L_1 + L_2$

$= \mu_0 G A K X(t) + \mu_0 \mu_r G A (N - K X(t))$

ex: let $\mu_0 G A N = 1 \mu H$ and let $\mu_r = 5000$ (Fe)

let $L = 1cm$ with 1 turn/mm

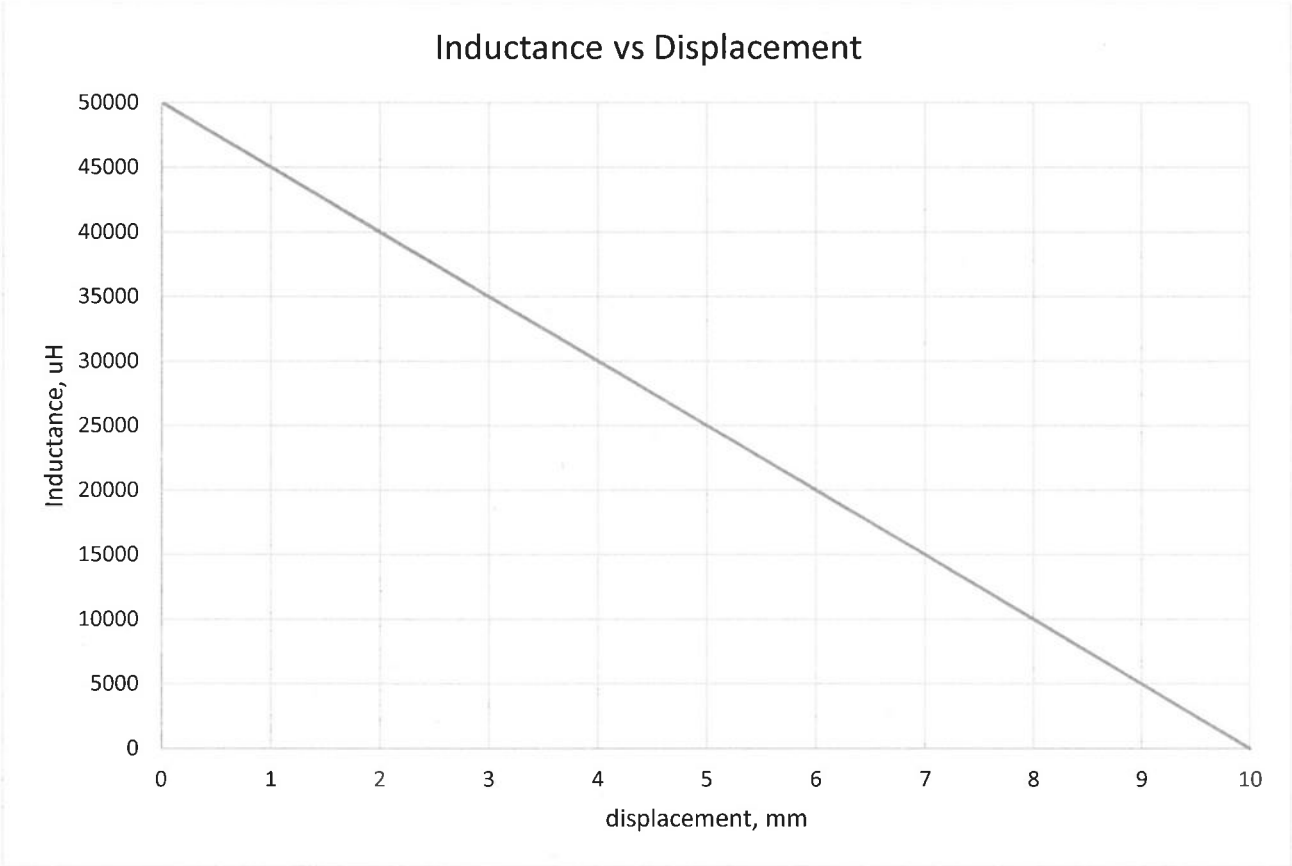
→ show plot

for $\mu_r >> \mu_0$, $L \approx L_2 = \mu_0 \mu_r G A (N - K X(t))$

where K = turns/distance

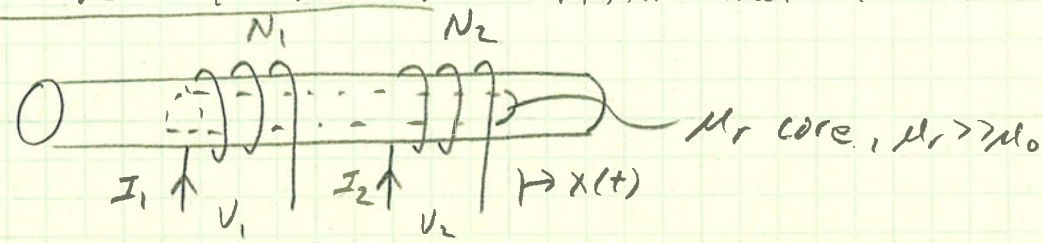
$\therefore$ Variable Core Inductor

Variable Core Inductor



Nearly Linear

a. <u>Variable Core Transformer</u> → Differential Transformer



Given L_1 and L_2

<u>Assume</u> $L_1 = \mu_0 \mu_r GA(N - Kx(t))$
$L_2 = \mu_0 \mu_r GA(N + Kx(t))$
} assumes N inc as core moves beyound neutral position

let $N_1(t) = N - Kx(t)$
$N_2(t) = N + Kx(t)$

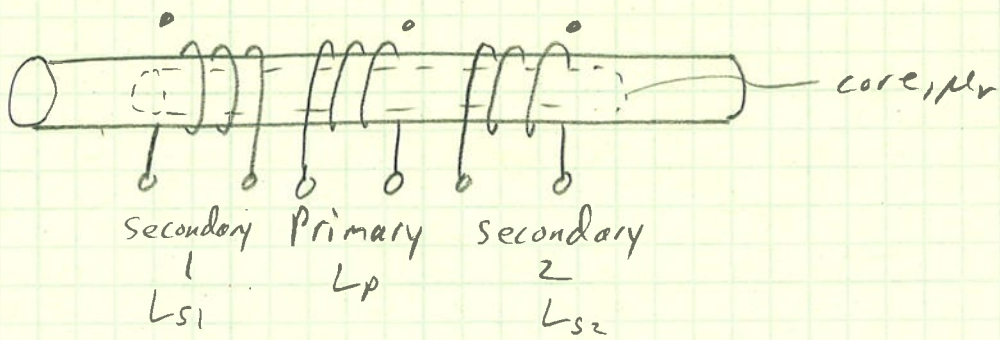
$$\therefore V_2 = \frac{N_2}{N_1} V_1 = \frac{N + Kx(t)}{N - Kx(t)} V_2$$

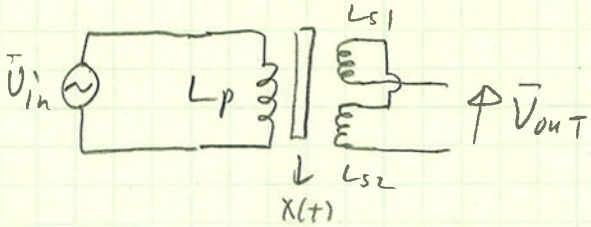
example: $N_1 \max = N_2 \max = 20$

→ show plot

$V_2 = V_{OUT}$ is a nonlinear function of displacement

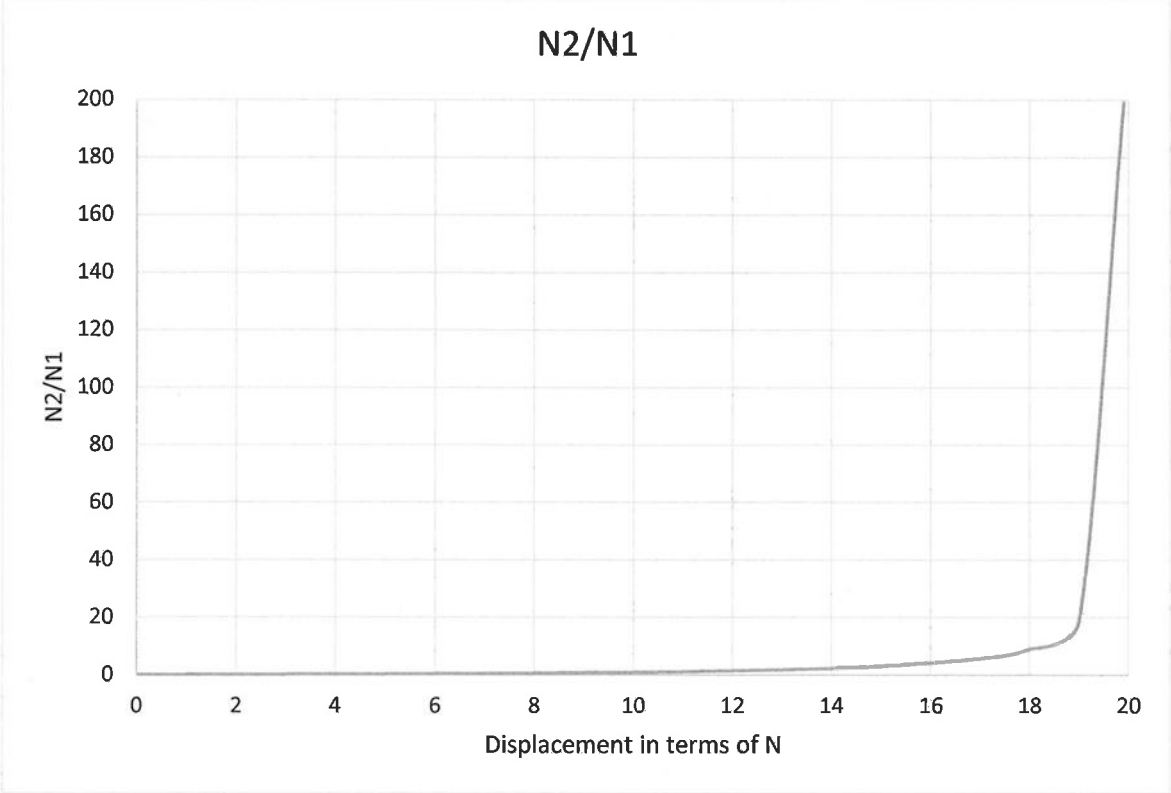
b. Linear Variable Differential Transformer (LVDT)

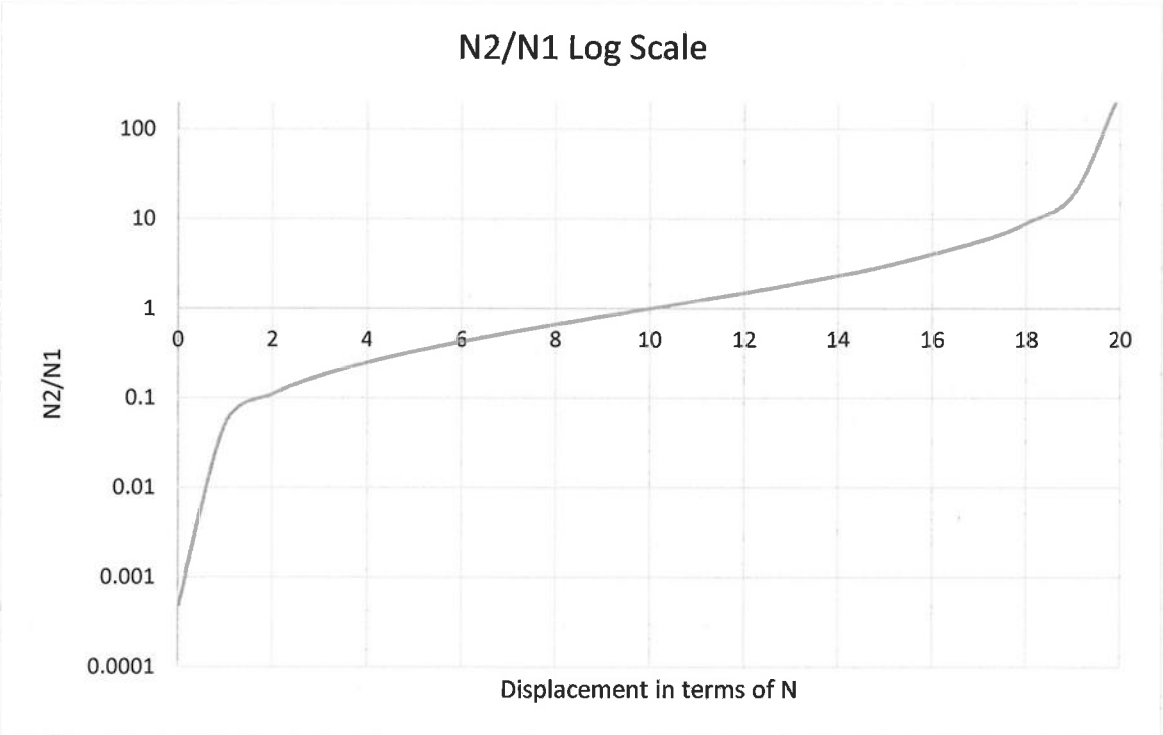




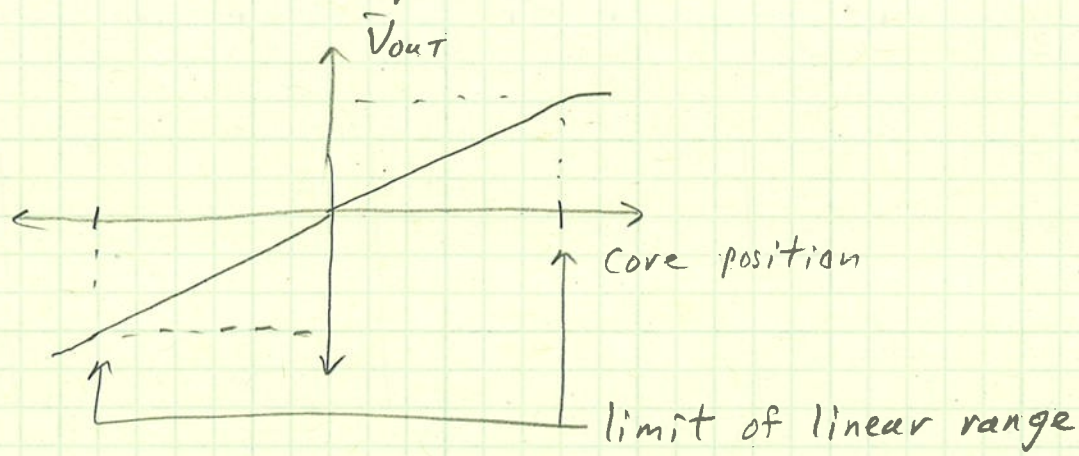
L_{S1} and L_{S2} are connected so that $\bar{V}_{OUT} \cong 0V$ when $L_{S1} = L_{S2}$

Differential Transformer





As the core moves over its range, the amplitude of V_{OUT} is a linear function of displacement over a wide range

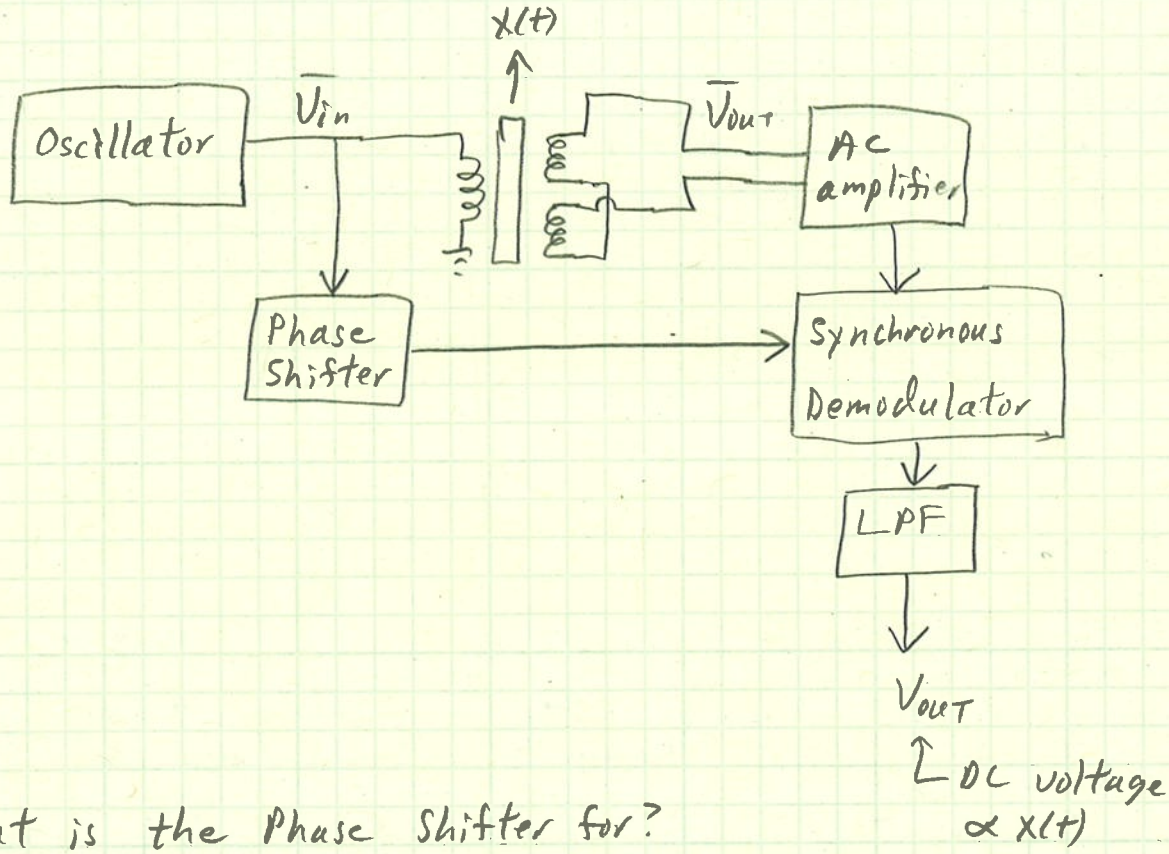


→ moving past the balanced position of the core, the polarity of V_{OUT} flips

→ At the balanced position of the core, $\bar{V}_{OUT}$ is ideally 0V. In reality, $\bar{V}_{OUT} \neq 0V$ and is called the <u>null voltage</u> → due to quadrature voltages and harmonic components of the excitation voltage which do not cancel out

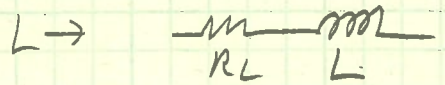
→ Quadrature voltages → due to the difference in winding capacitance between the primary and secondary

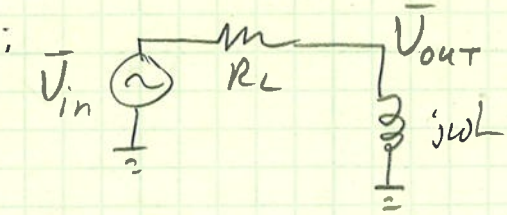
① LVDT Interface Electronics



What is the Phase Shifter for?

consider an inductor: L





there is a phase difference between $\bar{V}_{out}$ and $\bar{V}_{in}$

Synchronous Demodulation needs $\bar{V}_{in}$ and $\bar{V}_{out}$ to be in phase → the Phase Shifter provides this