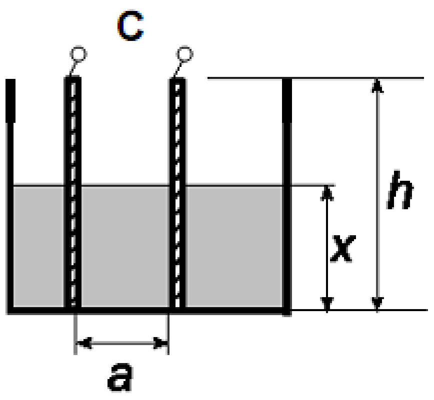
filling level sensor using reference principle

The figure shows a setup for measuring the filling level of a can. Filling level will be measured by measuring the change in capacity. The can will be filled by a nonconducting liquid. Leakage field can be neglected.

The width of the plates is b=10cm, the precisely measured height is h=90cm and distance is a=1mm.



The maximum filing level is x_{max}=h. Dielectric permittivity of the liquid is given by ε_r=80. The dielectric permittivity of the air above the liquid is given by ε_r=1.

The value of absolute permittivity is ε_0 = 8,855 10^{-12}As/Vm

a) What is the value if the maximum capacity C_{max} of the completely filled can?

b) Calculate the analytical expression of the sensitivity of the filling level sensor. What is the numerical value?

Because the dielectric permittivity ε_r of the liquid and the distance a of the plates are not precicely known, a calibration is required. Calibration should be done with low effort.

c) Use the reference principle for the filling level sensor. Which filling levels are suitable as reference? Calculate the filling level depending on capacity values of reference levels, the corresponding filling levels and the actual capacity.

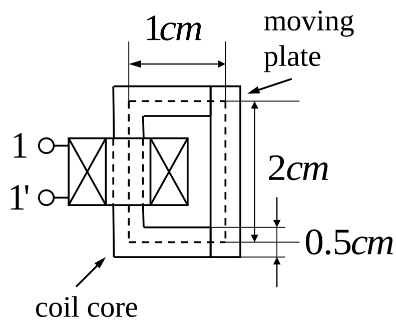
d) At the reference filling levels capacity values were measured. The values are C_1= 810pF (state 1) and C_2 = 64nF (state 2). Calculate the values for dielectric permittivity ε_r and distance a after calibration.

e) What is the numerical value of the difference Δx of the filling level between calibrated and noncalibrated filling level sensor?

f) Is it possible to overfill the can when stopping filling the can at C_{max} (see question a)? What is the reason (calculation or graphics required)?

displacement sensor using differential principle

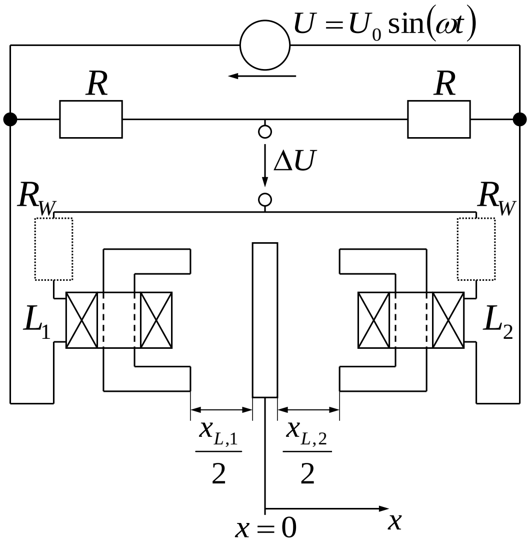
Two coils are used for a displacement sensor applying the differential principle. The figure shows the geometry of the coils. The magnetic circuit has a quadratic cross section.



Further known quantities:
- magnetic permeability of the coil core material: $\mu_r = 250$
- number of coil windings: $w = 500$

a) What is the mean value of the length x_m of the magnetic circuit?
b) What is the value of the inductivity L_0 of the coil between terminals 1 and 1'?

Two coils are placed and connected according to the following figure. Coupling of the two magnetic circuits and leakage flux should be neglected. The resistance of the coil windings should be neglected also. While the moving plate is in the centred position the air gap has a value of $x_{L,1} = x_{L,2} = 2x_0$, $x_0 = 1cm$.



c) What is the value of the inductance L_1 depending on the length of the air gap $x_{L,1}$? Calculate the numerical value of the inductance L_1 while the air gap has a length of $x_{L,1} = 0cm, x_{L,1} = 2cm$ and $x_{L,1} = 4cm$.
d) Calculate the values of the inductances L_1 and L_2 depending on the position x of the moving plate. Draw the behaviour of inductances L_1 and L_2 in one common diagram. The measured displacement x is $-1cm < x < 1cm$.
e) Calculate the analytical expression for the voltage ΔU depending on the displacement x of the moving plate. What is the value of the sensitivity?
f) Now the ohmic resistance R_W of the coil windings will be considered. Calculate the analytical expression for voltage ΔU depending on the displacement x of the moving plate while also considering the ohmic resistance R_W of the coil windings. How the influence of the ohmic resistance R_W can be reduced?
g) What is the advantage of using two coils and the differential principle instead of one coil? What are the disadvantages?