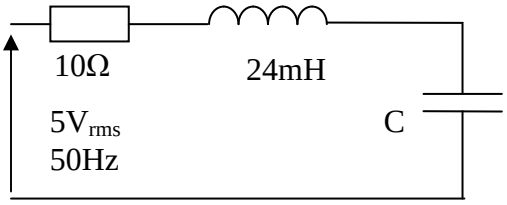
Tutorial Sheet 2 – Voice Coil Actuators

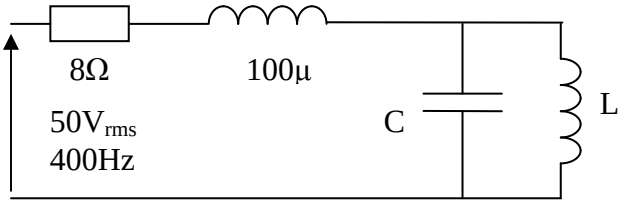
2.1 Terms

k_e: electromagnetic/force constant
k_d: damping coefficent
k_v: voltage constant
F: force on…
V(E): induced EMF

Equivalent circuit Q1



Equivalent circuit Q2



2.2 Equations

$$F = BIlN = k_e I$$

$$V = E = BlvN = k_v v$$

$$C = m / k_e^{\,2}$$

$$L = k_e^{\,2} / \sigma_s$$

$$Z = R + j\omega L + 1/\, j\omega C = R + j(\omega L - 1/\omega C)$$

$$|Z| = \sqrt{R^2 + (\omega L - 1/\omega C)^2}$$

$$V = I|Z|$$

$$V_c = \frac{V}{|Z|} \times \frac{1}{\omega C} = \frac{V}{\sqrt{(\omega CR)^2 + (1 - \omega^2 LC)^2}}$$

$$x_{pk-pk} = \int v.dt = \int_0^{1/f} v_{pk-pk} \sin(\omega t) dt$$

$$x_{pk-pk} = 2x_{pk}$$

$$Z_{L-C\_parallel} = \frac{1}{j(\omega C - \frac{1}{\omega L})}$$

$$V_{induced} = I \times Z_{L-C\_parallel}$$

Tutorial Sheet 2: Voice Coil Actuator Solutions

Q1

a) $k_e = BLN = 0.6 \times 0.02 \times 150 = 1.8 Nm/A$

b) $k_v = BLN = 0.6 \times 0.02 \times 150 = 1.8 V/ms^{-1}$

c) $C = \frac{M}{k_e{}^2} = \frac{3E-3}{(1.8)^2} = 926 \mu F$

Q2

Impedance of RLC circuit:

$$Z = R + j\omega L + \frac{1}{j\omega C} = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

$$\therefore |Z| = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

Voltage across capacitor

$$V_c = I_c \times \frac{-1}{\omega C} = \frac{Vin}{|Z|} \times \frac{-1}{\omega C} = \frac{Vin}{-\omega C\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} = \frac{Vin}{\sqrt{(\omega CR)^2 + \left(1 - \omega^2 LC\right)^2}}$$

$$\omega = 2\pi f \text{.....} Vc = \frac{Vin}{\sqrt{(2\pi fCR)^2 + \left(1 - (2\pi f)^2 LC\right)^2}}$$

Q3

a) rms current in coil

$$|I| = \frac{V_{in}}{|Z|} = \frac{V_{in}}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} = \frac{5}{\sqrt{(10)^2 + \left(100\pi(24E-3) - \frac{1}{100\pi(926E-6)}\right)^2}} = 0.46A$$

b) peak velocity of the coil

$$vc\_peak = \frac{Vc\_peak}{k_v} = \frac{\sqrt{2} \times Vin}{k_v\sqrt{(2\pi fCR)^2 + \left(1 - (2\pi f)^2 LC\right)^2}} = \frac{2.248988}{1.8} = 1.249438 \text{ms}^{-1}$$

c)peak to peak movement of coil, the coil moves from 0 to x and back to 0 in 0.02s.
so peak movement from 0 to x in 0.01s

$$x_{pk} = \int_0^{0.01} v_{pk} \sin(100\pi t)dt = \left[-\frac{vpk}{100\pi}\cos(100\pi t)\right]_0^{0.01} = \frac{v_{pk}}{100\pi}(2) = 7.95\text{mm}$$

$$x_{round\ trip} = 15.9mm$$