Ch.1: Non-ideal behaviour

2018-2019 1.(a):

1. (a) The impedance of *a-a'* in Figure 1 shows an equivalent circuit of an inductor. L_s and R_s are the equivalent series inductance and equivalent series resistance, respectively; and C is the parasitic capacitance. The quality factor Q of the inductor is much larger than 10.

(i) What is the self-resonant frequency of the inductor? Calculate the Q of the inductor at its self-resonant frequency.

(6 Marks)

(ii) Sketch the impedance magnitude versus frequency of the inductor with its self-resonant frequency and the corresponding impedance value indicated.

(4 Marks)

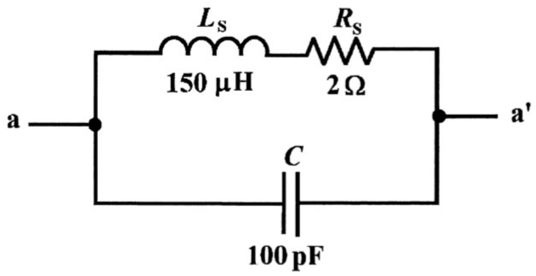


Figure 1

Solution:

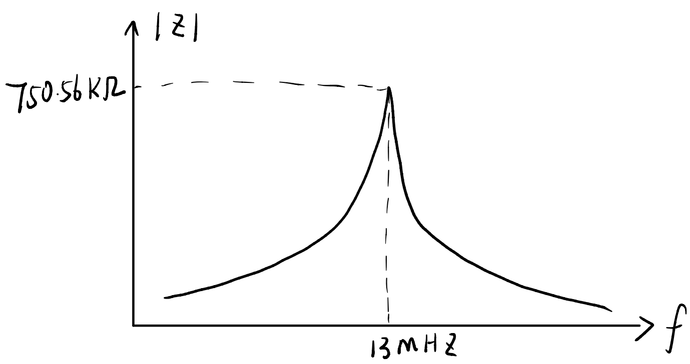
(i) Since $Q >> 10$, $L_p \approx L_s$, $R_p \approx Q^2 R_s$

The SRF is, $f_0 = \frac{1}{2\pi\sqrt{L_p C}} = \frac{1}{2\pi\sqrt{L_s C}} = \frac{1}{2\pi\sqrt{150\times10^{-6} \times 100\times10^{-12}}} = 1.3\,MHz$

The Q factor is $\frac{\omega L_s}{R_s} = \frac{2\pi f_0 L_s}{R_s} = \frac{2\pi\times1.3\times10^{6}\times150\times10^{-6}}{2\,\Omega} = 612.6$

(ii) SRF is 1.3 MHz

@ 1.3 MHz, the impedance is $R_p = Q^2 R_s = 750.56\,K\Omega$



2017-2018 1. (a)

1. (a) Figure 1 shows a 470 µF electrolytic capacitor with two copper leads. The diameter of the lead is 0.5 mm, the length of each lead is 30 mm and the centre-to-centre separation between leads is 5 mm. The capacitor will be used for low frequency applications where skin effect of the leads can be ignored. Conductivity and permeability of copper are 5.82×10^7 S/m and $4\pi \times 10^{-7}$ H/m, respectively.

(i) If the parasitic effects are mainly contributed by the leads, draw the equivalent circuit model of the capacitor and indicate the values of the respective parasitic elements clearly.

(6 Marks)

(ii) Sketch the impedance frequency response of the capacitor with its self-resonant frequency and the corresponding impedance value indicated.

(4 Marks)

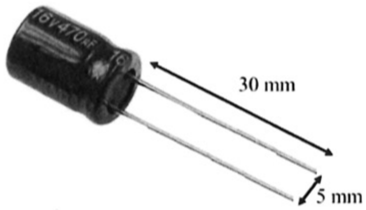
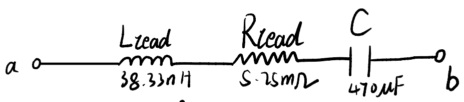


Figure 1

Note: Question No. 1 continues on page 2

(i) The equivalent circuit is



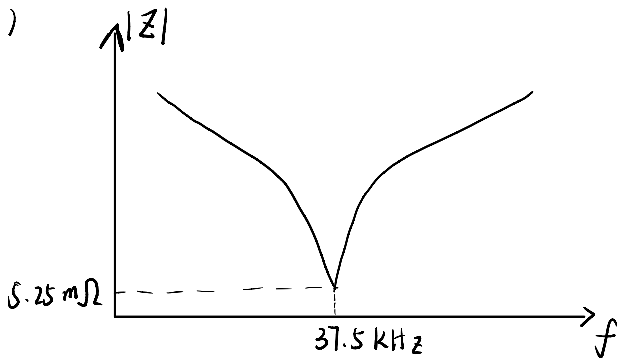
The skin effect doesn't exist,

$$L_{lead} = 4\times10^{-7} \times l \times \ln\left(\frac{D-r}{0.7788r}\right) H = 4\times10^{-7} \times 30\times10^{-3} \ln\left(\frac{5-0.25}{0.7788\times0.25}\right) = 38.33\ nH$$

$$R_{lead} = 2\times\left(\frac{l}{\sigma\pi r^2}\right) = 2\times\frac{30\times10^{-3}}{5.82\times10^7\times\pi\times(0.25\times10^{-3})^2}$$

$$= 5.25\ m\Omega$$

(ii)



The SRF is : $f_0 = \frac{1}{2\pi\sqrt{LC}}$

$= 37.5\ kHz$

$\Rightarrow \delta = 3.41\times10^{-4}\ m$

$r = 2.5\times10^{-4}\ m$

$\delta > r$, skin effect doesn't occur.

2016-2017 1.(a)

1. (a) Figure 1 shows the impedance magnitude versus frequency of three capacitors with the same packaging technology in a manufacturer's catalogue. Based on these frequency response curves, draw the equivalent circuit models of 0.1 µF, 0.01 µF and 1000 pF capacitors in terms of RLC series circuits. Indicate clearly the values of R, L and C in the equivalent circuit models.

(10 Marks)

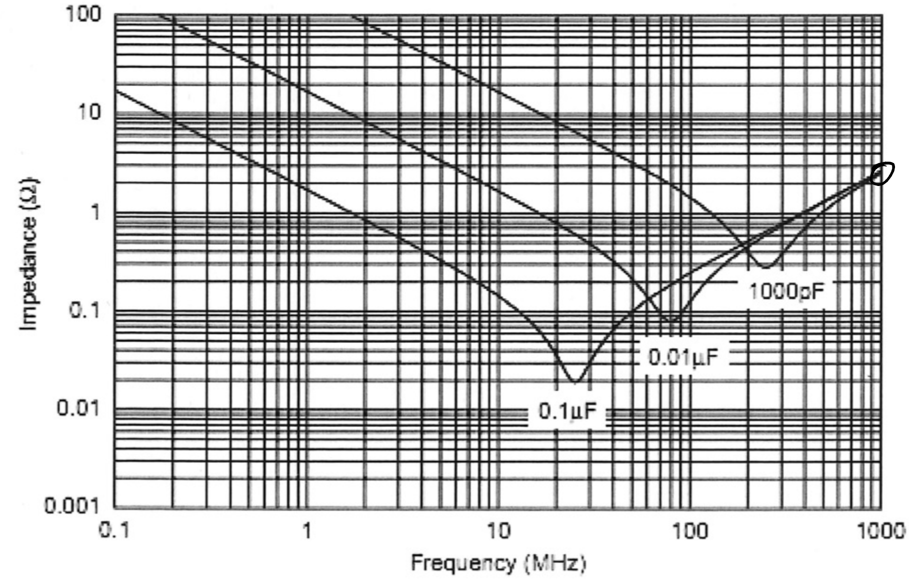


Figure 1

(a) From the graph we can get

Capacitor	SRF	R
0.1 µF	25 MHz	0.02 Ω
0.01 µF	80 MHz	0.08 Ω
1000 pF	250 MHz	0.3 Ω

The ESLs of these three capacitor are the same, Since at 1000 MHz, the three lines have the same Impedance. $ESL \approx \frac{2.5\Omega}{2\pi \times 10^3 \times 10^6 Hz} = 0.40nH$

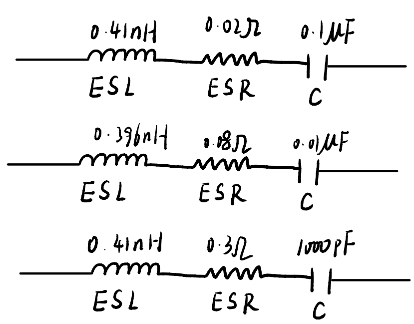
Since $SRF = \frac{1}{2\pi\sqrt{LC}} \Rightarrow L = \frac{1}{(2\pi f_0)^2 C}$

$C = 0.1\mu F, \quad L = 0.41 nH$

$C = 0.01\mu F, \quad L = 0.396 nH$

$C = 1000 pF, \quad L = 0.41 nH$

The equivalent circuit is



2021-2022 Quiz. 1.

1. Fig. 1 shows a 0.1 μF ceramic capacitor with two parallel copper leads. The diameter of the copper lead is 0. 5 mm and the length of each lead is 25 mm. The centre-to-centre separation between leads is 4 mm. In your calculation, consider only the inductance and resistance of the leads. The capacitance of the leads is negligible and can be ignored. Electrical properties of copper: $\sigma = 5.82 \times 10^{7}$ S/m and $\mu = 4\pi \times 10^{-7}$ H/m.

(a) Draw the equivalent circuit of the capacitor between points "a" and "b" in terms of resistance (R), inductance (L) and capacitance (C).

(5 Marks)

(a) Determine the self-resonant frequency of the capacitor.

(10 Marks)

(a) Sketch the magnitude of the impedance versus frequency and indicate the value of SRF and the value of the impedance at SRF.

(10 Marks)

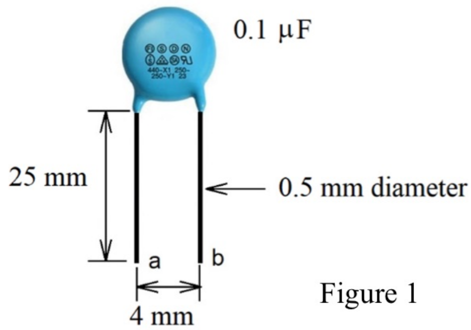
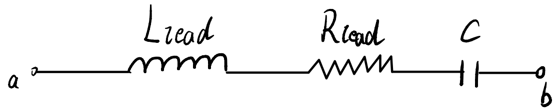


Figure 1

(a) The equivalent circuit is,



(b) Assuming that SRF is high enough that skin effect exists.

$$L_{lead} = L_{HF} = 4\times10^{-7} \times l \times \ln\left(\frac{D-r}{r}\right)$$

$$= 4\times10^{-7} \times 25\times10^{-3} \times \ln\left(\frac{4-0.25}{0.25}\right)$$

$$= 27.08 \text{ nH}$$

Hence SRF is $f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{27.08\times10^{-9}\times0.1\times10^{-6}}} = 3.06 \text{ MHz}$

At SRF, the skin depth is $\delta = \frac{1}{\sqrt{\pi f \sigma \mu}} = \frac{1}{\sqrt{3.06\times10^{6}\pi\times5.82\times4\pi}} = 3.77\times10^{-5}$ (m)

$r = 0.25\times10^{-3}$ m, $\delta < r$. So the assumption is valid.

$$R_{lead} = 2\times\frac{l}{2\pi r\sigma\delta} = 2\times\frac{25\times10^{-3}}{2\pi\times0.25\times10^{-3}\times5.82\times10^{7}\times3.77\times10^{-5}} = 14.5 \text{ m}\Omega$$

(c)