

Načrtovanje elektronike za

EMC²

študentska delavnica
in tekmovanje

 FE UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

 LPVO Laboratorij za fotovoltaike
in optoelektroniko

 KC ČIP.SI
SLOVENSKI KOMPETENČNI
CENTER ZA ČIPE

KOLEKTOR

Glavna nagrada 1500 €

FORVIA


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MORE THAN
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 iskraemeco
BY ELSEWEDY ELECTRIC

 GEMmotors

 INSTRUMENTATION
TECHNOLOGIES

svet
ELEKTRONIKE

 Hidria
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 simtec

Ansys
part of **SYNOPSYS**
SELECT
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PARTNER

Seminar in delavnica

Načrtovanje elektronike za EMC

Napajanje in prevodne motnje

M. Jankovec

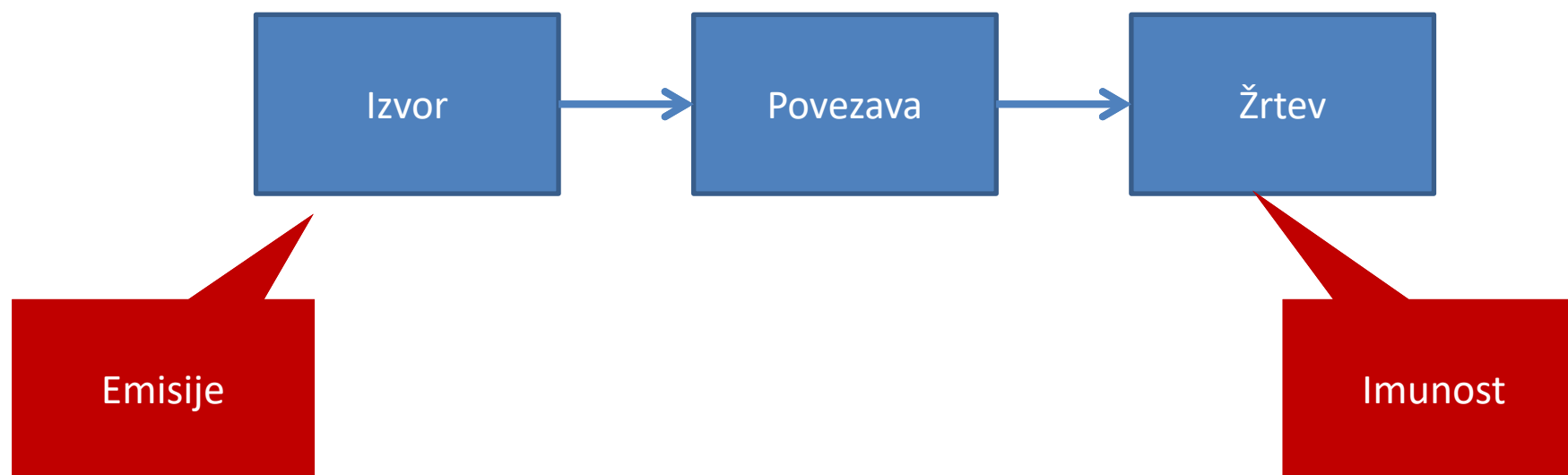
Univerza v Ljubljani

Fakulteta za elektrotehniko

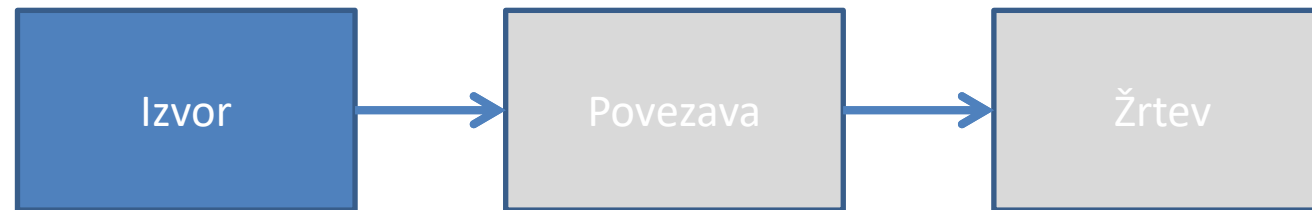
Tržaška 25, SI-1000 Ljubljana, Slovenia

Model EMC

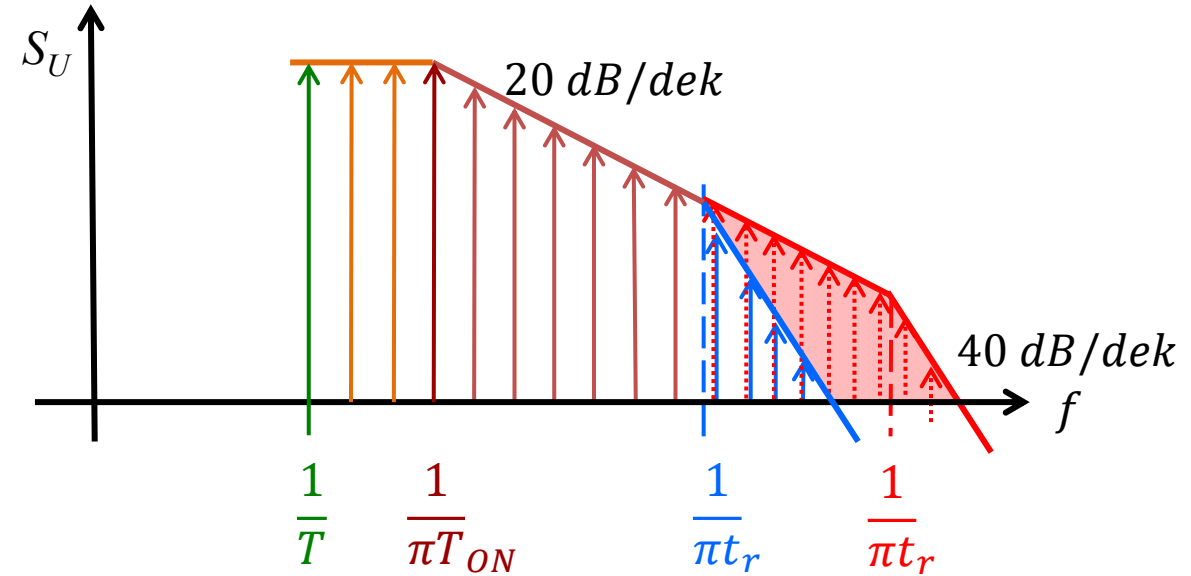
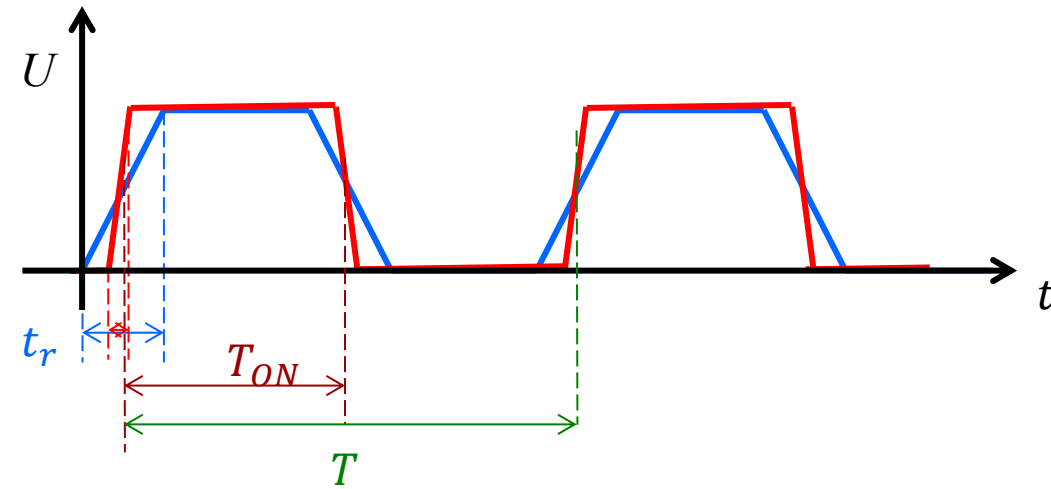
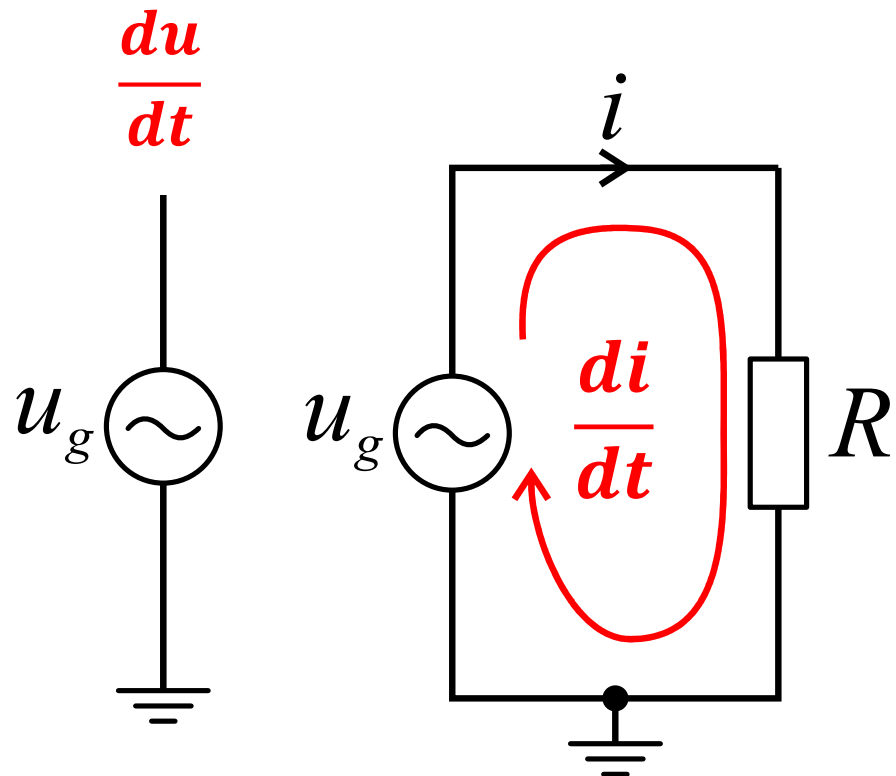
- **izvor** sevanja (motenj),
- **Sprejemnik**
- **povezava** med izvorom in sprejemnikom.



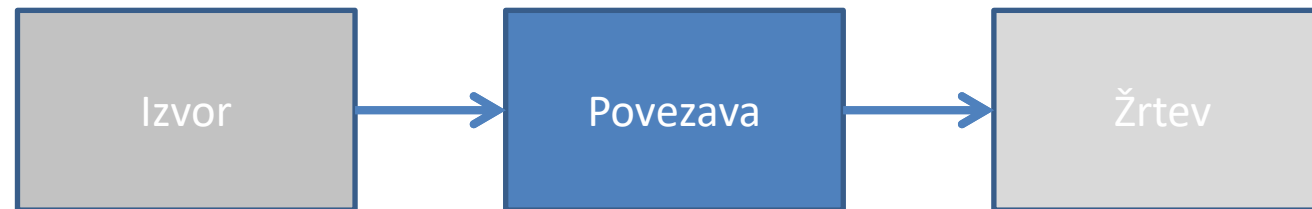
Model EMC



Izvori motenj

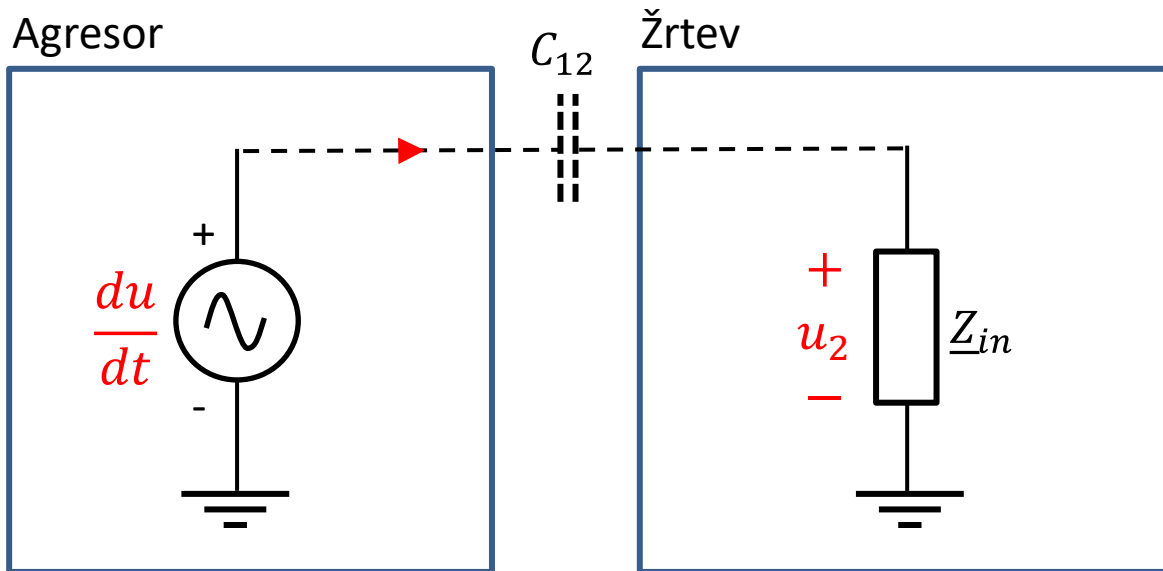


Model EMC

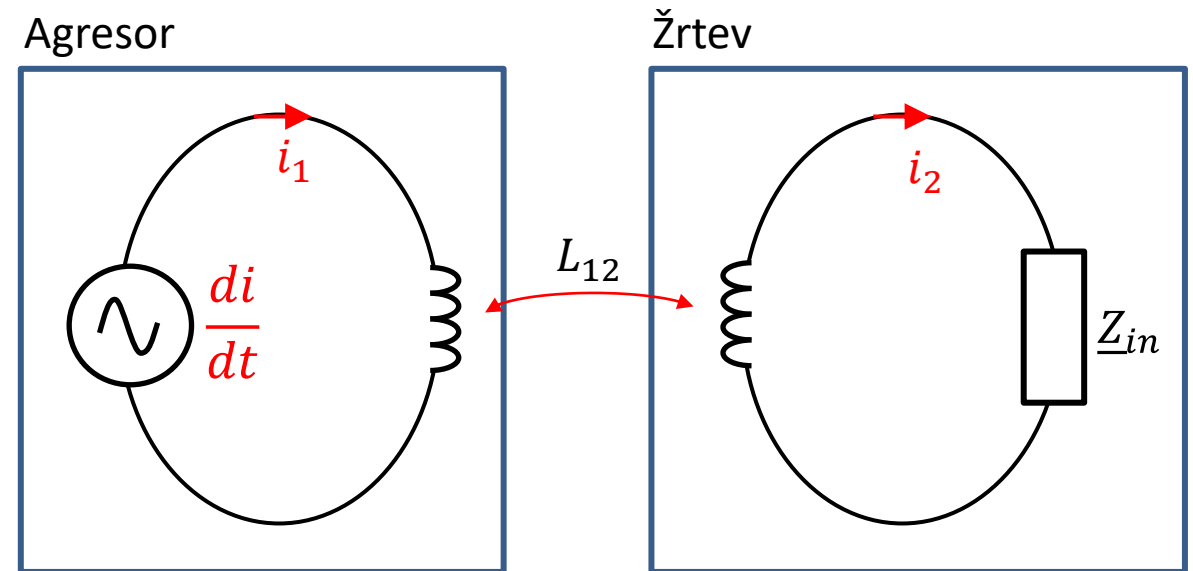


Sevalni prenos motenj

Kapacitivni – napetostno generirane motnje

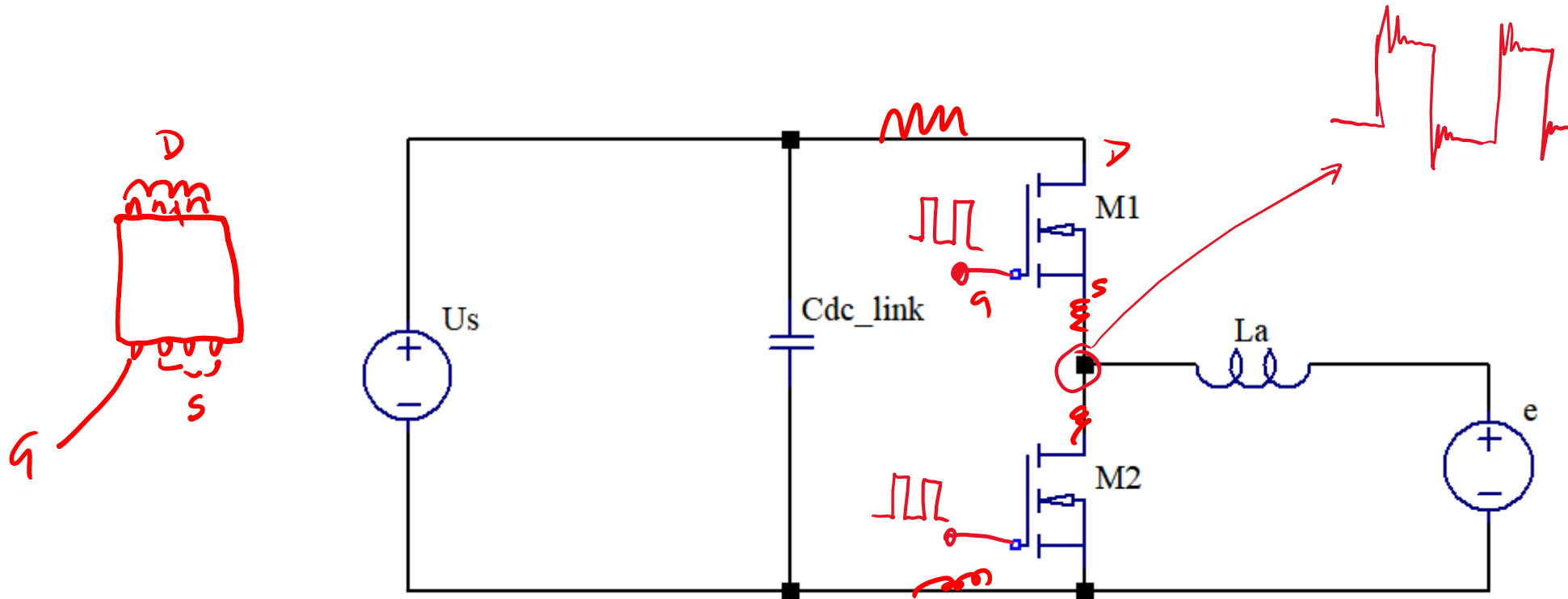


Induktivni – tokovno generirane motnje



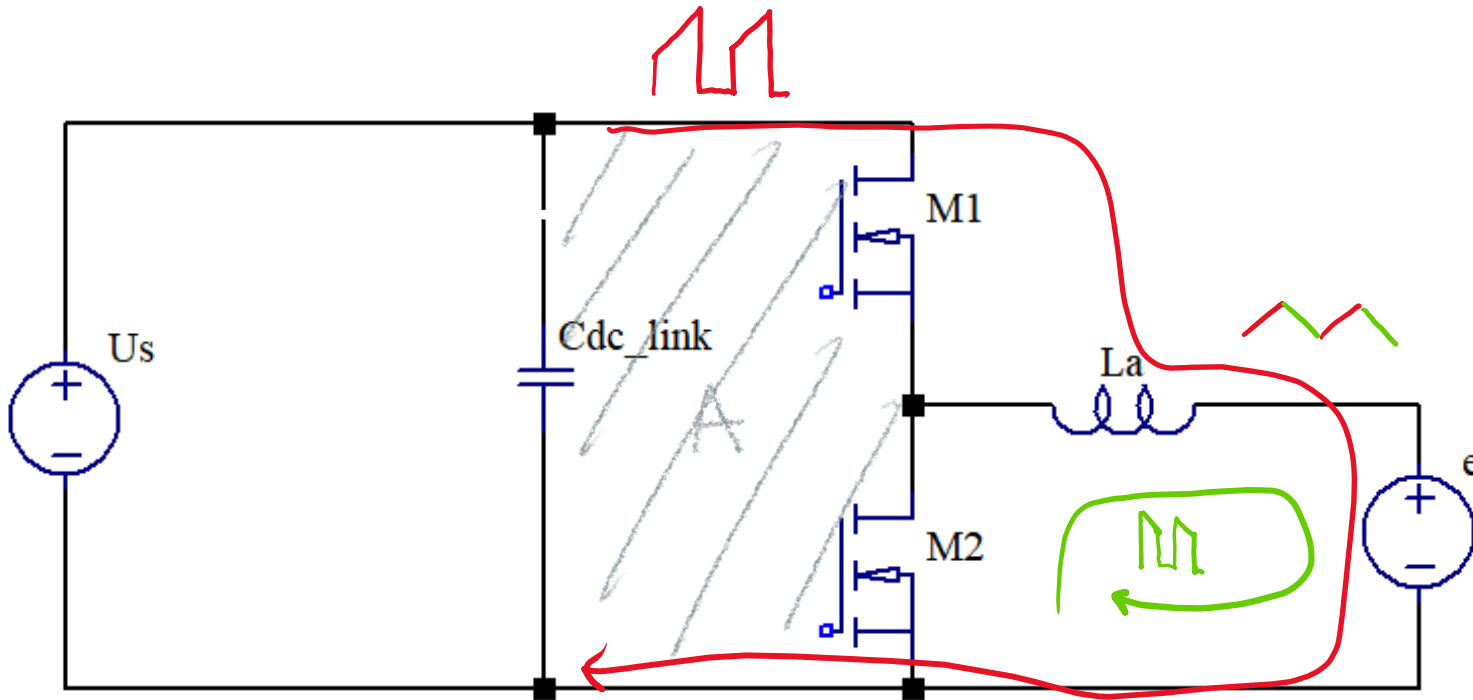
Napetostno generirane diferencialne motnje

Stikalno vozlišče

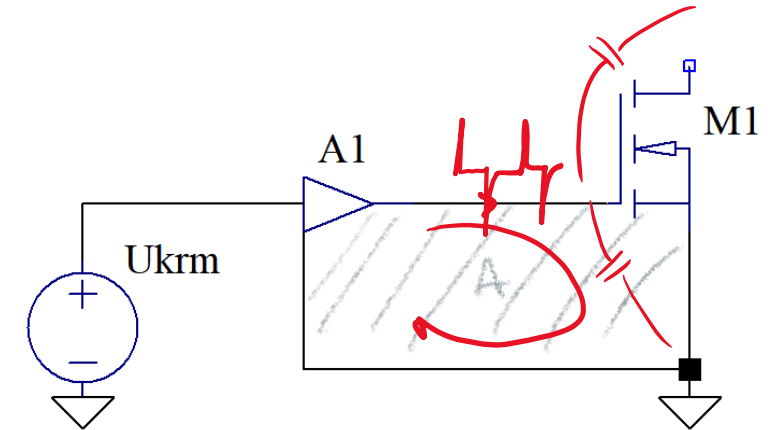


Tokovno generirane diferencialne motnje

Glavna preklopna zanka



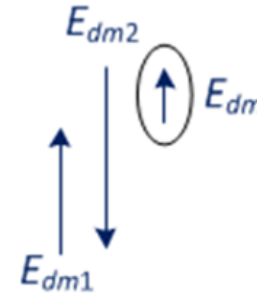
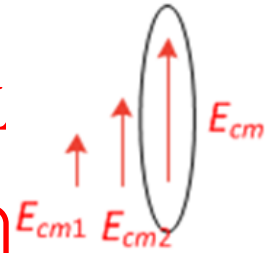
Tokovna zanka krmiljenja MOFET-ov



Diferencialni in sofazni signali

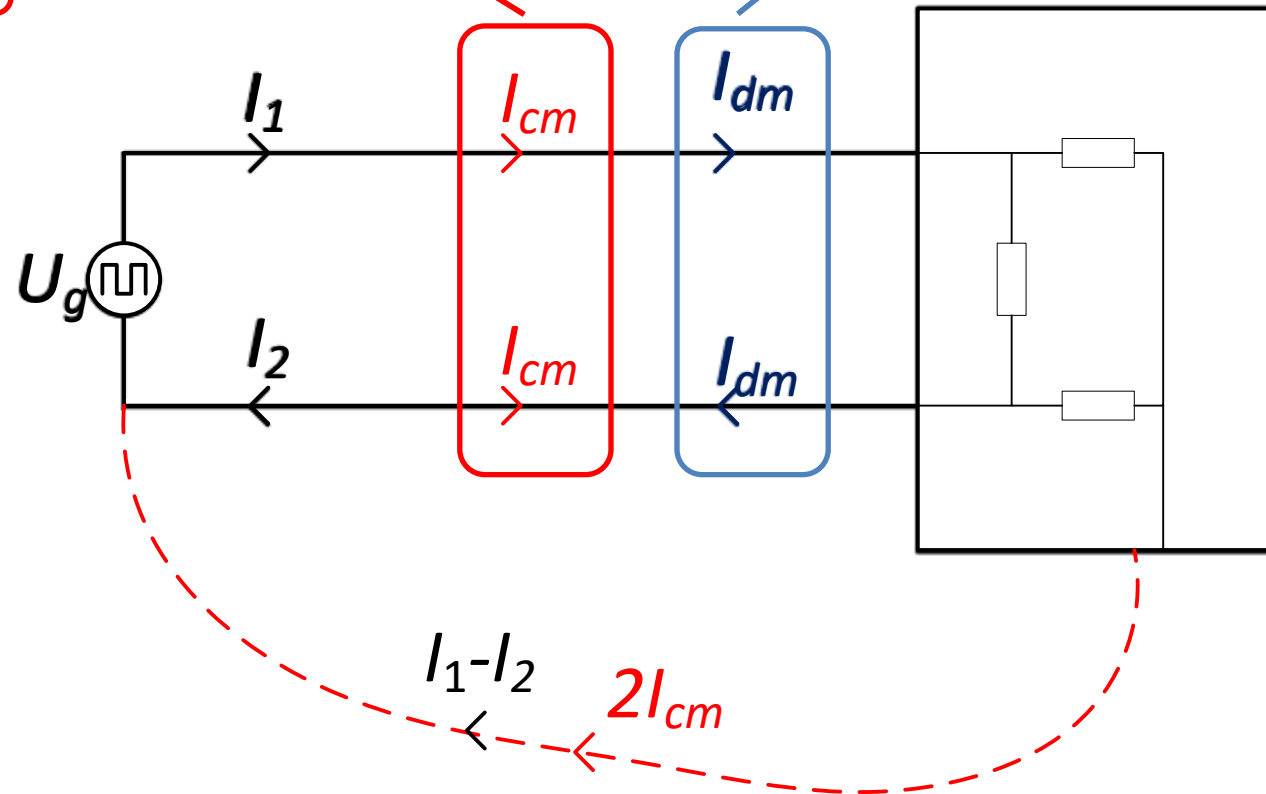
$$E_{cm}(f) \approx I_{cm}(f) f L$$

dolžina

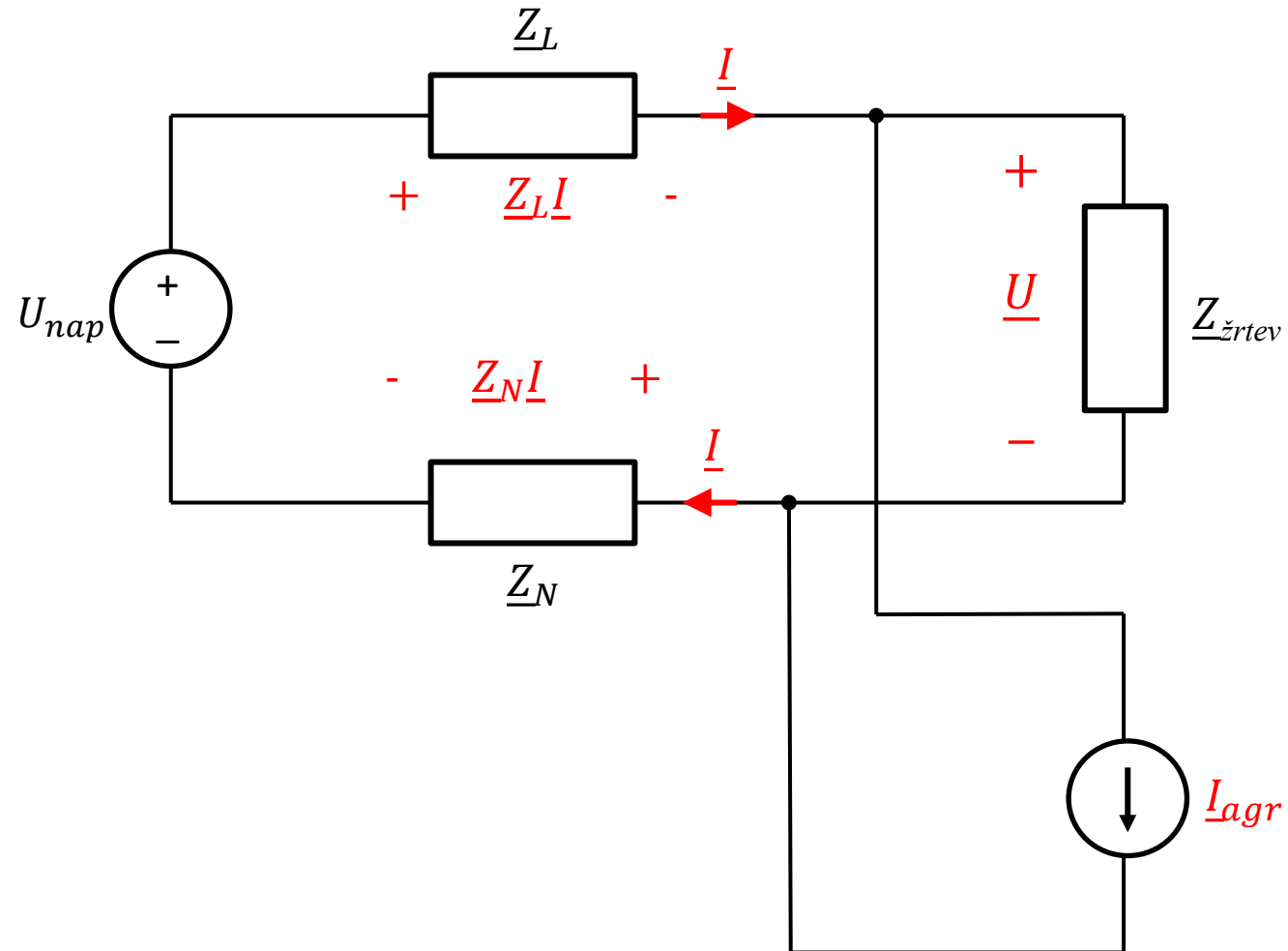


$$E_{dm}(f) \approx I_{dm} f^2 L d$$

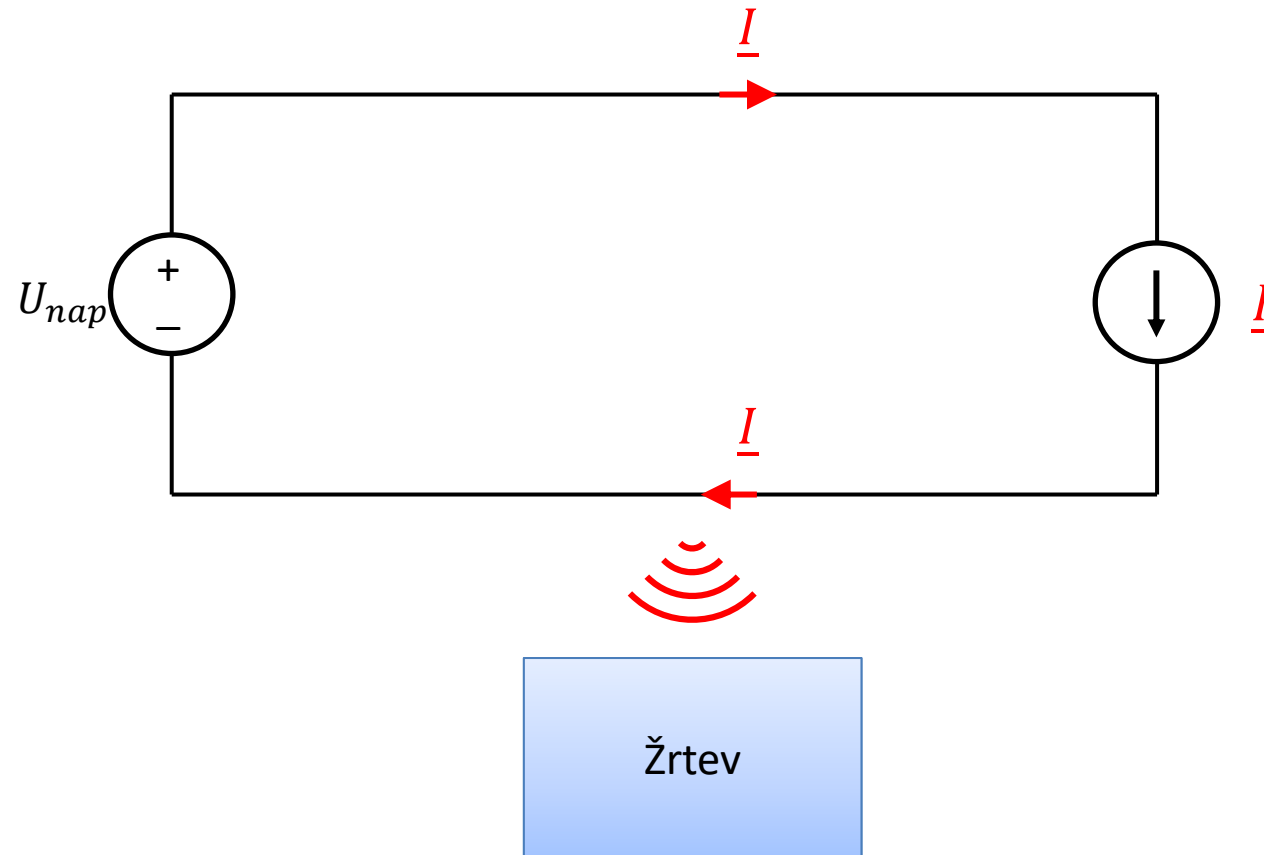
površina



Prevodni (konduktivni) sklop motnje

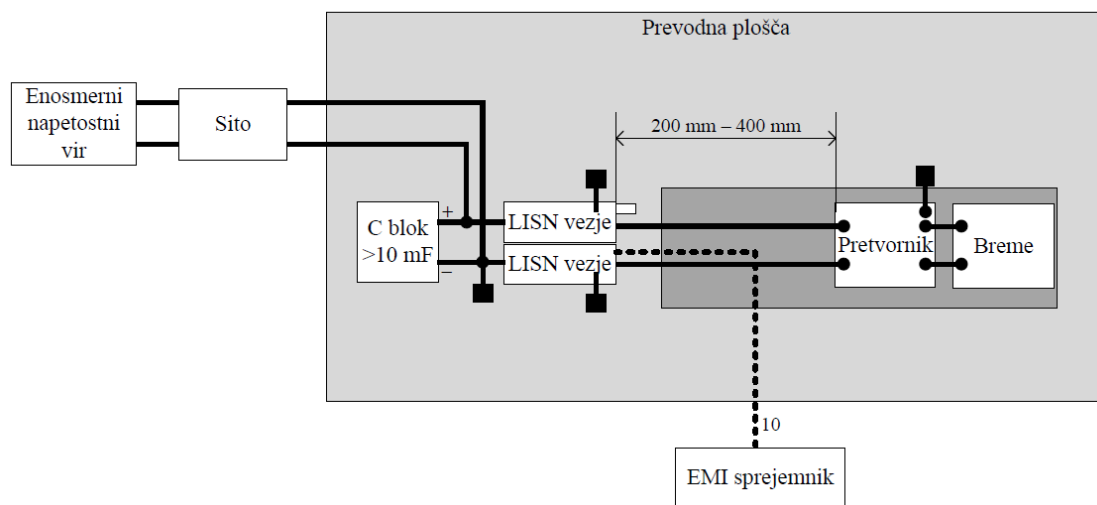


Prevodno-sevalni prenos motnje

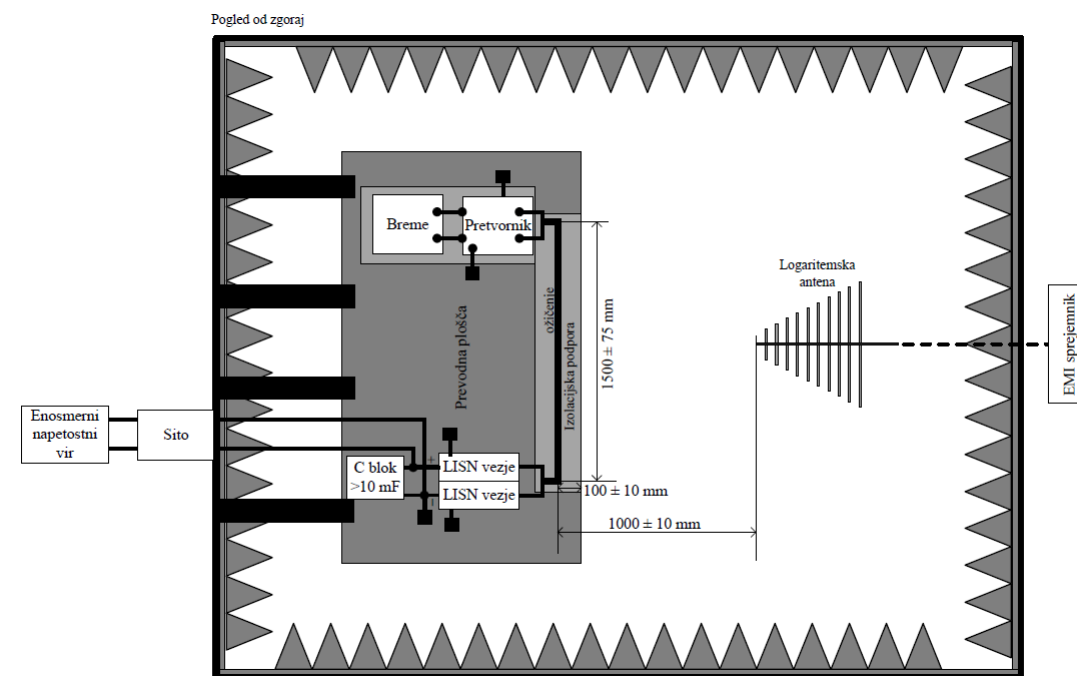


Vpliv prevodnih motenj

Merjenje prevodnih motenj

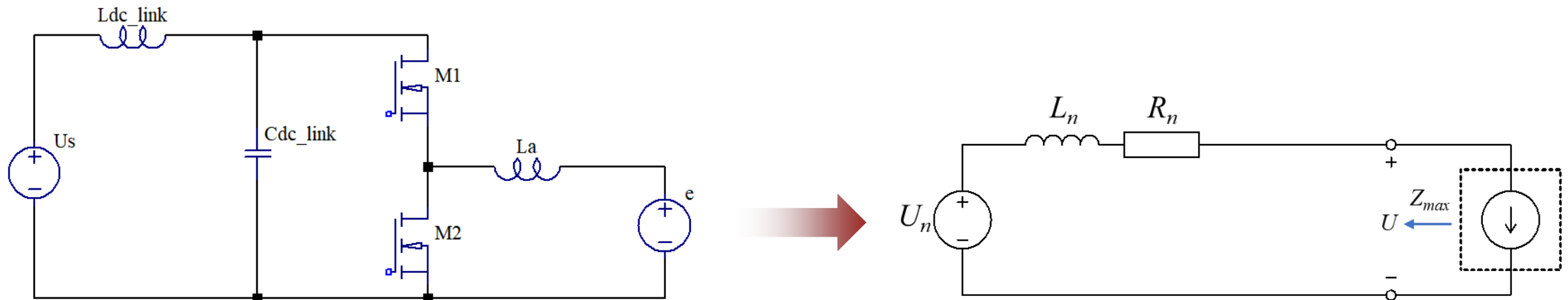


Merjenje sevalnih motenj



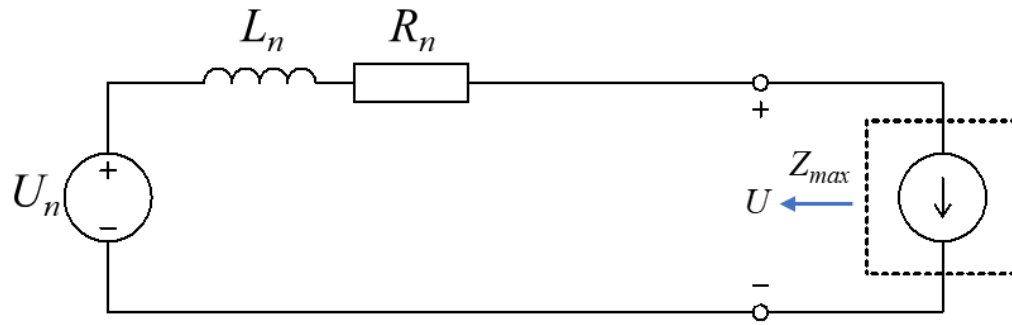
Stabilizacija napajalne napetosti

Napetostni vir – nizka impedanca



Stabilizacija napajalne napetosti

Impedanca napajanja -> DC link kondenzatorji

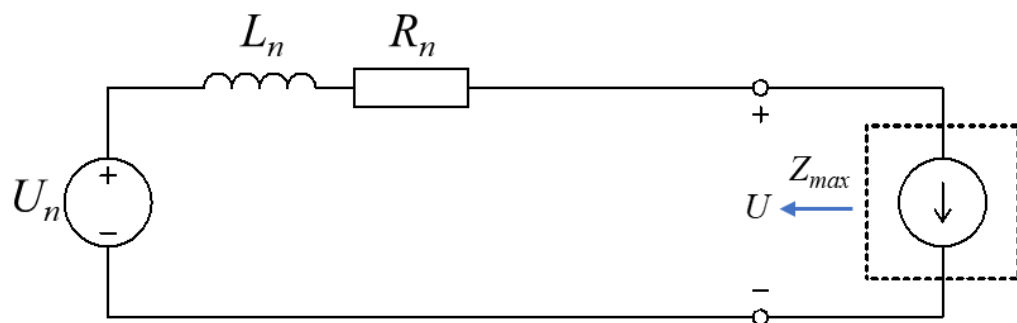


- Razmerje med
 - › dopustno spremembo napetosti (ΔU_{DDmax}) in
 - › spremembo toka (ΔI_{max})
- je največja dopustna impedanca napajanja.

$$Z_{max} = \frac{\Delta U_{max}}{\Delta I_{max}}$$

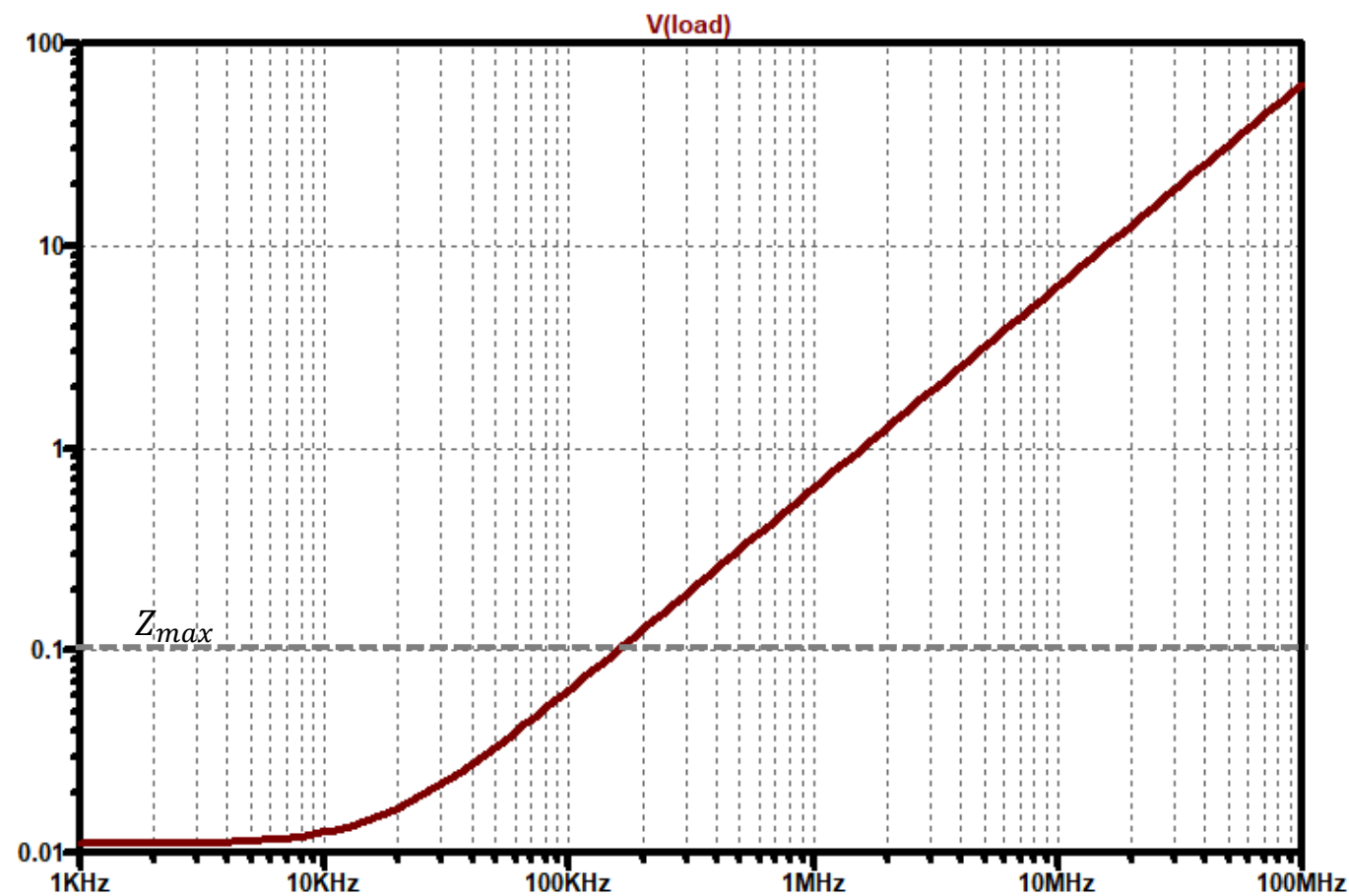
Stabilizacija napajalne napetosti

Impedanca napajanja -> DC link kondenzatorji

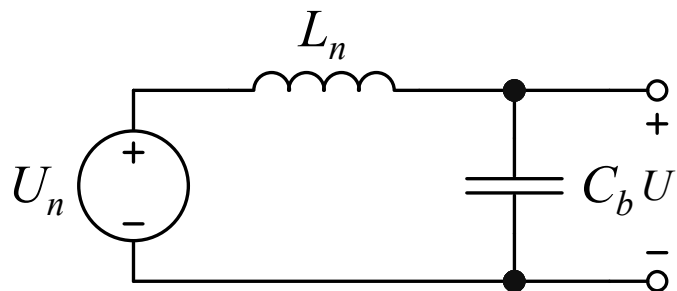


$$L_n = 100 \text{ nH} \quad R_n = 10 \text{ m}\Omega$$

$$Z_{max} = \frac{\Delta U_{max}}{\Delta I_{max}} = \frac{0,1 \text{ V}}{1 \text{ A}} = 100 \text{ m}\Omega$$



DC-link kondenzatorji



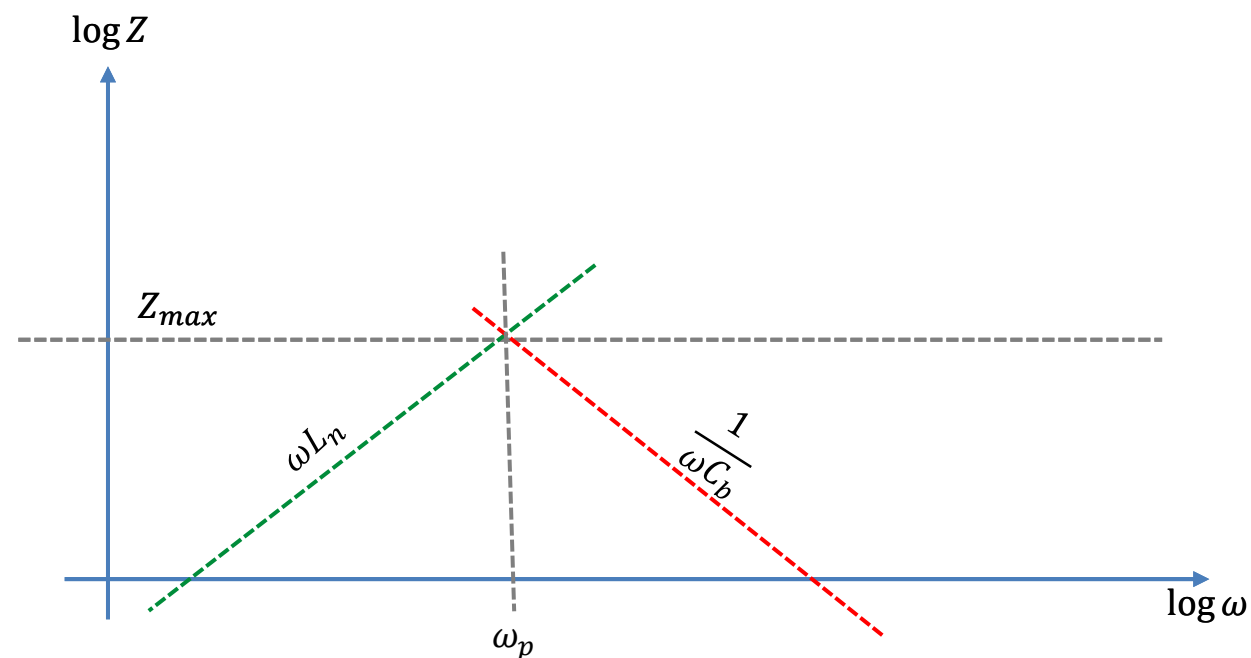
$$L_n = 100 \text{ nH}$$

$$Z_{max} = 100 \text{ m}\Omega$$

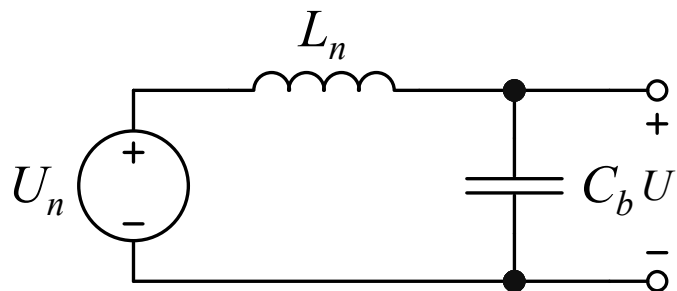
$$\omega_p = \frac{Z_{max}}{L_n} = \frac{1}{\sqrt{L_n C_b}}$$

$$\omega_p = 160 \text{ kHz}$$

$$C_B = 10 \text{ }\mu\text{F}$$



DC-link kondenzatorji

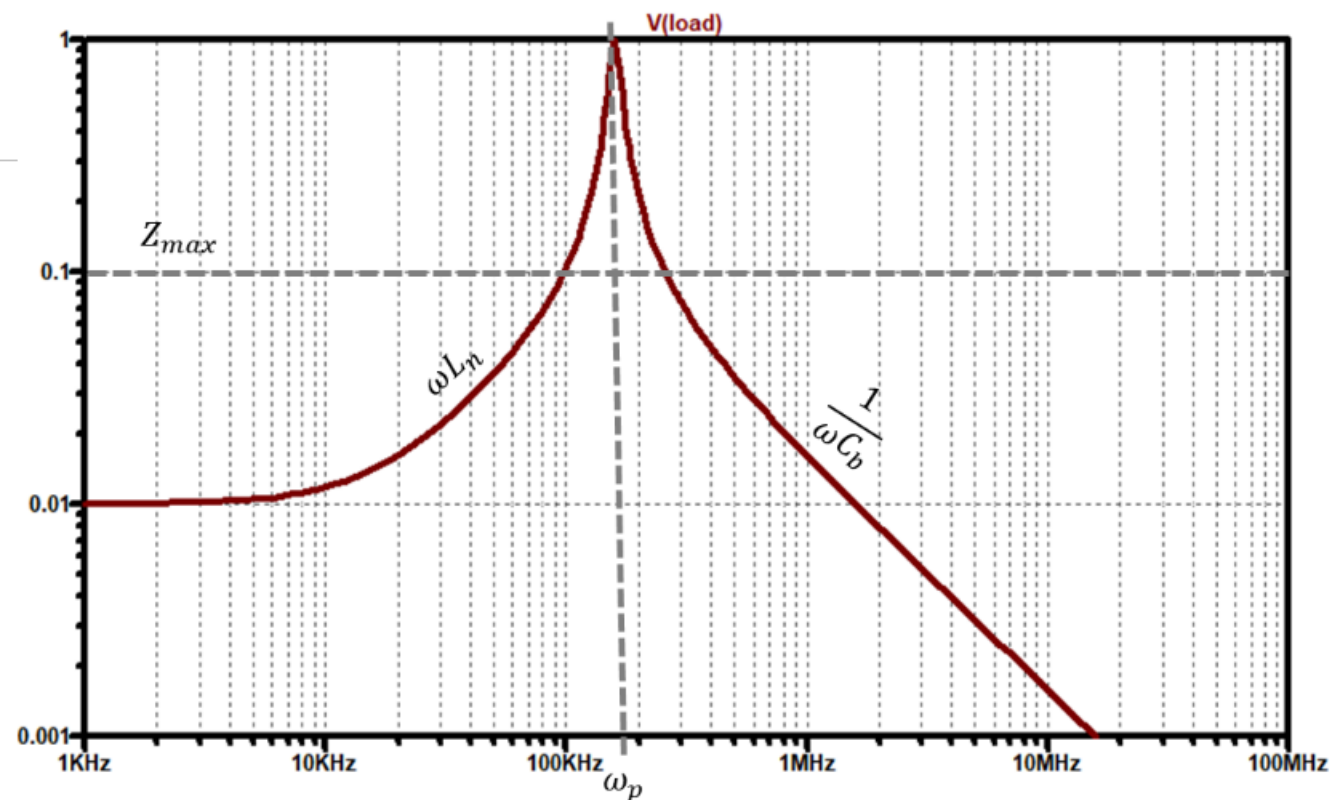


$$L_n = 100 \text{ nH}$$

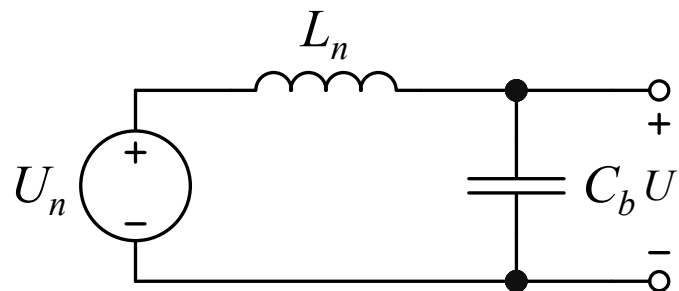
$$Z_{max} = 100 \text{ m}\Omega$$

$$\omega_p = 160 \text{ kHz}$$

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DC-link kondenzatorji

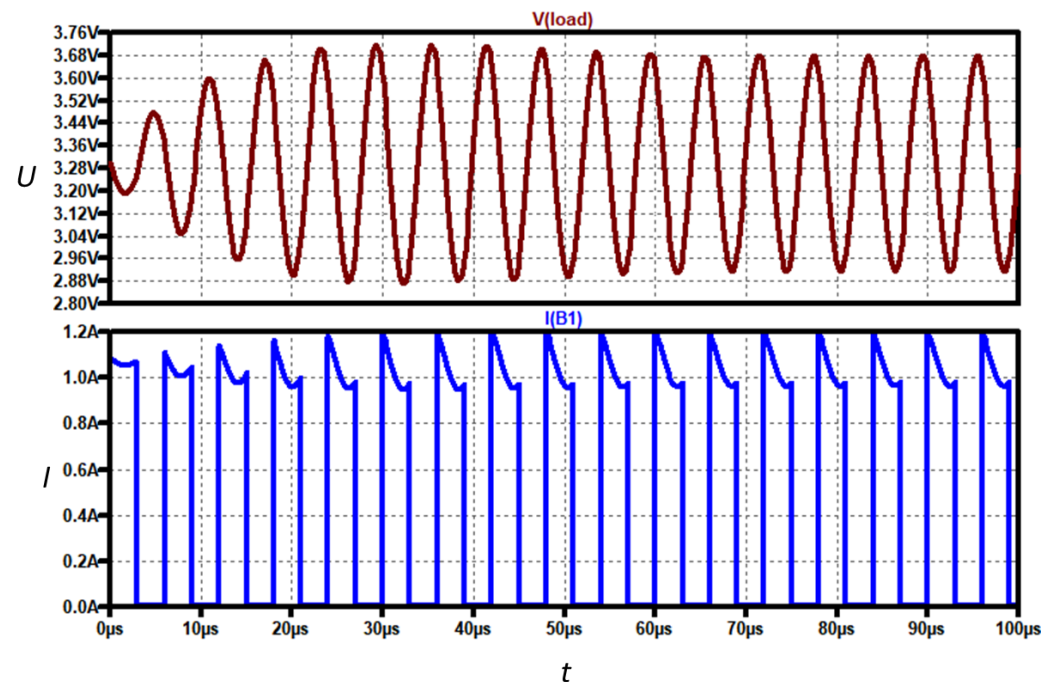


$$L_n = 100 \text{ nH}$$

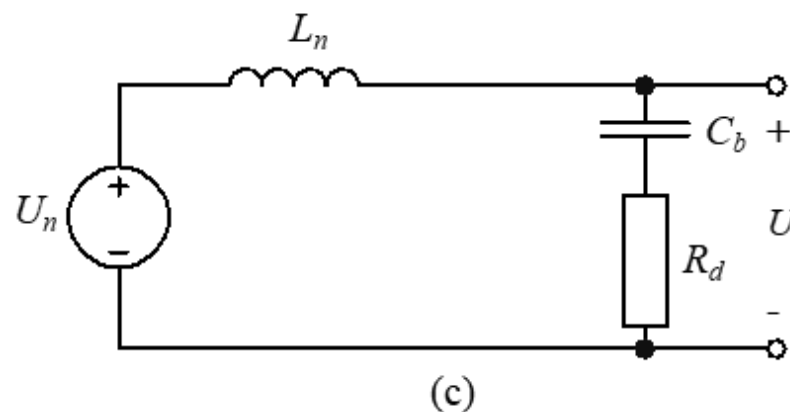
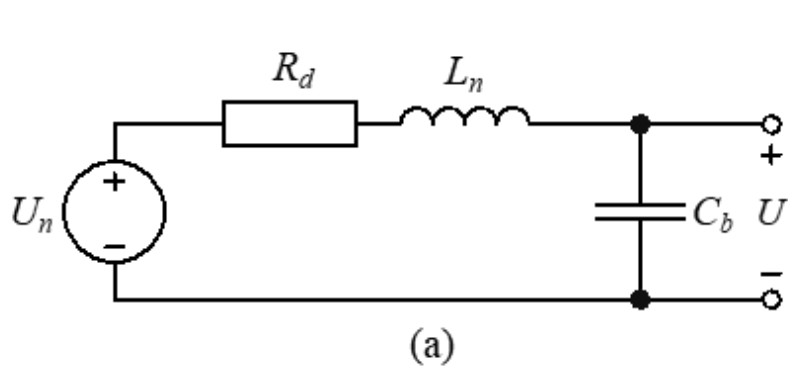
$$Z_{max} = 100 \text{ m}\Omega$$

$$\omega_p = 160 \text{ kHz}$$

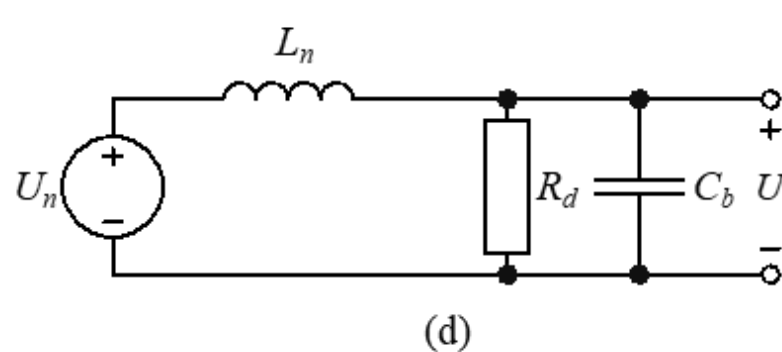
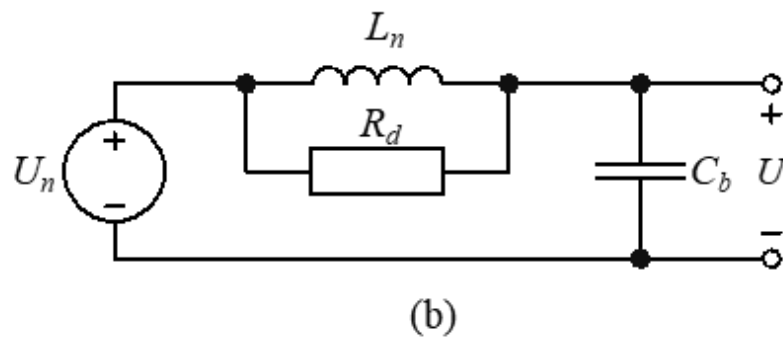
$$C_B = 10 \text{ }\mu\text{F}$$



Dušenje paralelne resonance

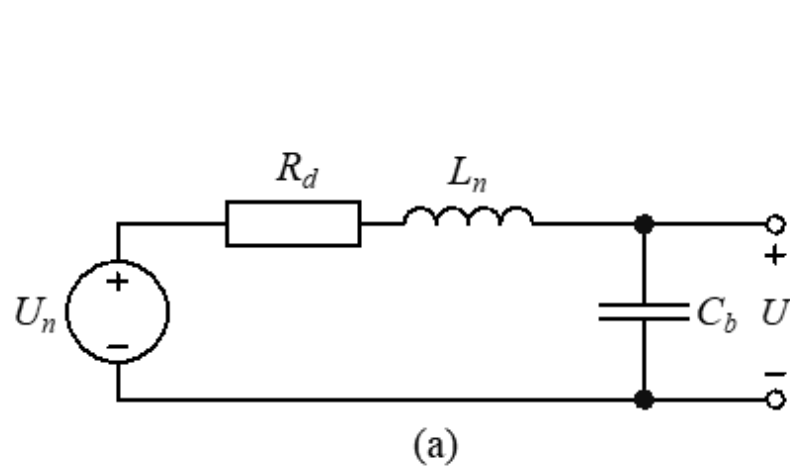


$$R_d = 2 \sqrt{\frac{L_n}{C_b}}$$



$$R_d = \frac{1}{2} \sqrt{\frac{L_n}{C_b}}$$

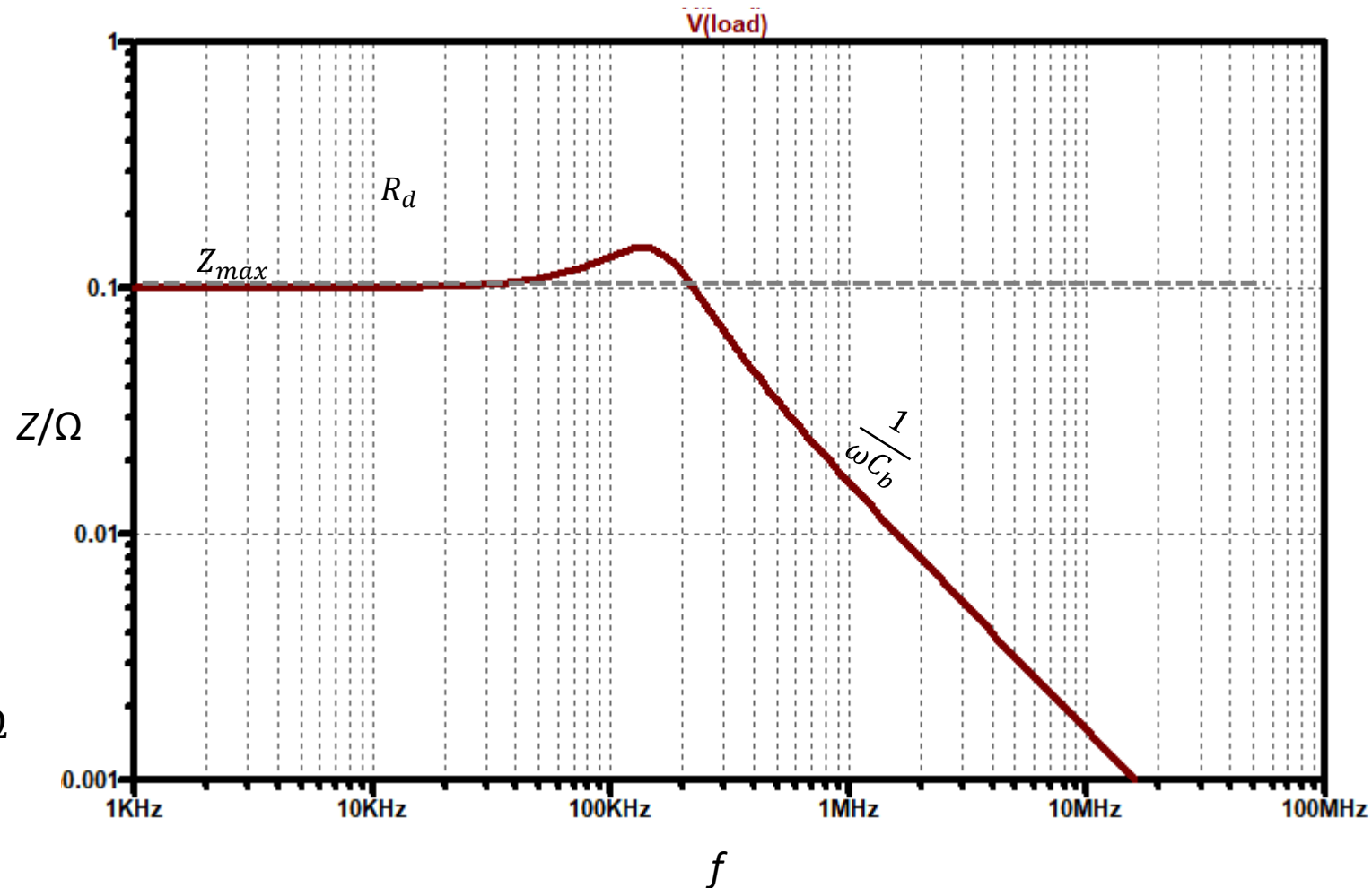
Dušenje paralelne resonance



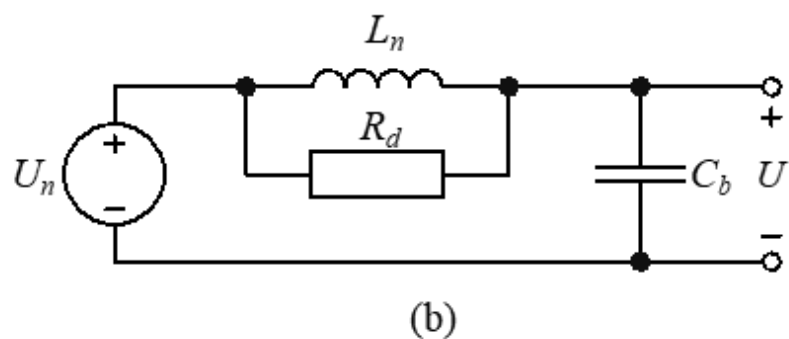
$$L_n = 100 \text{ nH}$$

$$C_b = 10 \text{ } \mu\text{F}$$

$$R_d = 2 \sqrt{\frac{L_n}{C_b}} = 0,2 \text{ } \Omega \quad R_d = 0,1 \text{ } \Omega$$



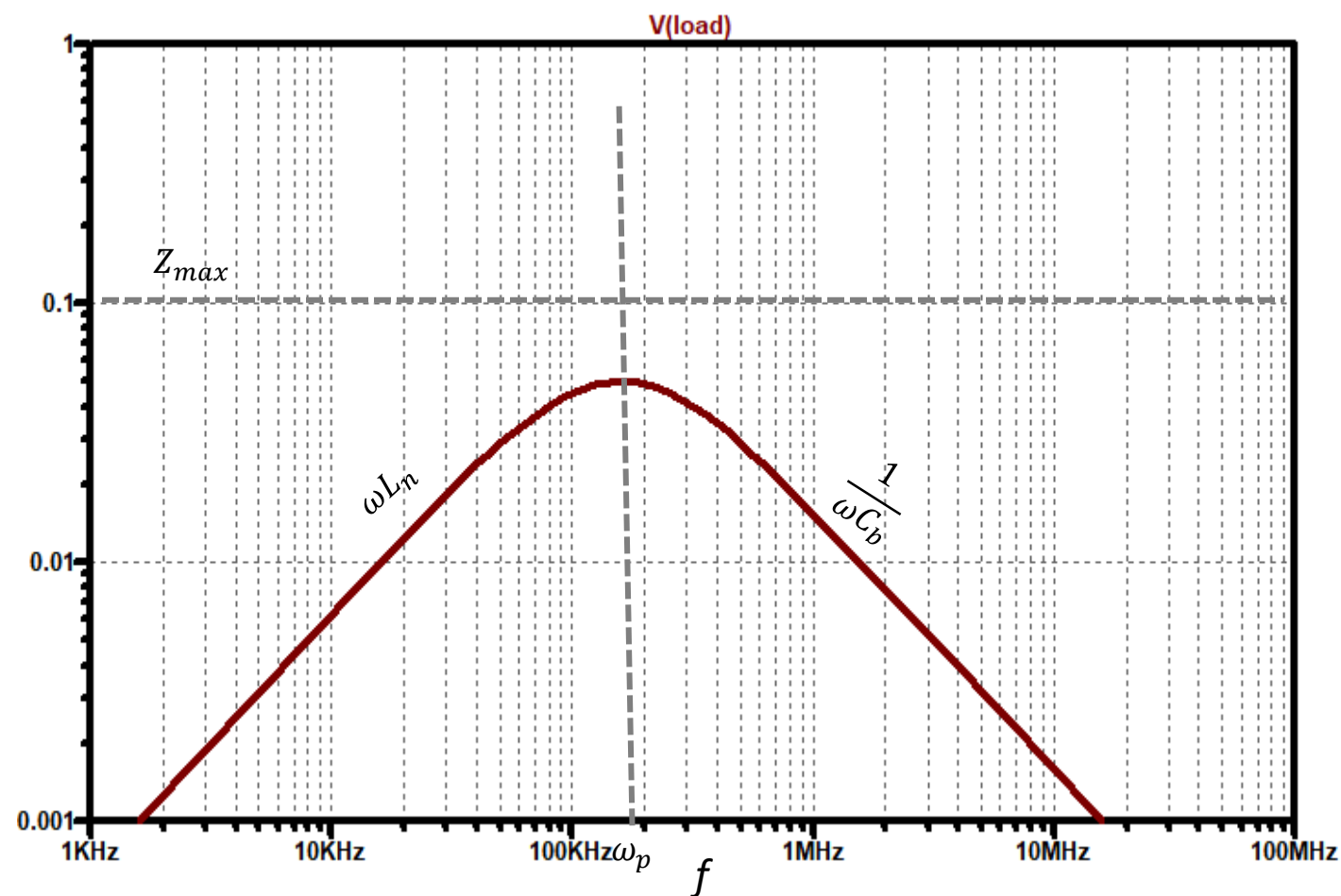
Dušenje paralelne resonance



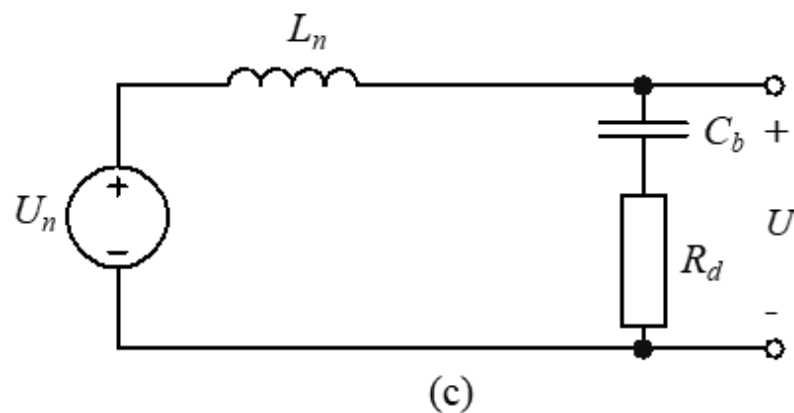
$$L_n = 100 \text{ nH}$$

$$C_b = 10 \text{ } \mu\text{F}$$

$$R_d = \frac{1}{2} \sqrt{\frac{L_n}{C_b}} = 0,05 \text{ } \Omega$$



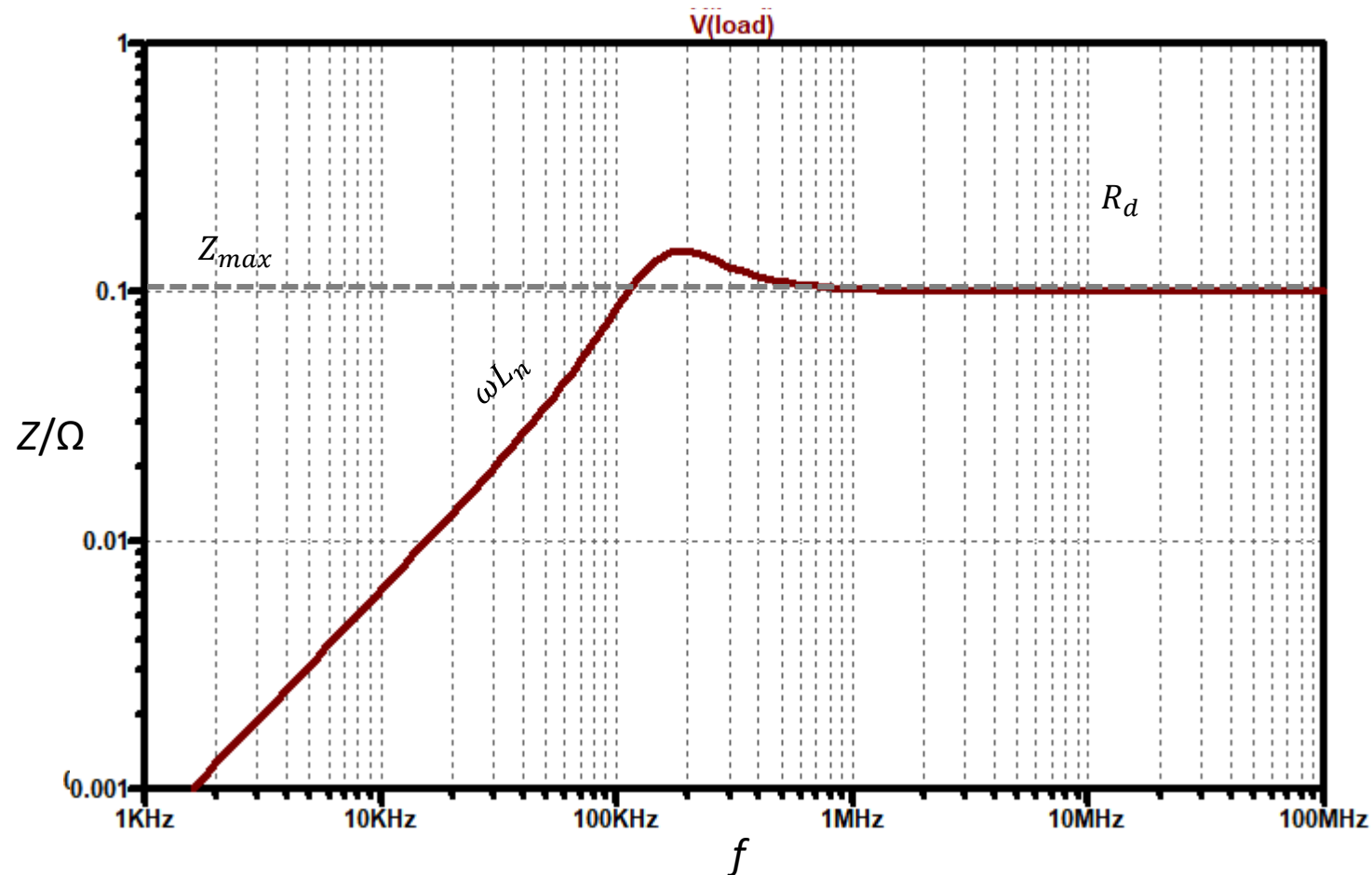
Dušenje paralelne resonance



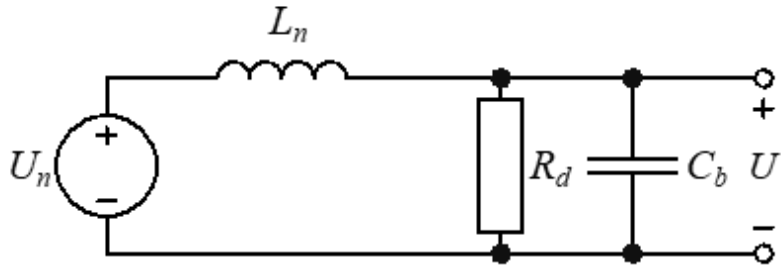
$$L_n = 100 \text{ nH}$$

$$C_b = 10 \text{ } \mu\text{F}$$

$$R_d = 2 \sqrt{\frac{L_n}{C_b}} = 0,2 \text{ } \Omega \quad R_d = 0,1 \text{ } \Omega$$



Dušenje paralelne resonance

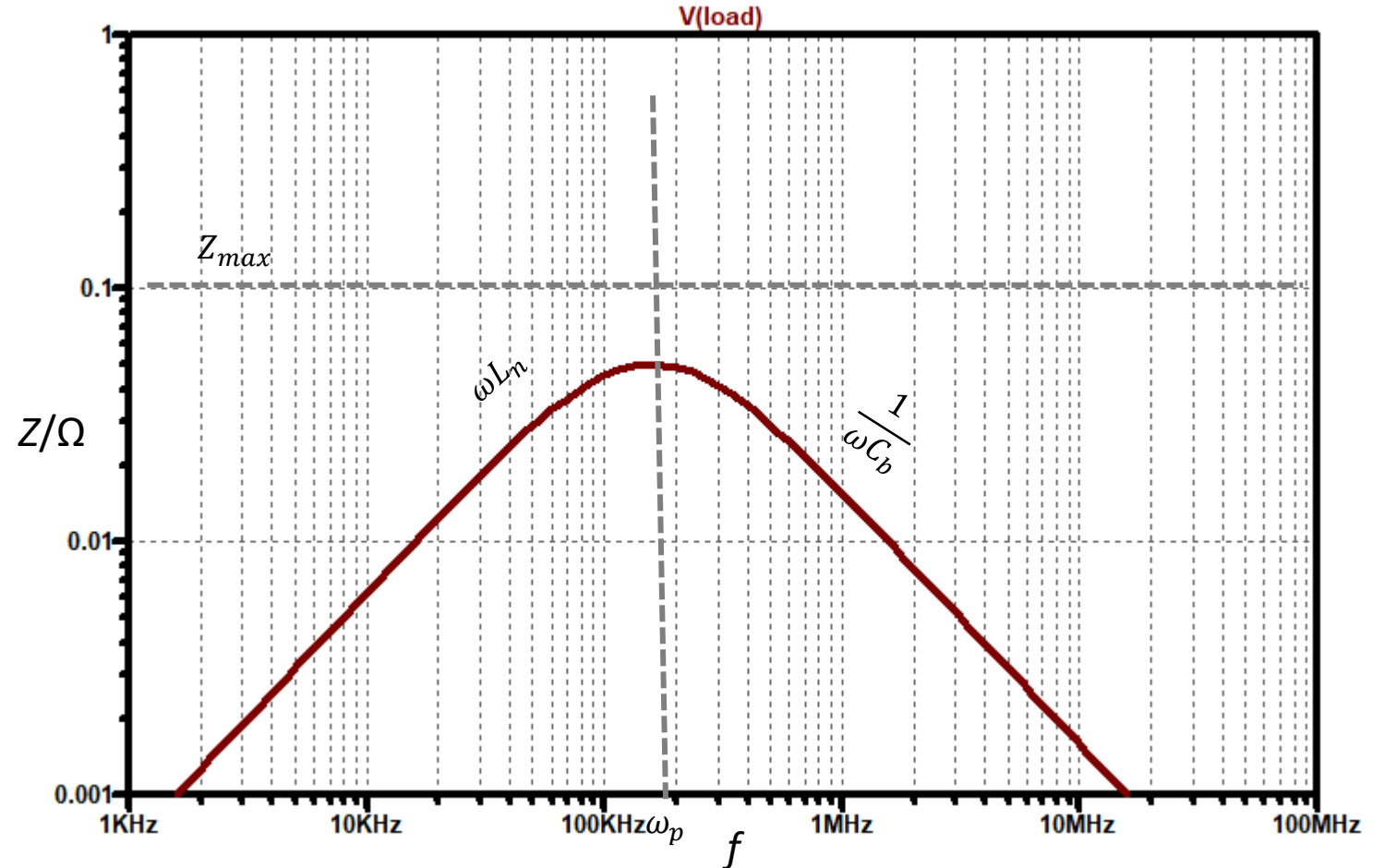


(d)

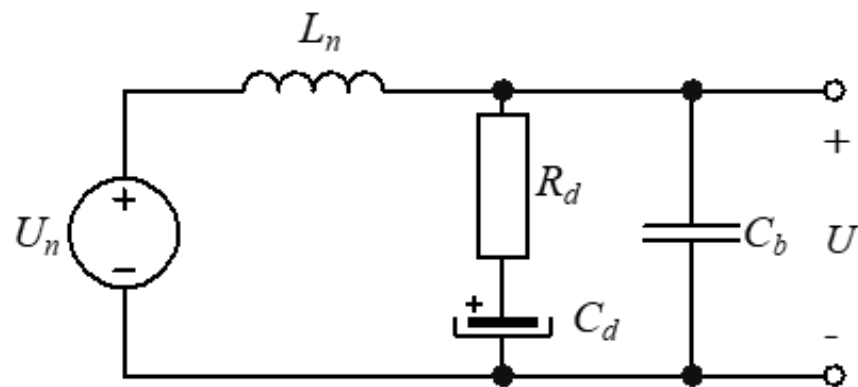
$$L_n = 100 \text{ nH}$$

$$C_b = 10 \text{ }\mu\text{F}$$

$$R_d = \frac{1}{2} \sqrt{\frac{L_n}{C_b}} = 0,05 \text{ }\Omega$$

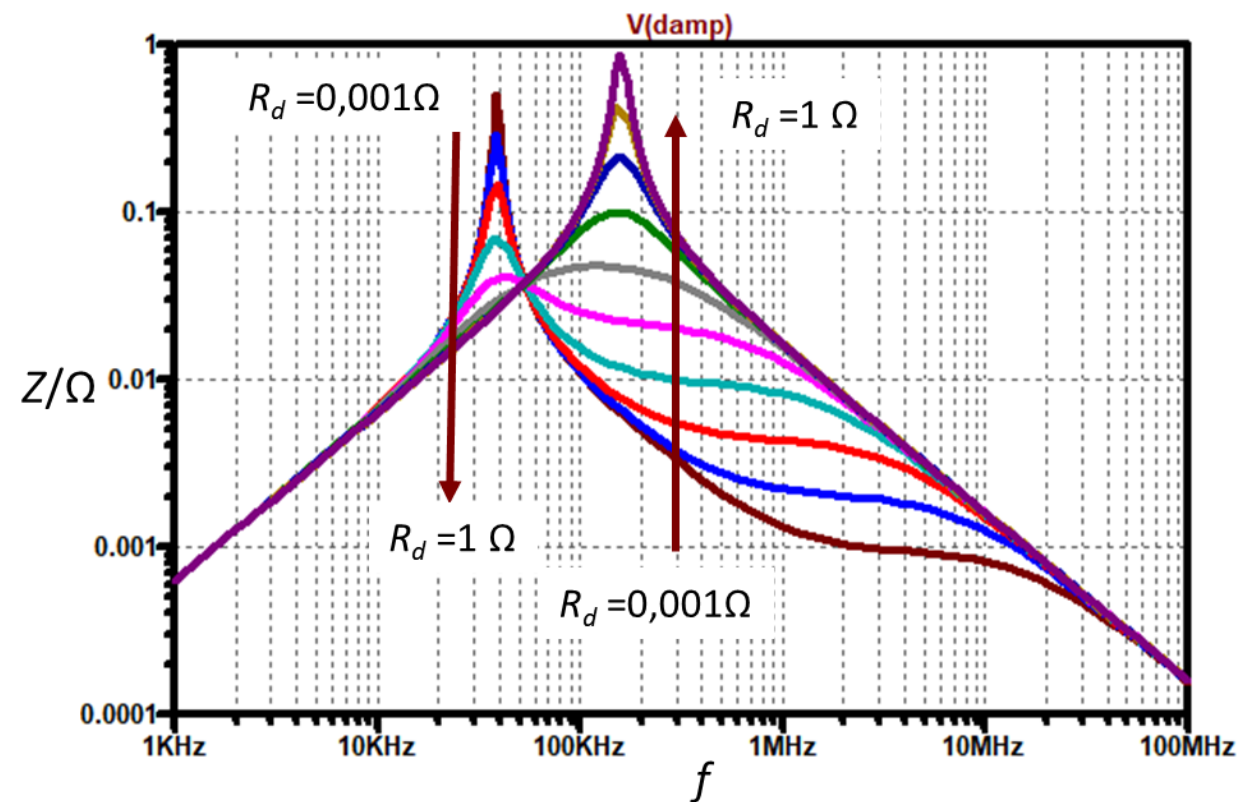


Dušenje paralelne resonance

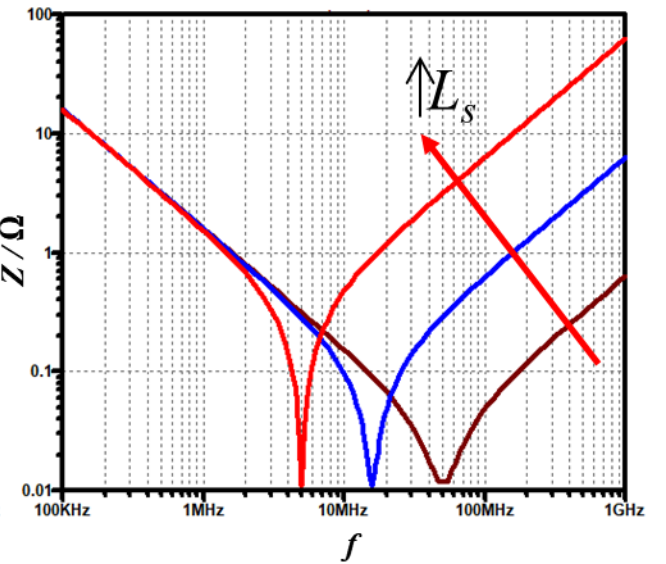
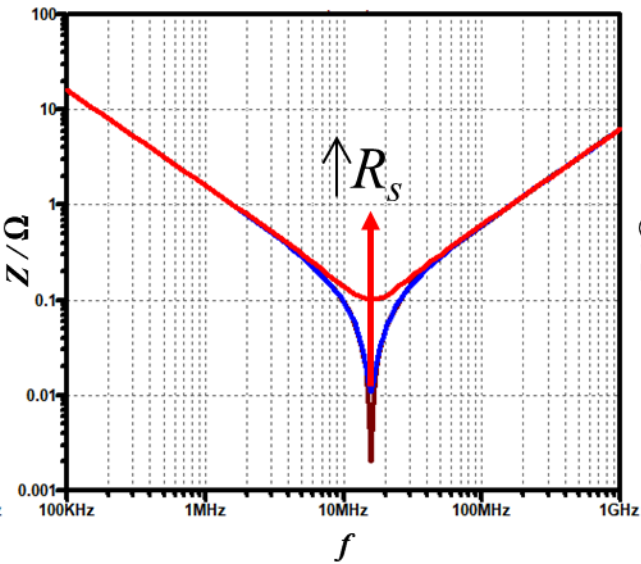
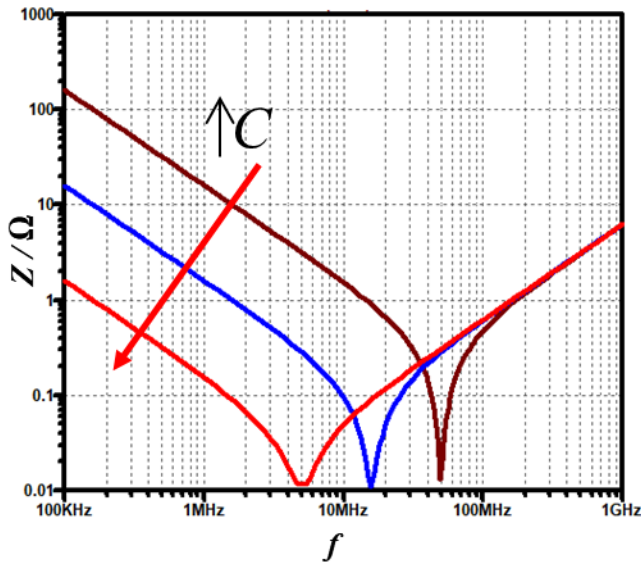
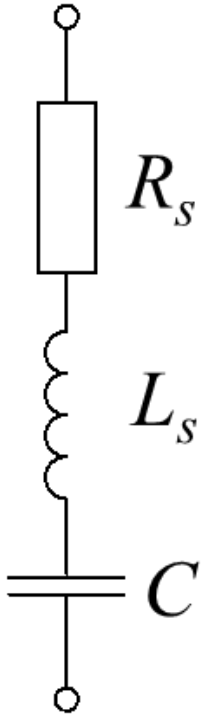


$$C_d \geq 16C_b$$

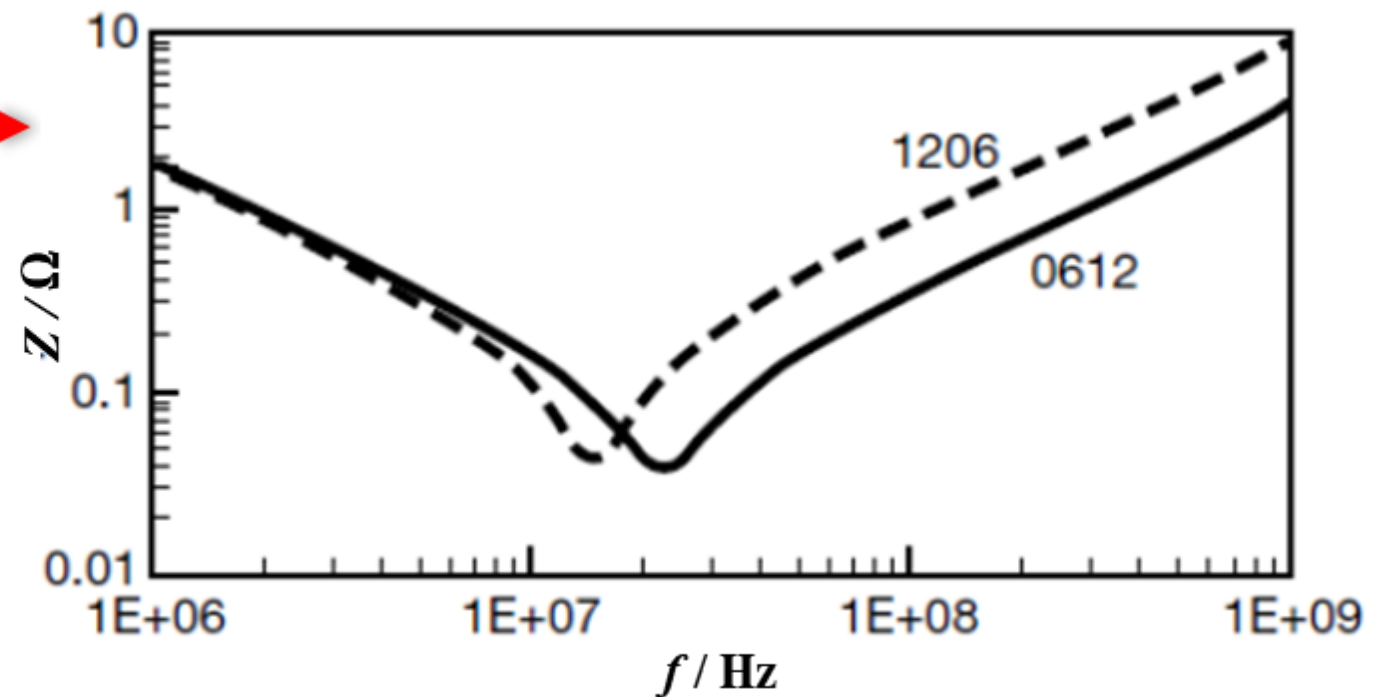
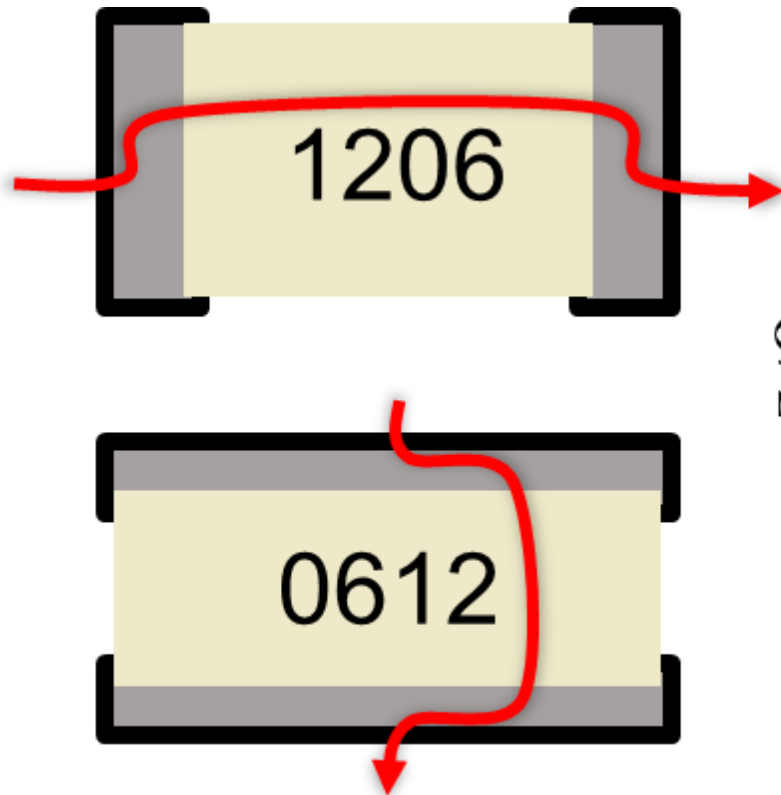
$$2 \sqrt{\frac{L_n}{C_d}} < R_d < \frac{1}{2} \sqrt{\frac{L_n}{C_b}}$$



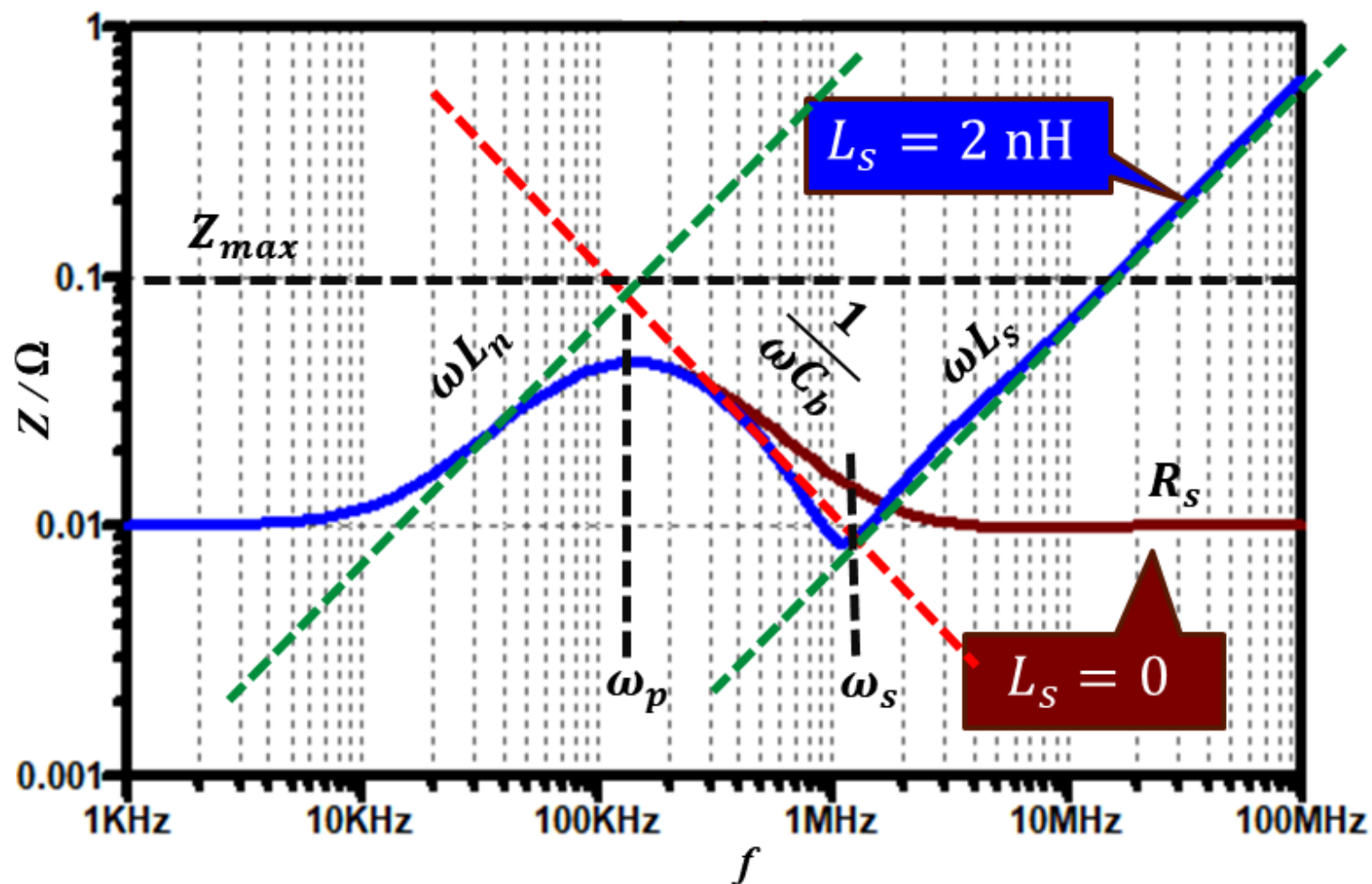
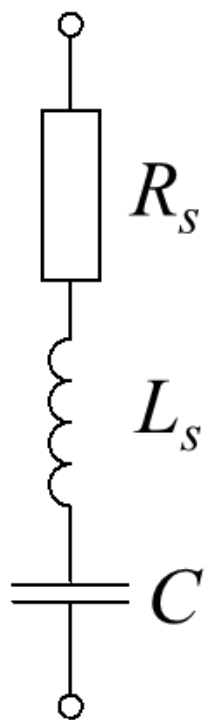
Kaj pa parazitne vrednosti kondenzatorjev?



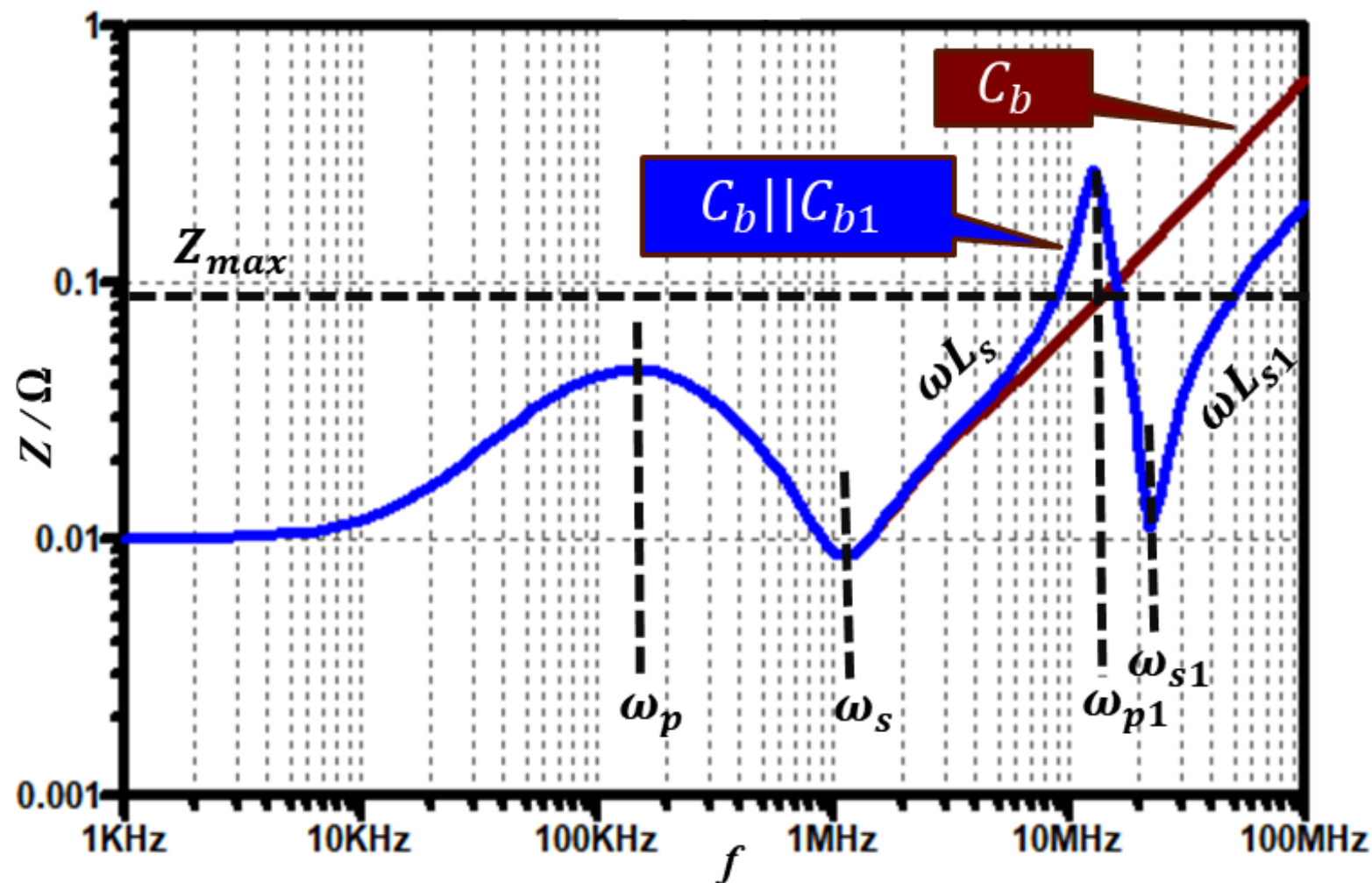
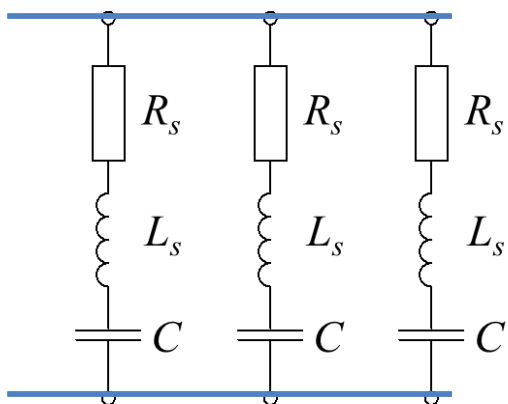
Vpliv oblike ohišja



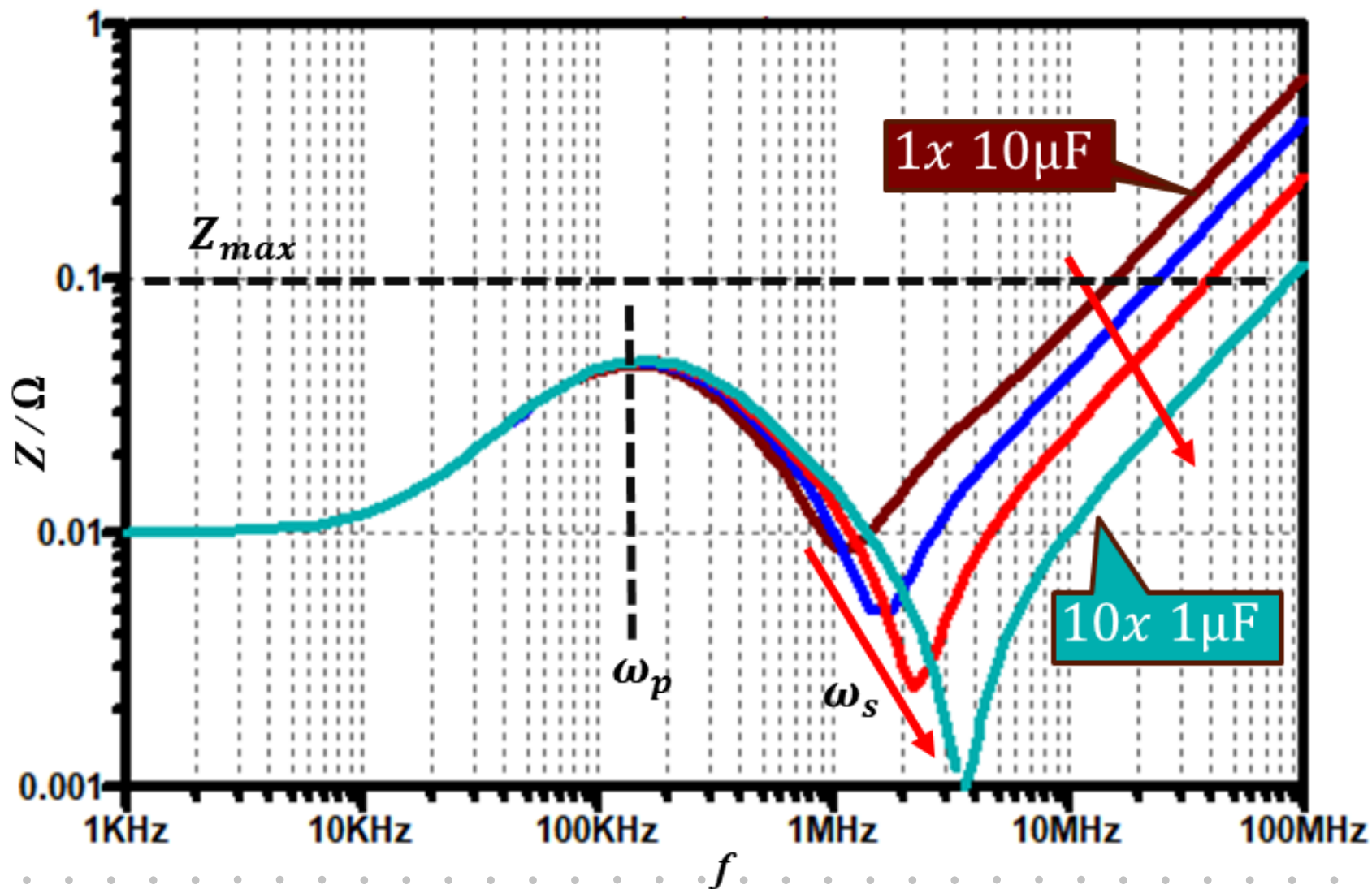
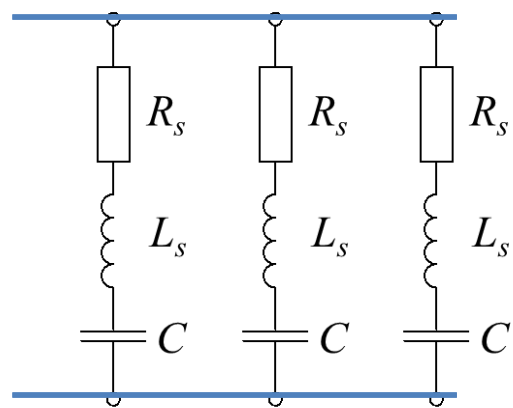
Potek impedance napajanja z realnimi kondenzatorji



Potek impedance napajanja z več različnimi realnimi kondenzatorji

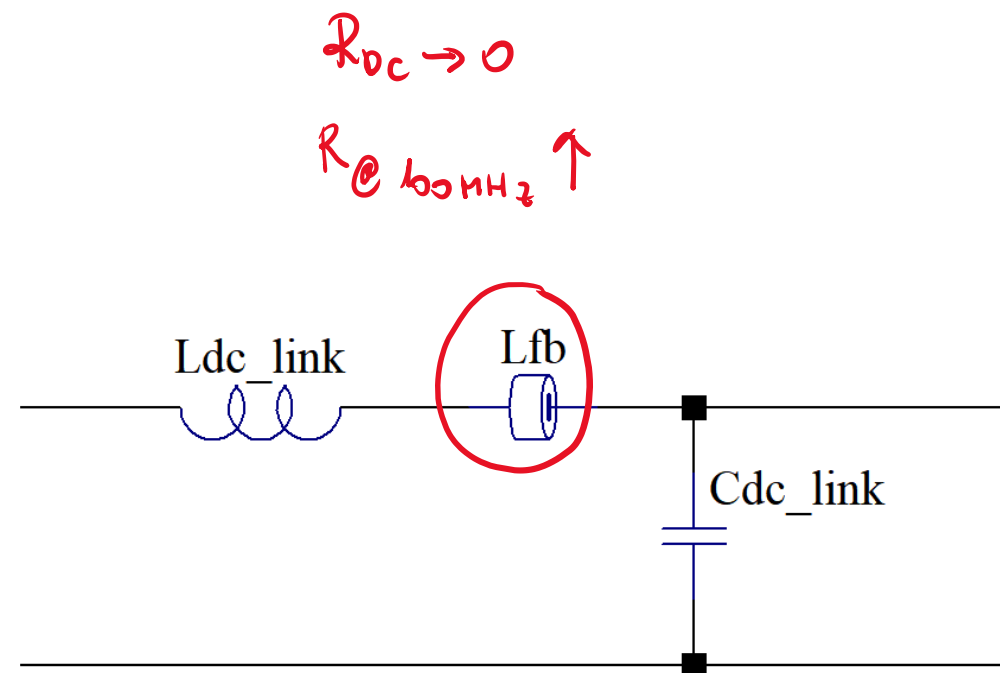
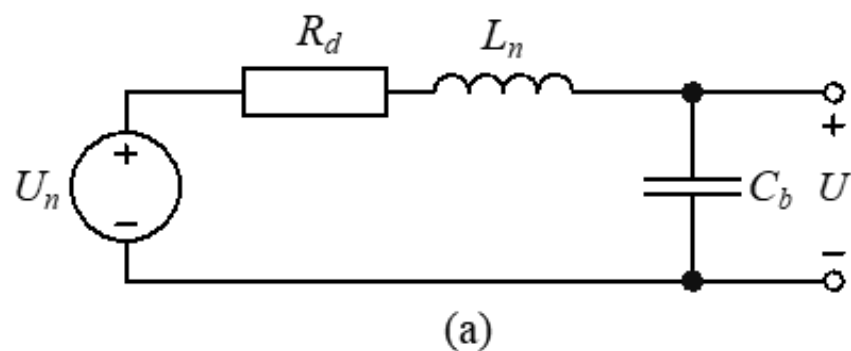


Potek impedance napajanja z več enakimi realnimi kondenzatorji



Kaj pa visokofrekvenčna nihanja?

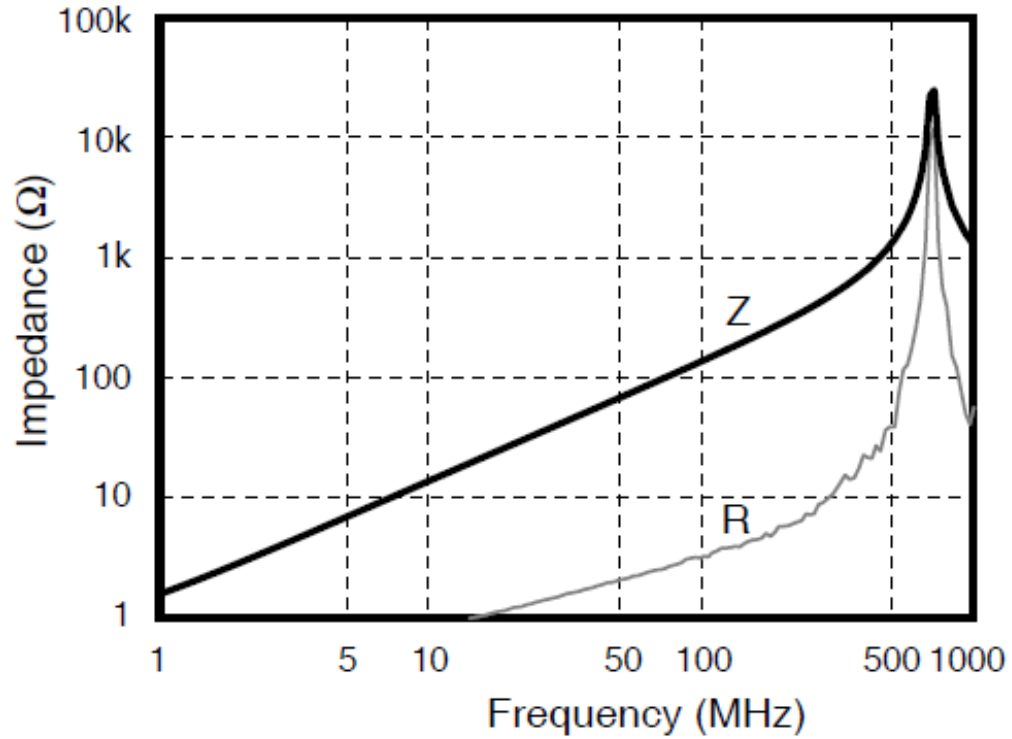
Dušenje kvalitete nihajnega kroga s feritno dušilko



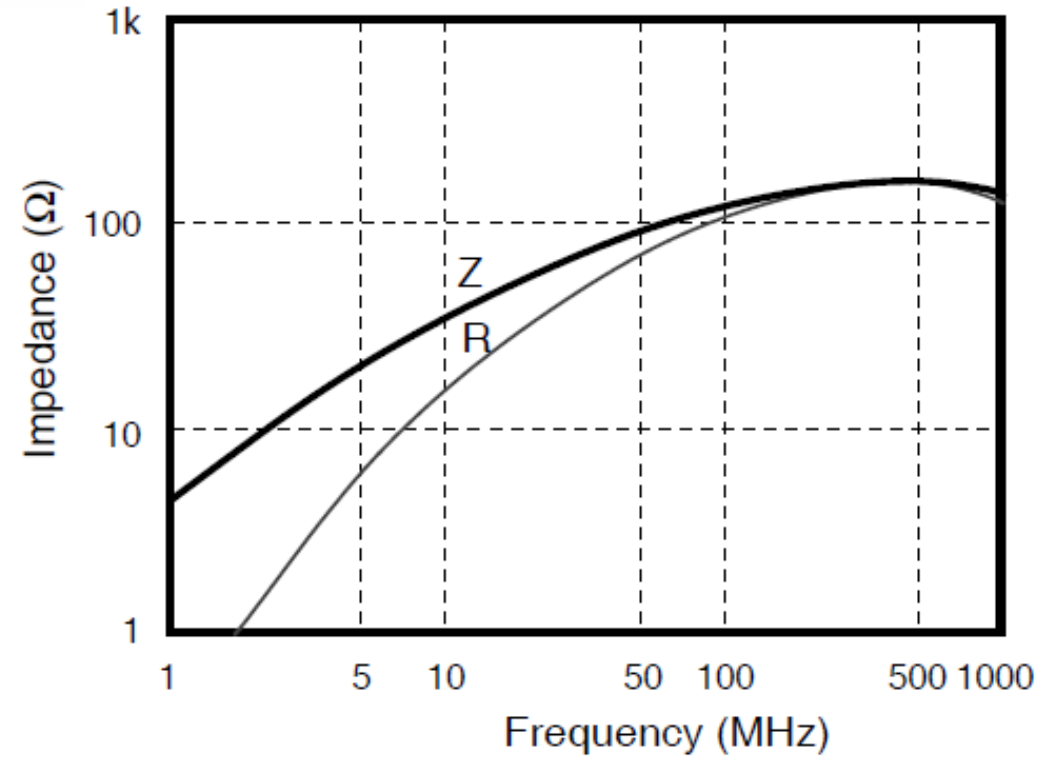
Feritna dušilka



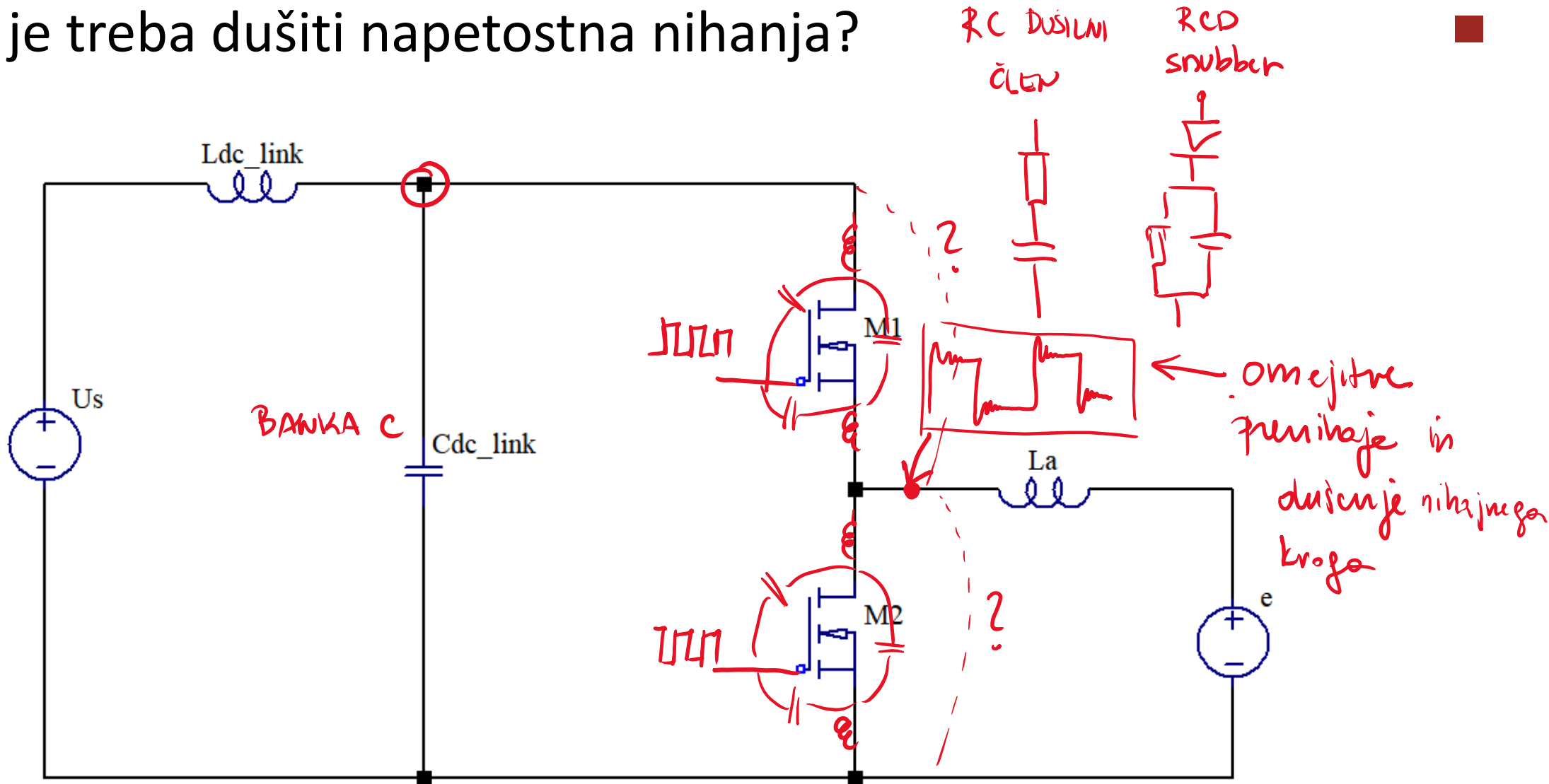
Navadna dušilka



Feritna dušilka



Kje vse je treba dušiti napetostna nihanja?



Primer celotnega sklopa

Kje se generirajo motnje?

