

# Seminar in delavnica

# Načrtovanje elektronike za EMC

## Filtriranje

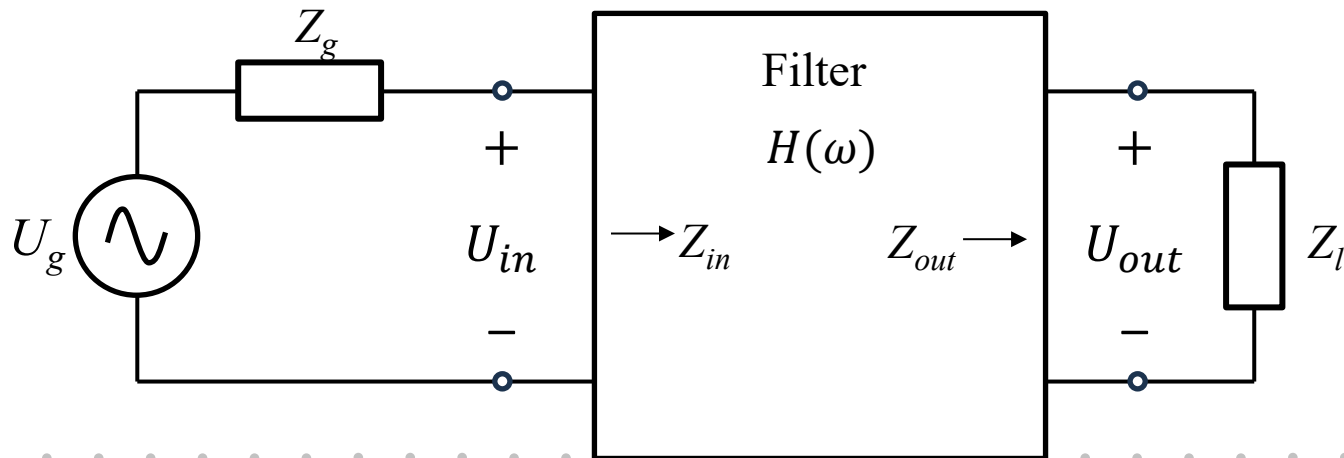
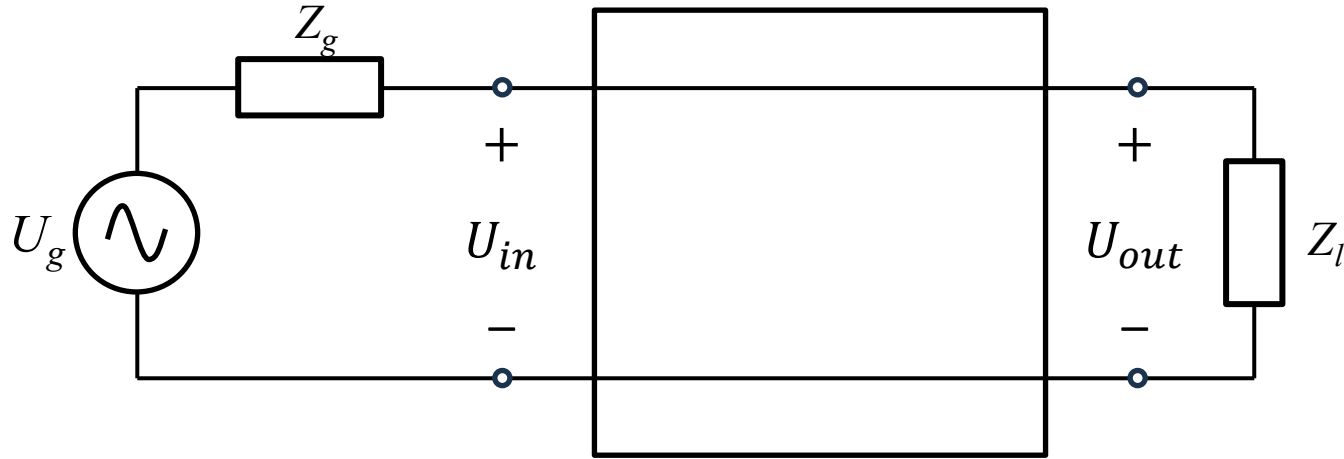
Izr. prof. dr. Marko Jankovec

Univerza v Ljubljani

Fakulteta za elektrotehniko

Tržaška 25, SI-1000 Ljubljana, Slovenia

# Vstavitveno dušenje



$$S_{init}(\omega) = \frac{U_g}{U_{out}} = 1 + \frac{Z_g}{Z_l}$$

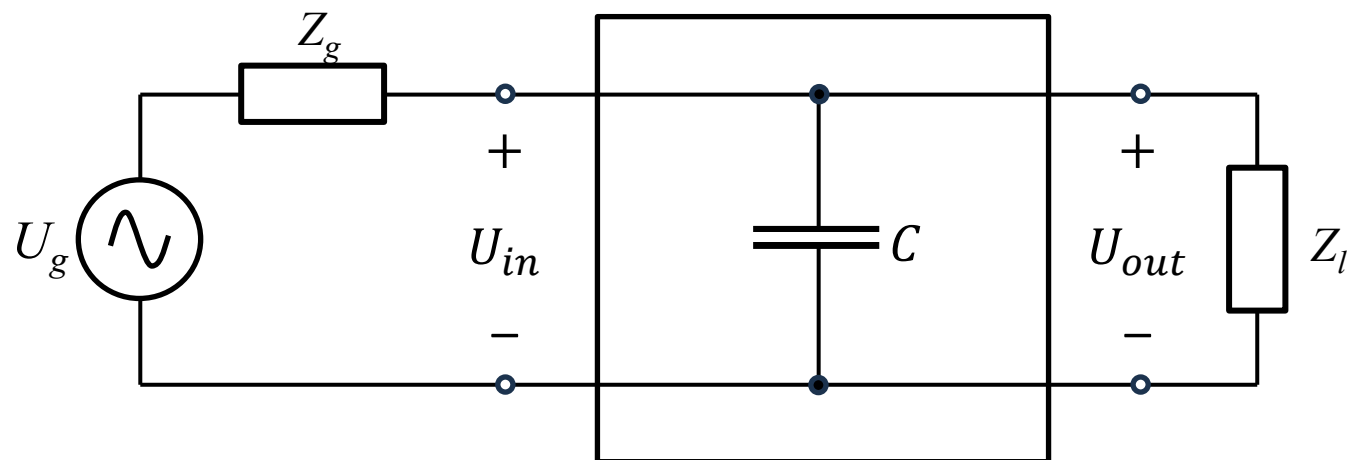


$$IL(\omega) = 20 \log \frac{S_{filt}(\omega)}{S_{init}(\omega)}$$



$$S_{filtr}(\omega) = \left(1 + \frac{Z_g}{Z_{in}}\right) \cdot \frac{1}{H(\omega)} \cdot \left(1 + \frac{Z_{out}}{Z_l}\right)$$

# Primer kondenzatorja - analitično



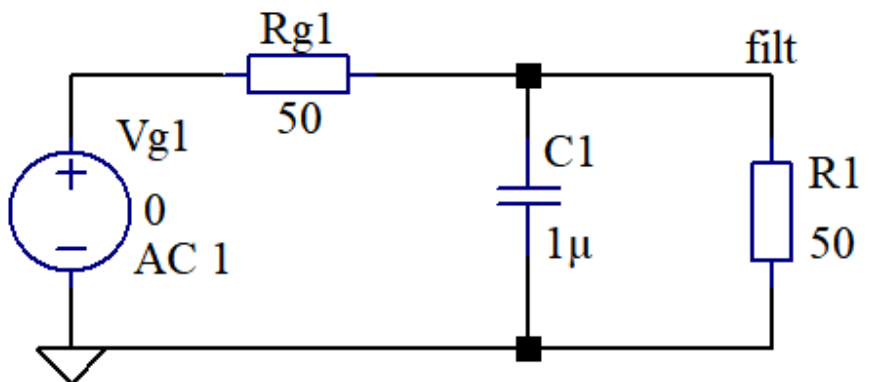
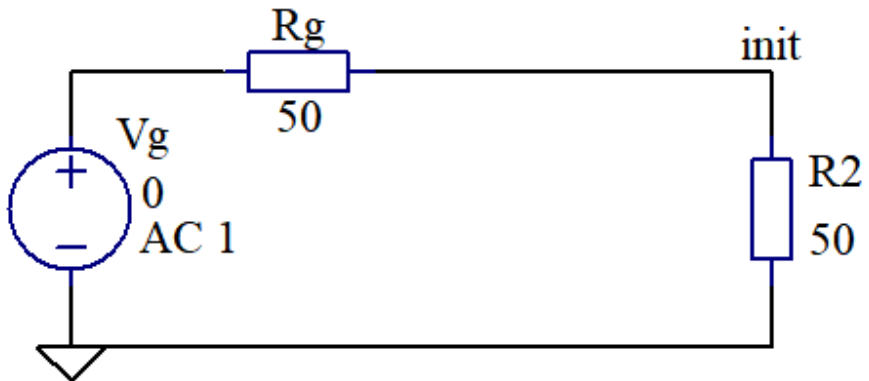
$$S_{init} = 1 + \frac{Z_g}{Z_l}$$

$$S_{filtr} = \frac{Z_g + Z_l \parallel \frac{1}{j\omega C}}{Z_l \parallel \frac{1}{j\omega C}} = 1 + Z_g \left( \frac{1}{Z_l} + j\omega C \right)$$

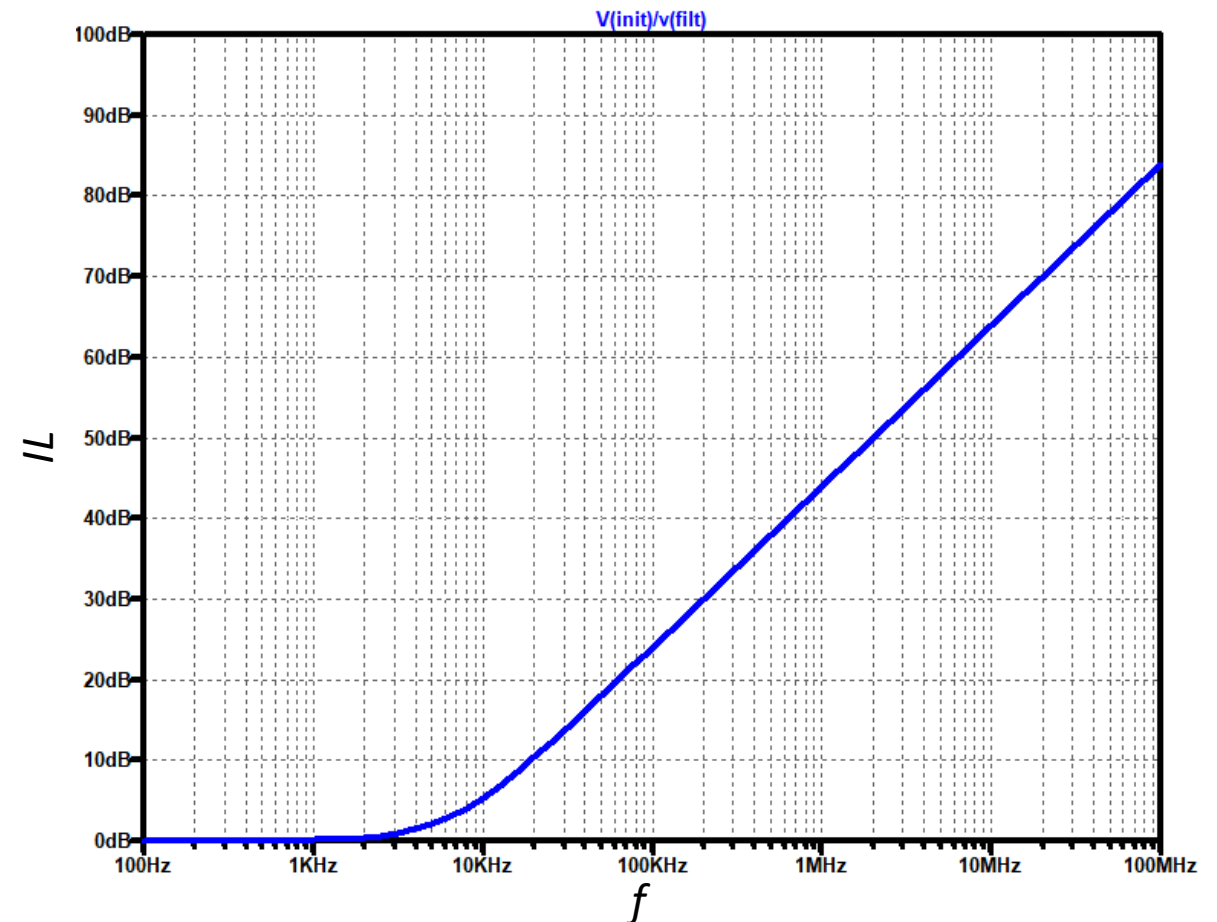


$$IL = 20 \log \left( 1 + j\omega C \frac{Z_l Z_g}{Z_g + Z_l} \right)$$

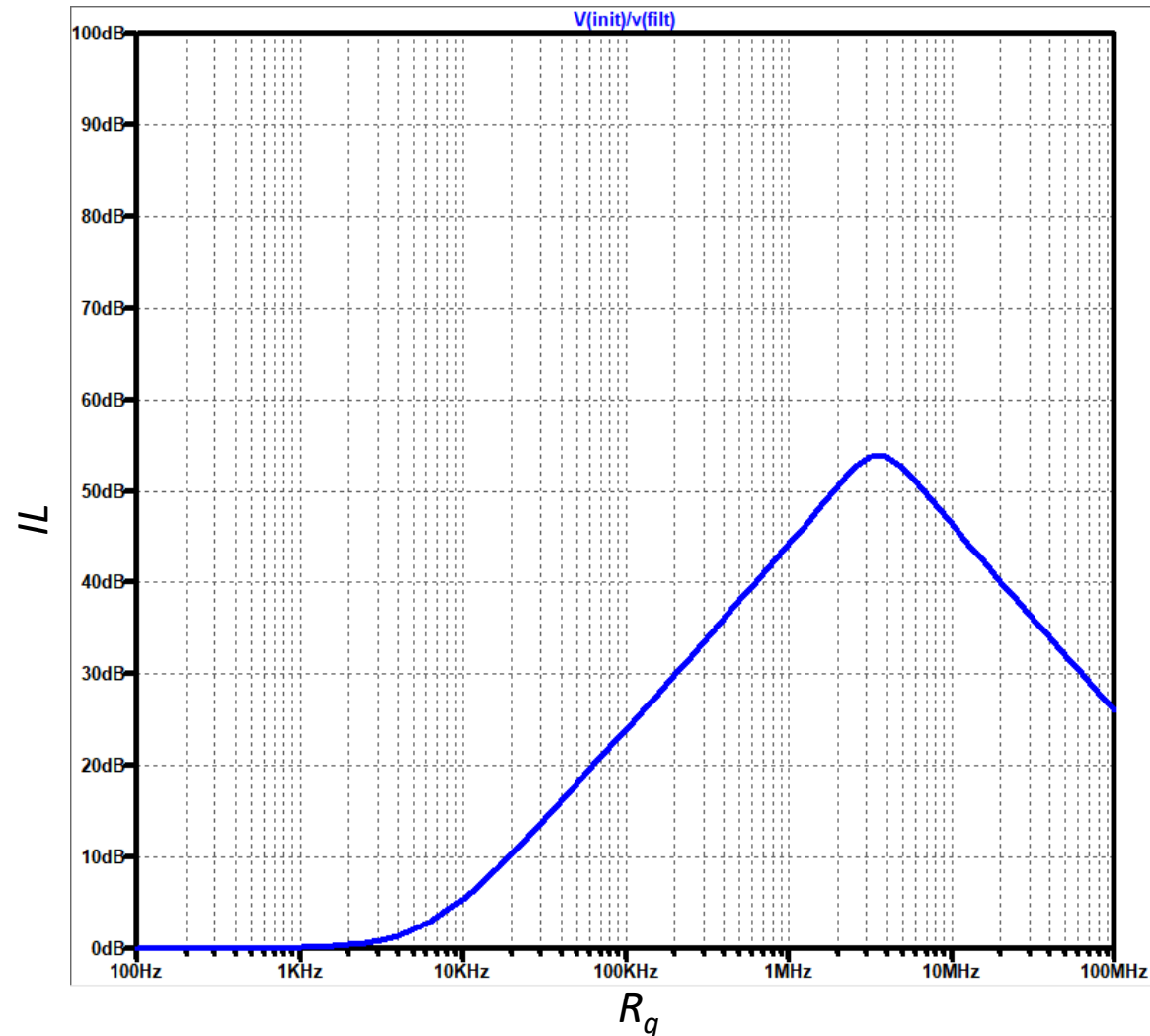
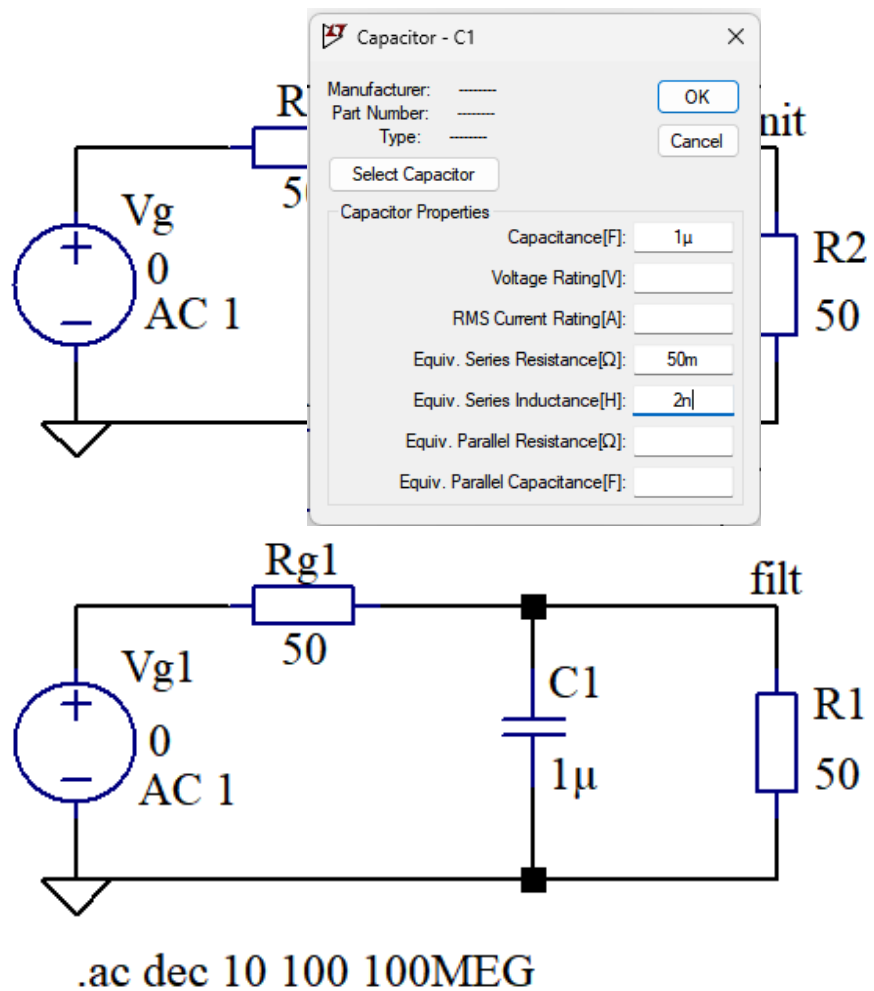
# Primer kondenzatorja - LTspice



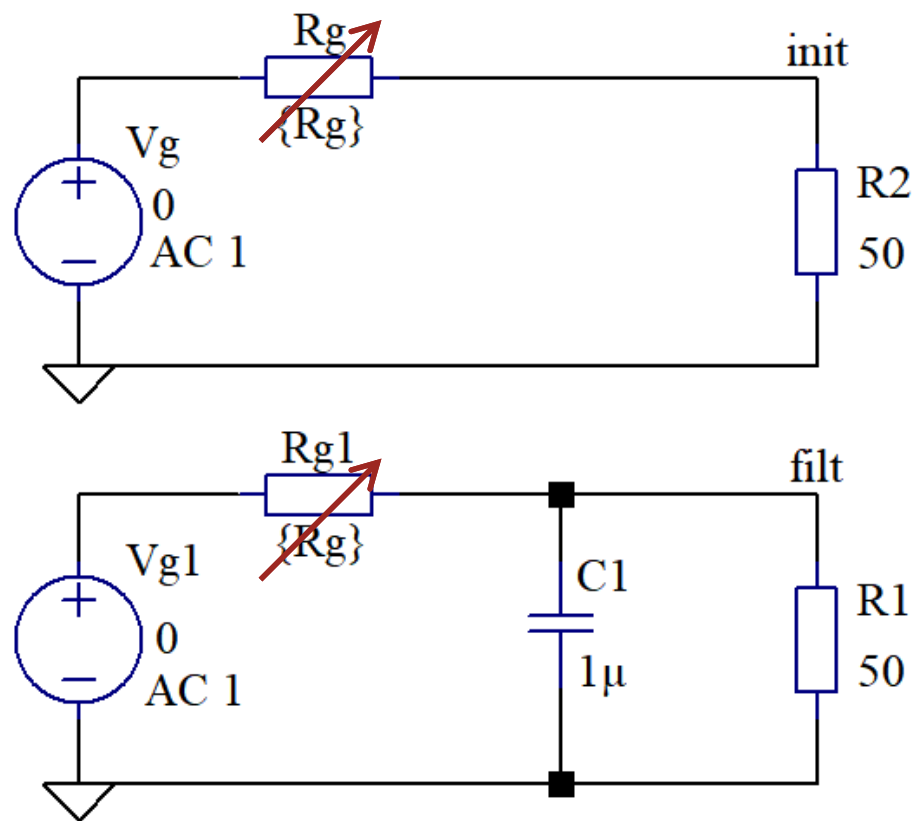
.ac dec 10 100 100MEG



# Primer realnega kondenzatorja

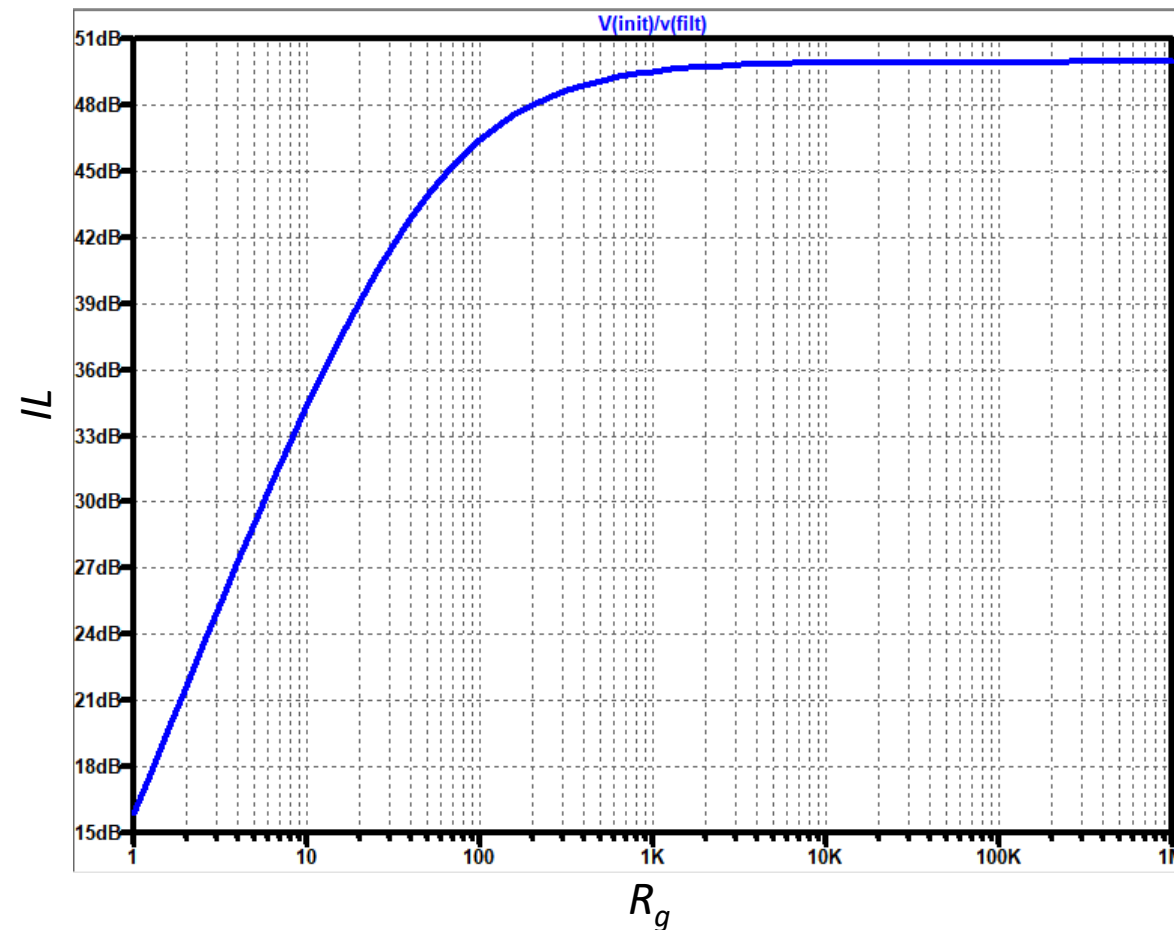


# Primer kondenzatorja – vpliv upornosti vira $R_g$ pri 1 MHz

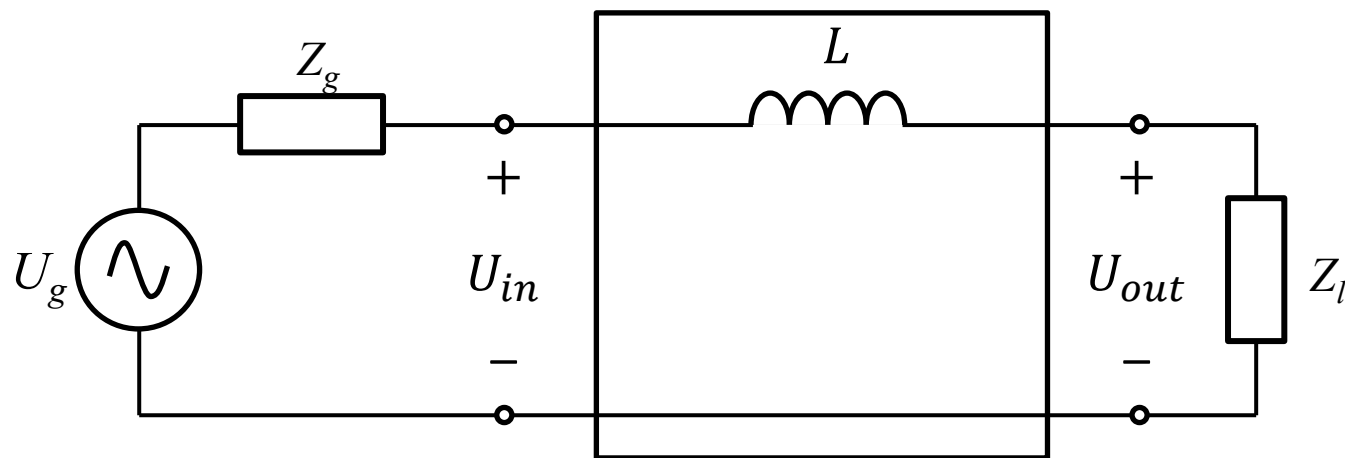


```
.ac list 1MEG
```

```
.step dec param Rg 1 1MEG 10
```



# Primer tuljave - analitično



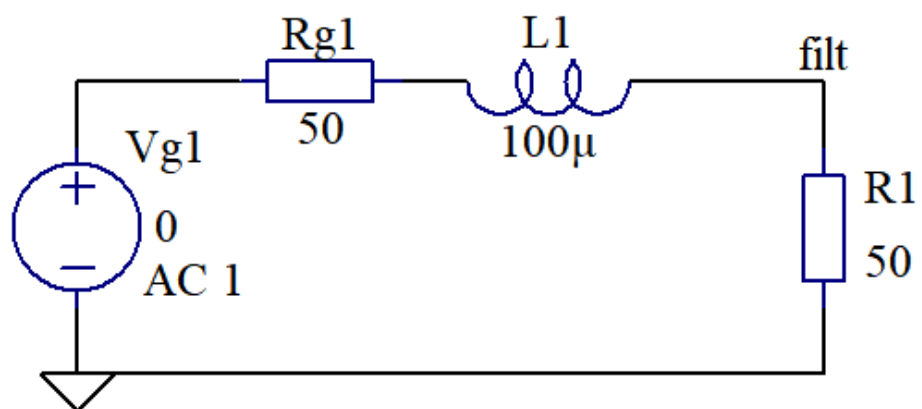
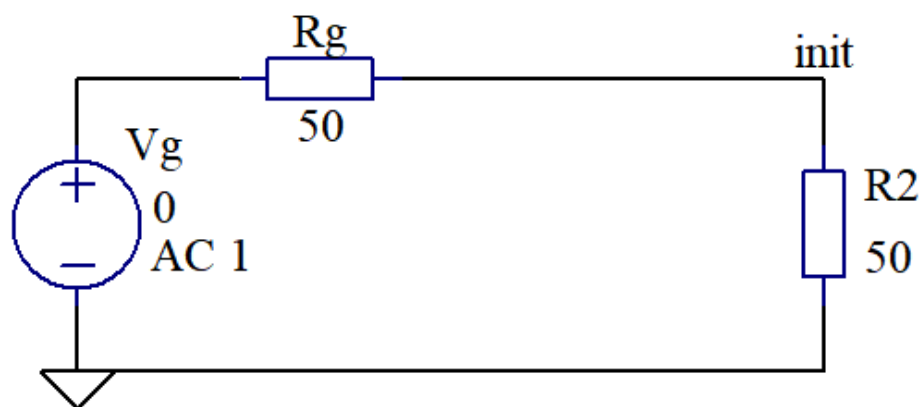
$$S_{init} = 1 + \frac{Z_g}{Z_l}$$



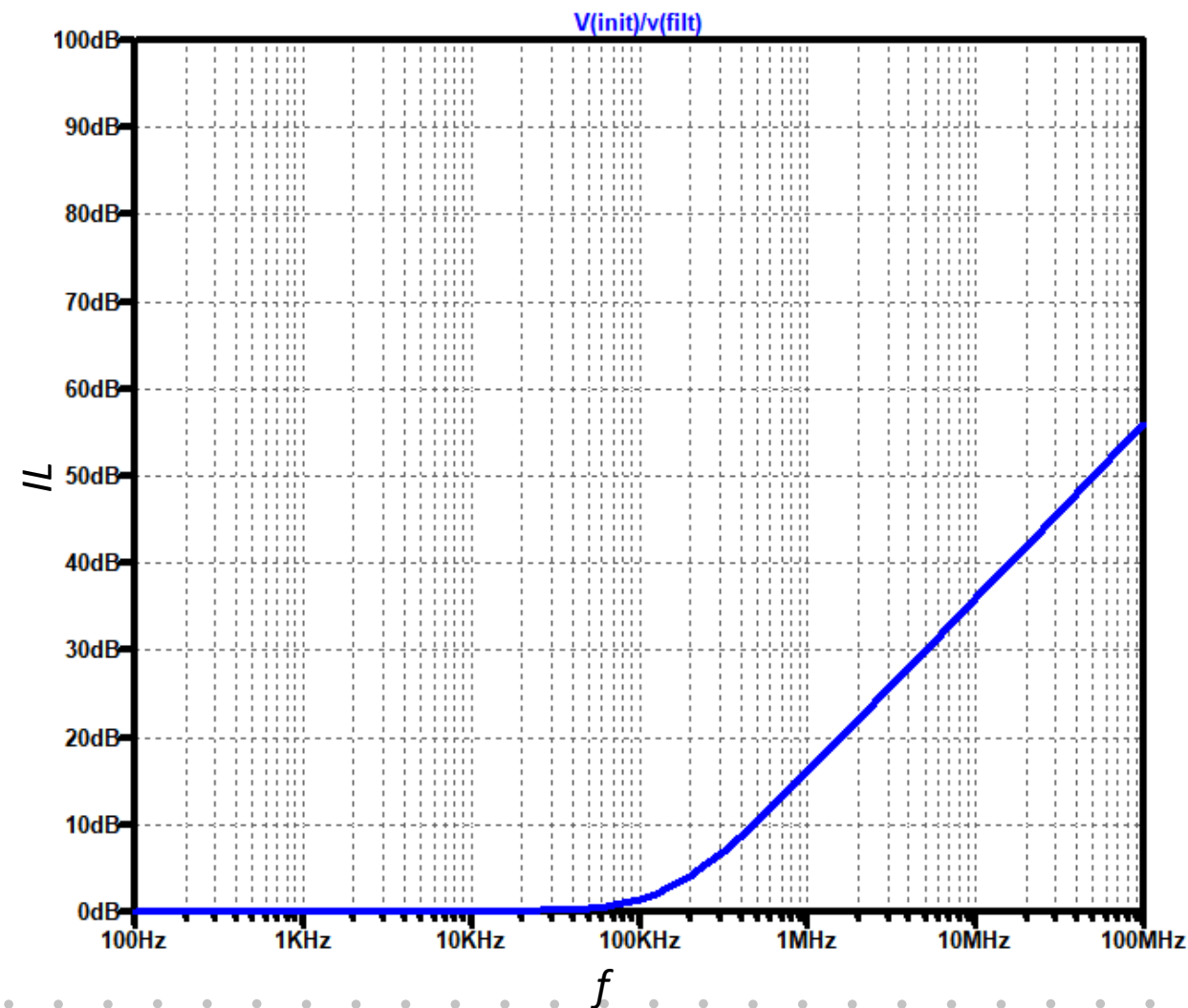
$$IL = 20 \log \left( 1 + \frac{j\omega L}{Z_g + Z_l} \right)$$

$$S_{filtr} = \frac{Z_g + Z_b + j\omega L}{Z_b}$$

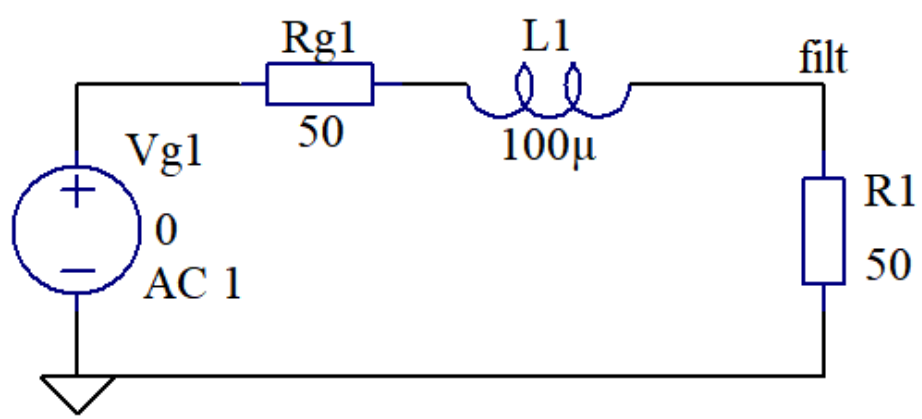
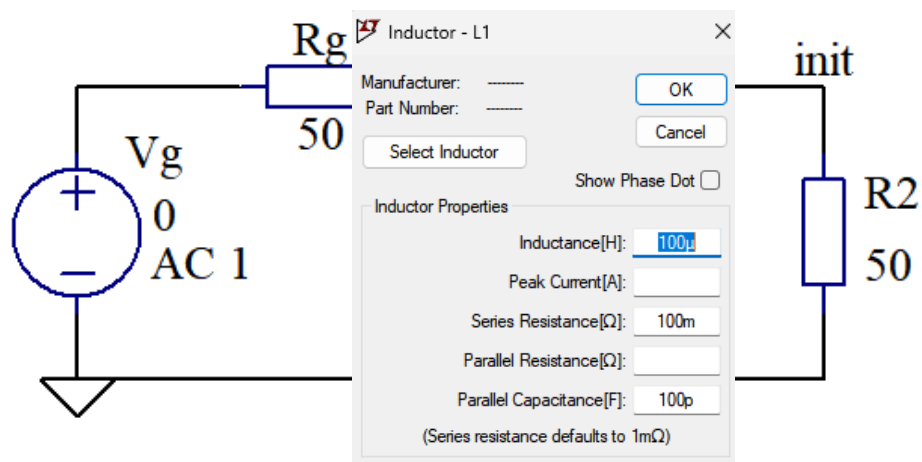
# Primer tuljave - LTspice



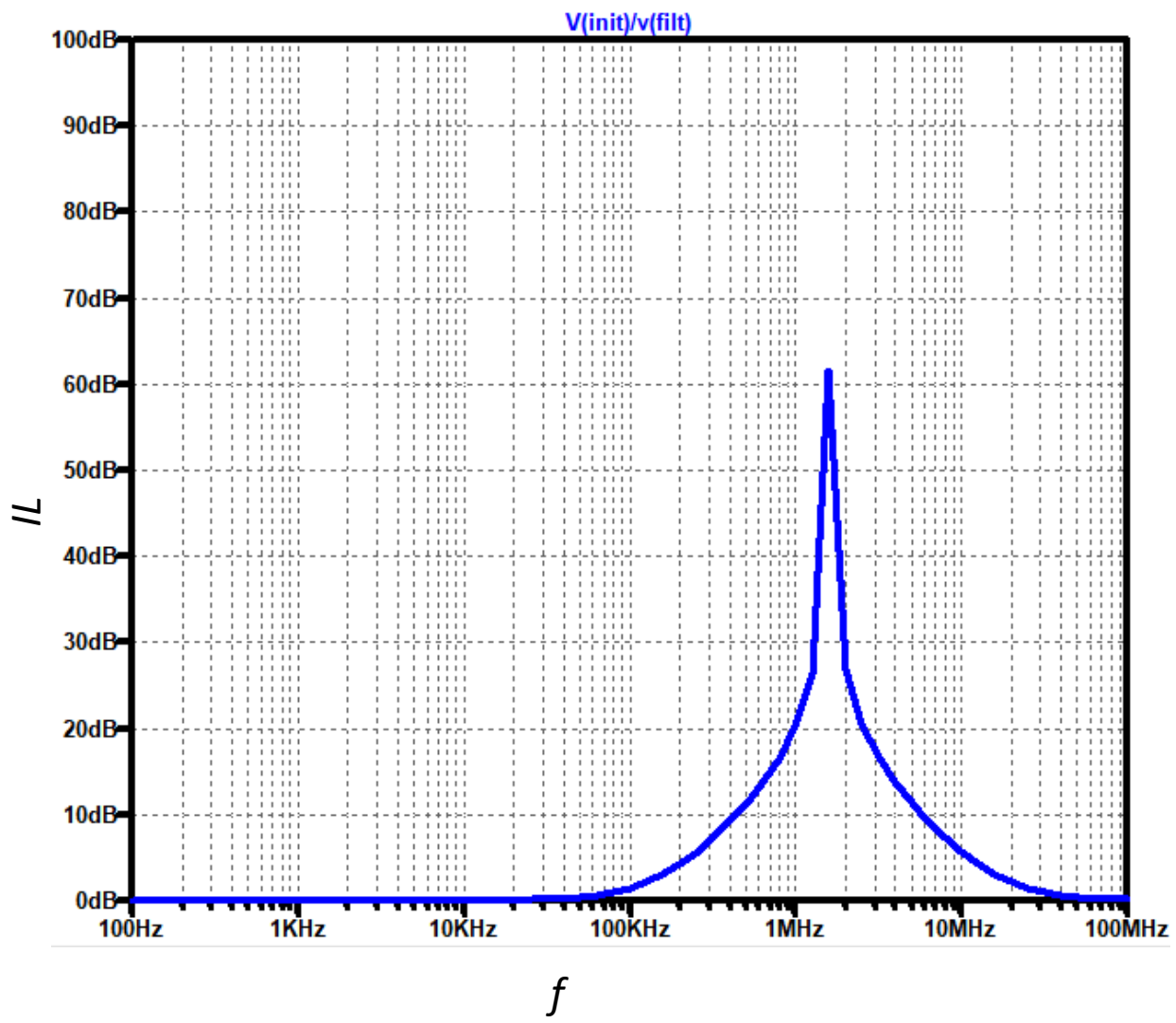
.ac dec 10 100 100MEG



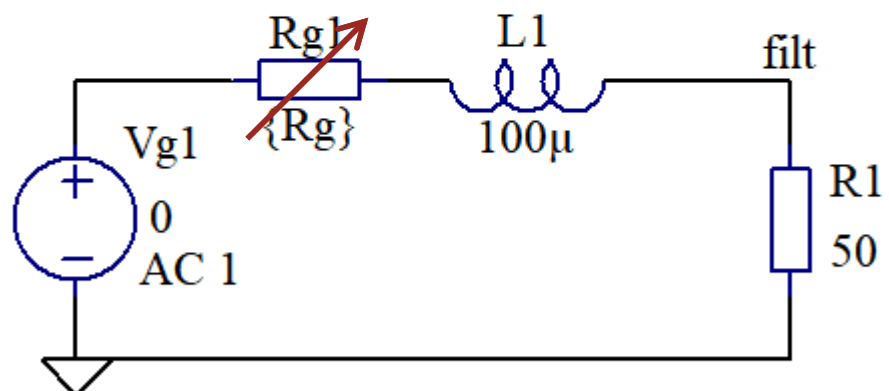
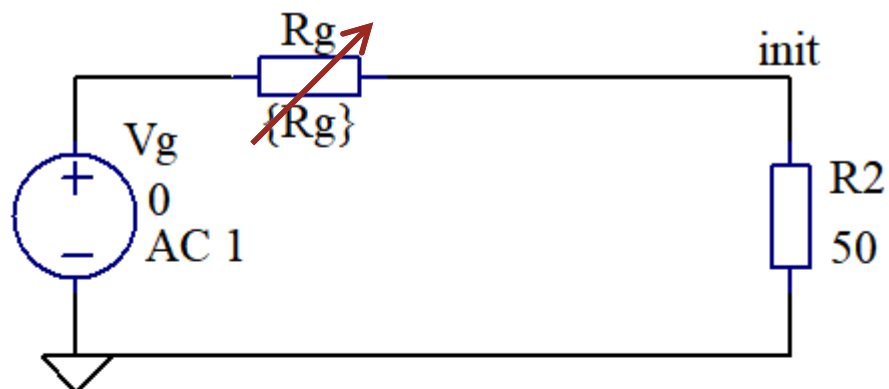
# Primer realne tuljave



.ac dec 10 100 100MEG

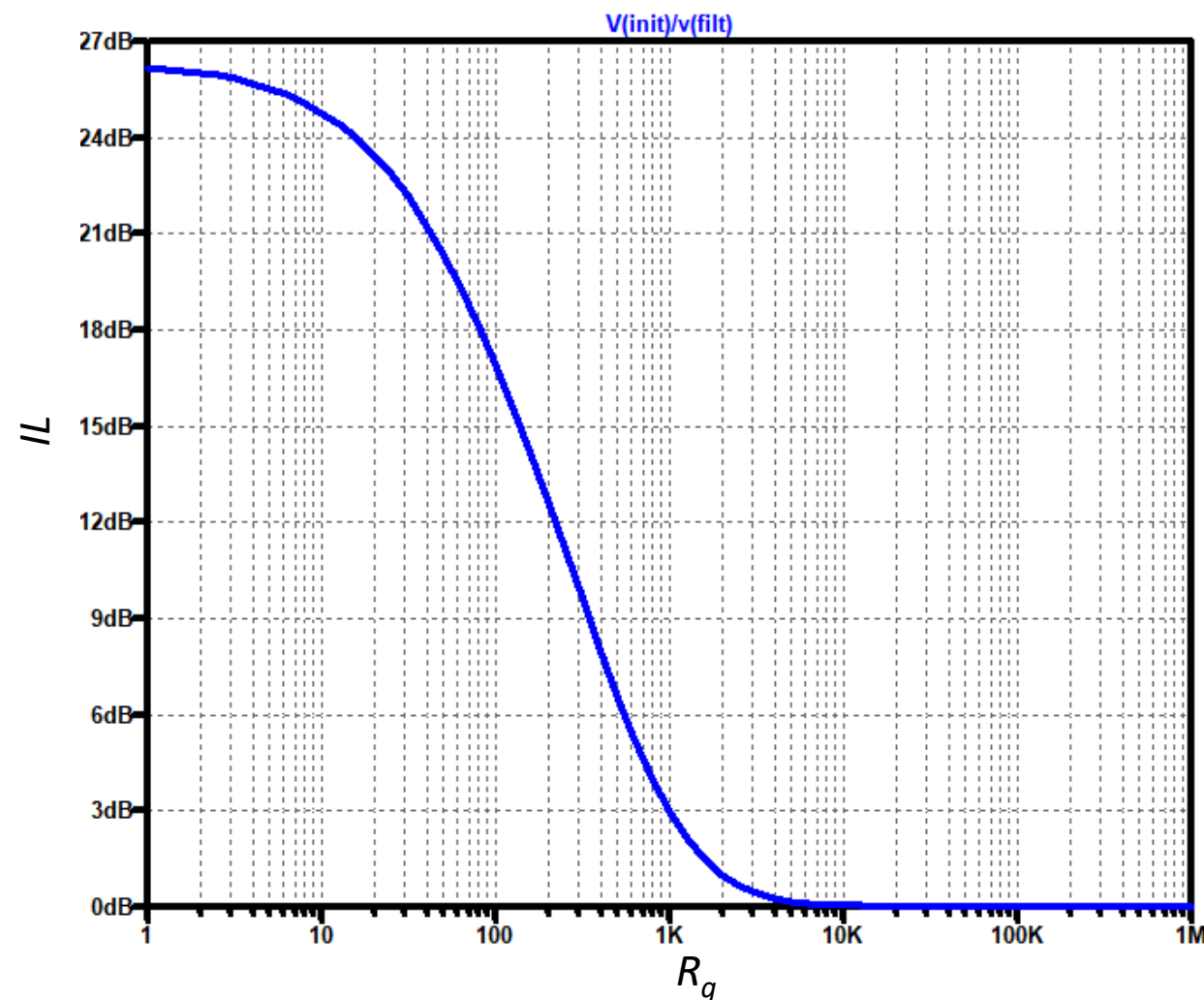


# Primer tuljave – vpliv upornosti vira $R_g$ pri 1 MHz

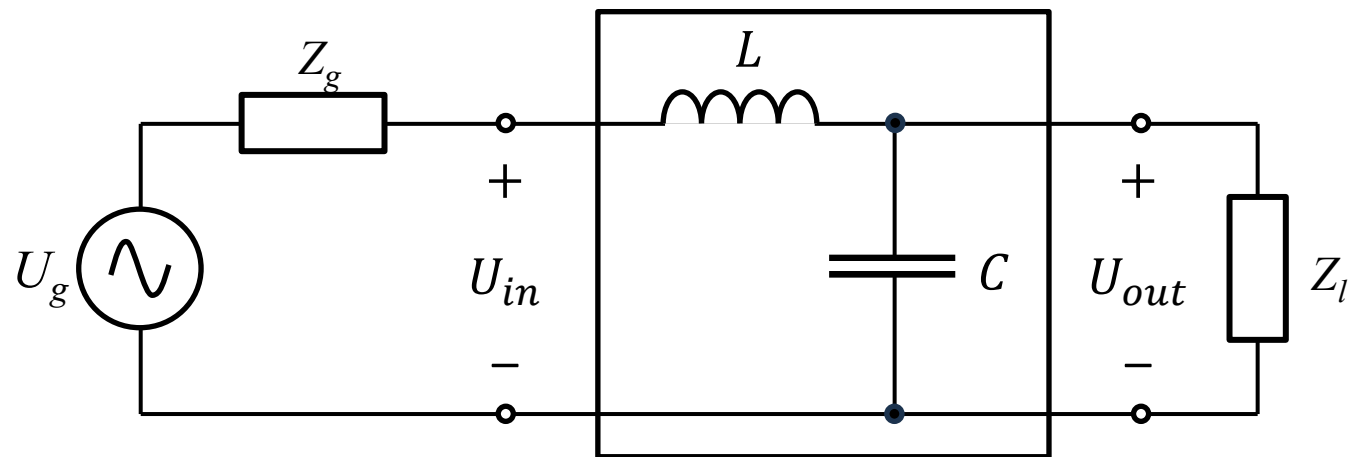


```
.ac list 1MEG
```

```
.step dec param Rg 1 1MEG 10
```



# Primer LC - analitično



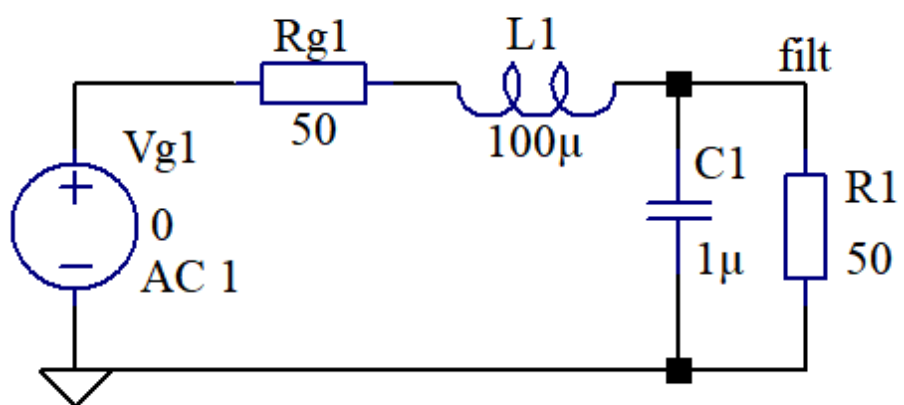
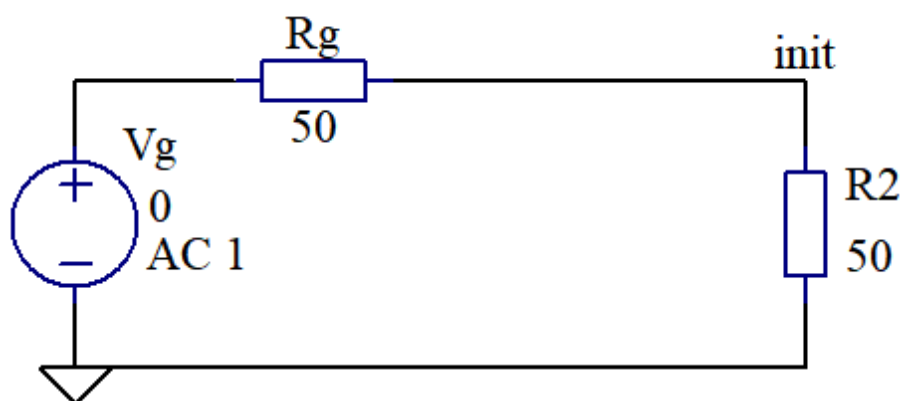
$$S_{init} = 1 + \frac{Z_g}{Z_l}$$

$$S_{filtr} = \frac{Z_g + j\omega L + Z_l \parallel \frac{1}{j\omega C}}{Z_l \parallel \frac{1}{j\omega C}} = 1 + (Z_g + j\omega L) \left( \frac{1}{Z_l} + j\omega C \right)$$

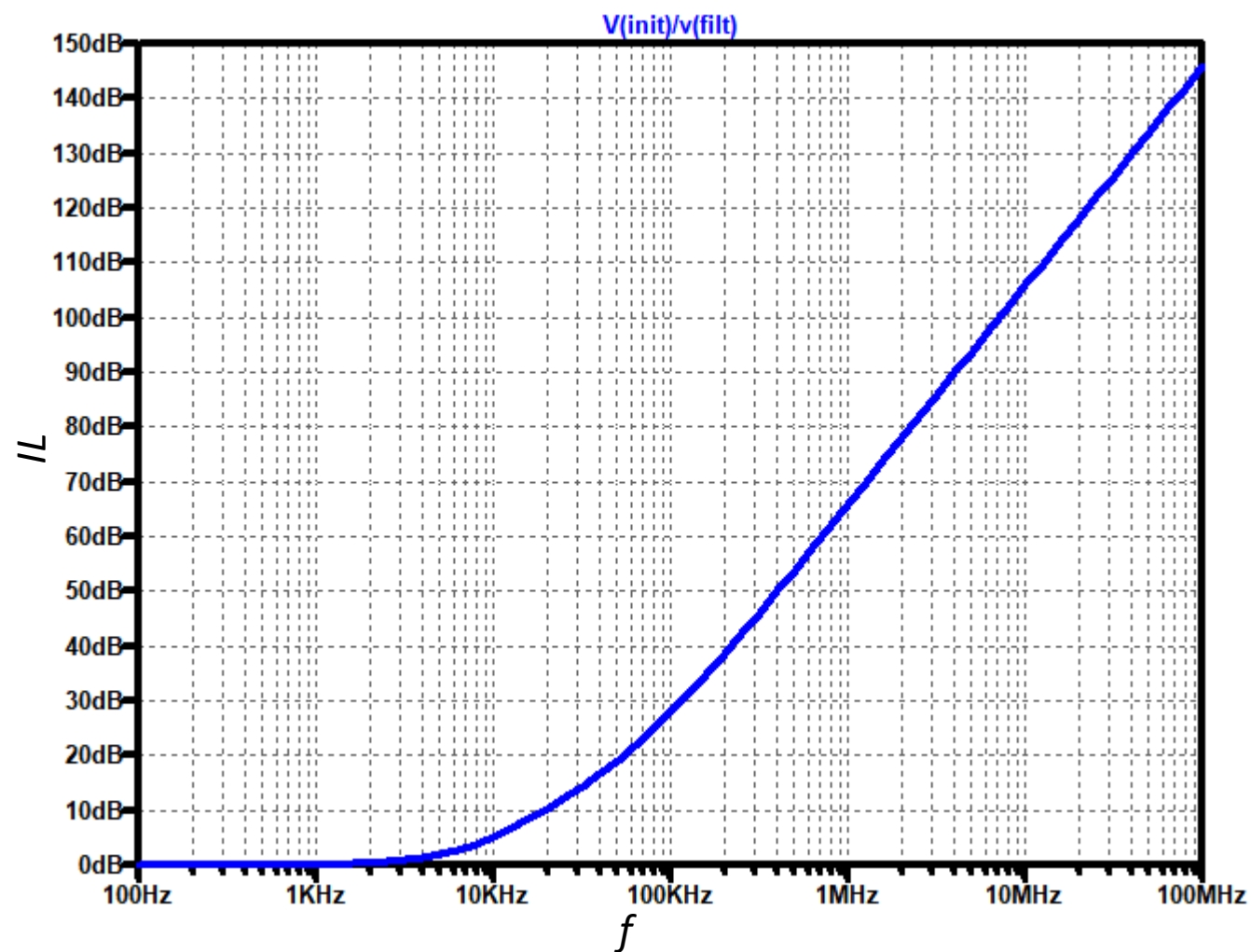


$$IL = 20 \log \frac{1 + \frac{Z_g}{Z_l}}{1 + \frac{Z_g}{Z_l} + j\omega \left( \frac{L}{Z_l} + CZ_g \right) - \omega^2 LC}$$

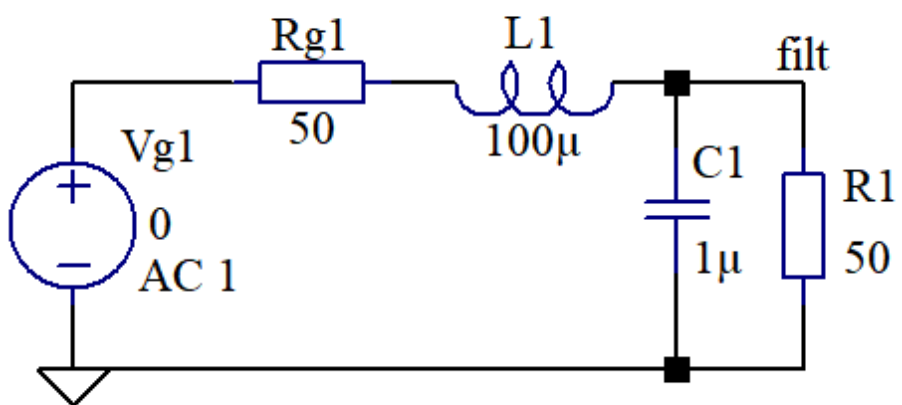
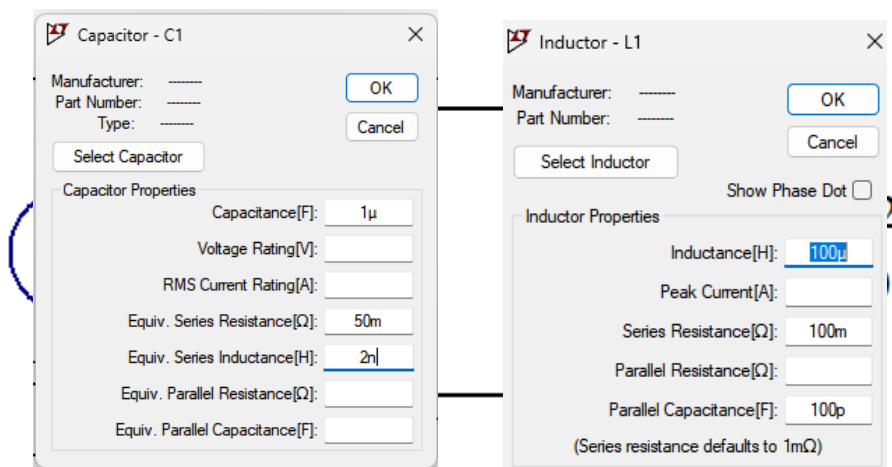
# Primer LC - LTspice



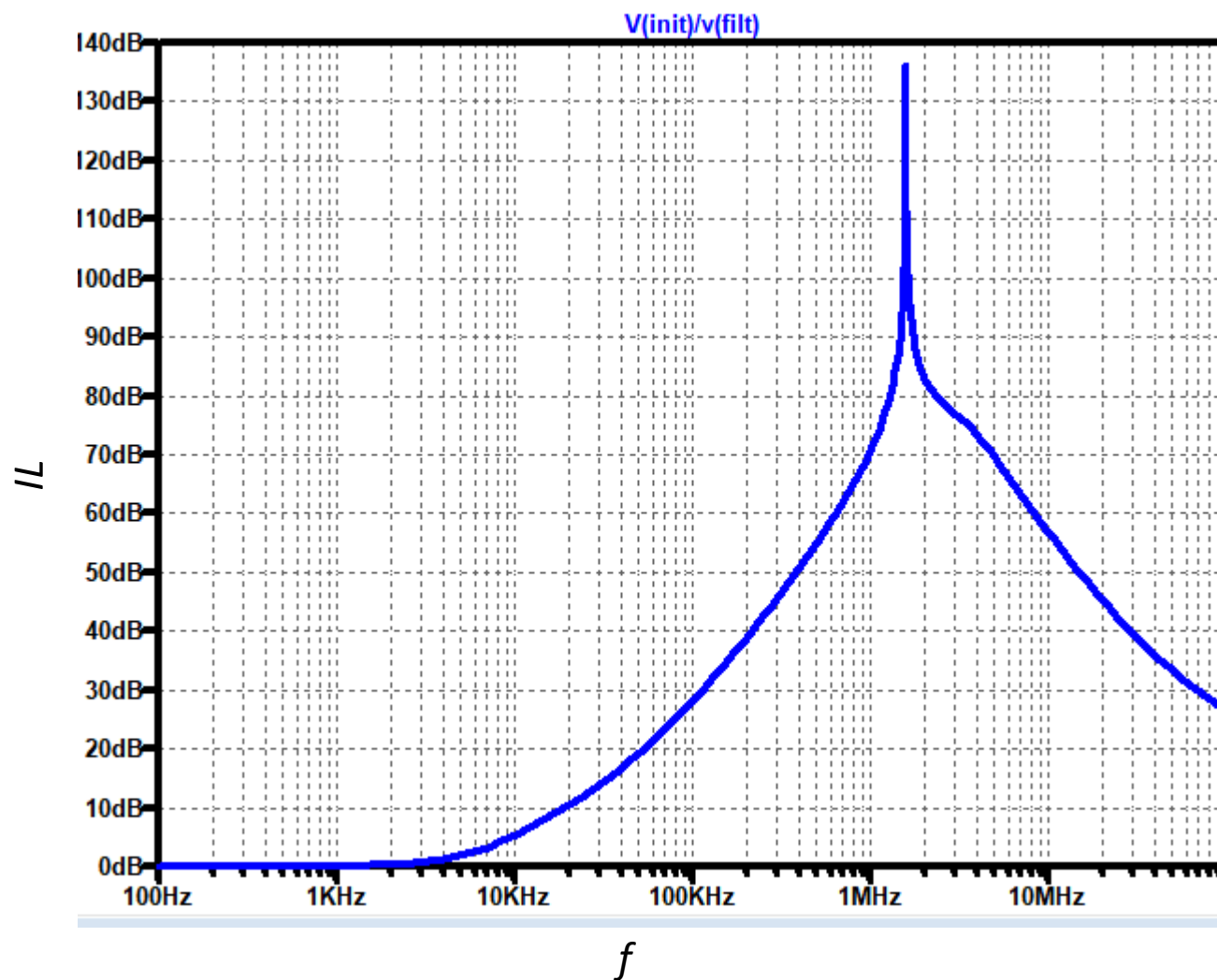
.ac dec 10 100 100MEG



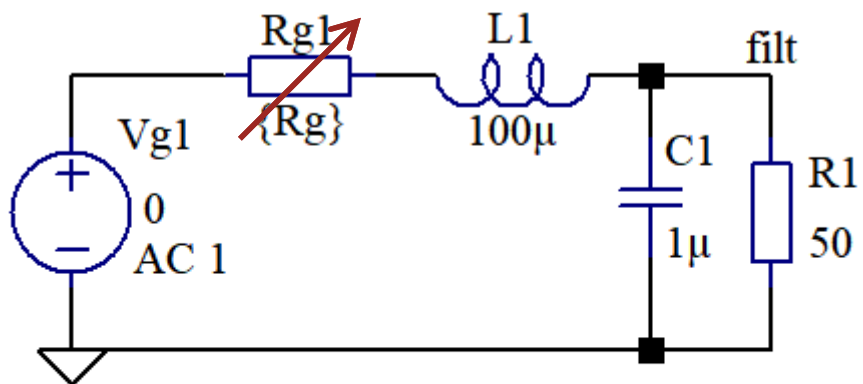
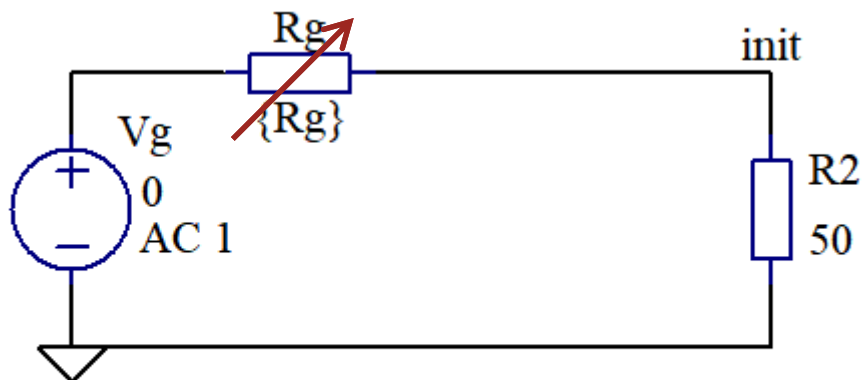
# Primer realnega LC



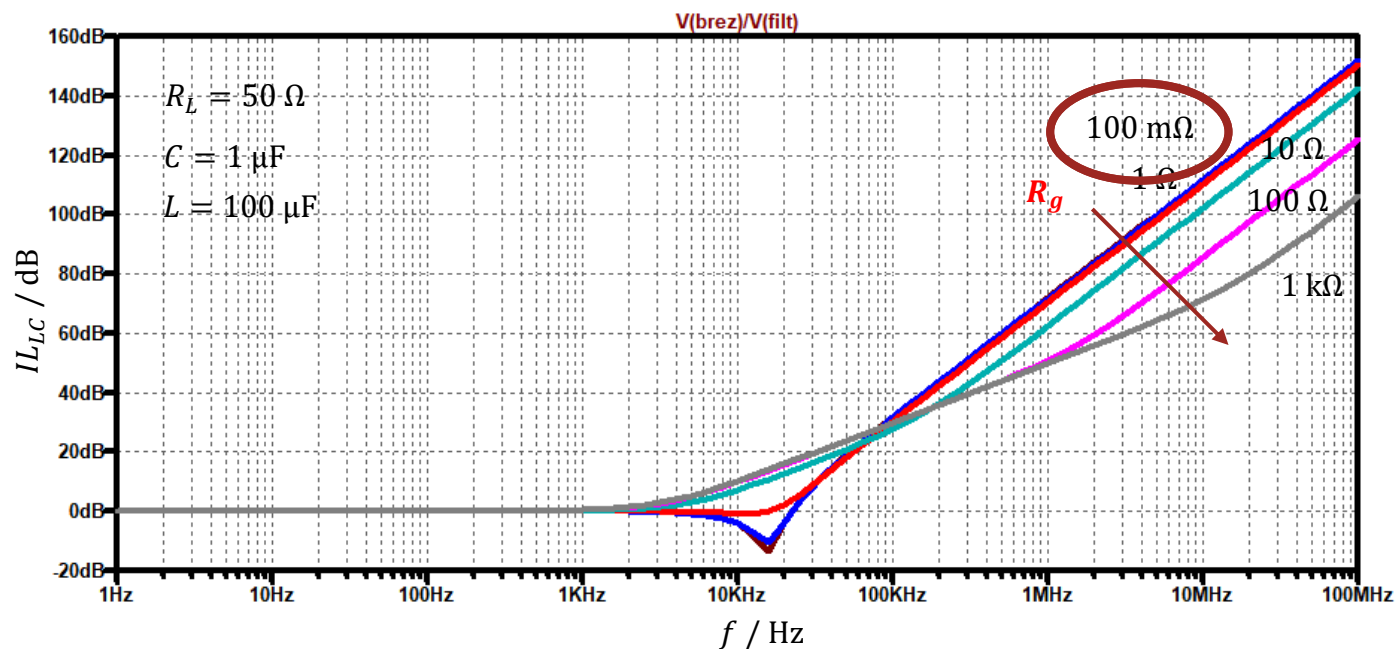
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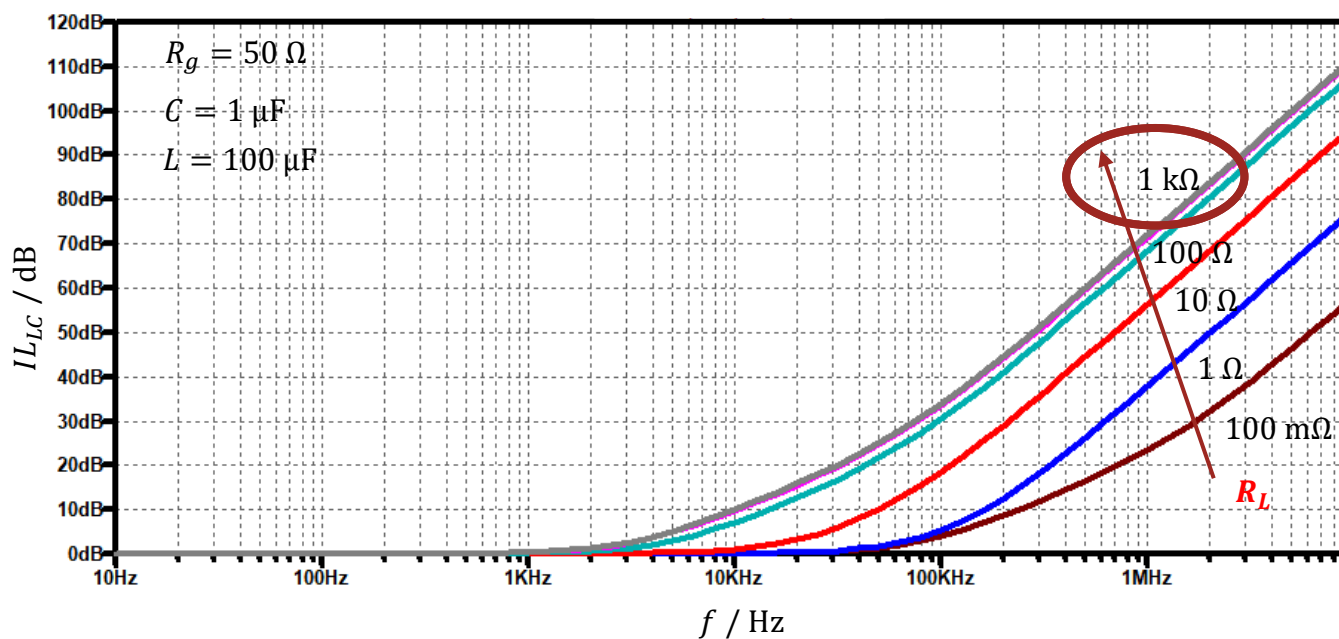
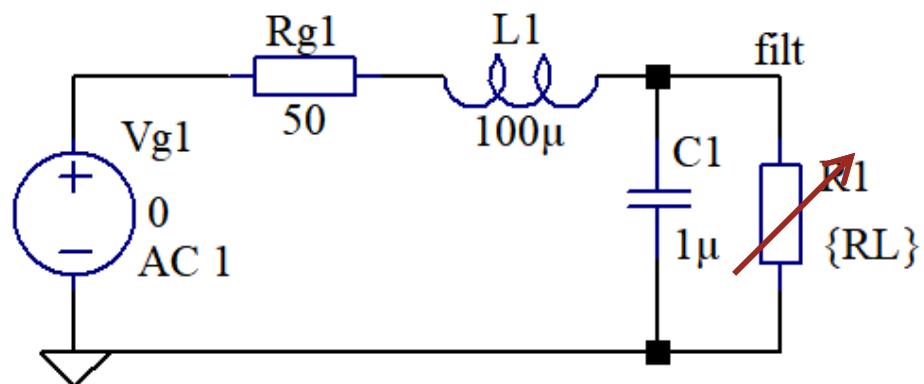
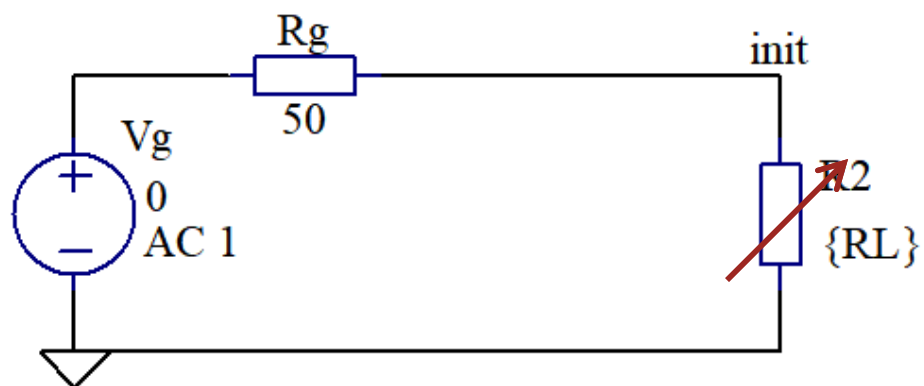
# Primer LC - vpliv upornosti generatorja $R_g$



```
.ac dec 1000 100 100MEG
.step dec param Rg 1 1MEG 1
```

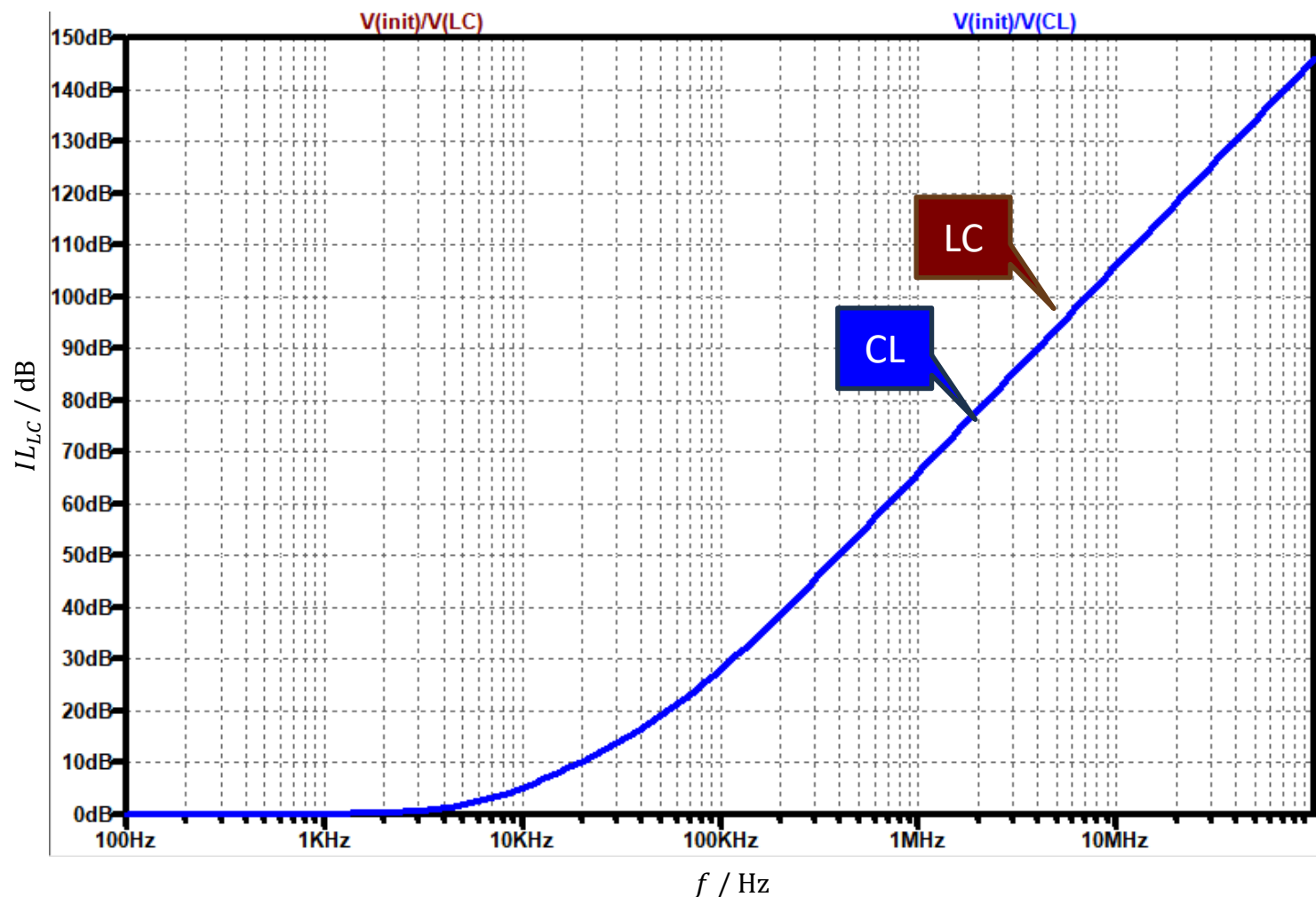
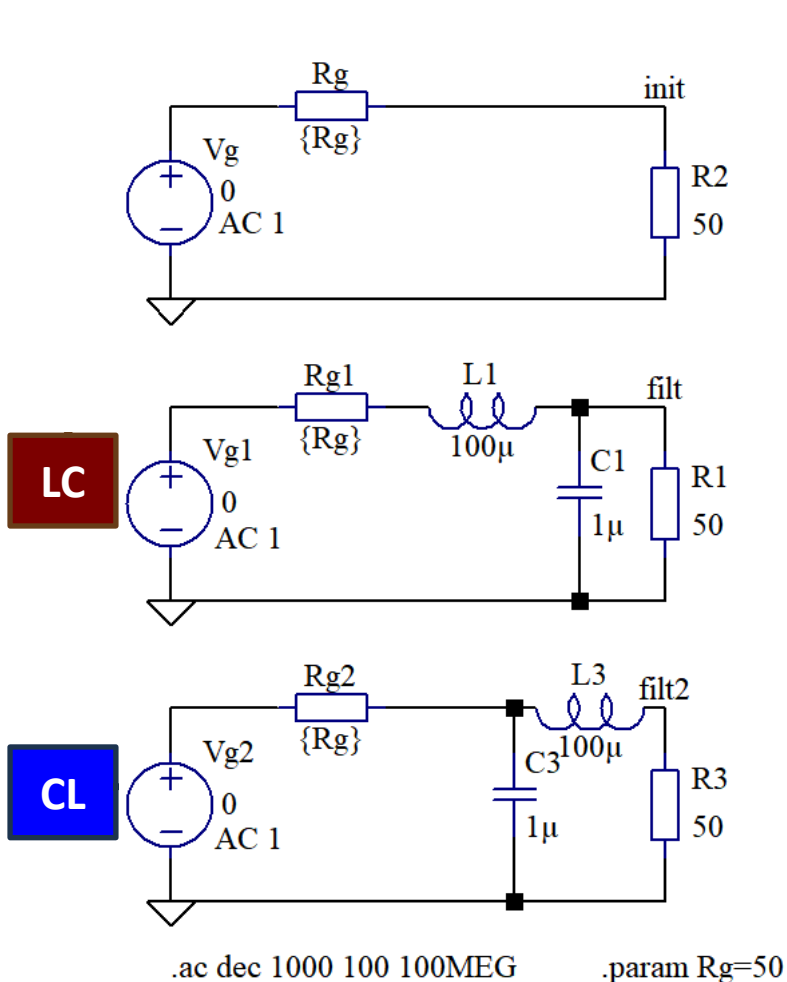


# Primer LC - vpliv upornosti bremena $R_L$

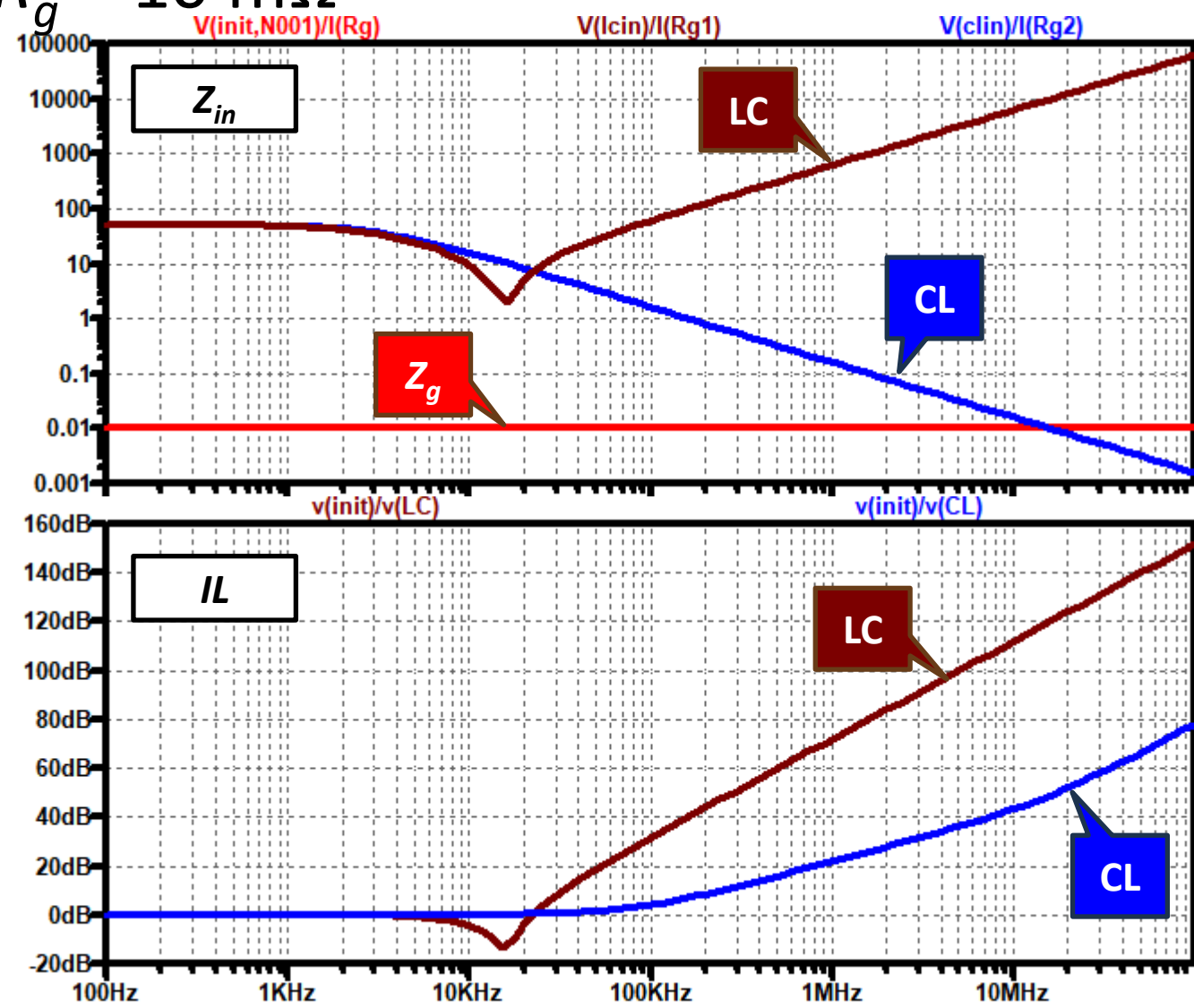
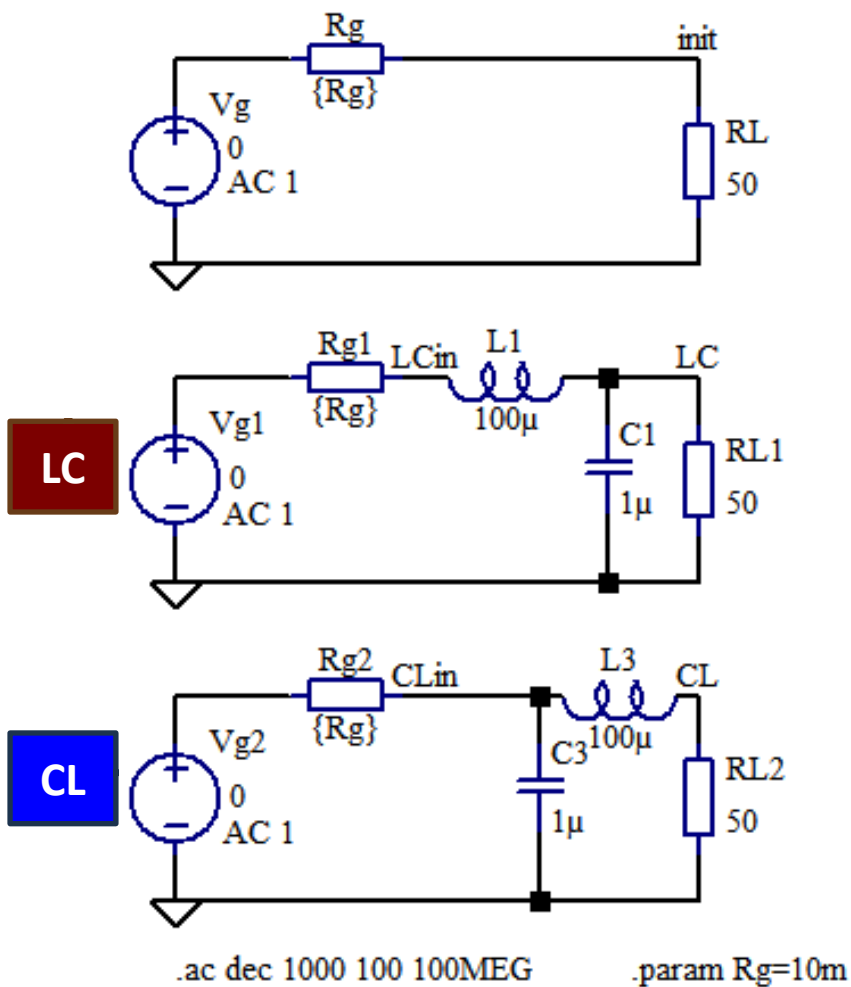


```
.ac dec 1000 100 100MEG
.step dec param RL 1 1MEG 1
```

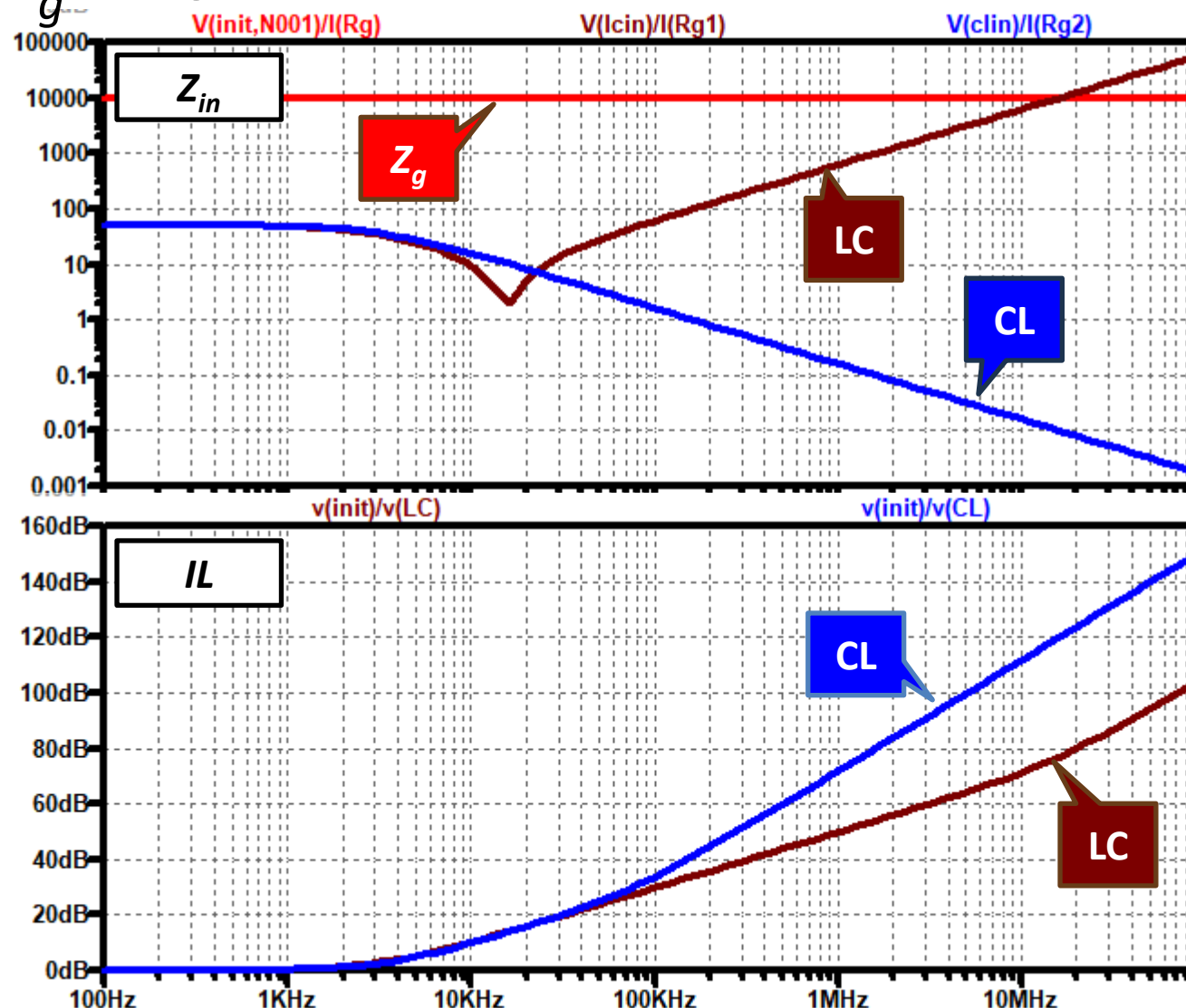
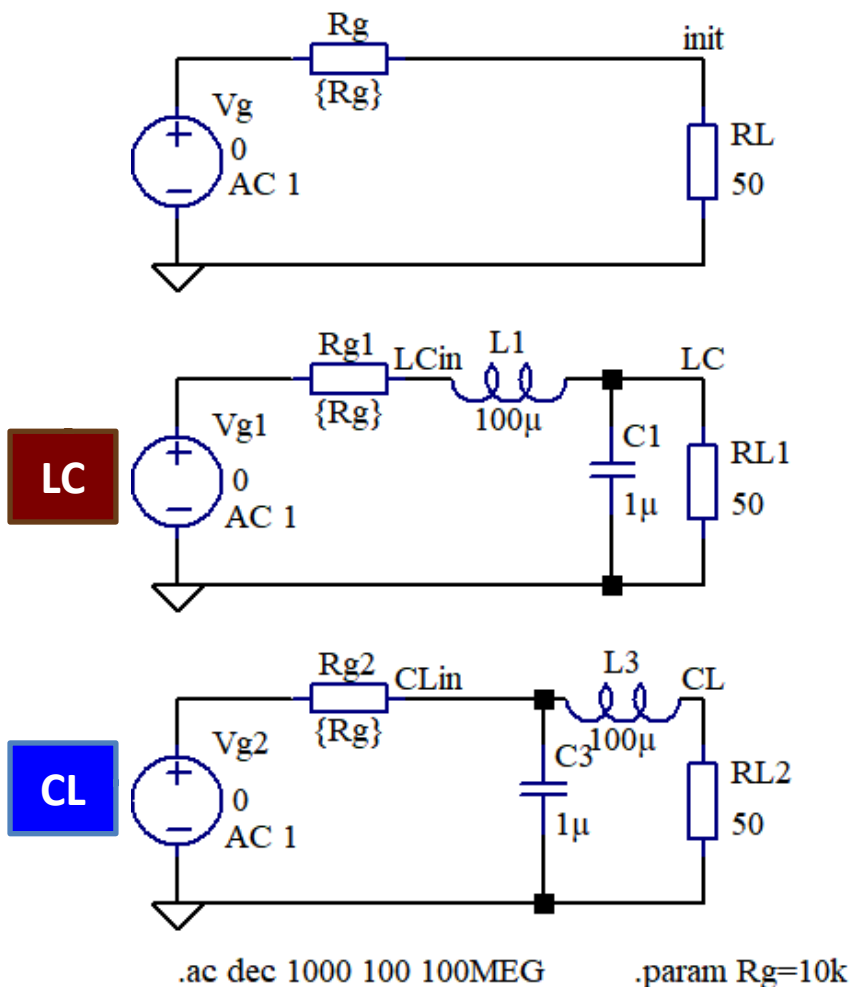
# (Ne)ujemanje impedanc – $R_g = 50 \Omega$



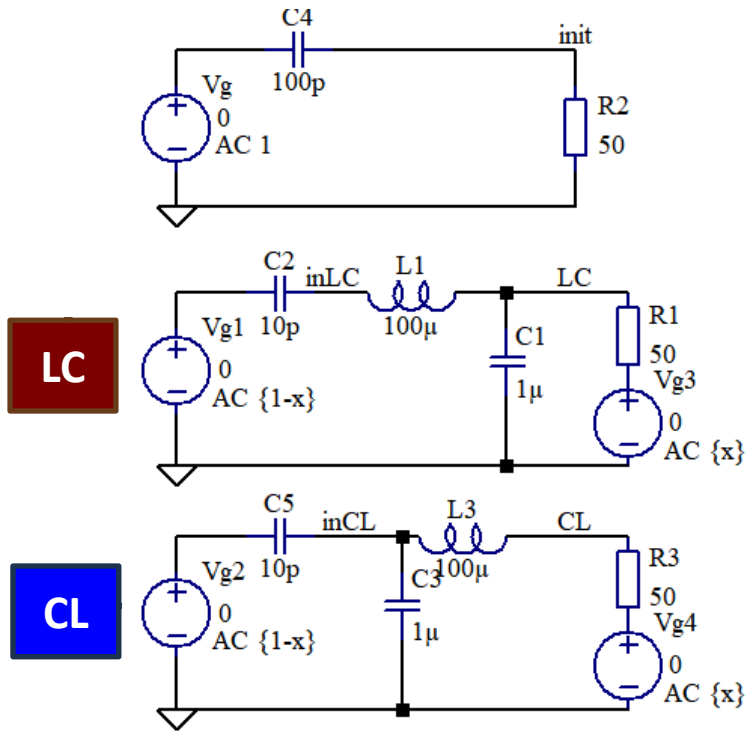
# (Ne)ujemanje impedanc – $R_g = 10\text{ m}\Omega$



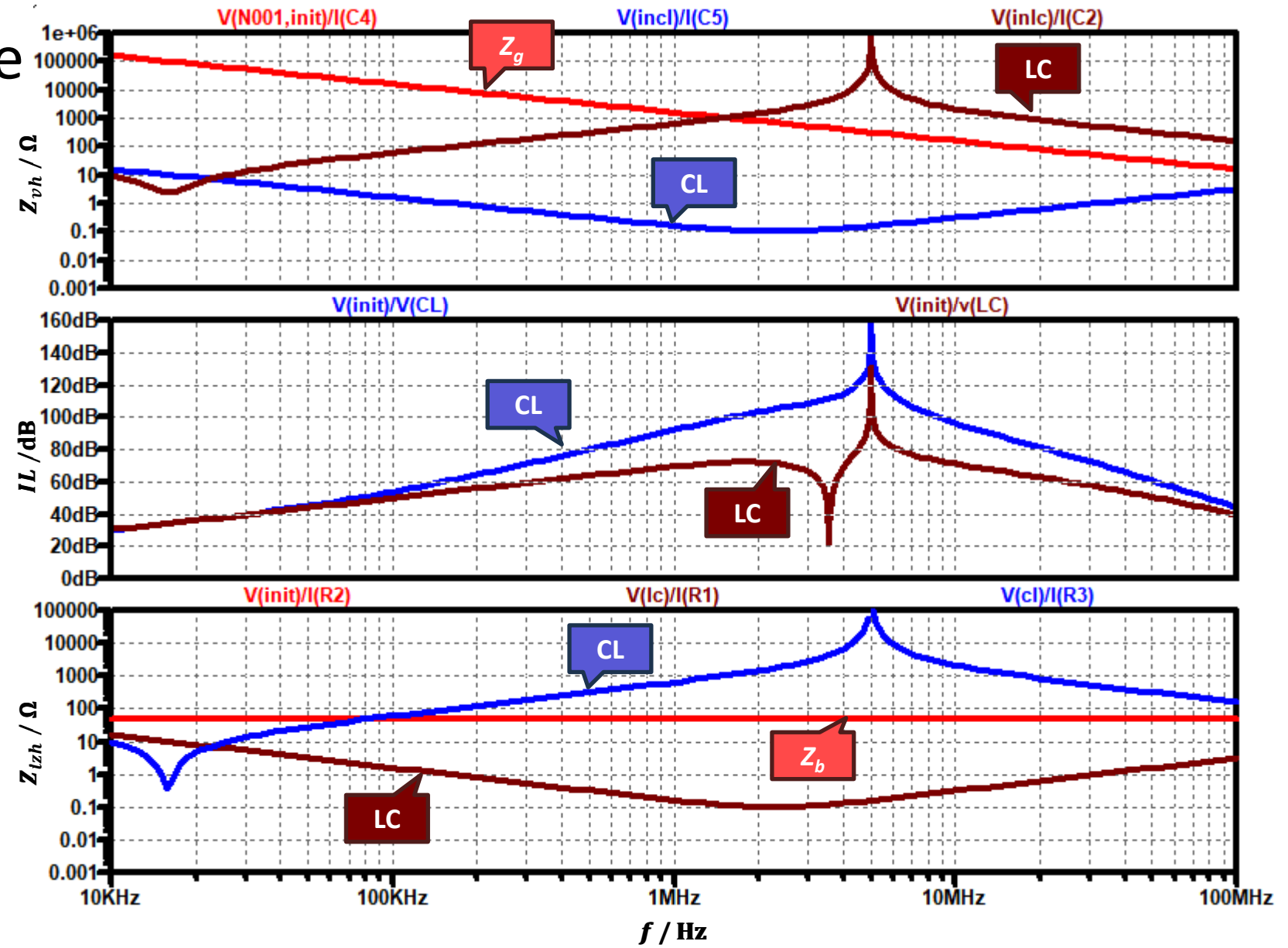
# (Ne)ujemanje impedanc – $R_g = 10\text{ k}\Omega$



# Kapacitivni vir motnje



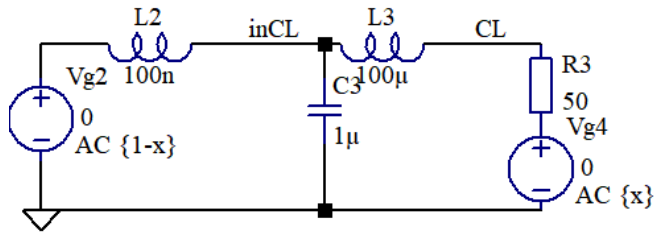
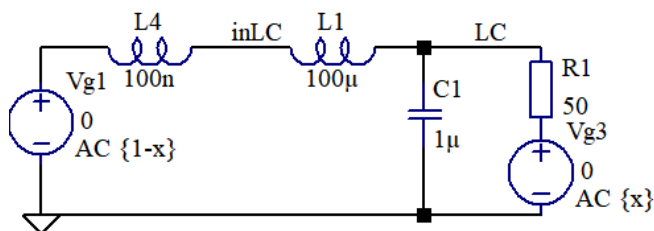
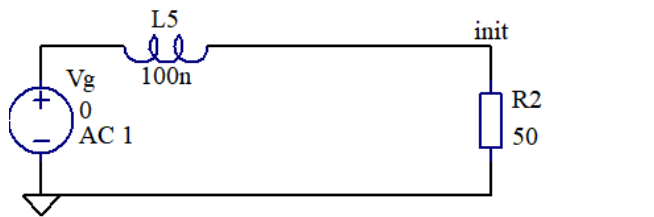
.ac dec 1000 100 100MEG  
.param x=0



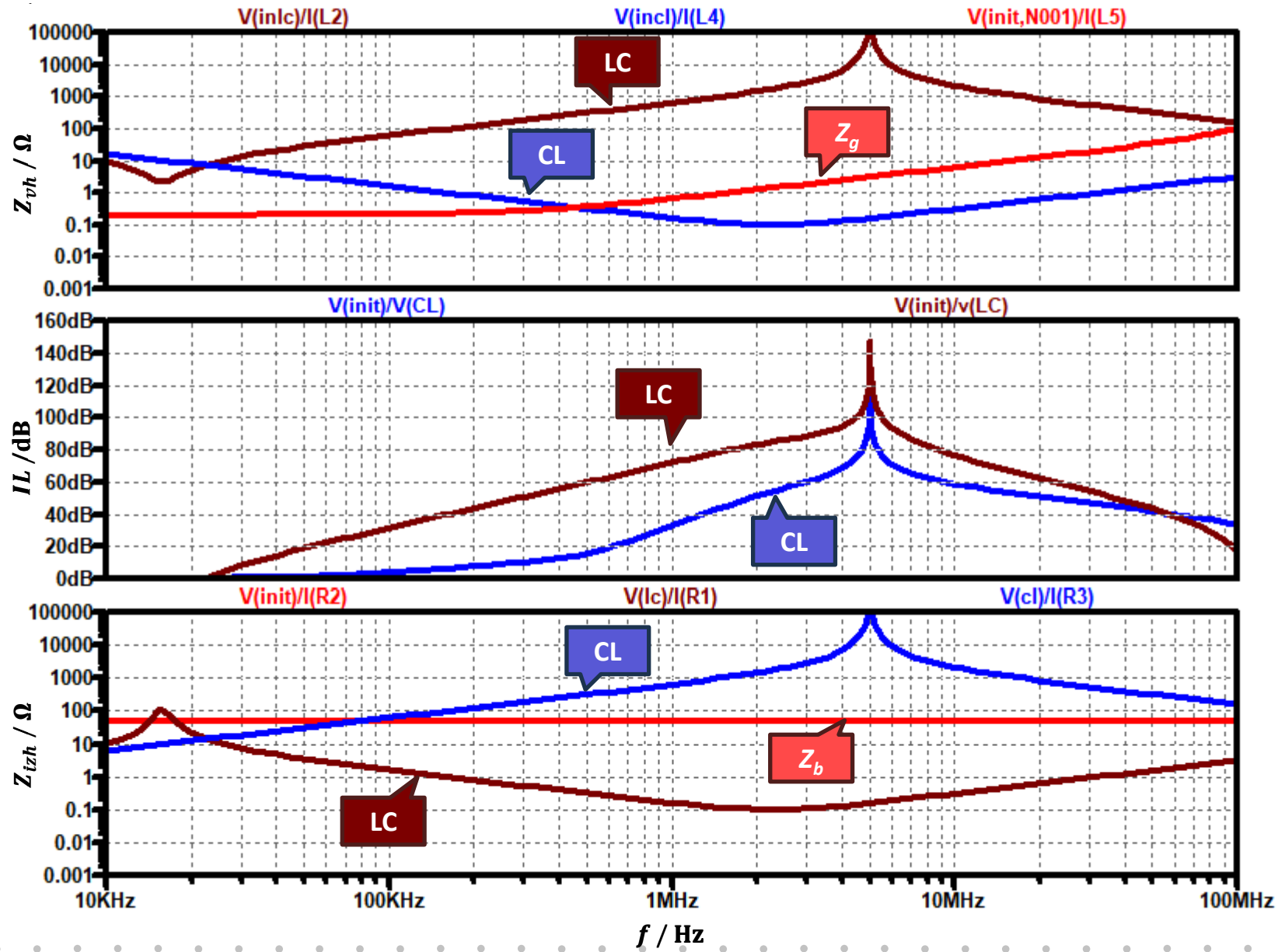
# Induktivni vir motnje

LC

CL



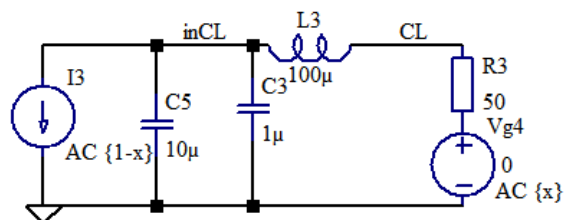
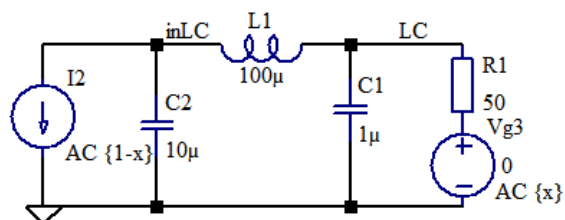
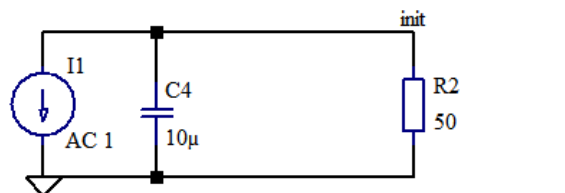
```
.ac dec 1000 100 100MEG
.param x=1
```



# Kapacitivni vir motnje 2

LC

CL



.ac dec 1000 100 100MEG  
.param x=0

