ELE 215
Linear Circuits Laboratory

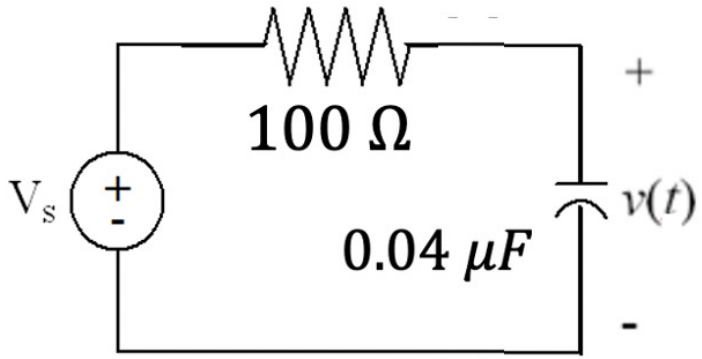
Recitation 9

Circuit Discovery

Useful for BB

Terminology, Circuit Analysis

- Consider the RC circuit

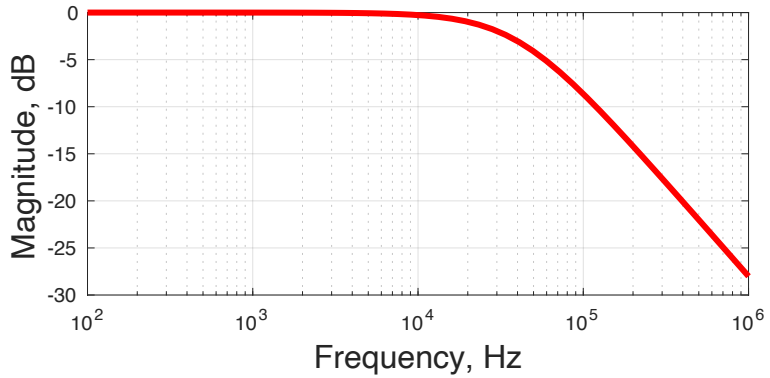


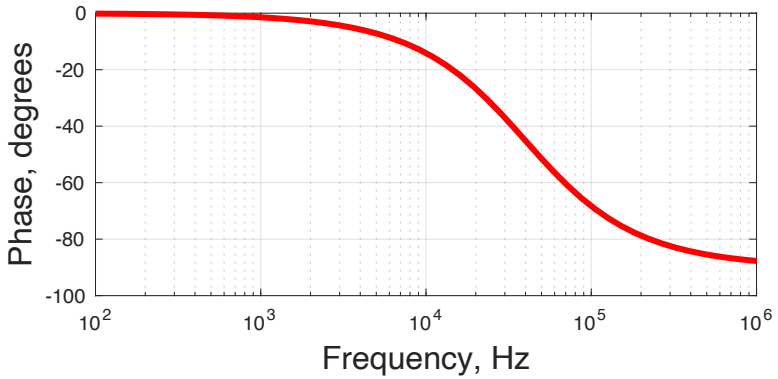
- From phasor analysis

$$H(\omega) = \frac{1/j\omega C}{R+1/j\omega C}$$

$$= \frac{1}{1 + j\omega RC}$$

Lowpass filter

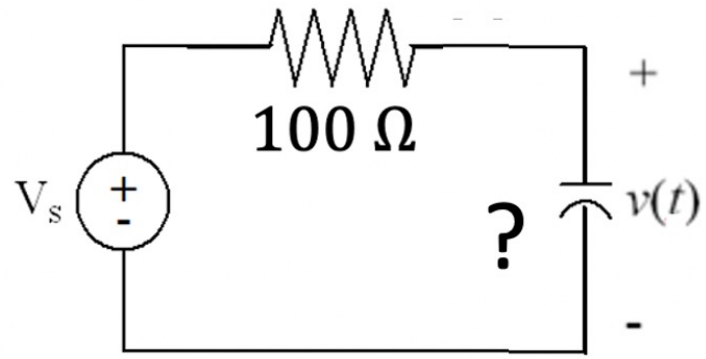


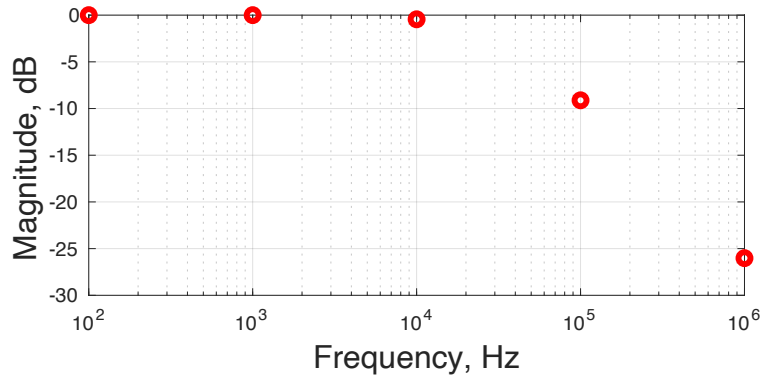


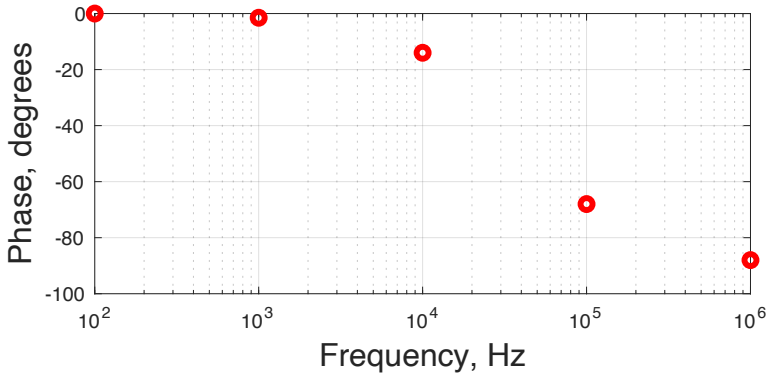
Now, Circuit Discovery

- But what if C is not known?
- Can we find it from some measurements?
- Take some data (limited accuracy)

freq	amp	phase
100 Hz	1.00	0°
1 kHz	1.00	−1.5°
10 kHz	0.95	−14°
100 kHz	0.35	−68°
1 MHz	0.05	−88°







- If it's a simple circuit, then we could "do the math":
  - The k^{th} measurement pair is

$$A_k = \frac{1}{\sqrt{1 + (\omega_k RC)^2}} = \frac{1}{\sqrt{1 + (100\ \omega\ C)^2}}$$

$$\text{or} \qquad C = \frac{1}{100\ \omega}\sqrt{\frac{1}{A^2} - 1}$$

$$\theta_k = -\tan^{-1}(\omega_k RC) = -\tan^{-1}(100\ \omega\ C)$$

$$\text{or} \qquad C = \frac{1}{100\ \omega}\tan(-\theta)$$

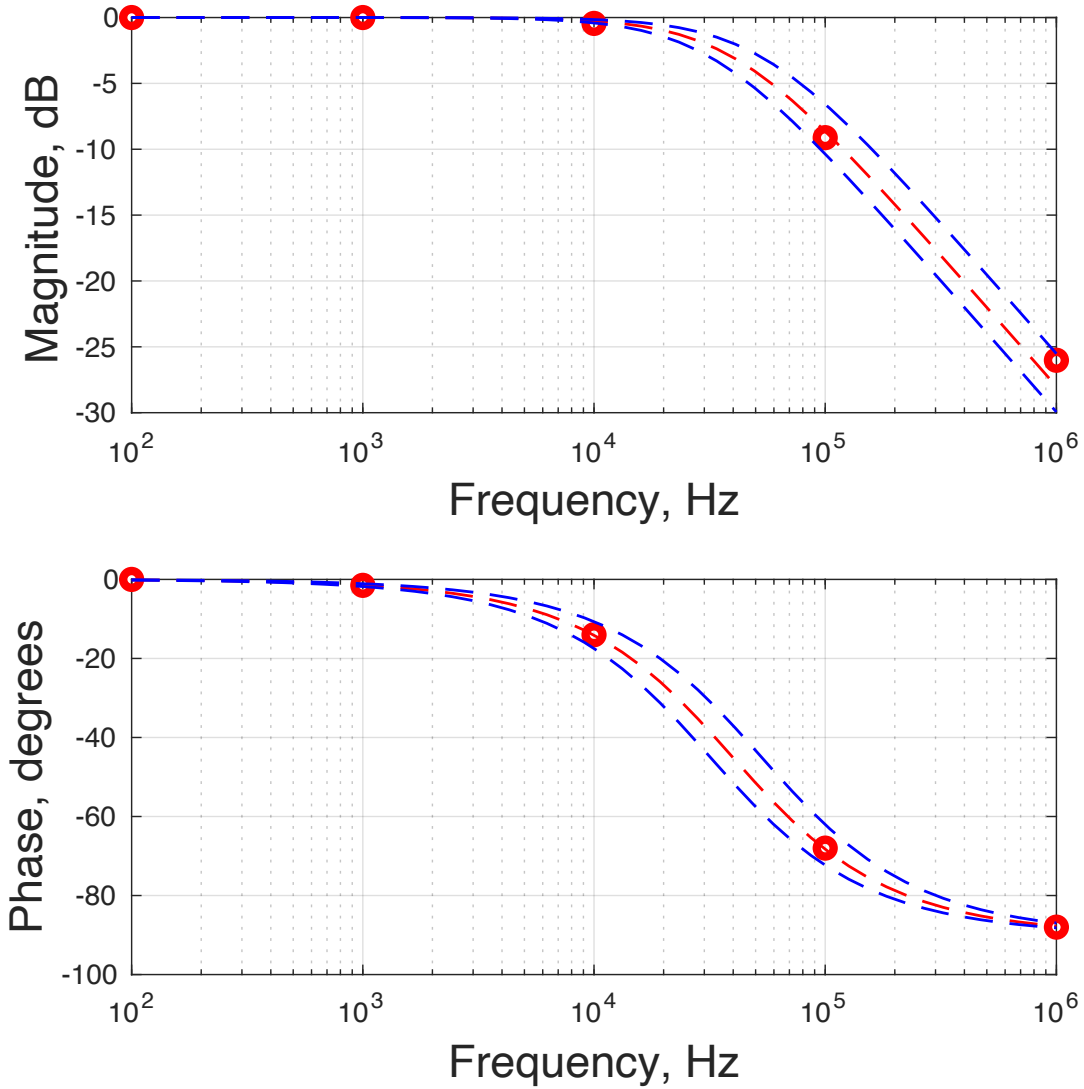
$$C = \frac{1}{100\,\omega}\sqrt{\frac{1}{A^2} - 1} \qquad C = \frac{1}{100\,\omega}\tan(-\theta)$$

freq	amp	C from amp
100 Hz	1.00	0
1 kHz	1.00	0
10 kHz	0.95	5.23×10^{-8}
100 kHz	0.35	4.26×10^{-8}
1 MHz	0.05	3.18×10^{-8}

freq	phase	C from phase
100 Hz	0°	0
1 kHz	−1.5°	4.17×10^{-8}
10 kHz	−14°	3.96×10^{-8}
100 kHz	−68°	3.94×10^{-8}
1 MHz	−88°	4.56×10^{-8}

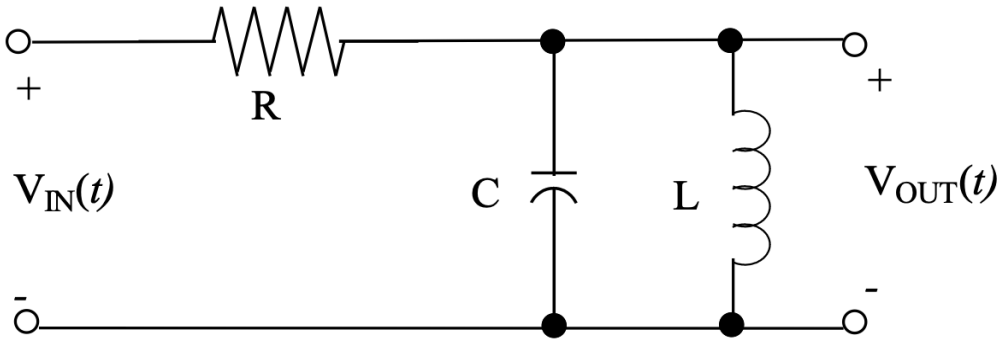
Which value to use?

– Or could “guess and check” graphically – try the values 30, 40, and 50 nF (red dots are data, dotted lines are guesses) – essentially, curve fitting



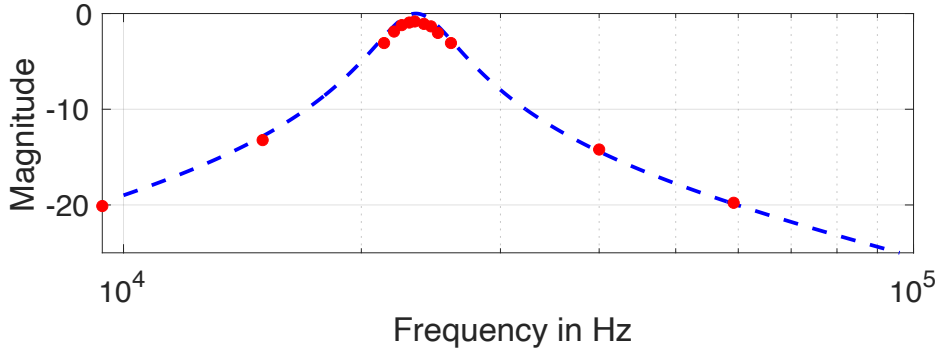
Application

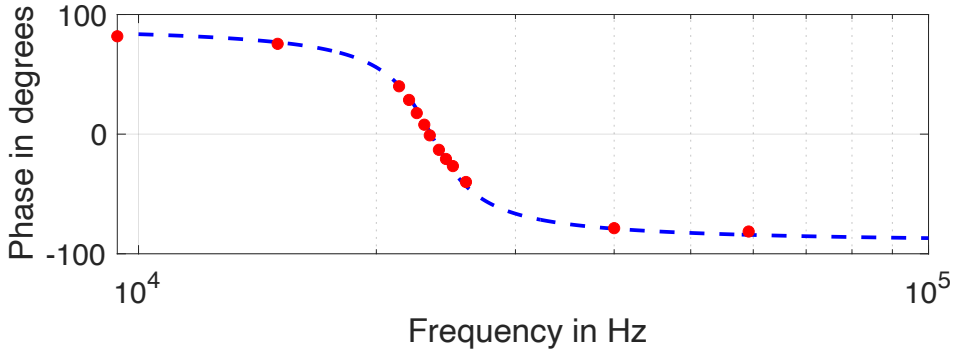
- Lab 6 circuit:



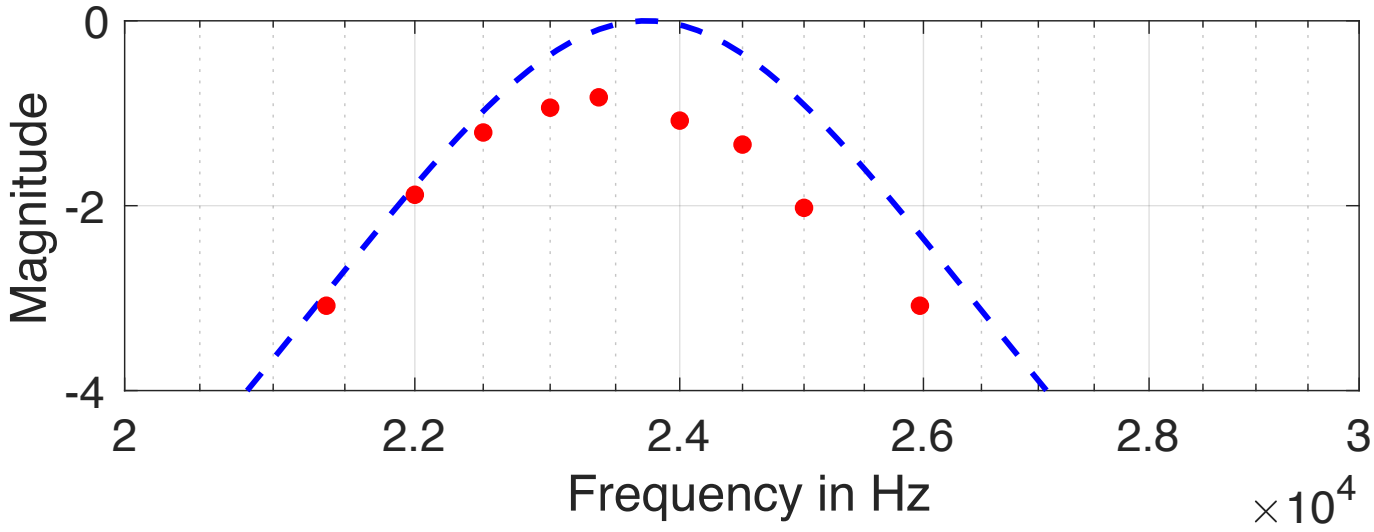
- My example:
  - $R = 3909\ \Omega$
  - $L = 4.75\ mH$
  - $C = 9.46\ \text{nF}$

  - Looks good, but…



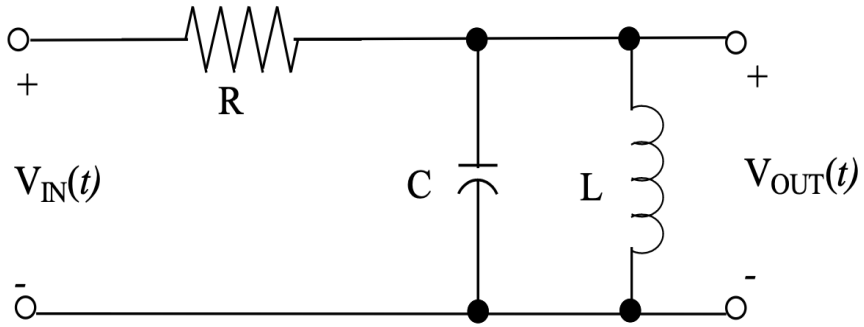


- Upon closer inspection, the data is not a great fit near the peak



  - Right general shape , but …
    - Leftward shift ?
    - Downward shift ?

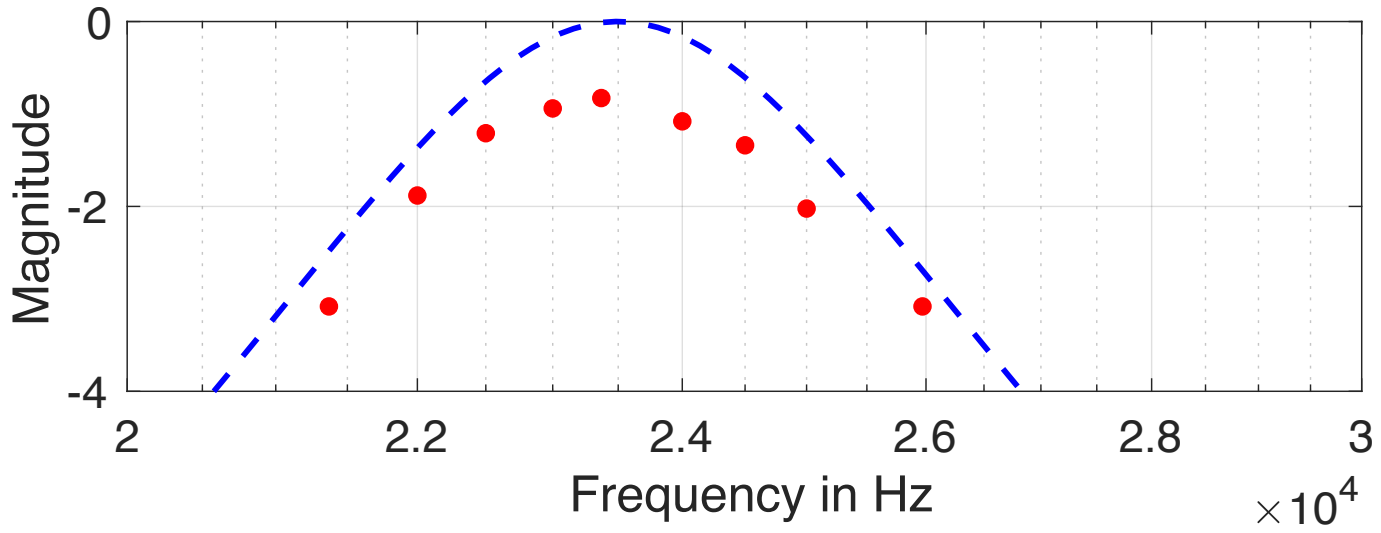
- What did we expect ?



$$H(\omega) = \frac{Z_p}{R + Z_p} = \cdots = \frac{1}{1 - j\dfrac{R(1 - \omega^2 LC)}{\omega L}}$$

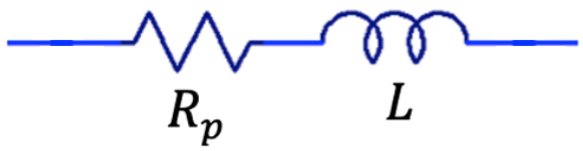
  - Peak of $|H(\omega)| = 1$ when $\omega^2 LC = 1$, so left/right shift is likely an error in the inductor value

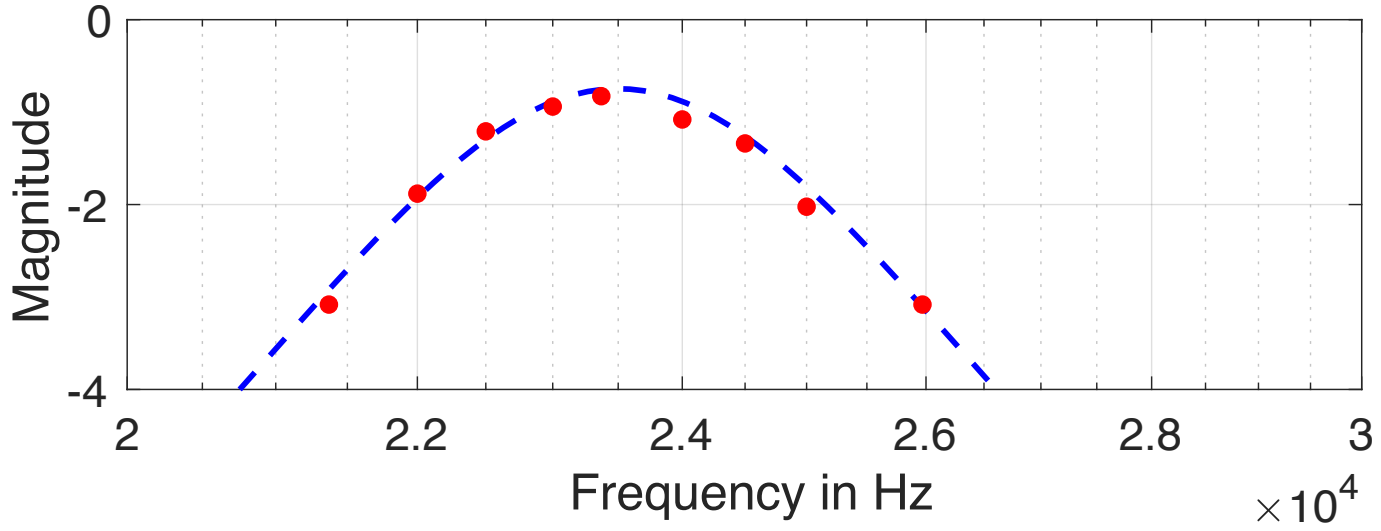
– Using 4.85 mH (found by “guess and check”):



– But what about the downward shift? Model the wire resistance in the inductor

- Including $R_p = 15\ \Omega$ (again, by guess and check)



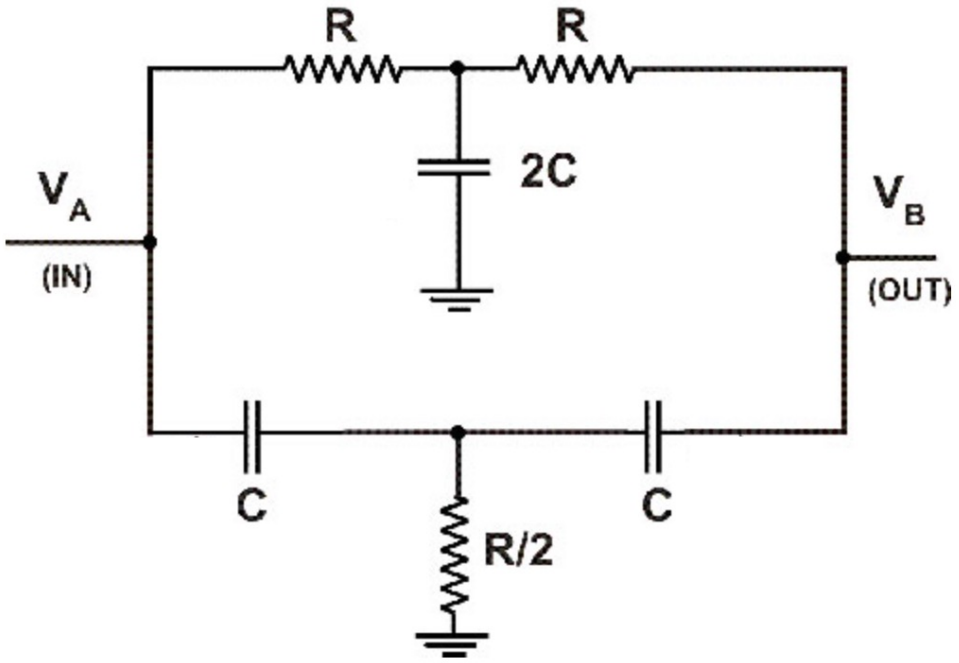


Lab 7 – A Notch Filter

- Type beyond LPF, BPF, HPF
- Typical use – to remove a specific signal from interfering with a system. E.g.:
  - 60 Hz from power grid
  - 88 kHz fish finder from a nav system

- Twin-T circuit:

$$H(f) = \frac{V_B}{V_A} = \frac{1-(2\pi fRC)^2}{(1+j2\pi fRC)^2}$$



Specifics for next week

- Continue Exercise 1 – due April 6

- Prelab 7 for 9 AM Monday March 30 – 20 points
  - Theoretical characteristics of your BPF; expected Bode plot
  - Instructions posted on ELE 215 website

- Lab 7 – 80 points (pairs):
  - Instructions posted on ELE 215 website
  - Summary sheets available in lab rooms and on website
  - Due by 5 PM Wednesday April 8

- Exercise 4 – 50 points – same pairs as Lab 7
  - Getting a better fit to your Lab 7 data
  - See instructions/summary page on the ELE 215 website
  - Due by 5 PM Wednesday April 15