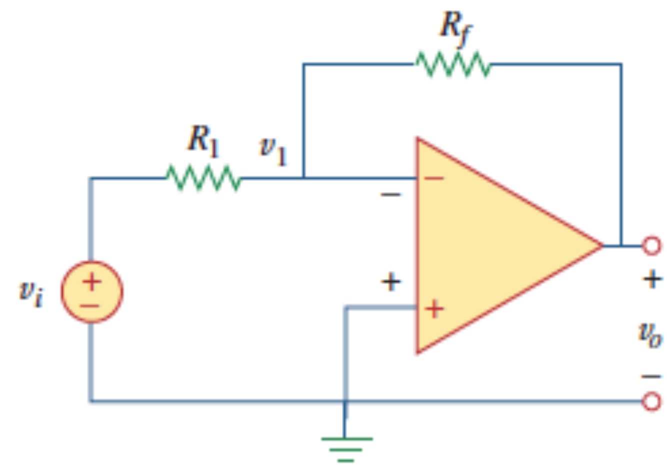
Lecture 22
Phasors – 8 of 9

op amps; start design

Op Amps and Phasors

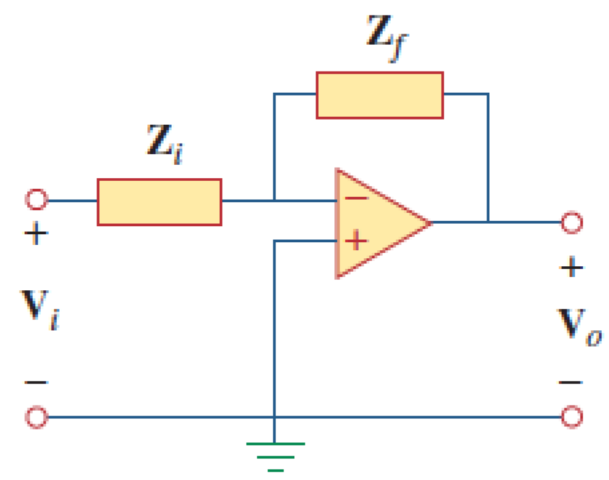
- Recall the inverting amplifier

$$\text{gain} = -\frac{R_f}{R_i}$$

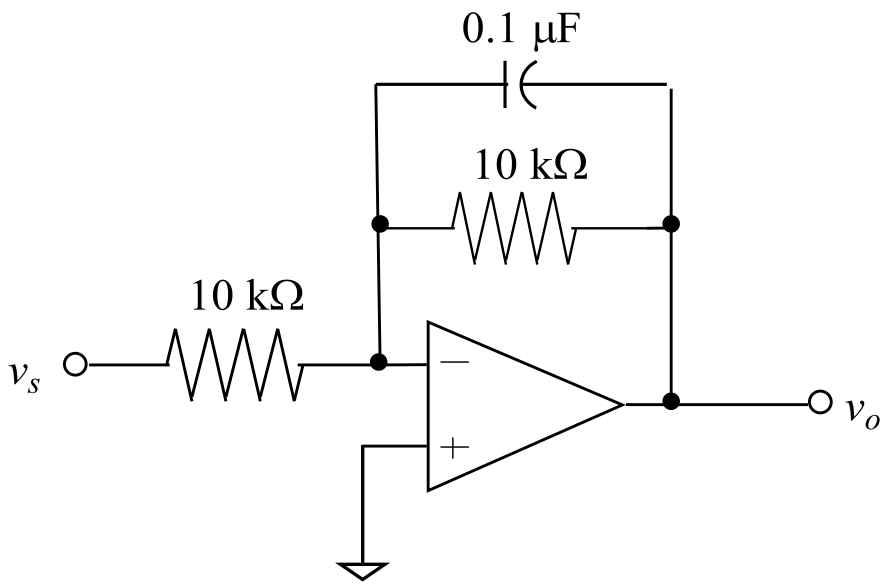


- Now, an “active” filter

$$H(\omega) = -\frac{Z_f}{Z_i}$$

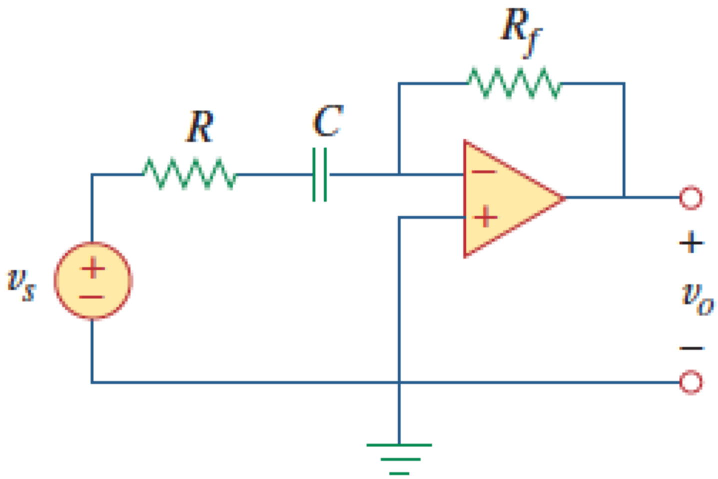


Example: find v_o if $v_s(t) = 2\cos 1000t$ V



$v_o(t) = \sqrt{2}\cos(\omega t + 135°)$ V

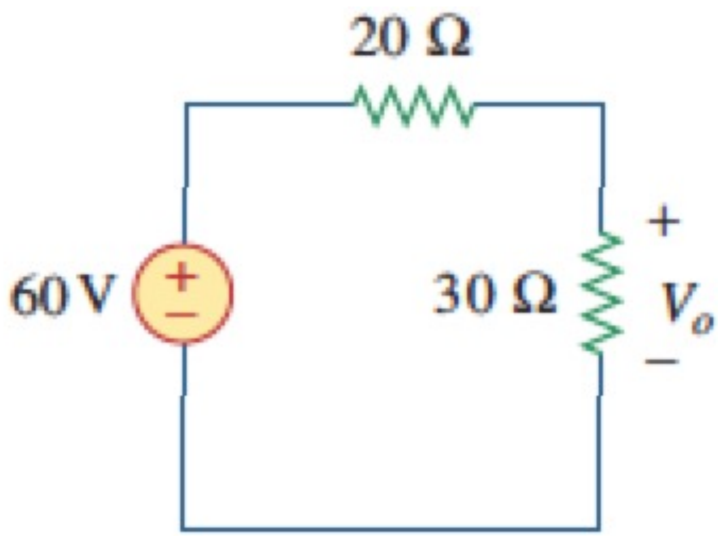
Example: find v_o if $v_i(t) = A\cos\omega t\ V$ Is the result low pass, bandpass, or highpass?



$$v_o(t) = \frac{A\omega R_f C}{\sqrt{1+\omega^2 {R_i}^2 C^2}} \cos(\omega t + 180° - \tan^{-1}(\omega R_i C))\ \text{V}$$

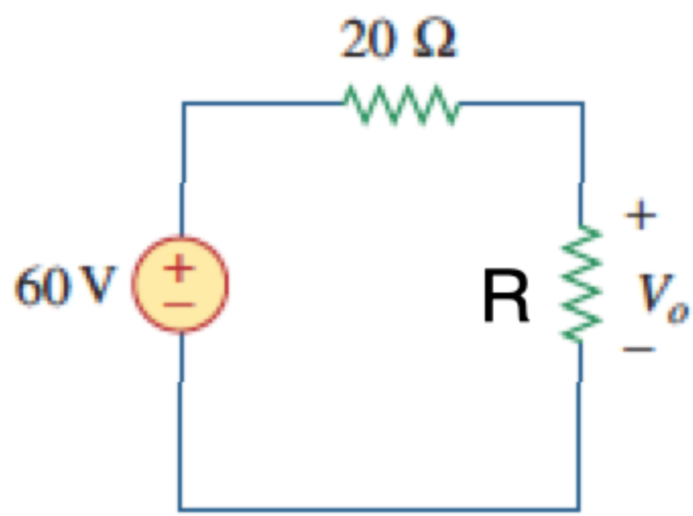
Analysis vs Design

- Voltage division **analysis** yields



$$V_o = \frac{30}{20+30} 60 = 36 \text{ volts}$$

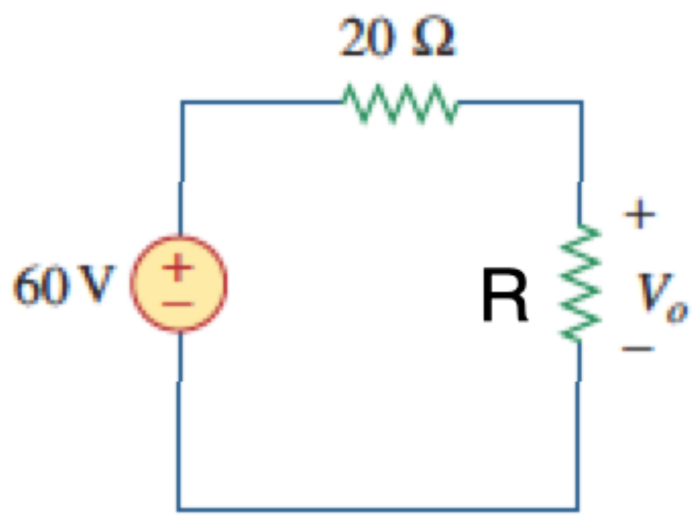
- **Design**: How do we choose R for $V_o = 10$ volts? And is this even possible?



- Solving :

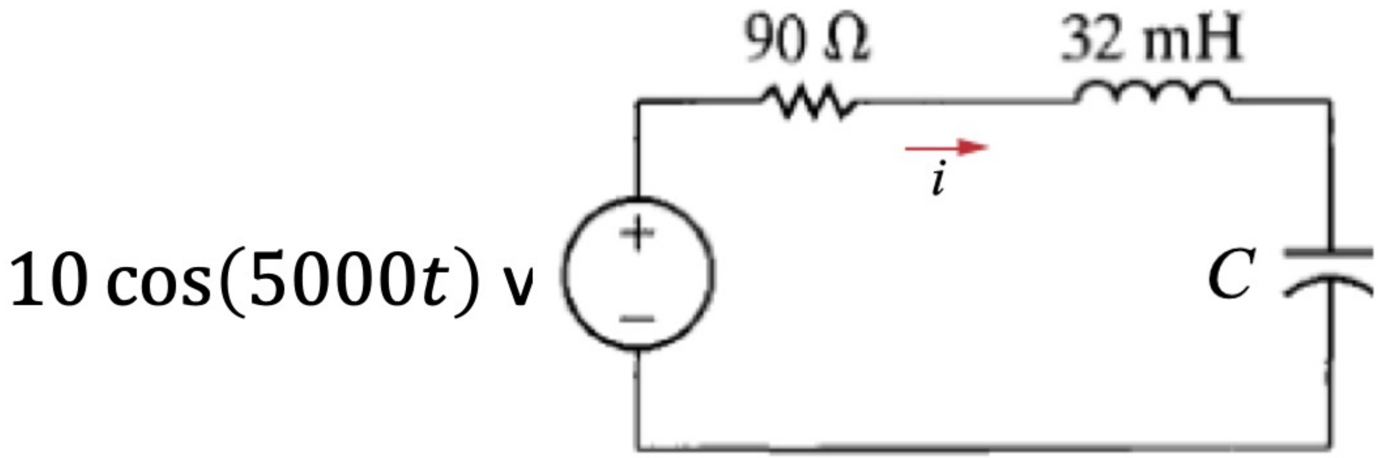
$$V_o = \frac{\boldsymbol{R}}{20 + \boldsymbol{R}} 60 \quad \Longrightarrow \quad R = \frac{20V_o}{60 - V_o}$$

  - One solution if $0 < V_o < 60$
  - None otherwise



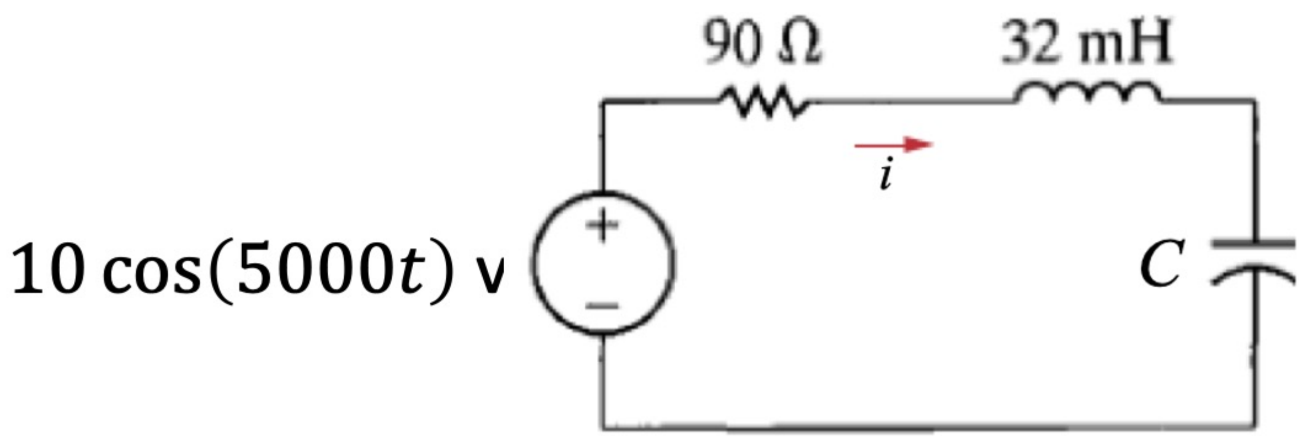
Phasor Circuit **Design**

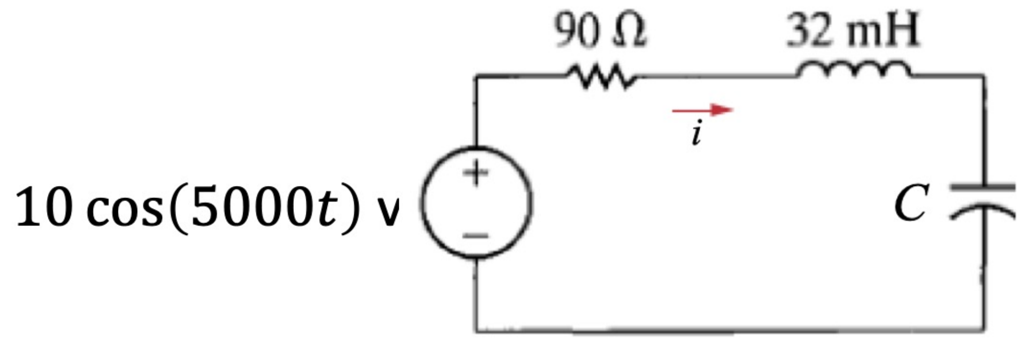
- Choose components to achieve a certain goal.
- Example:



  – Can you choose a capacitor C so that the steady state current i has a phase angle of $-45°$ relative to the source ? If so, what is the current's amplitude?

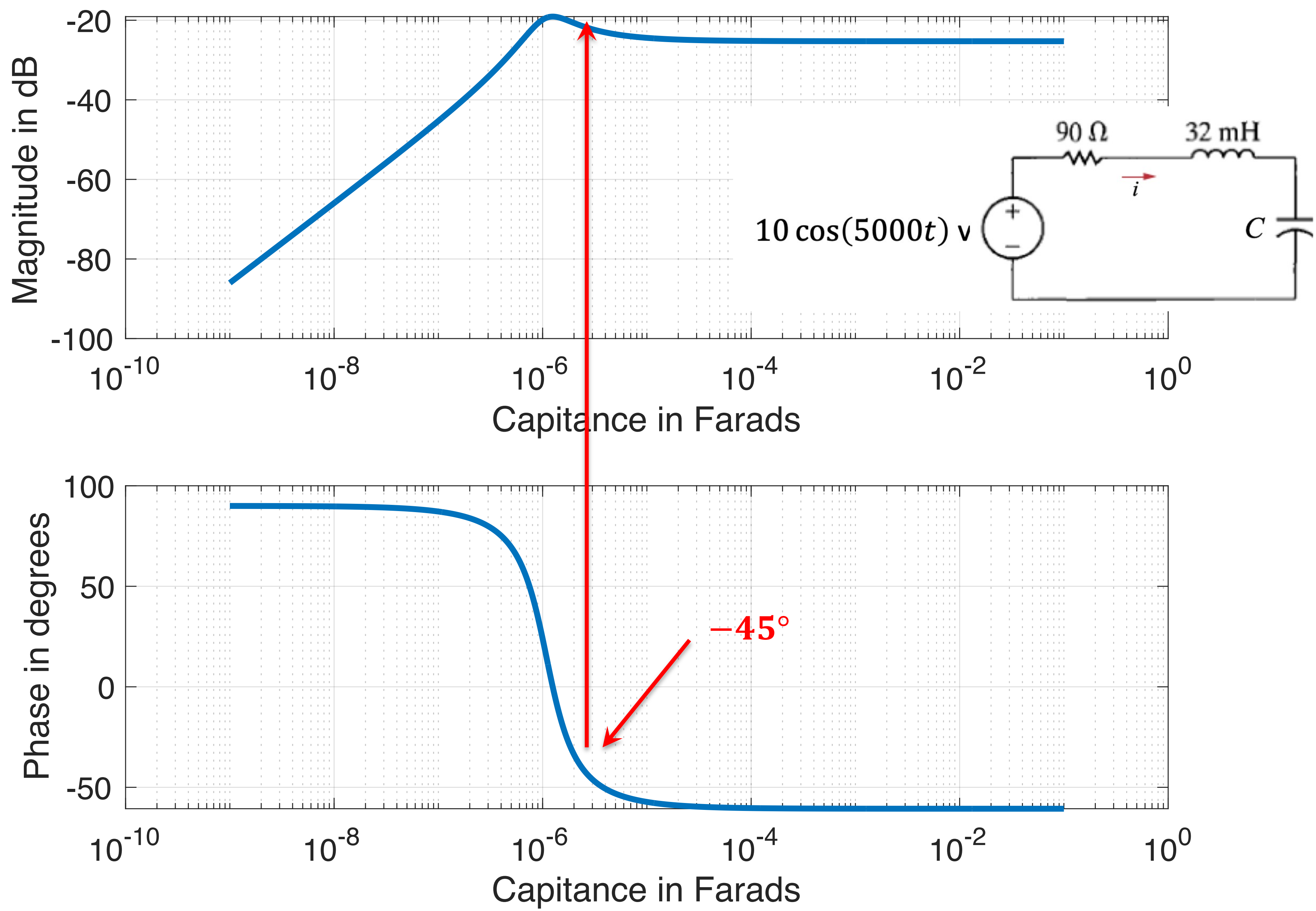
- Considerations:
  - Is the request even possible? How many degrees of freedom do you have versus the number of quantitative goals? Is more than one solution possible?
  - For our example, what range of angles is even possible?





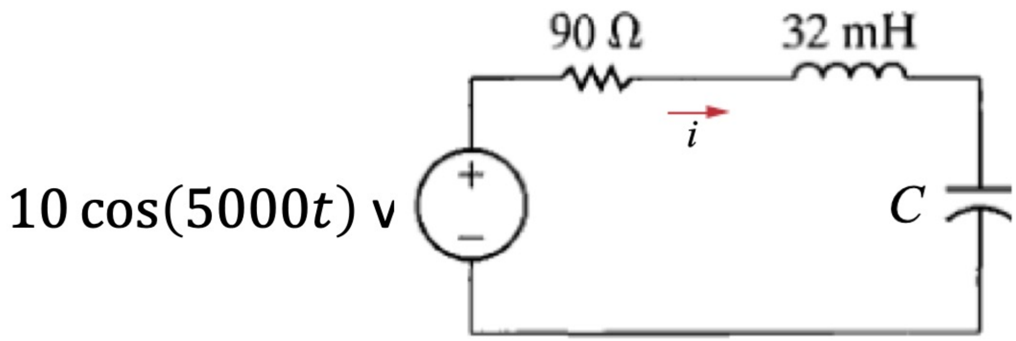

```
om = 5000;
R = 90;
L = 32e-3;
ZL = 1j*om*L;
C = logspace(-9,-1,1000);
ZC = 1./(1j*om*C);
I = 10./(R+ZL+ZC);
```

```
subplot(211)
semilogx(C,20*log10(abs(I)),'linewidth',3)
xlabel('Capitance in Farads')
ylabel('Magnitude in dB')
set(gca,'fontsize',16)
grid on
subplot(212)
semilogx(C,180/pi*angle(I),'linewidth',3)
xlabel('Capitance in Farads')
ylabel('Phase in degrees')
set(gca,'fontsize',16)
grid on
```



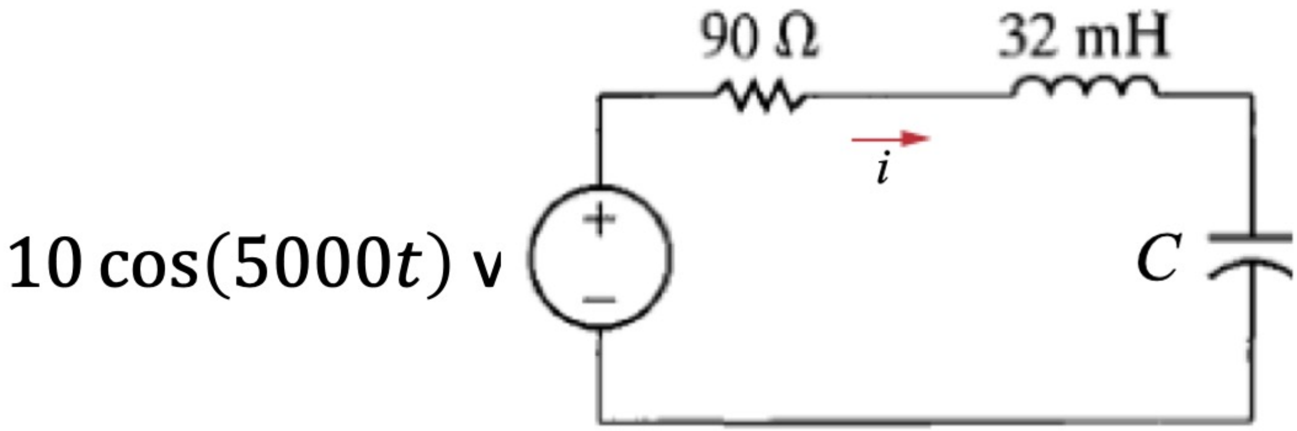
Magnitude in dB
-20
-40
-60
-80
-100
10-10
10-8
10-6
10-4
10-2
100
Capitance in Farads
90 Ω
32 mH
i
10 cos(5000t) v
C
Phase in degrees
100
50
0
-50
−45°
Capitance in Farads

Let’s actually solve for C and the current’s amplitude



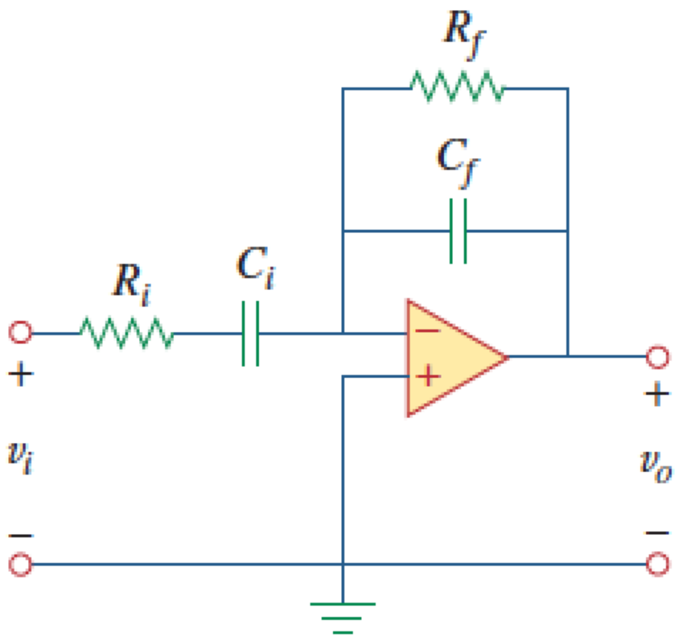
$2.86\ \mu F; 78.6\ \ mA$

Example: For the same circuit, can you choose a capacitor C so that the steady state current i has a magnitude of 0.1 A?



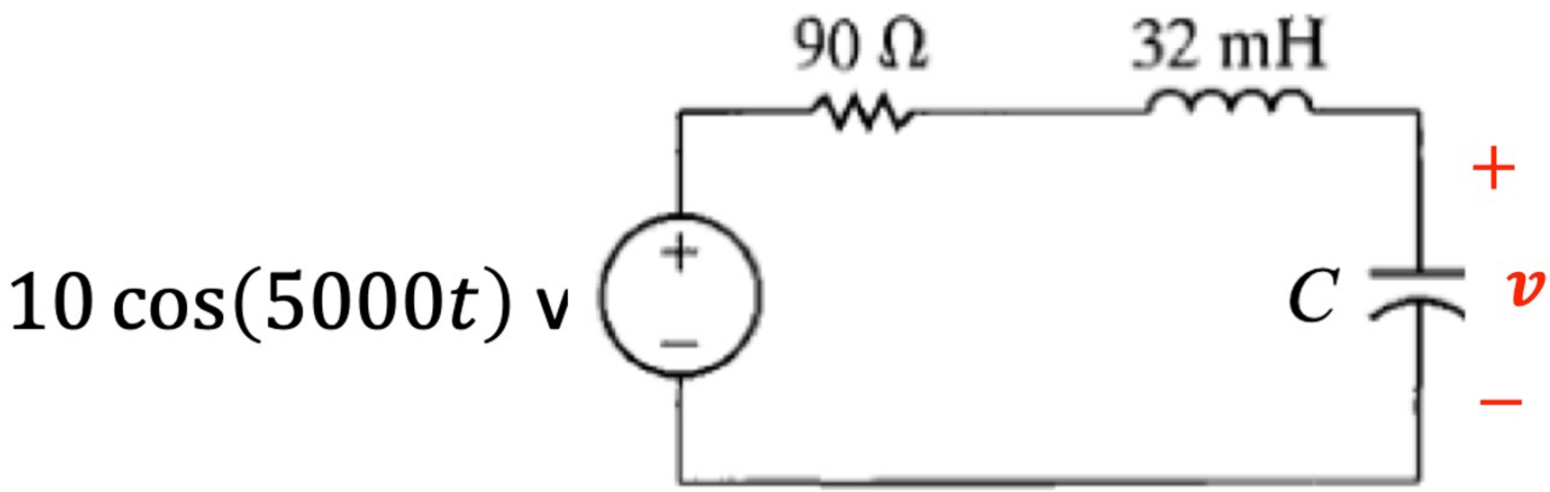
$0.172\ \mu F$

Practice problem: find v_o if $v_i(t) = A\cos\omega t\ \ V$



$$v_o(t) = \frac{A\omega R_f C_i}{\sqrt{1+\omega^2 {R_i}^2 {C_i}^2}\sqrt{1+\omega^2 {R_f}^2 {C_f}^2}}\cos\left(\omega t + 270° - \tan^{-1}(\omega R_i C_i) - \tan^{-1}\left(\omega R_i C_f\right)\right) \text{V}$$

Practice problem: For the same circuit, can you choose a capacitor C so that its steady state voltage v has a phase angle of $-45°$ relative to the source ?



$0.118\ nF$