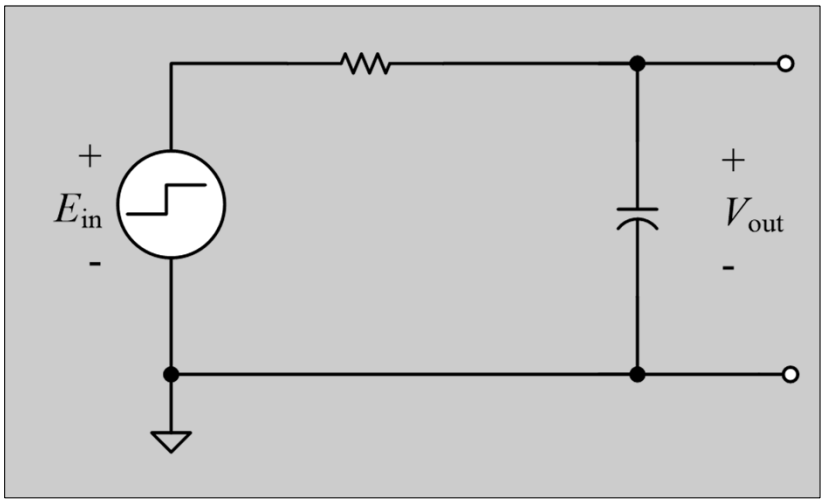
RC Circuit – Transfer Function



$V_{out}(s) =$

$$\frac{V_{out}(s)}{E_{in}(s)} =$$

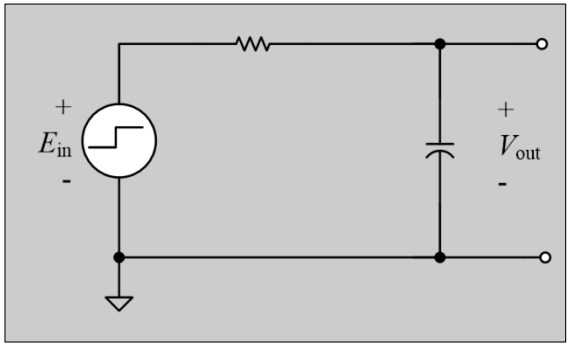
```
clc
clear
s=tf('s')

R=500;
C=0.5e-6;
tau=R*C
wo=1/tau
fo=wo/(2*pi)

G=
  ____________________________________


opts = bodeoptions('cstprefs');
opts.FreqUnits = 'Hz';
opts.grid = 'on';
opts.PhaseWrapping = 'on';
opts.MagLowerLimMode = 'manual';
opts.MagLowerLim = -90;

bodeplot(G,{1e2,1e6},opts);
```



RC Circuit – Frequency Response i.e. Bode' Plot

$$critical\ frequency$$

$$\omega_o = \frac{1}{\tau} \quad \frac{\text{radians}}{second}$$

$$\omega_o = 2\pi f_o \quad \frac{cycles}{sec}$$

$$f_o = \frac{\omega_o}{2\pi}$$

RC Circuit – Frequency Response i.e. Bode' Plot

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wo=1/tau
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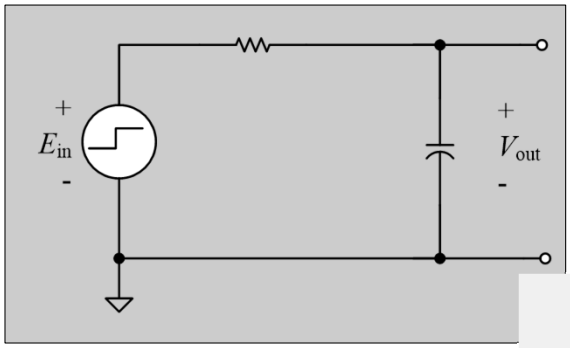


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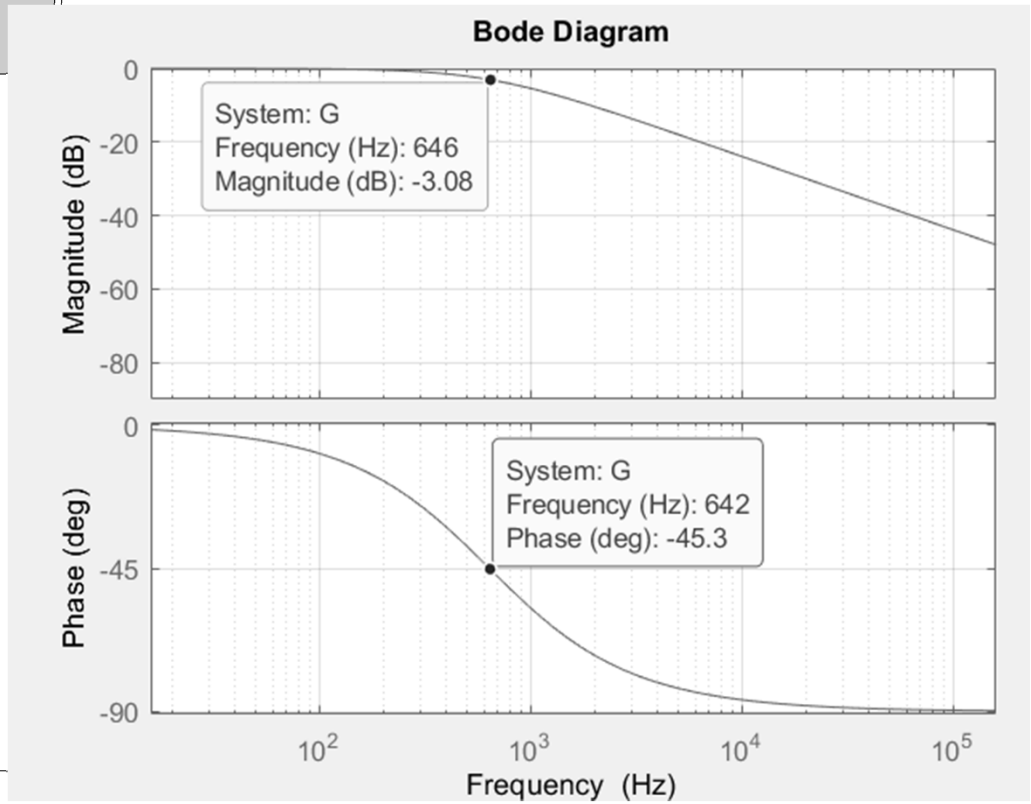

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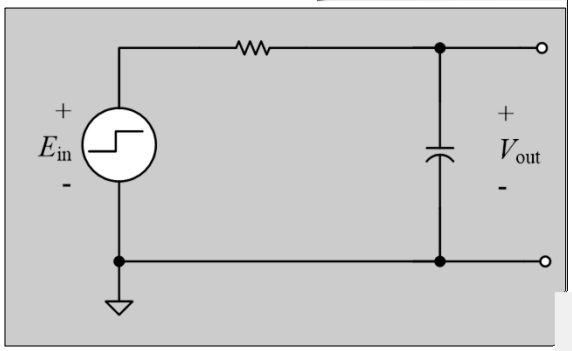
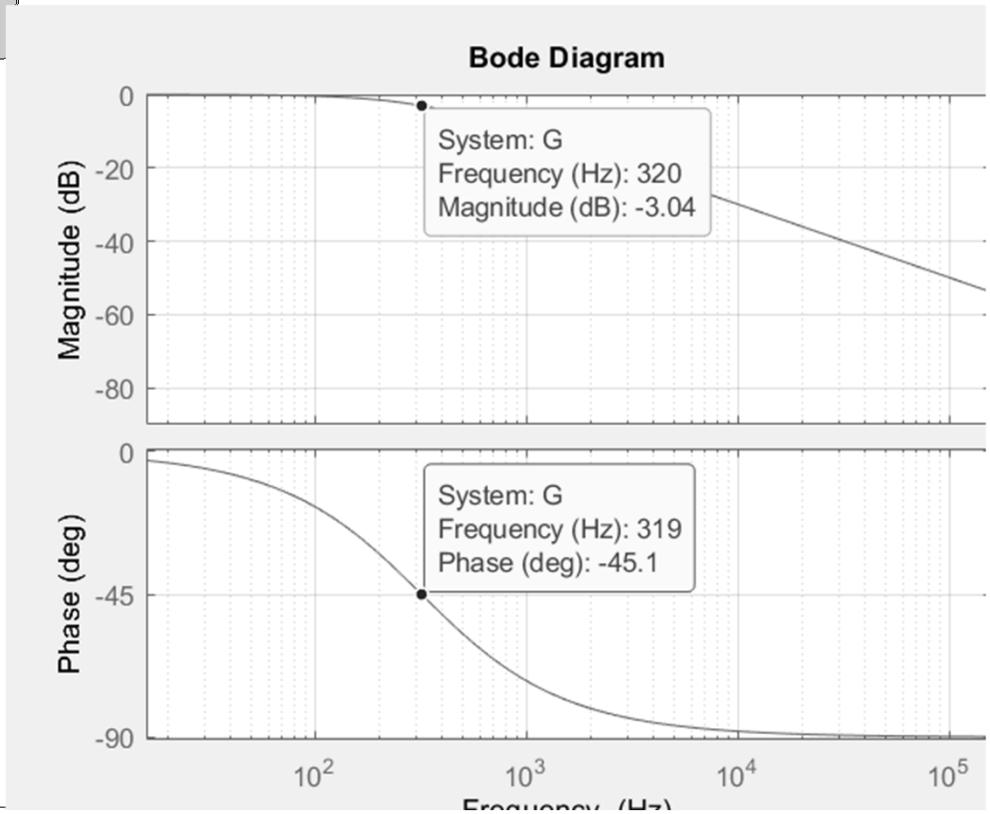


Effect of *doubling* R ??



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wo=1/tau
fo=wo/(2*pi)

G=__________________ ;


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opts.MagLowerLimMode = 'manual';
opts.MagLowerLim = -90;

bodeplot(G,{1e2,1e6},opts);
```

Effect of *reversing* R and C ??

$$s = j\omega$$

$$\frac{V_{out}}{E_{in}} = \frac{1}{Rj\omega C + 1} = \frac{1}{1 + j\omega RC}$$

This is an equation with real and imaginary parts in its denominator. To separate these parts, multiply both the numerator and the denominator by the complex conjugate of the denominator.

$$\frac{V_{out}}{E_{in}} = \frac{1}{1 + j\omega RC} \times \frac{1 - j\omega RC}{1 - j\omega RC}$$

$$= \frac{1 - j\omega RC}{1 - j^2\omega^2 R^2 C^2}$$

$$= \frac{1 - j\omega RC}{1 + \omega^2 R^2 C^2}$$

$$= \frac{1}{1 + \omega^2 R^2 C^2} - j\frac{\omega RC}{1 + \omega^2 R^2 C^2}$$

$$\frac{V_{out}}{E_{in}} = \text{real} + j\ \text{imaginary}$$

Laplace from *s* to ω

$$\text{real} = \frac{1}{1 + \omega^2 R^2 C^2} \qquad \text{imaginary} = \frac{-\omega RC}{1 + \omega^2 R^2 C^2}$$

$$\left|\overline{G}\right| = \text{magnitude} = \sqrt{\text{real}^2 + \text{imaginary}^2}$$

$$= \sqrt{\left(\frac{1}{1 + \omega^2 R^2 C^2}\right)^2 + \left(\frac{\omega RC}{1 + \omega^2 R^2 C^2}\right)^2}$$

$$= \sqrt{\frac{1 + \omega^2 R^2 C^2}{\left(1 + \omega^2 R^2 C^2\right)^2}}$$

$$\left|\overline{G}\right| = \frac{1}{\sqrt{1 + \omega^2 R^2 C^2}}$$

$$\phi = \text{phase shift} = \arctan\left(\frac{\text{imaginary}}{\text{real}}\right)$$

$$= \arctan\left(\frac{\frac{-\omega RC}{1 + \omega^2 R^2 C^2}}{\frac{1}{1 + \omega^2 R^2 C^2}}\right)$$

$$\phi = -\arctan(\omega RC)$$

Frequency response at a glance

$G = \frac{A}{\tau s+1} \Rightarrow s \propto \omega \Rightarrow G \propto \frac{A}{\omega+1}$

As $\omega \Rightarrow 0$ G=>A As $\omega \Rightarrow \infty$ G=> 0 Low pass $A_0 = A$

$G = \frac{A\omega}{\tau s+1} \Rightarrow s \propto \omega \Rightarrow G \propto \frac{A\omega}{\omega+1}$

As $\omega \Rightarrow 0$ G=> $\frac{0}{1} = 0$ As $\omega \Rightarrow \infty$ $\frac{\infty}{\infty+1} = 1$ High pass $A_0 = 1$

$G = \frac{A}{s^2+Bs+C}$ => $s \propto \omega$ => $G \propto$

As ω => 0 G=> As ω => ∞ G=> _____ pass A_0 =

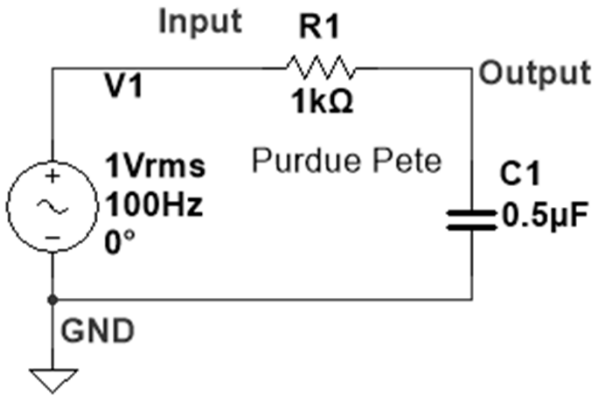
$G = \frac{As^2}{s^2+Bs+C}$ => $s \propto \omega$ => $G \propto$

As ω => 0 G=> As ω => ∞ G=> _____ pass A_0 =

$G = \frac{As}{s^2+Bs+C}$ => $s \propto \omega$ => $G \propto$

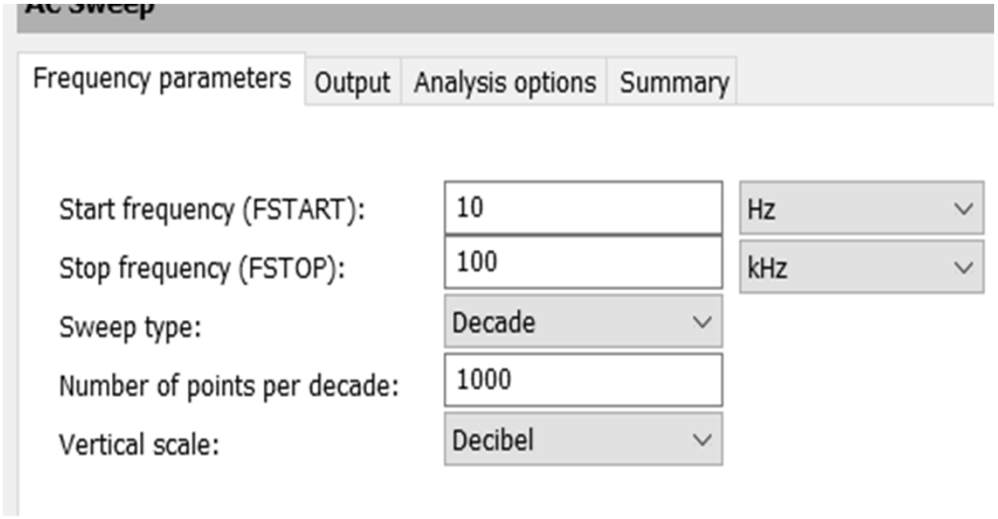
As ω => 0 G=> As ω => ∞ G=> _____ pass A_0 =

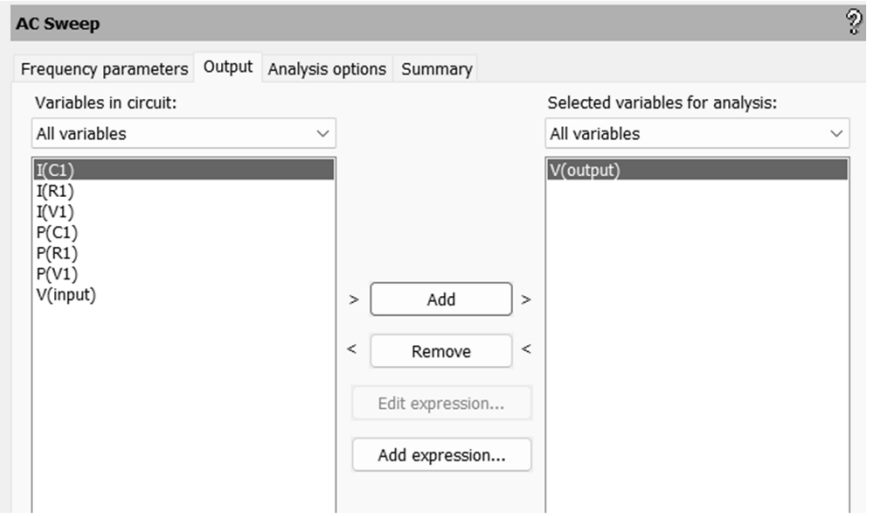
Multisim – AC Sweep



Right click on Output node
Properties/Netname/Show

Simulate/Analysis & Simulations/AC Sweep





Plots and Cursors - Is f_o right?