ELECTRICAL & COMPUTER ENGINEERING
TEXAS A&M UNIVERSITY

Pre-Lab 1: First Order Circuits

Kylan Lewis

UIN: 719001131

ECEN 325 -501

TA: Jian Shao

Date: 8/26/2020

Calculations:

1. **Solution**:

$$H_{LP}(s) = \frac{V_{LP}}{V_i}(s) = K_L \frac{1}{1+\frac{s}{\omega_L}}$$

$$H_{HP}(s) = \frac{V_{HP}}{V_i}(s) = K_H \frac{s}{s+\omega_H}$$

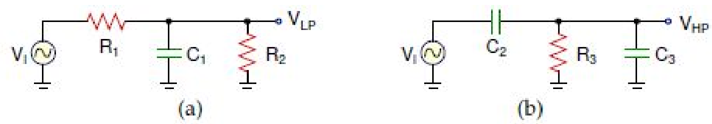


Figure 3: First order (a) lowpass filter (b) highpass filter

A capacitor in the s-domain (Laplace Transform) = $\frac{1}{sC}$

Figure (a): First we take the parallel combination of C_1 & R_2

$$C_1 || R_2 = \frac{\frac{1}{sC_1}\cdot R_2}{\frac{1}{sC_1}+R_2} = \frac{R_2}{1+sC_1R_2}$$

$$Voltage\ Division: V_{LP} = \frac{\left(\frac{1}{sC_1}||R_2\right)\cdot V_i}{\left(\frac{1}{sC_1}||R_2\right)+R_1}$$

$$H_{LP}(s) = \frac{V_{LP}}{V_i} = \frac{\left(\frac{1}{sC_1}||R_2\right)}{\left(\frac{1}{sC_1}||R_2\right)+R_1}$$

$$= \frac{\frac{R_2}{1+sC_1R_2}}{\frac{R_2}{1+sC_1R_2}+R_1} = \frac{R_2}{R_2+R_1\left(1+sC_{1R_2}\right)} = \frac{R_2}{R_2+R_1+sC_1R_1R_2}$$

$$H_{LP}(s) = \frac{R_2}{R_1+R_2}\cdot\frac{1}{1+\dfrac{R_1\cdot R_2\cdot sC_1}{R_1+R_2}}, \quad \left(H_{LP}(S) = K_L\cdot\frac{1}{1+\dfrac{s}{\omega_L}}\right)$$

$$K_L = \frac{R_2}{R_1+R_2}$$

$$\omega_L = \frac{R_1+R_2}{R_1R_2C_1}$$

Figure (b): Taking a KCL at V_{HP} .

$$\frac{V_{HP}(s)-V_i(s)}{\dfrac{1}{sC_2}} + \frac{V_{HP}(s)}{\dfrac{1}{sC_3}} + \frac{V_{HP(s)}}{R_3} = 0, \qquad \frac{R_3\cdot s\left(C_2+C_3\right)+1}{R_3}\cdot V_{HP}(s) = C_2\cdot sV_i(s)$$

$$H_{HP}(s) = \frac{V_{HP}(s)}{V_i(s)} = \frac{R_3\cdot sC_2}{R_3\cdot s\left(C_2+C_3\right)+1}$$

$$= \frac{C_2}{C_2+C_3}\cdot\frac{s}{s+\dfrac{1}{R_3\left(C_2+C_3\right)}}$$

$$K_H = \frac{C_2}{C_2+C_3}$$

$$\omega_H = \frac{1}{R_3\left(C_2+C_3\right)}$$

2. Solution

$f_L = f_L = 5kHz$
$K_L = K_H = 0.5$

$$K_L = 0.5 = \frac{R_2}{R_1 + R_2},$$

$$0.5\,R_1 + 0.5\,R_2 = R_2,$$

$$0.5\,R_1 = 0.5\,R_2,$$

$$R_1 = R_2$$

$$f_L = \frac{\omega_L}{2\pi} = 5\ kHz,$$

$$\omega_L = \frac{R_1 + R_2}{R_1 \cdot R_2 \cdot C_1},$$

$$\frac{\frac{R_1 + R_2}{R_1 \cdot R_2 \cdot C_1}}{2\pi} = 5kHz,$$

$$5kHz \cdot 2\pi = \frac{R_1 + R_2}{R_1 \cdot R_2 \cdot C_1}, \left(\&\ R_1 = R_2\right)$$

$$\frac{1}{R \cdot C_1} = 5kHz \cdot \pi,$$

$$RC_1 = 63.66 \cdot 10^{-6},\ assuming\ C_1\ to\ be\ 1\mu F\ \left(10^{-6}\,F\right)$$

$$R_1 = 63.66\ \Omega$$

$$K_H = 0.5,$$

$$\frac{C_2}{C_2 + C_3} = 0.5,$$

$$\ldots\ C_2 = C_3$$

$$f_H = \frac{\omega_H}{2\pi} = 5kHz,$$

$$\omega_H = \frac{1}{R_3\left(C_2 + C_3\right)},$$

$$\frac{\frac{1}{R_3\left(C_2 + C_3\right)}}{2\pi} = 5kHz, \left(\&\ C_2 = C_3\right)$$

$$\frac{1}{2 \cdot R_3 C_2} = 5kHZ \cdot 2\pi,$$

$$R_3 C =\ assuming\ C_1\ to\ be\ 1\mu F\ \left(10^{-6}\,F\right)$$

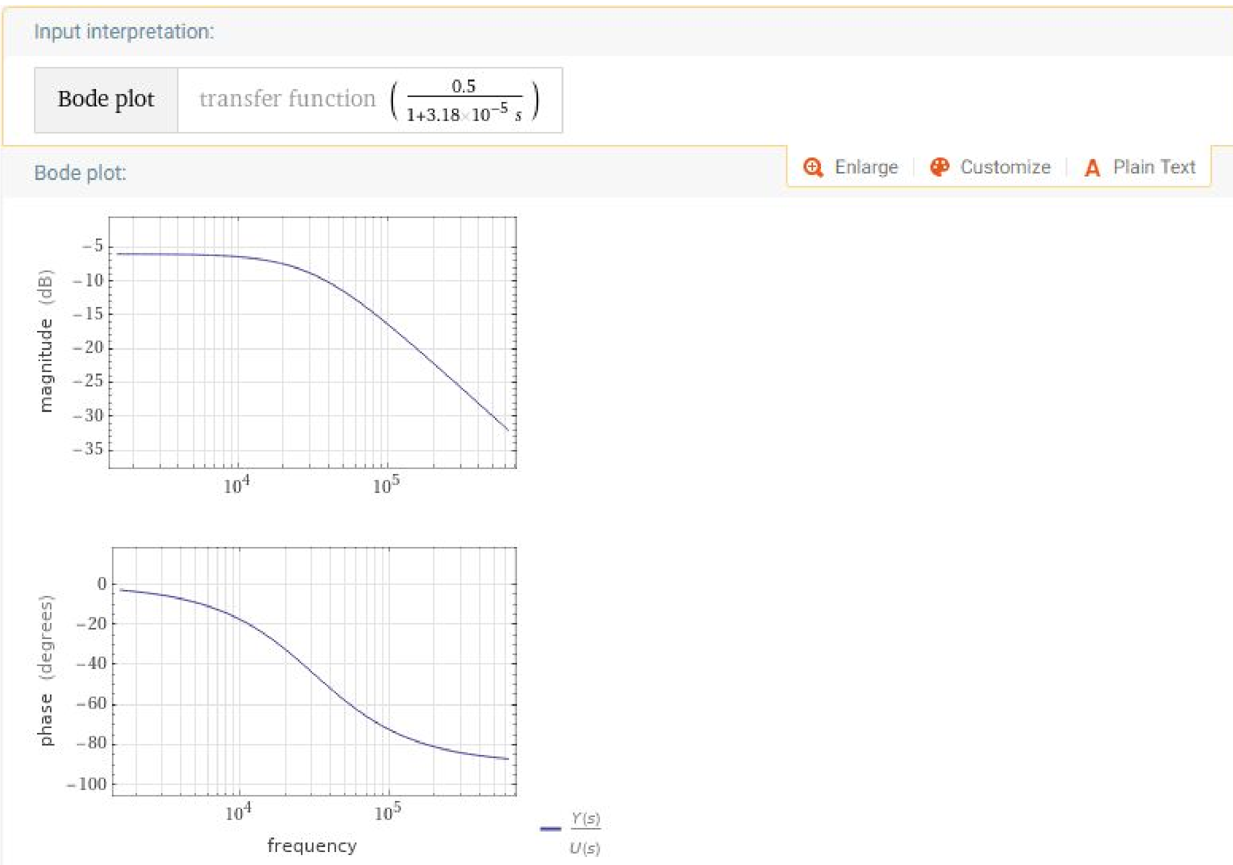
$$R_3 = 15.915\ \Omega$$

Computed values are:
$C_1 = C_2 = C_3 = 1\mu F$
$R_1 = R_2 = 63.66\Omega$
$R_3 = 15.915\ \Omega$

3. Solution:

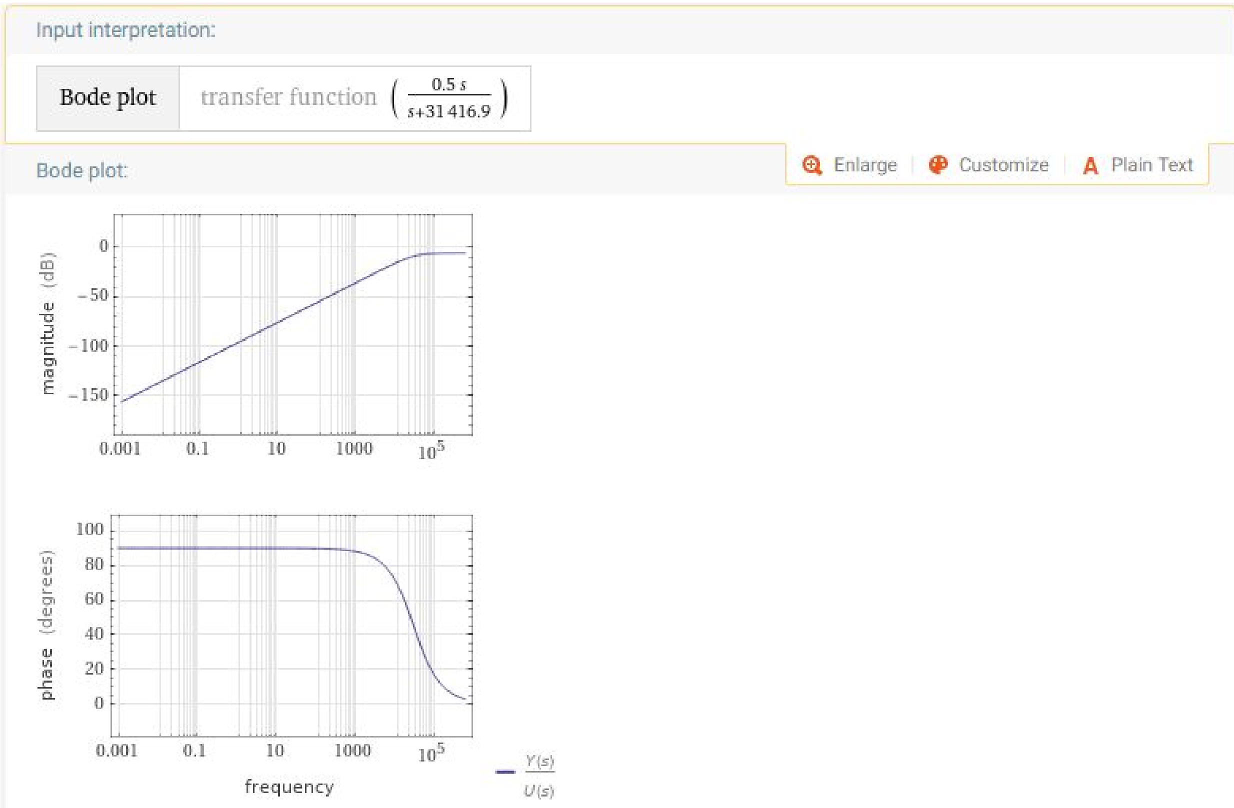
$$H_{LP}(s) = \frac{63.66\Omega}{63.66\Omega + 63.66\Omega} \cdot \frac{1}{1 + \dfrac{s}{\dfrac{63.66\Omega + 63.66\Omega}{(63.66\Omega)\,(63.66\Omega)\,(10^{-6})}}}$$

$$= \frac{0.5}{1 + 3.18 \cdot 10^{-5} \cdot s}$$



$$H_{HP}(s) = \frac{10^{-6}}{10^{-6} + 10^{-6}} \cdot \frac{s}{s + \dfrac{1}{15.915 \cdot \left(10^{-6} + 10^{-6}\right)}}$$

$$= \frac{0.5s}{s + 31416.9}$$



4. Solution

$$\frac{V_{LP}(s)}{V_i(s)} = \frac{15708.5}{s + 31416.9},\ s = j\omega$$

$$V_i(t) = 0.4\sin(2\pi 4000t)\ ;\ \omega = 2\pi \cdot 4000$$

$$V_{LP}(j\omega) = \frac{15708.5}{j(2\pi \cdot 4000) + 31416.9} V_i(j\omega)$$

$$V_{LP}(t) = (0.39044\angle -38.6589) \cdot (0.4\angle 0) =$$

$$V_{LP}(t) = 0.156\sin(2pi \cdot 4000t - 38.6589)\ V$$

$$\frac{V_{HP}(s)}{V_i(s)} = \frac{0.5s}{s + 31416.9},\ s = j\omega$$

$$V_{HP}(j\omega) = \frac{j0.5(2\pi 4000)}{j(2\pi 4000) + 31416.9} V_i(j\omega)$$

$$V_{HP}(t) = (0.312\angle 51.34)(0.4\angle 0)$$

$$V_{HP}(t) = 0.125\sin(2\pi 4000t + 51.34)\ V$$

(* Note that the solution for the low-pass and high-pass output voltages should have a degree symbol in the parentheses to indicate phase shift)

5. **Solution**

$$V_{LP}(j\omega) = \frac{15708.5}{j(2\pi \cdot 6000) + 31416.9} \cdot V_i(j\omega)\ ,$$

$$V_i(t) = 0.3\sin(2\pi \cdot 6000t) = 0.3\angle 0$$

$$V_{LP}(t) = (0.32\angle -50.1936)(0.3\angle 0)$$

$$V_{LP}(t) = 0.96\sin(2\pi \cdot 6000t - 50.1936^\circ)$$

$$V_{HP}(j\omega) = \frac{j0.5(2\pi 6000)}{j(2\pi 6000) + 31416.9} \cdot V_i(j\omega)$$

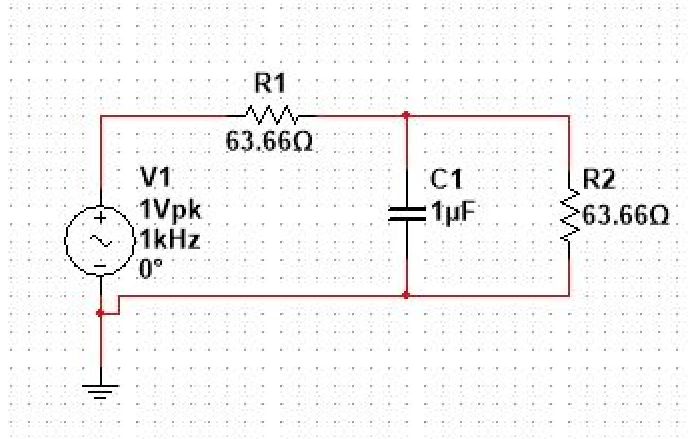
$$= (0.384\angle 39.8)(0.3\angle 0)$$

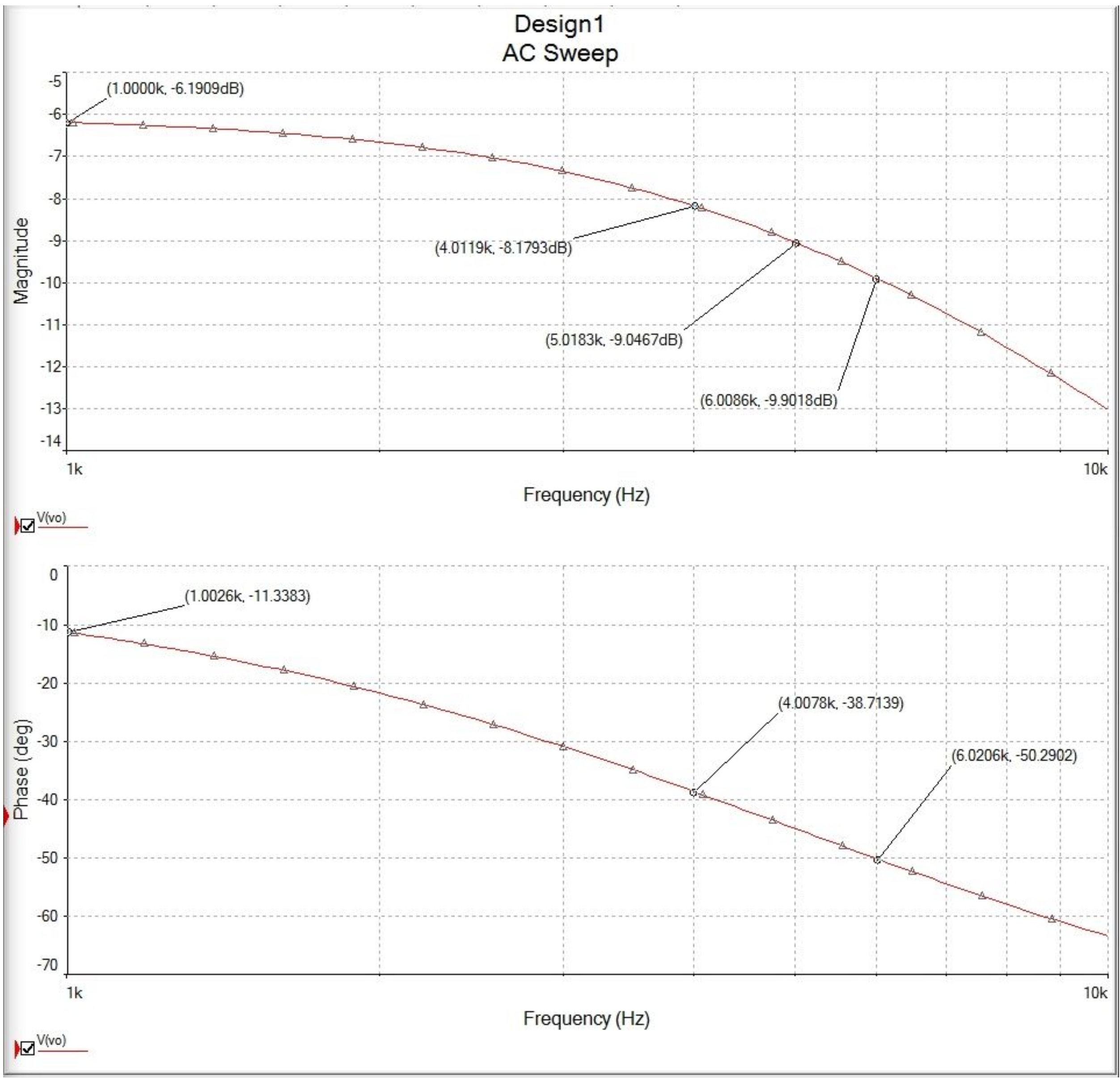
$$= 0.1152\angle 39.8\ V$$

$$V_{HP}(t) = 0.115\sin(2\pi \cdot 4000\mathrm{t} + 39.8^\circ)\ V$$

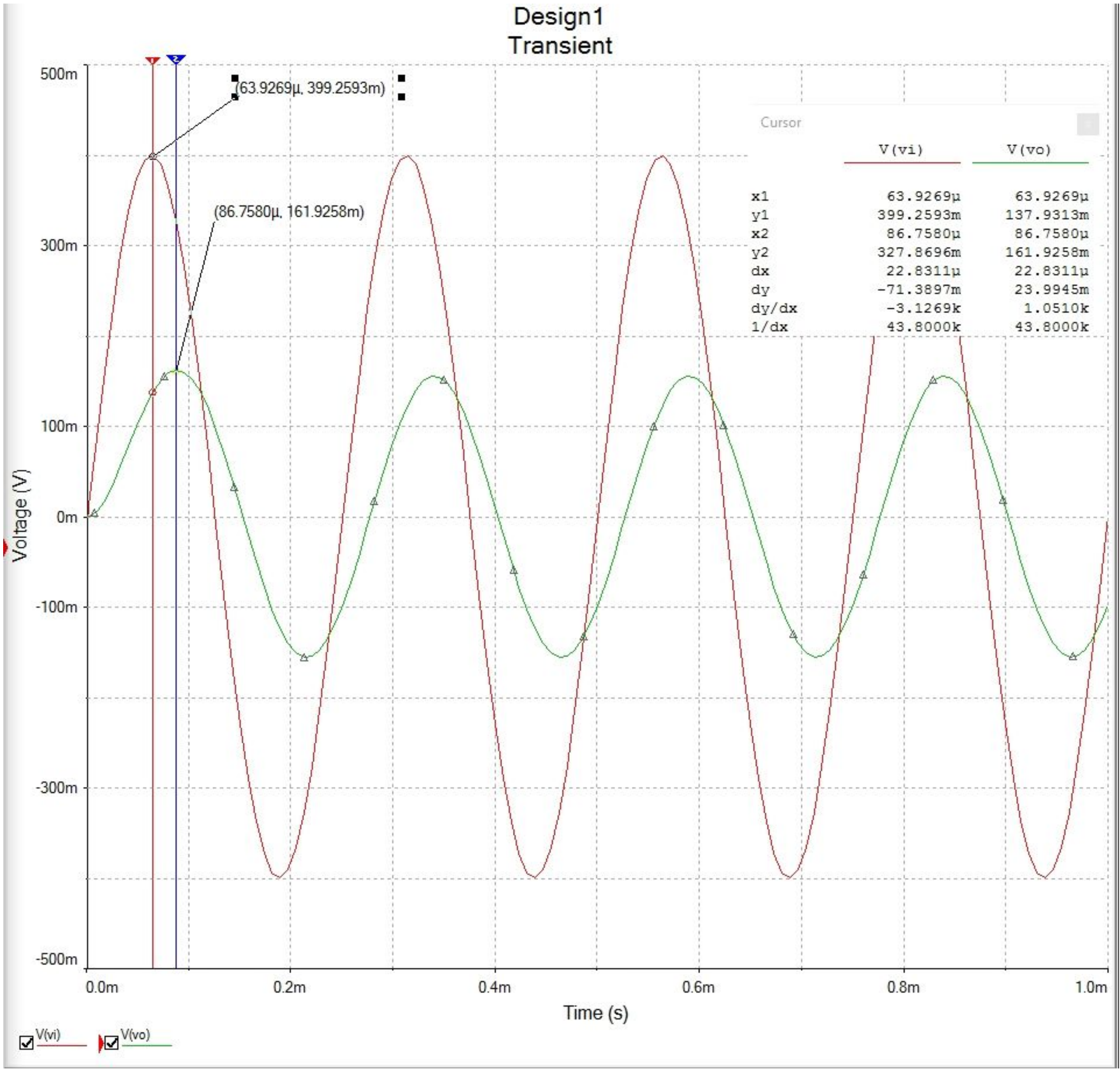
Kylan Lewis (719001131)

Multisim:

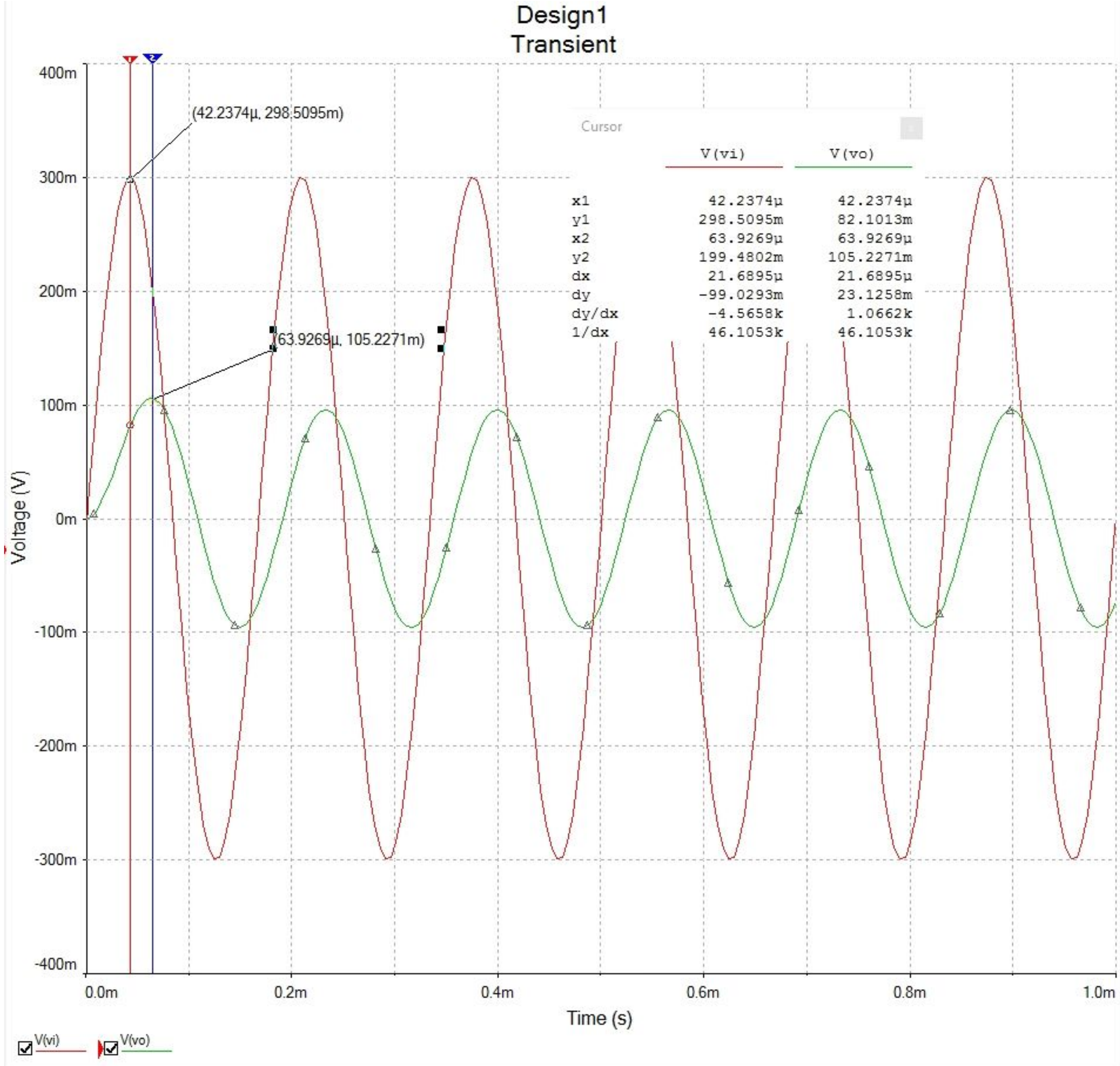




Kylan Lewis (719001131)

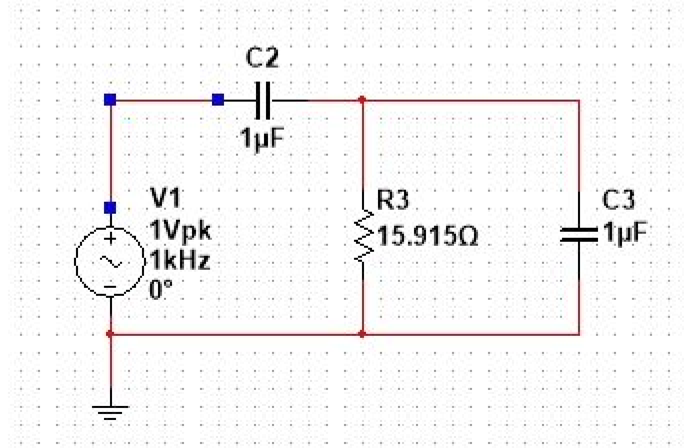


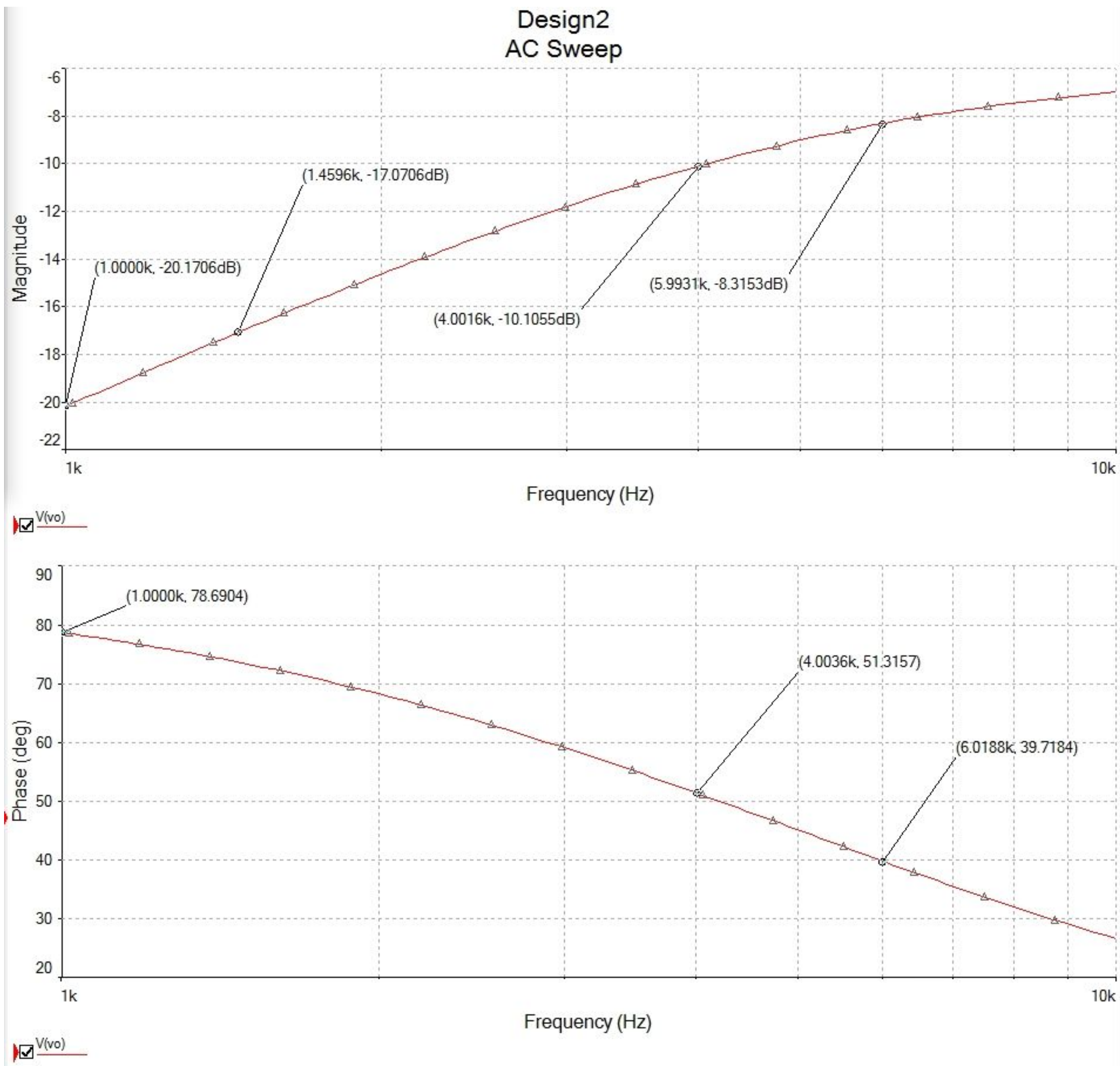
Transient for Vi (t) = 0.4 sin(24000t)



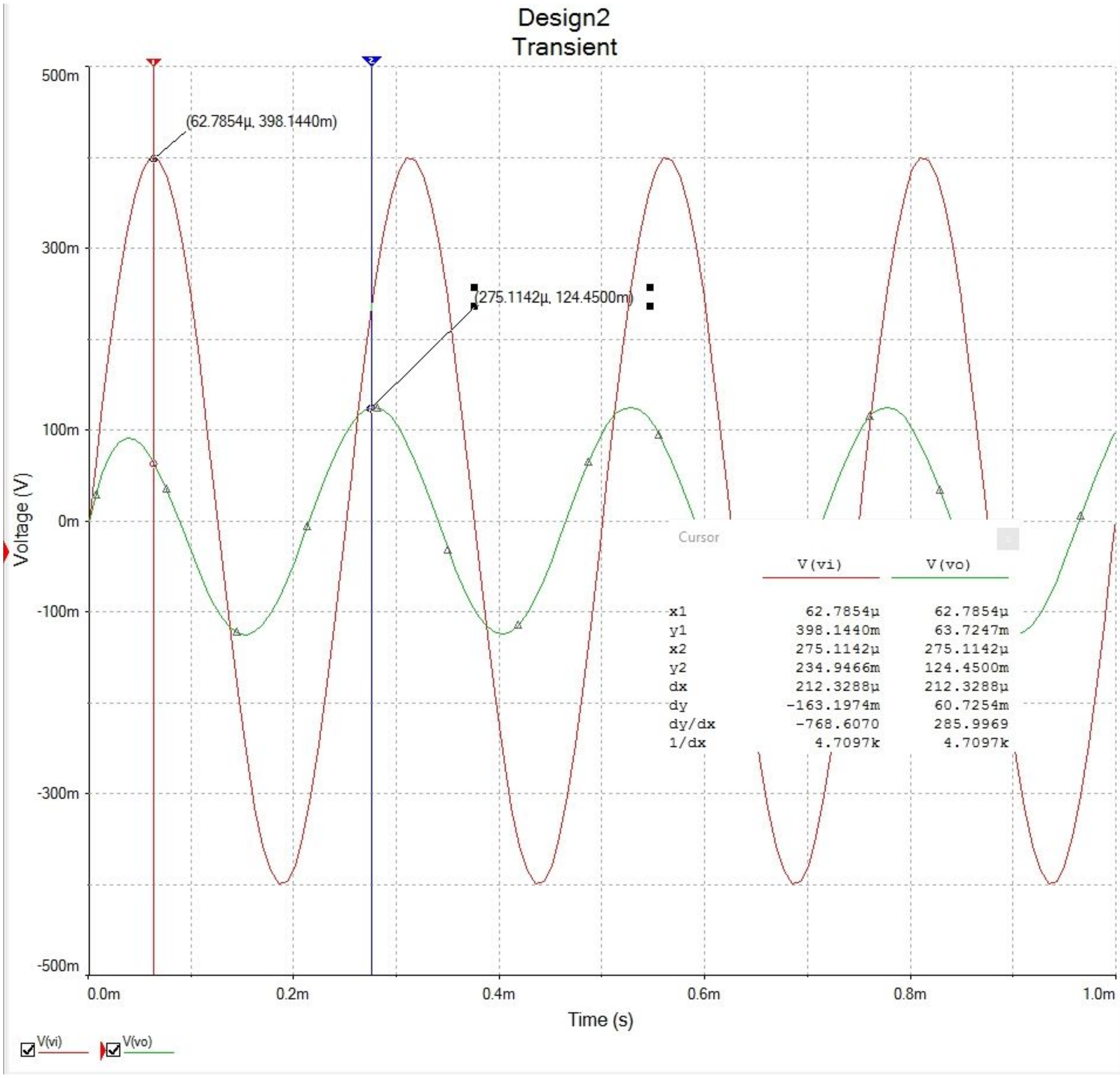
Transient for Vi (t) = 0.3 sin(26000t).

Kylan Lewis (719001131)

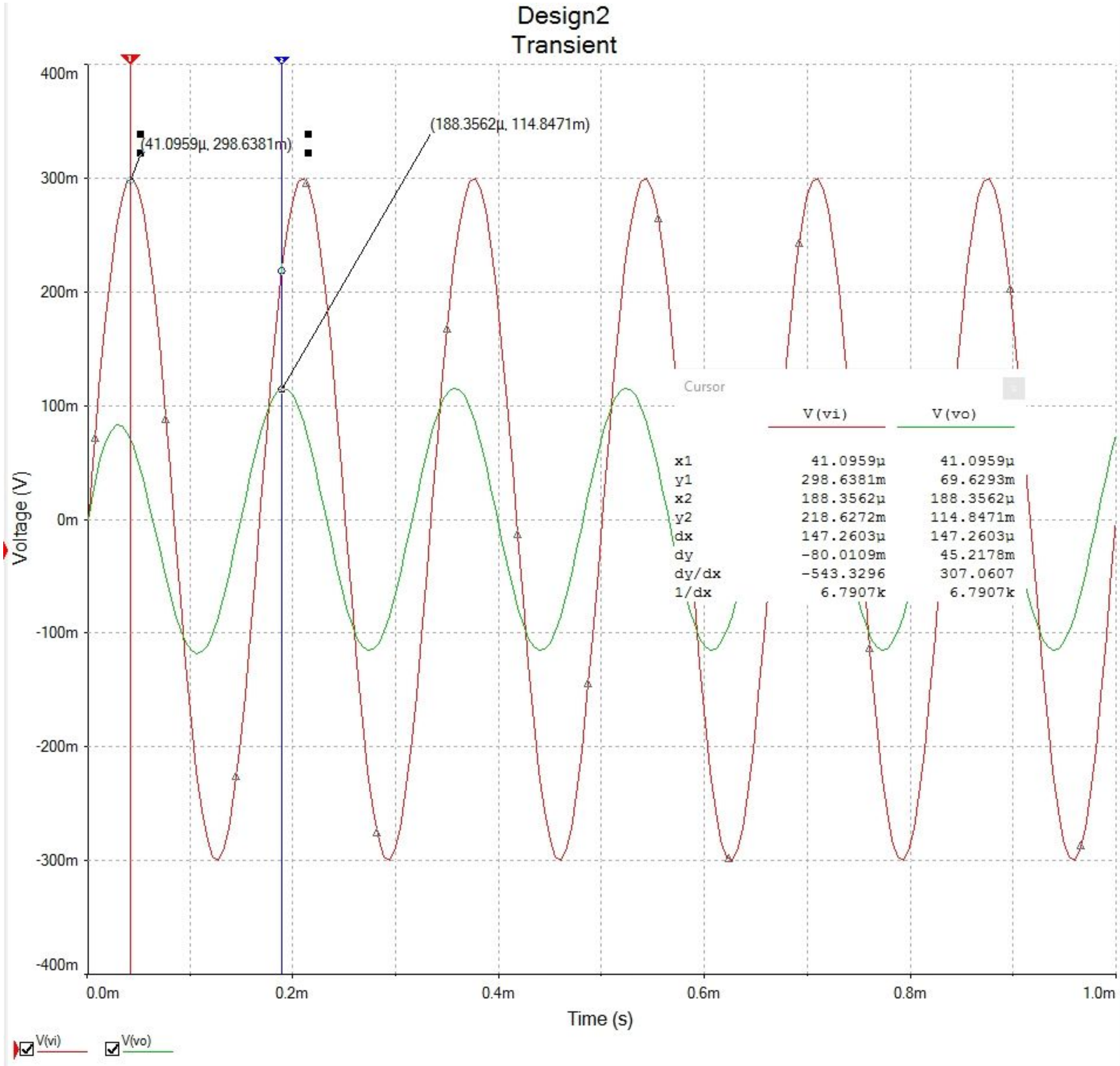




Kylan Lewis (719001131)



Transient for Vi (t) = 0.4 sin(24000t)



Transient for Vi (t) = 0.3 sin(26000t).