<table>
<tr><th></th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th><th>G</th><th>H</th><th>I</th></tr>
<tr><td>1</td><td>Xi Kun Zou</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Friday</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>PART 1.1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>V</td><td>C</td><td>R</td><td>w</td><td>Frequency</td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>=1</td><td>0.00000001</td><td>1000</td><td>=E6*2*PI()</td><td>10000</td><td></td><td></td><td></td><td></td></tr>
<tr><td>7</td><td></td><td></td><td>2000</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>11</td><td>1/wCR</td><td>Phase Angle</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>12</td><td>=1/(D$6*B$6*C6)</td><td>=(ATAN(A12))*(180/PI())</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>13</td><td>=1/(D$6*B$6*C7)</td><td>=(ATAN(A13))*(180/PI())</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>14</td><td>=1/(D$6*B$6*C8)</td><td>=(ATAN(A14))*(180/PI())</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>15</td><td>=1/(D$6*B$6*C9)</td><td>=(ATAN(A15))*(180/PI())</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>16</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>17</td><td>1.2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>18</td><td>Frequency</td><td>w</td><td>wCR</td><td>Vout</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>19</td><td>1000</td><td>=A19*2*PI()</td><td>=B19*B$6*1000</td><td>=(C19/(SQRT((C19)^2+1)))</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>20</td><td>10000</td><td>=A20*2*PI()</td><td>=B20*B$6*1000</td><td>=(C20/(SQRT((C20)^2+1)))</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>21</td><td>100000</td><td>=A21*2*PI()</td><td>=B21*B$6*1000</td><td>=(C21/(SQRT((C21)^2+1)))</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>22</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>23</td><td>1.3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>24</td><td>R</td><td>Frequency</td><td>C</td><td>W</td><td>|N|</td><td>|D|</td><td>Phase Angle|N|</td><td>Phase Angle (D)</td><td>Phase Difference</td></tr>
<tr><td>25</td><td>1000</td><td>10000</td><td>0.00000001</td><td>=B25*2*PI()</td><td>1</td><td>=SQRT((D$25*C$25*A25)^2+1)</td><td>=0</td><td>=(ATAN((D$25*C$25*A25)/1))*(180/PI())</td><td>=G25-H25</td></tr>
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<tr><td>31</td><td>R</td><td>Frequency</td><td>C</td><td>w</td><td>|N|</td><td>|D|</td><td>Vout</td><td></td><td></td></tr>
<tr><td>32</td><td>1000</td><td>1000</td><td>0.00000001</td><td>=B32*2*PI()</td><td>1</td><td>=SQRT((D32*C$32*A$32)^2+1)</td><td>=E32/F32</td><td></td><td></td></tr>
<tr><td>33</td><td></td><td>10000</td><td></td><td>=B33*2*PI()</td><td>1</td><td>=SQRT((D33*C$32*A$32)^2+1)</td><td>=E33/F33</td><td></td><td></td></tr>
<tr><td>34</td><td></td><td>100000</td><td></td><td>=B34*2*PI()</td><td>1</td><td>=SQRT((D34*C$32*A$32)^2+1)</td><td>=E34/F34</td><td></td><td></td></tr>
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<tr><td>37</td><td>R</td><td>Frequency</td><td>L</td><td>w</td><td>|N|</td><td>|D|</td><td>Vout</td><td></td><td></td></tr>
<tr><td>38</td><td>1000</td><td>1000</td><td>0.047</td><td>=B38*2*PI()</td><td>=D38*C$38</td><td>=SQRT((A$38^2)+(D38*C$38)^2)</td><td>=E38/F38</td><td></td><td></td></tr>
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<tr><td>40</td><td></td><td>100000</td><td></td><td>=B40*2*PI()</td><td>=D40*C$38</td><td>=SQRT((A$38^2)+(D40*C$38)^2)</td><td>=E40/F40</td><td></td><td></td></tr>
<tr><td>41</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>43</td><td>R</td><td>Frequency</td><td>L</td><td>w</td><td>|N|</td><td>|D|</td><td>Vout</td><td></td><td></td></tr>
<tr><td>44</td><td>1000</td><td>1000</td><td>0.047</td><td>=B44*2*PI()</td><td>=A$44</td><td>=SQRT((A$44)^2+(D44*C$44)^2)</td><td>=E44/F44</td><td></td><td></td></tr>
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<tr><td>46</td><td></td><td>100000</td><td></td><td>=B46*2*PI()</td><td>=A$44</td><td>=SQRT((A$44)^2+(D46*C$44)^2)</td><td>=E46/F46</td><td></td><td></td></tr>
<tr><td>47</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>48</td><td>PART 3.2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>49</td><td>Frequency</td><td>R</td><td>L</td><td>C</td><td>w</td><td>|N|</td><td>|D|</td><td>Phase Angle(N)</td><td>Phase Angle(D)</td></tr>
<tr><td>50</td><td>5000</td><td>270</td><td>0.047</td><td>0.00000001</td><td>=A$50*2*PI()</td><td>=B$50</td><td>=SQRT((B$50^2)+((E$50*C$50)-(1/(E$50*D$50)))^2)</td><td>=ATAN(0/270)</td><td>=(ATAN(((E$50*C$50)-(1/(E$50*D$50)))/B$50))*(180/PI())</td></tr>
<tr><td>51</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>52</td><td>3.3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>53</td><td>Frequency</td><td>R</td><td>L</td><td>C</td><td>w</td><td>|N|</td><td>|D|</td><td>Phase Angle(N)</td><td>Phase Angle(D)</td></tr>
<tr><td>54</td><td>5000</td><td>270</td><td>0.047</td><td>=0.047*10^-6</td><td>=A$54*2*PI()</td><td>=B$54</td><td>=SQRT((B$54^2)+((E$54*C$54)-(1/(E$54*D$54)))^2)</td><td>=ATAN(0/B$54)</td><td>=(ATAN(((E$54*C$54)-(1/(E$54*D$54)))/B$54))*(180/PI())</td></tr>
<tr><td>55</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>56</td><td>PART 4</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>57</td><td>Frequency</td><td>R</td><td>c</td><td>w</td><td>|N|</td><td>|D|</td><td>Phase Angle(N)</td><td>Phase Angle(D)</td><td></td></tr>
<tr><td>58</td><td>10000</td><td>910</td><td>=1*10^-8</td><td>=A$58*2*PI()</td><td>=1</td><td>=SQRT((E$58)^2+1)</td><td>=ATAN(0/1)</td><td>=(ATAN(D$58*C$58*B$58/1))*(180/PI())</td><td></td></tr>
<tr><td>59</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>60</td><td>PART 5.1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>61</td><td>Vo/Vi</td><td>phase</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>62</td><td>3</td><td>0</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>64</td><td>C</td><td>R</td><td>1/wC</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>65</td><td>0.00000001</td><td>100000</td><td>=1/(10000*2*PI()*A65)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>66</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>67</td><td>R</td><td>|N|</td><td>|D|</td><td>Vout/Vin</td><td>Phase Angle(N)</td><td>Phase Angle(D)</td><td>Phase Difference</td><td></td><td></td></tr>
<tr><td>68</td><td>1000</td><td>=SQRT((B$65*C$65^2)^2+(B65^2*C65)^2)</td><td>=(B65^2+C65^2)*A68</td><td>=1+B68/C68</td><td>=DEGREES(ATAN2(B</td><td>=DEGREES(ATAN2(C68,0))</td><td>=E68-F68</td><td></td><td></td></tr>
<tr><td>69</td><td>2000</td><td>=SQRT((B$65*C$65^2)^2+(B65^2*C65)^2)</td><td>=(B65^2+C65^2)*A69</td><td>=1+B69/C69</td><td>=DEGREES(ATAN2(B</td><td>=DEGREES(ATAN2(C69,0))</td><td>=E69-F69</td><td></td><td></td></tr>
<tr><td>70</td><td>5600</td><td>=SQRT((B$65*C$65^2)^2+(B65^2*C65)^2)</td><td>=(B65^2+C65^2)*A70</td><td>=1+B70/C70</td><td>=DEGREES(ATAN2(B</td><td>=DEGREES(ATAN2(C70,0))</td><td>=E70-F70</td><td></td><td></td></tr>
<tr><td>71</td><td>10000</td><td>=SQRT((B$65*C$65^2)^2+(B65^2*C65)^2)</td><td>=(B65^2+C65^2)*A71</td><td>=1+B71/C71</td><td>=DEGREES(ATAN2(B</td><td>=DEGREES(ATAN2(C71,0))</td><td>=E71-F71</td><td></td><td></td></tr>
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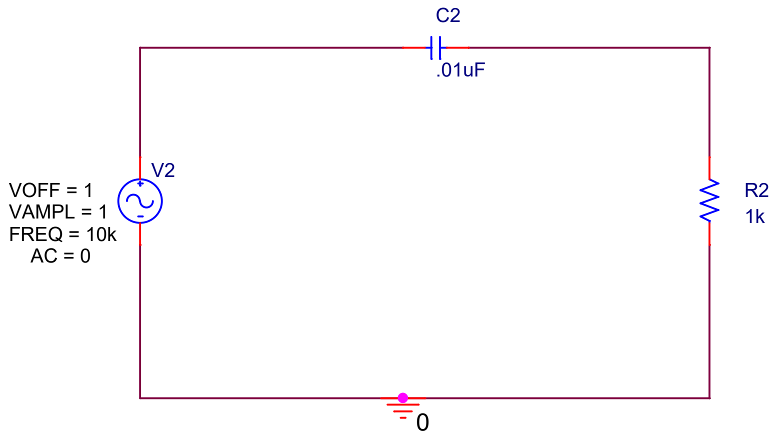
	A	B	C	D	E	F	G	H	I
1	Xi Kun Zou								
2	Friday								
3									
4	PART 1.1								
5	V	C	R	w	Frequency				
6	1	1.00E-08	1000	62831.8531	10000				
7			2000						
8			5600						
9			10000						
10									
11	1/wCR	Phase Differrence							
12	1.59E+00	57.85809236							
13	7.96E-01	38.51188725							
14	2.84E-01	15.86542838							
15	1.59E-01	9.043061079							
16									
17	1.2								
18	Frequency	w	wCR	Vout					
19	1000	6283.185307	6.28E-02	0.06270819					
20	10000	62831.85307	6.28E-01	0.53201804					
21	100000	628318.5307	6.28E+00	0.98757049					
22									
23	1.3								
24	R	Frequency	C	W	|N|	|D|	Phase Angle|N|	Phase Angle (D)	Phase Difference
25	1000	10000	1.00E-08	6.28E+04	1	1.181009812	0	32.14190764	-32.14190764
26	2000				1	1.605969086	0	51.48811275	-51.48811275
27	5600				1	3.657927249	0	74.13457162	-74.13457162
28	10000				1	6.362265132	0	80.95693892	-80.95693892
29									
30	1.4								
31	R	Frequency	C	w	|N|	|D|	Vout		
32	1000	1000	1.00E-08	6283.18531	1	1.001971977	0.998031905		
33		10000		62831.8531	1	1.181009812	0.846733016		
34		100000		628318.531	1	6.362265132	0.157176725		
35									
36	PART 2.1								
37	R	Frequency	L	w	|N|	|D|	Vout		
38	1000	1000	0.047	6283.18531	295.3097094	1042.692584	0.283218385		
39		10000		62831.8531	2953.097094	3117.816936	0.947168212		
40		100000		628318.531	29530.97094	29547.89747	0.99942715		
41									
42	2.2								
43	R	Frequency	L	w	|N|	|D|	Vout		
44	1000	1000	0.047	6283.18531	1000	1042.692584	0.959055445		
45		10000		62831.8531	1000	3117.816936	0.32073724		
46		100000		628318.531	1000	29547.89747	0.033843356		
47									
48	PART 3.2								
49	Frequency	R	L	C	w	|N|	|D|	Phase Angle(N)	Phase Angle(D)
50	5000	270	0.047	1.00E-08	31415.92654	270	1727.777178	0	-81.00953174
51									
52	3.3								
53	Frequency	R	L	C	w	|N|	|D|	Phase Angle(N)	Phase Angle(D)
54	5000	270	0.047	4.7E-08	31415.92654	270	843.6646558	0	71.33511745
55									
56	PART 4								
57	Frequency	R	c	w	|N|	|D|	Phase Angle(N)	Phase Angle(D)	
58	10000	910	0.00000001	62831.8531	1	1.414213562	0	29.75962026	
59									
60	PART 5.1								
61	Vo/Vi	phase							
62	3	0							
63	5.2								
64	C	R	1/wC						
65	1E-08	100000	1591.54943						
66									
67	R	|N|	|D|	Vout/Vin	Phase Angle(N)	Phase Angle(D)	Phase Difference		
68	1000	1.59175E+13	1.0003E+13	2.5913479	57.20254411	0	57.20254411		
69	2000	1.59175E+13	2.0005E+13	1.79567395	38.15408643	0	38.15408643		
70	5600	1.59175E+13	5.6014E+13	1.28416927	15.79377756	0	15.79377756		

	A	B	C	D	E	F	G	H	I
71	10000	1.59175E+13	1.0003E+14	1.15913479	9.018347633	0	9.018347633		



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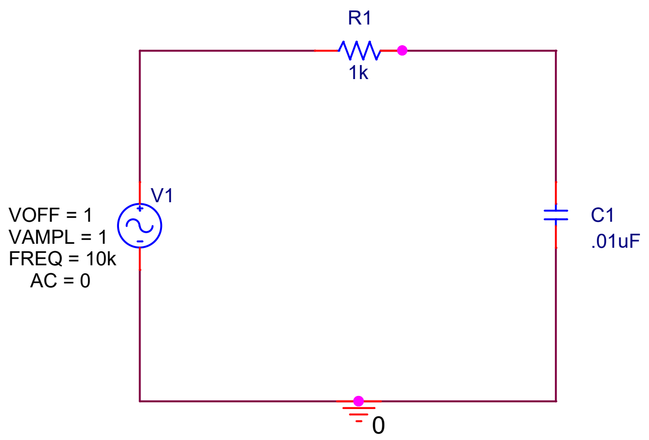

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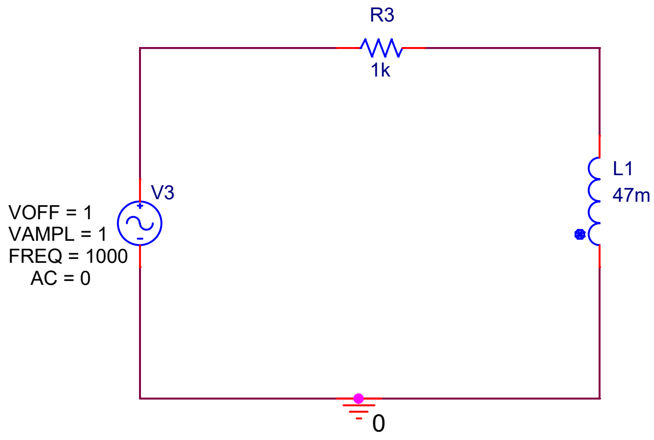

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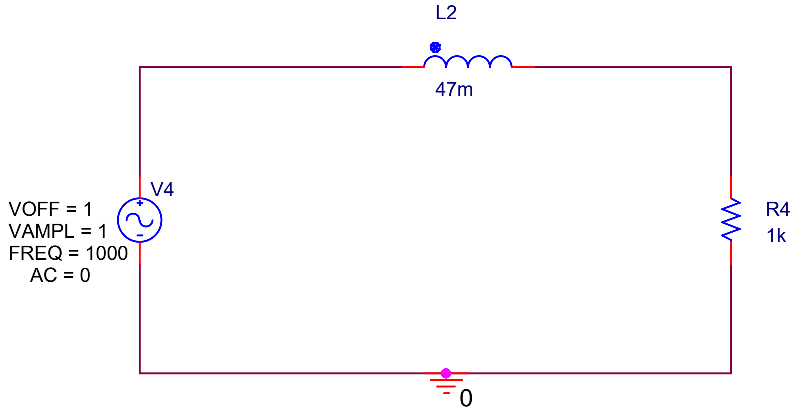

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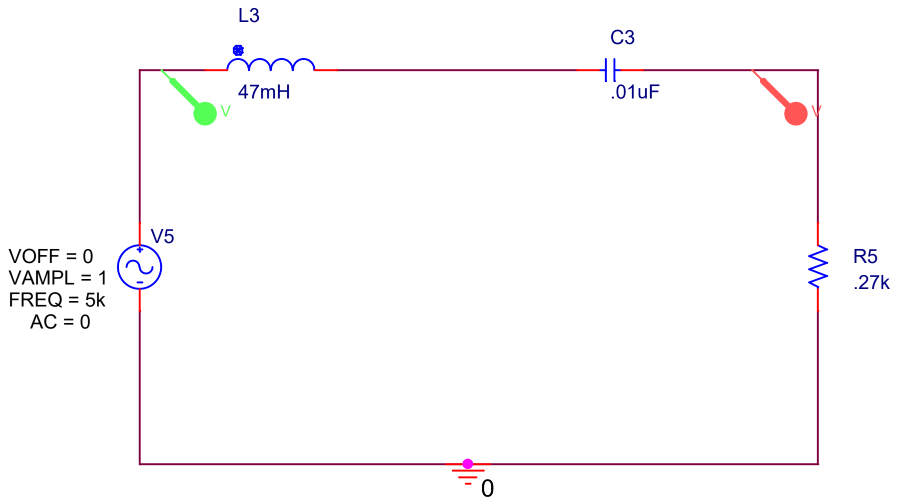

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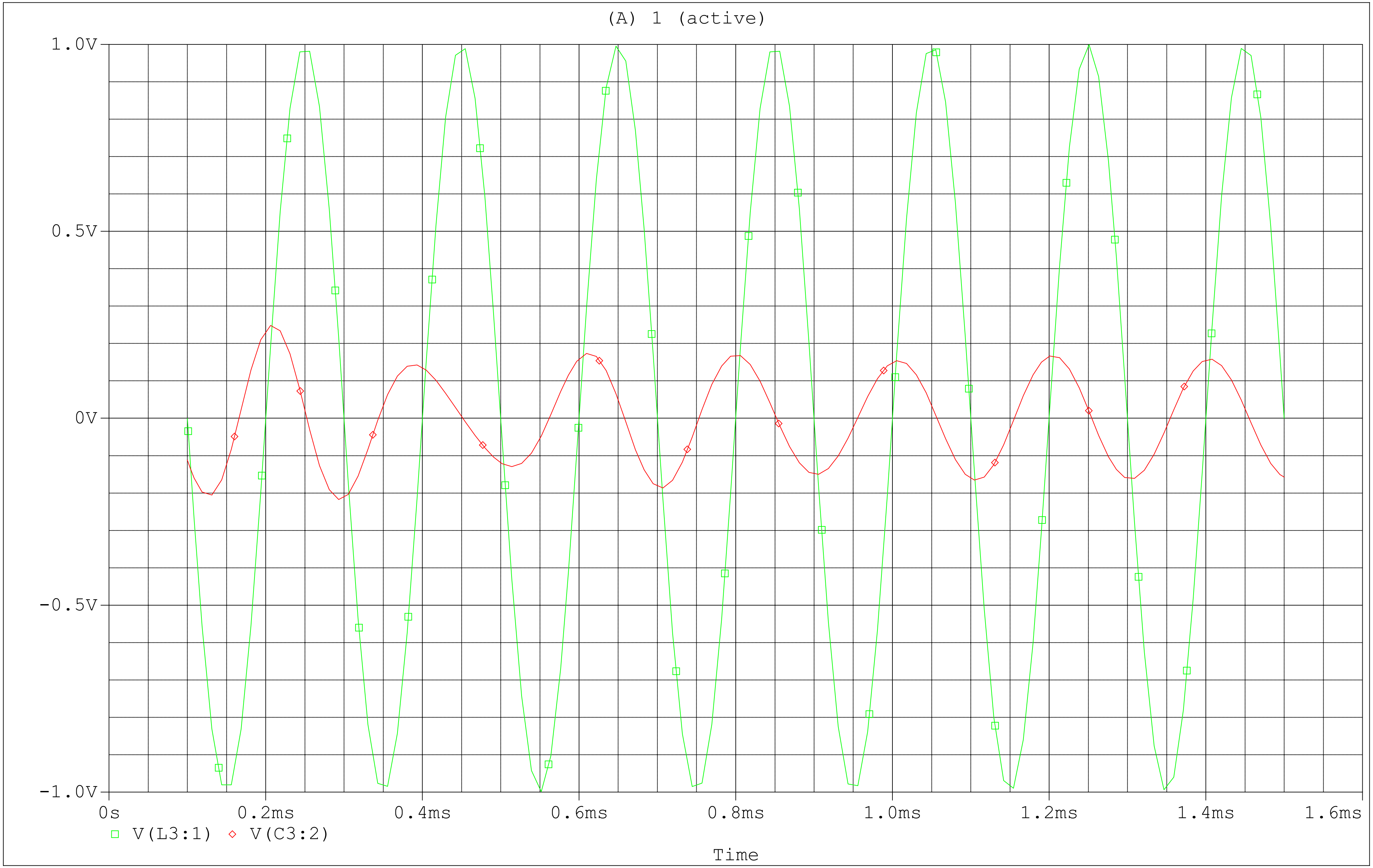
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0.5V
0V
-0.5V
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0s
0.2ms
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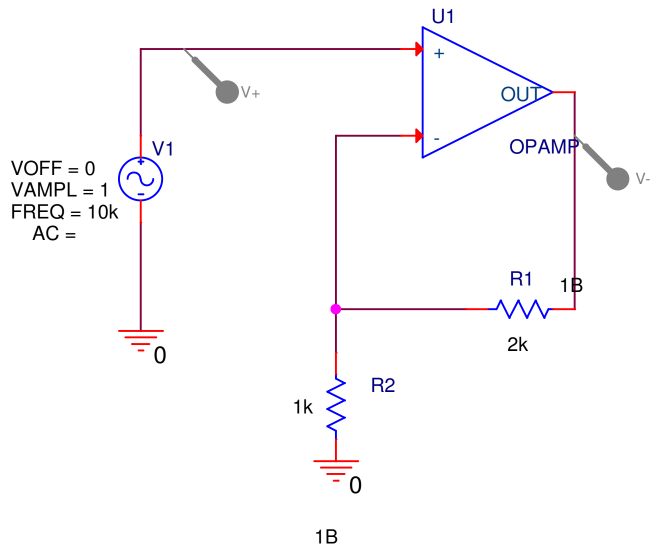
V(L3:1) V(C3:2)
Time



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X ikun zou

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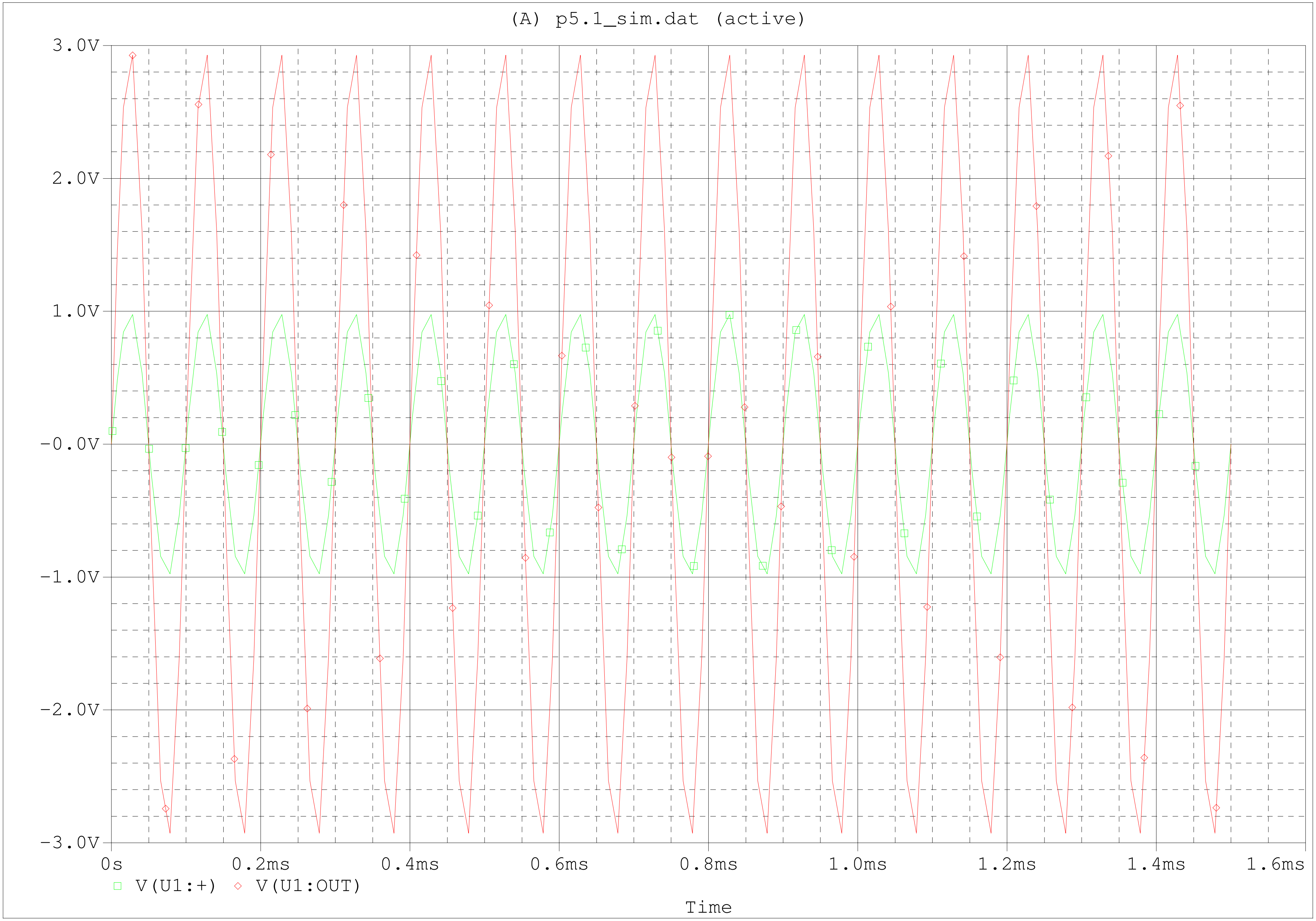

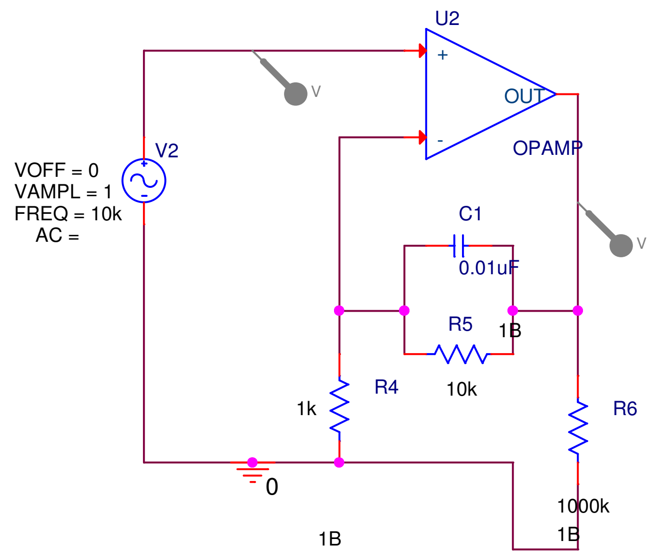

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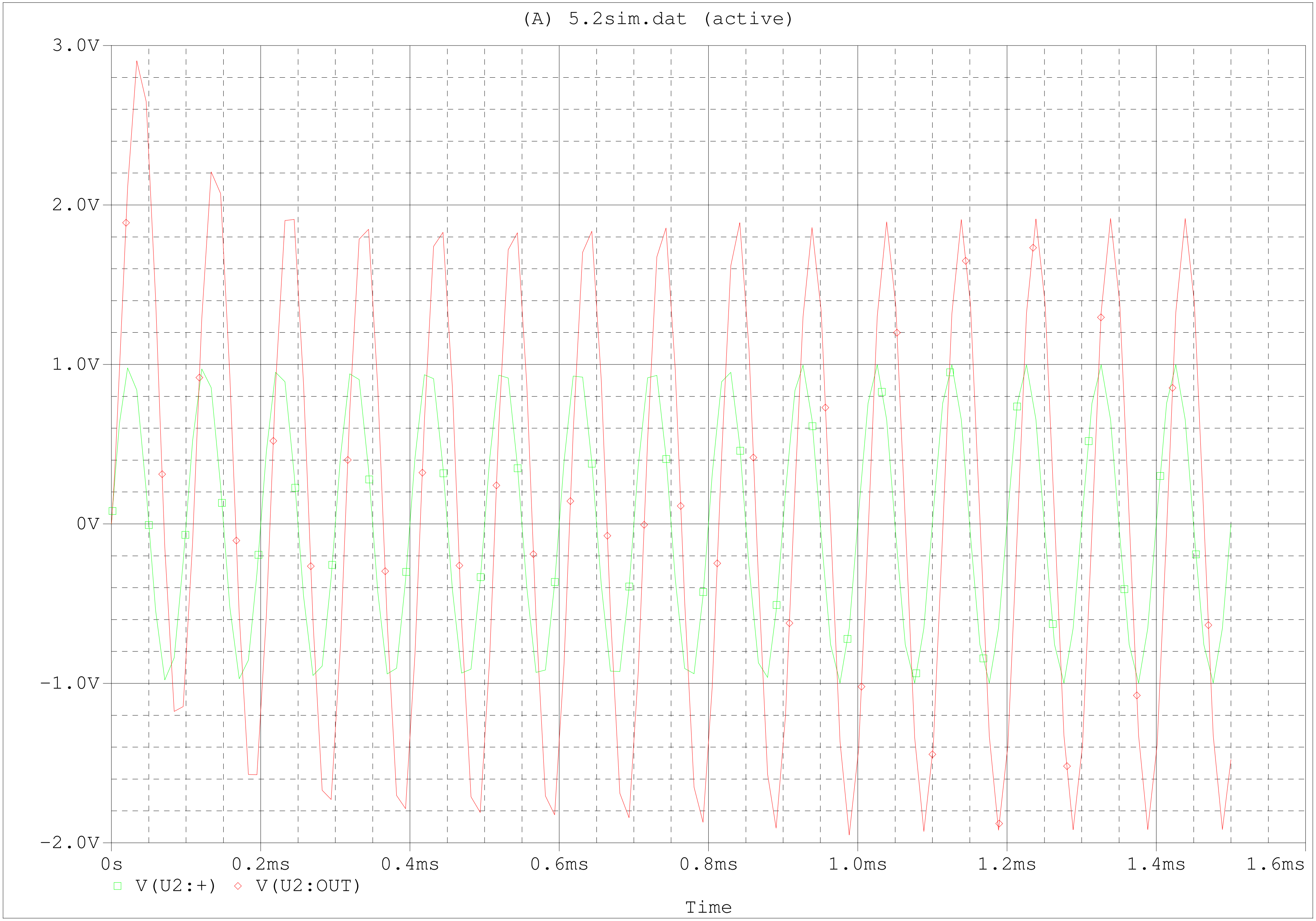

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Circuit Analysis II Group A / B Meng Ling Shit

Lab 2: Gain and Phase Measurements of RC, RL, and RLC Networks

Objectives

In this lab exercise you will analyze and measure the phase and amplitude relationships of input voltages and responses in circuits comprised of resistors, capacitors, and inductors. An op-amp with a capacitor in the feedback loop will also be analyzed and measured. Prior to performing the lab, you will analyze each circuit by hand and check your results using PSpice.

The purpose of the pre-lab work is to make sure you understand how each circuit works and what results to expect when you make measurements in the lab. This should allow you to spend nearly all of your time in the lab building circuits and making measurements. If you know what results to expect, you will know when you have done each experiment correctly. If your hand calculations and PSpice results agree, you will know that your pre-lab work is correct.

Pre-Lab Instructions (10pts)

Calculations and comparisons

1. Using circuit analysis techniques such as nodal analysis and/or voltage dividers with phasors, calculate the theoretical gains and phase relationships asked for in each part of this lab (see the Appendix A for an example). **All calculations should be shown on a separate sheet to be handed in**; that is, your results should **not** be recorded in the spaces designated throughout this assignment until you are in lab (or just before lab) and comparing your prelab results with those of your lab partner. You must use Excel to speed up these hand calculations. In other words, program each formula once, then copy the formula in Excel and change R or the frequency to compute the other required answers. Also, note that you must hand in the sheet of results and the sheet of formulas using the <ctrl-backquote/tilde> key (above the <tab> key).

Excel

2. Verify every hand calculation by simulating each circuit in PSpice using the given parameters. (See Appendix B for some tips on how to use PSpice efficiently.) Record the simulated results in the appropriate spaces. Specifically, you should add a column in your spreadsheet to record the simulated results. The hand calculations and simulated results should be the same (typically within 1%) and will be used when looking at the actual circuit measurements made in the lab. The schematic for every circuit needs to be printed out. If a parameter of a circuit is varied (for example, the value of a resistor changes), only print the circuit once for its initial parameters. In addition, print out the input/output waveforms for part 4 and part 5.2, as well as the circuit schematics for part 5.2. Attach these printouts to the lab. In the interest of saving paper, you may print more than one circuit schematic per page. **(NOTE: Your name must appear in the filename of all circuit and waveform printouts!)**

3. After both you and your lab partner have completed parts 1 and 2 above, compare answers, determine what the best answers are, and fill in the appropriate parts of the table for one copy of the In-Lab portion. (Only one copy needs to be handed in.) NOTE: All questions asked in this lab should be answered while actually doing the lab, after you have built the corresponding circuits and made measurements. In other words, you should not answer them before going to lab!

In-Lab Instructions (15pts)

Part One: RC Networks

1. Assume $v_i(t) = \cos(\omega t)$ in the circuit in Figure 1, such that $f = \omega/(2\pi) = 10\text{kHz}$. Measure the phase shift in degrees between v_i and v_o for the following values of R in the RC network shown in Figure 1.

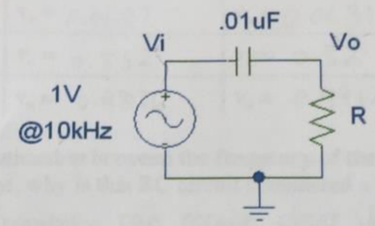

Figure 1: First RC Network

Value of R (Ω)	Hand Calculation	PSpice Simulation	Circuit Measurement	
R = 1k	φ = 57.86	φ = 55.98	φ = 57.6	Δ1.6
R = 2k	φ = 38.52	φ = 36.61	φ = 39.6	Δ1
R = 5.6k	φ = 15.87	φ = 15.72	φ = 14.4	Δ4
R = 10k	φ = 9.04	φ = 9.12	φ = 10.8	Δ3

To calculate phase shift on the oscilloscope, display both waveforms on the screen. Then press the "Cursor" button, set the "Type" to "Time," and adjust the two position knobs until one vertical cursor intersects the peak of the waveform of CH1 and the other cursor intersects the peak of the waveform of CH2. If you can't see the vertical cursor, adjust the knob until the cursor appears. The oscilloscope should show the time difference between these two peaks. Multiplying this time by the frequency (f, in Hz) of the signal and then again by 360 will give the phase shift in degrees.

Phase shift (degrees): $\varphi = t_{p\text{-}p} * f * 360$

Does v_o lead or lag v_i? (Circle one.) lead / lag

2. Using a 1kΩ resistor for R, record the amplitude (1/2 the peak to peak) of the output voltage for the following three input voltage frequencies. (The amplitude of the input voltage should remain at 1V peak, i.e. 2V peak to peak)

Frequency	Hand Calculation	PSpice Simulation	Circuit Measurement
1kHz	v_o = 0.0627	v_o = 0.0631	v_o = 0.072
10kHz	v_o = 0.532	v_o = 0.52	v_o = 0.526
100kHz	v_o = 0.9876	v_o = 0.9912	v_o = 0.98

Based on the relationship between the frequency of the input voltage and the amplitude of the output voltage, why is this RC circuit considered a "high-pass" filter?

High Frequency can receive closer Vout to Vin, while lower frenquency cause low Vout
1V

3. In the circuit in Figure 2, again assume that $v_i(t) = \cos(\omega t)$, such that $f = \omega/(2\pi)$ = 10kHz. Measure the phase shift between v_i and v_o for the following values of R in the RC network shown in Figure 2.

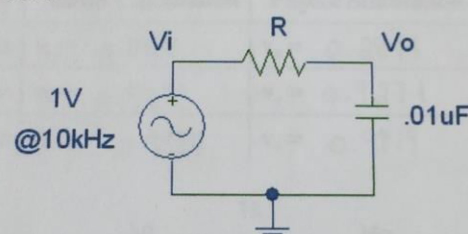

Figure 2: Second RC Network

Value of R (Ω)	Hand Calculation	PSpice Simulation	Circuit Measurement
R = 1k	φ = -32.142	φ = -31.15	φ = -32.4
R = 2k	φ = -51.488	φ = -52.73	φ = -50.4
R = 5.6k	φ = -74.135	φ = -80.12	φ = -75.6
R = 10k	φ = -80.957	φ = -80.3	φ = -79.2

Does v_o lead or lag v_i? (Circle one.) lead / lag

4. Using a 1kΩ resistor for R, record the output voltage for the following three input voltage frequencies. (The amplitude of the input voltage should remain at 1V peak.)

Frequency	Hand Calculation	PSpice Simulation	Circuit Measurement
1kHz	v_o = 0.99803	v_o = 0.912	v_o = 1.02
10kHz	v_o = 0.8467	v_o = 0.736	v_o = 0.92
100kHz	v_o = 0.1572	v_o = 0.156	v_o = 0.162

Based on the relationship between the frequency of the input voltage and the amplitude of the output voltage, why is this RC circuit considered a "low-pass" filter?

high frequency cause low Vout, lost Vin.

-1 what happen to gain?

Part Two: RL Networks

1. Record the amplitude of the output voltage for the circuit shown in Figure 3, where $v_i(t) = \cos(\omega t)$, and f is the following three input voltage frequencies.

Frequency	Hand Calculation	PSpice Simulation	Circuit Measurement
1kHz	v_o = 0.2832	v_o = 0.2841	v_o = 0.28
10kHz	v_o = 0.9472	v_o = 0.9271	v_o = 0.98
100kHz	v_o = 0.9995	v_o = 0.9819	v_o = 1.06

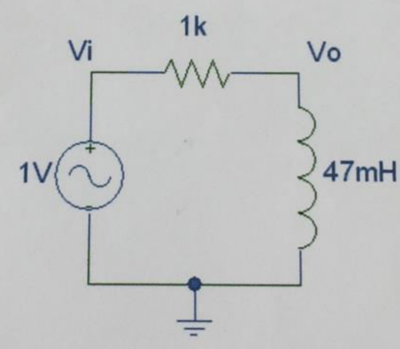

Figure 3: First RL Network

Based on the relationship between the frequency of the input voltage and the amplitude of the output voltage, would this circuit be considered a "low-pass" or a "high-pass" filter?

high pass / low pass

Does v_o lead or lag v_i? (Circle one.) lead / lag

2. Record the amplitude of the output voltage for the circuit shown in Figure 4, where $v_i(t) = \cos(\omega t)$, and f is the following three input voltage frequencies.

Frequency	Hand Calculation	PSpice Simulation	Circuit Measurement
1kHz	v_o = 0.9591	v_o = 0.961	v_o = 0.910
10kHz	v_o = 0.3207	v_o = 0.4101	v_o = 0.335
100kHz	v_o = 0.0358	v_o = 0.0312	v_o = 0.06

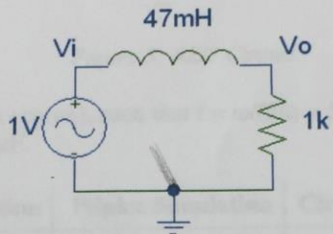

Figure 4: Second RL Network

Based on the relationship between the frequency of the input voltage and the amplitude of the output voltage, would this RL circuit be considered a "low-pass" or a "high-pass" filter?

high pass / low pass

Does v_o lead or lag v_i? (Circle one.) lead / lag

Part Three: Analysis of an RLC Circuit

1. Construct the RLC circuit shown in Figure 5.

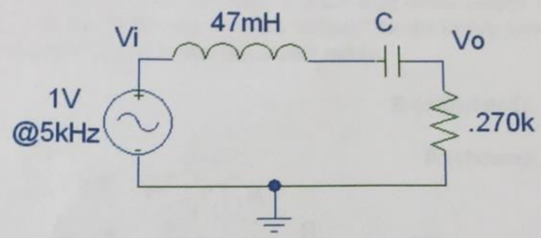

Figure 5: RLC Circuit

2. Assuming that $v_i(t) = \cos(\omega t)$, such that $f = \omega/(2\pi) = 5\text{kHz}$, measure the phase shift between v_i and v_o for $C = 0.01\mu F$.

Hand Calculation	PSpice Simulation	Circuit Measurement
φ = 81.0095	φ = 78.23	φ = 79.2

Does v_o lead or lag v_i? (Circle one.) lead / lag

3. Measure the phase shift between v_i and v_o for $C = 0.047\mu F$.

Hand Calculation	PSpice Simulation	Circuit Measurement
φ = -71.33511	φ = -71.5	φ = -72

Does v_o lead or lag v_i? (Circle one.) lead / lag