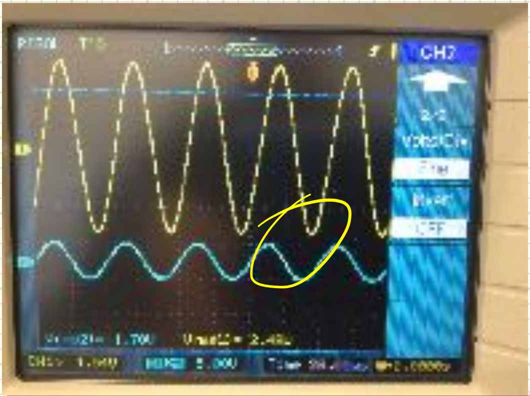
#28 RLC Series
LARGE MANY PICS.

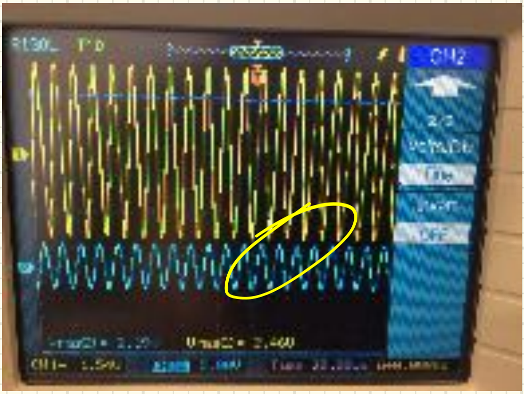
Series RCL LAB #28 Greg Moore 2015



Resistor voltage out of phase with source voltage

Series RCL Circuit Analysis & AC Power 28

← 50KHz Resistor Voltage in phase with source Voltage

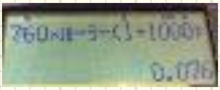


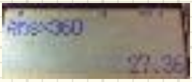
MEASURED		
V_R	∠θ	V_L
1.77	-43°	
2.34	68°	
2.13	-31.5°	

Resistor Voltage out of phase with source voltage.

J

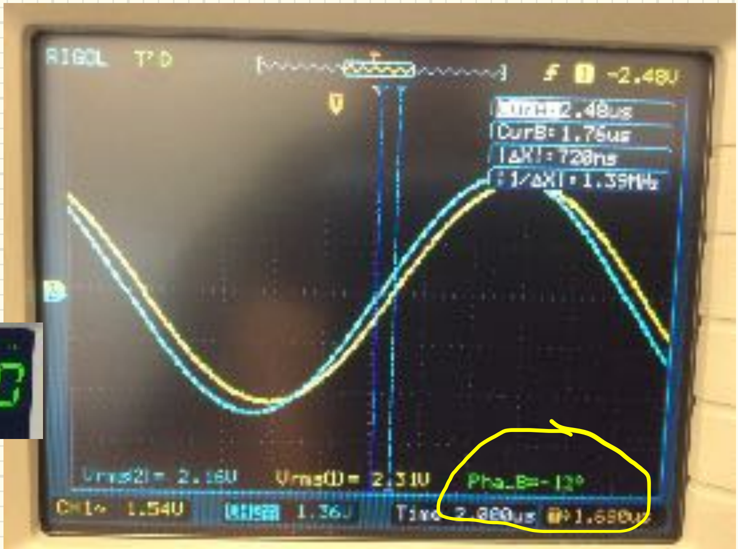
Phase angle @100KHz
25°





Vs leading V_R when the circuit is inductive.

Phase angle @ 50KHz
-11°



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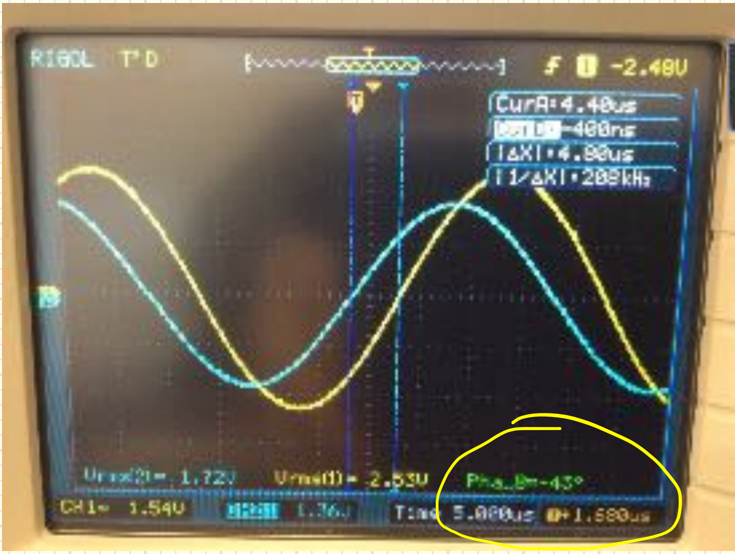
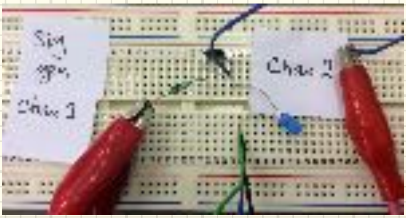
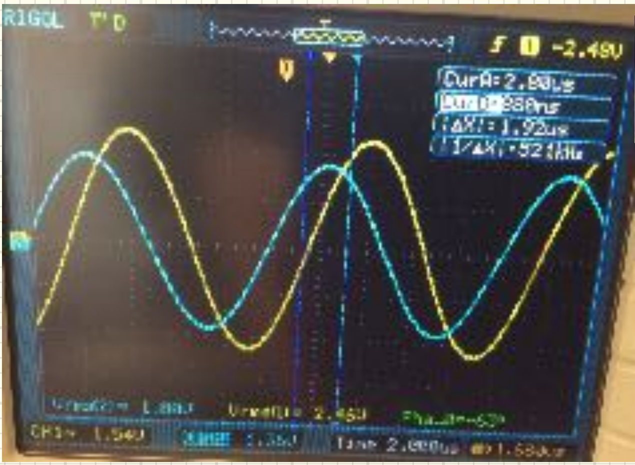
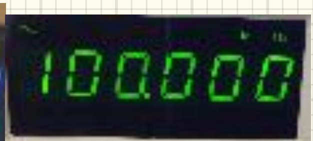


Phase angle @ 25KHz
−43°
V_L leading V_S here.

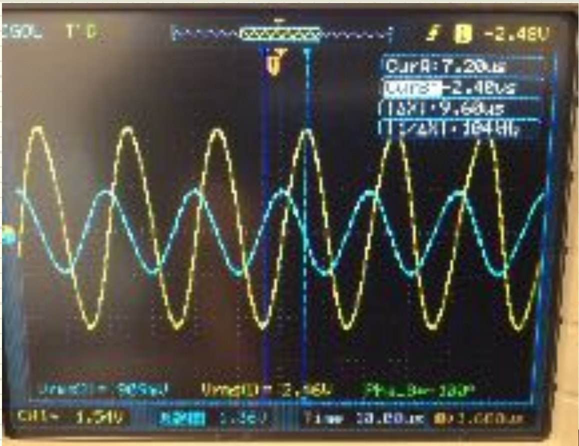


circuit rewired to put inductor in parallel for V_L measurements.



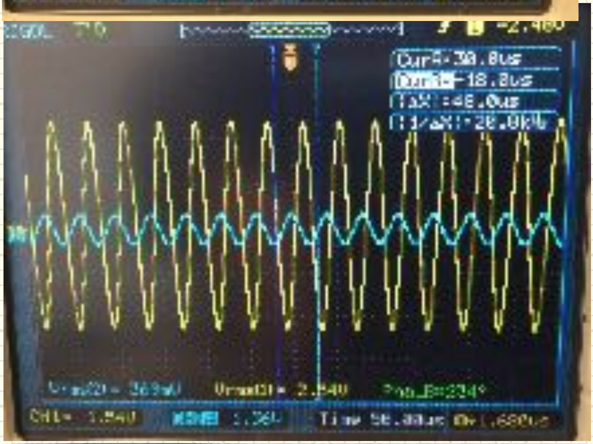


V_L @ 100KHz
$1.8 V_{Rms}$



V_L @ 25KHz

909mVrms



V_L @ 50KHz

369mVrms

	EXPERIMENTAL						
	MEASURED				CALC.		
6 $\angle\theta$	7 V_R	8 $\angle\theta$	9 V_L	10 V_C	11 I_T	12 Z_T	
	1.77	-43°	0.37		3.16 mA	781Ω	
	2.34	-11°	0.91		4.17	592Ω	
	2.19	25°	1.8		3.91	637Ω	

$Z_T = \frac{V_4}{I_T}$

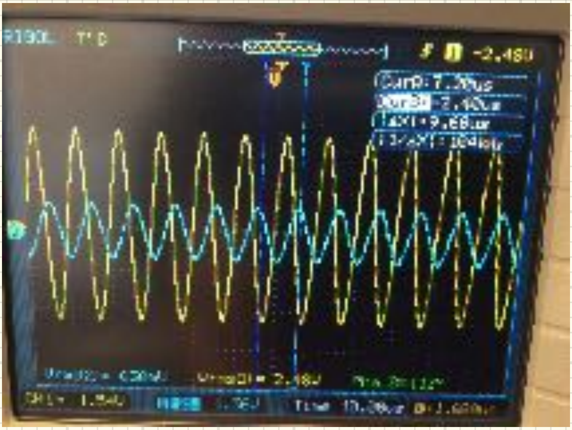
$\frac{3.47\,V_A}{I\,(\text{measured})}$

$I_T = \frac{V_R}{R} \rightarrow \frac{V_R\,(\text{measured})}{560\Omega}$

Maintain a neat log of the results in the table.

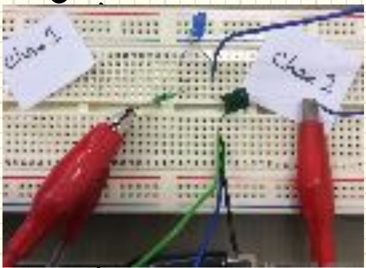
Circuit rewired 3rd time

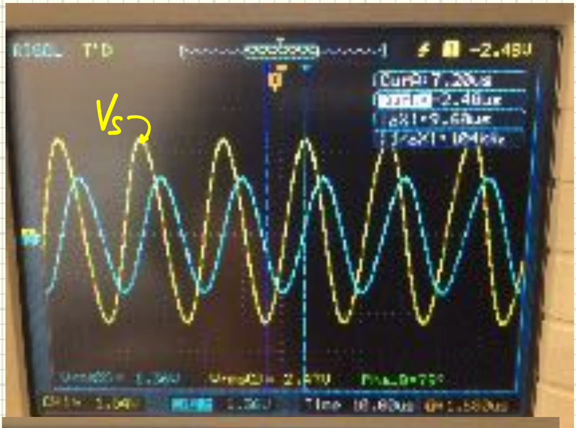
Cap in parallel.



V_C @ 100K

630mV

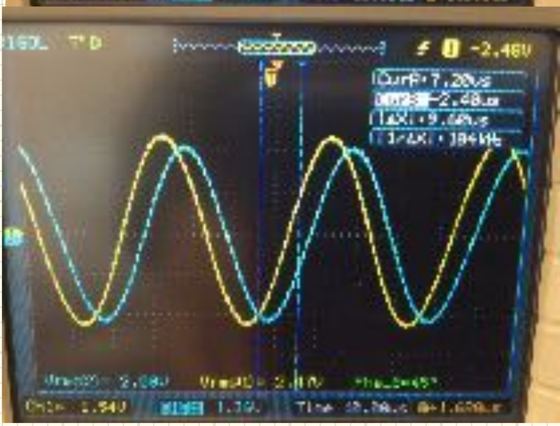




V_C @ 50K

1.36 V_{Rms}

Capacitor Voltage lagging V_s



V_C @ 25K

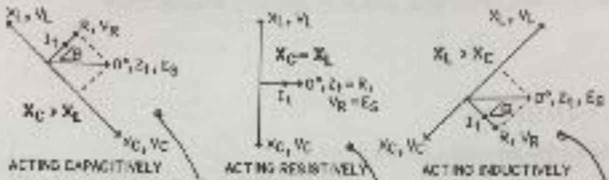
2 V_{Rms}.

PART ONE: SERIES RCL AC CIRCUIT ANALYSIS $(X_C - X_L)^2$

$X_L = 2\pi fL$ $X_C = 1/(2\pi fC)$ $Z_t = \sqrt{R^2 + (X_L - X_C)^2}$ $I_t = E_G / Z_t$

$V_R = R \cdot I_t$ $V_L = X_L \cdot I_t$ $V_C = X_C \cdot I_t$ $\angle\theta = \tan^{-1}[(X_L - X_C)/R]$

In this part of the experiment, you will analyze a series RCL AC circuit. Your analysis will be theoretical, using formulas only, then experimental, combining circuit measurements and formulas. You will see the same circuit acting: inductively at a frequency where $X_L > X_C$, resistively at a frequency where $X_L = X_C$, and capacitively at a frequency where $X_C > X_L$. You will discover that, how a circuit acts depends upon component values and the frequency of the source voltage.



1. Take a few minutes to mathematically analyze the circuit shown in Figure 1 at the three different frequencies (25 kHz, 50 kHz, and 100 kHz). Use the RMS value of the source voltage for your calculations. Record your answers for total impedance, total current, resistor voltage, inductor voltage, capacitor voltage and angle theta in Table 1. Calculate the inductive and capacitive reactance at the different frequencies and record them here.

0.8 mH X_L @ 25 kHz = 125 Ω, X_L @ 50 kHz = 251 Ω, X_L @ 100 kHz = 502 Ω

0.01 μF X_C @ 25 kHz = 634 Ω, X_C @ 50 kHz = 318 Ω, X_C @ 100 kHz = 159 Ω

2. Assemble the circuit shown in Figure 1a. Apply the first sine wave frequency (25 kHz) at an amplitude of 7 V_{PP}. Set the oscilloscope to trigger on CH-1 (AUTO). CH-1 and CH-2 input mode selects should be set to AC. Select a TIME/DIV setting that will display about two cycles on the screen.

2.47 V rms

NAME: $\sqrt{560^2 + (634-125)^2}$ CLASS: DATE:

7 Vpp = 2.47 V rms

TABLE 1

	THEORETICAL						EXPERIMENTAL					
	CALCULATED						MEASURED				CALC.	
f	1 Z_t	2 I_t	3 V_R	4 V_L	5 V_C	6 $\angle\theta$	7 V_R	8 $\angle\theta$	9 V_L	10 V_C	11 I_t	12 Z_t
25 kHz ($X_C > X_L$ Capacitive)	756	3.26 mA	1.82 V	400 mV	2.0	42.3°	1.77	-45°	0.317	2.0	3.16 mA	781 Ω
50 kHz (Resistive)	563	4.38	2.45	1.09 V	1.39 V	6.5	2.34	-11°	0.91	1.36	4.17	592 Ω
100 kHz (Inductive $X_L > X_C$)	656	3.76	2.1	1.88	0.577	31.5°	2.19	25°	1.8	0.630	3.91	631 Ω

$Z_T = \frac{V_A}{I_T} = \frac{2.47 V_A}{I (measured)}$

$\sqrt{560^2 + (318-251)^2} = 67^2$

$I_T = \frac{V_R}{R} = \frac{V_R (measured)}{560 Ω}$

$\sqrt{560^2 + (502-159)^2}$ 343^2

PART ONE QUESTIONS

1. At which frequency does the circuit act capacitively? ______ Explain why.

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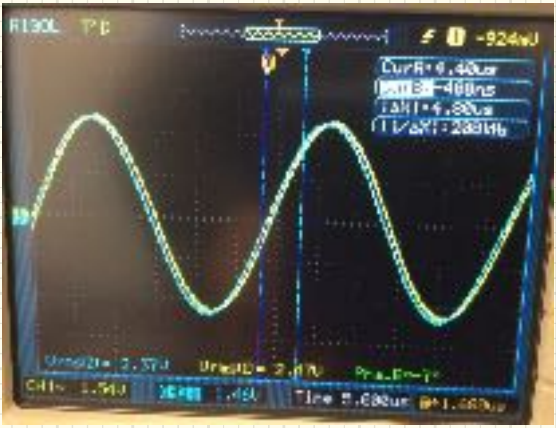
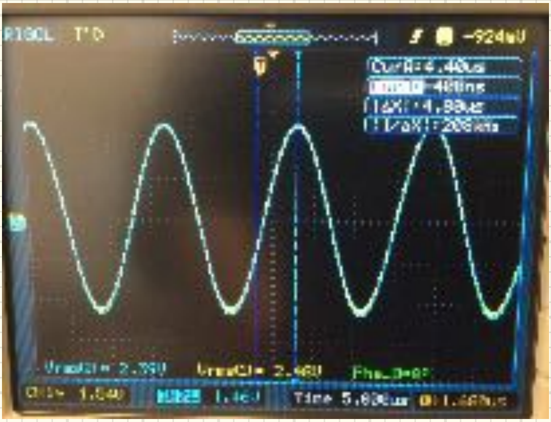
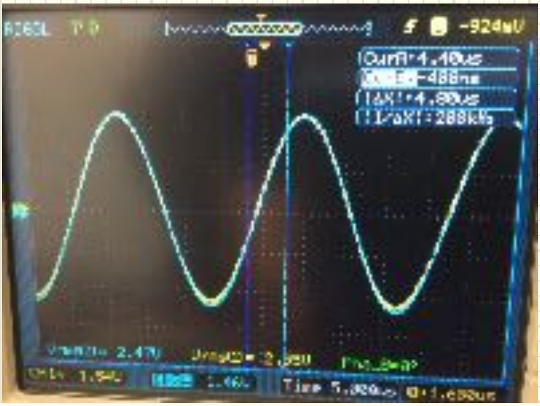


Two capacitors as per Lab guide to improve phase angle & power factor.

per page 170 step 6 + 7



One capacitor with freq increased to give 0° phase shift.



two 0.01μF in parallel & 43 KHz for 0° phase shift

$\sqrt{560^2+(318-251)^2}=67$

$I_T = \frac{V_R}{R} \rightarrow \frac{V_R(\text{measured})}{560\Omega}$

PART ONE QUESTIONS

$\sqrt{560^2+(502-159)^2}$

1. At which frequency does the circuit act capacitively? ______ Explain why.
   25KHz because $X_C > X_L$
2. At which frequency does the circuit act inductively? ______ Explain why.
   100KHz because $X_L > X_C$
3. At which frequency does the circuit act resistively? 50KHz Explain why.
   Because X_C & X_L begin to equal & cancel out.
4. When the circuit is acting inductively, what is the amount of effective inductive reactance in the circuit? $X_{L(effective)} = X_L - X_C =$ 502 − 159 = 343 Ω
5. When the circuit is acting capacitively, what is the amount of effective capacitive reactance in the circuit? $X_{C(effective)} = X_C - X_L =$ 634 − 125 = 509 Ω
6. List at least three factors that determine how a series RCL circuit will act.
   1. frequency
   2. choice of components
   3. which component is in shunt with the o/p.
7. At which frequency was the resistor voltage in phase with the source voltage? 50KHz
8. At any given frequency, what condition must exist in order for the resistor voltage to be in phase with the source voltage applied to a series RCL circuit?
   Should be no inductive or capacitive effect.

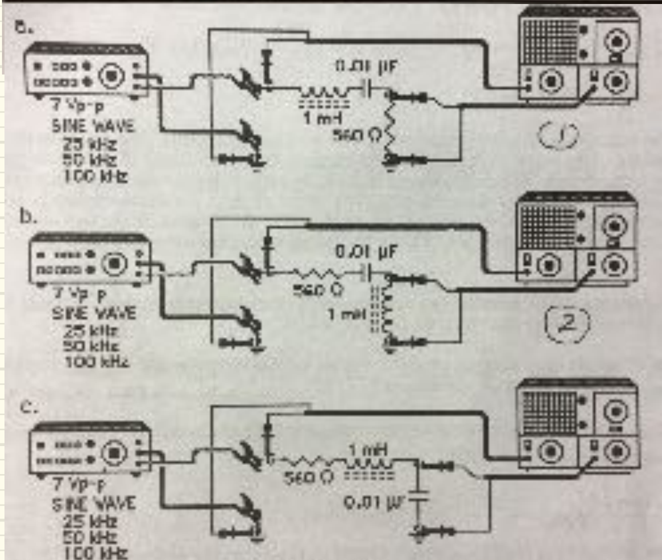


FIGURE 1

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over page →

9. At what frequency was the resistor voltage the greatest? 50KHz Explain why.
Maximum power transfer, the R is all that exists

10. When the circuit is acting inductively, does the resistor voltage lead the source voltage? Yes Explain. Vs leads VR when circuit behaves inductively to develop Vdrop across.

TABLE 2

f	P_A ($I_T \times V_T$)	P_R (I^2R)	P_L ($I.V$)	P_C ($I.V$)	P_r (I^2R_{ww})	PF	
25 kHz (3.26mA)	8.05m VA	5.95m W	1.3mVAR	6.52mVAR	5.95 mW	5.95 / 8.05	0.74
50 kHz (4.38mA)	10.8mVA	10.7mW	4.7mVAR	5.9mVAR	10.7mW	10.7 / 10.8	PF=1
100 kHz (3.76mA)	9.28mVA	7.9mW	7mVAR	2.2mVAR	7.9mW	7.9 / 9.28	0.85

PART TWO QUESTIONS

1. At which frequency is the power factor closest to 1 (100%)? 50KHz
2. At which frequency is the real power closest to the apparent power? 50KHz
3. In step 6, a second 0.01 µF capacitor was added to the circuit. What was the total capacitance of the two capacitors. C_t = 0.01 µF || 0.01 µF = 0.02 µF
4. Calculate the inductive reactance and the total capacitive reactance, using the total capacitance calculated above, as the circuit operated at 35 kHz. X_L = (176Ω), X_C = 227Ω (219Ω @ 1mH) (* our inductor 0.8mH)
5. Explain why the power delivered to the resistor increased when the second capacitor was added. I think they planned $X_C = X_L$ so cancellation of reactance.
6. What happened to the phase shift between the resistor voltage and the source voltage when the second capacitor was added? zero phase shift See my lab notes.
7. Explain how the power factor of a series RCL circuit that is acting inductively can be corrected. add more capacitance to balance the circuit current.
8. List three characteristics of a series RCL circuit whose power factor is 1 (100% efficient).
   1. $X_L = X_C$
   2. Vs = VR with no phase shift
   3. phase angle is zero
   4. at resonance fr

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PART TWO: POWER AND POWER FACTOR IN SERIES RCL AC CIRCUITS

$P_A = I_t \cdot E_S$ $P_R = I_t \cdot V_R$ $P_L = I_t \cdot V_L$ $P_C = I_t \cdot V_C$

$P_r = P_L - P_C$ $PF = P_R/P_A$

In this part of the experiment, you will calculate the power at each frequency of each component in the RCL test circuit. You will also experimentally improve the power factor (PF) of your circuit while it is acting capacitively. Recall that power factor is the ratio of real power to apparent power. When multiplied by 100%, it expresses the efficiency of the circuit. An improvement in power factor, or efficiency, is obtained when changes are made to the circuit to cause the two reactances to be closer in value. The RCL circuit is 100% efficient when the inductive and capacitive reactances are equal.

1. Use the experimental data from Table 1 to calculate all of the power parameters in Table 2. Don't forget to label all values correctly (W, VA, VAR).
2. Connect your circuit once again as shown in Figure 1a. Set the generator frequency to 35 kHz, 7 V_{P-P}. How is the circuit acting now? 30° phase shift
3. Measure and record the peak-to-peak resistor voltage and the phase shift between the resistor voltage and the source voltage (∠θ).

   $V_{R(P-P)}$ = 2.1 V_{Rms}, ∠θ = 30° $I_T = \frac{2.10}{560}$ = 3.75 mA

4. Convert the peak-to-peak resistor voltage to RMS and calculate the resistor power (real power).

   V_R = 2.1 V_{Rms}, $P_R = V_R^2/R$ = 7.87 mW

5. List two things that can be done to correct, or improve, the power factor.
   1. ________
   2. ________
6. Place a second 0.01 µF capacitor in parallel with the one that is in your circuit.
7. Measure and record the peak-to-peak resistor voltage and the phase shift between the resistor voltage and the source voltage (∠θ).

   $V_{R(P-P)}$ = 2.31 V_{Rms}, ∠θ = −7° $P_F = \frac{P_T}{P_A}$

8. Convert the peak-to-peak resistor voltage to RMS and calculate the resistor power (real power).

   V_R = 2.31 V_{Rms}, $P_R = V_R^2/R$ = 9.52 mW I_T = 4.1 mA

9. Remove power and answer all questions for Part Two.