Lab 9:

Power Transfer in AC Circuits

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Performed on: 11/26/2019
Submitted on: 12/01/2019

Procedure:

In this lab we will test different ways to maximize the power delivered to a load in an AC circuit. In the circuit below, the source voltage is a sinusoidal source with internal impedance. For this lab the frequency of the input source is 10k Hz, Rs = 2200 Ohms, and L = 0.12 H.

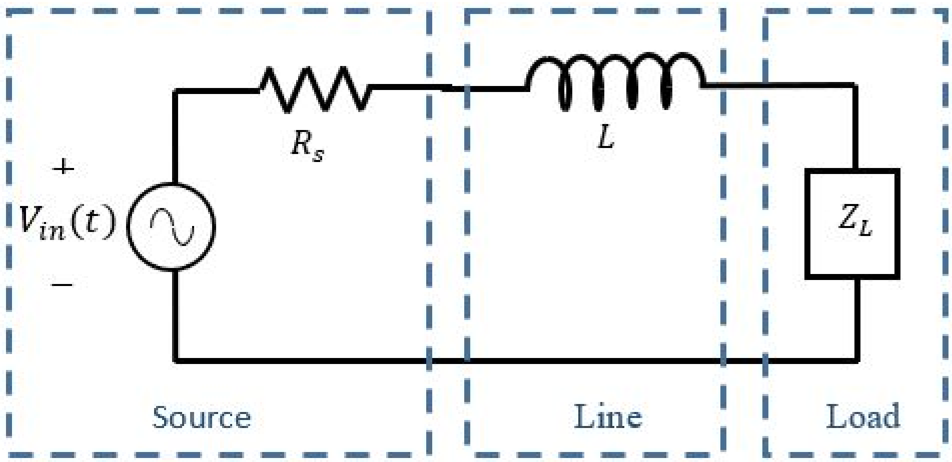


Figure 9.1 – Model of an AC source delivering power to a load.

In task 1 the impedance of the load was purely resistive with no imaginary component. In this task the resistance was varied to determine which value yields the maximum power output. To determine the power dissipated across the load, the voltage was measured using the Analog Discovery 2. Then using the formulas derived in the prelab, power was calculated.

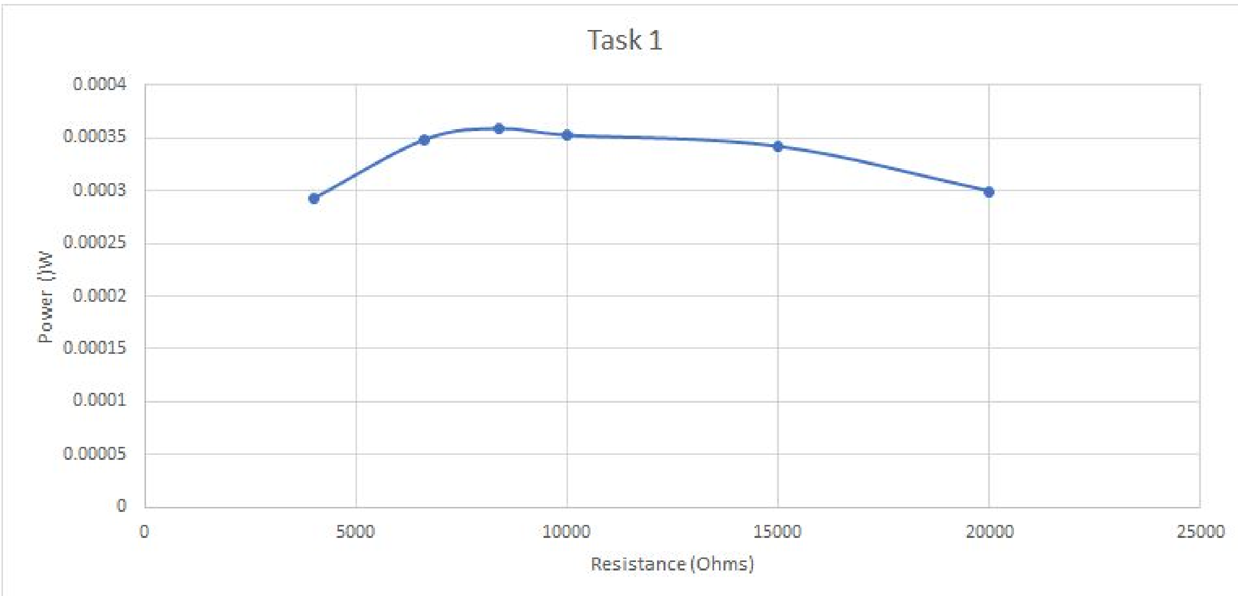
In task 2 a shunt capacitor was added across the load resistance to create a complex impedance. In this task the capacitance of the shunt capacitor was varied while the resistor was fixed with the maximum value determined from the previous task, in order to determine which impedance yielded the largest power output. Power was calculated using the same method as in task 1.

For task 3 the values of the resistor and capacitor could be varied. In this case the maximum power output is achieved when the impedance of the source is exactly equal to the impedance of the load. This was determined algebraically and the power across the optimal resistor and capacitor was measured.

Data and Results:

Task 1:

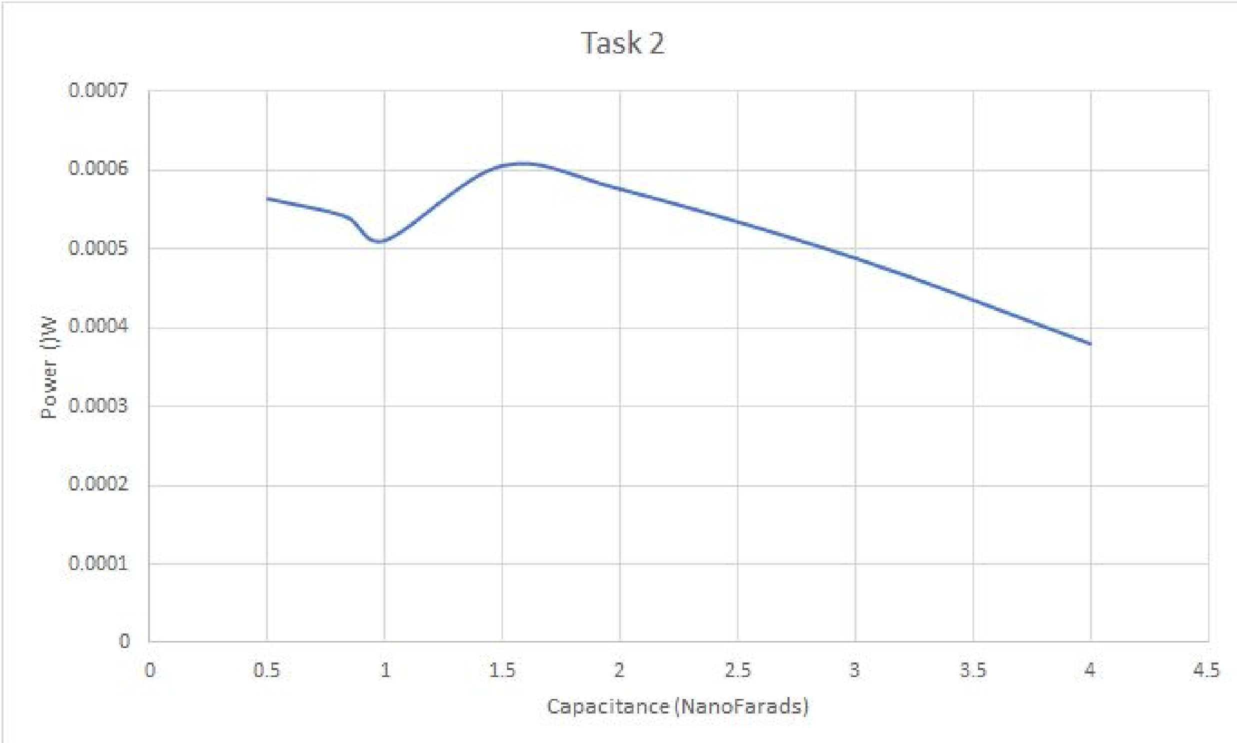
Below is a plot of the calculated power output versus the 6 resistance values that were tested in task 1.



The data shows a somewhat smooth curve with a maximum that occurs between 7000 and 10000 Ohms. The resistance 8400 Ohms gave us the maximum power, 0.358704 mW, of all the experimental values. This is near the theoretical values that were calculated in the prelab, as the theoretical maximum occurred with a resistor of 7854.23 Ohms and maximum power output of 0.397 mW

Task 2:

Below is a plot of the calculated power output versus the 7 capacitor values that were tested in task 1.



The data shows a relatively smooth curse with a maximum between 1.5 and 2 nanoFarads. The reading at 1 nanoFarad shows a sharp dip, however, this could be due to an inaccurate reading, possibly caused by a shorted connection within the breadboard. The 1.5 nanoFarads gave us the maximum power, 0.605872 mW, of all the experimental values. This is near the theoretical maximum, which was calculated to be at 1.92 nanoFarads with a maximum of 0.622 mW.

<u>Task 3:</u>

In task three, the values R = 18000 Ohms and C = 0.945 nF were calculated to yield the maximum power output. In the limit there were limitations on available components so the values R = 15000 Ohms and C = 1nF were used instead. The measured power in this case was calculated to be 0.680 mW, which was the largest measured in all three cases.

Discussion:

The lab results follow the same trends as displayed in the theoretical results calculated in the prelab. The measured maximum power was close in value to calculate maximum power in all three tasks. Additionally, as predicted the maximum power in task 3 was the largest since both the resistor and the capacitor were optimized so that the load would receive the maximum power.

While the measured data followed the same trends as the theoretical data, the values measured were different than the predicted values. This error was in large part caused by the fact that there were limitations on which components were available to construct the circuit with. Since there were only a few resistors and capacitors available, the exact values calculated in the prelab could not be fully implemented in practicality. Additionally, the measurements were subject to other errors such as internal resistance of connecting components like wires, and faulty connections into the breadboard which may cause shorts or open circuits.

In general, in this lab we discovered that the power delivered to a source can be optimized by changing the resistance of the source or adding a shunt capacitor. While the maximum power output can be achieved when both are optimized, often it is not practical to change the resistance of a load, since this might be an inherent part of the load itself. However, a shunt capacitor is relatively easy to add into a circuit and gave significant gains to the power delivered to a circuit just by itself. Therefore, when optimizing the power delivered to a circuit, a shunt capacitor may be the optimal choice.

Appendix: Raw Data and Documentation

Task 1:

R (Ohms)	Voltage (volts)	Time difference in micro seconds	Time difference in radians	Phasor Real part	Phasor Imaginary part	Phasor Magnitude	Power (W)
20000	6.93	-5.608	-0.352361032	3.25	-1.19	3.461011413	0.000299465
15000	6.41	-7.528	-0.47299819	2.85	-1.46	3.202202367	0.000341803
10000	5.315	-10.369	-0.651503485	2.11	-1.611	2.654697911	0.000352371
8400	4.914	-11.51	-0.723194629	1.84	-1.625	2.454837062	0.000358704
6600	4.3105	-11.96	-0.751468963	1.57	-1.46	2.143944962	0.00034822
4000	3.0545	-14.464	-0.908799923	0.941	-1.208	1.53125602	0.000293093

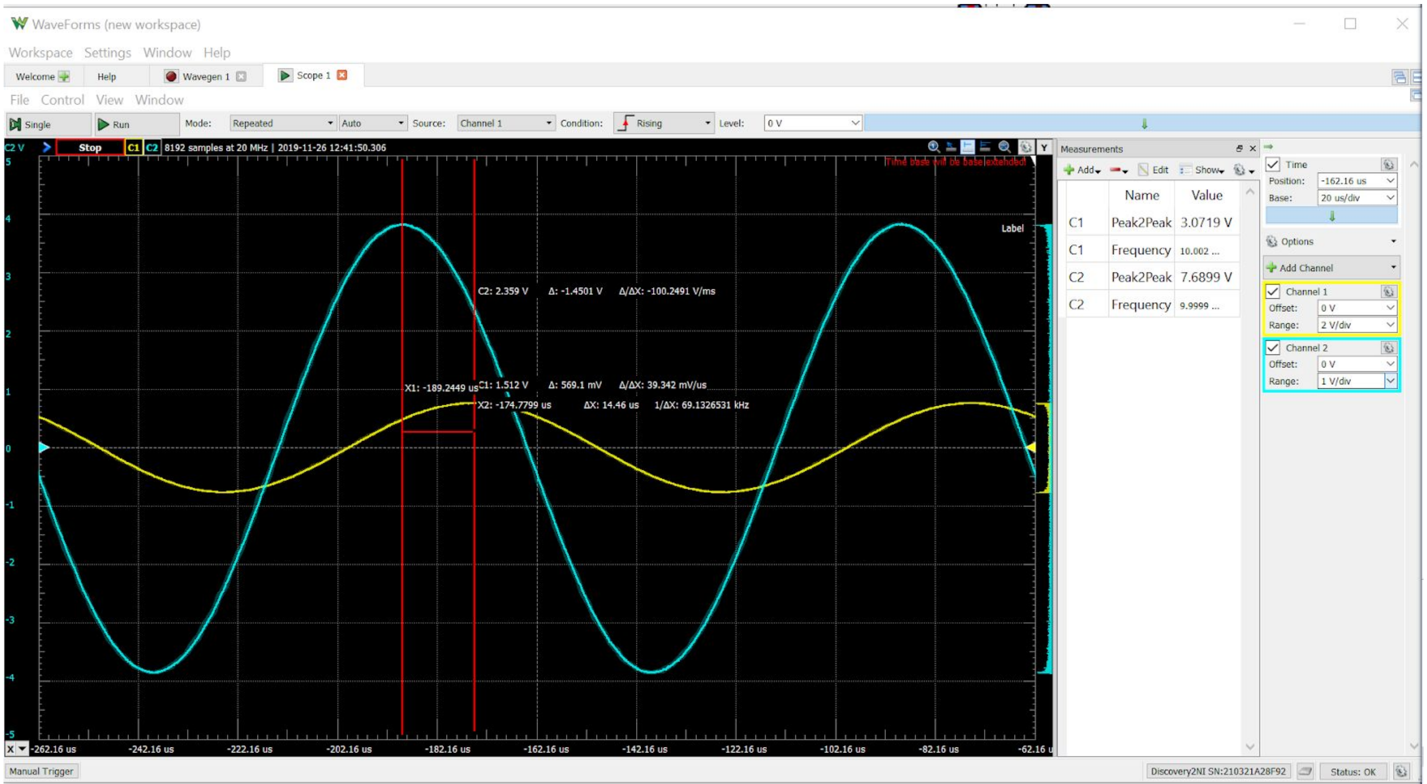
Task 2:

C (nanoFarads)	Voltage (volts)	Time difference in micro seconds	Time difference in radians	Phasor Real part	Phasor Imaginary part	Phasor Magnitude	Power (W)
0.5	5.75	-11.6	-0.728849496	2.14	-1.91	2.868396765	0.000563541
0.83	5.64	-13.28	-0.834407009	1.89	-2.08	2.810427014	0.000540993
1	5.47	-15.06	-0.946247707	1.59	-2.22	2.730659261	0.000510719
1.5	5.95	-17.27	-1.085106103	1.402	-2.623	2.974177701	0.000605872
2	5.8	-20.66	-1.298106084	0.803	-2.786	2.899414596	0.000575795
3	5.34	-27.01	-1.697088351	0.317	-2.65	2.668892842	0.000487876

Task 3:

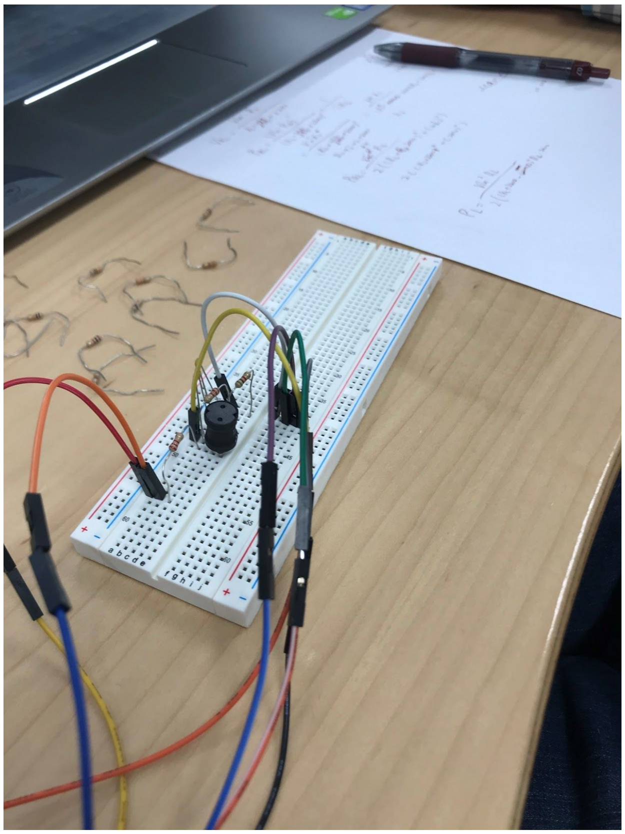
Resistance (Ohms)	15000
C (nanoFarads)	1
Voltage (volts)	8.6
Time difference in micro seconds	12.15
Time difference in radians	0.763407015
Phasor Real part	3.11
Phasor Imaginary part	2.96
Phasor Magnitude	4.293448497
Power (W)	0.000614457

Screenshot:

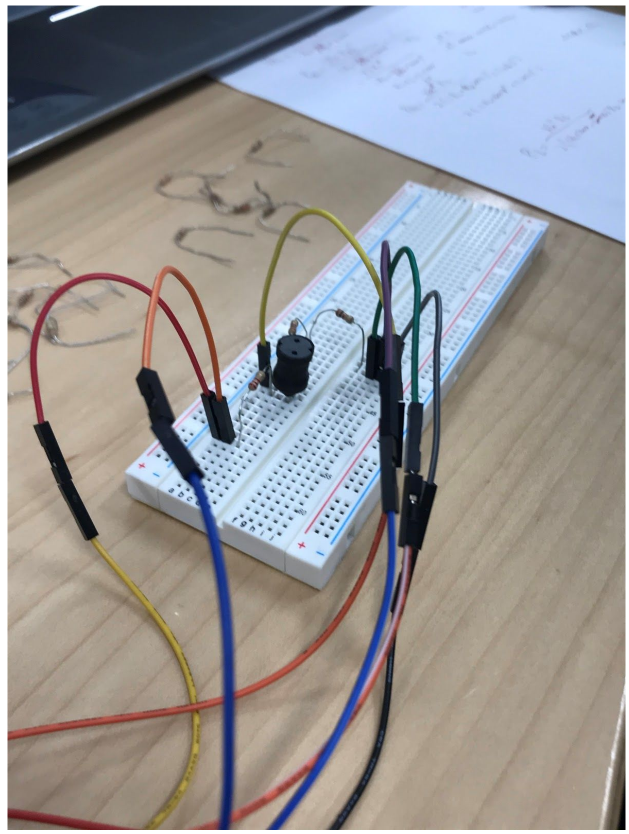

WaveForms (new workspace)
Workspace Settings Window Help
Welcome
Help
Wavegen 1
Scope 1
File Control View Window
Single
Run
Mode: Repeated
Auto
Source: Channel 1
Condition: Rising
Level: 0 V
Stop
C1 C2 8192 samples at 20 MHz | 2019-11-26 12:41:50.306
C2: 2.359 V Δ: -1.4501 V Δ/ΔX: -100.2491 V/ms
X1: -189.2449 us
C1: 1.512 V Δ: 569.1 mV Δ/ΔX: 39.342 mV/us
X2: -174.7799 us ΔX: 14.46 us 1/ΔX: 69.1326531 kHz
Label
-262.16 us
-242.16 us
-222.16 us
-202.16 us
-182.16 us
-162.16 us
-142.16 us
-122.16 us
-102.16 us
-82.16 us
-62.16 u
Measurements
Add Edit Show
Name Value
C1 Peak2Peak 3.0719 V
C1 Frequency 10.002 ...
C2 Peak2Peak 7.6899 V
C2 Frequency 9.9999 ...
Time
Position: -162.16 us
Base: 20 us/div
Options
Add Channel
Channel 1
Offset: 0 V
Range: 2 V/div
Channel 2
Offset: 0 V
Range: 1 V/div
Manual Trigger
Discovery2NI SN:210321A28F92
Status: OK

Circuit Design

Task 1



Task 2



Task 3