Maximum Power Transfer in AC Circuit

Monday, November 15, 2021 6:32 PM

Objective:

- Design a lab to investigate maximum power transferred in AC circuits

Procedure:

1. Wire circuit designed in figure 2 with the standard values
2. Adjust the power supply on the function wave generator to be at 10 volts and 200 Hz
3. Calculate power dissipated through the load
4. Change out the load to have various resistor and capacitor loads
5. Calculate power dissipated through the load for the various resistor values and capacitor values
6. Record current and voltage for various load values

Pre-Lab:

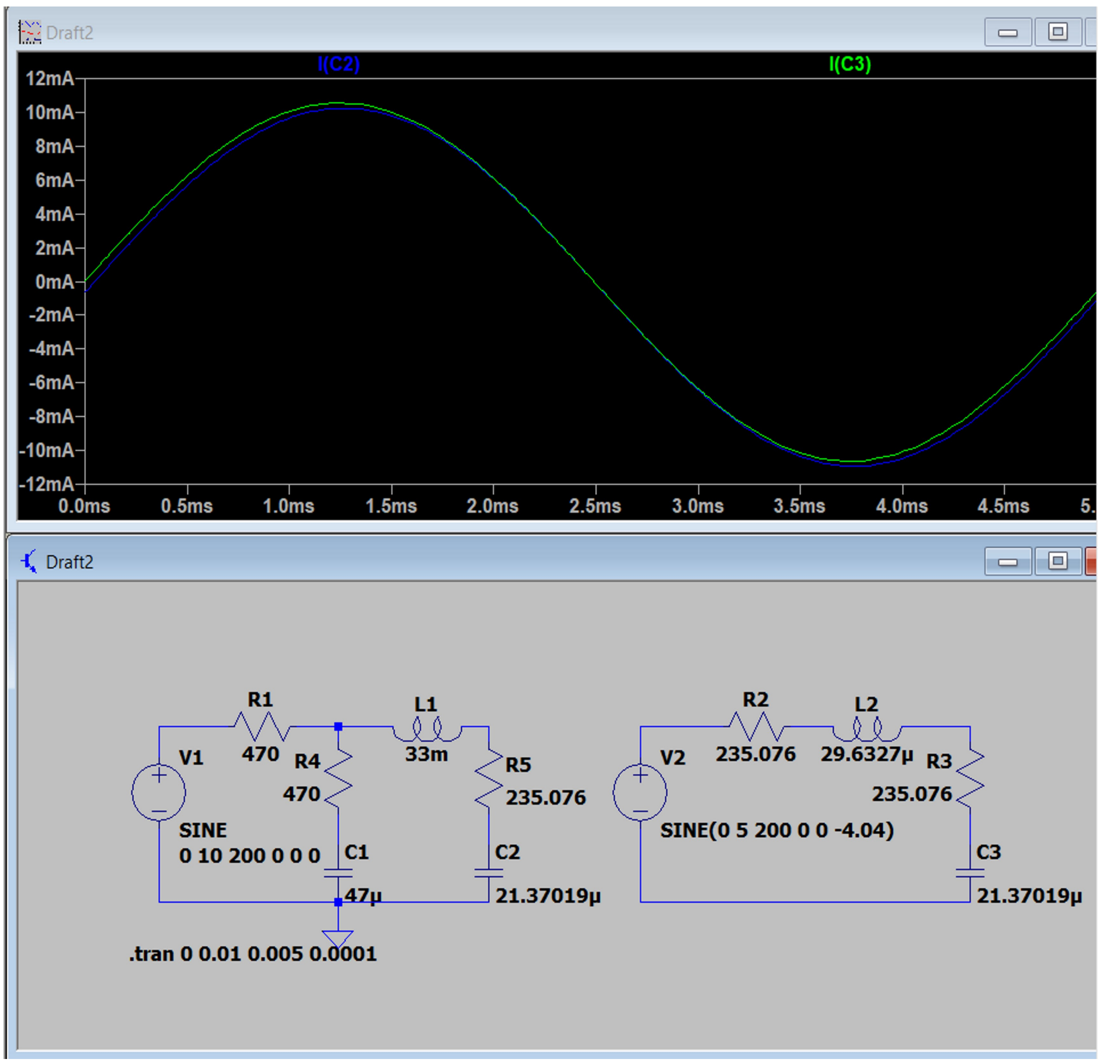

Figure 1: Initial AC max power design(left) with simplified equivalent(right)

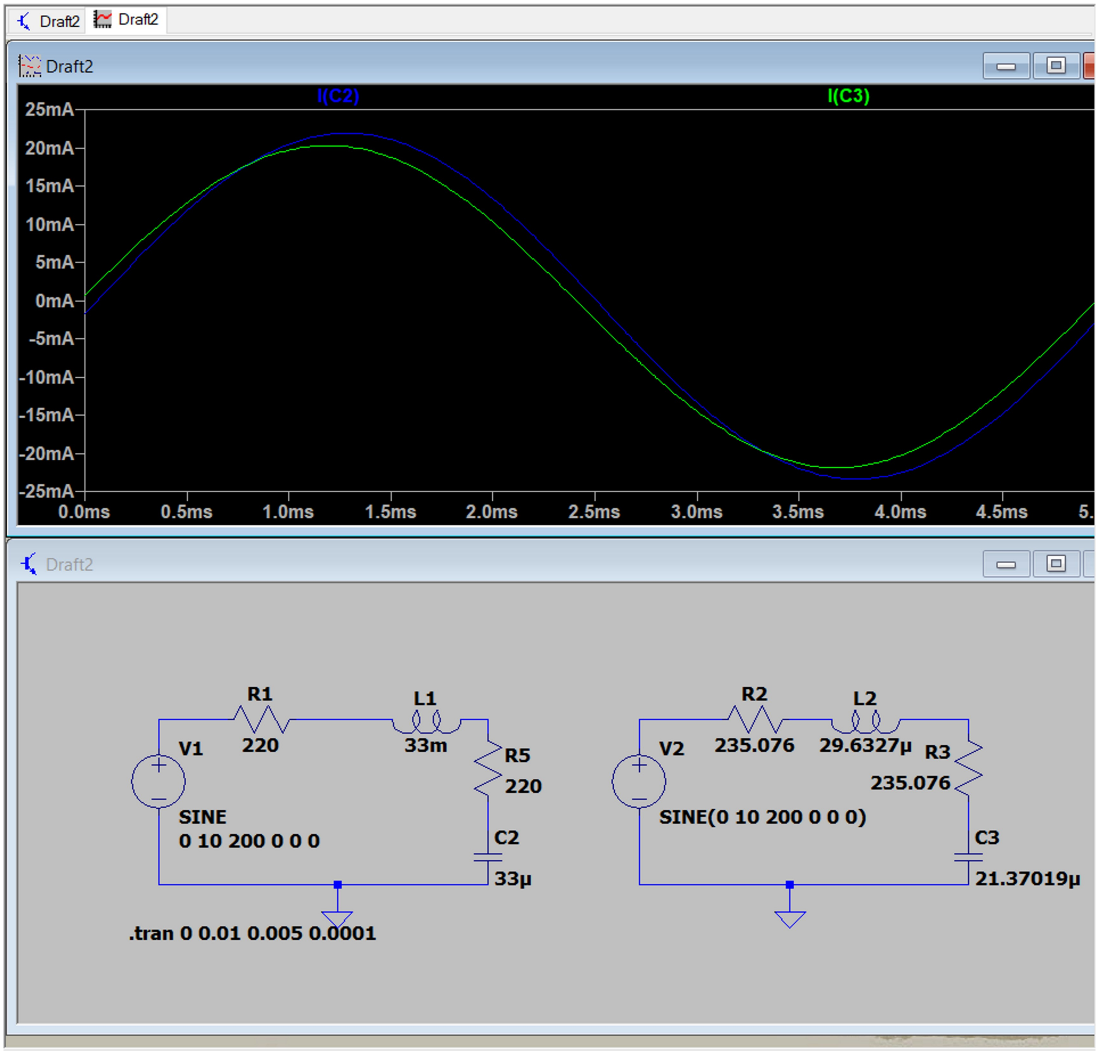

Figure 2: Previous max power simplified equivalent design(right) with standard values design(left)

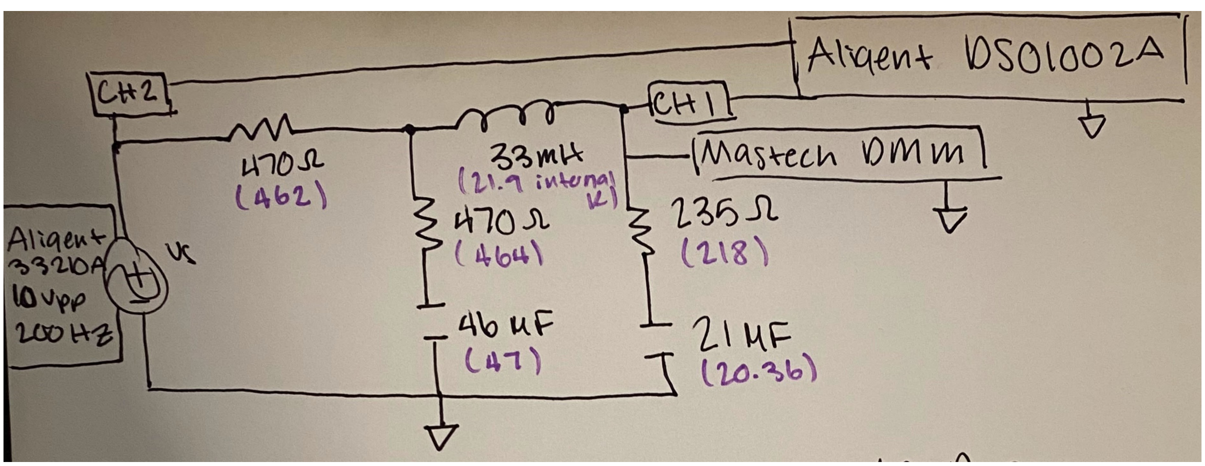

Figure 3: Full circuit schematic for Max AC Power

LT Spice Values at CH1 (full circuit):

Vm = 1.34 V

Im = 5.1 mA

T = 5 ms

Δx = 5.41508 - 5.25922 = 0.15586

$$Phase\ Shift = \frac{360\Delta x}{T}$$

$$Phase\ Shift = \frac{360(0.15586)}{0.005}$$
$$Phase\ Shift = 11.2° \ - current\ leading$$
$$P_{ave} = \frac{1}{2}V_M I_M \cos(\theta_V - \theta_I)$$
$$P_{ave} = \frac{1}{2}(1.34)(5.1m)\cos(11.2)$$
$$P_{ave} = 3.35\ mW$$

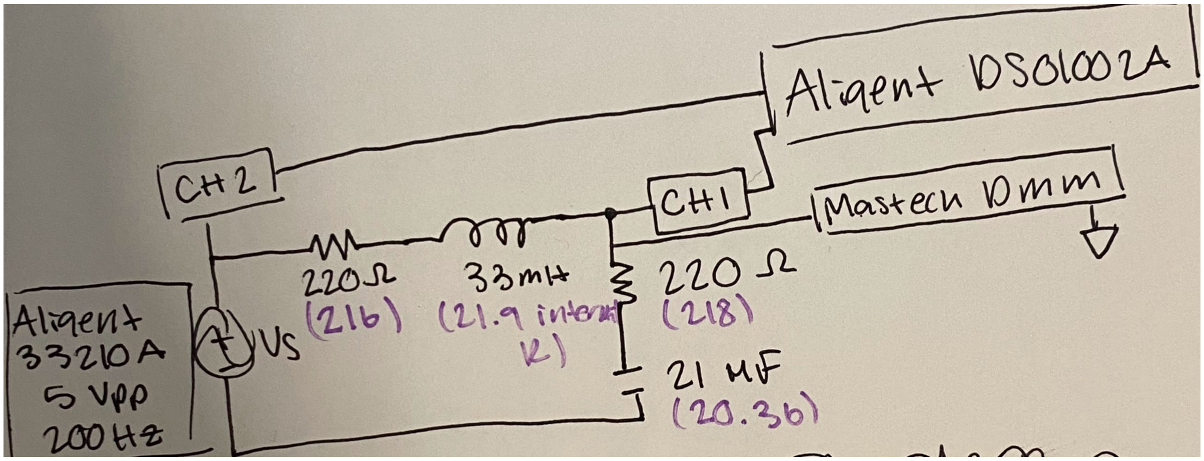

Figure 4: Simplified Thevenin equivalent circuit schematic

LT Spice Values at CH2 (Thevenin circuit):

Vm = 1.32 V

Im = 5.4 mA

T = 5 ms

Δx = 5.40816 - 5.29592 = 0.1122

$$Phase\ Shift = \frac{360\Delta x}{T}$$
$$Phase\ Shift = \frac{360(0.1122)}{0.005}$$
$$Phase\ Shift = 8.08° \ - current\ leading$$
$$P_{ave} = \frac{1}{2}V_M I_M \cos(\theta_V - \theta_I)$$
$$P_{ave} = \frac{1}{2}(1.32)(5.4m)\cos(8.08)$$
$$P_{ave} = 3.53\ mW$$

Maximum power transfer occurs when the resistance load is equal to the source resistance and the complex values of the load and the source are inverted but equal. To find the max power:

$$P_{MAX} = \frac{{V_{TH}}^2}{8 * R_{TH}}$$

Using this equation and our Thevenin circuit, we can determine the max power:

$$P_{MAX} = \frac{2.5^2}{8 * 220}$$

$P_{MAX} = 3.55\ mW$ - max power

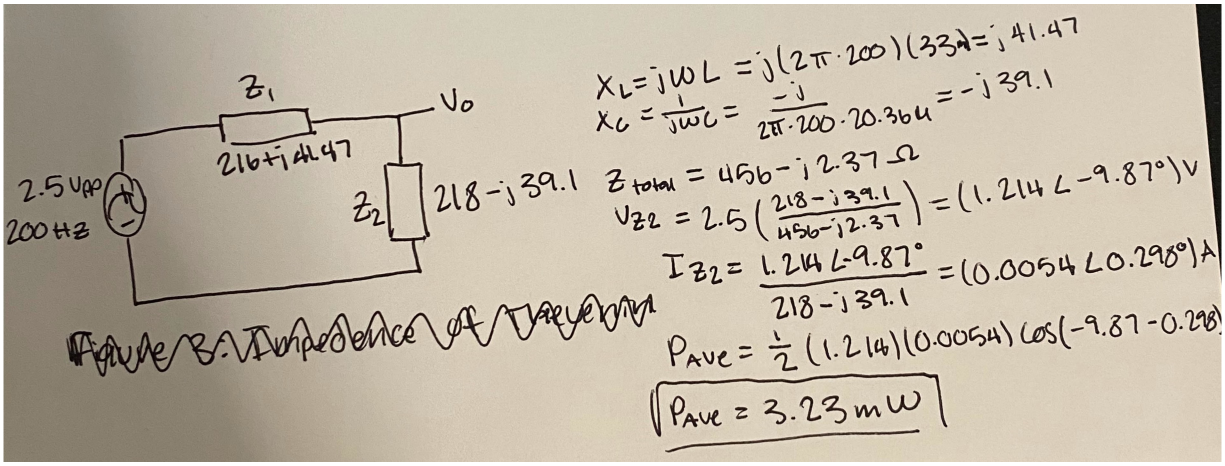

Figure 5: Average power from measured circuit components

Our calculated max power from our Thevenin circuit is relatively close to the calculated max powers from LT Spice and the expected power using our real measurements.

Figure 6: Sinusoidal wave for full circuit schematic in figure 3

Table 1: Actual Values of full circuit

Vin RMS	CH1 V RMS	RL I RMS	Power
3.38 V	0.796 V	3.44 mA	2.74 MW

% Difference = $\frac{3.53-2.74}{2.74} = 28\%$

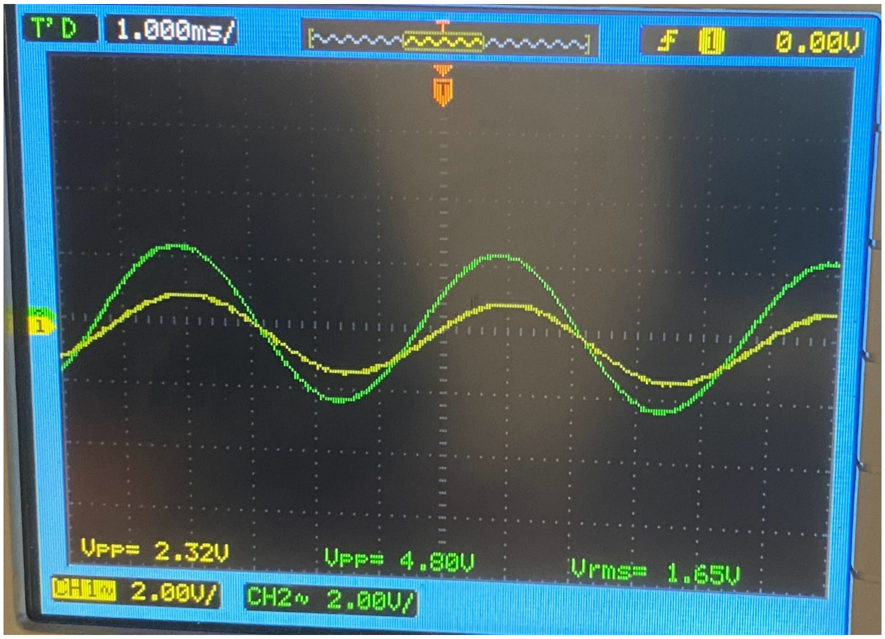

Figure 7: Sinusoidal wave for simplified Thevenin circuit schematic in figure 4

Table 2: Actual Values of Thevenin Circuit

Vin RMS	CH1 V RMS	RL I RMS	Power
1.65 V	0.796 V	3.26 mA	2.60 MW

% Difference = $\frac{3.35-2.60}{2.60} = 29\%$

Since the results of the full circuit and simplified (Thevenin) circuit match, I can conclude that the two circuits are equivalent and we successfully created a Thevenin equivalent circuit. There is a slight phase shift in the two circuits meaning the two circuits are not identical.

Note: We were not able to measure the inductor directly so the true value is unknown so we were unable to determine how close the true value is to 33 mH. This may account for the difference between the measured power value and calculated power value.

Table 3: Varying frequencies of Thevenin Circuit

Frequency	CH1 V RMS	RL I RMS	Power
100 Hz	0.873 V	3.27 mA	2.85 mW
400 Hz	0.847 V	3.29 mA	2.79 mW
600 Hz	0.820 V	3.23 mA	2.65 mW

The varying frequency from the waveform source had a lesser effect than expected. There were only slight changes in all measured values. After evaluating, the inductor and capacitor cancel each other out resulting in minimal change.

Table 4: Varying load resistor values of Thevenin Circuit

Resistor	CH1 V RMS	RL I RMS	Power
100 Ω	1.62 V	4.53 mA	3.67 mW
470 Ω	3.36 V	2.33 mA	3.91 mW
1k Ω	1.75 V	1.36 mA	1.19 mW

As our load impedance value gets farther from the ideal circuit impedance, there is more power lost and results in a lower power transfer.

Conclusion:

Similar to DC circuits, max power transfer occurs when the impedance is equal with the complex impedance being inversely equivalent to the complex impedance of the load. The inductance and impedance cancel out which results in max average power to dissipate across the given load.