

Experiment 2b: Series Compensation

Electrical power is transmitted and distributed by long wires and transmission lines. The wire's resistance is proportional to its length, but the power loss in the wire is proportional to the square of its current. Long wires also have a significant inductive and capacitive reactance. The voltage developed across the inductance of the wire reduces the voltage and power supplied to the load.

Series compensation is used to cancel the effect of wire inductance. Capacitance in series with an inductive transmission can be used to increase the power delivered to the load. The reactance of the capacitance must be approximately equal to the inductance of the transmission line. This experiment also demonstrates the effect of under compensation and over compensation on the power delivered to the load.

Equipment and Parts

Function Generator, Oscilloscope, and Breadboard

R2: 560Ω , $\frac{1}{4}$ watt, 5%. Cx: Three $0.1\mu\text{F}$, 5%.

L: 56mH , 5%. Mouser part #434-02-563J (see appendix 2).

Use 5% tolerance parts. The part values do not need to be measured.

Procedure

1. Connect the circuit in figure 2-5 below with $C_x = .1\mu\text{F}$. Connect a jumper wire across the capacitor, C_x . This will be the uncompensated circuit.

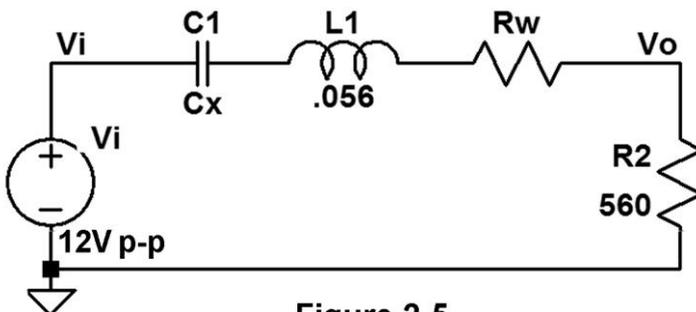


Figure 2-5

3. Set the function generator to produce a 12.0V peak-to-peak, 1500Hz, sine wave as measured by the oscilloscope channel 1.
4. Set up a spreadsheet for your measurements as shown below:

	A	B	C	D	E	F	G	H	I	J
1	Circuit	t mS	Vo mag	Vo θ	I mA	I θ	Si mVA	Pi mW	Po mW	% Eff.
3	Comp 0									
4	Comp 1									
5	Comp 2									
6	Comp 3									

Note: Columns D through J will be calculated by the spreadsheet. Instructions for the calculations are given in the analysis section of this lab exercise.

5. Connect channel 2 of the oscilloscope to measure V_o . Measure the peak-to-peak value of the voltage V_o , convert it to RMS, and record in cell C3.
 Measure the time between the positive slope zero crossings of V_i and V_o (in milliseconds). Record the result in cell B3. The time is negative if V_o crosses zero after V_i .
6. Remove the jumper wire across the .1uF capacitor. This will be the compensated circuit "Comp 1" with $C_x = .1\mu\text{F}$.
7. Repeat step 5 but enter the measurements in cells C4 and B4.
8. Connect a .1uF capacitor in parallel with the .1uF capacitor on the board so $C_x = .2\mu\text{F}$.
9. Repeat step 5 but enter the measurements in cells C5 and B5.
10. Connect another .1uF capacitor in parallel with the two .1uF capacitors on the board so $C_x = .3\mu\text{F}$.
11. Repeat step 5 but enter the measurements in cells C6 and B6.

Analysis

1. Enter the following equations into the indicated cells:

$$\text{Cell D3:} = (B3/667)*360 \quad \text{Cell E3:} = C3/.560 \quad \text{Cell F3:} = D3$$

$$\text{Cell G3:} = 4.242*E3 \quad \text{Cell H3:} = G3*\cos(3.14*F3/180)$$

$$\text{Cell I3:} = C3*E3 \quad \text{Cell J3:} = (I3/H3)*100$$

Verify that the above equations are correct. Note that **V_o** is in volts peak-to-peak. **I** is in milliamps RMS.

2. The example spreadsheet below was produced with R2 = 510 ohms using simulation data and the labeled values of capacitance and inductance. Your results should be similar.

	A	B	C	D	E	F	G	H	I	J
1	Circuit	t μ S	V _o	V _o θ	I mA	I θ	Si mVA	Pi mW	Po mW	% Eff.
3	Short	-74.80	2.93	-40.39	5.75	-40.39	24.36	18.56	16.83	90.70
4	Cx=.1	79.80	2.77	43.09	5.43	43.09	23.03	16.82	15.04	89.43
5	Cx=.2	0.00	3.79	0.00	7.43	0.00	31.51	31.51	28.16	89.39
6	Cx=.3	-31.40	3.63	-16.96	7.12	-16.96	30.18	28.87	25.84	89.50

3. Simulate the circuit for each value of Cx using AC analysis. Set the sweep to octave, 1 point per octave, start frequency to 1500Hz and stop frequency to 1500Hz. Refer to the example simulation in the next section.
4. Explain the results for V_o in terms of the circuit's power factor. Calculate the percent difference between the simulated results and the measured results for **V_o**.
5. Given the $\pm 5\%$ tolerance of the inductor and capacitor values, calculate the possible range of the circuit's impedance..

LTspice Example

This example uses different value of R2 than the experiment. Use this as a guide to simulate your experiment.

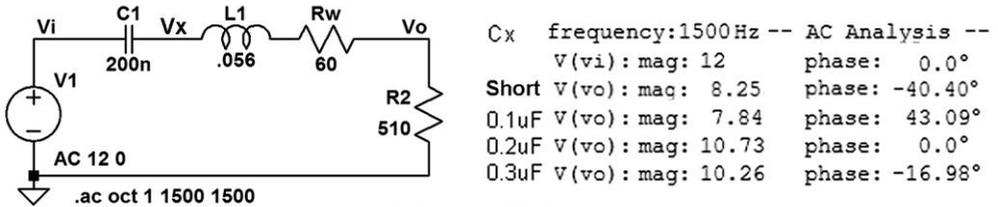


Figure 2-6

The simulation was run four times, once for each value of Cx. Voltage at node Vx can be used to calculate the reactive power in the inductor and capacitor. The reactive power of the capacitor will equal the reactive power of the inductor when the power factor equals one.