

4.6.1: Maximum Power Transfer

Overview:

This assignment involves the maximum power transfer theorem. We will inappropriately attempt to maximize the power delivered to a load resistor by, in some sense, re-defining the source circuit.

Before beginning this lab, you should be able to:

- Create a Thevenin equivalent of an arbitrary linear circuit
- Determine the load resistance necessary to draw the maximum power from a circuit

After completing this lab, you should be able to:

- Compare measured voltages and currents in an electrical circuit with predictions based on superposition techniques

This lab exercise requires:

- Analog Discovery module
- Digilent Analog Parts Kit
- Digital multimeter

Symbol Key:

	Demonstrate circuit operation to teaching assistant; teaching assistant should initial lab notebook and grade sheet, indicating that circuit operation is acceptable.
	Analysis; include principle results of analysis in laboratory report.
	Numerical simulation (using PSPICE or MATLAB as indicated); include results of MATLAB numerical analysis and/or simulation in laboratory report.
	Record data in your lab notebook.

General Discussion:

Thévenin's theorem tells us that the power delivered to a load is maximized if the load resistance is equal to the Thevenin resistance of the circuit supplying the power. It is often desirable to design our load resistance to draw the maximum power from a source circuit – this results in the minimum power being lost as heat dissipated within the source circuit. In this case, the load is said to be *matched* to the source.

In this lab exercise, we will attempt to maximize power transfer to a load by modifying the source circuit. (We will, in essence, attempt to match the source to the load rather than the other way around.) We will see that this approach is inappropriate; the maximum power transfer theorem does not apply in “reverse”.

Pre-lab:

Our goal is to transfer the maximum amount of power to a 2.2k Ω load resistor. The circuit schematic shown in Figure 1 illustrates connection of the load resistor directly to a non-ideal source. Assuming that the source resistance R_S is much less than the load resistance R_L (e.g. $R_S \ll R_L$), calculate the power delivered to the load resistor.

ANALYSIS

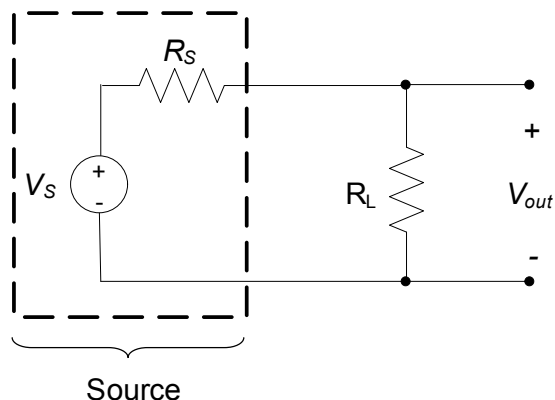


Figure 1. “Loaded” non-ideal source.

We know that the maximum power will be delivered to the load resistor of Figure 1 if $R_L = R_S$. In this lab assignment, we do not have the luxury of changing our load, but we can re-define our “source”. Add a resistance to the “source” as shown in Figure 2; note that the “source” resistance and the load resistance are now the same. Calculate the power delivered to the load resistor for this case and compare this power delivery to that of Figure 1.

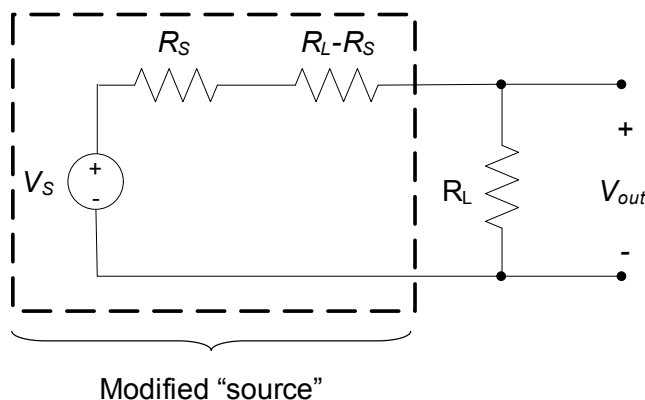


Figure 2. “Loaded” source with modified source resistance.

Lab Procedures:

DATA

1. Implement the circuit of Figure 1 with $R_L = 2.2\text{k}\Omega$ and $V_S = 5\text{V}$. Use a $5\text{k}\Omega$ potentiometer to implement R_L ; we will vary the load resistance in step 3 below. Measure V_{OUT} and calculate the power delivered to the load. Compare this power delivery with the power delivered to the 25Ω resistor in lab assignment 2.4. Are the relative powers delivered consistent with your estimate of the source resistance determined in lab assignment 2.4 and the maximum power theorem?

DATA

2. Modify the “source” according to Figure 2, with $R_L = 2.2\text{k}\Omega$ and $V_S = 5\text{V}$. You may assume that $R_S \ll R_L$, so that $R_L - R_S \approx R_L = 2.2\text{k}\Omega$. You may use a fixed $2.2\text{k}\Omega$ resistor to implement the added source resistance $R_L - R_S$. Measure V_{OUT} and calculate the power delivered to the load. Is this power consistent with your previous results and the maximum power theorem?
3. In step 1 above, we (hopefully) realized that attempting to modify the source resistance does not result in the maximum overall power transfer to the load. In this step, we will see that the modified circuit of step 2 does provide the maximum power transfer for that value of source resistance. (That maximum power is just less than the maximum possible power transfer if we vary the source resistance.)

DATA

In order to do this, measure V_{OUT} and calculate the power delivered to the load for at least five values of load resistance over a range of (approximately) $1\text{k}\Omega < R_L < 4\text{k}\Omega$. Use $V_S = 5\text{V}$, as in steps 1 and 2. (This is easy if the load resistance is implemented with a potentiometer, as recommended in step 1 above.) Plot the power delivered to the load vs. the load resistance. Are your results consistent with the maximum power theorem?

DEMO

4. Demonstrate operation of your circuit to the Teaching Assistant. Have the TA initial the appropriate page(s) of your lab notebook and the lab checklist.