Load Matching & Maximum Power

Air Washington Electronics ~ Direct Current Lab

Load Matching & Maximum Power

Overview

In this lab, the student will verify that maximum source power is transferred to a load when the internal resistance (r_i) equals the resistance of the load (R_L). This will be accomplished by building the circuit, taking measurements, and plotting a graph of the relationship between load resistance and maximum power. Students must also provide observations and conclusions to demonstrate understanding of the concept of maximum efficiency compared to maximum power.

Requirements

To meet all requirements for this lab, you must complete all activities, questions, critical thinking activities and questions, and observations and conclusions.

Course Objectives

- Demonstrate proper measurement techniques for: Voltage, Current, and Resistance.
- Demonstrate proper operating techniques and evaluate for proper operation the following list of test equipment: DC power supply and Digital Multi-Meter.
- Understand the loading effect of various types of test equipment.
- Understand the limitations of the various test equipment.
- Demonstrate acceptable techniques to construct circuits from schematic drawings on solderless and/or solder type breadboards.
- Demonstrate ability to predict circuit operation.

Module Objectives

- Build a circuit per schematic and take/analyze measurements.
- Verify maximum source power is transferred to a load when the internal resistance (r_i) equals the resistance of the load (R_L).
- Analyze relationship between maximum efficiency and maximum power.
- Demonstrate understanding of internal resistance.

Activities & Assessments

1. Load Matching and Maximum Power
2. Critical Thinking

1: Load Matching and Maximum Power

A meter connected across the terminals of a good 1.5-volt battery reads about 1.5 volts. When the same battery is inserted into a complete circuit, the meter reading decreases to something less than 1.5 volts. This difference in terminal voltage is caused by the INTERNAL RESISTANCE of the battery (the opposition to current offered by the electrolyte in the battery). All sources of electromotive force have some form of internal resistance which causes a drop in terminal voltage as current flows through the source.

This principle is illustrated in figure 1, where the internal resistance of a battery is shown as Ri. In the schematic, the internal resistance is indicated by an additional resistor in series with the battery. The battery, with its internal resistance, is enclosed within the dotted lines of the schematic diagram. With the switch open, the voltage across the battery terminals reads 15 volts. When the switch is closed, current flow causes voltage drops around the circuit. The circuit current of 2 amperes causes a voltage drop of 2 volts across Ri. The 1-ohm internal battery resistance thereby drops the battery terminal voltage to 13 volts. Internal resistance *cannot* be measured directly with a meter. An attempt to do this would damage the meter.

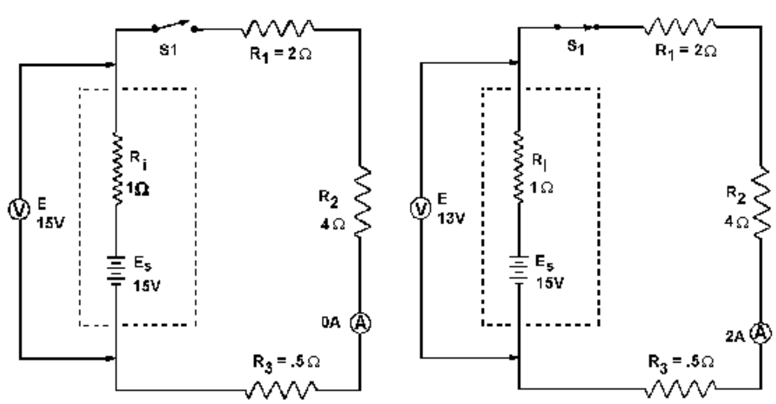


Figure 1.—Effect of internal resistance.

The effect of the source resistance on the power output of a dc source may be shown by an analysis of the circuit in figure 2. When the variable load resistor (RL) is set at the zero-ohm position (equivalent to a short circuit), current (I) is calculated using the following formula:

$$I = \frac{E_s}{R_i} = \frac{100\ V}{5\ \Omega} = 20\ A$$

This is the maximum current that may be drawn from the source. The terminal voltage across the short circuit is zero volts and all the voltage is across the resistance within the source.

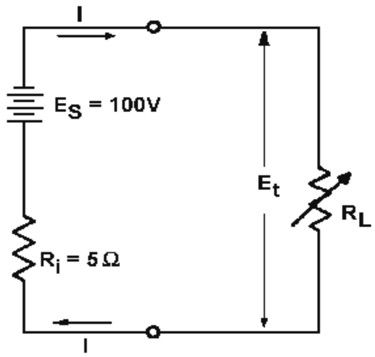
If the load resistance (RL) were increased (the internal resistance remaining the same), the current drawn from the source would decrease. Consequently, the voltage drop across the internal resistance would decrease. At the same time, the terminal voltage applied across the load would increase and approach a maximum as the current approaches zero amps.

Power Transfer and Efficiency

Maximum power is transferred from the source to the load when the <u>resistance of the load is equal to</u> <u>the internal resistance of the source.</u> This theory is illustrated in the table and the graph of figure 2. When the load resistance is 5 ohms, matching the source resistance, the maximum power of 500 watts is developed in the load.

The efficiency of power transfer (ratio of output power to input power) from the source to the load <u>increases as the load resistance is increased.</u> The efficiency approaches 100 percent as the load resistance approaches a relatively large value compared with that of the source, since less power is lost in the source. The efficiency of power transfer is only 50 percent at the maximum power transfer point (when the load resistance equals the internal resistance of the source). The efficiency of power transfer approaches zero efficiency when the load resistance is relatively small compared with the internal resistance of the source. This is also shown on the chart of figure 2.

The problem of a desire for both high efficiency and maximum power transfer is resolved by a compromise between maximum power transfer and high efficiency. Where the amounts of power involved are large and the efficiency is important, the load resistance is made large relative to the source resistance so that the losses are kept small. In this case, the efficiency is high. Where the problem of matching a source to a load is important, as in communications circuits, a strong signal may be more important than a high percentage of efficiency. In such cases, the efficiency of power transfer should be only about 50 percent; however, the power transfer would be the maximum which the source is capable of supplying.

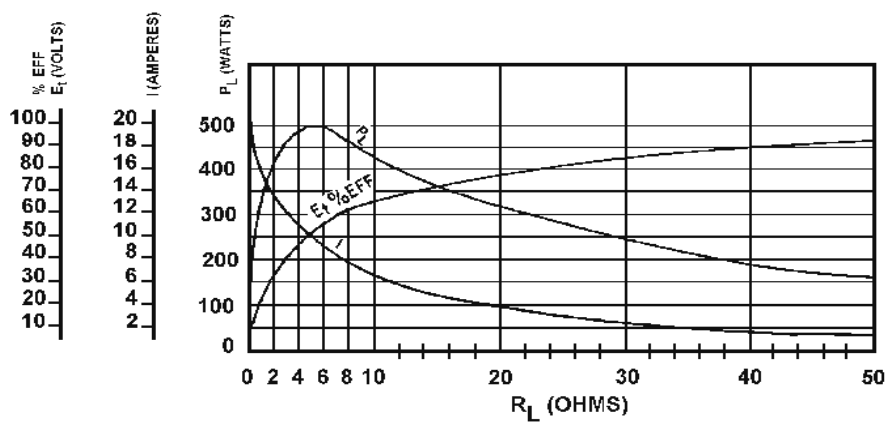


E_S = OPEN - CIRCUIT VOLTAGE OF SOURCE
R_i = INTERNAL RESISTANCE OF SOURCE
E_t = TERMINAL VOLTAGE
R_L = RESISTANCE OF LOAD
P_L = POWER USED IN LOAD
I = CURRENT FROM SOURCE
% EFF. = PERCENTAGE OF EFFICIENCY

(A)
CIRCUIT AND SYMBOL DESIGNATION

R_L	E_t	I	P_L	%EFF.
0	0	20	0	0
1	16.7	16.7	278.9	16.7
2	28.6	14.3	409	28.6
3	37.5	12.5	468.8	37.5
4	44.4	11.1	492.8	44.4
5	50	10	500	50
6	54.5	9.1	496.0	54.5
7	58.3	8.3	483.9	58.3
8	61.6	7.7	474.3	61.6
9	64.3	7.1	456.5	64.3
10	66.7	6.7	446.9	66.7
20	80	4	320	80
30	85.7	2.9	248.5	85.7
40	88.9	2.2	195.6	88.9
50	90.9	1.9	172.7	90.9

(B)
CHART



(C)
GRAPH

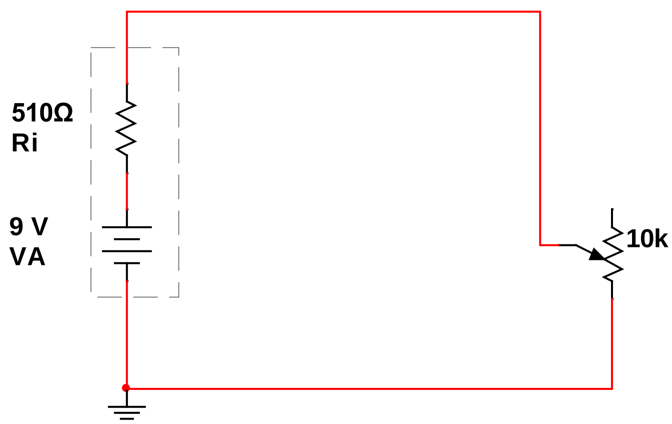
Figure 2.—Effect of source resistance on power output.

You should now understand the basic concepts of series circuits. The principles which have been presented are of lasting importance. Once equipped with a firm understanding of series circuits, you hold the key to an understanding of the parallel circuits to be presented next.

Components & Equipment Needed

- DC Power Supply or 9 V Battery
- Multimeter
- 10 kΩ (or greater) Potentiometer

Schematic



Formulae

- $\% \, efficiency = \frac{P_L}{P_T} \times 100$
- $V_T = V_{R_L} + V_{r_i}$, for use when calculation P_T

Procedure

Step 1: Build the circuit as shown in the schematic.

Step 2: Using the chart below, record your measured load voltage and current for each resistance shown. Complete calculated values.

	Measured Values		Calculated Values				
R_L, Ω	**V_{RL}, V**	**I, A**	**V_{ri}, V**	**P_L, W**	**P_{ri}, W**	**P_T, W**	**Efficiency, %**
100							
200							
300							
400							
500							
600							
700							
800							
900							
1000							
2000							
3000							
4000							
5000							
6000							
7000							
8000							
9000							
10000							

Step 3: Prepare a graph using R as the x-axis and P_L as the y-axis. Be sure to include your analysis of this graph in your lab report. Include any conclusions you draw concerning the relationship between maximum power and maximum efficiency.

References

United States Navy. (September 1998). Module 1 - Introduction to Matter, Energy, and Direct Current (NAVEDTRA 149173). In *Naval Electricity & Electronics Training Series (NEETS)* (NAVSUP Logistics Tracking Number: 0504-LP-026-8260). Prepared by ETCS (SW) Donnie Jones. Naval Education and Training - Professional Development and Technology Center. Pages 3-46 to 3-48.