ECE 109 - TRANSFER FUNCTIONS - INVESTIGATION 23
LOADING IN RESISTOR CIRCUITS

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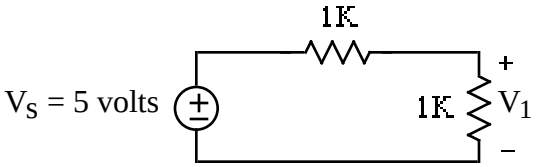
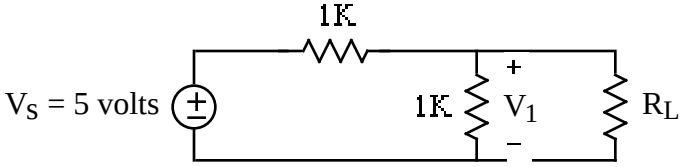
To do "well" on this investigation you must not only get the right answers but must also do neat, complete and concise writeups that make obvious what each problem is, how you're solving the problem and what your answer is. You also need to include drawings of all circuits as well as appropriate graphs and tables.

Circuits are very often built in sections which are then connected together. This is great except that sections that work fine by themselves may not work well or at all when connected together. The objective of this Investigation is to see how connecting circuits together affects their output voltages - how the gain of a circuit is affected by the equivalent resistance of the load.

1. Given the following circuit

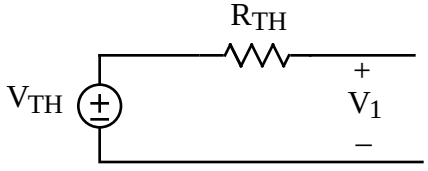


   a. Find V_1
   b. Now suppose we connect a load R_L as follows

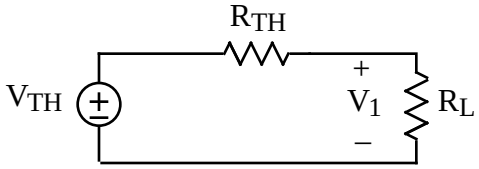


      Does the adding of R_L cause V_1 to go up, to go down or to stay the same. Hint - replace the original circuit by its Thevenin Equivalent
   c. Now find and sketch V_1 as a function of R_L. Describe the graph.
   d. Why do we say R_L **loads down** the circuit when R_L is small

2. Generalizing on the result of Problem (1) we see that if we take a general resistor circuit with Thevenin Equivalent as follows



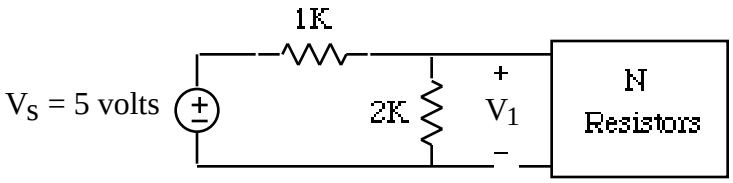
   and then connect a load resistor R_L as follows



then V_1 will decrease from

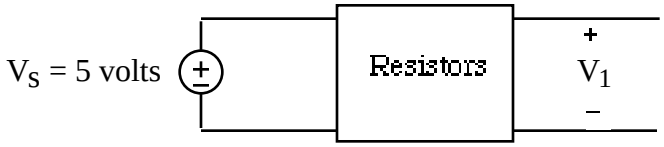
$$V_1 = V_{TH} \qquad \text{to} \qquad V_1 = \frac{R_L}{R_L + R_{TH}} V_{TH}$$

Memorize this result. Then make use of it to find and sketch V_1 in the following circuit

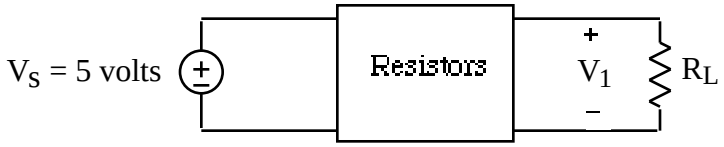


as a function of the equivalent resistance R_{EQ} of N. Describe your graph

3. Suppose we take the following circuit

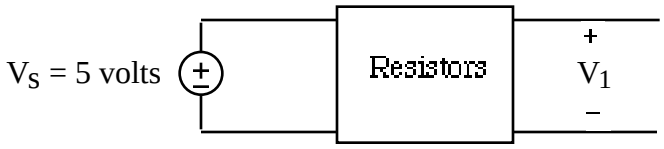


with open circuit gain $G = V_1/V_S = 0.8$ and Thevenin Equivalent Resistance R_{TH} and add a load resistor R_L as follows

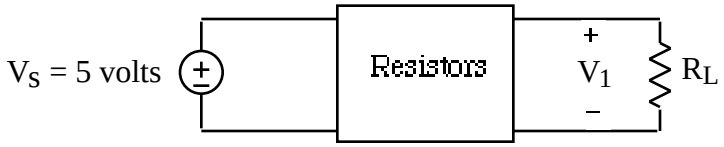


a. How did adding R_L affect V_1. Did it go up, down or stay the same. How do you know
b. Find and sketch V_1 as a function of R_L if $R_{TH} = 1K$. Describe your graph
c. Find and sketch V_1 as a function of R_{TH} if $R_L = 1K$. Describe your graph
d. For what value of R_{TH} is V_1 maximum

4. Suppose we take the following circuit



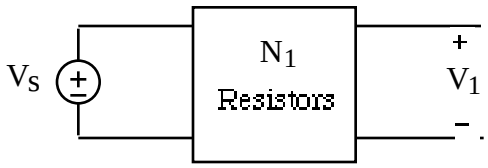
with open circuit gain $G = V_1/V_S = G_{OC}$ and add a load resistor R_L as follows



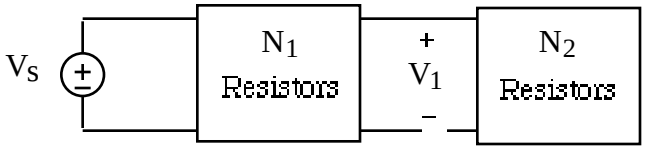
a. How did adding R_L affect the gain $G = V_1/V_S$. Did it go up, down or stay the same. How do you know

b. Sketch G as a function of R_L. Describe your graph

5. Suppose we take the following circuit

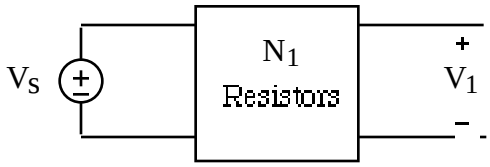


with Thevenin Equivalent resistance R_{TH} and open circuit voltage gain $G_1 = V_1/V_S$ and connect to it a second circuit N_2 with equivalent resistance R_{EQ} as follows

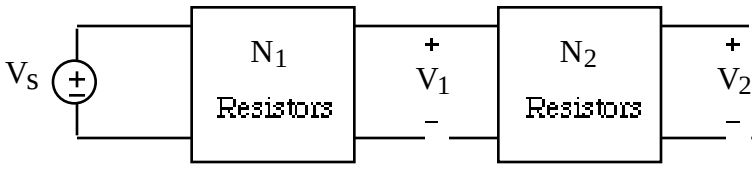


How will V_1 be affected by connecting N_2 if the equivalent resistance R_{EQ2} of N_2 satisfies $R_{EQ2} >> R_{TH}$. Justify your answer. Test your result by calculating V_1 when $V_{TH} = 5$ volts, $R_{TH1} = 100\ \Omega$ and $R_{EQ2} = 10K$

6. Now suppose we now take the same circuit N_1 as in Problem (6)



with Thevenin Equivalent resistance R_{TH1} and open circuit gain $G_1 = V_1/V_S$ but this time connect up a second circuit N_2 with equivalent resistance R_{EQ2} and open circuit voltage gain $G_2 = V_2/V_1$ as follows



a. First draw the circuit with V_S and N_1 replaced by its Thevenin Equivalent
b. Now justify the fact that if $R_{EQ2} >> R_{TH1}$ then for all practical purposes $V_1 = G_1 V_S$
c. Make use of your result in part (b) to find an equation for V_2 in terms of V_S, G_1 and G_2 when $R_{EQ2} >> R_{TH1}$
d. We have from part (c) that the overall voltage gain of our circuit is $G = G_1 G_2$ when there is no loading of N_1 by N_2. **Memorize** this result. It's very important. Now let's consider the case when N_2 does load down N_1. Would this result in a smaller or larger overall voltage gain than when there is no loading. Explain how you know

7. Would you rather your voltmeter have a large equivalent resistance or a small equivalent resistance. Why

8. Math Review: Given $x(t) = 3\cos(2\pi 1000t)$
    a. What is the period of $x(t)$
    b. How much time does it take $x(t)$ to go through 5 periods