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IE HW1

1) Sources : Consider the following two circuits. Assume that the two circuits are equivalent with respect to their properties at the two terminals.
   a) Based on the circuit elements shown in the figure, give the output-voltage-versus-output-current function of the LHS (left-hand side) circuit. Sketch the function (Suggestion: y -axis = V and x -axis = I) .

$V = V_S - R_S I$

   b) Give the output-current-versus-output-voltage function of the RHS (right-hand side) circuit. Sketch the function (Suggestion: y -axis = I and x -axis = V).

$I = I_S - G_S V$

   c) The two functions you sketched should be linear functions (straight lines). Can the two functions be identical?

Well, one is V(I) and one is I(V), but otherwise, yes, they're the same equation as long as $G_S = R_S^{-1}$ and $I_S = V_S$.

   d) How can one show that the two functions are identical?

$I = I_S - G_S V$

$I = I_S - R_S^{-1} V$

$I + R_S^{-1} V = I_S$

$R_S^{-1} V = I_S - I$

$V = R_S I_S - R_S I$

$V = V_S - R_S I$

   e) For the two circuits to be equivalent, which two quantities (one of them a voltage and the other one a current) must be identical?

Connecting any two different loads and having the voltage and current be equivalent shows that they're identical given that it's a linear system, but generally, the math is a lot easier if you just use open circuit voltage and short circuit current.

2) Linear and non-linear circuits : There are linear circuits and non-linear circuits.

a) Define a linear circuit (in words).

Zero input, zero output. Double input, Double output. Everything is directly proportional to what it's dependent on, everything is a linear relationship.

b) Define a non-linear circuit (in words).

Zero input does not mean zero output. Double input does not mean double output. There are values that are not directly proportional to the values they depend on. There are variables that do not have a linear relationship.

c) List all linear circuit elements that you know of.

Resistor, Capacitor, Inductor, ideal independent Voltage source, ideal independent Current source, linear dependent Voltage source, linear dependent Current source, OpAmp, Transformer.

d) List some non-linear circuit elements.

Realistically, anything listed above because nothing is ideal. Any Diode, any Transistor, saturated core transformers.

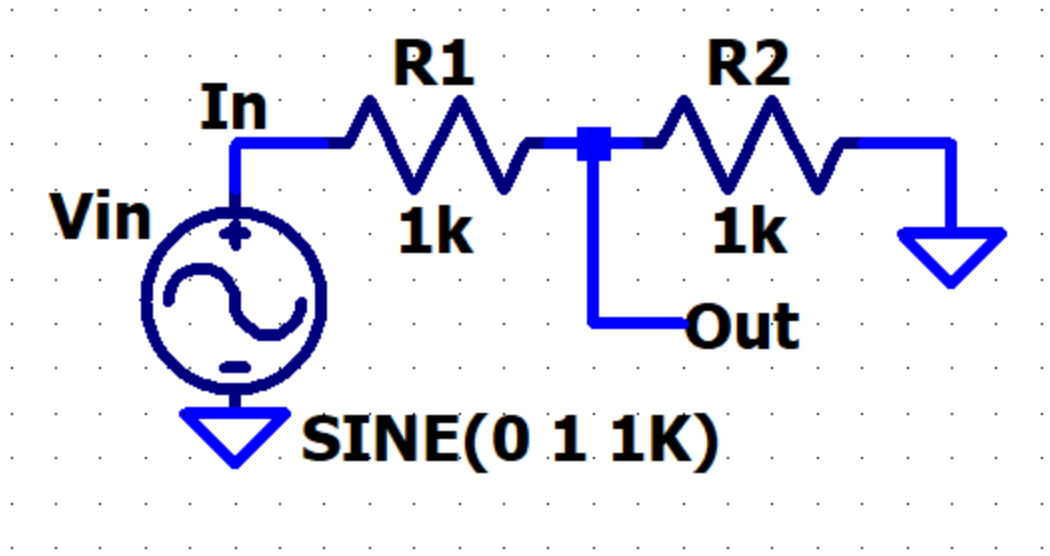
e) Is a real voltage source (ideal voltage source plus internal resistance) a linear circuit element? Justify your answer.

Yes, anything made of linear elements is still linear. In this case, an ideal voltage souce would provide voltage according to $V = V_S$, but a real voltage souce adds another linear term to get $V = V_S - R_S I$.

f) Is a real current source (ideal current source plus internal conductance) a linear circuit element? Justify your answer.

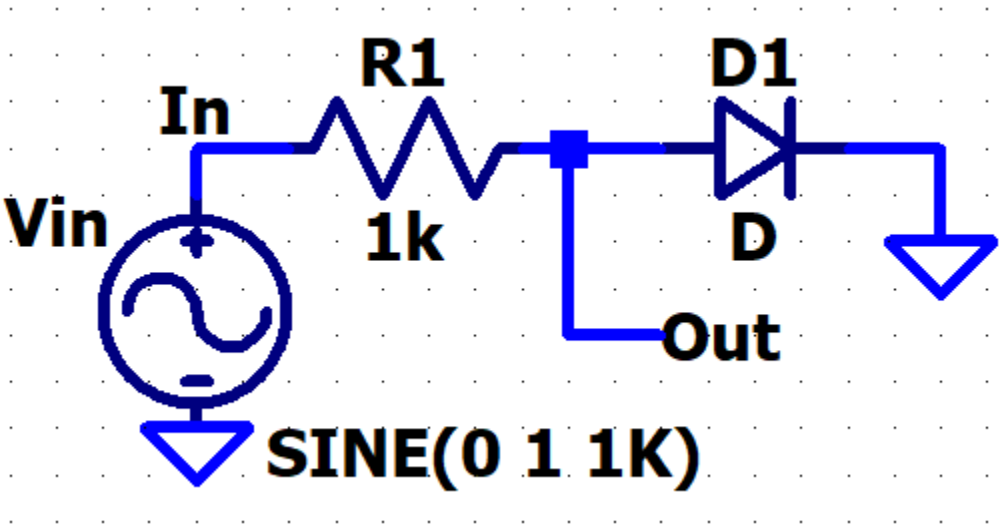
Yes, anything made of linear elements is still linear. In this case, an ideal current souce would provide current according to $I = I_S$, but a real current souce adds another linear term to get $I = I_S - G_S V$.

g) Draw an example of a linear circuit having an input and an output.



A simple voltage divider

h) Draw an example of a non-linear circuit having an input and an output.



A simple voltage limiter

i) Is a linear circuit or a non-linear circuit generally simpler to analyze? Explain your answer.

Linear is much easier to analyze. There are lots of shortcuts and tricks that work because all you need to do is basic addition, subtraction, multiplication, and division. Once things aren't linear, the actual values make a difference and you can't simplify much with variables. No more linear algebra :(

3) Superposition principle : This problem concerns the superposition principle.

a) Which condition must be met for us to be allowed to apply the superposition principle?

We must have a linear circuit.

b) Express the superposition principle in your own words .

When you have a linear system, a variable that’s dependent on the sum of many factors can be broken down into each factor individually. It allows you to analyze the effect of each component and then simply sum them together to get the combined effect of all components.

c) Express the superposition principle by using an equation .

I(V1,V2,V3)=I(V1)+I(V2)+I(V3), generally, f(x,y)=f(x)+f(y)

d) Which type of system prevents us from applying the superposition principle?

Non-linear systems. f(x,y)!=f(x)+f(y), the output is no longer simply the sum of its parts.