EECS 42 Introduction to Electronics for Computer Science

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Lecture #5

- Nonlinear (NL) elements
- Graphical NL solutions
- Power for NL circuits

http://inst.EECS.Berkeley.EDU/~ee42/

Game Plan 02/05/03

Monday 02/03/03

- ❑ Capacitors and Inductors; Equivalent Sources
  Schwarz and Oldham: 5.1-5.2, 3.1

Wednesday 02/05/03

- ❑ N-L Elements; Graphical Solutions; Power
  Schwarz and Oldham: 3.2-3.4

Next (4th) Week

- ❑ RC Transient
  Schwarz and Oldham: 8.1 plus Handouts

Problem Set #3 – Out 2/2/03 - Due 2/12/03 2:30 in box near 275 Cory

3.1 and 3.2 charging capacitors; 3.3 –3.5; Equivalent Circuits;

Example of I-V Graphs

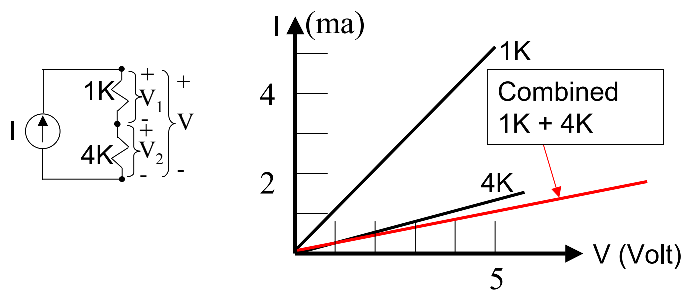
Version Date 02/02/03

Resistors in Series

If two resistors are in series the current is the same; clearly the total voltage will be the sum of the two IR values i.e. $I(R_1+R_2)$.

Thus the equivalent resistance is R_1+R_2 and the I-V graph of the series pair is the same as that of the equivalent resistance.

Of course we can also find the I-V graph of the combination by adding the voltages directly on the I-V axes. Lets do an example for 1K + 4K resistors



Version Date 02/02/03

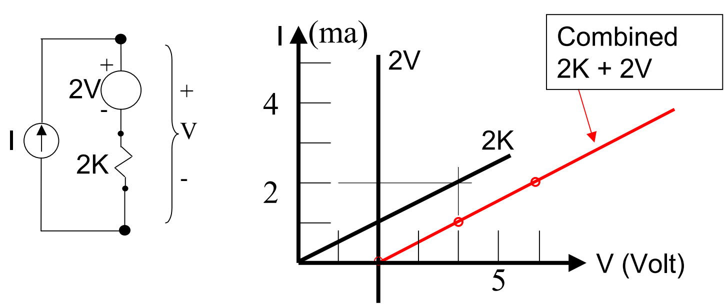
Example of I-V Graphs

Simple Circuit, e.g. voltage source + resistor.

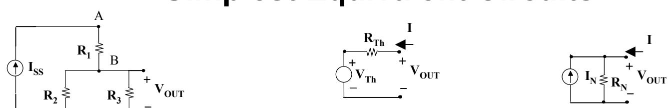
If two circuit elements are in series the current is the same; clearly the total voltage will be the sum of the voltages i.e. V_S + IR.

We can graph this on the I-V plane. We find the I-V graph of the combination by adding the voltages V_S and I R at each current I.

Lets do an example for =2V, R=2K

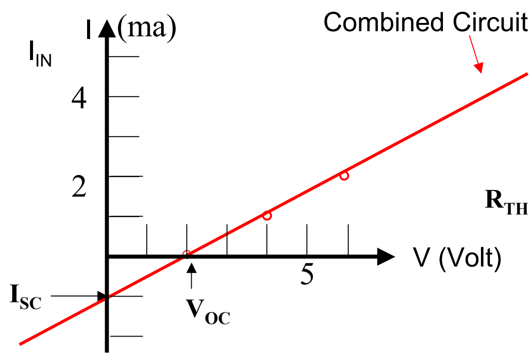


Simplest Equivalent Circuits



Thevenin Norton

An adequately equivalent circuit is one that has an I vs. V graph that is identical to that of the original circuit.



$V_{TH} = V_{OC}$

$I_N = -I_{SC}$

$R_{TH} = R_N = (-I_{SC}/V_{OC})$

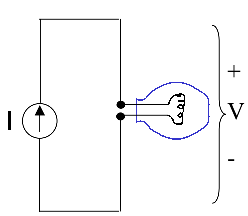
Example of I-V Graphs

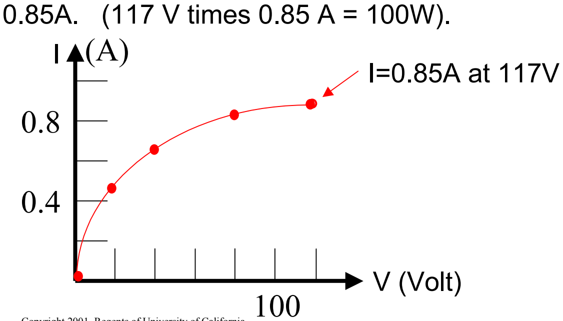
Nonlinear element, e.g. lightbulb

If we think of the light bulb as a sort of resistor, then the resistance changes with current because the filament heats up. The current is reduced (sort of like the resistance increasing). I say "sort of" because a resistor has, by definition a linear I-V graph and R is always the same.

But for a light bulb the graph kind of "rolls over", becoming almost flat.

Consider a 100 Watt bulb, which means at at the nominal line voltage of 117 V the current is 0.85A. (117 V times 0.85 A = 100W).



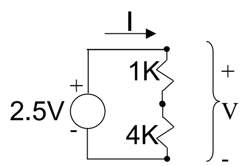


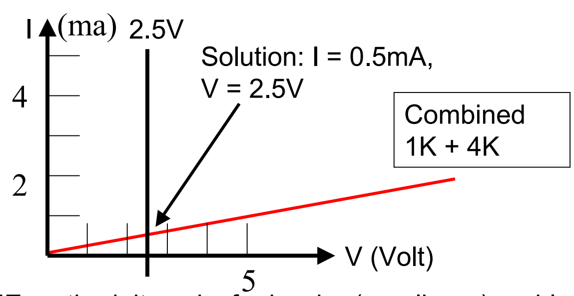
I-V Graphs as a method to solve circuits

We can find the currents and voltages in a simple circuit graphically. For example if we apply a voltage of 2.5V to the two resistors of our earlier example:

We draw the I-V of the voltage and the I-V graph of the two resistors on the same axes. Can you guess where the solution is?

At the point where the voltages of the two graphs AND the currents are equal. (Because, after all, the currents are equal, as are the voltages.)





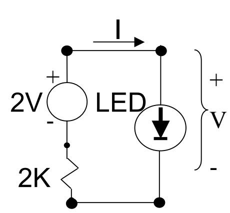
This is called the LOAD LINE method; it works for harder (non-linear) problems.

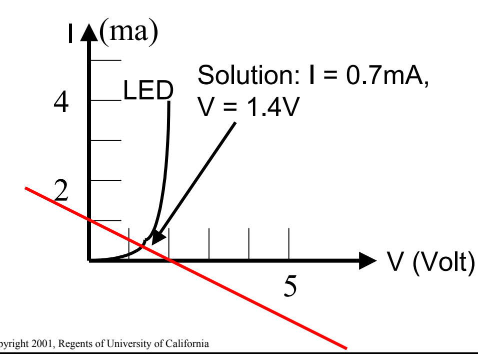
Another Example of the Load-Line Method

Lets hook our 2K resistor + 2V source circuit up to an LED (light-emitting diode), which is a very nonlinear element with the IV graph shown below.

Again we draw the I-V graph of the 2V/2K circuit on the same axes as the graph of the LED. Note that we have to get the sign of the voltage and current correct!! (The sing of the current is reversed from page 3)

At the point where the two graphs intersect, the voltages and the currents are equal, in other words we have the solution.





Power of Load-Line Method

We have a circuit containing a two-terminal non-linear element "NLE", and some linear components.

We will show in a few days that the entire linear part of the circuit can be replaced by an equivalent, called the Thevenin equivalent. This equivalent circuit consists of a voltage source in series with a resistor. (Just like the example we just worked!).

So if we replace the entire linear part of the circuit by its Thevenin equivalent our new circuit consists of (1) a non-linear element, and (2) a simple resistor and voltage source in series.

If we are happy with the accuracy of graphical solutions, then we just graph the I vs V of the NLE and the I vs V of the resistor plus voltage source on the same axes. The intersection of the two graphs is the solution. (Just like the problem on page 6)

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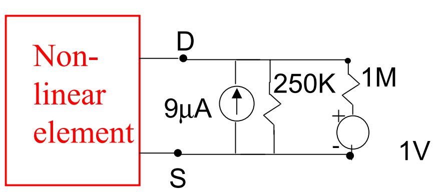
Version Date 02/02/03

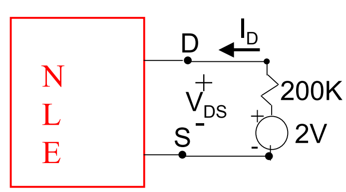
The Load-Line Method

We have a circuit containing a two-terminal non-linear element "NLE", and some linear components.

First replace the entire linear part of the circuit by its Thevenin equivalent (which is a resistor in series with a voltage source). We will learn how to do this in Lecture 11.

Then define I and V at the NLE terminals (typically associated signs)





NOTE: In lecture 11 we will show that the circuit shown on the left is equivalent to a 200K resistor in series with 2V.

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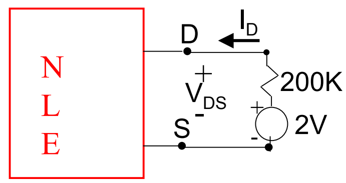
Example of Load-Line method (con't)

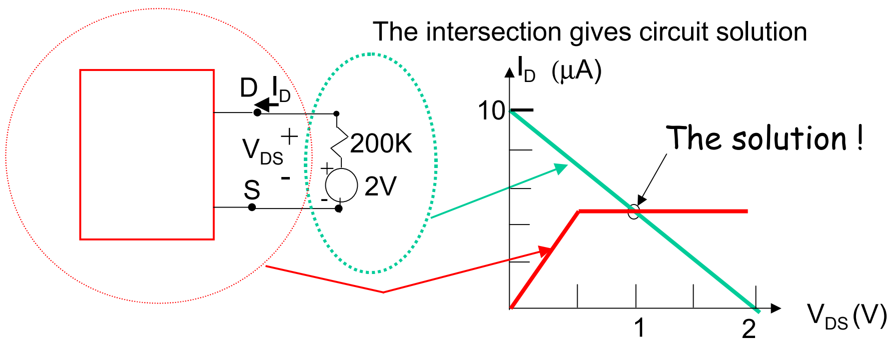
Given the graphical properties of two terminal non-linear circuit (i.e. the graph of a two terminal device)

And have this connected to a linear (Thévenin) circuit

Whose I-V can also be graphed on the same axes ("load line")



The intersection gives circuit solution



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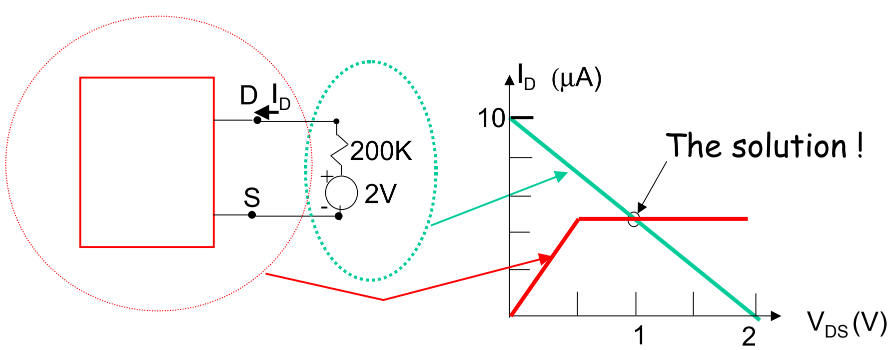
Load-Line method

The method is graphical, and therefore approximate

But if we use equations instead of graphs, it could be accurate

It can also be use to find solutions to circuits with three terminal nonlinear devices (like transistors) See lectures 21-22



Power Calculation Review

Power is calculated the same way for linear and non-linear elements and circuits.

For any circuit or element the dc power is I X V and, if associated signs are used, represents heating for positive power or extraction of energy for negative signs.

For example in the last example the NLE has a power of +1V X 5μA or 5μW . It is absorbing power. The rest of the circuit has a power of - 1V X 5μA or - 5μW , because the signs are unassociated. It is delivering the 5μW to the NLE.

So what it the power absorbed by the 200K resistor?

Answer: I X V is + 5mA X (5mA X 200K) = 5mW. Then the voltage source must be supplying a total of 10mW. Can you show this?