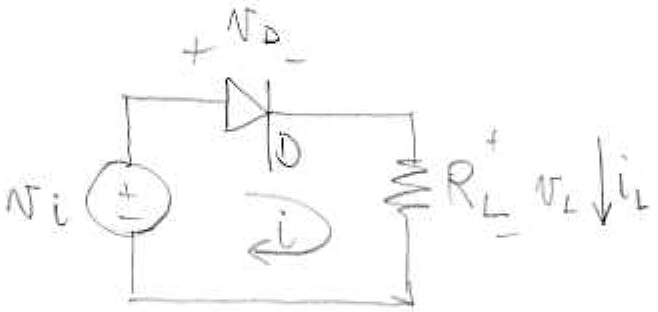
• LOAD LINE

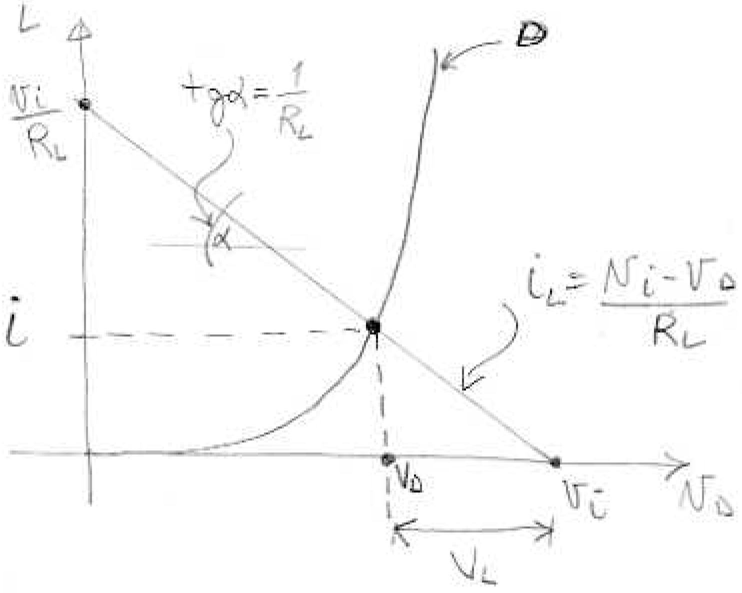
This is a graphical method to understand what is the current and voltage in a circuit containing diodes. It works in general for non linear circuits.
Usually the i-v characterization of a device like a diode is given by the manufacturer and the way the graph is plot is by points. Using measurements, the manufacturer can buil a table of pairs i-v and then can plot the result.
The curve is plot on the diode datasheet and engineers can use a graphical method to analyze a circuit.
Consider the following circuit:



Using KVL:

$$v_i = v_D + v_L = v_D + R_L i_L$$

we want to represent everyting on the i-v_D plane. The relation between current an voltage of the diode is an exponential



One the same grof we can represent the current through R_L as a function of v_D:

$$i_L = \frac{v_i - v_D}{R_L}$$

this function is clearly a line. We only need two points to draw a line.

If $v_D = 0 \Rightarrow i_L = \frac{v_i}{R_L}$

If $v_D = v_i \Rightarrow i_L = 0$

The angular coefficient of that line only depend on R_L which is the load. That line is called the load line.

Since the two elements, diode an resistor, are in series, their currents have to be the same so the only possible solution is when the currents are equal, meaning the intersection of the load line with the i-v characteristic of the diode.
That point is basically the solution of the system of equations:

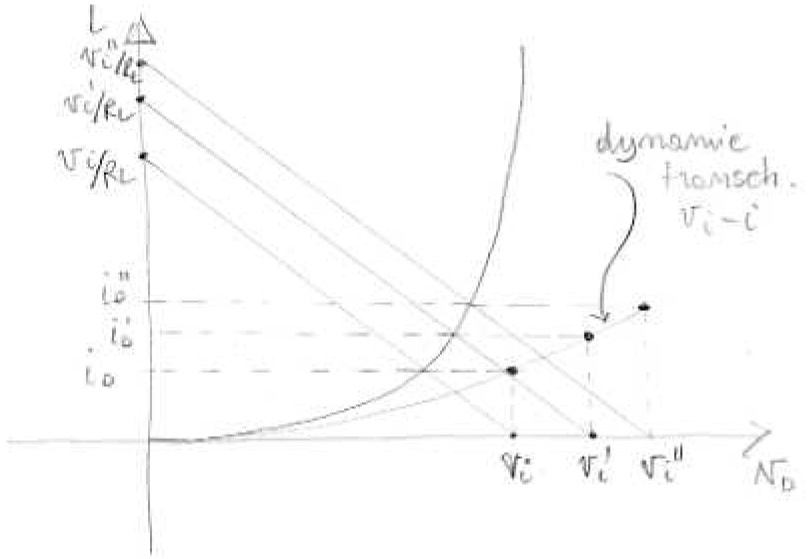
$$\begin{cases} i - I_0 e^{v_D/qV_T} = 0 \\ i - \frac{v_i - v_D}{R_L} = 0 \end{cases}$$

(we will see how this system is solved in spice).

DYNAMIC TRANS CHARACTERISTIC

We have considered v_i fixed. What happens il v_i changes. For the example Described in the previous section, it is interesting to look at the $v_i - i$ characteristic. The reason is that i is proportional to V_L which can be taken as output voltage.

The method that we can follow is still a graphical method:

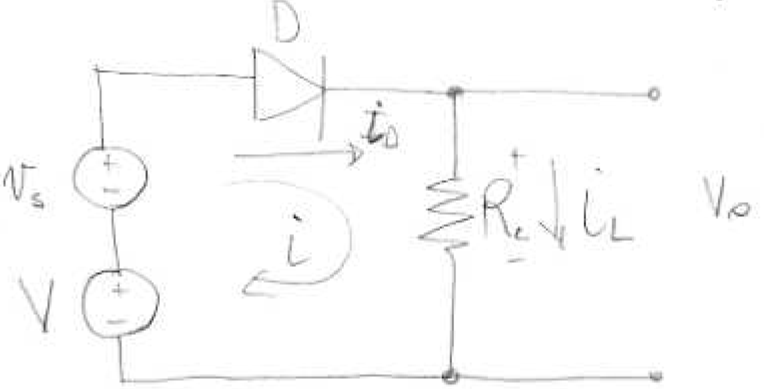


We draw a load line for different values of v_i. These lines are paralles because their angual coefficient are all equal to $1/R_L$ and R_L does not change. We then graphically find the current in the circuit an finally we mark the point (v_i, i_D). Those points lie on a graph which is the $v_i - i$ ~~dy~~ dynamic transcharacteristic.

DC POINT

The load line method can help us in understandig the current an voltage of a diode in DC conditions (where the source ar not time veriant an the circuit is at steady state).

Consider the following case:



$v_s = A\sin(w_o t)$

Consider $A=0$ first. Then is exactly as before. Let's write the equations for a general case:

$i = I_o e^{\left(v_D/\eta V_T\right)}$ where v_D is determined using the load line.

When $A \neq 0$ then the volteg across the diode is $v_D + v_s' = v_D'$ where v_s' is a time veriant voltage:

$$i' = I_o e^{v_D'/\eta V_T} = I_o e^{v_D + v_s'/\eta V_T} = I_o e^{v_D/\eta V_T} \, e^{v_s'/\eta V_T}$$ 12.6

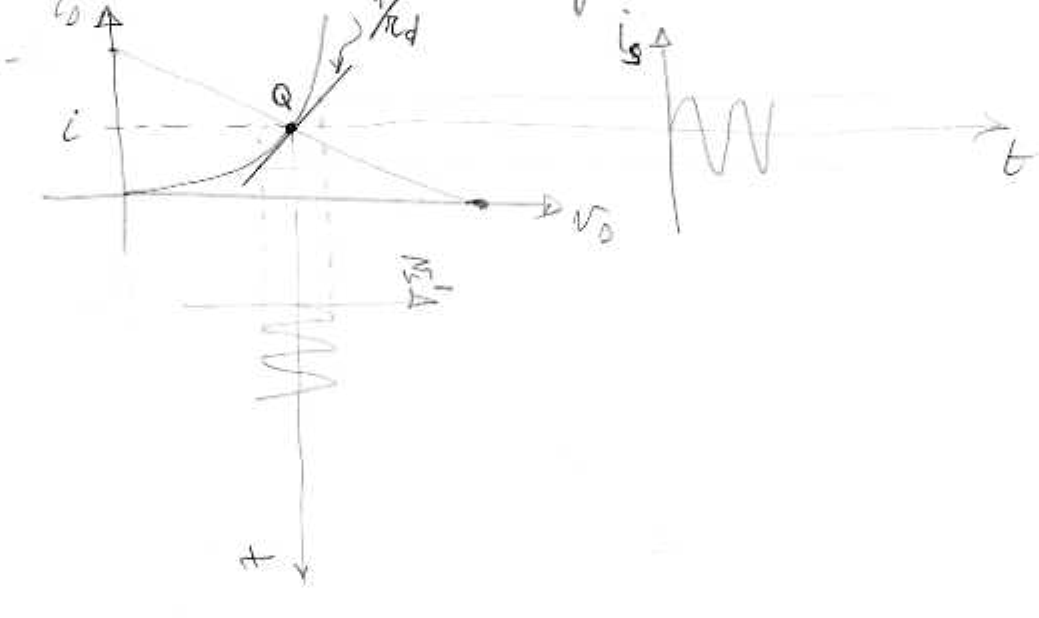
we can use the taylor expansion:

$$i' = I_o e^{v_D/\eta V_T} \left(1 + \frac{v_s'}{\eta V_T} + \frac{v_s'^2}{(\eta V_T)^2 \, 2!} + \cdots \right)$$

is $\frac{v_s'}{\eta V_T}$ is very small ($v_s' \ll V_T$) then

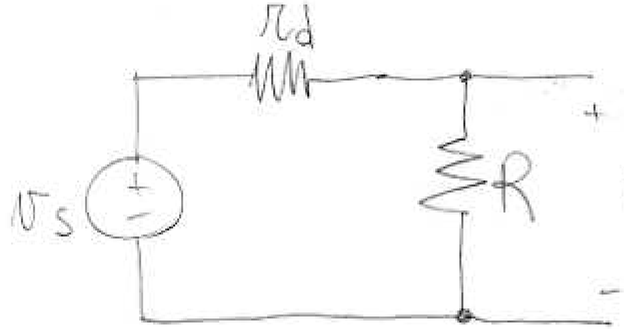
$$i' \simeq I_o e^{v_D/\eta V_T} + I_o e^{v_D/\eta V_T} \frac{v_s'}{\eta V_T} = i + i_s$$

$i_s = \frac{i}{\eta V_T} v_s'$ where $\frac{i}{\eta V_T}$ is a constant factor. The quantity $\frac{\eta V_T}{i} = r_D$ is the dynamic resistance of the diode:



The current is then the sume of the DC bias current pluse a current due to the small signal v_s. This current can be considered proportional to the small voltage variation.

So we can first compute the DC bias voltage i, the we comput the dinamyc resistance $r_d = \frac{\eta V_T}{i}$ and we can analyze the circuit from the point of view of v_s only:



this circuit is called "small signals" circuit because it comes from the assumption that $v_s \ll V_T$.

Q is called the quiescient point and you can verify that

$$r_d = \left[\left. \frac{\partial i_D}{\partial v_D} \right|_Q \right]^{-1}$$