8.2 Dynamic Behavior of pn-Junctions

8.2.1 General Observations

First, lets consider the dynamic behavior of a simple **pn**-junction.

- Whereas the *small* signal behavior at low frequencies is exactly that of <u>the example given before</u>, the *large* signal response in practice is simply what we (and everybody else) calls the **switching behavior** of the diode. In other words, we are looking at either

  - Suddenly switching the voltage from **0 V** to some forward value U_f , or
 - Suddenly switching the current from **0 A** to some constant forward value I_f .

In order to have some idea of what we want to find out, here are some typical results of experiments with modulated inputs. First, we look at the *small signal* behavior by plotting the amplitude of the *current output* versus the amplitude of the *voltage input* as a function of the frequency. What we will find looks like this:
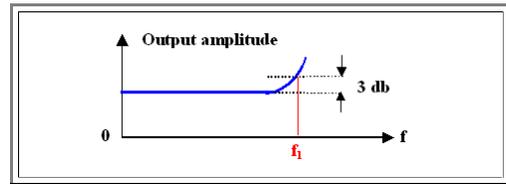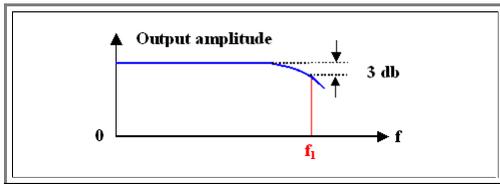
- While real curves may look quite different, we always will find that with increasing frequency the output amplitude will eventually come down or go up. Often, the frequency where the output value is **3 db** below or above its low frequency value is identified as some limit frequency f_1, giving us a time constant $\tau = 1/f_1$ which we want to understand in terms of materials properties.

Now we look at the *switching behavior for the voltage*, i.e. we suddenly switch off the voltage across the diode from **0 V** (or some reverse voltage) to some forward voltage, e.g. **0,7 V**.

- This is experimentally easy to do and to measure. What we obtain looks like this:
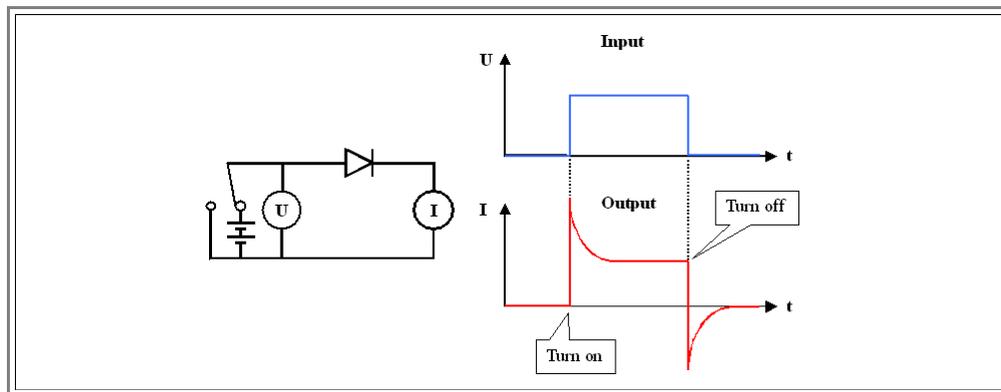
- We have pronounced current "**transients**" describable by one (or possibly more) time constants; and we want to know how these time constants relate to materials properties of the **pn**-junction.

Next, we *switch the current* "suddenly". The question is how to do this. In formal electrical terms, we just take a "constant current source" and turn it on. In reality this might be a voltage source with a resistor R_{CS} much larger than anything else in the circuit. The current than is simply **U/ R_{CS}** and switching is obtained by switching the voltage which now could be rather large.

- If we do the experiment, we will observe the following behavior:
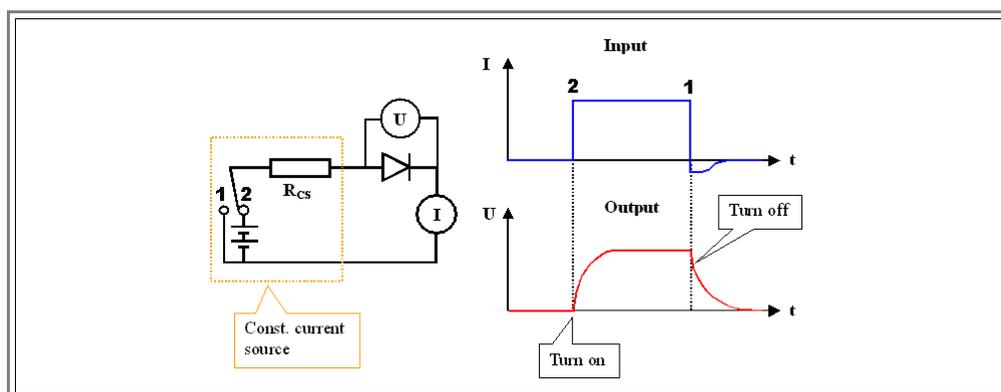
- Again, we have **transients** in the diode behavior, this time the voltage is affected. But we also have a kind of transients in the current - we will not be able to switch it off abruptly, but for some time a **reverse current flow** will be observed
- Since the current pulse was "made" by a (rectangular) voltage pulse and the external voltage is zero after the switching, we are forced to conclude that the diode acts for some time as a *voltage/current source* after the primary voltage was turned off. More details can be found in an advanced module

- Once more we measure some time constants and we must ask ourselves how they relate to the time constants of the voltage switching experiment and to material parameters.
- Accepting all these "experimental" findings, we even must conclude that there might be *several* time constants which, moreover, might depend on the particulars of the experiment, e.g. the working point, or the amplitudes of the input signal.
  - This does not just *look* a bit involved; it really *is*. And the "ideal" **pn**-junction diode is about the most simple device we have.
- We are going to look at it in some detail in the next subchapters, even so we are not particuarly interets in plain **pn**-junctions. But this will help to develop some basic understanding of the underlying processes and make the dicussion of more involved devices easier.