25/05/2020

Istituto Nazionale di Fisica Nucleare
SEZIONE DI FIRENZE

HIDRA input circuit study: model and simulation

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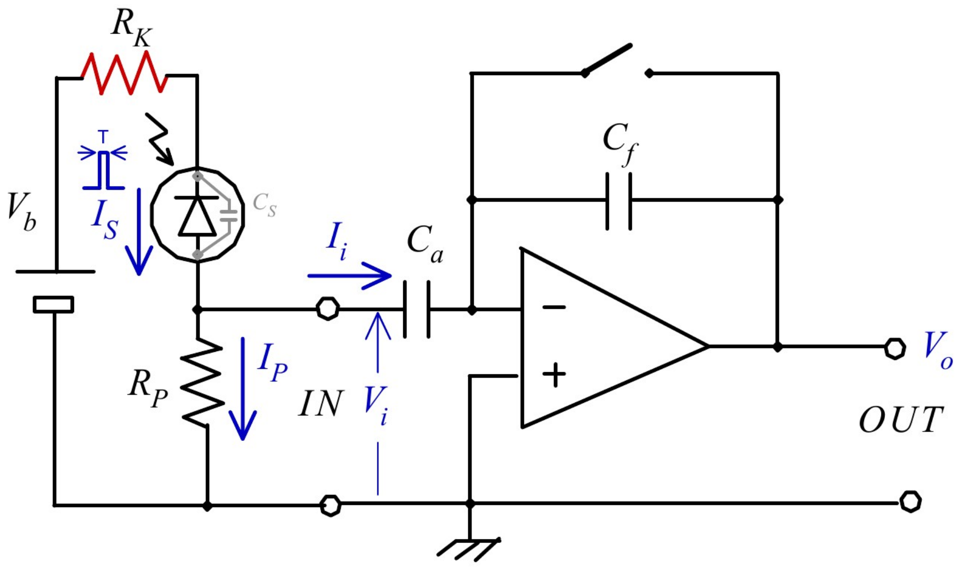
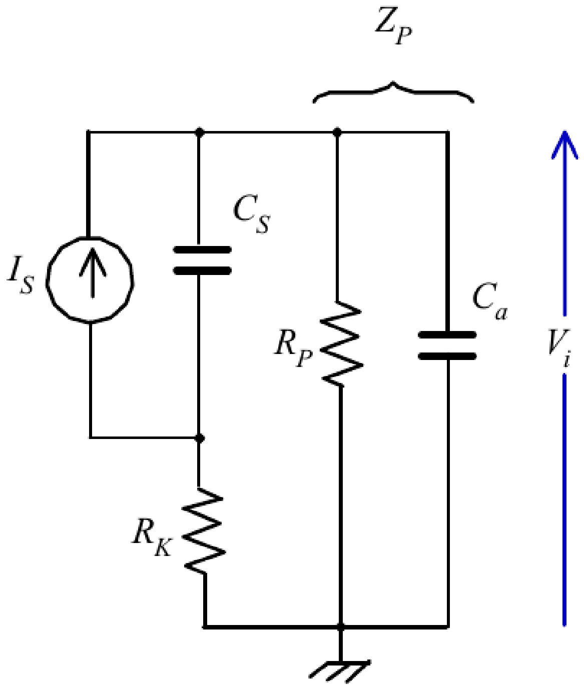
Approximation of the circuit

Simplified scheme



Equivalent circuit



The exact calculation is described in: “Risposta globale all'impulso Sebastiano Detti”

Results of the calculation: equation

Check Sebastiano's report

$$V_{idG}=\left[V_{iT}\cdot\left(\frac{1}{2}+\frac{\omega_o}{2\cdot\sqrt{\omega_o^2-4\cdot\omega_n^2}}\right)+\frac{V_{ST}\cdot R_P-V_{iT}\cdot(R_P+R_K)}{\sqrt{\omega_o^2-4\cdot\omega_n^2}\cdot C_a\cdot R_P\cdot R_K}\right]\cdot e^{-\frac{1}{2}\cdot\left(\omega_o-\sqrt{\omega_o^2-4\cdot\omega_n^2}\right)\cdot t}+$$
$$+\left[V_{iT}\cdot\left(\frac{1}{2}-\frac{\omega_o}{2\cdot\sqrt{\omega_o^2-4\cdot\omega_n^2}}\right)-\frac{V_{ST}\cdot R_P-V_{iT}\cdot(R_P+R_K)}{\sqrt{\omega_o^2-4\cdot\omega_n^2}\cdot C_a\cdot R_P\cdot R_K}\right]\cdot e^{-\frac{1}{2}\cdot\left(\omega_o+\sqrt{\omega_o^2-4\cdot\omega_n^2}\right)\cdot t}$$

Sintesi rete d'ingresso

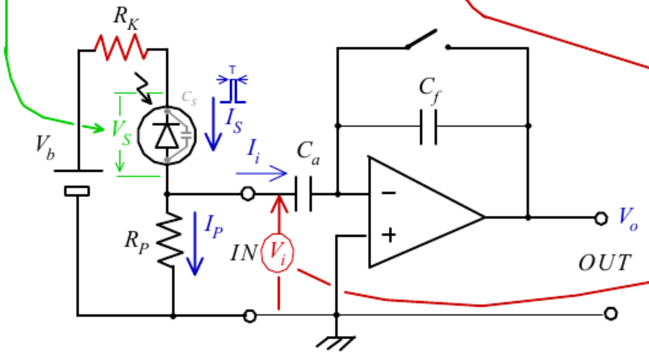
$$V_{ST}=I_S\cdot\left\{\frac{\left[2-C_S\cdot(R_P+R_K)\cdot\left(\omega_o+\sqrt{\omega_o^2-4\cdot\omega_n^2}\right)\right]\cdot e^{-\frac{1}{2}\left(\omega_o-\sqrt{\omega_o^2-4\cdot\omega_n^2}\right)\cdot T}+\left[C_S\cdot(R_P+R_K)\cdot\left(\omega_o-\sqrt{\omega_o^2-4\cdot\omega_n^2}\right)-2\right]\cdot e^{-\frac{1}{2}\left(\omega_o+\sqrt{\omega_o^2-4\cdot\omega_n^2}\right)\cdot T}}{2\cdot C_S\cdot\sqrt{\omega_o^2-4\cdot\omega_n^2}}+R_P+R_K\right\}$$

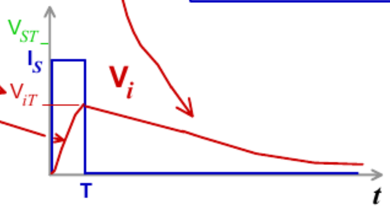
$$V_{iG}=I_S\cdot R_P\cdot\left[\frac{2\cdot\omega_n^2}{\sqrt{\omega_o^2-4\cdot\omega_n^2}}\cdot\left(\frac{e^{-\frac{\omega_o+\sqrt{\omega_o^2-4\cdot\omega_n^2}}{2}\cdot t}}{\omega_o+\sqrt{\omega_o^2-4\cdot\omega_n^2}}-\frac{e^{-\frac{\omega_o-\sqrt{\omega_o^2-4\cdot\omega_n^2}}{2}\cdot t}}{\omega_o-\sqrt{\omega_o^2-4\cdot\omega_n^2}}\right)+1\right]$$

$$V_{iT}=V_{iG}\big|_{t=T}$$

$$\omega_o=\frac{R_P\cdot(C_a+C_S)+C_S\cdot R_K}{C_S\cdot C_a\cdot R_P\cdot R_K}$$

$$\omega_n^2=\frac{1}{C_S\cdot C_a\cdot R_P\cdot R_K}$$





Results of the calculation: some plots

Vi vs Time

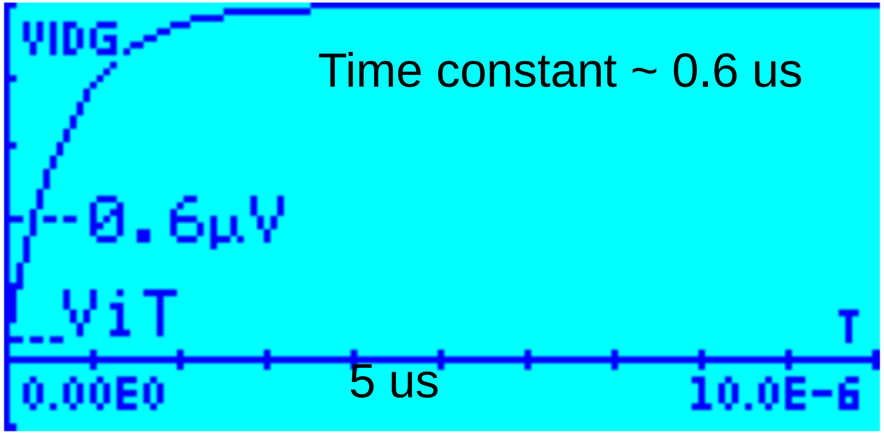
Current pulse parameters:

Width : 50 ns

Amplitude: 300 nA

Charge: 15 fC

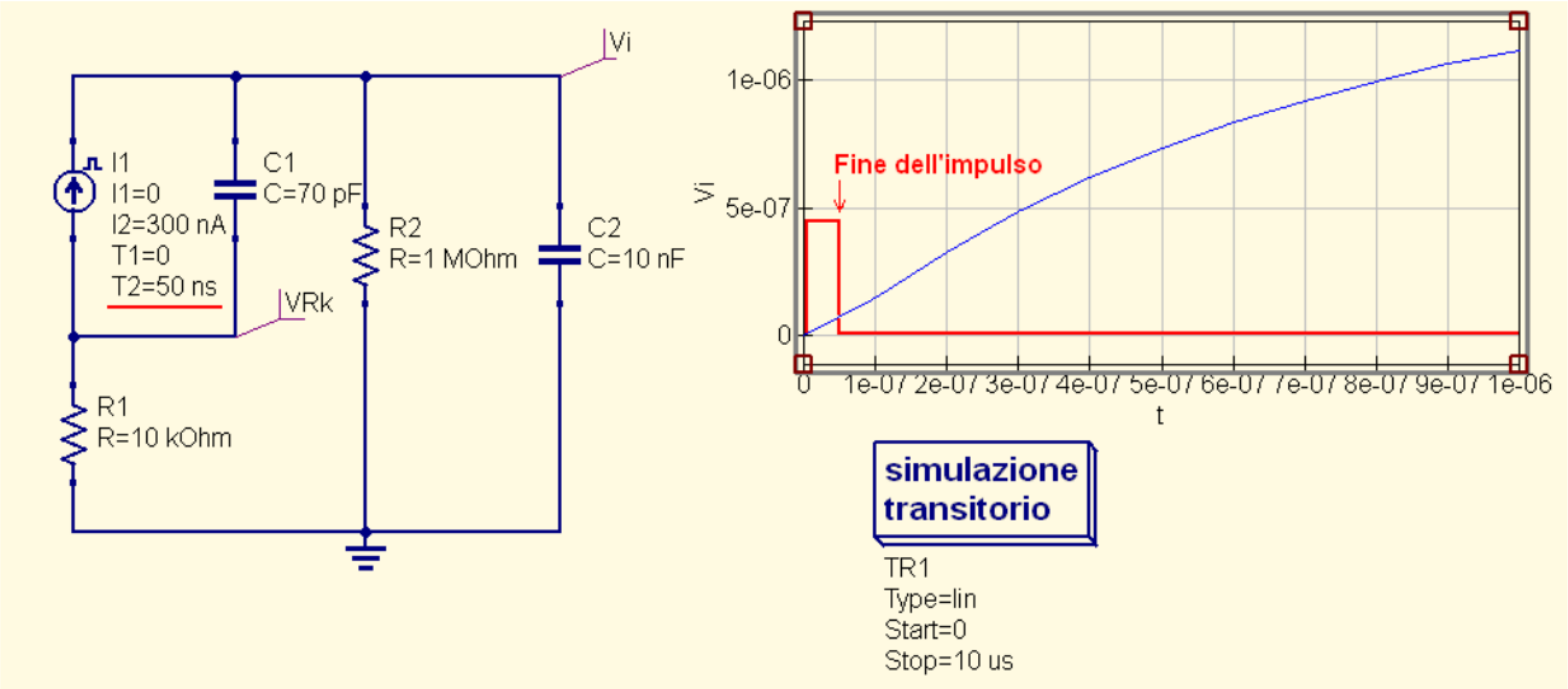
$$\begin{cases} R_K = 10\,K\Omega \\ R_P = 1\,M\Omega \\ C_S = 70\,pF \\ C_a = 10\,nF \end{cases}$$



The input voltage of the HIDRA chip increases for a long time (~1 us) after the end of the input current.

This feature is not present when the Rk is ~ 0.

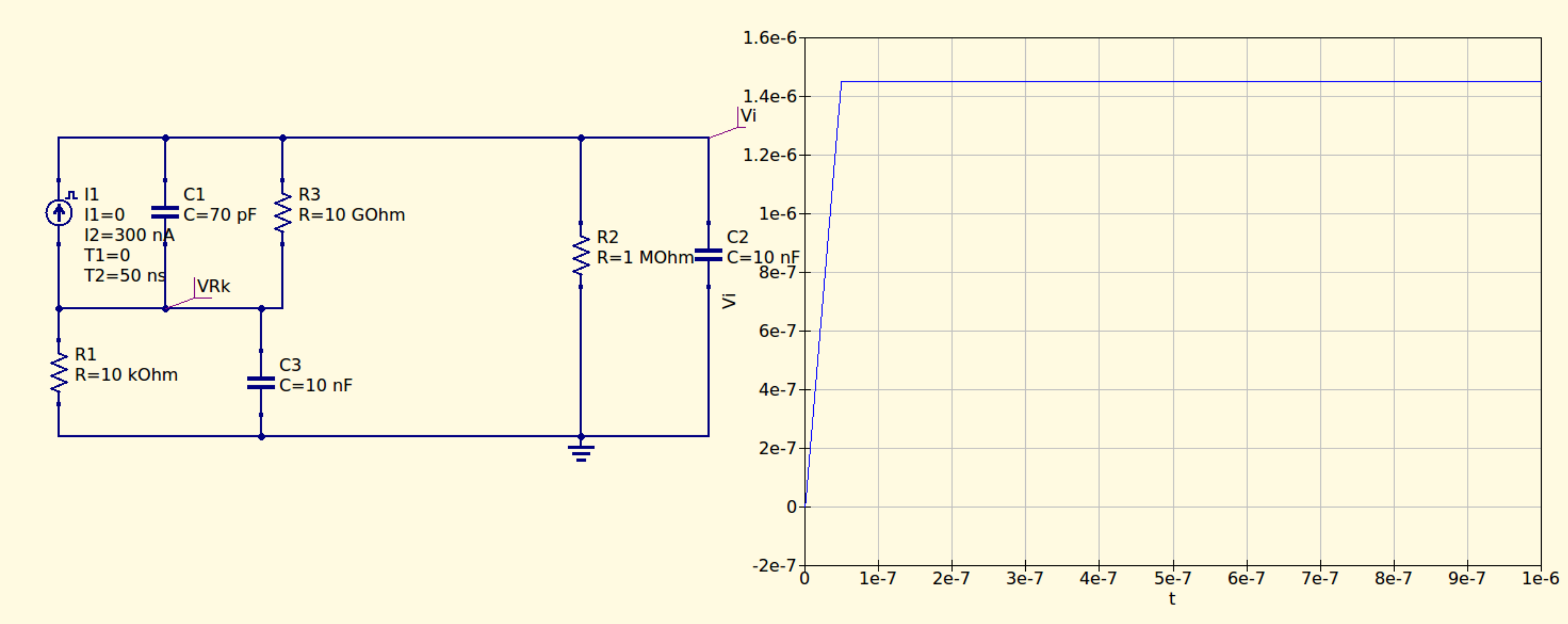
QUCS simulation confirmation



QUCS simple simulation confirm the model.

How to solve: remove Rk (of course), add a big capacitance after Rk

QUCS: test of the 10 nF capacitance



Both solutions seems to completely remove the issue.

Real case: a residual dependence steel remains, is it due to a parasitic R? Unknown effect?

Summary

Rk separates the diode capacitor and Ci. This allows a different voltage of Ci and Cs during the injection of the current. A long time is needed to recover from this difference, since Cs discharges through Rk (**Cs*Rk** ~ **0.7** us as observed by simulation and calculation)

Removing Rk or adding a big capacitor solves the issue.

Residual dependence remains: to be understood.

Next step:

– confirm the residual dependence with MIP (using SiPMs in parallel to the PD to select true MIP signals).

– check the LED light tentative slow talis.