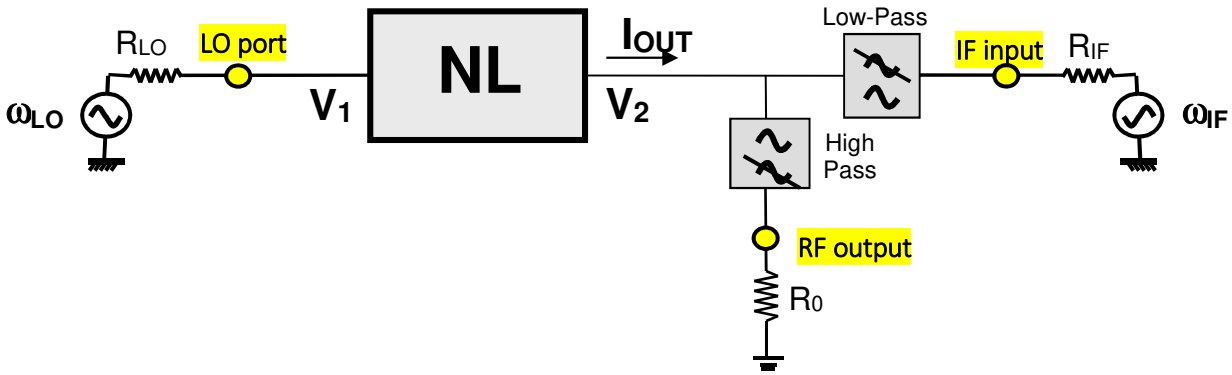
Exam: Basics of active and nonlinear electronics (SEM Mixer) January 8, 2020

The following nonlinear device NL is used to design a SEM up-converter where the LO voltage signal V_1 is applied to the input while the IF voltage signal V_2 is applied to the output so that the output current I_{OUT} is generated with all its frequency components.

The nonlinear operation of this device (NL) is expressed by the following equation that gives the output current I_{OUT} as a function of input and output control voltages V_1 and V_2:

$$I_{OUT} = p\,V_1^3 - q\,V_2 + r\,V_1 V_2 \qquad \textbf{(eq1)}$$ where p , q and r are constants

The SEM cold-FET mixer is shown below and the main frequencies are f_{LO}= 9 GHz and f_{IF}= 0.5 GHz



The two control voltages V_1 and V_2 are:

- LO voltage: $V_1 = V_{LO}\cos(\omega_{LO}t)$ **(eq2)**
- IF voltage: $V_2 = V_{IF}\cos(\omega_{IF}t)$ **(eq3)**

1) Using equations 1 to 3, express the output current I_{OUT} as a function of signal magnitudes (V_{LO}, V_{IF}), nonlinearity constants (p, q, r) and mixing frequencies. The following notations can be used for mixing frequencies: $\omega_{RF}=(\omega_{LO}+\omega_{IF})$; $\omega_{IM}=(\omega_{LO}-\omega_{IF})$

2) The high-pass filter is designed to reject frequencies lower than 5GHz while the low-pass frequency is designed to cut frequencies greater than 5GHz. Therefore, what are the mixing frequencies at the RF output port?

3) Determine the expression of the voltage conversion gain G_{CV}.

4) If the LO port is assumed to be matched to R_{LO},
   a) express the LO-to-RF isolation in dB
   b) what is the LO-to-IF isolation ?
   c) express the equivalent impedance Z_{IN} seen by the IF generator @ ω_{IF} at the IF input port
   d) express the required value of R_{IF} to match the IF input port?