

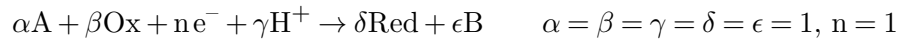
EE-517: Bio-Nano-Chip Design

Exercises 12: Bio-CMOS interfaces in voltage scan

December 1, 2020

Problem 1

Consider a redox reaction of the type



Evaluate the change in concentration of the compound Red (at constant pH) that would induce a similar change in potential than a pH increase from 6 to 8.

Initial concentration of Red: $[Red]_0 = 1 \text{ mM}$

Problem 2

In *cyclic voltammetry* (CV), the electrochemical cell potential is scanned as $E = E_0 - \nu t$. The **Randles-Sevcik** equation relates the peak current, around the redox potential, to the concentration of the redox compound C as

$$i_{\text{peak}} = 0.4463 n F A \sqrt{\frac{n F D \nu}{R T}} C$$

n : number of electrons exchanged

A : active area of the electrode

D : diffusion coefficient of the redox compound

ν : voltage scan rate

C : concentration of the redox compound

The calibration of the sensor yields faradaic currents ranging from $80 \mu\text{A}$ to $100 \mu\text{A}$, for concentration varying from $200 \mu\text{M}$ to $700 \mu\text{M}$.

Compute the concentration of the redox compound if the peak current measured is of $92 \mu\text{A}$.

Problem 3

In CV experiments, a voltage sweep is needed to stimulate the electrochemical cell. A *Direct Digital Synthesizer* (DDS) is used to output staircase waveforms in a form of sub-Hz triangular signals. Consider that the DDS is implemented with a Timer/Counter module of an on-chip micro-controller unit and a 10-bit *Digital-to-Analog Converter* (DAC). Each time the Timer/Counter overflows, the DAC outputs a voltage shifted by the step voltage δE of the desired stair-case waveform.

What should be the overflow period of the timer if a scan rate of $20 \text{ mV} \cdot \text{s}^{-1}$ is required?

(a) Assume that the LSB of the DAC is used as voltage step, that is $\delta E = \text{LSB}_{\text{DAC}}$.

(b) Assume that $\delta E = 5 \text{ mV}$.

Supply voltage: $V_{\text{cc}} = 3.3 \text{ V}$

Problem 4

Consider a three-electrodes electrochemical cell able to detect both *Flurbiprofen* and *Naproxen* with CV technique. The latter has a peak current around 50 nA , while the former drug has its peak current around 0 V when a voltage ranging from -100 to 200 mV is swept to the cell.

(a) Design the circuit that allows the aforementioned detection by using a single sensing electrode. Include a peak detector in the readout circuitry.

(b) Draw the Randles equivalent circuit of the electrochemical cell.