# BENG 186B Winter 2014

Quiz 2

February 12, 2014

## NAME (Last, First):

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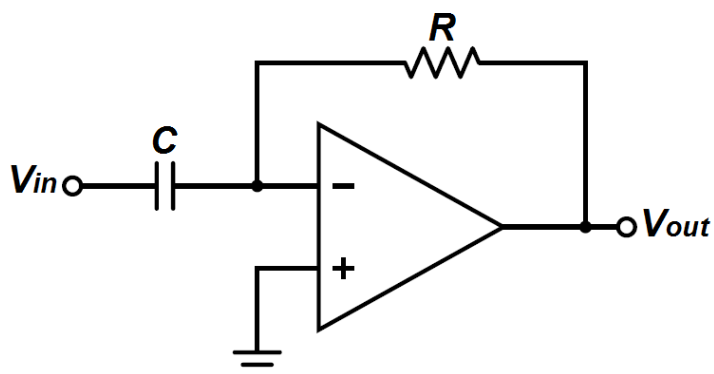
- This quiz is closed book and closed notes. You may use a calculator for algebra.
- Circle your final answers in the space provided; show your work only on the pages provided.
- Do not attach separate sheets. If you need more space, use the back of the pages.
- There are 5 problems. Points for each problem are given in [brackets]. There are 100 points total. You have 50 minutes to complete this quiz.

| | |
|---|---|
| 1 | / 20 |
| 2 | / 25 |
| 3 | / 20 |
| 4 | / 20 |
| 5 | / 15 |
| Total | / 100 |

1. [**20 pts**] Consider the following active circuit with voltage input $V_{in}$ and voltage output $V_{out}$. You may assume that the op-amp is ideal.




a) [10 pts] Derive the transfer function $H(j\omega) = V_{out}(j\omega)/V_{in}(j\omega)$. Which function does this circuit perform?

b) [5 pts] Derive the input impedance $Z_{in}(j\omega)$.

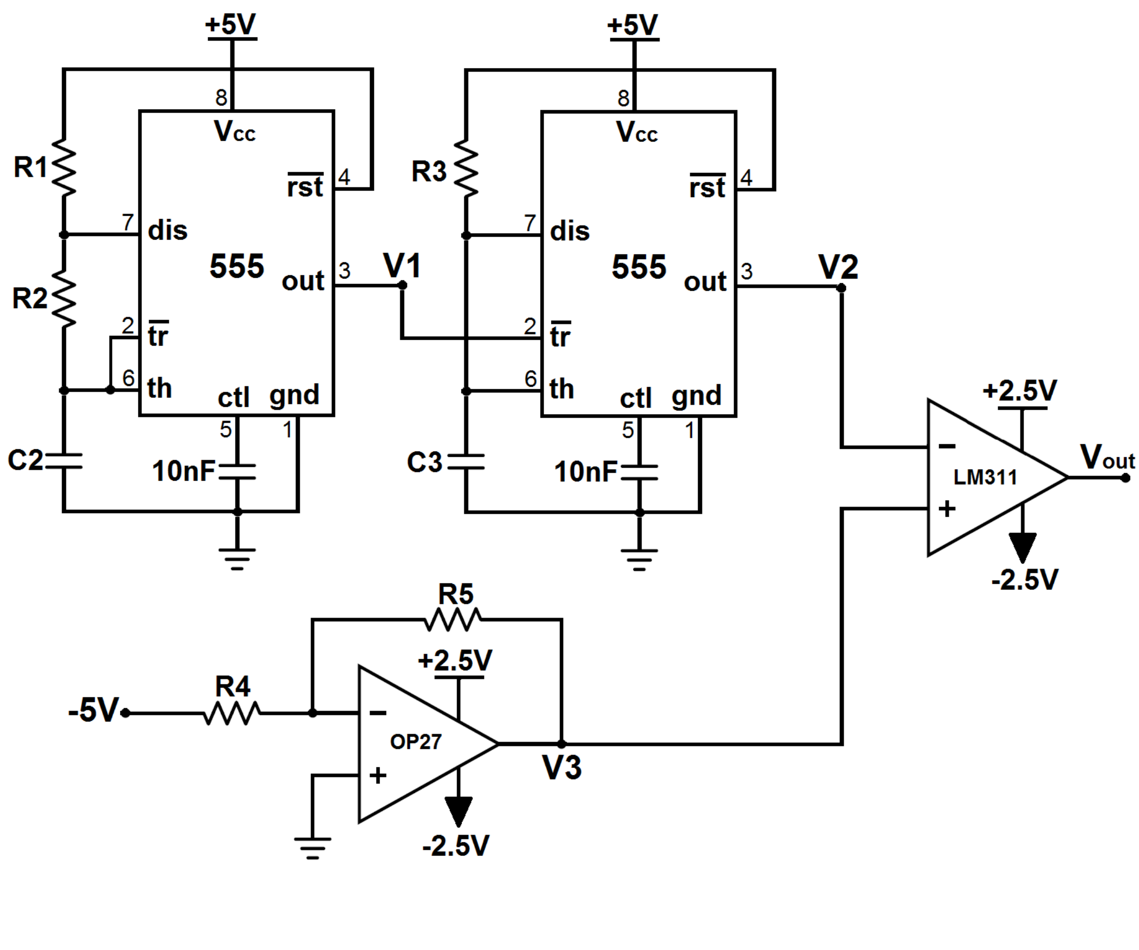
c) [5 pts] Derive the output impedance $Z_{out}(j\omega)$.

2. [**25 pts**] Consider the following circuit, with ideal components OP27, LM311, and 555.

The dynamics of the leftmost 555 system is governed by equations $T_{high} \cong 0.7(R_1 + R_2)C_2$ and $T_{low} \cong 0.7R_2C_2$.

The dynamics of the rightmost 555 system is governed by equation $T \cong 1.1R_3\,C_3$.

(*Hint*: Try to approximate your solutions to facilitate the calculations.)




R1 = 100kΩ R3 = 9kΩ R4 = 47kΩ
R2 = 100kΩ C3 = 0.5μF R5 = 47kΩ
C2 = 0.5μF

Sketch the waveforms for $V_1$, $V_2$, $V_3$, and $V_{out}$ on the diagrams on next page, clearly indicating the voltage levels and time intervals of the transitions in the waveforms. Show your work below.


V1
t


V2
t

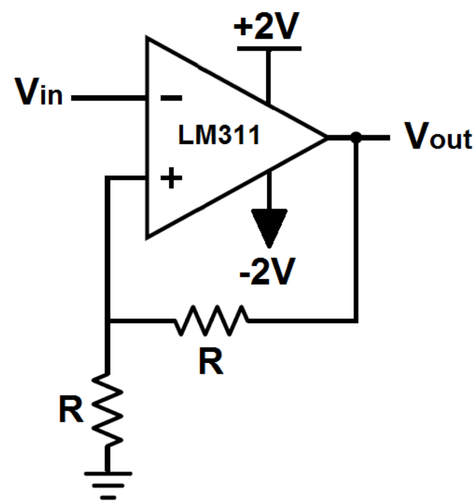

V3
t


Vout
t

3. [**20 pts**] Circle the best answer (only one answer per question):

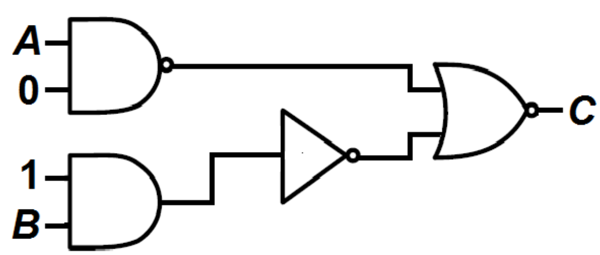
a) [6 pts] The following inverting hysteretic comparator transitions from -2V to +2V and from +2V to -2V when $V_{in}$ crosses respectively:

i. -0.1V and +0.1V
ii. +1.0V and -1.0V
iii. -0.5V and +0.5V
iv. +2.0V and -2.0V
v. None of the above




b) [6 pts] The output *C* in the digital circuit can be represented as:

i. AND(*A*,*B*)
ii. *A*
iii. *B*
iv. 0
v. 1



c) [8 pts] Indicate whether each of the following statements is true or false:

[ **TRUE / FALSE** ] The Nernst potential can only be measured across a membrane when it is permeable to the specific ion type being analyzed.

[ **TRUE / FALSE** ] The typical resting potential of excitable cells in the human body is positive.

[ **TRUE / FALSE** ] The permeability of the ion affects its Nernst potential.

[ **TRUE / FALSE** ] The action potential and synaptic potential are actually special cases of the membrane potential.

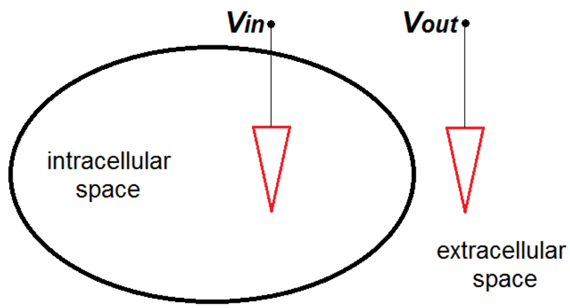
[ **TRUE / FALSE** ] The action potential in neurons is usually triggered by the influx of $Na^+$ ions and propagates down the axon.

[ **TRUE / FALSE** ] Atrial repolarization is normally not observed in ECGs due to the ventricular repolarization.

[ **TRUE / FALSE** ] Despite being non-invasive, electroencephalography has higher temporal resolution than electrocorticography.

[ **TRUE / FALSE** ] The half-cell potential of electrodes is simply a function of the electrode material.

4. [**20 pts**] Two identical electrodes are inserted in the intracellular and extracellular media of a cell, with the cell membrane separating both media. The concentrations are given in the table. At rest, the membrane permeability to $Cl^-$ is twice that of the permeability to $Na^+$ and $K^+$.




| Solution | Intra (mM) | Extra (mM) |
|---|---|---|
| NaCl | 10 | 100 |
| KCl | 110 | 20 |

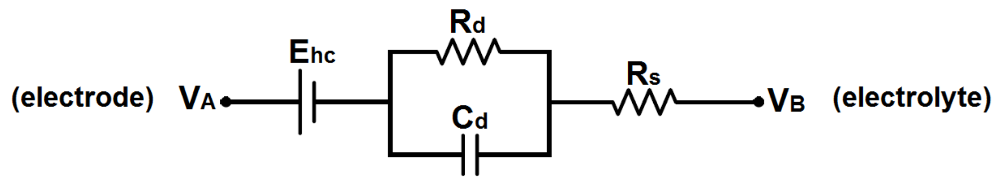
The Goldman-Hodgkin-Katz (GHK) equation is given by:

$$E = (60mV)\ \log_{10} \frac{P_K[K^+]_o + P_{Na}[Na^+]_o + P_{Cl}[Cl^-]_i}{P_K[K^+]_i + P_{Na}[Na^+]_i + P_{Cl}[Cl^-]_o}$$

a) [10 pts] Find the Nernst potentials for $Na^+$ and $Cl^-$.

b) [10 pts]  Find the value of the equilibrium rest potential of the cell.

5. [**15 pts**] The circuit model for a non-polarizable electrode is shown below.




a) [10 pts] Write the impedance between the electrode and electrolyte as a function of radial frequency ω, and in the two limiting cases of very low frequency and very high frequency.

b) [5 pts] Two identical electrodes are immersed in the same solution. Find the open-circuit voltage, and closed-loop current, between the electrodes.