BENG 186B Winter 2018

Quiz 1

Friday, January 26, 2018

***Name** (Last, First):* _____

- This quiz is closed book and closed notes. You may use a calculator for algebra and arithmetic.
- Do not attach separate sheets. If you need more space, use the back of the pages.
- Circle or box your final answers and show your work on the pages provided.
- There are 4 problems. Points for each problem are given in **[brackets]**. There are 100 points total.
- You have 50 minutes to complete this quiz.

1. **[10 pts]** Circle the **best answer (only one answer per question)**:

(a) [2.5 pts] Indirect physiological measurements are typically:

i. higher bandwidth.
ii. more accurate.
iii. more expensive.
iv. less invasive.

(b) [2.5 pts] The transfer function of a critically damped second-order low-pass filter has:

i. two complex conjugate poles.
ii. two identical real poles.
iii. one real zero and one real pole.
iv. one real zero and one imaginary pole.

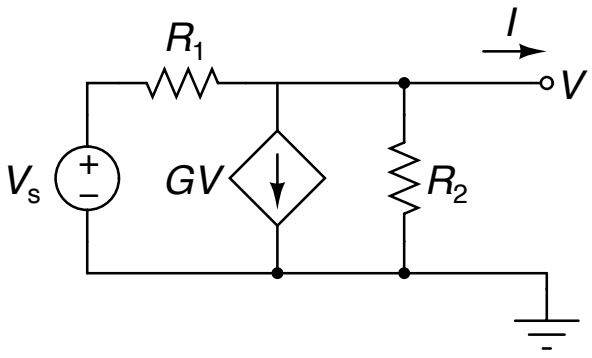
(c) [2.5 pts] The gauge factor of a strain gauge is independent of:

i. piezo-resistive effect.
ii. Poisson's ratio.
iii. Young's modulus.
iv. temperature.

(d) [2.5 pts] A linear variable differential transformer is a type of inductive sensor that offers:

i. zero offset.
ii. greater linearity.
iii. greater noise suppression.
iv. all of the above.

2. **[25 pts]** Derive the Thévenin equivalent at node V in the circuit below:

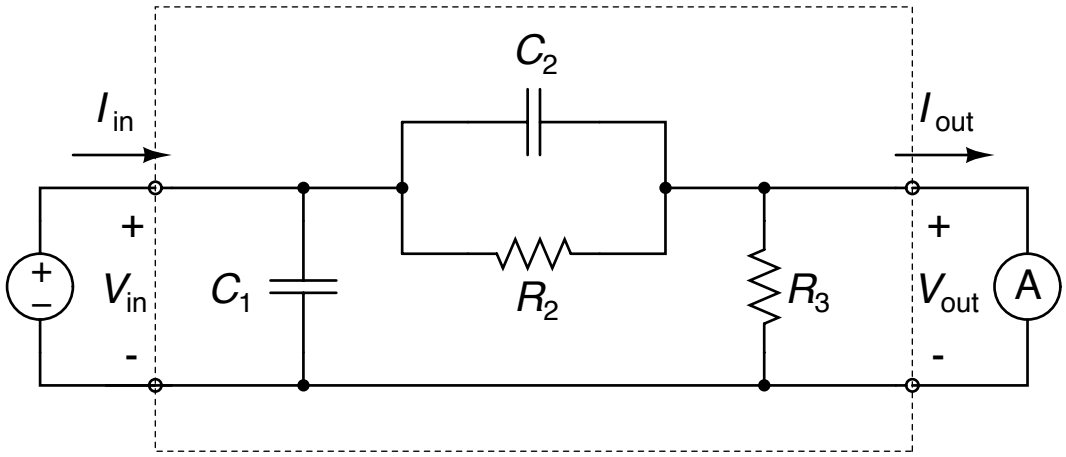


(a) [10 pts] Find the Thévenin equivalent open-circuit voltage V_{oc}.

(b) [10 pts] Find the Thévenin equivalent impedance Z_{th}.

(c) [5 pts] Draw the Thévenin equivalent diagram.

3. **[35 pts]** Consider the voltage-input, current-output filter circuit below.



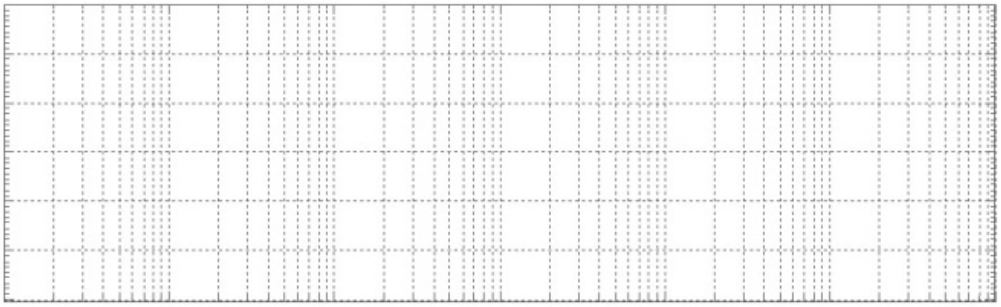
(a) [10 pts] Find the input impedance $Z_{in}(j\omega)$.

(b) [10 pts] Find the output impedance $Z_{out}(j\omega)$.

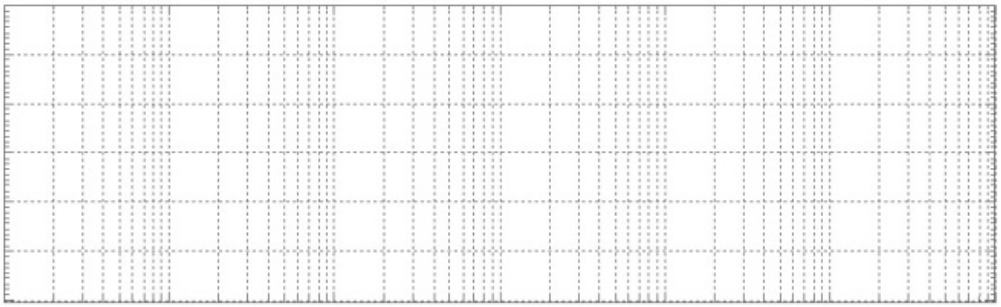
(c) [5 pts] Find the transfer function $H(j\omega) = I_{out}(j\omega) \,/\, V_{in}(j\omega)$.

(d) [10 pts] Sketch the Bode plot of the transfer function $H(j\omega)$ for $C_1 = 100$ nF, $C_2 = 10$ μF, $R_2 = 1$ kΩ, and $R_3 = 100$ kΩ. Be sure to label the axes and indicate the units (rad/s, dBΩ^{-1}, and degrees).

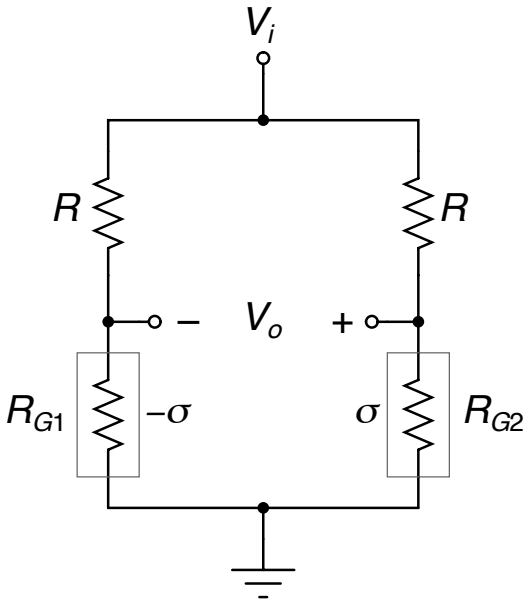
H(*j*ω) Magnitude



H(*j*ω) Phase



4. **[30 pts]** Consider the stress transducer below, with constant supply voltage $V_i = 3$ V, two constant resistors each with resistance $R = 100$ kΩ, and two strain gauges R_{G1} and R_{G2} with identical nominal resistance R_{nom} and gauge factor $G = -100$ that are differentially activated by complementary strain due to complementary stress σ and $-\sigma$ as shown. Both strain gauges have the same Young's modulus $E = 100$ kPa.



$$
\begin{aligned}
R_{G1} &= R_{nom}\,(1 - G\epsilon) \\
R_{G2} &= R_{nom}\,(1 + G\epsilon) \\
\sigma &= E\,\epsilon
\end{aligned}
$$

(a) [10 pts] Find the output voltage V_o as a function of stress σ.

(b) [10 pts] Find the value of R_{nom} that maximimizes the sensitivity of the stress transducer, for low levels of stress $\sigma \approx 0$.

(c) [10 pts] A 10-bit analog-to-digital converter (ADC) is used to digitize the voltage output V_o for a digital reading of stress σ. The full-scale voltage range of the ADC is from 1 V to 2 V. Find the accuracy of the stress reading for low levels of stress $\sigma \approx 0$.