BENG 186B Winter 2020

Quiz 1

Friday, January 24, 2020

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 3 problems. Points for each problem are given in **[brackets]**. There are 100 points total.
- The quiz takes 50 minutes to complete.

1. **[15 pts]** Circle the **best answer (only one answer per question)**:

   (a) [3 pts] Averaging readings from multiple measurements of the same measurand improves its:

      i. sensitivity.
      ii. accuracy.
      iii. precision.
      iv. none of the above.

   (b) [3 pts] The transfer function of an underdamped ($\zeta < 1$) second-order low-pass filter has:

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

   (c) [3 pts] Measuring the open-circuit voltage and short-circuit current of a circuit element determines its:

      i. Thévenin equivalent.
      ii. Norton equivalent.
      iii. equivalent impedance.
      iv. all of the above.

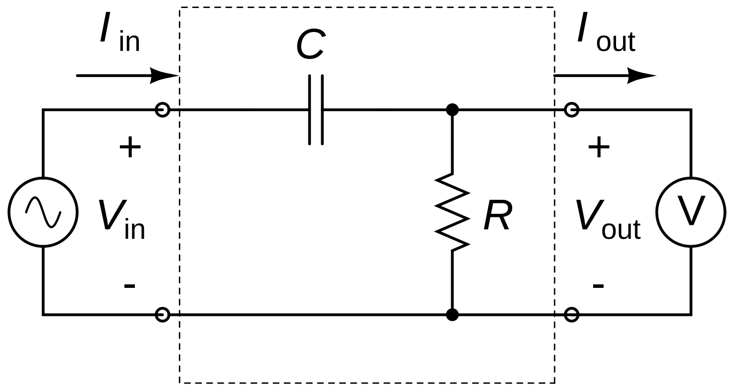
   (d) [3 pts] The sensitivity of a piezoresistive stress transducer depends on the:

      i. gauge factor.
      ii. Young's modulus.
      iii. nominal resistance.
      iv. all of the above.

   (e) [3 pts] The sensitivity of a capacitive displacement transducer can be improved by:

      i. decreasing the area of the two plates
      ii. decreasing the distance between the two plates.
      iii. lowering the dielectric constant of the insulator between the plates.
      iv. all of the above.

2. **[45 pts]** Consider the voltage-input, voltage-output filter circuit below.



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

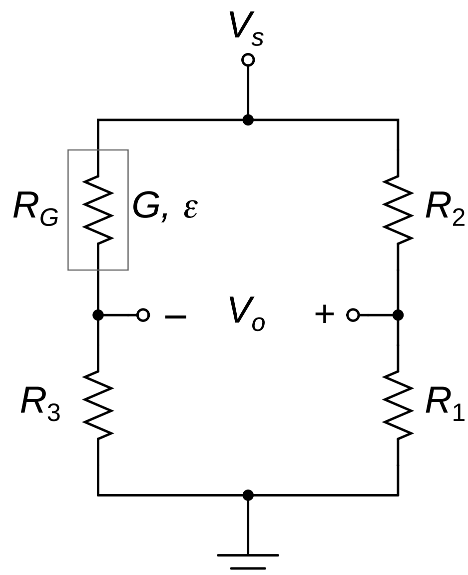
(b) [10 pts] Find the output impedance $Z_{out}(j\omega)$.

(c) [10 pts] Find the transfer function $H(j\omega) = V_{out}(j\omega) \,/\, V_{in}(j\omega)$.

(d) [10 pts] Sketch the Bode plot of the transfer function $H(j\omega)$ for $C = 100$ nF and $R = 100$ kΩ. Be sure to label the axes and indicate the units (*e.g.*, rad/s, dB, and degrees). What type of filter is this?

(e) [10 pts] Sketch the Bode plot of the input impedance $Z_{in}(j\omega)$ for the same values of C and R as in (d). Again be sure to label the axes and indicate the units (*e.g.*, rad/s, dBΩ, and degrees).

3. **[40 pts]** Consider the strain transducer below, with constant supply voltage $V_s = 1$ V, three resistors with identical resistances $R_1 = R_2 = R_3 = R$, and a strain gauge R_G with nominal resistance $R_{nom} = 100\ \mathrm{k}\Omega$ and gauge factor $G = 100$. The transducer produces a differential output voltage V_o in response to a strain ϵ applied to the strain gauge.



$$R_G = R_{nom}\,(1 + G\epsilon)$$

(a) [10 pts] Find the value of resistance R that maximizes the sensitivity of the transducer. Find this maximum sensitivity. *Hint*: you may assume that the applied strain is sufficiently small in magnitude so that $|G\epsilon| \ll 1$.

(b) [5 pts] Find the offset of the transducer.

(c) [10 pts] Due to mismatch in manufacturing, the actual R_1 is 1% smaller than expected, and the actual R_2 is 1% larger than expected. Find the accuracy of the strain measurement.

(d) [10 pts] An 8-bit analog-to-digital converter (ADC) is used to digitize the voltage output V_o for a digital reading of the strain ϵ. The full-scale voltage range of the ADC is from 0.4 V to 0.6 V. Find the resolution of the strain measurement.

(e) [5 pts] You observe that the transducer is sensitive to temperature. What simple change could you make to the design to eliminate this temperature dependence? *Hint*: you may assume that all resistances R have identical temperature coefficient, and also that strain gauge nominal resistances have identical temperature coefficient, but these two are different.