SYSC 3203: Midterm Exam #1

October 13, 2016

Carleton University, Systems and Computer Engineering

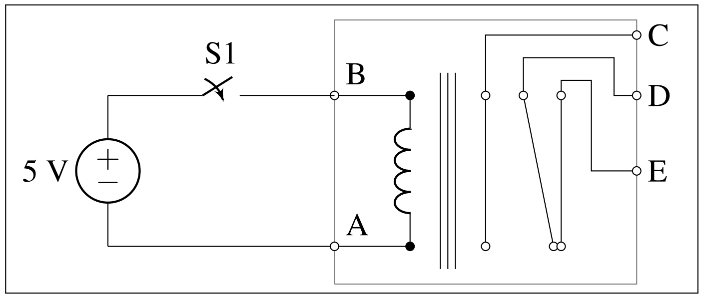
Name: ______________________________ **Student Number:** ____________________

Instructions:

- This exam has **12** pages and **4** questions. Answer all questions. Marks for each question are indicated.
- You have **80 minutes** to complete this exam. Write your answers in the booklet provided.
- This is a closed book exam; however, you are permitted to bring one 8.5”×11” sheet of notes.
- You are permitted to use a non network-connected calculator.
- All electronics components may be assumed ideal, unless stated otherwise.
- You may need the following table of filter properties.

N	F_s(40dB)	F_s(60dB)	F_s(80dB)	f_n	G	f_n	G	f_n	G	f_n	G
FILTER = Chebychev 0.05dB											
2	21.58	68.23	215.77	2.162	1.664						
4	3.37	5.89	10.42	0.885	1.334	1.221	2.500				
6	1.90	2.67	3.85	0.569	1.279	0.870	2.176	1.091	2.759		
8	1.48	1.86	2.39	0.422	1.261	0.670	2.072	0.912	2.544	1.050	2.861
FILTER = Chebychev 0.10dB											
2	18.11	57.28	181.13	1.820	1.697						
4	3.10	5.41	9.55	0.789	1.384	1.153	2.542				
6	1.81	2.54	3.64	0.513	1.332	0.834	2.249	1.063	2.784		
8	1.43	1.79	2.30	0.382	1.314	0.645	2.155	0.894	2.592	1.034	2.876
FILTER = Chebychev 0.20dB											
2	15.21	48.08	152.05	1.535	1.745						
4	2.85	4.95	8.75	0.701	1.452	1.095	2.589				
6	1.72	2.40	3.44	0.460	1.402	0.803	2.330	1.038	2.810		
8	1.39	1.73	2.21	0.343	1.386	0.623	2.246	0.878	2.642	1.021	2.892
FILTER = Chebychev 0.50dB											
2	11.99	37.84	119.67	1.231	1.842						
4	2.55	4.42	7.78	0.597	1.582	1.031	2.660				
6	1.61	2.23	3.19	0.396	1.537	0.768	2.448	1.011	2.846		
8	1.33	1.64	2.09	0.297	1.522	0.599	2.379	0.861	2.711	1.006	2.913
FILTER = Chebychev 1.00dB											
2	9.95	31.41	99.31	1.050	1.955						
4	2.34	4.03	7.08	0.529	1.725	0.993	2.719				
6	1.54	2.11	3.01	0.353	1.686	0.747	2.545	0.995	2.875		
8	1.29	1.58	2.01	0.265	1.672	0.584	2.489	0.851	2.766	0.997	2.930
FILTER = Chebychev 2.00dB											
2	8.13	25.59	80.91	0.907	2.114						
4	2.14	3.65	6.41	0.471	1.924	0.964	2.782				
6	1.46	1.99	2.82	0.316	1.891	0.730	2.648	0.983	2.904		
8	1.25	1.52	1.93	0.238	1.879	0.572	2.605	0.842	2.821	0.990	2.946
FILTER = Chebychev 5.00dB											
2	5.87	18.49	58.34	0.778	2.412						
4	1.86	3.12	5.46	0.415	2.288	0.938	2.870				
6	1.36	1.82	2.55	0.280	2.266	0.715	2.790	0.972	2.943		
8	1.20	1.44	1.80	0.211	2.259	0.561	2.764	0.835	2.894	0.984	2.968

1. (Electrical Safety) Electrical safety is obviously an important factor in biomedical electronics. In class we studied the relay (shown below). The relay coil has a series resistance of 2.5 kΩ. The inductance of the coil is low and its time constant is close to zero.



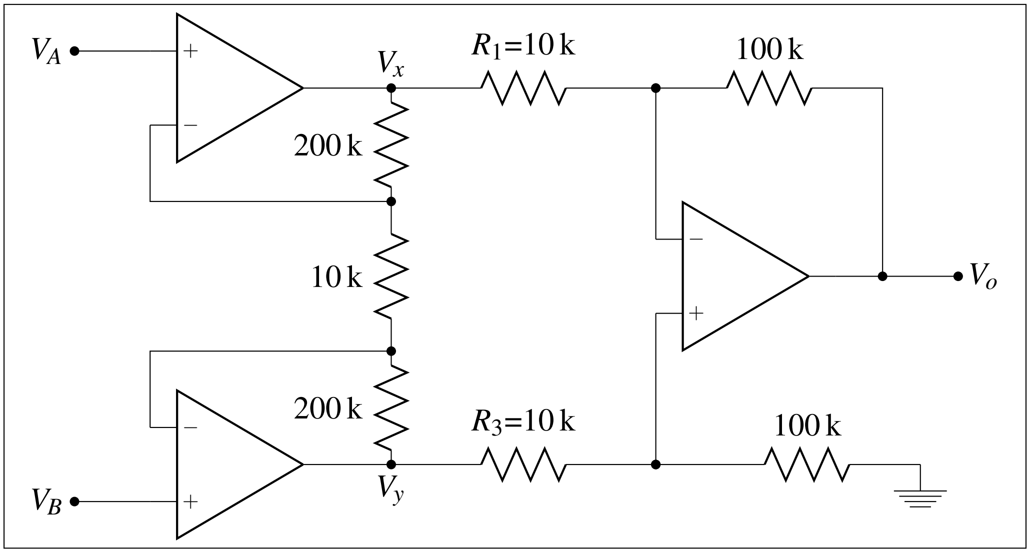
   (a) (5 points) Describe how a relay works. What is the function of each of the elements in the diagram above? How does a relay provide electrical protection? On the diagram, show the isolation barrier.

(b) (5 points) Define the **terms "let-go current" and "threshold of perception"**, and explain the difference between them.

(c) (5 points) Typically, a diode is required to prevent damage during switching of the relay. Assume the switch is initially open; it closes closes at $t = 2.5$ s and opens at $t = 3.0$ s. Sketch the current flowing in the inductor as a function of time (without a diode).

(d) (5 points) Show where a diode be placed to prevent damage. Again, assume the switch is initially open; it closes closes at $t = 2.5$ s and opens at $t = 3.0$ s. Sketch the current flowing in the inductor as a function of time with the protection diode.

2. (Instrumentation amplifiers) An instrumentation amplifier as shown in the figure below is used.

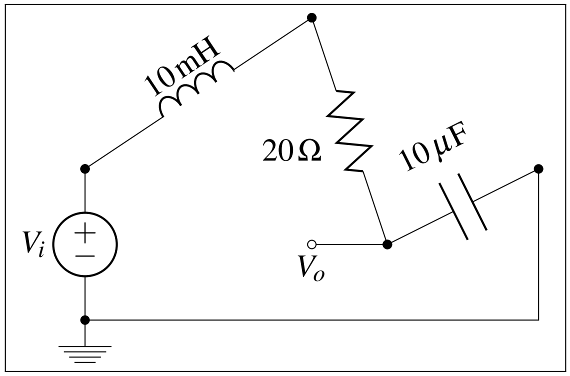


(a) (5 points) **Calculate the value differential gain,** G_d. When the CMRR = 80 dB, **calculate the the output** V_o when $V_A = 10.003\,\text{V}$ and $V_B = 10.004\,\text{V}$.

(b) (5 points) An instrumentation amplifier is used in many biomedical applications. Describe *two* requirements of a biomedical amplifier, and explain how these are met in the instrumentation amplifier.

(c) (10 points) When new, the common mode gain of this circuit is zero. Due to aging of the chip, R_3=10.1 k rather than R_3=10 k (Note that the other resistor R_1=10 k does not change value). Does the common mode gain change? **What is the new value?**

3. (Filter Design)



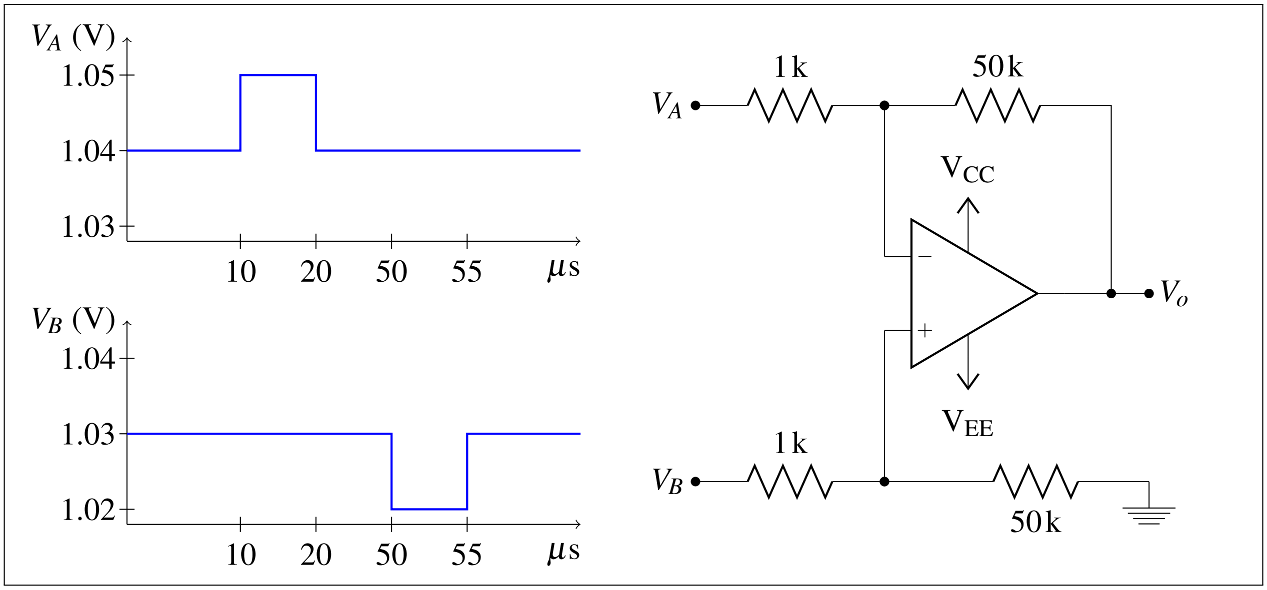
(a) (5 points) **What type of filter is this?** (high pass, low pass, band pass, band stop) Sketch the amplitude of $\frac{V_o}{V_i}$ as a function of frequency. Label the passband, stopband and roll-off rate.

(b) (5 points) What is the cut-off frequency (f_c) and damping constant (ζ)?

(c) (5 points) If a Salen-Key filter were designed to have the same frequency-domain response as this LRC filter, what would be the corresponding value of the filter gain, G?

(d) (5 points) Using the table of filter properties, estimate the attenuation which can be achieved at 25 kHz? Explain your use of the table. (*There are several approaches to making this estimate which are acceptable. Your approach should be reasonable & justified*)

4. (Amplifier circuits) You design the circuit given in the figure below. It receives an input signals, $\mathrm{V_A}(t)$ and $\mathrm{V_B}(t)$, as shown (time axis not to scale).



(a) (10 points) **Sketch the output of the op-amp,** $\mathrm{V_o}(t)$, over the time indicated. Show maximum and minimum voltage levels, and the time of any transitions. (Assume the op amp is ideal, and $\mathrm{V_{CC}}$ and $-\mathrm{V_{EE}}$ are large).

(b) (10 points) **Sketch the output of the op-amp,** $V_o(t)$, over the time indicated. Show maximum and minimum voltage levels, and the time of any transitions. Take into account the fact that the op amp has a slew rate, SR=$0.5\,V/\mu s$.