SYSC 3203: Midterm #2

Nov 15, 2017

Carleton University, Systems and Computer Engineering

Name: ______________________________ **Student Number:** ____________________

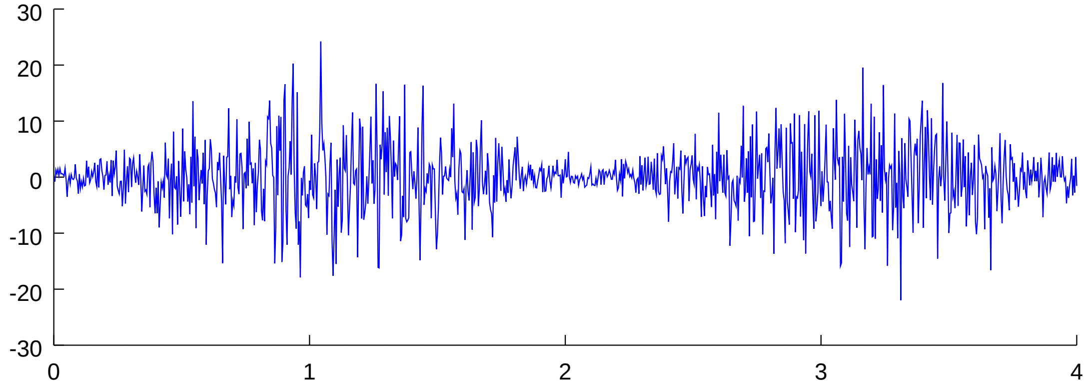
Instructions:

- This test has **6** pages and **4** questions. Answer all questions and subparts. Marks are indicated.
- You have **80 minutes** to complete this exam.
- 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.
- Answers should be written in this exam document. Write your answers in the space provided. If you require more space, attach extra pages to the exam, and indicate that extra space was used.
- 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	ζ	f_n	ζ	f_n	ζ	f_n	ζ
FILTER = Chebychev 0.05dB											
2	21.58	68.23	215.77	2.162	0.668						
4	3.37	5.89	10.42	0.885	0.833	1.221	0.250				
6	1.90	2.67	3.85	0.569	0.860	0.870	0.412	1.091	0.120		
8	1.48	1.86	2.39	0.422	0.870	0.670	0.464	0.912	0.228	1.050	0.069
FILTER = Chebychev 0.10dB											
2	18.11	57.28	181.13	1.820	0.652						
4	3.10	5.41	9.55	0.789	0.808	1.153	0.229				
6	1.81	2.54	3.64	0.513	0.834	0.834	0.375	1.063	0.108		
8	1.43	1.79	2.30	0.382	0.843	0.645	0.423	0.894	0.204	1.034	0.062
FILTER = Chebychev 0.20dB											
2	15.21	48.08	152.05	1.535	0.628						
4	2.85	4.95	8.75	0.701	0.774	1.095	0.205				
6	1.72	2.40	3.44	0.460	0.799	0.803	0.335	1.038	0.095		
8	1.39	1.73	2.21	0.343	0.807	0.623	0.377	0.878	0.179	1.021	0.054
FILTER = Chebychev 0.50dB											
2	11.99	37.84	119.67	1.231	0.579						
4	2.55	4.42	7.78	0.597	0.709	1.031	0.170				
6	1.61	2.23	3.19	0.396	0.731	0.768	0.276	1.011	0.077		
8	1.33	1.64	2.09	0.297	0.739	0.599	0.310	0.861	0.144	1.006	0.043
FILTER = Chebychev 1.00dB											
2	9.95	31.41	99.31	1.050	0.523						
4	2.34	4.03	7.08	0.529	0.637	0.993	0.140				
6	1.54	2.11	3.01	0.353	0.657	0.747	0.227	0.995	0.062		
8	1.29	1.58	2.01	0.265	0.664	0.584	0.256	0.851	0.117	0.997	0.035
FILTER = Chebychev 2.00dB											
2	8.13	25.59	80.91	0.907	0.443						
4	2.14	3.65	6.41	0.471	0.538	0.964	0.109				
6	1.46	1.99	2.82	0.316	0.555	0.730	0.176	0.983	0.048		
8	1.25	1.52	1.93	0.238	0.560	0.572	0.197	0.842	0.090	0.990	0.027

Q		#
1A	/5	
1B	/5	
1C	/5	
1D	/5	
1E	/5	
2A	/5	
2B	/15	
2C	/5	
3A	/5	
3B	/15	
3C	/5	
4A	/5	
4B	/15	
4C	/5	

1. **EMG Signals and Demodulation** (25 points)



An example EMG signal (mV vs. time (s)) from a muscle which is active at two different episodes

1A. (5 marks) Sketch the signal envelope on the graph above.

ANSWER:

The signal envelope is the line joining the peaks of the graph. It should be smooth with two broad peaks

1B. (5 marks) What is the origin of the envelope of the signal? ($\leq$ 25 words)

ANSWER:

The envelope is created by the musclar activity. As the voluntary level increases, motor neurons recruit (via temporal and spatial recruitment) more neurons to be more active. The amplitude of the signal increases.

1C. (5 marks) What is the origin of the high-frequency component in the signal? ($\leq$ 25 words)

ANSWER:

The high-frequency component of the signal is due to the the action potentials generated by individual muscle fibres and the individual motor units. The individual action potentials are fast, high-frequency events and these electrical signals sum together to create the EMG.

1D. (5 marks) Why does the EMG look random and not structured like an ECG signal? ($\leq$ 25 words)

ANSWER:

The EMG has a random appearance, since the individual motor units acts independently, and there is no spatial correlation between their activity. There is no requirement for coordinated activity since all muscle fibres point in the same direction.

The ECG, on the other hand, has a highly structured appearance, since the cardiac muscle works in a coordinated way and the signal passes from systematically through the heart cells.

1E. (5 marks) What output would you get if you try to extract the envelope from the signal using only a linear low-pass filter? ($\leq$ 25 words)

ANSWER:

A low pass filter will extract a moving average of the signal. Since the high-frequency EMG signals have an average of zero, the low pass filter will produce this zero value.

In order to obtain the envelope, it is necessary to have a non-linear operation. In class we looked at using a diode (non-linear) to extract only the positive phase of the signal. This positive-only signal does not have a zero average, and a low pass filter of the positive-only signal will produce the envelope.

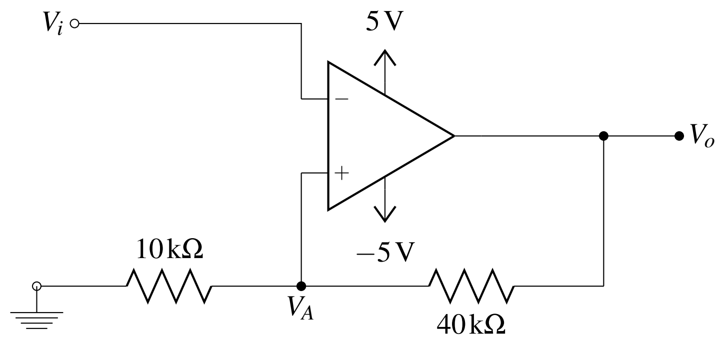
2. **Schmitt Trigger** (25 points)

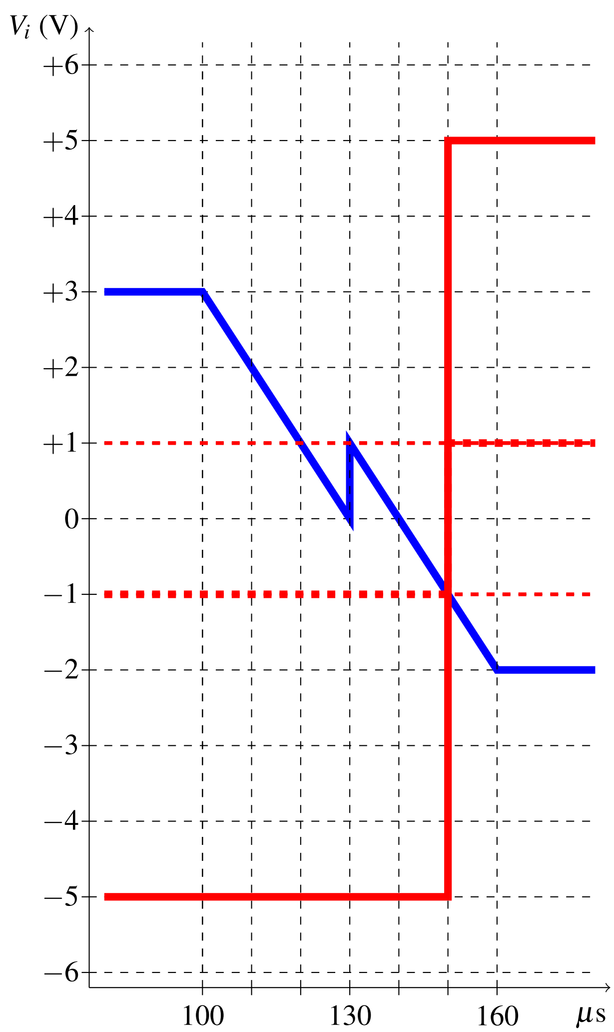
   Op amps are ideal, except the output, V_o, is limited to the power supply range (from V_{EE} to V_{CC})

   2A. (5 points) What is V_A when $V_o = \pm 5\,\text{V}$?

   2B. (15 points) When V_i is as shown below, **sketch** V_A **and the output**, V_o, on the same graph.

   2C. (5 points) **Indicate times** when the $V_o = \pm 5\,\text{V}$.





ANSWER:

A $V_A = V_+ = \frac{10}{10+40} V_o = (0.2) V_o = \pm 1\,V$

B Shown in Red (and dotted line).

C Before $t = 150\,\mu\text{s}$, $V_o = -5\,\text{V}$. After $t = 150\,\mu\text{s}$, $V_o = +5\,\text{V}$.

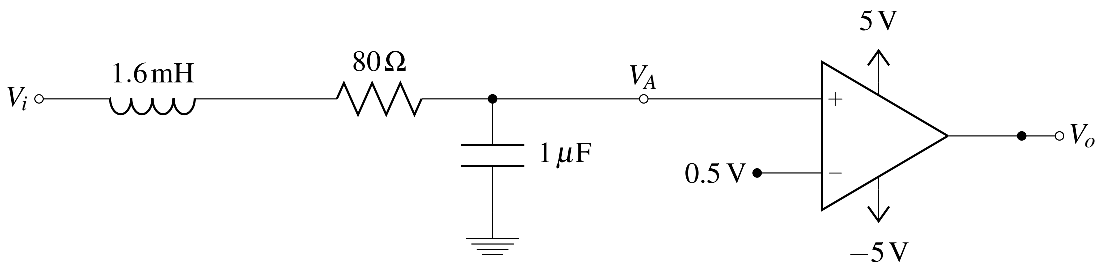
3. **Low-pass filters** (25 points)

   Op amps are ideal, except the output, V_o, is limited to the power supply range (from V_{EE} to V_{CC})

   3A. (5 points) **What type of filter** is this? **What is** its cut-off frequency and damping constant?

   3B. (15 points) When V_i is as shown below, **sketch** V_A **and the output**, V_o, on the same graph.

   3C. (5 points) **Indicate times** (approximately) when the $V_o = \pm 5\,\text{V}$.



ANSWER:

A This is a 2nd-order LRC low pass filter.

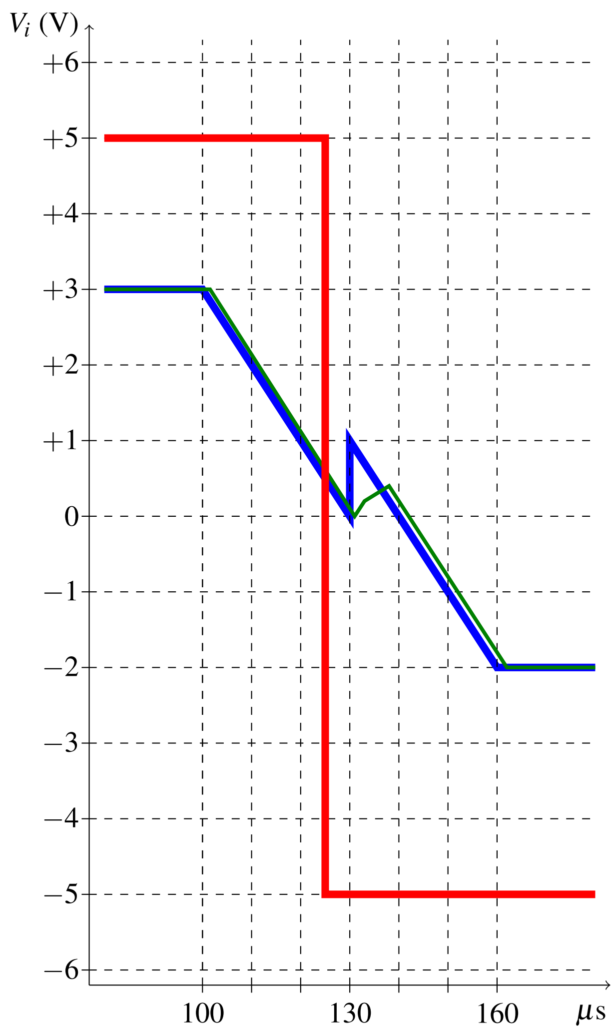
$f_c = \frac{1}{2\pi\sqrt{LC}} = \frac{25000\,\text{rad/s}}{2\pi} = 4.0\,kHz$

$\zeta = \frac{R}{2}\sqrt{\frac{C}{L}} = 1.00$

B Time constant $\tau = 1/\omega_c = 40\mu\text{s}$.

Drop in $10\mu s$ is $1 - e^{-10/(40/2)} = .39$ (factor of 2 because 2nd order)

C Output crosses $0.5\,\text{V}$ at just after $125\,\text{ms} = T$. Before $t = T, V_o = +5\,\text{V}$. Afterwards $V_o = -5\,\text{V}$. Afterwards Because the time constant is long, the output does not drop below 0.5, so no multiple transitions.



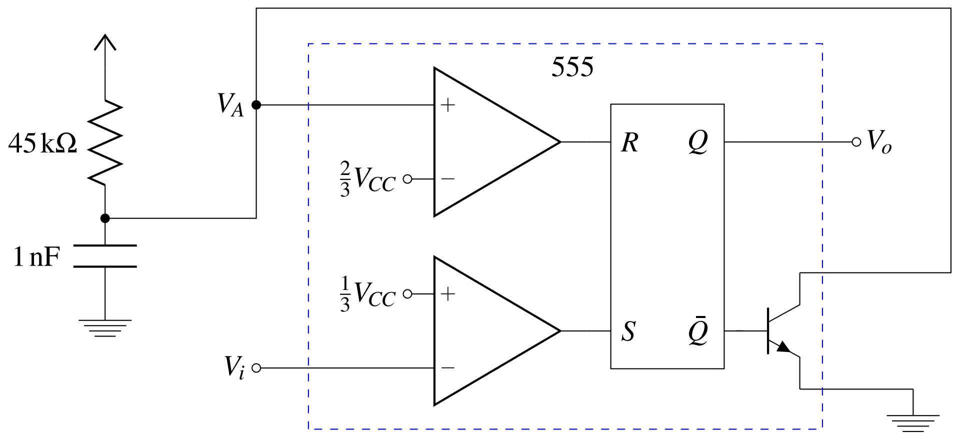
4. **Monostable Oscillator** (25 points)

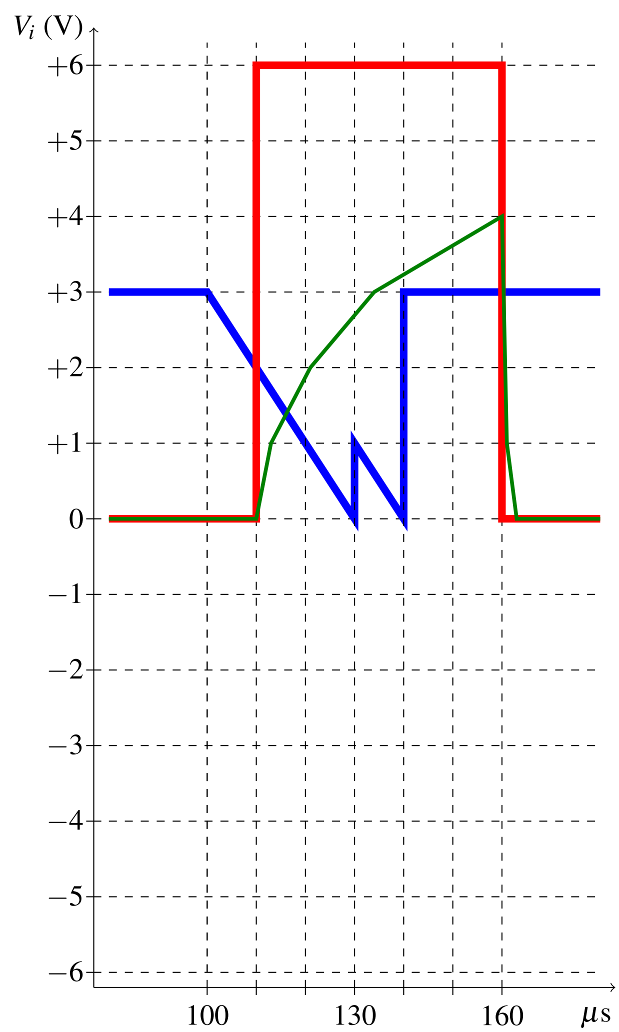
   An idealized 555-based monostable is shown. The 555 is connected to $V_{CC} = 6V$ and ground.

   4A. (5 points) **What is the duration** of the pulse from this 555-based monostable?

   4B. (15 points) When V_i is as shown below, **sketch** V_A **and the output**, V_o, on the same graph.

   4C. (5 points) **Indicate times** when the $V_o = \pm 6\,\text{V}$.





ANSWER:

A Time is $ln(\frac{6-0V}{6-4V})RC = 1.1(45\,\text{k}\Omega)(1\,\text{nF}) = 50\mu\text{s}$.

B As shown. V_A in green is an exponential. V_o (red) is the output pulse.

C $V_o = 6\,\text{V}$ from $110 \le t \le 160\,\text{ms}$. Otherwise it is zero.