ECE 214 — Exam #1

Estimated time for completion: $\leq$ 1.25 hour
28 February 2018

Rules of the Exam

Rule 1: The examination period begins at 9:30am on Tuesday 28 February 2017 and ends at 10:45am on Tuesday 28 February 2017.

Rule 2: The exam is 15% of your grade.

Rule 3: There are a total of 15 answers. Each answer is worth 1 point. Circle the most correct answer.

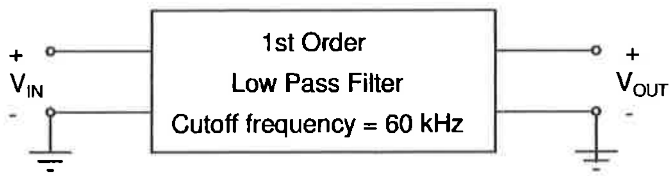
Rule 4: The exam is closed book and closed notes. You may use your ECE 214 Laboratory Notebook, a ruler, and a calculator.

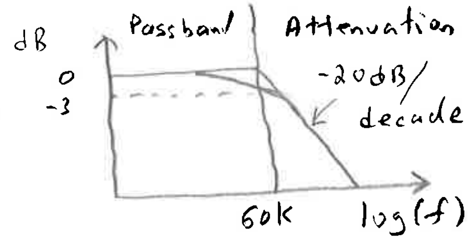
Answer Key

Name

Problem 1: 1st Order Low Pass Filter

Consider the first order low pass filter shown below. The filter has a cutoff frequency of 60 kHz.





1. V_{IN} is a sinusoidal waveform with a frequency of 10 kHz. What is the relative amplitude of the 3rd harmonic to the fundamental frequency at the output of the filter?

   (a) 0 dB
   (b) -3 dB
   (c) -6.5 dB
   (d) -9.5 dB
   (e) -12.4 dB
   (f) -16.1 dB
   (g) -19.1 dB
   (h) none of the above

   Sinusoidal signals do not have any harmonics

2. V_{IN} is a square wave with a 50% duty cycle and a frequency of 10 kHz. What is the relative amplitude of the 3rd harmonic to the fundamental frequency at the output of the filter?

   (a) 0 dB
   (b) -3.0 dB
   (c) -6.5 dB
   (d) -9.5 dB
   (e) -12.4 dB
   (f) -16.1 dB
   (g) -19.1 dB
   (h) none of the above

   Both fundamental (10kHz) and 3rd harmonic are in the passband of the filter.

   For a square wave, 3rd harmonic is $\frac{1}{3}$ amplitude of the fundamental

   $20 \log\left(\frac{1}{3}\right) = -9.54$ dB

3. V_{IN} is a square wave with a 50% duty cycle and a frequency of 20 kHz. What is the relative amplitude of the 3rd harmonic to the fundamental frequency at the output of the filter?

   (a) 0 dB
   (b) -3.0 dB
   (c) -6.5 dB
   (d) -9.5 dB
   (e) -12.4 dB
   (f) -16.1 dB
   (g) -19.1 dB
   (h) none of the above

   Fundamental (20kHz) is in the passband, 3rd harmonic is at the cutoff frequency and attenuated by -3dB

   $\frac{\text{3rd harmonic}}{\text{fundamental}} = -9.54 - 3 = -12.54$ dB

4. V_{IN} is a square wave with a 50% duty cycle and a frequency of 60 kHz. What is the relative amplitude of the 3rd harmonic to the fundamental frequency at the output of the filter?

(a) 0 dB
(b) -3.0 dB
(c) -6.5 dB
(d) -9.5 dB
(e) -12.4 dB
(f) -16.1 dB
(g) -19.1 dB
(h) none of the above

Fundamental is attenuated by -3 dB

3rd harmonic is attenuated by -20dB/decade

$\hookrightarrow \frac{\log(3)}{\log(10)}$ of a decade = 0.477 of a decade

$\frac{-20\,dB}{decade} \times 0.477 = -9.54\,dB$

3rd harmonic
$-9.54 - 9.54 = -19.1\,dB$

$-19.1\,dB - (-3\,dB) \rightarrow$ (f)

5. V_{IN} is a square wave with a 50% duty cycle and a frequency of 80 kHz. What is the relative amplitude of the 3rd harmonic to the fundamental frequency at the output of the filter?

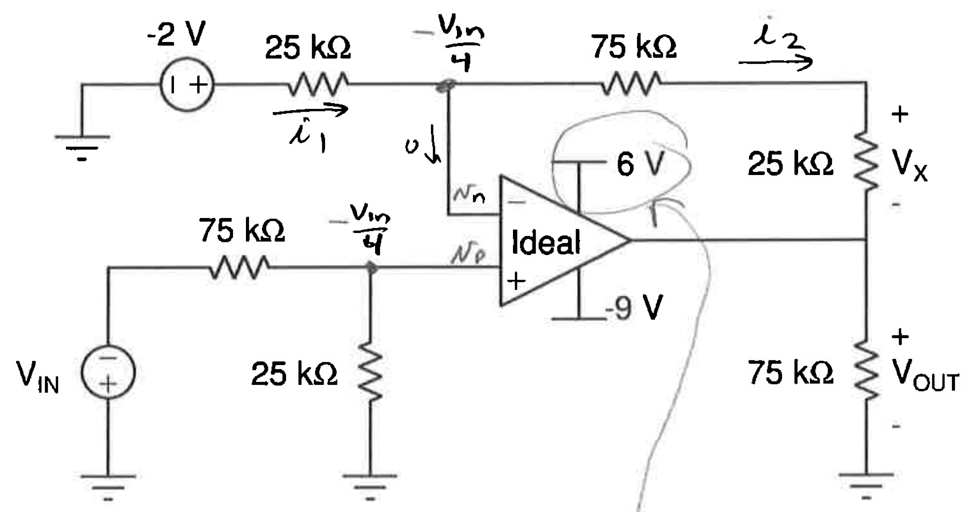
(a) 0 dB
(b) -3.0 dB
(c) -6.5 dB
(d) -9.5 dB
(e) -12.4 dB
(f) -16.1 dB
(g) -19.1 dB
(h) none of the above

Both fundamental and 3rd harmonic on -20dB/decade slope

$-9.54 - 9.54 = -19.1\,dB$

(square wave) (from filter) (TOTAL)

Problem 2: Consider the OpAmp circuit below. The OpAmp is ideal.



1. Which of the following best describes this amplifier circuit?
   (a) inverting amplifier with a dc offset
   (b) non-inverting amplifier with a dc offset
   (c) inverting integrator with a dc offset
   (d) non-inverting integrator with a dc offset
   (e) Schmitt trigger
   (f) None of the above

2. When $V_{IN} = 0$ V what is the value of V_{OUT}?
   (a) -9 V
   (b) -6 V
   (c) -2 V
   (d) 0 V
   (e) +2 V
   (f) +6 V
   (g) None of the above

$i_1 = i_2$

KCL @ N_n

$$\frac{-2 - \left(-\frac{V_{in}}{4}\right)}{25K} = \frac{-\frac{V_{in}}{4} - V_{OUT}}{100K}$$

$$-8 + V_{in} = -\frac{V_{in}}{4} - V_{OUT}$$

$$V_{OUT} = 8 - \frac{5V_{in}}{4}$$

Dc offset

Inverting amplifier

$V_{in} = 0 \Rightarrow V_{OUT} = 8$ V

However, saturation voltage is 6 V

3. When $V_{IN} = 8$ V what is the value of V_{OUT}?

(a) -9 V
(b) -6 V
(c) -2 V
(d) 0 V
(e) +2 V
(f) +6 V
(g) None of the above

$V_{OUT} = 8 - \frac{5}{4} \times 8 = -2V$

4. When $V_{IN} = 8$ V what is the value of V_X?

(a) -9 V
(b) -6 V
(c) -2 V
(d) 0 V
(e) +2 V
(f) +6 V
(g) None of the above

Since $v_n = V_{OUT}$ $i_2 = 0$

and $v_x = 0$

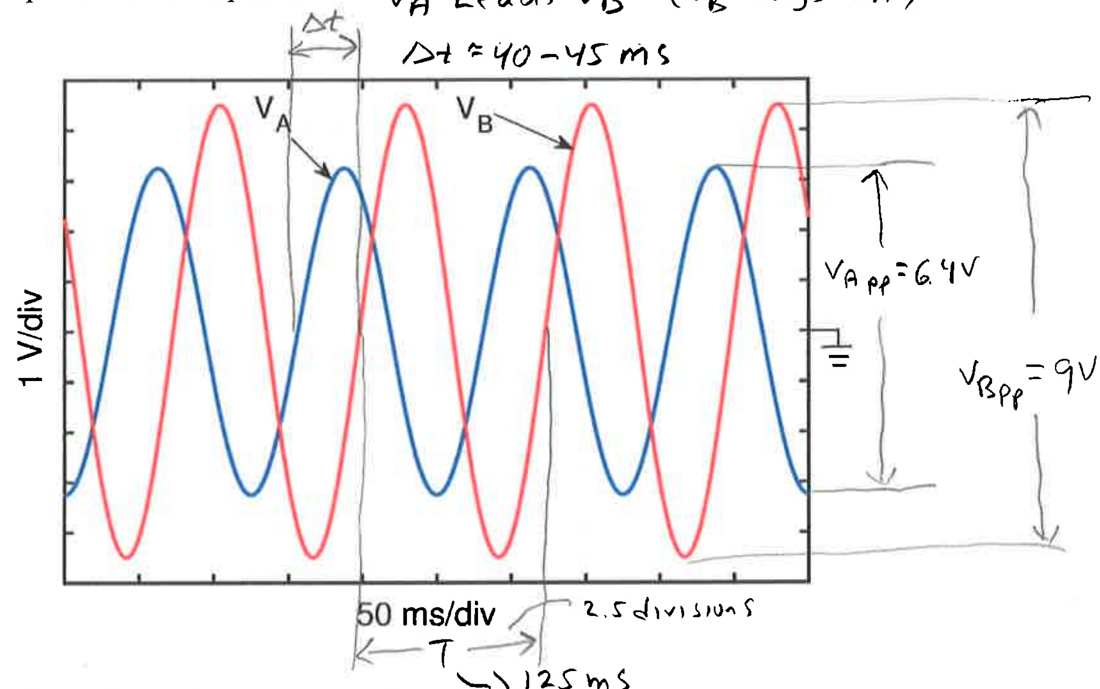
5. If the ideal OpAmp in this circuit is replaced with a TL082 OpAmp, what would you expect for the maximum obtainable output voltage?

(a) +5 V
(b) +6 V
(c) +8 V
(d) +9 V
(e) +11 V

From Lab #4: About 1V lower than the supply voltage

Problem 3: Consider the oscilloscope trace shown below. Signal V_A is the input to an amplifier and V_B is the output from an amplifier. V_A Leads V_B (V_B Lags V_A)

$\Delta t \approx 40-45$ ms



The two sinusoidal signals can be represented by:

$$V_A(t) = A\cos(\omega t + \phi_1)V$$

and

$$V_B(t) = B\cos(\omega t + \phi_2)V$$

1. What is the gain of the amplifier? $\frac{9V}{6.4V}$

   (a) 1.4
   (b) 2.8
   (c) 4.2
   (d) 5.6
   (e) None of the above

2. What is ω?

   (a) 2k rad/s
   (b) 4k rad/s
   (c) 8k rad/s
   (d) 25k rad/s
   (e) 50k rad/s
   (f) none of the above

   $w = 2\pi f = \frac{2\pi}{T} = 50$ rad/s

3. Which of the following statements best describes the phase shift between V_A and V_B?

(a) V_A lags V_B by 60°

(b) V_A leads V_B by 60°

(c) V_A lags V_B by 120°

(d) V_A leads V_B by 120°

(e) V_A lags V_B on the positive cycle and V_A leads V_B on the negative cycle

V_A Leads V_B

$\theta_{ps} = \frac{\Delta t}{T} \times 360$

$\frac{40ms}{125ms} \times 360^\circ = 115^\circ$

$\frac{45ms}{125ms} \times 360^\circ = 130^\circ$

4. What is B?

(a) 2.3 V

(b) 3.2 V

(c) 4.5 V

(d) 6.4 V

(e) 9.0 V

$V_B = \frac{V_{Bpp}}{2} = \frac{9V}{2} = 4.5V$

5. If the voltage B is measured on a DVM set to measure an AC voltage, what value would it read?

(a) 2.3 V

(b) 3.2 V

(c) 4.5 V

(d) 6.4 V

(e) 9.0 V

measures rms voltage

$V_{B_{rms}} = \frac{4.5}{\sqrt{2}} = 3.2V$