BME154L (Palmeri)

Spring 2012

Exam #2

Instructions:

- Write your name at the top of each page.
- Show all work (this is *critical* for partial credit!), including block diagrams for all design problems!
- Remember to include units with all answers and label all plot axes.
- Clearly box all answers.
- Assume that all components are ideal unless otherwise stated.
- Assume that op amps rail at $\pm$ 12 V unless otherwise stated.

Abbreviations:

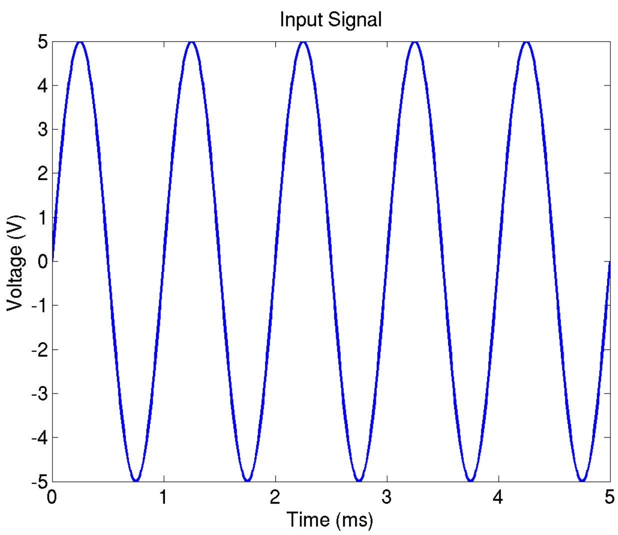
ADC	Analog-to-Digital Converter
DAC	Digital-to-Analog Converter
MSB	Most Significant Bit
LSB	Least Significant Bit
RMS	Root Mean Square
SNR	Signal-to-Noise Ratio

In keeping with the **Duke Community Standard**, *I have neither given nor received aid in completion of this examination.*

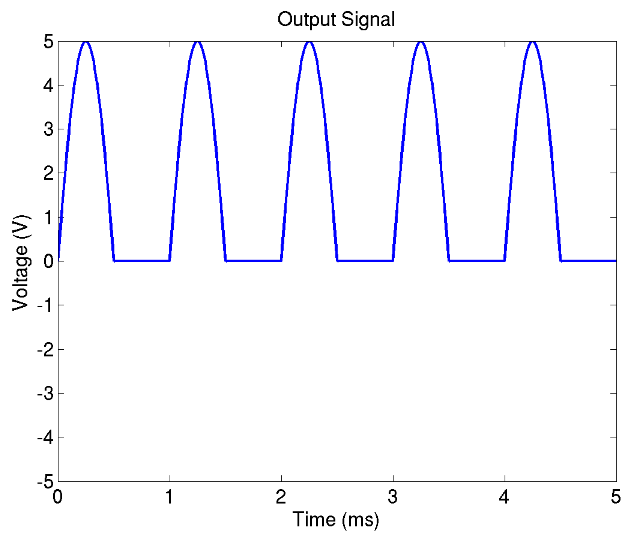
Signature:________________________________

Problem #1 [70 points]

Another approach to half-wave rectification is to utilize the ADC/DAC process instead of diodes. We will work through this process in the following problem. Consider a sinusoidal signal $f(t) = 5\sin(2000\pi t)$ V (Figure 1.1(a)) and a desired output signal (a half-wave rectified input signal) (Figure 1.1(b)):



(a) Input Signal



(b) Output Signal

Figure 1.1: Input and Output Signals

We will use the following block diagram:

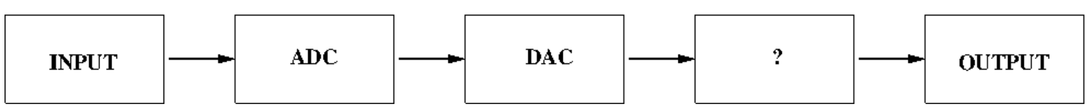


Figure 1.2: Block Diagram

(a) Sketch the power spectra of input (Figure 1.1(a)) and output (Figure 1.1(b)) signals, labeling key features.[1] [10 points]

(b) Some sampling frequency considerations:

- What is the minimum sampling frequency of the ADC that you need to faithfully reproduce the input signal to the DAC? [5 points]
- What is the minimum DAC update frequency that you need to faithfully reproduce the output signal? Consider your answer to (a) and if there is any benefit to updating your DAC output more frequently than the sampling frequency of the ADC? [5 points]

(c) Given an RMS white noise voltage of 0.5 V (not shown in Figure 1.1(a)),

- What is the SNR of the input signal? [5 points]
- What is the ideal number of bits that should be used to sample the input signal to generate the desired output signal?[2][3] [5 points]

(d) Design the fastest ADC possible for this process. Be sure to specify all relevant component values. [10 points]

(e) Successive Approximation ADC

- If you were to use a successive approximation ADC for this problem, then how many approximations would be needed for each binary number representation? [5 points]
- Write a general expression that relates the minimum frequency of these successive approximations to the sampling rate of the input signal such that there is no loss of frequency content of the input signal. [5 points]

(f) Design an R-2R DAC for your circuit. Be sure to specify all component values. [10 points]

(g) What error would be introduced into your DAC if the "2R" for your MSB was 20% greater than your ideal design? (Provide a quantitative answer.) [5 points]

(h) Design the "?" block in Figure 1.2 to achieve the desired output signal (Figure 1.1(b)). [5 points]

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[1] If you are having trouble sketching these power spectra, then describe your thought process for partial credit.

[2] "Ideal" means the number of bits needed to fully represent the signal without wasting bits sampling just noise.

[3] Hint: Saturation of an ADC can be considered a design flaw in some circuits, but it can be taken advantage of in this problem to remove parts of your input signal that you do not want in your output signal.

Problem #2 [30 points]

Various physiologic systems in the body can be represented as second-order systems. Below is a voltage trace from a lab group measuring the output (impulse response) of the system you designed in Lab 8 with a finger tap ("delta-like") input.

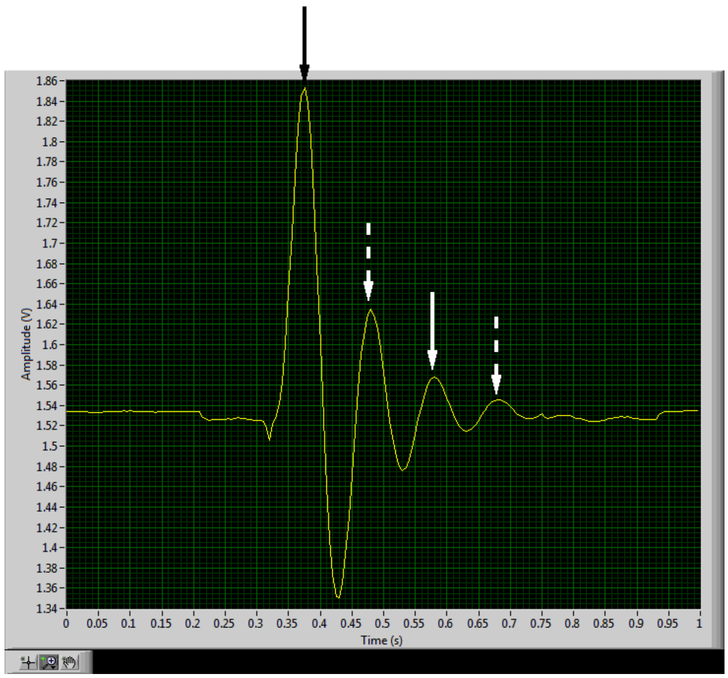

Figure 2.3: Second-Order System Impulse Response

(a) The oscillations in Figure 2.3 occur at the damped frequency of this system (ω_d). Is ω_d greater than or less than the natural frequency (ω_n) of this system given this impulse response? Why? [5 points]

(b) Bandwidth:

- What is the relative bandwidth (greater or less) of this impulse response compared to that of a continuous sinusoid oscillating at ω_d? Why? [5 points]
- What would happen to the bandwidth of this impulse (increase or decrease) if the damping coefficient of this system increased? Why? [5 points]

(c) Draw the block diagram for a circuit that powers an LED with a 0.7 V threshold voltage on every **other** positive peak of the impulse response signal above 1.54 V (two solid arrows in Figure 2.3) (i.e., use the impulse response as the input signal into your circuit). The LED can remain on until the next temporal positive peak occurs (dashed arrows in Figure 2.3). Be as detailed as possible in your block diagram. [15 points]