SYSC 4405: Midterm Exam (#:1) October 24, 2011

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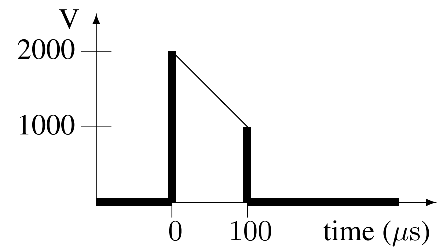
Background: Conducted Energy Weapons (CEWs), such as those manufactured by TASER International, are seeing increasing deployment in police forces as a less lethal force option; but, at the same time, these weapons are also seeing an increased level of concern in terms of their safety of use. These weapons send a sequence of electrical pulses into the subject, and are designed to stimulate nerves and cause muscular incapacitation. We consider a CEW which sends pulses of the shape below at a rate of 20 pulses/s.

In order to validate the reliability of these devices, they are tested by firing into a dummy load (normally a 600Ω resistor) and the voltage signal measured and digitized. A recent standard recommends a sampling frequency of 10 MSample/s. Instead, in this exam, consider an inadequately sampled signal using $f_s = 50\ k$Sample/s, used with a 6 bit A/D converter. The A/D converter's input range is $\pm 1500V$.

The electrical output from the weapon is a series of pulses, $x(t)$, described by the equation below and the graph at right.

$$x(t) = 2000\ u(t)u(100\mu\text{s} - t)(1 - \frac{t}{200\mu\text{s}})\ \text{V}$$



1. (1 point) Your exam is exam number **1**. Write down this number.

2. (5 points) The pulse, $x(t)$, is sampled at the indicated rate. **Sketch a stem plot of the sampled signal and write the sequence** $x[n]$, for $0\mu\text{s} \leq t \leq 100\mu\text{s}$.

3. (5 points) In order to calculate the net charge in a pulse, we use an integrating filter $y[n] = x[n] + y[n-1]$. **Calculate and sketch** $y[n]$ **for** $n = 0 \ldots 5$.

4. (5 points) Briefly indicate whether the filter in Q3 is: a) linear, b) memoryless, c) shift-invariant, d) LSI, e) stable, f) causal, g) FIR.

5. (5 points) In Q2, we considered the case in which the sampling was aligned with the pulse timing. If the samping and pulse are offset in time, the peak ouput will appear to be lower. **What pulse offset, in** t**, results in the minimum peak in** $x[n]$**? Sketch a stem plot of the sampled signal in this case?**

6. (5 points) **Is there aliasing in signal** $x[n]$**?** Briefly (≤30 words) indicate the relationship between the lower peak measurement and an aliased signal. *Note: you do not need to prove it mathematically for this question, an explanation is sufficient.*

7. (5 points) **What is the resolution of the digitized signal,** $x_s[n]$**?**

8. (5 points) Calculate the sampled sequence $x_s[n]$, for $0\mu\text{s} \leq t \leq 100\mu\text{s}$?

9. (5 points) To detect the pulse arrival time, the FIR filter $h[n] = \{-1, 1\}$ is useful to amplify edges in the signal. **Calculate the DTFT,** $H(\omega)$**, of this filter.**

10. (5 points) To detect the pulse arrival time, the FIR filter $h[n] = \{-1, 1\}$ is useful to amplify edges in the signal. **Using with** $N = 4$**, calculate** $H[0]$ **and** $H[1]$**. What does** $H[0]$ **represent?**

11. (5 points) Consider the first four samples of $x[n] = \{2000, 1900, 1800, 1700\}$. **What is** $y[n] = x[n] * h[n]$**?**

12. (10 points) Consider the first four samples of $x[n] = \{2000, 1900, 1800, 1700\}$. **Calculate the circular convolution** $y[n] = x[n] \circledast h[n]$ **by calculating** $H[k]$ **and** $X[k]$.

13. (5 points) We wish to filter $x[n]$ by $h[n]$ using $N = 4$ using the overlap add. **Calculate the maximum block size of** $x[n]$**. Sketch a diagram of the filter using overlap-add.** Indicate each operation and the sizes of the sequences involved.

14. (5 points) (bonus?) Such a sequence of pulses can be generated by a recursive linear filter in response to a trigger. **Sketch a filter which outputs an infinite train of pulses in response to an input** $x[n] = \delta[n]$**.**