

Project 7: Convolution: Computations and Applications

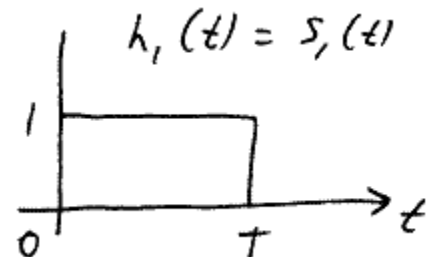
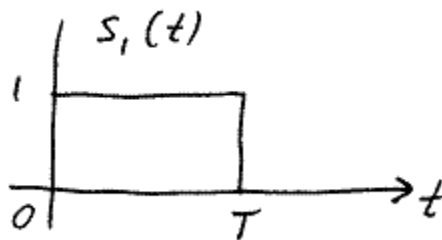
Project Report **Due Dates:** Monday Lab: November 18, 2009
Wednesday Lab: November 20, 2009

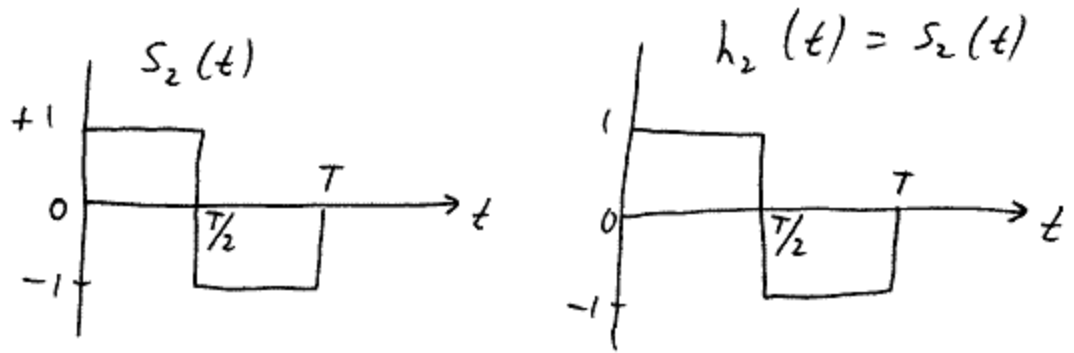
You were introduced to convolution in Quiz 1 without using the term convolution and in class and homework we have been practicing how to compute the convolution integral. We will also learn about the impulse response of continuous-time systems, where you will determine the impulse response of an RC circuit two ways, analytically and experimentally. In addition, we will provide you with the impulse response of the Powers Theater and ask you to experiment with music

1. Consider a series RC circuit driven by a voltage source, with the output voltage measured across the capacitor. We will use $R = 10$ kohms and $C = 0.1$ microfarads.

- Analyze this circuit and derive the expression for the impulse response, $h(t)$. In your analysis, consider applying a rectangular pulse that gets briefer and briefer while maintaining unit area.
- Analyze the circuit and derive an expression for the output, $y(t)$.
- Devise a procedure to experimentally measure the step response of the circuit.
- Obtain the impulse response of the circuit, $h(t)$. (Hint: Input a square wave and use the derivative function of the oscilloscope to obtain $h(t)$.)
- Use convolution to predict the response of this circuit to a 5 volt step function. Apply a 5 volt square wave and compare the response with your prediction.
- Use convolution to predict the response of this circuit to a 2 volt sinusoidal signal, $f(t) = 2 \sin(\omega t)$. Then apply a 2 volt sinusoidal signal and compare the response with your prediction.

- Convolve a unit step function with itself: $y(t) = u(t) * u(t)$, and sketch $y(t)$. What is $Y(s)$?
- Please do the convolution problems in [HW 10](#). Sketch the results and show them to a lab instructor for verification.
- Consider the signals $s_1(t)$, $s_2(t)$ and filters with impulse response $h_1(t)$, $h_2(t)$ as shown below. Compute the output of each filter due to each input. That is, compute the four convolutions $y_{11}(t) = s_1(t) * h_1(t)$, $y_{12}(t) = s_1(t) * h_2(t)$, $y_{21}(t) = s_2(t) * h_1(t)$, $y_{22}(t) = s_2(t) * h_2(t)$.





These signals and filters are commonly used in digital communication systems that transmit bits (0s and 1s) from one place to another.

4. An application of convolution:

The impulse response can be measured easily in practice in order to obtain a model for a listening room. Simulations of this type are used to understand how an audio speaker or a listening room with a certain impulse response will affect the music that is heard in the room. The impulse response can be measured easily in practice in order to obtain a model for a listening room.

- Sample the impulse response, $h(n)$, of the RC circuit.
- Load a music file, $x(n)$ and convolve it with $h(n)$. $y(n)=h(n)*x(n)$. Use the **conv** function. What effect does convolution with $h(t)$ have on the music, i.e. what is different about the music after the processing?
- Would you please load the impulse response of the Power Theater that is available in the public class folder? The objective is to use convolution to hear digitized music and then play the resulting music and to listen to it as if you are in the Powers Theater.
- Plot the impulse response, $h(n)$, of the Powers Theater vs. sample number.
- Load a music file, $x(n)$ and convolve it with $h(n)$. $y(n)=h(n)*x(n)$. Use the **conv** function.
- Play $x(n)$ and $y(n)$. What effect does convolution with $h(n)$ have on the music, i.e. what is different about the music after the processing?
- Please write a project report that addresses all the questions and the in-lab exercises, using the IEEE Regional Student Paper Contest Guidelines. You are encouraged to expand on these questions and our class discussions and applications.

Thank you, and have fun!

Acknowledgements: We thank Heath Hansum and Rich Kozick for their help in preparing this exercise.