Introduction

In this lab, we studied the real-world implications of impulse responses and practiced computing them in order to describe the behavior of circuits. First, we took a hypothetical circuit and calculated the impulse response. Next, the circuit was constructed and an actual impulse response was captured using an oscilloscope and function generator. Finally, various impulse responses were convolved with audio signals to observe and study the outputs.

Part 1: Calculating the Impulse Response

The impulse response was calculated using the derivation shown in Figure A. An input was convolved with the impulse response to show what an output from the circuit would look like. The impulse response h(t) and output for the sample, y(t) are shown in Figures B and C, respectively.

Part 2: Plotting the Impulse Response

Next, the actual circuit was constructed. A function generator was used to create an impulse across the circuit, representing an input signal equal to the Dirac delta function. In the real world, an impulse of infinite amplitude is impossible, but a pulse from the function generator works as a close enough approximation. Another signal was then also input and measured. The impulse response is shown in Figure D, and Figures E and F show the other output of the convolved signal with the impulse response at various scales. Please note that the oscilloscope was broken, so saving proper screenshots was not possible.

Part 3: Further Exploration of Convolution

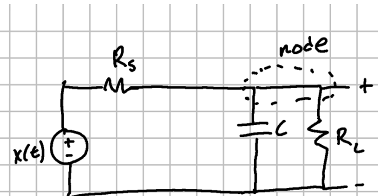
For the last part of the experiment, an audio signal was recorded using the lab computer, at 48000 samples per second. The sample was then convolved with a very simple artificial impulse response, which consisted of three pulses. When the impulse response was listened to, three audible popping noises could be heard, each quieter than the last. The convolution of this impulse response with the input signal (a voice talking) led to the same recording but with several echoes in the background, each one corresponding to the pulses of the convolution. Figure G shows the recorded audio from the lab computer.

Next, several audio samples from Queen Mary University were downloaded. These are shown in Figure H. Each one sounded like a popping noise in a series of different rooms with slightly different echoes and acoustic patterns. These were convolved with an audio recording I took from my phone, shown in figure I.

Finally, I was able to make my own impulse response by popping a balloon in a stairwell in the Clyde Building and recording it. I then convolved the impulse response with the previous audio recording using Matlab, leading to a new recording which was (ostensibly) the same thing as if the audio recording had been taken within the CB stairwell. Of course, this is subject to the recording limitations of my smartphone, which can only take recordings of 44.1k samples per second and of very limited amplitude. This final convolved audio signal is shown in Figure J.

Appendix:

Figure A: Impulse response is derived and suitable choices for resistors and capacitors are chosen



$$I = \frac{V}{R}$$

$$\frac{y(t)-x(t)}{R_s} + C\frac{dy}{dt} + \frac{y(t)}{R_L} = 0$$

$$Cy'(t) + \left[\frac{1}{R_s}+\frac{1}{R_L}\right]y(t) = \frac{1}{R_s}x(t)$$

$$\boxed{y'(t) + \underbrace{\frac{1}{C}\left[\frac{1}{R_s}+\frac{1}{R_L}\right]}_{a} y(t) = \underbrace{\frac{1}{R_s}}_{b} x(t)}$$ Figure 1

$$y'(t) + a\,y(t) = b\,x(t)$$

Solve Homogeneous: Assume $x(t)$ is zero

$$(D+a)y(t) = 0$$

$$\lambda + a = 0 \rightarrow \lambda = -a \quad \therefore \; y(t) = Ce^{-at}u(t)$$

$$h'(t) + a\,h(t) = b\,\delta(t)$$

$$\frac{d}{dt}\left[Ce^{-at}u(t)\right] + aCe^{-at}u(t) = b\,\delta(t)$$

$$Ce^{-at}\delta(t) = b\,\delta(t)$$

$$C\,\delta(t) = b\,\delta(t)$$

$$C = b$$

$$\boxed{h(t) = be^{-at}u(t)}$$

$$\boxed{h(t) = \frac{1}{R_s}\exp\left(\frac{1}{C}\left[\frac{1}{R_s}+\frac{1}{R_L}\right]t\right)u(t)}$$

$$R_s \approx 51.3$$

$$\frac{1}{C}\left[\frac{1}{R_L}+\frac{1}{51.3}\right] = 6000\pi$$

$$\frac{1}{C}\underbrace{\left[\frac{1}{500}+\frac{1}{51.3}\right]}_{d} = 6000\pi$$

$$\frac{6000\pi}{d}$$

$$\boxed{\begin{array}{l} C = 1.1uF \\ R_L = 300 \end{array}}$$

Figure B: Plotted impulse response using Matlab

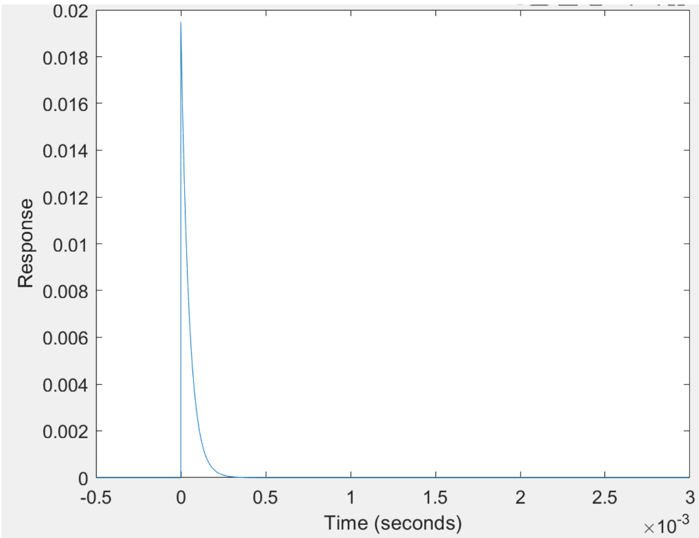


Figure C: Plotted Output signal using Matlab

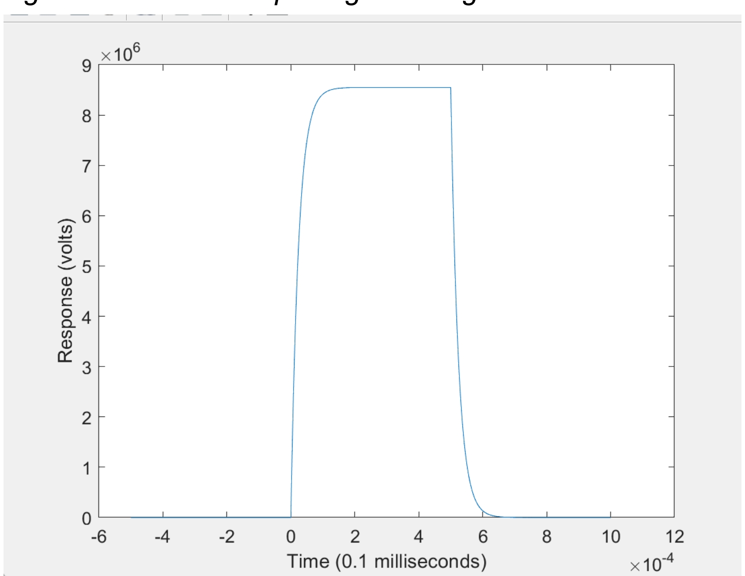


Figure D: Charted Impulse Response with Oscilliscope

Figure E: Plotted Output Signal using Oscilloscope

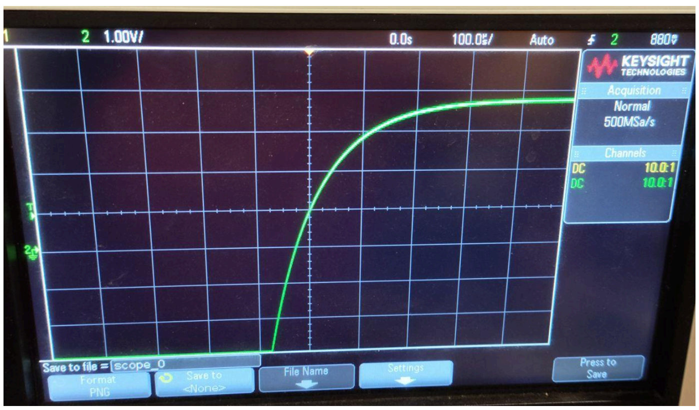


Figure F: Plotted Output Signal using Oscilloscope (Panned Out)

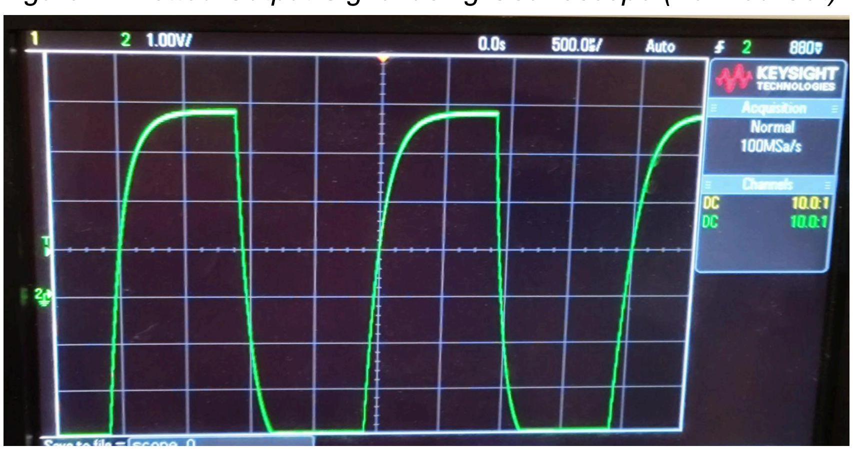


Figure G: PC Audio Sample at 48k samples per second

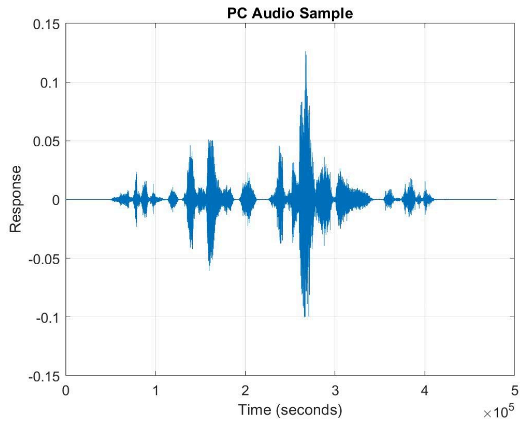


Figure H: Plotted Impulse Responses from Queen Mary University

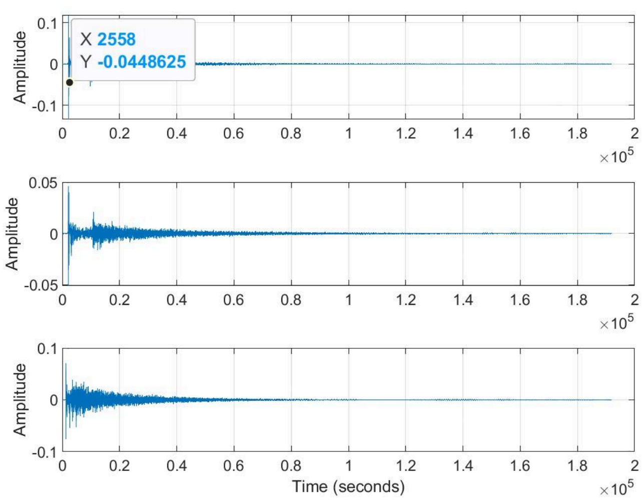


Figure I: Mobile Phone Audio Sample at 44.1K Samples/Sec

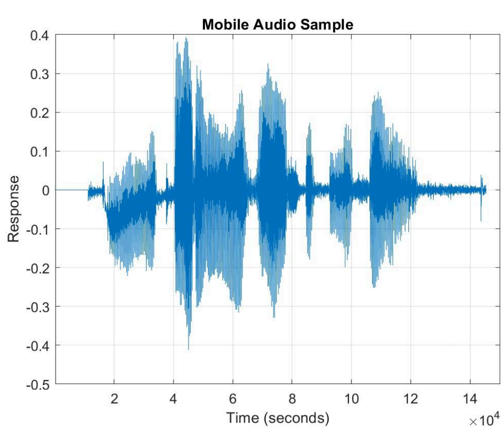


Figure J: Phone Audio Signal Convolved with Balloon Impulse Response