Laboratory 4

Electronics Engineering 3210

Impulse Response

Purpose:

This lab allows students to investigate the impulse response of a system, first by calculating the response in the time domain, then by deriving the transfer function of the system and taking the inverse Fourier transform. Students will then verify these results by experiment. The student is also introduced to integration tools in MATLAB.

Parts:

1 - 1kΩ resistor.
1 - 0.033μF capacitor.
1 - 1mH inductor

Preliminary:

Write a title and short description of this lab on a new page of your lab book. Make an entry in the table of contents for this lab.

Consider the system we used in Lab 3, shown below for convenience:

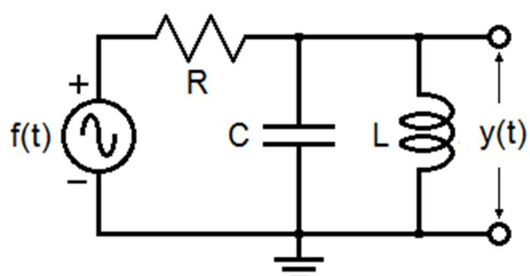

Figure 1. Series/Parallel Resonant Circuit

Let R = 1kΩ, C = 0.033μF and L = 1mH. Recall that this system is described by the differential equation:

$$\left(D^2 + \frac{1}{RC}D + \frac{1}{LC}\right)y(t) = \left(\frac{1}{RC}D\right)f(t)$$

Write a MATLAB script that computes and plots the unit impulse response, $h(t)$, for this system over the interval [0,300μs] using each of the techniques below.

1. Find the impulse response by computing P(D)$y_n(t)u(t)$ as described in Section 2.3 of the text. Your script will need to find the two characteristic roots (λ_1, λ_2) and the coefficients for $y_n(t)$. It can then then calculate and plot P(D) $y_n(t)$. (You can omit $u(t)$ because it is 1 over the entire interval [0,300μs].) Label and print the graph of $h(t)$ and affix it, along with your MATLAB script, to your lab book.

2. Find the inverse Fourier transform of the transfer function $H(j\omega) = P(j\omega)/Q(j\omega)$:

$$h(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} H(j\omega)\, e^{j\omega t} d\omega$$

MATLAB is able to approximate this integral numerically using a function called **quadgk()**. **quadgk()** accepts functions that take a vector (e.g. x) and return a vector (e.g. y) where $y_i = f(x_i)$. In MATLAB, such functions can be defined several ways. Often, they are declared in separate files, but if a function can be written as a simple expression, it can be defined in-line. For example:

```
H=@(w) (1j*w)./(-R*C*w.*w+1j*w+R/L)
```

The periods preceding the slash and asterisk indicate to MATLAB that the divide and multiply operations should be applied element-by-element rather than to the vector as a whole. Also note that adding a scalar (e.g. R/L) to a vector is legal, and result is that the scalar is added to each element of the vector.

MATLAB documentation claims that **quadgk()** may use $\pm\infty$ for the limits of integration, but those claims are somewhat exaggerated, at least for the integrals we are trying to solve. Instead, you'll need to plot $|H(j\omega)|$ and examine it to determine appropriate limits for integration. (Hint, the range will be in excess of (-10^6,10^6).) Affix a copy of the graph of $|H(j\omega)|$ to your lab book. (It is instructive to also plot and affix a copy of the phase, $\angle H(j\omega)$ as well.)

Recall that you must integrate $H(j\omega)e^{j\omega t}$ over ω, which is a function of two values (ω and t) instead of just one (as **quadgk()** requires). The easiest way to handle this is to declare an unnamed function right in the parameter list of **quadgk()**:

```
f(i) = quadgk(@(w)H(w).*exp(1j*w*t(i)), w_min, w_max)/(2*pi);
```

This assumes **t** is a vector that contains time steps in the range [0,300us].

Write your script so it performs the integral for each time step, **t(i)**, and plots it. Compare this graph of $h(t)$ with the impulse response you obtained in step 1. The two should be almost identical. Label and print the graph and affix it, along with the MATLAB script that produced it, to your lab book.

Procedure:

The goal of this laboratory procedure is to verify that the impulse response computed in the preliminary section matches reality. Ideally, we would like to provide a delta function, $\delta(t)$, to the input of the system and measure the response at its output. There is one major problem with this approach (aside from trying to safely measure a 30kV signal): we do not have equipment that will generate a delta function. We can, however, come close enough for practical purposes.

Assemble the circuit shown in Figure 1. Configure the function generator to produce pulses (not a square wave) at 1kHz. (The 1ms period gives the system sufficient time for the response to decay between pulses). Adjust the pulse duty cycle to 0.1% and adjust the low and high voltage levels to 0V and 10V respectively. This will produce a pulse 1μs wide and 10V in amplitude.

In your lab book, show that this pulse approximates $10^{-5}\delta(t)$. (Hint, integrate it.)

Make sure the oscilloscope probe is set to x10 and attach it to the output of the system. Verify that the response shown on the oscilloscope matches the responses you computed earlier (considering the factor of 10^{-5}). Sketch the oscilloscope output into your lab book, making note of both the horizontal and vertical scales.

Record your observations and write a conclusion in your lab book that summarizes what you have observed or discovered.