University of Minnesota-Duluth

EE 2212

Electronics I

Lab 1: RC Transient & Frequency response

February 1, 2018

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Abstract

This lab will cover the fundamentals of RC circuits with one of two complimenting techniques. The purpose is to show the relationship between the behavior an RC circuit with impulse excitation. Various circuit concepts will be reexamined such as the transfer function.Both circuit in lab are duals of one another, meaning that if put together port-to-port they would functionally cancel each other out. This follows with the concepts learned in fundamental calculus, like that the integration is an operation opposite to differentiation. These functional building blocks are critical analogues circuits that are much more complex in scale, and are vital in the understanding of many concepts within signal processing. Concepts such as the bandpass or notch filtering can be taken with the results from this lab.Additional analysis in the frequency domain will be used confirm the results of the transient response and add another layer of theory to the approach. To verify, the results for both a three-pronged approach will be implemented to show all forms of analysis converge on the same behavior. Wherein the results taken from the O-scope PSpice and what was calculated will be consistent with each other.

Introduction:

This lab will be a broad overview of many of the concepts from EE 2006. It will be a review of how to use a lot of the lab equipment in the context of circuits which vary with respect to frequency and time. Concept of impedance and transfer functions will be explored through constructing a circuit dual of a filter. This lab will focus first on the transient analysis first. The second component of this lab that covers things in the frequency domain will happen in lab 2.

Background:

The concept of this experiment to stimulate an RC circuit with a unit impulse. And look at the resulting natural response with respect to time. The theory is that the time that it takes for the capacitor to discharge is dependent upon Kirchhoff current laws. And forms a first order linear differential equation derived below.

$$C\frac{dV}{dt} + \frac{V}{R} = 0 \qquad E.g.\ 10nF\frac{dV}{dt} + \frac{V}{10\,\text{k}\Omega} = 0 \tag{1}$$

$$\tau = RC \qquad E.g.\ 10K * 10n = 1\mu S \tag{2}$$

The time taken for the voltage to fall is given by the RC time constant. In lab we verified this constant through finding the amount of time taken to reach 1τ with the cursor (given the constraints of the circuit both the experimental and theoretical results should match). To verify the settling time 5τ was used as the window used. For the second part of the lab the corner frequency was determined to be $1.6KHz$ (see EQU 6). Using f_c a window of frequency sweep was determined.

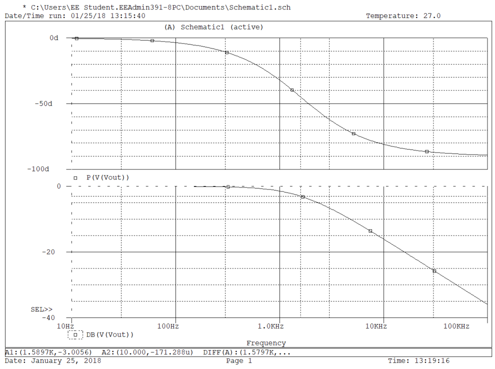
Procedure:

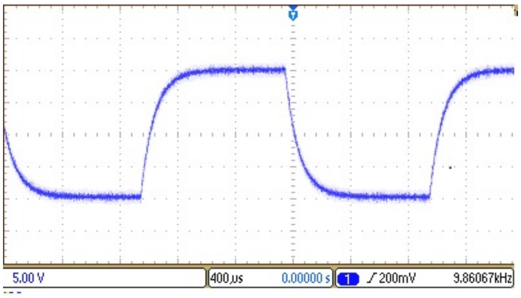
First in Pspice we created a schematic (taken from the EE 2212 course page) to stimulate the behavior of a passive integrator. Drive circuit 1 with a 2 volt peak-to-peak square wave (the two volt amplitude is not critical-look for minimal noise to set the amplitude) and observed the output. Our V_{in} used the Vpulse component in Pspice. To create the passive differentiator flip the capacitor $10nF$ with the $10\,\text{k}\Omega$ resistor. Each of the following steps were mirrored on the breadboard with the function generator used at the port of V_{in} and the oscilloscope attached across V_{out}. With probes running from the O-scope Ch_1 should be attached to V_{in} and Ch_2 with V_{out}. To measure the frequency response repeat the same construction, but perform a frequency sweep manually to create the freq resp table. Sampling in multiples of 2 from 100Hz to $\geq$ 3.2KHz, the corresponding phase difference between Ch_1 and Ch_2. In Pspice change the Vpulse to Vac component and change the attributes so that V_{PP} us 1 volt. Run the simulation of the circuit in frequency sweep mode and add macros to sample decible db() and phase p(). In addition to that make a bode plot as well selecting the appropriate nodes to trace.

Materials needed for lab:

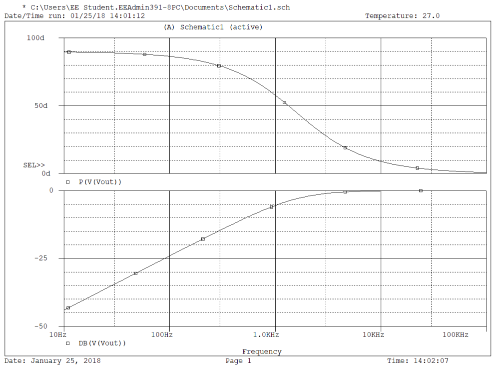
- Breadboard
- Function Generator
- Oscilloscope
- $10\,\text{k}\Omega$ Resistor and $10nF$ Capacitor

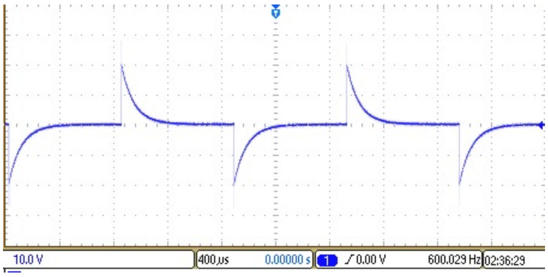
Passive Integrator





Passive Differentiator





0.1 Equations

$$V_{out}(t) = A(1 - e^{-\frac{t}{\tau}}) \qquad \text{“}Stablization\text{”} \qquad (3)$$

$$V_{out}(t) = A(e^{-\frac{t}{\tau}}) \qquad Negative\ Decay \qquad (4)$$

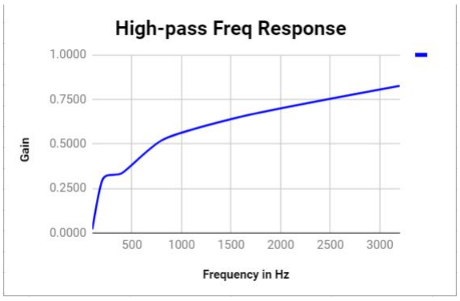
$$V_{out}(t) = \alpha \frac{d(V_{in}(t))}{dt} \qquad Passive\ diffeneriator \qquad (5)$$

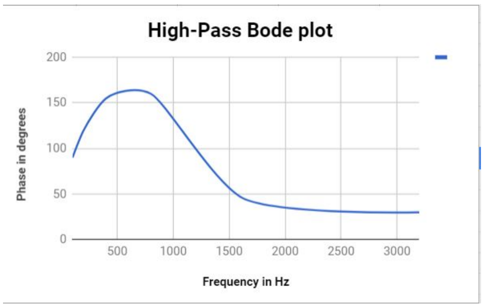
$$f_c = \frac{1}{2\pi RC} \qquad Corner\ Frequency \qquad (6)$$

Where $\tau = RC$ is the time constant, A is the amplitude, t is the variable time

Measurement and Analysis of Results:

In addition to verifying the solution to equation 1 for both critical decay and stabilization . We also saw some oddities on the oscilloscope first that it displayed both the signal and a 180° mirror image of the signal. My lab partner hypothesized that this may be due to bandwidth that is much shorter than what is required to measure the signal. Once we made a few adjustments on the O-scope the signal had much less noise. Additionally, we observed that that the dual circuits that we used generated both a integral of the square wave and the derivative of the square wave. This is similar to a previous lab done in 2006 involving an Op amp's slew rate which generated an equivalent distortion.





0.2 Tables:

Transient Response of High-Pass filter				
Parameter	Calculated	SPICE	Measured	Comments
Fall Time, t_f	0.22	0.23	0.29	Consistent
Time Constant, τ	0.1	.097	0.1	Consistent

Frequency Response of High-Pass filter					
Hz	Ch_1	Ch_2	V_{out}/V_{in}	db	$Phase\ \theta$
100	1.96	.04	.0204	-33.81	90°
200	1.96	.58	.2959	-10.58	120°
400	1.96	.66	.3367	-9.45	155°
800	1.96	1.02	.520	-5.68	160°
1600	1.96	1.28	.6530	-3.70	47°
3200	1.96	1.62	.8265	-1.65	30°

Conclusion:

The lab went well overall there was a little ambient RF noise that on the signal itself. The results that we attained in lab were consistent with the theory devised in class. You can clearly see from the graphs generated are consistent with both the behavior of the circuit for both transient and frequency response.At the tail ends of the graphs constructed from data in the lab, there's much more variation. Overall, both labs confirmed the results of each other. With the calculated corner frequency confirmed and taken bode plot that demonstrates that τ has a role in both the time and frequency domains when compared with the table. One suggestion I would make for this lab would be to demonstrate and model the response of an Op amp slew rate with an equivalent RC circuit (perhaps using the $\mu A741$).