VE216 Lab 1 Report
LTI Systems

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Contents

1 Objectives

- Measure the output response of the series RC circuit for a variety of inputs, including a step, a combination of a step and a ramp, and a sinusoid
- svCompare results to those computed as part of pre-lab assignment

2 Theoretical Background

2.1 Linear Circuit as a linear system

An RC circuit can be expressed by following equation:

$$RC\frac{dV_{out}(t)}{dt} + V_{out}(t) = V_{in}(t) \tag{1}$$

We can calculate V_{out} through solving this equation:

$$V_{out}(t) = V_0 e^{-t/RC} + \int_0^t \frac{1}{RC} e^{-(t-\tau)/RC} V_{in}(\tau) d\tau \tag{2}$$

So an RC circuit is an LTI system if and only if $V_{out} = V_0 = 0$.

2.2 Impulse Response

The impulse response, $h(t)$, is the output response when the input of the system is a delta function, $\delta(t)$. And in the experiment, the delta function is simulated by two step function with short interval, $p_\Delta(t) = \frac{1}{\Delta}(u(t) - u(t-\Delta))$ for $\Delta > 0$ and $\Delta \to 0$.

2.3 Step Response

The impulse response can be computed from the unit step response by calculating the derivative of the step response as followed.

$$\frac{dy(t)}{dt} = \frac{dx(t)}{dt} * h(t) \tag{3}$$

3 Experiment Procedures

Step Response Set the function generator with: square wave, Vpp 1V, frequency 100Hz; oscillator with: CH1 200mV/div, CH2 200mv/div, Time: 2ms.

Pulse Response Set the function generator with: frequency 100hz; For the first trial: width 1ms, A 100mV; For the second trial: width 0.5ms, A 200mV;

Ramp Response Set the function generator with: ramp, Vpp 100mV, frequency 100Hz;

Sine Response Set the function generator with: Vpp 10V, frequency 50, 500, 5kHz respectively;

4 Experimental Results

4.1 Step Response

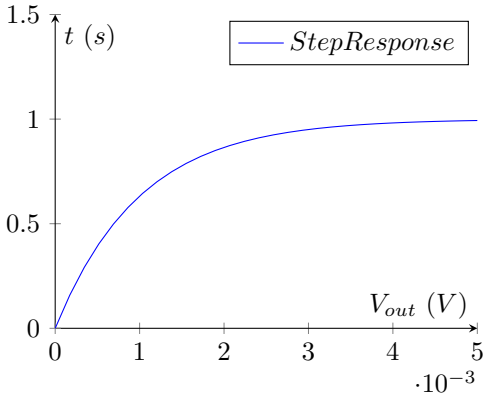
The experimental step response is shown in Figure 1a. For the theoretical output, we can calculate the solution of Eq.1 when $V_{in}(t) = u(t)$:

$$V_{out} = (1 - e^{-1000t})u(t) \tag{4}$$

And the plot is shown in Figure 1 Also, we can see the comparison between the experimental and theoratical result.

We can see that the experimental result is similar to the theoretical result.

(a) Step Response (experimental)



(b) Step Response (theoretical)

Figure 1: Step Response

4.2 Impulse Response

The impulse response (Vpp: 100mV, width: 1ms) is shown in Figure 2a. The impulse response (Vpp: 200mV, width: 0.5ms) is shown in Figure 2b. We can see that the V_{out} of two impulse response is similar.

(a) Pulse Reponse with Vpp:100mV & width:1ms

(b) Pulse Reponse with Vpp:200mV & width:0.5ms

Figure 2: Pulse Reponse

And smaller width will cause more similarity between the theoretical one and experimental one.

$$h(t) = \frac{e^{-t/RC}}{RC}$$

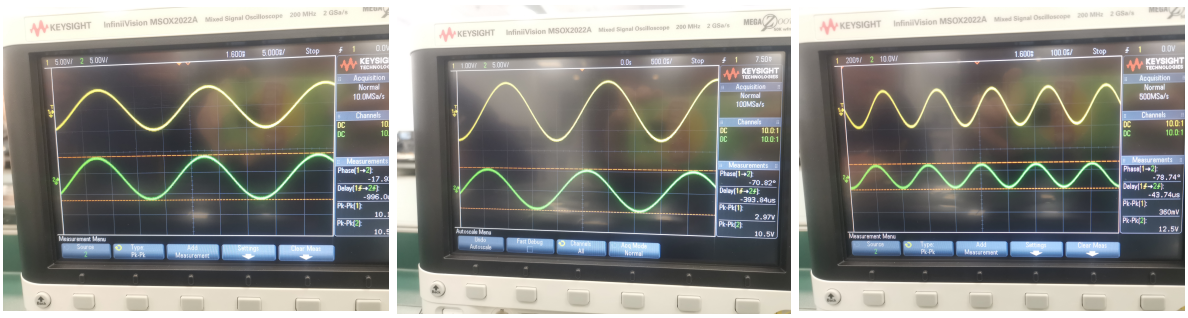
4.3 Ramp Response

The ramp response (Vpp: 100mV & frequency: 100Hz) is shown in Figure 3.

Figure 3: Pulse Reponse with Vpp: 100mV & frequency: 1000Hz

4.4 Sine Reponse

The experimental response is shown in Figure 4. Then the compare experimental results iwith the



(a) 50Hz (b) 500Hz (c) 5kHz

Figure 4: Sine Reponse (Vpp: 10V)

theoretical results calcutaled in prelab in Table 1. And we can see that the when the frequency is not

Freq (Hz)	Vin	Vout	$\|H(j\omega)\|$		Time Shift (ms)		Phase Shift(°)	
			E	T	E	T	E	T
50	5.05	5.25	0.962	0.954	0.996	0.967	-17.93	-17.44
500	1.485	5.25	0.283	0.303	0.394	0.402	-70.82	-72.34
5000	0.18	6.25	0.029	0.038	0.044	0.049	-78.74	-88.177

Table 1: Sine Reponse: **E**xperimental results v.s. **T**heoretical results

that big, the theoretical results and experimental results are close to each other.

4.5 Discussion & Error Anlaysis

After comparing the simulated results and the theoretical results, we can find that he theoretical results and experimental results are close to each other. However, the magnitude of transfer function $|H(j\omega)|$, phase shift and time shift are all a little bit smaller than expected. It may cause by the cursor position and the system error of oscillator.

5 Conclusion

In this lab, we analyzed the LTI system (RC circuit)'s reponses with different input signals (step, impulse, square, ramp and sine signal).

1. The impulse response of LTI system can be calculated in two ways. One is calculate the derivative of step response. And the other is use two step response with small width to simulate it.

2. For response to sine input, the input with higher frequency will have lower magnitude of the transfer function, smaller time shift and greater phase shift.