EEAP 243
Lab 3

Lab Work:
Questions Due:

TIME RESPONSE

READING ASSIGNMENT: Horowitz, pgs. 20-25, Millman and Taub, p.50-54.

Abstract:
This lab demonstrates and measures the time response of RC networks and oscilloscope probes.

Part I - RC circuits
In Circuits I you analyzed the time response of the circuit shown in Figure 3.1 assuming that the switch S was closed at time t=0. We will experimentally verify your analysis except, instead of using a switch, we will use the signal generator. A square wave signal generator output which goes from 0 to some positive voltage V will simulate the opening and closing of the switch S connected to a battery of voltage V as shown in Figure 3.1.

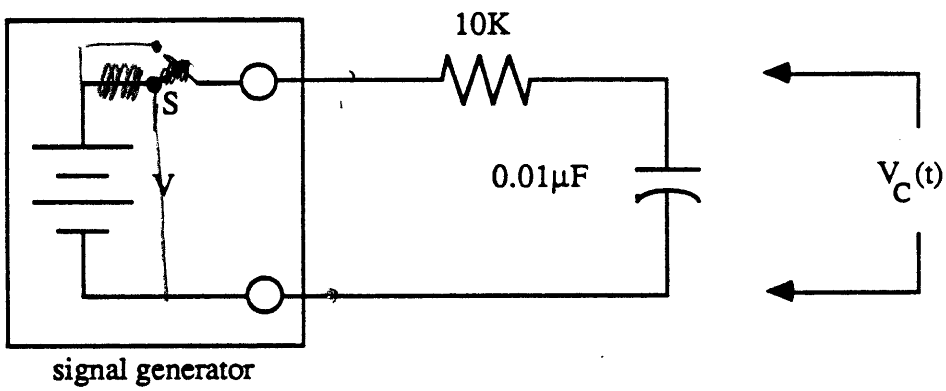

Figure 3.1 - Time response of RC circuit

To begin this lab construct the circuit shown in Figure 3.1. Adjust your signal generator output to produce a 0 to 10 volt, 500 Hz square wave. (change to 0-1 volt) Note that this may require adjusting both the output amplitude and DC offset of the generator output. Connect the output of the signal generator to your circuit. Measure the voltage across the capacitor with your oscilloscope. Plot the time dependent voltage waveform you see on the scope on the graph in Table 3.1.

Change your generator output to a 100 kHz square wave. Measure the amplitude of $V_C(t)$ with the oscilloscope. You may need to turn the generator output all the way up to get a measurable output. Plot your results in Table 3.2.

This circuit now functions as an integrator, i.e. a low-pass filter. Verify this by changing your generator output from a square wave to a triangle waveform. Plot your results in Table 3.3. (compare to a sine wave)

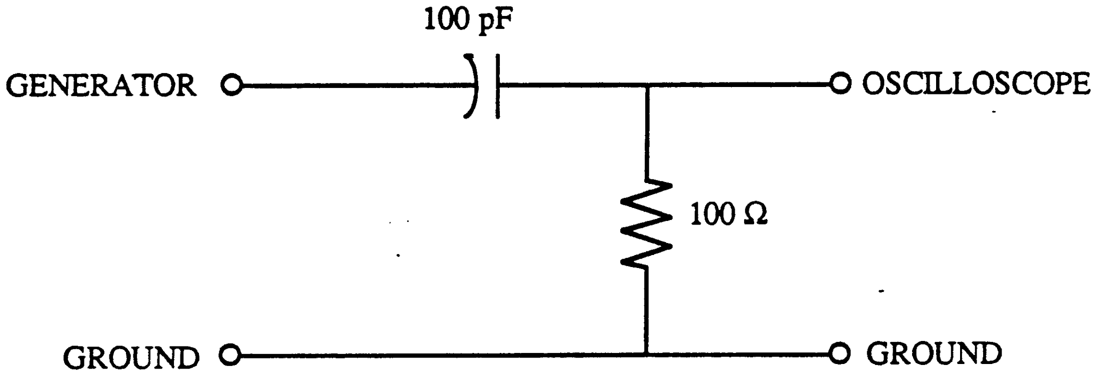

Figure 3.2 - RC Network

Build the RC circuit shown in Figure 3.2. Adjust the generator output to a 0-1 volt, 100 kHz square wave. Connect the circuit of Figure 3.2 to the output of the signal generator. Measure the voltage across the 100Ω resistor with the oscilloscope. Plot your results in Table 3.4. This circuit functions as a differentiator, i.e. a high-pass filter. Verify its performance by switching the generator output to a triangle waveform and measuring the voltage across the resistor. Plot your results in Table 3.5.

Part II - Oscilloscope probes

Unshielded wires connected to a scope often act like antennas and introduce unwanted random signals (noise). These signals often originate from the 60 Hz power lines or from nearby unconnected signal sources. To see if you can actually see any noise from the 60 Hz power lines: probably will not see 60 H.

(1) Set your scope to AC coupling and disconnect any wires from its input jacks.
(2) Observe what happens to the straight line displayed as you switch to each scale factor setting from 10 V/cm to 2 mV/cm. can oscillate (Sweep = 1 msec/cm)
(3) Plug a test lead into the scope input and let the free end lie on the lab bench.
(4) Repeat step 2.

Coaxial cables are often used to reduce unwanted noise.

(5) Repeat steps 3 and 4 using a coaxial cable and the BNC scope input instead. The connector/clip assembly should be removed from the cable while making this observation.

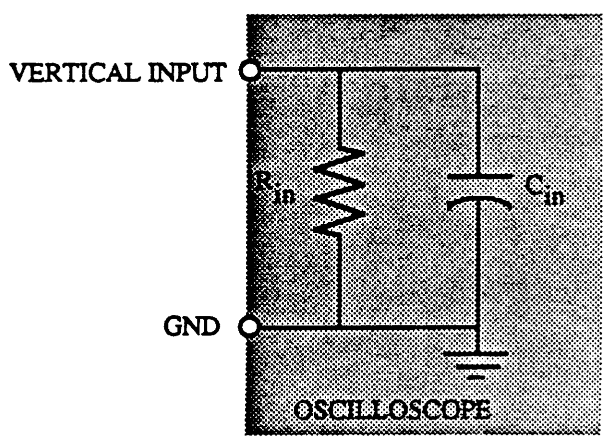

Figure 3.3 - Equivalent input circuit of oscilloscope

As shown in Fig. 3.3, the input of the oscilloscope appears as a parallel resistance and capacitance to ground. Unfortunately, the use of a coaxial cable adds additional capacitance to the scope input. You will learn in fields that a coaxial cable is a cylindrical capacitor and, consequently, has a certain capacitance per unit length. (This capacitance may be as high as 20-30 pF per foot.) The combined input capacitance of the scope and coax, coupled with the high resistances in the circuit to be measured, can introduce errors in measuring waveforms.

(6) Use your coaxial cable assembly to observe the generator output.
(7) Set the generator to produce a maximum amplitude 10 kHz square wave with zero DC offset.
(8) Record the voltage waveform you see in Table 3.6.

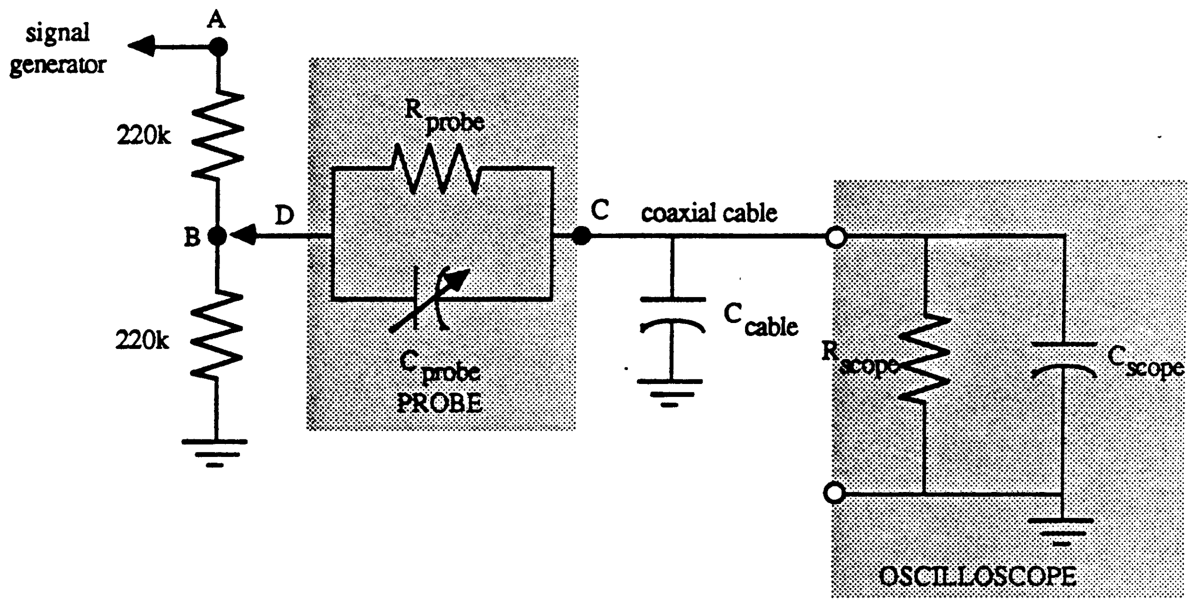

Figure 3.4 - Compensated scope probe circuit

A resistor and variable capacitor, as shown in Fig. 3.4, can be used to form what is called a compensated probe which can eliminate cable capacitance effects. Basically, the circuit is a capacitative voltage divider in parallel with a resistive voltage divider.

(1) Set the generator to a 10 KHz square wave at maximum amplitude and zero DC offset. Connect the signal generator to a divider composed of two 220k resistors as shown in Figure 4. These resistors can be on your protoboard.
(2) Use the coaxial cable to directly look at the output of the generator at point A in Figure 3.4.
(3) Connect a 10 M resistor (R_{probe}) and a 1.2-30 pF variable capacitor (C_{probe}) to the coax as shown in Fig. 3.4. This circuit should be soldered to the end of your coaxial cable to eliminate any capacitance you might pick up from constructing it on your protoboard. NOTE: If soldering is not possible, construct the compensated probe on your protoboard using the layout shown in Figure 3.5.

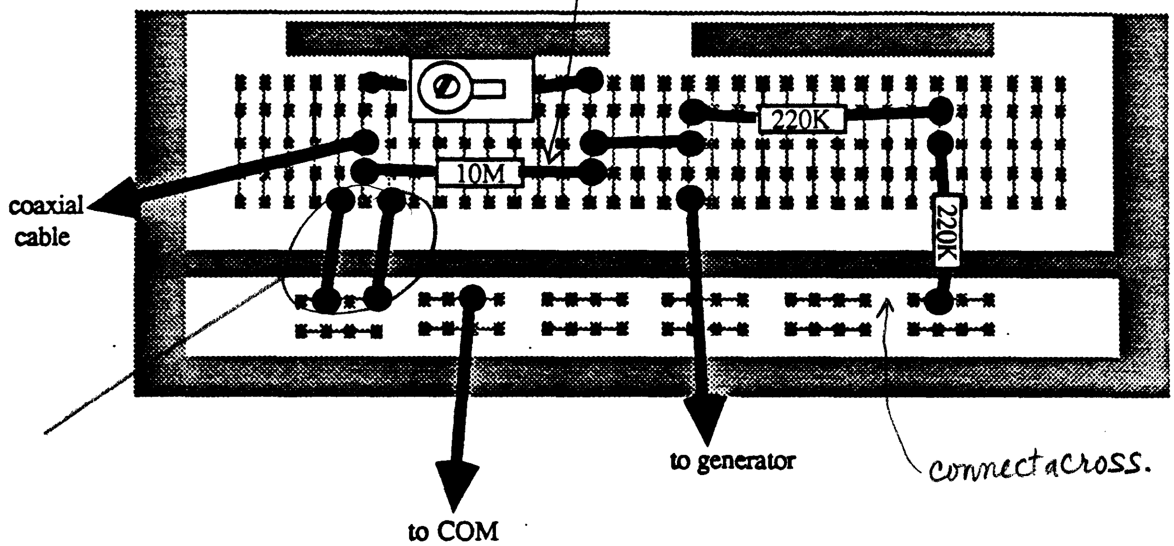

Figure 5 - Recommended protoboard construction of compensated probe

(4) Connect the input to your probe (point D) to point A.
(5) Observe what happens as you turn the variable capacitor a full 360 degrees.
(6) Adjust the capacitor so that the tops and bottoms of the square wave are perfectly flat and horizontal.(Note that this is how you would adjust any commercial compensated probe. A terminal (C-7) on your scope provides a square wave source for adjusting compensated probes.)
(7) ~~Now connect your probe (point D) to point B.~~
(8) Record the displayed voltage waveform in Table 3.7.

We studied the compensated probe from a viewpoint of a RC filter in this lab; we will consider its frequency response characteristics in Lab #4.

PLEASE CALL A TEACHING ASSISTANT TO CHECK YOUR DATA BEFORE YOU LEAVE.

Questions:

1. What was the measured time constant of your circuit? ~~Did it~~ agree with the calculated value?
2. Under what conditions does a RC circuit function as a differentiator? As an integrator?
3. Calculate the combined input capacitance of the cable and oscilloscope from your data.
4. By what factor did the compensated probe circuit divide the input signal?
5. The compensated scope probe was alluded to as a voltage divider in parallel with a resistive voltage divider. Analyze the circuit of Figure 3.4 with this viewpoint. What are the required time constants for compensation? HINT: See Millman and Taub, Pulse, Digital and Switching Waveforms, p.50-54.

EEAP 243 LAB 3 EVALUATION

NAME (print)_______________________ CHECKPOINT #1 ___ DATE _____
GRADE _____/_____ CHECKPOINT #2 ___ DATE _____

With respect to the course material, this lab was: (pick one)
___ highly relevant ___ relevant ___ not relevant ___ completely irrelevant

This lab was: (pick one)
___ too long ___ long ___ just right ___ short ___ too short

This lab was: (pick one)
___ too hard ___ hard ___ just right ___ easy ___ too easy

The background material in the lab assignment was: (pick one)
___ too detailed ___ just right ___ sufficient ___ insufficient ___ totally inadequate

The step by step procedures in the lab assignment were: (pick one)
___ too detailed ___ just right ___ sufficient ___ insufficient ___ totally inadequate

Describe any mistakes made in the lab assignment.

Describe anything that just didn't work right.

Describe how this lab could be made better.

QUIZ

NOTE: THE TEACHING ASSISTANT IS TO SELECT BOTH QUESTIONS FROM THE UNDERLINED OPTIONS AT THE SECOND CHECKPOINT

Question #1

The value of C_{coax} is proportional to the length of coaxial cable used. Suppose that you have a compensated probe. How would you re-compensate it if you made its cable (longer/shorter) ?

I would (increase/decrease) the value of R_{probe} / C_{probe} / R_{scope} / C_{scope}.

Question #2

What will happen to the (amplitude/frequency) of the resonance, i.e. the peak in the Bode plot, of Fig. 3.7 if we (increase/decrease) the value of the resistance/inductance/capacitance ?

It will increase / decrease / stay the same.

EEAP 243

NAMES: ______________________________

Lab 3 Data STATION 12

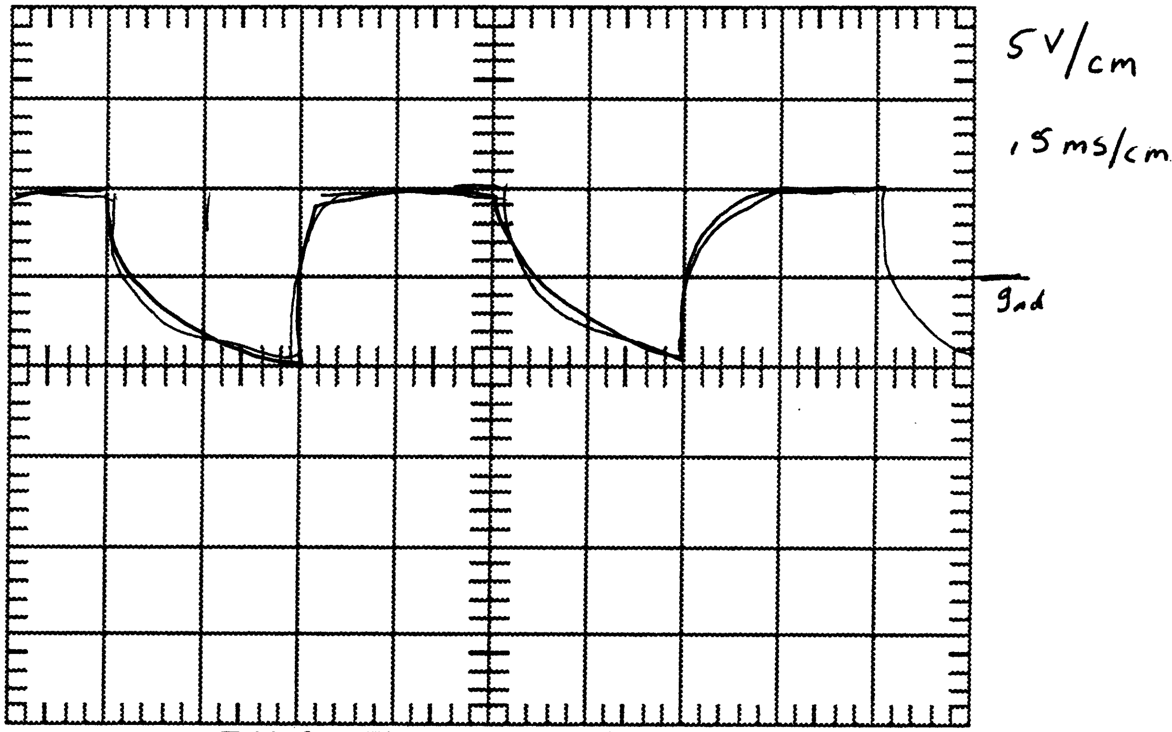

Table 3.1 - Time dependent RC waveform

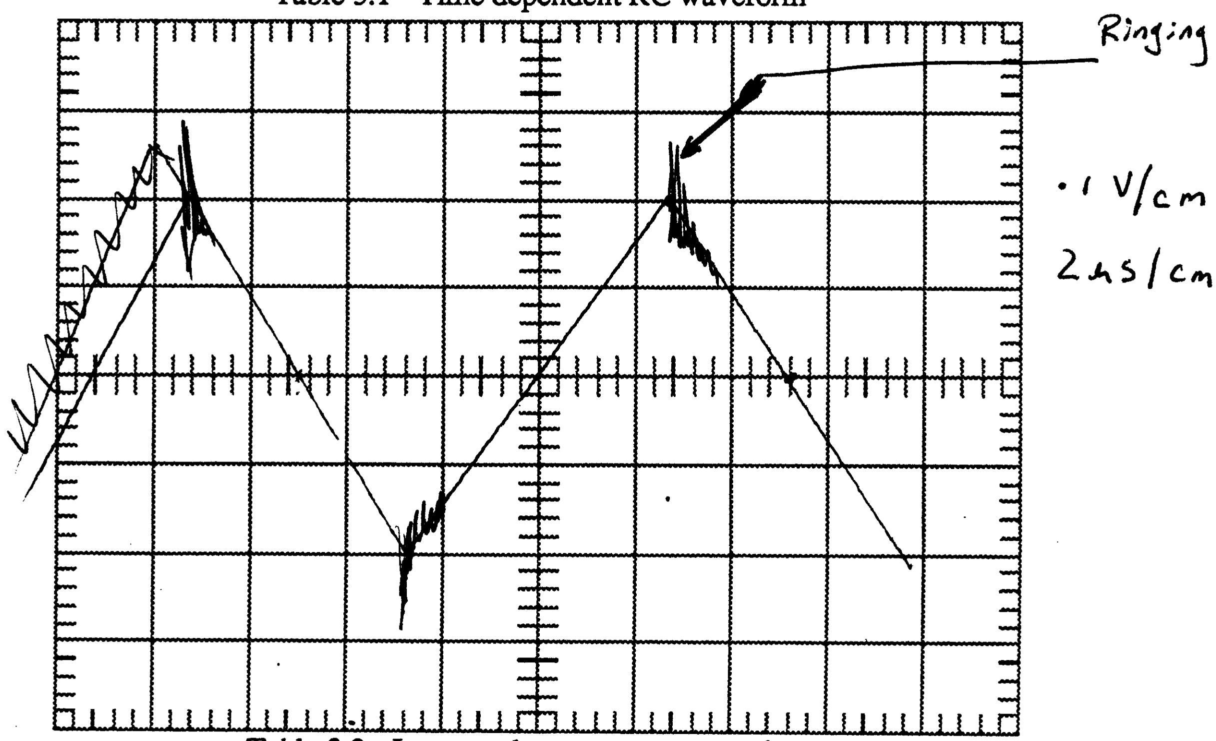

Table 3.2 - Integrated square wave waveform

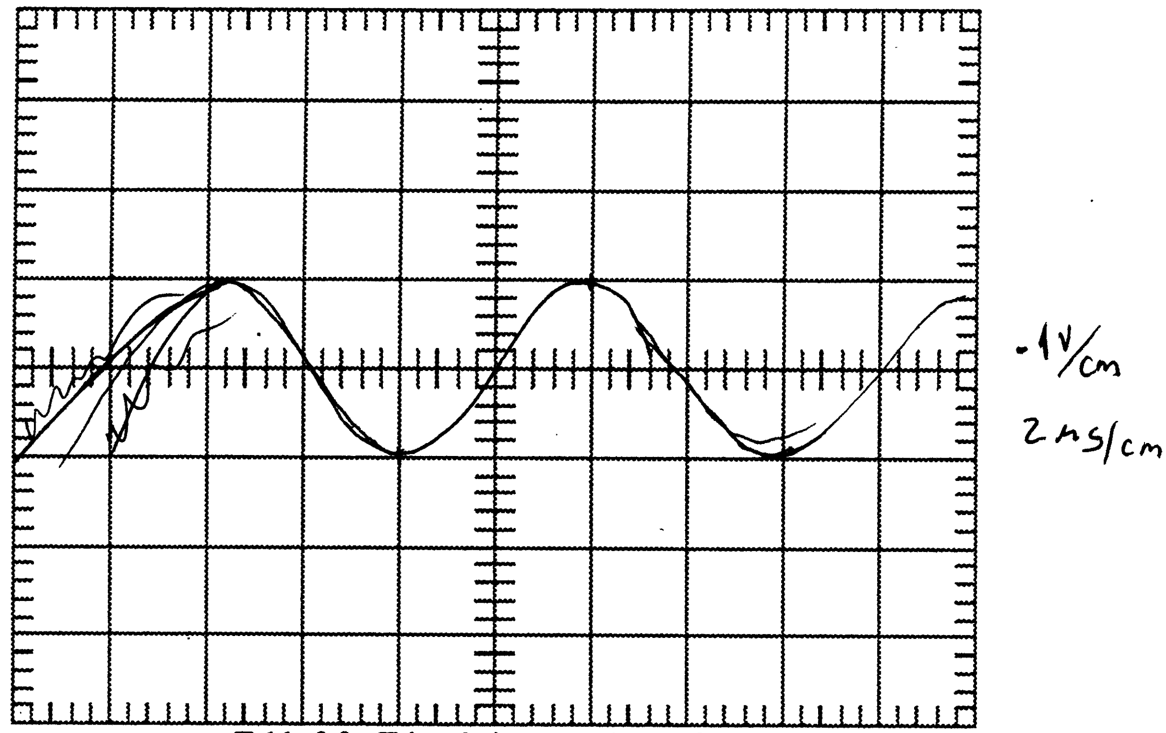

Table 3.3 - Triangle integrated waveform

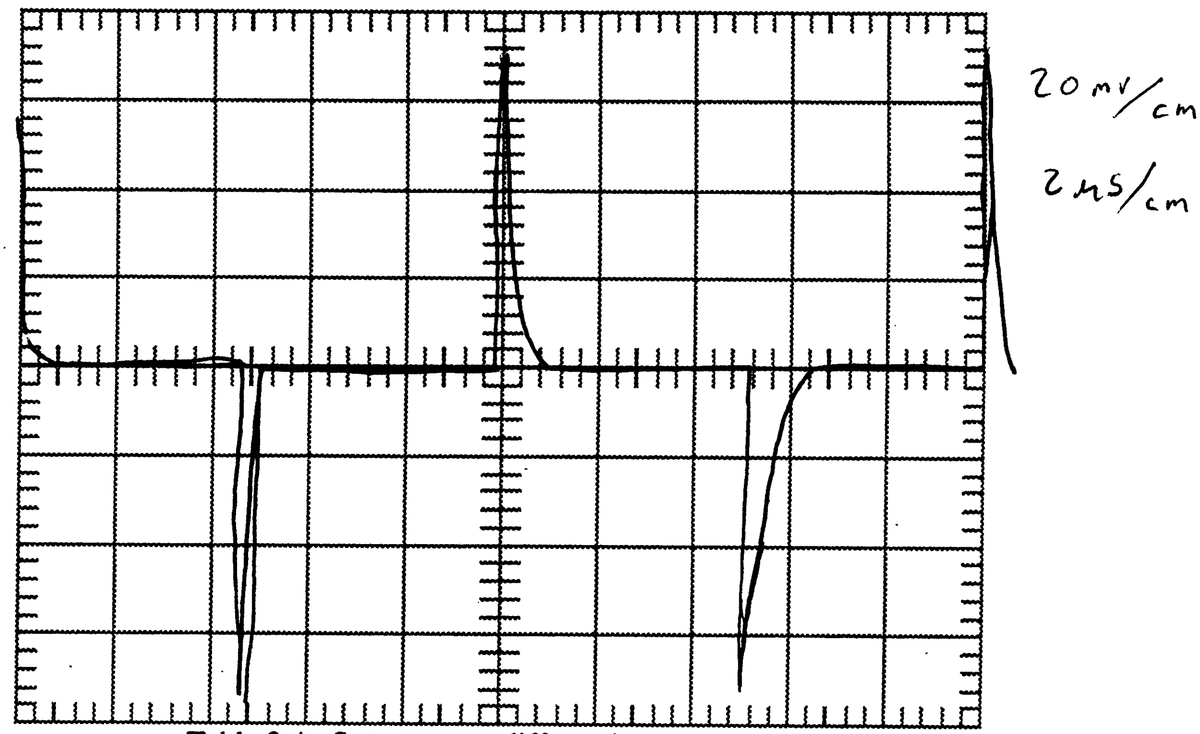

Table 3.4 - Square wave differentiator waveform

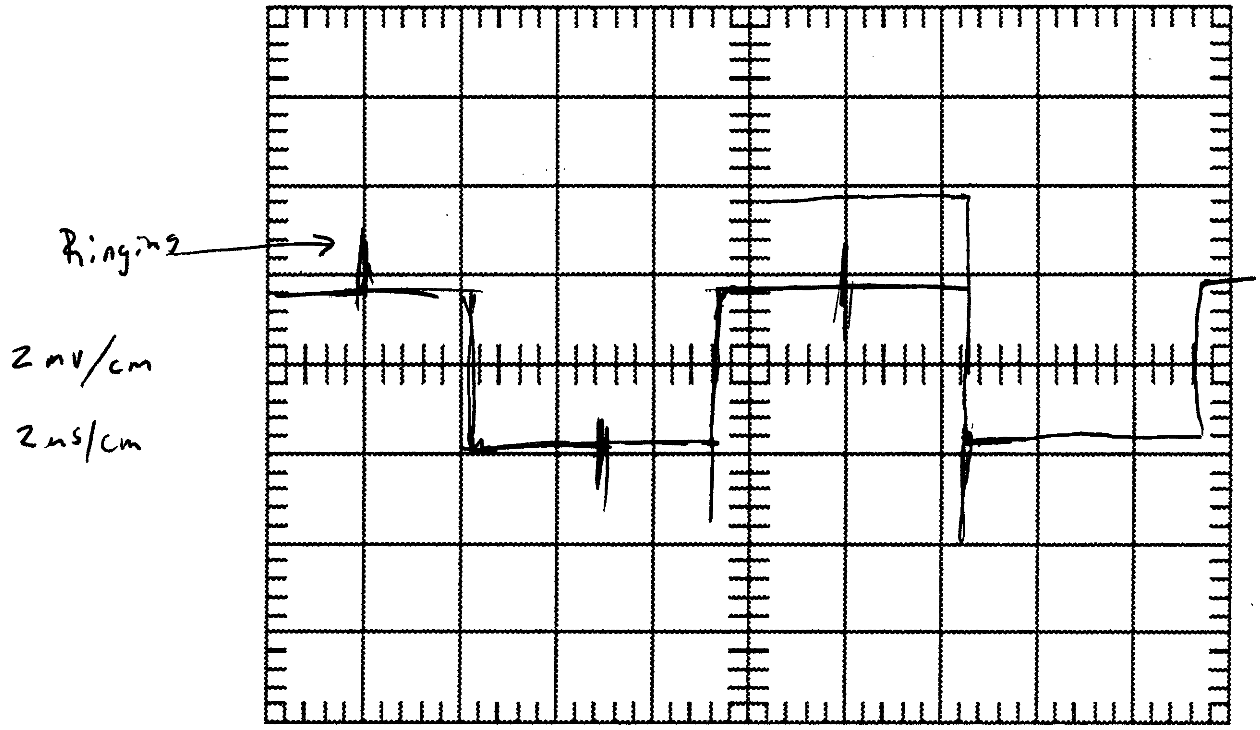

Table 3.5 - Triangle wave differentiator waveform

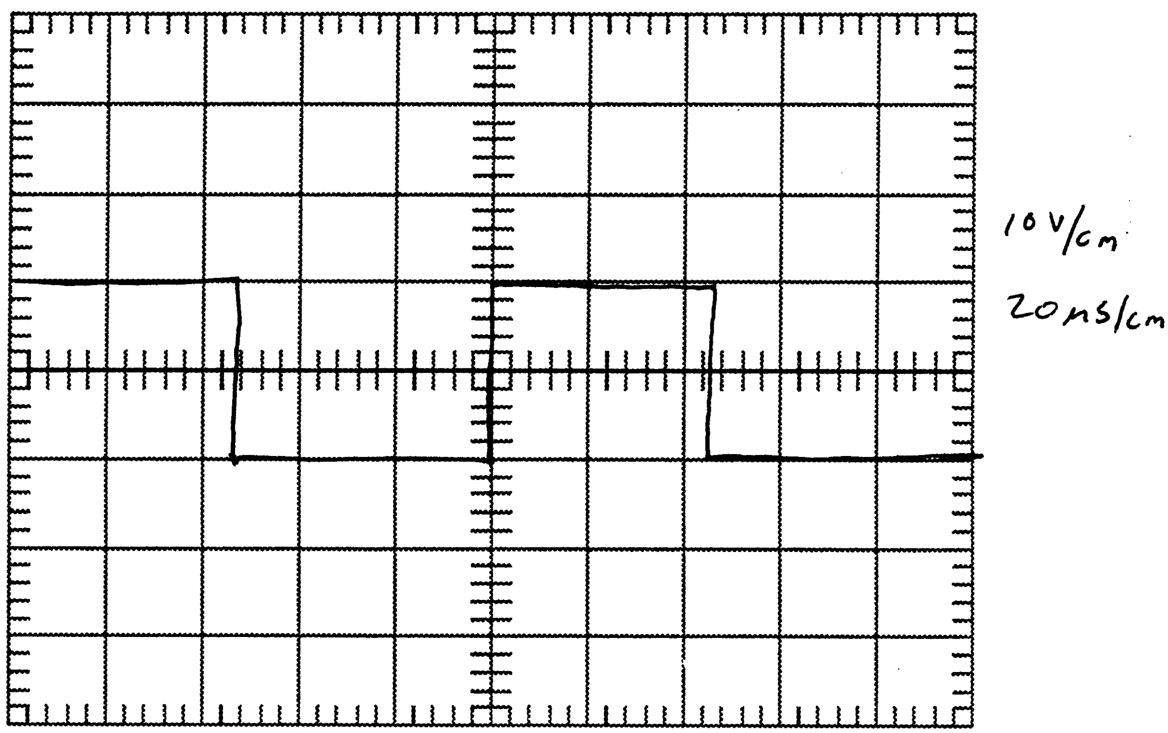

Table 3.6 - Probe measurements

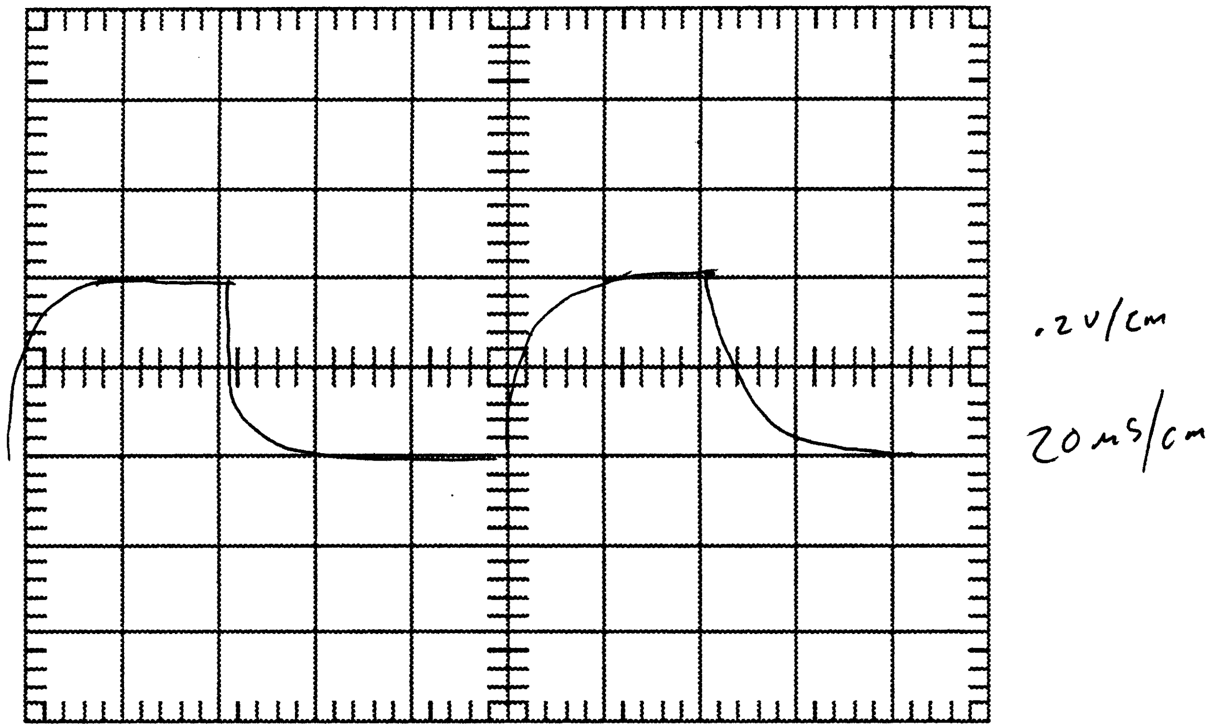

Table 3.7 - Compensated probe measurement