Lab 2-3: Time dependent signals

Due to the unexpected class cancellation last Wednesday, we will need to squeeze together Lab 2 and Lab 3. We will skip the voltage divider measurements that would have been in Lab 2, but keep the introduction to oscilloscope measurements. Then we'll see how much of Lab 3 we can complete in the remaining time.

1 Oscilloscope

(a) Turn on your scope, and initialize it by doing this. You may want to hit the "default settings" button to get started.

(b) Clip the CH1 probe onto the **Probe Comp** terminal at the lower right corner of the scope screen. There are two terminals here. One is the probe comp (the one you want) and the other one is chassis ground. We'll use this signal to get used to the scope controls.

1. use the trigger to get a stable image of the waveform (trace).

2. adjust the CH1 scale to place the trace nicely on the screen.

3. adjust the horizontal scale to display several cycles of square wave.

4. read off the amplitude and period of the waveform; write them down here:

   amplitude =

   period =

   frequency =

5. use the scope's Cursor controls to estimate the *risetime* of the square wave: how long does it take for the signal to plateau?

   risetime =

6. finally, attach a $1\,\mathrm{k}\Omega$ resistor (a "load") between the signal and ground, and deduce the Thévenin source resistance.

   (Drawing a diagram will probably help here. Try to make this problem look like a voltage divider problem.)

   $R_{\mathsf{Th}} =$

(c) Turn on the protoboard, and use the scope to look at the output of the built-in signal generator (top left of protoboard).

Remember: the scope's ground clip must be connected to the circuit ground! In this case, that's the Protoboard's ground.

1. set the signal generator to make **sine waves**, and adjust the sliders (and switches) to generate $1\,\mathrm{kHz}$ output with an amplitude of $10\,\mathrm{V}$ peak-to-peak (i.e., going between $\pm 5\,\mathrm{V}$).

2. go into the scope's TRIGGER menu and see what happens when you reverse the SLOPE.

3. change the generator's waveform to triangle and **square waves**. How square are these waves, really?

4. switch back to sine waves and attach a $1\,\mathrm{k}\Omega$ load to the generator. From the drop in amplitude deduce its Thévenin source resistance:

   $R_{\mathsf{Th}} =$

2 Capacitors in the Time Domain

In physics classes you learn about RC circuits — their exponential charging and discharging, and their *time constant* $\tau = RC$ — which you can model and understand with a first-order differential equation.

Rig up the circuit of Figure 1 on your Protoboard.

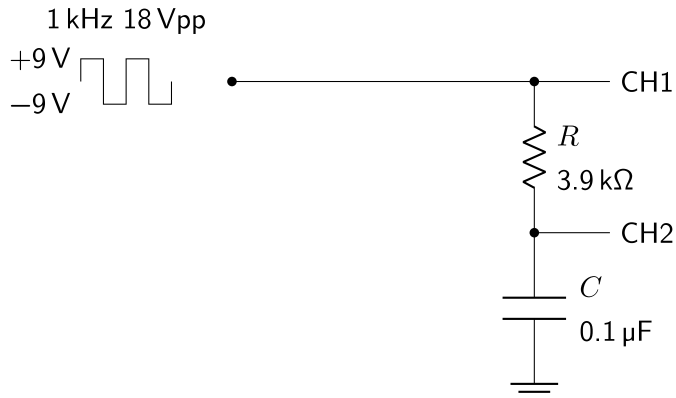

Figure 1: Exploring capacitors in the time domain.

(a) Set the function generator to make a 1 kHz square wave, 18 Vpp (±9 V). To see the function generator signal, connect CH1 across the resistor. Set your oscilloscope to a good view of the signal.

(b) Predict what the voltage across C wil look like. Sketch your prediction below.

(c) Now probe the voltage across C with CH2 of the scope. Describe what you see and compare it to your prediction.

(d) What is the difference in the signals shown in CH1 and CH2? Explain what is happening.

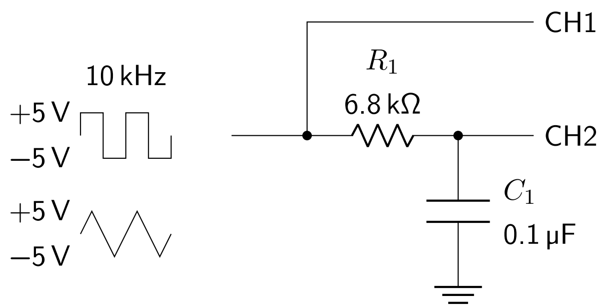

Figure 2: Approximate RC integrator.

3 Integrator

(a) If you were to input a square wave to an **idealized** integrator, what output waveform would you expect? Sketch it here:

(b) Rig up the approximate integrator circuit in Figure 2, and drive it with a 10 kHz square wave of ±5 V amplitude, as indicated.[1]

For this setup set the scope to 2 V/div (CH1) and 200 mV/div (CH2), and set the horizontal scale to 40 µs/div.

Does this agree with your prediction?

(c) Next change the waveform to "ramp", same frequency and amplitude. Set it to 50% symmetry, if it isn't already there, to make a symmetrical triangle wave, and enjoy the display. What is that output waveform? [2]

(d) The simple RC acts as an integrator only when $V_{\text{out}} \ll V_{\text{in}}$. Explain why that is a necessary condition:

[1] If you are getting nasty spikes at the input transitions, it may be better to set the function generator to "pulse," 10 kHz, 50 µs pulse width, and 50 ns risetime and falltime (these slower "edges" help eliminate spurious transients); be sure to arrange the correct high- and low-voltages.

[2] bzzztt — not a sine wave!

4 Differentiator

(a) Now you're going to make an (approximate) **differentiator** circuit. If you were to input a triangle wave to such a circuit, what would you expect the output to look like? Sketch it here:

(b) Now rig up the circuit in Figure 3, and drive it with the same 10 kHz triangle wave.

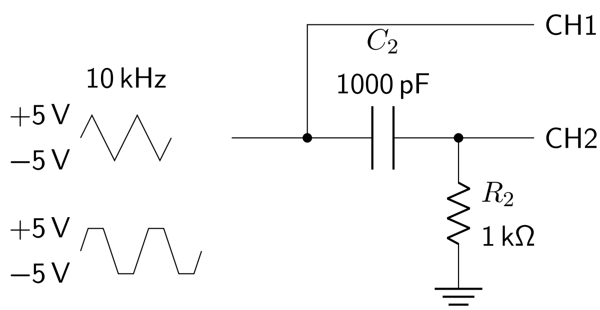

Figure 3: Approximate RC differentiator.

Sketch the result below.

5 Time permitting: Light-Emitting Diode (LED)

Now switch the generator back to **triangle waves**, and increase the amplitude to 20 Vpp (i.e., going between ±10 V).

(a) Use the triangle wave to drive an LED, with a 1 kΩ current-limiting series resistor (Fig. 4A). LEDs are a type of diode. We'll learn more about these later, but for now you can think of them as a one-way door for the electrical current — a device that allows the current to flow only in one direction, and requires a non-zero amount of forward voltage.

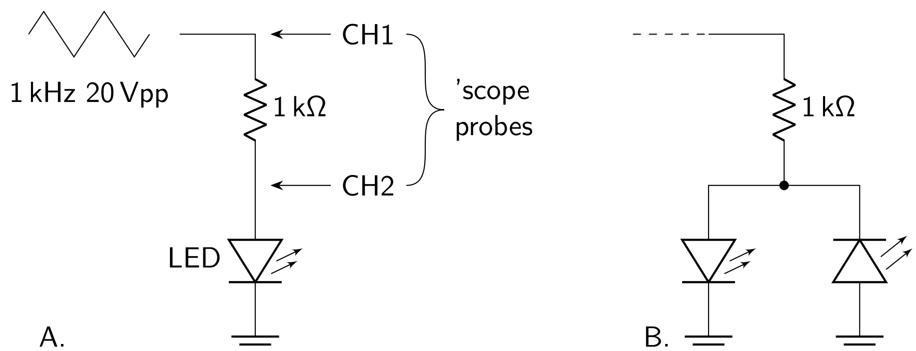

Figure 4: Protoboard's triangle-wave generator drives (A) one LED, or (B) two back-to-back LEDs, through a current-limiting series resistor.

Explain why the resistor is necessary, if the diode is a one-way current switch.

(b) Probe the triangle wave with the scope's CH1, and probe the voltage across the LED with CH2 as shown. (Remember to correctly place the ground clip!)

Sketch the CH1 and CH2 waveforms here, and explain what's going on.

(c) Now add a second LED, reversed in polarity, across the first LED (Fig. 4B).

Sketch the waveforms here, and explain what's going on:

(d) *Time permitting:* Try a different color of LED. What changes? Can you explain why?

(This is more of a physics question than an electronics one!)