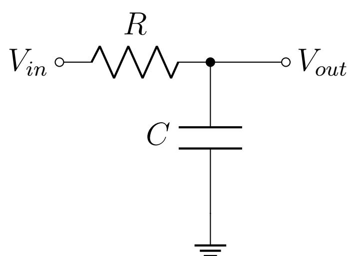
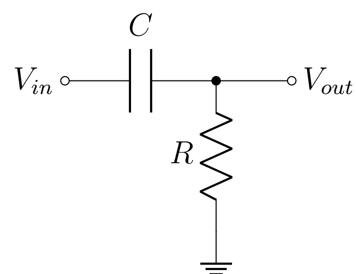
PHY 335, Unit 2 RC circuits

Mini Lecture topics:

- **Capacitors in series and in parallel**
- **Capacitor charging-discharging (transient) behavior**
- **AC circuits with capacitors, phasors, impedance**
- **Theory of low-pass and high-pass filters (amplitude and phase shift as a function of frequency); the "-3 dB" point**
- **RC differentiators and integrators**



(a) A filter.



(b) Another filter.

1. Of the two circuits above: which one is a high pass, and which one is a low pass filter? Qualitatively explain the idea of their operation thinking of an RC filter as a kind of voltage divider with frequency-dependent capacitor reactance. Make sure that you can reproduce a complete RC filter theory; present this complete theory in your report (no derivations).

2. Choose R and C values from available components so that "-3dB" frequency is between 1 and 2 kHz. Build the two filters shown above on your board (have both of them on the board, i.e. don't use the parts for one then for the other).

3. Using the SG and dual-channel scope capability, simultaneously display the output of the SG (V_{in}) and the output of a filter (V_{out}) on the scope. Measure V_{out}/V_{in} in a wide range of frequencies for both filters. Plot your results for V_{out}/V_{in} vs. frequency, f, on a linear f-scale as well as on a logarithmic scale (both axis). Measure the phase shift between V_{in} and V_{out} and plot it vs. f on linear scales and logarithmic scale for the x-axis.

4. Make a detailed comparison between filter theory and the measurements you performed: plot theoretical functions on the same plots with measurements; calculate the frequencies of "-3dB" points; compare to your measurements. Does the measured $f(-3dB)$ correspond to the calculated $f(-3dB)$ to within the uncertainty based on the R and C values?

5. Connect your filter (Fig. 1b) to the output of filter (Fig. 1a), making a combined filter from the low pass and high-pass filters with the same $f(-3dB)$. Measure V_{out}/V_{in} for the combined filter, and plot the results as before. Does the resultant transfer function qualitatively correspond to your expectations? At what frequency does the combined filter transfer function V_{out}/V_{in} reaches its maximum value, and what is that maximum value?

6. Experimentally identify the frequency range in which one of these filters works as a differentiator, and use it to differentiate the sine, triangular and square waves. Sketch what you see on the scope's screen. Do you indeed see the derivatives? Comment on the quality of this differentiator as a function of frequency. In your report, present differentiator theory. Also observe and explain the phase shift between the V_{in} and V_{out}.