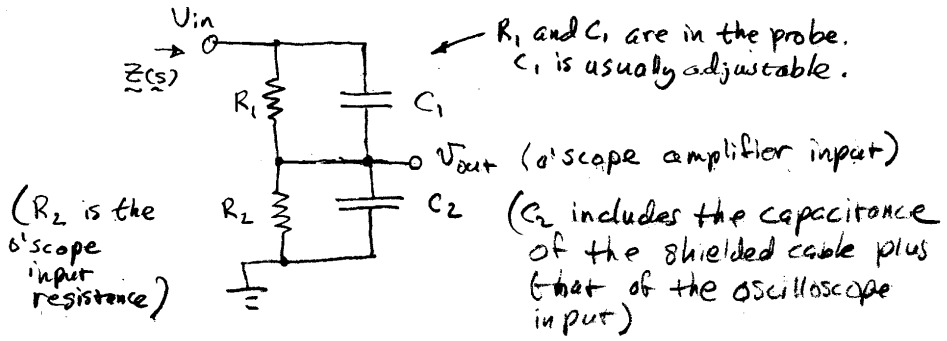
Physics 116B Pulse Problem

1. The input resistance on an oscilloscope can be increased and the parallel capacitance to ground can be reduced through the use of a compensated x10 oscilloscope probe:

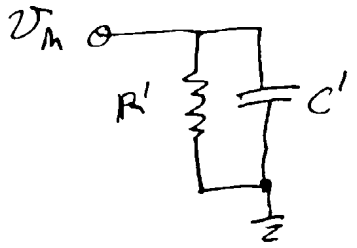


This is a 10:1 resistive voltage divider in parallel with a 10:1 capacitive voltage divider designed so the voltage division is independent of frequency. Suppose $R_2 = 1\ \mathrm{M}\Omega$ and $C_2 = 50\ \mathrm{pF}$. Assume no load current flows through the output terminal (since the oscilloscope input impedance is part of this circuit). We choose $R_1 = 9R_2$ and $C_1 = C_2/9$ (and $R_1C_1 = R_2C_2$).

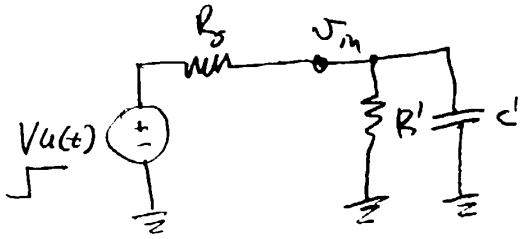
(a) Prove $\mathbf{H}(j\omega) \equiv \mathbf{v}_{\mathrm{out}}/\mathbf{v}_{\mathrm{in}} = 0.1$.

Since $\mathbf{H}$ does not depend on ω, all Fourier components of the input waveform are affected the same. The output should look like the input, just scaled down by a factor of 10. We can prove this explicitly using Laplace transforms since $\mathbf{H}(\mathrm{s}) = 0.1$.

(b) Find $\mathbf{Z}(j\omega)$ looking into the input terminal and show that the circuit is equivalent to the one below with $R' = 10R_2$ and $C' = 0.1C_2$.



(c) Find the rise time of v_{out} if we use the oscilloscope with its x10 probe in the circuit below (the equivalent circuit for the probe is shown). Assume currents and voltages are 0 for $t < 0$ and use $R_s = 300\ \Omega$, $R_2 = 1\ \text{M}\Omega$ and $C_2 = 50\ \text{pF}$.



Hints:

i. The rise time (RT) is defined as the time required for the pulse to go from 10% to 90% of its full pulse height. It was proved in class that $\text{RT} = 0.35/f_c$ for the simple RC low pass filter.

ii. Laplace tells us $\mathbf{v}_{\text{out}}(t) = 0.1\mathbf{v}_{\text{in}}(t)$.

iii. Use Thévenin to combine R' with R_s.