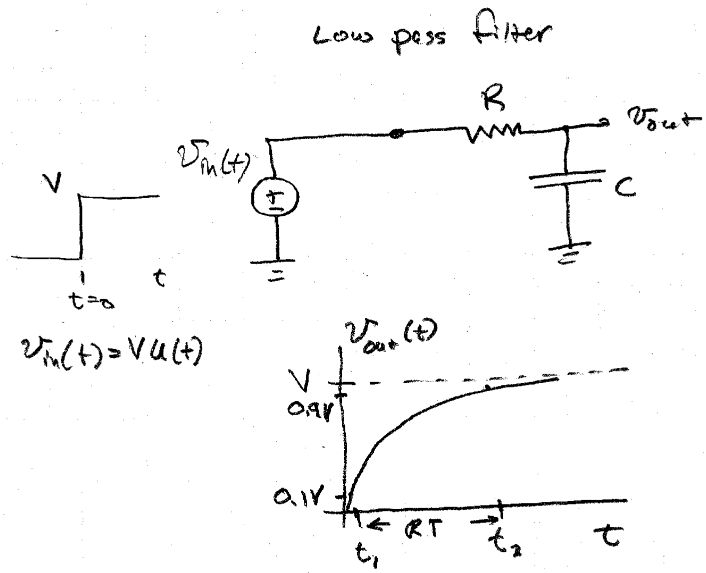
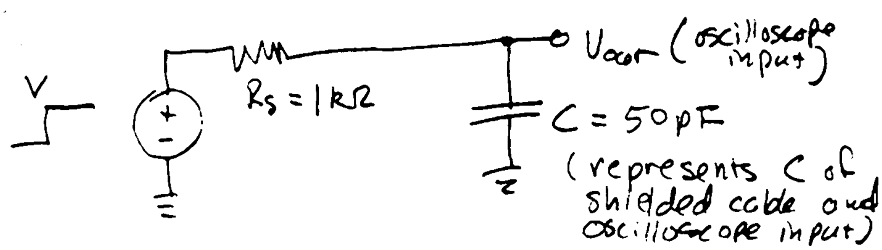
Physics 116B Winter 2005: Pulse Problems

1/13/2005

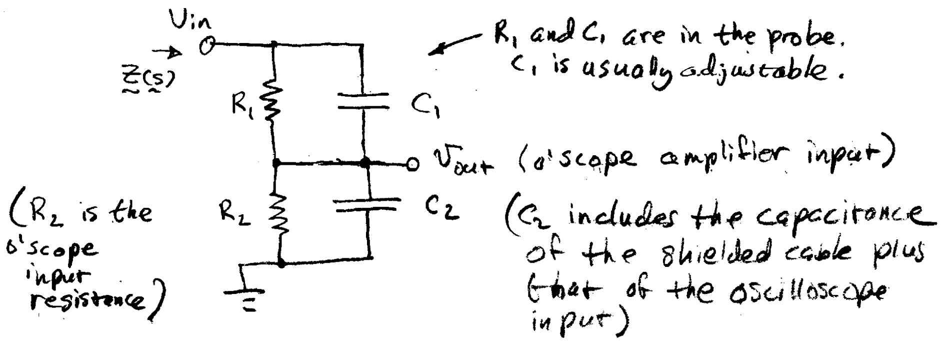


1. A step function pulse of height V is input to an RC low pass filter. The bandwidth of the filter is $\mathrm{BW} = f_c = 1/(2\pi RC)$. The rise time (RT) is the time required for the output pulse to go from 10% to 90% of the full pulse height. Prove RT = 0.35/BW (to two sig. figures).

2. The figure below represents a fast-rising pulse from a voltage source with source resistance of 1000 Ω. The capacitance of the oscilloscope input and shielded cable connecting the pulse source is $C = 50$ pF. Find the rise time of the signal at the oscilloscope input. Hint: use the formula for the rise time in terms of the bandwidth.



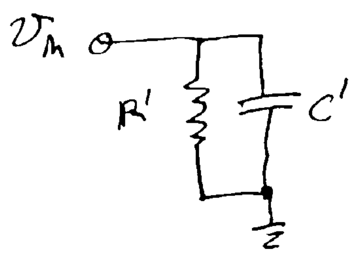
3. This can be improved by using a compensated "10X" oscilloscope probe (10:1 voltage divider). Its circuit is given below:



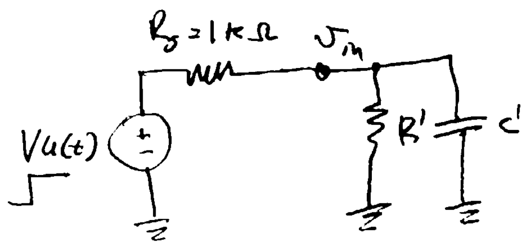
This is a 10:1 resistive voltage divider in parallel with a 10:1 capacitive voltage divider designed so the voltage division is independent of frequency. Suppose $R_2 = 1\ \mathrm{M}\Omega$ and $C_2 = 50\ \mathrm{pF}$. Assume no load current flows through the output terminal (since the oscilloscope input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

(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 $\mathbf{H}(\mathbf{s}) = 0.1$.

(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 probe with the voltage source and source resistance of Prob. 2. Assume currents and voltages are 0 for $t < 0$ and use $R_2 = 1\ \mathrm{M}\Omega$ and $C_2 = 50\ \mathrm{pF}$. The equivalent circuit is given below.



Hints:

i. Laplace tells us $\mathbf{v}_{\mathrm{out}}(t) = 0.1\mathbf{v}_{\mathrm{in}}(t)$.
ii. Use Thévenin to combine R' with R_s.

4. Trailing edge detector.

A 4V, 10 μs pulse enters the circuit below at $t = 0$. The Schmitt trigger inverters have a negative-going threshold of 0.9V and a positive-going threshold of 1.7V. The Schmitt trigger output is 3.3V in the high state and 0.2V in the low state. For $t < 0$, $V_{in} = 0$, $V_a = 3.3V$ and $V_b = 0V$. Neglect the propagation delay through the inverters. The diode is ideal: the forward voltage drop = 0V and the forward resistance is 0 Ω.

(a) Make a timing diagram showing the input pulse at V_{in}, V_a, V_b and V_{out}. (4 waveforms) (see Fig. 10.46(b) for an example of a timing diagram).

(b) Calculate the width of the output pulse.