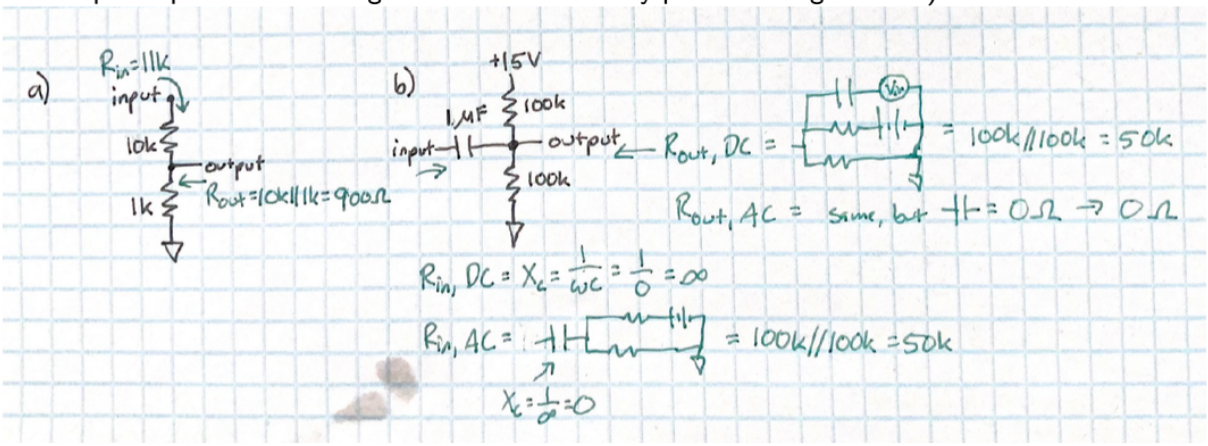
Determine input and output impedance (aka load and source resistance) of circuit blocks.

Input and output impedance

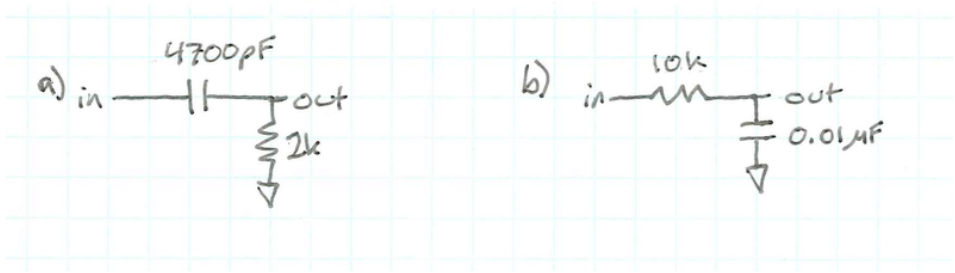
What are the input and output impedances of the two circuits shown below at a) DC and b) infinite frequency? (Calculate input impedance assuming the circuit is not attached to a load, and output impedance assuming the circuit is driven by perfect voltage source.)



Recognize a low pass filter and a high pass filter, and be able to calculate the corner frequencies (aka cutoff or 3dB frequencies).

RC Filters

Which of the following circuits is a high pass filter? Low pass? What are the corner frequencies of each? Which filter will attenuate 100 Hz signals? Which will attenuate 100 kHz signals?



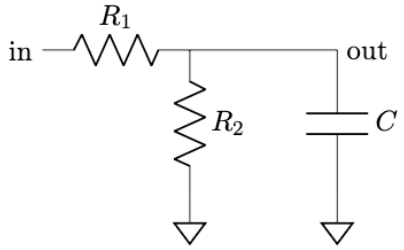
a) High pass, attenuates low frequencies like 100 Hz. Corner frequency: $f_c = 1/2\pi RC$=17 kHz.

b) Low pass, attenuates high frequencies like 100 kHz. Corner frequency = 1.6 kHz.

. Qualitatively interpret the transfer function of a circuit composed of resistors and capacitors in the limits of high and low frequency. Identify any points (corner frequencies) where the transfer function qualitatively changes.

Transfer Functions

What is the gain $G = \frac{V_{out}}{V_{in}}$ of the following circuit, in terms of Z_R and Z_C (keep it qualitative, using $A \parallel B$ to mark parallel combinations)? What are the zero- and infinite-frequency limits for the gain? Bonus (this requires complex algebra): what is the cutoff frequency?



Thinking of the circuit as a voltage divider, with the lower leg being the parallel combination of R_2 and C, and the upper leg being R_1:

$$G = \frac{Z_2}{Z_1 + Z_2} = \frac{R_2 \parallel Z_C}{R_1 + R_2 \parallel Z_C}.$$

This is enough to give us qualitative limits, without writing down any complex math. At zero frequency, $R_2 \parallel Z_C = R_2$, so we have a voltage divider with gain of $\frac{R_2}{R_1+R_2}$. At infinite frequency, the parallel combination goes to zero as the impedance of the capacitor goes to zero, and the gain is zero.

For the bonus, the corner frequency is the point where the behavior qualitatively changes between a voltage divider and a filter. To find it, we write the full complex voltage divider equation:

$$G(\omega) = \frac{\left(R_2 \parallel \frac{1}{j\omega C}\right)}{R_1 + \left(R_2 \parallel \frac{1}{j\omega C}\right)} = \frac{\frac{R_2}{1+j\omega R_2 C}}{R_1 + \frac{R_2}{1+j\omega R_2 C}} = \frac{R_2}{R_1 + R_2 + j\omega R_1 R_2 C}$$

The crossover frequency occurs when the denominator crosses over from being dominated by the real part to the imaginary part. This occurs when the real and imaginary parts are equal in magnitude:

$$R_1 + R_2 = \omega R_1 R_2 C$$

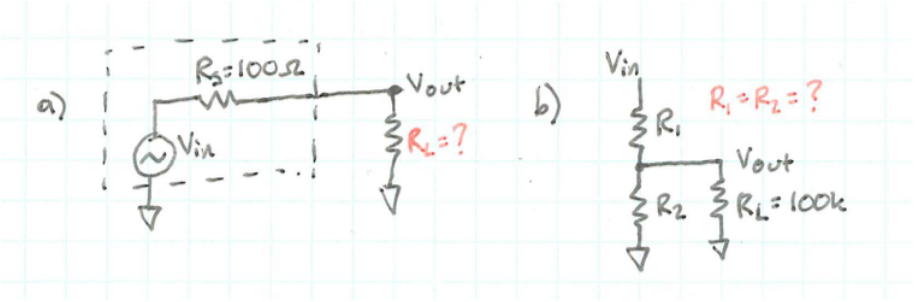
. Solving for the frequency, we find:

$$f_c = \frac{\omega_c}{2\pi} = \frac{R_1 + R_2}{2\pi R_1 R_2 C} = \frac{1}{2\pi(R_1 \parallel R_2)C}.$$

How to choose input and output impedances to cascade circuits.

Cascading

What resistor values would you choose for the two situations shown below, to prevent the input voltage from dropping by more than 10% when loaded?



a) We want R_L to be at least 10 times larger than R_s, so it should be no less than 1k.
b) We want R_s to be at least 10 times less than R_L, so it should be no more than 10k. The output impedance is the parallel resistance of R_1 and R_2, so these should be no more than 20k each.