Active Filters Worksheet - Circuits fall 2022

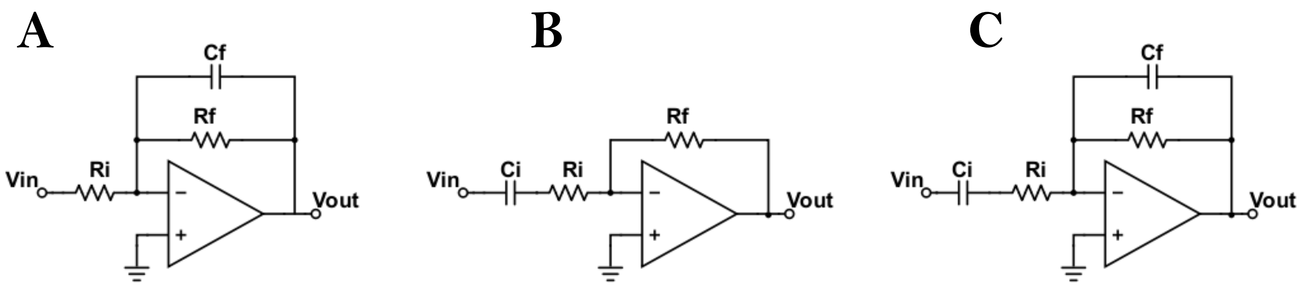

Figure 1. Three active filters built around inverting amplifier configuration.

Write the impedance of a capacitor Z_c. What element does the cap act like in limiting frequency cases?

For each filter, A, B, and C:

1. Draw the circuit replacing the capacitor with limiting case behavior ($\omega = 0; \quad \omega \rightarrow \infty$)
2. What type of filter is it?
3. Derive the transfer function $\boldsymbol{H}(\omega)$. Hint: You can check your answers on the Circuits Summary [.pdf] under the 'Active Filters' sections posted to the course webpage:
4. Compute the cutoff frequency(-ies) for each filter given that: R_f = 220 kΩ; R_i = 2.2 kΩ; C_i = 2.2 μF; C_f = 1.4 nF
5. ***Sketch*** the magnitude response (decibel gain $G = 20\ log10\ Vout/Vin$) response for each filter vs $log10\ f$ (Hz).

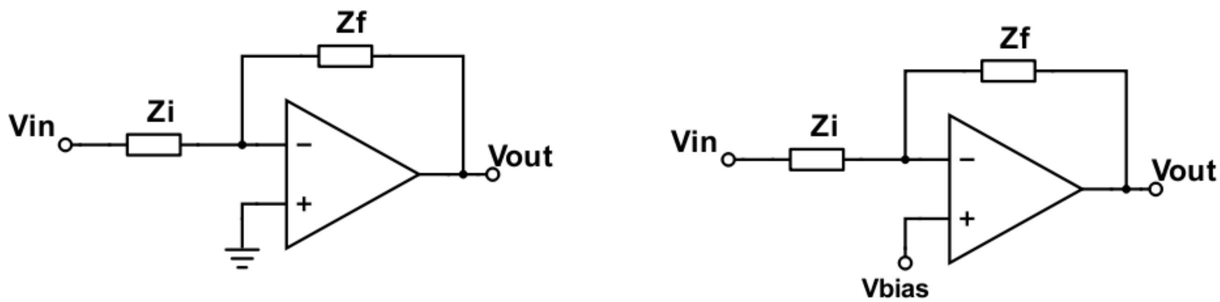

Figure 2. Inverting amplifier configuration without (left) and with offset bias (right). The bias potentional is often set to half the power rail. For example, powering with +5V and GND with Arduino, Vbias would be set to 2.5V

The schematic in Figure 2 left should look familiar. It's an op-amp configured as an inverting amplifier. Note that v+ = ground = 0V. On the right side of Figure 2, the configuration is nearly the same, but with one crucial difference: the non-inverting input is now connected to a "bias" or "reference offset". We often use this bias offset when designing with single supply power systems. For example, powering a system with Arduino's +5V and GND means we have a 5V working range from 0 to 5V. It is often convenient to have output of the op-amp centered at 2.5V when the input signal is 0V. This allows positive and negative fluctuations of the input signal to be measured (think: temperature could go up or down; a bridge go oscillate up or down; same with music; or biomedical signals; etc.) The biased configuration allows us to do this.

1. Using the Golden Rules + KCL, KVL, and Ohm's Law, show that the biased inverting amplifier input – output relationship is the following:

$$\tilde{V}_{out} = -\frac{\tilde{Z}_f}{\tilde{Z}_i}\tilde{V}_{in} + \left(1 + \frac{\tilde{Z}_f}{\tilde{Z}_i}\right)V_{bias}$$

2. What is the angular frequency ω of a constant (d.c.) voltage?
3. Show that the output voltage is a constant V_{bias}, provided that $\frac{Z_f}{Z_i} = 0$ at ω = 0.
4. What filters (LPF, HPF, BPF) meet the condition specified in 3 above? Which one(s) don't?
5. In practice, how would you produce a 2.5V bias given access to +5V and GND on the Arduino? Draw a schematic for an active bandpass filter with 2.5V bias implemented.