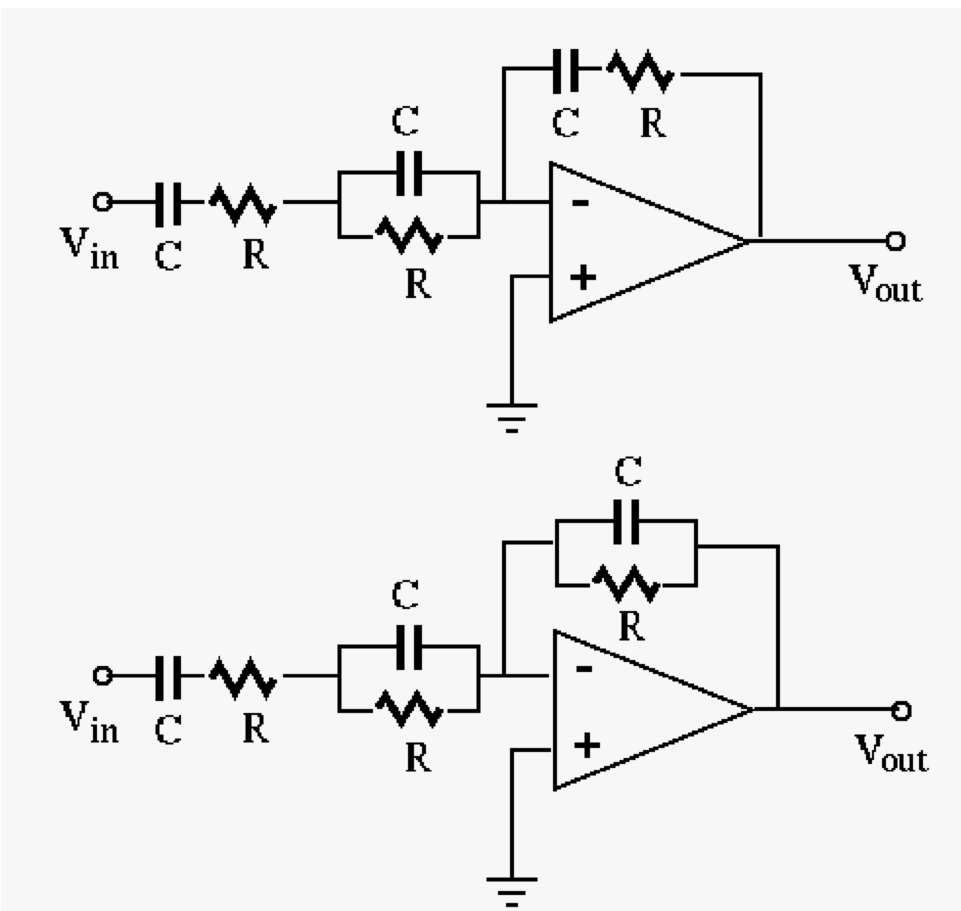
Do not click until you are ready to take the final

1. **Problem 1. (40 points)**

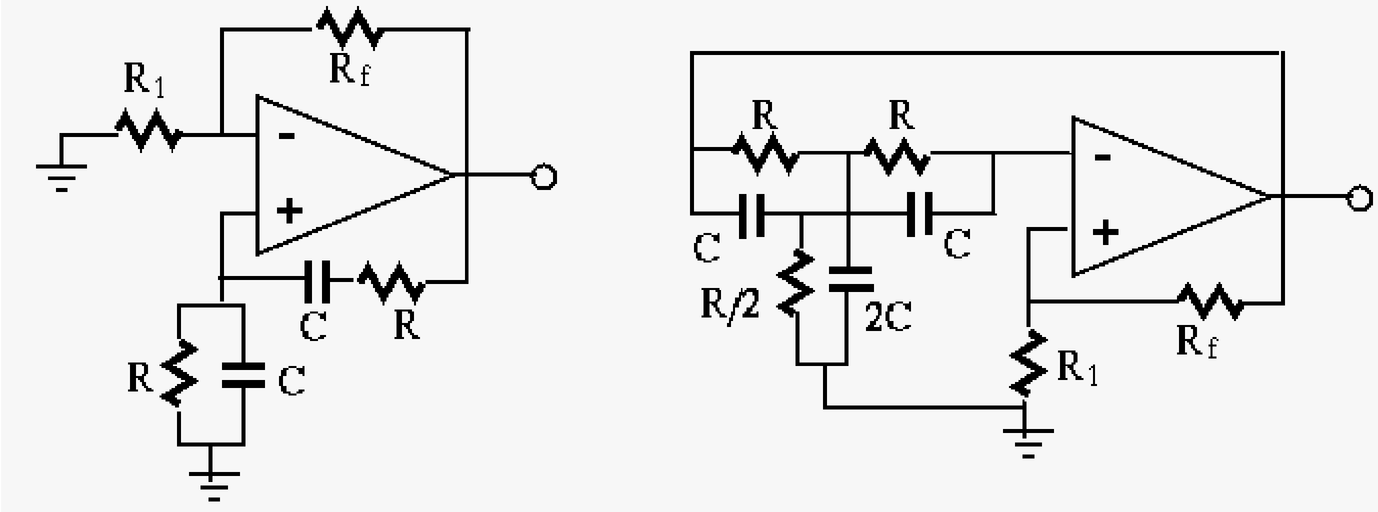
   In the two op-amp circuits shown below, all resistors have the same value R and all capacitors have the same value C. For each of the two circuits (20 points each), do the following:

   - (5 points) Derive the frequency response function $H(j\omega)=V_{out}(j\omega)/V_{in}(j\omega)$.
   - (5 points) Find $\vert H(j\omega)\vert$ at $\omega=0$ and $\omega=\infty$.
   - (5 points) Find the frequency ω_0 at which $\vert H(j\omega_0)\vert$ is either maximized or minimized, and give the value of this extremum.
   - (5 points) Determine if the filter is a low-pass, high-pass, band-pass, or band-stop filter.

2. **Problem 2. (10 points)**

   Analyze qualitatively the two op-amp circuits in the figure to find what each of them may be used for. (5 points each.)

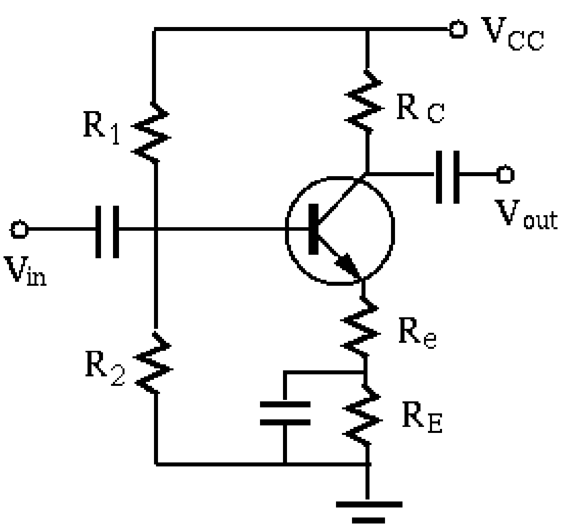


Hints:

- A signal path from the output to the inverting input is a negative feedback, to the nono-inverting input is a positive feedback.
- As the feedback through an RC network is frequency-dependent, and can therefore considered as a filter.

3. **Problem 3. (50 points)**

In the circuit shown below $R_1 = 70k\Omega$, $R_2 = 30k\Omega$, $R_e = 0.2k\Omega$, $R_E = 1.8k\Omega$, $\beta = 150$, and $V_{CC} = 12V$. As always, we assume $V_{be} = 0.7V$.



1. (15 points) Find R_C so that the DC operating point in terms of I_C and V_{CE} is in the middle of the linear region of the output characteristic plot (I_C vs. V_{CE}). Find I_B, I_E, V_E, V_B and V_C.

2. (15 points) Find the AC small signal equivalent circuit, assuming the frequency ω of the AC signal and the capacitances C in the circuit are both high enough so that $Z_C = 1/j\omega C$ is approximately zero when compared with other resistances in the circuit, i.e., all capacitors can be treated as AC short

circuit. Alos, for simplicity, assume the voltage source has zero internal resistance $R_S = 0$ and no load $R_L = \infty$.

3. (15 points) Based on the AC small signal equivalent circuit found above, give the expressions of the following in terms of system parameters β and r_{be} as well as all the resistors in the circuit:
   - AC voltage gain $G_V = v_{out}/v_{in}$;
   - input resistance $r_{in} = v_{in}/i_{in}$;
   - output resistance $r_{out} = v_{oc}/i_{sc}$.
4. (5 points) Find the numerical values of G_V, r_{in}, and r_{out}. Assume $r_{be} = 1k\Omega$.

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Ruye Wang 2018-12-17