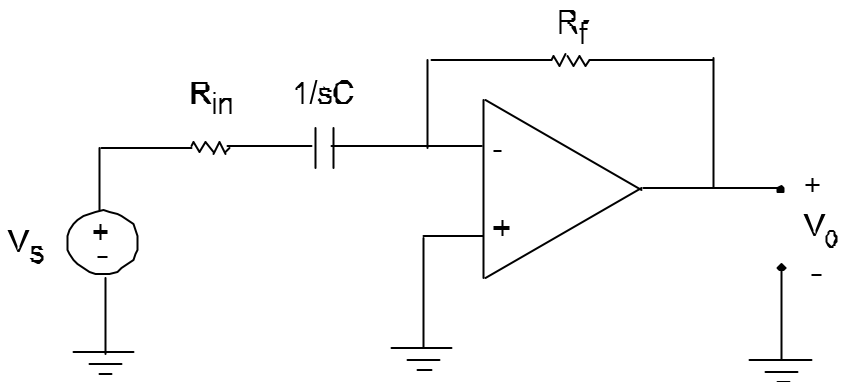
Frequency Response

High Pass

This filter has a break frequency (in rad/s), $\omega_b = 1/R_{in}C$ and a high frequency (HF) gain of $-R_f/R_{in}$.



$$\frac{V_0}{V_s} = -\frac{Z_f}{Z_{in}} = -\frac{R_f}{(sR_{in}C + 1)/sC} = -\frac{sR_fC}{sR_{in}C + 1}$$

Example

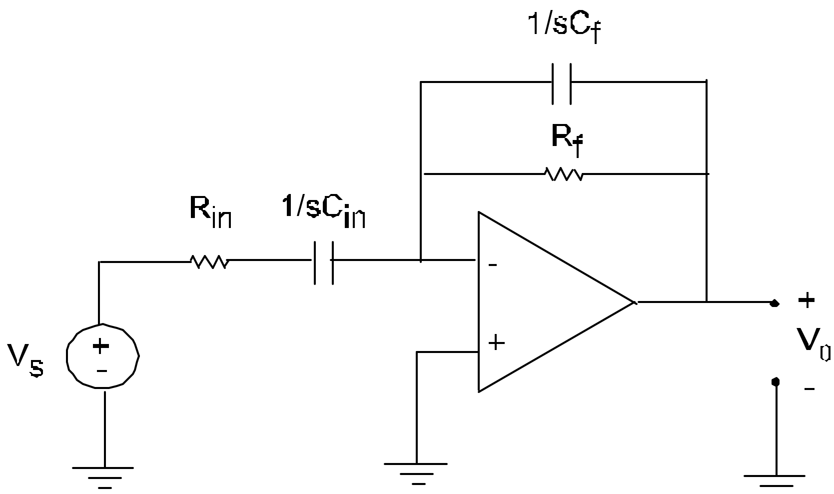
A 2V amplitude sinusoidal signal at 20 kHz is corrupted by a 4V noise signal at 120 Hz. Design a HP filter with a HP gain of 3 that significantly attenuates the noise signal.

HP example (cont.)

Band Pass

Bandpass filters are useful when we wish to pass a band of frequencies while, at the same time, we wish to attenuate lower and higher frequencies.

Active bandpass filters, like the one shown below, can not only filter unwanted frequencies, but can amplify signals in a band of frequencies (frequencies in the “pass band.”)



General analysis

$$\frac{V_0}{V_s} = -\frac{Z_f}{Z_{in}} = -\frac{R_f \big/ (sR_fC_f + 1)}{(sR_{in}C_{in} + 1) \big/ sC_{in}} = -\frac{sR_fC_{in}}{s^2R_fR_{in}C_fC_{in} + s(R_fC_f + R_{in}C_{in}) + 1}$$

$$\frac{V_0}{V_s} = -\frac{sR_fC_{in} \big/ R_fR_{in}C_fC_{in}}{s^2 + s\left(\frac{R_fC_f + R_{in}C_{in}}{R_fR_{in}C_fC_{in}}\right) + \frac{1}{R_fR_{in}C_fC_{in}}}$$

where $\frac{1}{R_fR_{in}C_fC_{in}} = w_n^2$ and $\frac{R_fC_f + R_{in}C_{in}}{R_fR_{in}C_fC_{in}} = w_{hp}$, the half-power bandwidth

at $s = jw = jw_n$, $\frac{V_0}{V_s} = -\frac{jw_nR_fC_{in} \big/ R_fR_{in}C_fC_{in}}{jw_n\left(\frac{R_fC_f + R_{in}C_{in}}{R_fR_{in}C_fC_{in}}\right)} = -\frac{R_fC_{in}}{R_fC_f + R_{in}C_{in}}$

$R_{in}C_{in} >> R_fC_f$

When $R_{in}C_{in} >> R_fC_f$, we obtain significant simplifications.

1st, the lower corner frequency, ω_L, can be approximated entirely in terms of R_{in} and C_{in}.

$$w_L \cong \frac{1}{R_{in}C_{in}}$$

2nd, the upper corner frequency, ω_u, can be approximated entirely in terms of R_f and C_f.

$$w_u \cong \frac{1}{R_fC_f}$$

3rd, the resonant frequency, ω_n, is geometric mean of ω_L and ω_u.

$$w_n = \sqrt{w_L w_u} = \sqrt{\frac{1}{R_{in}C_{in}R_fC_f}}$$

Finally, the gain at resonance is $-R_f/R_{in}$.

$$\frac{V_0}{V_s} = -\frac{R_fC_{in}}{R_fC_f + R_{in}C_{in}} = -\frac{R_fC_{in}}{R_{in}C_{in}} = -\frac{R_f}{R_{in}}$$

Example

A signal, 2V peak-to-peak, at 2.4 kHz is corrupted by 10V peak-to-peak LF noise at 60 Hz and by 5V peak-to-peak HF noise at 20 kHz.

Design a BP filter with a passband gain of 10 that significantly attenuates the LF and HF noise.

BP example (cont.)