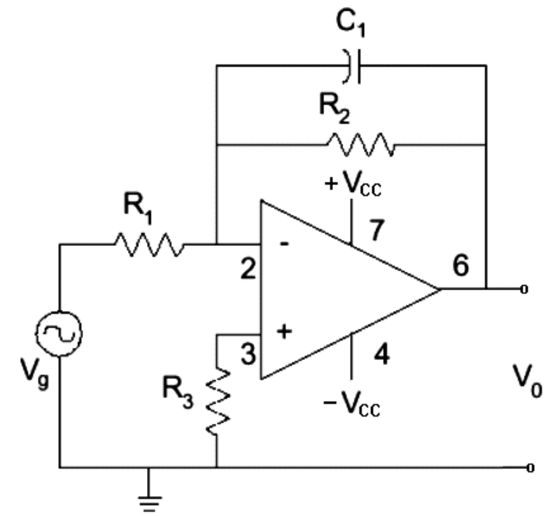
ECE 3254 PreLab 10 notes
Edited 10-26-2009

Op Amp Active Filters

Op Amp active filters are widely used to limit the bandwidth of signals. Active high pass and low pass elements may easily be combined to form band pass and band stop (notch) filters.

Inverting Low Pass Filter



The Op Amp ideal characteristics mean that
$I_{R3} = 0$, $V_{pin\ 2} = V_{pin\ 3} = 0$, so $V_{pin\ 2} = 0$.

From Lab 7, $Vo = -Vg\ (Z_2/R_1)$ where Z_2 is the complex parallel equivalent of R_2 and C_1. Remember that $Z_C = 1/j\omega C$

$Z_2 = 1/(1/R_2 + 1/Z_{C1}) = R_2 / (1 + j\omega R_2C_1)$
Vo / Vg = *you derive from the information above*

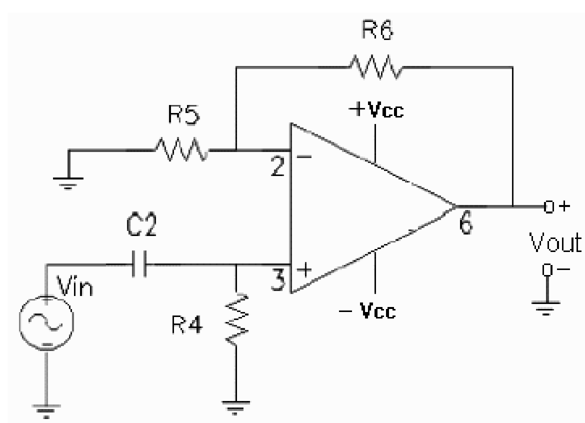
Note: This circuit is identical to the integrator from lab 9. When operated well above the cutoff frequency, this low pass filter becomes an integrator.

What happens at $\omega = 0$ (passband response)? The capacitor is an open circuit, $j\omega R_2C_1 = 0$, and $Vmax = Vo_{\text{in the passband}}/Vg = -R_2 / R_1$ as in Lab 7. Output phase is 180º due to the inverting Amplifier configuration.

Above the cutoff frequency, the denominator is dominated by the capacitor and the output phase will be adjusted by +90º to an ultimate phase of 90º

How do you find the cutoff freq? You are solving for the frequency where $|V_O| = .707\ |Vmax|$. *This is NOT where* $|V_O| = 0.707$. The correct result should be an equation where the Vo/Vg denominator real part equals the Vo/Vg denominator imaginary part, and you solve for ω as you did in Lab 3.

Non-Inverting High Pass Filter



The Op Amp ideal characteristics mean that
$I_{pin\ 3} = 0$ and $V_{pin\ 2} = V_{pin\ 3}$

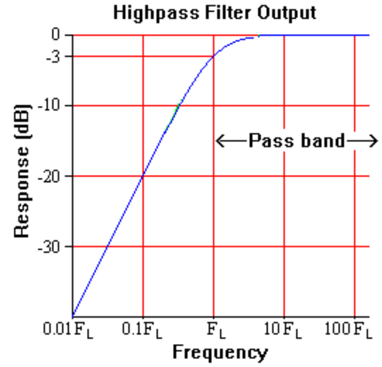
By voltage division: $V_{pin\ 3} = Vin\ R_4 / (R_4 + Z_{C2})$
$= Vin\ R_4 / (R_4 + 1/j\omega C_2)$

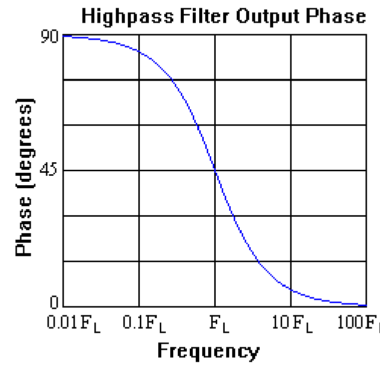
From Lab 7, $Vo = V_{pin\ 3}\ (1 + R_6/R_5)$
So $Vo = Vin\ (1 + R_6/ R_5)\ [R_4 / (R_4 + 1/j\omega C_2)]$

What happens when $\omega = \infty$ (passband response)?
The capacitor short circuits and $Vo/Vin = 1 + R_6 / R_5$

Active High pass Filter

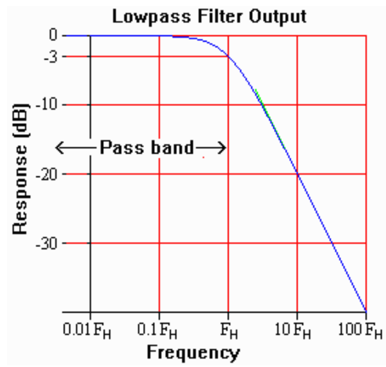
The passband extends from the cutoff frequency (F_L) to ∞. At very low frequencies the capacitor creates a +90º phase shift in the output signal. At the cutoff frequency the phase angle is 45º (where real = imaginary). At very high frequencies the capacitor produces no phase shift because it acts as a short circuit.

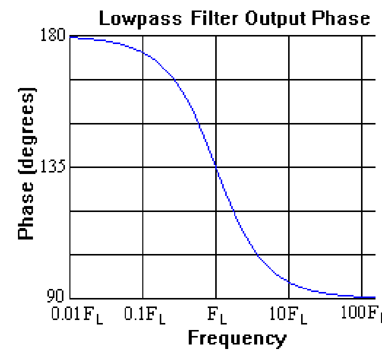




Active Low pass Filter

The passband extends from DC (F = 0) to the cutoff frequency (F_H). At very low frequencies the capacitor is an open circuit and does not affect the phase of the transfer function and the inverting amplifier configuration produces a 180º phase shift in the output. The phase angle is shifted by -45º (where real = imaginary) at the cutoff frequency, resulting in an output phase of 135º.

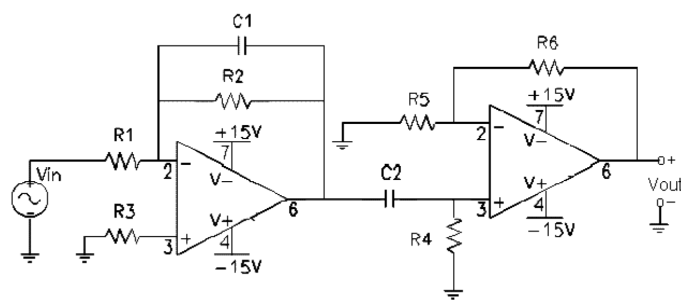


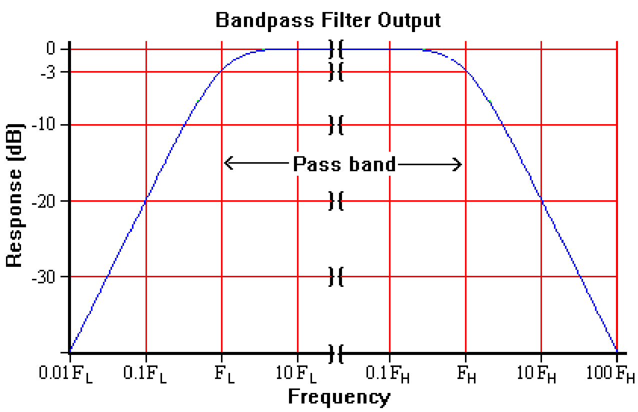


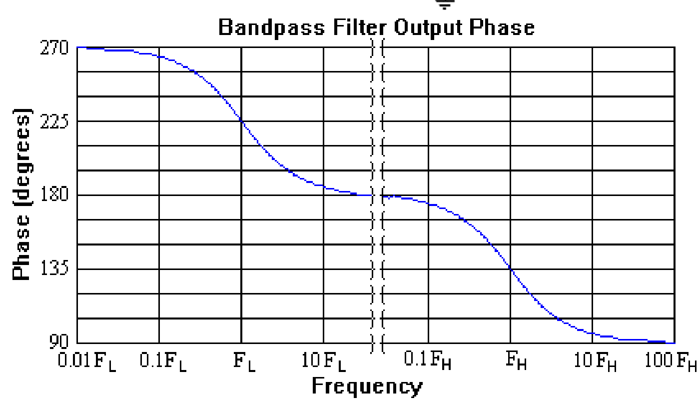
At very high frequencies the capacitor adds -90º to the phase, shifting the output from 180º to 90º.

Band pass Filter

The high pass filter and the low pass filter can be cascaded by connecting them in series to create a band pass response.







The pass band extends from F_L to F_H, and the dB response and phase angles of the two filters add together. At very low frequencies the output phase is 180+90=270º (Note: 270º can also be measured as -90º). The output phase passes through 225º (or -135º) at F_L, then through 180º (or -180º) in the center of the passband, then through 135º (or -225º) at F_H, and then to 90º (or -270º) at very high frequencies.

Pspice simulation: Modify the Schematics from Lab 9 to build one filter. Add a second OpAmp to complete the Bandpass filter. Review the Prelab 4 notes for tips on setting up the AC Sweep simulation.