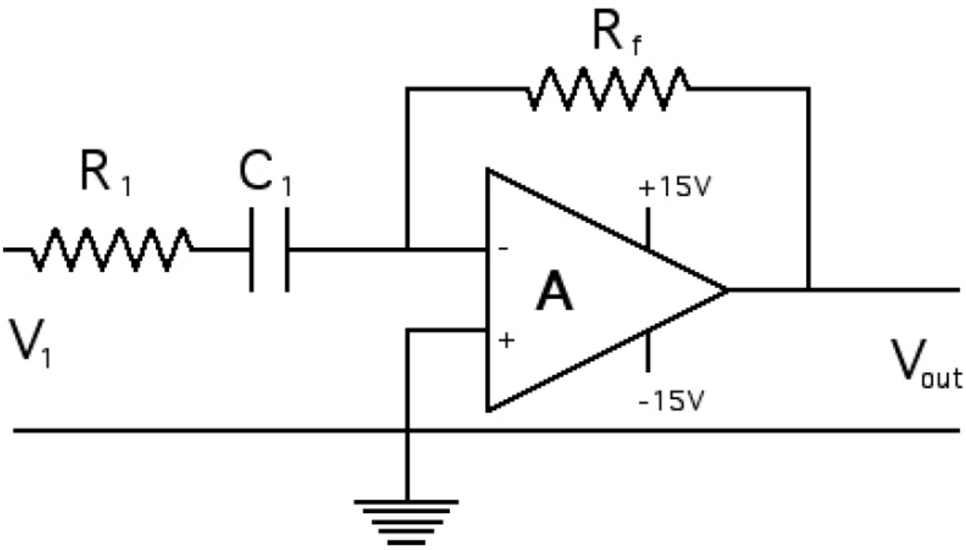
Highpass Filter

A low frequency cutoff point, f_L, for a simple RC series circuit is given by the equation:

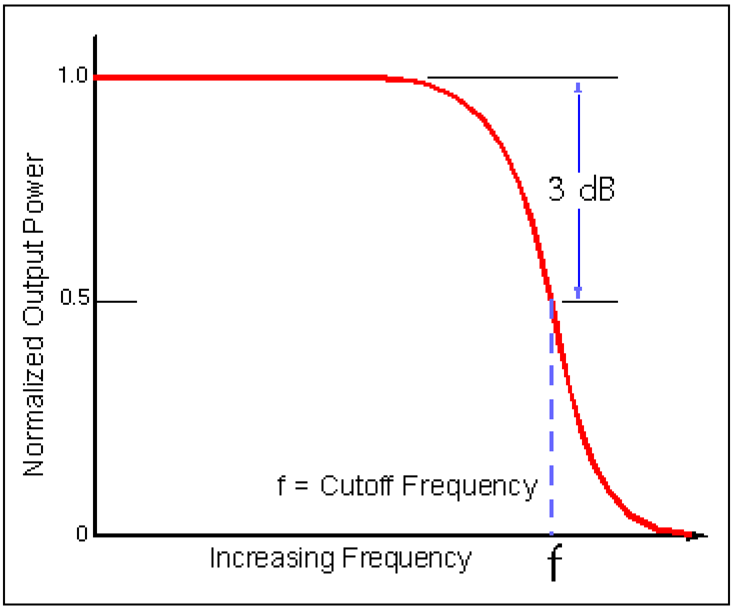
$$2\pi f_L = 1/RC$$

where f_L is measured in hertz. The low-frequency cutoff point is the frequency where the gain (dB) has fallen by -3 dB. This (-3 dB) point occurs when the impedance of the capacitor equals that of the resistor.



The highpass op amp filter equation has a low-frequency cutoff point, f_L, where the gain has fallen to -3 dB. In other words, when $\mathbf{X_c = R}$:

$$2\pi f_L = 1/ R_1C_1$$

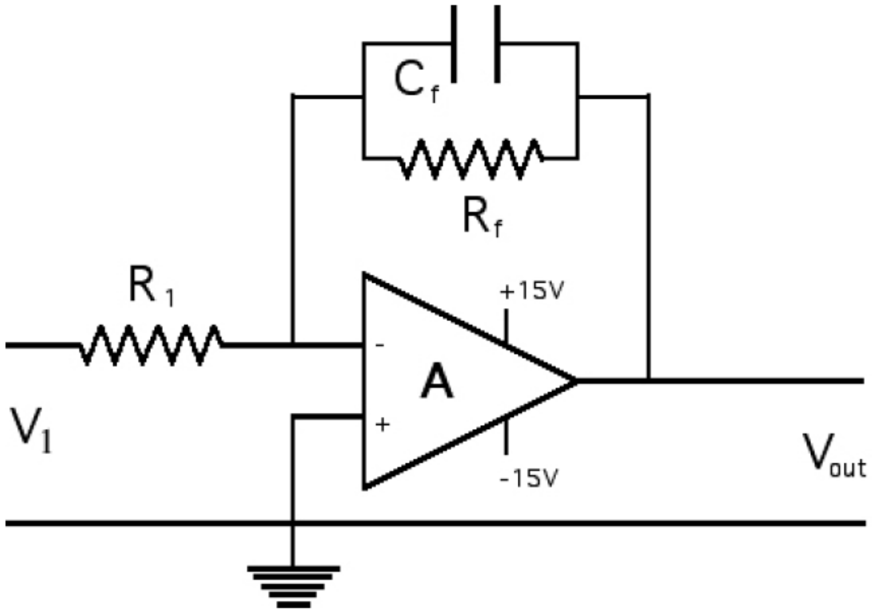


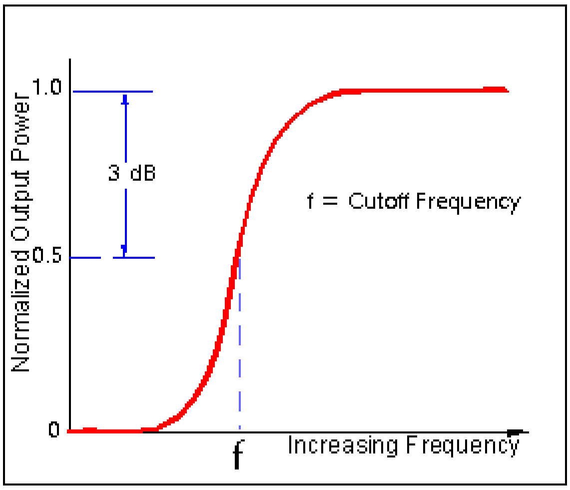
low pass filter

Lowpass Filter

The high-frequency roll-off in the op amp circuit is due to the internal capacitance of the 741 chip being in parallel with the feedback resistor, R_f. If you add an external capacitor, C_f, in parallel with the feedback resistor, R_f, you can reduce the upper frequency cutoff point. It turns out that you can predict this new cutoff point from the following equation:

$$2\pi f_U = 1/R_f C_f$$

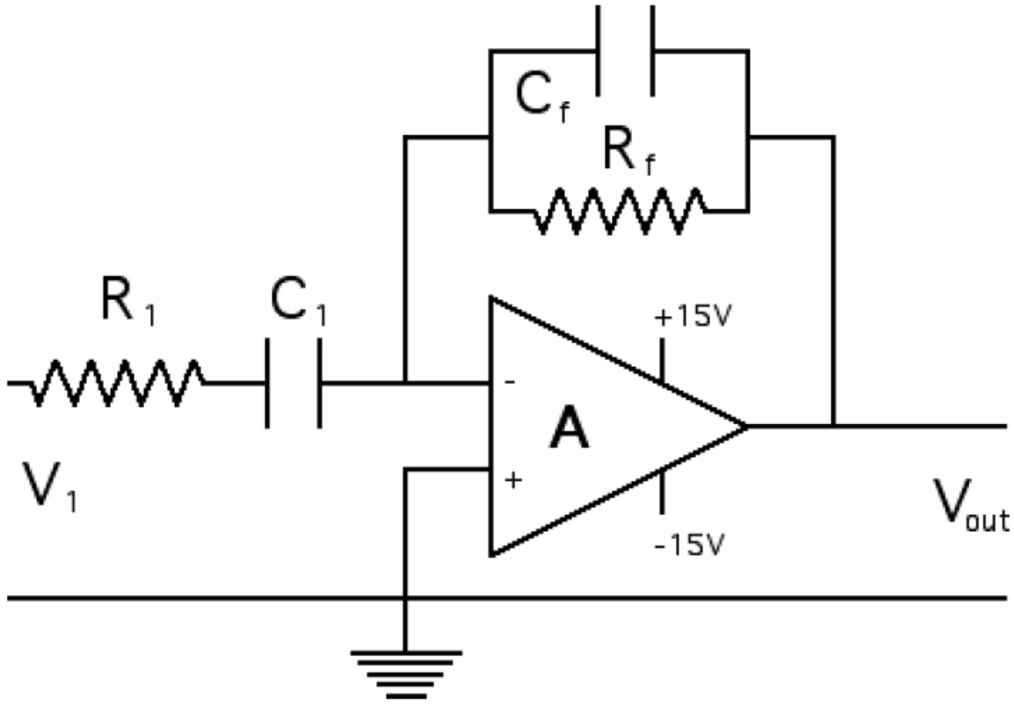


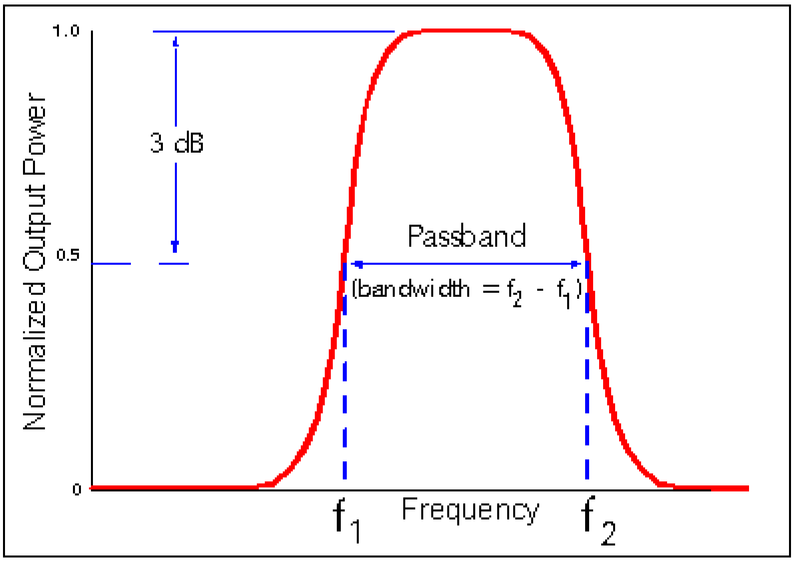


high-pass filter

Bandpass Filter

If you allow both an input capacitor and a feedback capacitor in the op amp circuit, the response curve has both a low-cutoff frequency, f_L, and a high-cutoff frequency, f_U. The frequency range ($f_U - f_L$) is called the bandwidth. For example, a good stereo amplifier has a bandwidth of at least 20,000 Hz.





bandpass filter

The generalized op amp transfer curve is given by the following phasor equation

$$\mathbf{V}_{out} = (\mathbf{Z}_f/\mathbf{Z}_1)\mathbf{V}_{\mathbf{in}}$$

where the impedance values for the four circuits are:

Op Amp	$\mathbf{Z}_f$	$\mathbf{Z}_1$	**Gain**
Highpass	R_f	$R_1 + X_{C1}$	$R_f/(R_1 + X_{C1})$
Lowpass	$R_f + X_{Cf}$	R_1	$(R_f + X_{Cf})/R_1$
Bandpass	$R_f + X_{Cf}$	$R_1 + X_{C1}$	$(R_f + X_{Cf})/(R_1 + X_{C1})$