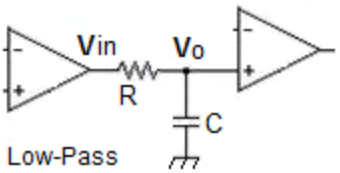
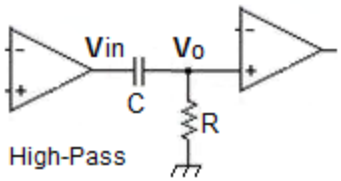
## Using RC Filters as Phase Shifters

The Phase Tripler BD-3A60 from Antoch Labs uses a low-pass filter to obtain a -60 degree phase shift and a high-pass filter to obtain a +60 degree phase shift. Both filters are driven by the low output impedance of an op-amp so that the source resistance of Vin is close to zero ohms and can be neglected. Also, the output of both filters are connect to the very high input resistance of an op-amp so that the load resistance for Vo can be neglected. Refer to the diagrams and equations below.




LOW-PASS RC FILTER EQUATIONS.

$$\mathbf{Vo} = \frac{-j\frac{1}{\omega C}}{R - j\frac{1}{\omega C}} = \frac{1}{1 + j\omega RC}\mathbf{Vin}, \quad |\mathbf{Vo}| = \frac{1}{\sqrt{1+(\omega RC)^2}}|\mathbf{Vin}|, \quad \theta = -\tan^{-1}(\omega RC), \quad RC = \frac{-\tan\theta}{\omega} = k,$$

$$C = \frac{k}{R}, \quad R = \frac{k}{C}. \quad \text{If } \theta = -60^0 \text{ and } \omega = 377, \text{ then } k = 4.594 \times 10^{-3}. \quad \text{If } C = 56nF,\ R = 82K.$$

HIGH-PASS RC FILTER EQUATIONS.

$$\mathbf{Vo} = \frac{R}{R + \mathbf{j}\frac{1}{\omega C}} = \frac{1}{1 + \mathbf{j}\frac{1}{\omega RC}}\mathbf{Vin}, \quad |\mathbf{Vo}| = \frac{1}{\sqrt{1+\left(\frac{1}{\omega RC}\right)^2}}|\mathbf{Vin}|, \quad \theta = \tan^{-1}\left(\frac{1}{\omega RC}\right), \quad RC = \frac{1}{\omega\tan\theta} = k,$$

$$C = \frac{k}{R}, \quad R = \frac{k}{C}. \quad \text{If } \theta = -60^0 \text{ and } \omega = 377, \text{ then } k = 1.531 \times 10^{-3}. \quad \text{If } C = 56nF,\ R = 27.35K.$$

The magnitude of the output is exactly one-half of the input voltage for both the low-pass and the high=pass filter.

$$\frac{|\mathbf{Vo}|}{|\mathbf{Vin}|} = \frac{1}{\sqrt{1+(\omega RC)^2}} = \frac{1}{\sqrt{1+\left(377 \cdot 82000 \cdot 56 \times 10^{-9}\right)^2}} = \frac{1}{2}$$

The values of R and C for each filter are chosen so that the filters present a reasonable load to the op-amp output and so that precision resistors and capacitors are available for the chosen R and C values. This usually requires choosing an available capacitor value and calculating the required resistor value. If the resistor value is not commercially available, choose another capacitor value and repeat the calculation.