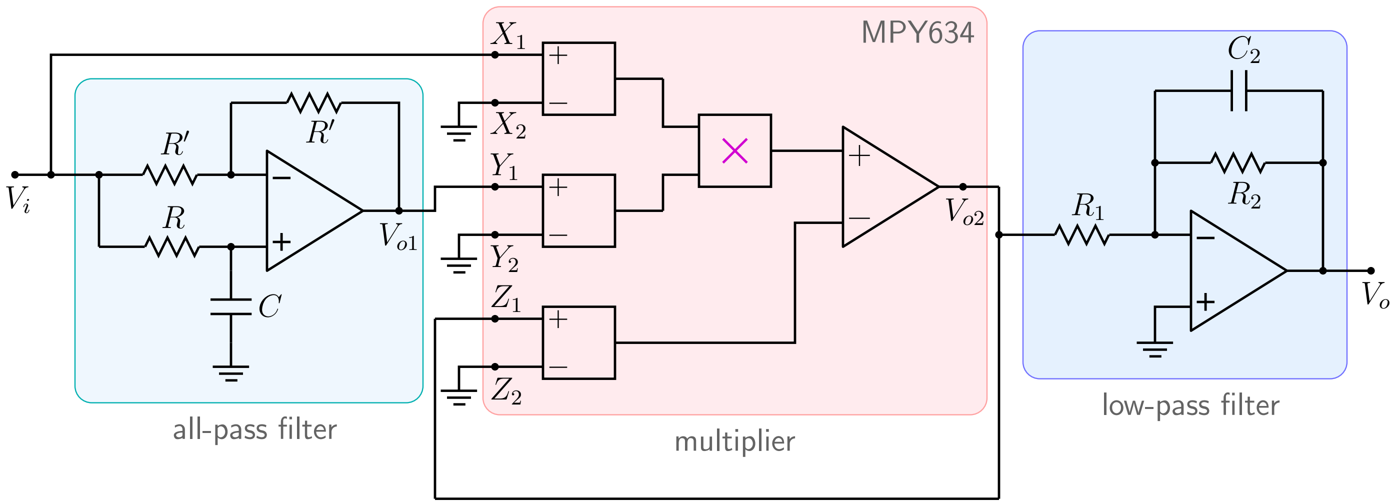
phase_detector_1.sqproj



Shown in the figure is a circuit which produces an output voltage proportional to $\cos\alpha$, where α is the phase difference between two voltages. An all-pass filter is used to generate a phase-shifted version (V_{o1}) of the input voltage V_i, and these two voltages (V_i and V_{o1}) are used as the test voltages. In a simulation exercise, it is possible to bypass this step and directly apply two voltages with the same amplitude and different phase angles; however, the set-up shown here is advantageous when an experimental implementation is desired. The circuit operation can be explained as follows.

The output of the all-pass filter is given by

$$V_{o1}(s) = \frac{1-sRC}{1+sRC}\,V_i(s)\,,$$

which means that $V_{o1}(s)$ has the same amplitude as $V_i(s)$, but a different phase. If $V_i(t) = V_m \sin\omega t$, V_{o1} is given by $V_{o1}(t) = V_m \sin(\omega t + \alpha)$ where $\alpha = -2\,\tan^{-1}(\omega RC)$.

The output of the multiplier is given by,

$$\begin{aligned} V_{o2} &= \frac{1}{SF} \times V_i(t) \times V_{o1}(t) \\ &= \frac{1}{SF} \times V_m \sin\omega t \times V_m \sin(\omega t + \alpha) \\ &= \frac{1}{2}\,\frac{V_m^2}{SF} \times [\cos\alpha - \cos(2\omega t + \alpha)]\ , \end{aligned}$$

where SF is the scaling factor of the multiplier and is equal to 10 V (unless it is changed by the user with an external arrangement).

The low-pass filter is meant to filter out the 2ω component of $V_{o2}(t)$, giving

$$V_o = -\frac{R_2}{R_1}\frac{V_m^2}{2\,SF} \times \cos\alpha \equiv -k\,\cos\alpha\,.$$

Exercise Set

1. For $R' = 1\,\text{k}$, $C = 0.1\,\mu\text{F}$, $R = 1\,\text{k}$, $R_1 = 10\,\text{k}$, $R_2 = 47\,\text{k}$, $C_2 = 1\,\mu\text{F}$, $V_m = 1\,\text{V}$, $f = 1\,\text{kHz}$,

   (a) What is the phase difference α between $V_i(t)$ and $V_{o1}(t)$?

   (b) What is the corner frequency of the low-pass filter?

   (c) What is V_o?

   (d) Simulate the circuit and compare the simulation results with your answers.

2. Repeat the above calculations for $R = 2.2\,\text{k}$, $4.7\,\text{k}$, and $10\,\text{k}$.