ee101_osc_3.sqproj

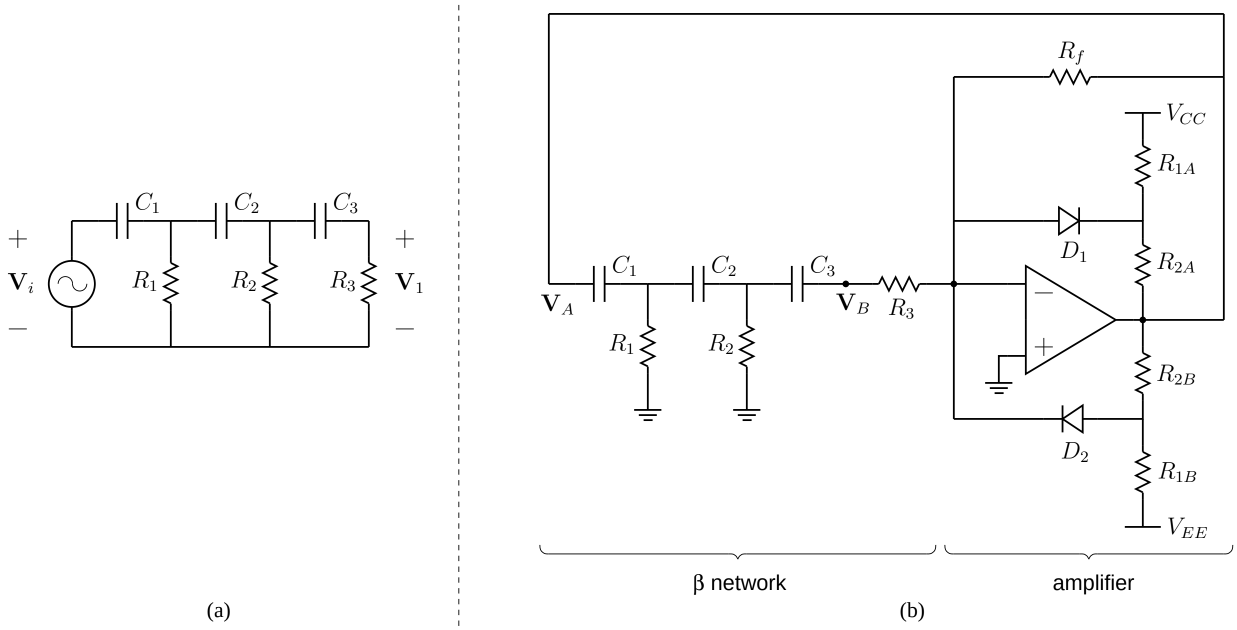

Figure 1: (a) RC phase-shift network ($R_1 = R_2 = R_3 = R$, $C_1 = C_2 = C_3 = C$), (b) Op Amp based phase-shift oscillator.

Fig. 1 (a) shows an RC network for which,

$$\frac{\mathbf{V}_1}{\mathbf{V}_i} = \frac{(\omega RC)^3}{\omega RC\,[(\omega RC)^2 - 5] + j\,[1 - 6(\omega RC)^2]}\,. \tag{1}$$

This network can be used to make an oscillator (see Fig. 1 (b)) if the Barkhausen criterion of unity loop gain is satisfied. Since the inverting terminal of the Op Amp is at $0\,V$ (virtual ground), the RC networks in Figs. 1 (a) and (b) are identical, and Eq. 1 for $\mathbf{V}_1/\mathbf{V}_i$ in Fig. 1 (a) also holds for $\mathbf{V}_B/\mathbf{V}_A$ in Fig. 1 (b). The loop gain is therefore

$$A\beta = -\frac{R_f}{R_3} \times \frac{(\omega RC)^3}{\omega RC\,[(\omega RC)^2 - 5] + j\,[1 - 6(\omega RC)^2]}\,. \tag{2}$$

For the loop gain to be $1\angle 0$, we require the denominator to be real, i.e.,

$$\omega_0 = \frac{1}{\sqrt{6}\,RC}\,. \tag{3}$$

At this frequency,

$$A\beta = -\frac{R_f}{R_3}\left(-\frac{1}{29}\right), \tag{4}$$

thus requiring $R_f = 29\,R$ (a little larger than that in practice) for oscillations to be sustained. The output amplitude depends on the nonlinearities in the circuit due to the diode network (consisting of D_1, D_2, R_{1A}, R_{2A}, R_{1B}, R_{2B}).

Exercise Set

1. Simulate the circuit of Fig. 1 (a) with $\mathbf{V}_i = 1\angle 0\,V$, $R = 10\,\mathrm{k}\Omega$, $C = 16\,\mathrm{n}F$. In this case, the output $\mathbf{V}_1$ is the same as $\mathbf{V}_1/\mathbf{V}_i$.

   (a) Compute ω_0 (see Eq. 3).

   (b) Plot $|\mathbf{V}_1|$ and $\angle\mathbf{V}_1$ versus $\log f$, and verify that the gain at ω_0 is $-1/29$, i.e., the magnitude is $1/29$ and the phase is π (same as $-\pi$).

   (c) Increase R by a factor of 2 and verify that ω_0 shifts appropriately.

   (Circuit file: `ee101_osc_2.sqproj`)

2. Simulate the oscillator circuit of Fig. 1 (b) with the same values of R and C as in (1) above, and with $R_f = 310\,\mathrm{k}$.

   (a) Verify that the frequency of oscillations observed is consistent with that predicted by Eq. 3.

   (b) Change R_f to $280\,\mathrm{k}$, simulate the circuit, and obtain the output waveform. Explain your observations.