opamp_monostable_1.sqproj

Description

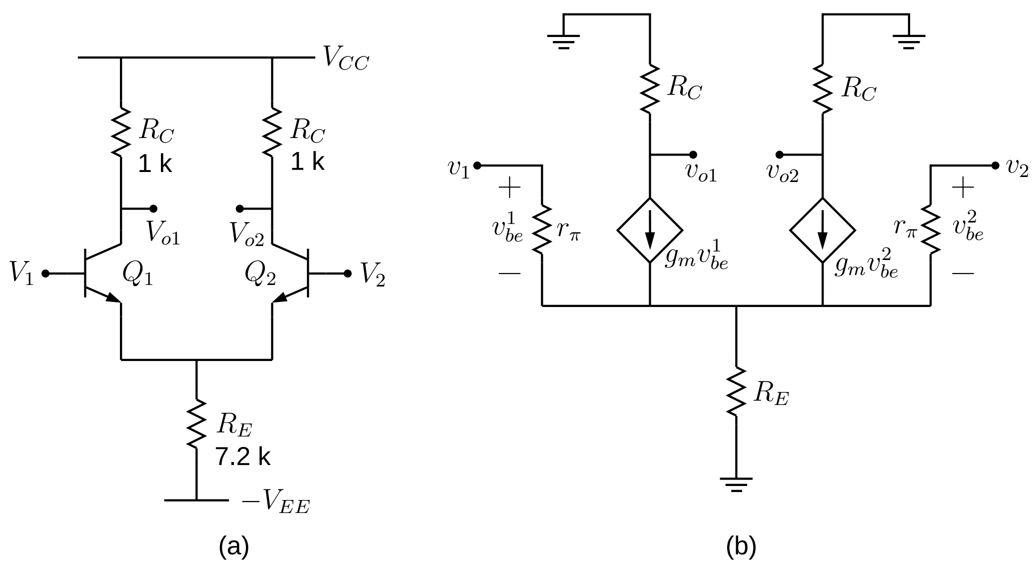

Figure 1: (a) BJT differential pair, (b) small-signal equivalent circuit.

In a differential amplifier, the output V_o is given by,

$$V_o = A_d\, v_d + A_c\, v_c\,, \tag{1}$$

where v_d and v_c, the differential- and common-mode input voltages, are given by,

$$v_d = V_1 - V_2\,, \tag{2}$$

$$v_c = \frac{1}{2}\,(V_1 + V_2)\,. \tag{3}$$

Ideally, we would like to have $A_c = 0$. In practice, however, A_c is finite (although small), and the common-mode rejection ratio (CMRR) is used as a figure of merit to describe the differential amplifier:

$$\text{CMRR} = \frac{A_d}{A_c}\,. \tag{4}$$

In the differential amplifier shown in Fig. 1(a), the differential-mode gain for single-ended output (i.e., $V_o = V_{o1}$ or V_{o2}) is given by

$$A_d = \frac{1}{2}\,g_m R_c\,, \tag{5}$$

where $g_m = I_C/V_T$ is the BJT transconductance.

Regarding the common-mode output voltage, if the output is taken in a double-ended manner (i.e., $V_o = V_{o1} - V_{o2}$), the common-mode gain A_c is zero. However, if it is taken in a single-ended manner ($V_o = V_{o1}$ or V_{o2}), the common-mode gain is finite and is given by,

$$A_c = -\frac{\alpha R_c}{2R_E}\,. \tag{6}$$

Exercise Set

1. Derive the results given above from the small-signal equivalent circuit shown in Fig. 1(b).

2. With $V_1 = V_2 = 0\,V$, what is the DC collector current for $Q1$ and $Q2$? Verify with simulation.

3. Plot V_{o1} versus t for $V_1 = V_{DC} + V_m \sin \omega t$ and $V_2 = V_{DC} - V_m \sin \omega t$, where $V_1 = 0\,V$, $V_m = 10\,\mathrm{m}V$, and $f = 10\,\mathrm{kHz}$. Find the single-ended differential gain A_d and compare with your analytic result.

4. Repeat with $V_{DC} = 1\,V$. From the shift in the waveform at V_{o1}, find the single-ended common-mode gain A_c. Compare with your analytic result.

5. Change the Early voltage of $Q1$ and $Q2$ from $130\,V$ to $50\,V$. Find A_d and A_c by simulation. Explain your observations.

References:

1. A. S. Sedra, K. C. Smith, and A. N. Chandorkar, *Microelectronic Circuits: Theory and Applications*, Fifth edition, Oxford University Press, 2009.