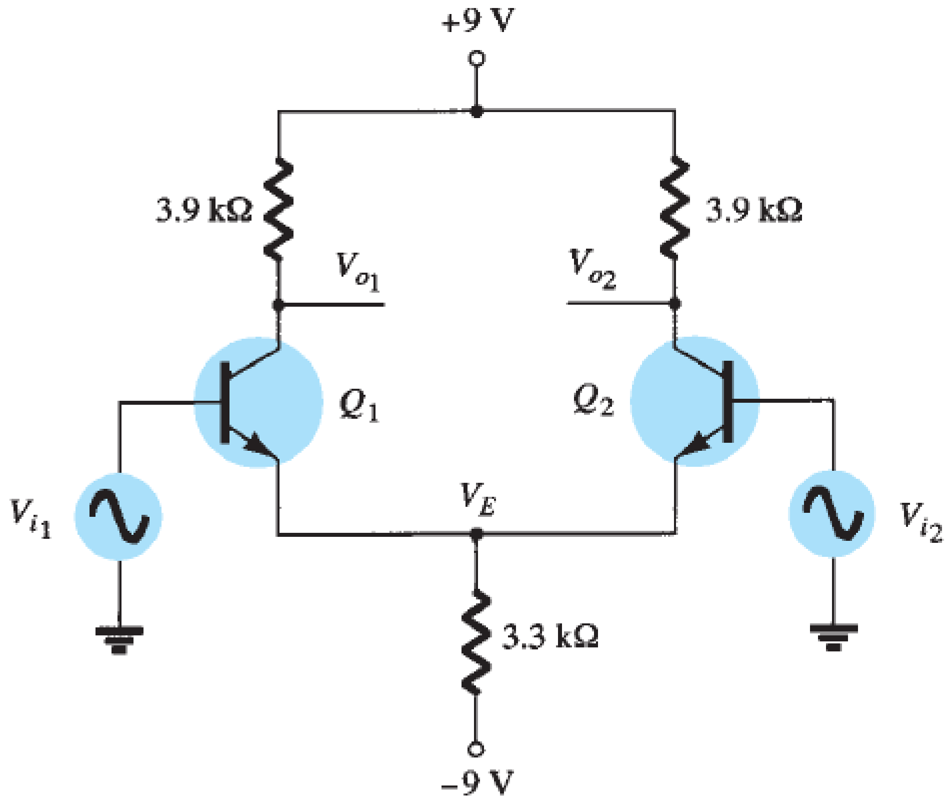
1. Calculate the dc voltages and currents in the circuit and draw the small signal hybrid equivalent model



Solution is example 10.1

Solution:

$$\text{Eq. (10.1):} \quad I_E = \frac{V_{EE} - 0.7\text{ V}}{R_E} = \frac{9\text{ V} - 0.7\text{ V}}{3.3\text{ k}\Omega} \approx \mathbf{2.5\text{ mA}}$$

The collector current is then

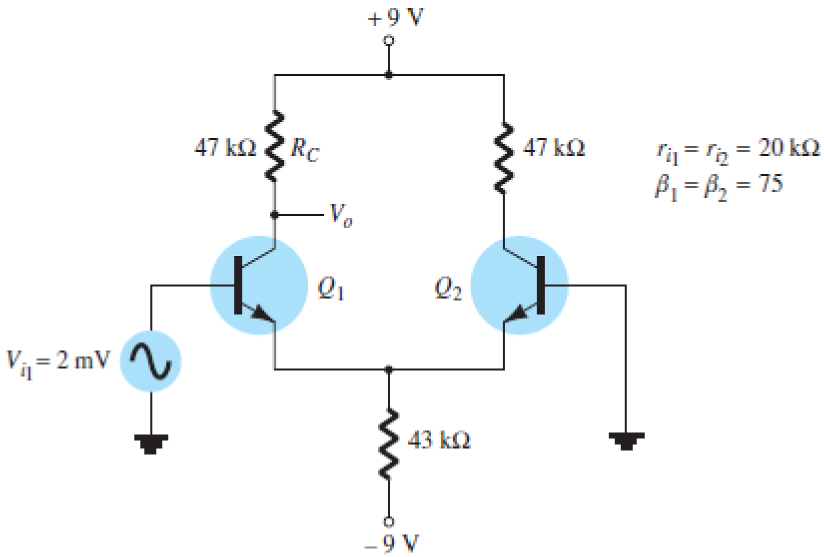
$$\text{Eq. (10.2):} \quad I_C = \frac{I_E}{2} = \frac{2.5\text{ mA}}{2} = \mathbf{1.25\text{ mA}}$$

resulting in a collector voltage of

$$\text{Eq. (10.3):} \quad V_C = V_{CC} - I_C R_C = 9\text{ V} - (1.25\text{ mA})(3.9\text{ k}\Omega) \approx \mathbf{4.1\text{ V}}$$

The common-emitter voltage is thus –0.7 V, whereas the collector bias voltage is near 4.1 V for both outputs.

2. Calculate the single-ended output voltage V_{O1} for the circuit and calculate the differential and common mode gain and the CMRR



Solution is example 10.2 and 10.3

Solution: The dc bias calculations provide

$$I_E = \frac{V_{EE} - 0.7\text{ V}}{R_E} = \frac{9\text{ V} - 0.7\text{ V}}{43\text{ k}\Omega} = 193\ \mu\text{A}$$

The collector dc current is then

$$I_C = \frac{I_E}{2} = 96.5\ \mu\text{A}$$

so that $$V_C = V_{CC} - I_C R_C = 9\text{ V} - (96.5\ \mu\text{A})(47\text{ k}\Omega) = 4.5\text{ V}$$

The value of r_e is then

$$r_e = \frac{26}{0.0965} \cong 269\ \Omega$$

The ac voltage gain magnitude can be calculated using Eq. (10.31):

$$A_v = \frac{R_C}{2r_e} = \frac{(47\text{ k}\Omega)}{2(269\ \Omega)} = 87.4$$

providing an output ac voltage of magnitude

$$V_o = A_v V_i = (87.4)(2\text{ mV}) = 174.8\text{ mV} = \mathbf{0.175\ V}$$

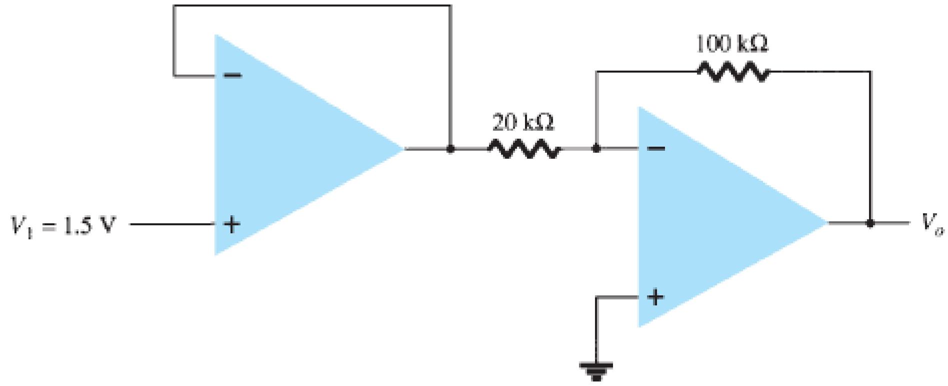
EXAMPLE 10.3 Calculate the common-mode gain for the amplifier circuit of Fig. 10.17.

Solution:

Eq. (10.6): $$A_c = \frac{V_o}{V_i} = \frac{\beta R_C}{r_i + 2(\beta + 1)R_E} = \frac{75(47\text{ k}\Omega)}{20\text{ k}\Omega + 2(76)(43\text{ k}\Omega)} = \mathbf{0.54}$$

The CMRR is Ad/Ac = 87.4/0.54 = 162

3. Calculate the output voltage of the circuit



Solution

$$V_o = -\frac{R_f}{R_1}V_1 = -\frac{100\text{ k}\Omega}{20\text{ k}\Omega}(1.5\text{ V})$$
$$= -5(1.5\text{ V}) = \mathbf{-7.5\ V}$$

4. For an op-amp having a slew rate of SR = 2.4 V>ms, what is the maximum closed-loop voltage gain that can be used when the input signal varies by 0.3 V in 10 ms?

$$A_{CL} = \frac{SR}{\Delta V_i / \Delta t} = \frac{2.4\text{ V}/\mu s}{0.3\text{ V}/10\ \mu s} = \mathbf{80}$$

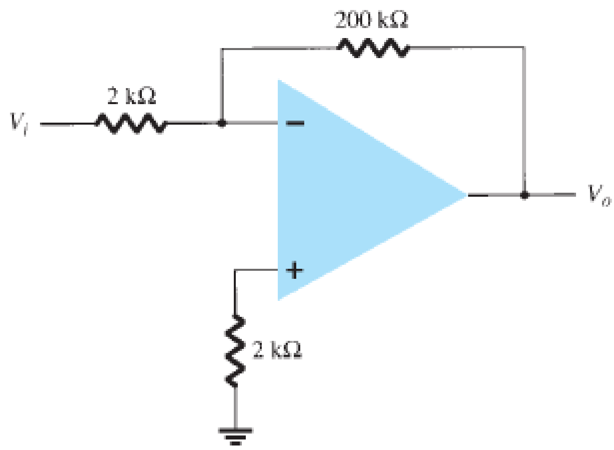
5. For an input of V_1 = 50 mV in the circuit, determine the maximum frequency that may be used. The op-amp slew rate SR _ 0.4 V>ms.

$$A_{CL} = \frac{R_f}{R_1} = \frac{200\text{ k}\Omega}{2\text{ k}\Omega} = 100$$
$$K = A_{CL}\,V_i = 100(50\text{ mV}) = 5\text{ V}$$
$$w_s \le \frac{SR}{K} = \frac{0.4\text{ V}/\mu s}{5\text{ V}} = \mathbf{80 \times 10^3\ rad/s}$$
$$f_s = \frac{w_s}{2\pi} = \frac{80\times10^3}{2\pi} = \mathbf{12.73\ kHz}$$

6. Using the specifications listed in the table below , calculate the typical offset voltage for the circuit below

μA741 Electrical Characteristics: $V_{CC} = \pm 15$ V, $T_A = 25°C$

Characteristic	Minimum	Typical	Maximum	Unit
V_{IO} Input offset voltage		1	6	mV
I_{IO} Input offset current		20	200	nA
I_{IB} Input bias current		80	500	nA
V_{ICR} Common-mode input voltage range	±12	±13		V
V_{OM} Maximum peak output voltage swing	±12	±14		V
A_{VD} Large-signal differential voltage amplification	20	200		V/mV
r_i Input resistance	0.3	2		MΩ
r_o Output resistance		75		Ω
C_i Input capacitance		1.4		pF
CMRR Common-mode rejection ratio	70	90		dB
I_{CC} Supply current		1.7	2.8	mA
P_D Total power dissipation		50	85	mW



$V_{Io} = 1$ mV, typical
$I_{Io} = 20$ nA, typical

$$V_o(\text{offset}) = 1 + \frac{R_f}{R_1} V_{Io} + I_{Io}R_f$$

$$= 1 + \frac{200\text{ k}\Omega}{20\text{ k}\Omega} (1\text{ mV}) + (200\text{ k}\Omega)(20\text{ nA})$$

$$= 101(1\text{ mV}) + 4000 \times 10^{-6}$$

$$= 101\text{ mV} + 4\text{ mV} = \mathbf{105\ mV}$$

7. For the typical characteristics of the 741 op-amp, calculate the following values for the circuit above

a. A_{CL}.

b. Z_i.

c. Z_o.

Typical characteristics for 741

$R_o = 25\ \Omega$, $A = 200$ K

(a) $A_{CL} = -\dfrac{R_f}{R_1} = -\dfrac{200\ \text{k}\Omega}{2\ \text{k}\Omega} = \mathbf{-100}$

(b) $Z_i = R_1 = \mathbf{2\ k\Omega}$

(c) $$Z_o = \frac{R_o}{1+\beta A} = \frac{25\ \Omega}{1+\frac{1}{100}(200{,}000)}$$

$$= \frac{25\ \Omega}{2001} = \mathbf{0.0125\ \Omega}$$