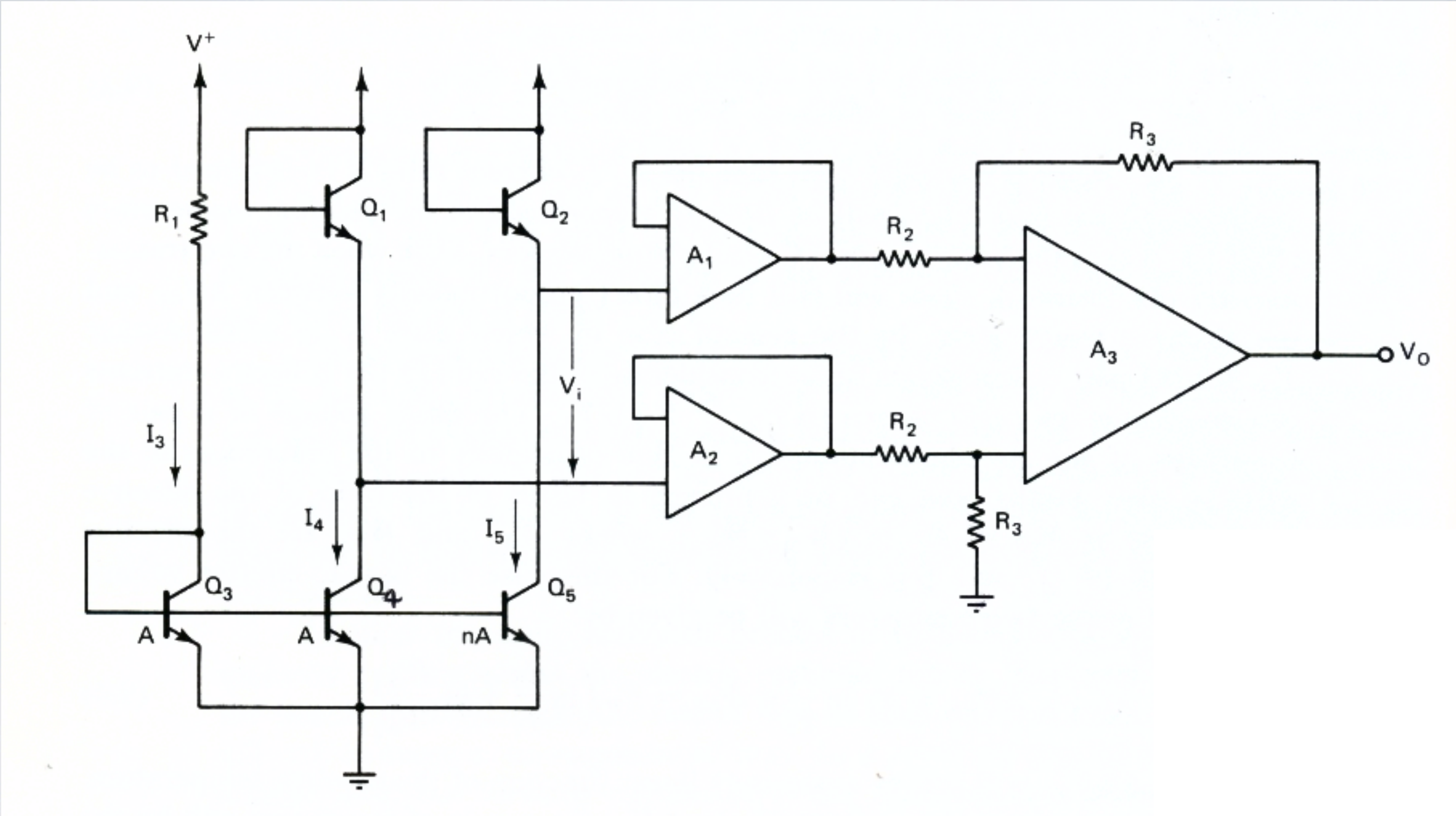
SENSORES DE TEMPERATURA ICS

INEL 5205 - Instrumentación



Vo es proporcional a T absoluta

$$
\begin{aligned}
v_{BE5} &= v_{BE4} \\
I_2 &= I_5 = nI_4 = nI_1 \\
\frac{I_2}{I_1} &= \frac{I_5}{I_4} = n \\
v_i &= V_+ - v_{BE1} - (V_+ - v_{BE2}) = v_{BE2} - v_{BE1} \\
I_1 &= I_s exp(v_{BE1}/V_T) \\
I_2 &= I_s exp(v_{BE2}/V_T) \\
\frac{I_2}{I_1} &= n = \exp\left(\frac{v_{BE2} - v_{BE1}}{V_T}\right) \\
v_i &= V_T ln(n) \\
v_o &= \frac{R_3}{R_2} ln(n) V_T = \left(\frac{k}{q}\frac{R_3}{R_2} ln(n)\right) T = TC \times T \\
TC &= \frac{dv_o}{dT} = \frac{k}{q}\frac{R_3}{R_2} ln(n)
\end{aligned}
$$

For $TC = 1mV/^\circ C = 1mV/^\circ K$, at $T = 25^\circ C = 298^\circ K$

$$\frac{kT}{q} = 25.678mV$$

$$\frac{k}{q} = \frac{25.678mV}{298^\circ K}$$

and

$$TC = 1mV/^\circ K = \frac{25.678mV}{298^\circ K}\frac{R_3}{R_2}ln(n)$$

Select n to some reasonable number, like $\boxed{n = 2}$, and

$$\frac{R_3}{R_2} = \frac{1mV/^\circ K}{ln(2)}\frac{298^\circ K}{25.678mV} = \boxed{16.74}$$

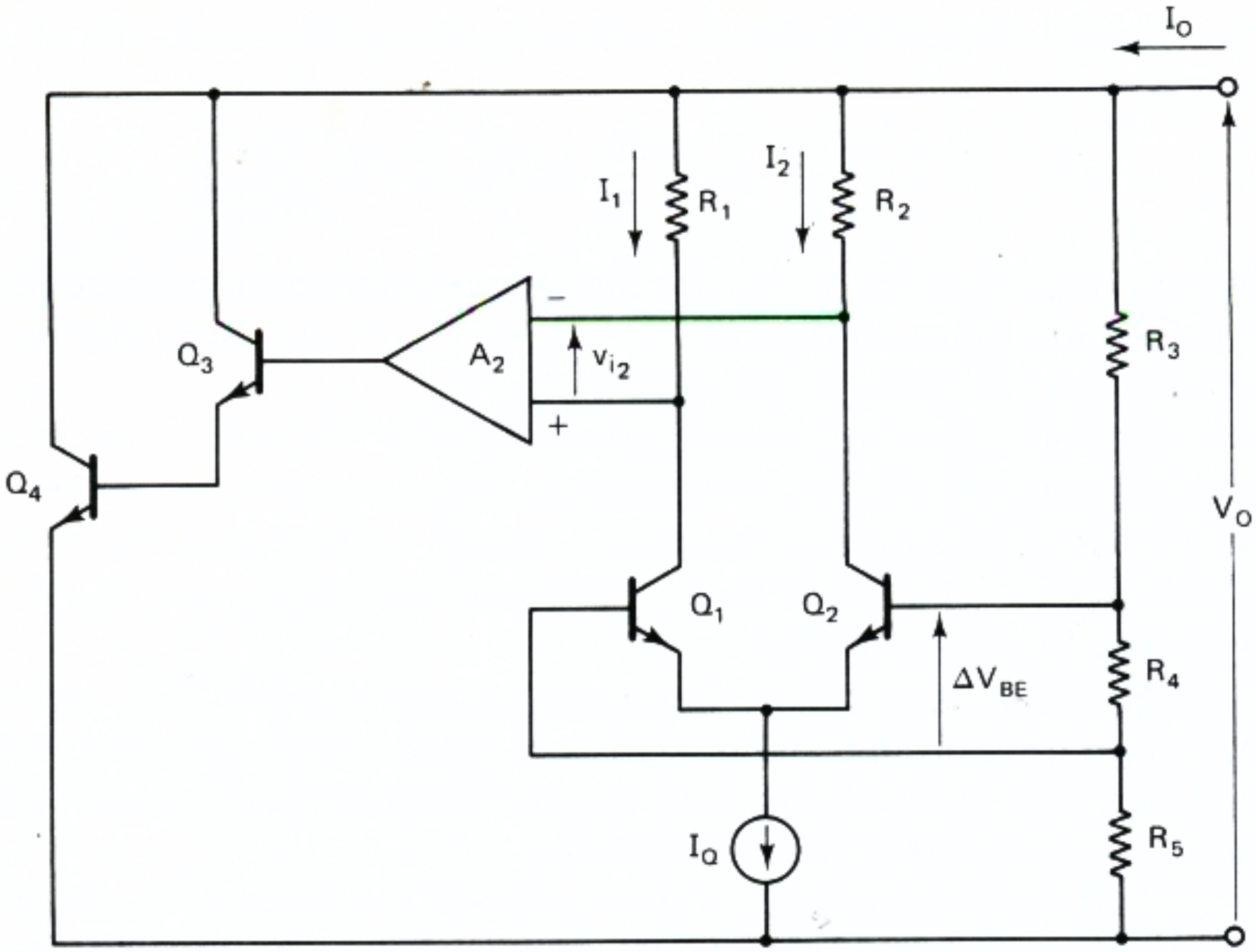


Figure 9.2 Two-terminal VPTAT temperature sensor.

V_O es proporcional a T absoluta

$$
\begin{aligned}
v_p &= v_n \Rightarrow I_1 R_1 = I_2 R_2 \Rightarrow \frac{I_2}{I_1} = \frac{R_1}{R_2} \\
\frac{I_2}{I_1} &= \frac{R_1}{R_2} = \exp\left(\frac{v_{BE2} - v_{BE1}}{V_T}\right) \\
v_{BE2} - v_{BE1} &= V_T ln\left(\frac{R_1}{R_2}\right)
\end{aligned}
$$

Neglecting base currents,

$$
\begin{aligned}
v_{BE2} - v_{BE1} &= V_T ln\left(\frac{R_1}{R_2}\right) = V_{R4} = \frac{R_4}{R_3 + R_4 + R_5} v_o \\
v_o &= \left(\frac{R_3 + R_4 + R_5}{R_4} ln\left(\frac{R_1}{R_2}\right)\frac{k}{q}\right) T \\
TC &= \frac{R_3 + R_4 + R_5}{R_4} ln\left(\frac{R_1}{R_2}\right)\frac{k}{q}
\end{aligned}
$$

For $TC = 10mV/^\circ K$ and using $\frac{R_1}{R_2} = 10$,

$$
10mV/^\circ K = \frac{R_3 + R_4 + R_5}{R_4} ln\left(10\right) \frac{25.678mV}{298^\circ K}
$$

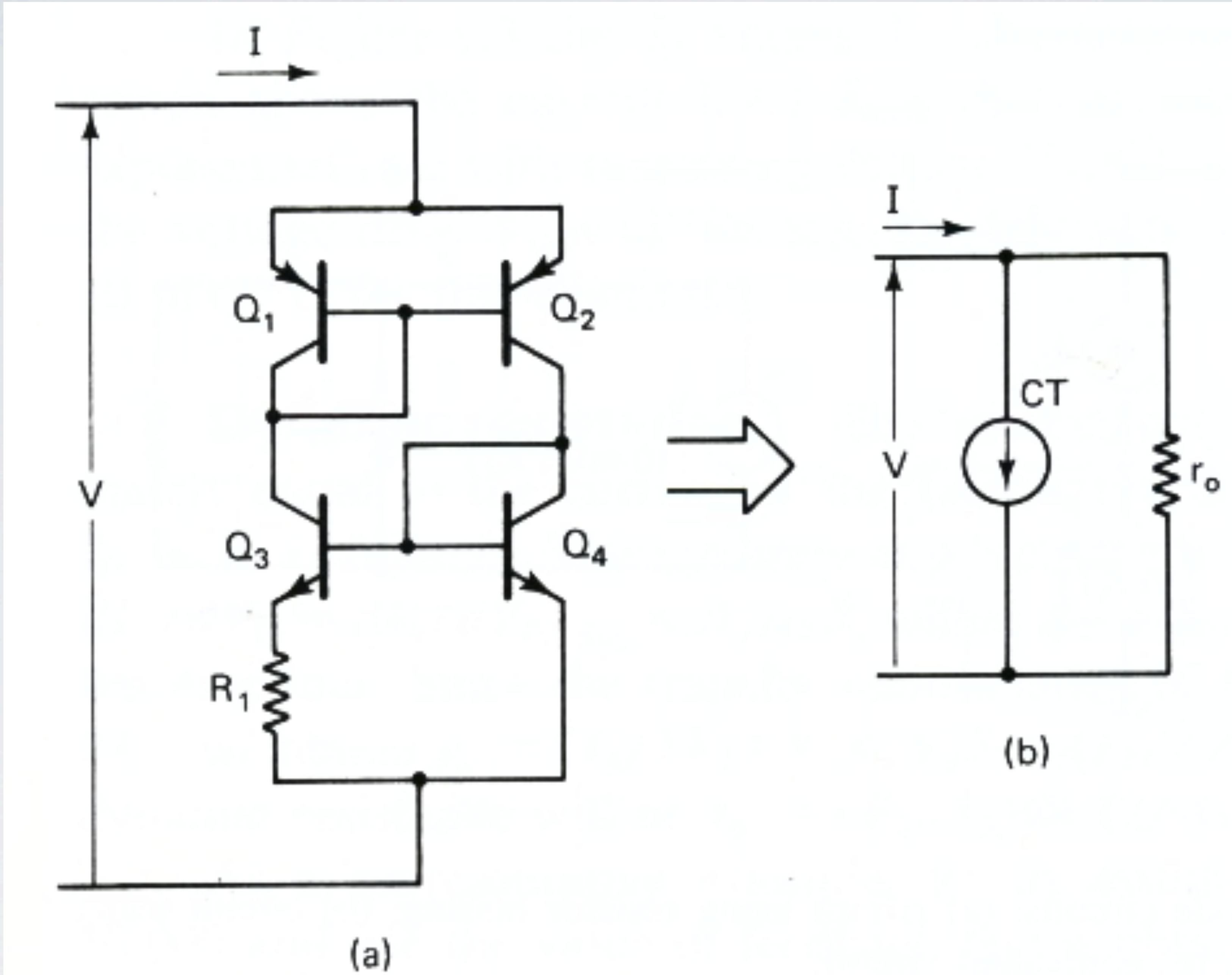
$$
R_3 + R_5 = 49.4 R_4
$$

Assign $I_{R3} = 1\mu A$, $V_{B2} = 1.0V$ and $v_o = 2.98V$ at $T = 298^\circ K$. Then

$$
R_5 + R_4 = \frac{1V}{1mA} = 1k\Omega \qquad R_3 + R_4 + R_5 = 2.98k\Omega
$$

$$
\boxed{R_3 = 1.98k\Omega} \qquad R_5 = 49.4R_4 - 1.98k\Omega = 1k\Omega - R_4
$$

$$
\boxed{R_4 = 2.98k\Omega \div 50.4 = 59\Omega} \Rightarrow \boxed{R_5 = 941\Omega}
$$



I es proporcional a T absoluta

$$
\begin{aligned}
I_1 &= I_2 = I_3 = I_4 \\
r &= A_3/A_4 \\
\frac{I_3}{A_3} &= J_3 = J_S exp(v_{BE3}/V_T) \\
\frac{I_4}{A_4} &= J_4 = J_S exp(v_{BE4}/V_T) \\
\frac{I_4}{A_4} \div \frac{I_3}{A_3} &= \frac{I_4}{I_3}\frac{A_3}{A_4} = 1 \times r = exp((v_{BE4} - v_{BE3})/V_T) \\
v_{BE4} - v_{BE3} &= I_1 R_1 = V_T ln(r) \\
I_o &= 2I_1 = \left(\frac{2ln(r)}{R_1}\frac{k}{q}\right) T = TC \times T \\
TC &= \frac{2ln(r)}{R_1}\frac{k}{q}
\end{aligned}
$$

For $TC = 1.0\mu A/^\circ K$ and selecting $r = 8$,

$$
R_1 = \frac{2ln(8)}{1\mu A/^\circ K}\frac{25.678mV}{298^\circ K} = \boxed{358.4\Omega}
$$