10.1

(a) Let Vs increase by a positive increment. This will cause the drain current of Q_1 to increase. The increase in I_{d1} will be fed to the Q_3-Q_4 mirror, which will provide a corresponding increase in the drain current of Q_4. The latter current will cause the voltage at the output node to rise. A fraction of the increase in V_O is applied through the divider (R_1, R_2) to the gate of Q_2. The increase in the voltage of the gate of Q2 will subtract from the initially assumed increase of the voltage of the gate of Q_1, resulting in a smaller increase in the differential voltage applied to the (Q_1, Q_2) pair. Thus, the feedback counter acts the originally assumed change, verifying that it is negative.

(b) The negative feedback will cause the dc voltage at the gate of Q_2 to be approximately equal to the dc voltage at the gate of Q_1, that is zero. Now, with V_{G2} =0, the dc current in R_2 will be zero and similarly the dc current in R_1 will be zero, resulting in V_O= 0 V dc.

(c) Figure 1 shows the A circuit. It also shows how the loading effect of the β network on the A circuit, namely R_{11} and R_{22}, are found. The gain of the A circuit can be written by inspection as:

A= $g_{m1,2}(r_{o2}||r_{o4}||R_{22})$ where: $g_{m1,2} = \frac{2I_{D1,2}}{V_{OV1,2}} = \frac{2\times 0.1}{0.2} = 1\ \text{mA/V}$

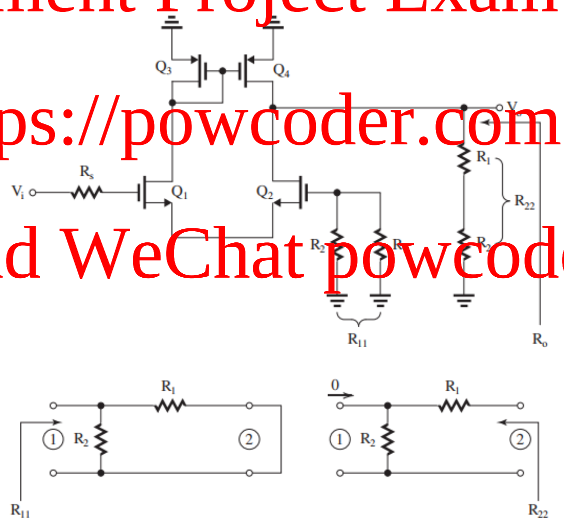

Figure 1

$$r_{o2} = r_{o4} = \frac{|V_A|}{I_{D3,4}} = \frac{10}{0.1} = 100\ \text{k}\Omega$$

$R_{22} = R_1 + R_2 = 1\ \text{M}\Omega$

A=1(100||100||1000) = 47.62 V/V

(d)

$$\frac{V_o}{V_s} = A_f = \frac{A}{1 + A\beta} \rightarrow 5 = \frac{47.62}{1 + 47.62\beta} \rightarrow \beta = 0.179$$

Thus, $\frac{R_2}{R_1 + R_2} = 0.179 \rightarrow R_2 = 0.179\ \text{M}\Omega = 179\ \text{k}\Omega$

$R_1 = 1000 - 179 = 821\ \text{k}\Omega$

(e) Refer to fig. 1:

$R_o = R_{22}||r_{o2}||r_{o4} = 1000||100||100 = 47.62\ \text{k}\Omega$

$$R_{out} = \frac{R_o}{1 + A\beta} = \frac{47.62}{1 + 47.62 \times 0.179} = 5\ \text{k}\Omega$$

(f) With $R_L = 10\ \text{k}\Omega$,

$$\frac{V_o}{V_s} = 5 \times \frac{R_L}{R_L + R_{out}} = 5 \times \frac{10}{10 + 5} = 3.33 \frac{V}{V}$$

(g)

With $R_L = 10\ \text{k}\Omega$:

$A = g_{m1,2}(R_L||R_{22}||r_{o2}||r_{o4}) = 1(10||1000||100||100) = 8.26\ \text{V/V}$

Using $\beta = 0.179$, we obtain:

$$A_f = \frac{8.26}{1 + 8.26 \times 0.179} = 3.33\ \text{V/V}$$

10.2:

(a) If V_s increases, the output of A_1 will decrease and this will cause the output of A_2 to increase. This, in turn, causes the output of A_3 which is V_o, to increase. A portion of the positive increment in V_o is fed back to the positive input terminal of A_1 through the voltage divider (R_2, R_1), the increased voltage at the positive input terminal of A_1 counteracts the originally assumed increase at the negative input terminal, verifying that the feedback is negative.

(b) $A_f = \frac{1}{\beta}$; where: $\beta = \frac{R_1}{R_1+R_2}$

Thus, to obtain an ideal closed-loop gain of 5 V/V we need $\beta = 0.2 \rightarrow 0.2 = \frac{20}{20+R_2} \rightarrow R_2 =$ 80 kΩ

(c)

Figure 1 shows the small signal equivalent circuit of the feedback amplifier.

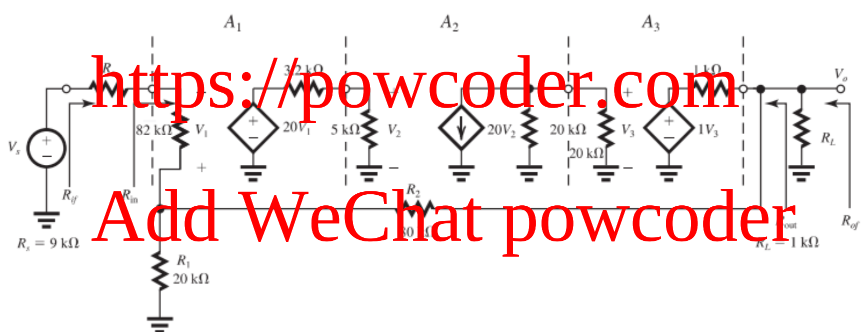

Figure 1

(d)

Figure 2 shows the A circuit and the β circuit together with the determination of its loading effects, R_{11} and R_{22}.

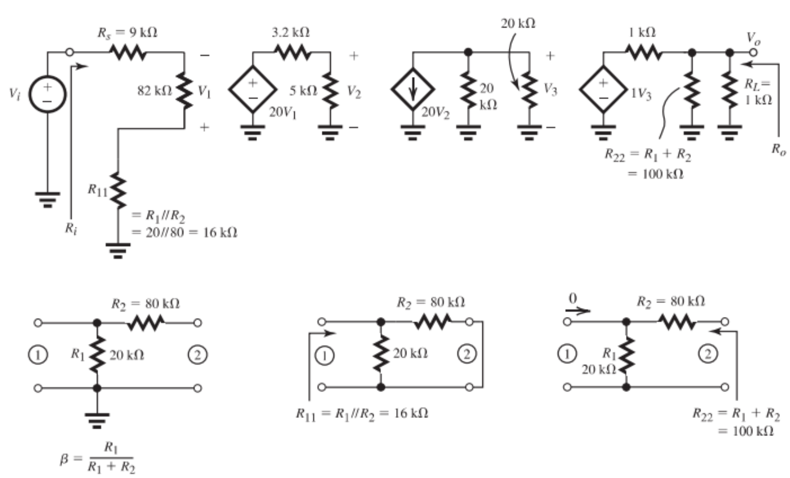

Figure 2

We can write:

$$\frac{V_1}{V_i} = -\frac{82}{82 + 9 + 16} = -0.766\frac{V}{V}$$

$$V_2 = 20V_1 \times \frac{5}{3.2 + 5} = 12.195V_1$$

$$V_3 = -20V_2(20||20) = -200V_2$$

$$V_o = V_3\frac{1||100}{(1||100) + 1} = 0.497V_3$$

Thus,

$$A \equiv \frac{V_o}{V_i} = 0.497 \times -200 \times 12.195 \times -0.766 = 925.5\ V/V$$

(e) $\beta = \frac{20}{20+80} = 0.2\frac{V}{V}$; $1 + A\beta = 1 + 928.5 \times 0.2 = 186.7$

(f) $A_f = \frac{V_o}{V_i} = \frac{A}{1+A\beta} = \frac{928.5}{186.7} = 4.97\frac{V}{V}$

(g)

From the A circuit:

$$R_i = 9 + 82 + 16 = 107\ k\Omega$$

$$R_{if} = R_i(1 + A\beta) = 107 \times 186.7 = 19.98\ M\Omega$$

$$R_{in} = R_{if} - R_s = 19.98\ M\Omega$$

(h) From the A circuit:

$$R_O = R_L||R_{22}||1k\Omega = 1||100||1 = 497.5\ \Omega$$

$$R_{Of} = \frac{R_O}{1 + A\beta} = \frac{497.5}{186.7} = 2.66\ \Omega$$

$$R_{Of} = R_{out}||R_L \rightarrow R_{out}||1000 = 2.66\ \Omega \rightarrow R_{out} = 2.66\ \Omega$$

(i) $f_{Hf} = f_H(1 + A\beta) = 100 \times 186.7 = 18.67 \text{ kHz}$

(j) if A_1 drops to half its nominal value, A will drop to half its nominal value:

$$A = \frac{1}{2} \times 928.5 = 464.25$$

And A_f becomes:

$A_f = \frac{464.25}{1+464.25\times 0.2} = 4.947 \text{ V/V}$

Thus, the percentage change in A_f is

$= \frac{4.947-4.97}{4.97} = -0.47\%$