51.

(a) Breaking the feedback loop results in the following circuit:

\[ R_{o,l} = \frac{V_X}{I_{in}} \frac{V_{out}}{V_X} = g_m R_D \left( \frac{1}{g_m} \| R_F \right) \times (-g_m R_F) \]

\[ R_{in,open} = \frac{1}{g_m} \| R_F \quad R_{out,open} = R_F \]

Feedback factor \( k \):

\[ k = \frac{V_X}{I_X} = -\frac{1}{R_F} \]

\[ R_{o,l} = \frac{R_{o,l}}{1 + R_{o,l} \times k} = \frac{-g_m g_m R_D R_F \left( \frac{1}{g_m} \| R_F \right)}{1 + g_m g_m R_D \left( \frac{1}{g_m} \| R_F \right)} \]

\[ R_{in,closed} = \frac{\left( \frac{1}{g_m} \| R_F \right)}{1 + g_m g_m R_D \left( \frac{1}{g_m} \| R_F \right)} \]

\[ R_{out,closed} = \frac{R_F}{1 + g_m g_m R_D \left( \frac{1}{g_m} \| R_F \right)} \]
(b) Breaking the feedback loop results in the following circuit:

\[ \text{Feedback factor } K : \quad K = \frac{U_x}{i_x} = -\frac{1}{R_F} \]

\[ \Rightarrow R_{cl.} = -\frac{9g_mR_F^2}{1 + 9g_mR_F} \]

\[ R_{in, open} = R_F \quad R_{out, open} = R_F \]

\[ R_{in, closed} = \frac{R_F}{1 + 9g_mR_F} \]

\[ R_{out, closed} = \frac{R_F}{1 + 9g_mR_F} \]
(c) Breaking the feedback loop results in the following circuit:

\[ R_{\text{in, open}} = \left( \frac{L}{g_{m1} \| R_F} \right) \]

- Feedback factor \( K \):
  \[ K = \frac{V_{\text{out}}}{V_x} = -\frac{1}{R_F} \]

\[ (\lambda = 0) \]

\[ \begin{align*}
R_{\text{out, open}} &= \frac{V_{\text{out}}}{i_n} = \frac{V_{\text{out}}}{i_n} \cdot V_x \\
&= g_{m1} R_D \left( \frac{1}{g_{m1} \| R_F} \right) \times g_{m2} \left( R_F \| \frac{1}{g_{m2}} \right)
\end{align*} \]

\[ R_{\text{out, open}} = (R_F \| \frac{1}{g_{m2}}) \]

(Note: Feedback is positive.)

\[ R_{\text{cl.}} = \frac{R_{\text{b.l.}}}{1 + R_{\text{b.l.}} \times K} \]

\[ = \frac{g_{m1} g_{m2} R_D \left( \frac{1}{g_{m1} \| R_F} \right) \left( \frac{1}{g_{m2} \| R_F} \right)}{1 - g_{m1} g_{m2} \left( \frac{R_D}{R_F} \right) \left( \frac{1}{g_{m1} \| R_F} \right) \left( \frac{1}{g_{m2} \| R_F} \right)} \]

\[ R_{\text{in, closed}} = \left( \frac{1}{g_{m1} \| R_F} \right) \]

\[ R_{\text{out, closed}} = \left( \frac{1}{g_{m2} \| R_F} \right) \]

\[ \frac{1}{1 - \frac{R_{\text{b.l.}}}{R_F}} \]
\[ H(s) = \frac{A_0}{1 + \frac{s}{W_p}} \]

\[ k = 1. \]

Phase margin = \(180^\circ - 90^\circ = 90^\circ\) (i.e. system is stable)
71.

![Circuit Diagram]

**Specs:**
- \( A_{OL} = 50 \)
- \( A_{CL} = 4 \)
- \( R_L + R_2 \approx 10(13.3 \Omega) \)

As \( R_L + R_2 \approx 10(13.3 \Omega) \) we can neglect the output loading.

**\( A_{OL} = g_{m1} \left( \frac{r_{o2}}{r_{o4}} \right) = 50 \)**

\[
\frac{1}{r_{o2}} = \frac{1}{\lambda N T_{5/2}} = \frac{1}{(0.1V)\lambda(0.25mA)} = 40k\Omega
\]

\[
\frac{1}{r_{o4}} = \frac{1}{\lambda P T_{5/2}} = \frac{1}{(0.2V)\lambda(0.25mA)} = 20k\Omega
\]

\[
\frac{1}{r_{o2} || r_{o4}} = 13.3k\Omega
\]

\[
g_{m1} = \frac{50}{13.3k\Omega} = 3.75 \text{ mA/}\text{V}
\]

This can be achieved with

\[
\frac{W}{L_{1,2}} = \frac{g_{m1}}{\mu C_{ox} 2I_0} = \frac{(3.75 \text{ mA/V})^2}{(100 \text{ mA/V})^2(2)(0.25 \text{ mA})} = 281
\]

**\( A_{CL} = \frac{A_{OL}}{1 + K A_{OL}} \)**

\[
K = \frac{A_{OL} - A_{CL}}{A_{OL} A_{CL}} = \frac{50 - 4}{(50)(4)} = 0.23
\]

Need: \( k = \frac{R_2}{R_1 + R_2} = 0.23 \) and \( R_1 + R_2 = 10(13.3 \Omega) \)

\[
R_2 = 0.23(13.3 \Omega) = 30.6k\Omega
\]
\[ R_1 = 133\text{KN} - 30.6\text{KN} = 102.4\text{KN} \]

- \[ R_1 = 102.4\text{KN} \]
- \[ R_2 = 30.6\text{KN} \]
75.

\[ |R_{\text{CL}}| = 1 \text{ k\Omega} \]

\[ I_{c1} = I_{c2} = 1 \text{ mA} \]

\[ I = 100 \]

\[ V_A = \infty \]

\[ R_F \text{ is large} \]

\[ I_{1} = I_{2} \]

| \text{Need} | \| R_{\text{CL}} | = 20 \text{ k\Omega} \text{, } R_{\text{OUT,OL}} = 500 \text{ k\Omega} |}

Open-loop small-signal model \( w \text{ large } R_F \text{ (ignored)} \)

\[ V_{\text{OUT}} = \frac{V_{\text{X}}}{1 + \frac{R_C}{R_M}} \]

\[ R_{\text{CL}} = \frac{V_{\text{OUT}}}{I_{\text{IN}}} = \frac{V_{\text{X}}}{I_{\text{IN}}} \]

\[ V_{\text{OUT}} = -\alpha (\frac{-I_{\text{IN}}(R_C || R_M)}{I_{\text{IN}}}) \cdot (\frac{1}{\frac{1}{R_C} + \frac{1}{R_M}}) \]

\[ R_{\text{OL}} = -\alpha (R_C || R_M) \cdot 3 \text{ M\Omega} \]

\[ R_{\text{OUT,OL}} = R_M = 500 \text{ k\Omega} \]

\[ |R_{\text{OL}}| = \frac{\alpha \cdot 3 \text{ M\Omega}}{\frac{1}{R_C} + \frac{1}{R_M}} \]

\[ \Rightarrow \frac{1}{R_C} = \frac{\alpha \cdot 3 \text{ M\Omega}}{|R_{\text{OL}}|} - \frac{1}{R_M} \]

\[ \frac{1}{R_C} = \frac{(100)(1 \text{ mA})}{(25 \text{ k\Omega})} \cdot (5 \text{ M\Omega}) - \frac{1 \text{ mA}}{100(25 \text{ k\Omega})} = 570 \text{ mA} \]

\[ R_C = 1.76 \text{ k\Omega} \]
b. Find \( R_F \) for \( R_{CL} = -1\,k\Omega \)

\[
R_{CL} = \frac{R_{CL}}{1 + KR_{CL}} \quad \Rightarrow \quad K = \frac{R_{CL}}{R_{CL} - 1}
\]

\[
K = \frac{-20\,k\Omega}{-1\,k\Omega} - \frac{1}{-20\,k\Omega} = -950 \, \text{mA/}^1
\]

For \( K \)

\[
I_F \quad \frac{I_F}{V_{OUT}} = \frac{-V_{OUT}}{R_F}, \quad K = -\frac{1}{R_F}
\]

\[
R_F = -\frac{1}{K} = -\frac{1}{(-950 \, \text{mA/}^1)} = 1.05 \, k\Omega
\]

\[
R_F = 1.05 \, k\Omega
\]

C. \( R_{IN,CL} \), \( R_{OUT,CL} \)

\[
R_{IN,CL} = \frac{R_{IN,CL}}{1 + KR_{CL}} = \frac{R_{CL}}{1 + KR_{CL}} = \frac{25.9 \, \text{mA}}{1 \, \text{mA}(950 \, \text{mA/}^1)}
\]

\[
R_{IN,CL} = 1.28 \, k\Omega
\]

\[
R_{OUT,CL} = \frac{R_{OUT,CL}}{1 + KR_{CL}} = \frac{R_{M}}{1 + KR_{CL}} = \frac{500 \, \text{mA}}{1 + (-950 \, \text{mA/}^1)(-20\,k\Omega)}
\]

\[
R_{OUT,CL} = 25 \, k\Omega
\]