Calculating the "Loop Gain" of a Feedback Circuit

Why do we need Loop Gain??

1) Can calculate "R_in" and "R_out" in presence of feedback

\[ \text{Shunt: } R_{inF} = \frac{R_{in}}{1 + \text{Loop Gain}}; \quad R_{outF} = \frac{R_{out}}{1 + \text{Loop Gain}} \]

\[ \text{Series: } R_{inF} = R_{in}(1 + \text{Loop Gain}); \quad R_{outF} = R_{out}(1 + \text{Loop Gain}) \]

2) To find the stability of a negative feedback loop.

There are two methods for calculating the Loop gain:

1) Direct
2) Successive voltage and current injection

Example of Direct method

\[ R_{id} = 100K \]
\[ R_0 = 0 \]
\[ A_0 = 10^4 \text{ V/V} \]

\[ \frac{V_T}{V_X} = ?? \]
\[ V_o = -10^4 V_i = 10^4 \left( \frac{-R_d/1/R_1}{R_x + R_d/1/R_1} \right) V_x \]

\[ T = \frac{V_r}{V_x} = -10^4 \left( \frac{9.09}{109.09} \right) = -83.33 \]

**Stability of Feedback Amplifiers**

\[ A_F(s) = \frac{A(s)}{1 + A(s)B(s)} = \frac{A(s)}{1 + T(s)} \]

\[ T(s) = A(s)B(s) \]

\[ \sigma = \sigma \pm j \omega \]

**Two approaches:**

1. **Nyquist approach**
   - Plot \( T(j\omega) \) on a complex plane, varying \( \omega \) from \(-\infty \) to \(+\infty\).

   ![Nyquist plot](image)
Bode plot

- \( H(j\omega) \)
- \( \angle H(j\omega) \)
- \( \log_{10}(\omega) \)
- Phase margin (PM)
- Gain margin (GM)

Phase margin (PM)
- PM is less (-30°)
- PM is more (+60°)

Gain margin (GM)

V_{in} \rightarrow V_{out}

V_{in} \rightarrow V_{out} \rightarrow \text{time}
\[ A(s) = \frac{10^3}{\left(1 + \frac{s}{100}\right) \left(1 + \frac{s}{10^3}\right)}; \quad B(s) = 1 \]

\[ T(s) = A(s) \cdot B(s) \]

\[ |T(j\omega)| \text{ at 60 dB} \]

\[ \theta - 20 \text{ dB/dec} \text{ (slope)} \]

\[ \theta = 90^\circ \]

\[ \text{Phase margin} = 45^\circ \]

\[ \text{Gain margin} = 40 \text{ dB} \]
\( \frac{\text{Rin}}{\text{Rout}} \) with feedback

1. Draw the circuit without feedback.
2. Find \( \frac{\text{Rin}}{\text{Rout}} \) without feedback.
3. Find loop-gain \((T)\)
4. If input signal is
   a) Voltage \( \rightarrow \) \( \frac{\text{Rin}}{1+T} \)
   b) Current \( \rightarrow \) \( \frac{\text{Rin}}{(1+T)} \) \( \{ \text{Rin} \} \)

If output signal is
   a) Voltage \( \rightarrow \) \( \frac{\text{Rin}}{1+T} \)
   b) Current \( \rightarrow \) \( R_o (1+T) \) \( \{ \text{Rout} \} \)