Real gain and impedances

Alessandro Spinelli
Phone: (02 2399) 4001
alessandro.spinelli@polimi.it
home.deib.polimi.it/spinelli
Slides are supplementary material and are NOT a replacement for textbooks and/or lecture notes.
Loop gain calculation (concept)

\[ S_{test} \quad -G_{open}S_{test} \]

\[ F \]

\[ -G_{open}FS_{test} \]
Loop gain calculation

\[ G_{\text{loop}} = -A \frac{R_1}{R_1 + R_2} \]
Impedance reconstruction

\[ Z = R_1 \]

\[ I_o = I_T \]

\[ R_1 \]

\[ R_2 \]
Closed-loop gain

\[ G = \frac{V_o}{V_i} = \frac{G_{id}}{1 - \frac{1}{G_{loop}}} = \frac{\frac{R_1 + R_2}{R_1}}{1 + \frac{AR_1}{R_1 + R_2}} = \frac{G_{open}}{1 - G_{loop}} \]
Open-loop gain calculation (concept)

\[ G_{open} \times S_{test} \]

\[ F \]

\[ 0 \]
Open-loop gain calculation

\[ G_{\text{open}} = A \]
Impedance reconstruction

\[ R_1 \parallel R_2 = R_1 + R_2 \]

\[ G_{\text{open}} = A \frac{R_1 + R_2}{R_1 + R_2 + R_o} \]
Inverting amplifier case

\[ G_{open} = -A \frac{R_2}{R_1 + R_2} \]
Closed-loop gain

\[ G = \frac{V_o}{V_i} = \frac{G_{id}}{1 - \frac{1}{G_{loop}}} = \frac{-\frac{R_2}{R_1}}{1 + \frac{R_1 + R_2}{AR_1}} = \frac{G_{open}}{1 - G_{loop}} \]
A few notes

• Always remember to reconstruct the impedance if $R_o$ is present
• In any case, $G_{open}$ can always be calculated as
  \[ G_{open} = -G_{loop}G_{id} \]
• The closed-loop gain may contain an additional term (called direct gain or feedthrough gain) due to direct transfer through the feedback network. This term is usually small and neglected
Direct gain calculation (concept)

\[
G_{\text{open}} = 0
\]

\[
G_{\text{dir}} S_{\text{test}} = 0
\]

\[
G_{\text{dir}} = 0 \text{ is expected}
\]
$G_{dir}$ calculation (simple case)

$G_{dir} = 0$ is obtained
\[ G_{dir} = \frac{R_o}{R_o + R_1 + R_2} \]

\[ G = \frac{G_{\text{open}} + G_{dir}}{1 - G_{\text{loop}}} \]
Input impedance

\[ Z_{in} = \frac{V_T}{I_T} \approx R_d (1 - G_{loop}) \]

For \( G_{loop} = -\infty \) (ideal case), we get \( Z_{in} = \infty \)

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Output impedance

\[ Z_{\text{in}} = \frac{V_T}{I_T} \approx R_o \]

Impedance for \( G_{\text{loop}} = 0 \) (\( Z_{\text{open}} \))

\[ Z_{\text{in}} = \frac{V_T}{I_T} \approx \frac{R_o}{1 - G_{\text{loop}}} \]

For \( G_{\text{loop}} = -\infty \) (ideal case), we get \( Z_{\text{in}} = 0 \)
Procedure

1. Compute $Z_{in/out}$ in the ideal case

2. Decide between $Z_{open}(1 - G_{loop})$ (i.e., $Z_{ideal} = \infty$) and $Z_{open}/(1 - G_{loop})$ (i.e., $Z_{ideal} = 0$)

3. Compute terms
The inverting case

\[ Z_{in} = R_1 + \frac{R_2}{1 + A} \]
Closed-loop output impedance

- $I_0 = 1\text{ mA}$
- $V_S = \pm 15\text{ V}$
- $T_A = 25^\circ\text{C}$

**LT1128**
- $A_V = 1000$
- $A_V = 5$

**LT1028**

**LF155**
- $A_V = 100$
- $A_V = 1$
- $A_V = 10$

**FREQUENCY (Hz)**

**OUTPUT IMPEDANCE (Ω)**

- 100
- 10
- 1
- 0.1
- 0.01
- 0.001

- 1M
- 100k
- 10k
- 1k
- 100
- 10
- 1