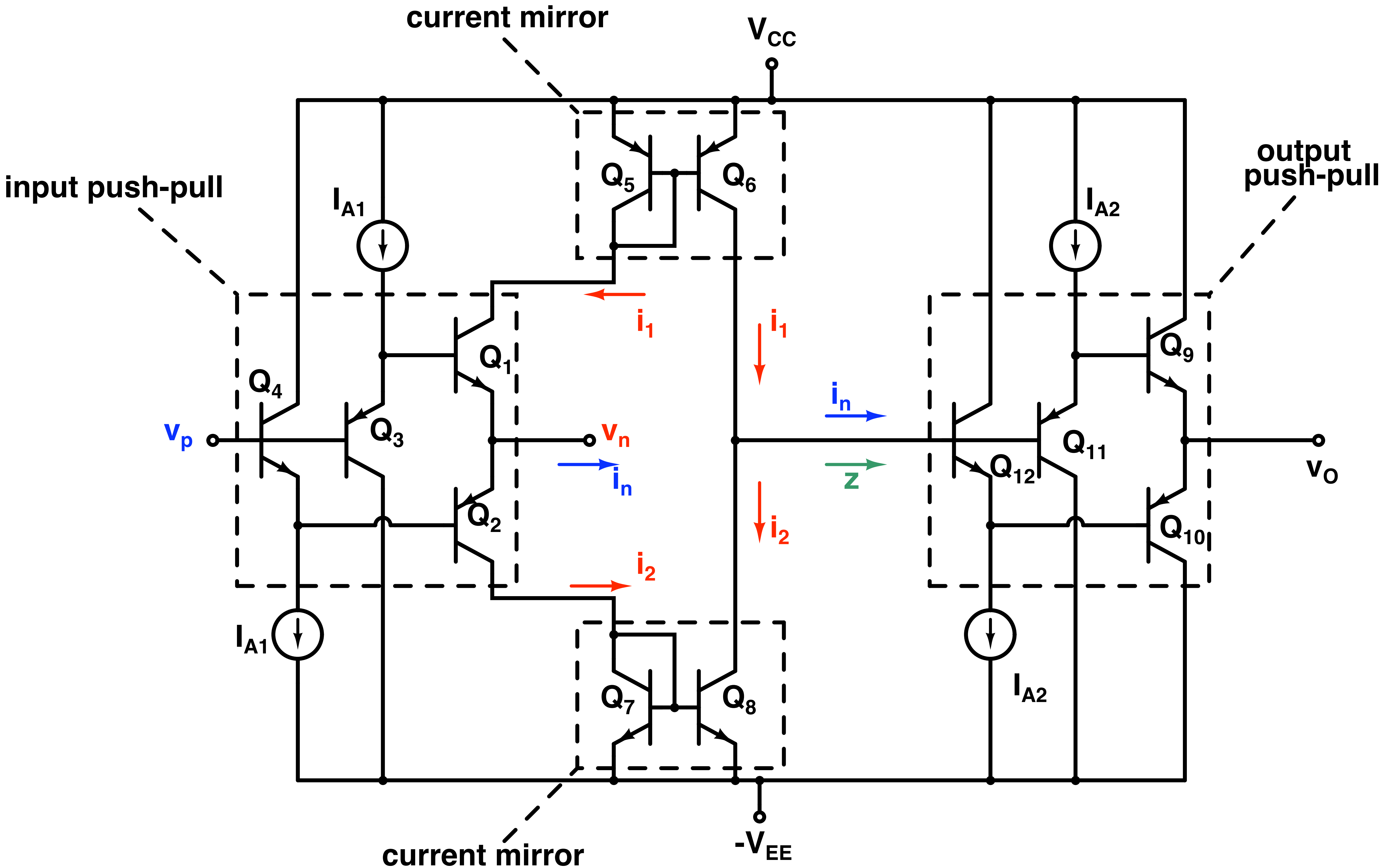
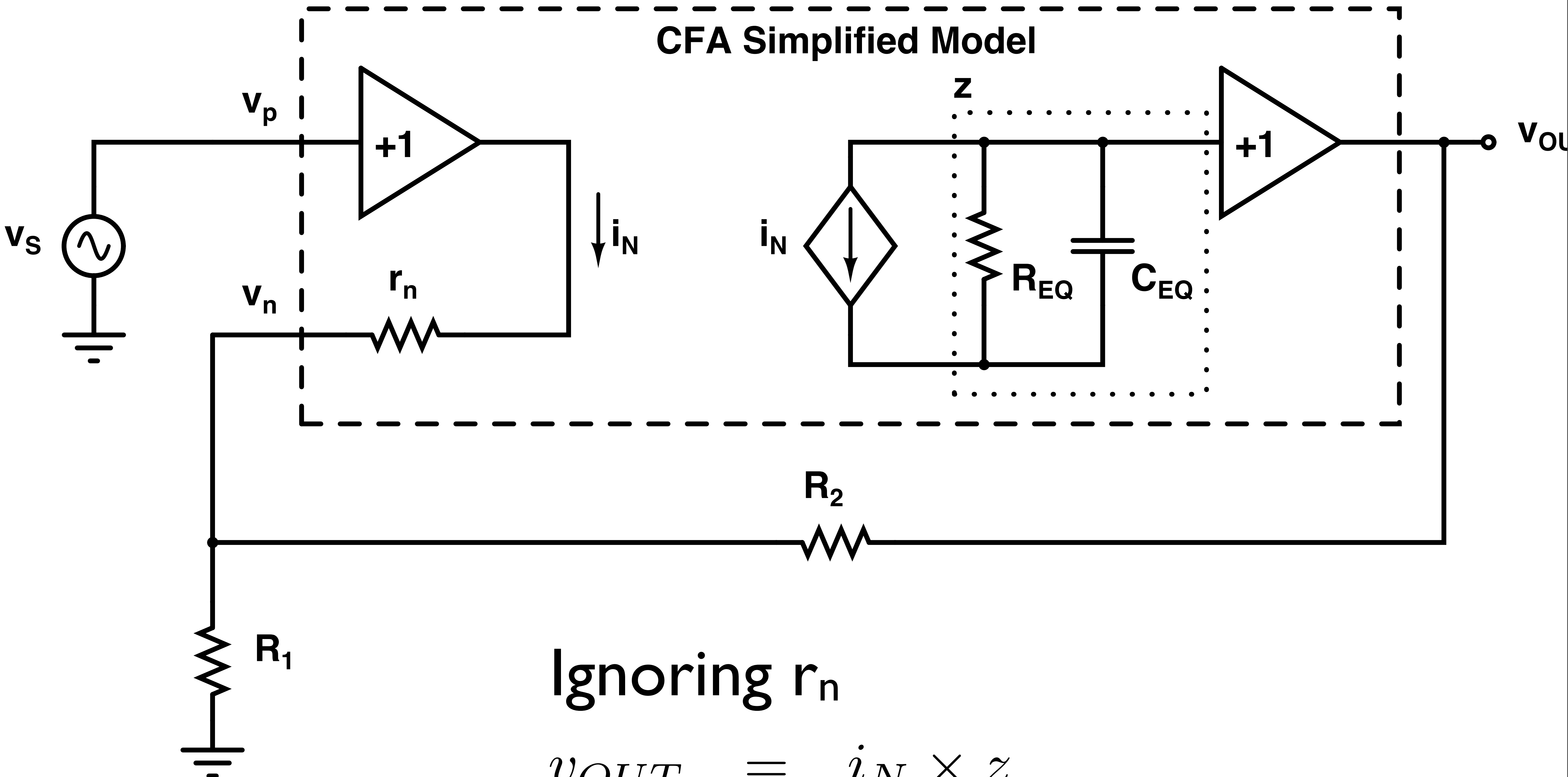
Current-feedback amplifiers (CFA)

INEL 5207 - Spring 2009


current mirror
V_{CC}
input push-pull
I_{A1}
Q_5
Q_6
output push-pull
I_{A2}
i_1
i_1
Q_1
Q_9
Q_4
i_n
v_p
Q_3
v_n
Q_{11}
Q_{12}
v_O
i_n
z
Q_2
i_2
Q_{10}
i_2
I_{A1}
I_{A2}
Q_7
Q_8
current mirror
$-V_{EE}$

- input buffer forces v_n to track v_p
- v_p: high input impedance and low bias current
- v_n: low output impedance and high current sourcing/sinking capability
- $i_n \approx 0$ during quescient operation (only error current)
- i_n is mirrored into the output section
- $v_{OUT} = z \times i_n$
- z is the *transimpedance gain* (like open-loop gain in VFA)



Ignoring r_n

$$
\begin{aligned}
v_{OUT} &= i_N \times z \\
i_N &= v_{OUT}/z \\
&= \frac{v_S}{R_1} + \frac{v_S}{R_2} - \frac{v_{out}}{R_2}
\end{aligned}
$$

$$v_S\left(\frac{1}{R_1}+\frac{1}{R_2}\right)=\left(\frac{1}{R_2}+\frac{1}{z}\right)v_{OUT}$$

For $z \gg R_2$,

$$\begin{aligned}\frac{v_{OUT}}{v_S} &= \frac{\frac{1}{R_1}+\frac{1}{R_2}}{\frac{1}{R_2}+\frac{1}{z}} \\ &= \left(1+\frac{R_2}{R_2}\right)\frac{1}{1+\frac{R_2}{z}} \\ &= \left(1+\frac{R_2}{R_2}\right)\frac{1}{1+\frac{1}{T}} \\ &\approx 1+\frac{R_2}{R_1}\end{aligned}$$

$$
\begin{aligned}
A &= \left(1+\frac{R_2}{R_1}\right)\frac{1}{1+\frac{R_2}{z}} \\
z &= \frac{R_{EQ}}{1+sR_{EQ}C_{EQ}} \\
A(s) &= \left(1+\frac{R_2}{R_1}\right)\frac{1}{1+\frac{R_2}{R_{EQ}}+sR_2C_{EQ}} \\
&\approx A_0\frac{1}{1+sR_2C_{EQ}} \\
A_0 &= 1+\frac{R_2}{R_1}
\end{aligned}
$$

- Select bandwidth with R_2, gain with R_1
- Bandwidth is independent of gain
- Stability is determined by loop gain $T = a\beta = \frac{z}{R_2}$
- $a = z$
- $\beta = \frac{1}{R_2}$
  - R_2 should never be zero since then $a\beta \to \infty$
  - R_2 is key for stability
  - typical optimal value $R_2 \approx 1k\Omega$.
- Step response $\tau = R_2 C_{eq}$

When r_n is taken into account,

$$
\begin{aligned}
R_2 &\rightarrow R_2\left(1 + r_n / \left(R_1 \| R_2\right)\right) \\
\frac{1}{\beta} &= R_2\left(1 + r_n / \left(R_1 \| R_2\right)\right) \\
f_B &= \frac{f_t}{1 + r_n / (R_2 \| R_1)} \\
f_t &= \frac{1}{2\pi R_2 C_{eq}}; \qquad A_0 = 1 + \frac{R_2}{R_1}
\end{aligned}
$$

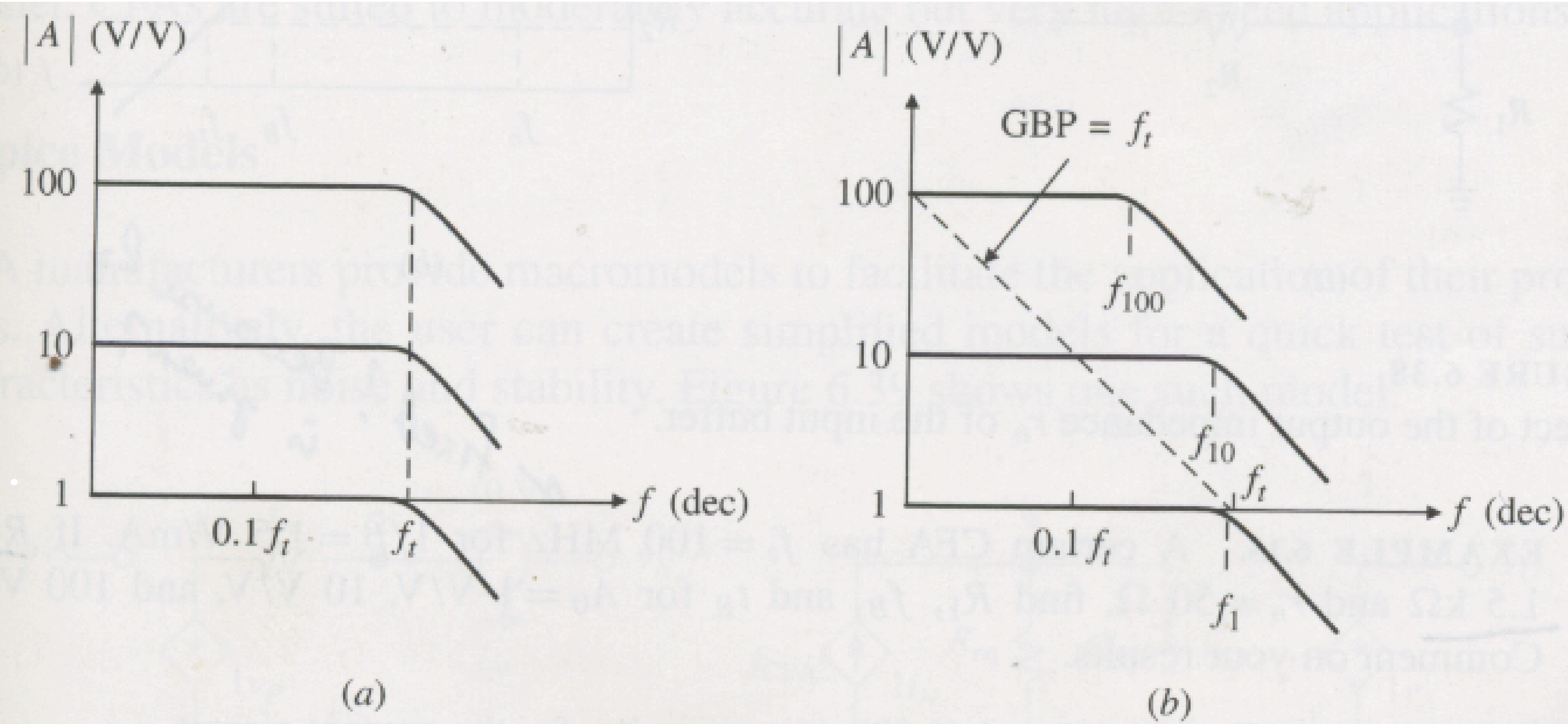


FIGURE 6.37
Closed-loop bandwidth as a function of gain for (*a*) an ideal CFA and (*b*) a practical CFA.

Inverting configuration is also possible; $A_0=-R_2/R_1$