AMPLIFIER INPUT AND OUTPUT IMPEDANCES

INEL 5207 - SPRING 2008

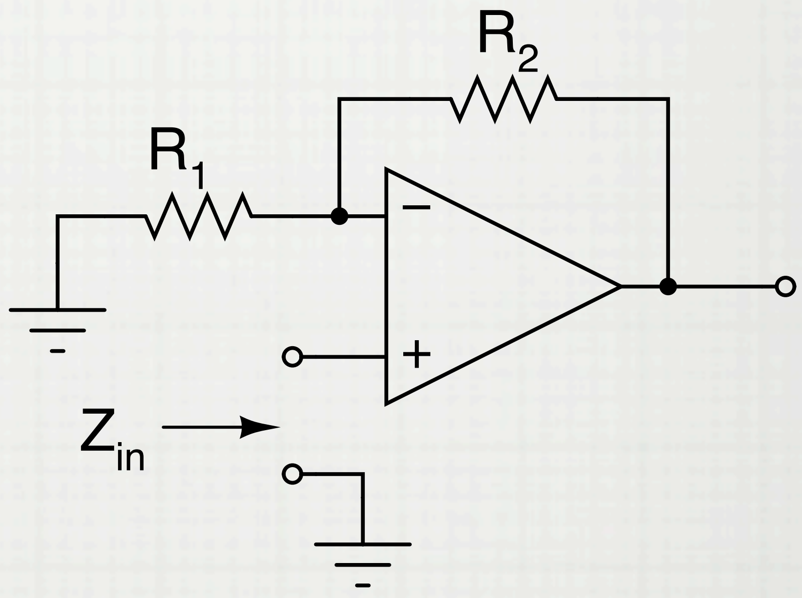
ECE DEPT. UPRM

EQUIVALENT IMPEDANCES

- OPAMP GAIN INTRODUCES A POLE IN THE CIRCUIT'S EQUIVALENT INPUT & OUTPUT IMPEDANCES
- THIS MEANS THAT THE SOURCE/LOAD WILL SEE A COMPLEX EQUIVALENT QUANTITY I.E. AND IMPEDANCE INSTEAD OF A RESISTANCE
- THUS THE LOADING AT THE INPUT/OUTPUT CAN POTENTIALLY AFFECT THE FREQUENCY RESPONSE
- NOTICE THAT THIS IS INDEPENDENT OF THE OPAMP COMMON-MODE AND -DIFERENTIAL-MODE PARASITIC CAPACITANCES

INPUT-SERIES

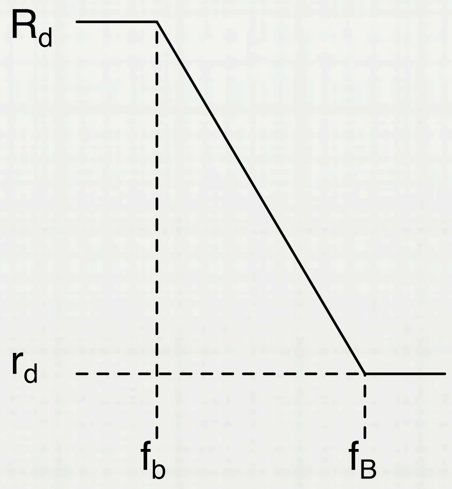
$$
\begin{aligned}
a &= \frac{a_0}{1 + j\frac{f}{f_b}} \\
Z_{IN} &= (1+T)r_d = \left(1 + \frac{\beta a_0}{1 + j\frac{f}{f_b}}\right) r_d \\
&= \frac{1 + \beta a_0 + j\frac{f}{f_b}}{1 + j\frac{f}{f_b}} r_d \\
&= \frac{1 + j\frac{f}{(1+\beta a_0) f_b}}{1 + j\frac{f}{f_b}} \left(1 + \beta a_0\right) r_d \\
&\approx \frac{1 + j\frac{f}{\beta a_0 f_b}}{1 + j\frac{f}{f_b}} \left(1 + \beta a_0\right) r_d \\
&= \frac{1 + j\frac{f}{f_B}}{1 + j\frac{f}{f_b}} R_d
\end{aligned}
$$

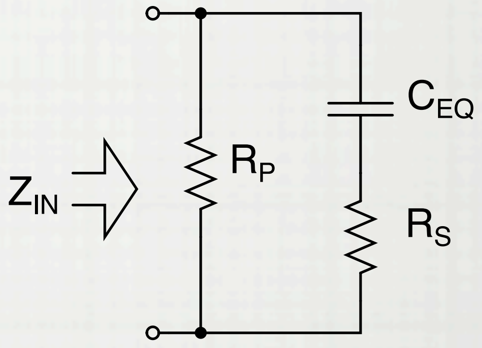


$$
\begin{aligned}
f_B &= \beta f_t = \beta a_0 f_b \\
R_d &= (1 + \beta a_0) r_d
\end{aligned}
$$

INPUT-SERIES

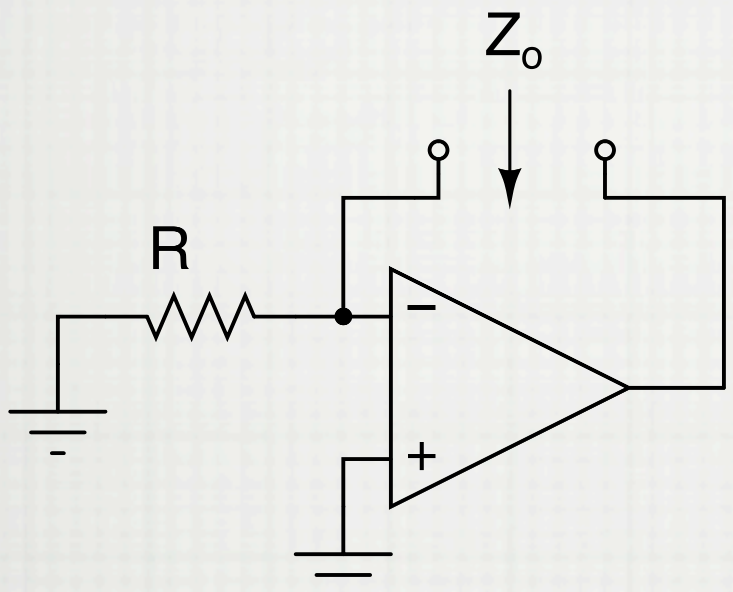
$$Z_{IN} = \frac{1 + j\frac{f}{f_B}}{1 + j\frac{f}{f_b}} R_d$$

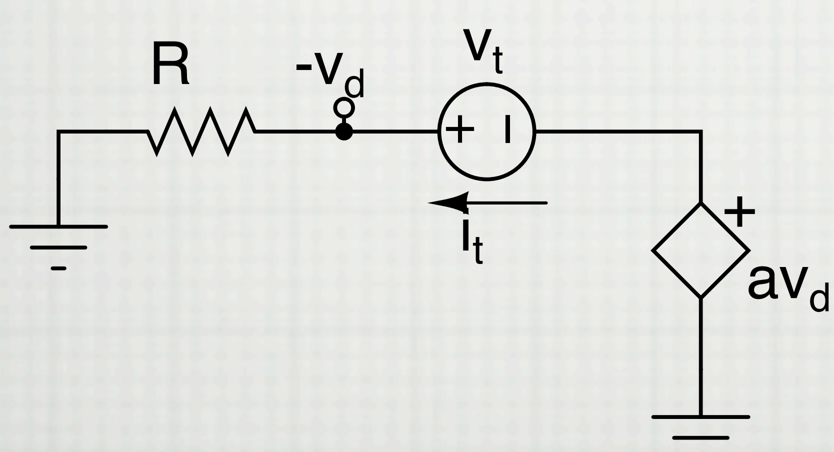




$$\begin{aligned} R_P &= R_d \\ R_S &= r_d \\ C_{EQ} &= \frac{1}{2\pi r_d f_B} = \frac{1}{2\pi r_d \beta f_t} \end{aligned}$$

OUTPUT-SERIES





$$i_t = -\frac{v_d}{R} \quad \Rightarrow \quad v_d = -i_t R$$

$$v_t = (1+a)v_d \quad = \quad -(1+a)Ri_t$$

$$a \quad = \quad \frac{a_0}{1 + j\frac{f}{f_b}}$$

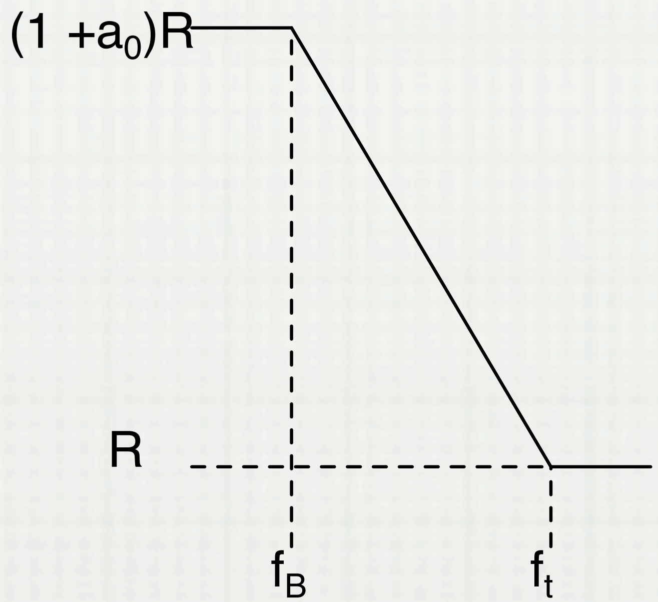
$$Z_{EQ} \quad = \quad -\left(1 + \frac{a_0}{1 + j\frac{f}{f_b}}\right) R$$

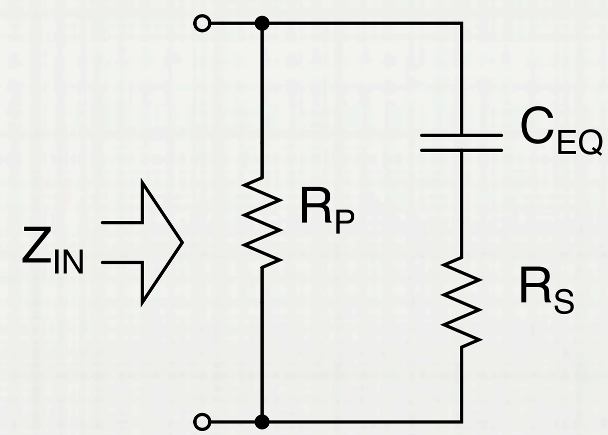
$$= \quad -\left(\frac{1 + j\frac{f}{f_b(1+a_0)}}{1 + j\frac{f}{f_b}}\right)(1+a_0)\,R$$

$$\approx \quad -\left(\frac{1 + j\frac{f}{a_0 f_b}}{1 + j\frac{f}{f_b}}\right)(1+a_0)\,R$$

$$\approx \quad -\left(\frac{1 + j\frac{f}{f_t}}{1 + j\frac{f}{f_b}}\right)(1+a_0)\,R$$

OUTPUT-SERIES

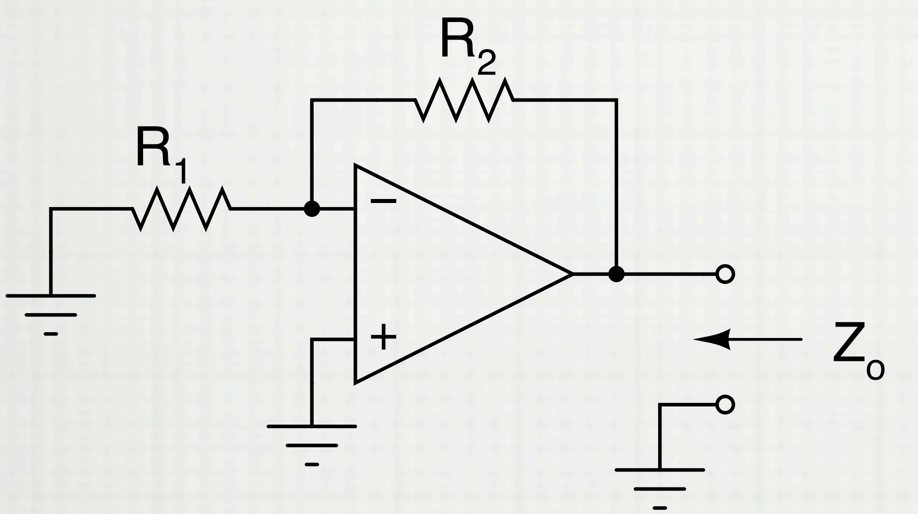




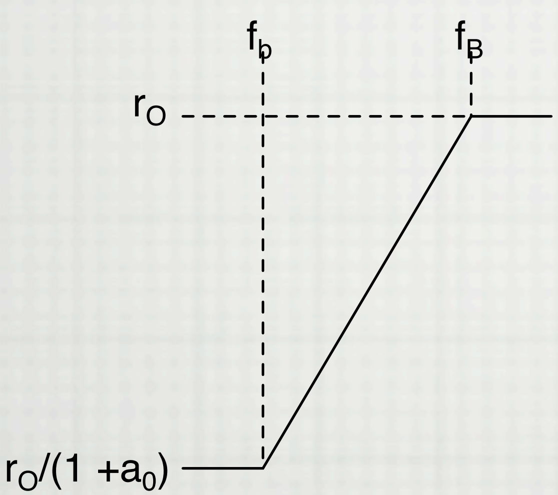
$$Z_{EQ} \quad \approx \quad -\left(\frac{1+j\frac{f}{f_t}}{1+j\frac{f}{f_b}}\right)(1+a_0)\,R$$

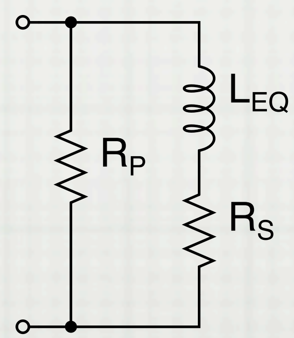
$$R_P = (1+a_0)R \quad R_S = R \quad C_{EQ} = \frac{1}{2\pi f_t R}$$

OUTPUT-SHUNT



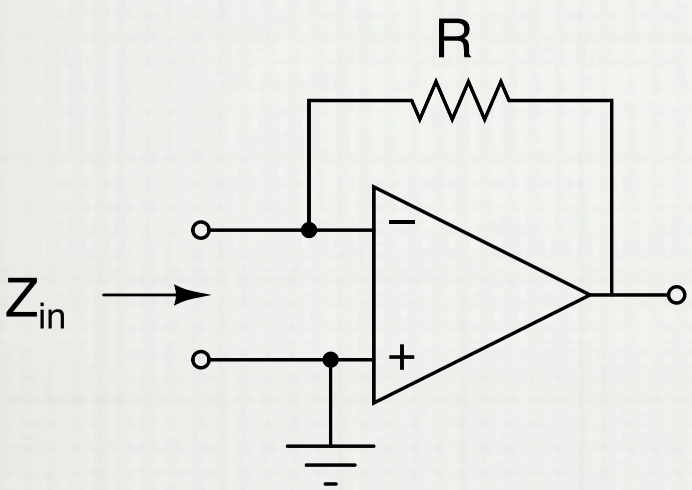
$$
\begin{aligned}
Z_O &= \frac{r_O}{1+\beta a} = \frac{r_O}{1+\frac{\beta a_0}{1+jf/f_b}} \\
&= \frac{(1+jf/f_b)\,r_O}{1+jf/f_b+\beta a_0} \\
&= \frac{1+jf/f_b}{1+jf/(1+\beta a_0)f_b}\,\frac{r_O}{1+\beta a_0} \\
&\approx \frac{1+jf/f_b}{1+j\frac{f}{\beta a_0 f_b}}\,\frac{r_O}{1+\beta a_0} \\
&\approx \frac{1+jf/f_b}{1+j\frac{f}{\beta f_t}}\,\frac{r_O}{1+\beta a_0} \\
&\approx \frac{1+j\frac{f}{f_b}}{1+j\frac{f}{f_B}}\,\frac{r_O}{1+\beta a_0}
\end{aligned}
$$

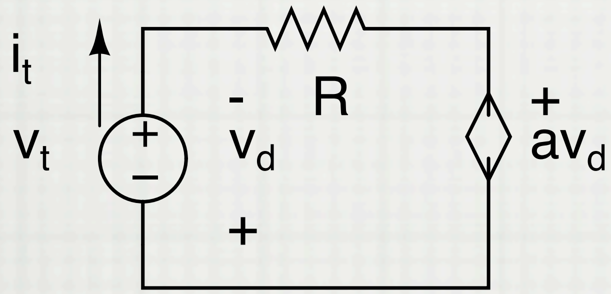




$$R_S = \frac{r_O}{1+a_0} \quad R_P = r_0 \quad L_{EQ} = \frac{r_O}{2\pi f_B}$$

INPUT-SHUNT

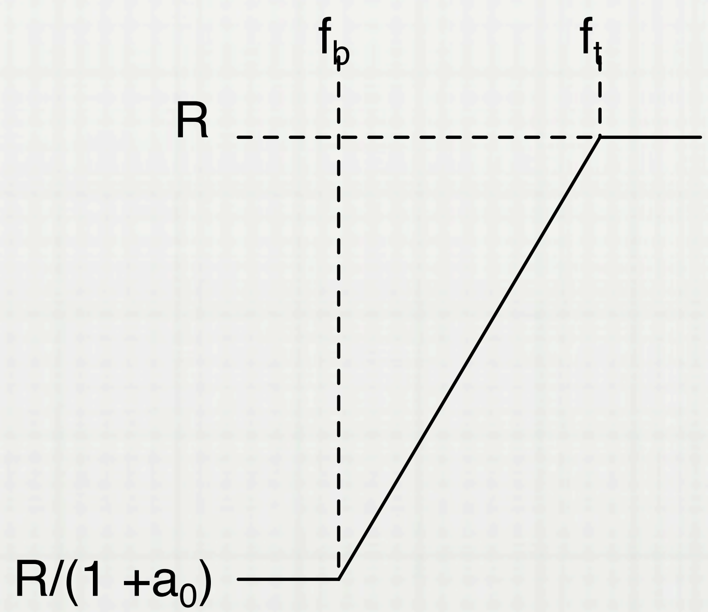


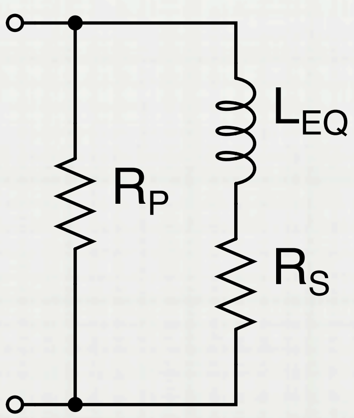


$$\begin{aligned} v_t &= i_t R - a v_t \\ v_t(1+a) &= i_t R \\ \frac{v_t}{i_t} &= Z_{EQ} = \frac{R}{1+a} \end{aligned}$$

$$\begin{aligned} Z_{EQ} &= \frac{R}{1 + \frac{a_0}{1+j\frac{f}{f_b}}} \\ &= \frac{1 + j\frac{f}{f_b}}{1 + a_0 + j\frac{f}{f_b}} R \\ &= \frac{1 + j\frac{f}{f_b}}{1 + j\frac{f}{(1+a_0)f_b}} \frac{R}{1+a_0} \\ &\approx \frac{1 + j\frac{f}{f_b}}{1 + j\frac{f}{a_0 f_b}} \frac{R}{1+a_0} \\ &\approx \frac{1 + j\frac{f}{f_b}}{1 + j\frac{f}{f_t}} \frac{R}{1+a_0} \end{aligned}$$

INPUT-SHUNT





$$R_P = R \quad R_S = \frac{R}{1 + a_0} \quad L_{EQ} = \frac{R}{2\pi f_t}$$