Frequency Response

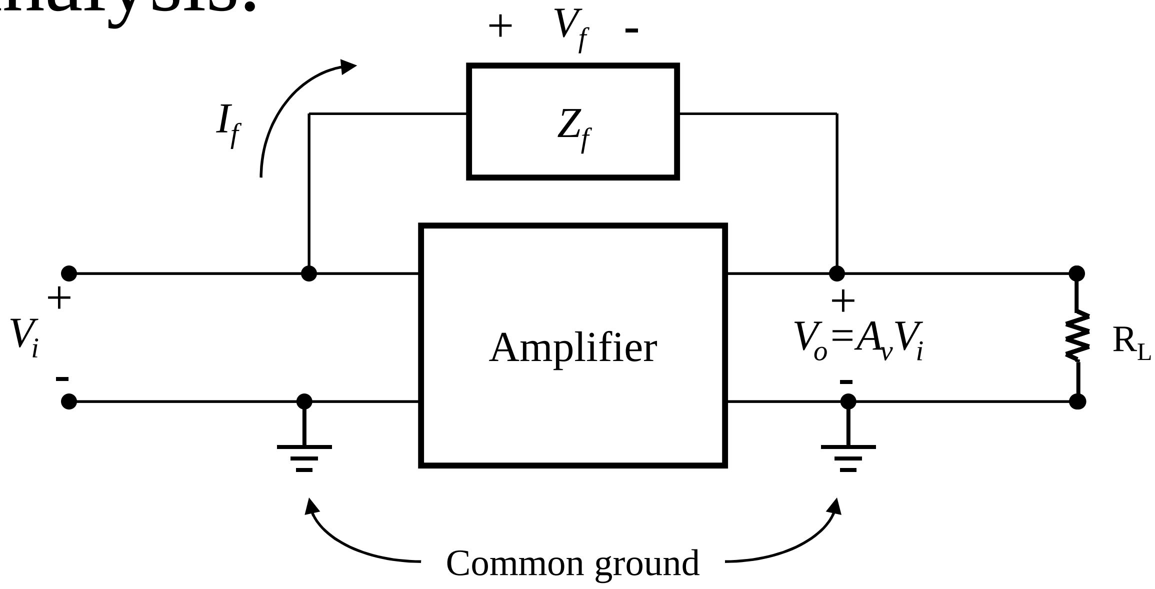
Lesson #11

Miller Effect

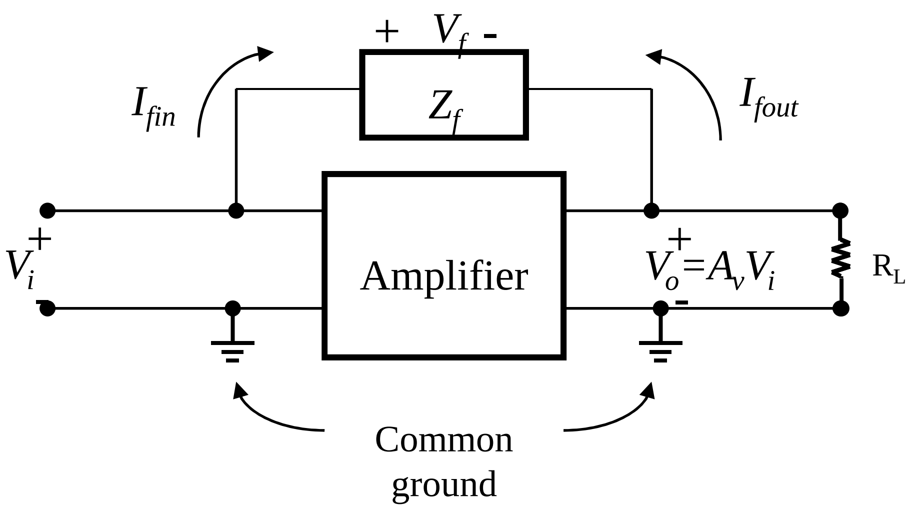
Section 8.3

Miller Effect for Feedback Amplifier

- The transformation of a feedback impedance into the input and output for ease of analysis.



Miller Effect Impedances



$$\mathbf{V}_f = \mathbf{V}_i - \mathbf{V}_o$$

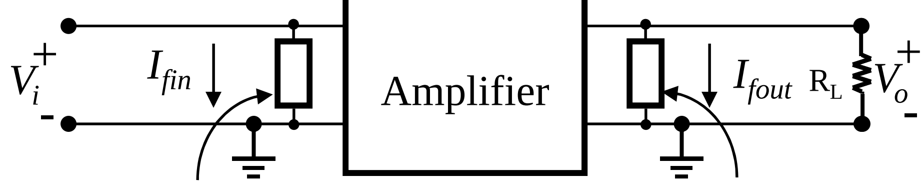
$$\mathbf{V}_o = A_v \mathbf{V}_i$$

where A_v is the voltage gain with Z_f in place and NOT A_{vo}

$$\mathbf{V}_f = (1 - A_v)\mathbf{V}_i$$

In the input

$$\mathbf{I}_{fin} = \frac{\mathbf{V}_f}{Z_f} = \frac{(1-A_v)\mathbf{V}_i}{Z_f} = \frac{\mathbf{V}_i}{Z_f/(1-A_v)} = \frac{\mathbf{V}_i}{Z_{\text{in Miller}}}$$



$$Z_{in\text{ Miller}} = \frac{Z_f}{1 - A_v}$$

$$Z_{\text{out Miller}} = \frac{Z_f A_v}{A_v - 1}$$

For $A_v >> 1,\ Z_{\text{out Miller}} = Z_f$

In the output

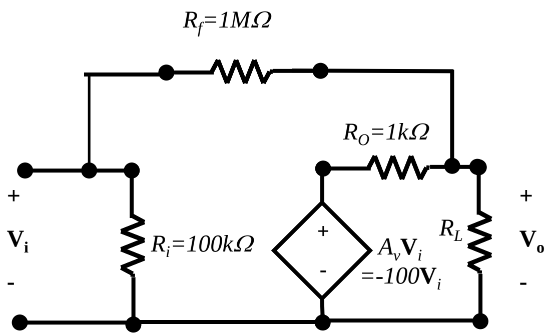
$$\mathbf{V}_f = \mathbf{V}_i - \mathbf{V}_o; \mathbf{V}_o = A_v \mathbf{V}_i$$

$$\mathbf{V}_f = \frac{\mathbf{V}_o}{A_v} - \mathbf{V}_o = \frac{(1-A_v)}{A_v}\mathbf{V}_o$$

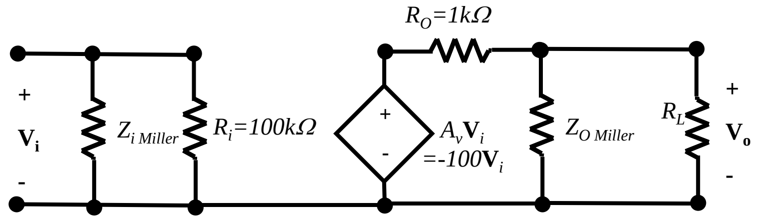
$$\mathbf{I}_{fout} = -\frac{\mathbf{V}_f}{Z_f} = -\frac{\mathbf{V}_o/A_v}{Z_f/(1-A_v)}$$

$$= \frac{\mathbf{V}_o}{Z_f A_v/(A_v - 1)} = \frac{\mathbf{V}_o}{Z_{\text{outMiller}}}$$

Miller Effect Example



$\Rightarrow$



Case A: Let $R_L = 9k\Omega$,

Case B: Let $R_L = 1k\Omega$

$$Z_{o\text{ Miller}} = \frac{Z_f A_v}{A_v - 1} = \frac{Z_f}{1 - 1/A_v} \approx Z_f \text{ for } A_v >> 1$$

$$Z_{o\text{ Miller}} = 1M\Omega$$

Case A: $R'_L = Z_{o\text{ Miller}} \| R_L = Z_f \| R_L = 1M \| 9k = 9k\Omega$

Case B: $R'_L = Z_{o\text{ Miller}} \| R_L = Z_f \| R_L = 1M \| 1k = 1k\Omega$

$$A_v = \frac{R'_L}{R'_L + R_o} A_{vo}$$

Case A: $A_v = \frac{9k}{9k + 1k}(-100) = -90$

Case B: $A_v = \frac{1k}{1k + 1k}(-100) = -50$

$$Z_{i\text{ Miller}} = \frac{Z_f}{1 - A_v}$$

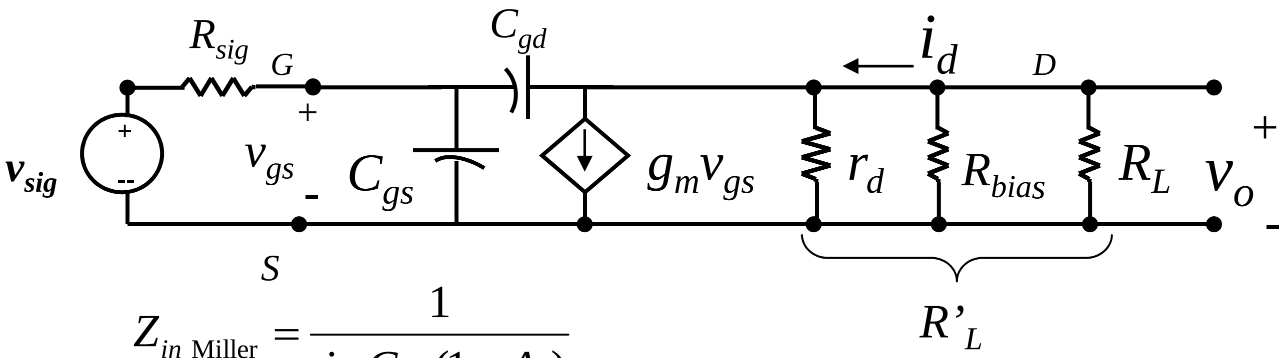
Case A: $Z_{i\text{ Miller}} = \frac{1M\Omega}{1-(-90)} = 10.98k\Omega;$

$$Z_{in} = Z_{i\text{ Miller}} \| R_i = 10.98k \| 100k = 9.9k\Omega$$

Case B: $Z_{i\text{ Miller}} = \frac{1M\Omega}{1-(-50)} = 19.6k\Omega;$

$$Z_{in} = Z_{i\text{ Miller}} \| R_i = 19.6k \| 100k = 16.39k\Omega$$

Miller Effect for Feedback Capacitance

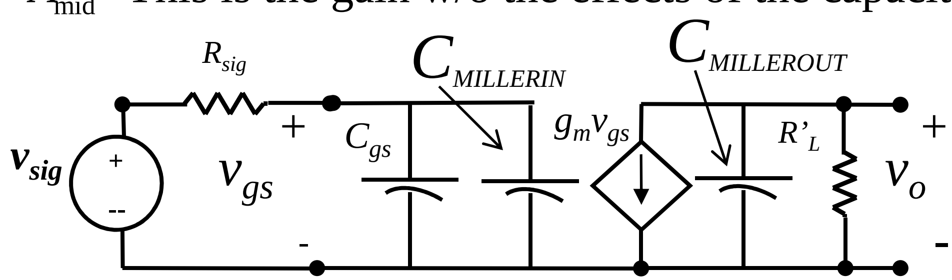


$$Z_{in\ \mathrm{Miller}} = \frac{1}{j\omega C_{gd}(1 - A_v)}$$

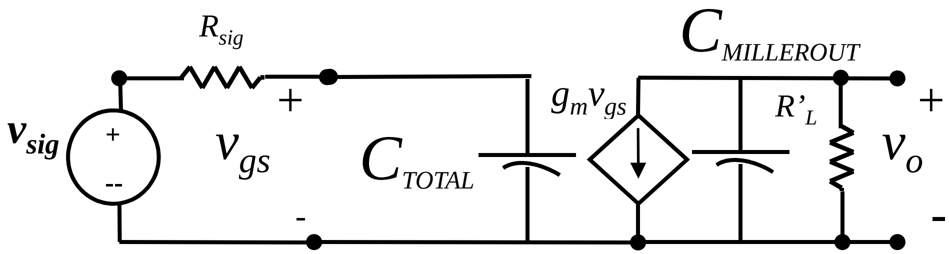
$$Z_{out\ \mathrm{Miller}} = \frac{A_v}{j\omega C_{gd}(A_v - 1)} \approx \frac{1}{j\omega C_{gd}}$$

Note:

$A_v = A_{\mathrm{mid}}$ This is the gain w/o the effects of the capacitance i.e., all resistive.



Miller Effect for Feedback Capacitance



$$v_o = -g_m v_{gs} R_L' \| Z_{MILLEROUT} = -g_m v_{gs} \frac{R_L' \times \frac{1}{j\omega C_{MILLEROUT}}}{R_L' + \frac{1}{j\omega C_{MILLEROUT}}}$$

$$= -g_m v_{gs} \frac{R_L'}{j\omega C_{MILLEROUT} R_L' + 1} = -g_m v_{gs} \frac{R_L'}{j(\frac{f}{f_{bOUT}}) + 1}$$

$$f_{bOUT} = \frac{1}{2\pi R_L' C_{MILLEROUT}} = \frac{1}{2\pi R_L' C_{gd}}$$

Miller Effect for Feedback Capacitance

$$v_{gs} = \frac{Z_{CTOTAL}}{Z_{CTOTAL} + R_{sig}} v_{sig} = \frac{\frac{1}{j\omega C_{TOTAL}}}{\frac{1}{j\omega C_{TOTAL}} + R_{sig}} v_{sig} = \frac{1}{1 + j\omega C_{TOTAL} R_{sig}} v_{sig} = \frac{1}{j(\frac{f}{f_{bIN}}) + 1} v_{sig}$$

$$f_{bIN} = \frac{1}{2\pi R_{sig} C_{TOTAL}} = \frac{1}{2\pi R_{sig}[C_{gs} + (1 - A_{mid})C_{gd}]}$$

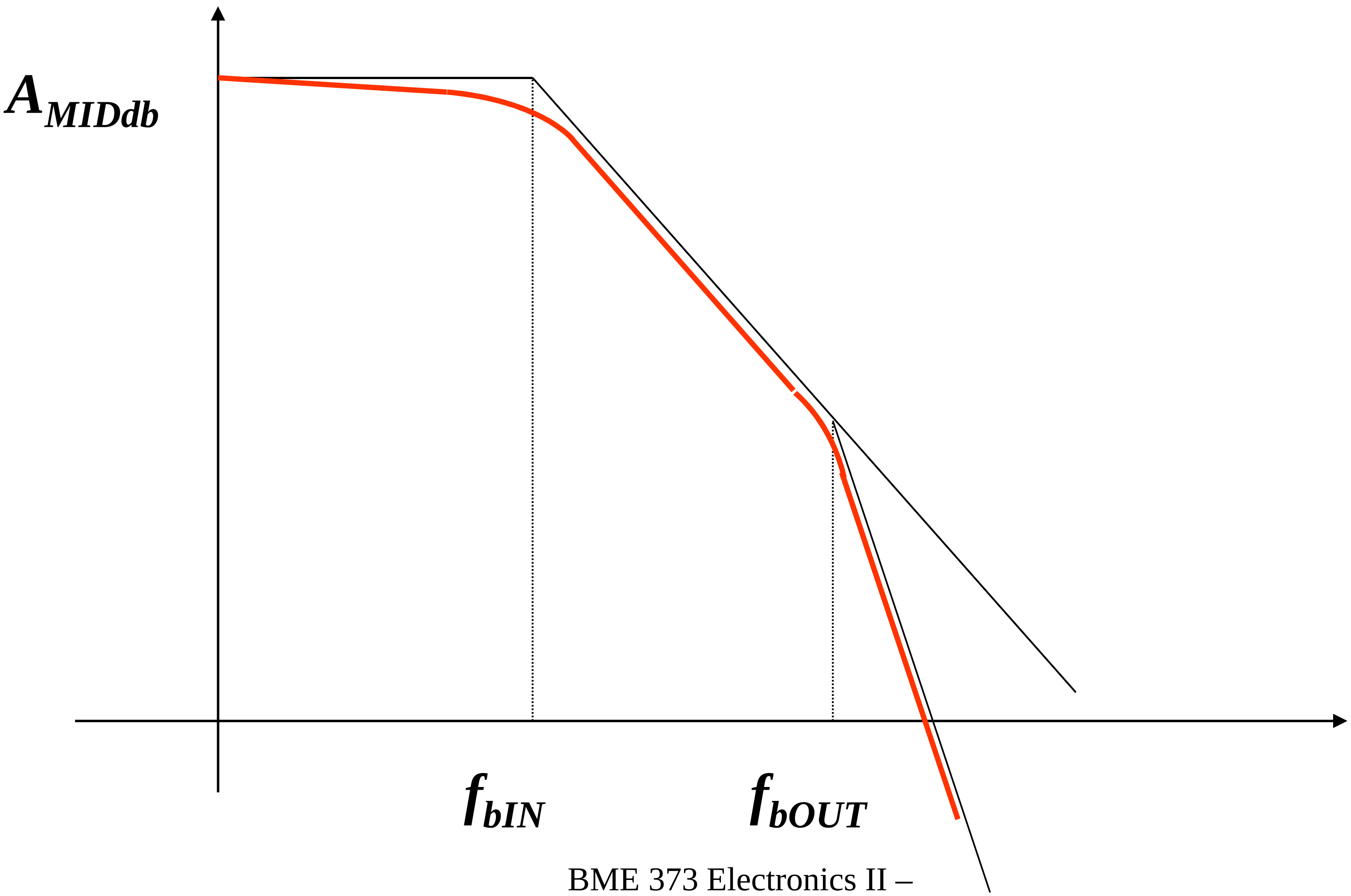
$$\frac{v_o}{v_{sig}} = A_{vs} = -g_m \frac{R_L'}{j(\frac{f}{f_{bOUT}}) + 1} \times \frac{1}{j(\frac{f}{f_{bIN}}) + 1} = -g_m R_L' \frac{1}{[j(\frac{f}{f_{bOUT}}) + 1][j(\frac{f}{f_{bIN}}) + 1]}$$

If $R_{sig}[C_{gs} + (1 - A_{mid})C_{gd}] >> R_L' C_{gd}$, then $f_{bIN} << f_{bOUT}$

$$BW = f_{bIN} = \frac{1}{2\pi R_{sig}[C_{gs} + (1 - A_{mid})C_{gd}]}$$

$$GB = A_{mid} f_{bIN} = A_{mid} \frac{1}{2\pi R_{sig}[C_{gs} + (1 - A_{mid})C_{gd}]} \approx \left| \frac{1}{2\pi R_{sig} C_{gd}} \right| \text{ for } A_{mid} >> 1$$

Miller Effect for Feedback Capacitance



Homework

- Miller Effect
  - Problems: 8.20-24, 8.27