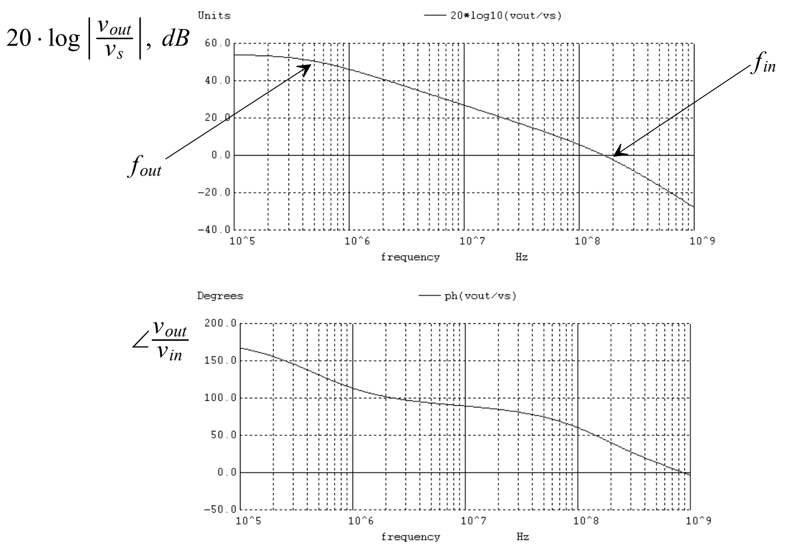



**Figure 21.36** The simulation results for Ex. 21.12.

*Class A Operation*

The cascode amplifier in Fig. 21.35 is another example of a class A amplifier. When the input of the amplifier goes sufficiently negative, M1 shuts off. M3 and M4 are a current source and so the maximum rate that the load capacitance can be charged is given by Eq. (21.38). For the amplifier in Fig. 21.35, this is 10 μA/100 *fF* or 100 mV/ns.

*Noise Performance of the Cascode Amplifier*

The cascode's output noise power spectral density is given by

$$V_{onoise}^2(f) = \left(g_{mn} r_{on}^2 || g_{mp} r_{op}^2\right)^2 \left(I_{M1}^2 + I_{M4}^2\right) \qquad (21.79)$$

where the noise contributions from M2/M3 are negligible, see Fig. 21.44. The input-referred noise power is then ($g_{m1} = g_{mn}$)

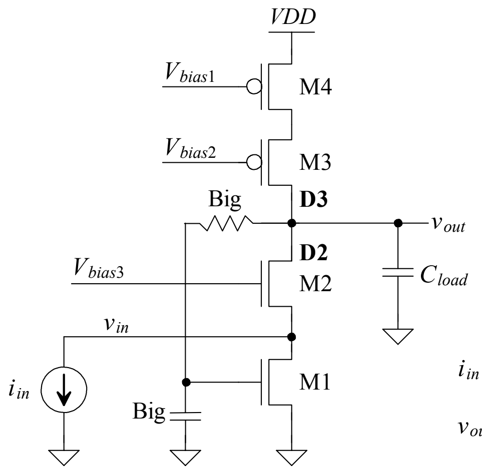
$$V_{inoise}^2(f) = \frac{V_{onoise}^2(f)}{A_v^2} = \frac{\left(I_{M1}^2 + I_{M4}^2\right)}{(g_{m1})^2} \qquad (21.80)$$

Again, maximizing the transconductance of the amplifying device (equivalent to saying maximizing the gain of the amplifier) reduces the input-referred noise.

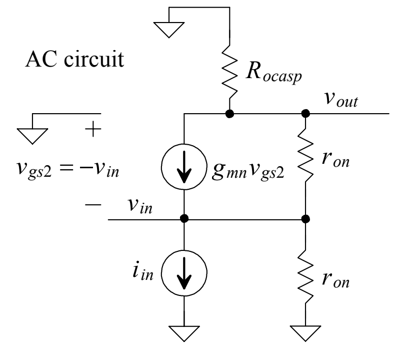
*Operation as a Transimpedance Amplifier*

Figure 21.37 shows a transimpedance amplifier (current input and voltage output). Note that the AC voltages between the gates and sources of M1 and M4 are zero (both the gates and the sources are at AC ground). From the figure the input resistance is

$$R_{in} = \frac{-v_{in}}{i_{in}} = \frac{1 + \frac{R_{ocasp}}{r_{on}}}{g_{mn} + \frac{2}{r_{on}} + \frac{R_{ocasp}}{r_{on}^2}} \qquad (21.81)$$




See Table 9.2 and Fig. 20.47




$$i_{in} + \frac{v_{in}}{r_{on}} = g_{mn} \cdot (-v_{in}) + \frac{v_{out} - v_{in}}{r_{on}}$$

$$v_{out} = -\left(i_{in} + \frac{v_{in}}{r_{on}}\right) \cdot R_{ocasp}$$

$$i_{in}\left(1 + \frac{R_{ocasp}}{r_{on}}\right) = -v_{in}\left(g_{mn} + \frac{2}{r_{on}} + \frac{R_{ocasp}}{r_{on}^2}\right)$$

**Figure 21.37** A transimpedance amplifier.

noting that if the drain of M2 is at AC ground or a low impedance then $R_{in}$ is approximately $1/g_{mn}$. If $r_{on} \approx r_{op} \approx r_o$, $g_m = g_{mn} \approx g_{mp}$, and $R_{ocasp} \approx R_{ocasn} \approx g_m r_o^2$ then

$$R_{in} \approx \frac{\frac{R_{ocasp}}{r_{on}}}{2g_{mn}} \approx \frac{r_o}{2} \text{ and thus } v_{in} = -\frac{r_o}{2} \cdot i_{in} \tag{21.82}$$

To calculate the gain we can write

$$v_{out} = -\left(i_{in} + \frac{v_{in}}{r_{on}}\right) \cdot R_{ocasp} \rightarrow \frac{v_{out}}{i_{in}} = -\frac{R_{ocasp}}{2} \tag{21.83}$$

In terms of the NMOS and PMOS cascodes we can write

$$\frac{v_{out}}{i_{in}} = -g_{mn}r_{on}^2 || g_{mp}r_{op}^2 = -R_{ocasn} || R_{ocasp} \tag{21.84}$$

In other words the output voltage is simply the product of the input current with the cascode amplifier's output resistance.

### 21.2.3 The Common-Gate Amplifier

M2 in Fig. 21.37 is an example of a common-gate (CG) amplifier. We can redraw this circuit, as seen in Fig. 21.38 with a voltage source input, to show how the gate of the amplifying device, M2, is common to both the input and the output of the amplifier. Though the gate of M2 is at a DC voltage of $V_{bias3}$, we think of it as being at AC ground. M1 is simply an ordinary current source while M3 and M4 are a cascode current source load. The input resistance of this amplifier is given by Eq. (21.81); however, by connecting the input to a voltage source the output resistance and gain change. The voltage gain can be calculated by first writing

$$\frac{v_{out}}{R_{ocasp}} + g_{mn} \cdot (-v_{in}) + \frac{v_{out} - v_{in}}{r_{on}} = 0 \tag{21.85}$$

See Table 9.2 and Fig. 20.47

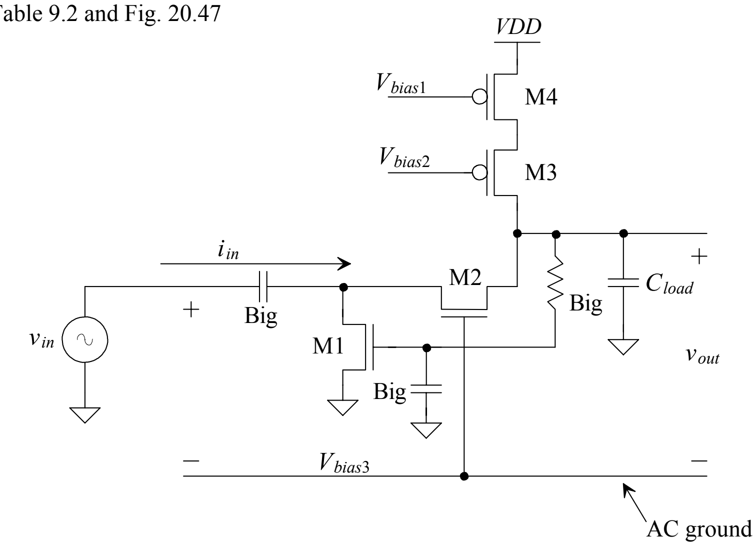



**Figure 21.38** A common-gate amplifier.

or

$$A_v = \frac{v_{out}}{v_{in}} = \frac{g_{mn} + \frac{1}{r_{on}}}{\frac{1}{R_{ocasp}} + \frac{1}{r_{on}}} = \frac{R_{ocasp}||r_{on}}{\frac{1}{g_{mn}}||r_{on}} \approx g_{mn} \cdot r_{on} \tag{21.86}$$

where, because the source of M2 is connected to a voltage source, the amplifier's output resistance is $R_{ocasp}||r_{on} \approx r_{on}$.

### 21.2.4 The Source Follower (Common-Drain Amplifier)

The source follower (SF) with current source load is seen in Fig. 21.39. Looking at the NMOS SF, we can write, for AC small signals,

$$v_{in} = v_{gs2} + v_{out} \tag{21.87}$$

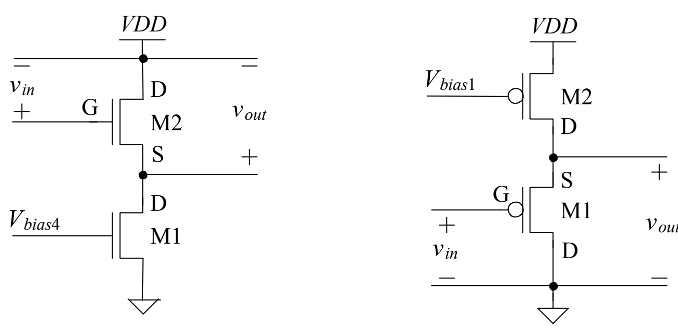



**Figure 21.39** Source followers (common drain) using current source loads.