In other words the gain of the amplifier is $R_F\,(v_{out}/i_s)$ and its bandwidth is

$$f_{3dB} = \frac{1}{2\pi R_F C_F}$$

which is 1.59 kHz. We can estimate the output RMS noise knowing the gain-bandwidth product, f_{un}, of the TLC220 op-amp is 2 MHz, the gain of the op-amp's input-referred noise to the output is one (and thus has a bandwidth of 2 MHz), and using Eqs. (8.56), (8.15), and (8.24) as

$$V^2_{onoise,RMS} = \overbrace{49 \cdot 3.14 \times 10^{-15}}^{=154\times10^{-15}} + \overbrace{64 \times 10^{-18} \cdot \frac{\pi}{2} \cdot 2\ MHz}^{=200\times10^{-12}} + \overbrace{\frac{kT}{C_F}}^{=4\times10^{-12}}$$

$$V_{onoise,RMS} \approx \sqrt{(0.392)^2 + (14.14)^2 + (2.07)^2} = 14.3\ \mu V$$

The op-amp's thermal noise dominates the output RMS noise. Our estimate for the flicker noise is high. However, it's easy to throw some numbers in for high and low frequencies in Eq. (8.55) and convince ourselves that the result isn't impacted too much. For example, we used $\ln\frac{10^{11}}{10^{-10}} \approx 49$ (yes, it's closer to 48 but we use 49 because the square-root is a whole number, i.e., 7) when we derived Eq. (8.55). If we were to use instead $\ln\frac{10^{5}}{10^{-10}}$ (a million times smaller upper frequency), we get 34.5 (a square root of roughly 6). The impact on the result is too small to worry about (unless, of course, the bandwidth is very narrow as in Ex. 8.16).

Dropping the feedback capacitance to 1 pF increases the bandwidth to 1.59 MHz and increases the RMS output noise due to R_F (kT/C noise) to 64 µV.

Our output signal is determined using $i_s \cdot R_F$. An SNR_{out} of 0 dB, in this example with C_F = 1,000 pF, would correspond to an i_s of roughly 143 pA (= $I_{inoise,RMS} = V_{onoise,RMS}/R_F$). If we wanted an input signal to produce an output that is larger than the peak-to-peak value of the output noise (here, from Fig. 8.33, $> 6 \times 14.3\,\mu V$), then $i_s > 858\ pA$. ■

Example 8.18
Verify Ex. 8.17 using SPICE. Use a voltage-controlled voltage source for the op-amp (neglect the op-amp noise).

The schematic used for simulations is seen in Fig. 8.37. Instead of connecting the op-amp's noninverting input (the + input) to ground directly, we connect it to

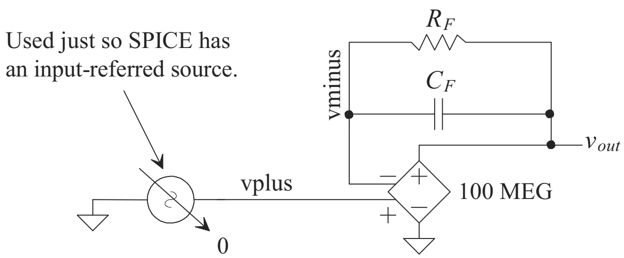

Figure 8.37 Using a voltage-controlled voltage source for an op-amp in SPICE.