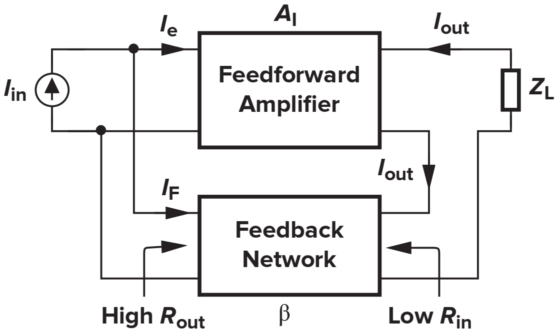

Figure 8.41 Current-current feedback.

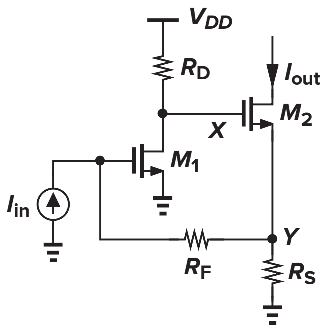

Figure 8.42

Figure 8.42 illustrates an example of current-current feedback. Here, since the source and drain currents of M_2 are equal (at low frequencies), resistor R_S is inserted in the source network to monitor the output current. Resistor R_F plays the same role as in Fig. 8.39.

8.3 ■ Effect of Feedback on Noise

Feedback does not improve the noise performance of circuits. Let us first consider the simple case illustrated in Fig. 8.43(a), where the open-loop voltage amplifier A_1 is characterized by only an input-referred noise voltage and the feedback network is noiseless. We have $(V_{in} - \beta V_{out} + V_n)A_1 = V_{out}$, and hence

$$V_{out} = (V_{in} + V_n)\frac{A_1}{1 + \beta A_1} \tag{8.54}$$

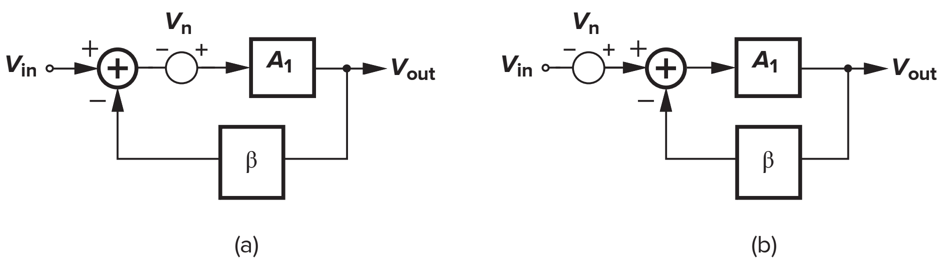

Figure 8.43 Feedback around a noisy circuit.

Thus, the circuit can be simplified as shown in Fig. 8.43(b), revealing that the input-referred noise of the overall circuit is still equal to V_n. This analysis can be extended to all four feedback topologies to prove that the input-referred noise voltage and current remain the same if the feedback network introduces no noise. In practice, the feedback network itself may contain resistors or transistors, degrading the overall noise performance.

It is important to note that in Fig. 8.43(a), the output of interest is the same as the quantity sensed by the feedback network. This need not always be the case. For example, in the circuit of Fig. 8.44, the output is provided at the drain of M_1 whereas the feedback network senses the voltage at the source of M_1. In such cases, the input-referred noise of the closed-loop circuit may not be equal to that of the open-loop circuit even if the feedback network is noiseless. As an example, let us consider the topology of Fig. 8.44 and, for simplicity, take only the noise of R_D, $V_{n,RD}$, into account. The reader can prove that the closed-loop voltage gain is equal to $-A_1 g_m R_D/[1 + (1 + A_1)g_m R_S]$ if $\lambda = \gamma = 0$, and hence the input-referred noise voltage due to R_D is

$$\left|V_{n,in,closed}\right| = \frac{|V_{n,RD}|}{A_1 R_D}\left[\frac{1}{g_m} + (1 + A_1)R_S\right] \tag{8.55}$$

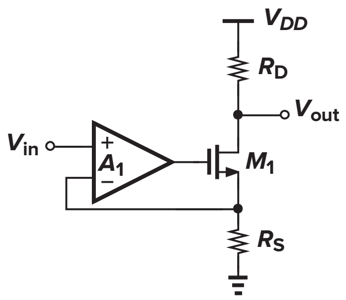

Figure 8.44 Noisy circuit with feedback sensing the source voltage.

For the open-loop circuit, on the other hand, the input-referred noise is

$$\left|V_{n,in,open}\right| = \frac{|V_{n,RD}|}{A_1 R_D}\left[\frac{1}{g_m} + R_S\right] \tag{8.56}$$

Interestingly, as $A_1 \to \infty$, $|V_{n,in,closed}| \to |V_{n,RD}|R_S/R_D$ whereas $|V_{n,in,open}| \to 0$.

8.4 ■ Feedback Analysis Difficulties

Our study of feedback systems has made some simplifying assumptions that may not hold in all circuits. In this section, we point out five difficulties that arise in the analysis of feedback circuits, and in subsequent sections, we deal with some of them.

The analysis approach described previously proceeds as follows: (a) break the loop and obtain the open-loop gain and input and output impedances, (b) determine the loop gain, βA_0, and hence the closed-loop parameters from their open-loop counterparts, and (c) use the loop gain to study properties such as stability (Chapter 10), etc. However, this approach faces issues in some circuits.

The first difficulty relates to breaking the loop and stems from the "loading" effects imposed by the feedback network upon the feedforward amplifier. For example, in the noninverting amplifier of Fig. 8.45(a) and its simple implementation shown in Fig. 8.45(b), the feedback branch consisting of R_1 and R_2 may draw a significant signal current from the op amp, reducing its *open-loop* gain. Figure 8.45(c) depicts another case, in which the open-loop gain of the forward CS stage falls if R_F is not very large. In both cases, this "output" loading results from the nonideal input impedance of the feedback network.