It is this subtraction that makes the feedback negative. In essence, *negative feedback reduces the signal that appears at the input of the basic amplifier*. Here, too, we assume that connecting the output of the feedback network to the amplifier input, through the subtractor or differencing circuit, does not change the gain $A$; that is, *the feedback network does not load the amplifier input.*

### 11.1.2 The Closed-Loop Gain

The gain of the feedback amplifier, known as the closed-loop gain or the **gain-with-feedback** and denoted $A_f$, is defined as

$$A_f \equiv \frac{x_o}{x_s}$$

Combining Eqs. (11.1) through (11.3) provides the following expression for $A_f$:

$$A_f = \frac{A}{1+A\beta} \tag{11.4}$$

The quantity $A\beta$ is called the **loop gain**, a name that follows from Fig. 11.1. For the feedback to be negative, the loop gain $A\beta$ must be positive; that is, the feedback signal $x_f$ should have the same sign as $x_s$, resulting in a smaller difference signal $x_i$. Equation (11.4) indicates that for positive $A\beta$ the gain with feedback $A_f$ will be smaller than the open-loop gain $A$ by a factor equal to $1 + A\beta$, which is called the **amount of feedback**.

If, as is the case in many circuits, the loop gain $A\beta$ is large, $A\beta \gg 1$, then from Eq. (11.4) it follows that

$$A_f \simeq \frac{1}{\beta} \tag{11.5}$$

which is a very interesting result: *When the loop gain is large, the gain of the feedback amplifier is almost entirely determined by the feedback network*. Since the feedback network usually consists of passive components, which usually can be chosen to be as accurate as we want, the advantage of negative feedback in obtaining accurate, predictable, and stable gain should be apparent. In other words, the overall gain will have very little dependence on the gain of the basic amplifier, $A$, a desirable property because the gain $A$ is usually a function of many manufacturing and application parameters, some of which might have wide tolerances. We saw a dramatic illustration of all of these effects in op-amp circuits in Chapter 2, where the closed-loop gain is almost entirely determined by the feedback elements. Generally, we will consider $(1/\beta)$ to be the ideal value of $A_f$,

$$A_f\,|_{\text{ideal}} = \frac{1}{\beta} \tag{11.6}$$

The deviation of $A_f$ from the ideal value can be quantified by writing the expression in Eq. (11.4) in the form

$$A_f = \left(\frac{1}{\beta}\right)\frac{A\beta}{1+A\beta} \tag{11.7}$$

Thus,

$$A_f = A_f\,|_{\text{ideal}}\;\frac{1}{1+(1/A\beta)} \tag{11.8}$$