2-5 NOISE FIGURE

Noise factor, F, also called *noise figure*, is a figure-of-merit for a device or a circuit with respect to noise. According to IEEE standards, *the noise factor of a two-port device is the ratio of the available output noise power per unit bandwidth to the portion of that noise caused by the actual source connected to the input terminals of the device, measured at the standard temperature of 290°K* [2]. This definition of noise factor in equation form is

$$F = \frac{\text{total available output noise power}}{\text{portion of output noise power caused by } E_t \text{ of source resistance}} \tag{2-9}$$

An equivalent definition of noise factor is

$$F = \frac{\text{input signal-to-noise ratio}}{\text{output signal-to-noise ratio}} = \frac{S_i/N_i}{S_o/N_o} \tag{2-10}$$

Noise factor, since it is a power ratio, can be expressed in dB. The logarithmic expression for noise figure NF is

$$\text{NF} = 10 \log F \tag{2-11}$$

As in much of the literature, the symbol F refers to noise factor and NF is used for the logarithmic noise figure.

Noise figure is a measure of the signal-to-noise degradation attributed to the amplifier. For a perfect amplifier, one that adds no noise to the thermal noise of the source, noise factor $F = 1$ and the noise figure $\text{NF} = 0$. It is sometimes possible to approximate a perfect system.

The noise figure NF can be defined in terms of E_n and I_n. Thus

$$\text{NF} = 10 \log \frac{E_{ni}^2}{E_t^2} = 10 \log \frac{E_t^2 + E_n^2 + I_n^2 R_s^2}{E_t^2} \tag{2-12}$$

This equation shows that the noise figure can also be expressed as the ratio of the total mean square equivalent input noise to the mean square thermal noise of the source.

An illustration of noise factor can be obtained from Fig. 2-2*b*. Noise factor is proportional to the square of the ratio of total equivalent input noise (dotted curve) to thermal noise (solid curve). At low resistances, the ratio of total noise to thermal noise is very large and the noise figure is large, representing poor performance. As source resistance increases, thermal noise increases, but total input noise does not. The noise factor therefore decreases. The plot of total input noise E_{ni} is closest to thermal noise when $E_n = I_n R_s$. This is the point of minimum noise factor. As we go to higher source resistances, total noise follows the $I_n R_s$ curve, and the noise factor again becomes large.

The definition of NF used
290°K. When this definition is
negative values of NF can resu

The term *spot noise factor* F_o,
a narrowband F. Often F_o is
such as 1000 Hz can be used.
quency and is sometimes simpl

The principal value of F is to
is not necessarily the appropria
Because of the definition, F can
of the source resistance. Since
amplifier design, F is not as us
as E_{ni} or S_o/N_o.

2-6 OPTIMUM SOURCE RE

The point at which total eq
thermal noise curve in Fig. 2-
adds minimum noise to the t
reaches a minimum value. Thi
R_o and may be obtained from

The value of noise factor at t
of Eq. 2-12 can yield

F

Noise figure variations are ill
noise figure occurs at $R_s = R$
only does F_{opt} increase, but N
variations. The lowest curve g
source resistance, whereas the
the source is not equal to R_o.
figure is less than 3 dB, there i
noise reduction effort because

Optimum source resistance,
transfer. There is no direct
impedance Z_i. R_o is determine
a bearing on the maximum sig