I.52 NOISE CALCULATIONS . . . NOISE GAIN . . . MINIMIZING NOISE. For an example of how to make a noise calculation, we shall use the circuit of Figure 1.6. The response to a noise current, i_s, injected at the negative summing point, and to a noise voltage, e_s, in series with one of the inputs (assuming an otherwise ideal amplifier) is:

$$|e|^2 = \left|\frac{Z}{Z_0} + \frac{Z}{Z_1} + 1\right|^2 |e_s|^2 + |Z|^2 \left[i_{NB}{}^2 + 4KTB\,\Re\left(\frac{1}{Z_0} + \frac{1}{Z_1} + \frac{1}{Z}\right)\right]$$

$$e_{RMS} = \left|\frac{Z}{Z_0} + \frac{Z}{Z_1} + 1\right| (e_s)_{RMS} \sqrt{1 + \left|\frac{\frac{1}{R_s}}{\frac{1}{Z_0} + \frac{1}{Z_1} + \frac{1}{Z}}\right|^2}$$

Note that $\left(\frac{Z}{Z_0} + \frac{Z}{Z_1} + 1\right) = \frac{1}{\beta}$, which is called the *noise gain*, and $R_s = \frac{e_{sRMS}}{i_{sRMS}}$ is called the *characteristic noise resistance.*

To minimize the noise-to-signal ratio at the output:

(a) Use as small a noise gain (as high a value of β) as possible, without reducing signal gain below an acceptable minimum.

(b) Design the circuit to function at the lowest practical impedance level. This reduces the influence of i_s, and also reduces the effect of thermal noise generated by the network resistors.

(c) Minimize external sources of e_s and i_s, by taking sensible precautions to prevent excessive pickup. This includes providing adequate shielding of the summing point—from power lines, chopper-drive excitation, signal lines, and from r.f. radiation. Summing-point leads should be as short as possible.

(d) Select an amplifier with suitably low (internally-generated) voltage and current noise, in the frequency band of interest.

● To the reader: this page will undoubtedly be filled with a *miscellany of afterthoughts* in forthcoming editions. Meanwhile, the remaining $\frac{2}{3}$ of this page, $\frac{1}{3}$ of page 62, and *all* of pages 103 and 104, as well as the margins and other blank spaces, are available for notes, calculations, circuits, inventions, etc.