

slightly larger β_o and f_T , and therefore can be more useful at the higher end of the resistance range.

At higher values of source resistance, FETs are more desirable because of their very low noise current I_n . In some instances they are even preferred when a low E_n is desired. For instance, at frequencies of less than 10 Hz, a JFET can be selected that has lower noise than available bipolar transistors because some units do not show as much $1/f$ noise. In fact, when operating with a very wide range of source resistances, such as in an instrumentation amplifier application, a FET is generally preferred for the input stage. A good FET has E_n slightly larger than that of a bipolar transistor, and its I_n is significantly lower. This is of particular value when operating from a reactive source over a wide frequency range because the source impedance is linearly related to frequency. Another advantage of the FET is its high-input resistance and low-input capacitance; thus it is particularly useful as a voltage amplifier. FET input impedance is highly frequency sensitive because of the high-input resistance. The low-noise FET can be several times more expensive than a comparable bipolar transistor.

In general, the JFET has low excess noise; with high source resistances the MOSFET with its extremely low values of I_n has an advantage, although the MOSFET may have 10 to 1000 times the $1/f$ noise voltage. As processing techniques improve, the MOSFET becomes increasingly more attractive.

Often, because of their small size and low cost, we would like to use IC amplifiers. In general, if the lowest obtainable noise is not required, ICs can be used to good advantage. Frequently an IC can be selected that exhibits a noise level of only two to five times that of a discrete transistor circuit. If maximum state-of-the-art performance is desired, it is possible to use one or two discrete (bipolar or FET) stages ahead of the IC. This option is often selected in practical design. One caution must be observed when applying ICs: if a low gain, less than 10, is desired, frequently the feedback resistors are a serious additional source of noise.

7-4 DESIGN WITH FEEDBACK

After determination of the input device, its operating point and configuration, we can add overall multistage negative feedback to achieve the required input impedance, amplifier gain, and frequency response. In effect, single-stage negative feedback is utilized if the design employs either the common-base or common-collector configurations because these stages have 100% current and voltage feedback, respectively. An additional dimension is added by using negative feedback around several cascaded stages. As discussed in Chapter 12, negative feedback does not increase or decrease the

equivalent input noise except for the additional noise contribution of the feedback resistors themselves.

If an amplifier with a low input resistance is desired, the common-base configuration can be used as an input stage. The input resistance can be further reduced by the addition of overall negative feedback to the emitter input of the common-base stage. See Fig. 7-3a. The input resistance is reduced

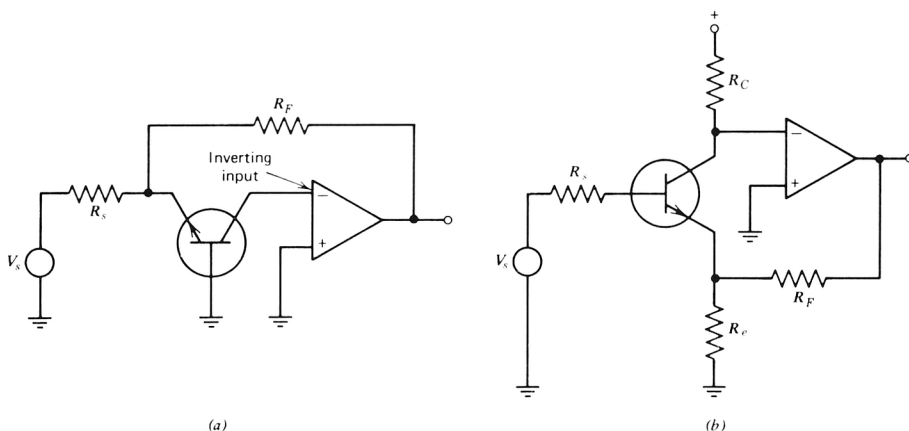


Fig. 7-3. Feedback circuits.

in proportion to the feedback factor, the ratio of the open-loop to closed-loop amplifier gains. A low input resistance is required when an amplifier must respond to signal current rather than voltage. The CB stage is also useful to minimize the effects of shunting capacitance on frequency response.

A high impedance is desirable when the amplifier must respond to the voltage signal from the source. A high input impedance can be obtained with either the common-emitter or the common-collector configurations. The FET, however, potentially offers the highest input resistance. Overall negative feedback to the emitter of a common-emitter input stage raises the amplifier input impedance. An example of this connection is shown in Fig. 7-3b.

Determining the input impedance of an amplifier with overall negative feedback can be confusing. If the input impedance is measured with the typical low-resistance impedance bridge, the measured values will agree well with calculations. On the other hand, the input impedance can be measured by inserting a variable resistor in series with the input and increasing its value until the output signal halves; the input impedance then should equal the value of the series resistor. Using this method on a negative feedback amplifier often produces a lower measured value of input impedance than that measured with the impedance bridge. Which value is correct? That depends on the source resistance. For low-source resistances the bridge value

is correct. For very large resistances, greater than open loop R_i , the second method is correct. If we do not simulate actual system conditions when making measurements of this type, the test results obtained can be erroneous.

The question arises, "How can we design an amplifier with a 600- Ω input resistance to operate from a 600- Ω source without doubling the system noise?" If a 600- Ω resistor were connected in parallel with the amplifier input terminals to provide the proper input resistance, the noise of that resistor would equal the noise of the source and give a minimum NF of 3 dB. The answer is to use negative feedback. As was pointed out, for a common-emitter input stage overall negative feedback to the emitter increases the input impedance, and overall negative feedback to the base decreases the input impedance. By the use of negative feedback to both emitter and base simultaneously it is possible to obtain the desired input resistance without substantially increasing the noise. One such arrangement is shown in Fig. 7-4.

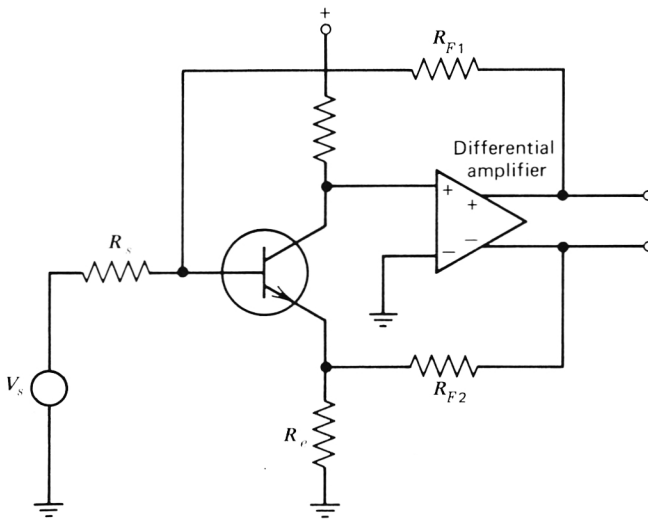


Fig. 7-4. Common-emitter stage with feedback to base and emitter.

7-5 BANDWIDTH AND SOURCE REQUIREMENTS

An important point to remember when designing low-noise amplifiers is not to overdesign for wide bandwidth. Be sure that the amplifier has definite low- and high-frequency roll-offs and that these are set as narrow as possible to pass only the signal spectrum required. The amplifier has a certain amount of noise in each hertz of bandwidth, and the greater the amplifier bandwidth the greater the output noise. There is no value in a response wider than the spectrum of the signal.