

## Comparison of the JFET and the BJT

An exact comparison of the BJT and the FET is impossible, in general, because the noise performance of each is so dependent on device parameters and bias currents. The JFET exhibits only  $v_n$  noise, whereas the BJT exhibits both  $v_n$  and  $i_n$  noise. For a low source resistance, the BJT  $v_n$  noise is its dominant noise. In this case, the BJT usually has a lower noise than the JFET. For a high source resistance, the BJT  $i_n$  noise can cause it to exhibit more noise than the FET. This assumes that the BJT bias current remains fixed as the source resistance is increased. If the BJT is biased for minimum noise, the collector bias current must be decreased as the source resistance is increased. In this case, the FET may not be the better choice device for the lowest noise.

To make an example comparison of the noise performance of the BJT and the JFET, typical numerical values for device parameters must be assumed. Although the conclusions may not be applicable to specific devices, such an example serves to illustrate the differences between the devices. Because flicker noise is so device dependent, it will be neglected. For the BJT, we will assume that  $r_x = 40 \Omega$ ,  $V_A = \infty$ , and  $\beta = 500$ . For the JFET, we will assume the parameters  $\beta = 5 \times 10^{-4} \text{ A/V}^2$ ,  $\lambda = 0$ , and  $V_{T0} = -2 \text{ V}$ . For these values, the drain-to-source saturation current is  $I_{DSS} = \beta V_{T0}^2 = 2 \text{ mA}$ .

Let the BJT be connected as a common-emitter amplifier with its emitter connected to ac ground. We calculate the noise both for a constant collector bias current and for the optimum collector bias current  $I_{C(\text{opt})}$ . Let the JFET be connected as a common-source amplifier with its source connected to ac ground. We calculate the noise for a constant drain bias current. For the constant current cases, we will assume that both the BJT and the JFET are biased at 1 mA so that the devices are compared at the same power dissipation. This assumes the same bias voltage across each device.

Let  $R_s$  be the source resistance. For  $I_C = 1 \text{ mA}$ , the BJT spot noise voltage in  $\text{V}/\sqrt{\text{Hz}}$  is

$$\begin{aligned} \sqrt{\frac{v_{ni}^2}{\Delta f}} &= \left[ 4kT(R_s + r_x) + 2qI_B(R_s + r_x)^2 + 2qI_C \left( \frac{R_s + r_x}{\beta} + \frac{V_T}{I_C} \right)^2 \right]^{1/2} \\ &= \left[ 3.58 \times 10^{-14} 1.30 \times 10^7 (R_s + 40) + 500 (R_s + 40)^2 + (R_s + 13000)^2 \right]^{1/2} \end{aligned} \quad (1)$$

For  $I_C = I_{C(\text{opt})}$ , it is

$$\begin{aligned} \sqrt{\frac{v_{ni}^2}{\Delta f}} &= \left[ 4kT(R_1 + r_x + R_2) \Delta f \times \frac{\sqrt{1 + \beta}}{\sqrt{1 + \beta} - 1} \right]^{1/2} \\ &= 1.32 \times 10^{-10} \sqrt{R_s + 40} \end{aligned} \quad (2)$$

For  $I_D = 1 \text{ mA}$ , the JFET spot noise voltage is

$$\sqrt{\frac{v_{ni}^2}{\Delta f}} = \left[ 4kTR_s + \frac{4kT\Delta f}{3\sqrt{\beta I_D}} \right]^{1/2} = 1.29 \times 10^{-10} \sqrt{R_s + 471} \quad (3)$$

Figure 1 shows the plots of  $\sqrt{v_{ni}^2/\Delta f}$  versus  $R_s$  for the three cases. Curve (a) is a plot of (1). Curve (b) is a plot of (2). Curve (c) is a plot of (3). For  $R_s$  small, the two BJT cases give the lowest noise. Although the curves almost coincide, the noise is slightly lower for the BJT biased at  $I_{C(\text{opt})}$ . For  $R_s$  large, the JFET and the BJT biased at  $I_{C(\text{opt})}$  give the lowest noise. Although the curves almost coincide, the JFET noise is slightly lower than the BJT noise. For  $R_s$  in the 3 to 4 k $\Omega$  range, the JFET and the BJT biased at  $I_C = 1 \text{ mA}$  give approximately the same noise, while the BJT biased at  $I_{C(\text{opt})}$  gives slightly lower noise.

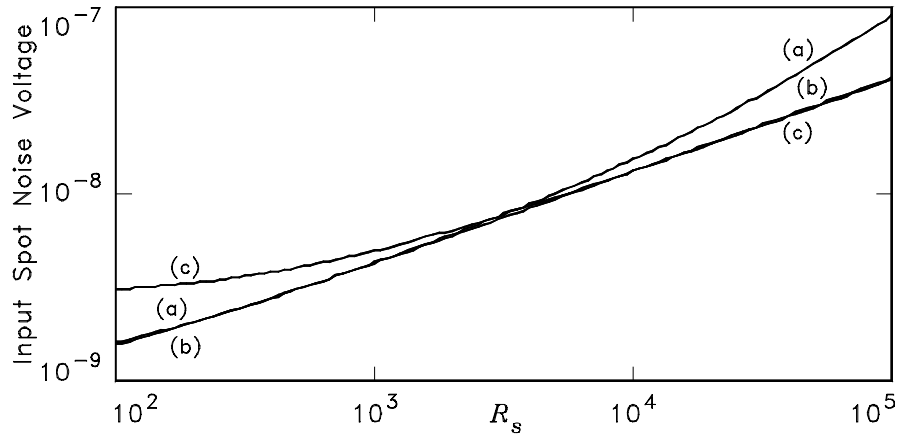


Figure 1: Spot noise voltage versus source resistance. (a) BJT biased at 1 mA. (b) BJT biased at  $I_{C(opt)}$ . (c) JFET biased at 1 mA.

It can be concluded that the BJT gives better noise performance for low  $R_s$ . For large  $R_s$ , the BJT and JFET give approximately the same noise performance provided that the BJT is biased at  $I_{C(opt)}$ . For large  $R_s$ ,  $I_{C(opt)}$  for the BJT can become very small. A very small bias current is a disadvantage when the amplifier slew rate, e.g. in an op-amp design, is a consideration. For this reason, the JFET may be preferable when the source resistance is high. These conclusions neglect flicker noise effects. Flicker noise is so device dependent that it is difficult to make general conclusions. However, the JFET usually exhibits more flicker noise at low frequencies than the BJT. In JFETs not selected for low flicker noise, the flicker noise corner frequency can be as high as several kHz. In MOSFETs, it can be even higher.

A consideration in the noise comparisons of the CE BJT and CS JFET amplifiers is the difference in input bias currents. To prevent the BJT input bias current from flowing through the signal source, either a coupling capacitor or an offset current source is required. The value of a coupling capacitor may be large if it is chosen to minimize the noise. Because there is no such thing as a noiseless current source, an offset current source can increase the noise. The zero FET gate current can eliminate the need for the capacitor and offset current source.