



- Noise figure is an indication of how much noise a given circuit or piece of equipment adds to a signal. It is typically spec'ed in dB.
- The larger the noise figure, the less sensitive the equipment is.
- Noise figure is rarely used in audio specifications but the theory is the same. It is typically used in radio and radar systems.

NOISE FIGURE IN DETAIL

- Definitions:

K = Boltzman's constant = 1.38×10^{-23} Joules/K

T = Temperature in degrees Kelvin; room temp is
~300K

B = Bandwidth in Hertz

G = Gain; can be a linear ratio or in dB

$$\text{Gain}_{\text{dB}} = 10\log(\text{Gain}_{\text{linear ratio}})$$

NF = Noise Figure can be a linear ratio or dB

$$\text{NF}_{\text{dB}} = 10\log(\text{NF}_{\text{linear ratio}})$$

NOISE FIGURE IN DETAIL

(CONT.)

- The thermal noise power present at the input of a signal chain is defined by KTB in watts.

EX: $T = 300\text{K}$, $B = 10\text{MHz}$

$$KTB = 4.14 \times 10^{-14} \text{ watts}$$

- Typically this would be referenced to 1 milliwatt (0dBm):

$$\text{dBm level} = 10\log(4.14 \times 10^{-14}/.001) = -103.83 \text{ dBm}$$

This says that the noise power is 103.83 dB below 1 milliwatt

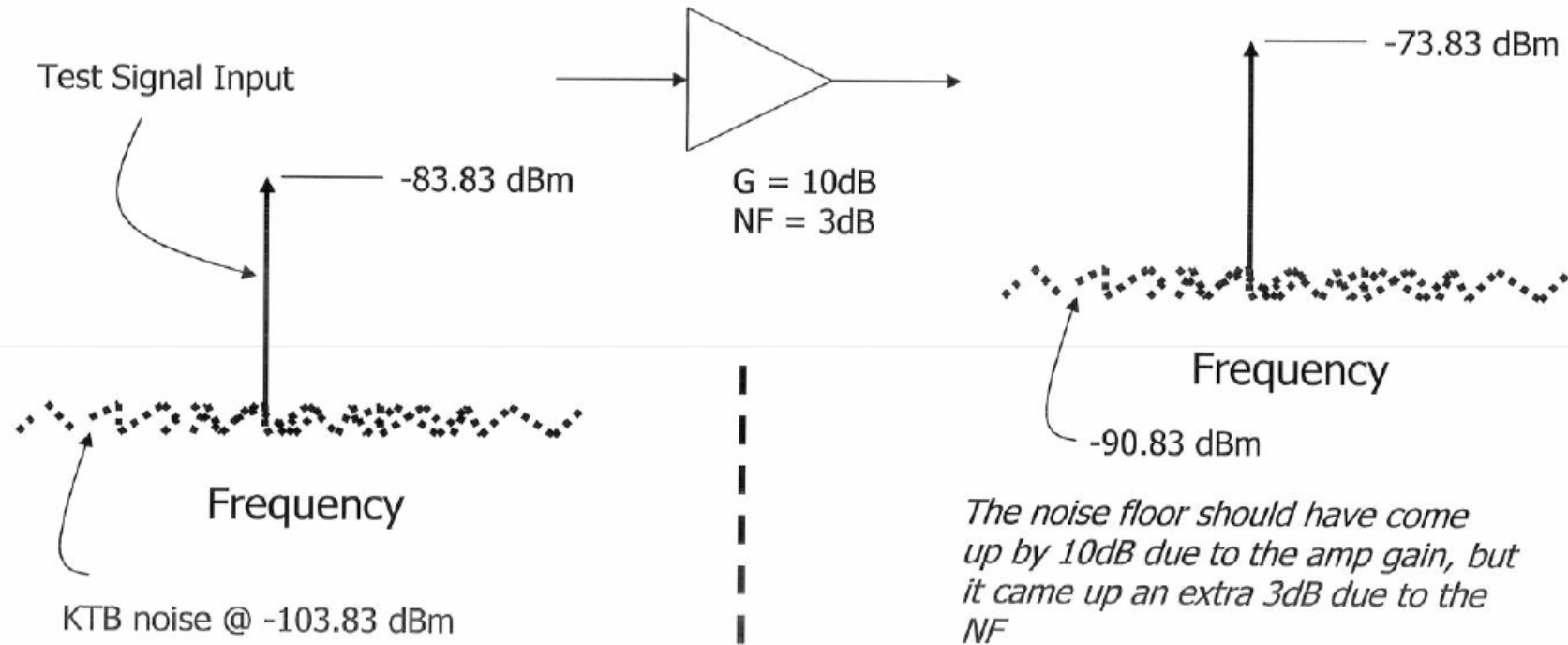
- The noise figure of a circuit element represents the amount the S/N ratio is degraded from the input to the output of that circuit element, **when and only when**, the noise input power = KTB .

NOISE FIGURE IN DETAIL

INPUT

(CONT.)

OUTPUT



S/N ratio at input = 20dB

S/N ratio at output = 17dB

The noise floor should have come up by 10dB due to the amp gain, but it came up an extra 3dB due to the NF

NOISE FIGURE IN DETAIL

(CONT.)

- It is easy to see how a signal present at the input noise floor (KTB), would be lost or masked by the noise as it “traveled” through the amplifier due to the noise figure.
- The higher the noise figure, the less sensitive the system.



NOISE FIGURE IN DETAIL

(CONT.)

- *There is good news* - Noise Figures do NOT add. For multiple amplifiers in a signal chain:

$$NF_{\text{total}} = NF_1 + (NF_2 - 1)/G_1 + (NF_3 - 1)/(G_1 * G_2) + \dots$$

where NF_1 = noise figure of amp1 in linear ratio

NF_2 = noise figure of amp2 in linear ratio

NF_3 = noise figure of amp3 in linear ratio

G_1 = gain of amp1 in linear ratio

G_2 = gain of amp2 in linear ratio

etc.



What does all of this mean?

NOISE FIGURE EXAMPLE



First convert dB to linear ratios using $10\log(LR) = \text{dB}$

We now have:

$$G1 = 15.85$$
$$NF1 = 2.51$$

$$G2 = 10$$
$$NF2 = 2.24$$

The total NF for the two amp chain is $= 2.51 + (2.24-1)/(15.85) = 2.59$

$$10*\log(2.59) = 4.13\text{dB}$$

You can never do better than the 1st NF (4.13dB > 4.0dB) but you can minimize the impact of the succeeding stages.

NOISE FIGURE IN DETAIL

(CONT.)

- Based on the Noise Figure equation

$$NF_{\text{total}} = NF_1 + (NF_2 - 1)/G_1 + (NF_3 - 1)/(G_1 * G_2) + \dots$$

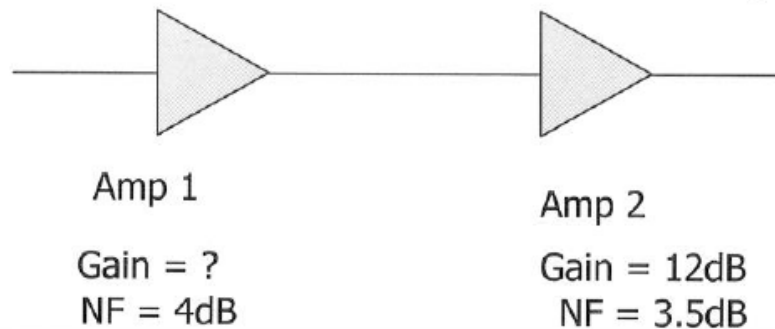
In general, it is best to put a lot of gain in the first stage, which should also have a low noise figure.

NOISE FIGURE IN DETAIL

SAMPLE PROBLEM

Given:

$B = 50\text{MHz}$, $T = 300\text{ K}$



What does the gain of amp 1 need to be in order for the NF_{tot} for the chain $< 4.15\text{dB}$?

First convert from dB to linear ratios using $\text{dB} = 10\log(\text{LR})$

4dB => 2.51 12dB => 15.85 3.5dB => 2.24dB 4.15dB => 2.6

Now solve for Gain 1: **$2.6 = 2.51 + (2.24-1)/G1$ **$G1 = 13.78$****

$13.78 \Rightarrow 11.39\text{dB}$

NOISE FIGURE IN DETAIL

SAMPLE PROBLEM

What is the S/N ratio at the output of the amp chain if the input signal is a CW signal at -85dBm? (use specs on previous page)

First, we know the signal level at the input, what is the noise level at the input?

Answer: $KTB = (1.38 \times 10^{-23} \text{ J/K})(300 \text{ K})(50 \text{ MHz}) = 2.07 \times 10^{-13} \text{ watts}$

$2.07 \times 10^{-13} \text{ watts} \Rightarrow 10\log(2.07 \times 10^{-13} / (.001)) = -96.84 \text{ dBm}$

S/N ratio at input = $(85 \text{ dBm} - 96.84 \text{ dBm}) = 11.84\text{dB}$

We know the signal comes up from -85 dBm to -61.61 dBm due to the Gain of the amp chain (12dB + 11.39dB)

However, the noise comes up not only by the amount of gain (23.39dB) but an additional 4.15 dB due to the NF of the total amp chain, and the fact that the input noise is = KTB.

Therefore the noise out of the amp chain is $-96.84\text{dBm} + 23.39\text{dB} + 4.15\text{dB} = -69.3\text{dBm}$

The S/N ratio at the output of the amp is $(61.61 - 69.3) = 7.69\text{dB}$