Noise intro

[SLVA043a + AN-358]

Types of noise

- Types of noise
  - *Interference noise*
  - *Inherent noise*
- How do they sum?
  - normally they are both uncorrelated -> their *powers* sum together, not their intensities

$$\overline{E_t^2} = \overline{e_1^2} + \overline{e_2^2}.$$

  - e.g.: 1 mV + 3 mV = 3.16 mV

Sources of *inherent* noise

- In electrical circuits there are several common noise sources:

  - *thermal noise*: white

  - *shot noise*: white

  - *flicker* ("1/*f*") noise: pink, power density is proportional to *1/f*

    -> - 3 dB/octave roll-off

    -> RMS value is proportional to $1/f^{1/2}$

  - *burst* ("popcorn") noise: neglectable in opamp

  - *avalanche noise*: in junctions in breakdown; neglectable in opamp

- Thermal noise: $$\overline{e^2} = \int 4kTR\,df \text{ or } \overline{i^2} = \int (4kT/R)\,df$$

- Shot noise: $$\overline{i_n^2} = \overline{(i - i_D)^2} = \int 2qi_D\,df$$

- Flicker noise: $$\overline{e^2} = \int \left(K_e^2/f\right) df \text{ or } \overline{i^2} = \int \left(K_i^2/f\right) df$$

  - in flicker noise, each decade contributes (in voltage or current, not in power) with 1.52 K_e, where K_e is e_n or i_n at 1 Hz

Thermal noise is $\overline{e^2} = \int 4kTR\,df$ or $\overline{i^2} = \int (4kT / R)\,df$

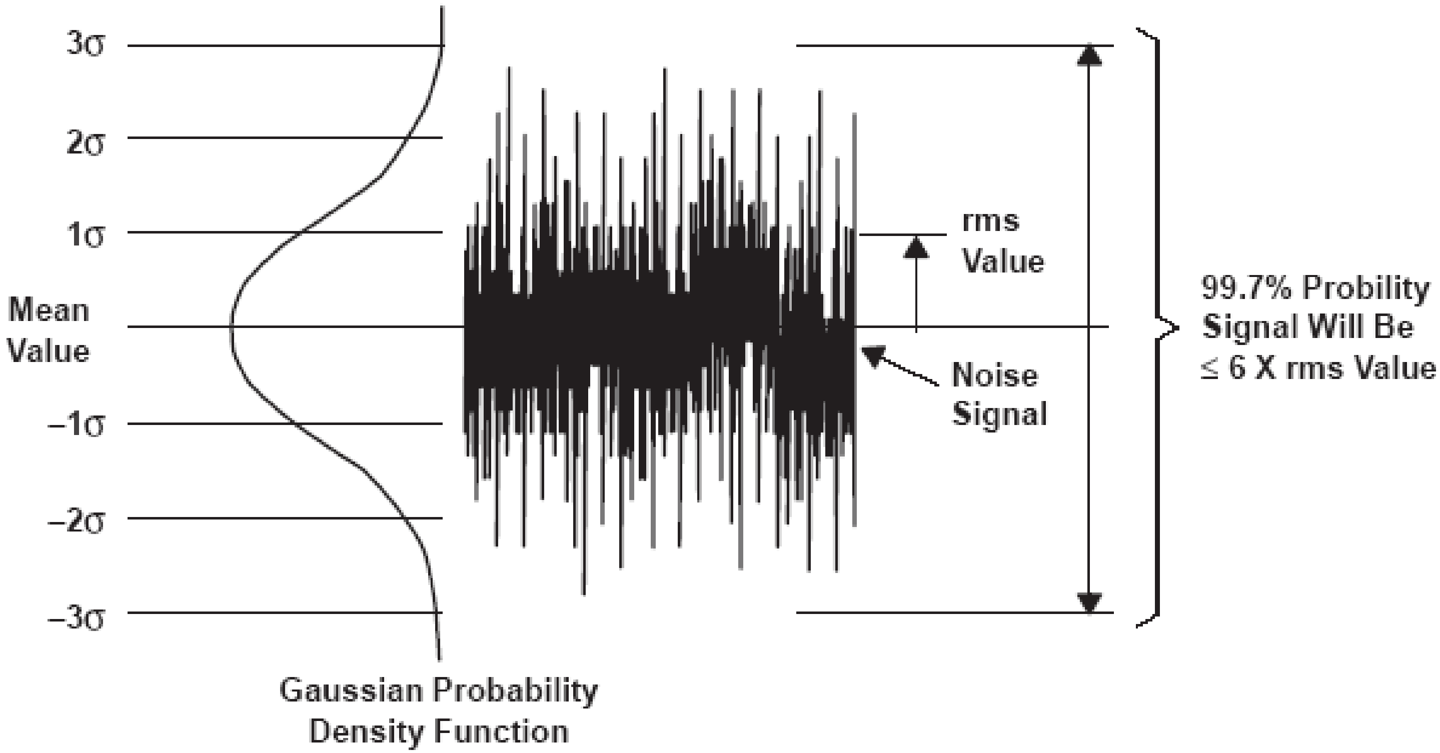
So, a real resistor is modeled an ideal noiseless resistor with

- a noise generator *e* in series, or
- a noise generator *i* in parallel

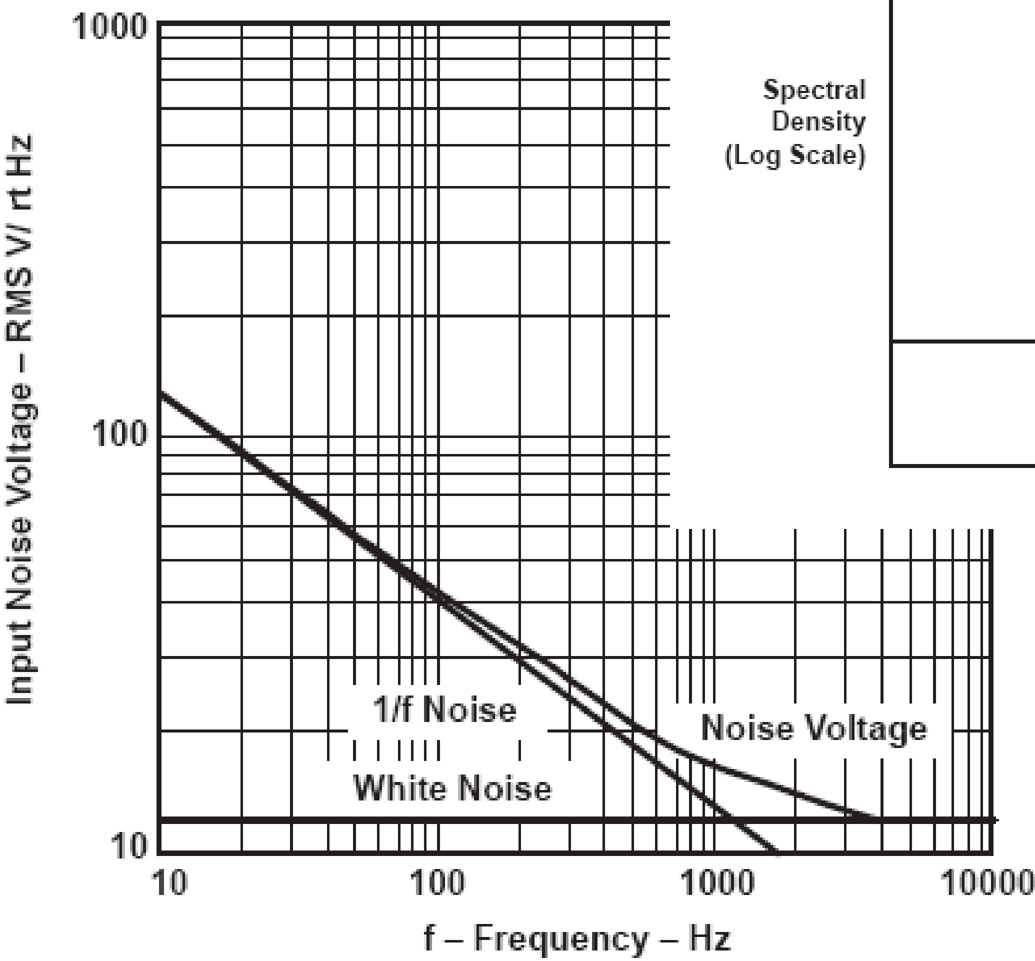
RMS values and peak-to-peak values

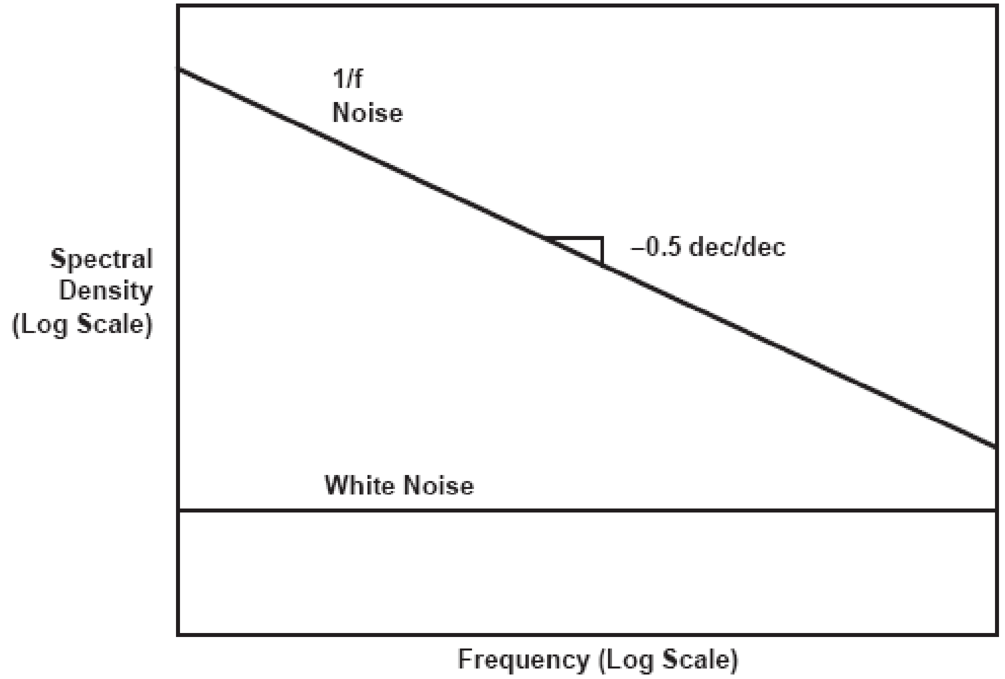
Nominal "peak-to-peak"	Percentage of time that noise will exceed nominal "peak-to peak" value
2.0 x RMS	32%
3.0 x RMS	13%
4.0 x RMS	4.6%
5.0 x RMS	1.2%
6.0 x RMS	0.27%
6.6 x RMS	0.10%
7.0 x RMS	0.046%
8.0 x RMS	0.006%

Peak-to-peak vs. RMS (Gaussian distribution)



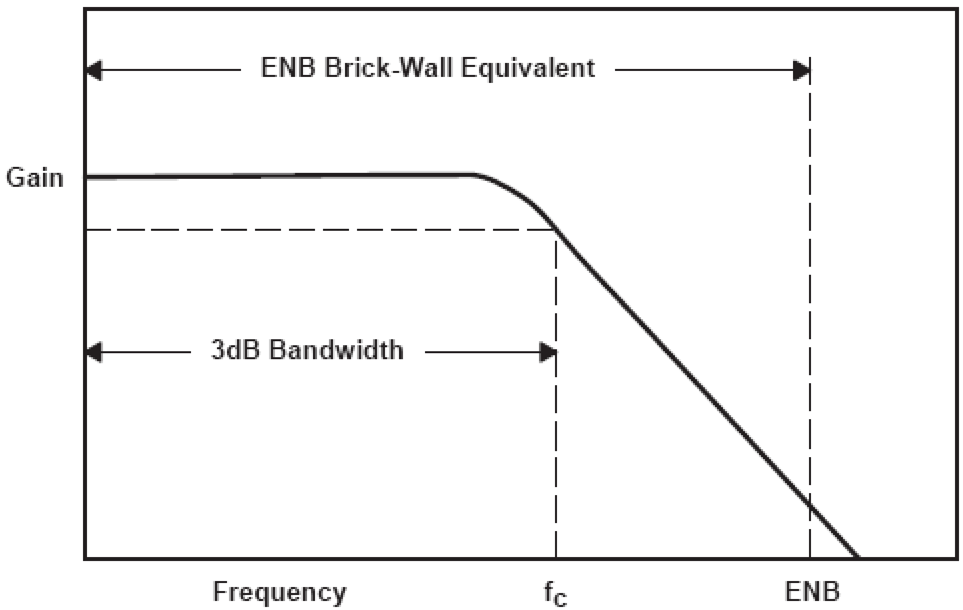
Noise spectra





Equivalent Input Noise Voltage vs Frequency for TLV2772 on Log-Log Scale

Equivalent noise bandwidth



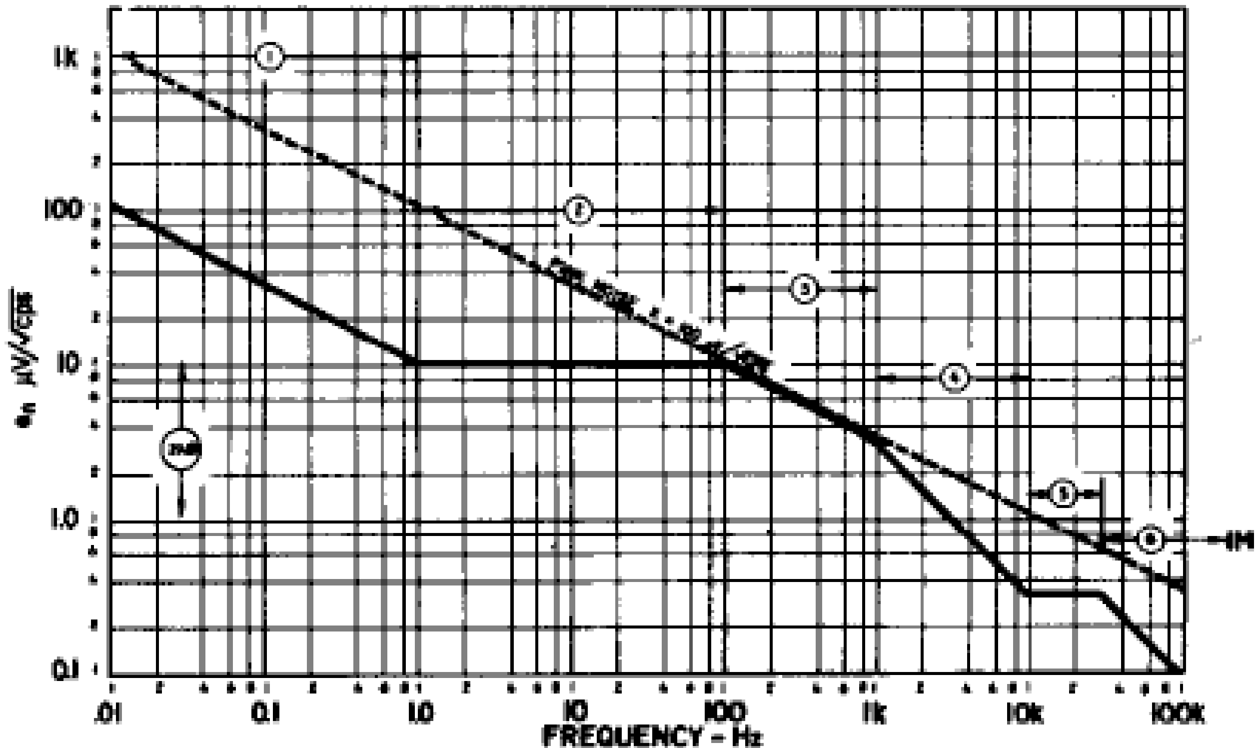
FILTER ORDER	ENB
1	$1.57 \times f_C$
2	$1.11 \times f_C$
3	$1.05 \times f_C$
4	$1.025 \times f_C$

For a 1st order filter (i.e. one pole only)

- total RMS = 1.26 times the RMS up to f_c (1.26^2=1.57)
- the RMS contribute of the *skirt* only is 0.76 $e_n\ (f_c)^{1/2}$
    - in fact ($1^2+0.76^2$)=1.57

Example

- only the zones close to the dashed line are important!



Region	RMS Noise	Why
1	22μV	Pink noise, 2 decades, $\sqrt{2}$x1.52x10
2	100μV	White noise, 2 decades, 10x$\sqrt{100}$
3	152μV	Pink noise, 1 decade, 1.52x$\sqrt{100}$
4	72μV	6dB/octave skirt, 0.76x3x$\sqrt{1000}$
5	42μV	White noise, 0.3x$\sqrt{20,000}$
6	40μV	6dB/octave skirt, 0.76x0.3$\sqrt{30,000}$

actually, it should be sqrt(100-1)

no, without the root!

20k=30k-10k

The RMS total of these noises is

$$\sqrt{152^2 + 100^2 + 72^2 + 42^2 + 40^2 + 22^2} = 205 \text{ microvolts}$$