# Thermal noise

## AWGN (additive white Gaussian noise)

A passive resistor generates an RMS noise voltage equal to

is Boltzmann’s constant, is temperature in kelvin, is resistance in Ohms, and is the integration/measurement BW in Hz.

Room temperature is ~300 K.

Model the resistor as the Thevenin equivalent: a voltage source in series with a noise-free resistance. If the resistor is the source impedance (antenna) of a receiver or a load (antenna) connected to a transmitter, then maximum power is delivered when source and load impedances are matched. Then the power delivered is

is thermal noise density in Watts/Hz.

**Noise figure and sensitivity:**

**Cascaded noise voltage in IC design:**

**AWGN in simulations:**

AWGN can be generated using a function that returns normally distributed pseudorandom numbers.

The RMS level of the noise sequence controls the noise power, which will usually be specified relative to the signal power (as SNR).

Given and SNR, we can calculate

In simulation, the noise is spread out over , but SNR is defined within the signal bandwidth. This means that the previous equation specifies RMS noise within the signal bandwidth, so the RMS level of the noise in the simulation must be scaled:

## Flicker noise and AWGN modeling

Flicker noise = 1/f noise.

1/f noise because flicker noise PSD scales as 1/f, i.e. -10 dB/decade.

The corner frequency is defined as where the flicker noise is equal to the thermal noise floor.

The total noise PSD is

This is a one-sided PSD. To create , we need to convert this to a two-sided PSD, define a phase spectrum to go with it, and apply IDFT.

First, define the phase spectrum as a uniformly distributed random process over , i.e.

# Oscillator phase noise