Electronic Design

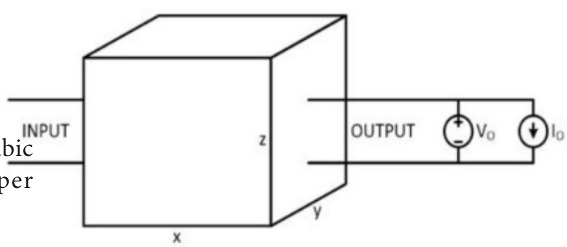
By STEVE TARANOVICH, Contributing Editor

What's the Difference Between Power Density and Power Spectral Density?

One is defined as a converter's rate output power, while the other is a measure of a signal's power content versus frequency. This article makes further distinctions between the two.

The basic definition of power density is the rated (or nominal) output power of a device divided by the volume (volume = x · y · z) occupied by the device (Fig. 1). Common units of measurement for power density can be watts per cubic meter (W/m^3) or watts per cubic inch (W/in.^{3}).

$$PowerDensity = \frac{V_O \cdot I_O}{x \cdot y \cdot z}$$



1. This is how to calculate power density. (Image courtesy of Texas Instruments)

Power Spectral Density Basics

Power spectral density (PSD) is the measure of a signal's power content versus frequency. PSD gives designers an idea of how the power of a signal is distributed over frequency. A PSD is usually chosen to characterize random broadband signals *(Fig. 2)*.

When we have a discrete case, as in *Figure 2*, the PSD can be calculated by using the fast Fourier transform (FFT) algorithm. Also, in the discrete case, the time-domain signal x(t) will contain N samples, where n is the sample number (total sampling time of T = NΔt). The lower integration limit, in the discrete case, will start at t = 0 to account for causal signal behavior.

Designers and scientists use stochastic processes as mathematical models of their systems as well as phenomena that can seem to vary in a random manner.

Power spectral density also can be calculated quite simply via different methods; one of them is known as a modified periodogram method. This technique is an estimate of the spectral density of a signal, which is the windowed squared magnitude of a FFT. Periodograms can typically be used to identify the dominant cyclical periods (or frequencies) of a time series.

2. Power spectral density is simply the Fourier transform of the signal. (Image courtesy of Cadence)

Continuous

$$S(f) = \left| \int_0^\infty x(t) e^{-i2\pi f t} dt \right|^2$$

Discrete

$$S(f) = \frac{1}{N} \left| \sum_{n=1}^{N} x_n(t = n\Delta t) e^{-i2\pi f n\Delta t} \Delta t \right|^2$$

Power Density of a Laser Beam

The power density (a.k.a. irradiance) of a laser beam is defined as a ratio of power (P) in watts (W) to the cross-sectional area ($I = W/cm^2$). The Laser Power Density Calculator is pretty handy.

Examples of a Laser Beam's Power Density

• Cutting sheet metal: Power density here will define how quickly a laser beam can perform a good quality cut.

• In laser surgery, the power density of a laser scalpel will need to remain in a narrow range to perform successfully.

• When testing a laser for safety, the power density will need to be less than a specifically designated level to be safe for the human eye.

Laser beam users need to know the overall power of the beam, while keeping in mind the level of power reaching the area of interest.

Summary

Power density is defined as the rated (or nominal) output power of a converter, which is then divided by the occupied volume of that converter.

Power spectral density will give an idea as to how the power of the signal is distributed over frequency. PSD is defined as a measure of a signal's power content versus frequency. PSD is typically employed to characterize broadband random signals. The amplitude of the PSD becomes normalized by the spectral resolution used in digitizing the signal.

References

1. Delving Into Power Density | Electronic Design

2. Power Density: What All EEs Need to Know | Electronic Design

3. Power Spectrum vs. Power Spectral Density: What Are You Measuring? | Advanced PCB Design Blog | Cade (cadence.com)

4. Introduction to the fundamental technologies of power density - Power management - Technical articles - TI E2E support forums