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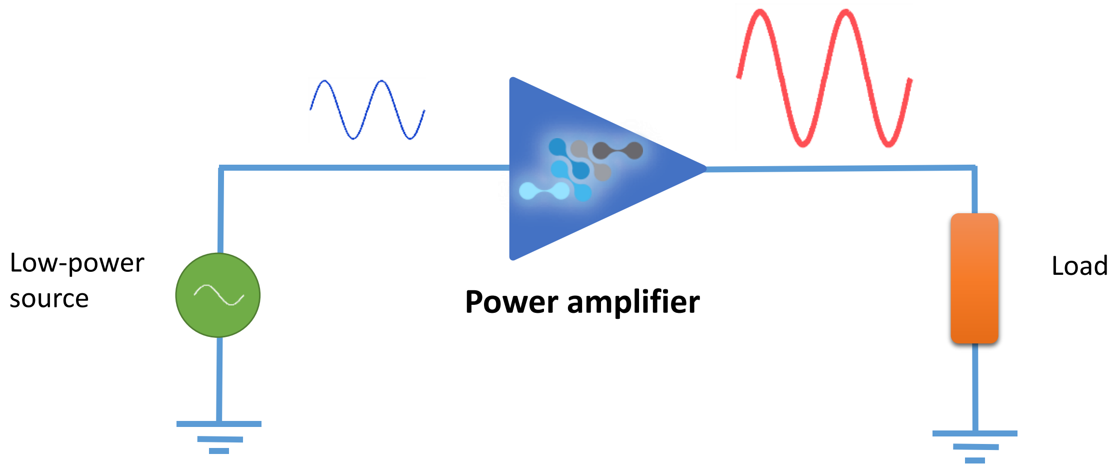
INTRODUCTION:

Power amplifiers are devices that convert a small signal into a high-power signal intended to drive specific loads such as piezoelectric transducers, loudspeakers, EMATs, antennas, etc. (see figure below). There are different types of power amplifiers which are mainly differenced by their frequency range of operation. Although any type has specific properties, the basic behavior of every amplifier can be explained in terms of a few parameters. This document provides a basic understanding of a power amplifier and is intended to help users in the selection of a proper device and its correct usage.



BASIC PARAMETERS:

- Gain: It is the ratio of the output to the input voltage of the amplifier (that is, $V_{out} = G \cdot V_{in}$). Its value can be directly specified, although sometimes it is expressed in a logarithmic scale in decibels (dB). Linear and logarithmic values are related through the expression $G(dB)=20 \cdot \log_{10}(G)$.

- Output impedance: As just introduced, the amplifier supplies an output voltage of $V_{out} = G \cdot V_{in}$. In practice the voltage applied to the load is lower because the amplified signal is divided between the load and the internal output impedance of the amplifier. To get $V_{out} \approx G \cdot V_{in}$, the output impedance is often much lower than the load.

- Input impedance: The input impedance indicates the amount of current that the input of the amplifier demands to the signal source. Its value can be high to reduce the current supplied by the source, although low values can be considered depending on specific requirements.

- Bandwidth: It refers to the range of frequencies where the amplifier works properly. The gain of the amplifier is frequency-dependent and the bandwidth defines the frequencies where it is high enough and stable. In power applications, it is worth to note that the bandwidth can depend on the load. For example, for capacitive loads the higher the capacitance the lower the bandwidth.

- Slew rate: It is the maximum time-derivative of the output signal that the amplifier can generate. It is usually expressed in V/µs or V/ns. If the output signal changes with a rate higher than the slew rate, distortion will occur. For the case of square waves, the slew rate is directly related to the slope of the transitions. For sinusoidal signals ($s(t) = V_{max} \cdot \sin(\omega t)$), the slew rate of the amplifier should be higher than the maximum time derivative, that is, $SR \geq V_{max} \cdot \omega$. Note that many amplifiers does not meet this criterion at their maximum operating frequencies.

POWER DELIVERED TO THE LOAD:

Imagine you have a 400V power amplifier. Can you apply these 400V to any load? It depends on the load, and the answer may be no.

Any amplifier is rated for a maximum voltage, current and power. The device works properly until one of these limits is reached, whichever comes first. When this occurs, the amplifier cannot increase the voltage and current levels because one of them is limiting.

A typical scenario of severe limitation takes place when working with ultrasonic transducers, which can be considered as capacitive loads. Consider an amplifier rated for 400V - 100mA, and a capacitive load of 1nF connected to its output. If the user tries to excite the load at 1MHz, the current demanded at 400V is 2.51A (see calculations in Appendix 1). Since the limit of the amplifier is 100mA, the maximum voltage cannot be applied to the load. In fact, the low value of the current limit will result in a maximum output voltage of 15.9V!

Because of it, a high voltage limit can be insignificant if the amplifier is not able to provide enough current. When selecting an amplifier, the user should check that voltage, current and power ratings are equal or higher than the requirements of the application. This is especially important when working with capacitive loads at high frequencies or inductions at low frequencies because they will demand large amounts of current.

Appendix 1: Ohm's law basics.

The Ohm's law relates voltage (V), current (I) and impedance (Z) in a simple way:

$$V = I \cdot Z$$

The table below shows the expressions corresponding to the impedance of the three types of passive loads:

Resistor	Capacitor	Inductor
$\boldsymbol{Z_R = R}$	$Z_C = \frac{1}{j\omega C}$	$Z_L = j\omega L$

Here $\omega = 2\pi f$ (with f being the frequency of the signal) and $j = \sqrt{-1}$. For example, the current required by a capacitor would be:

$$I = \frac{V}{Z_C} = V \cdot (j\omega C)$$

Note that these expressions involve complex values. Thereby not only the amplitude of the signals is determined, but also the phase relationships.

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