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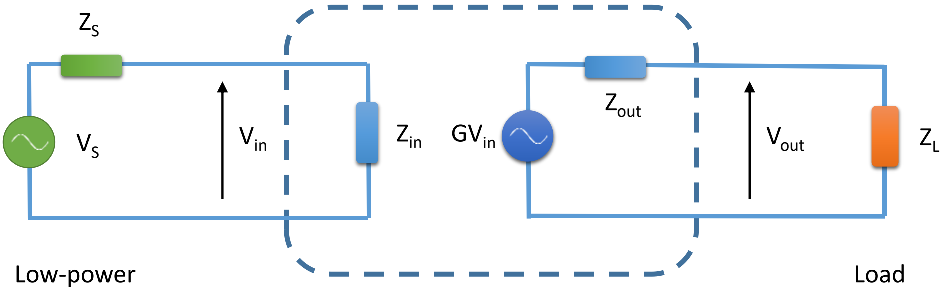
INTRODUCTION:

Power amplifiers are devices that convert small signals to high-level signals and drive a great variety of power loads and transducers. The basic parameters characterizing them were presented in the note “Power amplifier basics”. In the present document, more parameters of power amplifiers are introduced, and others already explained are discussed in more depth. Basic notions of circuit analysis are recommended for reading this note.

EFFECT OF OUTPUT IMPEDANCE:

The following figure illustrates a simplified model of an amplifier connected to a signal source and a load:



Here the input voltage V_{in} is amplified a factor G and driven to the load Z_L. However, not all this voltage is applied to the load because part of it is consumed in the output impedance Z_{out}. The actual voltage that reaches the load is:

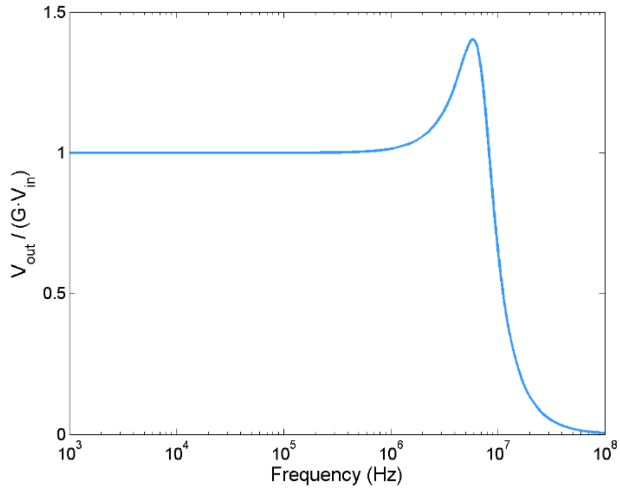
$$V_{out} = (G \cdot V_{in}) \frac{Z_L}{Z_L + Z_{out}}$$

In general $V_{out} < G \cdot V_{in}$, although Z_{out} is usually low to get $V_{out} \approx G \cdot V_{in}$. In high frequency systems, these impedances must be matched typically to 50Ω, but in this case only half the voltage is applied to the load. Please, read “Do I need a 50 ohms input/output?” for information about the cases where RF amplifiers are required.

An exception where $V_{out} > G \cdot V_{in}$ may occur for capacitive loads. The output impedance is often modelled as a resistor R_{out} in series with an inductor L_{out}, both having low values. In this case the above formula has the form:

$$V_{out} = (G \cdot V_{in}) \frac{1}{(1-\omega^2 L_{out} C_{load}) + j\omega R_{out} C_{load}}$$

The load capacitance C_{load} and the output inductor L_{out} resonates at a given frequency and the term $(1-\omega^2 L_{out} C_{load})$ vanishes. At this point V_{out} could be greater than $G \cdot V_{in}$, leading to a phenomenon known as peaking. The next figure shows an example of the frequency response of a system with peaking:



The peaking may be considered in order to avoid voltage levels that exceed the maximum ratings of the load. It can be overcome by reducing the input voltage or adding a resistor in series with the load. In some practical cases, this effect may be exploited to work at higher voltages. Please, contact us if this effect is of concern in your design.

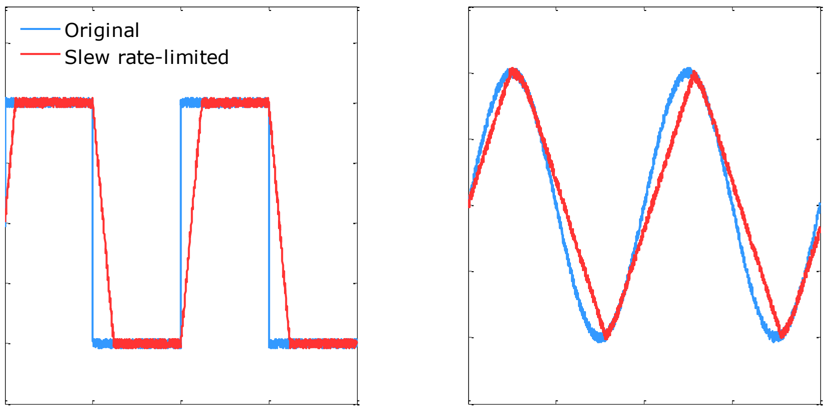
Note that, although the same principles apply to the input impedance (not all the voltage of V_s is applied to the amplifier due to Z_{in}), this case is of less concern because the input stage deals with low power. Different values of Z_{in} can be easily set depending on the application requirements. If you need an amplifier with a specific Z_{in} or more information about this parameter, please contact us.

BANDWIDTH AND SLEW RATE:

The bandwidth defines the range of frequencies where the amplifier provides its rated gain (G). The frequencies limiting this range are defined as the points where the gain drops at $G/\sqrt{2}$ or, equivalently, where the gain expressed in decibels falls 3dB. A high and low cutoff frequencies should be provided by the fabricant.

In power amplifiers the bandwidth can be affected by the load impedance. The effect is due to a low-pass filtering that occurs between the inductive part of the output impedance (L_{out}) and the load. In most amplifiers the high cutoff frequency moves to lower values for increasing capacitive loads. For resistive loads, the high cutoff frequency may decrease if the value of the load is too low. Anyway, it should be considered that in both cases the high current consumption of the load could be more limiting than the reduction of the bandwidth.

On the other hand, the slew rate (SR) is the maximum time derivative that the amplifier can generate in its output port. The amplification of signals that exceed this rating leads to distortion, as shown in the figures below. The SR is obviously related to the bandwidth, although it provides extra information that help users to determine if an amplifier is suitable for their applications.



For square waves the minimum slew rate required for an amplifier is just the slope of the rising and falling edges. For example, a square wave of ±200V with rising and falling times of 100ns will need an amplifier with a minimum SR = 4000V/µs. In the case of sinusoidal waveforms ($V_{max}\cdot\sin(\omega t)$), the maximum slope is $V_{max}\cdot\omega$ and therefore the amplifier should guarantee that $SR \geq V_{max}\cdot\omega$. For example, for a signal with an amplitude of 200V at 5MHz we would need SR ≥ 6283V/µs. Care should be taken when assessing an amplifier since in many cases the maximum voltage and maximum frequency cannot be simultaneously obtained because the device is slew rate limited ($SR<V_{max}2\pi f_{max}$).

MORE PARAMETERS:

- Offset: It only affects to amplifiers with DC operation. The offset is a spurious DC level that appears at the output port. Its value is low and it can be neglected in most applications, although it should be considered in cases such as inductive loads where a small DC voltage can result in a high current.

- Total harmonic distortion: Non-linearities in amplifiers are manifested through the generation of harmonics at frequencies corresponding to multiples of the frequency of interest. The total harmonic distortion (THD) is a parameter widely employed to assess the linearity of amplifiers working below RF frequencies. It expresses the ratio of the RMS voltage of the spurious harmonics to that of the fundamental harmonic. The lower the THD, the more accurate signal amplification. Typical values are below 1% (-20dB).

OTHER DETAILS:

Apart from the load, there is an element that many users disregard but can affect the amplifier operation, especially at high frequencies. Such an element is the cable. A simple RG-58 coaxial cable presents a stray capacitance of 80pF/m. This means that 2m of cable behave as a parasitic capacitor of 160pF. It seems a low value, but consider a high-voltage amplifier operating with 200V at 2MHz. The current consumption in these conditions is 400mA, perhaps a value much higher than expected for a simple cable. The best advice here is to keep cables as short as possible. This will minimize parasitic effects and avoid the necessity of employing RF techniques and devices.

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