HUBERT
amp up your process

White Paper No. 8
Bandwidth and Slew-Rate

1 Introduction

Various inquiries in the past regarding bandwidth and slew rate have shown, that these terms are often not interpreted correctly. Therefore the terms are briefly explained in the following, and their impact on the everyday amplifier usage clarified.

2 Small signal-bandwidth

When speaking of bandwidth of amplifiers, usually the small-signal bandwidth is meant. Each voltage- or current-amplifier has an upper frequency limit at which the gain drops, as against low frequencies.

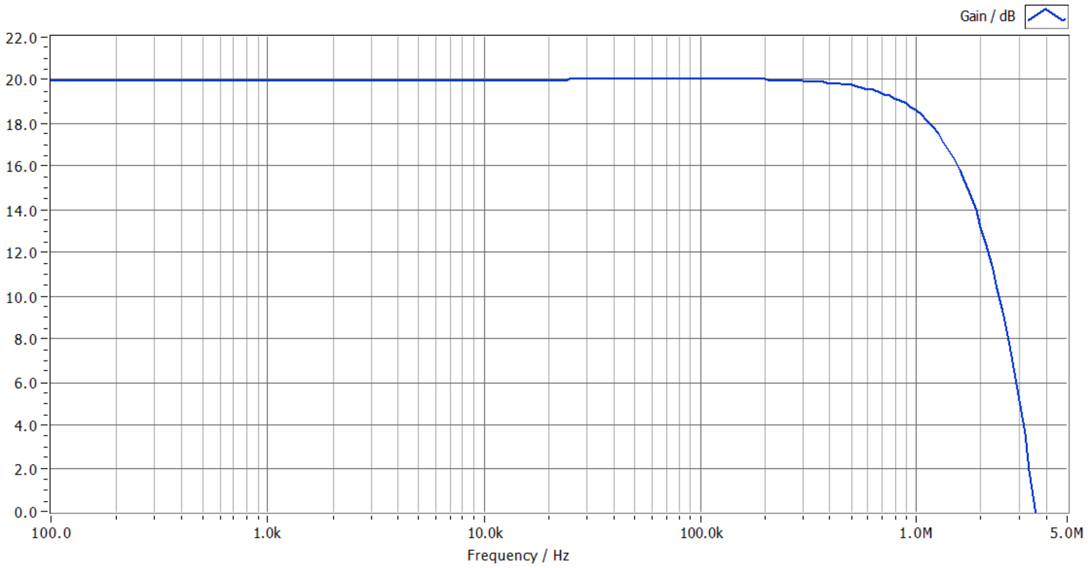
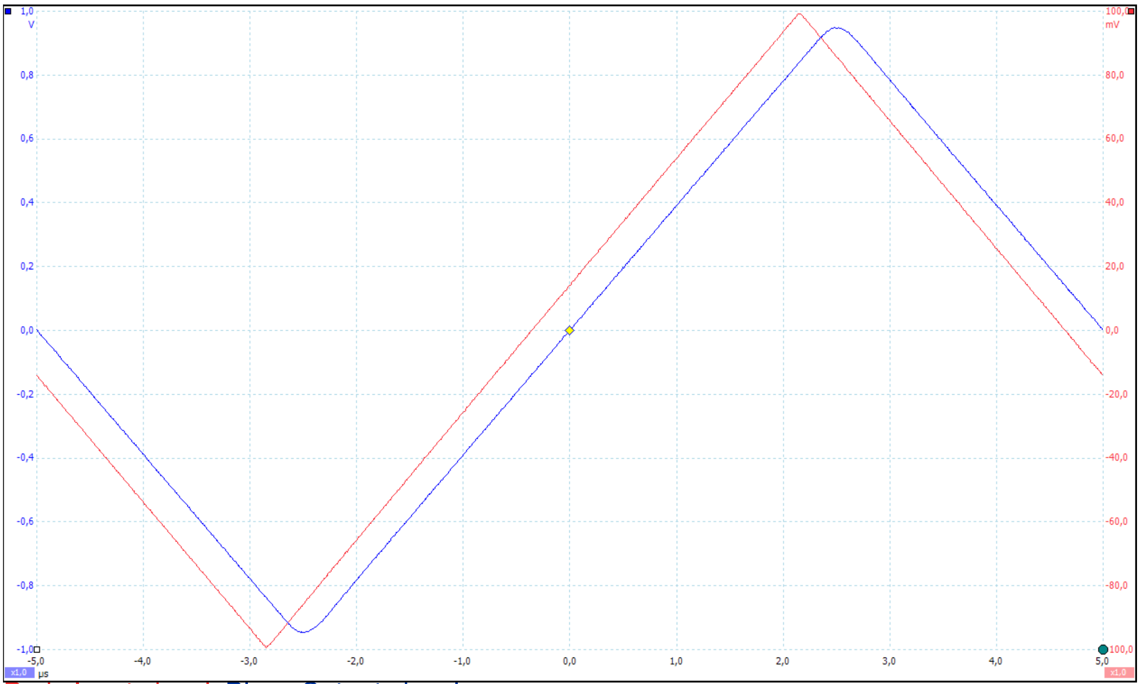


Figure 1: amplifier gain as a function of the frequency

The frequency point at which the decrease is -3 dB (= 0.7071), is referred to as a small-signal bandwidth. It is measured in idle or at high load impedance and low output voltages (typ. <1 V), to exclude all other limiting factors.

For the amplification of sinusoidal signals it is an easy case, the amplifier must have a sufficient high gain for the desired frequency. More difficult is the case for other test signals, which not only consist of a sine of a fundamental frequency, but can be understood as a sum of several sinusoidal oscillations at different frequencies and amplitudes. Here, the reduced bandwidth can lead to signal corruption, although the fundamental frequency is within the bandwidth.
As an example, a triangular wave with 100 kHz is given. As can be seen in the graph, the amplifier can produce the signal without a significant drop in amplitude. However, it comes to a significant rounding of the tips by the limited bandwidth of the amplifier.



Red : Input signal Blue : Output signal

Figure 2: Signal distortion due to insufficient small signal bandwidth

For the reproduction of non-sinusoidal output signal, a high small-signal bandwidth is advantageous for a good signal fidelity .

3 Slew-Rate

In addition to the small-signal bandwidth the slew rate also determines, whether an amplifier can put out an undistorted output signal at all. This parameter specifies how fast an amplifier can change the output amplitude. A short rise and fall time automatically results from high slew-rates, which, for example, is of great interest at square-wave signals.
The slew rate is, same as the small signal bandwidth, measured at idle or high load impedance. But in contrast to the small signal bandwidth, the amplifier is operated to just below his modulation amplitude limits.
Whether a sinusoidal voltage of specific frequency and size can be produced, is simply to be calculated by using the following formula.

$$\text{Slew-Rate} > 2\pi * f * V_{peak}$$

If we assume a slew rate of 100 V / µs, it can thus theoretically generate a sinusoidal voltage of 50 Vrms to 225 kHz, at 30 Vrms this even would be 375 kHz. Above this frequency, the slew rate for this sinusoidal output voltage is too small, which means, there is a trapezoidal distortion of the output signal. The distortion increases abruptly.

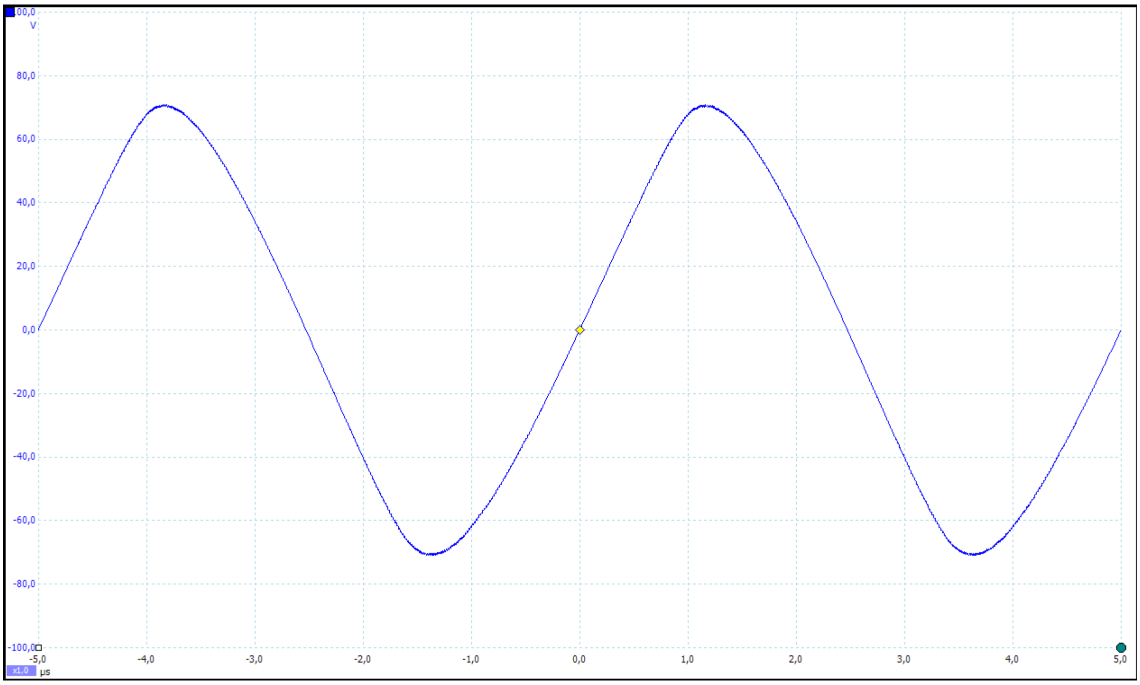


Figure 3: Distortion of the output signal due to insufficient slew rate

4 Large signal-bandwidth

The output impedance of an amplifier is only close to zero at low frequencies. Various physical parameters such as the low negative feedback at higher frequencies or decreasing current gain of the output stage transistors, to name just two key points, leading to an increase in the output impedance.

Output Voltage vs. Frequency (THD + N < 1%)
Red: @ 8 Ohm
Blue: @ 4 Ohm
Green: @ 2 Ohm

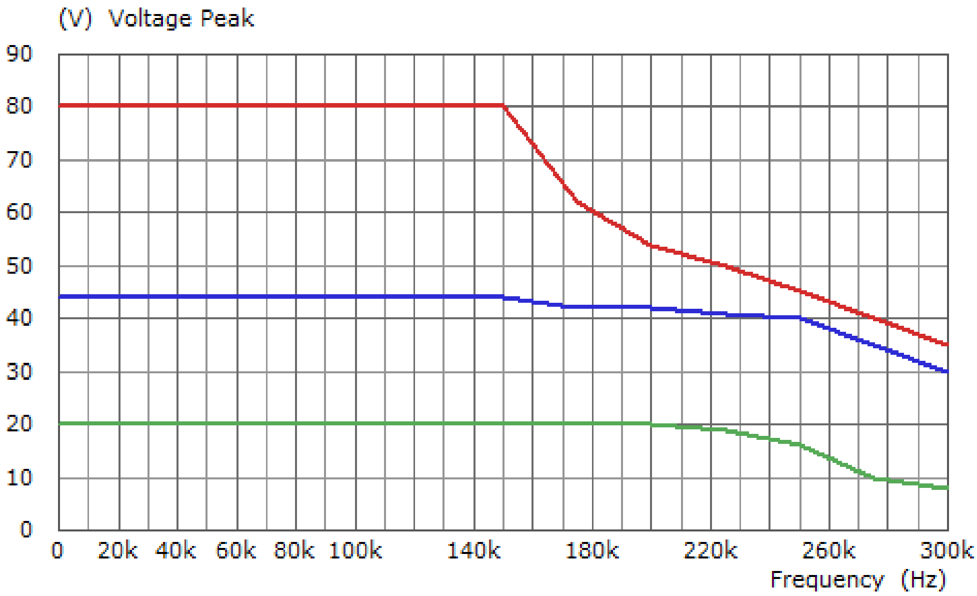


Figure 4: Amplifier output voltage at various load impedances

Small-signal bandwidth and slew rate are both parameters at the unloaded amplifier. If the amplifier has to provide an appreciable load current, the large signal bandwidth is limited by the output impedance. It can then be considerably less than the slew rate theoretically allows. Above 100 kHz the internal and external wiring plays a decisive role in how much power an amplifier can provide.

5 Conclusion

In addition to small-signal bandwidth and slew rate, there are a number of other parameters that determine the output power of an amplifier. Output specifications in the data sheet at various loads thereby provide valuable clues as to whether the respective amplifier is suitable for the test and measurement task.
As with operational amplifiers usual, HUBERT amplifiers have always a higher small-signal bandwidth than the slew rate for maximum sine modulation allows. Testing and test signals are often not sinusoidal, so that the higher bandwidth benefits the signal fidelity.

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