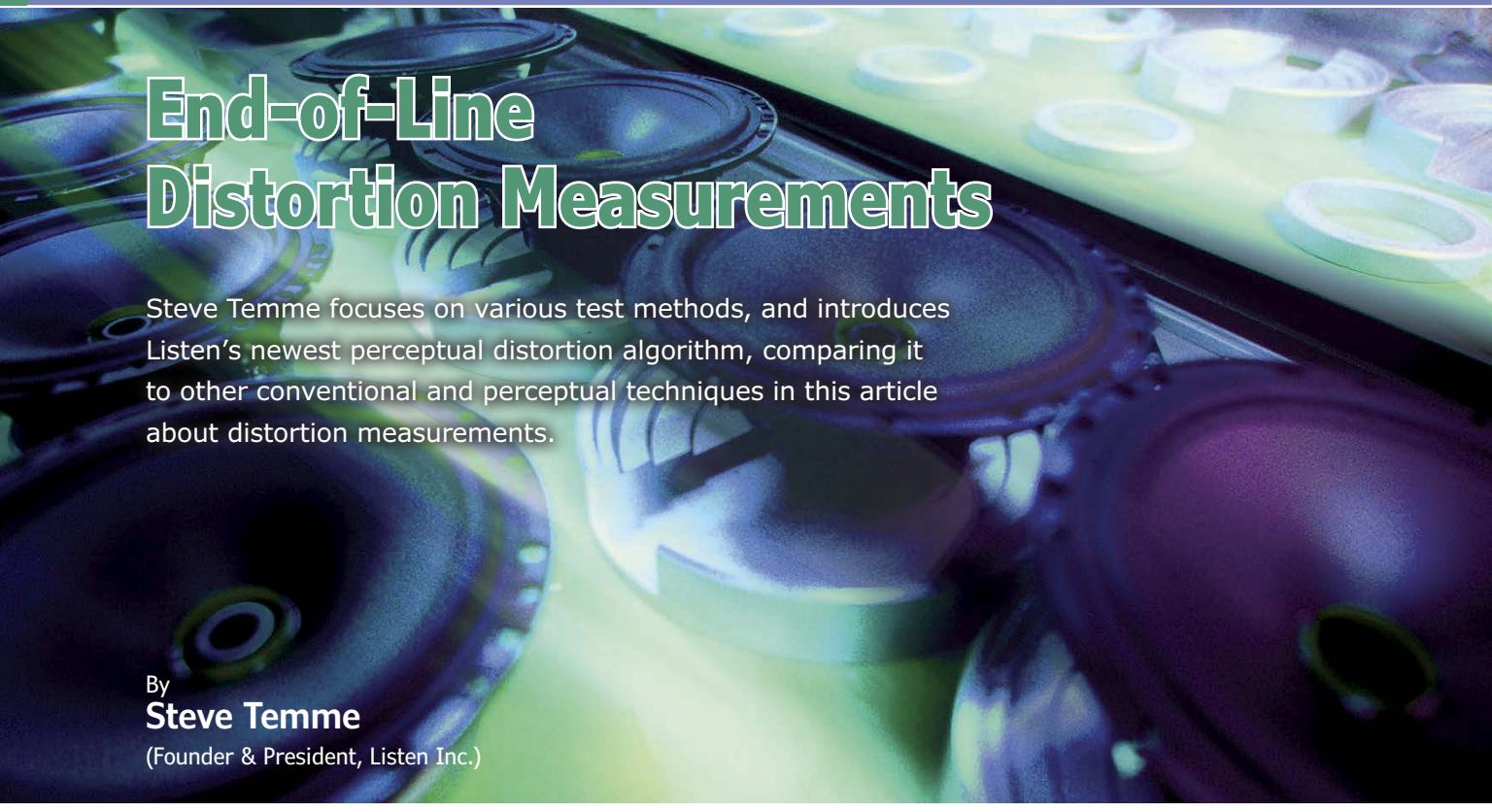


End-of-Line Distortion Measurements

Steve Temme focuses on various test methods, and introduces Listen's newest perceptual distortion algorithm, comparing it to other conventional and perceptual techniques in this article about distortion measurements.

By
Steve Temme
(Founder & President, Listen Inc.)

It is important to catch speakers with Rub & Buzz and transient distortion defects at the end of the production line, as such defects sound harsh and quickly give the impression of poor quality. These manufacturing-induced distortion defects are easy to screen for, but what exactly should you be measuring? In this short guide to end-of-line distortion measurement, we discuss various test methods, and introduce Listen's newest perceptual distortion algorithm, comparing it to other conventional and perceptual techniques.

What Causes Rub & Buzz and Loose Particles

Rub & Buzz and Loose Particle faults are pretty much exclusively introduced during the manufacturing process. Rub & Buzz is usually caused by small aberrations in the manufacturing process that make some parts rub or rattle when the speaker is operated, such as off-center voice coils, poorly glued surrounds, or incorrectly trimmed lead wires. This can be a random manufacturing issue with one product, or a drift in production line characteristics over time. Loose particles are caused when foreign particles, such as glue or magnet fragments, become trapped in the gap behind the diaphragm or dust cap during the manufacturing process.

Conventional Detection Methods

Although Rub & Buzz, and Loose Particles sound different to the trained ear than they do to the average consumer, both manifest themselves as an annoying vibration sound that may be more prominent at certain frequencies and worse at higher output levels. Despite this similarity, the detection methods are very different.

Rub & Buzz is a periodic distortion effect. Conventionally, it is measured using Higher Order Harmonic Distortion (HOHD) analysis, examining typically the 10th order harmonic and above. These harmonics contribute most significantly to Rub & Buzz as their separation from the fundamental frequency makes them less masked and more easily detected by the ear. There are several widely used measurement methods. A high-pass filter algorithm is common, but has its limitations as it combines all the harmonics into an overall metric, and does not distinguish between periodic and transient distortion. Other methods sequentially measure individual harmonics using a tracking filter that moves from one harmonic to the next. While this technique provides accurate and detailed information on each harmonic, it is not fast enough for use on automated production lines.

The most sophisticated methods utilize advanced algorithms to measure each harmonic

discretely and simultaneously. This offers two significant benefits. First, the individual harmonic analysis offered by this technique reveals much about the failure mode, enabling a deeper analysis of the failure mechanism. The user's complete control over which harmonics are analyzed enables the test to be highly customized to highlight the manufacturer's specific production line issues.

Second, the advanced filtering in algorithms—such as Listen's HarmonicTrak (**Figure 1**)—exclude the noise between the harmonics, which means that in addition to its extremely fast analysis speed, it is also highly immune to background noise—an important characteristic for production line use.

Even more advanced than this is the Normalized Rub & Buzz measurement. This is really an enhancement to the method just described. With normalization, the harmonic levels are first compared to the fundamental level at their measured frequency, then their ratio is plotted at their excitation frequency (**Figure 2**). This removes the effect of the frequency response from the distortion, which makes it easier to see the peaks in the distortion response, and simpler to set limits as the frequency response of each speaker is eliminated—both significant advantages for production line use.

Perceptual Detection Methods

HOHD detection methods have been around for decades, and work well. Any manufacturer with an emphasis on product quality likely already uses one of the techniques mentioned above on their production line. However, such methods detect all faults whether they are audible or not. This ensures that only good products are shipped, but since not all harmonic distortion faults are audible, either due to their frequency or masking by other frequencies, products that actually sound good may be rejected, therefore decreasing the yield.

Perceptual Rub & Buzz metrics enable identification of only the audible faults. If just these are rejected, yield is improved with no negative impact to your customers. Generally speaking, perceptual metrics use a combination of psychoacoustic models and other measurement techniques to arrive at a single number for distortion loudness in Phons, although the implementation and specific filtering models vary (**Figure 3**). This is a relatively new development, with the first perceptual metric launched in 2011, and others more recently. Such algorithms are not without their challenges. Many suffer repeatability issues and sensitivity to background noise, and

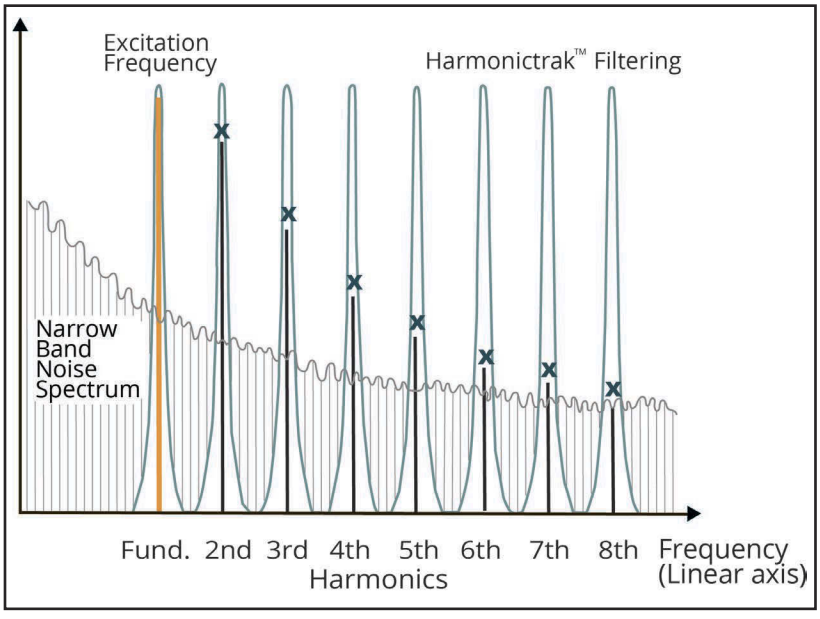


Figure 1: Demonstration of how the Harmonictrak algorithm filters and isolates the harmonics to measure them discrete and simultaneously.

the common remedy for this—longer test signals or expensive test chambers—is not conducive to rapid production line testing.

Listen's new enhanced Perceptual Rub & Buzz (ePRB) algorithm overcomes the limitations of earlier implementations, making it a truly viable end-of-line perceptual test. This product is the result of years of original research covering both perceptual filtering and noise reduction techniques.

There are two main differences between Listen's ePRB and other perceptual algorithms. First, it is significantly more repeatable due to the advanced noise filtering techniques. Most perceptual algorithms can correctly distinguish varying levels of perceptual distortion, with the

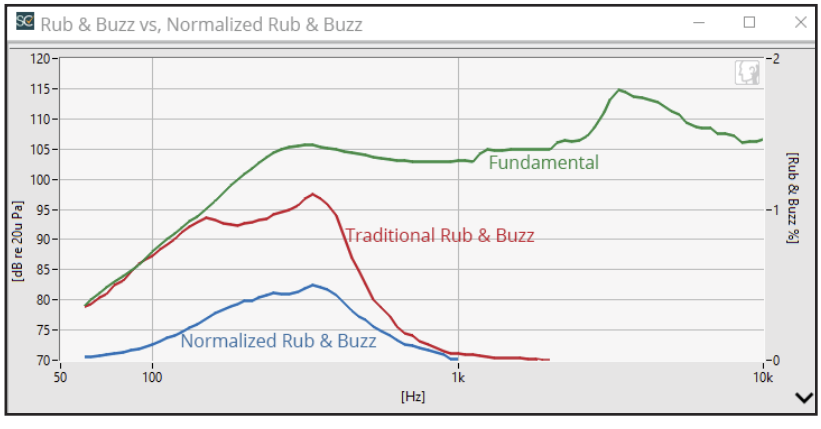


Figure 2: Comparison of traditional and normalized Rub & Buzz distortion

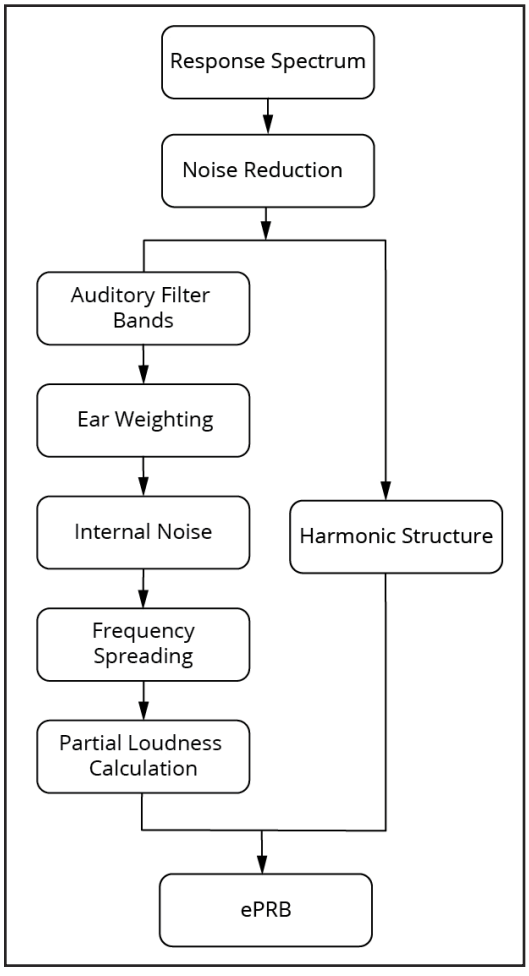


Figure 3: Perceptual Rub & Buzz Detection Algorithm

average response of multiple measurements giving a clear picture (**Figure 4**). However, it can be seen that the only one of the three algorithms that offers close correlation between multiple sweeps is the new ePRB algorithm. For production line use, where there is only one sweep, such repeatability is critical for setting limits and ensuring the integrity of the results. Second, the advanced perceptual filtering algorithms result in much closer correlation with human hearing and, for audible defects, conventional methods.

End-of-Line Metrics

Finally, let's discuss how these various algorithms each add value in an end-of-line test. To maximize yield and profitability from the line without compromising quality, there are three measurements that you should make: Perceptual Rub & Buzz, Normalized Rub & Buzz distortion, and Loose Particles. Here's why.

Perceptual Rub & Buzz can be considered the "Should I ship it?" metric. If the device passes this test, even though it fails conventional Rub & Buzz, the defects are inaudible so will not affect customer perception. Basing pass/fail decisions on this, rather than conventional Rub & Buzz metrics, can increase yield.

Traditional Rub & Buzz measures all incidences of higher-order harmonic distortion, whether audible or not, provided that you use a technique such as HarmonicTrak, which measures each

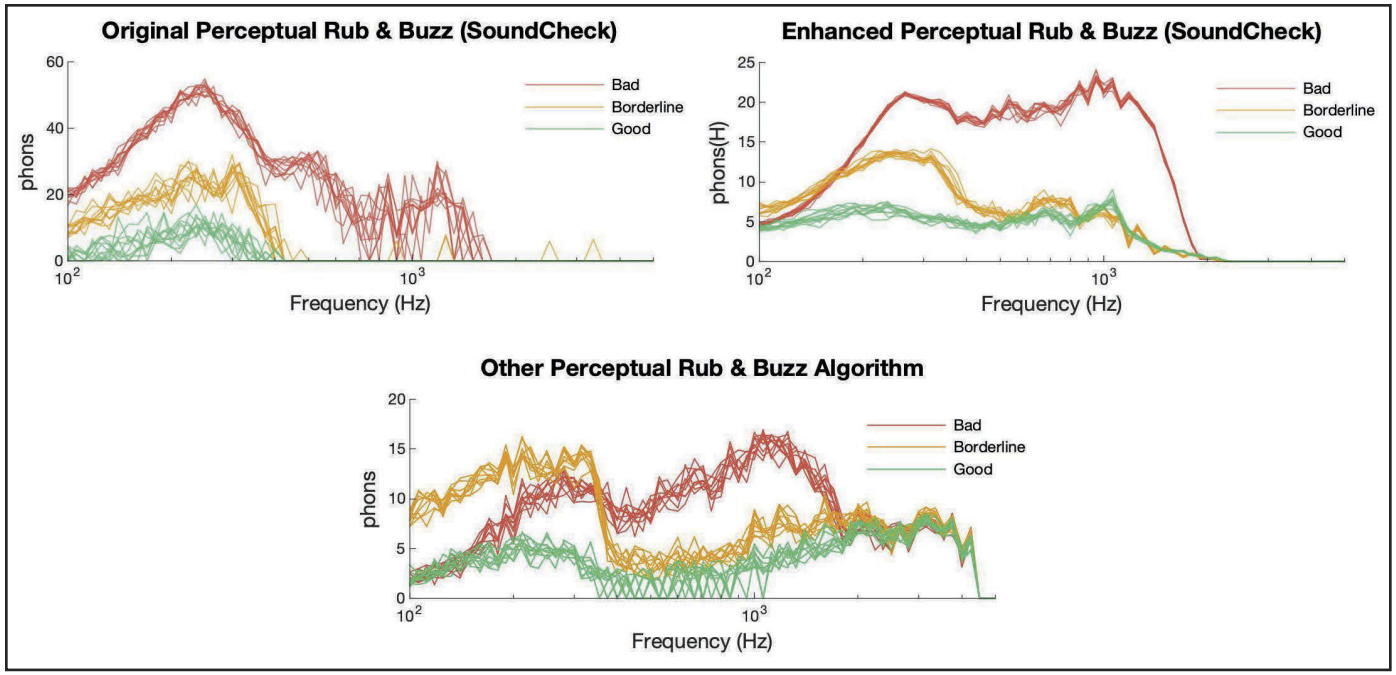


Figure 4: Comparison of three different perceptual Rub & Buzz algorithms, SoundCheck's original 2011 algorithm (the first of its kind), SoundCheck's new 2022 algorithm, and a recent algorithm from a different manufacturer

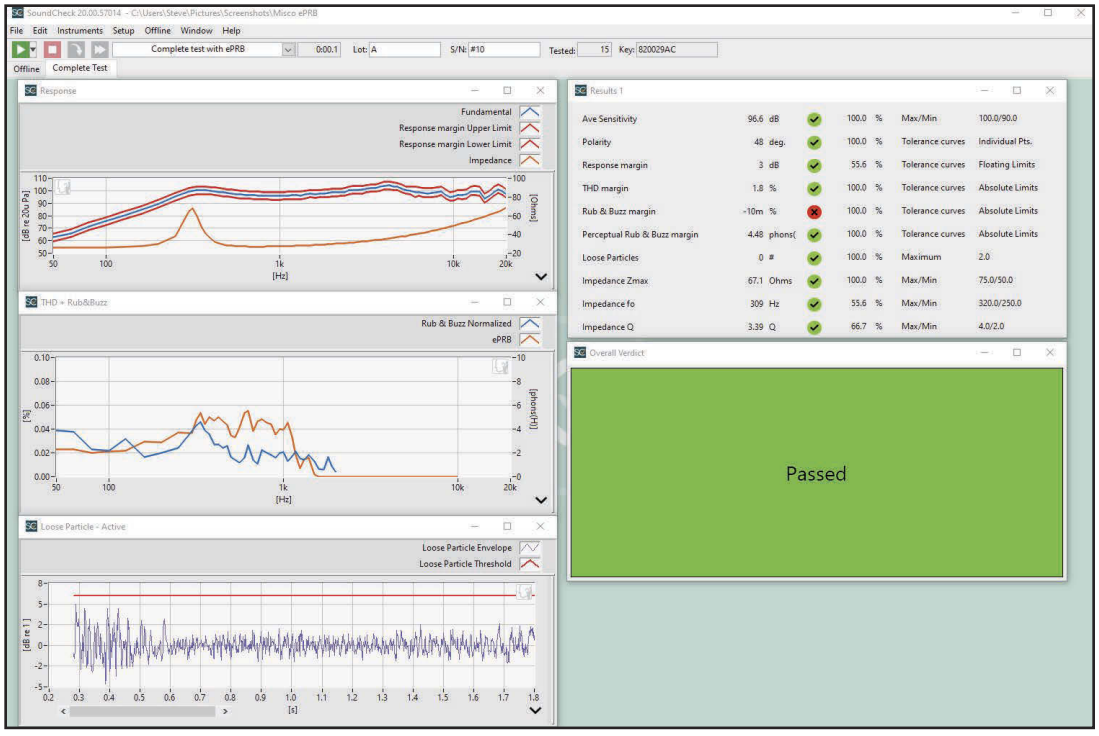


Figure 5: Complete end-of-line loudspeaker test demonstrating how a speaker may pass Perceptual Rub & Buzz metrics and overall test, while failing conventional Rub & Buzz because it is not audible

harmonic discretely and offers valuable information to understanding the distortion you might be hearing. Normalized Rub & Buzz measurement is preferred because it normalizes the result to remove the effect of the frequency response, making it more accurate and easier to set limits.

Examination of the exact harmonics reveals much about the cause of the distortion. For example, even-order harmonics are an indication of an asymmetrical nonlinearity, such as the voice coil not being centered in the magnetic gap. Odd-order harmonics are an indication of a symmetrical nonlinearity, such as clipping or reaching speaker cone and spider excursion limits. High levels of harmonic distortion in the 10th to the 15th order range usually indicate a rubbing voice coil.

Distortion at the 50th harmonic and above is frequently caused by voice coil lead wires hitting the cone. Careful selection of the analyzed harmonics can reveal production line issues and enable early correction before waste occurs. Trends can also be monitored over time, so that production line adjustments can be made if something is drifting out of specification.

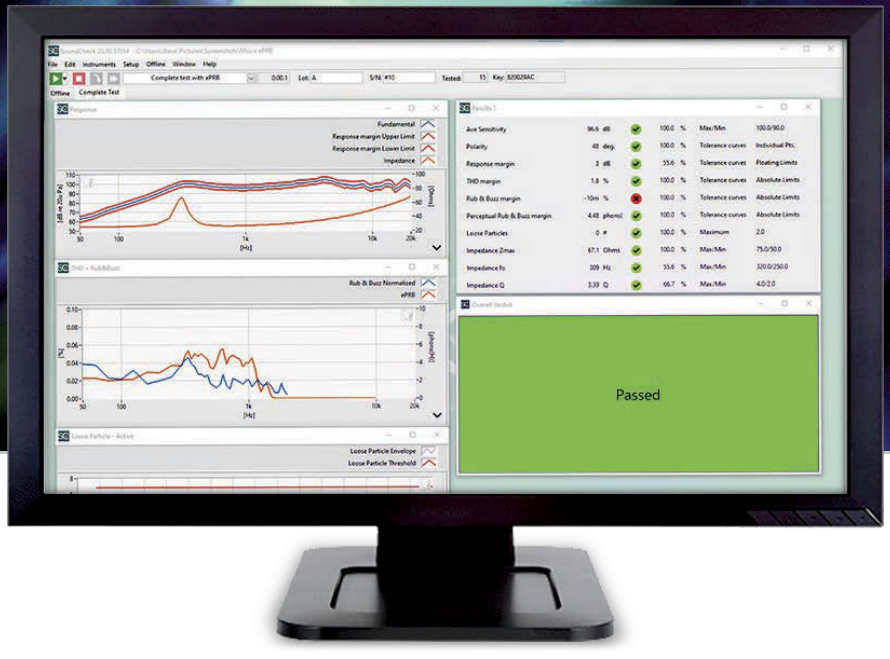
Let's not forget loose particles. As we explained earlier, the random clicking, popping or rattling noises made by these trapped particles cause transient, rather than periodic distortion. This means that they're not identified using the same methods as Rub & Buzz, but rather by using time-envelope analysis of the waveform. Like conventional Rub & Buzz, this is a valuable metric for identifying where problems are occurring on the production line before they become serious enough to cause audible defects.

One of the really convenient things about these measurements is that all of them, along with other end-of-line measurements such as frequency response, total harmonic distortion (THD), polarity, impedance, and more can be made simultaneously using the same stepped sweep test signal. This means that a complete array of measurements (**Figure 5**), including both conventional and perceptual distortion metrics, can be made in as little as one second, ensuring rapid throughput for high volume production lines. In other words, perceptual distortion can be added to your end-of-line test with no change in your existing setup, and no increase in test time. ***LIS***

About the Author

Steve Temme is founder and President of Listen, Inc., manufacturer of the SoundCheck audio test system. Steve founded the company in 1995, and for the past 25 years the company has remained on the cutting edge of research in audio measurement, regularly introducing new measurement techniques, algorithms, and hardware to enable testing of all kinds of devices ranging from basic transducers to complex audio systems. In recent years, Listen's product development focus has been on creating the algorithms, interfaces and test methods to measure today's many and varied wireless and cloud-communicating devices. Prior to founding Listen, Steve worked for many years as an acoustic test and measurement applications engineer at Brüel & Kjær, and also as a loudspeaker design engineer at Apogee Acoustics. He holds a BSME from Tufts University, has authored numerous papers on acoustic testing, and has lectured extensively throughout the world.

IS IT A DEFECT IF NO ONE CAN HEAR IT?



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