About The Author
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Alex first picked up a bass when studying engineering at university, and his quest for sonic perfection led him to found Barefaced Audio, while also leading The Reluctant, an alt-ska/funk outfit.

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This column is brought to you in association with Barefaced Ltd who manufacture high-output speaker cabs for the gigging bassist. Barefaced have recently launched their new Big Baby and Big Twin cabs, the most accurate and extended range bass cabs ever made. An archive of previous articles plus a glossary of terms can be found at **www.barefacedbass.com**

But This Goes to 11...

Welcome to the world of bass rigs.

What is Clipping?

If we go back many months to when we started discussing gain and voltage in amplifiers, we saw that clipping is the distortion that occurs when the input voltage multiplied by the amplifier gain causes the output voltage to try to exceed the maximum output voltage of the amplifier, thus the peak of the note is 'clipped' off. 99.999% of the overdrive, distortion and fuzz sounds that you've heard on recordings and gigs are the result of clipping. That clipping can happen in solid-state components or valves and in pedals, preamps or power amps. Sometimes it sounds nice, sometimes it doesn't – and sometimes those nasty clipped tones sound fantastic in one context (Larry Graham's double-tracked fuzz on 'Dance To The Music') but would be awful if you applied them to other tunes (imagine that on a country record!). So the first things to note are that clipping is common and can be applied musically.

Power Density In Square Vs Sine Waves

When a signal is fully clipped the waveform approaches that of a square wave. If we make some simplistic assumptions, such as a bass guitar signal being like that of a sine wave (which it absolutely and categorically is nothing like!), we might then calculate that a square wave has 1.414 x (sqrt2) the mean voltage amplitude of a sine wave of equal peak amplitude.

Fig 1 – sine wave

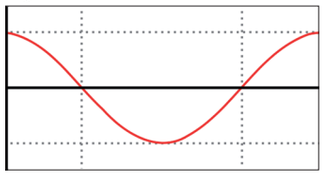
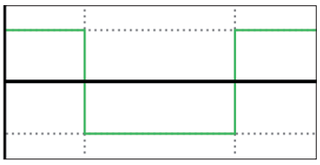


Fig 2 – square wave (cone acceleration)



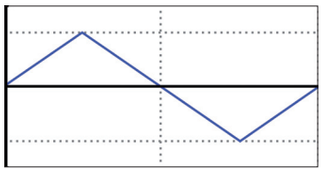
This might then lead us to assume that if we push a 500 W amp to full clipping we can get twice the power out that it's rated for, which is true to a point. However, it won't manage to sustain this power for very long at all before it runs out of current capacity, which tends to manifest itself either in the voltage rail sagging (so the power output drops) or in thermal shutdown (and fortunately the vast majority of amps will switch back on once they've cooled down).

The Myth Of The Stationary Cone

One oft-quoted lie is that when you play a square wave through a loudspeaker the voice coil will overheat because the cone doesn't move for the duration of the flat top and bottom segments of the square wave (and voice coils partly rely on movement for cooling), and also that the violent movement as the cone moves from all the way out to all the way in (the vertical parts of the square wave) can almost instantly damage the suspension. Happily, I'm pleased to inform you that this is not only completely untrue but whoever came up with this myth also demonstrated an abject lack of understanding of loudspeaker mechanics!

The reality is that when you apply a square wave to a loudspeaker it moves with constant acceleration thus increasing velocity from the centre point towards the maximum forwards excursion, and then when the wave reverses it decelerates steadily until its velocity reverses and then moves with increasing velocity inwards towards the centre point and then on towards the maximum rearwards excursion … and then decelerates again and resumes its forward motion. And so on, back and forth. A mathematical way to describe this is that the loudspeaker velocity is the integral of power (ie force and thus acceleration) over time, so square wave integrates to triangular wave, while the loudspeaker excursion is the integral of velocity, so triangular wave then integrates to a curve not dissimilar to our original unclipped sine wave!

Fig 3 – triangular wave (cone velocity)



Fourier Transforms And Harmonic Content

Many years ago a clever gentleman by the name of Mr Fourier worked out that any repeated waveform can be broken down into a series of sine waves of varying frequency, amplitude and phase. This is actually how our ears and brains work together to understand sound and music, by taking a complex eardrum vibration and dissecting it instantly into its component parts. Not only are the sounds of an orchestra or band able to be broken down into lots of separate

parts for each instrument, but so too are the separate notes from the chords that polyphonic instruments are playing and also the separate harmonics that make up each musical note. If we take our hypothetical square wave and break it down to its constituent harmonics we find it's actually made up of an infinite series of odd-order harmonics, and the higher this series goes in frequency, the squarer the wave. Now, as I'm sure you've noticed, no woofer goes all that high – that's why many bass cabs have tweeters (and/or mid-range drivers). Correctly you might assume that one of the reasons for woofers not going that high is that the mass of the cone is too large for the motor to accelerate it quickly enough to reproduce high frequencies. However, there is also a second reason, which is very important in this context.

Voice Coil Inductance And Low-pass Filters

If you coil up a length of wire to make a loudspeaker motor, one inescapable fact is that this coil will exhibit a characteristic called 'nductance'. When you apply an alternating voltage to a coil it acts as an electromagnet, generating a magnetic field. The larger the inductance of the coil, the longer it takes to charge and discharge the electromagnet (as the north-south poles of the magnet have to flip every time the voltage reverses), and this resistance to rapid charging and discharging blocks high frequencies. We call this ability of an inductor to block high frequencies a 'low-pass filter' (because it only allows lower frequencies to pass through). So if we apply a square wave voltage to a voice coil, the voice coil's own inductance blocks the higher-frequency components that make the wave square and thus unsquares the wave, making it more like a sine wave. Therefore, although the power amp may be attempting to deliver twice its rated power when fully clipped, the low-pass filter built into any woofer reduces the resulting current that actually flows and thus the power the speaker has to handle (because power = voltage x current).

Fig 4 – clipped amp

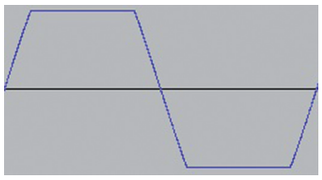
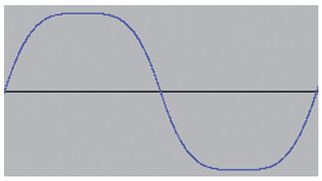


Fig 5 – output filtered by woofer inductance



Guitar, Bass And PA Speakers Are Very Different Things

One of the rules of thumb when putting PA systems together is that your main FOH speakers should be driven by an amp rated at twice the RMS power handling of the cabs. The reason behind this is that the sound engineer wants to be able to drive the loudspeakers hard without the amp clipping. So why the fear of clipping with PA systems? If you were to dissect a typical high-end PA speaker, say one with a potent 15" woofer and high-power compression driver tweeter on a large horn, you might be shocked to find that the thermal power handling of the woofer is far greater than that of the tweeter. This might lead you to worry that if you use an amp that can push the woofer to its limits you will blow the tweeter. In fact, this won't be the case, for two reasons: firstly, the sensitivity of a typical compression driver is much higher than that of a typical PA woofer, so you don't need to put as many watts in to get as many dB SPL out (but we'll overlook that for this example); and secondly, the power distribution in music is not even – above 100 Hz the power density tends to halve for each octave you ascend (table 1).

Table 1

Power distribution for a high-quality two-way PA cab with a 1 kHz crossover point			
Octave band (Hz)	Proportion of power	Power for 1000 W input	PA speaker split
125 – 250	50.4%	504 W	Power to woofer = 882 W
250 – 500	25.2%	252 W	
500 – 1,000	12.6%	126 W	
1,000 – 2,000	6.3%	63 W	Power to tweeter = 118 W
2,000 – 4,000	3.1%	31 W	
4,000 – 8,000	1.6%	16 W	
8,000 – 16,000	0.8%	8 W	

Now, if we try to get that 1000 W clean signal from an 800 W amp we end up clipping the amp, and because clipping and thus squaring off the wave increases the proportion of power in the higher frequencies we see that the amount of power going to the tweeter rapidly increases. Therefore, clipping PA power amps is likely to blow tweeters, hence those two PA 'rules': amps should be more powerful than cabs, and clipping is bad because it blows speakers (but tweeters, not woofers!).

Let's now look at the power distribution for a bass guitar going through a bass cab (table 2). As typical music demonstrates a halving of power as you ascend each octave, and as many of the instruments are both higher pitched and louder in the mids and treble than for bass guitar, the power distribution is even more skewed. If we take a conservative approach and assume a thirding of power for each octave.

Table 2

Power distribution for a typical two-way bass cab with 4 kHz crossover point			
Octave band (Hz)	Proportion of power	Power for 1000 W input	Bass cab speaker split
125 – 250	66.7%	667 W	Power to woofer = 996 W
250 – 500	22.2%	222 W	
500 – 1,000	7.4%	74 W	
1,000 – 2,000	2.5%	25 W	
2,000 – 4,000	0.8%	8 W	
4,000 – 8,000	0.27%	2.7 W	Power to tweeter = 4 W
8,000 – 16,000	0.009%	0.9 W	

This shows there is very little power going to the tweeter in normal use and that unless you're running lots of effects earlier in the signal chain even the most vicious clipping isn't going to skew the power balance enough to upset the tweeter.

Bass Rig Power Matching Rule Of Thumb #1

What we're trying to demonstrate with all this is that if you're playing bass guitar and your amp clips frequently (but not constantly), then as long as it still sounds good it isn't a problem. It's only on more modern amps that we have clip LEDs – if we had those indicators on older lower-power amps we'd see them lighting up all the time, but as there are none we don't worry about clipping until our ears think we should. So if your preferred bass sound is relatively clean, as long as your amp-power-output-to-cab-power-handling ratio is little greater than 2:1 you need not worry about clipping unless it starts sounding nasty or the clip light never goes out.

But what about dirty sounds and effects? That's where our instrument needs treating a little more like a guitar – and we'll deal with that next month .