When Bad Amplification is Good: Distortion as an Artistic Tool for Guitar Players

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Abstract: This paper surveys how distortion is used to enhance the tone and the expressive range of electric guitars in modern music, especially jazz, blues, and rock.

HISTORY

Practical electric guitars and guitar amplifiers became available in the early 1930's. They initially were developed to allow guitars to compete with loud instruments such as horns and drums, but musicians such as Charlie Christian quickly realized that electric guitars offered a voice very different from that of acoustic guitars. It let them develop new playing styles that incorporated expressive single-note phrases, which had been the exclusive territory of horn players. Distortion was an integral part of the new voice. It was not necessarily considered desirable, but was a side-effect of early amplifiers being extremely simple. In the 1950's, blues guitarists started to turn up their amplifiers far beyond the rated power because their guitars had to be even louder as electric blues evolved to be a hard-driving, raunchy music played in loud clubs. This produced significant distortion, which gave the guitar yet another voice that was cultivated by pioneers such as "T-Bone" Walker and B.B. King. Distortion also became part of country music as it was played in increasingly large venues that strained the power capacity of guitar amplifiers. As rock-and-roll appeared in the mid-fifties, more powerful amplifiers became available. However, guitarists had then discovered that they liked distortion for certain styles of music and it now became a sought-after quality rather than a design flaw of underpowered amplifiers. Starting in the 1960's, the sound of distorting amplifiers grew exceedingly popular. Guitarists such as Jimi Hendrix, Eric Clapton, and Carlos Santana exploited masterfully the artistic possibilities offered by high-power amplification with massive amounts of distortion. Today distortion is an essential part of the electric-guitar sound and is used in various amounts for all kinds of contemporary music.

TECHNOLOGY

Most guitar pickups exhibit a lowpass characteristic with a cutoff between 2.5 and 4 kHz. Thus, guitar amplifiers need not reproduce a very wide range of frequencies. However, the output from electric guitars has a very wide dynamic range. The signal can have onset peaks up to several volts, but decays to a fraction of a millivolt. Early guitar amplifiers reflected the state of electronics at the time. They contained a very simple tube circuit producing about 5 to 15 Watts and were mounted in a wooden box together with a loudspeaker of about 10" diameter. Their sensitivity was relatively high to ensure that even weak guitar pickups could produce full output power. As a result, stronger pickups could easily drive the amplifier into saturation, which caused audible non-linear distortion. In the 1950's and early 60's when distortion became a deliberate part of the electric-guitar sound, amplifiers typically produced between 20 and 100 Watts and used a variety of loudspeaker arrangements. These amplifiers, which are now considered 'classic,' still used rather simple tube designs and lacked the sophisticated features used to reduce distortion and increase bandwidth in hi-fi tube amplifiers of that period. Accordingly, they often produced considerable distortion even at low output levels. Whereas such distortion is unacceptable for hi-fi, it adds a desirable coloration to the electric-guitar sound without being noticeable as distortion. As the output level increases, the harmonic and intermodulation distortion increase gradually because absent or weak negative feedback allows the simple tube circuit to saturate gradually. The different sections of the amplifier (input, driver, and output tube stages; the output transformer and loudspeakers; and last, but not least, the unstabilized power supply, which causes the supply voltage to sag as the current increases) all contribute in different ways to the overall distortion. The final
sound is also enhanced by the limited frequency response of a 'good' guitar speaker, which does not reproduce
frequencies above 6 kHz or so. Reproducing higher frequencies results in an undesirable, harsh and brittle sound. In
summary, the great sound of a 'classic' guitar amplifier results from a number of characteristics, most of which would
be considered serious design flaws in hi-fi amplifiers.

Newer amplifier designs often include many improvements such as more flexible tone controls and extra gain
stages, which give the amplifier extremely high sensitivity and allow massive amounts of distortion to be generated
in the preamp. Interestingly, musicians continue to prefer tube designs and shun solid-state amplifiers, mainly
because the first solid-state guitar amplifiers were poor: they sounded 'cold' (i.e., they were too linear and
unresponsive in terms of distortion) and were unreliable. Reliability problems have long been overcome, but the
'good flaws' of classic tube amplifiers have only recently been reproduced in solid-state amplifiers. Creative
engineering is required to produce 'classic' distortion by nearly perfect, highly linear solid-state devices.

The industry also produces numerous distortion devices that can be connected between the guitar and the
amplifier. They range from simple 'fuzz-boxes' to digital signal processors that include virtual models of the circuitry
and behavior of 'classic' amplifiers. These devices allow musicians to obtain any desired amount of distortion at
levels well below those produced by fully overdriven power amplifiers. They also can add distortion to an existing
amplifier, thus replacing or augmenting extra high-gain stages in the preamplifier.

WHY BAD AMPLIFICATION IS GOOD: PUTTING DISTORTION TO USE

The attraction of distortion may be understood by considering its effects in the frequency domain (how it affects
the timbre or 'sound') and in the time domain (how it affects 'sustain', which is the time until a note fades away).
The two domains are interrelated, of course.

**Frequency domain:** The output from an electric guitar consists of a fundamental frequency and a number of
higher-frequency near-harmonics. The higher frequencies deviate from integer multiples of the fundamental due to the
nature of the decaying string vibration. Distortion adds harmonics as well as sum and difference frequencies resulting
in a rich tone with slow, irregular modulations. The distortion components increase faster than the input level and
become a greater and greater part of the total sound as the strings are picked harder. Because saturation (and thus
distortion) occurs rather gradually in tube amplifiers, the amount of distortion components can be finely controlled
by the touch of the guitar player. Thus, distortion provided by a 'good' guitar amplifier puts an extremely wide
variety of timbres literally at the fingertips of the musician. This control is attractive to the player because it expands
vastly the expressive 'vocabulary' of the guitar sound.

Distortion also has a pronounced limiting effect. Strong input signals produce an output power that is only
moderately higher than that produced by weak input signals. Thus, softly-picked notes played with heavy distortion
are easily heard with all their nuances intact, whereas they would all but disappear without distortion. Finally,
distortion makes extraneous sounds that can be produced with a guitar stand out. This allows guitar players to put
artificial harmonics, 'squeals,' 'scratches,' and other interesting sounds to artistic use.

**Time domain:** Guitarists also value distortion because it increases sustain. The distortion entails limiting, which
prevents the amplifier output from decreasing significantly until the vibration amplitude of the string has decayed
considerably. The long notes thus produced are particularly amenable to expressive gestures such as vibrato, string
bending, and double-stops. Sustain is also enhanced by the construction of modern electric guitars.

A spectacular sustain can be produced by playing loudly. The electroacoustic feedback loop from string, via pick-
up and amplifier to loudspeaker and back to the string can form an oscillator when appropriate gain and phase
conditions are present. If the amplifier is turned up sufficiently and the distance between guitar and loudspeaker is
right, the sound wave from the loudspeaker will excite the string and help maintain its vibration amplitude. The
'endless' sustain produced in this way makes the instrument 'come alive' and is prized by many guitarists, but
control of the feedback loop is difficult to master. Recordings by Jimi Hendrix and Carlos Santana showcase the
musical use of high-power amplification and controlled feedback.

Apart from the endless sustain, reasons for guitarists' desire to play loudly may be found in the non-linear
properties of human hearing. For example, masking depends strongly on sound level. Therefore, the perceived
spectrum or timbre of a distorted guitar is likely to change with level and be more pleasing at high than at low
levels. In addition, recent research indicates that loudness may grow faster at high than at moderate levels. Thus,
subtle variations in the amplitude of an amplifier driven into soft saturation may be heard as more prominent at high
than at moderate levels.