

# Digital Audio: Understanding Pitch and Time Manipulation

BY KURT GARTNER

The manipulation of the time (duration) and pitch in the realm of digital audio has become an invaluable tool in the practice, performance, and production of music. Thanks to faster computer processors and robust software packages, entire audio tracks can be transposed and/or slowed down incrementally for practice purposes. Files (individual notes or phrases or entire tracks) can be manipulated to fit the tempo and key of an existing project. Advanced applications even allow users to tweak intonation, note length, and other parameters of individual notes within a multi-track recording—powerful editing tools in a professional audio production environment. In order to utilize this technology, it's useful to have a basic understanding of what's going on “under the hood.”

## PITCH BEND

Perhaps the easiest and simplest means of altering the pitch of digital audio is to change the speed at which it's played back. Those who remember analog tape recorders know the results of recording at one speed and playing back at another. For example, we may record a single A-440 tone on a vibraphone for a note length of four seconds. If we record the original tone at 9.5 centimeters per second, then play back the recording at 4.75 cm/s, the most obvious change is that the playback time has doubled, from four to eight seconds. Additionally, the note we hear in playback is A-220, an octave lower than the original note. Many musicians have used this technique to facilitate the transcription of jazz solos, to hear a stark representation of the accuracy of one's performance, or for other (sometimes comedic) purposes.

The same process of pitch alteration may be achieved using

digital audio editing software such as Sonic Foundry's “Sound Forge” (PC) or Bias' “Peak” (Mac). Observe the visual representation of a motive played on marimba (see Figure 1), followed by a close-up look at the first note of the motive (see Figure 2). In these examples, the sound is represented by amplitude (in decibels) on the vertical axis, and time (in seconds) on the horizontal axis.

Applying the pitch bend process to the entire motive, we double the length of the motive from approximately four to eight seconds, while shifting the pitch down by 12 semitones, or one octave (see Figure 3).

A close-up view of the first note of the altered motive shows the same basic “shape” of sound (see Figure 4). Note, however,

Figure 2. Original motive, zoom view of first note.

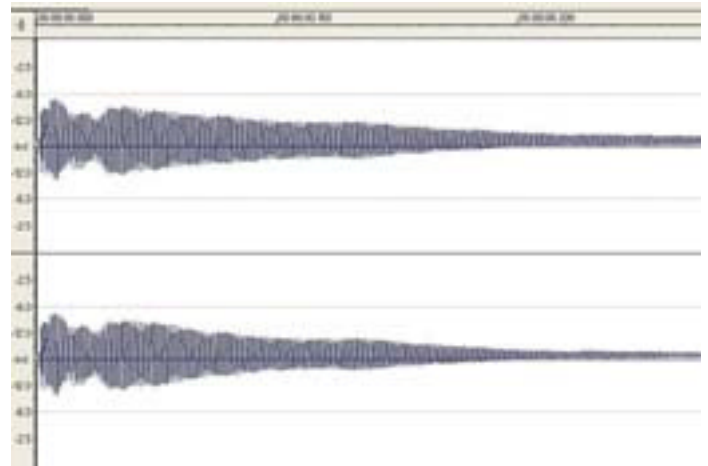


Figure 1. Original marimba motive.

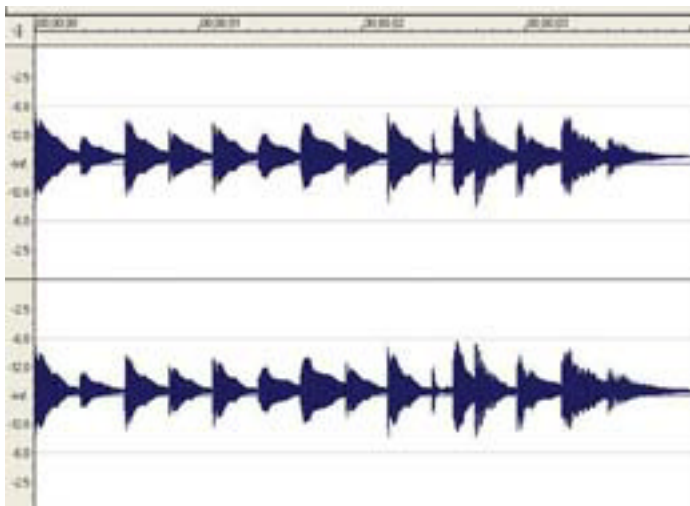
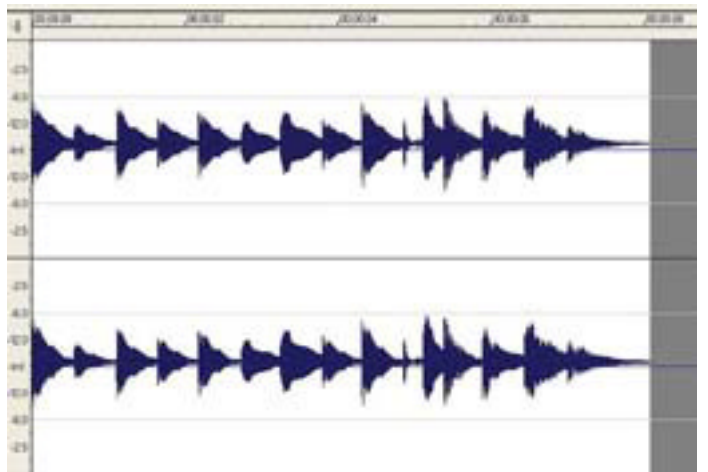


Figure 3. Marimba motive with pitch bend effect, 12 semitones down.





## Sound Enhanced

Visit the Members Only section of the PAS website ([www.pas.org](http://www.pas.org)) to hear audio examples of the concepts discussed in this article.

Audio Example 1 is the original marimba motive, as shown in Figure 1.

Audio Example 2 demonstrates the pitch-bend effect, as shown in Figure 3.

Audio Example 3 is the original marimba motive with 200% time expansion, as shown in Figure 5.

Audio Example 4 is the original motive with 200% time expansion, drums-specific algorithm, as shown in Figure 7.

Audio Example 5 is the original motive in Melodyne with 200% time expansion, as shown in Figure 10.

that the duration of the note is double the length of the note shown in Figure 2.

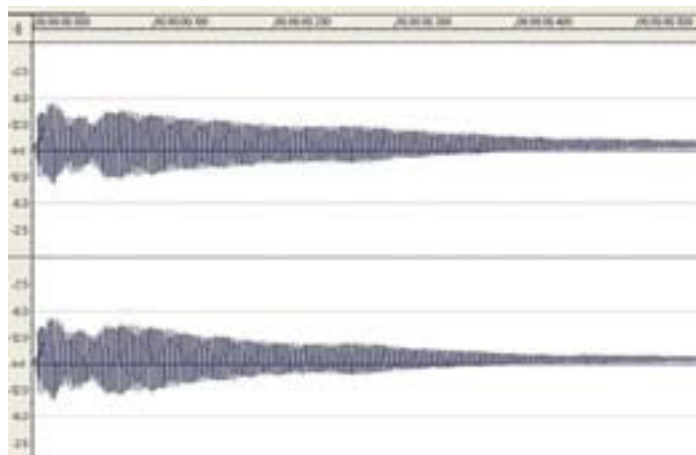
Applying a 12-semitone pitch bend is perfect for yielding a half-speed playback. Incidentally, Sound Forge allows the application of pitch bend of up to +/- 24 semitones, and the process may be repeated if you want your clip seriously low and slow (or chirping away like a hummingbird). If we simply need a 3/4-speed playback, we can apply a six-semitone pitch bend. If we're interested in staying in the original key, however, a six-semitone pitch bend creates obvious problems. In this case, we may want to apply the time expansion effect instead of pitch bend.

### TIME COMPRESSION/EXPANSION

In time expansion, the software directs the computer to apply an algorithm to the original audio file. In the basic (linear) algorithm, fragments of the original file are uniformly copied and re-injected into the file. In other words, original data ABCD becomes AABBCDD. In Figure 5, 200 percent time expansion has been applied to the original motive, essentially yielding half-speed playback.

The time-expanded motive appears to have not only twice the duration of time, but also twice the number of attacks! A

Figure 4. Zoom view of first note with 12-semitone pitch bend effect.



close-up view of the first note of the motive gives a clear view of the echo effect created by extreme levels of time expansion (see Figure 6).

The echo effect of extreme time expansion is acute with percussion instrument sounds, which are characteristically “front-loaded” with transient peaks, followed by quick decay. For best results, Sound Forge users are advised to keep time compression and expansion within a range of 75–115 percent of the original duration.

Programs like Sound Forge include other algorithms for time expansion, including one designed specifically for “non-pitched” drums. The algorithm includes adjustments for the characteristic properties of drums and other percussion instruments, reducing the echo effect. Applied to the original motive, the time expansion routine designed for “non-pitched” drums has successfully doubled the duration (see Figure 7).

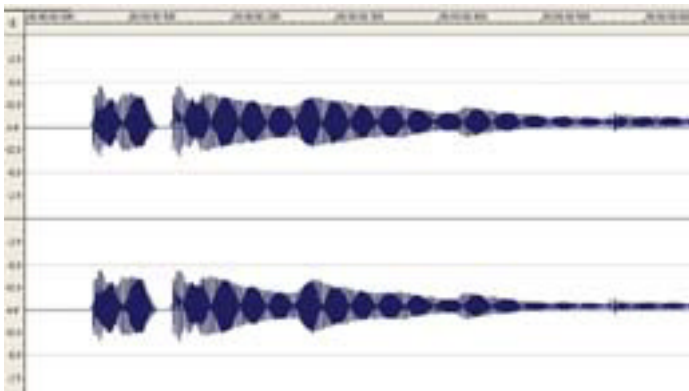
While the duration is correct and the echo effect has been minimized, the resultant clip includes complex, “buzzy” timbres of reduced audio quality. Compare the shape of the first note of the “drum-expanded” motive (see Figure 8) with that of Figure 2, the first note of the original motive.

When creating a slow-tempo practice track, you have to experiment and find the optimal combination of algorithm type and rate of expansion to suit the sounds on the original track.

Figure 5. Marimba motive with 200% time expansion.



Figure 6. Zoom view (first note) of motive with 200% time expansion.



You have to decide how much echo or timbre effect you're willing to accept in order to achieve the tempo that you want to hear in your finished product. If you need to change both the

Figure 7. Motive with 200% time expansion, drums-specific algorithm.



Figure 8. Zoom view of 200% time expansion, drums-specific algorithm.

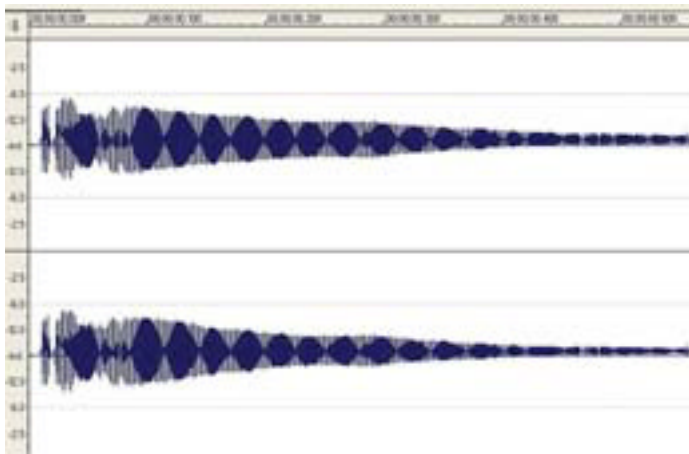
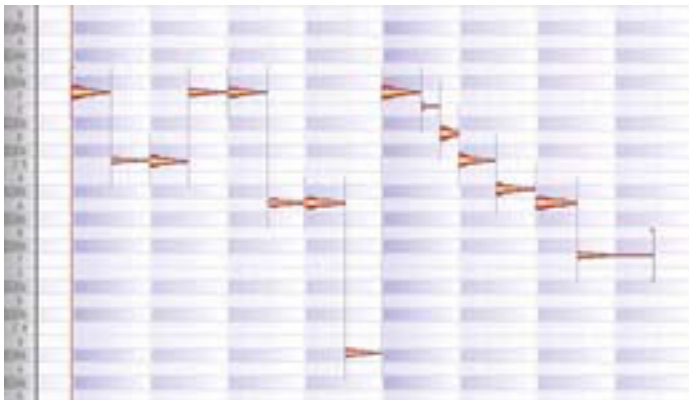


Figure 9. Original motive in Melodyne.



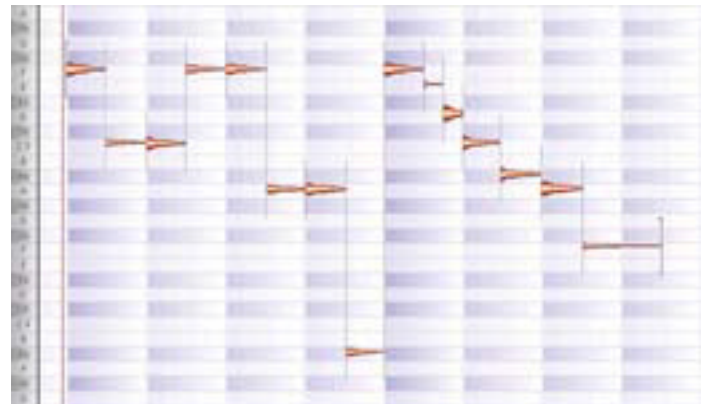
tempo and key of a track, you may apply the pitch bend and time compression/expansion processes in succession.

For the purposes of practicing with a reduced-tempo audio play-along track, the pitch bend and time expansion techniques discussed heretofore should yield acceptable results with patient tweaking. For production-level audio quality with extreme time expansion at original pitch, even more robust software becomes necessary. One program capable of such dramatic effects is Celemony's Melodyne software, available for Mac or PC. This software allows note-by-note pitch bend *and* concurrent time compression or expansion capabilities. Figure 9 shows the original motive again, as recognized by Melodyne.

Notice that the basic view is similar to the familiar MIDI "piano roll" view. Each note is represented by its own wave form at its specific frequency (pitch). Melodyne allows the user to combine the best qualities of both the pitch bend and time compression algorithms, allowing one to greatly expand the duration of the motive, while essentially "bending the pitch straight" or preventing it from being transposed (the default mode in this software). All of this takes place without significant loss of audio quality. After applying a "tempo adjustment" of half-speed, the individual notes remain at original pitch, without the negative side effects of echo or buzzy tone (see Figure 10). (The screen shot may look the same as the original Melodyne clip, because you must zoom out your view in order to see the entire clip.)

Of course, this technology creates possible applications of processes that go far beyond the global tempo change of an audio file. Users may tweak characteristics of any single note within a track. Consider the example of timpani—percussion instruments that are subject to variables of both pitch and duration with each note played. If a timpani track includes a note that is a bit sharp but not long enough, pitch and duration tweaks may both be applied to the targeted note without changing the timing or intonation of any other notes. The algorithms may even create the audio "smoothing" of tweaked notes with surrounding notes, to make the tweak imperceptible to listeners. Naturally, a program this powerful is not without cost; however, it may be well worth the expense if it means fewer recorded takes before completing a professional production.

Figure 10. Motive with 200% time expansion in Melodyne.



## STANDALONE SYSTEMS

Currently, musicians may use standalone systems to play back standard audio CDs while altering either pitch or tempo. This technology offers an affordable solution to percussionists who see portability as a priority, or who simply don't wish to spend computer time in order to practice with tracks at reduced tempos.

One example of a standalone CD player that allows you to maintain pitch while altering tempo (or maintaining tempo while altering key) is Tascam's CD-VT1mkII Portable Instrument and Vocal Trainer. It allows tempo-altered playback of up to +32/-50% at 1% increments. Additionally, it allows key change of +/- 6 semitones (with additional fine tuning capabilities). This unit also includes a metronome, looping, and several audio effects.

## YOUR TURN

Like any other aspect of percussion, you may spend any amount of money, time, and energy in learning and implementing digital audio pitch bend and time compression/expansion processes for practice, performance, or production. In any case, you can get started by experimenting with some demo software and learning techniques by trial and error. Once you're up and running with a particular software program, try the tutorials, save your work often, and remember that the "undo" feature of

digital audio software can be your best friend at critical moments!

Here are the URLs of companies that specialize in digital audio editing software or standalone playback systems:

Sonic Foundry – Sound Forge (for PC): <http://www.sonymediasoftware.com/products/soundforgefamily.asp>

Bias – Peak (for Mac): <http://www.bias-inc.com/>

Celemony – Melodyne (for PC and Mac): <http://www.celemony.com/cms/>

Tascam – CD-VT1mkII (standalone CD player) <http://www.tascam.com/PersonalCreativity.html>

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