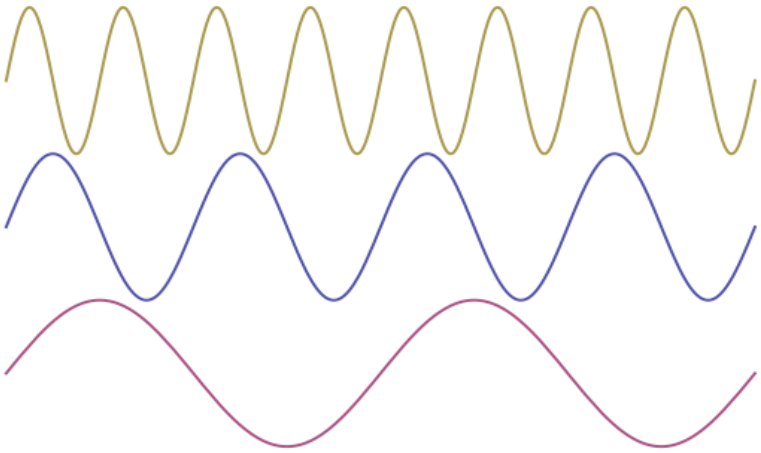
Project: Variable Undertone Effects Unit

Project Desciption:

Two major, but connected challenges, faced by both wind and string players are the sluggishness and large scale of bass instruments and the need for low harmonic support in roles which are so menial as to not merit the addition of another player to an ensemble. One principle which has been used to attempt to remedy either or both of these problems is undertonality- the production of tones with frequencies at a whole-number divisor of a fundamental frequency. This can be seen as the opposite of an overtone, which are the whole-number *multiples* of a fundamental frequency. (It is important to note that almost any sound in existance has overtones, whereas undertones must be actively generated from their fundamental.)

A fundamental wave (center) seen with its first overtone above it and first undertone below it:



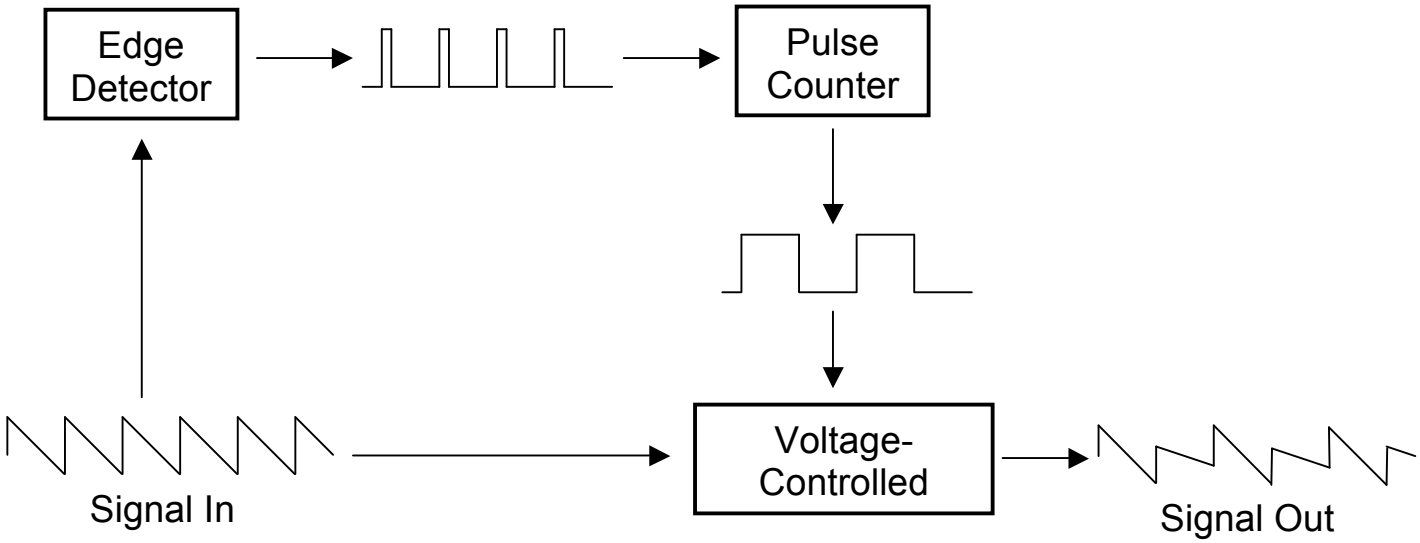
For example, if one brought out the first overtone of a sound, they would be boosting an octave above the fundamental of that sound. If the first undertone were created and added in, this would add an octave down below the fundamental of that sound. As the instrument need only be capable of producing the octave above in this case, this instrument would be able to play the octave lower, without changing any significant part of the instrument. (This case can be extended- if the 3rd undertone could be accessed, the instrument could be doubled two octaves down, and so on for higher-number undertones). However, this principle has been used very little until modern times due to the difficulty of mechanically producing undertones.

Before digital signal processing, essentially only one method was available to exploit undertonality- a small, hard object held lightly against a vibrating string, bouncing off the string as it vibrates. By carefully adjusting the firmness of the contact, the object can be made to bounce off the string once over a constant number of cycles, accessing any of the undertones of the vibrating string. (For example, if this object was adjusted so it bounced off the string every two cycles, it would generate a tone an octave under the vibrating string.) However, this method is very sensitive, and the object must be manually controlled to keep the undertone constant (the amount of force which must be applied to the bouncing object varies with the amplitude of vibration of the string). With one hand used to control this object, only one hand is available to play the instrument, seriously limiting such an instrument. Given these limitations, this technique has been applied to a very few instruments in the past- some zithers and, occaisionally, a bass or drone instrument from the viol or viola family.

With the advent of digital signal processing, a few new options became available for harmonic support. Octave (and other interval) pedals generally rely on one of two methods to generate their extra pitches- either identifying the fundamental and synthesizing a waveform at the desired extra pitch (older method), or taking a fast Fourier transform of the entire input, shifting its pitch, and rebuilding the waveform at the new pitch (newer method). Each of these methods has its upsides and downsides: The older method has a faster response, but it is unsuitable for multiple notes played at once (unless very large distortion is desired), as well as some examples of the type (i.e. MXR's Blue Box) having a distinctively synth-like tone which can sound quite disruptive. The newer method can handle multiple notes and is not as disruptive in its sound, but is slower in response, and can sound very muddy in certain conditions.

My project would aim to produce an electronic effects unit that provides a third option for harmonic support, by modeling the physical process of the bouncing-object technique. The unit would be built from three main sections, first, a edge detector, which reads the signal as it comes in, and produces a pulse for every complete cycle. This would feed into a counter circuit, which would output a pulse when a set number of waves had passed. (This number would be set externally, and would select the desired undertone- if it was set to 2, this would be an octave down, if it was set to 3, an octave and a fifth, etc.) The final part of the circuit would rejoin the simulated object with the original signal, using a variable amplifier, which would suppress (by a variable amount) the input signal at each pulse from the counter.

Signals and Components in Design:



The net result of this would be to return a signal the same as the original, except with an added-in component at the desired undertone. The use of the variable amplifier would give the feedback a tone color very similar to that of the original signal, removing some of the problems encountered in similar units with an overly synth-like tone. An additional feature over these units would be the ability to set which undertone to access- (including some, like the 2nd and 4th undertone, for which no unit currently exists). In sum, the sound would be very like applying a bouncing object to a vibrating string.

Beyond just building this effects unit, this project would equip me better, in both a material and mental way, for further projects in electronic sound. The effects unit includes components which are some of the most-useful and often-used in analog audio processing, building it will give me an improved working knowledge of the field. Also, a good portion of the expenditure would be into instrumentation and test equipment that are necessary for any further work in electronic audio.

Potential issues with this project include the usual problems with prototyping electronics- no component is ideal, and this circuit has never been built before, so there will be unintended behavior. To compensate for this, I have set aside most of the time in the project for debugging the unit. The unit will also be limited in its application to monophonic instruments, however, this is a consequence of the system it models- the bouncing-object technique is not suitable for more than one note at once. (It could still be applied to instruments playing chords, but the results would be unpredictable.)

Creation of an outcome report or presentation could be accomplished in a few different ways: First, with very little effort (simply patching the effects unit across a computer's sound card) recordings can be made with almost any sound as an input. These demonstration recordings would be enough to show almost anybody the range of tone possible with the effects unit. A live presentation could be composed of a demonstration, where a wide range of instruments (elec. guitar, synths, even a miked wind instrument) would be connected through the effect and played, and a short lecture on the underlying principle of operation.

Responses to some questions:

How will this device best alter a performance?

This unit is designed as a multi-use tool- it will be useful when applied both a “touch-up” to a sound and as heavy modulation that dominates the tone. Its primary strength is that it will be able to subtly add in undertones without changing the high components of the sound, so it could be used for light, phaser-like modulation (as well as its original purpose, adding in a clear, light undertone). However, in the design is also the capability for very aggressive modulation, capable of turning a very smooth sound into a very edgy sound. (Some settings should allow for sounds somewhat like a wavetable synth to be produced from an acoustic instrument or clean electric guitar). However, most of the settings that will be available on the unit will have effects that just can't be predicted right now- there may yet be additional uses for the unit that will be discovered after it is built and tested.

Will a composition result from this?

This will depend on the amount of time remaining after the unit is built and completely tested. The primary aim of the project is to build a tool for creating music, so creating a dedicated composition for the unit is of secondary importance (especially as this is unit is built for a supporting role- mainly for adding depth or changing the tone color of another instrument). That said, if the unit is completed ahead of schedule, a dedicated composition may be feasable.