# Outcome Report: Variable Undertone Effects Unit

The object of this project was to develop and produce a prototype of a new class of electronic musical effect. Original inspiration for the effect was from a powerful, but hard-to-produce extended technique possible on certain string instruments- the placing of a bouncing hard object near the end of a vibrating string, and carefully adjusting the pressure on it so that it bounced off the string at a constant frequency. This technique can be used to access the *undertone series* of the original frequency on the string. However, this technique is only useful with certain stringed instruments, and requires careful adjustment, making it ill-suited to most performance situations.

To further clarify a term central to this project, *undertone series*: This refers to the set of frequencies that are a whole number of times *slower* than a fundamental frequency. It is much less commonly referenced than the related *overtone series*, which is the set of frequencies that are a whole number of times *faster* than a fundamental frequency. This is due to the fact that any continuous pitch is composed of a fundamental frequency and its *overtone series*, whereas the *undertone series* is, in most circumstances, an interesting concept rather than one with practical signficance.

The ability to access an undertone series can be, however, of significant practical utility to a musician, due to the limitations of most physical instruments today. Almost every instrument today is composed of a resonator (string, tube, etc.) which is driven by a some source (a bow, a pick, air over a hole or past a reed). The fundamental limitation of this system is that, for the instrument to respond, the resonator must be set vibrating consistantly. By the nature of resonant systems, the more strongly resonant the system is, or the lower the resonant frequency, the longer this takes. So, the lower (or more powerfully-toned) a physical instrument is, the longer it takes to respond. This difference can be seen in the difference between the agility of a violin and a double bass (greatly similar instruments, the principal difference being in size). This problem can be averted if techniques can be found to access the undertone series of an instrument. The pitch difference between a double bass and a violin, to return to the earlier example, is slightly over two octaves. This corresponds, roughly to the third or fourth undertone. So, if some method was used to access the third or fourth undertone on the strings of a violin, pitches could be reached that are in the same range as a double bass, but, keeping the quick response (and most of the tone color) of the violin. (Important note here- this would not mean that the violin would sound *like* a double bass, it just would be able to reach pitches comparable to it).

The final result of the project was an hand-built prototype of the effect, reproducing the original technique well in sound character- producing a distinctive edge and adding in a clear lower tone. Best performance was achieved with instruments with a muted tone- older suitcase electric pianos, and electric basses, as well as subtractive synths. Good results were also achieved with samples of clarinets and soft-toned flutes. The effect proved very difficult to apply, however, to any instrument with a rich lower overtone series- guitars, violins, and most orchestral wind instruments. This is because of the design of the wave detection circuit- in order to produce the responsiveness needed for the effect, the circuit (a zero-crossing detector) can be triggered by strong harmonics as well as the fundamental wave, causing unpredictable effects.

Going further into the performance of the effect requires a technical description of its workings, which I provide here:

The effect works by analog multiplication between a source signal and an manually set undertone wave- this is accomplished using the AD633 IC (dedicated 4-quadrant analog multiplier). The undertone wave is generated using first a zero-crossing detector (with a small hysteresis) made from a LM311 comparator. This feeds into the clock input of a 74HC174 4-bit counter (only the first three bits are used in this system). The counter's output bits feed two different chips, an 74LS148 3-8 octal decoder and a ADG408 analog multiplexer. The octal decoder is used to reset the counter after a variable number of counts (depending on the setting of an 8-position switch). The analog multiplexer is used to pass through the values of the step waveform that will be multiplied with the original signal. These values are set manually using eight slide potentiometers mounted on the case.

Agressive debouncing was needed for the comparator, which was done by sampling its output at discrete times using a D-flop and a 555 timer, then passing only that value to the counter- frequency was set to ~75kHz (well above what might cause sample rate issues with the audio signal).