Serendipity, Pitch Tracker

Superclipping, differentiating, rectifying and integrating: a frequency to voltage converter, or a Pitch Tracker.

A gift from the old analog world
I consider myself lucky that I experience a serendipity moment every now and then. As it happened to me a long time ago. Like a real homo ludens I was playing around with Reaktor 3.0. Didn't really work towards something in particular, just fiddling around.

Suddenly, a picture appeared on my retina in a flash. It looked like a page from an electronics book or magazine. A diagram of a meter with which the frequency of an oscillator could be read. Just as simple as it is smart. That I had not thought of that myself. Yes, that comes when you have been working with advanced hardware and software for years now. Then you forget the time-honored analog techniques of yesteryear ...

Long before this experience I had already decided to try to make a Pitch Tracker, which was not yet implemented in Reaktor 3.0, just as it wasn't in the Nord Modular Classic. Well then you go googling and surfing on the internet. A lot of literature and algorithms were found, each and every one very advanced, based on, for example, autocorrelation and FFT.

In short, all very complex. But not that obvious super simple principle that I found because of that serendipity experience. I realized that this old-fashioned analogue principle was applied with digital precision in Reaktor. What bothered me, that after a lot of searching in my bookcase, I could not find the diagram that had appeared like a flash on my retina.

Long time after the working Reaktor version I went upstairs to pick up an audio cable from the clutter room. What did I see? An old Elex, Dutch magazine for hobby electronics, number 10 of October 1984. Herein I found the article with schematics. It did not include a meter that measured the frequency of an oscillator, but a bicycle speedometer. For the rest it was correct.

How it works
1) A random **monophonic** signal, with any waveform, goes into a '**superclipper**' (1 Invert). This transforms the input signal into a rectangular waveform with a constant maximum amplitude value '1' and a minimum value '0'.

2) Next, this rectangular signal goes into a **high pass filter** (2 FltHP) that is set to a very high cutoff frequency. This high pass filter now functions as a **differentiator**. This means that if the amplitude value at the input of this filter is a constant, the output of the filter gives the value '0'. Only if the

value at the input changes then does this differentiator generate a value that is proportional to the speed of the change.

Because the input signal is a rectangular voltage with a constant amplitude, we only see a value at the output of the filter for a short time, at the rising edge of the rectangle and at the falling edge. A rising amplitude at the input adds a positive value to the output. However, a decreasing amplitude has a negative value. Well, the output of the high pass filter now produces a positive and negative needle pulse.

3] This alternating positive and negative pulse train now goes into a **double-sided rectifier** (3 Rect). This leaves the positive needle points untouched, but 'folds' the negative 'up' to positive. This then results in a pulse train with only positive pulses of uniform amplitude and the same extremely short duration. The number of pulses per unit of time is now directly proportional to the input period of the input signal to be followed.

4) This positive pulse train goes to the input of a **low pass filter** (4 FltLP) which, unlike the high pass filter, is set to a very low cutoff frequency. Because of this low frequency setting, this low pass filter behaves like an **integrator**. The pulses are, as it were, averaged out, spread out. The result at the output of the LPF is now a constant value that is linearly related to the entry periodicity.

With this output we can now control an oscillator on the linear FM input. It is now only a matter of finding the correct multiplication factor (5 LevAmp) to let the tracking oscillator run unison. An extra multiplier (6 LevAmp) can be set to let the slave oscillator, for example, one or two octaves higher or lower. The moral of this story: an old analogue technique that used to be useful for not very precise measurements, suddenly becomes extremely up-to-date due to digital precision. It works so accurately and quickly that you can even build a Pitch Tracker with it.

The NMG2Demo Pitch Track example patch
Although the conversion precision is very good, the slave oscillator can not simply be synchronized one-to-one with the input signal. This results in a kind of chorus effect between the input signal and the follow-up oscillator. In most cases that is welcome though, as you really hear it as two identities that are very similar.

However, in order to really sync the slave osc to the input signal, a control circuit has been introduced which consists of a sample & hold module whose sample command input is triggered by the input signal and in which the output of the slave oscillator is sampled. These sample output values are inverted and added to the DC value from the converter. This feedback loop ensures that the slave osc can really be synchronized to the input signal. This synchronization can be activated by setting a value greater than 0 of the Inv input on mixer module 7 Lock Tune. The values for locking, lie between '2' and '12'. The optimal value is 8.6, the sync speed is then the largest and the lock range as well. Experiment with this. In variation preset 5 you notice that there is a kind of percussive tone.

What you hear is the alignment process to full synchronization. During this process the phase of the slave oscillator shifts. At Inv value 10.9 the phase of the slave is rotated exactly 180 degrees with respect to the master oscillator. Now, they extinguish each other. If you switch off one of the two oscillators in module Mix 2-1, you will hear the tone of either the master or slave appear again.

Global structure
In the left column in the patch example the actual conversion takes place in the green modules. The purple function units include the S&H feedback control circuit. In the right column you will find both the master oscillator that serves as the input signal, and the slave oscillator. You can manually tune the master oscillator, or opt for 'with loose hands', then the mini sequencer does the work, which you find back in the left column as gray modules.

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This article was previously published as 'Van fietssnelheidsmeter tot pitch tracker' in Interface 107 April 2007.

literature
Arp 2600 Patch Book
Interface 92, synth workshop
Interface 106, synth workshop

internet
about the simplest analog differentiator and integrator with only one resistor and one capacitor, an interactive Java applet
www.st-andrews.ac.uk/~jcgl/Scots_Guide/experiment/diff/diff.html
www.st-andrews.ac.uk/~jcgl/Scots_Guide/experiment/integ/int.html

block diagrams analog differentiator and integrator with Opamps
http://nl.wikipedia.org/wiki/Operationele_versterker