A different view at filters

Which three terms do not belong in the following list?
Flywheel, speedometer, hotplate, portamento, high pass filter, smoother, low pass filter, interest fluctuation rate.

Mention filters and immediately everyone thinks about the frequency domain. The filtering of high frequencies for example. And preferably with a fat 24 dB/oct filter, if possible, the Moog ladder design. No the simplest 6 dB/oct variants do not enjoy the highest interest. That should change, because these low and high pass filters can also be used very effectively in the time domain.

Differentiate
I accidentally found out a long time ago. Serendipity so to speak. Just discovering something that you were not looking for at all. The Voltage Controlled Amplifier on my Arp 2600 was already occupied. But I needed another one.

No problem though. The Arp also had a nice analog multiplier. In this machine it was called a ring modulator. This referred to its main application: connect two audio signals, for example, two sine waves, and you hear at the output the sum and difference frequencies of the signals at the input.

But I did not want that at all. Just using this multiplier as a voltage controlled amplifier (VCA) that was the intention. At one input a sawtooth oscillator and on the other side a controllable DC voltage, an adjustable 'constant' in G2 terms.

Well that was not a problem at all, there was a DC voltage available. In fact, the output of the DC voltage was pre-patched to one of the ring modulator inputs. In between was still a switch with which AC, alternating current, or DC, direct current, could be chosen. I had the switch sitting at AC, alternating current. Well that means that a capacitor is connected to the signal path. And: it does not allow a DC voltage to pass.

A DC block in technical jargon. So I did not hear anything coming out of the multiplier. Clearly, because the capacitor made sure there was 0 volt at the control input. Well you can multiply as much signal by 0, but the result is of course still nothing.

Anyway, I hadn’t notice the switch nor that it was on AC. Surprised that I did not hear anything because the fader with which I could control the control voltage was about halfway. What to do next? You slide back and forth with that thing.

Serendipity! Suddenly I had found what I was not looking for at that moment: it looked like strings were being bowed. Move slowly with the fader: soft

sound, faster movement: louder sound. And then I clued in to the math behind this phenomenon. A wonderful example of differentiation. Such a differentiator only allows change. A static value at the input gives value 0 to the output. A DC or constant block. When the value at the input rises at constant speed, this results in a constant value at the output of the differentiator. However, if the value decreases at constant speed, you will get a negative constant value at the output.

It acts just like a speedometer. But one that also indicates whether 'going forward or backward': a capacitor viewed in the time domain. Until then, I thought of a capacitor (connected in series) as a high pass filter. Then you are immediately in the frequency or pitch domain with your head.

High pass filter as differentiator
The G2 has no capacitor on board. But a high pass filter! In principle, that makes no difference. If the frequency of such HPF is set very low and the value variation at the input in the time domain fluctuates, let's say slower than about 20 times per second, then the changes to the output of the high-pass filter occur as variations in the time domain.

Our perception is now focused on the differentiating effect of the high pass filter. The cutoff frequency of the high pass filter actually represents the time constant for the speed measurement.
The lowest frequency of the G2 high pass filter is 13.75 Hz. To find the time constant, we must use the formula $T = 1/f$. That amounts to a rounded 73 ms.
If the filter frequency could be set even lower, this would result in a larger output value with the same input. That is simply not possible on the G2, but that is not really a problem either. You can always put an amplifier behind the high pass output when the output values are too small.

A differentiator as a control processor
Returning to the Arp 2600. By slowly or quickly moving the fader up and down (varying the DC value) I was able to create beautiful, smooth, crescendi and decrescendi. Where you ended with the fader movement, it did not matter: it always yielded a nice decrescendo to silence.

Years later I came across such a differentiator implementation. At the time, we had purchased an AKAI EWI at the Rotterdam Conservatory, a wind instrument controller. There is a somewhat peculiar rubbery mouthpiece in which the blowing force is measured and converted to a control voltage with which synthesis parameters (amplitude and filter frequency) can be controlled.

You could also bite in this mouthpiece. And what happened? Right, the ARP patch came back to mind. At the moment you bit, the pitch went up, but also came back to the normal pitch if you did not move your jaws any more. If you started rhythmically biting, the pitch increased with increasing bite, with decreasing bite force the pitch went down.

If you were able to bite somewhat rhythmically you could already make a perfect vibrato, you always came back to the right pitch. If you vibrated slowly, it was less deep than when you rhythmically bit faster. You also got a vibrato intensity that increased with speed. That gave a beautiful natural feeling.

I've always wondered why that was not implemented on my Yamaha WX11 wind MIDI controller. This was/is equipped with a fake reed, with clarinet and sax as an example. The pressure on the reed is measured and converted to a pitch bend value. If you want to play a nice vibrato this way, it is a lot harder. So you really have to move the reed up and down from the neutral position. For pitch bending that worked fine after some practice. However, with a simple capacitor in series with the output of the reed-pitch bender you could obtain a nice ready-to-use vibrato control signal as with the EWI.

Integrate
A low pass filter is actually the opposite of a high-pass filter. It leaves the lower frequencies, as the name implies. This is because frequencies above the set cut-off frequency are increasingly being suppressed

When we look at the behavior of such a low pass filter in the time domain, we see the opposite behavior in comparison with a differentiator. We assume a very low cutoff frequency, sub-audio. In contrast to the Voltage Controlled Low Pass Filter of the Arp 2600, which goes through deep sub-audio, the lowest frequency of the G2 low pass filter is limited to 13.75 Hz. That is just not low enough for what I want to make clear.

No problem though. We also have a Glide module in the Clavia. This Glide object is nothing less than a (special) low pass filter (in Log mode) that indeed goes through to sub audio. If the filter frequency is sub-audio and we apply a step voltage to the input, for example an abrupt transition from a low to a high positive value, this 'filter' will not be able to follow the input signal immediately. It takes a while before the output is raised from the low input value to the higher one. Interpolating is called sliding from one value to another in jargon. Interpolating is now integrating.

How fast that happens, you suspect it, is related to the set frequency. Because we are now talking about the time domain, in the Glide module the time is immediately indicated in milliseconds instead of the frequency. If you now put an integrator between your MIDI note numbers output and the control input of the Pitch input of an oscillator, you will hear an effect at the correct time setting that you have known for a long time as portamento or glide. See the patch GlideLowPass where the Glide module is used as a low pass filter by making the integration time very short.

Load and experiment with the sample patches and discover that with a simple first order, 6 dB/oct, low and high pass filter you can do much more than filter in the usual sense of the word. You can also discover that

counting modules in a soft synth does not always mean that more is better. For example in Reaktor you will find low and high pass filters, which can be set from 0 Hz. With the same object you can filter both low pass and use portamento or smoother to interpolate incoming MIDI control changeways. Now, that list at the top must not be too difficult anymore.

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G2 patches:
Bellows1, bellows2, bellowsMIDI (for the hardware G2), cvProcessing, EnvASR, GlideLowPass, ModWheelVibrato.

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 Opamp
http://nl.wikipedia.org/wiki/Operationele_versterker