Inside DX/TX Envelopes

The envelopes used in an Yamaha FM synthesis chip are programmed with eight numbers representing quantities from 0 to 99. Many people may be under the impression that these numerical scales represent linear scales in the sense of time or amplitude. Nothing could be further from the truth! Apparently, the engineers at Yamaha decided to give musicians/programmers a model which would allow a variety of envelopes to be created with a minimum of complications. The outward "simplification" was to take choice settings for rates and amplitudes that vary over a huge range and then let each setting be represented by a number from 0 to 99.

Calculating time differences between breakpoints

This past year I used a digital sound editing program at CCRMA called EdSnd to examine digitized DX7 envelopes at the millisecond level. At the time I was attempting to simulate the DX7 with another synthesizer which only costs about 50 times as much... and had no idea I'd be writing *this* program. There is a certain irony in the fact that I had to make recordings of the analog output of a DX7 and then digitize them when of course the DX is internally a digital machine. The fact that I also used a stopwatch to time longer envelopes (over 5 *minutes*!) should tell you that the times between breakpoints are quite varied. Though don't have access to the internal design of the DX7 hardware, I think I have figured out a formula which can be used to calculate the time differences based on the eight rate and level numbers. The formula is rather complicated, but I will outline how the calculation might be done.

Let's say we have an envelope with a Level 1 of 90, a Level 2 of 40, and a Rate 2 (which will affect the time between Level 1 and Level 2) of 35. Assume, for simplicity, that the output level of the Operator is 99, and that there is no Keyboard Level Scaling or Keyboard Rate Scaling.

Step 1: Find the time it takes to go from a level of 99 *down* to 0 at a Rate of 35. Notice that the word "down" is italicized. This is because the times for envelopes going down is much longer than the times for going up for the same rate and distance numbers. In my emulation of DX envelopes, I used the data in found in Appendix C (tables 4A-4D) and interpolated linearly between indicated points. So, for a rate of 35, we have a time of 7 seconds.

Step 2: Find the percentage of the 99-0 time for the initial level (90). This turns out to be a constant percentage for *every* possible rate. From table 4D, we have 92 percent for a level of 90. In other words, the time to go from 90 to 0 would be 92 percent of the 99-0 time, or about 6.4 seconds for a rate of 35.

Step 3: Find the percentage of the 99-0 time for the final level (40). From table 4D, we have 52 percent. Thus it takes 3.6 seconds to go from 40 to 0.

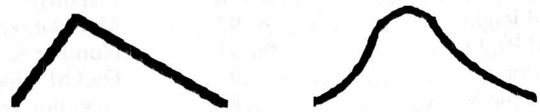
Step 4: Subtract the time found in Step 3 from the time in Step 2. Thus we have 6.4 - 3.6 or 2.8 seconds.

Time Factors You should note that the Output Level and Scaling factors affect what the real Initial and Final Levels are *before* the Envelopes are calculated. Thus there are six factors which appear to determine the time it takes for an Envelope to get from one point to another:

- Operator Output Level (determines the actual level)
- Keyboard Level Scaling (determines the actual level)
- Operator EG Levels (determines difference in rise or decay and actual level)
- Operator EG Rate (time difference from maximum to minimum value or vice versa)
- Keyboard Rate Scaling (how much the Rates are increased)
- The pitch of the note (for Keyboard Rate Scaling and Keyboard Level Scaling)

Exponential Envelopes

The shape of the DX Envelopes is consistently exponential (an example is shown below). Even the rapid Rates of 99 have an exponential curve to them!



Linear Envelope   Exponential Envelope

In psychoacoustical tests, subjects report that slow Exponential rises and decays in amplitude rise "constantly" (or linearly) whereas linear rises and decays sound exponential. Another experiment that shows this phenomenon is an experiment where a subject is told to "turn down" the volume of a sound source with a knob at a "constant" rate. The actual decrease in amplitude will be exponential.

It also seems to be the case that most natural instruments have exponential attacks and decays. A prime example is the piano.

Summary If you were hoping that the Opcode Patch Editor would display real time representations of Envelopes, I hope that the preceding information has at least made you realize how complex it is to do the job right. First of all, any representation would involve some kind of distortion, since there's no way to display a time difference of .003 seconds against one of 5 minutes on a 512x342 pixel screen with any sort of signifant resolution. Secondly, there are so many factors which determine the actual envelope, some of which are beyond the control of the program (like what note you play!), that the speed of using the Patch Editor would decrease considerably if it had to recalculate and/or redraw the envelopes every time you changed something.