ITU FRP 2010

Lecture 6:

Switched-on Yampa: Programming Modular Synthesizers in Haskell

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Modular synthesizers?

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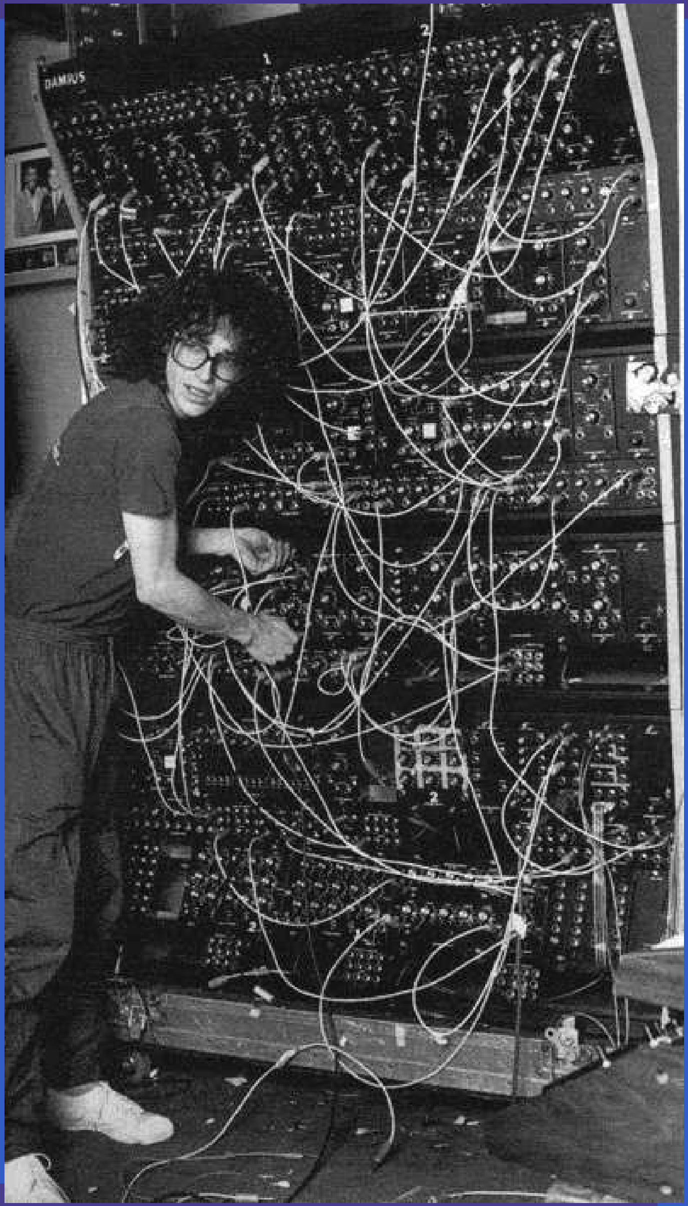
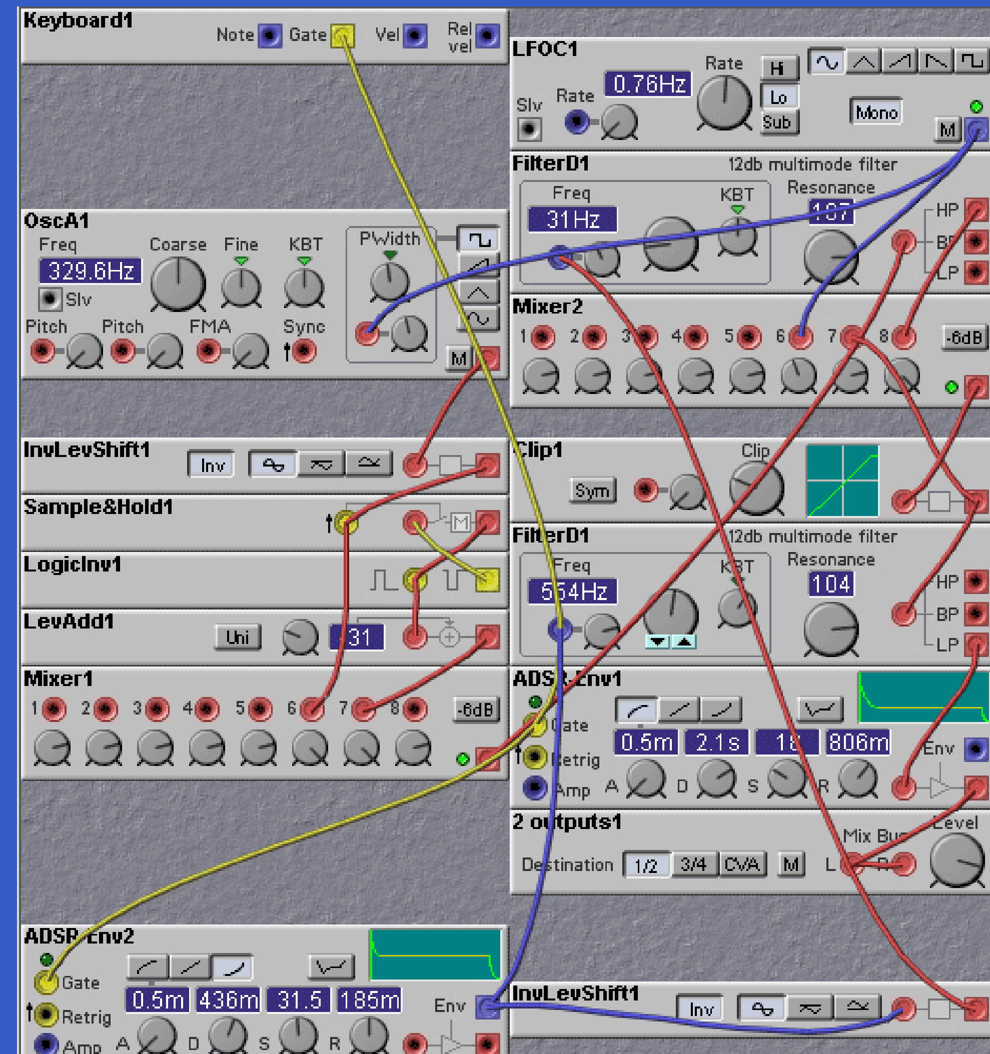


Steve Pocaro, Toto, with Polyfusion Synthesizer

Modern Modular Synthesizers



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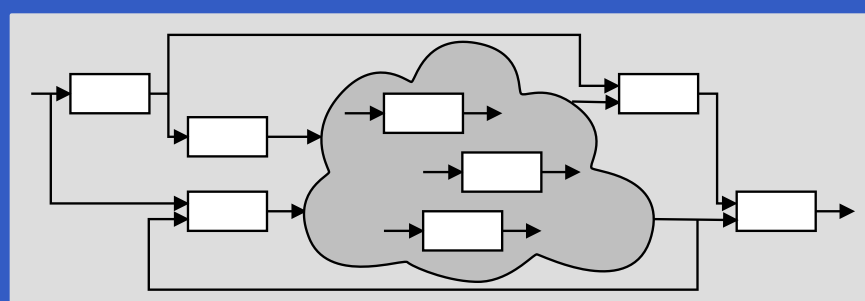

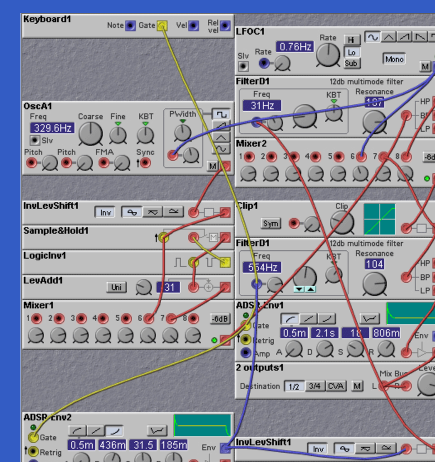

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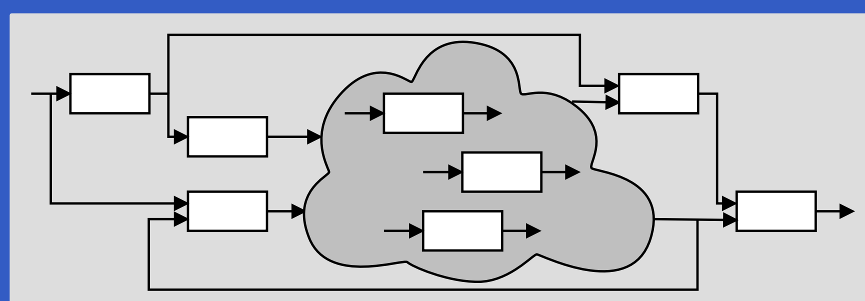

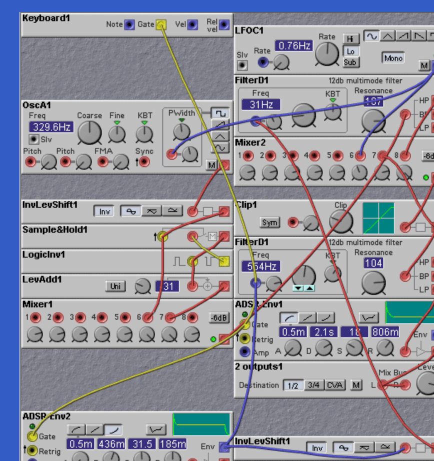

- Fun application! Useful for teaching?

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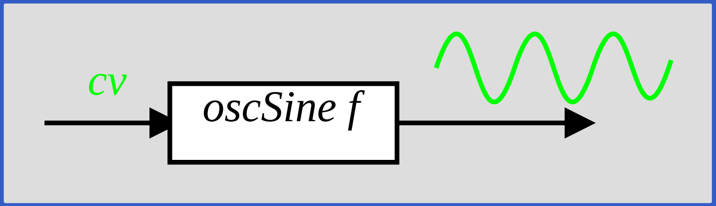
- Sound-generating and sound-shaping modules
- Additional supporting infrastructure:
  - Input: MIDI files (musical scores), keyboard
  - Output: audio files (.wav), sound card
  - Reading SoundFont files (instrument definitions)

What have we done?

Framework for programming modular synthesizers in Yampa:

- Sound-generating and sound-shaping modules
- Additional supporting infrastructure:
  - Input: MIDI files (musical scores), keyboard
  - Output: audio files (.wav), sound card
  - Reading SoundFont files (instrument definitions)
- Status: proof-of-concept, but decent performance.

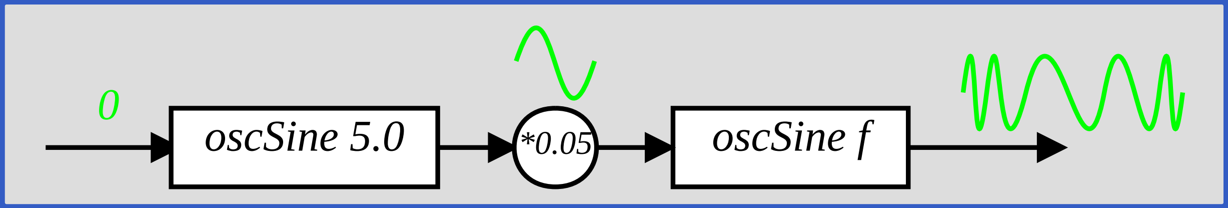
Example 1: Sine oscillator



$$
\begin{aligned}
&oscSine :: Frequency \rightarrow SF\ CV\ Sample\\
&oscSine\ f0 = \textbf{proc}\ cv \rightarrow \textbf{do}\\
&\quad \textbf{let}\ f = f0 * (2 ** cv)\\
&\quad phi \leftarrow integral \prec 2 * pi * f\\
&\quad returnA \prec sin\ phi
\end{aligned}
$$

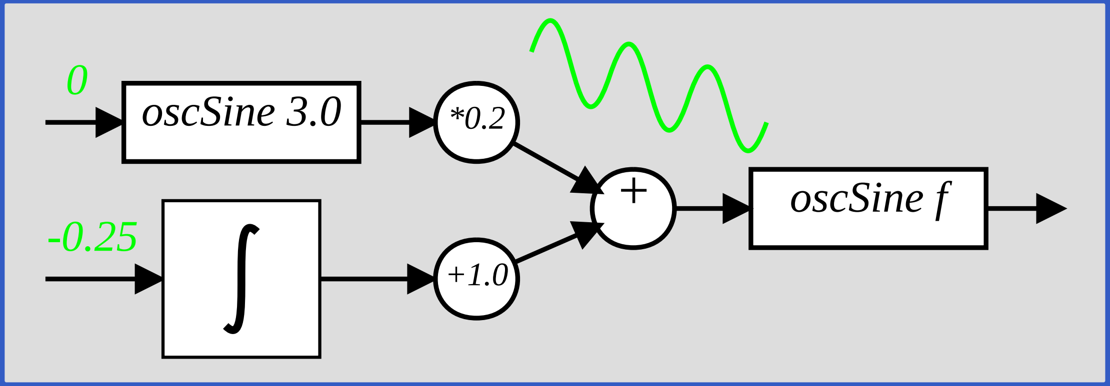
$$constant\ 0 \ggg oscSine\ 440$$

Example 2: Vibrato



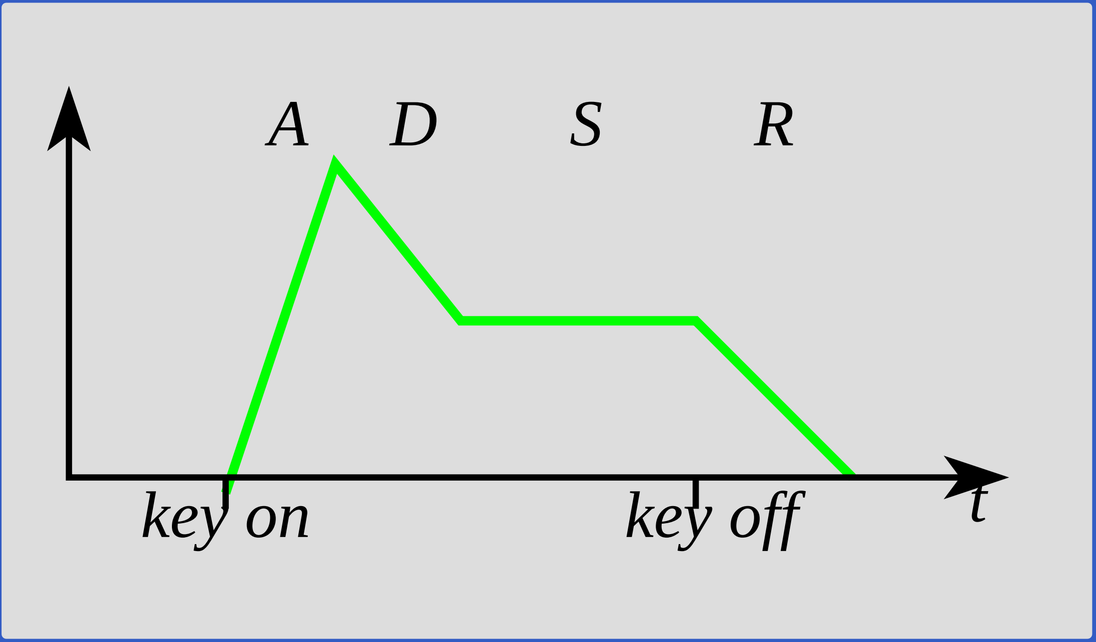
$$constant\ 0$$
$$\ggg\ oscSine\ 5.0$$
$$\ggg\ arr\ (*0.05)$$
$$\ggg\ oscSine\ 440$$

Example 3: 50's Sci Fi



$$
\begin{array}{l}
sciFi :: SF\ ()\ Sample \\
sciFi = \textbf{proc}\ () \rightarrow \textbf{do} \\
\quad und \leftarrow arr\ (*0.2) \lll oscSine\ 3.0 \prec 0 \\
\quad swp \leftarrow arr\ (+1.0) \lll integral \prec -0.25 \\
\quad audio \leftarrow oscSine\ 440 \prec und + swp \\
\quad returnA \prec audio
\end{array}
$$

Envelope Generators (1)



$$envGen :: CV \rightarrow [(Time, CV)] \rightarrow (Maybe\ Int)$$
$$\rightarrow SF\ (Event\ ())\ (CV, Event\ ())$$

$$envEx = envGen\ 0\ [(0.5, 1), (0.5, 0.5), (1.0, 0.5), (0.7, 0)]$$
$$(Just\ 3)$$

Envelope Generators (2)

How to implement?

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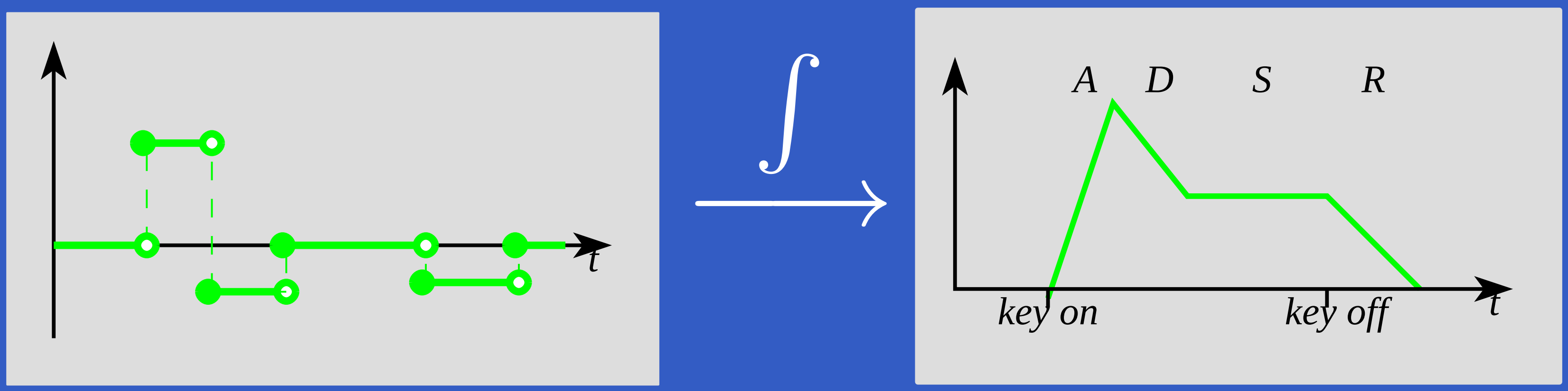
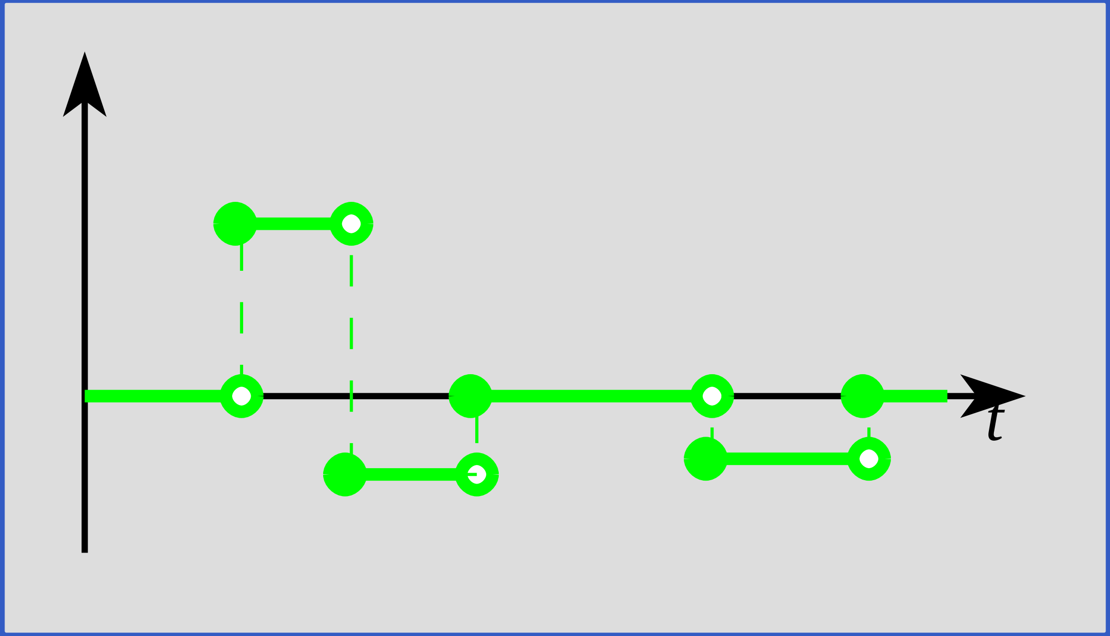
How to implement?

Integration of a step function yields suitable shapes:



Envelope Generators (3)



$$afterEach :: [(Time, b)] \rightarrow SF\ a\ (Event\ b)$$

$$hold \qquad :: a \rightarrow SF\ (Event\ a)\ a$$

$$steps = afterEach\ [(0.7, 2), (0.5, -1), (0.5, 0), (1, -0.7), (0.7, 0)$$

$$\ggg hold\ 0$$

Envelope Generators (4)

Envelope generator with predetermined shape:

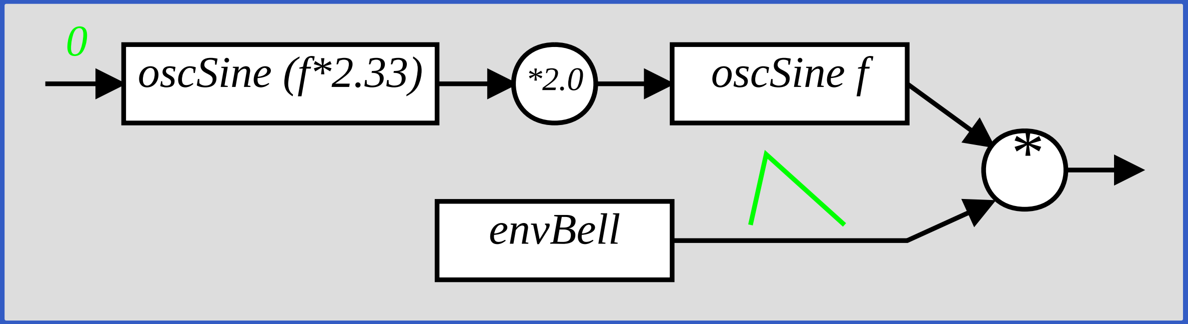
$$
\begin{aligned}
&\mathit{envGenAux} :: \mathit{CV} \rightarrow [(\mathit{Time}, \mathit{CV})] \rightarrow \mathit{SF}\ a\ \mathit{CV} \\
&\mathit{envGenAux}\ l0\ \mathit{tls} = \mathit{afterEach}\ \mathit{trs} \ggg \mathit{hold}\ r0 \\
&\qquad\qquad\qquad \ggg \mathit{integral} \ggg \mathit{arr}\ (+l0) \\
&\quad \textbf{where} \\
&\qquad (r0, \mathit{trs}) = \mathit{toRates}\ l0\ \mathit{tls}
\end{aligned}
$$

Envelope Generators (5)

Envelope generator responding to key off:

$$
\begin{array}{l}
envGen :: CV \rightarrow [(Time, CV)] \rightarrow (Maybe\ Int) \\
\qquad\qquad \rightarrow SF\ (Event\ ())\ (CV, Event\ ()) \\
envGen\ l0\ tls\ (Just\ n) = \\
\quad switch\ (\mathbf{proc}\ noteoff \rightarrow \mathbf{do} \\
\qquad\qquad l \leftarrow envGenAux\ l0\ tls1 \prec () \\
\qquad\qquad returnA \prec ((l, noEvent), noteoff\ `tag`\ l)) \\
\qquad\quad (\lambda l \rightarrow envGenAux\ l\ tls2 \\
\qquad\qquad \&\&\&\ after\ (sum\ (map\ fst\ tls2))\ ()) \\
\quad \mathbf{where} \\
\qquad (tls1, tls2) = splitAt\ n\ tls
\end{array}
$$

Example 4: Bell



$$bell :: Frequency \rightarrow SF\ ()\ (Sample, Event)$$

$$\begin{aligned}
&bell\ f = \textbf{proc}\ () \rightarrow \textbf{do} \\
&\quad m \leftarrow oscSine\ (2.33 * f) \prec 0 \\
&\quad audio \leftarrow oscSine\ f \prec 2.0 * m \\
&\quad (ampl, end) \leftarrow envBell \prec noEvent \\
&\quad returnA \prec (audio * ampl, end)
\end{aligned}$$

Example 5: Tinkling Bell

$$
\begin{aligned}
&tinkle :: SF\ ()\ Sample\\
&tinkle = (repeatedly\ 0.25\ 84\\
&\qquad\qquad \ggg constant\ ()\\
&\qquad\qquad\qquad \&\&\&\ arr\ (fmap\ (bell \circ midiNoteToFreq))\\
&\qquad\qquad \ggg rSwitch\ (constant\ 0))
\end{aligned}
$$

Example 6: Playing a C-major scale

$$
\begin{aligned}
&scale :: SF\ ()\ Sample \\
&scale = (afterEach\ [(0.0, 60), (2.0, 62), (2.0, 64), \\
&\qquad\qquad\qquad\qquad (2.0, 65), (2.0, 67), (2.0, 69), \\
&\qquad\qquad\qquad\qquad (2.0, 71), (2.0, 72)] \\
&\qquad\quad \ggg constant\ () \\
&\qquad\qquad \&\&\&\ arr\ (fmap\ (bell \circ midiNoteToFreq)) \\
&\qquad\quad \ggg rSwitch\ (constant\ 0)) \\
&\qquad \&\&\&\ after\ 16\ ()
\end{aligned}
$$

Example 7: Playing simultaneous notes

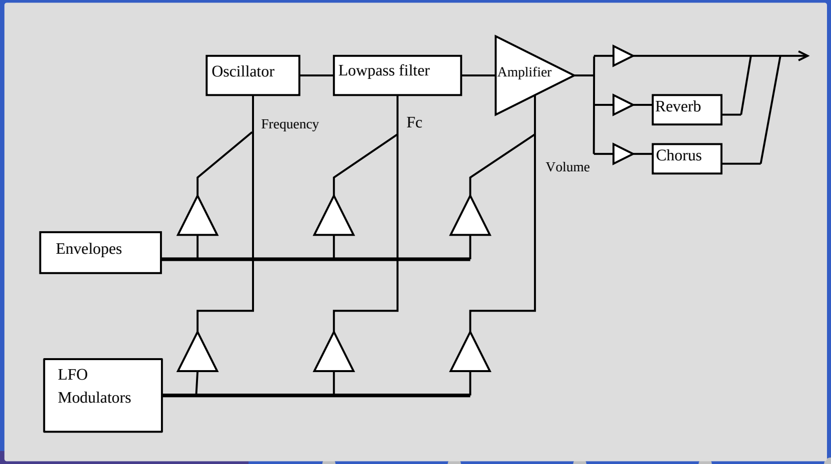
$$
\begin{aligned}
&\mathit{mysterySong} :: \mathit{SF}\ ()\ (\mathit{Sample}, \mathit{Event}\ ())\\
&\mathit{mysterySong} = \mathbf{proc}\ \_ \rightarrow \mathbf{do}\\
&\quad t \ \leftarrow \mathit{tinkle} \quad \prec ()\\
&\quad m \leftarrow \mathit{mystery} \prec ()\\
&\quad \mathit{returnA} \prec (0.4 * t + 0.6 * m)
\end{aligned}
$$

A polyphonic synthesizer (1)

Sample-playing monophnic synthesizer:

- Read samples (instrument recordings) from SoundFont file into internal table.
- Oscillator similar to sine oscillator, except table lookup and interpolation instead of computing the sine.

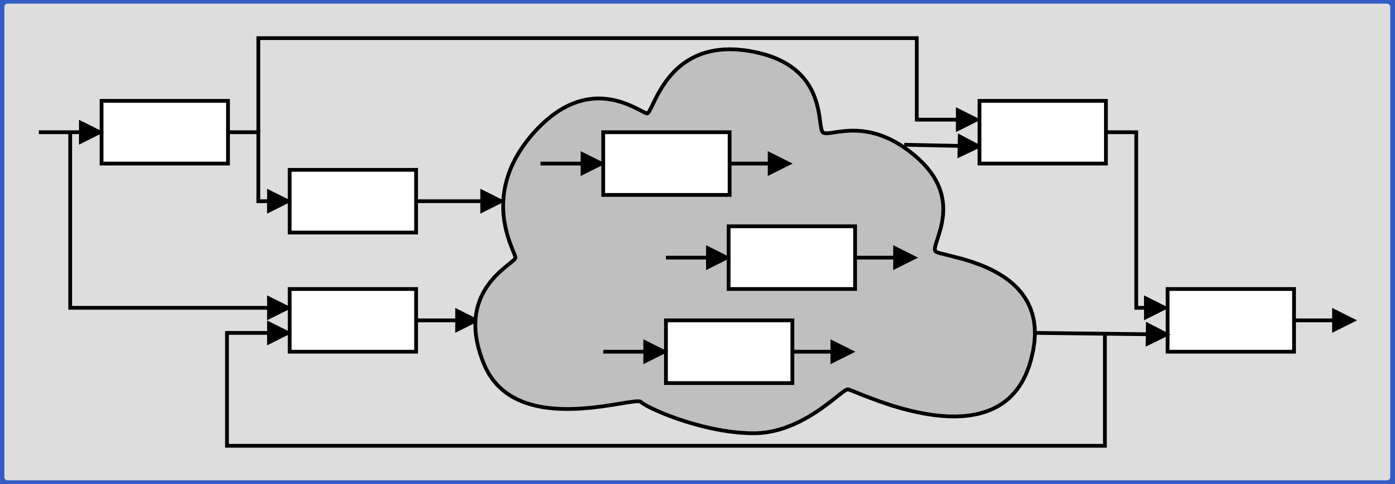
SoundFont synthesizer structure:



A polyphonic synthesizer (2)

Exploit Yampa's switching capabilities to:

- create and switch in a mono synth instance is response to each note on event;
- switch out the instance in response to a corresponding note off event.



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Software and paper: `www.cs.nott.ac.uk/~ggg`