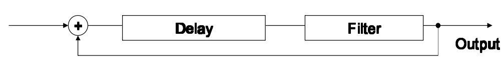
Some Waveguide Instruments: Notes for final projects

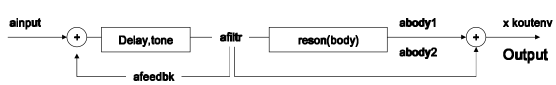
Project Guidelines

- Part 1-- Design and Implement an extension to your waveguide model
  - **Partners work together on this part**
- Part 2-- Write a report on what you did and why you did it.
  - **Each person turns in a separate report**
  - **I'll supply a list of questions to be answered**
- Let's look at some possible extensions

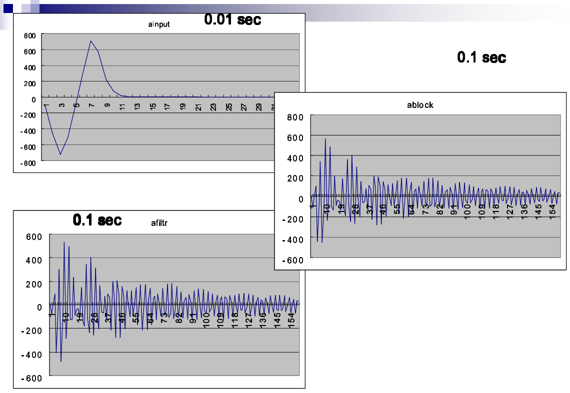
1. A Waveguide Bass



A block diagram of the Karplus-Strong Plucked-string algorithm



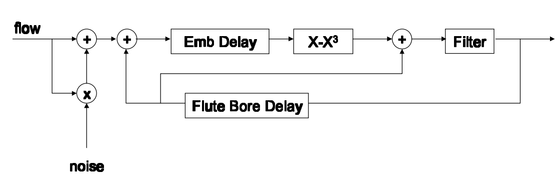
A waveguide plucked-bass



2. A Slide-Flute

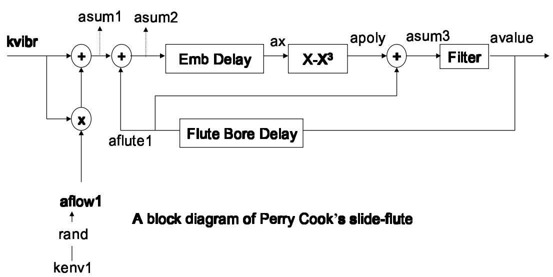
- Slide-flute derived from Perry Cook's instrument
- The input of this system is a flow of air
- Noise is added to simulate a breath sound
- The interaction between the embouchure and the flute bore is modeled by a cubic equation, $x-x^3$
- The end of the flute bore reflects low frequencies
- The pitch is changed by changing the length of the bore delay line
- Pitch varies slightly based on breath pressure

A Slide-Flute



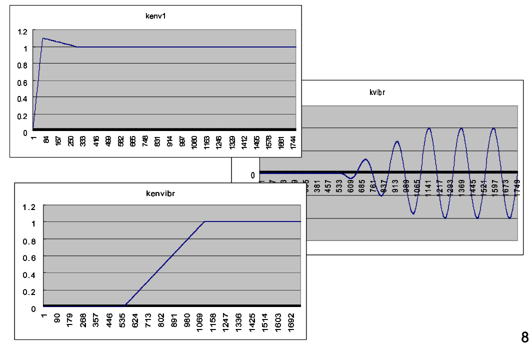
A block diagram of Perry Cook's slide-flute

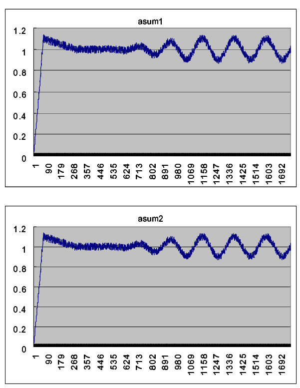
A Slide-Flute



A block diagram of Perry Cook's slide-flute

A Slide-Flute

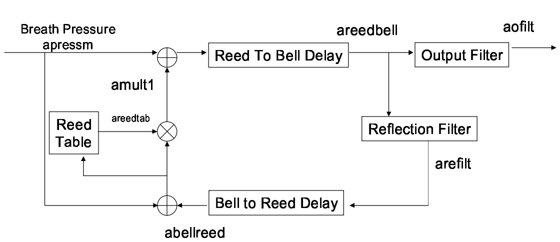


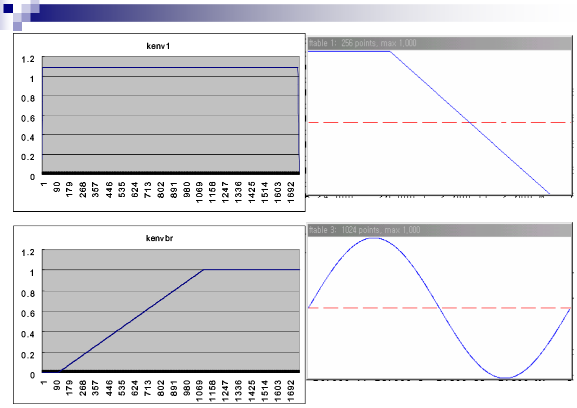


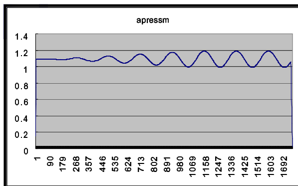
3. A Waveguide Clarinet

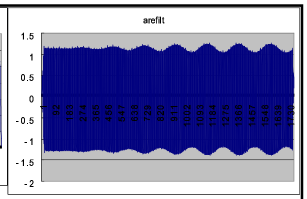
- Perry Cook(1995)
- Bi-directional delay line is used
- Feedback table
  - **Referenced by the pressure difference between the input pressure and the reflected wave**
  - **Can be modified to account for variations in reed stiffness and embouchure**

A Waveguide Clarinet









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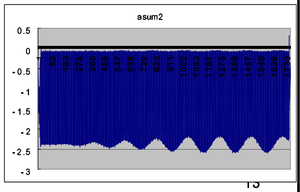
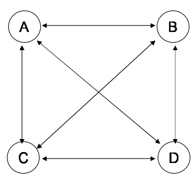


4. A Waveguide Drum

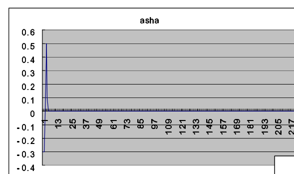
- There are two parts to this instrument
  - **Drum**
    - can be though of as a square membrane with waves traveling from each of the four corners to each of the other three corners.
  - **Drum stick**
    - Sends an impulse into the drum membrane

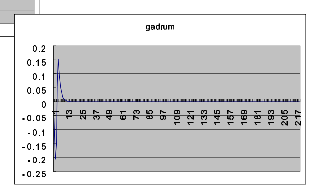
A Waveguide Drum



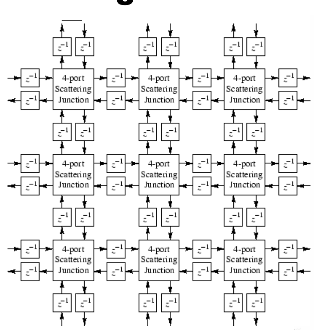
A Simplified diagram of a waveguide square drum.
Each double-arrowhead line represents a bi-directional delay line

Drum

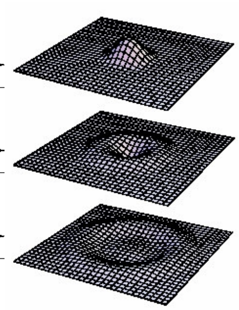




Waveguide Mesh

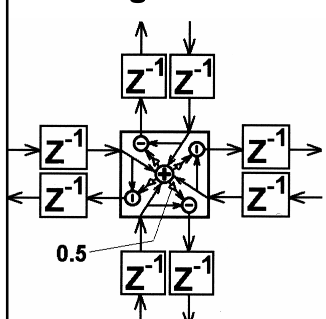


Mesh



Propagation

Waveguide Mesh



Junction Calculation:

$$Z_J = 0.5(Z_{inU} + Z_{inD} + Z_{inL} + Z_{inR})$$
$$Z_{outU} = Z_J - Z_{inU}$$
$$Z_{outD} = Z_J - Z_{inD}$$
$$Z_{outL} = Z_J - Z_{inL}$$
$$Z_{outR} = Z_J - Z_{inR}$$

Time-Multiplexing via C-Slowing/Retiming

- Simple 1D Example

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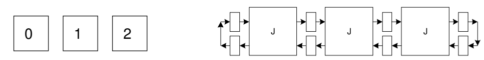

Starting circuit

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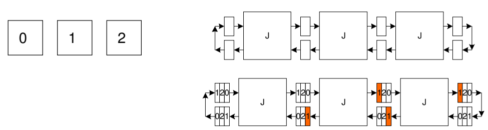

C-Slow by 3 (time-multiplexing factor)

Label register sets 0, 1 and 2

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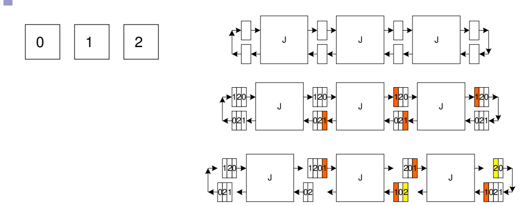

Retime orange registers backwards through junction to label middle junction inputs with 1

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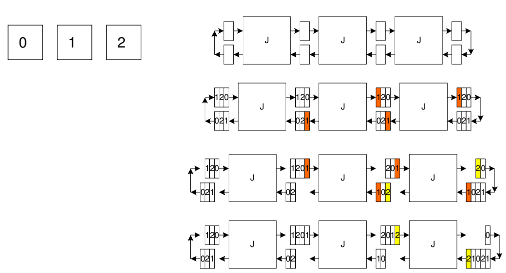

Retime yellow registers backwards through junction to label right hand junction inputs with 2

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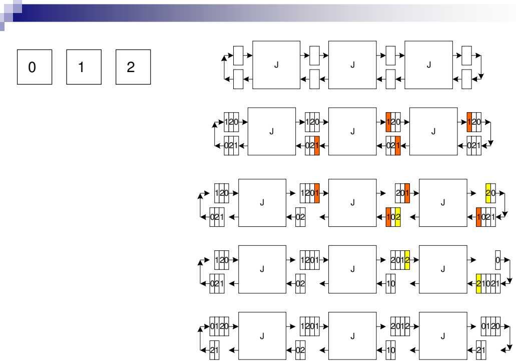

Retime end registers so that each section looks the same

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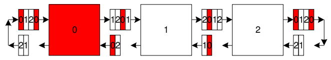

We will load only one data set into the registers labeled with a 0. The other registers are “empty”

On the 0th cycle, only junction 0 has work to do. Junction 1 and 2 are idle.

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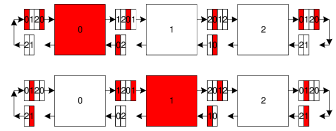

After the 0th cycle, the data is now all in register set 1.

On the 1th cycle, only junction 1 has work to do. Junction 0 and 2 are idle.

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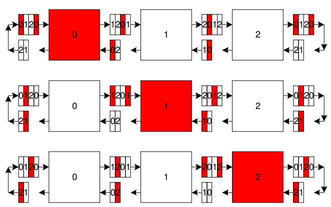

After the 1th cycle, the data is now all in register set 2.

On the 2th cycle, only junction 2 has work to do. Junction 0 and 1 are idle.

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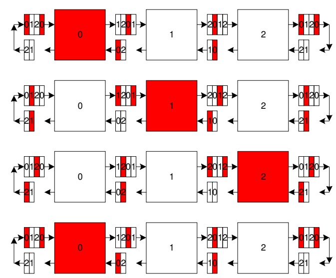

We are now back to the 0th cycle where all the data is in register set 0.

If you look at the registers that are used on each cycle, the three groups of registers on the left can all share a single group of registers.

This group on the right needs its own registers since it uses the same registers as the group on the left.

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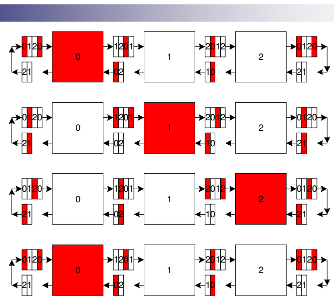

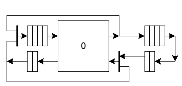

Since only one junction is active each cycle, we need only one. We can share registers but need muxes to implement what happens on the different cycles.

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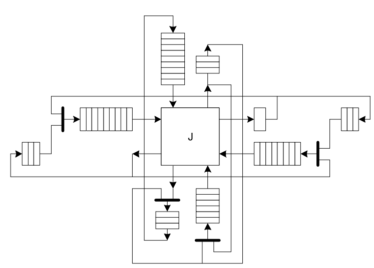
Combined time-muxed junction design incorporating both directions



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5. MIDI harpsichord

- Model a harpsichord
  - **Plucked string keyboard instrument**
- Make many strings
  - **Rotate through several strings so that notes can ring**
- Play 4-part Bach fugue from MIDI notation
- Microblaze:
  - **reads score**
  - **keeps time**
  - **Triggers string notes**

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