Digital Signal Processing for Music

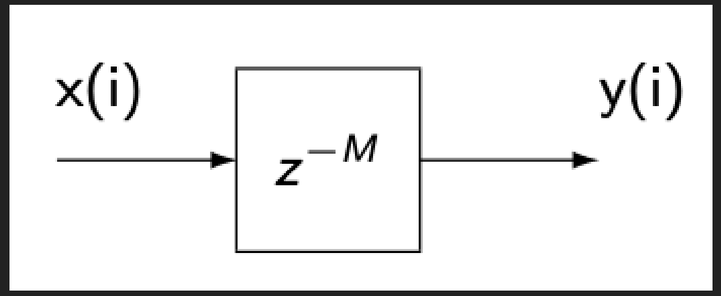
Part 19: Modulated Effects

Andrew Beck

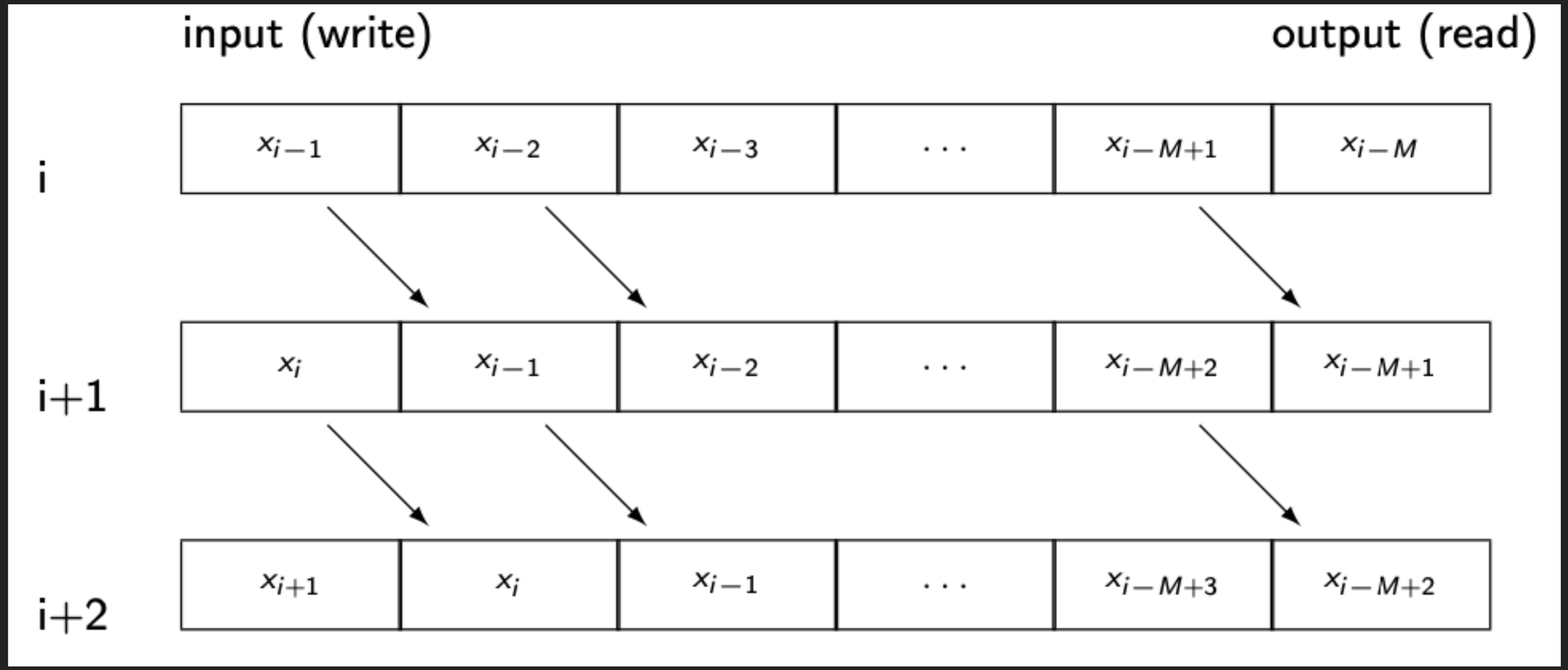
Introduction

- Modulated effects belong to one of the oldest class of audio effects
- Often used for guitar
- **Examples:**
  - Delay-Line Modulation
    - Vibrato
    - Chorus, Flanger
  - Other
    - Phaser
    - Wah-Wah

Delay Line

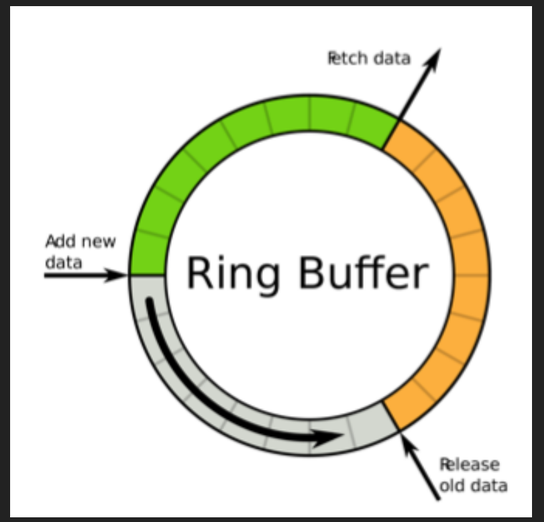


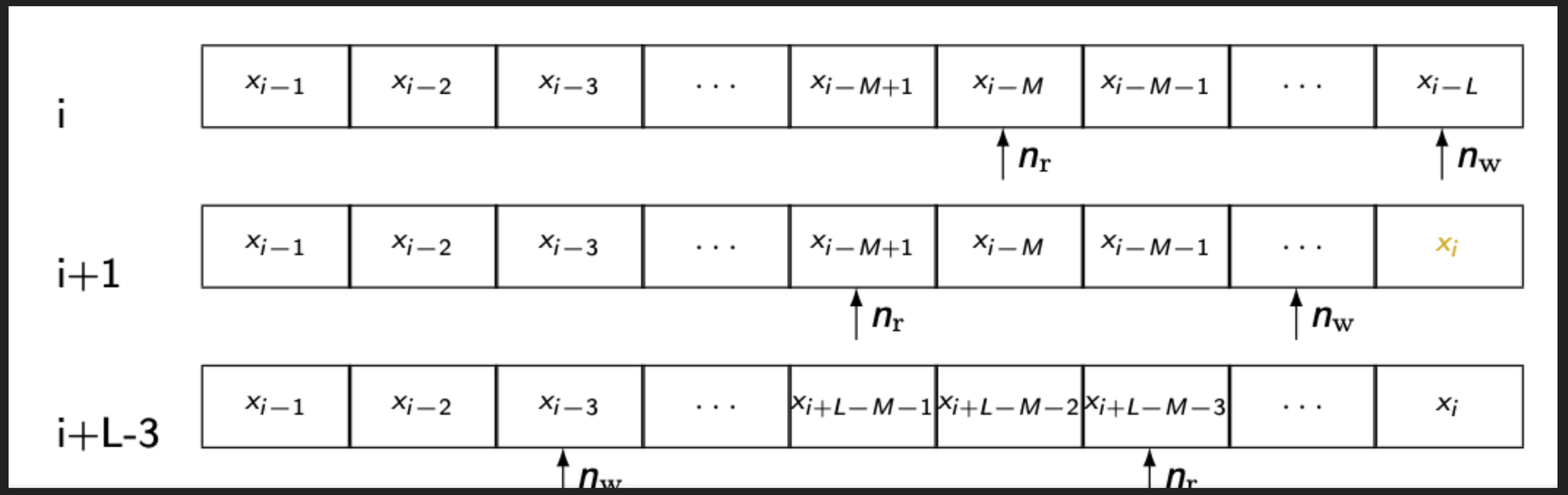
Implementation



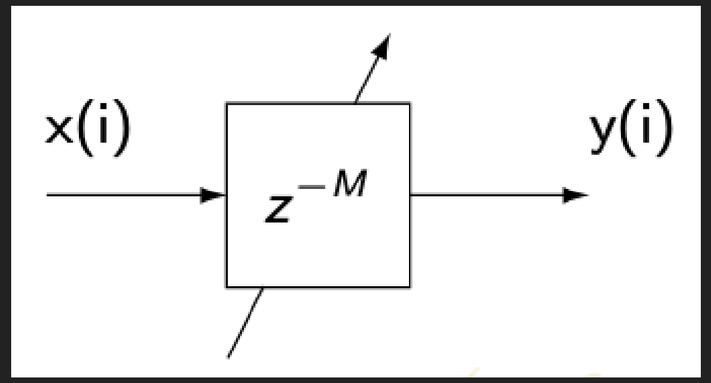
Ring Buffer

- **Idea**
  - Do not move buffer contents
  - Instead, increment write and read positions
- **Implementation**
  - Buffer length L: $L \geq M$
  - Store current write index n_w and read index n_r
- For a simple delay $(n_w - n_r) \bmod L = M$





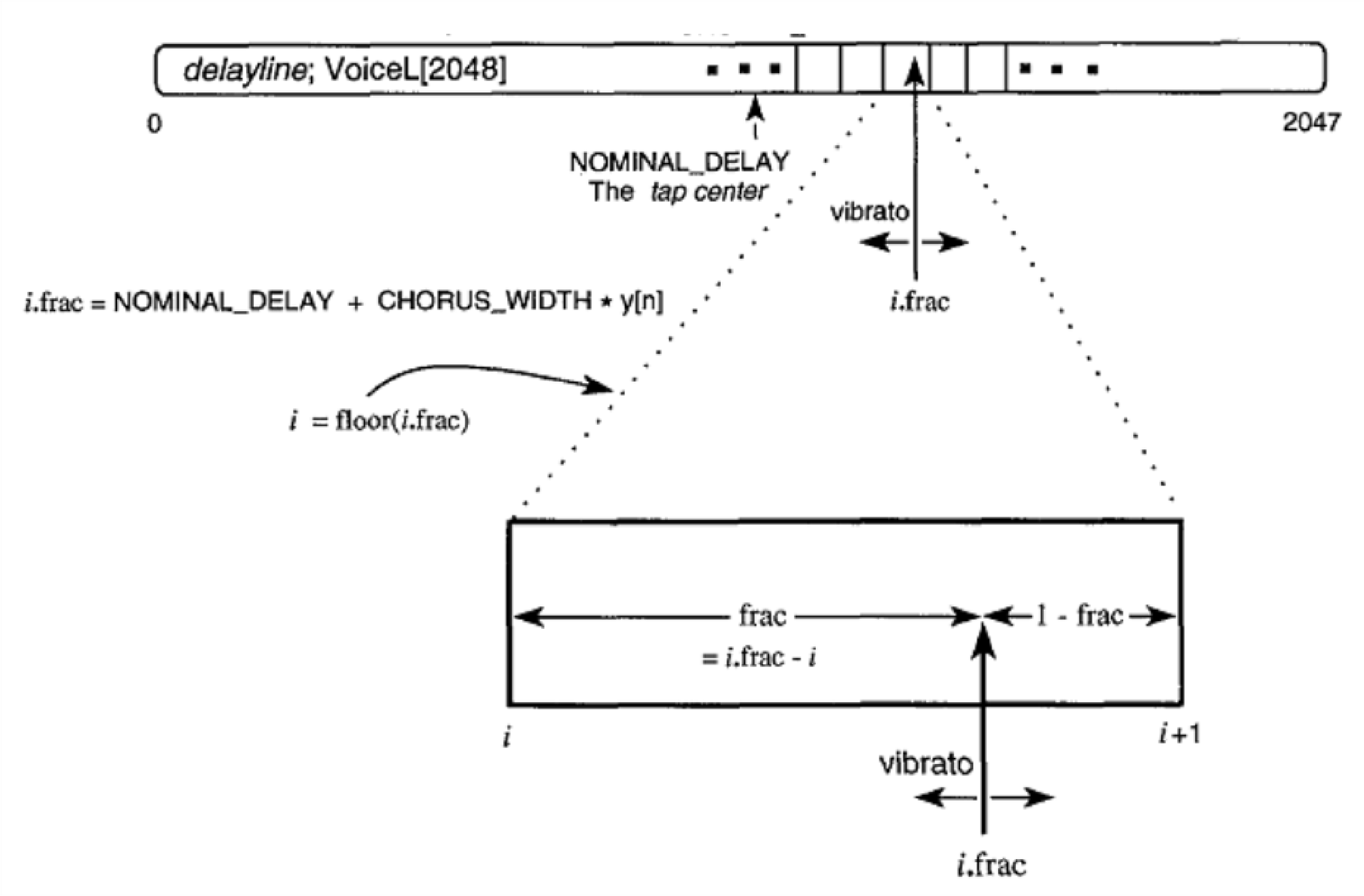
Modulated Delay Line



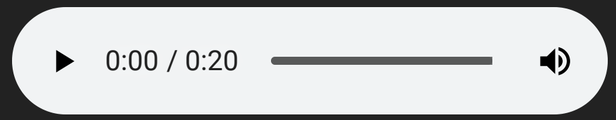
$$n.\,frac = M + A \cdot (2\pi \frac{f_{mod}}{f_s} i)$$

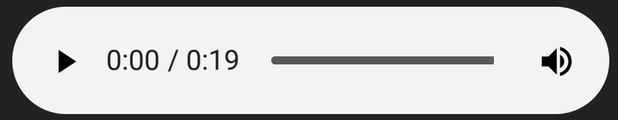
- M: Static delay in samples
- A: Modulation amplitude in samples
- f_{mod}: Modulation frequency in Hertz
- $\mathbf{sin}$: Oscillator function

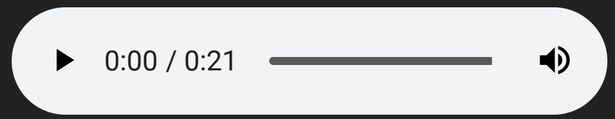
Fractional indexing



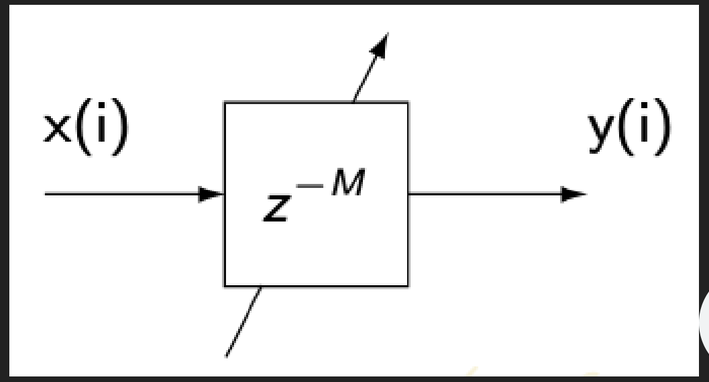
Linear Interpolation Examples

- **Original**: 

- **6% speed-up**: 

- **6% slow-up**: 

Vibrato



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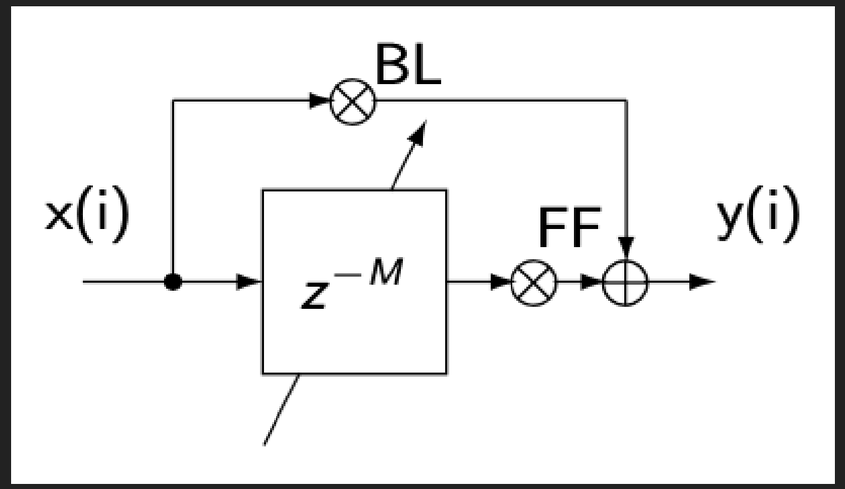
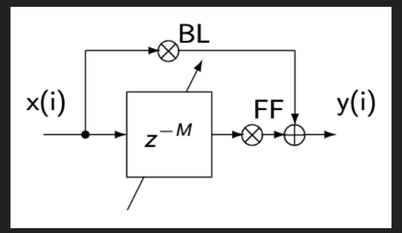
- M = any
- A = 200 samples
- f_{mod} = 1 Hz

Vibrato + Input Signal



Vibrato + Input Signal



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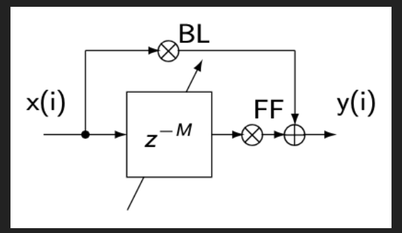
Slapback

- $f_{mod} = 0$
- $A = 0$
- $M = 20$ ms
- $BL = 0.7$
- $FF = 0.7$

Vibrato + Input Signal



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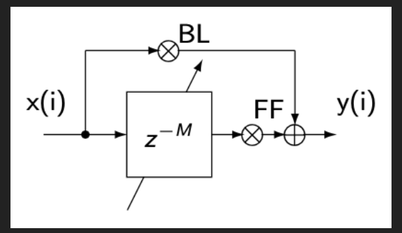
Simple echo

- $f_{mod} = 0$
- $A = 0$
- $M = 50$ ms
- $BL = 0.7$
- $FF = 0.7$

Vibrato + Input Signal



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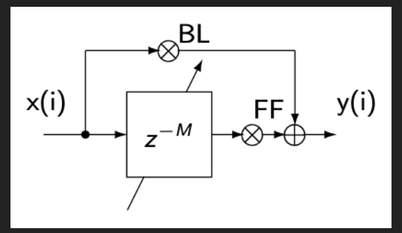
Simple Flanger

- f_{mod} = 0.2 Hz
- A = 2 ms
- M = 0
- BL = 0.7
- FF = 0.7

Vibrato + Input Signal



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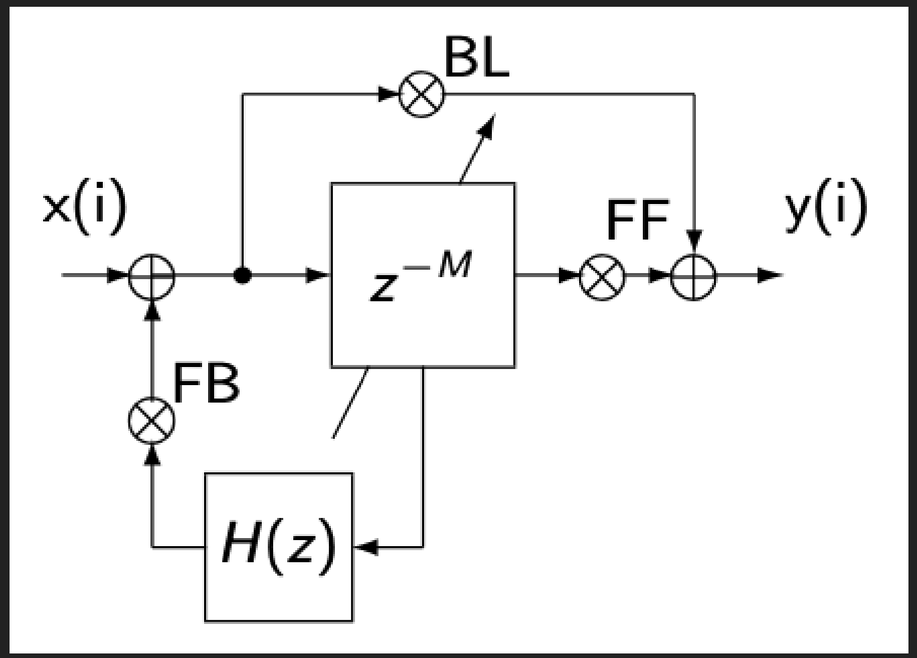
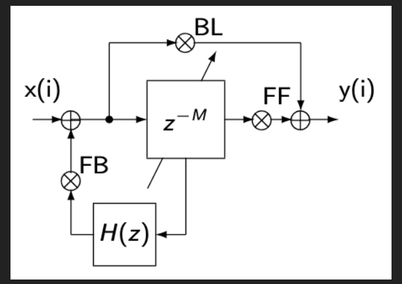
Simple Chorus

- f_{mod} = 1.5 Hz
- A = 2 ms
- M = 2 ms
- BL = 1.0
- FF = 0.7

Modulated Effect with Feedback Path



Modulated Effect with Feedback Path



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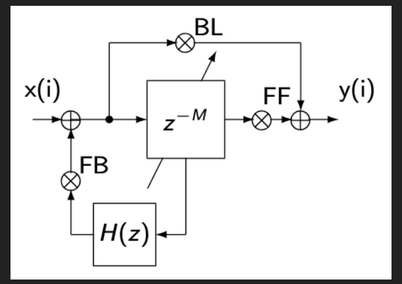
Simple Flanger with Feedback

Modulated Effect with Feedback Path



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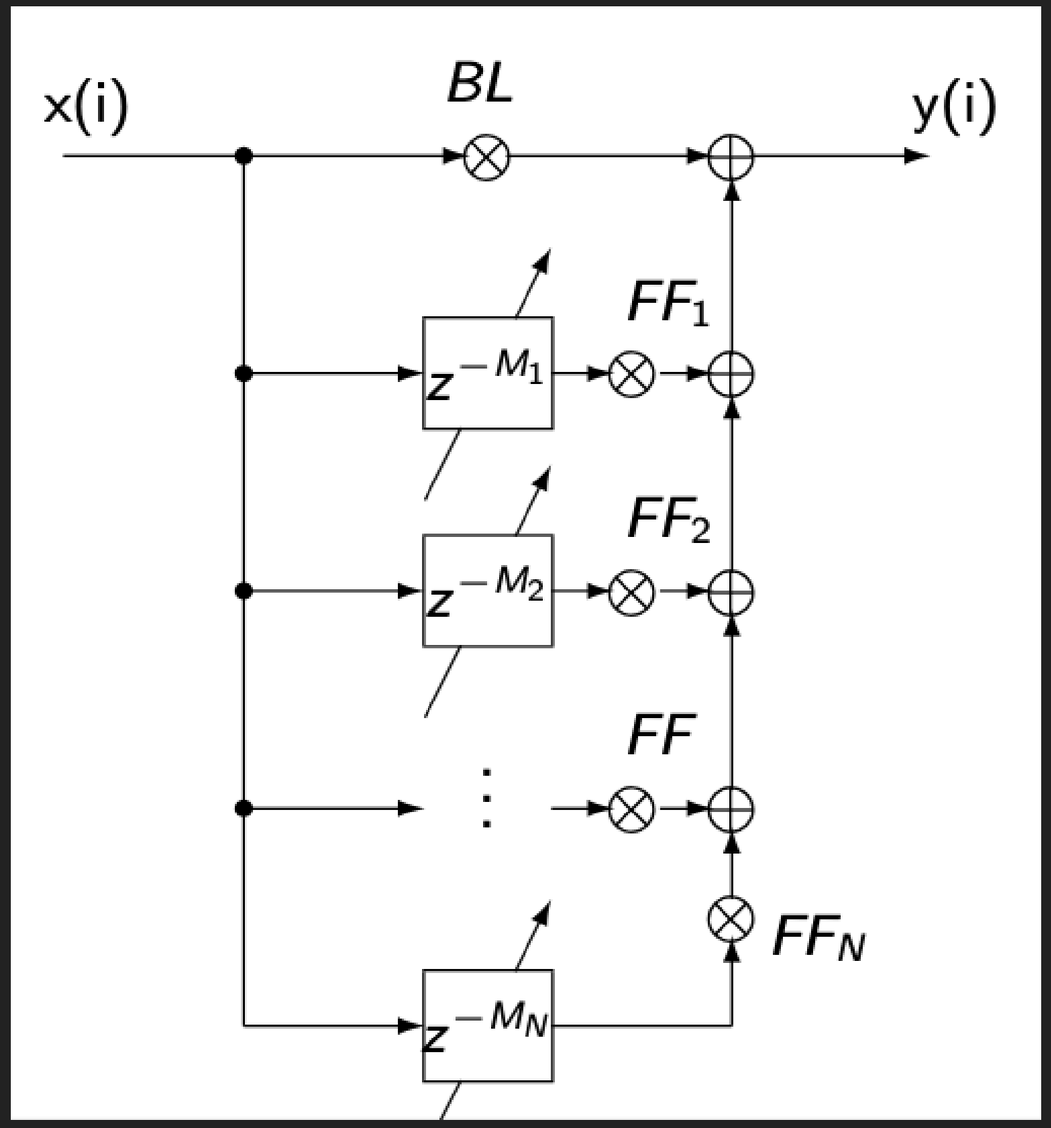
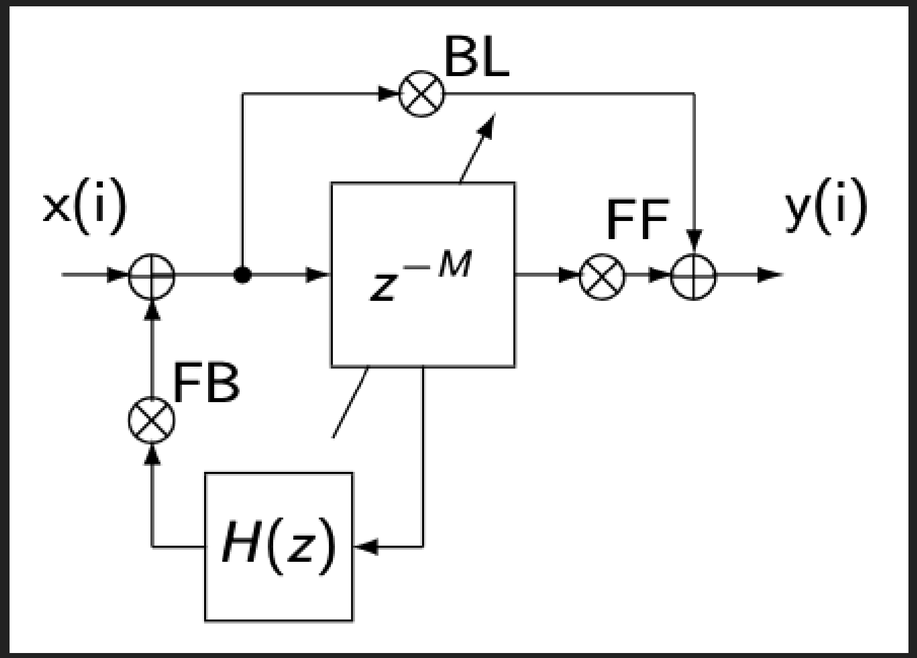
Simple Flanger with Feedback

Chorus: Implementation Variant



Modulated Effects: Typical Variants



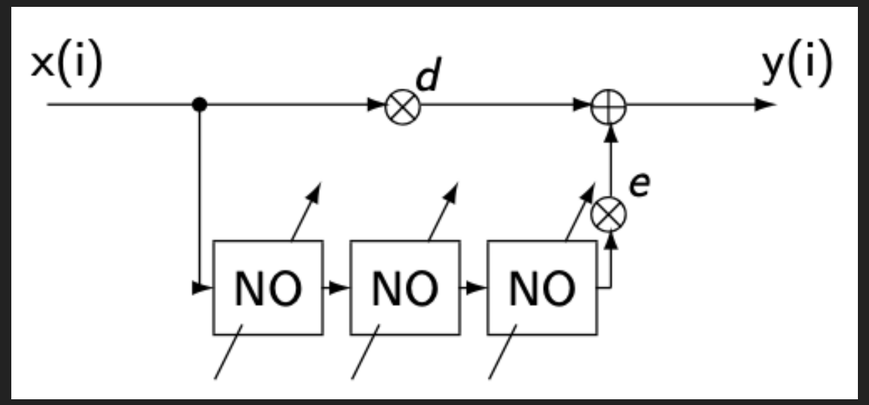
- Add lowpass / transfer function to feedback path
- Use stereo feedback

Modulated Effects: Modulation Signal

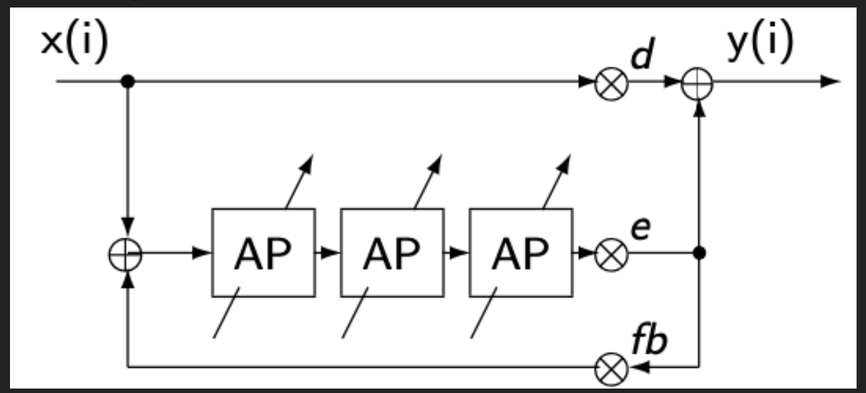
- **Shape**
  - Low frequency
  - *Sinusoidal* (typically) or *noise* (low pass filtered)
- **Phase**
  - **Phase response** becomes perceptually relevant when
    - 2 or more signals are added
    - Phase is time-variant
    - Phase shift between channels (localization)

Modulated Effects: Phaser

- Sounds similar to delay line effects
- but: different implementation
- Notch Filters



All-pass Filters



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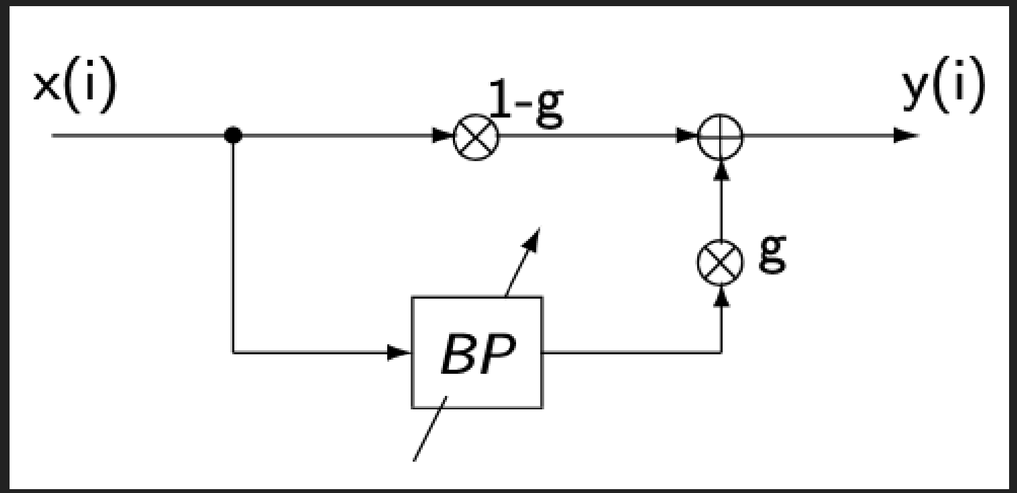
Modulated Effects: Wah-Wah



- 'Modulated' by pedal
- Often a biquad implementation
- Not really a bandpass
  - Changes shape depending on frequency (resonant at low freqs, broad at high freqs)

Summary

- Most modulated effects are based on **delay lines**:
  - Input signal is added to a delayed version of itself
  - Delay time is modulated
- Modulation is at very low frequencies (or manually controlled)
  - Often sinusoidal
- Filters can also be used to create wanted phasing artifacts
  - All-pass and notch filters for phaser
  - Band-pass for wah-wah