

# Digital Signal Processing for Music

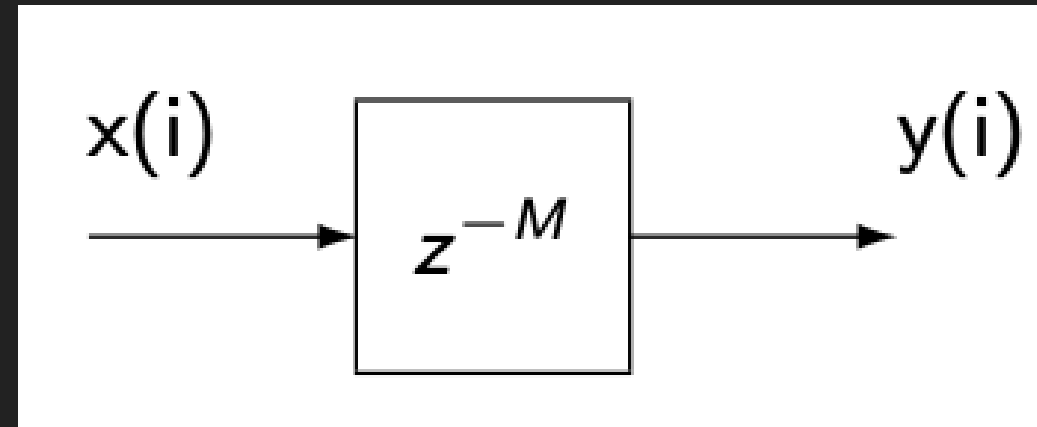
Part 19: Modulated Effects

Andrew Beck

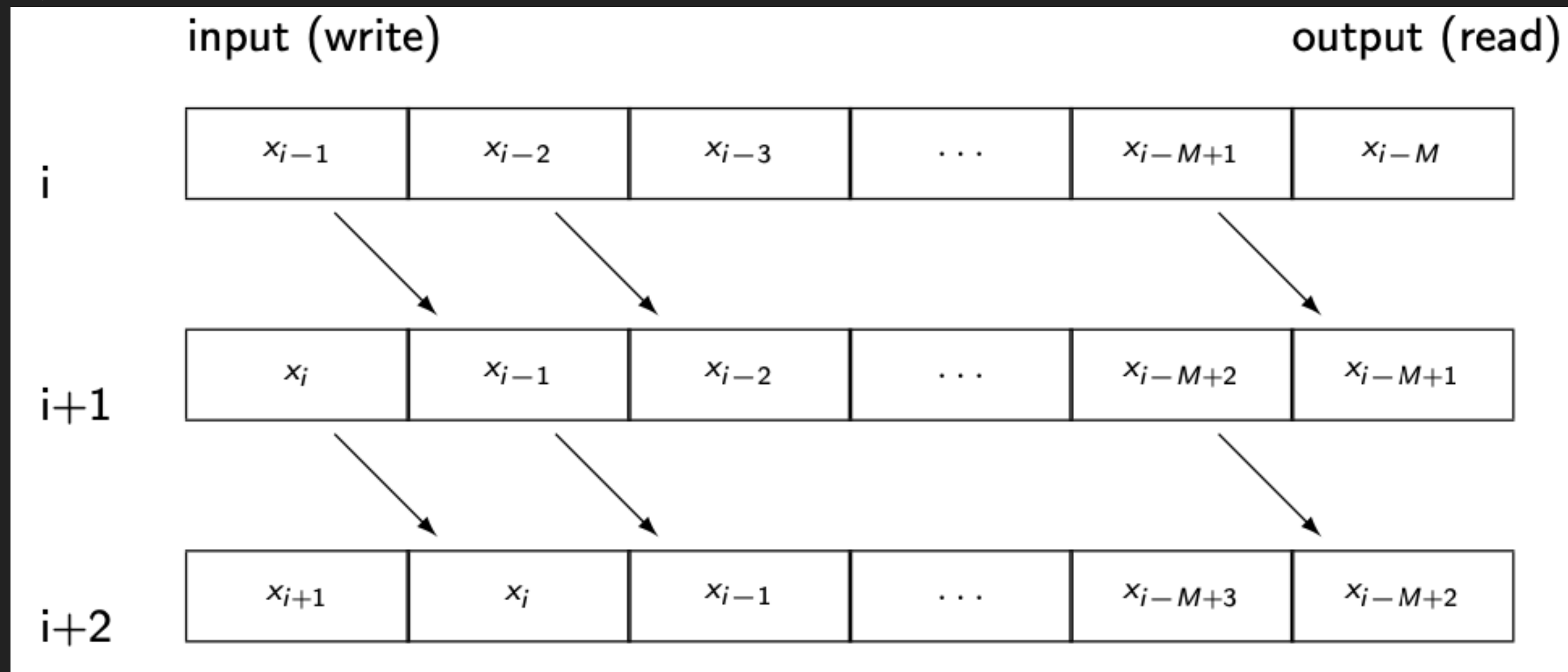
# Introduction

- » 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



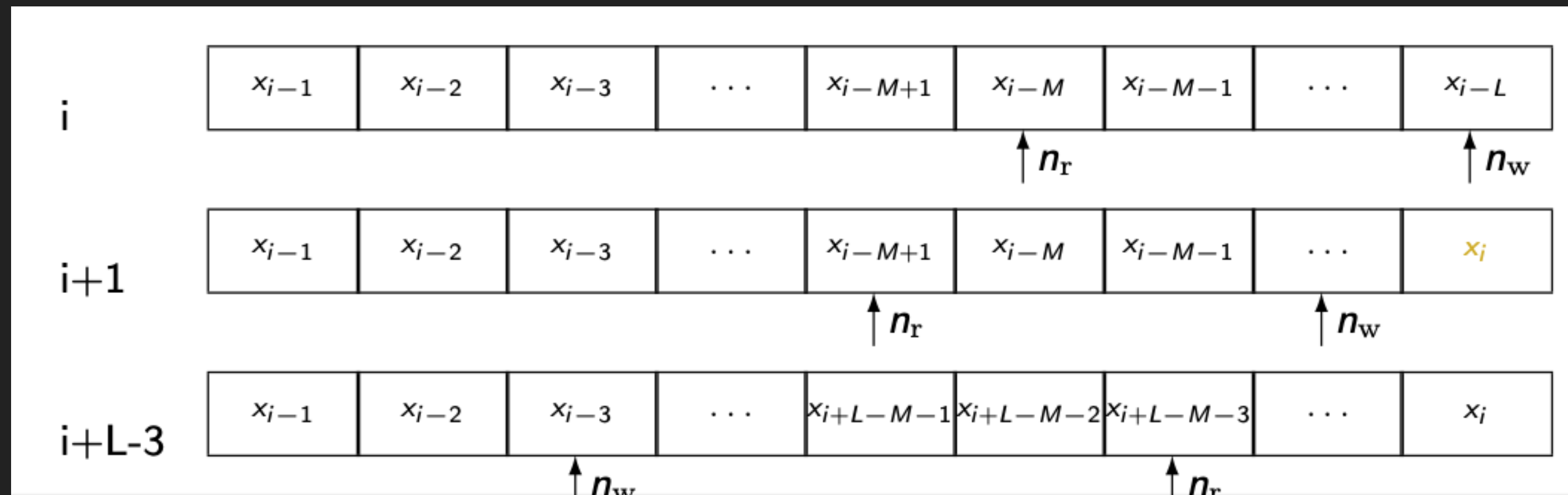
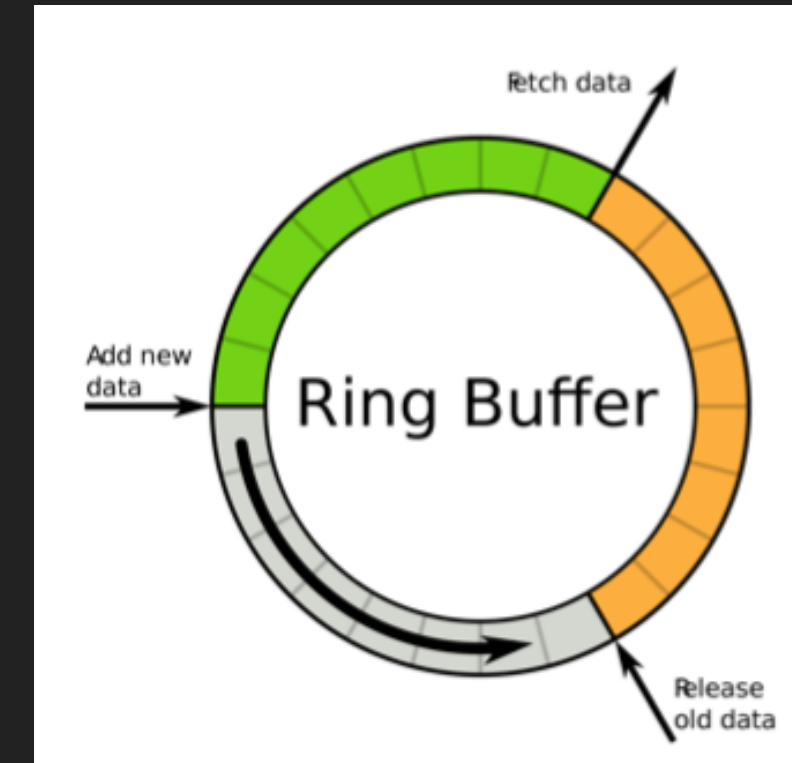
# Ring Buffer

## » Idea

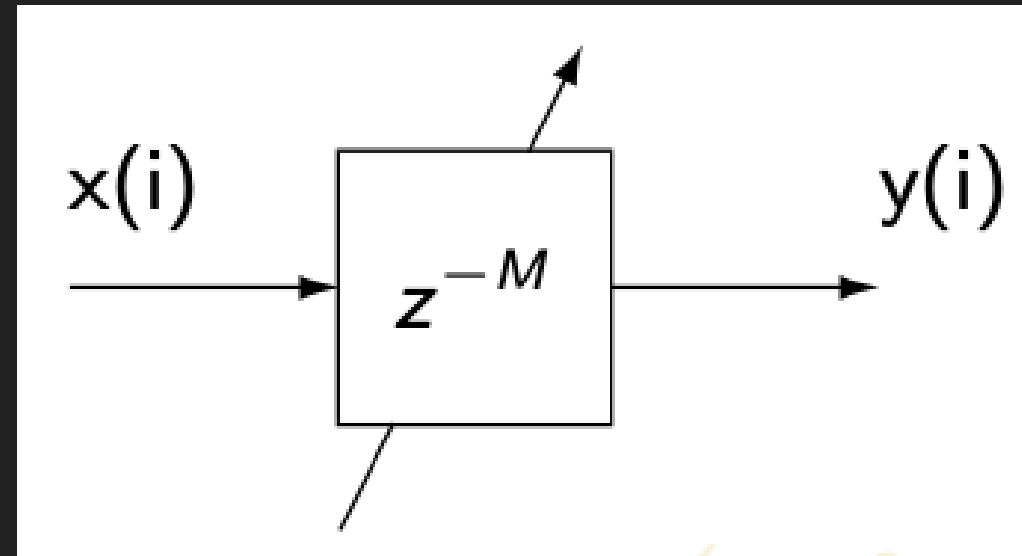
- » Do not move buffer contents
- » Instead, increment write and read positions

## » Implementation

- » Buffer length  $L$ :  $L \geq M$
- » Store current write index  $n_w$  and read index  $n_r$
- » For a simple delay  $(n_w - n_r) \bmod L = M$



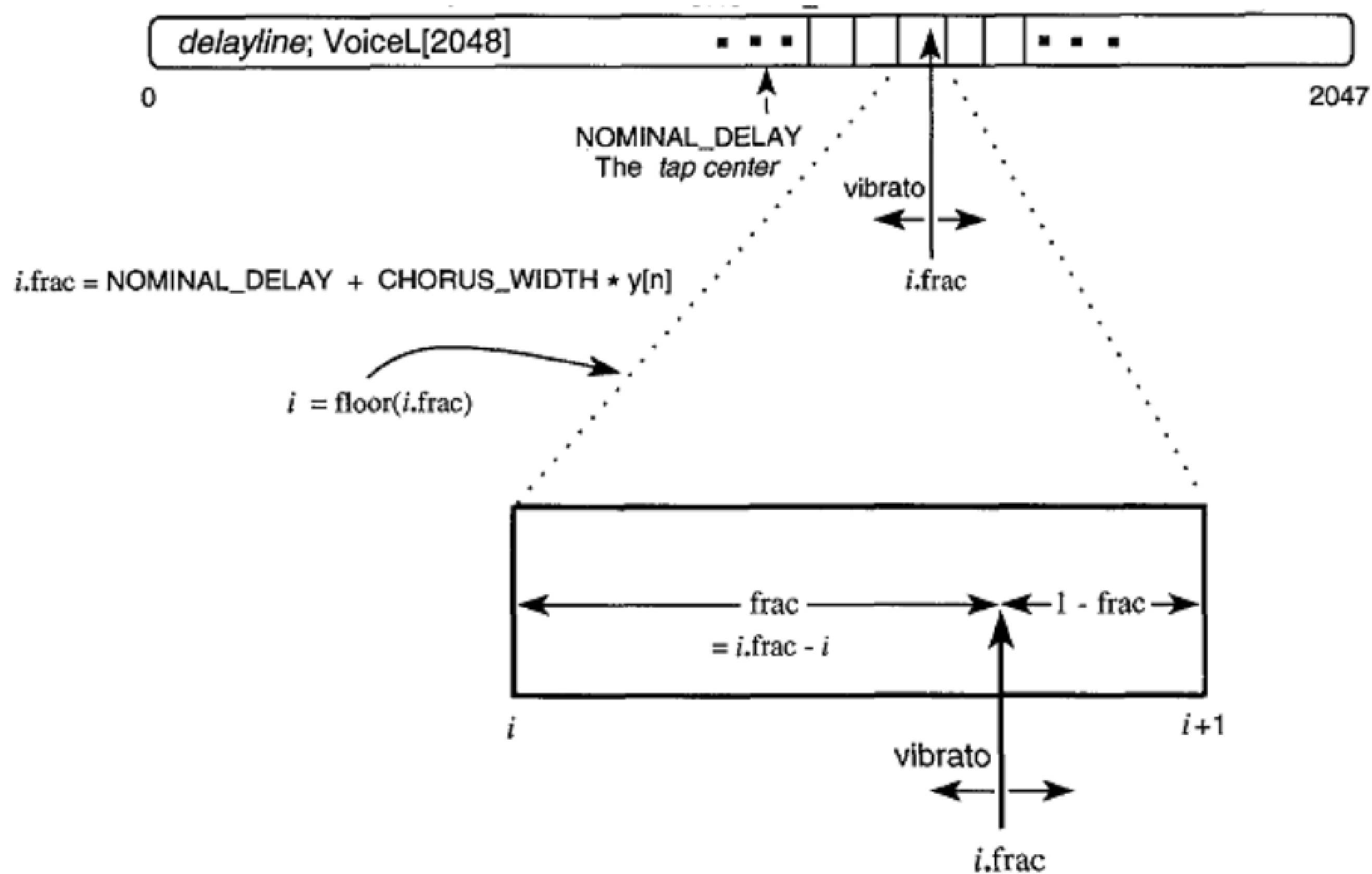
# Modulated Delay Line



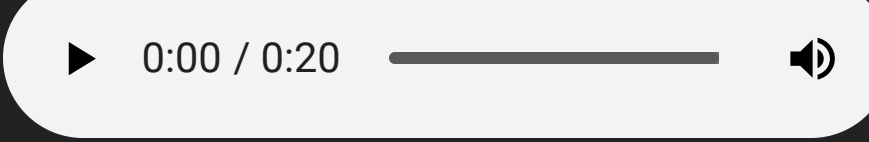
$$n.\text{frac} = M + A \cdot \left(2\pi \frac{f_{mod}}{f_s} i\right)$$

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

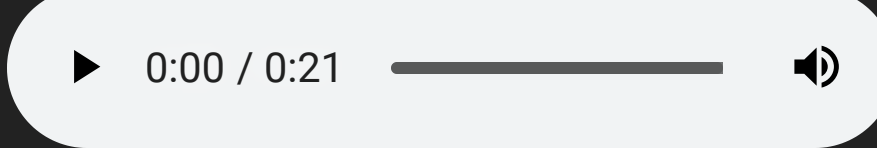
# Fractional indexing



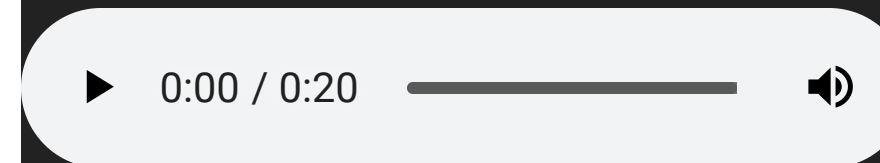
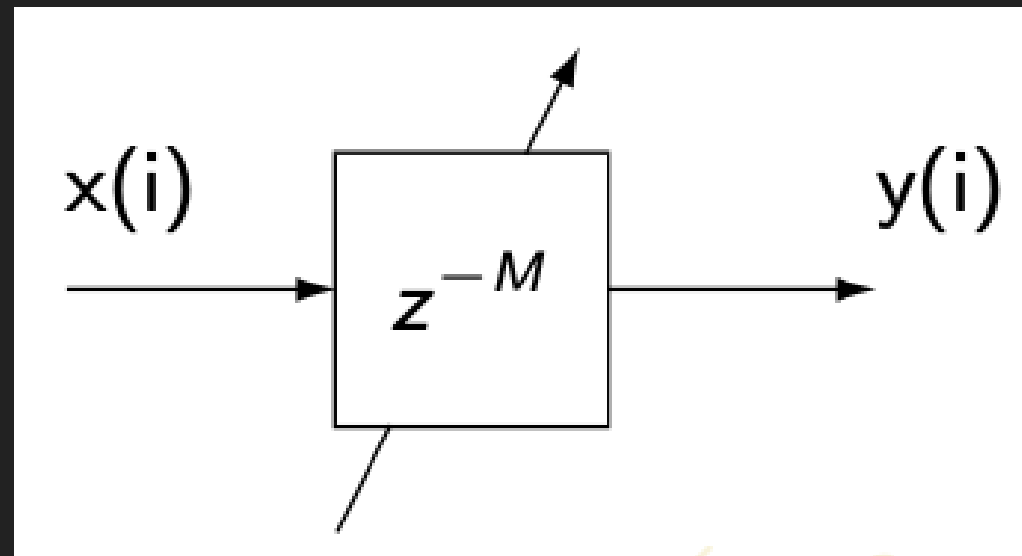
# Linear Interpolation Examples

» **Original:** 

» **6% speed-up:** 

» **6% slow-up:** 

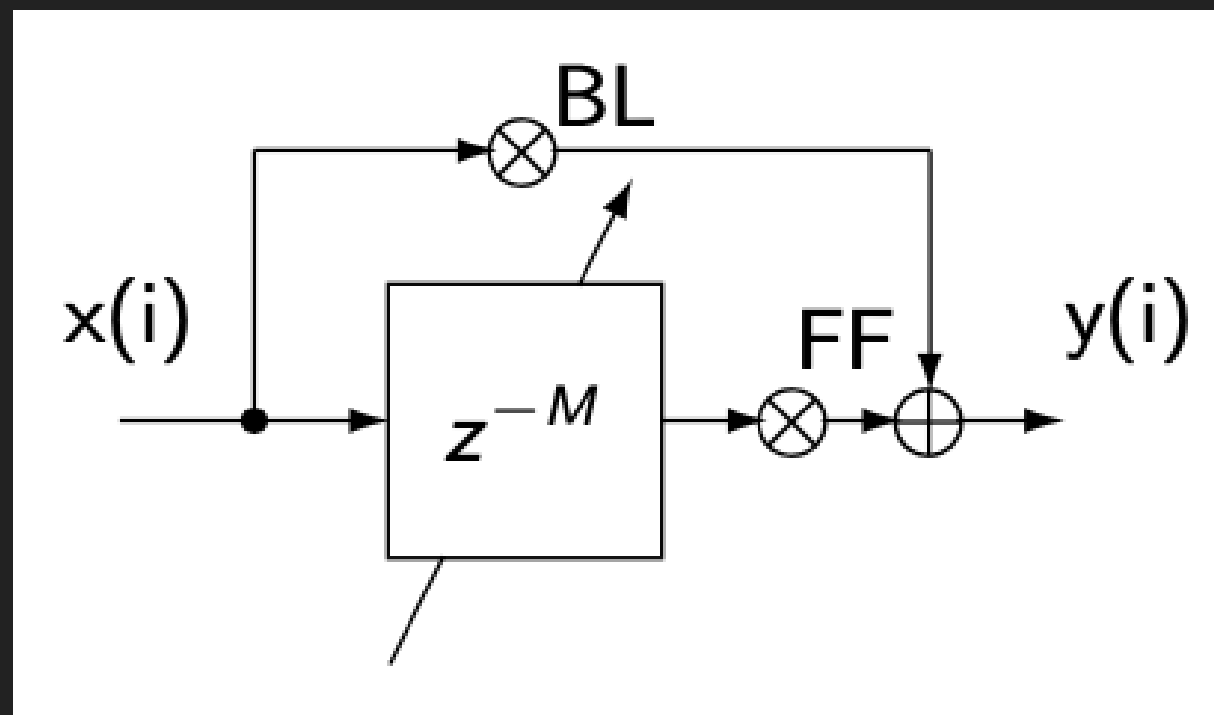
# Vibrato



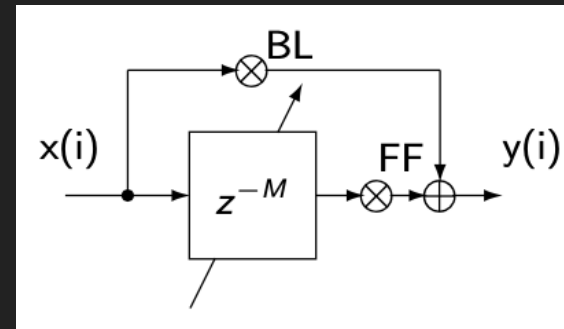
- »  $M = \text{any}$
- »  $A = 200$  samples
- »  $f_{mod} = 1$  Hz



## Vibrato + Input Signal



# Vibrato + Input Signal



▶ 0:00 / 0:20

## Slapback

»  $f_{mod} = 0$

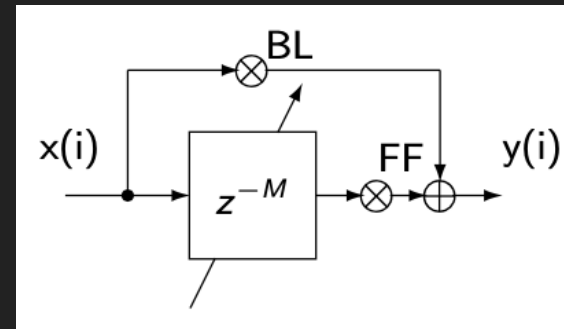
»  $A = 0$

»  $M = 20 \text{ ms}$

»  $BL = 0.7$

»  $FF = 0.7$

# Vibrato + Input Signal



▶ 0:00 / 0:20

## Simple echo

»  $f_{mod} = 0$

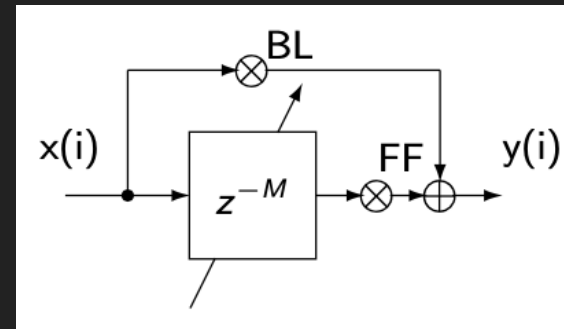
»  $A = 0$

»  $M = 50 \text{ ms}$

»  $BL = 0.7$

»  $FF = 0.7$

# Vibrato + Input Signal



▶ 0:00 / 0:20

## Simple Flanger

»  $f_{mod} = 0.2 \text{ Hz}$

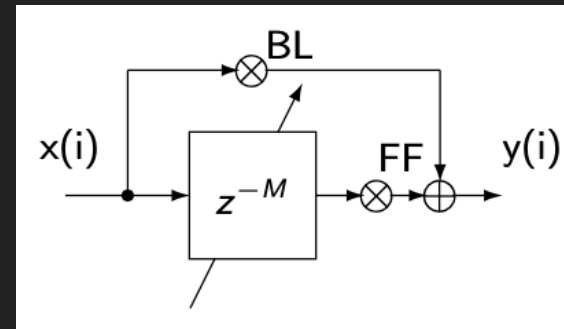
»  $A = 2 \text{ ms}$

»  $M = 0$

»  $BL = 0.7$

»  $FF = 0.7$

# Vibrato + Input Signal



▶ 0:00 / 0:20

## Slapback

»  $f_{mod} = 1.5 \text{ Hz}$

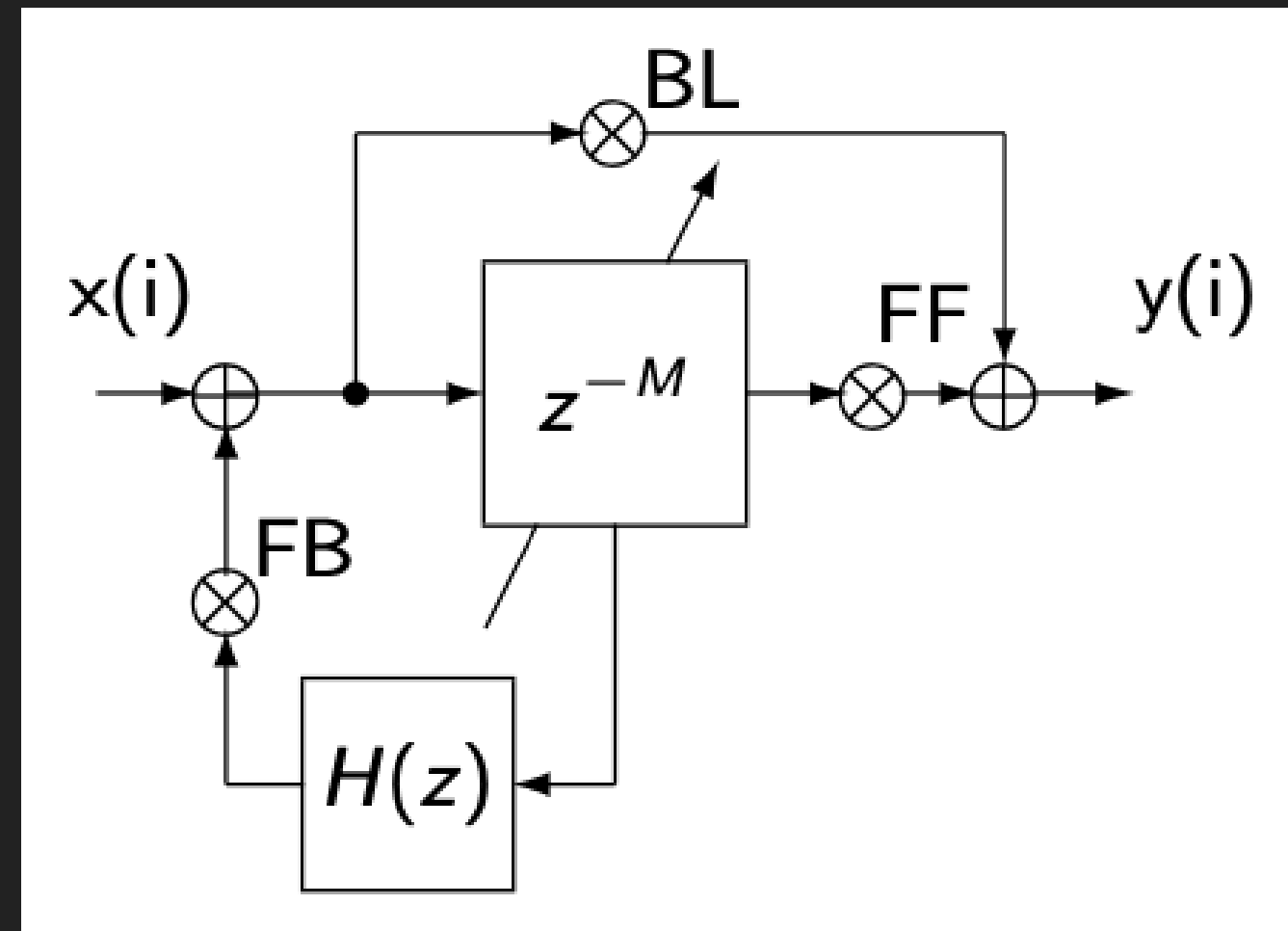
»  $A = 2 \text{ ms}$

»  $M = 2 \text{ ms}$

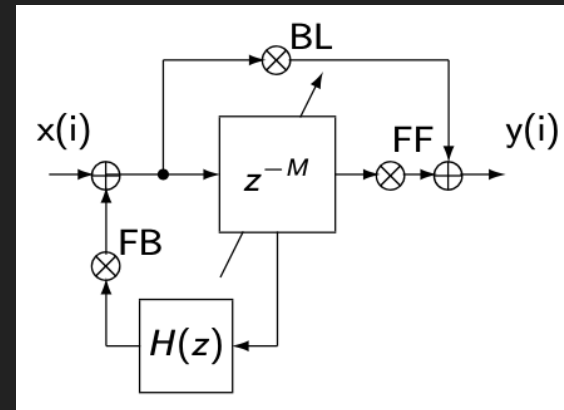
»  $BL = 1.0$

»  $FF = 0.7$

# Modulated Effect with Feedback Path



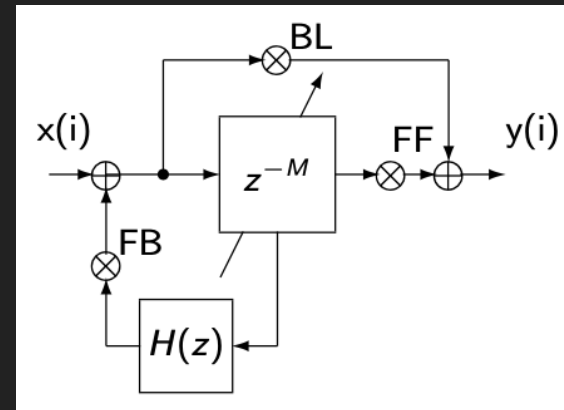
# Modulated Effect with Feedback Path



▶ 0:00 / 0:20

## Simple Flanger with Feedback

# Modulated Effect with Feedback Path

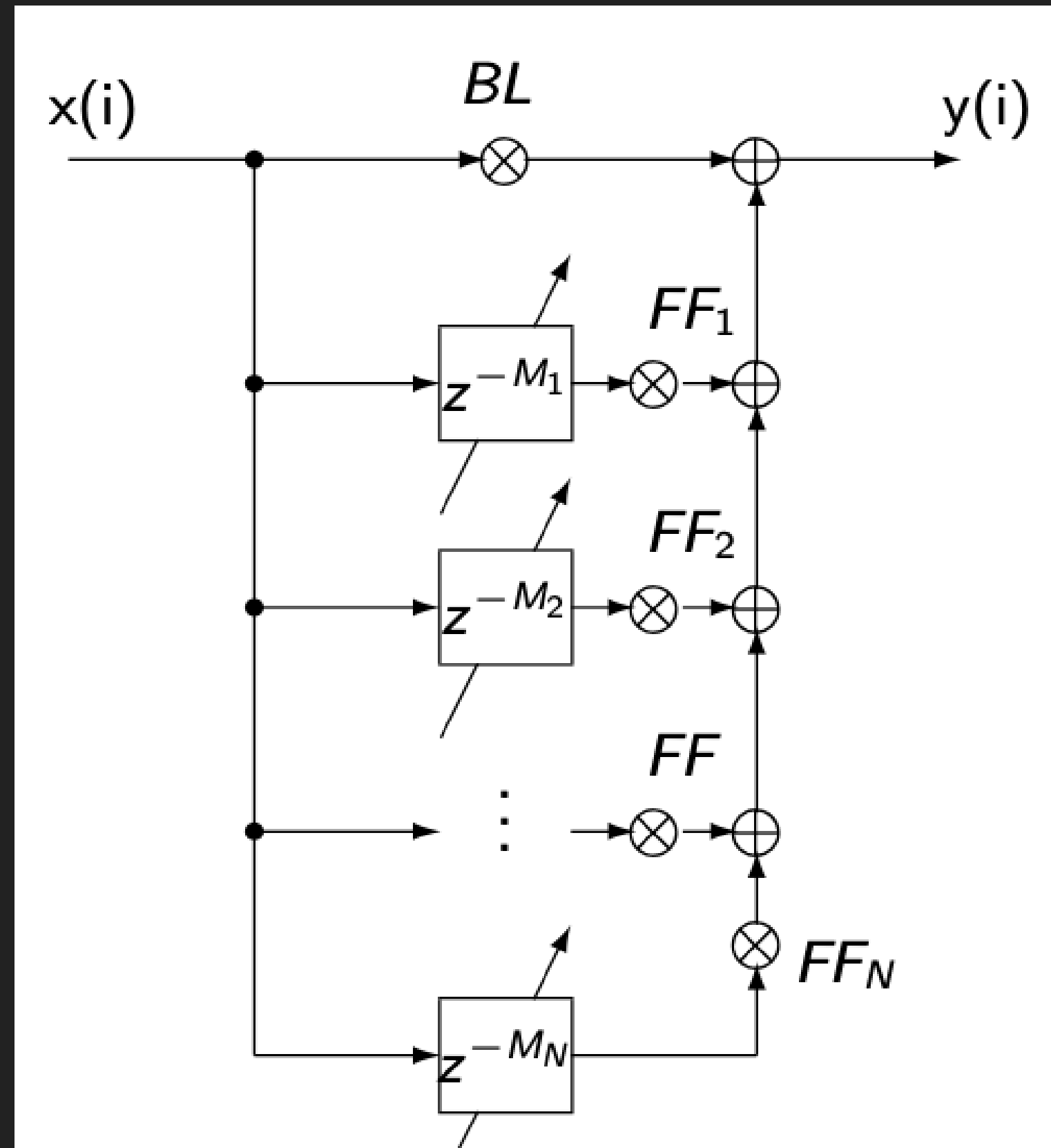


▶ 0:00 / 0:20

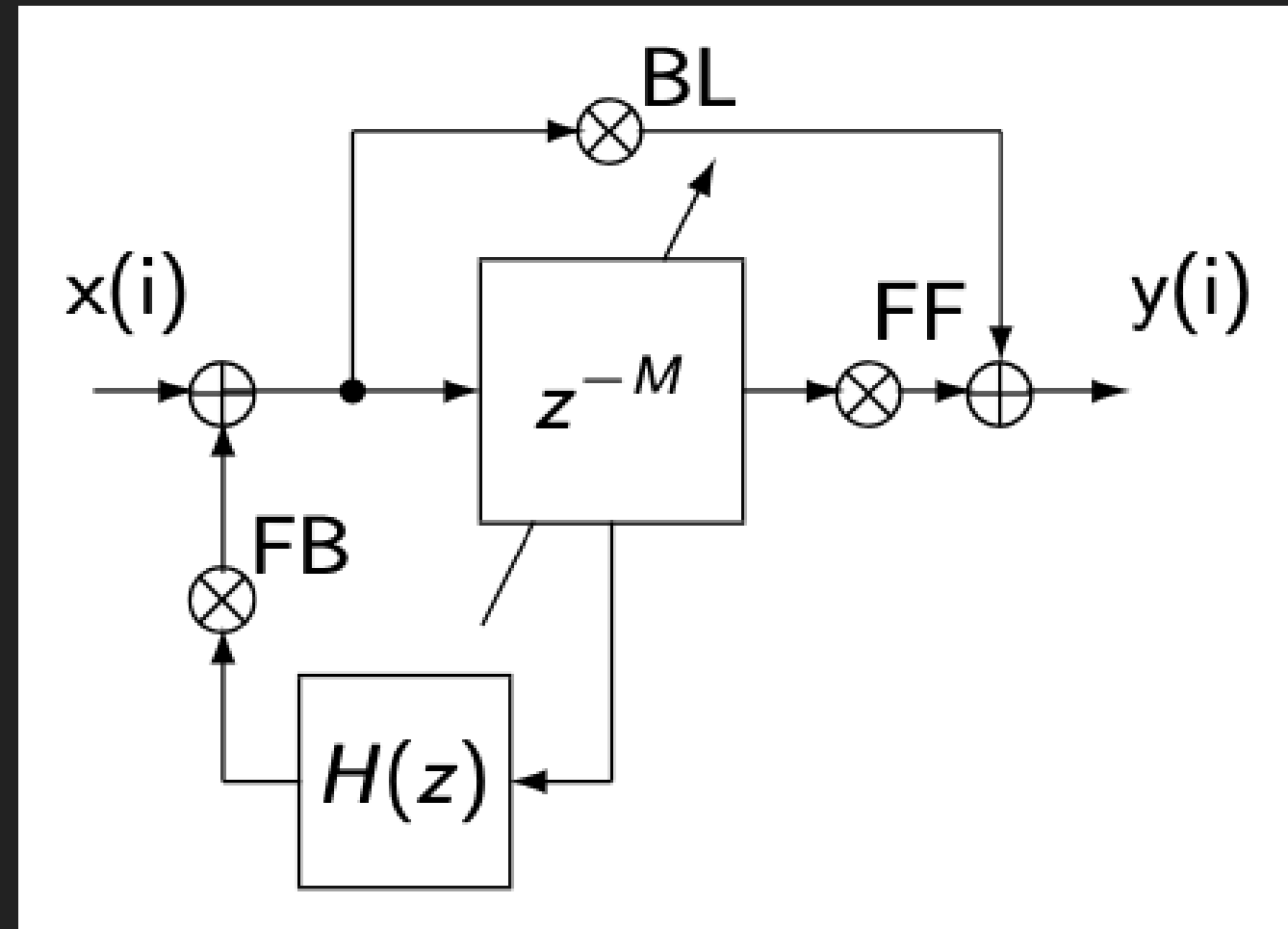
## Simple Flanger with Feedback



# 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

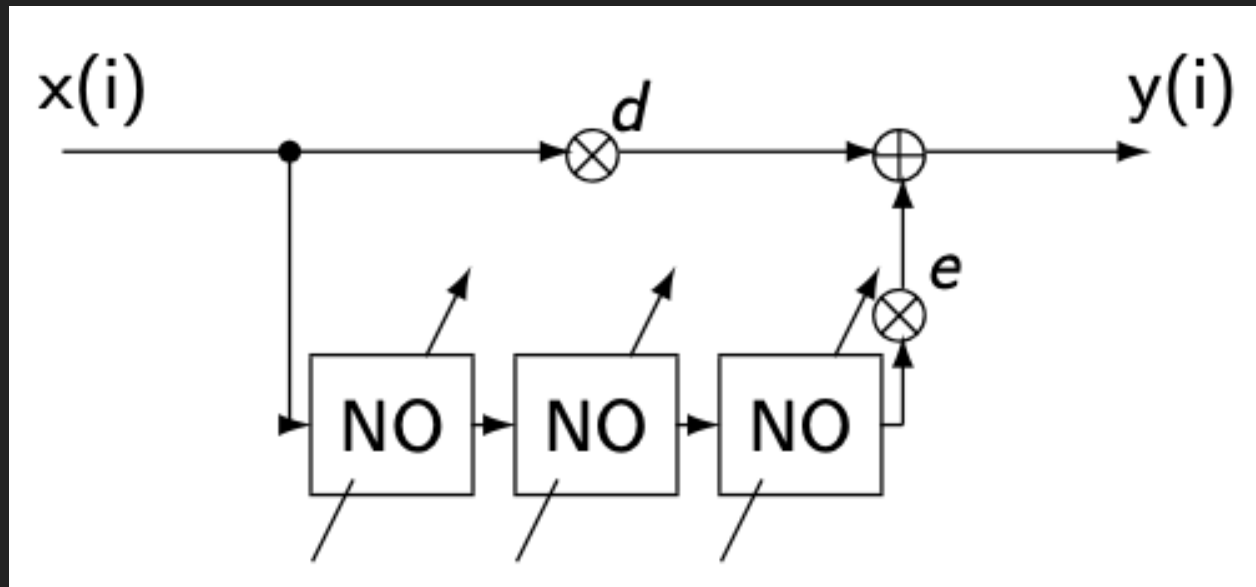
- » 2 or more signals are added

- » Phase is time-variant

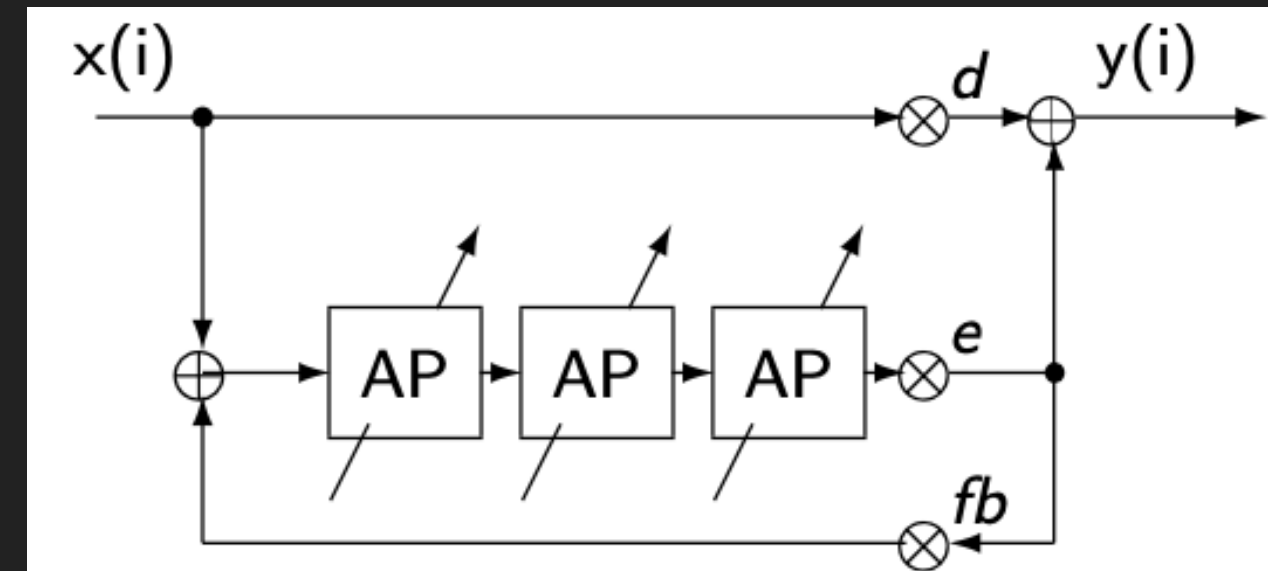
- » Phase shift between channels (localization)

## Modulated Effects: Phaser

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

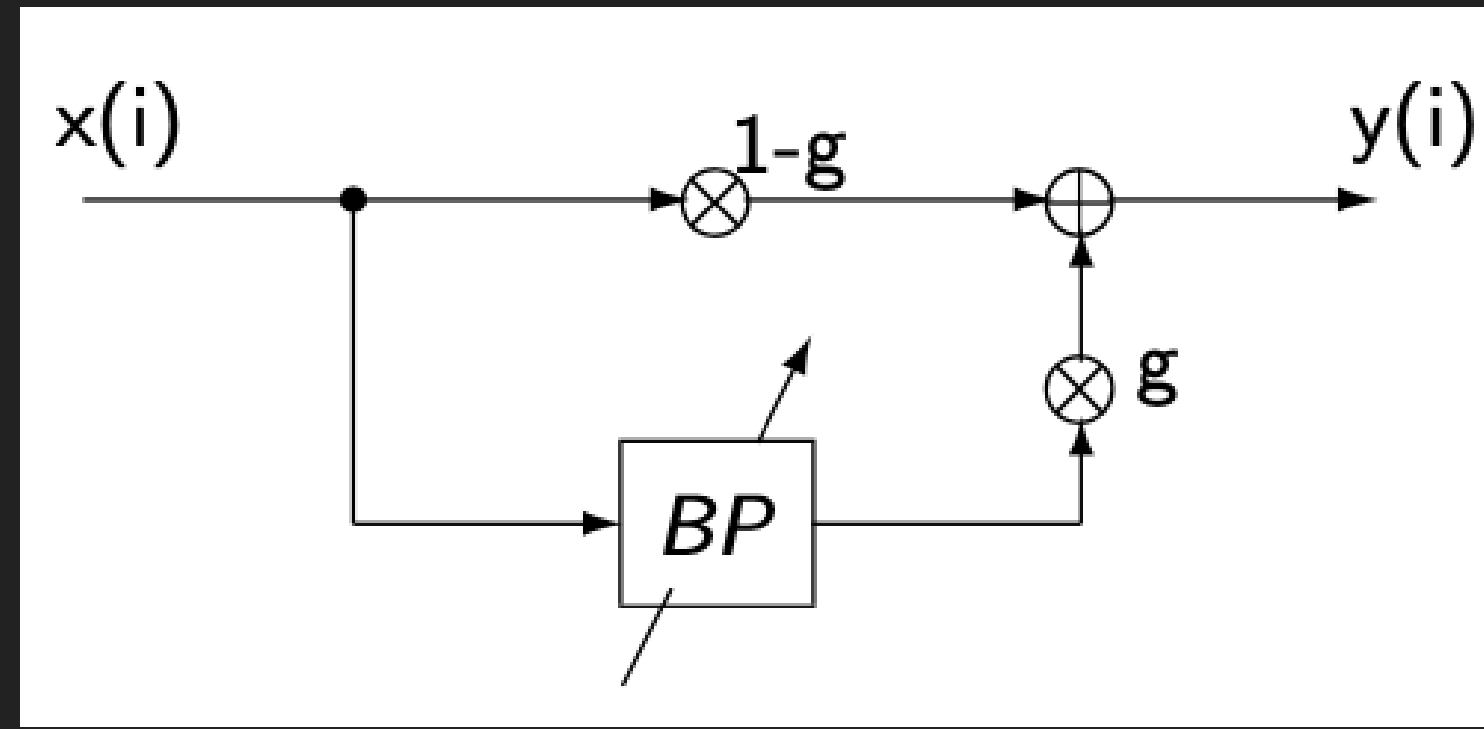


## All-pass Filters



▶ 0:00 / 0:20

## 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