# Digital Signal Processing for Music
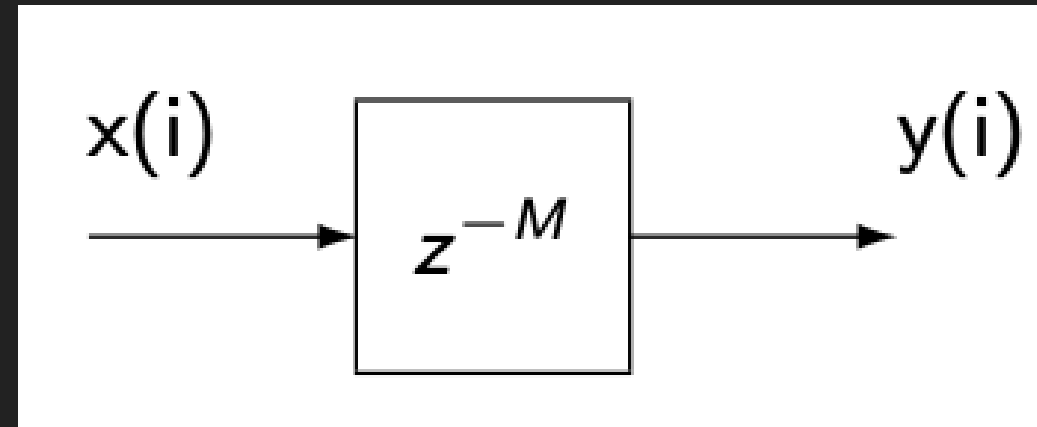
## Part 19: Modulated Effects

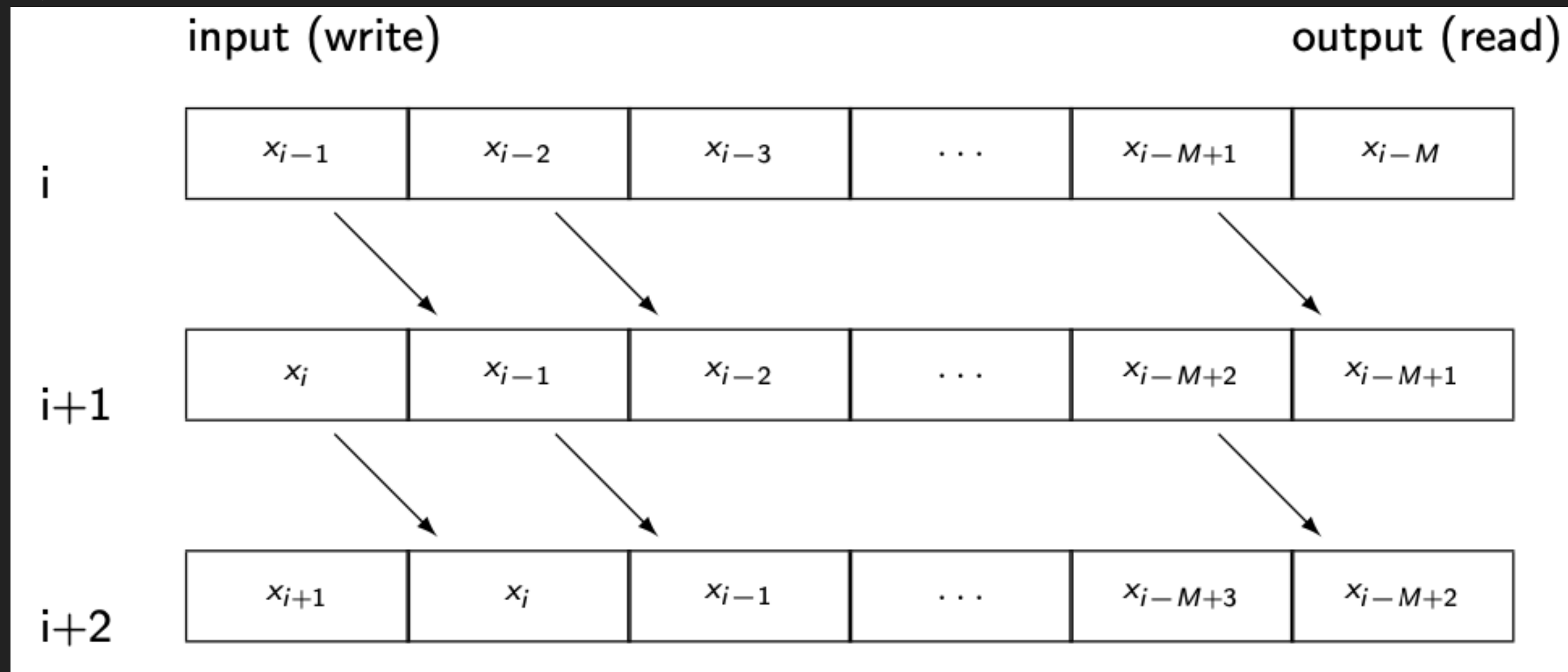Andrew Beck

# 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
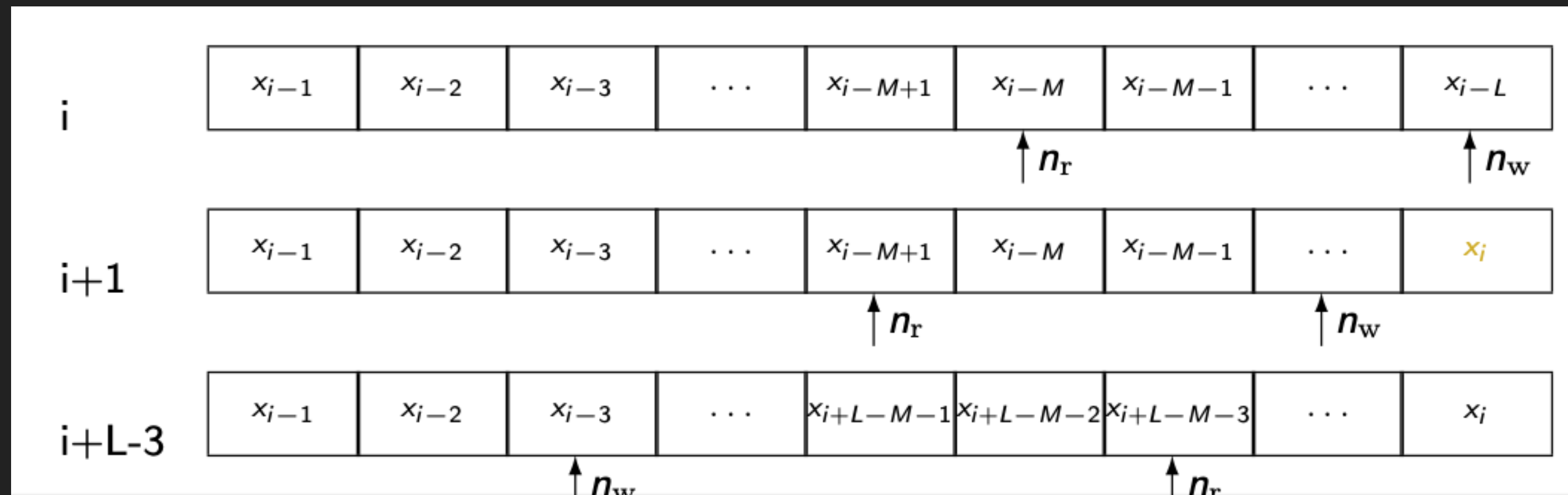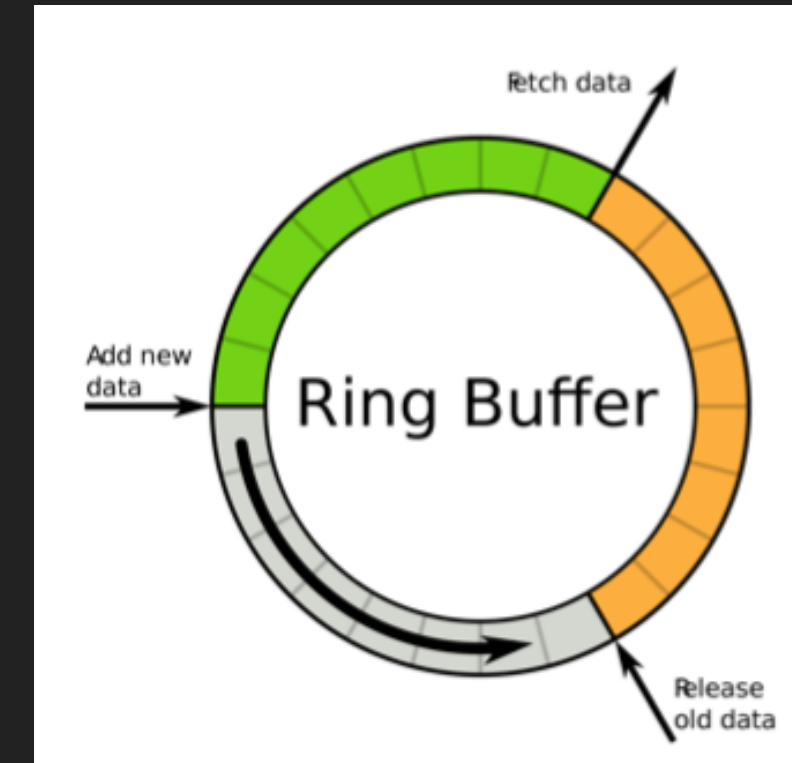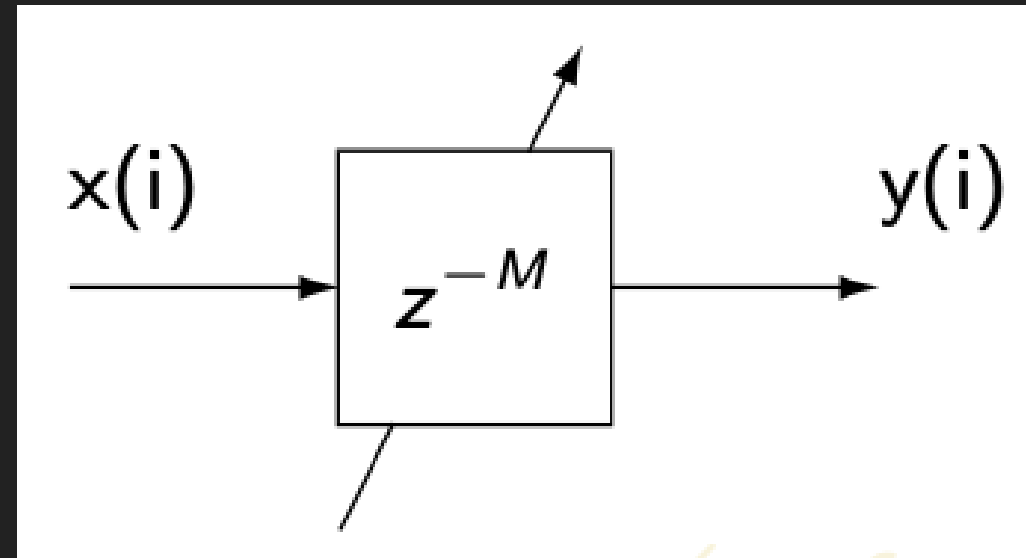
# Ring Buffer

>> **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 $n_r$

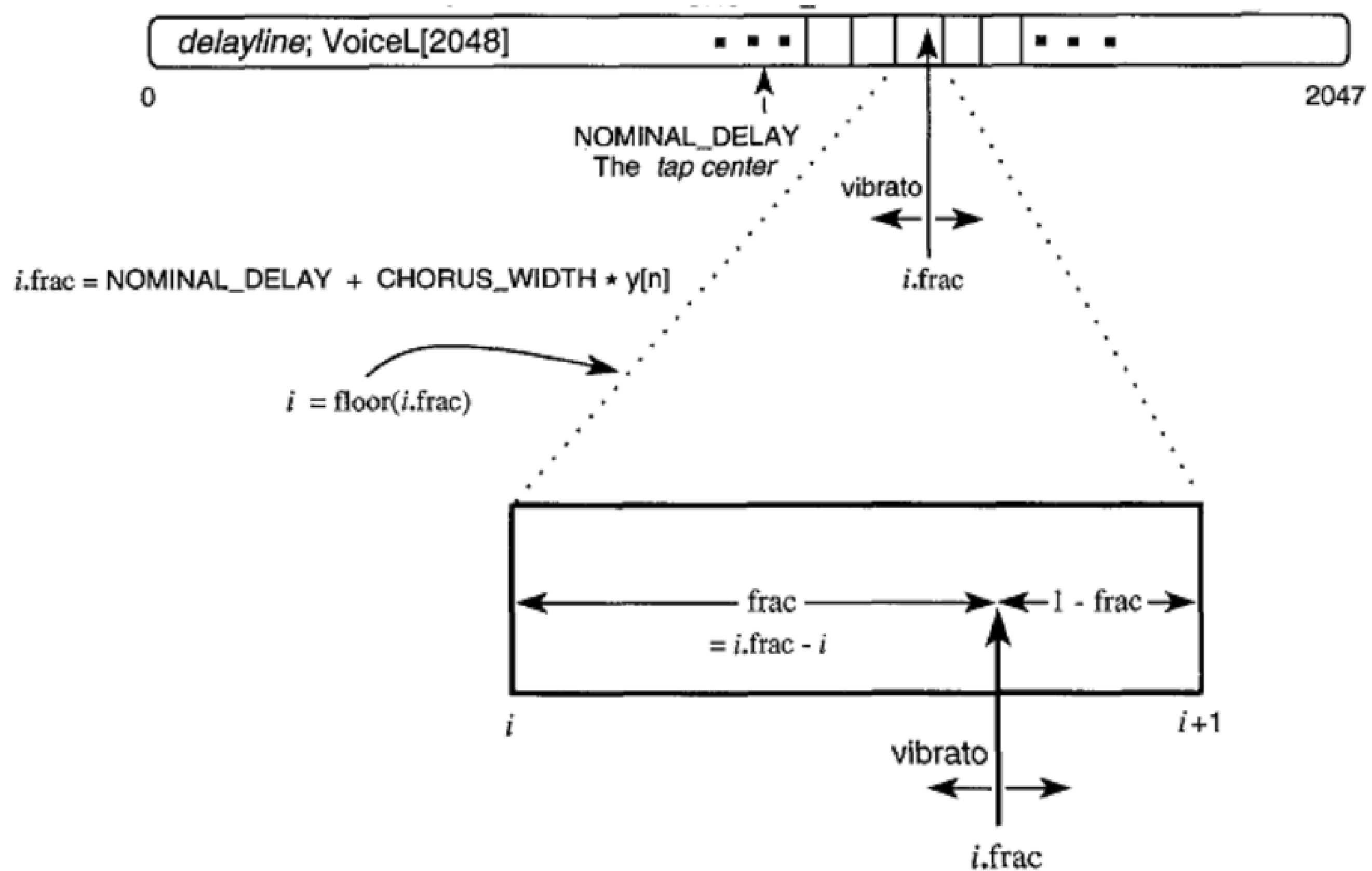>> For a simple delay $(n_w - n_r) \bmod L = M$

# 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
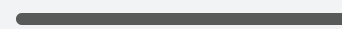
» $\sin$: Oscillator function

# Fractional indexing



delayline; VoiceL[2048]
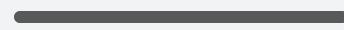
0        2047

NOMINAL_DELAY
The *tap center*

vibrato

$i$.frac = NOMINAL_DELAY + CHORUS_WIDTH $\star$ y[n]

$i$.frac

$i$ = floor($i$.frac)

frac
= $i$.frac - $i$

1 - frac

$i$       $i$+1

vibrato

$i$.frac

# Linear Interpolation Examples

» **Original**:  ▶  0:00 / 0:20 ━━━━━━ 🔊

» **6% speed-up**:  ▶  0:00 / 0:19 ━━━━━━ 🔊

» **6% slow-up**:  ▶  0:00 / 0:21 ━━━━━━ 🔊

# Vibrato
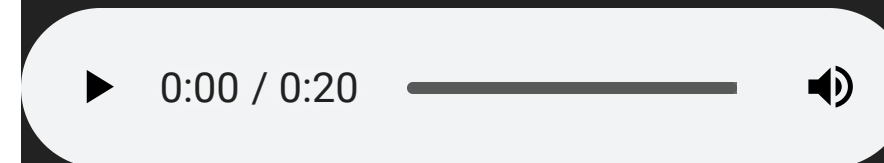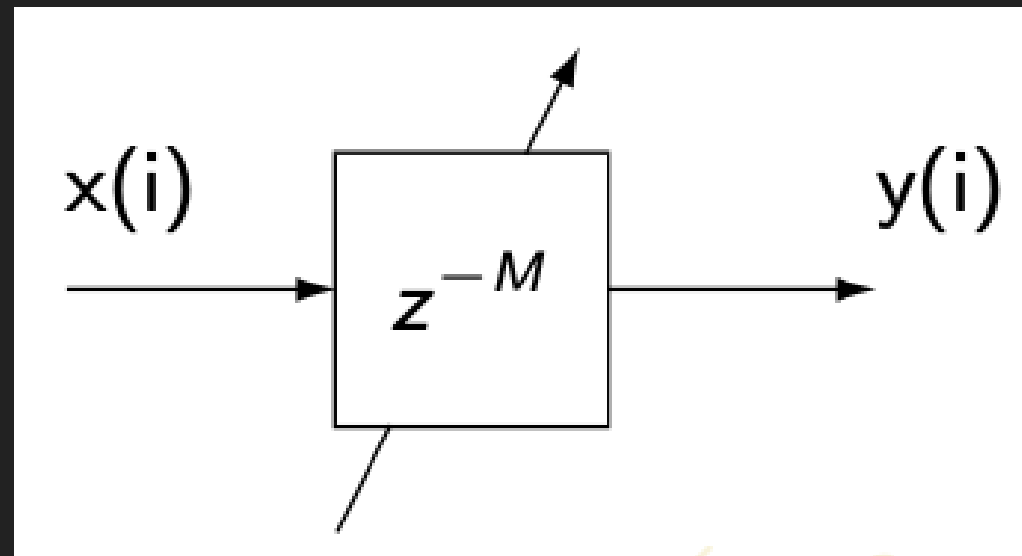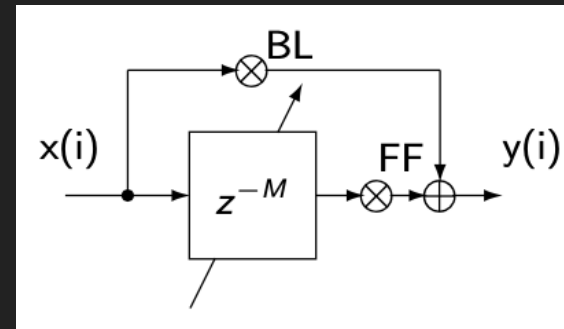


0:00 / 0:20

» $M$ = any

» $A$ = 200 samples

» $f_{mod}$ = 1 Hz

# Vibrato + Input Signal
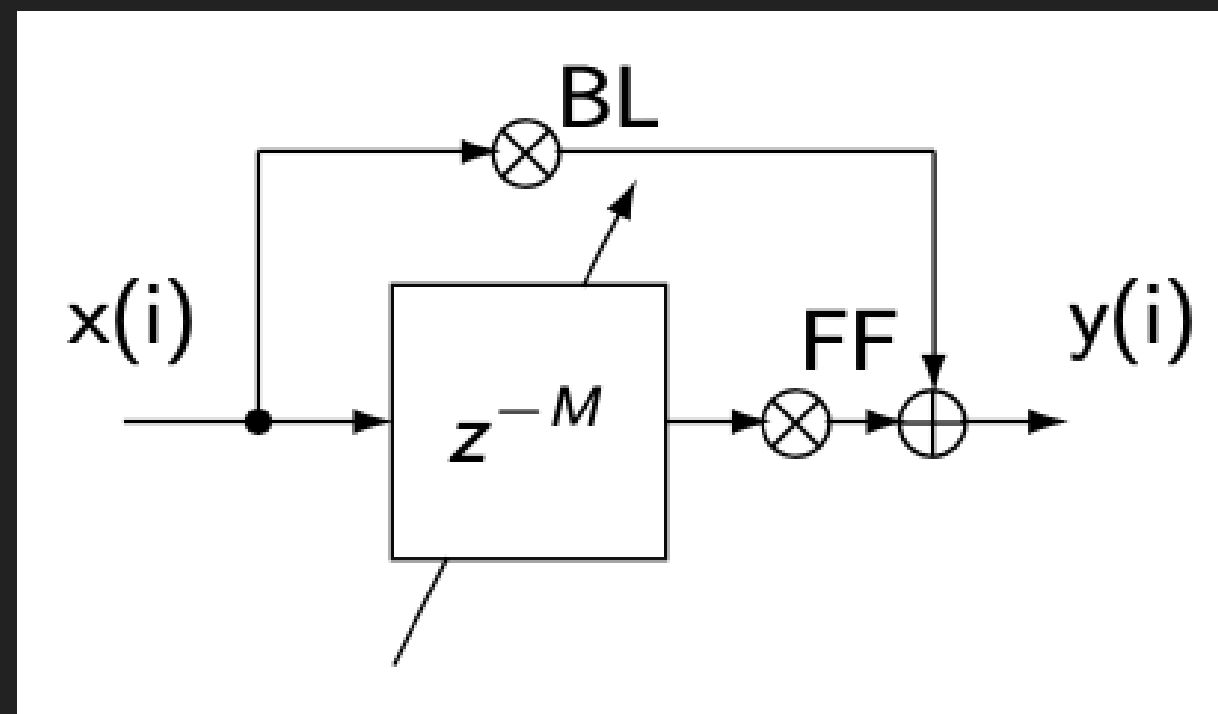
# Vibrato + Input Signal



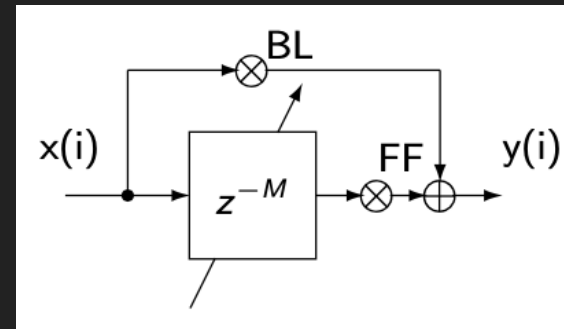▶ 0:00 / 0:20 ━━━━━━━━━ 🔊

## Slapback

» $f_{mod} = 0$

» $A = 0$

» $M = 20$ ms

» $BL = 0.7$

» $FF = 0.7$

# Vibrato + Input Signal



▶  0:00 / 0:20 ━━━━━━━━━━  🔊
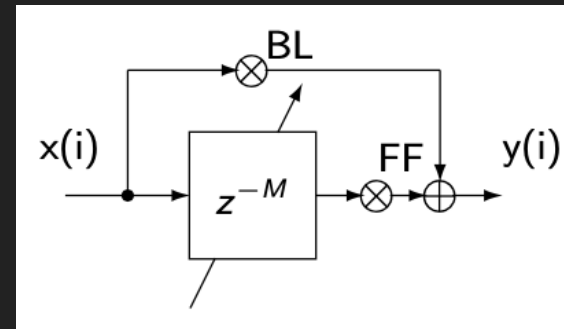
## Simple echo

» $f_{mod} = 0$

» $A = 0$

» $M = 50$ ms

» $BL = 0.7$

» $FF = 0.7$

# Vibrato + Input Signal



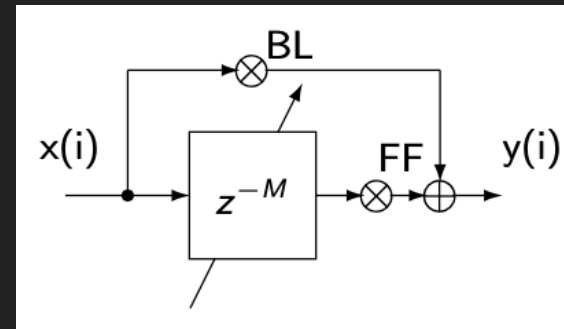▶ 0:00 / 0:20 ━━━━━━━━━ 🔊

## Simple Flanger

» $f_{mod} = 0.2\,\text{Hz}$

» $A = 2\,\text{ms}$

» $M = 0$

» $BL = 0.7$

» $FF = 0.7$

# Vibrato + Input Signal



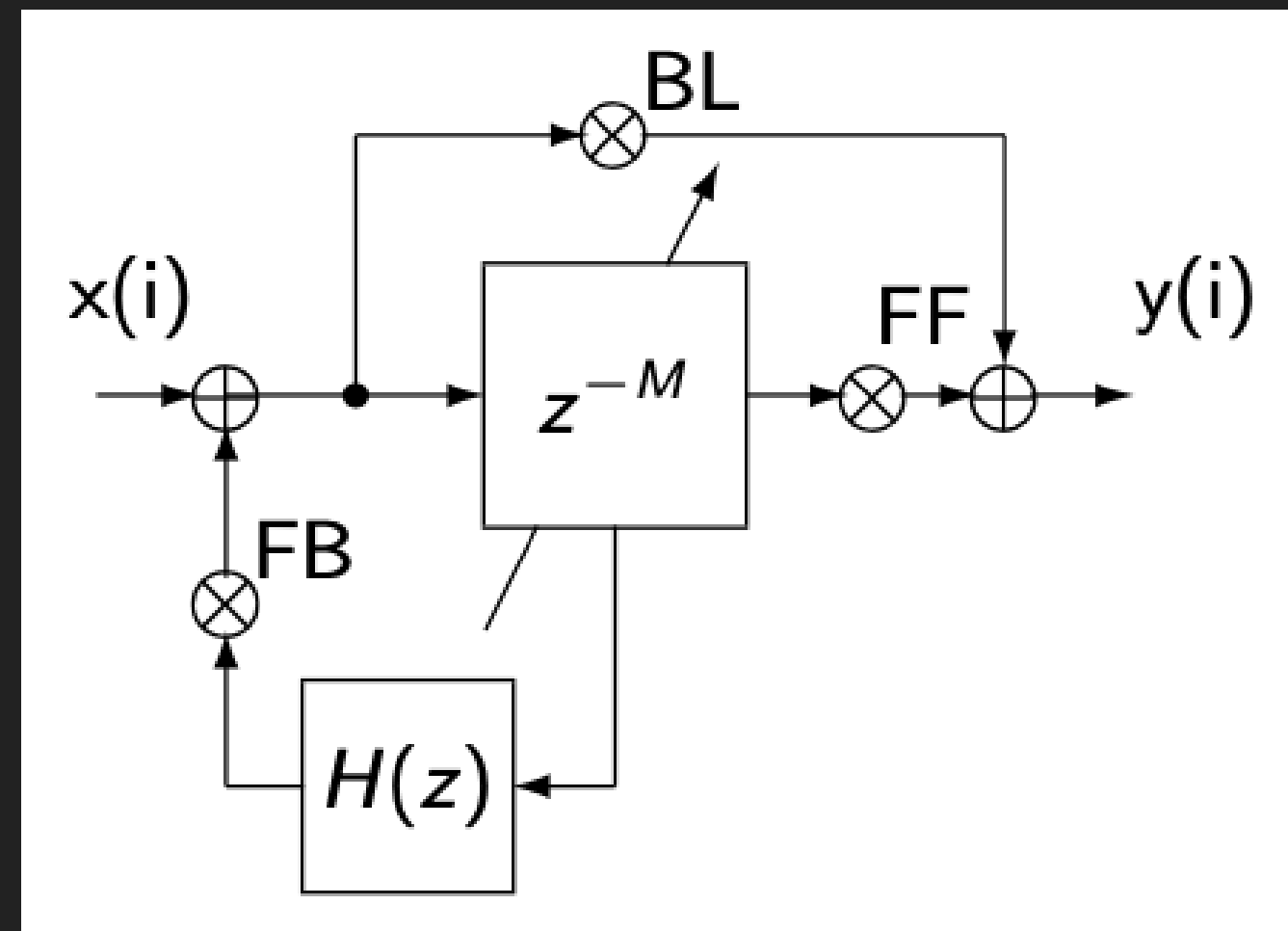▶  0:00 / 0:20 ━━━━━━━━━━━━━━  🔊

## Slapback
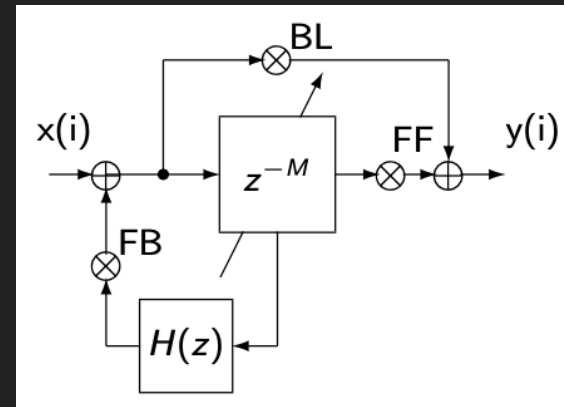
» $f_{mod}$ = 1.5 Hz

» $A$ = 2 ms

» $M$ = 2 ms

» $BL$ = 1.0

» $FF$ = 0.7

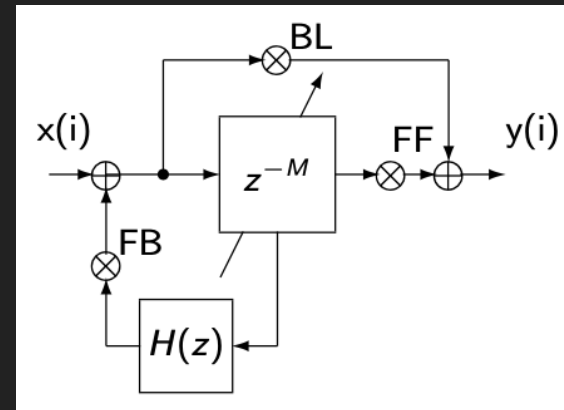# Modulated Effect with Feedback Path

# Modulated Effect with Feedback Path



▶  0:00 / 0:20  🔊
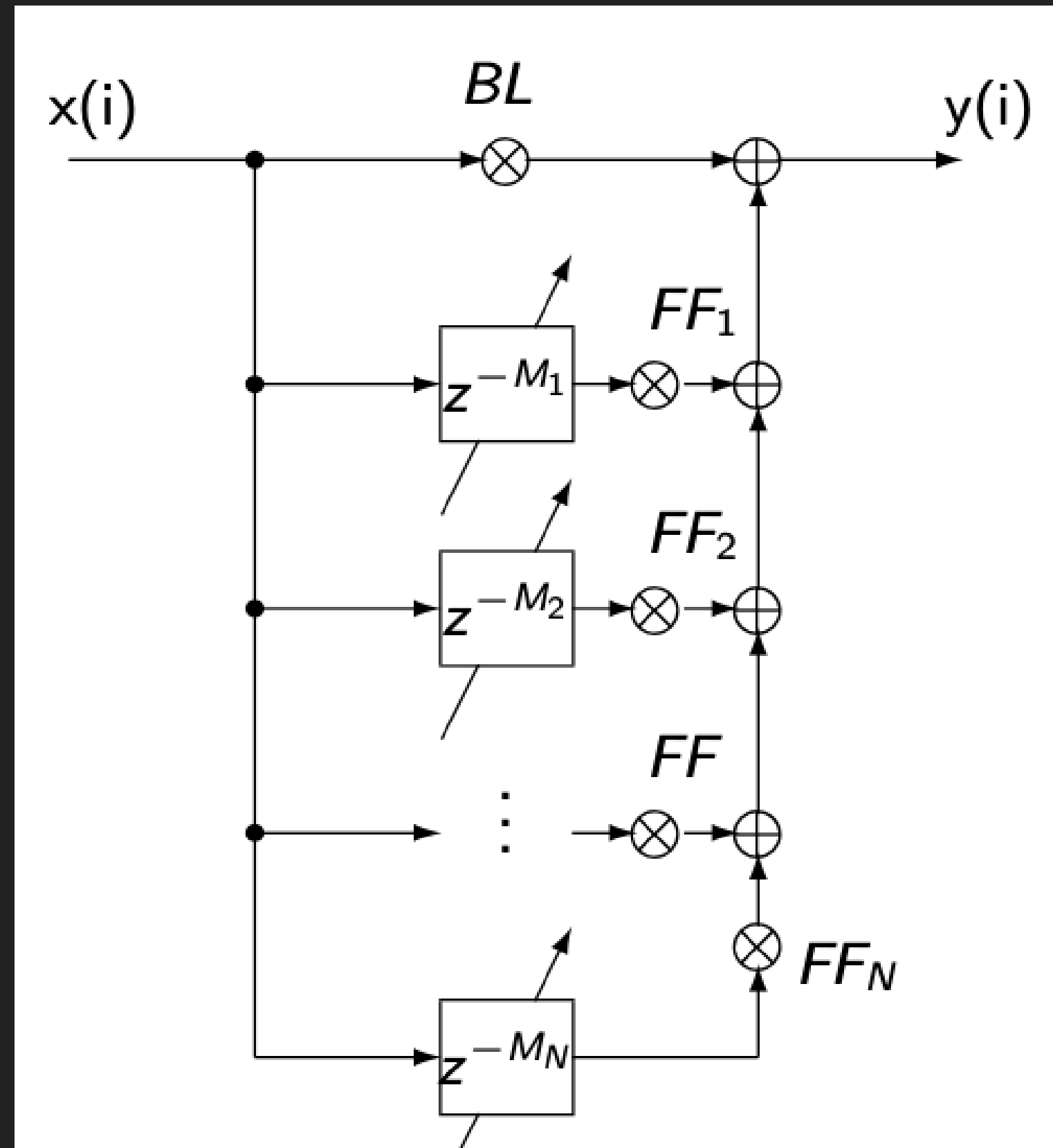
**Simple Flanger with Feedback**
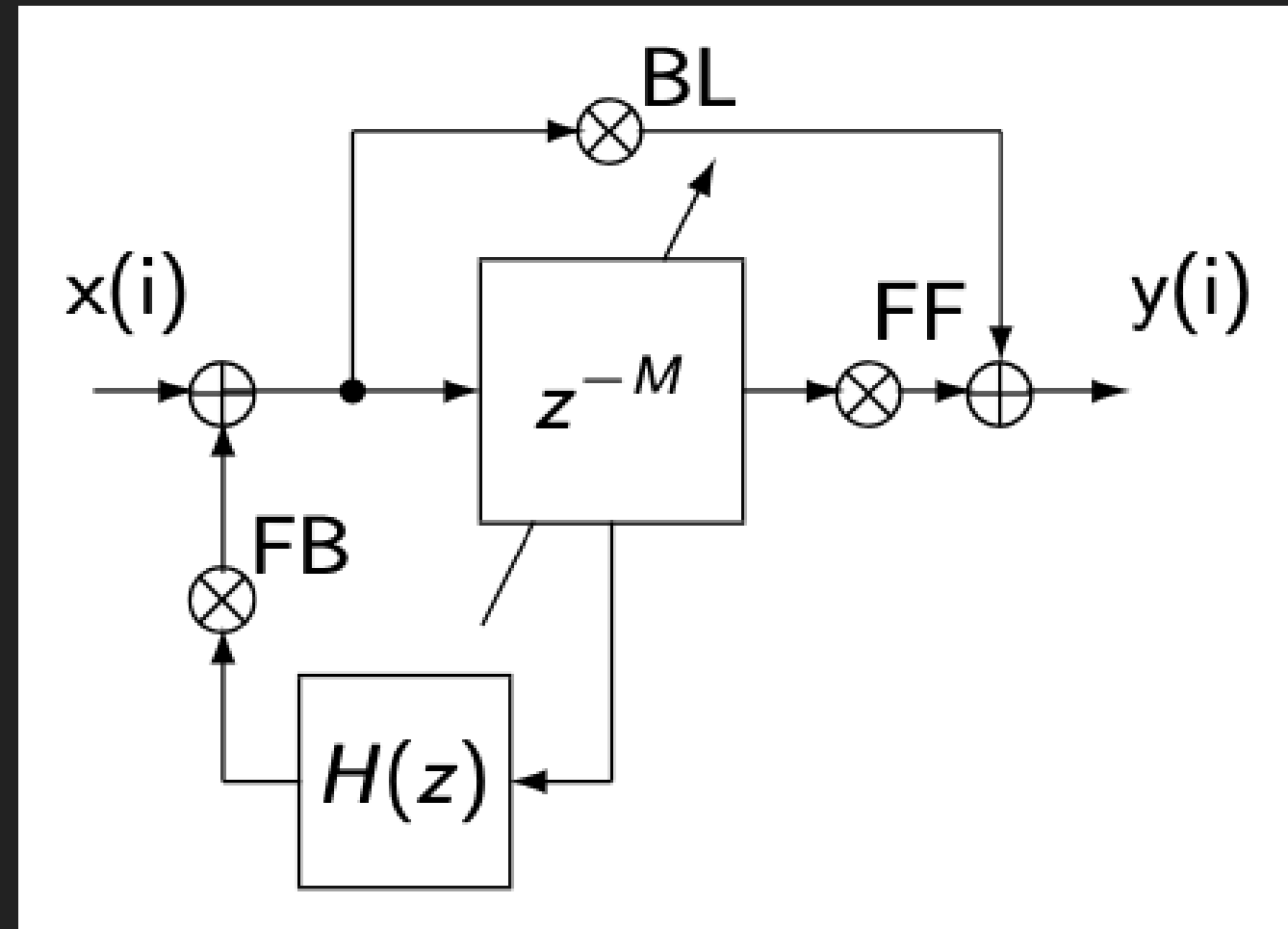
# Modulated Effect with Feedback Path



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**
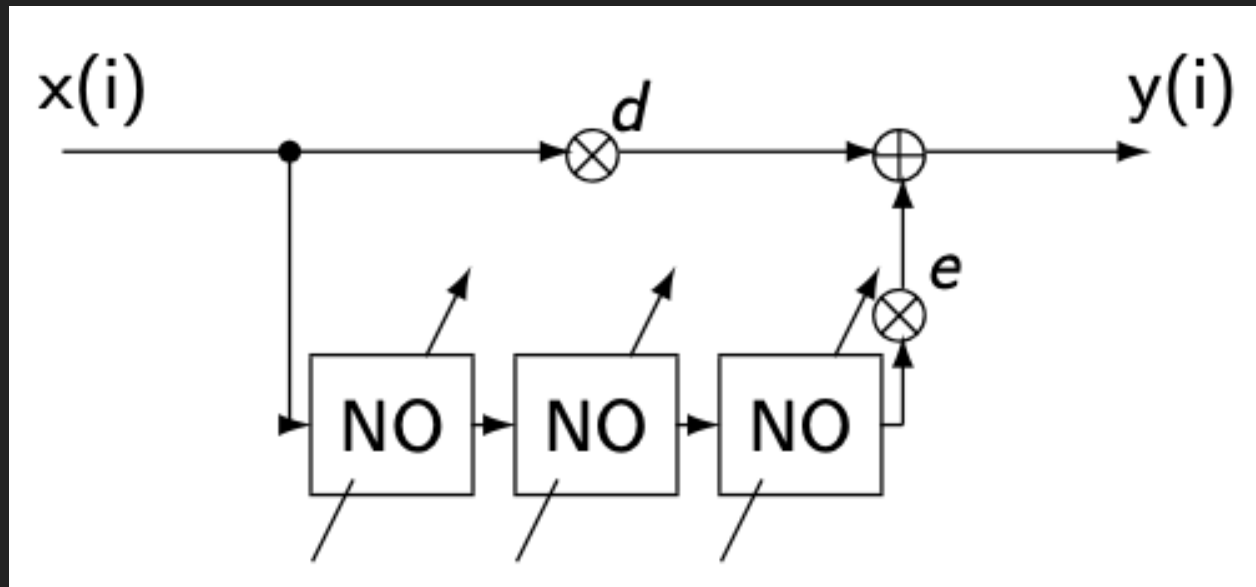  » **Phase response** becomes perceptually relevant when

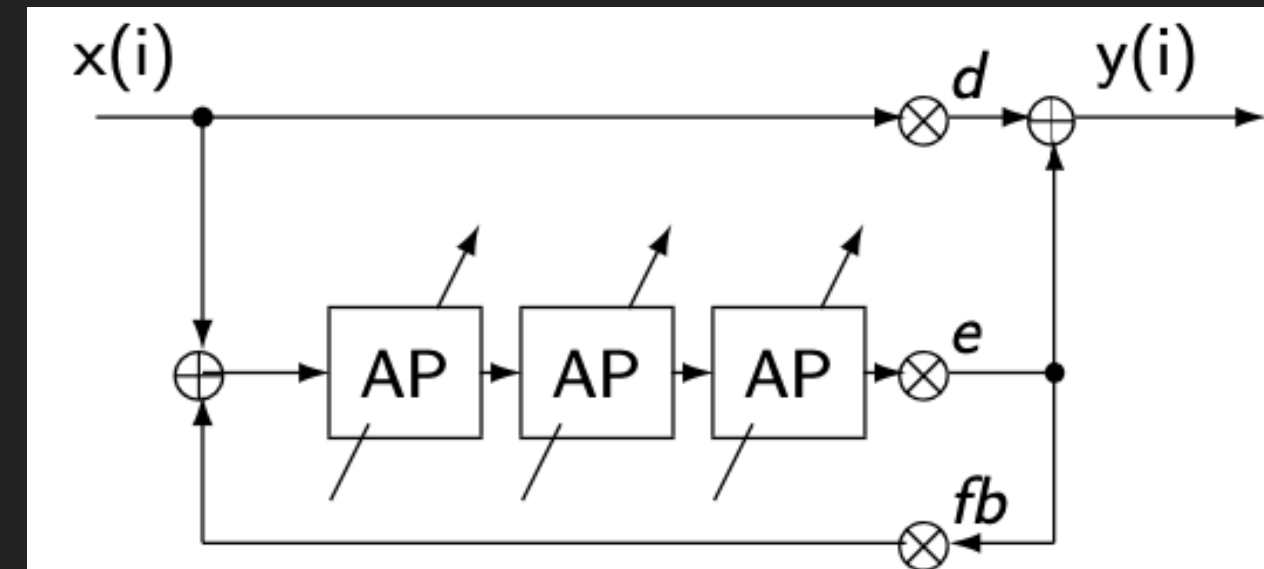    » 2 or more signals are added

    » Phase is time-variant

    » Phase shift between channels (localization)

# Modulated Effects: Phaser

» Sounds similar to delay line effects

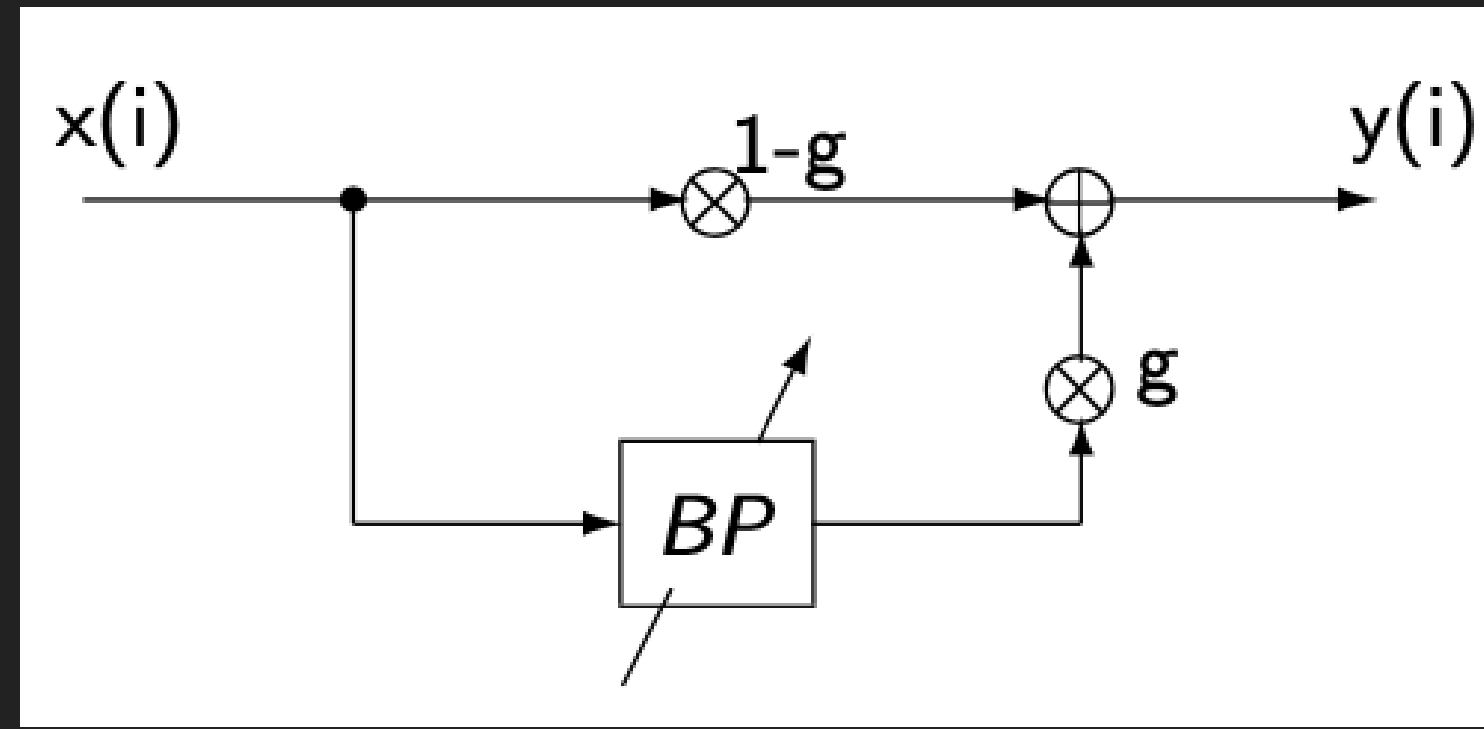» but: different implementation

» 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