# Real Time Counterpoint Synthesizer

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# Karaoke and Beyond

Ideal Karaoke Experience

What's missing?

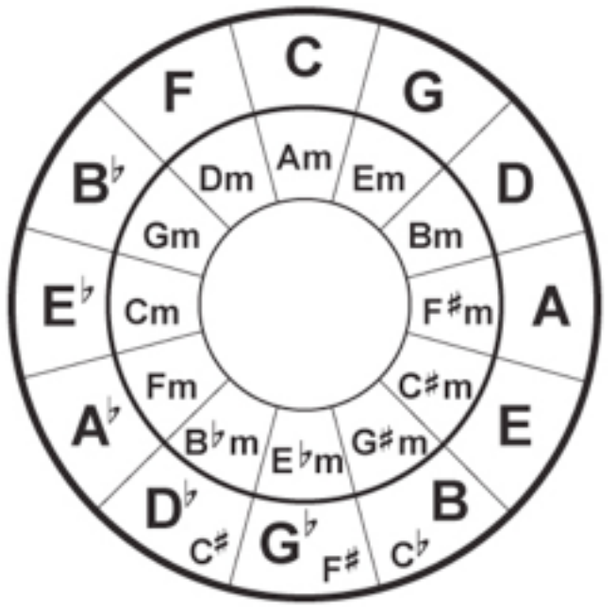
Every time you sing a song the background is the same!

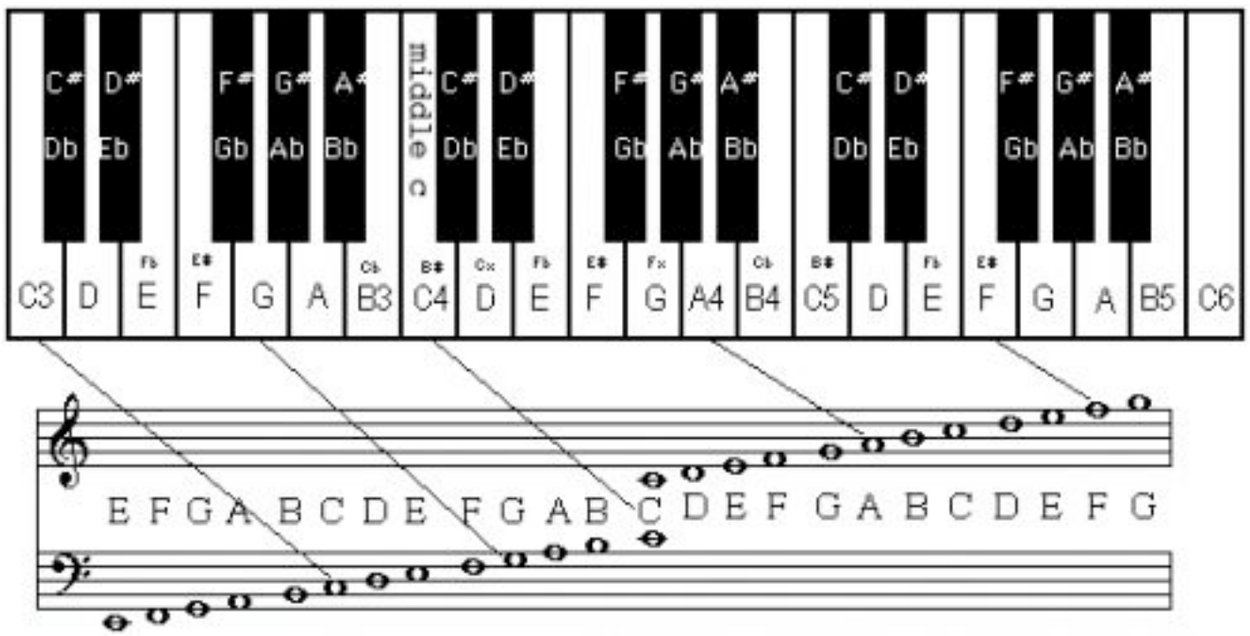
Almost insurmountable difference between a karaoke singer and a trained musician

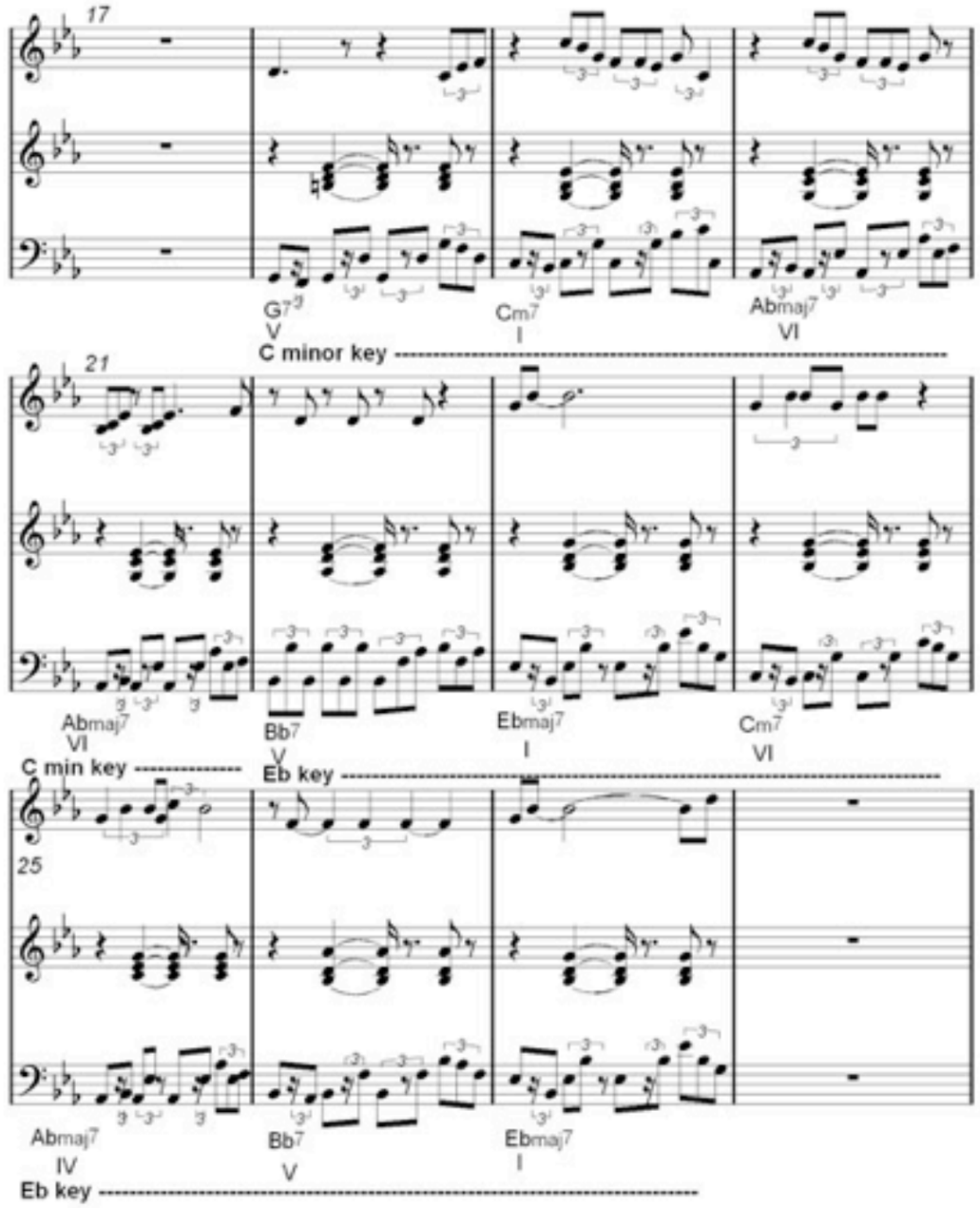
Creating music is hard



Even musicians can struggle with composition
Years in music theory classes



# General Goals

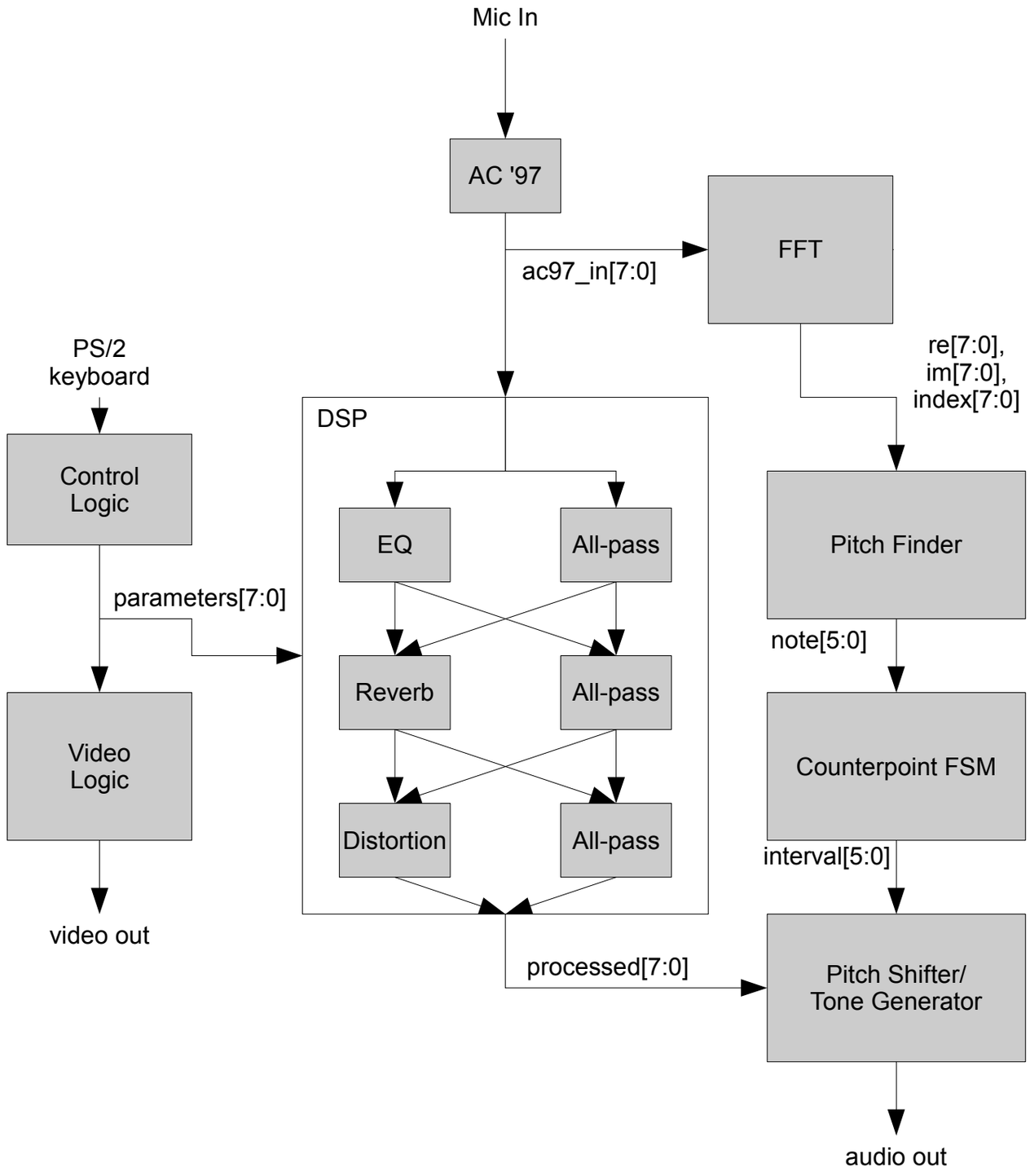
Audio In
(Melody)

**Counterpoint Synthesizer**

Audio Out
(Melody)

Audio Out
(Counterpoint)

# Block Diagram



# FFT

- 2048 Point
- 9.6kHz samples (1 in 5 from AC97)
- 1 Input: 8 bit audio from AC97 module
- 3 Outputs: FFT 8 bit index, real coefficient, imaginary coefficient

# Pitch Finder

- Input: 8 bit FFT real coefficient (re), imaginary coefficient(im), index
- Find FFT magnitude = $\sqrt{(re^2 + im^2)}$
  - 2 clock cycle delay
- Remember largest magnitude and matching index
- After all 2048 samples pass through the FFT, compare the saved largest magnitude's index to pitch lookup table, output closest note

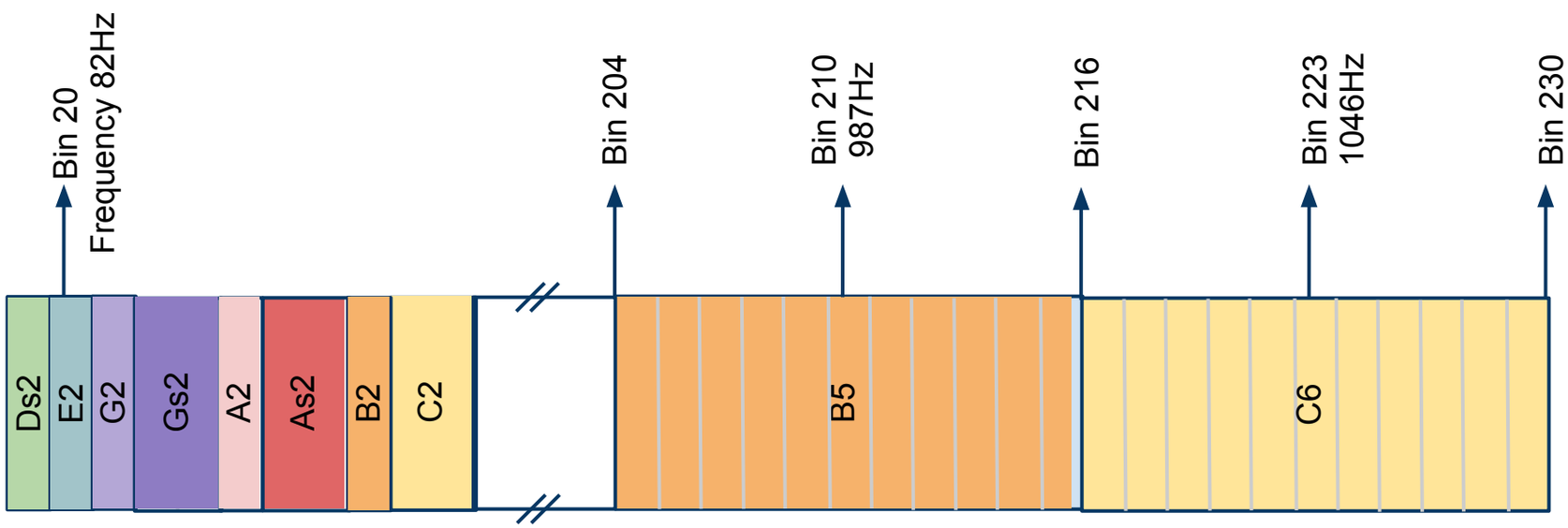
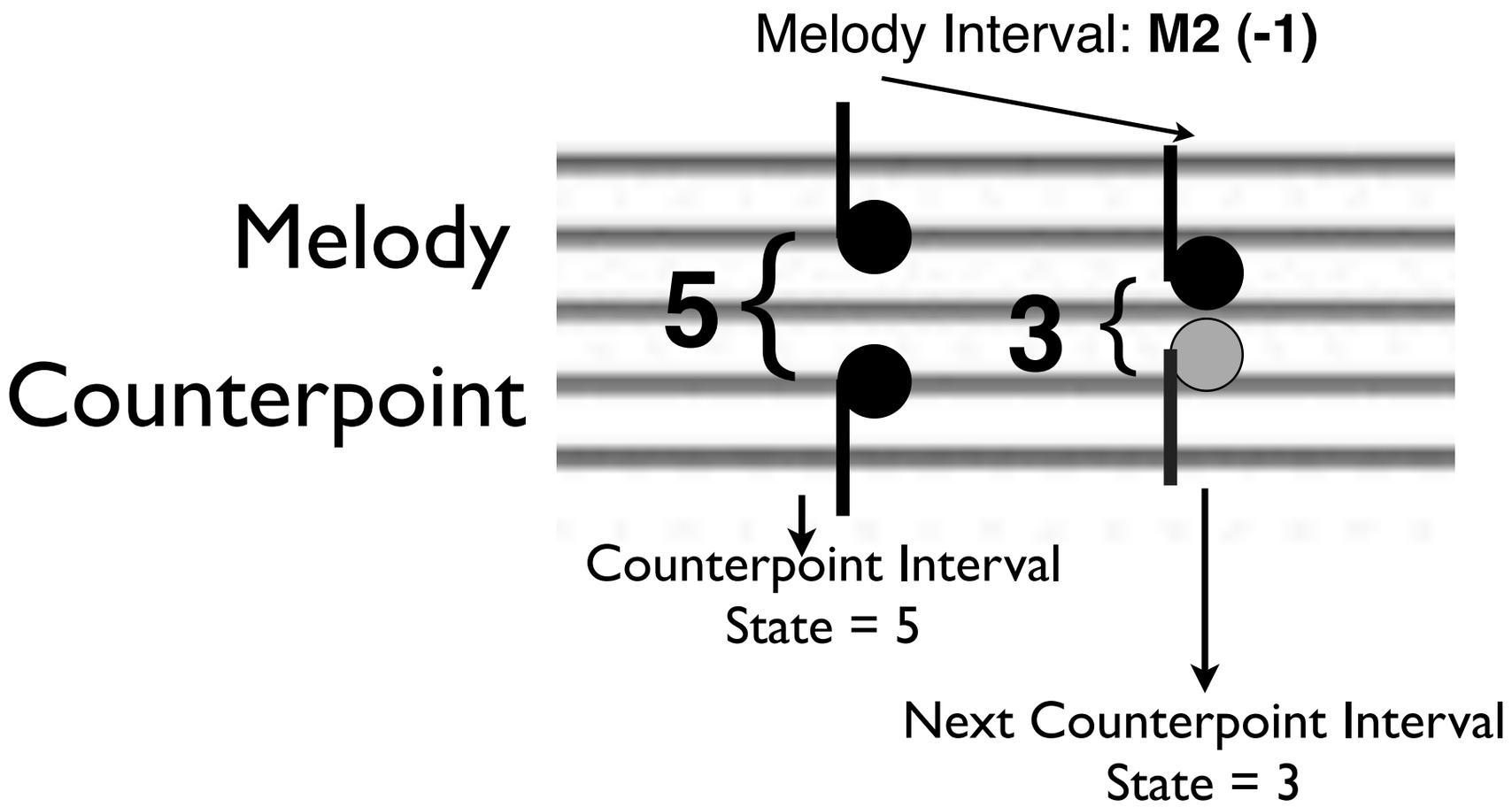



Figure 3. Pictorial model of frequency lookup table

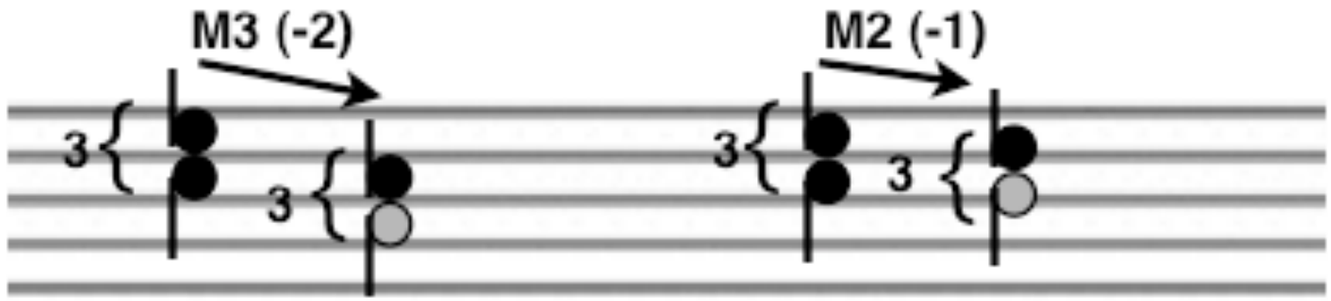
# Counterpoint FSM

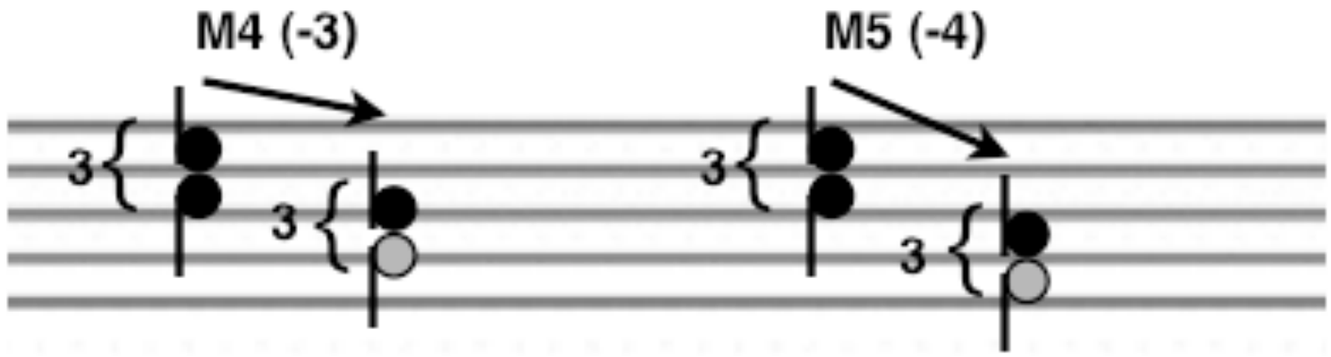



First Implementation:
1. Only Major Counterpoint intervals allowed (6 in all)
2. 12 possible next notes

Second Implementation:
1. Major and Minor Counterpoint intervals

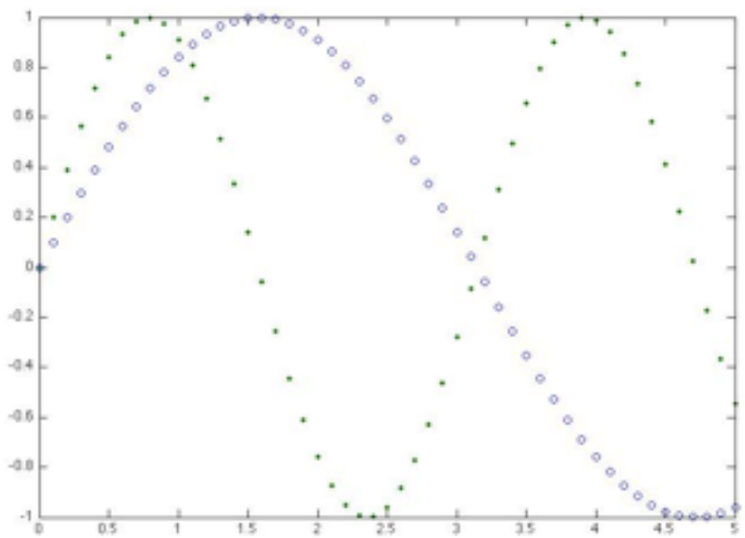
# Examples of State Transitions



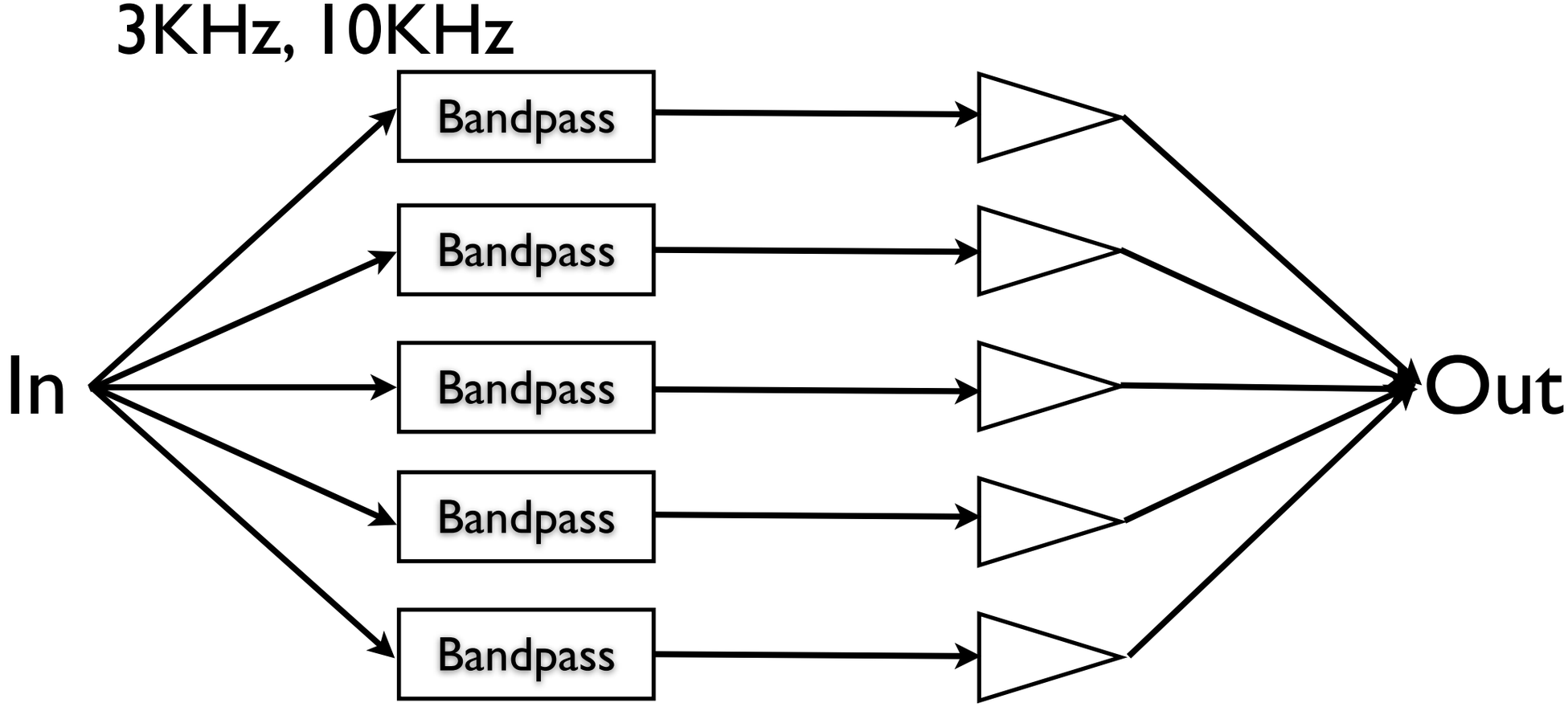
# Tone Generator

- Time Domain Pitch Shift
- Inputs: 8 bit audio from filters, shift interval
- Interval shift is *relative*; therefore output should always sound correct
- Alphas dependent on intervals
- 2 Dual BRAMs



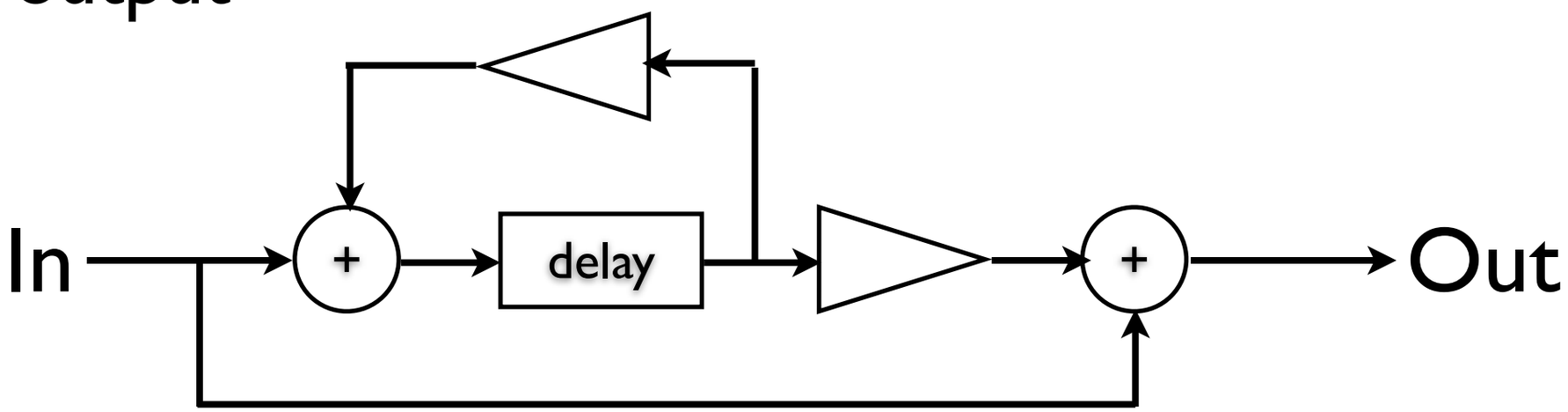
# Equalizer

- Attenuate unwanted frequencies
- Boost desired frequencies
- 5-band, centered around 100Hz, 300Hz, 1KHz, 3KHz, 10KHz

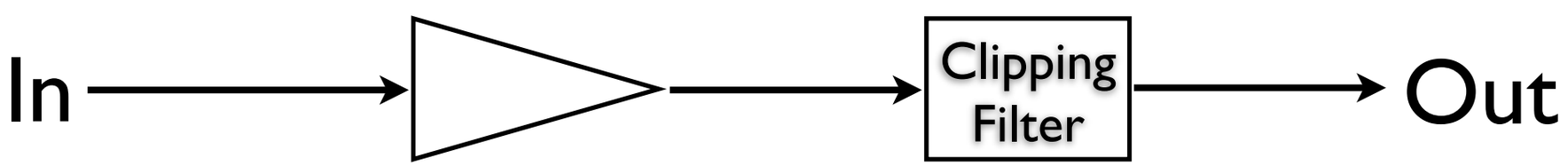


# Reverb, Distortion

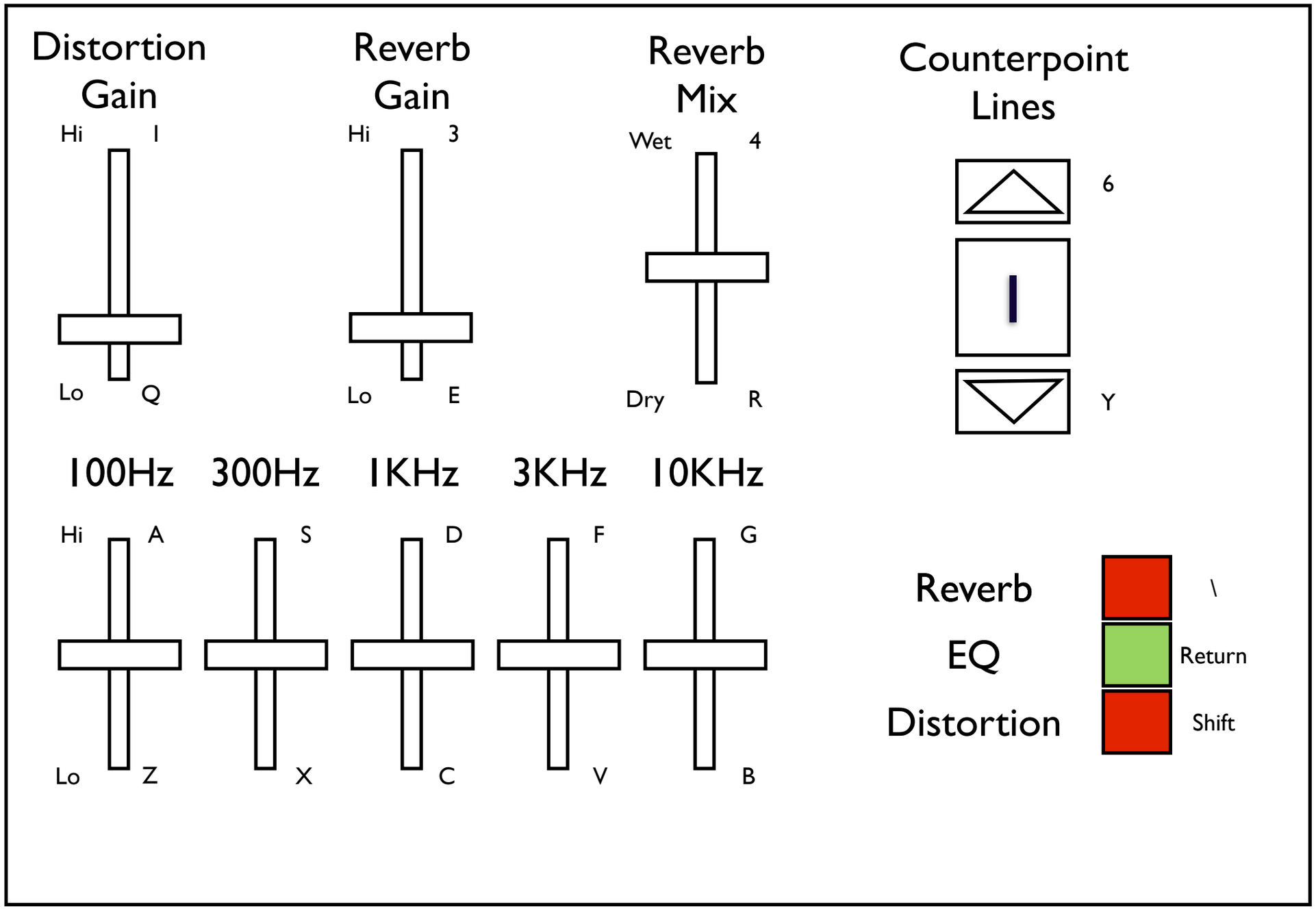
- Reverb adds delayed, attenuated copy of signal to output




- Distortion (overdrive) applies gain to signal, then artificially clips it



# GUI


Distortion Gain
Hi
I
Lo
Q
Reverb Gain
Hi
3
Lo
E
Reverb Mix
Wet
4
Dry
R
Counterpoint Lines
6
Y
100Hz
300Hz
1KHz
3KHz
10KHz
Hi
A
Lo
Z
S
X
D
C
F
V
G
B
Reverb
EQ
Distortion
\
Return
Shift

# Timeline

11/15: FFT module completed, memory allocated, Pitch Finder built

11/22: Effects filters built and tested in Matlab, on FPGA, Pitch Finder tested

Counterpoint Module built and tested

11/29: Tone Generator, UI

12/6: Module Integration