A Loudspeaker Management System with 
FIR / IIR Filtering

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Motivation

- Reproduce music signal as faithfully as possible
  - Time and frequency domain
  - Noise / THD
- Protect speakers
  - Mechanical damage
  - Overheating
Dual Range AD Conversion

- DR of LMS smaller than mixing desk
- Decision: headroom for limiter or noise
- Switches or dials to adjust DR boundaries
- Use stereo ADC in mono config.
- Two different gains
- Extend dynamic range by 19.1dB
Signal Processing
IIR Filtering
IIR Filtering (2)

Notch 200Hz, Q=512, -24dB, 24, 24+EFB, 48Bit, 16K-FFT.
FIR Filtering

Impulse response

\[ \begin{array}{cccccc}
Z^{-1} & Z^{-1} & Z^{-1} & Z^{-1} & Z^{-1} & Z^{-1} & Z^{-1} & Z^{-1} & Z^{-1} \\
b_0 & b_1 & b_2 & b_3 & b_4 & b_{n-4} & b_{n-3} & b_{n-2} & b_{n-1} & b_n
\end{array} \]

\[ \text{in} \quad \rightarrow \quad \text{out} \]

\[ V \]

50 100 900 \( \mu s \) 950
FIR Filters

- Minimum phase vs. linear phase

Freq. Resp | Phase | Group Delay | Imp. Resp
Equalizing the Loudspeaker

- **IIR Filters**
  - Filters introduce phase distortion as well as LS

- **Linear phase FIR filters**
  - Filters don’t introduce phase dist. but LS does

- **Complex equalizing**
  - Inverse of LS impulse response is used as filter thus (ideally) no phase distortion
FIR Filtering (3)

Loudspeaker responses

Overall system response

FIR filter responses

Rect pulse response

Min. phase equalization

Complex equalization
Phase Responses (Overall System)

- Identical mag. responses for all three options

Graphs showing frequency response and phase response across different frequencies.
Multirate Processing

- FIR filtering at low frequencies requires many many many many coefficients
  - $48000 \text{ Hz} / 512 \text{ taps} = 93.75 \text{ Hz resolution}$
  - High computational load for higher resolution
  - Use downsampling:
    - $48000 \text{ Hz} / 16 / 512 = 5.86 \text{ Hz}$
Advanced FIR Filtering

- Overlapping bands, e.g. to influence directivity
Look-Ahead Peak and RMS Limiter

- Dual limiter concept to avoid mechanical damage and overheating
Gain Reduction Spectrum

Anticipating Peak Limiter, Attack=2ms, Release=40dB/s

- Gain reduction
- Limiter threshold
- Limited audio signal

- Analog limiter
- Look ahead limiter
- Look ahead with LP

CAMCO
FOUR AUDIO
ITA
Controlled Overshoot

- Simulate capacitor surging in power supply
- Preserves the "Kick"

Graph showing voltage over time with labels: surge, power supply, amp output, and duration.
Summary

- Dual Range AD Conversion extends dynamic range
- Combined IIR and FIR filters
Summary (2)

- **FIR filters**
  - Allow using steep slopes for crossover networks without additional phase distortion
  - Using complex equalizing allows to equalize amplitude and phase
  - Beneficial for advanced concepts in crossover design
  - Multirate concept allows high frequency resolution at low frequencies
Summary (3)

- Dual limiter concept allows separate protection mechanisms against mechanical damage and overheating

- Toolbox for conventional and unconventional crossover design if you know what you are doing
Really the End

Thank You