For Loudspeaker Protection

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Department of Electronic Systems Aalborg University Denmark





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RMS Limiter

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Downsampling med faktor 2

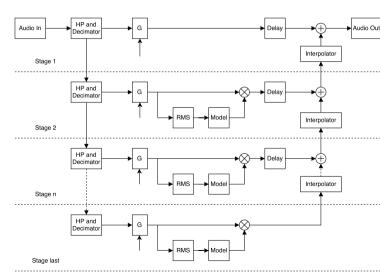
► 7 gange

▶ 48 kHz

▶ 24 kHz

12 kHz

▶ 375 Hz





Løsning & Design realization

## Decimation

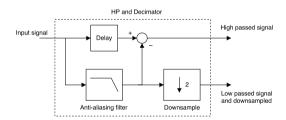
Konklusion

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# Funktionalitet:

- ► Lavpas filter til Anti-Aliasing
- Spektral subtraktion til høipas filtrering

- ► Overholde IEC 6964 Class
- Lineær fase
- ► 60 dB dæmpning ved fs 21





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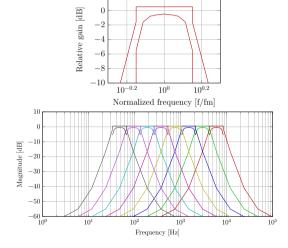
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- Overholde IEC 6964 Class
  - Lineær fase
- ► 60 dB dæmpning ved fs/21





Decimation

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# Krav:

- Overholde IEC 6964 Class 2
- Lineær fase

50. Orden FIR

Type 1

√ Symmetrisk

√ Lige orden

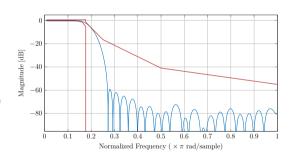
 $\sqrt{60}$  dB dæmpning ved  $\frac{fs}{2l}$ 

•  $\omega_{\text{pass}}$ = 0.125  $\frac{\pi rad}{sample}$  (3.000Hz)

•  $\omega_{\text{stop}} = 0.271 \frac{\pi rad}{sample} (6.500 \text{Hz})$ 

# **Metode brugt:**

- Kaiser Window method
  - Effektivt design
  - Justerbar beta-værdi





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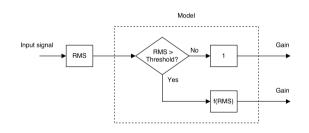
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# **Funktionalitet:**

- ► Beregn RMS værdi i bånd
- ► Bestem gain passende gain værdier
- ▶ Påfører gain

- ▶ Løbende Gennemsnit
- ▶ Dæmpning til grænseværdi ved input på ≥ grænseværdien
- ▶ 0 s attack time
- ▶ 5 s release time





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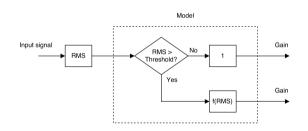
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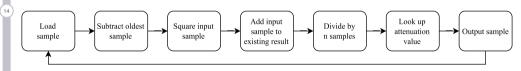
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- ✓ Løbende Gennemsnit
  - ► Nødvendige samples:  $n = \frac{f_S}{f_{lowest}}$ 
    - ► Band 1-4:  $n = \frac{375Hz}{30Hz} = 12.5 \approx 16$
    - ► Band 5:  $n = \frac{3000 Hz}{30 Hz} = 100 \approx 128$





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# Grænseværdier bestemmes ved at:

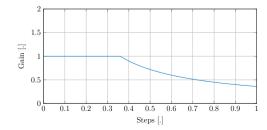
Finde Maksimalt gennem hele systemet = 40 dB

Grænseværdien findes ved Threshold =  $\frac{\sqrt{150W \cdot 5\Omega}}{100} = 0.3 V$ 

# Look up tabellen laves:

Opdele funktionen  $\sqrt{\frac{Threshold^2}{RMS^2}}$  i 1024 steps

Beregn en Lookup tabel ved brug af formlen  $\sqrt{\frac{\text{Threshold}^2}{(\frac{n}{1024})^2}}$ 





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- 0 s attack time
  - ► Påfør gain med det samme
- ▶ 5 s release time

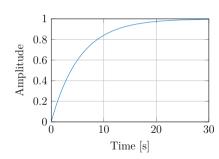
$$\rightarrow$$
  $H(s) - \frac{\omega_c}{\omega_c}$ 

$$\vdash H(s) = \frac{\omega_c}{s + \omega_c}$$

$$\omega_c = \frac{1}{2}$$

$$H(s) = \frac{0.2}{s+0.2}$$

- ► Impuls Invariant metode
  - $ightharpoonup H(s) = T \frac{0.2}{1-e^{-0.2T_z-1}}$





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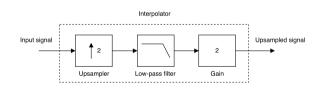
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# Lavpas filter til

Funktionalitet:

- rekonstruktion
- ▶ Zero-padding til upsampling
- ► Forstærkning med faktor *L*

- Må ikke interfere med decimation filter bandwidth
- ▶ 60 dB dæmpning ved fs





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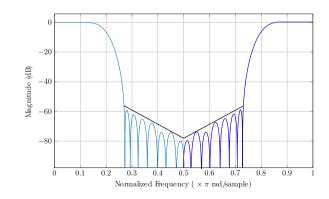
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# Krav:

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- ▶ Må ikke interfere med decimation filter bandwidth
  - over 0.3  $\frac{\pi rad}{sample}$
  - ▶ under 0.7  $\frac{\pi rad}{sample}$
- ► 60 dB dæmpning ved fs/21





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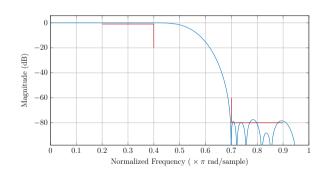
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# Krav:

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- Må ikke interfere med decimation filter bandwidth
- $\sqrt{60}$  dB dæmpning ved  $\frac{fs}{21}$ 
  - ▶ 34. Orden FIR
  - ► Type 1





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Relevante optimerings muligheder

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- ► Reducering af anvendte instruktioner.
  - ► Gennemsnitligt 900 instruktioner pr. sample.
    - 1. Generel optimering såsom cirkulære buffer og DUAL-MAC
    - 2. Polyphase FIR filtre
- Mindre delay gennem systemet
  - ► 111 ms delay gennem systemet
    - 1. Færre trin/bånd (stages) i systemet
    - 2. IIR filter i interpolation
- Bedre RMS limiter



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