

Multi-band RMS limiter

For Loudspeaker Protection

15. juni 2016

Kasper Kiis Jensen
Poul Hoang
Mikkel Krogh Simonsen
16gr640@es.aau.dk

Department of Electronic Systems
Aalborg University
Denmark



AALBORG UNIVERSITY
DENMARK

Multi-band RMS
Limiter
Gruppe 640

Introduktion

Problem

Foranalyse

Problemformulering

Løsning & Design
realization

Blokdiagram

Multi-Rate/stage

Decimation

RMS Limiter

RMS Limiter

Interpolation

Optimering

Relevante optimerings
muligheder

Implementerede
optimeringer

Perspektivering &
Konklusion

Demonstration

Dept. of Electronic Systems
Aalborg University
Denmark

Introduktion

Problem

Foranalyse

Problemformulering

Løsning & Design realization

Blokdiagram

Multi-Rate/stage

Decimation

RMS Limiter

RMS Limiter

Interpolation

Optimering

Relevante optimerings muligheder

Implementerede optimeringer

Perspektivering & Konklusion

Demonstration



Introduktion

Undertitel

Multi-band RMS
Limiter
Gruppe 640

2

Introduktion

Problem

Foranalyse
Problemformulering

Løsning & Design realization

Blokdiagram
Multi-Rate/stage
Decimation
RMS Limiter
RMS Limiter
Interpolation

Optimering

Relevante optimerings
muligheder
Implementerede
optimeringer

Perspektivering & Konklusion

Demonstration

Dept. of Electronic Systems
Aalborg University
Denmark

24

Something awesome



Problemet

Ja nemli' Ja

Multi-band RMS
Limiter
Gruppe 640

Introduktion

Problem

Foranalyse
Problemformulering

Løsning & Design
realization

Blokdiagram
Multi-Rate/stage
Decimation
RMS Limiter
RMS Limiter
Interpolation

Optimering

Relevante optimerings
muligheder
Implementerede
optimeringer

Perspektivering &
Konklusion

Demonstration

Dept. of Electronic Systems
Aalborg University
Denmark

3

Something awesome

24



Problemet

Foranalyse

Multi-band RMS
Limiter
Gruppe 640

Introduktion

Problem

Foranalyse

Problemformulering

Løsning & Design
realization

Blokdiagram

Multi-Rate/stage

Decimation

RMS Limiter

RMS Limiter

Interpolation

Optimering

Relevante optimerings
muligheder

Implementerede
optimeringer

Perspektivering &
Konklusion

Demonstration

Dept. of Electronic Systems
Aalborg University
Denmark

4

Something awesome

24



Problemet

Problemformulering

Multi-band RMS
Limiter

Gruppe 640

Introduktion

Problem

Foranalyse

Problemformulering

5

Løsning & Design
realization

Blokdiagram

Multi-Rate/stage

Decimation

RMS Limiter

RMS Limiter

Interpolation

Optimering

Relevante optimerings
muligheder

Implementerede
optimeringer

Perspektivering &
Konklusion

Demonstration

Dept. of Electronic Systems
Aalborg University
Denmark

24

Something awesome



Design Realization

Løsningen

Multi-band RMS
Limiter
Gruppe 640

Introduktion

Problem

Foranalyse

Problemformulering

**Løsning & Design
realization**

6

Something awesome

Blokdiagram

Multi-Rate/stage

Decimation

RMS Limiter

RMS Limiter

Interpolation

Optimering

Relevante optimerings
muligheder

Implementerede
optimeringer

Perspektivering &
Konklusion

Demonstration

Dept. of Electronic Systems
Aalborg University
Denmark

24



Blokdiagram

hold nu kæft et overblik!

Multi-band RMS
Limiter
Gruppe 640

Introduktion

Problem

Foranalyse

Problemformulering

Løsning & Design
realization

Blokdiagram

Multi-Rate/stage

Decimation

RMS Limiter

RMS Limiter

Interpolation

Optimering

Relevante optimerings
muligheder

Implementerede
optimeringer

Perspektivering &
Konklusion

Demonstration

Dept. of Electronic Systems
Aalborg University
Denmark

7

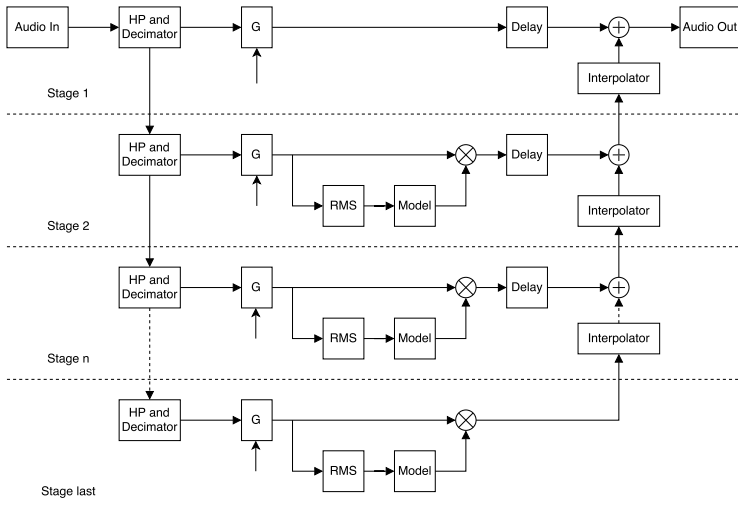
Something awesome

24

► Downsampling med faktor 2

► 7 gange

- 48 kHz
- 24 kHz
- 12 kHz
- ...
- 375 Hz

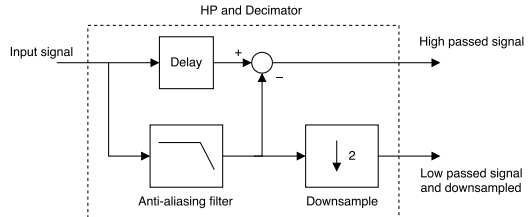


Funktionalitet:

- ▶ Lavpas filter til Anti-Aliasing
- ▶ Spektral subtraktion til højpas filtrering

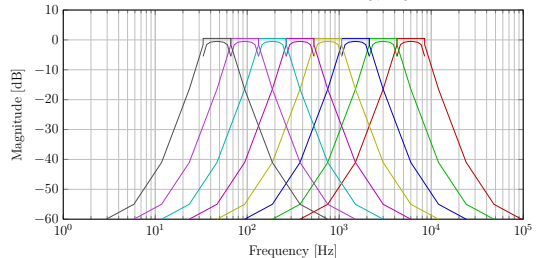
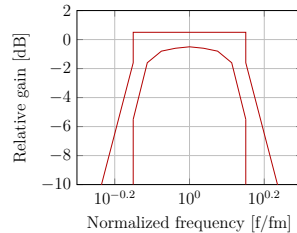
Krav:

- ▶ Overholde IEC 6964 - Class 2
- ▶ Lineær fase
- ▶ 60 dB dæmpning ved $\frac{f_s}{2L}$



Krav:

- ✓ Overholde IEC 6964 - Class 2
- ▶ Lineær fase
- ▶ 60 dB dæmpning ved $\frac{fs}{2L}$



Krav:

✓ Overholde IEC 6964 - Class 2

✓ Lineær fase

✓ 50. Orden FIR

✓ Type 1

✓ Symmetrisk

✓ Lige orden

✓ 60 dB dæmpning ved $\frac{fs}{2L}$

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

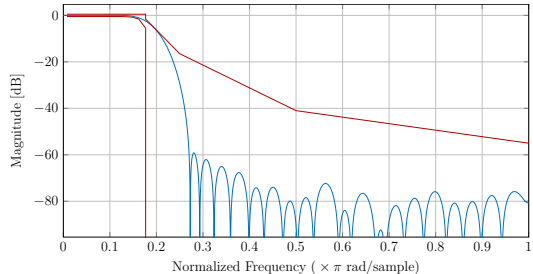
▶ $\omega_{\text{stop}} = 0.271 \frac{\pi \text{ rad}}{\text{sample}}$ (6.500Hz)

Metode brugt:

▶ Kaiser Window method

▶ Effektivt design

▶ Justerbar beta-værdi

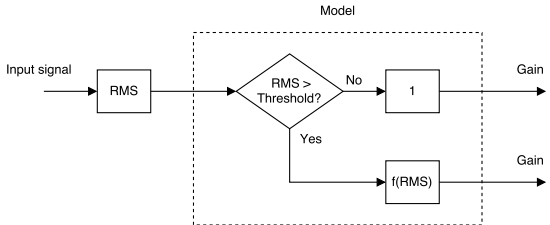


Funktionalitet:

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

Krav:

- Løbende Gennemsnit
- **Dæmpning til grænseværdi ved input på \geq grænseværdien**
- 0 s attack time
- 5 s release time

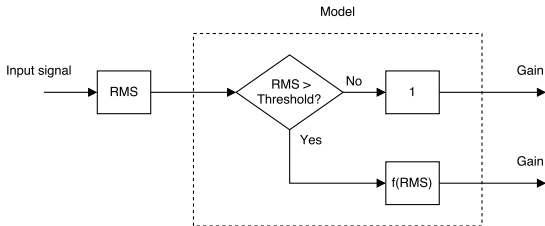


Funktionalitet:

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

Krav:

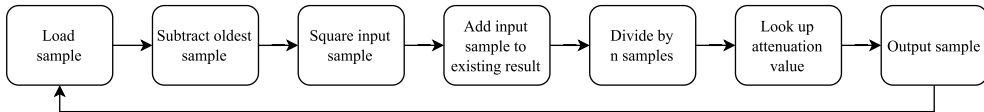
- Løbende Gennemsnit
- Dæmpning til grænseværdi ved input på \geq grænseværdien
- 0 s attack time
- 5 s release time



Krav:

✓ Løbende Gennemsnit

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



Grænseværdier bestemmes ved at:

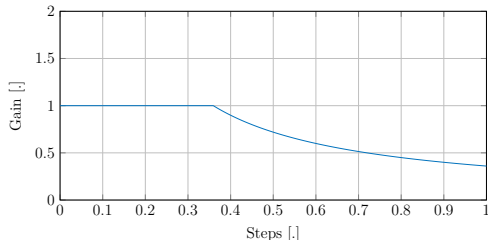
Finde Maksimalt gennem hele systemet = 40 dB

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

Look up tabellen laves:

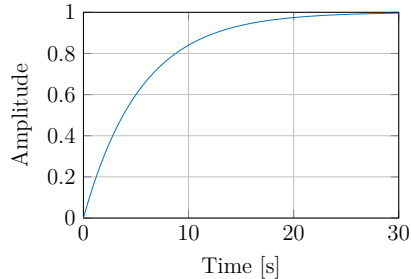
Opdele funktionen $\sqrt{\frac{\text{Threshold}^2}{\text{RMS}^2}}$ i 1024 steps

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



Krav:

- ▶ 0 s attack time
 - ▶ Påfør gain med det samme
- ▶ 5 s release time
 - ▶ $H(s) = \frac{\omega_c}{s + \omega_c}$
 - ▶ $\tau = 5 \text{ s}$
 - ▶ $\omega_c = \frac{1}{\tau}$
 - ▶ $H(s) = \frac{0.2}{s + 0.2}$
- ▶ Impuls Invariant metode
 - ▶ $H(s) = T \frac{0.2}{1 - e^{-0.2T} z^{-1}}$

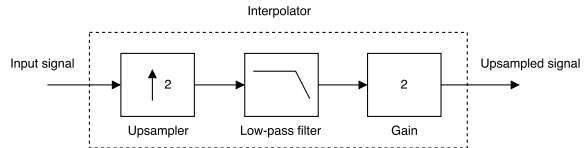


Funktionalitet:

- ▶ Lavpas filter til rekonstruktion
- ▶ Zero-padding til upsampling
- ▶ Forstærkning med faktor L

Krav:

- ▶ Må ikke interfere med decimation filter bandwidth
- ▶ 60 dB dæmpning ved $\frac{f_s}{2L}$



Opbygning

Må ikke interfere med decimation filter bandwidth

Multi-band RMS
Limiter

Gruppe 640

Introduktion

Problem

Foranalyse

Problemformulering

Løsning & Design
realization

Blokdiagram

Multi-Rate/stage

Decimation

RMS Limiter

RMS Limiter

Interpolation

18

Optimering

Relevante optimerings
muligheder

Implementerede
optimeringer

Perspektivering &
Konklusion

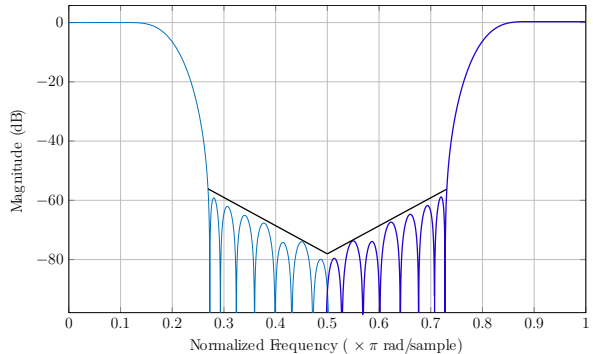
Demonstration

Dept. of Electronic Systems
Aalborg University
Denmark

24

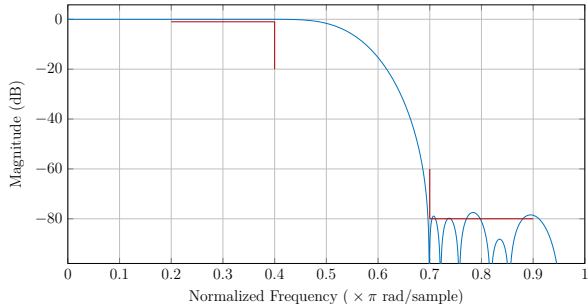
Krav:

- ▶ Må ikke interfere med decimation filter bandwidth
 - ▶ over $0.3 \frac{\pi \text{ rad}}{\text{sample}}$
 - ▶ under $0.7 \frac{\pi \text{ rad}}{\text{sample}}$
- ▶ 60 dB dæmpning ved $\frac{fs}{2L}$



Krav:

- ✓ Må ikke interfere med decimation filter bandwidth
- ✓ 60 dB dæmpning ved $\frac{fs}{2L}$
 - ▶ 34. Orden FIR
 - ▶ Type 1





Optimering

Multi-band RMS
Limiter
Gruppe 640

Introduktion

Problem

Foranalyse
Problemformulering

Løsning & Design
realization

Blokdiagram
Multi-Rate/stage
Decimation
RMS Limiter
RMS Limiter
Interpolation

Optimering

Relevante optimerings
muligheder
Implementerede
optimeringer

Perspektivering &
Konklusion

Demonstration

Dept. of Electronic Systems
Aalborg University
Denmark

20

24

Optimering

Relevante optimerings muligheder

Multi-band RMS
Limiter
Gruppe 640

Introduktion

Problem

Foranalyse

Problemformulering

Løsning & Design
realization

Blokdiagram

Multi-Rate/stage

Decimation

RMS Limiter

RMS Limiter

Interpolation

Optimering

Relevante optimerings
muligheder

Implementerede
optimeringer

Perspektivering &
Konklusion

Demonstration

Dept. of Electronic Systems
Aalborg University
Denmark

21

- ▶ 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

24



Optimering

Implementerede optimeringer

Multi-band RMS
Limiter
Gruppe 640

Introduktion

Problem

Foranalyse
Problemformulering

Løsning & Design
realization

Blokdiagram
Multi-Rate/stage
Decimation
RMS Limiter
RMS Limiter
Interpolation

Optimering

Relevante optimerings
muligheder
Implementerede
optimeringer

Perspektivering &
Konklusion

Demonstration

Dept. of Electronic Systems
Aalborg University
Denmark

Now it goes real crazy

22

24



Perspektivering/Konklusion

Multi-band RMS
Limiter
Gruppe 640

Introduktion

Problem

Foranalyse
Problemformulering

Løsning & Design
realization

Blokdiagram
Multi-Rate/stage
Decimation
RMS Limiter
RMS Limiter
Interpolation

Optimering

Relevante optimerings
muligheder
Implementerede
optimeringer

**Perspektivering &
Konklusion**

Demonstration

Dept. of Electronic Systems
Aalborg University
Denmark

► something

23

24



Demonstration

Jamen hva' ska' æ kost, Tonni?

Multi-band RMS
Limiter
Gruppe 640

Introduktion

Problem

Foranalyse
Problemformulering

Løsning & Design
realization

Blokdiagram
Multi-Rate/stage
Decimation
RMS Limiter
RMS Limiter
Interpolation

Optimering

Relevante optimerings
muligheder
Implementerede
optimeringer

Perspektivering &
Konklusion

Demonstration

24

Dept. of Electronic Systems
Aalborg University
Denmark

24

Now it goes real crazy



AALBORG UNIVERSITY
DENMARK