

# Active Noise Control of Speech in Headphones

using Linear Prediction

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Active Noise Control of  
Speech in  
Headphones using  
Linear Prediction  
Group 761

Introduction

What is Active Noise  
Control (ANC)

Problem of ANC

Present consumer  
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Methods

Feedforward FXLMS

Linear Prediction

Combined system

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## What is ANC

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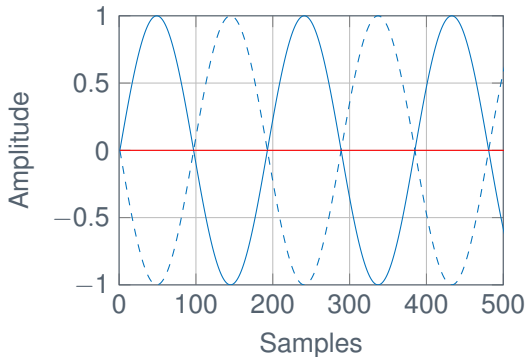
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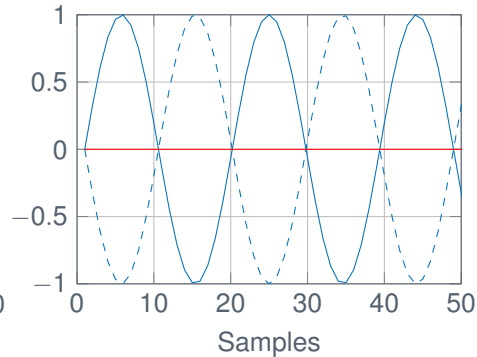
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### ► The basic theory of ANC

- 250 Hz
- 2500 Hz



- Original signal
- - Counterphase signal
- Error



# Introduction

## How does ANC work

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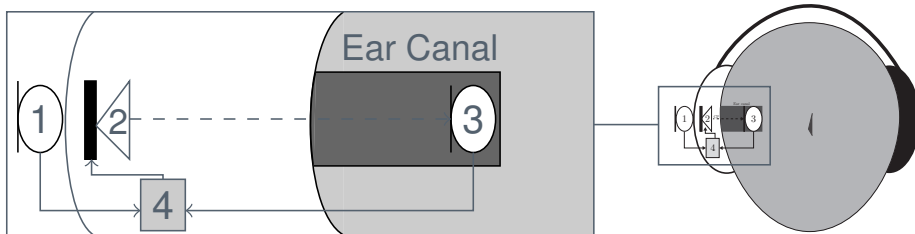
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### ► Feedforward system

- 1: Reference microphone
- 2: Headphone loudspeaker
- 3: Error microphone
- 4: Digital signal Processor (DSP)



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- ▶ Feedforward problem
- ▶ Sampling and reconstruction delay.
  - ▶ Anti Aliasing filter
  - ▶ Reconstructions filter
- ▶ The measured delay of a Sigma Delta converter TLV320AIC3204
- ▶ Spacing between microphones
  - ▶ Min: 75.5 mm
  - ▶ Max: 302 mm

$f_s$ [kHz]	48	96	192
Delay [ $\mu$ s]	900	450	225
Delay [samples]	43	43	43

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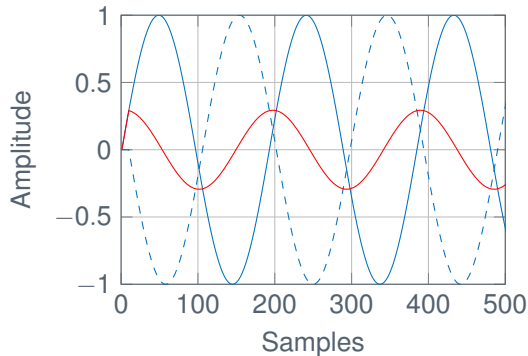
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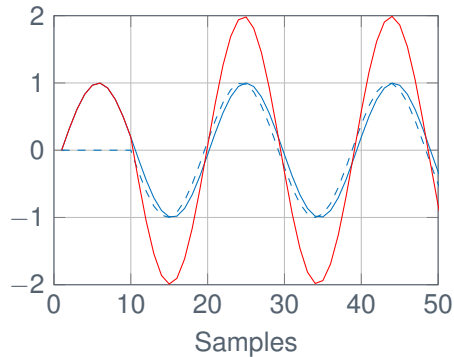
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### ▶ Counter phase signal delayed 10 samples

- ▶ 250 Hz
- ▶ 2500 Hz



- Original signal
- - Counterphase signal
- Error



# Introduction

## Speech vs Periodic Noise

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- ▶ Signal Characteristics
  - ▶ Periodic Signals
    - ▶ Periodic
    - ▶ Strict Sense Stationary (SSS)
  - ▶ Speech Signals
    - ▶ Quasiperiodic
    - ▶ Can be assumed Wide Sense Stationary for 20 *ms* – 30 *ms*
- ▶ Periodic noise is easy to cancel
- ▶ Speech noise is difficult to cancel

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## Present consumer headphones

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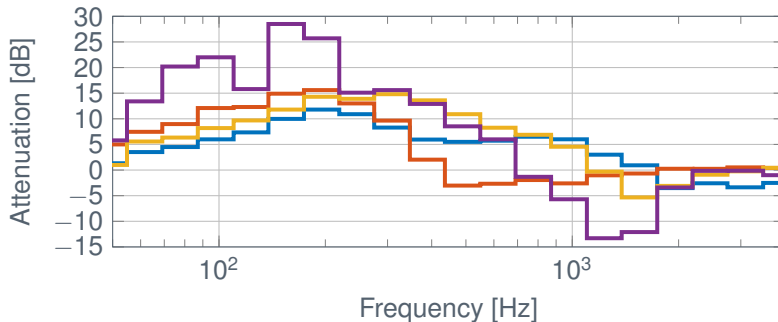
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### ► How well does the consumer headphones attenuate?

- Denon AH-GC20 2.200 kr (2016)
- Bose QC25 2.799 kr (2016)
- Bose QC15 2.696 kr (2011)
- BeoPlay H8 3.495 kr (2016)







# Introduction

A solution for the problem

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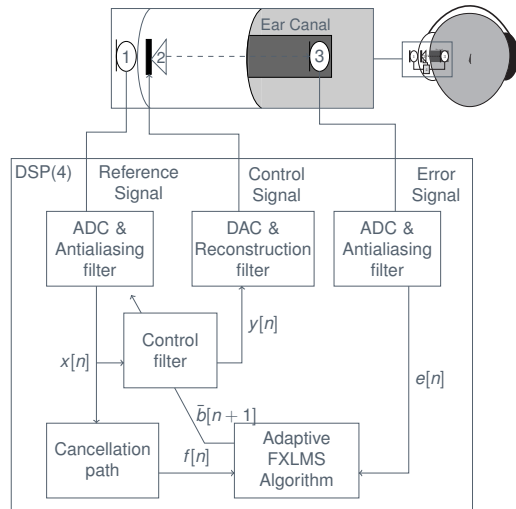
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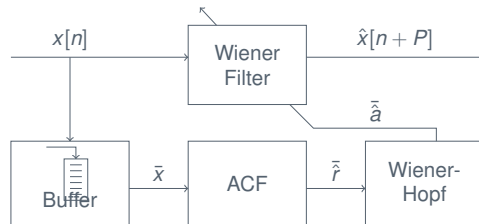
Combining a feedforward Filtered-x Least Mean Square (FXLMS) algorithm with a Linear prediction (LP) scheme to compensate for delay.

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- ▶ Control filter
  - ▶ Transfer function from (1) to (2)
  - ▶ Adaptive
- ▶ Cancellation path
  - ▶ Transfer function from (2) to (3)
  - ▶ Linear Time Invariant
- ▶ Adaptive FXLMS Algorithm
  - ▶ Optimization problem



- ▶ Auto Correlation Function estimation
  - ▶ Frame length N
  - ▶ Overlap O
- ▶ Wiener hopf equation:  $\hat{R}\bar{a} = -\bar{r}_x$ 
  - ▶ Inverting matrix
  - ▶ Levinson Durbin
- ▶ Wiener filtering in cascade
  - ▶ Prediction order P





# Methods

## Combined system

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# Simulation Results

## Optimal parameters

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Questions?



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