Active Noise Control : Study of the algorithm

Convergence speed, Latency time and Implementation on a board

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Marco Gallo – LMS International - marco.gallo@lmsintl.com

Marco Gallo – Personal Presentation

- Born in Asti 26/06/1984
- B.Sc & M.Sc. in Automotive Engineering at Politecnico di Torino, 2008
- Several projects during M.Sc:
  - Team member of Squadra Corse (2006-2008), Formula SAE team of Politecnico di Torino, as responsible of design and production of a dry sump system
  - Internship @ University of Surrey, Guildford, Uk

- Marie Curie fellowship from July 2009 in the frame SMART STRUCTURES for **LMS International** (12 months)
  - Main Research Topic: Active Car Noise Control
- Relational Skills: I enjoy team-working. I was 3 years responsible of the youth activities in San Damiano d’Asti, Asti, Italy. I played in many football team; my hobbies are football, reading, gardening, oenology.

LMS® ENGINEERING INNOVATION

Agenda

1 Introduction

2 Contr… xLM…

3 FxLM…

1 Introduction

4 Control Strategy – NEX LMS

5 NEX LMS - Results

6 Board - Processor

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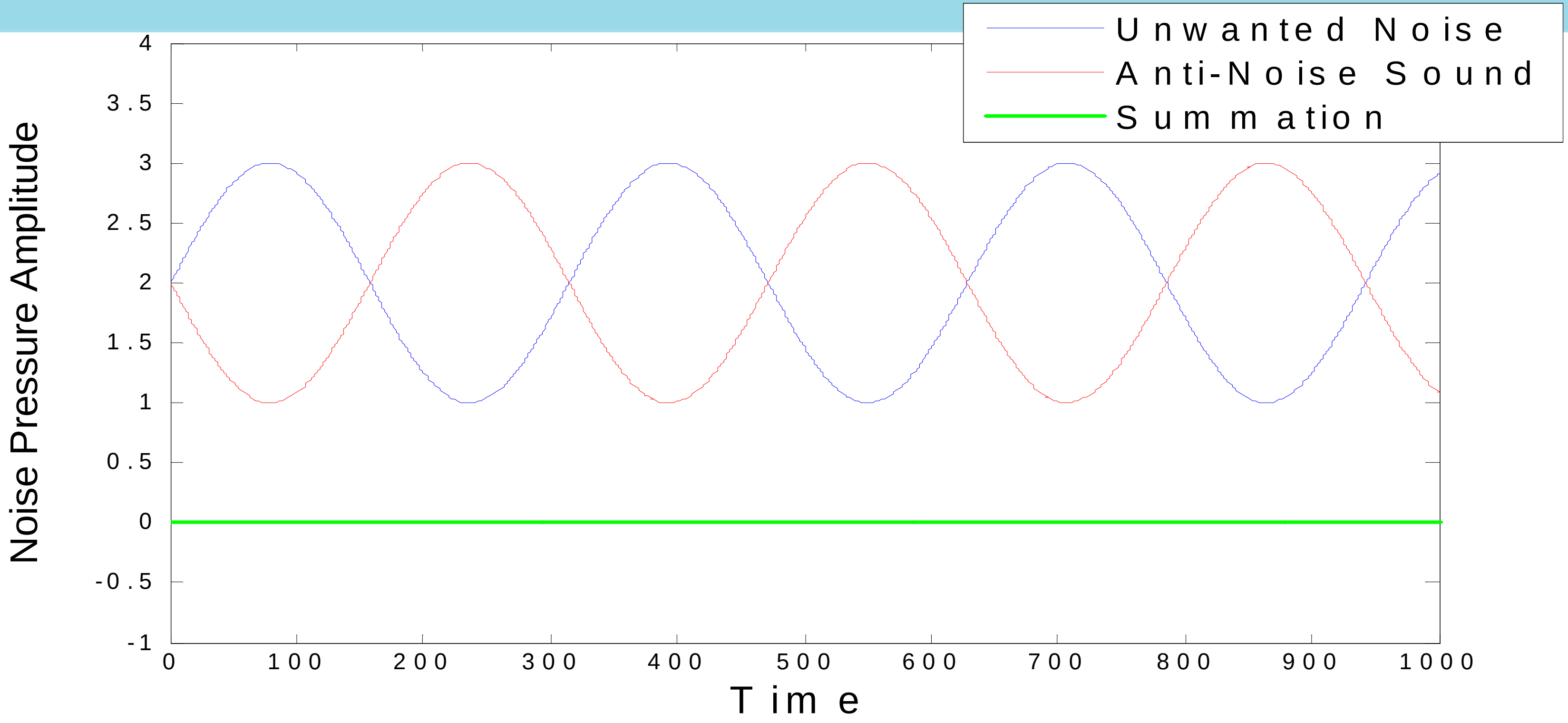
Introduction – Young's Principle



- Sound reduction with destructive interference (Young's principle)
- Obtained by the superposition of the original (primary) sound field with an artificially generated (secondary) sound field

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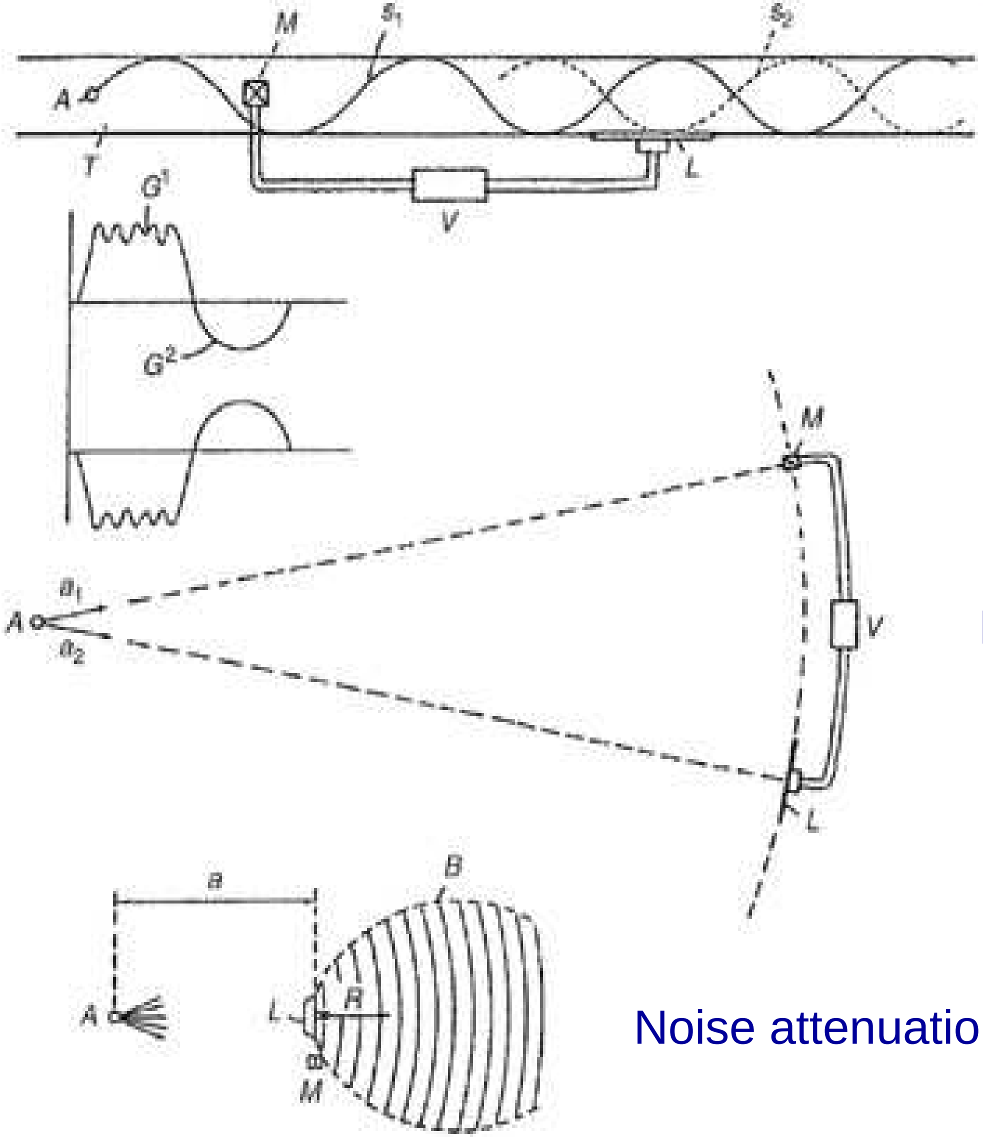
Introduction – Lueg Patent, 1936



Problem of cancelling sound in a duct

Problem of cancelling sound in an area

Noise attenuation in an open space

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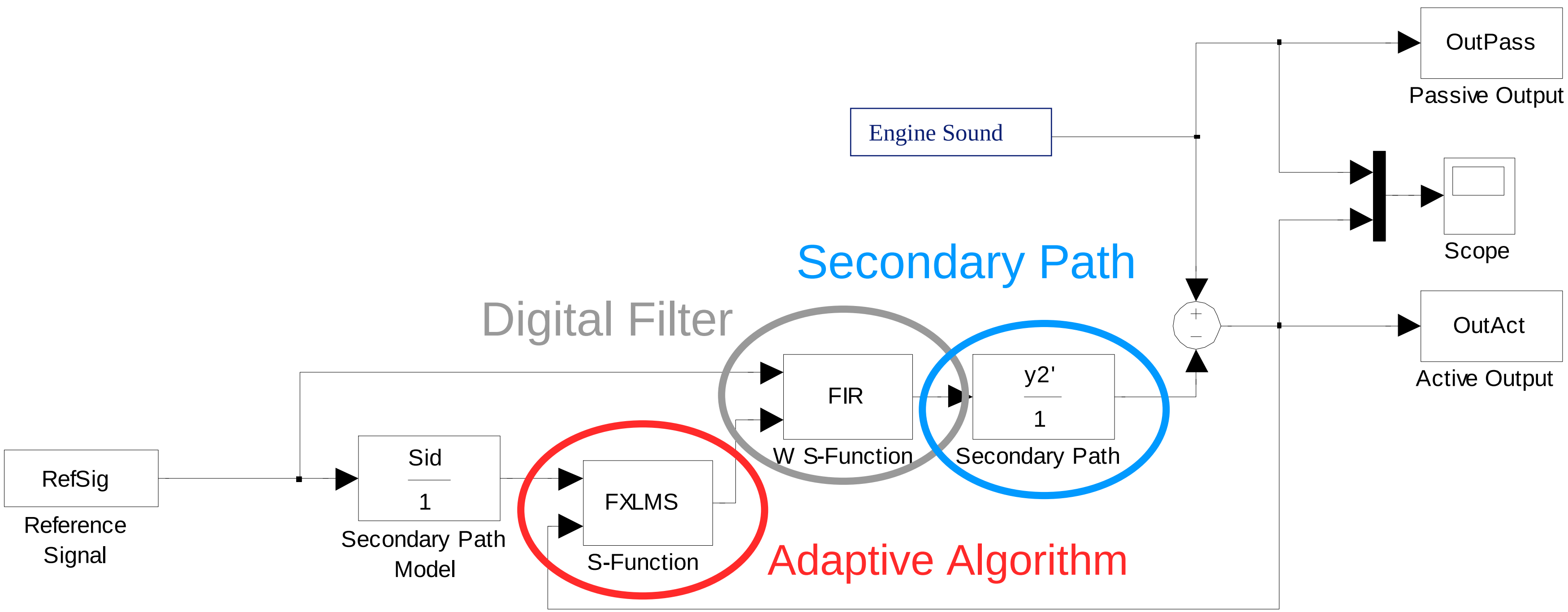
2 Control Strategy - FxLMS

Control Strategy - Algorithm

- Aim : Achieve a pre-defined order level vs RPM profile, achieve a desired sound quality
- Controller should work with varying engine speeds, disturbance
- Controller should have a fast convergence speed
- The adaptive algorithm adjust the coefficients of the digital filter
  $w(n) = [w_0(n)\ w_1(n) \ldots\ldots w_{L-1}(n)]^T$
- Steepest descent method, to minimize a quadratic cost function

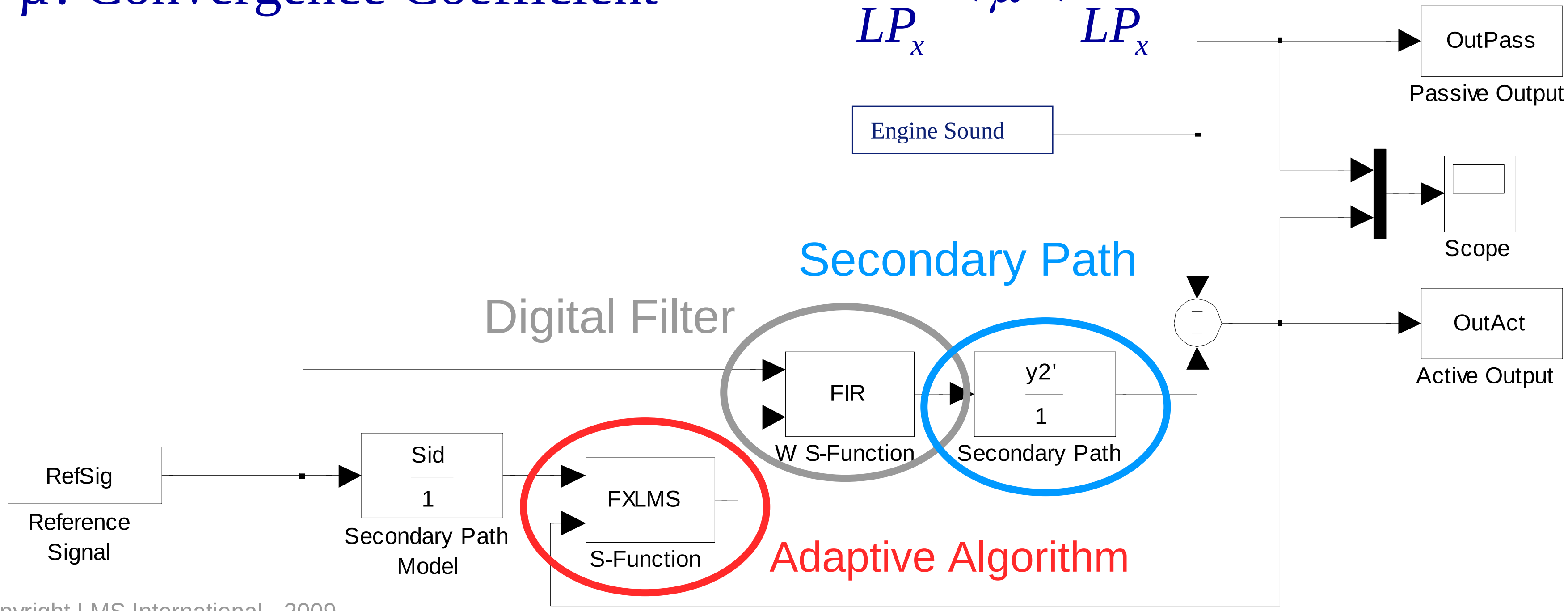


Control Strategy - Algorithm

- LMS algorithm for updating the coefficients of W:

$$w(n+1) = w(n) + \mu \cdot x(n) \cdot e(n)$$

  - *x(n)*: Reference Signal ⟶ RPM
  - *e(n)*: Error Signal
  - μ: Convergence Coefficient ⟶ $\frac{0.01}{LP_x} < \mu < \frac{0.1}{LP_x}$



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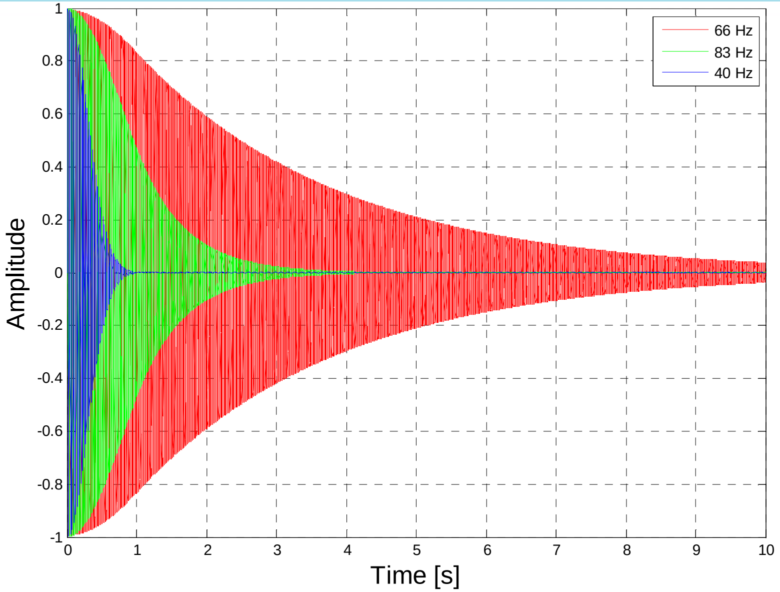
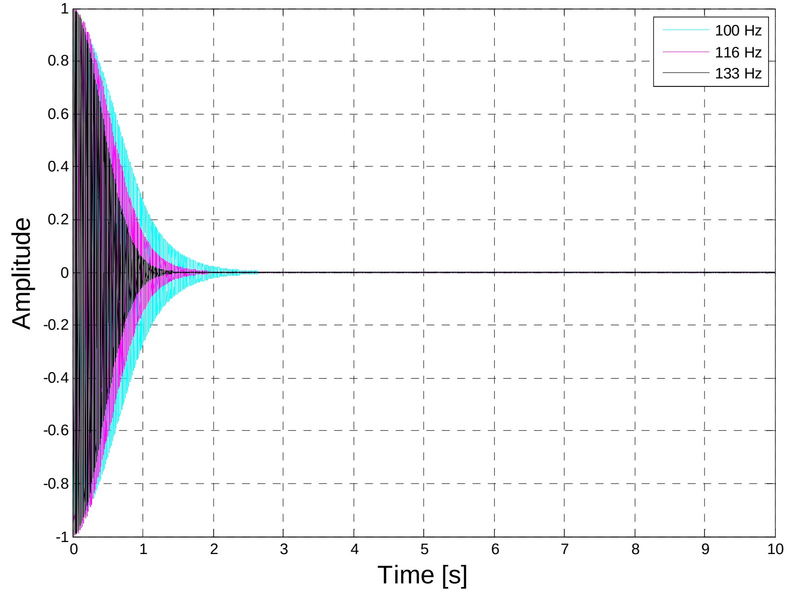
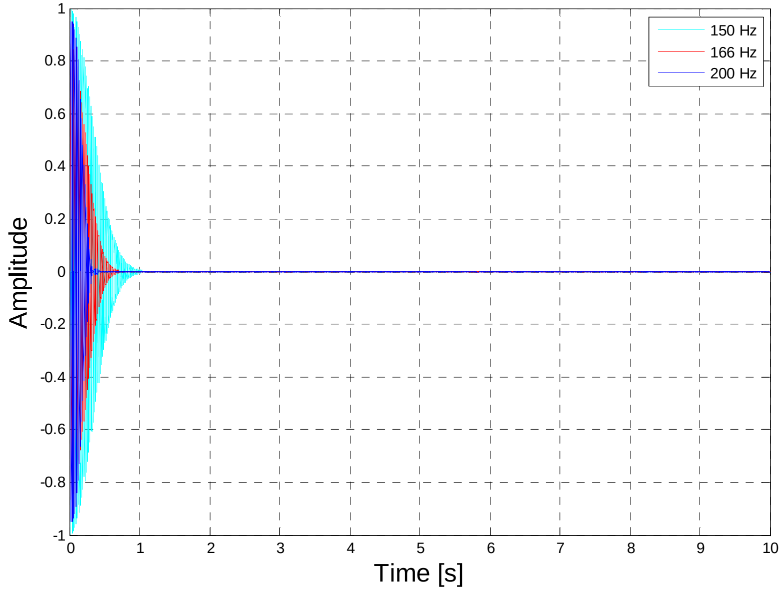
FxLMS - Results

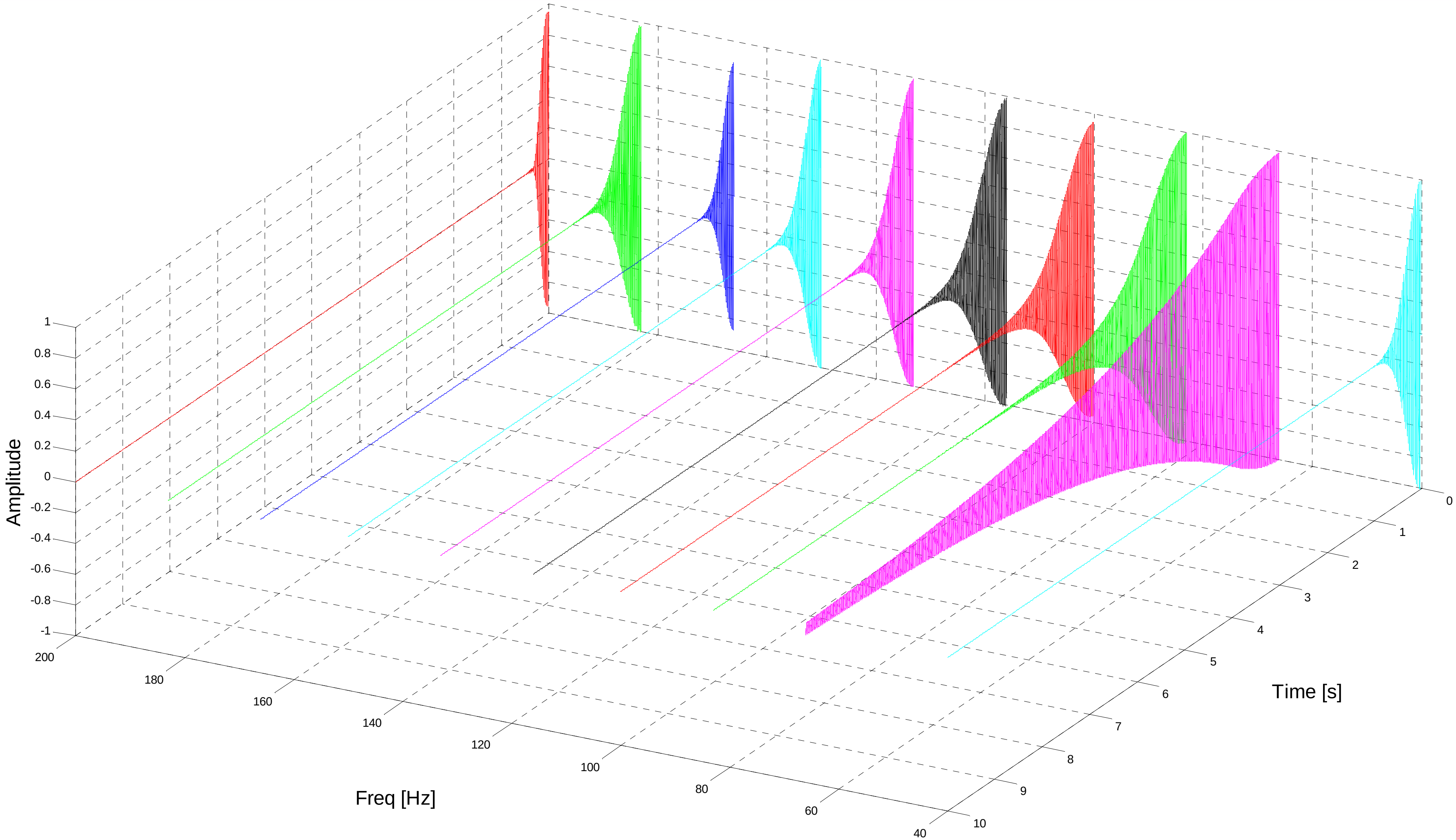






- Input: constant amplitude sinusoid
- Secondary path model : two poles
- Fast convergence near the secondary path resonances

FxLMS - Results



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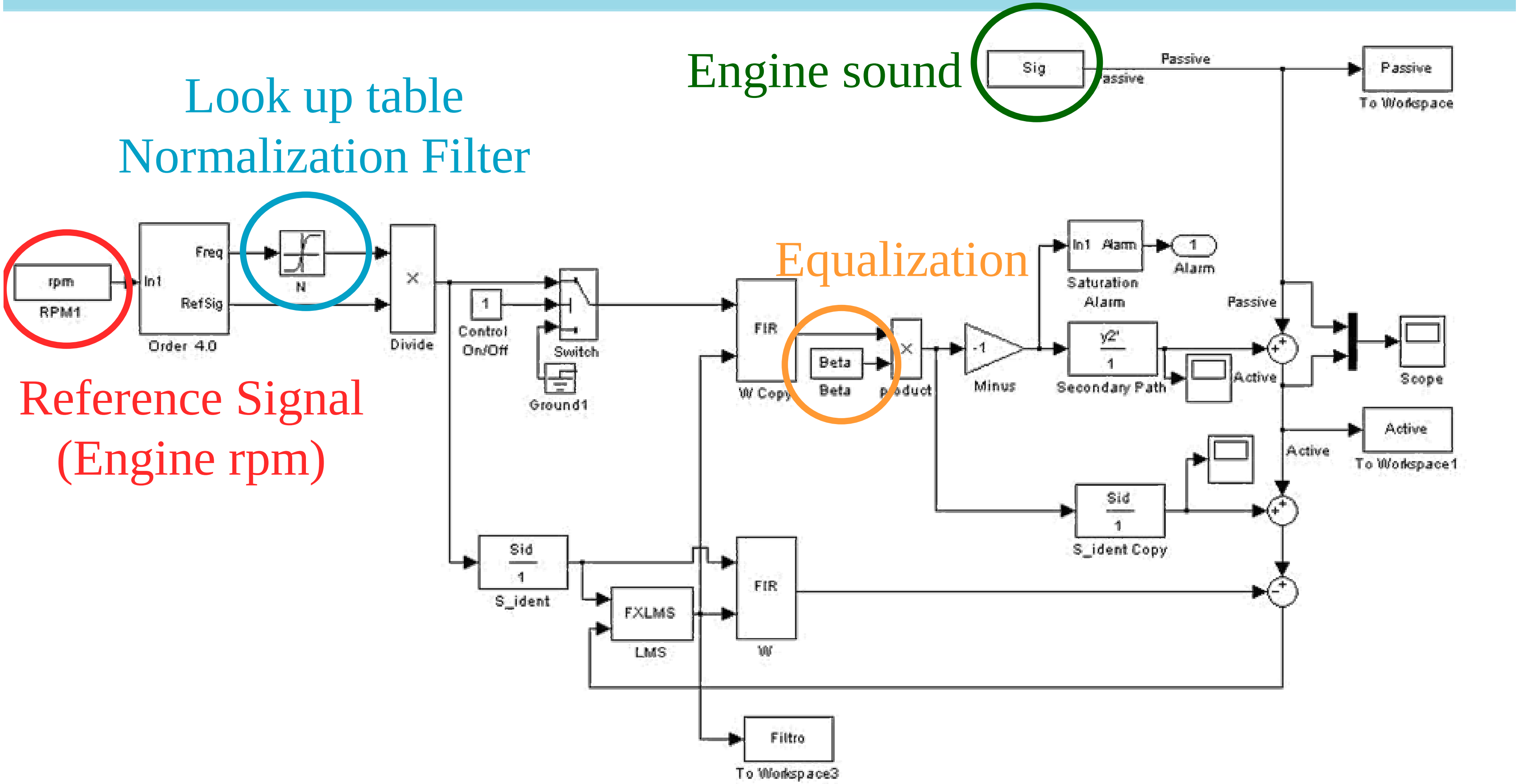
Control Strategy – NEX LMS



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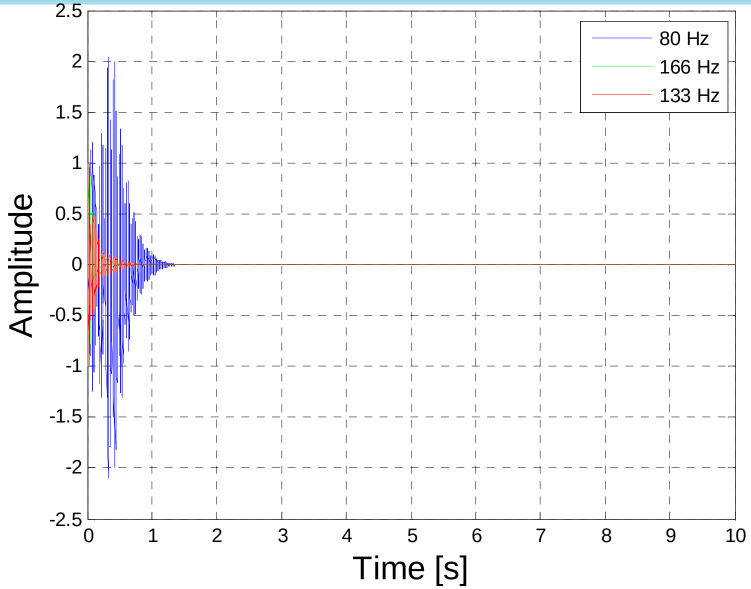
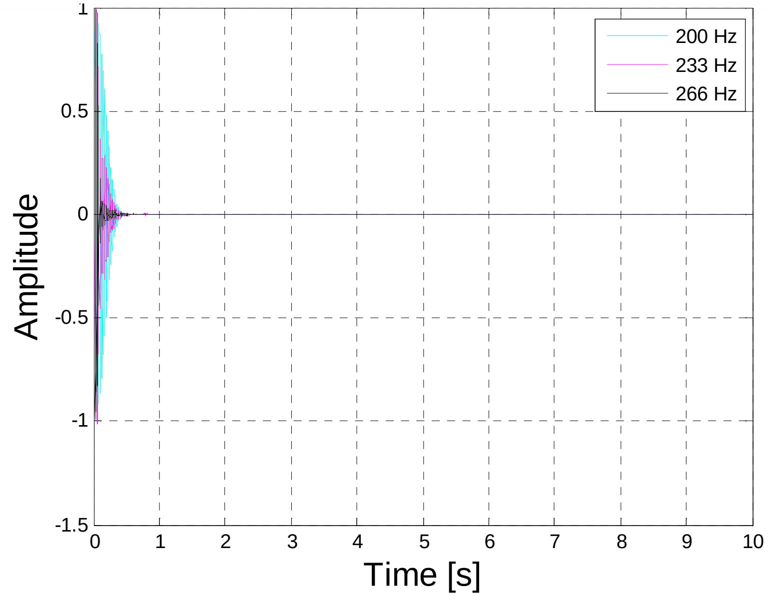
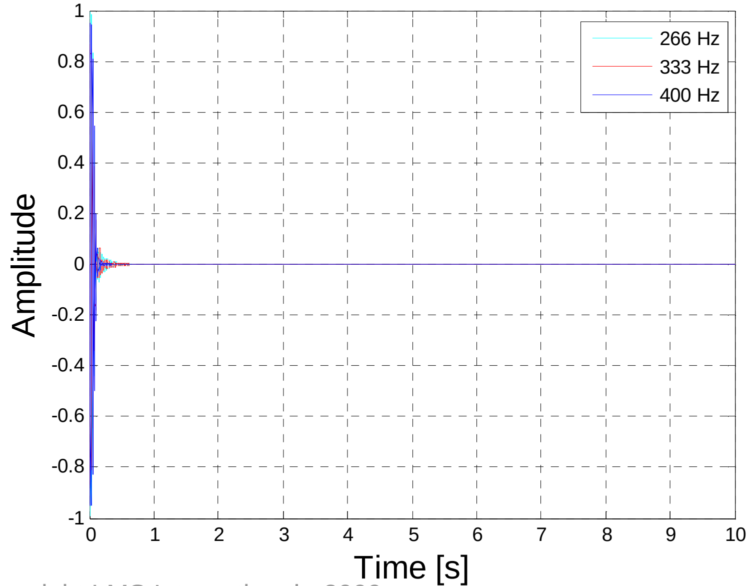
NEX LMS - Results







Fast convergence for each frequencies!!

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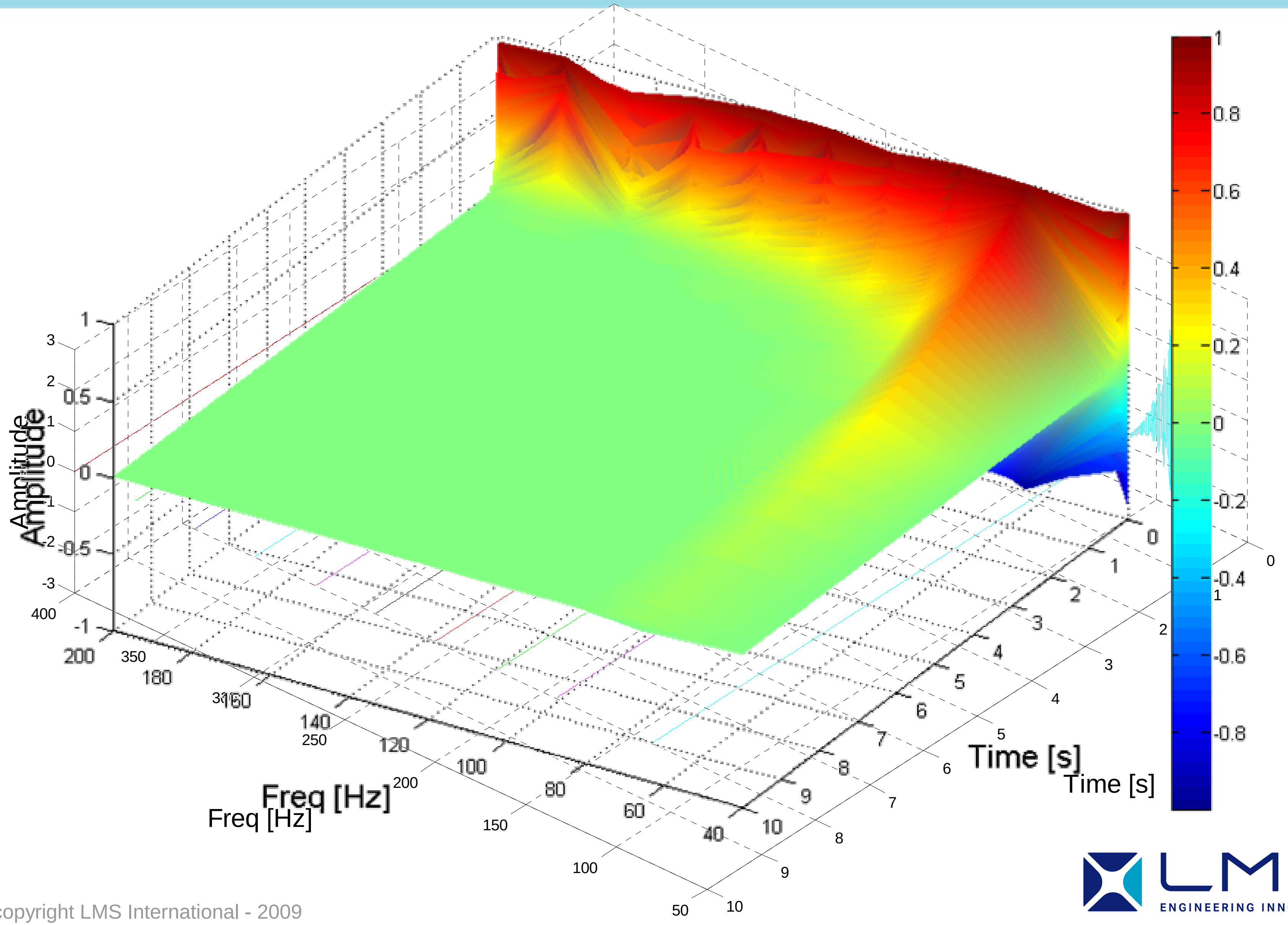
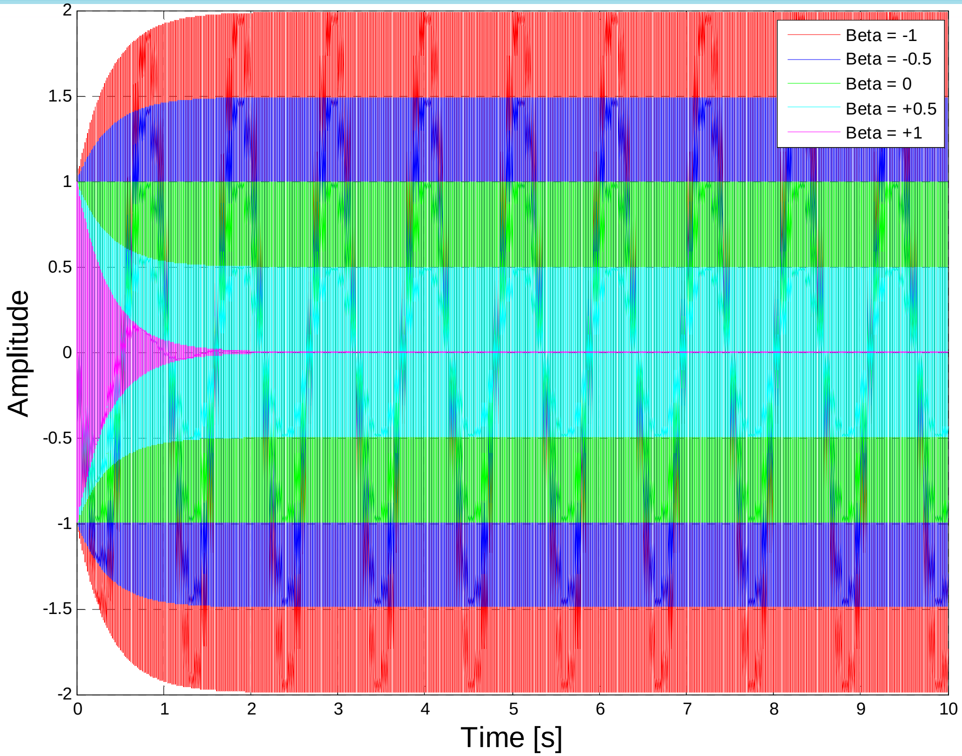
NEX LMS - Results



NEX LMS - Results



- For β=0 the residual noise is the unchanged primary disturbance
- For β=1: maximum reduction
- For β=+0.5: half reduction
- For β<0 the system amplifies the original disturbance.

$$e(n) = d(n) - y^*(n) = d(n) - \beta y(n)$$

$$\beta(w) = \frac{d(w) - e_d(w)}{d(w) - e_r(w)}$$

$$e(n) \approx (1-\beta)d(n)$$

$$\beta(w) \approx 1 - \frac{e_d(w)}{d(w)}$$

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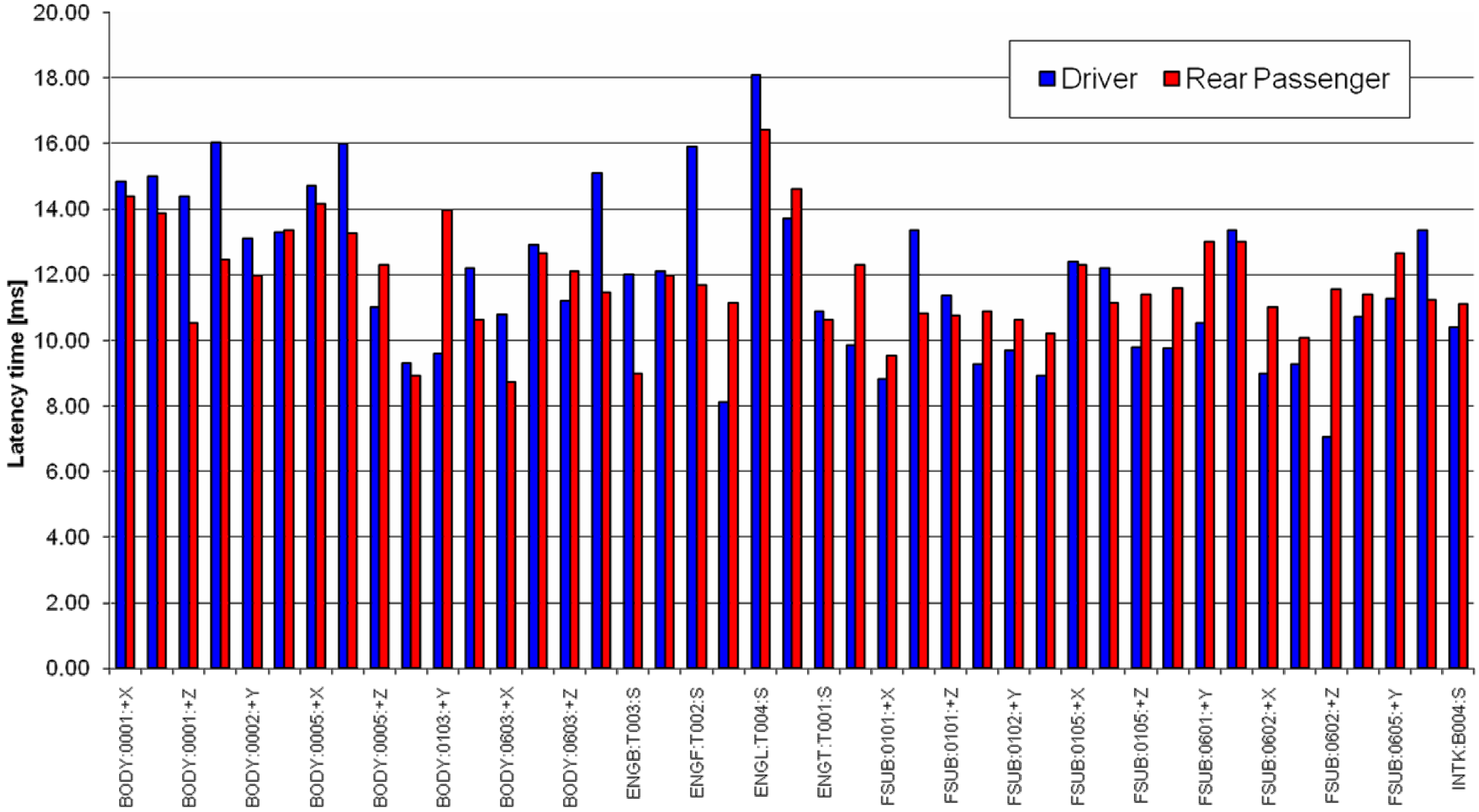
Latency time study



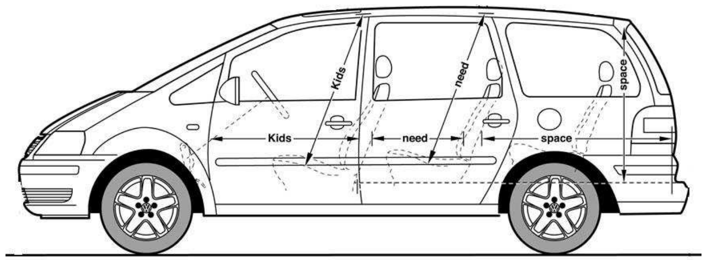
Latency time study

European Passenger Car

	Driver	Front Passenger
Average Latency [ms]	16.50	16.70
Max Value [ms]	21.52	21.98
Min Value [ms]	9.89	10.64

Monovolume Car

	Driver
Average Latency [ms]	12.64
Max Value [ms]	18.71
Min Value [ms]	9.17



American Passenger Car

	Driver	Rear Passenger
Average Latency [ms]	11.87	11.79
Max Value [ms]	18.10	16.41
Min Value [ms]	7.05	8.73

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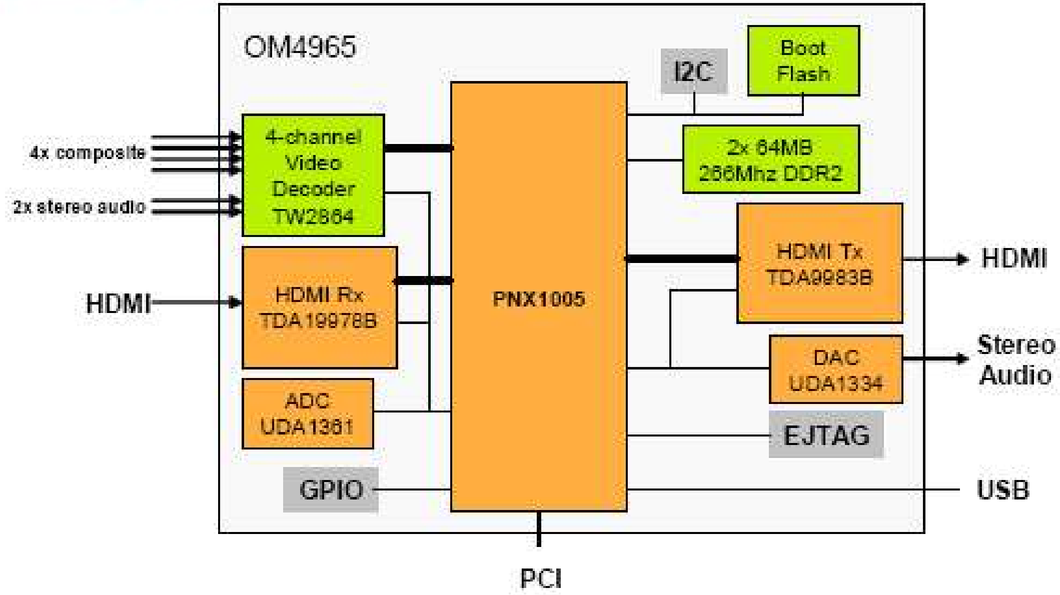
Board for audio processing

Block diagram



Front and side view

PNX1005 Series
- **power and cost optimized**
- **tm3282 350-400Mhz VLIW core**
- **integrated USB2.0 OTG**
- **2x quad-multiplexed video input**
- **HD 1080p/60 video in and out**

Applications
- **8 channel CIF H264 DVR**
- **2xD1 H264 or 720p H264 encode**
- **H264 SD IP Camera with analytics**
- **Picture optimization**

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Next Step

- Implementation of the algorithm (WIP)
- Test in the LMS research car
- MIMO implementation
- Implement adaptive feedforward control system in VCS
- Secondment @ VTT, Finland

- Based on :

L. De Oliveira, 2009, "*Active sound quality control: design tools and automotive applications*", Ph.D. thesis, K.U. Leuven, Fac. Eng., Dept. Mechanical Eng.

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Thank you

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