VCO1S Silent
Active Noise Cancellation

SIEMENS

Contents

AUTOMOTIVE BUSINESS UNIT

SIEMENS VCOS Vehicle Compute Solutions

SIEMENS Automotive Business Unit provides automotive grade solutions under the name of VCOS™. Audio solutions are provided under VCO1S™, Infotainment and Driver Information solutions under VCO2S™ and Car Central Compute under VCO3S™.

Highly integrated automotive solutions from SIEMENS

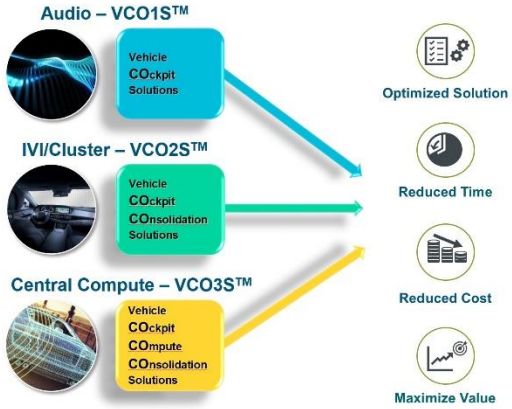

Figure 1 Vehicle Compute Solutions

Each of pillars of Vehicle Compute solutions are further tailored to address the needs of customers. The variants are shown in Figure 2.

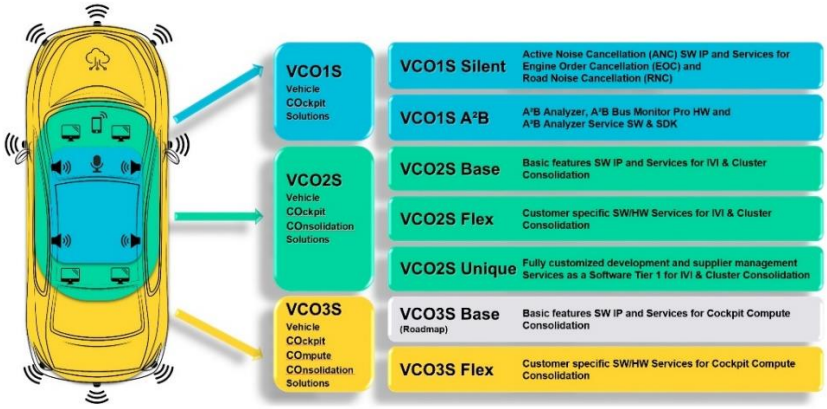

Figure 2 Vehicle Compute Solution variants

Variants

The variants allow the product line engagements with customers at varying degree of flexibility and turn-key-solutions.

Figure 3 Silent Cockpit

VCO1S™ – Silent ANC system overview

Introduction

Siemens offers a configurable and scale-able broad-band Active Noise Cancellation solution for automotive Engine Order Cancellation (EOC), and Road Noise Cancellation (RNC). It can be deployed for both near-field and far-field systems. Siemens provides a library containing the algorithm and other signal processing modules required for a complete system. The library may be integrated by customers, or by Siemens.

A PC-based tuning tool, and tuning services are also offered to complete the process required to configure, tune and optimize the system performance for each vehicle variant.

System Architecture

The following diagram provides a high-level illustration of how ANC may be deployed on a SoC. SIEMENS ABU has already deployed ANC on ADI SHARC processor. Assessment for deployment to other SoCs and Infotainment processors like Qualcomm Snapdragon 8155, where ANC signal processing is performed on the mDSP Hexagon core are ongoing.

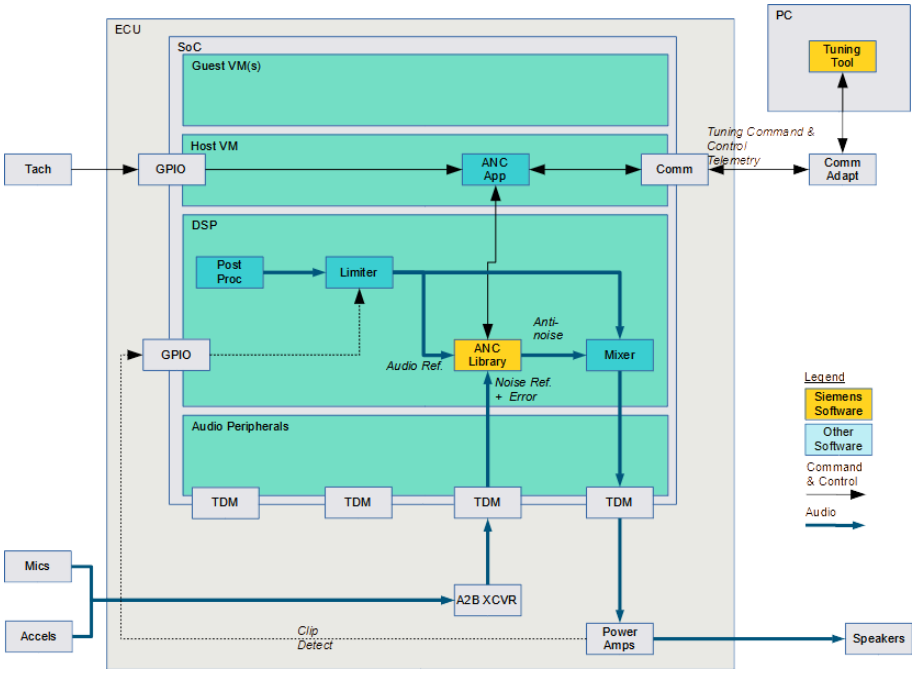

Figure 4 ANC deployment in an ECU

Decomposition

The key components of the ANC system are described below.

Component	Description
Accelerometers	Accelerometers measure noise sources in a RNC system. They provide noise reference signals for the ANC algorithm.
ANC Library	Contains the Siemens ANC algorithm and other signal processing modules required in an ANC system configuration. Provides tuning and telemetry services.
ANC Applications	Application software is the "glue" which ties together all of the I/O and the signal processing.
Limiter	A limiter controls the level of the infotainment audio to avoid distortion of the combined audio output.
Microphones	Microphones measure the noise in the vehicle cabin, the "error" in an ANC system.
Mixers	A low-latency mixer combines infotainment audio outputs with the anti-noise output.
Power Amplifier	Power amplifiers provide gain and convert the line-level audio signals to high-power audio signals for output to speakers.
Speaker	Speakers are the actuators of the ANC system. They transmit the combined infotainment audio and anti-noise signals into the vehicle cabin.
Tachometer	A tachometer measures engine speed in an EOC system. It is used to derive noise reference signals for the ANC algorithm.
Communication Adapters	Communication adapters are used to adapt between the PC interfaces (typically USB) and target ECU for tuning (e.g., UART, I2C, SPI, A2B, and Ethernet) and telemetry (e.g., SPI, TDM, A2B, and Ethernet).

Tuning Tools	Siemens's tuning tools provides the means to configure an ANC system, tune the algorithm parameters for best performance, and the capture telemetry data for real-time visualization, and post-processing.

Key Signals

The following table lists the key signals in an ANC system.

Signal	Description
Anti-Noise	Audio output of the ANC algorithm to cancel targeted noise.
Audio Reference Input	Desired infotainment audio signal. Input to ANC algorithm to avoid interference between anti-noise and desired audio.
Clip Detection	Signal indicating that an output is over-loaded and causing distortion (e.g., from mixer and/or power amplifier).
Error Input	Input signal from microphones measuring the cabin noise.
Noise Reference Input	Input signal from accelerometers (RNC) or derived from tachometer (EOC) measuring the noise source.
Telemetry	Output from ANC algorithm during the tuning process.
Tuning Command and Control	Command and response packets between tuning tool and ANC library to configure and tune the ANC algorithm.

Latency

Signal latency is a key performance metric of an ANC system. Siemens recommends the following:

- ECU sensor input to speaker output path should be within a couple of milliseconds.
- The latency through any ADC and DAC components in the signal path should be considered, and may be a factor when considering sample frequency for these components.

Greater latency may degrade ANC performance. Generally, Engine order Cancellation (EOC) is more tolerant of increased latency than Road Noise Cancellation (RNC).

Algorithm

The core of the solution is Siemens's proprietary ANC algorithm. It is an algorithm with enhancements for fast convergence, robust stability, and dynamic tuning to respond to changing vehicle conditions. The algorithm is delivered as a library which may be integrated by the customer, or by Siemens.

Sensors and Actuators

Microphones

Siemens ANC uses Invensense ADMP401 microphones for sensing. A^2B microphones are other possible alternatives. In a typical passenger vehicle system, four to six microphones are installed in the headliner. A microphone placement study is conducted to determine the number and best locations to meet the desired performance, while avoiding restricted areas such as sun/moon roof locations.

Accelerometers

Siemens uses Analog Devices ADXL335 accelerometer for sensing but other accelerometers are also possible to connect. In a typical passenger vehicle system, four to six three-axis accelerometers are installed under the body. An accelerometer placement study is conducted to determine the number of accelerometers, best locations, and which axes to use to meet the desired ANC performance.

Speakers

The speakers are key components of an ANC system. It is important that speakers have good low-frequency response in the desired band of cancellation (e.g. 30-500 Hz). A sub-woofer is helpful, but not necessarily required, depending upon performance requirements.
In a typical far-field passenger vehicle system, four to six speakers are used for ANC output. While some premium audio systems may have many more channels, there is a trade-off to be considered to balance DSP requirements and number of outputs. In a far-field ANC system typical audio/infotainment speaker locations are acceptable (e.g., doors, rear package tray, etc.). A near-field system requires speakers closer to each vehicle occupant's ears (e.g., head rests or seat shoulders).

Performance

The performance of an ANC system depends upon many factors including the performance of sensors and speakers, their placement, and the vehicle cabin acoustics. This section describes the performance achieved in two actual deployments.
Each of the charts in this performance section are for a specific ear microphone location. For each ear microphone, time and frequency domain plots are presented. The red lines indicate ANC is “off”, and the blue lines indicate ANC is “on”.

Actual EOC performance
The following performance was achieved in a production Asian SUV with a 1x4x6 configuration reducing the second engine order.

Attribute	Value
Average RMS Reduction, 50 - 200 Hz (dB)	7
Peak Cancellation (dB)	19

Cruise at 60 Kilometers per hour

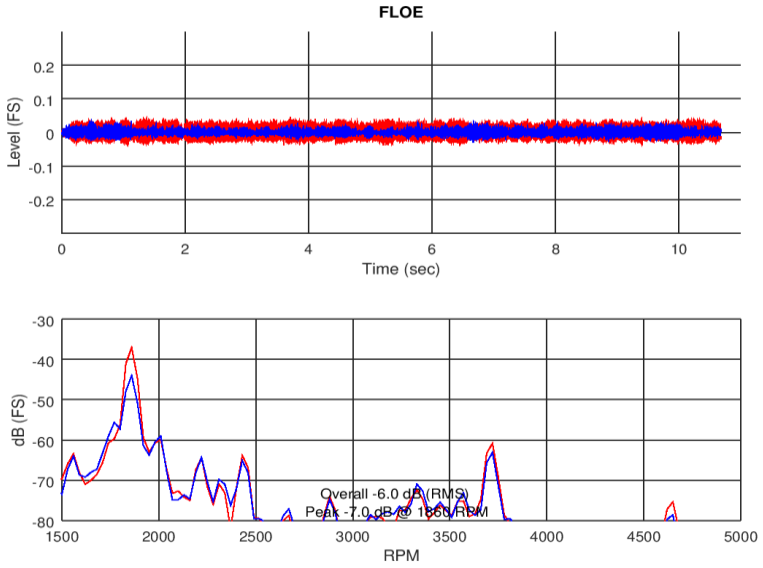

Figure 5 Front left outside ear noise cancellation

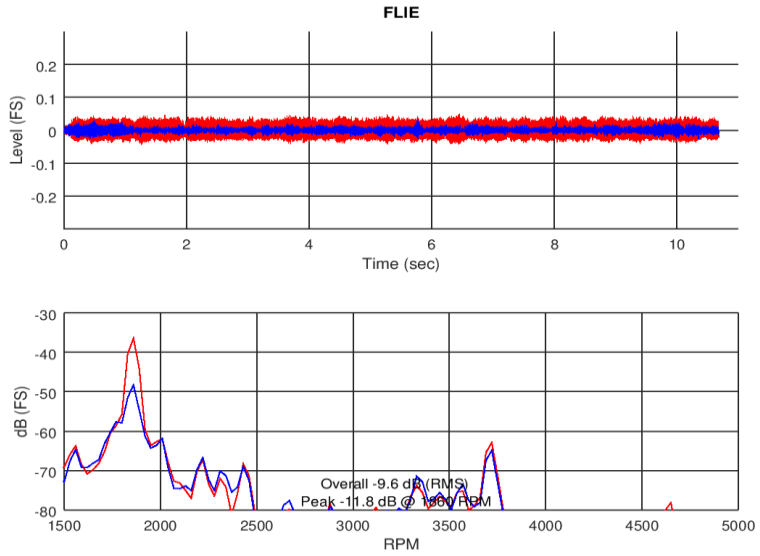

Figure 6 Front left inside ear noise cancellation

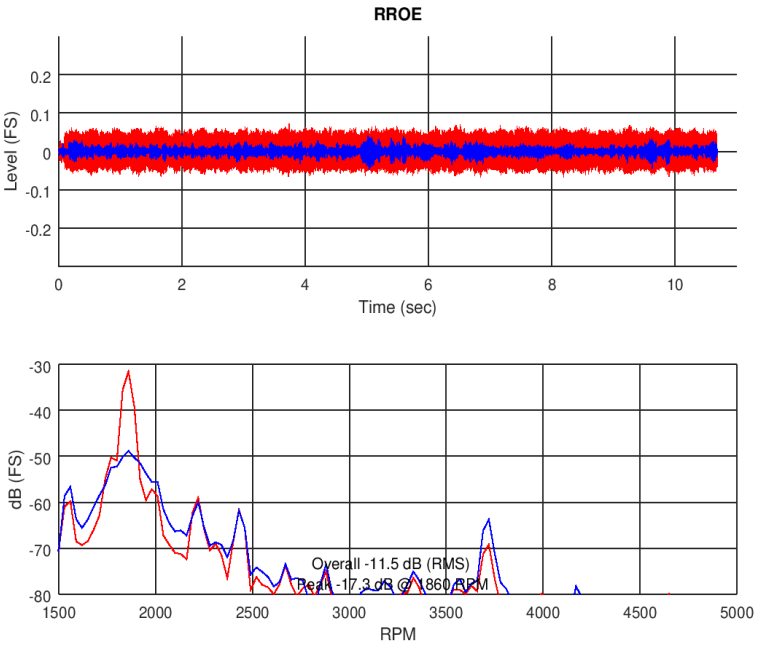

Figure 7 Rear right outside ear noise cancellation

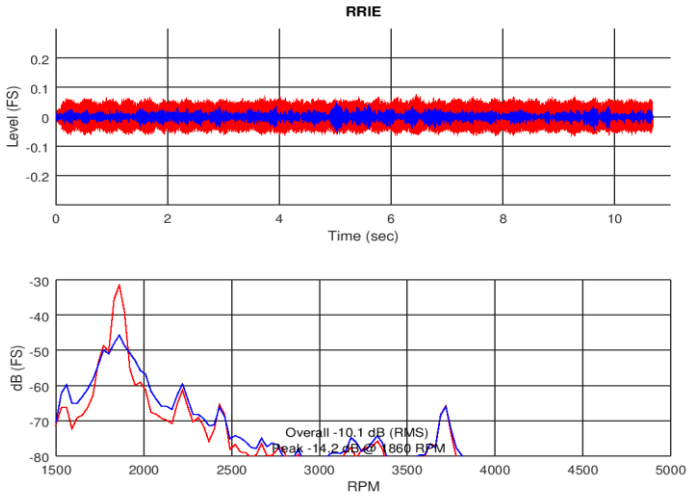

Figure 8 Rear right inside ear noise cancellation

Actual RNC performance

The following performance was achieved in a North American B-segment electric vehicle with a 10x6x5 RNC configuration.

Attribute	Value
Average RMS Reduction, 50 - 400 Hz (dB)	3-4
Peak Cancellation (dB)	10

Brushed Concrete 97 Kilometers per hour

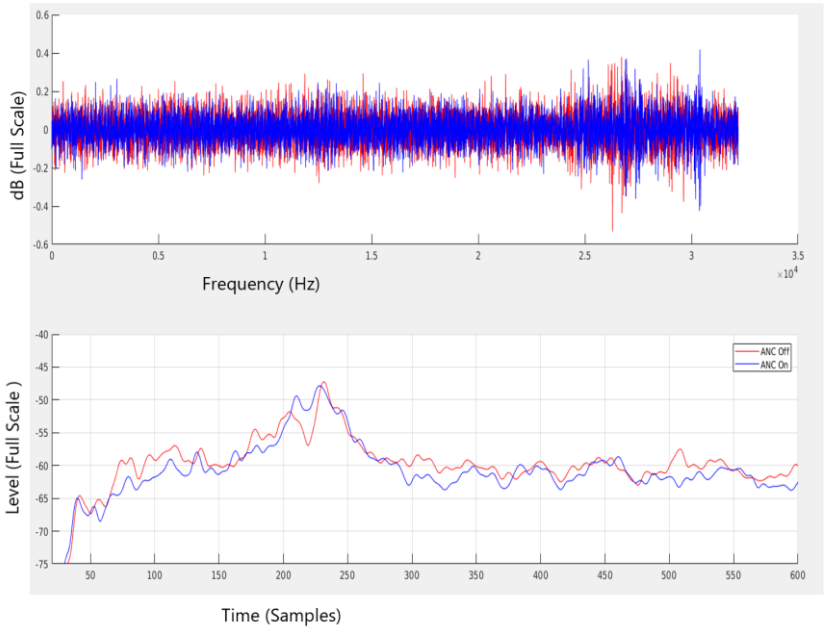

Figure 9 Front left outside ear noise cancellation

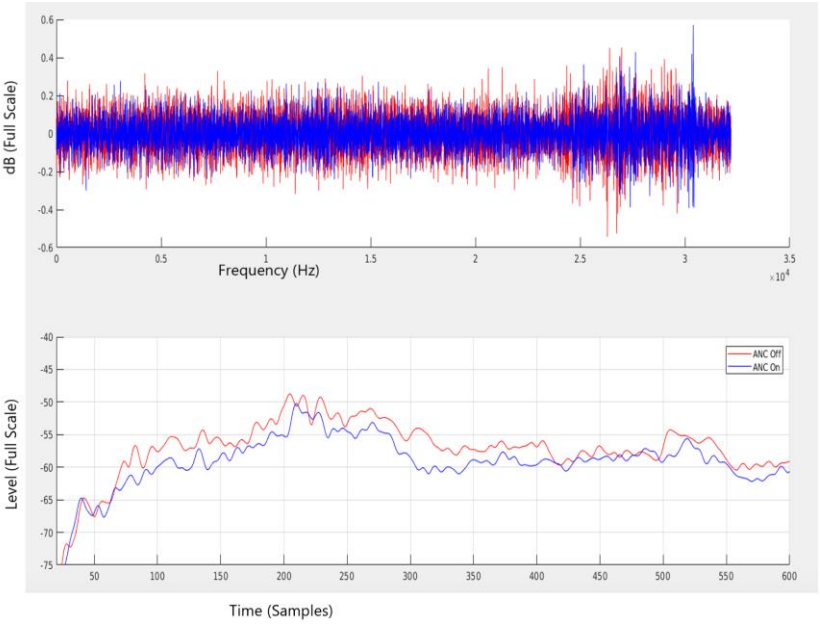

Figure 10 Front left inside ear noise cancellation

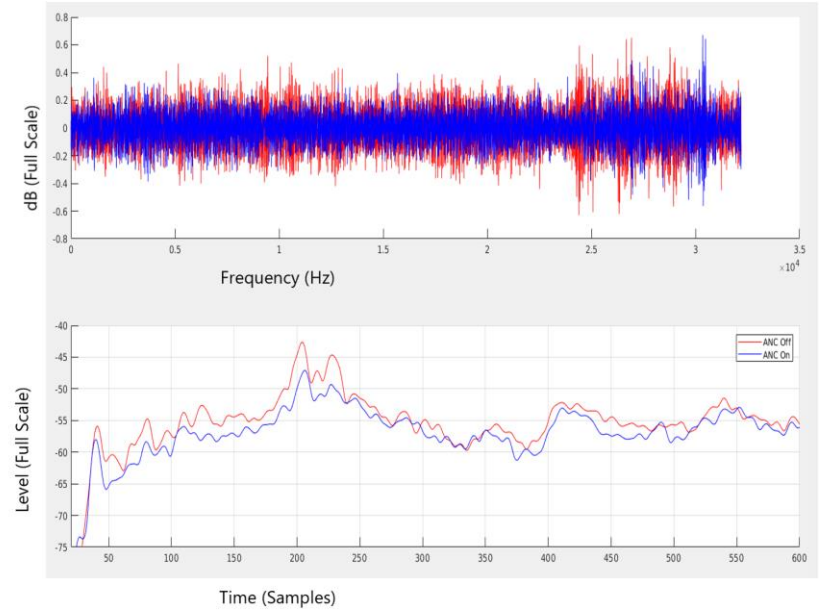

Figure 11 Rear right outside ear noise cancellation

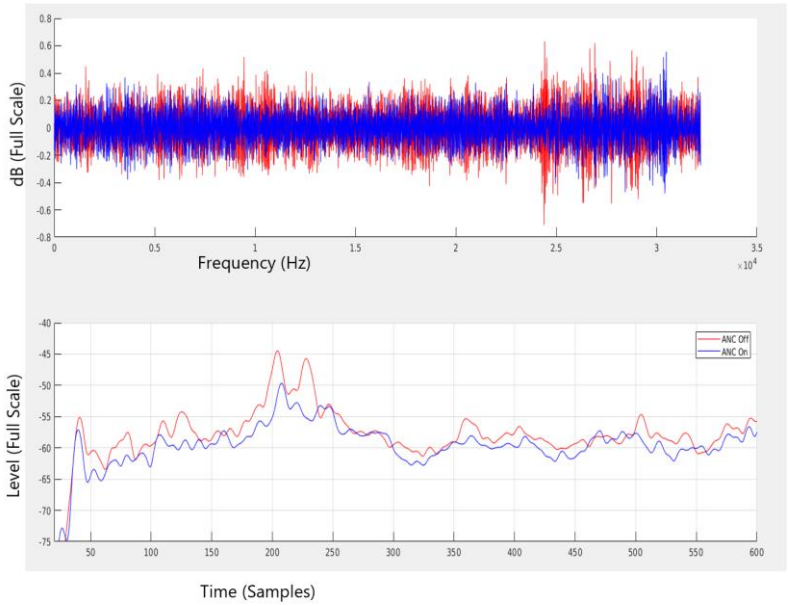

Figure 12 Rear right inside ear noise cancellation

Abbreviations

Abbreviation	Description
ANC	Active Noise Cancellation
DSP	Digital Signal Processor
ECU	Electronic Control Unit
EOC	Engine Order Cancellation
FLOE	Front Left Outside Ear
FLIE	Front Left Inside Ear
IVI	In Vehicle Infotainment
OS	Operating System
RNC	Road Noise Cancellation
RROE	Rear Right Outside Ear
RRIE	Rear Right Inside Ear
SoC	System on a Chip
VM	Virtual Machine
VCOS	Vehicle Compute Solutions
VCO1S	Vehicle Cockpit Solutions
VCO2S	Vehicle Cockpit Consolidation Solutions
VCO3S	Vehicle Cockpit Compute Consolidation Solutions

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