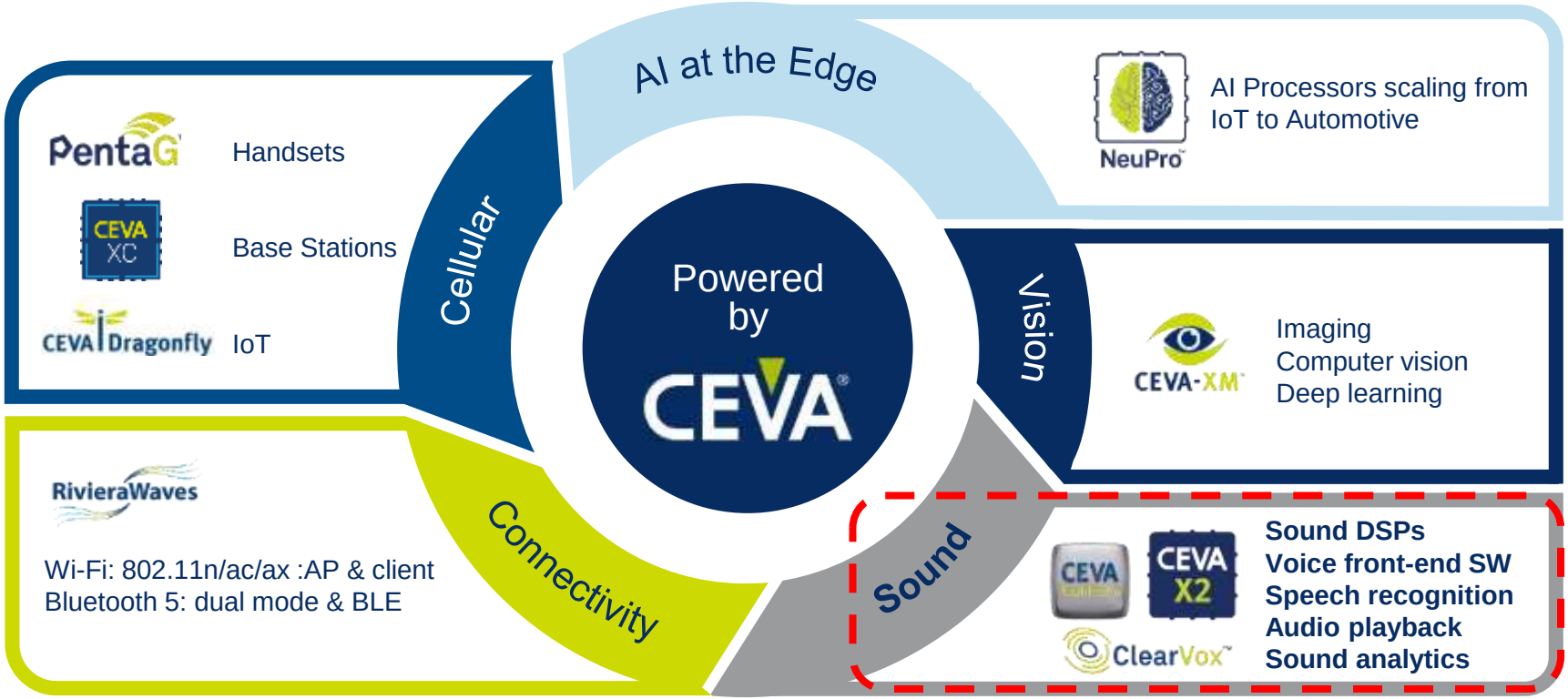
Wireless Headset Technologies and Trends

The proliferation of in-ear Active Noise Control

September 17th, 2018

www.ceva-dsp.com

CEVA IP Portfolio



Licensing & Royalty Business Model: upfront licensing fee plus royalty on each CEVA-powered chip shipped

CEVA's Unique Sound Processing Offering

DSP

- **CEVA-TeakLite-4** for Ultra Low Power
- **CEVA-X2** for high performance

Software

- **ClearVox** package for front-end voice pickup
  - Noise reduction
  - Beam forming
  - Acoustic echo cancellation
- Audio/Voice **Codecs**

AI

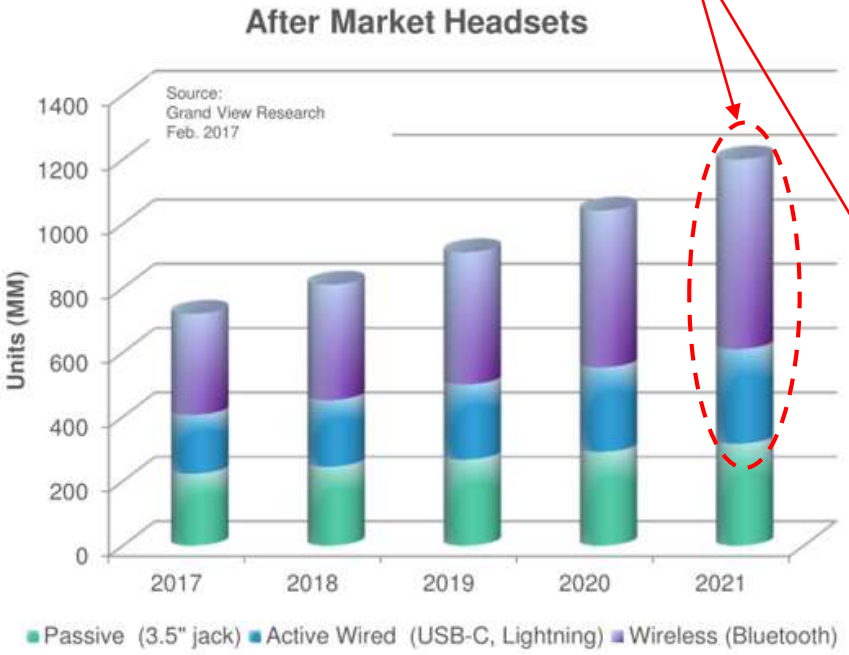
- **NN Libs**
- **DSP NN Compute library**

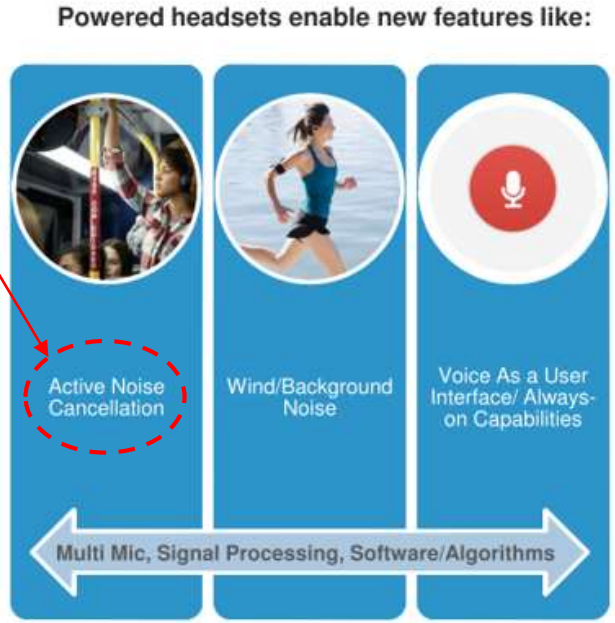
ClearVox™

CEVA offers a comprehensive sound solution

Headset Trends (earbuds, headphones, hearables …)

- Transition from 3.5mm jack creates opportunity for premium audio solutions for the powered (wired/wireless) headsets: ~1 Billion headsets in 2021





CEVA Sound DSP Headset Solution

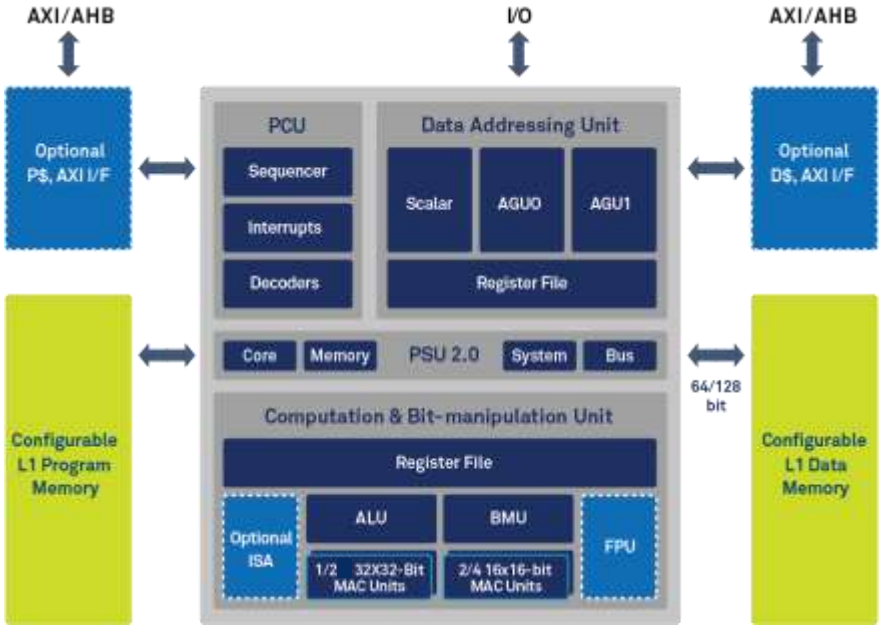
TeakLite-4 DSP

- Low-power always listening
- High performance voice pre-processing
- 1-3 mics noise reduction and beamforming
- Active Noise Control
- Voice trigger/commands/biometrics
- Low power audio playback / Audio over BLE
- Sound Neural Networks (audio analytics)

Ultra-Low-Power and High performance
Wireless headsets, Hearables , IoT

TeakLite-4 DSP Architecture

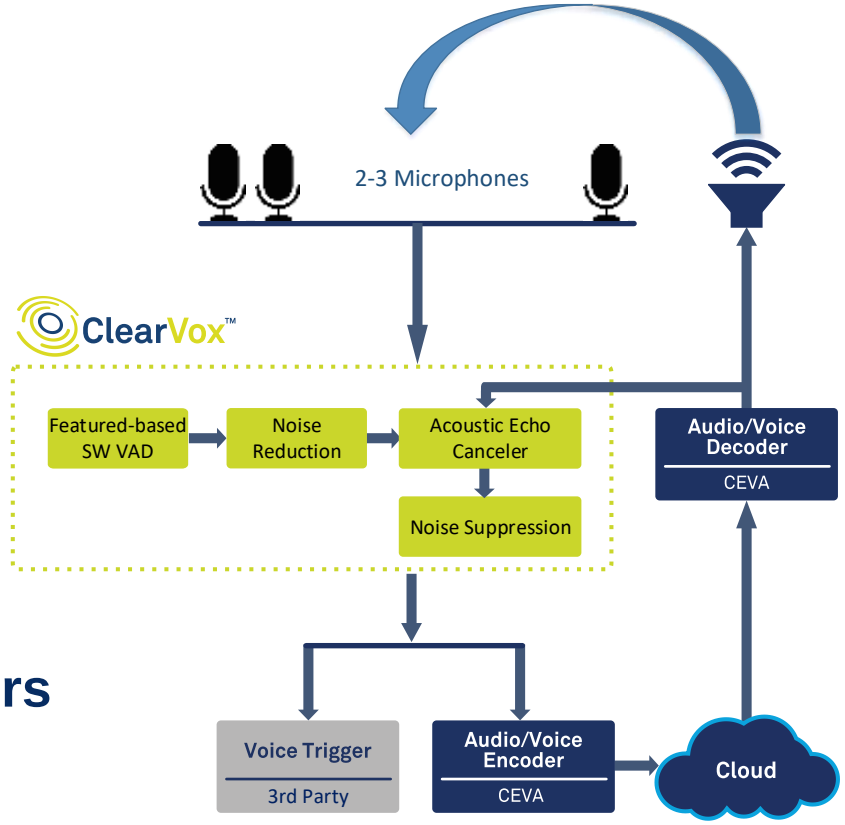
Feature	Configuration
Pipeline stages	10
SIMD [bit]	64
DSP arithmetic data types [bit]	16/32/64/72
MAC [16x16-bit]	2 or 4
MAC [32x32-bit]	1 or 2
Single Precision Floating-Point	Optional
Data Memory width [bit]	64 or 128
Dedicated audio instructions	Yes



World's Most Deployed Low Power 32-bit DSP Family

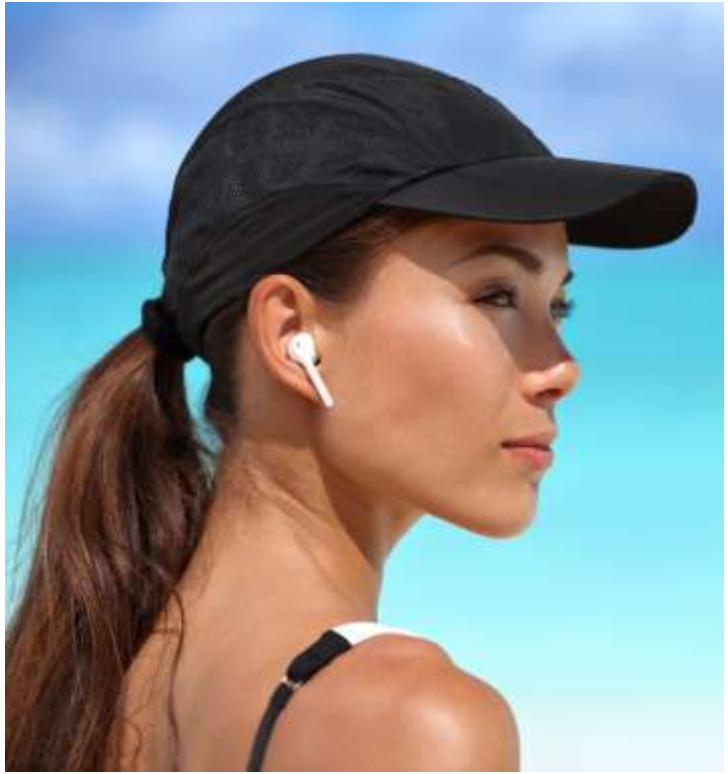
CEVA Sound Software Headset Solution

- **ClearVox** Voice Front-end Software
  1. **Noise Reduction**
     - Multi channel Noise Reduction including SW VAD and Beamforming
     - 2-3 MICs
  2. **Acoustic Echo Cancellation**
     - Mono and Stereo
  3. **Single channel Noise Suppression**
     - Suppresses the residual noise
- Audio and Voice **Encoders/Decoders**



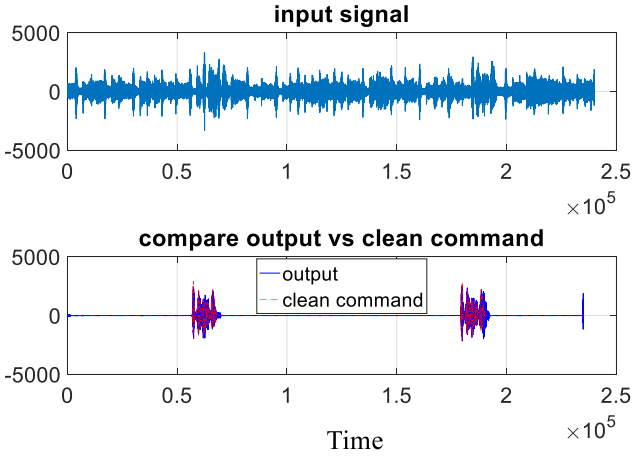
ClearVox Headset Noise Reduction

- **Supported features**
  - Configurable 2-3 microphones
  - Configurable microphone topology
  - SW VAD (Voice Activity Detection)
  - Fixed Direction of Arrival
  - Dynamic Noise reduction
    - Beamforming
    - Different noise environments: white, directed, diffused, etc.



ClearVox Headset Acoustic Echo Cancellation

- **Barge-in enabler**
  - Barge-in during music playback
  - Barge-in during personal assistant response
- **Clean voice call enabler**
  - Intelligible voice in BT hands-free mode
- **Supported Features:**
  - Configurable tail length
  - Mono/stereo echo cancellation
  - Advanced double-talk detector
  - Music and Voice



CEVA Sound NN Headset Solution

- **“Sound NN at the edge” is a major trend**
  - In Headsets it is used for environmental sound sensing and speech recognition
- **NN use-cases on CEVA TeakLite-4 sound DSP**
  - Voice trigger
  - Voice commands
  - Voice biometrics
  - Sound sensing
  - Customer proprietary NNs
- **All NNs employ similar concept**
  - Deep learning – offline training with massive data sets
  - Edge inference of NN to classify/filter real time signals

CEVA is offering NN lib and SW framework

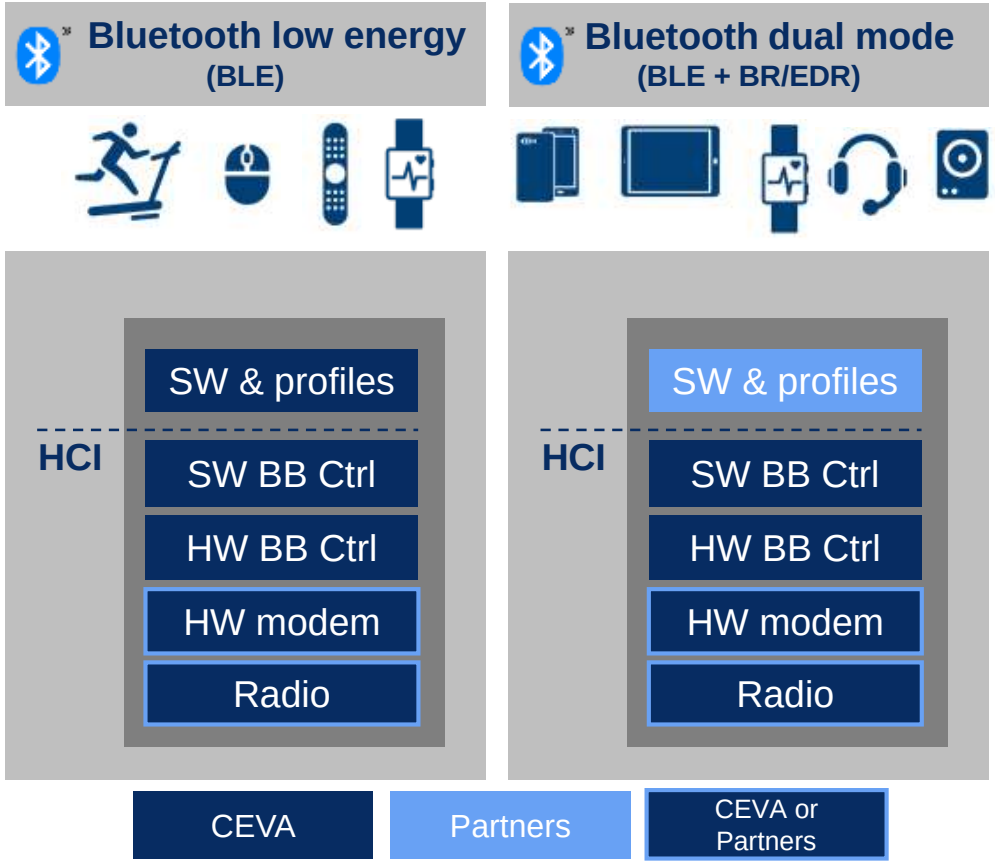
CEVA Sound NN Compute Library

- CEVA Neural Network Library is a set of **highly optimized** neural network building blocks
- CEVA Neural Network Library is carefully composed to facilitate easy building and deployment of neural networks, with an **emphasis on audio data**
- Library functions are called **“layers”** as they can be connected **hierarchically**
- **Sound neural network is a set of connected layers**

CEVA sound NN lib enables deep learning headset applications

CEVA Bluetooth Headset Solution

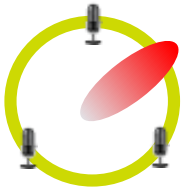
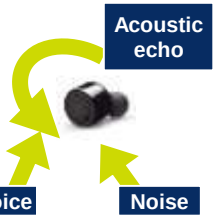
- Unique and comprehensive offering for both **Bluetooth Low Energy (BLE) & Bluetooth dual mode (BTDM):**
  - Baseband controller
  - Software protocol stack
  - Modem & Radio
  - Integrated platform with embedded RISC-V processor
- **Full BLE software stack** with a comprehensive list of profiles
  - Including mesh and audio over BLE
- **HCI BTDM software**, interoperable with 3rd party BTDM host stack and profiles from:
  - BlueDroid: Android / Wear / Things
  - BlueZ: linux
  - IVT, OpenSynergy, A&W, etc.



Audio over Bluetooth Dual Mode

- BT Dual Mode remains the optimum choice for wireless audio
  - Audio-over-BLE still an evolving technology
- CEVA's RW-BTDM5 is the only viable Bluetooth 5 Dual Mode IP available
  - 30+ Bluetooth Dual Mode design wins, many in mass production
- Additional challenges (& opportunities) now for headset type products
  - Power consumption: forwarding audio to peer earbud (aka TWS) is expensive
  - Left / Right audio synchronisation: sub-40us
  - CEVA has engaged in customized "Eavesdropping" type designs for a number of customers

One Stop Shop Ultra-Low-Power Sound Solution

VAD	Input	Beamforming	AEC	Voice Trigger	Output
Ultra low power	PDM to PCM	Multi-mic Beamforming	Acoustic Echo Canceller	Deep Neural Network VT	Opus encoded query "What is the weather in San Diego?"
					
VAD	PDM2PCM	Beamformer	AEC	Voice Trigger	Opus Codec

Silentium – Noise control across industries

Wearables

Appliances

Automotive

HVAC

Transportation

Military

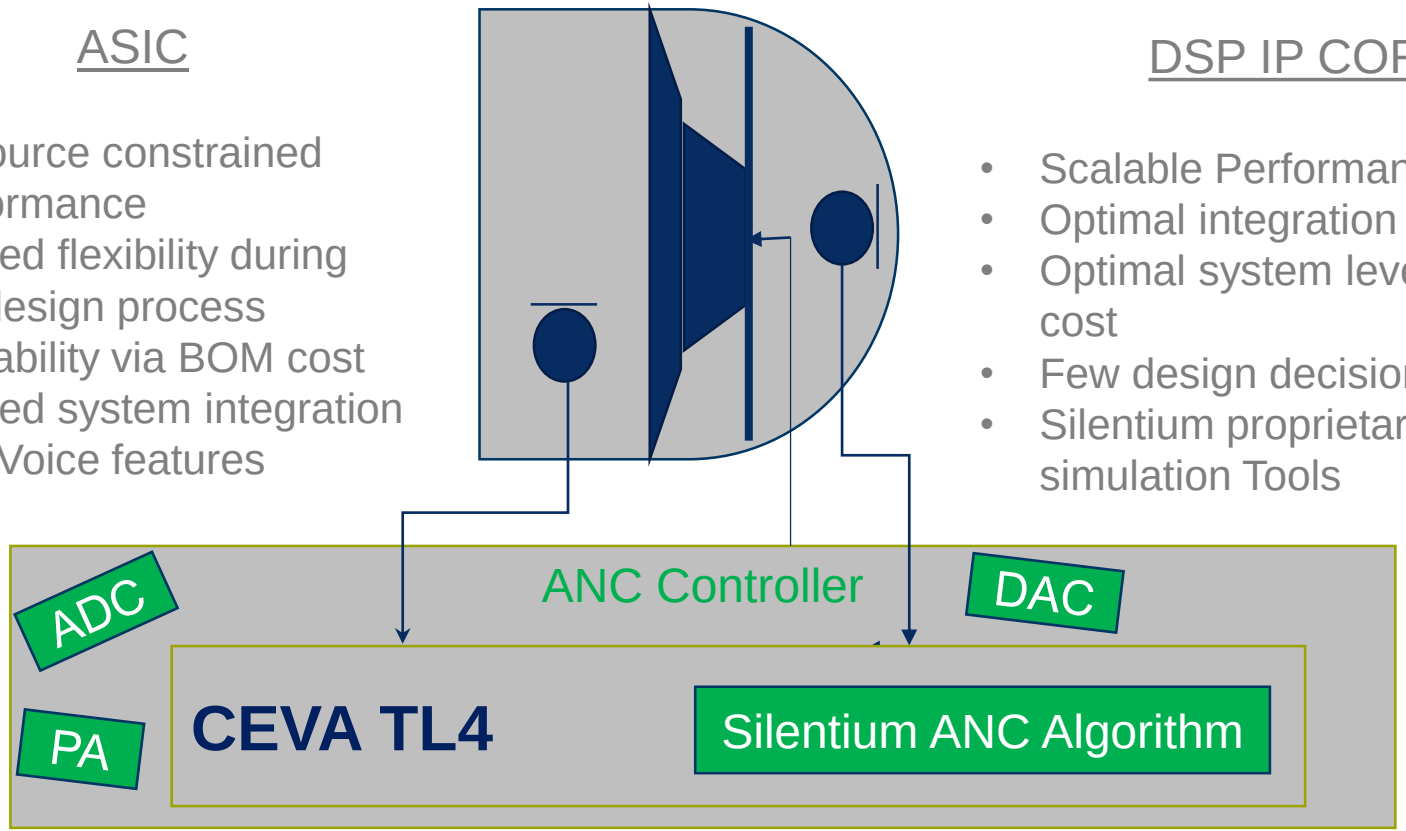
Heavy Industry

IT

ANC Signal Processing Controller

ASIC

- Resource constrained performance
- Limited flexibility during the design process
- Scalability via BOM cost
- Limited system integration with Voice features

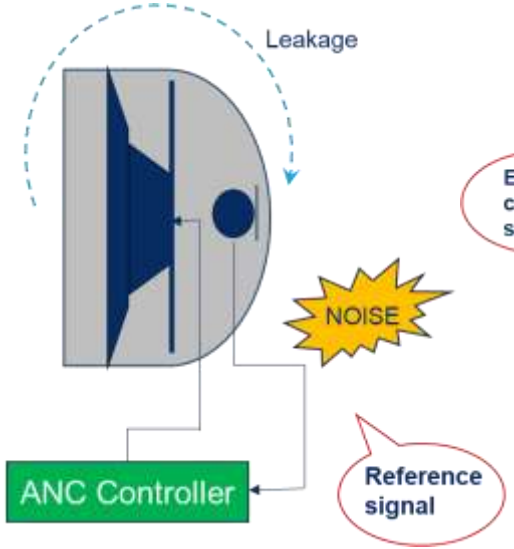


DSP IP CORE

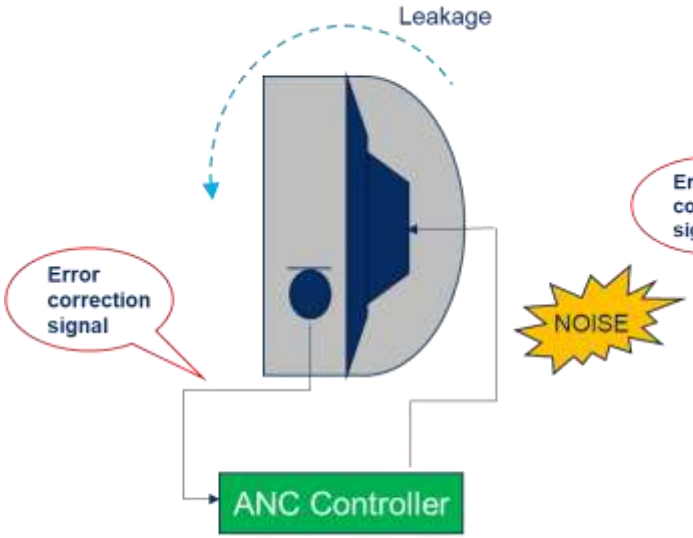
- Scalable Performance
- Optimal integration with Audio
- Optimal system level BOM cost
- Few design decisions upfront
- Silentium proprietary simulation Tools

Controller Architecture

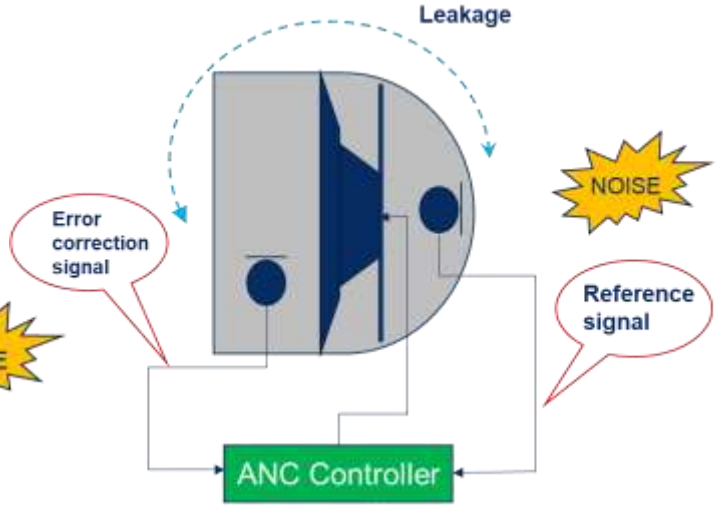
Feed Forward
1 Microphone



Feed Back
1 Microphone



Hybrid FF/FB
2 Microphones

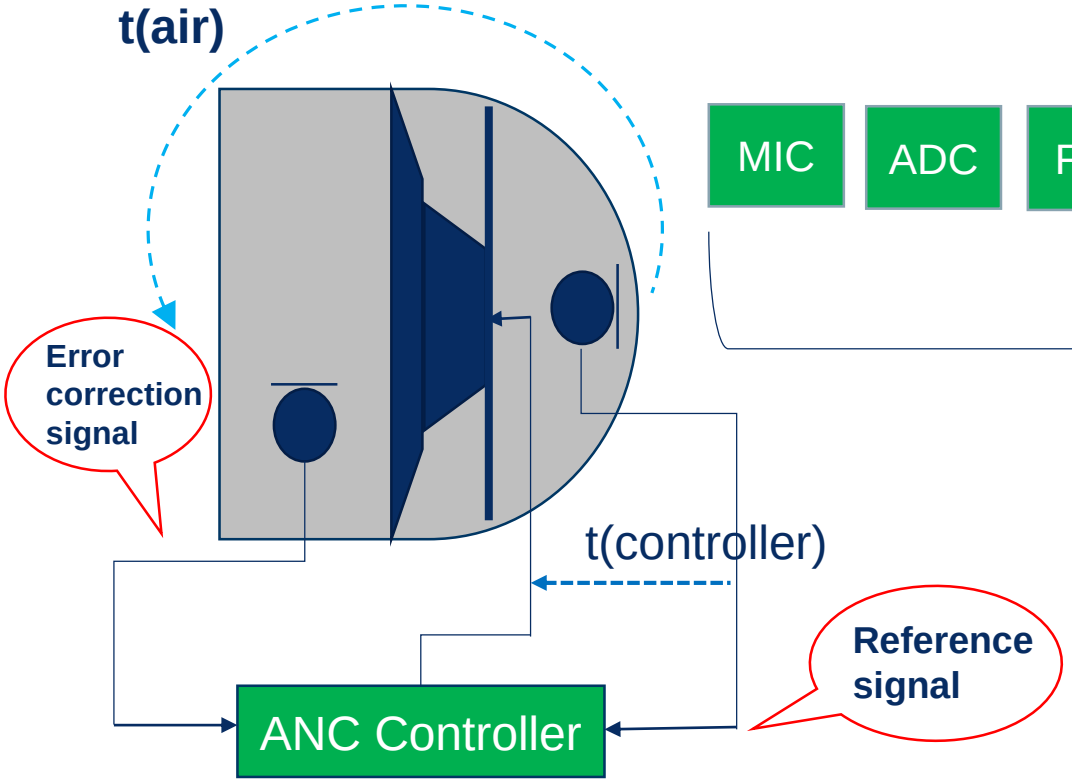


ANC Behavior and Performance

- **Dynamic adaptability**
  - Acoustic leakage from tips/foam
  - Dynamic noise sources, noise location, Noise PSD
- **Static adaptability**
  - Acoustic human physiology variations
  - Audio source/type variability, music, voice
- **Environmental adaptability**
  - Airplane, Train, etc.
  - Office

- **Control Interfaces**
- Device user Interface Inputs
- Phone App
- Sensors
- Voice
- IoT

Necessary Conditions for ANC

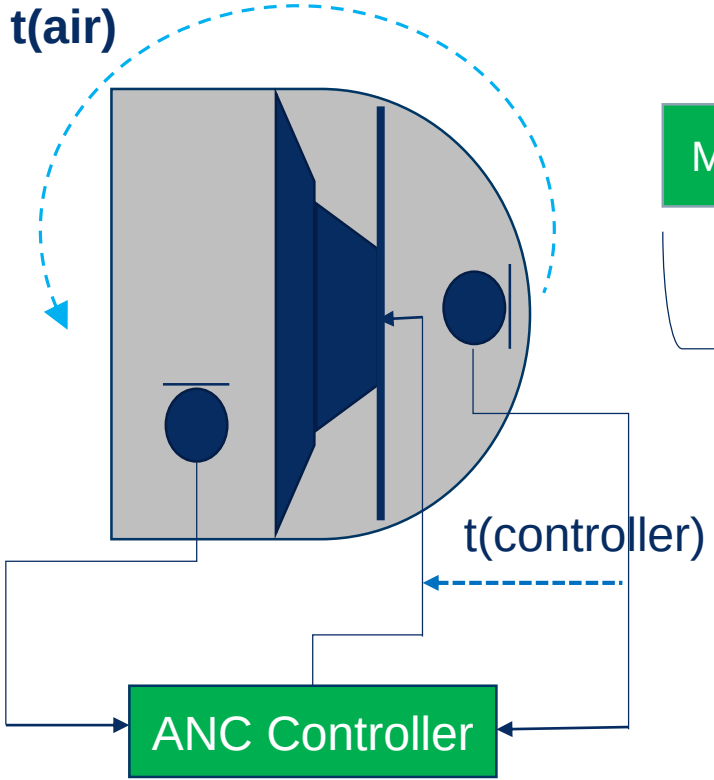


t(controller) < t(air)

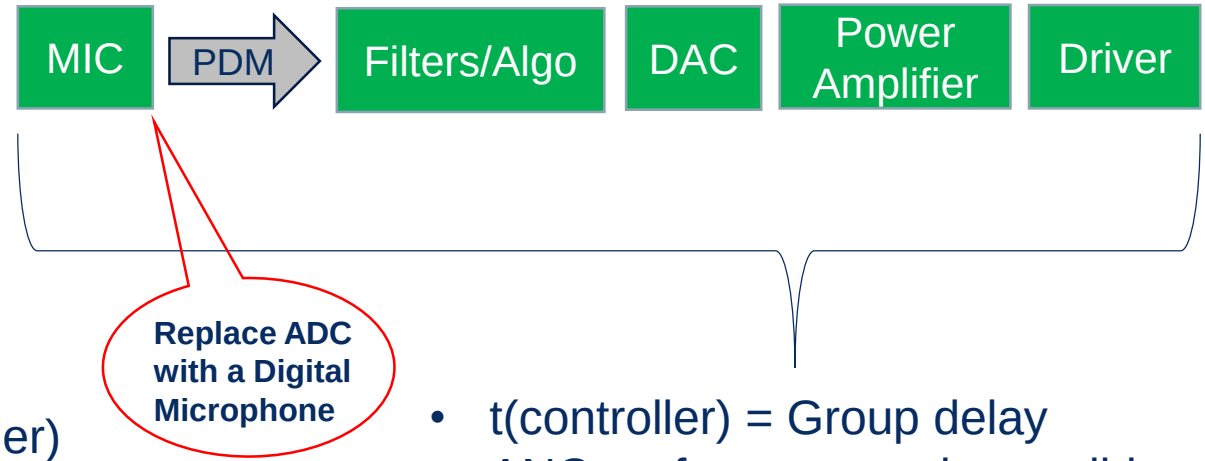
MIC | ADC | Filters/Algo | DAC | Power Amplifier | Driver

t(controller) = Group Delay
Acoustic path time ~ .050m/340m/s = 147uS

Necessary Conditions for ANC

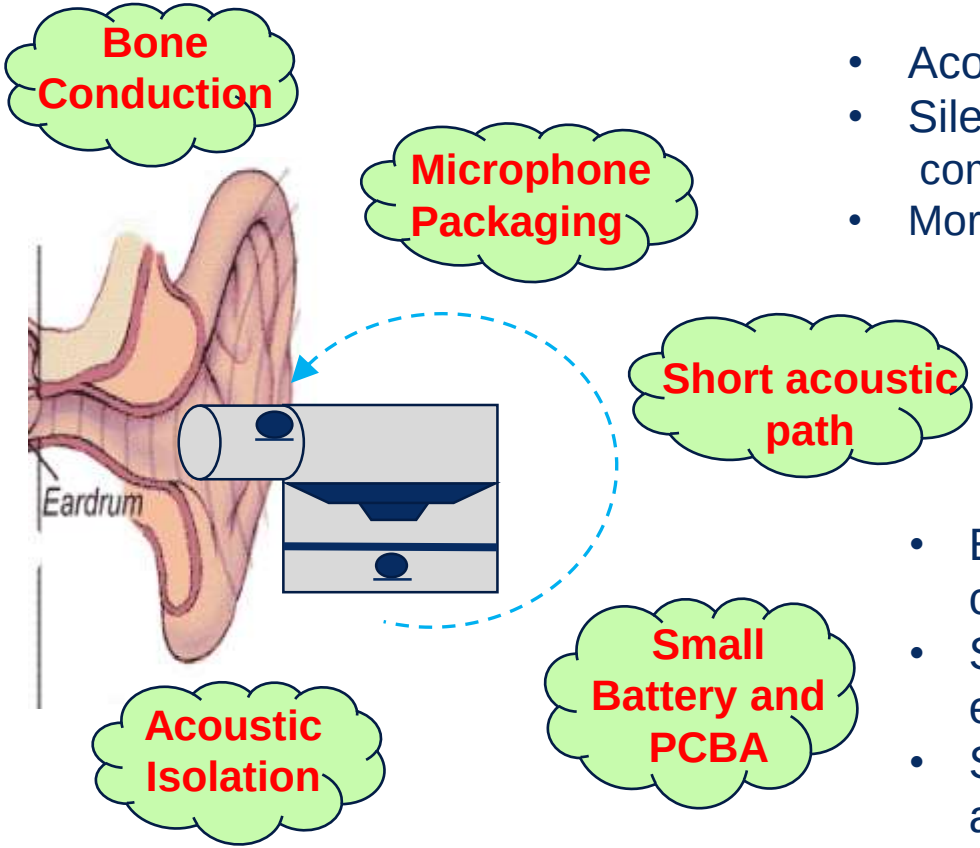


t(controller) < t(air)



- t(controller) = Group delay
- ANC performance only possible above 250Hz due to microphone latency

Challenges of Intra-Aural ANC



- Acoustic path time ~ .025m/340m/s = 74uS
- Silentium predictive algorithms are required to compensate for short Acoustic Path time
- More stringent ADC/DAC requirements

- Silentium offers maximum broadband performance with Feed Forward only designs, in case two microphones cannot be packaged

- Balanced armature drivers have sealed cavity, but lack in Freq response
- Silentium assists SOC designers with In-ear specific requirements
- Silentium can provide full acoustic design and component selection services

Milestones for an ANC ready SOC

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SOC Product feature definition

Microphone type- analog/digital
Mechanical form
True Wireless
Audio sources
ADC/DAC
Voice/VPA Support
Boot modes
IP Protection

SOC Target Critical Performance Parameters

ADC Latency/SNR
I2S Port Speed
Clock domains
Memory
DAC/PA SNR, THD
Hardware accel.
End Of Line programming

FPGA or initial test samples

Initial Library verification
Loopback testing
Early performance demonstrators
Speed & Group delay testing
Audio Integration
Initial MIPS & power modes

SOC Production Release

Production intent ANC Lib – V&V
SOC Final Customer specifications and parameters

End Product – Development Milestones

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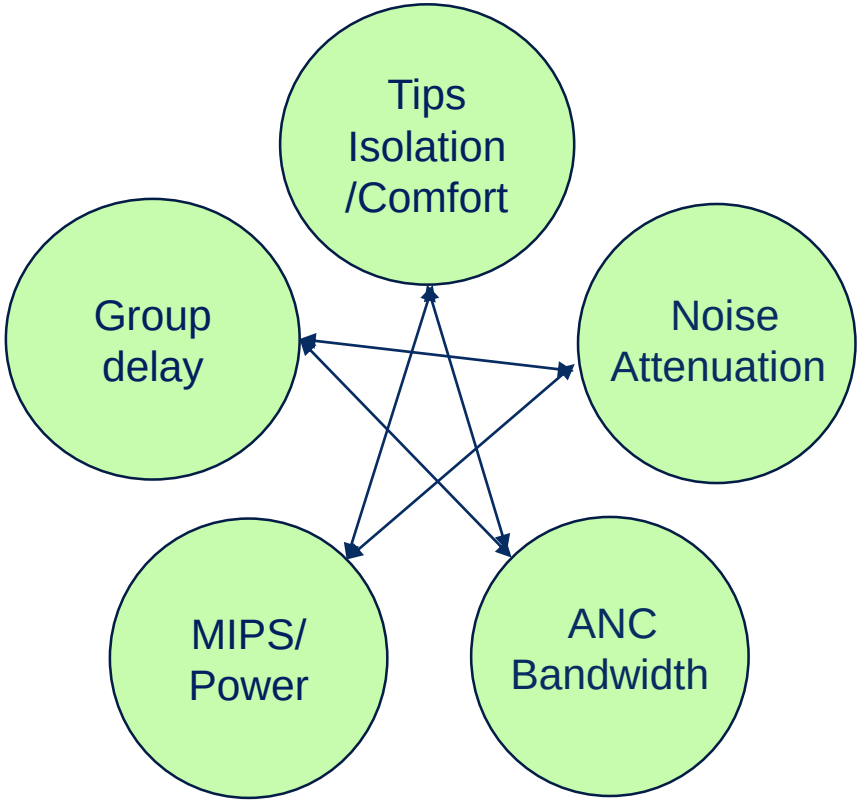
Silence in a Chip

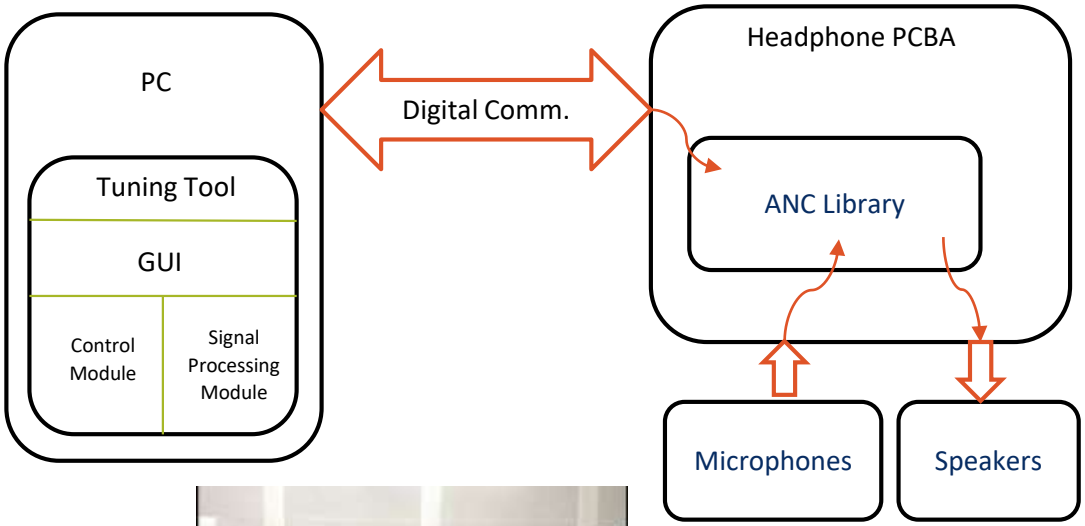
Product features and EU definitions	Acoustic components selection and modeling	Digital Audio Architecture	Release/ Alpha build
Audio sources for ANC. *Power requirements.* *Voice features.* *Use cases/UI.* *Audio Targets.* *ANC Targets.* *Wireless Features.*	*Driver & microphone Characterization.* *Design of tips/foam.* *Acoustic cavity modeling.* *Target ID design.* *Initial performance simulation.*	*Clocking, digital audio design.* *Target PCBA, electrical architecture.* *Prepare ANC library for production.* *ANC performance in target ID.*	*End-Of-Line calibration strategy.* *EOL equipment integration.* *Final mechanical tolerances.* *Critical characteristics measured, verified* *Final acoustic calibration.*

ANC Performance Continuum



- Predictive Filters - are employed to mitigate longer group delays.
- "Soft" ANC - unmatched capability in design and flexibility
  - MIPS vs. design goals adjustment.
- Flexible architectures - balance SOC and end product goals.
- Tight tips, foam cushions and bands provide isolation, but can reduce comfort. Broadband ANC can balance performance and comfort.

Calibration and Characterization



- Acoustic path modeling.
- Simulation environment for ANC performance prediction.
- Performance Simulation and Coherence Evaluation.
- Proprietary calibration strategy for dynamic noise sources.
- Ability to compensate for leakage in open design (no-tips)
- SOC/PCBA serial connection to tools required.

Steps to a successful customer demonstrator

- Identify demo goals and constraints: ANC, Audio, MIPS, power
- ANC library optimization with an FPGA version of a target SOC
- Identify necessary external components ADC, DAC, PA, etc.
- PCBA level integration
- Drivers, APIs, BSP for the full system with ADC, MICs, FPGA, etc.
- ANC ready acoustics/mechanical headphone prototype. Can also be an existing off the shelf product with quality acoustic components
- ANC acoustic calibration for a target acoustics/mechanics
- Silentium supports you to deliver a complete ANC solution to the end customer

Silentium ANC Key benefits

Low MIPS
and Memory

Full OEM/ODM
product support

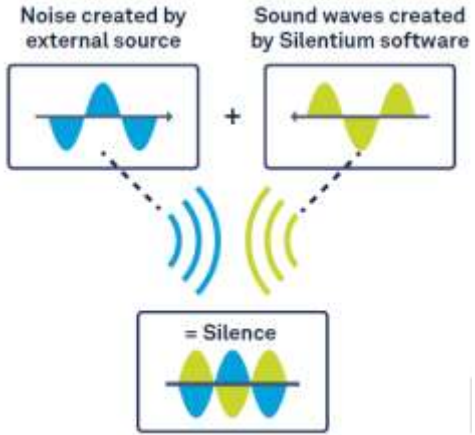
Flexible
Algorithms

Broadband
Performance

Strong Partnership
with DSP core IP

CEVA & Silentium ANC Solution

- Based on CEVA ultra-low-power sound DSP
- Fully adaptive broadband ANC technology
- Modular ANC solution:
  Feedforward/Feedback/Hybrid
- Suitable for multi-noise environment
- **Joint ANC demo is available**



Robust and fully integrated ANC solution for headset designs

Q&A

Wireless headset technologies and trends

The proliferation of in-ear Active Noise Control

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