sonion

# HUMANIZING THE DIGITAL EXPERIENCE

TDK Developers Conference 2018

TDK InvenSense EPCOS tronics microsystems Chirp MICRONAS

SONION

HUMANIZING THE DIGITAL EXPERIENCE

# Sonion Voice Pick Up (VPU) Sensor

*Finds your voice in the noise*

*Paul Clemens, head of product management, Sonion*

**TDK Developers Conference**
September 17-18, 2018
Santa Clara Marriott

# Agenda

- Introduction
- Basic Principle & Product Specifications
- Use-case Examples
- Application Guidelines
- Summary

**4100 receiver**
world's smallest Balanced Armature



**3800 receiver**
highest output dual BA receiver



NEW

**Electrostatic**
Tweeter

InvenSense



**Puma**
MEMS microphones

InvenSense



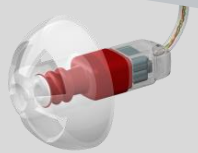
NEW

**VPU**
Voice Pickup Sensor

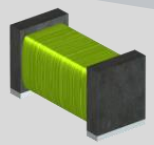
VALENCELL

NEW

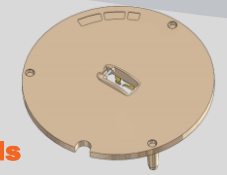
**PPG**
Biometric Sensors



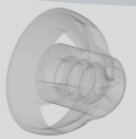
**Receiver in Canal**
extensive RIC portfolio



**SMD RF coils**
and telecoils

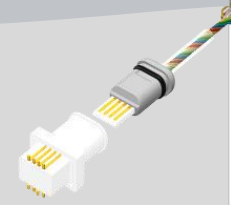


**Faceplates**
incl. assembly



**LSR**
domes and more

**DCU 193**
user interfaces



**CS9X**
plug and socket up to 8 connections

- **Hearing Aid Industry** (leading supplier transducers)
- **Pro Audio** (#1 supplier for BA receivers)
- **Hearables**
- **Communication**

SONION

- **>40 years in business**
- **>99% delivery performance**
- **~6200 employees worldwide**
- **>25.000m² production space in Asia**

# Megatrends in earphones/hearables

**Lifestyle**

- Best Audio Sound quality for Music
- Enhanced user experience (music, reading, gaming, etc.)
- **Best calling experience, no background, smart voice recognition, etc.**
- Ease of use for end users

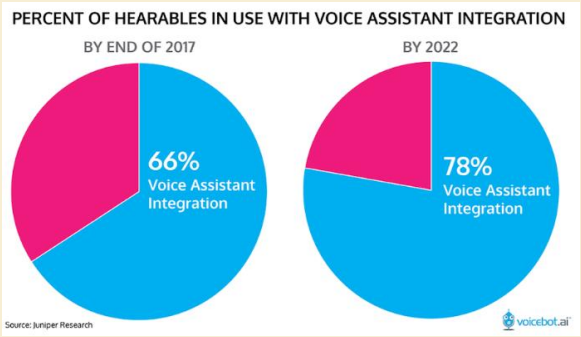
**Health care**

- Basic fitness use cases and compatibility with other devices
- Accuracy of fitness, data analytics and cloud/security sync's
- HR, Blood pressure, Diabetes, Cholesterol, Allergies, etc. etc.
- Smart connectivity and data analytics with hosts (clinic or self)
- Alerts from fall, pollution and or pings from host

**Artificial intelligence**

- Self driven devices per end user habits and pre settings
- **Ability to use voice command in most accurate and smart ways**
- **Read/write emails, voice calendar, instant language translation**
- Environment alerts, personal security, self charging

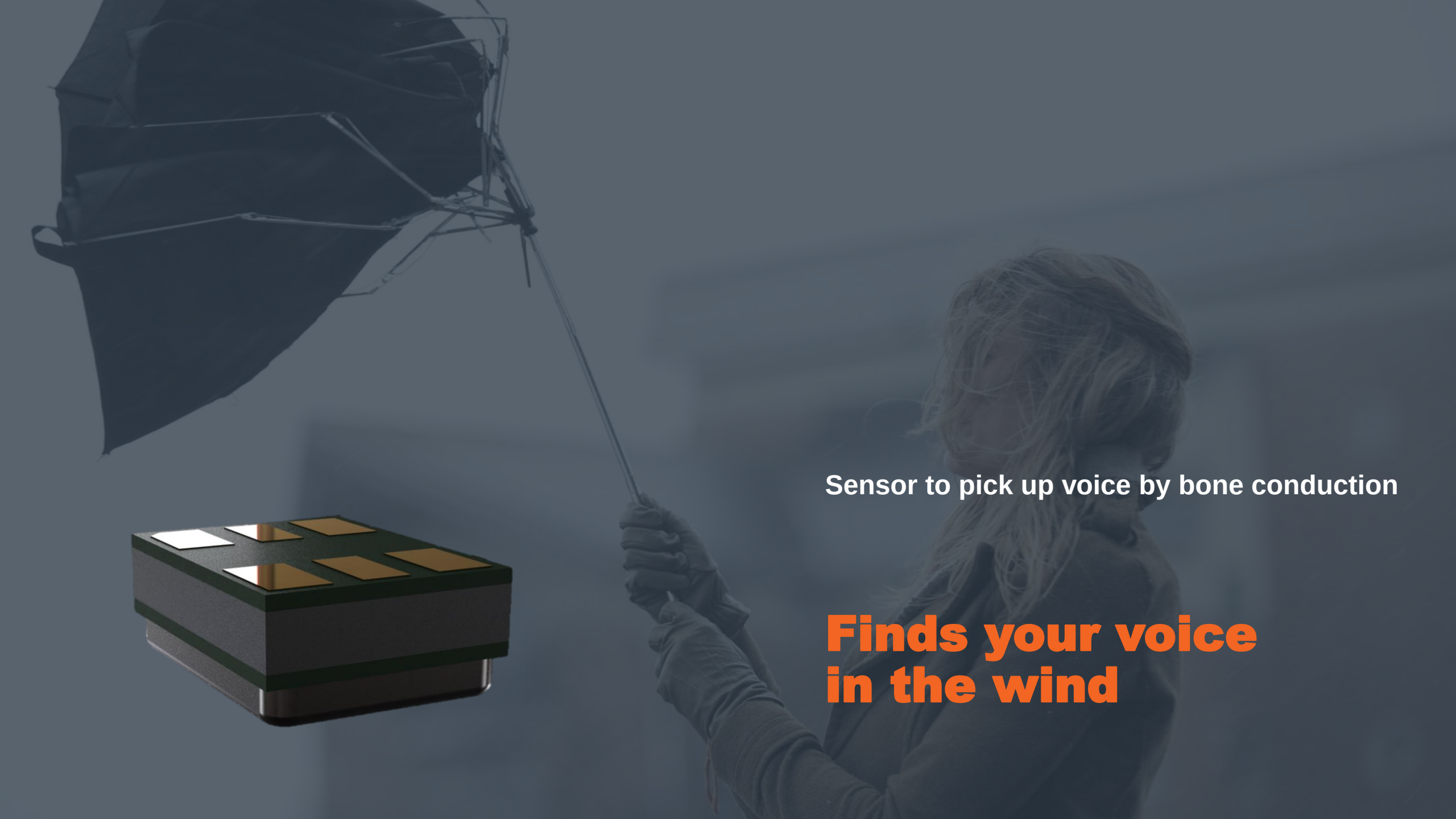
*We expect two-thirds (66%) of hearables to have voice assistants integrated to be in use at the end of 2017, rising to 78% by 2022. This is at the moment driven by Siri's integration into AirPods, but we expect a more diverse ecosystem to emerge over time.*




Source: Juniper research

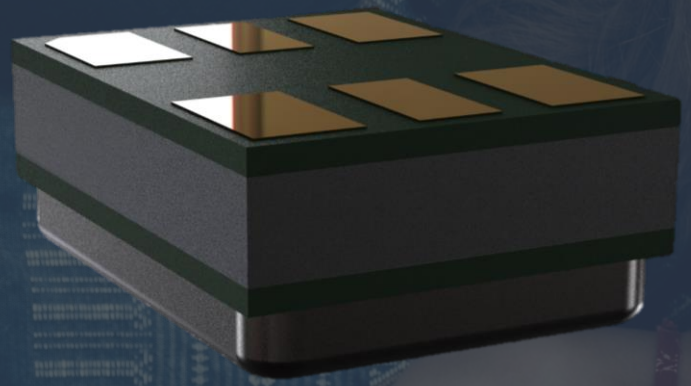
Sensor to pick up voice by bone conduction

# Finds your voice in the noise



Sensor to pick up voice by bone conduction

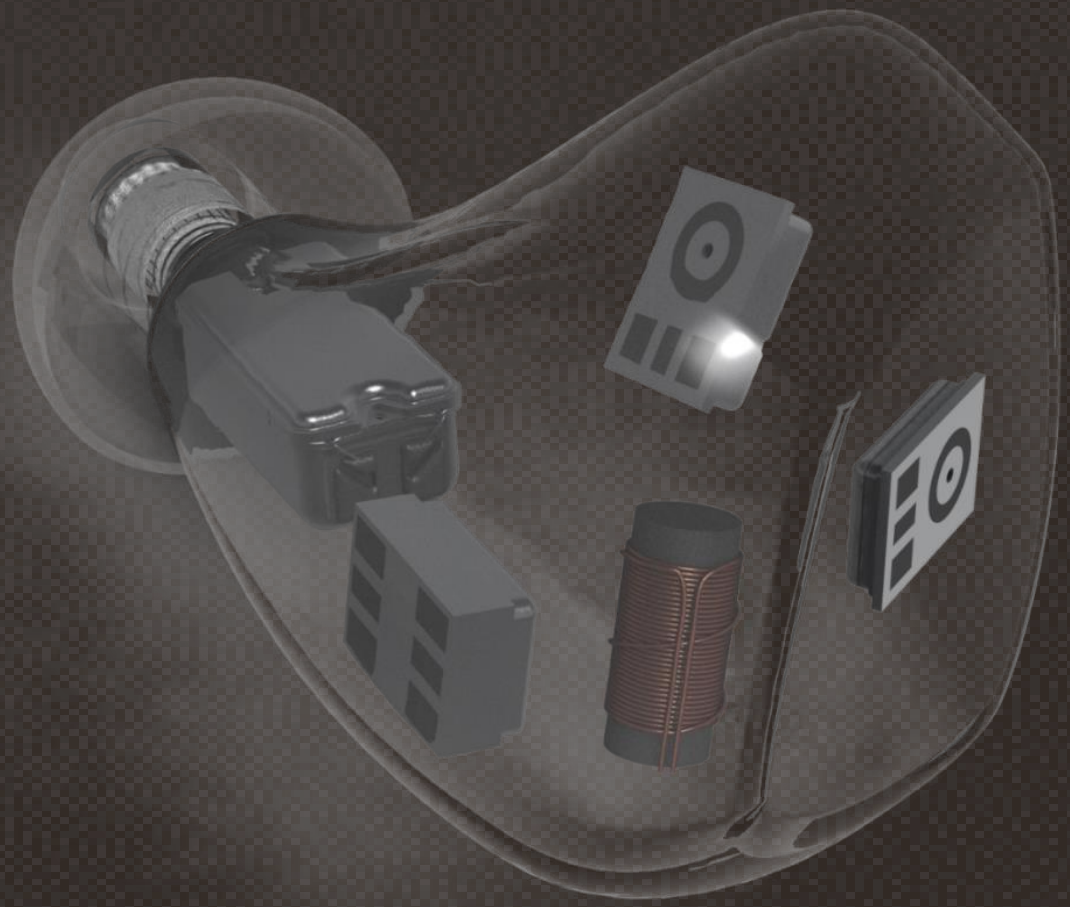
# Finds your voice in the wind

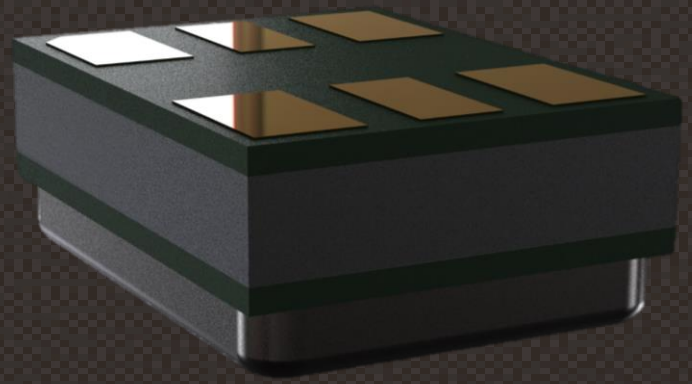


Sensor to pick up voice by bone conduction

# Finds your voice in the music

# Basic Principle & Specifications

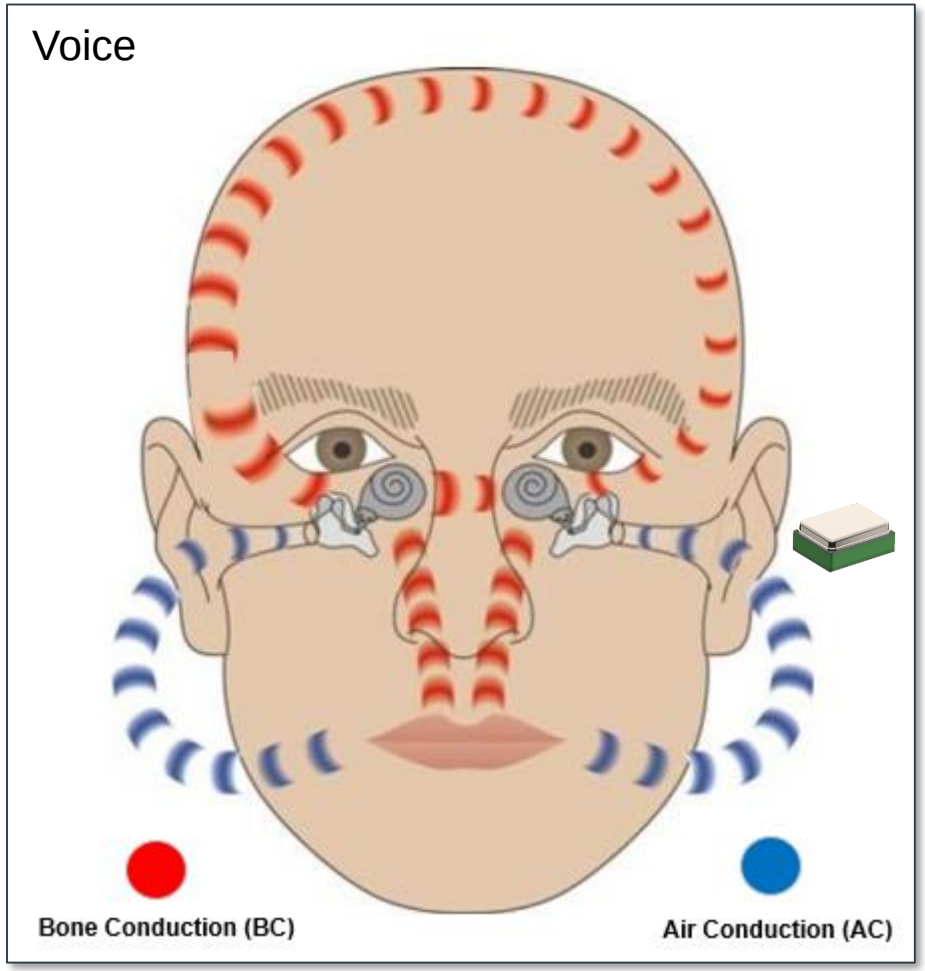




Sensor to pick up voice by bone conduction

**Always finds your voice**

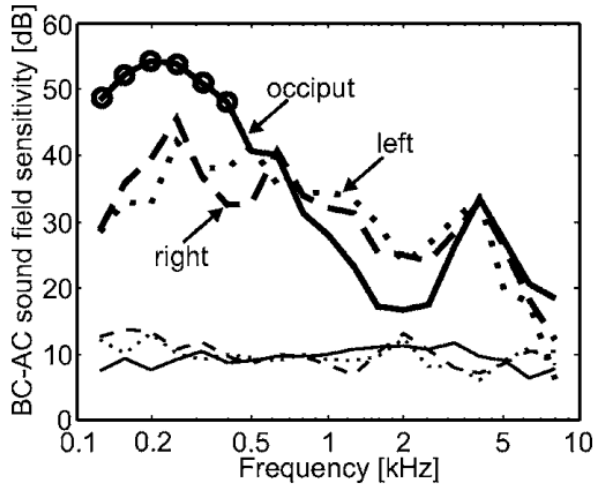
# Using Bone Conduction Sensor for Voice Pick Up




*Sabine Reinfeldt et al. 2009*

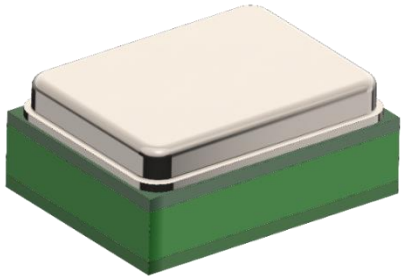
## Some considerations when using bone conduction:

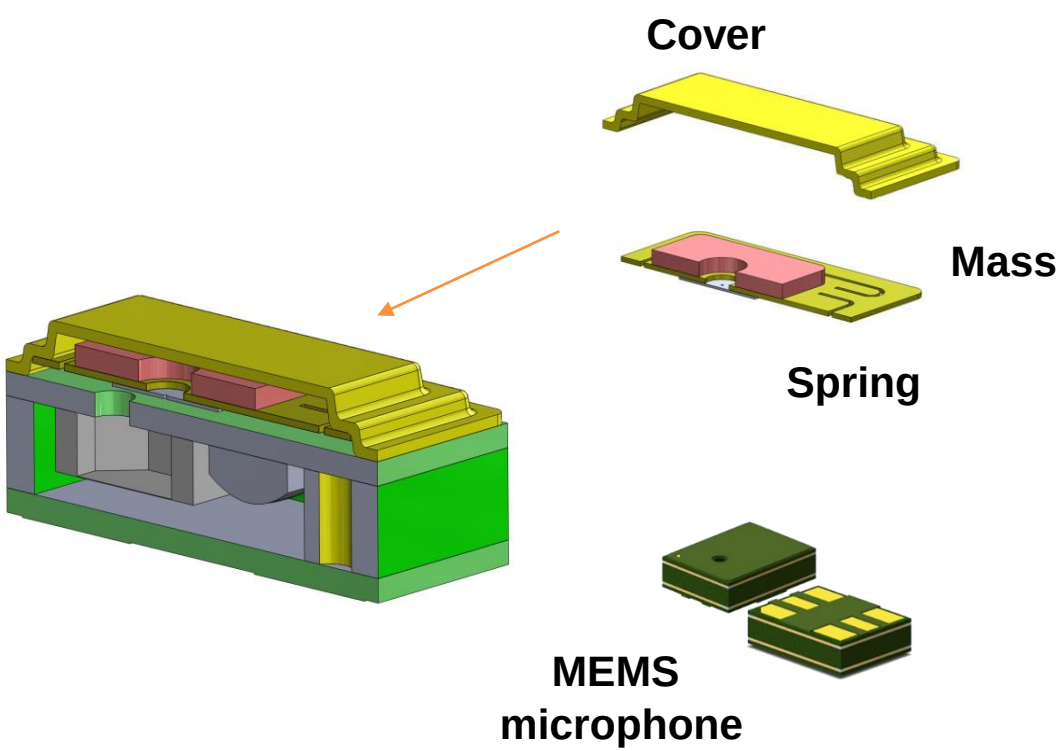
- Bone conducted voice is never influenced by background noise
- Human skin attenuates the high frequencies above 4 kHz in bone conduction voice
- It has variations in humans:
  - Anatomy of the skull
  - Speech production



# Basic Principle

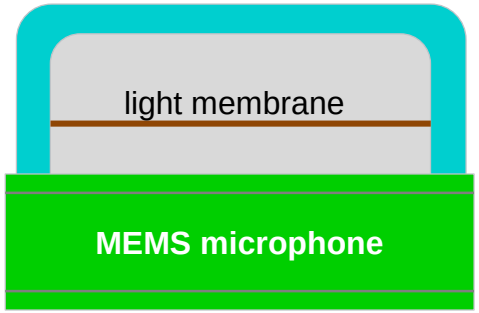
- Uses a top-port MEMS mic from INVN (ICS-40619) in low power mode (1.8V/55uA)
- Mass-spring on top of the sound port
- Movements of mass/spring create (sound) pressure
- Which is measured by the MEMS microphone





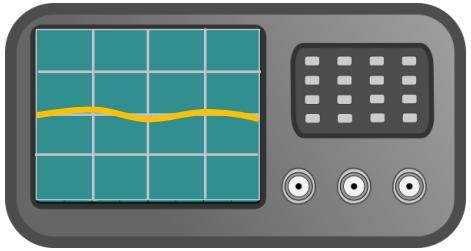
# Basic Principle

## System without Mass

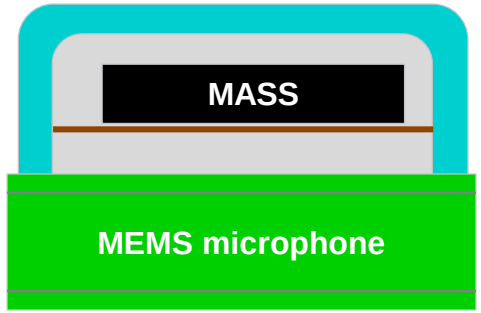



Due to low mass

Measurable pressure change is very low

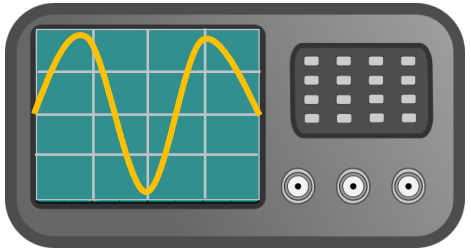


## System with Mass



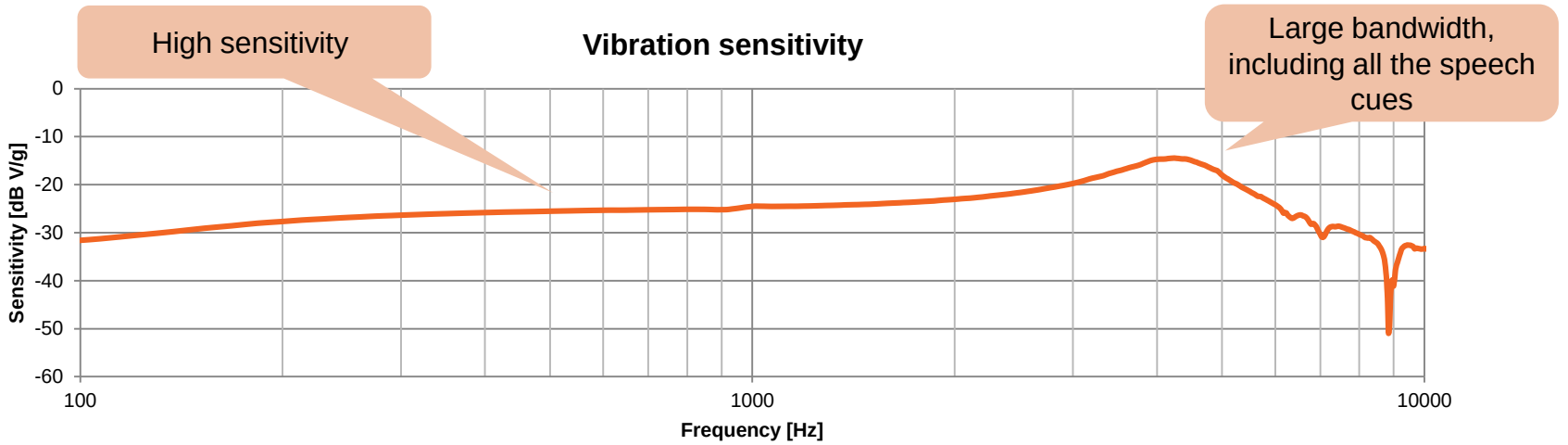

Due to additional mass

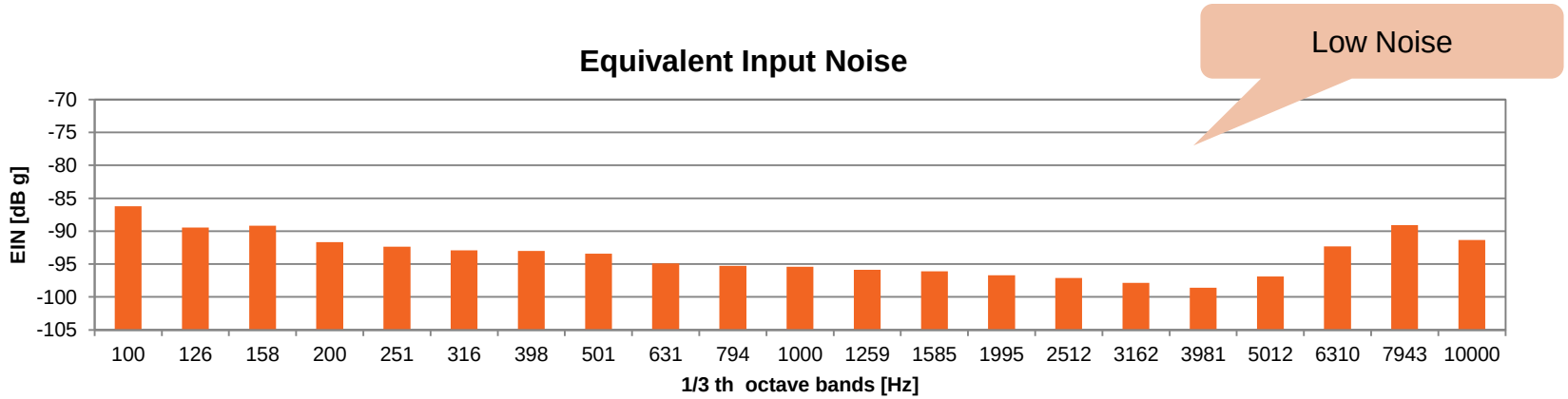
Significant measurable pressure change



# Performance

- ✓ High SNR
- ✓ Small size
- ✓ Hermetically sealed



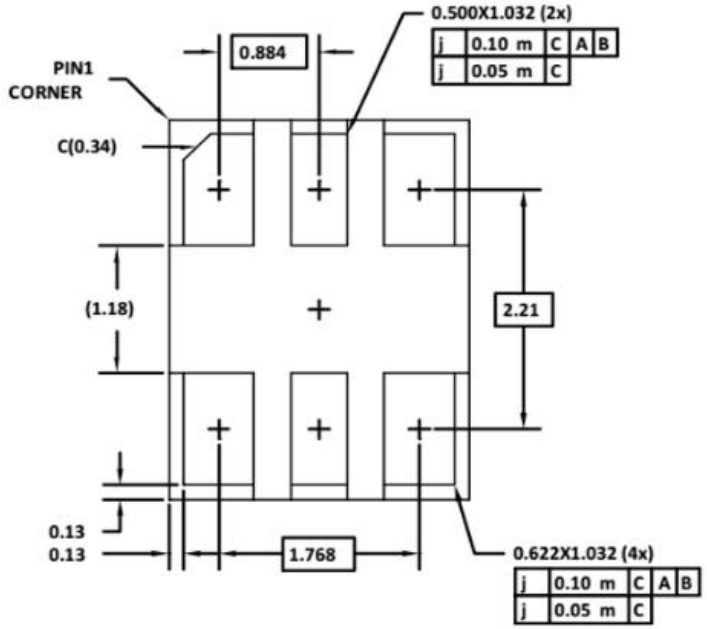

Noise density:

- 3.4 µg/ √Hz at 250Hz
- 1.2 µg/ √Hz at 1kHz

**The combination of high bandwidth and low noise does not exist in the market yet.**

# Performance

- ✓ High SNR
- ✓ Small size
- ✓ Hermetically sealed




## PIN CONFIGURATIONS AND FUNCTION DESCRIPTIONS

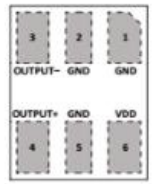



Figure 2. Pin Configuration (Top View, Terminal Side Down)

TABLE 4. PIN FUNCTION DESCRIPTIONS

| PIN | NAME | FUNCTION |
|---|---|---|
| 1 | GND | Ground |
| 2 | GND | Ground |
| 3 | OUTPUT− | Analog Output Signal− |
| 4 | OUTPUT+ | Analog Output Signal+ |
| 5 | GND | Ground |
| 6 | VDD | Power Supply |

**With a size of 3.5 x 2.65 x 1.5 mm (only 14 $mm^3$), it will fit inside the ear canal.**

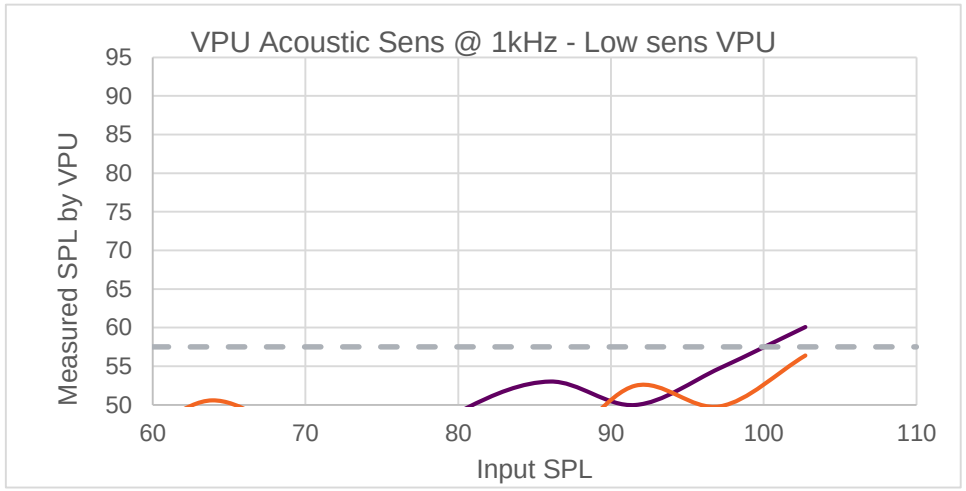
# Performance

- ✓ High SNR
- ✓ Small size
- ✓ Hermetically sealed


**The VPU is hermetically sealed and qualified with IP67 rating. This results in a very reliable component, under all conditions.**

# Performance

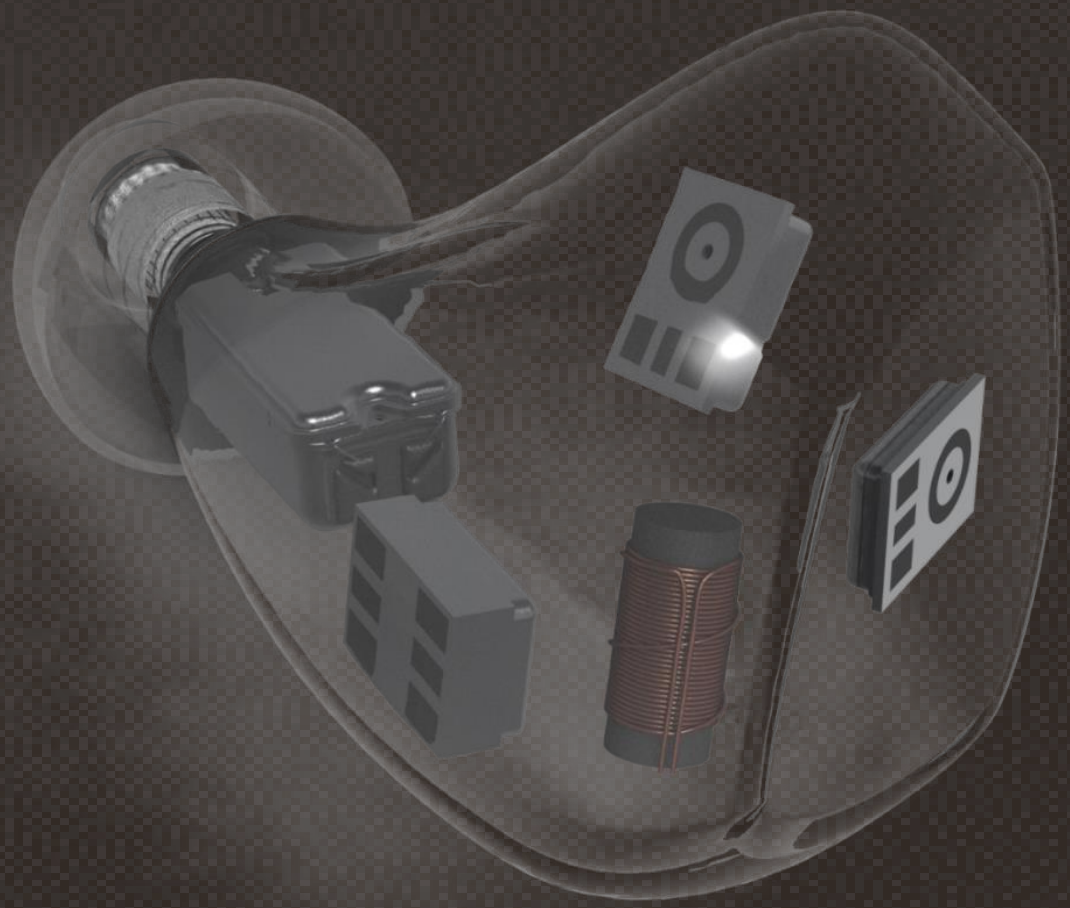
- ✓ High SNR
- ✓ Small size
- ✓ Hermetically sealed

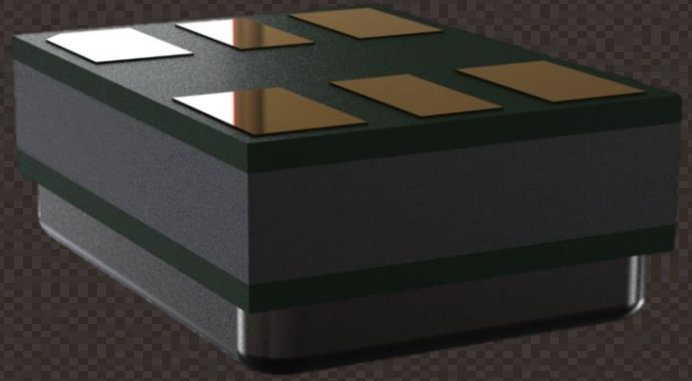



**Not sensitive for acoustics: will only pick up own voice**

**Maximized design freedom: No need to have sound inlet to the outside**

# Use-cases





Sensor to pick up voice by bone conduction

**Finds your voice in the noise**

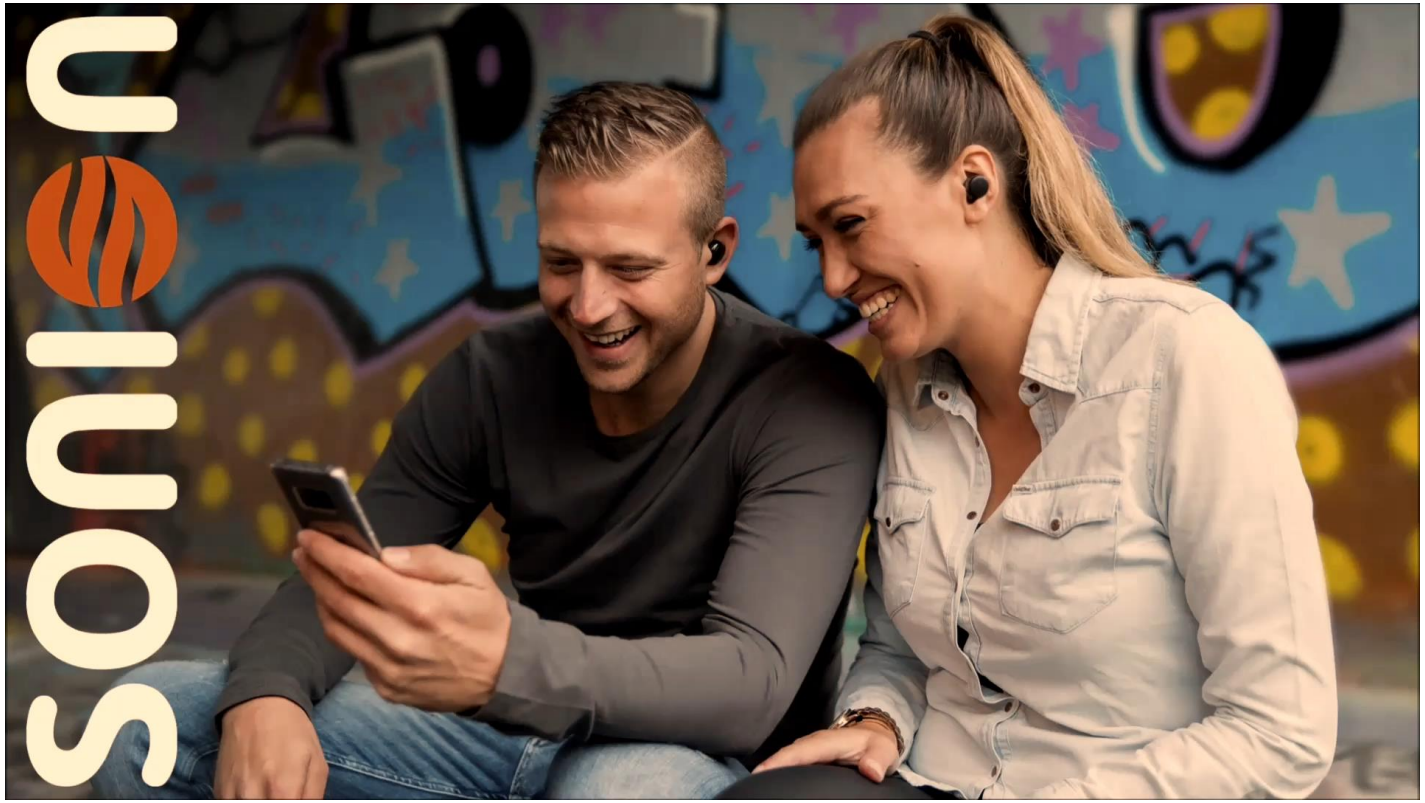
# Use-cases

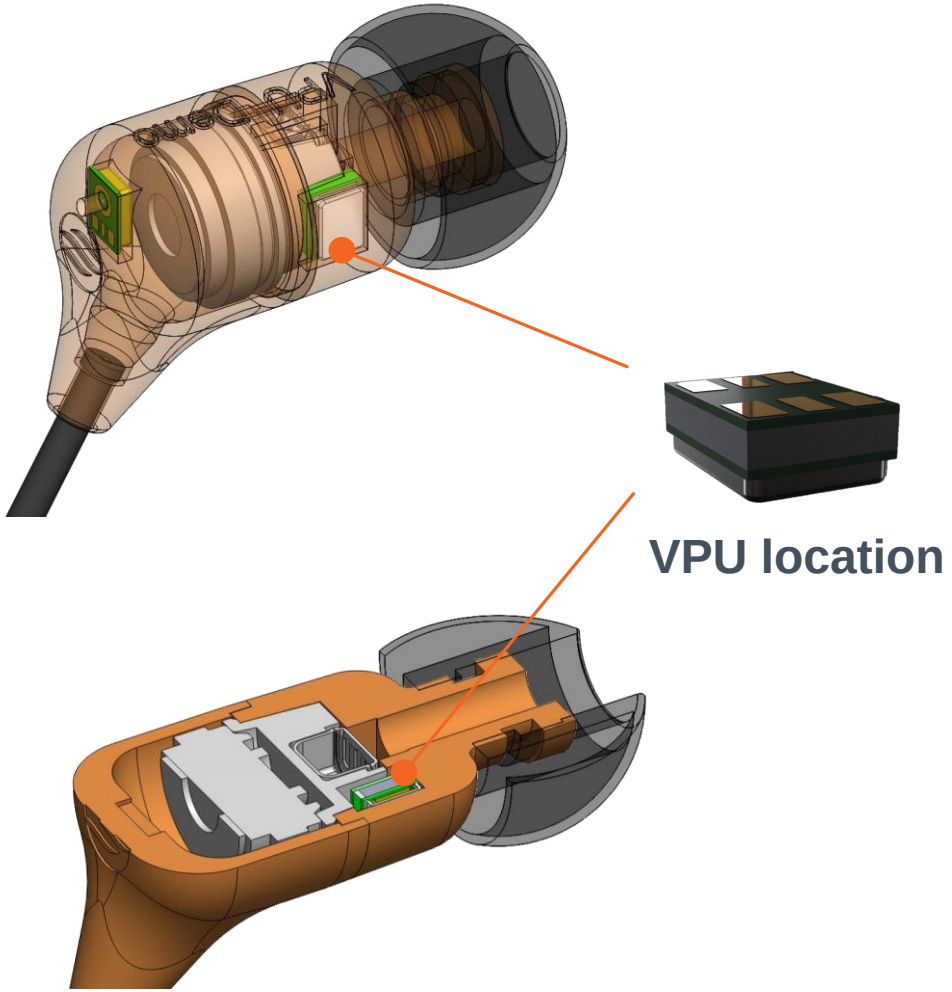
- Voice pick up in noisy situation
- Voice Detection
- Tap detection
- Barge-in
- Voice ID

## Use cases (in background noise)

| Sensors | Voice Activity Detection | Voice recognition | Voice pickup | Barge-in | Tapping | Ear wax proof |
|---|---|---|---|---|---|---|
| VPU | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Ear canal mic | ✗ | ✗ | ✗ | ✗ | ✓ | ✗ |
| Accelerometer | ✓ | ✗ | ✗ | ✗ | ✓ | ✓ |

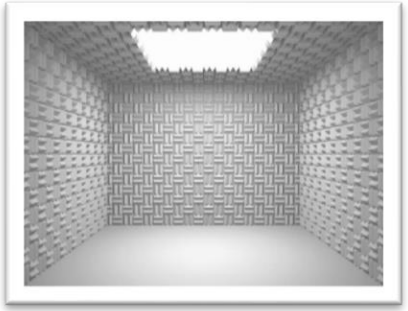
# Voice Pick Up in windy conditions

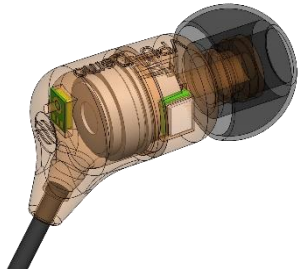


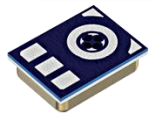
# Voice Pick Up in noisy environment

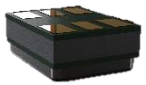
*Silent environment*

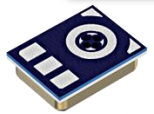


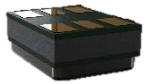



*Noisy environment*







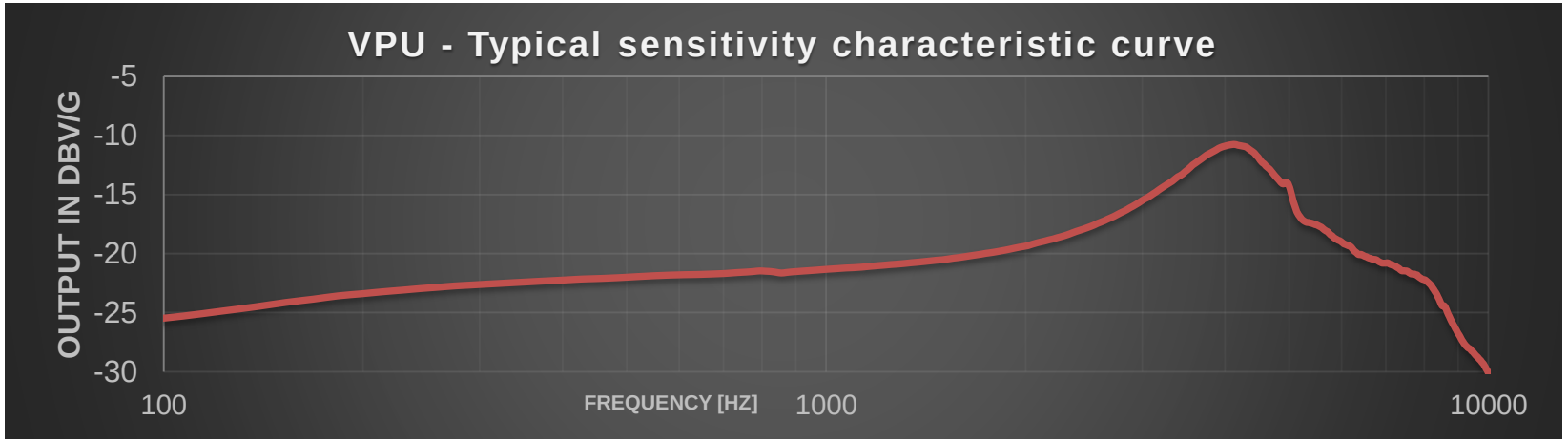


Earbud mic silent

VPU silent

Earbud mic + 78dBA noise

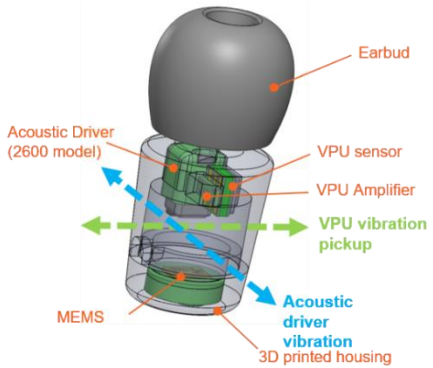
VPU + 78dBA noise



# Barge In Functionality

## Description

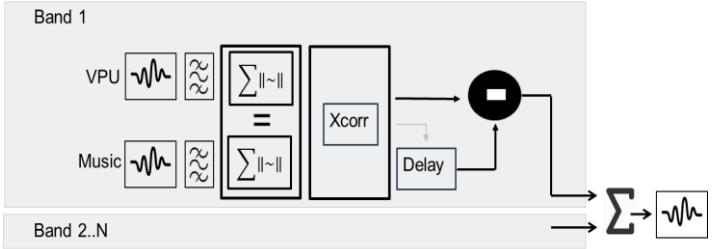
- Earbud with Balanced Armature receiver
- VPU mounted in next to the receiver
- The receiver is playing loud music




VPU + 78dBA noise + Beyoncé

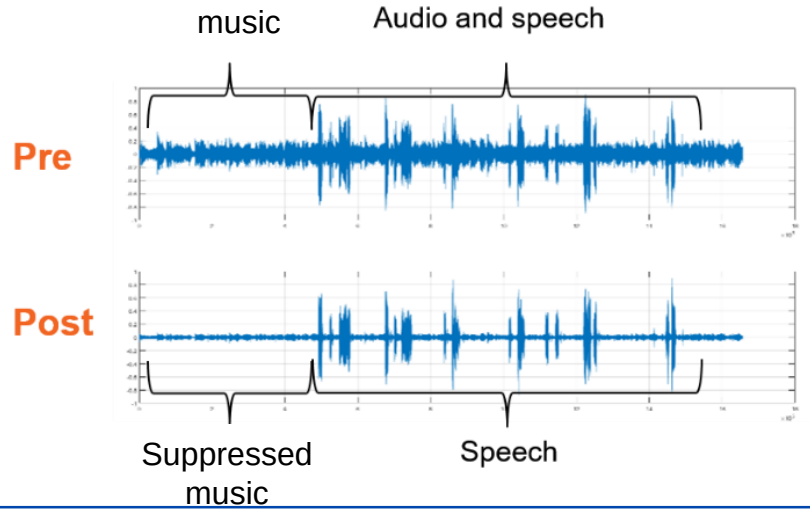
- Optionally: apply feedback suppression algorithm

*Cross talk suppression algorithm*




## Conclusions

- The VPU is always able to pick up own voice, even when playing music
- VPU can be used to give voice commands to google, Siri or other voice recognition systems
- The signal levels of a casual voice is well above the receiver crosstalk signal level
- The receiver crosstalk can be suppressed relatively easy by signal processing



# Tap Detection

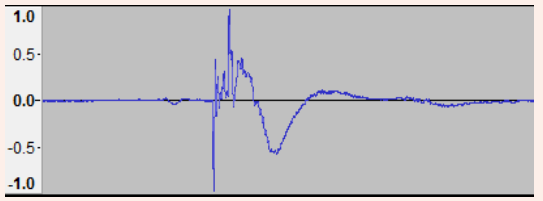
## Description

- Tapping detection has widely integrated in the modern digital products (smart phone, wearables, hearables, etc).
- Tapping can provide the user an interactive way to control the device by gestures
- Sonion VPU has been used in an in-ear device for single and double tap detection.

## Conclusions

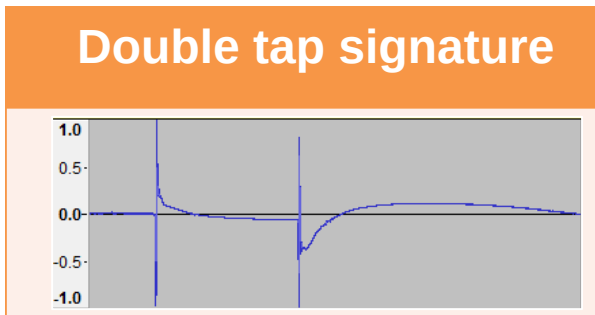
- By designing a software (algorithm) VPU detects single and double tapping signatures.

**Single tap signature**




Tap signature at sampling rate 44100Hz

**Double tap signature**




Tap signature at sampling rate 44100Hz

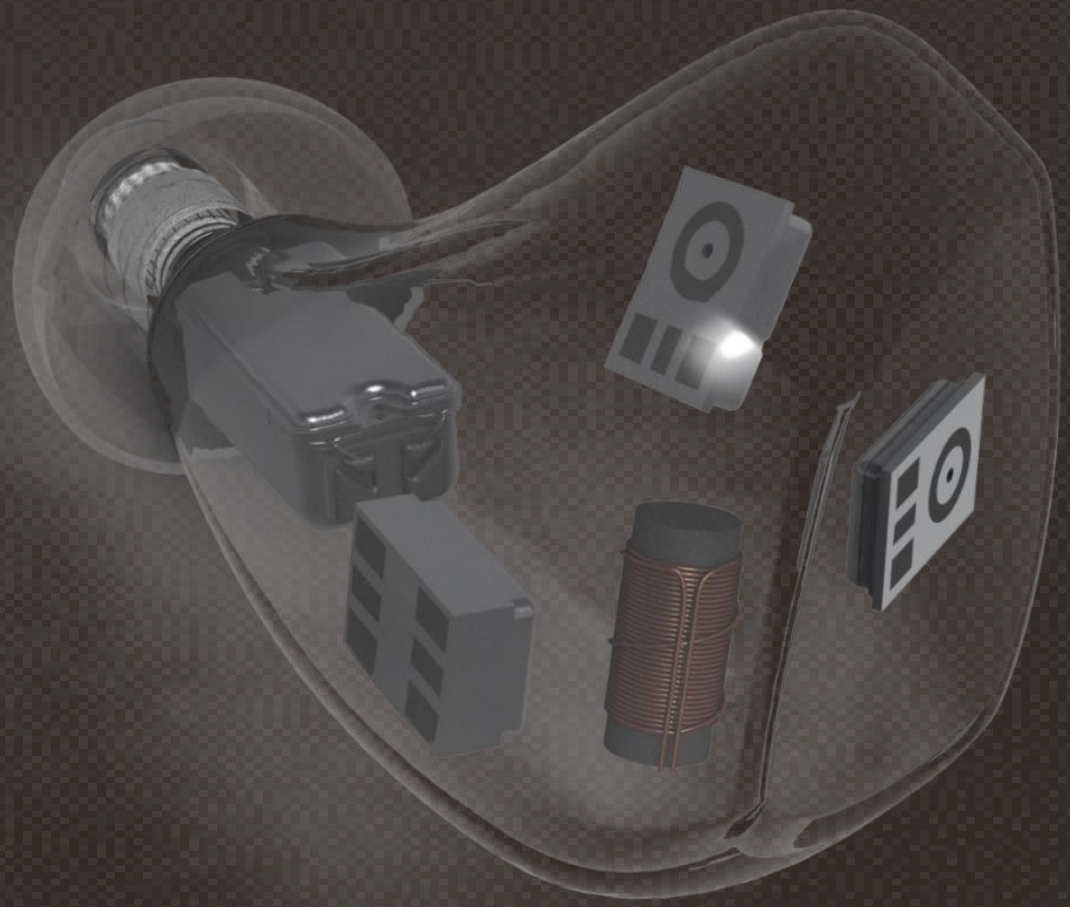
# Use-cases - summary

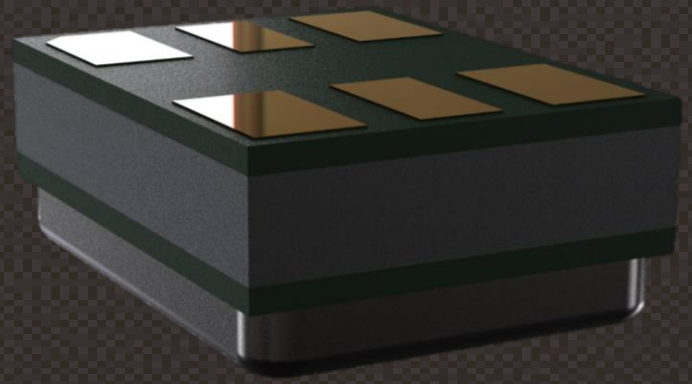
- Voice pick up in noisy situation
- Voice Detection
- Tap detection
- Barge-in
- Voice ID

## Use cases (in background noise)

| Sensors | Voice Activity Detection | Voice recognition | Voice pickup | Barge-in | Tapping | Ear wax proof |
|---|---|---|---|---|---|---|
| VPU | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Ear canal mic | ✗ | ✗ | ✗ | ✗ | ✓ | ✗ |
| Accelerometer | ✓ | ✗ | ✗ | ✗ | ✓ | ✓ |

# Application Guidelines

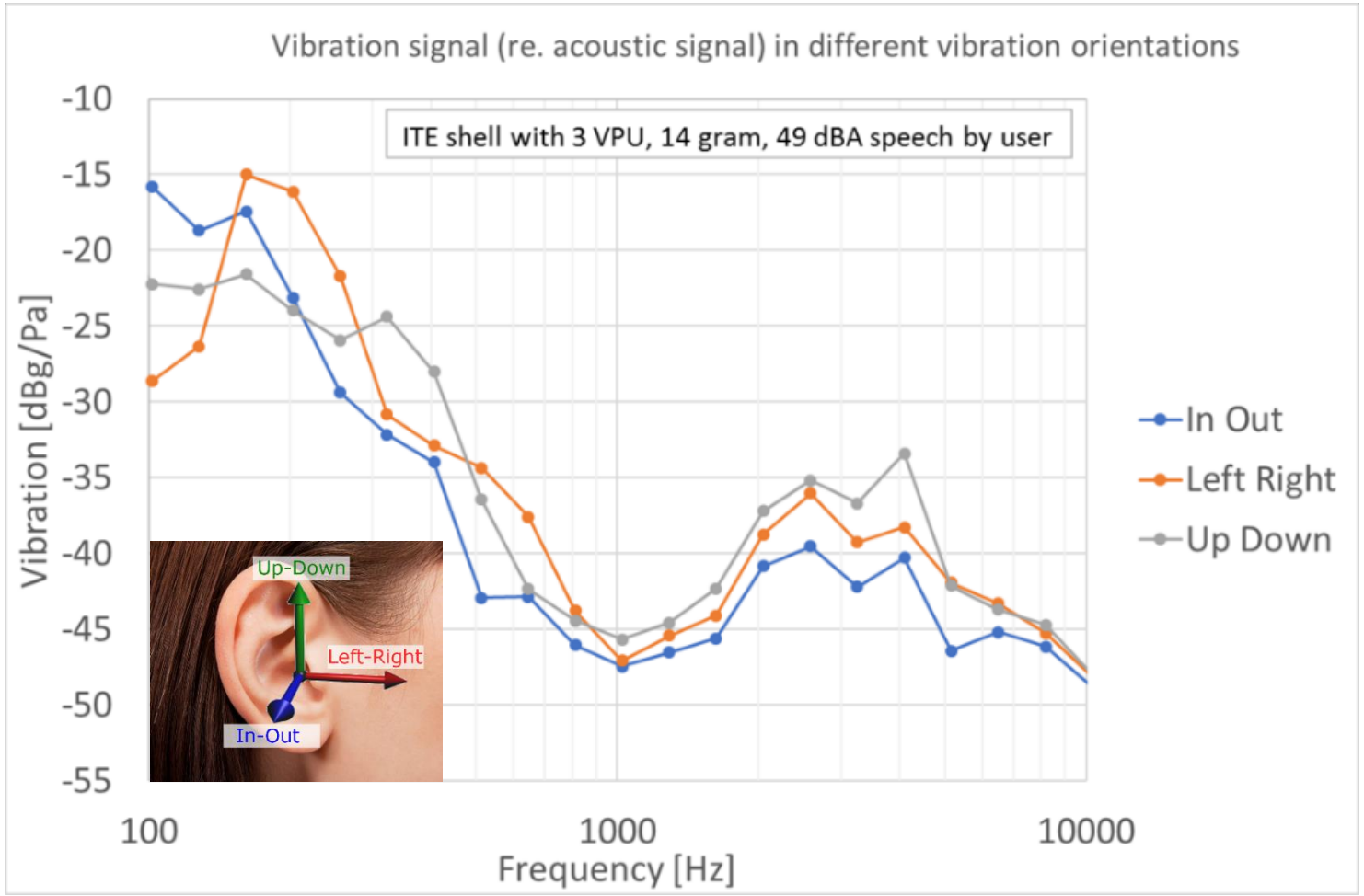


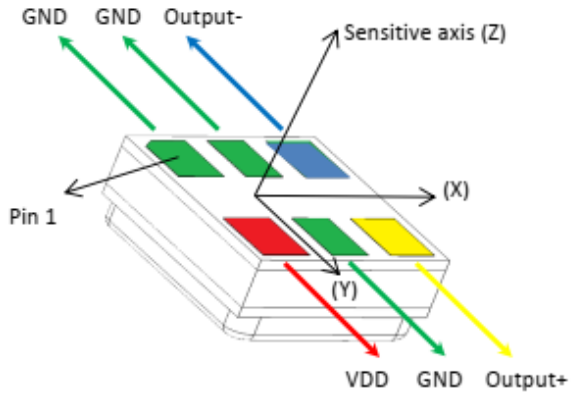


Sensor to pick up voice by bone conduction

**Finds your voice in the noise**

# How to mount the VPU sensor in the earbud ?




## Sensor Orientation

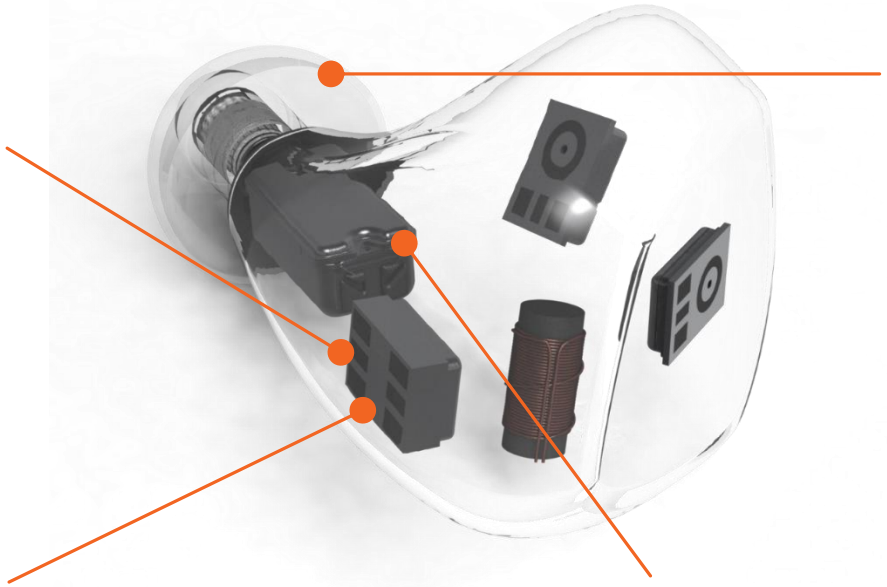
- VPU works in all three directions
- If you have the design freedom: in-out is slightly worse.

# How to mount the VPU sensor in the earbud ?

Use-cases successfully proven in all key designs !

## Mounting the VPU on PCB

- The Sonion VPU is designed to be reflow soldered directly onto a printed circuit board
- There is no need for a hole in the PCB, as the VPU is completely sealed sensor and does not require a sound inlet



## Mounting the VPU in the housing

- The VPU should be mounted in a location inside the housing/shell where it contacts the ear canal
- The VPU should be secured using some type of permanent adhesive/glue.

## Wired Applications

- When using wires, running them over the ear reduces vibration noise

## Effect of dome hardness

- At low vibration levels (casual conversation) the hardness of the domes does not have a big influence on the vibration transmission
- At high vibration levels (loud conversation) a softer dome does not provide adequate transmission of the own voice at frequencies above 1kHz. This results in a lower sensitivity for soft domes
- For optimum voice pickup we recommend using the hardest dome available for the application

## Receiver cross-talk

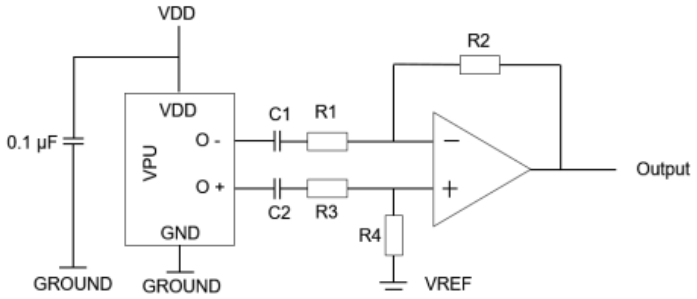
- Mount the VPU orthogonal to the driver's membrane helps reduce crosstalk
- X and Y are the least sensitive axis. Keeping the membrane's displacement in the (XY) plane helps with crosstalk

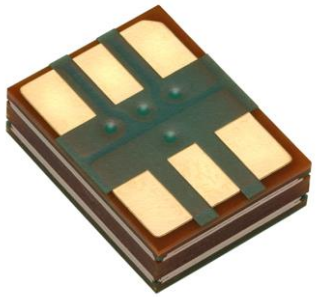
# Electrical connections

## The VPU can be used with 4-wire (differential) and 3-wire (single-ended)

### Differential output

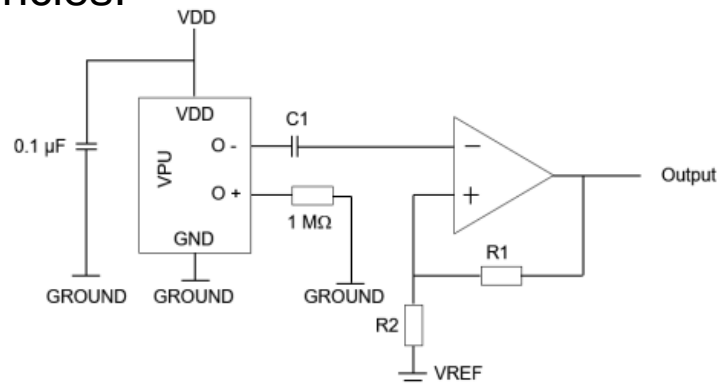
- The VPU has an analog differential output
- A ceramic capacitor could be placed close to the power supply pad of the VPU, to adequately decouple the VPU from any power supply noise.
- A DC blocking capacitor is required at the output of the VPU, and the resistor and capacitor values can be chosen based on the required cut-off frequencies.



### Single ended

- In 3-wire application, only one of the outputs of the VPU is used: the result is 6dB loss in sensitivity and possibly higher EMI noise
- The unused output can be left open, or be grounded via a 1Mohm resistor
- A DC blocking capacitor is required at the output of the VPU, and the resistor and capacitor values can be chosen based on the required cut-off frequencies.



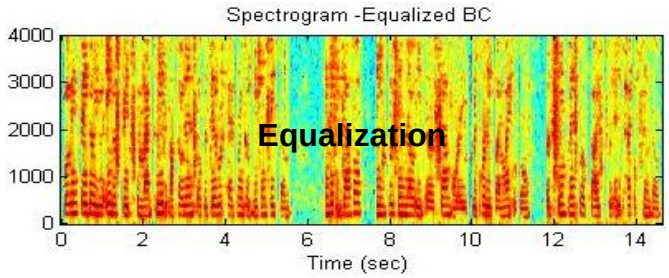
# Combining Microphone signal and VPU will enhance own voice pick-up even further

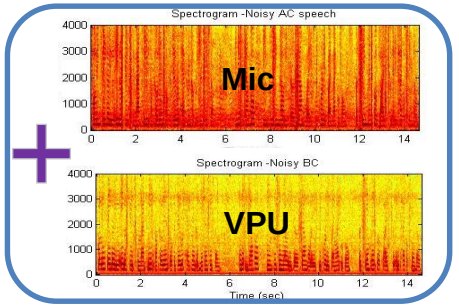
## Combining microphone and VPU Sensor signals:

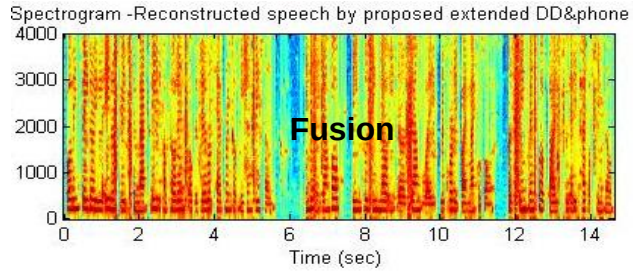
- VPU sensor: has no noise but speech has relatively low frequency content
- Microphone: picks up ambient noise, but has high frequency speech content

## Two ways to combine the signals

- **Equalization** – offline – apply a clean microphone filter to the VPU signal. This method needs algorithm to be trained and needs a calibration phase.
- **Fusion** – real-time - intelligently fuse the microphone signal with VPU signal in real-time

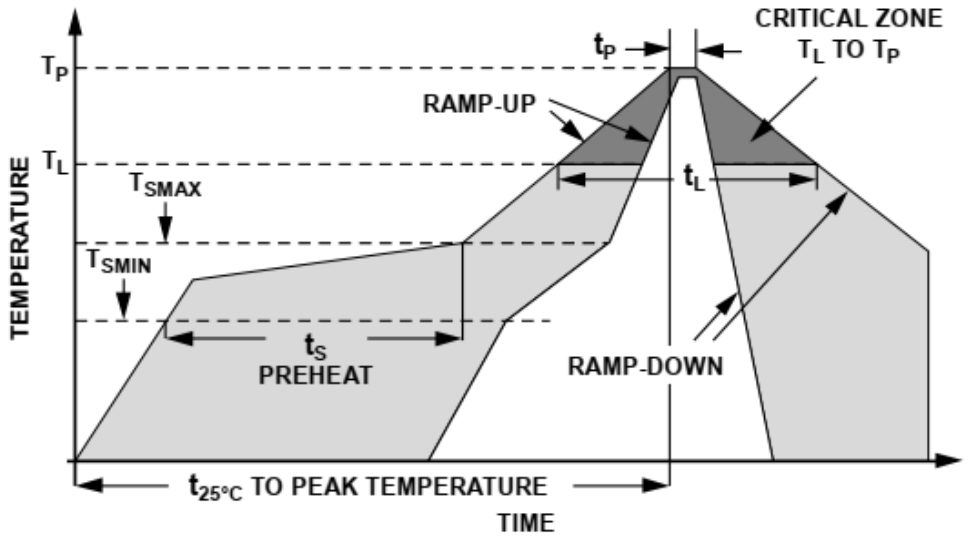


# Soldering profile

Same as any MEMS microphone




| PROFILE FEATURE | | Sn63/Pb37 | Pb-Free |
|---|---|---|---|
| Average Ramp Rate ($T_L$ to $T_P$) | | 1.25°C/sec max | 1.25°C/sec max |
| Preheat | Minimum Temperature ($T_{SMIN}$) | 100°C | 100°C |
| | Minimum Temperature ($T_{SMIN}$) | 150°C | 200°C |
| | Time ($T_{SMIN}$ to $T_{SMAX}$), $t_S$ | 60 sec to 75 sec | 60 sec to 75 sec |
| Ramp-Up Rate ($T_{SMAX}$ to $T_L$) | | 1.25°C/sec | 1.25°C/sec |
| Time Maintained Above Liquidous ($t_L$) | | 45 sec to 75 sec | ~50 sec |
| Liquidous Temperature ($T_L$) | | 183°C | 217°C |
| Peak Temperature ($T_P$) | | 215°C +3°C/–3°C | 260°C +0°C/–5°C |
| Time Within +5°C of Actual Peak Temperature ($t_P$) | | 20 sec to 30 sec | 20 sec to 30 sec |
| Ramp-Down Rate | | 3°C/sec max | 3°C/sec max |
| Time +25°C ($t_{25°C}$) to Peak Temperature | | 5 min max | 5 min max |

# Sealing the vent hole

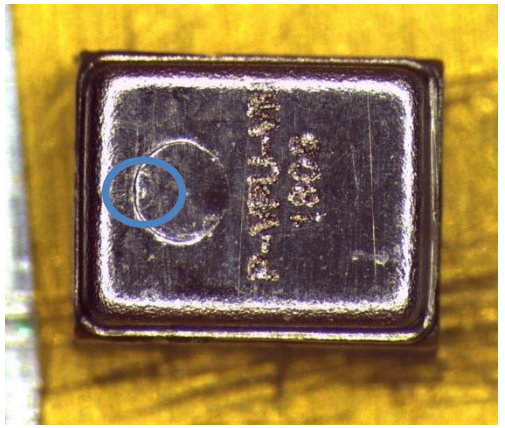
- After assembly into the application, the small vent hole should be sealed by lacquer or glue
- Sealing the vent hole ensures there is no acoustic leakage and makes the VPU IP67 compliant
- Please do not seal this vent hole before the reflow process, as there is a risk that the trapped air inside the VPU will expand and cause damage to the sensor

- Recommended glues/lacquer

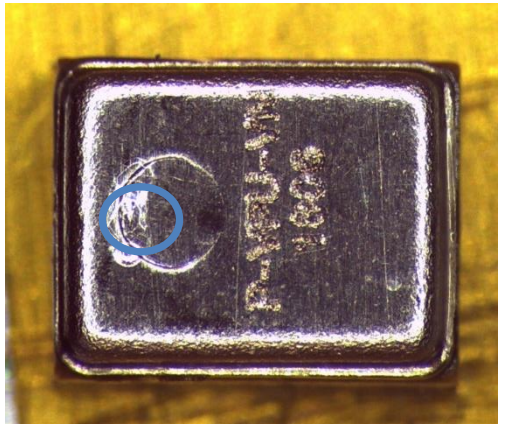
| Type | Description | Curing | Potlife | Layer thickness |
|---|---|---|---|---|
| Loctite 3921 | UV acrylic | 2-5 sec<br>100 mW/cm² @ 365 nm | - | 0.03 mm |
| Epotek 360 | 2c Epoxy | 1hour@80°C | 6 hours | 0.03 mm |
| HI-VEE Lacquer 0652 | Clear varnish based on acrylic resin dissolved in white spirits | 1-2 hrs@ 20°C<br>30 mn@100°C | - | 0.05 mm |

**Note, cyanoacrylate or low viscosity glue/lacquers should not be used*

*Location of vent hole*

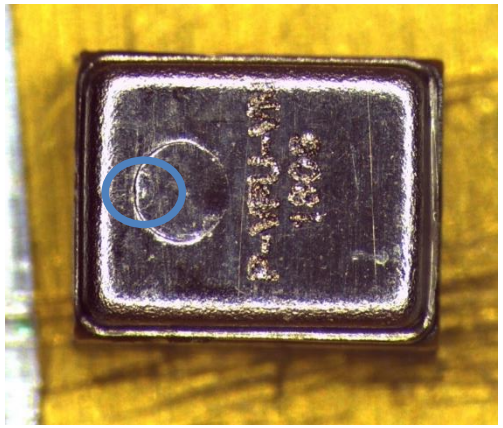



**Open vent hole**

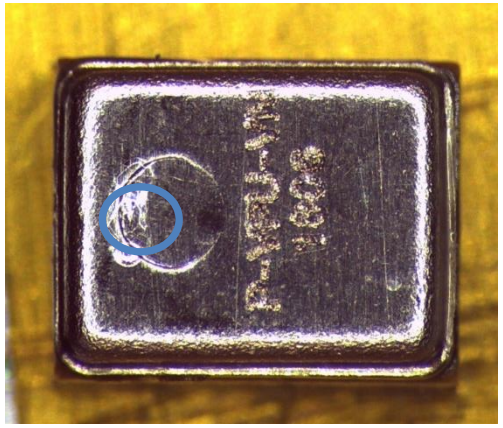


**Closed vent hole**

# Sealing the vent hole



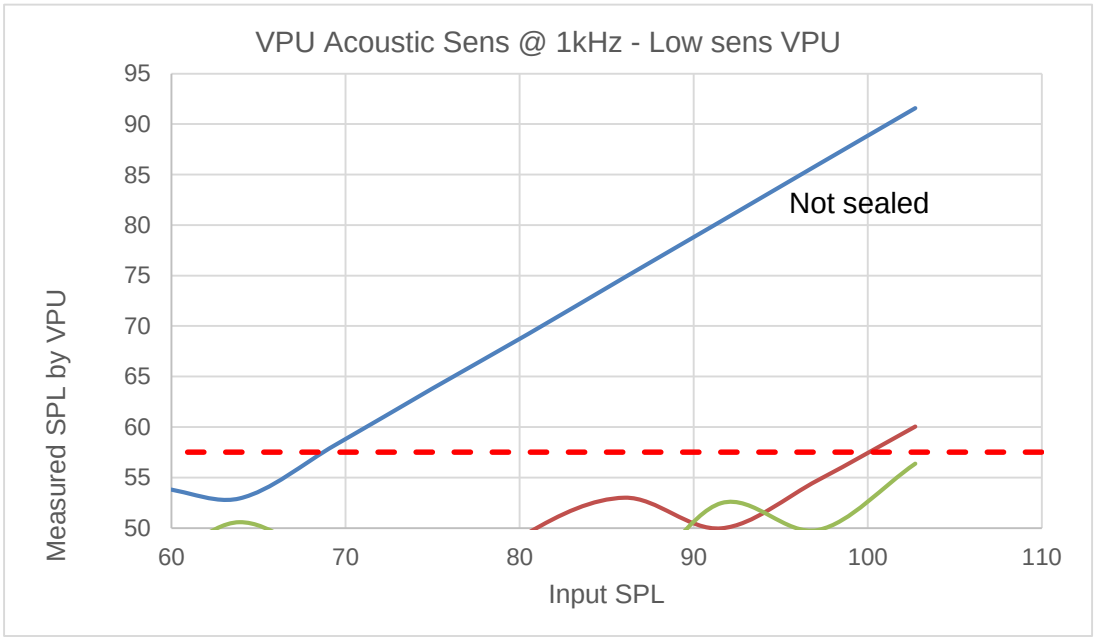
**Open vent hole**



**Closed vent hole**

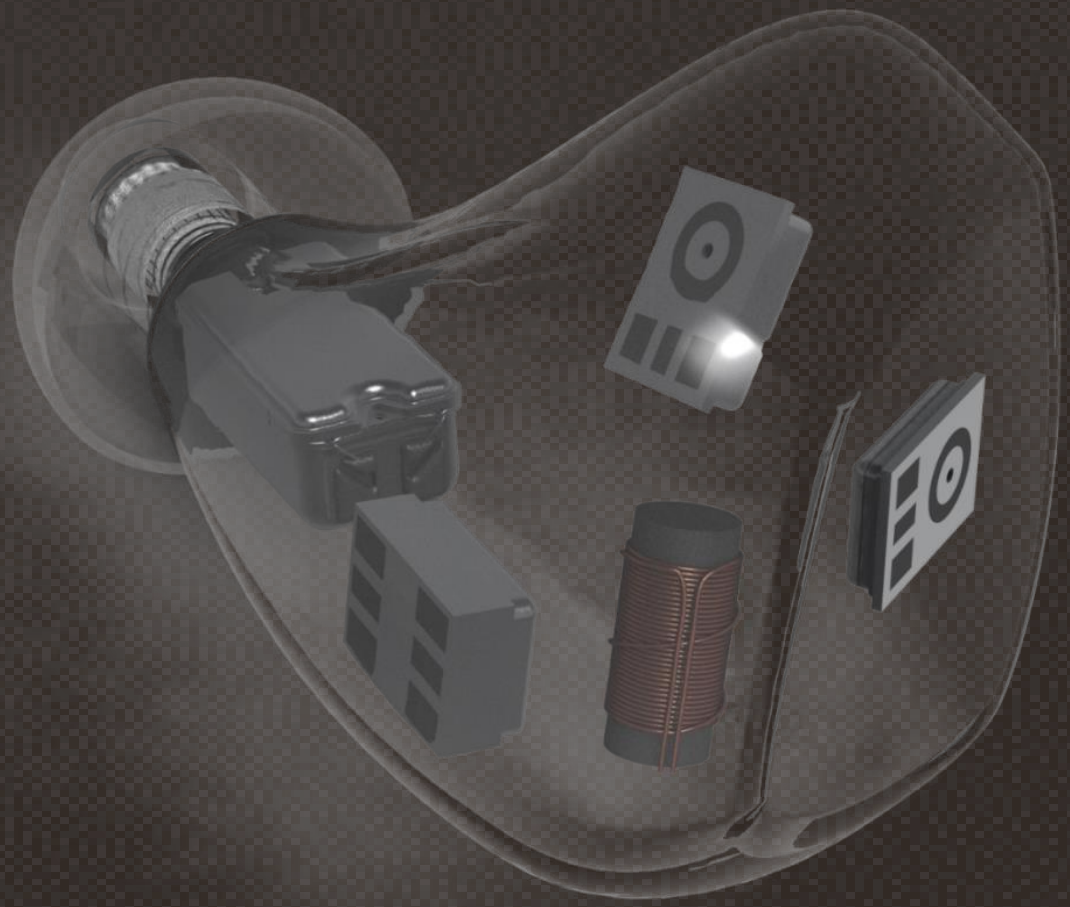
## Acoustical Sensitivity

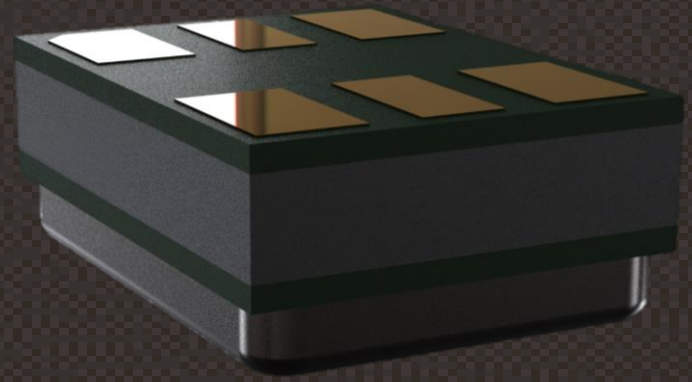
- VPU is virtually insensitive to acoustic signals when sealed (whether by tape / putty /…)
- If properly sealed, the VPU will not pick-up acoustic signals by itself



# VPU demo instruction - Speech in background noise

# Summary





Sensor to pick up voice by bone conduction

## Finds your voice in the noise

**Mass Production Q4 2018**

# Summary

**Performance**

- Low Noise
- High bandwidth
- Small Size
- Water & Dust proof
- Not sensitive for acoustics

**Use-cases**

- Voice Pick Up
- Voice Detection
- Barge In
- Tap Detection

**Application**

- Mounting guidelines
- Electrical connections
- Sealing the vent hole
- VPU demo

# Questions ?

**Paul Clemens**
Head of Product Management Sonion

pcl@sonion.com

# Questions ?

# Thank You!