HUMANIZING THE DIGITAL EXPERIENCE
TDK Developers Conference 2018
Sonion Voice Pick Up (VPU) Sensor

Finds your voice in the noise

Paul Clemens, head of product management, Sonion
Agenda

• Introduction
• Basic Principle & Product Specifications
• Use-case Examples
• Application Guidelines
• Summary
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
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**
- MEMS microphone
- Light membrane
- Due to low mass, measurable pressure change is very low

**System with Mass**
- MEMS microphone
- Additional mass
- Due to additional mass, significant measurable pressure change
Performance

✓ High SNR
✓ Small size
✓ Hermetically sealed

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

Noise density:
- 3.4 µg/√Hz at 250Hz
- 1.2 µg/√Hz at 1kHz
Performance

✓ High SNR
✓ Small size
✓ Hermetically sealed

With a size of 3.5 x 2.65 x 1.5 mm (only 14 mm³), 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)

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Voice Activity Detection</th>
<th>Voice recognition</th>
<th>Voice pickup</th>
<th>Barge-in</th>
<th>Tapping</th>
<th>Ear wax proof</th>
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<tbody>
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<td>VPU</td>
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<td>✗</td>
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</tbody>
</table>
Voice Pick Up in windy conditions
Voice Pick Up in noisy environment

Silent environment

Earbud mic silent  VPU silent

Noisy environment

Earbud mic + 78dBA noise  VPU + 78dBA noise

VPU - Typical sensitivity characteristic curve

OUTPUT IN DBV/G

FREQUENCY [HZ] 100 1000 10000
**Barge In Functionality**

**Description**
- Earbud with Balanced Armature receiver
- VPU mounted in next to the receiver
- The receiver is playing loud music
- Optionally: apply feedback 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

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Use cases (in background noise)

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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?

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.

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

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

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Curing</th>
<th>Fully</th>
<th>Layer thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loctite 3921</td>
<td>UV acrylic</td>
<td>2.5 sec</td>
<td>100 mlW/cm² @ 365 nm</td>
<td>0.03 mm</td>
</tr>
<tr>
<td>Epoxyte 360</td>
<td>Epoxy</td>
<td>1 hour@80°C</td>
<td>6 hours</td>
<td>0.03 mm</td>
</tr>
<tr>
<td>Hysol Lacquer 0452</td>
<td>Clear varnish based on acrylic resin dissolved in white spirits</td>
<td>1-2 min@20°C 30 mm@100°C</td>
<td>-</td>
<td>0.05 mm</td>
</tr>
</tbody>
</table>

*Note: any lacquers or viscoelastic glues/lacquers should not be used.
Sealing the 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

![Graph showing VPU Acoustic Sensitivity](image_url)

- Open vent hole
- Closed vent hole
VPU demo instruction - Speech in background noise

1. Connect the jack plug to the phone
2. Connect the jack plug to the circuit board and put the toggle switch on VPU.
3. Insert the earbud in the ear canal securely with good attachment to the ear.
4. Connect the speaker to the computer
5. Play the background noise very loudly. Speaker should be at 1 m distance from the earbud wearer on the same side of the earbud microphone.
6. Open the audio recording app and start recording own voice. Say some sentences.
7. While recording, change the toggle switch to the mic and continue own voice recording.
8. Playback the own voice recording and compare the speech pick up by VPU and microphone.

Play 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
Humanizing the Digital Experience: TDK Developers Conference 2018
Questions?

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Thank You!