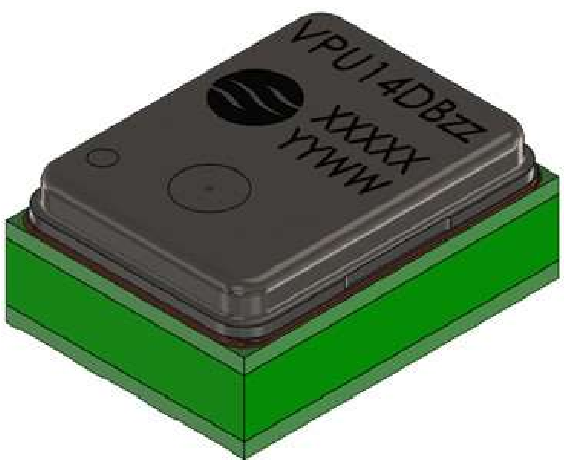
Voice Pick Up Sensor
with Digital PDM Interface



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Introduction

The Sonion Digital Voice Pick Up Sensor is a high-performance bone conduction sensor optimized for picking up a user's own voice.
The Digital Voice Pick Up (VPU) Sensor enhances communication in noisy/challenging types of environments. Picking up your own voice via vibrating bones in your skull and jaw, results in an intelligible voice with high SNR, high bandwidth and without the ambient sound/background noise. This highly intelligible signal from the VPU is perfect for accurately controlling a voice operated input system. For product details and specifications see the Sonion Digital VPU Datasheet.

Basic Features

- Digital Pulse Density Modulation (PDM) interface
- Small size 3.5 mm x 2.65 mm x 1.5 mm (13.9 mm^3)
- High bone conduction sensitivity (-12 dBFS/g) with ultra-low noise (-75.5 dB_A)
- Large bandwidth up to 8 kHz
- Optimized for picking up users' own voice on different positions on the human head
- Ultra-low power consumption (typ. 120 µA), designed to help save battery life in continuous active mode
- Halogen Zero
- REACH & RoHS Compliant
- Reflow solderable (SMD)
- Full hermetic package[1]

Applications

- Hearable / wearable devices, such as True Wireless Stereo earbuds, smart glasses, head worn devices, intelligent glasses, VR glasses
- On- / Over-ear headphones
- Professional headsets, such as call center headset, pilot headset, motorcycle headset
- Communication systems
- Smartphones

This application note provides background information and guidelines for implementation of the Sonion Digital VPU into your wearable/hearable housing design. The tiny size of the VPU package makes it ideal for usage in discrete and reliable communication devices.

[1] With sealed vent hole after VPU (reflow) soldering.

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This application note covers the following:

- Mechanical design considerations
- Electrical connections
- Application-enabling performance aspects
- Measurement set-up
- Reference design

Mechanical design

The Sonion VPU sensor 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 a completely sealed sensor and does not require a sound inlet. However, the VPU has a tiny vent hole that needs to remain open during reflow soldering and must be sealed afterwards (see handling of the VPU). The VPU, PCB and mechanical housing form a mechanical system that can affect the frequency response of the VPU sensor. This application note provides recommendations to ensure optimum bone conduction pick up performance and to achieve the best signal from the VPU. The following topics will be covered in the mechanical design section.

- Bone conduction transmission of own voice
- Mounting of the VPU in the housing
- Handling of the VPU
- Suggestions on glue/lacquer type
- Effect of dome hardness in closed-fit applications
- The VPU design considerations in wireless/wired applications

Bone conduction transmission of own voice

Publicized research has shown that human own voice transmission by bone conduction has limited speech pickup in the high frequencies above 3 kHz. Human skin behaves as a low pass filter and the higher speech frequencies of own voice pickup are attenuated by skin and soft tissue.

For more information, refer to the article *Hearing one's own voice during phoneme vocalization-Transmission by air and bone conduction, Reinfeldt et al, J. Acoust. Soc. Am. 128(2), August 2010*.

The Digital VPU provides the possibility to register the complete speech frequency range including these attenuated higher frequencies. And when compensated for by additional gain in the higher frequency regions, the resulting voice pick-up can be close to natural.

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Mounting of the VPU into the earbud

The VPU should be mounted on a printed-circuit board with rigid connection to the housing/shell, or just in a location of the housing/shell where it is easy to pick up bone vibration, and the VPU should be secured using some type of permanent adhesive/glue.

Figure 1 shows the VPU has a single sensitive axis (Z). When a person speaks, the whole skull vibrates. The speech induced skull vibration can be picked up on different head spots, such as ear canal, concha, behind the ear or nasal bridge. The VPU sensor should be ideally placed in the location and in the direction where the most bone conduction is transmitted for a person's own voice.

In other words, we have a wanted (H1: speech vibration) and an unwanted (H2: environmental vibration) transfer function to the VPU. An optimal VPU placement ensures that H1 is maximum and that H2 is minimum. This is very dependent on the specific design. For instance, to minimize crosstalk from moving coil speaker as H2, the sensitive axis Z of VPU is better to be orthogonal to the diaphragm of the speaker.
Figure 2 shows examples of VPU positions vs. MC(Moving coil) inside the earbud: position 3 VPU sensitive axis Z parallel to the MC vibration orientation, position 1 VPU sensitive axis Z give about 30° angle to the MC vibration orientation, and position 2 &4 VPU sensitive axis Z are both orthogonal to the MC vibration orientation. Figure 3 Curves show the crosstalk from MC to VPUs.

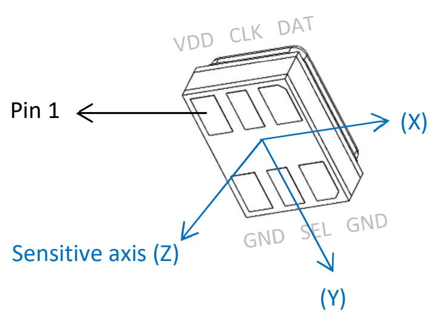

Figure 1 Sensitive axis (Z) of VPU

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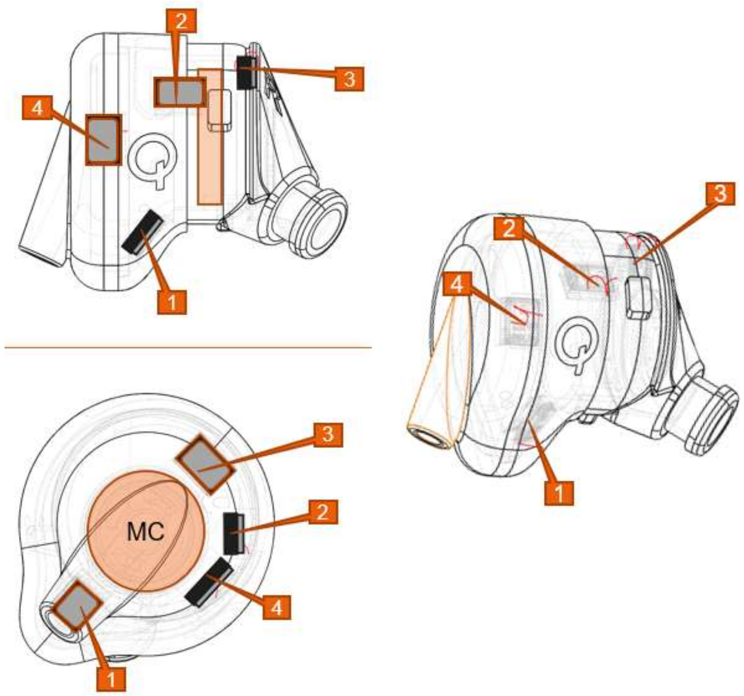

Figure 2 Examples of VPU positions vs. Moving coil

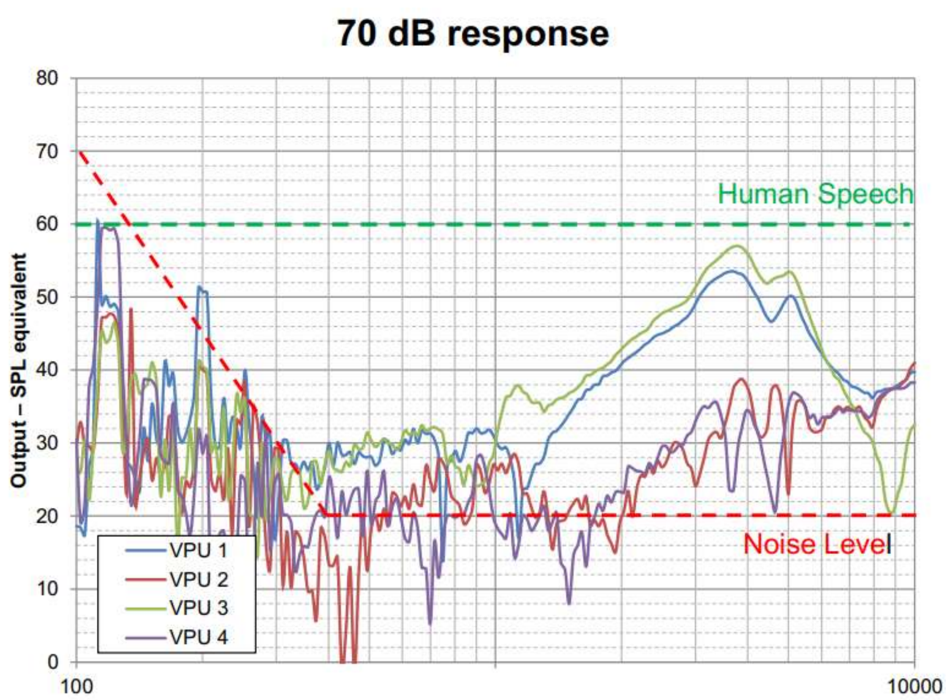

Figure 3 Crosstalk from MC to Different VPU positions

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Handling of the VPU

Please follow Sonion's generic application note *Handling of Transducers*.

After reflow soldering, the small vent hole should be sealed. Sealing the vent hole ensures there is no acoustic leakage and makes the VPU hermetically sealed. Please **do not seal this vent hole before the reflow soldering process**, as there is a risk that the trapped air inside the VPU will expand and cause damage to the sensor. Figure 4 shows the location of the vent hole on top side of VPU. Use lacquer or glue of the correct viscosity in order to prevent glue or lacquer to enter the vent hole and compromising the performance.

Please **do not blow compressed air directly into the vent hole** before sealing and curing the hole. This can permanently damage the VPU sensor. **Please do not let foreign material(s) enter the vent hole** also, that may downgrade the VPU performance.

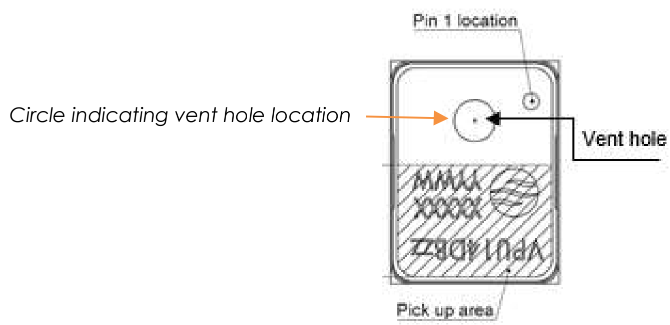

Figure 4 Location of the vent hole

If the VPU is mounted on the plastic housing/shell with glue/lacquer as shown in below figure 5 and figure , it is still recommended to seal the vent hole before mounting / gluing the VPU to its housing. If the VPU is mounted on rigid PCB/FPCB, the small vent hole should be sealed after reflow soldering, and ensure VPU make rigid contact with the device housing/shell.

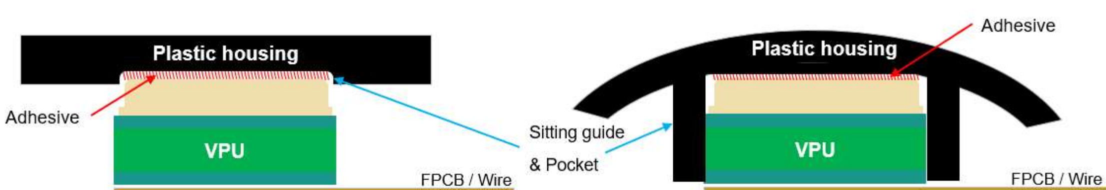

Figure 5 VPU mounting on plastic housing

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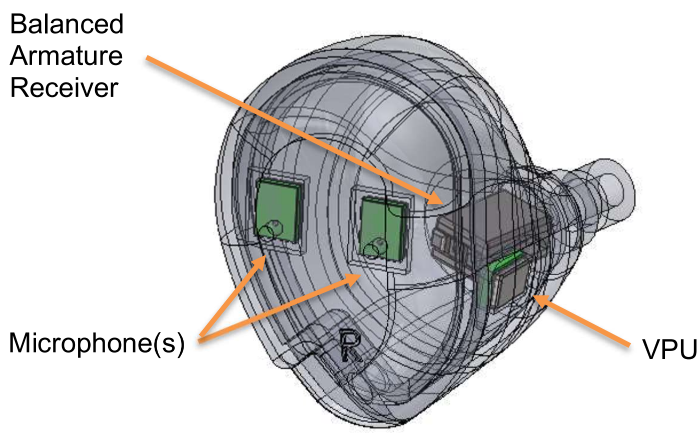

Figure 6 VPU mounting in a right earbud

Suggestions on vent hole sealing material

To ensure appropriate sealing the vent hole and attach the VPU on the plastic surface, Sonion recommends glues/lacquers with viscosity > 8000mPa·s and room temperature curing. As indication – but not restricted to, the following glues can be used:

- Loctite 3211
- Loctite 3525

Sealing the vent hole by tape is also possible, but need to be checked for reliability in application.

Effect of earbud dome hardness in closed-fit applications

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

The VPU design considerations in wireless/wired applications

The VPU is mainly designed for wireless applications. If the VPU is used in wired applications like headphones, some extra measures to decouple vibration from wires to VPU are highly

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recommended. Here are some design considerations and tips in application: the cable needs to be fixated to clothing by using some sort of a cable clip. This is needed to avoid cable movement vibrations (microphonics) that would be picked up by the VPU.

For both wired and wireless applications:

- If VPU is electrically connected with wires, Litz wires which contains many very thin strands are recommended for high compliance.
- The VPU sensitive axis is recommended to be orthogonal to the main vibrating direction of speaker, i.e. diaphragm of moving coil or vibration arm of balanced armature.
- Viton tubing can be used in balanced armature applications to reduce vibration transfer to housing.
- Silicone is a poor vibration damper. Some applications are using silicone as intermedia material for vibration conduction to VPU.

For wired applications:

- The noise picked up by VPU from hard wired cable is an issue in wired applications
- Cable vibration isolation / damping measures are highly recommended, such as over the ear cable routing, a cable clip to avoid cable rubbing against cloths.

Electrical connections

The VPU can be directly connected to one of the available digital microphone input(s) of the CODEC chipset supporting Pulse Density Modulation (PDM). See figure 7 for the connection diagram.

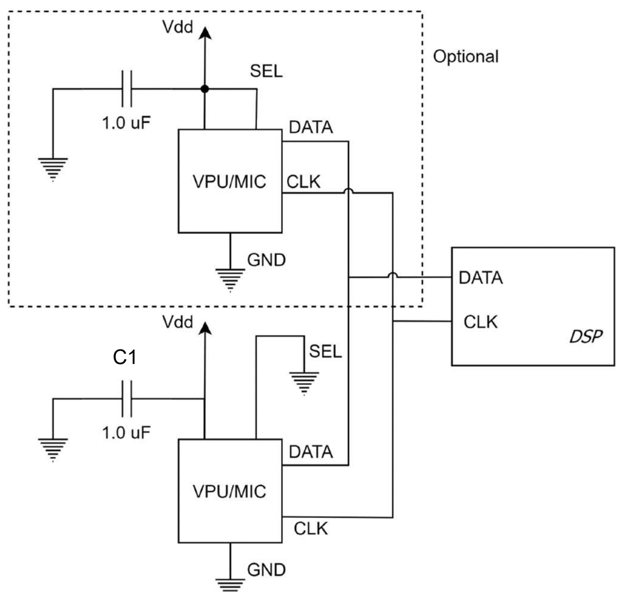

Figure 7 Connecting the Sonion Digital VPU to a PDM interface

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A 100nF - 1µF ceramic capacitor (C1) placed close to the VPU14DB01A supply pin is recommended to adequately decouple the VPU from noise on the power supply. A clean voltage supply in the application, e.g. the CODEC microphone bias supply, is recommended for the VPU VDD to ensure a minimal interference level at the signal line.

The SELECT (SEL) provides a possibility to share the same connection (DATA/CLK combination) with another digital PDM VPU or microphone. The SEL pin should be connected to either GND or VDD. When SEL is set LOW (connected to GND), the VPU output data is presented for the rising edge of the clock, while SEL set HIGH (connected to VDD) results in valid data to be present at the falling edge of the clock signal.

The CLOCK (CLK) signal is provided by the CODEC. The preferred CLK frequency is 768kHz, but also clock frequencies in nearby range will lead to similar performance of the digital VPU, as specified in the product datasheet. The CLK frequency ranges in which the VPU will function properly is presented in the State Diagram in the datasheet. Due to the digital nature of the VPU, the current consumption will increase with higher clock frequencies, while also SNR improves. 768kHz is an ideal tradeoff.

Performance

Ultra-low acoustic sensitivity

On component level, when the vent hole is properly sealed, the VPU shows virtually no sensitivity to acoustics. Note that on application level, a high acoustic level may convert into vibration that will be picked-up by the VPU. A control of the seal can be performed by exposing the VPU component to acoustic signals – hearing them as a microphone would indicates an inappropriate seal.

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Measurement set-up

The measurement setup in figure is used for frequency response measurement of the VPU.

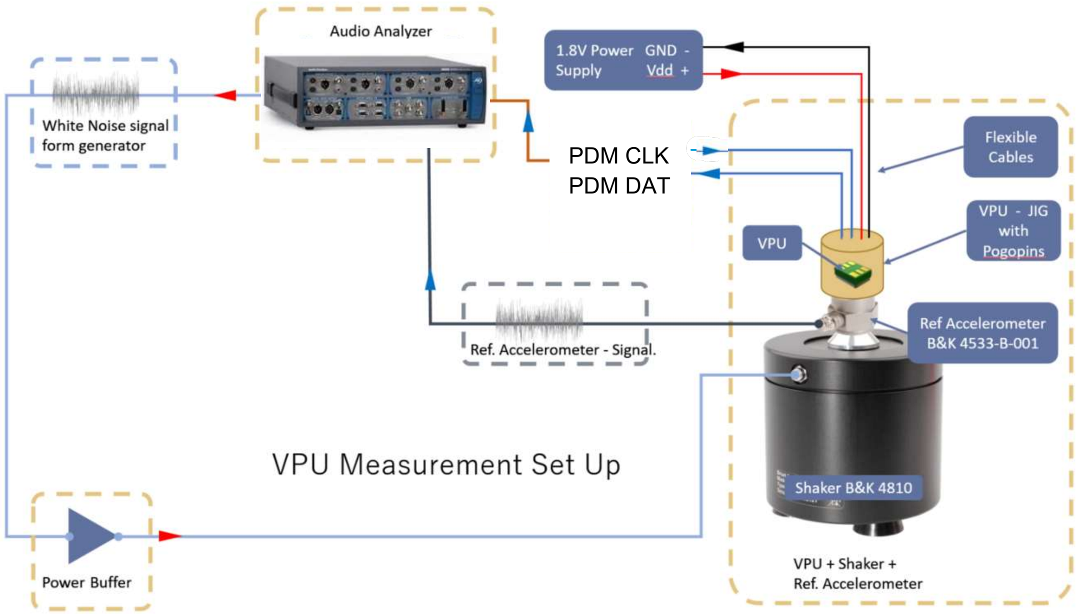

Figure 8 Sonion digital VPU frequency response measurement set up

The VPU is connected using a custom test fixture with pogo pins that connect power and signal to the VPU. The VPU is supplied using 1.8 V_{DC}. The VPU fixture is attached to a reference accelerometer (B&K type 4533-B-001) and the accelerometer is connected to a B&K shaker (type 4810). The accelerometer output is connected to the input channel of the audio analyzer. Flexible cables are used to connect the fixture to other equipment in the test setup. The digital PDM output of the VPU is connected to the inputs of the audio analyzer PDM input channel. The shaker is connected to the audio analyzer generator via a Power Buffer, which is driven with a white noise level of 100 mV_{rms}.
The frequency response of the VPU is measured by the audio analyzer from 100 Hz-10 kHz. We recommend an accelerometer, or Laser Doppler Vibrometer (LDV) as a reference sensor.

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