

eSense User Documentation

Platform, Sensors and Usage

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| Author | Pervasive Systems |
| Organization | Nokia Bell Labs, Cambridge |
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1 Platform Overview

eSense is a multi-sensory earable platform for personal-scale behavioural analytics research. It is a True Wireless Stereo (TWS) earbud augmented with a 6-axis inertial motion unit, a microphone, and dual mode Bluetooth (Bluetooth Classic and Bluetooth Low Energy).



eSense is built with a custom-designed $15 \times 15 \times 3$ mm PCB and composed of a Qualcomm CSR8670, a dual-mode Bluetooth audio system-on-chip (SoC) with a microphone per earbud; a InvenSense MPU6500 six-axis inertial measurement unit (IMU) including a three-axis accelerometer, a three-axis gyroscope, and a two-state button; a circular LED; associated power regulation; and battery-charging circuitry. There is no internal storage or real-time clock. It is powered by an ultra-thin 40-mAh LiPo battery. The carrier casing is equipped with a battery enabling recharging of eSense earbuds on the go (up to 3 full charges). Each earbud weighs 20 g and is $18 \times 20 \times 20$ mm.

The left earbud is the one containing the IMU sensor accessible through the BLE interface (refer to the **eSense BLE Specification** document for more details). Both earbuds are equipped with a microphone which can be used natively once the Bluetooth Classic interface of the earbud has been paired to a host device (e.g., phone or laptop).

Notice that this is a **research prototype** not a consumer product, so the functional behaviour may not always be as expected.

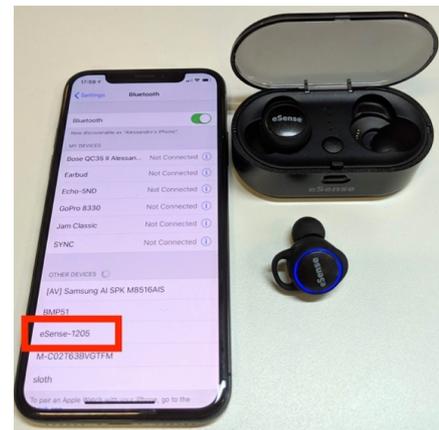
2 Getting Started

To turn on the earbuds press and hold the push button (under the eSense logo on the earbud) until the LED turns on blue, then release it. When a single earbud is on and not paired with any host device its LED will blink red, otherwise it will blink blue. To turn off an earbud press and hold the push button until the LED turns red. Switching off one earbud will switch off also the other earbud.

2.1 Pairing

The earbuds in the same case are already paired to each other and only one earbud needs to be paired to a host device. The pairing procedure connects the Bluetooth Classic interface of the earbud to the host device and allows to stream music to the earbud and record sound through its microphone.

To pair an earbud to a host device press and hold the push button until the LED starts blinking blue and red. Now the earbud is in pairing mode. In your host device you should see a new device with name *eSense- \langle Number \rangle* as shown on the right figure. You can pair the earbud by clicking this new device



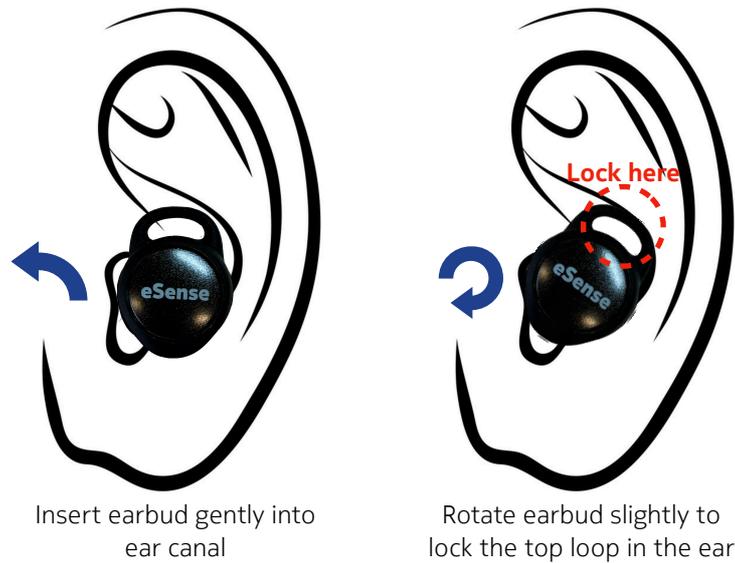
and the earbud will start blinking blue to indicate that it is paired. The earbud is now ready to be used for music listening, calls or audio recording.

Notice: we recommend pairing the right earbud to the host device when both earbuds are used. When a single earbud is in use we recommend pairing the left one which is the one containing the IMU sensor and the BLE interface. For the best experience make sure there is line of sight between the paired earbud and the host device streaming music. For example, if the right earbud is paired with a smartphone, keep the phone in the right pocket. We are aware of audio dropouts between left and right earbuds in environments with high radio noise (e.g., when there is high density of Bluetooth and/or WiFi devices nearby).

2.2 Wearing

To wear the earbuds and avoid them falling off during physical activities, insert first the earbud gently into the ear canal and then rotate it slightly to lock it in place as shown in the image

below. If the earbud does not fit comfortably (too loose or too tight) try with a different size ear tip provided.



2.3 Charging

To charge the earbuds place them in the charging case and make sure the LEDs in both earbuds turn on. Red colour means the earbud is charging, blue colour means the earbud is fully charged. The charger case is activated by pressing the button in the centre of the case, this is indicated by the four white LEDs which will turn on. A quick double press of the same button disables the charger. If the earbuds' LEDs do not turn on make sure the earbuds are well positioned in the case and make a good contact with the pins underneath them. Additionally, check that the golden pads under the earbuds and the pins in the charging case are free of dirt. Both earbuds can be fully charged in about 1 hour.



Charging

Fully Charged

Case 75% charged

The white LEDs in the centre of the charger indicate the charger's battery level in 25% steps. The case can be charged by plugging a micro-USB cable on its back. The four white LEDs will blink in sequence to indicate the charging is in progress. The earbuds will charge at the same time as the charging case.

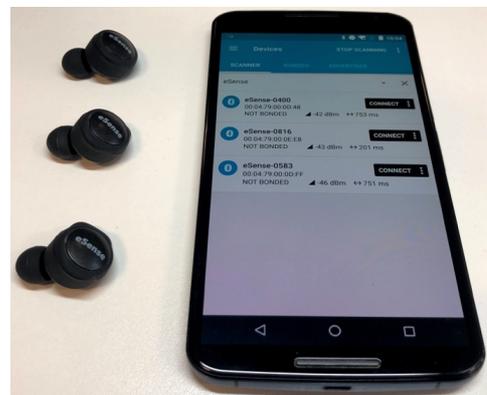
2.4 Reset

In cases when the earbuds are not working as expected or stop working, place them in the charging case and make sure the LEDs on both earbuds turn on. This will reset the earbuds.

3 Motion and Proximity Sensing – BLE Interface

All left earbuds have a BLE interface which can be used to configure various aspects of the IMU sensor and collect accelerometer and gyroscope data. The left earbuds also transmit periodic BLE advertisement packets (with an interval between 625ms and 750ms, by default), even during a BLE connection, and as such can be used for proximity detection. The right earbuds do not have a BLE interface.

Each left earbud has a unique device name in the format *eSense- \langle four digits number \rangle* . The easiest way to discover the name of an earbud is using a BLE scanner application on a host device (e.g. smartphone). We recommend Nordic nRF Connect for iOS and Android or BLE Scanner for iOS. As you can see in the image below once a scanning filter has been set up with the name **eSense** the app discovers the three earbuds and shows useful information (MAC address, RSSI and advertisement interval).



The same apps can also be used to connect to the earbuds and explore the available BLE characteristics. Please refer to the **eSense BLE Specification** for more details on the BLE interface.

Notice that it might take several seconds before the apps show the device name of the earbuds, during this initial period the apps might show only the MAC address and the other info but not the name.

The advertisement packets contain the Complete List of 16-bit Service Class UUIDs and the Complete Local Name of the device as defined by the Generic Access Profile (<https://www.bluetooth.com/specifications/assigned-numbers/generic-access-profile/>).

There is no need to pair the left earbud with a host device to use its BLE interface. The pairing of the Bluetooth Classic interface is required only to stream music to the earbud or record audio from its microphone. Only one BLE connection at the time is supported, if multiple hosts try to connect to the earbud's BLE interface at the same time, the earbud might become unstable and stop working.

4 Audio Sensing – Bluetooth Classic Interface

Both the left and right earbud have a microphone onboard. The microphone can be used to record audio samples as well as input source for phone or VoIP calls.

There is no need for special configuration to use the microphone on the earbud. Once the earbud is paired (Bluetooth Classic interface), the host device will recognise the earbud as a new input source. The audio recorded is mono, only from the earbud paired with the host device. The same happens for calls, only the speaker and microphone on the earbud paired with the host will be used during an active call.

As mentioned above either the right or left earbud (but not both) can be paired with a host device. If the left earbud is paired, the same host device can also connect to the BLE interface of the earbud to collect IMU data at the same time as audio is recorded from its microphone. The earbuds are limited devices and the achievable data rate of the sensors (microphone and IMU) might be affected by the number of operations performed. For example, if the IMU and the microphone are enabled on the same earbud while the user is also listening to music, it might not be possible to achieve the desired data rate and the music might be interrupted. In this situation it would be better to use the right earbud to record only sound samples and the left earbud to record only IMU data.

5 Orientation of IMU Axes

The figure below shows the orientation of the IMU axes and the polarity of rotation in relation to the earbud.

