Engage

An In-Ear Monitor with Ambient Aperture Technology

Allowing musicians to add ambient noise back into their performance experience.

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10 Page Summary

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THE GLASGOW SCHOOL OF ART

NOISY CLAN

Market & Context

Previously musicians relied on wedge monitors, but In-Ear Monitors (IEMs) allow reduced feedback and stage noise, more control over the user's personal mix and an improved relationship between a musician and their music.

Despite musicians at all stages of their career looking to use IEMs, the environment in smaller venues in which semi-professional musicians perform imposes different requirements for the product. Specifically, noise levels in such venues differ to what can be assumed for larger venues.

This creates a user experience which is currently not catered for in the market.

"I feel removed from the crowd and the environment. It just feels off"
- Murray Noble, Drummer, Declan Welsh and The Decadent West

Collaboration

Noisy Clan is an Edinburgh-based company who create and produce unique designs of accessories and music tools for musicians across the world to aid them on their musical journey. The relationship, which began with the company during a summer internship, led to the proposal to create a new IEM for which they would be the client. Noisy Clan wished for the project to be led by the research, and follow the design engineering process to achieve a successful product outcome based on the user requirements.

Noisy Clan agreed to offer their support by providing access to their user groups, and a product council was created to have an ongoing communication channel with IEM users. Regular meetings allowed technical support to be provided where possible and ensured key milestones were met and no important design decisions overlooked.

NOISY CLAN

Technology

Project Brief: Mission Statement

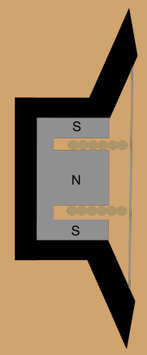
Musicians use IEMs to receive their mix directly in their ear during performance, but musicians dislike IEMs due to the occlusion effect caused, and feeling isolated and cut off from their audience. This is a major downfall in an industry where interaction, and engagement, is vital. With Noisy Clan's Engage IEMs, users can take back control of their performance environment.

The proposed solution focuses on the headset and receiver within an IEM system, which must provide semi-professional musicians with a method of controlling the amount of ambient noise they can hear whilst the IEM headset is secured in the ear. The solution must be easy to use under pressure, in the dark, whilst musicians play on stage during performances, practice and sound checks. The solution must improve the target users' overall experience of playing by allowing interaction with the audience and fellow band members, without the compromise of removing their headset or resorting to using wedge monitors.

"This is really interesting, having control over ambient sound"

- Sophie Bancroft,
Singer, Songwriter, Music Educator

"IEM" refers to the monitor system comprising of a headset (worn in the musician's ear), receiver (clipped onto a belt/guitar strap) and transmitter (central control box). When a sound engineer makes alterations to a musician's mix via their assigned transmitter channel, the mix it outputted through the musician's receiver to the headset.



The headset contains a driver, which is largely responsible for the sound quality of the system. Dynamic drivers contain a diaphragm connected to a voice coil, which moves between magnets when an electrical signal (current) is applied. Movement of the coil causes vibration of the diaphragm, and these vibrations create the audio signal which transmits to the ear canal.

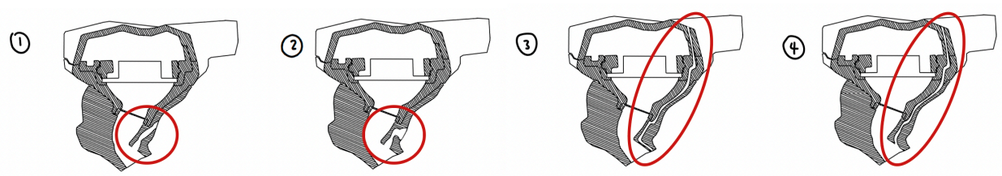
Product Design Specification (PDS)

Ambient Aperture Technology	The ability to control ambient noise, now named by the client Ambient Aperture Technology (AAT). Assigned as the highest priority specification within the PDS and is the product's USP.
Maximum Volume Control	A limit set on the sound pressure level (SPL) of 100dB(A) as per Standard EN 50332 for sound system equipment.
Cost	A high priority requirement to minimize the retail cost allowing semi-professional musicians access to the product. Achieved in numerous way, including designing for a universal fit.
Comfort	Designed to fit the majority of users' ears with a universal silicone ear tip. Future development of the product has commenced, allowing custom fitting.
Ergonomics	Designed to fit the user and operational environment of the product, including full range of motion during performance and comfortable and intuitive use of the mechanism.
Sound Quality	Dynamic drivers provide audio with 20Hz-20kHz frequency response (the entire audible frequency range) and an improved bass response than alternative balanced armature drivers.
Power Supply	Disposable batteries reduce the retail cost and provide 10 hours of battery life for the 1.5V power requirement. Users also encouraged to use at-home removable, rechargeable batteries.
Aesthetic	Industrial design work allowed creation of a faceplate which aims to celebrate interaction, function and rotation of the mechanism, with inspiration from art and jewellery.
Storage & Transportation	A storage case allows the headset, receiver and any spare parts to be stored safely in one place and transported to the performance venue, minimising the risk of damage/loss of parts.

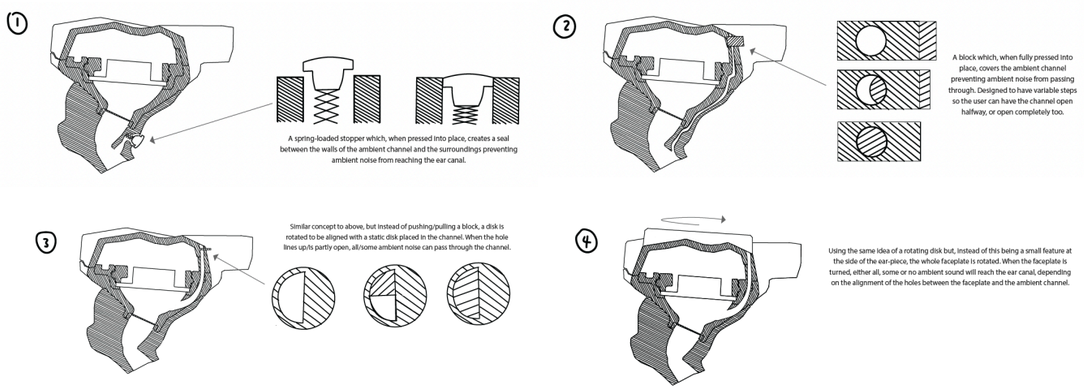
Concept Generation

Ambient Aperture Technology (AAT)

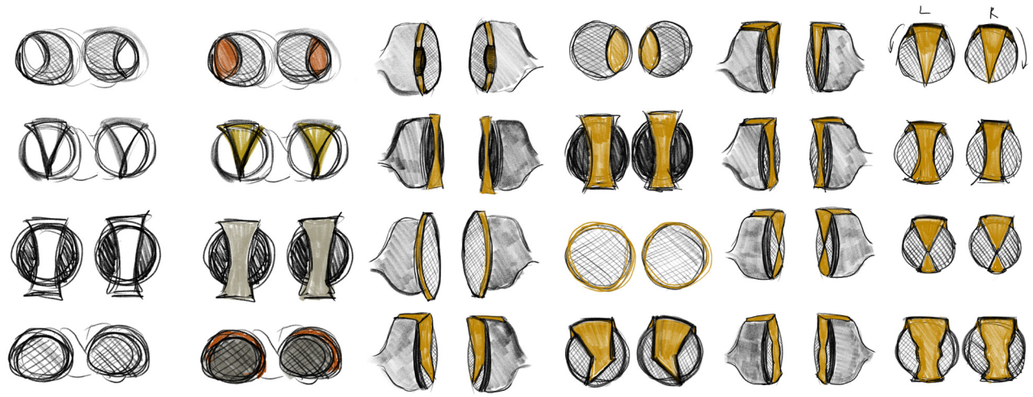
AAT allows the user to receive variable amounts of ambient noise to the ear canal. This first set of sketches explored how noise might be collected from the surroundings and travel from some external surface of an IEM headset to the internal wave guide leading into the ear canal.



The second set of sketches take these methods of collecting ambient noise, and explore how this could be controlled to allow more/less of the noise to enter the aperture and transmit through the headset to the ear canal.



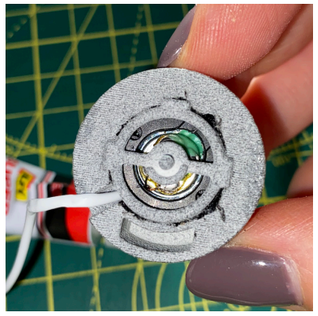
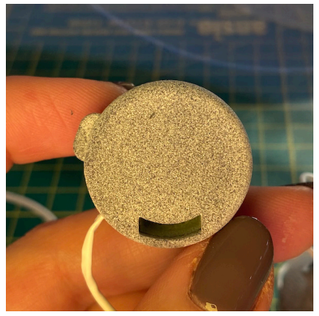
Additional phases of 2D sketching, brainstorming and creation of mind-maps and a morphological chart supported product development. Some sketches from the aesthetics and ergonomics investigation are shown here.

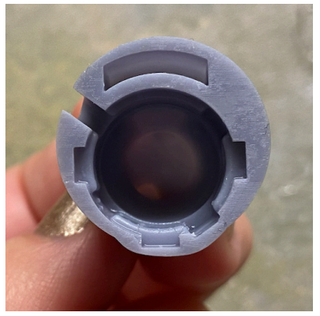
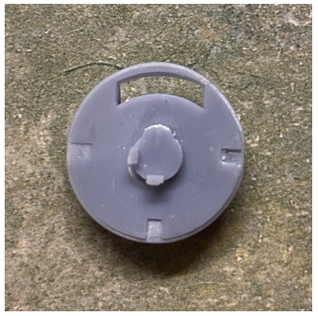













3D prototypes have undergone many iterations of development and refinement. Prototyped mechanisms were submitted for user and technical evaluation to verify the concept that would undergo further refinement. User evaluation focused on parameters such as instinctive first use of the mechanism, ease of use thereafter, error tolerance and comfort to the user. Technical evaluation considered possible tooling costs, ease of assembly, procurement and repairability.

The verified mechanism uses the principle of rotation of the exterior faceplate to open/close the ambient aperture by variable amounts.

Ambient Aperture Technology (AAT)

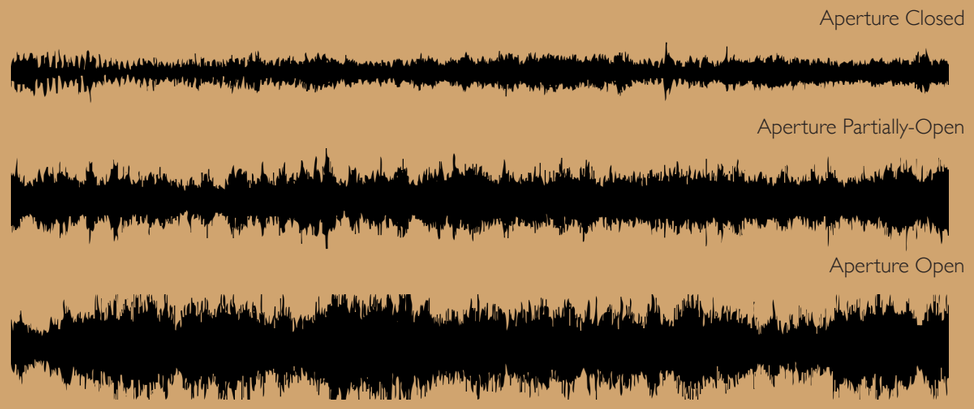
Concept Generation

“Opening the aperture by a moderate amount is going to do exactly what you’re looking for”

- Tom Lyne,
Musician, Sound Engineer, MSc Sound Design

Concept Refinement

An experiment was designed to test the success of the mechanism for controlling the amount of ambient noise (in dB) recorded by a measurement microphone when the aperture is opened by variable amounts. The results shown below for the final prototype demonstrate that a 15dB increase in ambient noise can be heard should the user choose to open the aperture.



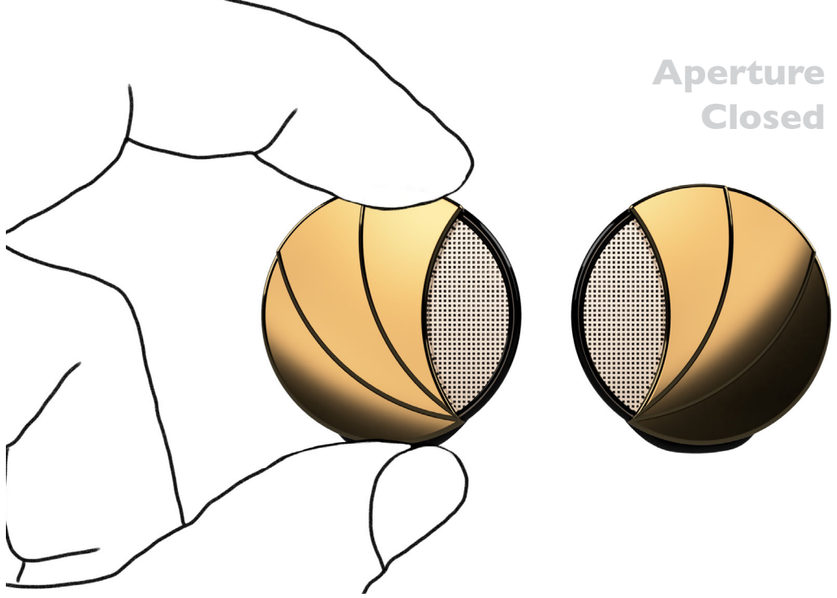
Careful design of the IEM headset architecture is required to ensure there is appropriate space above and below the driver (called the front and rear gas chamber) to allow sufficient movement of air as the diaphragm vibrates.

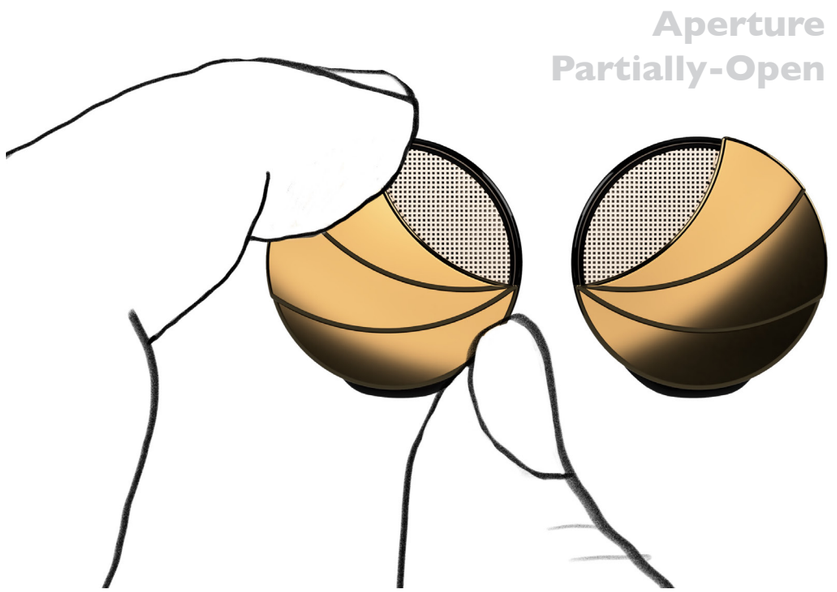
Key Technical Benefits

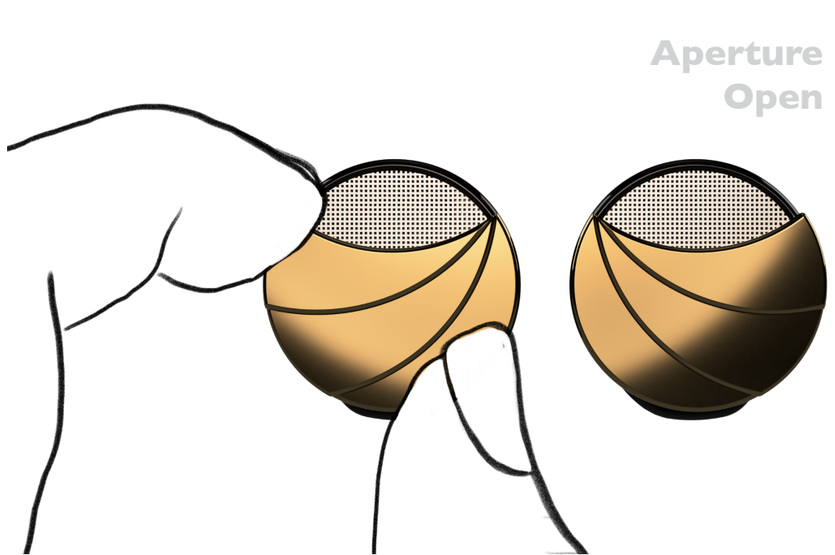
- Lightweight (10g/ear) and compact
- MMCX connectors for detachable cables
- Low cost/feasible procurement of bought parts
- Simple assembly, snap fits and interference fits minimise need for adhesive
- Designed for disassembly, in-line with “Right To Repair” regulations
- Designed for ease of repair/replacement parts
- Recyclable materials and easy separation of materials for recycling

Key User Benefits

- Instinctive first use
- Simple user interaction in time-pressured, dark/unlit environment
- Analogous with similar rotational applications (volume control knobs etc.)
- Tactile incremental feedback reduces error
- Comfortable design for anthropometric wrist motion capabilities
- High overall user satisfaction during testing







Human Factors

Interface Design & Aesthetics

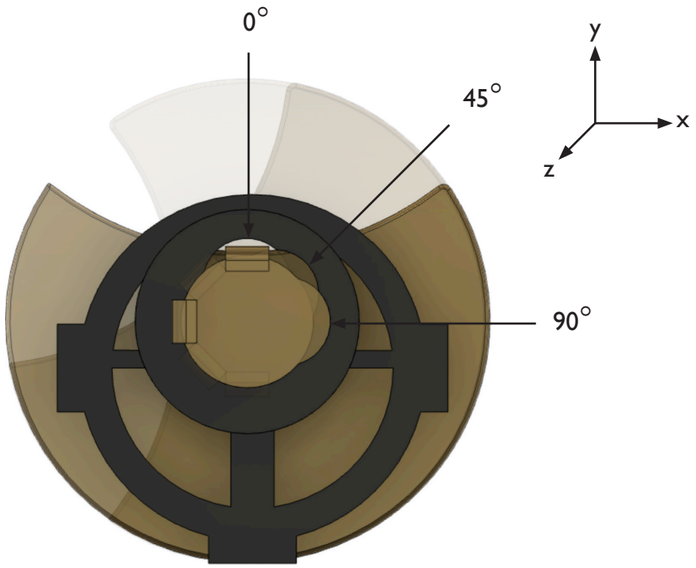
Interaction with the mechanism, which to the user is via rotation of the faceplate, required human factors investigation. Initially, aesthetic was explored by putting aside the functional aesthetic that might be expected of the audio industry and instead drawing inspiration from art and jewellery. The industrial design became a challenge when trying to separate this from the mechanical engineering approach employed so far.

Affordances

The resulting aesthetic can be seen on the left, which demonstrates how the user interacts with the AAT to open/close the ambient aperture. This motion of the fingers/hand/wrist was documented following observation of user interaction. Human Factors affordances consider how the user may instinctively interact with the product, whether this be in the way the product was designed for use or not. Observation showed that most users position their thumb as an anchor whilst using their index finger to rotate the faceplate.

Tactile Feedback

Tactile feedback is provided to the user to alert them as to how far the mechanism has rotated i.e., how open the aperture is. This is a consequence of the loud operational environment where an audible feedback would be unheard. After investigating a range of mechanisms to achieve this, a cam was developed with a rise section such that enough friction is applied to notify the user that they have turned the mechanism by 0°, 45° or 90°. Snap fits restrict movement of the faceplate shaft (gold) in the z-direction, but allow rotation within the driver cover hole (black) in the x-y plane.



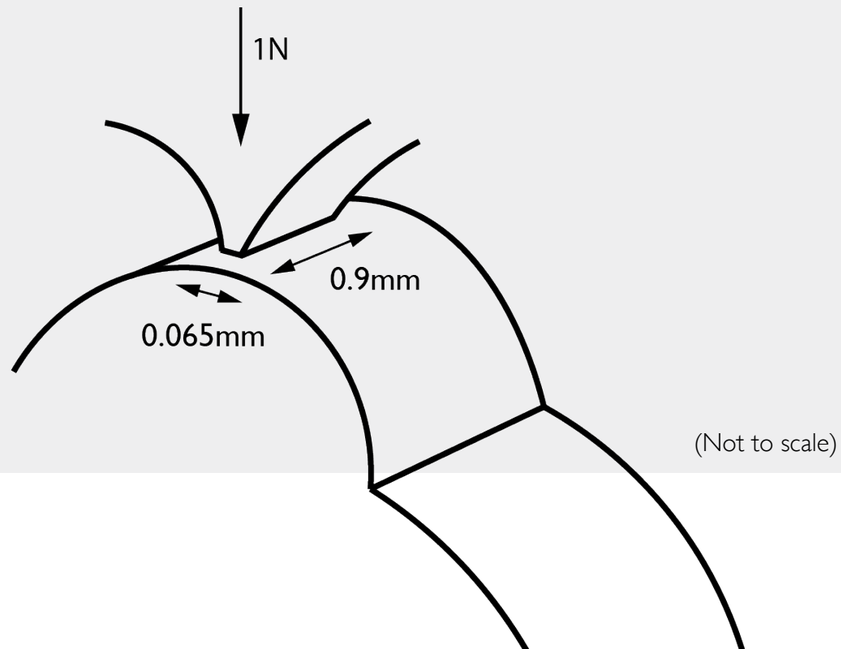
Materials & Manufacturing

The properties of prospective manufacturing processes were detailed and ranked. Injection moulding offers capabilities including high quality parts with a range of materials and surface finishes, high precision and accuracy for production of small parts, and the ability to produce high quantity batches with decreasing part per cost as the batch size increases. Care should be given to capital costs of tooling, but high quality moulds means service life of tooling will outlive the production run. The appropriateness of certain materials for injection moulding was applied as a limit in the material selection process.

Mechanism Refinement

Technical Analysis & Service Life

- Proposed service life: 10 years
- Estimated no. cycles: 192,000
- Normal force applied: 1N
- Contact type: Unlubricated, dynamic plastic-plastic contact
- Friction coefficient: 0.4
- Mating surface contact area: 0.058 μm^2
- Total stress on mating surfaces of mechanism: 6.84MPa
- Fatigue strength at 10^7 cycles, PET (driver cover): 29MPa
- Fatigue strength at 10^7 cycles, PA6 (faceplate): 15.3MPa
- Likelihood of premature failure: Low

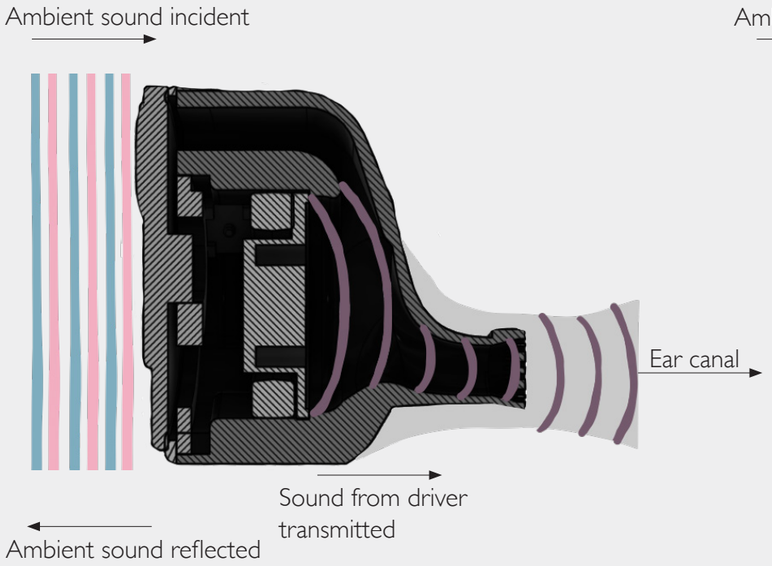


(Not to scale)

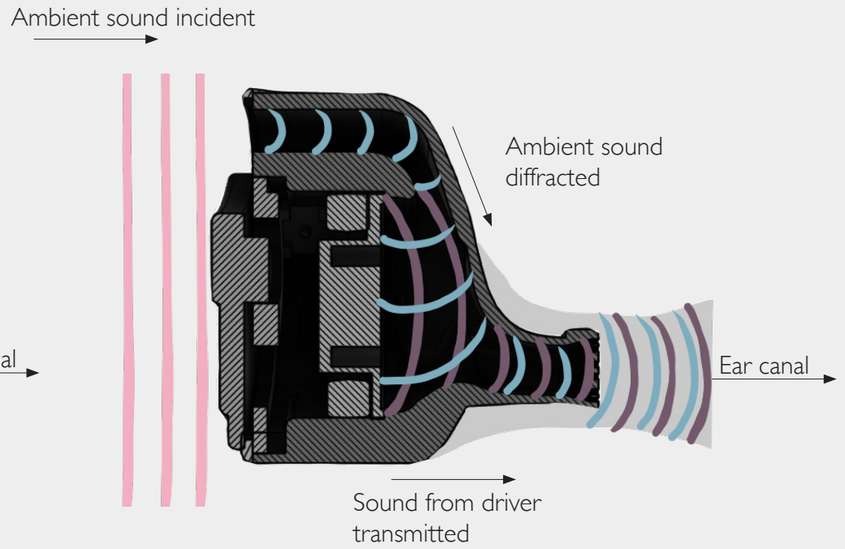
Mechanism Refinement

The section views show the transmission of the audio signal inside the developed headset, from the driver to the ear canal. They compare the behaviour of the wavefront when the mechanism, and thus the aperture, is closed vs when it is opened by the user. When closed, with the mechanism at 0°, the ambient sound incident on the headset is reflected back into the surroundings. When the aperture is opened by 45° or 90° the ambient sound instead diffracts through the ambient aperture and into the ear canal. The levels of ambient noise heard by the user, in dB, depends on the amount by which the mechanism has been rotated.

Aperture Closed



Aperture Open

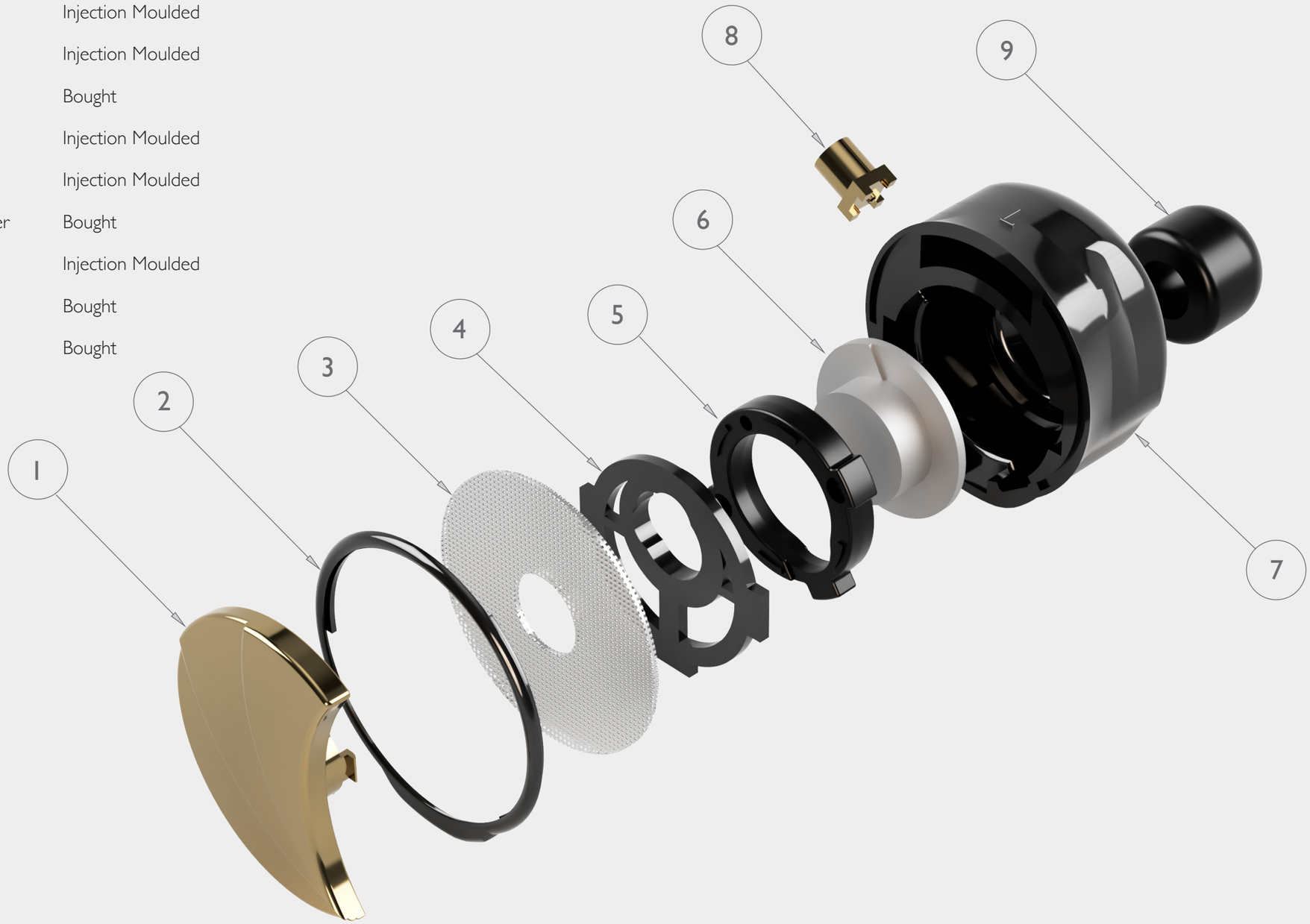


As well as testing carried out throughout the project, experienced musicians took part in final testing of the working prototypes. Some quotes from them feature throughout this summary. Their feedback was invaluable and has inspired future work for the project.

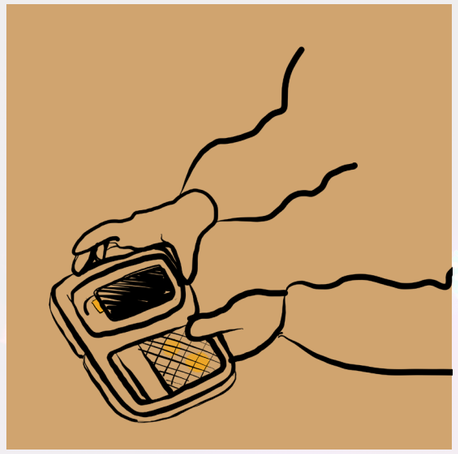
Simulation & Testing

Parts Analysis

Item	Description	Material	Manufacture
1	Faceplate	PA6	Injection Moulded
2	Mesh Housing	PA6	Injection Moulded
3	Mesh Filter	Steel Mesh	Bought
4	Driver Cover	PET	Injection Moulded
5	Seating Ring	PA6	Injection Moulded
6	Driver	Dynamic Driver	Bought
7	Driver Housing	PA6	Injection Moulded
8	MMCX Connector	MMCX (female)	Bought
9	Universal Ear Tip	Silicone	Bought

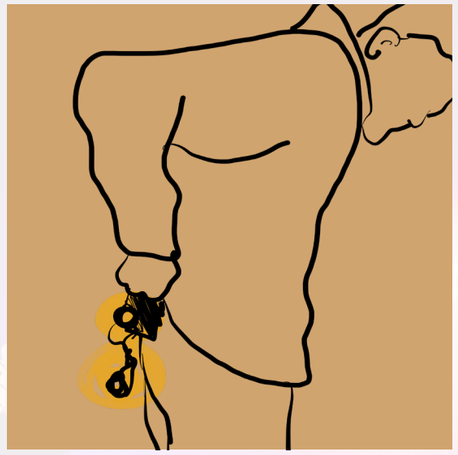


User Journey



Remove the IEM from its storage case & power-on the receiver

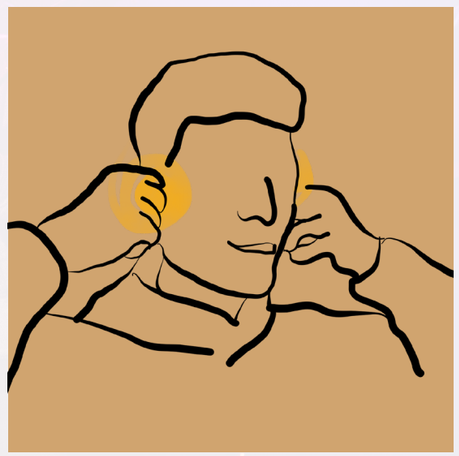
Plug the headset into the receiver & connect wirelessly to the transmitter



Attach the receiver to a belt or guitar strap

Secure the headset in the ears, ensuring a tight & secure fit

Remove the headset from the receiver & power-off the receiver



Rotate the faceplates until a desired level of ambient noise is detected

Unclip the receiver from the belt or guitar strap

At the end of the performance, remove the headset from the ears

More/less ambient noise can be detected by adjusting the faceplates

Perform, enjoying the crowd feedback & reduced occlusion effect