

Extended Project Qualification

EPQ 2024



[Exploring the functionality of noise-cancellation headphones]



Content Page

1. Chapter 1: Introduction
 - 1.1 Background
 - 1.2 Aim, Objective, Rational
 - 1.3 My Structural outline
2. Chapter 2: Research Review
 - 2.1 Introduction
 - 2.2 ANC Functionality
 - 2.2.1 ANC Frequency Range Capability
 - 2.2.2 ANC Structure and Components
 - 2.2.3 ANC Advantages
 - 2.2.4 ANC Disadvantages
 - 2.3 PNC Technology
 - 2.3.1 PNC Functionality
 - 2.3.2 PNC Structure and Components
 - 2.3.3 PNC Advantages
 - 2.3.4 PNC Disadvantages
3. Chapter 3: Market Research
 - 3.1 Objective
 - 3.2 Design, Aesthetics and Components
 - 3.3 The Price
 - 3.4 Wearing Comfort
 - 3.5 Compatibility
 - 3.6 Charging And Battery
 - 3.7 Microphone
 - 3.8 Nosie Cancelling techonology
 - 3.9 Conclusion and inspire to my product
 - 3.10 References and Resources
4. Chapter 4: Making Process
 - 4.1 Design Process
 - 4.1.1 Design Concept
 - 4.1.2 Technology Supply
 - 4.1.3 Size of headphone

4.1.4 Material Selection

4.2 Making Design Diagram

4.3 Modeling Process

4.3.1 Modeling File

4.3.2 Problems of Modeling and How to Fix

5. Chapter 5: Conclusion

6. Evaluation

7. Chapter 7: Bibliography

Abstract

One of the many problems people face in this society is the increasing amount of noise, and with this phenomenon noise cancelling headphones have become popular. This project focuses on how headphones can reduce noise. Because of the wide variety of noise-cancelling headphones on the market, how to determine the most suitable for your use to investigated. Finally, Active Noise Cancelling and Passive Noise Cancelling techniques are found. I use these two techniques to expand my description and research and apply them to my products. At the same time, I have an understanding and learning of product design. To see which aspects of product design should be focused on for everyday human use.

Keywords: Headphone, Physic, Principle of wave, design

Chapter 1: Introduction

Nowadays, more and more people would face some noise problems. About twenty-five million French citizen said that their lives are influenced by noise. 432,000 people said they were taking tranquillizers to cope with it (Bloomberg, 2022).¹ Increasing noise exists in our lives now. As a result, people need a type of product to isolate from outside noise and provide a comfortable hearing environment. In real life, we can reduce noise by using foam panels or soundproof curtains to block the transmission of sound. Or using low-noise appliances and equipment. Also, the noise cancelling technology headphones can provide a solution. It can be applied in some headphones and this technology can be widely used in our real life. Such as in the moving car and the aeroplane. So this is very meaningful for us to study. I would bring this to reduce some distractions. So I want to further study this application theory in my EPQ project.

1.1 Background

The global noise-cancelling headphones market was valued at \$13.1 billion in 2021 and is projected to reach \$45.4 billion by 2031, growing at a CAGR of 13.2% from 2021 to 2031. Noise-cancelling headphones are popular these days.² Several reasons contribute to this situation. In the first place, when people listen to music, they can reduce noise including car noise and human voices among other sources. They can not only reduce the unwanted engine noise from aeroplanes and car rides but can also help create a quieter environment while travelling. This facilitates a more tranquil and focused listening environment when the user needs to concentrate. Another determinant it compared to normal headphones, they can even help protect hearing to some degree. One study explored how noise-cancelling technology impacts preferred listening levels (PLLs)³ in the presence of café

¹ Its effectiveness is accurate. The sources are also reliable so this information is reliable. Based on my research, I found a close match. So the data is accurate.

² This is a book excerpt from the website. There are publishers and writers so this information is also reliable. It's a little bit less timely but it doesn't have much impact because the trend of headsets is getting more and more popular over time.

³ The timeliness of this does not affect the use of this material. There are many scientific sources of accuracy so it's basically accurate.

and bus noise. It found that volume levels decreased by six to twelve levels for bus noise and four to eleven levels for café noise once noise cancellation was activated. This showed that the noise cancelling function significantly decreased the sound pressure levels of the noise signal, suggesting a potential for this technology in hearing protection (Seol et al., 2022).⁴ After I finished my background study, I found it is worse to study and research what benefits people in our lives by canceling the noise.

1.2 Aim, Objective, Rational

For this project, I want to learn about the principles of various noise-cancelling technologies as well as investigate the factors which influence their effectiveness. At the same time, I wish to understand how noise-cancelling systems operate, and how their components function and are structured. This will enable me to deliver my main objective which is to design, model and build a set of noise-cancelling headphones. Conversely, several products show distinct technology, and some may incur significant costs. Hence I want to explore how these technologies are applied to the headphones and compare different products' performance. Then use the information I learn to design a product.

1.3 My Structural outline

So the next chapter is my literature review part, I will report the findings after I research the two major ways of cancelling the noise in headphones. In the following part of my report, I will illustrate the objectives for the Analysis and make a multicriteria analysis table then rate each of the different techniques out of 10 or 100. For the last part, I will show my process of designing my model.

⁴ The timeliness is not good but it does not affect my use. The accuracy is not verifiable but it is based on the source so it is not a problem.

Chapter 2: Research Review

2.1 Introduction

The purpose of this chapter is to discuss two ways for canceling noise in headphones: Active Noise Cancelling (ANC) and Passive Noise Cancelling (PNC) technology. It is important to explore the structure and components of the headphones and their suitable applications. We will consider appropriate factors such as component sensitivity, materials, the effectiveness of their isolating capabilities and their cost.

2.2 ANC Functionality

The principal that ANC uses is to capture ambient noise through microphone sensors. These sensors can sense sound waves coming from the external environment. ANC then generates a wave that is the opposite of this sound wave and emits it (Sony, 2022)⁵. When the two waves meet, they cancel each other out and the noise is eliminated. It is based on the principle of wave superposition. In the case of wave cancellation, this is destructive interference as shown in Figure 1.

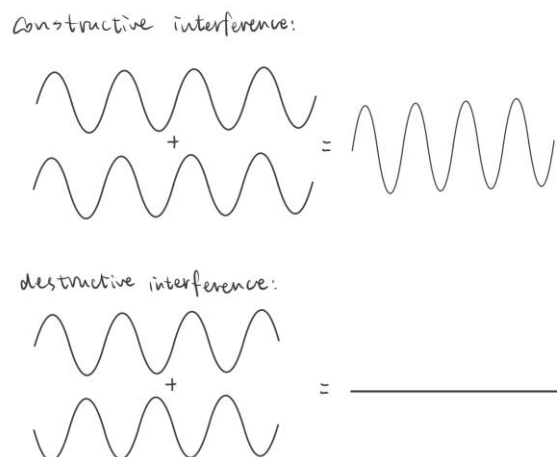


Figure 1. illustrates both waves meeting and thus being cancelled out

⁵ Timeliness is reliable. Because it's sony's official website. The official website may have exaggerated components, but this is the theoretical part and not its product, so it is also reliable.

2.2.1 ANC Frequency Range Capability

Most active noise-cancelling headphones have a noticeable dip in usefulness at the 1 kHz point due to this technology is most effective on lower frequencies of sound, between 50 Hz and 1 kHz. For example, the noise produced by motors and aeroplane engines. Because lower frequencies have longer waveforms that can be lined up properly. Low frequencies have longer wavelengths as shown by the inverse relationship in the equation.

$$\lambda = \frac{v}{f}$$

The wavelength is defined as the distance moved by the wavefront in one period, in other words, the minimum distance between two adjacent wavefronts. At higher frequencies, if waveforms do not line up exactly, it is more likely to that feedback will be encountered. In contrast, it is worse at blocking out the high-pitched sounds of screaming kids (Science8SC, n.d.).⁶ At high frequencies, people are less likely to feel the vibration of sound than to hear it. However, low-frequency noise has longer wavelengths and it can travel longer distances with high durability(What's the Difference?, 2022).⁷

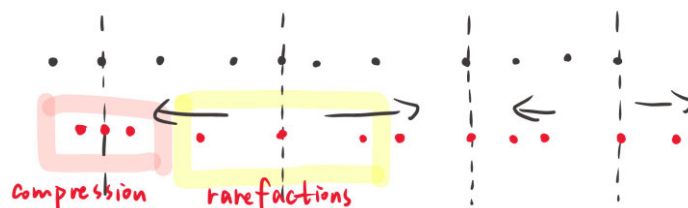


Figure 2. shows the two types of wavelength of different ranges of frequency

2.2.2 ANC Structure and Components

Next, I will explore the physical components of noise cancellation. According to William Harris of 'How Stuff Works', several components are required to generate the inverse sound wave for

⁶ The timeliness and accuracy of this data cannot be verified but this is the knowledge part. So there are plenty of other places to check. I found it matches everything I found on this file so it works.

⁷ Time-sensitive and reliable. Released within two years. Then there's accuracy. There's no big problem because it's about theory.

noise cancellation. Firstly, a microphone is needed and is usually placed inside the ear cup to capture the external sounds, which cannot be blocked by the earcup. Circuitry is then placed in the ear cup for amplifying the input sound from the microphone, performing analysis on the noise, and noting both frequency and amplitude. Then a new wave is generated that is 180 degrees out of phase with the waves associated with the noise. This 'anti-sound' wave is fed into the headphones' speakers and combined with the normal audio signal; the anti-sound erases the noise by destructive interference but does not affect the desired sound waves in the normal audio. The term "active" refers to the fact that energy must be added to the system to produce the noise-cancelling effect. Therefore, the final component, which is the source of this, is most commonly a rechargeable battery.

2.2.3 ANC Advantages

Best handle the low-frequency noise, as mentioned in 2.2.1. ANC Frequency range capability. And almost all the noise that exists in the living area is low-frequency noise. Motor vehicles, power equipment, and refrigeration equipment, also include the sound of people speaking.

2.2.4 ANC Disadvantages

ANC requires good accuracy and time to generate the wave for noise cancellation by superposition. Accurate sampling of the external environment will result in the desired maximum attenuation of noise. Therefore, good quality microphones must capture the noise, and the phase of the cancellation waveform leaving the headphone drivers needs to perfectly line up with the phase of the noise when it reaches the ear. This requires intricate circuits to perform the digital signal processing to minimise the delay and perform calculations to deliver the appropriate wave. ANC is also less effective for unpredictable noise, for example, an explosion. However, Passive Noise Cancelling (PNC) can shut out these sounds. I understand that they are not effective at cancelling out sudden and unpredictable sounds, such as a car horn or a dog barking. This is because there isn't enough

time to process the sound and generate the phase-inverted wave – they are generally good at cancelling out periodic sounds because it's easier to predict the sound wave and generate the inverted wave on time .

2.3 PNC Technology

2.3.1 PNC Functionality

Passive noise cancellation (PNC) is the most traditional way to eliminate unnecessary noise. It relies on closed earmuffs or comfortable in-ear headphones to physically block outside sounds. This is usually done with extra padding on the earbuds to seal any space where external sound waves might leak through to your eardrums. Noise isolation is also known as passive noise cancellation or physical noise cancellation. ‘Passive’ or ‘physical’ refers to there being no technology actively blocking out sounds, like the tiny microphones in ANC earbuds. It only possesses a physical modification such as extra padding or an ear-enclosing structure .

2.3.2 PNC Structure and Components

PNC’s predominant principle is creating a barrier between the ears and the surrounding environment. This technique is used in a variety of audio devices, including headphones, earphones, earbuds, ear cups, circumaural, supra-aural, in-ear monitors, earplugs, foam pads, and earmuffs (Rosen, 2021). Passive noise-cancelling headphones mainly wrap the ear and use silicone earplugs and other sound insulation materials to block outside noise and form a closed space (Addasound, n.d.).

2.3.3 PNC Advantages

With this technology, there is no need for electricity consumption, making it an energy-efficient option. Additionally, it is often more affordable than ANC headphones and has no risk of interference or distortion caused by ANC wave antiphases. PNC headphones are also easier to construct as they require fewer components that need to be assembled.

2.3.4 PNC Disadvantages

PNC is not as effective as ANC when blocking out noise – though explosions or loud noises can be better blocked out with this technology, consistent and periodic noise sources are unable to be attenuated effectively. This leaves the user finding it hard to distinguish between noise and music. The quality of the noise isolation will depend on the fit and seal, which can vary from person to person. Also, most high-quality modern headphones are now made with ANC; it's the new normal. This means better materials and finishes are more commonly used with ANC headphones (Passive vs. Active Noise Cancelling, n.d.).

Chapter 3: Market Research

3.1 Objective

The intention of analyzing the existing products on the market is to provide an understanding of the important and effective design features for noise-cancelling headphones. It is essential to consider key features such as the cost, charging capabilities, sound quality, battery life, microphone, comfort, noise isolation, noise cancellation and ease of use. I will give a rating out of ten for each feature for each product before giving total scores and analysing the best design approaches for each feature such that I can create the best product possible. I will divide my investigation into two types of headphones, overall-ear headphones and in-ear headphones.

3.2 Design, Aesthetics and Components

For the AirPods Pro, the overall colour is white, which uses polycarbonate plastic as its material. The overall design is simple and makes people feel comfortable. I enjoyed the appearance looked simple and brief, but it is really easy to be dirty. For another product Apple, the AirPods Max, among all the over-ear headphones, I prefer this design most, which provides people with a feeling of simplicity and advancement. Another brand is Vivo. Its product iQOO TWS Air2 adopts a vertical oval design, piano paint texture, and very thin and light volume, compared with the previous generation, the cabin adopts a curved design. However the combination of the colours caused the feeling of complex and incongruity. Then for the iKF King, it has both the design of a telescopic arm and a rotating head cover. The iKF King's head beam also features a metal design. However, it is no different from the general public types. Had no major characteristics and no memory points. Then for the Sennheiser CX 80S, it is wired, tiny spherical earbuds, with black-silver bodies, that are small and discrete. But it has no difference from the general public types. Had no characteristics and no memory points. Then for the Skullcandy Hesh Evo, is over the ear, black or white colour, it is the

same as the previous two products which have no big difference to the general types and every place is the same which makes it feel very greasy.

Product	AirPods Pro	Airpods Max	Vivo iQOO TWS Air2	iKF King	Sennheiser CX 80S	Skullcandy Hesh Evo
Rating	8	10	4	7	6	6

3.3 The Price

Product	AirPods Pro	Airpods Max	Vivo iQOO TWS Air2	iKF King	Sennheiser CX 80S	Skullcandy Hesh Evo
ANC/PNC	ANC	ANC	ANC	ANC	PNC	PNC
Cost	2000 Yuan	4999 Yuan	300 Yuan	369 Yuan	189 Yuan	79 Yuan
Reason	Too expensive	Too expensive	Can be afford by most people.	Very cost-effective.	Too expensive for a wire head-phone.	No such cost-effective, but this price can be afford by more people.
Rating	5	4	8	9	4	8

3.4 Wearing Comfort

The Airpods Max is too heavy to carry. All the user I seen comment that the airpods max is too heavy to carry. This table shows how there weights.

Product	AirPods Pro	Airpods Max	Vivo iQOO TWS Air2	iKF King	Sennheiser CX 80S	Skullcandy Hesh Evo
ANC/PNC	ANC	ANC	ANC	ANC	PNC	PNC
Weight	50.8 g	384.8 g	38.4g	300g	10g	213g
Rating	9	2	8	9	10	10

Product	AirPods Pro	Airpods Max	Vivo iQOO TWS Air2
Comfort	1) Comfortable silicone cushion in-ear fit	1) Comfortable over ear fit with soft ear pads 2) Cause ears sweat	1) no cushion for the ear, 2) plastic tough the skin
Rating	9 light enough	5 Too heavy	9 light enough
Product	iKF King	Sennheiser CX 80S	Skullcandy Hesh Evo

Comfort	1) Comfortable due to the careful design of the ear pads.	1) Comfortable silicone cushion in-ear fit. 2) 3 sizes (S,M,L) of earplugs for the perfect fit	1) Comfortable over ear 2) Not very tight against the head.
Rating	7 is not so heavy	7 wire is annoyed	8 light enough

3.5 Compatibility

The compatibility illustrates the way whether their product can be connected with any system's product.

Product	AirPods Pro	Airpods Max	Vivo iQOO TWS Air2
ANC/PNC	ANC	ANC	ANC
Connectivity	Very good bluetooth connectivity with the Apple Ecosystem. don't work well with non-apple products	1) Made of aluminum and steel 2) Do not work well with non-apple products 3) A little bit of a leak of sound so it would not be suitable to wear and use a high volume of sound while working in company or study in library	1) Can connect both apple system and android system. 2) Can be connected with both iPhone and computers
Rating (1-10)	5	5	7
Product	iKF King	Sennheiser CX 80S	Skullcandy Hesh Evo
Active/Passive	ANC	PNC	PNC
Ease of Use	Can be connected with both apple and android system. Also, it allows both bluetooth connection and wireless connection. It also fits all the types of electronic devices which have the function of bluetooth. However, desktop computers need a Bluetooth adapter to use.	Because it is connected through wire so it can be connected with every electronic device which has the port to connect with.	fits both apple system and android system. Both the computer, iPad and phone can be used with the connection.
Rating (1-10)	9	6	6

3.6 Charging And Battery

For the Airpods Pro At the bottom of the charging case, there are some spring-loaded contact points used to charging. According to Apple’s official website, charging for 5mins gives 1 hour of listening. So only 30 mins for a full charge. It contains two battery, it can be used up to six hours for one single charge. 30 hours with case. Each airpod has a 49.7 mAh battery.

While for the Airpods Max, you need to plug the lightning cable into the bottom of the right headset, and plug the other end of the cable into a USB charger or port. To charge AirPods Max in the smart earphone case, align the opening on the earphone case with the lightning port on the earphone. When not using AirPods Max. Store your headphones in a smart case so they go into ultra-low power mode to save battery power. ([Apple's official website](#)). There are two batteries, both in the same earcup.

For the vivo one, only need to use usb-C airpods 1.5 hours for charging the case. Contact springs with uch shallower depth. It is up to 6 hours without case, charging case enables charging for 30 hours, 300 mAh charging case, each pod has 29 mAh battery.

For the iKF King one, I learned from the official website page of iKF, it uses 40mm oversized dual-core moving coil speakers, closed ear canal design, high- resolution restoration of sound details, like being in a concert scene. The headset can be used for 80 hours on a full charge, which can meet the needs of daily use for several days without worrying about battery life.

Unlike the other products, Sennheiser CX 80S do not need charging for using. Because it has no battery, can be used until the phone runs out of charge. Then For the Skullcandy Hesh Evo, the 10 mins of rapid charge gives 3 hours of listening. 2 hours for a full charge. It can use 36 hours of battery life.

Product	AirPods Pro	Airpods Max	Vivo iQOO TWS Air2	iKF King	Sennheiser CX 80S	Skullcandy Hesh Evo
Rating (1-10)	10	10	8	9	10	6

3.7 Microphone

Product	AirPods Pro	Airpods Max	Vivo iQOO TWS Air2
	<ul style="list-style-type: none"> 1) One on the outside and one on the inside 2) The main microphone is located at the end of the handle 3) Used for making calls and interacting with Siri 4) It is suitable for recording and responding to voice commands 5) An auxiliary microphone located inside the headset 6) Focuses on eliminating background noise 7) Offer enhanced noise reduction 	<ul style="list-style-type: none"> 1) 9 microphones in total 2) Eight microphones for ACN technology 3) Voice pick up would use 3 microphone 4) Two of these three are shared with the ANC part and the other one is an additional one 	<ul style="list-style-type: none"> 1) 2 per earbud 2) one of which is for noise cancelling 3) Voice microphone is located on the bottom of the earbud.
Product	iKF King	Sennheiser CX 80S	Skullcandy Hesh Evo
	<ul style="list-style-type: none"> 1) Built-in microphone + external microphone 2) ENC call noise reduction technology, + Complimentary pluggable professional-grade mic 	<ul style="list-style-type: none"> 1) The built-in microphone covers a frequency range of 100 to 10,000 hertz 2) Distortion factor is less than 0.5 per cent at 1 kHz and 100 dB SPL 3) Located on a button quite close to the ears on a wire. 	<ul style="list-style-type: none"> 1) Integrated microphone 2) Struggles to separate your voice from moderately loud background noise 3) It's best suited for less noisy spaces like at home.

3.8 Noise Cancelling technology

Product	AirPods Pro	Airpods Max	Vivo iQOO TWS Air2	iKF King	Sennheiser CX 80S	Skullcandy Hesh Evo
Active/Passive	ANC	ANC	ANC	ANC	PNC	PNC

Noise Isolation	silicone earplugs, If it falls off, you can buy another one for \$4. (Can not use other types to instead) Inserted into ear	Quality over ear cups which block out sound with acoustically engineered memory foam	no silicone earplugs, relying only on the plastic casing to create a seal	The earmuffs are made of all-in-ear protein leather with zero pressure-sensitive memory foam. They are skin-friendly and soft, light and breathable, and you will know how comfortable you are when you wear them.	1) Silicone Ear pieces 2) 3 sizes (S,M,L)	1) Not good at blocking out bass due to imperfect over ear fit 2) Better for higher frequencies
Noise Cancellation	1) 2 times more ANC technology. 2) A driver and acoustic algorithms help Active Noise Cancellation reduce more unwanted noise(Apple).	1) Max use a total of six outward-facing microphones - detect noise in your environment, and two inward-facing microphones to measure what you're hearing. 2) Beamforming microphones help isolate your voice on phone calls, so it's heard clearly — even in windy situations.	1) suppresses up to 51% of noise	1) ANC 2) Noise reduction depth reach up to 38dB.	n/a	n/a
Rating	10	10	7	8	3	4

3.9 Conclusion and inspire to my product

Apple’s everything is better than the other product, except the heavy and price. However, the demand of a product also depend on the cost-effective and wearing comfort. So I decide to prove the lightness of my product. And choose the lighter material with the lower price.

Then I found that product based on ANC technology is more effective than PNC ones, which can cancell most noise out, and as I mentioned in the Research Review, which is ANC can handle the low frequency better. And in our daily life, most noise is low frequency noise, so I decide to do a Headphone with the ANC technology.

3.10 References and Resources

Most of the comment are from the TaoBao and Xiaohongshu apps. Which is the apps with most valuable reference in China market. I also search the information on Amazon and some comments on Instagram and Twitter in order to get some information about the other markets. And the data (size, heavy, techonology base) resource come from the official website from each brand and offical shop's description on Taobao.

Chapter 4: Making Process

4.1 Design Process

4.1.1 Design Concept

Inspiration are from the shell. To create a feeling that listening to music by the seaside. Similarly with listening to the sound of the sea with seashells. So make the earbuff into a shape of shell would give the headphone a feeling tends to nature. And the overall color would be blue which is more likely to the color of ocean.

4.1.2 Technology Supply

This headphone would use the ANC technology. Due to few reasons. First, the ANC's effectiveness is better than PNC. This cause a more perfect listening environment and feeling. Provide a suitable and better quantity of sound. Second, PNC mostly rely on the material. However, different material may cause sweating then. Give a bad experience. Thus, this headphone will be designed with ANC technology

4.1.3 Size of headphone

In the article about ear on LiveScience (2015) illustrate that the size of average human ear is about 6.3 centimeters long, and the average ear lobe is 1.88 cm long and 1.96 cm wide.

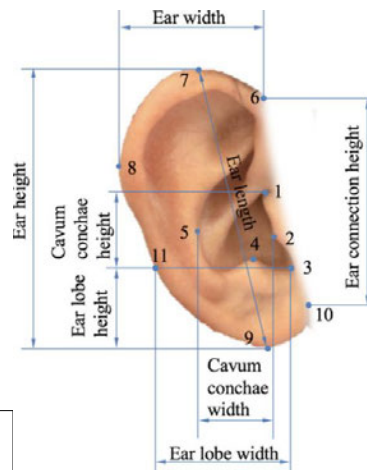


Figure 3. illustrates the dimensions of people’s ear on average (Wiley Online Library, 2022)

Then the final decision about size is: Height is about 180 mm, the transverse is about 170 mm, and the longitudinal thickness is about 80 mm.

4.1.4 Material Selection

This material I choose is photopolymer. It refers to a class of light-sensitive resins that solidify when exposed to ultraviolet light. It can print small parts with high precision, also it take a shorter time to finish print. It is good at protecting the water. It has a light quality and good texture.

Compare with the SLS, which material I considered to choose in the initial time period. However, its surface is too rough to make a headphone.

And for the shell part, it is more suitable to use a real one to combined with the headphone.

In order not to make mistake about the shape and to maximize the concept.

4.2 Making Design Diagram

Figure 4 is the initial picture of the design. Then after the first revising, the ear bridge and the shape of it had been changed.

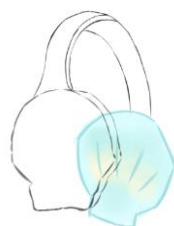


Figure 4. The initial design of the headphone



Figure 5. The second design diagram of the headphone

This is the design after first revise, which had a more right shape and structure.



Figure 5. Final version of headphone

The difference is the angle and size of the shell. Additionally make the diagram more detailed. Then I drew the diagram from three position.



Figure 6. design from three positions

4.3 Modeling Process

4.3.1 Modeling File



Figure 7. is the first diagram I finished modeling

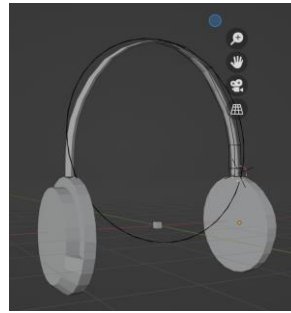


Figure 8. is the diagram of the file version

4.3.2 Problems of Modeling and How to Fix

Do not know how to combine two different objects. Because any function in the apps can not solved this problem. By searching the information and knowledge online find control+J can combined two objects in blender. After that, another problem is that after combination the shape would have some difference. Then by using the renderer solved this. However, manufacture said the model is too thin to print. Which maybe broken then. Then make the change to the bridge and more thick in order to be capable to print.

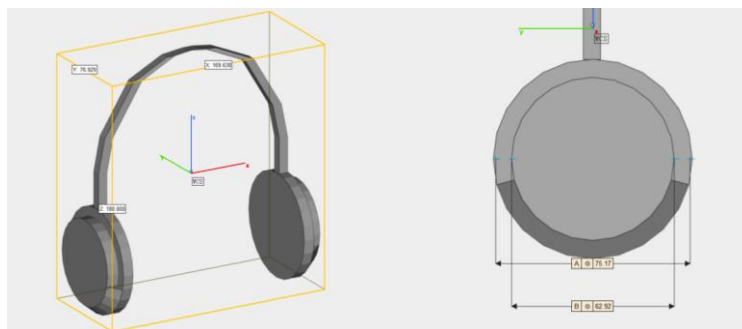


Figure 9. shows the design with size

After that receive the product, the real product is too big to combine with the shell.



Figure 10. shows the final product



Figure 11. shows the top view



Figure 12. shows the front view

Chapter 5: Conclusion

I research the question 'How noise cancelling headphone work?'. I find there are two ways which is Active Noise Cancelling and Passive Noise Cancelling Technology. ANC is based on the superposition of wave this law while the PNC do not based on any technology part which only physically block noise out. Their comparison are just like the robot and doll. After researching various types of headphones, next time if I want to be a new noise cancelling headphone, I would choose ANC technology based headphone. Due to it is suitable and functional than the PNC technology for my daily necessary. I first research the methods of these two method in order to have a clear idea and understanding. This can help me analysis the headphone's function better and give me more clear direction when choosing the technology would be used in my product. The reason to make the analysis of various headphones is because I have less knowledge on doing a product, especially on electronic area. So I wanted to learn some design idea and other knowledge of the electronic region after the analysis. After all the research base question. I started to make model with the video online. These video give me some inspiration with great job of modeling. Helping me gain these abilities and get enough preparation for the upcoming study in university. In the future I can further discuss the ANC and PNC technology. Like how these material and devices affect the effectiveness. Then avoiding delay the work for a too long time. Though I handle the time limit problem now, but it cause many problem then, like material choosing and size can not be changed. This also remained me that in the future, I will take a notice at the details of any product been produced. If anyone want to develop this topic in future, I recommend you to take a more careful notice of the electric component.

Chapter 6: Evaluation

6.1 Whether I have met expectations and objectives

I have not met my expectation and objectives in the final product. My biggest expectation is to restore the diagram of the design picture. And for my objectives, I learn about the principles behind various noise reduction technologies well and gain an understanding of the operation of noise reduction modules. I did not successfully understand all the information about how different headphones utilize noise cancelling module. I did not get a well method to enhance noise cancelling effectiveness. I well designed my model of the headphone.

6.2 Things I learned, developed and improved

For this project, I enjoyed the design part most. I enjoy make revision to the diagram and further all my idea in the design. This make me have a feeling of creating. I am making creating and useful thinking to this world. And in my mind, I did this part well. Though I did not make it perfectly real in the final artefact. But this idea would be live further. And I would do this again after having the greater ability on model and making headphone. In order to make a idea much more perfect and restored. Also, the modeling part is interesting. For the modeling, though this part is really difficult, but the feeling of finishing it and have a picture of it make me feeling good at encounter these problems.

6.3 Any difficulties I met and how I solve them

As I mentioned in the front chapter, I mentioned many problem while modeling. The next problem affect me most except the skill based ability is the skill of time management. I struggled with the deadline so that affect me on my effectiveness.

6.4 Help you in your future study

Give me a better awareness of time management and my research skill

6.5 For second chance

I would focus more on the component which will benefit my design most. And I will focus on the time management more, and keep regular weekly journals and thoughts. As soon as you have any ideas, write them down. I will know all the files needed for 3D printing in advance to prevent a lot of knowledge loopholes when communicating with manufacture.

Chapter 7: Bibliography

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