BME Design-Fall 2022
Complete Notebook

PDF Version generated by

KYLE EVERSON

on

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Table of Contents

Team contact Information

Mark RICE - Sep 13, 2022, 2:44 PM CDT

Last Name	First Name	Role	E-mail	Phone	Office Room/Building
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Project

ETHAN HANNON (ehannon@wisc.edu) - Nov 03, 2022, 8:06 PM CDT

Course Number: BME 300/200 Lab 310

Project Name: Smart headphones to measure Pulse Transit Time and Pulse Wave Velocity

Short Name: smHEART Headphones

Project description/problem statement:

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached to it. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphone and the user's watch will create a pulse that should thus measure the PTT and PWV of the body. This data will be recorded and shown on an app that can be accessed by the user on their phone or smart watch. The design of the headphones should be similar to that of Apple airpods and should work with ios systems.

About the client:

Dr. Jeffrey Koziol is a retired eye surgeon, teacher, inventor, and research scientist. An expert in his field, he has performed Lasik Surgery for over 10 years. He currently is holding eight patents that are used in eye surgery. In his career, he has published many articles, contributed in writing two major books, and been featured in various news segments.

9/12/2022 Client Questions

9/16/22 - Client Meeting #1

RACHEL NOSSEN - Sep 16, 2022, 4:27 PM CDT

Title: Client Meeting

Date: 9/16/22

Content by: Rachel Nossen

Present: Whole team and Dr. Koziol

Goals: To ask questions from our Client Question List; to gain more information on the purpose/uses/expectations of the device

Content:

Dr. Koziol - retired optomalogist

Smart headphones that can measure Pulse Wave Velocity.

Microphone to pick up heart beat.

Auditory signal from the heartbeat.

Wants us to create an app that would determine PWV

He's not aware of anybody checking the auditory signal for PWV --> no past projects

<u>Specifications:</u>

Budget - Up to $5,000

Designs - He likes the idea of an "air-pod" like structure or headset that would have the microphone connected to the device. Nothing invasive. Regards to the app - just get the heart beat (nothing specific in terms of the design)

Age/ Audience - people with heart disease and/or high blood pressure (40 years old - 80 years old)

Testing - test one another by checking blood pressure with typical inflatable blood pressure pump device and then see how our device compares

Parameters of accuracy - Wants to mirror the arm blood pressure pump

**Ideally:

- would be a commercial product.

- would be for everyday/all day use -- monitoring automatically, continuous run with stored data

- app would have data with graphs to look at, etc.

Conclusions/action items:

- Continue to keep in contact with Dr. Koziol with prototypes, designs, etc.

- Start brainstorming design ideas

2022/10/03 - Client Meeting #2

RACHEL NOSSEN - Dec 12, 2022, 3:50 PM CST

Title: Client Meeting #2

Date: 10/03/22

Content by: Kyle Everson

Present: Carson, Ethan, Mustafa, Mark, Kyle, Dr. Koziol

Goals: Show the team's design ideas to Dr. Koziol and clarify any areas of confusion.

Content:

- Can used wired headphones to prove idea can work, add bluetooth later
- Over-the-ear headphones will work fine for prototype, just need data
- Microphone should be used to pick up heart sound
- 2 signals used to measure time difference (PTT)
    - Speaker picks up heart sound
    - Smartwatch measures time it takes for pulse to travel to wrist
- As a control, can measure heart sound with stethoscope and compare to headphones
- Just wants to prove that concept can work, app will not be needed at this stage
    - Can use computer program to record data instead
-

Conclusions/action items:

- continue to research equations, circuits, etc.

9/16/22 - Advisor Meeting

RACHEL NOSSEN - Sep 16, 2022, 12:21 PM CDT

Title: Advisor Meeting

Date: 9/16/22

Content by: Rachel Nossen

Present: Whole Team and Advisor

Goals: To discuss initial questions and ideas

Content:

Advisor:

PWV can detect stiffness of arteries which can cause and is a major factor into Cardiovascular disease.

Initially, it can be easier to start with a bulkier/ over the head- headphones --> then we can see how we can minimize this product. This is because it can be difficult to put sensors/ all necessary materials into a small "airpod" like structure.

Recommends different people researching various topics regarding the project, see how we can implement certain technologies and maybe combine different aspects.

Conclusions/action items:

Continue to research current patents/ standards and designs. Continue to research physiology. Meet with the client to ask him further questions on how this device will be used and his expectations for the project.

9/23/22 - Advisor Meeting 2

MUSTAFA AL SAKHBOURI - Sep 23, 2022, 12:57 PM CDT

Title: Advisor Meeting #2

Date: 9/23/22

Content by: Rachel Nossen

Present: Whole team and advisor

Goals: To discuss our progress and to receive feedback

Content:

*Mark files accordingly

*Document everything in notebook that you wrote about in progress report:

- One entry, at least for each person, plus one team entry per week.

Design Matrix --> will allow you to outweigh technologies based on client wants --> auditory may be a want but not necessarily best means of taking measurements

Ant+ --> helps broadcast heartbeat; in a lot of fitness based technology/ wearables

Conclusions/action items:

Design matrix; ask client more specific questions

9/30/2022 - Review Design Matrix

RACHEL NOSSEN - Sep 30, 2022, 12:27 PM CDT

Title: Advisor Meeting

Date: 9/30/22

Content by: Rachel Nossen

Present: Justin Williams, Rachel Nossen, Ethan Hannon Carson Endries, Mustafaal Sakhbouri, Kyle Everson

Goals: To go over the design matrix

Content:

Sensitivity test - is one criteria's weight changing the type of design that will be chosen

Design 1 and Design 2 scores were very close, so if we do decide in the middle that this may not be the direction that should be followed- possible to switch.

Digikey - place to get small parts for headphone, etc - has great documentation and customer service

*might be useful to get a microphone with bluetooth connectivity already included

Conclusions/action items:

start presentation slides

10/14/22 - Advisor Meeting

RACHEL NOSSEN - Oct 14, 2022, 12:19 PM CDT

Title: Advisor Meeting

Date: 10/14/22

Content by: Rachel Nossen

Present: Whole team and Justin Williams

Goals: To get feedback on presentation and look forward to see what goals are for upcoming week

Content:

- Did great job setting up the problem, why blood pressure is important to measure and keep track of?

- Did good job with overview of matrix, didn't recite much?

** Some sketches could have been better due to that they were harder to read, in future work on sketches

** Make note that references were short

Goals for upcoming week:
1) Materials to start ordering

2) Begin 3d printing, check with the MakerSpace

**Note: lot of materials are on delay/ shortage

--> check ECB first floor for left over materials

Conclusions/action items:

Look for materials

10/28/2022 PreShow-And-Tell Meeting

ETHAN HANNON (ehannon@wisc.edu) - Oct 31, 2022, 5:30 PM CDT

Title: Meeting Before Week of Show-And-Tell

Date: 10/28/2022

Content by: Ethan

Present: Ethan, Rachel, Kyle, Mustafa, Mark, Carson

Goals: To go over and detail the fabrication progress of the design before show-and-tell

Content:

- Advisor said Arduino Nano had a built in speaker that could be used to hook up the watch and computer
- Progress towards show-and-tell content seemed positive in terms of having a presentable showcasing
- Progress report grading still underway
- Microphone circuit was producing difficult results to work with

Conclusions/action items:

The team is making good progress to have deliverables in the show-and-tell period next week, Friday. Work will need to be done to further specify and ensure proper outputs of the microphone data. Preparing all content for show-and-tell will be carried out to ensure a descriptive and informative detailing of the design is capable of being showcased.

11/21/22 Project Testing Results Discussion

RACHEL NOSSEN - Nov 21, 2022, 12:50 PM CST

Title: Advisor Meeting

Date: 11/21/22

Content by: Rachel Nossen

Present: Whole Team and Dr. Williams

Goals: To update on progress, gain clarity of timeline/questions

Content:

* poster presentation in 18 days

--> prelim test by next Friday to discuss with advisor about results

Currently:

**Using the stethoscope --> cant find/hear a heart beat when placing it near the neck, found with chest

Conclusions/action items:

-- Continue on circuit, later testing to get some data starting

12/2/2022 - Review prototype

RACHEL NOSSEN - Dec 02, 2022, 12:21 PM CST

Title: Review prototype

Date: 12/2/2022

Content by: Rachel Nossen

Present: Team and Dr. Williams

Goals: To discuss where we are at in terms of final steps and prototype

Content:

*Be able to understand and explain to future group (if applicable) where to start and what worked/failed

*Show in data what failed and worked, use matlab real time microphone processing

*Reserve a slot for printing by Thursday 12/8

Conclusions/action items:

--> gather data and show inability to listen from ear area

--> print out poster

2022/9/12 Client Questions and Getting Started

ETHAN HANNON (ehannon@wisc.edu) - Sep 12, 2022, 4:48 PM CDT

Title: Client Questions Meeting

Date: 9/12/2022

Content by: Ethan Hannon

Present: Ethan Hannon, Carson Endries, Rachel Nossen, Kyle Everson, Mustafa Al-Sakhbouri

Goals: To come up with questions for the first client meeting and begin writing the first report

Content:

Questions for the client were created in the pdf shown below. The team also began working on the first progress report for this week, largely focused around preliminary research on the project and questions for the client meeting. The team also began work on the PDS to detail their parameters and work they will have to achieve throughout the semester. Early research on the project was also shared by the team that went over various topics like ppg designs and the science behind Pulse Wave Velocity and Pulse Transit Time. The team used this information in figuring out the types of questions that would be asked regarding the client.

Conclusions/action items:

It is important to meet with the client for any project in order to gain a strong understanding what the team must achieve to complete the project on time and in the best fashion possible. The team will work to set up a meeting with the client in the coming weeks to go over the exact parameters for the project and get any early information and tips on how to solve the problem at hand. Work will also be done to continue to finish the PDS and weekly report.

ETHAN HANNON (ehannon@wisc.edu) - Sep 12, 2022, 4:48 PM CDT

What materials/budget provided to us? Are there any specific materials that you do not provide that you recommend using?

How does your proposal differ from headphones already on the market with similar functionality?

Who is this product targeted to? (i.e. General public, Professionals, People with heart conditions)

What is the general age range this product will cater to?

Is there a certain design or style that we should make these (i.e. for a certain age range or group of people)?

What is the budget given for this project?

Should connection from the headphones to the recording device be wireless or wired?

Are we given a specific type of headphones to use or can we choose a certain style?

Are there past projects carried out on this that we can use as sample information?

What testing results would you like to see from this project?

Is this device meant to be used more for commercial purposes or professional purposes (i.e. price meant to be minimized as much as possible)?

Are there any safety precautions we must be aware of and consider?

What is the estimated life of service of this device?

How long are you expecting this device to last for before it needs to be repaired or replaced?

What are the parameters of accuracy and the intended accuracy of the headphones?

Will these headphones be used for everyday use or in a lab/immobile setting?

Is there a size or weight restraint to this project?

Download

Client_Questions.pdf (24.9 kB) List of questions for the client

2022/9/19 PDS draft

RACHEL NOSSEN - Sep 20, 2022, 8:01 PM CDT

Title: PDS Meeting

Date: 9/19/2022

Content by: Rachel Nossen

Present: Ethan Hannon, Carson Endries, Rachel Nossen, Kyle Everson, Mustafa Al-Sakhbouri

Goals: To start our draft of the PDS and our week 2 progress report; Look into ordering parts

Content:

Need to ask client more catered questions now that researching has taken different directions

--> ask about all he knows regarding how auditory signal can be used to take heart measurements (equations, etc)

Design ideas...

- 3d printed

- ordering parts of certain headphones

- ordering full device and seeing how microphone would be integrated

Conclusion/Action Items

- Complete PDS and progress report #2

- Individually come up with ideas to bring up for next meeting

2022/9/26 - Design Matrix Discussion

RACHEL NOSSEN - Sep 26, 2022, 4:48 PM CDT

Title: Team Meeting

Date: 9/26/22

Content by: Rachel Nossen

Present: Whole Team

Goals: To create the design matrix and go over preliminary designs

Content:

Criteria of design matrix:

1) Effectiveness - can it accurately record measurements?

-- weight = 25

2) Ease of fabrication - how easy it is to make?

-- weight = 20

3) Comfort - is it comfortable for daily use and wear?

-- weight =

4) Cost - Is it cost friendly?

-- weight =

5) Safety - Will this design pose any safety concerns for the user?

-- weight = 10

6) Ease of use - is it easy for the user to access these recordings and use the headphones?

-- weight = 20

Conclusions/action items:

Ask and send client the additional questions.

RACHEL NOSSEN - Sep 30, 2022, 12:08 PM CDT

		Design 1 - Headband		Design 2 - Wrap-Around		Design 3 - [illegible] Headphones	
Criteria	Weight	Score (10 max)	Weighted Score	Score (10 max)	Weighted Score	Score (10 max)	Weighted Score
Effectiveness of measurements	25	10	25	10	25	7	18
Ease of fabrication	20	10	20	6	12	10	20
Comfort	15	8	12	9	14	10	15
Ease of use	20	7	14	10	20	6	12
Cost	10	5	5	7	7	8	8
Safety	10	10	10	10	10	10	10
Sum	100	Sum	86	Sum	88	Sum	83

[Download](#)

Design_Matrix_-_Sheet1.pdf (518 kB)

2022/10/03 - Preliminary Presentation and Client Questions

KYLE EVERSON - Oct 03, 2022, 5:55 PM CDT

Title: Preliminary Presentation and Client Questions

Date: 10/03/22

Content by: Kyle Everson

Present: Ethan, Carson, Mark, Mustafa, Kyle

Goals: Prepare for the second client meeting and talk about the preliminary presentation.

Content:

- Decided to focus on over-ear headphone design going forward
- Questions for the second client meeting were created
- Started discussing what possible parts the team should look at buying

Conclusions/action items:

10/11/2022 Preliminary Report Meeting

ETHAN HANNON (ehannon@wisc.edu) - Oct 12, 2022, 12:46 AM CDT

Title: General Preliminary Report Discussion Meeting

Date: 10/11/2022

Content by: Ethan

Present: Ethan, Carson, Mustafa, Mark

Goals: To go over and work on the preliminary report for submission.

Content:

The team worked to discuss relevant information to use when creating the preliminary report. Work was also divided up among team members in order to ensure efficient usage of time as well as communication on available times to work on the report going ahead so that all material was completed on time. Further information was then given to the members who couldn't make the meeting so that they could be caught up for what they missed in the meeting.

Conclusions/action items:

Continue to work on and finish the preliminary report. Work will be undertaken as well to research parts for the chosen preliminary design of the project.

2022/10/17 - Materials and Payment Plans

RACHEL NOSSEN - Oct 17, 2022, 4:39 PM CDT

Title: Team Meeting

Date: 10/17/22

Content by: Rachel Nossen

Present: Whole Teams

Goals: To put together a list of materials we plan on purchasing, to compile this list and send it to client

Content:

https://docs.google.com/spreadsheets/d/1YOq6WPQ1vaTaZ4EumVv7BFtX8hXdk3YuKV5TcPSskLY/edit#gid=529386342

**Completing/ working on BPAG Expense Sheet

** Looked for materials for 3d printed parts, estimating its cost

**Email Dr. Koziol about payment method

Conclusions/action items:

Hear back from client, send him link to some parts, inquire about Makerspace availability

2022/10/24 - Printing/ Starting Circuits

RACHEL NOSSEN - Oct 24, 2022, 4:41 PM CDT

Title: Team Meeting

Date: 10/24/22

Content by: Rachel Nossen

Present: Whole Team

Goals: To start 3d printing

Content:

**2 of us started our 3d print job on the Stratasys using TPU material --> costed a total of $45

**Rest are gathering electronics and setting up circuits, code

Conclusions/action items:

Pick up printed material tomorrow (10/24), finish the electronics, understand how the ANT+ will gather the data

10/31/2022 - Prepare for Show/Tell

RACHEL NOSSEN - Oct 31, 2022, 4:46 PM CDT

Title: Team Meeting

Date: 10/31/22

Content by: Rachel Nossen

Present: Whole Team

Goals: To fix the physical headphones by printing with another material

Content:

** Material used for headphone may be too flexible

--> try to print out frame with tougher material

Result: Found a different model: https://dedesigned.com/project/3d-printed-headphones/

--> printed with ASA M30 on the Stratasys

Conclusions/action items:

Pick up new model in one day --> test each to see which may work better

2022/11/03 - More Show and Tell Preparation

KYLE EVERSON - Nov 03, 2022, 9:01 PM CDT

Title: More Show and Tell Preparation

Date: 11/03/22

Content by: Kyle Everson

Present: Whole team

Goals: To create our elevator pitch in preparation for Show and Tell

Content:

- Continued working on the circuit

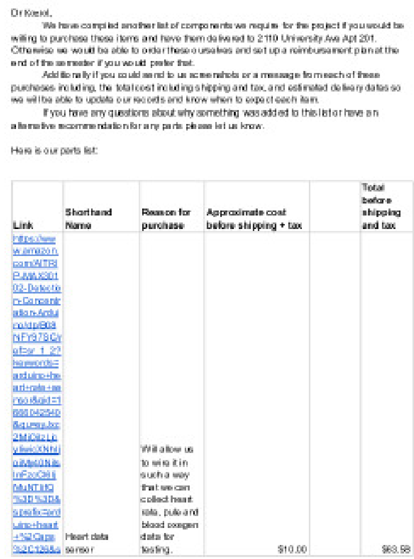
- Created elevator pitch

Conclusions/action items:

Present show and tell, finish working on circuit.

2022/11/14 - materials and questions for client

RACHEL NOSSEN - Nov 14, 2022, 4:53 PM CST



Dr Kesid,

We have compiled another list of components we require for the project if you would be willing to purchase these items and have them delivered to 2110 University Ave Apt 201. Otherwise we would be able to order these ourselves and set up a reimbursement plan at the end of the semester if you would prefer that.

Additionally if you could send to us screenshots or a message from each of these purchases including the total cost including shipping and tax, and estimated delivery dates so we will be able to update our records and know when to expect each item.

If you have any questions about why something was added to this list or have an alternative recommendation for any parts please let us know.

Here is our parts list:

Link	Shorthand Name	Reason for purchase	Approximate cost before shipping + tax		Total before shipping and tax
[illegible]	Heart data sensor	Will allow us to wire it in such a way that we can collect heart rate, pulse and blood oxygen data for testing.	$10.00		$63.58

[Download](#)

Part_list_order_2.pdf (122 kB)

RACHEL NOSSEN - Nov 14, 2022, 4:53 PM CST

Title: Team Meeting

Date: 11/14/22

Content by: Rachel Nossen

Present: Whole Team

Goals: To see what materials we made need for circuit, ask client

Content:

See attachment above

Conclusions/action items:

-- Once materials arrive, can begin testing with stethoscope (see if its an alternate solution)

-- work on circuit more

10/10/2022 Design Matrix

ETHAN HANNON (ehannon@wisc.edu) - Nov 03, 2022, 7:51 PM CDT

Title: Team Design Matrix

Date: 10/10/2022

Content by: Ethan

Present: Ethan, Kyle, Rachel, Mark, Carson, Mustafa

Goals: To create and rate a design matrix for the top three team design choices.

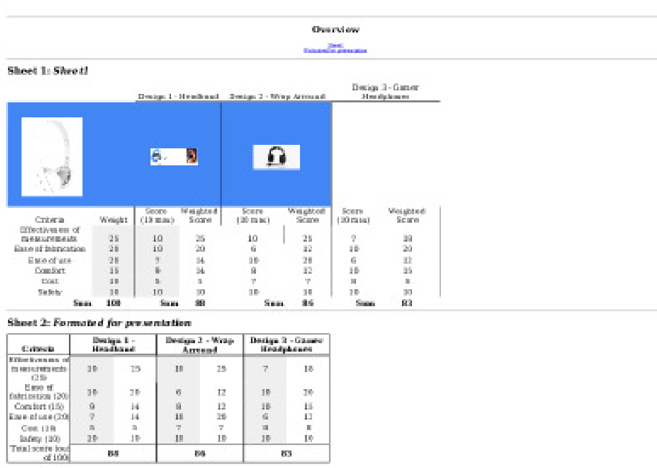
Content:

The team came up with three design choices to use for the matrix that could carry out their respective methods. The first was a simple headphone design that would have the microphone attached to the audio earmuffs to listen the user's pulse and record the PTT/PWV. The second was a wrap around system that the team could use to easily fit and listen to the user and could be easier to wear. The third was a gamer headphone style with the microphone hanging off on a speaker wire that the user could adjust to better orient itself near the pulse zone. Ultimately the team scored the headband design the highest at 88 for its assumed effectiveness of results and ease of fabrication. The wrap around scored second at 86, this score was lower largely due to the smaller nature of its design potentially making fabrication harder to work with. The lowest scored design was the gamer headset at 83 with its major drawback being the ease of use and accuracy as the microphone wire could be easily moved away from its optimal position and would be annoying to work with by the user.

Conclusions/action items:

The team has decided to go with the over the ear headphone design for its ease of fabrication and potential accuracy of its measurements which should produce a potentially viable prototype. Work will be carried out to research proper fabrication methods of the circuitry, headphone shell, and other accompanying devices.

ETHAN HANNON (ehannon@wisc.edu) - Nov 03, 2022, 7:51 PM CDT



Sheet 1: *Sheet1*

Criteria	Weight	Design 1 - Headband Score (10 max)	Design 1 - Headband Weighted Score	Design 2 - Wrap Around Score (10 max)	Design 2 - Wrap Around Weighted Score	Design 3 - Gamer Headphones Score (10 max)	Design 3 - Gamer Headphones Weighted Score
Effectiveness of measurements	25	10	25	10	25	7	18
Ease of fabrication	20	10	20	6	12	10	20
Ease of use	20	7	14	10	20	6	12
Comfort	15	9	14	8	12	10	15
Cost	10	5	5	7	7	8	8
Safety	10	10	10	10	10	10	10
Sum	100	Sum	88	Sum	86	Sum	83

Sheet 2: *Formated for presentation*

Criteria	Design 1 - Headband		Design 2 - Wrap Around		Design 3 - Gamer Headphones	
Effectiveness of measurements (25)	10	25	10	25	7	18
Ease of fabrication (20)	10	20	6	12	10	20
Comfort (15)	9	14	8	12	10	15
Ease of use (20)	7	14	10	20	6	12
Cost (10)	5	5	7	7	8	8
Safety (10)	10	10	10	10	10	10
Total score (out of 100)	88		86		83	

Download

Design_Matrix.xlsx (470 kB) Xcel file of the design matrix

9/26/22 - First Headphone Design

ETHAN HANNON (ehannon@wisc.edu) - Dec 13, 2022, 9:43 PM CST

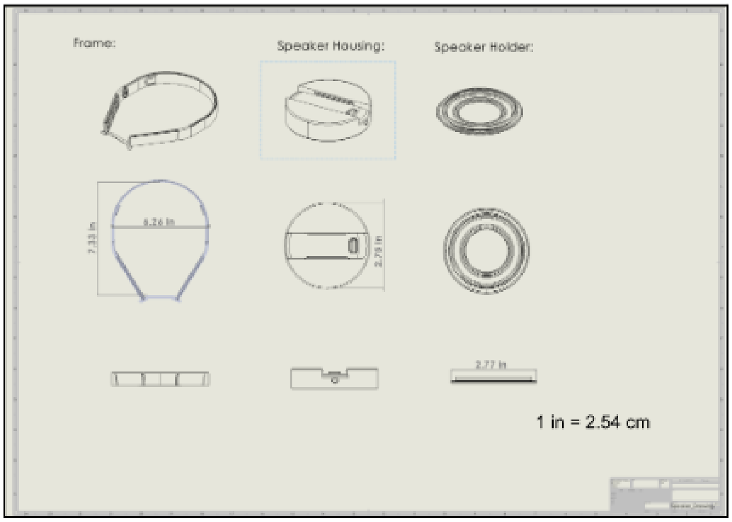
Title: Build headphones

Date: 9/26/2022

Content by: Rachel Nossen, Ethan Hannon

Goals: To design and create the first iteration of the headphones for fabrication

Content:



Final Design Dimensions (Above)

-- Decided to use TPU filament

TPU Filament:

Pros - flexible, smooth finish, seen as a bridge between rubber and plastics --> good for stretch (comfortability for the user)

Cons - relatively expensive, may have no durability and strength for everyday use

Conclusions/action items:

See how we can manipulate the file for the speaker holders so that it could fit necessary tech.

10/24/2022 Updated Headphone Design

ETHAN HANNON (ehannon@wisc.edu) - Dec 13, 2022, 9:52 PM CST

Title: Headphone Design Updated

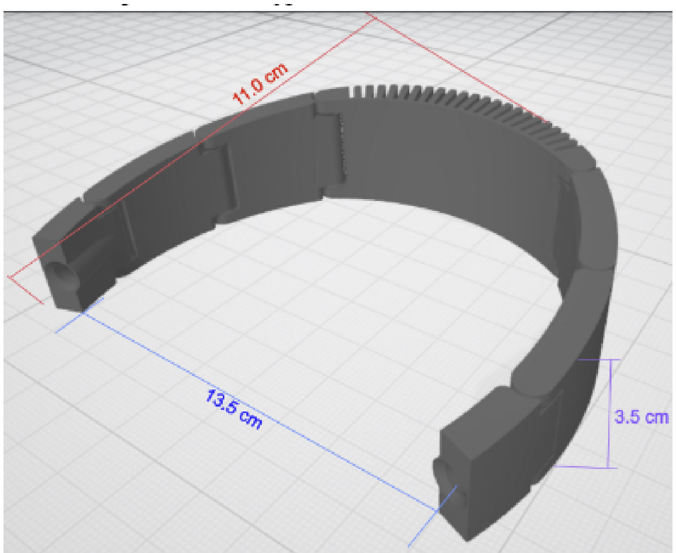
Date: 10/24/2022

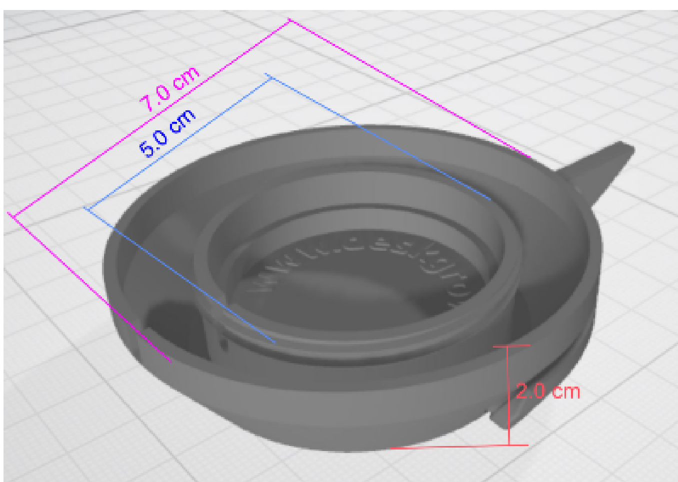
Content by: Ethan Hannon, Rachel Nossen

Present: Ethan Hannon, Rachel Nossen

Goals: To update and design a better, more structurally sound headphone design

Content:





This new design would utilize ABS material for fabrication as it provides a more stable, firmer properties than TPU filament.

Pros:

1. More rigid offering better structural support (improvement around headband as previous one was too flexible)

2. More housing space for electronics in the ear pieces
3. Moving parts allow for adjustment of size for user as well as ease of packaging

Cons:

1. More complex parts result in more potential for breaking
2. Takes longer to fabricate and may require more touch up after fabrication for optimal usage

Conclusions/action items:

The next step is to fabricate the design to see its capabilities as a usable headphone shell. This new design should fix the high flexibility problems the previous model has while allowing for more ease of usage and alteration in its size per the user's preference.

12/4 HRM circuit design process

Mark RICE - Dec 14, 2022, 10:43 AM CST

Title: Heart Rate Monitor circuit design process.

Date: 12/4

Content by: Mark Rice

Present: Mark Rice

Goals: document design process for HRM circuit

Content:

The MAX30102 board was chosen because of it's relative adorableness, and capability for other heart rate information like blood oxygen level should information like that become necessary. All code was based on the "SparkFun MAX3010x Pulse and Proximity Sensor" library available within the Arduino IDE. This library allowed us to adjust the heart rate code to change the output such that it could work alongside our smart headphones.

One struggle that we faced using this board is trying to run 2 of them on the same Arduino simultaneously. According to my research it is extremely complicated if not impossible to run 2 of this type of sensor through Arduino, so if a future project were to continue with this project replacing the microphone with a LED sensor, it would be recommended to use a different brand of sensor. However, if this problem were to be overcome, using another LED sensor instead of a microphone on the smart headphones should be relatively easy to implement into our existing code to measure PTT with an Arduino.

Conclusions/action items: N/A

10/20 Part List Order #1

Mark

Title: Part List order #1

Date: 10/20

Content by: whole team

Present: whole team

Goals: order preliminary materials needed to progress with circuit design and testing.

Content: The following is the materials we requested to be ordered, this will allow us to begin our circuit design and testing.

Link	Shorth Name
https://www.amazon.com/CooSpo-CycleOps-TrainerRoad-Extension-Included/dp/B07CB4328P/ref=sr_1_1_sspa?keywords=ant%2Bdongle&qid=1663620132&sr=8-1-spons&th=1	ANT+ reciev
https://www.amazon.com/DORHEA-Microphone-Amplifier-Electret-Programmable/dp/B09N92M6V5	Micro
https://www.arrow.com/en/products/cma-4544pf-w/cui-devices?gclid=Cj0KCQjwhY-aBhCUARIsALNIC07JSq7yDiOaUO1hdJ8x6vj20FWGdvyH0YCJ_AMp7ItenRbUp6mk-N8aAve_EALw_wcB&gclsrc=aw.ds	Micro
https://www.amazon.com/Powr-Labs-Bluetooth-Monitor-Armband/dp/B088RMK1GX/ref=sr_1_3?crid=SC5GCSXI6W87&keywords=ant%2B+watch&qid=1663624060&sprefix=ant%2B+watch%2Caps%2C94&sr=8-3	Heart armba
https://www.amazon.com/Gikfun-Breakout-Headphone-Arduino-AE1223/dp/B01KFP0HBG/ref=sr_1_2?keywords=arduino+aux+input&qid=1666032203&qu=eyJxc2MiOiIwLjAwIiwicXNhIjoiMC4wMCIsInFzcCI6IjAuMDAifQ%3D%3D&sprefix=arduino+aux%2Caps%2C109&sr=8-2	AUX p

https://www.amazon.com/AITRIP-MAX30102-Detection-Concentration-Arduino/dp/B08NFY97SC/ref=sr_1_2?keywords=arduino+heart+rate+sensor&qid=1666042540&qu=eyJxc2MiOiIzLjcyIiwicXNhIjoiMy40NiIsInFzcCI6IjMuNTIifQ%3D%3D&sprefix=arduino+heart+%2Caps%2C126&sr=8-2	Heart senso
https://medical.andonline.com/product/ultraconnect-premium-wireless-blood-pressure-monitor-ua-1200ble/#tab-id-4	Blood pressu cuff

Conclusions/action items: wait for items to be received and begin testing with them, formulate orders for secondary items we may need.

11/14 Part List Order #2

Title: Part List order #2

Date: 11/14

Content by: whole team

Present: whole team

Goals: order additional materials

Content: The following is the materials we requested to be ordered, this will allow us to continue/better our circuit design and testing.

Link
https://www.amazon.com/AITRIP-MAX30102-Detection-Concentration-Arduino/dp/B08NFY97SC/ref=sr_1_2?keywords=arduino+heart+rate+sensor&qid=1666042540&qu=eyJxc2MiOiIzLjcyIiwicXNhIjoiMy40NiIsInFzcCI6IjMuNTIifQ%3D%3D&sprefix=arduino+heart+%2Caps%2C126&sr=8-2
https://www.amazon.com/Professional-Bose-QC35-Cushions-Replacement/dp/B07TZJ1CMC/ref=sr_1_7?c=ts&keywords=Headphone+Earpads&qid=1666042180&qu=eyJxc2MiOiI2LjMzIiwicXNhIjoiNS43MSIsInFzcCI6IjUuMzkifQ%3D%3D&s=electronics&sr=1-7&ts_id=13880181
https://www.amazon.com/TraderPlus-Contact-Microphone-Mandolin-Ukulele/dp/B07795XHLH/ref=sr_1_1_sspa?crid=3QNHK80MU6YOQ&keywords=contact+microphone&qid=1668463835&sprefix=contact%2520microphone%2Caps%2C124&sr=8-1-spons&sp_csd=d2lkZ2V0TmFtZT1zcF9hdGY&psc
https://www.amazon.com/Everdixie-Dual-Head-Stethoscope-Pink/dp/B000FSIV6M?th=1

https://www.amazon.com/PoP-voice-Microphone-Omnidirectional-Smartphones/dp/B075VQ7VG7/ref=asc_df_B075VQ7VG7/?tag=hyprod-20&linkCode=df0&hvadid=312118595187&hvpos=&hvnetw=g&hvrand=17228464567582278820&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9018948&h
524514360158&psc=1

Conclusions/action items: wait for items to be received and begin testing with them, formulate orders for secondary items we may need.

12/12 Final Materials list

Mark RICE - Dec 12, 2022, 4:33 PM CST

Title: Final Materials List

Date: 12/12/2022

Content by: Mark Rice

Present: All

Goals: document final materials list

Content: see attached the final expenses and materials spreadsheet.

Conclusions/action items: N/A

Mark RICE - Dec 12, 2022, 4:35 PM CST

Download

BPAG_Expense_Spreadsheet.xlsx (15 kB)

10/24/2022 Headphone 3D Print Fabrication

ETHAN HANNON (ehannon@wisc.edu) - Oct 31, 2022, 4:51 PM CDT

Title: 3D Printing of Headphone Shell

Date: 10/24/2022

Content by: Ethan

Present: Ethan, Rachel

Goals: To print out the 3D model of the headphone casing shell for usage in design

Content:

Picture of Headphone Shell After Printing

TPU plastic was chosen for this print. The outcome was a largely flexible material with more rigidity and stiffness occuring on the earpieces. This design however resulted in too high of flexibility around the headband part of the headphones which decreased the overall comfort and ease of use for the headphones. The ear piece casing also was too filled in which made implementing electronic systems inside it difficult and hard to work with. Overall, a newer design would be needed in order to ensure greater stability and ease of use for the project.

Conclusions/action items:

The first round of the headphone printing was able to show a possible working model but fell short on stability and ease of fabrication. Research and design a thicker headband piece with a more spacious earpiece for the headphones to fix the previously stated problems would be undertaken.

Microphone Circuit

RACHEL NOSSEN - Dec 12, 2022, 3:32 PM CST

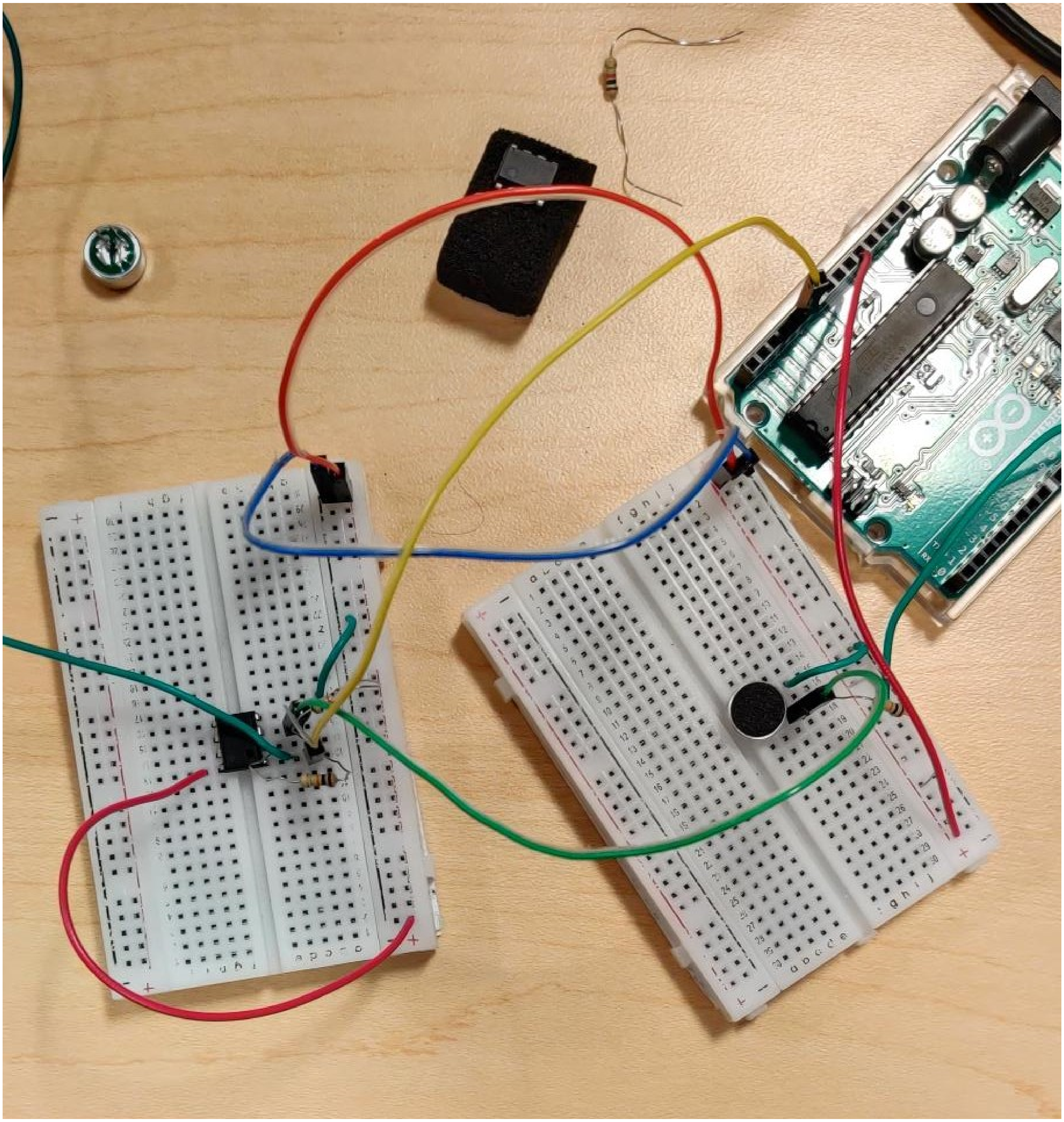
Title: Microphone Circuit

Date: 11/3/22

Content by: Carson

Present: Carson and Mustafa

Content:



We created a microphone circuit using an operational amplifier with gain of ~3 and a microphone. We chose to amplifier the signal since the output from the microphone without an amplifier didn't utilize the full range of the Arduinos input reading capabilities.

Conclusions/action items:

- Begin testing the circuits, gather data

12/5/22 - Headphones

RACHEL NOSSEN - Dec 12, 2022, 1:31 PM CST

Title: Final Headphones

Date: 12/5/22

Content by: Rachel Nossen

Present: Rachel, Ethan

Goals: To fabricate the final headphone design

Content:

- The design was printed using ABS filament.

- Costed roughly $30

How does the design/material compare to the original?

*The ABS filament is proven to be more durable with stronger structural integrity than the TPU. Believe that the ABS was a great choice with this design. This could be due to the fact that the headphones were designed properly, headband able to be stretched greatly to fit most user's heads.

Assembled?

* Pieces were assembled with the help of an instructional video, without the use of screws, etc

*The soft headphone pads were glued onto the cups to provide cushion on the ears.

Conclusions/action items:

*Future work includes manipulating the cuffs and grills to be able to house the electronics.

HRM Circuit

Mark RICE - Dec 12, 2022, 3:42 PM CST

Title: Heart Rate Monitor Circuit

Date: 12/5/2022

Content by: Mark Rice

Present: Mark Rice

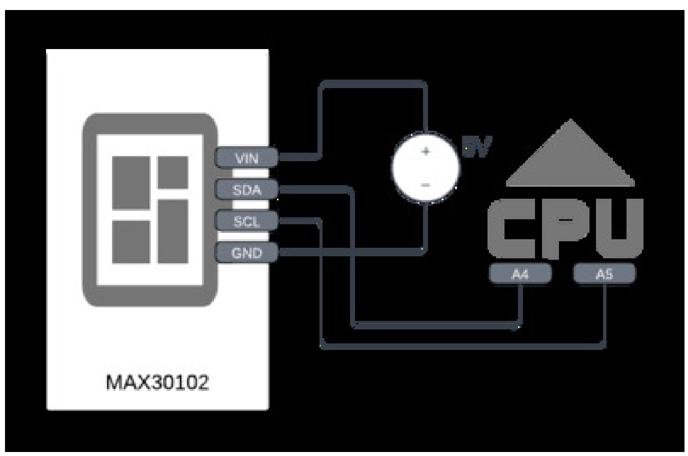
Goals: Visualize the heart rate monitor circuit for final presentation and poster

Content: attached is the circuit necessary for running the MAX30102 heart rate sensor board with an Arduino as the CPU, VIN and GND can be hooked up to a voltage source between 3.2 and 5 volts, for the sake of testing we used the 5V pins on the Arduino. Alongside the "11/18 Editing Arduino Code" entry this circuit can be used to compare heart beats measured with those found by an on the market heart rate monitor running ANT+.

Conclusions/action items:

test to compare this circuit to comparable on the market smartwatch running ANT+.

Mark RICE - Dec 12, 2022, 3:38 PM CST



Download

HRM_Circut_Diagram.png (15.3 kB)

12/7 Steps taken for comparison between Arduino circuit and Powr Labs HRM

Mark RICE - Dec 13, 2022, 8:25 PM CST

Title: Steps taken for comparison between Arduino circuit and Powr Labs HRM

Date: 12/7-13

Content by: Mark Rice

Present: Mark Rice

Goals: Test data from Arduino LED heart rate monitor and an on the market heart rate monitor.

Content:

1. Begin Arduino code from "11/18 Editing Arduino Code" and place sensor on finger with constant pressure, works best with a rubber band.

2. Begin simulation in Antware 2 software, be sure to use settings found in "10/31 ANT+ HRM Pairing", tighten hart rate monitor with a comfortable pressure on forearm or wrist.

3. Begin timer for 60 seconds, once it is complete record total beats sensed, not average beats per minute.

4. Repeat 1-3 for at least 5 trials.

Conclusions/action items: add info and adapt for final report.

12/7/2022 Microphone Testing Protocol

ETHAN HANNON (ehannon@wisc.edu) - Dec 13, 2022, 8:33 PM CST

Title: Testing Protocol for the Reliability of the Microphone

Date: 12/7/2022

Content by: Ethan Hannon

Present: Ethan Hannon

Goals: To provide a useful and informative approach to carrying out the microphone reliability testing.

Content:

1. Place microphone up to the user's neck or chest firmly to keep pressure on contact with body to ensure closed audio
2. Begin program (found below) in Matlab
3. Stay quiet when "Recording started" has is shown until "Recording ended" is seen
4. Matlab will calculate the results and output the testing graph data for the user to see in fast fourier transformation for proper analysis
5. Repeat steps 1-4 on different areas of the body to test for different results

Matlab Code Used:

```
L= 30*10000; %Recording Length (30 seconds)

Fs = 10000; %Sample Rate (Hz)

dev = audiodevinfo;

rec = audiorecorder(Fs, 16, 1, -1); %setting up recorder for audio length, bit rate, number of channels, and channel ID

disp('Recording started');

recordblocking(rec,L/10000); %Recording begins with type chosen (rec) and amount of time in seconds

disp('Recording Ended');

play(rec);

y = getaudiodata(rec);

figure(1);

plot(y);

x = fft(y); %fast fourier transformation program

P2 = abs(x/L);

P1 = P2(1:L/2+1);

P1(2:end-1) = 2*P1(2:end-1);
```

```
f = Fs*(0:(L/2))/L;

figure(2);

plot(f, P1);

title("Rate of Occurence Of Each Frequency Value");

xlabel("f (Hz)"); %frequency magnitude in Hz

ylabel("|P1(f)|"); %relative rate of frequency occurences (unitless)

xlim([0,500]);
```

Conclusions/action items:

This protocol will help future users of this project determine the reliability of future used microphones in order to ensure proper recording and analysis for a heartbeat can take place. If frequency threshold or recording time wants to be adjusted, simply alter Fs and L in the Matlab code respectively for alternate results. It may be beneficial to run the recording for longer periods of time to gain more instances of the heartbeat frequency occurring for more accurate results.

12/7 HRM circuit testing and results

Mark RICE - Dec 13, 2022, 8:16 PM CST

Title: Heart rate monitor circuit testing and results.

Date: 12/7-13

Content by: Mark Rice

Present: Mark Rice

Goals: Test and analyze data from Arduino LED heart rate monitor and an on the market heart rate monitor.

Content:

Comparison of beats in one minute from the Arduino circuit to beats measured by the Powr Labs heart rate monitor was run 5 times by running Arduino code that can count the total number of beats it sensed at the users finger and by using ANT+ software to record the number of beats registered by the Powr Labs heart rate monitor over the course of one minute.

The circuit had a mean of 67.2 BPM (beats per minute) over the 5 trials with a standard deviation of 3.35 BPM, while the Powr Labs heart rate monitor had an average BPM of 63.6 and a standard deviation of 3.85 BPM. Both of these results are within reasonable error given the method of collection, however some error may have occurred due to inconsistent pressure of the sensor area with the Arduino circuit.

The standard error of the mean was slightly higher 1.72 from the heart rate monitor over 1.5 from the circuit. Each had 5 runs. The t value was relatively small meaning that the groups had similar results, however due to the small sample size, larger testing should be completed for more accurate results. The results showed 8 degrees of freedom.

The fabricated Arduino circuit shows that this is a reasonable alternative to use for testing instead of integration with an on the market smart watch running ANT+. Results from using the heart rate monitor circuit could be improved by fabricating a way to more securely attach the sensor to the user. From physical use of watching when the circuit depicted a beat and when beats were felt by placing the fingers over the arteries it was obvious that the circuit sometimes misses beats. This could be fixed in a final product by having values of PTT that are approximately double or more that of recent measurements to be ignored. It was also concluded that for the sake of testing it is reasonable to use a LED heart rate monitor to represent a typical smart watch.

This circuit, without a protective casing is not prepared for public use of the device. Having exposed wires that are prone to disconnecting sometimes leads to connecting them in the wrong way, causing the board to short circuit and overheat. Additionally most sensors used in smartwatches have a layer of transparent material between the sensor and the wrist for comfort, applying this sensor directly to the skin can cause discomfort in the user which is not ideal for extended use. If this were to be used for extended testing or in a final product the above mentioned issues must be addressed.

Some error in the results found could have come from inconsistent pressure from both devices and human error in starting each sensor at the same time. Like mentioned in the introduction, smart watch LED sensors are inconsistent already, so it would be recommended that in a final product where PTT is measured to automatically search for values that are over double the expected value coming from the sensor missing a beat to be ignored.

Conclusions/action items: add info and adapt for final report.

12/7/2022 Microphone Testing Results

ETHAN HANNON (ehannon@wisc.edu) - Dec 13, 2022, 9:01 PM CST

Title: Microphone Testing Results

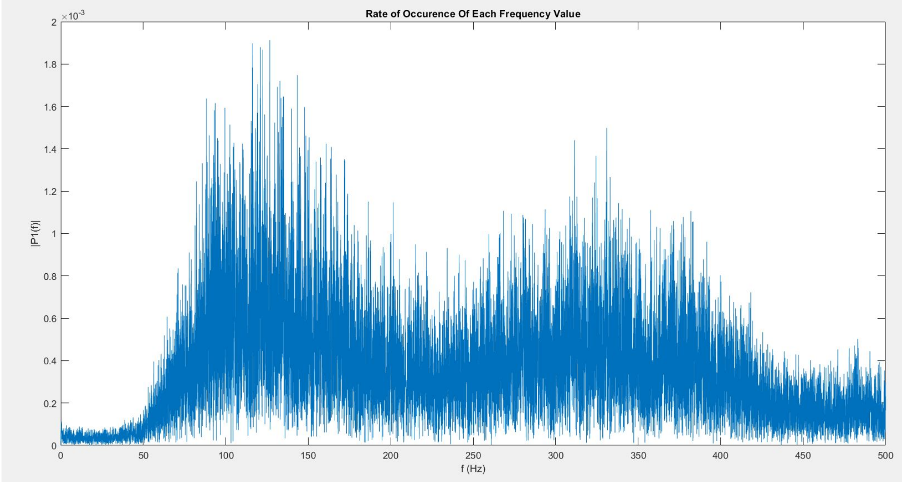
Date: 12/7/2022

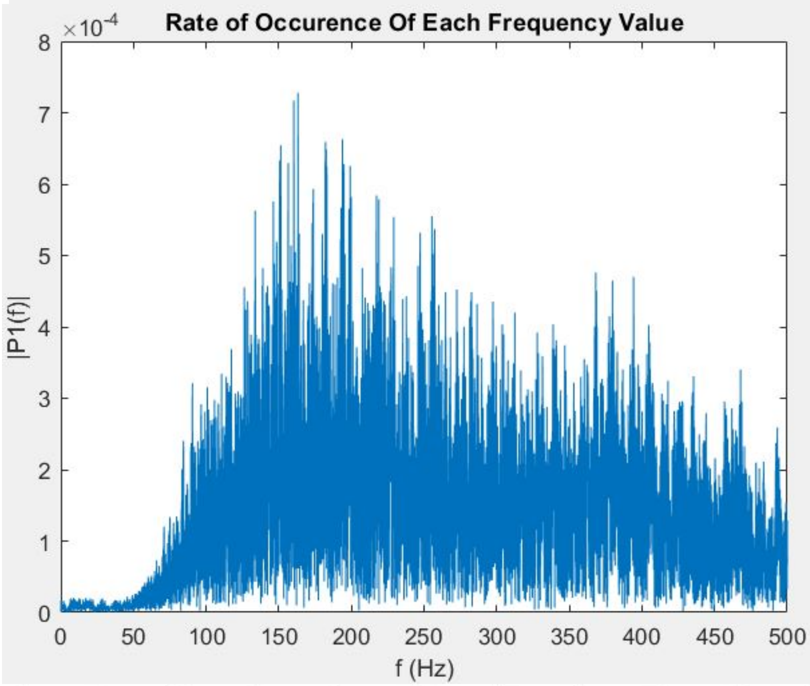
Content by: Ethan Hannon

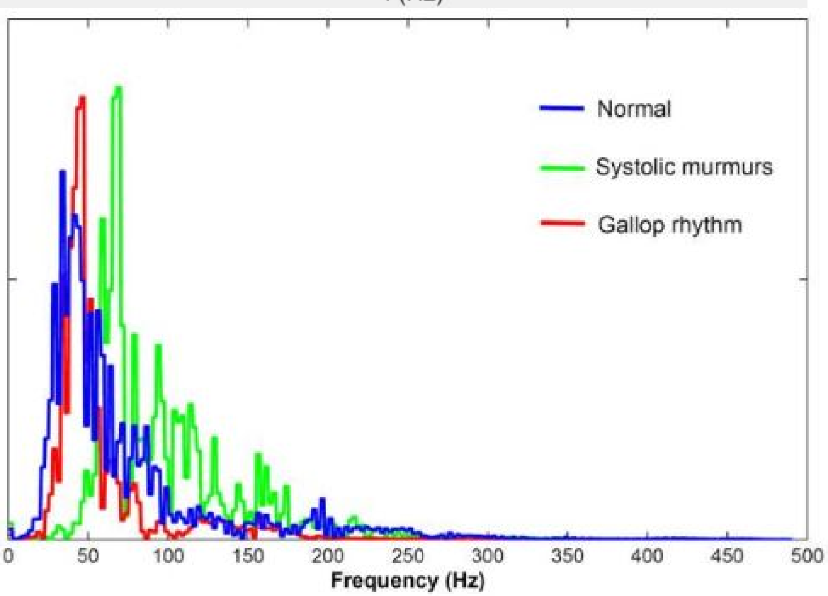
Present: Ethan Hannon

Goals: Analyzing and explaining the experimental results of the microphone test.

Content:







The null hypothesis for this experiment was that the microphone would not be capable of properly listening to and recording the heartbeat frequency accurately for further design analysis. The images shown above show the found frequency results for the microphone testing on the chest (left) on the neck (right) and the ideal results (bottom). What can be seen on the ideal curve is the that the most common rate for the three heartbeat types (Normal, systolic murmurs, and gallop/running rhythm) is a common frequency of about 20 to 75Hz. However, what can be seen on the chest and neck recording is the actual outputs had the highest frequency occurrences around 75 to 150Hz. This means that the microphone fails to reject the null hypothesis thus indicating that a new type of microphone is needed that is orientated towards lower frequency recording while ignoring higher frequency waves.

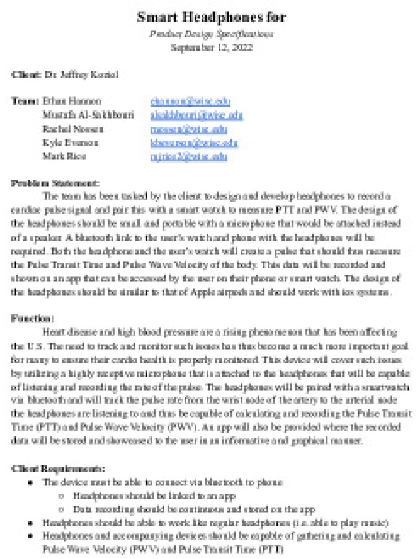
Due to the factor of the microphone not being capable of accurately recording the heartbeat, further testing analyses will have to postponed as any attempted tests to showcase efficient/more detailed PPT measurements will be inaccurate unless a working microphone type is discovered. Due to the time limitations of the project, ordering of a new microphone is unable to be carried out and thus future iterations of this project will have to prioritize finding a proper, low frequency microphone for better results. However, while this test didn't showcase an accurate analysis, it does prove that the concept of recording the heartbeat on the body is possible via soundwaves.

Conclusions/action items:

Finding a lower frequency microphone is paramount to gaining a better design for the headphones. Future group projects on this topic will need to look for a microphone that can block out frequencies shortly after the 75Hz range.

Team PDS for Headphone Design

ETHAN HANNON (ehannon@wisc.edu) - Oct 12, 2022, 12:49 AM CDT



Smart Headphones for

Product Design Specifications

September 12, 2022

Client: Dr. Jeffrey Kosiol

Team: Ethan Hannon ehannon@wisc.edu
Mustafa Al-Sakkhouri alsakkhouri@wisc.edu
Rachel Nessen rnessen@wisc.edu
Kyle Evenson kevenson@wisc.edu
Mark Rice mjrice2@wisc.edu

Problem Statement:

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached instead of a speaker. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphone and the user's watch will create a pulse that should then measure the Pulse Transit Time and Pulse Wave Velocity of the body. This data will be recorded and shown on an app that can be accessed by the user on their phone or smart watch. The design of the headphones should be similar to that of Apple airpods and should work with ios systems.

Function:

Heart disease and high blood pressure are a rising phenomenon that has been affecting the U.S. The need to track and monitor such issues has thus become a much more important goal for many to ensure their cardio health is properly monitored. This device will cover such issues by utilizing a highly receptive microphone that is attached to the headphones that will be capable of listening and recording the rate of the pulse. The headphones will be paired with a smartwatch via bluetooth and will track the pulse rate from the wrist node of the artery to the arterial node the headphones are listening to and thus be capable of calculating and recording the Pulse Transit Time (PTT) and Pulse Wave Velocity (PWV). An app will also be provided where the recorded data will be stored and showcased to the user in an informative and graphical manner.

Client Requirements:

- The device must be able to connect via bluetooth to phone
  - Headphones should be linked to an app
  - Data recording should be continuous and stored on the app
- Headphones should be able to work like regular headphones (i.e. able to play music)
- Headphones and accompanying devices should be capable of gathering and calculating Pulse Wave Velocity (PWV) and Pulse Transit Time (PTT)

Download

Smart_Headphones_PDS.pdf (101 kB) pdf of the team PDS for the headphone design

Preliminary Report

RACHEL NOSSEN - Dec 12, 2022, 3:34 PM CST

1

SmHeart Headphones Preliminary Report

October 10, 2022

BME 200/300

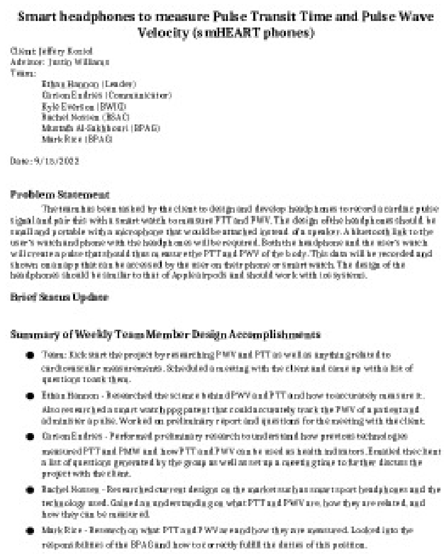
Leader: Ethan Hannon
BSAC: Rachel Nossen
BPAG: Mark Rice
BPAG: Mustafa Al-Sakhbouri
Communicator: Carson Endries
BWIG: Kyle Everson
Advisor: Dr. Justin Williams
Client: Dr. Jeffrey Koziol

Download

Preliminary_Report.pdf (1.36 MB) SmHeart Headphones Preliminary Report

Progress Report Week 1

RACHEL NOSSEN - Dec 12, 2022, 3:37 PM CST



Smart headphones to measure Pulse Transit Time and Pulse Wave Velocity (smHEART phones)

Client: Jeffrey Kosiol
Advisor: Justin Williams
Team:
Ethan Hannon (Leader)
Carson Endries (Communicator)
Kyle Everton (BWIG)
Rachel Nossen (BSAC)
Murtada Al-Sakkhouri (BPAG)
Mark Rice (BPAG)

Date: 9/15/2022

Problem Statement

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached instead of a speaker. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphones and the user's watch will create a pulse that should then measure the PTT and PWV of the body. This data will be recorded and shown on an app that can be accessed by the user on their phone or smart watch. The design of the headphones should be similar to that of Apple airpods and should work with ios systems.

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

- Team: Kick start the project by researching PWV and PTT as well as anything related to cardiovascular measurements. Scheduled a meeting with the client and came up with a list of questions to ask them.
- Ethan Hannon - Researched the science behind PWV and PTT and how to accurately measure it. Also researched a smart watch ppg patent that could accurately track the PWV of a patient and administer updates. Worked on preliminary report and questions for the meeting with the client.
- Carson Endries - Performed preliminary research to understand how previous technologies measured PTT and PWV and how PTT and PWV can be used as health indicators. Emailed the client a list of questions generated by the group as well as set up a meeting time to further discuss the project with the client.
- Rachel Nossen - Researched current designs on the market such as smart sport headphones and the technology used. Gained an understanding on what PTT and PWV are, how they are related, and how they can be measured.
- Mark Rice - Research on what PTT and PWV are and how they are measured. Looked into the responsibilities of the BPAG and how to correctly fulfill the duties of this position.

Download

ProgressReport1.docx (13.3 kB) Week 1 Progress Report (9/15/2022)

Progress Report Week 2

RACHEL NOSSEN - Dec 12, 2022, 3:38 PM CST

Smart headphones to measure Pulse Transit Time and Pulse Wave Velocity (smHEART phones)

Client: Jeffrey Kordel
Advisor: Justin Williams
Team:
Ethan Hannon (Leader)
Carson Endries (Communicator)
Kyle Everton (BWIG)
Rachel Nossen (BSAC)
Mustafa Al-Sakkhouri (BPAG)
Mark Rice (BPAG)

Date: 9/22/2022

Problem Statement

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached to it. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphone and the user's watch will create a pulse that should then measure the PTT and PWV of the body. This data will be recorded and shown on an app that can be accessed by the user on their phone or smart watch. The design of the headphones should be similar to that of Apple airpods and should work with ios systems.

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

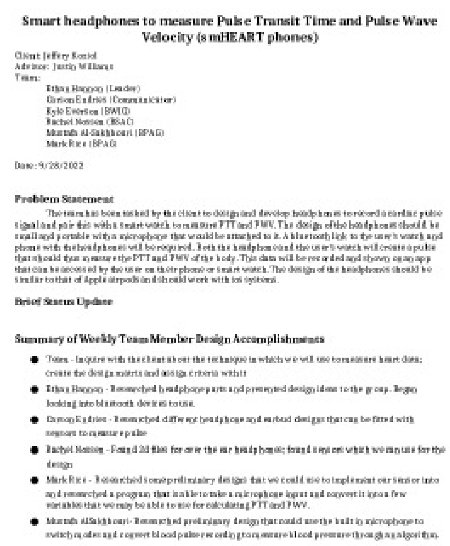
- Team - Understanding how PWV and PTT can be calculated using just audio signals. Looking at headphones that we could order and/or make for preliminary designs. Understanding the technology needed for these designs. Draft the PDS using the information researched and given by the client.
- Ethan Hannon - Researched devices that could listen and track pulses through sound. Worked on the PDS draft for submission.
- Carson Endries - Performed research on how devices can measure and calculate PWV and PTT to see how it can be applied to our project. Performed preliminary on potential components.
- Rachel Nossen - Research how auditory signal could be translated into electrical signals for measuring/recording, look into heart sensors that could be used with smart watches
- Mark Rice - research into ANT+ which could be used to transmit/receive heart rate data, added some possible budget expenses into spreadsheet, research into 3-d printable over the ear headphones "skeleton" for ease of use in the design process.

Download

Progress_Report_Week_2.docx (13.2 kB) Progress Report (9/22/22)

Progress Report Week 3

RACHEL NOSSEN - Dec 12, 2022, 3:39 PM CST



Smart headphones to measure Pulse Transit Time and Pulse Wave Velocity (smHEART phones)

Client: Jeffrey Kosiol
Advisor: Justin Williams
Team:
Ethan Hannon (Leader)
Carson Endries (Communicator)
Kyle Everson (BWIG)
Rachel Nossen (BSAC)
Murtada Al-Sakkhouri (BPAG)
Mark Rice (BPAG)

Date: 9/28/2022

Problem Statement

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached to it. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphone and the user's watch will create a pulse that should then measure the PTT and PWV of the body. This data will be recorded and shown on an app that can be accessed by the user on their phone or smart watch. The design of the headphones should be similar to that of Apple airpods and should work with ios systems.

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

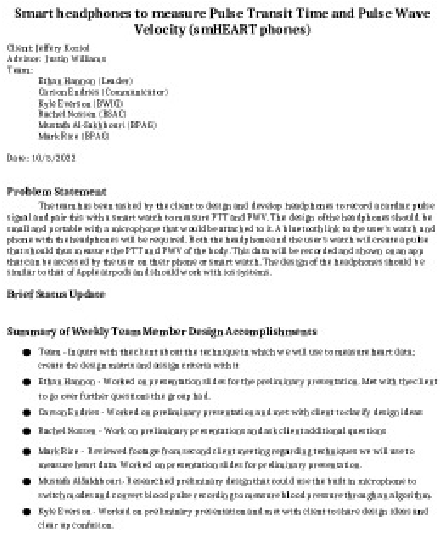
- Team - Inquire with the client about the technique in which we will use to measure heart data; create the design matrix and design criteria with it
- Ethan Hannon - Researched headphone parts and presented design ideas to the group. Began looking into bluetooth devices to use.
- Carson Endries - Researched different headphone and earbud designs that can be fitted with sensors to measure pulse
- Rachel Nossen - Found 3d files for over the ear headphones; found sensors which we can use for the design
- Mark Rice - Researched some preliminary designs that we could use to implement our sensor into and researched a program that is able to take a microphone input and convert it into a few variables that we may be able to use for calculating PTT and PWV.
- Murtada AlSakkhouri - Researched preliminary design that could use the built in microphone to switch modes and convert blood pulse recording to measure blood pressure through an algorithm.

Download

BME_smHEART_Phones_Progress_Report_Week_3.docx (13.1 kB) Progress Report Week 3 (9/28/22)

Progress Report Week 4

RACHEL NOSSEN - Dec 12, 2022, 3:40 PM CST



Smart headphones to measure Pulse Transit Time and Pulse Wave Velocity (smHEART phones)

Client: Jeffrey Kontel
Advisor: Justin Williams
Team:
Ethan Hannon (Leader)
Carson Endries (Communicator)
Kyle Everson (BWIG)
Rachel Nossen (BSAC)
Mustafa Al-Sakkhouri (BPAG)
Mark Rice (BPAG)

Date: 10/5/2022

Problem Statement

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached to it. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphones and the user's watch will create a pulse that should then measure the PTT and PWV of the body. This data will be recorded and shown on an app that can be accessed by the user on their phone or smart watch. The design of the headphones should be similar to that of Apple airpods and should work with ios systems.

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

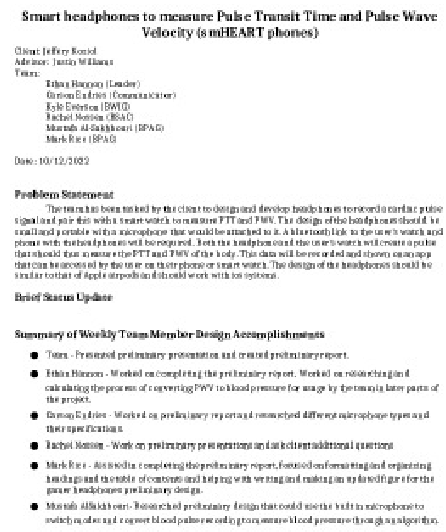
- Team - Inquire with the client about the technique in which we will use to measure heart data; create the design matrix and design criteria with it
- Ethan Hannon - Worked on presentation slides for the preliminary presentation. Met with the client to go over further questions the group had.
- Carson Endries - Worked on preliminary presentation and met with client to clarify design ideas
- Rachel Nossen - Work on preliminary presentation and ask client additional questions
- Mark Rice - Reviewed footage from second client meeting regarding techniques we will use to measure heart data. Worked on presentation slides for preliminary presentation.
- Mustafa AlSakkhouri - Researched preliminary design that could use the built in microphone to switch modes and convert blood pulse recording to measure blood pressure through an algorithm.
- Kyle Everson - Worked on preliminary presentation and met with client to share design ideas and clear up confusion.

Download

BME_smHEART_Phones_Progress_Report_Week_4.docx (13.1 kB) Progress Report Week 4 (10/5/22)

Progress Report Week 5

RACHEL NOSSEN - Dec 12, 2022, 3:40 PM CST



Smart headphones to measure Pulse Transit Time and Pulse Wave Velocity (smHEART phones)

Client: Jeffrey Kordel
Advisor: Justin Williams
Team:
Ethan Hannon (Leader)
Carson Endres (Communicator)
Kyle Everson (BWIG)
Rachel Nossen (BSAC)
Mustafa Al-Sakkhouri (BPAG)
Mark Rice (BPAG)

Date: 10/12/2022

Problem Statement

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached to it. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphones and the user's watch will create a pulse that should then measure the PTT and PWV of the body. This data will be recorded and shown on an app that can be accessed by the user on their phone or smart watch. The design of the headphones should be similar to that of Apple airpods and should work with ios systems.

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

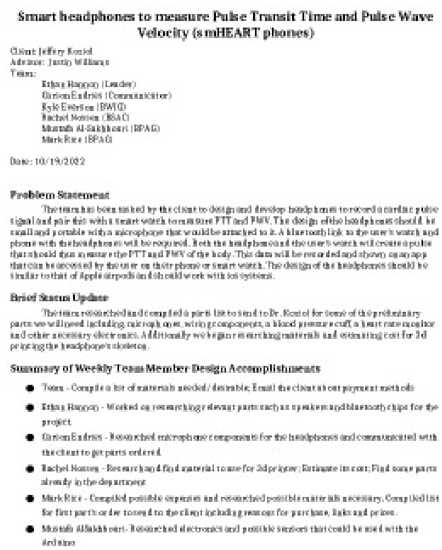
- Team - Presented preliminary presentation and created preliminary report.
- Ethan Hannon - Worked on completing the preliminary report. Worked on researching and calculating the process of converting PWV to blood pressure for usage by the team in later parts of the project.
- Carson Endres - Worked on preliminary report and researched different microphone types and their specifications.
- Rachel Nossen - Work on preliminary presentations and ask client additional questions
- Mark Rice - Assisted in completing the preliminary report, focused on formatting and organizing headings and the table of contents and helping with writing and making an updated figure for the gamer headphones preliminary design.
- Mustafa AlSakkhouri - Researched preliminary design that could use the built in microphone to switch modes and convert blood pulse recording to measure blood pressure through an algorithm.

Download

BME_smHEART_Phones_Progress_Report_Week_5.docx (13.1 kB) Progress Report Week 5 (10/12/22)

Progress Report Week 6

RACHEL NOSSEN - Dec 12, 2022, 3:41 PM CST



Smart headphones to measure Pulse Transit Time and Pulse Wave Velocity (smHEART phones)

Client: Jeffrey Kentol
Advisor: Justin Williams
Team:
Ethan Hannon (Leader)
Carson Endres (Communicator)
Kyle Everson (BWIG)
Rachel Nossen (BSAC)
Mustafa Al-Sakkhouri (BPAG)
Mark Rice (BPAG)

Date: 10/19/2022

Problem Statement

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached to it. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphone and the user's watch will create a pulse that should then measure the PTT and PWV of the body. This data will be recorded and shown on an app that can be accessed by the user on their phone or smart watch. The design of the headphones should be similar to that of Apple airpods and should work with ios systems.

Brief Status Update

The team researched and compiled a parts list to send to Dr. Kentol for some of the preliminary parts we will need including microphones, wiring components, a blood pressure cuff, a heart rate monitor and other necessary electronics. Additionally we began researching materials and estimating cost for 3d printing the headphone's skeleton.

Summary of Weekly Team Member Design Accomplishments

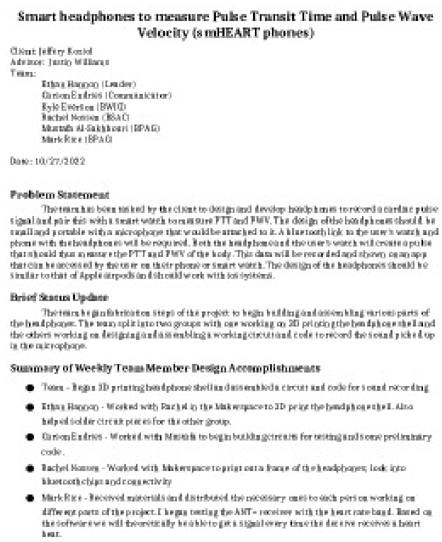
- Team - Compiled a list of materials needed / desirable; Email the client about payment methods
- Ethan Hannon - Worked on researching relevant parts such as speakers and bluetooth chips for the project.
- Carson Endres - Researched microphone components for the headphones and communicated with the client to get parts ordered.
- Rachel Nossen - Research and find material to use for 3d printer; Estimate its cost; Find some parts already in the department
- Mark Rice - Compiled possible expenses and researched possible materials necessary. Compiled list for first parts order to send to the client including reasons for purchase, links and prices.
- Mustafa AlSakkhouri - Researched electronics and possible sensors that could be used with the Arduino

Download

BME_smHEART_Phones_Progress_Report_Week_6.docx (15.5 kB) Progress Report Week 6 (10/19/22)

Progress Report Week 7

RACHEL NOSSEN - Dec 12, 2022, 3:43 PM CST



Smart headphones to measure Pulse Transit Time and Pulse Wave Velocity (smHEART phones)

Client: Jeffrey Kosiol
Advisor: Justin Williams
Team:
Ethan Hannon (Leader)
Carson Endries (Communicator)
Kyle Everson (BWIG)
Rachel Nossen (BSAC)
Mustafa Al-Sakkhouri (BPAG)
Mark Rice (BPAG)

Date: 10/27/2022

Problem Statement

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached to it. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphones and the user's watch will create a pulse that should then measure the PTT and PWV of the body. This data will be recorded and shown on an app that can be accessed by the user on their phone or smart watch. The design of the headphones should be similar to that of Apple airpods and should work with ios systems.

Brief Status Update

The team began fabrication steps of the project to begin building and assembling various parts of the headphones. The team split into two groups with one working on 3D printing the headphone shell and the others working on designing and assembling a working circuit and code to record the sound picked up in the microphone.

Summary of Weekly Team Member Design Accomplishments

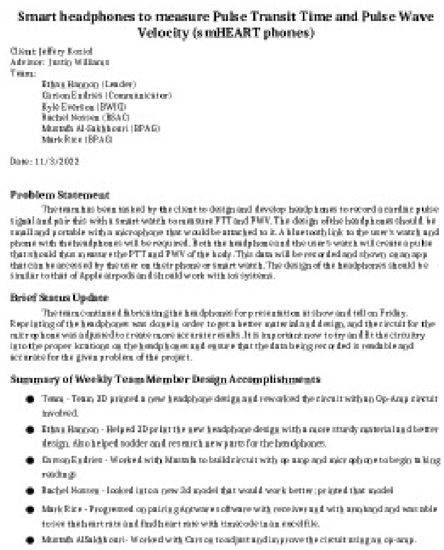
- Team - Begin 3D printing headphone shell and assembled a circuit and code for sound recording
- Ethan Hannon - Worked with Rachel in the Makerspace to 3D print the headphone shell. Also helped solder circuit pieces for the other group.
- Carson Endries - Worked with Mustafa to begin building circuits for testing and some preliminary code.
- Rachel Nossen - Worked with Makerspace to print out a frame of the headphones; look into bluetooth chips and connectivity
- Mark Rice - Received materials and distributed the necessary ones to each person working on different parts of the project. I began testing the ANT+ receiver with the heart rate band. Based on the software we will theoretically be able to get a signal every time the device receives a heart beat.

[Download]

BME_smHEART_Phones_Progress_Report_Week_7.docx (16.3 kB) Progress Report Week 7 (10/27/22)

Progress Report Week 8

RACHEL NOSSEN - Dec 12, 2022, 3:43 PM CST



Smart headphones to measure Pulse Transit Time and Pulse Wave Velocity (smHEART phones)

Client: Jeffrey Kentol
Advisor: Justin Williams
Team:
Ethan Hannon (Leader)
Carson Endries (Communicator)
Kyle Everson (BWIG)
Rachel Nossen (BSAC)
Murtadh Al-Sakkhouri (BPAG)
Mark Rice (BPAG)

Date: 11/3/2022

Problem Statement

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached to it. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphones and the user's watch will create a pulse that should then measure the PTT and PWV of the body. This data will be recorded and shown on an app that can be accessed by the user on their phone or smart watch. The design of the headphones should be similar to that of Apple airpods and should work with ios systems.

Brief Status Update

The team continued fabricating the headphones for presentation at show and tell on Friday. Reprinting of the headphones was done in order to get a better material and design, and the circuit for the microphone was adjusted to create more accurate results. It is important now to try and fit the circuitry into the proper locations on the headphones and ensure that the data being recorded is readable and accurate for the given problem of the project.

Summary of Weekly Team Member Design Accomplishments

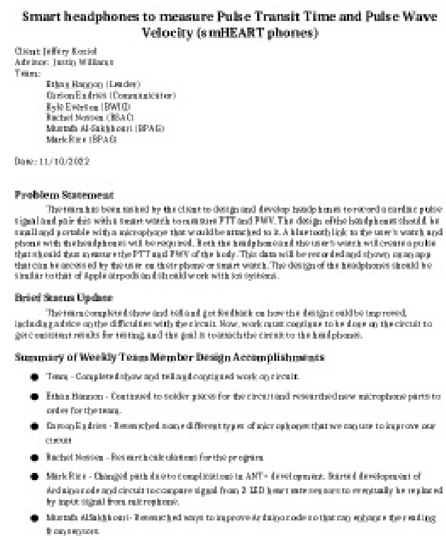
- Team - Team 3D printed a new headphone design and reworked the circuit with an Op-Amp circuit involved.
- Ethan Hannon - Helped 3D print the new headphone design with a more sturdy material and better design. Also helped solder and research new parts for the headphones.
- Carson Endries - Worked with Murtadh to build circuit with op amp and microphone to begin taking readings
- Rachel Nossen - looked into a new 3d model that would work better; printed that model
- Mark Rice - Progressed on pairing Arduino software with receiver and with armband and wearable to see the heart rate and find heart rate with timecode in an excel file.
- Murtadh AlSakkhouri - Worked with Carson to adjust and improve the circuit using an op-amp.

[Download]

BME_smHEART_Phones_Progress_Report_Week_8.docx (16.7 kB) Progress Report Week 8 (11/3/22)

Progress Report Week 9

RACHEL NOSSEN - Dec 12, 2022, 3:44 PM CST



Smart headphones to measure Pulse Transit Time and Pulse Wave Velocity (smHEART phones)

Client: Jeffrey Koziol
Advisor: Justin Williams
Team:
Ethan Hannon (Leader)
Carson Endries (Communicator)
Kyle Everson (BWIG)
Rachel Nossen (BSAC)
Murtada Al-Sakkhouri (BPAG)
Mark Rice (BPAG)

Date: 11/10/2022

Problem Statement

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached to it. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphones and the user's watch will create a pulse that should then measure the PTT and PWV of the body. This data will be recorded and shown on an app that can be accessed by the user on their phone or smart watch. The design of the headphones should be similar to that of Apple airpods and should work with ios systems.

Brief Status Update

The team completed show and tell and got feedback on how the design could be improved, including advice on the difficulties with the circuit. Now, work must continue to be done on the circuit to get consistent results for testing, and the goal is to attach the circuit to the headphones.

Summary of Weekly Team Member Design Accomplishments

- Team - Completed show and tell and continued work on circuit.
- Ethan Hannon - Continued to solder pieces for the circuit and researched new microphone parts to order for the team.
- Carson Endries - Researched many different types of microphones that we can use to improve our circuit
- Rachel Nossen - Research calculations for the program.
- Mark Rice - Changed path due to complications in ANT+ development. Started development of Arduino code and circuit to compare signal from 2 LED heart rate sensors to eventually be replaced by input signal from microphone.
- Murtada AlSakkhouri - Researched ways to improve Arduino code so that can enhance the reading from sensors.

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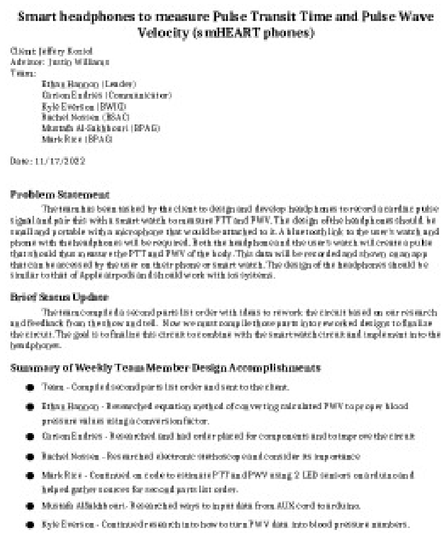
BME_smHEART_Phones_Progress_Report_Week_9.docx (16.5 kB) Progress Report Week 9 (11/10/22)

Progress Report Week 10

RACHEL NOSSEN - Dec 12, 2022, 3:45 PM CST



Smart headphones to measure Pulse Transit Time and Pulse Wave Velocity (smHEART phones)

Client: Jeffrey Kordel
Advisor: Justin Williams
Team:
Ethan Hannon (Leader)
Carson Endries (Communicator)
Kyle Everson (BWIG)
Rachel Nossen (BSAC)
Mustafa Al-Sakkhouri (BPAG)
Mark Rice (BPAG)

Date: 11/17/2022

Problem Statement

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached to it. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphone and the user's watch will create a pulse that should then measure the PTT and PWV of the body. This data will be recorded and shown on an app that can be accessed by the user on their phone or smart watch. The design of the headphones should be similar to that of Apple airpods and should work with ios systems.

Brief Status Update

The team compiled a second parts list order with ideas to rework the circuit based on our research and feedback from the show and tell. Now we must compile those parts into reworked designs to finalize the circuit. The goal is to finalize this circuit to combine with the smart watch circuit and implement into the headphones.

Summary of Weekly Team Member Design Accomplishments

- Team - Compiled second parts list order and sent to the client.
- Ethan Hannon - Researched equation method of converting calculated PWV to proper blood pressure values using a conversion factor.
- Carson Endries - Researched and had order placed for components and to improve the circuit.
- Rachel Nossen - Researched electronic stethoscope and consider its importance
- Mark Rice - Continued on code to estimate PTT and PWV using 2 LED sensors on arduino and helped gather sources for second parts list order.
- Mustafa AlSakkhouri - Researched ways to input data from AUX cord to arduino.
- Kyle Everson - Continued research into how to turn PWV data into blood pressure numbers.

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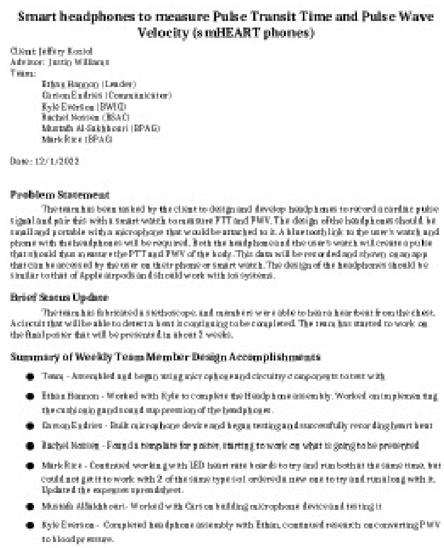
BME_smHEART_Phones_Progress_Report_Week_10.docx (16.5 kB) Progress Report Week 10 (11/17/22)

Progress Report Week 11/12

RACHEL NOSSEN - Dec 12, 2022, 3:47 PM CST



Smart headphones to measure Pulse Transit Time and Pulse Wave Velocity (smHEART phones)

Client: Jeffrey Kaniol
Advisor: Justin Williams
Team:
Ethan Hannon (Leader)
Carson Endries (Communicator)
Kyle Everson (BWIG)
Rachel Nossen (BSAC)
Mustafa Al-Sakkhouri (BPAG)
Mark Rice (BPAG)

Date: 12/1/2022

Problem Statement

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached to it. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphones and the user's watch will create a pulse that should then measure the PTT and PWV of the body. This data will be recorded and shown on an app that can be accessed by the user on their phone or smart watch. The design of the headphones should be similar to that of Apple airpods and should work with ios systems.

Brief Status Update

The team has fabricated a stethoscope, and members were able to hear a heartbeat from the chest. A circuit that will be able to detect a beat is continuing to be completed. The team has started to work on the final poster that will be presented in about 2 weeks.

Summary of Weekly Team Member Design Accomplishments

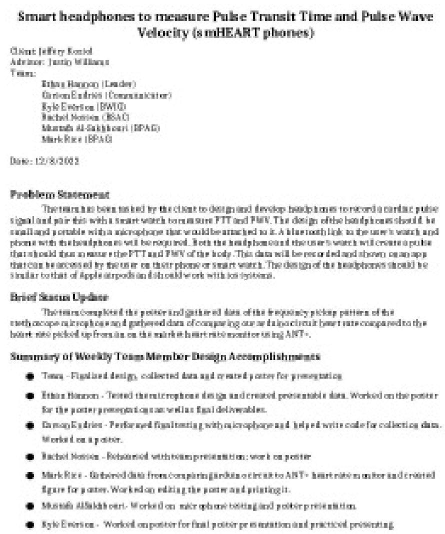
- Team - Assembled and began using microphone and circuitry components to test with
- Ethan Hannon - Worked with Kyle to complete the Headphone assembly. Worked on implementing the cushioning and sound suppression of the headphones.
- Carson Endries - Built microphone device and began testing and successfully recording heart beat
- Rachel Nossen - Found a template for poster, starting to work on what is going to be presented
- Mark Rice - Continued working with LED heart rate boards to try and run both at the same time, but could not get it to work with 2 of the same type so I ordered a new one to try and run along with it. Updated the expenses spreadsheet.
- Mustafa AlSakkhouri - Worked with Carson building microphone device and testing it
- Kyle Everson - Completed headphone assembly with Ethan, continued research on converting PWV to blood pressure.

Download

BME_smHEART_Phones_Progress_Report_Week_11.docx (16.6 kB) Progress Report Week 11 (12/1/22)

Progress Report Week 13

RACHEL NOSSEN - Dec 12, 2022, 3:48 PM CST



Smart headphones to measure Pulse Transit Time and Pulse Wave Velocity (smHEART phones)

Client: Jeffery Kenkel
Advisor: Justin Williams
Team:
Ethan Hannon (Leader)
Carson Endries (Communicator)
Kyle Everson (BWIG)
Rachel Nossen (BSAC)
Mustafa Al-Sakkhouri (BPAG)
Mark Rice (BPAG)

Date: 12/8/2022

Problem Statement

The team has been tasked by the client to design and develop headphones to record a cardiac pulse signal and pair this with a smart watch to measure PTT and PWV. The design of the headphones should be small and portable with a microphone that would be attached to it. A bluetooth link to the user's watch and phone with the headphones will be required. Both the headphones and the user's watch will create a pulse that should then measure the PTT and PWV of the body. This data will be recorded and shown on an app that can be accessed by the user on their phone or smart watch. The design of the headphones should be similar to that of Apple airpods and should work with ios systems.

Brief Status Update

The team completed the poster and gathered data of the frequency pickup pattern of the stethoscope microphone and gathered data of comparing our arduino circuit heart rate compared to the heart rate picked up from an on the market heart rate monitor using ANT+.

Summary of Weekly Team Member Design Accomplishments

- Team - Finalized design, collected data and created poster for presentation
- Ethan Hannon - Tested the microphone design and created presentable data. Worked on the poster for the poster presentation as well as final deliverables.
- Carson Endries - Performed final testing with microphone and helped write code for collecting data. Worked on a poster.
- Rachel Nossen - Rehearsed with team presentation; work on poster
- Mark Rice - Gathered data from comparing arduino circuit to ANT+ heart rate monitor and created figure for poster. Worked on editing the poster and printing it.
- Mustafa AlSakkhouri - Worked on microphone testing and poster presentation.
- Kyle Everson - Worked on poster for final poster presentation and practiced presenting.

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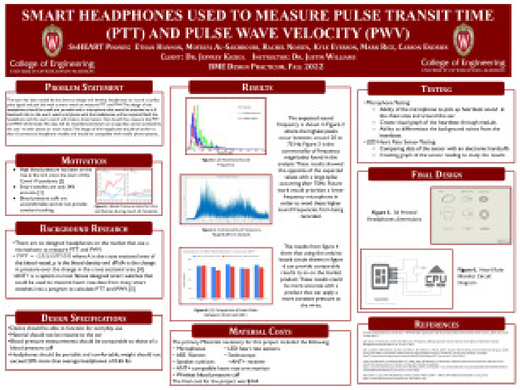
BME_smHEART_Phones_Progress_Report_Weeks_13.docx (16.3 kB) Progress Report Week 13 (12/8/22)

Final Poster

RACHEL NOSSEN - Dec 12, 2022, 3:50 PM CST



Download

Final_Poster.pptx.pdf (1.14 MB) Final Poster that will be displayed during the Poster Presentation on 12/9/22

Final Report

KYLE EVERSON - Dec 14, 2022, 4:18 PM CST

1

SmHeart Headphones Final Report
December 14, 2022
BME 200/300

Leader: Ethan Hannon
BSAC: Rachel Nossen
BPAG: Mark Rice
BPAG: Mustafa Al-Sakhbouri
Communicator: Carson Endries
BWIG: Kyle Everson
Advisor: Dr. Justin Williams
Client: Dr. Jeffrey Koziol

Download

Final_Report.pdf (5.1 MB) SmHeart Headphones Final Report

9/11/2022 Information on Pulse Transmit Time and Pulse Wave Time

ETHAN HANNON (ehannon@wisc.edu) - Sep 11, 2022, 7:15 PM CDT

Title: Pulse transit time estimation of aortic pulse wave velocity and blood pressure using machine learning and simulated training data

Date: 9/11/2022

Content by: Ethan Hannon

Present: Ethan Hannon

Goals: To understand the science and importance behind Pulse Transmit Time (PTT)

Citation:

[1] J. M. J. Huttunen, L. Kärkkäinen, and H. Lindholm, “Pulse transit time estimation of aortic pulse wave velocity and blood pressure using machine learning and simulated training data,” *PLoS Comput Biol*, vol. 15, no. 8, p. e1007259, Aug. 2019, doi: 10.1371/journal.pcbi.1007259.

Content:

Pulse Wave Time is best recorded as the transmit distance between two artial sites divided by the travel time between them.

$$\mathrm{PWV} = \frac{\text{distance between the sites}}{\text{travel time between the sites}}.$$

The Travel Time of this equation is commonly known as the Pulse Travel Time (PTT). A photoplethysmogram (PPG) is commonly used to measure such waves and their times. The most accurate results can be found by plugging the first nodal sight of measurement at the major artery, or starting artery.

Conclusions/action items:

Further information will have to be required by meeting with the client. This information will still be integral to understand the scientific and mathematical purposes of the team's device.

9/23/2022 WHO Standard on Headphone Safety

ETHAN HANNON (ehannon@wisc.edu) - Sep 23, 2022, 3:06 PM CDT

Title: Safe Listening Devices and Systems

Date: 9/23/2022

Content by: Ethan Hannon

Present: Ethan Hannon

Goals: To research and document relevant standards to the safety and protocol of headphone usage and fabrication

Citation:

"Safe Listening Devices and Systems." World Health Organization and International Telecommunication Union, Geneva, 2019.

Content:

Intense sounds or noise frequencies for prolonged periods of time can be detrimental on the auditory health of a person and can have lasting consequences if no steps to prevent such damage occurs. WHO recommends that a user only listen to about 80dB over a period of 48 hours in order to minimize hearing damage that can occur which is known as "sound allowance" or "calculated sound dose". WHO also states that there is a risk factor for listening to various sounds regardless of the time one is subjected to it according to the Equal Energy Principle. In summary, this states that a person listening to a low volume sound for long periods of time can have the same amount of damage to their hearing as they would listening to a very loud amount of sound for only a short period of time.

This principle can be mathematically introduced as:

dose=

$$dose = \int_{t1}^{t2} (p_A(t))^2 dt$$

Likewise, the WHO also showcases a possible listening routine a person could follow for their daily usage of headphones based on 2 modes.

- Mode 1: For adults
- Mode 2: For sensitive hearing (e.g. children):

Table 1: Example of weekly listening time for Mode 1

dB(A) SPL	Weekly (*1.6 Pa²h*)
107	4.5 minutes
104	9.5 minutes
101	18.75 minutes
98	37.5 minutes
95	75 minutes
92	2.5 hours
89	5 hours
86	10 hours
83	20 hours
80	40 hours

Table 2: Example of weekly listening time for Mode 2

dB(A) SPL	Weekly (*0.51 Pa²h*)
107	1.5 minutes
104	3 minutes
101	6 minutes
98	12 minutes
95	24 minutes
92	48 minutes
89	1 hours 36 minutes
86	3 hours 15 minutes
83	6 hours 24 minutes
80	12 hours 30 minutes
77	25 hours
75	40 hours

Measuring sound allowance

Conclusions/action items:

It is important to understand the danger and health factors when working with devices that would effect our hearing in many ways. The team will work to implement these standards in the level of sound and frequency the final product headphones will provide. Further research will be done to figure out the proper way to control sound levels and how a user can accurately adjust them for the final design.

ETHAN HANNON (ehannon@wisc.edu) - Sep 23, 2022, 3:06 PM CDT

[Download]

9789241515276-eng.pdf (820 kB) WHO standard on headphone sound design

5/10/2022 Rise in Blood Pressure Over Covid for Men and Women

ETHAN HANNON (ehannon@wisc.edu) - Oct 12, 2022, 1:03 AM CDT

Title: Common Trend of the Rise in Blood Pressure for Both Men and Women Over COVID

Date: 5/10/2022

Content by: Ethan Hannon

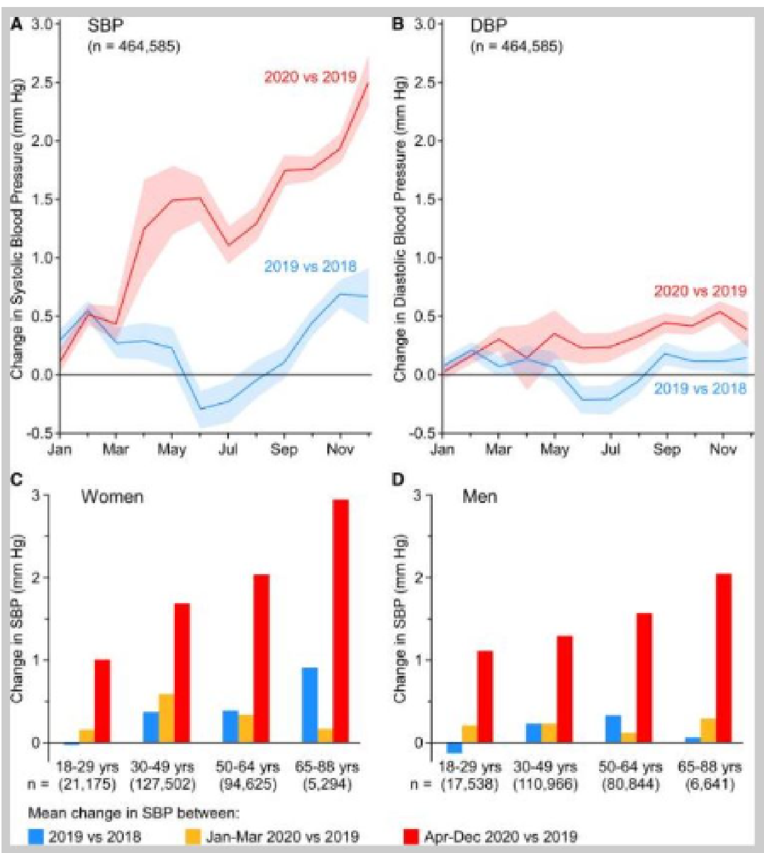
Present: Ethan Hannon

Goals: To determine the common rise of blood pressure over the course of someone's age.

Citation:

L. J. Laffin, H. W. Kaufman, Z. Chen, J. K. Niles, A. R. Arellano, L. A. Bare, and S. L. Hazen, “Rise in blood pressure observed among us adults during the COVID-19 pandemic,” *Wolters Kluwer Public Health Emergency Collection*, 18-Jan-2022. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8763044/figure/F1/. [Accessed: 12-Oct-2022].

Content:



What can be seen in the image above is the common trend of risking blood pressure since the outbreak of COVID-19. What can be seen is an overall rise in high blood pressure for both men and women with women rising drastically in overall blood pressure. This is a clear health risk for the population as a larger average blood pressure can mean much more people are at risk of heart disease due to high blood pressure.

Conclusions/action items:

The need for a device that can properly track and record this rise is important to ensure that the general population can properly monitor and treat their health when they need to. The team will work with this information to further make a better target audience for the intended final product of the project.

5/10/2022 Information On Rise in Blood Pressure

ETHAN HANNON (ehannon@wisc.edu) - Oct 12, 2022, 12:30 AM CDT

Title: The Rise in Blood Pressure Over the Years

Date: 5/10/2022

Content by: Ethan Hannon

Present: Ethan Hannon

Goals: To determine the trend of rising blood pressure rates in the general population.

Citation:"Facts about hypertension," *Centers for Disease Control and Prevention*, 12-Jul-2022. [Online]. Available: https://www.cdc.gov/bloodpressure/facts.htm. [Accessed: 02-Sep-2022]

Content:

This report by the CDC sheds insightful information on the common trend and information regarding rising and high blood pressure.

- Elevated blood pressure is 120-129/<80 mmHg
- Hypertension blood pressure is achieved around 140/90 mmHg
- Men are more common to have high blood pressure with 50% of all men in the U.S. having it and 44% of all women in the U.S. having it
- High blood pressure is more commonly found in the southern U.S. but can be found in larger parts across the East Coast and Midwest.

Conclusions/action items:

High blood pressure is very problematic and widespread issue among much of the U.S. population. The team will work to better apply such knowledge in representing the work they do as well as targeting the final design of the prototype to stress importance to such criteria of the population affected.

10/10/2022 Equation for Calculating Blood Pressure

Mark RICE - Dec 04, 2022, 7:13 PM CST

Title: Relating Blood Pressure to PWV and PTT

Date: 10/10/2022

Content by: Ethan Hannon

Present: Ethan Hannon

Goals: To find an equation to relate PWV(pulse wave velocity) and PTT(pulse transit time) to one another.

Citation:

M. Yavarimanesh, A. Chandrasekhar, J.-O. Hahn, and R. Mukkamala, “Commentary: Relation between blood pressure and pulse wave velocity for human arteries,” *Frontiers*, 01-Jan-2001. [Online]. Available: https://www.frontiersin.org/articles/10.3389/fphys.2019.01179/full#:~:text=(C%2CD)%20Corresponding%20P,where%20%CF%81%20is%20blood%20density). [Accessed: 12-Oct-2022].

Content:

$$(PWV = \sqrt{(A/\rho)\,(dP/dA)}$$

The above equation details how one can calculate blood pressure from PWV(and PTT) where A is the cross sectional area of the blood vessel, ρ is the blood density, and dP/dA is the change in pressure over the change in the cross sectional area. This equation can also be known as Frank/Bramwell-Hill Equation.

Conclusions/action items:

This equation can help the team properly calculate and determine blood pressure based off the the findings for PWV found using the device. This will be important when writing the code for the tracking software as it will need to properly calculate blood pressure values when recording data. Further information to properly determine change in the cross sectional area will need to be undertaken to find all unknowns except the blood pressure before solving.

11/14/2022 Blood Pressure Conversion

KYLE EVERSON - Nov 21, 2022, 4:54 PM CST

Title: Using Pulse Wave Velocity to Convert to Blood Pressure

Date: 11/14/2022

Content by: Ethan Hannon

Present: Ethan Hannon

Goals: To determine an effective estimation to convert pulse wave velocity to blood pressure.

Citation:

A. Tripathi, Y. Obata, P. Ruzankin, N. Askaryar, D. E. Berkowitz, J. Steppan, and V. Barodka, “A pulse wave velocity based method to assess the mean arterial blood pressure limits of autoregulation in peripheral arteries,” *Frontiers in Physiology*, 02-Nov-2017. [Online]. Available: https://www.frontiersin.org/articles/10.3389/fphys.2017.00855/full. [Accessed: 11-Nov-2022].

Content:

One of the main issues the team was having troubles from was finding an effective method for converting measured Pulse Wave Velocity into usable blood pressure data. This was mainly do to the fact that many accurate conversion methods utilized too many unknown variables that the headphone design wouldn't be capable of measuring such as the user's arterial wall thickness as well as their change in wall thickness during heart contractions and recovery. Therefore, the best alternative to finding such a conversion was using an equation found from comparison data of blood pressure with pulse wave velocity and taking the equation for its line of best fit. What was found was an equation as follows:

$$\Delta PWV = -7.58 \times e^{(-0.07 \times pressure\ at\ the\ fingertips)} - 0.03$$

Where PWV is in m/s and pressure is in mmHg.

This new method of conversion utilized change in pulse wave velocity to calculate blood pressure in the fingertips. Using this equation, only one unknown (blood pressure) is needed to be calculated for where the change in Pulse Wave Velocity can simply be found using the difference of two different pulse wave velocity recordings in time. While this method greatly simplifies the method of calculating blood pressure, it does come with a few drawbacks. First, the blood pressure calculated is assumed to occur in the fingertips which is not the main focus of the measurements where the smartwatch is meant to track pulse wave velocity up to the wrist. While this could prove potentially problematic for the accuracy of blood pressure, it can be assumed that such pressure will remain consistent in both areas of the body making the need of further conversion minimal. Second, this data is ultimately based off of trends found through observation, so the precision of the equation is debatable, however, the equation found was done using multiple participants with presumed healthy cardiovascular health over various age groups. This ensures that the data presented is consistent for all age groups and should correlate to accurate blood pressure results.

Conclusions/action items:

It is important to create an accurate conversion equation for determining the cardiovascular health of individuals. The team will work to implement this conversion factor when creating the data analysis portion of the project.

2022/9/11 PPG Watch Patent

ETHAN HANNON (ehannon@wisc.edu) - Sep 11, 2022, 7:47 PM CDT

Title: System and Method for Generating A PPG Signal

Date: 9/11/2022

Content by: Ethan Hannon

Present: Ethan Hannon

Goals: To find and learn the design others have used to make PPGs and measure PWV

Citation:

C. J. Kulach, " SYSTEM AND METHOD FOR GENERATING A PPG SIGNAL," 01-Aug-2017.

Content:

This patent details the ppg method of a fitness watch in how it can accurately measure the user's blood flow and PWV values while being worn. The device itself uses various LED lights to measure the amount of reflected light given off by the moving blood flow in the user's wrist. The wrist has a very commonly known artery node and is therefore ideal for pulse measurement. The reflected light can then tell how much blood is being carried through and thus calculate the exact velocity and rate of the blood flow in the person.

Conclusions/action items:

Utilizing an LED system of blood measurement would be an ideal and noninvasive method of PWG tracking for the device the team wishes to make and thus further research to learn to how utilize such a technology will be undertaken.

2022/9/19 Wireless Ultrasound System

ETHAN HANNON (ehannon@wisc.edu) - Sep 19, 2022, 11:59 AM CDT

Title: Wireless Ultrasound Personal Health Monitoring System

Date: 9/19/2022

Content by: Ethan Hannon

Present: Ethan Hannon

Goals: To research designs and patents that relate to the team's intended project goal.

Citation:

[1] D. Albert, B. R. Satchwell, and K. N. Barnett, "(54) WIRELESS, ULTRASONIC PERSONAL," p. 22.

Content:

This device utilized a phone attachment that was linked to an app to properly track the pulse rate of the user. This would then have the pulse data converted into an audible sound wave for the user to hear in order to gauge their level of cardiovascular health at the moment. The most important aspects in terms of the project here, however, is the the way the device seems to interact with the app as that would work as an important step in the overall development process for the team's final design.

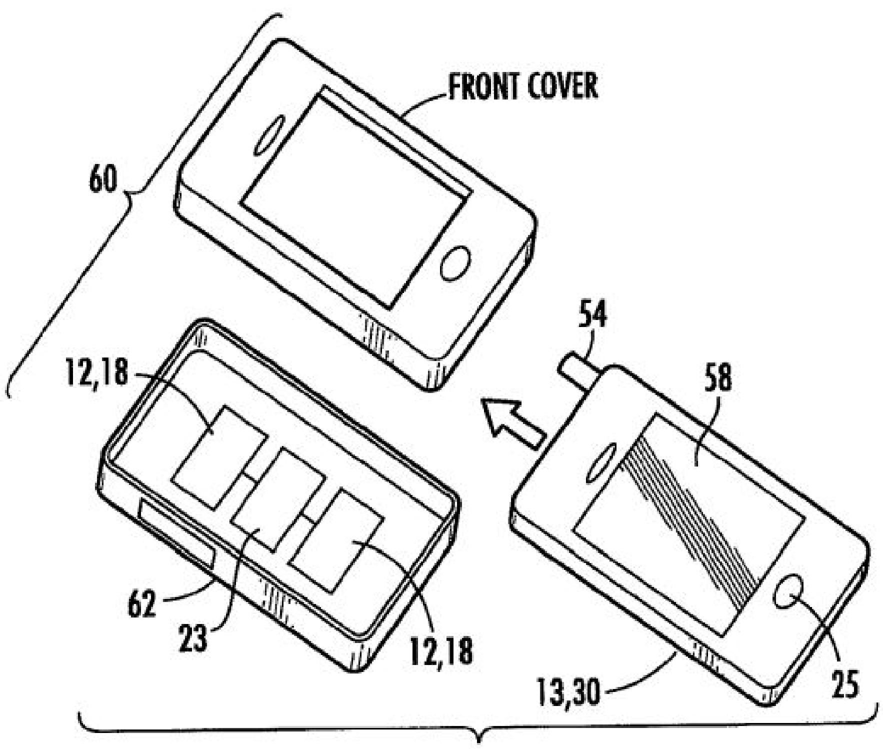


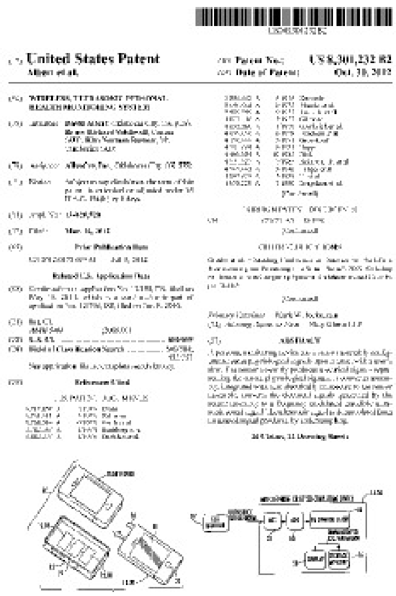
FIG. 8B

(Image above is the patent design for the phone cover case)

Conclusions/action items:

This method of linking physical, cardiovascular data to a phone app via wireless connection will be highly useful as the client wishes for the final design to include a wireless, bluetooth connection. Further research into how to physically achieve this connection will thus be carried out especially into how to implement a similar bluetooth system into the team's design.

ETHAN HANNON (ehannon@wisc.edu) - Sep 19, 2022, 12:00 PM CDT


United States Patent
Albert et al.
Patent No.: US 8,301,232 B2
Date of Patent: Oct. 30, 2012

Download

US8301232.pdf (1.79 MB) PDF copy of the Wireless Ultrasound System patent

9/26/2022 Preliminary Design Ideas

ETHAN HANNON (ehannon@wisc.edu) - Oct 03, 2022, 1:46 PM CDT

Title: Preliminary Designs To Bring Up For Team

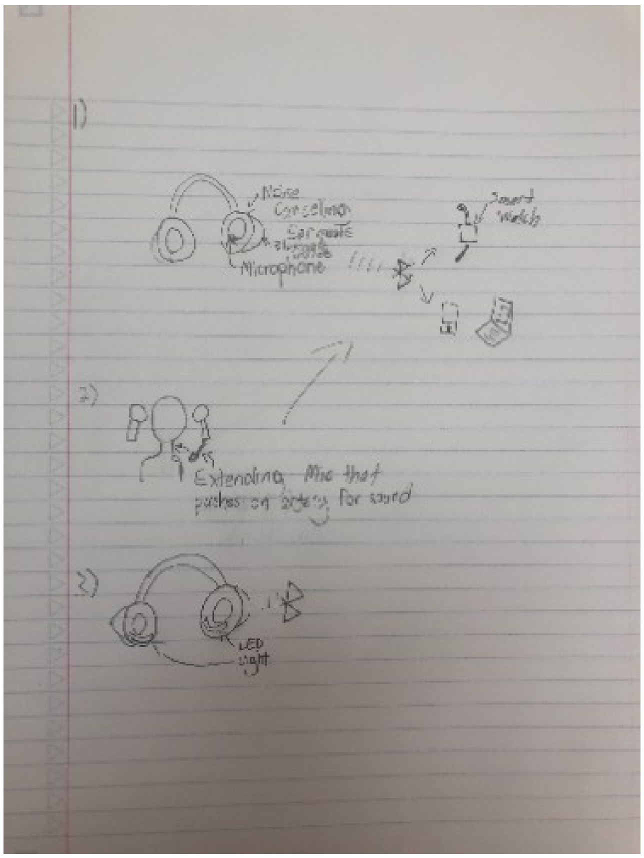
Date: 9/26/2022

Content by: Ethan Hannon

Present: Ethan Hannon

Goals: To design and created initial preliminary drawings to use for the team design matrix meeting.

Content:



The picture above showcases the different sketch ideas that were created for the preliminary designs. The first one (number 1) utilizes the blood tracking microphone inside the noise canceling over-the-ears headphones. This would negate the issue of outside noises interfering with the audio reception of the microphone and allow for more accurate PWV and PTT results. However, the desire by the client to have the headphones work like regular headphones could compromise the design as the internal sound produced by the user's music or other audio sources could interfere with the mic. The second design uses a microphone attached to airpods that could place itself firmly near the major arteries on the neck and thus be capable of listening in on the pulse much better, however, this design might be tricky in keeping the mic firmly in place as movement by the user could cause greater distance between the microphone and artery. The third design would use an led light on the headphone hear muffs and allow for easy tracking of the blood using this method, however, the client wishes for the use of a microphone instead of an LED system for pulse tracking. This might make it complicated thus to complete the desired design specifications.

Conclusions/action items:

Further analysis by the team and their ideas will need to be undertaken to fully determine which idea is best to go with. Continuing to figure out new ideas or how to improve the already existing preliminary designs will be undertaken to better improve and refine ideas in the future.

9/14 - PWV/PTT

RACHEL NOSSEN - Sep 16, 2022, 12:36 PM CDT

Title: Pulse Wave Velocity and Pulse Transit Time

Date: 9/14/22

Content by: Rachel Nossen

Goals: To understand what is pulse wave velocity and pulse transit time

Content:

PTT

- a measurement in units of time that it takes for a pulse wave from artery to artery

- this measurement is directly related to blood pressure --> increase in blood pressure causes PTT to shorten (decrease in number)

- ECG (R wave used as a starting point and it represents the opening of the aortic valve) and photoplethysmograph used to calculate

- widely used for cuff-less measuring of Blood pressure

R. C. Block, M. Yavarimanesh, K. Natarajan, A. Carek, A. Mousavi, A. Chandrasekhar, C.-S. Kim, J. Zhu, G. Schifitto, L. K. Mestha, O. T. Inan, J.-O. Hahn, and R. Mukkamala, “Conventional pulse transit times as markers of blood pressure changes in humans,” *Nature News*, 02-Oct-2020. [Online]. Available: https://www.nature.com/articles/s41598-020-73143-8. [Accessed: 14-Sep-2022].

PWV

- reflects ones segmental arterial elasticity --> the distance traveled by the pulse wave divided by the time taken to travel the distance

PWV = L/PTT ; L = length/distance traveled ; PTT = time taken to travel between two places
- Can be measured in any arterial segment between two regions where pulse can be detected in the body

Moens-Korteweg Equation:
PWV^2 = E x (h/r) x p ; E = elastic modulus ; h = vessel wall thickness ; r = vessel radius ; p = blood density

- age and blood pressure have strong influence on PWV

-PWV great predictor of hypertension and cardiovascular events/mortality

H. Tomiyama and A. Yamashina, “Ankle-brachial pressure index and pulse wave velocity in cardiovascular risk assessment,” *Encyclopedia of Cardiovascular Research and Medicine*, 30-Nov-2017. [Online]. Available: https://www.sciencedirect.com/science/article/pii/B9780128096574995929?via%3Dihub. [Accessed: 14-Sep-2022].

Conclusions/action items:

PWV and PTT can be measured with the right technology and equations. How do we implement them into the technology?

10/25/22 - High Blood Pressure

RACHEL NOSSEN - Dec 14, 2022, 12:59 PM CST

Title - High Blood Pressure

Date - 10/25/22

Content by - Rachel

Goals - To understand high blood pressure and its effects

Content -

BLOOD PRESSURE CATEGORY	SYSTOLIC mm Hg (upper number)		DIASTOLIC mm Hg (lower number)
NORMAL	LESS THAN 120	and	LESS THAN 80
ELEVATED	120 – 129	and	LESS THAN 80
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 1	130 – 139	or	80 – 89
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 2	140 OR HIGHER	or	90 OR HIGHER
HYPERTENSIVE CRISIS (consult your doctor immediately)	HIGHER THAN 180	and/or	HIGHER THAN 120

*Table shows the ranges of blood pressure in both systolic and diastolic measurements

*People with elevated blood pressure are on the path to likely develop high blood pressure unless they take cautionary steps to control this path

*Those with Hypertension most often need to take medication to reduce risk of heart attack/stroke

<u>High Blood Pressure can threaten life dramatically</u>

- Stroke - causes blood vessels to the brain to become blocked or burst

- Heart attack - damages arteries can cause them to prevent flow to heart

- Other threats include: vision loss, kidney disease, peripheral artery disease, etc

9/11-9/12 Technology

RACHEL NOSSEN - Sep 12, 2022, 4:07 PM CDT

Title: Competing Designs

Date: 9/11/2022

Content by: Rachel Nossen

Goals: Find the technology already in some headphones on the market that have similar intended functions

Content:

Jabra sports headphones - they are in-ear headphones and measure the heart rate from your inner ear; also tracks VO2

--> The earbuds "incorporate Valencell's patented PerformTek biometric measurement technology, which enables an end-user to monitor multiple personal biometrics such as: continuous heart rate" https://valencell.com/press/jabra-utilizes-valencells-biometric-sensor-technology-first-true-wireless-earbuds-certified-performtek-accuracy/

R. Kraudel, "Jabra utilizes Valencell's biometric sensor technology for first true wireless earbuds certified with PerformTek® Accuracy," *Valencell*, 01-Sep-2016. [Online]. Available: https://valencell.com/press/jabra-utilizes-valencells-biometric-sensor-technology-first-true-wireless-earbuds-certified-performtek-accuracy/. [Accessed: 12-Sep-2022].

--> Valencell Perform Tek sensor systems allow the devices to accurately measure blood flow signals even during extreme physical activity --> Valencell has 35 patents grants and more than 70 additional patents pending at the time of the publication which was 2016

Bose SoundSport Pulse

----

*Most earbud heart rate monitors use photoplethysmography to take the pulse. These devices take a PPG by shining a small light onto your skin and measuring blood flow by how that lights reflects off blood vessels (same process as the fingertip clamps used in doctors offices/hospitals)

*the ear is a good place to capture pulse information because its an effective pressure point and little room for sensor movement

Active signal characterization - works like noise cancellation to filter out environmental impactors; can relieve concerns on distractions from the measurements

Conclusions/action items: Find more on PPG and how it works

RACHEL NOSSEN - Sep 12, 2022, 4:50 PM CDT

Title - What is PPG?

Date - 9/12

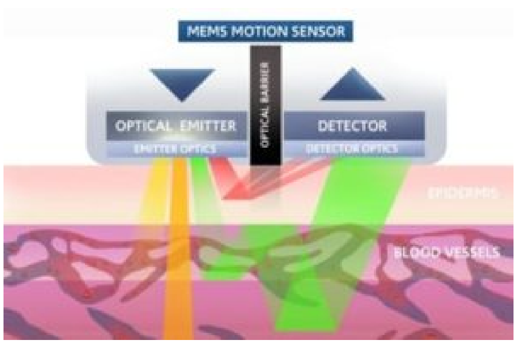
Content by - Rachel Nossen

Goals- to understand how PPG works

Content -

PPG - https://valencell.com/blog/active-signal-characterization/

R. Kraudel, “Jabra utilizes Valencell's biometric sensor technology for first true wireless earbuds certified with PerformTek® Accuracy,” *Valencell*, 01-Sep-2016. [Online]. Available: https://valencell.com/press/jabra-utilizes-valencells-biometric-sensor-technology-first-true-wireless-earbuds-certified-performtek-accuracy/. [Accessed: 12-Sep-2022].



Conclusion / Action Items - PPG is a complicated process, but necessary for a lot of devices to carry out its intended purpose. Continuing to understand is needed.

9/20/22 - Patent for similar device

RACHEL NOSSEN - Sep 20, 2022, 9:24 PM CDT

Title: Patent WO2003088841A2

Date: 9/20/22

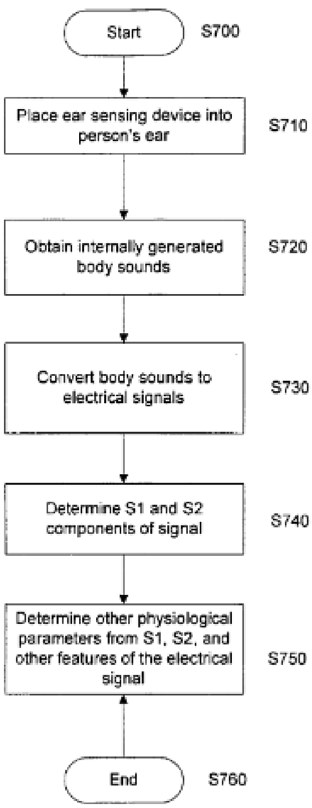
Content by: Rachel Nossen

Goals: Understand the patent

Content:

Heart sounds obtained by using a transducer within an ear to detect internally generated body sounds which can translate to heart sound, etc

**These body generated sounds can be converted to electrical signals



Conclusions/action items:

- Find a small/modern tranducer that could translate sound waves to electrical waves.

10/6/2022 - Echoes App

RACHEL NOSSEN - Oct 06, 2022, 3:28 PM CDT

Title: Echoes App

Date: 10/6/22

Content by: Rachel Nossen

Goals: to understand if this app may help us with our design

Content:

https://www.echoesapp.org/

**An app that allows you to capture your heart sounds from your phone's built in microphone

- allows you to play your heart sounds after the recording

- done by putting the microphone directly on your skin , must be done in a quiet environment

Conclusions/action items:

- see if we can use similar technology was distinct sounds to find measurements

11/14/2022 - Digital Stethoscope Technology

RACHEL NOSSEN - Nov 14, 2022, 4:51 PM CST

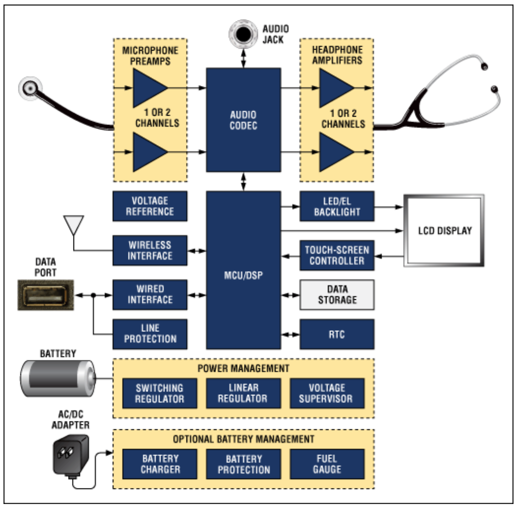
Title: Digital Stethoscope Tech

Date: 11/14/22

Content by: Rachel Nossen

Goals: To understand how a digital stethoscope functions

Content:



main elements include -->

1) sound transducer

2) audio codec electronics

3) the speakers

** Summary

- Can be useful because once the sound enters the microcontroller unit (MCU) or digital signal processor (DSP), it goes through ambient noise reduction and filtering which can limit the bandwidth to the range for cardiac or pulmonary listening --> then converted back to analog by audio codec

**What are the ranges of sound?

- Stethoscope is sensitive to cardiac sound in the 20Hz to 400 Hz range

** How to transfer data?

- once sound is converted to voltage, can be sent out through and audio jack and played back on computer

False. (n.d.). *Introduction to digital stethoscopes and: Maxim integrated*. Introduction to Digital Stethoscopes and | Maxim Integrated. Retrieved November 14, 2022, from https://www.maximintegrated.com/en/design/technical-documents/tutorials/4/4694.html#:~:text=The%20essential%20elements%20of%20a,critical%20piece%20in%20the%20chain.

Filters are used in the circuits so that the high frequency noise is removed
*Small signal amplifiers are used to increase the voltage amplitude and/or current amplitude of a signal, to provide some increase in the power --> need for power gain is most evident in wireless communication system where the signal received may be to weak to process w/o amplification *

Oludare Fagbohun, O. (2015). *A versatile low cost Electronic Stethoscope design*. IOSR Journal. Retrieved November 14, 2022, from https://iosrjournals.org/iosr-jece.html

Conclusions/action items:

10/5/22 - Microphone and Heart beat

RACHEL NOSSEN - Oct 06, 2022, 3:29 PM CDT

Title: Microphone to store heartbeat

Date: 10/5/22

Content by: Rachel Nossen

Goals: To figure out how a microphone can pick up a heart beat from the ear

Content:

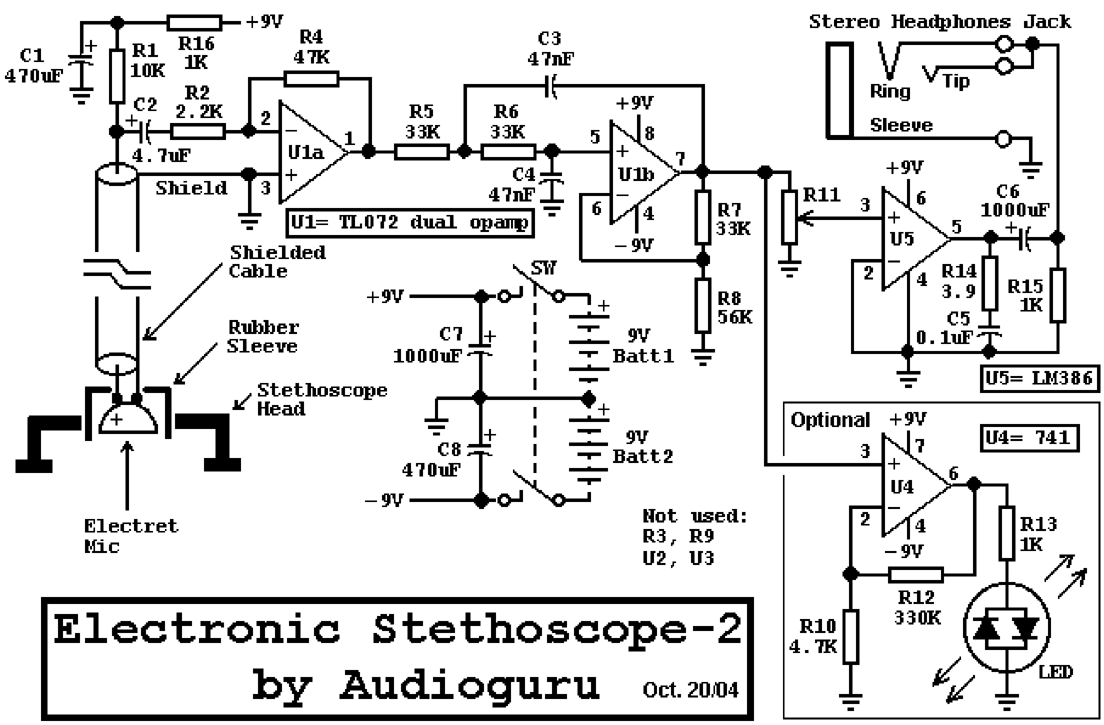
***Describes how to develop a digital heart sound signal detection device based on high gain MEMS MIC which would be able to store human heart sounds**

***MEMS microphone sensor converts sound ressure signal into a voltage signal and then filters the collected signal**

D. Ding, Q. Li, W. Y. Wang, and B. Yang, "[design and implementation of heart sound detection device based on MEMS mic]," *Zhongguo yi liao qi xie za zhi = Chinese journal of medical instrumentation*, 30-Sep-2019. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/31625330/. [Accessed: 06-Oct-2022].

"My fixed circuit uses an inverting opamp as a preamp because the original circuit had it but its input impedance is low and it loads down the level from the mic a little. it should be a non-inverting preamp circuit with a high input impedance. The next opamp is a Sallen-Key Butterworth lowpass filter to reduce sounds above 103Hz.
The output uses an LM386 little power amplifier IC to drive headphones that can have a low impedance. if a speaker is used then there will be acoustical feedback howling.
There is a 741 opamp that is used to blink an LED with each heartbeat. EDIT: The shielded audio cable that connects the mic to the preamp blocks mains hum pickup. If the preamp is built on a solderless breadboard then the strips of contacts and many wires all over the place are antennas that pickup mains hum. Use a printed circuit board."

https://www.edaboard.com/threads/microphone-for-heart-sound.312040/



Conclusions/action items:

How can we use components of a stethoscope ?

9/20/22 - Arduino Heart Rate Sensor

RACHEL NOSSEN - Sep 23, 2022, 10:56 AM CDT

Title: Arduino PTT Sensor

Date: 9/20/22

Content by: Rachel Nossen

Goals: To understand how this component may be used to help our design

Content:

https://create.arduino.cc/projecthub/protocentral/pulse-transit-time-for-cuff-less-bp-from-ecg-and-ppg-06c229?ref=search&ref_id=blood%20pressure&offset=4

^ This site describes a DYI project that was created to calculate PTT using a Cuffless sensor and PPG/ECG

- An Arduino was used and coded

Conclusions/action items:

This may give our team a good start in terms of coding; but reliability/accuracy of measurement may be off.

9/25/22 - PPG device

RACHEL NOSSEN - Sep 26, 2022, 1:27

Title: PPG device for sale

Date: 9/25

Content by: Rachel Nossen

Goals: To integrate this into a preliminary device

Content:

https://www.alibaba.com/product-detail/Okystar-OEM-ODM-MAX30102-Heartbeat-Frequency_62314644032.html?spm=a2700.7724857.0.0.1c5b50beQq5hCn

^^ A link to purchase a wearable PPG sensor that can be used for the fingertip, earlobe.

---

https://protocentral.com/product/protocentral-max86150-ppg-and-ecg-breakout-with-qwiic-v2/

^^ Link to purchase sensor that detects PTT

Description for this product is copied from the website below

> ***This is the new v2 version of this product**. As compared to the previous device, this one one has the optical sensor on the top of the board itself, for easier access. The optical sensor is also protected by a clear epoxy resin to prevent electrical noise from touch.*
>
> The new smart MAX86150 from Maxim rolls three devices into one for easy measurement of vital signs: an ECG frontend, an optical pulse oximeter and an optical heart rate sensors. This breakout board helps you unlock new applications for such devices.
>
> This means that it integrates the photoplethysmogram(PPG) and Pulse oximeter (SPO2), Electrocardiogram (ECG) and Heart rate sensor module into the same chip. A PPG is obtained by optically measuring the changes in the volume of blood over the skin tissue, whereas the Electrocardiogram sensor can detect the electrical activity of th heart. **The coolest feature of this chip is that the PPG and ECG are simultaneously sampled, resulting in synchronised ECG and PPG values.** This allows us to calculate the Pulse transit time (PTT) as an indirect measur of blood pressure.

Conclusions/action items:

How do we find/ make space for this sensor to fit on the device?

9/26/22 - 3d printed headphones

RACHEL NOSSEN - Dec 12, 2022, 1:01 PM CST

Title: Build headphones

Date: 9/26/22

Content by: Rachel Nossen

Goals: To determine dimensions of the headphones

Content:

https://www.print.plus/download

^^ This link contains solid work files that would print out headphone set.

-- Decided to use TPU filament

TPU Filament:

Pros - flexible, smooth finish, seen as a bridge between rubber and plastics --> good for stretch (comfortability for the user)

Cons - relatively expensive, may have no durability and strength for everyday use

Conclusions/action items:

See how we can manipulate the file for the speaker holders so that it could fit necessary tech.

10/15/22 - Alternate Headphone Design

RACHEL NOSSEN - Dec 12, 2022, 1:17 PM CST

Title: Alternate Headphone Design

Date: 10/15/22

Content by: Rachel Nossen

Present: Rachel

Goals: To determine if the alternate headphone design will better serve our purpose

Content:

https://dedesigned.com/project/3d-printed-headphones/

^^ --> this link provides a better design, provides files to be able to print the headphones

Why is it better? -- The design includes wedges on its headband to ensure that the user is able to stretch it as much as needed to fit the head appropriately

-- The headband has 4 degrees of freedom == adjustable!

--The link also provides the builder instructions with a video to easily assemble the parts together.

** Will pair these headphones with soft earpads to ensure comfort.

ABS Filament:

Pros - structural strength with ability to be somewhat flexible, cheaper than TPU

Cons - less 'stretchy' than TPU, more expensive than PLA

Conclusions/action items:

- Print the headphones, compare it to the first design

9/16/2022 Importance of PTT and how It's Measured

KYLE EVERSON - Oct 12, 2022, 1:48 AM CDT

Title: Pulse Transit Time Technique for Cuffless unobtrusive blood pressure measurement: From theory to algorithm

Date: 9/16/2022

Content by: Kyle Everson

Present: N/A

Goals: To learn what PTT is and how it can be used to measure blood pressure

Content:

- Only 46% of hypertensive patients are aware of their disease and monitor blood pressure regularly
- Velocity of arterial pressure pulse varies with underlying physiological variation, BP big part of
- PWV measured from PTT: PWV = L/PTT
- PTT obtained by two cardiac pulse signals, translated into BP with calibration procedure

Conclusions/action items:

Over time, PTT has slowly becoming a more popular way of measuring blood pressure among doctors and engineers. PTT refers to the time it takes for a pulse wave to travel between two points in the cardiovascular system, and it can be translated into BP with a calibration procedure.

Citation:

X. Ding and Y.-T. Zhang, “Pulse Transit Time Technique for cuffless unobtrusive blood pressure measurement: From theory to algorithm,” *Biomedical Engineering Letters*, vol. 9, no. 1, pp. 37–52, 2019.

2022/11/07 - Relation Between PWV and Blood Pressure

KYLE EVERSON - Nov 21, 2022, 4:31 PM CST

Title: Relation Between PWV and Blood Pressure

Date: 11/07/22

Content by: Kyle Everson

Present: N/A

Goals: To learn more about the relationship between PWV and blood pressure

Content:

- Moens-Korteweg (MK) + Hughes Equations generally used to relate PWV to blood pressure P
  - MK Equation: where E is the elastic modulus at blood pressure P, h_0 is the thickness of the artery, R_0 is the radius of the artery, and p is the blood density
  - Hughes Equation: $E = E_0 exp(\zeta P)$ where E_0 is the elastic modulus at zero blood pressure and ζ is a material coefficient of the artery
- As blood pressure increases, artery stiffens and PWV increases
- MK equation involves 2 assumptions
  - artery wall can be modeled as thin shell
  - thickness and radius of artery remain fixed as blood pressure changes
- Two assumptions for MK equation may not hold for human arteries; Hughes equation has no theoretical foundation
- PWV related to P, inner area of artery (A), and rho(blood density) by:
  - $PWV = \sqrt{\frac{AdP}{\rho dA}}$
  -

Conclusions/action items: I will continue research to figure out how to convert PWV to blood pressure

References:

Y. Huang, “Relation between blood pressure and pulse wave velocity for human arteries,” *PNAS*, vol. 115, no. 44, 2020.

2022/11/28 - Size of the Carotid Artery

KYLE EVERSON - Nov 28, 2022, 4:49 PM CST

Title: Average Size of the Carotid Artery

Date: 11/28/22

Content by: Kyle Everson

Present: N/A

Goals: To find the average size of the carotid artery to be used in calculations for blood pressure

Content:

- In 103 cases (47 male, 56 female), the average diameter of common carotid artery was 0.97cm with standard deviation of 0.14cm
  - Average in male was 1.01 cm; average in female was 0.93 cm
- In 139 cases (63 male, 76 female), the average diameter of the internal carotid artery was 0.74 cm with a standard deviation of 0.16 cm
  - Average in male cases was 0.77 cm, average in female cases was 0.71 cm
- In 206 cases (95 male, 111 female), the average diameter of the external carotid artery was 0.49 cm with a standard deviation of 0.08 cm
  - No statistically significant difference was observed in average diameter of external carotid artery between female and male cases ($p > 0.05$)
- Both internal and external carotid arteries originate from common carotid artery
  - Pearson correlation test found no statistically significant correlation between diameters of common and internal carotid arteries or common and external arteries ($p > 0.05$)
  - Statistically significant association obtained in correlation between internal and external carotid arteries' diameters

Conclusions/action items: We will use these numbers to convert PWV/PTT data into blood pressure

Citation:

R. Cobiella, S. Quinones, M. Konschake, P. Aragones, X. León, T. Vazquez, J. Sanudo, and E. Maranillo, “The carotid axis revisited,” *Scientific Reports*, vol. 11, no. 1, 2021.

2022/09/19 Smartwatch designs and Their Flaws

KYLE EVERSON - Sep 22, 2022, 9:28 PM CDT

Title: Smartwatch Designs and Their Flaws

Date: 09/19/22

Content by: Kyle Everson

Present: N/A

Goals: To learn more about smartwatches that monitor blood pressure and some flaws that might be able to be improved upon.

Content:

- American Heart Association recommends people with high blood pressure engage in home monitoring
- Omron Healthcare's HeartGuide first wearable blood pressure monitor, uses oscillometric cuff method - standard for medical-grade personal blood-pressure measurement
    - App provides readings and shares data with patient's doctor
- Arteries in wrist are narrow, not as deep as upper arm
- Arm and wrist must be at heart level to capture correct reading
- PTT denotes time for pulse pressure waveform to move through length of arterial tree, can provide indicator of arterial stiffness
    - Can be measured through calculations on ECG and PPG signals
    - PPG provides optical measurement of volumetric change of blood during cardiac cycle
- Studies have shown that combining PTT, heart rate, and previous blood pressure measurement will provide more accurate blood pressure value

Conclusions/action items: While strides have been made in the use of smartwatches to help monitor blood pressure, there are still issues that make getting an accurate reading a difficult, time-consuming task.

Citation: https://www.maximintegrated.com/en/design/blog/is-pulse-transit-time-needed-for-accurate-blood-pressure-monitoring-from-wearables.html

10/19/2022 - In-ear Microphones for Heart Rate Monitoring

KYLE EVERSON - Dec 05, 2022, 4:40 PM CST

Title: Heart Rate Monitoring with In-ear Microphones

Date: 10/19/22

Content by: Kyle Everson

Present: N/A

Goals: To learn how an in-ear microphone can be used to measure heart rate

Content:

- Bone conduction - sound is conducted through the bones directly to the inner ear, causing vibrations in the wall of the ear
- Occluding ear canal results in amplification of low-frequency sounds conducted by bones
    - Bone-conducted heart sounds will be amplified in occluded ear canal
- Occlusion effect also amplifies other vibrations inside the body
    - Heart sound will be overwhelmed if person is not stationary
- Heart sounds captured by microphone are low frequency with less than 50Hz bandwidth
- Used two analogue omnidirectional MEMS microphones
    - Has relatively flat frequency response from 10Hz to 10kHz

Conclusions/action items:

I will continue to do research on how in-ear microphones can be used to listen to heartbeats.

Citation:

K.-J. Butkow, T. Dang, A. Ferlini, D. Ma, and C. Mascolo, “Heart: Motion-resilient heart rate monitoring with in-ear microphones,” *arXiv.org*, 25-Jul-2022. [Online]. Available: https://doi.org/10.48550/arXiv.2108.09393. [Accessed: 20-Oct-2022].

2022/09/26 Earbuds with LED Designs

KYLE EVERSON - Sep 30, 2022, 12:26 PM CDT

Title: Earbud Design with LEDs

Date: 09/26/22

Content by: Kyle Everson

Present: N/A

Goals: To show a possible design for earbuds that would use LED lights to measure pulse rate

Content:

- DashPro
    - Uses infrared light by reflection measurement to gather pulse rate in external auditory canal
    - Fitted to user's ear using silicone caps
- Cosinnus One
    - Uses green light in reflection measurement to measure pulse rate
    - +/- 1bm accuracy
    - Design may be more secure in ear

Conclusions/action items:

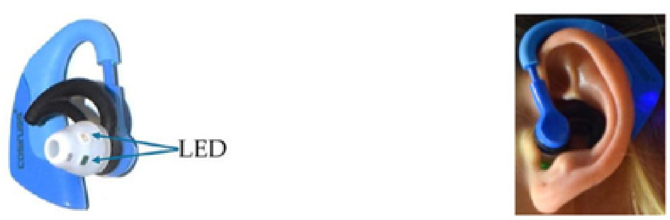
KYLE EVERSON - Sep 26, 2022, 3:22 PM CDT

(a) (b)

Download

DashProJPG.jpeg (12.4 kB)

KYLE EVERSON - Sep 26, 2022, 3:37 PM CDT



(a) (b)

Download

ConissusOne.jpeg (37.5 kB)

2022/9/12 Cuffless blood pressure monitoring

CARSON ENDRIES (crendries@wisc.edu) - Oct 11, 2022, 10:41 PM CDT

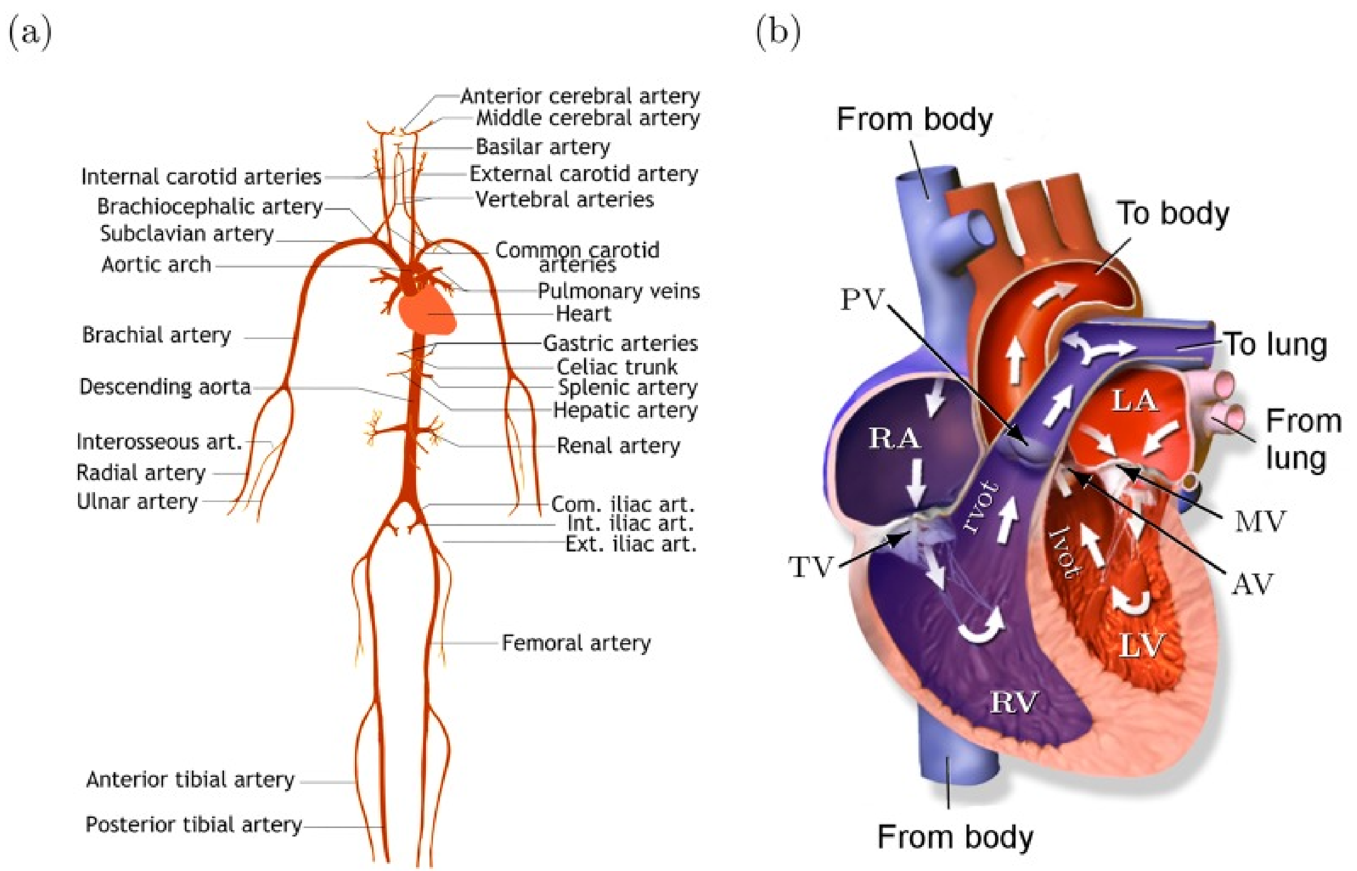
Title: Cuffless blood pressure monitoring

Date: 9/12/22

Goals: Gain an understanding of how cuff-less blood pressure monitors work

Content:

Cuff-less blood pressure monitors most frequently use photoplethysmography. Photoplethysmography utilizes a photodetectors to measure blood volumetric variations at the skin which can be used to calculate PTT and PWV. PPG measure the volumetric change in blood which can be used to calculate PWV and PTT when paired with a device such as an ECG. The ECG is used to get the moment of when the electrical impulse at the heart occurs and then the PPG can detect when the blood from the heart beat arrives to the destination.



$$\mathrm{PWV} = \frac{\text{distance between the sites}}{\text{travel time between the sites}}.$$

PTT = PWV / L (L is the distance between the two places of the propagation.)

X. Ding and Y.-T. Zhang, “Pulse Transit Time Technique for cuffless unobtrusive blood pressure measurement: From theory to algorithm,” *Biomedical Engineering Letters*, vol. 9, no. 1, pp. 37–52, 2019.

J. M. Huttunen, L. Kärkkäinen, and H. Lindholm, “Pulse transit time estimation of aortic pulse wave velocity and blood pressure using machine learning and simulated training data,” *PLOS Computational Biology*, vol. 15, no. 8, 2019.

B. Mishra and N. Thakkar, “Cuffless Blood Pressure Monitoring using PTT and PWV methods,” *2017 International Conference on Recent Innovations in Signal processing and Embedded Systems (RISE)*, 2017.

Conclusions/action items:

The most efficient method of measuring PTT and PWV seems to be using a PPG sensor that measures volumetric change in blood to detect pulse and can then be used to calculate PWV and PTT when paired with an ECG.

Sound Based Heart Rate Monitoring 9/19/22

CARSON ENDRIES (crendries@wisc.edu) - Sep 19, 2022, 3:31 PM CDT

Title: Sound Based Heart Rate Monitoring for Wearable Systems

Date: 9/19/22

Content by: Carson Endries

Goals: Gain an understanding of how others have measured heart rate with sound

Content:

Due to wearable heart rate monitors having an increasing interest, the paper proposed, "Instead of using an ECG sensor, the proposed design uses sound signals received from a microphone which does not require skin-contact." The heart rate was measured using an electret microphone which is placed at the at the cardiac apex. By using a microphone it was hypothesized that an accurate reading could be made regardless of external noise compared to other methods of measured which are sensitive to things such as movement, noise, cough and laughing. The tested microphone data was processed using efficient algorithms to produce a pulse graph. The paper concluded that, "Preliminary results show that the proposed approach can be an effective alternative way of monitoring cardiac (heart) sounds in a natural environment where lung sounds and other environmental sounds and noises are present."

T. T. Zhang, W. Ser, G. Y. Daniel, J. Zhang, J. Yu, C. Chua, and I. M. Louis, “Sound based heart rate monitoring for Wearable Systems,” *2010 International Conference on Body Sensor Networks*, 2010.

Conclusions/action items:

Microphone measured heart rate appears to have a a promising alternative way to get accurate measures of cardiac sounds in environments where sounds and noise are present

Microphone To Detect Heartbeat

CARSON ENDRIES (crendries@wisc.edu) - Oct 11, 2022, 10:46 PM CDT

Title: Microphone to pick up heartbeat

Date: 10/10/22

Present:

Goals: Research microphones to determine ones that might be able to detect a heart beat

Content:

A microphone which is capable of hearing the heart beat must have the capability of detecting sounds in the frequency range of the heart beat. The standard heart sounds are within 20 and 650 Hz, however the frequency range that is used for most critical heart sounds is within 70 and 120 Hz [1]. There are also two types of microphones that have to be considered, omnidirectional and unidirectional.

$32.83

Frequency Range: 20-16KHz

Directivity: Omni-directional

3.5mm connector

https://www.a1securitycameras.com/ets-ml1-c.html?gclid=Cj0KCQjwhY-aBhCUARIsALNIC05VFy_f620RL4feZnOlhWoVefPNJiK7eKeK_oU5FEk4j3HunH11LCUaApbNEALw_wcB

[1] A. A. Ahmad, *Frequency Responses of Conventional and Amplified Stethoscopes for Measuring Heart Sounds*, May 2020. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7305673/#:~:text=%5B15%5D%20stated%20that%20the%20heart,between%2050%20and%201200%20Hz

Conclusions/action items:

Frequency range of human heartbeat

CARSON ENDRIES (crendries@wisc.edu) - Dec 13, 2022, 5:02 PM CST

Title: Frequency range of the human heart beat

Date: 11/14/22

Content by: Carson Endries

Goals: Identify the frequency range of the human heartbeat

Content:

[1]F. Arvin, S. Doraisamy, and E. Safar Khorasani, “Frequency shifting approach towards textual transcription of Heartbeat sounds,” Biological Procedures Online, vol. 13, no. 1, 2011.

In order to record the sound of the heart beat, it is necessary to be able to record in the frequency range if the heart beat. As stated in “Frequency shifting approach towards textual transcription of Heartbeat sounds”, the normal heart beat noise lies in the range of roughly ~15-100Hz (Figure 1). In order to record this sound, the group would require a microphone capable of recording sounds of that frequency. Most microphone on the market claim to have a frequency range of 20-20k Hz. Although, after completing the testing and acquire a frequency response graph (Figure 2), it appears the microphone we are using don't start recording noise until the 50Hz mark. This means that the microphone is not sensitive enough to accurately record heartbeat sound data. After performing additional research on microphones available on the market, it appears most microphone that are capable of measuring heart beat noise are much more expensive, such as the "Earthworks Omnidirectional Measurement Microphone, 3Hz-30kHz Frequency Response" which costs $700.00.

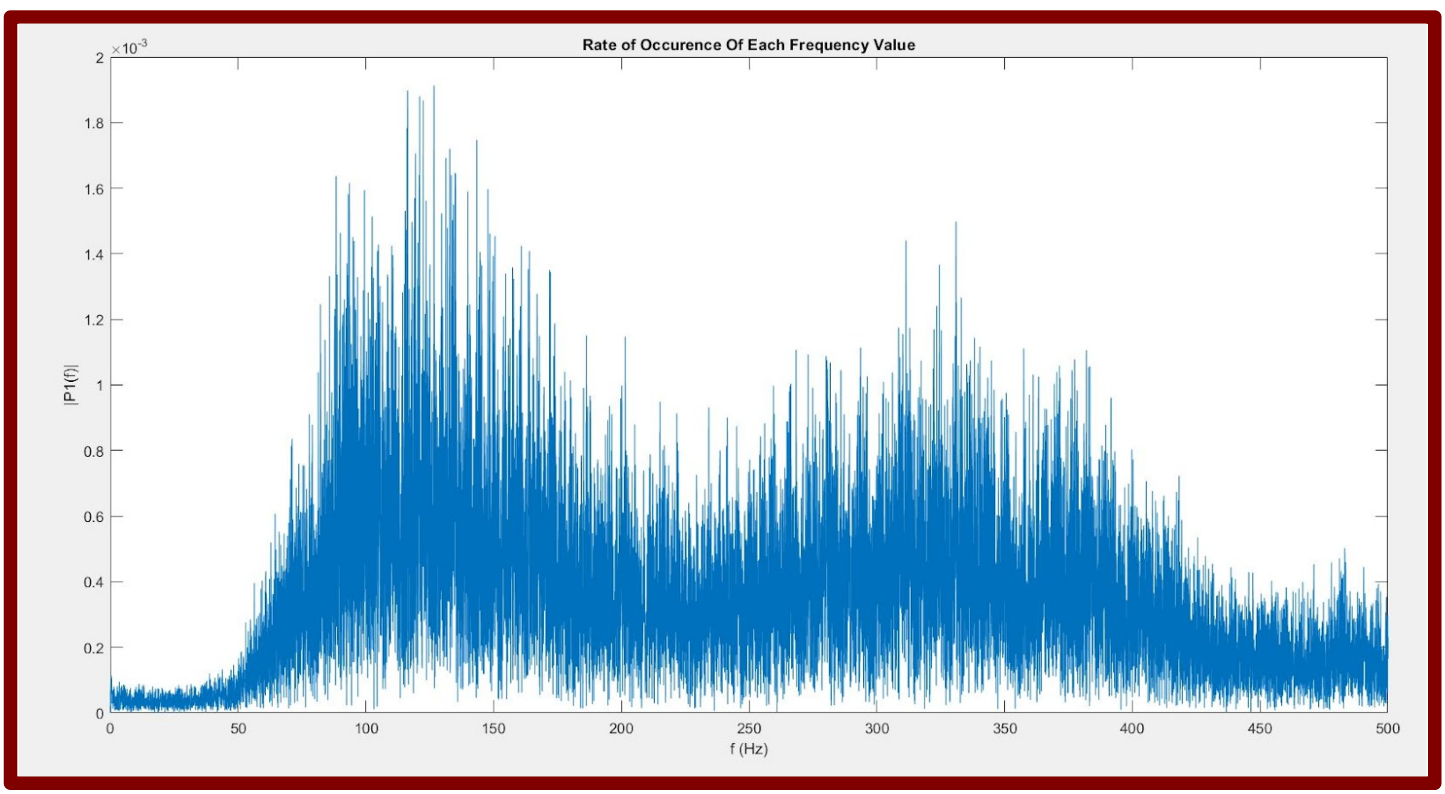


Figure 2

Conclusions/action items:

To record heartbeat noises with a microphone, a much more sensitive microphone would be required than the one we are currently using. The required range is ~15-200Hz and our current microphone is only capable of measurements past 50Hz, thus we miss most of the potential heartbeat sound data.

Competing headphone designs

CARSON ENDRIES (crendries@wisc.edu) - Oct 11, 2022, 10:47 PM CDT

Title: Competing headphone/earbud devices.

Date: 9/27/22

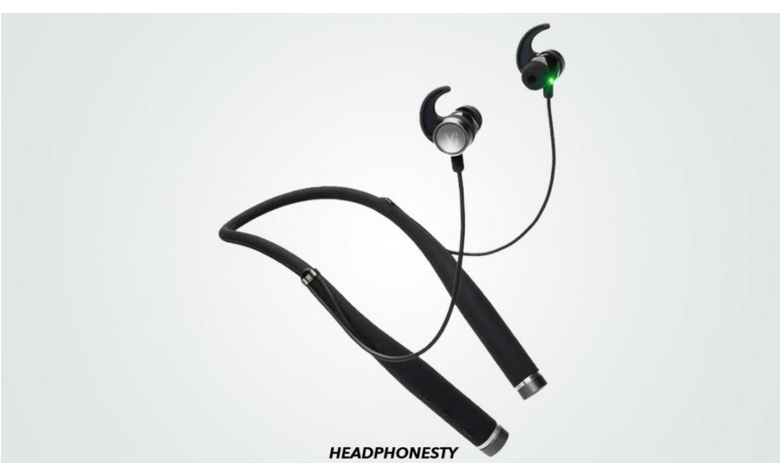
Goals: See what is currently in production and the type of technologies they use

Content:

Amazfit PowerBuds

The amazon wireless earbuds, "PowerBuds", measure pulse inside the left ear with a PPG sensor. The earbuds have a 8 hour battery life and come with a hook to put around the ear to use during activity to ensure they stay on well and so that the PPG can accurately measure pulse accurately. The "PowerBuds" also have noise canceling technology. The earbuds also provide warnings to the user when their heart rate appears to be getting too high. The PowerBuds come with an app that tracks all of your heart data that. These earbuds are considered one of the best fitness earbuds currently on the market.

LifeBEAM Vi Sense



The LifeBeam Vi Sense is a earbud with a weighted neckband that provides stability during workouts. The LifeBEAM earbuds measure the pulse in both ears with a PPG sensor. The Vi Trainer App uses an AI personal trainer that uses real-time tracking to help with your workouts.

Currently, almost all earbuds on the market that measure pulse use a PPG sensor to do so. The PPG sensor can be compact, provide accurate data and is very easy for the user to use.

G. L, “5 best heart rate headphones [2022],” *Headphonesty*, 31-Jan-2022. [Online]. Available: https://www.headphonesty.com/2021/04/best-heart-rate-headphones/. [Accessed: 11-Oct-2022].

Conclusions/action items:

It appears that all of the leading designs for earbuds currently use PPG sensors to monitor pulse. They also all have apps to keep track of your data.

Using smart speakers to contactlessly monitor heart rhythms

CARSON ENDRIES (crendries@wisc.edu) - Oct 11, 2022, 10:49 PM CDT

Title: Pulse transit time technique for cuffless unobtrusive blood pressure measurement: from theory to algorithm

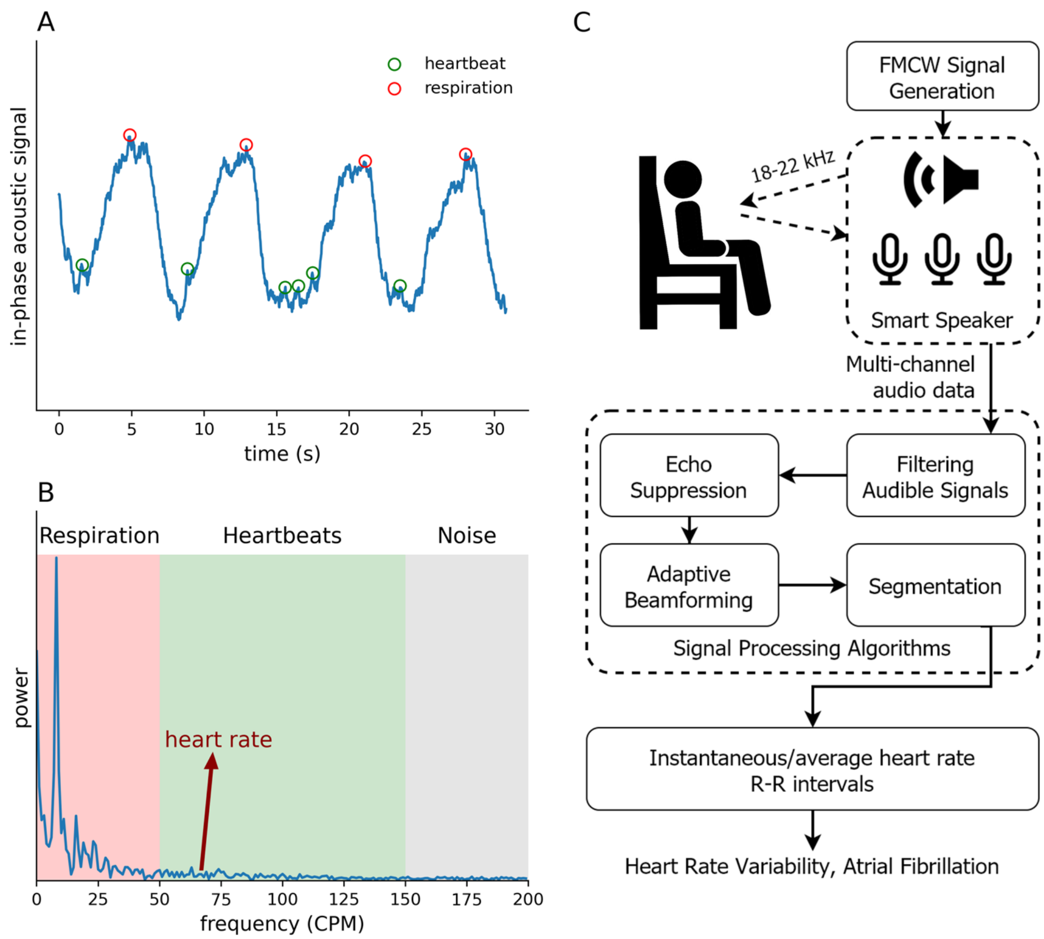
Date: 9/19/22

Content by: Carson Endries

Goals: Understand how heart rate has been measured using speakers

Content:

The smart speaker acts as a short range sonar which can contact-free measure the heart rate for both a normal and irregular rhythm. The sonar speaker was capable of measuring the heart rhythms with only a 28ms error compared to a ECG. The sonar speaker emits a inaudible sounds in the 18-22kHz range which reflects from the human body and can measured the displacement due to the heart beats. This technology can be very helpful in brining accessible and easy to use methods of detecting heart conditions which is on of the leading causes of death in America.



A. Wang, D. Nguyen, A. R. Sridhar, and S. Gollakota, "Using smart speakers to contactlessly monitor heart rhythms," *Nature News*, 09-Mar-2021. [Online]. Available: https://www.nature.com/articles/s42003-021-01824-9. [Accessed: 11-Oct-2022].

Conclusions/action items:

A speaker can emit sound in the inaudible range and be picked up by a speaker. This can detect the displacement in the body due to the heart beating.

Electronic Stethoscope

CARSON ENDRIES (crendries@wisc.edu) - Dec 13, 2022, 5:37 PM CST

Title: Frequency shifting approach towards textual transcription of heartbeat sounds

Content by: Carson Endries

Goals: Understand the competing design utilizing an electric stethoscope.

Content:

F. Arvin, S. Doraisamy, and E. Safar Khorasani, “Frequency shifting approach towards textual transcription of Heartbeat sounds,” Biological Procedures Online, vol. 13, no. 1, 2011.

A project with a similar goal attempted to listen for and process heart beat sound data using an electronic-stethoscope. The group collected the heart beat sound data which was then processed with an FFT and frequency shifted. This was used to remove noise and amplify the sound of the heart beat data since the frequency of the heart beat noise is so low. The frequency shifting of the heart beat noise improve the accuracy of the groups data collection significantly. After the shifting, they used an inverse FFT and then ran the data through the FFT and frequency shifting an additional time to further amplify the heart beat sound. All of this non-real time processing was performed with MATLAB. Utilizing these signal processing methods, the group was able to accurately determine a health complications with 90% accuracy when using non-real time processing methods on patients whom had pre-diagnosed health conditions.

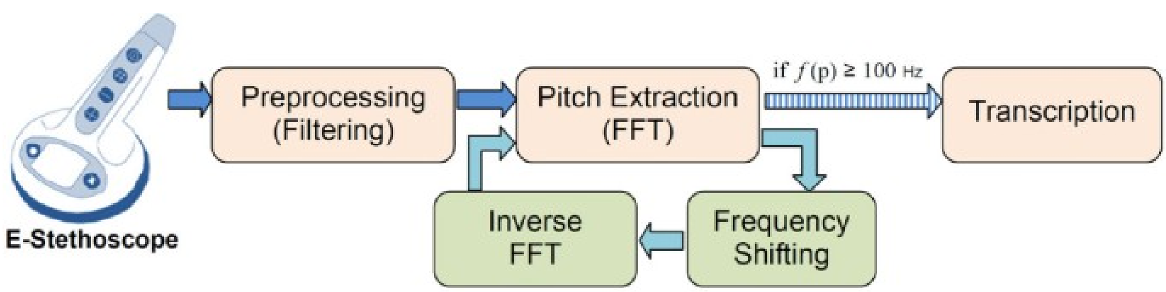


Figure 1: Showing the signal processing flow chart

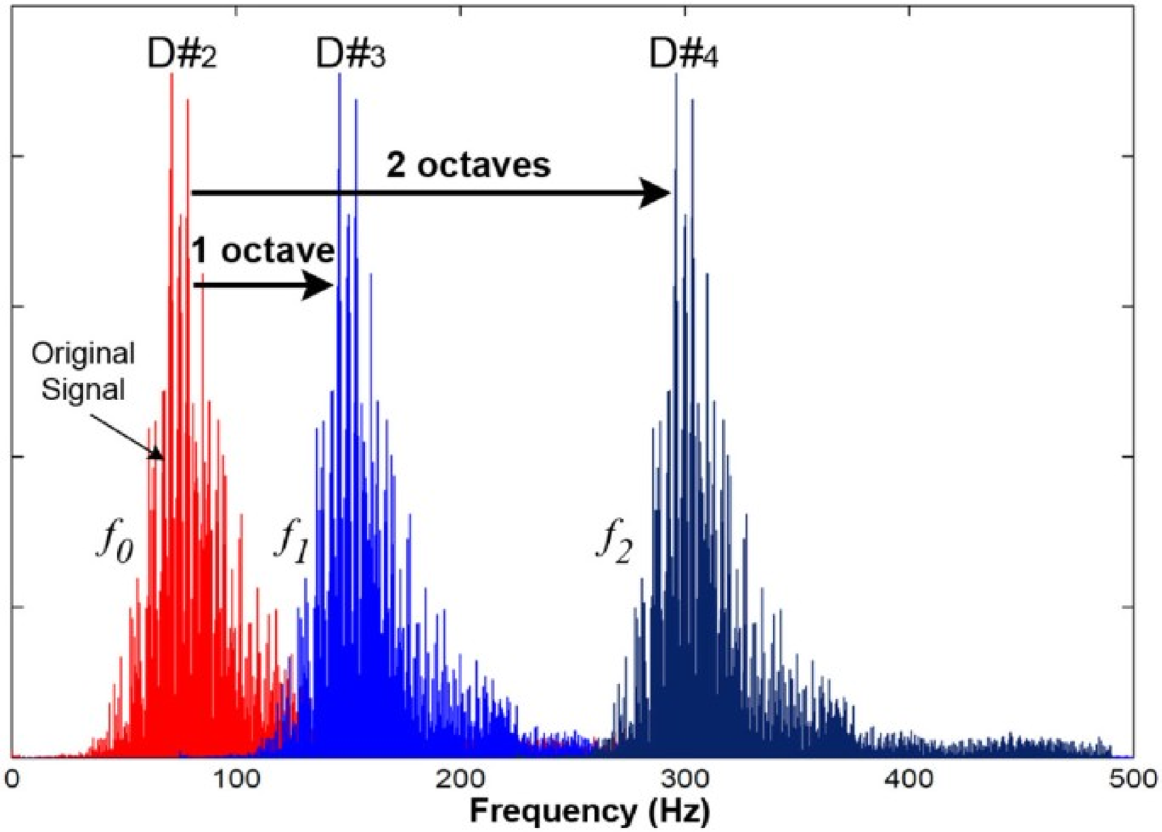


Figure 2: Frequency shifting the heartbeat sounds to a higher frequency

Conclusions/action items:

By utilizing different signal processing methods such as the FFT and frequency shifting, this group was able to obtain accurate heart beat data that could make diagnoses. If we can apply similar methods to our project we can improve the accuracy of our data and remove unwanted noise.

Preliminary Design Ideas

CARSON ENDRIES (crendries@wisc.edu) - Sep 30, 2022, 10:43 AM CDT

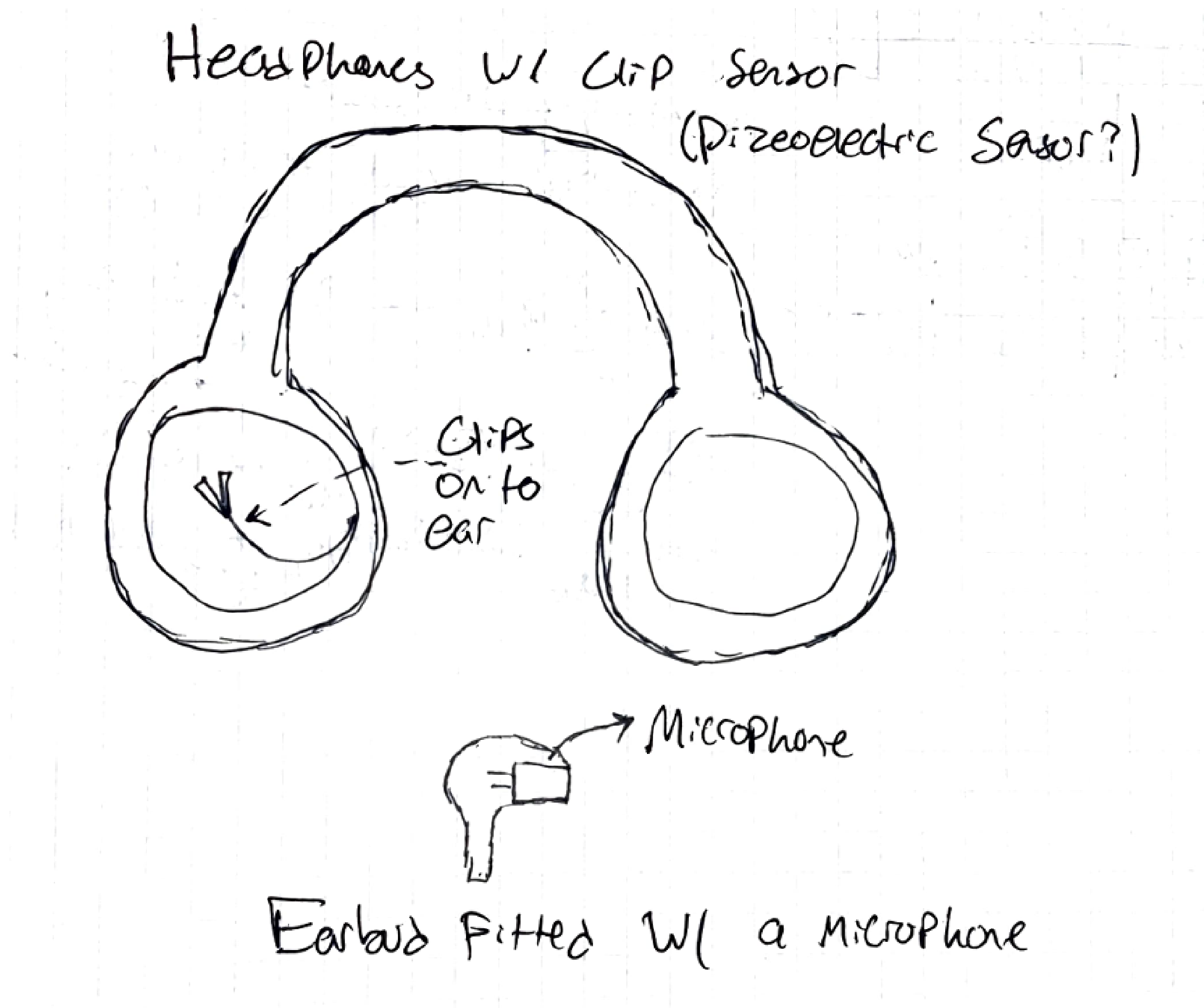
Title: Determine some preliminary design ideas

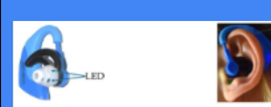
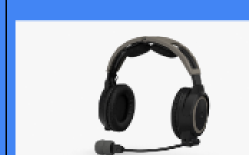
Date: 9/27/22

Content by: Carson and Group

Goals: Sketch preliminary ideas and determine primary design

Content:



			Design 1 - Headband		Design 2 - Wrap Arround		Design 3 - Gamer Headphones	
								
	Criteria	Weight	Score (10 max)	Weighted Score	Score (10 max)	Weighted Score	Score (10 max)	Weighted Score

	Effectiveness of measurements	25	10	25	10	25	7	18
	Ease of fabrication	20	10	20	6	12	10	20
	Comfort	15	8	12	9	14	10	15
	Ease of use	20	7	14	10	20	6	12
	Cost	10	5	5	7	7	8	8
	Safety	10	10	10	10	10	10	10
	Sum	**100**	**Sum**	**86**	**Sum**	**88**	**Sum**	**83**

Conclusions/action items:

We concluded that the 3D printed headphones were the best design since they could be easily manufactured, are cheap, and are easily fitted with different sensors which would make it effective at making measurements

Using an electronic stethoscope to listen for heartbeat

CARSON ENDRIES (crendries@wisc.edu) - Dec 13, 2022, 5:19 PM CST

Title: Using an electronic stethoscope to listen for heartbeat

Date: 11/14/22

Content by: Carson Endries

Goals: Try to use a stethoscope with a microphone to listen for heart beat at the ear

Content:

"Digital Stethoscope AI," *Arduino Project Hub*. [Online]. Available: https://create.arduino.cc/projecthub/mixpose/digital-stethoscope-ai-1e0229. [Accessed: 13-Dec-2022].

An Arduino project showcase the use of a microphone in a stethoscope which is then used to listen for the heart and lungs. This data can be ran through an app which can identify illnesses. This could similarly be in the case of our microphone headphones. Utilzing a microphone in a stethoscope to listen for the heartbeat at the ear will allow for PWV and PTT calculations when paired with a smart watch. Plugging in the microphone into a computer that can use software to isolate the data (such as the FFT) can allow for PWV and PTT calculations.

Conclusions/action items:

Using a simple microphone attached to a stethoscope could allow us to listen for the sound of the heart beat at the ear. This will allow for PWV and PTT measurements.

Fast Fourier Transform To Isolate Heartbeat Sound

CARSON ENDRIES (crendries@wisc.edu) - Dec 13, 2022, 5:12 PM CST

Title: Fast Fourier Transform To Isolate Heartbeat Sound

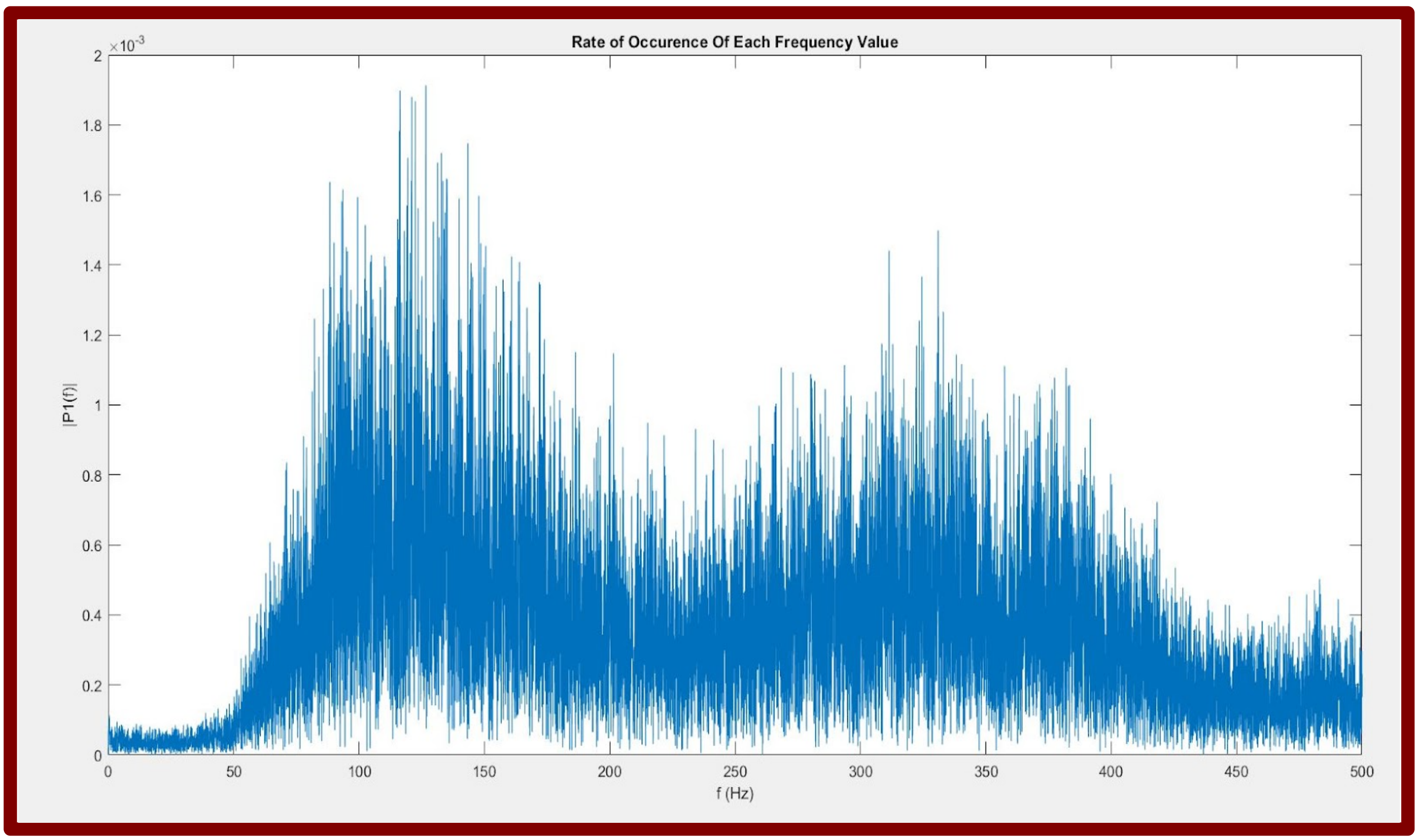
Date: 12/2/22

Content by: Carson Endries

Goals: Utilize the fast Fourier transform function in MATLAB to isolate the heartbeat sound

Content:

We have been having a lot of troubles with the microphone side of the project so far and on top of that, the data we are able to collect from the microphone is very messy. After talking with advisor Dr. Williams, he suggested we use the fast Fourier transformation (FFT) function which is built into MATLAB. The fast fourier transformation allows us to take the microphone data and find the frequency response which will show the dominate frequencies in the data. The heartbeat sound should be one of the dominate frequencies thus we can work to isolate that frequency and remove all extra noise.



After performing a FFT on the microphone data, it became apparent that the frequencies of the heart beat sound range are not seen. This means that the microphone would not be capable of accurately measuring the heartbeat. In the future, it would be important to obtain a microphone able to measure heart beat noise in the frequency range of the heart.

"Fast Fourier Transform," *Fast Fourier transform - MATLAB*. [Online]. Available: https://www.mathworks.com/help/matlab/ref/fft.html. [Accessed: 2-Nov-2022].

Conclusions/action items:

The FFT will allow to create a graph of the frequency response to show which frequency are most prominent. This can allow us to create a filter that will isolate the sound of the heart beat, thus allowing us to have cleaner data to perform calculations.

"09/12" The ear as a location for wearable vital signs monitoring

MUSTAFA AL SAKHBOURI - Sep 16, 2022, 3:21 PM CDT

Title: The ear as a location for wearable vital signs monitoring

Date: 09/12/2022

Content by: Mustafa Al-Sakhbouri

Present: N/A

Goals: Learn about the vital signs that could be monitored from the ear

Citation:

Winokur ES, He DD, Sodini CG. A wearable vital signs monitor at the ear for continuous heart rate and pulse transit time measurements. Annu Int Conf IEEE Eng Med Biol Soc. 2012;2012:2724-7. doi: 10.1109/EMBC.2012.6346527. PMID: 23366488; PMCID: PMC4395519.

Content:

This research study talks about why the ear is a good location for vital signs monitoring, as this location is ideal for both physiological and mechanical reasons. Physiologically, the reflectance photoplethysmograph (PPG) signal behind the ear shows similar signal quality compared to traditional finger transmission PPG measurements. Ballistocardiogram (BCG) can be obtained behind the ear using 25mm×25mm differential capacitive electrodes constructed using fabric. The BCG signal is able to provide continuous heart rate and respiratory rate, and correlates to cardiac output and blood pressure.

Conclusions/action items:

The review study could be used as proof of why developing a smart headphone is a good idea.

10/25"Heart Disease and the Doctor's Exam"

MUSTAFA AL SAKHBOURI - Dec 12, 2022, 1:48 PM CST

Title: Heart Disease and the Doctor's Exam

Date:10/25/2022

Content by: Mustafa Al-Sakhbouri

Goals: Find an explanation of why picking the heartbeat sound is important

Citation:

"Heart disease and the doctor's exam," *WebMD*. [Online]. Available: https://www.webmd.com/heart-disease/guide/heart-disease-diagnosis#:~:text=They'll%20feel%20your%20pulse,beating%20by%20feeling%20your%20pulse. [Accessed: 25-Oct-2022].

"Stethoscope 101 what do doctors listen for?," *SCL Health*. [Online]. Available: https://www.sclhealth.org/blog/2021/12/stethoscopes-101-what-doctors-listen-for/. [Accessed: 26-Oct-2022].

T. English, "How doctors detect heart abnormalities through sound," *WHYY*, 09-Jan-2015. [Online]. Available: https://whyy.org/segments/how-doctors-detect-heart-abnormalities-through-sound/. [Accessed: 25-Oct-2022].

Content:

Picking up and Listening to the heartbeat can provide a lot of useful information to the patient about their health, such as:

1)HEART MURMURS - Unusual wooshing or swishing sound in heart. Most murmurs are normal but some can indicate problems related to heart valves like regurgitation(due to improper closure of valve the blood flows backwards), stenosis(when blood flows through a narrow or stiffened valve).

2)Sounds indicating CONGENITAL HEART DISEASES like heart valve defects,holes or passageways between left and right side of heart or issues with heart muscle or bad connections among blood vessels

3)ABNORMAL HEART RHYTHM - Heart beats too fast/slow/irregularly

It's also called ARRHYTHMIA

(a)TACHYCARDIA - heart beats too fast exceeding 100 BPM

(b)ATRIAL FIBRILLATION - heart rate is 100-200 BPM

(c)ATRIAL FLUTTER - It's observed in the right atrium and causes heart to beat faster.

(d)BRACHYCARDIA- Slow heart rate with 60 BPM or less.

(e)VENTRICULAR FIBRILLATION - ventricle is unable to pump blood out of the heart to different organs including brain due to irregular heart beat and can cause death (cardiac arrest) if not treated immediately.

(f)PREMATURE HEART CONTRACTIONS - Skipping of beats, other types include extra beats or early beats occurring in upper or lower heart chambers.

4)CONGESTIVE HEART FAILURE - Which causes pulmonary edema (excess fluid in lungs)

5)Other sounds like squeaking or grating sounds (friction rub) indicates pericarditis (inflammation of pericardium) or inflammation of pleural membranes

Conclusions/action items:

Learning about the usefulness of listening to the heartbeat is important because it is important to understand why we are creating such a project.

11/13 "Cardiovascular Disease"

MUSTAFA AL SAKHBOURI - Dec 12, 2022, 3:19 PM CST

Title: Cardiovascular Disease

Date: 11/13/2022

Content by: Mustafa Al-Sakhbouri

Goals: Look for types of diseases our project may be able to detect

Citation:

[1] “Cardiovascular disease: Types, causes & symptoms,” *Cleveland Clinic*. [Online]. Available: https://my.clevelandclinic.org/health/diseases/21493-cardiovascular-disease. [Accessed: 13-Nov-2022].

[2] F. P. 2017 J. 5):S26-S29, “Cardiovascular Disease Federal Health Data Trends (full),” *(Full)* | *Federal Practitioner*, 14-Jul-2018. [Online]. Available: https://www.mdedge.com/fedprac/article/152653/cardiology/cardiovascular-disease-federal-health-data-trends-full. [Accessed: 14-Oct-2022].

Content:

The importance of this project comes with the fact that most cardiovascular diseases are hard to diagnose without heart rate and blood pressure measurements.

Types of Cardiovascular Disease:

-
- High blood pressure (hypertension).
- High cholesterol (hyperlipidemia).
- Tobacco use (including vaping).
- Type 2 diabetes.
- Family history of heart disease.
- Lack of physical activity.
- Having excess weight or obesity.
- Diet high in sodium, sugar and fat.
- Overuse of alcohol.
- Misuse of prescription or recreational drugs.
- Preeclampsia or toxemia.
- Gestational diabetes.
- Chronic inflammatory or autoimmune conditions.
- Chronic kidney disease.
-

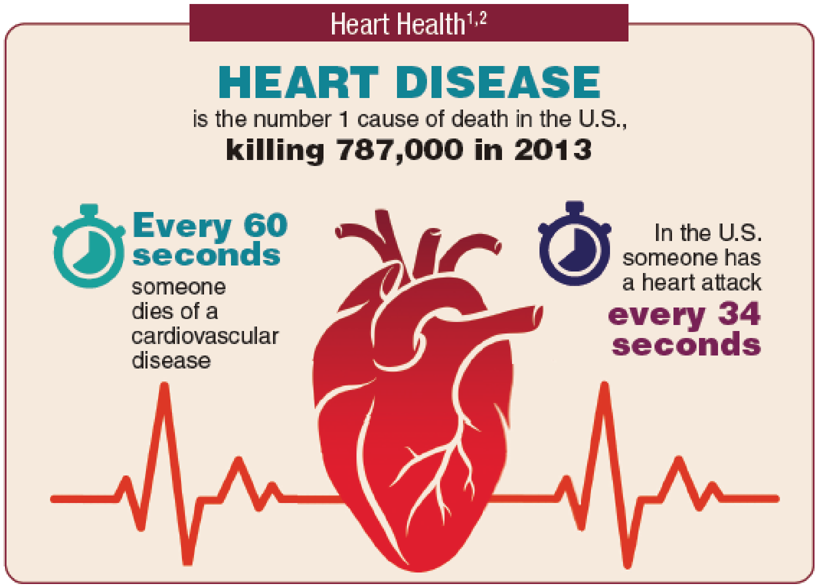


Figure.1[2]

Conclusions/action items:

Our project aims to produce data to detect the patients' health and alert the user of any chances of cardiovascular disease.

"09/12" e-BP

MUSTAFA AL SAKHBOURI - Sep 16, 2022, 12:48 PM CDT

Title: e-BP

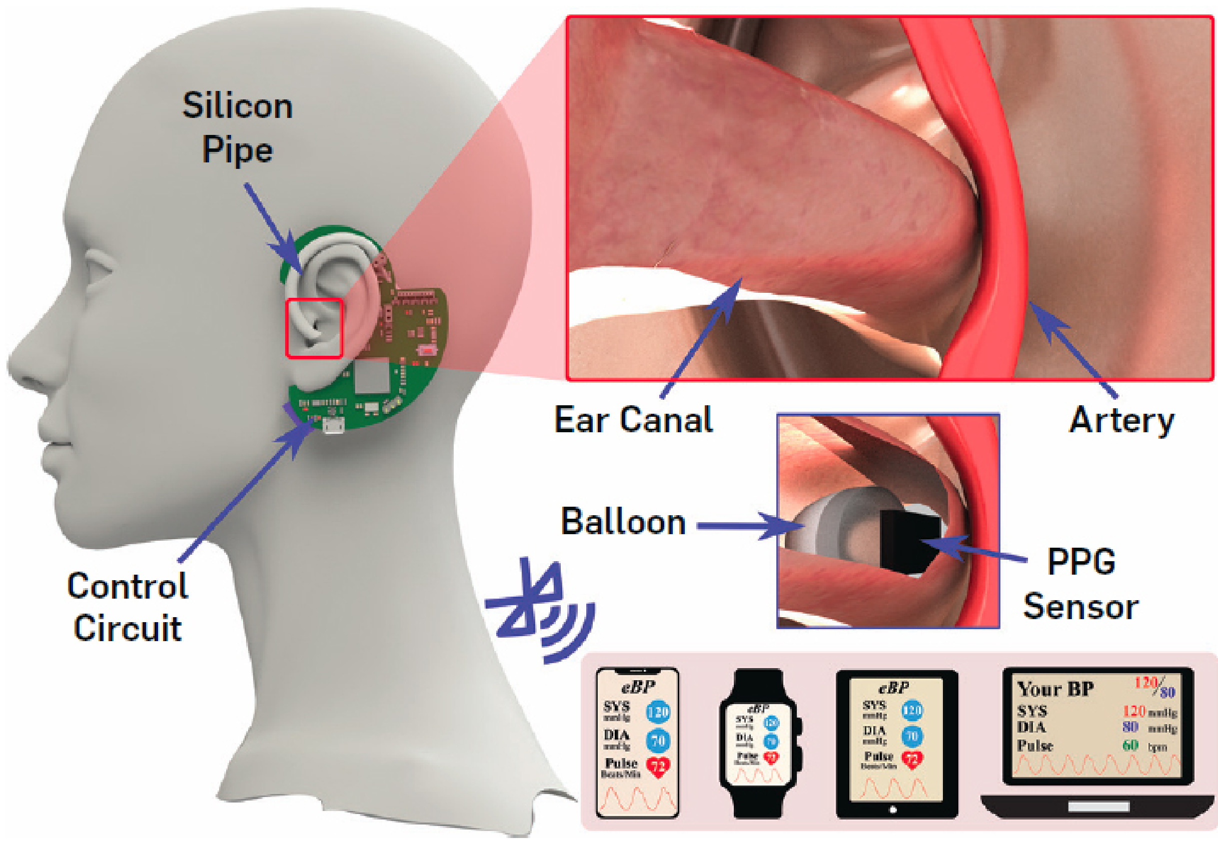
Date: 09/12/2022

Content by: Mustafa

Present: N/A

Goals: Look for existing devices to find ideas

Content:



e-BP includes a light-based pulse sensor attached to an in-ear inflatable pipe balloon, an air pump, a pressure sensor, and a valve controlling module to control the balloon's contact with the in-ear skin for pulse measurement, and (3) a BP estimation algorithm. The digital pump slowly inflates the in-ear pipe to create slight pressure on the outer ear canal until the diastolic and the systolic values are estimated

Conclusions/action items:

This device seems efficient in measuring blood pressure, but it is not a headphone and can't be used for listening to music. We could implement this idea into the smart headphone.

Citation:

N. P. Nam Bui, “EBP: An ear-worn device for frequent and comfortable Blood Pressure Monitoring,” *ACM*, 01-Aug-2021. [Online]. Available: https://cacm.acm.org/magazines/2021/8/254316-ebp/fulltext. [Accessed: 12-Sep-2022].

11/30 "Digital Stethoscope"

MUSTAFA AL SAKHBOURI - Dec 14, 2022, 12:38 AM CST

Title: Digital Stethoscope

Date: 11/30/2022

Content by: Mustafa Al-Sakhbouri

Goals: Look for existing devices that could provide ideas for our project

Citation:

Leng S, Tan RS, Chai KT, Wang C, Ghista D, Zhong L. The electronic stethoscope. Biomed Eng Online. 2015 Jul 10;14:66. doi: 10.1186/s12938-015-0056-y. PMID: 26159433; PMCID: PMC4496820.

"Analog vs. digital stethoscopes: Is electronic really an improvement?," *Cardiovascular Business*, 23-Jan-2019. [Online]. Available: https://cardiovascularbusiness.com/topics/clinical/heart-rhythm/are-electronic-stethoscopes-better-analog. [Accessed: 28-Nov-2022].

Content:

A digital stethoscope overcomes the low sound levels by electronically amplifying the body sounds. Electronic stethoscopes convert the acoustic sound waves obtained through the chest piece into electrical signals, which can then be amplified for optimal listening.

The electronic stethoscope was preferred 99 percent of the time during lung examinations. "We found that **a digital stethoscope records clearer sounds through a patient's clothes**, and the Korotkoff sounds are heard better with a digital stethoscope when measuring manual blood pressures," the authors wrote.

Conclusions/action items:

Digital stethoscopes could be the best device in the marker to pick up the heartbeat sound. However, they are significantly more expensive than traditional stethoscopes, so they may not be an option for everyone. Using a digital stethoscope in our project could solve the biggest challenge in our project, but it will make the smart headphone not commercial friendly.

09/24 "Headset Standards"

MUSTAFA AL SAKHBOURI - Oct 11, 2022, 8:48 PM CDT

Title: Headset Standards

Date: 09/24/2022

Content by: Mustafa Al-Sakhbouri

Present:

Goals: Look for Headphones Standards to implement in our design

Citation:

"Devices and systems - world health organization." [Online]. Available: https://apps.who.int/iris/bitstream/handle/10665/280085/9789241515276-eng.pdf.

Content:

Standard EN 50332 applies only to battery-operated portable consumer audio entertainment equipment with mono or stereo headphones or earphones, intended for presenting broadcast or recorded sound or video, for example CD players, MP3 players, MP3 players in mobile phones, or PDAs and tablets.

EN 50332 Part 1 requires a specified test signal to be replayed from the device being tested. The test signal, or "programme simulation noise" is a pink noise signal which has been filtered to change the spectrum shape and then soft-clipped to reduce the crest factor. The test signal is recorded or uploaded to the player at a specified level.

The test signal is played from the player at the maximum volume setting and the sound levels from the attached headphones are measured using a Head and Torso Simulator (HATS).

PMPs must be equipped with user protection if they are capable of delivering an Sound Pressure Level (SPL) of 85 dB(A) when playing a static test signal including:

– an active warning when SPL (of the test signal) is above 85 dB(A);

– a maximum SPL no higher than 100 dB(A).

When testing a player without headphones, the signal is replayed at the player's maximum volume setting and the voltage at the player's headphone socket is measured across a 32 Ω load.

Conclusions/action items:

We must implement these Headphones Standards when start fabricating our design as well as during testing process.

09/23 "Reduce Background Noises on Microphone"

MUSTAFA AL SAKHBOURI - Sep 23, 2022, 12:53 PM CDT

Title: Reduce Background Noises on Microphone

Date: 09/23/2022

Content by: Mustafa Al-Sakhbouri

Present:

Goals: Learn how to eliminate background noises on the microphone

Citation:

S. Babayan, “How to reduce background noise on microphone,” *Krisp*, 16-Aug-2022. [Online]. Available: https://krisp.ai/blog/how-to-reduce-background-noise-microphone/#:~:text=To%20reduce%20ambient%20sounds%20while,t%20causing%20interference%20as%20well. [Accessed: 22-Sep-2022].

Frank EdwardsFrank Edwards is the founder and owner of churchsoundtips.com and has over 10 years experience running sound in his local church., “9 ways to get rid of microphone background noise,” *Church Sound Tips*, 15-Sep-2022. [Online]. Available: https://churchsoundtips.com/mic-backgnd-noise/. [Accessed: 23-Sep-2022].

Content:

First, we should determine the types of noises we will eliminate:

- Impulse noises
- Broadband noise
- Narrow band noises
- Electrical noises
- Irregular noises

There is existing software that could reduce background noises like, krisp.

We should do a quick sweep of the area when we set up the microphone's sound. we also need to make sure that any nearby devices aren’t causing interference as well. We can create an audio track in which We can reduce the ambient noises manually through a program later.

Conclusions/action items:

We should get a good quality Microphone which will help us minimize background noises. we could also use a windshield around the mic for better isolation.

09/26 "Design ideas"

MUSTAFA AL SAKHBOURI - Oct 12, 2022, 12:05 AM CDT

Title: Design Ideas

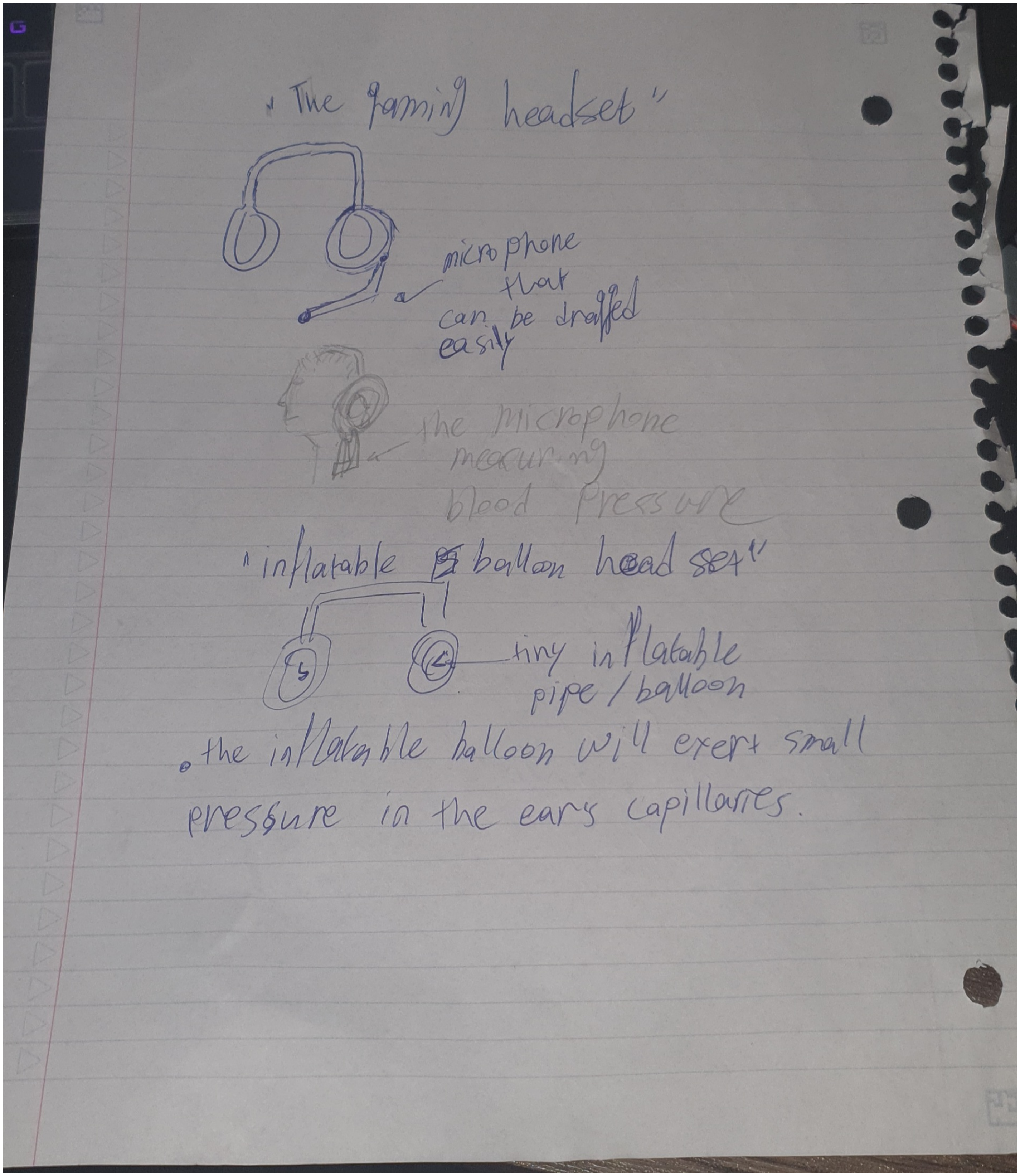
Date: 09/26

Content by: Mustafa Al-Sakhbouri

Present: N/A

Goals: Create preliminary design ideas

Content:



Conclusions/action items:

These design ideas will be shared with team members and produce feedback as a team.

10/16 "Microphone in Arduino"

MUSTAFA AL SAKHBOURI - Oct 23, 2022, 9:23 PM CDT

Title: Microphone in Arduino

Date: 10/16/2022

Content by: Mustafa Al-Sakhbouri

Goals: to better understand how to use microphone sensors in Arduino

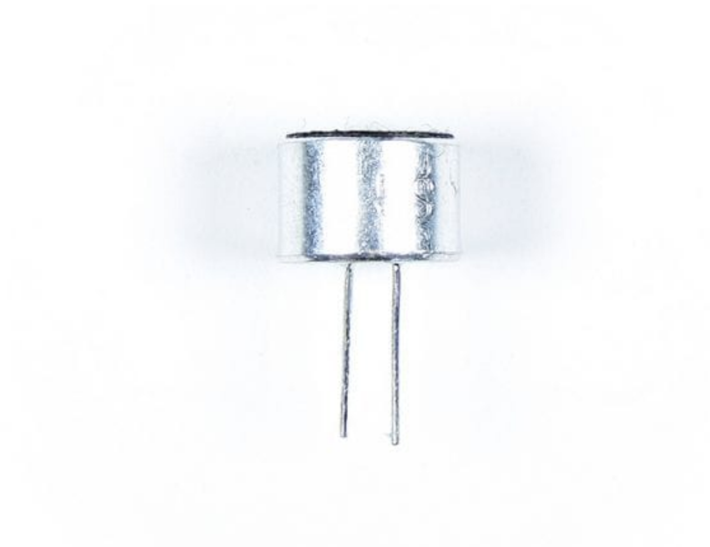
Citation:

S. Campbell, “How to use microphones on the Arduino,” *Circuit Basics*, 13-Nov-2021. [Online]. Available: https://www.circuitbasics.com/how-to-use-microphones-on-the-arduino/.

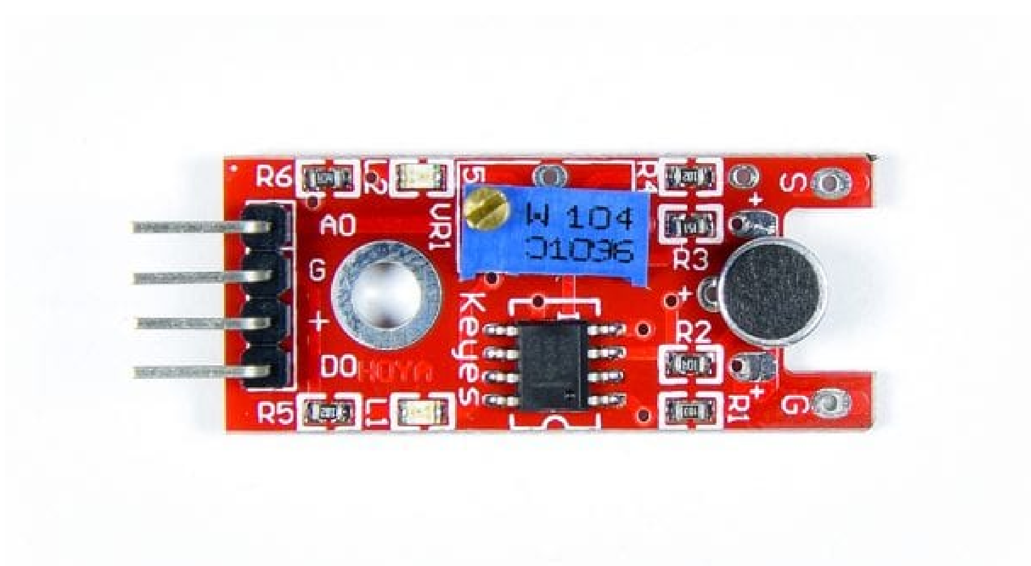
Content:

There are two types of Microphone sensors:

1)Electret microphones come as a stand-alone unit like this one:

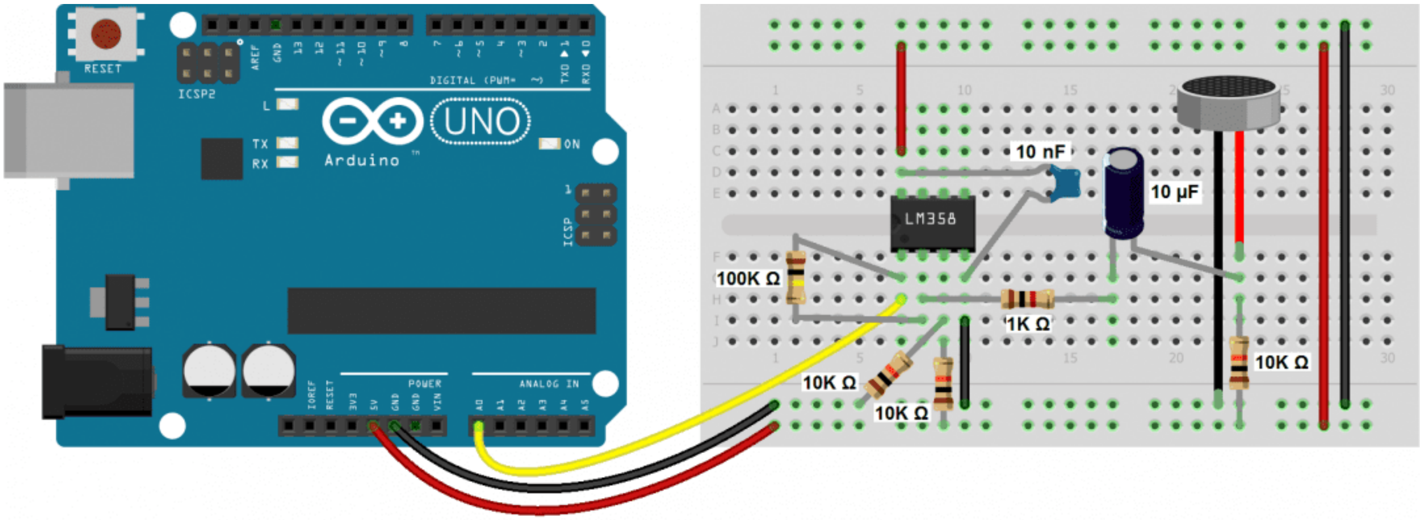


2) The same one above but attached to a breakout board that has a pre-build amplifier:



a Stand alone microphones are a little harder to set up since they don't have a pre-amplifier. You will need to build and connect one yourself.

a simple circuit design with a stand alone microphone:



Conclusions/action items:

Our team has Standalone microphones so that we may implement the simple circuit design. Next, we need to create Arduino Code.

10/23 "Microphone Code Sample"

MUSTAFA AL SAKHBOURI - Oct 23, 2022, 9:32 PM CDT

Title: Microphone Code Sample

Date: 10/23/2022

Content by: Mustafa Al-Sakhbouri

Goals: Find Arduino code for the microphone

Citation:

S. Campbell, “How to use microphones on the Arduino,” *Circuit Basics*, 13-Nov-2021. [Online]. Available: https://www.circuitbasics.com/how-to-use-microphones-on-the-arduino/.

Content:

```
const int microphonePin = A0;

void setup() {
  Serial.begin(9600);
}

void loop() {
  int mn = 1024;
  int mx = 0;

  for (int i = 0; i < 10000; ++i) {

    int val = analogRead(microphonePin);

    mn = min(mn, val);
    mx = max(mx, val);
  }

  int delta = mx - mn;

  Serial.print("Min=");
  Serial.print(mn);
  Serial.print(" Max=");
  Serial.print(mx);
  Serial.print(" Delta=");
  Serial.println(delta);
}
```


const int microphonePin = A0;

```
void setup() {  Serial.begin(9600); }

void loop() {  int mn = 1024;  int mx = 0;

 for (int i = 0; i < 10000; ++i) {

  int val = analogRead(microphonePin);
```

```
   mn = min(mn, val);
   mx = max(mx, val);  }
 int delta = mx - mn;
 Serial.print("Min=");
 Serial.print(mn);
 Serial.print(" Max=");
  Serial.print(mx);
  Serial.print(" Delta=");
 Serial.println(delta); }
```

Conclusions/action items:

We will refer to the above when writing our code for the Microphone. We'll take a series of analog reads from the microphone pin. Then we'll calculate the minimum and maximum values measured in that series of analog reads.

11/2 "Input Audio from Audio Jack to Arduino"

MUSTAFA AL SAKHBOURI - Dec 12, 2022, 8:19 PM CST

Title: Input Audio from Audio Jack to Arduino

Date:11/2/2022

Content by: Mustafa Al-Sakhbouri

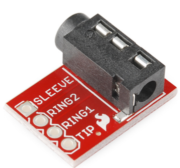
Goals: Learn how to collect audio data from a microphone that has an aux cord

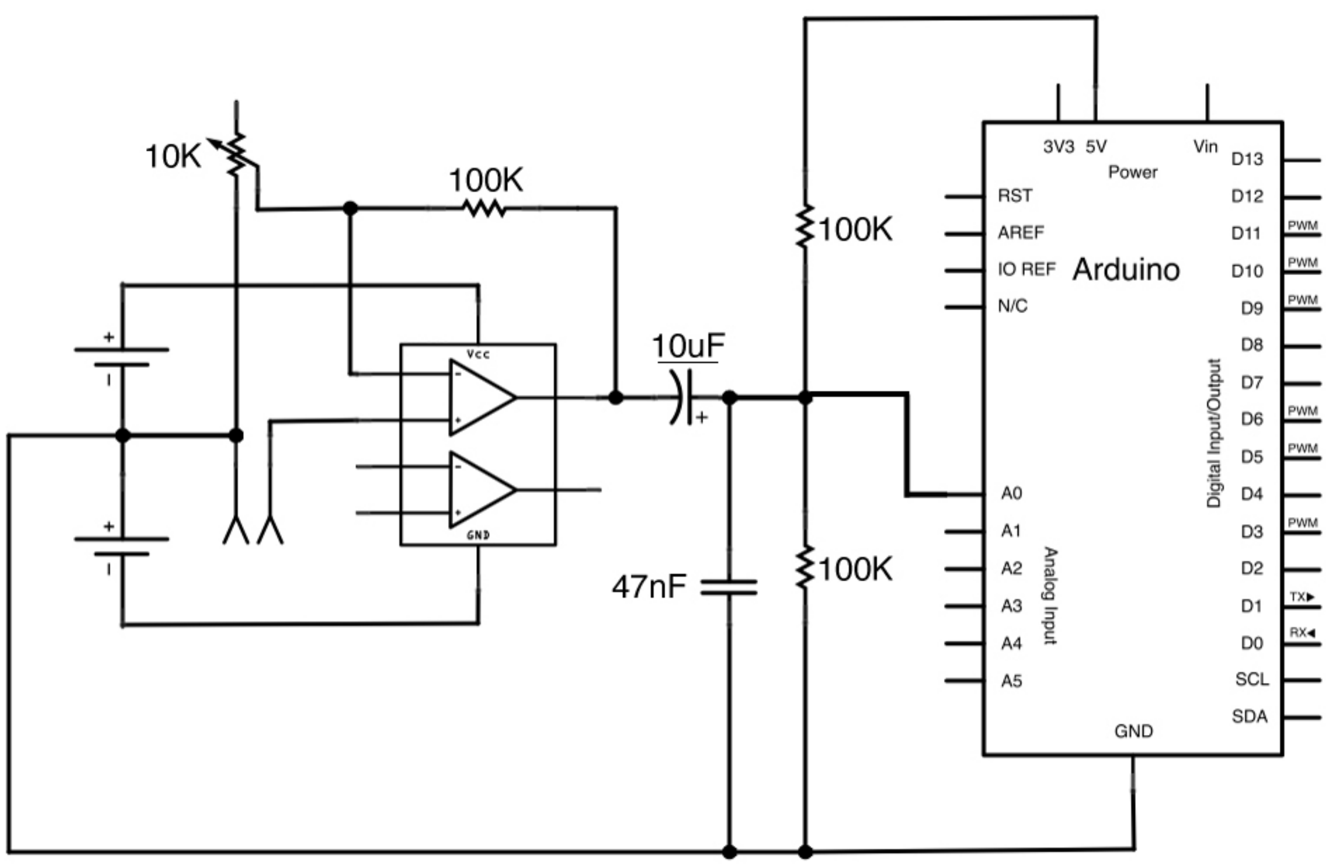
Citation:

Amandaghassaei and Instructables, “Arduino audio input,” *Instructables*, 27-Oct-2017. [Online]. Available: https://www.instructables.com/Arduino-Audio-Input/. [Accessed: 01-Nov-2022].

Content:

We will be using SparkFun TRRS 3.5mm Jack Breakout for our input element (stereo audio jack type):





The above circuit above is using a non-inverting amplifier with a mono audio jack. We will try to mimic the circuit to safely create an audio input with an extensive range of voltage.

The equation below is used to calculate the Vout from the amplifier:

Vout =~ Vin * (1 + R2/R1)

Useful equations for Arduino code that will print out meaningful data that can be graphed and analyzed below:

Min voltage = Center Voltage - Amplitude
Min voltage = 2.5V - 2.5V = 0V

Max Voltage = Center Voltage + Amplitude
Max Voltage = 2.5V + 2.5V = 5V

Conclusions/action items:

We will need to look for Arduino code to run our circuit.

11/9 " Audio Jack Code"

MUSTAFA AL SAKHBOURI - Dec 12, 2022, 8:37 PM CST

Title: Audio Jack Code

Date: 11/9/2022

Content by: Mustafa Al-Sakhbouri

Goals: Prepare code for Audio jack

Citation:

Amandaghassaei and Instructables, “Arduino audio input,” *Instructables*, 27-Oct-2017. [Online]. Available: https://www.instructables.com/Arduino-Audio-Input/. [Accessed: 01-Nov-2022].

Content:

The code below from Amanda Ghassaei is compatible with our audio jack. The code outputs a sine wave centered around 2.5V, oscillating up to a max of 5V and a min of 0V. In the loop() function, the variable "t" is incremented from 0 to 100.

```
//Simple Audio In w output to 8 bit DAC

//by Amanda Ghassaei

//https://www.instructables.com/id/Arduino-Audio-Input/

//Sept 2012

/*

 * This program is free software; you can redistribute it and/or modify

 * it under the terms of the GNU General Public License as published by

 * the Free Software Foundation; either version 3 of the License, or

 * (at your option) any later version.

*/

int incomingAudio;

void setup(){

  for (byte i=0;i<8;i++){

    pinMode(i,OUTPUT);//set digital pins 0-7 as outputs (DAC)

 }}

void loop(){
```

```
  incomingAudio = analogRead(A0);//read voltage at A0

  incomingAudio = (incomingAudio+1)/4 - 1;//scale from 10 bit (0-1023) to 8 bit (0-255)

  if (incomingAudio<0){//deal with negative numbers

    incomingAudio = 0;

  }

  PORTD = incomingAudio;

}
```

Conclusions/action items:

The code above will be implemented with the audio jack circuit if a microphone with an aux cord is used in the project.

9/12/2022 understanding PTT and PWV

Mark RICE - Sep 12, 2022, 4:52 PM CDT

(IEEE formatting)

Title: Pulse transit time technique for cuffless unobtrusive blood pressure measurement: from theory to algorithm

Date: 9/12/2022

Content by: Mark Rice

Present: Mark Rice

Goals: To understand PTT and PWV and how to measure them.

Citation:

X. Ding and Y.-T. Zhang, “Pulse Transit Time Technique for cuffless unobtrusive blood pressure measurement: From theory to algorithm,” Biomedical engineering letters, 18-Feb-2019. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6431352/#:~:text=PWV%20can%20be%20measured%20from,two%20places%20of%20the%20propagation. [Accessed: 12-Sep-2022].

Content:

PWV can be measured from PTT. PWV = L/PTT (PTT time it takes a pulse wave to travel between two places in the cardiovascular system, L is the distance between 2 places of the propagation).

PTT can be measured from 2 cardiac pulse signals such as ECG and PPG and can be translated into BP with a calibration procedure.

PWV can be calculated using Moens and Kortweg (M-K) equation where PWV = sqrt(Eh / ρD) where E = elasticity of the artery, h = thickness of arterial wall, D = diameter of the artery, ρ = density of the blood.

Conclusions/action items:

9/20/2022 ANT+ protocol

Mark RICE - Sep 20, 2022, 12:23 PM CDT

Title: ANT+ protocol

Date: 9/20/2022

Content by: Mark Rice

Present: Mark Rice

Goals: understand how current smart watches share health data like heart rate.

Content:

The ANT+ program is a program that is already integrated into many fitness type watches (popular brands garmin,fitbit etc.) that allows the device to broadcast live data (heart rate is what we would be interested in) to be able to be picked up by a smartphone, computer or Arduino (most devices will require an additional receiver ~10$).

most benefits of adopting this program are free for public use, certain use cases may require subscription to their protocol ~$1500 per year. Information: https://www.thisisant.com/business/go-ant/levels-and-benefits

Cons: not integrated in apple watches, may require payment to introduce into our product, requires usb receiver and will not work over Bluetooth

Pros: don't need to "reinvent the wheel", seemingly easy implementation into ios, android, pc or ardiuno

Conclusions/action items:

can data transmitted over ANT+ be grabbed by a program (java?) to be used in our calculations? Is this possible for our use case, designing a new product? How would we transmit our data in the same way that others do using ANT+?

Is all of this much more difficult that sending data over Bluetooth connection?

9/26 preliminary design ideas

Mark RICE - Sep 26, 2022, 3:13 PM CDT

Title: preliminary headphone concepts

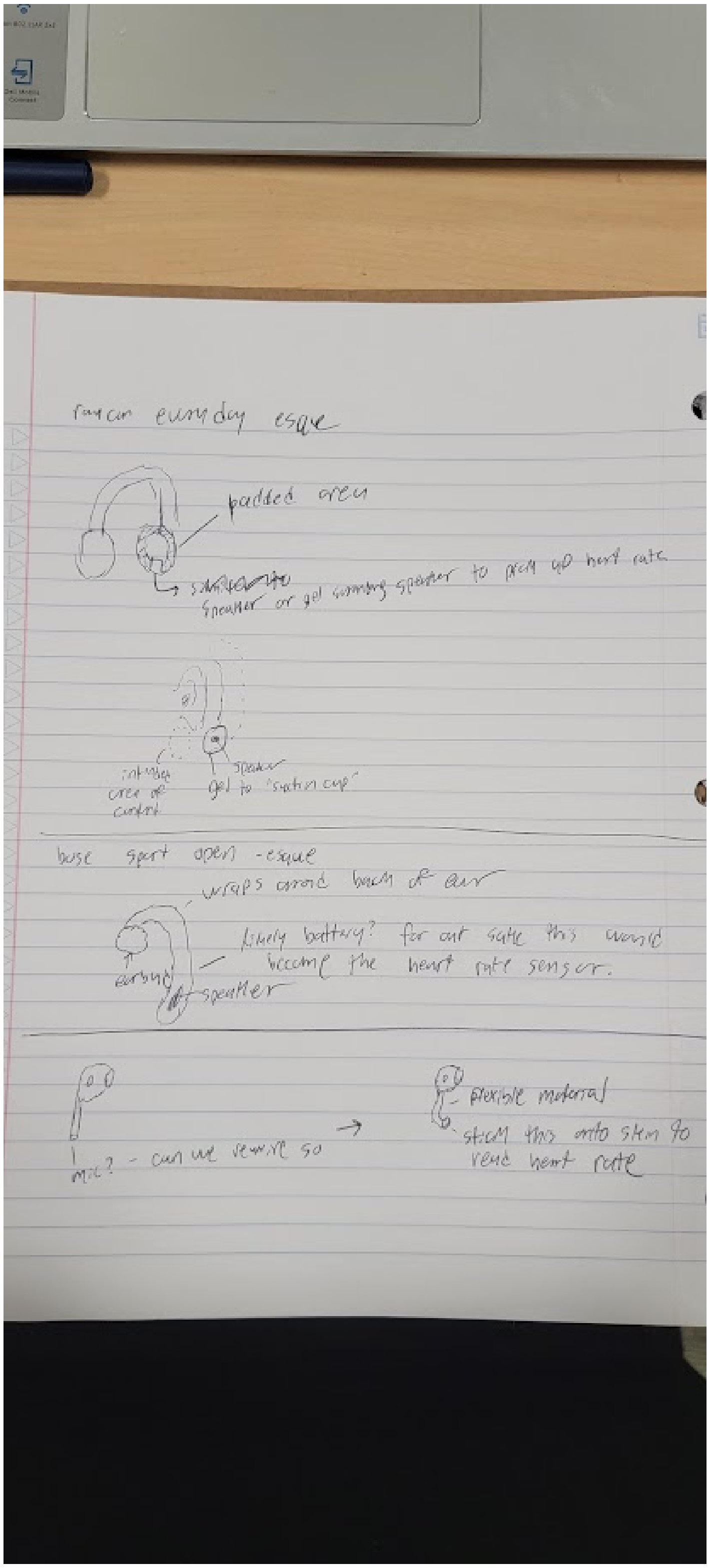
Date: 9/26/2022

Content by: Mark Rice

Present: Mark Rice

Goals: To brainstorm ideas that can be used for headphone design

Content:



see reference pictures for my form ideas for 3 types of headphones:

1. Raycon everyday headphones which are an over the ear fit that I imagine being able to add some sort of gel or padded material to hold a microphone onto the back of the ear where it would be able to pick up on heart rate signals.
2. Bose smart open which have a lobe that stretches around the back of the ear, which I assume is filled with the battery where we may be able to put a speaker that could be in contact with the skin behind the ear.
3. Apple air pods 1/2 which already have a mic on the end of the bud, which if we were able to make into a flexible material we could in theory stretch that microphone onto the skin where it could be used to get the heart rate data.

Conclusions/action items: How will audio input be translated into heart rate? Are we able to take the audio input from the airpod microphone to even be able to hear the heart rate? what kind of speaker will we need that is sensitive enough to hear the heart rate?

9/26 microphone input

Mark RICE - Sep 26, 2022, 3:41 PM CDT

Title: Microphone input java program

Date: 9/26

Content by: Mark Rice

Present: Mark Rice

Goals: To understand how a microphone input may be able to turned into digital numbers in order to do calculations.

Content:

https://github.com/lucns/Android-Audio-Sample
I found this program on github that would take a input from android mic and gives a live output of the Amp, db, and Hz from that, if we could edit this program to use those values as variables in our heart rate calculation and also input the heart rate data from the smart watch.
I also communicated with a few of my CS major friends, they said that using this seemingly may work as an input into our own heart rate calculation program, the problem may come into play in this would be that we need such a dynamic calculation do be done and recorded so that would require research into the android framework, which even they don't have the required knowledge to do so.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4613720/
I also found this article that describes the process to be able to take audio input and change it into heart rate. The information was much higher than my current understanding of sound will allow me to comprehend, but it seems that it may be able to help turn the above information into heart rate.

Conclusions/action items: How can I turn this into heart rate? Would I be able to edit this in order to do the calculations of heart rate and also input the heart rate data from smartwatch in order to also get that heart rate data?

10/31 ANT+ HRM Pairing

Mark RICE - Oct 31, 2022, 6:01 PM CDT

Title: ANT+ HRM Pairing

Date: 10/31/2022

Content by: Mark Rice

Present: Whole team but working on separate problems

Goals: Understand Pairing HRM to ANT+ software to get heart rate data.

Content:

HRM = Heart Rate Monitor

Steps:

Download ANTWareII and SimulANT+ from ANT+ website. (must become adopter to access necessary downloads, so this will take about a day for them to verify your email)

SimulANT+ settings: Extended device number (device ID found on USB device) ours is 34788. Full Serial Data (ID of HRM) ours is 362468. Under Heart Rate Display profile.

ANTWare profile as seen below:

<ChannelProfile>

<channelType type="ANT_Managed_Library.ANT_ReferenceLibrary+ChannelType">BASE_Slave_Receive_0x00</channelType>

<channelTypeExt type="ANT_Managed_Library.ANT_ReferenceLibrary+ChannelTypeExtended">0</channelTypeExt>

<networkNum type="System.Byte">0</networkNum>

<deviceNumber type="System.UInt16">0</deviceNumber>

<pairingOn type="System.Boolean">true</pairingOn>

<deviceType type="System.Byte">120</deviceType>

<transmissionType type="System.Byte">0</transmissionType>

<msgPeriod type="System.UInt16">8070</msgPeriod>

<radioFreq type="System.Byte">57</radioFreq>

<chTxPower type="ANT_Managed_Library.ANT_ReferenceLibrary+TransmitPower">RADIO_TX_POWER_0DB_0x03</chTxPower>

<searchTimeout type="System.Byte">10</searchTimeout>

<lowPriSearchTimeout type="System.Byte">2</lowPriSearchTimeout>

</ChannelProfile>

</SingleChannelProfile>

Channel assignment: Slave, network number = 0. Channel ID: device # = 0, device type = 120, trans type = 0, pairing = checked. Channel Period = 8070 (4.06 Hz). Radio Frequency = 57 Mhz. All other settings are on defaults.

under these settings in ANTWare we are able to output data from a python program into hr_log.csv under location: C:\Users\marko\OneDrive\Desktop\ant\SimulANT+_2.3.0\SimulANT+ 2.3.0\SimulANT+

This has a excel with event time and heart rate, so if we are able to input this file and relate out input times to the heart rate for that time from this file we should be able to use this for our program.

Conclusions/action items: understand how event time is used and figure out how we may be able to implement this onto an Arduino. Also: figure out if it is possible to get HRM to display that it is connected to avoid user confusion. Also: test comparing verified method of heart rate calculation via my smart watch to the data we are getting from the heart rate monitor to see if it is within acceptable uncertainty.

11/11 Arduino code to estimate PTT and PWV using 2 LED sensors

Mark RICE - Nov 11, 2022, 12:32 PM CST

Title: Arduino code to estimate PTT and PWV using 2 LED HRM sensors

Date: 11/11

Content by: Mark Rice

Present: Mark Rice

Goals: develop outline of code to estimate PTT and PWV using 2 LED HRM sensors, one of which to eventually be replaced by a microphone.

Content:

here is the rough outline of the code I want to run in order to estimate PTT and PWV:

```
//on neck

// if pickip beat, then start timer



if (Signal.neck > threshold) {

    timer = true;

  }




timer {

while (timer = true){

  time = time + (frequency);

    if (Signal.wrist > threshold){

    timer = false;

  }

  wait (frequency);

}

if (timer = false){

PTT = time;

System.out.print("PTT: " + PTT);
```

```
PWV = (distance) / PTT;

System.out.print("PWV: " + PWV);

time = 0;

}

}


// once timer starts, wait for pulse at wrist

// once wrist picks up signal, save time as PTT

// Distance / PTT = PWV
```

This code outline is based on this code that lights up a LED for when one HRM LED sensor is used on arduino:

```
/*  PulseSensor Starter Project and Signal Tester

 *  The Best Way to Get Started  With, or See the Raw Signal of, your PulseSensor.com™ & Arduino.

 *

 *  Here is a link to the tutorial

 *  https://pulsesensor.com/pages/code-and-guide

 *

 *  WATCH ME (Tutorial Video):

 *  https://www.youtube.com/watch?v=RbB8NSRa5X4

 *

 *

--------------------------------------------------------------

1) This shows a live human Heartbeat Pulse.

2) Live visualization in Arduino's Cool "Serial Plotter".

3) Blink an LED on each Heartbeat.

4) This is the direct Pulse Sensor's Signal.

5) A great first-step in troubleshooting your circuit and connections.

6) "Human-readable" code that is newbie friendly."
```

```
*/



//  Variables

int PulseSensorPurplePin = 0;        // Pulse Sensor PURPLE WIRE connected to ANALOG PIN 0

int LED13 = 13;   //  The on-board Arduion LED



int Signal;                // holds the incoming raw data. Signal value can range from 0-1024

int Threshold = 550;            // Determine which Signal to "count as a beat", and which to ingore.



// The SetUp Function:

void setup() {

  pinMode(LED13,OUTPUT);         // pin that will blink to your heartbeat!

   Serial.begin(9600);         // Set's up Serial Communication at certain speed.


}


// The Main Loop Function

void loop() {


  Signal = analogRead(PulseSensorPurplePin);  // Read the PulseSensor's value.

                                              // Assign this value to the "Signal" variable.


   Serial.println(Signal);                    // Send the Signal value to Serial Plotter.
```

```
  if(Signal > Threshold){                         // If the signal is above "550", then "turn-on" Arduino's on-Board LED.

    digitalWrite(LED13,HIGH);

  } else {

    digitalWrite(LED13,LOW);                 //  Else, the sigal must be below "550", so "turn-off" this LED.

  }




delay(10);




}
```

Conclusions/action items: start to build circuits to test this code and edit it until I can get PTT and PWV outputs, then test to see how accurate these are by finding how to estimate these to blood pressure and compare to the readings from blood pressure cuff.

11/14 Arduino code to estimate PTT and PWV continued

Mark RICE - Nov 14, 2022, 3:40 PM CST

Title: Arduino code to estimate PTT and PWV continued

Date: 11/14

Content by: Mark Rice

Present: Mark Rice

Goals: create code to estimate PTT and PWV using 2 LED heart rate sensors.

Content: the following code was adapted to use 2 MAX30105 breakout boards to estimate PTT and PWV, unfortunately, the framework of the code is laid out but due to physical issues with boards not working I could only get one to work.

Conclusions/action items: adapt the code to include input from the speaker, add timer method, find constants a and b based on physical dimensions of distance from average heart to wrist and heart to neck. Create a wristband to house the heart rate board for easier testing.

Mark RICE - Nov 14, 2022, 3:36 PM CST

Download

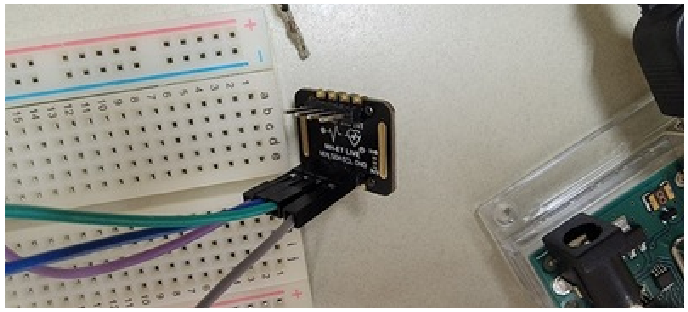
Heart_rate_My_code.ino (3.61 kB)

Mark RICE - Nov 14, 2022, 3:36 PM CST

Download

License.ino (1.62 kB)

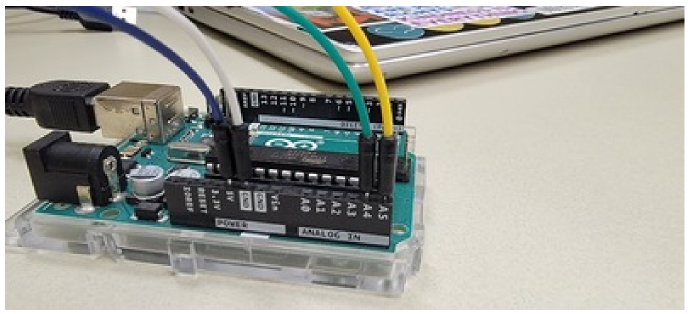
Mark RICE - Nov 14, 2022, 3:42 PM CST



Download

20221112_161023.jpg (104 kB) Where to connect wires to breakout board

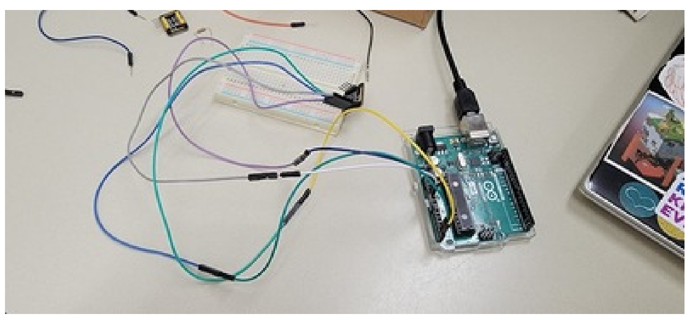
Mark RICE - Nov 14, 2022, 3:42 PM CST



Download

20221112_161015.jpg (104 kB) where to connect wires onto Arduino

Mark RICE - Nov 14, 2022, 3:43 PM CST



Download

20221112_161011.jpg (91.7 kB) Wide shot to see which color wires connect to each other.

11/18 Editing Arduino Code

Mark RICE - Nov 28, 2022, 5:28 PM CST

Title: Editing Arduino Code

Date: 11/28/2022

Content by: Mark Rice

Present: Mark

Goals: Use 2 heart rate sensors to estimate PTT and PWV

Content: hooking up 2 particle sensors to the Arduino with the same address is proving to be very difficult and beyond the scope of this project, so my plan to use 2 LED sensors to estimate PTT and PWV seems to not be pressable with my current approach. Instead I took a different approach to begin to edit the existing code for getting BPM in order to eventually be used in conjunction with the microphone. The code attached below is used to attach one heart rate sensor to the finger to get pulse. when it senses a beat it makes an LED attached to digital pin 7 on the Arduino to blink. This "blink" section of the code will eventually be updated to wait to detect a pulse at the neck to calculate PTT.

Conclusions/action items: Work with members working on the speaker in order to implement it into Arduino and finalize the code for that section. Alternatively also try using a heart rate sensor with a different address to make hooking up 2 sensors much easier.

Mark RICE - Nov 28, 2022, 5:29 PM CST

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sketch_nov28b.ino (1.37 kB)

10/24 Part List 1 order

Title: 10/24 Part List 1 order

Date: 10/24

Content by: Mark Rice

Present: Mark Rice

Goals: document what was placed in part list 1 order

Content:

The following are the tables form the part's list order 1 we sent to the client, edited during the 10/17 meeting and order placed on 10/21. I updated the BPAC information as needed. As of 10/24 3 of the items listed below have been received.

Link	Shorth Name
https://www.amazon.com/CooSpo-CycleOps-TrainerRoad-Extension-Included/dp/B07CB4328P/ref=sr_1_1_sspa?keywords=ant%2Bdongle&qid=1663620132&sr=8-1-spons&th=1	ANT+
https://www.amazon.com/DORHEA-Microphone-Amplifier-Electret-Programmable/dp/B09N92M6V5	Microp
https://www.arrow.com/en/products/cma-4544pf-w/cui-devices?gclid=Cj0KCQjwhY-aBhCUARIsALNIC07JSq7yDiOaUO1hdJ8x6vj20FWGdvyH0YCJ_AMp7ItenRbUp6mk-N8aAve_EALw_wcB&gclsrc=aw.ds	Microp
https://www.amazon.com/Powr-Labs-Bluetooth-Monitor-Armband/dp/B088RMK1GX/ref=sr_1_3?crid=SC5GCSXI6W87&keywords=ant%2B+watch&qid=1663624060&sprefix=ant%2B+watch%2Caps%2C94&sr=8-3	Heart armba
https://www.amazon.com/Gikfun-Breakout-Headphone-Arduino-AE1223/dp/B01KFP0HBG/ref=sr_1_2?keywords=arduino+aux+input&qid=1666032203&qu=eyJxc2MiOiIwLjAwIiwicXNhIjoiMC4wMCIsInFzcCI6IjAuMDAifQ%3D%3D&sprefix=arduino+aux%2Caps%2C109&sr=8-2	AUX p
https://www.amazon.com/AITRIP-MAX30102-Detection-Concentration-Arduino/dp/B08NFY97SC/ref=sr_1_2?keywords=arduino+heart+rate+sensor&qid=1666042540&qu=eyJxc2MiOiIzLjcyIiwicXNhIjoiMy40NiIsInFzcCI6IjMuNTIifQ%3D%3D&sprefix=arduino+heart+%2Caps%2C126&sr=8-2	Heart sensor
https://medical.andonline.com/product/ultraconnect-premium-wireless-blood-pressure-monitor-ua-1200ble/#tab-id-4	Blood pressu

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Category 1 - Circuit Materials								
ANT+ reciever	Allows for data collection from most fitness marketed smart watches	CooSpo	N/A	10/20/2022	1	$9.99	$9.99	https://www.amazon.com/CooSpo-CycleOps-TrainerRoad-Extension-Included/dp/B07CB43 spons&th=1
MAX9814 Microphone	Microphone design #1 for testing for heart signal pickup.	Dorhea	MAX9814	10/20/2022	10	$2.50	$24.99	https://www.amazon.com/DORHEA-Microphone-Amplifier-Electret-Programmable/dp/B09
Microphone	Microphone design #2 for testing for heart signal pickup.	CUI Devices	CMA-4544PF-W	10/20/2022	2	$0.76	$1.52	https://www.arrow.com/en/products/cma-4544pf-w/cui-devices?gclid=Cj0KCQjwhY-aBhCU N8aAve_EALw_wcB&gclsrc=aw.ds
3.5mm Jack	For arduino wiring, it will allow us to listen directly to the microphone input so we can tell how distorted our input signal is while testing.	Gikfun	AE1223	10/20/2022	3	$2.66	$7.98	https://www.amazon.com/Gikfun-Breakout-Headphone-Arduino-AE1223/dp/B01KFP0HBG keywords=arduino+aux+input&qid=1666032203&qu=eyJxc2MiOiIwLjAwIiwicXNhIjoiMC4w
Heart Rate Sensor	Will allow us to wire it in such a way that we can collect heart rate, pulse and blood oxygen data for testing.	AITRIP	MAX30102	10/20/2022	2	$4.65	$9.29	https://www.amazon.com/AITRIP-MAX30102-Detection-Concentration-Arduino/dp/B08NF keywords=arduino+heart+rate+sensor&qid=1666042540&qu=eyJxc2MiOiIzLjcyIiwicXNhIjoi 2
Category 2 - Headphone Materials								
3D Printed Parts	Includes the frame, speaker housings, speaker covers	N/A	N/A		5		~ <$50.00	N/A
Speaker Cushions	Professional Replacement Earpads Cushions for Bose QuietComfort	SoloWit			1	$19.95	$19.95	https://www.amazon.com/Professional-Bose-QC35-Cushions-Replacement/dp/B07TZJ1CM c=ts&keywords=Headphone+Earpads&qid=1666042180&qu=eyJxc2MiOiI2LjMzIiwicXNhIjo
Category 3 - Testing Materials								
Heart Rate Monitor	ANT Compatible so should be able to be used so we can gather the general "smart watch" signal from this.	POWR LABS	N/A`	10/20/2022	1	$59.99	$59.99	https://www.amazon.com/Powr-Labs-Bluetooth-Monitor-Armband/dp/B088RMK1GX/ref= crid=SC5GCSXI6W87&keywords=ant%2B+watch&qid=1663624060&sprefix=ant%2B+watch

Wireless Blood Pressure Cuff	This will allow us to compare to a baseline of what our blood pressure should be within a +- 5% accuracy. This also allows us to store data over long periods of time and can export data directly to excel for comparison to what data we collect from our design.	A&D Medical	UA-1200BLE	10/20/2022	1	$99.99	$99.99	https://medical.andonline.com/product/ultraconnect-premium-wireless-blood-pressure-m
						TOTAL:	**$233.70**	

Conclusions/action items: awaiting delivery of certain items and awaiting totals for 3d printing costs

11/14 Part List 2 order

Title: 10/24 Part List 2 order

Date: 11/14

Content by: Mark Rice

Present: Mark Rice

Goals: document what was placed in part list 2 order

Content:

The following are the tables form the part's list order 2 we sent to the client, edited during the 11/14 meeting. I will update the BPAG spreadsheet with totals

Link
https://www.amazon.com/AITRIP-MAX30102-Detection-Concentration-Arduino/dp/B08NFY97SC/ref=sr_1_2?keywords=arduino+heart+rate+sensor&qid=1666042540&qu=eyJxc2MiOiIzLjcyIiwicXNhIjoiMy40NiIsInFzcCI6IjMuNTIifQ%3D%3D&sprefix=arduino+heart+%2Caps%2C126&sr=8-2
https://www.amazon.com/Professional-Bose-QC35-Cushions-Replacement/dp/B07TZJ1CMC/ref=sr_1_7?c=ts&keywords=Headphone+Earpads&qid=1666042180&qu=eyJxc2MiOiI2LjMzIiwicXNhIjoiNS43MSIsInFzcCI6IjUuMzkifQ%3D%3D&s=electronics&sr=1-7&ts_id=13880181
https://www.amazon.com/TraderPlus-Contact-Microphone-Mandolin-Ukulele/dp/B07795XHLH/ref=sr_1_1_sspa?crid=3QNHK80MU6YOQ&keywords=contact+microphone&qid=1668463835&sprefix=contact%2520microphone%2Caps%2C124&sr=8-1-spons&sp_csd=d2lkZ2V0TmFtZT1zcF9hdGY&ps
https://www.amazon.com/Everdixie-Dual-Head-Stethoscope-Pink/dp/B000FSIV6M?th=1

https://www.amazon.com/PoP-voice-Microphone-Omnidirectional-Smartphones/dp/B075VQ7VG7/ref=asc_df_B075VQ7VG7/?tag=hyprod-20&linkCode=df0&hvadid=312118595187&hvpos=&hvnetw=g&hvrand=17228464567582278820&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9018948&h
524514360158&psc=1

12/5 Circuit Testing

Mark RICE - Dec 11, 2022, 12:33 PM CST

Title: Comparing ANT+ to Arduino circuit

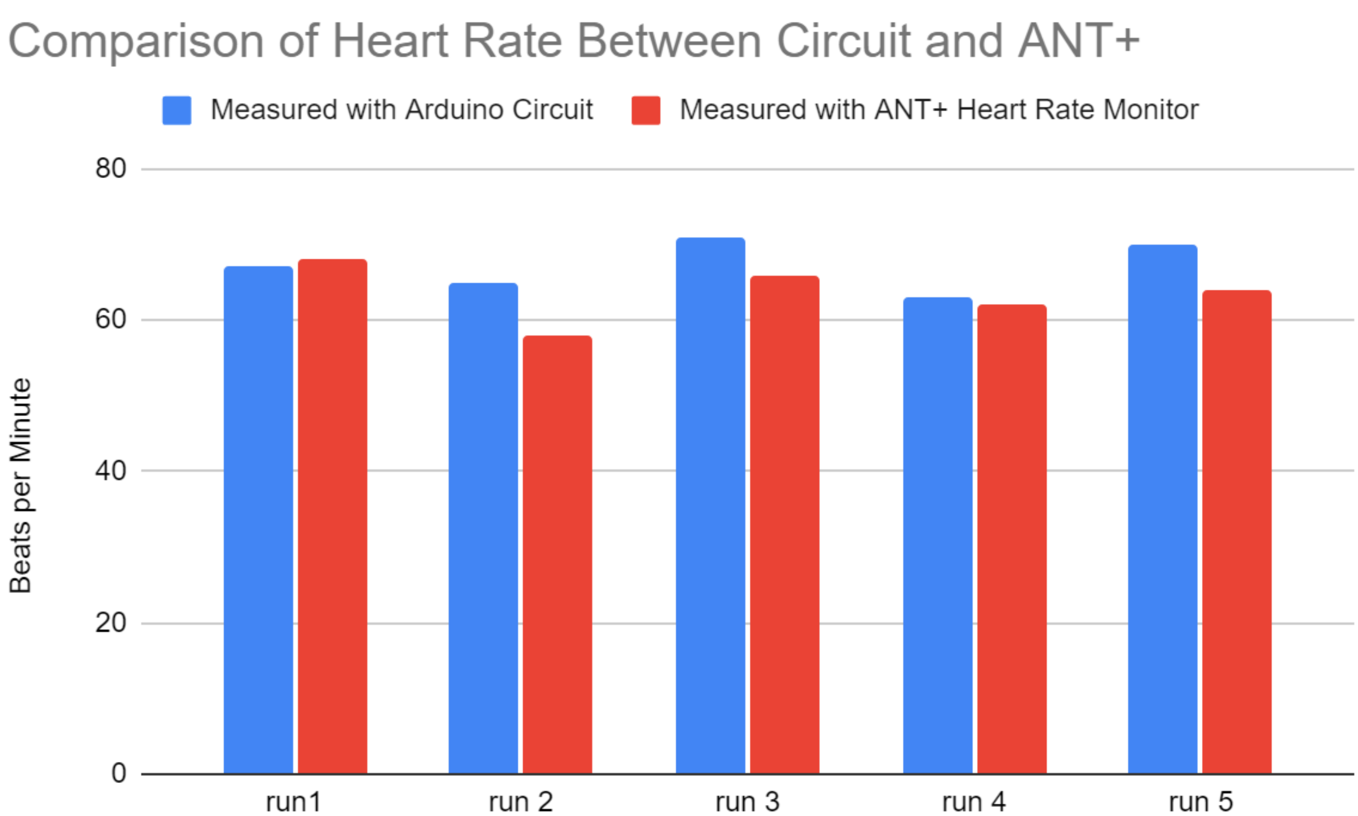
Date: 12/5

Content by: Mark Rice

Present: Mark Rice

Goals: Compare effectiveness of ANT+ heart rate monitor to Arduino Circuit.

Content: my testing produced the following results, as expected each circuit produced a similar amount of heart beats within one minute. As expected while watching the Arduino circuit it seemed to miss a few beats due to inconsistent pressure, this could be improved in a prototype that has an enclosure and a band to hold it on the wrist evenly.



Conclusions/action items: add this data to the poster.

2014/11/03-Entry guidelines

John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

MUSTAFA AL SAKHBOURI - Oct 23, 2022, 9:23 PM CDT

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: