TEAM 10173C:

REVERSE ENGINEERING CHALLENGE

LABDHI (HBS MOMENTUM)
BARNETT, LONDON, UNITED KINGDOM

15/12/2022

WHY WE CHOSE THIS

The item that we deconstructed is a Willful fitness tracker. The purpose of this device is to track number of steps taken, heart rate, and sleep patterns. Some also have connected apps that allow you track your overall progress, set goals as well as offer guidelines to help you achieve your fitness goals.

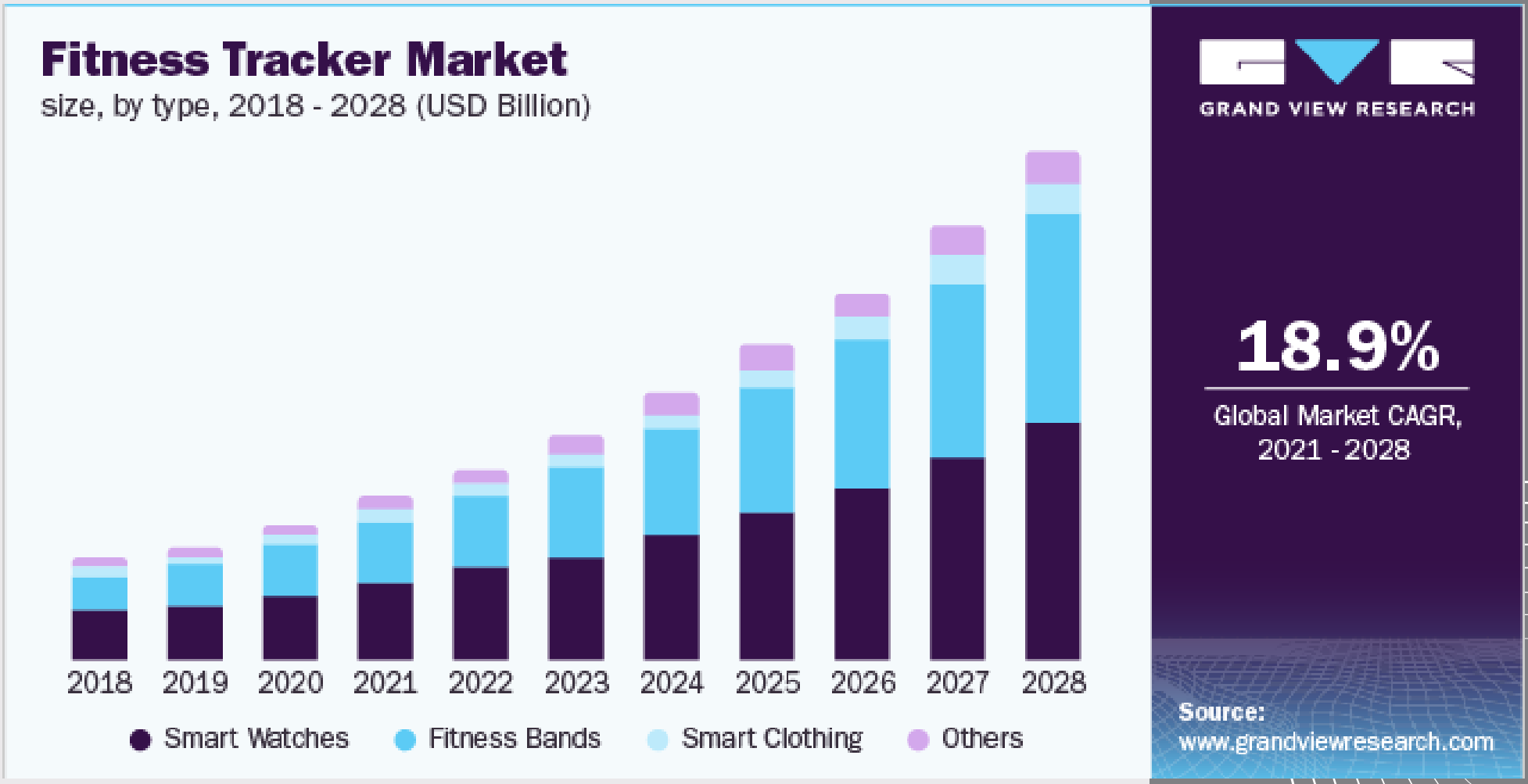
We chose this item as we thought it would be a very reliable and dependent factor in many lives right now, especially for people who want to improve and change their image. This device also is reflects technology that is used daily, and sets people's routines and lifestyles, showing its further importance in our lives.

Although many smartwatches like Apple encompass the same abilities, a fitness tracker is still widely used in our world.. so 10173C PRESENTS

DECONSTRUCTING A FITNESS TRACKER!

INCREASING POPULARITY OF FITNESS TRACKERS

As shown in the chart below, the fitness tracker market growth is extensively attributed to the rising health & fitness awareness, which proves as another reason for us to chose this device to deconstruct. It shows how much importance it plays in our daily lives.



SAFETY PRECAUTIONS

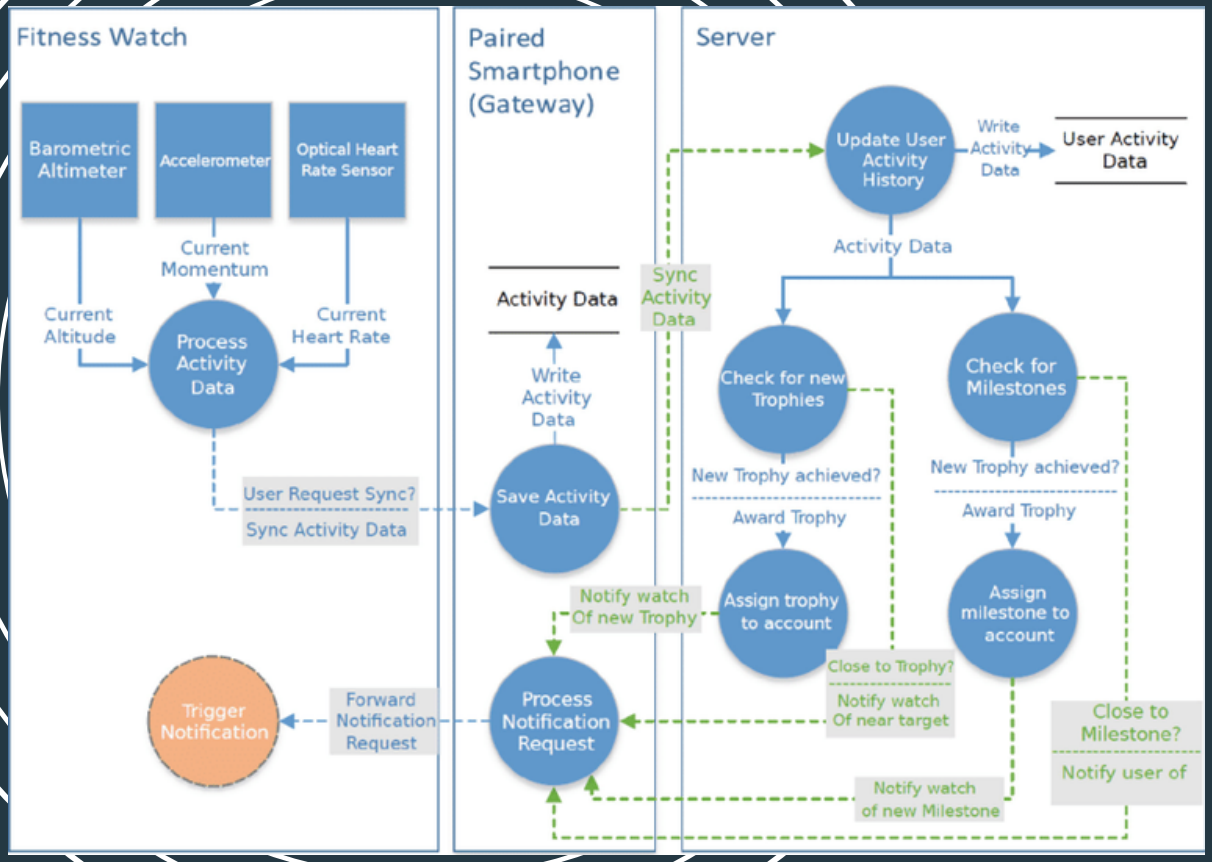
To make sure everything went the right and expected way, we had to make sure certain precautions were taken.

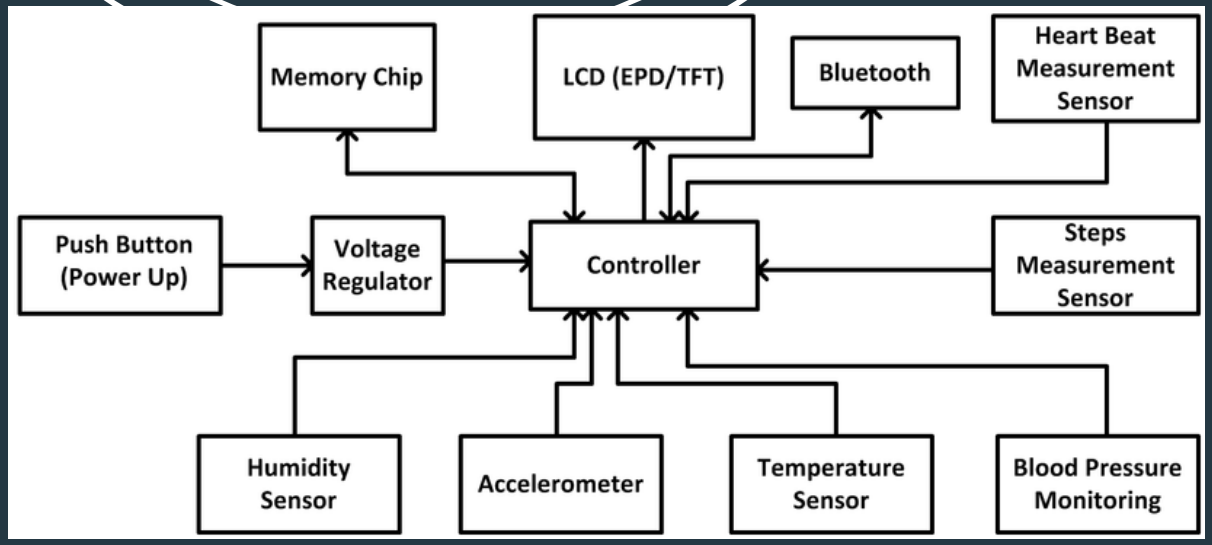
- The device chosen is approved by everyone
- Extreme caution is taken in every taken step
- Any power sources and batteries are disconnected before the deconstruction, making it safe.
- We wore safety goggles during the deconstruction.

HAZARDS

identifying the hazards is quite an important step before taking any action such as deconstruction. The hazards are possible electrocution, burning a hand or fire or a water spillage (which may cause people to slip) or a short circuit as water is a good conductor of electricity.

ARCHITECTURE DIAGRAM

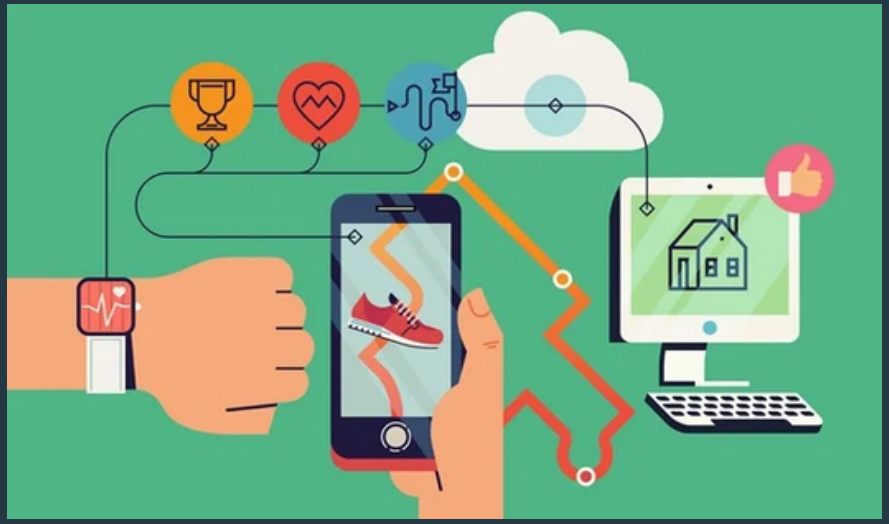




This diagram shows how different parts interact with each other to create a successful system. We used this Diagram to help us identify and understand all the different components in the Willful Fitness Tracker, along with using it to get the firm understanding of their designated purpose in the overall electronic piece. We believe that getting to know, and understanding the most basic components of a device before actually deconstructing it will massively help us in our disassembly process.

5 LAYERED ARCHITECTURE

5 LAYERED ARCHITECTURE OF A FITNESS TRACKER



Service layer: This layer provides the analysed and processed data to other services like mobile application on Android or iOS.

Processing and storage layer: In this layer, the data received from the sensing layer is analysed and stored in databases. This layer is also responsible for security control.

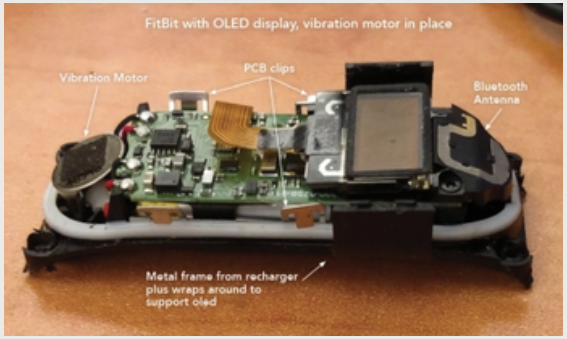
Network layer: This layer takes care of transmission, routing, and addressing using IPV6. With IPV6, address allocation and management can be done more efficiently, hence it is chosen over other Internet protocols.

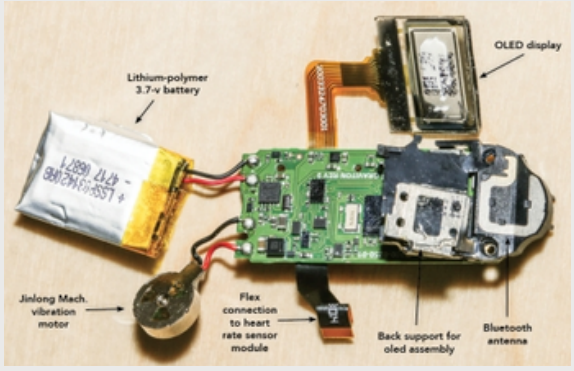
MAC Layer: This layer is responsible for device monitoring and control, quality-of-service management, and power management.

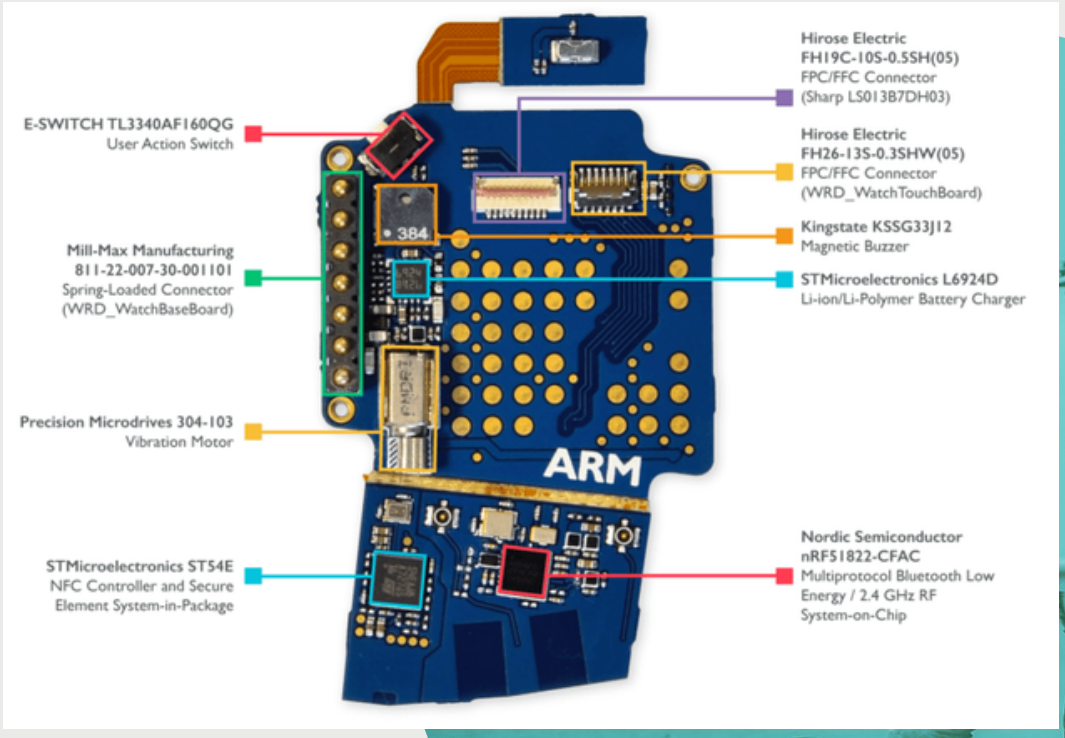
Sensing layer: This layer has sensors embedded in the device; these sensors collect data like number of footsteps, heart rate, body temperature, etc. The data collected by sensors are sent to servers using Wide Area Network such as GSM, GPRS, and LTE.

PRIOR RESEARCH

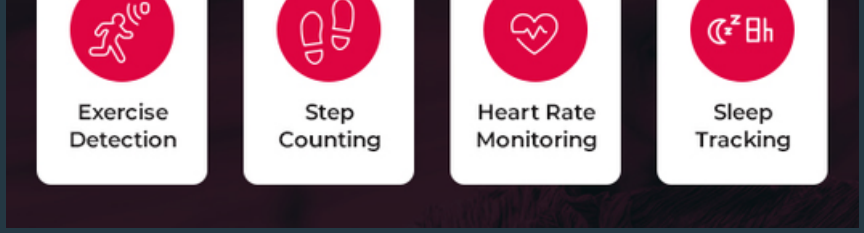
Prior to deconstructing, we wanted to gather as much information about these fitness trackers. For this, we researched a lot and understood the necessities. Fitness tracker development has benefits for both sports and fitness companies as well as hospitals. To create one, it is essential to learn benefits, features, hardware components, and what pain points a fitness tracker app development solves. These devices measure steps, distance, calories burned, floors climbed and active minutes, monitors sleep, and some may have caller ID that can read out incoming calls when your phone is nearby. It's said to have a battery life of seven to ten days – considered good for trackers like this — and can monitor sleep patterns.







ESSENTIAL FEATURES: FOR THE DEVICE



1. Exercise Detection

Fitness tracking comes handy for people participating in different sports activities. While the manual selection of sports activities proves to be useful but to add convenience, automatic detection through sensors play a critical role.

2. Step Counting

The step counting feature is the most basic requirement of any fitness enthusiast. Irrespective of which sports activity a user is part of, he is likely to monitor the daily steps key performance indicator (KPI). Business owners need to understand the importance of the step-counting feature and implement its fitness tracker app development.

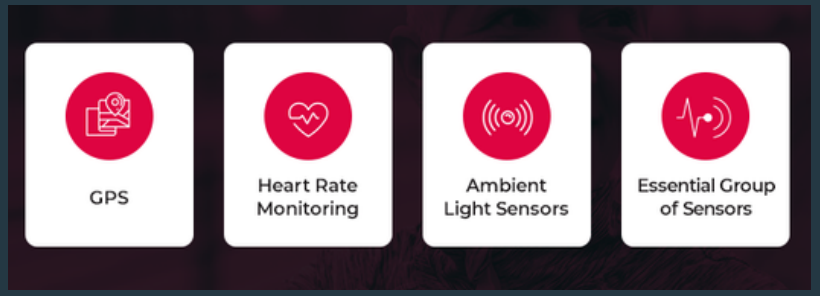
3. Heart Rate Monitoring

As capabilities are added to mobile devices and wearables, more health monitoring benefits can be leveraged. One such capability is heart rate monitoring. Additional value can be provided to users who experience unusual changes in the heartbeat and receive irregular heartbeat notifications using sensors and advanced software capabilities.

4. Sleep Tracking

Often underestimated, sleep is perhaps an essential activity for any sports or general fitness enthusiast. Businesses operating in the sports industry can leverage this feature in their app and enable their users to – identify sleep patterns, monitor sleep quality, and more.

IMPORTANT HARDWARE COMPONENTS



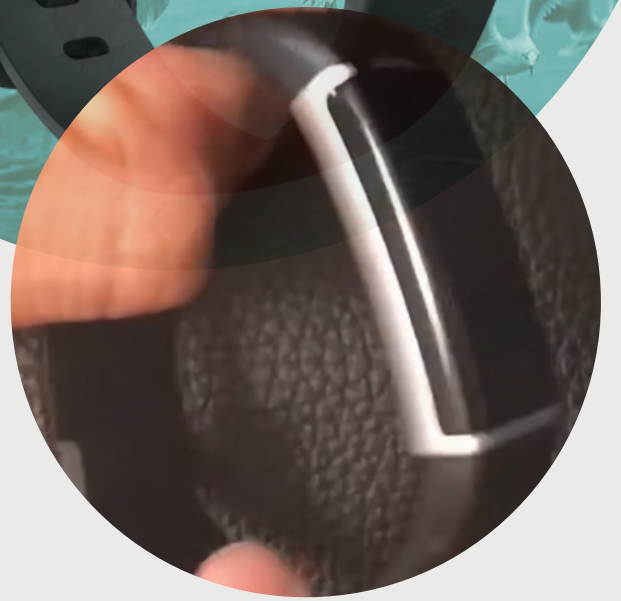
1. GPS - The use of GPS is not limited to people who enjoy running. This capability is leveraged by mobile apps that provide features for cyclists, hikers, and others as well. Nearly thirty satellites are used to know the exact position of the user. Later, this data is processed and presented in a visually pleasing way.

2. Heart Rate Monitor -While there are external devices such as chest straps that enable the fitness tracker app to monitor the heartbeat rate, effective use of this capability can also be leveraged through the use of these trackers. Few fitness tracker models use optical sensors while others use ECG sensors.

3. Ambient Light Sensors - Fitness enthusiasts favour an odd time to practice their sport. Some may prefer to follow their fitness routine during the day when light is abundant while few may prefer early morning before sunrise or late at night after the sunset. Due to varying daylight, it may be inconvenient to view the screen when the daylight is too low or too high. Hence, ambient light sensors add value.

4. Essential Group of Sensors - The essential group of sensors is an integral part of most fitness tracker app development. The three most important sensors are – accelerometer, gyroscope, and compass.

- Accelerometer – Used for measurement of acceleration.
- Gyroscope – Identifies the orientation of the device.
- Compass – Determines the direction.



DAILY LOGS: DISASSEMBLY PROCESS

FITNESS TRACKER

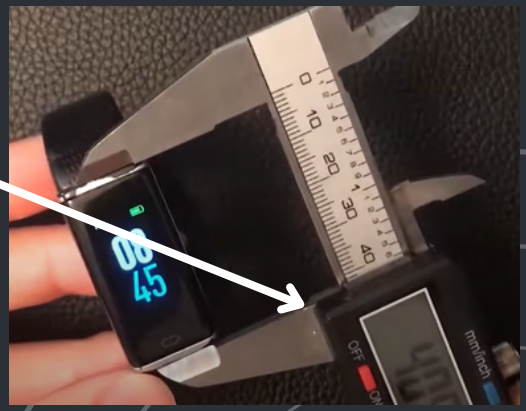
DAY 1: DIMENSIONS

19.5 mm
wide

14 slots and
6mm pitch

about 15mm
wide band

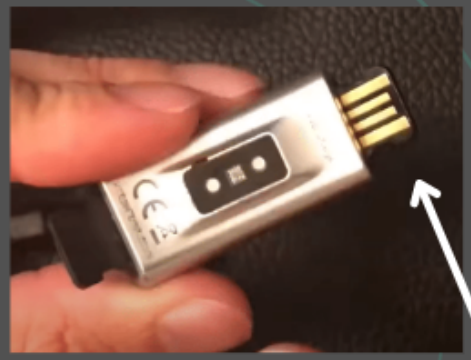
41mm long
approx

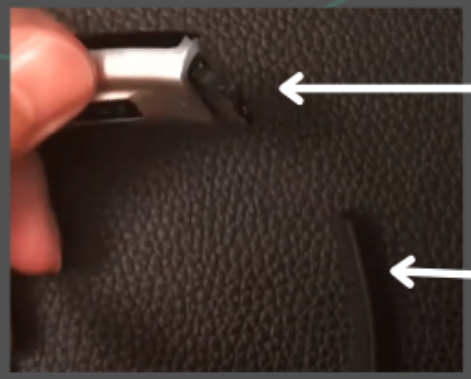


10.05mm wide
(4mm wider than
a Fitbit HR)

15/12/2022

DAY 1: REMOVING STRAPS





- Removable straps from main body
- Reveals the USB charging male plug from one side (shown on the right)
- Therefore no cables are needed to charge which makes the charging process easy

plug inside the computer, charging it

USB charging male plug

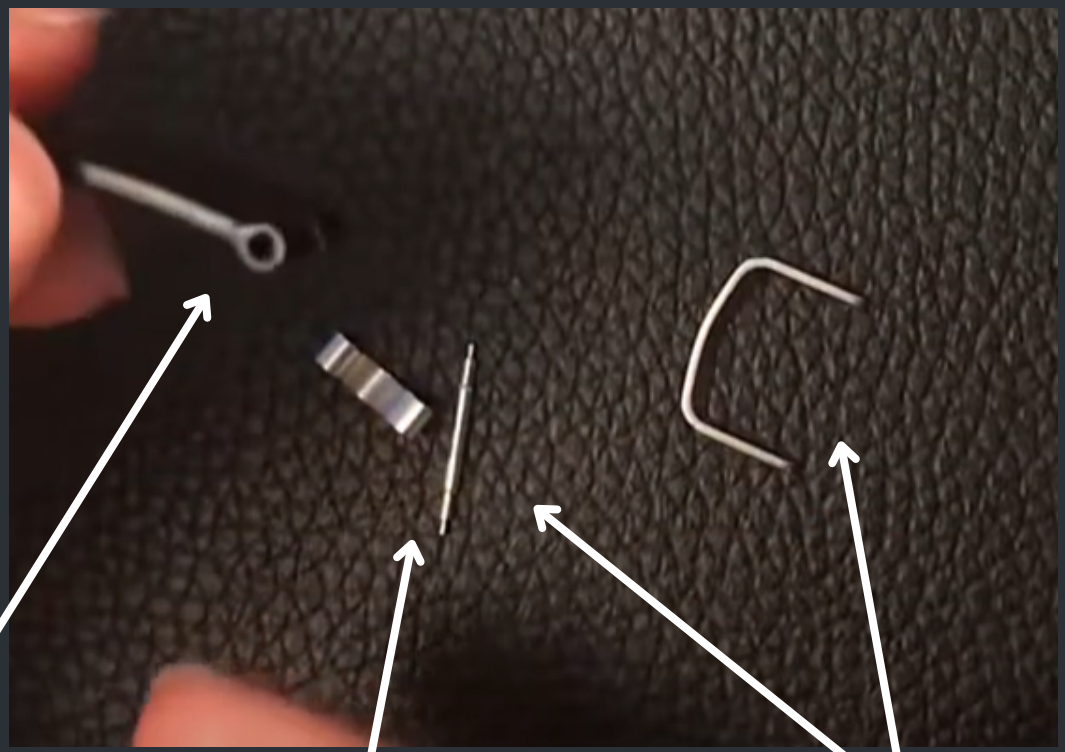
Removable strap

15/12/2022

15/12/2022

DAY 1
CONTINUED

Buckle: seems to be made of sturdy yet light aluminium alloy.



hole to insert double sided spring pin

compression or injection moulded polyurethane

Strap: made of a flexible plastic (polyurethane with sure hardness)

- We started by removing this double sided spring pin in the buckle.

DAY 2 : 16/12/22

ASSESSING COMPONENTS

The main pod assembly is split into two pieces: the upper enclosure and the lower enclosure. Both of these parts are made of plastic and are painted.

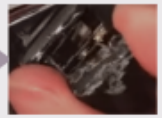
Injection moulding: *the shaping of rubber or plastic articles by injecting heated material into a mould. The main advantage of injection moulding is being able to scale up production to produce a large number of parts. Therefore the price of manufacturing is very low.*

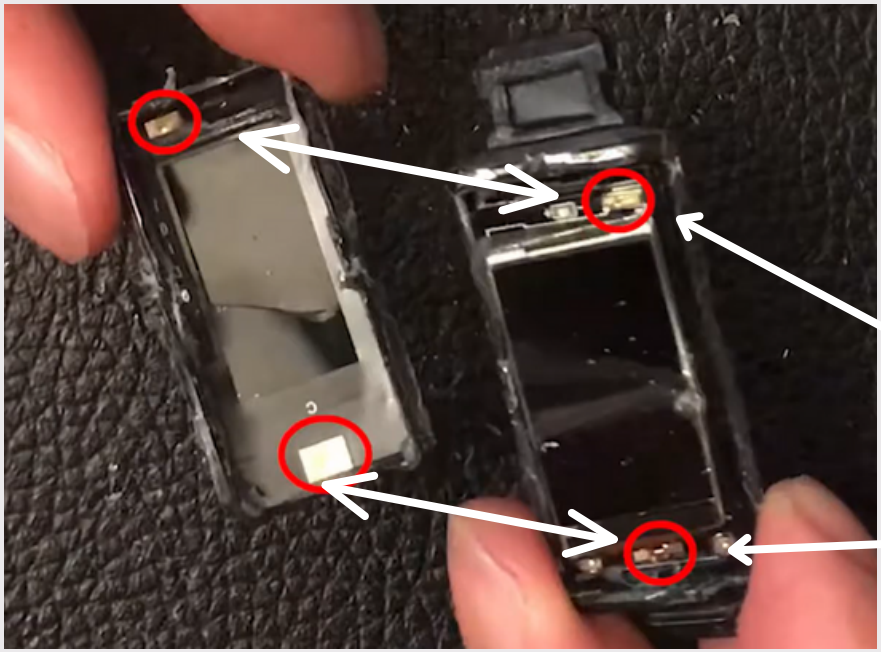
Screen is a translucent ABS or a polycarbonate piece with a black tint, also injection moulded.

Body could potentially be a fire resistant black ABS plastic which is definitely injection moulded.

DAY 2: 16/12/22

To make this body a completely sealed and **IP65 rated**, the cover and body enclosure will have to be physically meshed with one another with a fairly tight structure. They are both glued together around the edge, with the intention that the product will never be opened again. Cheap from a design perspective, but works to achieve that IP rating.

glue 



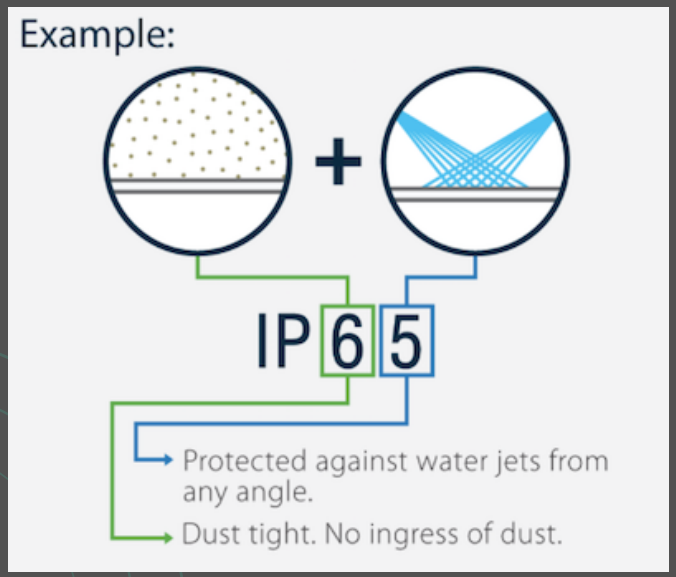
Opening the plastic cover and screen enclosure to reveal the insides of the fitness tracker.

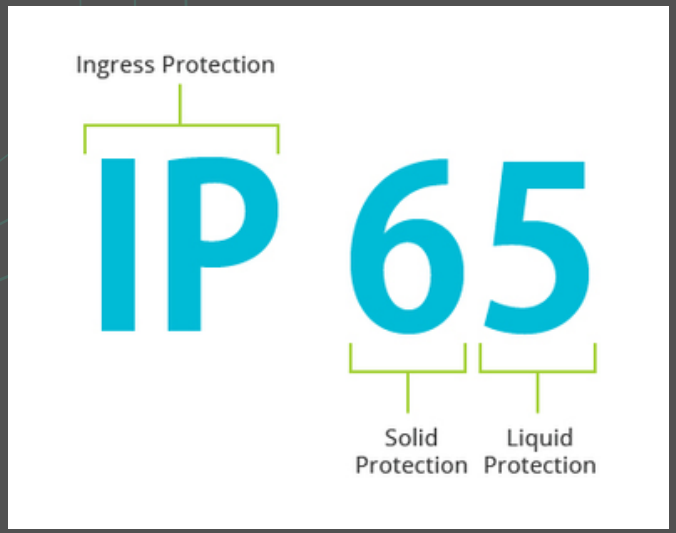
First thing we saw were these contact plates (in red) on the other side of the screen connecting with the PCB. The lower part (on the PCB) is for the touch sensor and the upper one is for connection to the vibration motor.

connection contact plate (upper)

touch sensitive contact plate (lower)

*WHAT IS THE **IP65** RATING?*



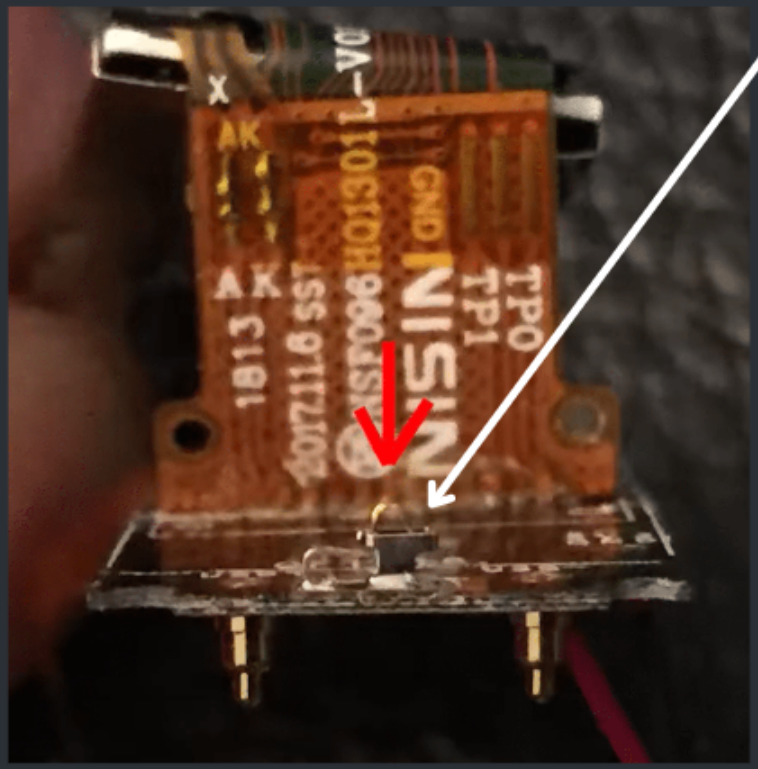


IP65 rating means that the enclosure can only provide protection against low pressure (6.3mm) water jets. The rating indicates that it can withstand up to a pressure of 1.5 meters of water for 30 minutes. IP65 Rating products offer reliable protection and are used for many indoor and outdoor applications (for example a fitness tracker). It is considered as 'waterproof' since it has protection from total dust ingress and protection from low-pressure water jets from any direction.

Fitness trackers need an IP65 rating, which is done through various modifications in the development of the electronic structure, to make sure they are rated fine for domestic use, safety and protection. These ratings are also enough to stop airborne particulates from damaging the screen and components inside the enclosure.

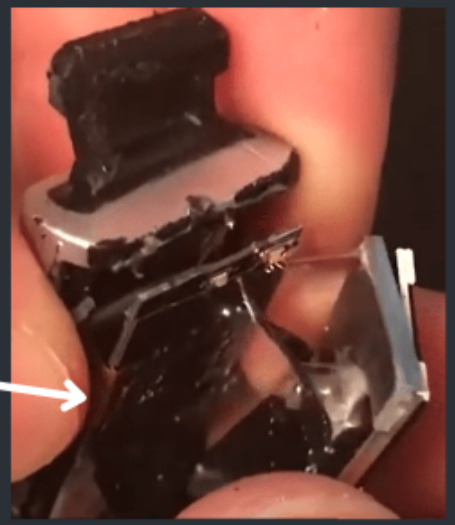
DAY 3: 17/12/22

We can see that the touch sensitive button is like a compressible switch, so if there are light taps on the external of the screen, this switch is connected and pressed due to the contact pads we saw yesterday.



touch sensitive button

We can see how the LED screen is attached with its flexi solder connecter and then further taped into place.



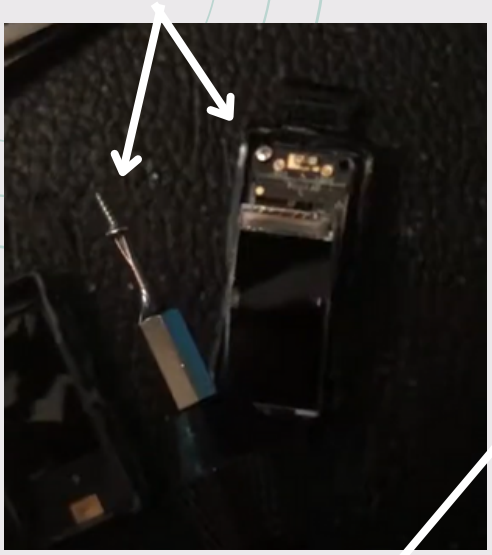
DAY 3
CONTINIUED

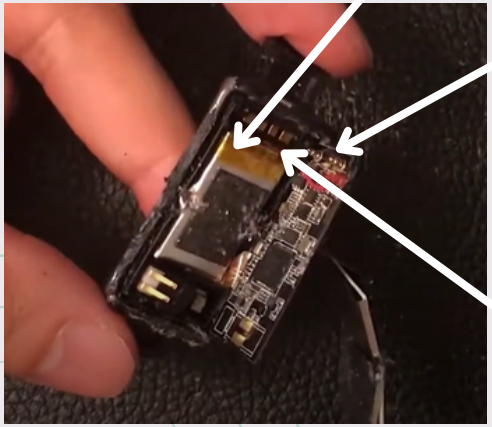
PCB: printed circuit board

SELF TAPPING SCREWS

Two self tapping screws hold down the main PCB to the lower enclosure. Self tapping screws are ideal for assembly and manufacture because it means that there is no need for threaded inserts in the mould, which consequently saves money. Self taps are useful if there is no intention to maintain the product because the threads can wear out over time.

We can see that the PCB is wired, and the battery is sitting directly underneath. We can also see that there are 2 pogo pin spring connectors which touch the outer contact pads for the USB power connection.

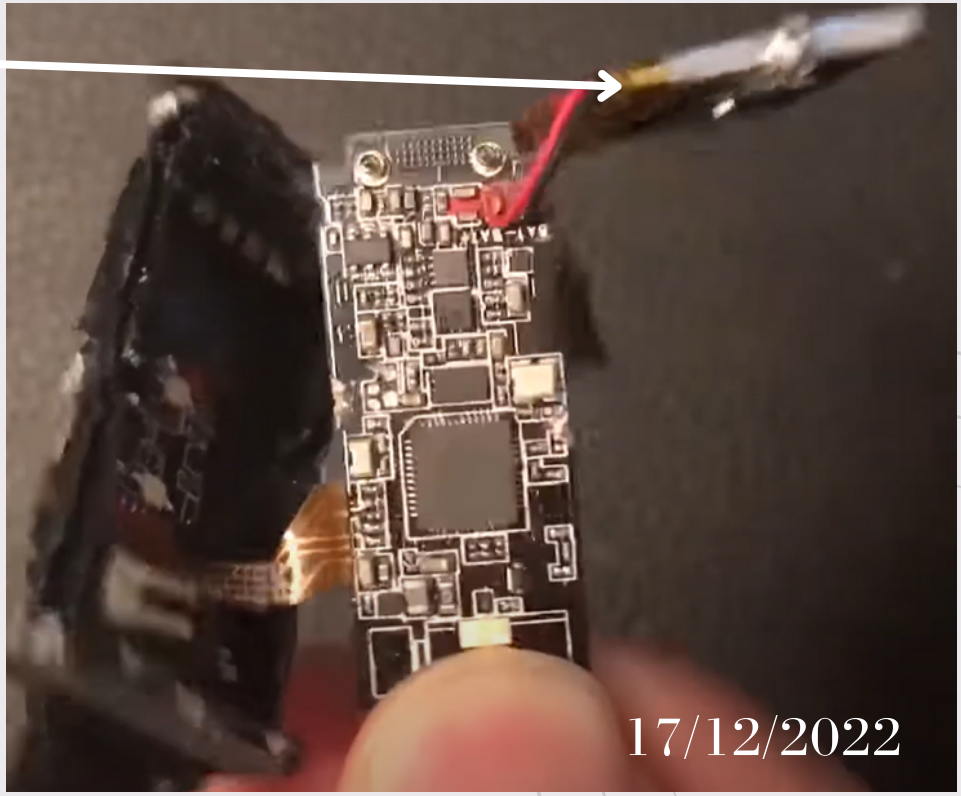




battery

POGO spring connectors

outer contact pads



The lower PCB which has the heart rate sensor is connected to the main PCB by a small ribbon connection. The main PCB has an accelerometer, which allows the fitness tracker to measure movement, specifically counting footsteps, for the step counter or exercise tracker. The accelerometer is able to achieve this because it can detect fractional changes in the X Y or Z axes.

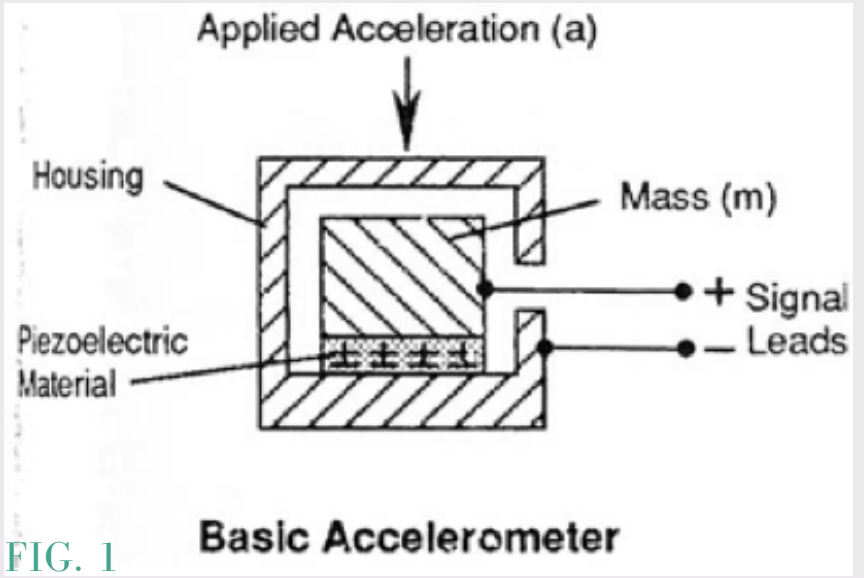


FIG. 1

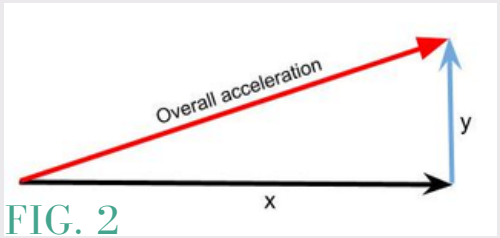


FIG. 2

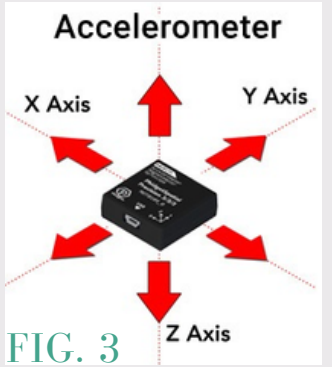


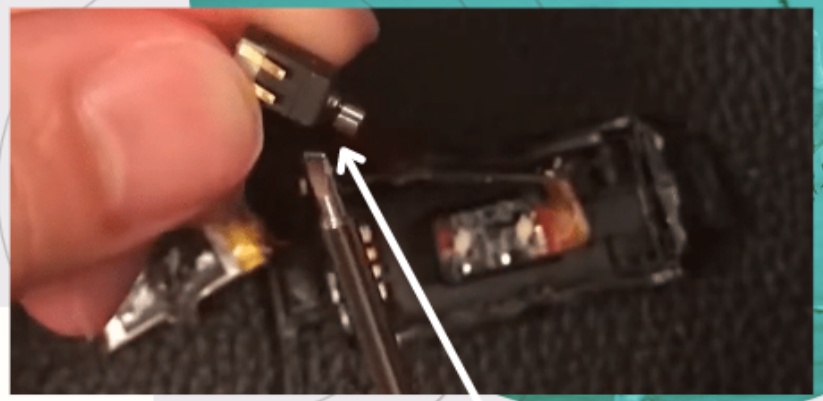
FIG. 3

DAY 3: THE ACCELEROMETER

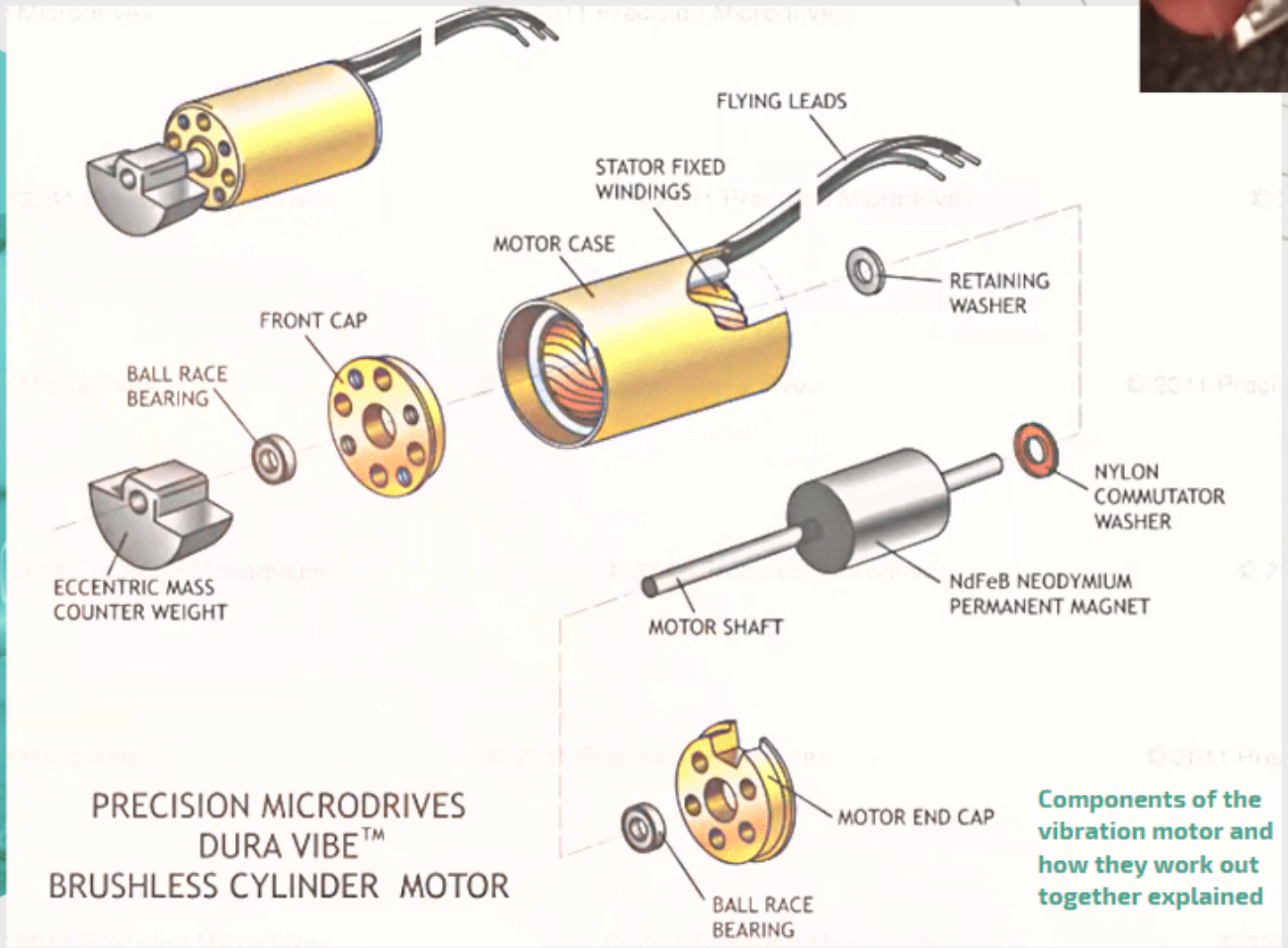
17/12/2022

DAY 4: 18/12/22

VIBRATION MOTOR



vibration motor



Components of the vibration motor and how they work out together explained

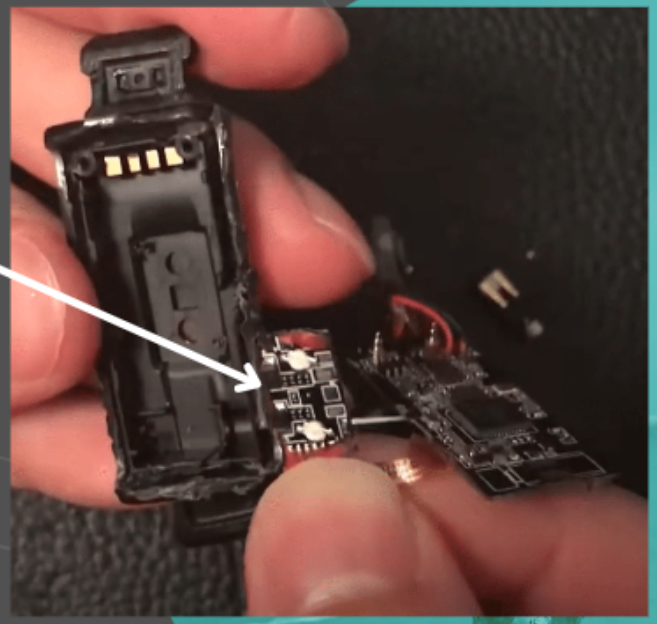
Next, we spotted a pager/vibration motor and took it out. It is used for haptic feedback when the touch button is tapped or when the alarm clock goes off. It works by rotating the eccentric mass counter weight on the shaft rapidly to create the effect of the whole device vibrating (as shown in the diagram)

This type of vibration motor is actually a Precision Microdrives Dura Vibe **Brushless** Cylinder Motor. These brushless motors tend to be more efficient, but the major benefit is the extended lifetime, which is why we see this in a fitness tracker right now. This means they are popular in products that require prolonged or constant rotation. In the past, DC brushless motors have been used devices such as VCRs, printers and hard disk drives.

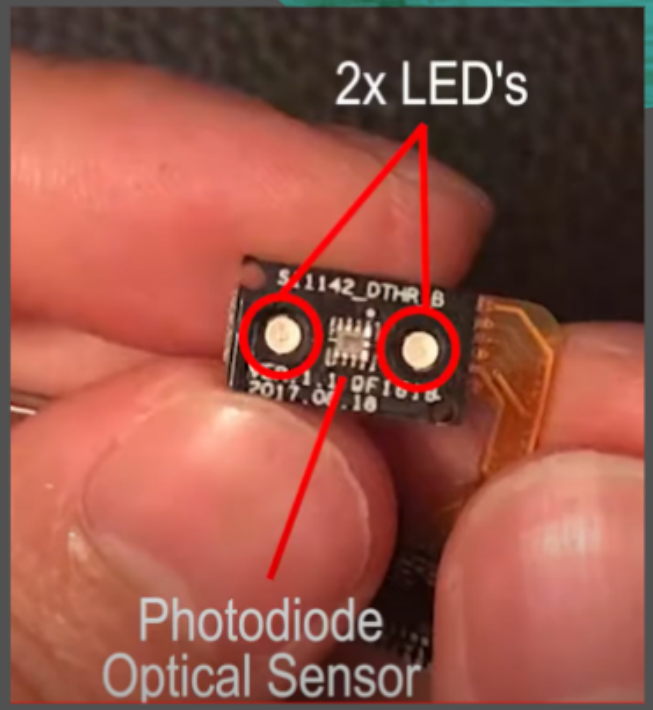
DAY 4: 18/12/22

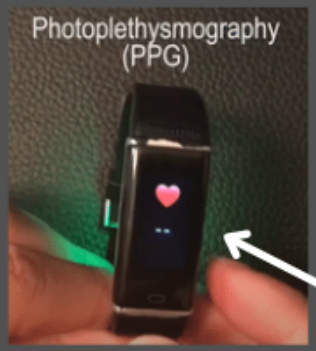
HEART RATE SENSOR

One of the most essential components, the heart rate sensor is on this PCB.



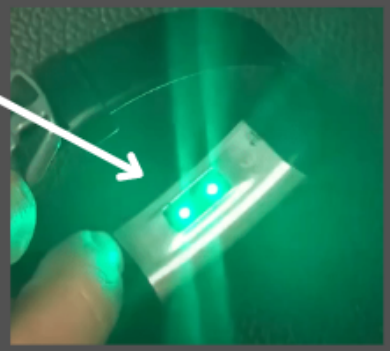
Optical heart rate monitors are the most common pulse sensors and wearables. This heart rate sensor uses 2 small LED's on each side, about 7 millimetres apart with a single optically photodiode sensor in the middle. Both LED's flash with green light simultaneously, hundred of times per second on your skin. That light is then either reflected back to the sensor by no pulse in your vein, or absorbed by blood flow. The fluctuations in the light level can then be translated by the sensor into the heart rate. The green light colour is purposefully chosen because because our blood absorbs this wavelength most effectively, which produces the most accurate readings. This process of using lights to measure blood flow is called Photoplethysmography or PPG.





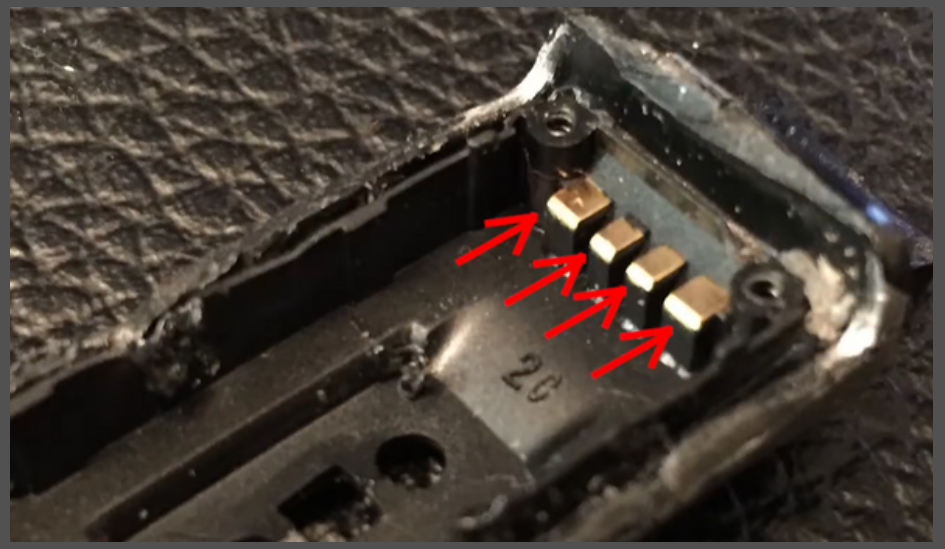
2 flashing green lights (from the LED's) from the outside that measure heart rate.

This process of using lights to measure blood flow is called Photoplethysmography.



ANALYSING COMPONENTS

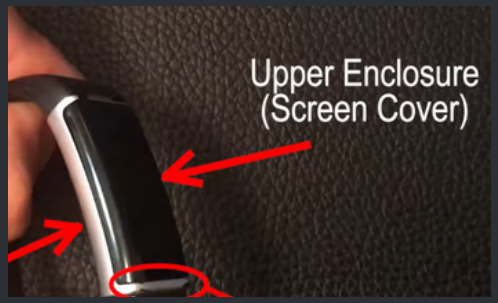
USB POWER CONNECTION: this would have been manufactured using insert moulding where the four gold-plated copper contact plates would have been placed in the mould prior to the plastic being injected. This is to ensure the IP65 rated seal of the overall product.



WHAT COMPONENT CAN DO + ROLE IN THE SYSTEM

USB ports allow USB devices to be connected to each other with and transfer digital data over USB cables. They can also supply electric power across the cable to devices that need it, and can accommodate many different hardware devices, ranging from printers and keyboards to cell phones and flash drives. This power connecter mainly allows the device (Willful fitness tracker) to be charged, for it to be functioning.

WHAT COMPONENTS CAN DO + ROLE IN THE SYSTEM



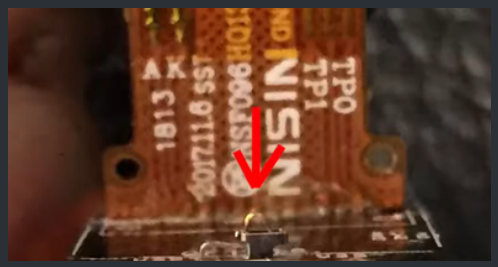
The Screen cover is a translucent ABS / polycarbonate piece with a black tint, which is an incredibly useful plastic for applications requiring transparency and high impact resistance. It's role in the system is mainly to protect the electronic device against physical damage.

The Body (lower enclosure) is made up of Black Pinseal Flame Retardant ABS Sheet, which is perfect for use in areas that are at risk of fire and need extra protection. The role that it plays in the system is mainly protection and for safety, whilst also covering the inner components of the device.

Contact pad/plate is the exposed region of metal on a circuit board that the component lead is soldered to. Multiple pads in conjunction are used to generate the component footprint or land pattern on the PCB. The two types of pads available are through-hole and surface mount pads. Their role in the system is to prevent arc burning and ensure reliable electrical contact.

TRYING TO ACHIEVE THE MAXIMUM FOR ALL THE REQUIREMENTS IN THE JUDGING CRITERIA

WHAT COMPONENTS CAN DO + ROLE IN THE SYSTEM



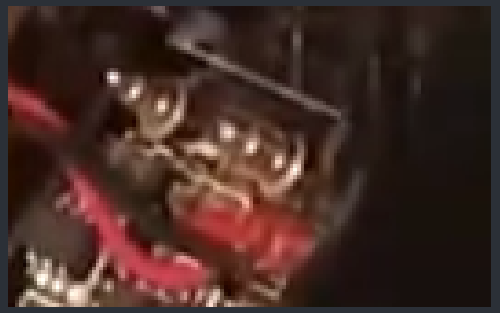
Touch-sensitive button/switch works using body capacitance, a property of the human body that gives it great electrical characteristics. The switch keeps charging and discharging its metal exterior to detect changes in capacitance. When a person touches it, their body increases the capacitance and triggers the switch.

LED display is a flat panel display that uses an array of light-emitting diodes as pixels for a video display. Their brightness allows them to be used outdoors where they are visible in the sun, useful for a fitness tracker. Their role in the system is to display everything on the screen.

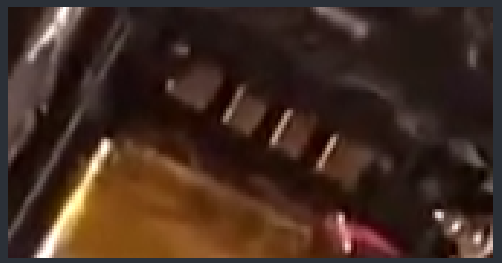
Lithium polymer battery is a device that stores chemical energy and converts it to electrical energy. The chemical reactions in a battery involve the flow of electrons from one material (electrode) to another, through an external circuit. The flow of electrons provides an electric current that can be used to do work. Its role is to power everything in the device, to give the energy for everything to successfully work.

Self-tapping screws are screws that have the ability to tap threads into the material. These screws cannot drill through metal and require a pilot hole to be pre-drilled before installation. This helps fight vibration loosening and allows the parts to be taken apart if needed. Its role is to secure all components in the device in their respective places.

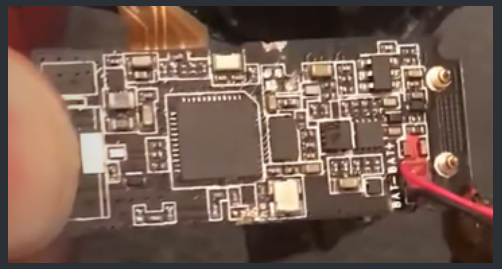
WHAT COMPONENTS CAN DO + ROLE IN THE SYSTEM



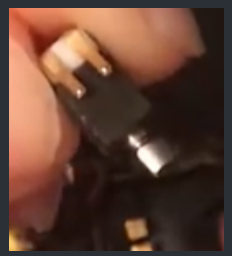
Pogo Spring connectors provide a reliable electrical connection in the most rigorous environments. These interconnect components are typically used as the base unit (battery/charger) interface for portable equipment (like fitness trackers). In the system, their role is to maintain an electrical connection that is resilient to mechanical shock and vibration.

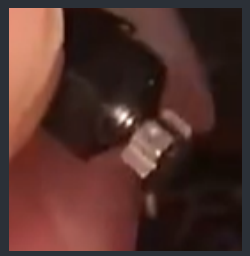


Spring finger contact pad is a small mechanical part used to make connection or grounding on electronic projects. These contacts are made to support harsh environment (humidity, temperature, and vibrations). They have the same role in the system as the pogo spring connectors. They are also designed to provide grounding in electronic equipment.



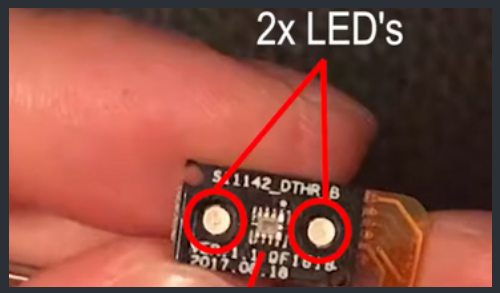
Accelerometer measures the vibration, or acceleration of motion of a structure. The force caused by vibration or a change in motion (acceleration) causes the mass to "squeeze" the piezoelectric material which produces an electrical charge, proportional to the force exerted upon it. Its role in the system is to measure acceleration, the change in velocity of an object over time for the step counter in the fitness tracker.



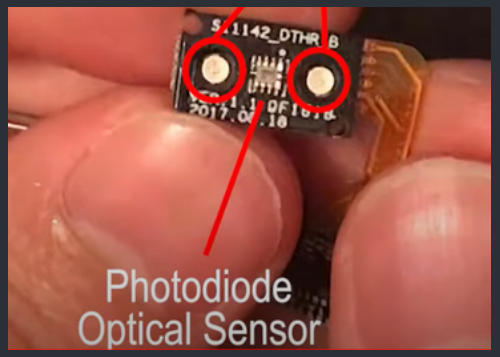


Vibration motor works by rotating the eccentric mass counter weight on the shaft rapidly to create the effect of the whole device vibrating. These motors have significantly higher efficiency and performance. In the system, its used for haptic feedback when the touch button is tapped or when the alarm clock goes off.

WHAT COMPONENTS CAN DO + ROLE IN THE SYSTEM

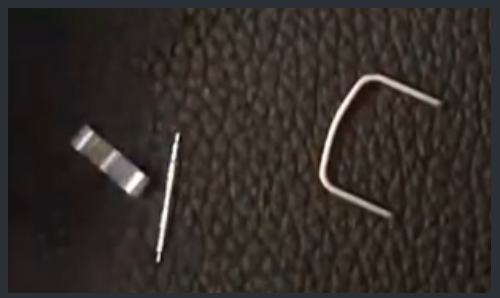


LEDs (Light Emitting Diodes) convert electrical energy directly into light, delivering efficient light generation with little-wasted electricity. The high efficiency and directional nature of LEDs makes them ideal for many industrial uses. In the system, the LED's flash with green light, hundred of times per second on skin to measure the heart rate.



A photodiode is a type of light detector, used to convert the light into current or voltage, comprising **optical filters**. These diodes have a slow response time when the surface area of the photodiode increases. Since photodiodes generate current flow directly depending upon the light intensity received, they can be used as photodetectors to detect optical signals. Here, they are used to measure the heart rate.

This is the plastic outer casing of the fitness tracker. It's role in the system is mainly protection and security.



Compression/injection moulded polyurethane (other parts involved in the integral system of the fitness tracker).

CONCLUSION

We learned a lot from disassembling our fitness tracker. For example, we now know all the various components are all part of the structure and are necessary to keep the device together. Now we know all the hardware, including screws and connectors, hold the electronics to the structural parts, along with the necessary additional components (such as an accelerometer and a vibration motor and a photodiode optical sensor that are clearly very important in making the device the way it is).

We also learnt the deep thought, understanding and knowledge it is needed to manufacture products like these, which are consequently so deeply instilled in daily lives, with so many people dependent on modern devices like these to live their lives properly.

Surprisingly, we found that most of the parts were glued in with either flex tape of liquid glue, whilst we expected some of the components to be soldered into the system, such as the buttons and battery. However, gluing these components in made it easy for us to take them apart.

Another important thing we learned was that many small parts are put together to create a functional device. Every little piece plays a role in helping the fitness tracker work. Even the smallest of circuits can make a huge impact on the performance of the entire device, which is quite similar to how our robot and team works, where we all aim to make a impact, however small it is, however minute our effort is, we know that as a team, it will all be compiled into an efficient, successful team.

REFERENCES

https://microbit-challenges.readthedocs.io/en/latest/tutorials/accelerometer.html - accelerometer FIG 2

https://www.fatbit.com/fab/fitness-tracker-app-development-guide/#essential-features - research for slides 7 and 8

https://www.precisionmicrodrives.com/ab-018 - research on vibration motors

https://www.hackerearth.com/blog/developers/fitness-tracker-w - research behind fitness trackers as general and for overall information

https://www.connectortips.com/benefits-spring-loaded-contacts/ - spring pogo contacts

https://www.youtube.com/watch?v=i00Blpbiabk - video on fitness tracker teardown

https://www.phidgets.com/docs/Accelerometer_Primer - accelerometer FIG 3

https://www.microcontrollertips.com/inside-fitbit-charge/ - INSIDE THE FITBIT creds to all the images presented on slide 6 (for reference and information on teardown)

https://www.pc-control.co.uk/accelerometers.html - accelerometer FIG 1

https://www.grandviewresearch.com/industry-analysis/fitness-tracker-market - growth

https://www.electronicsforu.com/electronics-projects/fitness-tracker - IMGS

https://www.flexfireleds.com/led-ip-ratings-led-flex-strip-waterproofing-explained-waterproof-v-nonwaterproof-led-strip-lights/ - research + info + img credit on IP65 rating

THANK YOU.