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# Design Project – Health Monitoring Device

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ECSE 322 – Computer Engineering

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# 1. Introduction

The use of computers and technology has been increasing at a rapid pace in the past years. The processing power per dollar has increased almost exponentially while the size and power requirements have decreased. Computers can be used in new areas which could not obtain their help before. One of those areas is personal health, and more precisely, the monitoring of health and environmental constants. Heart rate monitors, GPS trackers, or even body movement trackers have now become more portable than ever. All these features can now be monitored directly from a lightweight wristband attachment. These wrist monitoring devices have many applications in sports such as running or cycling. They improve the athlete's performance by providing real time health data, such as monitoring of heart rate within a certain range, and warning the athlete if the rate goes out of range. While great for sport applications, these devices can also be applied to actual health care, and more specifically, as the population of western countries ages, elderly care.

Monitoring conventional health indicators such as blood pressure, heart rate, body temperature, or prescription drug intake along with environmental conditions such as ambient temperature and humidity can potentially safe keep and greatly improve health. Heart attacks (tracked with heart rate) or falls (tracked with an accelerometer) could be detected by such devices. Authorities could be immediately contacted by the device, and an ambulance or a health care personnel could be dispatched to help the person. This means greatly reduced response times, and less room for accidents to go unnoticed.

For the purpose of this course and project, our team will propose an initial design for a monitoring device that will collect the state of an individual's health and capabilities 24 hours a day. Our device will monitor heart rate, acceleration in the x-y-z axes, body temperature, ambient temperature and humidity, and medication intake. Data from the device will be remotely accessible and programmable by healthcare professionals. In the event of an accident, the individual will be able to request help by pressing an emergency button on the device, and if the accident is picked up by the sensors, a paramedic team or health center will automatically be contacted and potentially dispatched to the individual's location.

The technology used in this project will be evaluated in terms of size, cost, and power consumption. A system architecture will be devised and take into account sensors, input/output system, memory and processor capabilities, communication needs, OS, and power supply. The goal will be to evaluate trends in these technologies, and create a device with the technology available within the next two years.

## 2. Requirements

For our monitoring system to be considered feasible, it needs to comply with a few basic requirements. For starters, because it will be worn by an elderly person, it needs to be light enough to be put comfortably on one's wrist, like a watch, while also having simple and intuitive functionality that is understandable by anyone. The system's main goal is to aid the individual to live independently with less frequent visits to the doctor.

This device should be able to take several measurements for the individual's body and their surrounding. The individual's body measurements should include blood pressure which should be measured every minute, heart rate which should be measured every second due to it's sensitivity, body temperature which should be measured every minute and body's position which should be measured every second so that it can detect if the individual have experienced a severe fall. In addition to this, the individual's surrounding measurements should include room's temperature and humidity, which should be measured every 10 minutes at least, since it won't change frequently.

The device will need to communicate externally for three reasons: to download collected data from the sensors to a central database for storage and trend analysis, to be programmed remotely by the health care provider in the case where the medication must be changed and to call a local health center in the case of an emergency. The device's memory should have the capacity to store all the measurements taken for the last 24 hours. For the last 7 days, a daily average should be stored for each measurement, which should be used to calculate the daily trend. A weekly average for each measurement should be stored for the last 8 weeks, which should be used to calculate the weekly trend. Lastly, a monthly average for each measurement should be stored for the last 12 months which should be used to calculate the monthly trend.

The device will also be connected to the Internet via Wi-Fi to download the acquired data to an external database monitored by health professionals. All the newly measured data will sync with this external database on a daily basis, so that the doctors would determine any instability in the individual's health as quick as possible. The device must also be able to communicate with health professionals concerning the medication supply of the patient or if any changes must be brought to the medication regime.

The device must also be able to connect to the telephone system to contact health professionals in the case of an emergency, and this must be accessible as fast as possible. Since the battery life of the device must be maximized as much as possible, a separate base station with telephone and Wi-Fi capabilities will be considered, with which the device will communicate via Bluetooth, which has low power consumption [20].

In terms of Battery life, the device will use a rechargeable battery. It should be able to last at least 48 hours before needing to be recharged. The user will be notified when power falls below 20% capacity, again at 10% capacity and one last time at 5% capacity. The total capacity of the battery should not decrease below a point that it cannot last for 48 hours for at least 200 cycles (or roughly one year).

Furthermore, the individual should be able to monitor their current health through the device by viewing the last measured values of each of the measurements described above. Also, they should be able to view the daily, weekly and monthly trends in their health. Therefore, the device should include an output terminal like a screen. Additionally, the individuals should be asked to enter specific information about them so that in case of any emergency this information will be sent out to the emergency contact hospital. Information should include some details about the current medications used as well as details about their medical history. This will help the doctors to get the appropriate help to the individual in case of emergency. The device should be programmed in a way so that it calculates a maximum and a minimum value for each of the specified measurements, thus any deviation from these values will trigger the device to contact the emergency hospital for an instant assistance.

Considering the requirements imposed on the device, quick calculations (see appendix) show that the processor should have at least a RAM of 12k to carry out the calculations and carry the appropriate software and OS. It should also have at least 128k of flash drive to hold memory for the data and software needs.

## 3. Current products

Current products range in price from (50$) to (200$) and have a wide range of functionality from simple self-input of data to continuous heart rate monitoring, temperature, humidity, GPS and even brain activity. Though devices tend to stick to a couple of these data inputs and rarely cover more than 3. They are commonly connected via Bluetooth to an external system that then analyses the data and sends the data to and alerts the appropriate healthcare professionals.

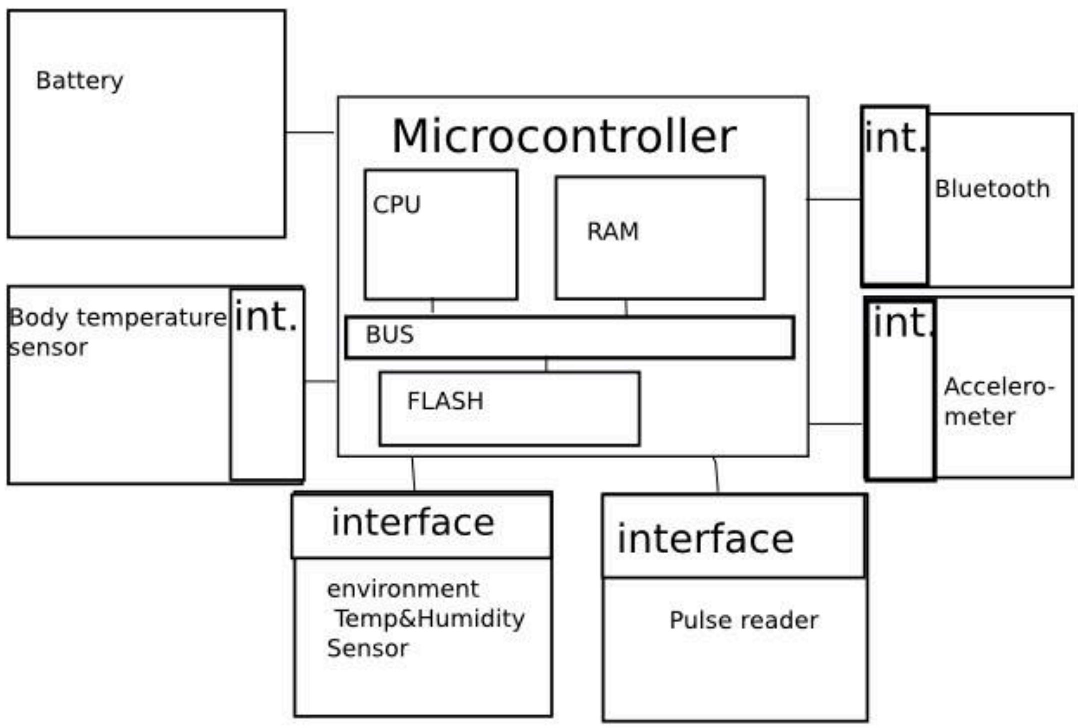
Low range price devices includes Metria disposable smartwatch [1] which measures the heart rate and takes some measurements for exercise activities, the downside of this product it is disposable after 7 days, it costs 50$.

One of the mid price range devices is the Fitbit Flex device [2] which is an activity tracker aimed at measuring an individual's physical exercise, diet and sleep. This is a lightweight device that makes it comfortable to use. The device is like a flat band that is about the width of a watchband. One of the advantages of this device that it syncs with the individual's phone via Bluetooth and all the monitoring and input is done through the individual's phone. The device calculates data like the daily number of steps of the individual, the distance travelled by the individual on foot, trends in the daily individual's activity, calories burned and many other data that relates to the individual's physical exercise, diet and sleep. The cost of this device is 99$. Another device that's relatively cheap as well, is the Nike plus fuelband [3], this device takes measurements that are related to the individual's exercise/activity. The device's cost is 150$.

Other current devices in the market includes: Basis Carbon steel which measures the heart rate and communication is done mostly via the Bluetooth and the TomTom multisport GPS wristwatch [4] which takes measurements using various sensors like GPS, accelerometer and pedometer, both devices cost 200$.

Most of the current products concentrate more on the physical activity of the individual, rather than the health of the individual. Several attempts were recently done to create a wearable device for measuring the heart rate only, but there is no current product that monitors the health of the individual through the many measurements that were stated in the requirements section above.

## 4. Sketch of proposed system architecture




The considered microcontroller (MC9S12XEP100) offers various ports which allow the sensors to be plugged directly. For most sensors, the interface is included, otherwise we will need to incorporate one in the design.

## 5. Forecast state of the art

**Battery:**

Batteries do not change dramatically over the course of years. The composition of a battery is incredibly important to its capacity and small changes often have unforeseen results. [19] This makes progress in the battery industry slow and in small increments.

Because of this fact it seems reasonable to assume the battery technology will be very similar in two years than it is today.

**Blood pressure:**

Recent research into noninvasive techniques to measure blood pressure has developed a procedure that uses light to get a measurement [23]. A small cuff is placed around the finger of the patient, and an LED shines light into the finger. The amount of light absorbed is recorded on the other side, and can be used to determine blood pressure. Though this method is currently being tested, and at the moment has problems with unreliability. However, it is reasonable to assume that the accuracy will be refined in the coming years.

**Heart rate:**

Similarly, it is possible to use this same cuff to measure heart rate. This is done with a process called pulse oximetry[24].The principle is that deoxygenated blood absorbs more infrared light and allows through more red light that oxygenated blood. By shining the two types of light through the finger and reading the amount absorbed, one can determine the concentration of oxygenated blood in the bloodstream. Knowing that peak values always happen during heartbeat, one can then determine heart rate by counting between peaks.

The benefit of this type of reading is that it could use the same LED and sensors to take both blood pressure and heart rate measurements. This would both save space and allow for more efficient power usage.

**Clothing:**

Smart clothing taking ecg, ecc and ekg now in development stages [5]. Aiq Smart Clothing has taken the approach of incorporating electrical measurements and clothing. Although keeping the hardware small enough and practical enough for people to actually wear comfortably may is a big challenge to overcome significant progress is being made.

**Body position:**

Danfoss Polypower a Danish technology company is developing technology to detect body position changes applicable for monitoring posture, micromovements, breathing and swelling [6]. This technology is attracting a lot of attention in the field of optimizing athletics. It will also be useful in preventative medicine. Being able to detect swelling or improper posture or movements potentially caused by medical ailment.

**Respiration:**

Research into capacitive sensors for measuring respiration rate done in February 2014 indicates that a low cost solution to constantly measuring respiration rate may be available in the near future [7]. Juan Aponte Luis and his colleagues believe there is

promise in overcoming the impractical and burdensome nature of current respiration sensors. They also claim that current sensors are affected by the patients weight and position especially when sleeping and hope capacitive sensors will overcome this issue.
Current devices:

Imec is developing and integrated wearable system aspiring to be an all in one medical device [8]. Measuring positioning, ecg, eeg, heart rate and even glucose levels. Imec is employing two potential devices an ECG necklace as well as a EEG headset. The necklace's main advantage will be low battery usage while the headset produces more accurate recordings. Research in the Netherlands has proven increased ease of use for patients and doctors compared to current products already on the market.

**Processor:**

Considering that the price of processors decreases approximately by half every two years (Moore's law), one can deduce that a processor with specifications appropriate for our use will cost twice as less in 2017. Therefore, for a processor such as the MC9S12XEG128MAA-ND by Freescale which costs 8.177$ per unit for an order of 100 units [22] should cost roughly 4.08$ in 2017.

## 6. Proposed design for the health monitor

The embedded software is the key in making this device able to perform the appropriate functionalities autonomously. During the first time using the device, the user will have to input some data to setup the device. The input data will include the name, city, country, age, contact hospital in case of emergency, contact person in case of emergency, used medications and their timings and the supervising doctor if the user is already following up with a specific doctor. The setup procedure will be done through the computer, by connecting the wearable device to the computer through the USB port and then an application will be launched to enable the user to enter this data. The device will be programmed so that it is triggered for the first time usage to open this application once connected to the computer. The setup application will be stored internally on RAM.

Once the device is setup, the user can perform the various functionalities. The user will have the ability to navigate through the current values of their heart rate, blood pressure, body temperature, room temperature, surrounding humidity and the medication timings. This will be done through navigation buttons (up, down, back and select buttons). In addition to viewing the current values, the user can view the calculated daily, weekly and monthly trends. This will allow the user to have an overview of their health over time. The system will include four levels of health indications; a green indicator means that their health is stable, a yellow indicator for means that they are experiencing instability in their health and seeing a doctor is strongly recommended, a light red indicator means that the user should see a doctor as soon as possible and a dark red indicator means that the emergency hospital is being contacted and the user's location with other data is being sent to them. Also, the user will have the ability to inform the software if they are performing a physical exercise, so that the expected values would be calculated to avoid false indications.

Moreover, the doctor will be able to pull out the information in the device with the calculated trends, by connecting the device to the computer and navigating through the history of the user's health. This will be done via an application that is stored in the internal RAM. The application will act like a database of the user's health and the doctor will be able to query the data, which will help the doctor in identifying any health problems in a timely fashion.

The basic version of the device will be equipped with bluetooth to communicate to a separate base station which will be plugged to a wall power outlet. Thus this basic version will be designed for people who spend most of their time alone at home. This separate base station will be connected to the internet via wifi to download the acquired data to the central database where data analysis can be carried out. This separate base station will also be connected to the telephone system via a phone wall outlet in the case of an emergency. This has the advantage of limiting the power requirements on the portable device while giving all the required need, since the most recent bluetooth technology uses on average 0.0239 mA[21] while maintaining a range of over 100m.

Following the calculations made in the appendix, the microcontroller MC9S12XEG128MAA by Freescale Semiconductors seems to be an appropriate CPU for our requirements. It is a 16-bit microprocessor, which corresponds to the number of bit under which most sensors we use will encode their data. Furthermore, it has a RAM of 12 kbytes and a flash memory of 128 kbytes, which should be sufficient to carry out the OS and software instructions and store the data.

The largest current draw is the pulse reader, at 4mA. Assuming total power consumption is less than 6mA, using the GB/T18287-2000 lithium ion battery by Samsung would allow for roughly 15 days [18].This is calculated as follows:
assuming usage sensors consume about 5mA and processor consumes about 15mA
total consumption < 21mA
usage per hour is < 21mAh
usage per day is < 504mAh

the GB/T18287-2000 has a minimal capacity of 2150 mAh
2150/504 = ~4 days of operating time

This is more than enough power to ensure the device stays active within the required period of time. It's capacity also does not drop over 200 cycles, with minor decreases only showing after 500 cycles. These drops in capacity do not lower the lifetime of the device to under two days, so they are still acceptable.

The following table displays the different components needed for the device, along with an expect price for 2017 (following Moore's law) and their specifications.

| Type | Brand/Model | Price ($) | Specifications |
|---|---|---|---|
| Buzzer | Piezo [9] | 1.13 | Vibration Frequency: 2-10kHz |
| Accelerometer | Sparkfun [10] | 14 | Current: 40µA (1µA standby)<br>Voltage: 2-3.6V |
| Humidity - Pressure - Temperature sensor | BME 280 [11][12] | 5.03 | Current: 3.6µA (1µA standby)<br>Frequency: 1Hz |
| Heart rate sensor | Pulse sensor [14] | 20 | Current: 4mA @ 5V<br>Voltage: 3-5V |
| Microcontroller | Freescale Semiconductors MC9S12XEG128MAA-ND [22] | 4.05 | 16-bit microprocessor<br>RAM: 12 kbytes<br>Flash:128 kbytes<br>speed: 50 MHz<br>consumption: 15 mA (average) |
| Bluetooth | BL600-SA [25] | 10 | Range: 100 m [20]<br>consumption: 0.02mA (average) |
| Battery | Samsung GB/T18287-2000 | 23.00 | Required usage: 6mAh/hour, 504mAh/day<br>Minimal capacity: 2150 mAh<br>Operating time: 2150/504 = 4 days<br>Number of cycles: 200, minor decreases after 500 (no more than two days - acceptable) |
| LCD Screen | LS013B4DN04[26] | 9 | Static consumption: 6 µW<br>Active consumption: 12 µW |
| Total | N/A | 86.21 | N/A |

If we add casing, design, and manufacturing costs, a production price of $125 to $150 should be expected. This would make the selling price for the device $200.

## 7. Alternate choices that were considered and rationale for choices made

**Blood pressure:**

Currently, there are two basic methods for measuring blood pressure. The first is using sphygmomanometers. Sphygmomanometers do not supply an instantaneous nor continuous stream of data they only supply data whenever pumped. It cannot be constantly pumped or there will be a lack of bloodflow to the pressured limb. The energy needed for the pump also uses a lot of battery rendering it quite impractical for a small device. Researchers at Seoul National University have tried to simplify this method.[15] They have developed an unobtrusive device though they still encounter the problem of non-continuous data. And though the pressure band is wrapped around a finger and not around a limb measurements throughout the day still lead to discomfort and pain of the finger.

The second method for measuring blood pressure is using the IV method with a blood pressure transducer as done in hospitals is not practical and not used for obvious reasons. As stated in section 5, there are other methods for taking blood pressure readings, but they are not accurate enough and will not improve to the required level within 2 years. Therefore the impractical nature of measuring blood pressure has led us to exclude it from our device.

**Respiration rate:**

We have also chosen to exclude measuring respiration rate from our device. Respiration rate is cumbersome to measure as well as being expensive. Respiration rate measuring devices require inconvenient hardware, which is not practical for everyday use. The classical and quite large belt respiration monitors start at 300$. [16]

**Battery:**

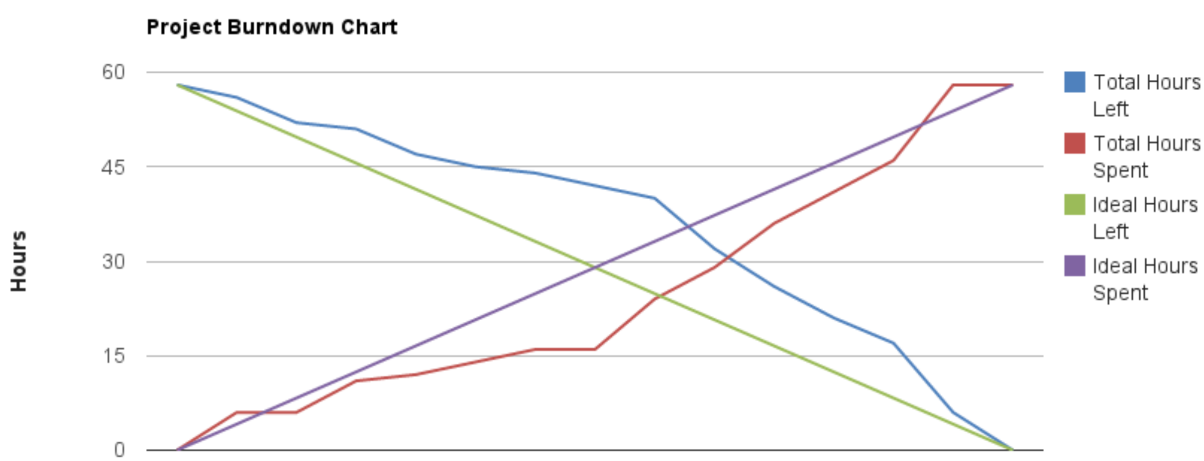
Originally, it was thought that the device would use a lithium primary non-rechargeable battery due to its high capacity and the low demand of the system in general. These types of batteries have higher energy density than rechargeable ones [17], and the thinking behind this was that our device would be similar to a pacemaker, and would thus have power requirements similar to one.

However, we quickly realized that the multitude of sensors combined with the communication functionality and the fact that the processor has to do more complex tasks than simply pulsing at a constant rate, the low power limits given by lithium primary batteries would not suffice.

We then realized that if a patient can be assumed to be following his/her prescription instructions each day, then charging the device on a consistent basis would not be a large step further. Thus, it was decided to go with lithium ion rechargeable batteries as a power source.

A second version of the device adapted for people who spend more time out of their home might be considered. This device will have a larger memory in the case where it would not be able to download the data on a daily basis. Furthermore, this version will have a SIM card to be connected to the phone system, and a GPS to detect the exact position of the client in case of an emergency. These capabilities will be enabled as soon as the Bluetooth becomes out of range. However, Since both Wi-Fi and the cellphone network consume a considerable amount of energy, it was rationalized that setting up a base station would be appropriate to considerably increase the longevity of the battery, considering that this device is intended to elderly people who spend most of their time at home.

## 8. Timeline




We were on time with the project deliverance, and as visible, progress followed closely to the ideal planning times. The task list and hours per task can be viewed in the appendix.

## References


[1] Yamada, K "6 Metria Informed Health: The Disposable Smartpatch" 2014.
http://www.makeuseof.com/tag/6-upcoming-wearable-devices-compared-whats-hot-and-whats-not/

[2] Duffy, J, "Fitbit Flex", 2013.
http://www.pcmag.com/article2/0,2817,2418525,00.asp

[3] Duffy, J, "Nike+ FuelBand",2012.
http://www.pcmag.com/article2/0,2817,2404087,00.asp

[4] Duffy, J, "TomTom Multi-Sport GPS Watch", 2013.
http://www.pcmag.com/article2/0,2817,2428355,00.asp

[5] No author, "Aiq smart clothing", 2015.
http://www.aiqsmartclothing.com/

[6]McNickle,M, "10 Wearable Health Tech Devices To Watch", 2012.
http://www.informationweek.com/mobile/10-wearable-health-tech-devices-to-watch/d/d-id/1107148?page_number=6

[7] Luis, J, A et al., "Design and Implementation of a Smart Sensor for Respiratory Rate Monitoring", 2014.
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3958216/

[8] No Author, "Integrated wearable systems", 2015.
http://www.imec.be/ScientificReport/SR2009/HTML/1213373.html

[9] No Author, "Piezo Buzzer - PS1240", 2015.
http://www.adafruit.com/products/160

[10] No Author, "SparkFun Triple Axis Accelerometer Breakout - ADXL345", 2015.
https://www.sparkfun.com/products/9836

[11] No Author, "BME 280",2015.
http://www.bosch-sensortec.com/de/homepage/products_3/environmental_sensors_1/bme280/bme280_1

[12] No Author, "Bosch Sensortec BME280", 2015.
http://ca.mouser.com/ProductDetail/Bosch-Sensortec/BME280/?qs=2OnyuXx6vpj2fK9HX7qb3g%3D%3D

[13] No Author, "Low price GPS module low power consumption GPS receiver module gps tracking module UART G7020 position u-blox7", 2015.
http://www.alibaba.com/product-detail/Low-price-GPS-module-low-power_60208017597.html?s=p

[14] No Author, “Pulse Sensor”, 2015.
https://www.sparkfun.com/products/11574

[15] No Author, “Unobtrusive, wearable blood pressure sensor for long-term continuous monitoring”, 2014,
http://phys.org/news/2014-02-unobtrusive-wearable-blood-pressure-sensor.html

[16] Neurolog, “NEULOG Respiration Monitor Belt Logger Sensor, 13 bit ADC Resolution, 100 S/sec Maximum Sample Rate“, 2015,
http://www.amazon.ca/NEULOG-Respiration-Monitor-Resolution-Maximum/dp/B00B76OZ9I

[17] No Author, “Gravimetric Energy Density”, 2015,
http://www.batteryuniversity.com/images/parttwo-50.gif

[18] No Author, “Li-ion Battery Specifications (Steel)”, 2015,
http://www.batteryspace.com/prod-specs/icr18650nh-2200.pdf

[19] Bullis, K, “Why We Don’t Have Battery Breakthroughs”, 2015,
http://www.technologyreview.com/review/534866/why-we-dont-have-battery-breakthroughs/

[20] Pothuganti,K. “A Comparative Study of Wireless Protocols: Bluetooth, UWB, ZigBee, and Wi-Fi”, 2014 http://www.ripublication.com/aeee_spl/aeeev4n6spl_18.pdf

[21] Sandeep K. “Measuring Bluetooth® Low Energy Power Consumption” 2015.
http://www.ti.com.cn/cn/lit/an/swra347a/swra347a.pdf

[22] digiKey “Freescale Semiconductor MC9S12XEG128MAA” ,2015.
http://www.digikey.com/product-detail/en/MC9S12A32CFUE/MC9S12A32CFUE-ND/1167726

[23] Ward, Matthew and Langton, Jeremy A. “Continuous Non-Invasive Blood Pressure Measurement”, 2007
http://www.medscape.com/viewarticle/563819_4

[24] No Author, “Principles of Pulse Oximetry Technology” 2002
http://www.oximetry.org/pulseox/principles.htm

[25] No Author. “Embedded Wireless Solutions BL600-SA”, 2015
http://www.digikey.ca/product-detail/en/BL600-SA/BL600-SA-ND/3995738

[26] No Author, “Sharp Microelectronics LS013B4DN04”, 2015.
http://www.digikey.ca/product-detail/en/LS013B4DN04/LS013B4DN04-ND/5054064

## Appendix

The required data collected from the sensors can be described as follow:

The body temperature, environment temperature and humidity are encoded by 2 bytes each, for a total of 6 bytes. The heart rate is encoded by 1 byte, so for all the biometric data is encoded using 7 bytes. Every measurement will also come with a time, encoded the following way:
year: 7 bits to encoded years from 2000 to 2127
month: 4 bits to encode month from 1 to 12
day: 5 bits to encore from 1 to 31
hour: 5 bits to encode from 0 to 23
minutes: 6 bits to encode from 0 to 60
This amounts to a total of 27 bits to encode time, which is roughly 4 bytes. Therefore, each measurement will take 11 bytes of memory.

The processor will work as follow: it will scan through every sensor constantly to check for any anomaly. every 5 seconds, it will save the value of each sensor in RAM. after 5 minutes, if no anomaly has been detected, it will perform an average value and store it in flash memory and erase the RAM. Since the device needs to be running 24/7, we can assume volatile memory to be appropriate.

Therefore, the memory requirement for the ram is at least 1320 bytes for the data.

60 seconds /5 seconds *5 minutes* 11 bytes =660 bytes

So the data would take up 660 bytes in RAM

Concerning the flash memory of the device, it is required to have a least 3.168 bytes

24 hours * 60 minutes/5 minutes=288 measurements
288*11 bytes=3168 bytes.

So the data would take up 3168 bytes in flash memory.

If we consider the program and OS to take at least 20kbytes, a microcontroller chip such as the MC9S12XEG128MAA with a RAM of 12 Kbytes and a flash of 128 Kbytes should be sufficient.

| | | 3/30/15 | 3/31/15 | 4/1/15 | 4/2/15 | 4/3/15 | 4/4/15 | 4/5/15 | 4/6/15 | 4/7/15 | 4/8/15 | 4/9/15 | 4/10/15 | 4/11/15 | 4/12/15 | 4/13/15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Florent** | | | | | | | | | | | | | | | | |
| Write introduction | **Time Left** | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| | **Time Spent** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| Look up sensors | **Time Left** | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| | **Time Spent** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| Elaborate on our device's sensors | **Time Left** | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 0 |
| | **Time Spent** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 |
| Take care of timeline and work monitoring | **Time Left** | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 0 |
| | **Time Spent** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| **Benjamin** | | | | | | | | | | | | | | | | |
| Elaborate system architecture | **Time Left** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| | **Time Spent** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Research communication systems | **Time Left** | 4 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Time Spent** | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Find the device's processor & memory requirements | **Time Left** | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 0 |
| | **Time Spent** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 1 | 0 |
| Determine rate of measurements per sensor | **Time Left** | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 0 | 0 |
| | **Time Spent** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| **Ossama** | | | | | | | | | | | | | | | | |
| Design operating system | **Time Left** | 6 | 6 | 5 | 5 | 3 | 3 | 3 | 3 | 3 | 1 | 1 | 0 | 0 | 0 | 0 |
| | **Time Spent** | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 |
| Design software and required software inputs | **Time Left** | 5 | 5 | 4 | 4 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 |
| | **Time Spent** | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| **Jonathan** | | | | | | | | | | | | | | | | |
| Research battery technology and select a battery | **Time Left** | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 2 | 2 | 0 |
| | **Time Spent** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 2 | 0 |
| Determine rate of energy consumption | **Time Left** | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 3 | 0 |
| | **Time Spent** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 |
| **Pascal** | | | | | | | | | | | | | | | | |
| Research sensor history and future two year trend | **Time Left** | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 2 | 1 | 1 | 0 | 0 |
| | **Time Spent** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 1 | 0 | 0 |
| Select device's sensors | **Time Left** | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 0 |
| | **Time Spent** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| Propose and compare alternate choices | **Time Left** | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 2 | 2 | 0 | 0 |
| | **Time Spent** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 0 |
| | **Total Hours Left** | 57 | 55 | 51 | 50 | 46 | 45 | 43 | 42 | 41 | 34 | 28 | 22 | 17 | 8 | 0 |
| | **Total Hours Spent/Day** | 0 | 6 | 0 | 5 | 1 | 0 | 3 | 0 | 8 | 5 | 7 | 6 | 9 | 9 | 0 |
| | **Total Hours Spent** | 0 | 6 | 6 | 11 | 12 | 12 | 15 | 15 | 23 | 28 | 35 | 41 | 50 | 57 | 57 |
| | **Ideal Hours Left** | 57 | 52.9286 | 48.8571 | 44.7857 | 40.7143 | 36.6429 | 32.5714 | 28.5 | 24.4286 | 20.35714 | 16.28571 | 12.21429 | 8.142857 | 4.071429 | 0 |
| | **Ideal Hours Spent** | 0 | 4.07143 | 8.14286 | 12.2143 | 16.2857 | 20.3571 | 24.4286 | 28.5 | 32.5714 | 36.64286 | 40.71429 | 44.78571 | 48.85714 | 52.92857 | 57 |