

SEPA

SENIOR ELECTRONIC PERSONAL ASSISTANT

Prototyping a personal daily scheduler for the elderly.

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Abstract

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Title of publication SEPA: Senior Electronic Personal Assistant Prototyping a personal daily scheduler for the elderly		
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Abstract <p>The objective of this thesis was to explore how modern technologies fail in being adopted by older people; the issues that come with older age, and how current technology is proving unable to solve or ease the problems faced by elderly people.</p> <p>Drawing conclusions from this analysis, accessible and adequate design choices for the elderly were studied in order to build a prototype. Based on the study, choices were made trying to balance different factors such as the scope of the project, available parts and time constraints.</p> <p>The last step was to analyze on goal completion and any improvements for better achieving this thesis goals. Also, interesting features that were not included due to constraints were listed.</p>		
Keywords Elders, prototype, technology, microcontroller		

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TERMINOLOGY

ADC: analog to digital converter

Captive portal: webpage seen before having access to the rest of the network

DAC: digital to analog converter

EEPROM: electrically erasable programmable read-only memory

GPIO: general purpose input/output

I2C: two wire interface serial communication protocol

LCD: liquid-crystal display

NTP Server: network time protocol

PCB: printed circuit board

SPI: serial peripheral interface

SoC: system on chip

TFT: thin-film-transistor

Brown out: drop in voltage that causes a reset

dB: decibel, measures sound pressure

dB SPL: decibel sound pressure level

E-fuse: part in a chip which allows permanently changing it via software

EPD: electronic paper display

OLED: organic light emitting diode

xTN: Twisted nematic field effect

1 INTRODUCTION

There is a disconnection between older generations and technology that is causing isolation and prevents many people from enjoying modern technology. This technology that is not being used may prove useful in elderly life, as it has proven already useful for younger generations by surrounding many aspects of modern society.

The end goal of this thesis is to understand the nature of this technological generational gap and design a prototype for an electronic assistant designed for elderly usage which will bring modern technology's benefits to more people who need said technology.

Said device will be designed with the goal of accommodating elderly needs, providing a means to promote healthier habits and create routines as well as providing a platform for healthcare professionals to treat health problems where they can set up habit reminders and routines for their patients.

This thesis will be comprised of the following steps.

- Firstly, the current situation of elders when it comes to modern technology will be explored
- Research in design options and recommendations for elderly usage will be documented alongside with complications that arise with older age.
- A prototype will then be designed according to elder needs found while researching, carefully taking into consideration each individual system that will comprise the whole.
- Based on the research and availability of materials and equipment, ponder on design choices for building the prototype.
- Assembling the prototype inside its casing and testing its functionality

Some research is done about health status of older people, but this thesis however will not give medical advice and should not be taken as such. It will not deeply delve into healthcare matters, but rather try to explain the health issues that come with older age with clarity.

2 SENIORS AND TECHNOLOGY

2.1 Background

As people age, changes occur both in their bodies and in their psyche. These changes may greatly impact the basic routines of elderly life. Actions that seemed trivial or that took almost no time at all, can become long, tedious and in some cases, undoable in the span of just a few more years. This is worsened even further by the decrease in memory which usually accompanies the old age.

Fortunately, with the common availability of smartphones, reminders and alarms can be set-up to ease the daily routine and to make sure an organized life is followed.

It could be expected that the modern generations, those who were born or grew up with the first personal computer, will have little to no problem in utilizing such technologies in their elderly lives. Therefore, if technologies such as smartphones do not get more and more complicated, then it can be expected that when these younger generations reach late adulthood and beyond, they will be able to use tools at their disposal to ease their lives.

Nevertheless several questions arise: What about today's elderly people? Are they able to profit from today's technology? Will modern generations be able to use smartphones when they age? What if technology keeps demanding more and more cognition from the end user? What if modern technologies are too demanding already for the elderly?

2.2 Definition of elderly

Aging is commonly measured by chronological age. Conventionally, a person aged 65 years or older is often referred to as 'elderly'. However, said dichotomy fails to address the disparity in needs that people in the elderly age present because aging is not a uniform process. It's instead influenced by other, harder to measure, factors such as lifestyle, genetics and overall health.

Currently, clinical practice guidelines do not adequately define 'elderly' persons. This classification needs to be made focusing more on the individual patient characteristics and not necessarily on age.

Therefore the definition of 'elderly' used in this document will refer to people older than 65 years old and those who, in a younger age, present conditions typically associated with the elderly age group

2.3 Fleeting technology

Modern technologies offer commodity and valuable information such as finding efficient routes, news, quick means of communication just to list a few. However, to benefit from said technologies one must be able to use them without said usage resulting cumbersome or taking way too long.

With the quick and vast improvements that are taking place in the technology field, especially in the phone industry. Figure 1 illustrates how mobile technology has changed in just 13 years, yet the elderly people are expected to adapt as quickly and autonomously as it is possible for them, following technology advancements. This is frequently not possible for elderly people as data shows low adjustment values when comparing old and younger generations.



Figure 1 - Samsung E250 (2006) vs Samsung S10

Some contributing factors to this disparity between younger and older generations can be a product of different factors such as having limited experience with technology, or demographic ones: income, education, geographical location and difficulties with the complexity

of modern technology. Other factors include: lack of incentive to learn such technologies, lack of digital skills, lack of proper training and lack of investing on innovations for the elder users.

It can be especially frustrating that even though innovations are constantly found, almost none of them target elderly people, leaving them dependent on others and fearful of technology.

As technology advances, closely followed by society, it is in society's best interest to ensure that technology is at everyone's service and within everyone's reach.

3 RESEARCH

3.1 Scope

In order to complete this thesis goals adequately, some research must be conducted in order to guarantee that design choices are made with reason and facts behind them.

The areas that primarily concern the prototype will be those that dictate the appearance and functionality of the final device. Functionality will be prioritized for the purpose of building the prototype. Nevertheless, appearance design choices and their impact in the adoption of the device will be carefully studied.

3.2 Research planning

To aid in establishing a well-constructed and focused research, the topics will be listed and classified in overarching categories that will contain a brief description of the matter at hand.

- Elderly characteristics study: target demographic, daily activities, capabilities and struggles.
 - a. Life expectancy
 - b. Adoption of change/ technology - The technological barrier?
 - c. Habit building
 - d. Adequate daily routine
 - e. Mental health (Depression, Anxiety, Loneliness, Abandonment)
 - f. Psychomotor and sensorial limitations
- User interface: adapting the solution's interface to best suit its demographics' needs.
 - g. Aging vision and screens
 - h. Aging hearing and sound
 - i. Aging motor system and input systems (Psychomotor needs of the elderly)
- Physical characteristics: prototyping an elegant and adequate solution best suited for a portable device.
 - j. Friendly shapes and figurines

k. Ergonomics, weight and practicality

3.3 Research approach

Since most fields that have conducted research in late-adulthood life are complex, take years of previous training to fully understand and the scope of this thesis must be kept grounded in building a usable prototype, two options arise: conduct bibliographic research or interview healthcare workers.

On one hand, bibliographic research often provides the most theoretical knowledge of a subject and, provided there are enough sources of information, it is relatively easy to check whether the information is correct plus, most of the information contained in articles and papers has been published and reviewed by trusted institutions.

On the other hand, interviewing professionals can often give an insight on how actually servicing seniors is done and how industry professionals think it can be improved, which is part of this thesis objectives. Nevertheless, this information often comes from personal experience and can be biased, checking against official sources is advised.

In conclusion, bibliographic research will be conducted, with a special effort put into keeping the research as useful for prototyping as possible. The topics however, will not cover specific technologies as none have been selected prior to the research conclusion.

3.4 Research deployment

3.4.1 Life expectancy

Life expectancy has been on the rise since the 19th century in the industrialized countries as seen on Figure 2. The World Health Organization predicts that, by 2050 the population aged 60 years or more will double.

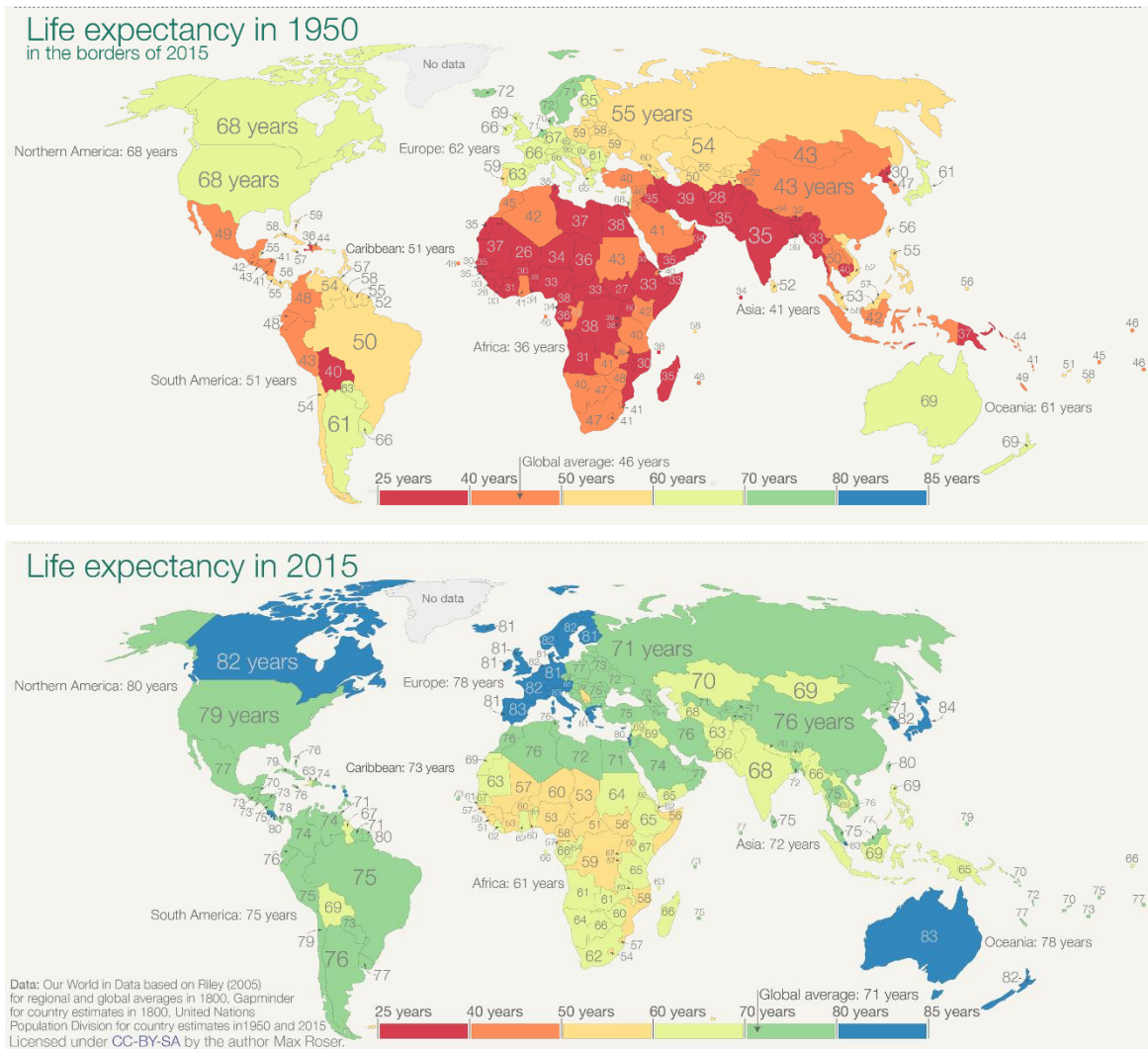


Figure 2 – Evolution of life expectancy from 1950 to 2015 (WHO, 2016)

This increase in life span is in direct correlation with the improvements in sanitation, housing education, the increase in the quality of life in both developed and developing countries and the vast improvement on the pharmacology and medical sectors that have taken place in recent years. This increase in life expectancy is expressed in Figure 3.

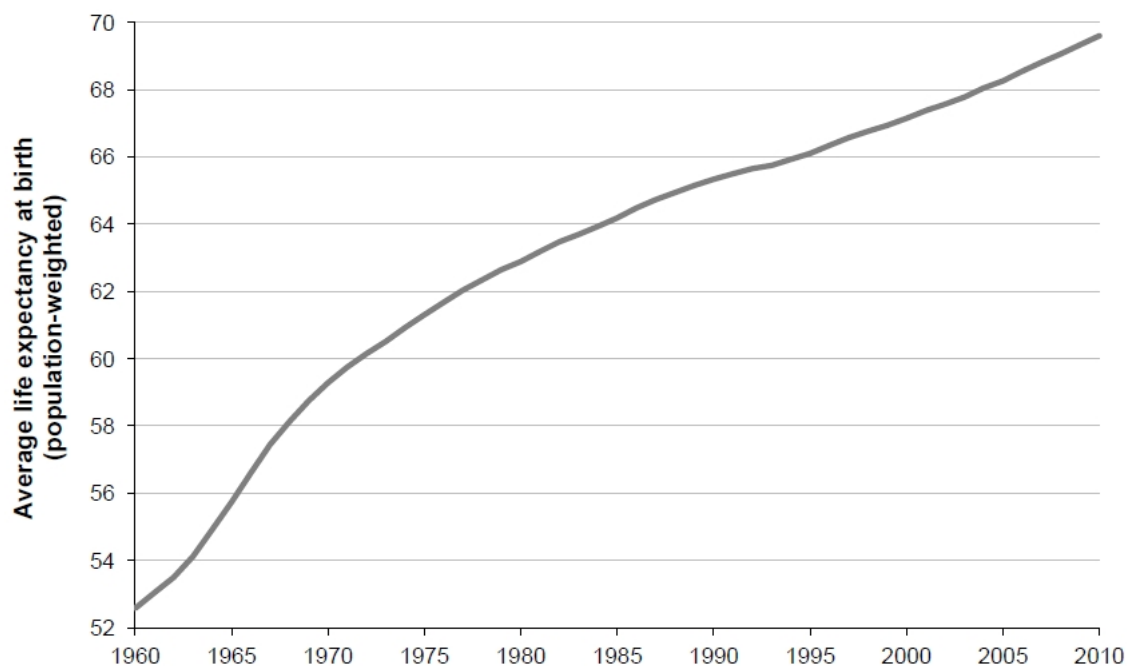


Figure 3 - Graph of life expectancy at birth throughout the years (WHO, 2019)

With the increase in elderly population, providing a means towards a healthier and more organized lifestyle to those who more need it, is now more important than ever before.

3.4.2 Adoption of technology

According to the Journal of Medical research, there are factors that are not usually considered when studying elderly people and technology withdrawal.

These factors were reported by elderly people who do not use the internet and can be categorized in two groups: psychological and health related. Psychological reasons group 'no available time', 'no meaningful use', 'nothing worth reading/watching'. Health related reason on the other hand include 'eyes or body deteriorate with Internet usage'.

Two-thirds (66%) reported that psychological reasons were the ones stopping them from utilizing the internet while 21% said that it was health barriers stopping them. Other studies also suggest that also 'computer anxiety', 'online problems' and 'privacy issues' highly concern the elderly. This ultimately suggests that the elderly people are distancing themselves from technology, not because of being physically unable to use it, but because they find it unappealing, complex and even dangerous.

3.4.3 Habit building

Habits are defined as 'actions triggered automatically in response to cues associated to their performance'. Psychological research shows that, the mere repetition of an action when in the same context leads, through associative learning, to the action being promoted when exposed to the contexts' cues. Once the activation of the action is dependent on external cues, dependence on conscious attention or motivation is reduced, making those actions more likely to persist even after conscious interest dissipates.

When healthy actions are proposed, initially the conscious effort is enough to sustain such tasks. But, usually, in little to no time, motivation and attention to these actions fade, and those healthier habits do not get a chance to become part of everyday lives.

It is also important to note that it's not possible to create a habit for not doing something. This implies that, to rid oneself of an unhealthy habit, a new and more desirable habit has to replace the old one.

These new habits should be small and manageable. Since failure on the pursuit of a new complex habit can be discouraging, breaking down a new task into simpler and smaller goals can greatly improve the chances of achieving said goal. With every new small task successfully integrated, it's easier to spot the progress and benefits of pursuing a change in lifestyle, it reminds people why those changes were of importance in the first place and it stimulates their sense of autonomy and the pursuit of new changes and challenges.

In short: the key to habit building is, to promote a response to a cue or event. Said response will become automatic once it has been consistently repeated enough after a certain cue occurs. Said habits should be attainable, progressive and as simple and impactful as it is possible to design them.

How long does it take for a new habit to fully form? While some people believe that 21 days or around 3 weeks is enough to create a new habit, more relevant research has shown that the automated behavior peaked at around 66 days of daily performance but with some considerable variations between the participants of said study. It's also important to note that the switch in behavior is not sudden but rather progressive throughout the time of adaptation, greatly reducing the effort of repeating a task the longer it is repeated. Also, the simplicity of the habit at hand can reduce both the time of adoption and the risk of its abandonment.

3.4.4 Mental health

Mental health is typically wrongly associated with the absence of a mental illness or disorder. Mental health is instead much more than 'not having any illnesses'.

According to the World Health Organization (WHO), mental health is defined as 'a state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community'.

Studies have shown that mental and psychological health are heavily linked, giving the well-known Latin saying '*mens sana in corpore sano*' (a healthy mind in a healthy body) a new scientific confirmation. This means that health conditions, which the elderly are especially susceptible to, can surface problems such as depression or anxiety and said psychological troubling can worsen the outcome of illnesses such as heart disease. Conversely, caring and treating mental conditions as best as it's possible may lead to better overall health in the elderly.

Risk factors for mental health problems in the elderly are exacerbated by age and socioeconomic factors. Older people experience common stresses to all people, plus new stressors that are commonly found in later adulthood: reduced mobility, chronic pains and frailty just to name some of the most common. Furthermore, older people are more likely to go through the loss of a loved one or a drop in socioeconomic status after retirement. These additional stresses often lead to loneliness, isolation and psychological distress for which they may require special caretaking.

The main issues affecting the psyche of the elderly are dementia and depression, but they are not the only ones.

- **Dementia**

Definition:

Dementia is a broad category of brain diseases, the most well-known being Alzheimer's disease (contributing to 60-70% of cases), that cause a gradual deterioration in the behavior and ability to think, remember and performance of daily activities. This causes disability and dependency on those who suffer from it. Furthermore it often causes a huge impact and stress on families and care-takers of those who suffer from dementia as it implies new physical, social, emotional and economic pressures.

Prevention:

Even though there is no known cure for dementia, there's research which correlates dementia with risk factors besides age such as: physical inactivity, obesity, unhealthy diets, tobacco and alcohol use, diabetes and midlife hypertension. Other potential risk factors include depression, social isolation and cognitive inactivity. Promotion of new habits that replace these risk factors may be beneficial in reducing the risk of developing dementia.

Treatment:

Even though a treatment to cure dementia doesn't exist, there's much to do when it comes to improving the life of both dementia patients, their caretakers and families: early diagnosis promotes quick and optimal management, informing care-takers and families, treating accompanying physical illness, detection and treatment of challenging behavioral symptoms and optimizing physical health, cognition, activity and well-being.

- **Depression**

Definition:

Depression is a common illness worldwide that manifests with long-lasting and moderate to intense mood fluctuations and emotional responses to challenges in everyday life. It can cause suffering and functioning poorly at work. At its worse, depression can lead to suicide. Although there are effective treatments for depression, fewer than 50% receive proper treatment. Barriers such as social stigma associated with mental disorders, lack of resources and lack of trained specialists result in depressed people not receiving proper treatment and others with wrongly diagnosed depression being prescribed antidepressants.

Prevention:

Depression often develops as a product of the interaction of social, psychological and biological factors. People who undergo traumatic events are more likely to develop depression. There's correlation between depression and physical health, cardiovascular diseases can lead to depression nonetheless depression can worsen one's physique.

Exercise programs for the elderly are therefore effective in depression prevention.

- **Other issues**

Elders are also vulnerable to elder abuse, often mistreated physically, verbally and taken profit of financially. Abandonment and neglect are also common in elders with

difficulties and special needs. Recent evidence supports that 1 in 6 older adults experience some form of elder abuse. As a consequence of this abuse not only physical injuries can occur but also serious and even long-lasting psychological repercussions such as depression and anxiety.

To summarize, the increase in the elderly population, cases of dementia are on the rise and the projections for future years also show a similar increasing trend, See Figure 4. On the other hand, depression is present in 7% of those older than 60 years old and its symptoms are often overlooked and untreated because they happen simultaneously with other late-adulthood problems.

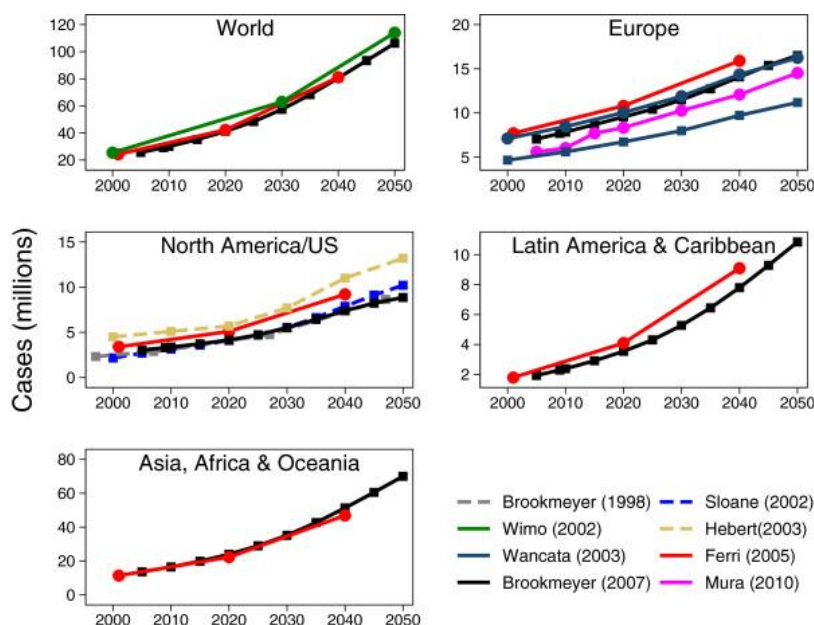


Figure 4 - Dementia statistics and projections (neuRA, 2019)

Mental health is important throughout all stages of life, yet the elderly, despite being particularly susceptible to developing mental disorders, are under-identified by health-care professionals, the stigma makes the elderly reluctant to seek help which ends up in them underutilizing mental health services, not seeking help

The mental health can be improved by promoting active and healthy ageing together with living conditions and environments that support wellbeing and allow elders to live a healthy life and the promotion of healthy habits and routines that substitute inactivity, unhealthy diets and substance abuse.

3.4.5 Psychomotor and sensorial limitations

Mental health issues are not the only problems that come with ageing. It is common that, as years pass, the human body that once was in its prime starts now losing some capabilities, reflexes and strength. This deterioration on the body takes place in both the ability to perceive the world, known as sensorial skills, and in the capability to process senses and act according to them, called psycho-motor skills.

The two most prevalent sensorial skills failures, as a consequence of ageing, are often located in the vision and hearing departments. Smell, taste and touch deteriorate as well, but they are outside the scope of this research and therefore will not be covered in this paper.

- Visual impairments can range from low vision to being completely blind. According to the world health organization most people who are visually impaired are aged 50 years or older as seen in Table 1. Blindness being the most uncommon vision impairment means that interaction with screens is still an accessible and sensible option as long as it is complemented with alternatives for those who lack vision.

Table 1- Data on Visual Impairments by age (WHO, 2010)

Ages (in years)	Population (millions)	Blind (millions)	Low Vision (millions)	Visually Impaired (millions)
0-14	1,848.50	1.421	17.518	18.939
15-49	3548.2	5.784	74.463	80.248
50 and older	1,340.80	32.16	154.043	186.203
all ages	6,737.50	39.365 (0.58)	246.024 (3.65)	285.389 (4.24)

- Hearing loss associated with ageing is also called '*presbycusis*'. Hearing loss in adults above 65 years is five times more present than on everyone else. This decrease in hearing ability can cause exclusion from communication, loneliness, isolation and frustration. (WHO, 2019). Nonetheless, hearing loss is present across all ages as illustrated by Figure 5.

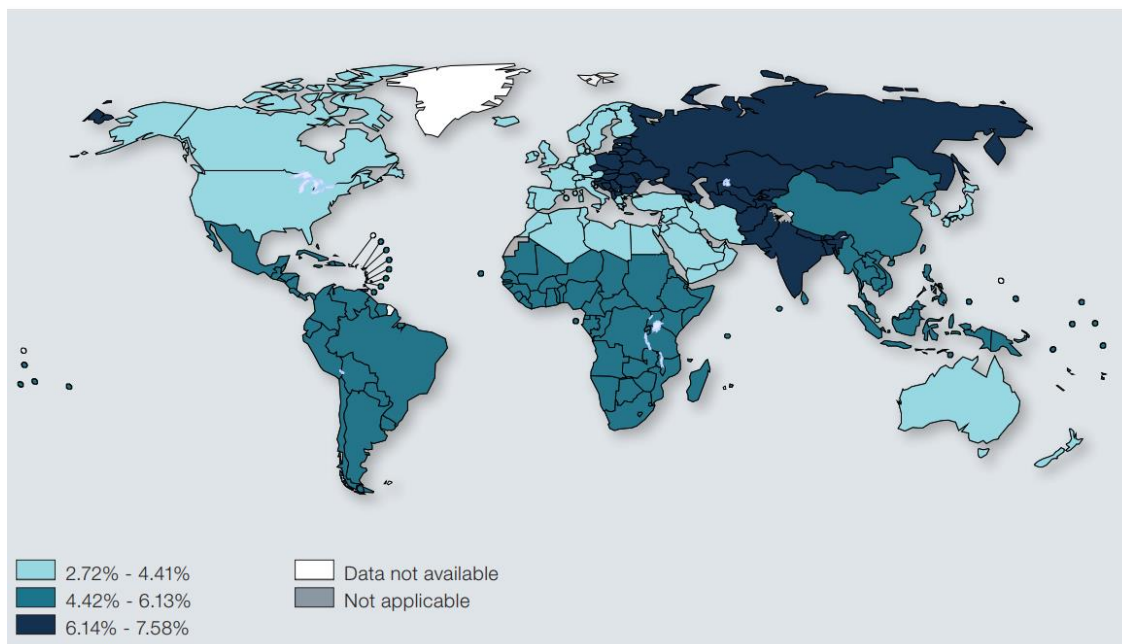


Figure 5 - Prevalence of disabling hearing loss for all populations (WHO, 2019)

Psychomotor skill decreases, on the other hand, describe the loss of cognitive function, as in perceiving and processing information, and also the loss on speed of execution of a response. This loss in psychomotor skills may difficult or prevent older adults from for example, driving, and further increasing the sense of dependence to others.

Studies found that several measures can be put in place in order to aid people with receding sensorial and cognitive functions. Sensory function loss can be aided if irrelevant or noisy information is avoided, placement and coloring are kept constant, usage of bigger letter with higher contrast and slower and clearer text interactions. In a similar way, cognitive function loss is minimized when time restraints are not present and when the environment is supportive. It's easy for elderly people to get discouraged, so it's important to allow long times for decision making and opportunity to correct previous choices.

Despite these losses in day to day functionality taking place as result of ageing, experience can, in limited ways, somewhat compensate for the loss of physical ability. This compensation however cannot occur when it comes to a newly learnt task or a radically different action. So, when adapting systems for elderly usage it's important to consider whether usage of the new system can be made familiar in order to reduce drastically the learning time.

3.4.6 Ergonomics

Ergonomics is the applied science concerned with the understanding of human interaction with elements of a system. Particularly, with the efficiency on which people can interact with objects in a precise, healthy and stress-free manner.

There are many factors to take into consideration when designing with good ergonomics in mind. For instance, when designing the shape of a handheld product, it's important to keep in mind who the end user is going to end up being so that the design can adapt to both their needs and physical characteristics. It is also important to keep in mind the intended usage of a product, otherwise injuries and long-term problems like bad posture can occur.

A striking fact to realize is that highly used products such as laptops, who fail basic ergonomic design as they do not allow to both allocate the keyboard and screen in optimal position and smartphones can cause problems on shoulders, neck and elbows when being held on ears and can also put stress on fingers shoulders and neck if users text too much such as to create long and dense e-mails or documents.

When designing handles or handheld items, there are some criteria that designers should carefully consider in order to maximize handiness and safety. Some of them are:

- Size: length in order to fit the width of the palm and thickness to allow the thumb to cover the index and middle fingers.
- Shape: Cylindrical if the grip is to twist round the handle. Uniform diameter and smooth surface to allow sliding or thickened centrally if there's a need to protect against sliding. Flat part to allow and accommodate the thumb and allow it to straighten as a precision variant of the power grip. Flattening for the thumb and fingers to prevent unwanted twisting.
- Surface: Smoothness allows the rotation of the handle within the hand. Roughness may increase grip if used correctly. Insulation against heat, vibration and electricity.
- Slip prevention: an enlargement of the end prevents slip if the grip relaxes. A hilt can prevent sliding to the front when exerting force against a surface. Central thickening helps to trap the handle in the hand when it's slippery. Non-rounded design avoids the possibility of the product rolling and falling off a sloped surface.

- **Stiffness:** Controls should be stiff enough to avoid accidental activation, as it can cause an increase in error percentage. A bulkier design signals a resistant and strong material while a more delicate handle indicates a more delicate and soft material.
- **Positioning:** In reach and following the arc of body movement (curving inwards to the user). Not requiring body lean or uncomfortable arm separation. Bench height over or just under the center of gravity.
- **Covers:** Grip covers or 'shields' help to avoid finger damage. Gloves can have harder parts as a protection.
- **Function indicators:** A certain shape in the design can express the way an object is meant to be used. Clear symbols on labels that express functionality must be able to resist wear.
- **Feedback:** Effects of using the control should be expressed to the user, either by sound, light or touch. The reaction of use may be signaled by a special device.
- **Storage:** Including a loop, hook or narrowed waist to ease storage.
- **Other features:** surface easy to clean. Ability to replace parts that allow extra adaptability or extend the lifetime of the product.

Once ergonomic design considerations have been taken, testing is required to check if they fulfill their intended purpose. Although functionality is the driving motive when designing ergonomics, looks shouldn't be ignored and a compromise between functionality and aesthetics must be found. Questioning whether the design looks right, is used in the intended way, can resist a certain stress or whether it's slippery, should be done not only by a user but by a group that present distinct characteristics. These considerations will vary depending on usage and purpose of the handle and the target demographic to which it is addressed. (Ref 23)

4 CASE: SEPA – PROTOTYPE DESIGN

The design of the prototype will feature and describe the relevant parts of the system that were chosen as a byproduct of the research conducted. With each part listed, the reasoning behind its inclusion in the project will be consequently justified. The listing order will be deployed in such way as to explain firstly the systems on which others are dependent of, as to maximize clarity.

4.1 System parts

4.1.1 Integrated circuit

When designing a mobile hardware solution there are several things to keep in mind.

Battery usage is one of the most important features as the system must be capable of running the intended programs but with a reasonable usage of energy. As the intended usage of this prototype is to be always on for as long as it is possible, a low-power solution is needed.

As the product must communicate with its user in different ways, it will need to have GPIO capabilities. A display must be drawn for showing event information along with a speaker for the alarm and text-to-speech systems. This can be done with SPI or I2C protocols for the display, and an ADC for the speaker.

The size of the microcontroller must necessarily be significantly smaller than the hand so it can comfortably fit within the design of the shell or case.

Lastly, it must also be capable of preserving information even when power is lost. This can be achieved with usage of an EEPROM or an SD card for example.

The chip ESP32 seen in Figure 6 and manufactured by 'Espressif Systems', fully complies with the prototype's needs. The development board ESP-WROOM32 will be used. It also has other benefits like being inexpensive, having two processing cores and having integrated by Wi-Fi and Bluetooth technologies, which are both great for a prototype and for a portable device. It also requires 3,3V to operate which can be provided by a rechargeable battery or a CR2032 coin cell battery.

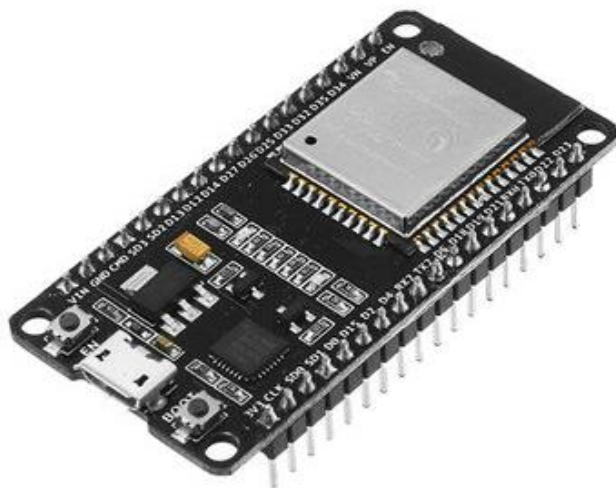


Figure 6 – ESP32 chipset mounted on a development board (Banggood.com, 2019)

4.1.2 Screen

The need to visually communicate with the user could be solved with colored LED's, however this allows for little interaction. A display is a more adequate choice when designing for the general public. When choosing a display there are several characteristics to consider that will result in the choice of a particular display technology: size, clarity and, because it will be used in a battery powered system, energy consumption is also crucial.

The importance of screen size is increased when designing for the elderly, who have statistically higher rates of visual impairments. The screen must be big enough so that the contents on it can be viewed at an arms distance clearly and with little to no difficulty.

Clarity is affected by several factors. The brightness of the display will allow for it to be used in direct sunlight and in darkness but will severely cut into battery life. Color can help contrast and readability, but will also impact energy usage. Resolution also affects how much pixel density is present, effectively impacting the sharpness of the image.

Energy consumption depends mainly on the technology used, but also on the size of the display. The chart in Table 2 illustrates the power consumption of common screen technologies as well as other useful data.

Table 2 – Comparison between display technologies (Qualityinspection, 2019)

	EPD	OLED	TFT LCD	xTN
Applications	E-book, watches...	Mobile devices	Wide range of applications	Toys, cheap electronics
Resolution (Dot Per Inch)	200-230	100-180	200	0-130
Min. power consumption	<0.1mA	~1-5mA	10mA	0.1-1mA
Visual quality	Very good	Very good	Medium to high	Low to medium
Polarized (Visual angle) ?	No	Yes	Yes	Yes
Unit cost	Medium/high	Medium/high	Medium	Low
Tooling cost (USD)	200k+	50-100k	100k-200k	10-20k

With this terms for selecting the most appropriate technology, EPD and OLED stand out as seen in Table 2 for having the best visual quality and a generally low minimum power consumption as it can show the same image without energy usage. This low energy usage of EPD technology is striking when comparing it with other technologies, however it comes with its limitations. EPD works by reflecting ambient light, making great use of sunlight but making it unusable in dark settings. It also takes much longer to change the displayed contents on screen, as it relies in electrically controlled ink for color. They are expensive and not the best fit for a test prototype.

OLED on the other hand has much faster refresh rates, produces its own light with each pixel making it usable under sunlight, but drains more battery specially when dealing with bigger displays. When searching for a big enough model they become a quite expensive option just to design basic functionalities for a prototype.

TFT LCD has the highest energy consumption as it relies on backlighting for visibility when ambient light is low. Visibility can still be low under harsh sunlight. However its high range of applications makes it a widespread option, and this considerably lowers the price of the technology as more manufacturers are available.

xTN technologies will not be considered because no I2C or SPI compatible modules were found. Although with their low energy consumption and low cost, they propose an interesting choice for prototyping purposes.

For testing purposes the display in Figure 7 was chosen. It has a resolution of 240 by 320 pixels, uses SPI as its interface protocol, offers 18 bit color resulting in 262.144 possible combinations and works with 3.3V, the same voltage output by the ESP32. When replacing this part with a superior, albeit more expensive, OLED display there will be no compatibility issues as long as the new display uses a SPI interface and the same 240*320 resolution.



Figure 7 - 2.8" TFT LCD Color display (Banggood, 2019)

4.1.3 Audio

The ESP32 can produce an 8 bit analog signal with its built-in DAC that ranges from 0V with a value 0 to 3.3V with value 255 with some discrepancies for which the hardware implementation is responsible. This allows for a good sound representation though it is not suitable for an exceptional music player. (Xtronical, 2019).

Adding a speaker is necessary for producing audio. However directly connecting a speaker to the ESP32 won't produce a good quality sound nor will it make the speaker loud enough. An audio amplification circuit can solve both of these problems.

In order to determine how loud the speaker must be, it is important to consider the settings where the prototype will be used. It should notify the user even in noisy conditions such as heavy traffic on the street. As seen on Table 3, usual average decibels for heavy traffic conditions vary between 80 to 89 dB. In order to notify the user while in these conditions, the prototype must produce a louder noise than the residual noise arriving at the

user from a distance. Accounting with the hearing loss that comes with older age, maximizing the sound output will make the alarm system more effective and the voice system more reliable for hearing impaired people.

Table 3 - Decibel level of commonly occurring sounds (Healthlink and psbspeakers, 2019)

Noise	Average decibels (dB)
Whisper, leaves rustling	30
Average home noise	40
Normal conversation	60
Office noise, on a 100km/h car	70
Vacuum cleaner, average radio	75
Heavy traffic, noisy restaurant	80 – 89 [Above 85dB noise is harmful]
Subway, shouted conversation	90-95
Motorsport bike, Boom box	96-100
Orchestral climax	101-105
Chainsaw, leaf blower	106-115
Rock concert, sports crowd	120-129
Stock car races	130 [Pain threshold]
Gun shot, siren at 30 meters, jet	140

With the PAM8403 amplifier circuit it is possible to, in combination with the analog ping of the ESP32, use a moderately powerful speaker that will call to the attention of the user even in outdoor conditions. This amplifier circuit will also enhance the audio quality that the speaker can output.

Speaker loudness, on the other hand, is not determined by the amount of power it is given. In fact, its efficiency, sensitivity and dispersion of sound will affect its perceived loudness. 'Each time you double the power you only get 3dB more volume [...]. All other things being equal, a speaker with a sensitivity of 98 dB (usually rated as dB SPL with 1 watt applied, measured at a 1 meter distance) that is handling 500 watts will actually be

the same volume as a speaker rated 95 dB sensitivity handling 1000 watts (Sweetwater, 2019).

Speakers typically come with various resistance ratings, these being 4, 6, 8 and 16 ohms. Speakers with 4 ohm ratings are considered as really good speakers, however they require high current and not any speaker will work fine. For a 3.3V using it results in a peak current of 0.825 Amps according to Equation 1 which can be too much for low power projects and it can cause the ESP32 to brown out and reset. With an 8 ohms speaker instead, it results in get half the current, 0.4125 Amps which is more suitable.

$$\text{Equation 1 – Ohm's law: } Current = \frac{Voltage}{Resistance}$$

The current is now safe, but the audio system can't exceed the power rating of the PAM8403. Using Equation 2 reveals that the peak power going through the device will be 1.36 Watt. As the PAM8403 is rated for 3 Watts this is fine. The speaker of choice must be rated also above 1.36 Watts.

$$\text{Equation 2 – Electric power: } Power = \frac{Voltage^2}{Resistance}$$

The highest voltage usable to drive the PAM8403 is 0.3V, but the ESP32 analog output can range between 0 – 3.3V. To solve this, a voltage divider is required between the ESP32 and the PAM8403. Equation 3 calculates a voltage division where V_{out} is the voltage coming from the ESP32 (0 - 3.3V) and V_{in} is the voltage required by the PAM8403. The values of the R1 and R2 can be any as long as the ratio is kept the same. However, it is advised to use a big resistor as R1 as to limit the current output from the ESP32 which could damage the board. With R1 = 10k Ohms, R2 = 1k Ohms. For added volume control, a potentiometer can be connected between the voltage divider and the PAM8403 as seen in Figure 8.

$$\text{Equation 3 – Voltage divider: } V_{out} = V_{in} * \frac{R2}{R1+R2}$$

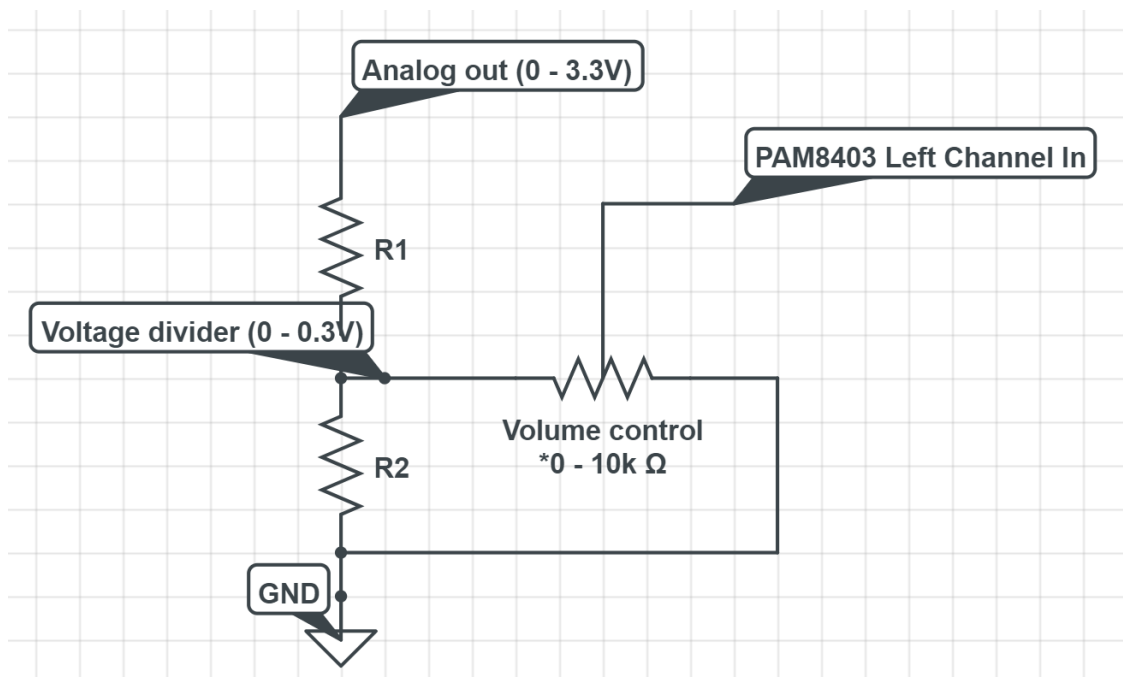


Figure 8 - Voltage divider circuit with volume control added

An 8 Ohm speaker with an S.P.L. rating of 92dB at 0.1 meters when applying 1 watt is the one chosen for this prototype. It has a maximum input power of 1.5 watts which suits the setup perfectly.

Finally, the speaker is connected to the left channel of the PAM8403, this is an arbitrary choice as both channels function in the same way. The resulting circuit can be seen in Figure 9.

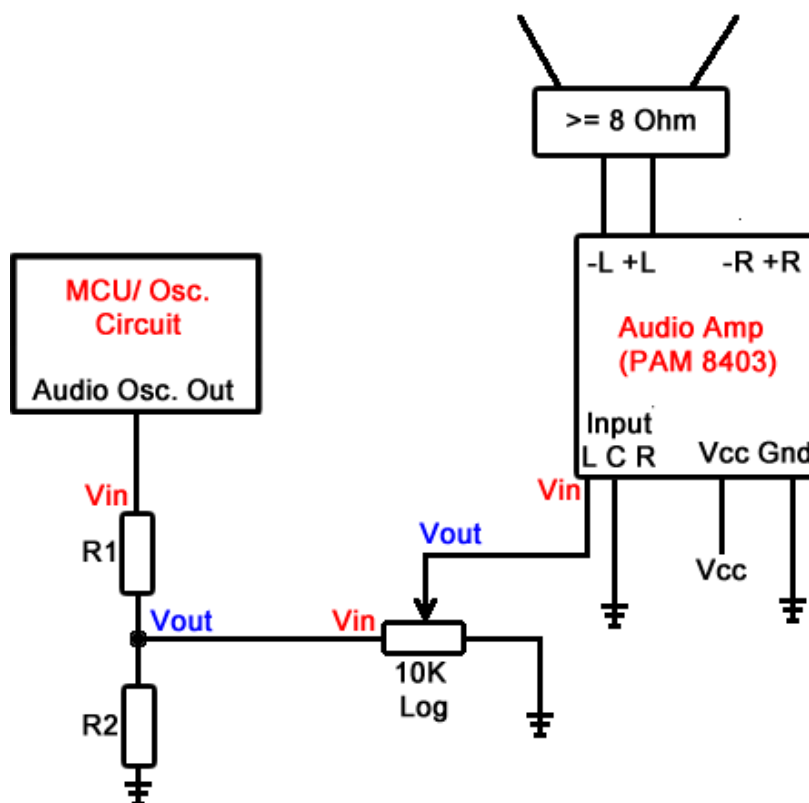


Figure 9 - Final audio system for the prototype

4.1.4 Battery

A power option must be considered when prototyping portable devices, as it is not possible to power them constantly with a power outlet. Batteries come with different specifications but, looking over different cell types, the most important characteristics are output voltage and capacity. Capacity will determine how long the prototype can run without needing to be recharged, but this duration can be increased reducing the energy usage of the other modules: ESP32 can enter different sleep modes if no events are scheduled in X minutes or the user has not interacted with the prototype in a while and turning off the screen when no interaction has occurred in some minutes. Voltage must match the prototype setup, 3.3V. However, batteries usually have different voltages depending on their charge: higher voltage when fully charged which decreases as they become depleted as illustrated in Figure 10. Nominal voltage represents the voltage output of the battery when at 50% capacity, this means that at full capacity voltage might be high enough to damage the board and when battery still has charge it may not have enough voltage to fully the board. The solution to this problem is a voltage regulator, which is included in the prototyping board of the ESP32 but will need to be included when using only the ESP32 SoC. A linear regulator is based on a switching resistance based on input voltage and thus it

can only output a lower voltage. Specifically, a low dropout voltage (LDO) voltage regulator is needed in order to access as much battery capacity as possible. This slightly decreases the efficiency of the battery system, but is necessary to ensure the safety and reliability of the device.

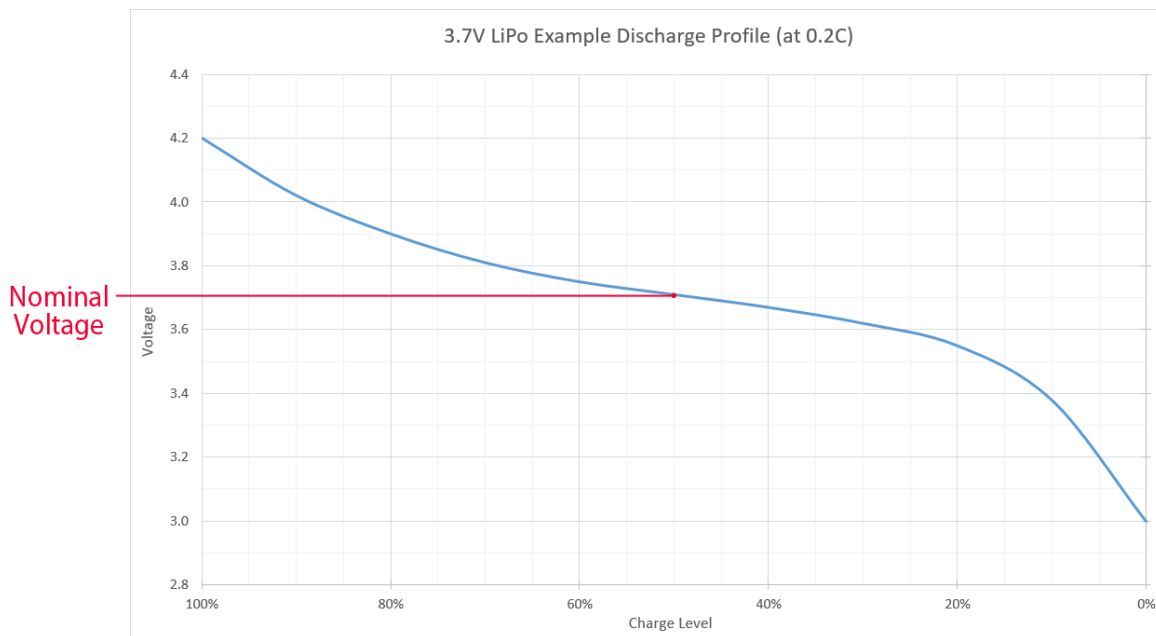


Figure 10 - Discharge diagram illustrating nominal voltage (Wr-labs, 2019)

The ESP32 when in deep sleep uses $10\mu\text{A}$. As this will be its main state except when displaying events or the user interacting with it, theoretically the prototype can idle for a maximum of 35000 hours or short of 4 years with a 350mAh battery and 150000 hours or 17 years with a on a typical 1500mAh modern phone battery. A 350mAh battery theoretically offers 437 hours or 18 days of screen and speaker usage and a 1500mAh can sustain interaction for 1875 hours or 78 days. This are theoretical estimates and can't be achieved by the prototype, but they serve as a good point of reference.

In the end, the 350mAh 3.7V Li-Ion battery was chosen as the power requirements of the prototype are low and testing on power consumption and autonomy are required. Furthermore by attaching an analog pin to the battery before the LDO, the ESP32 is capable of checking the remaining charge of the battery by reading the voltage output of the battery. This means that the user can be reminded to charge the device once the battery starts running low on charge.

4.1.5 Clock

The ESP32 can track time with its internal RTC. However if power is suddenly ever lost or the board is reset and the time value was only stored in temporary memory, the device

would lose track of time and it would need reconfiguration, which it could prove annoying if it ever happened. There are two possible solutions: to store time in a permanent memory unit, which would need to be updated each second at least and would reduce the capabilities of the system or to use an external RTC with its own power supply.

An external RTC is a dedicated unit for keeping track of time. Provided it has its own dedicated power supply, it can keep track of time even in the main circuit loses power. The ESP32 has access to time whenever it needs to using an I2C connection. The DS3231 RTC module, as seen in Figure 11, uses a standard 3V button battery which, according to the data sheet, it needs to be replaced every 9 years.



Figure 11 - External RTC power with button 3V battery (Indiamart, 2019)

With this setup it is ensured that once the device is configured it can keep track of time reliably and without needing a connection to a NTP server. It also serves as redundancy just in case battery gets completely depleted which is not a very unlikely scenario.

4.1.6 Calendar

This system is responsible for the basic functionality of the prototype which is supporting different daily alarms and event reminders. It must precisely trigger and it has to be easy to setup. It should also allow to easily add and remove events and alarms.

The standard for iCal, defines an '.ical' file consisting of plain text which contains types of events, times, durations, descriptions and many other different event identifiers as depicted in Figure 12.

```

BEGIN:VCALENDAR
VERSION:2.0
PRODID:-//ZContent.net//Zap Calendar 1.0//EN
CALSCALE:GREGORIAN
METHOD:PUBLISH
BEGIN:VEVENT
SUMMARY:Abraham Lincoln
UID:c7614cff-3549-4a00-9152-d25cc1fe077d
SEQUENCE:0
STATUS:CONFIRMED
TRANSP:TRANSPARENT
RRULE:FREQ=YEARLY;INTERVAL=1;BYMONTH=2;BYMONTHDAY=12
DTSTART:20080212
DTEND:20080213
DTSTAMP:20150421T141403
CATEGORIES:U.S. Presidents,Civil War People
LOCATION:Hodgenville\, Kentucky
GEO:37.5739497;-85.7399606
DESCRIPTION:Born February 12\, 1809\nSixteenth President (1861-1865)\n\n\n
\nhttp://AmericanHistoryCalendar.com
URL:http://americanhistorycalendar.com/peoplecalendar/1,328-abraham-lincol
n
END:VEVENT
END:VCALENDAR

```

Figure 12 - Sample iCalendar file containing a single event (iCalendar, 2019)

While in the configuration phase of the device, events and reminders can be added and are then stored in permanent memory. This will preserve the information in case the battery gets depleted and the prototype turns off.

Additionally, if Wi-Fi is configured and a connection is available, the device can access an existing online calendar as its default event calendar or can react to both offline and online events. It is important to note that the iCal standard is supported by Google Calendar, so a calendar directly exported from Google calendar is fully compatible with the device.

4.1.7 Storage

RAM memory is lost if the device runs out of battery. If the device configuration and events are stored in RAM memory they will disappear, causing the user to reconfigure the device each time battery runs out. To prevent this, a permanent storage system is needed. Typically, when storing little information, an EEPROM with 256 KB to 2 MB of memory would suffice. But as plain text files such as the standard iCal are not compressed and quite memory inefficient a higher capacity solution is required.

An SD/micro SD module, such as the one seen in Figure 13, can be used to store configuration and event files directly to an SD card, which allow for bigger storage spaces. Although a 512 MB SD card would be more than enough. With this big of a storage space the entire English dictionary could be stored approximately 250 times.

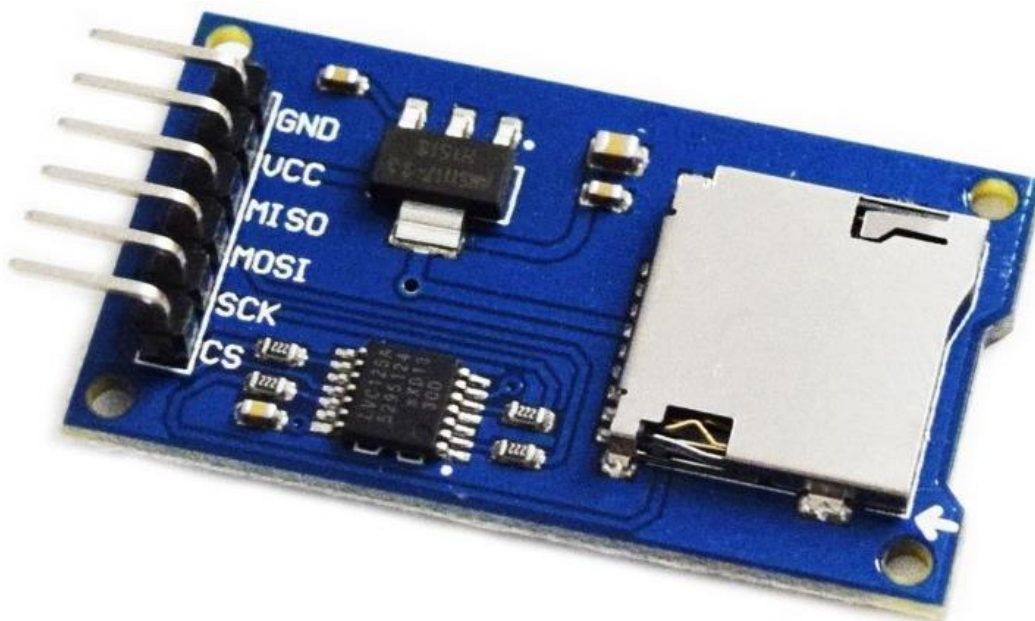


Figure 13 - Micro SD module with SPI interface (makerlab-electronics, 2019)

An important note to make is that the Wi-Fi configuration password and other sensible information should be encrypted. The ESP32 comes with an internal cryptography accelerator as well as an internal encryption key stored in an e-fuse internal to the chip. The encryption and decryption of the content can be done by the cryptography accelerator of the ESP32, ensuring high security. The only way to decrypt the encrypted data without access to the key is to physically read with a microscope the internal e-fuses of the chip that contain the key, which is really hard; or to brute-force the key, which would take 13.75 billion years with state-of-the-art technology, making it even harder. This technology is used in SSL to establish secure internet connections.

4.1.8 Configuration

The device must go through a configuration phase before it is usable. An internet connection can be configured to provide the device with an internet connection so it can fetch the date and time and events from a Google calendar. Otherwise manually introducing the desired time and events is possible as well as importing an '.ical' file containing events.

Taking advantage of the Wi-Fi capabilities of the ESP32, a captive portal is deployed. Any device capable to connect to a Wi-Fi network can configure the device in the configure state. The ESP32 displays an HTML page with the configuration interface, then the client sends the desired configuration and the ESP32 parses, encrypts and saves/updates the sensible data in the SD module.

4.1.9 Voice

As a redundancy measure and as a measure to increase accessibility for users with visual impairments, a way to convert text based information to audio is required.

The solution is speech synthesis or text to speech. This technology struggles with heteronyms: word that are written the same but they are pronounced differently.

Google offers an online solution, where text can be uploaded and a '.wav' file is returned corresponding to an audio response. This solution however, does not allow for speech synthesis without an internet connection.

Alternatively, there are programs written for microcontrollers such as the ESP32 that can take text as an input and output a variable voltage through a speaker producing recognizable speech. Flite will be used in this prototype as it allows for offline speech generation and is open source. "Flite (festival-lite) is a small, fast run-time synthesis engine developed at CMU and primarily designed for small embedded machines and/or large servers. Flite is designed as an alternative synthesis engine to Festival for voices built using the FestVox suite of voice building tools" (CMU Speech Software, 2019).

4.1.10 Software development

It is important to design how the software running in the prototype will function as well as its states. This massively simplifies the developing and debugging process. Figure 14 illustrates a typical workflow of the software running in the prototype.

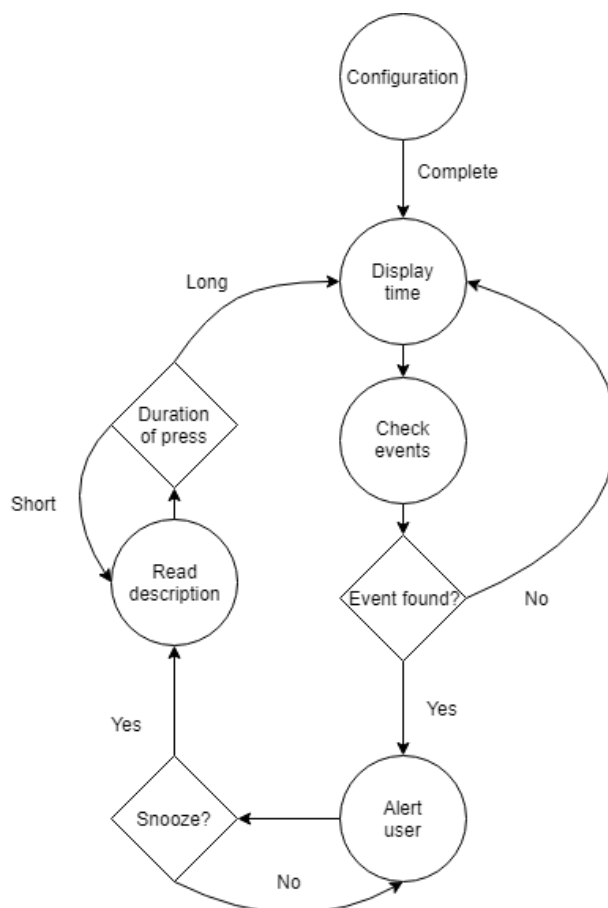


Figure 14 - Workflow for the prototype's software

The ESP32 can be programmed in different ways. It can run a Micro Python system, which allows for web live deployment without needing to recompile a binary each time. It can also be programmed in C/C++ using the Arduino programming environment which simplifies linking and compiling libraries as well as debugging via serial monitor.

In the end the Arduino programming environment was chosen as it features more options, is easier to use and is more refined than the Micro Python web environment. Because C/C++ is a compiled language, while python has to be interpreted, it will allow the code to execute faster as it is natively translated to machine instruction by the C compiler.

4.2 Assembly

With all the parts listed, defined and functional, it is finally time to put everything together. The final circuit diagram can be seen in Figure 15, and it must be fitted inside a case.

1. DS3231 RTC module
2. 8 Ohm speaker
3. Low dropout voltage linear regulator equivalent

4. Micro SD storage module
5. ESP32 development board
6. 350mAh 3.7V Li-Ion battery
7. 2.8" TFT LCD Color display

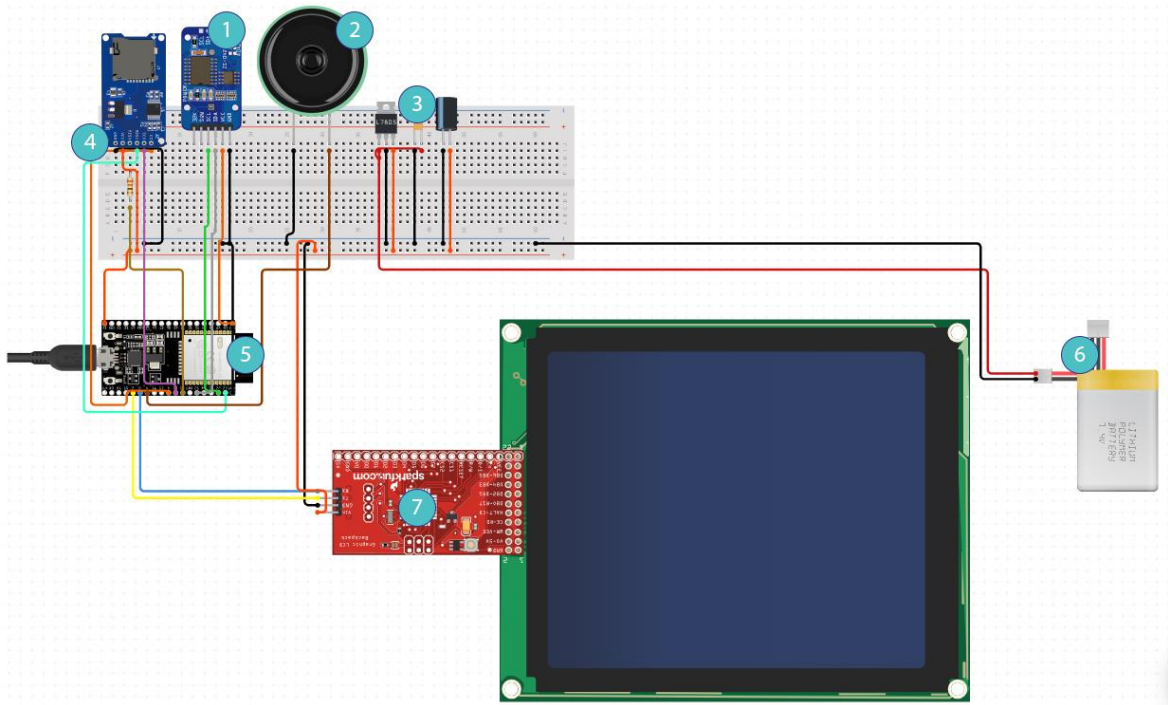


Figure 15 - Final circuit assembly with part numbering

4.3 Casing

In order to contain all the parts of the prototype, a casing must be carefully designed, as to follow the ergonomic principles that were found during research. Once the casing is design, it must be built. Once designed, the result will be 3D printed, as 3D printers are available at the LAMK campus and is an inexpensive way to get a feel for the shape and basic ergonomics of the device.

4.3.1 Design

The look of the casing was to be similar to old 'flip' phones with the goal of being relatable to older generations. It was bended on both sides as to give better grip and prevent it from being accidentally dropped, as it currently does not contain any impact mitigation measures. It was first sketched in Adobe Illustrator as seen in Figure 16 and later ported to AutoCAD, where measures where specified.

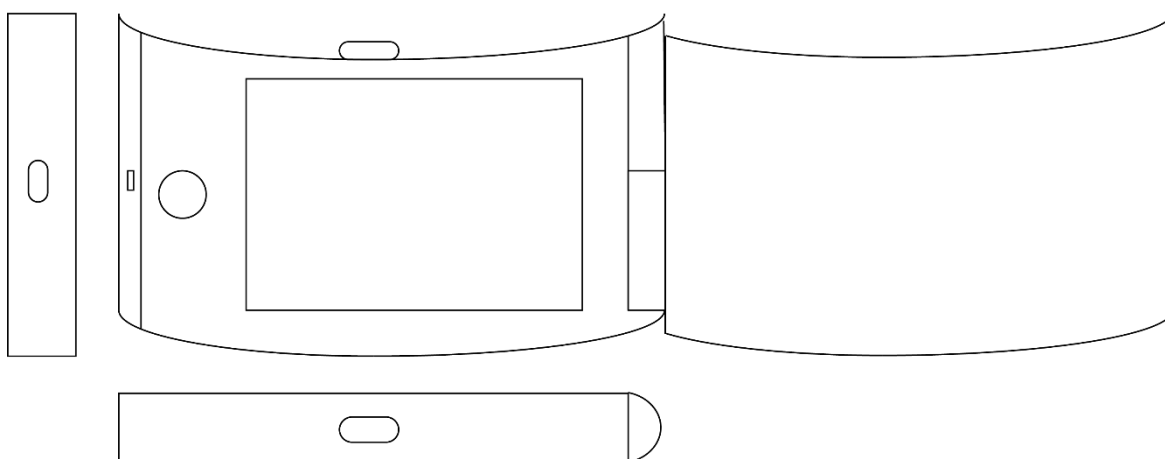


Figure 16 - Bottom, up and side views of the first sketch

Finally the CAD files were taken to SolidWorks, creating a 3D model of the prototype. As seen in Figure 17. The harsh edges were rounded as to avoid possible injuries and a hole was added so a cable to fit and charge the battery.

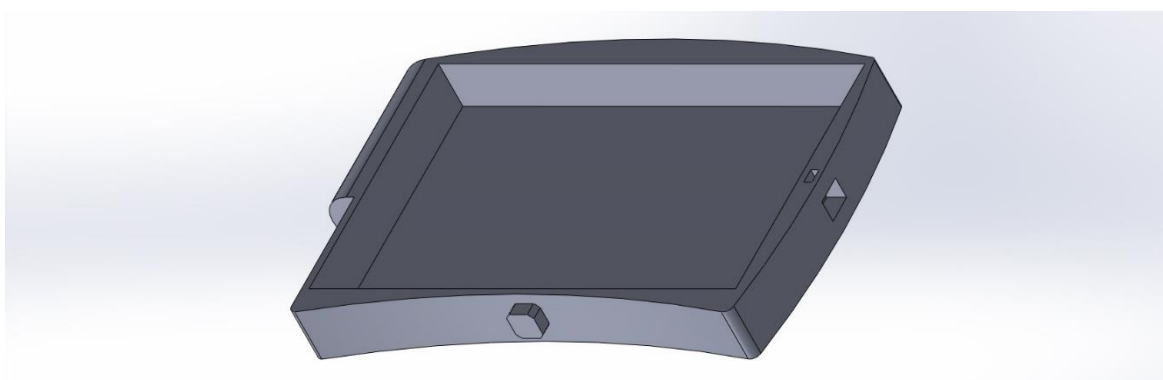


Figure 17 - 3D model of the bottom part of the prototype

4.3.2 Printing and assembly

The 3D models were exported into STL files and then taken to the 3D printing lab. With the software 3DSlash, some 'G-code' is generated from the STL file so that the 3D printer can interpret and bring the model into shape. The printing process took roughly 8 hours total, for all pieces.

The components were carefully fitted inside the casing and secured in place with hot glue. The cover and screen were then placed on top and secured also with hot glue to the sides of the back casing.

5 CONCLUSION

5.1 Initial plan

First, research why are old people falling apart from technology, what issues get worse or appear with age and what can be done to bridge the gap between old people and modern technology while solving real problems. Also get professional interviews from healthcare workers in the elders nursing department.

Then, design a physical device that implements the findings in the first research step while providing somewhat of a replacement for modern technology.

Finally test the prototype on elderly patients, get feedback from both patients and nurses as to improve future versions of the prototype and reveal areas where the design is lacking in any way.

5.2 Outcome

Bibliographic research was conducted consulting reputable healthcare sources but no healthcare professionals were interviewed due to lack of resources.

The prototype mainly focused in the implementation of measures to palliate signs of early dementia, such as being disoriented and losing track of time and what to do, and promoting wellbeing in the formation of healthy habits with reminders.

Parts were carefully chosen according to the needs of the prototype while trying to minimize resource impact. The casing was then 3D modelled and printed in the LAMK 3D printer lab. Finally the model was assembled.

An unexpected amount of insight on actual elder problem was gained. Also some misconceptions about old adulthood were proven wrong, like dementia not being part of normal ageing or other facts coming to light like habit building being an effective tool for fighting brain degeneration.

5.3 Room for improvement

5.3.1 Missing due to constraints or oversights

This were planned features that either did not work completely as intended or were not affordable resource-wise. It also includes choices that were deliberately left out as to speed the development of the first prototype.

Testing and getting feedback on the prototype design and implementation as well as contacting industrial designers for advice in the casing design part could have led to insight on how to better the prototype for the next iteration. A better, OLED screen provides better image which can be critical for people with vision impairments. Next case iteration must feature dedicated speaker holes so the sound can easily exit the case. Battery for RTC clock should feature a 'first time use' plastic that prevents it from draining before the device is ever used. Finally, the casing could use redesigning as it was made too wide in order to fit all of the components but a custom PCB could easily reduce the space needed for the circuitry and solve the problem.

5.3.2 Future additions and suggestions

Features that were suggested or could prove useful but require major redesign and greater resource usage. It also includes features that were out of scope for this thesis.

- Added compatibility with Bluetooth hearing-aids
- Jack 3.5 output for headphone users
- Radio/ media center capabilities
- Calling, messaging and browsing capabilities
- SIM/GSM/4G technology implementation
- Added touchscreen for a more intuitive interface

Bluetooth hearing aid compatibility would make full usage of the ESP32 connection capabilities. As the target for this product is typically older adults too, it could greatly benefit both products as well as prove really useful by allowing only the user to hear the alarms, making it a more discrete and elegant solution.

Some suggestions point towards building a replacement for current phone technology as well as serving as a media center and security/ tracker device. This involves SIM technology implementation which allows for calls and messaging systems as well as tracking and internet access without requiring a Wi-Fi signal. It is a great suggestion and it will be considered for future iterations.

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