NeoPixel Sunrise Clock

An intelligent bed lamp

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Declaration

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Acknowledgments

Abstract

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Chapter 1

Introduction

1.1 Background to the study

Human behavioural and anatomical activities are influenced by several internal cycles. Among these internal cycles is the **circadian rhythm**, a rhythm studied for many years and whose impacts on the human activity have led to new interests in the regulation of these activities. Formally defined as a "cyclical changes in hormones, body temperature, and other biological processes over the course of a 24 hour period" [1], the Natural Institute of Health (NIH) defines it as "a physical, mental and behavioural changes that follow a roughly 24-hour cycle, responding primarily to light and darkness in an organism's environment"[1]. The circadian rhythm plays an important role as it also affects the human sleeping and rising pattern. The circadian rhythm is influenced by the production of *melatonin* produced by the *pineal gland* whose activities are dependent on the presence of light on the *retinal-hypothalamic tract*[3].These studies have shown that the presence of light of specific wavelength at certain period of time during a day can affect the normal sleeping cycle.

According to the NIH, there is a correlation between long-term health problems and sleep disorders [6]. While stress levels and lifestyles affect the sleeping pattern, there is a strong evidence that the human sleep-wake cycle is strongly affected by light. With the invention of the electric light and the recent human exposure to LED screens, humans have more exposure to nocturnal light. Recent researches have shown that the usage of LED technologies at night is linked to sleep deficiency. Blueish light is said to have a huge impact on one of the human internal clock[4]. Sleep deficiency due to inappropriate light exposure can be cured using an optimal light exposure[4]. Researchers were able to quantify, qualify and time the light that is suitable to maintain the natural sleep-wake cycles [2]. With these results, it is possible to create an environment that will follow user specific light requirements needed to treat patients having a sleep disorder.

1.2 Objectives of this study

1.2.1 Problems to be investigated

This project investigates the feasibility of making a user-friendly embedded system, relatively cheap that could be used as a personal medical device in solving human sleep disorder. This problem envelops the following question:

1 Is this possible to use a programmable light source to emit light of around $460nm$ at $30lux$?
This is the light requirement as mentioned in section 1.3.

2 Can an embedded system meeting the light requirement mentioned above be used as a personal medical device?
The question focuses on the future use of the device in regulating the human sleep-wake cycle by medical prescription of light requirement.

1.2.2 Purpose of the study

The purpose of this study is to create a device that can be used to regulate the human sleep-wake cycle and to create a user-friendly and personalisable digital alarm clock. The product would need to be relatively cheap and have more features than its competitor. Moreover, the device should be able to use user-specific data in the regulation of the sleep-wake cycle.
Further objectives [1] includes:

- The use of user-specific medical lighting requirements and patterns to be used a personal medical device supplementing sleeping disorder treatment.
- Ability to pull events from an online calendar and set these events as alarms.
- User authentication for onboard screen usage and bluetooth connection

1.3 Scope and limitations

The scope of this project involves the design of an functional embedded system named NeoPixels Sunrise Clock also known as NPSC, capable of producing light of $460nm \pm 10nm$ with an intensity of $30lux$ as mentioned by the paper *"Action Spectrum for Melatonin Regulation in Humans: Evidence for a Novel Circadian Photoreceptor"*. The code and design artefact repository and a full documentation including a user manual, for anybody who wants to make use of the code design resources, also need to the delivered. Moreover, a description of future use of the device in the study of the effect

[1]These are sub-objectives that would be implemented depending on the time available

of light on the circadian rhythm will be required.
This project does not study the effect of light on the users. For ethical reasons, the NPSC will not be tested on human subjects in real situations of either waking humans or including lighting to facilitate sleep at night. Instead, the system will be tested based on the recommendation from the research literature.
The design and creation of the NPSC are subject to several constraints listed below:

- **Time:** The project has a duration of 12 weeks within which the research, design, development, implementation, verification, and report writing need to be done.
- **Budget:** The project budget allocation is **R1000**
- **Light:** The NPSC must be able to produce blue light with a wavelength of $460nm$ while providing enough light to meet the requirement of the research paper and provide a various range of colour for sunrise simulation. These requirements narrow the options for choosing the right light emitters.
- **Size:** The NPSC is meant to be a bedside lamp, this implies that it should have a relatively small size to be able to fit on a $50cm * 50cm$ bedside table.

1.4 Plan of development

The project was broken into sections and subsections with an estimated timeline.
The *Gantt Chart* used for this project is shown in fig. 1.1. The project started with the an intensive research on the science related to the human sleeping cycle. The research lead to the design of the NPSC consisting of its hardware and software modules. During the manufacturing process, the software framework of the NPSC was continously improved. The NPSC hardware and software integration were done later after the assembly of the hardware. Finally, the software was improved during the remaining lifetime of the project.

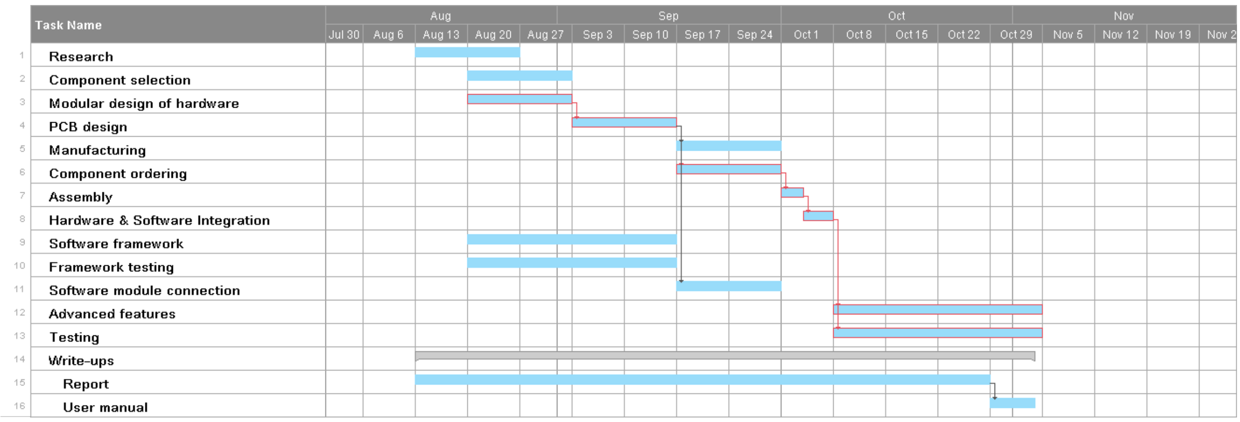


Figure 1.1: Gantt chart showing the timeline of every task in the project as well as its critical path.

1.4.1 Chronological progression of the report

The report organisation is displayed in fig. 1.2. The sections of the report are explained below:

- **Research**
  - **Introduction:** The feasability of the project as well as its scope and limitations are defined in the introduction.
  - **Literature Review:** The literature review gives an insight in the researches made for this project. This includes scientific discoveries on the human sleeping cycle, experiements and results performed by researchers on that matter, and some technical engineering design decisions.
- **Design**
  - **Methodology:** This section covers the hardware, softeare, and mechanical design of the NPSC.
  - **Results:** This section displays the results of the hardware and software testing.
- **Write-ups**
  - **Discussion:** The analysis of the results obtained. Here, the performance of the NPSC is evaluated. A costs and functional analysis of NPSC done to evaluate its performance compared to its competitors. Moreover, the future use of the NPSC is elaborated.
  - **Conclusion:** An evaluation of the project, did we achieve the intended goals.
  - **Recommendations:** We dive into the solutions or recommendations that could improve the design of such device.
  - **User manual:** This section is for any users of the NPSC. It provides a clear explanation of the features of the NPSC and a detailed manual.

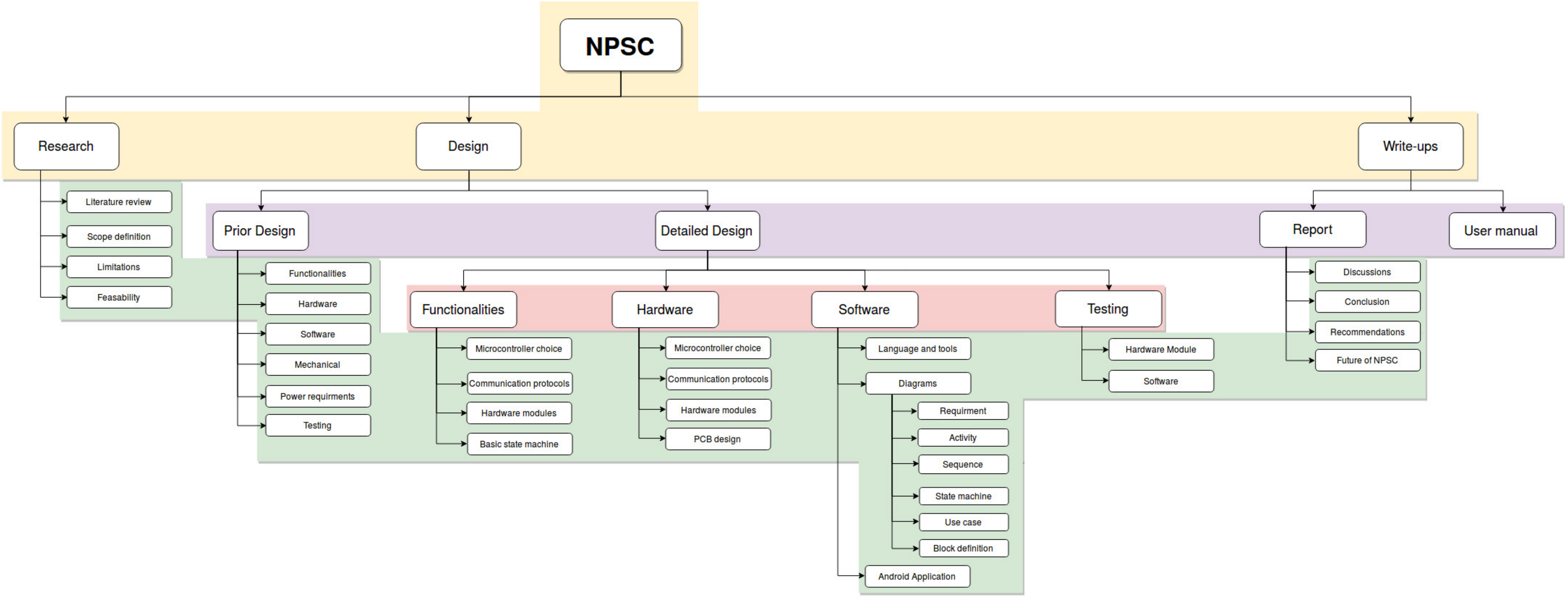


Figure 1.2: Report breakdown detailing the different sections needed to be included in the report.

Chapter 2

Literature Review

This chapter reviews the research papers, articles, books and other relevant forms of research used in the design of the NPSC. It has been divided into the sections illustrated by fig. 2.1: The literature review starts with an explanation of the problems to be solved,

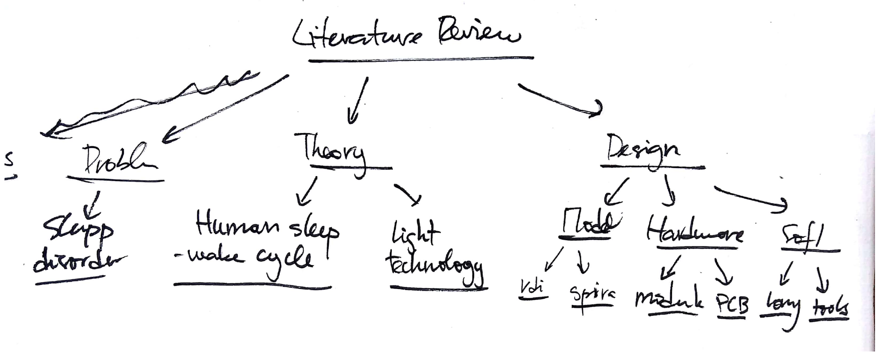


Figure 2.1: Overview and classification of the sections of the literature review.

it continues by uncovering the theory behind these problems and ends with a review of the design methods, hardware components and software tools used in this project.

2.1 The human sleep-wake cycle

Human has many "internal clocks" among them is the master clock located in the suprachiasmatic nuclei. These internal clocks or endegenous clocks are internal mechanisms in organisms reponsible for the regulations of certain functions or activities. The master clock cheif among them, regulates the secretion of melatonin is affected by light. The creation of artifical light expecially LEDs have caused a disruption in the sleep-wake cycle. This section give an overview of the human internal clocks and how they are affected by light.

2.1.1 The circadian rhythm

Human seasonal behaviours are synchronised to the environment by **biological clocks** responsible for the creation of biological rhythms. Biological clocks which are composed of proteins that act reciprocally on the body's cells are the natural timing devices found in many organs. The discovery of the genes from these biological clocks responsible for the control of these rhythms was made by three scientists Jeffrey C. Hall, Michael Rosbash and Michael W. Young winners of the Nobel Prize in Physiology or Medicine [14]. Their discovery made in the 1980s led to advanced research on the role of the circadian rhythms.
Circadian rhythms are biological rhythms which follow the same pattern in absence of external cues (endogenous), are influenced by the presence of external stimuli (entertainable), oscillating roughly every 24h[1] over a range of physiological temperatures. In the presence of external stimuli -also known as *zeitgebers*-, circadian rhythms synchronise their periodicity with these external stimuli. The zeitgebers of the circadian are the daily variation of the temperature and the dark/light cycle of the day.
Circadian rhythms have endogenous and exogenous components. Human placed in isolation without knowledge of the time continued exhibiting a circadian rhythm with their pacemakers notably the melatonin secretion, sleep-wake cycle, body temperature [13]. These results prove the existence of endogenous components of the circadian rhythms as it illustrates the effects of these internal signal on the circadian rhythms. A similar study shows that when people are exposed to light at night time, a shift in their pacemakers [9] which is an evidence of the exogenous component of circadian rhythms. These exogenous components of the circadian rhythms have the ability affect positively and negatively our natural endogenous cycle. With light being what we are mostly daily exposed to, what is the influence of light on the circadian rhythms?

2.1.2 Internal circadian rhythms influenced by light

Melatonin is the hormone produced by the pineal gland in the suprachiasmatic nuclei (SCN) which has a soporific effect and the ability to entertain the sleep-wake cycle. While melatonin itself is not the cause of a person sleeping, it however creates changes in a person's body that affect their sleepiness.
The pineal gland responsible for the secretion of the melatonin hormone is under the influence of one of the biological clocks, the master clock located in the SCN. The SCN receives visual information from the retinal-hypothalamic tract which entrains the SCN according to the photoperiod [3]. The SCN in turn activate a gene in the pineal cell (CREM) which produces a protein (ICER) needed for the production of melatonin. As a result, the secretion of pineal hormone melatonin tracks the light/dark cycle with its secretion being high during the day and low during the night.

[1] it oxalates generally a period near 24h

2.1.3 Quantitative and qualitative characteristics of light on melatonin production

Many types of research have been done to understand the impact of light on the circadian rhythms especially the sleep-wake cycle.
Kathleen *et al.* in their paper *Blue light from light-emitting diodes elicits a dose-dependent suppression of melatonin in humans*[4], provide details information on their finding of the effect of light on humans subject. Subjects used for the experiments were 5 males and 3 females with a mean of 23.9 ± 0.5 years, with each subject demonstrating normal colour vision. The lighting requirement was blue light of $\lambda_{max} = 469nm \pm 1nm$ with $\frac{1}{2}$ peak bandwidth= $26nm$ and a typical viewing distance of $35cm$. The subjects were blindfolded from midnight to 2 AM. From thereon, they were exposed to 90 min of blue light exposure followed by another dark exposure. Blood samples from the subject were taken from 2 AM at 30 min interval.From their experiment, they concluded that:

- *Blue LED light has an increased melatonin suppression following an increase in exposure irradiance*
- *Blue LED light may have stronger suppressing effect than 4000K white fluorescent light.*

A similar study was previously made by George C. Brainard *et al.* [5] used 72 healthy human subjects, with normal colour vision. The subjects composed of 37 females, 35 males, aged between 18 and 30 years (mean age of 24.5 ± 0.3 years), came from different ethnic (African, African Americans, Caucasians, Asian, Hispanic). The melatonin suppression action spectrum was formed using eight different wavelengths between $440nm$ and $600nm$ *(440, 460, 480, 505, 530, 555, 575, 600).* Using the same procedure as mentioned in the previous experiment, blood samples were taken at 30 min interval after 2 AM. The results of their research published in their paper *Action Spectrum for Melatonin Regulation in Humans: Evidence for a Novel Circadian Photoreceptor* the following conclusion:

- *Light irradiance greater or equal to* $3.1\mu W/cm^2$ *evoke a significant melatonin supression*
- *Smaller wavelength monochromatic light have a greater change in Plasma Melatonin as Percent Change Control-Adjusted for a fixed value of Photon density* ([5] pp. 4-5).

2.1.4 Impact of light on human behaviour and sleep-wake cycle

Among the Zeitgebers (natural phenomenon acting as a signal in the regulation of the circadian rhythm) of the circadian rhythms, light is the major Zeitgebers and has important effects on the human sleep-wake cycle. A study on the “Circadian and Light

Effects on Human Sleepiness-Alertness" made by Christian *et al.*[2] shows that with nor phase lag or lead between the circadian rhythm and the sleep-wake cycle, subjective sleepiness and core body temperature have opposite behaviour ([2], pp. 12, fig. 2.1). The human normal sleep-wake cycle is comprised of 8h of sleep and 16h of wakefulness [15]. This cycle is naturally affected by the human activities but is highly influenced by light exposure. The study shows that office workers with bright blue office light have a better sleep-wake cycle than those with dim and warm office light. Furthermore, it shows that light exposure of sufficient intensity at night can reduce the secretion of melatonin with alerting response starting within the first 20mm. With the recent advance in LED technologies, humans are no longer following the natural light/dark cycle causing numerous sleep disorders.

2.2 Lighting technologies

Light is capable of affecting the human sleep-wake cycle. However this impact can be used to reverse the negative impact of light on the sleep-wake cycle. This section introduces the different light technologies available and their use in regualting the human sleep-wake cycle.

2.2.1 Light

The sun's electromagnetic radiation has a broad light spectrum ranging from $100nm$ to $1mm$. After being filtered through the earth atmosphere, only certain portions of the spectrum are kept with the visible light spectrum having the maximum irradiance. Because the human circadian rhythms are automatically synchronised to the natural light-dark cycle, the characteristics of the sunlight are used as a benchmark in the emission of artificial light. These artificial lights are able to produce more or less the same wavelength as the sunlight but with much less irradiance.

2.2.2 Type of light technologies

Various light technologies have been developed over the years, their use and their usefulness in this project are detailed below.

Incandescent light

These are the most common and least efficient light technology. It produces light by passing a high current through a wire filament producing warm light as it glows. These type of lights produce only a specific spectrum of light (warm light) besides they are not designed to be programmable.

Fluorescent light

Light is produced by passing electricity through mercury vapour, the invisible light produced as a result of that interaction, connect with the coating of the glass emitting light. It produces all type of white light (warm, cool, daylight) with a good colour rendering. Compared to the incandescent light, it only produces one type of colour and it is not designed to be programmable.

Halogen light

It shares similarities with the incandescent light except that halogen gas is added to the glass. It produces a crisp white colour. As the previous technologies, it also produces one type of colour and it not designed to be programmed.

Xeon light

This type is another version of incandescent light with Xeon gas added to the glass instead, it produces a less yellow light. As the previous technologies, it also produces one type of colour and it not designed to be programmed.

LED light

This technology uses the passage of current through a diode to produce light. These light are very efficient and provide all sort of colour as well as cool and warm light. Moreover, their ability to work based on the passage on current allows these lights to be programmable. New LED technologies have a microcontroller which can be programmed the LEDs.

2.2.3 Light treatment of sleep disorder

With the discovery of the effect of light on the sleep-wake cycle, electronic devices producing specific light have been used in treating patients with sleep-disorder. Advanced sleep phase disorder (ASPD) have been treated using a therapeutic approach involving chronotherapy and timed light exposure [18]. The same concept has been used to create a home bed lamp or alarm clock facilitating the regulation of the sleep-wake cycle. **GE Sol** and **Philips***(which is actively involved in sleep-wake cycle treatment)* have created devices able to “influence” the human sleep-wake cycle.

C by GE Sol

C shown in fig. 2.2 is a “all-in-one smart light” [16] which has Amazon intelligent personal assistant Alexa built in. C has a various range of colours which are manually selected based on the user preference. It is capable of communicating with GE sol devices and smartphones inserting it among the user's network of devices. Despite its high technology features and its elegant design, C remains just a bed lamp as it is not clinically proven to be helpful in regulating the user's sleep-wake cycle.

Figure 2.2: C by GE Sol, an intelligent lamp bed using Amazon Alextra.

Philips wake-up lamps

Philips has created a broad range of wake-up lamps designed to impact the sleep-wake cycle of the users. Figures 2.3a and 2.3b are examples of the recent versions of Philips' clocks able to simulate sunrise and sunset which last from 20 to 40 mm. These simulations vary the colour of the light following the sun's natural sunrise colour and end with a selected channel or prefered user's music. These Sleep and Wake-up lights are the only wake-up lamp clinically proven to work as stated by Philips[17].

Some deep text here

2.3 Hardware modules

This section provides the research on the hardware texhnologies as well as the reasons behind the choice of some of these technologies.

(a) HF3531/60, coloured sunrise simulation, 7 natural sounds, Tap snooze and reading lamp, midnight light function

(b) HF3551/60, coloured sunrise simulation, 7 natural sounds, Tap snooze and reading lamp, midnight light function, Operated by iPhone App

Figure 2.3: Wake-up light by Philips

2.3.1 Processors and microcontrollers

A microcontroller is a computer, it contains a central processing unit (CPU), it has some random access menory (RAM), it has input and output peripherals. However, a microcontroller is way smaller, cheaper, use less electrical power, and has less processing capabilities than a computer making it the preference for tasks specific electronic design [19].
Numerous microcontrollers were analysed for this project. Each manufacturer provide various range of microcontroller suitable for different application. The NPSC's microcontroller needs to communicate to a smartphone application wirelessly, it need to control a GPS module and other external modules. While controlling the external module, the microcontroller need to perform processing of the sunrise and sunset patterns by continously organising and sending data to the neopixels. In order to reduce the complexity of finding the *perfect* microcontroller for the NPSC, the selection was based on the following characteristics:

- **Size of the FLASH:** How many lines of code can be loaded to the microcontroller?
- **Cost**
- **Clock speed**
- **Community:** Does the manufacturer have a large community of developers?
- **Bit precision:** Are we aiming at 8, 16, or 32 bits precision?
- **Familiarity:** How familliar are we with the microcontroller (time is a constraint)?
- **Number of pins:** How familliar are we with the microcontroller (time is a constraint)?

- **Extra features:** What are then built-in functionalities (wifi module, bluetooth)?

Table 2.1 provides the difference between the microcontrollers selected, this table was use to make the final decision on the microcontroller selection.

Characteristics	Microcontrollers			
	Arduino Due	**Intel Edison**	**Raspberry Pi Zero**	**STM32F407VGT6**
Clock speed	84MHz	dual-core, dual-threaded 500 MHz CPU	1GHz single core	168 MHz
Bit precision	32	32	32	32
FLASH	512KB	4GB	MicroSDHC	1MB
Pins	54	40	40	82
Cost	R549.25	R687.87	R79.8	R175.45

Table 2.1: Comparison between specifications of the Arduino Due [20], the Intel Edison [21], the Raspverry Pi Zero [22], and the STM32F407VGT6[23]

2.3.2 Storage

Storages are important in the development of embedded solutions. The **Electrical Erasable Programmable Read-Only Memory** (EEPROM) is a non-volatile memory capable of keeping its data after being powered off. Its design was based on the **Erasable Programmable Read-Only Memory** (EPROM) which required exposure to UV light for erasing its memory. There are two types of EEPROMs, serial and parallel EEPROMs. In a study made by Microship on the difference between serial and parallel EEPROM of 16KB, Tom Tyson from the Memory Product Divisions concluded that the serial EEPROM is *the best option for embedded solutions requiring a small EEPROM footprint, low current and low operating voltage, the ability and ease to programme a byte at a time, and the best price performance non-volatile memory solution available*[24] (pp. 4). The NPSC needs to store the user's data and the NPSC default's settings. Having an non-volatile external memory easy to program is of benifit to the NPSC.

2.3.3 Wireless technology

Different types of wireless technologies allow devices to commnunicate to each other wirelessly. The Institute of Electrical and Electronics Engineers (IEEE) has grouped them in the 802.15 technologies. Among these are the well known Wifi, the cellular machine to machine (M2M), the mesh network using **ZigBee**, **Z-wave** ... and bluetooth. The NPSC needs to make of an wireless connection to communicate with a smartphone application. The appropriateness of the technologies listed bellow for the NPSC must be analysed. Wifi is power efficient, inexpensive; however, the samrtphone communicating with the NPSC will require to be connected to the same wifi. Moreover, a web application might need to be designed as a platform for the NPSC, this will raise security unecessary issues that we would not be able to explore to the time constraint of the project. Cellular machine to machine has one main drawback, its reccuring cost. As its name indicate, this technology is to send informations from a machine to another machine and is not optimal for a graphic design platform[2]. Mesh networks are optimal for interaction of device/machine of the same kind (not a requirement), the NPSC does not fall into that category. Bluettoth is designed for short range communication (the typical distance is arround $10m^3$)being in almost all smartphones it has been extensively used by embedded systems device such as handset, bluetooth speakers. It has a full duplex communication with synchronous and asynchronous channel. Using bluetooth, the NPSC will not require any network or incur any recurring cost to the user.

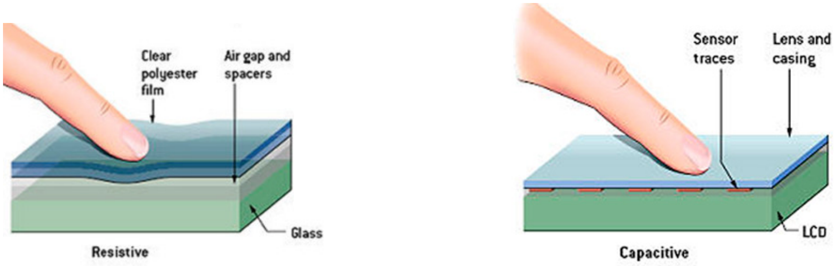
2.3.4 Touch screen

A touch-screen device can locate the position of a point of contact on its screen. The idea of a using contact presure of a object in application was initially from Hugh Le Caine with his Electronic Slackbut capable of change the volume of musical notes based on the amount of pressure applied to the keys. Later in 1969, E. A. Johnson created two major touch-screen technologies using a resistive and a capacitive approach.
Figure 2.4 illustrates the following explanation. Resistive touch-screens are made out of many layers among which two are composed of indium-tin oxide (ITO) which is highly resistive and transparent. By applying pressure on one of the layer, the layers come in contact creating a signal that is used to find the location of the point of contact. Capacitive touch-screens on the other hand make use of the conductivity of the object in contact with the screen to affect the electrostatic field between the ITO layers.
Resistive touch-screens are less complex than capacitive touch-screen, thus cheaper. Additionally, because they relie on pressure, any object whether conductive or not can be used on the screen which is made to be robust. However, resistive touch-screen do not support multi-touch and have poor contrast becaused of the extra layer used to protect the ITO layers.
The NPSC need to have an on-board controller. This controller must be user friendly, with the different features of the NPSC, a touch-screen is desirable over a controller with physical button. A resistive touch screen would add to the robustness of the NPSC as a whole.

2.3.5 Neopixels

The neopixel is an intelligent programmable light source using a MCU to control a RGB or RGBW. Each colour is capable of producing 255 brightness levels resulting in 16777216 different RGB colours. The light characteristics of the neopixel of choice are

[2]having a phone or web application that make use of this would be horrible
[3]can be increased by increasing the transmission power



(a) Resistive touch-screen technology[28]. (b) Resistive touch-screen technology [29].

Figure 2.4: Touch-screen technologies

presented in table 2.2. The light requirement of the NPSC is the emmission of light of $460nm$ (blue light) at an illuminance of $30lux$ minimum. The illuminance of a light

Emitting colour	**Wavelength (nm)**	**Luminous intensity (mcd)**	**Colour temperature (K)**
Red	620-630	390-420	N/A
Green	515-525	660-720	N/A
Blue	460-470	180-200	N/A
Natural White	N/A	N/A	4000-4500

Table 2.2: Light specification of the SK6812RGBW neopixels

source at a point is given by:

$$E_{v(lx)} = \frac{I_{v(cd)}}{d_m^2} \tag{2.1}$$

eq. (2.1) is the illuminance directly in front of the light source. **Lambert's Cosine Law** says that the illuminance *is directly proportional to the cosine of the angle made by the normal to the illuminated surface with the direction of the incident flux.* [38], mathematically it means:

$$E_{v_1} = E_v * \cos(\theta) \tag{2.2}$$

with θ, the angle between the direction of the incident light and the surface normal.
The dimension to be considered for the calculatio of the illuminance of the neopixel ring are shown in fig. 2.5. Using the dimension from fig. 2.5 and the intensity from table 2.2 for the blue light, the total illuminace of the rings at a specific distance can be calculated using the following equation:

$$E_{v_{total}} = N * Ev * (\cos(\theta_1) + \cos(\theta_2) + \cos(\theta_3)) \tag{2.3}$$

The result of the calculation are tabulated in the **??**. The NPSC will not meet the light requirement if the it is placed more than one meter away from the subject.

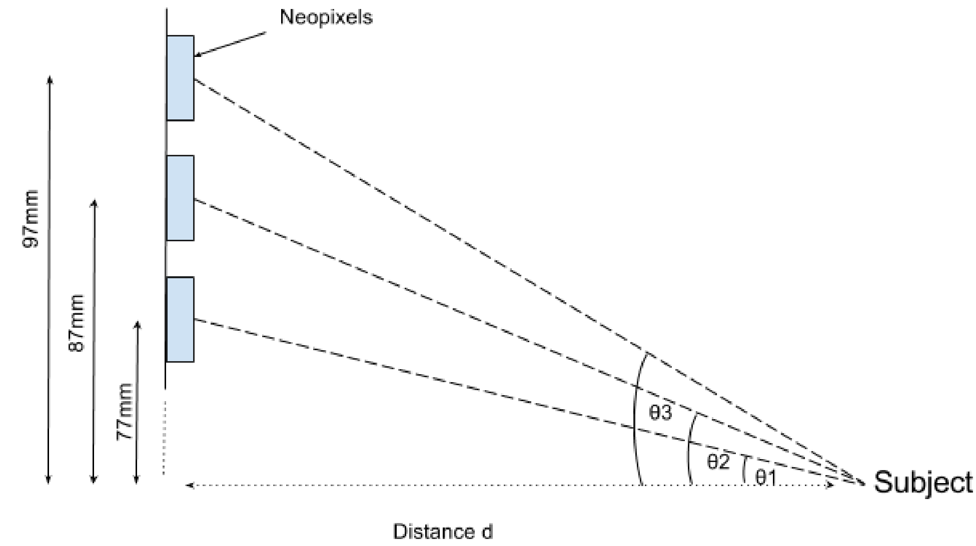


Figure 2.5: Relative position of the neopixel rings

Distance (cm)	Illuminance (lux)	
	no angle consideration	with angle
30	360	345.62
40	202.5	197.82
50	129.6	127.66
60	90	89.06
70	66.12	65.61
80	50.63	50.32
90	40	39.81
100	32.4	32.28
110	26.78	26.69

Table 2.3: Illuminance of the neopixel ring for distance ranging from 30cm to 110cm

2.4 Communication protocols

The NPSC requires different integrated circuits using various communication protocols, below is the a breif on the use of the protocol required.

2.4.1 Serial Peripheral Interface (SPI) Bus

SPI is a synchronous full duplex serial communication protocol used for short distance communication of electronic devices. With the protocol, one master can communicate to many slaves using a chip select pin (use to select the slave) but a slave can only talk to the master device. SPI uses 4 signals namely, the Master Out Slave In (MOSI), the Master In Slave Out (MISO), the clock (SCK), and the slave select or chip select (SS). Since SPI uses a clock, it does not require the configuration of a baud rate before communication. The main inconvenience with SPI is the number of pin require for a one to one communication, for every additional slave, the master must provide a SS pins which make SPI not the ideal protocol for communicating to multiple slaves devices [30].

2.4.2 Universal asynchronous receiver-transmitter (UART)

UART is a asynchronous full duplex communication protocol making use of two signals a transmit signal (TX) and a receive signal (RX). With UART, both devices need to agree on a baud-rate for communication, this rate define the number of bytes to be sent and received. The problem with UART is the complexity of the protocol required to ensure synchronous communication and correct transfer of information between device. Although theoretically UART baud-rate is infinite, it is practically limited to 230400 bits per seconds [31].

2.4.3 Inter-Integrated Circuit (I2C)

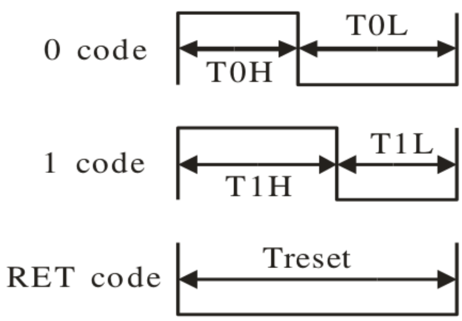
I2C is a serial protocol that allows communications fom multiple slaves to multiple masters. It takes a bit of both SPI and UART by being designed for short distance communication and requiring only two pins, namely the data line (SDA) and clock line (SCL). Its clock ranges from $100kHz$ to $400kHz$ and a bytes is sent at a time. Furthermore with the I2C protocol, each slave must have a unique address used by the master for communication [32].

2.4.4 Neopixels serial protocol

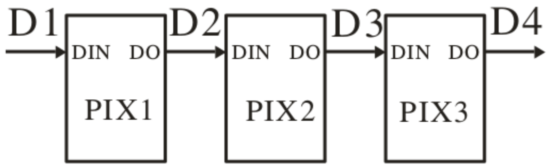
Each neopixel has a built-in IC controlling the LEDs' intensity based on the data received. The neopixels use a single wire communication protocol. The neopixels can be connected to form a daisy chain (cascade)fig. 2.6c allowing the programmation of a serie of neopixels using one signal. Each neopixel requires 24 Bytes (32 Bytes for RGBW LEDs), each bytes is an encoded bit using a Non-Return-to-Zero encoding fig. 2.6a. On receiving a sequence of data, the first neopixel in the chain takes the first 24 bytes and passes the rest of the data to the next neopixel in the daisy chain and so for. This operation continues until a *rest signal* is received by the first neopixel fig. 2.6c. This is possible because each neopixel is capable of reshaping the incoming signal preserving the integrity its integrity of continous transmission.

2.5 PCB Board Design

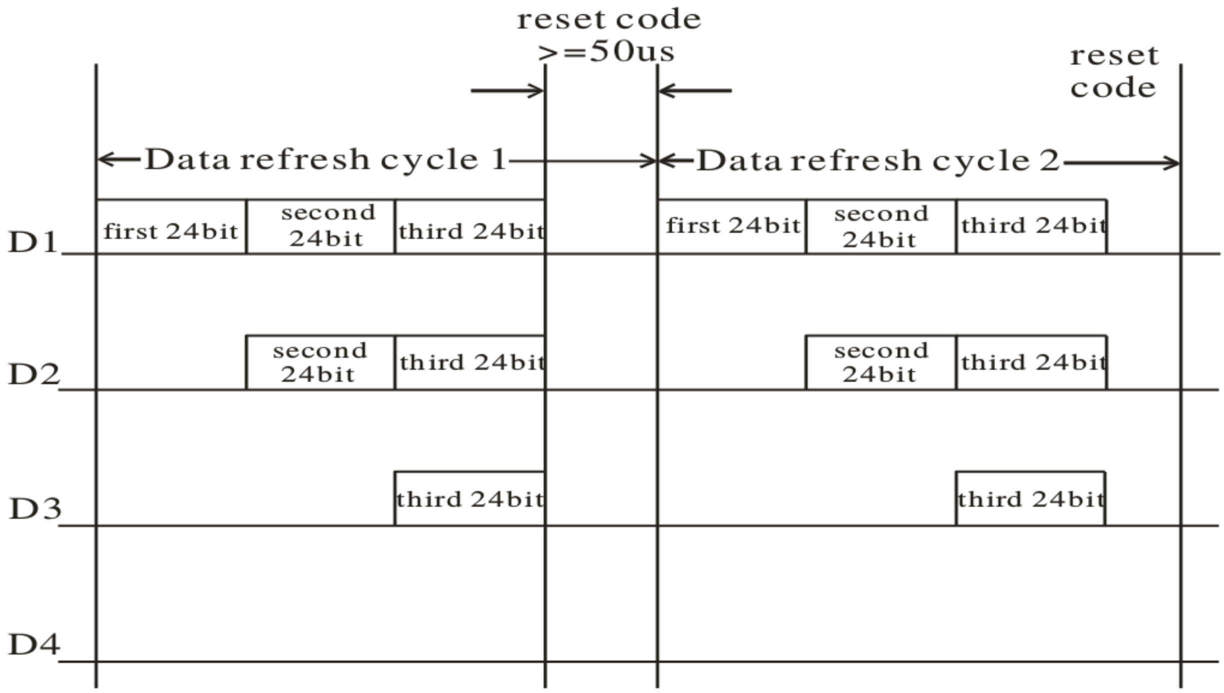
PCBs are almost present in every electronic circuit as they hold all the components together and implement the electricla connections in a elegant fashion. Designing a PCB is a process easily prone to errors, therefore a good PCB design requires the implementation of the design steps. Figure 2.7 illustrates an examples of the ideal pcb design steps. In making the NPSC PCBs these steps give an engineering approach that



(a) Non-return-to-zero encoding of a single bit in the neopixels programming protocol



(b) Neopixels connected in daisy chain (cascade).



(c) As the first neopixel receives a stream of multiple 8 Bytes chunck of data, it takes the first 8 Bytes from the stream and transmit the rest to the next neopixel in the cascade. A rest signal indicates where the stream of data ends.

Figure 2.6: Illustration of the neopixels serial interface

can be elaborated further based on the PCBs requirement. For example, the designer might question what is the best placement for certain component and thus be referred to some PCBs design standards such as the IPC2221.

One important design requirement (need) for the NPSC light requirement is its theoretical current ($10A$) drawn at full pixel brightness. The board-level diagram of the NPSC ring (*qoute pcb ring from design section*) of the neopixel board should therefore be designed so that the track are wide enought to dissipate all the heat evenly across the board. The **IPC2221**, a generic standard for printed board design published by the *Association Connecting Electronics Industries* [33] describes a method for finding the mininmal width track given a specific current (see fig 6-4 from the IPC2221 [33](pp. 41)). A Javascript program based on the IPC2221 standard can be easily use to determine the track width [34]. This web application use the track cuurent, thickness, temperature rise, ambient temperature and track lenght as input to determine the required track width.

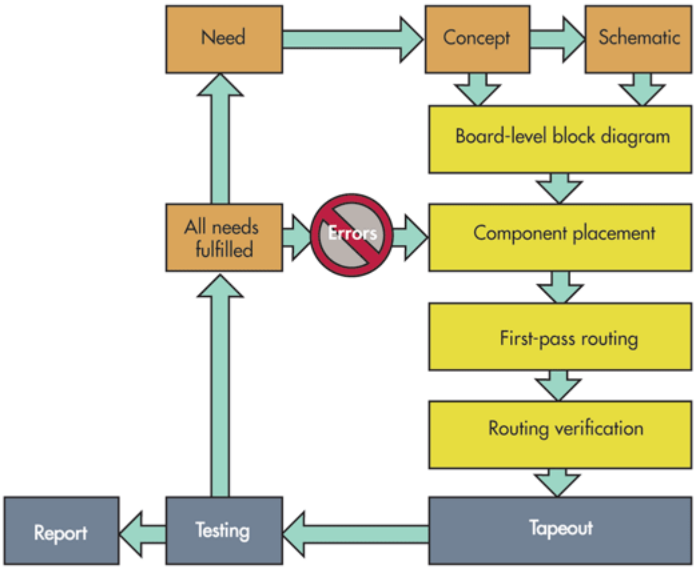


Figure 2.7: Ideal PCB design flow, starting from the need, followed by the design, implementation and testing

2.6 Programming Languages

Choosing the right programming language for software development is a crutial step, expecially in embedded system design as carefull manipulation of memory is required. The languages below are the ones chosen for the development of NPSC.

2.6.1 C

C is a mid-level programming language [4] providing the ability to get close to the hardware while keeping some abstract layers for programming [35].It has an easy and straight forward syntax compared to languages such as Java, C has accumulated a lot of support and has lots of functions and documentation. Although C does not support Object Orientated Programming, it is a Procedure Orientated Language (POL) which means it is designed to create programs that follow an algorithm. This latter feature of C make it the favourite programming language for Embedded System.

2.6.2 Java

Java is one of the most popular programming languages. It is an Object-Orientated programming language unlike C, enabling program to be more abstract and modular

[4]has the advantages of both ligh and low level language

[36]. Java is multithreaded, this feature is essential in the development of smartphone applications as they are inherently multithreaded. In Andrioid application development, Java is still the most common and has a great communities and great tutorial decreasing development time.

2.7 Software Tools and Libraries

Developing an embedded system software can be quite frustrating, for this reason tools with decent debugging features and programming interface should be chosen to reduce development to its minimal.

2.7.1 Atollic TrueSTUDIO for ARM

Atollic TrueSTUDIO is an IDE based on Eclipse. It comes with the GCC toolchain for ARM and with debugging features beuilt on top of GDB. It has more advanced features compared to Eclipse in the development embedded system application. Its debugging features include the use of any debug probe compatible with the GDB-server, P&E Micro, SEGGER J-Link / J-Trace, ST-Link, OpenOCD are all supported by Atollic TrueSTUDIO. It supports debugging of single and multi core devices and allows real time view of memory mapping, peripheral registers, advanced visualisation of variable and complex break point, CPU fault analysis and many more. Another important debugging feature of Atollic TrueSTUDIO is the instruction tracing and system analysis real time event analysis of Real Time Operating System [39].

2.7.2 Nextion IDE

Nextion IDE is the official IDE designed for programming any Nextion HMI touch-screen. The IDE allows the designed and programmation of a GUI interface and the definition of serial commands to be sent to a MCU. Nextion IDE is designed to reduce significantly development time of touch-screen interface in an embedded system project [40].

2.7.3 Android Studio

Android Sudio is the official IDE designed for reducing development time of android applications and improve their quality. It uses advanced code completion, refactoring, and code analysis method. With its variety of device simulations, Android Studio allows the developer to test the applicatio on various devices and android version [41].

Chapter 3

Design

3.1 Design scope and scpecifications

Scope and Scpecifications

3.1.1 Scope

3.1.2 Specification

3.1.3 Acceptance test

3.2 Preliminary design

Preliminary design

3.2.1 Modules interaction

3.2.2 Design considerations

Electrical

Communication

Mechanical

Software

3.2.3 Components selection

Microcontroller

Bluetooth

External memory

Sensors

Neopixels

3.3 Emboddiment design

Emboddiment Design

3.3.1 OPM Diagrams

3.4 Hardware Design and Testing

Schematics and hardware testing

3.4.1 Sensors

3.4.2 Neopixel Ring

3.4.3 Neopixel Time and Weekday

3.4.4 Date

3.4.5 EEPROM

3.5 Software Design and Testing

Algorithms and unit tests

3.5.1 Neopixles

3.5.2 Bluetooth

3.5.3 Sensors

3.5.4 RTC

3.5.5 EEPROM

3.6 Setup of Development Environement

Setup of Development Environement

3.6.1 Github

3.6.2 Nextion

3.6.3 Makefile

This is what I did to test and confirm my hypothesis.

You may want to split this chapter into sub chapters depending on your design. I suggest you change the title to something more specific to your project.

This is where you describe your design process in detail, from component/device selection to actual design implementation, to how you tested your system. Remember detail is important in technical writing. Do not just write I used a computer give the computer specifications or the oscilloscopes part number. Describe the system in enough detail so that someone else can replicate your design as well as your testing methodology.

If you use or design code for your system, represent it as flow diagrams in text.

Chapter 4

Implementation and Testing

4.1 Hardware design and testing

Schematics and hardware testing

4.1.1 Sensors

4.1.2 Neopixel Ring

4.1.3 Neopixel Time and Weekday

4.1.4 Date

4.1.5 EEPROM

4.2 Software design and testing

Algorithms and unit tests

4.2.1 Neopixles

4.2.2 Bluetooth

4.2.3 Sensors

4.2.4 RTC

4.2.5 EEPROM

4.3 Setup of development environement

Setup of Development Environement

4.3.1 Github

4.3.2 Nextion

4.3.3 Makefile

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If you use or design code for your system, represent it as flow diagrams in text.

Chapter 5

Results

These are the results I found from my investigation.

Present your results in a suitable format using tables and graphs where necessary. Remember to refer to them in text and caption them properly.

5.1 Simulation Results

5.2 Experimental Results

Chapter 6

Discussion

Here is what the results mean and how they tie to existing literature...

Discuss the relevance of your results and how they fit into the theoretical work you described in your literature review.

Chapter 7

Conclusions

These are the conclusions from the investivation and how the investigation changes things in this field or contributes to current knowledge...

Draw suitable and intelligent conclusions from your results and subsequent discussion.

Chapter 8

Recommendations

Make sensible recommendations for further work.

Use the IEEE numbered reference style for referencing your work as shown in your thesis guidelines. Please remember that the majority of your referenced work should be from journal articles, technical reports and books not online sources such as Wikipedia.

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Appendix A

Additional Files and Schematics

Add any information here that you would like to have in your project but is not necessary in the main text. Remember to refer to it in the main text. Separate your appendices based on what they are for example. Equation derivations in Appendix A and code in Appendix B etc.

Appendix B

Addenda

B.1 Ethics Forms