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INGENIERO ELECTROMECÁNICO

LIGHT SEQUENCE DETECTING CIRCUIT, EMMITED BY A PHONE -CONCEPTION AND REALIZATION OF AN ARDUINO SMART PHONE BASED ON LIGHT COMMUNICATION FOR SECURIY PURPOSES-

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-CONCEPTION AND REALIZATION OF AN ARDUINO SMART PHONE

BASED ON LIGHT COMMUNICATION FOR SECRURITY PURPOSES-

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LIGHT SEQUENCE DETECTING CIRCUIT, EMMITED BY A PHONE
CONCEPTION AND REALIZATION OF AN ARDUINO SMART PHONE BASED ON LIGHT
COMMUNICATION FOR SECURIY PURPOSES

AUTHOR: BRESSEL LARRÚ, ANA
DIRECTOR: PROF. DR. BLAKENBACH, KARLHEINZ
COLLABORATIVE ENTITY: HOCHSCHULE PFROZHEIM

Digital technology is getting into every possible field of life. Nowadays the trend is to connect every system and gadget to each other in order to work together. This has been also implanted in houses by developing home appliances to be used and controlled automatically or remotely by a smart phone or a computer. It is commonly denominated as Home Automation.

Security is considered by Maslow as one of the basic needs for a person and therefore it must be covered. This project is going to be focused on the last mentioned application, security, and specifically in doors and lockers. Is needed in many occasions to implement new security systems. In this project it is going to be designed and implemented one system based on a light code.

The aim of this project is to design and implement a new door opening system. In order to make a better approach to the product that is going to be developed, it is going to be studied the market characteristics, where is going to take part.

This product is oriented to a global market. It can be implanted in every place that requires a door with key to make a physical division between two environments.

As any new product that wants to enter into a market, is necessary to study some topics before deciding to launch it or not. Based on Michel E. Porter's book "Estrategia Competiva", there are four categories to analyze: substitutive products, providers, clients and potential competitors.

Substitutive products: are those of them which are currently in the market. In our case are Regular keys, remote controls, magnetic keys, magnetic cards, NFC, biometric access control tools, …

Provider: is the person or organization that will really give the means to develop the product.
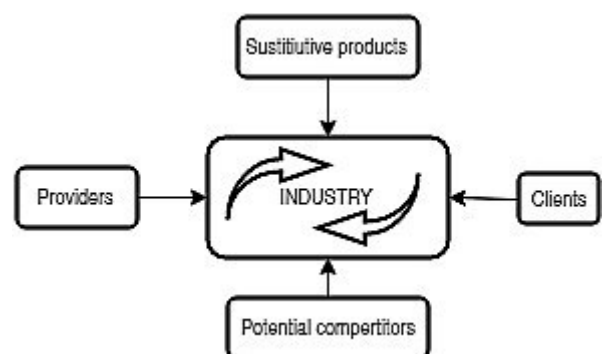
They are the ones to negotiate with. There can be distinguished into different categories, for example, material providers (like the Arduino company), electronics shops, engineers, programmers,.. Also for our product smartphones are going to be required, so it's the client the direct provider of them.

Clients: they have also a negotiation power in the market. The main clients of product are buildings architects or buildings administrators. The first one if he is looking for a new security system in a building, and the second one if he wants to update the current security systems he has in a cheap and effective way.
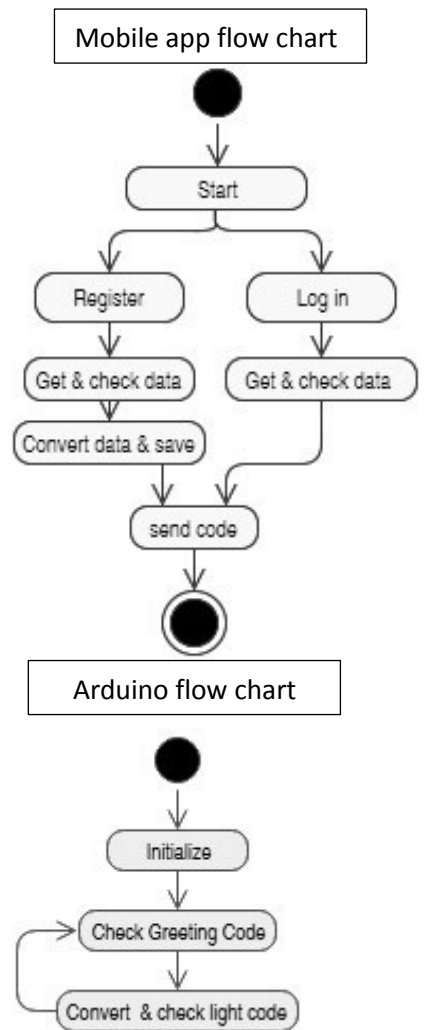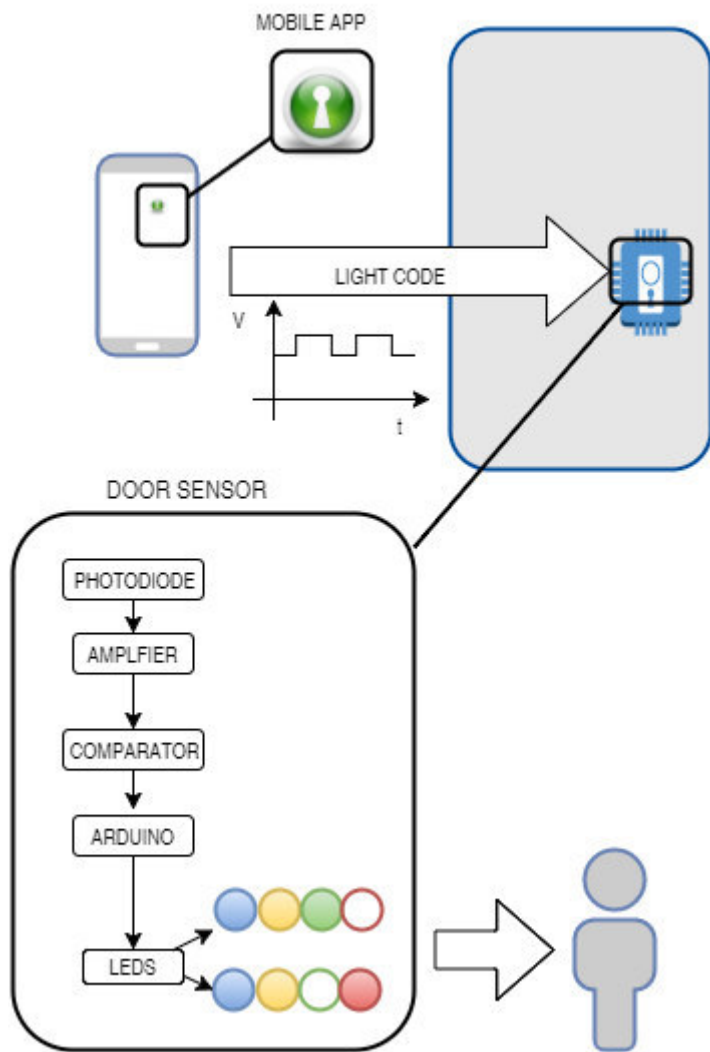
Potential competitors: they set the risk of new companies' appearance. These are the other available technologies like infrared technologies, Bluetooth, WLAN, ZigBee, NFC,… To sum up all existing short range WLANs.

The main entrance barrier to get into the market is that, it is saturated. However, the proposed product can be able to go over this problem. Because it is a low cost product, it can be set up in all existing wired doors, and it is adaptable to each "building administrator" necessities. It can be set the desired level of security .

In resume, the aim of this project is to:

- Develop and implement an app to send a light code.
- Develop and implement receiver that can process the received light information and send a signal to the user using an Arduino.

Therefore, an app will be designed to emit the light signal using a smartphone screen. This will be received in a photodiode and amplified by a physical circuit. The smart-phone should give one determined sequence that the Arduino compares with its data base, and allows or denies the user to get in. It is oriented to open a garage door.

MOBILE APP

LIGHT CODE

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t

DOOR SENSOR

PHOTODIODE

AMPLFIER

COMPARATOR

ARDUINO

LEDS

Mobile app flow chart

Start

Register Log in

Get & check data Get & check data

Convert data & save

send code

Arduino flow chart

Initialize

Check Greeting Code

Convert & check light code

1

[1] Green locker: [Online]. Available: http://cdn.mysitemyway.com/etc-mysitemyway/icons/legacy-previews/icons-256/3d-glossy-green-orbs-icons-business/103397-3d-glossy-green-orb-icon-business-key-hole-sc48.png

To sum up: a secure method as new control access tool has been developed. It works with regular illumination inside a building. May present some problems if it the photodiode is receiving directly sun light, therefore will be designed a cover in order to prevent this behavior.

It could have been used another types of operational amplifiers in order to use less space and components.

The Arduino microprocessor is able to receive and recognize several codes. This is usual for a regular door with many users like a garage door. This method can be also applied for hotels rooms. In this case, it will be used the same method but working with one photodiode per door.

It will be also possible to implement it simultaneously in several buildings. It will be needed just to duplicate the app, and making slight changes in the code.

Respect to the mobile app, it has been encrypted the user data saved in the mobile phone. To increase the system security it will be necessary to obfuscate the .bas file code.

CIRCUITO DETECTOR DE UNA SECUENCIA DE LUZ, EMITIDA POR UN TELÉFONO MÓVIL
CONCEPCIÓN Y REALIZACIÓN DE UNA COMUNCACIÓN POR LUZ ENTRE UN ARDUINO Y UN SMART PHONE PARA SISTEMAS DE SEGURIDAD.

AUTOR: BRESSEL LARRÚ, ANA
DIRECTOR: PROF. DR. BLAKENBACH, KARLHEINZ
ENTIDAD COLABORADORA: HOCHSCHULE PFROZHEIM

La tecnología digital se está implantando en todos las actividades cotidianas. Ahora la tendencia es conectar cada conjunto de sistemas y equipos entre sí para poder trabajar conjuntamente. Se ha ido desarrollando en diversas aplicaciones domésticas para ser controladas automáticamente o de un modo remoto por un ordenador o Smart-phone. Es lo que comúnmente se conoce como domótica.

La seguridad es considerada por Maslow como una de las necesidades básicas de la persona, y por lo tanto debe ser cubierta. Este proyecto estará enfocado en esto último, seguridad, y específicamente en puertas y cerraduras. En muchas ocasione es necesario crear nuevos sistemas de seguridad. En este proyecto se va a diseñar e implementar un sistema basado en un código de luz.

El objetivo de este proyecto es diseñar un Sistema de apertura de puertas. Para poder tener una mejor idea de lo que se va a desarrollar, se estudiará las características del mercado donde se querría implantar.

Este producto está dirigido a un mercado global. Puede ser implantado en cualquier lugar donde sea necesario tener una puerta con una llave, para tener una división física entre dos ambientes.

Como cualquier nuevo producto que quiere entrar en el mercado, es necesario estudiar algunos aspectos antes de decir si lanzarlo o no. Basándose en el libro "Estrategia Competitiva" de Michael E. Porter, se van a analizar distintas categorías: productos sustitutivos, proveedores, clientes y competidores potenciales.

Productos sustitutivos: son aquellos que se encuentran actualmente en el mercado. En nuestro caso se trata de las llaves normales,
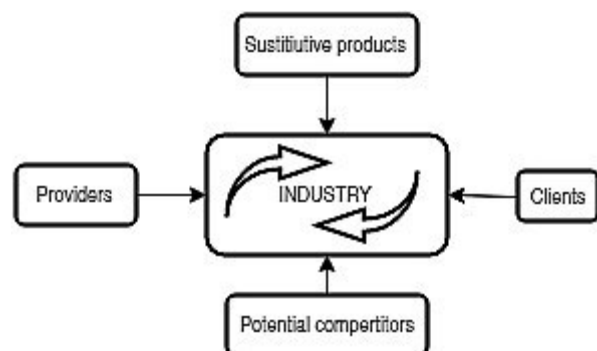
llaves y tarjetas magnéticas, NFC, métodos de control de acceso por biometría,…

Proveedor: es aquel que realmente proporciona los medios para desarrollar el producto. Son aquellos con los que se debe negociar. Se pueden distinguir distintas categorías, por ejemplo, proveedores de material (como la empresa Arduino), tiendas de componentes electrónicos, ingenieros, programadores,… Para nuestro producto también se necesitarán Smart-phones, por lo tanto, algunos clientes pasan a ser proveedores.

Clientes: también toman parte en la negociación. Los principales clientes en los que el producto está orientado son: el arquitecto y el administrador de la vivienda. El primero, si se encuentra buscando un nuevo sistema de seguridad para la vivienda, y el segundo si quiere actualizar el actual sistema de seguridad que tiene implantado.
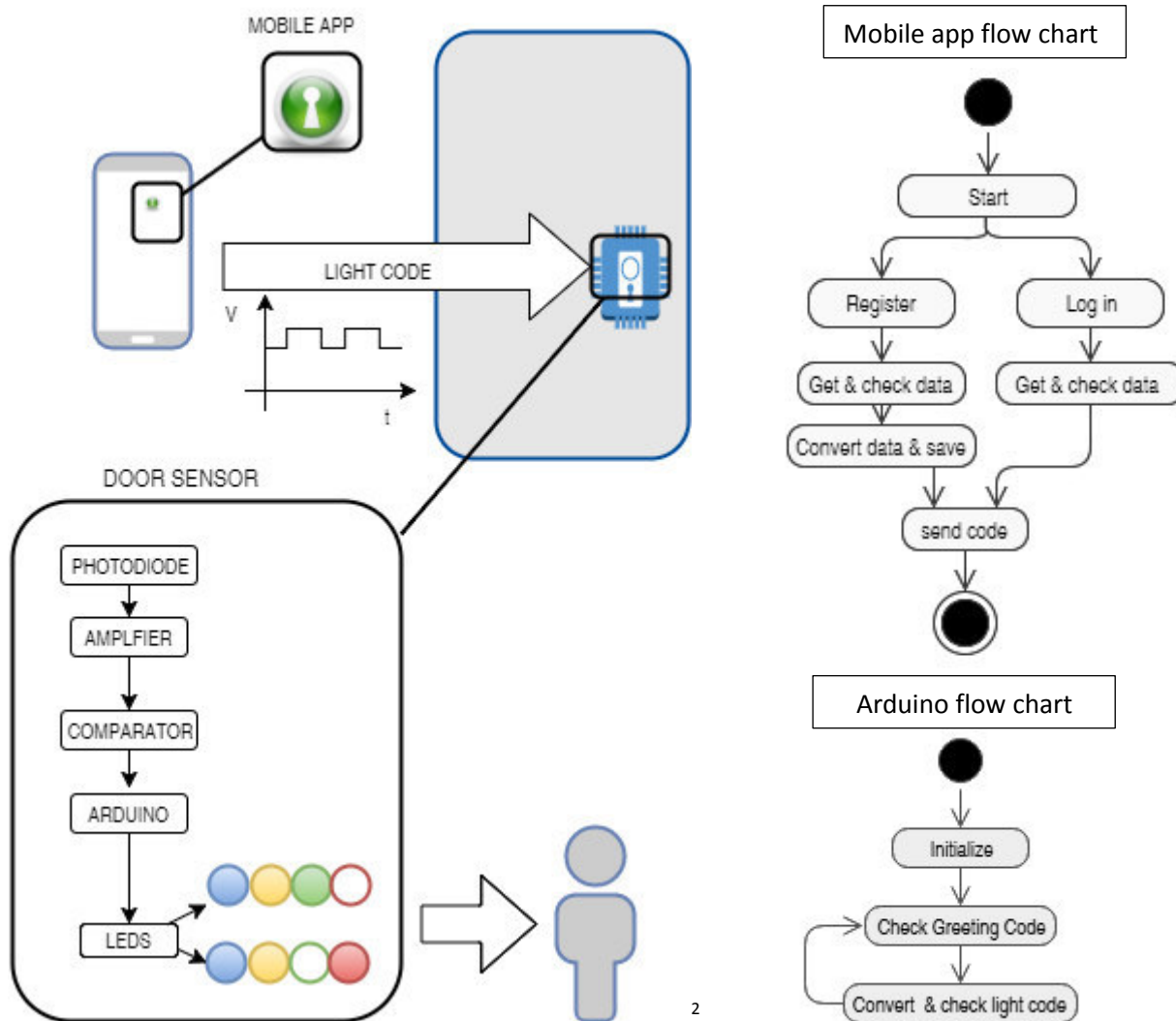
Competidores potenciales: son los que ponen en riesgo la aparición de la nueva empresa. Estos son las actuales tecnologías disponibles como por ejemplo: transmisión por infrarrojos, Bluetooth, WiFi, ZigBee, NFC,…En resumen, todas la WLANs de corto alcance.

La mayor barrera de entrada para llegar al mercado es que este se encuentra saturado. Sin embargo el producto propuesto puede superarla, ya que es de bajo coste, se puede implantar en todo tipo de puertas cableadas, y es adaptable a cualquier necesidad del administrador de la vivienda.

En resumen, el objetivo del proyecto es:

- Desarrollar e implementar una aplicación para enviar un código de luz.
- Desarrollar e implementar un receptor que puede procesar la señal de luz recibida y enviar una señal al usuario, empleando un Arduino.

Por lo tanto, será diseñada una aplicación para emitir un código de luz utilizando la pantalla de un Smart pone. Esta señal será recibida en un fotodiodo y amplificada por un circuito físico. El Smart-phone debe de trasmitir una determinada secuencia, que el Arduino comparará con su base de datos, y aceptará o negará la entrada del usuario. Está orientado para abrir la puerta de un garaje.

MOBILE APP

LIGHT CODE

DOOR SENSOR

PHOTODIODE → AMPLFIER → COMPARATOR → ARDUINO → LEDS

Mobile app flow chart

Start → Register / Log in

Register → Get & check data → Convert data & save

Log in → Get & check data

send code

Arduino flow chart

Initialize → Check Greeting Code → Convert & check light code

En conclusión: se ha realizado un nuevo método seguro como herramienta de control de acceso. Funciona con iluminación normal dentro de una vivienda. Puede presentar problemas si incide directamente sobre el fotodiodo luz solar, por lo que debería diseñarse una carcasa para prevenir este tipo de comportamiento.

Se podría haber empleado otro tipo de amplificadores operacionales para reducir el espacio empleado y los componentes usados.

El microprocesador del Arduino es capaz de recibir y reconocer diferentes códigos. Como es normal para una puerta con muchos usuarios. Este método también puede ser aplicado a las

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[2] Green locker: [Online]. Available: http://cdn.mysitemyway.com/etc-mysitemyway/icons/legacy-previews/icons-256/3d-glossy-green-orbs-icons-business/103397-3d-glossy-green-orb-icon-business-key-hole-sc48.png

habitaciones de los hoteles. En este caso, sería utilizado el mismo método, por se trabajaría con un fotodiodo por puerta.

También podría aplicarse simultáneamente en distintas viviendas. Sería necesario duplicar la app, y hacer pequeños cambios en el código de la misma.

Respecto a la aplicación del móvil, ha sido encriptados los datos que se guardan dentro del móvil del usuario. Para una mayor seguridad, sería necesario ofuscar el código del archivo .bas.

Content

PART 1: MEMORY

1.1. Introduction

Digital technology is getting into every possible field of life. This is happening, mainly because of its characteristics. For example, it is immaterial, which makes it easier and cheaper to make changes. Due to this fact, it is able to be carried or sent anywhere. All devices that we use in our everyday life whether it is a washing machine or a smart-phone have something in common, they have the same basic underlying principle. They execute, send or receive different type of codes, but every code is just a bunch of zeros and ones, which in a proper order can give some kind of logic to a system.

Nowadays the trend is to connect every system gadgets to each other in order to work together. This has been also implanted in houses by developing home appliances to be used and controlled automatically or remotely by a smart phone or a computer. It is commonly denominated as Home Automation.

Some of its applications are: Heating, ventilation and air conditioning (HVAC), lighting control system, leak detection, smoke and CO detectors, remote surveillance of security cameras over the Internet, or central locking of all perimeter doors and windows.

Security is considered by Maslow as one of the basic needs for a person and therefore it must be covered. This project is going to be focused on the last mentioned application, security, and specifically in doors and lockers.
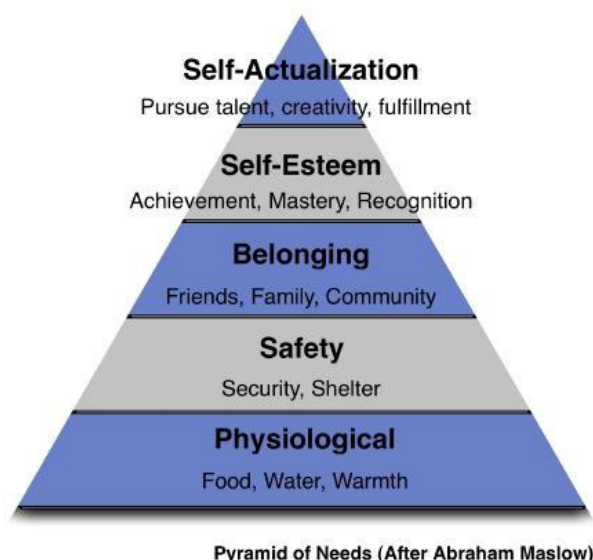

Figure 1.1.1: Pyramid of Needs[1]

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[1] [Online]. Available: http://davidhuerta.typepad.com/.a/6a01347ff0d110970c0133ed52754d970b-800wi

1.2. State of art

As far as the electronic security in systems are considered to be part of home automation, some systems are going to be explained related to them. Some existing communications protocols, mostly used in Home Automation are also going to be studied and compared.

1.2.1. Introduction to Domotics and Building automation

In this chapter, it is going to be introduced the concepts of home and building automation. Both of them are quite recent concepts. But they are needed to be taken into account to understand the project view.

Domotics

Domotics or house automation is a combination of diverse technologies applied to the intelligent control and automatization of a home, which enables an efficient energy management; gives the user security and comfort, and establishes a communication between the user and the system.

The domotic systems control net is integrated in the electrical net and all its derivate nets: phone and television networks, and information technologies (IT).The different networks coexist in the same building, each one is ruled by its own norm. Specifically home automation networks in Spain are ruled by ITC-BT-51(Systems automation installation, technical energy management and homes and buildings security).

A domotic system is capable to collect information that comes from sensors or inputs, process it and emit orders to some actuators or outputs. Home automation systems have been designed to increase life quality levels of its user through five main points:

1. **Saving energy**. Through home automation air conditioning, lighting, house appliances, hot water,… systems are managed in an intelligent way. If it is made a better use of natural resources and used lower hourly rates cost, it is possible to obtain a lower cost energy bill. Besides the previous benefits, through consume monitoring is obtained the information needed to change customs. This way, savings and efficiency will be increased.

2. **Accessibility.** Home automation should simplify the use of the house elements to people with disabilities. It will be adjusted in the best way to their necessities. It also aims to offer remote assistance services for those who need it.

3. **Communication.** Communications will be guarantee by means of remote control and supervision of the building through a smartphone or PC. Domotic installations allow voice and data transmission. This includes text, images, sounds or multimedia, using local networks (LAN) and sharing Internet access.

4. **Security.** It is implanted by means of intrusion controls, automatics lockers, dynamic presence simulation, security cameras, personal alarms,... All technical alarms to detect fire, gas escape, leaks, fails in the electrical supply,... will also form part of the security characteristic of the home automation.
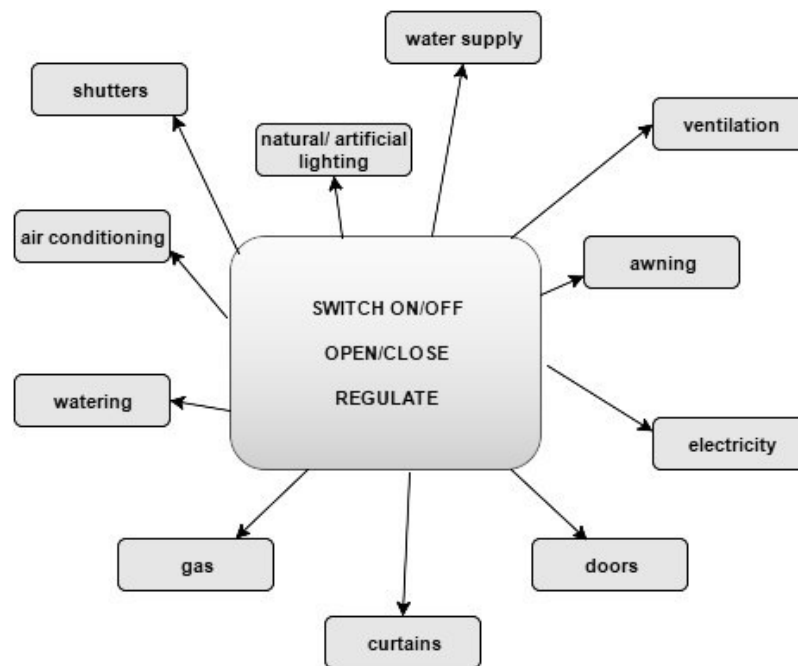
Figure 1.2.1: Comfort activities

5. **Comfort.** Living in a home will be more comfortable for their users by the management of devices and house holding activities. Home automation enables the user to do the usual house holding activities, but in a more comfortable way. These activities can be: opening, closing, switching on and off, regulating,... the air conditioning, ventilation, natural and artificial lighting, shutters, awning, doors, curtains, watering, gas, electricity and water supply,...(see Figure 1.2.2)

To sum up the characteristics is going to be used the following image (Figure 1.2.3.).
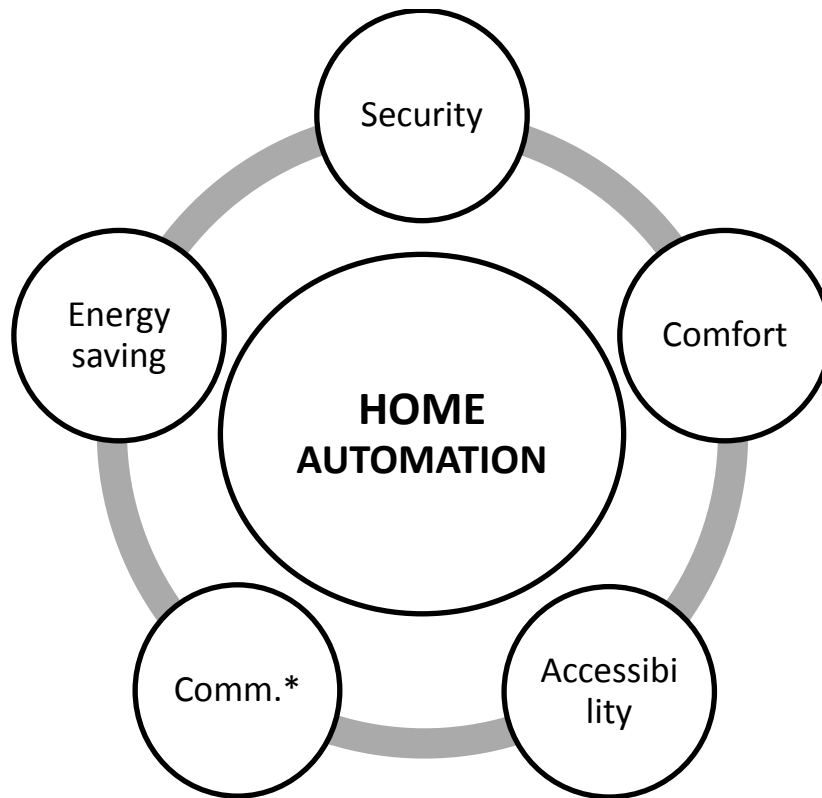
*Communication

Figure 1.2.2: Home automation characteristics

Besides the previously mentioned characteristics, domotics helps infrastructures introduction and the development of new scenarios that grow together in the information society.

- Maintenance: with the capacity of adding equipment tele-maintenance
- Leisure and free time: resting and having fun with radio, television, multiroom, cinema directly in the users' home. Capture, treatment and distribution of static or dynamic images and sounds (photos, videos and music) inside and outside home.
- Communication: all the current communication means from a current house nowadays trend to be operated by the same telephone company, and it is the one responsible for this aspect.
- Health: domotics helps in healthiness with sanitary assistance, nutritional consultancy, tele-control and heath alarms, medical care,…
- Sale and purchase: directly from home, also including finances consultancy, and managing banks accounts.

- Learning and Working: in an easier way through some home automation devices. Also providing information about public administration and other activities like visiting museums, libraries,… On the other hand the common activities of checking the meteorology or having a newspaper available will be set. [1]

All these topics and more will be taken into account by the home automation designers.

Home automation installations can be classified attending to many criteria. Taking into account the domotic systems management are distinguished centralized and decentralized/distributed systems.

- **Centralized systems**: this type of systems requires a specific installation. That is the reason why a house with this type of system is more expensive than a conventional installation. The domotic systems centralization has two main drawbacks. Firstly, it requires large wire amounts between sensors, actuators, and the central control unit. Secondly, the possibility, if the central control fails of crashing the whole system is also present. So this kind of option is not presently used.

- **Decentralized or distributed systems.** They do not have a single device which takes all decisions. Instead, there are many *devices* all around the installation. All of them can sum their sensors information, process it, and, if necessary, send it to another device or even though control its belonging actuators. The physical installation is much simpler compared to the centralized systems. Any change made in the installation (adding or removing elements) is much easier. Another advantage of this system is that, a failure in one or its control units, will not *kill* all the installation, but just part of it. [2]

Home automation trend has followed distributed systems mode, due to its advantages compared to the centralized one, for example:

- Better response to break downs because the whole system does not break down just by one control element failure.

- Less cable: all connections between sensors and actuator do not take place in a central unit, but in the closest process unit or the most directly related. Between the different distributed units is just connected a communication bus (supposed not wireless connection).

- More facilities to making changes in the installation, adding or removing elements.

Building automation

Building automation is the combination of technologies applied to the control and intelligent automation of buildings not destined to become homes, like hotels, shopping centers, schools, universities, hospitals and any tertiary building. Enabling an efficient energy management from the building and contributing to the security, comfort and communication between user and system.

Equipment and Building Automation and Control Systems (BACS) provide effective control functions for the heating, ventilation, refrigeration, hot water, lighting, … This leads to a higher operational and energy efficiency. Functions and routines for energy saving can be programmed based on the real building use. It is adjusted to the actual user needs to avoid unnecessary CO_2 emissions or energy consume.

Technical Building Management (TBM) functions as part from Building Management (BM), provide information about the running, maintenance, services and management of an edifice. The token information is relevant to energy managing, trends record measuring, alarms generating and needless energy consuming.

The functions which have an effect on building energy efficiency are divided into three main groups: automatic regulation functions, building automatization and control systems functions and technic building management functions.

The **automatic regulation functions** are:
- Heating and refrigeration regulation.
- Air conditioning and ventilation regulation
- Lighting control
- Shutters control

Buildings automation and control functions: Building automatization system is central adapted to the user needs. For example: timetable programs.

Building technical management with efficiency energy functions:
- Failure detection in buildings and its technical systems.
- Information presentation about energy consumption, interior conditions and improvement possibilities.

The use of BACS generally leads to an energy efficiency improvement. Control equipment automation provides the opportunity of saving energy compared to manual (not automated) occupant intervention. The energy saving effect due to the BACS application could be intensified taking into account complex and integrated control functions.

Integrated building automation and special control functions are described in the following way:

a) Temperature regulation of individual ambient in heating zones. These zones are affected with window contact effect.

b) Light and shutters optimized control. [3]

1.2.2. Some examples related to Home and Building automation systems

All these examples have been extracted from the book:

Therefore they are focused on ZigBee systems, but they can help us to understand the many applications. Most of them can be extrapolated for the medium and low rate LANs. Home automation is one of the major applications for ZigBee wireless networking. The typical data rate in home automation is only 10kbps. Figure 1.2.4 shows some of the possible ZigBee applications in a typical residential building. Most of the applications shown in figure 1.2.4 are briefly reviewed in this chapter.

Security systems

A security system can consist of several sensors, including motion detection, glass-break sensors, and security cameras. These devices need to communicate with the central security panel through either wire or a wireless network. ZigBee-based security systems simplify installing and upgrading security systems. Despite ZigBee's low data rate, it is still possible to transfer images wirelessly with acceptable quality. For example, ZigBee has been used in a wireless camera system that records videos of visitors at a home's front door and transmits them to a dedicated monitor inside the house.

Hotel Guest Room Access

ZigBee-based systems can replace the magnetic key card systems used in hotels to access guest rooms. The traditional room access plastic cards have a magnetic strip on theirs back; the card reader installed on the guest door reads the information encoded into the magnetic strip to allow or deny access to the room. Installing this reader for each door requires wiring

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[2] [Online]. Available: http://enerwaveautomation.com/wp-content/uploads/what-is-z-wave/House-Diagram2-1.png

through the door. Alternatively, a ZigBee-based room access system includes a portable ZigBee device that acts as the key a battery-powered ZigBee device inside the door that locks and unlocks it. Unlike the traditional method, the ZigBee-based room access system does not require wiring each door, which reduces the installation cost. [4]

1.2.3. Market study

In order to make a better approach to the product that is going to be developed, it is going to be studied the market characteristics, where is going to take part.

This product is oriented to a global market. It can be implanted in every place that requires a door with key to make a physical division between two environments.

As any new product that wants to enter into a market, is necessary to study some topics before deciding to launch it or not. Based on the book "Estrategia Competitiva" from Michael E. Porter, there are four main categories to be analyzed: substitutive products, providers, clients and potential competitors.
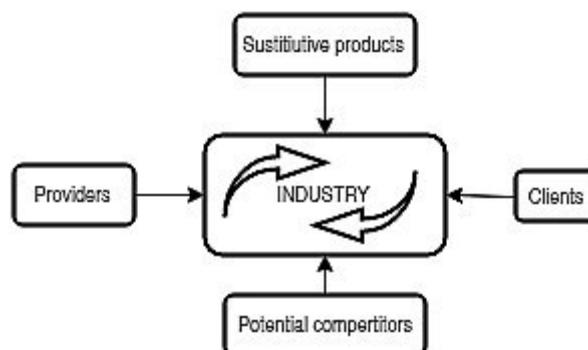
Figure 1.2.4: Market study

Substitutive products: are those of them which are currently in the market. In our case are Regular keys, remote controls, magnetic keys, magnetic cards, NFC, biometric access control tools, …

Provider: is the person or organization that will really give the means to develop the product. They are the ones to negotiate with.

There can be distinguished into different categories, for example, material providers, like the Arduino company, electronics shop,…

Engineers' providers: there are needed engineers or programmers to develop the different applications. Also, engineers are needed to that study where should the new products be

placed in a building. And they are the ones in charge of evaluating and stablishing a security level in the building, and therefore the best products or methods to achieve it.

Also for our product there are going to be needed smartphones, so it's the client the direct provider of them.

Clients: they have also a negotiation power in the market.

The main group, in which the product is going to be focused on are:

The building architect, or the building administrator. The first one if he is looking for a new security system in a building, and the second one if he wants o actualize the current security systems he has in a cheap and effective way.

Also the clients that will benefit of the decisions taken in the building design will be the people that is living there and people that is frequently in the building for working reasons.

Potential competitors: they set the risk of new companies' appearance.

Are the other available technologies like infrared technologies, Bluetooth, WLAN, ZigBee, NFC,… To sum up all existing short range WLANs.

The main entrance barrier to get into the market is that, it is saturated. But the proposed product can be able to go over this problem because:

It is a low cost product, it can be set up in all existing wired doors, and it is adaptable to each "building administrator" necessities. It can be set the level of security desired and also it can be installed in every type of wired door.

1.2.4. OSI

Home and building automation systems need to communicate to each other. As long as they are wireless communication, it is going to be made a little presentation to the OSI reference model. This one is the basic to understand every type of communication between two devices.

Since the exchange of information between communicating partners is complex in structure and difficult to understand, the entire communications process has been universally standardized and organized into individual well-defined hierarchical **layers.**

Each layer, with the exception of the top ones, offers **services** to the layer directly above it (vertical communication). The way these services are implemented is through the passing information between **peer entities** of the respective layer of the communicating systems by means of **protocols**. In this process a layer uses the services of the services of the next layer below it. Therefore within a process each entity communicates directly only with the entity immediately above it or below it. The higher-ranking layer is referred to as the service user and the lower-ranking layer as the service provider.

The hierarchical model facilitates communication between developers, suppliers and users of communications systems. Is a change is undertaken in one of the layers, it does not affect the others. Furthermore, the structure of the layers makes it easier for protocols to be implemented and standardized.

Taking these aspects into account, the International Standardization Organization (ISO) specified a generally accepted layered model, the **ISO/OSI Reference Model**, for Open Systems Interconnection (OSI), a description that refers to almost all the communications systems in use today. This model is called OSI, because it describes the connection of open digital systems compliant with the respective ISO standards.

The OSI model is based on different principles. Each layer carries out a precisely defined function, and each function has been stipulated in the line with internationally standardized protocols. The boundary lines between the individual layers have been established to minimize the information flow over the interfaces. Each higher layer represents a new level of abstraction from the layers below it. To keep the number of layers and interfaces to a minimum, several different functions have also been added to the same layer. A seven layer model (see Figure 1.2.6) was created as a result of these considerations.

The following is a brief description of the different tasks of the seven layers of the OSI Reference Model:

Physical layer: Layer 1 The bit transmission layer (Physical layer) provides the basis for communication and facilitates the transmission of bits over a communications medium. Layer 1 describes the electrical and mechanical characteristics, e.g., standardized plugs, synchronized transmission over cable or radio channels, synchronizing techniques, signal coding, and signal levels for the interface between terminal equipment and line termination.

Data link layer: Layer 2 The task of the data link layer is to interpret the nit stream of layer 1 as a sequence of data blocks and to forward them error-free to the network layer. Error-detection or correction codes are used to protect data from transmission errors. Thus, for example, systematic redundancy that is used at the receiving side for error detection is added by the transmitter to the data, which is transmitted in blocks (frames).

These frames are transmitted sequentially between peer entities of layer 2. If a transmission error is detected then an acknowledgement mechanism initiates a retransmission of the block and guarantees that the sequence will be maintained.

The data link layer adds special bit patterns to the start and to the end of blocks to ensure they are recognized. Because of flow control on both sides, the logical channel can be used individually by the communicating partner entities.

Layer 2 contains the access protocol for the medium and the functions for call set-up and termination with regard to the operated link.

Network layer: Layer 3 The network layer is responsible for the setting up, operation and termination of network connections between open systems. In particular, this includes routing and address interpretation, and optimal path selection when a connection is established or during a connection.

Layer 3 also has the task of multiplexing connections onto the channels of the individual subnets between the network nodes.

Transport layer: Layer 4 The transport layer has the responsibility from end-to-end data transport. It controls the beginning and the end of a data communication, carries out the segmentation and reassembly of messages and controls data flow. Error handling

and data security, coordination between logical and physical equipment addresses and optimization of information transport paths also fall within the range of this layer's tasks.

The transport layer represents the connecting link between the network-dependent layers 1 − 3 and the totally network-independent overlaid layers 5 − 7, and provides the higher layers with a network-independent interface. The transport layer provides **a** service with a given quality to the communicating applications processes, regardless of the type of network used.

Session layer: Layer 5 The session layer controls communication between participating terminals, and contains functions for exchange of terminal identifications, establishing the form of data exchange, dialogue management, tariff accounting and notification, resetting to an initialized logical check point after dialoguer errors have occurred, and dialogue synchronization**.**

Presentation layer: Layer 6 The presentation layer offers services to the application layer that transform data structures into a standard format for transmission agreed upon and recognized by all partners.

It also provides services such as data compression as well as encryption to increase the confidentially fan authenticity of data.

Application layer: Layer 7 the application layer forms the interface to the user or an applications process needing communications support. It contains standard services for supporting data transmission between user processes (e.g. file transfer), providing distributed database access, allowing a process to be run on different computers, and controlling and managing distributed systems. [5]

USER A — USER B

USER A		USER B	
7	Handles the actual interface with the user's application program	7	APPLICATION
6	Converts codes, encrypts/decrypts, or reorganizes data	6	PRESENTATION
5	Manages dialog, synchronizes data transfers with checkpoints	5	SESSION
4	Provides end-to-end error checking and data segmentation	4	TRANSPORT
3	Establishes logical circuits and routing between two machines	3	NETWORK
2	Controls orderly access to the physical medium	2	DATA LINK
1	Transmits and receives individual bits on the physical medium	1	PHYSICAL

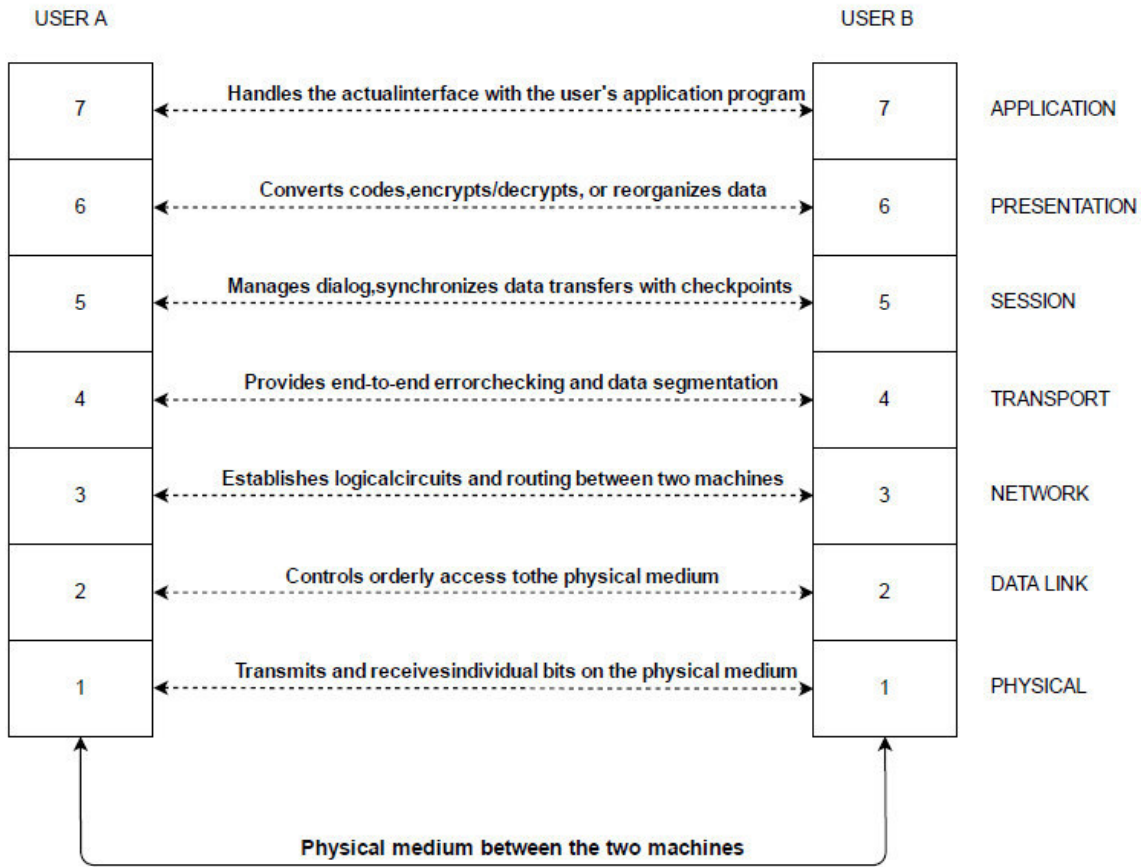Physical medium between the two machines

Figure 1.2.5: OSI Reference Model

1.2.5. ZigBee, WLAN, Bluetooth & Li-Fi

In this chapter are going to be discussed the advantages and disadvantages of this four types of short wireless communication. They are the most used in home and building automation applications, because they can work as short-range wireless networks.

What is ZigBee?

ZigBee is a standard that defines a set of communication protocols for low-data-rate short-range wireless networking. ZigBee-based wireless devices operate in 868 MHz, 915MHz, and 2.4 GHz frequency bands. The maximum data rate is 250 Kbits per second. ZigBee is targeted mainly for battery powered applications where low data rate, low cost, and long battery life are main requirements. In many ZigBee applications, the total time the wireless device is engaged in any type of activity is very limited. The device spends most of its time in a power saving mode, also known as sleep mode. As a result, ZigBee-enabled devices are capable of being operational for several years before their batteries need to be replaced.

The ZigBee standard has adopted IEEE 802.15.4 as its Physical Layer (PHY) and Medium Control Access (MAC) protocols. Therefore, a ZigBee-compliant device is a compliant with the IEEE 802.15.4 standard as well.

The ZigBee standard is specifically developed to address the need for very low-cost implementation of low-data-rate wireless networks with ultra-low power consumption.

The ZigBee standard helps reduce the implementation cost by simplifying the communications protocols and reducing the data rate. The minimum requirements to meet ZigBee and IEEE 802.15.4 specifications are relatively relaxed compared to other standards such as IEEE 802.11, which reduces the complexity and cost of implementing ZigBee compliant transceivers.

What is Bluetooth?

Bluetooth is a global wireless communication standard that connects devices together over a certain distance. Think headset and phone, speaker and PC, basketball to smartphone and more. It is built into billions of products on the market today and connects the Internet of Things (IoT).

A Bluetooth device uses radio waves instead of wires or cables to connect to a phone or computer. A Bluetooth product, like a headset or watch, contains a tiny computer chip with a Bluetooth radio and software that makes it easy to connect. When two Bluetooth devices want to talk to each other, they need to pair. Communication between Bluetooth devices happens over short-range, ad hoc networks known as piconets. A piconet is a network of devices

connected using Bluetooth technology. The network ranges from two to eight connected devices. When a network is established, one device takes the role of the master while all the other devices act as slaves. Piconets are established dynamically and automatically as Bluetooth devices enter and leave radio proximity.

Bluetooth can wirelessly connect devices together. It can connect your headset to your phone, car or computer. It can connect your phone or computer to your speakers. It can connect your lights, door locks, TV, shoes, basketballs, water bottles, toys—almost anything you can think of—to an app on your phone. Bluetooth takes it even further with connecting beacons to shoppers or travelers in airports or even attendees at sporting events. [6]

Wireless Local Area Network (WLAN)

A wireless local area network (WLAN) is a wireless distribution method for two or more devices that use high-frequency radio waves and often include an access point to the Internet. A WLAN allows users to move around the coverage area, often a home or small office, while maintaining a network connection.

In the early 1990s, WLANs were very expensive and were only used when wired connections were strategically impossible. By the late 1990s, most WLAN solutions and proprietary protocols were replaced by IEEE 802.11 standards in various versions (versions "a" through "n"). WLAN prices also began to decrease significantly.

Every component that connects to a WLAN is considered a station and falls into one of two categories: access points (APs) and clients. APs transmit and receive radio frequency signals with devices able to receive transmitted signals; they normally function as routers. Clients may include a variety of devices such as desktop computers, workstations, laptop computers, IP phones and other cell phones and Smartphones. [7]

Li-Fi

Li-Fi (Light Fidelity) is a kind of wireless communication. It uses the light spectrum (visible) to send binary codes between objects. Sending ones and zeros by switching on and off lights (usually LEDs). For humans, these changes are not appreciable. The spectrum used covers a lager frequency range than the actually used for networking communications.

The mechanism to use it is very similar to the WLAN but, it is much faster as it. Another advantage is that, it is much cheaper as the former technologies. This is due to the fact that there is no need to use cable to set the connections between the different gadgets and terminals. This characteristic allows the system to transmit data information in a much higher

speed. For example, the file transfer has reached a speed of 224 GBits per second. This is equivalent to downloading 18 movies with one snap. In 35 seconds could be possible to download one movie in high definition. Is said to be increased the speed.

Nowadays is a proposal for the IEEE committee to approve a new norm to describe and determine the standards for this new type of communication.

The Li-Fi communication is directly related with the internet of things (IoT). Ubiquitous sensing enabled by Wireless Sensor Network (WSN) technologies cuts across many areas of modern day living. This offers the ability to measure, infer and understand environmental indicators, from delicate ecologies and natural resources to urban environments. The proliferation of these devices in a communicating–actuating network creates the Internet of Things (IoT), wherein sensors and actuators blend seamlessly with the environment around us, and the information is shared across platforms in order to develop a common operating picture. The most important IoT application areas cover infrastructure construction, public security, environment protection, modern agriculture, intelligent industry, urban management, business service and other fields.

As is it a very recent technology we are not going to include it directly in our study, but the concept idea will be basic for the development of it. [8] [9]

LiFi versus ZigBee, Bluetooth and IEEE 802.11

Comparing the ZigBee standard with Bluetooth and IEEE 802.11 WLAN help us to understand how LiFi differentiates itself form existing established standards. Figure 1.2.6 and Table 1.2.1 summarizes the basic characteristics of these standards.
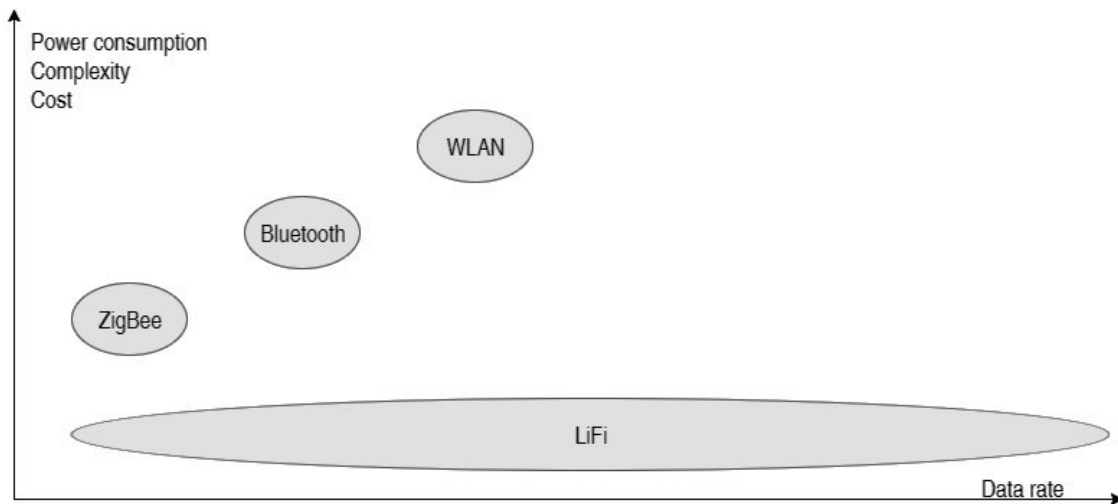
Figure 1.2.6: Bluetooth, ZigBee, WLAN & LiFi

	Bluetooth Classic	Bluetooth 4.0 Low Energy (BLE)	ZigBee	WLAN	LiFi
IEEE Standard	802.15.1	802.15.1	802.15.4	802.11 (a, b, g, n)	--
Frequency (GHz)	2.4	2.4	0.868, 0.915, 2.4	2.4 and 5	400-800 THz
Maximum raw bit rate (Mbps)	1-3	1	0.250	11 (b), 54 (g), 600 (n)	224000
Typical data throughput (Mbps)	0.7-2.1	0.27	0.2	7 (b), 25 (g), 150 (n)	No data available
Maximum (Outdoor) Range (Meters)	10 (class 2), 100 (class 1)	50	10-100	100-250	No data available
Relative Power Consumption	Medium	Very low	Very low	High	Very Low
Example Battery Life	Days	Months to years	Months to years	Hours	No data available
Network Size	7	Undefined	64,000+	255	No data available

Table 1.2.1: Data Rates Bluetooth, ZigBee & 802.11 WLAN

WLAN standards cover a large amount of options, that is why has loads of applicances. It is mostly used for establishing internet connection between devices. Therefore, the standards

should regulate all OSI layers available. Bluetooth is a little bit simpler than WLANs, and it makes it suitable for stablishing connection between close devices. ZigBee has a very low data range and, mostly is working in the four last layers.

LiFi it is not jet regulated, this makes it become as complex as one can determine. In this project, LiFi will be focused on transmitting very low data range, and not using a very high frequency. It has been chosen because it is a new and full of possibilities technology available. Also it will be able to overcome some existing transmission problems. For example, when transmitting a signal in the water. Light is one of the best solutions for this problem.

1.3. Motivation

The aim of this project is to design and implement a door opening system.

To give a further explanation, it is going to be reviewed some basic communication basics.

Every kind of communication, verbal, written, corporal, signs, telecommunications, has three main elements the sender, the receiver and a mean of transport. For example, for verbal communication the sender is person A, the receiver person B, mean of transport air. If it is well expressed it is not air, but a difference of pressure. Sound is just a variation of the air pressure that can be interpreted.
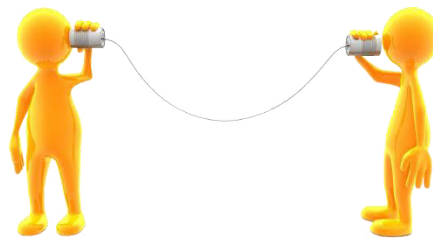

Figure 1.3.1: Communication elements[3]

A communication is effective when the sender emits some information that is completely understood by the receiver. Therefore the transmitted information has to be sufficient to make the sender understood.

As humanity has developed verbal communication was no longer enough to transmit messages and had also to evolution. We can see it along the history with the written communication, message pigeons, SMS, e-mails, etc.

There are three main types of communication taking into account the direction:

- Simplex: unidirectional communication from A to B.

- Semi-duplex: exchange of information between A and B in both directions, but in different times. (Walkie-Talkie).

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[3] [Online]. Available:

https://elizabethkuhnke.files.wordpress.com/2011/10/communicating.png
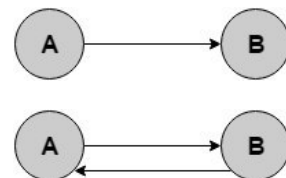
- Full duplex or Duplex: communication between A and B in both directions and in the same time.
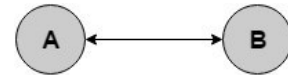

Figure 1.3.2: Directionality communication types

Attending to the number of receivers there are distinguished two main types of communication:

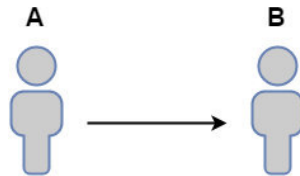1. Point to Point connection: logic connection between two members.

Figure 1.3.3: Point to Point connection

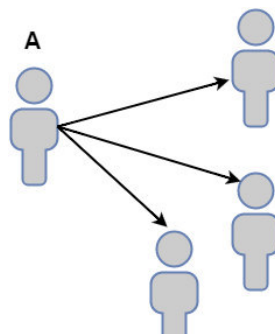2. Point to multipoint connection: logic connection between more than two members.

Figure 1.3.4: Point to multipoint connection

Doors have been always present in the history. People need to feel secure, and doors can provide it. The doors that are interesting in this project are the ones that have a locker.

The action opening a door can be considered a type of communication too.

The sender is an authorized user (the one that is allowed to enter to somewhere), the receptor is the locker.

The way that the locker has to interpret the information is for traditional doors physical. So to make communication effective the mean of transport has to be also physical, for example, a key, or a card.
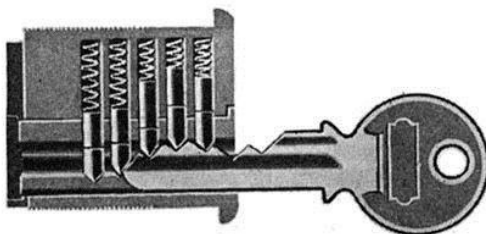
Figure 1.3.5: Key in locker[4]

In this thesis another kind of receptor is going to be presented, a light receptor. Therefore the way of transmission can only be light. As sender, it has been chosen a typical device that most people have, a smart phone.

It is a simplex, point- to point communication. Consisting in two steps (see Figure 1.3.6):

1. From smart phone to door
2. From door receiver to person.
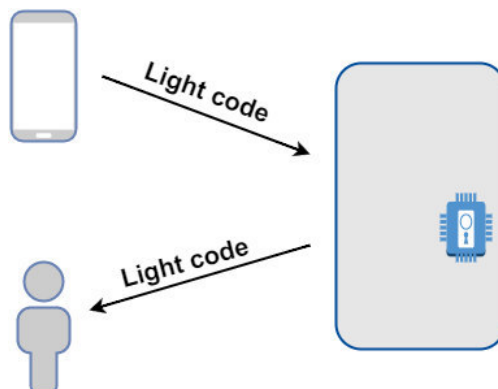
Figure 1.3.6: Project representation

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[4] [Online]. Available:
http://colonparenthesis.com/2013/SecretAgentMagazine/howto/images/lockpicks/lock-C-420x200.jpg

1.4. Objectives

The aim of this project is to:

1. Develop and implement an app to send a light code.
2. Develop and implement receiver that can process the received light information and send a signal to the user using an Arduino.

1.5. Used resources

Software	Name	Function
	Draw.io	Make diagrams
	Arduino	Develop Arduino code
	Basic!	Develop mobile App
	Notepad++	Program code for the App
	BASIC! Launcher	To debug faster the App in the smart-phone
	Led Torch	Evaluate the sensitivity from the sensor

Table 1.3.1: Software Components

Hardware	Name	Units
	Protoboard	1
	Wires	12
	Color leds	4
	Photodiode	1
	Resistors	2
	Operational amplifiers	2
	Arduino Uno	1

Table 1.3.2: Hardware components

Supportive Tools	Name	Units	Function
	Laptop	1	Programming app and Arduino code
	Smartphone	1	Developing app
	Oscilloscope	1	Measure

Table 1.3.3: Supportive tools

PART 2: DEVELOPMENT

2.1. Working Methodolgy

To design the mobile app is necessary to bear in mind the procedure that is going to be used.

In general this procedure can be applied to any kind of programming code.

First the objective has to be correctly understood. The programmer needs to get the main ideas and characteristics that he wants from his program.

Once this is completed, he needs a project plan to follow. This means, in which order he is going to act. One of the most basic models representing this are the ones showed in Figure 2.1.1.
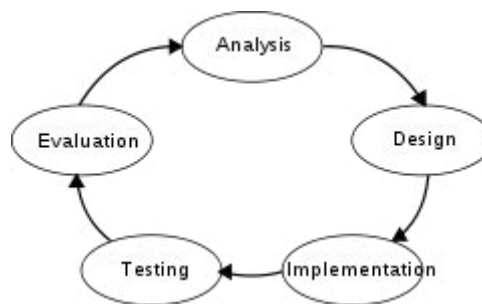
Figure 2.1.1: Project Management[5]

Here is explained the process. First the requirements need to be analyzed. Once they are understood comes the design part. Usually there is some kind of schema explaining what is going to be done. When this step is completed, it is time to implement the previous design. In other words, it is when the code is written. Then it comes the testing part. There are some tests usually designed by the quality management team that need to be passed to check the proper program function. With the obtained results is made an evaluation. Here conclusions are obtained and possible problems are detected. The results obtained from the evaluation part will be analyzed, in order to find possible solutions to solve the detected problems.

In Figure 2.1.2 is represented the same previous model, but it is included the starting and end point. Here are more visible the iterations that need to be made during the whole process.

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[5] [Online]. Available: https://upload.wikimedia.org/wikipedia/commons/thumb/a/aa/CPT-SystemLifeSycle.svg/240px-CPT-SystemLifeSycle.svg.png

Another way to develop a program is through the so known V Model (see Figure 2.1.3). In this model each step is the base for the next one and the regulator for its peer one.
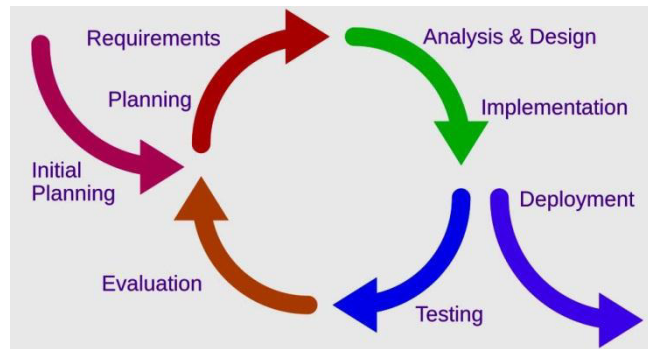
In order to have a better comprehension of the V Model, firstly is going to be read following the continuous lines. It starts when the user requirements are determined. Only when this happens, is possible to establish the system requirements. Once they are clear is possible to set the architecture for the program, in which subsystems are divided. Then each subsystem should be designed and implemented (coding).

At this point is needed to start testing the smallest parts to ensure the good functionality of the whole project. So firstly each unit will be tested, then the subsystems, after that the subsystems will be integrate into the system. The system will be tested and finally it will be made an acceptance test.

For each test step, the previous requirements for each level need to be met. This means, it is not acceptable for the subsystem integration test to have each subsystem properly working. It also, needs to match the previous design requirements. To sum up, the right part of the V, needs to match the requirements set in the right part. This is expressed with discontinuous lines.

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[6] [Online]. Available: http://currentscienceperspectives.com/wp-content/uploads/2015/11/Software-Engineering-Model-currentscienceperspectives.jpg
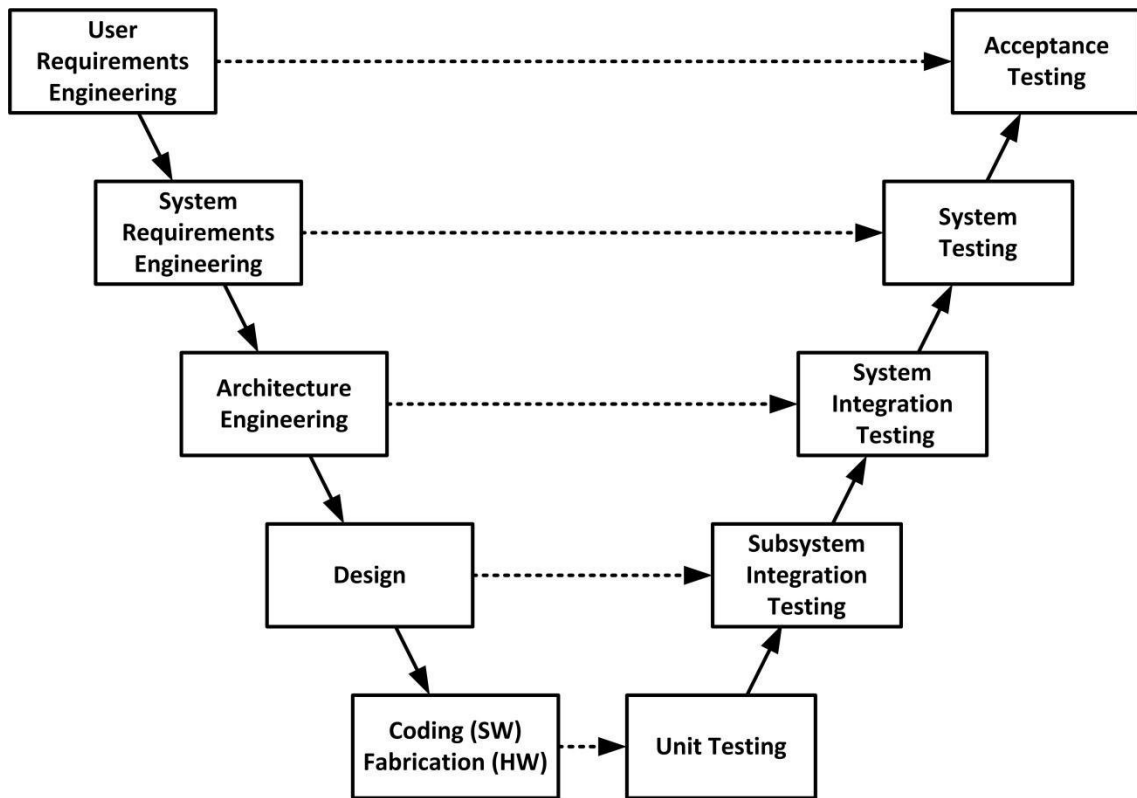
Figure 2.1.3: V model[7]

A third model that is commonly used is the spiral model. Here the iterations are showed in a spiral. The starting point is in the center of the spiral. The time is represented in the straight lines. This means, the more iterations you take, the longer the project will take and the more complex it will become.
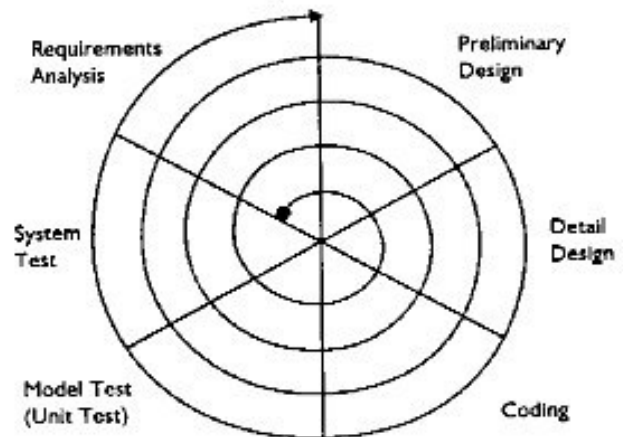
Figure 2.1.4: Spiral model[8]

For this bachelor thesis is going to be used the first model as reference.

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[7][Online].Available:https://insights.sei.cmu.edu/assets/content/F1%2020Traditional%20V%20Model.jpg

[8] [Online]. Available: http://www.acqnotes.com/wp-content/uploads/2014/09/Spiral-Model.png

2.2.   Objectives

With the previous motivation the objectives were set to the following ones:

1. Develop a light sender in a smart phone. This will be made with an app which will codify information in light form.
2. Develop a receiver that can process the received light information and send a signal to the user, using an Arduino.

Now, it has been decided to implement them in the following way:

1. Develop a light sender in a smart phone. This will be made with an app which will codify information in light form.
    a. It should be comfortable for the user.
    b. It will have to be fast enough for a garage door opening system.
    c. Cover security needs.
2. Develop a receiver that can process the received light information and send a signal to the user.
    a. Design a physical circuit to process the signal and send it to the user.
    b. Program an Arduino to process the signal and inform the user if he or she is allowed to pass through the door. This will be made using a red and a green LED.

Scheme 2.2.1: Arduino mini Flow Chart

Scheme 2.2.2: Mobile App mini Flow Chart

29
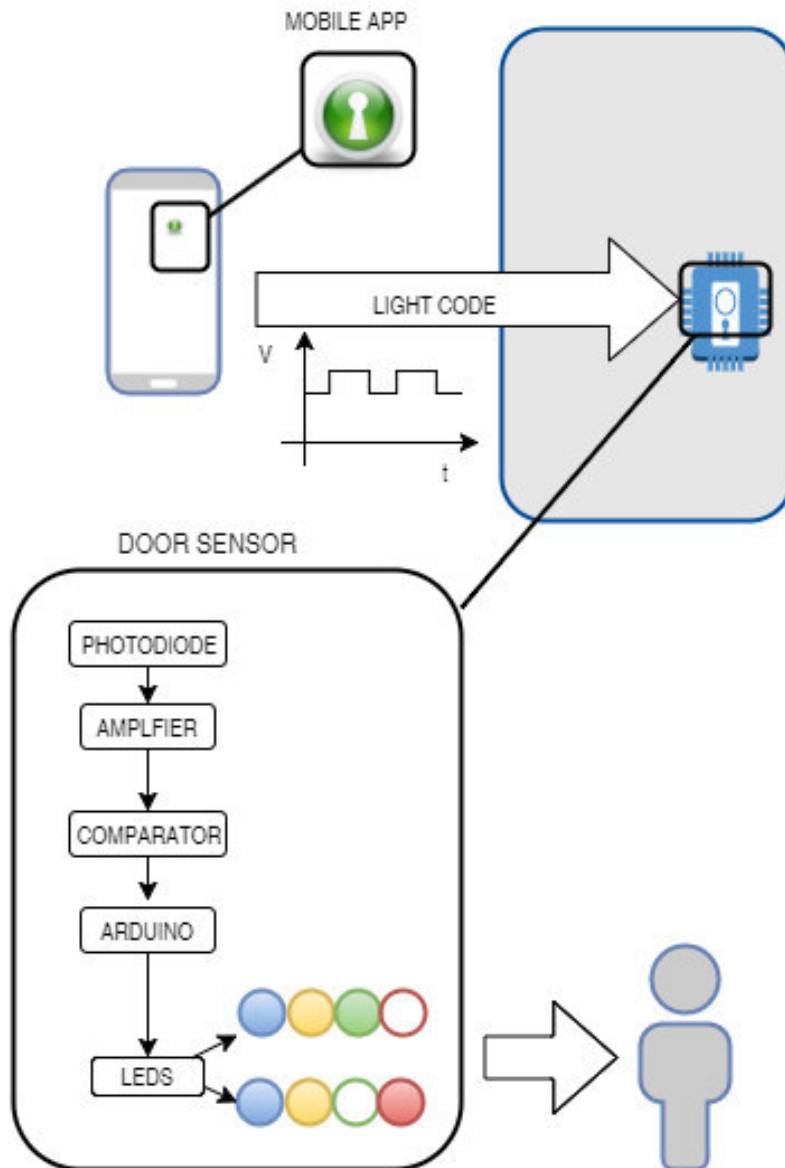
Figure 2.2.1:Objectives development[9]

[9] Green locker: [Online]. Available: http://cdn.mysitemyway.com/etc-mysitemyway/icons/legacy-previews/icons-256/3d-glossy-green-orbs-icons-business/103397-3d-glossy-green-orb-icon-business-key-hole-sc48.png

2.3.   Mobile app

To design it, it is going to be used Basic code (.bas).

  a.   It should be comfortable for the user.

  b.   It will have to be fast enough for a garage door opening system

The requirements it has to meet:

- It has to recognize the user name and mobile phone every time the app is started. The best way to achieve this is to save the users into a data base inside the phone.
- The phone number will be discomposed in single numbers, and applying some security criteria, there will be four selected and transmitted using binary code.

In order to prove that it is going to work properly there is need the help of one person, the administrator from the building to provide the "secret code" or "building code" and actualize the data base with all the mobiles numbers in the Arduino.

It has been decided to pick white screen color as representation of "1"value and black color for "0".
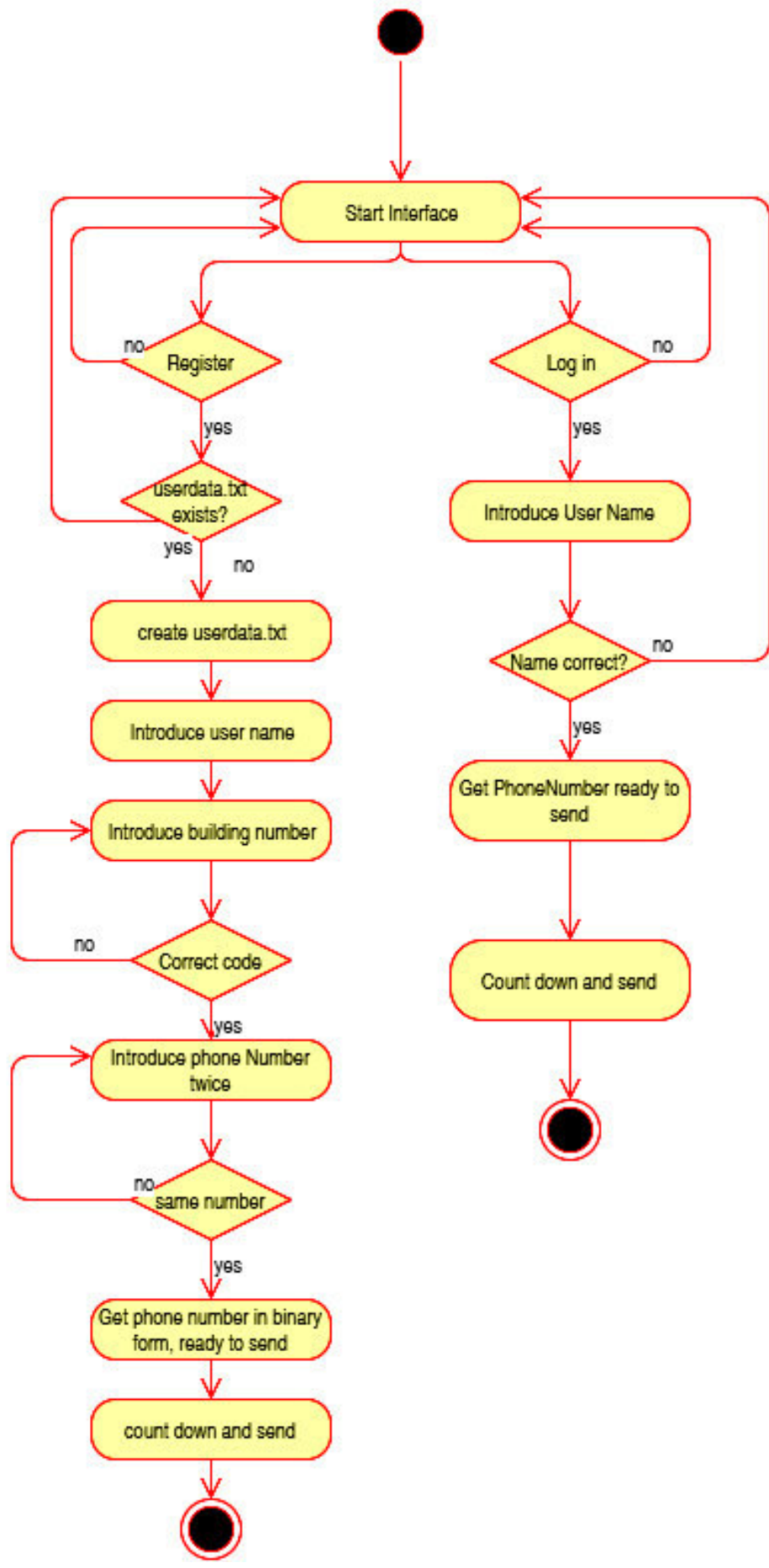
Some useful commands

Graphics display

In order to use some commands it is needed to work in the graphics interface.

```
gr.open 255,248,248,248
```

Here are set the colors and its saturation. In this case have been picked a grey scale.

```
gr.orientation 0%horizontal
gr.screen w, h
whalf=w/2
hhalf=h/2
```

These commands set the screen into a determinate position and divides the screen into two lengths (w) wide and (h) high. With w and h defined it is possible to draw a rectangle that will occupy the whole screen.

```
gr.color 255,0,0,0,1%black screen; alpha, red, green, blue,fill
gr.rect rect1,0, 0, w, h
gr.render
pause 500
```

In this code there are only going to be used black and white colors.

`gr.render` is used to display the last action in the screen.

Display messages

In order to make messages nice to the user view is going to be used the "popup" command.

```
message$= "Wrong name given / You are not a registered user."
popup message$, 0, 0, 0.5
pause 2500
```

It will look like this, placed in the middle of the screen in horizontal position.
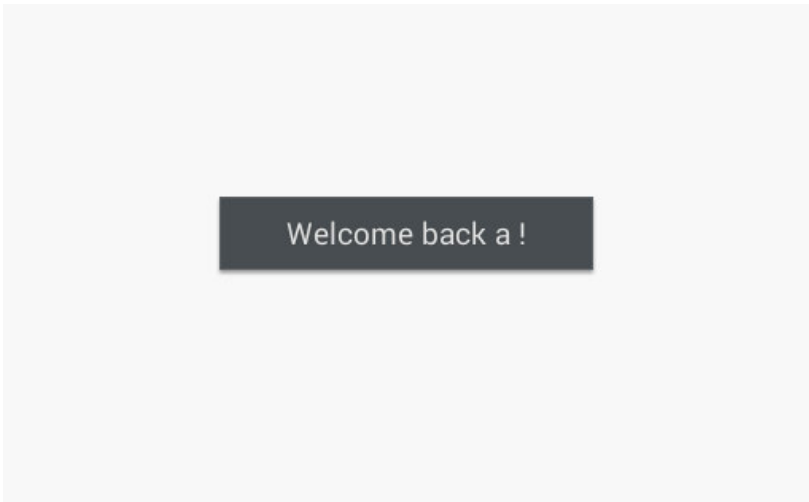
Others

```
num_d$=str$(num)  % convert integer to string

for i=1 to 12
    r$[i]=mid$(num_d$,i,1)   %divide a string in a array of dimension 12
next i
```

These two are important in order to manipulate the arrays.

Further operations and commands can be found in:

http://laughton.com/basic/help/De_Re_BASIC!.htm [10]

Head part of the program

Here will be defined the parameters and will be set the dialog message.

First thing to do is to define some parameters there are going to be used:

```
building_code=121212%to be modified by the building or the organisation
found=0
gr.open 255,248,248,248
n=20
dim r$[n]%it is bigger that supposed to avoid errors
dim phNum$[8]
m=1

dim line$[10]
```

The building_code will be provided by the building administrator and can be modifed by him.

Secondly the user data have to be recognized.

```
start:
    file.exists a, "userdata.txt"%where the data is in the phone
    DIALOG.MESSAGE ,"",B,"log in","register"
```
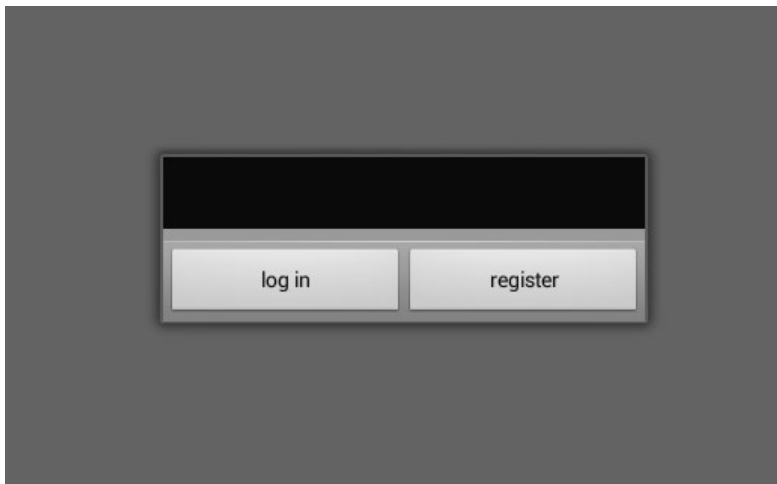
Figure 2.3.2: Dialog in screen

There is going to be checked if the userdata.txt exists if not it is created. "a" will be 1 if there is a userdata.txt file.

After that there is a dialog to ask the user if he wants to register or to directly log in. His answer will be checked with the available data.

Log in

If the user has chosen to log in:

```
if B=1 %wants to log in
    if a=1 %wants to log in and already registered
        grabfile s$, "userdata.txt"
        text.open r, myfile, "userdata.txt"
        p=0
        Do
            p=p+1
            Text.readln myfile, line$[p]
        Until line$[p] = "EOF"
        text.close myfile
```

The userdata.txt is picked up and read each line of it, and then the file will be closed.

"EOF" means End Of File

It is important to introduce the Username just in the same way it was first time stored. Taking into account the capital letters and the blank spaces

```
input "Username:", user$

if user$ =  line$[1]
    message$= "Welcome back "+user$+" !"%to show the user is properly working
    popup message$, 0, 0, 0.5
    pause 2500
    found=1
    for i=2 to 9
        phNum$[m]=line$[i]
        m=m+1
    next i
endif
```
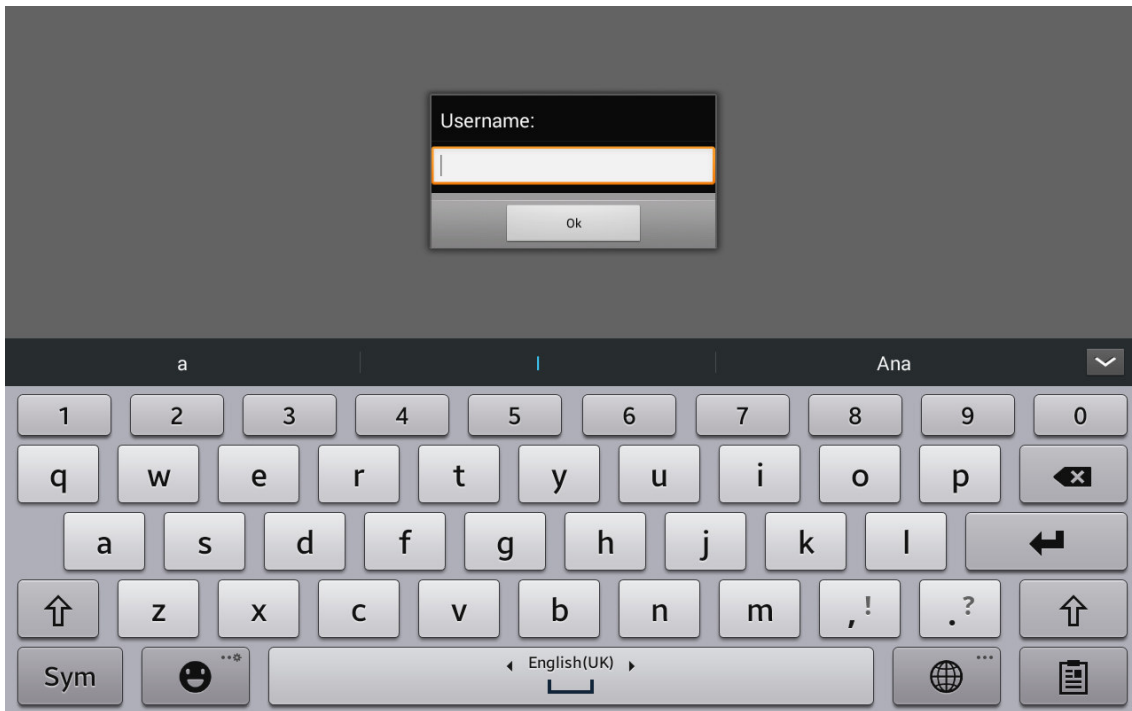
The Capitals letters and the spaces will be taken into account to make the username valid. If it is incorrect, the user will be redirected to the start dialog to choose a new option.

```
if found=0
    message$= "Wrong name given / You are not a registered user."
    popup message$, 0, 0, 0.5
    pause 2500
    goto start
endif
```

Register

Or if he chooses the option to register, will be proved that he is not already registered. If he is, he will be redirected to the start dialog.

```
elseif B=2 %wants to register
    %print "you want to register"
    if a=1 %wants to register and already registered, start
        message$= "You are already registered"
        popup message$, 0, 0, 0.5
        pause 2500
        goto start
    endif
```

If the user is not registered, then he will be asked to give his name and the building code.

```
if a=0 %wants to register and not registered

    input "New username:", user$

    do
        input "Enter your secret code:",code
        if code = building_code
            message$= "Code correct"
            popup message$, 0, 0, 0.5
            pause 2500
        else
            message$= "Wrong code, please try again"
            popup message$, 0, 0, 0.5
            pause 2500
        endif
    until code=building_code

    message$= "Welcome "+user$+" !"
    popup message$, 0, 0, 0.5
    pause 2500
```

Figure 2.3.4: Writing numbers in screen

After this the phone number will be asked twice to make sure it is not aleatory. It will be transformed to work with it in a more comfortable way.
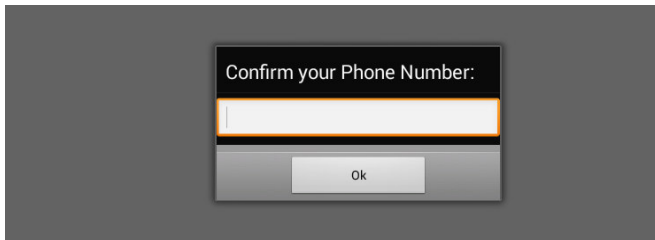
Figure 2.3.5: Phone number confirmation in screen

GetNumber

The user phone number has to be introduced twice to check that it is not aleatory. For our case of study it is not going to be determined the country prefix. This is just a suggestion to make the user concentrate more in what he is doing.

The code introduced is firstly stored as an integer but it has to be transformed into a type char to be stored in a text file. When an integer is transformed into a type char for large numbers is stored as scientific mode. The number in scientific mode is discomposed in an array. In each position of it is stored one character.

For example 659858000 will become 6.59858E5

And for 0049056235820000 will be 4.905623582E9

In order to prepare a standard code for every kind of phone number, it is created a new array which will contain the correct phone number to send. Therefore the two first characters are moved, that is "6." and "4.".

There will not be transmitted any kind of letter, so they will be removed too. So now the only number that we have is "59858" and "905623582". They have a very different length. To ensure a minimum array length of 8, it is count I which position appear the letter "E" and the array is fulfilled with "0"s. So finally the phone code that is stored in the mobile phone will be: "59858000" or "905623582".

All this process is reflected in the next function:

```
GetNumber:
    do
        input "Phone Number:", num
        input "Confirm your Phone Number:", num2
    until num2=num

    num_d$=str$(num)

    for i=1 to 12
        r$[i]=mid$(num_d$,i,1)
    next i
    for i=1 to 8%just to check
        print "num" r$[i]
    next i
    !copy the old array into a new depurated one,
    %we exclude 6. because is always the same for all mobiles
    if r$[1]="6"& r$[2]="."%for the spanish mobile phone
        for i=3 to 12
            if r$[i]="E"
                for n=i to 10
                    r$[n]="0"
                next n
            endif
        next i

        for i=1 to 8
            u=i+2
            phNum$[i]=r$[u]
        next i

    elseif r$[2]="."%doesnt matter how long is the new number,
    %    we will only pick the first eigth digits.(for our purpose will be fine)
        for i=3 to n
            if r$[i]="E"
                for n=i to (n-2)
                    r$[n]="0"
                next n
            endif
        next i
        for i=1 to 8 %be careful, first number of the array is one,
        no cero, take it into account for futher loops
            u=i+2
            phNum$[i]=r$[u]
        next i

    else%just in case.not likely to happen
        message$= "Please, introduce your country prefix.
        For example: 0049 **** *******"
        popup message$, 0, 0, 0.5
        pause 2500
        goto GetNumber
    endif
```

After this the code is ready to be stored in the text file. Each number will have to be stored in a new file.

The variable found is used to see if there is one user registered or not.

```
found=1
text.open w, myfile, "userdata.txt"
text.writeln myfile, user$
text.writeln myfile, phNum$[1]
text.writeln myfile, phNum$[2]
text.writeln myfile, phNum$[3]
text.writeln myfile, phNum$[4]
text.writeln myfile, phNum$[5]
text.writeln myfile, phNum$[6]
text.writeln myfile, phNum$[7]
text.writeln myfile, phNum$[8]
text.close myfile
```

Or what is the same but using less code lines:

```
!add it to the file

found=1
text.open w, myfile, "userdata.txt"
text.writeln myfile, e_user$
for i=1 to 8
    text.writeln myfile, e_phNum$[i]
next i
text.close myfile
```

With a normal editor we can see how the data were stored:

In this case:

- User name: a
- Phone number : 444444444
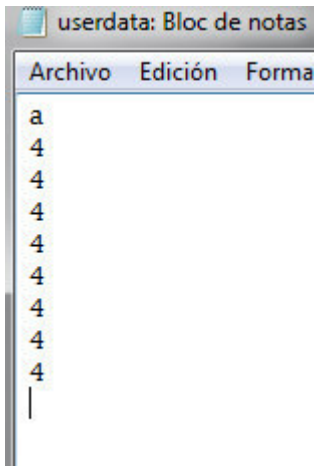
This method presents a main drawback. It is not very secure because everybody is able to read the code, and find out the information.

GetNumber encrypted version

Therefore to avoid the previous problem, it has been implemented an encryption. The command requires a password. It has been chosen to use the users' name. So the data stored in the text file will be no longer so understandable.

The command uses an encryption algorithm "PEBWithMD5AndDES".

```
!encrypt
encrypt user$,user$,e_user$
for i=1 to 8
  encrypt user$,phNum$[i],e_phNum$[i]
next i
```

The encrypted code is stored in a new variable e_phNum$. For each user name, will be generated a different type of code. It has one defect: the same numbers get the same code

And this one will be saved in the text file.
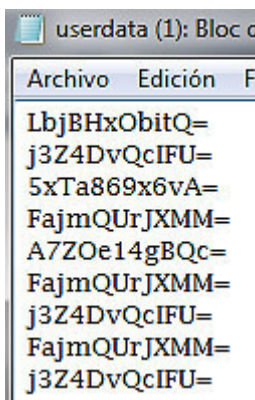
Figure 2.3.7: Userdata Encrypted.txt

Count Down

The countdown part is to make the user realize that he has to place the mobile phone in front of a receiver.

```
message$= "Phone number ready to send. Place your device in front
of the reciver."
popup message$, 0, 0, 1
pause 5000
for i=1 to 6
    r$=str$(count)
    gr.color 255,0,0,0,1%black screen; alpha, red,green, blue,fill
    gr.rect rect1,0, 0, w, h
    gr.render
    pause 500
    gr.color 255,255,255,255,1
    gr.text.size 100
    gr.text.draw pt, whalf,hhalf,r$
    gr.render
    pause 500
    count=count-1
next i
```

The count down will appear like this format on the screen:

Figure 2.3.8: Count down in screen

Greeting

The receiver is all the time working, and waiting to a "greeting" code to come. This is used to synchronize both devices.

The sequence it has to follow is represented in the next scheme (see scheme 4.2)

The chosen code is the following one (t=1s=1000ms):

	t1	t2	t3	t4		1st number (3)	2nd number (2)	3rd number (0)
	GREETING CODE					TRANSMISSION CODE		

Figure 2.3.9: Theorethical greeting signal

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The sequence followed to transmit the "greeting code" is always set through the lighting up of the screen for a time t1, t2, t3 and t4. T1 will take a quarter form t; t2 half of t; t3 will be .75 times t and finally t4 will be equal to t.
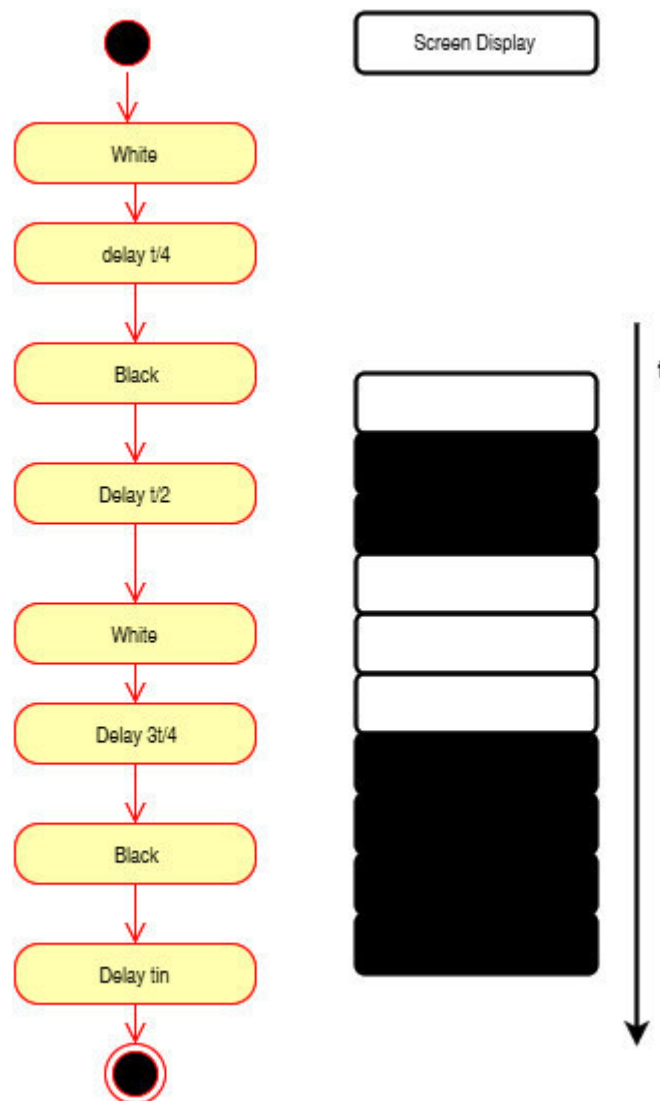
Scheme 2.3.2: greeting code from Mobile app

```
!greeting to receptor
gr.color  255,255,255,255,1%white
gr.rect rect1,0, 0, w, h
gr.render
pause t1
gr.color 255,0,0,0,1%black
gr.rect rect1,0, 0, w, h
gr.render
pause t2
gr.color  255,255,255,255,1%white
gr.rect rect1,0, 0, w, h
gr.render
pause t3
gr.color 255,0,0,0,1%black
gr.rect rect1,0, 0, w, h
gr.render
pause t4
```

For changing the color of the screen is needed to use the following command:

```
gr.color  255,255,255,255,1%white
gr.rect rect1,0, 0, w, h
gr.render
pause t1
```

Transmission code

There are many possibilities to transmit a light code. One of the oldest is the morse and binary codes:

Decimal	Morse	binary
0	- - - - -	0000
1	· - - - -	0001
2	· · - - -	0010
3	· · · - -	0011
4	· · · · -	0100
5	· · · · ·	0101
6	- · · · ·	0110
7	- - · · ·	0111
8	- - - · ·	1000
9	- - - - ·	1001

Table 2.3.1: Decimal, morse, binary

Both were implemented and, they did not have much impact on the mobile app code, but on the Arduino part. So the chosen code to transmit the selected part of the array phNum[] is a binary code, but not a regular one.

Decimal	a	b	c	d
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	1	0	0
4	1	0	0	0
5	1	0	0	1
6	1	0	1	0
7	1	1	0	0
8	1	1	0	1
9	1	1	1	0

Table 2.3.2: Decimal used code

So we can appreciate that the next rule is followed :

Decimal number= a*4+b*3+c*2+d*1

For example:

- 1010 will be equivalent to 1*4+0*3+1*2+1*0=6, but 6 can also be obtained as 0111, but the code is set to send the less number of ones as possible. In order to have a clearer code.
- 0101 will be equivalent to 0*4+1*3+0*2+1*1 =3+1 =4, but this does not exist in our case, it is not going to be sent like this. Instead just 1000.

Therefore each number stored in phNum[] will be compared to its decimal number and directly transformed into a combination of white and black screen displays.

In case of transmitting its flow chart will be:
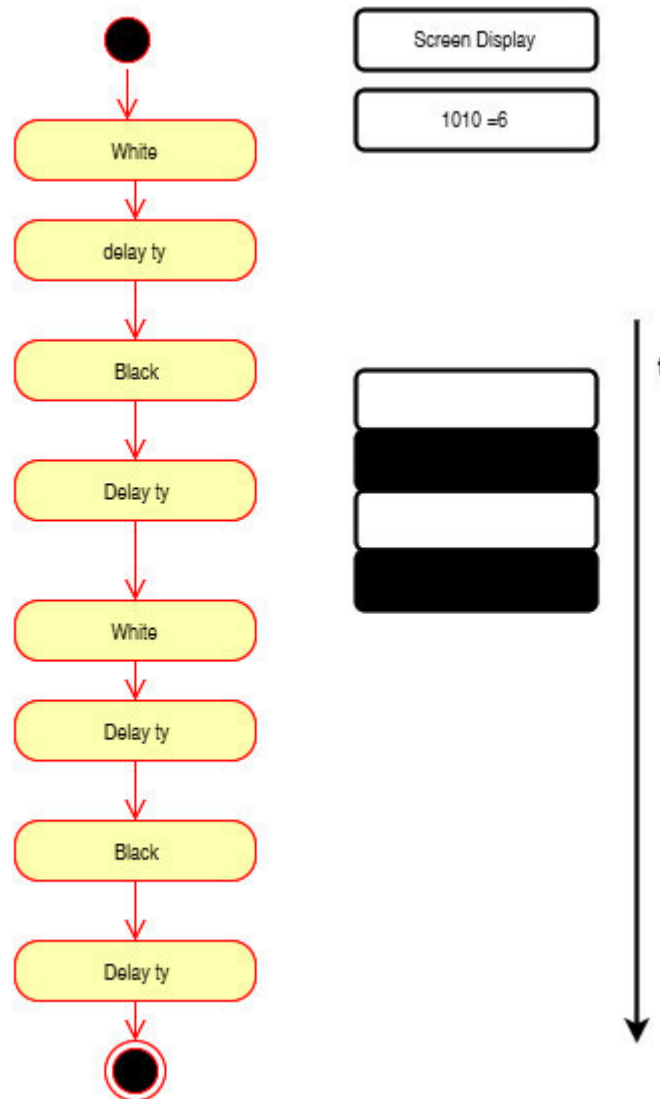
Scheme 2.3.3: Number 6 sequence

Number six will be codified in the following way:

```
elseif phNum$[k]="6"%1010
    gr.color 255,255,255,255,1%white
    gr.rect rect1,0, 0, w, h
    gr.render
    pause ty
    gr.color 255,0,0,0,1%black
    gr.rect rect1,0, 0, w, h
    gr.render
    pause ty
    gr.color 255,255,255,255,1%white
    gr.rect rect1,0, 0, w, h
    gr.render
    pause ty
    gr.color 255,0,0,0,1%black
    gr.rect rect1,0, 0, w, h
    gr.render
    pause ty
```

End of transmission

At the end of the loop the screen will turn black and a message will be displayed to indicate

the user that the transmission has ended.

```
!end the transmission
gr.color 255,0,0, 0,1%black screen
gr.rect rect1,0, 0, w, h
gr.render
message$= "End of transmission"
popup message$, 0, 0, 1
pause 10000%

end
```

Relationship between Building-administrator and User

On its first use, the user is going to be asked for a building code.

This should have been provided by the building system administrator.

The user should give the personal data that he will want to introduce in paper form. So the administrator can introduce the new user into the Arduino program to be recognized.

It has been decided to ask for a phone number because it is not aleatory, everyone who uses a mobile phone will have one, there are not going to be repeated.
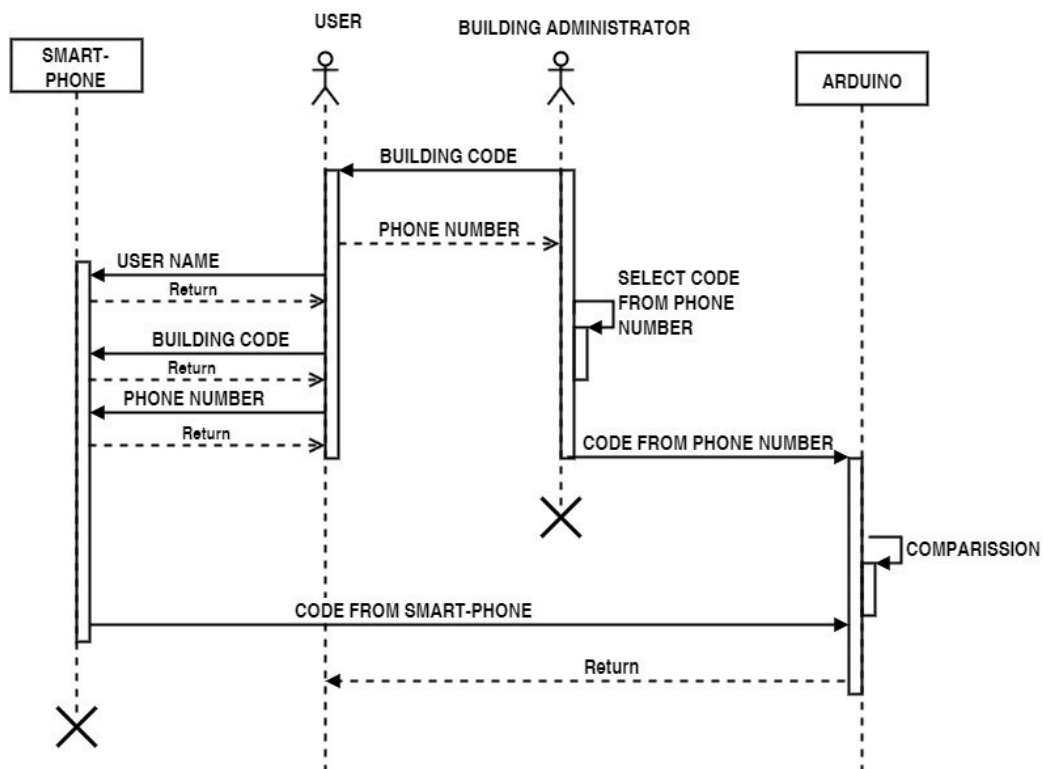
Scheme 2.3.4: Relationship between building administrator and user

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Programming tools used

 BASIC!: to develop the whole app in the smart phone.

 BASIC! Launcher: to connect the program from a laptop to the smart phone.

 NotePad++: to develop program in the laptop and launch it in BASIC! Launcher.

Creating a short cut in the smart phone

This is possible to make it with the basic! App widget. It has been selected the following Figure 2.3.10 for it:

Figure 2.3.10: Shortcut image[10]

---

[10] [Online]. Available: http://cdn.mysitemyway.com/etc-mysitemyway/icons/legacy-previews/icons-256/3d-glossy-green-orbs-icons-business/103397-3d-glossy-green-orb-icon-business-key-hole-sc48.png
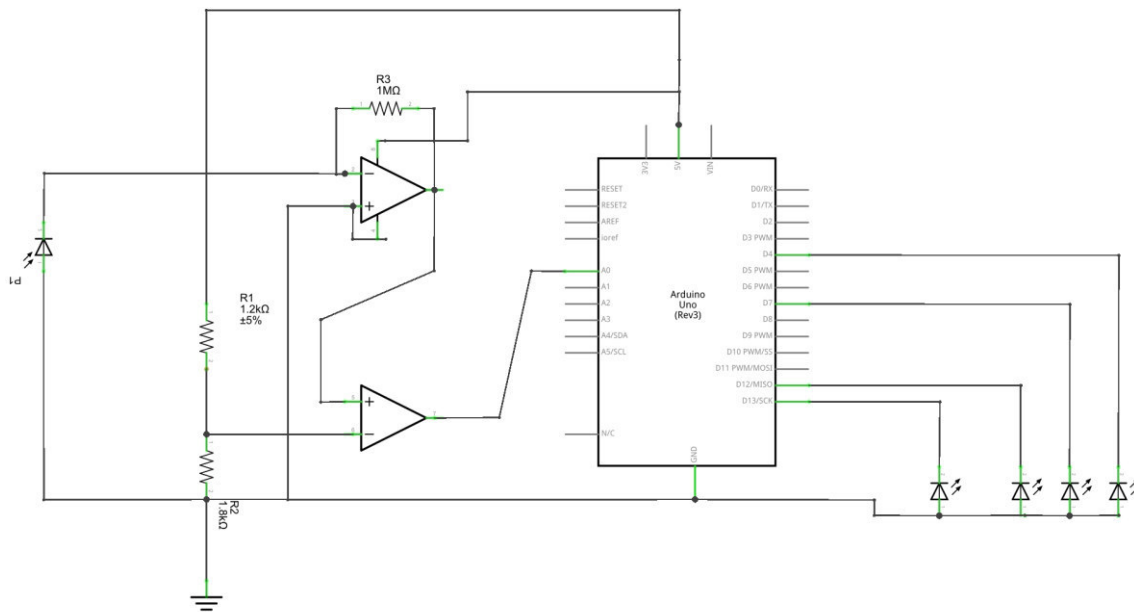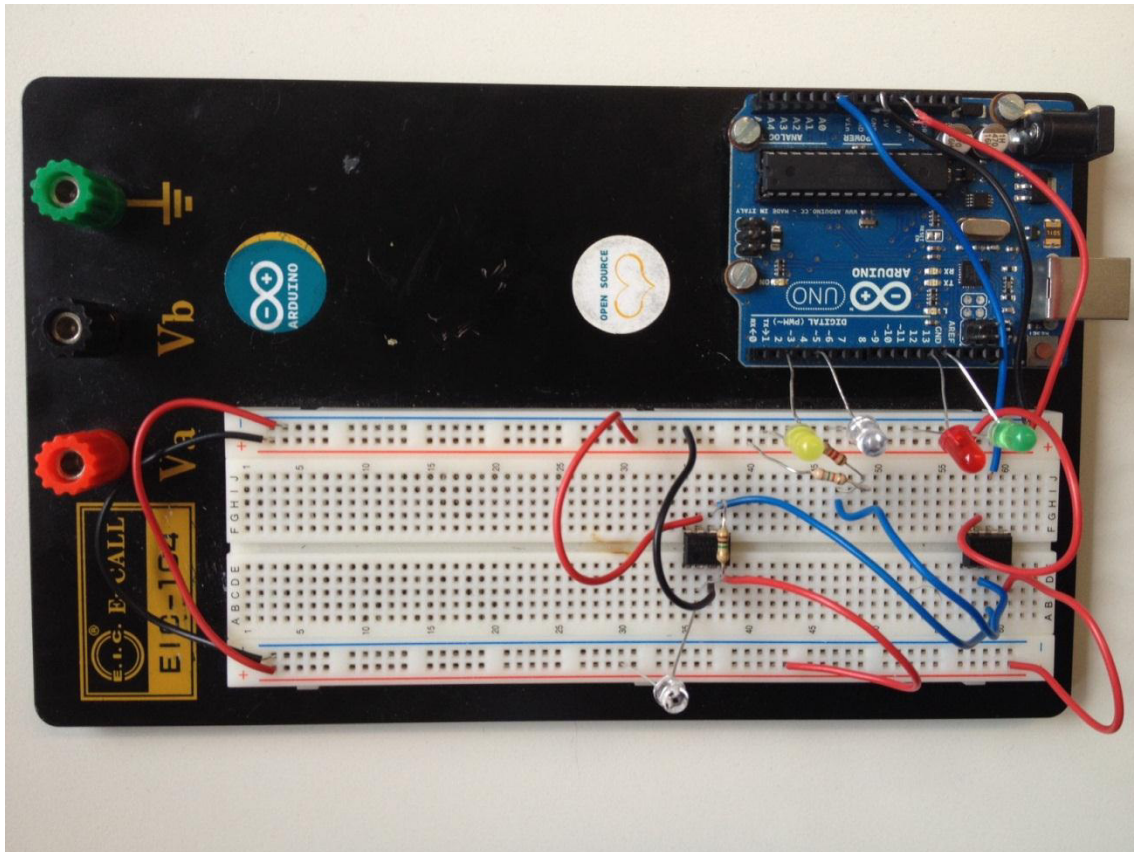
2.4.   PHYSICAL CIRCUIT.

Figure 2.4.1: Physical circuit

It is needed to design a circuit with a photodiode. It will have to be capable of transmit the amplified incoming signal to the Arduino.

The input of the circuit will be the signal received in the photodiode. It will be needed to be amplified to be able to work with it. Then the signal will be compared with a reference voltage in order to send to the Arduino only the part that is going to be interesting to work with.

The Arduino will process the signal and compare the data received with some already stored in it. If it recognizes the code, a green led will be switched on.
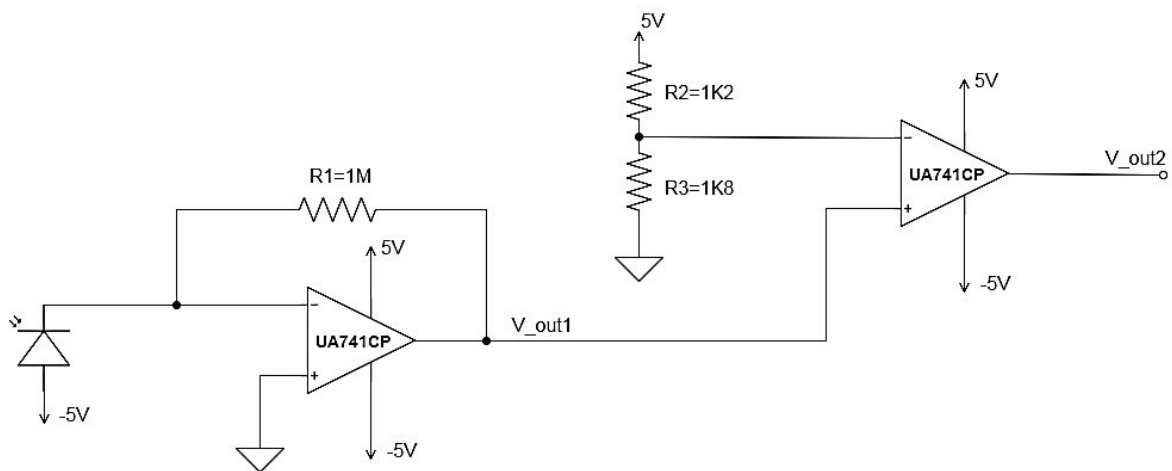
Figure 2.4.3: Physical circuit

In order to check the circuit behavior, it is going to be taken into account three different states:

- Without applying any direct light.
- With the flash of the mobile phone, sending pulses.
- With the screen of the mobile phone.

To take the measures it has been used MSO 3012 Mixed Signal Oscilloscope (Tektronix).

Amplifier phase
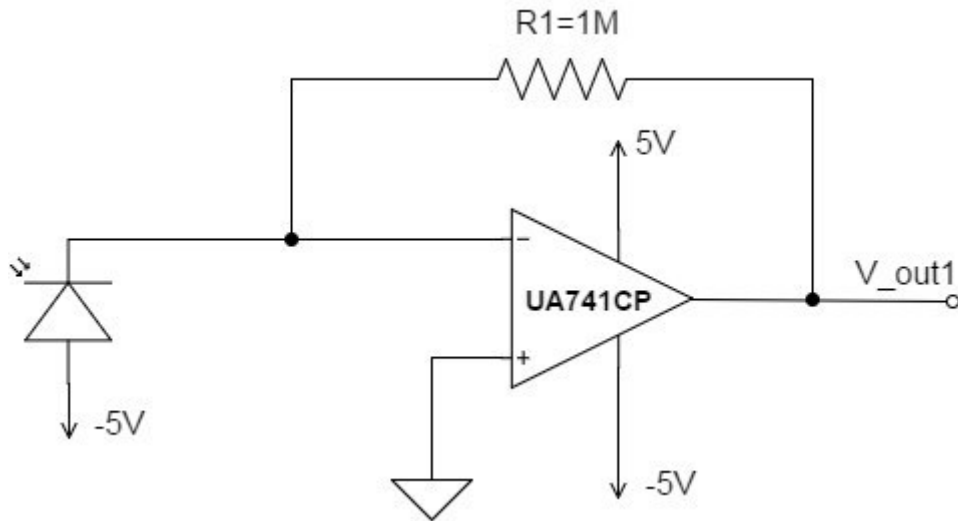
Figure 2.4.4: Amplifier Phase

This is a typical circuit to amplify the signal coming from a photodiode. The gain of the circuit is 1M. The photodiode is connected to -5V, due to the fact that when the light received, is able to send the intensity in the proper direction.
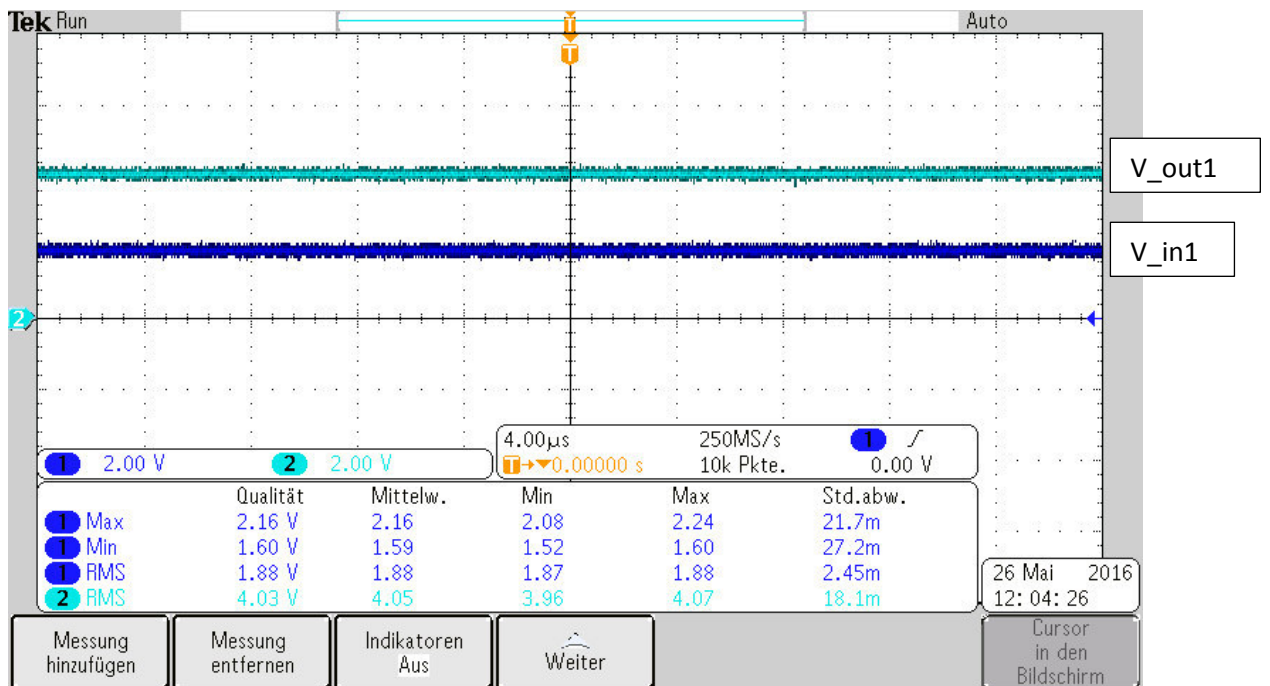
Figure 2.4.5: normal lighting in amplifier
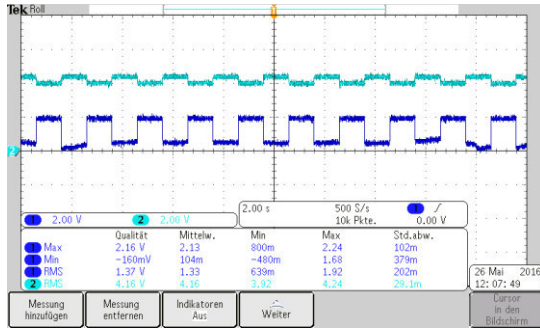
Figure 2.4.6: flash in amplifier   **Figure 2.4.7:Screen in amplifier**
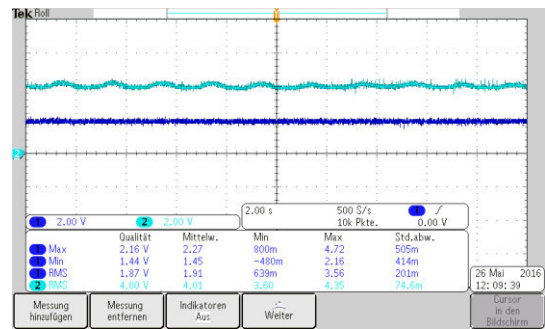
From the previous figures with measures, it has been ellaborated a table to compare the differences in the different parts of the circuit.
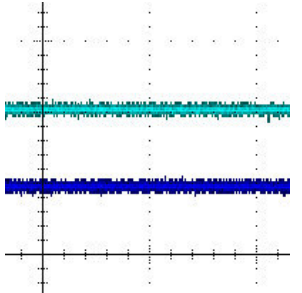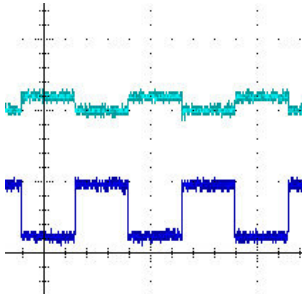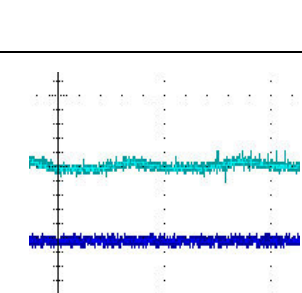
	V_in1 (V)	V_out1 (V)	
Normal light	1.88	4.03	
Flash	1.37	4.16	
Phone Screen	1.87	4	

Table 2.4.1: Amplifier phase measures

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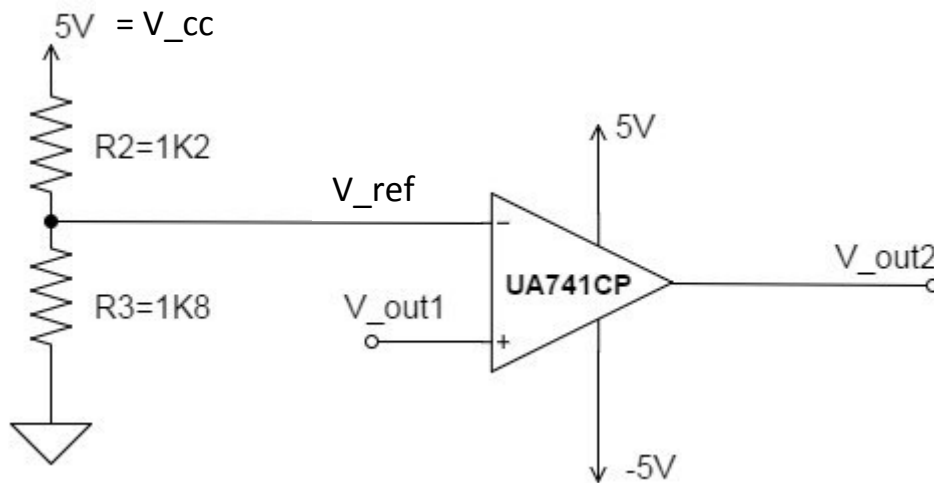
Comparator

Figure 2.4.8: Comparator phase

To build a comparator is needed to set a reference voltage. Depending on its situation the output signal will be or not inverted.

In our case the signal is not inverted. According to the division voltage the reference voltage is set to 2.2V.

$$V_{ref} = V_{cc} \cdot \frac{R3}{R3 + R2}$$

So if the incoming signal has a higher value than the reference voltage, the output signal will maintain the times and will acquire the value from V_{cc} =5V (see Figure 2.4.9).
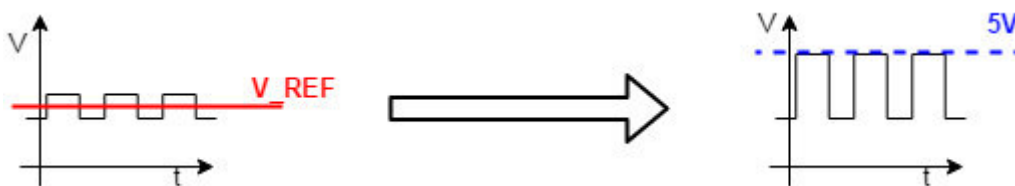
Figure 2.4.9: comparator signal

Results are gathered in the next table.
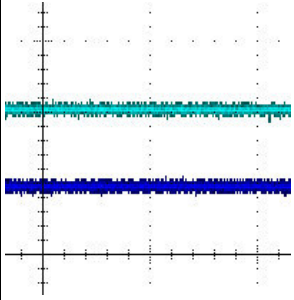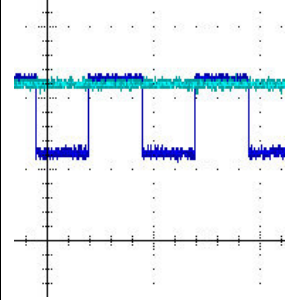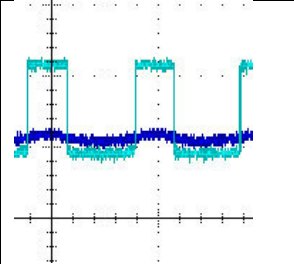
	V_out1 (V)	V_out2(V)	
Normal light	2.27	4.28	
Flash	3.52	4.45	
Phone Screen	2.21	2.95	

Table 2.4.2: Measures from comparation phase

The behavior that interests us is the phone screen mode. The fact is that the real signal which is going to be used is not going to be so regular as the one previously showed.
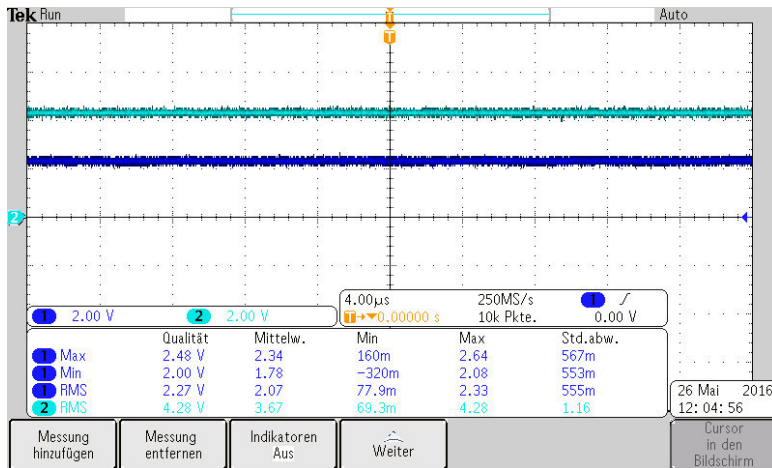
As the light is enough and constant, the output signal has also a high value.

Figure 2.4.10: Normal light in comparator phase
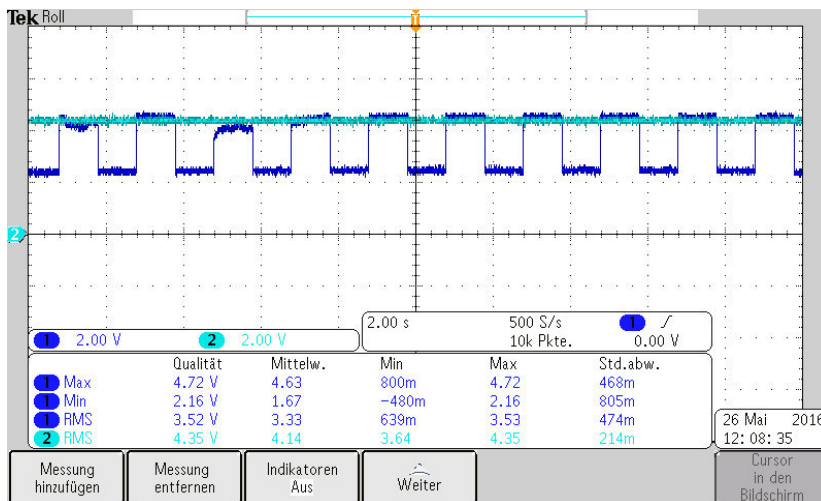
it is observed, that the intensity of the signal is too much for the comparator to make a difference.

Figure 2.4.11: Flash in comparator phase
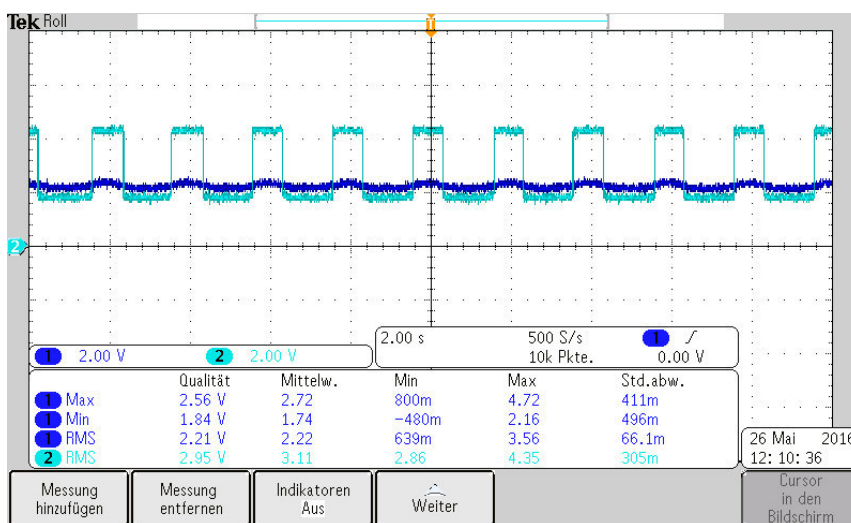
Here can be seen, that even if it seems to be that the input signal is not so amplified. The comparator is designed to recognize these little fluctuations and send them to the Arduino.

Figure 2.4.12: Screen in comparator phase

Program tools

LED torch HD : to try light signals with a determinate frequency.

2.5.   Arduino

Once the signal is transmitted correctly, it is time to process it using the Arduino Uno.

To indicate that the machine is on there will be a blue led switched on. The Arduino has also its own LED to indicate that is working. But this project has been designed to have the Arduino relative far and hidden from the user. This way is easier to identify whether it is working or not.

If the "greeting code" is correct a yellow led will be switched.

And in case that the whole code is correct will be switched on a green led and if not a red one.

Finally all LEDs, except for the blue one will be switched off.

The following programming logic is reviewed in the next scheme (see Scheme 5.1).

Firstly all variables that are going to be used need to be initialized. There the pins that are going to be used need to be declared.
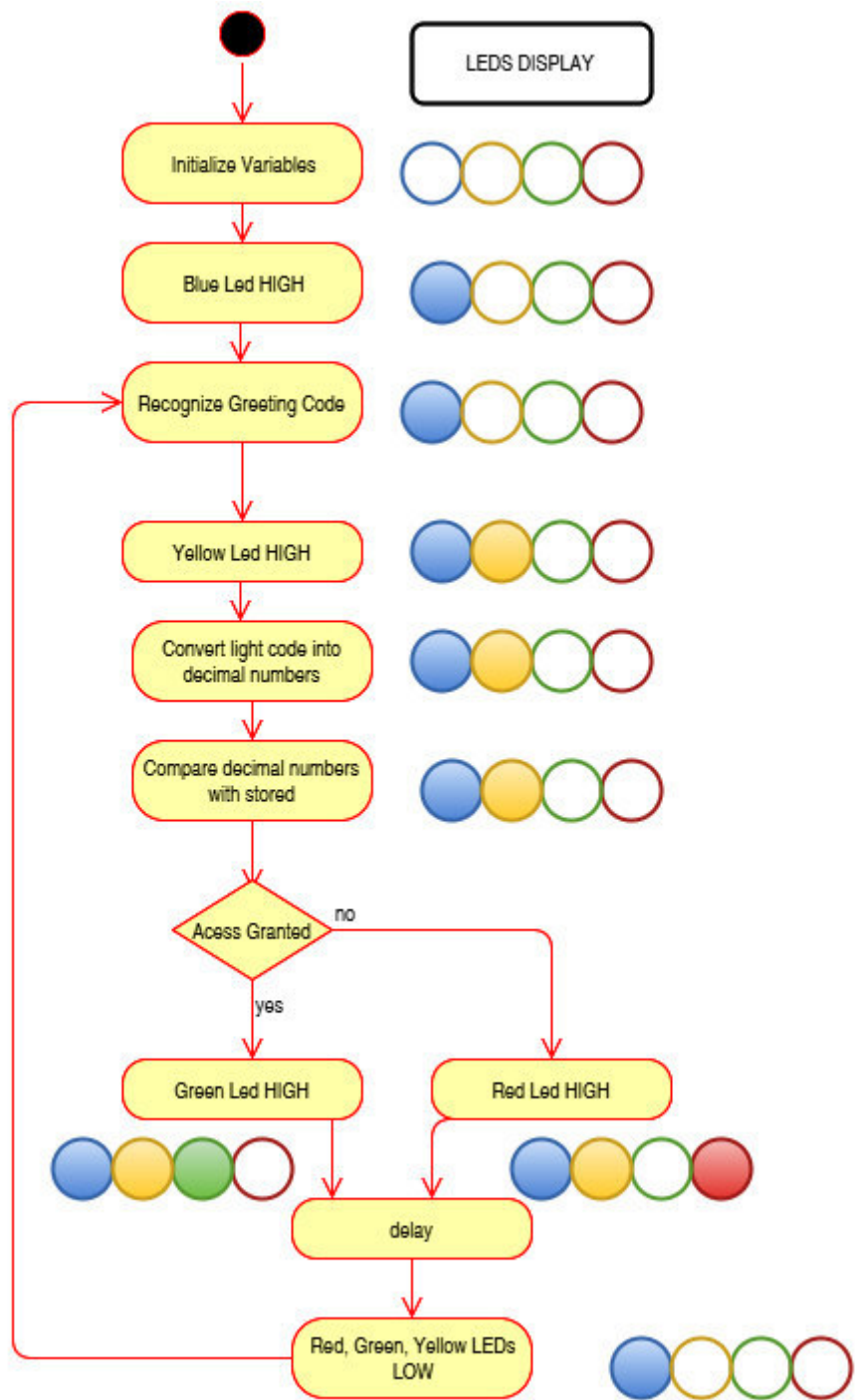
Scheme 2.5.1: Arduino Flow Chart

Initializing variables

In the first part of the code all variables that are going to be used are declared. Also there is one possibly to declare them inside the void loop. But to make sure that they have a value most of them are initialized in the header part.

```
/***** Declare variables****/
int inputPin = A0;     // select the input pin from
//output of the comparator
int ledGreen = 13;       // select the pin for the LED
//to be the output. Is the one in the Arduino board too.
int ledRed = 12;
int ledYellow =7;
int ledBlue=4;
int up= 4.0 * ( 1023.0/5.0);// Convert the analog
//reading (which goes from 0 - 1023) to a voltage (0 - 5V)


int ti=1000;//for the greeting code
int ti1=ti/4;
int ti2=ti/2;
int ti3=ti*0.75;


int ty=250;// for conversion part
int tx1=ty;
int tx2=1.3*ty;

int phNum1[]={
   10,10,10,10
};

int greeting=0;
int Num=0;
int look_num1=0;
int look_num2=0;
int look_num3=0;
int look_num4=0;
```

phNum1[] is initialized starting with value 10, so it will be recognized as wrong value if it is not overwritted.

```
void setup(){
  pinMode(ledGreen, OUTPUT);
  pinMode(ledRed, OUTPUT);
  pinMode(ledYellow, OUTPUT);
  pinMode(ledBlue, OUTPUT);


  digitalWrite (ledBlue, HIGH);


}
```

When the ledBlue is set as high in the void setup(), it will be high all the time the Arduino is working.

Greeting code

Here the greeting code sequence should be recognized. Therefore should be checked the high and low voltage form the signal.
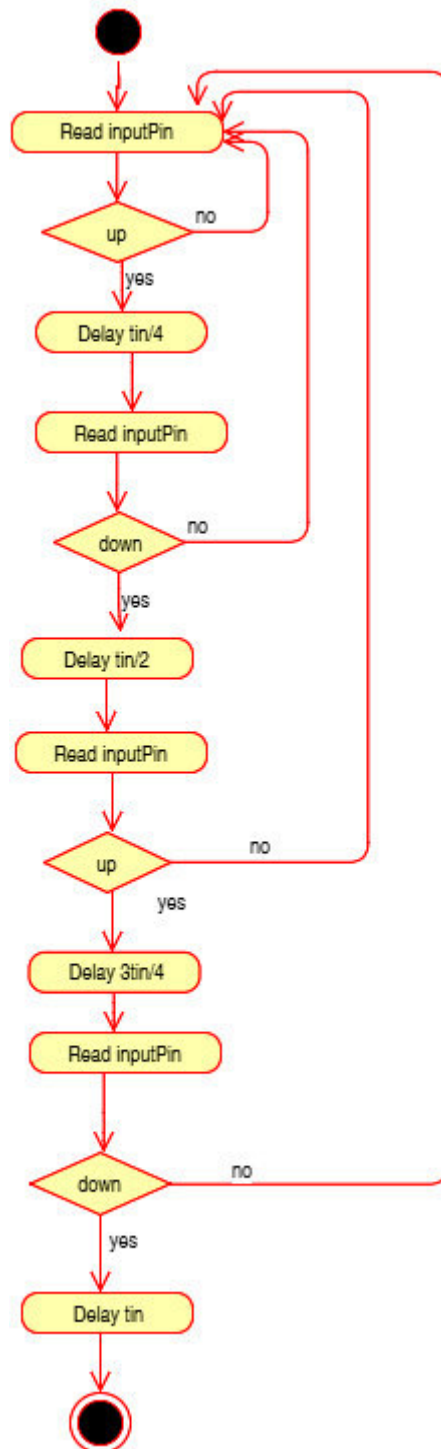
With the greeting code, it is make sure that the Arduino has received the correct signal. And then can start reading the phone code. The greeting code should have the same sequence as the previous set in the app.

```
void loop (){
    int look1= analogRead (inputPin);
    if (look1 >= up){
        delay (ti1);
        int look2= analogRead (inputPin);
        if (look2 < up){
            delay (ti2);
            int look3= analogRead (inputPin);
            if (look3 >= up){
                delay (ti3);
                int look4= analogRead (inputPin);
                if (look4 < up){
                    digitalWrite (ledYellow, HIGH);
                    delay(ti);
                    greeting=1;
                    goto Conversion;
                }
            }
        }
    }
}
```

It is going to be tried and measured. As programmed in the mobile app it is going to be sent (t=1s=1000ms):

				Code →….
t/4	t/2	3t/2	t	
t1	t2	t3	t4	
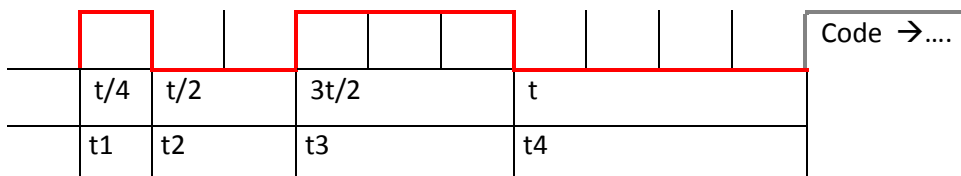
Figure 2.5.1: Theoretical greeting signal

The signal that is sent to the Arduino is the light blue one.

The measures obtained are shown in the next table. There is a little difference existing due to the devices delay. But is it considered to be working properly.
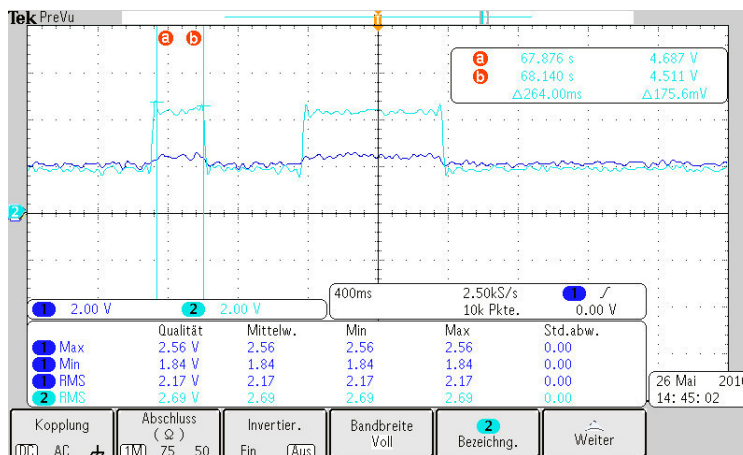
Figure 2.5.2: Oscilloscope greeting signal

- For t1=260 ms
- For t2=528 ms
- For t3=760 ms
- For t4= 1240 ms

This delay does not affect to the Arduino, because is set the same theoretical values into its code. It has enough time to read and process the information received. Besides is also checked that the yellow LED is switched on.

Conversion

Now both devices are synchronized and the important code can be transmitted.

This is the main reason that the transmitted code was chosen that way. Because, now it is possible to elaborate a quite simple loop.

Each digital number to be stored in the array phNum[] is formed of four binary digits.

In order to save time and logic doors, is decided to get the information, or "read" respecting the tx1,tx2 and ty times.

First bit		Second bit		Third bit		Fourth bit		First bit…	
tx1	ty		ty		ty		tx2	tx1	ty…

Figure 2.5.3: Reading sequence
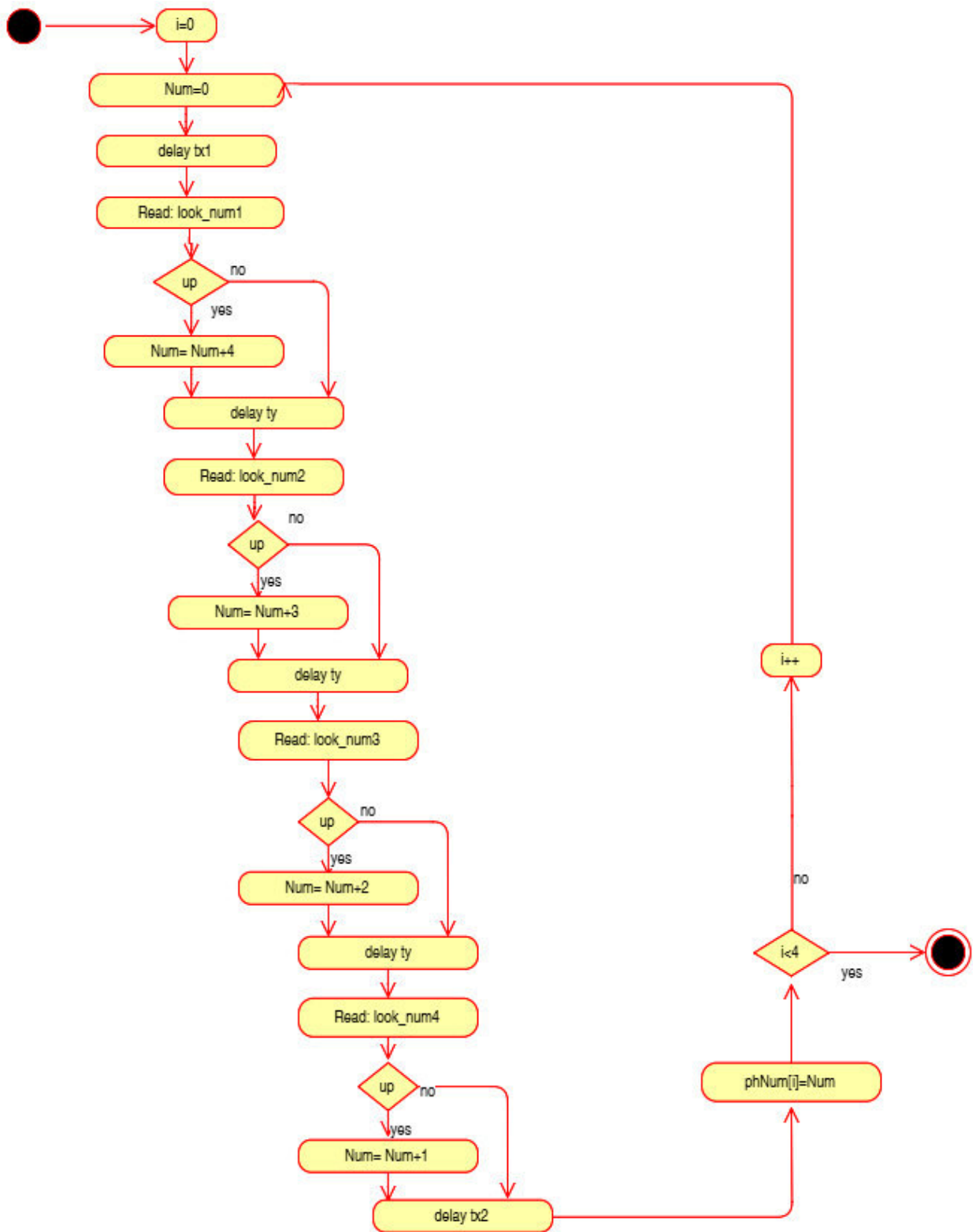
Scheme 2.5.3: Conversion sequence

The setup of the delay tx1 and tx2 had to be modified several times. These two parameters depend so much on the ty.

As it can be seen in the following Figure 2.4.5, there is not exactly transmitted the light code in the established time. This is mainly due that the commands need a little more time to go through and the operational amplifiers require certain time to work.

```
Conversion:
  if (greeting ==1){
    for (int i=0; i<4; i++){
      Num=0;
      delay (tx1);
      look_num1= analogRead (inputPin);
      if (look_num1 >= up){Num+=4;}
      delay (ty);
      look_num2= analogRead (inputPin);
      if (look_num2 >= up){Num+=3;}
      delay (ty);
      look_num3= analogRead (inputPin);
      if (look_num3 >= up){Num+=2;}
      delay (ty);
      look_num4= analogRead (inputPin);
      if (look_num4 >= up){Num+=1;}
      delay (tx2);

      phNum1[i]=Num;
    }
```

It is necessary to include `if (greeting ==1){` loop , because the whole Converison label is inserted inside the void loop().

What it was supposed to be 1s exact, turns to be 1.32 s (see Figure 2.5.4). This was measured before entering into the Arduino. So it is needed to play a little bit with the tx1 and tx2 to adjust them the better way.
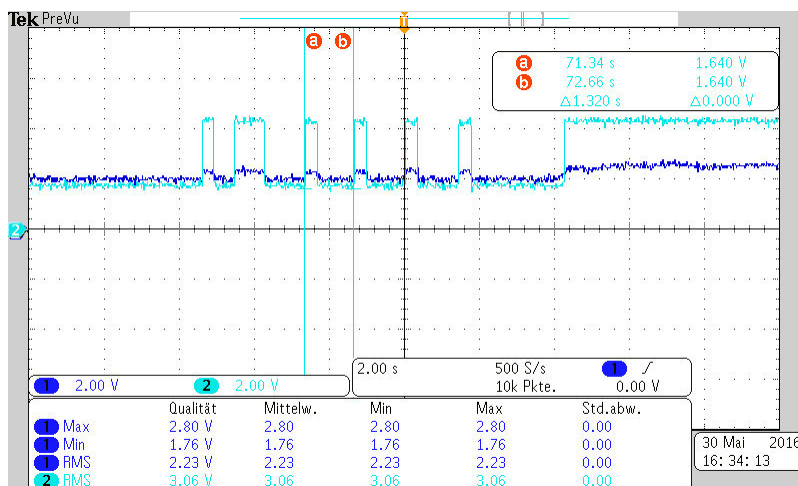
Figure 2.5.4: Time analysis

Regarding to last figure, there have been made several measurements (see Annexed C). And the conclusion is that if it is wanted to have a speed system it is not enough to read just one time. There is a slight difference of miliseconds that theroretically should work. But in the practice is observed the opposite effect. Therefore it has been implemented a second reading.

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Most of the times, the bits do not have the same length, due to the noise from the circuit, the lightness of the room, the movement of the device,… A bit can change its length from 340 and 350 ms. So these are the two measures that are going to be implemented.

So here is the implemented code:

```
Conversion:
  if (greeting ==1){
    for (int i=0; i<4; i++){
      Num=0;
      delay (tx1);
      look_num1_1= analogRead (inputPin);
      delay (tx2);
      look_num1_2= analogRead (inputPin);
      if ((look_num1_1 >= up )||(look_num1_2 >= up )){Num+=4;}
      delay (ty1);
      look_num2_1= analogRead (inputPin);
      delay (ty2);
      look_num2_2= analogRead (inputPin);
      if ((look_num2_1 >= up )||(look_num2_2 >= up) ){Num+=3;}
      delay (ty1);
      look_num3_1= analogRead (inputPin);
      delay (ty2);
      look_num3_2= analogRead (inputPin);
      if ((look_num3_1 >= up )||(look_num3_2 >= up)){Num+=2;}
      delay (ty1);
      look_num4_1= analogRead (inputPin);
      delay (ty2);
      look_num4_2= analogRead (inputPin);
      if ((look_num4_1 >= up )||(look_num4_2 >= up)){Num+=1;}
      delay (tx1);
      delay (tx2);

      phNum1[i]=Num;
    }
  }
```

And therefore new variables have to be declared and some of them redefined.

```
int ty1=340;
int tx1=170;
int ty2=10;
int tx2=5.25;

int phNum1[]={
   10,10,10,10
};

int greeting=0;
int Num=0;
int look_num1_1=0;
int look_num2_1=0;
int look_num3_1=0;
int look_num4_1=0;
int look_num1_2=0;
int look_num2_2=0;
int look_num3_2=0;
int look_num4_2=0;
```

Comparing values

After the conversion into decimal values, it is needed to compare the obtained code with the one set by the building administrator in the Arduino.

```
if(phNum1[0]==4 && phNum1[1]==4 ){
    if (phNum1[2]==4   && phNum1[3]==4){
        digitalWrite (ledGreen, HIGH);
    }
}else{
    digitalWrite (ledRed, HIGH);
}
delay (500);
digitalWrite (ledRed, LOW);
digitalWrite (ledGreen, LOW);
digitalWrite (ledYellow, LOW);
greeting=0;
delay(500);
```

Once one led green or red has been switched on is necessary to return to the original values, therefore all variables are set to low values or cero

This kind of "if " writing presents some problems when they are two users that have the same two first numbers. In order to make the process quicker, when setting the data, it has been opted for the next configuration:

```
if(((phNum1[0]==4 && phNum1[1]==4)&&phNum1[2]==4)&&phNum1[3]==4 ){
        digitalWrite (ledGreen, HIGH);

}else if(((phNum1[0]==4 && phNum1[1]==5)&&phNum1[2]==0)&&phNum1[3]==8 ){
        digitalWrite (ledGreen, HIGH);
```

.

Programming tools

Arduino: to develop the code for Arduino Uno.

2.6. Conclusions

During the whole process there have been made many modifications through all the designing plans.

There have been some difficulties while using the command from basic that is able to recognize the phone number. That had leaded us to several circuit modifications. The advantage of making the user introduce by hand his phone number increases the security of the system.

Thanks to this technique, it is possible to introduce another code different from a phone number that at least has eight digits. And the mobile phone app code could be reused without making any big modification.

Also is an advantage of having selected a photodiode circuit to recognize the signal. All of the components have resulted very cheap.

The only big deal of this circuit is to set in a very accurate way the comparator level. In our project it has been modelled to work under certain light present, but not directly exposed. It works good indoor with the building lights on. It presents some problems with natural light.

This might be solved protecting the Photodiode with some kind of coverture, or designing a high pass filter to avoid the natural light problems.

It has been developed an application for a smart-phone, working under Android system.
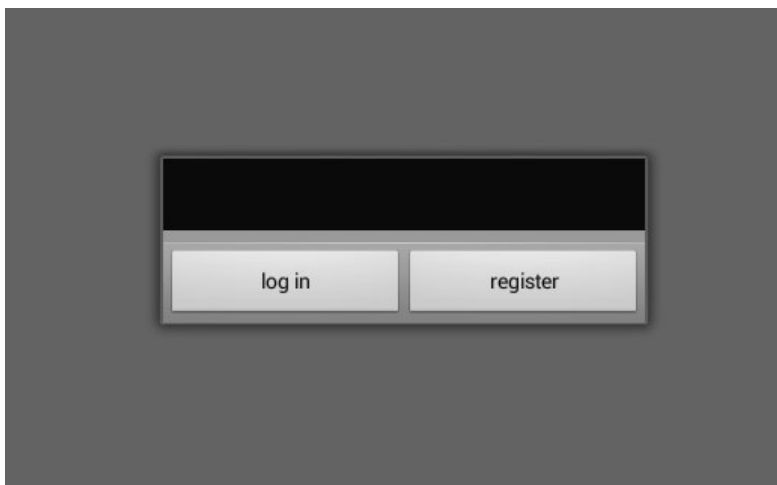
Figure 2.6.1: main menu

This application is able to ask for the users data and save them. There is a main menu "log in" or "register" (see Figure 2.6.1)to speed up the signing up process once the user is registered. The app is able to get some stored data from a text file and compare to the new received data.

In order to send a short code, it is selected a part of the user´s mobile phone and it is transformed into a special binary code (see Table 2.6.1) to make the Arduino work in an easier way.

Decimal number	a	b	c	d
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	1	0	0
4	1	0	0	0
5	1	0	0	1
6	1	0	1	0
7	1	1	0	0
8	1	1	0	1
9	1	1	1	0

a=4
b=3
c=2
d=1

Table 2.6.1: Used binar code

The user data are saved in a file. The user's name and phone number are encrypted and saved in a text file. This data are decrypted where they are needed to be read. The password to encrypt them is directly the user´s name, taking in to account up and low cases, and blank spaces. This presents a main advantage and draw back. The security is increased, but if the user forgets his username, then there is no direct method to find it.

Old codification

Encrypted
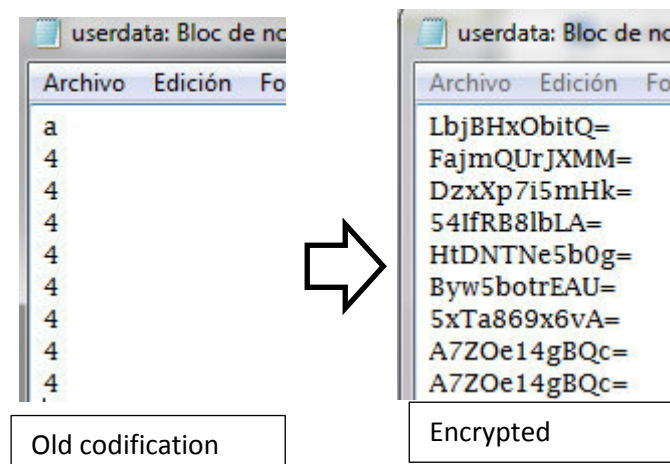
Figure 2.6.2: Userdata.txt modifications

Therefore it is necessary to have a business administrator that saves the user data in a hard copy.

Also is set up a greeting code to synchronize the mobile phone with the Arduino.

	t/4	t/2	3t/2	t	Phone →…. Number Code
	t1	t2	t3	t4	
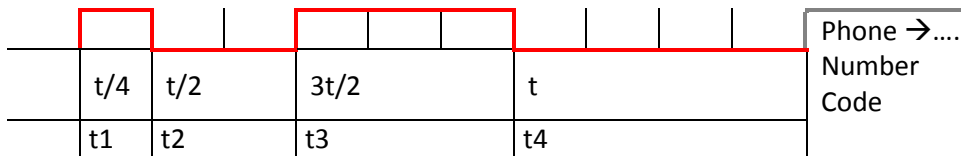
Figure 2.6.3: Greeting code

The receiver circuit amplifies the signal 1M times and then it is compared with a reference voltage from 2.2V and sent it to the Arduino. This reference voltage allows the signal to pass in pulse form. The design presents a main drawback; it does not work properly when sunlight is focused directly on the photodiode.

In order to know if the Arduino is working a blue led is switched on. The Arduino has to recognize the greeting code. When it does it a yellow led will be switched on.

Then starts recording the receiving code and decomposes it following the next logic:

First bit		Second bit		Third bit		Fourth bit		First bit…	
tx1	ty		ty		ty		tx2	tx1	ty…

Figure 2.6.4: Reading the received code

```
Conversion:
 if (greeting ==1){
  for (int i=0; i<4; i++){
    Num=0;
    delay (tx1);
    look_num1= analogRead (inputPin);
    if (look_num1 >= up){Num+=4;}
    delay (ty);
    look_num2= analogRead (inputPin);
    if (look_num2 >= up){Num+=3;}
    delay (ty);
    look_num3= analogRead (inputPin);
    if (look_num3 >= up){Num+=2;}
    delay (ty);
    look_num4= analogRead (inputPin);
    if (look_num4 >= up){Num+=1;}
    delay (tx2);

    phNum1[i]=Num;
  }
```

The previous code has been modified to the next one:

```
Conversion:
 if (greeting ==1){
  for (int i=0; i<4; i++){
    Num=0;
    delay (tx1);
    look_num1_1= analogRead (inputPin);
    delay (tx2);
    look_num1_2= analogRead (inputPin);
    if ((look_num1_1 >= up )||(look_num1_2 >= up )){Num+=4;}
    delay (ty1);
    look_num2_1= analogRead (inputPin);
    delay (ty2);
    look_num2_2= analogRead (inputPin);
    if ((look_num2_1 >= up )||(look_num2_2 >= up) ){Num+=3;}
    delay (ty1);
    look_num3_1= analogRead (inputPin);
    delay (ty2);
    look_num3_2= analogRead (inputPin);
    if ((look_num3_1 >= up )||(look_num3_2 >= up)){Num+=2;}
    delay (ty1);
    look_num4_1= analogRead (inputPin);
    delay (ty2);
    look_num4_2= analogRead (inputPin);
    if ((look_num4_1 >= up )||(look_num4_2 >= up)){Num+=1;}
    delay (tx1);
    delay (tx2);

    phNum1[i]=Num;
  }
```

The way to check the code it has been done following If's sequence. It might be also implemented using a look up table, in order to make it simpler when the number of users increases.

It has been some difficulties when adjusting the reading times, because of the delays in the physical circuit where processing the signal. See Annexed D and E. But thanks to the second reading, the system has increased its efficiency from a 60% to a 95.45%.

2.7. Further developments

This project was focused on several users sending their codes to one photodiode, that means one door.

Based on this idea, it could have been seen as one user sending his code to different building doors. For example, the users front home door, his garage door, and the garage door from his office. In order to develop this, it will be needed to modify the mobile app main menu to include the different options. For making the simulation it is not necessary needed to count with another Arduino. In the same one can be charged the new program.

For each building door, the user will be asked to give one different building code. His data will be stored in different files, one per door, and its content does not have to be the same. This means that the user can decide which name to give for each building door. This will increment the security for the whole system.

Another different focus would have been only one user per photodiode. This would have required making some modifications in the Arduino code and implement several photodiodes circuits.
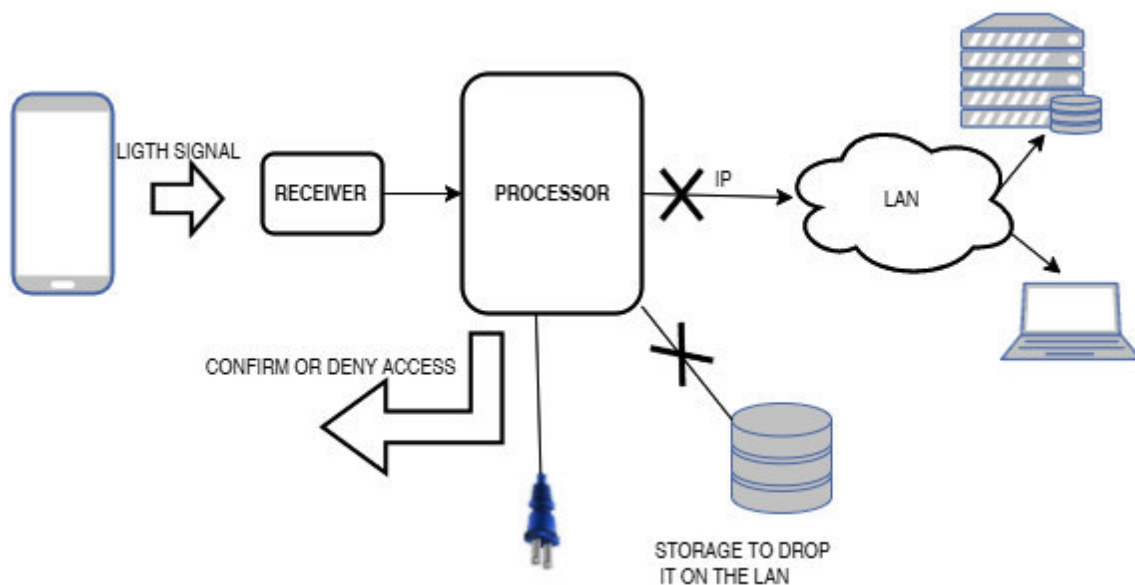
Figure 2.7.1: Further connections.

As it can be observed, it has not been implemented further connections to a LAN. This will make the whole process more suitable and secure for control access methods. Also, it will be interesting to count with a storage. This will allow the system to send the data later in case that the LAN is collapsed.
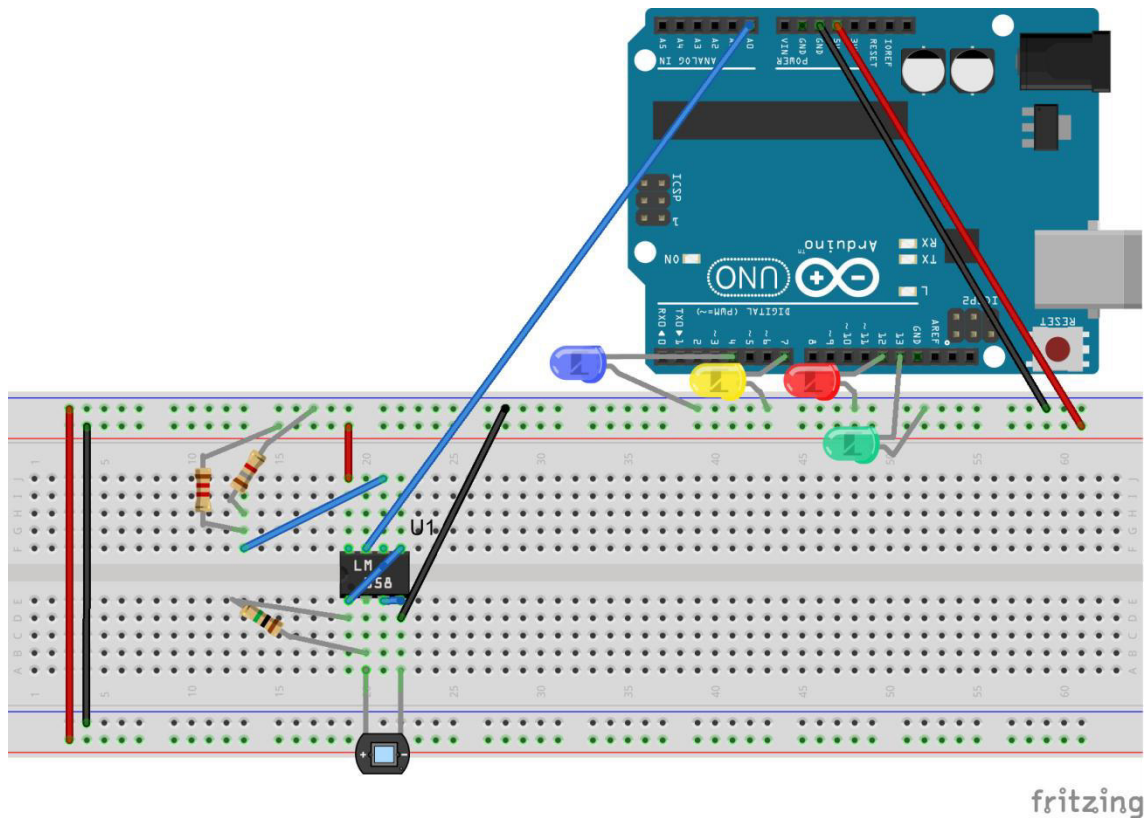
Figure 2.7.2: Less component circuit

Another implementation than can be done is to reduce the number of components in the physical circuit picking another kind of operational amplifier (LM 358) as showed in Figure 2.6.5.

Working with this kind of scheme gives the chance to make it larger. This means that there can be added till at least six photodiodes more per Arduino. There should be implemented the same code several times. With this method is possible to allow the entrance only to some users in some access points, or even assign one photodiode entrance per user. This last application will be suitable for hotels doors opening.

It was observed that the higher the frequency was, the more error transmitting the signal was accumulated. So to make the Arduino work properly, it was needed to change the reading times parameters. Making the waiting time before each analog read, was avoided this problem.

Working with an Arduino system allows the installation of Arduinos all around one building with no more requirements than one plug. The Arduino can work with one regular smartphone

transformer. This makes it very suitable to adapt it to any main building current. Also to avoid

system failures is better to count with a battery supply system.

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PART 3: ECONOMIC STUDY

List of elements used

Elements used in Physical Circuit

NAME	AMOUNT
Arduino UNO	1
Cables	12
Green Led 10 mm	1
High speed Cable 2.0	1
Led Blue 10mm	1
Led Red 10mm	1
Led Yellow 10 mm	1
Operational amplifier UA741CP	2
Photodiode	1
Protoboard	1
Resistor 1K5	1
Resistor 1K8	1
Resistor 1M	1
Total	25

Software tools

NAME	AMOUNT
Draw.io	1
LED torch HD	1
rfo-BASIC!	1
BASIC!- Launcher	2
Arduino	1
NotePad++	1
Total	7

Supportive equipment

NAME	AMOUNT
Smart Phone	1
Computer	1
Tektronix MSO 3012 Mixed Signal Oscilloscope	1
Total	**3**

Labor hours

FUNCTION	HOURS
Arduino programming	20
BASIC! Programming	45
BASIC! Study	20
Building circuit	1
Components selection	10
Design Arduino programm	12
Design Circuit	6
Design mobile App	7
Documentation	60
Evaluation Arduino Program	20
Evaluation Circuit	12
Evaluation mobile App	10
Information researching	20
Modification in Arduino	30
Modification in circuit design	10
Modification in mobile App	15
Presentations	8
Test Arduino Programm	30
Test Circuit	5
Test mobile App	20
ZigBee study	10
Total	**371**

Economic prices study from elements used

Elements used in Physical Circuit

NAME	UNITS	Units/Package	Price /Package		PRICE	
Arduino UNO	1	1	20	€	20	€
Cables	14	65	4,04	€	0,870153846	€
Cables oscilloscope	2	2	15,8	€	15,8	€
High speed Cable 2.0	1	1	3	€	3	€
Led Blue 10mm	1	4	1,51	€	0,3775	€
Led Green 10 mm	1	1	0,57	€	0,57	€
Led Red 10mm	1	1	0,57	€	0,57	€
Led Yellow 10 mm	1	1	0,57	€	0,57	€
Operational amplifier UA741CP	2	2	4,21	€	4,21	€
Photodiode SFH 2039 P	1	1	0,79	€	0,79	€
Protoboard	1	1	3	€	3	€
Resistor 1K5	1	1	0,05	€	0,05	€
Resistor 1K8	1	1	0,05	€	0,05	€
Resistor 1M	1	1	0,05	€	0,05	€
Smartphone Charger	1	1	5,68	€	5,68	€
Total			59,89	€	55,58765385	€

Software tools

NAME	UNITS	PRICE/UNIT	PRICE
Draw.io	1	0 €	0 €
LED torch HD	1	0 €	0 €
rfo-BASIC!	1	0 €	0 €
BASIC!- Launcher	2	0 €	0 €
Arduino	1	0 €	0 €
NotePad++	1	0 €	0 €
Total			**0 €**

Supportive equipment

NAME	UNITS	PRICE/UNIT	PRICE
Smart Phone	1	150 €	150 €
Laptop	1	400 €	400 €
Tektronix MSO 3012 Mixed Signal Oscilloscope	1	3.500 €	3.500 €
Total			4.050 €

Labor costs

FUNCTION	HOURS	PRICE/Hour		PRICE	
Arduino programming	20	6	€	120	€
BASIC! Programming	45	6	€	270	€
BASIC! Study	20	6	€	120	€
Building circuit	1	6	€	6	€
Components selection	10	4	€	40	€
Design Arduino programm	12	12	€	144	€
Design Circuit	6	12	€	72	€
Design mobile App	7	12	€	84	€
Documentation	60	6	€	360	€
Evaluation Arduino Program	20	8	€	160	€
Evaluation Circuit	12	8	€	96	€
Evaluation mobile App	10	8	€	80	€
Information researching	20	6	€	120	€
Modification in Arduino	30	16	€	480	€
Modification in circuit design	10	15	€	150	€
Modification in mobile App	15	16	€	240	€
Presentations	8	12	€	96	€
Test Arduino Programm	30	12	€	360	€
Test Circuit	5	30	€	150	€
Test mobile App	20	15	€	300	€
ZigBee study	10	12	€	120	€
Total				3568	€

Total calculation

In case of not counting with any element form the supportive equipment, they will be included in the direct cost.

Also by direct costs will be included electricity, working place, water supply, internet connection,…

CONCEPT	PRICE
Elements used in Physical Circuit	59,89 €
Software tools	4.050 €
Supportive equipment	0 €
Labor costs	3.568 €
Total	7.678 €

Final study:

CONCEPT		PRICE
Proyect		7.678€
IVA	21%	1.612,38€
Direct costs	10%	767,8€
Total		10.058,18€

Figures Index

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Abreviations

APs   Access Points

ASK   Amplitude Shift Keying

BACS   Building Automation and Control System

BM   Building Management

ED   Energy Detection

HR   High-Rate

HVAC   Heating, Ventilation, and Air-Conditioning

IEEE   Institute of Electrical and Electronics Engineers

IoT   Internet of Things

IP   Internet Protocol

IR   Infrared

ISO   International Standardization Organization

IT   Information Technology

LAN   Local Area Network

Li-Fi   Light Fidelity

LR   Low-Rate

MAC   Medium Control Access

MR   Medium-Rate

NWK   Network Layer

OME   Original Equipment Manufacturer

OSI   Open Sistems Interconnection

PC   Personal Computer

PHY   Physical Layer

RF   Radio Frequency

TBM   Technical Building Management

Wi-Fi   Wireless Fidelity

WLAN   Wireless Local Area Network

WPAN   Wireless Personal Area Networks

ANNEXED

Annexed A: ARDUINO CODE

```
/***** Declare variables****/
int inputPin = A0;     // select the input pin for  output of the
comparator
int ledGreen = 13;        // select the pin for the LED to be the
output. Is the one in the Arduino board.
int ledRed = 12;
int ledYellow =7;
int ledBlue=4;
int up= 4.0 * ( 1023.0/5.0);// Convert the analog reading (which goes
from 0 - 1023) to a voltage (0 - 5V):


int ti=1000;//i_input for the greeting
int ti1=ti/4;
int ti2=ti/2;
int ti3=ti*0.75;

int ty1=340;
int tx1=170;
int ty2=10;
int tx2=5.25;

int phNum1[]={
   10,10,10,10
};

int greeting=0;
int Num=0;
int look_num1_1=0;
int look_num2_1=0;
int look_num3_1=0;
int look_num4_1=0;
int look_num1_2=0;
int look_num2_2=0;
int look_num3_2=0;
int look_num4_2=0;


void setup(){
  pinMode(ledGreen, OUTPUT);
  pinMode(ledRed, OUTPUT);
  pinMode(ledYellow, OUTPUT);
  pinMode(ledBlue, OUTPUT);

  digitalWrite (ledBlue, HIGH);


}
void loop (){
  int look1= analogRead (inputPin);
  if (look1 >= up){
    delay (ti1);
    int look2= analogRead (inputPin);
    if (look2 < up){
      delay (ti2);
      int look3= analogRead (inputPin);
      if (look3 >= up){
        delay (ti3);
        int look4= analogRead (inputPin);
```

```
        if (look4 < up){
          digitalWrite (ledYellow, HIGH);
          delay(ti);
          //delay (236);
          greeting=1;
          goto Conversion;
        }
      }
    }
  }

  Conversion:
   if (greeting ==1){
    for (int i=0; i<4; i++){
      Num=0;
      delay (tx1);
      look_num1_1= analogRead (inputPin);
      delay (tx2);
      look_num1_2= analogRead (inputPin);
      if ((look_num1_1 >= up )||(look_num1_2 >= up )){Num+=4;}
      delay (ty1);
      look_num2_1= analogRead (inputPin);
      delay (ty2);
      look_num2_2= analogRead (inputPin);
      if ((look_num2_1 >= up )||(look_num2_2 >= up) ){Num+=3;}
      delay (ty1);
      look_num3_1= analogRead (inputPin);
      delay (ty2);
      look_num3_2= analogRead (inputPin);
      if ((look_num3_1 >= up )||(look_num3_2 >= up)){Num+=2;}
      delay (ty1);
      look_num4_1= analogRead (inputPin);
      delay (ty2);
      look_num4_2= analogRead (inputPin);
      if ((look_num4_1 >= up )||(look_num4_2 >= up)){Num+=1;}
      delay (tx1);
      delay (tx2);

      phNum1[i]=Num;
    }

    if(((phNum1[0]==4 && phNum1[1]==4)&&phNum1[2]==4)&&phNum1[3]==4 ){
        digitalWrite (ledGreen, HIGH);

    }else if(((phNum1[0]==4 &&
phNum1[1]==5)&&phNum1[2]==0)&&phNum1[3]==8 ){
        digitalWrite (ledGreen, HIGH);

    }else if(((phNum1[0]==1 && phNum1[1]==9)&& phNum1[2]==5
)&&phNum1[3]==2 ){
         digitalWrite (ledGreen, HIGH);

    }else if(((phNum1[0]==3 && phNum1[1]==9)&& phNum1[2]==1 )&&
phNum1[3]==7){
        digitalWrite (ledGreen, HIGH);

    }else if(((phNum1[0]==4 && phNum1[1]==6)&& phNum1[2]==1) &&
phNum1[3]==0 ){
        digitalWrite (ledGreen, HIGH);

    }else{
```

```
        digitalWrite (ledRed, HIGH);
   }
   delay (1000);
   digitalWrite (ledRed, LOW);
   digitalWrite (ledGreen, LOW);
   digitalWrite (ledYellow, LOW);
   greeting=0;
   delay(1000);
  }


}



        digitalWrite (ledRed, HIGH);
   }
   delay (1000);
   digitalWrite (ledRed, LOW);
   digitalWrite (ledGreen, LOW);
   digitalWrite (ledYellow, LOW);
```

Annexed B: MOBILE APP CODE

```
!Save as .bas to obtain a nice code view in Notepad++

building_code=121212%to be modified by the building or the
organisation
found=0
gr.open 255,248,248,248
n=20
dim r$[n]%it is bigger that supposed to avoid errors
dim phNum$[8]
dim e_phNum$[8]
m=1

dim line$[10]
dim d_line$[10]


!fist part, recognize the user and get its data

start:
      file.exists a, "userdata.txt"%where the data is in the phone
      DIALOG.MESSAGE ,"",B,"log in","register"


      if B=1 %wants to log in
            if a=1 %wants to log in and already registered


                  input "Username:", user$


                  grabfile s$, "userdata.txt"
                  text.open r, myfile, "userdata.txt"
                  p=0
                  Do
                        p=p+1
                        Text.readln myfile, line$[p]
                  Until line$[p] = "EOF"
                  text.close myfile

                  decrypt user$, line$[1], d_line$[1]

                  if user$ =  d_line$[1]
                        message$= "Welcome back "+user$+" !"%to show
the user is properly working
                        popup message$, 0, 0, 0.5
                        pause 2500
                        found=1
                        for i=2 to 9
                              decrypt user$, line$[i], d_line$[i]
                              phNum$[m]=d_line$[i]
                              m=m+1
```

```
                        next i
                endif


                if found=0
                        message$= "Wrong name given / You are not a
registered user."
                        popup message$, 0, 0, 0.5
                        pause 2500
                        goto start
                endif
            endif
            if a=0 %wants to log in and not registered, try again
                message$= "You are not a registered user."
                popup message$, 0, 0, 0.5
                pause 2500
                goto start
            endif


    elseif B=2 %wants to register

            if a=1 %wants to register and already registered, start
                message$= "You are already registered"
                popup message$, 0, 0, 0.5
                pause 2500
                goto start
            endif
            if a=0 %wants to register and not registered
                %text.open w ,data ,"userdata.txt" %big problem.
dont know how to create a new file
                message$= "Do rember your user name, will be your
password"%to show the user is properly working
                popup message$, 0, 0, 1
                pause 5000
                message$= "Capital letters and blank spaces will be
taken into account"%to show the user is properly working
                popup message$, 0, 0, 1
                pause 5000
                input "New username:", user$ %input
"Country:",country$

                do
                        input "Enter your secret code:",code
                        if code = building_code
                            message$= "Code correct"
                            popup message$, 0, 0, 0.5
                            pause 2500
                        else
                            message$= "Wrong code, please try again"
                            popup message$, 0, 0, 0.5
                            pause 2500
                        endif
                until code=building_code
```

```
                    message$= "Welcome "+user$+" !"
                    popup message$, 0, 0, 0.5
                    pause 2500

                    GetNumber:
                            do
                                    input "Phone Number:", num
                                    input "Confirm your Phone Number:", num2
                                    if num = num2

                                            message$= "Phone Number OK "
                                            popup message$, 0, 0, 0.5
                                            pause 2500
                                    else
                                            message$= "It is not the same
number, please try again"

                                            popup message$, 0, 0, 0.5
                                            pause 2500
                                    endif
                            until num2=num

                            num_d$=str$(num)

                            for i=1 to 12
                                    r$[i]=mid$(num_d$,i,1)
                            next i

                            !copy the old array into a new depurated one,
we exclude 6. because is always the same for all mobiles
                            if r$[1]="6"& r$[2]="."%for the spanish mobile
phone
                                    for i=3 to 12
                                            if r$[i]="E"
                                                    for n=i to 10
                                                            r$[n]="0"
                                                    next n
                                            endif
                                    next i

                                    for i=1 to 8
                                            u=i+2
                                            phNum$[i]=r$[u]
                                    next i
                            elseif r$[2]="."%doesnt matter how long is the
new number, we will only pick the first eigth digits.(for our purpose
will be fine)
                                    for i=3 to n
                                            if r$[i]="E"
                                                    for n=i to (n-2)
                                                            r$[n]="0"
                                                    next n
                                            endif
                                    next i
```

```
                        for i=1 to 8 %be careful, first number of
the array is one, no cero, take it into account for futher loops
                            u=i+2
                            phNum$[i]=r$[u]
                        next i
                    else%just in case.not likely to happen
                        message$= "Please, introduce your country
prefix. For example: 0049 **** *******"
                        popup message$, 0, 0, 0.5
                        pause 2500
                        goto GetNumber
                    endif

                    !encrypt
                    encrypt user$,user$,e_user$
                    for i=1 to 8
                      encrypt user$,phNum$[i],e_phNum$[i]
                    next i

                    !add it to the file

                    found=1
                    text.open w, myfile, "userdata.txt"
                    text.writeln myfile, e_user$
                    for i=1 to 8
                        text.writeln myfile, e_phNum$[i]
                    next i
                    text.close myfile
                endif
        endif



!code ready to send
gr.orientation 0%horizontal
gr.screen w, h
whalf=w/2
hhalf=h/2
count=5


t4=1000
t3=0.75*t4
t2=t4/2
t1=t4/4
ty=250



if found=1
    message$= "Phone number ready to send. Place your device in
front of the reciver."
    popup message$, 0, 0, 1
```

```
        pause 5000
        for i=1 to 6
                r$=str$(count)
                gr.color 255,0,0,0,1%black screen; alpha, red,green,
blue,fill
                gr.rect rect1,0, 0, w, h
                gr.render
                pause 500
                gr.color 255,255,255,255,1
                gr.text.size 100
                gr.text.draw pt, whalf,hhalf,r$
                gr.render
                pause 500
                count=count-1
        next i
        !greeting to receptor
        gr.color  255,255,255,255,1%white
        gr.rect rect1,0, 0, w, h
        gr.render
        pause t1
        gr.color 255,0,0,0,1%black
        gr.rect rect1,0, 0, w, h
        gr.render
        pause t2
        gr.color  255,255,255,255,1%white
        gr.rect rect1,0, 0, w, h
        gr.render
        pause t3
        gr.color 255,0,0,0,1%black
        gr.rect rect1,0, 0, w, h
        gr.render
        pause t4
else
        goto start
endif


        !start the transmission
        !transmit the number, k only can take from 1 to 8
for k=1 to 4 %for k=1 to 8 aproximately 20 seconds, we reduce it to 4
        i=0
        if phNum$[k]="0"  %0000
                for c=1 to 4
                        gr.color 255,0,0,0,1%black
                        gr.rect rect1,0, 0, w, h
                        gr.render
                        pause ty
                next c
        elseif phNum$[k]="1" %0001
                for c=1 to 3
                        gr.color 255,0,0,0,1%black
                        gr.rect rect1,0, 0, w, h
                        gr.render
                        pause ty
```

```
            next
            gr.color 255,255,255,255,1%whhite
            gr.rect rect1,0, 0, w, h
            gr.render
            pause ty
elseif phNum$[k]="2"%0010
        for c=1 to 2
                gr.color 255,0,0,0,1%black
                gr.rect rect1,0, 0, w, h
                gr.render
                pause ty
        next
        gr.color 255,255,255,255,1%white
        gr.rect rect1,0, 0, w, h
        gr.render
        pause ty
        gr.color 255,0,0,0,1%black
        gr.rect rect1,0, 0, w, h
        gr.render
        pause ty
elseif phNum$[k]="3"%0100
        gr.color 255,0,0,0,1%black
        gr.rect rect1,0, 0, w, h
        gr.render
        pause ty

        gr.color 255,255,255,255,1%white
        gr.rect rect1,0, 0, w, h
        gr.render
        pause ty

        for c=1 to 2
                gr.color 255,0,0,0,1%black
                gr.rect rect1,0, 0, w, h
                gr.render
                pause ty
        next
elseif phNum$[k]="4" %1000
        gr.color 255,255,255,255,1%white
        gr.rect rect1,0, 0, w, h
        gr.render
        pause ty
        for c=1 to 3
                gr.color 255,0,0,0,1%black
                gr.rect rect1,0, 0, w, h
                gr.render
                pause ty
        next
elseif phNum$[k]="5" % 1001
        gr.color 255,255,255,255,1%white
        gr.rect rect1,0, 0, w, h
        gr.render
        pause ty
        for c=1 to 2
```

```
                    gr.color 255,0,0,0,1%black
                    gr.rect rect1,0, 0, w, h
                    gr.render
                    pause ty
            next
            gr.color 255,255,255,255,1%white
            gr.rect rect1,0, 0, w, h
            gr.render
            pause ty
    elseif phNum$[k]="6"%1010
            gr.color 255,255,255,255,1%white
            gr.rect rect1,0, 0, w, h
            gr.render
            pause ty
            gr.color 255,0,0,0,1%black
            gr.rect rect1,0, 0, w, h
            gr.render
            pause ty
            gr.color 255,255,255,255,1%white
            gr.rect rect1,0, 0, w, h
            gr.render
            pause ty
            gr.color 255,0,0,0,1%black
            gr.rect rect1,0, 0, w, h
            gr.render
            pause ty
    elseif phNum$[k]="7"     % 1100

            for c=1 to 2
                    gr.color 255,255,255,255,1%white
                    gr.rect rect1,0, 0, w, h
                    gr.render
                    pause ty
            next
            for c=1 to 2
                    gr.color 255,0,0,0,1%black
                    gr.rect rect1,0, 0, w, h
                    gr.render
                    pause ty
            next

    elseif phNum$[k]="8" %1101

            for c=1 to 2
                    gr.color 255,255,255,255,1%white
                    gr.rect rect1,0, 0, w, h
                    gr.render
                    pause ty
            next
            gr.color 255,0,0,0,1%black
            gr.rect rect1,0, 0, w, h
            gr.render
            pause ty
```

```
            gr.color 255,255,255,255,1%white
            gr.rect rect1,0, 0, w, h
            gr.render
            pause ty

        elseif phNum$[k]="9" %1110

            for c=1 to 3
                gr.color 255,255,255,255,1%white
                gr.rect rect1,0, 0, w, h
                gr.render
                pause ty
            next
            gr.color 255,0,0,0,1%black
            gr.rect rect1,0, 0, w, h
            gr.render
            pause ty
        else
            print "error getting the numbers"
        endif

next k




!end the transmission
gr.color 255,0,0, 0,1%black screen
gr.rect rect1,0, 0, w, h
gr.render
message$= "End of transmission"
popup message$, 0, 0, 1
pause 10000%

end
```

Annexed C: Reading Test

1	T read	Acc. read t	t code	Acc.t code	Acc.read t-accu.t code	ok
4	175,25	175,25	340	340	164,75	x
	350	525,25	313,33	653,3333333	128,0833333	x
	350	875,25	313,33	966,6666667	91,41666667	x
	350	1225,25	313,33	1280	54,75	x
	175,25	1400,5		1280	-120,5	
4	175,25	1575,75	360	1640	64,25	x
	350	1925,75	333,33	1973,333333	47,58333333	x
	350	2275,75	333,33	2306,666667	30,91666667	x
	350	2625,75	333,33	2640	14,25	x
	175,25	2801		2640	-161	
4	175,25	2976,25	380	3020	43,75	x
	350	3326,25	260	3280	-46,25	
	350	3676,25	260	3540	-136,25	
	350	4026,25	260	3800	-226,25	
	175,25	4201,5		3800	-401,5	
4	175,25	4376,75	380	4180	-196,75	
	350	4726,75	260	4440	-286,75	
	350	5076,75	260	4700	-376,75	
	350	5426,75	260	4960	-466,75	
	175,25	5602		4960	-642	
		Average	310			

	T read	Acc. read t	t code	Acc.t code	Acc.read t-accu.t code	ok
4	175	175	380	380	205	x
	350	525	313,33	693,3333333	168,3333333	x
	350	875	313,33	1006,666667	131,6666667	x
	350	1225	313,33	1320	95	x
	175	1400		1320	-80	
4	175	1575	360	1680	105	x
	350	1925	326,66	2006,666667	81,66666667	x
	350	2275	326,66	2333,333333	58,33333333	x
	350	2625	326,66	2660	35	x
	175	2800		2660	-140	
4	175	2975	380	3040	65	x
	350	3325	340	3380	55	x
	350	3675	340	3720	45	x
	350	4025	340	4060	35	x
	175	4200		4060	-140	
4	175	4375	380	4440	65	x
	350	4725	340	4780	55	x
	350	5075	340	5120	45	x
	350	5425	340	5460	35	x

	T read	Acc. read t	t code	Acc.t code	Acc.read t-accu.t code	ok
4	175	175	360	360	185	x
	350	525	313,333333	673,3333333	148,3333333	x
	350	875	313,333333	986,6666667	111,6666667	x
	350	1225	313,333333	1300	75	x
	175	1400		1300	-100	
4	175	1575	360	1660	85	x
	350	1925	326,666667	1986,666667	61,66666667	x
	350	2275	326,666667	2313,333333	38,33333333	x
	350	2625	326,666667	2640	15	x
	175	2800		2640	-160	
4	175	2975	360	3000	25	x
	350	3325	346,666667	3346,666667	21,66666667	x
	350	3675	346,666667	3693,333333	18,33333333	x
	350	4025	346,666667	4040	15	x
	175	4200		4040	-160	
4	175	4375	380	4420	45	x
	350	4725	350	4770	45	x
	350	5075	350	5120	45	x
	350	5425	350	5470	45	x
	175	5600		5470	-130	
		Average:	341,875		no theorethical failure	

Annexed D:First failure recount

For code 4444:

Yes(y)/No(n)	Fail
n	getting second number
n	other
y	
y	
n	getting second number
y	
y	
n	getting second number
y	
y	
n	getting second number
y	

Recount		%
Fail	5	
Getting second number	4	
Other	1	
ok	7	58.3%
	12	

For code 1952:

Yes(y)/No(n)	Fail
y	
y	
y	
n	getting second number
y	
n	getting second number
n	getting third number
n	getting second number
y	
n	others
n	getting second number
y	
y	
n	getting second number
y	
y	
y	
y	
y	
n	getting third number

Recount		%
Fails	8	
Getting second number	5	
Getting third number	2	
Other	1	
ok	12	60%
	20	

Annexed E: Second Failure Recount

Now different codes are going to be executed one after other.

Code	Yes (y)/No(n)
4444	y
	y
	y
	y
	y
1952	y
	y
	y
	y
	y
3917	y
	y
	y
	y
	y
	y
4444	y
1952	n
	y
	y
	y
4610	y

Recount:		
Failure	1	
OK	21	95.45%
	22	

Annexed F: DATA SHEETS

Red LED: [Online]. Available: http://www.micropik.com/PDF/L-813SRC-E.pdf

Blue LED: [Online]. Available: http://www.micropik.com/PDF/ll-1003bc2d-b4-1c.pdf

Arduino UNO: [Online]. Available: http://digital.csic.es/bitstream/10261/127788/7/D-c-%20Arduino%20uno.pdf

Oscilloscope: [Online]. Available:

http://www.testequipmentdepot.com/tektronix/pdf/mdo3000-series_data.pdf

Operational Amplificator UA741CP: [Online]. Available:

http://pdf.datasheetcatalog.net/datasheet2/b/0dj0s6lpopzzuc0tji1z0qldzafy.pdf