BRNO UNIVERSITY OF TECHNOLOGY
VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION
FAKULTA ELEKTROTECHNIKY
A KOMUNIKAČNÍCH TECHNOLOGIÍ

DEPARTMENT OF FOREIGN LANGUAGES
ÚSTAV JAZYKŮ

SMART HOME
CHYTRÁ DOMÁCNOST

BACHELOR'S THESIS
BAKALÁŘSKÁ PRÁCE

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VEDOUCÍ PRÁCE

BRNO 2019

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
FAKULTA ELEKTROTECHNIKY A KOMUNIKAČNÍCH TECHNOLOGIÍ

Bakalářská práce

bakalářský studijní obor **Angličtina v elektrotechnice a informatice**
Ústav jazyků

Student: Ondřej Pitra ***ID:*** 185906
Ročník: 3 ***Akademický rok:*** 2018/19

NÁZEV TÉMATU:

Chytrá domácnost

POKYNY PRO VYPRACOVÁNÍ:

Cílem práce je navrhnout a realizovat smart home systém pro řízení vybraných spotřebičů. Zaměřte se na možnosti dálkového řízení spotřebičů. Popište aktuální trendy v oblasti automatizace chytrých domácností.

DOPORUČENÁ LITERATURA:

Dle instrukcí odborného konzultanta

Termín zadání: 4.2.2019 ***Termín odevzdání:*** 28.5.2019

Vedoucí práce: Mgr. Magdalena Šedrlová
Konzultant:

doc. PhDr. Milena Krhutová, Ph.D.
předseda oborové rady

ABSTRACT

The aim of this bachelor's thesis is to present and describe fundamental principles, characteristics, and application of my own project of Smart Home. In this thesis, I will present my current state of the project as well as the future plans for my Smart Home. I will also introduce and compare Smart Home systems from companies already established on the market.

KEYWORDS

Smart Home, electronics, control, Ethernet, smartphone, Arduino, Wemos R1 D2, Arduino shield, Blynk, Loxone, Philips Hue

ABSTRAKT

Cílem této bakalářské práce je seznámit čtenáře a popsat mu základní principy, charakteristiky a použití mého vlastního projektu s názvem Chytrá domácnost. V této práci se budu zabývat dosavadním stavem mého projektu a dále popíši budoucí plány pro moji Chytrou domácnost. Taktéž představím a porovnám systémy chytrých domů od firem, které se touto technologií zabývají několik let.

KLÍČOVÁ SLOVA

Chytrá domácnost, elektronika, ovládání, ethernet, chytrý telefon, Arduino, Wemos R1 D2, periferie Arduina, Blynk, Loxone, Philips Hue

PITRA, Ondřej. Chytrá domácnost [online]. Brno, 2019 [cit. 2019-05-24]. Dostupné z: https://www.vutbr.cz/studenti/zav-prace/detail/119374. Bakalářská práce. Vysoké učení technické v Brně, Fakulta elektrotechniky a komunikačních technologií, Ústav jazyků. Vedoucí práce Magdalena Šedrlová.

PROHLÁŠENÍ

Prohlašuji, že svou bakalářskou práci na téma Smart Home jsem vypracoval samostatně pod vedením vedoucího bakalářské práce a s použitím odborné literatury a dalších informačních zdrojů, které jsou všechny citovány v práci a uvedeny v seznamu literatury na konci práce.

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V Brně dne ....

Ondřej Pitra

ACKNOWLEDGMENTS

I would like to thank my supervisor Mgr. Magdalena Šedrlová for help, guidance and useful tips during my work. Furthermore I would also like to thank my mother JUDr. Ingrid Pitrová, my father Milan Pitra and my sister Lucie Pitrová for their support all the way through my studies.

Content

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1 Introduction

Home is a place, where all of us feel safe and where we spend a lot of time. Technology started entering our everyday lives only a few decades ago and since then it has come a long way. Because we are creative human beings, we started integrating technology into our homes as well. For the past few years, we have been installing security systems in our houses and now it is time to integrate a little bit of smartness as well.

It is possible that smart homes will become massively widespread. The definition of a smart home describes the ability of the house to do various tasks automatically and that the inhabitants of the house can control various appliances with their smart devices via the internet. The user can set the temperature, switch or dim the lights on and off, operate the blinds, open the garage when arriving home or close it when leaving the house, change the dynamic mood of the room with RGB LED strips or be able to see the temperature outside and inside in each room. The application of a smart home is vast, and it depends on the user's preferences.

I started to make my own smart home when I was in the second year of high school. That is when I discovered a little programmable micro-controller called Arduino and wrote my first few lines of code to blink a LED. Since then, I made a lot of prototypes of various smart homes, but now I have the final version, which I am proud of. My intention was only to make my life easier in my own room, but then it became a project for the whole upper floor and the garage. I am planning on expanding my smart home to the lower floor in the future as well.

My realization of a smart home consists of Arduino UNO for the house part of my project and for the control of the garage I used a Chinese copy called Wemos D1 R2, which is basically Arduino UNO, but with an integrated WI-FI chip. That way I do not have to use cables to connect two microcontrollers together, because the garage is situated next to my house. Wemos D1 R2 has fewer functions and it is working with a lower voltage, but it is suitable for this kind of application.

In this bachelor thesis, I will be comparing with my own smart home and other systems from big companies that are already established on the market.

2 Smart wiring in buildings

The conventional Smart home system includes homes that are automated and the home itself is taking care of the comfort of the inhabitants. In case the inhabitant wants to watch a movie, he or she will press the preconfigured button on the tablet and the home will automatically close the blinds, turn off the light and turn on TV and stereo. Temperature can be also automatically regulated. The user will set the desired temperature and the home does the rest. The temperature setting will depend on a few variables. Firstly, it will depend on the temperature outside, whether the sun is shining into the room and secondly if there is a person present in the room. The smart home is able to communicate with the air-conditioning, heating, blinds, etc. Most of the functions are accessible from anywhere in the world provided that the user has an internet connection and the Smart home app installed.

The conventional Smart home system also includes some sort of optional subsystems such as a garage door system, a sound system, electrical appliances, and a camera and security system which are interconnected to create one big system that controls everything. Smart home system requirements include a simple interacting with an app and intuitive User interface, safety and trouble-free functionality.

2.1 Types of wiring in buildings

2.1.1 Classical wiring

This type of wiring is one of the most used in the world. From the beginning, it was used for powering appliances and lights. This type of wiring consists of different circuits, for example: lights circuit, socket circuit or heating circuit. In a classical wiring circuit, there is no information sent over the wires but only the certain circuit is completed by for example switching on the light switch. The user is not able to easily modify such circuits. The advantage of this style of wiring is considerably lower costs and a wide range of electricians who can perform the job. I consider as the biggest disadvantage the impossibility to easily integrate a smart home into this type of wiring.

2.1.2 Smart wiring

It is used for controlling technological processes in buildings. This type of wiring is connecting all of the systems in the building and together creates one big independent system that is capable of working on its own. All of the systems can communicate with each other over a data bus and allow the system to be fully autonomous. The user is only controlling the main system which then sends signals to the rest of the subsystems. This function then allows for automatic regulation of the heating, air conditioning, lighting and motorized blinds. The main advantage is the comfort, automatization of the building and easy expansion of the smart home system.

The main (and very important part) of a smart home is wiring and preparation. Companies are trying to integrate the smart home into old buildings by making the smart devices wireless, but from my own experience, it often does not work properly. If we want to make smart home flawless, we need to start designing the building with the smart wiring in mind. That includes, as I said previously, making separate electrical circuits connected to each individual switch and outlet. That way we have individual control over the single circuit and can, for example, switch off only one light from the fuse box. The inhabitants have control of the light via a switch on the wall or with an application on their smartphone. The only disadvantage is the overuse of wires and circuit breakers which are not cheap. A traditional way of making electrical circuits is multiple lights being connected to one circuit breaker, but with this connection, you cannot control the lights individually.

The second way of integrating the smart home into the building is by making wireless modules that communicate with some sort of a base. Unfortunately, it is more expensive and not as reliable, because you need to change the batteries in all of the sensors and actuators. They also need to be in the range of the base.

The third way is the way I have chosen. Because I live in an old building, I used only one base micro-controller and connected every sensor, relay and other peripherals by wire. It is not efficient nor nicest way of connection, but it has been working without any maintenance for the past three years.

3 Hardware

The main part of the Smart Home system is the base, in which peripherals are connected to. The base is the brain of every smart home because it is communicating and setting the peripherals. This base, in general, must have inputs and outputs for communication, WIFI, cellular or Ethernet connection, power supply connection and back up battery in case of a power cut.

3.1 Arduino UNO

Arduino UNO is the best board one can start working with electronics and coding. Arduino UNO is the most robust and well-documented board of all Arduino boards. It is a microcontroller based on the ATmega328P. It has 14 digital input and output pins where six of them can be used for PWM modulation. For example, in my project, it is used for changing the brightness of the RGB LED strip. Furthermore, this board contains 6 analog inputs and 16MHz crystal, which sets the clock speed of the processor, a USB connection used for programming the board, power jack for powering the board and the reset button in case the board freezes. The input voltage of this board is from 5V DC up to 12V DC. Arduino has a 5V input voltage stabilizer. [5]

Coding of Arduino UNO is done via software called Arduino IDE which can be downloaded from Arduino website for free.

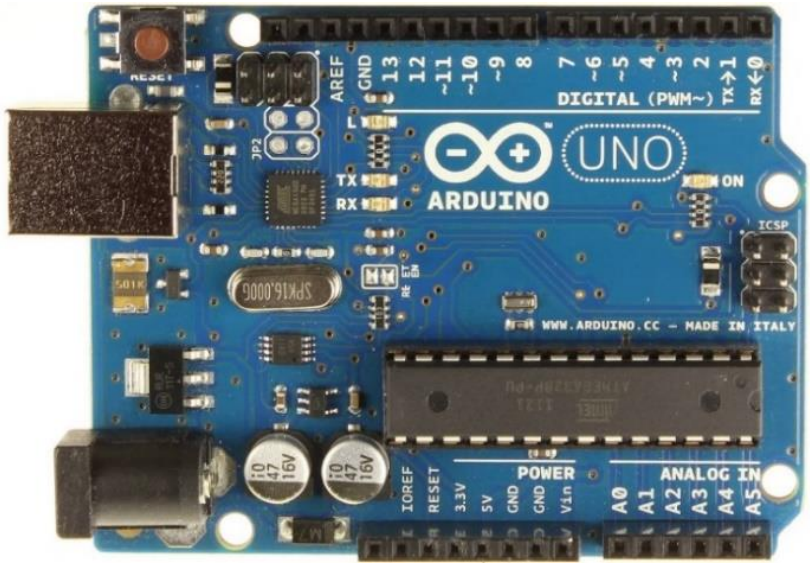

Figure 1. Arduino UNO [1]

3.2 Wemos D1 R2

Wemos D1 R2 is an Arduino (SW) compatible Chinese copy of Arduino UNO. It consists of 11 digital input pins with PWM modulation except for D0, only 1 analog input, which is working on a max input voltage of 3.2V, micro USB connection for programming and a power jack for an input voltage of 5V DC up to 24V DC. One of the biggest advantages over Arduino UNO is the existence of an integrated WI-FI chip. With only a few lines of code, this board can be connected to the WI-FI and communicate with other devices via the internet. This board needs special drivers for proper communication with the PC. The drivers can be found and downloaded from the website of the manufacturer. Wemos D1 R2 can be programmed via Arduino IDE as well with no complications. [6]

Figure 2. Wemos D1 R2 [2]

3.3 Sensors

Sensors are electronic parts, which are reading and converting physical analog values into digital electrical signals and sending them via serial bus into the processor. There are various sensors and toggles on the market such as switch, temperature, humidity, smoke, wind, rain or motion sensors. These sensors are constantly measuring and reading changing values around them. There are various sensors from different

companies that one can choose from. The market is now saturated with wireless and wired sensors that connect to the base.

3.3.1 Temperature sensor

For reading the temperature, I used a basic thermistor. This thermistor is connected to the Arduino UNO micro-controller by two wires and simple code is constantly calculating the temperature from the changing resistance of the thermistor, which is then sent into the application on my iPhone where I can finally see the temperature. See *figure 18* in chapter 10 *Connection diagrams* for further clarification.

There are many other possibilities of measuring the temperature, such as DHT11, which is in many ways better than a basic thermistor. DHT11 can measure temperature and humidity and can be bought as a self-contained module for Arduino. Unfortunately, I did not know about this product at the time and that is why I used a thermistor, which can be bought for 5 CZK in any shop with electrical components. The price of the DHT11 sensor is around 300 CZK on the internet.

3.3.2 Position sensor

For sensing the position of the garage door, I used a magnetic sensor, which consists of two parts. The magnet, which is located at the bottom of the garage door and the reed switch, which is located at the bottom of the garage door construction. The reed switch sends a signal when the magnet is situated next to it. As the door opens, the magnetic field is no longer switching the reed switch on and it is possible to see in the application on my iPhone whether the garage door is open or closed.

3.4 Switches and relays

Switching appliances on and off can be done by various switches. Most commonly used is a relay. The relay is a switch that works by creating an electromagnetic field and attracting two metals together where current flows, thus completing the circuit. In my application they are used for switching on/off the lights, opening and closing the garage door and to raise the blinds. In my application, the relay is integrated into the switches in the walls and acts like one. For a diagram of connection, look further down for *figures 19, 20 and 22*.

Transistors or thyristors can be used also for switching. Transistors are semiconductors used to amplify or switch electronic signals and electrical power. They are an integral part of every electric device. In my project, transistors are used for setting the brightness of the RGB LED strip that is under my desk and behind my bed for a nice ambient lighting of my room. Setting the brightness is done by Pulse Width Modulation (PWM) of three transistors. Each transistor is designated for one color. For connection diagram please look at *figure 21*. The transistors are switching rapidly to create small electrical impulses. Duration of the impulse determines how bright the LED will be shining. Longer the impulse the more will the LED shine.

Thyristors are used in my project for disconnecting the source of electricity for the RGB LED, that way the source is not constantly connected to the main power grid. Thyristors are small, similar to transistors and can be fitted into the power supply itself.

3.5 Power supply and backup battery

The power supply is the most important part in ensuring the Smart Home is working. There are endless possibilities of power supplies such as old chargers for phones capable of delivering a maximum of 500mA or big industrial power supplies capable of delivering currents in the order of Amperes. My project is running on 5V, but it is possible to use a power supply delivering up to 12V because of the voltage stabilizer integrated into Arduino.

The backup battery ensures proper functioning after the power is cut out. It is not necessary unless the Smart Home has integrated Home Security. If the backup battery is not connected, when the power cut out happens, all systems will stop working, thus compromising security and all functions of Smart Home.

4 Software

4.1 Arduino IDE

The Arduino IDE is a computer program used for creating, testing and compiling the code for the Arduino board. Arduino software has a user-friendly interface where everything is clear to the user. Arduino IDE includes a folder called “examples” where all of the basic sketches are located and explained in great detail. The user can open any one of these examples, upload it to the board and make necessary connections with peripherals for the project and circuit to work.

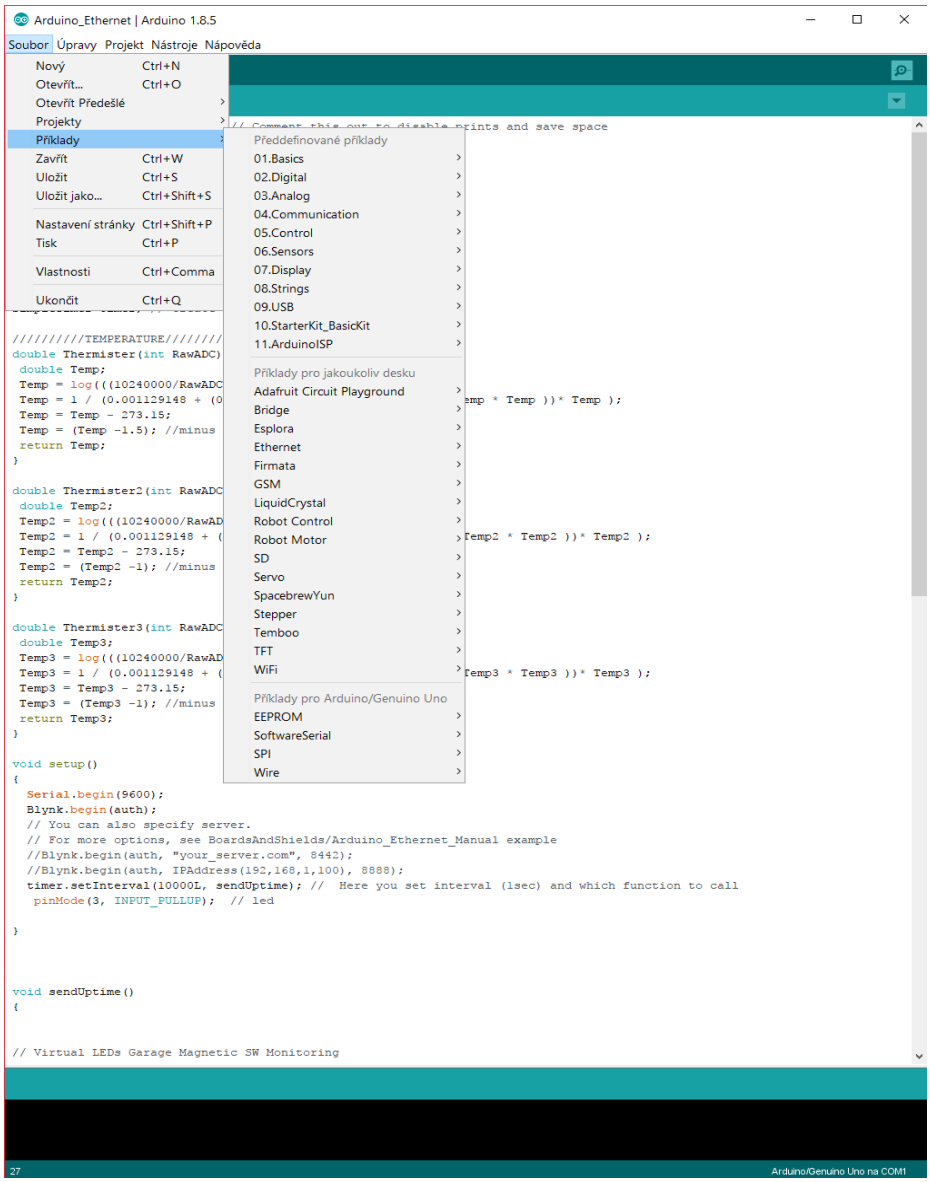

Figure 3. Arduino IDE

4.2 Blynk

While I was developing my smart home, I came across multiple mobile applications which supported Arduino. Unfortunately, it was not at the time when I started this project. In the initial stages, there was no way of interacting with Arduino via mobile phone other than through the website which was hosted on the actual Arduino, or by writing your own mobile app. The disadvantages of running a web server on Arduino were significant. The page could not have pictures because of the memory capacity of Arduino and it could be only accessed locally. It was impossible to load the page and interact with Arduino unless I was on the same network as Arduino. To access this website from outside of the local network, the public IP address was needed. Another disadvantage was the webpage address which was hard to remember (eg. http://192.168.2.1/) in contrast with a regular web address which is a combination of words.

Two years ago, a service called Blynk arrived. When I found out about this mobile application which supports iOS and Android, everything changed. Everything is simpler and the community on Blynk forum is superb. The founders of this service are constantly reading every post and trying to help other people as well as users of this service. I am personally using the Blynk since the start. Developers are constantly adding new features and they are trying to improve every aspect of this service. The community has grown because every day there are hundreds of new projects posted to the forum which you can be inspired by. The remarkable thing about this is that the authors of those projects often post code for the Arduino, all necessary electrical parts, diagrams, and their own experience or photos.

Mobile application Blynk is free of charge, but they recently added in-app purchase called the "*Energy balance"*. With this balance, you can buy widgets that make a certain action. For example, a Button, a Slider, and a Value display widget cost 200 energy. The Button widget is used for switching the lights, garage and blinds, Slider for changing the color of RGB LED strip and Value display is used to display temperatures. With 5 000 energy, which costs 3,99 dollars, it is possible to build a whole project. I found this price more than acceptable if you consider the work that developers of Blynk put in every day and also running costs of the servers, on which is the Blynk running.

Unlike in my initial stages, Smart Home built with Blynk is able to access the Arduino from anywhere around the world. Arduino is not connected to your smartphone directly, instead it is connected to the Blynk servers and the application on the mobile phone is communicating with servers which are then sending commands to the Arduino.

Safety is the main concern because I have connected my garage door to this project. Security is ensured by a unique and individual code which is generated when creating the project on your smartphone. If it was not safe, anyone in the world could open my garage or control the lights.

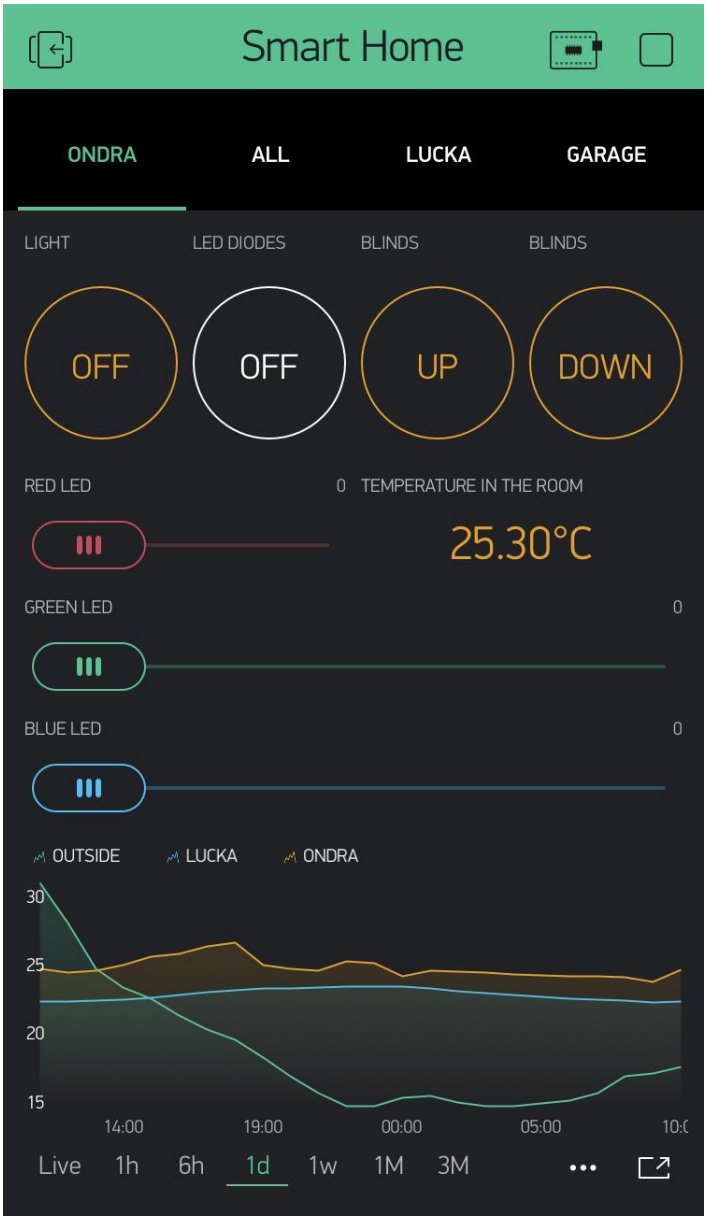

Figure 4. Blynk mobile application

5 Code

In the first part of the code, various libraries are initialized as well as Auth. code is added. Auth. code is used for authentication of the project, it ensures safety and connects the Arduino board with the user's smartphone.

In the second part of the code, analog values received from thermistors are calculated and converted into digital values separately with the help from *math.h* library. This library can be downloaded from the internet free of charge. It contains necessary mathematical operations that are used for converting analog values to digital values. [7]

In the third part of the code, Blynk is initialized with line *void setup()*. It contains necessary parts of the code and ensures proper communication with Blynk servers. Furthermore, it contains lines of code for displaying temperatures.

Programming Arduino to work with Blynk is simple and easy. There is no need for complex knowledge of coding. Everything is described in great detail in all of the examples. Blynk provides their own library and examples. The user needs to select which board he or she wants to use and lines of code made specifically for the user's board will appear. This code will ensure basic communication with Blynk servers and the smartphone. It is possible to add personal code like I did, but there will be some restrictions. For example, it is advised not to use the command *delay()*, because it would influence and delay the response of whole Arduino. It is tolerable to use small delays, but it will increase the ping. Ping tells us what time it will take for the information to travel from the application to the Arduino and back. If we add *delay(70)*, it will mean that the whole communication will be delayed for 70 milliseconds. For longer delays, one must call for a function *timer.setInterval()*, which will not influence the function of the Arduino and the communication with servers. The entire code can be seen in chapter *12 Code attachment.*

6 Future of my project

In the future I would like to add a support for motion detectors and other functions related to them, maintaining the perfect room temperature with respect to outside temperature, opening the blinds when my alarm clock goes off, automatically closing the blinds when it gets dark outside, switching lights automatically when a person comes to the room with the use of motion detectors or proximity sensors, RFID reader in the door for quick unlocking and locking with RFID keychain, smart doorbell and ability to control TV, PC, fridge or any other appliance in the house.

6.1 Motion detectors

The motion detector is a device that detects moving objects. This device is useful for various tasks, such as automatic light control, alerting the user of a motion in a certain area, energy efficiency and other possibilities of use. Several types of motion detection are in use, such as Passive infrared detector (PIR), Microwave detector, Ultrasonic detector or Video camera software. PIR detector works by capturing a person's skin temperature and it is one of the most widely used detectors. Microwave detectors detect motion by emitted continuous microwave and evaluating the phase shifts in their reflection. The ultrasonic detector emits ultrasonic waves, reflections from objects around it are received and then evaluated. Video camera software uses low-cost digital cameras that are able to shoot a video, which is then evaluated by software designed for motion detection.

In my project, the motion detectors could be used for switching the lights when someone walks into the room. It would have to be of course disengaged while daylight is present in the room. Another important use of such detectors can be in security. There could be one detector located in the garden and as soon as it detects movement it sends a notification to my phone. The only disadvantage is that it would detect members of my family as well, therefore there would have to be some sort of a sensor at the door to the back garden that would disengage the motion detector. Otherwise, it would be useless and irritating. [8]

6.2 Automatic temperature regulation

One of the biggest challenges will definitely be the automatic regulation of temperature in each room. This task will require a vast amount of temperature sensors, relays and communication between the air conditioning, heating elements in the room and the boiler. I have already done some research on the internet and found out that there are electronic thermostatic heads for the heating elements, which can be programmed and operated via a serial bus with a microcontroller such as Arduino. The control of the existing air conditioning will be most definitely the hardest task. In the worst-case scenario, the remote controller would have to be taken apart and hacked. Another complicated task will be taking the information from all of the sensors and combining it to form one system that is working accurately and none of the elements are interfering with each other.

6.3 Automatic operation of the blinds

One of the goals is to make the blinds go up by themselves when the alarm clock on my phone rings. This task is unfortunately impossible to do with the current iPhone because the operating system that is running on it is too strict. Apple does not support third-party applications interfering with iOS, thus it is impossible to send a command from the alarm clock to the Arduino. However, there is another way that will work. By adding a clock to the Arduino, I will tell the system the time. Then it is necessary to add another widget called Time input. This widget will allow selection of start/stop time, the day of the week, time zone or sunrise/sunset formatted values and send them to the Arduino. Then the user only has to set the desired time to wake up and Arduino does the rest.

The second goal of this topic is to make the blinds go down with sunset. There can be also used widget called Time input and as I said in the previous paragraph, one can set the widget to do an action with sunrise/sunset. The sunrise/sunset times are taken from the internet for a certain time zone.

Finally, the third goal is an ability to operate the blinds with a press of a button from the app. This can be done by adding a widget called Button, setting the correct digital

output and connecting to that output with a relay that will switch and activate the blinds. For connection diagram look at *figure 19.*

6.4 Automatic switching of lights

The ability to automatically switch on the light when a human comes to the room and switch it off again when the human leaves can be done by multiple kinds of sensors or with Bluetooth.

The easiest method is by the use of the motion detector, which I explained in previous paragraphs. The motion detector has to be installed in such place where it is visible from all of the angles. When the motion detector detects a movement, it sends a signal to the Arduino. This signal is then processed by the code and Arduino will then send another signal but to the desired digital output. This output is connected by wire with the relay or to the fuse box, where is located the special circuit breaker that will switch on the certain light. The disadvantage of this system is that the light will be programmed to stay switched on only for an exact period of time. This means that the light will be still switched on, even when the person is already out of the room. To eliminate this problem, one could set the switching timer on shorter periods of time, but this could maybe result in unwanted darkness even when the person is still in the room, but not moving, for example sitting on a chair.

To avoid this unwanted disadvantage, one can use, for example, Bluetooth shield that will be located in each room. When the human is present, the Bluetooth will connect to the phone and sent a signal to the Arduino, which then will switch the light on. When the person leaves the room, the Bluetooth is disconnected, and the light switched off. This solution relies on the presence of the phone, therefore it cannot be used with someone that does not have it on his person.

I personally do not believe that using Bluetooth is the right solution, because the disadvantages are more pressing than with the use of motion detectors. Maybe in the future, there will be some kind of new sensor that will eliminate difficulties of current systems and combine the advantages of these systems. Currently, there is a camera detection on the market that eliminated these issues, but it is not as cheap as a standard PIR detector.

6.4.1 PIR detector HC-SR501

The ideal PIR detector that is used with Arduino is the HC-SR501. This is a cheap motion detector capable of area capture of 120°. The input voltage, like with every other Arduino shield is 5V, but the output voltage is 3,3V. When the detector is sensing some movement, it sends logical 1 to the Arduino and when it does not sense any movement it sends logical 0 to the Arduino. This PIR detector also includes two potentiometers, one for setting the sensitivity of the detector and second for the duration of logical 1 on the output pin. When using the PIR detector it is advised to use some reasonable adjustment of these two potentiometers to ensure proper function and avoid unnecessary triggering of the detector with small objects or false alarms. The connection of this shield is simple, Vcc is connected to the +5V on the Arduino, the GND is connected to the GND on the Arduino and the out pin is connected to an arbitrary digital pin on the Arduino. [9]

Figure 5. PIR detector HC-SR501 [10]

6.5 Ability to control appliances

This is the only topic, where I do not really know how to accomplish the desired goal. One thing is certain, there must be some communication between the Arduino and for example, the TV. This communication must be more sophisticated than the one I am currently using. I am only using 5V signals, but not the information in the form of a coded message. For this purpose is used the I2C bus, which ensures the communication with multiple devices only over two wires. This is possible by assigning each device with a preset ID or its own unique address. By this unique address, the Arduino is able to send commands only to one device by sending this address first and then the message.

6.6 Ability to communicate wirelessly

6.6.1 NRF24L01 module

After doing some research I found out that the most effective and cheapest way of communicating will be with the use of a wireless module called NRF24L01. It is an Arduino compatible module which can provide communication between multiple Arduino boards. This module is using the 2,4GHz frequency band for communication and it is the same frequency as a WIFI. On the other hand, it cannot connect to the WIFI or to the internet. The manufacturer states, that in the sleep mode the module is consuming power in the order of microamperes, but when sending or receiving the information it consumes hundreds of milliamperes, thus it is low power consuming device. This module can communicate in the range up to a hundred meters when set to the maximum amplification of the signal. It is advised to use an external power source because the Arduino is not capable of delivering a current of that magnitude. To ensure proper function, we need two Arduino boards and two NRF24L01 modules. The price of one NRF24L01 module is about 50 CZK.

6.7 RFID reader

The RFID reader is composed of two parts: The base, where all of the main electronics are present and the keychain or card where some information is stored in the form of a code. When the card is in the proximity of the base, it will collect energy from the reader and send back the information stored on the card. This particular model is based

on 13,56 MHz frequency band and the brain of this RFID reader is a control circuit MF RC522. The price of this unit is about 220 CZK.

In my application, it will be used to quickly open a locked door or to perform some action. I plan to hide the RFID reader into the door itself, therefore I can just put the card over the door and it will automatically unlock, given the fact, that it will be a card that is registered in the system. This system of locking and unlocking doors has many advantages. The keychain is small and can replace your existing set of multiple keys and reduce the weight of your pockets to a minimum. The card is even more convenient because the user can put it into the phone case, or in the pocket and do not even know about it, because it is slim.

Figure 6. RFID reader [11]

6.8 LCD display

I would like to add in the future an LCD display. With this display, I would be able to see notification such as the state in which the garage is, who is home, who opened the door and when, the temperature without opening the app on my phone and other system messages. There would be multiple numbers of these LCDs throughout the house, therefore I would be able to see the status of my Smart Home from everywhere.

The LCD display that I have chosen for this purpose has a size of 2,4 inch, resolution of 320x240 pixels, backlight and is touch sensitive.

Figure 7. LCD display [12]

6.9 Smart doorbell

One of the most important features I want to add to my smart Home system is a combination of a camera, speaker, microphone and a button. This altogether will create a smart doorbell, which will be placed on the outside of the house at the door. The physical button will be used as a normal doorbell, but instead of having the function of a normal bell it will trigger a notification on my phone. This can be done by a few simple lines of code:

```
“void notifyOnButtonPress()
{
 int isButtonPressed = !digitalRead(0);
if (isButtonPressed) {
  Serial.println("Button is pressed.");   //serial message
   Blynk.notify("Somebody is at the door!!");   //The notification on the phone
}
}”
```

This simple code is constantly monitoring the digital input that I will choose and notify me when the change from 0V to 5V is registered. As you can see, the code is designed to also sent a serial message over the cable, which can be displayed either on my PC or on the LCD display that I mentioned earlier. The button will be connected to the standalone Arduino. That Arduino will be placed near the door and it will be also operating the RFID reader. That way I will not waste cables and two Arduino units.

The camera that I chose is a Mini PAL camera 700TVL FPV with a wide angle lens. This camera will be perfect for my use because it has a built-in microphone and sufficient resolution of the streamed video of 1280*960 pixels. The camera is working with 12VDC, therefore it will need an external power source because the Arduino is only capable of delivering 5VDC. Price of this camera is about 480 CZK. The video and audio will be transmitted to the Arduino via four cables: one is ground, one is sound and the other two are for the video. After the Arduino will receive the signal, it will send it to the Blynk servers, from where it will be sent to my mobile phone.

In the Blynk app on my phone, I will add a widget called “Video Streaming”. Video streaming widget allows the user to display any live stream. This widget also supports an RTSP and HTTPS streaming, therefore I will be able to display a live video feed from the camera, on my phone. In the Blynk app, I will also have a button for the unlocking of the door and letting any guest in. Unfortunately, as of now, the Blynk app does not support audio streaming, but the developers are constantly listening to the community and their wishes, therefore I believe that it is only a matter of time until this audio streaming widget will be available.

Figure 8. Mini PAL camera 700TVL FPV [13]

6.10 Automation based on my location.

Another useful widget is called GPS Trigger. This widget will allow the user to trigger certain events based on the user’s location. The widget will work in the background of the user’s smartphone and periodically check the coordinates. In case the user’s location is within or out of the required radius, that is selected on the map widget, the GPS Trigger widget will send a HIGH or LOW command to the Arduino.

Consider this situation, I will set up the perimeter around my house in the Map widget and set up commands. For example, when I leave the location that I selected on the Map, the Arduino will know that it has to make sure, that all the lights are off, locks are locked, air conditioning is not running while the house is empty, close the blinds to

prevent heating up of the house or in the winter, set the thermostat to lower temperature to not to waste energy and heat. When I arrive at the house it will do the opposite. Turn on the air conditioning, lights, unlock the doors, pull up the blinds or increase the temperature of the heated water in the heating elements.

6.11 Consumption meter

The last feature I want to add to my system of Smart Home is a Current meter ACS712. The working principle of this Current meter is Hall's effect. An integrated circuit that is mounted on the circuit board is generating an electrical voltage based on the magnetic field which is generated by the electrical current that is flowing through the input pins. Afterward, the electrical voltage is measured by the current meter ACS712, sent to the analog pin on the Arduino and calculates the actual consumption of electrical energy. This sensor is available in two variations, 5A and 20A.

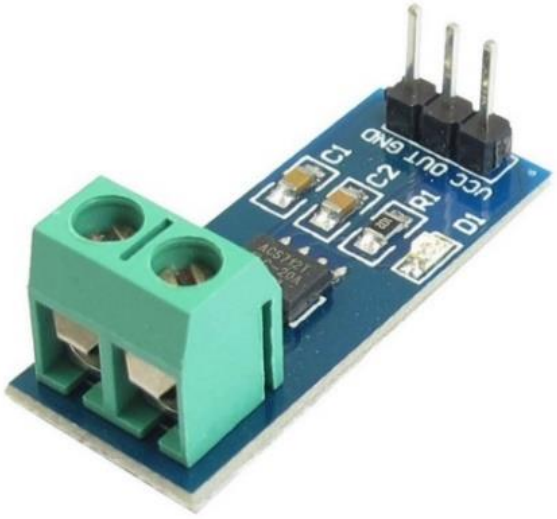

Figure 9.Current Meter ACS712 [14]

7 Shields for Arduino

7.1 Ethernet shield

In my project, I am using only the Ethernet shield, which enables the Arduino to connect to the internet via the Ethernet cable. This shield also contains an SD-card slot for a memory extension. This shield is necessary for the correct function of my project, because without the internet communication, it would not be possible to communicate with the Arduino. As you can see in the picture, the dimensions are the same as Arduino UNO, therefore the connection is very easy. It is just clipped onto the Arduino and the connection is made.

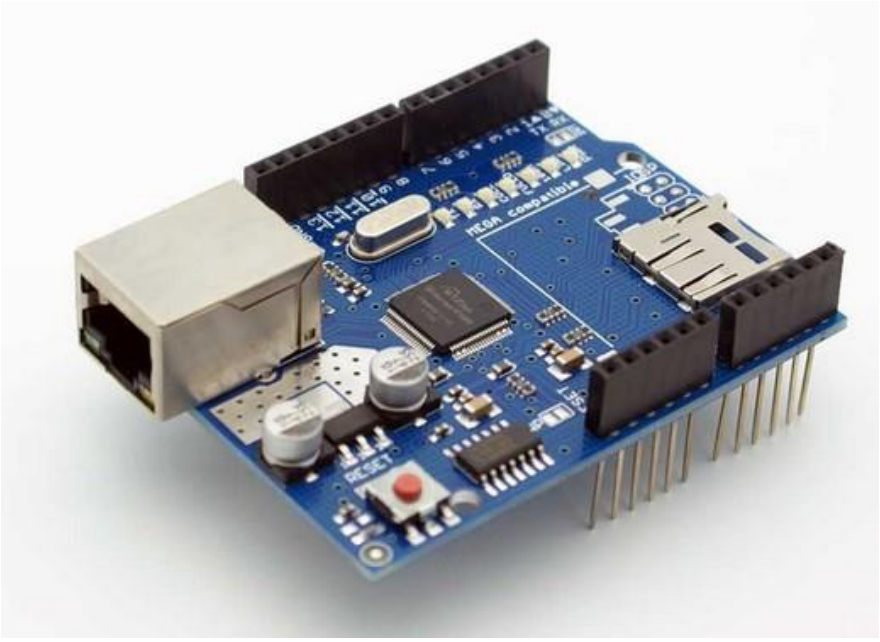

Figure 10. Ethernet shield [3]

7.3 Relay shield

The relay shield will be the most useful when using my first idea for the realization of the Smart Home. That means an individual circuit for each light. The relay shield would be located in the fuse box to control the circuit breakers.

Figure 11. Relay shield [4]

In my application, there are only used single relays, rather than on the shield. The relay that is used for the light control is located right in the wall in the switch and it is a part of the whole light circuit. My light was already possible to switch from two places using two switches series 6. I had to take out one of the switches and use series 7 instead. Then I connected the relay in the same way the series 6 switch is. The relay is acting like a 6-series switch. See *figure 22* in chapter *10 Connection diagrams* for further clarification.

8 Systems from other companies

8.1 Loxone

Loxone is a standalone smart home variation. The brain of this system is called Loxone Miniserver. The firm Loxone offers two variations of the Loxone Miniserver that the customer can buy.

The first one is for people who are planning to build a completely new house or an apartment. This system is using wires to communicate with the peripherals and is suitable for new buildings because of the need to run wires to every peripheral or sensor. The Loxone Miniserver is intended to be used in an electrical switchboard. This wired variation can be expanded up to 498 inputs and 372 outputs by using the extensions. The price of this brain is 13 671 CZK.[22]

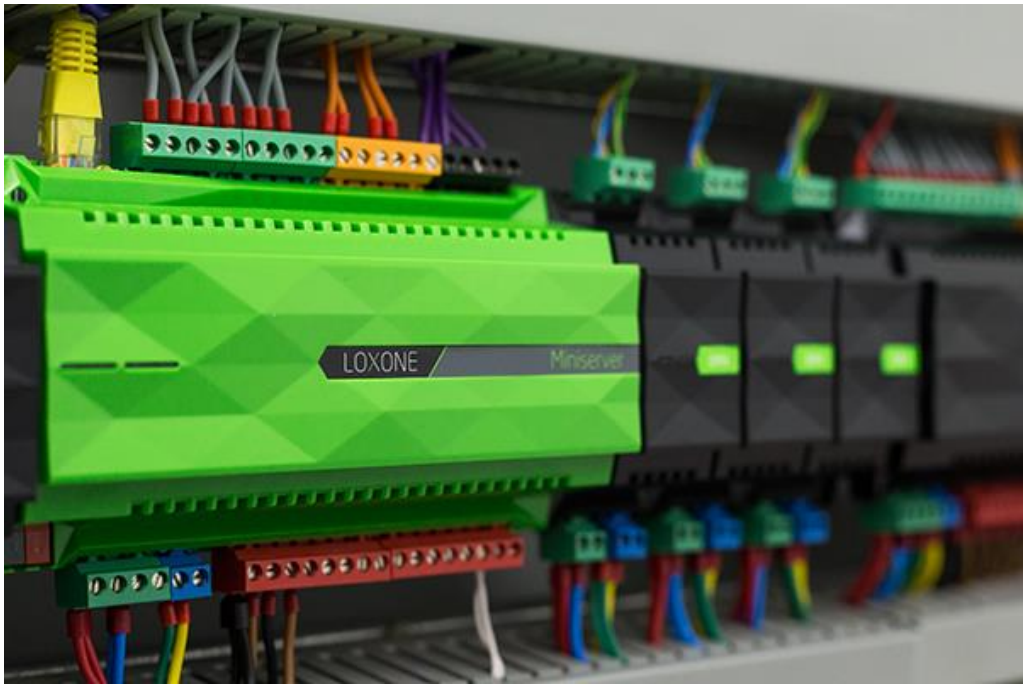

Figure 12. Wired Loxone Miniserver [19]

The second one is a wireless option. This variation of the Loxone Miniserver is intended to be used in an already standing buildings for people that does not want to destroy their home to run necessary wires. The wireless system is not limited and is able to perform as well as his wired brother. The price of this wireless brain is 10 936 CZK.[23]

Figure 13. Wireless Loxone Miniserver [20]

Loxone is making over 150 products specifically made for smart home. Configuration and setting up of the system is done by their easy to use software Loxone Config. I am sure that the system is fully debugged and is working flawlessly, but given the fact that the brain of this system costs 13 671 CZK and then the user will need another dozens of sensors, actuators, wires, extensions and monthly subscriptions, the price of this system can easily climb into the hundreds of thousands of Czech crowns. And this story is the same with every smart home system on the market. It always comes to the price and that is for me, as a student, very important topic. For example, as of now (2018), one simple switch can cost the customer up to 4 233 CZK.[25] If the customer would like to buy a Intercom that can be accessed via smartphone, he or she will have to pay an outrageous amount of 39 257 CZK.[24] Just for comparison, I intend to make this function for my smart home via Blynk for under 1 000 CZK.

8.2 Apple HomeKit

Apple HomeKit is a software smart home variation from the renowned firm called Apple. For this system to work you need iOS10 or newer enabled smart device from Apple (iPhone, iPod, iPad) with an already preinstalled application that is called HomeKit or in Czech *"Domácnost".* If the user wants to control the home from anywhere in the world, he or she needs, as well as other systems, some sort of a base. But unlike other systems, where you have to buy a designated base, it can be your already existing Apple TV, an old iPad that is always at home and nobody uses it, or a special device called HomePod, which is a smart speaker with Siri. Siri is a personal assistant from Apple. It can do certain tasks. For example, one can ask Siri "I am going to sleep" and Siri will automatically switch off all lights, close the blinds and lock the doors. There is also the possibility to run this system without the base, but you are able to control your home only from the local network.

Apple HomeKit excels in security. Because Apple has a closed ecosystem, the number of companies that can, and are allowed to sell products that are Apple HomeKit enabled is limited and carefully chosen. When you buy a camera from the internet, you must trust the company that the video feed will only go from the camera to your phone and it will not be abused in any way.

Another great feature of Apple HomeKit is the simplicity of controlling, function and adding new HomeKit enabled devices. The layout of the app is intuitively designed, therefore no one should have a problem when using it. Adding new devices such as lamps or outlets is done by scanning the unique code that is in the package with the device. This ensures the secure function of the system, but if you lose the particular code for the device, it will be useless. You cannot add the device without the unique code.

The user can configure his own commands or groups. The user can create a group called *"Good Night"* and when he or she presses the button all lights shut down, blinds go down, notifications turn off, door locks and the garage or gate will close. The app is also able to communicate with Siri, so you can say, *"Siri, Good Night"* and the command called *"Good Night"* will be triggered like you would press it in the app itself. The user can also say commands like *"Close the garage door"* or *"Lights on"* or *"Lights off in the living room"*. Those are one of the many endless possibilities of the Apple HomeKit configuration.

There are a lot of appliances to control, such as lights, switches, outlets, thermostats, windows, fans, air conditioners, humidifiers, air purifiers, sensors, security, locks, cameras, doorbells, garage doors and so on.

Figure 14. HomeKit [21]

8.3 Manufactures of HomeKit Enabled accessories

8.3.1 Philips HUE

Philips Hue is one of the best accessories on the market for Home Automation. It allows the user to control the RGB strips, bulbs, switches, sockets and so much more. Philips HUE bulbs cannot connect directly to your home network, but they must first connect to the included bridge. The bridge requires the user to connect it to the router using the included Ethernet cable. Three status lights on the top of the Philips hub indicate if it is powered on or connected to your router and to the internet. After plugging in lights and bridge, the user then pairs everything together through the Philips Hue app. The Philips Hue app gives you a view of the rooms in your house, and if Philips Hue lights are on or off in those rooms. You can either turn all the lights on or off in a given room or control the brightness and color of individual lights. The user is able to schedule times for lights to turn on or off in selected rooms. There is an interesting mode that will interest people that worry about their home at the time of their vacation. If the user turns on this mode, the lights will turn on and off randomly, to make it seem like there is actually someone home. There is also a geofencing feature present. This feature will allow you to trigger either the Coming Home or Leaving Home routine based on your phone's location. Unfortunately, there is no ability to specify how close the user has to be to the home to turn the lights on or off. Hopefully, this feature will come in the nearest upgrade. Philips Hue app enables the user to use and create Scenes, which adjust all the lights to a particular color or brightness, given the fact that the user has colored bulbs installed. Philips Hue has the most extensive compatibility with other smart-home systems, such as HomeKit, Alexa, Google Home, Nest and others.

I found a review of the Philips Hue to make sure that my opinion was the same as the majority of users and I want to quote it.

"With its wide range of different bulb types and switches, the Philips Hue lighting range has evolved into a formidable presence in the smart home market. All these models mean that it's possible to completely overhaul your entire lighting system to make it internet connected, converting everything from your bulbs to your light switches. The single biggest issue is cost. Individual bulbs are pricey, and the ecosystem gets more

pricey still when you start factoring in the cost of switches. Still, if you're prepared to fully invest, there are few smart home gadgets around that feel as convenient as the Philips Hue lighting system." (By Jon Porter, Matt Hanson, November 21, 2017) [15]

This web page also concludes that the Philips Hue is easy to setup, the app experience is streamlined, good integration with other services and decent automation options, but on the other hand, it is very expensive and reliance on the phone can be annoying without switches. [15] And that is the issue that I am seeing with these systems. Yes, they are professionally made and should work like a clock, but they are expensive, the user cannot modify the system to their needs and most importantly, you cannot fully integrate them into your existing lighting system in your home. By that, I mean that the existing switches, for example, must stay always in on position and then you only turn the lights on and off by using your smartphone. Or you need to buy extra wireless switches that are mounted on the wall. This is the biggest disadvantage, unlike in my system. In my design of the smart home, the switches still operate like normal switches. The user is able to turn on the lights by switches on the walls but also by using the Blink app. The price of the Philips Hue starter pack is around 3 500 CZK. In the price, there are included a Base and three light bulbs and a switch.

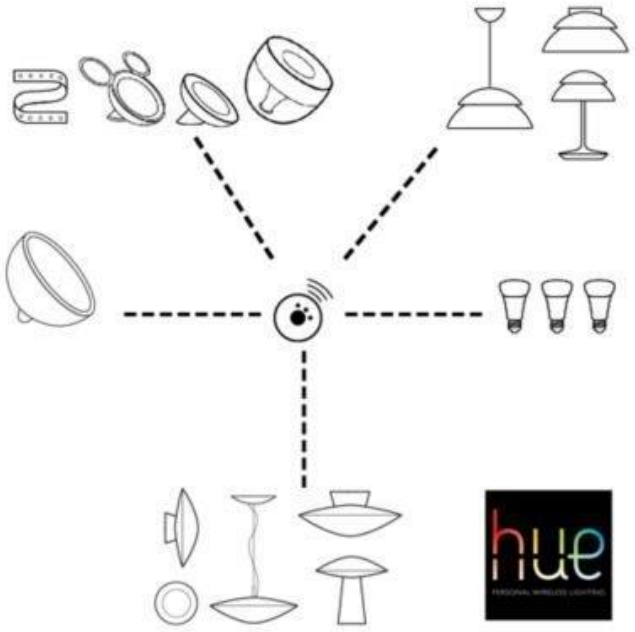

Figure 15. Philips Hue connection [15]

8.3.1.1 Philips Hue Starter Kit

With this set, you get the most bang for your buck and it is also the one that I was talking above. This set is Apple HomeKit, Amazon Alexa and Google Home compatible and is priced around 3500 CZK. For this price, the user gets three LED 9.5W bulbs, which are dimmable, the user is able to change the color of the light. Changing the color to the warm white can have benefits in the evening because the user will sleep better, rather than when he has the coldest white color of the light. In this packaging, the user will also get a switch that can be mounted on the wall and of course a base which is used to connect everything together and enable Apple HomeKit, Amazon Alexa, and Google Home compatibility.

Figure 16.Philips Hue Starter Kit [16]

8.3.1.2 Philips Hue LightStrip Plus

LightStrip is not a light bulb, but a 2-meter-long strip full of LEDs which are capable of delivering up to 16 million colors. This RGB LightStrip is easy to install and has a sticky tape sections on the other side to allow you to attach and stick the light strip everywhere.

This light strip fulfills the same function as the RGB light strip in my project. It is used to make a nice ambient lighting of the room or furniture. The user can choose between 16 million colors. The Hue app also includes a section called scenes, where the user can choose a scene, for example, noon. The light strip and the bulbs, if the user has both, will change their color to a nice evening, warm colors. The scenes that user can choose from are endless, for example: sunset, deep sea, relax, beach etc.

Here is an example of a room which contains Philips Hue bulbs in the lamps and the Philips Hue LightStrip under the kitchen unit and in the sealing. The user was able to assign each individual Philips Hue accessories with different color right from his iPad. The Hue LightStrips can be hidden underneath a counter, behind a furniture, underneath shelves or cabinets and of course installed in coves to diffuse the light. One main disadvantage of any RGB light strip is the fact that there are three small LEDs next to each other with the colors of Red, Green and Blue. Together these colors can create, as I said, 16 million colors. On the other hand, the fact that they are different colors makes them visible. The user can see the individual colors when it is not diffused by some see-through cover.

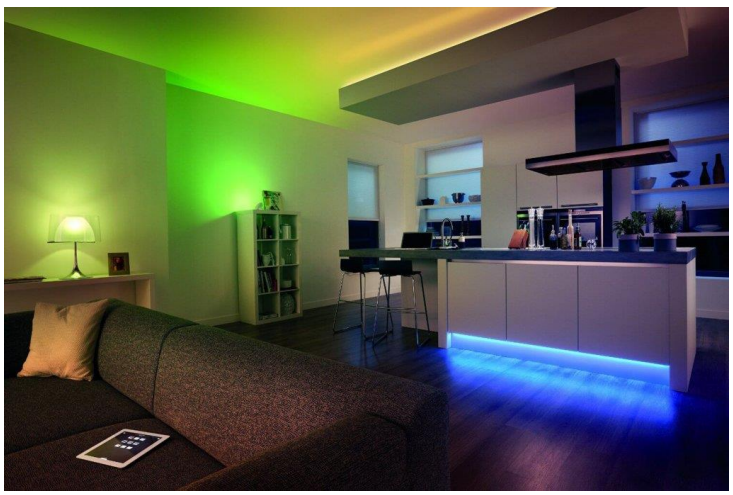

Figure 17. Philips Hue ambient lighting [17]

With the possibility to extend up to 10 meters you can integrate this module into the architecture of the room but bear in mind that 2 meters of the Philips Hue LightStrip are priced around 2200 CZK, therefore it can get really expensive really fast. The light that this strip can generate is enormous, 1400 lm/2m, twice the power output of 60 watts lamp.

In the end, I would like to add a quotation of a review from a Hal B. from Vancouver as I found it useful and our opinions were matching nicely. Also, his review seemed to help a lot of people because, at the time of my research, his review had a rating of 98 out of 100. My opinion was based only on experience in the shop and from videos on YouTube because I do not actually own any Philips Hue accessory.

"Good: Bright, good use of colours, matches existing Hue bulbs in colours and tones, easy installation, easy to add into Hue App. Works with Gen 1 hub (have not been able to purchase Gen 2 hub yet)

Bad: LED lights are spaced out, so may need a diffuser to prevent lights reflecting off services such as windows or tiles. Adhesive on double sided tape weak is spots (not a problem for my installation), light strand can only do solid colours and not have a mix of colours at the same time, Bottom Line: Highly Recommended. Easy to install, great light, fun to play with. Excellent addition to my Hue lighting.

Noteworthy: The LED strips come with a medium sized power plug as well as a small box closer to the LED strip. They have allowed for a long length of cable between the plug and the strip. For my installation this means I have to bundle up the cable and tether it out of the way as it's way too long. Before starting on your lighting project, make sure to take the long cord and power adaptors into consideration." (Hal B. from Vancouver, Nov 16, 2015)[18]

8.3.1.3 Philips Hue Tap

A gadget that caught my interest the most is a Philips Hue Tap. It is a switch, which after it is added and connected to the Philips Hue Bridge, can be programmed via Hue app on the user's phone. The user is able to assign four functions to four buttons. The functions can be, for example, Switch the lights on and off, preset scenes or custom scenes or colors.

The Hue Tap switch is powered by kinetic energy. This switch does not require any batteries. The name of this switch can be a little bit misleading. "Tap" is a bit misleading, as the buttons require the user to press them down hard before they will activate. I find this technology really amazing because the user does not need any batteries or cables running into the switch. It is remarkable that only by a press of a button, the user is able to create enough energy to send a signal to the base. You press the button and it just works. Unfortunately, there is the price again, which is high. This switch is priced at around 1700 CZK.

8.3.1.4 My opinion of Philips Hue

In my opinion, the Philips Hue and its accessories are a great smart home system that one can add to their home. Advantages of this system over mine are definitely manufactory process and easiness of installation. The Hue products are made with extreme precision and attention to detail. The installation is extremely easy compared to my system. Unfortunately, the disadvantages of Philips Hue Smart Home are enormous. The biggest disadvantage is in my opinion definitely the need for a smartphone. By this, I mean that the system cannot be integrated fully into the user's house. For example, the lights. Another disadvantage is the price. If the user would like to convert his whole house into a Philips Hue smart products, one would have to spend an enormous amount of money. Just think how many light bulbs there are in the house and multiply it by the price of one bulb. You also need the base, switches and Hue is also manufacturing individual lights, lamps etc. Price for a small home can be up to a low 30 000 CZK, which is 7,5 times more than my system.

8.4 Homebridge

I had a lot of time to try the Smart Home from Apple for myself. Since the launch of the Apple HomeKit, a different approach to achieving the same effect emerged. It is called the Homebridge. Homebridge is an unofficial way of making Apple think that you are using legitimate Apple Home Kit accessories. It was created by users from GitHub called @pieceofsummer, @KhaosT, @nfarina and many others. They managed to reverse engineer the Apple Home Kit code and enable "out of the Apple ecosystem" control of unsupported products.

8.4.1 Homebridge installation

Homebridge can be installed on any computer, but I had it installed on borrowed Raspberry Pi 2 model B. Raspberry Pi is a microcontroller that is much more sophisticated than Arduino. While the Arduino can run a code and operate its outputs, the Raspberry Pi is acting much like a computer. The user can install a version of Linux on it and use it as a regular computer with peripherals such as monitor, mouse and keyboard. The main part of the Raspberry Pi 2 model B is a four-core processor called Broadcom BCM2836 with the frequency 900 MHz per every core. This clock speed is in comparison with today's computers low, but it is sufficient in this case. The Raspberry Pi has also a VideoCore IV which is a graphical processor and it enables the user to display video output via HDMI on a monitor. This board also includes 1 GB of RAM clocked at 450 MHz. As a power source, one can use any 5V adapter capable of delivering a range of 600-2500 mA, depending on the peripherals connected to the outputs. The minicomputer also has an audio jack, a card reader for storage, an ethernet port and a four type A USBs for connecting a wide range of peripherals such as a keyboard, mouse etc. The board also includes a CSI and DSI connectors used for connecting cameras and displays, and 40 GPIO pins, which I will be using the most.

The initial setup was very stressful because I have never done anything with a Raspberry. Fortunately, there is a huge number of videos online with a step-by-step installation. Once the Homebridge is installed, the user has to install plugins for individual accessories. For example, I have downloaded a plugin called Homebridge-HTTP-base, that allowed me to communicate with my existing Arduino project. After a successful connection, I was able to add new scenes and commands into the native application called “Home” or in Czech “Domácnost” on my iPhone. Once all was setup, I had a full control by telling the commands to Siri or pressing buttons from my control center on my iPhone.

8.4.2 My experience with Homebridge

After living with Homebridge for a week I discovered that it was not much compatible with my existing project and I would have to rebuild it from the ground up and start all over again. Wiring and position of the base was mainly affected. Another drawback was that I could not get all of my functions working. Homebridge is mainly

created for accessories that are not supported by Apple HomeKit. That means that the user is able to add a smart accessory from Ikea that has no support for a HomeKit. The general rule for Homebridge is that if one can find a plugin on the internet, it means that the accessory will work.

One huge disadvantage is that the user must own either Apple TV, an old iPad or new Apple HomePod. Once the user pairs one of these devices to the Homebridge he or she will gain access to the Homebridge from anywhere in the world. Without this connection, the Homebridge will only work in a local network. And that is the main reason why I switched back to my old setup consisting only from Arduino Uno and Wemos D1 R2. Although I do not have support for voice commands and generally integration to the iOS, I am glad that I have a fully functional Smart Home using Blynk.

9 Conclusion

In the future, the integration of a Smart Home will be greater, and it will be an integral part of everyday life. Especially because the prices of Smart Home Kits are decreasing every year as well as more ideas for various Smart Home modules and parts are being developed.

I am personally satisfied with my current project and I have a lot of new ideas on how to improve it. I look forward to upgrading some of the existing features, such as replacing the thermistors with DHT11 sensors and gaining the ability to read humidity as well as the temperature. In the future I would also like to make my project into a small little box, fix some small issues and maybe even sell it sometime in the future.

I must admit that commercially available smart home systems and kits have two huge advantages. The first is an availability and quality of the product. The customer will order their desired product online, and just plug it in when it arrives. Fast and easy operation. My system is more designed for people who like to try and play with electronics and mainly have a certain idea how it works. The second is a customer support. I simply cannot compete with companies with thousands of employees that take care and provide technical support for their customers.

One of the advantages of my solution of the smart home is the price. In comparison with commercially available Smart Home Kits, my project is significantly cheaper. The difference in the price is in tens of thousands of Czech crowns. And in the end, my setup works flawlessly since the last version and could fully compete with systems from other manufactures. The final price of my project including the Arduino UNO, the Wemos D1 R2, thermistors, relays, transistors, thyristors, the SMD LED strip, power supplies, and cables is around 4 000 CZK.

10 Connection diagrams

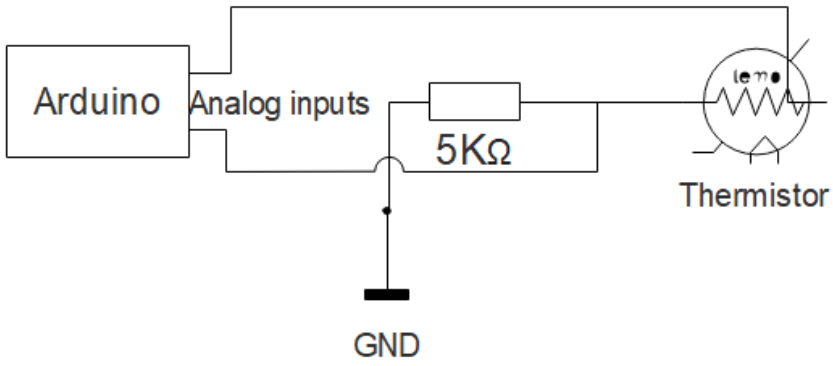

Figure 18. Thermistor connection

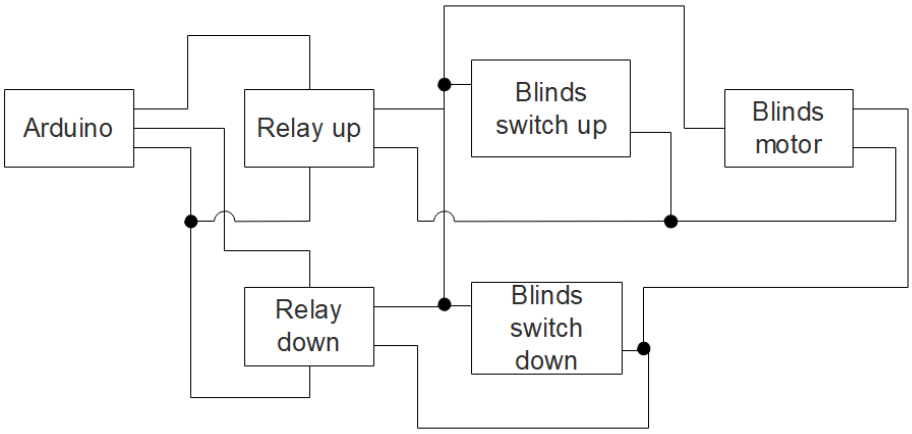

Figure 19. Blinds regulation

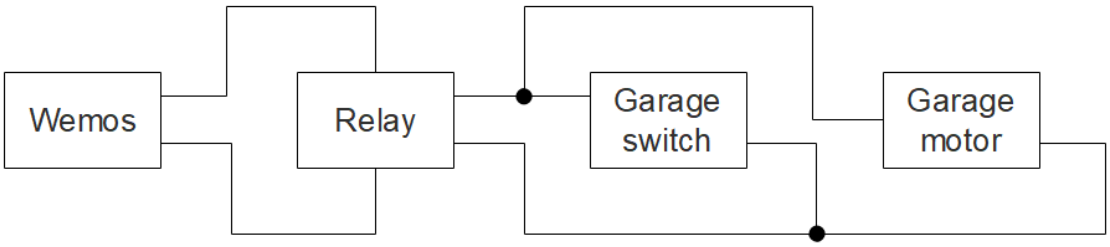

Figure 20. Garage control

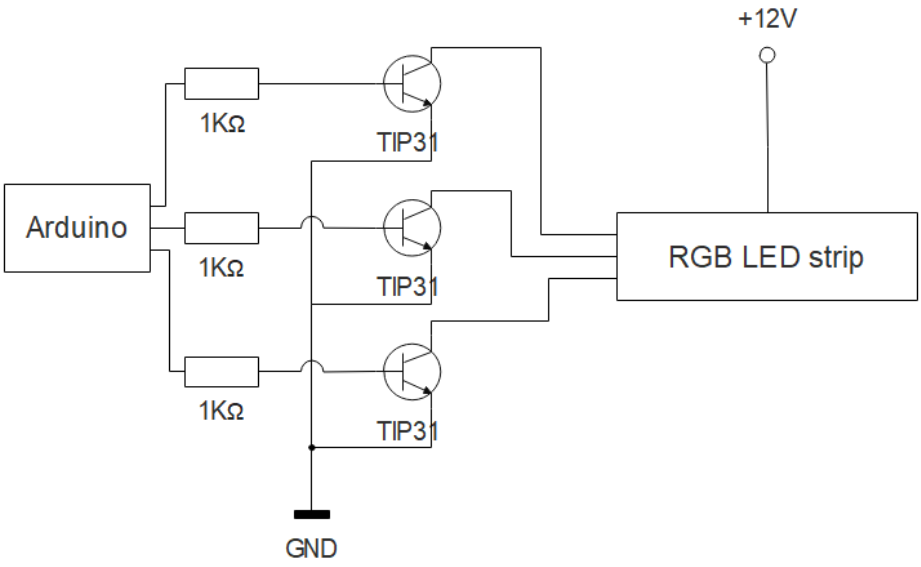

Figure 21. RGB PWM modulation

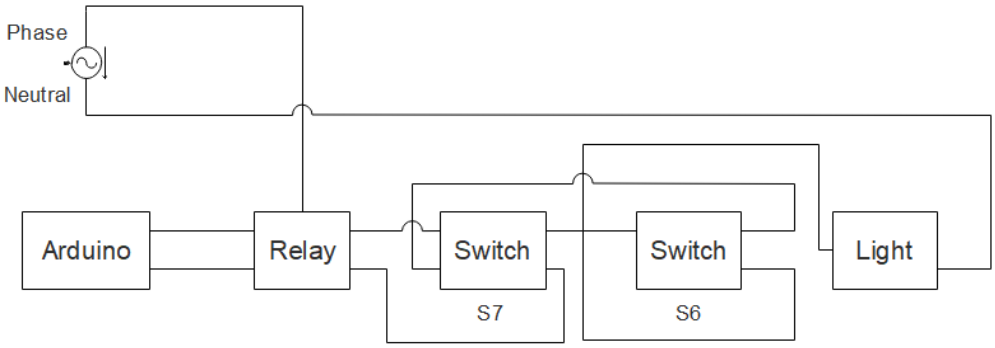

Figure 22. Lights control

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12 Code Attachment

12.1 First part

```
#define BLYNK_PRINT Serial // Comment this out to disable prints.
#include <SPI.h>
#include <Ethernet.h>
#include <BlynkSimpleEthernet.h>
#include <SimpleTimer.h> // here is the SimpleTimer library
#include <math.h>
WidgetLED led1(V2);
char auth[] = "Post your auth code here";
SimpleTimer timer; // Create a Timer object called "timer"!
```

12.2 Second part

```
//////////TEMPERATURE//////////
double Thermister(int RawADC) {
double Temp;
Temp = log(((10240000/RawADC) - 10000));
Temp = 1 / (0.001129148 + (0.000234125 + (0.0000000876741 * Temp * Temp ))* Temp );
Temp = Temp - 273.15;
Temp = (Temp -1.5); //minus 1° tuning the temperature
return Temp;
}
double Thermister2(int RawADC) {
double Temp2;
Temp2 = log(((10240000/RawADC) - 10000));
Temp2 = 1 / (0.001129148 + (0.000234125 + (0.0000000876741 * Temp2 * Temp2 ))*
Temp2 );
Temp2 = Temp2 - 273.15;
Temp2 = (Temp2 -1); //minus 1° tuning the temperature
return Temp2;
}
double Thermister3(int RawADC) {
double Temp3;
Temp3 = log(((10240000/RawADC) - 10000));
Temp3 = 1 / (0.001129148 + (0.000234125 + (0.0000000876741 * Temp3 * Temp3 ))*
Temp3 );
Temp3 = Temp3 - 273.15;
Temp3 = (Temp3 -1); //minus 1° tuning the temperature
return Temp3;
}
```

12.3 Third part

```
void setup()
{
Serial.begin(9600);
Blynk.begin(auth);
```

```
timer.setInterval(10000L, sendUptime); // Here you set interval (1sec) and which
function to call
pinMode(3, INPUT_PULLUP); // led
}

void sendUptime()
{
if (digitalRead(3) == HIGH)
{
led1.on();
} else {
led1.off();
}
// This function sends Arduino up time every 1 second to Virtual Pin (V5)
// In the app, Widget's reading frequency should be set to PUSH
// You can send anything with any interval using this construction
// Don't send more then 10 values per second

Blynk.virtualWrite(V5, millis() / 1000);
int val;
double temp;
val=analogRead(1);
temp=Thermister(val);
delay(70);
BLYNK_WRITE(V7);
{
Blynk.virtualWrite(7, temp);
}

int val2;
double temp2;
val2=analogRead(2);
temp2=Thermister2(val2);
delay(70);
BLYNK_WRITE(V8);
{
Blynk.virtualWrite(8, temp2);
}

int val3;
double temp3;
val3=analogRead(3);
temp3=Thermister3(val3);
delay(70);
BLYNK_WRITE(V9);
{
Blynk.virtualWrite(9, temp3);
}
}
// BLYNK_CONNECTED() {
// Blynk.notify("PŘIPOJENO");
// }
void loop()
{
Blynk.run();
timer.run(); // SimpleTimer is working
}
```