Design of a robot remote controller for „Magyarok a Marson” competition

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Abstract

This paper is introducing a "Magyarok a Marson" robot, which is developed at the Institute of Automation and Infocommunication in University of Miskolc. The controller was built for "Magyarok a Marson" student competition. Our goal was to create a controller, which looks like a magic wand and it is able to control remotely a spherical robot. It was the expectation of the competition. My main task was the hardware design of the remote controller. This paper presents the requirements of the competition, the development of the PCB panel and the controller itself.

Keywords: „Magyarok a Marson”, robotics, Bluetooth, spherical robot, remote controller

1. Introduction

In 2017 the XII. "Magyarok a Marson" competition of applied engineering sciences was held, where I participated before. This competition means for students to solve different interesting tasks and missions. The missions are always completed with a robot, according to the competition manual. This year the goal was to rotate perpendicular arms. There is a flag at the end of each arm, colored according to the team's color. The goal of the robot is to rotate the arms. This year's robot had to be a spherical robot controlled with a "magic wand". According to the physical restrictions of the wand, it was necessary to design a custom PCB for the task. During my studies I was involved with the design of PCBs that's why the design of this controller is an interesting task for me. During the design, I introduce the different parts of the circuit, it's tasks and detailed description of the sub-circuits. Besides these, the circuit design and its 3D model also will be introduced. The final size of the PCB is 35 mm x 300 mm. The maximum diameter of the wand is 35 mm and the length is 500 mm according to the competition manual [1]. This „magic wand” is also related to another research. This is about hand drawn character sensing with accelerometer. This design is directly connected to this topic, because this is the hardware for the research [2].

2. Design of the robot controller

According to the competition manual, the goal is to build a robot, which is operated by a remote controller. In our team, my task was to design the remote controller. The control of the robot is based on the movement of the remote controller. The orientation of the wand is defined by a 6 DOF inertial sensor. The microcontroller processes the accelerometer data from the MPU6050 sensor. For determining the orientation, we only use the data of the accelerometer. The gyroscope data is not used. The data is processed with an STM32F411 microcontroller. The data is transmitted towards the Bluetooth module via UART through the RX and TX lines. The module on both receiver and transmitter side is an RN4020 Bluetooth module using standard 4.1. The received signals are processed with an STM32F411 microcontroller and then the microcontroller operates the servomotors onboard.

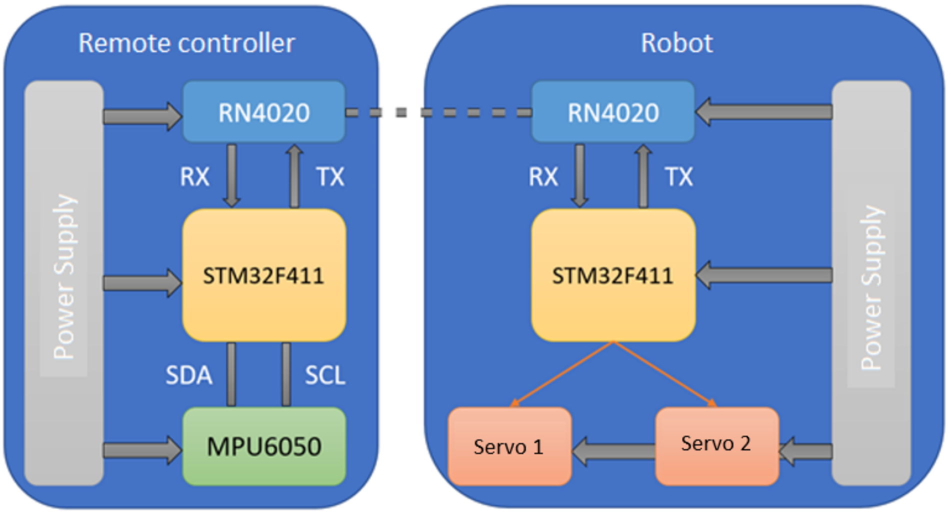

Figure 1. *Block diagram of the robot and the controller.*

I chose the RN4020 module for communication because it is quite easily programmable, and the pricing is also good for the device. The Bluetooth communication is accepted by the rules and has a good operating range for the application, with low power consumption. In the following parts of the article, I introduce the different sub-parts of the remote controller. On the following figure, we can see the physical structure of the remote controller to make easier the understanding.

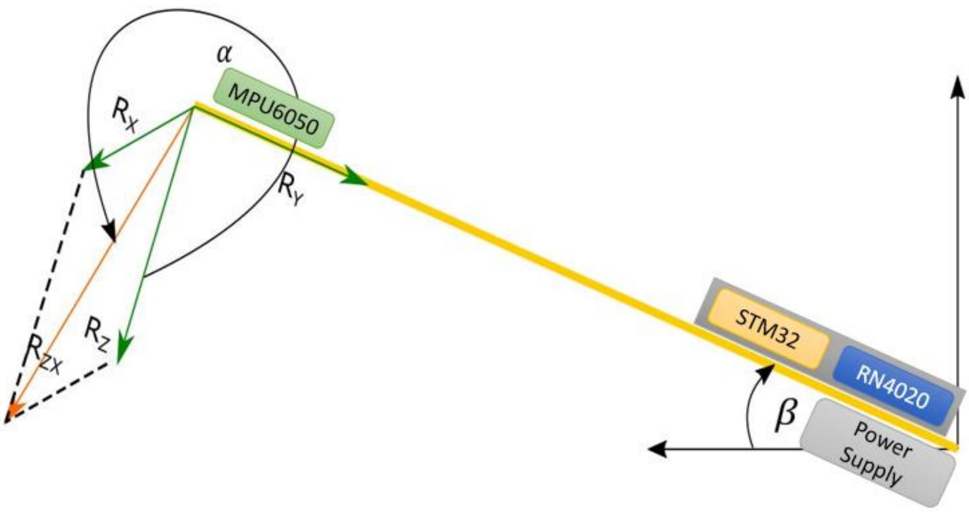

Figure 2. *Physical structure of the "magic wand [2].*

2.1 Power supply

The battery in the wand is a 7.5 V 800 mAh LiPo cell. This voltage is a stabilized 3.3 V for the system. The voltage stabilizer is a KA78RM33RTF circuit with 3.3 V output voltage. Maximum input voltage is 20 V for the module so in case of 7.5 V the heat dissipation is negligible, so additional cooling is not needed. The maximal output current of the D-pak device is 0.5 A [3]. During design the IC and the 1 uF filtering capacitors were placed close to each other on the PCB. The schematic of the power supply was designed according to the STM Nucleo-64 board documentation. The defined schematic was modified because of the use of different devices.

RN4020:

$$I_{max} = \ 33.6\ mA \tag{1}$$

MPU6050:

$$I_{max} = 3.9\ mA \tag{2}$$

STM32F411:

$$I_{max} = 160\ mA \tag{3}$$

$$\sum Imax = 33.6\ mA + 3.9\ mA + 160\ mA = 197{,}5\ mA \tag{4}$$

The calculated current is maximal in every case. The current of other devices in the circuit will be added to this value but those have low influence on the final result. Since the maximum output current for the voltage stabilizer is 0.5 A, the circuit will operate stabile, overcurrent or overtemperature will not be present in any time.

2.2. Bluetooth module

For controlling the robot, I chose the RN4020 Bluetooth module from Microchip. The device uses the 4.1 Bluetooth standard. It is a low power consumption surface mount device. The control is with simple ASCII commands via UART interface. It has 39 channels. Rx sensitivity (receiver sensitivity) is -92.5 dBm, Tx power is -19.0 dBm to +7.5 dBm according to its range. With the change of the Tx power, the consumed current is changing from 14 mA to 33.6 mA [4].

Figure 3. *RN4020 bluetooth module.[4]*

2.3 Inertial sensor

The used device is an MPU6050 accelerometer. This series is the World's first 6 DOF accelerometer. The movement tracker consists of a 3-axis gyroscope, a 3-axis accelerometer, and a so-called Digital Motion Processor. According to the compact design, the device is placed on a 15 mm* 20 mm factory made PCB. The PCB has eight pins and two holes for mounting the sensor. The accelerometer is seen on the picture below [5].

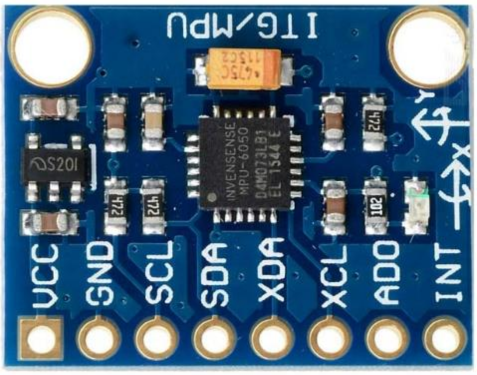

Figure 4. *MPU-6050 inertial sensor.[5]*

For accurate sensing of the remote controller's orientation, it is placed on the end of the designed PCB. For connecting it, the J2 header is being used. The circuit consumes 3.9 mA @ 3.3 V maximum during operation when all the built-in functions are used. The module uses I²C bus standard for communication. For the standard, 2 wires are needed, which are marked also on the PCB as SDA and SCL connecting points [5].

2.4 Microcontroller

The circuit is operated with an STM32F411 LQFP64 microcontroller. The core of the integrated circuit is an ARM® Cortex® 32-bit CPU with 512 Kbyte flash memory and 128 Kbyte SRAM. According to the base schematic, an 8 MHz crystal oscillator is stabilizing the circuit's clock source. The integrated circuit is reading the accelerometer data and sends that for the Bluetooth module. During the design of the circuit, it is mandatory to consider design rules according to the datasheet of the device. One of these rules is to place 6 pieces of 100 nF capacitors connected to the ground and the supply voltage as close to the power pins of the circuit as possible, or also close to the pins on the other side of the PCB, under the component[6].

3. Design flow

3.1. Proteus 8 Professional

For designing the circuit, I chose the Proteus8 Professional software. I chose this software because it is user friendly and easy to use. The design rules are easy to define, and the software gives straightforward help with its indicators. First, the components selected from the software's list had to be placed on the schematic editor. After this, it is possible to create a PCB design according to the schematic. For the components, not found in the software repository, it is possible to design custom components with schematic and PCB information. The RN4020 and the K1 switch are custom made components, so it was needed to create a schematic symbol and a PCB footprint for these components. The software also contains a 3D visualization part, where we can visualize our PCB in 3D.

3.2. Realization

The STM32F411 microcontroller controls the circuit based on its software. According to the package dimensions, the used track widths for the circuits are 0.25 mm. The before mentioned 6 pcs of 100 nF capacitors will take part in this chapter. According to the design guidelines the capacitors should be placed as close to the IC pins as possible to the same side or to the opposite side of the PCB.

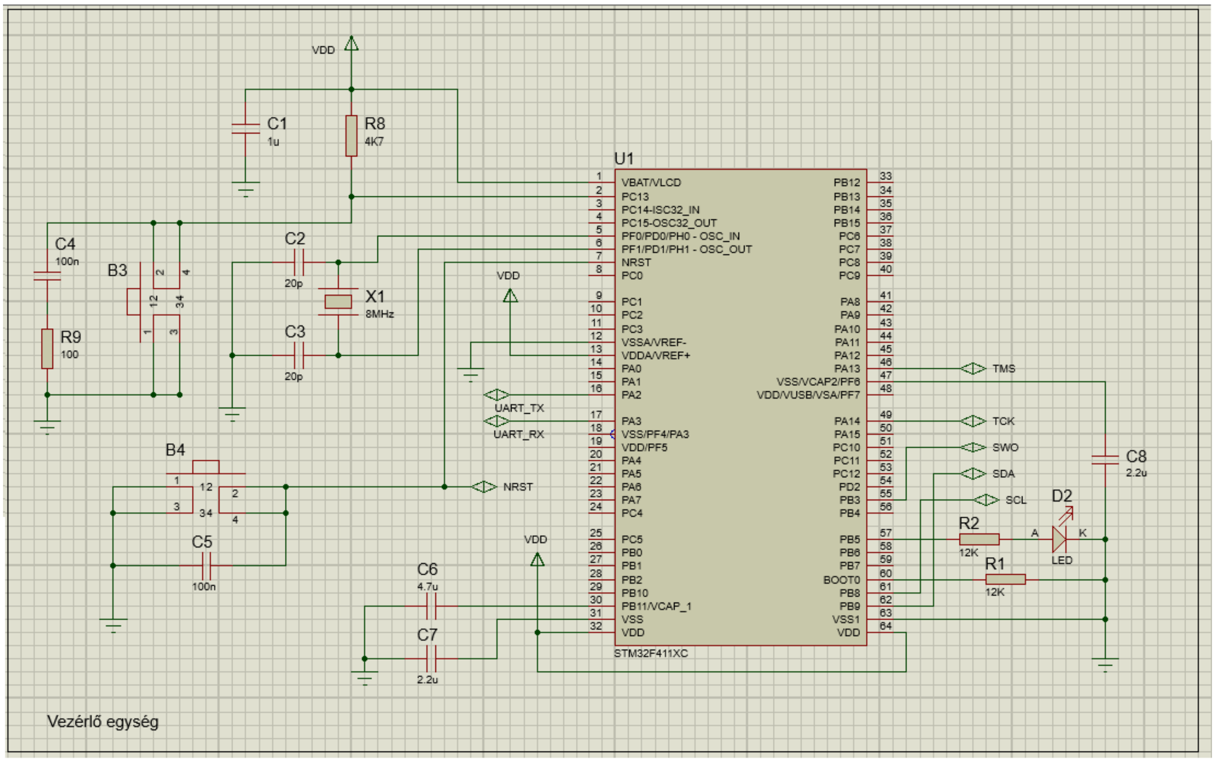

Figure 5. *Schematic of the wand.*

Asides from the 100 nF capacitors, the C6-C7 capacitor pair is also placed close to the according pins of the microcontroller. The X1-C2-C3 component combination stabilizes the external 8MHz clock signal, which is transformed to 100 MHz internal operating frequency by the microcontroller’s internal circuits. The triangles, facing towards each other represent connections, using these signs, creating the schematic are more efficient. The red color represents the TOP and the blue represents the BOTTOM traces of the PCB.

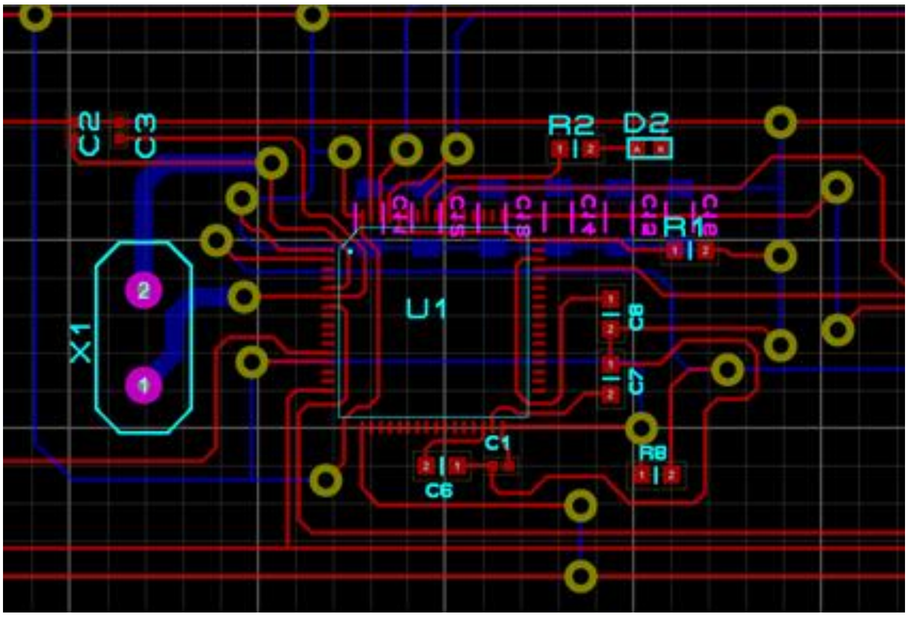

Figure 6. *PCB design of the remote controller.*

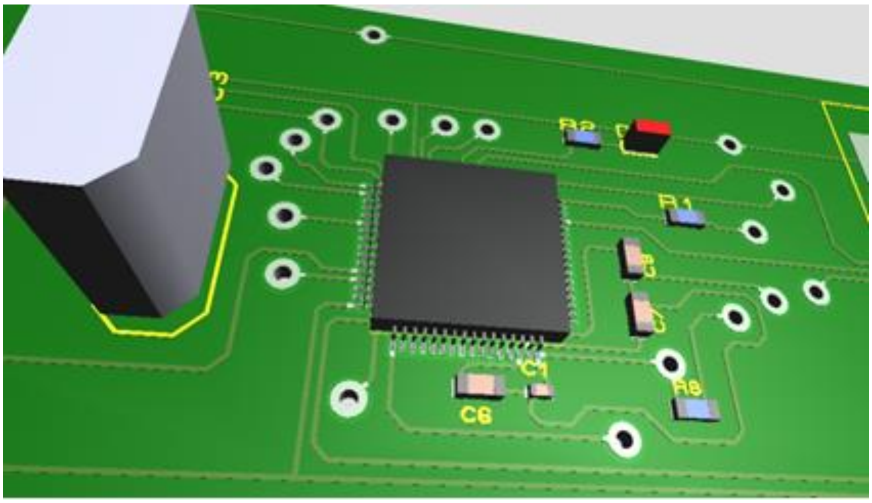

Figure 7. *3D model of the remote controller.*

The main purpose of the designed PCB is to provide exact commands to the spherical robot within a long range. By the moving of the wand, the robot moves to the specified direction. The PCB has a size limitation according to the competition rules. The maximum width of the PCB is 35 mm. Since the PCB is mounted inside a cylindrical body, the PCB is resistive for ESD. With the used components, it was easy to build a rule compliant PCB. Thanks to the easy use of the software, the design of the components non-present in the internal library was also an easy task. New components are easy to create and save for later use.

4. Conclusion

The remote controller operated well during the competition. The Bluetooth communication was stable and reliable. During the competition, smaller problems occurred on the robot. Unidentified software or hardware problem appeared, and it was needed to restart the robot sometimes because of this problem. The control was performed by the up-down and left-right movement of the wand and by pressing a button. The commands sent from the remote controller were properly interpreted, and the robot performed the commands easily. For further development it is considered to not control only with 2-dimension movement but to recognize gestures or predefined movements.

Acknowledgement

"The described article/presentation/study was carried out as part of the EFOP-3.6.1-16-2016-00011 "Younger and Renewing University – Innovative Knowledge City – institutional development of the University of Miskolc aiming at intelligent specialisation" project implemented in the framework of the Szechenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund."

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