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Design and implementation of remotely controlled robotic arm

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***Abstract* — the paper provides a brief description of the proposed robotic arm that can be controlled via serial interface using two 32-bit ARM microcontroller. The main construction parts are made with the help of a 3D printer. The paper also describes mechanical parts as well as an electrical part to familiarized reader about the whole concept of proposed robotic arm.**

***Keywords* — 32-bit ARM, 3D printer, microcontroller, robotic arm, servomotors**

I. Introduction

Since time immemorial, people have been trying to make things easier. Nowadays the technology is making great progress and electronics are found in almost every device like washing machines, mobile phones, etc. For this purpose, programmable microcontrollers have been created that can be customized to solve the problem using various programming languages. It is no longer necessary to create complicated mechanical controls, such as manual rail control, but it is easy and convenient to control devices using microcontrollers with the help of sensors and actuators. Thanks to one small semiconductor device, it is possible to control devices with different properties, which can be used to solve situations that are not enough for the people themselves. As an example is a robotic arm.

The robotic arm is a device that can replace human hands with its functionality. For years, industry has to use high temperature, toxic, heavy, and other objects. These objects can be very dangerous for human body. Therefore, these dangerous objects can be processed without human touch using the robotic arm. Today, the robotic arms are at a completely different level and are used in almost every industrial plant, whether for production, transmission or for certain technical operations. In many areas they become an integral part of the manufacturing process. The largest application of robotic arms in order to increase productivity and quality of work can be found in follows categories: Car industry, clothing industry, textile industry, food industry, chemical industry, mechanical engineering, medicine and others specialized departments.

The article shows a design and a control strategy of proposed robotic arm which can be wirelessly controlled by RF (Radio Frequency) module. Both sides (controlling and controlled side) of robotic arm uses ARM microcontrollers. Each mechanical part, except of bearings were modeled and printed using a 3D printer. The following chapters are described in two main parts. The first chapter describes a design of the mechanical parts. This chapter provides detailed illustrations of the proposed mechanical parts. The second part describes electronic parts. This chapter describes the proposed PCBs (Printed Circuit Boards), the used microcontroller, the way of servomotor control, and strategy of changing information between a controller and the robotic arm itself.

II. Mechanical Parts of the Robotic Arm

As it was mentioned above the mechanical parts are mostly created with the help of the 3D printer. To create the mechanical part with the 3D printer, a 3D model has to be made. Therefore the appropriate 3D software was considered. In this case the 3D software Catia V5 and PTC Creo were used. With this software's help the 3D models for robotic arm as well as 3D models for control device were created. The 3D model of the robotic arm is illustrated in Fig. 1.

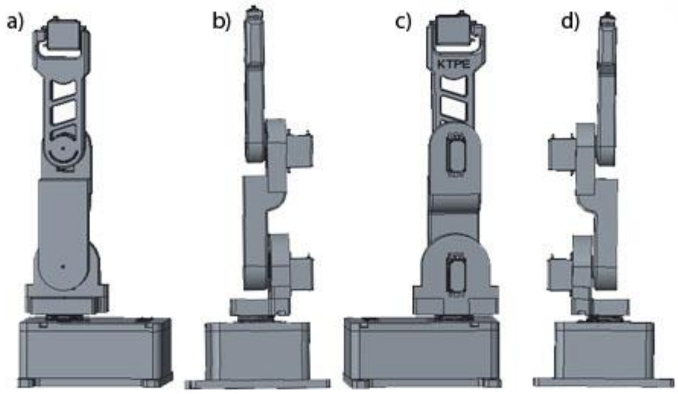

Fig.1 3D model of the robotic arm

The model is designed so that the printed circuit board, servomotor and cables enter into the base on which the robotic arm is placed. On the bottom plate of the robotic arm, there are pillars for the printed circuit board as well as four bolt holes for anchoring the entire robotic arm. For the capability of robotic arm movement to more than one direction, a four joints were implemented. Each joint is secured against breakage. The secure of each joint is handled by metal bearing so the whole construction is not hanging on the servomotor's shaft. The detailed illustration of the joint which handle the axial movement of the robotic arm is illustrated in Fig. 2.

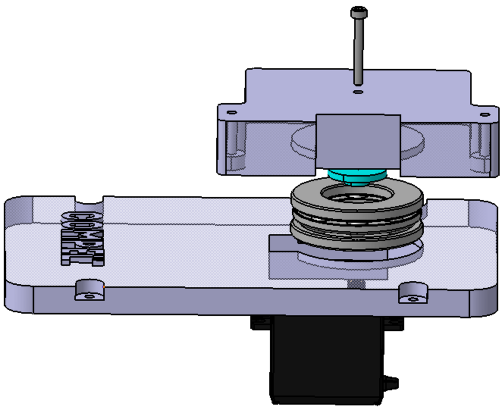

Fig. 2 3D model of joint for the axial movement of the robotic arm

The upper joints which are handling the vertical movement of the robotic arm uses bearings with different type and placement as can be seen in Fig. 3.

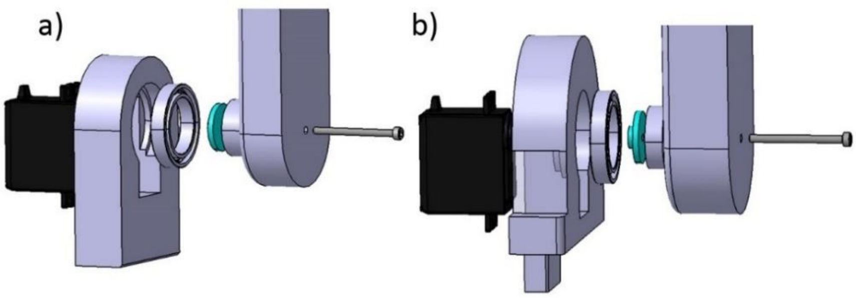

Fig. 3 3D model of joints for the vertical movement of the robotic arm

Same as the robotic arm the wireless controller was firstly 3D modeled as can be seen in Fig. 4.

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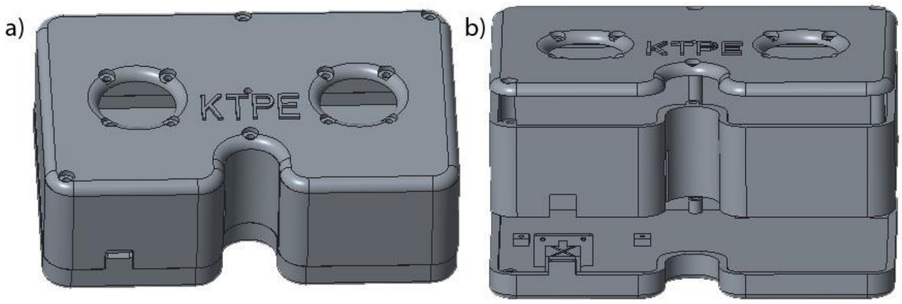

Fig.4 3D model of control device

Control device was designed to wirelessly control each movement part of the robotic arm by two analog joysticks.

For better understanding of whole concept the electrical parts have to be described. Therefore the next chapter will provide a brief description about electrical parts and communication way between the robotic arm and the control device using microcontroller ARM.

III. Electrical Parts of the Robotic Arm

The electrical parts of the robotic arm can be divided into two main parts. The first part describes used and designed electrical components for robotic arm itself. The second part can describe used and designed electrical components for control device.

A. Electrical parts for the robotic arm

Basically to make robotic arm move the actuators in this case servomotors were implemented. Specifically the two types of servomotors were used. The first type can provide higher torque. The second type can provide lower torque. The first type of servomotors was used in the bottom area of the robotic arm. Reason of that is because on these servomotors higher stress are applying. The bottom servomotors must lift except of the weight of the subject, the weight of the robotic arm with servomotors itself. The one servomotor can drain power up to 10W. Due to that the external power source was considered. The control such servomotor the PWM (Pulse Width Modulated) signal with a specific frequency and duty cycle has to be generated. Basically, all hobby servomotors can be controlled by the same PWM signals. Specifically the frequency is 50Hz which correspond to 20ms of the time period. The duty cycle must be between 5% and 10%, which correspond to time range from 1ms to 2ms. Maximum angle movement for used servomotors is 270 degrees. To reduce the number of wires for powering up servomotors, each servomotors were connected to each other in parallel as can be seen in Fig. 5.

Fig. 5 The illustration of servomotors connection

For wirelessly robotic arm controlling and PWM signal generating the 32-bit ARM microcontroller was implemented. Specifically the microcontroller with type of STM32F030F4. This type of microcontrollers consists of 15 general purpose programmable GPIO pins and can be used in many applications. [1]-[6]. Which for this purpose, it is far enough. Of course the MCU (Microcontroller Control Unit) provides much more functions. For the sake of simplicity only functions which were used will be described. The literature [7] provides closer information. In this case the two same types of MCU were implemented. One MCU is implemented in the robotic arm itself and the other MCU is implemented in the wireless controller. Both MCUs were programmed with the help of Graphic interface called CubeMX. With the help of this interface all peripheral of MCUs can be set much quicker. The logic of the whole system must be programmed separately in programming environment which can handle the ARM MCUs. In this case the Keil µvisin was used.

Peripheral settings for the MCU which controls the robotic arm is illustrated in Fig. 6.

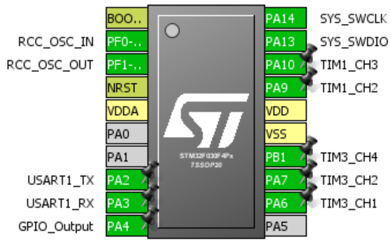

Fig. 6 Pin configuration for the robotic arm

For this type of MCU the maximum frequency of the CPU is 72 MHz. This frequency is also connected into the inputs of timer 1 and timer 3 which are used to generate PWM signals for servomotors. To achieve required frequency (in this case 50 Hz), the right value of PSC (Prescaler) and ARR (Auto Reload Register) must be set. Then the output frequency can be calculated by equation (1).

$$F_{PWM} = \frac{F_{CPU}}{(PSC+1)\cdot(ARR+1)} \tag{1}$$

For achieving better performance from servomotors the input voltage was set to 6 V. But the MCU can not handle such high voltage. Therefore the DC/DC buck converter has to be considered. The chosen MCU does not consist of an RF transmitter/receiver. For this purpose the APC220 module was chosen. The main advantage of this module is that it can communicate with MCU with serial interface such as a UART. The UART interface is well known, therefore the principle of this peripheral will be not presented in the next. The same RF module was used for the wireless controller. But the wireless controller has few more electrical components which will be described later.

The MCU is soldered into board which can be easily connected to the breadboard. But for the achieving smaller design the PCB (Printed Circuit Board) based on schematic was proposed as can be seen in Fig. 7.

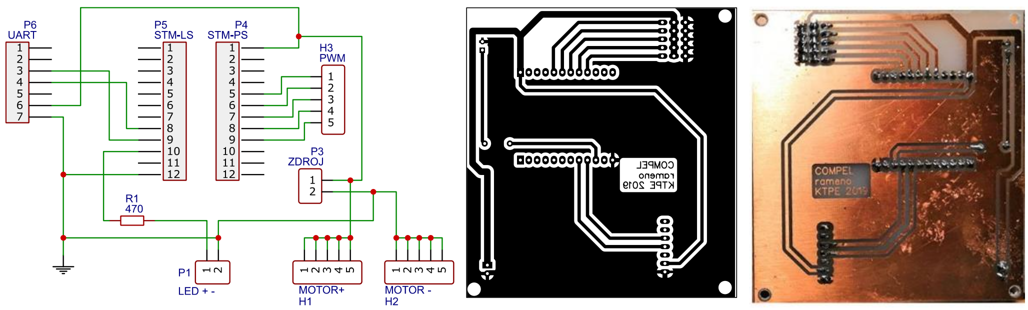

Fig. 7 Proposed PCB for robotic arm

Implemented proposed PCB on robotic side is illustrated in Fig. 8

Fig. 8 Displacement of electrical components into base of robotic arm

B. Electrical parts for wireless controller

The peripheral setting for the MCU whose main purpose is converting analog value from analog joysticks and sending control commands trough serial interface into robotic arm is illustrated in Fig. 9.

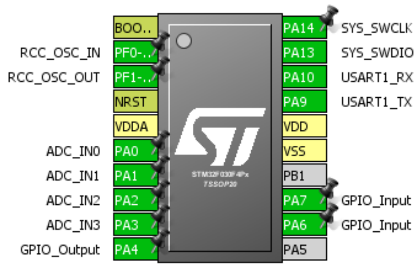

Fig. 9 Pin configuration for the wireless controller

As the power supply for wireless controller the lithium battery with type of LGEBE18650 was used. To capability of battery charging the TP4056 module was used. This module can charge battery with current up to 1 A. The maximum draining current is 3 A. Because the voltage of battery may during operation vary from 2.4 V to 4.2 V, the appropriate DC/DC controller has to be considered to achieve stabilized 5V. This 5V is in the next connected to the MCU through 3,3V linear voltage controller. The 2,4V indicates that the battery is discharged. In this situation the module disconnects battery from load to protect battery from over-discharge.

The communication module is same as for MCU controlling the robotic arm. The principle is as follows: The MCU on the wireless controller side converts an analog voltage value from joystick into digital form. Then processed data send through serial interface into MCU on robot side. The MCU on robot side process incoming serial data and apply the duty cycle change which results in robotic arm movement.

Same as for robotic arm side for wireless controller side the PCB based on the proposed electrical scheme was created as can be seen in Fig. 10.

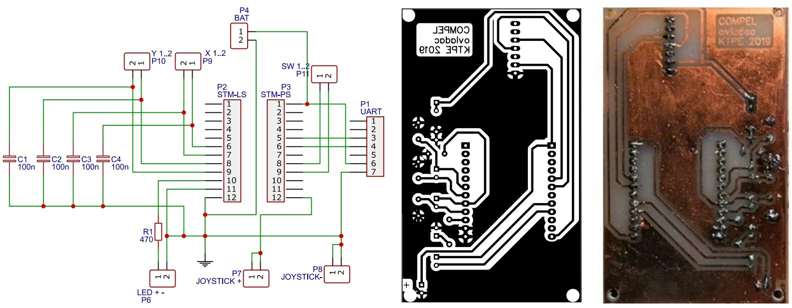

Fig. 10 Proposed PCB for wireless controller

Implemented proposed PCB with all electrical components on the wireless controller side is illustrated in Fig. 11.

Fig. 11 Displacement of electrical components in case of wireless controller

After printing and connecting each part the resulted look of the whole robotic arm can be seen in Fig. 12.

Fig. 12 Constructed all mechanical and electrical parts of the robotic arm and wireless controller

IV. CONCLUSION

To achieve completely functional robotic arm, which can be controlled wirelessly many things were done. The construction parts of the proposed robotic arm were created with the help of the 3D printer. The constructed robotic arm can be used for propagation purposes as well as for education purposes. The proposed robotic arm can be enhanced by using the wifi module to extend the possibility of controlling the robotic arm via internet.

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