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Synchronization between Arduino based appliance and MATLAB application

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Abstract Microcontrollers have usages in various types of processes and automation systems. What makes them so convenient is their programmability, low-cost, and a big number of possible extensions. Microcontroller ATMega328 with Arduino board is common when it comes to learning and experimenting. Liquid Crystal Displays are often used with microcontrollers, and in this project one with 16x4 dimensions is used. The programming logic of a project is built in Arduino IDE. Standard 4x4 keypad with 8 output pins is used with only one pin with some modifications in connection. The device can be controlled by the application built in MATLAB environment. The application and the device are communicating by Serial communication and are in synchronization. In this way, the device can be used directly, or by the application at the same time.

Keywords: microcontroller, LCD display, Arduino, calculator, serial communication, MATLAB, graphical user interface

1. Introduction

Modern technology cannot be conceived without the usage of microcontrollers from children's toys to advanced scientific projects. The usual misconception is that microcontrollers and microprocessors are the same thing. The main difference is that, in order to make microprocessor usable, many components must be added, and that is not the case with microcontrollers [1]. Microcontrollers contain one or more CPU, memory, I/O peripherals, etc., and there is no need for other external components [3], [1]. Microcontrollers are widely used, programmable, low-cost, and resistant electronic components which are often described as a small computer on a "single integrated circuit" [3]. The best-known manufacturers of microcontrollers are Intel,

Atmel, Microchip, Toshiba, etc. Arduino boards are one of the most affordable boards on the market. With them one can easily start working with microcontrollers [2]. LCD displays that are ideal for displaying text are character displays [5]. They come in various sizes, and the one used in this project is 16x2. These displays are the most inexpensive and simplest, and have 16 pins for connection with microcontroller [4]. Matrix keypads are often used in projects that need some kind of data entry, and use combination of rows and columns of switches to provide button states [6], [4]. MATLAB environment is one of the most commonly used in engineering world, and when it comes to this project, a GUI is created for device control.

2. ATmega328 microcontroller and Arduino boards

ATmega328 microcontroller is Atmel's product and is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture [2]. It has a lot of features and some of them are: advanced RISC architecture, 32Kbytes of In-System Programmable with Read-While-Write capabilities, 1Kbytes of EEPROM, 2Kbytes SRAM, etc [2], [9]. ATmega328 is a microcontroller of Arduino board used in this paper. Figure 1.1. is showing pinout of a board used in this paper.

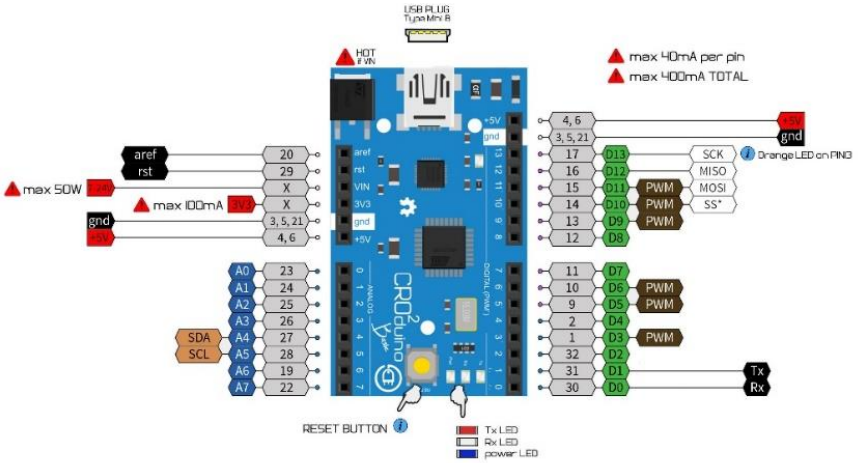


Fig. 1.1. *Arduino ATmega328 pinout [10]*

Arduino is a company, project that designs microcontroller kits since 2005 and it is a thriving industry, supported by a large community of people [4], [7]. Arduino kits are widely used from individuals, students, hobbyists, to educational institutions [8]. It is an open source project. The one used in this paper is a version called Croduino and it is shown in Figure 1.1. It is based on Arduino Nano.

Croduino board has all the features that any other Arduino board gives. It has 22 I/O pins, 8 analog, and 14 digital pins, and 6 of 14 digital are PWM. Figure 1 is showing some limitations of the board itself when it comes to current and power. The Arduino project has its own IDE written in Java which is originated from the IDE for languages Processing and Wiring [9]. Syntax for writing Arduino code is based on C and C++. The main structure must have a *setup* and *loop* functions [8]. A program made in Arduino IDE is called sketch.

3. LCD display and matrix keypad

Liquid Crystal Displays are the most inexpensive display modules for Arduino. Character displays are very easy to use, and can be purchased in various sizes. 16x2 us used in this paper. Connection of 16x2 LCD with Arduino board is shown on Figure 2.1.

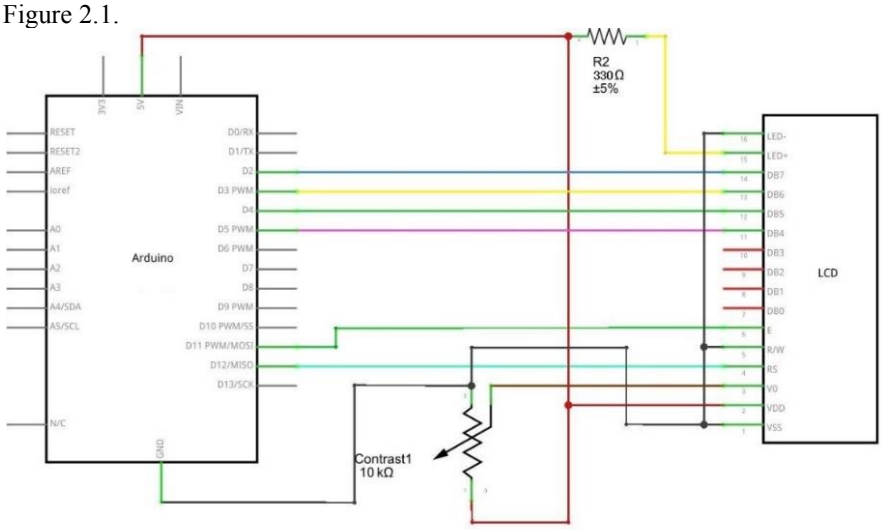


Fig. 2.1. *Connecting LCD to Arduino*

Variable resistor is used for display contrast adjustment since this display has a backlight. Pins for communication with LCD are D0 – D7, RS, E and RW. Only 6 pins are necessary for standard communication: RS, EN, D7, D6, D5 and D4.
Since this paper is based on Calculator as controlled device, some kind of module that will produce inputs was needed. Matrix keypad used in this paper is 4x4 keypad and has 8 connection pins for 16 buttons. It has thin design, good performance, and it is great as a human interface component in projects. In order to provide different states to microcontroller, four rows and four columns are used. In order to connect matrix keypad in this paper we use one analog pin instead of 8 pins. Every row has

its own resistance, and so do the columns. Figure 3.1. is showing (a) the appearance of a matrix keypad, and (b) wiring of a keypad used in this paper.

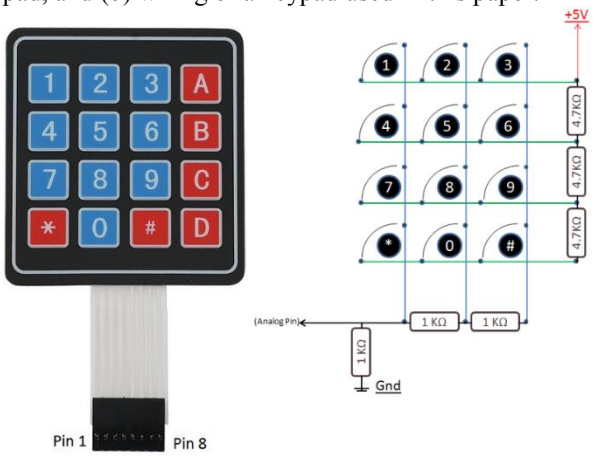


Fig. 3.1. *Matrix Keypad (a) appearance and (b) wiring*

OneWireKeypad library is used for keypad control. This library lets a user to define resistances of rows and columns, and calculates range of analog values for every button. When a button is pressed, microcontroller receives an analog value of resistance. In that way, it is determined which key has been pressed. As it was mentioned before, the main problem that is to be controlled in this paper is a calculator that uses matrix keypad, as well as four switches with pull-down resistors that are used for extra operations.

4. Synchronization between Arduino based appliance and MATLAB application

Arduino appliance in this paper is a calculator with four basic operations built in 4x4 matrix keypad, and 4 additional operations (square, square root, sine, cosine) added with switches and pull-down resistors. Calculator logic is written in Arduino IDE, and all of it is set on the microcontroller. Keys from matrix keypad are recognized by methods from included library, and work of switches is stabilized with *debounce* method that is dealing with switch bounce problem. In order for calculator to work well, after keys are recognized, flags, if-statements and methods are implemented. Figure 4.1. is showing the block diagram of behavior of this paper work.

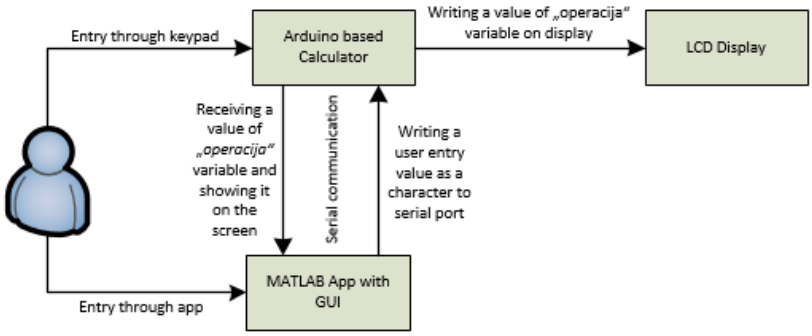
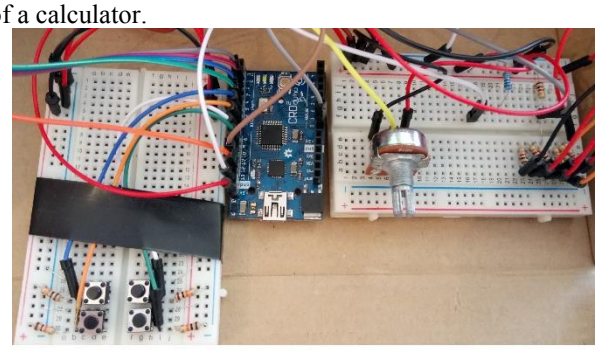


Fig. 4.1. *Block diagram of project usage*

Data entry can be realized through keypad, additional four switches, or graphical user interface built in MATLAB environment. As soon as microcontroller receives the key, part of the program logic is done and variable that contains current operation is filled. The same variable is shown on the LCD display, as well on the graphical user interface on the computer. MATLAB application is using timer method as a background task. This method is reloading every 0.05 seconds, reading from serial port, and showing result on GUI. Every button on GUI is using previously opened serial port and writing a character in it. Figure 4.2. is showing (a) wiring and (b) appearance of a calculator.



a)

b)

Fig. 4.2. *a) Wiring of the calculator b) Appearance of the calculator*

Graphical user interface is built in MATLAB environment as mentioned before. Figure 4.3. is showing appearance of GUI.

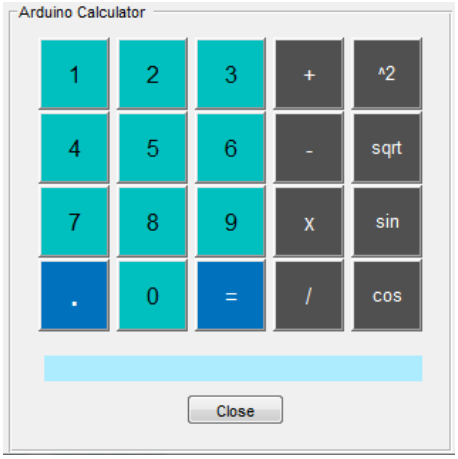


Fig. 4.3. *Graphical User Interface*

Figure 4.4. is showing the whole system in work including both the calculator and the GUI application.

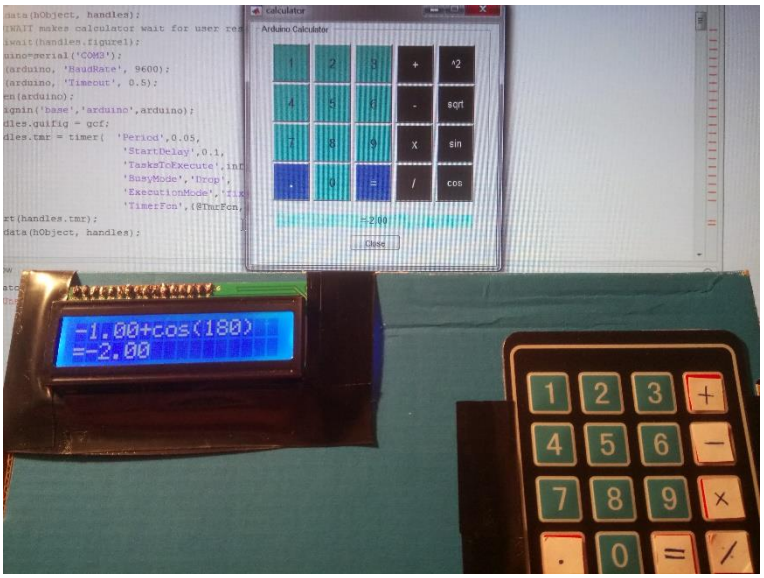


Fig. 4.4. *The calculator and the GUI application in work*

5. Experimental results

As it was explained through usage block diagram, user can send data through calculator itself, or through GUI. On Figure 5.1. ways of data entry and results of testing are shown on three images. On the Figure 5.1. (a), user is typing "*cos(0)*" on calculator, and "*+sin(90)"* on GUI, and the equal button is pressed on the calculator. Figure 5.1. (b) is showing result of typing only on the calculator, and on Figure 5.1. (c) equal button is pressed on GUI and operation is synchronously continued to the previous. It can be seen that both calculator's display and GUI are showing the same results.

Fig. 5.1. *(a) Combined usage (b) Calculator only (c) GUI only*

6. Conclusion

Experimental analysis has shown that synchronization between built appliance and MATLAB application works well. The speed of Arduino looping caused minimum problems with key recognition from keypad by the app, but it did not create any fatal error nor stop the application from working. Synchronization can be done between any other appliance through either guided, or unguided medium with serial communication.

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