



Arduino Uno's PIN Expansion with SPI Communication to Control 4 LCD Display

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Abstract. Arduino Uno is a minimum system board that use atmega 328p as a microcontroller IC (Integrated Circuit). Arduino Uno has 20 output pins. The running out of the pins owned by the Arduino Uno makes it cannot control many LCD, such as 3 LCDs that require 21 pins. With the lack of the Arduino Uno, this study is focusing on expand output pin of Arduino Uno so that it has 32 additional pins by making use of internal SPI communication. This expansion on the Arduino Uno uses 2 MCP23S17. MCP23S17 one to control LCD 1 and LCD 2 while MCP23S17 two to control LCD 3 and LCD 4. The method used in this study is a quantitative method. Data register that used to support SPI communication in this study was obtained from the MCP23S17 datasheet. The results of this study show a table of register data SPI set address that can be used to control the expansion pin on MCP23S17 and pictures of 4 LCD control display.

Keywords: *Arduino Uno · PIN Expansion · SPI Communication*

1 Introduction

Microcontroller is an electronic component that is able to control according to the given program. Microcontroller is also a computer that has been integrated and can be used for various types of control [1]. Microcontroller consists of several components in it such as CPU, memory, I/O, ADC, and others. There are various types of microcontrollers, including Atmel, Philip, Microchip, PIC, ARM, and so on [2]. Each type of microcontroller has its own specifications. However, in the era of 2005, Hernando Barragam made a thesis involving the microcontroller and was given the name arduino. This Italian citizen developed Arduino with Massimo Banzi and David Cuartielles [3]. When it was first made, Arduino was given the name Arduino of Ivrea, but the name was later changed to Arduino which means brave. At first Arduino was made for students who needed a microcontroller easily and at an affordable price. Arduino has many different variants depending on the IC used. One type of Arduino that is widely marketed is the Arduino Uno. Arduino uno uses the atmega328p IC (Integrated Circuit) as its microcontroller IC. The Atmega 328p IC is an 8-bit AVR-based microcontroller made by Atmel [4]. The atmega 328 IC used for Arduino Uno has 20 input or output (I/O) pins [5]. However,



Fig. 1. Arduino uno.

the availability of the number of 20 output pins that need to be controlled does not deny that Arduino Uno requires more output pins.

LCD (Liquid Crystal Display) is one component that takes up a lot of pins. In previous research conducted by Farid Baskoro, it can be found that one LCD can take 12 pins from Arduino Uno [6] [7]. In some systems, running text is used to display a lot of information without having to increase the number of LCDs. But in some cases saying that running text will only slow down the user to get the displayed data information. Adding an arduino to every LCD will only waste money and space becomes increasingly inefficient. With the various problems that have been described, this study aims to offer another solution by utilizing the internal SPI on the Arduino which is connected to the MCP23S17 as a slave to expand the pins in controlling more numbers of LCD.

IC MCP23S17 is made by Microchip which aims to expand pins by utilizing SPI communication. SPI communication supports high-speed communication and full duplex communication [8] [9]. This IC is equipped with a pin address so that users can use it multiple times and can be distinguished from the given address [10]. With the help of 2 MCP23S17 ICs as slaves that utilize SPI communication as a working system, Arduino Uno can be used as a master that can control the 32 output pins of the MCP23S17. The 32 output pins of the MCP23S17 which are controlled by Arduino Uno are then connected to 4 16x2 LCDs to display.

2 Literature Review

Arduino is an open source microcontroller that can be easily programmed, erased and reprogrammed at any time. The Arduino platform is designed to provide an inexpensive and easy way for students or professionals to create microcontroller devices that can interact with the environment using sensors and actuators. Arduino is built using an 8-bit Atmel AVR microcontroller IC produced by Atmel or Atmel ARM 32-bit, this microcontroller can be programmed easily using C or C++ in the Arduino IDE software. One type of Arduino that is sold in the market is Arduino Uno. The physical form of Arduino Uno can be seen in Fig. 1. Arduino uno consists of various components in it. Microcontroller IC is the core of the Arduino Uno which functions as a mini computer and can receive and send data or commands to the devices connected to it.

Arduino uno can work with an external voltage source of 6 V to 20 V. However, using a voltage source of less than 7 V can cause the Arduino uno to work unstable. And if the



Fig. 2. LCD 16x2.



Fig. 3. IC MCP23S17

voltage source is given above 20 V, it will overheat the components, causing damage. The recommended external voltage source is between 7 V to 12 V. The VCC on the Arduino pin has two values of voltage variance. The first voltage is 3.3 V, and the second voltage is 5 V. This will make it easier for users who want to use different input voltage variants. Reset Button is the component that has a function to reset the performance of the Arduino. When the reset button is pressed, the Arduino will stop the program it is running now, and repeat the program from the beginning when the Arduino first worked. The USB connector has an important role in Arduino. USB is a communication bridge from the computer to the Arduino. I/O pins or commonly referred to as input and output pins, are a part that is no less important than all the components that make up Arduino. With I/O pins, Arduino can communicate with any sensors and actuators connected to it. The more I/O pins the Arduino has, the more actuators the Arduino can control.

Liquid Crystal Display or commonly referred to as LCD is one of the electronic components that has a function as a display or displaying information determined by the microcontroller. LCD has various types, one example of the most commonly used LCD is the 16x2 LCD. 16x2 means that the LCD has 16 columns and 2 rows. 16x2 LCD has 16 pinout, Here is a little explanation of the LCD pinout:

- VSS is a pin that is connected to the microcontroller ground mikro
- VDD is a pin that is connected to the VCC microcontroller
- V0 is a pin connected to a resistance, so it can adjust the thickness of the display
- RS is a pin for register data
- D0-D7 is the data pin used to send data to the screen
- A is the Anode pin to be connected to the VCC microcontroller
- K is the cathode pin to be connected to the microcontroller ground (Fig. 2 and 3).

One example of a slave IC on the market today is the MCP23S17. This IC cannot work alone. The slave IC is only able to work when it has been given a command by the master IC. Master IC will generate and send register or SPI clock [11]. Slave ICs are generally used to control their output by commands from the master IC. This IC made by

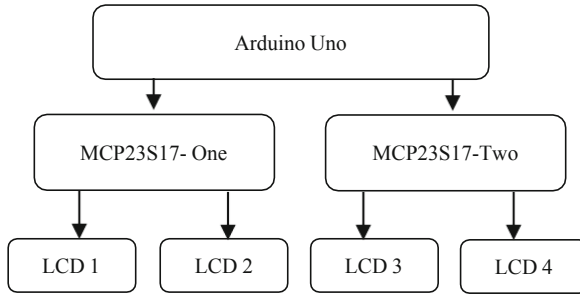


Fig. 4. The design system of research.

Microchip can work on orders from the master by utilizing SPI communication. SPI is one of synchronous communication protocol that able to use in short distance [12] [13]. All SPI communication involves 4 pins namely SS (Slave Select), SCK (Serial Clock), MISO (Master In Slave Out), and MOSI (Master Out Slave In) [14] [15] [16].

3 Method

This study uses quantitative methods. Quantitative research is a process of finding science and knowledge by using data in the form of numbers as a tool to analyze something you want to know [17]. The first literature study is to study previous journals regarding SPI communication from domestic and foreign sources. Next, learn about how to implement SPI on the MCP23S17 IC with Arduino Uno from the MCP23S17 datasheet published by Microchip. After the literature study has been completed, the next step is to design the system design.

Figure 4 shows a block diagram of the system design. On the Arduino Uno block, it has an arrow pointing to MCP23S17, this shows that Arduino is used as the master, the master function here is to give orders to MCP23S17 by utilizing SPI communication. MCP23S17 works as a slave. Slave will work when the master has given the command. When the Arduino Uno gives a command to the MCP23S17, the MCP23S17 responds to the command by controlling the display on the LCD.

4 Results and Discussion

Testing and final data collection did after collect register data from the MCP23S17. This register data that has been collected will then be tested after the hardware manufacturing process is complete. Making hardware requires understanding the pinout of each required component. One of them is the MCP23S17 pinout. IC MCP23S17 has a pinout which can be seen in Table 1.

In controlling the input and output, IC MCP23S17 has an 8-bit register configuration. IODIRA or IODIRB, is a configuration bit register that aims to declare the MCP23S17 pin will work as input or output. After the configuration is complete, this IC will store the register information.

The MCP23S17 IC has pins named A2, A1, and A0. These three pins have a function to declare the address on each IC. These 3 pins will form a sequence according to the binary code. To get a logic value of one, then one of the pins must be connected to a 5 V voltage source. After the address on the MCP23S17 IC has been declared, the next step is just to adjust the command accompanied by the address of the intended IC.

The first thing that must be done when giving orders to the MCP23S17 is that the master IC must send address information first. Master will not have a knowledge about slaves until slaves have the address which has been declared [18]. In sending address information, the address register is combined with 4 definite bits with a value of 0100. After 4 definite bits, it is followed by 3-digit address information. Then added with 1-bit address that serves to write or read. So the total bits sent are 8 bits.

After declaring the slave address, the master then sends 21 registers on the MCP23S17. This is intended as a sign for the MCP23S17 is ready to work. The description of the 21 registers on the MCP23S17 can be seen in Table 2.

The results and discussion in this study are divided into four parts, the first part is to display the display on LCD one using MCP23S17 one, the second part is to display the display on LCD two using MCP23S17 one, the third part is to display the display on LCD three using MCP23S17 two. The fourth part is displaying four LCD displays using MCP23S17 two.

The results of the first test are the results of tests carried out on LCD one and MCP23S17 one. To distinguish the command for MCP23S17 one and the command for MCP23S17 two, it is necessary to address the two ICs. IC MCP23S17 one has an address that is 0b01000000 or 64 in decimal form, while IC MCP23S17 two has an address that is 0b01000010 or 66 in decimal form. When the Arduino Uno is first connected to a voltage source, Arduino Uno as the master immediately processes coding containing the command address of 64 to the slave, so that the slave who has the command address 64 is able to respond or be ready to receive the next command. After sending the address, Arduino Uno sends a pin command that the MCP23S17 will use to display data on the LCD. LCD one uses pins GPB0 to GPB7 on the MCP23S17 one to display the display. The results of the first test on LCD one and MCP23S17 one can be seen in Fig. 5.

The results of the second test are the results of tests carried out on LCD two and MCP23S17 one. The address or address for sending the second test data has the same value as the first test, IC MCP23S17 one has an address with a value of 0b01000000 or 64 in decimal. After sending the address and command on LCD one, the Master or Arduino Uno sends the address and command data to LCD two. Two LCDs with MCP23S17 one using pins GPA0 to GPA7 on the MCP23S17. The results of the second test on LCD two and MCP23S17 one can be seen in Fig. 6.

IC MCP23S17 one can control LCD one and LCD two. By utilizing pins GPA0 to GPA7 and GPB0 to GPB7. LCD one and two on MCP23S17 one can be seen in Fig. 7.

In the results of the third test, there is a difference with the first test and the second test. The thing that distinguishes it lies in the difference between the MCP23S17 IC. The first test and the second test use one MCP23S17 IC, while the third and fourth tests use two MCP23S17 ICs which have an address or address 0b01000010 or a value of 66 in decimal. The results of the third test are the results of tests carried out on LCD three and MCP23S17 two. The triple LCD utilizes pins GPB0 to GPB7 on the MCP23S17 two.

Table 1. MCP23S17 pinout

Pin Name	Pin Number	Pin Type
GPB0	1	I/O
GPB1	2	I/O
GPB2	3	I/O
GPB3	4	I/O
GPB4	5	I/O
GPB5	6	I/O
GPB6	7	I/O
GPB7	8	I/O
VDD	9	Power
VSS	10	Power
CS	11	I
SCK	12	I
SI	13	I/O
SO	14	O
A0	15	Address Pin
A1	16	Address Pin
A2	17	Address Pin
RST	18	I
INTB	19	O
INTA	20	O
GPA0	21	I/O
GPA1	22	I/O
GPA2	23	I/O
GPA3	24	I/O
GPA4	25	I/O
GPA5	26	I/O
GPA6	27	I/O
GPA7	28	I/O

The program to activate LCD three will be executed after controlling LCD one and LCD two on MCP23S17 one. The results of the three LCD test can be seen in Fig. 7 (Fig. 8).

The results of the fourth test involved four LCDs and two MCP23S17. The four LCDs utilize pins GPA0 to GPA7 on the MCP23S17 two. The LCD four control program is run last after the control LCD one, LCD two, and LCD three. The results of the four LCD

Table 2. MCP23S17 register

Register Name	Value
IODIRA	1111 1111
IODIRB	1111 1111
IPOLA	0000 0000
IPOLB	0000 0000
GPINTENA	0000 0000
GPINTENB	0000 0000
DEFVALA	0000 0000
DEFVALB	0000 0000
INTCONA	0000 0000
INTCONB	0000 0000
IOCON	0000 0000
IOCON	0000 0000
GPPUA	0000 0000
GPPUB	0000 0000
INTFA	0000 0000
INTFB	0000 0000
INTCAPA	0000 0000
INTCAPB	0000 0000
GPIOA	0000 0000
GPIOB	0000 0000
OLATA	0000 0000
OLATB	0000 0000

**Fig. 5.** First Test Results.



Fig. 6. Second Test Results.

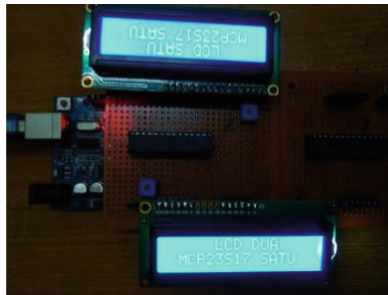


Fig. 7. LCD one and two on MCP23S17 one.

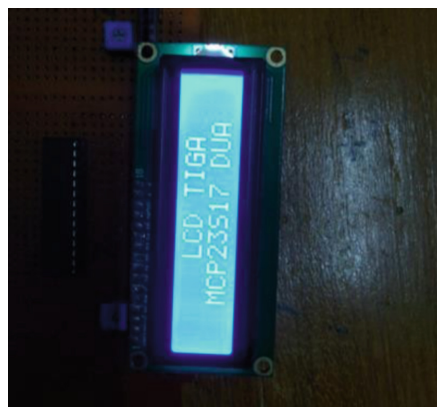


Fig. 8. Third Test Results.

test with MCP23S17 two can be seen in Fig. 9, and the physical form of the Arduino Uno circuit with MCP23S17 along with four LCDs can be seen in Fig. 10.



Fig. 9. Fourth Test Results.

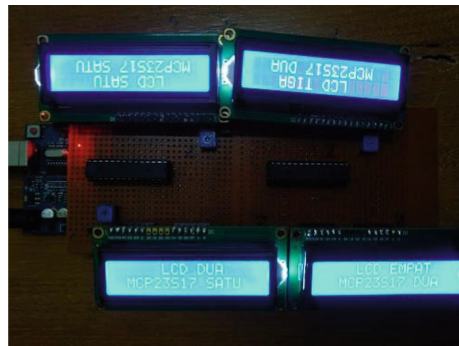


Fig. 10. Physical Form of Research Circuit.

Table 3. Address of each LCD

No.	Address	IC	LCD
1	0b01000000	MCP23S17 one	LCD 1
2	0b01000000	MCP23S17 one	LCD 2
3	0b01000010	MCP23S17 two	LCD 3
4	0b01000010	MCP23S17 two	LCD 4

5 Conclusion

From the research that has been done, the pin expansion on the Arduino Uno with SPI communication has been successfully carried out. Arduino Uno has managed to have expansion pins capable of controlling LCDs. The additional 32 pins on the Arduino Uno have worked well, as evidenced by 2 MPC23S17 ICs that can control the display of 4

16x2 LCDs. The first MCP23S17 IC is used to control LCD 1 and LCD 2, and the second MCP23S17 is used to control LCD 3 and LCD 4. Access on LCD 1 and LCD 2 using address 0b01000000. LCD 3 and LCD 4 can be accessed with address 0b01000010 as Table 3. This research is expected to be a support for further research.

Authors' Contributions. Baskoro developed the hardware under supervision of Suprianto and Anifah. Nurdiansyah and Miftahur Rochman collected and analyzed data.

References

1. F. Ferreira, L. Matos, M. Menendez and E. Mandado., MILES: A microcontroller learning system combining hardware and software tools, in Proceedings - Frontiers in Education Conference, 2015.
2. N. Chamim, Penggunaan Microcontroller Sebagai Pendeteksi Posisi Dengan Menggunakan Sinyal Gsm, *Jurnal Informatika*, 2010.
3. N. Zlatanov, Arduino and Open Source Computer Hardware and Software, *Journal of Water, Sanitation and Hygiene for Development*, vol. 10, no. 11, 2016, p. 1–8.
4. P. Handoko, Sistem Kendali Perangkat Elektronika Monolitik Berbasis Arduino Uno R3, 2017.
5. R. Endra, A. Cucus, N. Affandi and M. Syahputra, Fakultas ilmu komputer, *Jurnal Sistem Informasi Dan Telematika*, 2013, pp. 1-14.
6. B. Farid, A. Widodo, F. Rifki and N. A. P, Designing PQRST Signal Generator as One of The Learning Media, in 3rd International Conference on Education Innovation, 2019.
7. B. Farid, E. Sulistiyo, I. Basuki, A. Widodo and N. A. P, Design of Function Generator Using Arduino DUE 12 bit DAC, in International Conference on Science and Technology, 2019.
8. S. A. R and H. Rommy, Performance of C-BUS Communication in CMX7032 IC with SPI Communication in ATxmega128A1 IC, in IEEE International Conference on Aerospace Electronics and Remote Sensing Technology, 2019.
9. L. Li-Li, H. Jing-yu, Z. Yong-peng and Y. Jian-hong, Design of Microcontroller Standard SPI Interface, *Applied Mechanics and Materials*, vol. 618, 2014, pp. 563-568.
10. P. Visconti, G. Giannotta, R. Brama, P. Primiceri, A. Malvasi and A. Centuori, Features, operation principle and limits of spi and I2C communication protocols for smart objects: A novel spi-based hybrid protocol especially suitable for IoT applications, *International Journal on Smart Sensing and Inteligent Systems*, vol. 10, no. 2, 2017, pp. 262-295.
11. J. Bitty and J. S. I, Design of BIST(Built-In-Self-Test)embedded master-slave communication using SPI protocol, in 3rd International Conference on Signal Processing and Communication, Coimbatore, 2021.
12. D. N. H, Designing SPI to I2C Protocol Converter Base on ASIC Technology and Implementing on the FPGA Platform, *JST: Smart Systems and Devices*, vol. 3, no. 2, 2021, pp. 19-26.
13. Q. Jiayi, G. Yong and C. Guochu, FPGA Implementation of SPI Bus Communication Based on State Machine Method, in *Journal of Physics: Conference Series*, Shanghai, 2020.
14. B. Farid, R. Miftahur and P. N. Aristyawan, Serial Peripheral Interface (SPI) Communication Application as Output PIN Expansion in Arduino Uno, *Indonesian Journal of Electrical and Electronics Engineering*, vol. 3, no. 2, 2020, pp. 34-40.
15. N. Anand, G. Joseph, S. Oommen and R. Dhanabal, Design and implementation of a high speed Serial Peripheral Interface, in *International Conference on Advances in Electrical Engineering*, Vellore, India, 2014.

16. S. Yunpeng, K. Nikhil, A. Raja and L. Qin, A High Performance Communication Architecture for a Smart Micro-Grid Testbed Using Customized Edge Intelligent Devices (EIDs) With SPI and Modbus TCP/IP Communication Protocols, *IEEE Open Journal of Power Electronics*, vol. 2, 2021, pp. 2-17.
17. K. Moh, *Metodologi Penelitian*, Malang: UIN Maliki Press, 2008.
18. L. Frederic, *An introduction to I2C and SPI Protocols*, *IEEE Instrumentation & Measurement Magazine*, Belgium, 2009.
19. A. Pnueli, In transition from global to modular temporal reasoning about programs, in: K.R. Apt (Ed.), *Logics and Models of Concurrent Systems*, Springer, Berlin, Heidelberg, 1984, pp. 123-144. https://doi.org/10.1007/978-3-642-82453-1_5
20. B. Meyer, Applying Design by Contract, *Computer* 25(10), 1992, 40-51. DOI: <https://doi.org/10.1109/2.161279>
21. S. Bensalem, M. Bogza, A. Legay, T.H. Nguyen, J. Sifakis, R. Yan, Incremental component-based construction and verification using invariants, in: *Proceedings of the Conference on Formal Methods in Computer Aided Design (FMCAD)*, IEEE Press, Piscataway, NJ, 2010, pp. 257-256.
22. H. Barringer, C.S. Pasareanu, D. Giannakopoulou, Proof rules for automated compositional verification through learning, in *Proc. of the 2nd International Workshop on Specification and Verification of Component Based Systems*, 2003.
23. M.G. Bobaru, C.S. Pasareanu, D. Giannakopoulou, Automated assume-guarantee reasoning by abstraction refinement, in: A. Gupta, S. Malik (Eds.), *Proceedings of the Computer Aided Verification*, Springer, Berlin, Heidelberg, 2008, pp. 135–148. https://doi.org/10.1007/978-3-540-70545-1_14

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