Using PC and Microcontroller to Implement Lab kits for Educational Purpose

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Abstract. Undergraduate education usually characterized by a large number of students compared with graduate education. In laboratories, we mostly suffer from a limited number of lab boards compared to the students' number. Also, we need to help the students to improve their skills in electrical engineering; therefore it is important to implement lab boards using a personal computer (PC) and a microcontroller to help encourage the students, making them interested enough in building their own private practical projects. In this work implementation of a lab board using a microcontroller and reusable electronic equipment have been done, also a pulse generation and random data sequence for digital circuit and control application are done by using PC serial port (RS232) with Matlab software (m-file). Two kinds of stepper motors (polar and bipolar) driver circuits have been presented in this work using discrete components. The pulses to the stepper motors are applied by Arduino board (Atmega 2560). The software which is used is Atmel studio-7 and the program has been written in assembly language. Trying to produce an efficient lab board using assembly method of electronics parts is necessary nowadays to reduce the importation for similar tools that are used for educational purposes in Iraqi universities.

Keywords: Matlab (m-file), serial port (RS232), Atmel studio-7, assembly language, stepper motor driver circuit.

1. Introduction
Matlab is a very powerful tool and it is widely used in the electrical engineering curriculum. It's important to activate Matlab external interface with serial port in the electrical engineering laboratories. Most widely interface circuit for connecting computers to peripheral devices is the standard RS-232. RS-232 devices are very useful, particularly in industrial machines or scientific equipment [1][2][3][4]. In order to communicate with the peripheral devices, PC port has been used from many research papers to I/O signal; MATLAB with C++ compiler and related MATLAB toolboxes used to realize a control procedure [3]. An example of square wave generator programming on the Arduino hardware platform in Assembly language is presented [5], while parallel port with C language has been used [6]. Also, the Arduino board has been used and programmed using C/C++ language [7]. In this work, an experience of programming in high-level language Matlab m-file is presented to generate a pulse wave on the serial port. Matlab commands on the serial port have been used to enable and/or disable any output digital device like Arduino board. Arduino is programmed in assembly language, which makes a good covering for theoretical topics in instruction set architectures. Also, show that Arduino platform can be used to study microcontrollers on assembler. The aim of this
paper is to implement low-cost lab boards to help the students to improve their skills in electrical engineering.

2. Microcontroller
A microcontroller is used in many control system application, ranging from home appliances and ending aircraft. A microcontroller contains on a single semiconductor chip in most cases all digital electronic devices, from the logic elements (gates) to a processor. Each family group of microcontrollers has its own Assembly language. Arduino Mega 2560 as shown in figure 1 is high performance, low Power AVR 8-bit microcontroller. It has used advanced 135 powerful instructions; most of them are single clock cycle execution. Also, it’s consist of 32 x 8 general purpose registers (GPR), 54 I/O digital pin, and it's DC Current per I/O Pin is 40.0mA [5][8]. Maximum voltage applied to any I/O pin is 5.5V.

![Arduino Mega2560 pinout.](image)

3. IC MAX232
When a connection is required (rather than USB) between Arduino and PC COM port (RS232), an interface circuit called MAX232 must be used. MAX232 is a hardware voltage level converter integrated circuit (IC). It converts signals from an RS-232 serial port correspond to '-10VDC and 10VDC' to the appropriate signals for use in TTL (Transistor-Transistor Logic) matched with digital logic circuits correspond to '5VDC and 0VDC' respectively. This integrated circuit provides the interface that is required to communicate microcontroller (for example Arduino board) with RS232 based devices using a serial communication link [9][10][11][12].

4. Stepper motor
Stepper motors are available with either four coil unipolar or two coil bipolar windings. Figure 2 (a) shows bipolar stepper motor drive circuit that requires a push-pull bipolar. In bipolar winding - the stator flux can be reversed by reversing the current in the winding. Unipolar Winding - has two coils wound on the same bobbin per stator half. The use of a unipolar winding makes the drive circuit to be simplified as shown in figure 2 (b). The flux can be reversed by energizing one coil or the other coil from a single power supply [13]

![Stepper motor circuits](image)

(a) Bipolar Winding stepper motor, (b) unipolar Winding stepper motor
5. Developed Experiment

5.1. Pulse wave generator

A generation of clock signal and serial data are required in many lab experiments in the field of digital communication, digital control, and digital electronic circuits. A simple method, using specific data rate, can be used to produce random data and clock signals on the PC serial port with ATLAB. The format of serial data on COM port consist of one start bit, between five and eight data bits, and one or two stop bits. A parity bit (optional) may be included in the format for error detection figure 3.

![Figure 3. PC Serial port data format.](image)

By representing the number in eight-bit data using Matlab function and select the decimal number (85)Decimal = (01010101) Binary, then choose one stop bit and no parity we can obtain a data format like a clock pulse. In order to obtain a periodic square signal waveform, a conditional loop must be used, so that DSR (input signal to PC) is used as shown in the flowchart in figure 4, to continue output the same data (01010101) on the Tx pin of the serial port. The Matlab code was mentioned in appendix A.

![Figure 4. Illustrate the process of pulse generation using Matlab.](image)

Figure 5 illustrates the schematic diagram for the flow chart shown in figure 4. Tx and DTR signals are used for random data generation and peripherals controller respectively, while DSR, i/p signal to PC, was used to sense the output response from the peripheral devices. The application of MAX232 IC is used to regulate the signal from the PC to any logical circuit like microcontroller during the interfacing process.
Figure 5. Circuit diagram used to generate a square pulse on Tx pin.

Figure 6 shows the generated clock pulse on the serial port (Tx pin). The frequency of the obtained periodic clock pulse is limited by Matlab's standard baud rates. In this case, 110, 300, 600, 1200 and 2400 bits per second have been displayed on the oscilloscope and they can be used for low clock frequency application in the laboratories.

(a)                                                                 (b)

Figure 6. (a) An example of sending a data from serial port Tx pin output. (b) The upper trace is the square wave pulse, the lower trace represent the control signal DTR.

5.2. Stepper motor driver circuits

The operation of a step motor is dependent upon the pulse source and driver. Arduino board digital output pins are used to feed pulses to the driver which applies power to the appropriate motor windings. Two techniques have been used in this paper, bipolar transistors to drive bipolar stepper motor as shown in figure 7. The circuit is for one coil of the stepper motor and we must duplicate it for the second coil. A and B terminals (Figure 7) are connected to Arduino digital O/P pins. A MOSFETs are used to drive unipolar stepper motor as shown in figure 8, where PB0-PB3 connected to Arduino digital O/P pins while C1'-C1 and C2-C2' are connected to the stepper motor coils. Therefore two kinds of electronic theoretical subjects are covered in this method that helps the students for understanding electronic circuit applications.
Transistors BC559 and 2N4124 shown in figure 7, have a peak collector current of 200mA, so they are suitable to drive the stepper motor (2T2542) which has a standard current of 125mA/phase. From figure 8, IRF-3205 MOSFET has a maximum drain current $I_D$ of 110A, so it can be used to drive a high current stepper motors or any heavy loads. The equipment that was used in the proposed lab kit shown in figure 9 and they are listed in table 1 with their approximate prices. From table 1, the total price of the proposed lab kit is about 71.25 USD. To make the lab kit more flexible, Arduino mega 2560 which has 54 I/O digital pins is used to simplify the connection with the peripheral devices. Arduino board was programmed in assembly language by the assembler Atmel Studio 7 which make a better understanding of Arduino architecture. Matlab was used to enable and disable the Arduino board. Furthermore, the program that has been written to control stepper motor rotation and stepper motor speed listed in the appendix.

**Figure 7.** Bipolar stepper motor driver circuit for single coil using bipolar transistor.  
**Figure 8.** Unipolar stepper motor driver circuit using MOSFETs. 

**Figure 9.** The proposed lab kit using Arduino mega 2560.
Table 1. Equipment list.

| Board equipment                                      | Price (USD) |
|------------------------------------------------------|-------------|
| 1- Arduino Mega 2560                                  | 16          |
| 2- Key pad                                            | 5           |
| 3- 4 Digit 7-segment display                          | 2           |
| 4- Power adapter (+5V/+12V)                           | 5           |
| 5- Breadboard                                         | 1.25        |
| 6- MAX-232 IC                                        | 2           |
| 7- Two Stepper motors                                | 20          |
| 8- Power Transistors (12 pieces).                     | 16          |
| 9- PCB                                                | 2           |
| 10- Consumables.                                      | 2           |

**Total amount**  
71.25

6. Conclusion  
The proposed lab kit in this paper is cheap and easily realized. Its cost of 71.25 USD encourages related engineering departments in Iraqi universities which have large numbers of students especially when it is required to provide a lab kit for a group of no more than two students. A complete hardware and software solution can be obtained by using Arduino board to design an extensible lab kit. The combinational of using high and low-level programming languages like Matlab and assembly languages respectively in one lab experiment is very helpful to students for better understanding of related theoretical topics.

Appendix A

PC serial port COM (9 pin mail)

| Pin | Signal          | Signal Name           | DTE Signal direction |
|-----|-----------------|-----------------------|----------------------|
| 1   | DCD             | Data Carrier Detect   | In                   |
| 2   | RXD             | Receive Data          | In                   |
| 3   | TXD             | Transmit Data         | Out                  |
| 4   | DTR             | Data Terminal Ready   | Out                  |
| 5   | GND             | Ground                | -                    |
| 6   | DSR             | Data Set Ready        | In                   |
| 7   | RTS             | Request to Send       | Out                  |
| 8   | CTS             | Clear to Send         | In                   |
| 9   | RI              | Ring Indicator        | In                   |

PC Serial Port Pin and Signal Assignments

Appendix B

B.1  
The Matlab code below is to obtain a periodic square signal waveform from serial port.  
a=85;  
% a=(85)\text{Decimal equivalent to (01010101)}\text{Binary}
s=serial('com1','baudrate',110); % Baud-rate=110 bit/sec
fopen(s);
while strcmp(s.pinstatus.DataSetReady,'off'); % Test DSR pin status
s.DataTerminalReady = 'off';
fwrite(s,a,'uint8');
s.DataTerminalReady = 'on';
end
fclose(s);

B.2
Arduino program was written in assembly language to control the driving circuit of a stepper motor.

| .ORG 0x0000 | LDI R19,0x02 |
| RJMP START | OUT PORTB,R19 |
| START: | RCALL WAIT_5 |
| LDI R16,0xff | LDI R19,0x08 |
| OUT DDRB.R16 | OUT PORTB,R19 |
| LDI R16,0 | RCALL WAIT_5 |
| OUT DDRC.R16 | RJMP NEXT |
| NEXT: | WAIT_5: |
| IN R17,PORTC | LDI R18,0x01 |
| SBIC PINC.0 ; PORT C bit 0 test; skip if '0' | OUTER_LOOP: |
| RJMP NEXT | LDI R24,LOW(0x44) |
| LOOP: | LDI R25,HIGH(0x4F) |
| LDI R19,0x01 | DELAY_LOOP: |
| OUT PORTB,R19 | ADIW R24.4 |
| RCALL WAIT_5 | BRNE DELAY_LOOP |
| LDI R19,0x04 | DEC R18 |
| OUT PORTB,R19 | BRNE OUTER_LOOP |
| RCALL WAIT_5 | RET |

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