User Interface for Real Time Microcontroller System: Case Study of ESP32

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Abstract-An user interface for the modern microcontroller ESP32 has been developed in the present work. User interface includes low cost and commonly available keypad and character type Liquid Crystal Display (LCD) as input and output devices respectively. Interfacing of keypad is done by the scanning technique, where distinct row pattern is sent to the rows and columns are continuously scanned for detection of pressed key. Interfacing of 20X4 alphanumeric LCD is done in a four bit mode. The present work is helpful to the students as well as beginners in the field of electronics and computer science.

Keyword- *User interface, ESP32, keypad, LCD.*

I. INTRODUCTION

It is generally known that microcontroller (µC) is a System on Chip (SoC) [1]. It means that silicon chip of microcontroller fabricates complete system which includes most of the parts required for the small computing work. The main parts are Central Processing Unit (CPU), input/output (I/O) ports, all sort of memories, data convertors, communication devices, etc. It is true that it includes many parts but I/O devices are not integrated in SoC. They are not fabricated because they have non-electronic parts such as liquid, spring, membrane, etc. The users of microcontroller are suppose to connect these devices externally to the I/O pins of µC. The I/O devices like keypad, display, pointing devices provide interface between µC and user and hence the circuit containing them is called the User Interface (UI).

Since the invention of µC, UI is an essential part of any µC trainer kit or µC based embedded system. For instance, Intel 8051 based trainer kit, PIC or AVR based embedded system [2,3] use keypad and display as shown in figure 1. User interface has two parts input and output and with the help of them user gives commands to the µC, as well as monitors the result of execution of program. The commonly used input device is a Single Pole Single Throw (SPST) switch or the combination of SPST switches arranged in matrix, commonly known as keypad. A light emitting diode and its combination i.e. seven segment display are the commonly used output devices. Nowadays, LCD and a membrane type keypad are normally used I/O devices for µC based applications.

Semiconductor chip design and manufacturing is always one of the demanding area in research as well as electronic industry. The main outcome of semiconductor industry is an integrated circuit(IC) and µC IC is one of the largest manufacturing IC by majority of such industries.

Table .1: Types of switches used in keypad.

Type of SPST switch	Working principle	Advantages	Disadvantages	Example
Capacitive	When touched, the stored charge discharges through human body	Long life	Slow response	Touch
Spring tension	ON/OFF action achieved due to the operation of spring	Fast response	Short life	Dom
Membrane	Membrane operation gives ON/OFF action	Low cost	Moderate response	Tactile

Fig.1: Microprocessor trainer kit with keypad and seven segment display

µC IC is a very large scale integration (VLSI) type IC which fabricates more than one million transistors on a small wafer of silicon of typical size 5x5mm area [4]. Nowadays, µc are simulated using VHDL software [5]. The manufacturers improves the performance of µC which is also SoC, by including more number of transistors required for enhancing the features like data bus width from 8bit to 32bit, for improving the resolution of data convertor from 8bit to 10bit and so on. The first µC 8051 launched by Intel [6] in year 1981 and after that many other industries started manufacturing the clone and variant of this µC. During 1990s period, the development was in the improvement of speed, data bus size and memory space. In the next few years, more attention was given to the fabrication of analog data convertors in the µC chip which is also called a mixed signal [7] or digital signal processor (DSP). In recent years, there is development in the area of integration communication devices in the µC. Some communication devices and protocols are included in the new µC. For example, a Shanghai based chip manufacturing industry has recently developed the ESP32 [8,9] µC that includes communication devices such as Bluetooth and wifi.

In the present work, we have developed the user interface for ESP32 using keypad and LCD. This article is divided into following sections: methodology of user interface is discussed in next section, after that the experimental work is discussed, and finally the conclusions and future scope are given at the end.

II. METHODOLOGY

User interface has following different levels: low and high level. High level is also called graphical user interface (GUI) [10, 11] which is written in high level language. Such GUI are complicated and use techniques like multitasking and multithreading. The common examples of GUI are integrated development environment (IDE), GUI of word processor. The basic requirement for GUI development is a high level programming language that supports the graphics commands and the corresponding hardware should have graphics processor or graphics card.

The low level user interface (UI) is on the other hand, simple and can be prepared in either high or low level language. Such UI are designed for the real time stand alone system. The parts required for making of UI are given below.

A. Keypad

It is basically a group of SPST switches arranged in two dimensional matrix form. The SPST is 'press to ON and release to OFF' type switch. Switches that are preferred in making of keypad are given in table 1.

If one or very few SPST switches are required then they can be connected separately to the general purpose input output (GPIO) pins as shown in figure 2. Generally, user needs more number of keys for entering multidigit numbers and words constructed from A-Z characters. For example, a keyboard of PC has 101 keys and a numeric keypad of typical calculator has 16 keys. It is better to connect each key to a separate GPIO pin, but then it increases the pin-count of µC, for instance, if 101 keys are separately connected then the pin count of µC will be more than 101, which is practically not feasible. To overcome this problem the switches are arranged in some rows and column. In the present work, 4X4 matrix keypad is used as shown in figure 3.

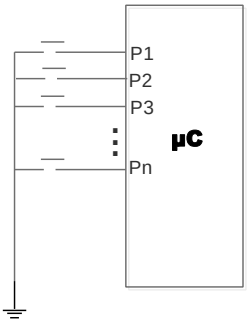

Fig.2: One to one interfacing of switches.

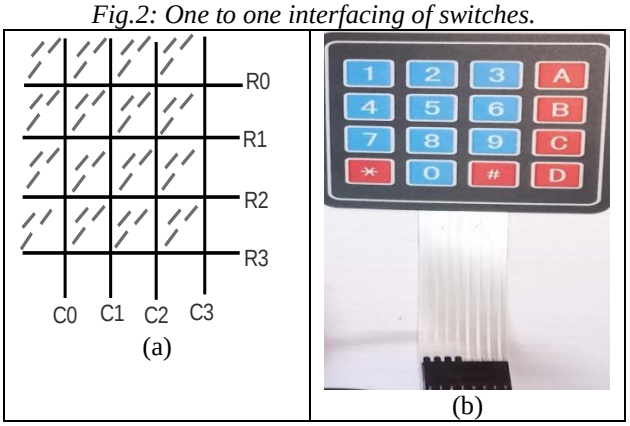

Fig.3:(3a): combination of SPST push button switches in 4X4 matrix. (3b): front panel of 4X4 keypad

B. Read-out device

It is a device on which user can read the real time data and output of executed program. Among all read out devices LED and LCD devices are more common because of their simplicity and availability. LEDs and LED based seven segment displays were extensively used till the end of 20th century. However, nowadays LCDs are preferred

because they keep less programming burden on CPU and due to low power consumption. There are two basic types of LCD namely, graphic and character LCD. Table 2 gives comparison between graphic and character LCD [12].

Both type of LCDs can be interfaced to µC but character LCD is preferred for most of the applications like metering and control. Figure 4 shows the 20X4 LCD which is used in the present work.

Table.2: Comparison between graphic and character LCD.

Parameter	Graphic	Character
Resolution	High	Low
Colour	Multicolour	Monocolour
Size	Large	Small
Back light	CFL or LED	LED
Use	Picture	Text
Cost	High	Low

Character LCDs are available in three background colours i.e. yellow, green and blue, with the characters are printed in black for yellow and green background, and in white for blue background. LCD works on the principle of polarisation [13] which is controlled by the controller HD44780 [14] mounted on the back side as chip on board (COB). The main parts of HD44780 are data memory for storing the data, character memory for storing the lookup table of ASCII character with its LCD segment code, and control logic. The functions of HD44780 are: to write command, to write data and store it in data memory, to convert code into character by use of lookup table. The commands used for selecting row, column, character size, clearing display, etc. LCD can be used in three modes: 8 bit, 4 bit and I2C. We have used 4 bit mode because it requires less number of GPIO pins.

III. EXPERIMENTAL WORK

Figure 5 shows the interfacing diagram of LCD and keypad with µC ESP32. Eight GPIO pins of µC are connected to the keypad and six pins are connected to the LCD. Keypad works on the principle of scanning in which the rows scan pattern is sent to the rows and the columns scan code are read for the detection of pressed key. Table 3 shows the scan code and the corresponding pressed key. The binary code shown in table 3 is unweighted code i.e. there is no definite relationship between value of pressed key and corresponding binary code. µC determines the value of pressed key either by executing one of the following logical method.

A. If-switch statement

In this method the scan code is compared with value of key by using if-switch statement. It has disadvantages that the code size increases with number of keys. [15].

B. Lookup table

The method for recognising the pressed key is known as lookup table method, where the scan code is used as a index of array or address of memory and the value of key is stored as element in array or data stored in a memory. Table 4 shows the lookup table for recognising the key.

Interfacing and programming of LCD is relatively easier than keypad because the HD44780 controller takes care of refreshing the displayed character. Figure 5 shows the complete circuit diagram of interfacing of keypad and LCD with ESP32 µC.

Table.3: Scan code of matrix keypad

Output Row pattern				Input Column scan code				Scan code (hex)	Key
R3	R2	R1	R0	C3	C2	C1	C0		
0	0	0	1	0	0	0	1	11	1
0	0	0	1	0	0	1	0	12	2
0	0	0	1	0	1	0	0	14	3
0	0	0	1	1	0	0	0	18	A
0	0	1	0	0	0	0	1	21	4
0	0	1	0	0	0	1	0	22	5
0	0	1	0	0	1	0	0	24	6
0	0	1	0	1	0	0	0	28	B
0	1	0	0	0	0	0	1	41	7
0	1	0	0	0	0	1	0	42	8
0	1	0	0	0	1	0	0	44	9
0	1	0	0	1	0	0	0	48	C
1	0	0	0	0	0	0	1	81	*
1	0	0	0	0	0	1	0	82	0
1	0	0	0	0	1	0	0	84	#
1	0	0	0	1	0	0	0	88	D

C. If-switch statement

In this method the scan code is compared with value of key by using if-switch statement. It has disadvantages that the code size increases with number of keys. [15].

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Table.4: lookup table for 4X4 keypad.

Index of array scan code (hex)	**Value of array element (ASCII code)**
11	31
12	32
14	33
18	41
21	34
22	35
24	36
28	42
41	37
42	38
44	39
48	43
81	2A
82	30
84	23
88	44

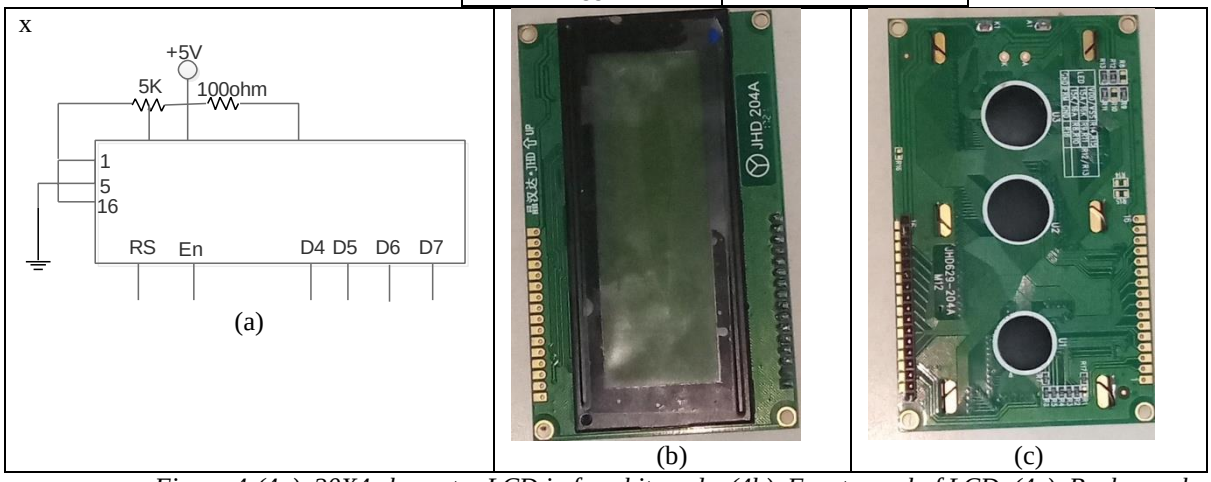

Figure.4:(4a). 20X4 character LCD in four bit mode. (4b). Front panel of LCD. (4c). Back panel of LCD

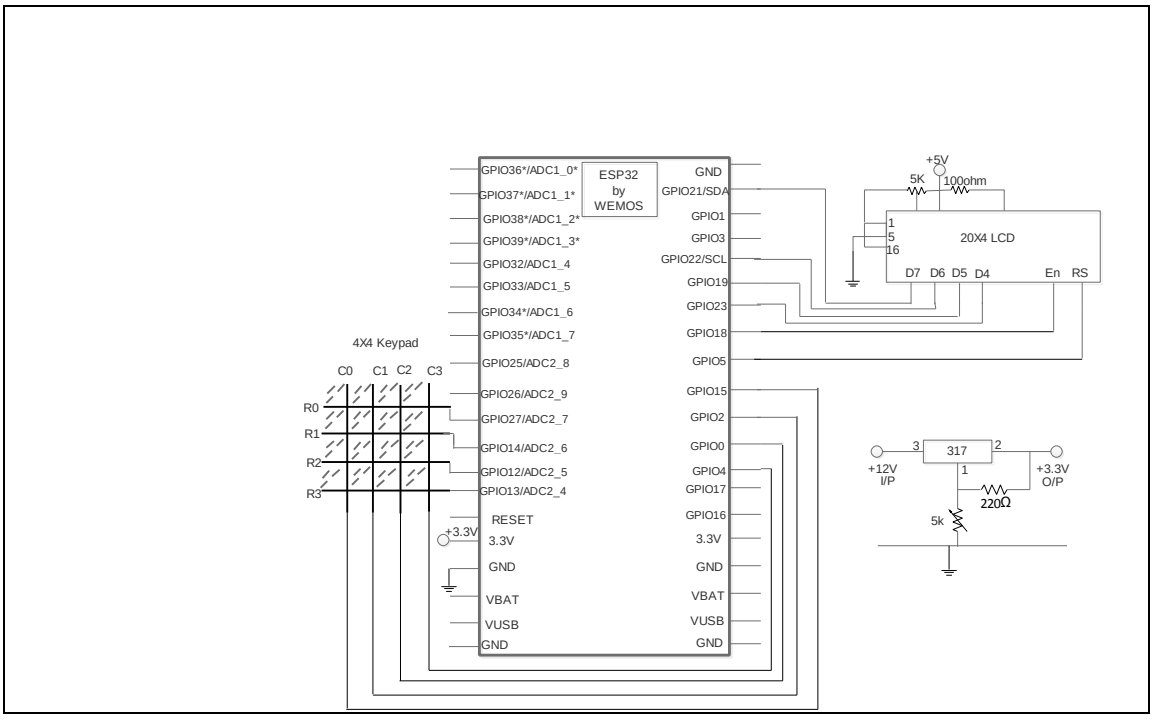

Fig.5a: Circuit diagram of keypad and LCD Interfacing with ESP32 µC.

IV. SOFTWARE SECTION

Software is basically a computer program written in some programming language such as C or Assembly. In the present work we have used Arduino programming language which is similar to C language [16]. The program is written for recognising the pressed key and displaying its value with the help of look up table on character LCD. The flowchart is given in figure 6. The list of program is given in figure 7. The flowchart shows the steps for writing the program. The program begins with inclusion of header files LiquidCrystal.h and Keypad.h. These two header files contain some functions related to keypad and LCD. The pins used for connecting LCD are assigned to some integer variables, similarly the lookup table is declared as well as the pins for rows and columns are assigned some variable names in the first few statements. The character is displayed on the LCD with the help of following three functions: lcd.begin, lcd.print, lcd.setCursor. Scanning of keypad is a repetitive procedure and it is done in a loop section. The pressed key is read by keypad.getKey function and then with the help of lookup table it is displayed on LCD using lcd.print function.

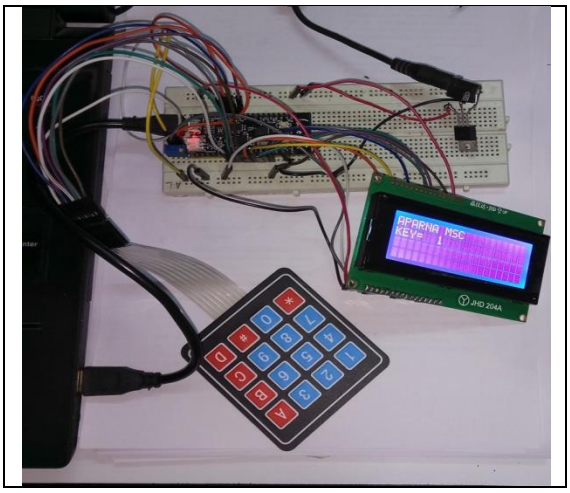

Fig. 5b: Assembly of devices on bread board

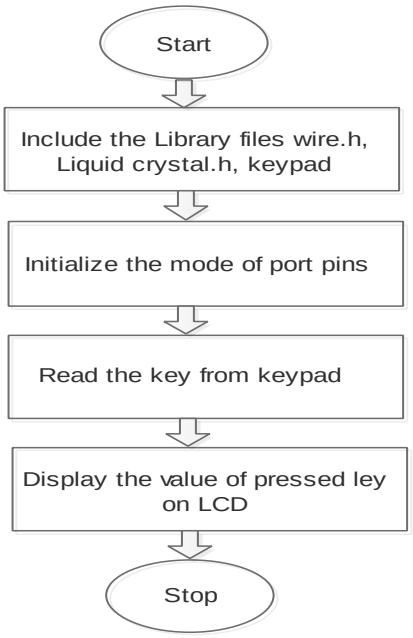

Fig. 6: Flowchart for keypad and LCD interfacing

```
#include <LiquidCrystal.h>
#include <Keypad.h>
constintrs = 5, en = 18, d4 = 23, d5 = 19, d6 = 22, d7 = 21;
LiquidCrystallcd(rs, en, d4, d5, d6, d7);const byte ROWS = 4; //four rows
const byte COLS = 4; //three columns
char keys[ROWS][COLS] = {
{'1','2','3','A'},{'4','5','6','B'},{'7','8','9','C'},{'*','0','#','D;
byte rowPins[ROWS] = {15,2,0,4};
byte colPins[COLS] = {27,14,12,13};
Keypad keypad = Keypad( makeKeymap(keys), rowPins, colPins, ROWS, COLS );
unsigned long loopCount;
unsigned long startTime;
String msg;
void setup() {
lcd.begin(20, 4);
lcd.print("APARNA MSC");
lcd.setCursor(0, 1);
lcd.print("KEY= ");}
void loop() {
    char key  = keypad.getKey();
lcd.setCursor(6, 1);
 if(key)
   {lcd.print(key);}}
```

Fig.7: Program for keypad and LCD interfacing.

V. CONCLUSION

Interfacing of LCD and keypad to the µC is not new and done by several hobbyist for their project work. We have also studied and implemented it successfully for ESP32 µC. The keypad is interfaced using scanning technique and the pressed key is recognised by lookup table method. LCD is used in a 4bit mode which requires less number of GPIO pins. Program is written in open source Arduino IDE in which we have included the library of ESP32. The work is helpful for beginners and students in the field of electronics and computer science.

VI. FUTURE SCOPE

The work can be extended for interfacing of I2C LCD and Analog keypad that will require less number of GPIO pins. It can be further used in some application like automation and control. Our future plan is to use it as UI in the experiment of sun photometer.

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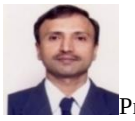
Authors Biography -



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