Design and Implementation of Micro-Controller Training Kit with GUI Support

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***Abstract*—Microcontrollers are paramount in various aspects of engineering. It has a wide range of applications in modern day urbanization and smart cities, thus making it a needful part of education. Microcontroller training kits with pre performed hardware connections, while less cumbersome than having to use an external board for connections, limit the user's knowledge of hardware interfacing. The practical sessions focus more on programming. While picking a training kit for learning, we face a tradeoff between convenience and awareness. This paper proposes a solution to tackle this problem with a new approach for the teaching of microcontroller courses. A microcontroller training kit that supports multiple microcontrollers, with GUI support is proposed. The GUI acts as a guide for the user to assist in hardware connection and programming. The proposed kit provides sockets to connect each component. The design is aimed at beginners to microcontroller programming while simultaneously catering to experts and industries.**

***Keywords*—microcontroller, training kit, LPC2148, PIC18**

I. Introduction

Automation and Control is a field whose significance has risen rapidly in the past decade and it has not shown any sign of slowing down. While once involved only in industries and manufacturing processes, automation has pervaded our daily lives. From baby monitors and door locks to smart lighting in homes and voice control in cars, there are a multitude of applications for control that make our lives a lot simpler. The importance of learning about microcontrollers stem from the fact that they are a stepping stone for beginners to the field. Microcontrollers can be used to develop a huge number of solutions and products.

A. Motivation

The market is saturated with various kinds of microcontroller training kits, starting from the beginner level to very advanced levels. Almost all these kits are limited in their ability to provide a complete understanding. On one hand, there are training kits that are simple and basic, necessitating the use of breadboards or other alternatives. These are not user friendly and is a hassle for proper use. On the other hand, there are very advanced kits in which most of the hardware connections are inbuilt and the user only needs to mind the software side. This deprives the user from the understanding of the hardware side and also about the basic working and functioning of the microcontroller.

In one case, kits come with only a few pre done connections. Examples include TI's MSP430 Launchpad [1], Arduino Uno Board [2], Atmel's AT89S52/AT89C51 Quick Start Board [3], STM32 Nucleo Boards [4], Silicon Labs' EFM32 Giant Gecko Starter Kit [5] etc. Though these deliver a solid understanding of hardware interfacing, the rest of the connections required to implement the circuit needs to be carried out externally either in some breadboards or some other alternatives. The user is burdened with educating themselves of hardware interfacing through other resources, which is very much inconvenient for beginners. In the other case, they have all the circuits inbuilt and the user needs to carry out only the programming side. Even though they provide a lot of features, they give very little information about hardware interfacing. The EnGeniusLab AVR AT89S51/52 Development Board [6] is one example. They are only meant to hone the programming skills of the user and are used mainly for industrial and laboratory applications, hence beginner and amateur level users cannot make proper use of these training kits. So there are very less or no training kits that help the user to understand both the hardware and programming side of a microcontroller. What is required, is a training kit that is able to provide the user with knowledge about both the aspects.

There are many examples of training kits developed for laboratory education. These approaches produce effective learning solutions but have limitations. The work of Yao Li [7] follows a modular approach but most connections are pre done. In other cases [8], [9], there is no separate baseboard for circuit connection and the design supports only one microcontroller.

The present work proposes a solution to the discussed problem in the form of the design of a microcontroller training kit that supports learning both hardware and software sides. Hence, the design is primarily aimed at beginners to microcontroller programming. Nevertheless, it can be made suitable for industrial applications by modifications.

Rest of the paper is organised as follows. Section II of the paper presents the general design of the training kit. Section III deals with the design process of the prototype. Section IV will delve into the testing of the kit and sample tutorials. Conclusion is Section V.

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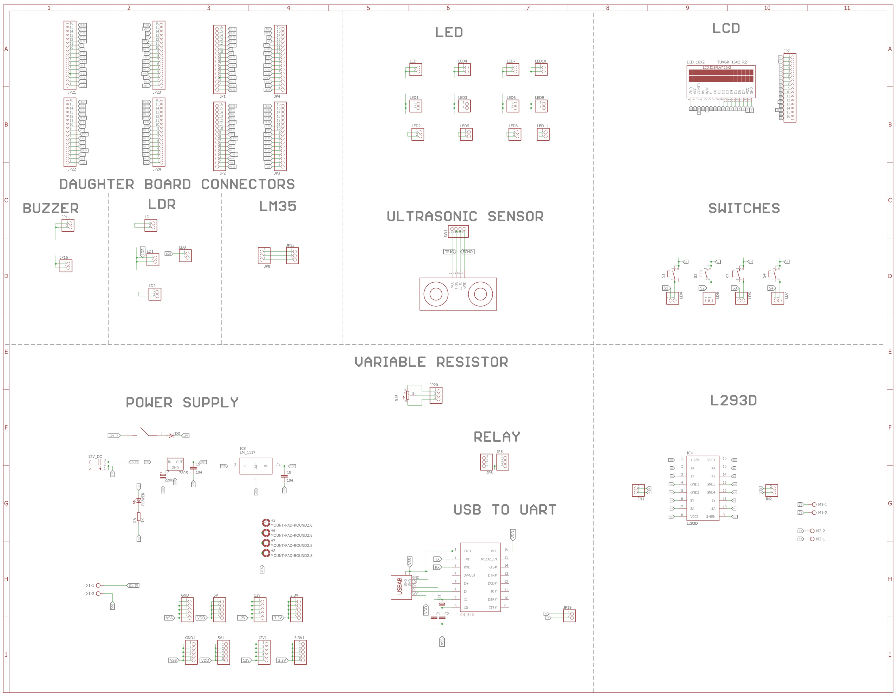

Fig. 1: Base Board Schematic

II. General Design

The overall design of the Kit involves a board that holds the microcontroller, a larger board to connect circuits on and a guide to help the user, which are called the daughter board, baseboard and the Graphical User Interface (GUI). The daughter board carries the microcontroller and the baseboard is where circuits are implemented. The baseboard is designed in such a manner that different daughter boards with compatible pinout can be attached to it. This modular approach is followed in order to enable the use of multiple microcontrollers with the same training kit, by using different daughter boards for different microcontrollers. The GUI is an application or webpage that helps the user to perform all tasks required during the learning period.

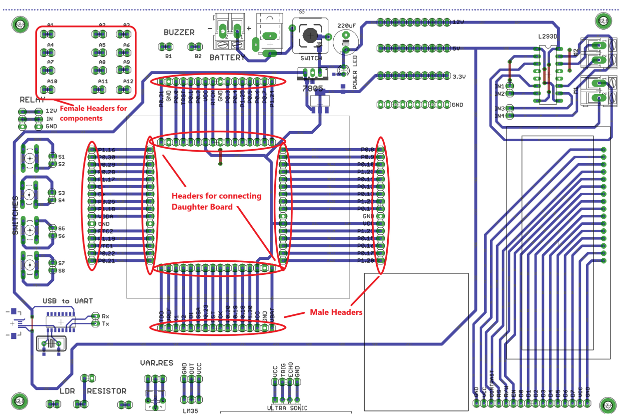

Fig. 2: Base board PCB Layout

A. Base Board

The standard procedure of learning microcontrollers is to assemble some basic circuits that utilise some feature of the microcontroller and then test it after coding. This process becomes bothersome when the circuit assembly has to be done on a breadboard. In the proposed system, base board is where all the circuits are assembled. Connection points are provided on the board for easy connections. Different daughter boards can be connected to the same board, if they have the same pinout.

B. Daughter Board

The daughter board contains only the circuits necessary for micro controller's basic functionalities, such as the crystal oscillator, reset circuitry, programming IC etc. This design enables the daughter boards to function as independent units without the help of any other external devices. All the I/O pins of the microcontroller are to be mapped to headers on the daughter board. Daughter boards for different microcontrollers are to be designed bearing in mind that the tutorials for the microcontroller will be implemented on the same baseboard that may later be utilised in a similar manner by other microcontrollers. Designing daughter boards with same header pinout will ensure that it will not be necessary to change the baseboard if the user wishes to learn about other microcontrollers.

C. Graphical User Interface

One of the features of this microcontroller training kit is the availability of a Graphical User Interface (GUI) as a part of its user experience. The GUI is a webpage which explains

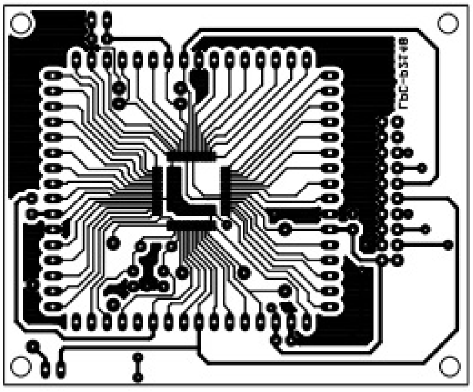

Fig. 3: LPC2148 PCB layout

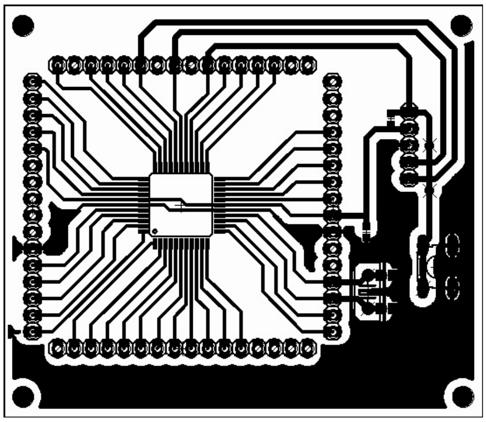

Fig. 4: PIC PCB layout

the features of the microcontroller, the connections to be performed and other usage instructions to the user. The purpose of the GUI is to walk the user through various topics like features of micro controller, required hardware connections, basics of downloading the program into the microcontroller etc.

A key feature of the GUI is that it provides some basic example programs. These programs deal with some of the fundamental features of the microcontrollers. This will help to get into the programming side of the microcontroller. The user can gradually learn complex programs, once they know the basic programming technique. Everything from how to program the microcontroller to the various registers of microcontroller is included in the GUI.

Step by step instructions for making hardware connections related to each program is provided in the GUI. The nomenclature used to name the connectors in the base board is used to give instructions regarding connecting the components between the connection points. This makes the task much easier for the user.

The example programs provided in the kit are based on some of the lab experiments performed in various academic institutions [10]. This is to make sure that the examples included are of basic nature and follows a proper training methodology.

III. Prototype Design

A prototype of the training kit was developed and a webpage was designed as the GUI. Two daughter boards were fabricated after selection of two microcontrollers best suited for beginners. The daughter boards and baseboards were designed using Eagle software [11]. The two daughter boards and the base board required double side PCB. The routing of all the PCB's were done manually.

A. Base Board

This board was designed keeping in mind the support for many microcontrollers, besides the ones used currently. Therefore, after manufacturing a daughter board for any other microcontrollers, the base board may be used with the same if the connector pinout of the daughter board is kept same as the one used here. Since the primary objective of the current design is to provide a hardware focused experience, only the most important and necessary connections are performed beforehand on the baseboard.

The base board contains connection points for different components and each of these is uniquely named. This naming is done so that it is easier for the user to identify the connections while doing examples provided in the GUI. Circuit connection for all the examples in the GUI will be explained on the basis of the nomenclature. This is a different approach of developing microcontroller training kits. Connections including VCC and ground are to be done by the user, which is a noticeable deviation from other microcontroller boards. The user can perform connections on the baseboard only using through-hole components. The base board schematic and PCB layout are shown in Fig. 1 and Fig. 2 respectively.

The GUI is an integral part of the user friendliness of the design. It acts in cohesion with the baseboard design to make the learning process easier for the user. All baseboard connectors are labelled and the GUI explains connections and working based on this nomenclature. A small breadboard is also provided on the base board. Some other circuits whose connections are facilitated by the baseboard include the motor control circuit, USB to UART interface etc.

1) Power Supply: Options for using 12V, 5V and 3.3V on base board as well as daughter board is given in this design. The power input to the board is a 12V DC source. IC LM7805 [12] and LM 1117 [13] are used to generate 5V and 3.3V with a current capacity of 1.5A and 1.2A respectively. Protection diode, bypass capacitors and LED indicators are also provided. The detailed circuit used in the design is shown in Fig. 1. Sufficient number of header pins are provided on the baseboard to supply 12V, 5V, 3.3V and GND.

2) Motor Driver: The motor driver IC enables control of components that require high driving current, which the microcontroller otherwise won't be able to provide. The motor driver setup is designed using L293D [14] IC, which is a quadruple half-H driver. Solid vias are used to connect the ground pins to the ground plane of the PCB so that it acts as a heat sink.

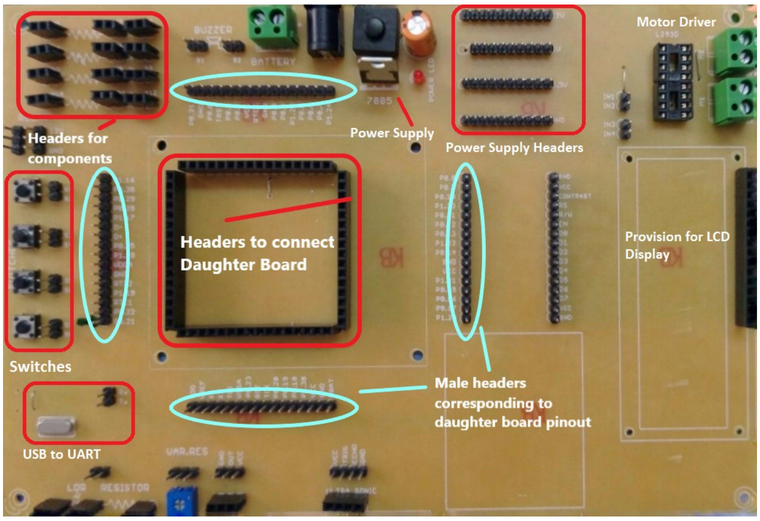

Fig. 5: Baseboard

3) USB to UART: A USB to Universal Asynchronous Receiver-Transmitter (UART) interface enables interfacing between the computer and the microcontroller. This is done using the IC CH340G [15]. which is a 16 pin USB to serial converter chip. TxD and RxD pins are given out as headers, to be connected to the microcontroller. A 12MHz crystal and load capacitors are also connected.

4) Relay, Switch and Connection points: The baseboard has connections for relay interface given out as headers. Connection points to connect resistors, LED's, Ultrasonic sensor etc. are also provided. Four push button switches are connected with floating ends. Provision for connecting a 4.5cmx3.3cm breadboard is also provided on the baseboard.

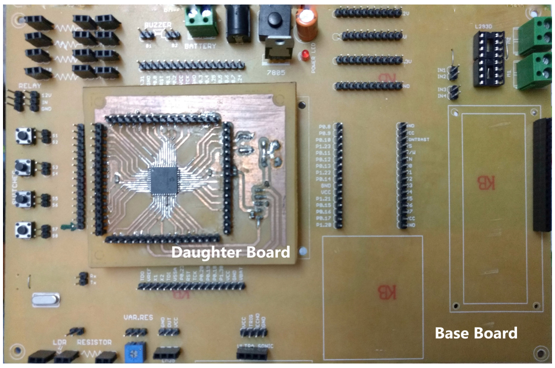

Fig. 6: Daughter board on Baseboard

B. LPC2148 Daughter Board

ARM architecture is the most prominent 32-bit architecture. ARM7 has got just enough features that make it suitable for beginner level learners. It is not difficult to get into and has got a vast range of applications. Learning LPC 2148 makes the user adept at developing more complex systems or moving on to more advanced microcontrollers. Hence, it was decided to test the design using the daughter board designed with LPC2148 [16] micro controller. A 64-pin LQFP package of LPC2148 is used in the design.

The following connections are implemented on the LPC2148 daughter board. A 12 MHz Crystal Oscillator circuit provides the clock signal for the microcontroller. LPC 2148 uses JTAG interface to provide access to its programming and debug functions, and the programmer used is the ULINK debug adapter. Keil uVision is the IDE used for LPC2148. The board is provided with necessary decoupling capacitors and a Power on Reset circuit, using IC MPC 130T. Rest of the pins are routed to the headers of the daughter board. The daughter board has 64 headers and the microcontroller requires a VCC of 3.3V. The layout of LPC2148 daughter board is shown in Fig. 3.

C. PIC Daughter Board

The other microcontroller that was chosen was PIC18F4550 [17]. A 44-pin TQFP package of the IC is used to design the daughter board which will be used on the same base board that was used along with LPC2148 daughter board. PIC18F4550 is a 44 pin microcontroller and requires VCC of 5V, while LPC2148 is 64 pin and requires VCC of 3.3V. There are a total of 64 header pins to connect the daughter board on the baseboard. The PIC daughter board is therefore designed with 64 headers, as shown in Fig. 4. The 44 pins of PIC is routed to the 64 daughter board pins excepting the pins that have been connected to 3.3 V VCC. The 5V connection is available on the base board and is connected to PIC daughter board from headers on base board.

The connections on the daughter board include a 11.0592MHz oscillator circuit, a reset switch and connections to headers for programming. The microcontroller supports in-circuit serial programming (ICSP). Programming pins along with VDD and VSS are given out as headers. On the daughter board, capacitors are connected between VDD and VSS. These act as bypass capacitors and eliminate high frequency noise.

MikroC is the IDE used to write program for PIC micro-

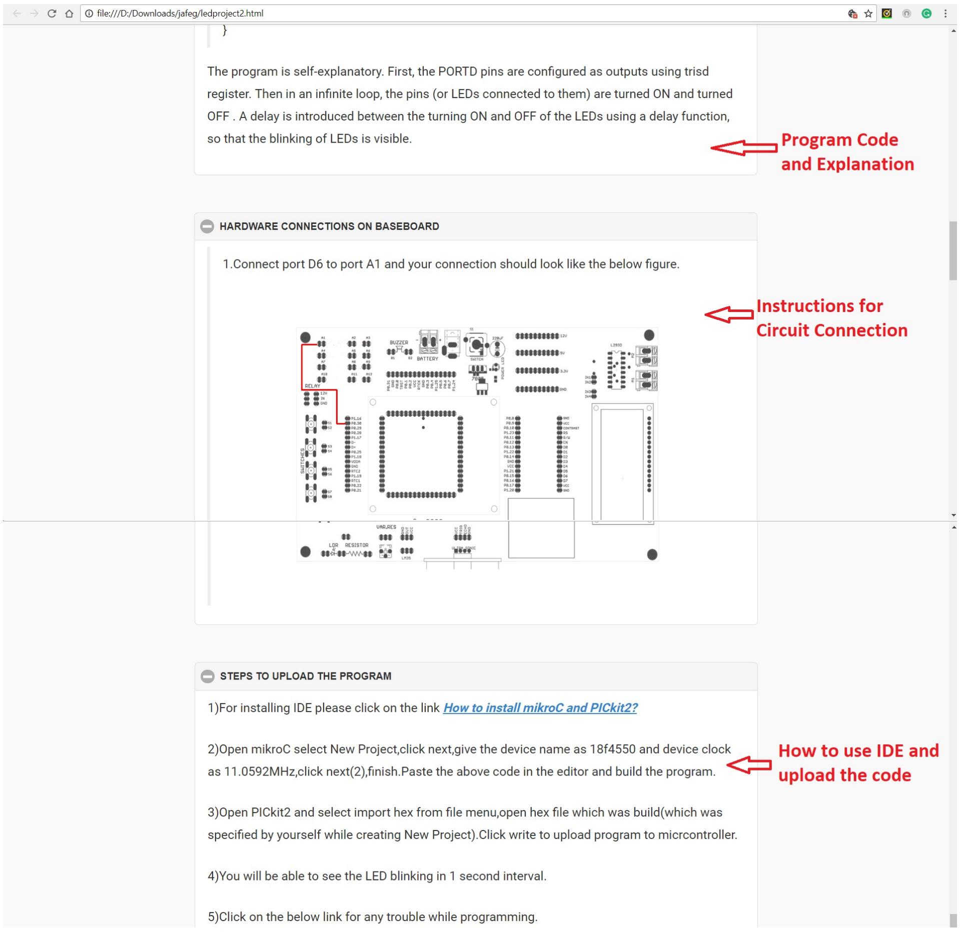

Fig. 7: Screenshot of tutorials page

controller. PICkit2 is the software used to upload the program to the microcontroller. It imports the Hex file generated using MikroC and then writes it into the microcontroller. The programmer used to program the microcontroller is called PICkit2 programmer/debugger. The PICkit2 programmer requires PICkit2 programmer application to upload the program.

D. GUI

A webpage was chosen to interact with users as it is easy to operate, and it can be accessed with any device with a proper internet connection and a browser. A major advantage of a webpage is its expandability. In the future, the webpage could be modified to act as a hub to access various IDEs depending on the microcontroller or to detect connections performed by using sensors on the baseboard. It is committed to provide users with basic knowledge of microcontrollers and detailed information about working and programming in the selected microcontroller (PIC or LPC2148). Webpage is developed using HTML and CSS [18]. The webpage develops the user through the tutorials selected for the kit. Some of the programs taught in academic institutions such as LED interfacing tutorial, LCD module tutorial, Interrupt handling, PWM tutorial, ADC tutorial with the help of sensors etc. were selected as tutorials [19], [20]. Using different microcontrollers require modifications to the GUI. The GUI was designed for LPC2148 and PIC18. For illustration purposes, only the PIC18 guide is shown.

IV. Integration and Testing

The development of the prototype was a long process, where several aspects of the microcontrollers involved had to be learned or taken into account. As such, several difficulties were faced and most hurdles were overcome.

Some of the essential concepts involved in microcontroller programming were handpicked to craft the tutorial programs involved. A graphical user interface was necessary to explain the working of microcontroller kit. The objective was to develop an interface which can be accessed easily and from different places. An application developed on a particular operating system (e.g.: Windows 10) has limited scope of working on a different operating system, a webpage could easily tackle this problem if there is net connectivity and a web browser. A webpage will give user information about the kit and guide user through various experiments. Web pages were coded in Hypertext Markup Language.

The daughter board for LPC2148 was developed first. The board was tested and errors were rectified. The baseboard was then developed so as to support many microcontroller daughter boards. The baseboard was designed with minimal preperformed connections. Initial plan was to include power supply for the daughter board on that board itself, but later it was decided to include the power supply on the base board which would be easier to support multiple daughter boards on a single base board. Ports for several components and power supply is provided on the baseboard, as shown in Fig. 5. Since most microcontrollers may use 3.3V or 5V supply, both are connected to pin headers. The baseboard components were all checked and verified to function properly.

To demonstrate the use of multiple daughter boards with the same base board, daughter board for PIC18 was also developed. Compatibility of baseboard and daughter boards were ensured before fabrication. The proper working of the daughter board was verified, by connecting daughter board to baseboard as in Fig. 6. Each of the tutorial programs were tested on the daughter board after programming. The testing was successfully performed and outputs were verified. The working of the webpage is shown in Fig. 7. The objective of the tutorial, the program code and its explanation, process of circuit connection and instructions to upload program code to the microcontroller is available in the GUI. The kit, as a whole, is able to efficiently teach the user about microcontrollers.

V. Conclusion

The training kit designed in this paper is targeted at beginner level learners. There are other products for the same audience available in the market. Kits like MSP430 Launchpad by TI are popular choices. While the microcontroller is excellent for beginners, the user will need breadboards or other alternatives to connect circuits. Connection of any external component like LCD displays, buzzers and sensors are inconvenient because of this. While certain boards like Arduino Uno and STM32 Nucleo provide some headers on the board, they only enable assembly of simple circuits. The proposed design provides slots for many components, switches and a breadboard for good measure. Besides, the same baseboard can support multiple daughter boards, making this an efficient learning method. Therefore, this design creates a versatile and convenient tool for microcontroller education.

The design of a microcontroller training kit that can support many microcontrollers is successfully developed and a prototype fabricated and tested. Daughter boards for multiple microcontrollers are developed and combined with the baseboard. Programming and testing of the microcontrollers and their daughter boards were successfully done on the baseboard. A GUI is designed to guide the user through using the training kit. The GUI is user friendly and has explanations regarding usage, from overview of the microcontrollers, software required to circuit connection. Further development of the design to include several microcontrollers can be done. The tutorials included in the GUI cater only to beginners in microcontroller programming. These may be expanded to involve complex programs and tutorials that are suitable for more experienced programmers. Another possible development of the training kit is the addition of sensors to the base board to verify whether the connections performed by the user match the instructions from the GUI. The GUI is always open for further improvements. An application could be developed in its place such that the GUI can be linked to the IDE to enable seamless switching between programs and a configuration to allow one-click programming of the microcontroller could be developed.

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