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High School and University Collaborative Engineering Technology Project

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Abstract

A current trend in education is to opt for science, technology, engineering, and mathematics (STEM) initiatives to help close the looming gap in technical talent in the U.S. labor force. Another trend in education is to build bridges between college and K–12 programs to bring more students into technical studies. This paper will focus on a PIC microcontroller project that was funded in a STEM program and was subsequently used by a high school electronics program. The PIC microcontroller project was originally developed in the summer undergraduate program in 2007. The project design and implementation was facilitated by a grant called MAGEC-STEM (Minority Access to Graduate Education and Careers) funded by NSF. This grant supported high caliber students with a GPA of 3.5 and above. Students sponsored by this grant worked summer semesters on a project that was mutually agreeable to the students and the professor. Cooperation between a university and high school led to the completed college project that provided the students in the Pre-Engineering Electronics program at the high school to use the college project as an engineering challenge. The project introduced the high school students to STEM concepts using hands-on activities.
Keywords: STEM, Microcontrollers, NSF

Introduction

Science, technology, engineering, and math (STEM) is a term that was introduced by the National Science Foundation (NSF) as an initiative in academia. The exponential growth in technology has left educational institutions with the enormous challenge of developing a workforce with sophisticated technological skills and, in particular, increasing the number of individuals graduating with degrees in STEM. Given the need, universities and colleges must meet the growing challenge of identifying and enrolling students in STEM areas. As the international participation in STEM disciplines increase and the national population becomes more diverse, it becomes essential to provide quality STEM education to all high school and college students, including women and those from racially diverse groups [1, 2, 3].

STEM, in a sense, is a goal or parameter to ensure an increase in the number of future engineers and scientists, eventually building a technically competent workforce for the future. We have been teaching science, technology, engineering, and math to so some degree all along. A current trend in economy demands a workforce with more knowledge in technology and an emphasis on science and math to a greater degree. Technology and engineering is also being taught as part of the curriculum in varying degrees in many states in the United States [4].

STEM also refers to a more integrated approach to teaching science, technology, engineering, and math. Traditionally, these areas have been taught as separate disciplines. Problems illustrating a concept in a math course may provide an example from the discipline of engineering or science to illustrate how the concept is used in the real world. The concept of STEM has emphasized integrating the subjects by project based teaching and presenting problems to students where they must develop skills in design and development to succeed [5].

The STEM concept has also emphasized the education system in the United States as a whole. Where and when do students decide to pursue a career that is STEM based, and why or why not? How do we enable students to build upon previous knowledge and give them opportunities to integrate the knowledge they have obtained? STEM also emphasizes integrating knowledge between and across institutions [6].

STEM has led to efforts and initiatives to increase cooperation between colleges and high schools. For instance, a college can act as a host and give training to high school teachers on STEM based projects, which they can in turn apply in their classrooms. Colleges can set up Web sites that act as clearinghouses of projects for high school students [7]. Direct collaboration between college and high school teachers is difficult but rewarding. The parking garage project designed and implemented by college students was successfully translated to an engineering project by high school students.

The parking garage was STEM in spirit at both the college and high school level. From the perspective of college teaching, concepts behind engineering design are traditionally reserved for a senior design project course. These concepts support the development of technology and increase competition in the world market, which provides our students with superior knowledge, skills, and more realistic design experience [8]. Furthermore, these concepts have served to usher in an education reform movement that involves a critical examination of the engineering and science curricula [9–12]. However, our observations show that the introduction of the design concepts at the sophomore level prepares the students to design/develop innovative projects when they reach their senior level in a typical electronics engineering technology curriculum[10]. The goal of this project is to extend our work on the development of an application based paradigm, which is capable of quantifying the engineering and high school students' conceptual and problem solving knowledge [13].

The project the students developed at the college level was basic and simple in nature so that they could develop robust concepts for advanced courses. There were numerous problems translating the project from the college level to the high school level [14]. The levels of knowledge and maturity gained by the students were obvious. Differences in lab equipment also played a major role in how the problem was defined and implemented by the high school students. In spite of the vast differences between the two teaching situations, it was definitely a motivating force to the high school students because they were to be able to implement the model previously built by the college students. The primary purpose of this project was to improve the knowledge and understanding of STEM through hands-on activity. At the high school level, the project was further based on the philosophical assumption that science, technology, engineering, and mathematics are related subjects that should be taught through hands-on experiences. Students at the high school level were also introduced to Ohm's law and a voltage divider activity so that they could relate the concepts learned to their project. A brief description of this activity that illustrates the relationship between mathematics and science through hands-on engineering activity is given below:

Ohm's Law and Voltage Divider Activity
Objectives:

- The learners are provided with instructions on how to calculate the resistance that is necessary for constructing a simple series and parallel circuit.
- Series/parallel circuit is constructed on the Multisim software, and the voltage and current is measured to verify the circuit calculations. The circuit is also constructed on the breadboard with real components.

Mathematical Standards:

- Use the algebraic methods in problem solving.
- Use data collection in problem solving.

Scientific Standards:

- Understanding the process of scientific design.
- Knowing that energy appears in different forms.
- Using a model to predict change.

This paper will first describe the design and implementation process at the college level. The MAGEC-STEM project was introductory for the college level. The implementation of the project at the high school level is then described briefly.

MAGEC-STEM Project

At Savannah State University, introducing the students to design and implementation of the project was facilitated by a grant called MAGEC-STEM funded by the National Science Foundation (NSF). This grant supported high caliber students with a GPA of 3.5 and above. Students sponsored by this grant worked for 10 hours each week during spring and summer semesters on a project that was mutually agreeable to the students and the professor. Students were required to submit the completed project and project report, as well as to present the project during a seminar at the university. The grant provided stipends to the students and funds for the equipment and parts.

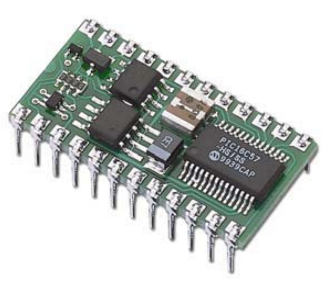
Under the MAGEC-STEM grant, two students from the Electronics Engineering Technology program were selected to design/develop the microcontroller based parking garage project.

At the high school level, this project was translated to a scope so that the students could perform at their 10th grade level of education, having completed a course in algebra.

Physical Overview of MAGEC-STEM

Over the past few years, we have seen numerous changes in the microprocessor and microcontroller market. Motorola stopped the development of its popular 8-bit 68HC11 microcontroller for approximately 10 years. With these advancements in technology, modern system design requires the use of advanced microcontroller chips and tools. Several new companies have emerged in the microcontroller market to meet the complex design requirements. To fulfill the demands of the new technology, universities and colleges have shifted from teaching the traditional 68HC11 microcontroller to teaching the PIC microcontroller. A PIC microcontroller is a single chip computer that is commonly found in everyday products such as microwave ovens, cell phones, alarm clocks, etc. If the device consists of push buttons and displays, chances are it also contains a programmable microcontroller [15]. The PIC is a popular, inexpensive single chip microcontroller for a low powered, complex embedded system [16].

A design project by enlarge is focused on developing a product that is robust, reliable, and economical. Keeping this in mind, our project team decided to incorporate Parallax Inc.'s BASIC Stamp2 module (shown in figure 1.0) in the parking car garage project. This compact BASIC Stamp2 module plugs into Parallax Inc.'s board of education carrier board, shown in figure 2.0.



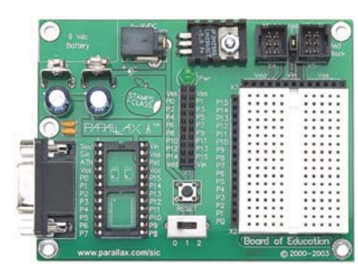


Figure 1.0: BASIC Stamp2 Module Figure 2.0: Board of Education

The major physical feature of the parking garage is a wooden board, which was hollowed out to make room for the mechanical controls, sensors, and electronics. Figure 3.0 shows the physical layout of the components. The physical layout is composed of the following:

- Toy cars
- Two security gates
- Servo motors
- Sensors (push-buttons)

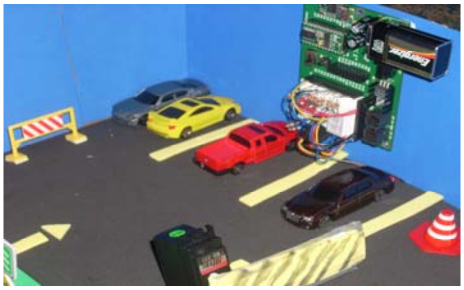


Figure 3.0: Physical Layout of the Parking Car Garage

The parking garage is controlled by a pre-programmed, embedded microcontroller that controls the entrance and exit security gates of the parking garage. The entrance and exit security gates are connected to the servomotors, which are controlled by the PIC16C57 microcontroller. These microcontroller servos are programmed to receive high and low signals that allow for the movement of the servomotors.

The parking garage employs sensors at the entrance and exit of the parking lot. The low/high signals are sent to the servos, which actually perform the movement. The servo has a horn, which is located on the side that confirms and executes the rotation that is needed for the security gate to move up and down.

The arms of the security gate ensure that only one vehicle enters and exits at a time. The security gate is activated via sensors. In this project, sensors were placed at the entrance and exit security gates to keep track of the number of cars that enter and exit the garage. The sensors are interfaced to the microcontroller and are programmed with the software. The sensor decrements the counter as a vehicle enters and increments the counter as the vehicle exits. A seven-segment digital display is used to display the number of empty spots. It is located at the entrance of the parking garage to notify the customers of the available spots before entering the garage. The information for the seven-segment digital display is sent from the pressure sensors via the board of education microcontroller.

Based on the aforementioned physical and architectural structure, a customer vehicle approaching the garage can see the seven-segment display, which shows the status of the parking garage. Typically, the seven-segment display reads “## Empty Spaces,” where ## is the number of empty spaces. When the vehicle enters the garage, it passes over a pressure sensor. The pressure sensor sends a signal to the security gate arm to open the gate so that the vehicle can enter the garage. The security gate arm goes up, a small delay allows the vehicle to pass through the gate, and then the gate arm goes down. Once the vehicle enters the garage and the security gate arm goes down, the seven-segment display decrements showing the current empty spaces in the parking garage. This process repeats each time a vehicle enters and exits the parking garage. If the garage reaches its parking capacity, the entrance gate will not go up and the parking garage “full” LED sign is activated. The hardware and software design to control the parking garage is discussed in the next section.

Hardware and Software Design Of MAGEC-STEM

Typically, development tools needed for the microcontroller can be divided into two different groups: software and hardware. Software tools include assemblers, compilers, program editors, debuggers, simulators, communication programs, and systems integration environments to implement solutions. In the parking garage project, the BASIC Stamp2 microcontroller is interfaced to the BASIC Stamp2 Editor software, which is used to write programs that the BASIC Stamp2 module will run. The software is also used to display messages sent by the BASIC Stamp2. The BASIC Stamp2 Editor is free software, and the two easiest ways to get it are:

- Download from the Internet. Search for “BASIC Stamp2 Windows Editor Version 2.0” on www.parallax.com, the Parallax Web site.
- Included on the Parallax CD.

Hardware and software control architectures were designed to control the parking garage. Assigned by the faculty, the project team was composed of two electronics engineering technology students. During the early execution stage, the students handled the mechanical design portion of the project. The electronic concepts, which included interfacing and programming of the microcontroller, were faculty led and the students were trained to program the parking garage in BASIC Stamp2 programming language. Students also kept a record of their progress in their individual notebooks, including design ideas and sketches, along with issues faced and their solutions. The hardware section of the parking garage uses the PIC16C57 microcontroller. The microcontroller is programmed in BASIC Stamp2 programming language to control the parking garage system.

Several hardware development tools are available for the PIC microcontrollers. Parallax provides the following hardware development tools to support the hardware development of the PIC based products:

- BASIC Stamp2 module
- Board of Education
- 9V battery
- Serial cable
- Strip of 4 adhesive rubber feet

Figure 4.0 shows the Board of Education, BASIC Stamp2 module, battery, and serial cable.

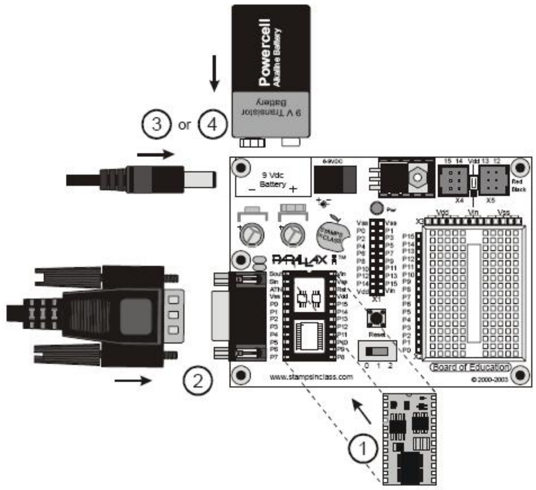


Figure 4.0: Board of Education Basic Stamp2 System

The role of control electronics was to create a clean interface between the parking garage and the BASIC Stamp2 programming language to control the security gate and seven-segment display of the parking garage. The block diagram of the hardware and software interface is shown in Figure 5.0.

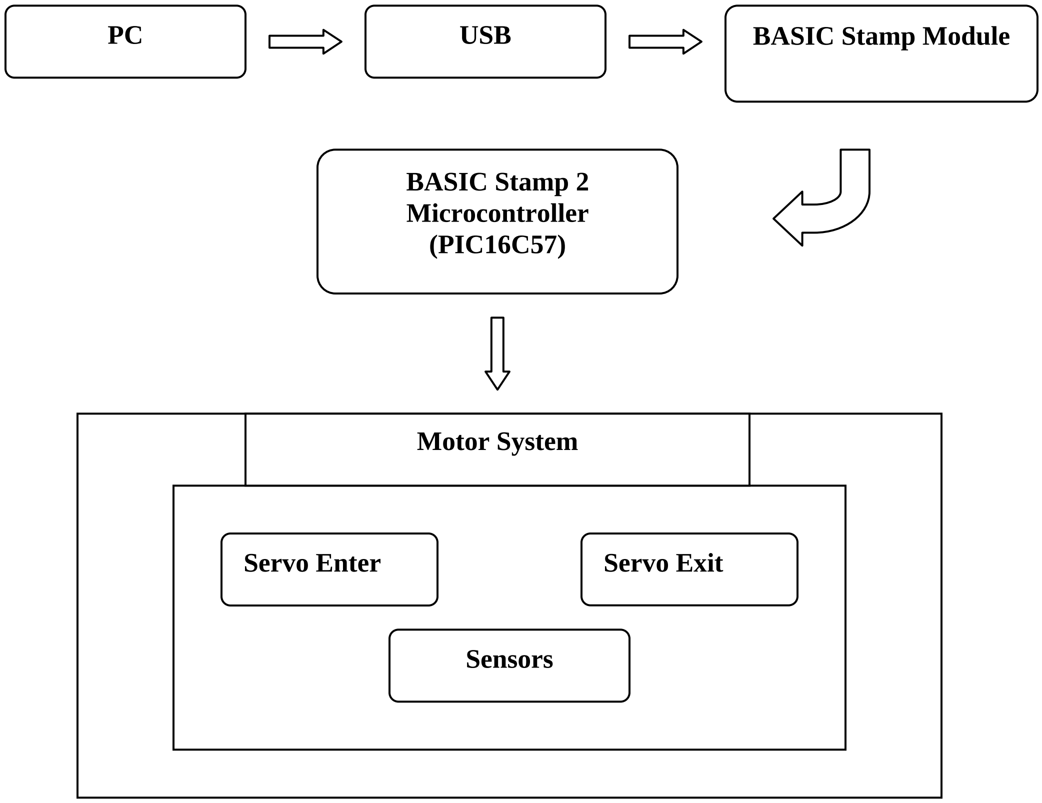


Figure 5.0. System Block Diagram

The hardware-interfacing diagram to connect various components is shown in Figure 6.0.

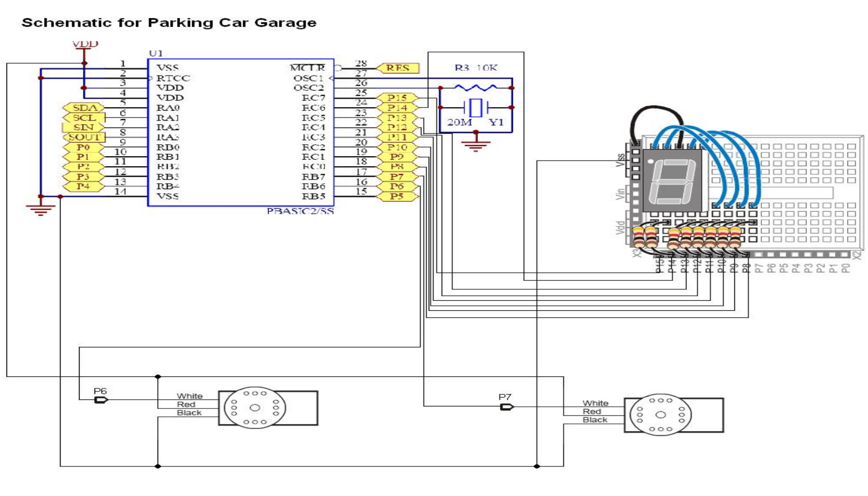


Figure 6.0: Hardware-interfacing Diagram

The parking garage circuit is built by plugging the components into small holes called sockets on the prototyping area. This prototyping area has black sockets along the top left. The black sockets along the top have these labels above them: Vdd, Vin, and Vss. These are called power terminals, and they are used to supply power to the parking garage circuits. The black sockets on the left have labels like P0, P1, up through P15. These sockets are connected to the BASIC Stamp2 module's input and output pins. The software developed is downloaded to the board of education via a serial or USB cable. The integration of the hardware and the software produces an integrated embedded system, which controls the parking garage.

The parking garage offered an opportunity for students to work with others in their program whom they had never worked with. The parking garage focused on important learning concepts such as physical layout, electronics, programming, teamwork, and cross-disciplinary interaction. The physical layout symbolizes the interrelationship between various substructures of the parking garage. This includes an understanding of components and the manner in which all these components function together as a deterministic whole system. Basic components, such as servos and electronics, which include microcontrollers, sensors, security gate arm, and digital display, are the major components of the parking garage. Integrating these components offered an opportunity for the students to understand the design/development of parking garage.

Parking garage carried out the concept of teamwork in all phases of design and implementation. The goal of linking the students into a learning community is to give the student a peer group where they feel comfortable. The teamwork prepares the students to solve technical problems in a group environment in addition to meeting new challenges encountered in the workplace. Students, being on successful teams, experience, understand, and appreciate the values of good teamwork. The parking garage emphasizes more than a collection of individuals; it emphasizes teamwork, which implies much more[8].

The curriculum in any specific area of study tends to narrowly focus students on that area, whereas real-world multifaceted systems tend to incorporate components from multiple disciplines. The development of such systems has shifted from designing individual components in segregation to working in cross-functional teams that include the variety of proficiencies needed to design an entire system[9]. The parking garage provides an opportunity for students to integrate the mechanics and electronics to build a real-life application.

The goal of this summer training program was to exemplify the impact of hardware and software design in embedded system products. Significant trends were measured from the parking garage project, which included mechanics, electronics, programming, teamwork, and student interaction. The results show that the students learned tangible lessons from each topic.

High School Parking Garage Project

Project based learning (PBL) was the result of interdisciplinary collaboration among university faculty, high school faculty, high school students, and university students. The goals of the PBL collaboration were the following:

- To provide role models and activities to change the attitudes of high school students concerning STEM disciplines and careers.
- To include high school faculty to improve the STEM awareness at the high school.

The program at the high school consisted of 10 high school students and a technology education high school faculty. The high school students were required to work on the parking garage and STEM focused activities.

The implementation of the parking garage project for high school mainly entailed reducing the scope of the project and translating the hardware solution from a Parallax BASIC Stamp to a PICAXE microcontroller solution. The PICAXE microcontroller was chosen at the high school level because of the low price of the controller as compared to the Parallax BASIC Stamp.

A large difference between the PICAXE 08M and the Parallax Stamp is that the 08M only have eight pins. Five of the pins are used for input and output. An advantage of using the 08M for younger students is a simulator built into the PICAXE software. The simulator helped students gain a better understanding of how BASIC works and assisted them in writing the software for the parking garage.

Due to the lower pin count for input and output, the single LED turns RED on the garage full condition, instead of showing the count of cars in the garage on seven-segment displays. Not using the seven-segment displays simplified the circuit and the software for the students.

The parking garage circuit for the high school version of the project is shown in Figure 7.0.

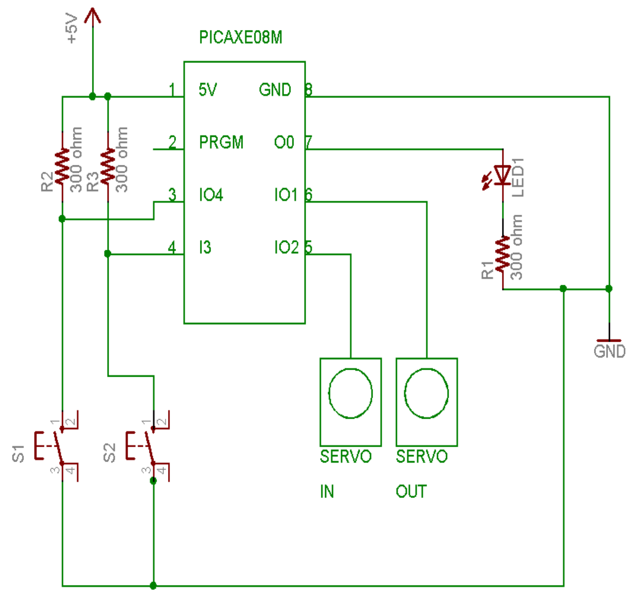


Figure 7.0: Parking Garage Circuit

Program assessment was essentially based on perceived attitude changes, such as whether or not the students developed an interest in STEM disciplines by scheduling for advanced STEM based courses in high school and applying to the university in a STEM related field. All of the high school students participating in the PBL were given a survey at the end of the project and were asked to rate their experience with the PBL. The survey was based on four of the Accreditation Board for Engineering and Technology (ABET) a–k skills. Table 1.0 shows the results of the survey, which rated project activities based on ABET student performance levels and expected outcomes. ABET a–k skills were redefined in terms of student perception of the PBL. Activities were rated on a Likert scale from 1(least-liked) to 5 (most-liked).

Table 1.0: Survey Results of PBL

How do you rate the…	On a scale of 1 to 5
Project helped you to apply current knowledge and adapt to emerging applications of mathematics, science, engineering, and technology.	2.35 (need more project activities)
Project helped to identify, analyze, and solve technical problems.	3.7 (best activity of the PBL)
Project helped to function effectively in teams.	3.2 (working in teams was cool)
Project helped to conduct, analyze, and interpret experiments and apply experimental results to improve processes.	2.26 (more activities are needed)

Assessment of PBL also included follow-up interviews with the participants. The overall impressions of the students were fairly positive. The students suggested more projects like this one should be done. The students did note that it was a difficult project and took a long time to complete. One student noted that the software was hard to understand, while another student mentioned it was not easy to come up with reliable pressure sensors (switches). The students had to learn that a cross hatched pattern of wires was more likely to make contact than a single point on a homemade pressure switch made out of cardboard and stripped wires. Other students complained about not being given a similar project to those students who built the parking garage after the students saw the working garage model.

Conclusion

This paper described the design and implementation of a parking garage. This activity has served as a reference for providing students with challenging and exciting hardware and software design experiences that involved various fields of mechanical, electrical, and physical layout design concepts. The parking garage provided an excellent opportunity for both the faculty and students to work in an application-oriented environment. It was not trivial to simplify the project so that high school students could benefit from the work of the college students, and it was a positive experience at the high school level, as well as a great motivator for the high school students. Our overall message was to take an application perspective in considering ways to improve STEM education and to create interest in STEM disciplines.

Future Directions

Future research plans include relating the reliability of implementation of the program to student
learning outcomes. In addition, teacher learning will be examined, and a method of measuring
teacher learning outcomes will be explored. The future plans of the project are to recognize, assess, classify, and distribute resources (via a Web site) for STEM educators (grades K–12) wishing to incorporate hands-on learning into their curriculum to encourage students to pursue careers in these fields. By helping students make connections between STEM subjects and real-world issues, these strategies are likely to enhance student interest in STEM disciplines, improve learning experiences for students, and enhance the skills of STEM educators on the content and application of STEM subjects. A collaborative team of university and high school students will be responsible for design/development of the Web site.

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