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Research Article

Design and implementation of a fully automated system dedicated to the control of an egg incubator

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Abstract

Nowadays, incubation systems are playing an increasingly important role in agriculture and poultry farming. With the evolution of technology, these systems must also be developed to keep up with a fast-changing world. Poultry egg incubation systems are based on the principle of providing a nest-like environment for the hen. A hen lays about 1 egg per day, and usually takes about ten days to start hatching. So, the incubation system presents a practical solution to increase the number of chicks.
In order to keep up to date, we designed and built an incubation system for poultry eggs equipped with advanced technology allowing it to ensure an adjustable humidity level and temperature degree, using a PID controller that we have implemented as well as an automatic turning egg mechanism and an automatic water filling system with other features allowing it to be completely autonomous (not requiring human intervention). The system is also equipped with 3 LCD screens allowing us to visualize the water levels in the two tanks (inside and outside), the date / time, the state of egg turning, humidity level and temperature degree. A keyboard is integrated into it, offering the possibility of easy handling while having an advanced technology. The fully automatic realized egg incubator has demonstrated a high hatching rate.

Keywords: PID, real time, multitasking system, egg Incubator, chick.

Bir yumurta kuluçka makinesinin kontrolüne adanmış tam otomatik bir sistemin tasarımı ve uygulanması

Öz

Günümüzde kuluçka sistemleri tarım ve kümes hayvancılığında giderek daha önemli bir rol oynamaktadır. Teknolojinin gelişmesiyle birlikte bu sistemlerin de hızla değişen dünyaya ayak uyduracak şekilde geliştirilmesi gerekmektedir. Kanatlı yumurta kuluçka sistemleri, tavuk için yuva benzeri bir ortam sağlama ilkesine dayanmaktadır. Bir tavuk günde yaklaşık 1 yumurta bırakır ve genellikle yumurtadan çıkmaya başlaması yaklaşık on gün sürer. Böylece kuluçka sistemi daha kısa sürede civciv sayısını artırmak için pratik bir çözüm sunar.
Güncelliği takip etmek için, kanatlı yumurtaları için, uyguladığımız bir PID kontrolör ve otomatik çevirme mekanizması kullanarak, nem seviyesi ve sıcaklık derecesi ayarlanabilen, ileri teknoloji ile donatılmış bir kuluçka sistemi tasarladık ve kurduk. tamamen otonom olmasını sağlayan (insan müdahalesi gerektirmeyen) diğer özelliklere sahip otomatik su doldurma sistemi. Sistem ayrıca iki tanktaki (iç ve dış) su seviyelerini, tarih/saati, yumurta dönüş durumunu ve nem seviyesi/sıcaklık derecesini görmemizi sağlayan 3 adet LCD ekran ile donatılmıştır. İçine entegre edilmiş bir klavye, gelişmiş bir teknolojiye sahipken kolay kullanım imkanı sunuyor.

Anahtar Kelimeler: PID, gerçek zamanlı, çoklu görev sistemi, yumurta kuluçka makinesi, civciv.

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1. Introduction

Nowadays, incubation systems occupy an increasingly important place in several and different fields (science, agriculture ... etc.), the egg incubator is a brooding system based on the principle of the creation of an environment similar to the one created by the oviparous species throughout the hatching period.

The system we are going to design may present a solution for endangered oviparous animals by increasing the number of chicks hached, which can help re-balance the ecosystem.

The avian egg incubation system presents a good alternative to replace the hen in its nest, using advanced technology in electronics and automatic, we can increase the number of eggs that hatch in 21 days without any intervention of hens.

Several parameters must be adjusted to ensure good hatching, the humidity level and the temperature degree are the two pillars on which the platform is based to ensure a high percentage of success.

Therefore, our project, aims to create an incubation system to increase the number of chicks hached, by creating an environment similar to that of a hen in its nest. It consists of the design of a fully automatic egg incubator based on multi-tasking concept with as much recyclable material as possible while applying the concepts of automatic control (PID, Bang-Bang controller...etc.), electronics (printed circuit ... etc.) and mechanics (turning eggs).

2. Incubators:

An incubator is a controlled enclosure thermostat that we find today in scientific laboratories, agricultural fields and they have even invaded the industrial world, thanks to their interior environment offering the possibility to easily set temperature and the humidity rate.

The incubator that we are going to design specializes in poultry farming, more precisely in the artificial incubation of chicken eggs, to do this, we must study the conditions under which an embryo can develop, its growth process and the different mechanisms that an incubator must be equipped with in order to ensure a good hatching rate.

2.1. The different parameters to control an incubator:

2.1.1. Temperature:

Temperature plays a central role in the hatching process of an egg, a small difference between the reference temperature and the actual one can cause embryo death.

2.1.2. Humidity:

This parameter is also essential for the development of the embryo; the control is done by either a humidifier or the steam resulting of the temperature rise using a water heater.

2.1.3. Egg positioning:

For the embryo to not stick to the shell, a mechanical system that allows the turning of the eggs is put in place. The explanation of its operating principle will be discussed in the next pages.

2.1.4. Air and ventilation:

Any incubator must have at least two holes allowing an exchange of air between the inside and the outside of the incubator; oxygen is needed for the egg to hatch.

The presence of fans in an incubator will play the role of:

-a distributor to ensure that the temperature is the same in different corners of the device;

-an extractor to facilitate the exchange of air in the incubator.

3. From egg to chick:

In this part of the paper, we will study the evolution of the embryo until it peels off its shell.

3.1 Chicken egg structure:

Before moving on to studies of embryonic development, we will start by defining the different components of a chicken egg which is layered and each layer has a specific role.

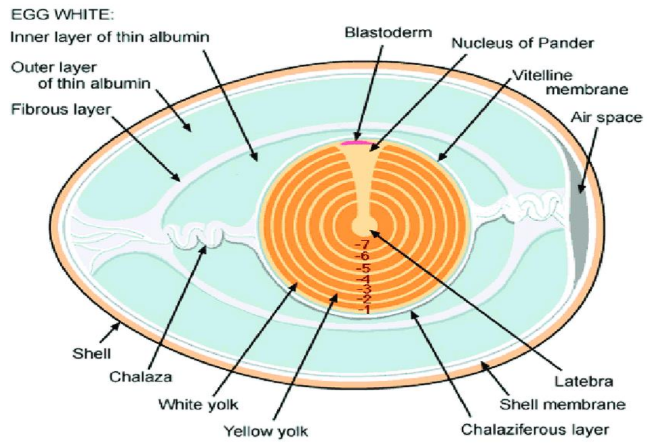

Figure 1. Egg structure [1]

3.1 Candling technique:

First, to incubate eggs, only fertilized ones can be used. A fertilized egg is when the hen has already lived with a rooster the days preceding the laying. we can only see all the transformations that take place inside the egg by using candling. Candling is to see the development of the embryo inside the egg using an LED light (high power torch) in the dark, while being careful not to have direct contact between the egg and the egg test pattern so as not to increase its temperature.

An egg consists of three levels, yolk, white and an air pocket, sometimes we mark the presence of a black point (germ) on the yolk which represents the cell that will give us the embryo, so we can differentiate it with the help of the air pocket, if it is very clear and occupies the upper part, it can be said that it is a fertilized egg. A few days later and under conditions of egg storage, this black point begins to grow and takes more and more place between the yolk and the white, this is called the development of an embryo.

Figure 2. Candling method [2]

3.2 Embryo devlopment:

An embryo turns into a chick in 21 days, and this can only be done in the presence of several parameters which we have already discussed in the previous section. During the incubation period, the operator must shoot at least twice, once on the eighth day and once on the eighteenth day, this control allows to visualize the evolution of the pocket air that is 1/10 the volume of the egg at the start of incubation and should be 1/3 at the end. During the first days of incubation, the embryo uses the holes in the shell for breathing and the nutrients of the yolk and white for food. Indeed, everything is based on the size of the air chamber, during incubation, the embryo will lose 13% of its weight in water through the pores of the shell, this loss of quantity of water will be occupied by air into the inner tube, which will serve as oxygen a few days before the chick hatches. Two cases are possible, if the air pocket is small, this means that the embryo obtained is of a large size and it will not be able to pierce an internal hole since it occupies all the space in the egg, which means that even freeing it up from the air pocket space, it would not be enough to allow it to pierce the shell. In a second case where the embryo loses a large amount of water (more than 13%) through the pores of the shell, this lost water will be replaced by air which gives a very evolved air pocket (large) and a weak embryo that won't have enough strength to pierce a hole in the shell. There is a second method which allows to see the evolution of the embryo, but it is rarely used, it consists in weighing the weight of the eggs before putting them in the incubator, and to react on the humidity rate of which we will talk later in order to have a loss of 13 percent a few days before the hatching period. Temperature, humidity, turning and aeration, are parameters that must be present and maintained in the case of natural or automatic brooding, in both cases, the process for obtaining a chick will be presented in Table 1.

Table 1. Embryon development stages

Days	**Embryo development**
1st day	Tissue development
2nd day	Formation of the heart, first beats Appear
3rd day	Formation of blood vessels
4-7th day	Separation of the head from the body
8-14th day	Development of feathers, scales on feet and paws, the embryo begins to turn to the widest end of the egg
14-18th day	The embryo takes up all the available space and absorbs the rest of the yolk (this is what nourishes the chick a few days after birth).
19th day	The embryo pierces an internal duct
20th day	The embryo pierces an external duct
21st day	Hatching, the chick is now in the air free and is now ready to face new events

4.Automatic control

Controlled systems can present faults in the presence of disturbances: instability, insufficient precision, response time that is too slow, with regard to the characteristics of the specifications. It is often necessary to incorporate an element called controller into the control loop in order to improve the performance of the closed loop.

The most common controller is the Proportional, Integral, Derivative or PID controller, the advantages of a PID controller are simplicity and efficiency, it is therefore used in various fields such as industry, aeronautics, medical equipment and automotive. It's also used especially in PA (process automation), equipment industry such as steel, petroleum, chemicals and food, it occupies a major place as an indispensable part of automation technology.

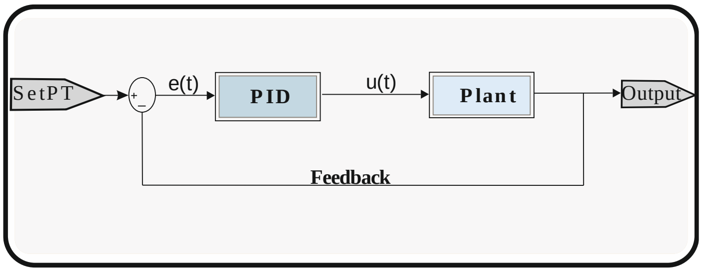

Figure 3. PID control scheme

4.1. Design and practical realization

In this section we will talk about our complete realization, while starting with the design, to properly structure the project it is necessary to divide it into several tasks, so the project becomes more easily manageable and controllable.

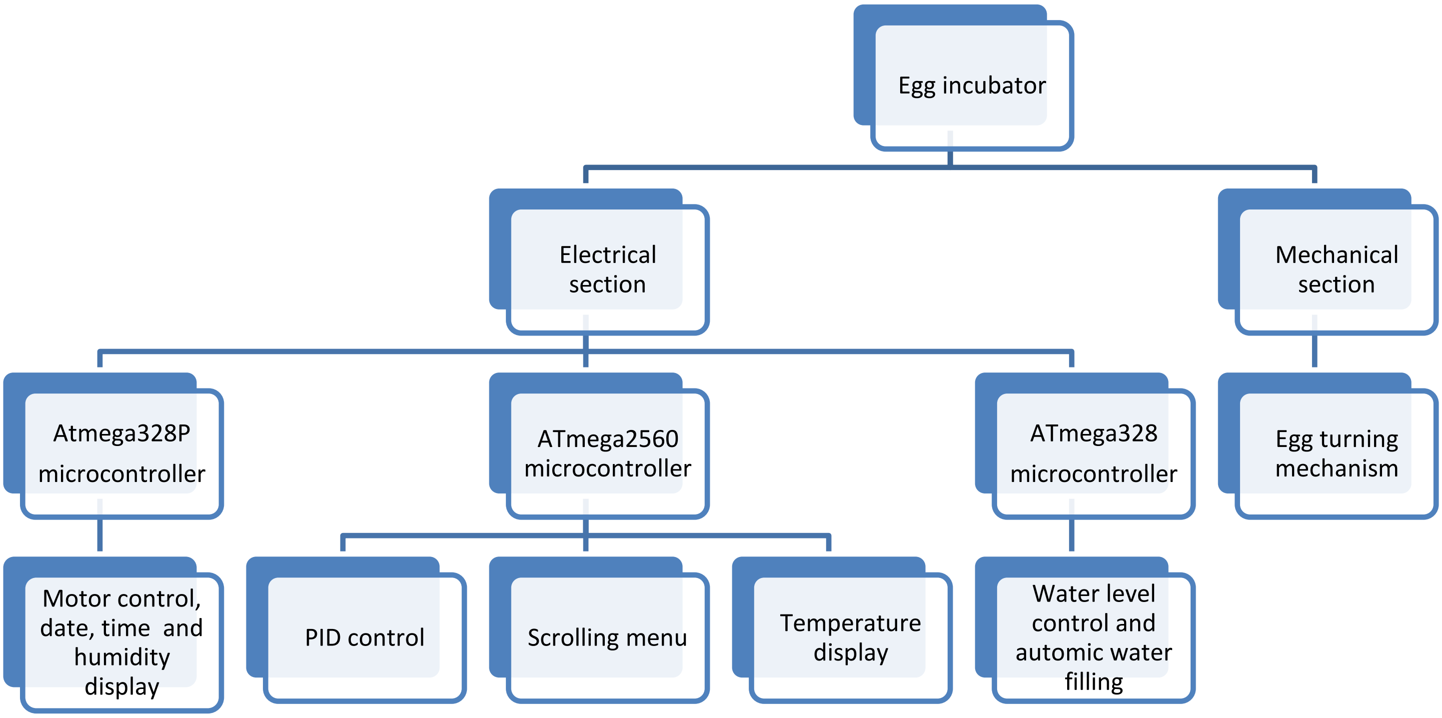

Figure 4. General synoptic diagram

4.2. Conception

4.2.1. Design of a push button keyboard

By using push-buttons and resistors, we were able to simulate the operation of a keypad which offers us the possibility of controlling a scrolling menu, changing the PID controller parameters, setting the temperature and humidity level.

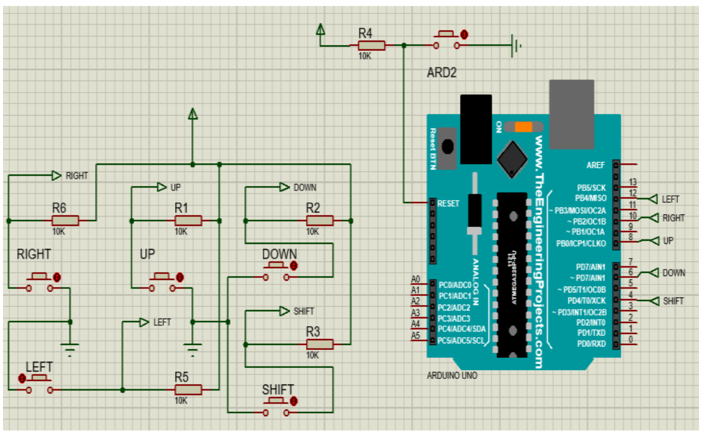

Figure 5. Electronique circuit simulation of the push button keyboard

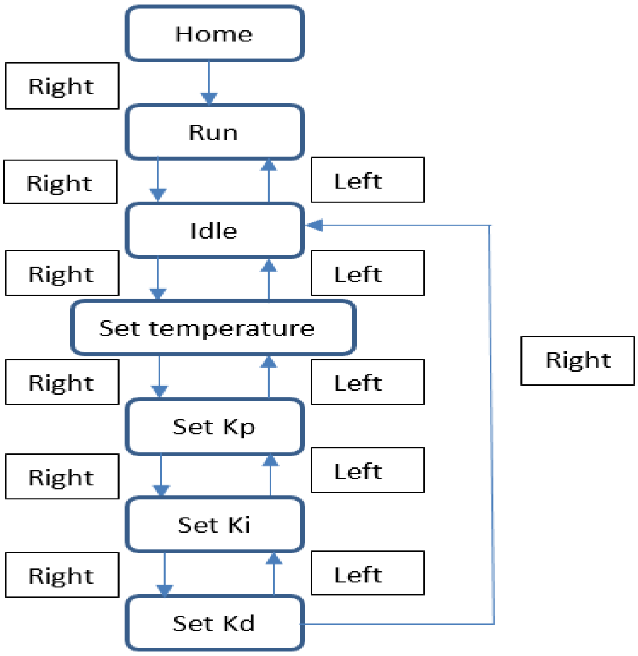

Figure 6. Synoptic diagram of the scrolling menu

4.2.2 Design of temperature control system

The system responsible for controlling the temperature consists of two relays whose purpose is to control a fan and a heating plate. The control of the relays is done by AVR micro-controllers and is proportional to the effort provided by the PID controller.

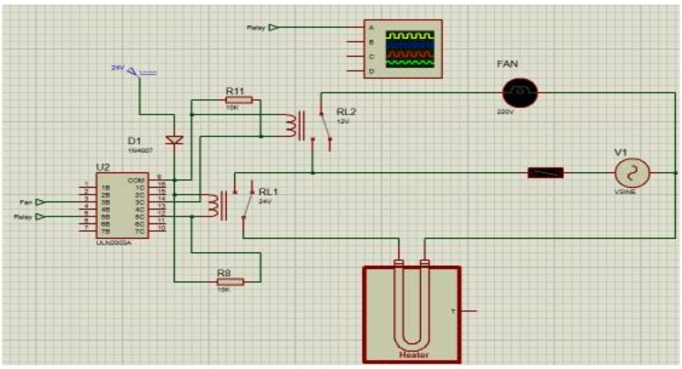

Figure 7. Simulation of the temperature control system

4.2.3 Design of an external watchdog timer:

we also used an external watchdog timer which aims to reset the microcontroller in case the program crashes. These kind of intelligent systems will limit human intervention and makes the system completely autonomous.

The value of the capacitor used in the external watchdog timer depends on the necessary time to reset the microcontroller in case of program crashes.

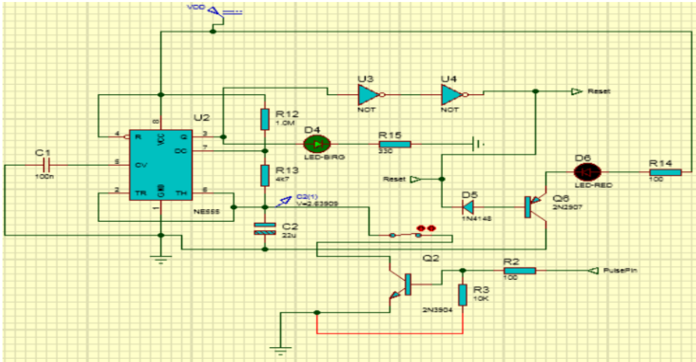

Figure 8 External watchdog timer using Ne555

4.3. Applied realization:

4.3.1. Realization of the turning egg mechanism

It is absolutely necessary to take into consideration the weight when making a mechanism for turning the egg (a hundred eggs), to do so, we opted for wheels whose role is to carry the plate (reducing the motor load), the rest of the mechanical part will take care of moving the plate (principle of an endless screw).

Figure 9. Turning egg mechanism

We also realized an H-bridge circuit to control (PWM and direction) the egg turning motor, the printed circuit design was made using Eagle Software as shown in figure (10).

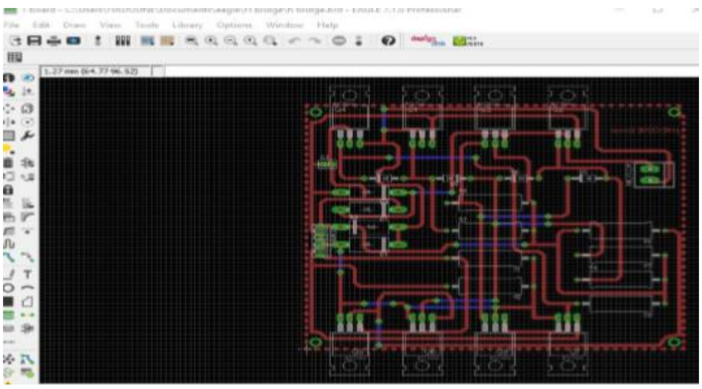

Figure 10. Printed circuit design using EAGLE software

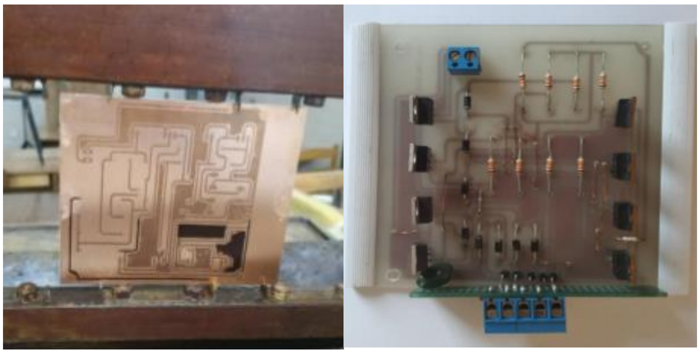

Figure 11. Printed circuit realization

The use of mosfet and schottky diode allowed us to control the motor with high current value and fast switching speed.

4.3.2 Realization of a push button keyboard

The handling of a scrolling menu is done by a push-button keyboard, the role of which is to enter the various parameters of the PID controller as well as the set values for the temperature and the humidity level.

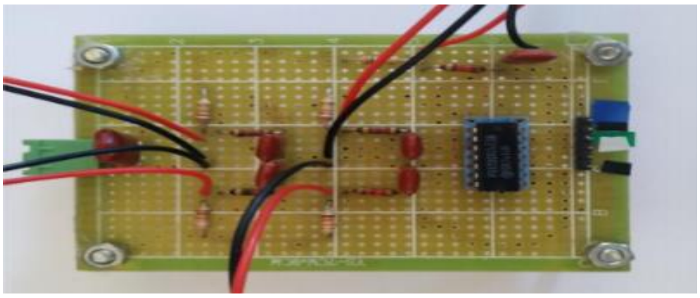

Figure 12. Push button keyboard electronic circuit

4.3.3 Realization of the temperature / humidity control system

To power the various AVR micro-controller boards, we used voltage controllers whose references are as follows: 7805, 7809 and 7812, each of the three is responsible for supplying the following equipment: micro-controllers, motor, sensors and screens. This card also allows the control of the fans and the heating plate, it represents the motherboard of our project.

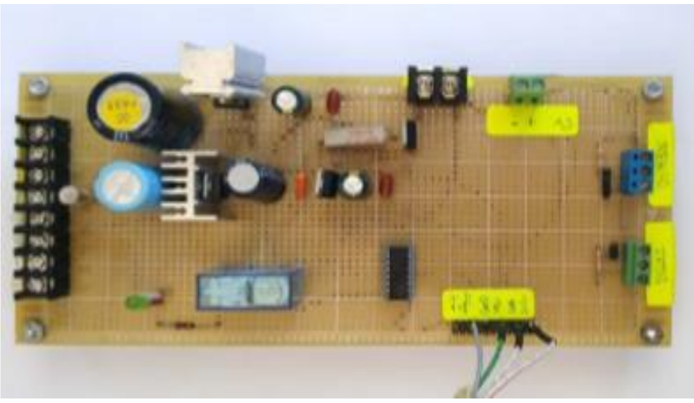

Figure 13. Temperature / Humidity control system

4.3.4. Date / time, humidity / water level and motor state display

We have made an electronic circuit on a perforated board that we have placed on the Avr Micro-controller board, which displays the date / time, water level in both internal and external tank, the state of the motor (translation of the plate on the left / right side) and humidity level as well as the I2C connection between the LCD screen and the RTC module as shown in figure (14).

If the water level:

Reaches a certain low level in the internal tank, it will fill up automatically;

Is low in the external tank the buzzer emits a sound to warn the operator.

Figure 14. Date / time, humidity level and motor state display electronic circuit

The following figures show the different parts of the realized egg incubator, where figure (15) displays the controller allowing the multitasking real time execution. Figure (16) illustrates the supervision and control interface (keyboard & LCD screens), while figure (17) represents the global egg incubator model.

Figure 15. Egg incubator controller

Figure 16. Supervision & control interface

Figure 17. Global egg incubator model

5. Conclusion

The goal of this project is the design and realization of a fully automatic incubation system specialized in the production of chicks with a high hatching rate (more than 80%). We have been able to achieve this objective by putting together many fields of study and using the knowledge acquired throughout this work, starting from the field of poultry farming to the design of a mechanical system and ending with the field of electronics and automation, by combining all this latter we have been able to:

Implement a PID (temperature) & bang-bang controllers (humidity);

Construct an automated turning egg mechanism;

Build a push button keyboard to handle a scrolling menu;

Implement an intelligent alarm and automatic filling system;

Realize an external watchdog timer to avoid program crashes;

Implement a multitasking display system (water level in both tanks, temperature, humidity, motor state and date/time).

The fully automatic realized egg incubator has demonstrated a very good hatching rate (more than 85%).

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