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Proposal for the possibility of promoting cross-curricular relationships of vocational subjects in the field of agriculture in relation to the subject of computer science

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Abstract **–** Today we are witnessing a great boom in computer science. We rely on our smart devices and the apps we have installed on our mobile phones. However, we must not forget the hardware side, which is taking a back seat, forming the basis of all the software we use. We are thinking of Boolean algebra and logic circuits. They find their use not only in computer science, but also in automation, control or regulation. In our paper we will describe one possible application not directly from the world of computer science but from agriculture, on the example of which we will try to teach in a form acceptable to students the procedures and reasons for minimizing logic functions and we will point out their importance in practical implementation. Our paper may find its application not only in computer science classes, but also in automation and related courses as an example of solving a real problem for students. Our aim is also to support cross-curricular relationships of professional subjects, in particular computer science - programming, automation - signaling, electronics - electrical circuit design or even sensing of electrical quantities.

Keywords – Education, Logic Circuits, Arduino, Tinkecad, Electronics, Vocational Subjects.

I. Introduction

Today we are witnessing a great development of many scientific disciplines and areas of the national economy. Agriculture is also undergoing development. As in other areas of the economy, elements of other scientific disciplines are also entering and becoming part of agriculture, such as statistics, computer science and automation. Economics and the food industry have long been an obvious part of this. [3][4][5][6][7][8] This development requires a multidisciplinary approach, and we must therefore also guide students along this path. It is important to cultivate and strengthen cross-curricular relationships in students. In relation to computer science, in turn, algorithmic thinking. The use of modern educational practices is also no longer a novelty. 12][13][14][15][16][17][18][19][20] In several of our publications, such as [9], [10] or [11], we have already discussed the need and the positives of fostering cross-curricular relationships, especially between academic subjects, but we must not forget about vocational subjects, and it is this area that we will address in our paper.

Tinkercad is an online development environment from Autodesk and is focused on electronic circuits, including their simulation and 3D modelling. [1][2]

In addition to simulating electronic circuits, it is also a good tool for simulating various other processes, whether in logistics, warehouse management, or for simulating selected smaller problems in agriculture. [15][16][17][18].

II. Materials and Method

We assume that students already have some knowledge on which we can build. In particular, we mean knowledge of Boolean algebra and logic circuits, electronics and automation. We begin the example by setting the problem. We are going to design a signaling device that will signal enough water for watering. In the next step, we will introduce the following convention for simplicity: Instead of the logical algebra characters "∧" and "∨", we will use "-" and "+". We will denote the negation by the symbol above the variable: $\bar{x}$.

Assignment

At times when more water is not needed, a pump gradually refills two water tanks for watering. 45 litres of water are needed for one watering. The first tank has a capacity of 60 litres and the second 30 litres. There are two level sensors in each tank - a full tank and a tank half full. This is shown in Figure 1. Watering is started automatically by the automatic watering machine if two conditions are met: it is time for watering according to the watering schedule (at specific hours) and if there is enough water (the designed signaling device sends information about this with the value of log 1 to the automatic watering machine on the corresponding line - driver).

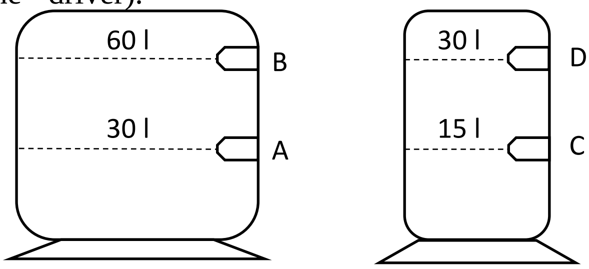


Fig. 1 Positioning of sensors in water tanks

In addition to the above, we will also suggest testing the functionality of our proposal. We will use an Arduino board for this. In order to save time, we will not create the entire system using physical parts, but we will use the option offered by the TinkerCad simulation environment.

Solution

In the first step, we create a truth table. We present it in table number 1. We have four sensors at our disposal, so we will mark them with variables: "a" - "b" - "c" - "d". Thus, the first columns of the table represent the variables - installed sensors, and we classically alternate the combinations of logical 1 and logical 0. For further calculations, the "y" column is important for us. The logical 1 state represents the case when the water level has reached the sensor. Logical 0 is the case when the water level has not yet reached the level of the sensor, so there is not enough water for the sensor to respond. On the first line, where the water level has not reached any sensor - only logical 0 values, that is, there is not enough water for watering, and therefore we also write the logical 0 value in the "y" column. On the fifth line, we see that the water level has reached the level of the sensor "b" " - logical 1 in column "b". Thus, there are 60 liters of water in the first tank, which is enough for watering, and therefore we will enter the value logical 1 in the "y" column. We will continue like this until we solve all the combinations. Let's continue our discussion with the fifth line. At first glance, this case may seem illogical, because the value should be logical 1 also on sensor "a", however, it is also logical that as long as the level reaches the level of sensor "b" it does not matter whether the second tank is filled in the field - row seven or not, there is enough water for watering. These cases in column "q" simply as "-".

Table 1. Truth table

a	b	c	d	q	y
0	0	0	0	0	0
0	0	0	1	0	0
0	0	1	0	0	0
0	0	1	1	0	0
0	1	0	0	1	1
0	1	0	1	-	1
0	1	1	0	-	1
0	1	1	1	-	1
1	0	0	0	0	0
1	0	0	1	1	1
1	0	1	0	1	1
1	0	1	1	-	1
1	1	0	0	-	1
1	1	0	1	-	1
1	1	1	0	-	1

1	1	1	1	-	1

We can specify a logic function by an algebraic form, a truth table, and a Karnaugh map. There is a possibility of using Venn diagrams but their use is not widespread in control engineering. In the next step, we proceed by rewriting the logic function in algebraic form and minimizing it. we write the logic function and minimize it:

- There are several ways of minimization where we can leave this activity to the students and compare what results they obtained by different minimization procedures. Since we are dealing with a larger number of terms in the equation, not every student has to work out the minimum form. Therefore, it is also useful to use Karnaugh's map which is clearer. Also by doing this we can show the effectiveness of the Karnaugh map.

$$y = \bar{a}b\bar{c}\bar{d} + \bar{a}b\bar{c}d + \bar{a}bc\bar{d} + \bar{a}bcd + a\bar{b}\bar{c}d + a\bar{b}c\bar{d} + a\bar{b}cd + ab\bar{c}\bar{d} + ab\bar{c}d + abc\bar{d} + abcd$$

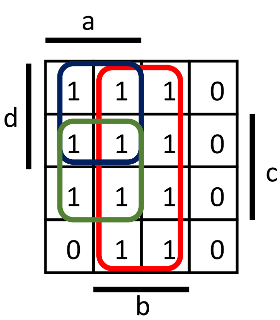
$$y = \bar{a}b(\bar{c}\bar{d} + \bar{c}d + c\bar{d} + cd) + a\bar{b}(\bar{c}d + c\bar{d} + cd) + ab(\bar{c}\bar{d} + \bar{c}d + c\bar{d} + cd)$$

$$y = \bar{a}b + a\bar{b}(c + d) + ab$$

$$y = b + a\bar{b}(c + d) = b + \bar{b}(ac + ad)$$

$$y_{min} = b + ac + ad$$

From the minimum form of the resulting function, we can see that there is enough water for watering when the water level has reached the level of sensor "b", or the level of sensor "a" in the first tank and sensor "c" in the second tank, or the level of sensor "a" in the first tank and sensor "d" in the second tank.



$$y_{min} = b + ac + ad$$

Fig. 2 Karnaugh map

Again, the third option can be confusing because logically it is sufficient if the water level in the first tank has reached the sensor level "a" and the second tank the level "c" and there is no need to deal with the level when the second tank is full. However, we have to remember that 45 litres of water is needed for watering and this may be available even when the second tank is full and the first tank is half full.

- Thus, there are indeed three possible combinations, which we have obtained by solving the equation. This also shows the efficiency of Boolean algebra.

In Figure 2 we also show the Karnaugh map of the example, which clearly shows that the minimal form is indeed the one obtained by algebraic minimization.

In practice, it is common that the realization using logic circuits is realized by the same gates. In our case, we also modify the equation to a form that is realizable using NAND or NOR gates:

$$y_{NAND} = \overline{\overline{b + ac + ad}} = \overline{\bar{b}.\overline{ac}.\overline{ad}}$$

$$y_{NOR} = b + \overline{\overline{ac}} + \overline{\overline{ad}} = b + \overline{\bar{a} + \bar{c}} + \overline{\bar{a} + \bar{d}}$$

The implementation using gates is shown in figure number 3.

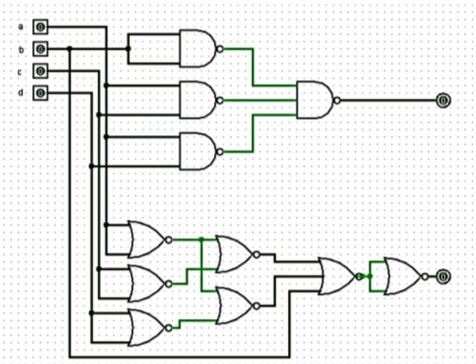


Fig. 3 Function implementation using NOR (up) and NAND (down) gates

In the next step, we will use the TinkerCad environment to wire these circuits.

III. Results and Discussion

We have had positive experiences with TinkerCad. See e.g. [1]. In Figure 3 we see the implementation in the Logic Sim software environment. We show the actual wiring and the circuit diagram in figure number 4. We can notice that we have used standard IO 7402, 7427, 7400 and 7410.

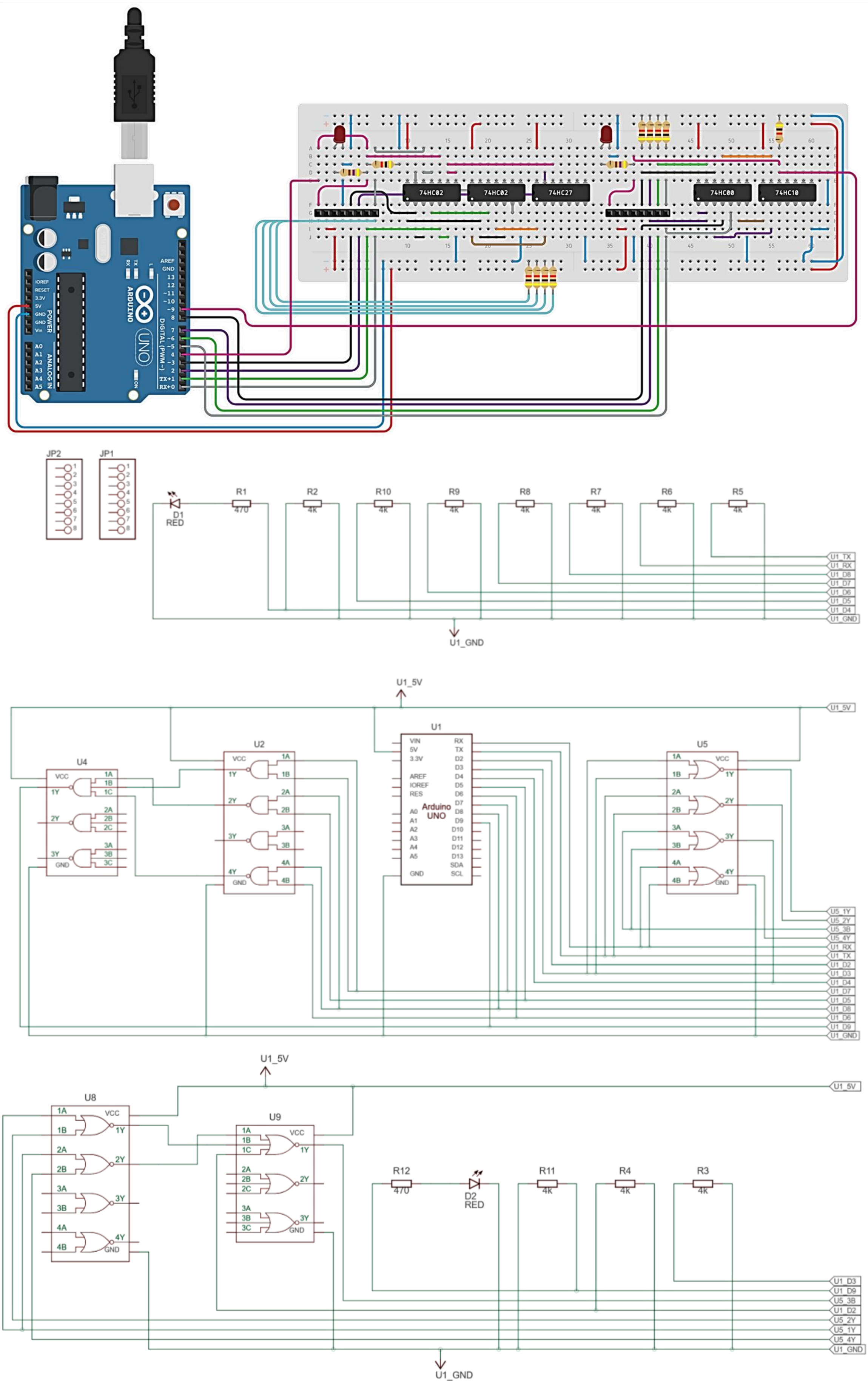


Fig. 4 Wiring using Arduino UNO board

We can also see two quads of resistors that act as pulldown resistors. Although they can also be replaced by the built-in resistors of the Arduino board, we have included them in the design for clarity. The Arduino board serves as the basis for testing our design. By forwarding a number through the serial port of the Arduino board, the corresponding pin, which simulates the presence of the log. 1 signal, is accordingly turned on. The JP1 and JP2 connectors will be used to connect to the higher-level unit. In the next step, we proceed to the programming of the Arduino board. The essential parts of the program are given below.

```
...
 int read_number = 0;
...
 Serial.begin(9600);
 pinMode(0, OUTPUT); pinMode(1, OUTPUT);
 pinMode(2, OUTPUT); pinMode(3, OUTPUT);
 pinMode(5, OUTPUT); pinMode(6, OUTPUT);
 pinMode(7, OUTPUT); pinMode(8, OUTPUT);
 pinMode(4, INPUT);    pinMode(9, INPUT);
 pinMode(10, OUTPUT); pinMode(11, OUTPUT);
 pinMode(4, OUTPUT); pinMode(9, OUTPUT);
...
 digitalWrite(0, LOW);       digitalWrite(1, LOW);
 digitalWrite(2, LOW);       digitalWrite(3, LOW);
 digitalWrite(5, LOW);       digitalWrite(6, LOW);
 digitalWrite(7, LOW);       digitalWrite(8, LOW);
...
 read_number = Serial.read();
 if (read_number >= 48) {
  if (read_number == 48) {digitalWrite(0, HIGH);}
  if (read_number == 49)  {digitalWrite(1, HIGH);}
  if (read_number == 50){digitalWrite(2, HIGH);}
  if (read_number == 51){digitalWrite(3, HIGH);}
  if (read_number == 53){digitalWrite(5, HIGH);}
  if (read_number == 54){digitalWrite(6, HIGH);}
  if (read_number == 55) {digitalWrite(7, HIGH);}
  if (read_number == 56){digitalWrite(8, HIGH);}
  if (read_number == 99) {
   digitalWrite(0, LOW);     digitalWrite(1, LOW);
   digitalWrite(2, LOW);     digitalWrite(3, LOW);
   digitalWrite(5, LOW);     digitalWrite(6, LOW);
   digitalWrite(7, LOW);     digitalWrite(8, LOW);
   Serial.println("- cleared - ");}}
...
if (digitalRead(4) == HIGH)
  { Serial.println("OLK_w_NORgates");}
if (digitalRead(9) == HIGH)
  { Serial.println("OLK_w_NANDgates");}
...
```

If programming can be problematic, we can use the Tinkercad environment to set up a program using blocks. The full project is available here: https://www.tinkercad.com/things/1KQgrSd44Xh

IV. CONCLUSION

Above we have shown with a concrete example that we can very appropriately use such examples to deepen and fix the knowledge that students have already acquired theoretically by learning in vocational subjects by giving a complex example whose solution requires knowledge from several lessons. Of course, in our paper we focus on high school students. To a large extent, we support cross-curricular relationships of many vocational subjects such as computer science, mathematics, electronics but also automation, electrical measurements or physics. The Arduino board and the possibility to simulate it in the Tinkercad environment is also a great help. The use of a computer and the possibility of programming is also not a bad thing. On the contrary. It motivates pupils and leads them to be independent in their solutions, often just by using google to help them find solutions to their problems. We are referring to the proven fact that pupils learn the most when they solve the problem themselves.

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