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Student program: Informatics

Subject: Expert systems

74xx Series Integrated Circuit Expert System

-Project-

Kragujevac 2023

Content

1. introduction

An expert system is software that uses a database of expert knowledge. The role of expert systems is to offer advice or make decisions with the help of collected expert knowledge. Expert systems can be used in a variety of fields, such as medicine, administration, science, computing, and many other fields.

Integrated circuits are assemblies of electronic components in which there are over hundreds of millions of interconnected transistors, resistors, diodes, capacitors installed on a small semi-conductor plate[1]. In electronics and computing, integrated circuits are used as computer memory, microprocessor, oscillator, logic gates, timer, microcontroller or signal amplifier. By combining integrated circuits with different functions, systems with many capabilities can be made.

The basic division of integrated circuits in digital electronics can be classified into combinational and sequential integrated circuits.

- **Combination circuit** is a circuit in which the output depends on the current combination of inputs. Combinational circuits are composed of logic gates. The output of each logic gate is determined by its logic function.
- **Sequential circuits** are circuits where their output depends on a series of events that occur at the circuit's inputs. Examples of such circuits include clocks, flip-flops, counters, memories, and registers. The actions of sequential circuits depend on the range of basic sub-circuits.

. The 74xx series integrated circuit expert system will deal mainly with the 74xx series combinational circuits. However, one can find some sequential circuit, which is an additional component to the combinational circuit, but such chips are mostly omitted.

1.1 Application

The 74xx series integrated circuit expert system can be used as an additional tool in electronics or computer science laboratories. This system can also be used in the design of electronic devices. Students, professors, digital electronics engineers who need quick access to the structure of combinational integrated circuits of the 74hh series can apply this expert system in their work.

1.2 Target group

The expert integrated circuit system of the 74xx series is intended for students involved in computer electronics. The expert system provides useful information for users

who deal with integrated circuits and do not have enough experience or have not dealt with the topic for a while.

In order to successfully use the expert system, the user should be familiar with combinational circuits and chip structure.

1.3 Series 74xx integrated circuits

74xx is one of the most popular families of integrated circuits on the market. In 1964 the technology company "Texas Instrumentals" developed the first series of integrated circuits which had the name "SN5400". Two years later in 1966 the same company released a new series of integrated circuits "SN7400". The only difference between these two series of integrated circuits is that the "SN5400" series was intended for military purposes, so the "SN5400" series chips had to be made of higher quality material, in order for the chips to function in larger temperature ranges. So for the rest of the market they made a cheaper alternative with less quality plastic.

The "" series chips have achieved great success in the market by setting the standard in the electrical component market. Over time, "Texas Instrumentals" has modernized and changed the series of chips, the most striking change is the transition from "TTL(Transistor-transistor logic)" technology to "CMOS(Complementary metal-oxide-semiconductor)" and "BiCMOS (Bipolar CMOS)", newer chips are made with this technology[2].

Today, there are over a thousand chips that have different functionalities, operating voltages, operating temperatures and technologies. Many chips from the series have a name that starts with 74 and has a suffix consisting of several numbers, but due to the mentioned changes, some chips have a combination of letters and numbers as a suffix, for better classification. Such as74LS74, LS stands for "low-power Schottky" in the chip.

1.4 Brief description of the expert system

This expert system consists of a simple interactive application that is connected to a database or knowledge base. The expert system will help the user by showing the pin layout and logic of the selected chip. The user selects a chip based on the answer he gave to the expert system. The user will select the available attributes of the integrated circuit in a step-by-step method, so that in the end he will receive the offered factory name of the chip. If necessary, an explanation will be displayed to the user, so that he knows the difference between two or more available attributes. Explanations, pins, logic, and attributes are stored in the knowledge base, and the application retrieves and displays that data as needed. The search method, by which the user of the expert system reaches the desired information, is the tree search method.

2. Technologies used for the development of the project

The aforementioned technologies were used to create an expert integrated circuit system of the 74xx series. These technologies will be discussed in more detail in this area.

- **Programming language: Object Pascal**
- **Development environment: Embarcadero Delphi**
- **Database: SQLite**
- **Operating system: Windows 7/Windows 10**

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2.1 Object Pascal programming language

"Object Pascal" is an extension of the "Pascal" programming language that provides object-oriented programming[3]. This programming language is similar to the C++ programming language. The advantages of the "Pascal" programming language are that it allows the definition of complex structured data types and the construction of dynamic and recursive data structures, such as lists, trees and graphs.

The disadvantage of this language is that when writing complex programs, sometimes in some specific scenarios the compiler will end up decoding the code in a different way than intended. However, this happens with more complicated programs and for this project this will not be a problem.

Today, this programming language is not seen and used often, simply because it has poor support and there are other programming languages that have more support, thus more opportunities for developers. Due to its simplicity, it is used more for learning programming techniques.

2.2 Embarcadero Delphi development environment

Embarcadero Delphi 11 Community Edition was used to develop the programming part of the expert system. "Delphi" has its own version of the "Object Pascal" programming language. Using element names, the attributes of elements can be changed in the code, and commands can be given to change attributes in a function, which is bound to an interactive element (such as a button). The platform contains a bunch of predefined functions, which contribute to faster application development. The Delphi development environment can connect to a database.

Much like the programming language on which it is based, "Delphi" is not extremely popular today. It is still used because of programs that were developed when this

development environment was more popular. Embarcadero still supports Delphi and occasionally releases new versions of the development environment.

2.3 SQLite database

The knowledge base was created using the "SQLite" database. It differs from other databases because it does not need a server to function. In addition, it is very compact and easy to use. It is often used to develop embedded software for devices such as televisions, mobile phones, cameras, and alike[4].

This was an ideal choice for the knowledge base in this expert system. Considering that the 74hh series IC expert system has no need for complex functionalities and that the "SQLite" database can be very easily connected to the "Embarcadero Delphi" program. The serverless database enabled faster and easier development of the expert system.

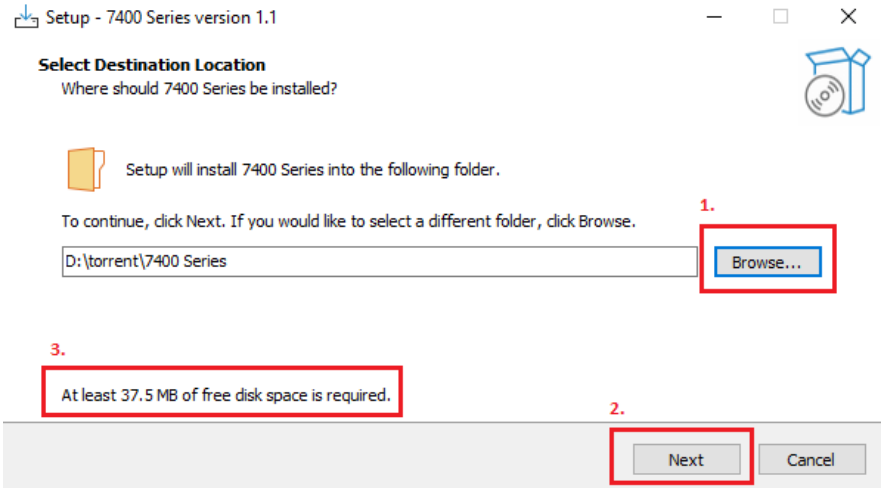
3. Project

Further in this text, it is discussed in more detail about the work of the expert system, how to italicize the expert system and what the knowledge base contains. The description and code of the 74xx series integrated circuits are taken from a document available online at this link[5]. Attributes of integrated circuits in the expert system are extracted from keywords in the chip description.

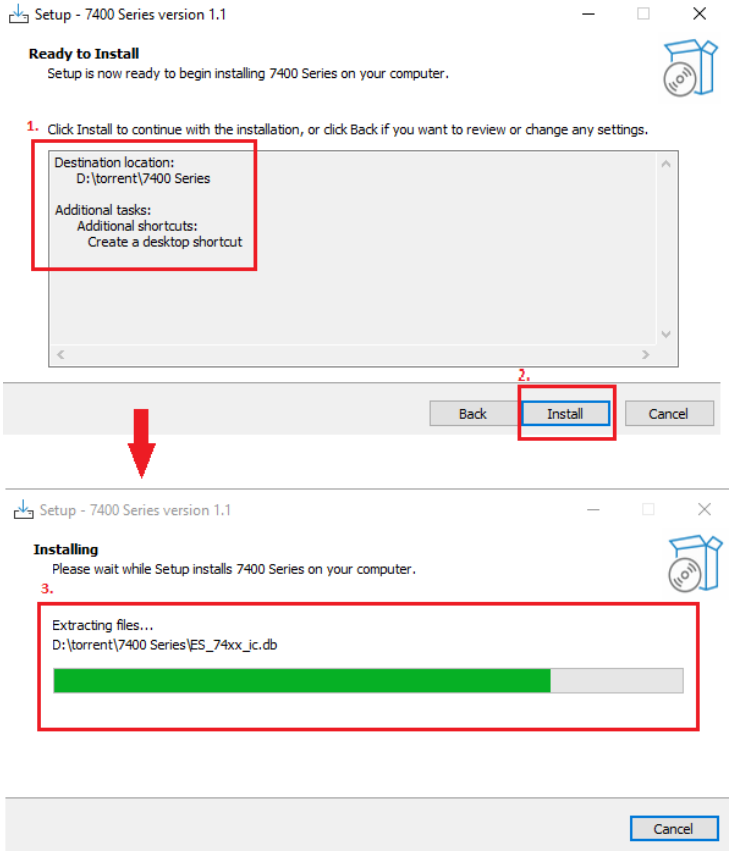
3.1 Installation and launch of the expert system

Installation of the 74xx series expert integrated circuit system is very simple. The entire installation process is shown here.

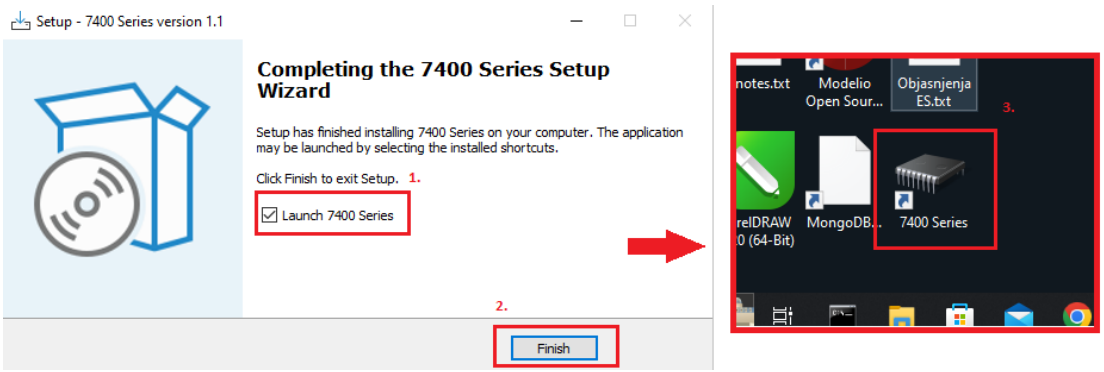
First run the installation called "74xx-setup" when the window appears, choose where you want your expert system folder(1). Then press the "Next" button to continue (2). In the lower left corner, you can see how much space the expert system takes up on your hard drive(3).(Figure 1.)



After that, you can check the box that will create a shortcut on your desktop. Press the "Next" button and in the next window you can view all configurations(1). If you are not satisfied, you can go back. If you are satisfied with the configurations, press the "Install" button (2) and the program will start installing (3). (Figure 2.)



Finally you can check the button that will error the program(1) and press the "Finish" button(2). You can find the program in the selected folder and if you checked that the installer creates a shortcut on your desktop, an icon with a picture of the chip will appear (3). (Figure 3.)



3.2 Knowledge base

All available data on integrated circuits of the 74xx series are taken from the mentioned document and their datasheets, which can be found on the web. Datasheets contain all the information about the integrated circuit. The database file is called "ES_74xx_ic.db" and consists of 81 tables.

The knowledge base includes descriptions of the 74xx series chips, pinout images, and integrated circuit logic images. Also, there are attribute descriptions and other tables contain interconnected attributes, so that the program knows how to connect the circuit type, attributes and chip code.

The table containing information about the chip is called "74xx", it consists of two text data and three images(1). The textual data is the chip code and chip description. As for the pictures, some have separate pictures of the pin layout and chip logic(2), and some have both combined in one picture(3). (Figure 4.)

1.	serial_number	description	pinout_and_logic	pinout	logic
1	7400	quad 2-input NAND gate	PNG	NULL	NULL
2	741G08	single 2-input AND gate	NULL	PNG	PNG
3	741G09	single 2-input AND gate with open drain output	NULL	PNG	PNG
4	7421	dual 4-input AND gate 2.	PNG	NULL	NULL
5	741G00	single 2-input NAND gate	NULL	PNG	PNG
6	7401	quad 2-input NAND gate with open collector outputs	PNG	NULL	NULL
7	741G01	single 2-input NAND gate with open drain output 3.	NULL	PNG	PNG
8	7402	quad 2-input NOR gate	PNG	NULL	NULL
9	741G02	single 2-input NOR gate	NULL	PNG	PNG
10	7403	quad 2-input NAND gate with open collector outputs	PNG	NULL	NULL
11	741G03	single 2-input NAND gate with open drain output	NULL	PNG	PNG
12	7408	quad 2-input AND gate	PNG	NULL	NULL
13	7409	quad 2-input AND gate with open collector outputs	PNG	NULL	NULL
14	7410	triple 3-input NAND gate	PNG	NULL	NULL
15	7411	triple 3-input AND gate	PNG	NULL	NULL
16	7412	triple 3-input NAND gate with open collector outputs	PNG	NULL	NULL
17	7413	dual Schmitt trigger 4-input NAND gate	PNG	NULL	NULL
18	7415	triple 3-input AND gate with open collector outputs	PNG	NULL	NULL
19	7418	dual 4-input NAND gate with Schmitt trigger inputs	PNG	NULL	NULL
20	7420	dual 4-input NAND gate	PNG	NULL	NULL

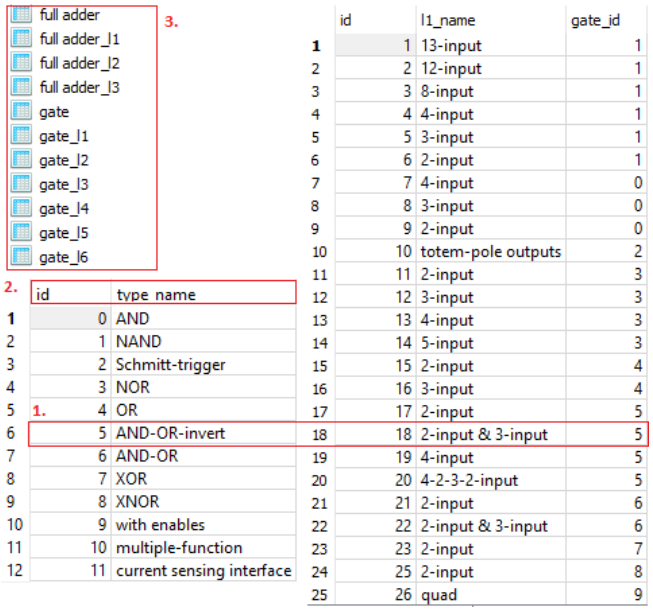
Слика 4. Табела 74xx

The table containing attribute descriptions is called "Description", it consists of two text data(1). One text data serves as a primary key or keyword that helps the program to find the correct description. The second text data is the description of the attribute itself. The attribute description is short, one to two sentences(2). Many chips have unique attributes, in which case the explanations are extracted and determined from the chip's information sheet, i.e. "Datasheet". Some keywords are repeated, this is because the same attribute is written differently in the description of the specified document (it may have a capital letter, for example)(3), but the meaning remains the same, so the description is the same. (Figure 5.)

1.	name	desc
1	dual	pair of logic gates
2	quad	two pairs of logic gates
3	hex	three pairs of logic gates
4	octal	four pairs of logic gates
5	single	one logic gate in IC
6	triple	three logic gates in IC
7	EDAC 2.	IC has Error Detection and Correction function
8	three-state output	IC has output with three states 1, 0 and open or Hi-Z
9	TTL	IC has Transistor-transistor logic a digital logic design in which bipolar transistor s act on direc
10	CMOS	IC uses complementary pairs of p-channel and n-channel MOSFETs
11	ODO	IC has open drain output pin that is driven by a transistor and pulls the pin to one voltage ground
12	inverting	IC gives opposite output logic value then noninverting
13	noninverting	IC has no inverted output logic value
14	negative enable	IC outputs are disabled when /G input is high
15	positive enable	IC outputs are disabled when G input is low
16	with enable	IC has input that enables or disables output depending on frequency
17	G and /G complementary inputs	IC has bouth positive and negative enable inputs
18	n-channel	IC has n-channel MOSFET composed of a majority of electrons as current carriers
19	p-channel	IC has p-channel MOSFET which is an inversion layer in an n-type it can conduct holes between p-type
20	OCO	IC has open collector output which is an NPN transistor allows the sinking of current to common
21	true	IC has true short for noninverting outputs
22	mixed enable polarity	IC has two outputs that are only bouth enabled when first complimentery input is low and second high
23	8 to 1-line	IC has eight inputs and one output
24	8-to-1	IC has eight inputs and one output 3.

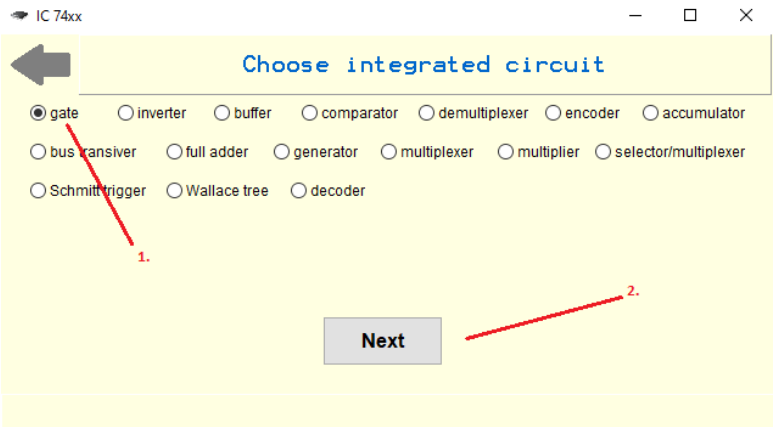
Most tables in a database carry a relationship between attributes. Links are made with integers as primary and foreign keys. Each attribute has its own primary number for the attributes that appear in the next step and its own foreign number that represents the link to the previous step(1). Chip types, i.e. the first step, do not have a foreign key because the user starts the search from the chip type(2). The table with the first attributes bears the name of the type, and the (_l1, _l2...) suffix (3) is added to each subsequent

step, depending on which step it is. Also, the name of the data changes based on which step it is. This helps the program display the correct information and function properly. (Figure 6).



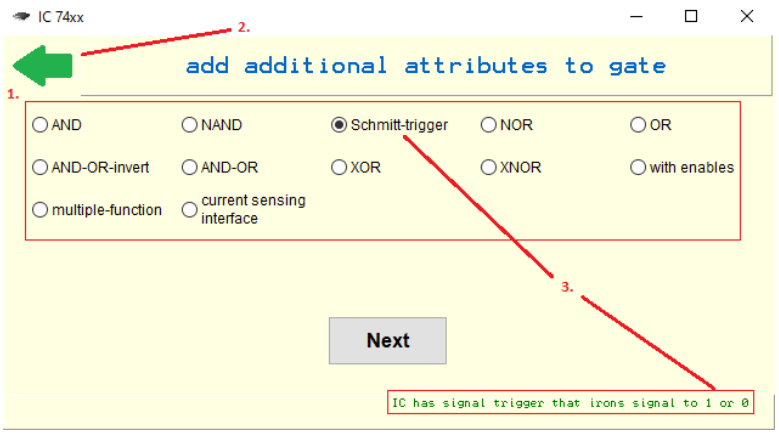
3.3 Funktionality

Immediately after the application is launched, a small window is displayed to the user. On that window there are sixteen radio buttons, two buttons and the text "Choose integrated circuit". This is the initial step where the user will select the circuit type. The user can continue after choosing one of the offered options(1) and pressing the button with the text "Next"(2). (Figure 7.)

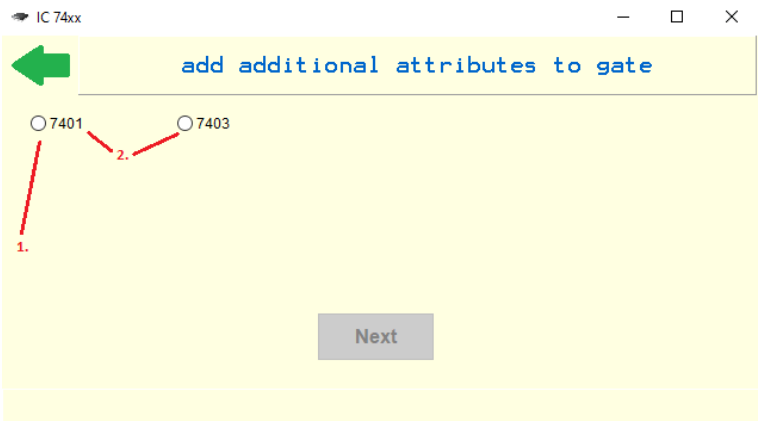


In the next step, the user is presented with a new set of radio buttons. In this case and in all subsequent steps, the options offered depend on the previously selected option. Now the user selects an attribute of the integrated circuit, for example if "gate" was selected in the previous step, the user now selects what kind of logic gate he wants (AND, OR, XOR, whether it has a special input or output...)(1). In this and all subsequent steps, the user will be able to go back one step by pressing the arrow that has lit up in green (2).

Also, in each subsequent user, an explanation is provided when pressing some of the radio buttons(3). The explanation is located in the lower left corner and expands to the right, depending on the length of the explanation. This information serves to briefly explain to the user in one sentence the differences between the offered options. These explanations are not shown for the first step, in the types of integrated circuits, because the user should be familiar with combinational circuits, and an explanation is not necessary. (Figure 8.)

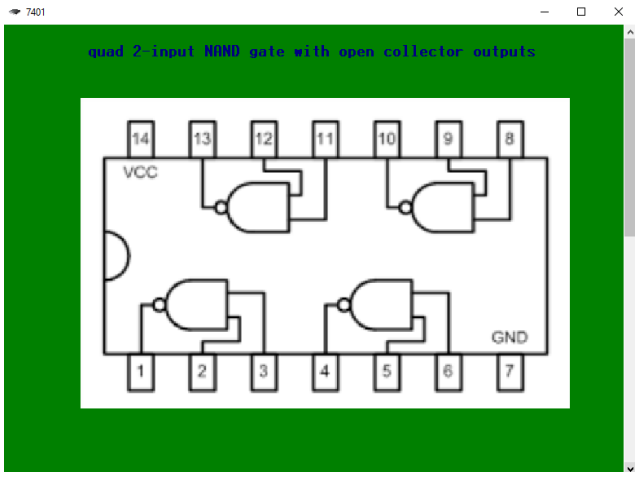


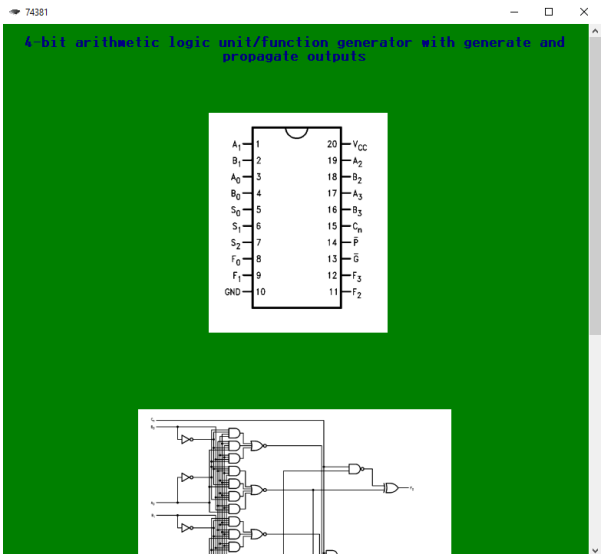
After a few steps, the user will come across a number starting with "74" as a radio button. This means that the user has reached the desired chip, and the number displayed is the code of that chip(1). In some cases, multiple numbers may be displayed. This means that multiple chips match the user-submitted description(2). Often the differences between these listed chips are minimal and can be determined by looking at the pin layout or chip logic. In case the user does not notice the difference between the offered chips, it is best to look at the "datasheet" to determine the difference. It is possible that there is a difference in the electronic characteristics or in the output and input waves. In any case, the differences are not large and should not mean much to a student with basic knowledge. (Figure 9.)



After the user selects the chip code and presses the "Next" button, a new window is displayed. That window can come out in two versions. In the first version, the user is shown an image with the pin layout and chip logic all in one (Figure 10). The second version is with two pictures, where the picture above shows the layout of the pins, and the

picture below shows the logic of the chip (Figure 11). This is done this way because the logic of individual chips may be too large to show along with the pinout of a combined image was not available. It can also work in the case of the second version that the first and second images are too far apart, this is due to the limitation of the development environment to expand the image frame depending on the image size. So this is a compromise to make the picture with the complex logic of the chip transparent. Regardless, all images are transparent and the window can be adjusted arbitrarily by the user. Next to the images at the top of the window is a full description of the selected integrated circuit. This window can be closed by pressing the red button H. After closing, the user can continue using the original window.





4. Conclusion

During the development of this expert system, I expanded my knowledge on the given topic. The speed of work and the quality of information I accessed grew with that knowledge. At the very beginning of working on this expert system, I did not have an exact vision of what this expert system would be and how it would function. The more I worked on the project, the clearer I got a vision of what the expert system would look like. If I were to start developing the expert system again from the very beginning, I would use the experience and knowledge I gathered while working on this project to create a knowledge base with better, more accurate and more organized data.

Things I wish I could have done better are more consistent attributes, a clearer interface with logic diagrams and pin layouts, less program code, more consistent database table naming, and I would have taken chip data from no more than three different sources. There are also some chips that didn't have enough information available about them, so it would be ideal if I was able to try the chips live and verify the missing information myself.

The expert system seems not interactive enough, but that's why it's simple. To fix this while keeping it simple, I would expand the knowledge base to provide even more useful data about the selected chip and add more search methods. The search method used in this expert system is a tree search method, and I could add a search based on attribute elimination, or something similar. Additionally I would allow the user to access the chip logic and pinout directly via the chip serial number.

The expert system is fast, simple, easy to use and install. A person who knows integrated circuits would have an efficient way to check the pin layout and logic of the chip, without knowing which chip would exactly match him.

5. Literature

[1] Zogović, M. (2009). Istorija razvoja integrisanih kola. ETF Journal of Electrical Engineering, 18(1), 125-139.

[2] Close, K. J., Yarwood, J., Close, K. J., & Yarwood, J. (1979). Logic gates. Experimental Electronics for Students, 164-182.

[3] Catambay, B. (2001). The Pascal Programming Language. URL: http://pascalcentral. com/ppl/(pristupljeno: 16.7. 2017.).

[4] Bhosale, S. T., Patil, T., & Patil, P. (2015). Sqlite: Light database system. Int. J. Comput. Sci. Mob. Comput, 44(4), 882-885.

[5] The 74xx series integrated chip list document is available online at this link:

http://raven1.magix.net/List%20of%207400%20series%20integrated%20circuits.pdf