LABORATORY REPORT - DIGITAL ELECTRONIC LABORATORY N° 2

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1 Topic

Logic comparators.

2 Introduction

The logic comparators are important elements in design and analysis of digital circuits. This electronic components realizes different logic operations like: comparation of binary values, detection of coincidences and generation of signals of electronic systems. Its application is fundamental in digital systems, where there are processes in computers and other electronic devices.

The logic comparators has applications in different systems electronic like: counters, multiplexers and arithmetic units. This electronic components helps to comparate binary signals to determinate relations between them, in equality or amplitude and generate outputs, which can be used to active more parts of system. A example, in a Central Processing Unit, the comparators are important for evaluate different conditions in instructions or logic decisions.

In this practice, will explore the function and use of logic comparators to solve real problems. Will design a circuit, on base a simulation in Proteus, in where analyze the principal comparations like: equality, inequality, mayor or less. The principal objective is understand the operation of logic comparators and its practice implementation, with the use of real components, digital simulations and guides. Reinforce the concepts of logic digital is important for the student, for applications more advances in circuits and programmation in embed systems.

Will work with circuits, which implements simple comparations, using specific components like: logic gates, dipswitchs, resistors, LEDs and others. Will analyze truth tables and diagrams to verify the correct function and behavior of circuit.

3 Objectives

3.1 General Objective

- Design circuits with logic comparators, for its comprehension of its function and application in digital systems, with the use of tools of simulation and electronic components.

3.2 Specific Objectives

- Implement circuits with basic logic comparators, which realizes operations like equality, inequality and comparation of amplitudes, with the use of simulation tools.
- Verify the behavior of comparators with the use of truth tables, diagrams, and output signals.

4 Theoretical Foundation

Logical functions of a comparator Comparator circuits are combinational logics that analyze the magnitude of two n-bit binary numbers and also indicate which of them is greater or less or if there is perhaps similarity between them.

Similarly, a comparator can perform a comparison of two words such as A and B of N bits which are taken as an integer without a sign or which can indicate whether they are equal or if one is larger than the other in three outputs $A = B$, $A > B$ and $A < B$. One of these outputs could be at 1 and the others would be at 0 depending on the values of the inputs.

4.1 1-bit comparators

For one-bit inputs A and B, a comparator can be developed from the following table:

A	B	A = B	A > B	A < B
0	0	1	0	0
0	1	0	0	1
1	0	0	1	0
1	1	1	0	0

$(A = B) = \overline{A \oplus B} = \overline{A\,\overline{B} + \overline{A}\,B}$

$(A > B) = A\,\overline{B}$

$(A < B) = \overline{A}\,B$

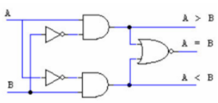
Figure 1: 1-bit logic functions. Source: Universidad-de-Cantabria (2020)

4.2 2-bit comparators

A comparator circuit can compare two binary inputs (A and B of n bits) that can indicate the relationship of equality or inequality that exists between them by means of logical functions that are called as "three logical flags" that conform to the relationships of A equal to B, A greater than B and A less than B.

Similarly, for inputs A and B, a comparator can be developed with the following table:

A	B	A = B	A > B	A < B
0	0	1	0	0
0	1	0	0	1
1	0	0	1	0
1	1	1	0	0



$(A = B) = \overline{A \oplus B} = \overline{A\,\overline{B} + \overline{A}\,B}$

$(A > B) = A\,\overline{B}$

$(A < B) = \overline{A}\,B$

Figure 2: 2-bit logic functions. Source: Universidad-de-Cantabria (2020)

4.3 4-bit comparator

It is an integrated circuit that can compare two 4-bit binary values A and B, which can have three outputs as an effect of the comparison which are $A > B$, $A < B$ and $A = B$. The outputs are based on the comparison made with the magnitudes of the input values.

One of the three outputs can have

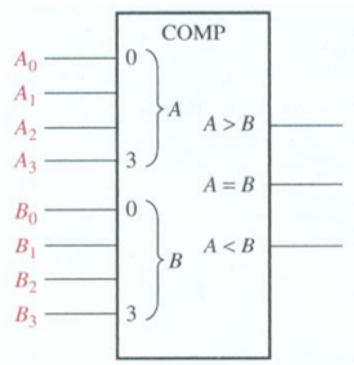


Figure 3: 4-bit logic comparator. Source: Universidad-de-Cantabria (2020)

- A greater than B $A > B$
- A equals B $A = B$
- A less than B $A < B$

4.4 Gates with comparator functions

- AND gate
  The AND gate generates the AND logic multiplication which means that the output is 1 if input A and input B are together in binary 1, otherwise the output is 0. MechatronicsLATAM (2021)
- OR gate
  It is also established as a Boolean sum, which means that whenever at least one of its inputs has a value equal to 1, the OR gate will deliver a logical 1 as output; however, if all the input variables have the value 0, its output result will be a logical 0.
- XOR gate
  logic operator that uses the exclusive OR; therefore, a true output (1/HIGH) results if one of the inputs to the gate is true and if both inputs are false (0/LOW) or if both are true its result will give a false output.

5 Representation of Binary Numbers

5.1 Binary Numbers

It is a numbering system in which numbers are displayed using only two digits, zero and one (0 and 1). It is one of the most widely used systems in computers, as a result of the fact that they work collectively with two voltage levels, for this reason its natural numbering scheme is the binary system (on 1 , off 0).

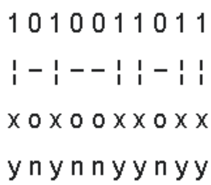


Figure 4: Representation of binary numbers. Source: Frank (2016)

According to the most commonly used interpretation, which is using Arabic numerals, binary numbers are often written using the symbols 0 and 1. Binary numbers are usually written with subscripts, prefixes or suffixes to indicate their base. The following notations are used:

- 100101 binary (explicit format declaration)
- 100101b (a suffix indicating binary format)
- 100101B (a suffix indicating binary format)
- bin 100101 (a prefix indicating binary format)
- 100101 2 (a subscript indicating base 2 (binary) notation)
- 100101 (a prefix denoting binary format)
- 0b100101 (a prefix indicating binary format, common in programming languages)

6 Conversion between binary and decimal

6.1 Decimal to binary

is divided by 2, which results in an integer that is divided again. between 2 , and so on repeatedly until the divided value is less than the divisor, 2. Therefore, when the number to be divided is 1, the definition can end.

```
131 dividido entre 2 da 65 con residuo igual a 1
 65 dividido entre 2 da 32 con residuo igual a 1
 32 dividido entre 2 da 16 con residuo igual a 0
 16 dividido entre 2 da 8 con residuo igual a 0
  8 dividido entre 2 da 4 con residuo igual a 0
  4 dividido entre 2 da 2 con residuo igual a 0
  2 dividido entre 2 da 1 con residuo igual a 0
                          el último cociente es 1
```

Figure 5: Division process. Frank (2016)

- Example: decimal number 131 is to be transformed into binary.

We order the remainders, from last to first: 10000011 in binary is 131.

7 Materials and Equipments

- Integrated Circuit 7408: This component realizes the operation of multiplication. When the all inputs are 1, the outputs will be 1.

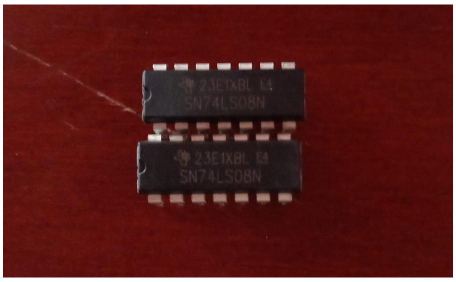


Figure 6: Integrated Circuit 7408 (AND). Source: Torres (2024)

- Integrated Circuit 7404: This component realizes the operation of inversion. When the input is 0, its output will be 1.

Figure 7: Integrated Circuit 7404 (NOT). Source: Torres (2024)

- Integrated Circuit 7432: This component realizes the operation of sum. When an input is 1, the output will be 1.

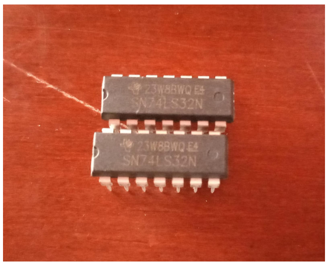


Figure 8: Integrated Circuit 7432 (OR). Source: Torres (2024)

- Integrated Circuit 7486: This component has a special operation for comparations.

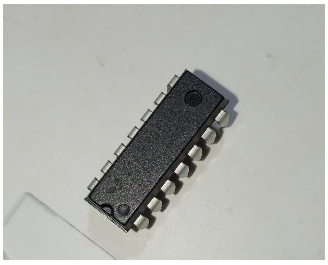


Figure 9: Integrated Circuit 7486 (XOR. Source: Torres (2024))

- Resistors of 10 K ohms and 220 ohms: These components control the current of the circuit.

Figure 10: Resistors of 10 K ohms. Source: Torres (2024)

Figure 11: Resistors of 220 ohms. Source: Torres (2024)

- LEDs: These components emit light.

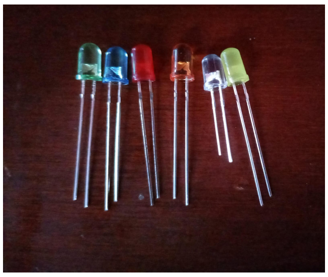


Figure 12: Leds of different colors. Source: Torres (2024)

- Cables: These components help to connect the whole circuit.

Figure 13: Cables for connection. Source: Torres (2024)

- Protoboard: This component help to connect the cables with the others electronic components.

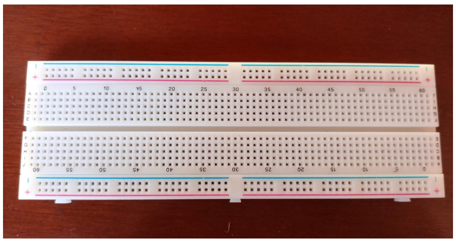


Figure 14: Protoboard. Source: Torres (2024)

- Charger of 5 Volts: This component is the voltage source of whole circuit.

Figure 15: Charger of 5 Volts. Source: Torres (2024)

7.1 Table of costs

Material	**Quantity**	**Unit Price**	**Total Price**
Protoboard	1	$ 5	$5
Integrated Circuit 7432	2	$0,70	$1,40
Integrated Circuit 7404	2	$0,70	$1,40
Integrated Circuit 7408	2	$0,80	$1,60
Integrated Circuit 7486	2	$1,50	$3,00
Dipswitch	2	$0,70	$1,40
Resistances	14	$0,10	$1,40
Leds	6	$0,10	$0,60
Charger of 5 Volts	1	$4,50	$4,50
Jumpers	26	$0,80	$1,60
Total			$21,90

Table 1: Results of materials. Source: Torres (2024)

8 Development

The activity of this practice is the following: Design a comparator of 2 bits with 16 inputs, realize a simulation with Proteus and Tinkercad, following the diagrams of blocks, guides and other sources. Assemble the respective circuit with specific electronic components and verify with its truth table.

8.1 Diagram of blocks

The inputs of bits (2 bits) will enter to a comparator, built with integrated circuits like 7486, 7404, 7432 and 7408. The outputs will represent the operations of comparation like equality, mayor or less and each output, will connect with Leds, to verify the correct function of circuit.

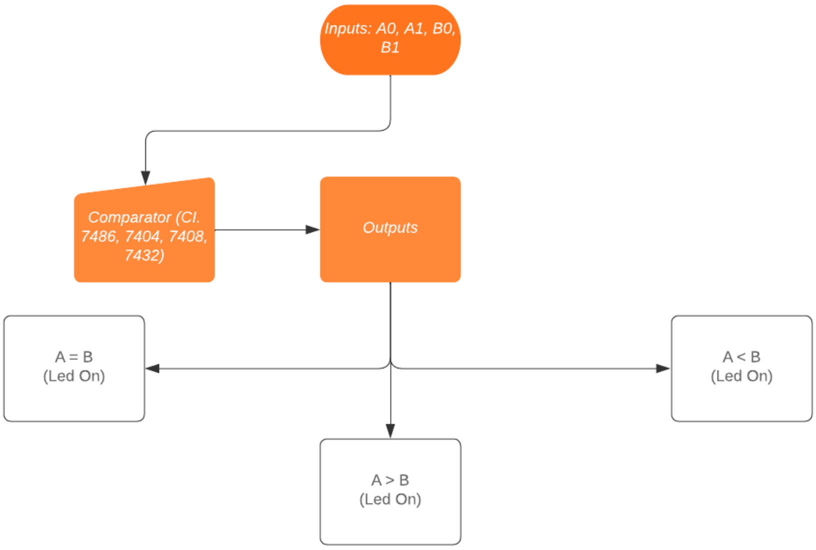


Figure 16: Diagram of blocks of comparator of 2 bits with 16 inputs

8.2 Simulation in Proteus

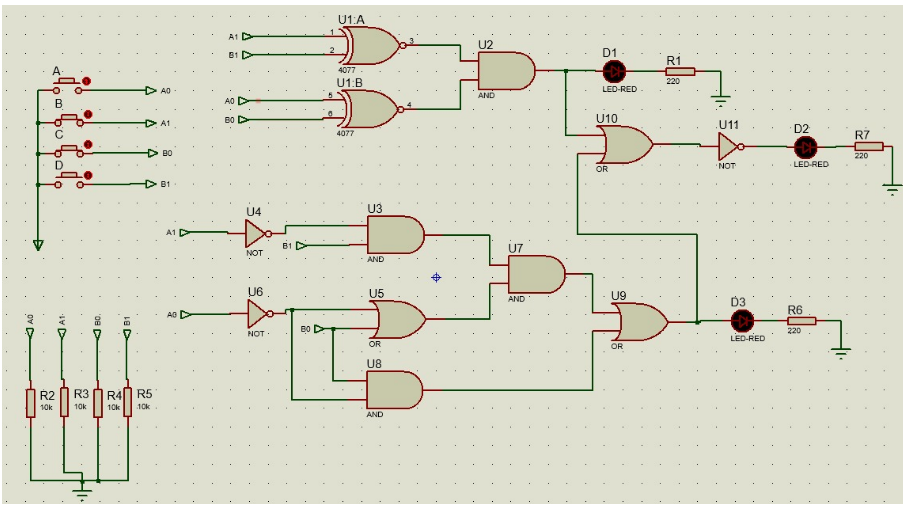


Figure 17: Diagram in Proteus of comparator of 2 bits with 16 inputs

8.3 Simulation in TinkerCad.

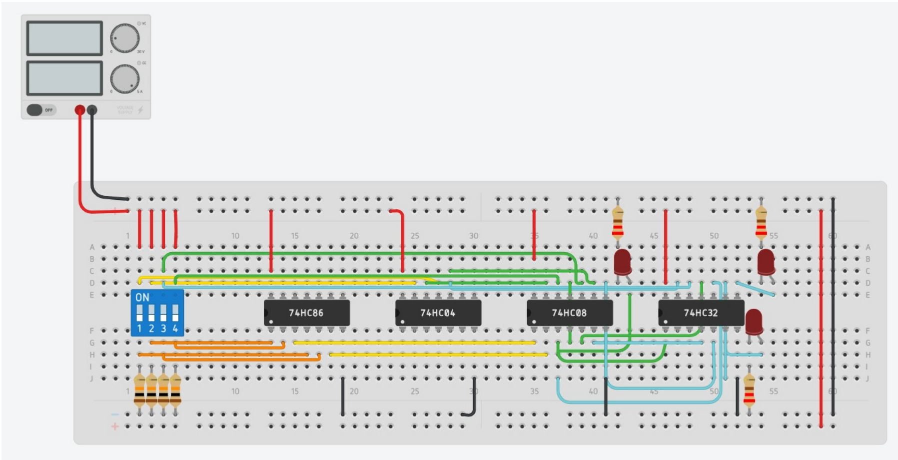


Figure 18: Simulation in TinkerCad of comparator of 2 bits with 16 inputs. Source: Torres (2024)

8.4 Assembled Circuit

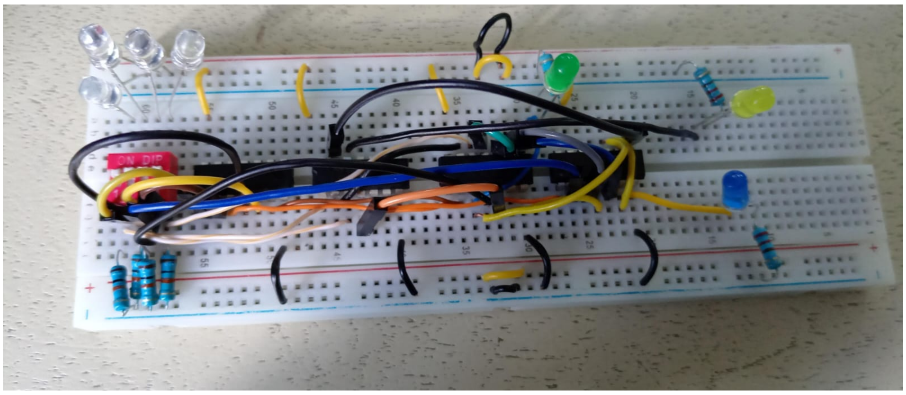


Figure 19: First assembled of circuit

In the assembled, used the mentioned electronic components, in where used four Leds as inputs, a dipswitch, resistors of 10 K ohms for configuration Pull-Down, cables of connection, four logic gates: 7486 (XOR), 7404 (NOT), 7408 (AND) and 7432 (OR) and more Leds for outputs.

Connections:

1. Connect the configuration Pull-Down: The dipswitch is connected in the protoboard, in positive voltage, the input will be connected (Leds of color white), and four resistors of 10 K ohms will be connected in the negative voltage.
2. Connect the inputs: There are four inputs (4 bits) named A0, A1, B0, B1.
3. The inputs A1 and B1 will be connected in two inputs of a gate XOR (7486) and the inputs A0 and B0 will be connected in two inputs of the other gate XOR, the inputs of these gates XOR will be connected to two inputs of gate AND (7408) and its output will be the input of operation: **equality**. This output will be connected to Led and this component will be connected to resistance to ground.
4. The input of A1 will be connected to a gate NOT (7404) and its output will be connected with B1 to two inputs of a gate AND and its output will be connected to other gate AND.
5. The input of A0 will be connected to other gate NOT and its output will be connected with B0 to two inputs of other gate OR (7432) and its output will be connected to gate AND of A1 (inverse) and B1.
6. The output of A1 (inverse) will be connected with B0 to other gate AND and its output will be connected with output of AND (of output OR and the second AND) to a gate OR and its output will be the output of operaion: **less**. This output will be connected to Led and this component will be connected to resistance to ground,
7. For the operation **mayor**, the output of mentioned gate OR and the output of AND (later of gate XOR)

will be connected to other gate OR and its output will be connected to a gate NOT and this output will have the operation mayor. This output will be connected to a resistance to ground,

9 Results and discussion

For the exercise, there was some problems with the correct function:

- Just the Led of Less turned on.
- Some inputs didn't operate of correct way.
- Some gates didn't operate of correct way in proposal order.

Solutions and corrections:
For correct function, realized the next changes:

- Change of cables: There were a cables with failures and incorrect ways of connection, these problems didn't allow that the current pass of fluid way.
- Change of order of gates: The proposal order of gates wasn't the correct, the original circuit had this order:
  Gate XOR - Gate NOT - Gate AND - Gate OR
  The new order is:
  Gate AND - Gate OR - Gate NOT - Gate XOR
  The correct assembled is:

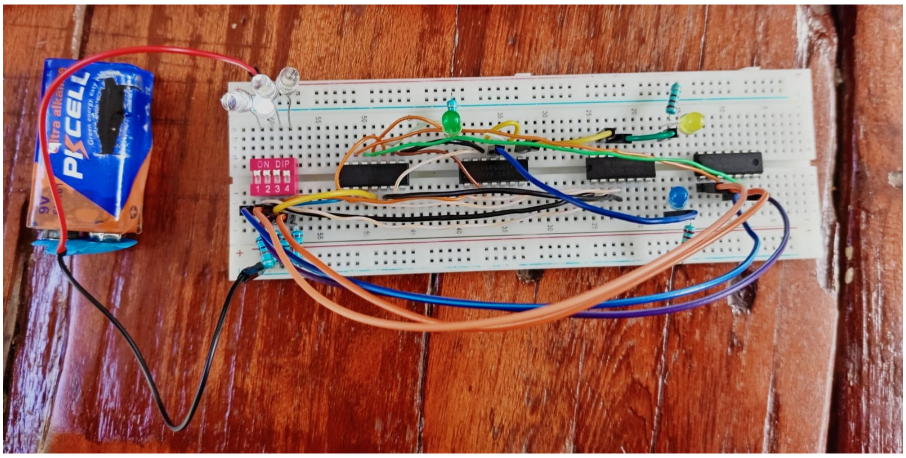


Figure 20: Correct assembled of circuit. Source: Torres (2024)

Results:
With the correct assembled, created the truth table for its verification:

A0	A1	B0	B1	A = B	$A > B$	$A < B$
0	0	0	0	1	0	0
0	0	0	1	0	0	1
0	0	1	0	0	0	1
0	0	1	1	0	0	1
0	1	0	0	0	1	0
0	1	0	1	1	0	0
0	1	1	0	0	0	1
0	1	1	1	0	0	1
1	0	0	0	0	1	0
1	0	0	1	0	1	0
1	0	1	0	1	0	0
1	0	1	1	0	0	1
1	1	0	0	0	1	0
1	1	0	1	0	1	0
1	1	1	0	0	1	0
1	1	1	1	1	0	0

Table 2: Results of exercise. Source: Torres (2024)

A 1 represent the active result, the Led will be turned on in each case of table.

10 Conclusions and recommendations

Conclusions

- The logic comparators are important components in digital systems, are used to compare two values and determinate operations like mayor, less or equality. Has been demonstrated the optimization of logic gates for comparation and its precision in decisions in circuits and electronic systems. Its correct function is important to evaluate conditions and generate binary outputs.
- The importance of using logic comparators in the laboratory highlights the importance of understanding the theory and specifications of the components. Analysis and simulation are essential to be able to carry out the practice in a better way.
- It was understood that logic comparators are versatile in conversions of analog to digital systems, being essential in sensors or circuits that involve a logical function.
- Some factors were observed, such as a bad connection that can lead to a certain error in the operation of the circuit, giving erroneous results in the truth table.

Recommendations

- Verify the correct function of each gate to use, can do it with previous simulations, tests, correct connections and diagrams. Chose a correct order for gates, depending its operation.
- Review the content of the topic beforehand to be able to carry out the practice successfully.
- Design the circuit in software to understand the behavior and thus find possible errors to avoid a possible risk to the components.
- It is essential to use a power supply that respects the values required for the comparator.
- Analyze the details sheet of the integrated circuits to better understand the operation and how the correct connection is in the input and output pins of the integrated circuit.

References

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