Modular logic gate emulator for on-line laboratory

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Abstract. The pandemic year represented a challenging time for educators, a time where the classical way of teaching change from contact to remote learning. While contact lectures can be replaced by videos or video conferences, the laboratory can be replaced with simulations or by instructing the students to buy and build ad hoc systems by supplying the essential instructions. A remote assisted experiment requires to be conducted safely, the components readily available, and possibly low-cost. Technical High Schools and universities teach the logic gates and how to assemble a circuit to solve a specific function. Several licensed and free software are available for simulation, and for a hypothetical real experiment, it is necessary to supply the students with several components and tools. This project proposes performing several digital electronics experiments by using a building block, a logic gate emulator. This device can be modified according to the teacher's needs and sent to the students to do remote experiments.

1. Introduction

During the pandemic year, the teaching activities move from contact to online, and what was established in the past years suddenly change. As videos can replace the contact lessons, the laboratory activity ensures that students are familiar with the experimental tools. The simulation software does not guarantee that students face the real challenge present in a natural practical environment. The students can replicate the mechanic's experiments using fortune components, but more complex activities, such as electronics, can be challenging. In this manuscript, a low-cost method is proposed to experiment with digital electronics for high school and potentially for tertiary institutions. Minimal laboratory equipment for digital electronics requires one breadboard, one logic probe, several digital IC, switches and one power supply[1]. Provides the students with the components cited above can result in costly and dangerous for less-skilled students. The proposed board only requires a smartphone power supply and a set of jumpers. The lecturer can program the board according to his needs and send the students two or more boards. A datasheet designed by the lecturer is provided for a specific board. The board can emulate up to 32 digital functions.

2. Board description

A minimal combinational digital electronic experiment requires integrated circuits, switches to emulate input and a logic probe. The board is represented in Figure 1 embed what is necessary for an electronic experiment. Through the picture is possible to identify the block of the board. The core of the boar is the EEPROM AT28C64b [1], which contains the logic function to be emulated. A detailed description of the components of the board is give here below:

[1] The student can use the power supply improperly.

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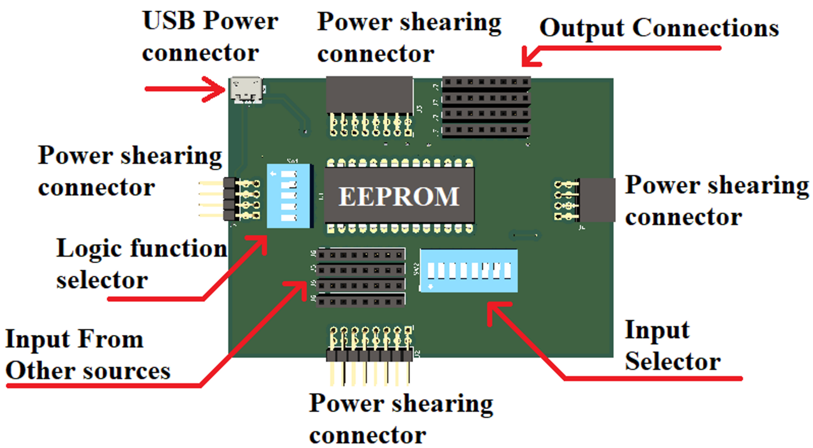

Figure 1. On the picture are represented the main accessible parts of the board. EEprom can be removed or placed into the board through a Dual In-line Package (DIP) socket. An integrated circuit buffer is placed on the back of the board to ensure an appropriate fan-out.

- USB Power connector: the power connector is a USB standard. This connector can be easily substitute with another.
- Output Connections: the female pin header is an 8 bit output port. The Most Significative Bit (MSB) is the firt bit on the left. The other pin header in parallel serves to connect a single bit to other 3 node of the circuit. Input and Output connections can be done by the Jumper leads 40W, Male- Male.
- Input selector port: If the user needs to control the input manually through the switches, the pin-header must be disconnected. If the output of another logic device must control the input, the switches must be set at logic level zero by placing the switch in the off position wich is normally indicated on the body of the component. The first bit starts from the left of the DIP switches, while in the input pin header, the Most Significative Bit starts from the right of the female pin header[2].
- Logic Function Selector: the switches named selector are used to define the programmed logic function to used. For our purposes only the switches can manually define the logic function, but the reader can modify the schematic by placing a pin header in parallel to the switch, to change the logic function by any digital external device.
- Power shearing connector: these pins only serve to connect another board and share the power. This king of configuration permits to create a complex circuit by using only one power point. One of the possible configuration is represented in Figure 2.

3. Programmer

The system was thought to allow the lecturer to design a specific experiment for the students. In particular, the lecturer must be able to program the board with a series of logic functions. In this section, the programmer used will be discussed. The programmer scheme is depicted in Figure 3. For simplicity, the realisation of the programmer can be designed as an Arduino shield. In our case, an Arduino Uno was used since it can be directly applied to the socket [2]. In our case, an Arduino Uno was used since it can be directly applied to the socket. The Arduino Uno is based on the microcontroller Atmega328 and does not have many digital pins

[2] This was decide to simplify the PCB of the board.

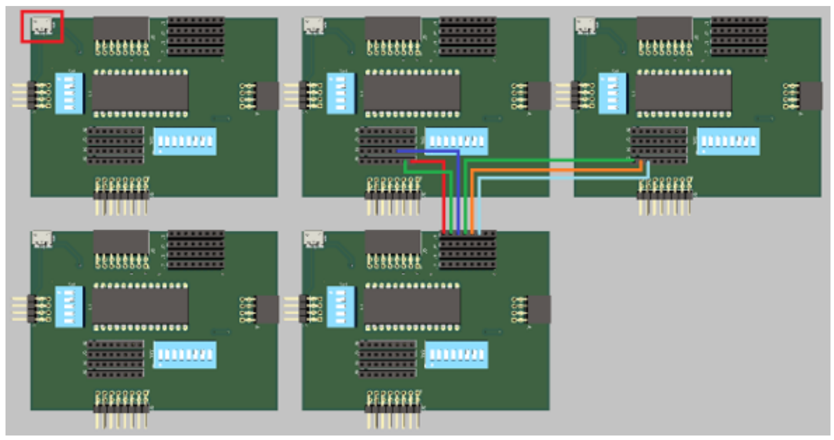

Figure 2. Possible connection between boards.

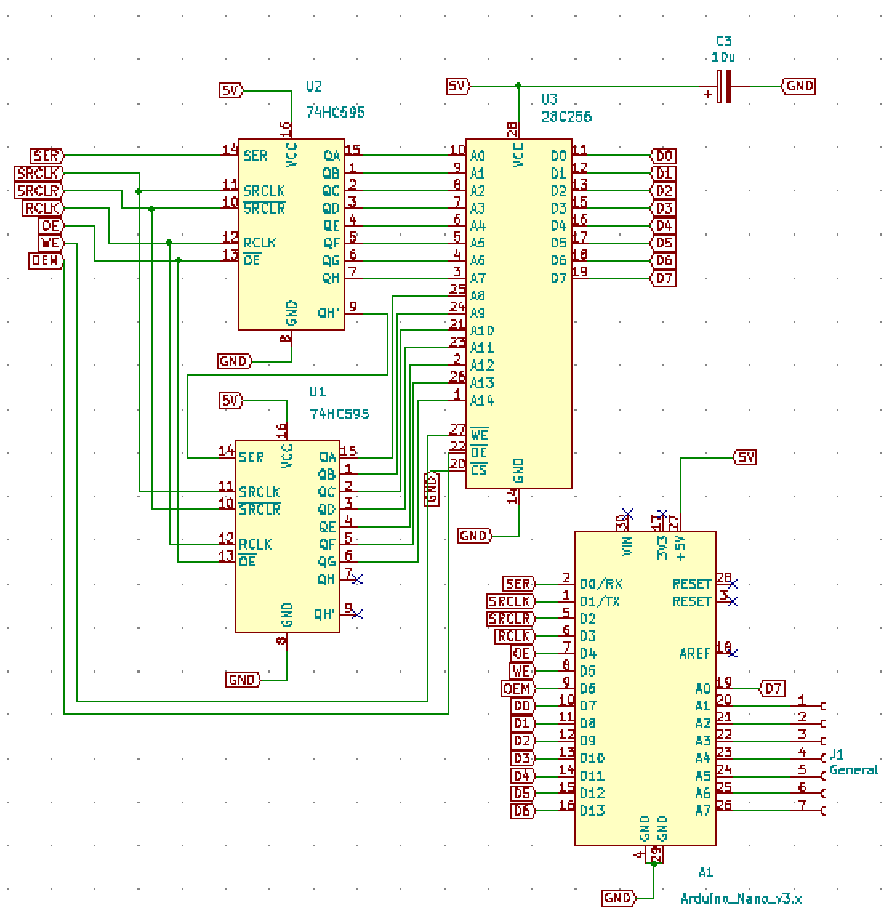

Figure 3. Scheme of the programmer.

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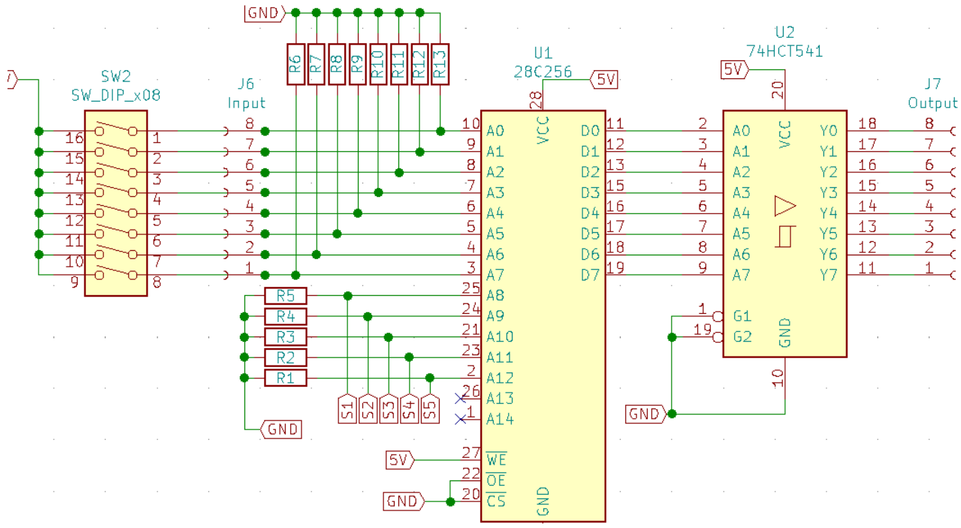

Figure 4. Universal board

to program the memory [3]. To program the memory is necessary to design a simple serial to parallel converter with the IC 74hc595[4]. The connector J1 is connected to the Digital to Analog Converter (DAC) of Arduino in case the user wants to save EEPROM an analog signal in the memory [3].

4. The board

The board's purpose is to prepare a specific experiment for digital electronics and send the programmed boards to the students. By a video conference the lecturer can teach the students how to assemble the circuit emulating an in-person laboratory experience. This philosophy follows what was done in a similar project to teach how robotic harm works[5]. The board is represented in Figure 4. The switch SW2 is connected to a pull down resistors and in parallel to the pin-header. The left side of the DIP switch SW2 is connected to 5 V. This particular configuration is used to set the input by the switch or by mean of an external signal. The Fan out of the memory may not be sufficient to drive the input of other universal boards, and the buffer 74HCT541 is used [6]. To monitor the output it is possible connect a string of LED, connected to the output pin-header.

5. Testing and limitation

In this section we expose the limit of the board by using a latch S-R as example. This circuit consists of two NAND ports closed in a loop as represented in Figure 5. These two ports are programmed in one board. The output *O1* is physically connected to the input *I3*, while the output *O2* is connected to the input *I2*. The latch S-R in this test is used as debouching circuit, and the change from 5V to 0V of the output should follows a step function without intermediate oscillations. By changing the input state of *I1* and *I4*, the output *O1* begins to oscillate and the circuit clearly does not work. For a functional debouching circuit it is necessary to use no less than two boards, in other words for each NAND gate a separate board must be used. The instability is reported in Figure 5. If for the same circuit two boards are used, the debouching circuit perfectly work with no output oscillations, as represented in Figure 6.

[3] This can be useful if the lecturer wants to do an experiment with a primitive Direct Digital Synthesis (DDS) function generator.

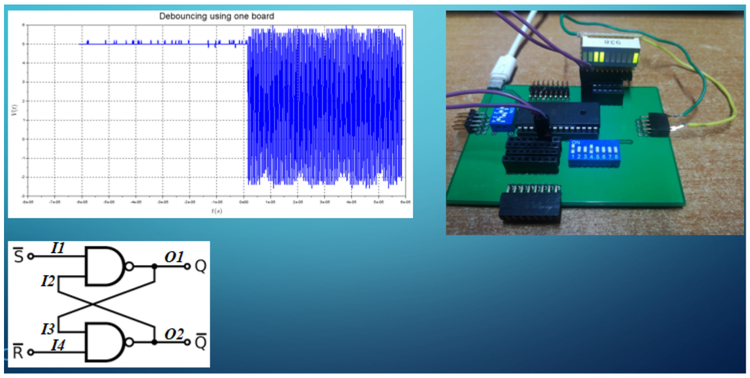

Figure 5. debounch circuit with only one board. On the bottom left of the Figure is represented the latch S-R. On the top left of the Figure is presented the output of the circuit.

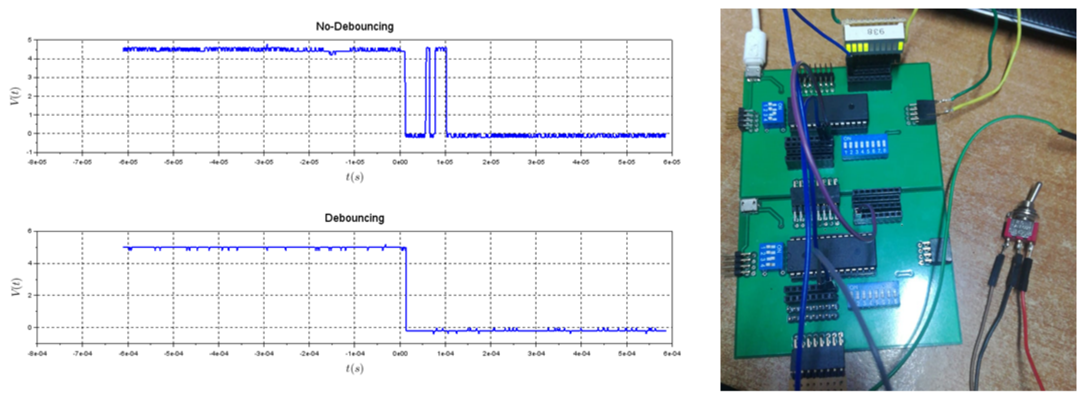

Figure 6. Debounce circuit using two different boards. The plot on the top represents the typical ON-OFF switch response, while the plot on the bottom represent the response of the Latch S-R.

5.1. Some example of logic function

The power of the board is given by the possibility to emulate any combinational logic function, previously programmed by the lecturer or the students. The prototype shown in this manuscript can emulate a 7-segment display driver, full-adder and all the basic logic functions, for example: the gate NOT, AND, XOR and OR. Many other functions can be implemented but, as was stated previously, the loops in the same board must be avoided.

6. Conclusion

This board aims to be an alternative system for laboratory activity in the field of digital electronics. Each board can emulate up to 32 digital logic functions programmed ad-hoc from the lecturer. Two or more boards can be given to the students and experiments can be monitored on-line by the lecturer or teacher. The structure of the board permits 8 inputs and 8 output, which permits to emulate more than one logic gate in a single board, but no closed-loops are allowed on a single board as shown in section 5. Approximately the cost for one board is 110 ZAR and is easy to repair. Using this system the students will learn how to read a data sheet, how a memory works, and how several parts of the circuit should be connected.

Acknowledgements
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URL `https:assets.nexperia.comdocumentsdata-sheet74HC_HCT541.pdf`