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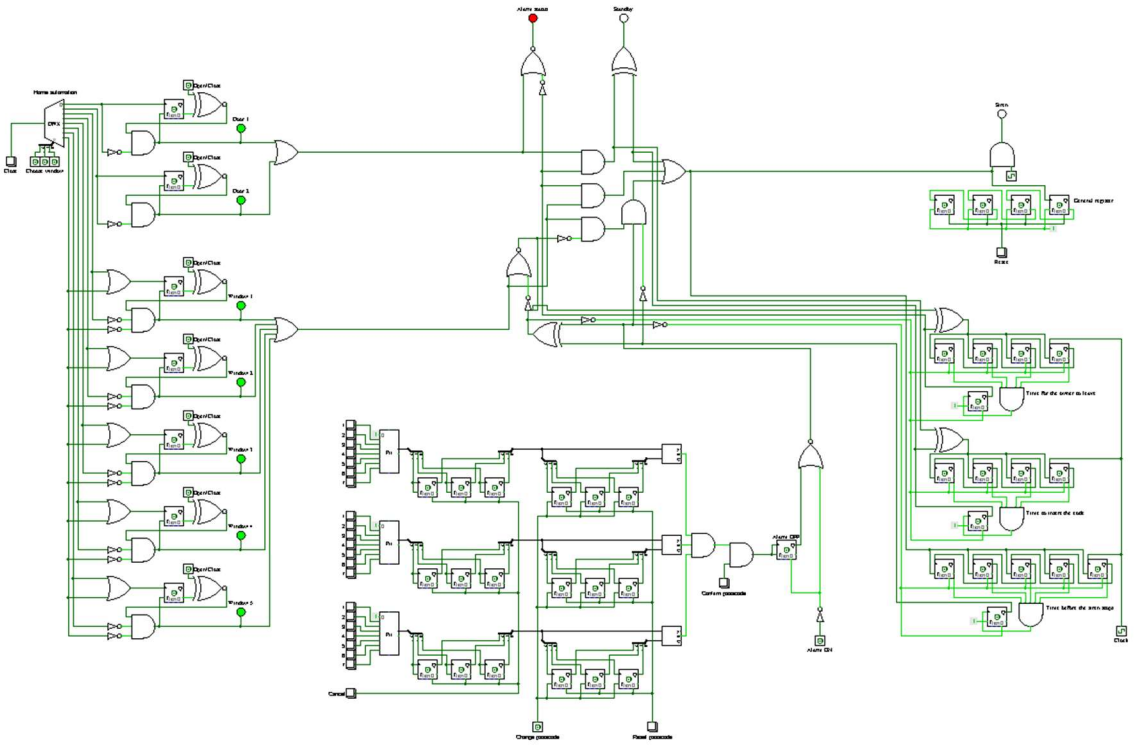
HOUSE ALARM



Abstract

For this project we decided to design a house alarm system. We chose this idea mainly for the possibility to expand it as much as one wants.

The project includes five main parts, each having different functions and different features for the owner to use. The home automation allows the user to close all the doors and windows in the house with the press of a few buttons. The numeric keypad is used to set, and later insert, a passcode that deactivates the alarm when the owner comes home: this makes it very difficult for a potential burglar to avoid the ringing of the siren. There are also three counters used to keep the time for the functioning of the whole circuit. Moreover, there is the siren part that activates if several conditions are met. All these part are then connected together in the main body.

One of the strong points of the project is that it covers all the possible cases for the everyday life, but also for a burglar to try and break into the house (e.g. the owner leaves the door open, someone opens a window, someone opens a door,…).

Our future goal would be to build the system for a real-life application.

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Introduction

Inspiration

There are several reasons why we chose this topic for our project.

The first one, the one that gave us the initial idea, is related to our personal life. Before coming to China, Vittorio was helping his father to build their new house and got really interested in the electronic parts: one of this part was the house alarm, but he hasn't had the time to work on it because he had to leave. For this reason he still had this idea in mind and thought it would be nice to use it for our project.

Then we started thinking about how it could be done and we realized that this topic would be of the right amount of difficulty: not too simple, but also doable for a couple of students at the second year.

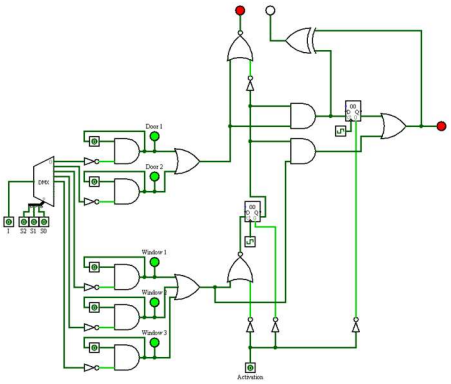
However, the feature that struck us the most about this idea was the possibility to expand the project as much as one wants. A house security system can be composed by many different additional features and it's possible to include any of them in the project. For example in our case we decided to include a home automation and a numeric keypad to turn off the alarm. This allowed us to make the project as big and complicated as we wanted, with the possibility to always expand it further if we had any good idea.

Lastly, we wanted to create a system that changes its behavior depending on different types of inputs. A house alarm system is perfect for this as there can be many different case scenarios happening around a house. In particular, we considered five.

Methodology

To create this project, first we started by designing the most basic part: connecting the opening of a door or a window to a siren. To do so, we first designed a working circuit on a piece of paper, then we reduced it using K-maps and finally we recreated it on the simulation program.

We tried reducing the circuit as much as possible to make it simpler to understand and, in the eventuality of a physical transposition in a real-life scenario, to make it cheaper in terms of materials used.



Then, with the same methodology, we added the home automation part and the numeric keypad part.

Also, while we were preparing for the final exam of the curse, we became more and more familiar with certain type of structures (e.g. counters) and we managed to implement them in a better and more efficient way.

Equipment

To carry out this project we used several sources, from which we got ideas and knowledge, and a program for the simulation.

The first one was the book “Verilog – Digital Design: With an Introduction to the Verilog HDL” by M. Morris Mano and Michael D. Ciletti, from which me took most of our theoretical knowledge. Together with this book we used our own notes from class.

Also, we got some information from the internet, comparing our ideas with the logic circuits of some existing house alarms and sharpening our knowledge about some logical components and how to use them properly.

For the simulation we used a program called “Logisim”, with a very useful online guide, that we found very practical to design the circuit we had in mind and simulate its working.

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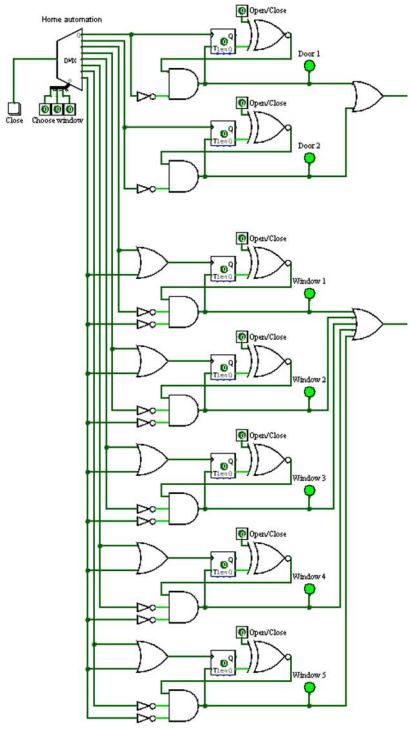
Main parts

Our project can be divided in 5 parts: the home automation, the numeric keypad, the three counters, the siren and general register and, at the end, the main body.

Home automation



First of all we will start to explain the structure of the home automation.

We designed 5 windows and 2 doors. They are all connected to a demultiplexer (DEMUX) with 3 inputs and 8 outputs. The 8 outputs represent the possibility to choose and close each single window and door or even all the windows at the same time. The selection input part of DEMUX is made by three pins: the owner inserts a binary number using the pins in order to decide which structure to close and then he pushes the button *Close* to enable the closure.

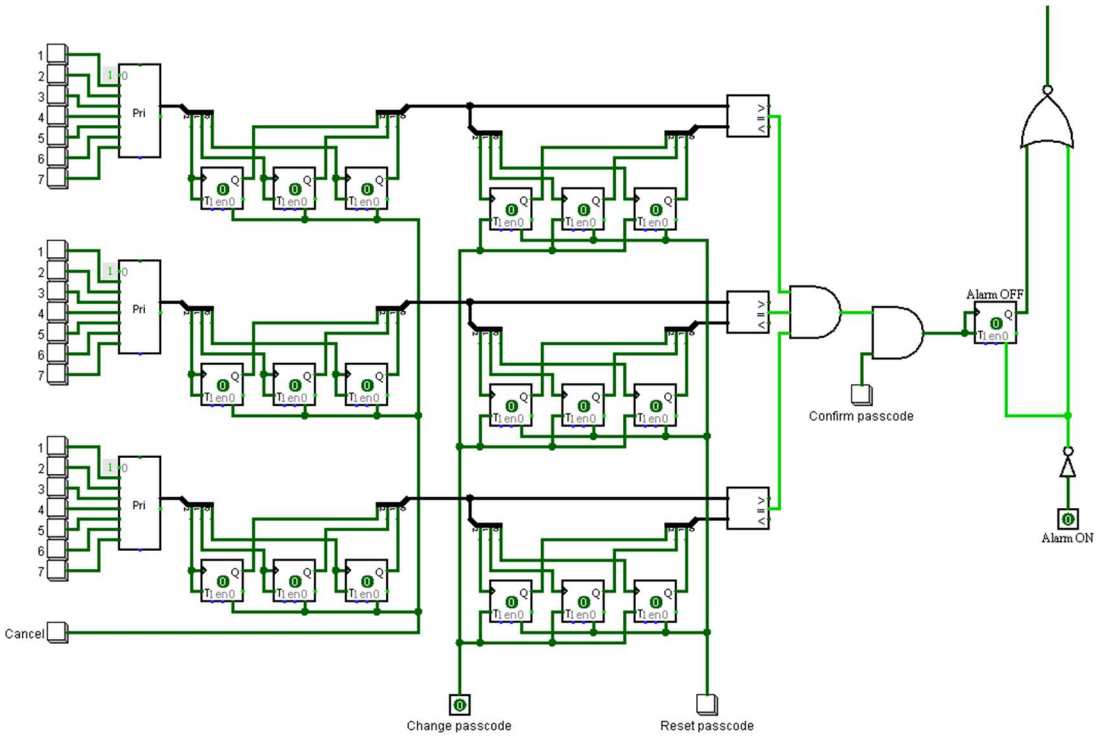
Doors and windows are designed in same way, exception made for just one feature: it's possible to close all the window at the same time while this can't be done with the doors. We thought that it wouldn't be practical to close all the doors at the same time because the owner would remain locked inside the house. So each door and window is composed by a T flip-flop, a XNOR gate, a switch (this represents the manual operation of opening and closing), an OR

gate, an AND gate and a NOT gate (in the case of the windows there are two of them because they are connected in two different ways to the DEMUX).

The LED color symbolizes whether the structures are closed (green) or open (red). The LED is the output of an AND gate, that has two inputs: the complemented connections with the DEMUX (one in case of doors and two in case of windows) and the output of the XNOR gate. the XNOR gate's inputs are the switch and the complement of the T-FF which is connected directly to the DEMUX. So, for example, if the switch is turned on (the door or window is open and the LED is red) and the owner enables the DEMUX, the complement of the T-FF is triggered and the output of the XNOR becomes zero. If it's zero, also the output of the AND gate is zero, so the led becomes green and the door or window is closed.

The clock pulse of all the T-FFs (trigger: rising edge) is the output of the corresponding connection to the DEMUX, while the T-FF input is represented by the output of the AND gate. In fact when the button of the DEMUX is pressed to change state, the clock pulse triggers the flipflop and changes its output. This now changes the output of XNOR gate that then modifies the output of the AND gate. All the windows and all the doors are connected with each other with an OR gate whose output is then connected to the main body.

Numeric keypad



The numeric keypad is used by the owner in order to activate and deactivate the alarm when he comes inside the house.

It is formed by T-FFs, two AND gates, a NOR gate, three encoders, three comparators (one for each digit of the passcode that the owner has to insert), some input buttons and one switch.

In order to turn the alarm on there is a switch connected to the NOR gate, while the turn-off is activated by the passcode.

With the numeric keypad the owner can set the initial passcode and a system of three T-FFs memorize it. Eventually with the *Reset passcode* button it's possible to change the memorized passcode.

The comparators compare the memorized passcode with the one inserted each time: if they are the same, by pressing the *Confirm passcode* button the output of the following AND gate becomes one. The latter is connected to a T-FF whose "no change" output is an input for the NOR gate: when the alarm is switched on and the passcode is inserted correctly the NOR gate output becomes 0 and turns off the system resetting the counters and eventually turning off the siren.

The structure to insert each digit of the passcode is composed by a primary encoder with 8 inputs (in our design each digit can range from 0 to 7 for simplicity) and one output. The input D0 is always on as in a priority encoder it is necessary to always have an active input in order to avoid an undetermined situation. Because it is a priority encoder, any other number has priority over D0 so it gets eventually inserted.

Looking at the figure, there are two flip-flop cascades: the second one is needed to memorize the fixed passcode while the first memorizes the digits inserted each time. The second cascade has a switch connected to its T input that makes it possible to modify the content of the memorized passcode. Both flip-flop systems have their own reset button.

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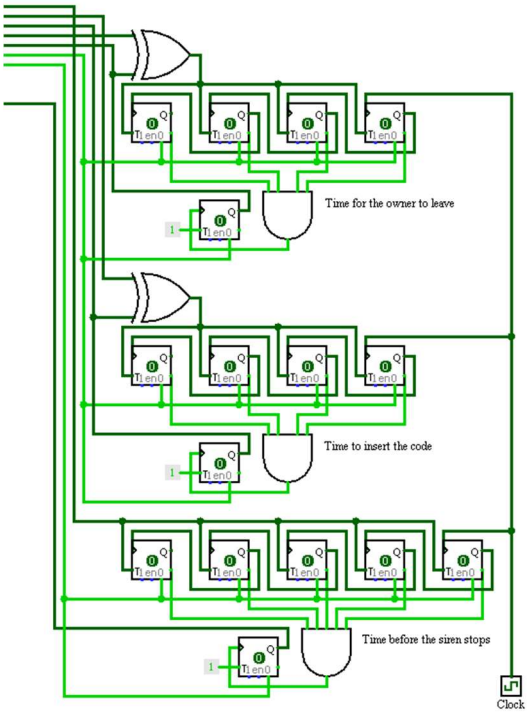
Counters



The projects also includes three ripple down-counters: two are identical, while the third one has a slightly different structure.

The first two counters are formed by four T-FFs in cascade, so their maximum value is 15. They are down-counters because each T-FF has its clock input connected to the “no change” output of the previous one. Each counter is made of the T-FFs, one AND gate, one XOR gate and another T-FF that stores the information of the counter reaching 0.

All the T-FF of the cascade have their T input connected to the output of the XOR gate which has two inputs: the first comes from the main body while the second comes from the “no change” output of the storage T-FF. In this way the counters stop counting when the output of the XOR gate becomes zero due to the output of the storage T-FF becoming one. The clock input of this flip-flop is the output of the AND gate whose inputs are the complemented output of each T-FF of the cascade. Instead, the T input of the storage flip-flop is kept at logic 1. The T output of the storage T-FF is also connected to the main body.

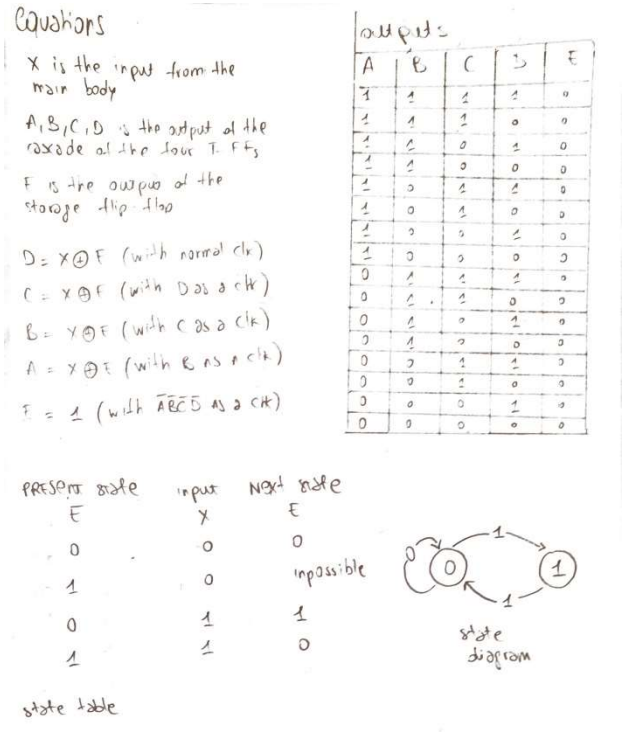
The third counter is a bit different from the other two: there are five flip-flops and there isn’t the XOR gate. The reason for this is that the input of the first T-FF comes directly from the siren. Having one T-FF more than the other counters, in this case it’s possible to count down from 31 instead of 15. This

choice was made to symbolize that the time for the third counter should be significantly greater than the other two.

The reset of all flip-flops of the counters are connected to the switching on and off of the alarm: when the alarm is turned on, the first counter starts, when it's turned off, all counters are deactivated.

All counters are triggered in rising edge by the same clock that is connected to the first T-FF of each structure.

From the following state diagram of the first counter we can deduce that, as soon as the output of the storage T-FF becomes one, the system goes back to the inactive state. Therefore the counter stops counting as soon as it reaches 0.



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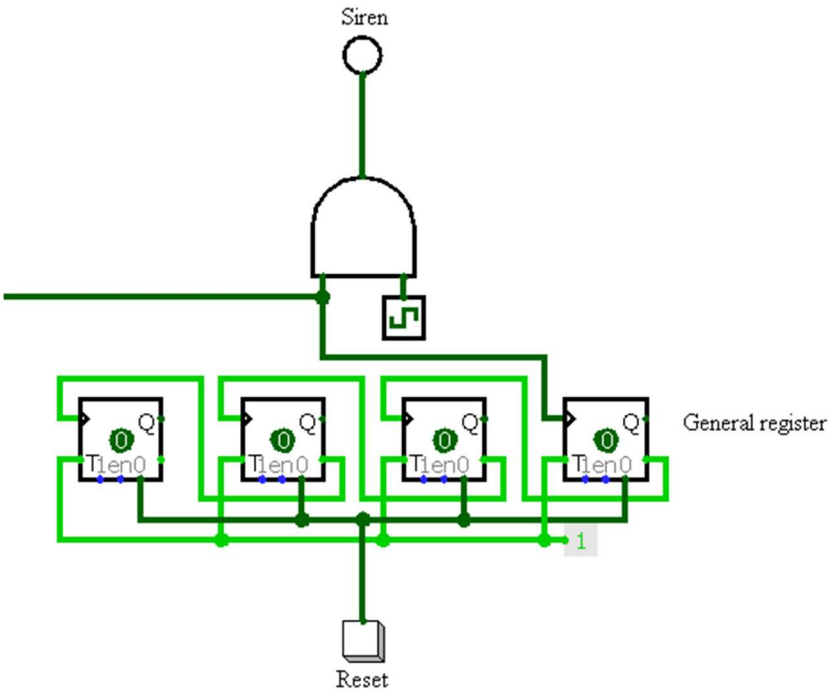
Siren and general register



The structure of the siren and of the general register is very simple. When the input from the main body becomes one, due to AND gate, the siren starts ringing. The presence of a clock connected to the AND gate is used in order to create the effect of flashing in intermittence.

This input is also connected to the first T-FF of the general register, which is connected in cascade with other three. This creates a register called asynchronous counter that can count from 0 to 15. The presence of the reset button allows the owner to decide when to restart the register. It has to be noticed that, compared to the other counters, this register is an up-counter. In fact the complement output of each flip-flop is connected to the clock input of the next flip-flop, while all T inputs are kept at logic 1.

Moreover, with the activation of the siren, comes an automatic notification to the nearest police station and, if needed, an automatic message to the owner's cellphone.

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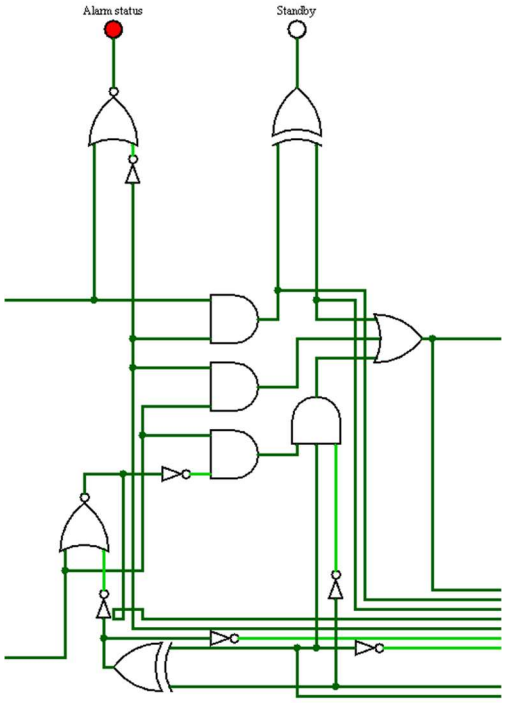
Main body



The main body is the part where all the components are connected to each other. It is composed by two led, two XOR gate, two NOR gate, four AND gate and one OR gate.

On the left, there is the connection with the doors at the top and the one with the windows at the bottom.

In the lower part the information about the switch on and off of the alarm arrives.

In the upright section, the main body sends the activation input to the siren while in the bottom right corner there are the wires that connect the main body to the counters.

Above the main part there are two LEDs that state the activation or not activation of the alarm (on the left) and the standby situation (on the right) that is triggered by the owner opening the door when he returns home: he has 15 seconds to insert the right passcode to disable the alarm.

To design and reduce the connection from the siren to all the inputs we used a K-map whose result was the following:

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SIREN (OR) = AND 3 · output counter 2 + AND 2 + AND 4

AND 3 : NOR · output counter 1 · output doors

AND 2 : NOR · output counter 1 · output windows

AND 4 : AND 1 · output from keypad · $\overline{\text{output from counter 3}}$

AND 1 : $\overline{\text{NOR}}$ · output windows

NOR : $\overline{\text{output windows + XOR}}$

XOR : output keypad ⊕ output from counter 3

=> SIREN (OR) : $\overline{\text{output windows + (output keypad ⊕ output counter 3)}}$ ·
· output counter 1 · output doors · output counter 2 +
+ $\overline{\text{output windows + (output keypad ⊕ output counter 3)}}$ ·
· output counter 1 · output windows +
+ output windows + $\overline{\text{(output keypad ⊕ output counter 3)}}$ ·
· output windows · output keypad · $\overline{\text{output counter 3}}$

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Functioning

As previously stated, one of our main goals was to analyze and cover several different situations and case scenarios depending on what the inputs from the outside world are. For this reason, in order to explain the functioning of this circuit is necessary to analyze five different cases, together with the initial settings and the working principle of the home automation.

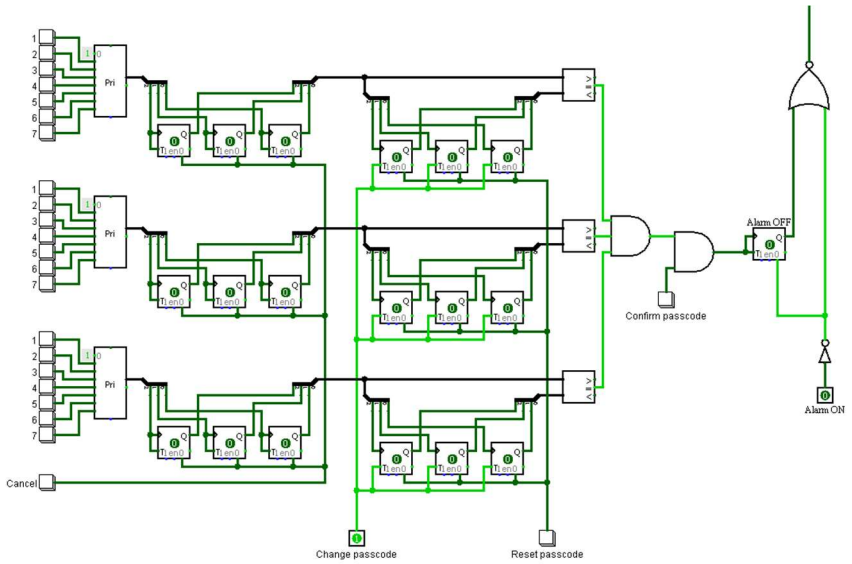
Initial setting

Before starting to analyze the various situations, it is necessary to create an initial setting for the alarm. It is not required to repeat this setting every time the user wants the alarm to turn on, but only initially or, it is advisable, every once in a while in order to improve the safety of the system.

This procedure basically consists of setting a passcode for the alarm turn-off and resetting the general register.

The passcode can be set with the numeric keypad.

First the *Change passcode* switch must be turn on.

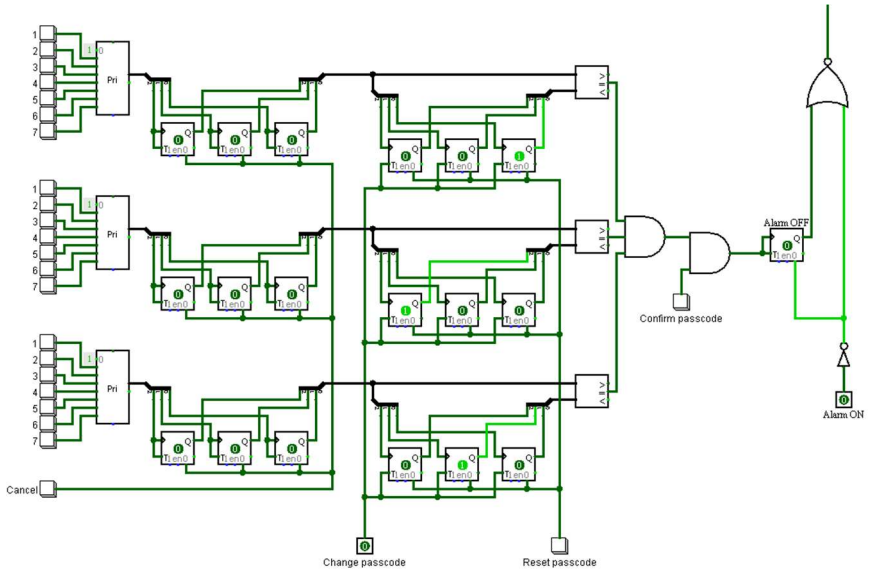


Then it's possible to select the 3-digit code by selecting the numbers with the buttons on the left (for number 0 no button should be pressed).

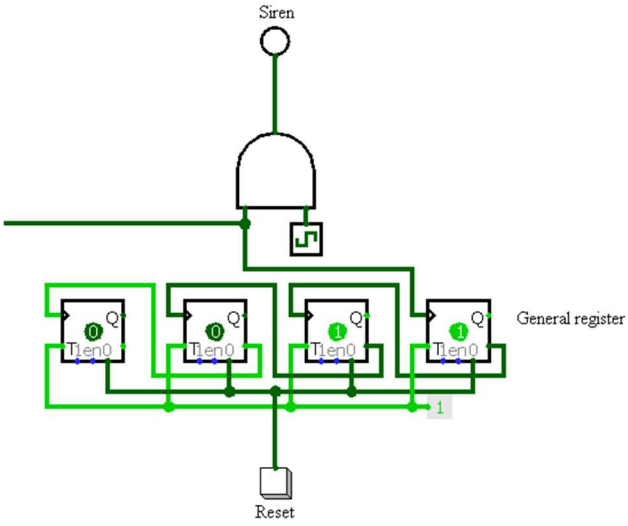
Then turn off the *Change passcode* switch.

Let's assume the code "142" has been set.

The final situation looks like this.



The second operation needed for the initial setting is the reset of the general register so that the owner can calculate how many times the alarm went off during a certain period of time.



To do so, it is just necessary to press the *Reset* button at the bottom of the register.

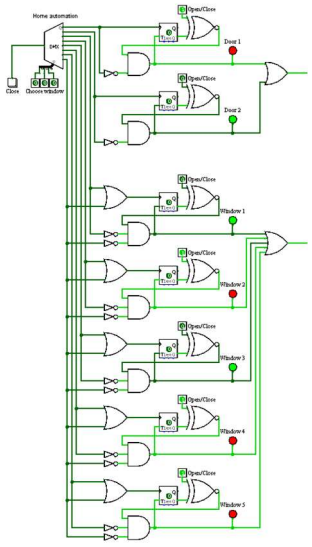
The system is now set and it is possible to enter the daily routine and analyze different case scenarios.

Home automation

One of the main parts of our project is the home automation that allows the user to automatically close the windows and lock the doors from a single automated interface.

Of course the doors and the window can be opened and closed manually as well.

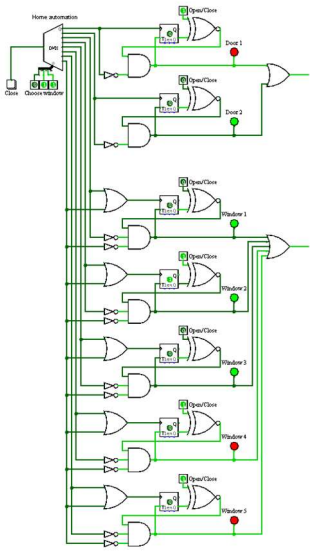
Let's assume a situation where one door and three windows are open.



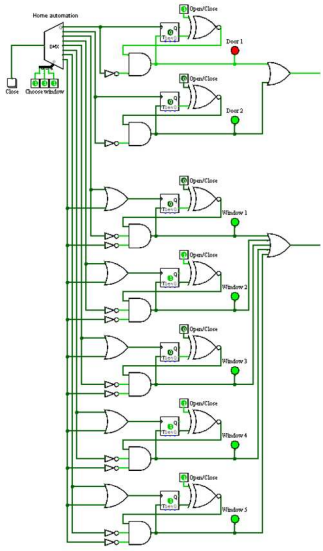
In order to close the windows with the home automation there are two possibilities: either close them singularly or close all the windows at the same time.

Each door and window has a numeric code:
0 – *Door 1*
1 – *Door 2*
2 – *Window 1*
3 – *Window 2*
4 – *Window 3*
5 – *Window 4*
6 – *Window 5*
7 – All windows

To close a window singularly it's necessary to input the corresponding code in binary in the keypad and then press the *Close* button. Here's and example with *Window 2*.



The other possibility is to input the code 7 and press the *Close* button. This automatically closes all open windows. Here's an example with *Windows 4* and *Windows 5*.



The procedure is the same with the doors, but there is no "close all" button.

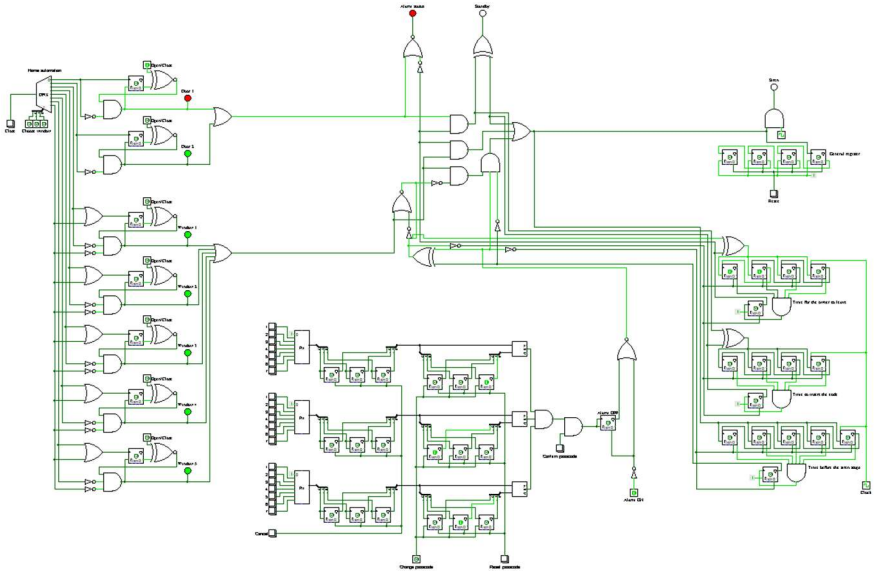
This system also allows the owner to check if all the doors and windows are closed correctly before leaving his house.

Case 1

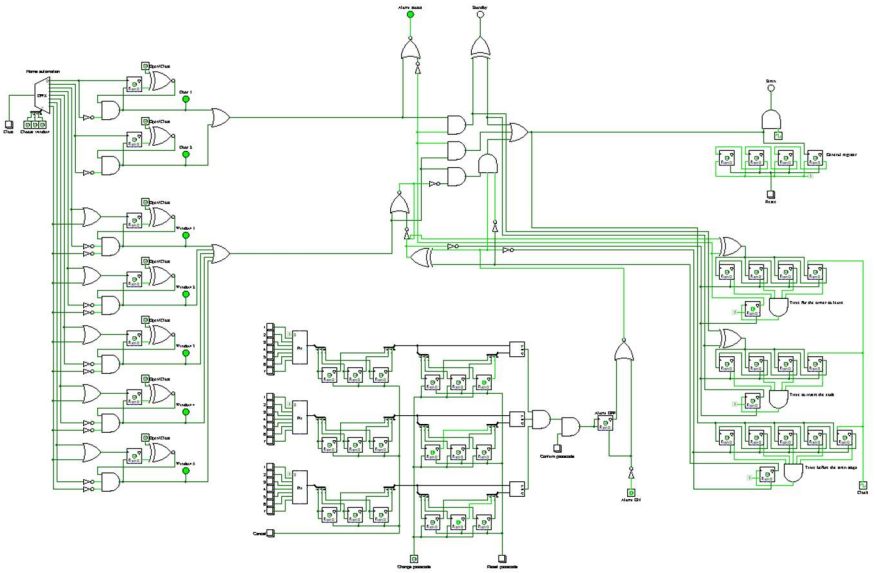
The first case that is going to be analyzed is the most frequent one, where nothing goes wrong.

Let's assume the owner has already closed everything, a part from the from door through which he is going to leave the house.

First the owner activates the alarm. The first counter starts counting the time the owner has to leave the house and close the front door (in the design we set 15 seconds for simplicity, but of course this time can be modified in a real-life situation).

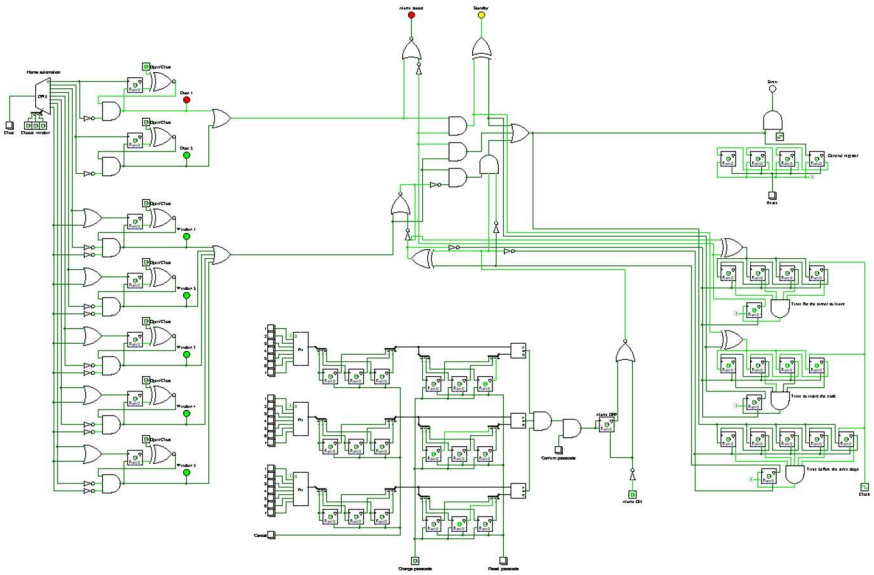


The owner leaves the house and closes the front door so, when the counter goes to zero, the alarm activates correctly as everything is closed properly.

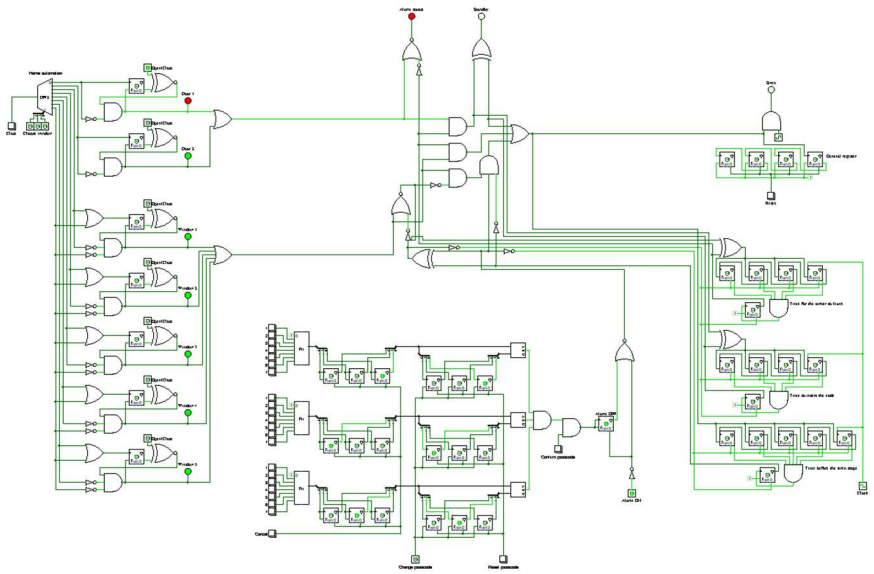


This will be called “base situation”.

The owner comes home and opens the front door. Now the second counter starts counting the time the owner has to input the passcode and deactivate the alarm (as before, we set 15 seconds for simplicity but the time can be increased) while the system is on standby.



The owner inputs the correct passcode (before “142” was set) and presses the button *Confirm passcode*. The alarm deactivates.



Case 2

Now let’s consider a case where, after leaving the house, the owner doesn’t close the door correctly.

Like before, we assume the owner has already closed everything except the front door. This time, however, after activating the alarm and leaving the house the owner doesn’t close the front door.

When the first counter reaches zero, the second counter starts, but considered that the owner already left he can’t insert the passcode.

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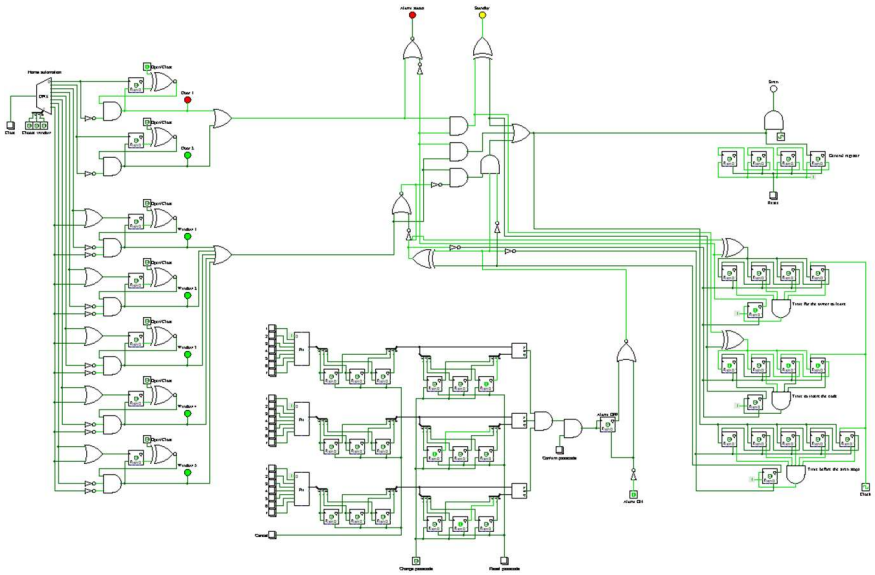
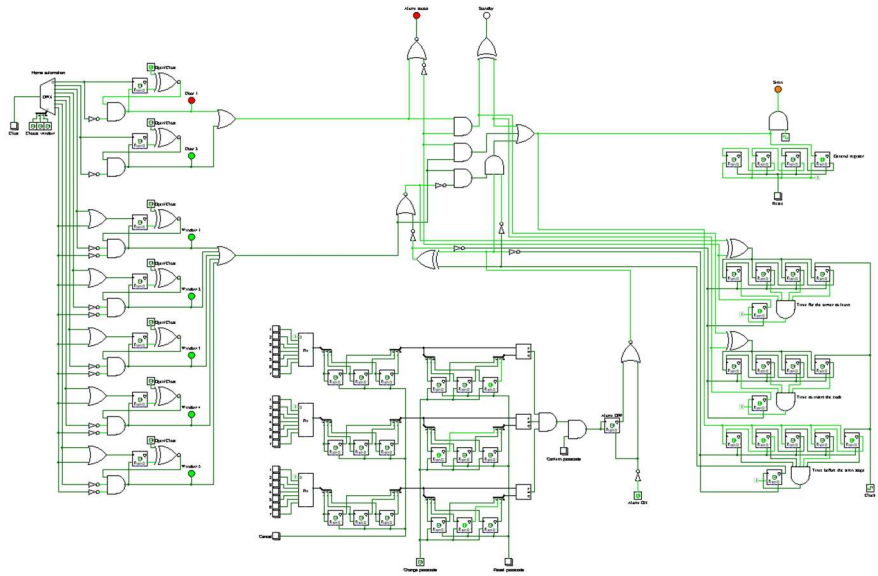
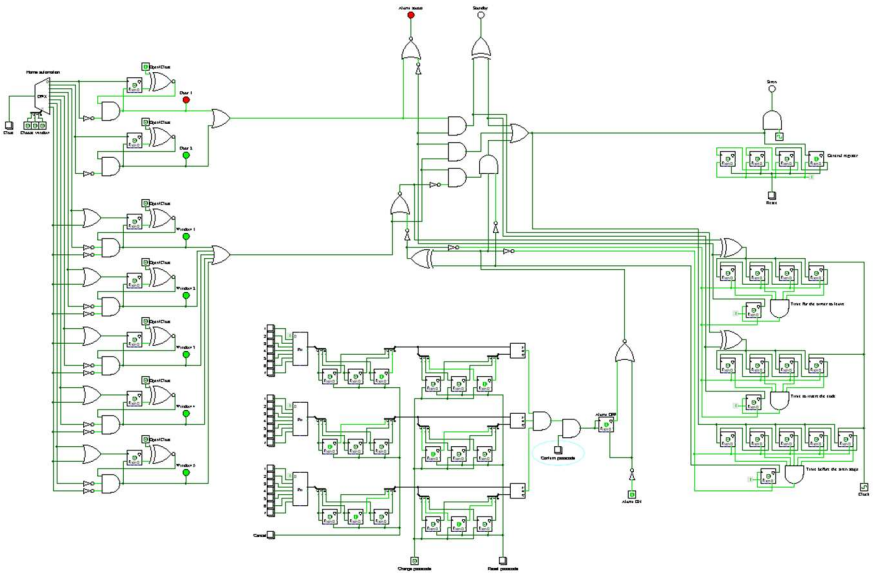


When even the second counter reaches zero, the siren sets off. The third counter starts counting the time before the siren shuts off automatically.



If the owner gets home in time, by inputting the passcode he turns the siren off and deactivates the alarm.

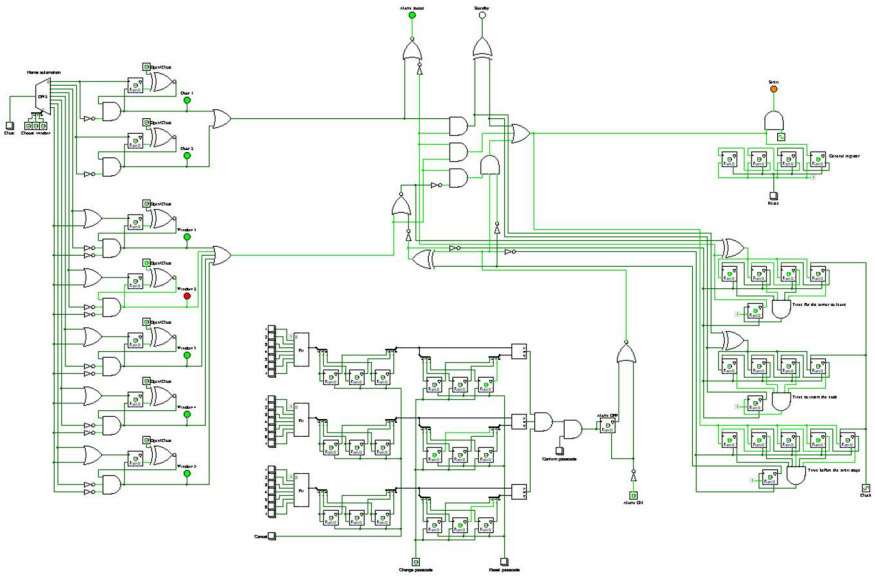


Case 3

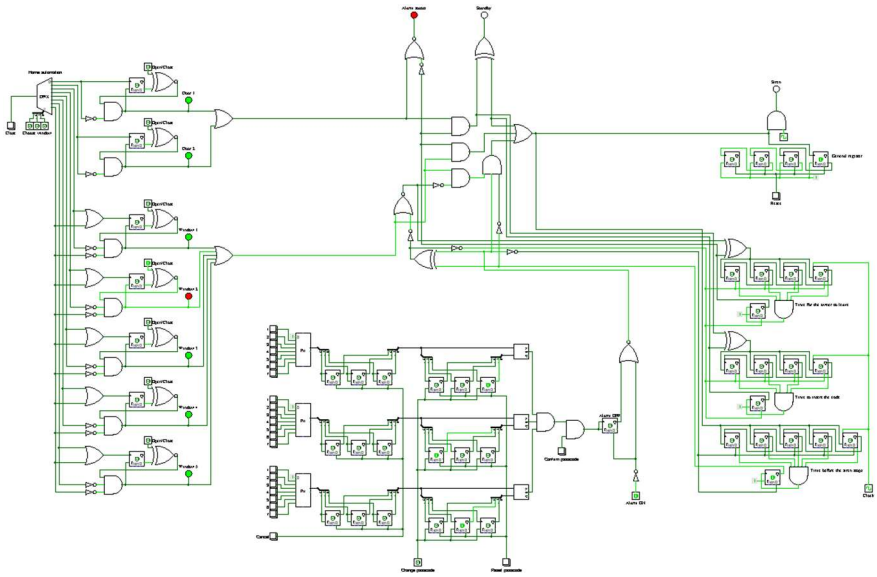
This case scenario describes a situation where, after the alarm is activated correctly, someone tries to get inside the house by opening a window.

Let's assume to be in the "base situation" described in Case 1.

When the alarm is activated, if a burglar tries to get in through a window, the opening of the window sets immediately off the siren, in order to scare the intruder away. Once again, with the siren the third counter starts.



If the owner isn't near home (probable scenario), after some time the third counter reaches zero and the siren shuts off automatically, turning off the alarm (once again, we set about 30 seconds time for simplicity, but usually this time would be about 10-15 minutes).



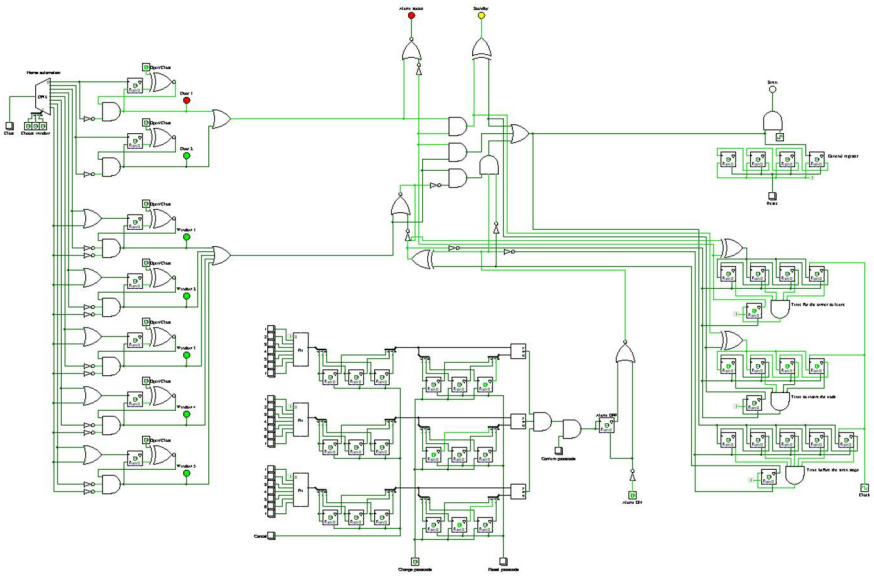
Around the time the siren shuts off, however, the police is supposed to be already on the site to take care of the situation.

Case 4

Another possible case scenario would be the one with a burglar entering from the door when the alarm is on. However the system can't work like in the previous case, otherwise the siren would set off every time the owner comes back home.

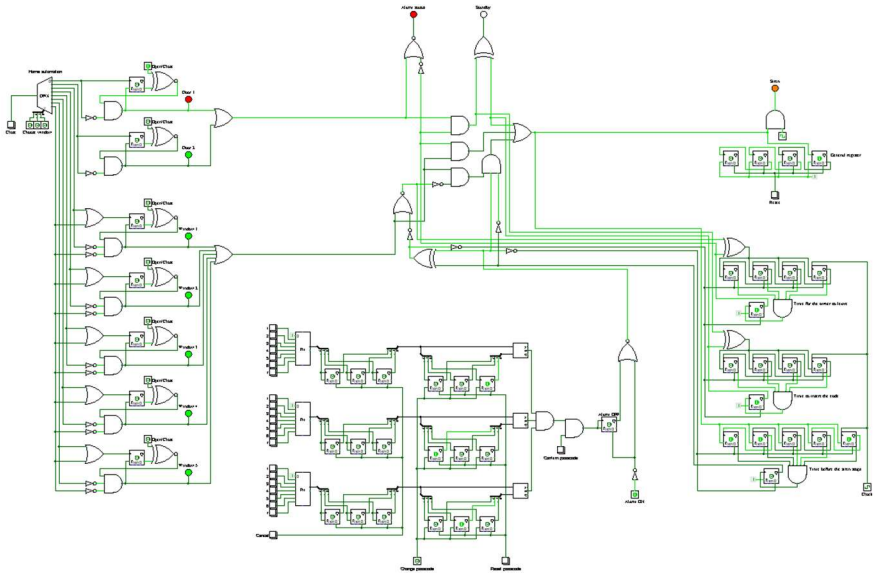
Let's assume to be in the "base situation" described in Case 1.

As previously explained, when someone enters from one of the two doors this triggers the second counter that starts counting down to zero.

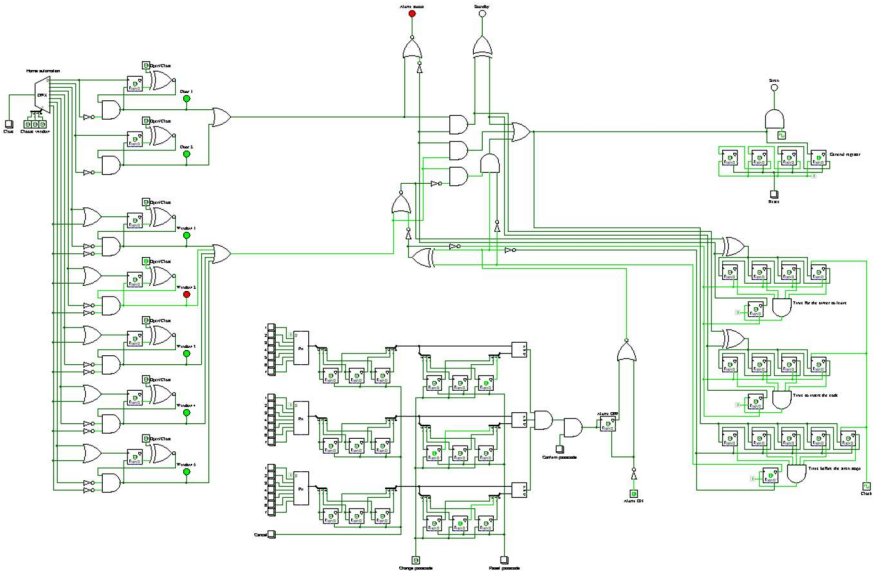


If the person entering is the owner, or someone who knows the passcode, he can deactivate the alarm just by inputting the code (like in Case 1). However, if the

person entering doesn't know the code, the second counter reaches zero and sets off the alarm.



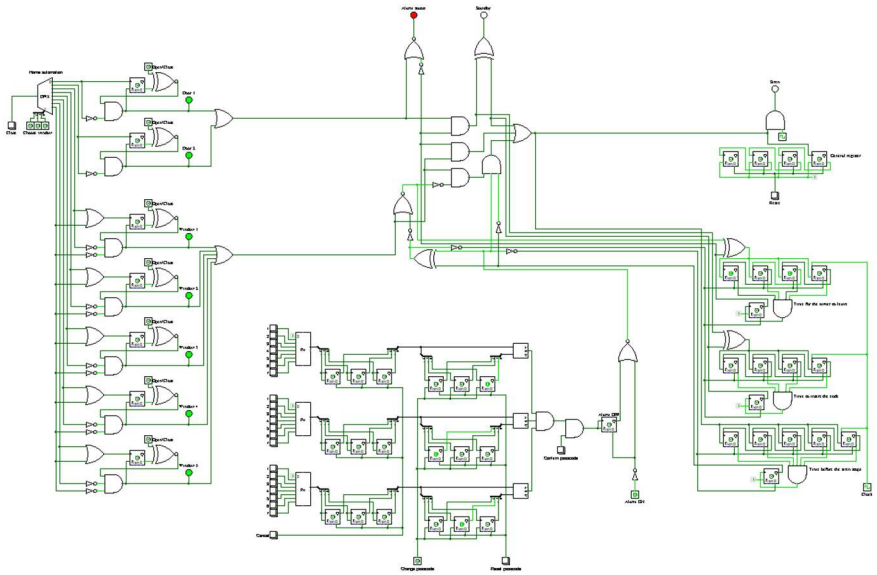
Like in Case 3, the siren rings for a fixed period of time (in this circuit 31 seconds) and then stops.



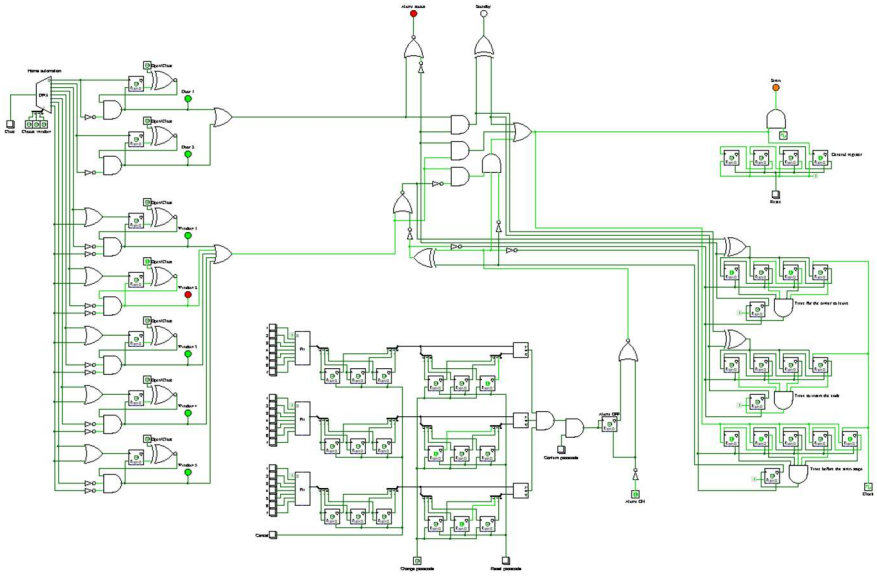
Case 5

When the alarm is on, either opening a window or opening a door without knowing the passcode would trigger the siren and avoid a break-in. However there is one situation that has not been covered yet: if someone opens a window when the alarm is still activating (when the owner is leaving the house from the front door).

In the situation described above, let’s assume the owner has already left closing all doors and the first counter is still counting.



In this case, if someone tries to open a window while the first counter is still on, the siren sets off immediately, even if the alarm isn’t fully activated yet.



Once again the siren will stop ringing after some time or, in this case, will be deactivated by the owner that comes back inside his house by inserting the passcode.

Conclusion

In conclusion, our project shows several interesting characteristics that not all house alarms actually have.

First of all, as has already been stated, we designed the circuit so that it can cover most, if not all, case scenarios so that the house can be as safe as possible (given that the burglars don't find a way to destroy it).

In order to make it more practical, we created a keypad that allows the user to set the initial passcode from the same interface that he has to use to insert the correct passcode every time he comes home.

We thought it would be possible to unify the numeric keypad with the interface of the home automation. However doing it in the design would make it extremely complicated and hard to understand. Therefore we decided to make it this way.

Talking about the home automation, the most interesting feature about it is that it can be used independently from the whole alarm. For example it can be used at night to close all the windows in the house without having to go around it.

A further advantage is the possibility to turn off the alarm with the passcode. This allows the owner not to take with him any device used to deactivate the alarm from the outside.

As already mentioned, it's possible to modify the time kept by the counters. For our design it would be sufficient to add, or subtract, one or more flip-flops to any counter.

Last but least, with the general register it's possible to keep track of the number of times the siren goes off in a certain period of time. The independent reset button for this register makes it possible decide from when to start counting the times (e.g. beginning of the year).

References

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