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A multi-protection, FPGA-based and VHDL programmed, object security and surveillance system, using PIR motion sensors, vibration sensor and touch-switches for activating a variety of alarm systems

Dr Evangelos I. Dimitriadis[1], Leonidas Dimitriadis[2]

Department of Computer, Informatics and Telecommunications Engineering, International Hellenic University,

End of Magnisias Str, 62124 Serres Greece[1]

Undergraduate student, Department of Information and Electronic Engineering, International Hellenic University,

57400, Sindos Thessaloniki, Greece[2]

Abstract: An object security, multi-protection and surveillance system, based on PIR motion sensors, vibration sensor and touch-switches, is presented here. The system uses FPGAs and can protect precious objects or industrial importance equipment, as well as laboratory and scientific instruments, against people who may cause damages or steal the above objects. It provides three main protection services. The first is by using its PIR sensors for detection of human presence and second is by activating its vibration sensor, in order to prevent possible moving of the object. It uses two PIR motion sensors for more complete coverage of the area and if human presence is detected four different alarm systems are activated. FPGA board LEDs light up, vibrator starts sounding, a laser module also lights up and step motor activates door closing equipment. Additionally if vibration sensor detects possible movement of the object, another FPGA board LED lights up. System administrator is aware of all the above activations, so he can decide whether to use the third protection ability, which is pressing one or more touch capacity switches, thus activating respective buzzer systems in different security service rooms. The system is programmed using VHDL language and can be implemented in a variety of security applications.

Keywords: Object security surveillance system, Sensors, FPGA, VHDL, Buzzer, LEDs, laser, vibrator, touch sensors, step motor.

INTRODUCTION

FPGAs present the advantage of combining software and hardware, thus having the ability of hardware programming for a series of applications. Languages used for FPGAs' programing are VHDL and Verilog and VHDL is the one used in our work.

An interesting application field of FPGAs is security, surveillance systems. [1-7] Presented works deal with topics such as object tracking systems, FPGA-based real-time motion detection for automated video surveillance systems, FPGA-based security system, FPGA-based accurate pedestrian detection with thermal camera for surveillance system, FPGA-based detection and tracking system for surveillance camera, standalone FPGA-based security monitoring through power side-channel, and FPGA-based object detection accelerator for sustainable edge devices. The study of all the above works makes it clear that there is a lack of a system that focuses on specific object protection, security and surveillance against thieves and possible damages, with multi-protection ability, using a variety of sensors and alarm systems. We believe that our work makes a contribution in that field. It must be also mentioned that another benefit of our system is that it can work with a variety of sensors and alarm systems and also its cost is remarkably low.

Design overview and operation of the system

Figure1 presents device overview and operational units of our system, using FPGA DE10-Lite board, while Figure 2 presents circuit diagram of the system.

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It is obvious from both of the above figures that our system, except from DE10-Lite FPGA board, contains also some basic circuit parts. We can see the PIR motion sensors circuit part, which plays decisive role at system operation, since it's the main surveillance and security part. It must be mentioned here that we used HC-SR501 PIR motion detector sensors. These sensors can cover maximum angle of 120 degrees, so we used two of them for better area coverage.

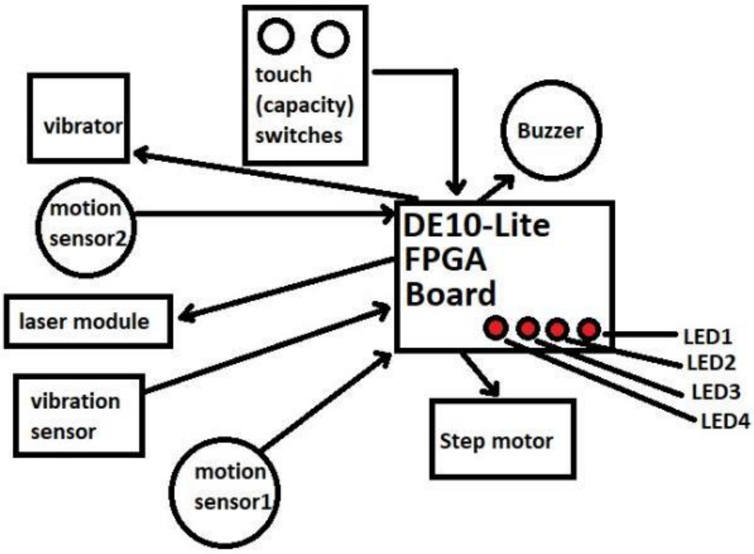

Figure 1: Device overview and operational units of our system.

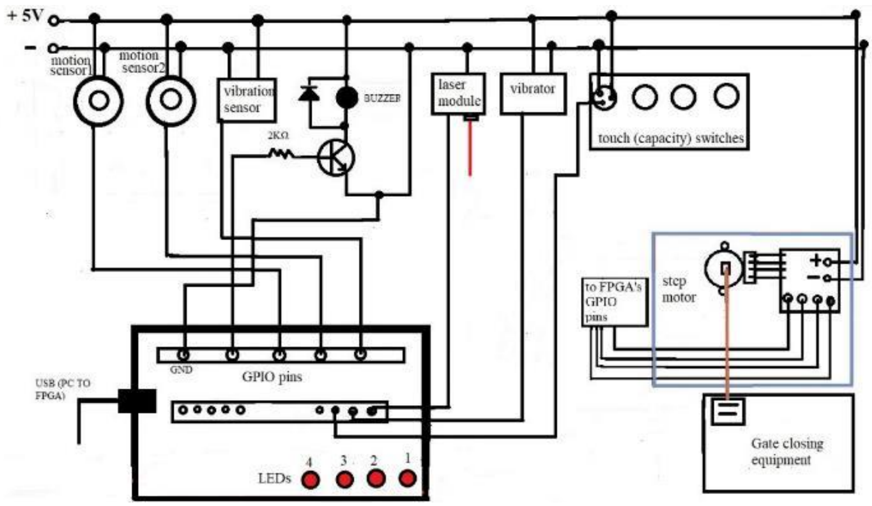

Figure 2: Circuit diagram of our system

Needless to say that they are the main input sensors of our system, sending bit 1 to FPGA's I/O pins, if human motion is detected. Second significant input sensor is the vibration sensor, which also sends bit 1 to FPGA's I/O pins, whenever a vibration of the protected object is detected. The third protection system is touch (capacity) switches module having 10 switches, which can be used by system administrator if he decides to do so, for activating equal number of buzzers existing in different security staff rooms.

Figures 1 and 2 also contain a number of alarm systems which can be activated from the above three security systems. FPGA's board LEDs are the first alarm system, while laser, vibrator and buzzer modules act also as alarm systems. Finally, step motor is the last system which, similar to the above alarm systems, is activated whenever danger appears for the protected object. Step motor is used for activating door-closing equipment, in order to achieve sufficient protection of the precious object.

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All the above systems can also be seen in Figure 3, where we present the manufactured multi-protection security system of this work.

Once our system starts operating its sensors start detecting procedure. If one or both PIR motion sensors detect human movement in the protected area, bit 1 is sent to FPGA's I/O pins, leading to simultaneous activation of four systems. LED1 and LED2 light up in the FPGA board, laser starts lighting administrator or other selected room, vibrator starts sounding and step motor starts rotating, thus activating door-closing equipment.

We used all the above alarm systems in order to be sure that system administrator, as well as other security persons will be aware of the danger reaching the protected object.

Simultaneously, vibration sensor detects possible attempts of moving the protected equipment. If this is true then bit 1 is sent to FPGA's I/O pins and the administrator will see LED3 light up. This means that protected object is in great danger, so administrator calls for help by pressing touch (capacity) switches. Simultaneously bit 1 is sent to I/O pins and a corresponding number of buzzers start operating.

Figure 4 presents our multi-protection security system, in operating mode.

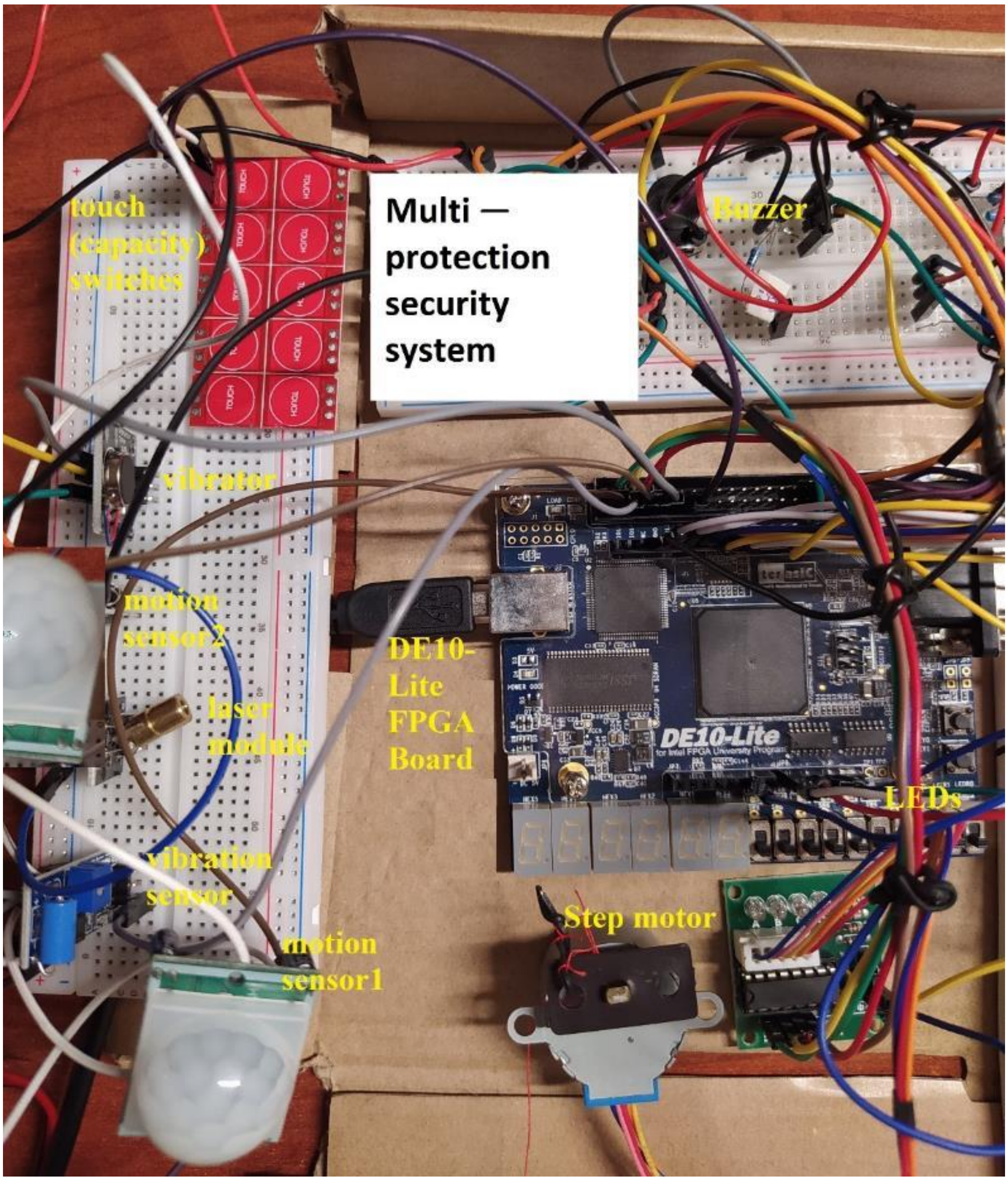

Figure 3: The multi-protection security system of this work

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It is obvious in Figure 4, that step motor, laser module, LED1 and LED2 are at the ON state, giving evidence of human presence in the protected area. Notice that LED3 and LED4 are OFF because no vibration is detected and also administrator did not press touch switches.

Figure 5 presents the system in operating mode in conjunction with a slight vibration caused by simultaneous touch switch pressing. Consequently LED3 is slightly ON due to small vibration, LED4 lights up due to touch switch pressing and buzzer sounds.

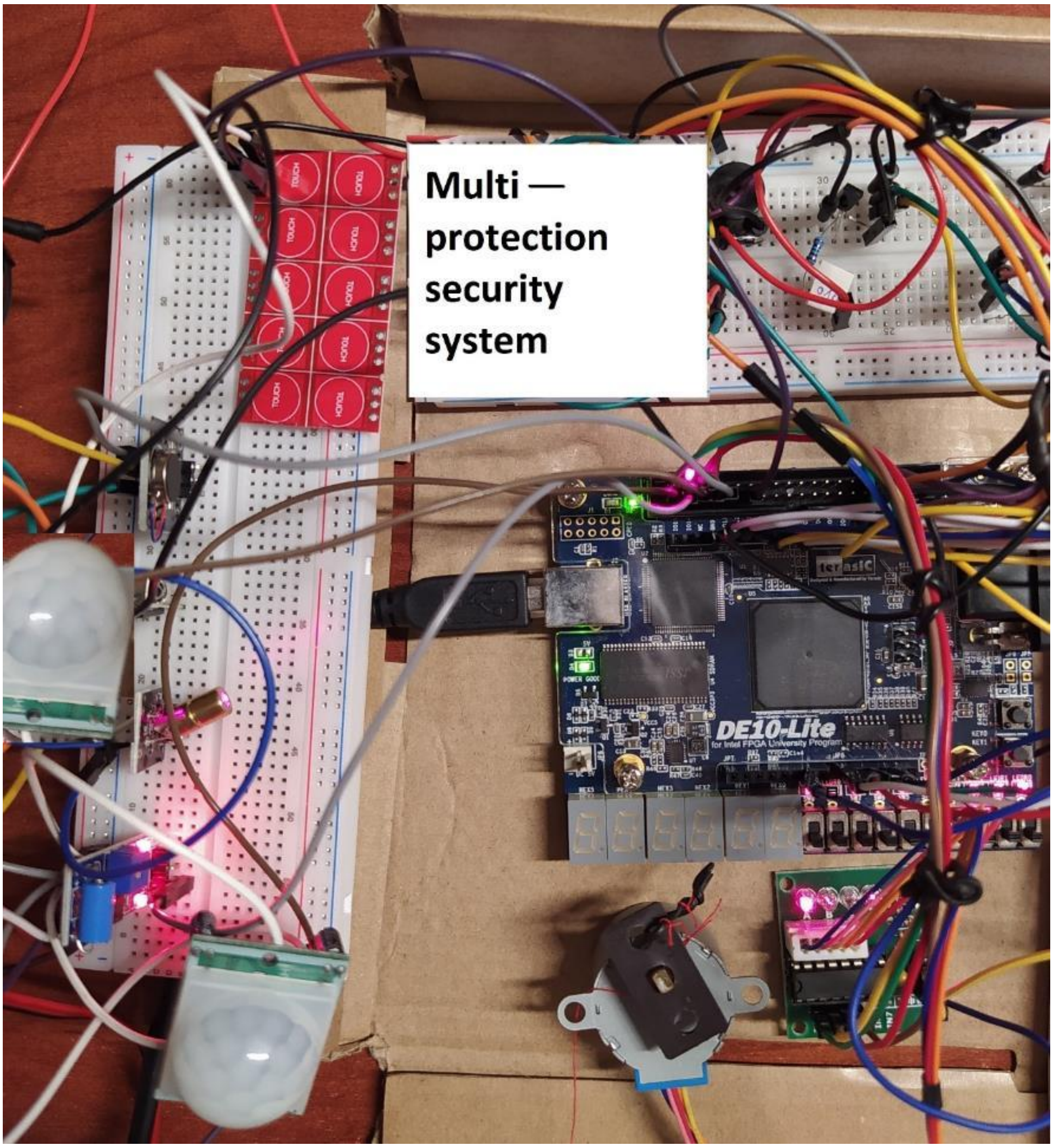

Figure 4: The multi-protection security system, operating.

It must be mentioned that in order to avoid vibration by using touch switches, we can put touch switches module to another connecting board. We avoided it here for space saving.

Deliberate experimental oscillation of the vibration sensor connecting board, led to LED3 flashing, thus proving movement of the protected object which is in touch with vibration sensor.

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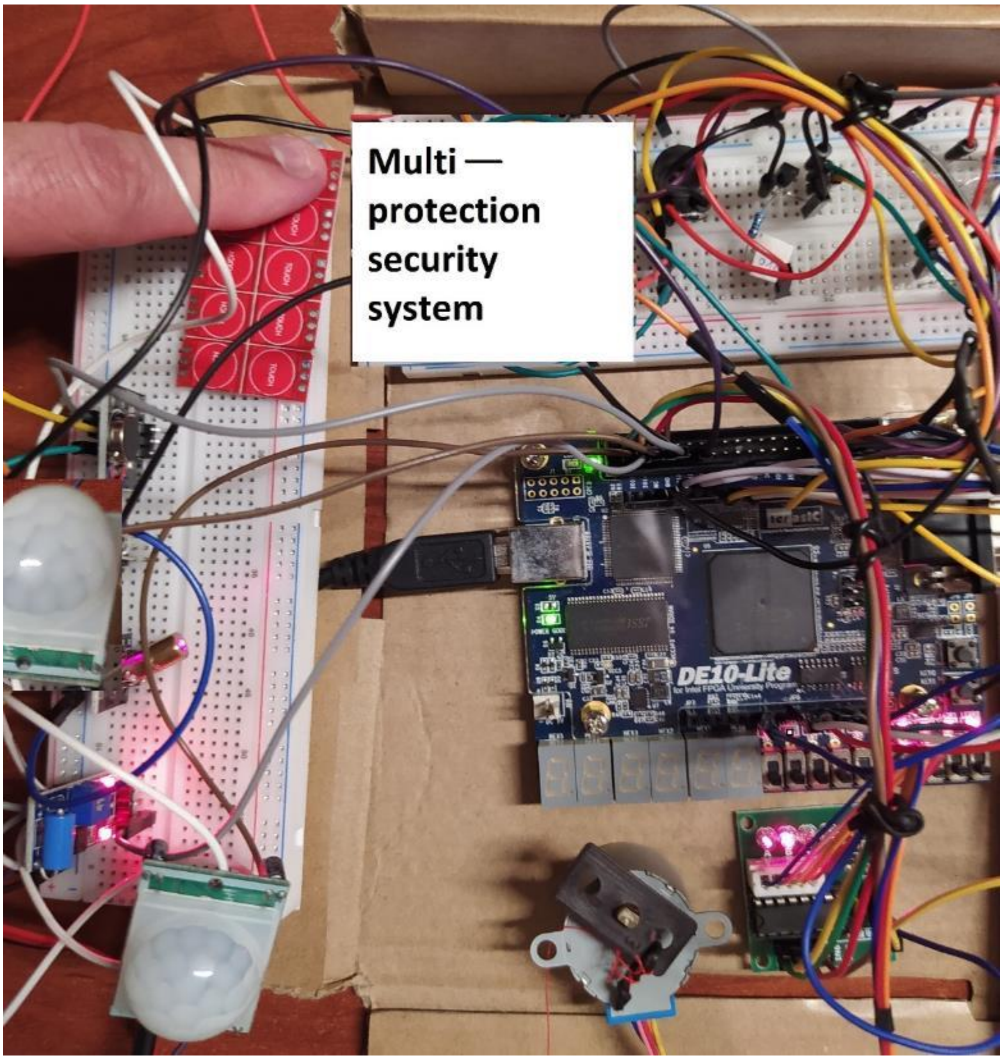

Figure 5: Our multi-protection security system, operating and touch switch pressed.

Programing the system

We used Quartus Prime Lite Edition 21.1.1 to create the VHDL program of our system. A flowchart diagram, presenting main functions of our operating system is presented in Figure 6, while the APPENDIX contains the whole VHDL program.

It is clear that the system basically operates four functions. All of them use processes in VHDL programming language. These processes are running as long as the system is ON. All functions depend on motion sensors, vibration sensor and touch switches input values. The first function playing definitive role in system operation, takes input from two motion sensors and if human presence is detected to one or both of them, LED1, LED2, laser module and vibrator are programmed to switch into ON state.

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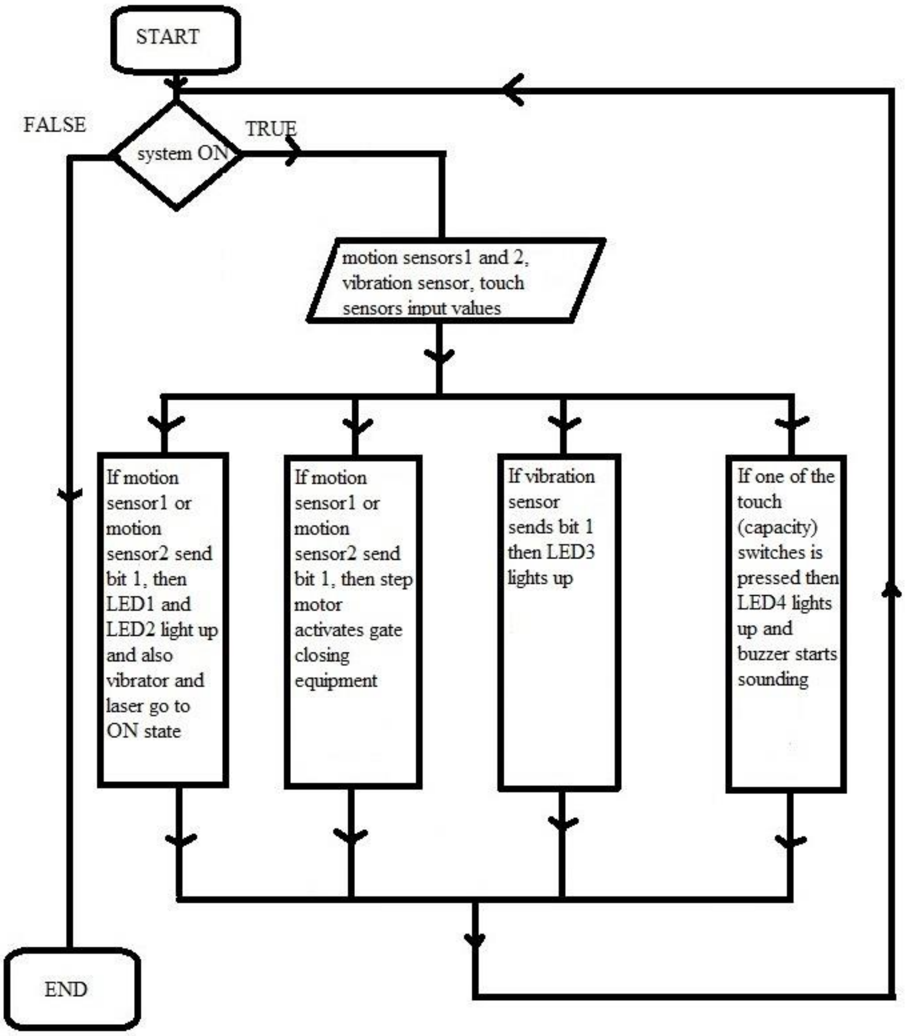

Figure 6: Flowchart diagram, presenting main functions-processes of our system.

Second function includes step motor activation if one or both motion sensors detect human presence and send bit 1 to FPGA board. Consequently step motor rotation causes the activation of door-closing equipment.

Third function of our system deals with vibration sensor detection and if the protected object vibrates, this means that someone is trying to transfer it. Consequently bit 1 is send to FPGA board and LED3 lights up.

Fourth function of our system constitutes a safety system, associated directly to administrator. He has the ability of warning safety guards of the building, that protected object is at risk. All he has to do is press one or more touch switches and corresponding bits 1 go as input to I/O pins of FPGA board, thus activating related buzzers in different rooms. Simultaneously LED4 of the FPGA board is programmed to light up.

CONCLUSIONS

A novel FPGA-based system is presented here, which manages to provide surveillance and multiple protection to a valuable object, which is housed in a specific and limited space. The system bases its operation on sensors and touch switches which act as inputs to the FPGA board. It uses two PIR motion sensors and a vibration sensor. If motion sensors detect human presence and movement, they simultaneously activate two of FPGA’s LEDs, make vibrator sound, force laser module to light up and activate step motor which consequently starts door-closing equipment operation. More alarm systems activation, obviously results in better protection of the valuable object.

Vibration sensor detects possible transfer of the valuable object and if this holds true, another FPGA board LED lights up. Finally administrator perceiving the danger for the protected object, decides whether to activate security staff buzz-

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ers by pressing touch switches. The system can work with a variety of sensors and it is easy to be manufactured for multiple applications, providing also the benefit of low cost.

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APPENDIX

```
library ieee;

use ieee.std_logic_1164.all;

use ieee.numeric_std.all;

use ieee.std_logic_unsigned.ALL;    -- step = step + 1

entity Project36_DE10_Lite_Sensors IS

generic(ClockFrequencyHz : integer:=50000000;

wait_count : natural := 1250000);  -- 50000000=1sec wait time for the stepper

PORT( LED1: OUT std_logic;

LED2: OUT std_logic;

LED3: OUT std_logic;

LED4: OUT std_logic;

clock : in std_logic;

rst : in std_logic;

coils : out std_logic_vector(3 downto 0); -- connected to IN1..IN4

nRst : in std_logic; -- Negative reset

vibration_sensor: IN std_logic;

IR_motion_sensor1: IN std_logic;

touch_sensor: IN std_logic;
```

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```
IR_motion_sensor2: IN std_logic;
laser: OUT std_logic;
buzzer: OUT std_logic;
vibrator: OUT std_logic);
END Project36_DE10_Lite_Sensors;
Architecture Sensors OF Project36_DE10_Lite_Sensors IS
SIGNAL LED1_s :std_logic;
SIGNAL LED2_s :std_logic;
SIGNAL LED3_s :std_logic;
SIGNAL LED4_s :std_logic;
SIGNAL touch_sensor_s: std_logic;
SIGNAL vibration_sensor_s: std_logic;
SIGNAL IR_motion_sensor_s1: std_logic;
SIGNAL IR_motion_sensor_s2: std_logic;
SIGNAL laser_s: std_logic;
SIGNAL vibrator_s: std_logic;
-- signal for step motor control
signal count : natural range 0 to wait_count;
BEGIN
touch_sensor_s<=touch_sensor;
vibration_sensor_s<= vibration_sensor;
IR_motion_sensor_s1<=IR_motion_sensor1;
IR_motion_sensor_s2<=IR_motion_sensor2;
process(clock,IR_motion_sensor_s1, IR_motion_sensor_s2,laser_s,vibrator_s,LED1_s,LED2_s)
begin
if clock'event and clock = '1' then
IF ((IR_motion_sensor_s1='1') OR (IR_motion_sensor_s2='1')) THEN
LED1_s<= '1';
LED2_s<='1';
laser_s<='1';
vibrator_s<='1';
else
LED1_s<= '0';
LED2_s<='0';
laser_s<='0';
vibrator_s<='0';
end if;
```

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```
end if;
end process;
process(clock, touch_sensor_s,LED4_s)
variable i : integer := 0;
begin
IF touch_sensor_s='1' THEN
LED4_s<='1';
else
LED4_s<='0';
end if;
IF touch_sensor_s='0' THEN
if clock'event and clock = '1' then
if i <= 50000000 then
i := i + 1;
buzzer <= '1'; -- active low
elsif i > 50000000 and i < 100000000 then
i := i + 1;
buzzer <= '0';
elsif i = 100000000 then
i := 0;
end if;
end if;
end if;
end process;
process(clock,LED3_s,vibration_sensor_s)
begin
if clock'event and clock = '1' then
IF vibration_sensor_s='1' then
LED3_s<='1';
else
LED3_s<='0';
end if;
end if;
end process;
laser<=laser_s;
vibrator<=vibrator_s;
LED1<=LED1_s;
```

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```
LED2<=LED2_s;
LED3<=LED3_s;
LED4<=LED4_s;
MICROSTEP_PROC : process(clock, rst, IR_motion_sensor_s1, IR_motion_sensor_s2)
    variable step : std_logic_vector(0 to 2) := "111";
  begin
    if rst = '1' then
      coils <= "0000";
      -- we start with a step
                    count <= wait_count;
    elsif rising_edge(clock) then
      if (count < wait_count) then
        -- wait for the next micro step
                    count <= count + 1;
      else
        -- perfom a single micro step
                    count <= 0;
        if ((IR_motion_sensor_s1='1') OR (IR_motion_sensor_s2='1')) then
          step := step + 1;
        end if;
        case step is
          when "000" => coils <= "0001";
          when "001" => coils <= "0011";
          when "010" => coils <= "0010";
          when "011" => coils <= "0110";
          when "100" => coils <= "0100";
          when "101" => coils <= "1100";
          when "110" => coils <= "1000";
          when "111" => coils <= "1001";
          when others => coils <= "0000";
        end case;
      end if;
    end if;
  end process;
END Sensors;
```