Bilkent University

Electrical and Electronics Department

EE102-01 Term Project Report:

“Guitar Hero”

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Purpose:

The main purpose of this project is to implement a Guitar Hero game on BASYS3 FPGA board via VHDL. The inspiration behind this project belongs to the popular game series “Guitar Heroes”. The original game was first introduced to the market by Harmonix in 2005 and then several companies made contribution to the development of the game. The goal of the game is to “play” the sliding notes of a song in time by pressing the appropriate buttons that match with the ones on the screen on a guitar shaped controller. BASYS3 FPGA Board, TRC-11, a VGA monitor, a pair of speakers and a guitar shaped game controller is used during the project.

Design Specifications:

The design has 5 inputs and 3 outputs. The inputs are reset, start, difficulty, song selection and the note buttons on the guitar shaped controller. The outputs are the VGA output, score output and the audial output. Here is a brief description of each input&output:

- **Reset:** The VGA screen reset button, does not have any effects on the gameplay, belongs in the project just in case if the synchronization of the VGA outputs (hsync, vsync and rgb) go wrong at some point. Reset basically resets these 3 outputs and the game goes on as expected.
- **Start:** The input that starts the game. This input is assigned to a switch; if the switch is on, the gameplay screen comes on; if it is off, the main menu screen appears.
- **Difficulty:** The difficulty input that determines the speed of the sliding notes during the gameplay, is assigned to a switch. 2 difficulty levels are present in the game: easy&hard.
- **Song Selection:** The input that determines the song that will be played, is assigned to a switch. There are two songs in the game: Smoke on the water and Thunderstruck. Different songs have different note combinations during the game.
- **Note Buttons:** The 8-bit input which comes from the guitar shaped main game controller.
- **VGA Outputs (hsync, vsync, rgb):** The three outputs that are required for the VGA output flowing out of the FPGA board. Hsync and vsync determines the specific pixel that will be painted on the monitor and the 12-bit rgb(red-green-blue) output which basically is the colour output for the chosen pixel via hsync&vsync. A 640*480 pixel VGA output was used in the project. This is quite a low-resolution but since the game

did not require high-resolution but required a high refresh rate, I kind of sacrificed the resolution rate and went for the screen refresh rate since they are inversely proportioned to each other for the same clock frequency.

- **Score:** The output that is projected onto the seven-segment display of the BASYS3. The score function shows how many notes have been hit correctly at the correct time throughout the entire song.
- **Audial Output:** The 1-bit output that changes its frequency according to the game logic. This output is connected to the speaker-amplifier of the TRC-11 and then exposed audially via a speaker.

The design requires some external components besides the BASYS3 FPGA Board. These external components are TRC-11, a VGA monitor, a guitar controller and a pair of speakers. Here is the description of each external component:

- **TRC-11:** This is the high frequency radio transceiver (transmitter&receiver) that I built during a full semester in another course I take this year EEE-211 Analog Electronics. Only the speaker amplifier of the TRC-11 is used in the project. It is used to amplify&transmit the square wave signal coming from the BASYS3 to a pair of speakers. Here you can see the schematic of the speaker amplifier of the TRC-11 **(Figure 1.1)**:

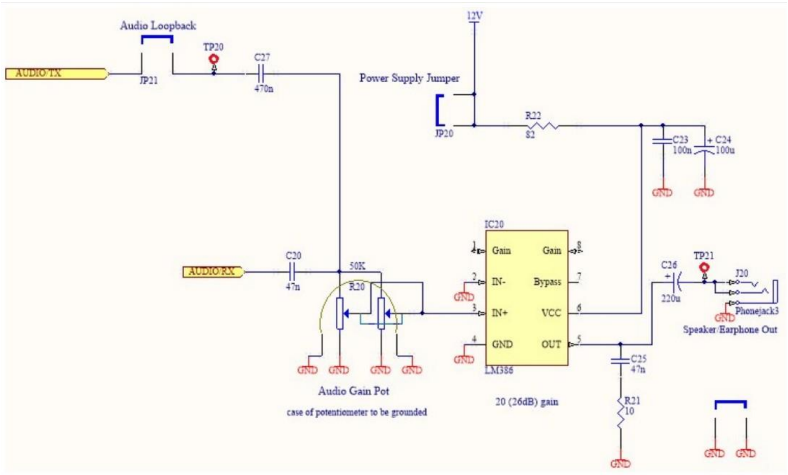

Figure 1.1: The Schematic of the speaker amplifier of TRC-11

- **VGA Monitor:** The game should be projected onto a monitor. Since BASYS3 has a VGA output, a VGA monitor is used to project the gameplay.
- **Guitar Controller:** The main game controller. Includes 8 buttons which are basically the ones on the gameplay screen.
- **Speakers:** Jack-input speakers that are used to expose the audial signal coming from the TRC-11.

Methodology:

Since I knew very little about VHDL at the start of the project, the very first task I committed myself was to learn the VGA process in VHDL. I did some research and understood the VGA process in VHDL. Then I wrote a VGA driver code by getting help from the internet. Understanding how VGA works in VHDL was definitely one of the trickiest and the most challenging parts within the project.

The second task I committed myself was to write the game logic. I aimed to just see the sliding notes on the monitor. There were no note inputs or a main menu present at this point of the project. After a few hours of hard work, I managed to see the sliding notes on the monitor even though I had some synchronization issues initially. This was a major mental and psychological stepping stone in the project since I started to feel like I could actually do the proposed design.

The third task I committed myself was to create a score function. I had initial thoughts about projecting the score value onto the VGA monitor, but I had second thoughts and decided to project it onto the seven-segment display of the BASYS3. This was mainly due to me wanting to use a variety of features present in the BASYS3 and not sticking with the VGA output only. At this part of the project, the seven-segment lab we did during the semester really helped me and significantly reduced the time I spent on this part. Also, I added the 8 note buttons on a breadboard and managed to successfully get the score data out of the game. At this point I had some initial struggle since the score function incremented more than once within the same note –once per every clock cycle-, but I managed to solve it via using a boolean array and made sure that no note was counted more than once for the score function.

The fourth task I committed myself was to create a main-menu screen and using a start input for switching back and forth the gameplay screen and the main menu. I used bitmap images and vector arrays for designing the main menu. I found out that designing a screen with VHDL is super time-consuming. For the main menu screen, I used image generating AI DALL-E 3 and the pixelion writing style. I converted jpg images to binary arrays via a website. Then, I manually determined the horizontal and vertical pixel information for each text or picture I put to the main menu screen.

The fifth task I committed myself was to obtain the audial output. I used digital square wave signals and transformed to soundwaves via TRC-11's speaker amplifier and a pair of speakers. In one of the labs of EEE-211, we connected the signal generator to the speaker amplifier of TRC-11 and generated square wave signals and listened to the sound of each frequency. This made me think using TRC-11 as the audial output amplifier instead of purchasing external audio synthesizers compatible with BASYS3. This approach was going to be more economic for a student. Different notes have different frequencies and I've manually coded the notes of the song in such a way that the melody of the real song could be heard from the speakers.

The last task I committed myself was to create the guitar shaped controller. This process involved only mechanical work and no electronical&programming work. I first drew the guitar hardware on a thin wooden plate. Then I shaped the wooden plate via a wood saw. I obtained two examples of this guitar shape which was going to be the two sides of the guitar. I wanted to pass the cables in between the two thin guitar plates. Therefore, I also obtained small but thick and strong wooden cubic shapes to support the two thin plates mechanically. Then I spray-painted and varnished both sides of the guitar shaped wooden plates and the supporting material. This helped me getting a smoother feeling and a better look for the guitar controller. Then I placed the breadboards with buttons on the guitar and passed the note button cables within the two plates. Finally, I sticked everything together via a two-component glue. The guitar controller was ready and set for the game.

Results:

This was the general setup after everything was ready **(Figure 1.2)**. You can see the guitar controller, the VGA monitor, TRC-11, BASYS3 FPGA board and the cable connections clearly.

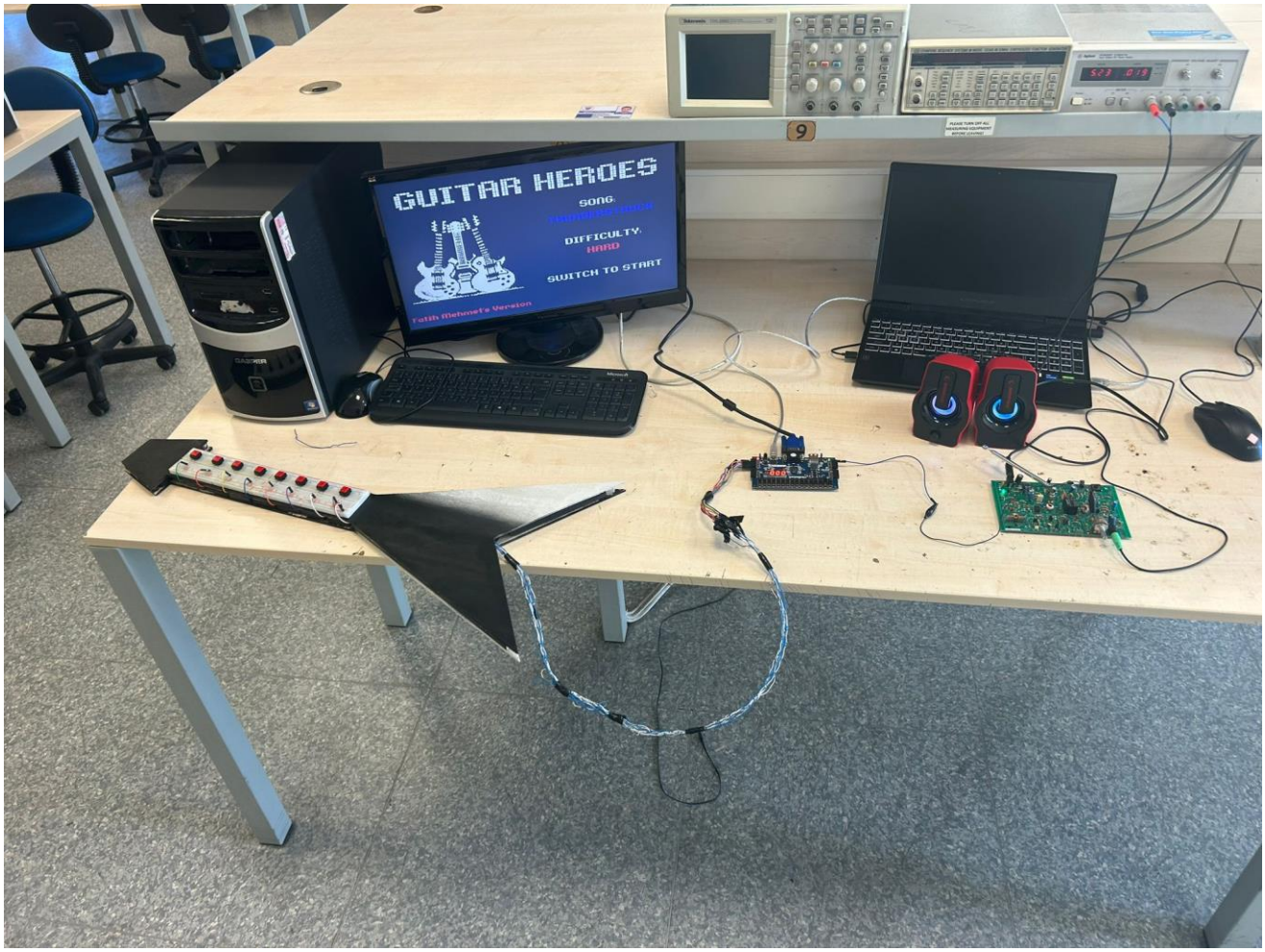

Figure 1.2: The General Setup for the Game

And here you can see me holding the controller **(Figure 1.3)**:

Figure 1.3: Me Holding the Guitar Shaped Controller

Conclusion:

This project is a significant milestone in my career. It is truly incredible what can we do with FPGA and VHDL. I aimed to make a guitar hero game and eventually managed to do so.

The biggest challenge throughout the project was definitely building the guitar hardware. It involved heavy work and consumed lots of hours. Besides that, the synchronization of the game logic was another major issue I faced. Therefore, I've written everything in a single module even though my initial intentions were using sub-modules. The final major drawback I'd like to mention is the memory issue I encountered. I had to reduce the number of notes per song to 80 because I encountered a warning about the number of LUT-cells present in the BASYS3. This memory issue was also the reason why I had to stick with two songs. When I tried to add more songs, I encountered the same warning from Vivado.

I believe having a lab about the VGA output of the BASYS3 is necessary during the course. It could have saved me and my friends a lot of time during the term project if we had that lab.

References:

https://studio.code.org/projects/applab/qiyLvNCBDuOYbaBB8oe0isTwNDYTOeGA5cpWlhHNTzM - very useful visualization of 12-bit rgb coding, helped me through the gameplay screen design

https://www.dcode.fr/binary-image - the site I used for jpg to binary array conversion

https://openai.com/dall-e-3 - the AI that generated the guitar image on the main menu

https://www.youtube.com/watch?v=eJMYVLPX0no&t=228s - VGA driver code source: highlighted with yellow in the appendix part.

Appendices:

Youtube Video Link: https://www.youtube.com/watch?v=hGeJhr4xRpw&t=324s

VHDL Code:

```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
use IEEE.NUMERIC_STD.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;

entity tester is
    Port ( clk : in STD_LOGIC; --100Mhz internal BASYS3 clock
           reset : in STD_LOGIC; --reset button
           start: in std_logic; --start switch
           difficulty: in std_logic; --difficulty selection switch
           select_song: in std_logic; --song selection switch
           note_buttons: in std_logic_vector (7 downto 0); --guitar buttons
           hsync : out STD_LOGIC; --horizontal sync output for vga driver
           vsync : out STD_LOGIC; --vertical sync output for vga driver
           audio_output: out std_logic; --the audial output
           anodes: out std_logic_vector(3 downto 0); --anodes of seven segment
           cathodes: out std_logic_vector(6 downto 0); -- cathodes of seven segment
           rgb : out STD_LOGIC_VECTOR (11 downto 0)); --the 12-bit RedGreenBlue colour
code
           --very useful visualization of 12-bit rgb coding at
https://studio.code.org/projects/applab/qiyLvNCBDuOYbaBB8oe0isTwNDYTOeGA5cpWlh
HNTzM
end tester;
architecture Behavioral of tester is
```

```
--25 MHz clock
signal clk25: std_logic := '0';
--50MHz clock
signal clk50: std_logic := '0';

--the horizontal constants for the 640*480 vga screen
constant hd: integer:= 639; --horizontal display
constant hfp: integer:= 16; --horizontal front porch
constant hsp: integer:= 96; --horizontal sync pulse
constant hbp: integer:= 48; --horizontal back porch
signal hpos: integer:= 0; --horizontal position

--the vertical constants for the 640*480 vga screen
constant vd: integer:= 479; --vertical display
constant vfp: integer:= 10; --vertical front porch
constant vsp: integer:= 2; --vertical sync pulse
constant vbp: integer:= 33; --vertical back porch
signal vpos: integer:= 0; --vertical position


--every single note height and widths in pixels
constant note_height: integer := 20;
constant note_width: integer := 50;

--horizontal and vertical difference between two notes in pixels
constant notes_height_diff: integer := 20;
constant notes_width_diff: integer := 10;

--different colours in 12-bit rgb representation for the notes
constant colour_green: std_logic_vector(11 downto 0):= "000011110000";
constant colour_red: std_logic_vector(11 downto 0):= "111100000000";
```

```
constant colour_yellow: std_logic_vector(11 downto 0):= "111111110000";
constant colour_blue: std_logic_vector(11 downto 0):= "000000001111";
constant colour_orange: std_logic_vector(11 downto 0):= "111110000000";
constant colour_violet: std_logic_vector(11 downto 0):= "110000001111";
constant colour_white: std_logic_vector(11 downto 0):= "111111111111";
constant colour_pink: std_logic_vector(11 downto 0):= "111100001100";
--different colours in 12-bit rgb representation for background screen (NOT THE NOTES)
constant colour_gray: std_logic_vector(11 downto 0):= "000100010001";
constant colour_black: std_logic_vector(11 downto 0):= "000000000000";

--the speed of the notes that are sliding down the screen
signal vertical_speed: integer;

--horizontal pixel information of each note according to the colour
constant note_green_horizontal: integer:= 85;
constant note_red_horizontal: integer:= 145;
constant note_yellow_horizontal: integer:= 205;
constant note_blue_horizontal: integer:= 265;
constant note_orange_horizontal: integer:= 325;
constant note_violet_horizontal: integer:= 385;
constant note_white_horizontal: integer:= 445;
constant note_pink_horizontal: integer:= 505;

-- the vertical pixel information of the strum area where the buttons must be hit exactly when the notes are there
constant strum_upper_limit: integer:= 390;
constant strum_lower_limit: integer:= 430;
constant strum_limit_height: integer:= 10;

-- the array that contains the vertical pixel information of each note
type note_vertical_properties_array is array (0 to 79) of integer; --each element of the array contains the vertical pixel info of every note
signal note_vertical_properties: note_vertical_properties_array;
```

--the arrays that contain the horizontal pixel information and the colour of each note

type note_horizontal_colours_string_array is array (0 to 79) of string(1 to 1);--each element of the array is one of "grybovwp" (note colours' initials)

signal note_horizontal_colours_string: note_horizontal_colours_string_array;

type note_horizontal_properties_array is array (0 to 79) of integer;--each element of the array contains the horizontal pixel info of every note

signal note_horizontal_properties: note_horizontal_properties_array;

type note_horizontal_colours_array is array (0 to 79) of std_logic_vector(11 downto 0);--each element of the array is a 12-bit rgb representation of the note colour

signal note_horizontal_colours: note_horizontal_colours_array;

--the following 11 bitmaps are displayed in the main menu / scroll all the way down and check the binary arrays at the very end of the behavioral part!

--shoutout to https://www.dcode.fr/binary-image which is the perfect site for jpg to binary array conversion

signal gamenamevisible: boolean;

type bitmap1 is array (0 to 47) of std_logic_vector(0 to 639);

signal gamename: bitmap1;

signal photovisible: boolean;

type bitmap2 is array (0 to 260) of std_logic_vector(0 to 299);

signal photo: bitmap2;

signal songvisible: boolean;

type bitmap3 is array (0 to 18) of std_logic_vector(0 to 339);

signal song: bitmap3;

signal thunderstruckvisible: boolean;

type bitmap4 is array (0 to 18) of std_logic_vector(0 to 339);

signal thunderstruck: bitmap4;

signal smokevisible: boolean;

type bitmap5 is array (0 to 18) of std_logic_vector(0 to 339);

```
signal smoke: bitmap5;


signal difficultyvisible: boolean;
type bitmap6 is array (0 to 18) of std_logic_vector(0 to 339);
signal difficulty_2: bitmap6;

signal easyvisible: boolean;
type bitmap7 is array (0 to 18) of std_logic_vector(0 to 339);
signal easy: bitmap7;

signal hardvisible: boolean;
type bitmap8 is array (0 to 18) of std_logic_vector(0 to 339);
signal hard: bitmap8;

signal startswitchvisible: boolean;
type bitmap9 is array (0 to 18) of std_logic_vector(0 to 339);
signal startswitch: bitmap9;

signal fatihmehmetvisible: boolean;
type bitmap10 is array (0 to 13) of std_logic_vector(0 to 299);
signal fatihmehmet: bitmap10;

signal lightningvisible: boolean;
type bitmap11 is array (0 to 144) of std_logic_vector(0 to 84);
signal lightning: bitmap11;

--the array that makes sure you only get 1 point from each note
--p.s. without this array you would get 1 point in each clock cycle -which means if you pressed the correct button for 1 sec, you would get 25 million points :)
type NoteScoredArray is array (0 to 79) of boolean;
signal note_scored : NoteScoredArray:= (others=>False); --set the initial value to False for all 80 elements of the array
```

```
--the score output which will be displayed on the seven segment display and its' three decimals
signal score: integer:= 0;
signal score0: integer;--least significant figure of the score signal
signal score1: integer;
signal score2: integer;
signal score3: integer; --most significant figure of the score signal

-- the necessary signals for creating a 3000Hz clock for seven segment display
signal ss_counter: std_logic_vector(19 downto 0):= "00000000000000000000";
signal clk3000: std_logic_vector(1 downto 0);--3000Hz clock
signal ss_leds: integer;

--the frequencies of the 8 different notes
--p.s. if you divide each value to 25MHz, you find the corresponding freqeuency value
--Ex: 25million/23889 = 1046.50 Hz for freq8
signal freq8 : integer := 23889; --pink
signal freq7 : integer := 25316; --white
signal freq6 : integer := 26409; --violet
signal freq5 : integer := 31887; --orange
signal freq4 : integer := 35790; --blue
signal freq3 : integer := 37936; --yellow
signal freq2 : integer := 42589; --red
signal freq1 : integer := 47801; --green
signal freqbuzz : integer := 150000; --buzzer
signal freqnull : integer := 100000000; -- no sound

--the necessary signals for the sound output
signal freq_counter: integer := 0;
signal frequency: integer:= 0;
signal audio_signal: std_logic:= '0';
```

```
begin


--this is the process where we give an output of a square wave signal with the selected frequency
audio_output <= audio_signal;
audio: process(clk25)
begin
    if rising_edge(clk25) then
        if freq_counter >= frequency then
            audio_signal <= not audio_signal;
            freq_counter <= 0;
        else
            freq_counter <= freq_counter + 1;
        end if;
    end if;
end process;


--obtain a nearly 3kHz clock which will be used in the seven segment display from the internal 100MHz BASYS3 clock
clkdivider2: process(clk)
begin
    if (rising_edge(clk)) then
        ss_counter <= ss_counter + 1;
    end if;
clk3000 <= ss_counter(16 downto 15);
end process;


--calculate the buzzing output and the score value, p.s. be very careful to not increase the score more than once at the same note :)
score_count: process(clk25)
begin
    if rising_edge(clk25) then
```

```
if start = '1' then
    for i in 0 to 79 loop
--this part needs a very clear explanation; first we basically set the limits and increased the score if the
--correct button has been hit at the right time. In order to not increase the score multiple times at the
--same note, we use the note_scored array and initialized it at false for every element.
--Then when a note is hit that element's note_scored property is locked to true until the restart of the game!
--Note that the buzzer signal is not dependent on the note_scored array
        if ((note_vertical_properties(i) + (note_height/2)) > strum_upper_limit) and ((note_vertical_properties(i) - (note_height/2)) < strum_lower_limit) then
            case note_horizontal_colours_string(i) is
                when "g" =>
                    if note_buttons(6)= '1' or note_buttons(5)= '1' or note_buttons(4)= '1' or note_buttons(3)= '1' or note_buttons(2)= '1' or note_buttons(1)= '1' or note_buttons(0)= '1' then
                        frequency <= freqbuzz;
                    elsif note_buttons(7) = '1' then
                        frequency <= freq1;
                    else
                        frequency <= freqnull;
                    end if;
                    if not note_scored(i) then
                        if note_buttons(7) = '1' then
                            score <= score + 1;
                            note_scored(i) <= True;
                        end if;
                    end if;
                when "r" =>
                    if note_buttons(7)= '1' or note_buttons(5)= '1' or note_buttons(4)= '1' or note_buttons(3)= '1' or note_buttons(2)= '1' or note_buttons(1)= '1' or note_buttons(0)= '1' then
                        frequency <= freqbuzz;
                    elsif note_buttons(6) = '1' then
```

```
                frequency <= freq2;
            else
                frequency <= freqnull;
            end if;
            if not note_scored(i) then
                if note_buttons(6) = '1' then
                    score <= score + 1;
                    note_scored(i) <= True;
                end if;
            end if;
        when "y" =>
            if note_buttons(7)= '1' or note_buttons(6)= '1' or note_buttons(4)= '1' or note_buttons(3)= '1' or note_buttons(2)= '1' or note_buttons(1)= '1' or note_buttons(0)= '1' then
                frequency <= freqbuzz;
            elsif note_buttons(5) = '1' then
                frequency <= freq3;
            else
                frequency <= freqnull;
            end if;
            if not note_scored(i) then
                if note_buttons(5) = '1' then
                    score <= score + 1;
                    note_scored(i) <= True;
                end if;
            end if;
        when "b" =>
            if note_buttons(7)= '1' or note_buttons(6)= '1' or note_buttons(5)= '1' or note_buttons(3)= '1' or note_buttons(2)= '1' or note_buttons(1)= '1' or note_buttons(0)= '1' then
                frequency <= freqbuzz;
            elsif note_buttons(4) = '1' then
                frequency <= freq4;
```

```
                else
                    frequency <= freqnull;
                end if;
                if not note_scored(i) then
                    if note_buttons(4) = '1' then
                        score <= score + 1;
                        note_scored(i) <= True;
                    end if;
                end if;
            when "o" =>
                if note_buttons(7)= '1' or note_buttons(6)= '1' or note_buttons(5)= '1' or note_buttons(4)= '1' or note_buttons(2)= '1' or note_buttons(1)= '1' or note_buttons(0)= '1' then
                    frequency <= freqbuzz;
                elsif note_buttons(3) = '1' then
                    frequency <= freq5;
                else
                    frequency <= freqnull;
                end if;
                if not note_scored(i) then
                    if note_buttons(3) = '1' then
                        score <= score + 1;
                        note_scored(i) <= True;
                    end if;
                end if;
            when "v" =>
                if note_buttons(7)= '1' or note_buttons(6)= '1' or note_buttons(5)= '1' or note_buttons(4)= '1' or note_buttons(3)= '1' or note_buttons(1)= '1' or note_buttons(0)= '1' then
                    frequency <= freqbuzz;
                elsif note_buttons(2) = '1' then
                    frequency <= freq6;
                else
```

```
                frequency <= freqnull;
            end if;
            if not note_scored(i) then
                if note_buttons(2) = '1' then
                    score <= score + 1;
                    note_scored(i) <= True;
                end if;
            end if;
        when "w" =>
            if note_buttons(7)= '1' or note_buttons(6)= '1' or note_buttons(5)= '1' or note_buttons(4)= '1' or note_buttons(3)= '1' or note_buttons(2)= '1' or note_buttons(0)= '1' then
                frequency <= freqbuzz;
            elsif note_buttons(1) = '1' then
                frequency <= freq7;
            else
                frequency <= freqnull;
            end if;
            if not note_scored(i) then
                if note_buttons(1) = '1' then
                    score <= score + 1;
                    note_scored(i) <= True;
                end if;
            end if;
        when others => --when "p" =>
            if note_buttons(7)= '1' or note_buttons(6)= '1' or note_buttons(5)= '1' or note_buttons(4)= '1' or note_buttons(3)= '1' or note_buttons(2)= '1' or note_buttons(1)= '1' then
                frequency <= freqbuzz;
            elsif note_buttons(0) = '1' then
                    frequency <= freq8;
            else
                frequency <= freqnull;
```

```
                    end if;
                    if not note_scored(i) then
                        if note_buttons(0) = '1' then
                            score <= score + 1;
                            note_scored(i) <= True;
                        end if;
                    end if;
                end case;
            end if;
        end loop;
--set the score&buzzer values to zero when game is stopped or not initialized
    else
        score <= 0;
        frequency <= freqnull;
        for i in 0 to 79 loop
            note_scored(i) <= False;
        end loop;
    end if;
  end if;
end process;

--display the score signal at the seven segment display for BASYS3
seven_segment: process(clk3000)
begin
--seperate each decimal of the score function
--remark that since #notes per song is 80, the score function can be max 80.
score0 <= score mod 10;
score1 <= (score mod 100/ 10);
score2 <= (score / 100);
score3<= (score/1000);

--match the anodes and each decimal of the score function
```

```
    case clk3000 is --3000Hz clock for seven segment display
        when "00" =>
            anodes <= "1111";
            ss_leds <= score3;
        when "01" =>
            anodes <= "1011";
            ss_leds <= score2;
        when "10" =>
            anodes <= "1101";
            ss_leds <= score1;
        when others => --when "11"
            anodes <= "1110";
            ss_leds <= score0;
    end case;

--determine the 7-bit vector cathode signals for each integer
    case ss_leds is
        when 1 => cathodes <= "1001111";
        when 2 => cathodes <= "0010010";
        when 3 => cathodes <= "0000110";
        when 4 => cathodes <= "1001100";
        when 5 => cathodes <= "0100100";
        when 6 => cathodes <= "0100000";
        when 7 => cathodes <= "0001111";
        when 8 => cathodes <= "0000000";
        when 9 => cathodes <= "0000100";
        when others => cathodes <= "0000001"; --when 0 =>
    end case;

end process;

--obtain a 25MHz clock from the internal 100MHz clock of BASYS3
```

```
clkdivider1: process(clk)
begin
    if rising_edge(clk) then
        clk50 <= not clk50;
    end if;

    if rising_edge(clk50) then
        clk25 <= not clk25;
    end if;
end process;

--create a horizontal position counter for the vga output
--very useful info on vga drivers at https://www.youtube.com/watch?v=eJMYVLPX0no&t=228s
horizontal_position_counter: process(clk25, reset)
begin
    if reset = '1' then
        hpos <= 0;
    elsif rising_edge (clk25) then
        if (hpos = hd + hfp + hbp + hsp) then
            hpos <= 0;
        else
            hpos <= hpos + 1;
        end if;
    end if;
end process;

--create a vertical position counter which updates the vertical pos every time the horizontal pos is resetted for the vga output
--very useful info on vga drivers at https://www.youtube.com/watch?v=eJMYVLPX0no&t=228s
vertical_position_counter: process(clk25, reset)
begin
```

```
    if reset = '1' then
        vpos <= 0;
    elsif rising_edge (clk25) then
        if (hpos = hd + hfp + hbp + hsp) then
            if (vpos = vd + vfp + vbp + vsp) then
                vpos <= 0;
            else
                vpos <= vpos + 1;
            end if;
        end if;
    end if;
end process;


--the horizontal sync output for basys3
--very useful info on vga drivers at
https://www.youtube.com/watch?v=eJMYVLPX0no&t=228s
horizontal_synchronization: process(clk25, reset, hpos)
begin
    if reset = '1' then
        hsync <= '0';
    elsif rising_edge(clk25) then
        if (hpos <= (hd + hfp)) or (hpos > (hd + hfp + hsp)) then
            hsync <= '1';
        else
            hsync <= '0';
        end if;
    end if;
end process;


--the vertical sync output for basys3
--very useful info on vga drivers at
https://www.youtube.com/watch?v=eJMYVLPX0no&t=228s
```

```
vertical_synchronization: process(clk25, reset, vpos)
begin
    if reset = '1' then
        vsync <= '0';
    elsif rising_edge(clk25) then
        if (vpos <= (vd + vfp)) or (vpos > (vd + vfp + vsp)) then
            vsync <= '1';
        else
            vsync <= '0';
        end if;
    end if;
end process;


--the initialization of the vertical pixel infos of the notes and the sliding mechanism logic of the game
vertical_pos: process(clk25, vpos, hpos)
begin
    if rising_edge(clk25) then
--increase the vertical pixel value of each note according to the vertical speed
        if start = '1' then
            if vpos = 0 and hpos=0 then
                for i in 0 to 79 loop
                    if note_vertical_properties(i) < vd then
                        note_vertical_properties(i) <= note_vertical_properties(i) + vertical_speed;
--set the vertical value info to a value which is greater than max screen vertical pixel (480 in our case)
                    else
                        note_vertical_properties(i) <= 1923; --the founding year of the Turkish Republic <3
                    end if;
                end loop;
            end if;
--initialization of vertical pixels of the notes, each of them starts at a negative value!
```

```
        else
            for i in 0 to 79 loop
                note_vertical_properties(i) <=  -1 * (i+1) * (note_height + notes_height_diff);
            end loop;
        end if;
    end if;
end process;


--set the horizontal pixel value and the 12-bit rgb colour representation of each note according to the initials array
--i am lazy and since the notes are manually inputted, i just coded the initials
horizontal_pos_and_colour: process(clk25)
begin
        for i in 0 to 79 loop
            if note_horizontal_colours_string(i) = "g" then
                note_horizontal_properties(i) <= note_green_horizontal;
                note_horizontal_colours(i)<= colour_green;
            elsif note_horizontal_colours_string(i) = "r" then
                note_horizontal_properties(i) <= note_red_horizontal;
                note_horizontal_colours(i)<= colour_red;
            elsif note_horizontal_colours_string(i) = "y" then
                note_horizontal_properties(i) <= note_yellow_horizontal;
                note_horizontal_colours(i)<= colour_yellow;
            elsif note_horizontal_colours_string(i) = "b" then
                note_horizontal_properties(i) <= note_blue_horizontal;
                note_horizontal_colours(i)<= colour_blue;
            elsif note_horizontal_colours_string(i) = "o" then
                note_horizontal_properties(i) <= note_orange_horizontal;
                note_horizontal_colours(i)<= colour_orange;
            elsif note_horizontal_colours_string(i) = "v" then
                note_horizontal_properties(i) <= note_violet_horizontal;
                note_horizontal_colours(i)<= colour_violet;
```

```
        elsif note_horizontal_colours_string(i) = "w" then
            note_horizontal_properties(i) <= note_white_horizontal;
            note_horizontal_colours(i)<= colour_white;
        else    --elsif note_horizontal_colours_string(i) = "p" then
            note_horizontal_properties(i) <= note_pink_horizontal;
            note_horizontal_colours(i)<= colour_pink;
        end if;
    end loop;
end process;


--change the initials array (Therefore the horizontal position and colour arrays) according to the song selection by the user
--remark that the notes are coded in a form such you would play on a real guitar if you actually played the real song
--easier to write the colour initials manually rather than the integer hpos and 12-bit vector rgb values :)
with select_song select note_horizontal_colours_string <=
        ("g","b","g","b","g","b","g","b","g","b","r","o","r","o","r","o","r","o","r","o",--first 20 notes of seek&destroy
         "g","b","g","b","g","b","g","b","r","o","r","o","r","o","r","o", --next 16 notes
         "p","v","o","v","o","y","o","r","y","g","r","g","r","g","r","g", --next 16 notes
         "p","v","o","v","o","y","o","r","y","g","r","g","r","g","r","g", --next 16 notes
         "p","p","w","w","v","v","o","b","y","r","g","g") when '0', --last 12 notes

        ("g","y","o","o","g","y","v","o","g","y","o","o","y","g",--first 14 notes of raining blood
         "r","b","v","v","r","b","w","v","r","b","v","v","b","r", --next 14 notes
         "y","o","w","w","y","o","p","w","y","o","w","w","o","y", --next 14 notes
         "r","b","v","v","r","b","w","v","r","b","v","v","b","r", --next 14 notes
         "g","y","o","o","g","y","v","o","g","y","o","o","y","g", --next 14 notes
         "p","w","v","o","b","y","r","g","r","g") when others; --last 10 notes
```

```
--change the note speeds according to the difficulty input by the user
with difficulty select vertical_speed <=
    1 when '0',
    2 when others;


--this is the huge&complex process where we finally get to draw things on the VGA display
draw: process(clk25, reset, vpos, hpos)
begin
    if start = '1' then
--It is always nice to have a reset if the synchronization goes wrong at some point :)
        if reset = '1' then
            rgb <= colour_black;
        elsif rising_edge(clk25) then
            rgb <= colour_black;
            if (((vpos > (strum_upper_limit - strum_limit_height)) and (vpos <= strum_upper_limit)) or
            ((vpos > strum_lower_limit) and (vpos <= (strum_lower_limit + strum_limit_height))))
            then
--paint the strum area to the note colour when the player has hit a correct note
                if frequency = freq1 and ((hpos > note_green_horizontal) and (hpos < note_green_horizontal + note_width)) then
                    rgb<= colour_green;
                elsif  frequency = freq2 and ((hpos > note_red_horizontal) and (hpos < note_red_horizontal + note_width)) then
                    rgb<= colour_red;
                elsif frequency = freq3 and ((hpos > note_yellow_horizontal) and (hpos < note_yellow_horizontal + note_width)) then
                    rgb<= colour_yellow;
                elsif frequency = freq4 and ((hpos > note_blue_horizontal) and (hpos < note_blue_horizontal + note_width))  then
                    rgb<= colour_blue;
                elsif frequency = freq5 and ((hpos > note_orange_horizontal) and (hpos < note_orange_horizontal + note_width))  then
```

```
            rgb<= colour_orange;
        elsif frequency = freq6 and ((hpos > note_violet_horizontal) and (hpos < note_violet_horizontal + note_width))  then
            rgb<= colour_violet;
        elsif frequency = freq7 and ((hpos > note_white_horizontal) and (hpos < note_white_horizontal + note_width))  then
            rgb<= colour_black;
        elsif frequency = freq8 and ((hpos > note_pink_horizontal) and (hpos < note_pink_horizontal + note_width))  then
            rgb<= colour_pink;
--paint the background of the gameplay screen
        elsif (((hpos > note_green_horizontal) and (hpos < note_green_horizontal + note_width)) or
        ((hpos > note_red_horizontal) and (hpos < note_red_horizontal + note_width)) or
        ((hpos > note_yellow_horizontal) and (hpos < note_yellow_horizontal + note_width)) or
        ((hpos > note_blue_horizontal) and (hpos < note_blue_horizontal + note_width)) or
        ((hpos > note_orange_horizontal) and (hpos < note_orange_horizontal + note_width)) or
        ((hpos > note_violet_horizontal) and (hpos < note_violet_horizontal + note_width)) or
        ((hpos > note_white_horizontal) and (hpos < note_white_horizontal + note_width)) or
        ((hpos > note_pink_horizontal) and (hpos < note_pink_horizontal + note_width)))
        then
            rgb <= colour_white;
        end if;
    end if;
    if lightningvisible = True then
        rgb<= colour_red;
    end if;
--paint the necessary positions of the screen where notes are currently in with the necessary note colours
    for i in 0 to 79 loop
        if note_vertical_properties(i) > (-1 * note_height) and note_vertical_properties(i) <= vd then
```

```
                if ((vpos > note_vertical_properties(i)) and (vpos <= note_vertical_properties(i)
+ note_height)) and
                ((hpos > note_horizontal_properties(i)) and (hpos <=
note_horizontal_properties(i) + note_width))
                then
                    rgb <= note_horizontal_colours(i);
                end if;
            end if;
        end loop;
    end if;
  else
--this is the code for the main menu
    rgb <= colour_black;
    if (gamenamevisible = True) or (photovisible = True) or (songvisible = True) or
    (difficultyvisible = True) or (startswitchvisible = True)
    then
        rgb<=colour_white;
    elsif (fatihmehmetvisible = True) or (hardvisible = True) then
        rgb<=colour_red;
    elsif (thunderstruckvisible = True)or (smokevisible = True)then
        rgb<=colour_blue;
    elsif (easyvisible = True) then
        rgb<=colour_green;
    end if;
  end if;
end process;


--the rest of the code is the design signals&bitmaps that belong to the main menu
--the guitar picture is designed by an AI and the writings are designed in canva app with
writing style 'Pixelion'
--shoutout to https://www.dcode.fr/binary-image is the site I used for jpg to binary array
conversion
```

gamename
<=("000000000000000000000000000000000000000000011111001111100111110011111000
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photovisible <= (vpos > 130) and (vpos < 392) and (hpos < 300) and (photo(vpos-131)(hpos) = '1');

song <= (
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songvisible <= (vpos>133) and (vpos<153) and (hpos>299) and (song(vpos-134)(hpos-300) = '1');

thunderstruck<=
("0000000000000000000000000000000000000000000000000001101101011011011 0001101
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0000000000000000000000000000000000000000");

thunderstruckvisible <= (vpos > 172) and (vpos < 192) and (hpos > 299) and
(thunderstruck(vpos-173)(hpos-300) = '1') and (select_song = '0');

smoke<=
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0011111000000111110001111100000000000000000000111110000001111100011111000000
0111110000000000000000000111110000000011111000000111110001111100000000000000
000001111100000011111000000111110001111100000011111000000001111100000000111
11000000000000111110000001111100000000000000",

"000000000110110000000000000001101000000011010000000101100001011000000110110
0011011000000110110001101000000000000000000000110110000001101100011010000000
0110100000000000000000000110110000000000101100000000101100011011000000000000000
000000101100000000101100000000101100011011000000110110000000000101100000000010
11000000000000101100000000101100000000000000",

"000000000111110000000000000001111100000011111000000111110001111100000011111
0011111000000111110001111100000000000000000000111110000001111100011111000000
0111110000000000000000000111110000000011111000000111110001111100000000000000
000001111100000011111000000111110001111100000011111000000001111100000000111
11000000000000111110000001111100000000000000",

"000000000111110000000000000001111100000011111000000111110001111100000011111
0011111000000111110001111100000000000000000000111110000001111100011111000000
0111110000000000000000000111110000000011111000000111110001111100000000000000
000001111100000011111000000111110001111100000011111000000001111100000000111
11000000000000111110000001111100000000000000",

"000000000110110100100001000011010000000110100000000101100001011000000110110
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0110100000000000000000000110110000000000101100001001011000110110100100000000000
000000101100000000101100000000101100011011010010110110000000000101100000000010
1100001000000001011000010010000000000000000",

"000000000111111111111111100011111000000111110000011111001111100000011111
0011111111111110000001111111110000000000000000000111110000001111100011111000000
1111110000000000000000000111110000000011111111111111110001111111111000000000
000001111100000011111000000111110001111111111111111110000000011111000000000111
111111100000011111111111111000000000000000",

"000000000111111111101101100011111000000011110000000011110001101100000011011
0011111111111110000001111111011000000000000000001111100000001111100011111000000
0111100000000000000000000111110000000000111111011111110001101101111000000000000
0000001111000000111110000000110110001111011110111110000000001101100000000011
1111101100000011111110111100000000000000000",

"00000000000000000000110110001111000000011110000000111100011011000000110110
00110110000001101100011110000000000000000000011011000000110110001111000000
01111000000000000000001101100000000111100000011011000110110000000000000000
00000011110000001101100000011011000110110000001101100000000110110000000011
11000000000000111100000011011000000000000",

"00000000000000000000111110001111100000111111000001111110011111000000111110
00111110000001111100011111000000000000000000001111100000011111000111110000
11111100000000000000001111100000000111110000011111000111110000000000000000
00000111110000001111100000011111000111110000001111100000000111110000000111
11000000000001111100000011111000000000000",

"00000000000000000000110110001101000000011010000000101100001011000000110110
00110110000001101100011010000000000000000000011011000000110110001101000000
01101000000000000000001101100000000010110000000101100011011000000000000000
00000010110000000101100000001011000110110000000110110000000001011000000010
11000000000000101100000001011000000000000",

"00000000011111000000111110001111100000011111000000111100011111000000111110
00111110000001111100011111000000000000000000001111100000011111000111110000
01111100000000000000001111100000000111110000011111000111110000000000000000
00000111110000001111100000011111000111110000001111100000000111110000000111
11000000000001111100000011111000000000000",

"00000000011111000000111110001111100000011111000000111100011111000000111110
00111110000001111100011111000000000000000000001111100000011111000111110000
01111100000000000000001111100000000111110000011111000111110000000000000000
00000111110000001111100000011111000111110000001111100000000111110000000111
11000000000001111100000011111000000000000",

"00000000000011000000110000001101000000011010000000101100000011000000110000
00110110000001101100011010000000000000000000011000000110000001101000000
01101000000000000000001101100000000010110000000101100011011000000000000000
00000000110000000000000000001000000110110000001101100000000010110000000010
11000000000000101100000001011000000000000",

"00000000000011111111110000001111100000011111000000111110000001111111110000
00111110000001111100011111111111111000000000000000011111111110000001111100000
01111100000000000000001111100000000111110000011111000111111111111110000000
00000000111111110000001111111100000111110000001111100000000011111000000111
11111111110011111000000111110000000000000",

"00000000000011111111110000001111100000011111000000111110000001111111110000
00111110000001111100011111111111111000000000000000011111111110000001111100000
01111100000000000000001111100000000111110000011111000111111111111110000000

00000000111111110000011111110000011111000001111100000001111100000000111
1111111111001111100000011111000000000000");

smokevisible <= (vpos > 172) and (vpos < 192) and (hpos > 299) and (smoke(vpos-173)(hpos-300) = '1') and (select_song = '1');

difficulty_2
<=("00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000011111111111110000011111111111000111111111111100011111111111111
10011111111111000001111111111100000111110000011111001111110000000000111
11111111111110001111100000011111000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000001111111111111000000111111111110001111111111111100011111111111111000
01111111111000000111111111110000011111000000111111000111110000000000111111
11111111100011111000000111110000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000001101100000011011000000110110000001101100000000000110110000000000
00001011000000001011000000110010001101100000001101000011110000000000000000
11110000000001101100000011011000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000001111100000011111000000111110000001111100000000000111110000000000
00011111000000111110000001111100011111000000111110001111100000000000000001
11111000000001111100000011111000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000001101100000011011000000110110000001101100000000000110110000000000
00011011000000110110000001111100011011000000111100001111000000000000000000
11110000000001101100000011011000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000001111100000011111000000111110000001111100000000000111110000000000
00011111000000111110000000000000011111000000111110001111100000000000000001
11110000000001111100000011111000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000

000000000011111000000111110000011111000000111110000000000011111000000000000
000111110000001111100000000000000111110000011111100111111000000000000000001
111110000000011111000001111100000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000000000000000000000000000000000000
000000000011011000001101100000110110000011010000000000011011000000000000
000010110000001101100000000000000101100000011010000110100000000000000000000
110100000000011011000001101100000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000000000000000000000000000000000000
000000000011111000001111100000111110000011111111110000001111111111000000
000111110000001111100000000000001111100000111111001111110000000000000001
111110000000000011111111111000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000000000000000000000000000000000000
000000000011111000001111100000111110000011111111110000001111111111000000
000111110000001111100000000000001111100000111111001111110000000000000001
111110000000000011111111111000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000000000000000000000000000000000000
000000000011011000001101100000110110000011010000000000011011000000000000
000010110000001101100000000000000110110000001101000011110000000000000000000
111100000000000000110100000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000000000000000000000000000000000000
000000000011111000001111100000111110000011111000000000001111100000000000
000111110000001111100000000000001111100000111111001111110000000000000001
111110000000000000111110000000011000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000000000000000000000000000000000000
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000111110000001111100000000000001111100000111111001111110000000000000001
111110000000000000111110000000011000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000000000000000000000000000000000000
000000000011011000001101100000110110000011010000000000011011000000000000
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111100000000000000110100000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
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"00000000000000000000000000000000000000000000000000000000000000000000000000000000
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11110000000000000001111100000000010000000000000000000000000000000000000000000
00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
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01011011011000000110100101100000000011011011011000000111110101101100000000
11010000000000000011010000000001100000000000000000000000000000000000000000000
00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000001111111111110000011111111111000111110000000000011111000000000
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11111000000000000001111100000000011000000000000000000000000000000000000000000
00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000001111111111110000011111011110001111100000000000111110000000000
01111111111000000110111111110000000011111111111000000111111111111000000001
11110000000000000001111100000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000");

difficultyvisible <= (vpos > 247) and (vpos < 267) and (hpos > 299) and (difficulty_2(vpos-248)(hpos-300) = '1');

easy
<=("00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000001111111111111
10000011111111111000000011111111111000000111110000011111000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000001111111111111000

000111111111110000000011111111111000000111110000001111100000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000011011000000000001011
000011010000011010000100110000011011000110110000001101100000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000011111000000000001111
100000111100001111100011111000000111110001111100000011111000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000011011000000000001011
000011110000011111000111110000001101100011111000000110110000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000011111000000000001111
100000111100001111100011111000000000000011111000000111110000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000011011000000000001011
000011110000011011000111110000000000000110110000001101100000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000011111111111000000111
111111111111111100011111111111111111000001111111111000000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000011111111111000000
11111111111111111000111111111111111100000011111111110000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000011011000000000000
01111000000011011000000000000011011000000001101000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000011111000000000000
01111100000011111000000000000011111000000001111100000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000011111000000000000
01111100000011111000000000000011111000000001111100000000000000000000000000000000
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"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000011011000000000000
01111000000011011000000000000011011000000001101000000000000000000000000000000000
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"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000011111000000000000
11111100000011111000111110000001111100000001111100000000000000000000000000000000
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00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000011111000000000000
11111100000011111000111110000001111100000001111100000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000011011010010110000
01111000000011011000001101001011000000000001101000000000000000000000000000000000

00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000001111111111111100
11111100000011111000001111111111000000000011111100000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000001111111111111000
01111100000011111000001111111111000000000011111000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000");

easyvisible <= (vpos > 286) and (vpos < 306) and (hpos > 299) and (easy(vpos-287)(hpos-300) = '1') and (difficulty = '0');

hard
<=("00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000001111100000011111
10000001111111111000000111111111111100000111111111111100000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000001111100000011111
00000111111111100000111111111111100000111111111111100000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000001101000000110110
00110110000001101000011011000000110010001111100000011010000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000001111100000011111
00111110000001111100011111000000111110001111100000011111100000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000110110000001111100
0011011000000111110001101100000011111000111110000000111100000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000111110000001111100
0011111000000111110001111100000011111000111110000000111100000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000111110000001111100
001111100000011111000111110000001111100011111000000011111000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000110100000001101100
0011011000000110110001101100000001111000111110000000111100000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000000011111111111111110
001111111111111111000111111111111110000011111000000011111000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000000011111111111111110
001111111111111111000111111111111110000011111000000011111000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000110110000001101100
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00000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000
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001111100000011111000111110000001111100011111000000011111000000000000000000

```
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00000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000
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000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000110100000001101100
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"00000000000000000000000000000000000000000000000000000000000000000000000000
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001111100000011111000111110000001111100011111000000111111000000000000000000
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00000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000
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001111100000011111000111110000001111100011111000000111111000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000110100000001101100
001101100000011011000110110000000111100011011011011010000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000111110000001111100
001111100000011111000111110000001111100011111111111111000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000",

"00000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000111110000001111100
001111100000011111000111110000001111100011111110111111000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000");
```

```
hardvisible <= (vpos > 286) and (vpos < 306) and (hpos > 299) and (hard(vpos-287)(hpos-
300) = '1') and (difficulty = '1');



startswitch <=(
"00000000000000000000000000000000001111111110000001111100000011111000000
111111001111111111100011111111111111100000011111111110000001111100000111
110000000000001111111111111111100000111111111110000000000000000001111111111
1000001111111111111111110000011111111111000000111111111111100000011111111111
1111100000000000000000000000000000000000",

"00000000000000000000000000000000001111111110000001111100000011111000000
111111000111111111100011111111111111100000011111111110000001111100000111
110000000000001111111111111111100000011111111110000000000000000001111111111
1000001111111111111111110000011111111111000000111111111111100000011111111111
1111100000000000000000000000000000000000",

"00000000000000000000000000000000001100000011011000110110000000110110000000
011010000001111100000000000001101100000000010110000000110100001111000000000110
110000000000000000001101100000000010110000000110100000000000000101100000001
001000000000110110000000001011100000011010000110110000000110110000000000011110
0000000000000000000000000000000000000000",

"0000000000000000000000000000000001111100000011111000111110000000111110000000
111111000000111110000000000000111110000000001111100000011111100111111000000111
110000000000000000011111000000000111111000000111110000000000000111110000011
111100000000011111000000000011111000000111110001111100000001111100000000011111
0000000000000000000000000000000000000000",

"0000000000000000000000000000000001111100000011011000110110000000110110000000
011110000000111110000000000001101100000000011111000000001111000011110000000111
110000000000000000011111000000000011110000000111110000000000000111110000001
111000000000110110000000000111110000001101100011011000000011011000000000011111
0000000000000000000000000000000000000000",

"0000000000000000000000000000000001111100000000000000111110000000111110000000
111111000000111110000000000000111110000000001111100000000000000000111110000000111
110000000000000000011111000000000111111000000111110000000000000111110000000000
000000000000111110000000000011111000000111110001111100000001111100000000011111
0000000000000000000000000000000000000000",

"0000000000000000000000000000000001111100000000000000111110000000111110000000
111111000000111110000000000000111110000000001111100000000000000000111111000000111
110000000000000000011111000000000111111000000111110000000000000111110000000000
```

000000000000111110000000000111110000001111100011111000000111110000000011111
00000000000000000000000000000000000000000",

"00000000000000000000000000000000110110000000000000001101100000001101100000000
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00000000000011011000000000011100000000110110001101100000011011000000000011010
00000000000000000000000000000000000000000",

"00000000000000000000000000000000111111111111111000111110000001111100000000
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"00000000000000000000000000000000111111111111111000111110000001111100000000
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111100000000111110000000001111111111111110001111111111111000000000000011111
00000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000110110001101100000001101100000000
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11000000000000000000110110000000000111000000001101000000000000000000000000001
01100000000001101100000000001111100000011011000110110000000110000000000011010
00000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000111110001111100000001111100000000
111111000001111100000000000001111100000000011111000000000000000111110000000111
110000000000000000001111100000000011111100000011111000000000000000000000000011
111000000000011111000000000011111000000111110001111100000011111000000000011111
00000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000111110001111100000001111100000000
111111000001111100000000000001111100000000011111000000000000000111110000000111
110000000000000000001111100000000011111100000011111000000000000000000000000011
111000000000011111000000000011111000000111110001111100000011111000000000011111
00000000000000000000000000000000000000000",

"000000000000000000000000000000000000000000110110001101100000001101100000000
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11000000000000000000110110000000000111000000001101000000000000000000000000001
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00000000000000000000000000000000000000000",

"00000000000000000000000000000001111100000011111000111110000001111100000
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11000000000000000000111110000000111111000000111110000000000001111100000011
11110000000111110000000011111000000111110001111100000011111000000000111110
00000000000000000000000000000000000000000",

"00000000000000000000000000000000111110000011111000111110000001111100000
11111100000111110000000000011111000000011111000000111110001111100000011
11000000000000000000111110000000111111000000111110000000000001111100000011
11100000000111110000000011111000000111110001111100000011111000000000111110
00000000000000000000000000000000000000000",

"00000000000000000000000000000000001101001011000000000110100100000001001
10110000010111110110000000001101100000000000110110100110000001111000000011
10000000000000000001101100000000000111010110110000000000000000000011011010
00000000000011011000000000111100000001101100011011000000110110000000001101
00000000000000000000000000000000000000000",

"00000000000000000000000000000000001111111111000000000111111110000001111
11100000111111111110000000001111100000000000111111111110000011111100000011
11000000000000000000111110000000000011111111111000000000000000000011111111
10000000000011111000000000111110000001111100011111000000111110000000001111
00000000000000000000000000000000000000000",

"00000000000000000000000000000000001111111111000000000111111110000001111
11100000111111111110000000001111100000000000111111111110000011111100000011
11000000000000000000111110000000000011111111011000000000000000000011011111
10000000000011111000000000111110000001111100011111000000111110000000001111
00000000000000000000000000000000000000000");

startswitchvisible <= (vpos > 366) and (vpos<386) and (hpos>299) and (startswitch(vpos-367)(hpos-300)='1');

fatihmehmet <=(
"00000000000011111111100000000000000000011110000011110000111100000000000
00000011111100111111111000000000000000000011110000000000000000000000000000
00000000000000000011110000110000000000000000000011100000111100000000000000
00000000000000000000000000000011100000000000000000000000000000000000000000
0",

"00000000000011111111100000000000000000011100000111100001111000000000000
00000011111100111111111000000000000000000011110000000000000000000000000000
00000000000000000011110000110000000000000000000011100000111100000000000000

000000000000000000000000000011100000000000000000000000000000000000000000
0",

"000000000000111000000000000000000000000111000000000000011100000000000000
000011110000111100001111000000000000000011110000000000000000000000000000
000000000000000001111000011000000000000000000001111000011110000000000000
000000000000000000000000000000000000000000000000000000000000000000000000
0",

"000000000000111000000000000000000000000111000000000000011100000000000000
000011110000111100001111000000000000000011110000000000000000000000000000
000000000000000001111000011000000000000000000001111000011110000000000000
000000000000000000000000000000000000000000000000000000000000000000000000
0",

"000000000000111000000000001111111110011111111001111111100111111111100000000
000011110000111100000111000011111111000011111111110000001111100001111100
000111111110000111111110000000011111111000000000111000001111000011111111000
000111111110000001111111100111111100000111111100000001111111000000000000000
0",

"000000000000111000000000001111111110001111111001111111100111111111100000000
000011110000111100000111000011111111000011111111110000001111100001111100
000111111110000111111110000000011111111000000000111000001111000011111111000
000111111110000001111111100111111100000111111100000001111111000000000000000
0",

"000000000000111111110000111000001110000111100000011110000111100001111000000
000011110000111100000111001111000011110011110000111100111100001111000011110
011110000111100001111000000001111000000000000001111000011110011100000111100
011110000111100111100000000000111000001110000011100011100000111000000000000
0",

"000000000000111111110000111000001110000111100000011110000111100001111000000
000011110000111100000111001111000011110011110000111100111100001111000011110
011110000111100001111000000001111000000000000001111000011110011100000111100
011110000111100111100000000000111000001110000011100011100000111000000000000
0",

"000000000000111000000000011100000111000001110000001111000011110000111100000
000011110000111100000111001111111111110011110000111100111100001111000001110
011111111111100001111000000001111111111000000000111000001111001111111111110
011110000111100111111111100001110000011100000111000111000001110000000000000
0",

"00000000000011100000000111100000111000011110000001111000011110000111100000
00001111000011110000011100111111111111001111000011110011110000111100001111
01111111111110000111100000000111111111100000000011110000111100111111111110
01111000011110011111111110000111000001110000011100011100000111000000000000
0",

"00000000000011100000000111100000111000011110000001111000011110000111100000
00001111000011110000011100111100000000001111000011110011110000111100000111
01111000000000000111100000000000000111100000000000111111110000111000000000
01110000000000000000111100001110000011100000111000111000001110000000000000
0",

"00000000000011100000000111100000111000011110000001111000011110000111100000
00001111000011110000011100111100000000001111000011110011110000111100000111
01111000000000000111100000000000000111100000000000111111110000111000000000
01111000000000000000111100001110000011100000111000111000001110000000000000
0",

"00000000000011100000000011111111110000111100001111111001111000011110000
00001111000011110000011100001111111100001111000011110011110000111100001111
00011111111000000111100000000111111110000000000000000111100000000111111100
01111000000000111111110000111111110000111111100000111000001110000000000000
0",

"00000000000011100000000011111111110000111100001111111001111000011110000
00001111000011110000011100001111111100001111000011110011110000111100001111
00011111111000000111100000000111111110000000000000000111100000000111111100
01111000000000111111110000111111110000111111100000111000001110000000000000
0");

fatihmehmetvisible<= (vpos>440) and (vpos<456) and (hpos<300) and (fatihmehmet(vpos-441)(hpos)='1');

lightning <=(
"00000000000000000000000000000000000111111111110000010000000000000000000000000",

"00000000000000000000000000000000000111111111110000000000000000000000000000000",

"00000000000000000000000000000000000111111111110000000000000000000000000000000",

"00000000000000000000000000000100000111111111111000000000000100000000100000000000",

"00000000000000000000000001000000000011111111111000000000000100000000000000000000",

"00000000000000000001000010000100000011111111111000001000000100000000000000000000",

"00000000000000000001000010000100000011111111111000001000000100000010000000000000",

"00000000000000000000000001000000000011111111111000000000000000000010000000000000",

"00000000000000000000000001000000000011111111111000000000000000000000000000000000",

"00000000000000000000000001000000000011111111111000001000010000010000000000000000",

"00000000000000000000000001000000000011111111111000001000010000110000000000000000",

"00000000000000000000000001000000000011111111111000001000010001000000000000000000",

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"00000000000000000000000000011000000000001111111110000000000110001100000000000000",

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```
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"0000000000000000000000000000000000000000010000000000000000000000000000000000000000000");


lightningvisible <= (((vpos>30) and (vpos<176) and (hpos<85) and (lightning(vpos-31)(hpos)='1')) or
                    ((vpos>250) and (vpos<396) and (hpos<85) and (lightning(vpos-251)(hpos)='1')) or
                    ((vpos>30) and (vpos<176) and (hpos>574) and (lightning(vpos-31)(84-(hpos-565))='1')) or
                    ((vpos>250) and (vpos<396) and (hpos>574) and (lightning(vpos-251)(84-(hpos-565))='1')));



--enjoy the game always rock&roll ;)


end Behavioral;
```