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International
Journal
Of Modern Engineering Research (IJMER)

Design of VGA Controller using VHDL for LCD Display using FPGA

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Abstract: *Basically, here I have used VGA for implementing basic characters/Symbols that can be either used in advertisements that deals with real-time application. So, I thought of using VGA as a standard for this implementation as it is the basic graphics array and compatible with other graphical arrays. This project also describes about the design of VGA (Video Graphic Array) Controller using combination of three bit input data to control eight differences colors to display text at monitor by using on board pushbuttons for the input. Three color signal referred to collectively as R (red), G (green) and B (blue) signal(i.e. RGB). The VGA monitor using resolution of 640 by 480 by mode to display Characters/Text/Images in different colors. Here, we used VHDL language on Xilinx ISE software for interfacing the required peripheral to the Xilinx FPGA Spartan Series. Where, I implementing the application of VGA with the help of VHDL language on Xilinx FPGA, that will contain the logic part. For Simulation part we are using Modelsim 10.2. Finally, the results that we obtained for VGA application implementation.*

Keywords: *FPGA, Modelsim 10.2a, VGA, VHDL, Xilinx ISE 14.2.*

I. Introduction

The term VGA stands for Video Graphic Array. This VGA is a graphics display systems for PCs developed by IBM. VGA has become one of the factor standards for PCs. In graphics, generally the resolution is either 640 by 480 within 16 colors or 320 by 200 within 256 colors. While this resolution has been superseded in the personal computer market, it is becoming a popular resolution on mobile devices. Figure 1 shows overview of VGA port connection to a monitor.

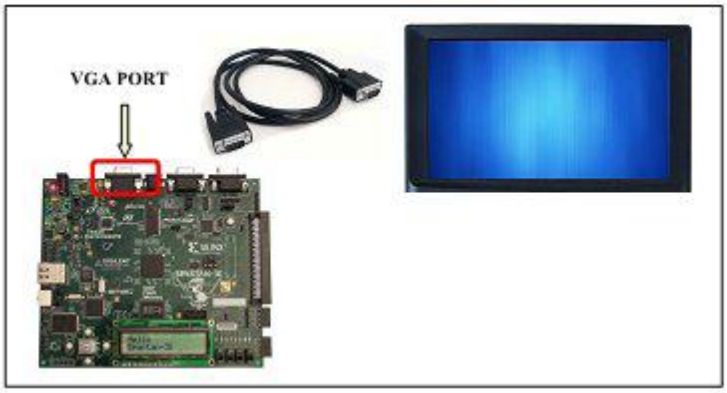


Fig 1: VGA port connection to a monitor

II. VGA Principal

A colorful image is generated when the electron beam from a cathode ray tube hits the fluorescent screen. To generate an image, the screen will be scanned by the electron beam. The scan mode can be divided into progressive scan and interlaced scan.

The progressive scan begins from the top left corner of the screen and it scans point by point from left to the right of one line. After one line is scanned, the electron beam moves back to the left start point of the next line and the beam is synchronized by horizontal synchronization signal. During this movement, the cathode ray tube blanks the electron beam. The beam scans the screen line by line until it reaches to the bottom right corner of the screen. After all lines scanned, the beam moves back to the top left corner of the screen and the beam is synchronized by horizontal synchronization signal. During this movement also, the cathode ray tube blanks the electron beam. At this point, an image frame is generated. Figure 2 shows the progressive scan.

The interlaced scanning scans every other line of the screen. After the screen is scanned once, the electron beam returns to scan the rest lines.

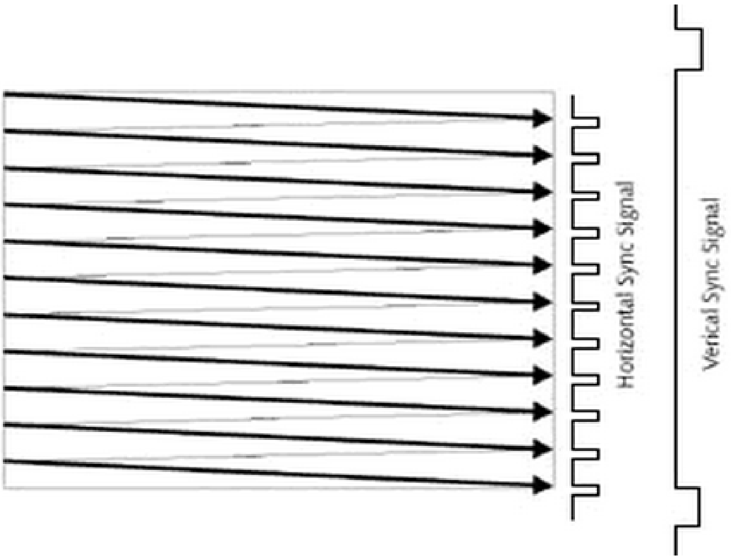


Fig 2: Progressive Scan

2.1 VGA Controller:

Video Graphics Array (VGA) is mostly used for computer monitors, with a high-definition resolution video standard. It has the ability the ability to transmit a sharp detailed image. VGA uses separate wires to transmit the three color component signals, vertical and horizontal synchronization signals. Red, green and blue are three signals that send color information to VGA monitor. There are four main components in VGA controller which are VGA interface signals, VGA interface definition, VGA control signal, VGA timing Control and VGA monitor.

2.1.1 VGA Interface Signals:

There are two types VGA interface signals to display which is data signal, and the other one is control signal. Data signal have three parts which is Red, Green and Blue and for control signal have two parts which is Horizontal Synchronization and Vertical Synchronization. There are different frequencies of the horizontal synchronization signal and vertical synchronization signal for the changeable output resolution. Here is a table to imply the range of

2.2 VGA Interface Definition:

VGA interface sends corresponding display signals to display through DB-15 linker which is directly connected to Monitor or LCD by monitor cable. There are 15 pinholes which are asymmetrically divided into 3 lines, and there are 5 on each line. [3] Here is Figure 3 showing how these pinholes are arranged.

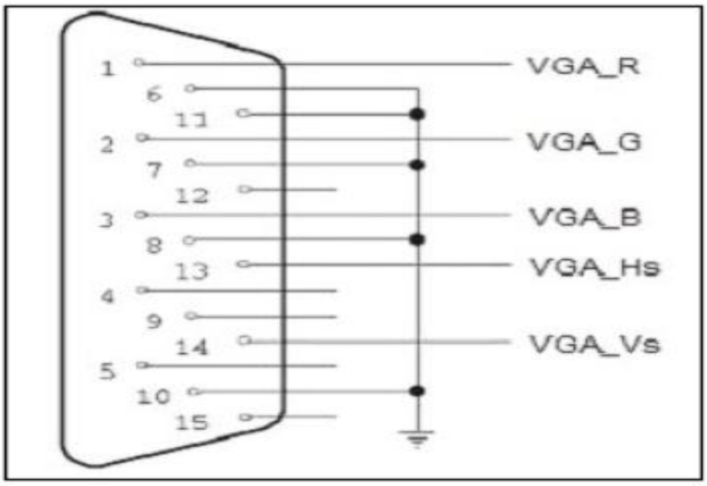


Fig 3: VGA display port

2.3 VGA Color Signal:

RGB Color Model is an additive color model. It generates various colors by adding three basic colors—red, green and blue. A color can be represented by how much each of the three basic colors is included. [4] Each of the three basic colors is one color component of the represented color. It can be concluded by the following expression:

color = f (r, g,b)

They are just shown in Table 1.

Table 1: 3-Bit Display Color Codes.

VGA_R	VGA_G	VGA_B	Resulting Color
0	0	0	Black
0	0	1	Blue
0	1	0	Green
0	1	1	Cyan
1	0	0	Red
1	0	1	Pink
1	1	0	Yellow
1	1	1	White

2.4 VGA Monitor:

Since a VGA monitor is the output device in this thesis, an understanding of how it works is necessary. This section describes the basics of the VGA technology, and how one goes about controlling it.

A VGA monitor is a complete video displaying system that provides a simple controlling interface, for the displaying of video images. This interface is defined in a VGA standard. Video images can be defined as images that consist of the 3 primary colors in various intensities; this creates a 2 dimensional image that is lifelike in appearance. The VGA monitor interface consists of 5 controlling signals. These are the Red, Green and Blue colour signals (RGB), the horizontal and vertical sync signals.

From Figure 3.2 below, it shows the VGA monitor with 640 columns by 480 rows. This VGA monitor is based on 25MHz clock. A single dot of colour on a video monitor does not impact much information. A horizontal line of pixels carries a bit more information. However, a frame composed of multiple lines can present an image on the monitor screen. A frame of VGA video typically has 480 lines and each line usually contains 640 pixels.

III. METHODOLOGY

3.1 The VGA Technology:

At the heart of the VGA monitor is the CRT described earlier. This time however, there are 3 electrons guns for each of the primary colours. The electron beam is scanned across the display section, row by row, starting from the top row. On the displaying end of the tube, there are 3 different phosphors, for each of the colours. The VGA monitor also contains the electronics that drive the horizontal and vertical deflection plates to control this scanning process. The scanning process takes place at a constant rate, which is defined in the VGA standard.

The viewing part of the monitor contains 480 x 640 picture elements, or pixels. The voltage levels on the RGB control signals determine the colour of each pixel, when the electron beam scans across this pixel. In order to provide motion in the image, the image needs to be refreshed at least 60 times per second as the human eye can spot flicker at refresh rates less than about 30 times per seconds. For 480 x 640 pixels VGA monitor, at a 60Hz refresh rate, approximately 40ns is needed per pixel. A 25 Mhz clock has a 40ns period

3.2 VGA Timing Control:

Pixels are updated in a serial fashion. The pixel clock runs at 25MHz. The electron beam starts at (0, 0) and goes horizontally through the first row, up to the last row, and last pixel at (479,639).

Timing of VGA signals are ruled by VESA. Here is a short introduction about how FPGA drive the VGA display with 640×480@60Hz. In the standard of VGA industry, the output frequency of pixel is 25.175MHz, and the frequencies of horizontal scan and vertical scan are 31.496 KHz and 59.940 Hz. If display receives this standard frequency, then the resolution will be 640×480, and refresh rate is 60Hz. [2]

The VGA vertical timing is basically the same as the VGA Horizontal Timing. The difference is that vertical synchronization pulse represents the end of one image frame and the start of the next frame. The RGB data during display interval includes all lines of the screen.

3.3 System Requirement Analysis:

Figure 4 shows the devices required in this project. We need Spartan 3E FPGA board which contain VGA interface. The host PC is used to configure the hardware design and download the designed from FPGA board. The display is controlled by the FPGA board interface and displayed on the LCD Monitor through VGA interface. From these devices, the following components are required:

- Spartan 3E FPGA board.
- SDRAM Controller for Memory
- VGA Controller Interface
- Clocks for processor, SDRAM and VGA

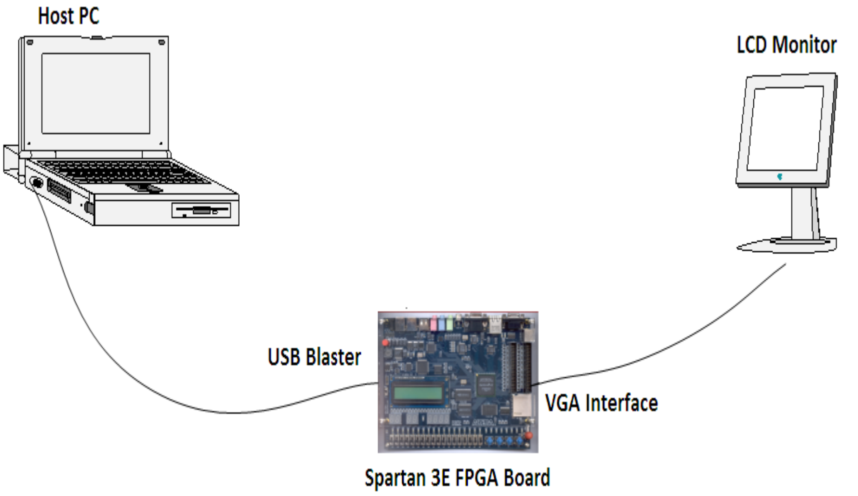


Fig 4: Required Devices and Collections

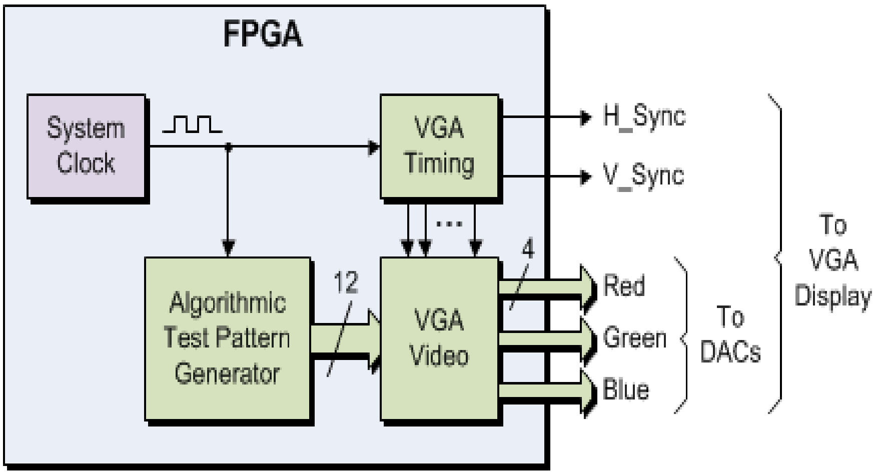


Fig 5: Block Diagram of VGA Controller

IV. Simulation Results

In this paper i interface a VGA port available on FPGA board to generate the character(s) from ASCII text characters. To display text on video controller is an important function. I made the Character generation circuit that took the character from internal ROM to facilitate the display of text characters on a screen. To display text on my VGA display, I organized the 640x480 display area into "tiles" where each tile represents a character location. In this project, the font size of each character is 16x8 (height & Width). This font will display 80 text characters in each line Mapped onto a 640x480 display (i.e., 640 pixels divided by 8 columns per character) and 30 lines (480 / 16). Each of the 640x480 pixels in the display are associated with one of the 80x30 character locations fig 6 shows the simulation result of VGA controller for display color input 100, display output color 100 and background color is 011.

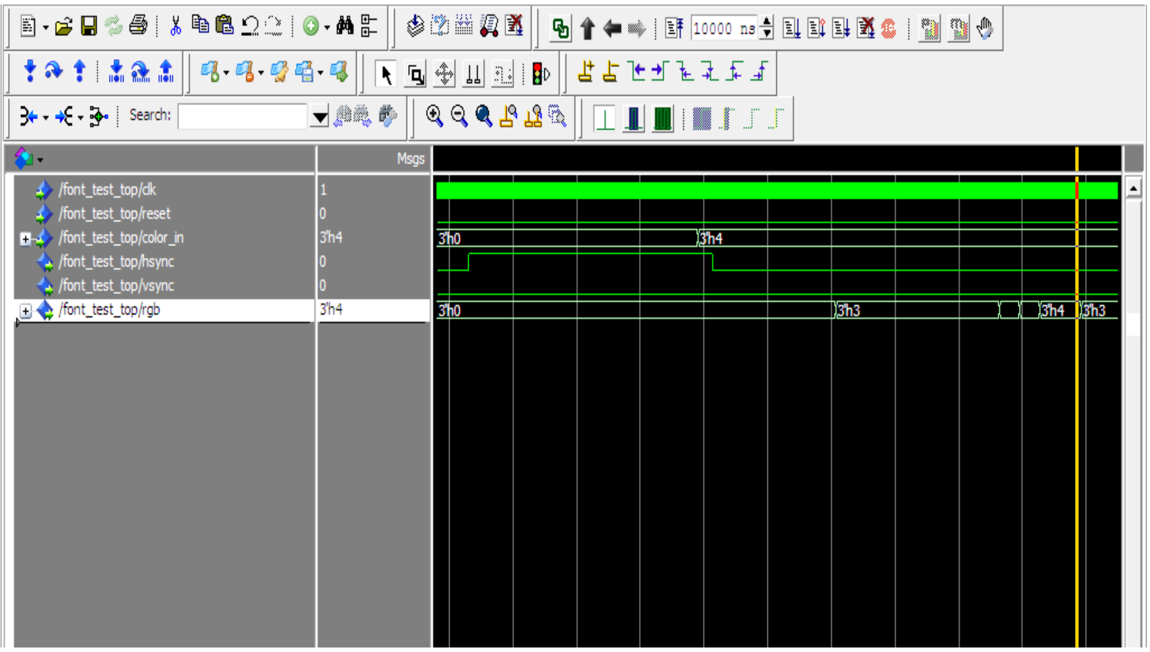


Fig 6: Simulation Result for VGA

Fig 7 shows the simulation result of VGA controller for display color input 110, display output color 110 and background color is 001.

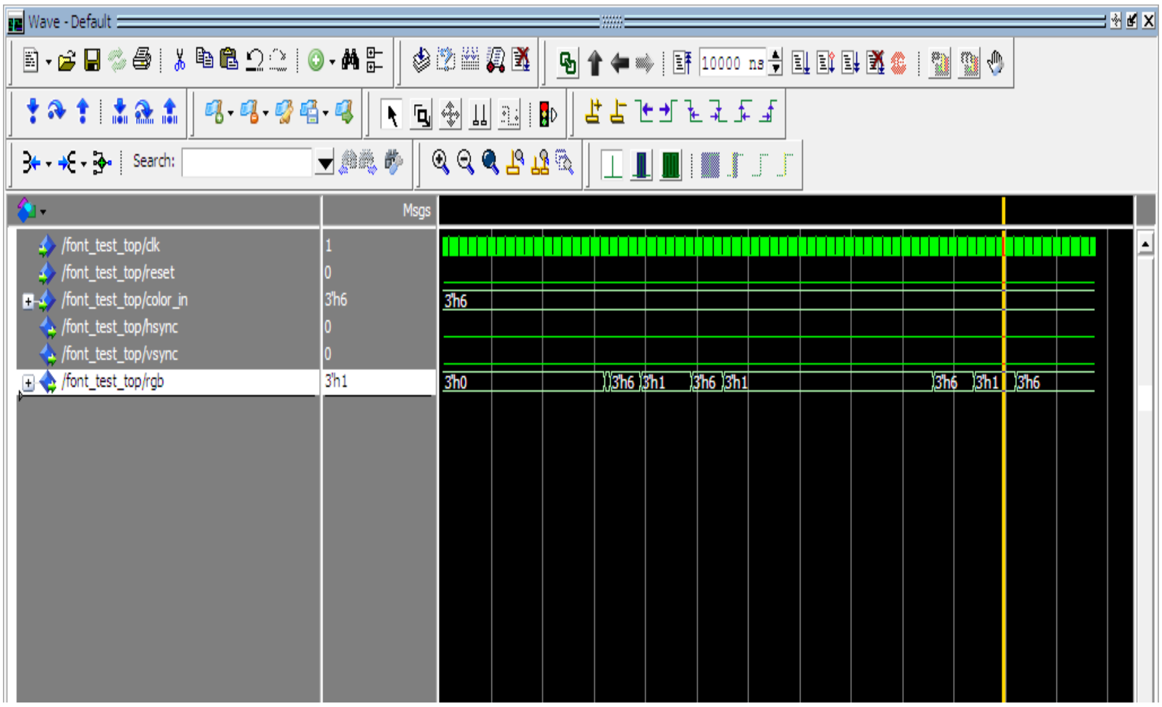
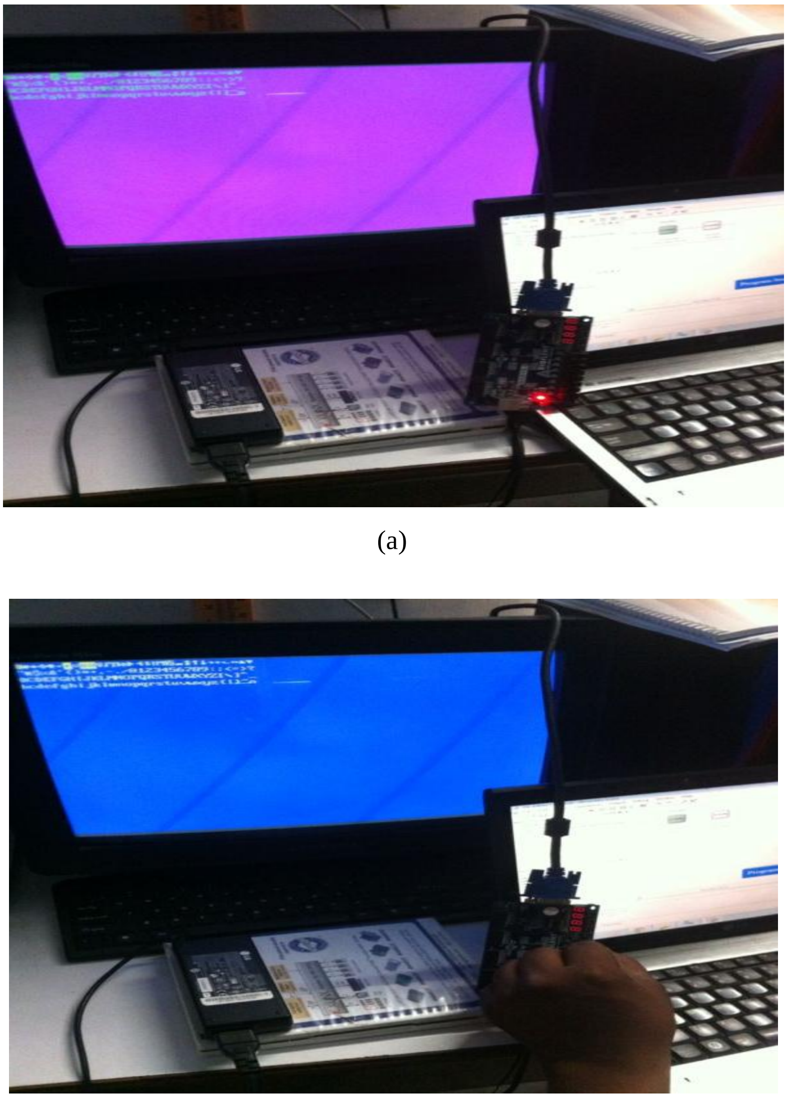


Fig 7: Simulation Result for VGA

We have implemented our work on FPGA Spartan3E also and we get result for different display color inputs by three DIP switches on FPGA board. DIP switches are responsible for the color of display character and background color. We need a CRT monitor to visualize the effects (Results may be vary for different CRT manufacturers) shows in fig 8.



(a)

(b)

Fig 8: Output display by FPGA kit.

We are using Xilinx tool for synthesis our code fig 9 shows the main RTL of our code.

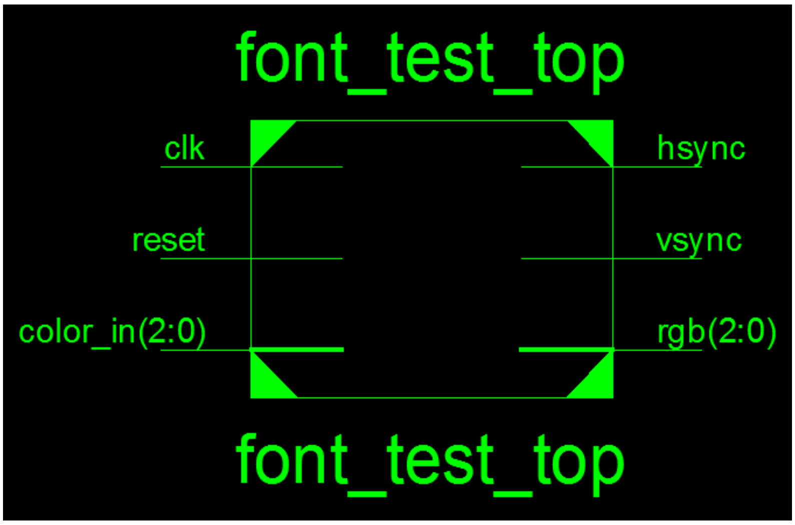


Fig 9: Main RTL

V. CONCLUSION

In this paper I interface a VGA port available on FPGA board to generate the character(s) from ASCII text characters. To display text on video controller is an important function. I made the Character generation circuit that took the character from internet ROM to facilitate the display of text characters on a screen. To display text on my VGA display, I organized the 640x480 display area into "tiles" where each tile represents a character location. In this project, the font size of each character is 16x8(height & Width). This font will display 80 text characters in each line Mapped onto a 640x480 display (i.e., 640 pixels divided by 8 columns per character) and 30 lines (480 / 16). Each of the 640x480 pixels in the display are associated with one of the 80x30 character locations.

VGA is an important output section for displaying the results. My work could be move further for interfacing the keyboard (PS2/USB) for more interesting real world implementation to a complete gaming device.

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