



O A X A C

Universidad Tecnológica de la Mixteca

Instituto de Electrónica y Mecatrónica

Ingeniería en Mecatrónica

Laboratorio de Potencia y Sistemas Electromecánicos

Semestre 2019-B

Reporte:

Implementación del módulo VGA gráficos y VGA Texto con la tarjeta de desarrollo Nexys 2

Antonio Madera Abisai
Camacena Ortiz Kevin
Cruz Juárez David Ricardo
Hernández Gutiérrez Luis Ángel
Equipo 01

M.E.C. José Antonio Juárez Abad



12 de junio de 2019

Índice

1. Resumen	4
2. Objetivos	4
2.1. Objetivo general	4
2.2. Objetivos específicos	4
3. Fundamentos	4
3.1. VGA (Video Graphics Array)	4
3.2. Basic operation of a CRT	4
4. VGA Gráficos	8
4.1. Esquemático	8
4.2. Demostración	9
4.3. Códigos	9
4.3.1. reloj	9
4.3.2. Video VGA	10
4.3.3. PRIMERO	13
5. VGA TEXTO	14
5.1. Esquematico	14
5.2. Demostración	15
5.3. fon unit rom	16
5.4. font test gen	56
5.5. VGA SYNC UNIT	57
6. Conclusiones	59
7. Bibliography	59

Índice de figuras

1.	Conceptual diagram of a CRT monitor.	5
2.	CRT scanning pattern.	6
3.	CRT scanning pattern.	7
4.	Esquemático del interface para controlar los gráficos VGA.	8
5.	Demostración.	9
6.	Esquemático del interface para controlar texto.	14
7.	Demostración.	15
8.	Demostración.	15
9.	Demostración.	16

Índice de tablas

Listings

1.	Digital Clock Manager	9
2.	Video VGA	10
3.	PRIMERO	13
4.	fon unit rom	16
5.	font test gen	56
6.	VGA SYNC UNIT	57

1. Resumen

Resumen

Escribir al final

Palabras clave: Xilinx, Simulación, ISim, VGA, Gráficos, Texto, Nexys-2, Spartan-3E

2. Objetivos

2.1. Objetivo general

Emplear la tarjeta Nexys II para controlar un monitor utilizando el protocolo VGA.

2.2. Objetivos específicos

- Desarrollar un módulo que permita la manipulación de gráficos (ej. Figuras, colores, etc.) en el monitor.
- Desarrollar un módulo que permita la manipulación de texto en el monitor.

3. Fundamentos

3.1. VGA (Video Graphics Array)

VGA is a video display standard introduced in the late 1980 in IBM PCs and is widely supported by PC graphics hardware and monitors. Here we are analyzing the interface for CRT monitors [1].

3.2. Basic operation of a CRT

The conceptual sketch of a monochrome CRT monitor is shown in Figure 1. The electron gun (cathode) generates a focused electron beam, which traverses a vacuum tube and eventually hits the phosphorescent screen. Light is emitted at the instant that electrons hit a phosphor dot on the screen. The intensity of the electron beam and the brightness of the dot are determined by the voltage level of the external video input signal, labeled mono in Figure 1. The mono signal is an analog signal whose voltage level is between 0 and 0.7 V.

A vertical deflection coil and a horizontal deflection coil outside the tube produce magnetic fields to control how the electron beam travels and to determine where on the screen the electrons hit. In today's monitors, the electron beam traverses (i.e., scans) the screen systematically in a fixed pattern, from left to right and from top to bottom, as shown in Figure 2.

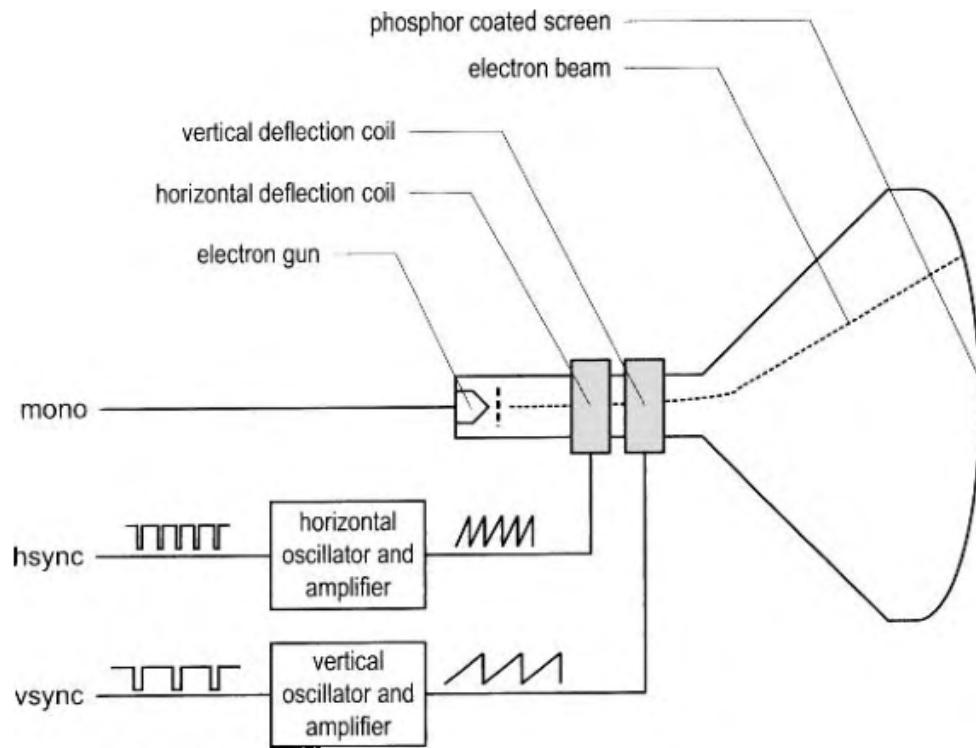


Figura 1: Conceptual diagram of a CRT monitor.

The monitor's internal oscillators and amplifiers generate sawtooth waveforms to control the two deflection coils. For example, the electron beam moves from the left edge to the right edge as the voltage applied to the horizontal deflection coil gradually increases. After reaching the right edge, the beam returns rapidly to the left edge (i.e., retraces) when the voltage changes to 0. The relationship between the sawtooth waveform and the scan is shown in Figure 3. Two external synchronization signals, hsync and vsync, control generation of the sawtooth waveforms. These signals are digital signals. The relationship between the hsync signal and the horizontal sawtooth is also shown in Figure 3. Note that the '1' and "0" periods of the hsync signal correspond to the rising and falling ramps of the sawtooth waveform.

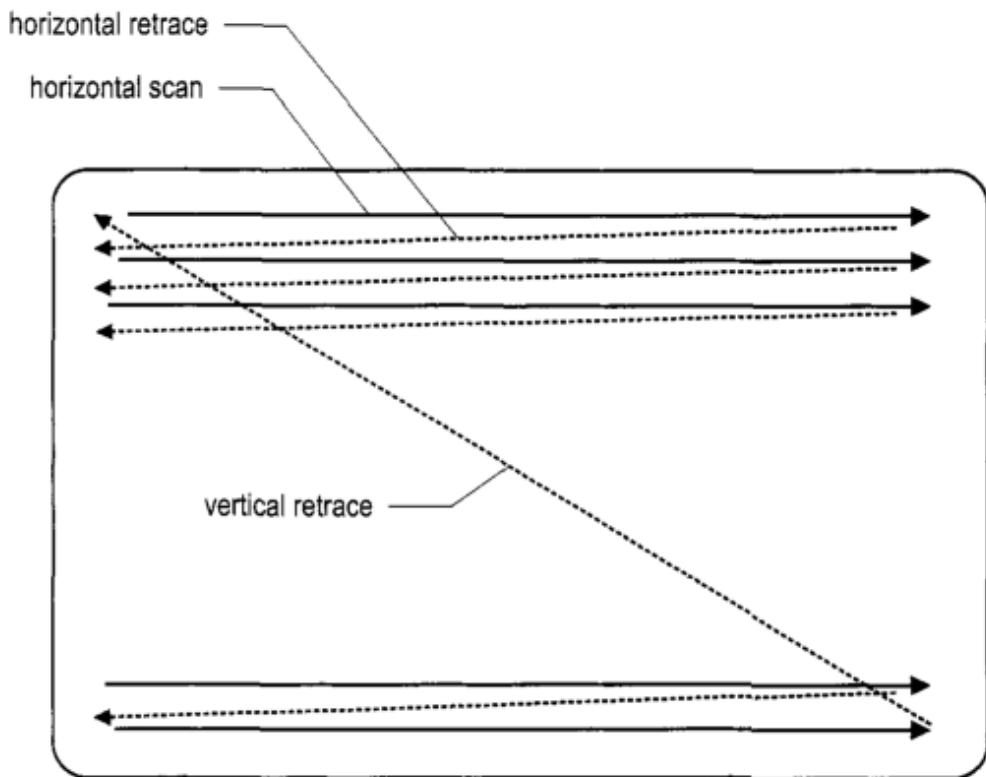


Figura 2: CRT scanning pattern.

The basic operation of a color CRT is similar except that it has three electron beams, which are projected to the red, green, and blue phosphor dots on the screen. The three dots are combined to form a pixel. We can adjust the voltage levels of the three video input signals to obtain the desired pixel color [2].

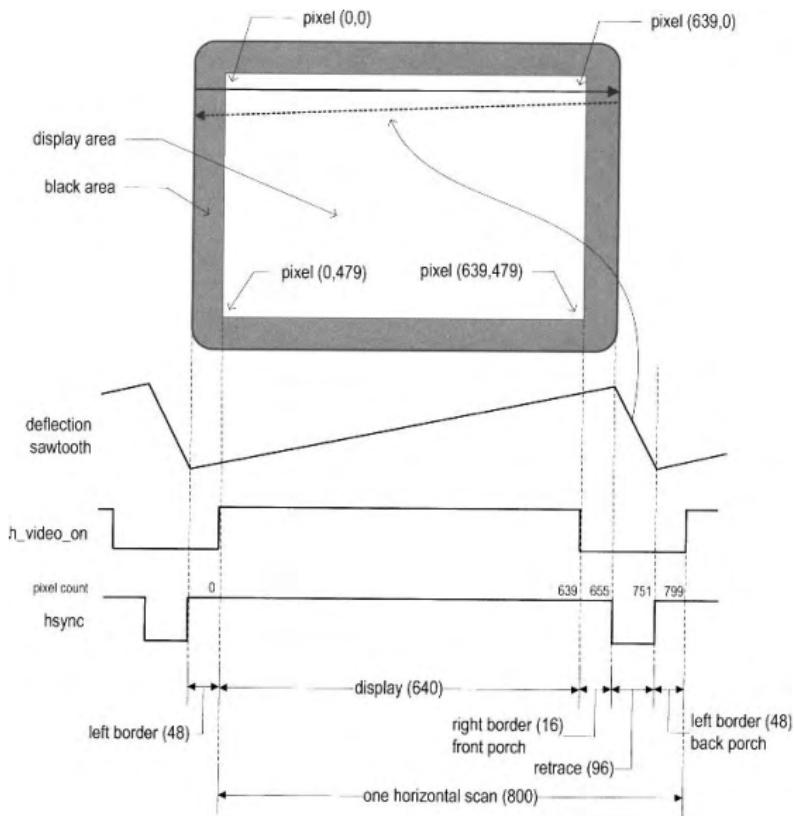


Figura 3: CRT scanning pattern.

4. VGA Gráficos

4.1. Esquemático

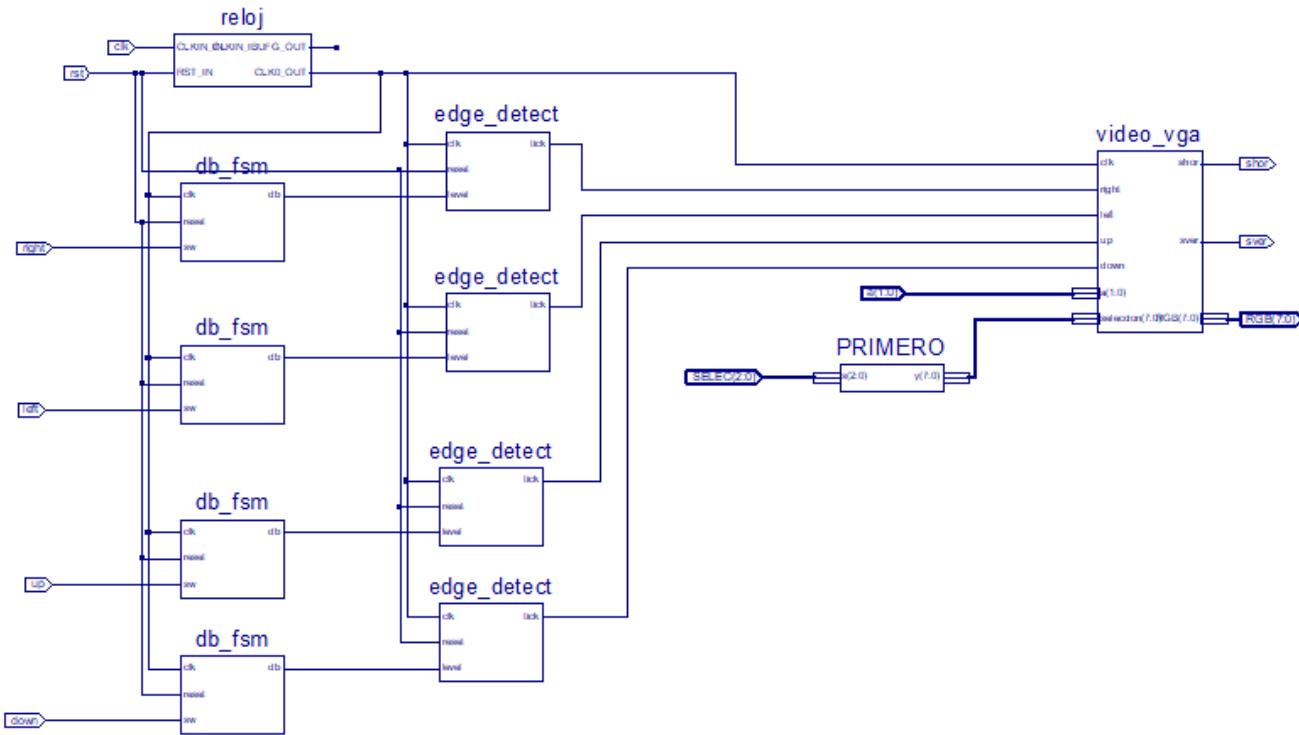


Figura 4: Esquemático del interface para controlar los gráficos VGA.

4.2. Demostración

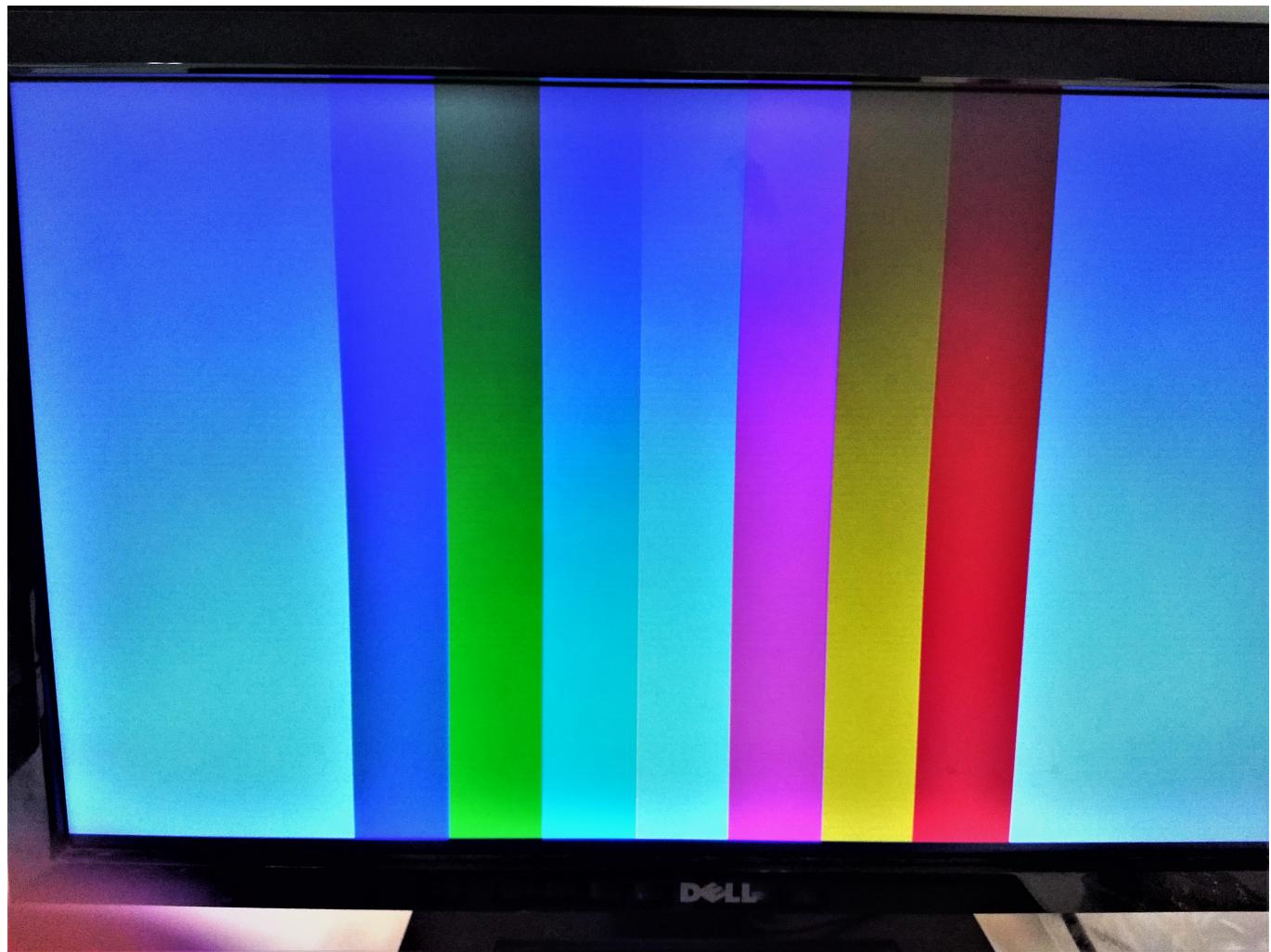


Figura 5: Demostración.

4.3. Códigos

4.3.1. reloj

Listing 1: Digital Clock Manager

```
library ieee;
use ieee.std_logic_1164.ALL;
use ieee.numeric_std.ALL;
library UNISIM;
use UNISIM.Vcomponents.ALL;

entity DCM0 is
port ( CLKIN_IN      : in  std_logic ;
RST_IN        : in  std_logic ;
CLKIN_IBUFG_OUT : out std_logic ;
CLK0_OUT       : out std_logic );
end DCM0;

architecture BEHAVIORAL of DCM0 is
```

```

signal CLKFB_IN : std_logic;
signal CLKIN_IBUFG : std_logic;
signal CLK0_BUF : std_logic;
signal GND_BIT : std_logic;
begin
GND_BIT <= '0';
CLKIN_IBUFG_OUT <= CLKIN_IBUFG;
CLK0_OUT <= CLKFB_IN;
CLKIN_IBUFG_INST : IBUFG
port map ( I=>CLKIN_IN,
O=>CLKIN_IBUFG);

CLK0_BUFG_INST : BUFG
port map ( I=>CLK0_BUF,
O=>CLKFB_IN);

DCM_SP_INST : DCM_SP
generic map( CLK_FEEDBACK => "1X",
CLKDV_DIVIDE => 2.0 ,
CLKFX_DIVIDE => 1 ,
CLKFX_MULTIPLY => 4 ,
CLKIN_DIVIDE_BY_2 => FALSE,
CLKIN_PERIOD => 20.000 ,
CLKOUT_PHASE_SHIFT => "NONE",
DESKEW_ADJUST => "SYSTEM_SYNCHRONOUS",
DFS_FREQUENCY_MODE => "LOW",
DLL_FREQUENCY_MODE => "LOW",
DUTY_CYCLE_CORRECTION => TRUE,
FACTORY_JF => x"C080",
PHASE_SHIFT => 0,
STARTUP_WAIT => FALSE)
port map (CLKFB=>CLKFB_IN,
CLKIN=>CLKIN_IBUFG,
DSSEN=>GND_BIT,
PSCLK=>GND_BIT,
PSEN=>GND_BIT,
PSINCDEC=>GND_BIT,
RST=>RST_IN,
CLKDV=>open ,
CLKFX=>open ,
CLKFX180=>open ,
CLK0=>CLK0_BUF,
CLK2X=>open ,
CLK2X180=>open ,
CLK90=>open ,
CLK180=>open ,
CLK270=>open ,
LOCKED=>open ,
PSDONE=>open ,
STATUS=>open );
end BEHAVIORAL;

```

4.3.2. Video VGA

Listing 2: Video VGA

```
library IEEE;
```

```

use IEEE.STD_LOGIC_1164.ALL;
use IEEE.STD_LOGIC_ARITH.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;

entity video_vga is
Port ( clk : in STD_LOGIC;
a : in STD_LOGIC_VECTOR(1 downto 0);
right: in std_logic;
left: in std_logic;
up: in std_logic;
down: in std_logic;
shor : out STD_LOGIC;
sver : out STD_LOGIC;
seleccion: in STD_LOGIC_VECTOR(7 DOWNTO 0);
RGB : out STD_LOGIC_VECTOR(7 downto 0));
end video_vga;

architecture arq_video_vga of video_vga is
constant hpixels : std_logic_vector(9 downto 0) := "1100100000"; —Valor de pixeles en linea horizontal
constant vlines : std_logic_vector(9 downto 0) := "1000001001"; —Valor de lineas horizontales
constant hbp : std_logic_vector(9 downto 0) := "0010010000"; —Limite horizontal inferior "background"
constant hfp : std_logic_vector(9 downto 0) := "1100100000"; —Limite horizontal superior "foreground"
constant vbp : std_logic_vector(9 downto 0) := "0000011111"; —Limite vertical inferior "background"
constant vfp : std_logic_vector(9 downto 0) := "0111111111"; —Limite vertical superior "foreground"
signal conh : std_logic_vector(9 downto 0) := (others=>'0'); —Contador horizontal
signal conv : std_logic_vector(9 downto 0) := (others=>'0'); —Contador vertical
signal clkdiv : std_logic := '0';
signal derecha: std_logic_vector(9 downto 0):="0000000000";
signal izquierda: std_logic_vector(9 downto 0):="0000000000";
signal arriba: std_logic_vector(9 downto 0):="0000000000";
signal abajo: std_logic_vector(9 downto 0):="0000000000";

signal der: std_logic_vector(9 downto 0):="0000000000";
signal iz: std_logic_vector(9 downto 0):="0000000000";
—Senal de reloj a 25Mhz
signal vidon : std_logic := '0';
—Habilita la senal de video
signal vsenable : std_logic := '0';
—Habilita el contador vertical
begin
—clk es de 50MHz del reloj interno de la FPGA. Se genera la senal clkdiv a 25 MHz.
process (clk)
begin
if (clk = '1' and clk' event) then
clkdiv <= not clkdiv;
end if;
end process;

—Contador horizontal
process (clkdiv)
begin
if (clkdiv = '1' and clkdiv' event) then
if conh = hpixels then —Monitoreo de numero de pixeles en linea horizontal
conh <= (others=>'0'); —Inicializa en 0's el contador
vsenable <= '1'; —Habilita el contador vertical cuando conh = 800.
else

```

```

conh <= conh + 1; --Incrementa el contador horizontal
vsenable <= '0'; --Deshabilita el contador vertical
end if;
end if;
end process;

--Pulso de sincronia horizontal
shor <= '1' when conh(9 downto 7) = "000" else '0'; --Las senales de sincronizacion se habilitan
--Contador vertical
process (clkdiv)
begin
if (clkdiv = '1' and clkdiv' event and vsenable = '1') then
if conv = vlines then --Monitorea el numero de lineas verticales
conv <= (others=>'0'); --Inicializa el contador
else conv <= conv + 1; --Incrementa el contador vertical
end if;
end if;
end process;
--Pulso de sincronia vertical
sver <= '1' when conv(9 downto 1) = "000000000" else '0';

process(right ,left ,up ,down)
begin
--derecha<=derecha+ "1010" when right='1' else derecha ;
--izquierda<=izquierda+ "1010" when left ='1' else izquierda;
if right ='1' then
derecha<= derecha+ "1";
else derecha<=derecha ;
end if;

if left ='1' then
izquierda<= izquierda+ "1";
else izquierda<=izquierda ;
end if;

if up='1' then
arriba<= arriba+ "1";
else arriba<=arriba ;
end if;

if down='1' then
abajo<= abajo + "1";
else abajo<= abajo ;
end if;

end process;

--*****--Pixels a visualizar

RGB <= "11111100" when (conh(4 downto 0) = "00000" and
conv(4 downto 0) = "00000" and
vidon = '1' and a = "00") else
-- Cuadro a visualizar
seleccion when (conh > ("0100001110" + hbp + derecha- izquierda) and conh < ("0101110010" + hb-
and conv > ("0010111110" + vbp+arriba-abajo) and conv < ("0100100010" + vbp+arriba-abajo)

```

```

and vidon = '1' and a = "11") else
-- Rayas verticales
"00011111" when (conh (4 downto 0) = "00000" and
vidon = '1' and a = "11" ) else
-- Rayas horizontales
"11100000" when (conv (4 downto 0) = "00000" and
vidon = '1' and a = "11" ) else "00000000";
-----*
--Habilitacion de la señal de video solo en los margenes de visualización (480 x 640)
vidon <= '1' when (((conh < hbp and (conh < hfp )) or ((conv > vbp) and (conv < vfp)))) else '
end arq_video_vga;

```

4.3.3. PRIMERO

Listing 3: PRIMERO

```

library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
use IEEE.STD_LOGIC_ARITH.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;

entity PRIMERO is
port(f:in std_logic;
s:in std_logic_vector(2 downto 0);
y:out std_logic_vector(7 downto 0));
end PRIMERO;

ARCHITECTURE PRIMERO of PRIMERO is

begin
y<="00000001" when s="000" else
"00000010" when s="001" else
"00000100" when s="010" else
"00001000"when s="011" else
"00010000" when s="100" else
"00100000" when s="101" else
"01000000" when s="110" else
"10000000" when s="111" else "00000000";

end PRIMERO;

```

5. VGA TEXTO

5.1. Esquematico

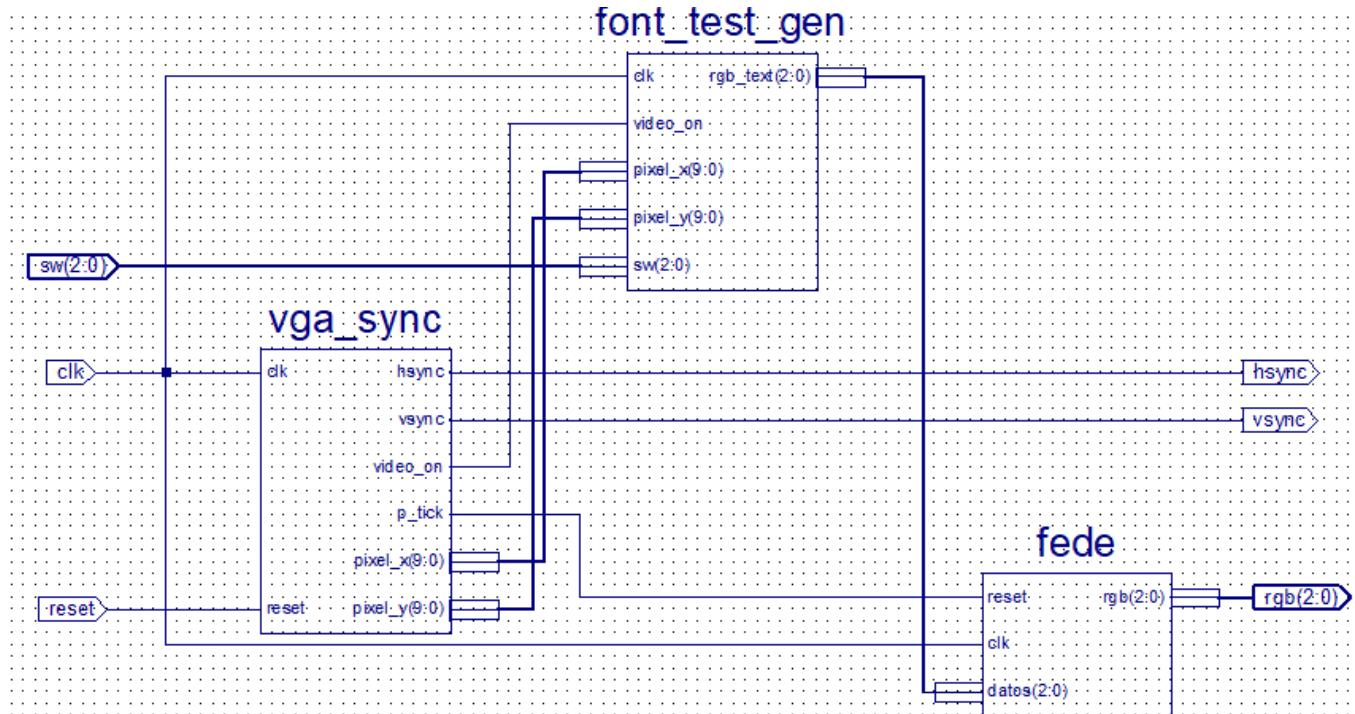


Figura 6: Esquemático del interface para controlar texto.

5.2. Demostración

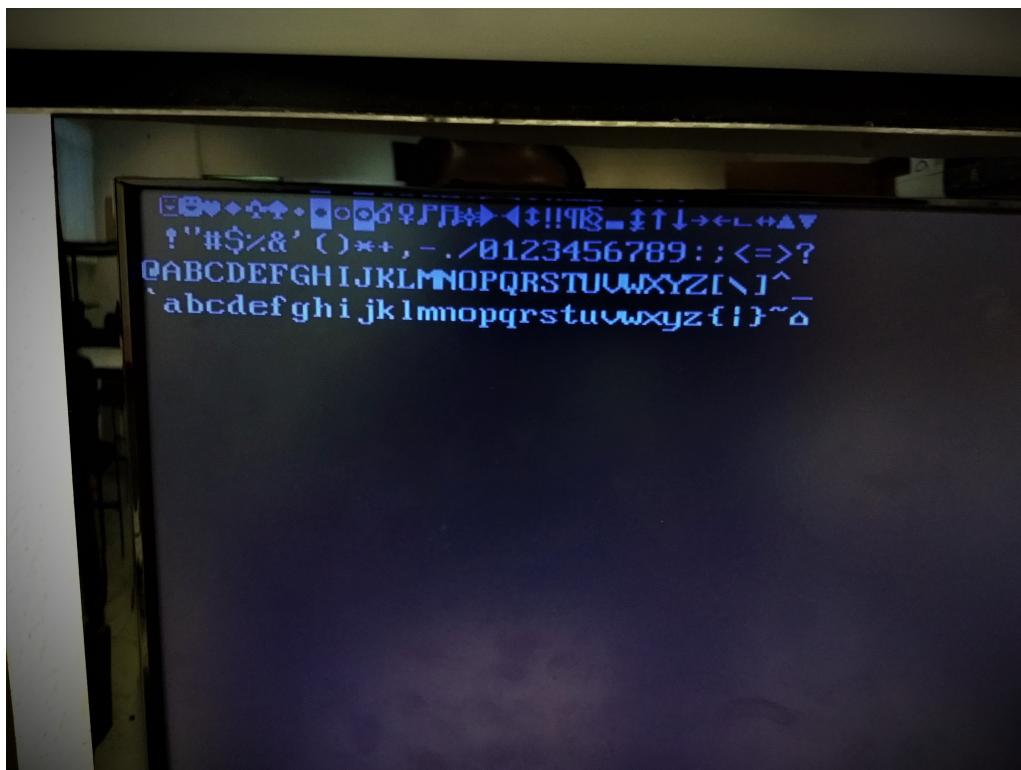


Figura 7: Demostración.

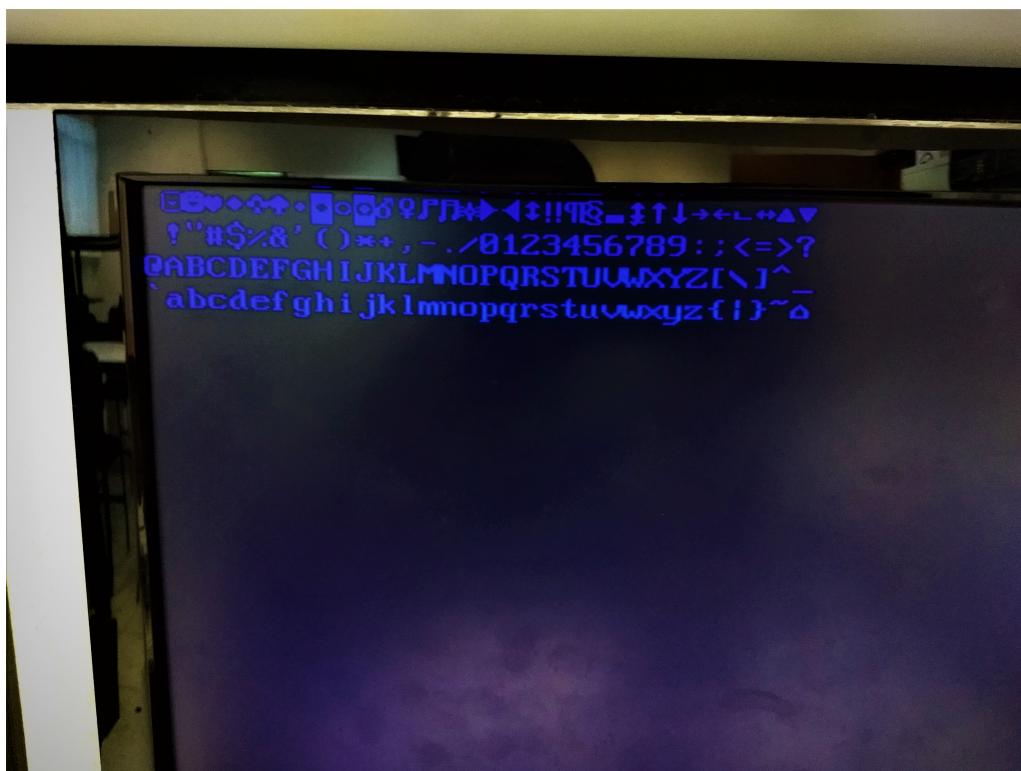


Figura 8: Demostración.

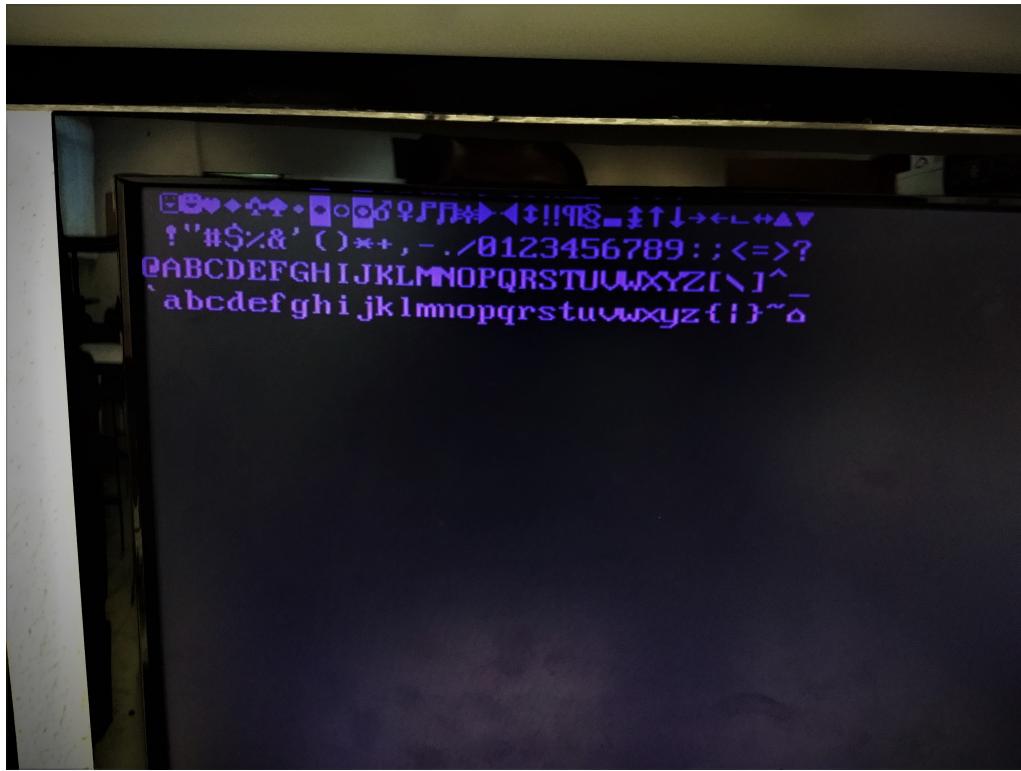


Figura 9: Demostración.

5.3. fon unit rom

Listing 4: fon unit rom

```

-- ROM with synchronous read (inferring Block RAM)
-- character ROM
-- - 8-by-16 (8-by-2^4) font
-- - 128 (2^7) characters
-- - ROM size: 512-by-8 (2^11-by-8) bits
--      16K bits: 1 BRAM
library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;
entity font_rom is
port(
clk: in std_logic;
addr: in std_logic_vector(10 downto 0);
data: out std_logic_vector(7 downto 0)
);
end font_rom;
architecture arch of font_rom is
constant ADDR_WIDTH: integer:=11;
constant DATA_WIDTH: integer:=8;
signal addr_reg: std_logic_vector(ADDR_WIDTH-1 downto 0);
type rom_type is array (0 to 2**ADDR_WIDTH-1)
of std_logic_vector(DATA_WIDTH-1 downto 0);
-- ROM definition
constant ROM: rom_type:=( -- 2^11-by-8
"00000000", -- 0
"00000000", -- 1

```

```
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"00000000", -- 5
"00000000", -- 6
"00000000", -- 7
"00000000", -- 8
"00000000", -- 9
"00000000", -- a
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x01
"00000000", -- 0
"00000000", -- 1
"01111110", -- 2 *****
"10000001", -- 3 * *
"10100101", -- 4 * * * *
"10000001", -- 5 * *
"10000001", -- 6 * *
"10111101", -- 7 * **** *
"10011001", -- 8 * ** *
"10000001", -- 9 * *
"10000001", -- a * *
"01111110", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x02
"00000000", -- 0
"00000000", -- 1
"01111110", -- 2 *****
"11111111", -- 3 ******
"11011011", -- 4 ** * *
"11111111", -- 5 ******
"11111111", -- 6 ******
"11000011", -- 7 ** *
"11100111", -- 8 *** ***
"11111111", -- 9 ******
"11111111", -- a ******
"01111110", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x03
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"01101100", -- 4 ** **
"11111110", -- 5 *****
"11111110", -- 6 *****
```

```
"11111110", -- 7 *****
"11111110", -- 8 *****
"01111100", -- 9 ****
"00111000", -- a ***
"00010000", -- b *
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x04
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00010000", -- 4 *
"00111000", -- 5 ***
"01111100", -- 6 *****
"11111110", -- 7 *****
"01111100", -- 8 ****
"00111000", -- 9 ***
"00010000", -- a *
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x05
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00011000", -- 3 **
"00111100", -- 4 ****
"00111100", -- 5 ***
"11100111", -- 6 *** ***
"11100111", -- 7 *** ***
"11100111", -- 8 *** ***
"00011000", -- 9 **
"00011000", -- a **
"00111100", -- b ****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x06
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00011000", -- 3 **
"00111100", -- 4 ****
"01111110", -- 5 *****
"11111111", -- 6 *****
"11111111", -- 7 *****
"01111110", -- 8 *****
"00011000", -- 9 **
"00011000", -- a **
"00111100", -- b ***
```

```
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x07
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"00000000", -- 5
"00011000", -- 6  **
"00111100", -- 7  ****
"00111100", -- 8  ****
"00011000", -- 9  **
"00000000", -- a
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x08
"11111111", -- 0 *****
"11111111", -- 1 *****
"11111111", -- 2 *****
"11111111", -- 3 *****
"11111111", -- 4 *****
"11111111", -- 5 *****
"11100111", -- 6 *** ***
"11000011", -- 7 ** **
"11000011", -- 8 ** **
"11100111", -- 9 *** ***
"11111111", -- a *****
"11111111", -- b *****
"11111111", -- c *****
"11111111", -- d *****
"11111111", -- e *****
"11111111", -- f *****
-- code x09
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"00111100", -- 5  ***
"01100110", -- 6 ** **
"01000010", -- 7 * *
"01000010", -- 8 * *
"01100110", -- 9 ** **
"00111100", -- a ****
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x0a
```

```
"11111111", -- 0 *****
"11111111", -- 1 *****
"11111111", -- 2 *****
"11111111", -- 3 *****
"11111111", -- 4 *****
"11000011", -- 5 ** **
"10011001", -- 6 * * *
"10111101", -- 7 * **** *
"10111101", -- 8 * **** *
"10011001", -- 9 * ** *
"11000011", -- a ** **
"11111111", -- b *****
"11111111", -- c *****
"11111111", -- d *****
"11111111", -- e *****
"11111111", -- f *****
-- code x0b
"00000000", -- 0
"00000000", -- 1
"00011110", -- 2 ****
"00001110", -- 3 ***
"00011010", -- 4 ** *
"00110010", -- 5 ** *
"01111000", -- 6 ****
"11001100", -- 7 ** **
"11001100", -- 8 ** **
"11001100", -- 9 ** **
"11001100", -- a ** **
"01111000", -- b ****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x0c
"00000000", -- 0
"00000000", -- 1
"00111100", -- 2 ****
"01100110", -- 3 ** **
"01100110", -- 4 ** **
"01100110", -- 5 ** **
"01100110", -- 6 ** **
"00111100", -- 7 ****
"00011000", -- 8 **
"01111110", -- 9 *****
"00011000", -- a **
"00011000", -- b **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x0d
"00000000", -- 0
"00000000", -- 1
"00111111", -- 2 *****
"00110011", -- 3 ** **
"00111111", -- 4 *****
```

```
"00110000", -- 5  **
"00110000", -- 6  **
"00110000", -- 7  **
"00110000", -- 8  **
"01110000", -- 9  ***
"11110000", -- a  *****
"11100000", -- b  ***
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x0e
"00000000", -- 0
"00000000", -- 1
"01111111", -- 2  *****
"01100011", -- 3  **  **
"01111111", -- 4  *****
"01100011", -- 5  **  **
"01100011", -- 6  **  **
"01100011", -- 7  **  **
"01100011", -- 8  **  **
"01100111", -- 9  **  ***
"11100111", -- a  ***  ***
"11100110", -- b  ***  **
"11000000", -- c  **
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x0f
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00011000", -- 3  **
"00011000", -- 4  **
"11011011", -- 5  **  **  **
"00111100", -- 6  ***
"11100111", -- 7  ***  ***
"00111100", -- 8  ***
"11011011", -- 9  **  **  **
"00011000", -- a  **
"00011000", -- b  **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x10
"00000000", -- 0
"10000000", -- 1  *
"11000000", -- 2  **
"11100000", -- 3  ***
"11110000", -- 4  ****
"11111000", -- 5  *****
"11111110", -- 6  *****
"11111100", -- 7  ****
"11110000", -- 8  ***
"11100000", -- 9  **
```

```
"11000000", -- a **
"10000000", -- b *
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x11
"00000000", -- 0
"00000010", -- 1      *
"00000110", -- 2      **
"00001110", -- 3      ***
"00011110", -- 4      ****
"00111110", -- 5      *****
"11111110", -- 6      *****
"00111110", -- 7      ****
"00011110", -- 8      ****
"00001110", -- 9      ***
"00000110", -- a      **
"00000010", -- b      *
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x12
"00000000", -- 0
"00000000", -- 1
"00011000", -- 2      **
"00111100", -- 3      ***
"01111110", -- 4      *****
"00011000", -- 5      **
"00011000", -- 6      **
"00011000", -- 7      **
"01111110", -- 8      *****
"00111100", -- 9      ***
"00011000", -- a      **
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x13
"00000000", -- 0
"00000000", -- 1
"01100110", -- 2      ** **
"01100110", -- 3      ** **
"01100110", -- 4      ** **
"01100110", -- 5      ** **
"01100110", -- 6      ** **
"01100110", -- 7      ** **
"01100110", -- 8      ** **
"00000000", -- 9
"01100110", -- a      ** **
"01100110", -- b      ** **
"00000000", -- c
"00000000", -- d
"00000000", -- e
```

```
"00000000", --- f
--- code x14
"00000000", --- 0
"00000000", --- 1
"01111111", --- 2 *****
"11011011", --- 3 ** ** *
"11011011", --- 4 ** ** *
"11011011", --- 5 ** ** *
"01111011", --- 6 **** *
"00011011", --- 7 ** *
"00011011", --- 8 ** *
"00011011", --- 9 ** *
"00011011", --- a ** *
"00011011", --- b ** *
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x15
"00000000", --- 0
"01111100", --- 1 *****
"11000110", --- 2 ** **
"01100000", --- 3 **
"00111000", --- 4 ***
"01101100", --- 5 ** *
"11000110", --- 6 ** **
"11000110", --- 7 ** *
"01101100", --- 8 ** *
"00111000", --- 9 ***
"00001100", --- a **
"11000110", --- b ** *
"01111100", --- c *****
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x16
"00000000", --- 0
"00000000", --- 1
"00000000", --- 2
"00000000", --- 3
"00000000", --- 4
"00000000", --- 5
"00000000", --- 6
"00000000", --- 7
"11111110", --- 8 *****
"11111110", --- 9 *****
"11111110", --- a *****
"11111110", --- b *****
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x17
"00000000", --- 0
"00000000", --- 1
"00011000", --- 2 **
```

```
"00111100", -- 3 *****
"01111110", -- 4 ***** 
"00011000", -- 5 **
"00011000", -- 6 **
"00011000", -- 7 **
"01111110", -- 8 *****
"00111100", -- 9 ***
"00011000", -- a **
"01111110", -- b *****
"00110000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x18
"00000000", -- 0
"00000000", -- 1
"00011000", -- 2 **
"00111100", -- 3 *****
"01111110", -- 4 *****
"00011000", -- 5 **
"00011000", -- 6 **
"00011000", -- 7 **
"00011000", -- 8 **
"00011000", -- 9 **
"00011000", -- a **
"00011000", -- b **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x19
"00000000", -- 0
"00000000", -- 1
"00011000", -- 2 **
"00011000", -- 3 **
"00011000", -- 4 **
"00011000", -- 5 **
"00011000", -- 6 **
"00011000", -- 7 **
"00011000", -- 8 **
"01111110", -- 9 *****
"00111100", -- a *****
"00011000", -- b **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x1a
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"00011000", -- 5 **
"00001100", -- 6 **
"11111110", -- 7 *****
```

```
"00001100", -- 8    **
"00011000", -- 9    **
"00000000", -- a
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x1b
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"00110000", -- 5  **
"01100000", -- 6  **
"11111110", -- 7 *****
"01100000", -- 8  **
"00110000", -- 9  **
"00000000", -- a
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x1c
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"00000000", -- 5
"11000000", -- 6  **
"11000000", -- 7  **
"11000000", -- 8  **
"11111110", -- 9 *****
"00000000", -- a
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x1d
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"00100100", -- 5  * *
"01100110", -- 6  ** **
"11111111", -- 7 *****
"01100110", -- 8  ** **
"00100100", -- 9  * *
"00000000", -- a
"00000000", -- b
"00000000", -- c
```

```
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x1e
"00000000", --- 0
"00000000", --- 1
"00000000", --- 2
"00000000", --- 3
"00010000", --- 4 *
"00111000", --- 5 ***
"00111000", --- 6 ***
"01111100", --- 7 *****
"01111100", --- 8 *****
"11111110", --- 9 ******
"11111110", --- a ******
"00000000", --- b
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x1f
"00000000", --- 0
"00000000", --- 1
"00000000", --- 2
"00000000", --- 3
"11111110", --- 4 ******
"11111110", --- 5 ******
"01111100", --- 6 ****
"01111100", --- 7 ****
"00111000", --- 8 ***
"00111000", --- 9 ***
"00010000", --- a *
"00000000", --- b
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x20
"00000000", --- 0
"00000000", --- 1
"00000000", --- 2
"00000000", --- 3
"00000000", --- 4
"00000000", --- 5
"00000000", --- 6
"00000000", --- 7
"00000000", --- 8
"00000000", --- 9
"00000000", --- a
"00000000", --- b
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x21
"00000000", --- 0
```

```
"00000000", -- 1
"00011000", -- 2  **
"00111100", -- 3  *****
"00111100", -- 4  *****
"00111100", -- 5  *****
"00011000", -- 6  **
"00011000", -- 7  **
"00011000", -- 8  **
"00000000", -- 9
"00011000", -- a  **
"00011000", -- b  **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x22
"00000000", -- 0
"01100110", -- 1 ** **
"01100110", -- 2 ** **
"01100110", -- 3 ** **
"00100100", -- 4 * *
"00000000", -- 5
"00000000", -- 6
"00000000", -- 7
"00000000", -- 8
"00000000", -- 9
"00000000", -- a
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x23
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"01101100", -- 3 ** **
"01101100", -- 4 ** **
"11111110", -- 5 ******
"01101100", -- 6 ** **
"01101100", -- 7 ** **
"01101100", -- 8 ** **
"11111110", -- 9 ******
"01101100", -- a ** *
"01101100", -- b ** *
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x24
"00011000", -- 0    **
"00011000", -- 1    **
"01111100", -- 2  *****
"11000110", -- 3 ** **
"11000010", -- 4 ** *
"11000000", -- 5 **
```

```
"01111100", -- 6    *****
"00000110", -- 7    **
"00000110", -- 8    **
"10000110", -- 9 *  **
"11000110", -- a **  **
"01111100", -- b    *****
"00011000", -- c    **
"00011000", -- d    **
"00000000", -- e
"00000000", -- f
-- code x25
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"11000010", -- 4 ** *
"11000110", -- 5 ** **
"00001100", -- 6    **
"00011000", -- 7    **
"00110000", -- 8    **
"01100000", -- 9    **
"11000110", -- a **  **
"10000110", -- b *  **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x26
"00000000", -- 0
"00000000", -- 1
"00111000", -- 2    ***
"01101100", -- 3 ** **
"01101100", -- 4 ** **
"00111000", -- 5    ***
"01110110", -- 6    *** **
"11011100", -- 7 ** ***
"11001100", -- 8 ** **
"11001100", -- 9 ** **
"11001100", -- a ** **
"01110110", -- b    *** **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x27
"00000000", -- 0
"00110000", -- 1    **
"00110000", -- 2    **
"00110000", -- 3    **
"01100000", -- 4    **
"00000000", -- 5
"00000000", -- 6
"00000000", -- 7
"00000000", -- 8
"00000000", -- 9
"00000000", -- a
```

```
"00000000", --- b
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x28
"00000000", --- 0
"00000000", --- 1
"00001100", --- 2    **
"00011000", --- 3    **
"00110000", --- 4    **
"00110000", --- 5    **
"00110000", --- 6    **
"00110000", --- 7    **
"00110000", --- 8    **
"00110000", --- 9    **
"00011000", --- a    **
"00001100", --- b    **
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x29
"00000000", --- 0
"00000000", --- 1
"00110000", --- 2    **
"00011000", --- 3    **
"00001100", --- 4    **
"00001100", --- 5    **
"00001100", --- 6    **
"00001100", --- 7    **
"00001100", --- 8    **
"00001100", --- 9    **
"00011000", --- a    **
"00110000", --- b    **
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x2a
"00000000", --- 0
"00000000", --- 1
"00000000", --- 2
"00000000", --- 3
"00000000", --- 4
"01100110", --- 5    **  **
"00111100", --- 6    ****
"11111111", --- 7    *****
"00111100", --- 8    ****
"01100110", --- 9    **  **
"00000000", --- a
"00000000", --- b
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
```

```
-- code x2b
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"00011000", -- 5  **
"00011000", -- 6  **
"01111110", -- 7 *****
"00011000", -- 8  **
"00011000", -- 9  **
"00000000", -- a
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x2c
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"00000000", -- 5
"00000000", -- 6
"00000000", -- 7
"00000000", -- 8
"00011000", -- 9  **
"00011000", -- a  **
"00011000", -- b  **
"00110000", -- c  **
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x2d
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"00000000", -- 5
"00000000", -- 6
"01111110", -- 7 *****
"00000000", -- 8
"00000000", -- 9
"00000000", -- a
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x2e
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
```

```
"00000000", -- 4
"00000000", -- 5
"00000000", -- 6
"00000000", -- 7
"00000000", -- 8
"00000000", -- 9
"00011000", -- a **
"00011000", -- b **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x2f
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000010", -- 4 *
"00000110", -- 5 **
"00001100", -- 6 **
"00011000", -- 7 **
"00110000", -- 8 **
"01100000", -- 9 **
"11000000", -- a **
"10000000", -- b *
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x30
"00000000", -- 0
"00000000", -- 1
"01111100", -- 2 *****
"11000110", -- 3 ** **
"11000110", -- 4 ** **
"11001110", -- 5 ** ***
"11011110", -- 6 ** ****
"11110110", -- 7 ***** **
"11100110", -- 8 *** **
"11000110", -- 9 ** **
"11000110", -- a ** **
"01111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x31
"00000000", -- 0
"00000000", -- 1
"00011000", -- 2
"00111000", -- 3
"01111000", -- 4 **
"00011000", -- 5 ***
"00011000", -- 6 ****
"00011000", -- 7 **
"00011000", -- 8 **
```

```
"00011000", -- 9  **
"00011000", -- a  **
"01111110", -- b  **
"00000000", -- c  **
"00000000", -- d  *****
"00000000", -- e
"00000000", -- f
-- code x32
"00000000", -- 0
"00000000", -- 1
"01111100", -- 2  *****
"11000110", -- 3  **  **
"00000110", -- 4  **
"00001100", -- 5  **
"00011000", -- 6  **
"00110000", -- 7  **
"01100000", -- 8  **
"11000000", -- 9  **
"11000110", -- a  **  **
"11111110", -- b  *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x33
"00000000", -- 0
"00000000", -- 1
"01111100", -- 2  *****
"11000110", -- 3  **  **
"00000110", -- 4  **
"00000110", -- 5  **
"00111100", -- 6  *****
"00000110", -- 7  **
"00000110", -- 8  **
"00000110", -- 9  **
"11000110", -- a  **  **
"01111100", -- b  *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x34
"00000000", -- 0
"00000000", -- 1
"00001100", -- 2  **
"00011100", -- 3  ***
"00111100", -- 4  ****
"01101100", -- 5  **  **
"11001100", -- 6  **  **
"11111110", -- 7  *****
"00001100", -- 8  **
"00001100", -- 9  **
"00001100", -- a  **
"00011110", -- b  ****
"00000000", -- c
"00000000", -- d
```

```
"00000000", -- e
"00000000", -- f
-- code x35
"00000000", -- 0
"00000000", -- 1
"11111110", -- 2 ******
"11000000", -- 3 **
"11000000", -- 4 **
"11000000", -- 5 **
"11111100", -- 6 *****
"00000110", -- 7 **
"00000110", -- 8 **
"00000110", -- 9 **
"11000110", -- a ** **
"01111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x36
"00000000", -- 0
"00000000", -- 1
"00111000", -- 2 ***
"01100000", -- 3 **
"11000000", -- 4 **
"11000000", -- 5 **
"11111100", -- 6 *****
"11000110", -- 7 ** **
"11000110", -- 8 ** **
"11000110", -- 9 ** **
"11000110", -- a ** **
"01111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x37
"00000000", -- 0
"00000000", -- 1
"11111110", -- 2 *****
"11000110", -- 3 ** **
"00000110", -- 4 **
"00000110", -- 5 **
"00001100", -- 6 **
"00011000", -- 7 **
"00110000", -- 8 **
"00110000", -- 9 **
"00110000", -- a **
"00110000", -- b **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x38
"00000000", -- 0
"00000000", -- 1
```

```
"01111100", -- 2 *****
"11000110", -- 3 ** **
"11000110", -- 4 ** **
"11000110", -- 5 ** **
"01111100", -- 6 *****
"11000110", -- 7 ** **
"11000110", -- 8 ** **
"11000110", -- 9 ** **
"11000110", -- a ** **
"01111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x39
"00000000", -- 0
"00000000", -- 1
"01111100", -- 2 *****
"11000110", -- 3 ** **
"11000110", -- 4 ** **
"11000110", -- 5 ** **
"01111110", -- 6 *****
"00000110", -- 7 **
"00000110", -- 8 **
"00000110", -- 9 **
"00001100", -- a **
"01111000", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x3a
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00011000", -- 4 **
"00011000", -- 5 **
"00000000", -- 6
"00000000", -- 7
"00000000", -- 8
"00011000", -- 9 **
"00011000", -- a **
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x3b
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00011000", -- 4 **
"00011000", -- 5 **
"00000000", -- 6
```

```
"00000000", -- 7
"00000000", -- 8
"00011000", -- 9  **
"00011000", -- a  **
"00110000", -- b  **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x3c
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000110", -- 3  **
"00001100", -- 4  **
"00011000", -- 5  **
"00110000", -- 6  **
"01100000", -- 7  **
"00110000", -- 8  **
"00011000", -- 9  **
"00001100", -- a  **
"00000110", -- b  **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x3d
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"01111110", -- 5 *****
"00000000", -- 6
"00000000", -- 7
"01111110", -- 8 *****
"00000000", -- 9
"00000000", -- a
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x3e
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"01100000", -- 3  **
"00110000", -- 4  **
"00011000", -- 5  **
"00001100", -- 6  **
"00000110", -- 7  **
"00001100", -- 8  **
"00011000", -- 9  **
"00110000", -- a  **
"01100000", -- b  **
```

```
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x3f
"00000000", -- 0
"00000000", -- 1
"01111100", -- 2 *****
"11000110", -- 3 ** **
"11000110", -- 4 ** **
"00001100", -- 5 **
"00011000", -- 6 **
"00011000", -- 7 **
"00011000", -- 8 **
"00000000", -- 9
"00011000", -- a **
"00011000", -- b **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x40
"00000000", -- 0
"00000000", -- 1
"01111100", -- 2 *****
"11000110", -- 3 ** **
"11000110", -- 4 ** **
"11000110", -- 5 ** **
"11011110", -- 6 ** ****
"11011110", -- 7 ** ****
"11011110", -- 8 ** ****
"11011100", -- 9 ** ***
"11000000", -- a **
"01111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x41
"00000000", -- 0
"00000000", -- 1
"00010000", -- 2 *
"00111000", -- 3 ***
"01101100", -- 4 ** **
"11000110", -- 5 ** **
"11000110", -- 6 ** **
"11111110", -- 7 ******
"11000110", -- 8 ** **
"11000110", -- 9 ** **
"11000110", -- a **
"11000110", -- b **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x42
```

```
"00000000", -- 0
"00000000", -- 1
"11111100", -- 2 *****
"01100110", -- 3 ** **
"01100110", -- 4 ** **
"01100110", -- 5 ** **
"01111100", -- 6 *****
"01100110", -- 7 ** **
"01100110", -- 8 ** **
"01100110", -- 9 ** **
"01100110", -- a ** **
"11111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x43
"00000000", -- 0
"00000000", -- 1
"00111100", -- 2 ****
"01100110", -- 3 ** **
"11000010", -- 4 ** *
"11000000", -- 5 **
"11000000", -- 6 **
"11000000", -- 7 **
"11000000", -- 8 **
"11000010", -- 9 ** *
"01100110", -- a ** **
"00111100", -- b ****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x44
"00000000", -- 0
"00000000", -- 1
"11111000", -- 2 *****
"01101100", -- 3 ** **
"01100110", -- 4 ** **
"01100110", -- 5 ** **
"01100110", -- 6 ** **
"01100110", -- 7 ** **
"01100110", -- 8 ** **
"01100110", -- 9 ** **
"01101100", -- a ** **
"11111000", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x45
"00000000", -- 0
"00000000", -- 1
"11111110", -- 2 ******
"01100110", -- 3 ** **
"01100010", -- 4 ** *
```

```
"01101000", --- 5 ** *
"01111000", --- 6 *****
"01101000", --- 7 ** *
"01100000", --- 8 **
"01100010", --- 9 ** *
"01100110", --- a ** **
"11111110", --- b *****
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x46
"00000000", --- 0
"00000000", --- 1
"11111110", --- 2 *****
"01100110", --- 3 ** **
"01100010", --- 4 ** *
"01101000", --- 5 ** *
"01111000", --- 6 ****
"01101000", --- 7 ** *
"01100000", --- 8 **
"01100000", --- 9 **
"01100000", --- a **
"11110000", --- b ****
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x47
"00000000", --- 0
"00000000", --- 1
"00111100", --- 2 ****
"01100110", --- 3 ** **
"11000010", --- 4 ** *
"11000000", --- 5 **
"11000000", --- 6 **
"11011110", --- 7 ** ****
"11000110", --- 8 ** **
"11000110", --- 9 ** **
"01100110", --- a ** **
"00111010", --- b *** *
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x48
"00000000", --- 0
"00000000", --- 1
"11000110", --- 2 ** **
"11000110", --- 3 ** **
"11000110", --- 4 ** **
"11000110", --- 5 ** **
"11111110", --- 6 *****
"11000110", --- 7 ** **
"11000110", --- 8 ** **
"11000110", --- 9 ** *
```

```
"11000110", -- a **  **
"11000110", -- b **  **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x49
"00000000", -- 0
"00000000", -- 1
"00111100", -- 2 *****
"00011000", -- 3 **
"00011000", -- 4 **
"00011000", -- 5 **
"00011000", -- 6 **
"00011000", -- 7 **
"00011000", -- 8 **
"00011000", -- 9 **
"00011000", -- a **
"00111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x4a
"00000000", -- 0
"00000000", -- 1
"00011110", -- 2 *****
"00001100", -- 3 **
"00001100", -- 4 **
"00001100", -- 5 **
"00001100", -- 6 **
"00001100", -- 7 **
"11001100", -- 8 ** **
"11001100", -- 9 ** **
"11001100", -- a ** **
"01111000", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x4b
"00000000", -- 0
"00000000", -- 1
"11100110", -- 2 *** **
"01100110", -- 3 ** **
"01100110", -- 4 ** **
"01100110", -- 5 ** **
"01111000", -- 6 *****
"01111000", -- 7 *****
"01101100", -- 8 ** **
"01100110", -- 9 ** **
"01100110", -- a ** **
"11100110", -- b *** **
"00000000", -- c
"00000000", -- d
"00000000", -- e
```

```
"00000000", --- f
--- code x4c
"00000000", --- 0
"00000000", --- 1
"11110000", --- 2 ****
"01100000", --- 3 **
"01100000", --- 4 **
"01100000", --- 5 **
"01100000", --- 6 **
"01100000", --- 7 **
"01100000", --- 8 **
"01100010", --- 9 ** *
"01100110", --- a ** **
"11111110", --- b *****
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x4d
"00000000", --- 0
"00000000", --- 1
"11000011", --- 2 ** **
"11100111", --- 3 *** ***
"11111111", --- 4 *****
"11111111", --- 5 *****
"11011011", --- 6 ** ** *
"11000011", --- 7 ** **
"11000011", --- 8 ** **
"11000011", --- 9 ** **
"11000011", --- a ** **
"11000011", --- b ** **
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x4e
"00000000", --- 0
"00000000", --- 1
"11000110", --- 2 ** **
"11100110", --- 3 *** **
"11110110", --- 4 **** *
"11111110", --- 5 *****
"11011110", --- 6 ** ****
"11001110", --- 7 ** ***
"11000110", --- 8 ** **
"11000110", --- 9 ** **
"11000110", --- a ** **
"11000110", --- b ** **
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x4f
"00000000", --- 0
"00000000", --- 1
"01111100", --- 2 ****
```

```
"11000110", -- 3 ** **
"11000110", -- 4 ** **
"11000110", -- 5 ** **
"11000110", -- 6 ** **
"11000110", -- 7 ** **
"11000110", -- 8 ** **
"11000110", -- 9 ** **
"11000110", -- a ** **
"01111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x50
"00000000", -- 0
"00000000", -- 1
"11111100", -- 2 *****
"01100110", -- 3 ** **
"01100110", -- 4 ** **
"01100110", -- 5 ** **
"01111100", -- 6 *****
"01100000", -- 7 **
"01100000", -- 8 **
"01100000", -- 9 **
"01100000", -- a **
"11110000", -- b ****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x510
"00000000", -- 0
"00000000", -- 1
"01111100", -- 2 *****
"11000110", -- 3 ** **
"11000110", -- 4 ** **
"11000110", -- 5 ** **
"11000110", -- 6 ** **
"11000110", -- 7 ** **
"11000110", -- 8 ** **
"11010110", -- 9 ** * **
"11011110", -- a ** ****
"01111100", -- b *****
"00001100", -- c **
"00001110", -- d ***
"00000000", -- e
"00000000", -- f
-- code x52
"00000000", -- 0
"00000000", -- 1
"11111100", -- 2 *****
"01100110", -- 3 ** **
"01100110", -- 4 ** **
"01100110", -- 5 ** **
"01111100", -- 6 *****
"01101100", -- 7 ** **
```

```
"01100110", -- 8 ** **
"01100110", -- 9 ** **
"01100110", -- a ** **
"11100110", -- b *** **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x53
"00000000", -- 0
"00000000", -- 1
"01111100", -- 2 *****
"11000110", -- 3 ** **
"11000110", -- 4 ** **
"01100000", -- 5 **
"00111100", -- 6 ***
"00001100", -- 7 **
"00000110", -- 8 **
"11000110", -- 9 ** **
"11000110", -- a ** **
"01111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x54
"00000000", -- 0
"00000000", -- 1
"11111111", -- 2 *********
"11011011", -- 3 ** ** **
"10011001", -- 4 * ** *
"00011000", -- 5 **
"00011000", -- 6 **
"00011000", -- 7 **
"00011000", -- 8 **
"00011000", -- 9 **
"00011000", -- a **
"00111100", -- b ***
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x55
"00000000", -- 0
"00000000", -- 1
"11000110", -- 2 ** **
"11000110", -- 3 ** **
"11000110", -- 4 ** **
"11000110", -- 5 ** **
"11000110", -- 6 ** **
"11000110", -- 7 ** **
"11000110", -- 8 ** **
"11000110", -- 9 ** **
"11000110", -- a ** **
"01111100", -- b *****
"00000000", -- c
```

```
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x56
"00000000", --- 0
"00000000", --- 1
"11000011", --- 2 ** **
"11000011", --- 3 ** **
"11000011", --- 4 ** **
"11000011", --- 5 ** **
"11000011", --- 6 ** **
"11000011", --- 7 ** **
"11000011", --- 8 ** **
"01100110", --- 9 ** **
"00111100", --- a *****
"00011000", --- b **
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x57
"00000000", --- 0
"00000000", --- 1
"11000011", --- 2 ** **
"11000011", --- 3 ** **
"11000011", --- 4 ** **
"11000011", --- 5 ** **
"11000011", --- 6 ** **
"11011011", --- 7 ** ** **
"11011011", --- 8 ** ** **
"11111111", --- 9 *********
"01100110", --- a ** **
"01100110", --- b ** **
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x58
"00000000", --- 0
"00000000", --- 1
"11000011", --- 2 ** **
"11000011", --- 3 ** **
"01100110", --- 4 ** **
"00111100", --- 5 *****
"00011000", --- 6 **
"00011000", --- 7 **
"00111100", --- 8 *****
"01100110", --- 9 ** **
"11000011", --- a ** **
"11000011", --- b ** **
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x59
"00000000", --- 0
```

```
"00000000", -- 1
"11000011", -- 2 **  **
"11000011", -- 3 **  **
"11000011", -- 4 **  **
"01100110", -- 5 ** **
"00111100", -- 6 *****
"00011000", -- 7 **
"00011000", -- 8 **
"00011000", -- 9 **
"00011000", -- a **
"00111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x5a
"00000000", -- 0
"00000000", -- 1
"11111111", -- 2 *****
"11000011", -- 3 **  **
"10000110", -- 4 *  **
"00001100", -- 5 **
"00011000", -- 6 **
"00110000", -- 7 **
"01100000", -- 8 **
"11000001", -- 9 **  *
"11000011", -- a **  **
"11111111", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x5b
"00000000", -- 0
"00000000", -- 1
"00111100", -- 2 *****
"00110000", -- 3 **
"00110000", -- 4 **
"00110000", -- 5 **
"00110000", -- 6 **
"00110000", -- 7 **
"00110000", -- 8 **
"00110000", -- 9 **
"00110000", -- a **
"00111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x5c
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"10000000", -- 3 *
"11000000", -- 4 **
"11100000", -- 5 ***
```

```
"01110000", -- 6 ***
"00111000", -- 7 ***
"00011100", -- 8 ***
"00001110", -- 9 ***
"00000110", -- a **
"00000010", -- b *
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x5d
"00000000", -- 0
"00000000", -- 1
"00111100", -- 2 *****
"00001100", -- 3 **
"00001100", -- 4 **
"00001100", -- 5 **
"00001100", -- 6 **
"00001100", -- 7 **
"00001100", -- 8 **
"00001100", -- 9 **
"00001100", -- a **
"00111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x5e
"00010000", -- 0 *
"00111000", -- 1 ***
"01101100", -- 2 ** **
"11000110", -- 3 ** **
"00000000", -- 4
"00000000", -- 5
"00000000", -- 6
"00000000", -- 7
"00000000", -- 8
"00000000", -- 9
"00000000", -- a
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x5f
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"00000000", -- 5
"00000000", -- 6
"00000000", -- 7
"00000000", -- 8
"00000000", -- 9
"00000000", -- a
```

```
"00000000", -- b
"00000000", -- c
"11111111", -- d *****
"00000000", -- e
"00000000", -- f
-- code x60
"00110000", -- 0 **
"00110000", -- 1 **
"00011000", -- 2 **
"00000000", -- 3
"00000000", -- 4
"00000000", -- 5
"00000000", -- 6
"00000000", -- 7
"00000000", -- 8
"00000000", -- 9
"00000000", -- a
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x61
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"01111000", -- 5 ****
"00001100", -- 6 **
"01111100", -- 7 ****
"11001100", -- 8 ** **
"11001100", -- 9 ** **
"11001100", -- a ** **
"01110110", -- b *** **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x62
"00000000", -- 0
"00000000", -- 1
"11100000", -- 2 ***
"01100000", -- 3 **
"01100000", -- 4 **
"01111000", -- 5 ****
"01101100", -- 6 ** **
"01100110", -- 7 ** **
"01100110", -- 8 ** **
"01100110", -- 9 ** **
"01100110", -- a ** **
"01111100", -- b ****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
```

```
-- code x63
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"01111100", -- 5 *****
"11000110", -- 6 ** **
"11000000", -- 7 **
"11000000", -- 8 **
"11000000", -- 9 **
"11000110", -- a ** **
"01111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x64
"00000000", -- 0
"00000000", -- 1
"00011100", -- 2 ***
"00001100", -- 3 **
"00001100", -- 4 **
"00111100", -- 5 ****
"01101100", -- 6 ** **
"11001100", -- 7 ** **
"11001100", -- 8 ** **
"11001100", -- 9 ** **
"11001100", -- a ** **
"01110110", -- b *** **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x65
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"01111100", -- 5 *****
"11000110", -- 6 ** **
"11111110", -- 7 ******
"11000000", -- 8 **
"11000000", -- 9 **
"11000110", -- a ** **
"01111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x66
"00000000", -- 0
"00000000", -- 1
"00111000", -- 2 ***
"01101100", -- 3 ** *
```

```
"01100100", -- 4 ** *
"01100000", -- 5 **
"11110000", -- 6 ****
"01100000", -- 7 **
"01100000", -- 8 **
"01100000", -- 9 **
"01100000", -- a **
"11110000", -- b ****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x67
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"01110110", -- 5 *** **
"11001100", -- 6 ** **
"11001100", -- 7 ** **
"11001100", -- 8 ** **
"11001100", -- 9 ** **
"11001100", -- a ** **
"01111100", -- b ****
"00001100", -- c **
"11001100", -- d ** **
"01111100", -- e ****
"00000000", -- f
-- code x68
"00000000", -- 0
"00000000", -- 1
"11100000", -- 2 ***
"01100000", -- 3 **
"01100000", -- 4 **
"01101100", -- 5 ** **
"01110110", -- 6 *** **
"01100110", -- 7 ** **
"01100110", -- 8 ** **
"01100110", -- 9 ** **
"01100110", -- a ** **
"11100110", -- b *** **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x69
"00000000", -- 0
"00000000", -- 1
"00011000", -- 2 **
"00011000", -- 3 **
"00000000", -- 4
"00111000", -- 5 ***
"00011000", -- 6 **
"00011000", -- 7 **
"00011000", -- 8 **
```

```
"00011000", -- 9  **
"00011000", -- a  **
"00111100", -- b  ****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x6a
"00000000", -- 0
"00000000", -- 1
"00000110", -- 2  **
"00000110", -- 3  **
"00000000", -- 4
"00001110", -- 5  ***
"00000110", -- 6  **
"00000110", -- 7  **
"00000110", -- 8  **
"00000110", -- 9  **
"00000110", -- a  **
"00000110", -- b  **
"01100110", -- c ** **
"01100110", -- d ** **
"00111100", -- e  ****
"00000000", -- f
-- code x6b
"00000000", -- 0
"00000000", -- 1
"11100000", -- 2  ***
"01100000", -- 3  **
"01100000", -- 4  **
"01100110", -- 5 ** **
"01101100", -- 6 ** **
"01111000", -- 7  ***
"01111000", -- 8  ***
"01101100", -- 9  ** **
"01100110", -- a  ** **
"11100110", -- b  *** **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x6c
"00000000", -- 0
"00000000", -- 1
"00111000", -- 2  ***
"00011000", -- 3  **
"00011000", -- 4  **
"00011000", -- 5  **
"00011000", -- 6  **
"00011000", -- 7  **
"00011000", -- 8  **
"00011000", -- 9  **
"00011000", -- a  **
"00111100", -- b  ****
"00000000", -- c
"00000000", -- d
```

```
"00000000", --- e
"00000000", --- f
-- code x6d
"00000000", --- 0
"00000000", --- 1
"00000000", --- 2
"00000000", --- 3
"00000000", --- 4
"11100110", --- 5 *** ***
"11111111", --- 6 *****
"11011011", --- 7 ** ** **
"11011011", --- 8 ** ** **
"11011011", --- 9 ** ** *
"11011011", --- a ** ** **
"11011011", --- b ** ** **
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
-- code x6e
"00000000", --- 0
"00000000", --- 1
"00000000", --- 2
"00000000", --- 3
"00000000", --- 4
"11011100", --- 5 ** ***
"01100110", --- 6 ** **
"01100110", --- 7 ** **
"01100110", --- 8 ** **
"01100110", --- 9 ** **
"01100110", --- a ** **
"01100110", --- b ** **
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
-- code x6f
"00000000", --- 0
"00000000", --- 1
"00000000", --- 2
"00000000", --- 3
"00000000", --- 4
"01111100", --- 5 *****
"11000110", --- 6 ** **
"11000110", --- 7 ** **
"11000110", --- 8 ** **
"11000110", --- 9 ** **
"11000110", --- a ** **
"01111100", --- b *****
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
-- code x70
"00000000", --- 0
"00000000", --- 1
```

```
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"11011100", -- 5 ** ***
"01100110", -- 6 ** **
"01100110", -- 7 ** **
"01100110", -- 8 ** **
"01100110", -- 9 ** **
"01100110", -- a ** **
"01111100", -- b *****
"01100000", -- c **
"01100000", -- d **
"11110000", -- e ****
"00000000", -- f
-- code x71
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"01110110", -- 5 *** **
"11001100", -- 6 ** **
"11001100", -- 7 ** **
"11001100", -- 8 ** **
"11001100", -- 9 ** **
"11001100", -- a ** **
"01111100", -- b *****
"00001100", -- c **
"00001100", -- d **
"00011110", -- e ****
"00000000", -- f
-- code x72
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"11011100", -- 5 ** ***
"01110110", -- 6 *** **
"01100110", -- 7 ** **
"01100000", -- 8 **
"01100000", -- 9 **
"01100000", -- a **
"11110000", -- b ****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x73
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"01111100", -- 5 *****
"11000110", -- 6 ** **
```

```
"01100000", -- 7 **
"00111000", -- 8 ***
"00001100", -- 9 **
"11000110", -- a ** **
"01111100", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x74
"00000000", -- 0
"00000000", -- 1
"00010000", -- 2 *
"00110000", -- 3 **
"00110000", -- 4 **
"11111100", -- 5 *****
"00110000", -- 6 **
"00110000", -- 7 **
"00110000", -- 8 **
"00110000", -- 9 **
"00110110", -- a ** **
"00011100", -- b ***
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x75
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"11001100", -- 5 ** **
"11001100", -- 6 ** **
"11001100", -- 7 ** **
"11001100", -- 8 ** **
"11001100", -- 9 ** **
"11001100", -- a ** **
"01110110", -- b *** **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x76
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"11000011", -- 5 ** **
"11000011", -- 6 ** **
"11000011", -- 7 ** **
"11000011", -- 8 ** **
"01100110", -- 9 ** **
"00111100", -- a ****
"00011000", -- b **
```

```
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x77
"00000000", --- 0
"00000000", --- 1
"00000000", --- 2
"00000000", --- 3
"00000000", --- 4
"11000011", --- 5 ** **
"11000011", --- 6 ** **
"11000011", --- 7 ** **
"11011011", --- 8 ** ** **
"11011011", --- 9 ** ** **
"11111111", --- a *****
"01100110", --- b ** **
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x78
"00000000", --- 0
"00000000", --- 1
"00000000", --- 2
"00000000", --- 3
"00000000", --- 4
"11000011", --- 5 ** **
"01100110", --- 6 ** **
"00111100", --- 7 ****
"00011100", --- 8 **
"00111100", --- 9 ****
"01100110", --- a ** **
"11000011", --- b ** **
"00000000", --- c
"00000000", --- d
"00000000", --- e
"00000000", --- f
--- code x79
"00000000", --- 0
"00000000", --- 1
"00000000", --- 2
"00000000", --- 3
"00000000", --- 4
"11000110", --- 5 ** **
"11000110", --- 6 ** **
"11000110", --- 7 ** **
"11000110", --- 8 ** **
"11000110", --- 9 ** **
"11000110", --- a ** **
"01111110", --- b ****
"00000110", --- c **
"00001100", --- d **
"11111000", --- e ****
"00000000", --- f
--- code x7a
```

```
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00000000", -- 4
"11111110", -- 5 *****
"11001100", -- 6 ** **
"00011000", -- 7 **
"00110000", -- 8 **
"01100000", -- 9 **
"11000110", -- a ** **
"11111110", -- b *****
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x7b
"00000000", -- 0
"00000000", -- 1
"00001110", -- 2 ***
"00011000", -- 3 **
"00011000", -- 4 **
"00011000", -- 5 **
"01110000", -- 6 ***
"00011000", -- 7 **
"00011000", -- 8 **
"00011000", -- 9 **
"00011000", -- a **
"00001110", -- b ***
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x7c
"00000000", -- 0
"00000000", -- 1
"00011000", -- 2 **
"00011000", -- 3 **
"00011000", -- 4 **
"00011000", -- 5 **
"00000000", -- 6
"00011000", -- 7 **
"00011000", -- 8 **
"00011000", -- 9 **
"00011000", -- a **
"00011000", -- b **
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x7d
"00000000", -- 0
"00000000", -- 1
"01110000", -- 2 ***
"00011000", -- 3 **
"00011000", -- 4 **
```

```

"00011000", -- 5  **
"00001110", -- 6  ***
"00011000", -- 7  **
"00011000", -- 8  **
"00011000", -- 9  **
"00011000", -- a  **
"01110000", -- b  ***
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x7e
"00000000", -- 0
"00000000", -- 1
"01110110", -- 2  ***  **
"11011100", -- 3  **  ***
"00000000", -- 4
"00000000", -- 5
"00000000", -- 6
"00000000", -- 7
"00000000", -- 8
"00000000", -- 9
"00000000", -- a
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000", -- f
-- code x7f
"00000000", -- 0
"00000000", -- 1
"00000000", -- 2
"00000000", -- 3
"00010000", -- 4  *
"00111000", -- 5  ***
"01101100", -- 6  **  **
"11000110", -- 7  **  **
"11000110", -- 8  **  **
"11000110", -- 9  **  **
"11111110", -- a  *****
"00000000", -- b
"00000000", -- c
"00000000", -- d
"00000000", -- e
"00000000" -- f
);
begin
-- addr register to infer block RAM
process (clk)
begin
if (clk'event and clk = '1') then
addr_reg <= addr;
end if;
end process;
data <= ROM(to_integer(unsigned(addr_reg)));
end arch;

```

5.4. font test gen

Listing 5: font test gen

```

library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;
entity font_test_gen is
port(
clk: in std_logic;
video_on: in std_logic;
pixel_x, pixel_y: std_logic_vector(9 downto 0);
sw: in std_logic_vector(2 downto 0);
rgb_text: out std_logic_vector(2 downto 0)
);
end font_test_gen;
architecture arch of font_test_gen is
signal rom_addr: std_logic_vector(10 downto 0);
signal char_addr: std_logic_vector(6 downto 0);
signal row_addr: std_logic_vector(3 downto 0);
signal bit_addr: std_logic_vector(2 downto 0);
signal font_word: std_logic_vector(7 downto 0);
signal font_bit, text_bit_on: std_logic;
signal changeTxtColour : std_logic_vector(2 downto 0);
begin
changeTxtColour<=sw;
-- instantiate font ROM
font_unit: entity work.font_rom
port map(clk=>clk, addr=>rom_addr, data=>font_word);
-- font ROM interface
char_addr<=pixel_y(5 downto 4) & pixel_x(7 downto 3);
row_addr<=pixel_y(3 downto 0);
rom_addr <= char_addr & row_addr;
bit_addr<=pixel_x(2 downto 0);
font_bit <= font_word(to_integer(unsigned(not bit_addr)));
-- "on" region limited to top-left corner
text_bit_on <=
font_bit when pixel_x(9 downto 8)="00" and
pixel_y(9 downto 6)="0000" else
'0';
-- rgb multiplexing circuit
process(video_on,font_bit,text_bit_on)
begin
if video_on='0' then
rgb_text <= "000"; --blank
else
if text_bit_on='1' then
if changeTxtColour ="000" then
rgb_text <= "001" ; -- green
else
rgb_text <= changeTxtColour ;-- green
end if;
else
rgb_text <= "000"; -- black
end if;
end if;
end process;

```

```
end arch;
```

5.5. VGA SYNC UNIT

Listing 6: VGA SYNC UNIT

```
Library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;
entity vga_sync is
port (
clk, reset: in std_logic;
hsync, vsync : out std_logic ;
video_on, p_tick: out std_logic;
pixel_x , pixel_y : out std_logic_vector (9 downto 0)
);
end vga_sync ;
architecture arch of vga_sync is
-- VGA 640 - b y - 480 s y n c p a r a m e t e r s
constant HD: integer :=640; -- h o r i z o n t a l d i s p l a y a r e a
constant HF: integer:=16 ; --h. f r o n t p o r c h
constant HB: integer:=48 ; --h. b a c k p o r c h
constant HR: integer:=96 ; --h. r e t r a c e
constant VD :integer :=480; -- v e r t i c a l d i s p l a y a r e a
constant VF :integer:=10; -- v . f r o n t p o r c h
constant VB: integer :=33; -- v . b a c k p o r c h
constant VR :integer :=2; -- v . r e t r a c e
-- mod-2 c o u n t e r
signal mod2_reg, mod2_next : std_logic;
-- s y n c c o u n t e r s
signal v_count_reg , v_count_next : unsigned(9 downto 0) ;
signal h_count_reg , h_count_next : unsigned (9 downto 0 ) ;
-- o u t p u t b u f f e r
signal v_sync_reg , h_sync_reg : std_logic ;
signal v_sync_next , h_sync_next : std_logic;
-- s t a t u s s i g n a l
signal h_end , v_end , pixel_tick: std_logic;
-- r e g i s t e r s
begin
process (clk , reset)
begin
if reset='1' then
mod2_reg <= '0' ;
v_count_reg <= ( others => '0' ) ;
h_count_reg <= ( others => '0' ) ;
v_sync_reg <= '0' ;
h_sync_reg <= '0' ;
elsif (clk'event and clk='1') then
mod2_reg <= mod2_next ;
v_count_reg <= v_count_next;
h_count_reg <= h_count_next;
v_sync_reg <= v_sync_next ;
h_sync_reg <= h_sync_next ;
end if ;
end process ;
-- mod-2 c i r c u i t t o g e n e r a t e 25 MHz e n a b l e t i c k
mod2_next <= not mod2_reg;
```

```

-- 25 MHz pixel tick
pixel_tick <= '1' when mod2_reg='1' else '0' ;
-- status
h_end <= end of horizontal counter
'1' when h_count_reg=(HD+HF+HB+HR-1) else --799
'0' ;
v_end <= end of vertical counter
'1' when v_count_reg=(VD+VF+VB+VR-1) else --524
'0' ;
-- mod-800 horizontal sync counter
process (h_count_reg,h_end,pixel_tick)
begin
if pixel_tick='1' then -- 25 MHz tick
if h_end='1' then
h_count_next <= ( others => '0' ) ;
else
h_count_next <= h_count_reg + 1 ;
end if ;
else
h_count_next <= h_count_reg;
end if ;
end process ;
process (v_count_reg,h_end,v_end,pixel_tick)
begin
-- mod-525 vertical sync counter
if pixel_tick='1' and h_end='1' then
if (v_end='1') then
v_count_next <= ( others => '0' ) ;
else
v_count_next <= v_count_reg + 1 ;
end if ;
else
v_count_next <= v_count_reg;
end if ;
end process ;
-- horizontal and vertical sync, buffer ready to avoid glitch
h_sync_next <=
'1' when (h_count_reg >=(HD+HF)) --656
and (h_count_reg<=(HD+HF+HR-1)) else --751
'0';
v_sync_next <=
'1' when ( v_count_reg >= ( VD+VF ) ) --490
and ( v_count_reg<=(VD+VF+VR-1)) else --491
'0' ;
-- video on / off
video_on <=
'1' when (h_count_reg<HD) and (v_count_reg<VD) else
'0' ;
-- output signal
hsync <= h_sync_reg ;
vsync <= v_sync_reg ;
pixel_x <= std_logic_vector(h_count_reg);
pixel_y <= STD_LOGIC_VECTOR ( v_count_reg ) ;
p_tick <= pixel_tick;
end arch;

```

```
\subsection{ font test top }
library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;
entity font_test_top is
port(
clk , reset: in std_logic;
hsync , vsync: out std_logic;
sw: in std_logic_vector(2 downto 0);
rgb: out std_logic_vector(2 downto 0)
);
end font_test_top;
architecture arch of font_test_top is
signal pixel_x , pixel_y: std_logic_vector(9 downto 0);
signal video_on , pixel_tick: std_logic;
signal rgb_reg , rgb_next: std_logic_vector(2 downto 0);
begin
-- instantiate VGA sync circuit
vga_sync_unit: entity work.vga_sync
port map(clk=>clk , reset=>reset , hsync=>hsync ,
vsync=>vsync , video_on=>video_on ,
pixel_x=>pixel_x , pixel_y=>pixel_y ,
p_tick=>pixel_tick );
-- instantiate font ROM
font_gen_unit: entity work.font_test_gen
port map(clk=>clk , video_on=>video_on ,
pixel_x=>pixel_x , pixel_y=>pixel_y ,
rgb_text=>rgb_next , sw=>sw );
-- rgb buffer
process (clk)
begin
if (clk'event and clk='1') then
if (pixel_tick='1') then
rgb_reg <= rgb_next;
end if;
end if;
end process;
rgb <= rgb_reg;
end arch;
```

6. Conclusiones

Realizando el modulo VGA nos dimos cuenta que este modulo es muy importante para el principio de funcionamiento de del muestreo de graficas y texto en alguna pantalla. Conociendo la frecuencia de refresco y numero de pixeles, podemos tener varias resoluciones de imagen-texto, desde una resolución muy mala hasta una resolución muy nítida. Desde que se consiguió poder controlar el modulo VGA fue el principio de funcionamiento para la tecnología de video, imagen, videojuegos etc.

7. Bibliography

Referencias

- [1] PONG P. CHU (2008). FPGA PROTOTYPING BY VHDL EXAMPLES. USA: JOHN WILEY & SONS, INC *VGA CONTROLLER I: GRAPHIC*, pp 257, 2019.

- [2] PONG P. CHU (2008). FPGA PROTOTYPING BY VHDL EXAMPLES. USA: JOHN WILEY & SONS, INC *VGA CONTROLLER I: GRAPHIC*, pp 259, 2019.