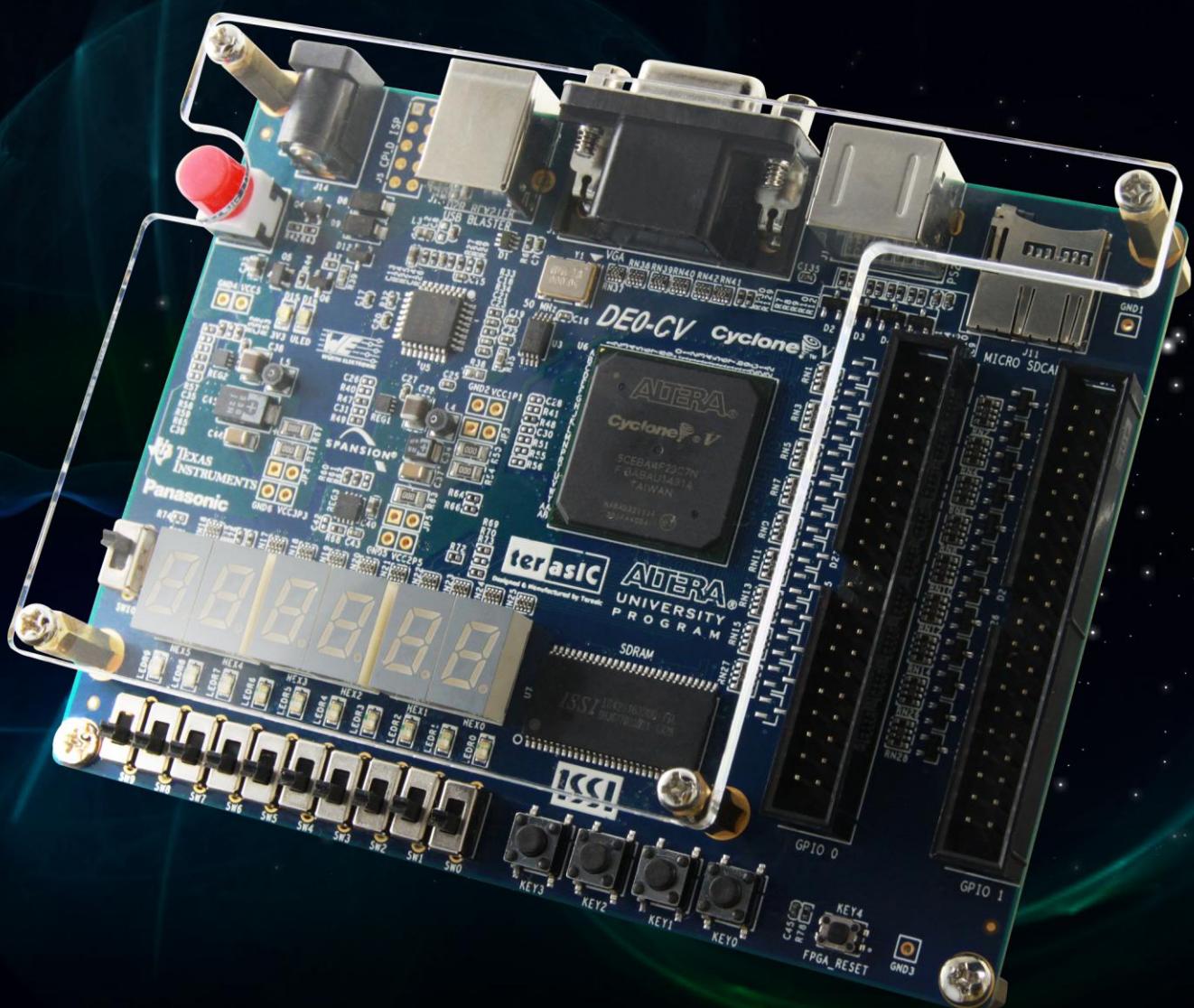


# DE0-CV

## User Manual



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www.terasic.com

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# Chapter 1

## Introduction

The DE0-CV presents a robust hardware design platform built around the Altera Cyclone V FPGA, which is optimized for the lowest cost and power requirement for transceiver applications with industry-leading programmable logic for ultimate design flexibility. With Cyclone V FPGAs, you can get the power, cost, and performance levels you need for high-volume applications including protocol bridging, motor control drives and capture cards, and handheld devices. The DE0-CV development board includes hardware such as on-board USB Blaster, video capabilities and much more. By leveraging all of these capabilities, the DE0-CV is the perfect solution for showcasing, evaluating, and prototyping the true potential of the Altera Cyclone V FPGA.

The DE0-CV contains all components needed to use the board in conjunction with a computer that runs the Microsoft Windows XP or later.

### 1. 1 Package Contents

Figure 1-1 shows a photograph of the DE0-CV package.



Figure 1-1 The DE0-CV package contents

**The DE0-CV package includes:**

- The DE0-CV board
- 5V DC Power Supply
- Type A Male to Type B Male USB Cable

## 1. 2 DE0-CV System CD

The DE0-CV System CD contains the documentation and supporting materials, including the User Manual, Control Panel, System Builder, reference designs and device datasheets. User can download this System CD from the web (<http://cd-de0-cv.terasic.com>).

## 1. 3 Layout and Components

This section presents the features and design characteristics of the board.

A photograph of the board is shown in **Figure 1-2** and **Figure 1-3**. It depicts the layout of the board and indicates the location of the connectors and key components.

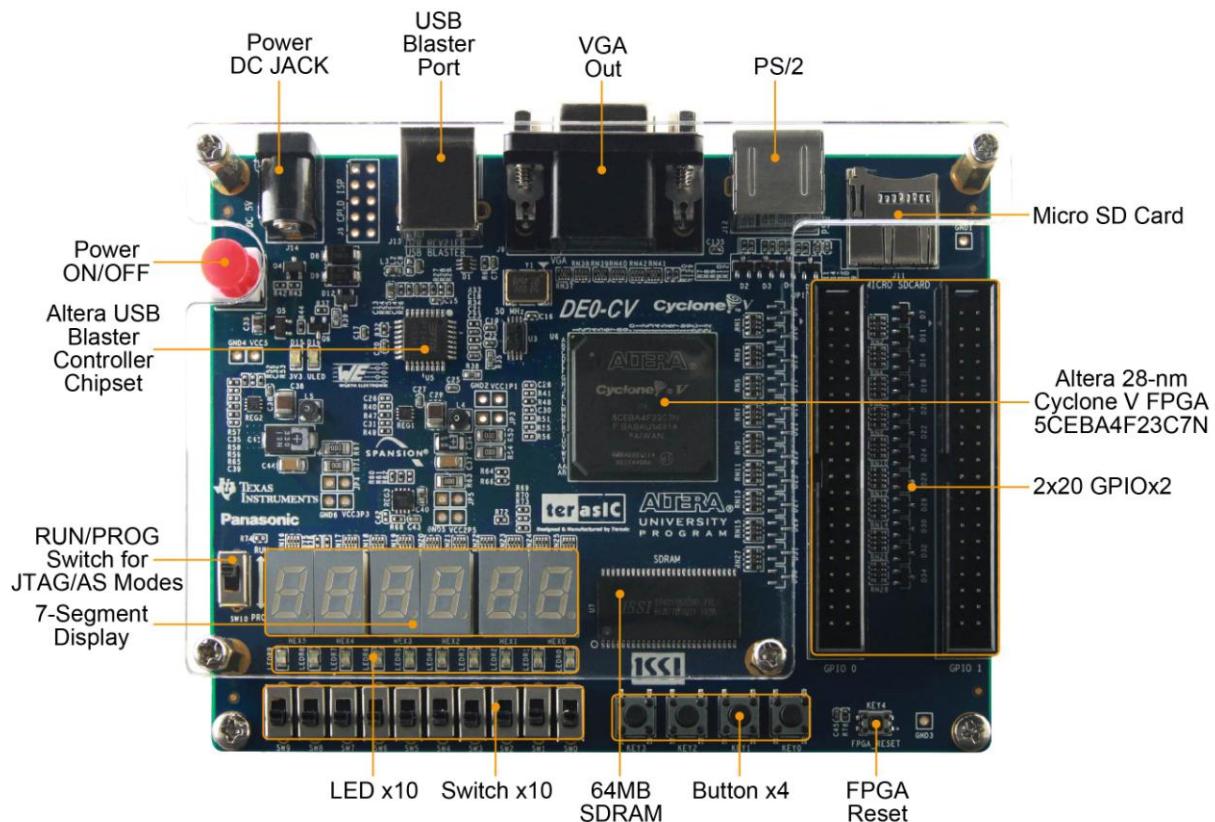
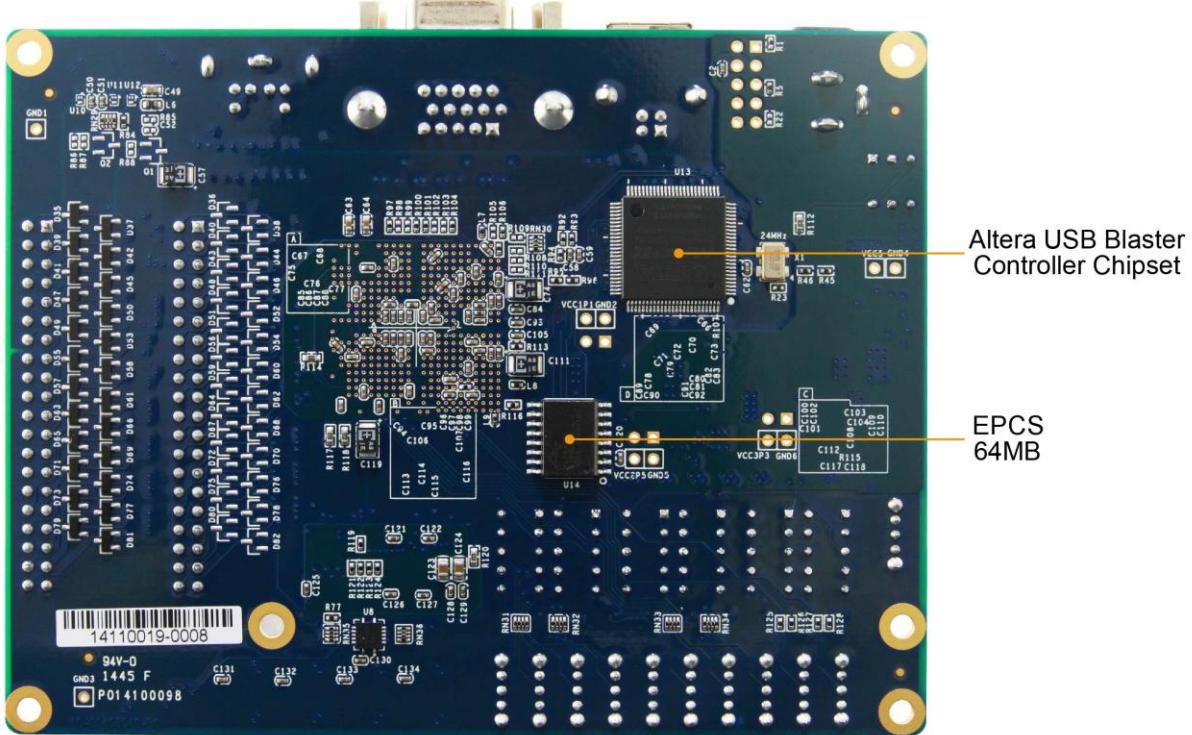


Figure 1-2 Development Board (top view)



**Figure 1-3 Development Board (bottom view)**

This board has many features that allow users to implement a wide range of designed circuits, from simple circuits to various multimedia projects.

The following hardware is provided on the board:

## FPGA Device

- Cyclone V 5CEBA4F23C7N Device
  - 49K Programmable Logic Elements
  - 3080 Kbits embedded memory
  - 4 Fractional PLLs

## Configuration and Debug

- Serial Configuration device – EPICS64 on FPGA
  - On-Board USB Blaster (Normal type B USB connector)
  - JTAG and AS mode configuration supported

## **Memory Device**

- 64MB SDRAM, x16 bits data bus

## Communication

- PS/2 mouse/keyboard

## Connectors

- 2x20 GPIO Header

## Display

- Uses a 4-bit resistor-network DAC
- With 15-pin high-density D-sub connector

## Micro SD Card Socket

- Provides SPI and 4-bit SD mode for Micro SD Card access

## Switches, Buttons and LEDs

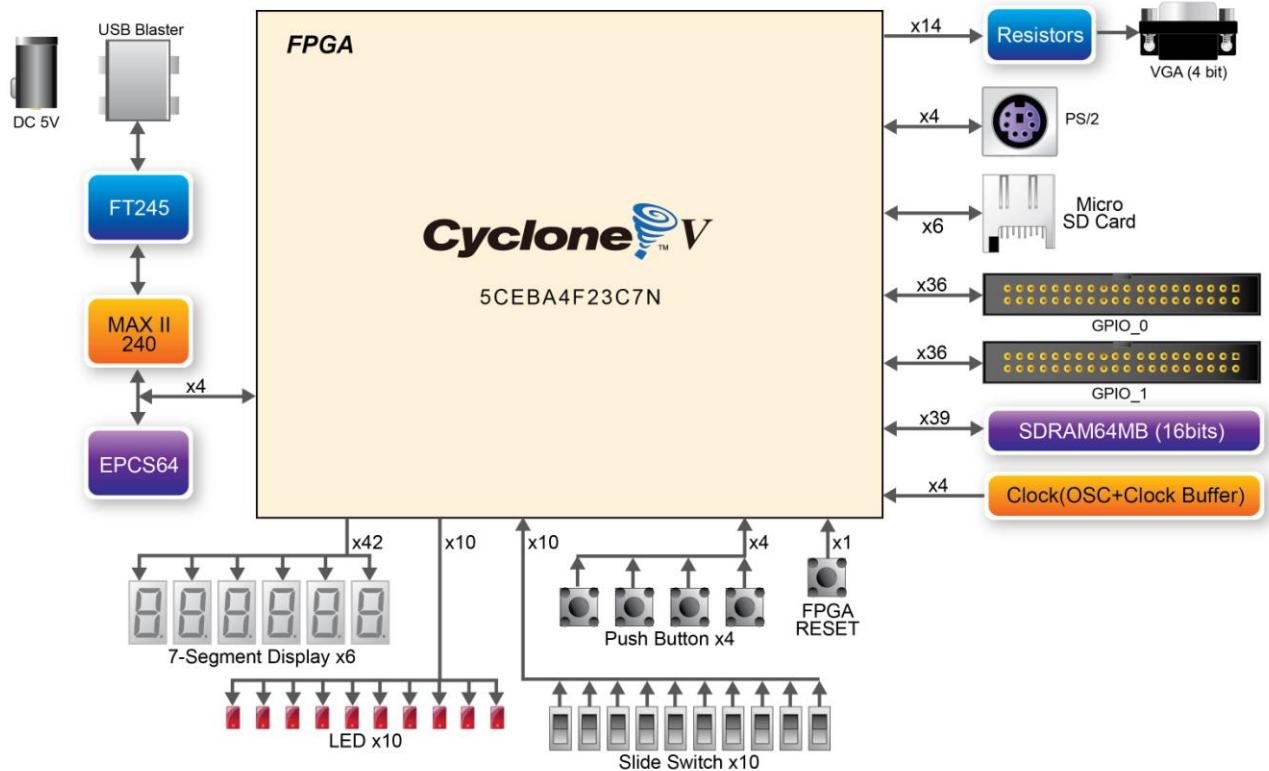
- 10 LEDs
- 10 Slide Switches
- 4 Debounced Push Buttons
- 1 CPU reset Push Buttons
- Six 7-Segments

## Power

- 5V DC input

## 1. 4 Block Diagram of the Cyclone V Starter Board

**Figure 1-4** gives the block diagram of the board. To provide maximum flexibility for the user, all connections are made through the Cyclone V FPGA device. Thus, the user can configure the FPGA to implement any system design.



**Figure 1-4 Board Block Diagram**

## 1. 5 Getting Help

Here are the addresses where you can get help if you encounter any problem:

- Terasic Inc.

9F., No.176, Sec.2, Gongdao 5th Rd, East Dist, Hsinchu City, 30070. Taiwan

Email: [support@terasic.com](mailto:support@terasic.com)

Tel.: +886-3-5750-880

Web: <http://www.DE0-CV.terasic.com>

## Chapter 2

# Control Panel

The DE0-CV board comes with a Control Panel program that allows users to access various components on the board from a host computer. The host computer communicates with the board through a USB connection. The program can be used to verify the functionality of components on the board or be used as a debug tool while developing any RTL code.

This chapter first presents some basic functions of the Control Panel, then describes its structure in the block diagram form, and finally describes its capabilities.

## 2. 1 Control Panel Setup

The Control Panel Software Utility is located in the directory “Tools/ControlPanel” in the **DE0-CV System CD**. It's free of installation, just copy the whole folder to your host computer and launch the control panel by executing the “DE0CV\_ControlPanel.exe”.

Specific control circuits should be downloaded to your FPGA board before the control panel can request it to perform required tasks. The program will call Quartus II tools to download the control circuit to the FPGA board through the USB-Blaster[USB-0] connection.

To activate the Control Panel, perform the following steps:

1. Make sure Quartus II 14.0 or a later version is installed successfully on your PC.
2. Set the RUN/PROG switch to the RUN position.
3. Connect the USB cable provided to the USB Blaster port, connect the 5V power supply, and turn the power switch ON.
4. Start the executable *DE0CV\_ControlPanel.exe* on the host computer. The Control Panel user interface shown in **Figure 2-1** will appear.
5. The *DE0CV\_ControlPanel.sof* bit stream is loaded automatically as soon as the *DE0CV\_ControlPanel.exe* is launched.
6. In case of a disconnect, click on CONNECT where the .sof will be re-loaded onto the board.

*Please note that the Control Panel will occupy the USB port until you close that port; you cannot use Quartus II to download a configuration file into the FPGA until the USB port is closed.*

7. The Control Panel is now ready to use; experience it by setting the ON/OFF status for some LEDs and observing the result on the DE0-CV board.

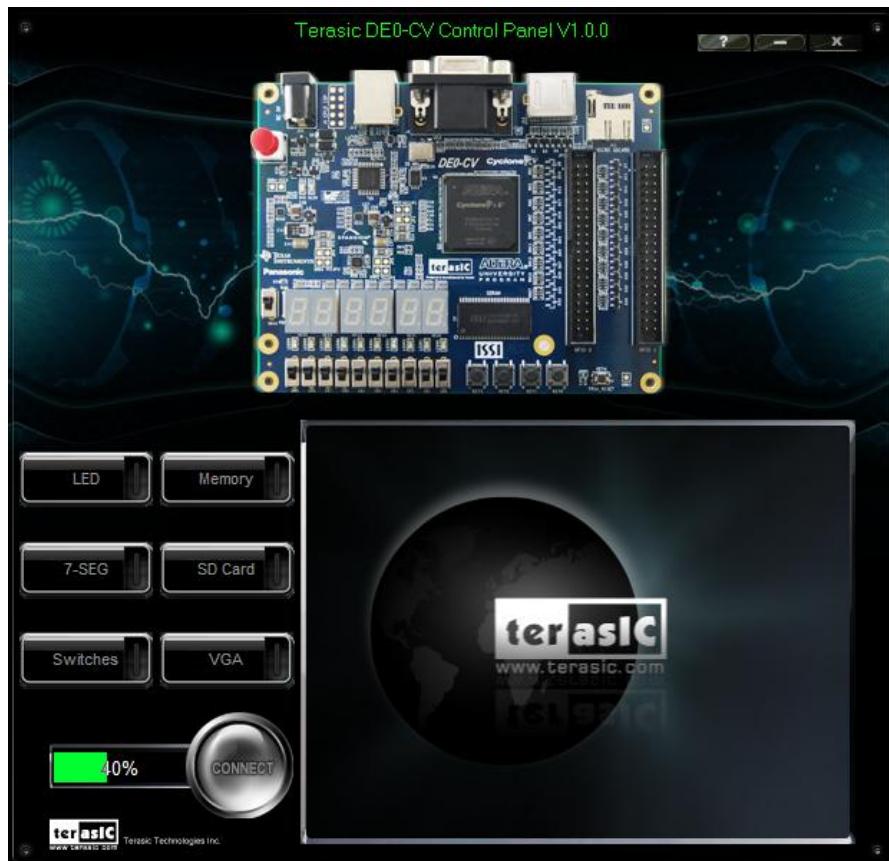
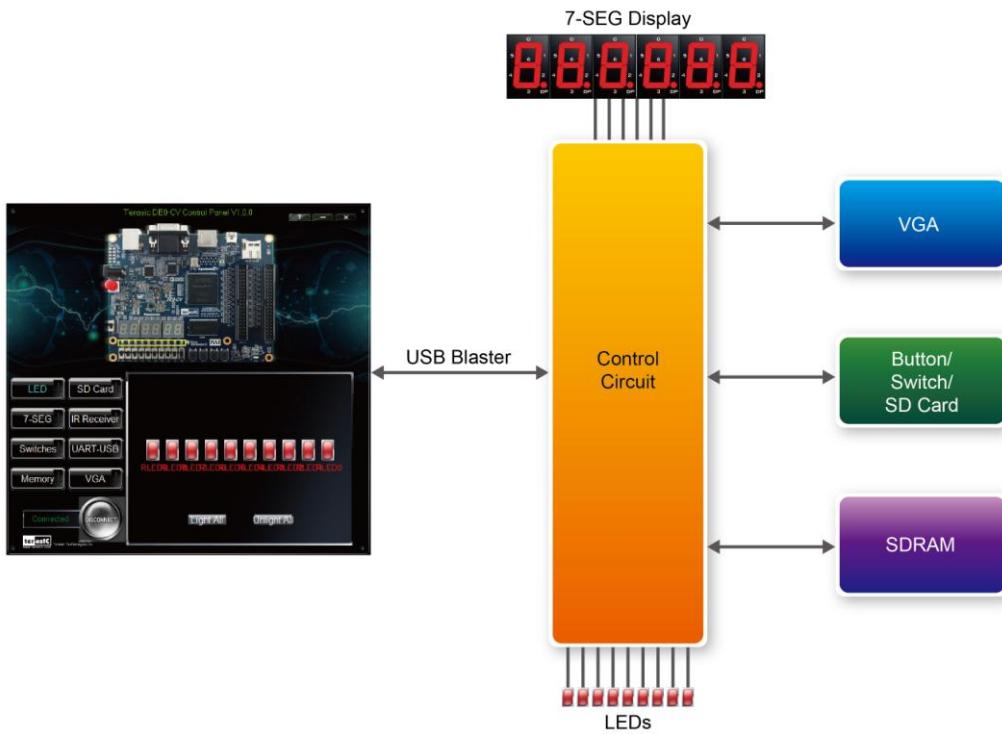


Figure 2-1 The DE0-CV Control Panel

The concept of the DE0-CV Control Panel is illustrated in [Figure 2-2](#). The “Control Circuit” that performs the control functions is implemented in the FPGA board. It communicates with the Control Panel window, which is active on the host computer, via the USB Blaster link. The graphical interface is used to send commands to the control circuit. It handles all the requests and performs data transfers between the computer and the DE0-CV board.



**Figure 2-2 The DE0-CV Control Panel concept**

The DE0-CV Control Panel can be used to light up LEDs, change the values displayed on the 7-segment, monitor buttons/switches status, read/write the SDRAM Memory, output VGA color pattern to VGA monitor, read SD Card specification information. The feature of reading/writing a word or an entire file from/to the Memory allows the user to develop multimedia applications without worrying about how to build a Memory Programmer.

## 2. 2 Controlling the LEDs, 7-segment Displays

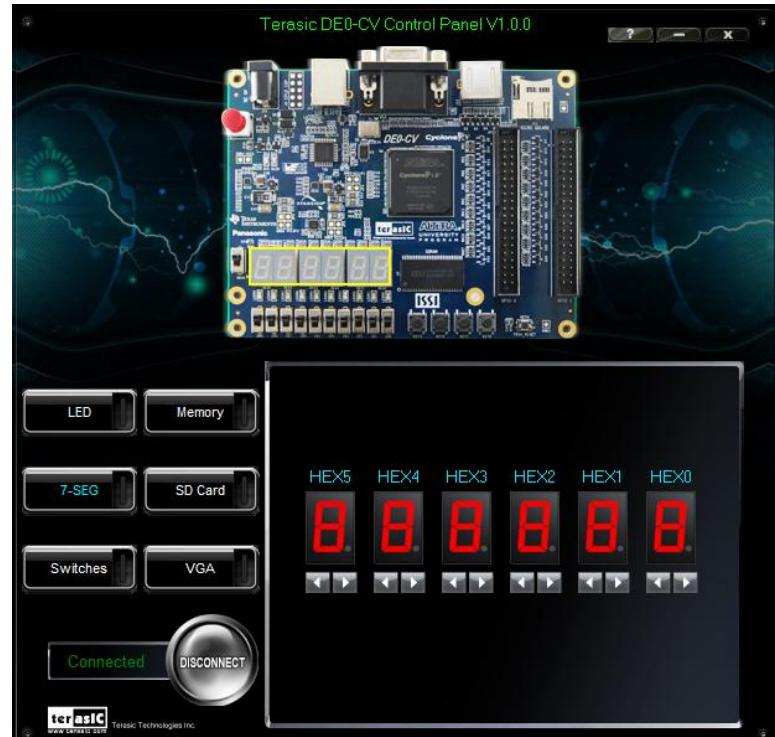
A simple function of the Control Panel is to allow setting the values displayed on LEDs, 7-segment displays.

Choosing the **LED** tab leads to the window in **Figure 2-3**. Here, you can directly turn the LEDs on or off individually or by clicking “Light All” or “Unlight All”.



**Figure 2-3 Controlling LEDs**

Choosing the 7-SEG tab leads to the window shown in **Figure 2-4**. From the window, directly use the left-right arrows to control the 7-SEG patterns on the DE0-CV board which are updated immediately. Note that the dots of the 7-SEGs are not enabled on the DE0-CV board.



**Figure 2-4 Controlling 7-SEG display**

The ability to set arbitrary values into simple display devices is not needed in typical design activities. However, it gives users a simple mechanism for verifying that these devices are functioning correctly in case a malfunction is suspected. Thus, it can be used for troubleshooting purposes.

## 2. 3 Switches and Push-buttons

Choosing the Switches tab leads to the window in **Figure 2-5**. The function is designed to monitor the status of slide switches and push buttons in real time and show the status in a graphical user interface. It can be used to verify the functionality of the slide switches and push-buttons.

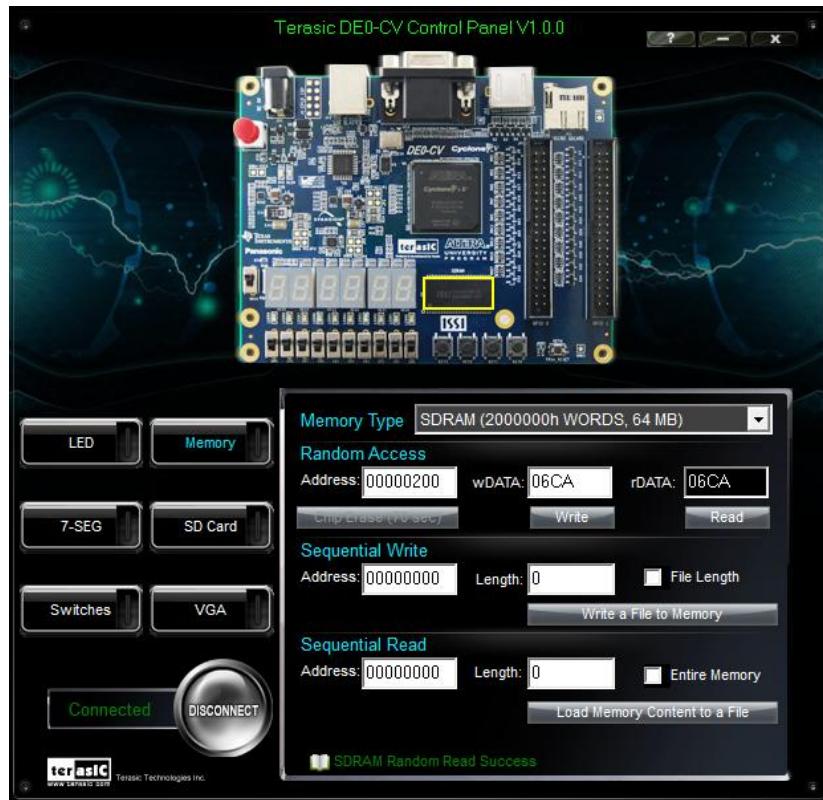


Figure 2-5 Monitoring switches and buttons

The ability to check the status of push-button and slide switch is not needed in typical design activities. However, it provides users a simple mechanism to verify if the buttons and switches are functioning correctly. Thus, it can be used for troubleshooting purposes.

## 2. 4 SDRAM Controller and Programmer

The Control Panel can be used to write/read data to/from the SDRAM chips on the DE0-CV board. As shown below, we will describe how the SDRAM may be accessed; Click on the Memory tab and select “SDRAM” to reach the window in **Figure 2-6**.



**Figure 2-6 Accessing the SDRAM**

A 16-bit word can be written into the SDRAM by entering the address of the desired location, specifying the data to be written, and pressing the Write button. Contents of the location can be read by pressing the Read button. **Figure 2-6** depicts the result of writing the hexadecimal value 06CA into offset address 200, followed by reading the same location.

The Sequential Write function of the Control Panel is used to write the contents of a file into the SDRAM as follows:

1. Specify the starting address in the Address box.
2. Specify the number of bytes to be written in the Length box. If the entire file is to be loaded, then a checkmark may be placed in the File Length box instead of giving the number of bytes.
3. To initiate the writing process, click on the Write a File to Memory button.
4. When the Control Panel responds with the standard Windows dialog box asking for the source file, specify the desired file location in the usual manner.

The Control Panel also supports loading files with a .hex extension. Files with a .hex extension are ASCII text files that specify memory values using ASCII characters to represent hexadecimal values. For example, a file containing the line

0123456789ABCDEF

defines eight 8-bit values: 01, 23, 45, 67, 89, AB, CD, EF. These values will be loaded consecutively into the memory.

The Sequential Read function is used to read the contents of the SDRAM and fill them into a file as follows:

1. Specify the starting address in the Address box.
2. Specify the number of bytes to be copied into the file in the Length box. If the entire contents of the SDRAM are to be copied (which involves all 64 Mbytes), then place a checkmark in the Entire Memory box.
3. Press Load Memory Content to a File button.
4. When the Control Panel responds with the standard Windows dialog box asking for the destination file, specify the desired file in the usual manner.

## 2. 5 SD Card

The function is designed to read the identification and specification information of the SD Card. The 4-bit SD MODE is used to access the SD Card. This function can be used to verify the functionality of the SD Card Interface. Follow the steps below to perform the SD Card exercise:

1. Choosing the SD Card tab leads to the window in [Figure 2-7](#).
2. Insert an SD Card to the DE0-CV board, and then press the Read button to read the SD Card. The SD Card's identification, specification, and file format information will be displayed in the control window.



**Figure 2-7 Reading the SD Card Identification and Specification**

## 2. 6 VGA

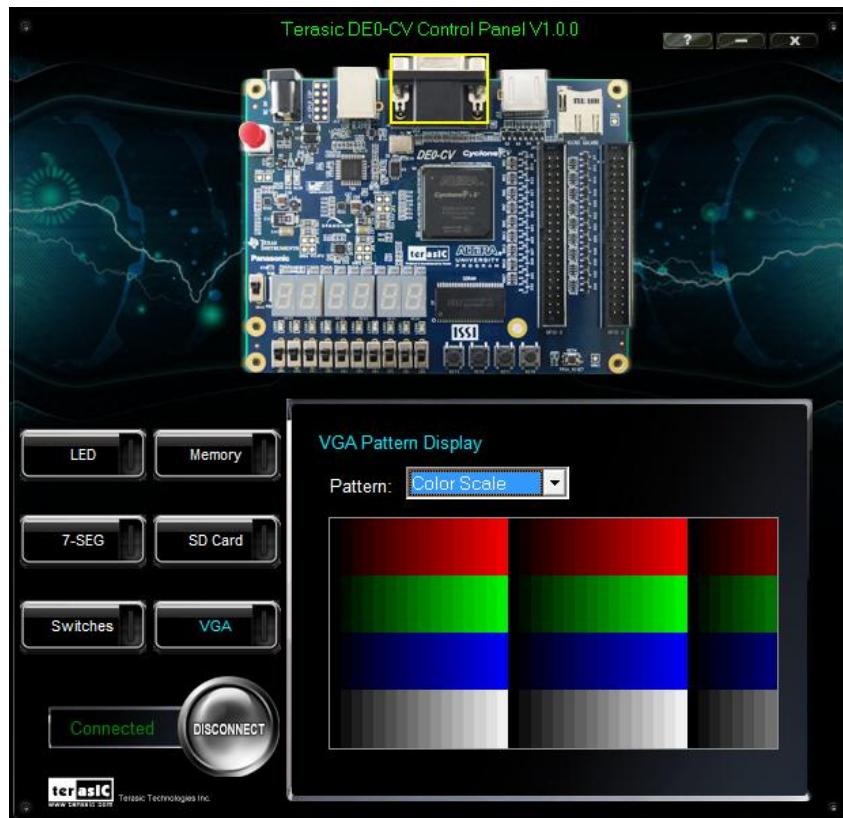
DE0-CV Control Panel provides VGA pattern function that allows users to output color pattern to LCD/CRT monitor using the DE0-CV board. Follow the steps below to generate the VGA pattern function:

Choosing the VGA tab leads to the window in **Figure 2-8**.

Plug a D-sub cable to the VGA connector of the DE0-CV board and LCD /CRT monitor.

The LCD/CRT monitor will display the same color pattern on the control panel window.

Click the drop down menu shown in **Figure 2-8** where you can output the selected pattern individually.

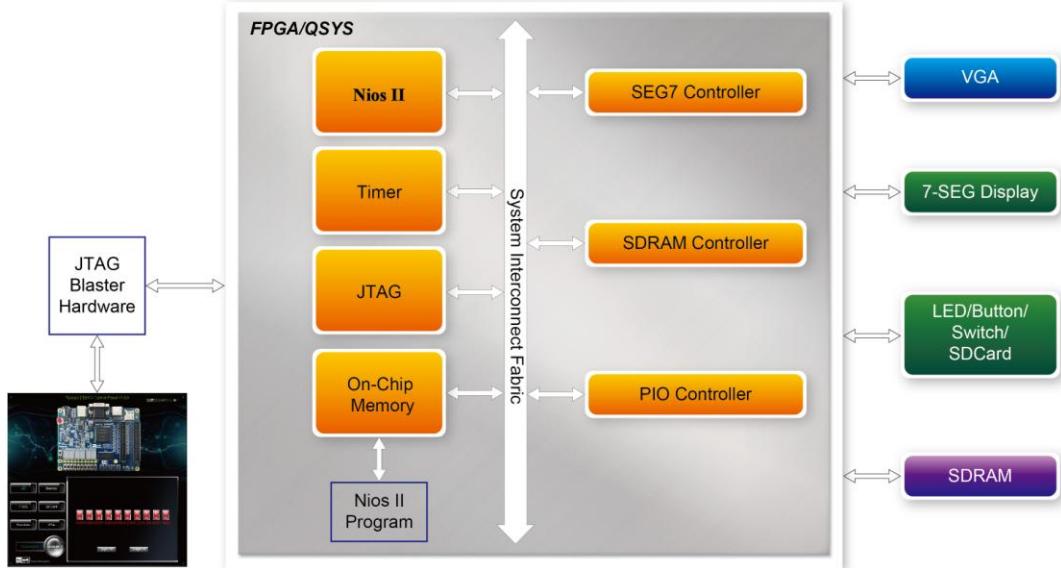


**Figure 2-8 Controlling VGA display under Control Panel**

## 2. 7 Overall Structure of the DE0-CV Control Panel

The DE0-CV Control Panel is based on a Nios II Qsys system instantiated in the Cyclone V FPGA with software running on the on-chip memory. The software part is implemented in C code; the hardware part is implemented in Verilog HDL code with Qsys builder. The source code is not available on the DE0-CV System CD.

To run the Control Panel, users should follow the configuration setting according to Section 3.1. **Figure 2-9** depicts the structure of the Control Panel. Each input/output device is controlled by the Nios II Processor instantiated in the FPGA chip. The communication with the PC is done via the USB Blaster link. The Nios II interprets the commands sent from the PC and performs the corresponding actions.



**Figure 2-9 The block diagram of the DE0-CV control panel**

## Chapter 3

# *Using the Starter Kit*

This chapter provides an instruction to use the board and describes the peripherals.

### **3. 1 Configuration of Cyclone V FPGA on DE0-CV**

The DE0-CV board contains a serial configuration device that stores configuration data for the Cyclone V FPGA. This configuration data is automatically loaded from the configuration device into the FPGA when powered on. Using the Quartus II software, it is possible to reconfigure the FPGA at any time, and it is also possible to change the non-volatile data that is stored in the serial configuration device. Both types of programming methods are described below.

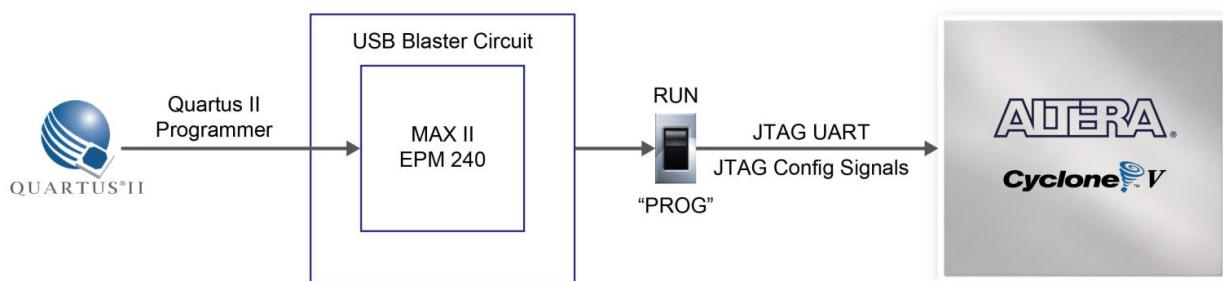
1. JTAG programming: In this method of programming, named after the IEEE standards Joint Test Action Group, the configuration bit stream is downloaded directly into the Cyclone V FPGA. The FPGA will retain this configuration as long as power is applied to the board; the configuration information will be lost when the power is turned off.
2. AS programming: In this method, called Active Serial programming, the configuration bit stream is downloaded into the Altera EPSCS64 serial configuration device. It provides non-volatile storage of the bit stream, so that the information is retained even when the power supply to the DE0-CV board is turned off. When the board's power is turned on, the configuration data in the EPSCS64 device is automatically loaded into the Cyclone V FPGA.

The sections below describe the steps to perform both JTAG and AS programming. For both methods the DE0-CV board is connected to a host computer via a USB cable. Using this connection, the board will be identified by the host computer as an Altera USB Blaster device.

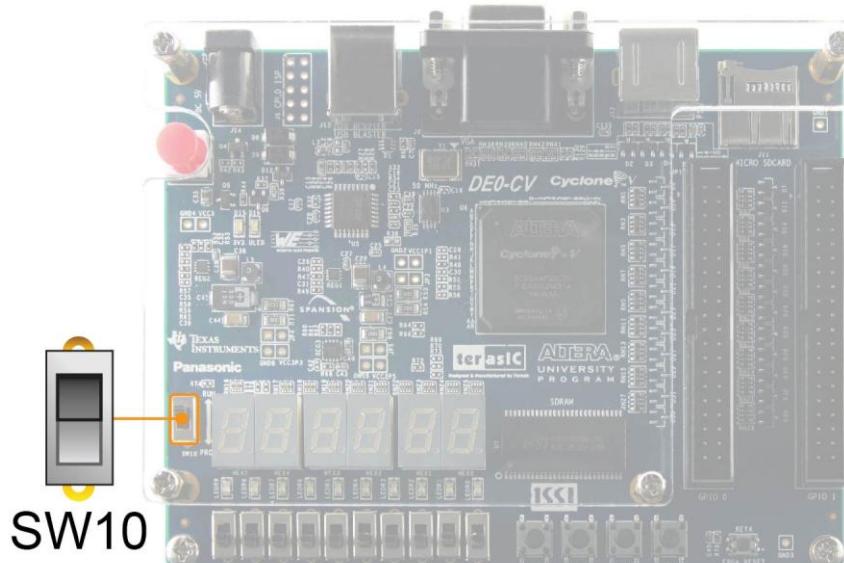
## ■ Configuring the FPGA in JTAG Mode

**Figure 3-1** illustrates the JTAG configuration setup. To download a configuration bit stream into the Cyclone V FPGA, you need to perform the following steps:

- Ensure that power is applied to the DE0-CV board
- Configure the JTAG programming circuit by setting the RUN/PROG slide switch (SW10) to the RUN position (See **Figure 3-2**)
- Connect the USB cable provided to the USB Blaster port on the DE0-CV board
- The FPGA can now be programmed by using the Quartus II Programmer to select a configuration bit stream file with the .sof filename extension



**Figure 3-1** The JTAG configuration scheme



**Figure 3-2** The RUN/PROG switch (SW10) is set in JTAG mode

## ■ Configuring the EPCS64 in AS Mode

Figure 3-3 illustrates the AS configuration setup. To download a configuration bit stream into the EPCS64 serial configuration device, you need to perform the following steps:

- Ensure that power is applied to the DE0-CV board.
- Connect the USB cable provided to the USB Blaster port on the DE0-CV board
- Configure the JTAG programming circuit by setting the RUN/PROG slide switch (SW10) to the PROG position.
- The EPCS64 chip can now be programmed by using the Quartus II Programmer to select a configuration bit stream file with the .pof filename extension.
- Once the programming operation is finished, set the RUN/PROG slide switch back to the RUN position and then reset the board by turning the power switch off and back on; this action causes the new configuration data in the EPCS64 device to be loaded into the FPGA chip.

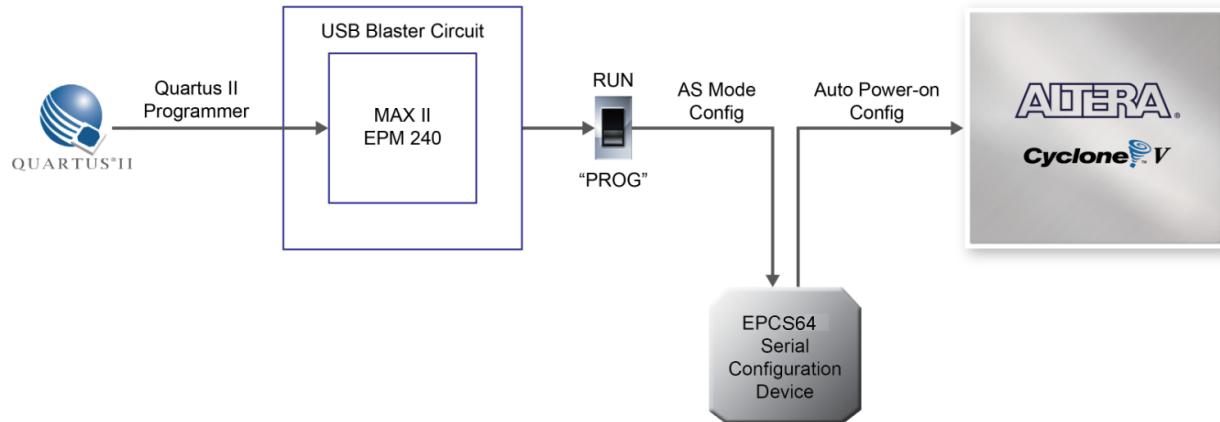


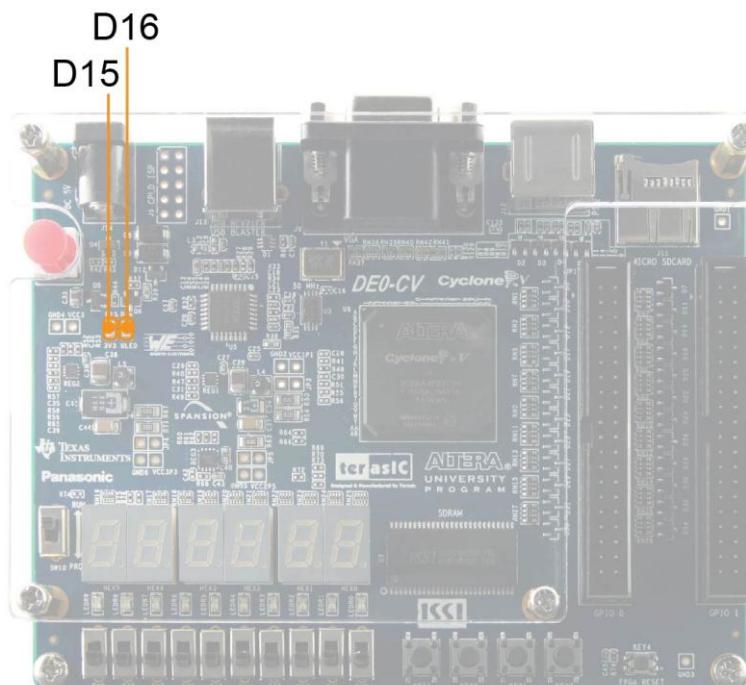
Figure 3-3 The AS configuration scheme

## ■ Status LED

- The FPGA development board includes board-specific status LEDs to indicate board status. Please refer to **Table 3-1** for the description of the LED indicator. Please refer to **Figure 3-4** for detailed LED location.

**Table 3-1 Status LED**

<i>Board Reference</i>	<i>LED Name</i>	<i>Description</i>
D15	3.3-V Power	Illuminates when 3.3-V power is active.
D16	ULED	Illuminates when the on-board USB-Blaster is working



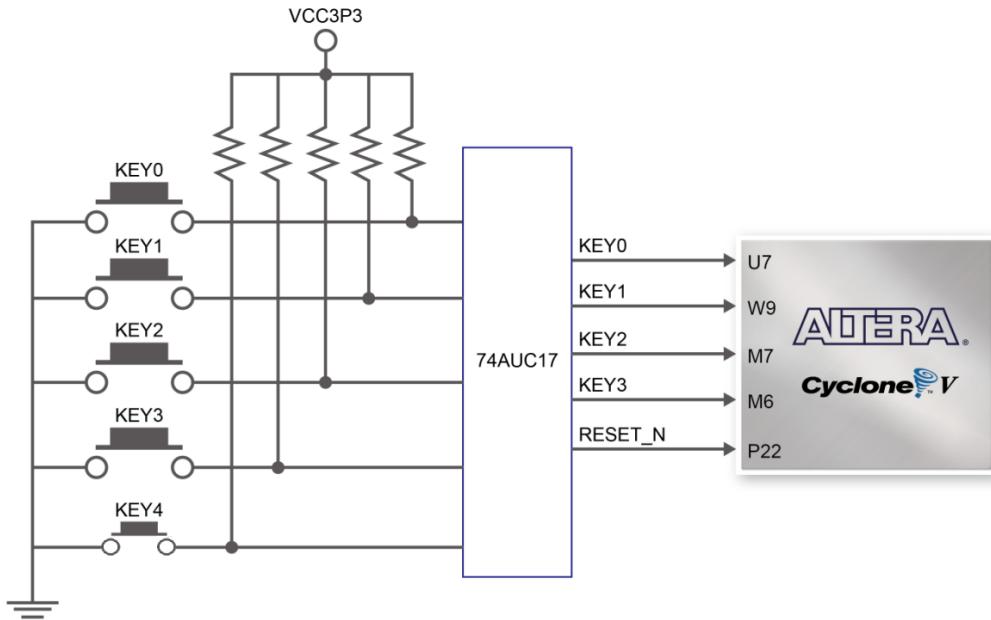
**Figure 3-4 Status LED position**

## 3. 2 Using the LEDs and Switches

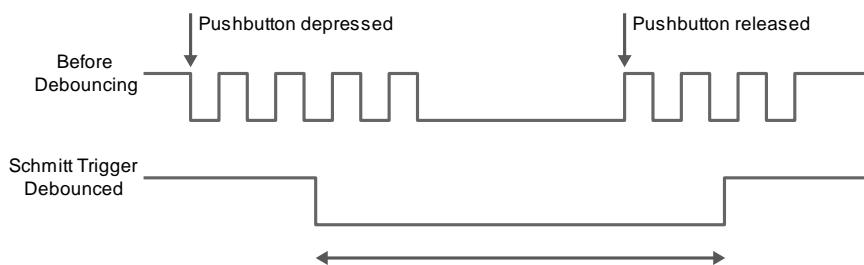
### ■ User-Defined Push-buttons

The board includes four user defined push-buttons and one FPGA reset button that allow users to interact with the Cyclone V device as shown in **Figure 3-5**. Each of these switches is debounced using a Schmitt Trigger circuit, as indicated in **Figure 3-6**. The five outputs called KEY0, KEY1,

KEY2, KEY3 and RESET\_N of the Schmitt Trigger devices are connected directly to the Cyclone V FPGA. Each push-button switch provides a high logic level when it is not pressed, and provides a low logic level when depressed. Since the push-button switches are debounced, they are appropriate for using as clocks or reset inputs in a circuit.



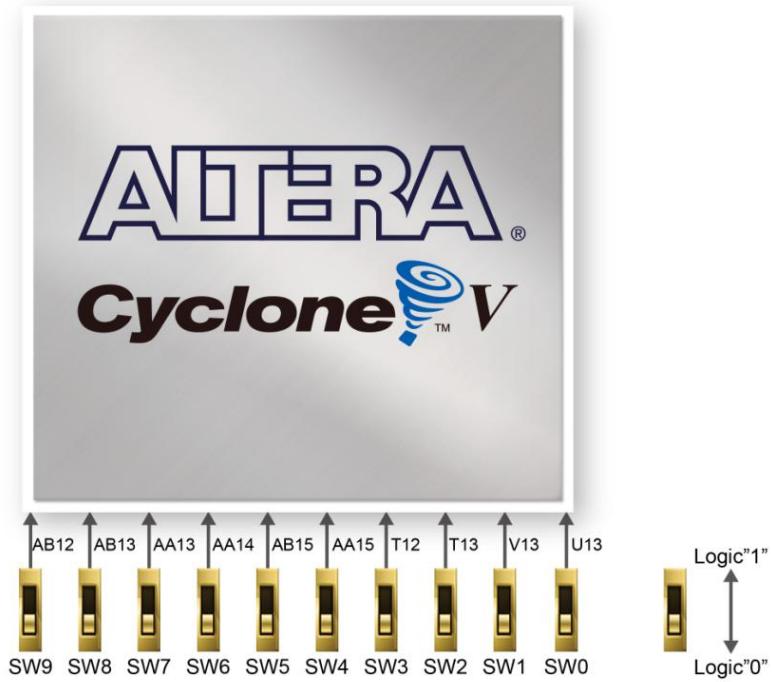
**Figure 3-5 Connections between the push-button and Cyclone V FPGA**



**Figure 3-6 Switch debouncing**

## ■ User-Defined Slide Switch

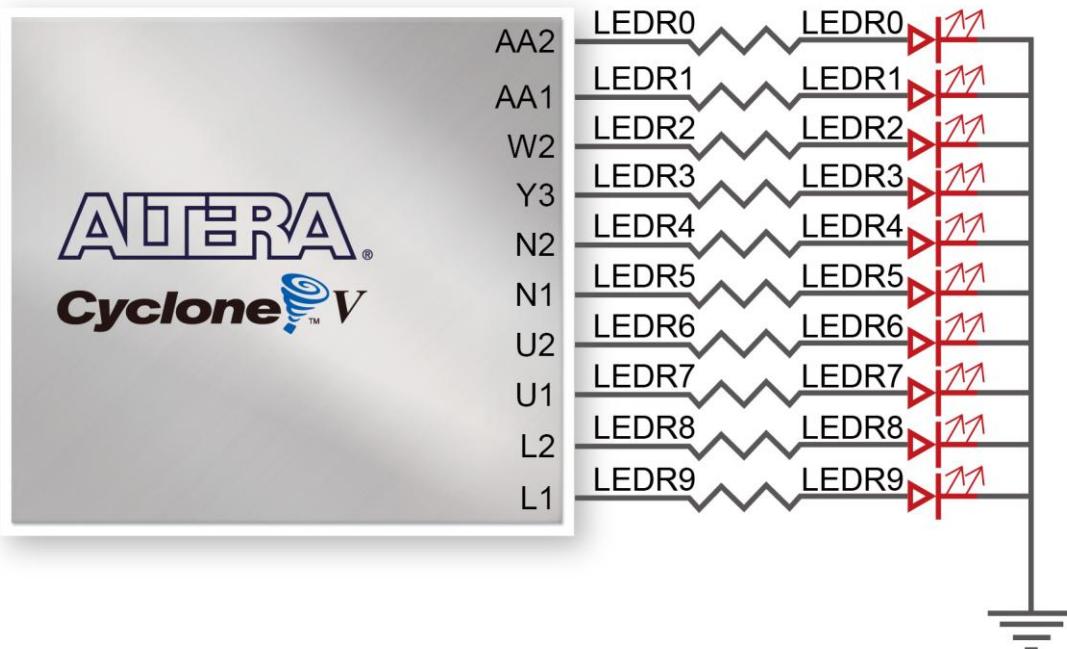
There are ten slide switches connected to FPGA on the board (See [Figure 3-7](#)). These switches are not debounced, and are assumed for use as level-sensitive data inputs to a circuit. Each switch is connected directly to a pin on the Cyclone V FPGA. When the switch is in the DOWN position (closest to the edge of the board), it provides a low logic level to the FPGA, and when the switch is in the UP position it provides a high logic level.



**Figure 3-7 Connections between the slide switches and Cyclone V FPGA**

## ■ User-Defined LEDs

There are also ten user-controllable LEDs connected to FPGA on the board. Each LED is driven directly by a pin on the Cyclone V FPGA; driving its associated pin to a high logic level turns the LED on, and driving the pin low turns it off. **Figure 3-8** shows the connections between LEDs and Cyclone V FPGA. **Table 3-2**, **Table 3-3** and **Table 3-4** list the pin assignment of user push-buttons, switches, and LEDs.



**Figure 3-8 Connections between the LEDs and Cyclone V FPGA**

**Table 3-2 Pin Assignment of Push-buttons**

<b>Signal Name</b>	<b>FPGA Pin No.</b>	<b>Description</b>
KEY0	PIN_U7	Push-button[0]
KEY1	PIN_W9	Push-button[1]
KEY2	PIN_M7	Push-button[2]
KEY3	PIN_M6	Push-button[3]
RESET_N	PIN_P22	Push-button which connected to DEV_CLRN Pin of FPGA

**Table 3-3 Pin Assignment of Slide Switches**

<b>Signal Name</b>	<b>FPGA Pin No.</b>	<b>Description</b>
SW0	PIN_U13	Slide Switch[0]
SW1	PIN_V13	Slide Switch[1]
SW2	PIN_T13	Slide Switch[2]
SW3	PIN_T12	Slide Switch[3]
SW4	PIN_AA15	Slide Switch[4]
SW5	PIN_AB15	Slide Switch[5]
SW6	PIN_AA14	Slide Switch[6]
SW7	PIN_AA13	Slide Switch[7]
SW8	PIN_AB13	Slide Switch[8]
SW9	PIN_AB12	Slide Switch[9]

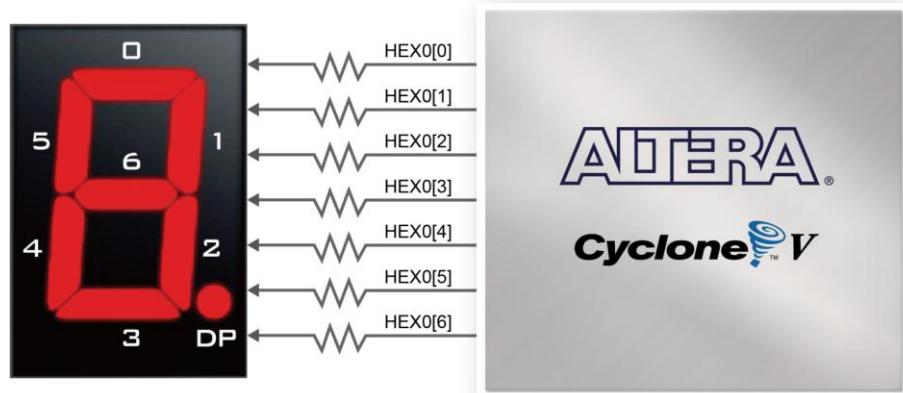
**Table 3-4 Pin Assignment of LEDs**

<i>Signal Name</i>	<i>FPGA Pin No.</i>	<i>Description</i>
<b>LEDR0</b>	<b>PIN_AA2</b>	<b>LED [0]</b>
<b>LEDR1</b>	<b>PIN_AA1</b>	<b>LED [1]</b>
<b>LEDR2</b>	<b>PIN_W2</b>	<b>LED [2]</b>
<b>LEDR3</b>	<b>PIN_Y3</b>	<b>LED [3]</b>
<b>LEDR4</b>	<b>PIN_N2</b>	<b>LED [4]</b>
<b>LEDR5</b>	<b>PIN_N1</b>	<b>LED [5]</b>
<b>LEDR6</b>	<b>PIN_U2</b>	<b>LED [6]</b>
<b>LEDR7</b>	<b>PIN_U1</b>	<b>LED [7]</b>
<b>LEDR8</b>	<b>PIN_L2</b>	<b>LED [8]</b>
<b>LEDR9</b>	<b>PIN_L1</b>	<b>LED [9]</b>

### 3. 3 Using the 7-segment Displays

The DE0-CV board has six 7-segment displays. These displays are paired to display numbers in various sizes. **Figure 3-9** shows the connection of seven segments (common anode) to pins on Cyclone V FPGA. The segment can be turned on or off by applying a low logic level or high logic level from the FPGA, respectively.

Each segment in a display is indexed from 0 to 6, with corresponding positions given in **Figure 3-9**. **Table 3-5** shows the pin assignment of FPGA to the 7-segment displays.



**Figure 3-9 Connections between the 7-segment display HEX0 and the Cyclone V FPGA**

**Table 3-5 Pin Assignment of 7-segment Displays**

<i>Signal Name</i>	<i>FPGA Pin No.</i>	<i>Description</i>
<b>HEX00</b>	<b>PIN_U21</b>	<b>Seven Segment Digit 0[0]</b>
<b>HEX01</b>	<b>PIN_V21</b>	<b>Seven Segment Digit 0[1]</b>

HEX02	PIN_W22	Seven Segment Digit 0[2]
HEX03	PIN_W21	Seven Segment Digit 0[3]
HEX04	PIN_Y22	Seven Segment Digit 0[4]
HEX05	PIN_Y21	Seven Segment Digit 0[5]
HEX06	PIN_AA22	Seven Segment Digit 0[6]
HEX10	PIN_AA20	Seven Segment Digit 1[0]
HEX11	PIN_AB20	Seven Segment Digit 1[1]
HEX12	PIN_AA19	Seven Segment Digit 1[2]
HEX13	PIN_AA18	Seven Segment Digit 1[3]
HEX14	PIN_AB18	Seven Segment Digit 1[4]
HEX15	PIN_AA17	Seven Segment Digit 1[5]
HEX16	PIN_U22	Seven Segment Digit 1[6]
HEX20	PIN_Y19	Seven Segment Digit 2[0]
HEX21	PIN_AB17	Seven Segment Digit 2[1]
HEX22	PIN_AA10	Seven Segment Digit 2[2]
HEX23	PIN_Y14	Seven Segment Digit 2[3]
HEX24	PIN_V14	Seven Segment Digit 2[4]
HEX25	PIN_AB22	Seven Segment Digit 2[5]
HEX26	PIN_AB21	Seven Segment Digit 2[6]
HEX30	PIN_Y16	Seven Segment Digit 3[0]
HEX31	PIN_W16	Seven Segment Digit 3[1]
HEX32	PIN_Y17	Seven Segment Digit 3[2]
HEX33	PIN_V16	Seven Segment Digit 3[3]
HEX34	PIN_U17	Seven Segment Digit 3[4]
HEX35	PIN_V18	Seven Segment Digit 3[5]
HEX36	PIN_V19	Seven Segment Digit 3[6]
HEX40	PIN_U20	Seven Segment Digit 4[0]
HEX41	PIN_Y20	Seven Segment Digit 4[1]
HEX42	PIN_V20	Seven Segment Digit 4[2]
HEX43	PIN_U16	Seven Segment Digit 4[3]
HEX44	PIN_U15	Seven Segment Digit 4[4]
HEX45	PIN_Y15	Seven Segment Digit 4[5]
HEX46	PIN_P9	Seven Segment Digit 4[6]
HEX50	PIN_N9	Seven Segment Digit 5[0]
HEX51	PIN_M8	Seven Segment Digit 5[1]
HEX52	PIN_T14	Seven Segment Digit 5[2]
HEX53	PIN_P14	Seven Segment Digit 5[3]
HEX54	PIN_C1	Seven Segment Digit 5[4]
HEX55	PIN_C2	Seven Segment Digit 5[5]
HEX56	PIN_W19	Seven Segment Digit 5[6]

### 3. 4 Clock Circuitry

Figure 3-10 shows the clock circuit of DE0-CV Board, the crystal 50 MHz buffered to four 50MHz clock. The associated pin assignment for clock inputs to FPGA I/O pins is listed in Table 3-6.

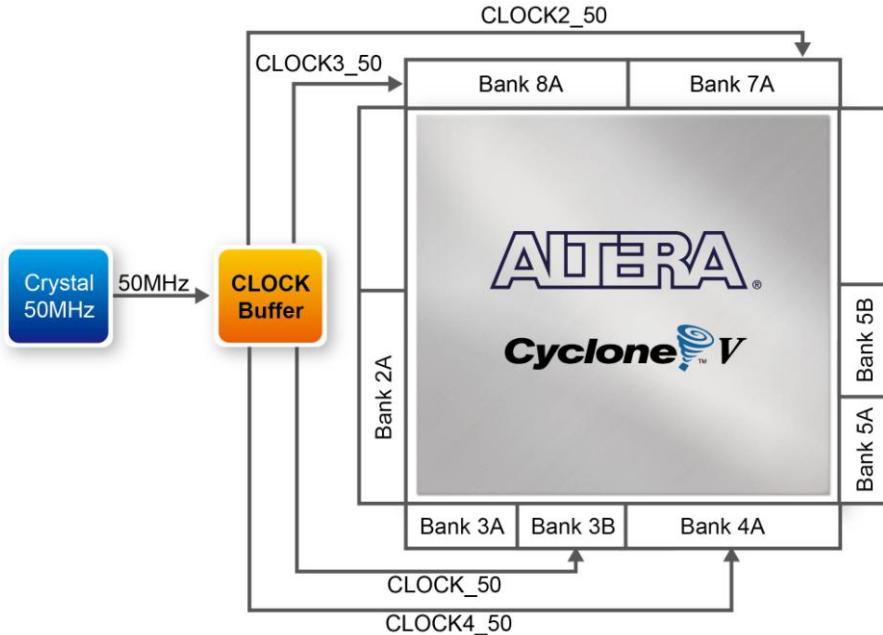


Figure 3-10 Clock circuit of the FPGA Board

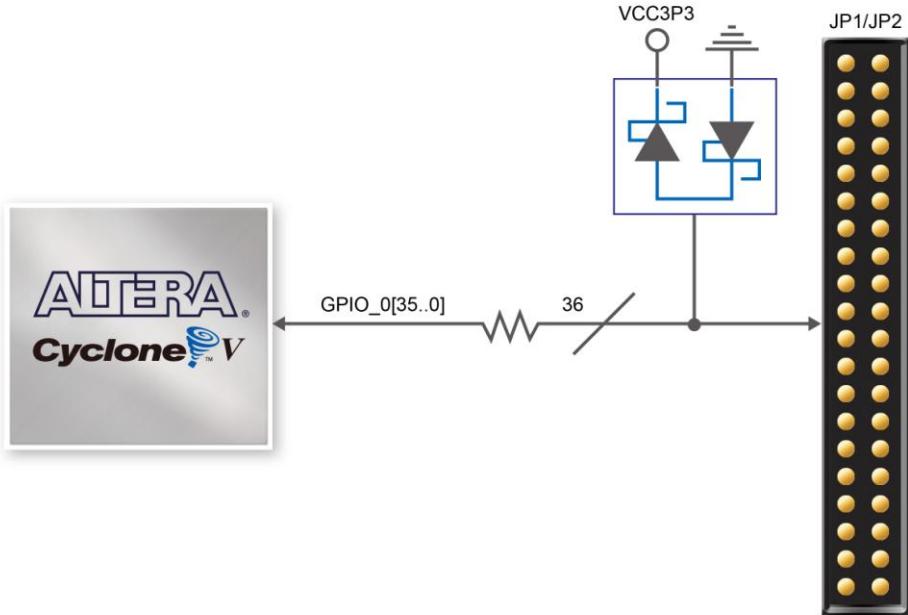
Table 3-6 Pin Assignment of Clock Inputs

Signal Name	FPGA Pin No.	Description
CLOCK_50	PIN_M9	50 MHz clock input(Bank 3B)
CLOCK2_50	PIN_H13	50 MHz clock input(Bank 7A)
CLOCK3_50	PIN_E10	50 MHz clock input(Bank 8A)
CLOCK4_50	PIN_V15	50 MHz clock input(Bank 4A)

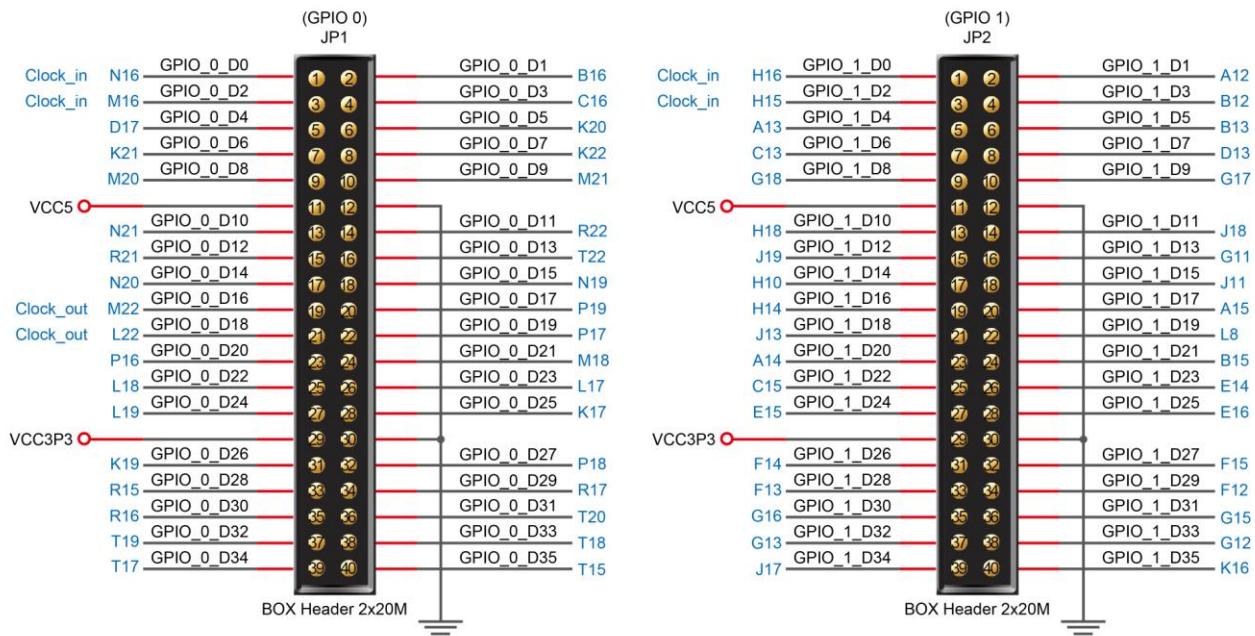
### 3. 5 Using 2x20 GPIO Expansion Headers

The board has two 40-pin expansion headers. Each header has 36 user pins connected directly to the Cyclone V FPGA. It also comes with DC +5V (VCC5), DC +3.3V (VCC3P3), and two GND pins. Both 5V and 3.3V can provide a total of 5W power.

Each pin on the expansion headers is connected to two diodes and a resistor for protection against high or low voltage level. Figure 3-11 shows the protection circuitry applied to all 2x36 data pins. Figure 3-11 shows the related schematics. Table 3-7 shows the pin assignment of two GPIO headers.



**Figure 3-11 Connections between the GPIO header and Cyclone V FPGA**



**Figure 3-12 I/O distribution of the expansion headers**

**Table 3-7 Pin Assignment of Expansion Headers**

Signal Name	FPGA Pin No.	Description
GPIO_0_D0	PIN_N16	GPIO Connection 0[0]
GPIO_0_D1	PIN_B16	GPIO Connection 0[1]
GPIO_0_D2	PIN_M16	GPIO Connection 0[2]
GPIO_0_D3	PIN_C16	GPIO Connection 0[3]
GPIO_0_D4	PIN_D17	GPIO Connection 0[4]
GPIO_0_D5	PIN_K20	GPIO Connection 0[5]
GPIO_0_D6	PIN_K21	GPIO Connection 0[6]

<b>GPIO_0_D7</b>	<b>PIN_K22</b>	<b>GPIO Connection 0[7]</b>
<b>GPIO_0_D8</b>	<b>PIN_M20</b>	<b>GPIO Connection 0[8]</b>
<b>GPIO_0_D9</b>	<b>PIN_M21</b>	<b>GPIO Connection 0[9]</b>
<b>GPIO_0_D10</b>	<b>PIN_N21</b>	<b>GPIO Connection 0[10]</b>
<b>GPIO_0_D11</b>	<b>PIN_R22</b>	<b>GPIO Connection 0[11]</b>
<b>GPIO_0_D12</b>	<b>PIN_R21</b>	<b>GPIO Connection 0[12]</b>
<b>GPIO_0_D13</b>	<b>PIN_T22</b>	<b>GPIO Connection 0[13]</b>
<b>GPIO_0_D14</b>	<b>PIN_N20</b>	<b>GPIO Connection 0[14]</b>
<b>GPIO_0_D15</b>	<b>PIN_N19</b>	<b>GPIO Connection 0[15]</b>
<b>GPIO_0_D16</b>	<b>PIN_M22</b>	<b>GPIO Connection 0[16]</b>
<b>GPIO_0_D17</b>	<b>PIN_P19</b>	<b>GPIO Connection 0[17]</b>
<b>GPIO_0_D18</b>	<b>PIN_L22</b>	<b>GPIO Connection 0[18]</b>
<b>GPIO_0_D19</b>	<b>PIN_P17</b>	<b>GPIO Connection 0[19]</b>
<b>GPIO_0_D20</b>	<b>PIN_P16</b>	<b>GPIO Connection 0[20]</b>
<b>GPIO_0_D21</b>	<b>PIN_M18</b>	<b>GPIO Connection 0[21]</b>
<b>GPIO_0_D22</b>	<b>PIN_L18</b>	<b>GPIO Connection 0[22]</b>
<b>GPIO_0_D23</b>	<b>PIN_L17</b>	<b>GPIO Connection 0[23]</b>
<b>GPIO_0_D24</b>	<b>PIN_L19</b>	<b>GPIO Connection 0[24]</b>
<b>GPIO_0_D25</b>	<b>PIN_K17</b>	<b>GPIO Connection 0[25]</b>
<b>GPIO_0_D26</b>	<b>PIN_K19</b>	<b>GPIO Connection 0[26]</b>
<b>GPIO_0_D27</b>	<b>PIN_P18</b>	<b>GPIO Connection 0[27]</b>
<b>GPIO_0_D28</b>	<b>PIN_R15</b>	<b>GPIO Connection 0[28]</b>
<b>GPIO_0_D29</b>	<b>PIN_R17</b>	<b>GPIO Connection 0[29]</b>
<b>GPIO_0_D30</b>	<b>PIN_R16</b>	<b>GPIO Connection 0[30]</b>
<b>GPIO_0_D31</b>	<b>PIN_T20</b>	<b>GPIO Connection 0[31]</b>
<b>GPIO_0_D32</b>	<b>PIN_T19</b>	<b>GPIO Connection 0[32]</b>
<b>GPIO_0_D33</b>	<b>PIN_T18</b>	<b>GPIO Connection 0[33]</b>
<b>GPIO_0_D34</b>	<b>PIN_T17</b>	<b>GPIO Connection 0[34]</b>
<b>GPIO_0_D35</b>	<b>PIN_T15</b>	<b>GPIO Connection 0[35]</b>
<b>GPIO_1_D0</b>	<b>PIN_H16</b>	<b>GPIO Connection 1[0]</b>
<b>GPIO_1_D1</b>	<b>PIN_A12</b>	<b>GPIO Connection 1[1]</b>
<b>GPIO_1_D2</b>	<b>PIN_H15</b>	<b>GPIO Connection 1[2]</b>
<b>GPIO_1_D3</b>	<b>PIN_B12</b>	<b>GPIO Connection 1[3]</b>
<b>GPIO_1_D4</b>	<b>PIN_A13</b>	<b>GPIO Connection 1[4]</b>
<b>GPIO_1_D5</b>	<b>PIN_B13</b>	<b>GPIO Connection 1[5]</b>
<b>GPIO_1_D6</b>	<b>PIN_C13</b>	<b>GPIO Connection 1[6]</b>
<b>GPIO_1_D7</b>	<b>PIN_D13</b>	<b>GPIO Connection 1[7]</b>
<b>GPIO_1_D8</b>	<b>PIN_G18</b>	<b>GPIO Connection 1[8]</b>
<b>GPIO_1_D9</b>	<b>PIN_G17</b>	<b>GPIO Connection 1[9]</b>
<b>GPIO_1_D10</b>	<b>PIN_H18</b>	<b>GPIO Connection 1[10]</b>
<b>GPIO_1_D11</b>	<b>PIN_J18</b>	<b>GPIO Connection 1[11]</b>
<b>GPIO_1_D12</b>	<b>PIN_J19</b>	<b>GPIO Connection 1[12]</b>
<b>GPIO_1_D13</b>	<b>PIN_G11</b>	<b>GPIO Connection 1[13]</b>
<b>GPIO_1_D14</b>	<b>PIN_H10</b>	<b>GPIO Connection 1[14]</b>
<b>GPIO_1_D15</b>	<b>PIN_J11</b>	<b>GPIO Connection 1[15]</b>
<b>GPIO_1_D16</b>	<b>PIN_H14</b>	<b>GPIO Connection 1[16]</b>
<b>GPIO_1_D17</b>	<b>PIN_A15</b>	<b>GPIO Connection 1[17]</b>

GPIO_1_D18	PIN_J13	GPIO Connection 1[18]
GPIO_1_D19	PIN_L8	GPIO Connection 1[19]
GPIO_1_D20	PIN_A14	GPIO Connection 1[20]
GPIO_1_D21	PIN_B15	GPIO Connection 1[21]
GPIO_1_D22	PIN_C15	GPIO Connection 1[22]
GPIO_1_D23	PIN_E14	GPIO Connection 1[23]
GPIO_1_D24	PIN_E15	GPIO Connection 1[24]
GPIO_1_D25	PIN_E16	GPIO Connection 1[25]
GPIO_1_D26	PIN_F14	GPIO Connection 1[26]
GPIO_1_D27	PIN_F15	GPIO Connection 1[27]
GPIO_1_D28	PIN_F13	GPIO Connection 1[28]
GPIO_1_D29	PIN_F12	GPIO Connection 1[29]
GPIO_1_D30	PIN_G16	GPIO Connection 1[30]
GPIO_1_D31	PIN_G15	GPIO Connection 1[31]
GPIO_1_D32	PIN_G13	GPIO Connection 1[32]
GPIO_1_D33	PIN_G12	GPIO Connection 1[33]
GPIO_1_D34	PIN_J17	GPIO Connection 1[34]
GPIO_1_D35	PIN_K16	GPIO Connection 1[35]

### 3. 6 Using VGA

The DE0-CV board includes a 16-pin D-SUB connector for VGA output. The VGA synchronization signals are provided directly from the Cyclone V FPGA, and a 4-bit DAC using resistor network is used to produce the analog data signals (red, green, and blue). The associated schematic is given in **Figure 3-13** and can support standard VGA resolution (640x480 pixels, at 25 MHz).

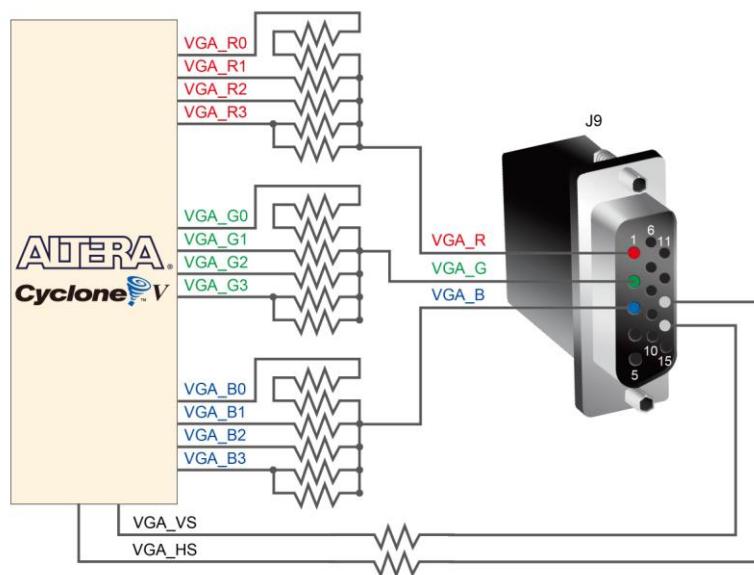
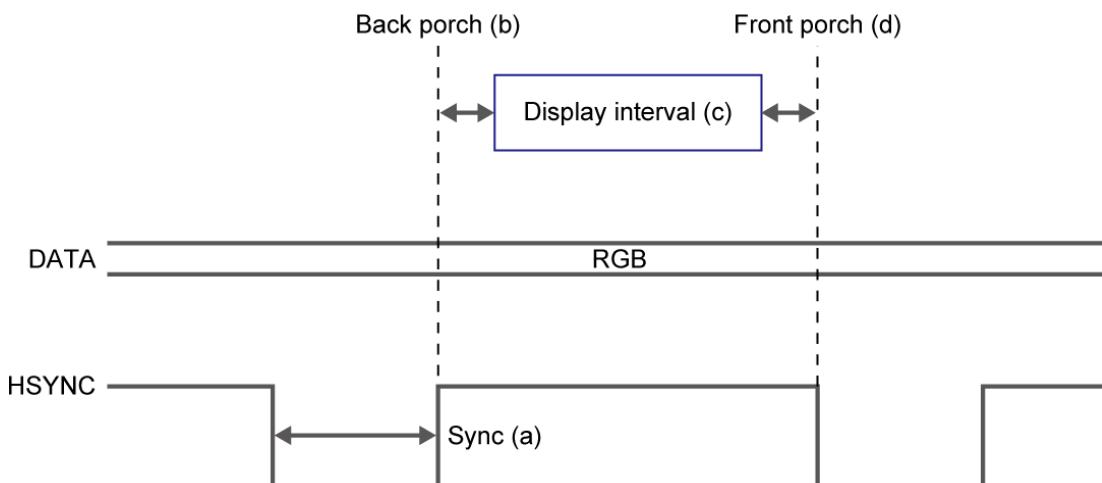


Figure 3-13 Connections between the FPGA and VGA

The timing specification for VGA synchronization and RGB (red, green, blue) data can be easily found on website nowadays. **Figure 3-13** illustrates the basic timing requirements for each row (horizontal) displayed on a VGA monitor. An active-low pulse of specific duration is applied to the horizontal synchronization (hsync) input of the monitor, which signifies the end of one row of data and the start of the next. The data (RGB) output to the monitor must be off (driven to 0 V) for a time period called the back porch (b) after the hsync pulse occurs, which is followed by the display interval (c). During the data display interval the RGB data drives each pixel in turn across the row being displayed. Finally, there is a time period called the front porch (d) where the RGB signals must again be off before the next hsync pulse can occur. The timing of vertical synchronization (vsync) is similar to the one shown in **Figure 3-14**, except that a vsync pulse signifies the end of one frame and the start of the next, and the data refers to the set of rows in the frame (horizontal timing). **Table 3-8** and **Table 3-9** show different resolutions and durations of time period a, b, c, and d for both horizontal and vertical timing.

The pin assignments between the Cyclone V FPGA and the VGA connector are listed in **Table 3-10**.



**Figure 3-14 VGA horizontal timing specification**

**Table 3-8 VGA Horizontal Timing Specification**

<b>VGA mode</b>		<b>Horizontal Timing Spec</b>				
<b>Configuration</b>	<b>Resolution(HxV)</b>	<b>a(pixel clock cycle)</b>	<b>b(pixel clock cycle)</b>	<b>c(pixel clock cycle)</b>	<b>d(pixel clock cycle)</b>	<b>Pixel clock(MHz)</b>
VGA(60Hz)	640x480	96	48	640	16	25

**Table 3-9 VGA Vertical Timing Specification**

<b>VGA mode</b>		<b>Vertical Timing Spec</b>				
<b>Configuration</b>	<b>Resolution(HxV)</b>	<b>a(lines)</b>	<b>b(lines)</b>	<b>c(lines)</b>	<b>d(lines)</b>	<b>Pixel clock(MHz)</b>
VGA(60Hz)	640x480	2	33	480	10	25

**Table 3-10 Pin Assignment of VGA**

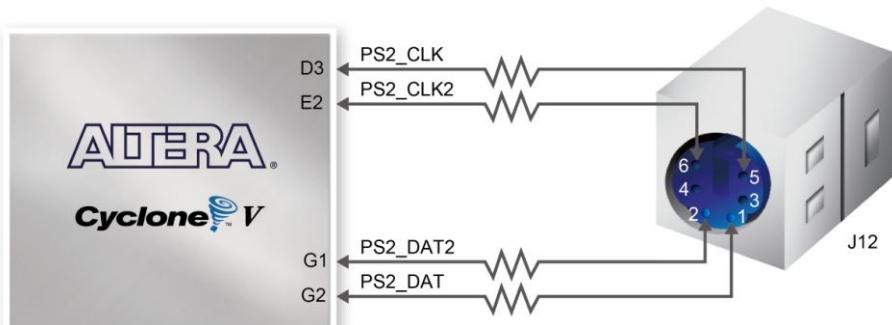
<i>Signal Name</i>	<i>FPGA Pin No.</i>	<i>Description</i>
VGA_R0	PIN_A9	VGA Red[0]
VGA_R1	PIN_B10	VGA Red[1]
VGA_R2	PIN_C9	VGA Red[2]
VGA_R3	PIN_A5	VGA Red[3]
VGA_G0	PIN_L7	VGA Green[0]
VGA_G1	PIN_K7	VGA Green[1]
VGA_G2	PIN_J7	VGA Green[2]
VGA_G3	PIN_J8	VGA Green[3]
VGA_B0	PIN_B6	VGA Blue[0]
VGA_B1	PIN_B7	VGA Blue[1]
VGA_B2	PIN_A8	VGA Blue[2]
VGA_B3	PIN_A7	VGA Blue[3]
VGA_HS	PIN_H8	VGA H_SYNC
VGA_VS	PIN_G8	VGA V_SYNC

### 3. 7 PS/2 Serial Port

The DE0-CV board comes with a standard PS/2 interface and a connector for a PS/2 keyboard or mouse. **Figure 3-15** shows the connection of PS/2 circuit to the FPGA. Users can use the PS/2 keyboard and mouse on the DE0-CV board simultaneously by a PS/2 Y-Cable, as shown in **Figure 3-16**. Instructions on how to use PS/2 mouse and/or keyboard can be found on various educational websites. The pin assignment associated to this interface is shown in **Table 3-11**.



*Note: If users connect only one PS/2 equipment, the PS/2 signals connected to the FPGA I/O should be “PS2\_CLK” and “PS2\_DAT”.*



**Figure 3-15 Connections between the FPGA and PS/2**



**Figure 3-16 Y-Cable for using keyboard and mouse simultaneously**

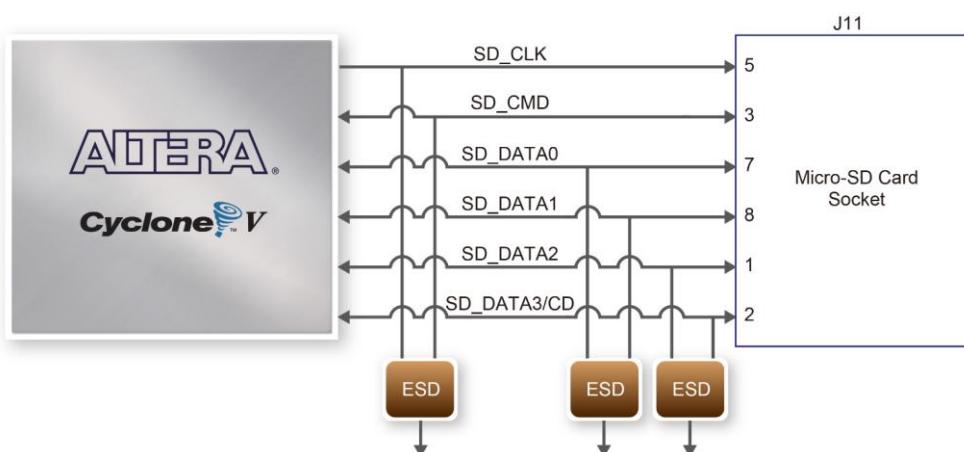
**Table 3-11 Pin Assignment of PS/2**

<i>Signal Name</i>	<i>FPGA Pin No.</i>	<i>Description</i>
<b>PS2_CLK</b>	<b>PIN_D3</b>	<b>PS/2 Clock</b>
<b>PS2_DAT</b>	<b>PIN_G2</b>	<b>PS/2 Data</b>
<b>PS2_CLK2</b>	<b>PIN_E2</b>	<b>PS/2 Clock (reserved for second PS/2 device)</b>
<b>PS2_DAT2</b>	<b>PIN_G1</b>	<b>PS/2 Data (reserved for second PS/2 device)</b>

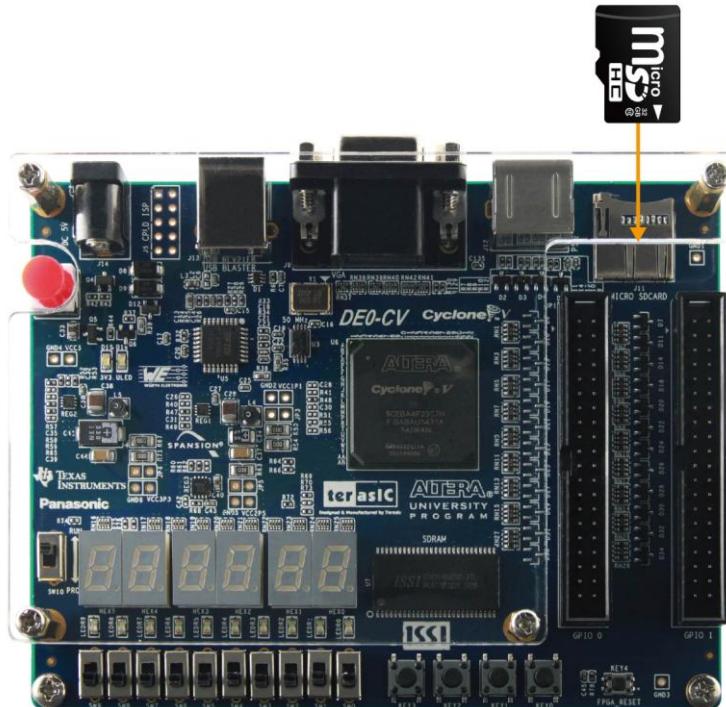
### 3. 8 Micro SD-Card Socket

The development board supports Micro SD card interface using x4 data lines. **Figure 3-17** shows the related signals connections between the SD Card and Cyclone V FPGA and **Figure 3-18** shows micro SD card plug-in position.

Finally, **Table 3-12** lists all the associated pins.



**Figure 3-17 Connection between the SD Card Socket and Cyclone V FPGA**



**Figure 3-18 Micro SD Card**

**Table 3-12 Pin Assignment of Micro SD Card Socket**

<i>Signal Name</i>	<i>FPGA Pin No.</i>	<i>Description</i>
<b>SD_CLK</b>	<b>PIN_H11</b>	<b>Serial Clock</b>
<b>SD_CMD</b>	<b>PIN_B11</b>	<b>Command, Response</b>
<b>SD_DATA0</b>	<b>PIN_K9</b>	<b>Serial Data 0</b>
<b>SD_DATA1</b>	<b>PIN_D12</b>	<b>Serial Data 1</b>
<b>SD_DATA2</b>	<b>PIN_E12</b>	<b>Serial Data 2</b>
<b>SD_DATA3</b>	<b>PIN_C11</b>	<b>Serial Data 3</b>

### 3. 9 Using SDRAM

The board features 64MB of SDRAM with a single 64MB (32Mx16) SDRAM chip. The chip consists of 16-bit data line, control line, and address line connected to the FPGA. This chip uses the 3.3V LVCMOS signaling standard. Connections between the FPGA and SDRAM are shown in **Figure 3-19**, and the pin assignment is listed in **Table 3-13**.

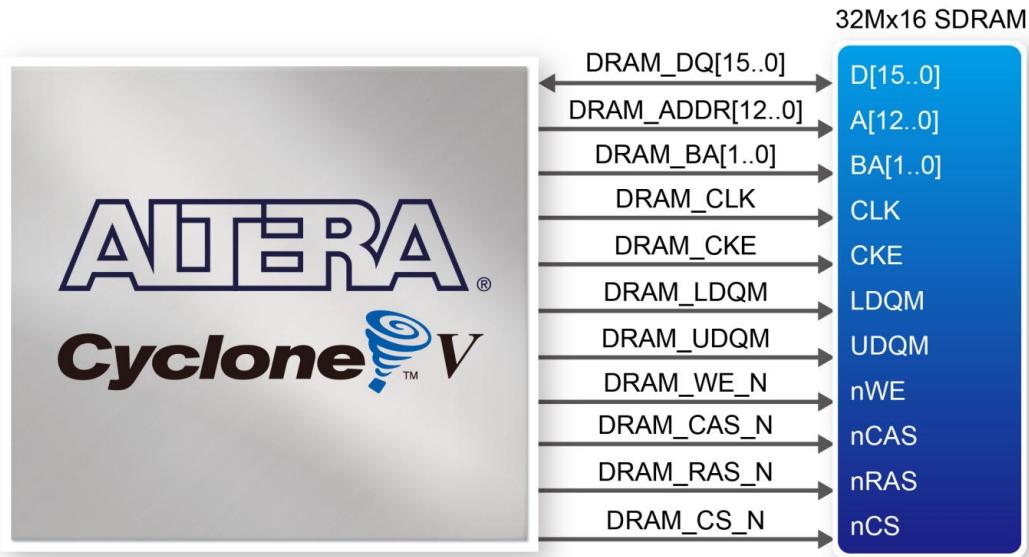


Figure 3-19 Connections between the FPGA and SDRAM

Table 3-13 Pin Assignment of SDRAM

<i>Signal Name</i>	<i>FPGA Pin No.</i>	<i>Description</i>
DRAM_ADDR0	PIN_W8	SDRAM Address[0]
DRAM_ADDR1	PIN_T8	SDRAM Address[1]
DRAM_ADDR2	PIN_U11	SDRAM Address[2]
DRAM_ADDR3	PIN_Y10	SDRAM Address[3]
DRAM_ADDR4	PIN_N6	SDRAM Address[4]
DRAM_ADDR5	PIN_AB10	SDRAM Address[5]
DRAM_ADDR6	PIN_P12	SDRAM Address[6]
DRAM_ADDR7	PIN_P7	SDRAM Address[7]
DRAM_ADDR8	PIN_P8	SDRAM Address[8]
DRAM_ADDR9	PIN_R5	SDRAM Address[9]
DRAM_ADDR10	PIN_U8	SDRAM Address[10]
DRAM_ADDR11	PIN_P6	SDRAM Address[11]
DRAM_ADDR12	PIN_R7	SDRAM Address[12]
DRAM_DQ0	PIN_Y9	SDRAM Data[0]
DRAM_DQ1	PIN_T10	SDRAM Data[1]
DRAM_DQ2	PIN_R9	SDRAM Data[2]
DRAM_DQ3	PIN_Y11	SDRAM Data[3]
DRAM_DQ4	PIN_R10	SDRAM Data[4]
DRAM_DQ5	PIN_R11	SDRAM Data[5]
DRAM_DQ6	PIN_R12	SDRAM Data[6]
DRAM_DQ7	PIN_AA12	SDRAM Data[7]
DRAM_DQ8	PIN_AA9	SDRAM Data[8]
DRAM_DQ9	PIN_AB8	SDRAM Data[9]

<b>DRAM_DQ10</b>	<b>PIN_AA8</b>	<b>SDRAM Data[10]</b>
<b>DRAM_DQ11</b>	<b>PIN_AA7</b>	<b>SDRAM Data[11]</b>
<b>DRAM_DQ12</b>	<b>PIN_V10</b>	<b>SDRAM Data[12]</b>
<b>DRAM_DQ13</b>	<b>PIN_V9</b>	<b>SDRAM Data[13]</b>
<b>DRAM_DQ14</b>	<b>PIN_U10</b>	<b>SDRAM Data[14]</b>
<b>DRAM_DQ15</b>	<b>PIN_T9</b>	<b>SDRAM Data[15]</b>
<b>DRAM_BA0</b>	<b>PIN_T7</b>	<b>SDRAM Bank Address[0]</b>
<b>DRAM_BA1</b>	<b>PIN_AB7</b>	<b>SDRAM Bank Address[1]</b>
<b>DRAM_LDQM</b>	<b>PIN_U12</b>	<b>SDRAM byte Data Mask[0]</b>
<b>DRAM_UDQM</b>	<b>PIN_N8</b>	<b>SDRAM byte Data Mask[1]</b>
<b>DRAM_RAS_N</b>	<b>PIN_AB6</b>	<b>SDRAM Row Address Strobe</b>
<b>DRAM_CAS_N</b>	<b>PIN_V6</b>	<b>SDRAM Column Address Strobe</b>
<b>DRAM_CKE</b>	<b>PIN_R6</b>	<b>SDRAM Clock Enable</b>
<b>DRAM_CLK</b>	<b>PIN_AB11</b>	<b>SDRAM Clock</b>
<b>DRAM_WE_N</b>	<b>PIN_AB5</b>	<b>SDRAM Write Enable</b>
<b>DRAM_CS_N</b>	<b>PIN_U6</b>	<b>SDRAM Chip Select</b>

# Chapter 4

## *DE0-CV System Builder*

This chapter describes how users can create a custom design project with the tool named DE0-CV System Builder.

### 4. 1 Introduction

The DE0-CV System Builder is a Windows-based utility. It is designed to help users create a Quartus II project for DE0-CV within minutes. The generated Quartus II project files include:

- Quartus II project file (.qpf)
- Quartus II setting file (.qsf)
- Top-level design file (.v)
- Synopsis design constraints file (.sdc)
- Pin assignment document (.htm)

The above files generated by the DE0-CV System Builder can also prevent occurrence of situations that are prone to compilation error when users manually edit the top-level design file or place pin assignment. The common mistakes that users encounter are:

- Board is damaged due to incorrect bank voltage setting or pin assignment.
- Board is malfunctioned because of wrong device chosen, declaration of pin location or direction is incorrect or forgotten.
- Performance degradation due to improper pin assignment.

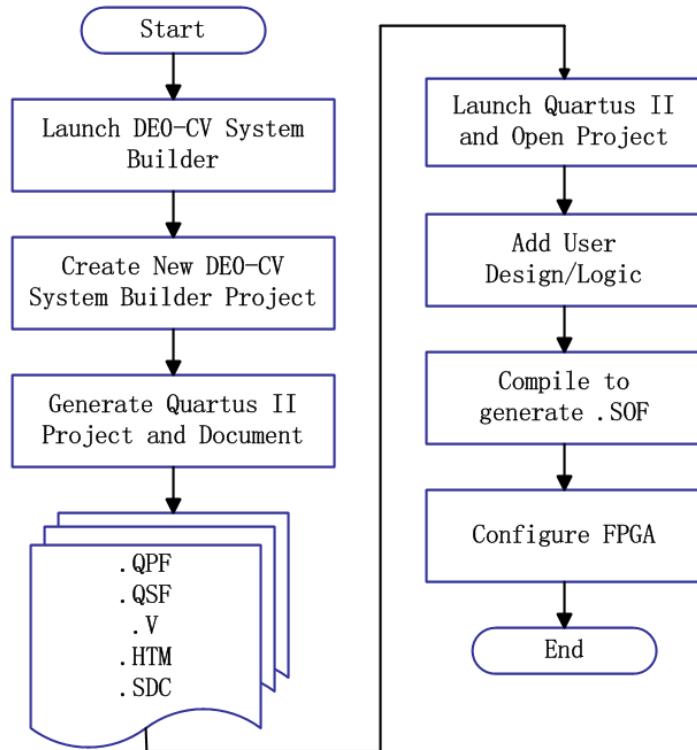
### 4. 2 General Design Flow

This section provides an introduction to the design flow of building a Quartus II project for DE0-CV under the DE0-CV System Builder. The design flow is illustrated in [Figure 4-1](#).

The DE0-CV System Builder will generate two major files, a top-level design file (.v) and a Quartus II setting file (.qsf) after users launch the DE0-CV System Builder and create a new project according to their design requirements

The top-level design file contains a top-level Verilog HDL wrapper for users to add their own design/logic. The Quartus II setting file contains information such as FPGA device type, top-level pin assignment, and the I/O standard for each user-defined I/O pin.

Finally, the Quartus II programmer is used to download .sof file to the development board via JTAG interface.



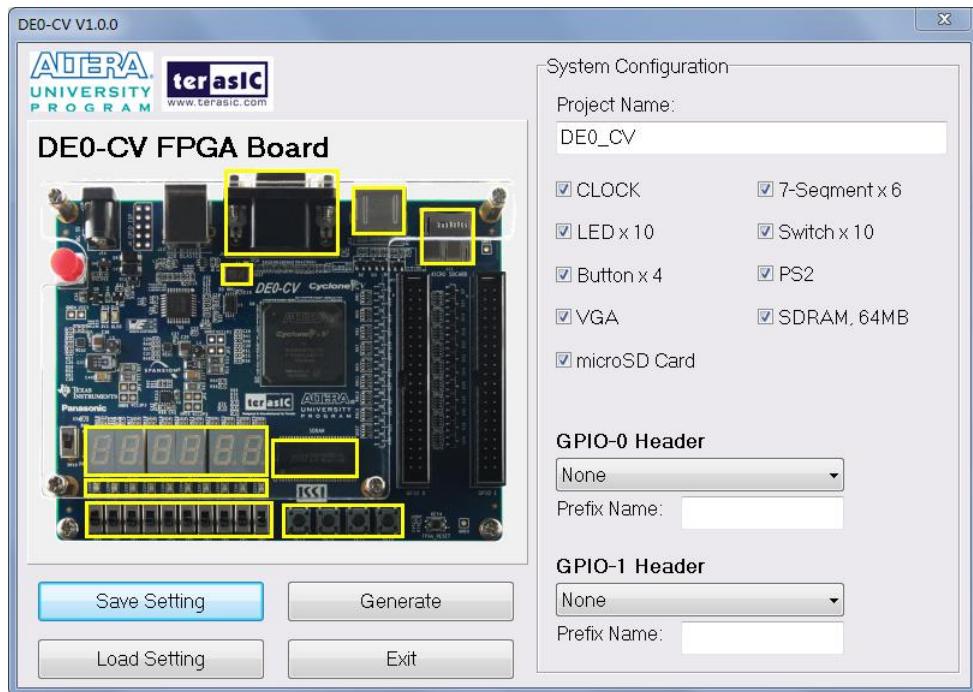
**Figure 4-1 Design flow of building a project from the beginning to the end**

## 4. 3 Using DE0-CV System Builder

This section provides the procedures in details on how to use the DE0-CV System Builder.

### ■ Install and Launch the DE0-CV System Builder

The DE0-CV System Builder is located in the directory: “Tools\SystemBuilder” of the DE0-CV System CD. Users can copy the entire folder to a host computer without installing the utility. A window will pop up, as shown in **Figure 4-2**, after executing the DE0-CV SystemBuilder.exe on the host computer.

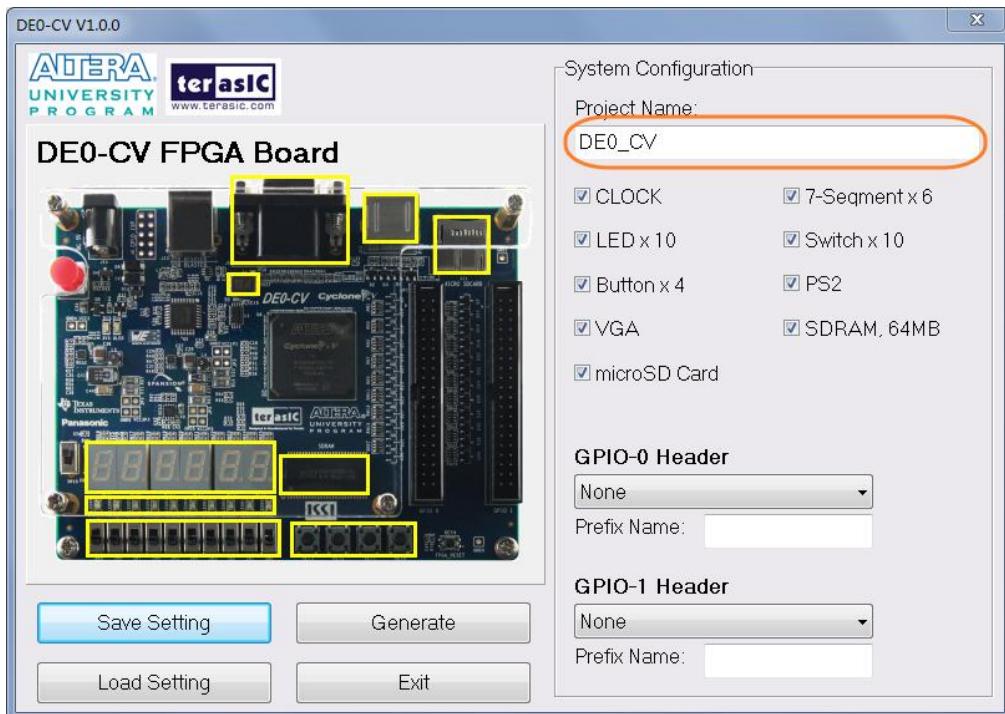


**Figure 4-2 The GUI of DE0-CV System Builder**

## ■ Enter Project Name

Enter the project name in the circled area, as shown in **Figure 4-3**.

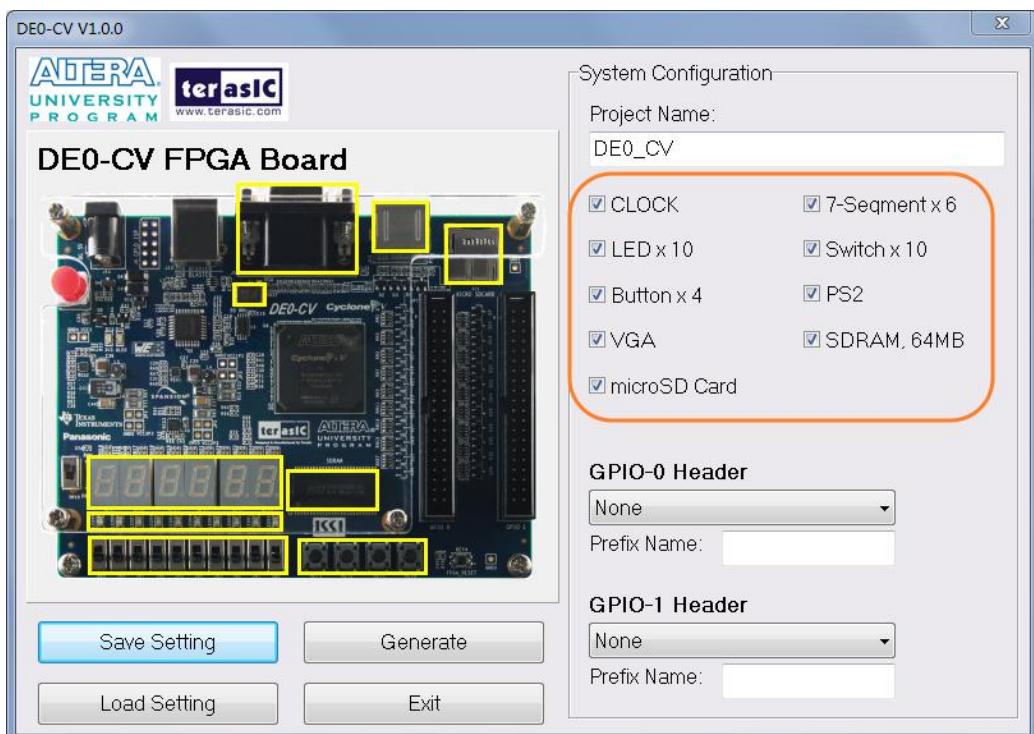
The project name typed in will be assigned automatically as the name of your top-level design entity.



**Figure 4-3 Enter the project name**

## ■ System Configuration

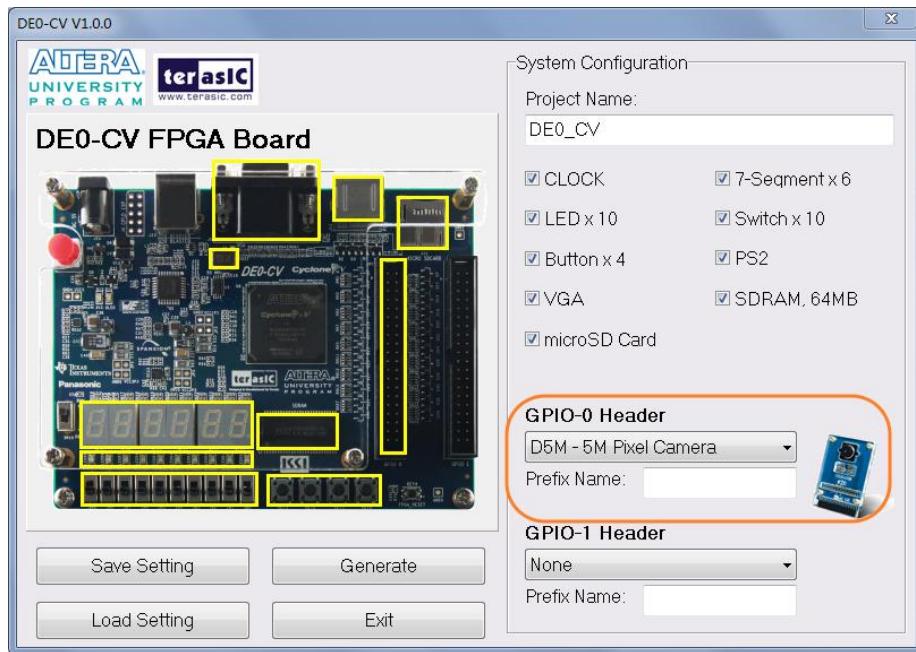
Users are given the flexibility in the System Configuration to include their choice of components in the project, as shown in **Figure 4-4**. Each component onboard is listed and users can enable or disable one or more components at will. If a component is enabled, the DE0-CV System Builder will automatically generate its associated pin assignment, including the pin name, pin location, pin direction, and I/O standard.



**Figure 4-4 System configuration group**

## ■ GPIO Expansion

If users connect any Terasic GPIO-based daughter card to the GPIO connector(s) on DE0-CV, the DEO-CV System Builder can generate a project that include the corresponding module, as shown in **Figure 4-5**. It will also generate the associated pin assignment automatically, including pin name, pin location, pin direction, and I/O standard.

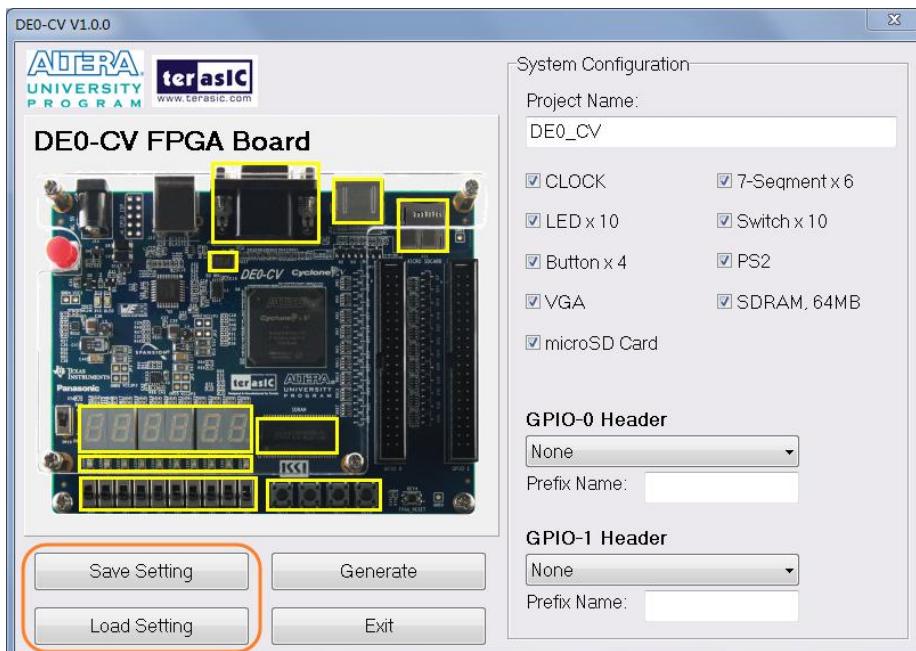


**Figure 4-5 GPIO expansion group**

The “Prefix Name” is an optional feature that denote the pin name of the daughter card assigned in your design. Users may leave this field blank.

## ■ Project Setting Management

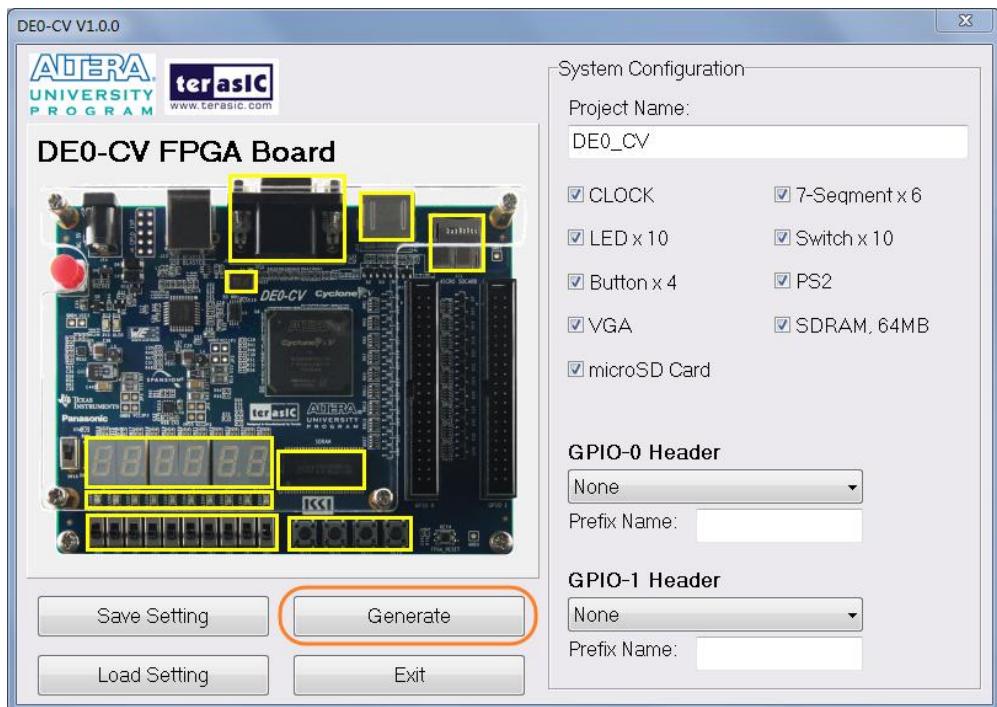
The DE0-CV System Builder also provides the option to load a setting or save users’ current board configuration in .cfg file, as shown in **Figure 4-6**.



**Figure 4-6 Project Settings**

## ■ Project Generation

When users press the *Generate* button as shown in **Figure 4-7**, the DE0-CV System Builder will generate the corresponding Quartus II files and documents, as listed in **Table 4-1**:



**Figure 4-7 Generate Quartus Project**

**Table 4-1 Files generated by the DE0-CV System Builder**

No.	Filename	Description
1	<Project name>.v	Top level Verilog HDL file for Quartus II
2	<Project name>.qpf	Quartus II Project File
3	<Project name>.qsf	Quartus II Setting File
4	<Project name>.sdc	Synopsis Design Constraints file for Quartus II
5	<Project name>.htm	Pin Assignment Document

Users can add custom logic into the project in Quartus II and compile the project to generate the SRAM Object File (.sof).

# Chapter 5

## *Examples of Advanced Demonstrations*

This chapter provides examples of advanced designs implemented by RTL or Qsys on the DE0-CV board. These reference designs cover the features of peripherals connected to the FPGA, such as PS/2, SDRAM, and SD card. All the associated files can be found in the directory \Demonstrations of DE0-CV System CD.

### ■ Installation of Demonstrations

To install the demonstrations on your computer:

Copy the folder Demonstrations to a local directory of your choice. It is important to make sure the path to your local directory contains NO space. Otherwise it will lead to error in Nios II.

Note : Quartus II v14.0 or later is required for all DE0-CV demonstrations to support Cyclone V FPGA device.

## 5. 1 DE0-CV Factory Configuration

The DE0-CV board has a default configuration bit-stream pre-programmed, which demonstrates some of the basic features onboard. The setup required for this demonstration and the location of its files are shown below.

### Demonstration File Locations

- Project directory: DE0\_CV\_Default
- Bitstream used: DE0\_CV\_Default.sof ,DE0\_CV\_Default.pof or DE0\_CV\_Default.jic

### Demonstration Setup and Instructions

- Power on the DE0-CV board with the USB cable connected to the USB-Blaster port. If necessary (that is, if the default factory configuration is not currently stored in the EPCS device), download the bit stream to the board via JTAG interface.
- You should now be able to observe the 7-segment displays are showing a sequence of characters, and the red LEDs are blinking.
- Press FPGA\_RESET to make LEDs and 7 SEGs all light on.
- If the VGA D-SUB connector is connected to a VGA display, it would show a color picture.

## Restore Factory Configuration

- Configuring the EPCS64 in AS Mode
  1. Ensure that power is applied to the DE0\_CV board.
  2. Connect the supplied USB cable to the USB Blaster port on the DE0-CV board
  3. Configure the JTAG programming circuit by setting the RUN/PROG slide switch (SW10) to the PROG position.
  4. Execute the demo batch file “pof\_DE0\_CV\_Default.bat” for USB-Blaster under the batch file folder, DE0\_CV\_Default /demo\_batch.
  5. Once the programming operation is finished, set the RUN/PROG slide switch back to the RUN position and then reset the board by turning the power switch off and back on; this action causes the new configuration data in the EPCS64 device to be loaded into the FPGA chip.
- Configuring the EPCS64 with .JIC File
  1. Ensure that power is applied to the DE0\_CV board.
  2. Connect the supplied USB cable to the USB Blaster port on the DE0-CV board.
  3. Execute the demo batch file “ DE0\_CV\_Default.bat” for USB-Blaster under the batch file folder, DE0\_CV\_Default /demo\_batch.
  4. As shown in **Figure 5-1**, It is able to not only load the bit stream into the FPGA in command line, but also program or erase .jic file to the EPCS by executing the batch file.
  5. If users want to program a new design into the EPCS device, an easy method is to copy the new .sof file (file name must be DE0\_CV\_Default.sof) into the demo\_batch folder and execute the DE0\_CV\_Default.bat. Option “2” will convert the .sof to .jic and option”3” will program .jic file into the EPCS device.

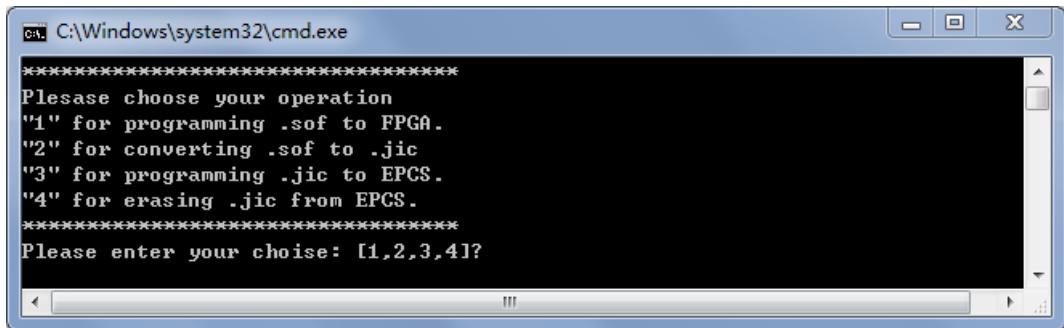


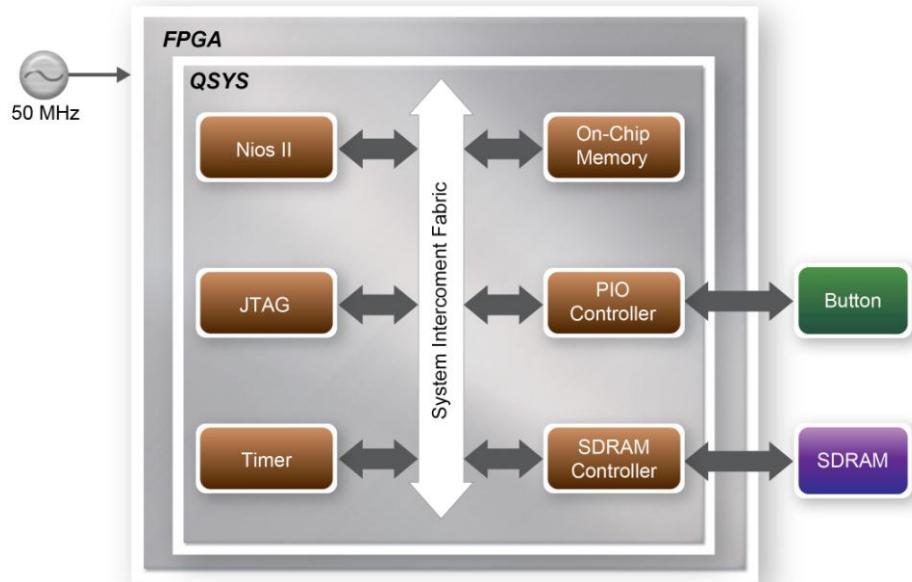
Figure 5-1 Command line of the batch file to program the FPGA and EPCS device

## 5. 2 SDRAM Test in Nios II

There are many applications using SDRAM as a temporary storage. Both hardware and software designs are provided to illustrate how to perform memory access in Qsys in this demonstration. It also shows how Altera's SDRAM controller IP accesses SDRAM and how the Nios II processor reads and writes the SDRAM for hardware verification. The SDRAM controller handles complex aspects of accessing SDRAM such as initializing the memory device, managing SDRAM banks, and keeping the devices refreshed at certain interval.

### ■ System Block Diagram

Figure 5-2 shows the system block diagram of this demonstration. The system requires a 50 MHz clock input from the board. The SDRAM controller is configured as a 64MB controller. The working frequency of the SDRAM controller is 143 MHz, and the Nios II program is running on the on-chip memory.



**Figure 5-2 Block diagram of the SDRAM test in Nios II**

The system flow is controlled by a program running in Nios II. The Nios II program writes test patterns into the entire 64MB of SDRAM first before calling the Nios II system function, `alt_dcache_flush_all`, to make sure all the data are written to the SDRAM. It then reads data from the SDRAM for data verification. The program will show the progress in nios-terminal when writing/reading data to/from the SDRAM. When the verification process reaches 100%, the result will be displayed in nios-terminal.

## Design Tools

- Quartus II v14.0
- Nios II Eclipse v14.0

## Demonstration Source Code

- Quartus project directory: DE0\_CV\_SDRAM\_Nios\_Test
- Nios II Eclipse directory: DE0\_CV\_SDRAM\_Nios\_Test \Software

## Nios II Project Compilation

- Click “Clean” from the “Project” menu of Nios II Eclipse before compiling the reference design in Nios II Eclipse.

## Demonstration Batch File

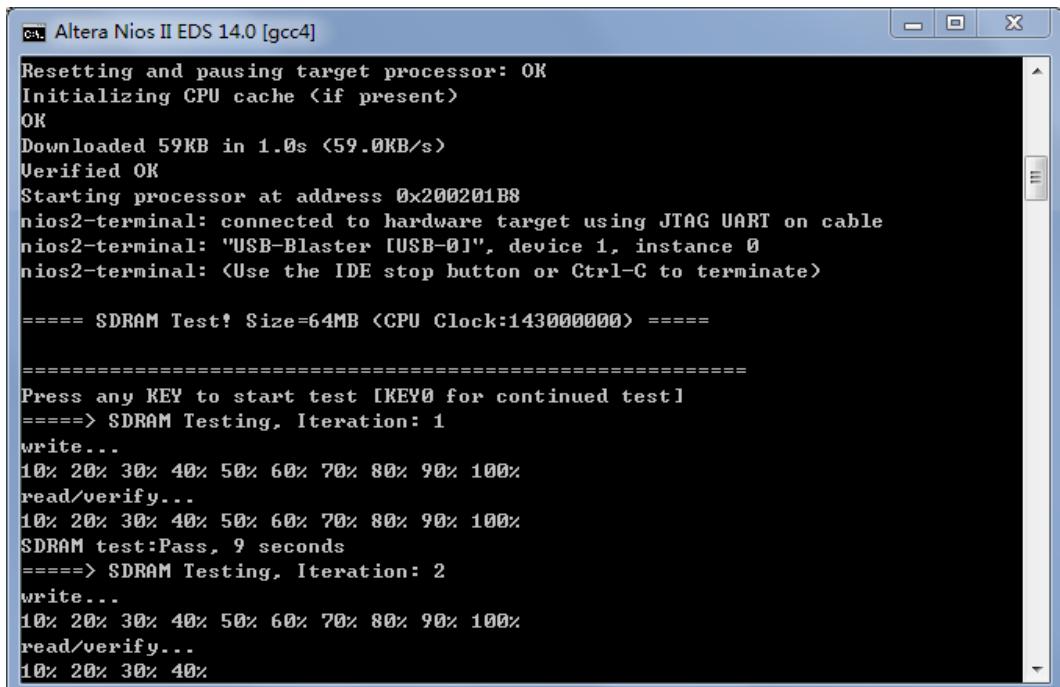
The files are located in the director: \DE0\_CV\_SDRAM\_Nios\_Test\demo\_batch.

The folder includes the following files:

- Batch file for USB-Blaster II : DE0\_CV\_SDRAM\_Nios\_Test.bat and DE0\_CV\_SDRAM\_Nios\_Test.sh
- FPGA configuration file : DE0\_CV\_SDRAM\_Nios\_Test.sof
- Nios II program: DE0\_CV\_SDRAM\_Nios\_Test.elf

## Demonstration Setup

- Quartus II v14.0 and Nios II v14.0 must be pre-installed on the host PC.
- Power on the DE0\_CV board.
- Connect the DE0\_CV board (J13) to the host PC with a USB cable and install the USB-Blaster driver if necessary.
- Execute the demo batch file “DE0\_CV\_SDRAM\_Nios\_Test.bat” from the directory DE0\_CV\_SDRAM\_Nios\_Test\demo\_batch
- After the program is downloaded and executed successfully, a prompt message will be displayed in nios2-terminal.
- Press any button (**KEY3~KEY0**) to start the SDRAM verification process. Press **KEY0** to run the test continuously.
- The program will display the test progress and result, as shown in **Figure 5-3**.



```
Altera Nios II EDS 14.0 [gcc4]
Resetting and pausing target processor: OK
Initializing CPU cache <if present>
OK
Downloaded 59KB in 1.0s <59.0KB/s>
Verified OK
Starting processor at address 0x200201B8
nios2-terminal: connected to hardware target using JTAG UART on cable
nios2-terminal: "USB-Blaster [USB-01]", device 1, instance 0
nios2-terminal: <Use the IDE stop button or Ctrl-C to terminate>

===== SDRAM Test! Size=64MB <CPU Clock:143000000> =====
=====
Press any KEY to start test [KEY0 for continued test]
=====> SDRAM Testing, Iteration: 1
write...
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
read/verify...
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
SDRAM test:Pass, 9 seconds
=====> SDRAM Testing, Iteration: 2
write...
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
read/verify...
10% 20% 30% 40%
```

Figure 5-3 Display of progress and result for the SDRAM test in Nios II

## 5. 3 SDRAM Test in Verilog

DE0\_CV system CD offers another SDRAM test with its test code written in Verilog HDL. The memory size of the SDRAM bank tested is still 64MB.

### ■ Function Block Diagram

Figure 5-4 shows the function block diagram of this demonstration. The SDRAM controller uses 50 MHz as a reference clock and generates 100 MHz as the memory clock.

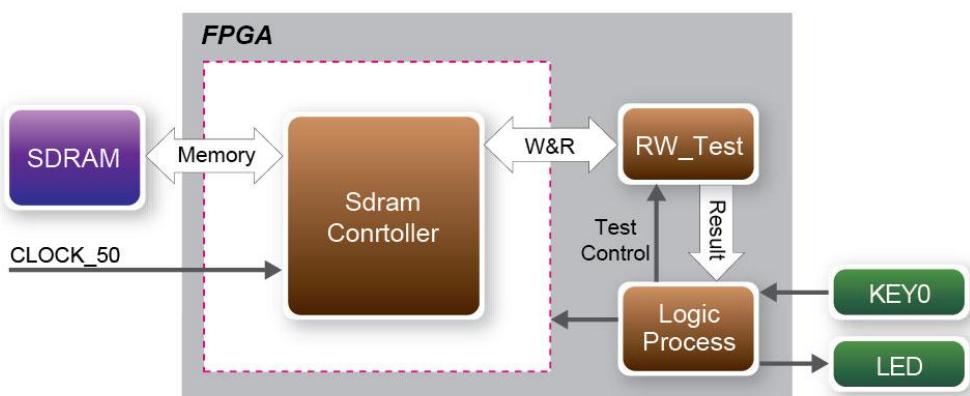


Figure 5-4 Block diagram of the SDRAM test in Verilog

RW\_Test module writes the entire memory with a test sequence first before comparing the data read back with the regenerated test sequence, which is same as the data written to the memory. KEY0 triggers test control signals for the SDRAM, and the LEDs will indicate the test result according to Table 5-1.

### Design Tools

- Quartus II v14.0

### Demonstration Source Code

- Project directory: DE0\_CV\_SDRAM\_RTL\_Test
- Bitstream used: DE0\_CV\_SDRAM\_RTL\_Test.sof

## Demonstration Batch File

Demo batch file folder: \DE0\_CV\_SDRAM\_RTL\_Test\demo\_batch

The directory includes the following files:

- Batch file: DE0\_CV\_SDRAM\_RTL\_Test.bat
- FPGA configuration file: DE0\_CV\_SDRAM\_RTL\_Test.sof

## Demonstration Setup

- Quartus II v14.0 must be pre-installed to the host PC.
- Connect the DE0\_CV board (J13) to the host PC with a USB cable and install the USB-Blaster II driver if necessary
- Power on the DE0\_CV board.
- Execute the demo batch file “ DE0\_CV\_SDRAM\_RTL\_Test.bat” from the directory \DE0\_CV\_SDRAM\_RTL\_Test \demo\_batch.
- Press **KEY0** on the DE0\_CV board to start the verification process. When **KEY0** is pressed, the **LEDR** [2:0] should turn on. When **KEY0** is then released, **LEDR1** and **LEDR2** should start blinking.
- After approximately 8 seconds, **LEDR1** should stop blinking and stay ON to indicate the test is PASS. **Table 5-1** lists the status of **LED** indicators.
- If **LEDR2** is not blinking, it means 50MHz clock source is not working.
- If **LEDR1** failed to remain ON after approximately 8 seconds, the SDRAM test is NG.
- Press **KEY0** again to repeat the SDRAM test.

**Table 5-1 Status of LED Indicators**

Name	Description
<b>LEDR1</b>	<b>ON if the test is PASS after releasing KEY0</b>
<b>LEDR2</b>	<b>Blinks</b>

## 5. 4 PS/2 Mouse Demonstration

A simply PS/2 controller coded in Verilog HDL is provided to demonstrate bi-directional communication with a PS/2 mouse. A comprehensive PS/2 controller can be developed based on it and more sophisticated functions can be implemented such as setting the sampling rate or resolution, which needs to transfer two data bytes at once.

More information about the PS/2 protocol can be found on various websites.

## ■ Introduction

PS/2 protocol uses two wires for bi-directional communication. One is the clock line and the other one is the data line. The PS/2 controller always has total control over the transmission line, but it is the PS/2 device which generates the clock signal during data transmission.

## ■ Data Transmission from Device to the Controller

After the PS/2 mouse receives an enabling signal at stream mode, it will start sending out displacement data, which consists of 33 bits. The frame data is cut into three sections and each of them contains a start bit (always zero), eight data bits (with LSB first), one parity check bit (odd check), and one stop bit (always one).

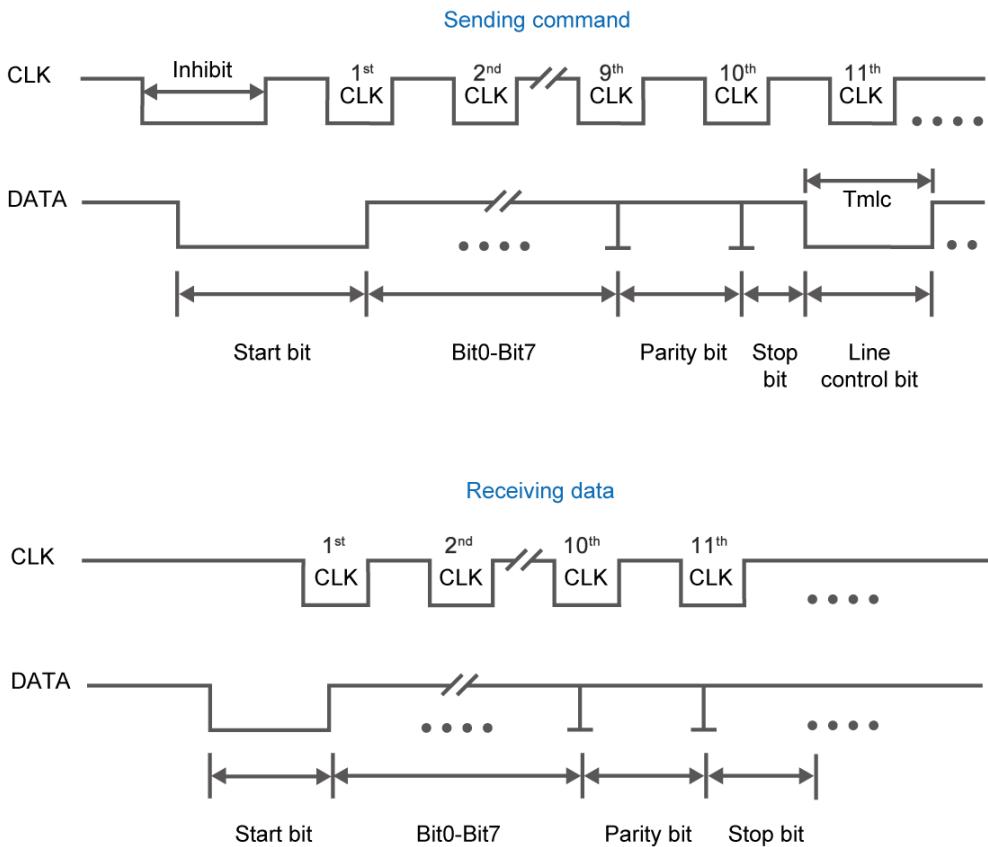
The PS/2 controller samples the data line at the falling edge of the PS/2 clock signal. This is implemented by a shift register, which consists of 33 bits.

easily be implemented using a shift register of 33 bits, but be cautious with the clock domain crossing problem.

## ■ Data Transmission from the Controller to Device

When the PS/2 controller wants to transmit data to device, it first pulls the clock line low for more than one clock cycle to inhibit the current transmission process or to indicate the start of a new transmission process, which is usually called as inhibit state. It then pulls low the data line before releasing the clock line. This is called the request state. The rising edge on the clock line formed by the release action can also be used to indicate the sample time point as for a 'start bit'. The device will detect this succession and generates a clock sequence in less than 10ms time. The transmit data consists of 12bits, one start bit (as explained before), eight data bits, one parity check bit (odd check), one stop bit (always one), and one acknowledge bit (always zero). After sending out the parity check bit, the controller should release the data line, and the device will detect any state change on the data line in the next clock cycle. If there's no change on the data line for one clock cycle, the device will pull low the data line again as an acknowledgement which means that the data is correctly received.

After the power on cycle of the PS/2 mouse, it enters into stream mode automatically and disable data transmit unless an enabling instruction is received. **Figure 5-5** shows the waveform while communication happening on two lines.



**Figure 5-5 Waveform of clock and data signals during data transmission**

## Demonstration Source Code

- Project directory: DE0\_CV\_PS2\_DEMO
- Bitstream used: DE0\_CV\_PS2\_DEMO.sof

## Demonstration Batch File

Demo batch file directoy: \DE0\_CV\_PS2\_DEMO \demo\_batch

The folder includes the following files:

- Batch file: DE0\_CV\_PS2\_DEMO.bat
- FPGA configuration file : DE0\_CV\_PS2\_DEMO.sof

## Demonstration Setup, File Locations, and Instructions

- Load the bitstream into the FPGA by executing \DE0\_CV\_PS2\_DEMO \demo\_batch\ DE0\_CV\_PS2\_DEMO.bat
- Plug in the PS/2 mouse
- Press KEY0 to enable data transfer
- Press KEY1 to clear the display data cache
- The 7-segment display should change when the PS/2 mouse moves. The LEDR[2:0] will blink according to **Figure 5-6** and **Table 5-2** when the left-button, right-button, and/or middle-button is pressed.

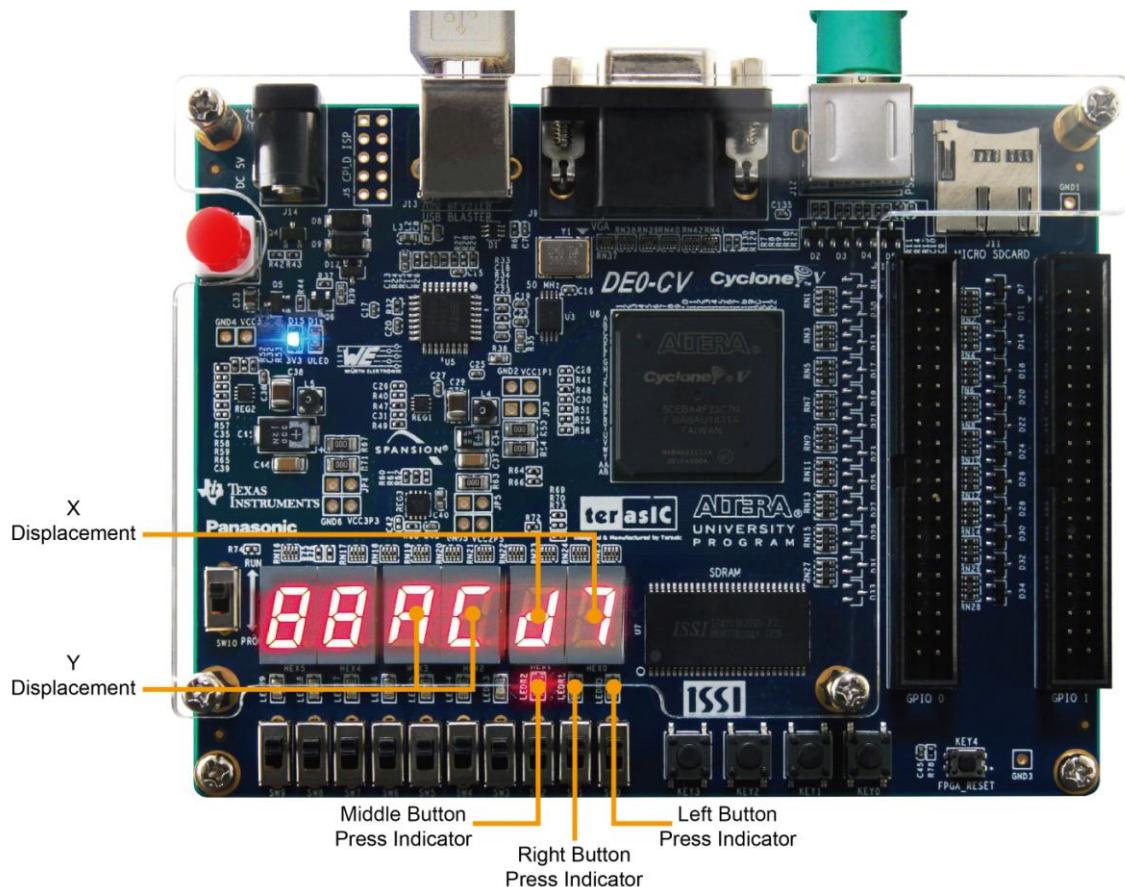


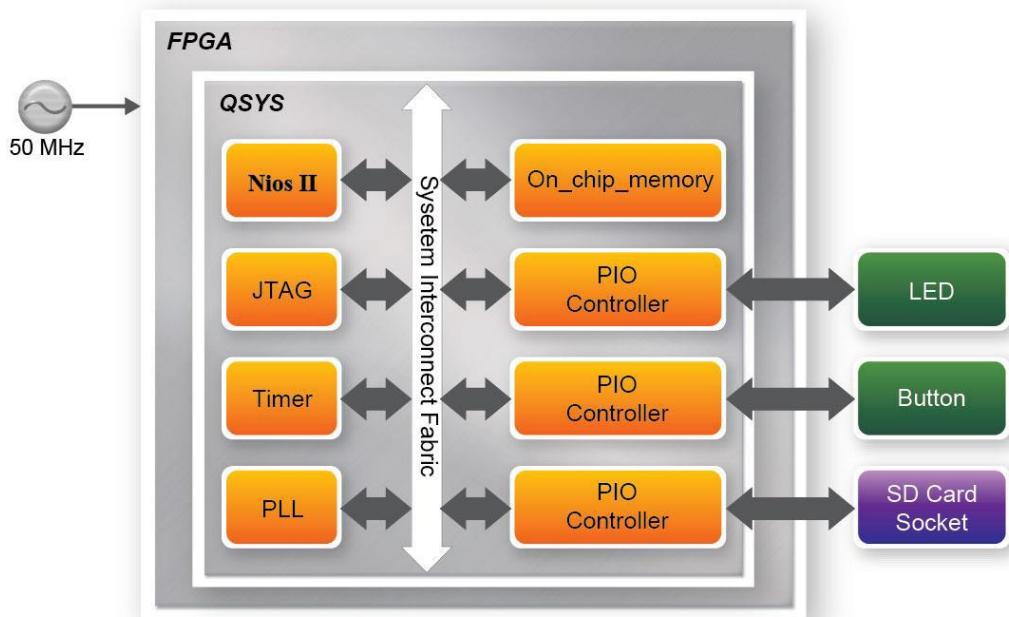
Figure 5-6 Description of 7-segment Display and LED Indicators

**Table 5-2 Description of 7-segment Display and LED Indicators**

<b>Indicator Name</b>	<b>Description</b>
<b>LEDR0</b>	<b>Left button press indicator</b>
<b>LEDR1</b>	<b>Right button press indicator</b>
<b>LEDR2</b>	<b>Middle button press indicator</b>
<b>HEX0</b>	<b>Low byte of X displacement</b>
<b>HEX1</b>	<b>High byte of X displacement</b>
<b>HEX2</b>	<b>Low byte of Y displacement</b>
<b>HEX3</b>	<b>High byte of Y displacement</b>

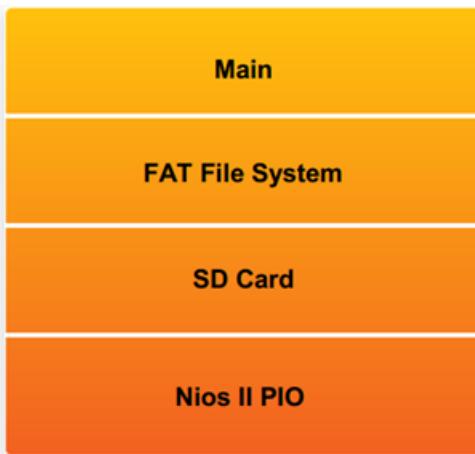
## 5. 5 Micro SD Card file system read

Many applications use a large external storage device, such as a SD Card or CF card to store data. The DE0-CV board provides the hardware and software needed for Micro SD Card access. In this demonstration we will show how to browse files stored in the root directory of an SD Card and how to read the file contents of a specific file. The Micro SD Card is required to be formatted as FAT File System in advance. Long file name is supported in this demonstration. **Figure 5-7** shows the hardware system block diagram of this demonstration. The system requires a 50MHz clock provided by the board. The PLL generates a 100MHz clock for the Nios II processor and other controllers. Four PIO pins are connected to the Micro SD Card socket. SD 4-bit Mode is used to access the Micro SD Card hardware. The SD 4-bit protocol and FAT File System function are all implemented by Nios II software. The software is stored in the on-chip memory.



**Figure 5-7 Block diagram of the Micro SD demonstration**

**Figure 5-8** shows the software stack of this demonstration. The Nios PIO block provides basic IO functions to access hardware directly. The functions are provided from Nios II system and the function prototype is defined in the header file <io.h>. The SD Card block implements 4-bit mode protocol for communication with SD Cards. The FAT File System block implements reading function for FAT16 and FAT 32 file system. Long filename is supported. By calling the public FAT functions, users can browse files under the root directory of the MicroSD Card. Furthermore, users can open a specific file and read the contents from the file. The main block implements main control of this demonstration. When the program is executed, it detects whether an Micro SD Card is inserted. If an MicroSD Card is found, it will check whether the MicroSD Card is formatted as FAT file system. If so, it searches all files in the root directory of the FAT file system and displays their names in the Nios II terminal. If a text file named “test.txt” is found, it will dump the file contents. If it successfully recognizes the FAT file system, it will turn on the LEDR4~LEDR0. On the other hand, it will turn on the LEDR9~LEDR5 if it fails to parse the FAT file system or if there is no SD card found in the SD Card socket of the DE0-CV board. If users press KEY3 of the DE0-CV board, the program will perform the above process again.



**Figure 5-8 Software of micro SD demonstration**

## Design Tools

- Quartus II14.0
- Nios II Eclipse14.0

## Demonstration Source Code

- Quartus Project directory: DE0\_CV\_SD\_DEMO
- Nios II Eclipse: DE0\_CV\_SD\_DEMO\Software

## Nios II Project Compilation

- Before you attempt to compile the reference design under Nios II Eclipse, make sure the project is cleaned first by clicking ‘Clean’ from the ‘Project’ menu of Nios II Eclipse.

## Demonstration Batch File

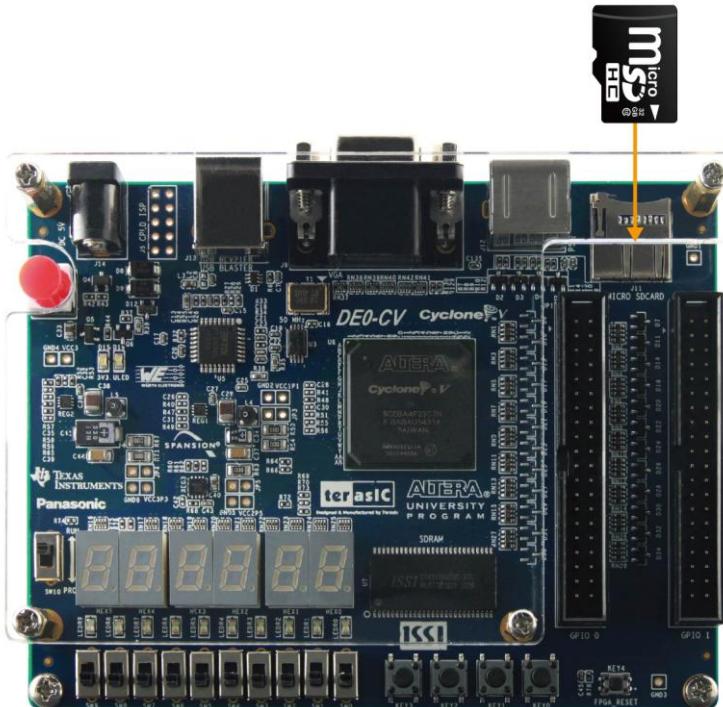
Demo Batch File Folder: DE0\_CV\_SD\_DEMO \demo\_batch

The demo batch file includes following files: Batch File for USB-Blaster:

- DE0\_CV\_SD\_DEMO.bat,
- DE0\_CV\_SD\_DEMO.sh
- FPGA Configure File: DE0\_CV\_SD\_DEMO.sof
- Nios II Program: DE0\_CV\_SD\_DEMO.elf

## Demonstration Setup

- Make sure Quartus II and Nios II are installed on your PC.
- Power on the DE0-CV board.
- Connect USB Blaster to the DE0-CV board and install USB Blaster driver if necessary.
- Execute the demo batch file “DE0\_CV\_SD\_DEMO.bat” for USB-Blaster II under the batch file folder, DE0\_CV\_SD\_DEMO\demo\_batch
- After Nios II program is downloaded and executed successfully, a prompt message will be displayed in nios2-terminal.
- Copy DE0\_CV\_SD\_DEMO\demo\_batch\test.txt files to the root directory of the SD Card.
- Insert the Micro SD Card into the SD Card socket of DE0-CV, as shown in **Figure 5-9**.



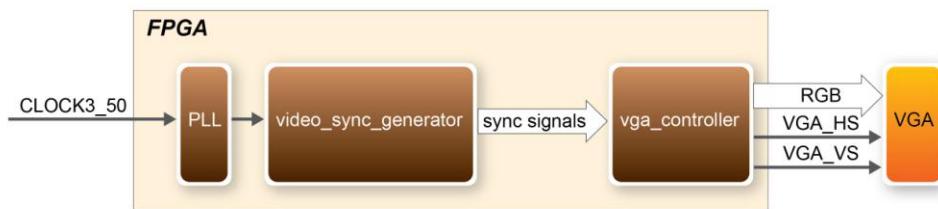
**Figure 5-9 Insert the Micro SD card into DE0-CV**

- Press KEY3 of the DE0-CV board to start reading SD Card.
  - The program will display SD Card information, as shown in **Figure 5-10**.

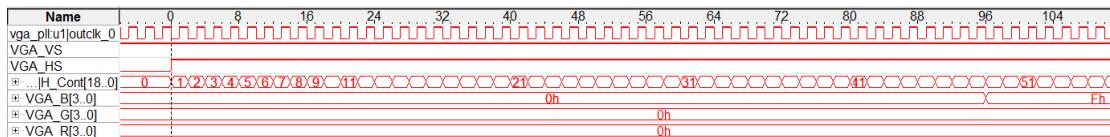
**Figure 5-10** Running result of SD\_CARD demo on DE0-CV board

## 5. 6 VGA Pattern

This demonstration displays a simple blue, red and green color pattern on a VGA monitor using the VGA output interface on DE0\_CV board. **Figure 5-11** shows the block diagram of the design. The major block called video\_sync\_generator generates the VGA timing signals, horizontal synchronization, vertical synchronization and blank in standard VGA resolution (640x480 pixels, at 25 MHz). These signals will be used in vga\_controller block for RGB data generation and data output. Please refer to the chapter 3.6 in DE0\_CV\_User\_Manual on the DE0\_CVSSystem CD for detailed information of using the VGA output. As shown in **Figure 5-12**, the RGB data drives each pixel in turn across the row being displayed after the time period of back porch.



**Figure 5-11 Block diagram of the VGA Pattern demonstration**



**Figure 5-12 Timing Waveform of VGA interface**

## Design Tools

- Quartus II 14.1

## Demonstration Source Code

- Quartus Project directory: DE0\_CV\_VGA\_Pattern
- Bitstream used: DE0\_CV\_VGA\_Pattern.sof

## Demonstration Batch File

Demo Batch File Folder: DE0\_CV\_SD\_DEMO\demo\_batch\

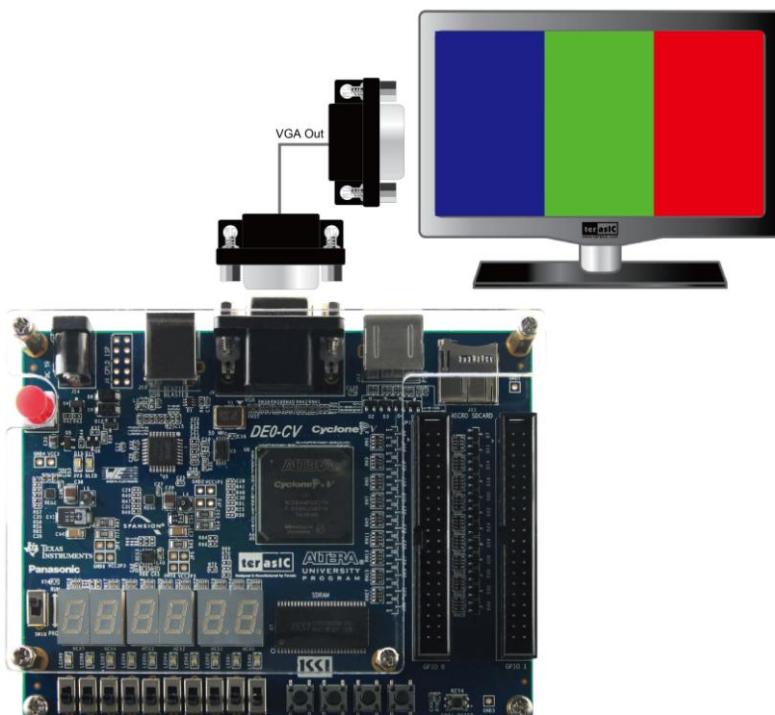
The demo batch file includes following files:

- Batch File for USB-Blaster: DE0\_CV\_VGA\_Pattern.bat
- FPGA Configure File: DE0\_CV\_VGA\_Pattern.sof

## Demonstration Setup

- Quartus II v14.1 must be pre-installed to the host PC..
- Power on the DE0-CV board.
- Connect USB Blaster to the DE0-CV board and install USB Blaster driver if necessary.
- Connect VGA D-SUB to a VGA monitor.
- Execute the demo batch file “DE0\_CV\_VGA\_Pattern.bat” from the directory :  
  \ DE0\_CV\_VGA\_Pattern \demo\_batch.
- The VGA monitor will display a color pattern.

**Figure 5-13** illustrates the setup for this demonstration.



**Figure 5-13 The setup for the VGA Pattern demonstration**

# *Additional Information*

## **Getting Help**

Here are the addresses where you can get help if you encounter problems:

- Terasic Inc.

9F., No.176, Sec.2, Gongdao 5th Rd, East Dist, Hsinchu City, 30070. Taiwan

Email: [support@terasic.com](mailto:support@terasic.com)

Web: [www.terasic.com](http://www.terasic.com)

DE0-CV Web: [www.DE0-CV.terasic.com](http://www.DE0-CV.terasic.com)

## **Revision History**

Date	Version	Changes
2014.12	<b>First publication</b>	
2015.04	<b>Document revision</b>	
2015.5	<b>Modified DE0-CV package content figure</b>	