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68,416
LEs
FPGA

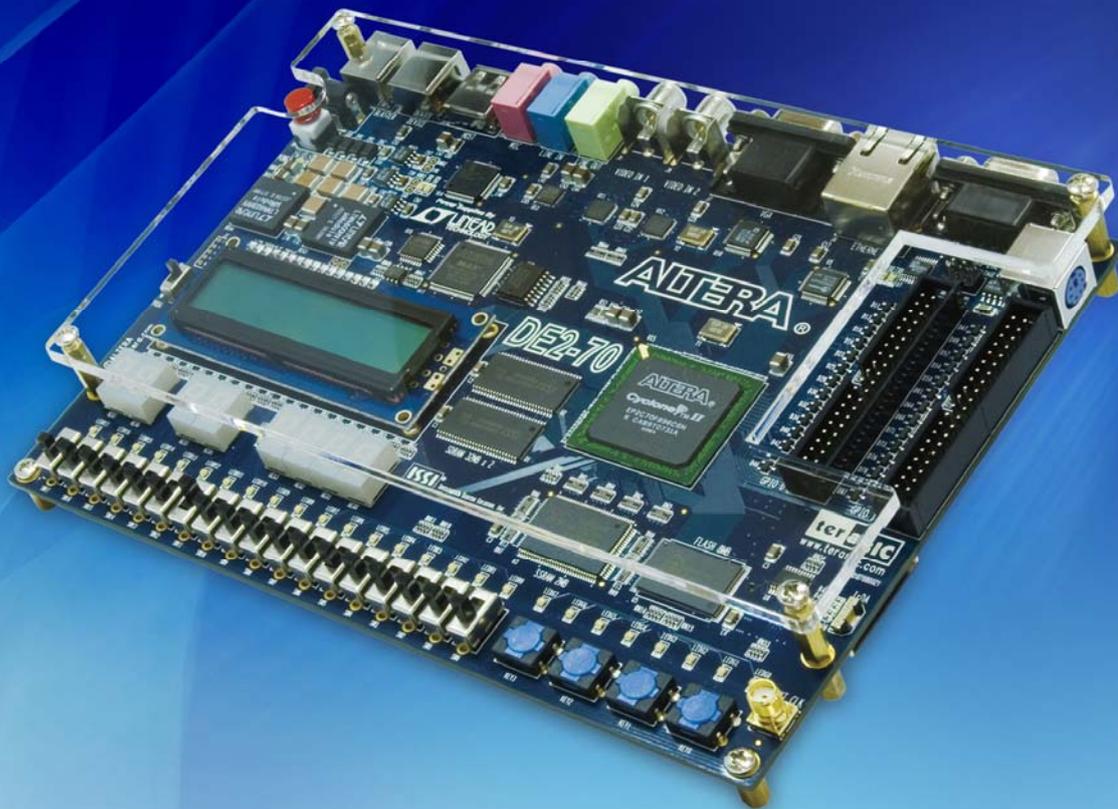
32M
Byte
X2
SDRAM

2M
Byte
SSRAM

8M
Byte
FLASH

X2
TV
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ALTERA
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PROGRAM

Learning through Innovation

DE2-70

Development and Education Board

User Manual



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Chapter 1

DE2-70 Package

The DE2-70 package contains all components needed to use the DE2-70 board in conjunction with a computer that runs the Microsoft Windows software.

1.1 Package Contents

Figure 1.1 shows a photograph of the DE2-70 package.



Figure 1.1. The DE2-70 package contents.

The DE2-70 package includes:

- The DE2-70 board
- USB Cable for FPGA programming and control
- DE2-70 System CD containing the DE2-70 documentation and supporting materials, including the User Manual, the Control Panel utility, reference designs and demonstrations, device datasheets, tutorials, and a set of laboratory exercises
- CD-ROMs containing Altera's Quartus[®] II Web Edition and the Nios[®] II Embedded Design Suit Evaluation Edition software.
- Bag of six rubber (silicon) covers for the DE2-70 board stands. The bag also contains some extender pins, which can be used to facilitate easier probing with testing equipment of the board's I/O expansion headers
- Clear plastic cover for the board
- 12V DC wall-mount power supply

1.2 The DE2-70 Board Assembly

To assemble the included stands for the DE2-70 board:

- Assemble a rubber (silicon) cover, as shown in Figure 1.2, for each of the six copper stands on the DE2-70 board
- The clear plastic cover provides extra protection, and is mounted over the top of the board by using additional stands and screws

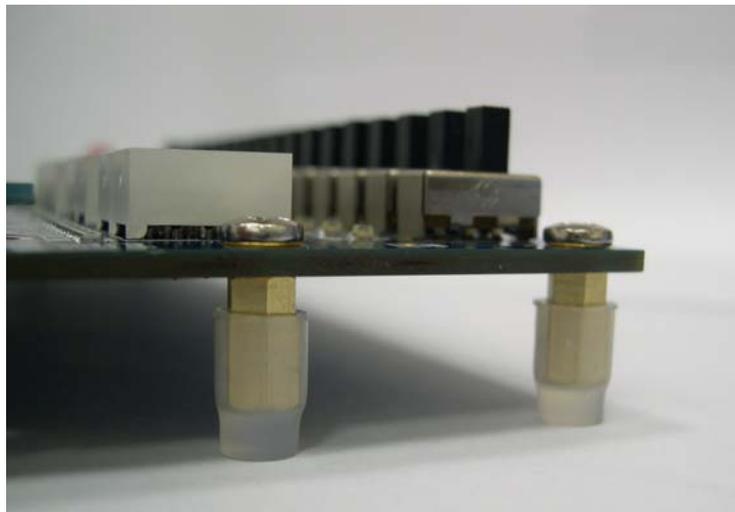


Figure 1.2. The feet for the DE2-70 board.

1.3 Getting Help

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

- Altera Corporation
101 Innovation Drive
San Jose, California, 95134 USA
Email: university@altera.com
- Terasic Technologies
No. 356, Sec. 1, Fusing E. Rd.
Jhubei City, HsinChu County, Taiwan, 302
Email: support@terasic.com
Web: DE2-70.terasic.com

Chapter 2

Altera DE2-70 Board

This chapter presents the features and design characteristics of the DE2-70 board.

2.1 Layout and Components

A photograph of the DE2-70 board is shown in Figure 2.1. It depicts the layout of the board and indicates the location of the connectors and key components.

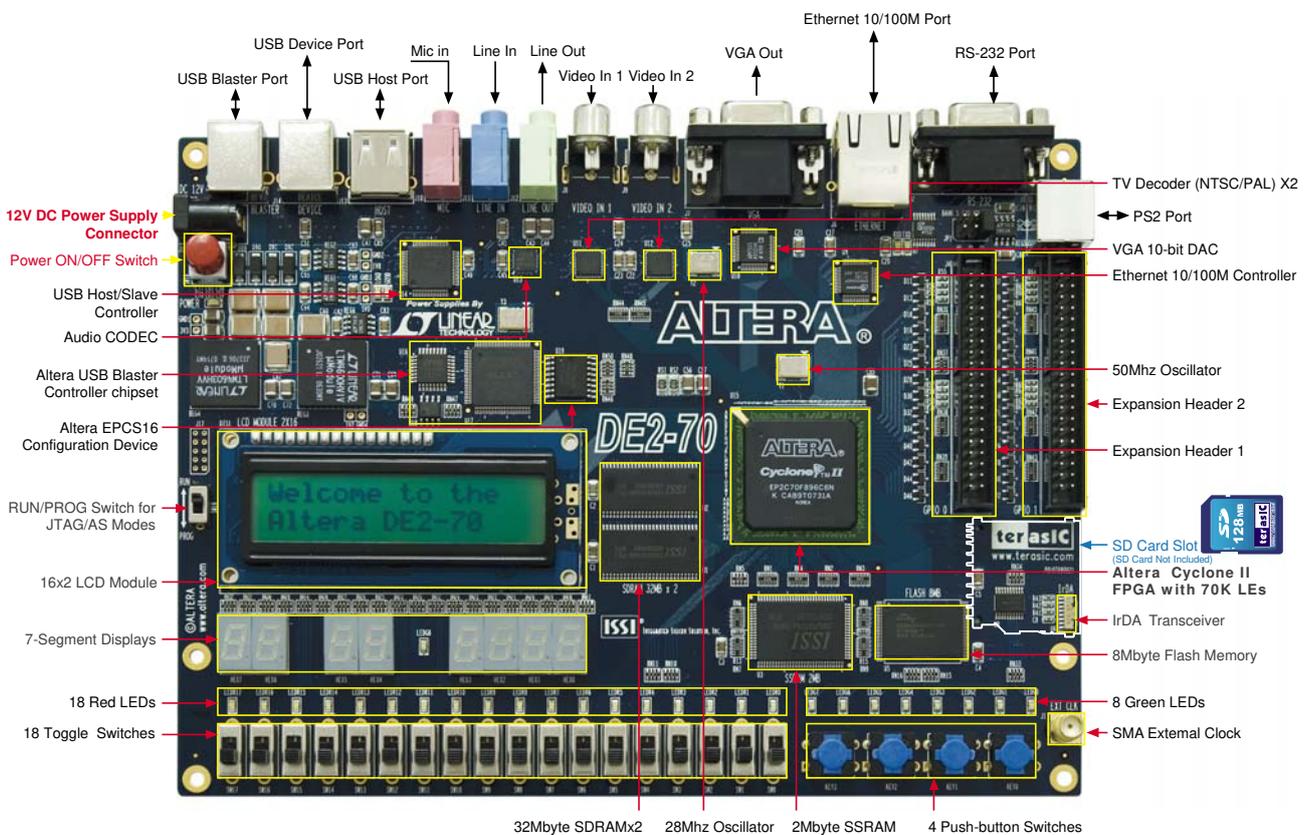


Figure 2.1. The DE2-70 board.

The DE2-70 board has many features that allow the user to implement a wide range of designed circuits, from simple circuits to various multimedia projects.

The following hardware is provided on the DE2-70 board:

- Altera Cyclone® II 2C70 FPGA device
- Altera Serial Configuration device - EPCS16
- USB Blaster (on board) for programming and user API control; both JTAG and Active Serial

(AS) programming modes are supported

- 2-Mbyte SSRAM
- Two 32-Mbyte SDRAM
- 8-Mbyte Flash memory
- SD Card socket
- 4 pushbutton switches
- 18 toggle switches
- 18 red user LEDs
- 9 green user LEDs
- 50-MHz oscillator and 28.63-MHz oscillator for clock sources
- 24-bit CD-quality audio CODEC with line-in, line-out, and microphone-in jacks
- VGA DAC (10-bit high-speed triple DACs) with VGA-out connector
- 2 TV Decoder (NTSC/PAL/SECAM) and TV-in connector
- 10/100 Ethernet Controller with a connector
- USB Host/Slave Controller with USB type A and type B connectors
- RS-232 transceiver and 9-pin connector
- PS/2 mouse/keyboard connector
- IrDA transceiver
- 1 SMA connector
- Two 40-pin Expansion Headers with diode protection

In addition to these hardware features, the DE2-70 board has software support for standard I/O interfaces and a control panel facility for accessing various components. Also, software is provided for a number of demonstrations that illustrate the advanced capabilities of the DE2-70 board.

In order to use the DE2-70 board, the user has to be familiar with the Quartus II software. The necessary knowledge can be acquired by reading the tutorials *Getting Started with Altera's DE2-70 Board* and *Quartus II Introduction* (which exists in three versions based on the design entry method used, namely Verilog, VHDL or schematic entry). These tutorials are provided in the directory *DE2_70_tutorials* on the **DE2-70 System CD-ROM** that accompanies the DE2-70 board and can also be found on Altera's DE2-70 web pages.

2.2 Block Diagram of the DE2-70 Board

Figure 2.2 gives the block diagram of the DE2-70 board. To provide maximum flexibility for the user, all connections are made through the Cyclone II FPGA device. Thus, the user can configure the FPGA to implement any system design.

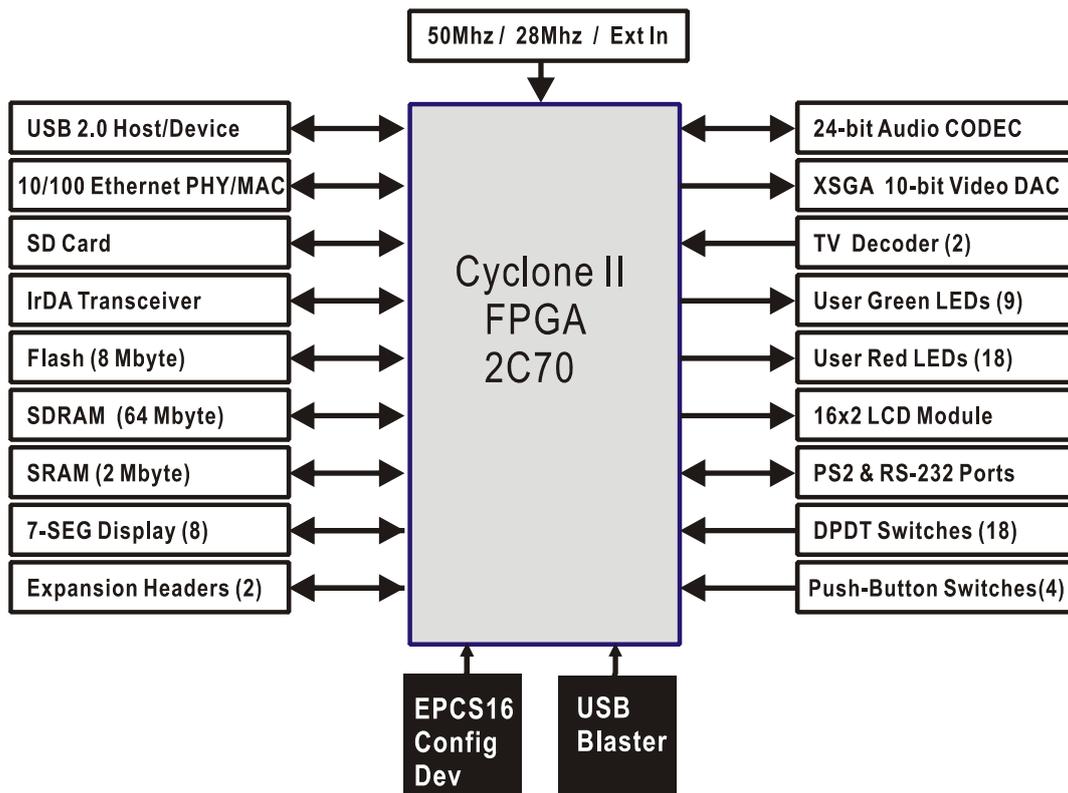


Figure 2.2. Block diagram of the DE2-70 board.

Following is more detailed information about the blocks in Figure 2.2:

Cyclone II 2C70 FPGA

- 68,416 LEs
- 250 M4K RAM blocks
- 1,152,000 total RAM bits
- 150 embedded multipliers
- 4 PLLs
- 622 user I/O pins
- FineLine BGA 896-pin package

Serial Configuration device and USB Blaster circuit

- Altera’s EPCS16 Serial Configuration device
- On-board USB Blaster for programming and user API control
- JTAG and AS programming modes are supported

SSRAM

- 2-Mbyte standard synchronous SRAM
- Organized as 512K x 36 bits
- Accessible as memory for the Nios II processor and by the DE2-70 Control Panel

SDRAM

- Two 32-Mbyte Single Data Rate Synchronous Dynamic RAM memory chips
- Organized as 4M x 16 bits x 4 banks
- Accessible as memory for the Nios II processor and by the DE2-70 Control Panel

Flash memory

- 8-Mbyte NOR Flash memory
- Support both byte and word mode access
- Accessible as memory for the Nios II processor and by the DE2-70 Control Panel

SD card socket

- Provides SPI and 1-bit SD mode for SD Card access
- Accessible as memory for the Nios II processor with the DE2-70 SD Card Driver

Pushbutton switches

- 4 pushbutton switches
- Debounced by a Schmitt trigger circuit
- Normally high; generates one active-low pulse when the switch is pressed

Toggle switches

- 18 toggle switches for user inputs
- A switch causes logic 0 when in the DOWN (closest to the edge of the DE2-70 board) position and logic 1 when in the UP position

Clock inputs

- 50-MHz oscillator
- 28.63-MHz oscillator
- SMA external clock input

Audio CODEC

- Wolfson WM8731 24-bit sigma-delta audio CODEC
- Line-level input, line-level output, and microphone input jacks
- Sampling frequency: 8 to 96 KHz
- Applications for MP3 players and recorders, PDAs, smart phones, voice recorders, etc.

VGA output

- Uses the ADV7123 140-MHz triple 10-bit high-speed video DAC
- With 15-pin high-density D-sub connector
- Supports up to 1600 x 1200 at 100-Hz refresh rate
- Can be used with the Cyclone II FPGA to implement a high-performance TV Encoder

NTSC/PAL/ SECAM TV decoder circuit

- Uses two ADV7180 Multi-format SDTV Video Decoders
- Supports worldwide NTSC/PAL/SECAM color demodulation
- One 10-bit ADC, 4X over-sampling for CVBS
- Supports Composite Video (CVBS) RCA jack input
- Supports digital output formats : 8-bit ITU-R BT.656 YCrCb 4:2:2 output + HS, VS, and FIELD
- Applications: DVD recorders, LCD TV, Set-top boxes, Digital TV, Portable video devices, and TV PIP (picture in picture) display.

10/100 Ethernet controller

- Integrated MAC and PHY with a general processor interface
- Supports 100Base-T and 10Base-T applications
- Supports full-duplex operation at 10 Mb/s and 100 Mb/s, with auto-MDIX
- Fully compliant with the IEEE 802.3u Specification
- Supports IP/TCP/UDP checksum generation and checking
- Supports back-pressure mode for half-duplex mode flow control

USB Host/Slave controller

- Complies fully with Universal Serial Bus Specification Rev. 2.0
- Supports data transfer at full-speed and low-speed
- Supports both USB host and device
- Two USB ports (one type A for a host and one type B for a device)
- Provides a high-speed parallel interface to most available processors; supports Nios II with a Terasic driver
- Supports Programmed I/O (PIO) and Direct Memory Access (DMA)

Serial ports

- One RS-232 port
- One PS/2 port
- DB-9 serial connector for the RS-232 port
- PS/2 connector for connecting a PS2 mouse or keyboard to the DE2-70 board

IrDA transceiver

- Contains a 115.2-kb/s infrared transceiver
- 32 mA LED drive current
- Integrated EMI shield
- IEC825-1 Class 1 eye safe
- Edge detection input

Two 40-pin expansion headers

- 72 Cyclone II I/O pins, as well as 8 power and ground lines, are brought out to two 40-pin expansion connectors
- 40-pin header is designed to accept a standard 40-pin ribbon cable used for IDE hard drives
- Diode and resistor protection is provided

2.3 Power-up the DE2-70 Board

The DE2-70 board comes with a preloaded configuration bit stream to demonstrate some features of the board. This bit stream also allows users to see quickly if the board is working properly. To power-up the board perform the following steps:

1. Connect the provided USB cable from the host computer to the USB Blaster connector on the DE2-70 board. For communication between the host and the DE2-70 board, it is necessary to install the Altera USB Blaster driver software. If this driver is not already installed on the host computer, it can be installed as explained in the tutorial *Getting Started with Altera's DE2-70 Board*. This tutorial is available in the directory *DE2_70_tutorials* on the **DE2-70 System CD-ROM**.
2. Connect the 12V adapter to the DE2-70 board
3. Connect a VGA monitor to the VGA port on the DE2-70 board
4. Connect your headset to the Line-out audio port on the DE2-70 board
5. Turn the RUN/PROG switch on the left edge of the DE2-70 board to RUN position; the PROG position is used only for the AS Mode programming
6. Turn the power on by pressing the ON/OFF switch on the DE2-70 board

At this point you should observe the following:

- All user LEDs are flashing
- All 7-segment displays are cycling through the numbers 0 to F
- The LCD display shows **Welcome to the Altera DE2-70**
- The VGA monitor displays the image shown in Figure 2.3.
- Set the toggle switch SW17 to the DOWN position; you should hear a 1-kHz sound
- Set the toggle switch SW17 to the UP position and connect the output of an audio player to the Line-in connector on the DE2-70 board; on your headset you should hear the music played from the audio player (MP3, PC, iPod, or the like)
- You can also connect a microphone to the Microphone-in connector on the DE2-70 board; your voice will be mixed with the music played from the audio player



Figure 2.3. The default VGA output pattern.

Chapter 3

DE2-70 Control Panel

The DE2-70 board comes with a Control Panel facility that allows users to access various components on the board from a host computer. The host computer communicates with the board through an USB connection. The facility can be used to verify the functionality of components on the board or be used as a debug tool while developing RTL code.

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

3.1 Control Panel Setup

The Control Panel Software Utility is located in the “*DE2_70_control_panel/SW*” folder in the **DE2-70 System CD-ROM**. To install it, just copy the whole folder to your host computer. Launch the control panel by executing the “*DE2_70_Control_Panel.exe*”.

Specific control codes should be downloaded to your FPGA board before the control panel can request it to perform required tasks. The control codes include one *.sof* file and one *.elf* file. To download the codes, just click the “**Download Code**” button on the program. The program will call Quartus II and Nios II tools to download the control codes to the FPGA board through USB-Blaster[USB-0] connection. The *.sof* file is downloaded to FPGA. The *.elf* file is downloaded to either SDRAM-U2 or SSRAM, according to the user option.

To activate the Control Panel, perform the following steps:

1. Make sure Quartus II and NIOS II are installed successfully on your PC.
2. Connect the supplied USB cable to the USB Blaster port, connect the 12V power supply, and turn the power switch ON
3. Set the RUN/PROG switch to the RUN position
4. Start the executable *DE2_70_control_panel.exe* on the host computer. The Control Panel user interface shown in Figure 3.1 will appear.
5. Select the target memory, **SDRAM-U2** or **SSRAM**, on the control panel. Note. The *.elf* file will be downloaded to the target memory and the memory will be read-only in later memory access operation.
6. Click **Download Code** button. **Note, 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 you close the USB port.

7. The Control Panel is now ready for use; experiment by setting the value of some LEDs display and observing the result on the DE2-70 board.

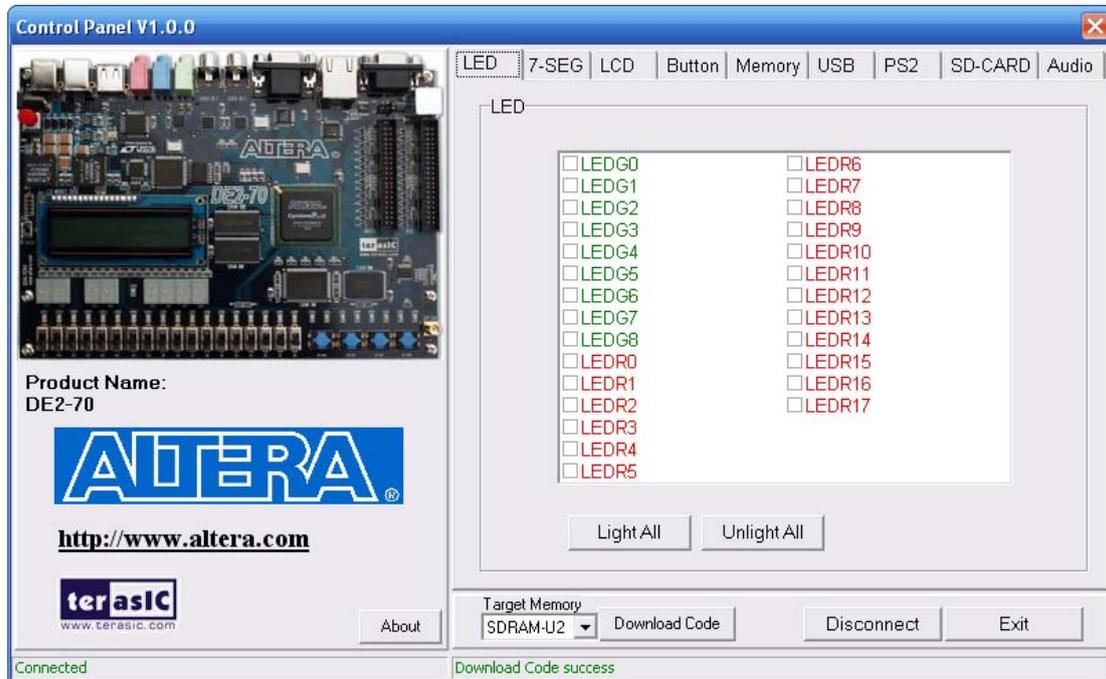


Figure 3.1. The DE2-70 Control Panel.

The concept of the DE2-70 Control Panel is illustrated in Figure 3.2. The “Control Codes” 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 issue commands to the control codes. It handles all requests and performs data transfers between the computer and the DE2-70 board.

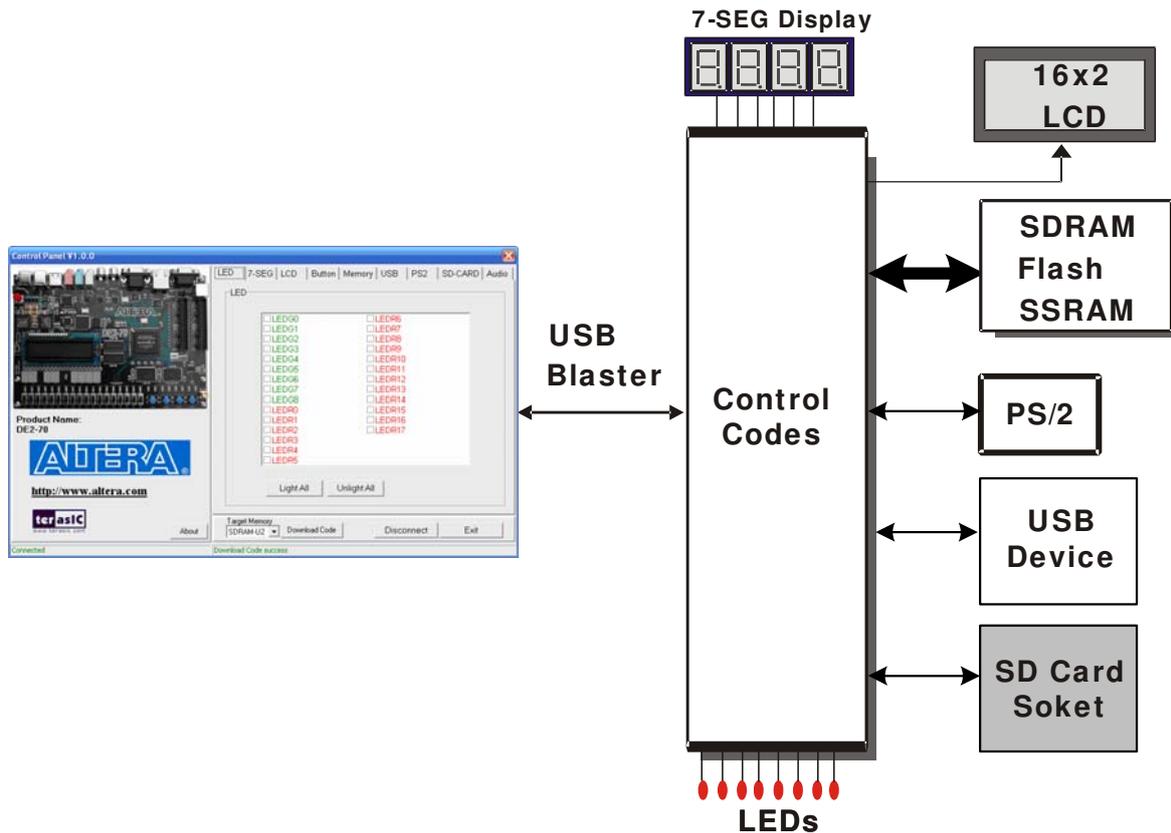


Figure 3.2. The DE2-70 Control Panel concept.

The DE2-70 Control Panel can be used to light up LEDs, change the values displayed on 7-segment and LCD displays, monitor buttons/switches status, read/write the SDRAM, SSRAM and Flash Memory, monitor the status of an USB mouse, read data from a PS/2 keyboard, and read SD-CARD specification information. The feature of reading/writing a word or an entire file from/to the Flash Memory allows the user to develop multimedia applications (Flash Audio Player, Flash Picture Viewer) without worrying about how to build a Memory Programmer.

3.2 Controlling the LEDs, 7-Segment Displays and LCD Display

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

Choosing the **LED** tab leads to the window in Figure 3.3. Here, you can directly turn the individual LEDs on or off by selecting them or click “Light All” or “Unlight All”.

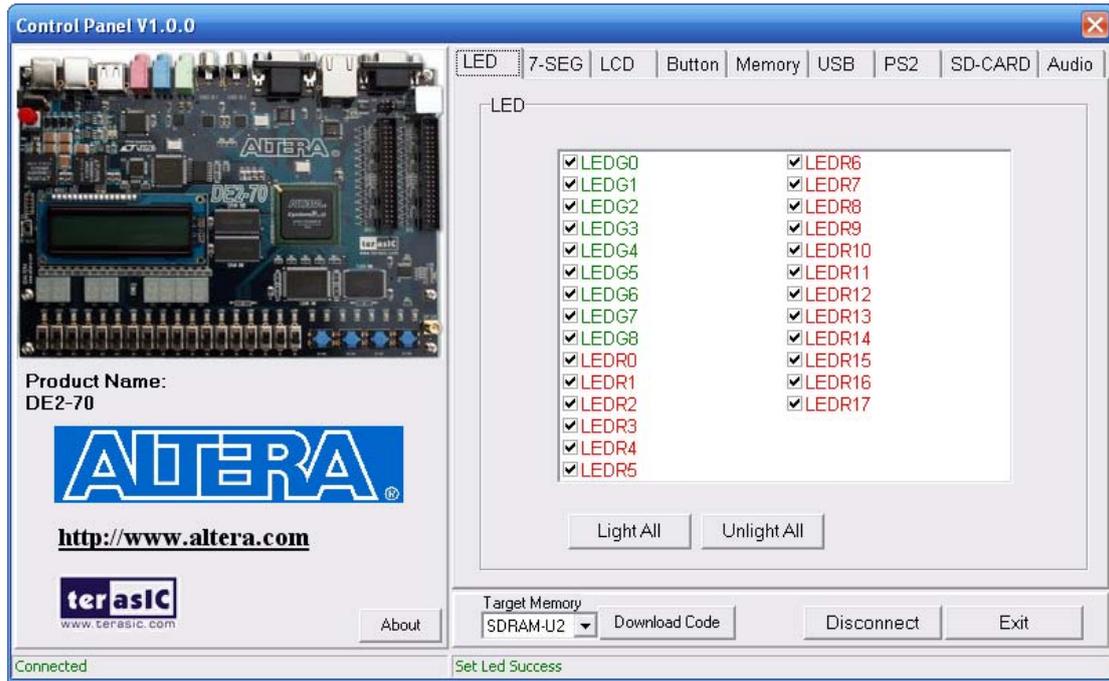


Figure 3.3. Controlling LEDs.

Choosing the **7-SEG** tab leads to the window in Figure 3.4. In the tab sheet, directly use the **Up-Down** control and **Dot Check** box to specified desired patterns, the 7-SEG patterns on the board will be updated immediately.

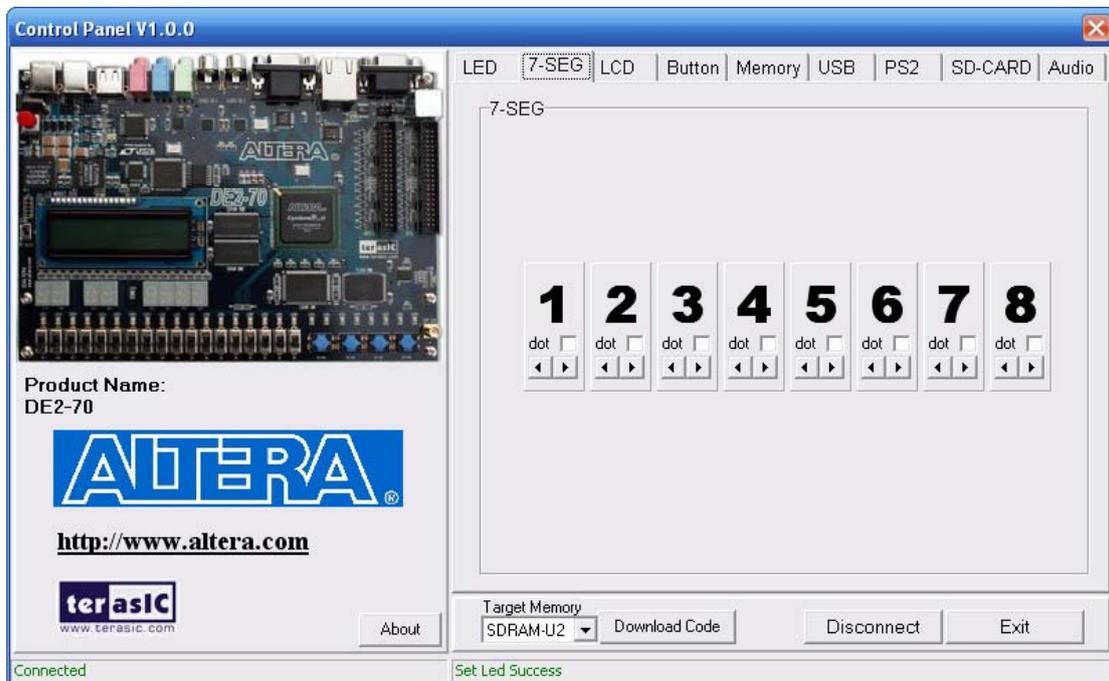


Figure 3.4. Controlling 7-SEG display.

Choosing the **LCD** tab leads to the window in Figure 3.5. Text can be written to the LCD display by typing it in the LCD box and pressing the **Set** button.

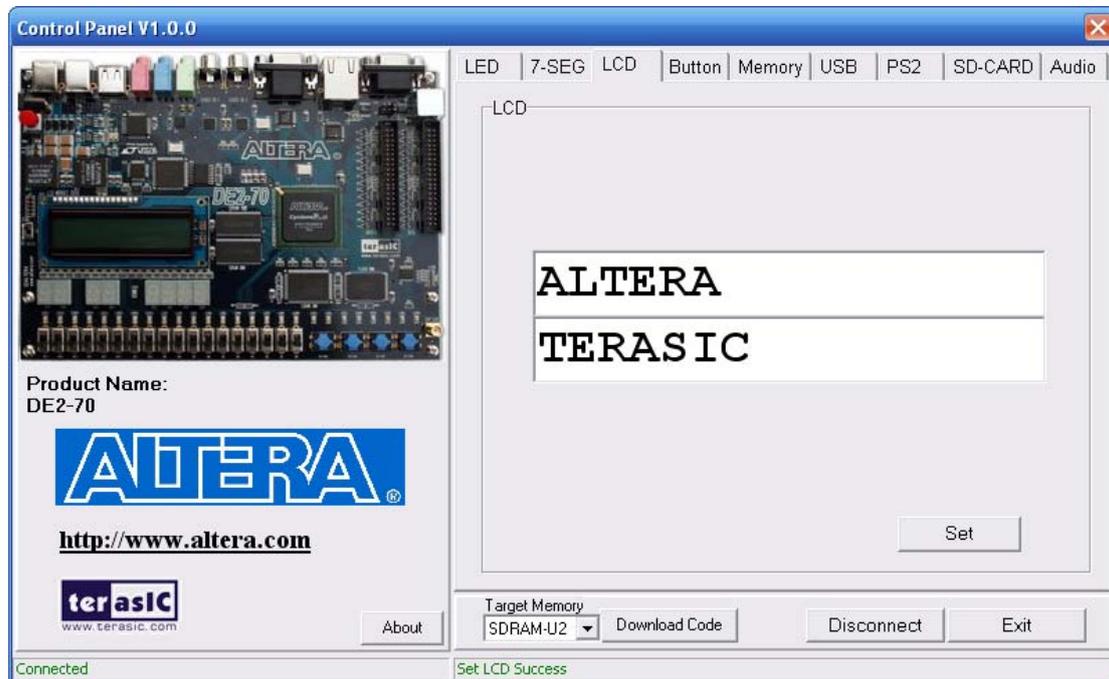


Figure 3.5. Controlling LEDs and the LCD display.

The ability to set arbitrary values into simple display devices is not needed in typical design activities. However, it gives the user 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.

3.3 Switches and Buttons

Choosing the **Button** tab leads to the window in Figure 3.6. The function is designed to monitor the status of switches and buttons in real time and show the status in a graphical user interface. It can be used to verify the functionality of the switches and buttons.

Press the **Start** button to start button/switch status monitoring process, and button caption is changed from **Start** to **Stop**. In the monitoring process, the status of buttons and switches on the board is shown in the GUI window and updated in real time. Press **Stop** to end the monitoring process.

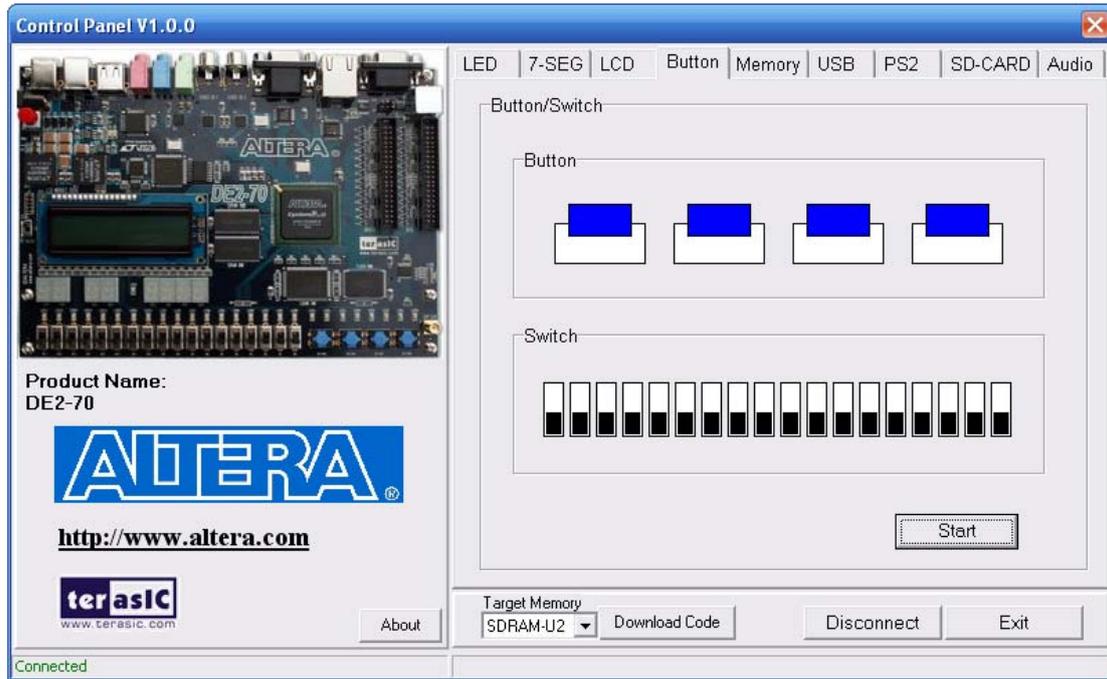


Figure 3.6. Monitoring switches and buttons.

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

3.4 SDRAM/SSRAM/Flash Controller and Programmer

The Control Panel can be used to write/read data to/from the SDRAM, SSRAM, and FLASH chips on the DE2-70 board. We will describe how the SDRAM-U1 may be accessed; the same approach is used to access the SDRAM-U2, SRAM, and FLASH. Click on the **Memory** tab and select “SDRAM-U1” to reach the window in Figure 3.7. Please note the target memory chosen for storing .elf file is read-only. Also, please erase the flash before writing data to it.

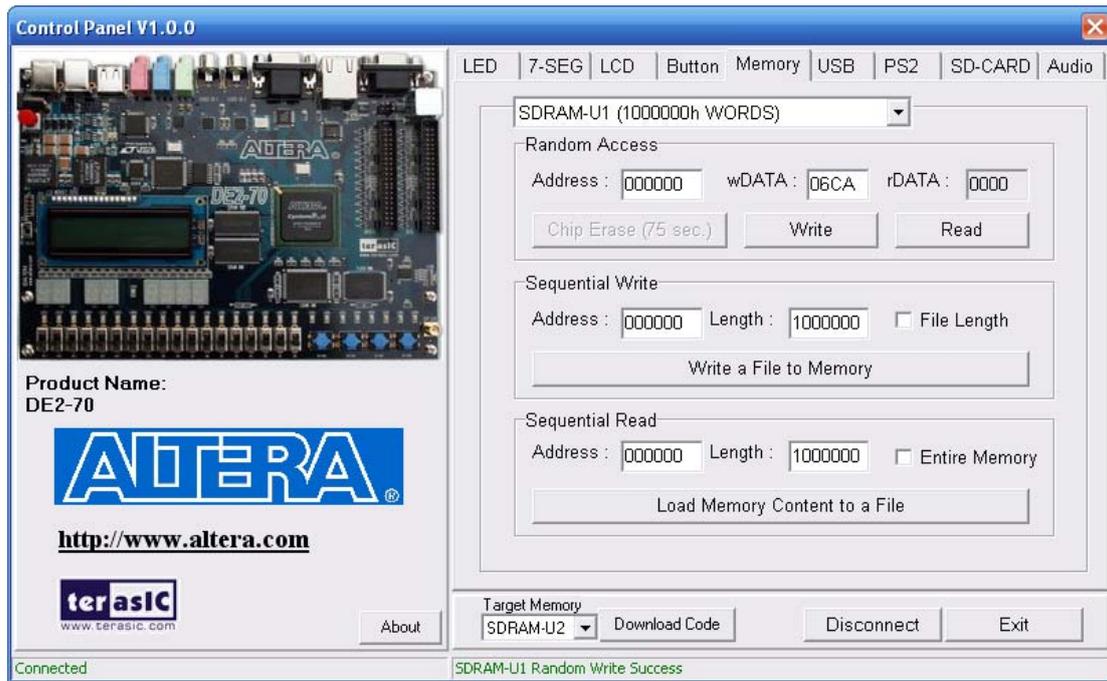


Figure 3.7. Accessing the SDRAM-U1.

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 3.7 depicts the result of writing the hexadecimal value 06CA into location 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 of data, 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 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 four 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-U1 and place 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-U1 are to be copied (which involves all 32 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.

Users can use the similar way to access the SSRAM and Flash. Please note that users need to erase the flash before writing data to it.

3.5 USB Monitoring

The Control Panel provides users a USB monitoring tool which monitors the real-time status of a USB mouse connected to the DE2-70 board. The movement of the mouse and the status of the three buttons will be shown in the graphical and text interface. The mouse movement is translated as a position (x,y) with range from (0,0)~(1023,767). This function can be used to verify the functionality of the USB Host.

Follow the steps below to exercise the USB Mouse Monitoring tool:

1. Choosing the **USB** tab leads to the window in Figure 3.8.
2. Plug an USB mouse to the USB HOST port on the DE2-70 board.
3. Press the **Start** button to start the USB mouse monitoring process, and button caption is changed from **Start** to **Stop**. In the monitoring process, the status of the USB mouse is updated and shown in the Control Panel's GUI window in real-time. Press **Stop** to terminate the monitoring process.

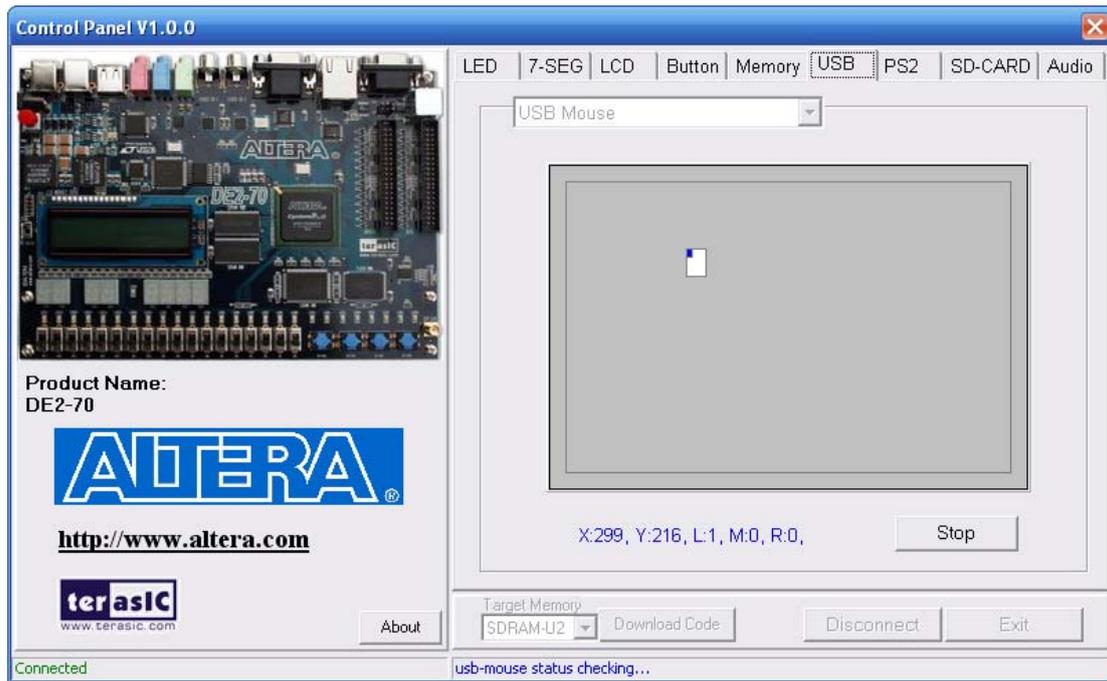


Figure 3.8. USB Mouse Monitoring Tool.

3.6 PS2 Device

The Control Panel provides users a tool to receive the inputs from a PS2 keyboard in real time. The received scan-codes are translated to ASCII code and displayed in the control window. Only visible ASCII codes are displayed. For control key, only “Carriage Return/ENTER” key is implemented. This function can be used to verify the functionality of the PS2 Interface. Please follow the steps below to exercise the PS2 device:

1. Choosing the **PS2** tab leads to the window in Figure 3.9.
2. Plug a PS2 Keyboard to the FPGA board. Then,
3. Press the **Start** button to start PS2Keyboard input receiving process; Button caption is changed from **Start** to **Stop**.
4. In the receiving process, users can start to press the attached keyboard. The input data will be displayed in the control window in real time. Press **Stop** to terminate the monitoring process.

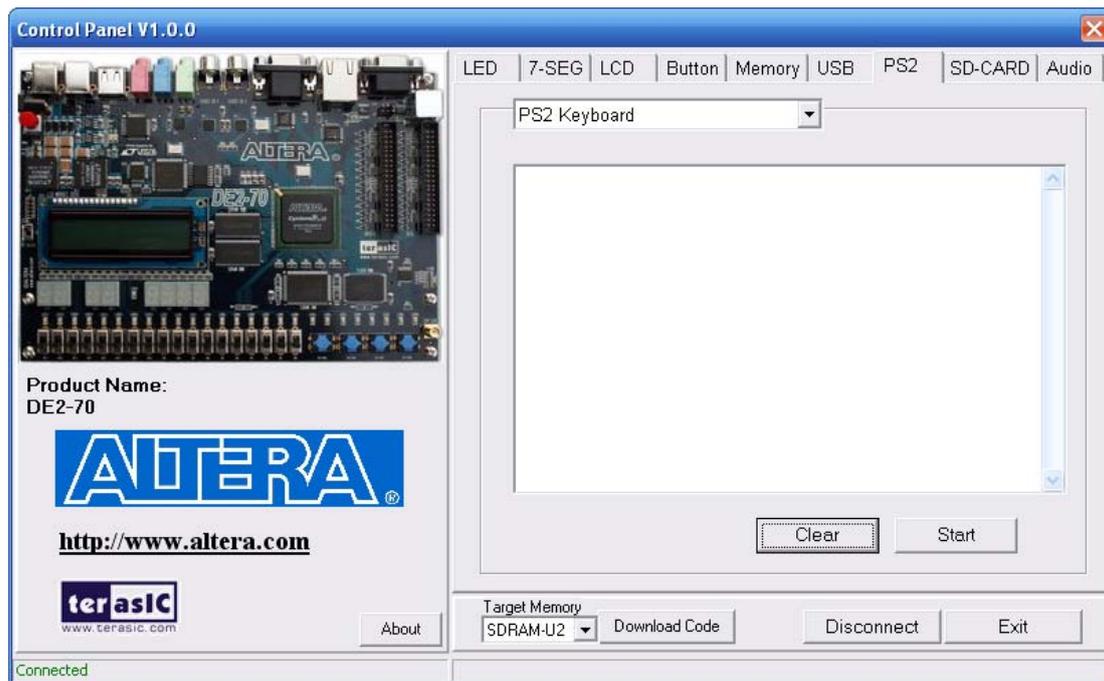


Figure 3.9. Reading the PS2 Keyboard.

3.7 SD CARD

The function is designed to read the identification and specification of the SD card. The 1-bit SD MODE is used to access the SD card. This function can be used to verify the functionality of SD-CARD Interface. Follow the steps below to exercise the SD card:

1. Choosing the **SD-CARD** tab leads to the window in Figure 3.10. First,
2. Insert a SD card to the DE2-70 board, then press the **Read** button to read the SD card. The SD card's identification and specification will be displayed in the control window.

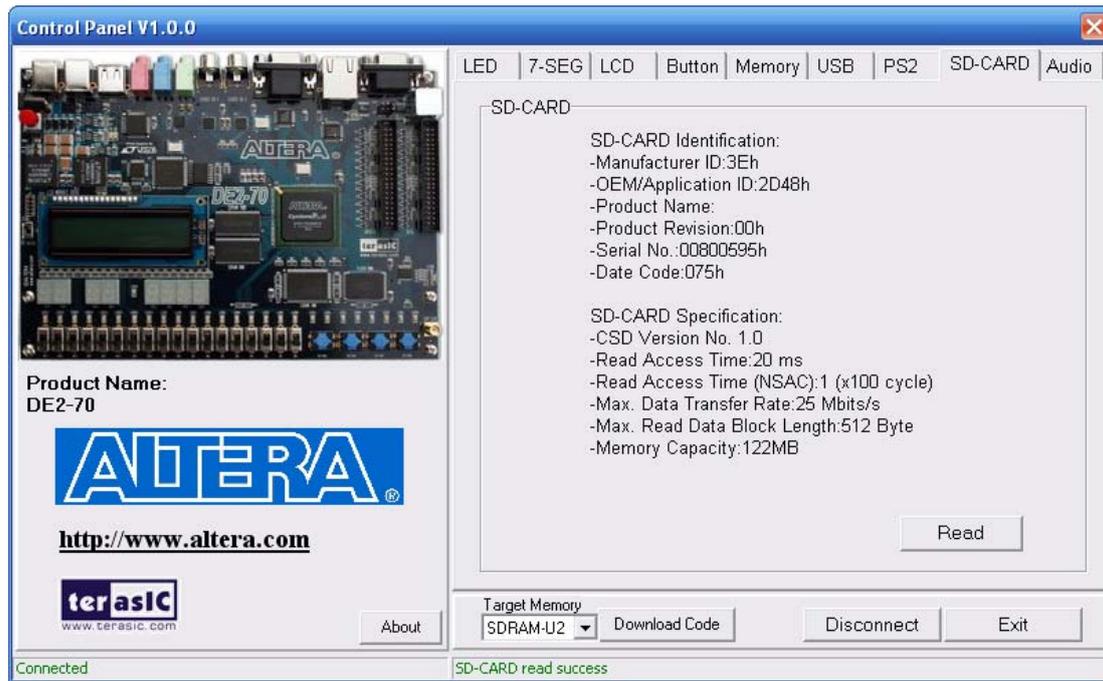


Figure 3.10. Reading the SD card Identification and Specification.

3.8 Audio Playing and Recording

This interesting audio tool is designed to control the audio chip on the DE2-70 board for audio playing and recording. It can play audio stored in a given WAVE file, record audio, and save the audio signal as a wave file. The WAVE file must be uncompressed, stereo (2 channels per sample), and 16-bits per channel. Its sample rate must be either 96K, 48K, 44.1K, 32K, or 8K. Follow the steps below to exercise this tool.

1. Choosing the **Audio** tab leads to the window in Figure 3.11.
2. To play audio, plug a headset or speaker to the LINE-OUT port on the board.
3. Select the "Play Audio" item in the com-box, as shown in Figure 3.11.
4. Click "Open Wave" to select a WAVE file. The waveform of the specified wave file will be displayed in the waveform window. The sampling rate of the wave file also is displayed in the Sample Rate Combo-Box. You can drag the scrollbar to browse the waveform. In the waveform window, the blue line represents left-channel signal and green line represents right-channel signal.
5. Click "Start Play" to start audio play. The program will download the waveform to SDRAM-U1, configure the audio chip for audio playing, and then start the audio playing process. You will hear the audio sound from the headset or speaker. To stop the audio playing, simply click "Stop Play".

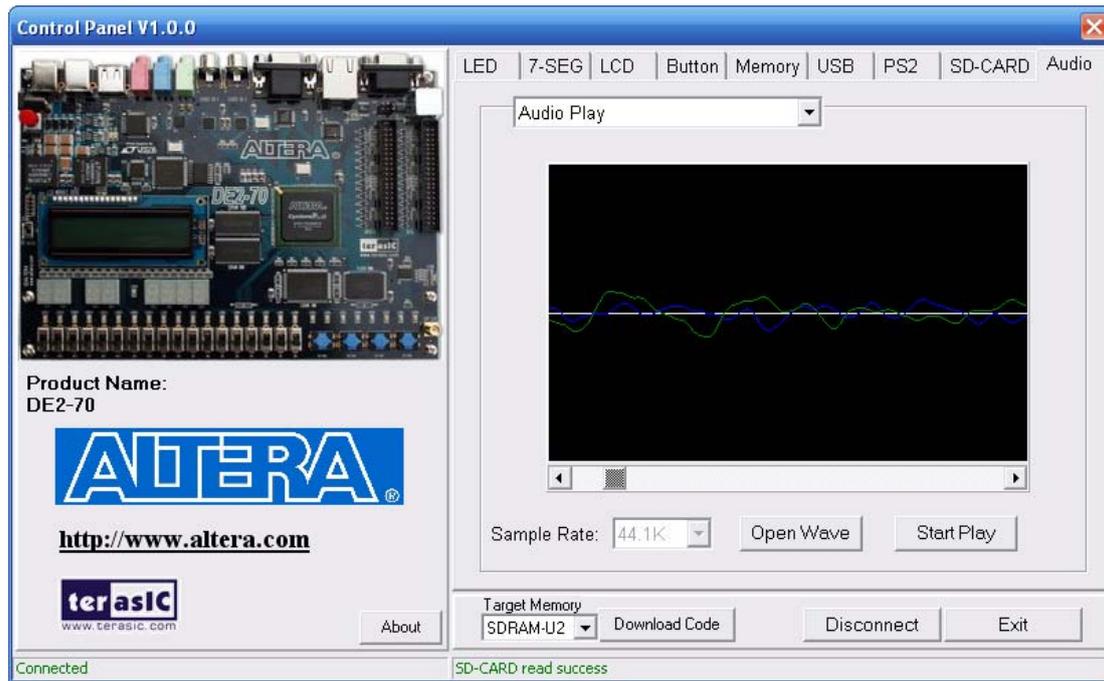


Figure 3.11. Playing audio from a selected wave file

To record sound using a microphone, please follow the steps below:

1. Plug a microphone to the MIC port on the board.
2. Select the “Record MIC” item in the com-box and select desired sampling rate, as shown in Figure 3.12.
3. Click “Start Record” to start the record process. The program will configure the audio chip for MIC recording, retrieve audio signal from the MIC port, and then save the audio signal into SDRAM-U1.
4. To stop recording, click “Stop Record”. Finally, audio signal saved in SDRAM-U1 will be uploaded to the host computer and displayed on the waveform window. Click “Save Wave” to save the waveform into a WAV file.