



# **DE1    Development and Education Board**

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## **User Manual**

# Chapter 2

## Altera DE1 Board

This chapter presents the features and design characteristics of the DE1 board.

### 2.1 Layout and Components

A photograph of the DE1 board is shown in Figure 2.1. It depicts the layout of the board and indicates the location of the connectors and key components.

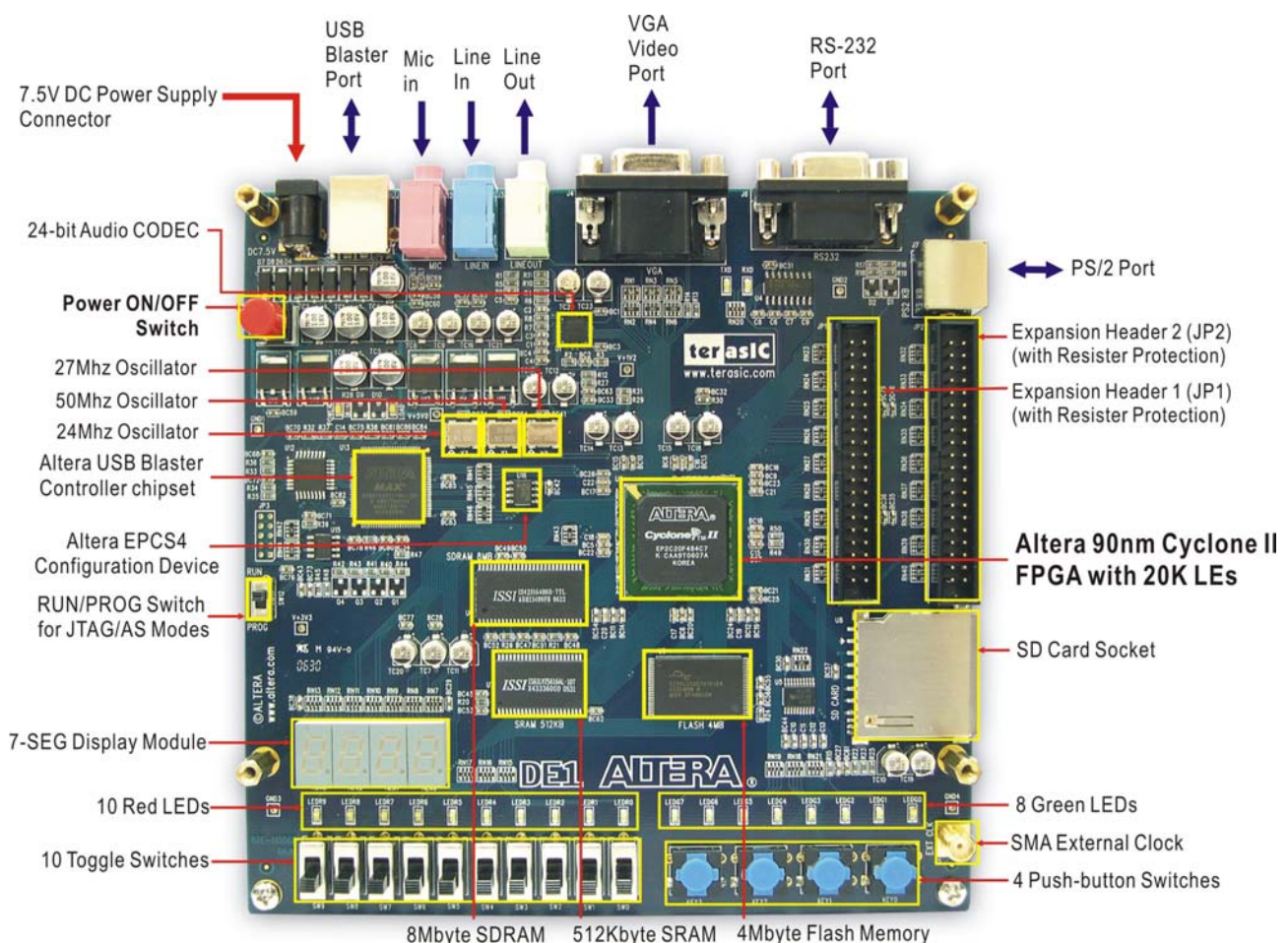


Figure 2.1. The DE1 board.

The DE1 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 DE1 board:

- Altera Cyclone® II 2C20 FPGA device
- Altera Serial Configuration device – EPCS4
- USB Blaster (on board) for programming and user API control; both JTAG and Active Serial (AS) programming modes are supported
- 512-Kbyte SRAM
- 8-Mbyte SDRAM
- 4-Mbyte Flash memory
- SD Card socket
- 4 pushbutton switches
- 10 toggle switches
- 10 red user LEDs
- 8 green user LEDs
- 50-MHz oscillator, 27-MHz oscillator and 24-MHz oscillator for clock sources
- 24-bit CD-quality audio CODEC with line-in, line-out, and microphone-in jacks
- VGA DAC (4-bit resistor network) with VGA-out connector
- RS-232 transceiver and 9-pin connector
- PS/2 mouse/keyboard connector
- Two 40-pin Expansion Headers with resistor protection
- Powered by either a 7.5V DC adapter or a USB cable

In addition to these hardware features, the DE1 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 DE1 board.

In order to use the DE1 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 DE1 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 *DE1\_tutorials* on the **DE1 System CD-ROM** that accompanies the DE1 board and can also be found on Altera's DE1 web pages.

## 2.2 Block Diagram of the DE1 Board

Figure 2.2 gives the block diagram of the DE1 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.

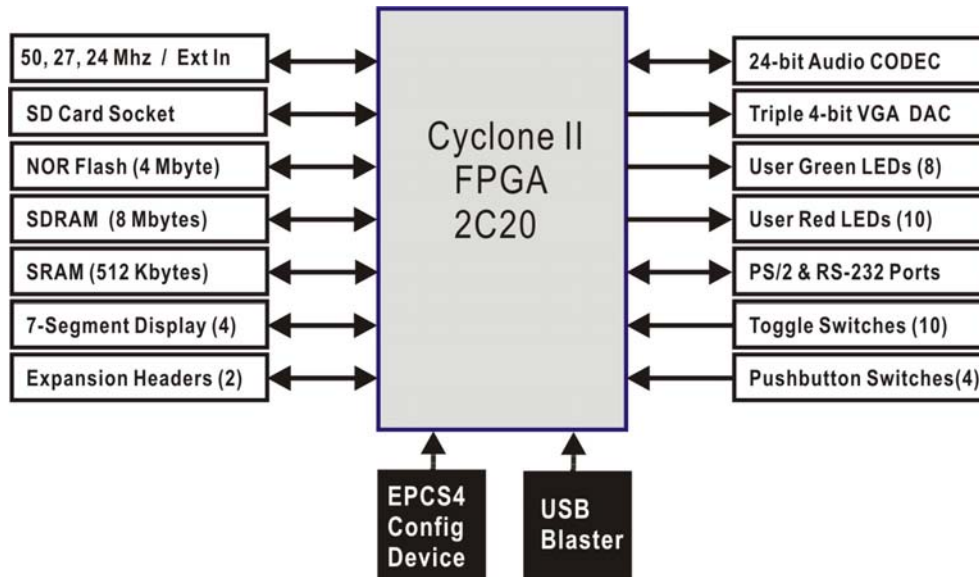


Figure 2.2. Block diagram of the DE1 board.

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

### Cyclone II 2C20 FPGA

- 18,752 LEs
- 52 M4K RAM blocks
- 240K total RAM bits
- 26 embedded multipliers
- 4 PLLs
- 315 user I/O pins
- FineLine BGA 484-pin package

### Serial Configuration device and USB Blaster circuit

- Altera's EPCS4 Serial Configuration device
- On-board USB Blaster for programming and user API control
- JTAG and AS programming modes are supported

### SRAM

- 512-Kbyte Static RAM memory chip
- Organized as 256K x 16 bits
- Accessible as memory for the Nios II processor and by the DE1 Control Panel

## SDRAM

- 8-Mbyte Single Data Rate Synchronous Dynamic RAM memory chip
- Organized as 1M x 16 bits x 4 banks
- Accessible as memory for the Nios II processor and by the DE1 Control Panel

## Flash memory

- 4-Mbyte NOR Flash memory.
- 8-bit data bus
- Accessible as memory for the Nios II processor and by the DE1 Control Panel

## SD card socket

- Provides SPI mode for SD Card access
- Accessible as memory for the Nios II processor with the DE1 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

- 10 toggle switches for user inputs
- A switch causes logic 0 when in the DOWN (closest to the edge of the DE1 board) position and logic 1 when in the UP position

## Clock inputs

- 50-MHz oscillator
- 27-MHz oscillator
- 24-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 a 4-bit resistor-network DAC
- With 15-pin high-density D-sub connector
- Supports up to 640x480 at 60-Hz refresh rate
- Can be used with the Cyclone II FPGA to implement a high-performance TV Encoder

**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 DE1 board

**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
- Resistor protection is provided

# Chapter 4

## Using the DE1 Board

This chapter gives instructions for using the DE1 board and describes each of its I/O devices.

### 4.1 Configuring the Cyclone II FPGA

The procedure for downloading a circuit from a host computer to the DE1 board is described in the tutorial *Quartus II Introduction*. This tutorial is found in the *DE1\_tutorials* folder on the **DE1 System CD-ROM**, and it is also available on the Altera DE1 web pages. The user is encouraged to read the tutorial first, and to treat the information below as a short reference.

The DE1 board contains a serial EEPROM chip that stores configuration data for the Cyclone II FPGA. This configuration data is automatically loaded from the EEPROM chip into the FPGA each time power is applied to the board. Using the Quartus II software, it is possible to reprogram the FPGA at any time, and it is also possible to change the non-volatile data that is stored in the serial EEPROM chip. 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 II FPGA. The FPGA will retain this configuration as long as power is applied to the board; the configuration is 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 EPCS4 serial EEPROM chip. It provides non-volatile storage of the bit stream, so that the information is retained even when the power supply to the DE1 board is turned off. When the board's power is turned on, the configuration data in the EPCS4 device is automatically loaded into the Cyclone II FPGA.

The sections below describe the steps used to perform both JTAG and AS programming. For both methods the DE1 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. The process for installing on the host computer the necessary software device driver that communicates with the USB Blaster is described in the tutorial *Getting Started with Altera's DE1 Board*. This tutorial is available on the **DE1 System CD-ROM** and from the Altera DE1 web pages.

### Configuring the FPGA in JTAG Mode



Figure 4.1 illustrates the JTAG configuration setup. To download a configuration bit stream into the Cyclone II FPGA, perform the following steps:

- Ensure that power is applied to the DE1 board
- Connect the supplied USB cable to the USB Blaster port on the DE1 board (see Figure 2.1)
- Configure the JTAG programming circuit by setting the RUN/PROG switch (on the left side of the board) to the RUN position.
- The FPGA can now be programmed by using the Quartus II Programmer module to select a configuration bit stream file with the *.sof* filename extension

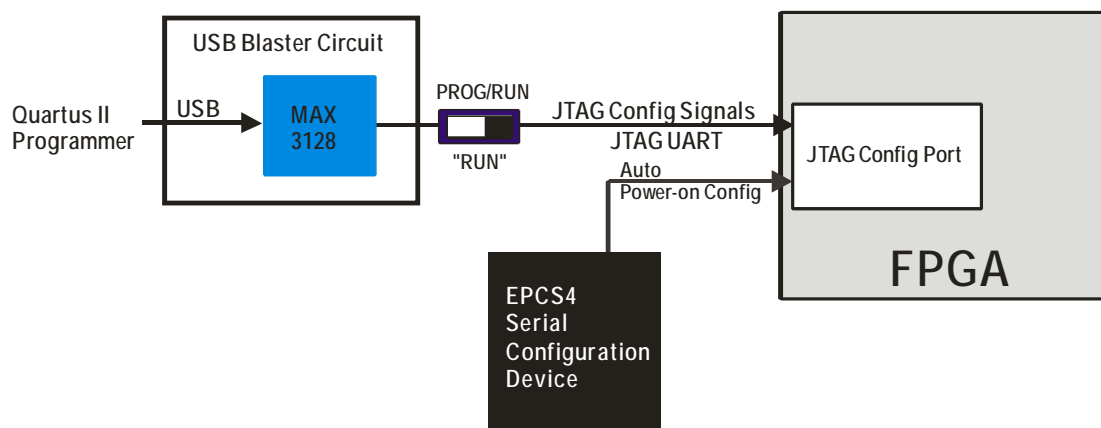


Figure 4.1. The JTAG configuration scheme.

## Configuring the EPCS4 in AS Mode

Figure 4.2 illustrates the AS configuration set up. To download a configuration bit stream into the EPCS4 serial EEPROM device, perform the following steps:

- Ensure that power is applied to the DE1 board
- Connect the supplied USB cable to the USB Blaster port on the DE1 board (see Figure 2.1)
- Configure the JTAG programming circuit by setting the RUN/PROG switch (on the left side of the board) to the PROG position.
- The EPCS4 chip can now be programmed by using the Quartus II Programmer module to select a configuration bit stream file with the *.pof* filename extension
- Once the programming operation is finished, set the RUN/PROG 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 EPCS4 device to be loaded into the FPGA chip.



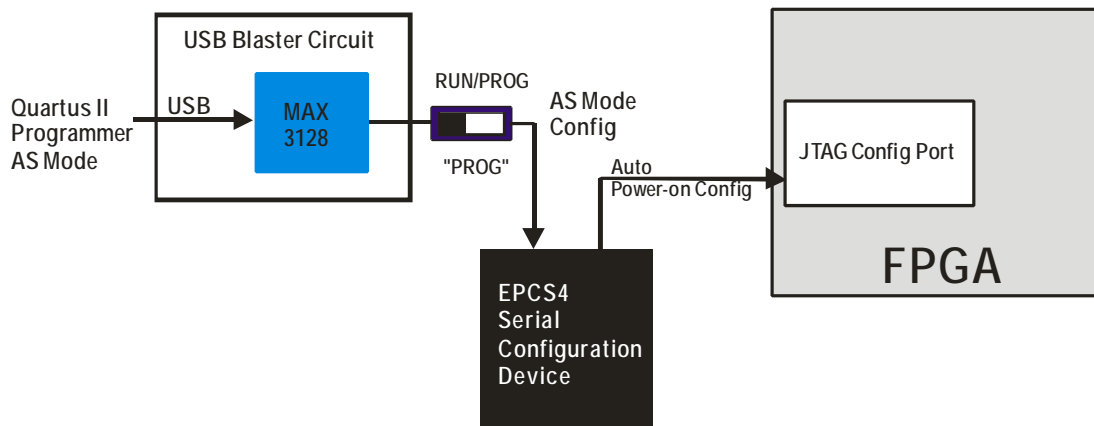


Figure 4.2. The AS configuration scheme.

In addition to its use for JTAG and AS programming, the USB Blaster port on the DE1 board can also be used to control some of the board's features remotely from a host computer. Details that describe this method of using the USB Blaster port are given in Chapter 3.

## 4.2 Using the LEDs and Switches

The DE1 board provides four pushbutton switches. Each of these switches is debounced using a Schmitt Trigger circuit, as indicated in Figure 4.3. The four outputs called *KEY0*, ..., *KEY3* of the Schmitt Trigger device are connected directly to the Cyclone II FPGA. Each switch provides a high logic level (3.3 volts) when it is not pressed, and provides a low logic level (0 volts) when depressed. Since the pushbutton switches are debounced, they are appropriate for use as clock or reset inputs in a circuit.

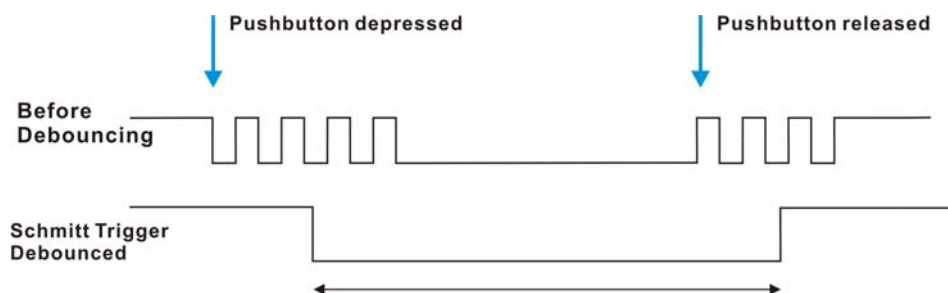


Figure 4.3. Switch debouncing.

There are also 10 toggle switches (sliders) on the DE1 board. These switches are not debounced, and are intended for use as level-sensitive data inputs to a circuit. Each switch is connected directly to a pin on the Cyclone II FPGA. When a switch is in the DOWN position (closest to the edge of the board) it provides a low logic level (0 volts) to the FPGA, and when the switch is in the UP position it provides a high logic level (3.3 volts).

There are 27 user-controllable LEDs on the DE1 board. Eighteen red LEDs are situated above the 18 toggle switches, and eight green LEDs are found above the pushbutton switches (the 9<sup>th</sup> green LED is in the middle of the 7-segment displays). Each LED is driven directly by a pin on the Cyclone II FPGA; driving its associated pin to a high logic level turns the LED on, and driving the pin low turns it off. A schematic diagram that shows the pushbutton and toggle switches is given in Figure 4.4. A schematic diagram that shows the LED circuitry appears in Figure 4.5.

A list of the pin names on the Cyclone II FPGA that are connected to the toggle switches is given in Table 4.1. Similarly, the pins used to connect to the pushbutton switches and LEDs are displayed in Tables 4.2 and 4.3, respectively.

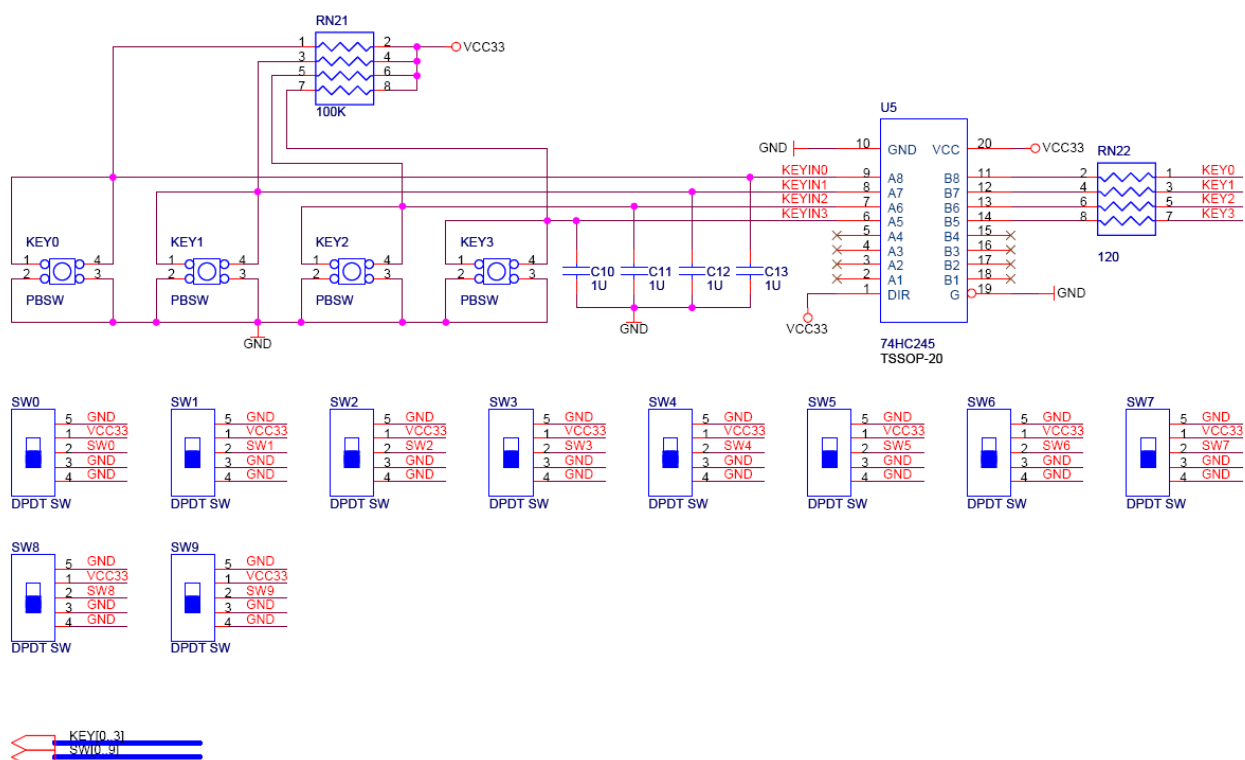


Figure 4.4. Schematic diagram of the pushbutton and toggle switches.

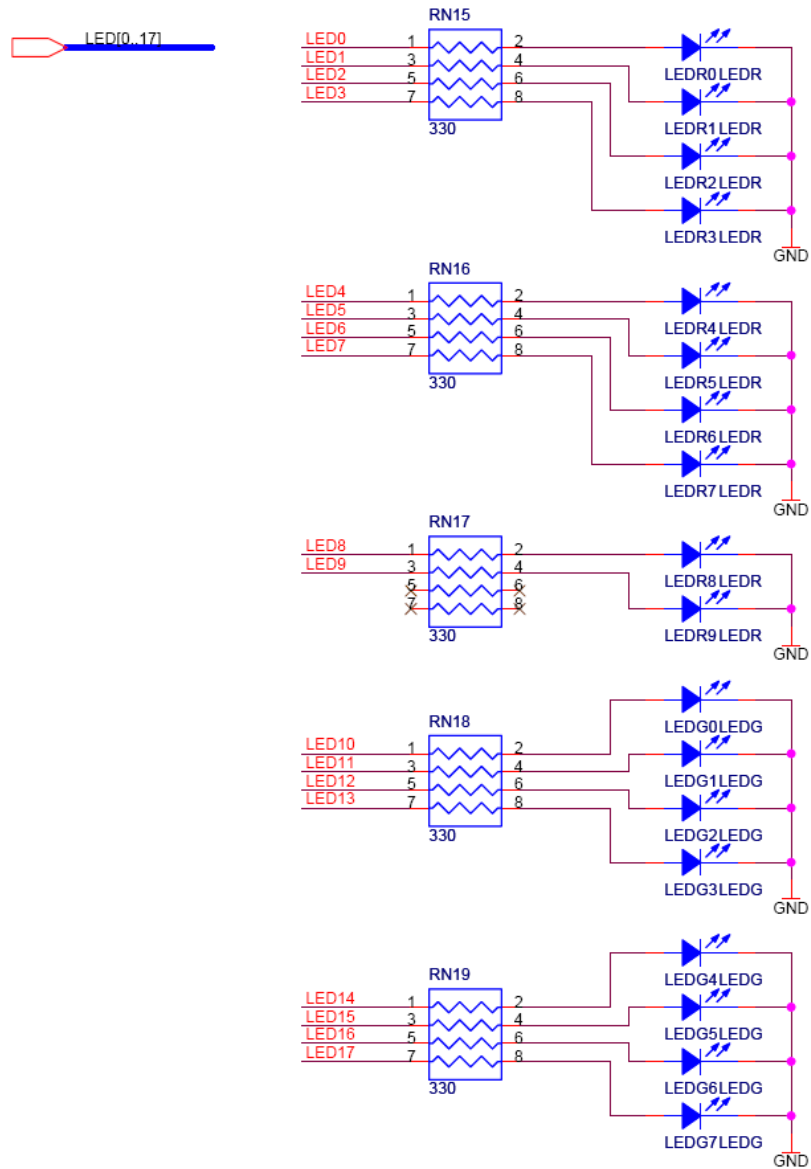


Figure 4.5. Schematic diagram of the LEDs.

Signal Name	FPGA Pin No.	Description
SW[0]	PIN_L22	Toggle Switch[0]
SW[1]	PIN_L21	Toggle Switch[1]
SW[2]	PIN_M22	Toggle Switch[2]
SW[3]	PIN_V12	Toggle Switch[3]
SW[4]	PIN_W12	Toggle Switch[4]
SW[5]	PIN_U12	Toggle Switch[5]
SW[6]	PIN_U11	Toggle Switch[6]
SW[7]	PIN_M2	Toggle Switch[7]

SW[8]	PIN_M1	Toggle Switch[8]
SW[9]	PIN_L2	Toggle Switch[9]

Table 4.1. Pin assignments for the toggle switches.

Signal Name	FPGA Pin No.	Description
KEY[0]	PIN_R22	Pushbutton[0]
KEY[1]	PIN_R21	Pushbutton[1]
KEY[2]	PIN_T22	Pushbutton[2]
KEY[3]	PIN_T21	Pushbutton[3]

Table 4.2. Pin assignments for the pushbutton switches.

Signal Name	FPGA Pin No.	Description
LEDR[0]	PIN_R20	LED Red[0]
LEDR[1]	PIN_R19	LED Red[1]
LEDR[2]	PIN_U19	LED Red[2]
LEDR[3]	PIN_Y19	LED Red[3]
LEDR[4]	PIN_T18	LED Red[4]
LEDR[5]	PIN_V19	LED Red[5]
LEDR[6]	PIN_Y18	LED Red[6]
LEDR[7]	PIN_U18	LED Red[7]
LEDR[8]	PIN_R18	LED Red[8]
LEDR[9]	PIN_R17	LED Red[9]
LEDG[0]	PIN_U22	LED Green[0]
LEDG[1]	PIN_U21	LED Green[1]
LEDG[2]	PIN_V22	LED Green[2]
LEDG[3]	PIN_V21	LED Green[3]
LEDG[4]	PIN_W22	LED Green[4]
LEDG[5]	PIN_W21	LED Green[5]
LEDG[6]	PIN_Y22	LED Green[6]
LEDG[7]	PIN_Y21	LED Green[7]

Table 4.3. Pin assignments for the LEDs.

## 4.3 Using the 7-segment Displays

The DE1 Board has four 7-segment displays. These displays are arranged into a group of four, with the intent of displaying numbers of various sizes. As indicated in the schematic in Figure 4.6, the seven segments are connected to pins on the Cyclone II FPGA. Applying a low logic level to a segment causes it to light up, and applying a high logic level turns it off.

Each segment in a display is identified by an index from 0 to 6, with the positions given in Figure 4.7. Note that the dot in each display is unconnected and cannot be used. Table 4.4 shows the assignments of FPGA pins to the 7-segment displays.

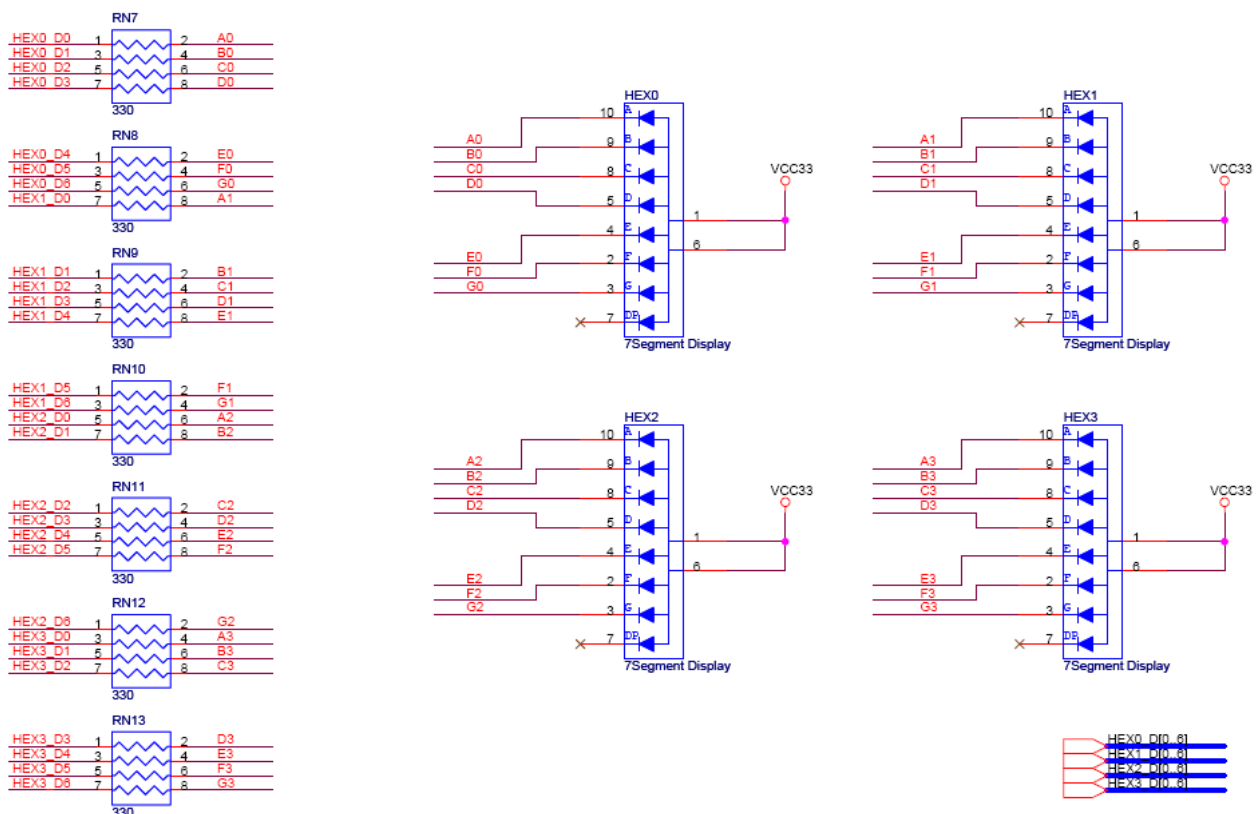


Figure 4.6. Schematic diagram of the 7-segment displays.

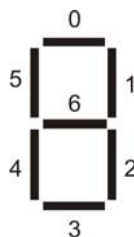


Figure 4.7. Position and index of each segment in a 7-segment display.

Signal Name	FPGA Pin No.	Description
HEX0[0]	PIN_J2	Seven Segment Digit 0[0]
HEX0[1]	PIN_J1	Seven Segment Digit 0[1]
HEX0[2]	PIN_H2	Seven Segment Digit 0[2]
HEX0[3]	PIN_H1	Seven Segment Digit 0[3]
HEX0[4]	PIN_F2	Seven Segment Digit 0[4]
HEX0[5]	PIN_F1	Seven Segment Digit 0[5]
HEX0[6]	PIN_E2	Seven Segment Digit 0[6]
HEX1[0]	PIN_E1	Seven Segment Digit 1[0]
HEX1[1]	PIN_H6	Seven Segment Digit 1[1]
HEX1[2]	PIN_H5	Seven Segment Digit 1[2]
HEX1[3]	PIN_H4	Seven Segment Digit 1[3]
HEX1[4]	PIN_G3	Seven Segment Digit 1[4]
HEX1[5]	PIN_D2	Seven Segment Digit 1[5]
HEX1[6]	PIN_D1	Seven Segment Digit 1[6]
HEX2[0]	PIN_G5	Seven Segment Digit 2[0]
HEX2[1]	PIN_G6	Seven Segment Digit 2[1]
HEX2[2]	PIN_C2	Seven Segment Digit 2[2]
HEX2[3]	PIN_C1	Seven Segment Digit 2[3]
HEX2[4]	PIN_E3	Seven Segment Digit 2[4]
HEX2[5]	PIN_E4	Seven Segment Digit 2[5]
HEX2[6]	PIN_D3	Seven Segment Digit 2[6]
HEX3[0]	PIN_F4	Seven Segment Digit 3[0]
HEX3[1]	PIN_D5	Seven Segment Digit 3[1]
HEX3[2]	PIN_D6	Seven Segment Digit 3[2]
HEX3[3]	PIN_J4	Seven Segment Digit 3[3]
HEX3[4]	PIN_L8	Seven Segment Digit 3[4]
HEX3[5]	PIN_F3	Seven Segment Digit 3[5]
HEX3[6]	PIN_D4	Seven Segment Digit 3[6]

Table 4.4. Pin assignments for the 7-segment displays.

## 4.4 Clock Inputs

The DE1 board includes **three oscillators that produce 27 MHz, 24Mhz, and 50 MHz clock signals**. The board also includes an SMA connector which can be used to connect an external clock source to the board. The schematic of the clock circuitry is shown in Figure 4.8, and the associated pin assignments appear in Table 4.5.

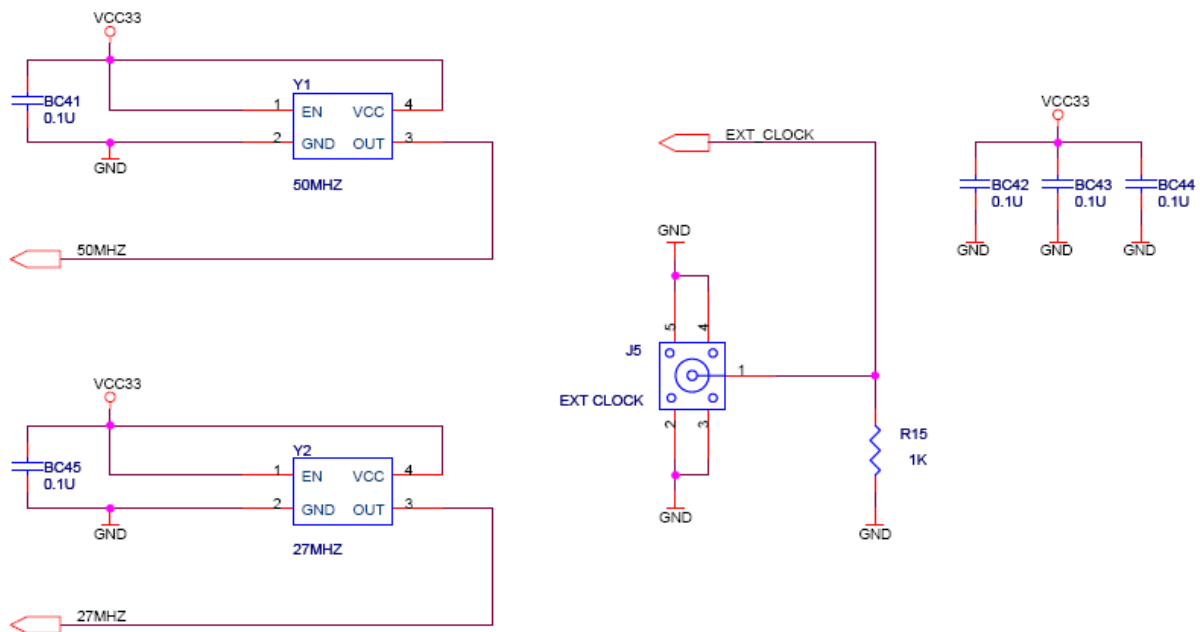


Figure 4.8. Schematic diagram of the clock circuit.

Signal Name	FPGA Pin No.	Description
CLOCK_27	PIN_D12, PIN_E12	27 MHz clock input
CLOCK_50	PIN_L1	50 MHz clock input
CLOCK_24	PIN_A12, PIN_B12	24 MHz clock input from USB Blaster
EXT_CLOCK	PIN_M21	External (SMA) clock input

Table 4.5. Pin assignments for the clock inputs.

## 4.5 Using the Expansion Header

The DE1 Board provides two 40-pin expansion headers. Each header connects directly to 36 pins on the Cyclone II FPGA, and also provides DC +5V (VCC5), DC +3.3V (VCC33), and two GND pins. Figure 4.10 shows the related schematics. Each pin on the expansion headers is connected to a resistor that provide protection from high and low voltages. The figure shows the protection circuitry for only four of the pins on each header, but this circuitry is included for all 72 data pins. Table 4.7 gives the pin assignments.



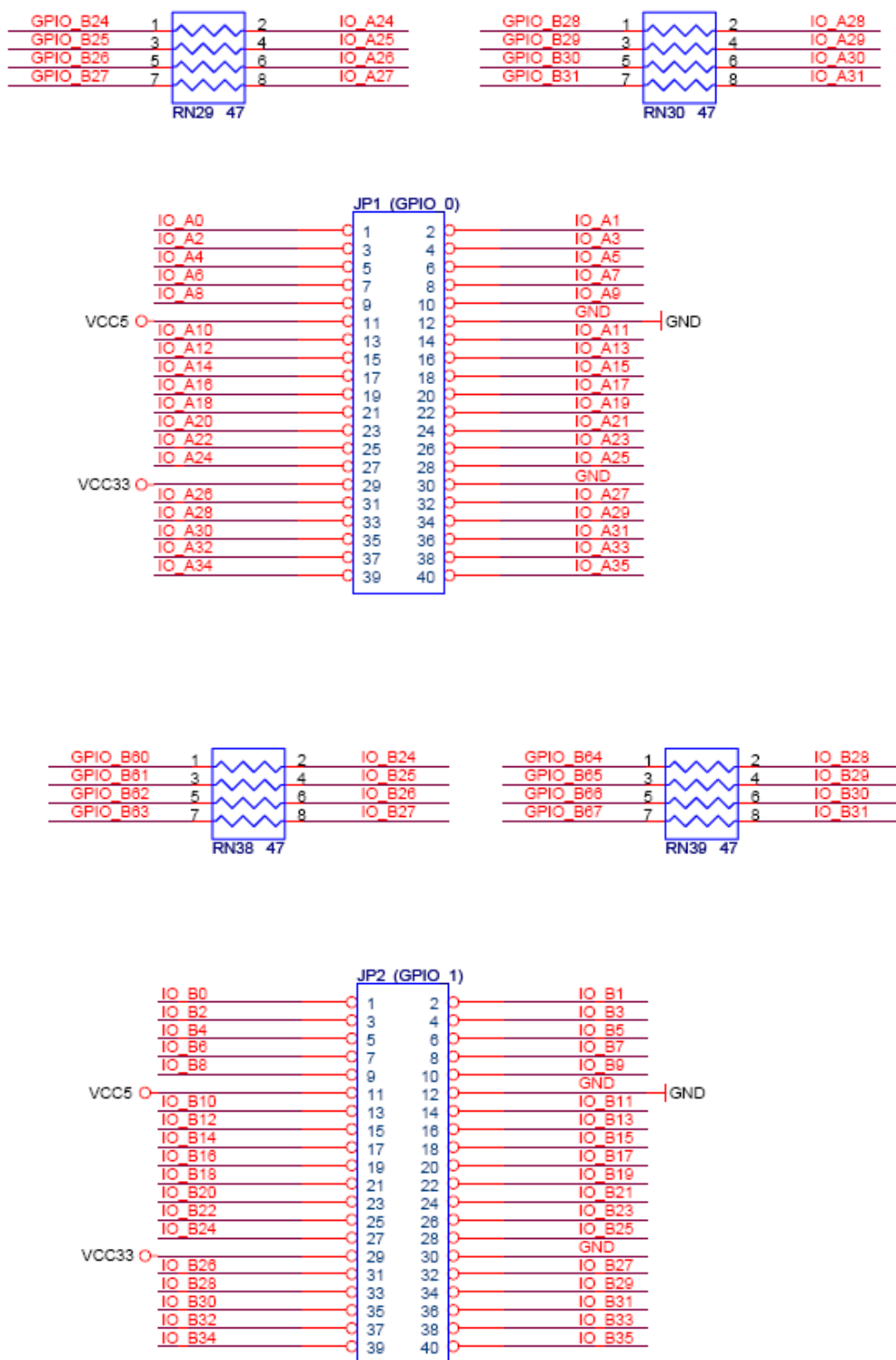


Figure 4.10. Schematic diagram of the expansion headers.

Signal Name	FPGA Pin No.	Description
GPIO_0[0]	PIN_A13	GPIO Connection 0[0]

GPIO_0[1]	PIN_B13	GPIO Connection 0[1]
GPIO_0[2]	PIN_A14	GPIO Connection 0[2]
GPIO_0[3]	PIN_B14	GPIO Connection 0[3]
GPIO_0[4]	PIN_A15	GPIO Connection 0[4]
GPIO_0[5]	PIN_B15	GPIO Connection 0[5]
GPIO_0[6]	PIN_A16	GPIO Connection 0[6]
GPIO_0[7]	PIN_B16	GPIO Connection 0[7]
GPIO_0[8]	PIN_A17	GPIO Connection 0[8]
GPIO_0[9]	PIN_B17	GPIO Connection 0[9]
GPIO_0[10]	PIN_A18	GPIO Connection 0[10]
GPIO_0[11]	PIN_B18	GPIO Connection 0[11]
GPIO_0[12]	PIN_A19	GPIO Connection 0[12]
GPIO_0[13]	PIN_B19	GPIO Connection 0[13]
GPIO_0[14]	PIN_A20	GPIO Connection 0[14]
GPIO_0[15]	PIN_B20	GPIO Connection 0[15]
GPIO_0[16]	PIN_C21	GPIO Connection 0[16]
GPIO_0[17]	PIN_C22	GPIO Connection 0[17]
GPIO_0[18]	PIN_D21	GPIO Connection 0[18]
GPIO_0[19]	PIN_D22	GPIO Connection 0[19]
GPIO_0[20]	PIN_E21	GPIO Connection 0[20]
GPIO_0[21]	PIN_E22	GPIO Connection 0[21]
GPIO_0[22]	PIN_F21	GPIO Connection 0[22]
GPIO_0[23]	PIN_F22	GPIO Connection 0[23]
GPIO_0[24]	PIN_G21	GPIO Connection 0[24]
GPIO_0[25]	PIN_G22	GPIO Connection 0[25]
GPIO_0[26]	PIN_J21	GPIO Connection 0[26]
GPIO_0[27]	PIN_J22	GPIO Connection 0[27]
GPIO_0[28]	PIN_K21	GPIO Connection 0[28]
GPIO_0[29]	PIN_K22	GPIO Connection 0[29]
GPIO_0[30]	PIN_J19	GPIO Connection 0[30]
GPIO_0[31]	PIN_J20	GPIO Connection 0[31]
GPIO_0[32]	PIN_J18	GPIO Connection 0[32]
GPIO_0[33]	PIN_K20	GPIO Connection 0[33]
GPIO_0[34]	PIN_L19	GPIO Connection 0[34]
GPIO_0[35]	PIN_L18	GPIO Connection 0[35]
GPIO_1[0]	PIN_H12	GPIO Connection 1[0]
GPIO_1[1]	PIN_H13	GPIO Connection 1[1]

GPIO_1[2]	PIN_H14	GPIO Connection 1[2]
GPIO_1[3]	PIN_G15	GPIO Connection 1[3]
GPIO_1[4]	PIN_E14	GPIO Connection 1[4]
GPIO_1[5]	PIN_E15	GPIO Connection 1[5]
GPIO_1[6]	PIN_F15	GPIO Connection 1[6]
GPIO_1[7]	PIN_G16	GPIO Connection 1[7]
GPIO_1[8]	PIN_F12	GPIO Connection 1[8]
GPIO_1[9]	PIN_F13	GPIO Connection 1[9]
GPIO_1[10]	PIN_C14	GPIO Connection 1[10]
GPIO_1[11]	PIN_D14	GPIO Connection 1[11]
GPIO_1[12]	PIN_D15	GPIO Connection 1[12]
GPIO_1[13]	PIN_D16	GPIO Connection 1[13]
GPIO_1[14]	PIN_C17	GPIO Connection 1[14]
GPIO_1[15]	PIN_C18	GPIO Connection 1[15]
GPIO_1[16]	PIN_C19	GPIO Connection 1[16]
GPIO_1[17]	PIN_C20	GPIO Connection 1[17]
GPIO_1[18]	PIN_D19	GPIO Connection 1[18]
GPIO_1[19]	PIN_D20	GPIO Connection 1[19]
GPIO_1[20]	PIN_E20	GPIO Connection 1[20]
GPIO_1[21]	PIN_F20	GPIO Connection 1[21]
GPIO_1[22]	PIN_E19	GPIO Connection 1[22]
GPIO_1[23]	PIN_E18	GPIO Connection 1[23]
GPIO_1[24]	PIN_G20	GPIO Connection 1[24]
GPIO_1[25]	PIN_G18	GPIO Connection 1[25]
GPIO_1[26]	PIN_G17	GPIO Connection 1[26]
GPIO_1[27]	PIN_H17	GPIO Connection 1[27]
GPIO_1[28]	PIN_J15	GPIO Connection 1[28]
GPIO_1[29]	PIN_H18	GPIO Connection 1[29]
GPIO_1[30]	PIN_N22	GPIO Connection 1[30]
GPIO_1[31]	PIN_N21	GPIO Connection 1[31]
GPIO_1[32]	PIN_P15	GPIO Connection 1[32]
GPIO_1[33]	PIN_N15	GPIO Connection 1[33]
GPIO_1[34]	PIN_P17	GPIO Connection 1[34]
GPIO_1[35]	PIN_P18	GPIO Connection 1[35]

Table 4.7. Pin assignments for the expansion headers.

## 4.6 Using VGA

The DE1 board includes a 16-pin D-SUB connector for VGA output. The VGA synchronization signals are provided directly from the Cyclone II 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 4.11 and can support standard VGA resolution (640x480 pixels, at 25 MHz).

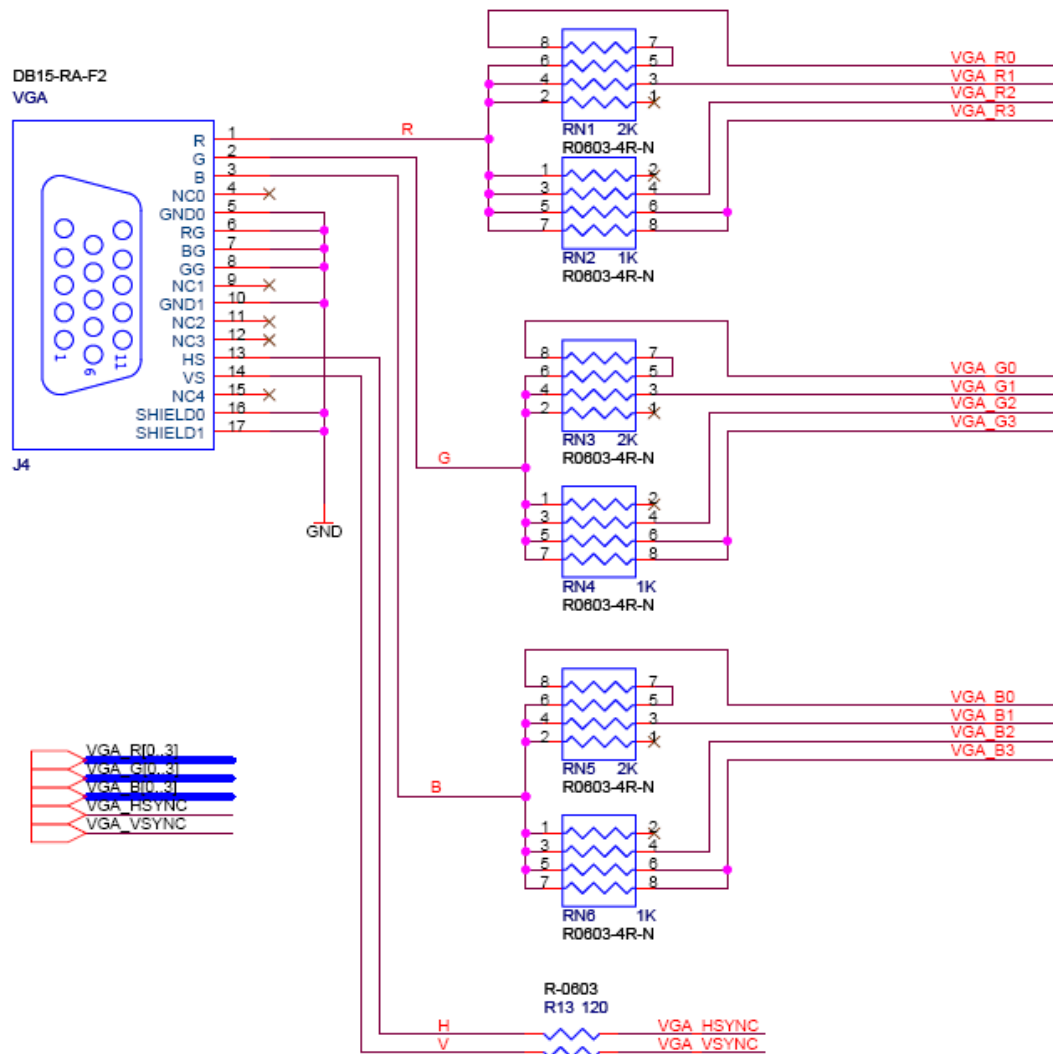


Figure 4.11. VGA circuit schematic.

The timing specification for VGA synchronization and RGB (red, green, blue) data can be found on various educational web sites (for example, search for “VGA signal timing”). Figure 4.12 illustrates the basic timing requirements for each row (horizontal) that is displayed on a VGA monitor. An active-low pulse of specific duration (time  $a$  in the figure) 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) inputs on 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 the vertical synchronization (*vsync*) is the same as shown in Figure 4.12, 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). Figures 4.13 and 4.14 show, for different resolutions, the durations of time periods  $a$ ,  $b$ ,  $c$ , and  $d$  for both horizontal and vertical timing.

The pin assignments between the Cyclone II FPGA and the VGA connector are listed in Table 4.8. An example of code that drives a VGA display is described in Sections 5.2 and 5.3.

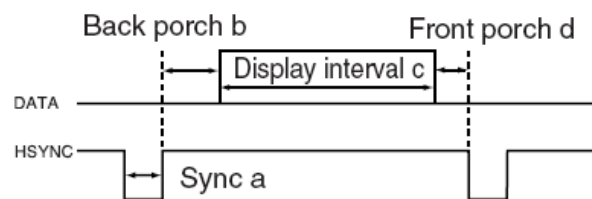


Figure 4.12. VGA horizontal timing specification.

VGA mode		Horizontal Timing Spec				
Configuration	Resolution(HxV)	a(us)	b(us)	c(us)	d(us)	Pixel clock(Mhz)
VGA(60Hz)	640x480	3.8	1.9	25.4	0.6	25 (640/c)

Figure 4.13. VGA horizontal timing specification.

VGA mode		Vertical Timing Spec			
Configuration	Resolution (HxV)	a(lines)	b(lines)	c(lines)	d(lines)
VGA(60Hz)	640x480	2	33	480	10

Figure 4.14. VGA vertical timing specification.

Signal Name	FPGA Pin No.	Description
VGA_R[0]	PIN_D9	VGA Red[0]
VGA_R[1]	PIN_C9	VGA Red[1]
VGA_R[2]	PIN_A7	VGA Red[2]
VGA_R[3]	PIN_B7	VGA Red[3]
VGA_G[0]	PIN_B8	VGA Green[0]
VGA_G[1]	PIN_C10	VGA Green[1]
VGA_G[2]	PIN_B9	VGA Green[2]
VGA_G[3]	PIN_A8	VGA Green[3]

VGA_B[0]	PIN_A9	VGA Blue[0]
VGA_B[1]	PIN_D11	VGA Blue[1]
VGA_B[2]	PIN_A10	VGA Blue[2]
VGA_B[3]	PIN_B10	VGA Blue[3]
VGA_HS	PIN_A11	VGA H_SYNC
VGA_VS	PIN_B11	VGA V_SYNC

Table 4.8. ADV7123 pin assignments.

## 4.7 Using the 24-bit Audio CODEC

The DE1 board provides high-quality 24-bit audio via the Wolfson WM8731 audio CODEC (enCOder/DECOder). This chip supports microphone-in, line-in, and line-out ports, with a sample rate adjustable from 8 kHz to 96 kHz. The WM8731 is controlled by a serial I2C bus interface, which is connected to pins on the Cyclone II FPGA. A schematic diagram of the audio circuitry is shown in Figure 4.15, and the FPGA pin assignments are listed in Table 4.9. Detailed information for using the WM8731 codec is available in its datasheet, which can be found on the manufacturer's web site, and from the *Datasheet* folder on the **DE1 System CD-ROM**.

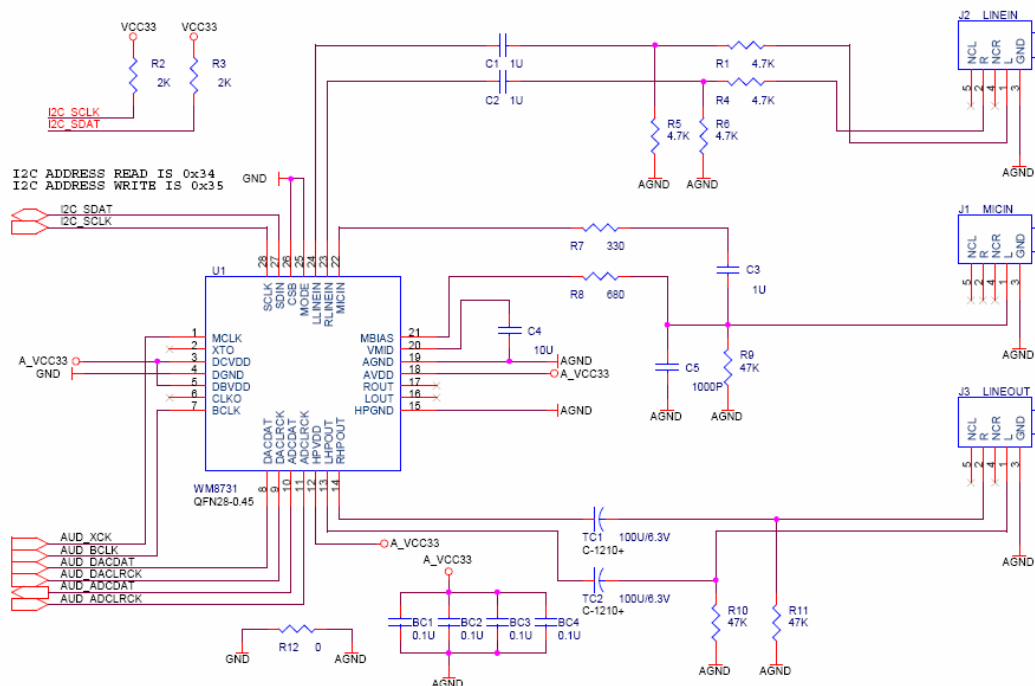


Figure 4.15. Audio CODEC schematic.

Signal Name	FPGA Pin No.	Description
AUD_ADCLRCK	PIN_A6	Audio CODEC ADC LR Clock
AUD_ADCDAT	PIN_B6	Audio CODEC ADC Data
AUD_DACLK	PIN_A5	Audio CODEC DAC LR Clock
AUD_DACDAT	PIN_B5	Audio CODEC DAC Data
AUD_XCK	PIN_B4	Audio CODEC Chip Clock
AUD_BCLK	PIN_A4	Audio CODEC Bit-Stream Clock
I2C_SCLK	PIN_A3	I2C Data
I2C_SDAT	PIN_B3	I2C Clock

Table 4.9. Audio CODEC pin assignments.

## 4.8 RS-232 Serial Port

The DE1 board uses the MAX232 transceiver chip and a 9-pin D-SUB connector for RS-232 communications. For detailed information on how to use the transceiver refer to the datasheet, which is available on the manufacturer's web site, and from the *Datasheet* folder on the **DE1 System CD-ROM**. Figure 4.16 shows the related schematics, and Table 4.10 lists the Cyclone II FPGA pin assignments.

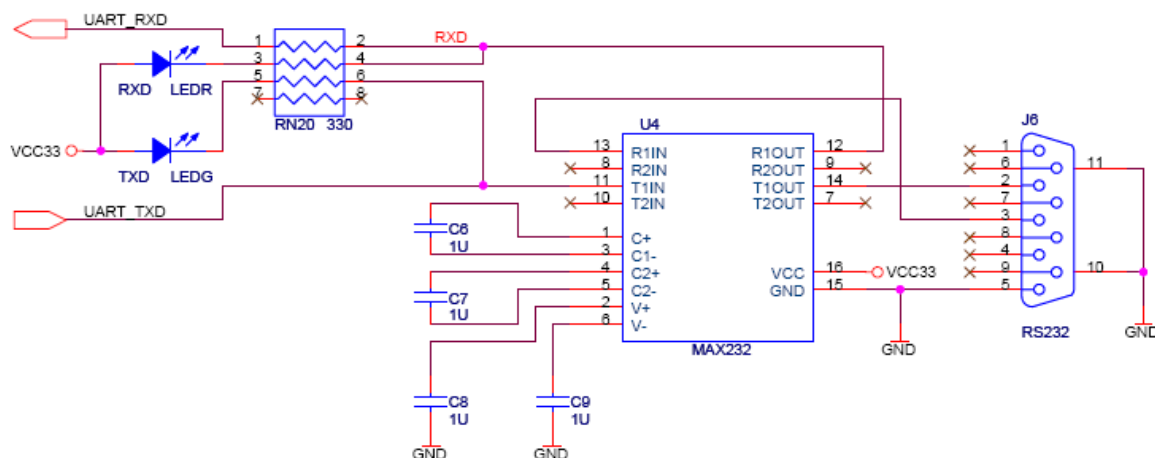


Figure 4.16. MAX232 (RS-232) chip schematic.

Signal Name	FPGA Pin No.	Description
UART_RXD	PIN_F14	UART Receiver
UART_TXD	PIN_G12	UART Transmitter

Table 4.10. RS-232 pin assignments.



## 4.9 PS/2 Serial Port

The DE1 board includes a standard PS/2 interface and a connector for a PS/2 keyboard or mouse. Figure 4.17 shows the schematic of the PS/2 circuit. Instructions for using a PS/2 mouse or keyboard can be found by performing an appropriate search on various educational web sites. The pin assignments for the associated interface are shown in Table 4.11.

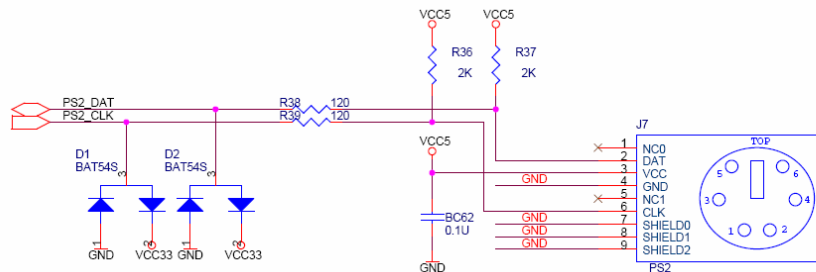


Figure 4.17. PS/2 schematic.

Signal Name	FPGA Pin No.	Description
PS2_CLK	PIN_H15	PS/2 Clock
PS2_DAT	PIN_J14	PS/2 Data

Table 4.11. PS/2 pin assignments.

## 4.10 Using SDRAM/SRAM/Flash

The DE1 board provides an 8-Mbyte SDRAM, 512-Kbyte SRAM, and 4-Mbyte (1-Mbyte on some boards) Flash memory. Figures 4.23, 4.24, and 4.25 show the schematics of the memory chips. The pin assignments for each device are listed in Tables 4.16, 4.17, and 4.18. The datasheets for the memory chips are provided in the *Datasheet* folder on the **DE1 System CD-ROM**.

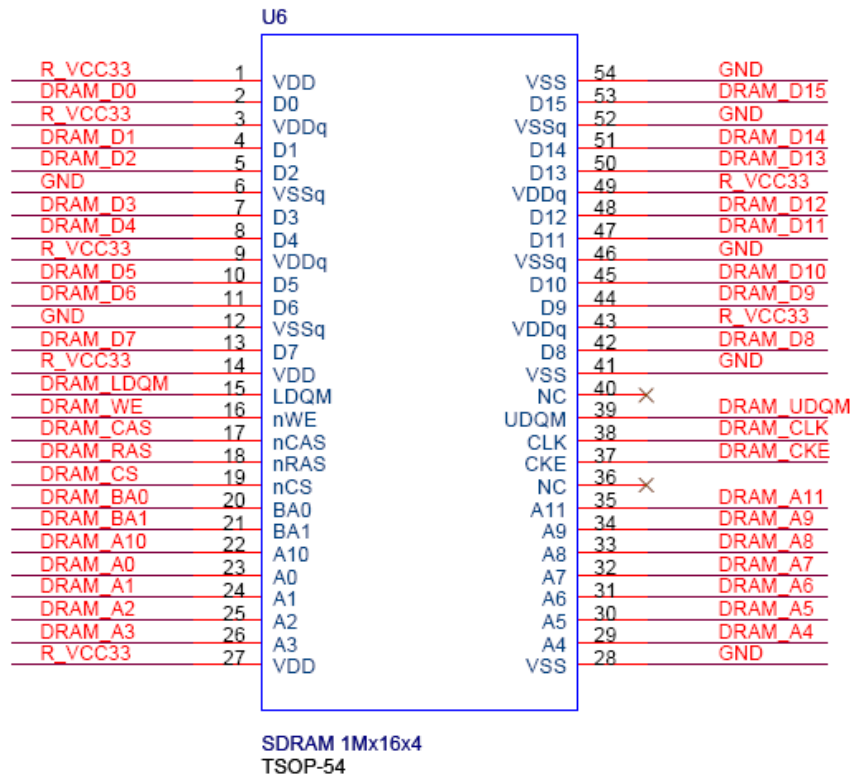


Figure 4.23. SDRAM schematic.

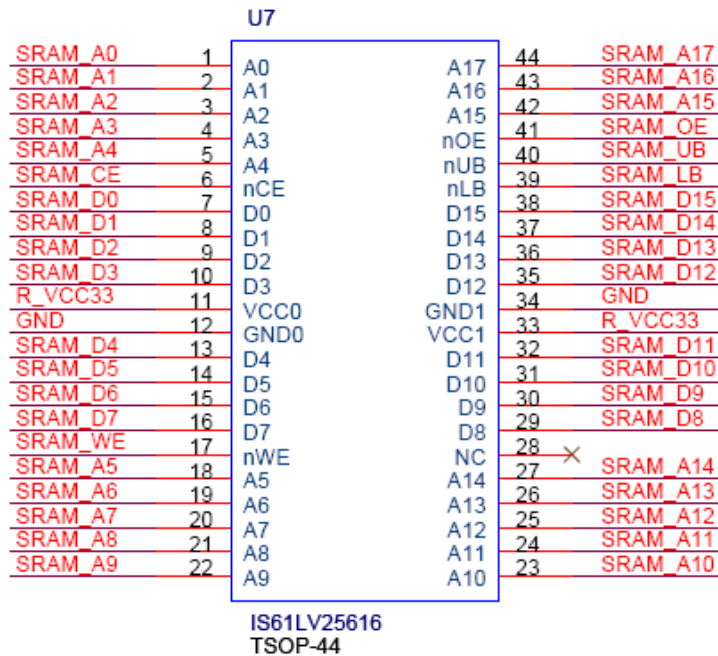


Figure 4.24. SRAM schematic.

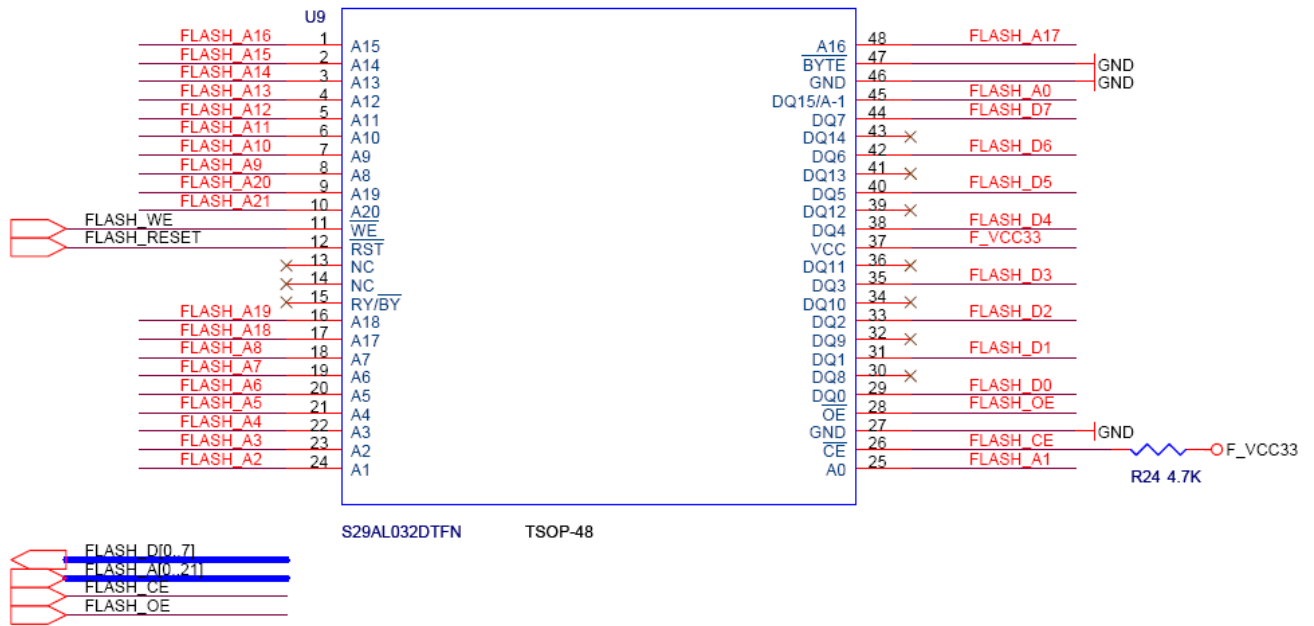


Figure 4.25. Flash schematic.

Signal Name	FPGA Pin No.	Description
DRAM_ADDR[0]	PIN_W4	SDRAM Address[0]
DRAM_ADDR[1]	PIN_W5	SDRAM Address[1]
DRAM_ADDR[2]	PIN_Y3	SDRAM Address[2]
DRAM_ADDR[3]	PIN_Y4	SDRAM Address[3]
DRAM_ADDR[4]	PIN_R6	SDRAM Address[4]
DRAM_ADDR[5]	PIN_R5	SDRAM Address[5]
DRAM_ADDR[6]	PIN_P6	SDRAM Address[6]
DRAM_ADDR[7]	PIN_P5	SDRAM Address[7]
DRAM_ADDR[8]	PIN_P3	SDRAM Address[8]
DRAM_ADDR[9]	PIN_N4	SDRAM Address[9]
DRAM_ADDR[10]	PIN_W3	SDRAM Address[10]
DRAM_ADDR[11]	PIN_N6	SDRAM Address[11]
DRAM_DQ[0]	PIN_U1	SDRAM Data[0]
DRAM_DQ[1]	PIN_U2	SDRAM Data[1]
DRAM_DQ[2]	PIN_V1	SDRAM Data[2]
DRAM_DQ[3]	PIN_V2	SDRAM Data[3]
DRAM_DQ[4]	PIN_W1	SDRAM Data[4]
DRAM_DQ[5]	PIN_W2	SDRAM Data[5]
DRAM_DQ[6]	PIN_Y1	SDRAM Data[6]

DRAM_DQ[7]	PIN_Y2	SDRAM Data[7]
DRAM_DQ[8]	PIN_N1	SDRAM Data[8]
DRAM_DQ[9]	PIN_N2	SDRAM Data[9]
DRAM_DQ[10]	PIN_P1	SDRAM Data[10]
DRAM_DQ[11]	PIN_P2	SDRAM Data[11]
DRAM_DQ[12]	PIN_R1	SDRAM Data[12]
DRAM_DQ[13]	PIN_R2	SDRAM Data[13]
DRAM_DQ[14]	PIN_T1	SDRAM Data[14]
DRAM_DQ[15]	PIN_T2	SDRAM Data[15]
DRAM_BA_0	PIN_U3	SDRAM Bank Address[0]
DRAM_BA_1	PIN_V4	SDRAM Bank Address[1]
DRAM_LDQM	PIN_R7	SDRAM Low-byte Data Mask
DRAM_UDQM	PIN_M5	SDRAM High-byte Data Mask
DRAM_RAS_N	PIN_T5	SDRAM Row Address Strobe
DRAM_CAS_N	PIN_T3	SDRAM Column Address Strobe
DRAM_CKE	PIN_N3	SDRAM Clock Enable
DRAM_CLK	PIN_U4	SDRAM Clock
DRAM_WE_N	PIN_R8	SDRAM Write Enable
DRAM_CS_N	PIN_T6	SDRAM Chip Select

Table 4.16. SDRAM pin assignments.

Signal Name	FPGA Pin No.	Description
SRAM_ADDR[0]	PIN_AA3	SRAM Address[0]
SRAM_ADDR[1]	PIN_AB3	SRAM Address[1]
SRAM_ADDR[2]	PIN_AA4	SRAM Address[2]
SRAM_ADDR[3]	PIN_AB4	SRAM Address[3]
SRAM_ADDR[4]	PIN_AA5	SRAM Address[4]
SRAM_ADDR[5]	PIN_AB10	SRAM Address[5]
SRAM_ADDR[6]	PIN_AA11	SRAM Address[6]
SRAM_ADDR[7]	PIN_AB11	SRAM Address[7]
SRAM_ADDR[8]	PIN_V11	SRAM Address[8]
SRAM_ADDR[9]	PIN_W11	SRAM Address[9]
SRAM_ADDR[10]	PIN_R11	SRAM Address[10]
SRAM_ADDR[11]	PIN_T11	SRAM Address[11]
SRAM_ADDR[12]	PIN_Y10	SRAM Address[12]
SRAM_ADDR[13]	PIN_U10	SRAM Address[13]

SRAM_ADDR[14]	PIN_R10	SRAM Address[14]
SRAM_ADDR[15]	PIN_T7	SRAM Address[15]
SRAM_ADDR[16]	PIN_Y6	SRAM Address[16]
SRAM_ADDR[17]	PIN_Y5	SRAM Address[17]
SRAM_DQ[0]	PIN_AA6	SRAM Data[0]
SRAM_DQ[1]	PIN_AB6	SRAM Data[1]
SRAM_DQ[2]	PIN_AA7	SRAM Data[2]
SRAM_DQ[3]	PIN_AB7	SRAM Data[3]
SRAM_DQ[4]	PIN_AA8	SRAM Data[4]
SRAM_DQ[5]	PIN_AB8	SRAM Data[5]
SRAM_DQ[6]	PIN_AA9	SRAM Data[6]
SRAM_DQ[7]	PIN_AB9	SRAM Data[7]
SRAM_DQ[8]	PIN_Y9	SRAM Data[8]
SRAM_DQ[9]	PIN_W9	SRAM Data[9]
SRAM_DQ[10]	PIN_V9	SRAM Data[10]
SRAM_DQ[11]	PIN_U9	SRAM Data[11]
SRAM_DQ[12]	PIN_R9	SRAM Data[12]
SRAM_DQ[13]	PIN_W8	SRAM Data[13]
SRAM_DQ[14]	PIN_V8	SRAM Data[14]
SRAM_DQ[15]	PIN_U8	SRAM Data[15]
SRAM_WE_N	PIN_AA10	SRAM Write Enable
SRAM_OE_N	PIN_T8	SRAM Output Enable
SRAM_UB_N	PIN_W7	SRAM High-byte Data Mask
SRAM_LB_N	PIN_Y7	SRAM Low-byte Data Mask
SRAM_CE_N	PIN_AB5	SRAM Chip Enable

Table 4.17. SRAM pin assignments.

Signal Name	FPGA Pin No.	Description
FL_ADDR[0]	PIN_AB20	FLASH Address[0]
FL_ADDR[1]	PIN_AA14	FLASH Address[1]
FL_ADDR[2]	PIN_Y16	FLASH Address[2]
FL_ADDR[3]	PIN_R15	FLASH Address[3]
FL_ADDR[4]	PIN_T15	FLASH Address[4]
FL_ADDR[5]	PIN_U15	FLASH Address[5]
FL_ADDR[6]	PIN_V15	FLASH Address[6]
FL_ADDR[7]	PIN_W15	FLASH Address[7]

FL_ADDR[8]	PIN_R14	FLASH Address[8]
FL_ADDR[9]	PIN_Y13	FLASH Address[9]
FL_ADDR[10]	PIN_R12	FLASH Address[10]
FL_ADDR[11]	PIN_T12	FLASH Address[11]
FL_ADDR[12]	PIN_AB14	FLASH Address[12]
FL_ADDR[13]	PIN_AA13	FLASH Address[13]
FL_ADDR[14]	PIN_AB13	FLASH Address[14]
FL_ADDR[15]	PIN_AA12	FLASH Address[15]
FL_ADDR[16]	PIN_AB12	FLASH Address[16]
FL_ADDR[17]	PIN_AA20	FLASH Address[17]
FL_ADDR[18]	PIN_U14	FLASH Address[18]
FL_ADDR[19]	PIN_V14	FLASH Address[19]
FL_ADDR[20]	PIN_U13	FLASH Address[20]
FL_ADDR[21]	PIN_R13	FLASH Address[21]
FL_DQ[0]	PIN_AB16	FLASH Data[0]
FL_DQ[1]	PIN_AA16	FLASH Data[1]
FL_DQ[2]	PIN_AB17	FLASH Data[2]
FL_DQ[3]	PIN_AA17	FLASH Data[3]
FL_DQ[4]	PIN_AB18	FLASH Data[4]
FL_DQ[5]	PIN_AA18	FLASH Data[5]
FL_DQ[6]	PIN_AB19	FLASH Data[6]
FL_DQ[7]	PIN_AA19	FLASH Data[7]
FL_OE_N	PIN_AA15	FLASH Output Enable
FL_RST_N	PIN_W14	FLASH Reset
FL_WE_N	PIN_Y14	FLASH Write Enable

Table 4.18. Flash pin assignments.