LatticeECP2M PCI Express Solutions Board

User's Guide

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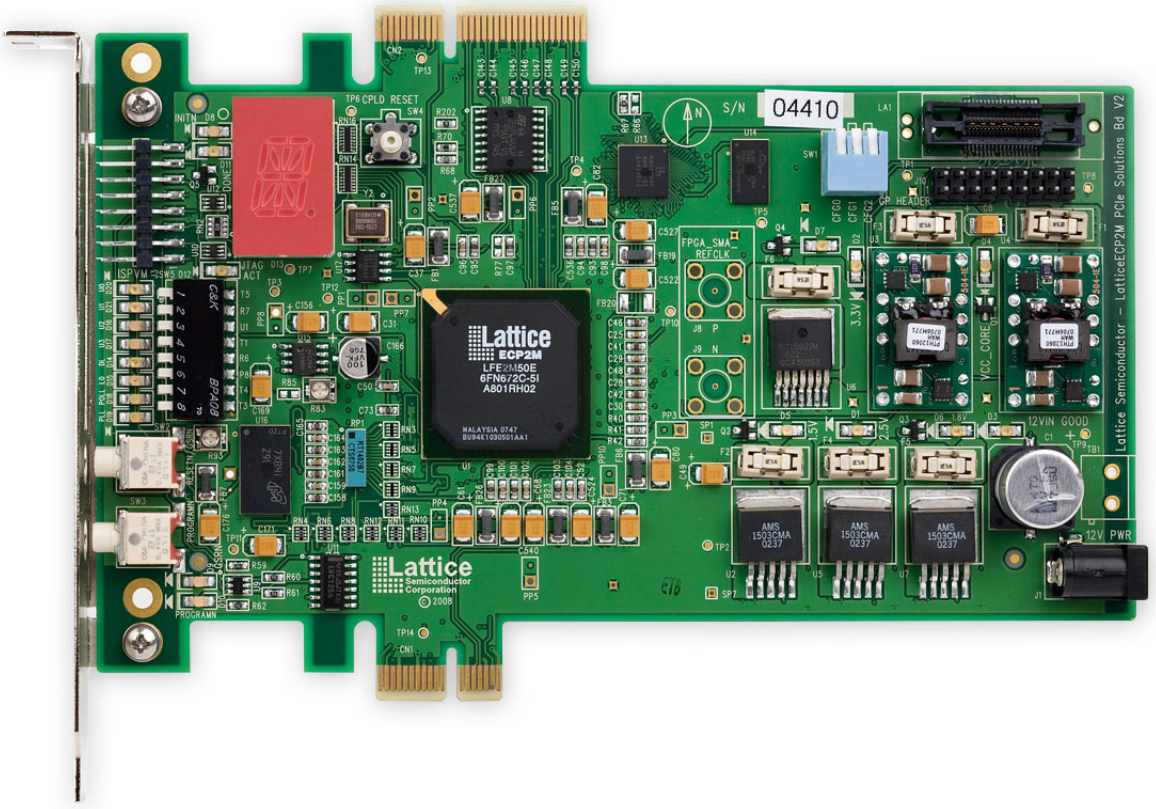
Introduction

As PCI Express applications have emerged, the LatticeECP2M™ FPGA family has become a well-suited solution for many system designs. The features of the LatticeECP2M PCI Express Solutions Board can assist engineers with rapid-prototyping and testing their designs. The board is an enhanced form-factor of the PCI Express add-in card specification. It allows for full x1 form-factor compliance and x4 is available for demonstration purposes with some non-standard form-factor issues. The flexibility to use the same board to demonstrate both x1 and x4 configurations is accomplished by simply changing the mounting hardware. The board has several debugging and analyzing features for complete evaluation of the LatticeECP2M device. This guide is intended to be referenced in conjunction with evaluation design tutorials to demonstrate the LatticeECP2M FPGA.

This user's guide describes the LatticeECP2M PCI Express Solutions Board featuring the LatticeECP2M LFE2M50-FF672 FPGA. The stand-alone evaluation board provides a functional platform for development and rapid prototyping of applications that require high-speed SERDES interfaces to demonstrate PCI Express capabilities using an add-on card form-factor. The board is manufactured using standard FR4 dielectric and through-hole vias. The nominal impedance is 50-ohm for single-ended traces and 100-ohm for differential traces.

Figure 1. LatticeECP2M PCI Express Solutions Board



Features

- PCI Express x1 and x4 edge connector interfaces
- Allows demonstration of PCI Express (x 1and x4) interfaces
  - x1 is form-factor compliant and will fit a standard PC-equipped PCI Express motherboard socket
  - x4 is non-compliant but will demonstrate x4 functionality by a simple change to the hardware
- Allows control of SERDES PCS registers using the Serial Client Interface (ORCAstra)

- On-board Boot Flash
  - Both Serial SPI Flash and Parallel Flash via MachXO™ programming bridge
- Shows interoperation with a high performance DDR2 memory component
- Includes driver based "run-time" device configuration capability via ORCAstra or PCI Express
- Switches, LEDs, displays for demo purposes
- Input connection for lab-power supply
- Power connections and power sources
- ispVM® programming support
- On-board and external reference clock sources

The contents of this user's guide include top-level functional descriptions of the various portions of the evaluation board, descriptions of the on-board connectors, diodes and switches and a complete set of schematics of the board.

Figure 2. PCI Express Solutions Board Outline Drawing, Top Side

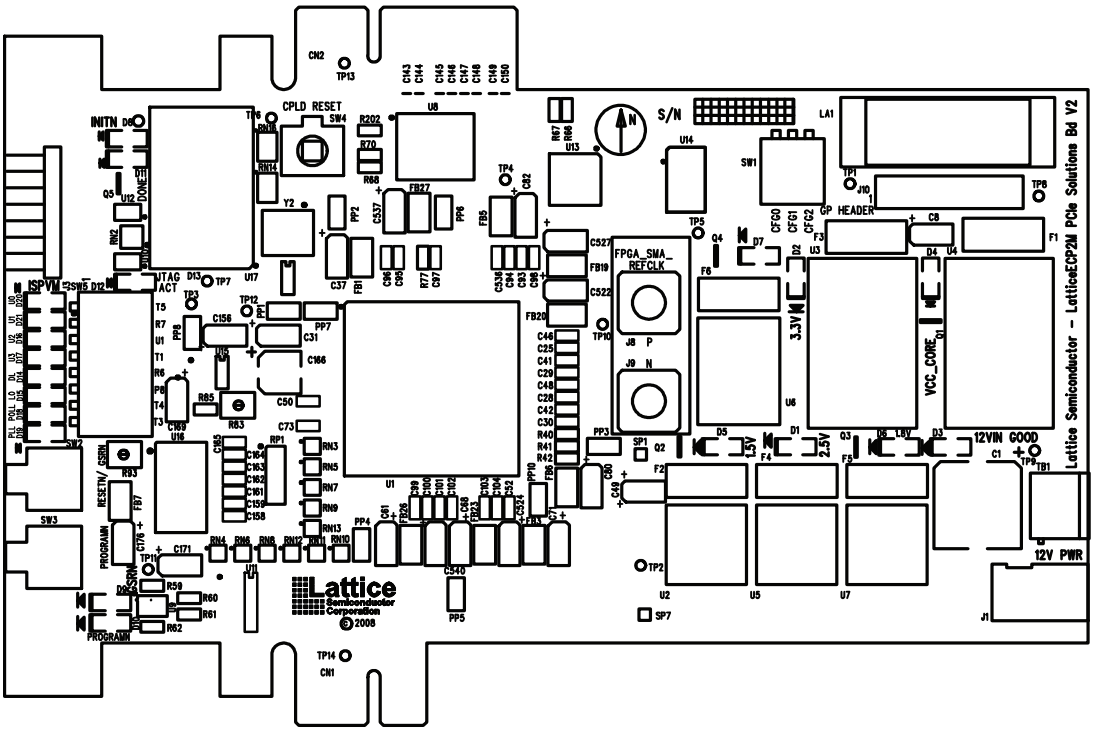
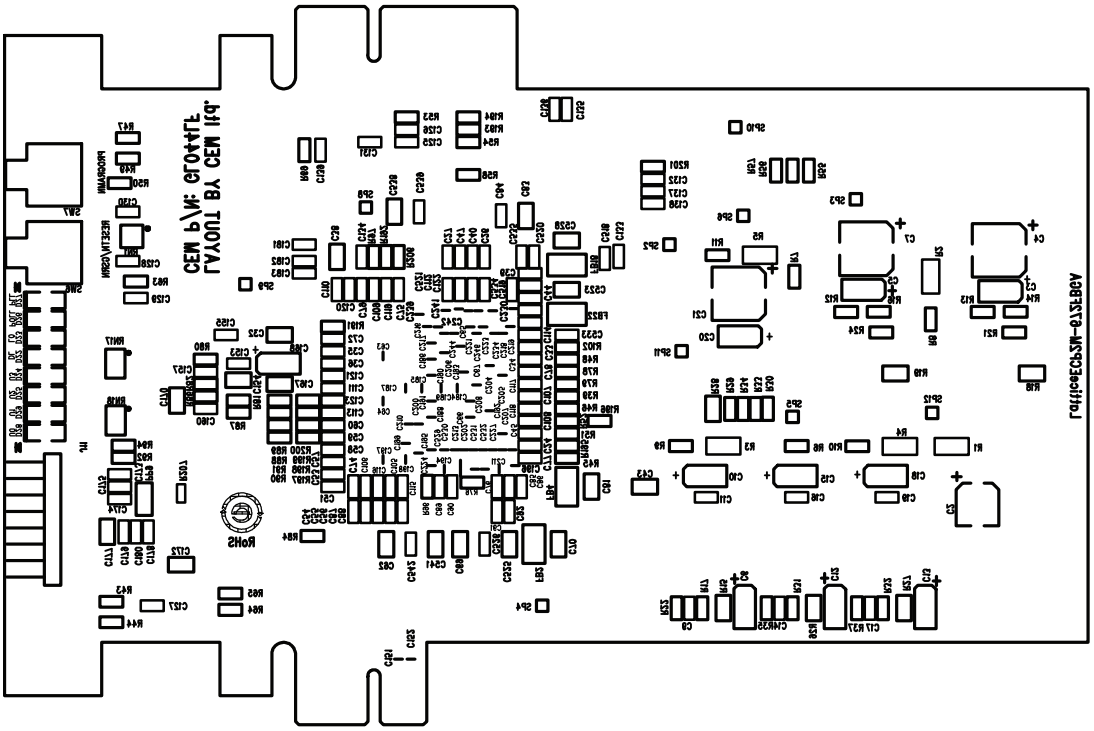


Figure 3. PCI Express Solutions Board Outline Drawing, Bottom Side

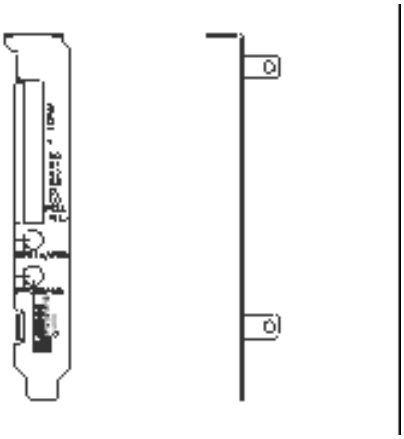


x1 and x4 PCI Express Support

PCI Express x1 and x4 is supported with the same PCB. This add-in PCB is designed to work in both types of motherboard slots. The PCB complies with the width and length dimensions of the PCI Express Card Electromechanical (CEM) Specification Revision 1.1. The only exclusion of the CEM specification is the component and back side of the add-in board may interfere with other boards in a fully-populated motherboard.

This board is easily interchanged from x1 to x4 configurations by removing the back-panel bracket and reinstalling it on the opposite side. This permits plug-in into PCI Express sockets on the motherboard and securing it in the chassis if desired. The back-panel bracket is shown below.

Figure 4. Back Panel Drawing



LatticeECP2M Device

This board features a LatticeECP2M FPGA with a 1.2V core supply. It can accommodate all pin compatible LatticeECP2M devices in the 672-ball fpBGA (1mm pitch) package. A complete description of this device can be found in the LatticeECP2M Family Data Sheet on the Lattice website at www.latticesemi.com.

Note: The connections referenced in this document refer to the LFE2M35E-FF672 device. Available I/Os and associated sysI/O™ banks may differ for other densities within this device family. However, only the LFE2M50E-FF672 device offers full functional use of the entire evaluation board.

Applying Power to the Board

The LatticeECP2M PCI Express Solutions Board is ready to power on. The board can be supplied with power from an AC wall-type transformer power supply shipped with the board. Or it can be supplied from a benchtop supply via terminal screw connections. It also has provisions to be supplied from the PCI Express edge fingers from a host board.

To supply power from the factory-supplied wall transformer, simply connect the output connection of the power cord to J1 and plug the wall-transformer into an AC wall-outlet.

Power Supplies

(see Appendix A, Figure 21)

The evaluation board incorporates an alternate scheme to provide power to the board. The board is equipped to accept a main supply via the TB1 connection. This connection is provided to use with a benchtop supply adjusted to provide a nominal +12V DC.

All input power sources and on-board power supplies are fused with surface-mounted fuses and have green LEDs to indicate power GOOD status of the intermediate supplies

Table 1. Board Power Supply Fuses (see Appendix A, Figure 21)

F1	1.2V Core Fuse
F2	1.5V Fuse
F3	3.3V Fuse
F4	2.5V Fuse
F5	1.8V Fuse
F6	1.2V Analog Supply

Table 2. Board Power Supply Indicators (see Appendix A, Figure 21)

D1	2.5V Source Good Indicator
D2	3.3V Source Good Indicator
D3	12V Input Good Indicator
D4	1.2V VCC Core Source Good Indicator
D5	1.5V Source Good Indicator
D6	1.8V Source Good Indicator
D7	1.2V Analog Source Good Indicator

External power can be alternatively connected rather than the wall transformer power pack.

Table 3. External Board Supply Input Terminal (see Appendix A, Figure 21)

TB1	Screw terminal for +12V DC Pin1 (square PCB pad): +12V DC Pin2: Ground

PCI Express Power Interface

Power can be sourced to the board via the PCB edge-fingers (CN1 and CN2). This interface allows the user to provide power from a PCI Express Host board.

Programming/FPGA Configuration

(see Appendix A, Figure 23)

A programming header is provided on the evaluation board, providing access to the LatticeECP2M JTAG port.

Note: An ispDOWNLOAD® Cable is included with each ispLEVER®-Base or ispLEVER-Advanced design tool shipment. Cables may also be purchased separately from Lattice.

ispVM Download Interface

J3 and J11 are 8-pin JTAG connectors used in conjunction with the ispVM USB download cable to program and control the device. These connectors are available through the back-panel bracket as needed for x1 or x4 PCI Express configurations. These connectors are used in conjuction with the ispVM programming cable and software to program the configuration memory or FPGA directly.

Table 4. Standard ispVM Programming Cable Configuration

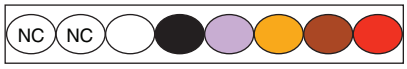
Pin 1	VCC
Pin 2	TDO
Pin 3	TDI
Pin 4	TMS
Pin 5	GND
Pin 6	TCK
Pin 7	DONE[1]
Pin 8	INITN[1]

1. Denotes optional connection to programming cable.

After initial board setup, use the following procedure to program the evaluation board. Instructions assume ispVM software has been installed on a local PC.

Connect the ispDOWNLOAD cable rainbow colored flywires to the connector J3.

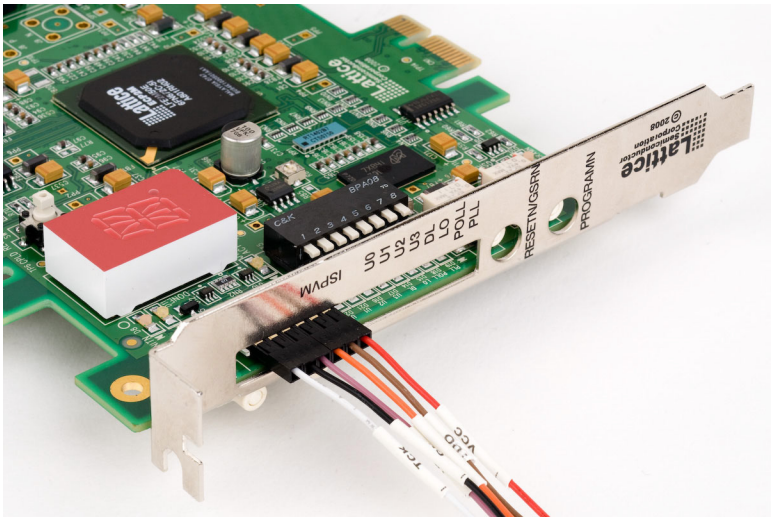
Table 5. ispVM JTAG Connector (see Appendix A, Figure 21)



Note: A dot denotes PIN 1 on the both the PCB or back-panel bracket.

Pin	Function	Color
1	PWR	Red
2	TDO	Brown
3	TDI	Orange
4	TMS	Purple
5	GND	Black
6	TCK	White

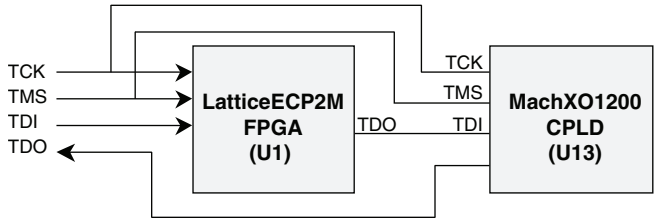
Figure 5. ispVM Programming Cable Connector



Programming the Daisy Chain

This board includes two Lattice Semiconductor programmable (U1=LFE2M50E, U13=LCMXO1200) devices that can be programmed in a daisy chain.

Figure 6. JTAG Chain



Download Procedures

Requirements:

- PC with ispVM System v.16.0 (or later) programming management software, installed with appropriate drivers (USB driver for USB Cable, Windows NT/2000/XP parallel port driver for ispDOWNLOAD Cable).

  Note: An option to install these drivers is included as part of the ispVM System setup.

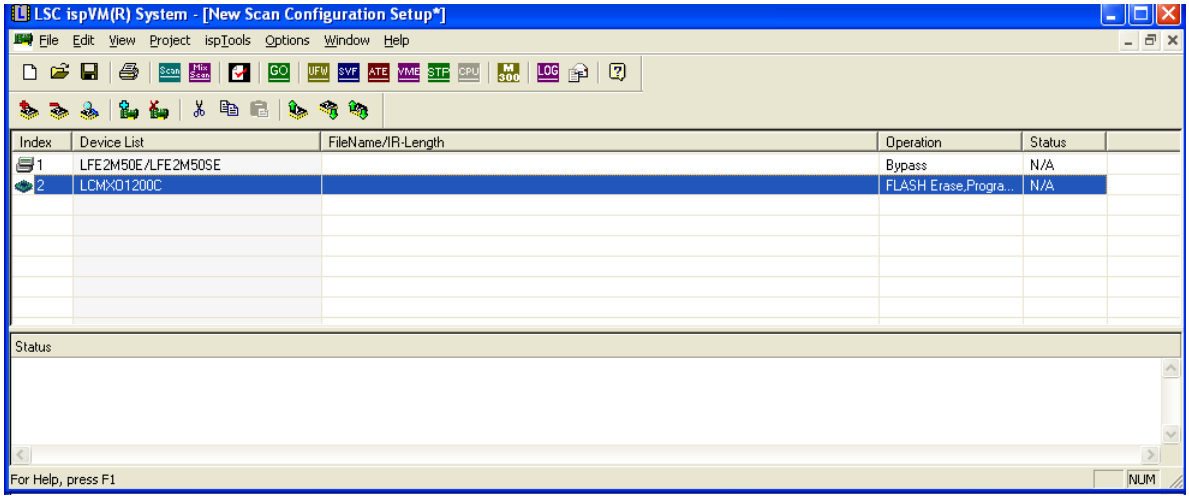
- ispDOWNLOAD Cable (pDS4102-DL2A, HW7265-DL3A, HW-USB-1A, etc.)

JTAG Download

The LatticeECP2M device can be configured easily via its JTAG port. The device is SRAM-based; it must remain powered on to retain its configuration when programmed in this fashion.

1. Connect the LatticeECP2M PCI Express Solutions Board to the appropriate power sources and power up board.
2. Connect the ispDOWNLOAD cable to the appropriate header. J3 is used for the 1x8 connection. J11 is used in the same manner for x4 configurations.
3. Start the ispVM System software.
4. Press the **SCAN** button located in the toolbar. The LatticeECP2M and the MachXO1200 devices should be automatically detected.

Figure 7. ispVM Main Window



5. Double-click the device to open the device information dialog. In the device information dialog, click the **Browse** button located under **Data File**. Locate the desired bitstream file (.bit). Click **OK** to both dialog boxes.
6. To program only the LatticeECP2M-50, place the LCMXO1200C device into **BYPASS** and the LFE2M50E should be in **FAST PROGRAM** mode.

Figure 8. ispVM Fast Programming Mode

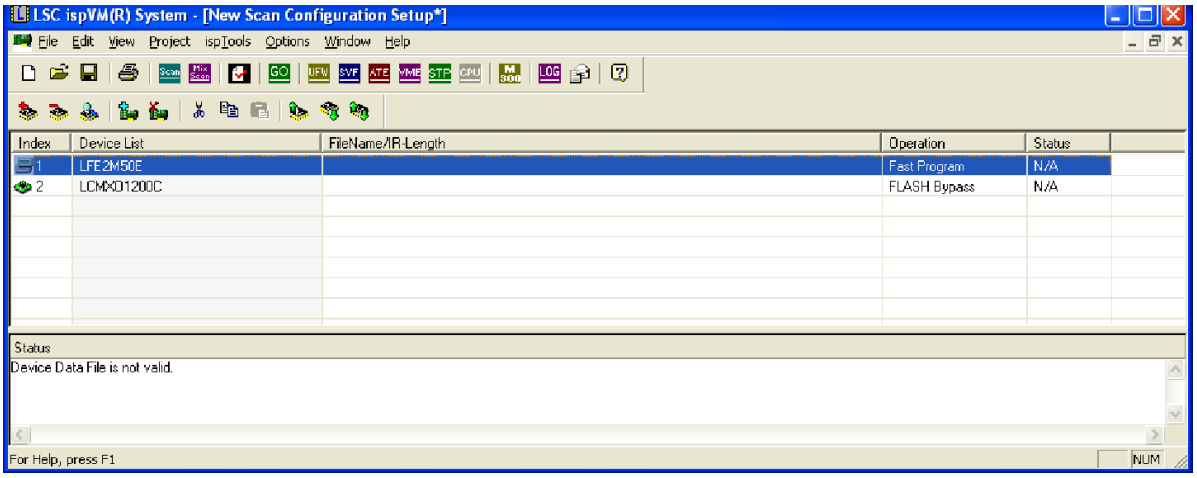
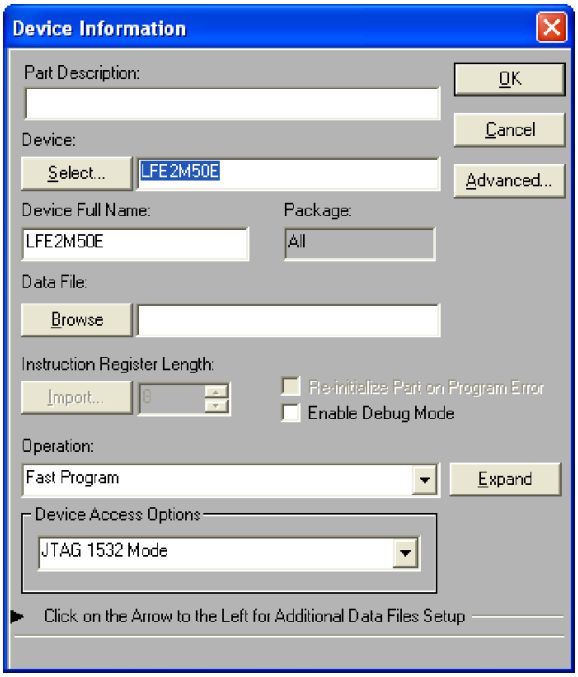


Figure 9. ispVM Device Information Dialog Box



7. Add Data File.
8. Click the green **GO** button. This will begin the download process into the device. Upon successful download, the device will be operational.

Configuration Status Indicators
(see Appendix A, Figure 23)

These LEDs indicate the status of configuration to the FPGA.

- D8 (red) illuminated, this indicates that the programming was aborted or reinitialized driving the INITN output low.
- D11 (green) is illuminated, this indicates the successful completion of configuration by releasing the open collector DONE output pin.

- D12 (green) will flash indicating TDI activity.
- D10 (red) illuminated, this indicates that PROGRAMN is low.
- D9 (red) illuminated, this indicates that GSRN is low.

PROGRAMN & GSRN
(see Appendix A, Figure 23)

- These push-button switches assert/de-assert the logic levels on the PROGRAMN (SW3) and GSRN (SW2). Depressing the button drives a logic level "0" to the device.
- These push-buttons are accessible from the back panel if the evaluation board is mounted in a PCI Express slot of a PC.

CFG [2:0]
(see Appendix A, Figure 23)

- The FPGA CFG pins are set on the board for a particular programming mode via the SW1 DIP switch.
- JTAG programming is independent of the MODE pins and is always available to the user.
- Pushing in (depressing) the switch is ON and sets the value to 0.

Table 6. CFG Mode Selections

CFG2	CFG1	CFG0	Configuration Mode
0 (ON)	0 (ON)	0 (ON)	SPI Flash
0 (ON)	1 (OFF)	0 (ON)	SPIm
1 (OFF)	0 (ON)	1 (OFF)	Slave Serial
1 (OFF)	1 (OFF)	1 (OFF)	Slave Parallel
X (don't care)	X (don't care)	X (don't care)	ispJTAG™

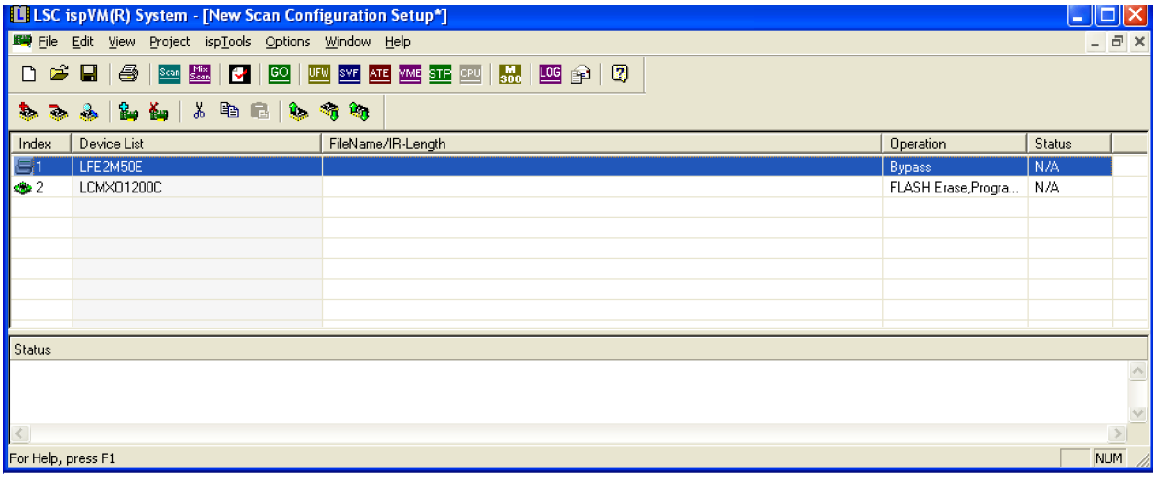
On-Board Serial SPI Flash Memory
(see Appendix A, Figure 23)

- One Serial SPI (16-pin tssop 64M) Flash memory device (U8) is on-board for non-volatile configuration memory storage. Either a STMicro M25P64VMF16 or Macronix MX25L6405 device is populated on-board.
- All CFG [2:0] need to be [000] depressed to read the Flash memory at power-up or after toggling the PROGRAMN pin.

Programming Serial SPI Flash Memory
The Serial SPI Flash memory device can be configured easily via its JTAG port. This mode enables the FPGA to be programmed at power-up or assertion of PROGRAMN with a bitstream stored in the memory device.

1. Connect the LatticeECP2M PCI Express Solutions Board to the appropriate power sources and power-up board.
2. Connect the ispDOWNLOAD cable to the appropriate header. J3 is used for the 1x10 cable.
3. Start the ispVM System software.
4. Press the **SCAN** button located in the toolbar. The LFE2M50E and the LCMXO1200C devices should be automatically detected.

Figure 10. Results of Scanning Board via ispVM



5. Double-click the **Operation** column for the LFE2M50E and the Device Dialog box shown below will open.

6. In the dialog box, select the **SPI Flash Programming** mode in the **Device Access Options** pull-down menu. This will open the SPI Serial Flash Dialog box.

Figure 11. Device Information Dialog Screen

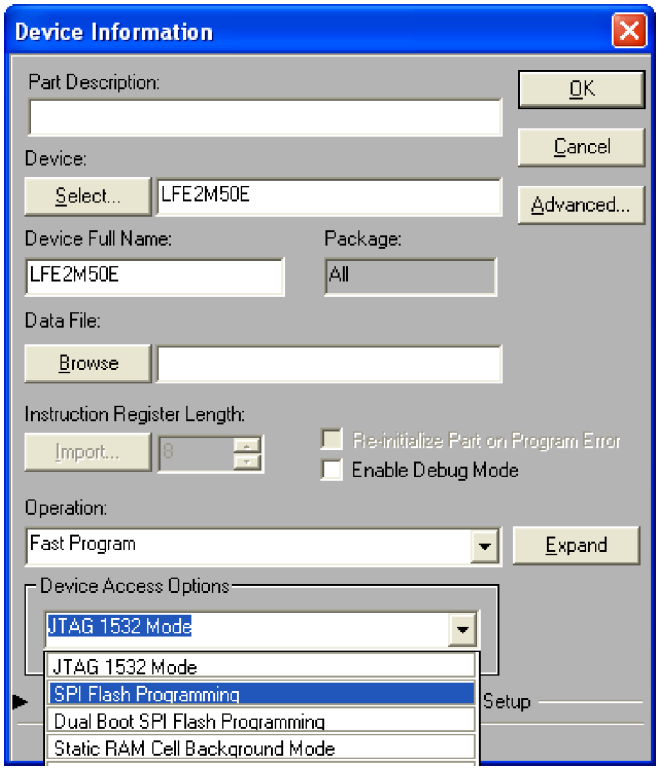
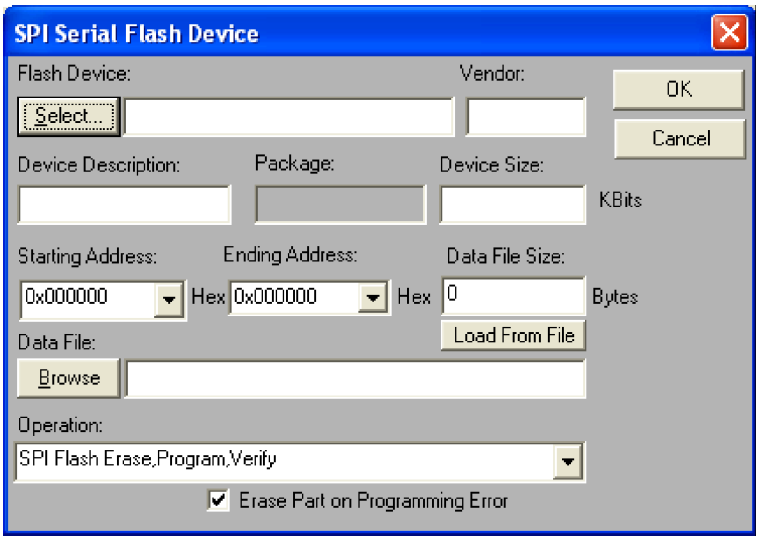


Figure 12. SPI Serial Flash Dialog Screen



7. The SPI Serial Flash Device dialog box will open. In this box select **SPI Flash Erase, Program, Verify** in the **Operation** pull-down menu.

8. Select **SPI Serial Flash** in the **Device Family** pull-down menu, **STMicro** under the **Vendor** pull-down menu, **SPI-M2564** under the **Device** pull-down menu, and **16-lead SOIC** under the **Package** submenu.

Figure 13. Select Device Dialog Box

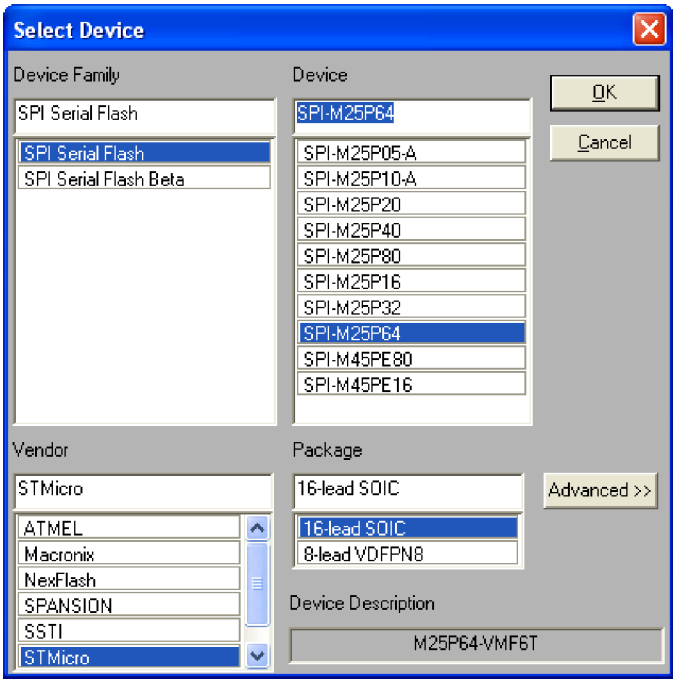
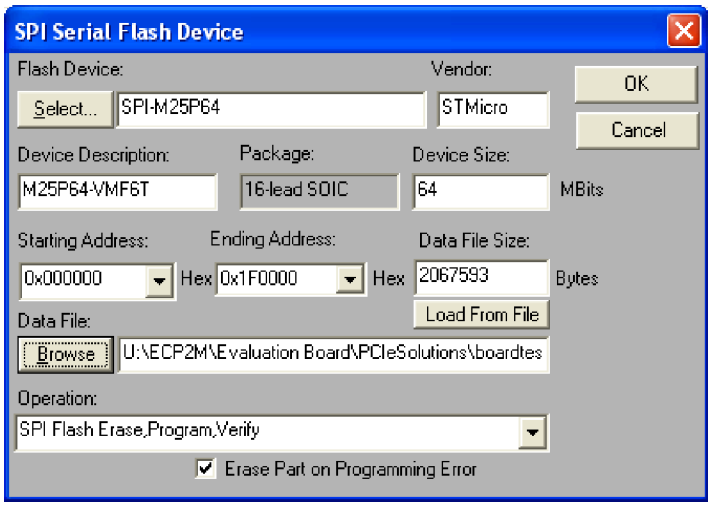


Figure 14. Sample SPI Serial Flash Device Dialog Box



9. Click **OK** in the **SPI Flash Device** dialog box. Then click **OK** in the **Select Device** dialog box. You will then return to the main configuration screen. If you do not desire to load the LCMXO1200C device, this device should be placed in Flash Bypass mode by double-clicking the **Operation** column and selecting the **Bypass** operation shown below.

Figure 15. FLASH Bypass for LCMXO1200C Device

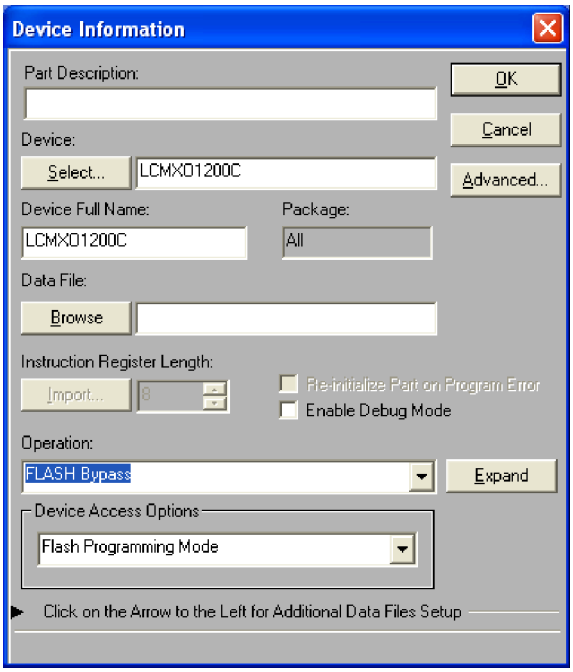
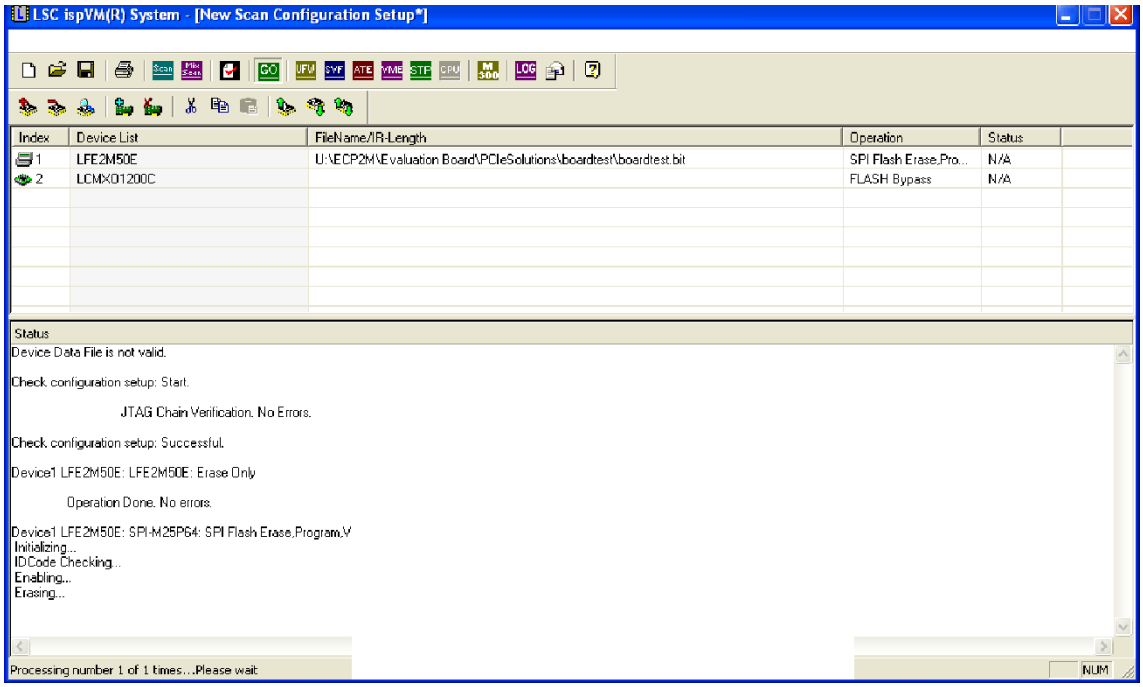


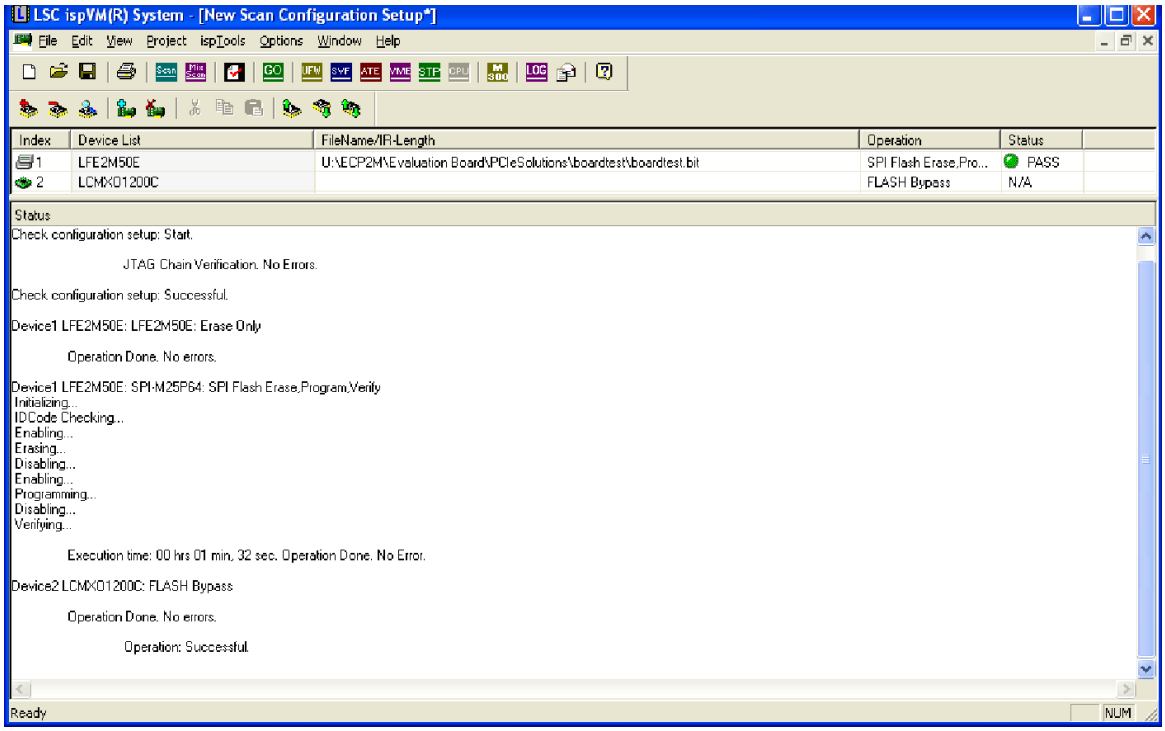
Figure 16. Programming Main Window



10. From the main programming window, select **GO** in the top toolbar. This will begin the SPI Serial Flash programming.

Figure 17. SPI Serial Flash Programming Status Window

Figure 18. Successful SPI Serial Flash Programming Session



On-Board Parallel SPI Flash Memory
(see Appendix A, Figure 24)

- A 16-bit parallel Flash device is also available. This board uses a Lattice MachXO CPLD device to act as a programming bridge from the Flash device.
- The CFG [2:0] need to be [111], all up.
- Lattice ispVM programming software can be used to program either the serial SPI Flash or the parallel Flash devices. Application note AN8077, *Parallel Flash Programming and FPGA Configuration,* addresses the use of the parallel Flash implementation. *Note: For parallel Flash loading, the board needs to remove shorting resistors to disable the serial SPI Flash interconnections. Remove R39 and R194 from the PCB.*

User-Defined General Purpose Clock Oscillator

(see Appendix A, Figure 27, Y2)

A 100MHz oscillator is included on-board. It is fanned-out to several destinations on the board, as described in Table 7.

Table 7. 100MHz Clock Destinations

Clock Destination	PCB Designation	Destination Pin
CPLD	U13	A8
FPGA	U1	P3- PCLK6_0
FPGA	U1	W4-LLM0_GPLL
FPGA	U1	P1- LLM2_SPLL

SERDES

(see Appendix A, Figure 25)

SERDES/FPGA Reference Clocks

The 50-ohm terminated SMA connectors are optionally provided to supply reference clocks directly to the LatticeECP2M device. Please contact the factory for information to populate the PCB with SMA connectors.

Table 8. SMA Inputs for External Clock Source

Connector	SERDES Signal	FPGA Pin
J8	FPGA_SMA_REFCLKP	N25
J9	FPGA_SMA_REFCLKN	N24

SERDES PCI Express Channels

(see Appendix A, Figure 25)

This board is equipped to communicate directly as an add-on card to a PCI Express host. It is designed with edge-fingers (CN1 or CN2) that fit directly into a PCI Express host receptacle. Power can be supplied directly from the PCI Express host via the edge-finger connections.

Table 9. x1 PCI Express Connections

CML Pin Name	FPGA Pin	PCIE	PCI Express Edge	Description
L_HDOUTP_0	AF21	PERp0	A16	Integrated endpoint block transmit pair
L_HDOUTN_0	AE21	PERn0	A17	
L_HDINP_0	AF24	PETp0	B14	Integrated endpoint block receive pair
L_HDINN_0	AE24	PETn0	B15	
L_REFCLKP	AC19	PCIe_CLKp	A13	Integrated endpoint block differential clock pair
L_REFCLKN	AB19	PCIe_CLKn	A14	
PCIE_PERSETN	C12	PERSTN	A11	Fundamental PCI Express reset

Table 10. x4 PCI Express Connections

CML Pin Name	FPGA Pin	PCIE	PCI Express Edge	Description
U_HDOUTP_3	A17	PERp0	A16	Integrated endpoint block transmit pair
U_HDOUTN_3	B17	PERn0	A17	
U_HDINP_3	A14	PETp0	B14	Integrated endpoint block receive pair
U_HDINN_3	B14	PETn0	B15	
U_HDOUTP_2	A18	PERp1	A21	Integrated endpoint block transmit pair
U_HDOUTN_2	B18	PERn1	A22	
U_HDINP_2	A15	PETp1	B19	Integrated endpoint block receive pair
U_HDINN_2	B15	PETn1	B20	

Table 10. x4 PCI Express Connections (Continued)

CML Pin Name	FPGA Pin	PCIE	PCI Express Edge	Description
U_HDOUTP_1	A20	PERp2	A25	Integrated endpoint block transmit pair
U_HDOUTN_1	B20	PERn2	A26	
U_HDINP_1	A23	PETp2	B23	Integrated endpoint block receive pair
U_HDINN_1	B23	PETn2	B24	
U_HDOUTP_0	A21	PERp3	A29	Integrated endpoint block transmit pair
U_HDOUTN_0	B21	PERn3	A30	
U_HDINP_0	A24	PETp3	B27	Integrated endpoint block receive pair
U_HDINN_0	B24	PETn3	B28	
U_REFCLKP	D19	PCIe_CLKp	A13	Integrated endpoint block differential clock pair
U_REFCLKN	E19	PCIe_CLKn	A14	
PCIE_PERSETN	C12	PERSTN	A11	Fundamental PCI Express reset

FPGA Test Pins
(see Appendix A, Figure 27)

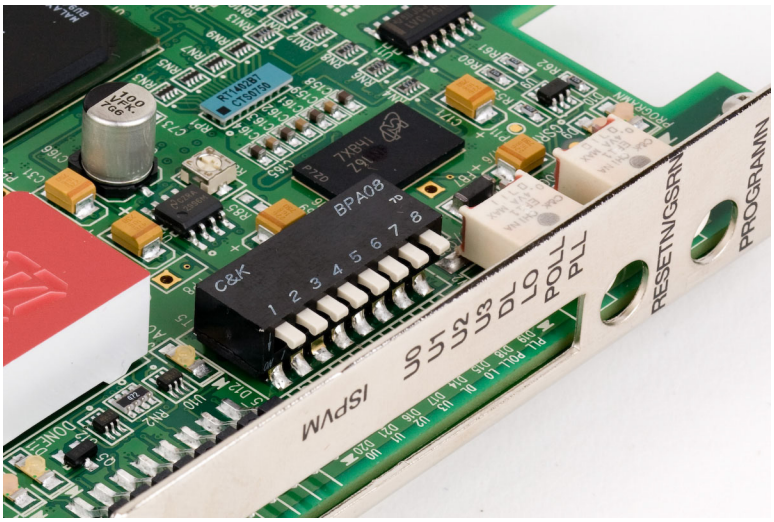
General Purpose DIP Switch
(see Appendix A, Figure 27, SW5)

General-purpose FPGA pins are available for user applications. FPGA pins are connected to a switch (SW5) which is an SPST side actuated DIP switch. The switch is physically located on the secondary side of the PCB along the back-panel edge. The switches are connected to a logic level 0 when depressed toward the board and a 1 when away from the board. The designated pins are connected according to Table 11.

Table 11. FPGA Test Pins (See Appendix A, Figure 26)

FPGA BGA	SW5 Switch Position
T5	1
R7	2
U1	3
T1	4
R6	5
P8	6
T4	7
T3	8

Figure 19. 8-position DIP Switch (SW5) on Secondary PCB Side



General Purpose LEDs
(see Appendix A, Figure 27, D14-D21)

LEDs are provided along the back panel edge of the PCB. These LEDs are connected to general-purpose FPGA I/Os. The LEDs are illuminated by the associated FPGA outputs being driven to a valid LOW level. The use of these LEDs is defined for PCI Express applications to observe the status of the PCI Express link during operation. The LEDs must be included in the FPGA design. These status LEDs are available in both x1 or x4 configurations. The back panel marking reflects PCI Express specific status.

Table 12. LED Definitions

PCI Express x1		PCI Express x4		
FPGA Pin#	**PCB Designator**	**FPGA Pin#**	**PCB Designator**	**Description**
U6	D20	W6	D28	User defined
V2	D21	Y5	D29	User defined
V1	D16	AA3	D25	User defined
U4	D17	Y4	D24	User defined
U3	D14	U3	D22	Data link up active
U2	D15	Y3	D23	L0 state active
U5	D18	U8	D26	Polling state active
W2	D19	V7	D27	PLL locked

General-Purpose Header
(see Appendix A, Figure 27, J10)

A 2x9 header (J10) provides a general-purpose connection to communicate with general purpose FPGA I/Os.

Table 13. General Purpose Header Connections

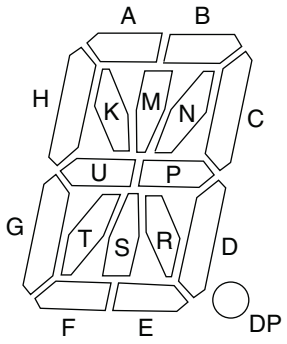
Header Pin	FPGA Pin	Header Pin	FPGA Pin
1	GND	2	GND
3	E23	4	H25
5	E24	6	H26
7	F26	8	G22
9	G26	10	K19
11	F21	12	G24
13	H20	14	G23
15	F24	16	J18
17	F23	18	F22

17-Segment LED Display
(see Appendix A, Figure 27, D13)

General-purpose FPGA pins are connected to a 17-segment display according to Table 14. These pins can be driven low to illuminate the display segments.

Table 14. 17-Segment LED Display

Segment	BGA
A	H16
B	H15
C	B10
D	G14
E	F13
F	H14
G	C10
H	B9
K	F12
M	G13
N	B8
P	D9
R	D6
S	C8
T	D8
U	A6
DP	A4

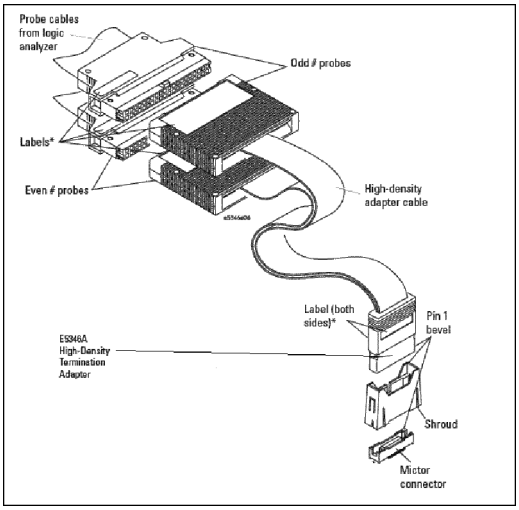


Logic Analyzer Probe
(see Appendix A, Figure 27, LA1)

An AMP/TYCO 767004 38-position .025 VERT SMD logic analyzer probe connection is provided for the user to utilize for test points. This connection provides 34 general I/O signals to be observed on a Logic Analyzer probe using Mictor connections such as the Agilent 5346A.

Table 15. Logic Analyzer To FPGA Pin Reference

Signal	FPGA Pin	Signal	FPGA Pin
LA1	N23	LA2	M21
LA3	P26	LA4	P25
LA5	N22	LA6	N20
LA7	P22	LA8	N21
LA9	P24	LA10	P23
LA11	N19	LA12	R22
LA13	R24	LA14	R23
LA15	P19	LA16	P21
LA17	R26	LA18	T26
LA19	R20	LA20	R21
LA21	R19	LA22	T19
LA23	U26	LA24	U25
LA25	T23	LA26	T22
LA27	T24	LA28	U24
LA29	V26	LA30	V25
LA31	U22	LA32	U18
LA33	W26	LA34	W25



DDR2 Memory Devices
(see Appendix A, Figure 26, U16)

- The LatticeECP2M PCI Express Solutions Board is equipped with an 84-ball BGA DDR2 SDRAM memory device such as a Micron MT47H16M16BG-3 device.
- The DDR2 memory interfaces include a 16-bit wide device.
- The evaluation board includes termination of address and command signals. It includes all power and external components needed to demonstrate the memory controller of the LatticeECP2M device.

CPLD Device
(see Appendix A, Figure 24, U13)

The board includes a Lattice Semiconductor LCMXO-1200C CPLD. This device is used in conjunction with the parallel Flash device for loading the configuration memory of the FPGA. It is also used for general-purpose board management functions. It has several connections to the FPGA and other devices on the PCB. It includes an active high, push-button (SW4) if needed for a user design.

Generic user-defined interconnections are defined in Table 16.

Table 16. CPLD TO FPGA Interconnections

CPLD Pin	FPGA Pin
M1	G7
P13	G8
P10	F8
N7	J10
N8	D4
P11	C3
N13	F7
N1	G9
N3	C4
N4	B2
P1	C5
M12	B3
M2	E7
M3	H10
M4	F9
M6	G10

Ordering Information

Description	Ordering Part Number	China RoHS Environment-Friendly Use Period (EFUP)
LatticeECP2M PCI Express Solutions Board		

Technical Support Assistance

Hotline: 1-800-LATTICE (North America)
+1-503-268-8001 (Outside North America)
e-mail: techsupport@latticesemi.com
Internet: www.latticesemi.com

Revision History

Date	Version	Change Summary
September 2008	01.0	Initial release.

Appendix A. Schematic

Figure 20. Cover Page

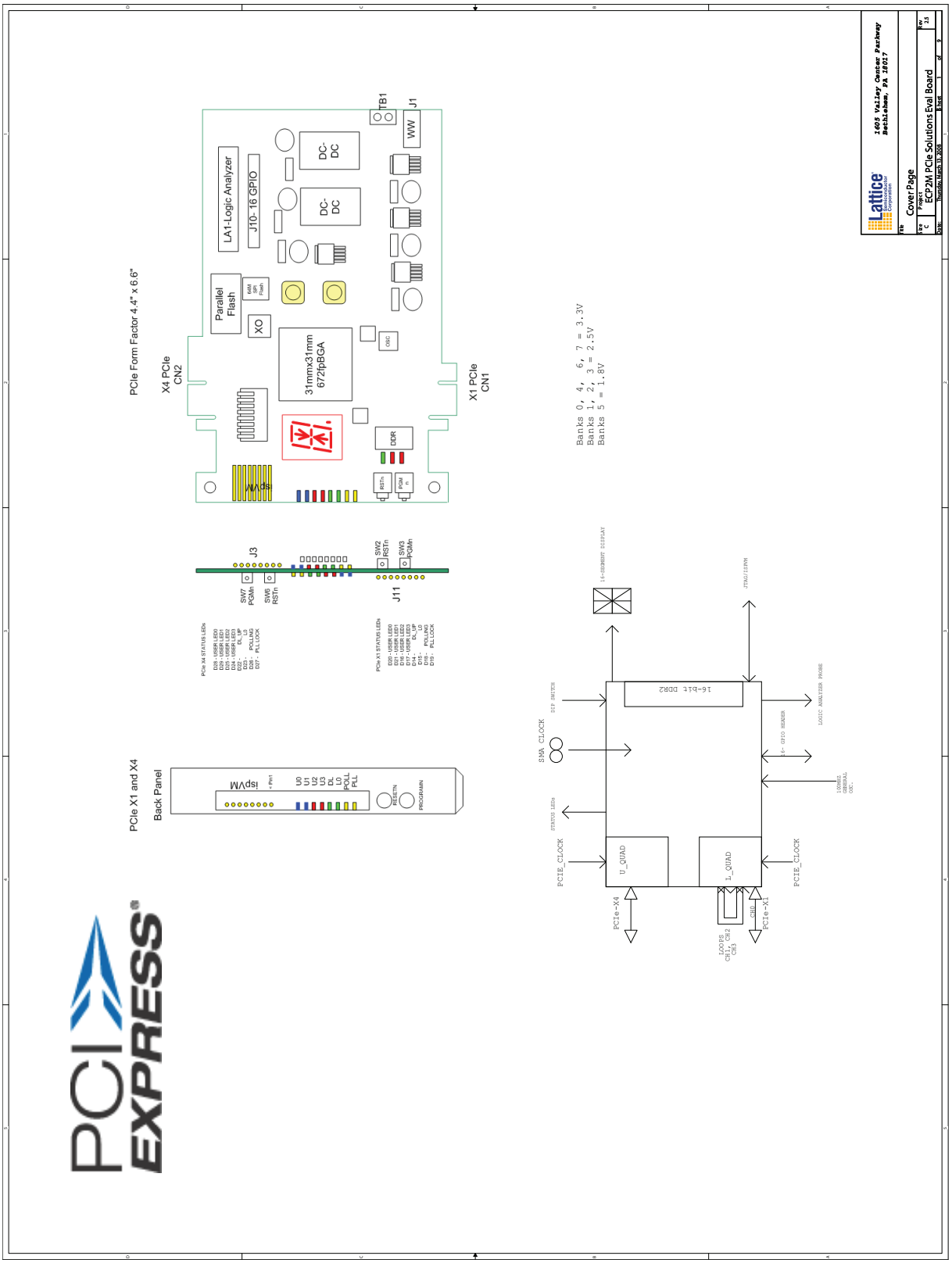


Figure 21. Power Generation

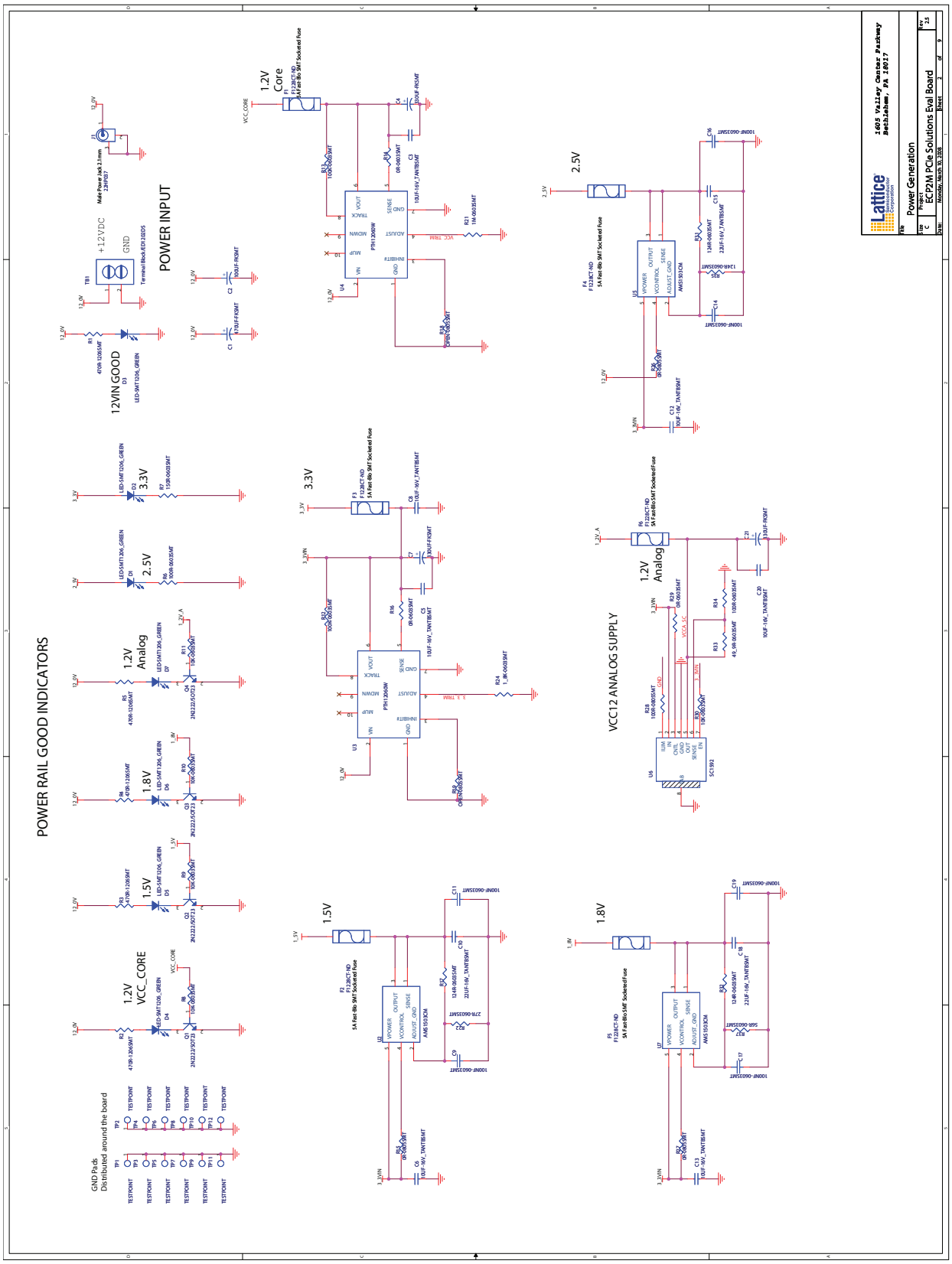


Figure 22. Power Supplies

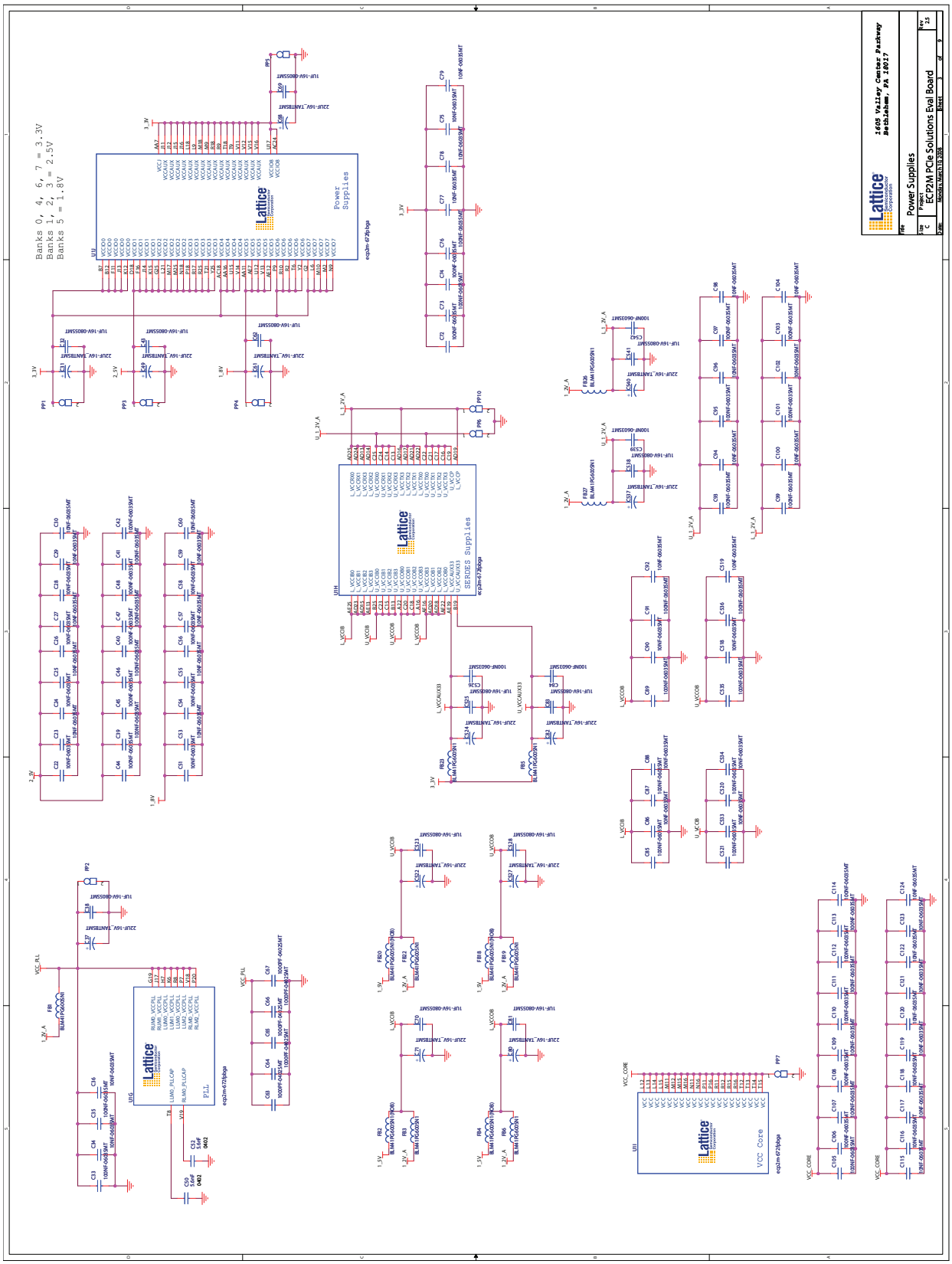


Figure 23. Programming

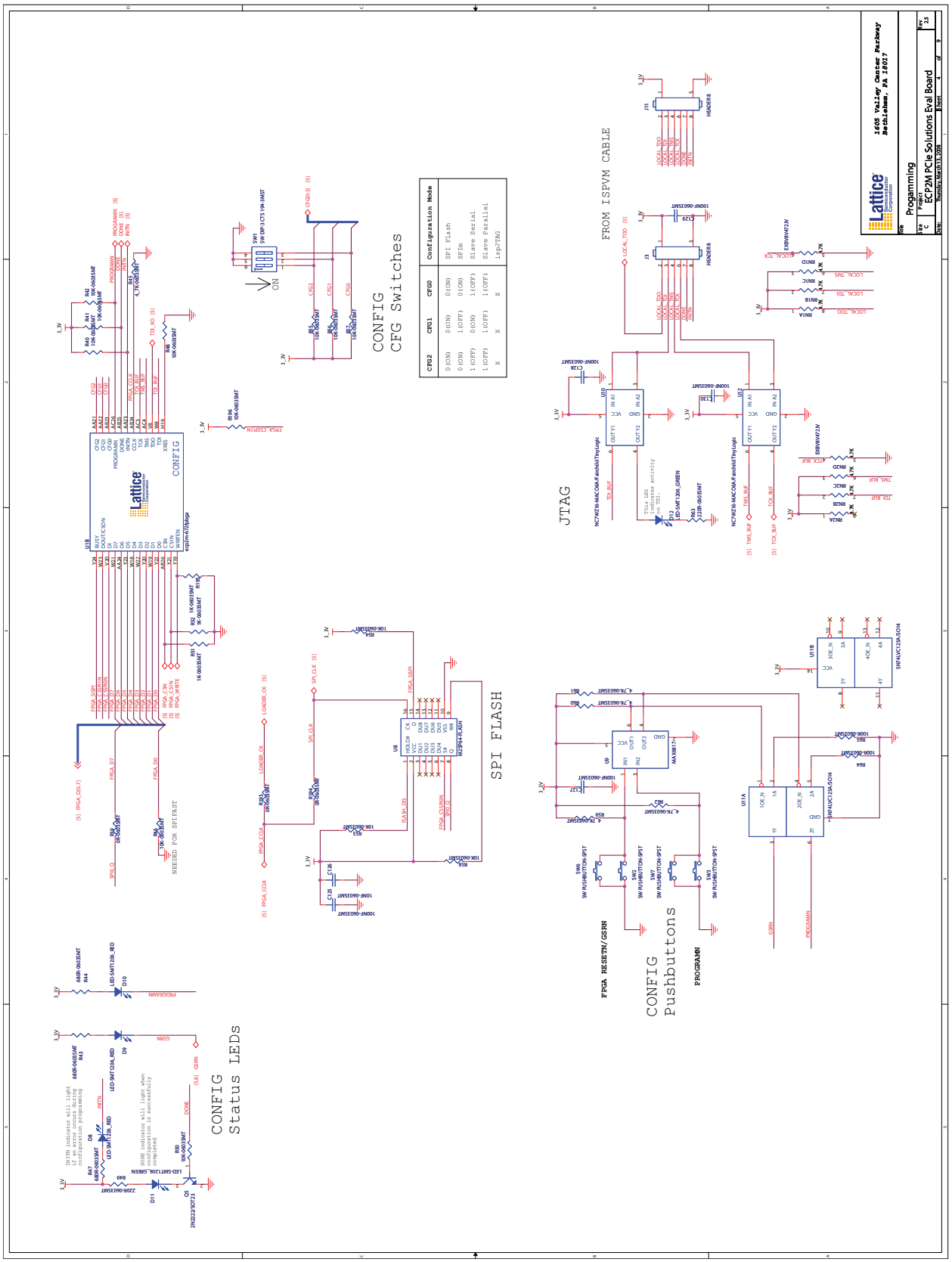


Figure 24. Parallel FPGA Loader

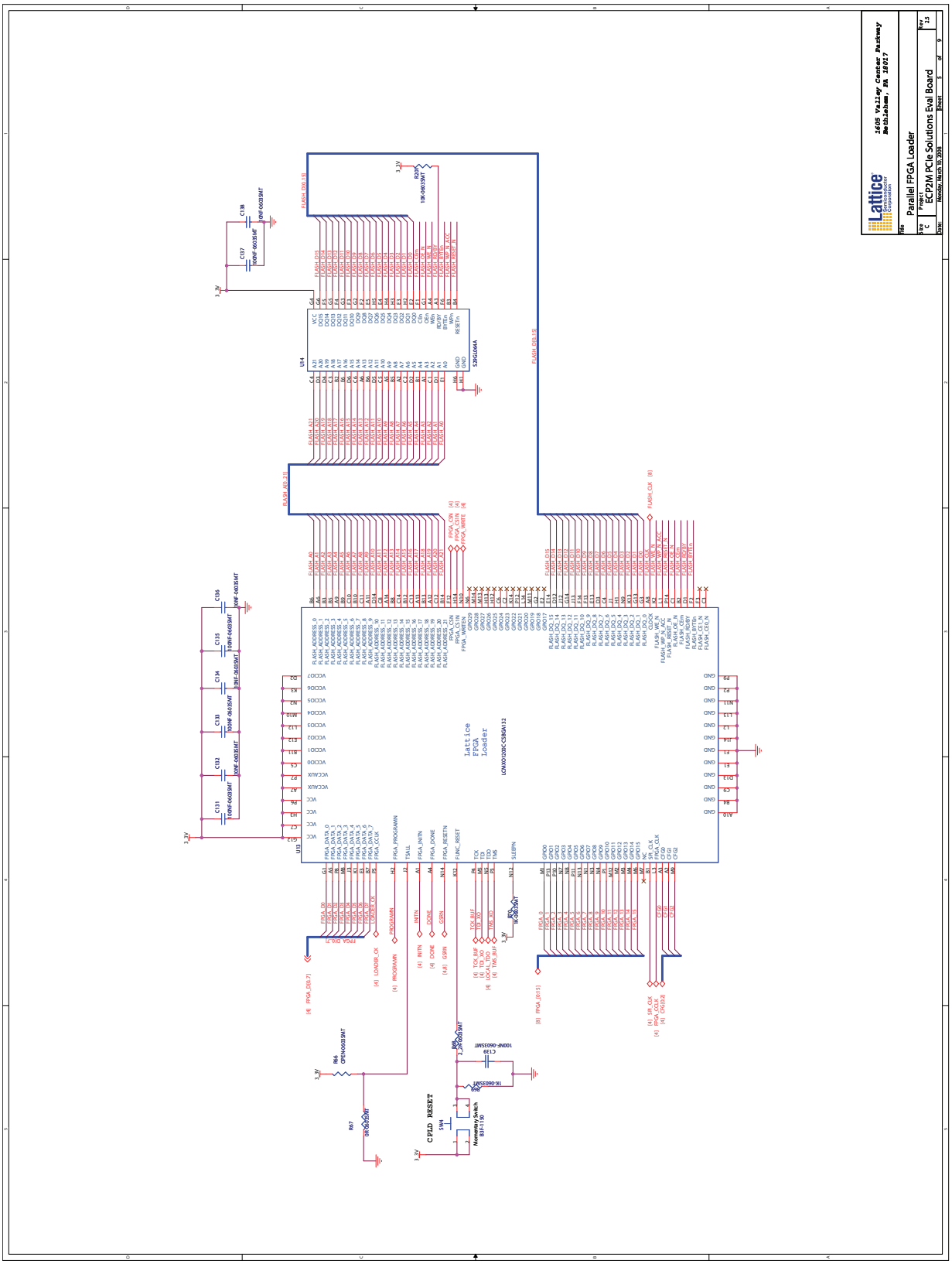


Figure 25. SERDES

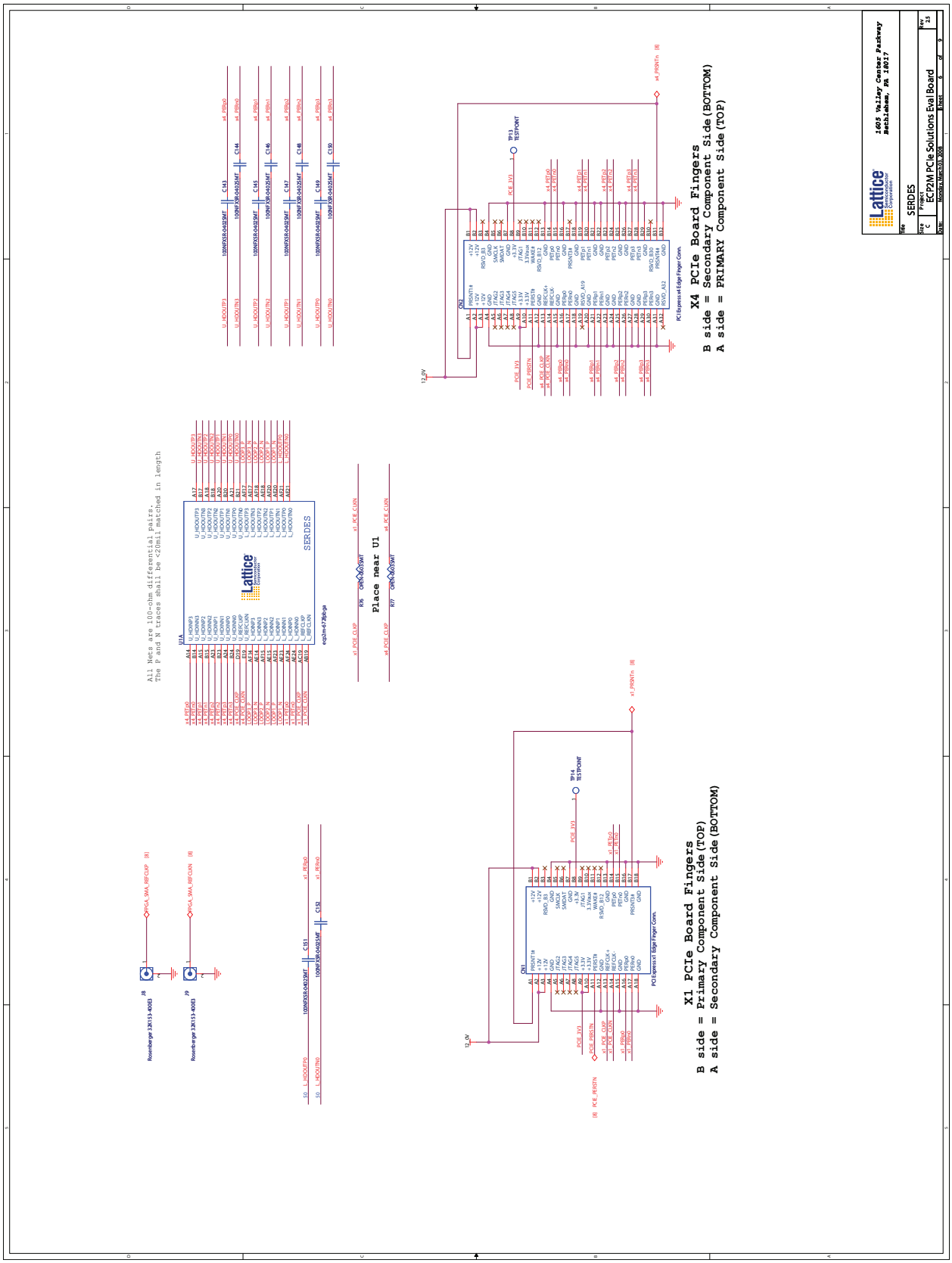


Figure 26. DDR2 Memory

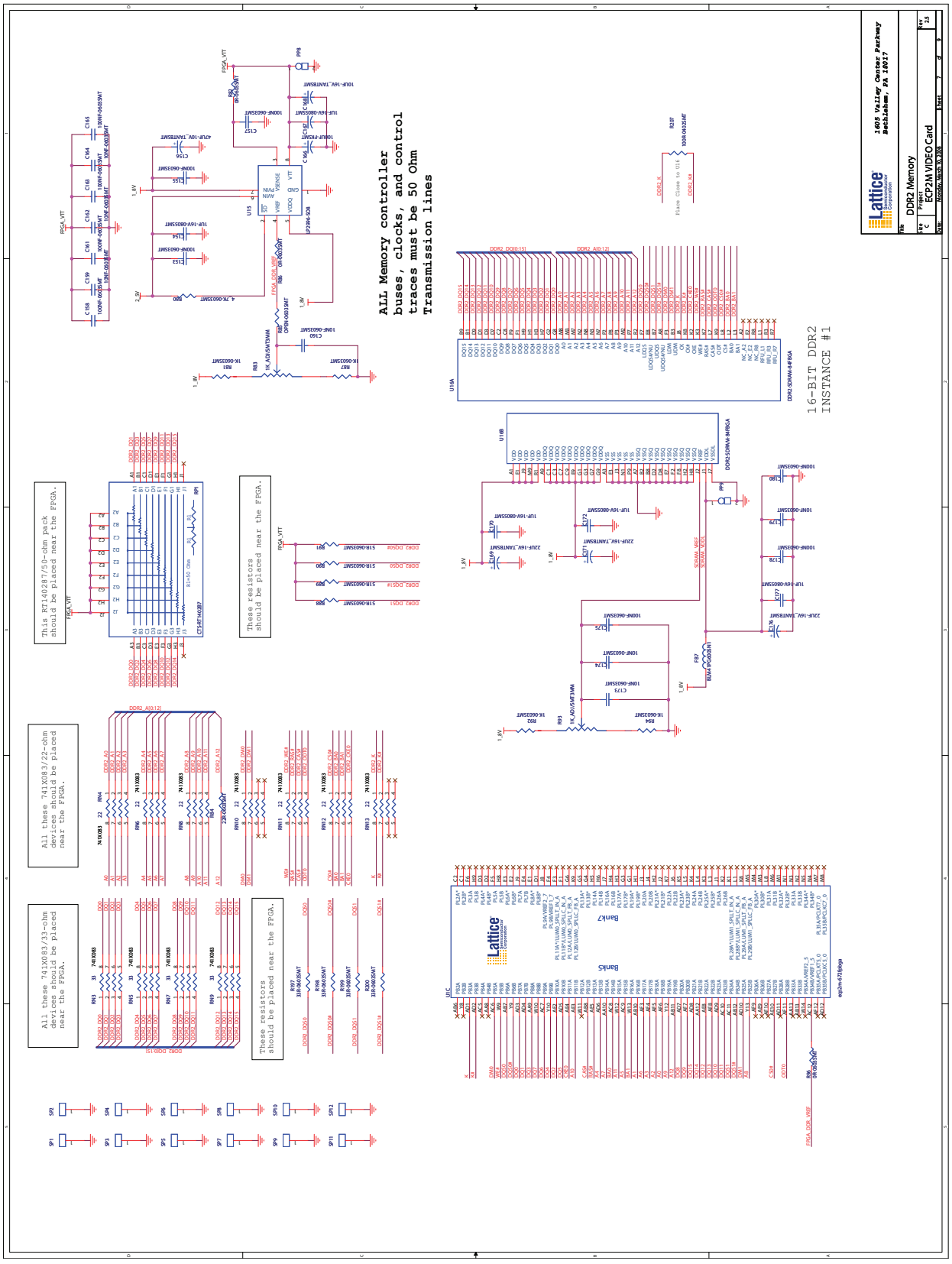


Figure 27. FPGA Test

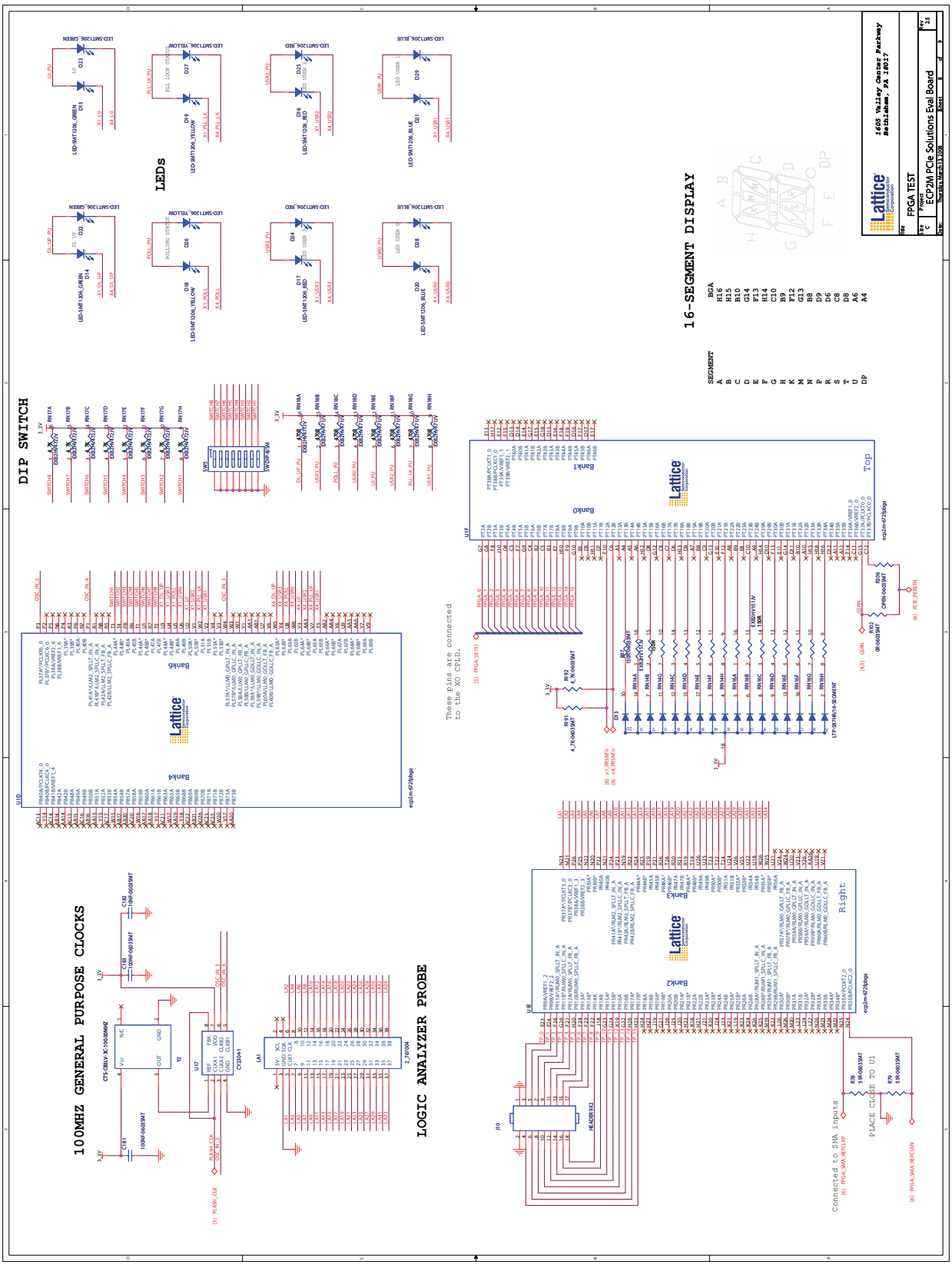
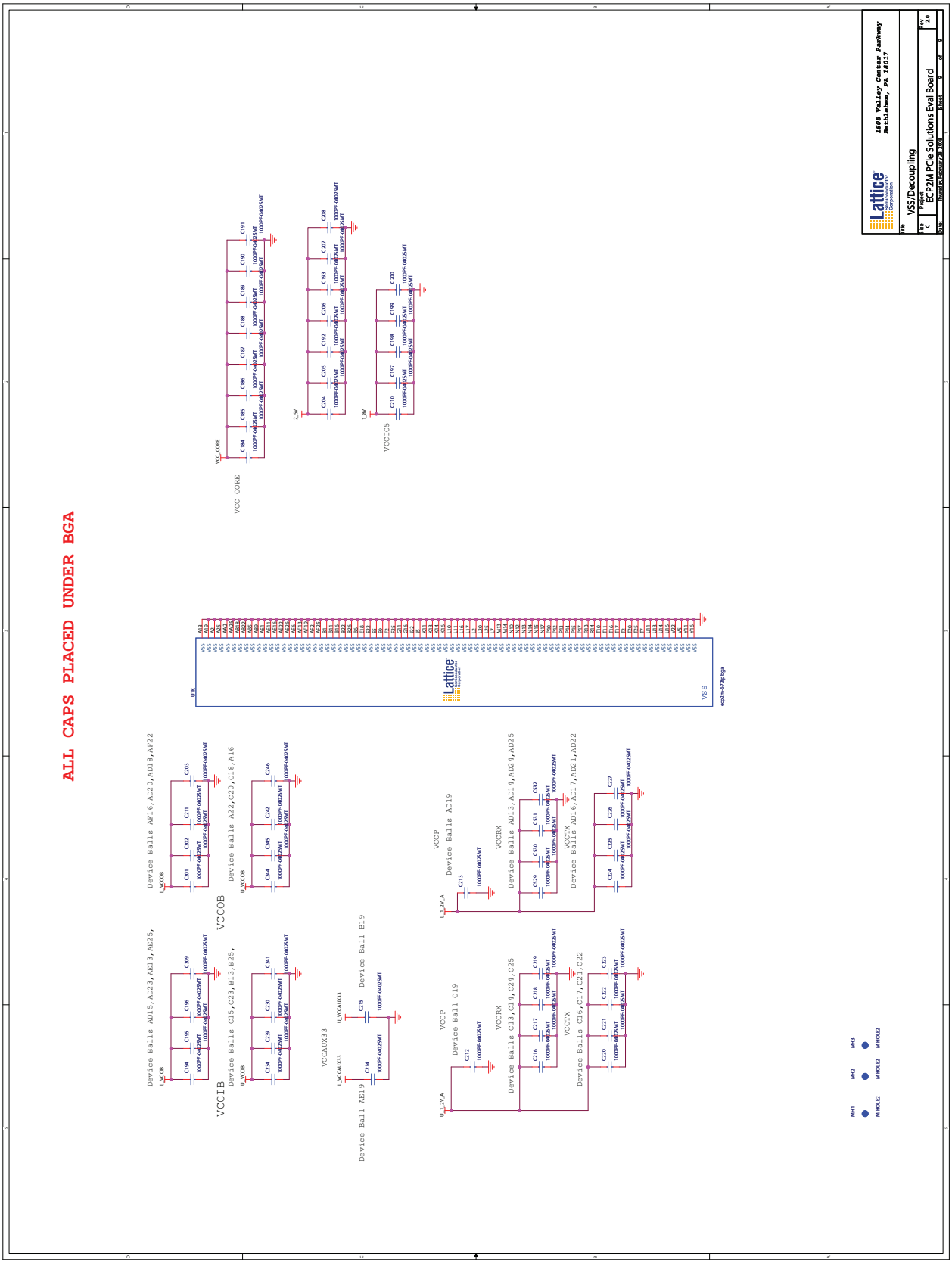


Figure 28. VSS/Decoupling



Appendix B. Bill of Materials

Table 17. Bill of Materials

Item	Quantity	Reference	Part	Manufacturer	Part Number	Description
1	1	CN1	PCI Express x1 Edge Finger Conn.			PCB Edge finger
2	1	CN2	PCI Express x4 Edge Finger Conn.			PCB Edge finger
3	1	C1	470UF-FKSMT	Panasonic	EEV-FK1V471Q	CAP 470UF 35V ELECT FK SMD
4	2	C2,C166	100UF-FKSMT	Panasonic	EEV-FK1V101XP	CAP 100UF 35V ELECT FK SMD
5	9	C3,C5,C6,C8,C12,C13,C20,C141,C168	10UF-16V_TANTBSMT	AVX	TAJB106K016R	CAP 10UF 16V TANT B-SIZE
6	3	C4,C7,C21	330UF-FKSMT	Panasonic	EEV-FK1C331P	CAP 330UF 16V ELECT FK SMD
7	73	C9, C11, C14, C16, C17, C19, C33, C35, C39, C40, C41, C42, C44, C45,C46, C47, C48, C72, C73, C74, C76, C84, C85, C87, C89, C91,C93, C95, C97, C99, C101, C103, C105, C106, C107, C108, C109, C110, C111, C112, C113, C114, C125, C127, C128, C129, C130, C131, C133, C135, C137, C139, C140, C142, C153, C155, C157, C158, C161, C163, C165, C175, C178, C180, C181, C183, C520, C521, C535, C536, C539, C542, C526	100NF-0603SMT	Panasonic	ECJ-1VF1C104Z	CAP .1UF 16V CERAMIC Y5V 0603
8	19	C10, C15, C18, C31, C37, C49, C61, C68, C71, C80, C82, C169, C171, C176, C522, C524, C537, C540, C527	22UF-16V_TANTBSMT	Kemet	T491B226M016AT	CAPACITOR TANT 22UF 16V 20% SMD
9	61	C22, C23, C24, C25, C26, C27, C28, C29, C30, C34, C36, C51, C53, C54, C55, C56, C57, C58, C59, C60, C75, C77, C78, C79, C86, C88, C90, C92, C94, C96, C98, C100, C102, C104, C115, C116, C117, C118, C119, C120, C121, C122, C123, C124, C126, C132, C134, C136, C138, C159, C160, C162, C164, C173, C174, C179, C182, C518, C519, C533, C534	10NF-0603SMT	Kemet	C0603C103K5RACTU	CAP .01UF 50V CERAMIC X7R 0603
10	18	C32, C38, C43, C62, C69, C70, C81, C83, C154, C167, C170, C172, C177, C523, C525,C528, C538, C541	1UF-16V-0805SMT	Panasonic	ECJ-2FB1C105K	CAP 1UF 16V CERAMIC 0805 X5R
11	2	C50,C52	5.6nF	Panasonic	ECJ-1VB1H562K	CAP 5600PF 50V CERAMIC X7R 0603
12	59	C63, C64, C65, C66, C67, C184, C185, C186, C187, C188, C189, C190, C191, C192, C193, C194, C195, C196, C197, C198, C199, C200, C201, C202, C203, C204, C205, C206, C207, C208, C209, C210, C211, C212, C214, C216, C217, C218, C219, C220, C221, C222, C223, C224, C225, C226, C227, C230, C234, C239, C241, C242, C244, C245, C246, C529, C530, C531, C532	1000PF-0402SMT	Panasonic	ECJ-0EB1E102K	CAP 1000PF 25V CERAMIC X7R 0402
13	10	C143, C144, C145, C146, C147, C148, C149, C150, C151,C152	100NFX5R-0402SMT	Kemet	C0402C104K8PACTU	CAP .10UF 10V CERAMIC X5R 0402
14	1	C156	47UF-10V_TANTBSMT	Kemet	T491B476M010AS	CAPACITOR TANT 47UF 10V 20% SMD
15	2	C213, C215	1000pf 25V Ceramic X7R 0402	Panasonic	ECJ-OEB1E102K	
16	11	D1, D2, D3, D4, D5, D6, D7, D11, D12, D14, D15	LED-SMT1206_GREEN	Panasonic	LNJ316C83RA	LED GREEN (UP) W/LENS 1206
17	5	D8, D9, D10, D16, D17	LED-SMT1206_RED	Panasonic	LNJ211R82RA	LED RED (UP) W/LENS 1206
18	1	D13	LTP-587HR/16-SEGMENT	Lite-On	LTP-587HR	16-segment array

Table 17. Bill of Materials (Continued)

Item	Quantity	Reference	Part	Manufacturer	Part Number	Description
19	2	D18, D19	LED-SMT1206_YELLOW	Panasonic	LNJ411K84RA	LED YELLOW (UP) W/LENS 1206
20	2	D20, D21	LED-SMT1206_BLUE	Panasonic	LNJ916C8BRA	LED BLUE (UP) W/LENS 1206
21	10	FB1, FB3, FB5, FB6, FB7, FB19, FB22, FB23, FB26, FB27	BLM41PG600SN1	Murata	BLM41PG600SN1L	FERRITE CHIP 60 OHM 6000MA 1806
22	0	FB2, FB4, FB18, FB20	BLM41PG600SN1(NOB)			
23	6	F1, F2, F3, F4, F5, F6	F1228CT-ND	Littlefuse	0154005.DR	FUSEBLOCK WITH 5A FUSE SMD
24	1	J1	22HP037-2.1mm	Condor		power input
25	0	J2	HEADER 3	Samtec	TSW-103-07-T-S	3x1-0.25 Header
26	2	J3, J11	HEADER 8	Samtec	TSW-108-09-T-S-RA	8x1-0.25 Header-Right Angle
27	2	J8, J9	Rosenberger 32K153-400E3	Rosenberger	32K153-400E3	TH- SMA connector
28	1	J10	HEADER 9X2	Samtec	TSW-109-07-T-D	9x2-0.25 Header
29	1	LA1	2_767004	Amp	2-767004-2	CONN RECEPT 38POS .025 VERT SMD
30	3	MH1, MH2, MH3	M HOLE2			
31	0	PP1, PP2, PP3, PP4, PP5, PP6, PP7, PP8, PP9, PP10	PROBEPOINT			
32	5	Q1, Q2, Q3, Q4, Q5	2N2222/SOT23	Diodes Inc.	MMBT2222A-7	TRANS NPN 40V 350MW SMD SOT-23
33	2	RN1, RN2	EXBV8V472JV	Panasonic	EXBV8V472JV	RES ARRAY 4.7K OHM 5% 4 RES SMD
34	4	RN3, RN5, RN7, RN9	33	CTS Corporation Resistor/Electrocomponents	741X083330J	RES ARRAY 33 OHM 8 TERM 4RES SMD
35	7	RN4, RN6, RN8, RN10, RN11, RN12, RN13	22	CTS Corporation Resistor/Electrocomponents	741X083220J	RES ARRAY 22 OHM 8 TERM 4RES SMD
36	2	RN14,RN16	EXB2HV151JV	Panasonic	EXB2HV151JV	RES ARRAY 150 OHM 5% 8 RES SMD
37	1	RN15	EXB2HV103JV	Panasonic	EXB2HV103JV	RES ARRAY 10K OHM 5% 8 RES SMD
38	1	RN17	EXB2HV472JV	Panasonic	EXB2HV472JV	RES ARRAY 4.7K OHM 5% 8 RES SMD
39	1	RP1	CTS-RT1402B7	CTS Corporation Resistor/Electrocomponents	RT1402B7TR7	RES NET DDR SDRAM 50 OHM 3X9 BGA
40	5	R1, R2, R3, R4, R5	470R-1206SMT	Panasonic	ERJ-8GEYJ471V	RES 470 OHM 1/4W 5% 1206 SMD
41	4	R6, R34, R64, R65	100R-0603SMT	Panasonic	ERA-3YEB101V	RES 100 OHM 1/16W .1% 0603 SMD
42	2	R7, R97	150R-0603SMT	Panasonic	ERA-3YEB151V	RES 150 OHM 1/16W .1% 0603 SMD
43	18	R8, R9, R10, R11, R30, R40, R41, R42, R46, R48, R50,	10K-0603SMT	Panasonic	ERJ-3GEYJ103V	RES 10K OHM 1/10W 5% 0603 SMD
		R53, R54, R55, R56, R57, R58, R201				
44	2	R12, R13	100K-0603SMT	Panasonic	ERJ-3GEYJ104V	RES 100K OHM 1/10W 5% 0603 SMD
45	10	R14, R16, R29, R39, R67, R82, R86, R96, R102, R194	0R-0603SMT	Panasonic	ERJ-3GEY0R00V	RES ZERO OHM 1/10W 5% 0603 SMD
46	3	R15, R26, R27	0R-0805SMT	Panasonic	ERJ-6GEY0R00V	RES 0.0 OHM 1/8W 5% 0805 SMD
47	4	R17, R31, R32, R35	124R-0603SMT	Panasonic	ERJ-3EKF1240V	RES 124 OHM 1/16W 1% 0603 SMD
48	2	R18, R19	OPEN-0805SMT			
49	2	R20, R23	BOURNS-3224W-10K	Bourns	3224W-1-103E	TRIMPOT 10K OHM 4MM TOP ADJ SMD
50	8	R66, R76, R77, R85, R202, R203, R204, R205	OPEN-0603SMT			

Table 17. Bill of Materials (Continued)

Item	Quantity	Reference	Part	Manufacturer	Part Number	Description
51	1	R22	27R-0603SMT	Panasonic	ERJ-3EKF270V	RES 27 OHM 1/16W 1% 0603 SMD
52	1	R24	1_8K-0603SMT	Panasonic	ERJ-3GEYJ182V	RES 1.8K OHM 1/10W 5% 0603 SMD
53	1	R25	BOURNS-3224W-2K	Bourns	3224W-1-202E	TRIMPOT 2K OHM 4MM TOP ADJ SMD
54	1	R28	100R-0805SMT	Panasonic	ERJ-6GEYJ101V	RES 100 OHM 1/8W 5% 0805 SMD
55	1	R33	49_9R-0603SMT	Yageo	RC0603FR-0749R9RL	RES 49.9 OHM 1/10W 1% 0603 SMD
56	2	R36, R38	BOURNS-3224W-5K	Bourns	3224W-1-502E	TRIMPOT 5K OHM 4MM TOP ADJ SMD
57	1	R37	56R-0603SMT	Panasonic	ERJ-3EKF560V	RES 56 OHM 1/16W 1% 0603 SMD
58	3	R43, R44, R47	680R-0603SMT	Panasonic	ERJ-3GEYJ681V	RES 680 OHM 1/10W 5% 0603 SMD
59	6	R45, R59, R60, R61, R62, R80	4_7K-0603SMT	Panasonic	ERJ-3GEYJ472V	RES 4.7K OHM 1/10W 5% 0603 SMD
60	2	R49, R63	220R-0603SMT	Panasonic	ERJ-3GEYJ221V	RES 220 OHM 1/10W 5% 0603 SMD
61	1	R68	2_2K-0603SMT	Panasonic	ERJ-3GEYJ222V	RES 2.2K OHM 1/10W 5% 0603 SMD
62	9	R51, R52, R69, R70, R81, R87, R92, R94, R195	1K-0603SMT	Panasonic	ERJ-3EKF1001V	RES 1.00K OHM 1/16W 1% 0603 SMD
63	2	R71, R72	130R-0603SMT	Panasonic	ERA-3YEB131V	RES 130 OHM 1/16W .1% 0603 SMD
64	1	R73	1_6R-0603SMT	Panasonic	ERJ-3GEYJ1R6V	RESISTOR 1.6 OHM 1/10W 5% 0603
65	2	R74, R75	82R-0603SMT	Yageo	RC06031A82R0FKHFT	RES 82.0 OHM 1/10W 1% 0603 SMD
66	6	R78, R79, R88, R89, R90, R91	51R-0603SMT	Panasonic	ERJ-3GEYJ510V	RES 51 OHM 1/10W 5% 0603 SMD
67	2	R83, R93	1K_ADJ/SMT3MM	BC Components	ST3A102CT	POT 1K 3MM CERM SQ S/T SMD
68	1	R84	22R-0603SMT	Yageo	RC0603FR-0722RL	RES 22.0 OHM 1/10W 1% 0603 SMD
69	8	R98, R99, R100, R101, R103, R104, R105, R106	680R-1206SMT	Panasonic	ERJ-8GEYJ681V	RES 680 OHM 1/4W 5% 1206 SMD
70	12	SP1, SP2, SP3, SP4, SP5, SP6, SP7, SP8, SP9, SP10, SP11, SP12	TEST POINT			
71	1	SW1	SW DIP-3 CTS 194-3MST	CTS Corporation Resistor/Electrocomponents	194-3MST	SWITCH SIDE ACTUATED GOLD 3 SEC
72	2	SW2, SW3	SW PUSHBUTTON-SPST	C&K Components	EP11SD1ABE	SPST- Momentary RA
73	1	SW4	B3F-1150	Omron	B3F-1150	SWITCH TACT 6MM 100GF H=7.3MM
74	1	SW5	SW DIP-8/SM	C&K Components	BPA08SB	8-POSITION DIP PACK
75	1	TB1	Terminal Block/ED1202DS	On-Shore Tech.	ED120/2DS	TERMINAL BLOCK 5.08MM VERT 2POS
76	14	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14	TESTPOINT			
77	1	U1	ecp2m-672fpbga	LATTICE SUPPLIED		
	ALT:	LFE2M50E-6FN672C				
78	3	U2, U5, U7	AMS1503CM	Advanced Monolithic Systems	AMS1503CM	3A LOW DROPOUT VOLTAGE REGULATORS
79	2	U3, U4	PTH12060W	Texas Instruments	PTH12060WAH	MODULE PIP 12VIN 10A ADJ 10-SMD
80	1	U6	SC1592	Semtech	SC1592IMTRT	IC LDO ADJ REG 3A TO-263-7
81	1	U8	M25P64-FLASH	Macronix	MX25L6405MC20G	IC SRL FLASH 64MBIT 3V 16-SOP Wide(300MIL)

Table 17. Bill of Materials (Continued)

Item	Quantity	Reference	Part	Manufacturer	Part Number	Description
82	1	U9	MAX6817	Maxim	MAX6817-EUT+T	±15kV ESD-Protected, Dual, CMOS Switch Debouncers
83	2	U10, U12	NC7WZ16-MACO6A/Fairchild TinyLogic	Fairchild	NC7WZ16P6X	IC BUFFER UHS DUAL SC70-6
84	1	U11	SN74LVC125A/SO14	Texas Instruments	SN74LVC125AD	IC QUAD BUS BUFFER GATE 14-SOIC
85	1	U13	LCMX01200C-3MN1321	LATTICE SUPPLIED		
86	1	U14	S29GL064A90BFIR40	Spansion	GL064N10BFIR30	48fBGA FLASH-VBN048
87	1	U15	LP2996-SO8	National Semi	LP2996M	IC DDR TERMINATION REG 8SOIC
88	1	U16	DDR2-SDRAM-84FBGA	Micron	MT47H16M16BG-37E	16-Bit DDR2
89	1	U17	CY2304-1	Cypress Semiconductor	CY2304SC-1	zero delay buffer
90	1	Y2	CTS-CB3LV-3C-100.00MHZ	CTS-Frequency Controls	CB3LV-3C-100M0000-T	OSC CLOCK 100.000 MHZ 3.3V SMD
91	1	RN18	EXB2HV471JV	Panasonic	EXB2HV471JV	RES ARRAY 470 OHM 5% 8 RES SMD
92	4	R197, R198, R199, R200	33R-0603SMT	Panasonic	ERJ-3EKF33R0V	RES 33 OHM 1/16W 1% 0603 SMD
93	1	R21	1M-0603SMT	Panasonic	ERJ-3GEYJ105V	RES 1M OHM 1/10W 5% 0603 SMD
94	1	R207	RES. 100 ohm 1 /16 W, 0402 SMD	Panasonic	ERJ-2GEJ101X	
95	1	Bracket	Back Panel Bracket			
96	2	Screw	4-40 x .250			
97	2	Flat washer	4-40			
98	2	Lock washer	4-40			