



MachXO5-NX Family Root-of-Trust Devices Hardware Checklist

Technical Note

FPGA-TN-02371-1.0

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Acronyms in This Document

A list of acronyms used in this document.

Acronym	Definition
AC	Alternating Current
ADC	Analog to Digital Converter
BGA	Ball Grid Array
DC	Direct Current
DLL	Delay-Locked Loop
DDR3	Double Data Rate 3
ESR	Equivalent Series Resistance
FPGA	Field-Programmable Gate Array
HCSL	High-Speed Current Steering Logic
HSUL	High-Speed Unterminated Logic
I/O	Input/Output
JTAG	Joint Test Action Group
LVDS	Low-Voltage Differential Signaling
LVSTL	Low-Voltage Swing Terminated Logic
MIPI	Mobile Industry Processor Interface
NDA	Non-Disclosure Agreement
OSC	Oscillator
PCB	Printed Circuit Board
PLL	Phase-Locked Loop
SSTL	Stub Series-Terminated Logic
SERDES	Serializer/Deserializer

1. Introduction

When designing complex hardware using the MachXO5™-NX Root-of-Trust devices, you must pay special attention to critical hardware configuration requirements. This technical note steps through these critical hardware implementation items relative to the MachXO5-NX Root-of-Trust devices. The document does not provide detailed step-by-step instructions but gives a high-level summary checklist to aid in the design process.

The device family consists of FPGA densities ranging from 14k to 53k logic cells. This technical note assumes that the reader is familiar with the MachXO5-NX Root-of-Trust device features as described in the [MachXO5-NX Root-of-Trust Devices Family Data Sheet \(FPGA-DS-02120\)](#). The data sheet includes the functional specifications for the device. Topics covered in the data sheet include, but are not limited to the following:

- High-level functional overview
- Pinouts and packaging information
- Signal descriptions.
- Device-specific information about peripherals and registers
- Electrical specifications

Refer to the [MachXO5-NX Root-of-Trust Devices Family Data Sheet \(FPGA-DS-02120\)](#) for details. The critical hardware areas covered in this technical note are:

- Power supplies as they relate to the MachXO5-NX Root-of-Trust power supply rails and how to connect them to the PCB and the associated system.
- Configuration mode selection for proper power-up behavior.
- Device I/O interface and critical signals.

Important: Refer to the following documents for detailed recommendations.

- [sysCONFIG User Guide for Nexus Platform \(FPGA-TN-02099\)](#)
- [sysI/O User Guide for Nexus Platform \(FPGA-TN-02067\)](#)
- [sysCLOCK PLL Design and User Guide for Nexus Platform \(FPGA-TN-02095\)](#)
- [Memory User Guide for Nexus Platform \(FPGA-TN-02094\)](#)
- [MachXO5-NX High-Speed I/O Interface \(FPGA-TN-02286\)](#)
- [Thermal Management \(FPGA-TN-02044\)](#)
- [sysDSP User Guide for Nexus Platform \(FPGA-TN-02096\)](#)
- [High-Speed PCB Design Considerations \(FPGA-TN-02178\)](#)
- [Power Decoupling and Bypass Filtering for Programmable Devices \(FPGA-TN-02115\)](#)
- HSPICE SERDES simulation package (available under NDA, contact the license administrator at lic_admin@latticesemi.com)
- [MachXO5-NX 15D pinout table \(FPGA-SC-02043\)](#)
- [MachXO5-NX 55TD pinout table \(FPGA-SC-02041\)](#)
- [Electrical Recommendations for Lattice SERDES \(FPGA-TN-02077\)](#)
- [ADC User Guide for Nexus Platform \(FPGA-TN-02129\)](#)

2. Power Supplies

At power up, the V_{CC} , V_{CCAUX} , V_{CCIO1} , and V_{CCIO2} power supplies are monitored to determine when the MachXO5-NX Root-of-Trust device should de-assert its internal Power-On Reset state and enter the Power Good condition, which starts device initialization and configuration. These supplies should come up monotonically. Other supplies are not monitored during power-up but need to be at a valid and stable level before the device configuration is complete. Several other supplies are used in conjunction with onboard SERDES blocks and ADCs.

Table 2.1 describes the LFMXO5-15D power supplies and the appropriate voltage levels for each supply.

Table 2.1. LFMXO5-15D Power Supplies

Supply	Voltage (Nominal Value)	Description
V_{CC}	1.0 V	FPGA core power supply. Required for Power Good condition.
V_{CCECLK}	1.0 V	FPGA core clock power supply.
V_{CCAUX}	1.8 V	Auxiliary power supply pin for I/O Bank 0, Bank 1, Bank 2, Bank 3, Bank 4, Bank 7, Bank 8, and Bank 9. Used for generating stable drive current for the I/O.
$V_{CCAUXHx}$	1.8 V	Auxiliary power supply pin for I/O Bank 5, and Bank 6. Used for generating stable drive current for the I/O and stable current for the differential input comparators.
V_{CCAUXA}	1.8 V	Auxiliary Supply Voltage for internal analog circuitry. Required for Power Good condition.
$V_{CCIO[9:0]}$	Wide-Range Banks: Bank 1: 3.3 V Only Banks 0, 2, 3, 4, 7, 8, 9: 1.2 V, 1.35 V, 1.5 V, 1.8 V, 2.5 V, 3.3 V High-Speed Banks: Banks 5, 6: 1.0 V, 1.2 V, 1.35 V, 1.5 V, 1.8 V	Bank I/O Driver Supply Voltage. Each bank has its own V_{CCIO} supply. Bank 1 is 3.3V only. 1.35V is for DDR3L only. V_{CCIO1} and V_{CCIO2} have pins used for device configuration and are required for Power Good condition.
$V_{CCADC18}$	1.8 V	ADC Block power supply. Should be isolated from excessive noise.

Table 2.2 describes the LFMXO5-55TD power supplies and the appropriate voltage levels for each supply.

Table 2.2. LFMXO5-55TD Power Supplies

Supply	Voltage (Nominal Value)	Description
V _{CC}	1.0 V	FPGA core power supply. Required for Power Good condition.
V _{CCCLK}	1.0 V	FPGA core clock power supply.
V _{CCAUX}	1.8 V	Auxiliary power supply pin for I/O Bank 0, Bank 1, Bank 2, Bank 6, Bank 7. Used for generating stable drive current for the I/O.
V _{CCAUXHx}	1.8 V	Auxiliary power supply pin for I/O Bank 3, Bank 4, and Bank 5. Used for generating stable drive current for the I/O and stable current for the differential input comparators.
V _{CCAUXA}	1.8 V	Auxiliary Supply Voltage for internal analog circuitry. Required for Power Good condition.
V _{CCIO[9:0]}	Wide-Range Banks: Bank 0: 3.3 V Only Banks 1, 2, 6, 7: 1.2 V, 1.35 V, 1.5 V, 1.8 V, 2.5 V, 3.3 V High-Speed Banks: Banks 3, 4, 5: 1.0 V, 1.2 V, 1.35 V, 1.5 V, 1.8 V	Bank I/O Driver Supply Voltage. Each bank has its own V _{CCIO} supply. Bank 0 is 3.3V only. 1.35V is for DDR3L only. V _{CCIO0} and V _{CCIO1} have pins used for device configuration and are required for Power Good condition.
V _{CCADC18}	1.8 V	ADC Block power supply. Should be isolated from excessive noise.
ADC_REFP[1:0]	1.0 V to 1.8 V Typical	ADC External Reference. Should be isolated from excessive noise and have high accuracy (< 0.1% tolerance).
V _{CCSDx}	1.0 V	SERDES Block Core power supply voltage. Should be isolated from excessive noise.
V _{CCSDCK}	1.0 V	SERDES Block Clock buffer supply voltage. Should be isolated from excessive noise.
V _{CCPLSDx}	1.8 V	SERDES Block PLL power supply voltage. Should be isolated from excessive noise.
V _{CCAUXSDQx}	1.8 V	SERDES Block Auxiliary power supply voltage. Should be isolated from excessive noise.

2.1. Power Noise

The power rail voltages of the FPGA allow for a worst-case normal operating tolerance of $\pm 5\%$ of these voltages. The 5% tolerance includes any noise.

2.2. Power Source

It is recommended that the designed voltage regulators are accurate to within 3% of the optimum voltage to allow power noise design margin.

When calculating the voltage regulator's total tolerance, include:

- Regulator voltage reference tolerance.
- Regulator line tolerance.
- Regulator load tolerance.
- Tolerances of any resistors connected to the regulator's feedback pin, which sets the regulator's output voltage.
- Expected voltage drops due to power filtering the ferrite bead's ESR * expected current draw.
- Expected voltage drops due to the current measuring resistor's ESR * expected current draw.

With a 3% tolerance allocated to the voltage source, the design has a remaining 2% tolerance for noise and layout related issues. The 1.0 V rail is especially sensitive to noise, as every 10 mV is 1% of the rail voltage. For SERDES power rails, it is recommended to target a maximum 1% peak noise. For PLLs, target less than 0.25% peak noise.

3. Power Supply Filtering

Providing a quiet, filtered supply is important for all rails and critical for the analog rails. Supplies should be decoupled with adequate power filters. Bypass capacitors must be located close to the device package pins with very short traces to keep inductance low.

For the best performance, use careful pin assignments to keep noisy I/O pins away from sensitive functional pins. The leading causes of PCB-related crosstalk with sensitive blocks are related to FPGA outputs found in close proximity to the sensitive power supplies. These supplies require cautious board layout to ensure noise immunity to the switching noise generated by FPGA outputs. Guidelines are provided to build quiet-filtered supplies for the analog supplies; however, robust PCB layout is required to ensure that noise does not infiltrate into these analog supplies.

It is critical to have very low-noise, highly filtered supplies for the SERDES and ADCs. These supplies are also paired with dedicated ground pins.

3.1. Recommended Power Filtering Groups and Components

Table 3.1. Recommended Power Filtering Groups and Components

Power Input	Recommended Filter	Notes
V _{CC} , V _{CCECLK}	10 μF x 2 + 100 nF per pin	Core and clock logic. Tie V _{CC} and V _{CCECLK} pins together. 1.0 V
V _{CCAUX} , V _{CCAUXHX}	120 Ω FB + 10 μF + 100 nF per pin	Auxiliary power supply pins. Tie V _{CCAUX} and V _{CCAUXHX} pins together. 1.8 V
V _{CCAUXA}	120 Ω FB + 10 μF + 100 nF per pin	Auxiliary power supply pin for internal sensitive analog circuitry. 1.8 V
V _{CCIOx}	10 μF + 100 nF per pin for each V _{CCIOx}	Bank I/O. Unused banks can use a single 1.0 μF. For banks with lots of outputs or large capacitive loading replace the 10 μF with a 22 μF (or use two 10 μF). LFMXO5-15D: Bank 1: 3.3 V Only Banks 0, 2, 3, 4, 7, 8, 9: 1.2 V, 1.35 V, 1.5 V, 1.8 V, 2.5 V, 3.3 V Banks 5, 6: 1.0 V, 1.2 V, 1.35 V, 1.5 V, 1.8 V LFMXO5-55TD: Bank 0: 3.3 V Only Banks 1, 2, 6, 7: 1.2 V, 1.35 V, 1.5 V, 1.8 V, 2.5 V, 3.3 V Banks 3, 4, 5: 1.0 V, 1.2 V, 1.35 V, 1.5 V, 1.8 V
V _{CCADC18}	220 Ω or 120 Ω FB + 10 μF + 100 nF per pin	ADC Blocks. If both ADC blocks are not used, leave open. 1.8 V
ADC_REFP[1:0]	220 Ω or 120 Ω FB + 1.0 μF + 100 nF per pin	ADC Block External Reference. Must have very low noise and high accuracy reference (≤ 0.1% Tolerance). Voltage source/regulator should be filtered by 220 Ω or 120 Ω FB + 1 μF. If ADC Block is not used, connect its ADC_REFPx to ground through 0 Ω resistor. 1.0 V to 1.8 V Typical

Power Input	Recommended Filter	Notes
V _{CCSDx}	120 Ω FB + 10 μF + 100 nF per pin	SERDES Block Core. If SERDES block is not used, leave open. 1.0 V
V _{CCSDCK}	120 Ω FB + 10 μF + 100 nF per pin	SERDES Block Clock buffer. If both SERDES blocks are not used, leave open. 1.0 V
V _{CCPLSDx}	220 Ω FB + 47 μF + 470 nF per pin IMPORTANT: Connect capacitor grounds only to FPGA pin SD _x _REFRET	SERDES Block PLL. If SERDES block is not used, leave open. Bypass capacitor grounds go only to SD _x _REFRET 1.8 V
V _{CCAUXSDQx}	120 Ω FB + (10 μF and 100 nF to each channel's SD _x _REFRET)	SERDES Block Auxiliary. If SERDES block is not used, leave open. Bypass capacitor grounds go only to SD _x _REFRET 1.8 V

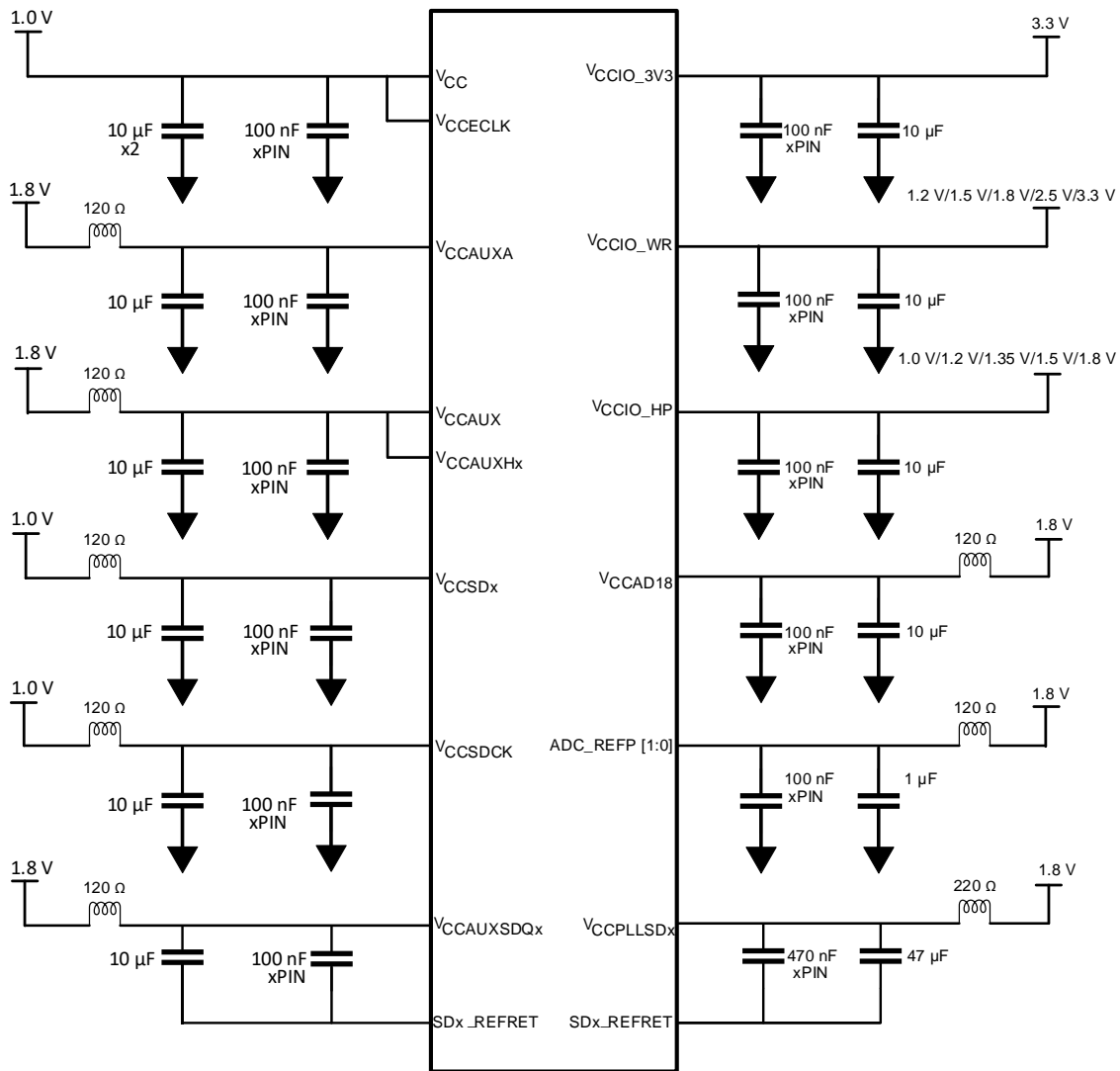


Figure 3.1. Recommended Power Filter

3.2. Ground Pins

- All ground pins need to be connected to the board's ground plane.
- V_{SSDX} and V_{SSADC} pins are sensitive to noise and should be isolated from fast switching high current pathways on the ground plane. Ground plane islands can be used to help isolate sensitive grounds from noisy ground areas. The ground plane islands must connect at only one location to the main ground plane. Connection locations should be at least 2 mm wide. Only signals in the same domain as the ground plane island should be referenced to that island.
- SDX_REFRET — Input SERDES Reference Return Input. This pin should be AC coupled (bypassed) to the $V_{CCPLSDX}$ supply.

3.3. Unused Bank V_{CCIOX}

- Connect unused V_{CCIOX} pins to a power rail. Do not leave them open.

3.4. Unused ADC Blocks

- If both ADC blocks are unused leave $V_{CCADC18}$ open.
- Unused ADC Blocks should connect ADC_REFx , ADC_DPx and ADC_DNx to board ground..
- V_{SSADC} pins should be connected to the board's ground plane even if ADC blocks are unused.

3.5. Unused Both SERDES Channels

- Connect to board ground V_{SSSDQ} pins, SDX_RXDP/N [$x=0$ and 3], SDX_REXT [$x=0$ and 3], SDX_REFRET [$x=0$ and 3] and $SDQ0_REFCLKP/N$.
- Leave the following open: V_{CCSDx} [$x=0$ and 3], $V_{CCPLSDx}$ [$x=0$ and 3], SDX_TXDP/N [$x=0$ and 3], $V_{CCAUXSDQ0}$, and V_{CCSDCK} .

3.6. Single Unused SERDES Channel

- Connect to board ground V_{SSSDQ} pins, along with unused channel's SDX_RXDP/N [$x=0$ or 3], SDX_REXT [$x=0$ or 3], and SDX_REFRET [$x=0$ or 3].
- Leave the following open on the unused channel: V_{CCSDx} [$x=0$ or 3], $V_{CCPLSDx}$ [$x=0$ or 3], SDX_TXDP/N [$x=0$ or 3].

3.7. Clock Oscillator Supply Filtering

When providing an external reference clock to the FPGA from, for example, a single-ended or differential clock oscillator, proper power supply isolation and decoupling of the clock oscillator are recommended.

When specifying components, choose *good-quality* ceramic capacitors in small packages and place them as close to the clock oscillator supply pins as practically possible. *Good-quality* capacitors for bypassing generally meet the requirement.

3.8. Ferrite Bead Selection

- Most designs work well using ferrite beads between 120 Ω at 100 MHz and 240 Ω at 100 MHz.
- Ferrite bead induced noise voltage from $ESR * CURRENT$ should be < 1% of rail voltage for non-analog rails and < 0.25% for sensitive rails.
- Non-PLL rails should use ferrite beads with an ESR between 0.025 Ω and 0.10 Ω depending on the current load.
- PLL rails draw low current, which allows ferrite beads with an $ESR \leq 0.3 \Omega$.
- Small package size ferrite beads have a higher ESR than large package size ferrite beads of the same impedance.
- High impedance ferrite beads have a higher ESR than low impedance ferrite beads in the same package size.

3.9. Capacitor Selection

When specifying components, choose good quality ceramic capacitors in small packages and place them close to the power oscillator supply pins with short low inductance connections. Good quality capacitors for bypassing generally meet the requirements discussed in the following sections.

3.9.1. Capacitor Dielectric

Use dielectrics such as X5R, X7R, and similar that have good capacitance tolerance ($\leq \pm 20\%$) over a temperature range. Avoid Y5V, Z5U, and similarly poor capacitance-controlled dielectrics.

3.9.2. Voltage Rating

Capacitor working capacitance decreases non-linearly with a higher voltage bias. To maintain capacitance, the capacitor voltage rating should be at least 80% higher than the voltage rail (maximum). Example: 3.3 V rail bypass capacitors should use the commonly available 6.3 V rating as a minimum.

3.9.3. Size

Smaller body capacitors have lower inductance, work at higher frequencies, and improve board layout. For a given voltage rating, smaller body capacitors tend to cost more than larger body capacitors. Optimizing between market pricing and size related inductance, the following capacitor sizes are recommended:

Table 3.2. Recommended Capacitor Sizes

Capacitance	Size Preferred	Size Next Best
0.1 μF	0201	0402
1.0 μF , 2.2 μF	0402	0201
4.7 μF	0402	0603
10 μF	0402	0603
22 μF	0805	0603

4. Power

There is no power-up sequence required for the MachXO5-NX Root-of-Trust device.

5. Power Estimation

Once the MachXO5-NX Root-of-Trust device density, package, and logic implementation are decided, power estimation for the system environment should be determined based on the Power Calculator provided as part of the Lattice Radiant™ design tool. When estimating power, the designer should keep two goals in mind:

Power supply budgeting should be based on the maximum power-up in-rush current, configuration current, and maximum DC and AC current for the given system environmental conditions.

Thermal considerations are also important. The thermal design of the system environment and MachXO5-NX Root-of-Trust device should be able to support operating at the maximum operating junction temperature.

The above two criteria should be taken into consideration early in the design phase.

6. Configuration Considerations

PCB layout design and breakout suggestions are outlined in [PCB Layout Recommendations for BGA Packages \(FPGA-TN-02024\)](#). For application-specific assembly guidance, consult the design guidelines of the assembly service provider.

The MachXO5-NX Root-of-Trust device includes provisions to configure the FPGA via the JTAG interface or several modes utilizing the sysCONFIG port. The JTAG port includes a 4-pin interface. The interface requires the following PCB considerations.

Table 6.1. JTAG Pin Recommendations

JTAG Pin	PCB Recommendation
TDI/SI	4.7 kΩ pull-up to V _{CCIO1} ¹
TMS/SCSN	4.7 kΩ pull-up to V _{CCIO1} ¹
TDO/SO	4.7 kΩ pull-up to V _{CCIO1} ¹
TCK/SCLK	2.2 kΩ pull-down to GND
JTAG_EN	4.7 kΩ pull-down to GND (JTAG port disabled) or 1.0 kΩ pull-up to V _{CCIO1} ¹ (JTAG port enabled)

Note:

1. Use V_{CCIO1} for LFMXO5-55TD and use V_{CCIO2} for LFMXO5-15D.

Every PCB is recommended to have easy access to FPGA JTAG pins, even if the primary configuration interface is not using the JTAG port. This JTAG port enables debugging in the final system. For best results, route the TCK, TMS, TDI, and TDO signals to a common test header along with the corresponding V_{CCIO} and ground.

External resistors are necessary on configuration signals if they are used to handshake with other devices. External pull-resistors are not necessary on individual configuration pins when the signal pin is not persisted.

Recommended pull-up resistors to the appropriate bank V_{CCIO} and pull-down resistors to board ground should be used on the pins in [Table 6.2](#).

Table 6.2. Pull-up/Pull-down Recommendations for Configuration Pins

Pin	PCB Connection
PROGRAMN	4.7 kΩ pull-up to V _{CCIO2} ²
INITN	10 kΩ pull-up to V _{CCIO2} ²
DONE	10 kΩ pull-up to V _{CCIO2} ²
JTAG_EN	4.7 kΩ pull-down to GND (JTAG port disabled) or 1.0 kΩ pull-up to V _{CCIO3} ³ (JTAG port enabled)
TMS/SCSN	10 kΩ pull-up to V _{CCIO3} ³
SCL/SDA ¹	1.0 kΩ to 4.7 kΩ pull-up to V _{CCIO3} ³

Notes:

1. Pull-up resistors are not required in target I3C configuration mode.
2. Use V_{CCIO0} for LFMXO5-55TD and use V_{CCIO1} for LFMXO5-15D.
3. Use V_{CCIO1} for LFMXO5-55TD and use V_{CCIO2} for LFMXO5-15D.

Table 6.3. Configuration Pins Needed per Programming Mode¹

Configuration Mode	Bank	Enablement	Clock		Bus Size	Pins
			Pin	I/O		
JTAG	1	JTAG_EN pin ²	TCLK	Input	1	TCK, TMS, TDI, TDO
SSPI	1	Activation key ²	SCLK	Input	1	SCLK, SCSN, SI, SO
					2	SCLK, SCSN, SD0, SD1
					4	SCLK, SCSN, SD0, SD1, SD2, SD3
I2C/I3C	1	Activation key	SCL	Input	1	SCL, SDA

Note:

1. Leave unused configuration ports open.
2. JTAG and SSPI ports share pins. When JTAG_EN is asserted, the JTAG port takes precedence over SSPI.

SRAM – JTAG/SSPI

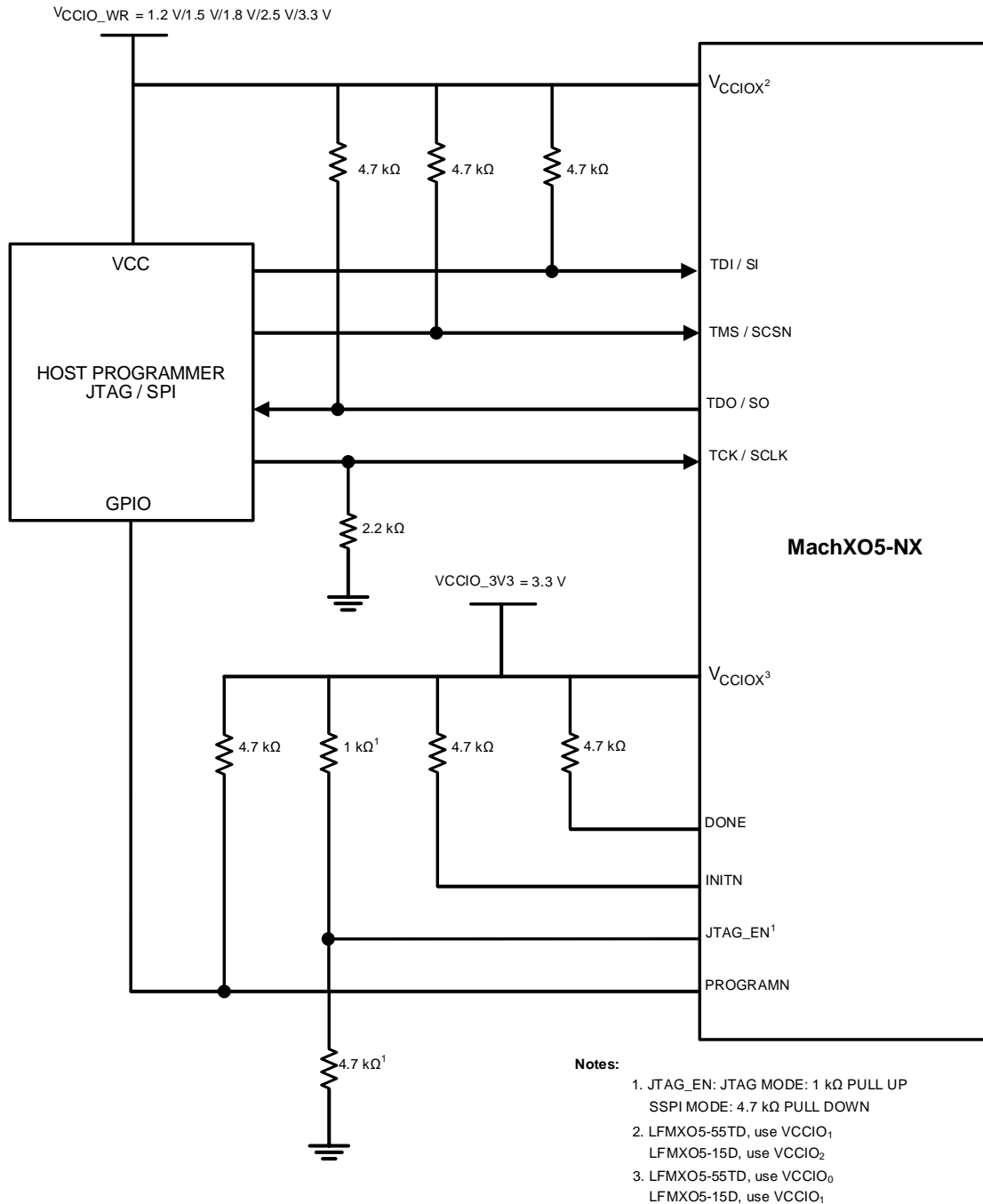


Figure 6.1. Typical Connections for Programming SRAM/FLASH via JTAG/SSPI

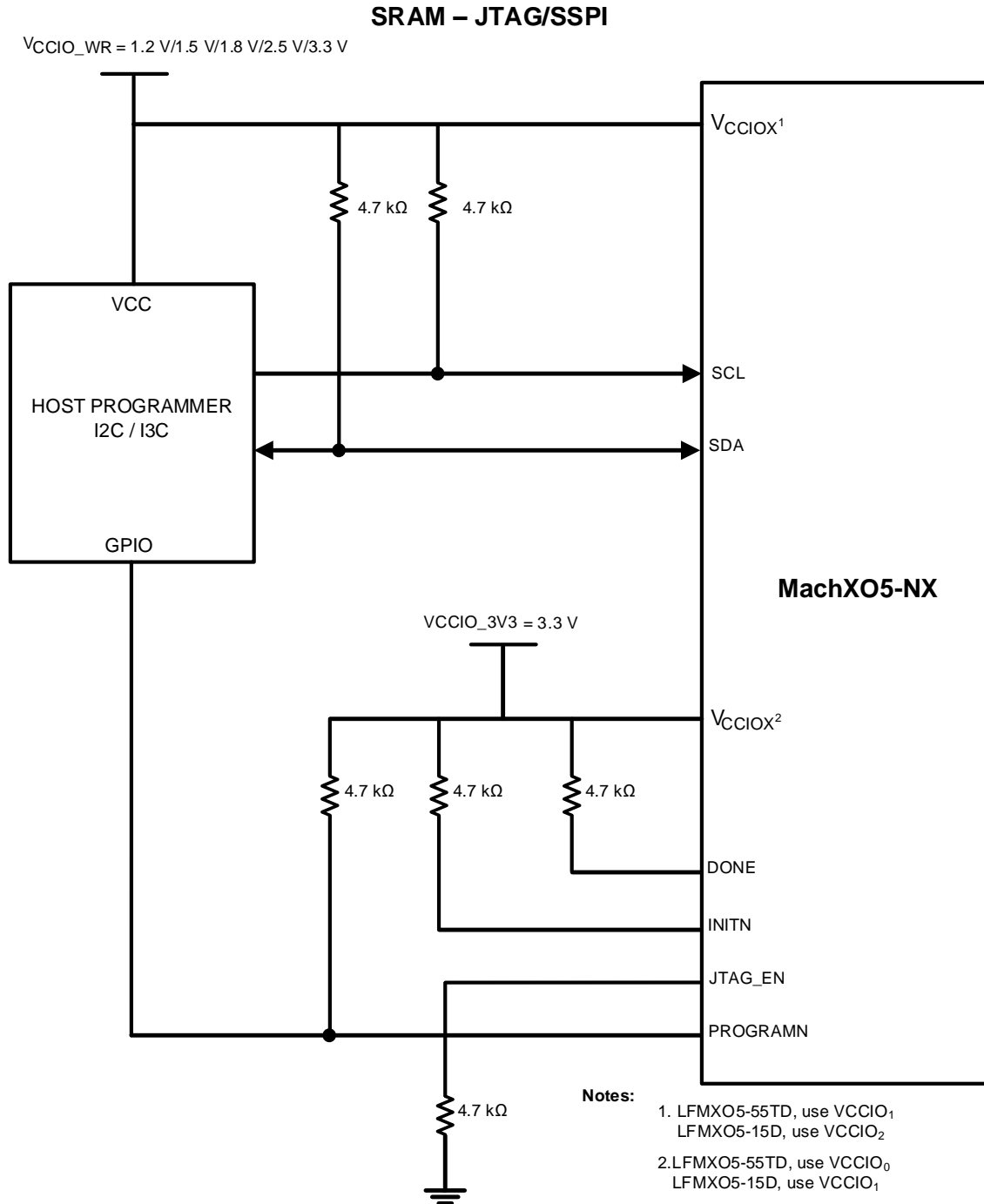


Figure 6.2. Typical Connections for Programming SRAM/FLASH via I2C/I3C

7. I/O Pin Assignments

The V_{CCSDCK} , $V_{CCPLLSDX}$ and $V_{CCAUUSDQX}$ provide quiet supplies for the SERDES blocks. For the best jitter performance, careful pin assignment keeps noisy I/O pins away from sensitive pins. The leading cause of PCB related SERDES crosstalk is related to FPGA outputs located in close proximity to the sensitive SERDES power supplies. These supplies require cautious board layout to ensure noise immunity to the switching noise generated by FPGA outputs. Guidelines are provided to build quiet filtered supplies; however, robust PCB layout is required to ensure that noise does not infiltrate into these analog supplies.

Although crosstalk generated coupling is reduced in the device packages of MachXO5-NX Root-of-Trust devices, the PCB board can cause significant noise injection from any I/O pin adjacent to SERDES data, reference clock, and power pins, as well as other critical I/O pins such as clock signals. [Electrical Recommendations for Lattice SERDES \(FPGA-TN-02077\)](#) provides detailed guidelines for optimizing the hardware to reduce the likelihood of crosstalk to the analog supplies. PCB traces running in parallel for long distances need careful analysis. Simulate any suspicious traces using a PCB crosstalk simulation tool to determine if they cause problems.

It is common practice for designers to select pinouts for their system early in the design cycle. For the FPGA designer, this requires detailed knowledge of the targeted FPGA device. Designers often use a spreadsheet program to initially capture the list of the design I/O. Lattice Semiconductor provides detailed pinout information that can be downloaded from the Lattice Semiconductor website in .csv format for designers to use as a resource to create pinout information. For example, by navigating to the pinout.csv file, you can gather the pinout details for all the different package offerings of the device in the family, including I/O banking, differential pairing, dual function of the pins, and input and output details.

7.1. Early I/O Release

The MachXO5-NX Root-of-Trust device supports an Early I/O Release feature, which allows the I/O that reside in the I/O banks on the left and right of the device (LFMXO5-15D Banks 2, 3, 4, 7, 8, 9 and LFMXO5-55TD Banks 1, 2, 6, 7) to assume user-defined drive states at the beginning of bitstream processing. The Early I/O Release feature releases the I/O after processing the I/O configuration for the left and right banks, which is located near the head of the bitstream data. Once data is programmed in the left/right Memory Interface Block (MIB), the I/O is released to a predefined state. This feature is enabled by setting the EARLY_IO_RELEASE preferences to ON in the Lattice Radiant Device Constraint Editor.

In addition, Early I/O Release requires you to instantiate an output buffer register with an asynchronous set or reset function to indicate the desired drive 1 or drive 0 behavior, respectively, during the Early Release period. Unregistered outputs in Early-Release banks drive High-Z until full device configuration is complete. Be aware that some of the I/O in Bank 2, including the dual-purpose sysCONFIG I/O, cannot be utilized as Early Released I/O. Also, if the ECDSA bitstream authentication is enabled for the MachXO5-NX Root-of-Trust device, the Early I/O Release feature is not supported.

8. sysI/O

The MachXO5-NX Root-of-Trust device provides the flexibility to configure each I/O according to your requirements. These pins can be configured as input, output, and tri-state. Additionally, attributes such as PULLMODE, CLAMP, HYSTERESIS, VREF, OPENDRAIN, SLEWRATE, DIFFRESISTOR, TERMINATION, and DRIVE STRENGTH can also be setup.

For the PULLMODE, pull-up and pull-down resistors can be set. The implementation of these resistors is by using a constant current that has the following values:

Table 8.1. Weak pull-up/down current specifications

Configuration	Parameter	Condition	Min	Max	Unit
Pull-up	I/O Weak pull-up resistor current	$0 \leq V_{IN} \leq 0.7 \times V_{CCIO}$	-30	-150	μA
Pull-down	I/O Weak pull-down resistor current	$V_{IL} (max) \leq V_{IN} \leq V_{CCIO}$	30	150	μA

MachXO5-NX devices also provide special I/Os like HPIO and WRIO that can be used for high-speed communication.

[Figure 8.1](#) shows the block diagram for HPIO. and [Figure 8.2](#) shows the block diagram for WRIO.

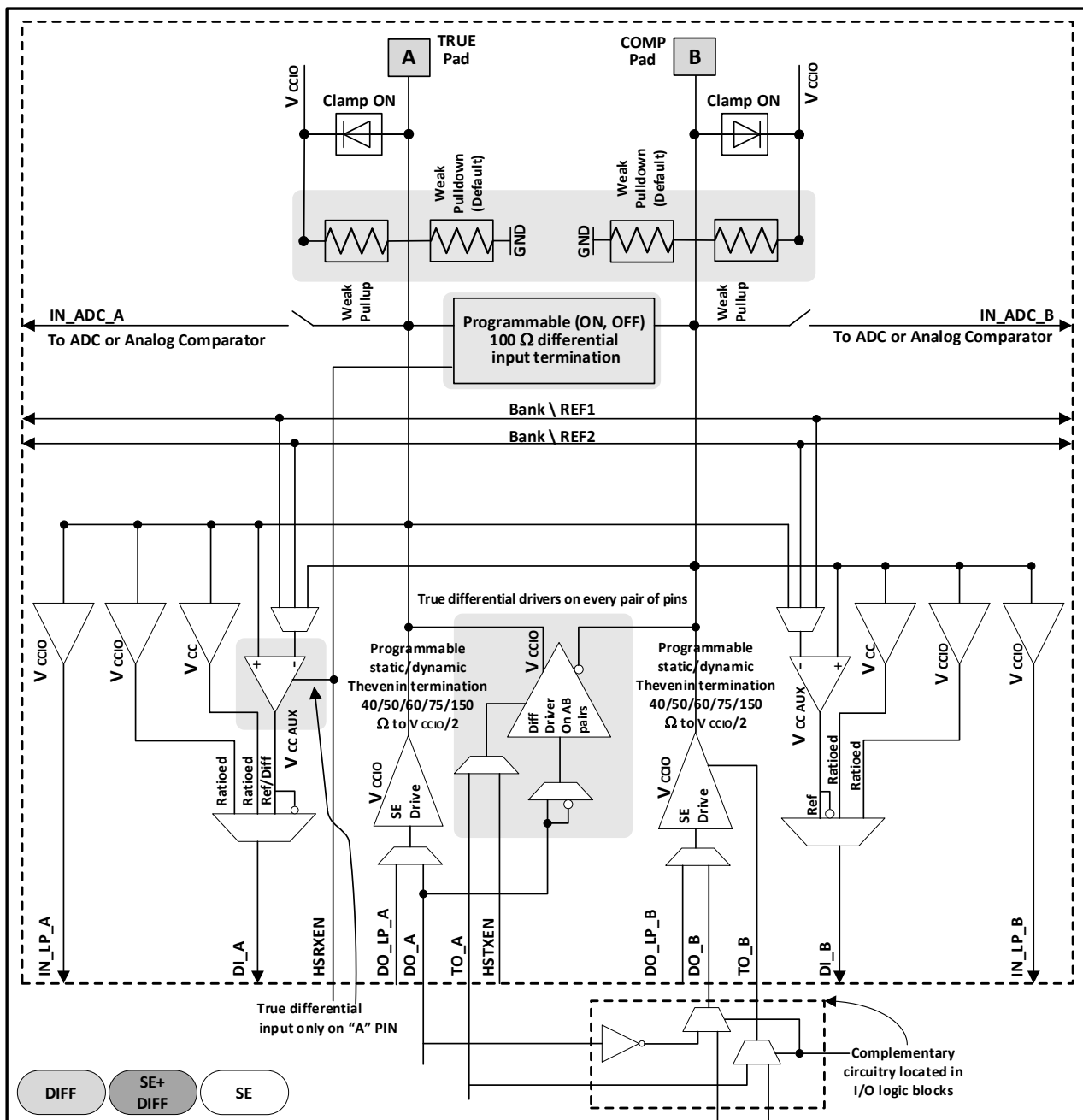


Figure 8.1. High-Performance sys/O Buffer Pair for Bottom Side

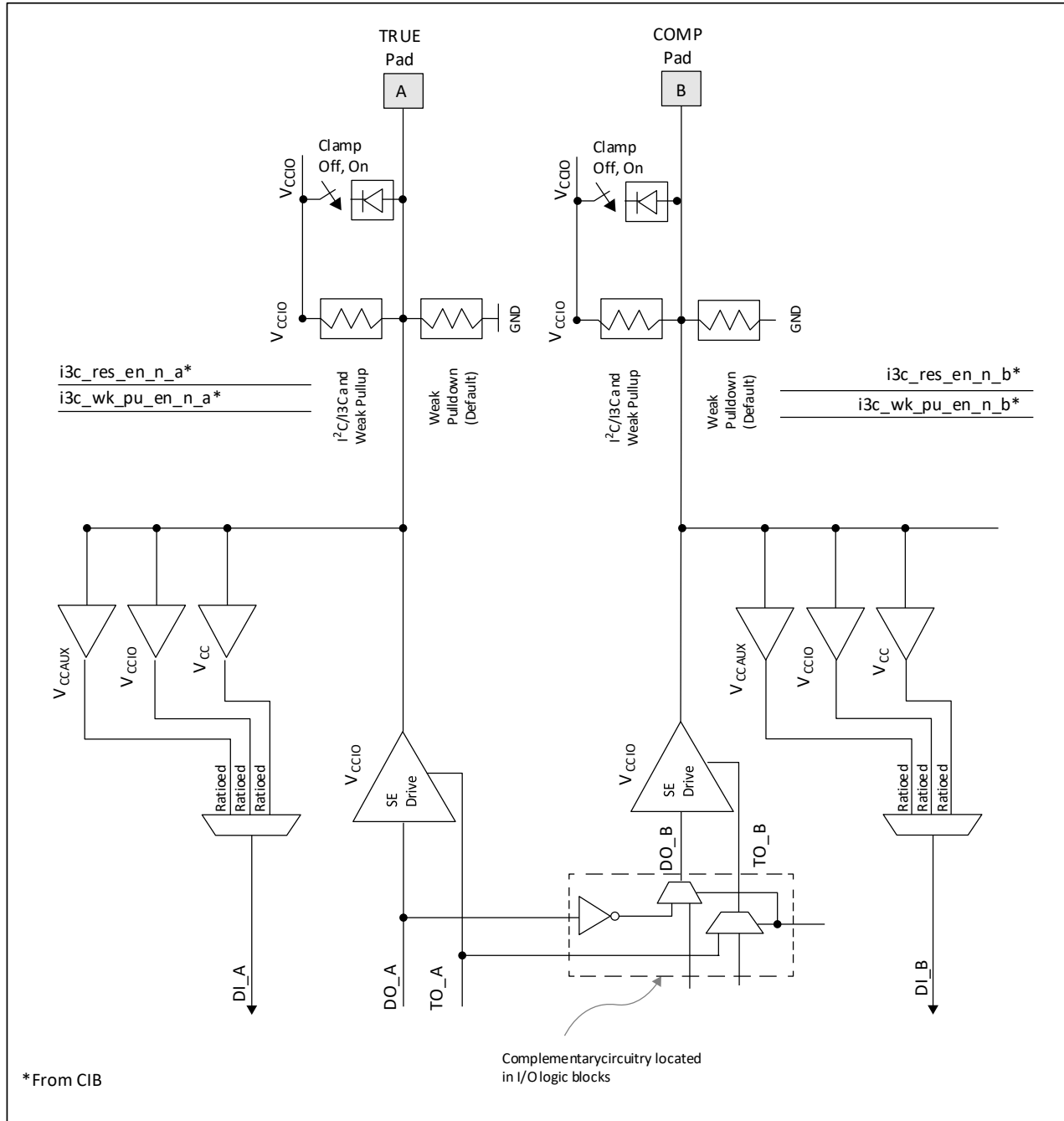


Figure 8.2. Wide Range sysI/O Buffer for Top, Left/Right Side

9. Clock Inputs

The MachXO5-NX Root-of-Trust device provides certain pins for use as clock inputs in each I/O bank. These pins are shared and can alternately be used for general purpose I/O.

When these pins are used for clocking purposes, you need to pay attention to minimize signal noise on these pins. Refer to the [MachXO5-NX High-Speed I/O Interface \(FPGA-TN-02286\)](#).

These shared clock input pins, typically named GPLL and PCLK, can be found under the Dual Function column of the pinlist **.csv** file.

High-speed differential interfaces (such as MIPI) being received by the FPGA must route their differential clock pair into a pair of inputs that support differential clocking, labeled PCLKTx_y (+true) and PCLKCx_y (-complement).

When providing an external reference clock to the FPGA, ensure that the oscillator's output voltage to the FPGA does not exceed the bank's voltage. Good power supply decoupling of the clock oscillator is required to reduce clock jitter. [Figure 9.1](#) shows a typical bypassing circuit.

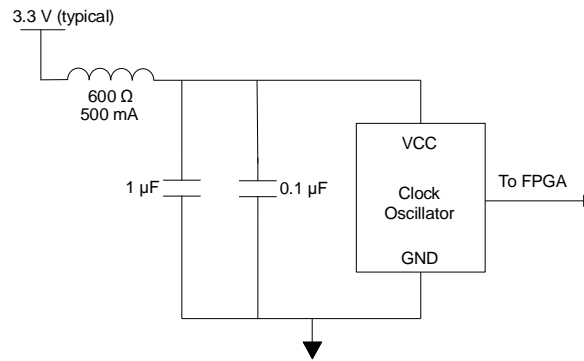


Figure 9.1. Clock Oscillator Bypassing

For differential clock inputs to banks with a V_{CCIO} voltage of 1.5 V or lower, it is recommended to use an HCSL oscillator to keep the clock voltage less than or equal to the bank's V_{CCIO} . An LVDS oscillator can also be used if AC is coupled and then DC is biased at half the V_{CCIO} voltage. Example dual footprint design supporting HCSL and LVDS is shown below in [Figure 9.2](#).

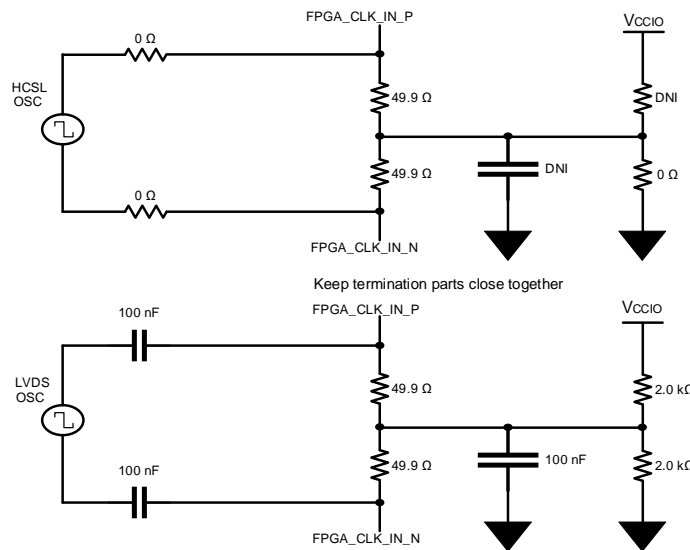


Figure 9.2. PCB Dual Footprint Supporting HCSL and LVDS Oscillators

10. Pinout Considerations

The MachXO5-NX Root-of-Trust device supports many applications with high-speed interfaces. These include various rule-based pinouts that need to be understood prior to the implementation of the PCB design on these high-speed interfaces. The pinout selection must be completed with an understanding of the interface building blocks implemented in the FPGA fabric. These include IOLOGIC blocks such as DDR3L, clock resource connectivity, and PLL and DLL usage. Avoid placing noisy I/Os next to sensitive analog I/Os. Refer to [MachXO5-NX High-Speed I/O Interface \(FPGA-TN-02286\)](#) for rules pertaining to these interface types.

10.1. LVDS Pin Assignments

True LVDS outputs are available on I/O pins on the device's bottom banks only (LFMXO5-15D Banks 5, 6 and LFMXO5-55TD Banks 3, 4, 5). Other banks do not support the True LVDS output standard. Differential input pairing can be found in the pin list csv file.

Emulated LVDS output is available in pairs around all banks and requires external termination resistors. This is described in the [sys/I/O Usage Guide for Nexus Platform \(FPGA-TN-02067\)](#).

10.2. Soft MIPI

Soft MIPI I/Os are available on the device's bottom banks only (LFMXO5-15D Banks 5, 6 and LFMXO5-55TD Banks 3, 4, 5).

10.3. HSUL, SSTL, LVSTL¹, V_{REF} Pin Assignments

The HSUL, SSTL, and LVSTL¹ interfaces are referenced I/O standards that require an external reference voltage. HSUL, SSTL, and LVSTL¹ are supported on the device's bottom banks only (LFMXO5-15D Banks 5, 6 and LFMXO5-55TD Banks 3, 4, 5).

The V_{REF} pin(s) should get high priority when assigning pins to the PCB. These pins can be found in the Dual Function column with the V_{REF} label. Each bank includes a separate V_{REF} voltage. V_{REF} sets the threshold for the referenced input buffers. Each I/O is individually configurable based on the bank supply and reference voltages.

Connect a 0.1 μF capacitor to ground close to each used V_{REF} pin. The V_{REF} power source should have a relatively low output impedance (<= 130 ohms).

Note:

1. Only supported in LFMXO5-55TD devices.

11. DPHY and SERDES Pin Considerations

High-speed signaling requires careful PCB design. Maintaining good transmission line characteristics is a requirement. A continuous ground reference should be maintained with high-speed routing. This includes tightly length matched differential routing (no larger than ± 4 mil length mismatch) with very few discontinuities.

The DPHY clock input must use a PCLK pin so that it can be routed directly to the edge clock tree. Refer to [High-Speed PCB Design Considerations \(FPGA-TN-02178\)](#) for suggested methods and guidance. In the MachXO5-NX Root-of-Trust device the DPHY is a soft DPHY implementation.

12. Layout Recommendation

A good design from a schematic should also reflect a good layout for the system design to work without any issues with noise or power distribution. Below are some of the recommended layouts in general.

1. All power should come from power planes. This is to ensure good power delivery and thermal stability.
2. Each power pin has its own decoupling capacitor, typically 100 nF, that should be placed as close as possible to each other.
3. The placement of analog circuits must be away from digital circuits or high-switching components.
4. High-speed signals should have a clearance of five times the trace width of other signals.
5. High-speed signals that transition from one layer to another should have a corresponding transition ground if both reference planes are grounded. If the reference on the other layer is a V_{CC} plane, then a stitching capacitor should be used (ground to V_{CC}).

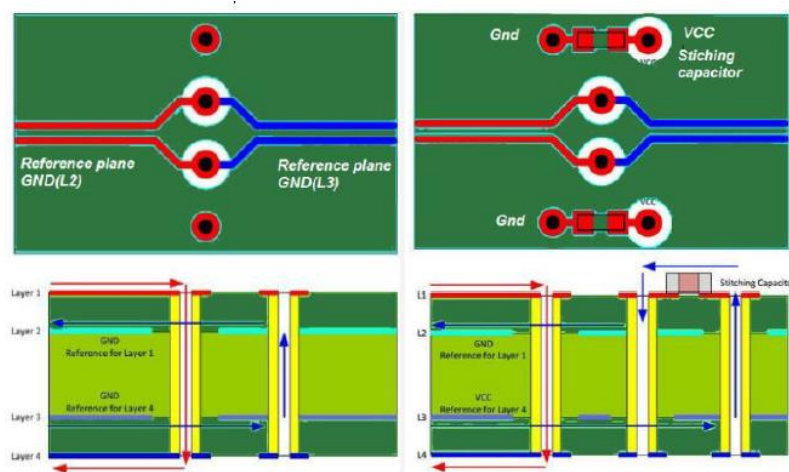


Figure 12.1. PCB Layout Recommendation

6. High-speed signals have a corresponding impedance requirement. Calculate the necessary trace width and trace gap (differential gap) according to the desired stack-up. Verify trace dimensions with the PCB vendor.
7. For differential pairs, be sure to match the length as closely as possible. A good rule of thumb is to match up to ± 5 mils.

For further information on layout recommendations, refer to:

- [PCB Layout Recommendations for BGA Packages \(FPGA-TN-02024\)](#)
- [PCB Layout Recommendations for Leaded Packages \(FPGA-TN-02160\)](#)

13. Checklist

Table 13.1. Hardware Checklist

	Item	OK	NA
1	FPGA Power Supplies		
1.1	Core Supplies		
1.1.1	V_{CC} and V_{CCECLK} tied together core @ 1.0 V $\pm 3\%$ (allowing for 2% noise).		
1.1.2	Use a PCB plane for V_{CC} and V_{CCECLK} core with proper decoupling.		
1.1.3	V_{CC} and V_{CCECLK} core sized to meet power requirement calculation from software.		
1.1.4	V_{CCAUX} , $V_{CCAUXHX}$, and V_{CCAUXA} @ 1.8 V $\pm 3\%$ (allowing for 2% noise).		
1.1.5	V_{CCAUX} , $V_{CCAUXHX}$, and V_{CCAUXA} Must be <i>quiet</i> and isolated from other switching noises.		
1.1.6	V_{CCAUX} pins ganged together with $V_{CCAUXHX}$ pins. Solid PCB plane is recommended.		
1.1.7	V_{CCAUXA} is sensitive, these pins should be ganged together and use a separate FB + Capacitor filtering. Solid PCB plane is recommended.		
1.2	I/O Supplies		
1.2.1	<i>Wide Range</i> V_{CCIO1} (LFMXO5-15D) 3.3 V Only. <i>Wide Range</i> V_{CCIO0} (LFMXO5-55TD) 3.3 V Only.		
1.2.2	<i>Wide Range</i> V_{CCIOx} LFMXO5-15D Banks 0, 2, 3, 4, 7, 8, 9 are between 1.2 V to 3.3 V. <i>Wide Range</i> V_{CCIOx} LFMXO5-55TD Banks 1, 2, 6, 7 are between 1.2 V to 3.3 V.		
1.2.3	<i>High Performance</i> V_{CCIOx} LFMXO5-15D Banks 5,6 are between 1.0 V to 1.8 V. <i>High Performance</i> V_{CCIOx} LFMXO5-55TD Banks 3, 4, 5 are between 1.0 V to 1.8 V.		
1.2.4	V_{CCIOx} bank voltage matches sysCONFIG peripheral devices such as system I3C, SPI Flash, etc.		
1.3	ADC power supply		
1.3.1	$V_{CCADC18}$ is 1.8 V $\pm 3\%$ (allowing for 2% noise).		
1.3.2	$V_{CCADC18}$ <i>quiet and isolated</i> .		
1.3.3	Use accurate voltage reference for ADC_REFP[1:0] ($\leq \pm 0.1\%$ tolerance)		
1.3.4	If both ADC Blocks are unused leave $V_{CCADC18}$ open.		
1.3.5	Unused ADC Blocks should connect ADC_REFPx to ground through 0 Ω resistor.		
1.3.6	V_{SSADC} pin should connected to the board's ground plane even if ADC Blocks are unused.		
1.4	SERDES Power Supplies		
1.4.1	V_{CCSDx} and V_{CCSDCK} are at 1.0 V $\pm 5\%$		
1.4.2	V_{CCSDx} and V_{CCSDCK} <i>quiet and isolated</i> from each other and other 1.0 V supplies		
1.4.3	$V_{CCPLLSdx}$ and $V_{CCAUXSDQ0}$ are 1.8 V +5%		
1.4.4	$V_{CCPLLSdx}$ and $V_{CCAUXSDQ0}$ <i>quiet and isolated</i> from each other and other 1.8 V supplies		
1.4.5	$V_{CCPLLSdx}$ and $V_{CCAUXSDQ0}$ bypass capacitor grounds go only to SDx_REFRET		
1.4.6	Unused Both SERDES Channels Connect to board ground V_{SSDQ} pins, SDx_RXDP/N [x=0 and 3], SDx_REXT [x=0 and 3], SDx_REFRET [x=0 and 3] and SDQ0_REFCLKP/N. Leave the following open: V_{CCSDx} [x=0 and 3], $V_{CCPLLSdx}$ [x=0 and 3], SDx_TXDP/N [x=0 and 3], $V_{CCAUXSDQ0}$, and V_{CCSDCK} .		
1.4.7	Single Unused SERDES Channel Connect to board ground V_{SSDQ} pins, along with unused channel's SDx_RXDP/N [x=0 or 3], SDx_REXT [x=0 or 3], and SDx_REFRET [x=0 or 3]. Leave the following open on the unused channel: V_{CCSDx} [x=0 or 3], $V_{CCPLLSdx}$ [x=0 or 3], SDx_TXDP/N [x=0 or 3].		
1.5	Grounds		
1.5.1	All ground pins must be connected to low impedance ground plane.		

	Item	OK	NA
2	JTAG		
2.1	Pull-up or Pull-down on JTAG_EN, per Table 6.1 .		
2.2	Keep JTAG_EN accessible on PCB to recover JTAG port, especially during development.		
2.3	Keep JTAG port pins accessible on PCB, especially during development		
2.4	Pull-down on TCK per Table 6.1 .		
2.5	Pull-up on TMS per Table 6.1 .		
3	Configuration		
3.1	Pull-ups or pull-downs on persisted configuration specific pins per Table 6.1 and Table 6.2 .		
3.2	V _{CCIOX} bank voltage matches sysCONFIG peripheral devices such as system I3C, SPI Flash, etc.		
4	Special Pin Assignments		
4.1	V _{REF} assignments followed for single-ended referenced inputs		
4.2	Properly decouple the V _{REF} pin		
4.3	The V _{REF} source should have relatively low output impedance (<= 130 ohms)		
4.4	Soft MIPI I/Os are on the device's bottom banks only (LFMXO5-15D Banks 5, 6 and LFMXO5-55TD Banks 3, 4, 5).		
5	Critical Pinout Selection		
5.1	Pinout is chosen to address FPGA resource connections to I/O logic and clock resources per MachXO5-NX High-Speed I/O Interface (FPGA-TN-02286) .		
5.2	Shared general purpose I/O are used as inputs for FPGA PLL and Clock inputs.		
5.3	Differential pair I/O polarity: I/O are named P[T/B/L/R] [Number]_[A/B] Diff pair positive signal connects to name ending in A, Negative connects to name ending in B.		
5.4	Differential clock inputs, including for soft MIPI, must use a PCLK pin so the clock input can be routed directly to the edge clock tree.		
6	DDR3L Interface Requirements		
6.1	DQ, DM, and DQS signals should be routed in a data group and should have similar routing and matched via counts. Using more than three vias is not recommended in the route between the FPGA controller and memory device.		
6.2	Maintain trace length matching to a maximum of ±20 mil between any DQ/DM and its associated DQS strobe within a DQ group. Use careful serpentine routing to meet this requirement.		
6.3	All data groups must reference a ground plane within the stack-up.		
6.4	DDR trace reference must be solid without slots or breaks. It should be continuous between the FPGA and the memory.		
6.5	Provide a separation of 3 W spacing between a data group and any other unrelated signals to avoid crosstalk issues. Use a minimum of 2 W spacing between all DDR traces excluding differential CK and DQS signals. (W is the minimum width of the signal trace allowed)		
6.6	Assigned FPGA I/O within a data group can be swapped to allow clean layout. Do not swap DQS assignments.		
6.7	Differential pair of DQS to DQS_N trace lengths should be matched to ±10 mil.		
6.8	Resistor terminations (DQ) placed in a fly-by fashion at the FPGA is highly recommended. Stub fashion terminations, if used, should not include a stub longer than 600 mil.		
6.9	LDQS/LDQS_N and UDQS/UDQS_N trace lengths should be matched within ±100 mil.		
6.10	Address/control signals and the associated CK and CK_N differential FPGA clock should be routed with a control trace matching ±100 mil.		
6.11	CK to CK_N trace lengths must be matched to within ±10 mil.		
6.12	Address and control signals can be referenced to a power plane if a ground plane is not available. Ground reference is preferred.		
6.13	Address and control signals should be kept on a different routing layer from DQ, DQS, and DM to isolate crosstalk between the signals.		

	Item	OK	NA
6.14	Differential terminations used by the CLK/CLKN pair must be located as close as possible to the memory.		
6.15	Address and control terminations placed after the memory component using a fly-by technique are highly recommended. Stub fashion terminations, if used, should not include a stub longer than 600 mils.		
7	ADC		
7.1	When using ADC function, use the PLL in the lower right corner (this PLL is closest on die to the ADC.)		

References

- [MachXO5-NX Root-of-Trust Devices Family Data Sheet \(FPGA-DS-02120\)](#)
- [MachXO5-NX High-Speed I/O Interface \(FPGA-TN-02286\)](#)
- [sysCONFIG User Guide for Nexus Platform \(FPGA-TN-02099\)](#)
- [sysI/O User Guide for Nexus Platform \(FPGA-TN-02067\)](#)
- [sysCLOCK PLL Design and User Guide for Nexus Platform \(FPGA-TN-02095\)](#)
- [Memory User Guide for Nexus Platform \(FPGA-TN-02094\)](#)
- [sysDSP User Guide for Nexus Platform \(FPGA-TN-02096\)](#)
- [Thermal Management \(FPGA-TN-02044\)](#)
- [High-Speed PCB Design Considerations \(FPGA-TN-02178\)](#)
- [ADC User Guide for Nexus Platform \(FPGA-TN-02129\)](#)
- [Power Decoupling and Bypass Filtering for Programmable Devices \(FPGA-TN-02115\)](#)
- [PCB Layout Recommendations for BGA Packages \(FPGA-TN-02024\)](#)
- [PCB Layout Recommendations for Leaded Packages \(FPGA-TN-02160\)](#)
- [Electrical Recommendations for Lattice SERDES \(FPGA-TN-02077\)](#)
- [Lattice Radiant FPGA design software.](#)
- [Lattice Insights](#) for Lattice Semiconductor training courses and learning plans.

Technical Support Assistance

Submit a technical support case through www.latticesemi.com/techsupport.

For frequently asked questions, refer to the Lattice Answer Database at <https://www.latticesemi.com/Support/AnswerDatabase>.

Revision History

Revision 1.0, June 2024

Section	Change Summary
All	Production release



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