INTRODUCTION

This Application Note describes various Vectron clock sources and interface circuits that can be used to drive the Reference Clock (REFCLK) Inputs of the SerDes Blocks of the RTG4 radiation-tolerant FPGA.

The Microchip RTG4 (Radiation-Tolerant Generation4) FPGA (Field Programmable Gate Array) can receive clock signals in two types of clock inputs:

1. Clock signals into the RTG4 general purpose and dedicated clock input pins, for use as a clock to the logic in the Digital Fabric.
2. Clock signals into the SerDes Blocks Reference Clock input pins, which input a reference clock for use by the dedicated high-speed SerDes Blocks on chip.

Of the two types of clock inputs, RTG4 REFCLK Inputs will be examined for this Application Note. The RTG4 REFCLK Inputs can be programmed by a FPGA designer to one of the various receiver types (differential or single-ended signal), and each has logic level requirements that will need direct interface or translation interface circuit connections to work properly when used with a standard clock driver (See Table 3). Information for providing clock input to the RTG4 Digital Fabric (type '1' above) is not presented here, but it can be connected with a standard driver clock the same as providing clock input to the RTG4 REFCLK receivers.

In addition to listing and discussing these devices, this Application Note also summarizes the RTG4 REFCLK Inputs specification logic levels required for the clock source drivers with output logic levels presented in Table 3. The Application Note also shows setups and measurements with some typical waveforms tested in the RTG4 DevKit, to provide confidence that the solutions do work in hardware.

CLOCKs FOR DRIVING RTG4 FPGA REFCLK INPUTs

The following Vectron differential signal crystal oscillators are recommended for use with the RTG4 FPGA REFCLK receivers:

- **LVDS** (See Setup Figure 2 and Figure 4):
  - DOC203679, Oscillator Specification, Hybrid Clock for Hi-Rel Standard, LVDS Output
  - DOC206903, Oscillator Specification, Hybrid Clock for Hi-Rel Standard, 300krad Tolerant, LVDS Output

- **LVPECL** (See Setup Figure 7, Figure 9, and Figure 11):
  - DOC203810, Oscillator Specification, Hybrid Clock for Hi-Rel Standard, LVPECL Output

- **CMOS** (See Figure 13):
  - OS-68338, Oscillator Specification, Hybrid Clock, Hi-Rel Standard, CMOS Output (3.3V supply, 100krad)
  - DOC206379, Oscillator Specification, Hybrid Clock for Hi-Rel Standard, 300krad Tolerant CMOS (3.3V supply, 300krad)
  - DOC204900, Oscillator Specification, Hybrid Clock for Hi-Rel Standard, High Frequency CMOS (2.5V/3.3V supply, 100krad)
RTG4 FPGA REFCLK INPUTS

The RTG4 REFCLK Inputs can be configured, by the FPGA designer, to any one of the IO Standards listed below (Reference: Table 5 of UG0567 User Guide, RTG4 FPGA High-Speed Serial Interfaces).

TABLE 1: INPUT CONFIGURATION OPTIONS

<table>
<thead>
<tr>
<th>SERDES_VDDI Supply</th>
<th>3.3V</th>
<th>2.5V</th>
<th>1.8V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supported Standards</td>
<td>LVTT/LVCMOS33</td>
<td>LVCMOS25</td>
<td>LVCMOS18</td>
</tr>
<tr>
<td>LVDS33</td>
<td>LVDS25 (Note 1)</td>
<td>SSTL18-Class 1</td>
<td></td>
</tr>
<tr>
<td>LVPECL</td>
<td>RSDS</td>
<td>SSTL18-Class 2</td>
<td></td>
</tr>
<tr>
<td>RSDS</td>
<td>Mini-LVDS</td>
<td>HSLT18-Class 1</td>
<td></td>
</tr>
<tr>
<td>Mini-LVDS</td>
<td>SSTL25-Class 1</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SSTL25-Class 2</td>
<td>---</td>
<td></td>
</tr>
</tbody>
</table>

Note 1: For LVDS33 and LVDS25, designers should reference RTG4 I/O Users Guide and DS0131 RTG4 FPGA data sheet for correct termination and common-mode recommendations to achieve optimal jitter performance.

2: HCSL inputs are supported directly with LVDS I/O STD inputs from the Libero. There is no specific HCSL I/O STD available in Libero and designs requiring HCSL are supported by using the LVDS25 I/O standard.

Programming the I/O Standard will also set the corresponding REFCLK Inputs type. The following popular REFCLK Inputs are presented in this Application Note with recommendations:

- LVDS25_ODT: ODT improves the signaling environment by reducing the electrical discontinuities introduced with off-die termination; thus, it enables reliable operation at higher signaling rates (Microchip_RTG4_FPGA_IO_user_Guide_UG0741_V4). This also provides the common-mode noise rejection on the transmission lines all the way to the receiver with the built-in ODT to reduce noise emission and noise interferences. An LVDS or LVPECL clock (interface circuit needed) can be used to drive the LVDS25_ODT.

- LVDS25: It is recommended to use LVDS25_ODT for best waveform and jitter performance. When LVDS25 is used an external differential termination is required. An external differential termination resistor of 200Ω (typical) may be implemented to improve the $V_{ID}$ minimum requirement margin when using with a standard LVDS driver. The 200Ω load must be placed as close as possible to the RTG4 receiver input pins for better waveform and jitter performance.

- LVDS33: This is not recommended for use due to the minimum $V_{ID}$ requirement of 0.50V, which is higher than a standard LVDS output differential voltage of 0.34V and is also higher than the minimum LVPECL output differential voltage of 0.470V according to Table 3.

- LVPECL33: This is not recommended for use due to the $V_{ICM}$ requirement of 1.8V maximum, which is lower than the standard LVPECL output common mode voltage of 2.0V, and due to the $V_{IP}$ requirement of 0.600V minimum, which is higher than the minimum LVPECL output differential voltage of 0.470V according to Table 3.

- LVCMOS33/LVCMOS25: This is recommended for use. These are single-ended REFCLK Inputs, requiring no interface translating circuit for simple direct connections to reduce component count. OS-68338 3.3V clock up to 100 MHz can be used for driving LVCMOS33. The 300-krad DOC203679 3.3V clock up to 80 MHz can be used for driving LVCMOS33. For faster speed, the high frequency 2.5V/3.3V CMOS clock of DOC204900 up to 125 MHz can be used for driving LVCMOS25 (used with 2.5V clock) or LVCMOS33 (used with 3.3V clock). The maximum operating frequency of the high frequency CMOS DOC204900 is 160 MHz, but the application is limited to 125 MHz due to high input capacitance 20 pF max of the RTG4 receiver. This application limit is based on the output sink/source current capability of the oscillator clocks and the capacitive load (20 pF in this case), using the power dissipation formula.

Capacitive-Load Power Consumption is calculated via the following equation.

**EQUATION 1:**

$$ P = C \times V_{CC}^2 \times f = V_{CC} \times I_C $$

$$ I_C = C \times V_{CC} \times f $$

Where:
- $C$ = The load capacitance.
- $f$ = The signal frequency.
- $I_C$ = The dynamic consumption current.
For example, at 125 MHz and 3.0V supply, the consumption current is calculated as 20 pF x 3.0V x 125 MHz = 7.5 mA, as expected to be lower than the recommended sink/source current of 12 mA (Reference: TI 54AC00-SP, output buffer used in the DOC204900 oscillator).

**RTG4 REFCLK INPUT VOLTAGE SPECIFICATIONS AND DRIVER OUTPUT DATA**

The input voltage requirements of the RTG4 REFCLK Inputs are listed in Table 2 to provide the specification limits to the driver output data presented in Table 3.

**TABLE 2: RTG4 SERDES REFCLK INPUT VOLTAGE SPECIFICATIONS (Note 1)**

<table>
<thead>
<tr>
<th>REFCLK Input</th>
<th>Supply Voltage (VDDI)</th>
<th>( V_{ID} ) (Note 2)</th>
<th>( V_{ICM} ) (Note 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVDS25_ODT</td>
<td>2.5V ±5%</td>
<td>0.20V</td>
<td>0.35V</td>
</tr>
<tr>
<td>LVDS25</td>
<td>2.5V ±5%</td>
<td>0.20V</td>
<td>0.35V</td>
</tr>
<tr>
<td>LVDS33 (Note 3)</td>
<td>3.3V ±5%</td>
<td>0.50V</td>
<td>—</td>
</tr>
<tr>
<td>LVPECL33 (Note 3)</td>
<td>3.3V ±5%</td>
<td>0.60V</td>
<td>—</td>
</tr>
<tr>
<td>LVC莫斯25</td>
<td>2.5V ±5%</td>
<td>—0.30V</td>
<td>—</td>
</tr>
<tr>
<td>LVC莫斯33</td>
<td>3.3V ±5%</td>
<td>—0.30V</td>
<td>—</td>
</tr>
</tbody>
</table>

**Note 1:** See Microchip RTG4_FPGA data sheet for more details on SerDes REFCLK Input Voltage Specifications.

**Note 2:** Figure 1 depicts the \( V_{ID} \) and \( V_{ICM} \) for the differential inputs. Note that \( V_{ID} \) is half of \( V_{DIFF} \), and is equivalent to a single-ended signal referenced from one input to ground.

**Note 3:** Do not use LVDS33 and LVPECL33 as explained in the RTG4 FPGA REFCLK INPUTS section for LVDS33 and LVPECL33. These specification limits compared with the output data ranges in Table 3 are used to support this conclusion.

**FIGURE 1:** \( V_{ID} \) and \( V_{ICM} \) for Differential Inputs.

Also, the \( V_{ICM} \) and \( V_{ID} \) have to meet the conditions of the formulas below:

**EQUATION 2:**

\[
V_{ICM} + \left( \frac{V_{ID}}{2} \right) < V_{DDI} + 0.4V
\]

and

\[
V_{ICM} - \left( \frac{V_{ID}}{2} \right) > -0.3V
\]
**TABLE 3: CLOCK DRIVER INTERFACE CONFIGURATION AND OUTPUT DATA (Note 1)**

<table>
<thead>
<tr>
<th>Setup Figure</th>
<th>Interface Configuration</th>
<th>( V_{ID} ) (Note 2)</th>
<th>( V_{ICM} ) (Note 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 2</td>
<td>LVDS to LVDS25_ODT Direct Interface</td>
<td>0.250V</td>
<td>0.340V</td>
</tr>
<tr>
<td>(Note 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Figure 4</td>
<td>LVDS to LVDS25 200Ω Termination</td>
<td>0.520V</td>
<td>0.610V</td>
</tr>
<tr>
<td>(Note 4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Figure 7</td>
<td>LVPECL to LVDS25_ODT ( V_{ICM} 3.3V-Bias )</td>
<td>0.470V</td>
<td>0.800V</td>
</tr>
<tr>
<td>(Note 5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Figure 9</td>
<td>LVPECL to LVDS25_ODT ( V_{ICM} ) Self-Bias</td>
<td>0.470V</td>
<td>0.800V</td>
</tr>
<tr>
<td>(Note 6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Figure 11</td>
<td>LVPECL to LVDS25_ODT ( V_{ICM} ) Self-Bias2</td>
<td>0.289V</td>
<td>0.493V</td>
</tr>
<tr>
<td>(Note 7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Figure 13</td>
<td>CMOS to LVCMOS33</td>
<td>0.297V</td>
<td>0.330V</td>
</tr>
<tr>
<td>(Note 8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.237V</td>
<td>0.250V</td>
</tr>
</tbody>
</table>

**Note 1:** Output Data is recorded as \( V_{ID} \) and \( V_{ICM} \) to be consistent with the RTG4 REFCLK Inputs Voltage references. See the Setup Figures and resulted waveforms for details on the clock source use and interface circuits. Also see the Jitter Measurements section for additional information.

**Note 2:** \( V_{ID} \) and \( V_{ICM} \) are referenced to Ground. \( V_{ID} \) is a single-ended signal measured at the input of the RTG4 receiver to correspond with the specification \( V_{ID} \) of the RTG4 REFCLK Inputs (see Note 2 of Table 2). All the logic levels also meet the conditions of the formulas required for the RTG4 REFCLK Inputs: \( V_{ICM} + (V_{ID}/2) < V_{DDI} + 0.4V \) and \( V_{ICM} – (V_{ID}/2) > –0.3V \).

**Note 3:** Setup Figure 2: The \( V_{ID} \) and \( V_{ICM} \) limits are defined by the output voltage levels from Table 2 of Vectron DOC203679 for standard LVDS.

**Note 4:** Setup Figure 4: The typical values of \( V_{ID} \) and \( V_{ICM} \) are determined by measurements.

**Note 5:** Setup Figure 7: The \( V_{ID} \) range is determined using the output voltage levels from Table 2 of Vectron DOC203810, “Output Voltage: \( V_{OH} = V_{CC} – 1.085 \) to \( V_{CC} – 0.880 \), \( V_{OL} = V_{CC} – 1.830 \) to \( V_{CC} – 1.555 \)”. The biasing network resistors (R3 to R6) and its supply voltage will determine the \( V_{ICM} \) range for this scheme.

**Note 6:** Setup Figure 9: The \( V_{ID} \) range is determined using the output voltage levels from Table 2 of Vectron DOC203810, “Output Voltage: \( V_{OH} = V_{CC} – 1.085 \) to \( V_{CC} – 0.880 \), \( V_{OL} = V_{CC} – 1.830 \) to \( V_{CC} – 1.555 \)”. The LVPECL output common mode voltage is calculated as \( V_{CC} = 1.3V \). With a \( V_{CC} \) of 3.3V \( \pm 10\% \), the \( V_{ICM} \) ranges from 1.030V to 1.437V for this interface scheme with the resistor nominal values.

**Note 7:** Setup Figure 11: The \( V_{ID} \) range is determined using the output voltage levels from Table 2 of Vectron DOC203810, “Output Voltage: \( V_{OH} = V_{CC} – 1.085 \) to \( V_{CC} – 0.880 \), \( V_{OL} = V_{CC} – 1.830 \) to \( V_{CC} – 1.555 \)”, and through the voltage divider, the 51Ω and 82Ω resistor network. The LVPECL output common mode voltage is calculated as \( V_{CC} = 1.3V \). With a \( V_{CC} \) of 3.3V \( \pm 10\% \), the \( V_{ICM} \) ranges from 1.030V to 1.437V for this interface scheme with the resistor nominal values.

**Note 8:** Setup Figure 13: The \( V_{IL} \) and \( V_{IH} \) range is determined by the standard CMOS logic levels as \( V_{IL} = V_{CC} \times 0.1 \) and \( V_{IH} = V_{CC} \times 0.9 \), where \( V_{CC} \) is the supply voltage 3.3V \( \pm 10\% \) or 2.5V \( \pm 5\% \).

**General Recommendations and Summary**

1. When an external resistor like the 200Ω termination for differential driving is used, it must be placed as close as possible to the differential receiver input pins. Otherwise, waveform and jitter will greatly degrade.

2. RTG4 differential receiver must be terminated at the inputs either with an external resistor (100Ω or 200Ω) or with ODT (RTG4 On-Die Termination) for all clock driver types for best waveform and jitter performance.

3. The clock oscillator driver should be placed as close as possible to the input pins of the RTG4 receiver to help reduce interferences and minimize reflection on the transmission line due to possible impedance mismatching.

4. It is recommended to use the drivers and interface circuits listed in Table 3. Do not use the RTG4 REFCLK Inputs LVDS33 and LVPECL33.
### TABLE 4: RTG4 REFCLK INPUTS AND CLOCK DRIVER MATRIX

<table>
<thead>
<tr>
<th>Signal Type</th>
<th>RTG4</th>
<th>Vectron Clock Driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>REFCLK Input</td>
<td>Clock Type</td>
<td>Spec Drawing</td>
</tr>
<tr>
<td>Differenial</td>
<td>LVDS25-ODT</td>
<td>LVDS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LVDS25-ODT</td>
<td>LVPECL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LVDS</td>
<td>LVDS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LVDS33</td>
<td>Do Not Use</td>
</tr>
<tr>
<td></td>
<td>LVPECL33</td>
<td>Do Not Use</td>
</tr>
<tr>
<td>Single-Ended</td>
<td>LVC莫斯33</td>
<td>CMOS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LVC莫斯25</td>
<td>CMOS</td>
</tr>
</tbody>
</table>

For differential signal application, the only choice for RTG4 to set to is LVDS25-ODT (used with LVDS or LVPECL clock driver) or LVDS25 (used with LVDS clock driver and external 200Ω termination). The CMOS single-ended signal solution offers the best Total Jitter and Deterministic Jitter performance (See Jitter Measurements Table 5, Table 6, and Table 7), simple direct interface and options to use either the 2.5V or 3.3V supply, but speed is limited to 100 MHz (OS-68338), 80 MHz (DOC206379) and 125 MHz (DOC204900) for the three Vectron CMOS clocks.
**CIRCUIT INTERFACE AND DATA**

**FIGURE 2:** LVDS to RTG4 LVDS25_ODT, Direct Interface.

**FIGURE 3:** Measured Waveforms, LVDS to LVDS25_ODT, Direct Interface (Waveforms Measured on RTG4 DevKit).

**Note 1:** A LeCroy active probe ZS1500 1.5 GHz was used for the measurements. VID1 and VID2 were measured with reference to Ground at room temperature.

**Note 2:** See Figure 2 for the setup diagram. The oscillator clock driver (1204R156M25000BF used) was mounted on the RTG4 DevKit in place of the REFCLK 125 MHz (disabled and isolated) and the whole board was tested over temperature from -40°C to +85°C with Microchip EPCS Demo GUI software used to check for the error-free transmission loop.
FIGURE 4: LVDS to RTG4 LVDS25 External 200Ω Termination.

FIGURE 5: Setup Diagram for LVDS 200Ω Termination.

Note 1: This test setup was used to measure the waveforms for the diagram Figure 4 to present here in place of the waveforms measured on the RTG4 DevKit. The waveforms measured on the DevKit using the setup of Figure 4 were not so representative because the 200Ω load resistor used with the RTG4 LVDS25 couldn’t be placed as close to the receiver inputs as recommended to obtain good waveforms.

2: The load was placed at the input of the oscilloscope for better waveform measurements. Only half of the signal was measured using this setup. The 50Ω series resistors connected via the oscilloscope ground form a load of 200Ω between two outputs of the LVDS oscillator. The clock source used was 1204R156M25000BF.

FIGURE 6: Measured Waveforms, LVDS to LVDS25, External 200Ω Termination (Waveforms Measured with Bench Fixture and 50Ω Coax Cables).

Note 1: The actual signal is two times the measured value, as explained in Figure 5. Waveform was measured at room temperature.
FIGURE 7: LVPECL to LVDS25_ODT, $V_{ICM}$ 3.3V-Bias.

Note 1: Use 1 kΩ for R4 and R6 if a supply voltage of 2.5V is used for the biasing network.

2: C1 and C2 of 0.1 μF not only serve as a DC block, but also provide a full LVPECL differential signal swing to drive the receiver with little attenuation. The AC-coupling capacitors should have low ESR and low inductance at targeted clock frequency.

FIGURE 8: Measured Waveforms, LVPECL to LVDS25_ODT, $V_{ICM}$ 3.3V-Bias (Waveforms Measured on RTG4 DevKit).

Note 1: A LeCroy active probe ZS1500 1.5 GHz was used for the measurements. VID1 and VID2 were measured with reference to Ground at room temperature.

2: See Figure 7 for the setup diagram. The oscillator clock driver (1304R156M25000BF used) was mounted on the RTG4 DevKit in place of the REFCLK 125 MHz (disabled and isolated) for testing.
FIGURE 9: LVPECL to LVDS25_ODT, $V_{ICM}$ Self-Bias.

Note 1: This $V_{ICM}$ Self-Bias Termination is an alternative to that of Figure 7. This scheme requires no external supply voltage for the biasing and saves two resistors over that of Figure 7.

2: C1 and C2 of 0.1 μF provide a full LVPECL differential signal swing to drive the receiver with little attenuation. The AC-coupling capacitors should have low ESR and low inductance at targeted clock frequency.

FIGURE 10: Measured Waveforms, LVPECL to LVDS25_ODT, $V_{ICM}$ Self-Bias (Waveforms Measured on RTG4 DevKit).

Note 1: A LeCroy active probe ZS1500 1.5 GHz was used for the measurements. VID1 and VID2 were measured with reference to Ground at room temperature.

2: See Figure 9 for the setup diagram. The oscillator clock driver (1304R156M25000BF used) was mounted on the RTG4 DevKit in place of the REFCLK 125 MHz (disabled and isolated) for testing.
FIGURE 11: LVPECL to LVDS25_ODT, V_{ICM} Self-Bias2.

Note 1: This V_{ICM} Self-Bias termination is similar to the setup of Figure 9 without the coupling capacitors C1 and C2. The driver output signal is divided down by the resistor network but is still large enough to drive the RTG4 LVDS25_ODT. The rad-hard oscillator 1304R156M25000BF can be used for the clock source.

FIGURE 12: Simulated Waveforms, LVPECL to LVDS25_ODT, V_{ICM} Self-Bias2 (Keysight ADS 2017 software used).
FIGURE 13: CMOS to RTG4 LVCMOS33.

Note 1: A Vectron OS-68338 1103R100M00000BF 3.3V CMOS clock was used in the setup to drive the RTG4 LVCMOS33 and the waveform at Q was measured and presented in Figure 14.

FIGURE 14: Measured Waveforms, CMOS CLOCK (OS-68338 100 MHz) to LVCMOS33.

Note 1: A LeCroy active probe ZS1500 1.5 GHz was used for the measurement. The waveform was measured at the output of the clock driver at room temperature.

2: See Figure 13 for the setup diagram. The oscillator clock driver (1103R100M00000BF used) was mounted on the RTG4 DevKit in place of the REFCLK 125 MHz (disabled and isolated) for testing.
JITTER MEASUREMENTS

Within each transmitter of the SerDes, the time base provided by the reference clock to the TXPLL directly affects the quality of the SerDes serial output data. The jitter and phase variations present on the reference clock the TXPLL receives will also appear on the high-speed serial data stream it produces. The following data represents the jitter content of the high-speed serial data from the SerDes using the various reference clock schemes. The data below shows the quality of a 3.125 Gbps PRBS7 data stream transmitted with the discussed reference clock solutions.

FIGURE 15: Jitter Data, LVDS to LVDS25_ODT, Direct Interface (Setup Figure 2).
FIGURE 16: Eye Diagram, LVDS to LVDS25_ODT, Direct Interface (Setup Figure 2).

FIGURE 17: Jitter Data, LVDS to LVDS25 200Ω External Termination (Setup Figure 4).
FIGURE 18:  Eye Diagram, LVDS to LVDS25 200Ω External Termination (Setup Figure 4).

FIGURE 19:  Jitter Data, LVPECL to LVDS25_ODT (Setup Figure 9).
FIGURE 20: Eye Diagram, LVPECL to LVDS25_ODT (Setup Figure 9).

The following tables present the study done by the Microsemi characterization team, comparing SerDes transmit jitter to different RefClk types.

TABLE 5: JITTER DATA, RTG4 SERDES OUTPUT AT 3.125 GBPS FOR ALL REFCLK STANDARDS

<table>
<thead>
<tr>
<th>Device Number</th>
<th>Temp.</th>
<th>Voltage Condition</th>
<th>Parameter</th>
<th>LVDS 2.5V</th>
<th>LVCMOS 2.5V</th>
<th>LVCMOS 3.3V</th>
<th>SSTL 1.8V</th>
<th>SSTL 2.5V</th>
<th>HSTL 1.8V</th>
</tr>
</thead>
<tbody>
<tr>
<td>902</td>
<td>125°C</td>
<td>Min.</td>
<td>Total Jitter (mUI)</td>
<td>318</td>
<td>309</td>
<td>306</td>
<td>481</td>
<td>371</td>
<td>445</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>257</td>
<td>266</td>
<td>265</td>
<td>438</td>
<td>328</td>
<td>403</td>
</tr>
<tr>
<td></td>
<td>25°C</td>
<td>Typ.</td>
<td>Total Jitter (mUI)</td>
<td>343</td>
<td>289</td>
<td>287</td>
<td>355</td>
<td>406</td>
<td>358</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>291</td>
<td>246</td>
<td>247</td>
<td>315</td>
<td>366</td>
<td>318</td>
</tr>
<tr>
<td></td>
<td>-55°C</td>
<td>Max.</td>
<td>Total Jitter (mUI)</td>
<td>257</td>
<td>263</td>
<td>273</td>
<td>340</td>
<td>458</td>
<td>316</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>221</td>
<td>222</td>
<td>232</td>
<td>304</td>
<td>414</td>
<td>275</td>
</tr>
<tr>
<td>905</td>
<td>125°C</td>
<td>Min.</td>
<td>Total Jitter (mUI)</td>
<td>309</td>
<td>304</td>
<td>301</td>
<td>429</td>
<td>362</td>
<td>453</td>
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<td></td>
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<td>Deterministic Jitter (mUI)</td>
<td>250</td>
<td>263</td>
<td>259</td>
<td>386</td>
<td>317</td>
<td>409</td>
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<tr>
<td></td>
<td>25°C</td>
<td>Typ.</td>
<td>Total Jitter (mUI)</td>
<td>325</td>
<td>287</td>
<td>286</td>
<td>371</td>
<td>458</td>
<td>364</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>275</td>
<td>251</td>
<td>246</td>
<td>334</td>
<td>422</td>
<td>326</td>
</tr>
<tr>
<td></td>
<td>-55°C</td>
<td>Max.</td>
<td>Total Jitter (mUI)</td>
<td>336</td>
<td>265</td>
<td>277</td>
<td>307</td>
<td>423</td>
<td>320</td>
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<td>Deterministic Jitter (mUI)</td>
<td>297</td>
<td>226</td>
<td>237</td>
<td>270</td>
<td>381</td>
<td>278</td>
</tr>
<tr>
<td>911</td>
<td>125°C</td>
<td>Min.</td>
<td>Total Jitter (mUI)</td>
<td>350</td>
<td>320</td>
<td>294</td>
<td>402</td>
<td>435</td>
<td>435</td>
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<tr>
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<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>286</td>
<td>276</td>
<td>250</td>
<td>357</td>
<td>391</td>
<td>390</td>
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<tr>
<td></td>
<td>25°C</td>
<td>Typ.</td>
<td>Total Jitter (mUI)</td>
<td>332</td>
<td>303</td>
<td>301</td>
<td>427</td>
<td>451</td>
<td>333</td>
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<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>273</td>
<td>257</td>
<td>253</td>
<td>384</td>
<td>407</td>
<td>291</td>
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<tr>
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<td>-55°C</td>
<td>Max.</td>
<td>Total Jitter (mUI)</td>
<td>320</td>
<td>277</td>
<td>264</td>
<td>312</td>
<td>365</td>
<td>331</td>
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<td></td>
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<td>Deterministic Jitter (mUI)</td>
<td>278</td>
<td>239</td>
<td>223</td>
<td>271</td>
<td>342</td>
<td>293</td>
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### TABLE 6: JITTER DATA, RTG4 SERDES OUTPUT AT 2.5 GBPS FOR ALL REFCLK

<table>
<thead>
<tr>
<th>Device Number</th>
<th>Temp.</th>
<th>Voltage Condition</th>
<th>Parameter</th>
<th>LVDS 2.5V</th>
<th>LVCMOS 2.5V</th>
<th>LVCMOS 3.3V</th>
<th>SSTL 1.8V</th>
<th>SSTL 2.5V</th>
<th>HSTL 1.8V</th>
</tr>
</thead>
<tbody>
<tr>
<td>902</td>
<td>125°C</td>
<td>Min.</td>
<td>Total Jitter (mUI)</td>
<td>202</td>
<td>164</td>
<td>168</td>
<td>188</td>
<td>188</td>
<td>224</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>164</td>
<td>135</td>
<td>129</td>
<td>157</td>
<td>159</td>
<td>216</td>
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<tr>
<td></td>
<td>25°C</td>
<td>Typ.</td>
<td>Total Jitter (mUI)</td>
<td>200</td>
<td>143</td>
<td>146</td>
<td>181</td>
<td>214</td>
<td>241</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>170</td>
<td>117</td>
<td>120</td>
<td>151</td>
<td>185</td>
<td>213</td>
</tr>
<tr>
<td></td>
<td>−55°C</td>
<td>Max.</td>
<td>Total Jitter (mUI)</td>
<td>169</td>
<td>161</td>
<td>148</td>
<td>186</td>
<td>186</td>
<td>231</td>
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<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>136</td>
<td>135</td>
<td>122</td>
<td>159</td>
<td>159</td>
<td>168</td>
</tr>
<tr>
<td>905</td>
<td>125°C</td>
<td>Min.</td>
<td>Total Jitter (mUI)</td>
<td>174</td>
<td>165</td>
<td>167</td>
<td>187</td>
<td>194</td>
<td>217</td>
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<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>146</td>
<td>131</td>
<td>136</td>
<td>153</td>
<td>166</td>
<td>190</td>
</tr>
<tr>
<td></td>
<td>25°C</td>
<td>Typ.</td>
<td>Total Jitter (mUI)</td>
<td>189</td>
<td>144</td>
<td>147</td>
<td>173</td>
<td>190</td>
<td>242</td>
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<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>163</td>
<td>118</td>
<td>118</td>
<td>147</td>
<td>161</td>
<td>196</td>
</tr>
<tr>
<td></td>
<td>−55°C</td>
<td>Max.</td>
<td>Total Jitter (mUI)</td>
<td>157</td>
<td>152</td>
<td>146</td>
<td>190</td>
<td>187</td>
<td>229</td>
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<td></td>
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<td>Deterministic Jitter (mUI)</td>
<td>130</td>
<td>127</td>
<td>120</td>
<td>161</td>
<td>158</td>
<td>156</td>
</tr>
<tr>
<td>911</td>
<td>125°C</td>
<td>Min.</td>
<td>Total Jitter (mUI)</td>
<td>193</td>
<td>185</td>
<td>184</td>
<td>200</td>
<td>223</td>
<td>252</td>
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<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>166</td>
<td>151</td>
<td>147</td>
<td>169</td>
<td>177</td>
<td>190</td>
</tr>
<tr>
<td></td>
<td>25°C</td>
<td>Typ.</td>
<td>Total Jitter (mUI)</td>
<td>182</td>
<td>163</td>
<td>175</td>
<td>197</td>
<td>196</td>
<td>215</td>
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<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>151</td>
<td>131</td>
<td>143</td>
<td>164</td>
<td>163</td>
<td>159</td>
</tr>
<tr>
<td></td>
<td>−55°C</td>
<td>Max.</td>
<td>Total Jitter (mUI)</td>
<td>159</td>
<td>145</td>
<td>150</td>
<td>208</td>
<td>199</td>
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<td>Deterministic Jitter (mUI)</td>
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<td>119</td>
<td>118</td>
<td>166</td>
<td>169</td>
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### TABLE 7: JITTER DATA, RTG4 SERDES OUTPUT AT 1.25 GBPS FOR ALL REFCLK STANDARDS

<table>
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<th>Device Number</th>
<th>Temp.</th>
<th>Voltage Condition</th>
<th>Parameter</th>
<th>LVDS 2.5V</th>
<th>LVCMOS 2.5V</th>
<th>LVCMOS 3.3V</th>
<th>SSTL 1.8V</th>
<th>SSTL 2.5V</th>
<th>HSTL 1.8V</th>
</tr>
</thead>
<tbody>
<tr>
<td>902</td>
<td>125°C</td>
<td>Min.</td>
<td>Total Jitter (mUI)</td>
<td>92</td>
<td>106</td>
<td>99</td>
<td>134</td>
<td>95</td>
<td>114</td>
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<td></td>
<td></td>
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<td>Deterministic Jitter (mUI)</td>
<td>73</td>
<td>85</td>
<td>80</td>
<td>114</td>
<td>66</td>
<td>91</td>
</tr>
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<td></td>
<td>25°C</td>
<td>Typ.</td>
<td>Total Jitter (mUI)</td>
<td>100</td>
<td>99</td>
<td>99</td>
<td>88</td>
<td>99</td>
<td>108</td>
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<tr>
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<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>16</td>
<td>77</td>
<td>76</td>
<td>68</td>
<td>76</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>−55°C</td>
<td>Max.</td>
<td>Total Jitter (mUI)</td>
<td>97</td>
<td>93</td>
<td>94</td>
<td>114</td>
<td>91</td>
<td>106</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>78</td>
<td>73</td>
<td>72</td>
<td>90</td>
<td>65</td>
<td>84</td>
</tr>
<tr>
<td>905</td>
<td>125°C</td>
<td>Min.</td>
<td>Total Jitter (mUI)</td>
<td>100</td>
<td>100</td>
<td>106</td>
<td>97</td>
<td>122</td>
<td>130</td>
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<td>Deterministic Jitter (mUI)</td>
<td>76</td>
<td>74</td>
<td>87</td>
<td>69</td>
<td>90</td>
<td>101</td>
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<tr>
<td></td>
<td>25°C</td>
<td>Typ.</td>
<td>Total Jitter (mUI)</td>
<td>90</td>
<td>97</td>
<td>104</td>
<td>103</td>
<td>103</td>
<td>99</td>
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<td>Deterministic Jitter (mUI)</td>
<td>66</td>
<td>70</td>
<td>83</td>
<td>79</td>
<td>80</td>
<td>77</td>
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<tr>
<td></td>
<td>−55°C</td>
<td>Max.</td>
<td>Total Jitter (mUI)</td>
<td>98</td>
<td>87</td>
<td>91</td>
<td>115</td>
<td>98</td>
<td>100</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>Deterministic Jitter (mUI)</td>
<td>79</td>
<td>67</td>
<td>70</td>
<td>93</td>
<td>71</td>
<td>74</td>
</tr>
<tr>
<td>911</td>
<td>125°C</td>
<td>Min.</td>
<td>Total Jitter (mUI)</td>
<td>82</td>
<td>108</td>
<td>117</td>
<td>137</td>
<td>730</td>
<td>155</td>
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<tr>
<td></td>
<td></td>
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<td>Deterministic Jitter (mUI)</td>
<td>65</td>
<td>79</td>
<td>97</td>
<td>105</td>
<td>101</td>
<td>107</td>
</tr>
<tr>
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<td>25°C</td>
<td>Typ.</td>
<td>Total Jitter (mUI)</td>
<td>115</td>
<td>115</td>
<td>776</td>
<td>108</td>
<td>110</td>
<td>146</td>
</tr>
<tr>
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<td>Deterministic Jitter (mUI)</td>
<td>90</td>
<td>83</td>
<td>85</td>
<td>72</td>
<td>82</td>
<td>116</td>
</tr>
<tr>
<td></td>
<td>−55°C</td>
<td>Max.</td>
<td>Total Jitter (mUI)</td>
<td>99</td>
<td>96</td>
<td>104</td>
<td>111</td>
<td>117</td>
<td>91</td>
</tr>
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<td>75</td>
<td>78</td>
<td>81</td>
<td>78</td>
<td>90</td>
<td>62</td>
</tr>
</tbody>
</table>

**Hardware and Software Tools Used**

The RTG4 Development Kit was used for testing the reference clocks and for waveform measurements. The RTG4 Development Kits on-board REFCLK CCLD-033-50-125.000 oscillator was disabled, isolated, and replaced with the Vectron clock driver LVPECL or LVDS along with the interface circuit for each testing of the clock types. Also, in-house test fixtures were developed for the specific tests of LVDS with a 200Ω load.
Microchip Software Libero SoC V11.9 was used to program the RTG4 Development Kits, loading project designs and setting the SerDes REFCLK Input receiver type for testing with the corresponding clock. Microchip EPCS Demo GUI was used to check the signal quality by testing the error-free data loop between the RTG4 transmitter and receiver of the SerDes block, and also to verify the clock circuit connections in the RTG4 development board.

Keysight ADS 2017 was used to generate circuit diagrams and for simulations when needed; IBIS models used in the simulations were Microsemi RTG4 REFCLK Receiver rt4g_msio.ibs, Micrel Semiconductor ibisTop_100e16 in sc07p07e0160a, Aeroflex/Cobham ut54lvds031lvucc.ibs, and Fairchild ACT3301 cgs3311m_3_3V.ibs.

REFERENCES, RELATED WEBSITES, AND DATA SHEETS

- Microchip Hi-Rel Clock Oscillators (XO): https://www.vectron.com/products/space/space.htm
- Microchip SY100EL16V: https://www.microchip.com/wwwproducts/en/SY100EL16V
- Cobham HiRel Microelectronics, UT54LVDS031LVE Quad Driver: https://www.cobhamaes.com/pagesproduct/prods-hirel-lvds.cfm
- TI SN54AC00-SP Radiation Hardened Quad 2 Input NAND Gate: http://www.ti.com/lit/ds/symlink/sn54ac00-sp.pdf
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