

RC2121xA

AutoClock Automotive Programmable Clock Generator Family

Description

The RC2121xA family of devices are high-performance programmable clock generators with added diagnostic features to support automotive applications. The RC2121xA has the following characteristics:

- ISO9001 compliant
- AEC-Q100 qualified
- -40° to +105°C (Grade 2 equivalent) operation
- PPAP support

Diagnostic Features

- Redundant crystal option with automatic switching
- Cyclic Redundancy Check (CRC) monitors for OTP image, I²C accesses, and register contents
- Output frequency monitors
- APLL loss-of-lock monitor
- Power-on self-test
- Programmable GPIO to indicate internal error or fault conditions

Applications

- Infotainment
- Gateway
- Domain controller
- Zone controller

Features

- 169fs RMS phase jitter (12kHz to 20MHz, 156.25MHz)
- PCIe® Gen6 Common Clock (CC) 27fs RMS
- PCIe SRIS and SRNS support
- 1kHz to 650MHz (differential) and 1kHz to 200MHz (single-ended) outputs
- LVCMOS, LVDS, or Low-Power HCSL output types with simple AC-coupling to LVPECL and CML. LP-HCSL integrates terminations.
- Seven programmable General Purpose Input-Outputs (GPIO)
- 1MHz I²C serial port
- Multiple configurations can be stored in internal One-Time Programmable (OTP) memory.
- 1.8V and/or 3.3V operation
- Package options:
 - 12 differential or 24 single-ended outputs
 - 6 × 6 × 0.75 mm, 48-QFN package
 - RC21211: Single crystal
 - RC21212: Dual crystal
 - 8 differential or 16 single-ended outputs
 - 5 × 5 × 0.75 mm, 40-QFN package
 - RC21213: Single crystal
 - RC21214: Dual crystal

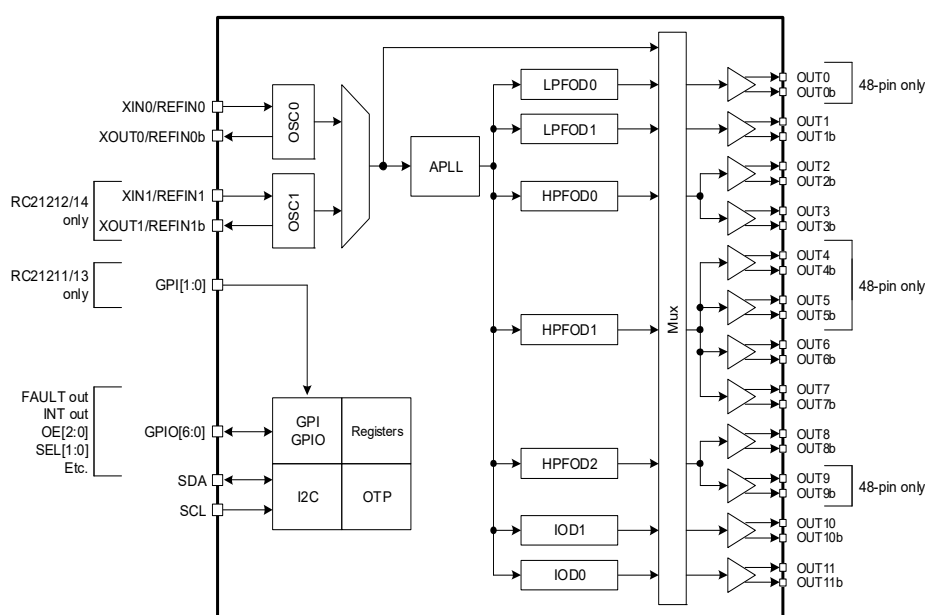


Figure 1. RC2121xA Block Diagram

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1. Pin Information

1.1 Pin Assignments

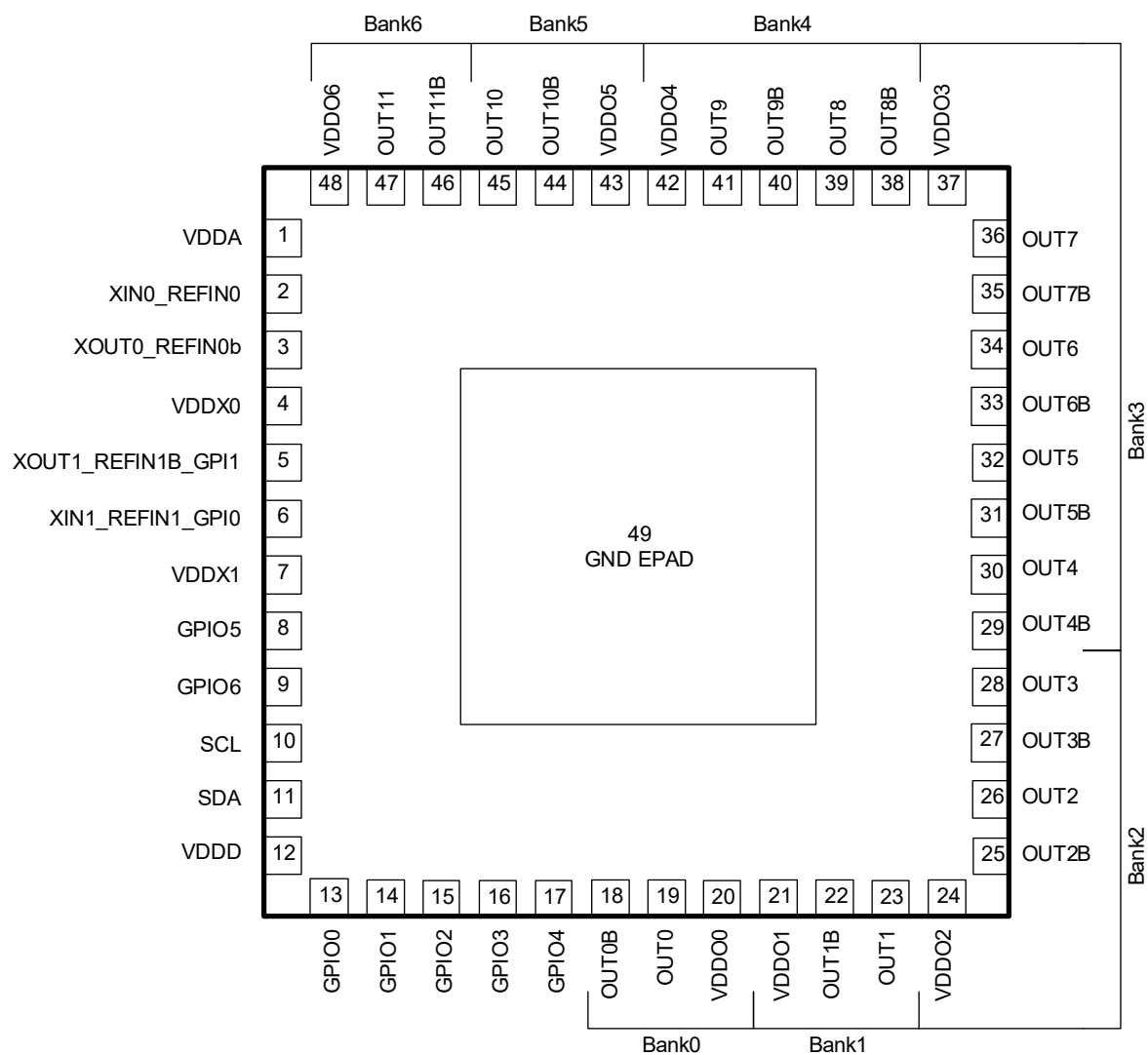


Figure 2. 48-QFN (6 × 6) Pin Assignments – Top View

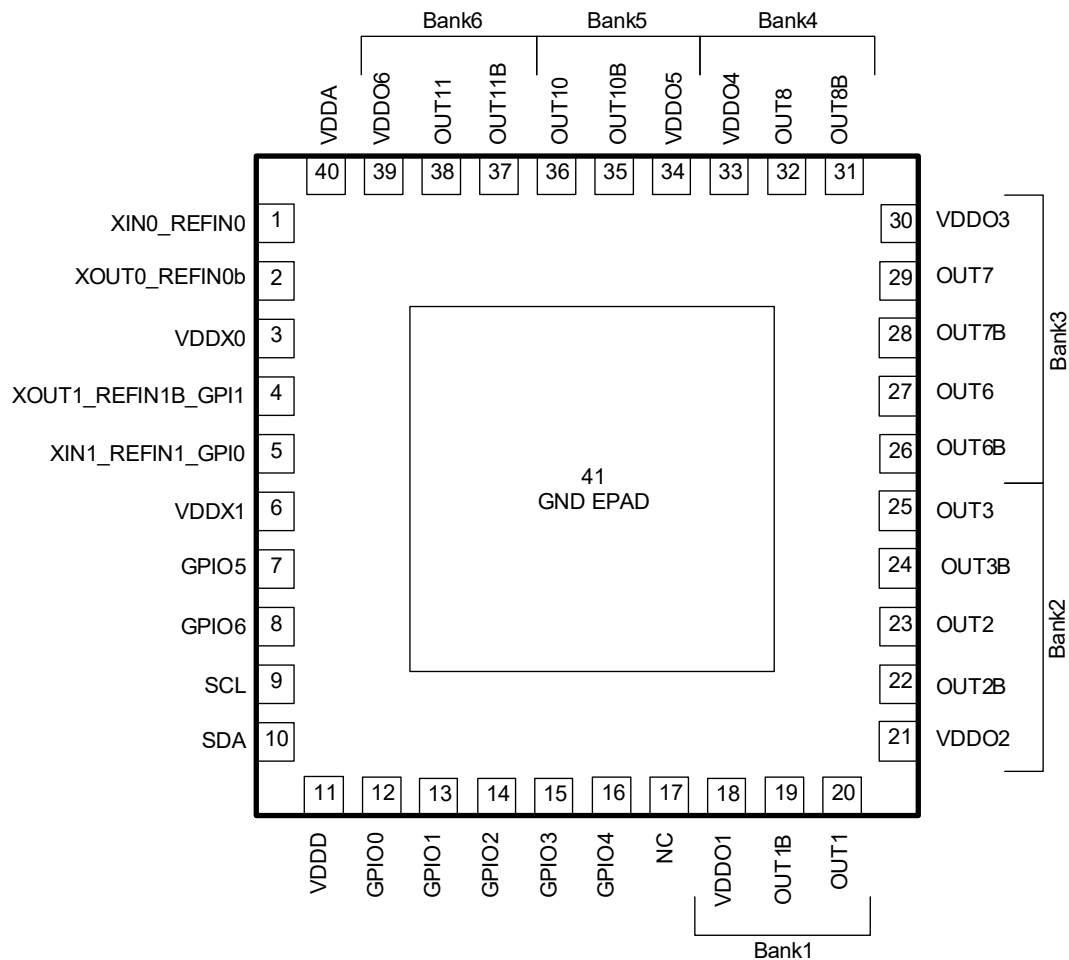


Figure 3. 40-QFN (5 × 5) Pin Assignments – Top View

1.2 Pin Descriptions

Table 1. Pin Descriptions

| 48-QFN | 40-QFN | Name | Type | Description |
|--------|--------|--------------------|-------|---|
| 1 | 40 | VDDA | Power | Power supply for analog, 1.8/3.3V supported |
| 2 | 1 | XIN0_REFIN0 | I | Crystal Input or differential reference clock positive input / CMOS single-ended reference clock input. For more information, see Crystal/Reference Input . |
| 3 | 2 | XOUT0_REFIN0b | I/O | Crystal Output or differential reference clock negative input. This pin should be connected to a crystal. If an oscillator is connected to XIN0_REFIN0, then this pin must be left unconnected. |
| 4 | 3 | VDDX0 | Power | Power supply for Crystal oscillator. 1.8/3.3V supported |
| 5 | 4 | XOUT1_REFIN1b_GPI1 | I/O | For single crystal variants: General purpose input. Not 3.3V tolerant. For dual crystal variants: Crystal Output or differential reference clock negative input. This pin should be connected to a crystal. If an oscillator is connected to XIN1_REFIN1, then this pin must be left unconnected. |
| 6 | 5 | XIN1_REFIN1_GPI0 | I | For single crystal variants: General purpose input. Not 3.3V tolerant. For dual crystal variants: Crystal Input or differential reference clock positive input / CMOS single-ended reference clock input. For more information, see Crystal/Reference Input . |
| 7 | 6 | VDDX1 | Power | Power supply for Crystal oscillator. 1.8/3.3V supported |
| 8 | 7 | GPIO5 | I/O | General purpose input/open drain output, 3.3V tolerant. |
| 9 | 8 | GPIO6 | I/O | General purpose input/open drain output, 3.3V tolerant. |

Table 1. Pin Descriptions (Cont.)

| 48-QFN | 40-QFN | Name | Type | Description |
|--------|--------|--------|-------|--|
| 10 | 9 | SCL | I | I ² C interface clock input, 3.3V tolerant. |
| 11 | 10 | SDA | I/O | I ² C interface bi-directional data in open-drain mode, 3.3V tolerant. |
| 12 | 11 | VDDD | Power | Power supply for digital core. 1.8/3.3V supported When programming the OTP, this supply must be 3.3V. |
| 13 | 12 | GPIO0 | I/O | General purpose input/output, not 3.3V tolerant. |
| 14 | 13 | GPIO1 | I/O | General purpose input/open drain output, 3.3V tolerant. |
| 15 | 14 | GPIO2 | I/O | General purpose input/open drain output, 3.3V tolerant. |
| 16 | 15 | GPIO3 | I/O | General purpose input/open drain output, 3.3V tolerant. |
| 17 | 16 | GPIO4 | I/O | General purpose input/open drain output, 3.3V tolerant. |
| NA | 17 | NC | | No Connect |
| 18 | NA | nOUT0b | O | Output Clock 0 negative. |
| 19 | NA | OUT0 | O | Output Clock 0 positive. |
| 20 | NA | VDDO0 | Power | Supply voltage for output bank 0 and LPFOD 0. 1.8/3.3V supported |
| 21 | 18 | VDDO1 | Power | Supply voltage for output bank 1 and LPFOD 1 (on 40 pin variant also LPFOD 0). 1.8/3.3V supported. |
| 22 | 19 | OUT1b | O | Output Clock 1 negative. |
| 23 | 20 | OUT1 | O | Output Clock 1 positive |
| 24 | 21 | VDDO2 | Power | Supply voltage for output bank 2 and HPFOD 0. 1.8/3.3V supported |
| 25 | 22 | OUT2b | O | Output Clock 2 negative. |
| 26 | 23 | OUT2 | O | Output Clock 2 positive. |
| 27 | 24 | OUT3b | O | Output Clock 3 negative. |
| 28 | 25 | OUT3 | O | Output Clock 3 positive. |
| 29 | NA | OUT4b | O | Output Clock 4 negative. |
| 30 | NA | OUT4 | O | Output Clock 4 positive. |
| 31 | NA | OUT5b | O | Output Clock 5 negative. |
| 32 | NA | OUT5 | O | Output Clock 5 positive. |
| 33 | 26 | OUT6b | O | Output Clock 6 negative. |
| 34 | 27 | OUT6 | O | Output Clock 6 positive. |
| 35 | 28 | OUT7b | O | Output Clock 7 negative. |
| 36 | 29 | OUT7 | O | Output Clock 7 positive. |
| 37 | 30 | VDDO3 | Power | Supply voltage for output bank 3 and HPFOD 1. 1.8/3.3V supported |
| 38 | 31 | OUT8b | O | Output Clock 8 negative |
| 39 | 32 | OUT8 | O | Output Clock 8 positive. |
| 40 | NA | OUT9b | O | Output Clock 9 negative. |
| 41 | NA | OUT9 | O | Output Clock 9 positive. |
| 42 | 33 | VDDO4 | Power | Supply voltage for output bank 4 and HPFOD 2. 1.8/3.3V supported. |
| 43 | 34 | VDDO5 | Power | Supply voltage for output bank 5 and IOD 1. 1.8/3.3V supported |
| 44 | 35 | OUT10b | O | Output Clock 10 negative. |
| 45 | 36 | OUT10 | O | Output Clock 10 positive. |
| 46 | 37 | OUT11b | O | Output Clock 11 negative. |
| 47 | 38 | OUT11 | O | Output Clock 11 positive. |
| 48 | 39 | VDDO6 | Power | Supply voltage for output bank 6 and IOD 0. 1.8/3.3V supported |
| EPAD | EPAD | GND | Power | Ground. EPAD must be connected to ground before any VDD is applied. |

1.3 Pin Characteristics

Table 2. Pin Characteristics

| Symbol | Parameter | Test Conditions | Minimum | Typical | Maximum | Unit |
|-----------------------|---|---|---------|---------|---------|------|
| C _{IN} | Input Capacitance | XIN0_REFIN0 [1] | 7 | 7.9 | 9 | pF |
| | | XOUT_REFIN0b [1] | 1.5 | 2.6 | 4 | |
| | | XIN1_REFIN1_GPI0 [2] | 7 | 7.9 | 9 | |
| | | XOUT1_REFIN1b_GPI1 [2] | 1 | 2.4 | 3.5 | |
| | | SCL, SDA | 1 | 2.3 | 3.5 | |
| | | GPIO[0] | 4.5 | 5.8 | 7.5 | |
| | | GPIO[1:6] | 2 | 3.4 | 5.5 | |
| R _{PULLUP} | Input Pull-up Resistor | All pins with internal pull up capability | 49.6 | 53 | 58.1 | kΩ |
| R _{PULLDOWN} | Input Pull-down Resistor | All pins with internal pull down capability | 49.7 | 53 | 58.3 | kΩ |
| Z _{OUTDC} | LP-HCSL Single-ended Output Impedance, VDDO = 3.3V | 50Ω single-ended (100Ω differential). | 42 | 47.5 | 63 | Ω |
| | | 42.5Ω single-ended (85Ω differential). | 35 | 41.2 | 55 | |
| | | 17Ω single-ended (33Ω differential). | 12 | 18.2 | 28 | |
| | LP-HCSL Single-ended Output Impedance, VDDO = 1.8V. | 50Ω single-ended (100Ω differential). | 49 | 53.1 | 71 | Ω |
| | | 42.5Ω single-ended (85Ω differential). | 42 | 46.5 | 73 | |
| | | 17Ω single-ended (33Ω differential). | 20 | 22.1 | 41 | |
| | LVCMOS Output Impedance | V _{DDO} = 3.3V | 14 | 19.1 | 23 | Ω |
| | | V _{DDO} = 1.8V | 15 | 20 | 27 | |

1. When used as a reference clock input.

2. When used as a reference clock input or a General Purpose Input (GPI).

2. Specifications

The absolute maximum ratings are stress ratings only. Stresses greater than those listed below can cause permanent damage to the device. Functional operation of the RC2121xA at absolute maximum ratings is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

2.1 Absolute Maximum Ratings

Table 3. Absolute Maximum Ratings

| Symbol | Parameter | Conditions | Minimum | Maximum | Unit |
|-----------|---------------------------------------|--|---------|----------------|------|
| V_{DD} | Supply Voltage with respect to Ground | Any VDD pin | -0.5 | 3.63 | V |
| V_{IN} | Input Voltage ^[1] | XIN_REFIN, XOUT_REFINb ^[2] | -0.5 | $V_{DD} + 0.3$ | V |
| | | CLKIN[1:0]_GPI[1:0], CLKIN[1:0]b_GPI[3:2] | -0.5 | $V_{DD} + 0.3$ | V |
| | | GPIO[6:0] used as inputs | -0.5 | $V_{DD} + 0.3$ | V |
| | | SCL, SDA | -0.5 | 3.63 | V |
| I_{IN} | Input Current | CLKIN[1:0]_GPI[1:0], CLKIN[1:0]b_GPI[3:2] | - | ±50 | mA |
| I_{OUT} | Output Current - Continuous | OUT[11:0], OUT[11:0]b | - | 30 | mA |
| | | GPIO[6:0] used as outputs, SDA | - | 25 | mA |
| | Output Current - Surge | OUT[11:0], OUT[11:0]b | - | 60 | mA |
| | | GPIO[6:0] used as outputs, SDA | - | 50 | mA |
| T_J | Maximum Junction Temperature | | - | 150 | °C |
| T_S | Storage Temperature | Storage Temperature | -65 | 150 | °C |
| ESD | Human Body Model | JESD22-A114 (JS-001) Classification | - | 2000 | V |
| | Charged Device Model | JESD22-C101 Classification | - | 500 | V |

1. VDD refers to the VDD pin that supplies the particular input. To determine to which VDD pin the specification applies, see [Table 30](#).
2. This limit only applies when XIN_REFIN/XOUT_REFINb are configured as an "Input Buffer" for use with an external oscillator. No limit is implied when connected directly to a crystal.

2.2 Recommended Operating Conditions

Table 4. Recommended Operating Conditions ^{[1][2]}

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|-----------|--|---|---------|---------|---------|------|
| T_J | Maximum Junction Temperature | | - | - | 125 | °C |
| T_A | Ambient Operating temperature | | -40 | - | 105 | °C |
| V_{DDx} | Supply Voltage with respect to Ground | Any VDD pin, 1.8V supply | 1.71 | 1.8 | 1.89 | V |
| | | Any VDD pin, 3.3V supply | 3.135 | 3.3 | 3.465 | V |
| t_{PU} | Power-up time for all VDDs to reach minimum specified voltage. | Power ramps must be monotonic. For more considerations, see Application Information . | 0.2 | - | 5 | ms |

1. All electrical characteristics are specified over Recommended Operating Conditions unless noted otherwise. VDDA must be ≤ VDD.
2. All conditions in this table must be met to guarantee device functionality and performance.

2.3 Electrical Characteristics

All parameters in this section are specified over the recommended operating conditions as specified in [Table 4](#).

Table 5. PCIe Refclk Jitter, VDDO = 1.8V or 3.3V [1][2]

| Symbol | Parameter | Conditions | Typical | Maximum | PCIe Limit | Unit |
|--------------------|--|-----------------------------|---------|---------|------------|----------|
| $t_{jphPCIeG1-CC}$ | PCIe Refclk Jitter in Clock Generator Mode (Common Clocked Architecture, SSC = 0%, -0.3%, -0.5%) | PCIe Gen 1 (2.5 GT/s) | 6,674 | 15,282 | 86,000 | fs pk-pk |
| $t_{jphPCIeG2-CC}$ | | PCIe Gen 2 Hi Band (5 GT/s) | 587 | 1,114 | 3000 | fs RMS |
| $t_{jphPCIeG3-CC}$ | | PCIe Gen 2 Lo Band (5 GT/s) | 154 | 367 | 3100 | |
| $t_{jphPCIeG4-CC}$ | | PCIe Gen 3 (8 GT/s) | 193 | 372 | 1000 | |
| $t_{jphPCIeG5-CC}$ | | PCIe Gen 4 (16 GT/s) [3][4] | 141 | 372 | 500 | |
| $t_{jphPCIeG6-CC}$ | | PCIe Gen 5 (32 GT/s) [3][5] | 77 | 150 | 150 | |
| $t_{jphPCIeG6-CC}$ | | PCIe Gen 6 (64 GT/s) [3][6] | 34 | 86 | 100 | |
| $t_{jphPCIeG2-IR}$ | PCIe Refclk Jitter Clock Generator Mode (IR Architecture, SSC = 0% or -0.5%) | PCIe Gen 2 (5 GT/s) | 245 | 905 | N/A [7] | fs RMS |
| $t_{jphPCIeG3-IR}$ | | PCIe Gen 3 (8 GT/s) | 199 | 542 | | |
| $t_{jphPCIeG4-IR}$ | | PCIe Gen 4 (16 GT/s) | 161 | 535 | | |
| $t_{jphPCIeG5-IR}$ | PCIe Refclk Jitter Clock Generator Mode (IR Architecture, SSC = 0% or -0.3%) | PCIe Gen 5 (32 GT/s) | 54 | 147 | | |
| $t_{jphPCIeG6-IR}$ | | PCIe Gen 6 (64 GT/s) | 40 | 109 | | |

1. The Refclk jitter is measured after applying the filter functions found in *PCI Express Base Specification Revision 6.2*. See the Test Loads section of the data sheet for the exact measurement setup. The worst case results for each data rate are summarized in this table. Equipment noise is removed from all measurements.
2. Jitter measurements shall be made with a capture of at least 100,000 clock cycles captured by a real-time oscilloscope (RTO) with a sample rate of 20 GS/s or greater. Broadband oscilloscope noise must be minimized in the measurement. The measured PP jitter is used (no extrapolation) for RTO measurements. Alternately - Jitter measurements may be used with a Phase Noise Analyzer (PNA) extending (flat) and integrating and folding the frequency content up to an offset from the carrier frequency of at least 200 MHz (at 300 MHz absolute frequency) below the Nyquist frequency. For PNA measurements for the 2.5 GT/s data rate, the RMS jitter is converted to peak-to-peak jitter using a multiplication factor of 8.83.
3. SSC spurs from the fundamental and harmonics are removed up to a cutoff frequency of 2 MHz taking care to minimize removal of any non-SSC content.
4. Note that 0.7 ps RMS is to be used in channel simulations to account for additional noise in a real system.
5. Note that 0.25 ps RMS is to be used in channel simulations to account for additional noise in a real system.
6. Note that 0.15 ps RMS is to be used in channel simulations to account for additional noise in a real system.
7. The *PCI Express Base Specification Revision 6.2* provides the filters necessary to calculate SRIS and SRNS (IR) jitter values; it does not provide specification limits, hence the N/A in the Limit column. IR values are informative only. A common practice is to split the common clock budget in half. For 16GT/s data rates and above, the user must choose whether to use the output jitter specification, or the input jitter specification, which includes an allocation for the jitter added by the channel. Using 32GT/s, the Refclk jitter budget is 150fs RMS. One half of the Refclk jitter budget is 106fs RMS. At the clock input, the system must deliver 250fs RMS. One half of this value is 177fs RMS. If the clock is placed next to the PCIe device in an IR system, the channel is short and the user may choose to use this more relaxed value as the jitter limit.

Table 6. Phase Jitter and Phase Noise – 1.8V or 3.3V VDDO [1][2]

| Symbol | Parameter | Conditions | Typical | Maximum | Unit |
|-----------------|---|--|---------|---------|----------------|
| $t_{jit}(\Phi)$ | Random Phase Jitter, (50MHz XTAL, Synthesizer Mode) | OUT0: Frequency = 24MHz Integration Range: 12kHz-5MHz | 850 | 1,050 | f_s (RMS) |
| | | OUT10: Frequency = 40MHz Integration Range: 12kHz-5MHz | 160 | 270 | |
| | | OUT8, OUT9: Frequency = 80MHz Integration Range: 12kHz-20MHz | 300 | 450 | |
| | | OUT4, OUT5, OUT6, OUT7: Frequency = 100MHz, Integration Range: 12kHz-20MHz, SSC Off | 230 | 440 | |
| | | OUT11: Frequency = 125MHz Integration Range: 12kHz-20MHz | 260 | 380 | |
| | | OUT2: Frequency = 156.25MHz Integration Range: 12kHz-20MHz | 240 | 330 | |

1. Electrical parameters are guaranteed over the specified ambient operating temperature range, which is established when the device is mounted in a test socket with maintained transverse airflow greater than 500lfpm. The device will meet specifications after thermal equilibrium has been reached under these conditions.
2. Characterized using a Rohde and Schwarz SMA100 overdriving the XTAL interface. All outputs active at the same time.

Table 7. Clock Input Frequencies [1]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|--------------|--|---|---------|---------|---------|------|
| f_{INAPLL} | APLL Input Frequency for clock generation. | Over-driving Crystal Input, Doubler Logic Disabled | 16 | - | 625 | MHz |
| | | Over-driving Crystal Input, Doubler Logic Enabled | 8 | - | 312.5 | |

1. For crystal characteristics, see Table 8.

Table 8. External Crystal Characteristics

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|-----------------|------------------------------|--|-------------|---------|---------|---------------|
| - | Resonance Mode | | Fundamental | | | - |
| f_{INTAL} [1] | Crystal input frequency | Fundamental mode | 8 | - | 62.5 | MHz |
| ESR [1] | Equivalent Series Resistance | $8\text{MHz} \leq f_{INTAL} \leq 12\text{MHz}$, $C_L = 12\text{pF}$ | - | - | 120 | Ω |
| | | $12\text{MHz} < f_{INTAL} \leq 28\text{MHz}$, $C_L = 12\text{pF}$ | - | - | 80 | |
| | | $28\text{MHz} < f_{INTAL} \leq 54\text{MHz}$, $C_L = 12\text{pF}$ | - | - | 50 | |
| | | $54\text{MHz} < f_{INTAL} \leq 80\text{MHz}$, $C_L = 8\text{pF}$ | - | - | 50 | |
| C_O [1] | Shunt Capacitance | | - | 7 | - | pF |
| C_L [1] | Load Capacitance | | 6 | 8 | 12 | |
| Drive [1] | Drive Level | | - | - | 100 | μW |
| F_{TOL} | Frequency Tolerance | Center frequency at 25°C | - | - | [2] | ppm |
| F_{STAB} | Frequency Stability | Over Operating Temperature Range with respect to F_{TOL} | - | - | | |
| Aging | Per Year | | - | - | | |

1. These parameters are required, regardless of crystal used.
2. These parameters are customer/application dependent. Common maximum values are $F_{TOL} = \pm 20\text{ppm}$, $F_{STAB} = \pm 20\text{ppm}$, and Aging = $\pm 5\text{ppm}/10\text{years}$. The customer is free to adjust these parameters to their particular requirements.

Table 9. Output Frequencies and Startup Times [1]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|---------------|---------------------------------------|----------------------|---------|---------|---------|------|
| f_{OUT} | Output Frequency | Differential Output. | 0.001 | - | 650 | MHz |
| | | LVC MOS Output. | 0.001 | - | 200 | |
| f_{MON} | Reference Monitor Operating Frequency | | - | - | 40 | MHz |
| f_{VCO} | VCO (APLL) Operating Frequency | | 9.5 | - | 10.7 | GHz |
| $t_{STARTUP}$ | Start-up Time [2][3] | Synthesizer mode. | - | 8 | 11 | ms |

1. Electrical parameters are guaranteed over the specified ambient operating temperature range, which is established when the device is mounted in a test socket with maintained transverse airflow greater than 500lfpm. The device will meet specifications after thermal equilibrium has been reached under these conditions.
2. Measured from when all power supplies have reached > 90% of nominal voltage to the first stable clock edge on the output. A stable clock is defined as one generated from a locked PLL (as appropriate for the configuration listed) with no further perturbations in frequency expected. Includes time needed to load a configuration from internal OTP. For important additional power supply sequencing considerations, see [Power Considerations](#).
3. Start-up time will depend on the actual configuration used. For more information, please contact Renesas technical support

Table 10. Output-to-Output Skew – LP-HCSL Outputs 1.8V or 3.3V VDDO [1]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|----------|------------------------------|--|---------|---------|---------|------|
| t_{SK} | Output-to-Output Skew [2][3] | Any two outputs within the same bank | - | 13 | 50 | ps |
| | | Any two outputs across all outputs banks sources from the same divider | - | 15 | 92 | |
| | | Any two outputs across all output banks source from a different divider. | - | 17 | 119 | |

1. Electrical parameters are guaranteed over the specified ambient operating temperature range, which is established when the device is mounted in a test socket with maintained transverse airflow greater than 500lfpm. The device will meet specifications after thermal equilibrium has been reached under these conditions.
2. Defined as the time between the rising edges of two outputs of the same frequency, configuration, loading, and supply voltage.
3. This parameter is defined in accordance with JEDEC Standard 65

Table 11. Output-to-Output Skew – LVDS Outputs 1.8V or 3.3V VDDO [1]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|----------|------------------------------|--|---------|---------|---------|------|
| t_{SK} | Output-to-Output Skew [2][3] | Any two outputs within the same bank | - | 13 | 50 | ps |
| | | Any two outputs across all outputs banks sources from the same divider | - | 15 | 92 | |
| | | Any two outputs across all output banks source from a different divider. | - | 17 | 119 | |

1. Electrical parameters are guaranteed over the specified ambient operating temperature range, which is established when the device is mounted in a test socket with maintained transverse airflow greater than 500lfpm. The device will meet specifications after thermal equilibrium has been reached under these conditions.
2. Defined as the time between the rising edges of two outputs of the same frequency, configuration, loading, and supply voltage.
3. This parameter is defined in accordance with JEDEC Standard 65

Table 12. Output-to-Output Skew – LVCMOS Outputs 1.8V or 3.3V VDDO [1]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|----------|------------------------------|--|---------|---------|---------|------|
| t_{SK} | Output-to-Output Skew [2][3] | Any two outputs within the same bank | - | 26 | 85 | ps |
| | | Any two outputs across all outputs banks sources from the same divider | - | 34 | 203 | |
| | | Any two outputs across all output banks source from a different divider. | - | 60 | 310 | |

1. Electrical parameters are guaranteed over the specified ambient operating temperature range, which is established when the device is mounted in a test socket with maintained transverse airflow greater than 500lpm. The device will meet specifications after thermal equilibrium has been reached under these conditions.
2. Defined as the time between the rising edges of two outputs of the same frequency, configuration, loading, and supply voltage.
3. This parameter is defined in accordance with JEDEC Standard 65

Table 13. LVCMOS AC/DC Output Characteristics – 1.8V VDDO [1]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|----------|-------------------------|--------------------|-------------|-------------|------------|---------|
| V_{OH} | Output High Voltage [2] | $I_{OH} = -2mA$ | VDDO - 0.45 | VDDO - 0.04 | VDDO + 0.3 | V |
| V_{OL} | Output Low Voltage [2] | $I_{OL} = 2mA$ | - | 0.04 | 0.45 | |
| I_{OZ} | Output Leakage Current | Outputs Tri-stated | -5 | 0 | 5 | μA |
| dV/dt | Slew Rate[3] | ODRV_CNFG[3:2] = 0 | 0.64 | 1.25 | 2.7 | V/ns |
| | | ODRV_CNFG[3:2] = 1 | 0.63 | 1.25 | 2.7 | |
| | | ODRV_CNFG[3:2] = 2 | 0.64 | 1.25 | 2.7 | |
| | | ODRV_CNFG[3:2] = 3 | 0.61 | 1.3 | 2.8 | |
| t_{DC} | Output Duty Cycle | $V_T = VDDO/2$ | 45 | 49.8 | 55 | % |

1. See Test Loads for additional information.
2. These values are compliant with JESD8-7A.
3. $V_T = 20\%$ to 80% of VDDO, $C_L = 4.7pF$.

Table 14. LVCMOS AC/DC Output Characteristics – 3.3V VDDO[1]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|----------|-------------------------|--------------------|---------|---------|------------|---------|
| V_{OH} | Output High Voltage [2] | $I_{OH} = -2mA$ | 2.4 | 3.2 | VDDO + 0.3 | V |
| V_{OL} | Output Low Voltage [2] | $I_{OL} = 2mA$ | - | 0.04 | 0.4 | |
| I_{OZ} | Output Leakage Current | Outputs Tri-stated | -5 | 0 | 5 | μA |
| dV/dt | Slew Rate[3] | ODRV_CNFG[3:2] = 0 | 1 | 4.2 | 5.1 | V/ns |
| | | ODRV_CNFG[3:2] = 1 | 0.8 | 2.7 | 4.2 | |
| | | ODRV_CNFG[3:2] = 2 | 0.7 | 2.2 | 4.2 | |
| | | ODRV_CNFG[3:2] = 3 | 0.9 | 2.6 | 4.8 | |
| t_{DC} | Output Duty Cycle | $V_T = VDDO/2$ | 45 | 50.7 | 55 | % |

1. See Test Loads for additional information.
2. These values are compliant with JESD8C.01.
3. $V_T = 20\%$ to 80% of VDDO, $C_L = 4.7pF$.

Table 15. LVDS AC/DC Output Characteristics – 1.8V V_{DDO} [1]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|------------------|--|--|---------|---------|---------|------|
| $V_{OT}(+)$ | TRUE binary state. | out_prog = 0x00 | 233 | 340 | 447 | mV |
| $V_{OT}(-)$ | FALSE binary state. | | -493 | -360 | -227 | |
| $V_{OT}(+)$ | TRUE binary state. | out_prog = 0x01 | 227 | 341 | 454 | mV |
| $V_{OT}(-)$ | FALSE binary state. | | -483 | -369 | -254 | |
| $V_{OT}(+)$ | TRUE binary state. | out_prog = 0x02 | 189 | 319 | 450 | mV |
| $V_{OT}(-)$ | FALSE binary state. | | -483 | -337 | -191 | |
| $V_{OT}(+)$ | TRUE binary state. | out_prog = 0x03 | 211 | 331 | 452 | mV |
| $V_{OT}(-)$ | FALSE binary state. | | -474 | -349 | -224 | |
| ΔV_{OT} | Change in V_{OT} between Complimentary States | | - | 43 | 59 | mV |
| V_{CMR} | Common Mode Voltage | | 1 | 1.17 | 1.32 | V |
| ΔV_{CMR} | Change in V_{CMR} between Complimentary States | | - | 25 | 40.1 | mV |
| I_{OS} | Short Circuit Current | $V_{OUT+} = 0V$ | - | 8.1 | 8.9 | mA |
| | | $V_{OUT+} = V_{DD}$ | - | 0.7 | 1.8 | mA |
| | | $V_{OUT-} = 0V$ | - | 0.1 | 0.2 | mA |
| | | $V_{OUT-} = V_{DD}$ | - | 9.6 | 11 | mA |
| I_{OSD} | Differential Short Circuit Current | $V_{OUT+} = V_{OUT-}$ | 4 | 4.5 | 6 | |
| t_R/t_F | Rise/Fall Time [2] $V_T = 20\%$ to 80% of swing. | $F_{out} \leq 400MHz$ | 221 | 374 | 522 | ps |
| | | $F_{out} > 400MHz$ | 152 | 305 | 457 | ps |
| t_{DC} | Duty Cycle | $V_T = 0V$ differential, $F_{out} \leq 400MHz$ | 47 | 50 | 53 | % |
| | | $V_T = 0V$ differential, $F_{out} > 400MHz$ | 45 | 49.5 | 55 | % |

1. See Test Loads for additional test conditions.

2. Single-ended measurement

Table 16. LVDS AC/DC Output Characteristics – 3.3V V_{DDO} [1]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|------------------|--|-----------------|---------|---------|---------|------|
| $V_{OT}(+)$ | TRUE binary state. | out_prog = 0x00 | 240 | 348 | 457 | mV |
| $V_{OT}(-)$ | FALSE binary state. | | -464 | -356 | -247 | |
| $V_{OT}(+)$ | TRUE binary state. | out_prog = 0x01 | 255 | 366 | 477 | mV |
| $V_{OT}(-)$ | FALSE binary state. | | -483 | -372 | -261 | |
| $V_{OT}(+)$ | TRUE binary state. | out_prog = 0x02 | 211 | 311 | 411 | mV |
| $V_{OT}(-)$ | FALSE binary state. | | -427 | -325 | -224 | |
| $V_{OT}(+)$ | TRUE binary state. | out_prog = 0x03 | 225 | 330 | 434 | mV |
| $V_{OT}(-)$ | FALSE binary state. | | -446 | -341 | -235 | |
| ΔV_{OT} | Change in V_{OT} between Complimentary States | | 14 | 37 | 60 | mV |
| V_{CMR} | Common Mode Voltage | | 1.16 | 1.21 | 1.32 | V |
| ΔV_{CMR} | Change in V_{CMR} between Complimentary States | | - | 25 | 40 | mV |

Table 16. LVDS AC/DC Output Characteristics – 3.3V V_{DDO} [1] (Cont.)

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|--------------------------------|---|---|---------|---------|---------|------|
| I _{OS} | Short Circuit Current | V _{OUT+} = 0V | - | 7.3 | 8 | mA |
| | | V _{OUT+} = VDD | - | 0.7 | 6 | mA |
| | | V _{OUT-} = 0V | - | 0.1 | 0.2 | mA |
| | | V _{OUT-} = VDD | - | 12.6 | 15 | mA |
| I _{OSD} | Differential Output Short Circuit Current | V _{OUT+} = V _{OUT-} | 3 | 4 | 5 | |
| t _R /t _F | Rise/Fall Time [2] V _T = 20% to 80% of swing. | Fout ≤ 400MHz | 221 | 374 | 527 | ps |
| | | Fout > 400MHz | 152 | 305 | 458 | ps |
| t _{DC} | Duty Cycle | V _T = 0V differential, Fout ≤ 400MHz | 47 | 50 | 53 | % |
| | | V _T = 0V differential, Fout > 400MHz | 45 | 49.5 | 55 | % |

1. See Test Loads for additional test conditions.
2. Single-ended measurement

Table 17. LP-HCSL AC/DC Output Characteristics, Non-PCIe Frequencies – 1.8V V_{DDO} [1]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|--------------------------------|---|---|---------|---------|---------|------|
| V _{OH} | Output High Voltage [2] | V _{HIGH} = 800mV, Fast Slew Rate. | 826 | 879 | 932 | mV |
| V _{OL} | Output Low Voltage [2] | | 12 | 23 | 34 | |
| V _{CROSS} | Crossing Voltage (abs) [3] | | 119 | 364 | 608 | |
| ΔV _{CROSS} | Crossing Voltage (var) [3][4][5] | | - | 20 | 72 | |
| t _R /t _F | Rise/Fall Time [2] V _T = 20% to 80% of swing | V _{HIGH} = 800mV, Fast Slew Rate, f ≤ 400MHz. | 374 | 499 | 624 | ps |
| | Rise/Fall Time [2] V _T = 20% to 80% of swing | V _{HIGH} = 800mV, Fast Slew Rate, f > 400MHz. | 118 | 247 | 376 | |
| V _{OH} | Output High Voltage [2] | V _{HIGH} = 900mV, Fast Slew Rate. | 850 | 913 | 980 | mV |
| V _{OL} | Output Low Voltage [2] | | -1 | 5 | 11 | |
| V _{CROSS} | Crossing Voltage (abs) [3] | | 120 | 376 | 632 | |
| ΔV _{CROSS} | Crossing Voltage (var) [3][4][5] | | - | 21 | 91 | |
| t _R /t _F | Rise/Fall Time [2] V _T = 20% to 80% of swing. | V _{HIGH} = 900mV, Fast Slew Rate, f ≤ 400MHz. | 386 | 498 | 609 | ps |
| | Rise/Fall Time [2] V _T = 20% to 80% of swing. | V _{HIGH} = 900mV, Fast Slew Rate, f > 400MHz. | 107 | 241 | 374 | |
| t _{DC} | Output Duty Cycle [6] | Across all settings, V _T = 0V. | 45 | 50 | 55 | % |

1. Standard high impedance load with C_L = 2pF. See Test Loads. Tested at 25MHz, 100MHz, 156.25MHz, 312.5MHz and 625MHz.
2. Measured from single-ended waveform.
3. Measured at crossing point where the instantaneous voltage value of the rising edge of CLK equals the falling edge of CLKb.
4. Refers to the total variation from the lowest crossing point to the highest, regardless of which edge is crossing. Refers to all crossing points for this measurement.
5. Defined as the total variation of all crossing voltages of Rising CLK and Falling CLKb. This is the maximum variance in V_{CROSS} for any particular system.
6. Measured from differential waveform.

Table 18. LP-HCSL AC/DC Output Characteristics, Non-PCIe Frequencies – 3.3V V_{DDO} [1]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|--------------------------------|--|---|---------|---------|---------|------|
| V _{OH} | Output High Voltage [2] | V _{HIGH} = 800mV, Fast Slew Rate. | 858 | 910 | 963 | mV |
| V _{OL} | Output Low Voltage [2] | | 12 | 22 | 33 | mV |
| V _{CROSS} | Crossing Voltage (abs) [3] | | 223 | 414 | 605 | mV |
| ΔV _{CROSS} | Crossing Voltage (var) [3][4][5] | | - | 23 | 90 | mV |
| t _R /t _F | Rise/Fall Time [2] V _T = 20% to 80% of swing | V _{HIGH} = 800mV, Fast Slew Rate, f ≤ 400MHz. | 344 | 500 | 656 | ps |
| | Rise/Fall Time [2] V _T = 20% to 80% of swing | V _{HIGH} = 800mV, Fast Slew Rate, f > 400MHz. | 124 | 200 | 276 | |
| V _{OH} | Output High Voltage [2] | V _{HIGH} = 900mV, Fast Slew Rate. | 800 | 934 | 1051 | mV |
| V _{OL} | Output Low Voltage [2] | | -95 | 5 | 68 | mV |
| V _{CROSS} | Crossing Voltage (abs) [3] | | 222 | 437 | 651 | mV |
| ΔV _{CROSS} | Crossing Voltage (var) [3][4][5] | | - | 24 | 100 | mV |
| t _R /t _F | Rise/Fall Time [2] V _T = 20% to 80% of swing | V _{HIGH} = 900mV, Fast Slew Rate, f ≤ 400MHz. | 348 | 502 | 656 | ps |
| | Rise/Fall Time [2] V _T = 20% to 80% of swing | V _{HIGH} = 900mV, Fast Slew Rate, f > 400MHz. | 126 | 209 | 292 | |
| t _{DC} | Output Duty Cycle [6] | Across all settings, V _T = 0V. | 45 | 50 | 55 | % |

1. Standard high impedance load with C_L = 2pF. See Test Loads. Tested at 25MHz, 100MHz, 156.25MHz, 312.5MHz and 625MHz.
2. Measured from single-ended waveform.
3. Measured at crossing point where the instantaneous voltage value of the rising edge of CLK equals the falling edge of CLKb.
4. Refers to the total variation from the lowest crossing point to the highest, regardless of which edge is crossing. Refers to all crossing points for this measurement.
5. Defined as the total variation of all crossing voltages of Rising CLK and Falling CLKb. This is the maximum allowed variance in V_{CROSS} for any particular system.
6. Measured from differential waveform.

Table 19. LP-HCSL AC/DC Output Characteristics, 100MHz PCIe – 1.8V or 3.3V V_{DDO} [1]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Spec. Limit [2] | Unit |
|---------------------|---|--|---------|---------|---------|-----------------|------|
| V _{MAX} | Absolute Max Voltage Includes 300mV of overshoot (Vovs) [3][4] | Across all settings in this table. | - | - | 1120 | 1150 | mV |
| V _{MIN} | Absolute Min Voltage Includes -300mV of undershoot (Vuds) [3][5] | | -143 | - | - | -300 | |
| V _{HIGH} | Voltage High [3] | V _{HIGH} set to 800mV. | 767 | 904 | 1041 | - | mV |
| V _{LOW} | Voltage Low [3] | | -69 | -13 | 44 | - | |
| V _{CROSS} | Crossing Voltage (abs) [3][6][7] | V _{HIGH} set to 800mV, scope averaging off. | 290 | 417 | 543 | 250 to 550 | |
| ΔV _{CROSS} | Crossing Voltage (var) [3][6][8] | | - | 30 | 42 | 140 | |
| dv/dt | Slew rate [9][10] | V _{HIGH} set to 800mV, Fast slew rate, scope averaging on. | 1 | 2,3 | 3.7 | 1 to 4 | V/ns |
| | | V _{HIGH} set to 800mV, Slow slew rate, scope averaging on. | 0.7 | 1.9 | 3.1 | | |
| ΔT _{R/F} | Rise/fall matching [3][11] | V _{HIGH} set to 800mV. Fast or slow slew rate. | - | 8 | 20 | 20 | % |

Table 19. LP-HCSL AC/DC Output Characteristics, 100MHz PCIe – 1.8V or 3.3V V_{DDO} [1] (Cont.)

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Spec. Limit [2] | Unit |
|----------------------|----------------------------------|---|---------|---------|---------|-----------------|------|
| V _{HIGH} | Voltage High [3] | V _{HIGH} set to 900mV. | 825 | 973 | 1121 | - | mV |
| V _{LOW} | Voltage Low [3] | | -71 | -14 | 43 | - | |
| V _{CROSS} | Crossing Voltage (abs) [3][6][7] | V _{HIGH} set to 900mV, scope averaging off. | 322 | 460 | 597 | 300 to 600 | |
| ΔV _{CROSS} | Crossing Voltage (var) [3][6][8] | | - | 30 | 46 | 140 | |
| dv/dt | Slew rate [9][10] | V _{HIGH} set to 900mV, Fast slew rate, scope averaging on. | 1.1 | 2.5 | 3.9 | 1 to 4 | V/ns |
| | | V _{HIGH} set to 900mV, Slow slew rate, scope averaging on. | 0.8 | 2 | 3.2 | | |
| ΔT _{R/F} | Rise/fall matching [3][11] | V _{HIGH} set to 900mV. Fast or slow slew rate. | - | 8 | 20 | 20 | % |
| t _{DC} | Output Duty Cycle [9] | Across all settings in this table, V _T = 0V. | 49 | 50 | 52 | 45 to 55 | |
| t _{jcc-cyc} | Jitter, Cycle to cycle [9] | Across all settings in this table. | - | 34 | 45 | 50 | ps |

- Standard high impedance load with C_L = 2pF. See Test Loads.
- The specification limits are taken from either the *PCIe Base Specification Revision 6.2* or from relevant x86 processor specifications, whichever is more stringent.
- Measured from single-ended waveform.
- Defined as the maximum instantaneous voltage including overshoot.
- Defined as the minimum instantaneous voltage including undershoot.
- Measured at crossing point where the instantaneous voltage value of the rising edge of REFCLK+ equals the falling edge of REFCLK-.
- Refers to the total variation from the lowest crossing point to the highest, regardless of which edge is crossing. Refers to all crossing points for this measurement.
- Defined as the total variation of all crossing voltages of Rising REFCLK+ and Falling REFCLK-. This is the maximum allowed variance in V_{CROSS} for any particular system.
- Measured from differential waveform.
- Measured from -150 mV to +150 mV on the differential waveform (derived from REFCLK+ minus REFCLK-). The signal must be monotonic through the measurement region for rise and fall time. The 300 mV measurement window is centered on the differential zero crossing.
- Matching applies to rising edge rate for REFCLK+ and falling edge rate for REFCLK-. It is measured using a ±75 mV window centered on the median cross point where REFCLK+ rising meets REFCLK- falling. The median cross point is used to calculate the voltage thresholds the oscilloscope is to use for the edge rate calculations. The Rise Edge Rate of REFCLK+ should be compared to the Fall Edge Rate of REFCLK-; the maximum allowed difference should not exceed 20% of the slowest edge rate.

Table 20. 100MHz PCIe Output Clock Accuracy and SSC

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | PCIe Limit[1] | Unit |
|--|--|---|---------|---------|---------|---------------|------|
| T _{PERIOD_AVG_3} 2G_64G_CC | Average Clock Period Accuracy for devices supporting 32GT/s or 64GT/s CC mode at any speed. [2][3] | SSC ≤ -0.5%, includes spread-spectrum modulation, if any. | 0 | - | 2410 | -100 to +2600 | ppm |
| T _{PERIOD_AVG_3} 2G_64G_SRIS | Average Clock Period Accuracy for devices supporting 32GT/s SRIS mode at any speed. [2][3] | SSC ≤ -0.3%, includes spread-spectrum modulation, if any. | 0 | - | 1430 | -100 to +1600 | |
| T _{PERIOD_AVG_3} 2G_64G | Average Clock Period Accuracy for devices supporting 32GT/s CC/SRNS mode at any speed. [2][3] | SSC = 0% (SSC Off). | 0 | - | 0 | ±100 | |

Table 20. 100MHz PCIe Output Clock Accuracy and SSC (Cont.)

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | PCIe Limit ^[1] | Unit |
|--|---|--|---------|---------|---------|---------------------------|--------|
| T _{PERIOD_ABS_32G_64G_CC} | Average Clock Period Accuracy for devices supporting 32GT/s CC mode at any speed. [2][4] | SSC ≤ -0.5%, includes jitter and spread-spectrum modulation. | 10 | - | 10.024 | 9.849 to 10.201 | ns |
| T _{PERIOD_ABS_32G_64G_SRIS} | Average Clock Period Accuracy for devices supporting 32GT/s SRIS mode at any speed. [2][4] | SSC ≤ -0.3%, includes jitter and spread-spectrum modulation. | 10 | - | 10.014 | 9.849 to 10.181 | |
| T _{PERIOD_ABS_32G_64G} | Average Clock Period Accuracy for devices supporting 32GT/s CC/SRIS mode at any speed. [2][4] | SSC = 0% (SSC Off), includes jitter. | 10 | - | 10 | 9.849 to 10.151 | |
| F _{REFCLK_32G_64G} | Refclk Frequency for devices that support 32GT/s or 64GT/s. | SSC = 0% (SSC Off) | 100 | - | 100 | 99.99 to 100.01 | MHz |
| F _{SSC} | SSC Modulation Frequency | | 31.1 | 31.6 | 32.1 | 30 to 33 | kHz |
| T _{SSC_FREQ_DEV} | SSC Deviation for all devices and architectures except 32GT/s or 64GT/s devices operating in SRIS mode. | SSC = -0.5% | -0.490 | -0.488 | -0.486 | -0.5 | % |
| T _{SSC_FREQ_DEV_32G_64G_SRIS} | SSC Deviation for devices that support 32 or 64GT/s operating in SRIS mode, at any speeds. | SSC = -0.3% | -0.300 | -0.295 | -0.290 | -0.3 | % |
| T _{SSC_MAX_FREQ_SLEW} | Max df/dt of the SSC. [5] | | - | 310 | 372 | 1250 | ppm/μs |
| T _{TRANSPORT_DELAY} | Tx-Rx transport delay used for PCIe Jitter calculations. [6] | Applies to Common Clocked architectures only. | - | - | 12 | 12 | ns |

1. The specification limits are taken from either the *PCIe Base Specification Revision 6.2* or from relevant x86 processor specifications, whichever is more stringent.
2. Measured from differential waveform.
3. PPM refers to parts per million and is a DC absolute period accuracy specification. 1 PPM is 1/1,000,000th of 100.000000MHz exactly or 100Hz. For 100PPM, then we have an error budget of 100Hz/PPM * 100PPM = 10kHz. The period is to be measured with a frequency counter with measurement window set to 100 ms or greater. The ±100PPM applies to systems that do not employ Spread-Spectrum Clocking, or that use common clock source. For systems employing Spread-Spectrum Clocking, there is an additional 2,500PPM nominal shift in maximum period resulting from the 0.5% down spread resulting in a maximum average period specification of +2,600PPM for Common Clock Architectures. SRIS Architectures may have a lower allowed spread percentage. Devices meeting these specifications automatically meet the less stringent -300ppm to +2800ppm tolerances for data rates ≤16GT/s. Refer to Section 8.6 of the *PCI Express Base Specification, Revision 6.0*.
4. Defined as the absolute minimum or maximum instantaneous period. This includes cycle-to-cycle jitter, relative PPM tolerance, and spread-spectrum modulation. Devices meeting these specifications automatically meet the less stringent and 9.847ns to 10.203ns tolerances for data rates ≤16GT/s.
5. Measurement is made over a 0.5μs time interval with a 1st order LPF with an fC of 60x the SSC modulation frequency (1.89MHz for 31.5kHz modulation frequency).
6. This is the default value used for all PCIe Common Clock architecture jitter calculations. There are form factors (for example topologies including long cables) that may exceed this limit. Contact Renesas for assistance calculating jitter if your topology exceeds 12ns.

Table 21. Spread-Spectrum Programmability

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|---------------------|--------------------------|---|---------|---------|---------|------|
| f _{SSCMOD} | SSC Modulation Frequency | Modulation frequency. | 30 | - | 63 | kHz |
| SSC% | Spread percentage [1] | Down Spread. | -1 | - | -0.5 | % |
| | | Center Spread. | ±0.025 | - | ±0.75 | |
| f _{OUTSSC} | Output frequency | Allowable output frequency range when SSC is enabled. | 30 | - | 650 | MHz |

1. Spread off is 0%.

Table 22. GPI/GPIO Electrical Characteristics – 1.8V VDDD, VDDR, or VDDX [1][2]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|-----------------|-------------------------|--|------------|---------|-----------|------|
| V _{IH} | Input High Voltage [3] | XIN_REFIN, XOUT_REFINb, GPI[3:0], GPIO[6:0]. | 0.65 VDD | - | VDD + 0.3 | V |
| V _{IL} | Input Low Voltage [3] | XIN_REFIN, XOUT_REFINb, GPI[3:0], GPIO[6:0]. | -0.3 | - | 0.35 VDD | |
| V _{OH} | Output High Voltage [3] | GPIO[6:0], I _{OH} = -2mA. | VDD - 0.45 | - | VDD + 0.3 | |
| V _{OL} | Output Low Voltage [3] | GPIO[6:0], I _{OL} = 2mA. | - | - | 0.45 | |

1. Input specifications refer to signals XIN_REFIN, XOUT_REFINb, GPI[3:0], GPIO[6:0], when acting as inputs. Output specifications refer to signals GPIO[6:0], when acting as outputs. To determine which VDD pin is referenced for each group in Table 22, see GPI and GPIO VDD pin assignments in Pin Information. For SCL, SDA_SDI, see the I2C/SMBus electrical characteristics Table 26 and Table 27.
2. CLKIN[1:0]/CLKIN[1:0]b used as two single-ended clocks rather than as a differential clock.
3. These values are compliant with JESD8-7A. These values only apply to XIN_REFIN and XOUT_REFINb when "Input Buffer" mode is selected. See the Applications section for more details.

Table 23. GPI/GPIO Electrical Characteristics – 3.3V VDDD, VDDR, or VDDX [1][2]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|-----------------|-------------------------|--|---------|---------|-----------|------|
| V _{IH} | Input High Voltage [3] | XIN_REFIN, XOUT_REFINb, GPI[3:0], GPIO[6:0]. | 2.2 | - | VDD + 0.3 | V |
| V _{IL} | Input Low Voltage [3] | XIN_REFIN, XOUT_REFINb, GPI[3:0], GPIO[6:0]. | -0.3 | - | 0.8 | |
| V _{OH} | Output High Voltage [3] | GPIO[6:0], I _{OH} = -2mA. | 2.4 | - | VDD + 0.3 | |
| V _{OL} | Output Low Voltage [3] | GPIO[6:0], I _{OL} = 2mA. | - | - | 0.4 | |

1. Input specifications refer to signals XIN_REFIN, XOUT_REFINb, GPI[3:0], GPIO[6:0], when acting as inputs. Output specifications refer to signals GPIO[6:0], when acting as outputs. To determine which VDD pin is referenced for each group in Table 23, see GPI and GPIO VDD pin assignments in Pin Information. For SCL, SDA_SDI, see the I2C/SMBus electrical characteristics Table 26 and Table 27.
2. CLKIN[1:0]/CLKIN[1:0]b used as two single-ended clocks rather than as a differential clock.
3. These values are compliant with JESD8C-01. These values only apply to XIN_REFIN and XOUT_REFINb when "Input Buffer" mode is selected. See the Applications section for more details.

Table 24. CMOS GPI/GPIO Common Electrical Characteristics [1][2]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|-----------------|-----------------------|--|---------|---------|---------|------|
| I _{IL} | Input Leakage Current | Includes input pull up/pull down resistor current. V _{IL} = 0V, V _{IH} = V _{DD} . | -74 | - | 74 | μA |
| | | Does NOT include input pull up/pull down resistor current. V _{IL} = 0V, V _{IH} = V _{DD} . | -5 | - | 5 | |

1. Input specifications refer to signals XIN_REFIN, XOUT_REFINb, GPI[3:0], GPIO[6:0], when acting as inputs. Output specifications refer to signals GPIO[6:0], when acting as outputs. For VDD pin mapping, see GPI and GPIO VDD pin assignments in Pin Information.
2. CLKIN[1:0]/CLKIN[1:0]b used as two single-ended clocks rather than as a differential clock.

Table 25. Power Supply Current [1]

| Symbol | Parameter | Conditions | Typical | Maximum | Unit |
|-------------------|----------------------------------|---------------------------------------|---------|---------|------|
| I _{DDX0} | V _{DDX0} Supply Current | V _{DDXn} = any valid supply. | 7.5 | 8.1 | mA |
| I _{DDX1} | V _{DDX1} Supply Current | | 8 | 11 | mA |
| I _{DDA} | V _{DDA} Supply Current | V _{DDA} = any valid supply. | 106 | 138 | mA |
| I _{DDD} | V _{DDD} Supply Current | V _{DDD} = any valid supply. | 54 | 64 | mA |

Table 25. Power Supply Current ^[1] (Cont.)

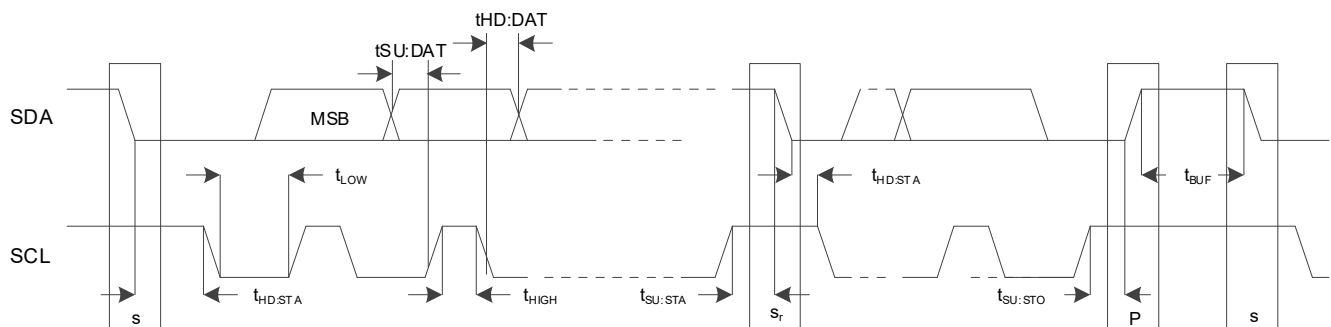
| Symbol | Parameter | Conditions | Typical | Maximum | Unit |
|------------------------------------|---|--|---------|---------|------|
| $I_{DDOx_1.8V}$ ^{[2][3]} | Output Buffer Supply Current, $V_{DDO} = 1.8V$ | 100MHz, CMOS differential or x2 mode (both OUT[x] and OUT[x]b enabled). | 4 | 5 | mA |
| | | 100MHz, CMOS positive output (only OUT[x] enabled). | 2 | 3 | |
| | | 100MHz, LVDS mode | 5 | 6.5 | |
| | | 100MHz, LP-HSCL 85ohm mode. ^[4] | 5 | 7 | |
| | | 200MHz, CMOS differential or x2 mode (both OUT[x] and OUT[x]b enabled). | 9 | 12 | mA |
| | | 200MHz, CMOS positive output (only OUT[x] enabled). | 5 | 6 | |
| | | 650MHz, LVDS mode. | 12 | 16 | mA |
| | | 650MHz, LP-HSCL 85ohm mode. | 15 | 22 | |
| $I_{DDOx_3.3V}$ ^{[2][3]} | Output Buffer Supply Current, $V_{DDO} = 3.3V$ | 100MHz, CMOS differential or x2 mode (both OUT[x] and OUT[x]b enabled). | 6 | 9 | mA |
| | | 100MHz, CMOS positive output (only OUT[x] enabled). | 3 | 5 | |
| | | 100MHz, LVDS mode. | 5 | 6 | |
| | | 100MHz, LP-HSCL 85ohm mode. | 5 | 6 | |
| | | 200MHz, CMOS differential or x2 mode (both OUT[x] and OUT[x]b enabled). | 16 | 20 | mA |
| | | 200MHz, CMOS positive output (only OUT[x] enabled). | 8 | 10 | |
| | | 650MHz, LVDS mode. | 13 | 14 | mA |
| | | 650MHz, LP-HSCL 85ohm mode. ^[4] | 17 | 19 | |
| $I_{DDOD_1.8V}$ | Output Divider Supply Current, $V_{DDO} = 1.8V$ | 100MHz. Current consumed per LPFOD (V_{DDO0} and V_{DDO1}) or IOD (V_{DDO5} and V_{DDO6}). | 23 | 25 | mA |
| | | 100MHz. Current consumed per HPFOD (V_{DDO2} , V_{DDO3} , and V_{DDO4}) | 38 | 41 | |
| | | 200MHz. Current consumed per LPFOD (V_{DDO0} and V_{DDO1}) or IOD (V_{DDO5} and V_{DDO6}). | 24 | 26 | mA |
| | | 200MHz. Current consumed per HPFOD (V_{DDO2} , V_{DDO3} , and V_{DDO4}) | 39 | 42 | |
| | | 650MHz. Current consumed per LPFOD (V_{DDO0} and V_{DDO1}) or IOD (V_{DDO5} and V_{DDO6}). | 25 | 28 | mA |
| | | 650MHz. Current consumed per HPFOD (V_{DDO2} , V_{DDO3} , and V_{DDO4}) | 45 | 50 | |
| $I_{DDOD_3.3V}$ | Output Divider Supply Current, $V_{DDO} = 3.3V$ | 100MHz. Current consumed per LPFOD (V_{DDO0} and V_{DDO1}) or IOD (V_{DDO5} and V_{DDO6}). | 24 | 27 | mA |
| | | 100MHz. Current consumed per HPFOD (V_{DDO2} , V_{DDO3} , and V_{DDO4}) | 40 | 51 | |
| | | 200MHz. Current consumed per LPFOD (V_{DDO0} and V_{DDO1}) or IOD (V_{DDO5} and V_{DDO6}). | 25 | 28 | mA |
| | | 200MHz. Current consumed per HPFOD (V_{DDO2} , V_{DDO3} , and V_{DDO4}) | 43 | 53 | |
| | | 650MHz. Current consumed per LPFOD (V_{DDO0} and V_{DDO1}) or IOD (V_{DDO5} and V_{DDO6}). | 26 | 28 | mA |
| | | 650MHz. Current consumed per HPFOD (V_{DDO2} , V_{DDO3} , and V_{DDO4}) | 47 | 53 | |

1. Outputs are not terminated and are driving traces < 1 inch long. This information is provided to allow design of appropriate power supply circuits to support all possible register-based configurations for the device. To determine actual consumption for the user's configuration and circuit board see [Power Considerations](#) for details on estimating current consumption for various output loads. Values apply to all voltage levels unless noted.
2. I_{DDOx} denotes the current consumed by each output driver and does not include output divider current.
3. Please refer to the Output Driver and Output Divider V_{DDO} Pin Assignments Table to determine the allocation of I_{DDOD} to each V_{DDO} pin.
4. LP-HCSL 100ohm mode will have 15% lower I_{DDOx} values.

Table 26. I²C Bus DC Electrical Characteristics [1]

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|------------------|--|-----------------------|-----------------------|---------|----------------------|------|
| V _{IH} | High-level input voltage for SCL and SDA | | 0.7 V _{DDD} | - | - | V |
| V _{IL} | Low-level input voltage for SCL and SDA | | - | - | 0.3 V _{DDD} | V |
| V _{HYS} | Hysteresis of Schmitt trigger inputs | | 0.05 V _{DDD} | - | - | V |
| V _{OL} | Low-level output voltage for SCL and SDA | I _{OL} = 4mA | - | - | 0.4 | V |
| I _{IN} | Input leakage current per pin | | -5 | - | 5 | μA |
| C _B | Capacitive Load for Each Bus Line | | - | - | 400 | pF |

1. V_{OH} is governed by the V_{PUP}, the voltage rail to which the pull up resistors are connected.

Figure 4. I²C Slave Timing DiagramTable 27. I²C Bus AC Electrical Characteristics

| Symbol | Parameter | Conditions | 100kHz Class Minimum | 100kHz Class Maximum | 400kHz Class Minimum | 400kHz Class Maximum | Unit |
|-----------|---|------------|--|----------------------|----------------------|----------------------|------|
| fSMB | I2C Operating Frequency ^[1] | | 10 | 100 | 10 | 400 | kHz |
| tBUF | Bus free time between STOP and START Condition | | 4.7 | - | 1.3 | - | μs |
| tHD:STA | Hold time after (REPEATED) START Condition ^[2] | | 4 | - | 0.6 | - | |
| tSU:STA | REPEATED START Condition setup time | | 4.7 | - | 0.6 | - | |
| tSU:STO | STOP Condition setup time | | 4 | - | 0.6 | - | |
| tHD:DAT | Data hold time ^[3] | | 300 | - | 300 | - | ns |
| tSU:DAT | Data setup time | | 250 | - | 100 | - | |
| tTIMEOUT | Detect SCL low timeout ^[4] | | 25 | 35 | 25 | 35 | ms |
| tTIMEOUT | Detect SDA low timeout ^[5] | | 25 | 35 | 25 | 35 | |
| tLOW | Clock low period | | 4.7 | - | 1.3 | - | μs |
| tHIGH | Clock high period ^[6] | | 4 | 50 | 0.6 | 50 | |
| tLOW:SEXT | Cumulative clock low extend time (slave device) ^[7] | | N/A, the RC2121xA do not extend the clock low. | | | | ms |
| tLOW:MEXT | Cumulative clock low extend time (master device) ^[8] | | N/A, the RC2121xA are not bus masters. | | | | |
| tF | Clock/Data Fall Time ^[9] | | - | 120 | - | 120 | ns |
| tR | Clock/Data Rise Time ^[9] | | - | 120 | - | 120 | |
| tsPIKE | Noise spike suppression time ^[10] | | - | N/A | - | 50 | |

1. A master shall not drive the clock at a frequency below the minimum f_{SMB} . Further, the operating clock frequency shall not be reduced below the minimum value of f_{SMB} due to periodic clock extending by slave devices as defined in Section 5.3.3 of the *SMBus 2.0 Specification*. This limit does not apply to the bus idle condition, and this limit is independent from the $t_{LOW:SEXT}$ and $t_{LOW:MEXT}$ limits. For example, if the SCK is high for $t_{HIGH:MAX}$, the clock must not be periodically stretched longer than $1/f_{SMB:MIN} - t_{HIGH:MAX}$. This requirement does not pertain to a device that extends the SCK low for data processing of a received byte, data buffering and so forth for longer than 100 μ s in a non-periodic way.
2. A device must internally provide sufficient hold time for the SDA signal (with respect to the $V_{IH:MIN}$ of the SCK signal) to bridge the undefined region of the falling edge of SCK.
3. Slave devices may have caused other slave devices to hold SDA low. The maximum time that a device can hold SDA low after the master raises SCK after the last bit of a transaction. A slave device may detect how long SDA is held low and release SDA after the time out period.
4. Devices participating in a transfer can abort the transfer in progress and release the bus when any single clock low interval exceeds the value of $t_{TIMEOUT:MIN}$. After the master in a transaction detects this condition, it must generate a stop condition within or after the current data byte in the transfer process. Devices that have detected this condition must reset their communication and be able to receive a new START condition no later than $t_{TIMEOUT:MAX}$. Typical device examples include the host controller, and embedded controller, and most devices that can master the SMBus. Some simple devices do not contain a clock low drive circuit; this simple kind of device typically may reset its communications port after a start or a stop condition. A timeout condition can only be ensured if the device that is forcing the timeout holds the SCK low for $t_{TIMEOUT:MAX}$ or longer.
5. The device has the option of detecting a timeout if the SDA pin is also low for this time.
6. $t_{HIGH:MAX}$ provides a simple guaranteed method for masters to detect bus idle conditions. A master can assume that the bus is free if it detects that the clock and data signals have been high for greater than $t_{HIGH:MAX}$.
7. $t_{HIGH:MAX}$ provides a simple guaranteed method for masters to detect bus idle conditions. A master can assume that the bus is free if it detects that the clock and data signals have been high for greater than $t_{HIGH:MAX}$.
8. $t_{LOW:SEXT}$ is the cumulative time a given slave device is allowed to extend the clock cycles in one message from the initial START to the STOP. It is possible that another slave device or the master will also extend the clock causing the combined clock low extend time to be greater than $t_{LOW:SEXT}$. Therefore, this parameter is measured with the slave device as the sole target of a full-speed master.
9. The rise and fall time measurement limits are defined as follows:
Rise Time Limits: ($V_{IL:MAX} - 0.15V$) to ($V_{IH:MIN} + 0.15V$)
Fall Time Limits: ($V_{IH:MIN} + 0.15V$) to ($V_{IL:MAX} - 0.15V$)
10. Devices must provide a means to reject noise spikes of a duration up to the maximum specified value.

Table 28. Power Supply Noise Rejection

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Unit |
|--------|---|---|---------|---------|---------|------|
| PSNR | Power Supply Noise Rejection [1][2][3][4] 1.8V operation | VDDO[0:6] [5], $f_{NOISE} \leq 1\text{MHz}$, LVDS/LPHCSL output type | -40 | -36 | - | dBc |
| | | VDDO[0:6] [5], $f_{NOISE} \leq 1\text{MHz}$, LVCMOS output type | -30 | -28 | - | |
| | | VDDD, VDDA, VDDX0, VDDX1, $f_{NOISE} \leq 1\text{MHz}$ | -47 | -38 | - | |
| | | VDDD, VDDA, VDDX0, VDDX1, $100\text{kHz} \leq f_{NOISE} \leq 1\text{MHz}$ | -134 | -120 | - | |
| | | VDDD, VDDA, VDDX0, VDDX1, $f_{NOISE} \leq 100\text{kHz}$ | -139 | -135 | - | |
| PSNR | Power Supply Noise Rejection [1][3][4][6] 3.3V operation | VDDO[0:6] [5], $f_{NOISE} \leq 1\text{MHz}$, LVDS/LPHCSL output type | -70 | -32 | - | dBc |
| | | VDDO[0:6] [5], $f_{NOISE} \leq 1\text{MHz}$, LVCMOS output type | -47 | -32 | - | |
| | | VDDD, VDDA, VDDX0, VDDX1, $f_{NOISE} \leq 1\text{MHz}$ | -72 | -65 | - | |
| | | VDDD, VDDA, VDDX0, VDDX1, $100\text{kHz} \leq f_{NOISE} \leq 1\text{MHz}$ | -132 | -110 | - | |
| | | VDDD, VDDA, VDDX0, VDDX1, $f_{NOISE} \leq 100\text{kHz}$ | -17 | -130 | - | |

1. Electrical parameters are guaranteed over the specified ambient operating temperature range, which is established when the device is mounted in a test socket with maintained transverse airflow greater than 500lpm. The device will meet specifications after thermal equilibrium has been reached under these conditions.
2. VDDX0 = VDDX1 = VDDD = VDDA = VDD[0:6] = 1.8V $\pm 5\%$, VSS = 0V, TA = -40°C to 105°C.
3. 50mV peak-to-peak sine wave applied injected on indicated power supply pin(s).
4. Noise spur amplitude measured relative to 156.25MHz carrier frequency.
5. Excluding VDDOx of the output being measured.
6. VDDX0 = VDDX1 = VDDD = VDDA = VDD[0:6] = 3.3V $\pm 5\%$, VSS = 0V, TA = -40°C to 105°C.

3. Overview

The following sections provide an overview of the RC2121xA family.

3.1 Power-Up, Configuration, and Serial Interfaces

The RC2121xA can be powered-up and configured from one of eight configurations stored in internal OTP. These configurations are referred to as User Configurations (UserCfg). The power-up configuration can be selected via external GPIO pins or by programming a field to select a default configuration to load. This is useful when external GPIO are not used to select a UserCfg at power-up.

The crystal oscillator starts, the APLL locks, and various power-on-self tests are run. The outputs remain disabled until the power-up sequence completes successfully. After the power-up sequence completes, the outputs are enabled according to register settings and OE pins as programmed into the OTP.

The RC2121xA has a slave I²C serial interface that can be used to change configuration after power-up or monitor the device during operation. The I²C slave address is programmable.

3.2 Input Clocks

The RC2121[2/4]A supports two crystal/reference inputs.

The RC2121[1/3]A supports one crystal/reference inputs.

3.2.1 Crystal/Reference Input

The crystal input supports crystal frequencies as defined in [Table 8](#). It has programmable internal load capacitors to support crystals with CL = 6pF to 12pF.

The crystal input also supports being over-driven with a single-ended or differential clock, or a 0.8VPP clipped sine-wave TCXO. For more information, see [Overdriving the XTAL Interface](#).

The supported input frequency range is defined in [Table 7](#). Input reference monitoring is not supported for input frequencies > 62.5MHz.

3.3 GPIO and GPI

There are seven GPIO pins GPIO[6:0] and two GPI pins. The GPI pins are only available in single crystal variants. These pins are typically assigned special functions such as the following:

- INT – Interrupt, up to 1 pin (GPIO only)
- FAULT – Fault, up to 1 pin (GPIO only)
- SEL – OTP image select, up to 3 pins
- OE – Output enable, up to 6 pins

GPIO[6:1] are open drain (or input), and are 3.3V tolerant when powered from 1.8V. GPIO[0] is push-pull driver (or input), and is *not* 3.3V tolerant when powered at 1.8V VDDD. All GPIO pins are 3.3 V tolerant when powered at 3.3V VDDD.

GPI pins are *not* 3.3V tolerant when powered at 1.8V VDDX1. GPI pins are 3.3 V tolerant when powered at 3.3V VDDX1.

In addition, the GPIO pins can be used to read/write a logic level on a pin. Similarly, the GPI pins can be used to read a logic level.

All GPI and GPIO pins have programmable pull-down.

3.4 APLL

The APLL is fractional LC-VCO based PLL with an operating range from 9.5GHz to 10.7GHz.

Any of the available crystals or input reference clock can be selected to provide a reference to the APLL. The input reference can be frequency doubled for increased performance. The APLL is temperature compensated for the utmost frequency stability. Lock detect status is also provided and can be read from an internal register.

3.5 Dividers

3.5.1 Output Dividers

The RC2121xA provides two integer, two limited-performance fractional output dividers, and three high-performance fractional output dividers.

3.5.2 Integer Output Dividers (IOD)

There are two IODs. IODs use a 25-bit divider to provide output frequencies from 1kHz to 650MHz from the VCO clock. Changing IOD values results in an immediate change to the new frequency. Glitch-less squelch and release of the IOD clock is supported. When enabled, this mimics a gapped clock behavior when an IOD frequency is changed.

3.5.3 Limited-Performance Fractional Output Dividers (LPFOD)

There are two limited-performance fractional output dividers (LPFODs). Each LPFOD can divide down the VCO clock to provide frequencies of 1kHz to 650MHz. Each LPFOD is implemented in a similar manner as the IOD. The difference is that the MMD (Multi Modulus Divider) is modulated by a first order SDM (sigma delta modulator). The output period has an additional ~1.0ps (VCO frequency ~10GHz) cycle-to-cycle jitter, from the modulation. The LPFOD can be programmed to operate in IOD mode with the same performance as an IOD.

3.5.4 High-Performance Fractional Output Dividers (HPFOD)

There are three high-performance fractional output dividers (HPFODs). Each HPFOD can divide down the VCO clock to provide frequencies of 1kHz to 650MHz. Each HPFOD is implemented in two stages. The first stage is an 8-bit fractional divider with Digital Control Delay (DCD) correction followed by a divide-by-2. The DCD is a phase interpolator to reduce cycle-to-cycle jitter introduced by the first order SDM. The first stage allows a divide down of the VCO clock to 33MHz to 657MHz. The HPFOD's second stage divider is a 17-bit integer divider with minimum divide ratio of 4. This allows output frequencies lower than 30MHz. For output frequencies above 33MHz, this second-stage divider can be bypassed.

3.5.4.1 Spread-Spectrum Clocking (SSC)

HPFOD0 and HPFOD1 support SSC. SCC modulation is supported from 25MHz to 650MHz.

If SSC is enabled then the spread-spectrum engine modulates a triangular frequency profile onto the HPFOD divider ratio. The modulation amplitude is programmable. The modulation type can be programmed to either down-spread or center-spread. The supported modulation frequency is from 30kHz to 63kHz. When turning off spreading, it stops when the current spreading cycle completes (the frequency returns to the SSC off value).

Table 29. SSC Characteristics

| SSC Direction | SSC Modulation Freq. (kHz) | Minimum SSC Amount (%) | Maximum SSC Amount (%) |
|---------------|----------------------------|------------------------|------------------------|
| Down | 30 - 63 | < -0.05 | - 3 |
| Center | 30 - 63 | < ± 0.025 | ± 1.5 |

If the HPFOD0 and HPFOD1 SSC are programmed to the same modulation frequency, they can be programmed to be in phase. The modulation amplitude and mode (down or center spread) can be set differently. SSC clock outputs meets the phase jitter and ppm accuracy requirements of PCI-Express Gen1 to Gen5.

3.6 Clock Outputs

The RC2121xA outputs are individually programmable to support single-ended and differential output types.

3.6.1 Output Types

Differential outputs can be set to 85ohm HCSL, 100ohm HCSL, or LVDS. The HCSL outputs types are low-power push-pull HCSL (LPHCSL). They require external terminations to drive standard HCSL inputs, such as those found in PCIe applications. HCSL outputs have programmable output swing and HCSL outputs also have two slew rate settings (2V/ns to 4V/ns and 3V/ns to 5V/ns). LVDS outputs require only a 100ohm resistor between the true and complement inputs of the clock input being driven. Both LVDS and HCSL provide output swing levels that are compatible with LVPECL and CML with external AC coupling.

If set to single-ended mode, the output pair can drive either pin or both pins. If both pins are enabled, they can be in phase, or inverted phase. The single-ended outputs support LVCMOS swings of 1.8V or 3.3V as determined by their VDDO voltage.

3.6.2 Output Banks

The RC2121xA maps the internal and external frequency sources to output banks according to the following table.

Table 30. Output Bank Source Mapping

| | Bank 0 VDDO0 (OUT0) | Bank 1 VDDO1 (OUT1) | Bank 2 VDDO2 (OUT[3:2]) | Bank 3 VDDO3 OUT[7:4]) | Bank 4 VDDO4 (OUT[9:8]) | Bank 5 VDDO5 (OUT10) | Bank 6 VDDO6 (OUT11) |
|----------|---------------------------|---------------------------|-------------------------------|------------------------------|-------------------------------|----------------------------|----------------------------|
| LPFOD0 | Yes(48) [1] | Yes(40) [2] | | | | | |
| LPFOD1 | Yes | Yes [3] | Yes | | | | |
| HPFOD0 | Yes | Yes | Yes | Yes | | | |
| HPFOD1 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| HPFOD2 | | | | Yes | Yes | Yes | Yes |
| IOD1 | | | | | Yes | Yes | Yes |
| IOD0 | | | | | | Yes | Yes |
| APLL REF | | | | | | Yes | Yes |

1. Bold **Yes(48)** indicates that the divider is powered from the bank VDD0 on 48-pin variant.

2. Bold **Yes(40)** indicates that the divider is powered from the bank VDD0 on 40-pin variant.

3. Bold **Yes** indicates that the divider is powered from the bank VDD0 on all variants.

3.7 Fault Monitors and Diagnostics

3.7.1 Overview

The RC2121xA implements many diagnostic and fault detection features. Some at power on and some run during operation. When a fault is detected either the interrupt pin (INT) or fault pin (FAULT) is activated, if enabled. The mechanisms are as follows:

- Each monitor maps to the FAULT output or to the INT output, or none, configurable by register bit.
- Supports fail safe: when an error is detected (and enabled, and set to FAULT mode) the RC2121xA goes to its safe state:
 - All outputs are disabled.
 - FAULT pin asserted, active low.
 - I²C is operational
- Provides fault insertion capabilities to insert all faults that are monitored.
- Dual crystal support, such that if the active crystal fails the device performs a hitless switch.
- If an error is detected, and enabled, the associated output is disabled.

3.7.2 System Interface

The RC2121xA provides an I²C slave interface, whereby the system may read various status information to determine if there are any issues. The I²C slave interface is CRC protected. Default configuration provides a GPIO pin used for INT, and another GPIO pin is used for FAULT; both are open-drain active-low signals. The expected use case is that some errors (e.g., a crystal switch over or a single output clock failure) would be mapped to an interrupt, and the SoC could take appropriate action. Other failures (e.g., the APLL loss of lock) would trigger a FAULT, and this would be used to put the system in a safe state. APLL losing lock would affect all outputs.

3.7.3 Redundant Crystals

The RC2121[2/4]A supports redundant crystals. If the active crystal monitors detect an error condition, the mux will perform a hitless switch to the other crystal, assuming it is operating correctly. The crystals must operate within 200ppm of each other, for crystals equal to or lower than 50MHz, and 100ppm for crystals greater than 50MHz. The switching between crystals is non-revertive.

3.7.4 Monitors

The RC2121xA provides the following monitors:

- Loss of signal on crystal of reference input.
- PPM warning and error thresholds between the two crystals.
- Loss of lock on APLL.
- Frequency error detection at each enabled output, and if enabled, the output is disabled.
- 8-bit CRC check on I²C interface.
- 32-bit CRC check on OTP download.
- 32-bit CRC check on control registers for soft errors, every 10ms.

3.7.5 Power-on Self Test

The RC2121xA provides the following:

- Digital built-in self test.
- Checking of monitors via fault insertion.

4. Application Information

4.1 Recommendations for Unused Input and Output Pins

4.1.1 XIN0_REFIN0/XOUT0_REFIN0b, XIN1_REFIN1_GPI0/XOUT1_REFIN1b_GPI1

If used as crystal inputs, each set of pins must be connected to a crystal. For applications using the pins as REFIN inputs, both inputs of each pair should be left floating. If used as LVCMOS control pins, GPIO and GPI1 have internal pull-ups or pull-downs. Additional resistance is not required but can be added for additional protection. A 10k Ω resistor can be used. If using these pins as REFIN0/REFIN0b or REFIN1/REFIN1b, see [Overdriving the XTAL Interface](#) for important information.

4.1.2 LVCMOS Outputs

Any LVCMOS output can be left floating if unused. There should be no trace attached. The output buffer should be set to high-impedance state to avoid unnecessary noise generation.

4.1.3 Differential Outputs

All unused differential outputs can be left floating. Renesas recommends that no trace be attached and that the outputs be set to high impedance. Both sides of the differential output pair should be treated the same, either left floating or terminated.

4.2 Crystal or Reference Clock Inputs

The RC2121xA provides a programmable input buffer for reference clock inputs, as shown in [Figure 5](#). This programmable buffer supports most standard signaling protocols with no need for external termination components at the receiver end of the transmission line.

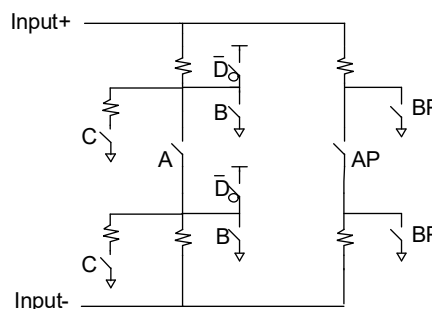


Figure 5. Programmable Input Buffer Logical Diagram

By making appropriate register selections, the switches labeled in [Figure 5](#) can be closed as shown in [Table 31](#) to support the indicated protocols. With the switches closed as indicated, the input buffer will operate as shown in [Figure 6](#) for the various input reference signal protocols. Note that HCSL is used in both 100ohm and 85ohm transmission line environments and this input buffer supports both with no external terminations required.

Table 31. Input Buffer Programming Options for Specific Signaling Protocols

| Input Signaling Protocol | Switches Closed | V _{DDR} Voltage Required |
|--------------------------|-----------------|-----------------------------------|
| 2.5V LVPECL | A, C | 2.5V |
| 3.3V LVPECL | A, C | 3.3V |
| LVDS (85 ohms) | A, AP | 1.8V / 2.5V / 3.3V |
| LVDS (100 ohms) | A | 1.8V / 2.5V / 3.3V |
| 1.8V LVCMOS | - | 1.8V |
| 2.5V LVCMOS | - | 2.5V |
| 3.3V LVCMOS | - | 3.3V |
| CML | D | 3.3V |

Table 31. Input Buffer Programming Options for Specific Signaling Protocols (Cont.)

| Input Signaling Protocol | Switches Closed | V _{DDR} Voltage Required |
|--------------------------------------|-----------------|-----------------------------------|
| HCSL (42.5 ohms) | B, BP | 1.8V / 2.5V / 3.3V |
| HCSL (42 ohms) | B | 1.8V / 2.5V / 3.3V |
| Externally AC-coupled ^[1] | - | 1.8V / 2.5V / 3.3V |

1. In this mode of operation, AC-coupling capacitors must be used to isolate the voltage level of the transmitter from the receiver. The signal must be properly terminated on the transmitter side of the AC-coupling capacitors. Bias terminations are needed between the AC-coupling capacitors and the RC2121xA.

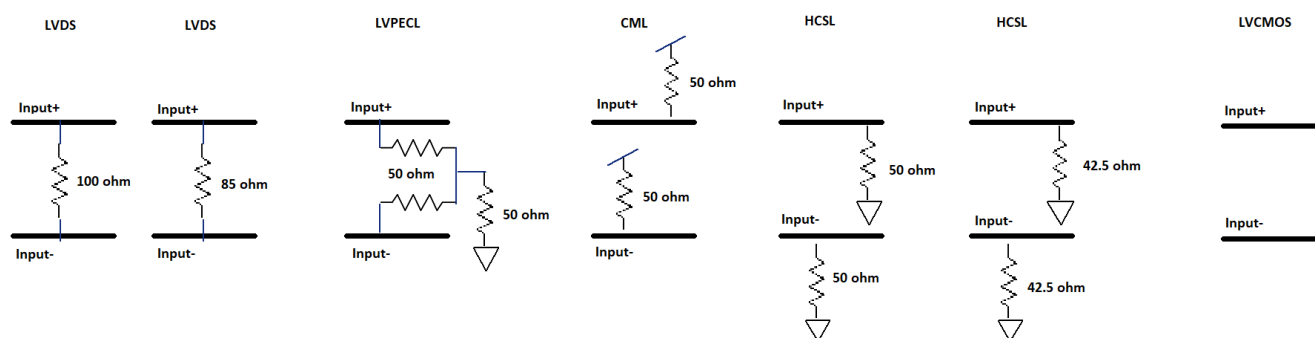


Figure 6. Input Buffer Behavior by Protocol

4.3 Overdriving the XTAL Interface

4.3.1 XTAL Interface Set to Input Buffer (REFIN) Mode

The RC2121xA has two bits to disconnect the internal XO and enable input buffer mode on the XIN_REFIN/XOUT_REFINb and XIN_REFIN0_GPI0/XOUT_REFIN1_GPI1 pins. First, setting `sel_ib_xo = 0`, disconnects the internal XO. Next, setting `xo_ib_cmos_sel = 1` enables the LVCMOS input clock path. Setting these two bits as indicated removes any AC-coupling or input voltage requirements for overdriving the XTAL interface. Note that the maximum input swing is still governed by the VDDX0 and VDDX1 supply rails. When set to Input Buffer Mode, the input can be directly driven with a single-ended or differential oscillator. There is no internal termination capability when using input buffer mode.

4.3.2 XTAL Interface in XO Mode, Input Buffer (REFIN) Mode Not Selected

If the two bits mentioned above are not set as indicated, then there is a limitation of 1.2V on the XIN_REFIN/XOUT_REFINb pins. Input buffer mode is preferred as described in section 4.3.1.

The XIN_REFIN input may be overdriven by an LVCMOS driver or by one side of a differential driver through an AC coupling capacitor. The XOUT pin can be left floating. The amplitude of the input signal should be between 500mV and 1.2V, and the slew rate must be $\geq 0.2\text{V/ns}$. For 1.2V LVCMOS, inputs can be DC-coupled into the device as shown in Figure 7. For LVCMOS drivers with $> 1.2\text{V}$ swing, the amplitude must be reduced from full swing to less than 1.2V in order to prevent signal interference with the power rail. The sum of the driver output impedance and R_s must equal the transmission line impedance to prevent overshoot and undershoot.

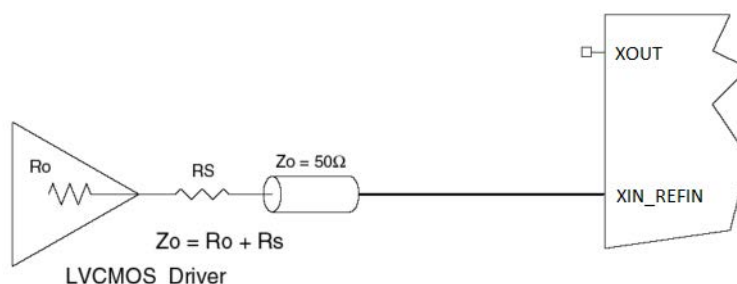


Figure 7. 1.2V LVCMOS Driver to XTAL Input Interface

Figure 8 shows an example of the interface diagram for a high-speed 1.8V LVCMOS driver. This configuration requires that the sum of the output impedance of the driver (R_o) and the series resistance (R_s) equal the transmission line impedance. In addition, matched termination at the XIN_REFIN input will attenuate the signal in half. This can be done in one of two ways. First, R_1 and R_2 in parallel should equal the transmission line impedance. For most 50Ω applications, R_1 and R_2 can be 100Ω. Attenuation can also be accomplished by removing R_1 and changing R_2 to 50Ω. The values of the resistors can be increased to reduce the loading for a slower and weaker LVCMOS driver.

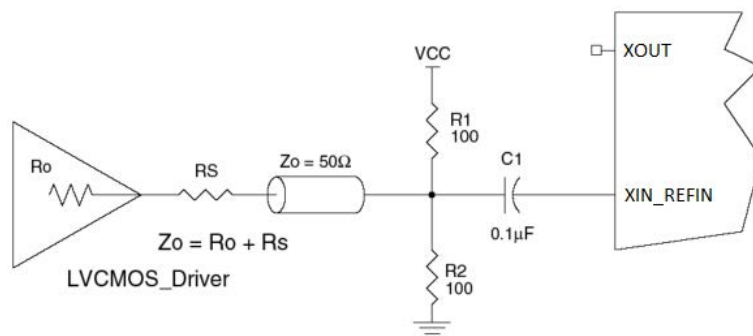


Figure 8. LVCMOS Driver to XTAL Input Interface with Amplitude Attenuation

Figure 9 shows an example of the interface diagram for an LVPECL driver. This is a standard LVPECL termination with one side of the driver feeding the XIN_REFIN input. It is recommended that all components in the schematics be placed in the layout. Though some components may not be used, they can be used for debugging purposes.

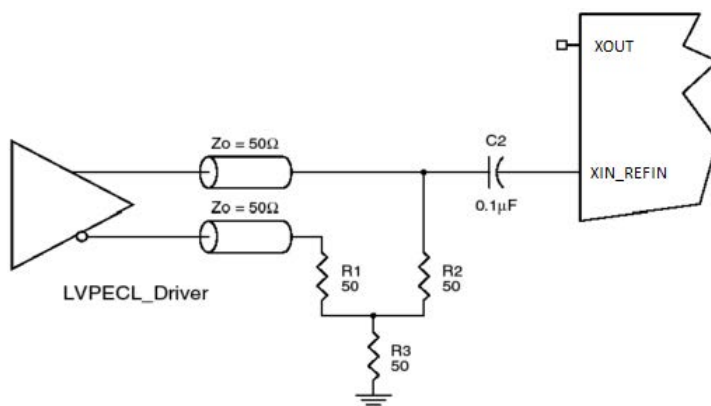


Figure 9. LVPECL Driver to XTAL Input Interface

4.4 Differential Output Termination

4.4.1 Direct-Coupled LP-HCSL Termination

For LP-HCSL differential protocol, the following termination scheme is recommended (see Figure 10). The RC2121xA supports integrated source termination in the figure that presents a differential output impedance of 85 or 100 ohms.

Note: For Rev A silicon with output monitoring is turned on then the LP-HCSL output impedance is ~17 ohms and external series resistors must be used. The monitor looks at the voltage on the output pin and transmission line reflections may interfere with the monitor when the internal terminations are used.

For alternate termination schemes, see *Driving LVPECL, LVDS, CML, and SSTL Logic with Renesas' "Universal" Low-Power HCSL Outputs* (AN-891) at Renesas.com, or contact Renesas Electronics for support.

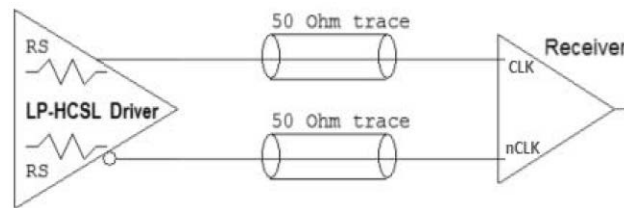


Figure 10. Standard LP-HCSL Termination

4.4.2 Direct-Coupled LVDS Termination

For LVDS differential protocol, the following termination scheme is recommended (see Figure 11). The recommended value for the termination impedance (Z_T) is between 90Ω and 132Ω . The actual value should be selected to match the differential impedance (Z_0) of your transmission line. A typical point-to-point LVDS design uses a 100Ω parallel resistor at the receiver and a 100Ω differential transmission-line environment. In order to avoid any transmission-line reflection issues, the components should be surface-mounted and must be placed as close to the receiver as possible.

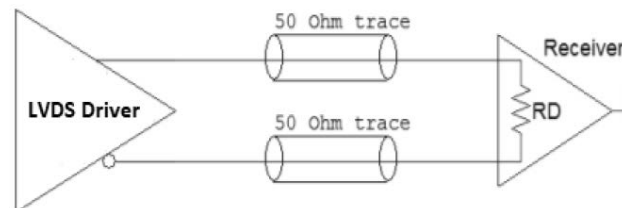


Figure 11. Standard LVDS Termination

For alternate termination schemes, see "LVDS Termination" in *Quick Guide - Output Terminations* (AN-953) located on the RC2121xA product page, or contact Renesas for support.

4.4.3 AC-Coupled Differential Termination

For any other type of differential protocol, AC-coupling should be used as shown in Figure 12, which assumes a 100Ω differential transmission-line environment. The RC2121xA should be programmed in LP-HCSL mode when using AC-coupling, with an appropriate voltage swing selection for the receiver being driven. The device supports a wide range of programmable voltage swing options.

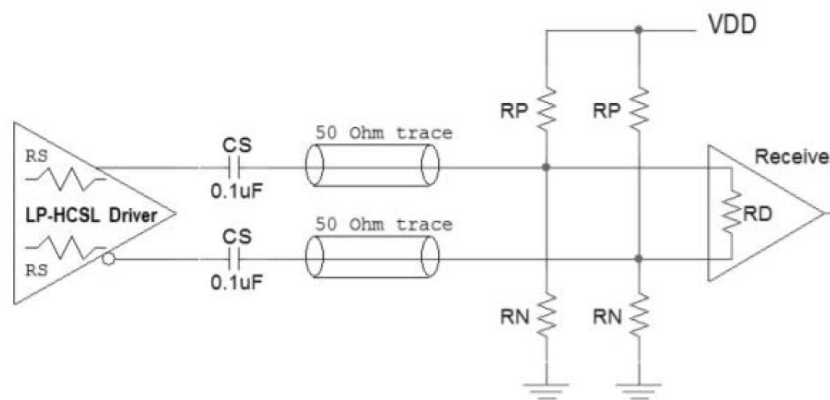


Figure 12. AC-Coupling Termination

No terminations are needed between the RC2121xA and the AC-coupling capacitors. The resistors on the receiver side of the AC-coupling capacitors should be selected to provide an appropriate voltage bias for the

particular receiver. For details, consult the receiver specifications. Finally, a 100Ω resistor across the differential pair (located near the receiver), will attenuate or prevent reflections that may corrupt the clock signal integrity.

It may also be useful to consult *Driving LVPECL, LVDS, CML, and SSTL Logic with Renesas' "Universal" Low-Power HCSL Outputs* (AN-891) located on the RC2121xA product page, or contact Renesas for support.

It should be noted that many receivers of the type expected to be used with a high-performance device like the RC2121xA are equipped with internal terminations that can include trace termination, voltage biasing, and even AC-coupling in some cases. Please consult with the receiver specifications to determine if any or all of the above indicated external components are needed.

4.5 Crystal Recommendation

For the latest vendor / frequency recommendations, please contact Renesas.

4.6 Power Considerations

The electrical characteristics tables provide current consumption values for various blocks and output configurations, and can be used to estimate total current consumption for a particular design. Designers can use the Clock Tool excel file, available on the Renesas website, to estimate output current consumption for specific loads.

Driver current due to output loads consists of two parts:

1. I_{CAP} (Current consumed charging and discharging the load capacitance)
 - a. $I_{CAP} \text{ (mA)} = V_{OH} \times F \times C_{LOAD} \times 1000$
2. I_{TLINE} (Current consumed charging and discharging the transmission line)
 - a. $I_{TLINE} \text{ (mA)} = [V_{OH} / 2 / (L_{LENGTH} \times t_{PV} \times Z_O \times 2 \times F)] \times 1000$

Units are:

V_{OH} Volts, F (MHz), C_{LOAD} (pf), L_{LENGTH} (inches), t_{PV} (ps/in), Z_O (ohms)

As an example, let's specify a 5 inch, 50 ohm transmission line with a load capacitance of 4pF driven by a 1.8V CMOS output at 100MHz. Let us also assume that the propagation velocity is 156 ps/in.

$$I_{CAP} \text{ (mA)} = [1.8V \times 100MHz \times 4pF] / 1000 = 0.72mA$$

$$I_{TLINE} \text{ (mA)} = [(1.8V / 2) / (5in \times 156ps/in / 50ohms)] \times 1000 = 2.8mA$$

$$\text{Total Current} = 3.5mA$$

From [Table 25](#), we can see that a single CMOS output driver powered from 1.8V operating at 100MHz consumes 2mA typical and 3mA worst case. Total current to drive the output is 5.5mA typical and 6.5mA maximum.

Powering a single CMOS output from 1.8V results in 9.9mW typical or 11.7mW maximum power consumption. If both CMOS outputs in an output pair were active, the current and power consumption would be doubled.

4.6.1 Power Sequencing Considerations

Note: In this section, the term “power rail” refers to the power connection to a particular VDD pin. This means that different VDD pins may be connected to the same voltage, yet may also be connected to different power rails. “Power rail” is also used when discussing power sequencing considerations.

The power sequencing considerations must be followed to ensure robust operation of the RC2121xA. When the entire RC2121xA is powered from a single power rail, these considerations are easy to meet. For applications where multiple supply rails are used, meeting these considerations requires a bit of planning.

Renesas recommends ramping the V_{DDA} and V_{DDD} power supply rails at the same time. They do not need to be the same voltage, although they may be. In all cases V_{DDA} must be $\leq V_{DDD}$. Logic powered by the V_{DDA}/V_{DDD} pins controls the internal reset sequencer. After the V_{DDA}/V_{DDD} rails ramp, the V_{DDO} rails need to ramp within $t_{VDDODLY}$ of the V_{DDA}/V_{DDD} rails. This means the V_{DDO} rails may ramp at the same time as the V_{DDA}/V_{DDD} rails,

or may be delayed as much as 4ms. The reference voltage for measuring the ramp is 1.62V regardless of the supply voltage. Figure 13 shows the power supply timing requirements.

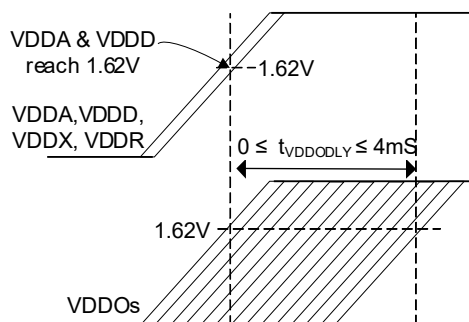


Figure 13. Power Supply Sequencing without PWRGD/PWRDN# or PWRGD/RESTART#

5. Thermal Information

5.1 Epad Thermal Release Path

In order to maximize both the removal of heat from the package and the electrical performance, a land pattern must be incorporated on the Printed Circuit Board (PCB) within the footprint of the package corresponding to the exposed metal pad or exposed heat slug on the package, as shown in [Figure 14](#). The solderable area on the PCB, as defined by the solder mask, should be at least the same size/shape as the exposed pad/slug area on the package to maximize the thermal/electrical performance. Sufficient clearance should be designed on the PCB between the outer edges of the land pattern and the inner edges of pad pattern for the leads to avoid any shorts.

While the land pattern on the PCB provides a means of heat transfer and electrical grounding from the package to the board through a solder joint, thermal vias are necessary to effectively conduct from the surface of the PCB to the ground plane(s). The land pattern must be connected to ground through these vias. The vias act as “heat pipes”. The number of vias (i.e., “heat pipes”) are application specific and dependent upon the package power dissipation as well as electrical conductivity requirements. Thus, thermal and electrical analysis and/or testing are recommended to determine the minimum number needed.

Maximum thermal and electrical performance is achieved when an array of vias is incorporated in the land pattern. It is recommended to use as many vias connected to ground as possible. It is also recommended that the via diameter should be 12 to 13mils (0.30 to 0.33mm) with 1oz copper via barrel plating. This is desirable to avoid any solder wicking inside the via during the soldering process which may result in voids in solder between the exposed pad/slug and the thermal land. Precautions should be taken to eliminate any solder voids between the exposed heat slug and the land pattern.

Note: These recommendations are to be used as a guideline only. For additional information, see the Application Note on the Surface Mount Assembly of Amkor’s Thermally/ Electrically Enhance Lead frame Base Package, Amkor Technology.

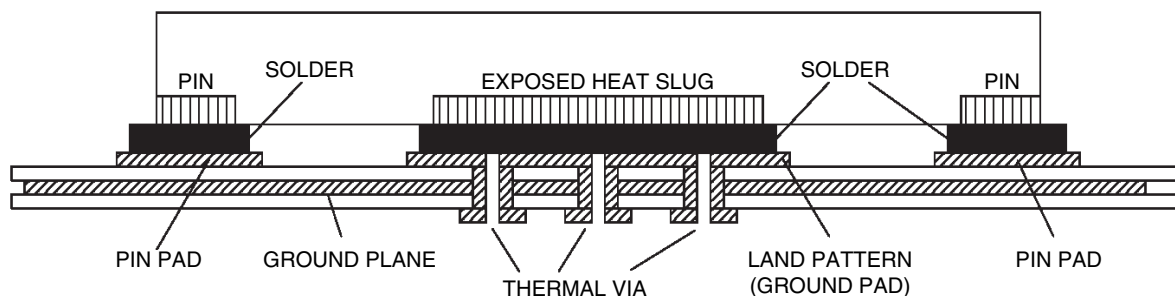


Figure 14. P.C. Assembly for Exposed Pad Thermal Release Path – Side View (Drawing not to Scale)

5.2 Thermal Characteristics

Table 32. Thermal Characteristics (48-pin) [1]

| Symbol | Parameter | Value | Unit |
|---------------|---|-------|------|
| θ_{JC} | Junction to Device Case Thermal Coefficient [2] | 20.1 | °C/W |
| θ_{JB} | Junction to Board Thermal Coefficient [2] | 1.9 | |
| θ_{JA} | Junction to Ambient Air Thermal Coefficient (still air) | 25.2 | |
| | Junction to Ambient Air Thermal Coefficient (1 m/s airflow) | 21.7 | |
| | Junction to Ambient Air Thermal Coefficient (2 m/s airflow) | 20.2 | |
| | Junction to Ambient Air Thermal Coefficient (3 m/s airflow) | 19.3 | |
| - | Moisture Sensitivity Rating (Per J-STD-020) | 3 | |

1. Multi-Layer PCB with two ground and two voltage planes.
2. Assumes ePAD is connected to a ground plane using a grid of 25 thermal vias.

Table 33. Thermal Characteristics (40-pin) [1]

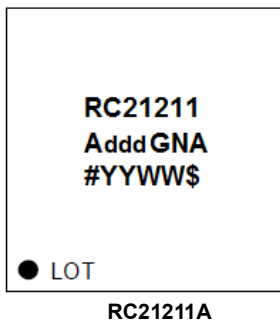
| Symbol | Parameter | Value | Unit |
|---------------|--|-------|------|
| θ_{JC} | Junction to Device Case Thermal Coefficient [2] | 26.9 | °C/W |
| θ_{JB} | Junction to Board Thermal Coefficient [2] | 1.3 | |
| θ_{JA} | Junction to Ambient Air Thermal Coefficient (still air) | 30.5 | |
| | Junction to Ambient Air Thermal Coefficient (1 m/s air flow) | 26.8 | |
| | Junction to Ambient Air Thermal Coefficient (2 m/s air flow) | 25.2 | |
| | Junction to Ambient Air Thermal Coefficient (3m/s air flow) | 24.3 | |
| - | Moisture Sensitivity Rating (Per J-STD-020) | 3 | |

1. Multi-Layer PCB with two ground and two voltage planes.
2. Assumes ePAD is connected to a ground plane using a grid of 16 thermal vias.

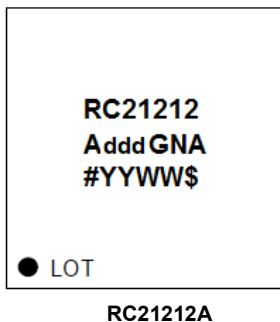
6. Package Outline Drawings

The package outline drawings are located at the end of this document and are accessible from the Renesas website. The package information is the most current data available and is subject to change without revision of this document.

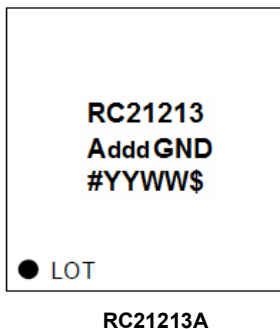
7. Marking Diagrams



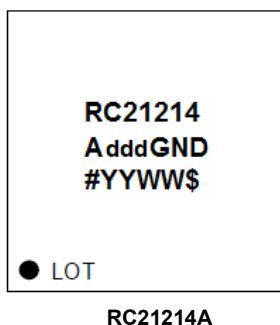
- Lines 1 and 2: part number.
 - “ddd” indicates preprogrammed device custom configuration dash code.
- Line 3:
 - “#” indicates the stepping number.
 - “YYWW” indicates the last two digits of the year and work week the part was assembled.
 - “\$” indicates the mark code.



- Lines 1 and 2: part number.
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 - “#” indicates the stepping number.
 - “YYWW” indicates the last two digits of the year and work week the part was assembled.
 - “\$” indicates the mark code.

8. Ordering Information

Table 34. Ordering Information

| Part Number [1] | Description | XTALS | Carrier Type | Package | Temp. Range | | |
|--------------------|--|-------|--|---|----------------|---|----------------|
| RC21211A000GNA#BB0 | 12-output Unprogrammed part | 1 | Tray | 6 × 6 × 0.75 mm 48-VFQFN Wettable flank | -40° to +105°C | | |
| RC21211A000GNA#KB0 | | | Tape and Reel, Pin 1 Orientation: EIA-481-D | | | | |
| RC21211AdddGNA#BB0 | Tray | | | | | | |
| RC21211AdddGNA#KB0 | Tape and Reel, Pin Orientation: EIA-481-D | | | | | | |
| RC21212A000GNA#BB0 | 12-output Unprogrammed Part | 2 | Tray | | | 5 × 5 × 0.75 mm 40-VFQFN Wettable flank | -40° to +105°C |
| RC21212A000GNA#KB0 | | | Tape and Reel, Pin 1 Orientation: EIA-481-D | | | | |
| RC21212AdddGNA#BB0 | Tray | | | | | | |
| RC21212AdddGNA#KB0 | Tape and Reel, Pin 1Orientation: EIA-481-D | | | | | | |
| RC21213A000GND#BB0 | 8-output Unprogrammed part | 1 | Tray | 5 × 5 × 0.75 mm 40-VFQFN Wettable flank | -40° to +105°C | | |
| RC21213A000GND#KB0 | | | Tape and Reel, Pin 1 Orientation: EIA-481-D | | | | |
| RC21213AdddGND#BB0 | Tray | | | | | | |
| RC21213AdddGND#KB0 | Tape and Reel, Pin Orientation: EIA-481-D | | | | | | |
| RC21214A000GND#BB0 | 8-output Unprogrammed Part | 2 | Tray | | | 5 × 5 × 0.75 mm 40-VFQFN Wettable flank | -40° to +105°C |
| RC21214A000GND#KB0 | | | Tape and Reel, Pin 1 Orientation: EIA-481-D | | | | |
| RC21214AdddGND#BB0 | Tray | | | | | | |
| RC21214AdddGND#KB0 | Tape and Reel, Pin 1 Orientation: EIA-481-D | | | | | | |

1. Replace "ddd" with the desired pre-programmed configuration code provided by Renesas in response to a custom configuration request.

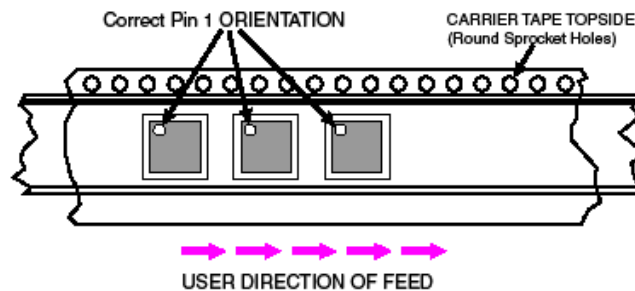


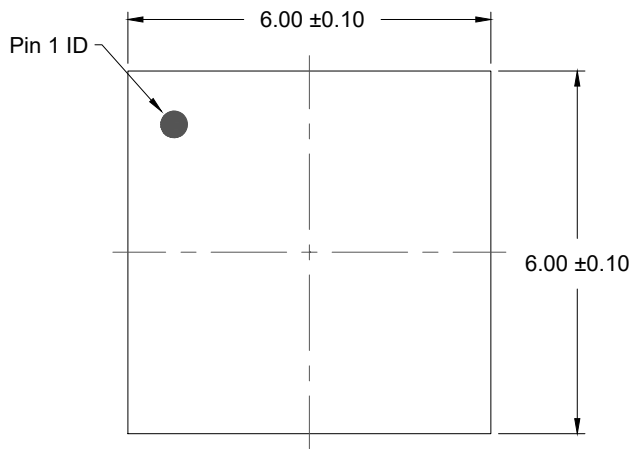
Figure 15. Pin 1 Orientation in Tape and Reel Packaging

Table 35. Product Identification

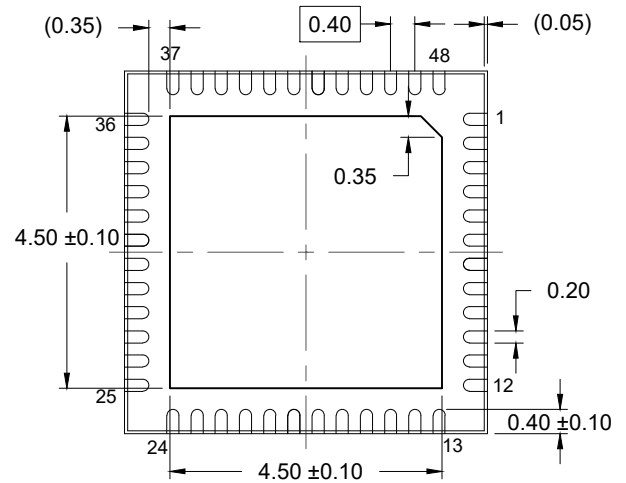
| Part Number | Product ID |
|-------------|------------|
| RC21211 | 212B |
| RC21212 | 212C |
| RC21213 | 212D |
| RC21214 | 212E |

9. Revision History

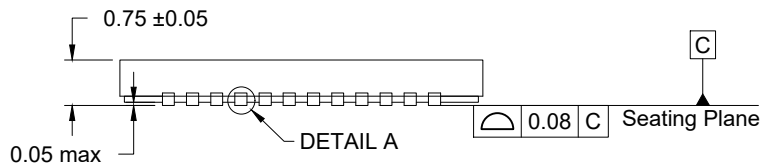
| Revision | Date | Description |
|----------|--------------|--|
| 1.04 | Jul 4, 2025 | <ul style="list-style-type: none">▪ Corrected the specification values in Clock Input Frequencies▪ Updated Power Supply Current with corrected values for different frequencies and output voltages▪ Updated Power Considerations with information on calculating current consumed by output loading |
| 1.03 | Apr 3, 2025 | <ul style="list-style-type: none">▪ Updated the last paragraph in Crystal/Reference Input.▪ Updated Table 7.▪ Completed other minor changes. |
| 1.02 | Dec 11, 2024 | <ul style="list-style-type: none">▪ Changed all references to GPIO[4:0] to GPIO[6:0].▪ Changed GPIO[1:4] to GPIO[1:6] in Table 2. |
| 1.01 | Apr 24, 2024 | Completed minor changes to the front matter. |
| 1.00 | Apr 4, 2024 | Initial release. |



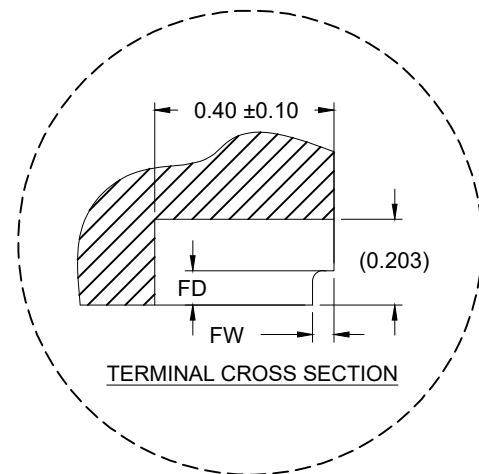
TOP VIEW



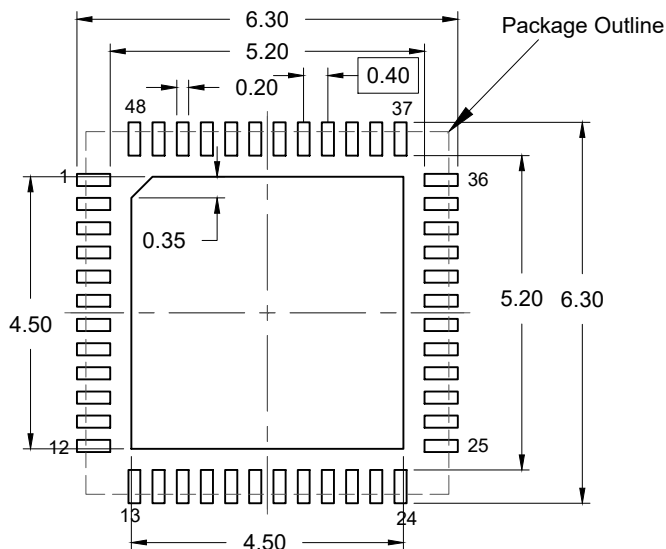
BOTTOM VIEW



SIDE VIEW



DETAIL A



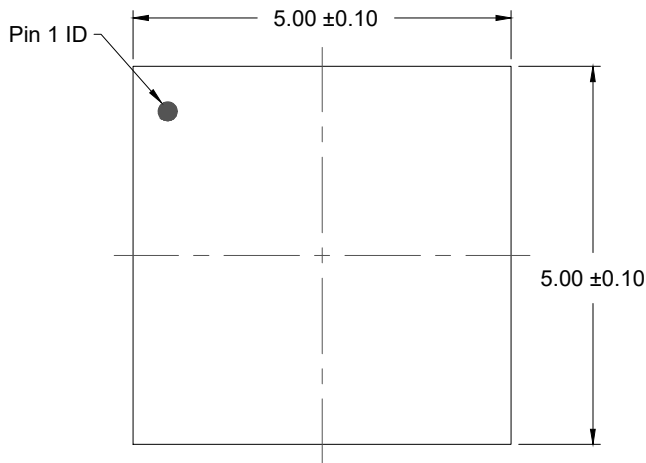
RECOMMENDED LAND PATTERN
(PCB Top View, NSMD Design)

Table 1: Dimensions of wettable flank (DETAIL A)

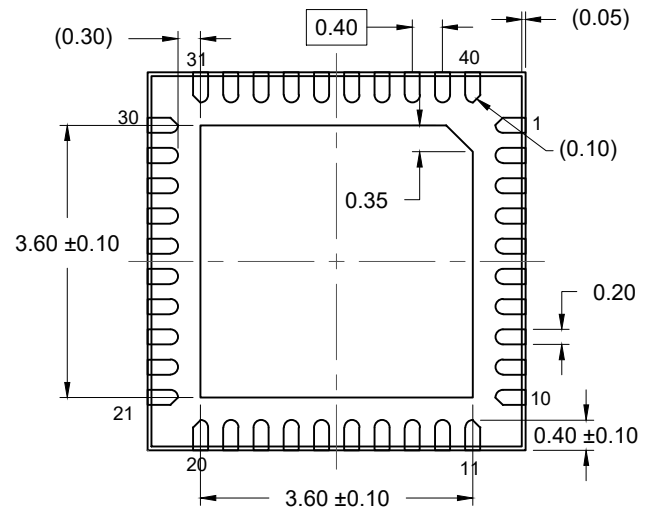
| Symbol | Dimension (mm) | |
|--------|----------------|-------|
| | MIN | MAX |
| FD | 0.100 | - |
| FW | 0.010 | 0.075 |

NOTES:

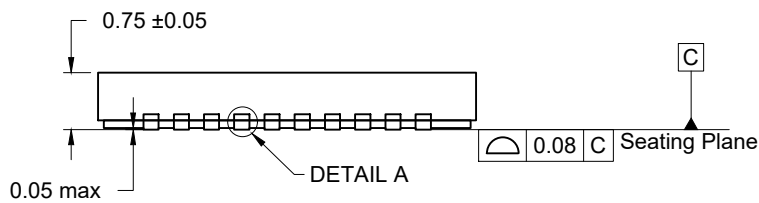
1. JEDEC compatible.
2. All dimensions are in mm and angles are in degrees.
3. Use ± 0.05 mm for the non-toleranced dimensions.
4. Numbers in () are for references only.



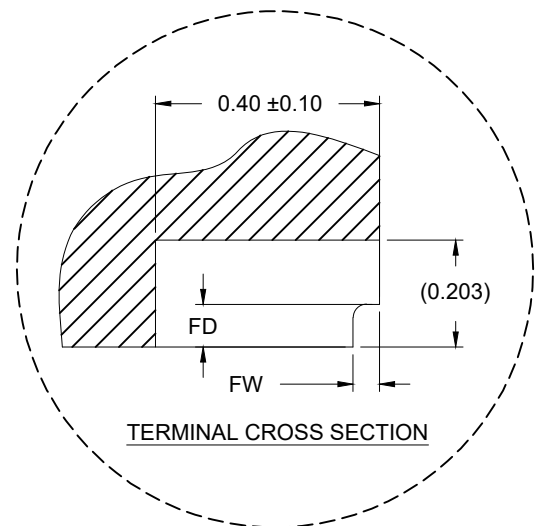
TOP VIEW



BOTTOM VIEW



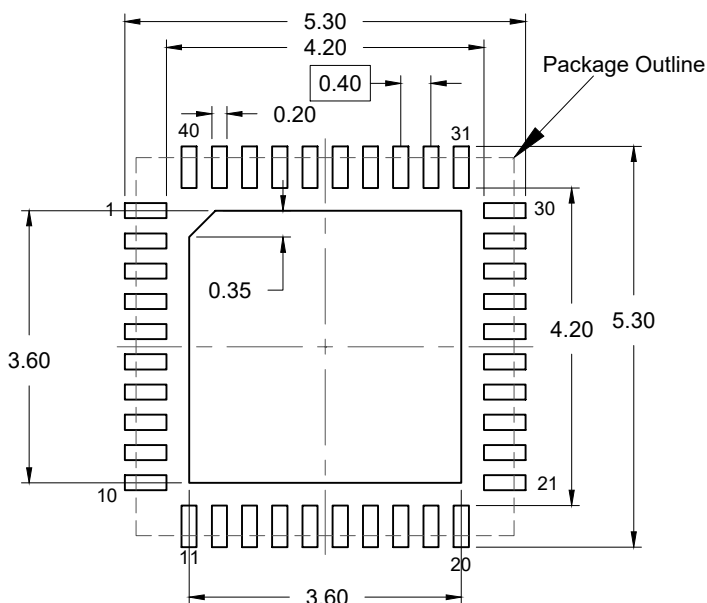
SIDE VIEW



DETAIL A

Table 1: Dimensions of wettable flank (DETAIL A)

| Symbol | Dimension (mm) | |
|--------|----------------|-------|
| | MIN | MAX |
| FD | 0.100 | - |
| FW | 0.010 | 0.075 |



RECOMMENDED LAND PATTERN
(PCB Top View, NSMD Design)

NOTES:

1. JEDEC compatible.
2. All dimensions are in mm and angles are in degrees.
3. Use ± 0.05 mm for the non-toleranced dimensions.
4. Numbers in () are for references only.

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