

# RC22112A

FemtoClock Clock Generator

## Description

The RC22112A is a fully integrated, low-power, high-performance clock generator.

The RC22112A is ideal for providing reference clocks for high-speed serial links up to 28Gbps Ethernet in fabric cards in data center equipment. The device is a member of Renesas' high-performance FemtoClock family.

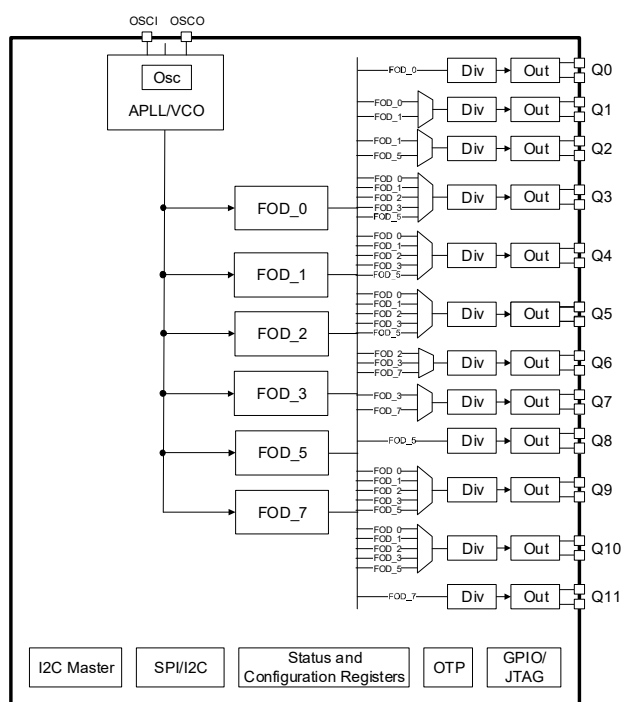
## Applications

- Switches/routers
- Clock generation for 10 / 25 / 40 / 100 / 200 / 400 Gbps Ethernet PHYs in Switch Fabric Cards
- Medical Imaging
- Professional Audio and Video

## Product Options

- 10 × 10 × 0.9 mm 72-VFQFPN package
- 12 differential or 24 single-ended outputs

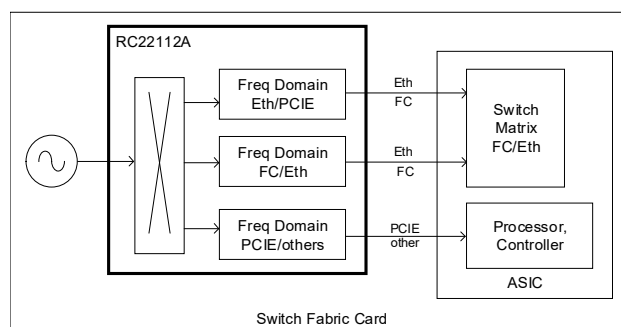
## Block Diagram



## Features

- Low power, less than 1.4W typical
- Low jitter, less than 100 fs-RMS
- PCIe Gen 1-6 CC, SRIS, and SRNS support
- Up to six fractional output dividers and 12 integer output dividers
  - Each fractional output divider is free-run and locked to APLL
- Each fractional output divider can be configured as NCO or DCO
- LVC MOS, LVPECL, LVDS, HCSL, CML, SSTL, HSTL output modes supported with programmable output swing and common mode voltage
- One crystal/XO input
- Up to nine GPIO pins programmable to device select or system monitor options
- Supports 1MHz I<sup>2</sup>C, 400kHz SMBus, or 50MHz SPI serial port
- Internal non-volatile memory (up to 16 different configurations), or external serial I<sup>2</sup>C EEPROM provide default device settings on power-up.
- 2.5V and 3.3V core and 1.8V, 2.5V, and 3.3V output operation
- 40° to +85°C industrial temperature operation

## Typical Application Diagram



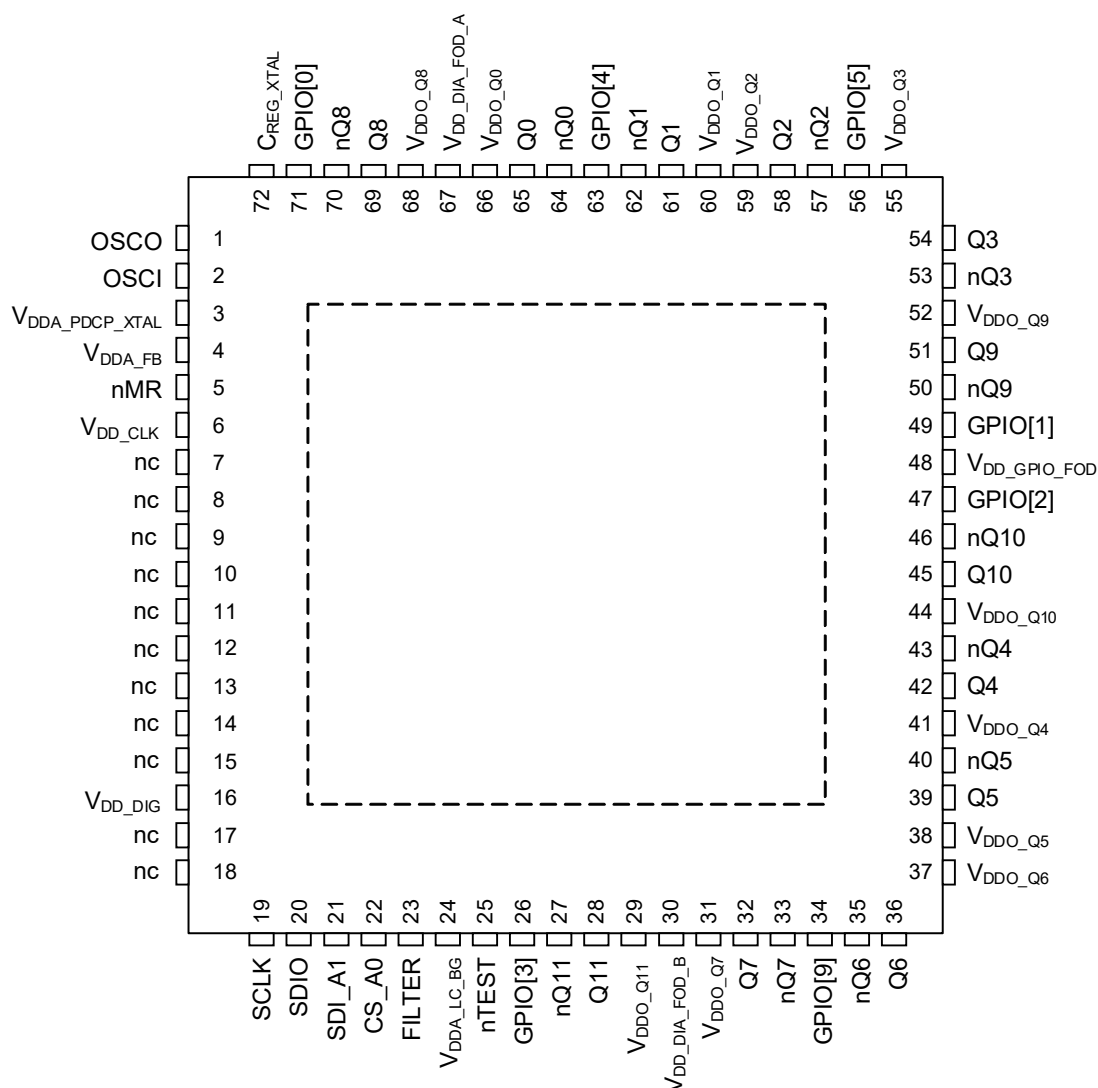
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## 1. Pin Information

### 1.1 Pin Assignments<sup>[1]</sup>



### 1.2 Pin Descriptions

Table 1. Pin Descriptions <sup>[1]</sup>

| Number | Name                       | Type   |  | Description  |
|--------|----------------------------|--------|--|--|
| 1      | OSCO                       | Output |  | Crystal Output. This pin should be connected to a crystal. If an oscillator is connected to the OSCI pin, this pin should be left unconnected.   |
| 2      | OSCI                       | Input  |  | Crystal Input. Accepts a reference from a clock oscillator or a fundamental mode parallel-resonant crystal.  |
| 3      | V <sub>DDA_PDCP_XTAL</sub> | Power  |  | Analog power supply voltage for System Analog PLL's phase detector and charge pump, as well as the oscillator circuit associated with OSCI / OSCO pins. 2.5V or 3.3V operation supported. <sup>[2]</sup> |

1. Indexed signals (e.g., GPIO[5]) are not necessarily numbered sequentially (i.e., some indexes may be skipped). This is to maintain software compatibility with other members of the family of devices.

Table 1. Pin Descriptions <sup>[1]</sup> (Cont.)

| Number | Name                   | Type   |                        | Description   |
|--------|------------------------|--------|------------------------|---|
| 4      | V <sub>DDA_FB</sub>    | Power  |                        | Analog power supply voltage for System Analog PLL's feedback divider, 1.8V required.  |
| 5      | nMR                    | Input  | Pull-up                | Master Reset input (see <a href="#">Power-Up, Configuration, and Serial Interfaces</a> ).   |
| 6      | V <sub>DD_CLK</sub>    | Power  |                        | Power supply for input section. Supports 1.8V, 2.5V, or 3.3V.   |
| 7      | nc                     | N/A    |                        | No connect.   |
| 8      | nc                     | N/A    |                        | No connect.   |
| 9      | nc                     | N/A    |                        | No connect.   |
| 10     | nc                     | N/A    |                        | No connect.   |
| 11     | nc                     | N/A    |                        | No connect.   |
| 12     | nc                     | N/A    |                        | No connect.   |
| 13     | nc                     | N/A    |                        | No connect.   |
| 14     | nc                     | N/A    |                        | No connect.   |
| 15     | nc                     | N/A    |                        | No connect.   |
| 16     | V <sub>DD_DIG</sub>    | Power  |                        | Power supply for digital logic. 1.2V or 1.8V supported.   |
| 17     | nc                     | N/A    |                        | No connect.   |
| 18     | nc                     | N/A    |                        | No connect.   |
| 19     | SCLK                   | I/O    | Pull-up                | Main serial port clock input. Used in both SPI and I <sup>2</sup> C modes as the clock.<br>This pin can also be used when the device boots as I <sup>2</sup> C Clock Output for I <sup>2</sup> C Master Operation. An external pull-up recommended in I <sup>2</sup> C mode.  |
| 20     | SDIO                   | I/O    | Pull-up                | Main serial port bi-directional data pin. Used as a bi-directional data pin in I <sup>2</sup> C and 3-wire SPI modes. Used as Serial Data Output pin in 4-wire SPI mode.<br>This pin can also be used when device boots as I <sup>2</sup> C Bi-directional Data for I <sup>2</sup> C Master Operation. External pull-up recommended in I <sup>2</sup> C mode. |
| 21     | SDI_A1                 | Input  | Pull-up                | Main serial port input. Used as Serial Data In in 4-wire SPI mode and optionally as an Address Bit 1 select input in I <sup>2</sup> C mode. Unused in 3-wire SPI mode.  |
| 22     | CS_A0                  | Input  | Pull-up                | Main serial port input. Used as a chip-select input in SPI mode and optionally as an Address Bit 0 select input in I <sup>2</sup> C mode.   |
| 23     | FILTER                 | Analog |                        | Reference capacitor for System Analog PLL Loop Filter. This pin requires a 2.2nF capacitor to ground.   |
| 24     | V <sub>DDA_LC_BG</sub> | Power  |                        | Analog power supply voltage for System Analog PLL's LC Resonator and bandgap regulator, 3.3V or 2.5V supported. <sup>[2]</sup>  |
| 25     | nTEST                  | Input  | Pull-up                | Test Mode enable pin. Must be high for normal operation   |
| 26     | GPIO[3]                | I/O    | Pull-up <sup>[3]</sup> | General Purpose Input / Output 3.   |
| 27     | nQ11                   | Output |                        | Q11 clock negative output.  |
| 28     | Q11                    | Output |                        | Q11 clock positive output.  |
| 29     | V <sub>DDO_Q11</sub>   | Power  |                        | Power supply for Q11/nQ11 output buffers. <sup>[4]</sup>  |

Table 1. Pin Descriptions <sup>[1]</sup> (Cont.)

| Number | Name                      | Type   |                        | Description  |
|--------|---------------------------|--------|------------------------|--|
| 30     | V <sub>DD_DIA_FOD_B</sub> | Power  |                        | Power supply for FOD control logic for FOD_2 and FOD_7. It also powers FOD_2 and FOD_7. 1.8V supply required.                          |
| 31     | V <sub>DDO_Q7</sub>       | Power  |                        | Power supply for Q7/nQ7 output buffers. <sup>[4]</sup>   |
| 32     | Q7                        | Output |                        | Q7 clock positive output.  |
| 33     | nQ7                       | Output |                        | Q7 clock negative output.  |
| 34     | GPIO[9]                   | I/O    | Pull-up <sup>[3]</sup> | General Purpose Input / Output 9.  |
| 35     | nQ6                       | Output |                        | Q6 clock negative output.  |
| 36     | Q6                        | Output |                        | Q6 clock positive output.  |
| 37     | V <sub>DDO_Q6</sub>       | Power  |                        | Power supply for Q6/nQ6 output buffers. <sup>[4]</sup>   |
| 38     | V <sub>DDO_Q5</sub>       | Power  |                        | Power supply for Q5/nQ5 output buffers. <sup>[4]</sup>   |
| 39     | Q5                        | Output |                        | Q5 clock positive output.  |
| 40     | nQ5                       | Output |                        | Q5 clock negative output.  |
| 41     | V <sub>DDO_Q4</sub>       | Power  |                        | Power supply for Q4/nQ4 output buffers. <sup>[4]</sup>   |
| 42     | Q4                        | Output |                        | Q4 clock positive output.  |
| 43     | nQ4                       | Output |                        | Q4 clock negative output.  |
| 44     | V <sub>DDO_Q10</sub>      | Power  |                        | Power supply for Q10/nQ10 output buffers. <sup>[4]</sup>   |
| 45     | Q10                       | Output |                        | Q10 clock positive output.   |
| 46     | nQ10                      | Output |                        | Q10 clock negative output.   |
| 47     | GPIO[2]                   | I/O    | Pull-up <sup>[3]</sup> | General Purpose Input / Output 2.  |
| 48     | V <sub>DD_GPIO_FOD</sub>  | Power  |                        | Combined Power Supply input for all the digital pins, including GPIO pins and serial ports pins as well as FOD_5. Only 1.8V supported. |
| 49     | GPIO[1]                   | I/O    | Pull-up <sup>[3]</sup> | General Purpose Input / Output 1.  |
| 50     | nQ9                       | Output |                        | Q9 clock negative output.  |
| 51     | Q9                        | Output |                        | Q9 clock positive output.  |
| 52     | V <sub>DDO_Q9</sub>       | Power  |                        | Power supply for Q9/nQ9 output buffers. <sup>[4]</sup>   |
| 53     | nQ3                       | Output |                        | Q3 clock negative output.  |
| 54     | Q3                        | Output |                        | Q3 clock positive output.  |
| 55     | V <sub>DDO_Q3</sub>       | Power  |                        | Power supply for Q3/nQ3 output buffers. <sup>[4]</sup>   |
| 56     | GPIO[5]                   | I/O    | Pull-up <sup>[3]</sup> | General Purpose Input / Output 5.  |
| 57     | nQ2                       | Output |                        | Q2 clock negative output.  |
| 58     | Q2                        | Output |                        | Q2 clock positive output.  |
| 59     | V <sub>DDO_Q2</sub>       | Power  |                        | Power supply for Q2/nQ2 output buffers. <sup>[4]</sup>   |
| 60     | V <sub>DDO_Q1</sub>       | Power  |                        | Power supply for Q1/nQ1 output buffers. <sup>[4]</sup>   |
| 61     | Q1                        | Output |                        | Q1 clock positive output.  |
| 62     | nQ1                       | Output |                        | Q1 clock negative output.  |
| 63     | GPIO[4]                   | I/O    | Pull-up <sup>[3]</sup> | General Purpose Input / Output 4.  |
| 64     | nQ0                       | Output |                        | Q0 clock negative output.  |
| 65     | Q0                        | Output |                        | Q0 clock positive output.  |

Table 1. Pin Descriptions <sup>[1]</sup> (Cont.)

| Number | Name                      | Type   |                        | Description   |
|--------|---------------------------|--------|------------------------|---|
| 66     | V <sub>DDO_Q0</sub>       | Power  |                        | Power supply for Q0/nQ0 output buffers. <sup>[4]</sup>  |
| 67     | V <sub>DD_DIA_FOD_A</sub> | Power  |                        | Power supply for FOD control logic for FOD_0 and FOD_5. Also powers FOD_0. 1.8V supply required.  |
| 68     | V <sub>DDO_Q8</sub>       | Power  |                        | Power supply for Q8/nQ8 output buffers. <sup>[4]</sup>  |
| 69     | Q8                        | Output |                        | Q8 clock positive output.   |
| 70     | nQ8                       | Output |                        | Q8 clock negative output.   |
| 71     | GPIO[0]                   | I/O    | Pull-up <sup>[3]</sup> | General Purpose Input / Output 0.   |
| 72     | C <sub>REG_XTAL</sub>     | Power  |                        | Filter capacitor for voltage regulator for oscillator circuit associated with OSCI / OSCO pins. Requires a 10μF filter capacitor to ground. |
| ePAD   | V <sub>SS</sub>           | Power  |                        | Device ePad must be connected to Ground.  |

1. Pull-up and pull-down refer to internal input resistors (see [Table 2](#), Pin Characteristics, for typical values).
2. V<sub>DDA\_PDCP\_XTAL</sub> and V<sub>DDA\_LC\_BG</sub> can be driven with either 2.5V or 3.3V; however, both must use the same voltage level. Register programming is required to configure the device for either 2.5V or 3.3V operation. For more information, see the *8A3xxx Family Programming Guide*.
3. GPIO pins can be configured via EEPROM and/or OTP with a pull-up or a pull-down. Pull-up is the default configuration.
4. For voltages supported, see [Clock Outputs](#).

## 1.3 Pin Characteristics

Table 2. Pin Characteristics

| Symbol                          | Parameter                                       |                | Test Condition                              | Minimum | Typical | Maximum | Unit |
|---------------------------------|---|----------------|---|---------|---------|---------|------|
| C <sub>IN</sub>                 | Input Capacitance                               | OSCI, OSCO     |   |         | 9       |         | pF   |
|                                 |   | All Other pins |   |         | 2       |         |      |
| R <sub>PULLUP</sub>             | Input Pull-up Resistor                          | nCLK[4:0]      |   |         | 50      |         | kΩ   |
| R <sub>PULLDOWN</sub>           | Input Pull-down Resistor                        | CLK[4:0]       |   |         | 50      |         | kΩ   |
| C <sub>PD</sub>                 | Power Dissipation Capacitance (per output pair) | LVCMOS         | V <sub>DDO_Qx</sub> <sup>[1]</sup> = 3.465V |         | 9       |         | pF   |
|                                 |   |                | V <sub>DDO_Qx</sub> = 2.625V                |         | 8.8     |         |      |
|                                 |   |                | V <sub>DDO_Qx</sub> = 1.89V                 |         | 8.8     |         |      |
|                                 |   |                | V <sub>DDO_Qx</sub> = 1.575V                |         | 9.2     |         |      |
|                                 |   |                | V <sub>DDO_Qx</sub> = 1.26V                 |         | 8.7     |         |      |
|                                 |   | Differential   | V <sub>DDO_Qx</sub> = 3.465V                |         | 1.4     |         |      |
|                                 |   |                | V <sub>DDO_Qx</sub> = 2.625V                |         | 3.5     |         |      |
|                                 |   |                | V <sub>DDO_Qx</sub> = 1.89V                 |         | 5       |         |      |
| R <sub>OUT</sub> <sup>[2]</sup> | Output Impedance                                | GPIO[9,5:0]    | V <sub>DD_GPIO_FOD</sub> = 1.8V             |         | 32      |         | Ω    |
|                                 |   | SDIO, SCLK     | V <sub>DD_GPIO_FOD</sub> = 1.8V             |         | 38      |         |      |

1. V<sub>DDO\_Qx</sub> denotes: V<sub>DDO\_Q0</sub>, V<sub>DDO\_Q1</sub>, V<sub>DDO\_Q2</sub>, V<sub>DDO\_Q3</sub>, V<sub>DDO\_Q4</sub>, V<sub>DDO\_Q5</sub>, V<sub>DDO\_Q6</sub>, V<sub>DDO\_Q7</sub>, V<sub>DDO\_Q8</sub>, V<sub>DDO\_Q9</sub>, V<sub>DDO\_Q10</sub>, or V<sub>DDO\_Q11</sub>
2. Output impedance values for the Qx / nQx outputs are provided in [Table 21](#).

## 2. Specifications

### 2.1 Abbreviations Used

Many signals will be concatenated for simplicity in the specification tables that follow. [Table 3](#) lists the abbreviations used and is referred to in footnotes for the various other tables.

**Table 3. Abbreviated Signal Names and Referenced Signal Names**

| Abbreviation        | Signals Referenced by this Abbreviation  |
|---------------------|--|
| Output Q            | Q[11:0], nQ[11:0]  |
| Status Outputs      | GPIO[9,5:0], SDIO  |
| GPIO                | GPIO[9,5:0]  |
| V <sub>DDx</sub>    | V <sub>DDA_PDCP_XTAL</sub> , V <sub>DD_CLK</sub> , V <sub>DDA_FB</sub> , V <sub>DDA_BG_LC</sub> ,<br>V <sub>DD_DIG</sub> , V <sub>DD_GPIO_FOD</sub> ,<br>V <sub>DDA_DIA_FOD_A</sub> , V <sub>DDA_DIA_FOD_B</sub> ,<br>V <sub>DDO_Q0</sub> , V <sub>DDO_Q1</sub> , V <sub>DDO_Q2</sub> , V <sub>DDO_Q3</sub> , V <sub>DDO_Q4</sub> , V <sub>DDO_Q5</sub> , V <sub>DDO_Q6</sub> , V <sub>DDO_Q7</sub> , V <sub>DDO_Q8</sub> , V <sub>DDO_Q9</sub> ,<br>V <sub>DDO_Q10</sub> , V <sub>DDO_Q11</sub> , |
| V <sub>DDO_Qx</sub> | V <sub>DDO_Q0</sub> , V <sub>DDO_Q1</sub> , V <sub>DDO_Q2</sub> , V <sub>DDO_Q3</sub> , V <sub>DDO_Q4</sub> , V <sub>DDO_Q5</sub> , V <sub>DDO_Q6</sub> , V <sub>DDO_Q7</sub> , V <sub>DDO_Q8</sub> , V <sub>DDO_Q9</sub> ,<br>V <sub>DDO_Q10</sub> , V <sub>DDO_Q11</sub>   |

### 2.2 Absolute Maximum Ratings

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 RC22112A at absolute maximum ratings is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

**Table 4. Absolute Maximum Ratings**

| Symbol                          | Parameter                    | Test Condition  | Minimum | Maximum | Unit |
|---------------------------------|------------------------------|---|---------|---------|------|
| V <sub>DDx</sub> <sup>[1]</sup> | Any voltage supply           |   | -0.5    | 3.63    | V    |
| V <sub>IN</sub>                 | Voltage on any input         | OSCI <sup>[2]</sup> , OSC0, FILTER, C <sub>REG_XTAL</sub> | 0       | 2.75    | V    |
|                                 |                              | All other inputs  | -0.5    | 3.63    | V    |
| I <sub>O</sub>                  | Output Current - Continuous  | Output Q <sup>[1]</sup>                                   |         | 30      | mA   |
|                                 |                              | Status Outputs <sup>[1]</sup>                             |         | 25      | mA   |
|                                 | Output Current - Surge       | Output Q  |         | 60      | mA   |
|                                 |                              | Status Outputs  |         | 50      | mA   |
| T <sub>JMAX</sub>               | Maximum Junction Temperature |   |         | 150     | °C   |
| T <sub>S</sub>                  | Storage temperature          |   | -65     | 150     | °C   |
| -                               | ESD - Human Body Model       |   |         | 2000    | V    |
| -                               | ESD - Charged Device Model   |   |         | 1500    | V    |

1. For information on the signals referenced by this abbreviation, see [Table 3](#).

2. This limit only applies to the OSCI input when being over-driven by an external signal. No limit is implied when this is connected directly to a crystal.



## 2.3 Recommended Operating Conditions

Table 5. Recommended Operating Conditions [1]

| Symbol | Parameter               | Minimum | Typical | Maximum | Unit |
|--------|-------------------------|---------|---------|---------|------|
| $T_A$  | Ambient air temperature | -40     |         | 85      | °C   |
| $T_C$  | Case temperature [2]    | -40     |         | 105     | °C   |

1. It is the user's responsibility to ensure that device junction temperature remains below the maximum allowed.
2. Measured at solder connection to Printed Circuit Board on any signal, voltage, or ePAD.

## 2.4 Supply Voltage Characteristics

Table 6. Power Supply DC Characteristics [1][2]

| Symbol                  | Parameter  | Test Condition   | Minimum | Typical | Maximum | Unit   |
|-------------------------|--|--|---------|---------|---------|--------|
| $V_{DD\_CLK}$           | Supply Voltage for Input Clock Buffers and Dividers                                |  | 1.71    | [3]     | 3.465   | V      |
| $I_{DD\_CLKx}$ [4]      | Supply Current for $V_{DD\_CLK}$   |  |         | 1       |         | mA     |
| $V_{DDA\_PDCP\_XTAL}$   | Analog Supply Voltage for oscillator and for APLL Phase detector and Charge Pump   |  | 2.375   | [5]     | 3.465   | V      |
| $I_{DDA\_PDCP\_XTAL}$   | Supply Current for $V_{DDA\_PDCP\_XTAL}$   | $V_{DDA\_PDCP\_XTAL} = 3.3V$   |         | 48      |         | mA     |
|                         |  | $V_{DDA\_PDCP\_XTAL} = 2.5V$   |         | 33      |         | mA     |
| $V_{DDA\_FB}$           | Analog Supply Voltage for APLL Feedback Divider                                    |  | 1.71    | 1.8     | 1.89    | V      |
| $I_{DDA\_FB}$           | Supply Current for $V_{DDA\_FB}$   | $V_{DDA\_FB} = 1.89V$  |         | 22      |         | mA     |
| $V_{DDA\_BG\_LC}$       | Analog Supply Voltage for APLL Bandgap reference and LC Resonator                  |  | 2.375   | [5]     | 3.465   | V      |
| $I_{DDA\_BG\_LC}$       | Supply Current for $V_{DDA\_BG\_LC}$   | $V_{DDA\_BG\_LC} = 3.465V$   |         | 125     |         | mA     |
|                         |  | $V_{DDA\_BG\_LC} = 2.625V$   |         | 88      |         | mA     |
| $V_{DD\_DIG}$           | Digital Supply Voltage   |  | 1.14    | [6]     | 1.89    | V      |
| $I_{DD\_DIG}$           | Supply Current for $V_{DD\_DIG}$   | $V_{DD\_DIG} = 1.89V$  |         | 190     |         | mA     |
|                         |  | $V_{DD\_DIG} = 1.26V$  |         | 180     |         | mA     |
| $V_{DD\_GPIO\_FOD}$     | Power Supply Voltage for FOD blocks FOD_5, GPIO and other status / control signals |  | 1.71    | 1.8     | 1.89    | V      |
| $I_{DD\_GPIO\_FOD}$ [7] | Supply Current for $V_{DD\_GPIO\_FOD}$ [8]   | $V_{DD\_GPIO\_FOD} = 1.89V$<br>Base current (FOD Off)<br>$I_{DD}(FODBASE)$ |         | 30      |         | mA     |
|                         |  | Adder for FOD at 500MHz<br>$I_{DD}(FODPERFOD)$                             |         | 27      |         | mA     |
|                         |  | Adder per 1MHz over 500MHz on FOD<br>$I_{DD}(FODPERMHZ)$                   |         | 0.012   |         | mA/MHz |

Table 6. Power Supply DC Characteristics [1][2]

| Symbol                      | Parameter  | Test Condition                     | Minimum | Typical | Maximum | Unit   |
|-----------------------------|--|------------------------------------|---------|---------|---------|--------|
| $V_{DD\_DIA\_FOD\_A}$       | Supply Voltage for FOD control logic for FOD_0, FOD_1 and FOD_5 and for FOD_0, FOD_1           |                                    | 1.71    | 1.8     | 1.89    | V      |
| $I_{DD\_DIA\_FOD\_A}$       | Supply Current for $V_{DD\_DIA\_FOD\_A}$ [9]   | $V_{DDA\_DIA\_FOD\_A} = 1.89V$     |         | 45      |         | mA     |
|                             |  | Adder per FOD at 500MHz            |         | 30      |         | mA     |
|                             |  | Adder per FOD per 1MHz over 500MHz |         | 0.012   |         | mA/MHz |
| $V_{DD\_DIA\_FOD\_B}$       | Supply Voltage for FOD control logic for FOD_2, FOD_3 and FOD_7 and for FOD_2, FOD_3 and FOD_7 |                                    | 1.71    | 1.8     | 1.89    | V      |
| $I_{DDA\_DIA\_FOD\_B}$ [10] | Supply Current for $V_{DDA\_DIA\_FOD\_B}$ [9]  | $V_{DDA\_DIA\_FOD\_B} = 1.89V$     |         | 69      |         | mA     |
|                             |  | Adder per FOD at 500MHz            |         | 30      |         | mA     |
|                             |  | Adder per FOD per 1MHz over 500MHz |         | 0.012   |         | mA/MHz |
| $V_{DDO\_Qx}$ [11]          | Output Clock Q Supply Voltage [12]   |                                    | 1.14    |         | 3.465   | V      |

1.  $V_{SS} = 0V$ ,  $T_A = -40^{\circ}C$  to  $85^{\circ}C$ .
2. Current consumption figures represent a worst-case consumption with all functions associated with the particular voltage supply being all enabled and running at full capacity. This information is provided to allow for design of appropriate power supply circuits that will support all possible register-based configurations for the device.
3. Supports 1.8V  $\pm 5\%$ , 2.5V  $\pm 5\%$ , or 3.3V  $\pm 5\%$  operation, not a continuous range.
4.  $I_{DD\_CLK}$  denotes the current consumed by the  $V_{DD\_CLK}$  supply voltage.
5. Supports 2.5V  $\pm 5\%$  or 3.3V  $\pm 5\%$  operation, not a continuous range.
6. Supports 1.2V  $\pm 5\%$  or 1.8V  $\pm 5\%$  operation, not a continuous range.
7.  $I_{DD\_DCO\_Qx}$  denotes the current consumed by the appropriate  $V_{DD\_DCO\_Qx}$  supply voltage. This is the current consumption for each supply, not the total for all  $V_{DD\_DCO\_Qx}$ .
8. The  $I_{DD\_GPIO\_FOD}$  current consumed is dependent on the number of FODs attached to the voltage rail that are supported and the frequency of operation of those FODs. For information on which FODs are supported by which power supply, see [Pin Descriptions](#) and [Pin Characteristics](#). A calculation needs to be performed using the formula below, where  $f_{FOD}$  is the operating frequency of each FOD, NumFOD is the number of FODs on that supply that are enabled. Note that only the base current is needed if all FODs are disabled.

$$I_{DD(FOD)} = I_{DD(FODBASE)} + \text{NumFOD} \times I_{DD(FODPERFOD)} + \sum_{\text{operatingDCO}} (f_{FOD} - 500) \times I_{DD(FODPERMHZ)}$$

9. The  $I_{DDA\_DIA}$  current consumed is dependent on the number of FODs attached to the voltage rail that are supported and the frequency of operation of those FODs. For information on which FODs are supported by which power supply, see [Pin Descriptions](#) and [Pin Characteristics](#). A calculation needs to be performed using the formula below, where  $f_{FOD}$  is the operating frequency of each FOD, NumFOD is the number of FODs on that supply that are enabled. Note that only the base current is needed if all FODs are disabled.

$$I_{DD(DIA)} = I_{DD(DIABASE)} + \text{NumFOD} \times I_{DD(DIAPERFOD)} + \sum_{\text{operatingDCO}} (f_{FOD} - 500) \times I_{DD(DIAPERMHZ)}$$

10.  $V_{DDA\_DIA\_FOD\_B}$  consumes higher current than  $V_{DDA\_DIA\_FOD\_A}$  because it has some additional circuitry, besides the FODs on it.
11. For information on the signals referenced by this abbreviation, see [Table 3](#).
12. Currents for the outputs are shown in [Table 7](#) or [Table 8](#) as appropriate for the mode the individual output is operating in.

**Table 7. Output Supply Current (Output Configured as Differential) [1][2][3]**

| Symbol                       | Parameter                              | Test Condition                        | SWING <sup>[4]</sup> = 00 | SWING = 01 | SWING = 10 | SWING = 11 | Unit |
|------------------------------|--|---------------------------------------|---------------------------|------------|------------|------------|------|
| $I_{DDO\_Qx}$ <sup>[5]</sup> | Qx / nQx Supply Current <sup>[6]</sup> | $V_{DDO\_Qx}$ <sup>[7]</sup> = 3.465V | 15                        | 17         | 19         | 20         | mA   |
|                              |  | $V_{DDO\_Qx}$ = 2.625V                | 14                        | 16         | 18         | 19         | mA   |
|                              |  | $V_{DDO\_Qx}$ = 1.89V                 | 14                        | 15         | 16         | 16         | mA   |

1. Output current consumption is not affected by any of the core device power supply voltage levels.
2. Internal dynamic switching current at maximum  $f_{OUT}$  is included.
3.  $V_{DDO\_Qx}$  = 3.3V  $\pm$ 5% or 2.5V  $\pm$ 5%, or 1.8V  $\pm$ 5%,  $V_{SS}$  = 0V,  $T_A$  = -40°C to 85°C.
4. Refers to the output voltage (swing) setting programmed into device registers for each output.
5.  $I_{DDO\_Qx}$  denotes the current consumed by each  $V_{DDO\_Qx}$  supply.
6. Measured with outputs unloaded.
7. For information on the signals referenced by this abbreviation, see [Table 3](#).

**Table 8. Output Supply Current (Output Configured as LVCMOS) [1][2][3]**

| Symbol                       | Parameter  | Test Condition                        | TERM <sup>[4]</sup> = 00 |      | TERM = 01 |      | TERM = 10 |      | TERM = 11 |      | Unit |
|------------------------------|--|---------------------------------------|--------------------------|------|-----------|------|-----------|------|-----------|------|------|
|                              |  |                                       | Typ.                     | Max. | Typ.      | Max. | Typ.      | Max. | Typ.      | Max. |      |
| $I_{DDO\_Qx}$ <sup>[5]</sup> | Qx, nQx Supply Current <sup>[6]</sup><br>Qx and nQx Both Enabled       | $V_{DDO\_Qx}$ <sup>[7]</sup> = 3.465V | 24                       | 32   | 25        | 35   | 25        | 37   | 25        | 39   | mA   |
|                              |  | $V_{DDO\_Qx}$ = 2.625V                | 18                       | 25   | 19        | 27   | 19        | 29   | 20        | 30   |      |
|                              |  | $V_{DDO\_Qx}$ = 1.89V                 | 12                       | 20   | 14        | 21   | 15        | 22   | 15        | 23   |      |
|                              |  | $V_{DDO\_Qx}$ = 1.575V                | 9                        | 17   | 11        | 18   | 11        | 19   | 12        | 20   |      |
|                              |  | $V_{DDO\_Qx}$ = 1.26V                 | 6                        | 13   | 6         | 13   | 6         | 14   | 6         | 14   |      |
|                              | Qx, nQx Supply Current <sup>[8]</sup><br>Qx enabled and nQx Tri-stated | $V_{DDO\_Qx}$ = 3.465V                | 14                       | 23   | 14        | 24   | 14        | 25   | 14        | 26   | mA   |
|                              |  | $V_{DDO\_Qx}$ = 2.625V                | 11                       | 19   | 11        | 20   | 11        | 20   | 11        | 21   |      |
|                              |  | $V_{DDO\_Qx}$ = 1.89V                 | 9                        | 16   | 10        | 17   | 10        | 17   | 10        | 18   |      |
|                              |  | $V_{DDO\_Qx}$ = 1.575V                | 8                        | 15   | 8         | 16   | 9         | 16   | 9         | 16   |      |
|                              |  | $V_{DDO\_Qx}$ = 1.26V                 | 5                        | 12   | 5         | 12   | 5         | 12   | 5         | 12   |      |

1. Output current consumption is not affected by any of the core device power supply voltage levels.
2. Internal dynamic switching current at maximum  $f_{OUT}$  is included.
3.  $V_{SS}$  = 0V,  $T_A$  = -40°C to 85°C.
4. Refers to the LVCMOS output drive strength (termination) setting programmed into device registers for each output.
5.  $I_{DDO\_Qx}$  denotes the current consumed by each  $V_{DDO\_Qx}$  supply.
6. Measured with outputs unloaded.
7. For information on the signals referenced by this abbreviation, see [Table 3](#).
8. Measured with outputs unloaded.

## 2.5 DC Electrical Characteristics

Table 9. LVCMOS/LVTTL DC Characteristics [1][2][3][4]

| Symbol   | Parameter           |   | Test Condition  | Minimum                    | Typical | Maximum                    | Unit    |
|----------|---------------------|---|---|----------------------------|---------|----------------------------|---------|
| $V_{IH}$ | Input High Voltage  | nMR, nTEST, GPIO[9,8,5:0], SCLK, SDIO, SDI_A1, CS_A0, SDA_M | $V_{DD\_GPIO} = 1.8V \pm 5\%$                           | $0.65 \times V_{DD\_GPIO}$ |         | $V_{DD\_GPIO} + 0.3$       | V       |
| $V_{IL}$ | Input Low Voltage   | nMR, nTEST, GPIO[9,5:0], SCLK, SDIO, SDI_A1, CS_A0, SDA_M   | $V_{DD\_GPIO} = 1.8V \pm 5\%$                           | -0.3                       |         | $0.35 \times V_{DD\_GPIO}$ | V       |
| $I_{IH}$ | Input High Current  | nMR, nTEST, GPIO[9,5:0], SDA_M, SCLK, SDIO, SDI_A1, CS_A0   | $V_{IN} = V_{DD\_GPIO} = V_{DD\_GPIO} (max)$            |                            |         | 5                          | $\mu A$ |
| $I_{IL}$ | Input Low Current   | nMR, nTEST, GPIO[9,5:0], SDA_M, SCLK, SDIO, SDI_A1, CS_A0   | $V_{IN} = 0V$ ,<br>$V_{DD\_GPIO} = V_{DD\_GPIO} (max)$  | -150                       |         |                            | $\mu A$ |
| $V_{OH}$ | Output High Voltage | GPIO[9,5:0], SDA_M, SCL_M, SCLK, SDIO                       | $V_{DD\_GPIO} = 1.8V \pm 5\%$ ,<br>$I_{OH} = -100\mu A$ | $V_{DD\_GPIO} - 0.2$       |         |                            | V       |
|          |                     |   | $V_{DD\_GPIO} = 1.8V \pm 5\%$ ,<br>$I_{OH} = -2mA$      | $V_{DD\_GPIO} - 0.45$      |         |                            |         |
| $V_{OL}$ | Output Low Voltage  | GPIO[9,5:0], SDA_M, SCL_M, SCLK, SDIO                       | $V_{DD\_GPIO} = 1.8V \pm 5\%$ ,<br>$I_{OL} = 100\mu A$  |                            |         | 0.2                        | V       |
|          |                     |   | $V_{DD\_GPIO} = 1.8V \pm 5\%$ ,<br>$I_{OL} = 2mA$       |                            |         | 0.45                       |         |

1.  $V_{IL}$  should not be less than -0.3V.
2. 3.3V characteristics in accordance with JESD8C-01, 2.5V characteristics in accordance with JESD8-5A.01, 1.8V characteristics in accordance with JESD8-7A, 1.5V characteristics in accordance with JESD8-11A.01, 1.2V characteristics in accordance with JESD8-12A.01.
3.  $V_{SS} = 0V$ ,  $T_A = -40^\circ C$  to  $85^\circ C$ .
4. When Output Q are configured as LVCMOS, their output characteristics are specified in [Table 13](#).

**Table 10. Differential Output DC Characteristics ( $V_{DDO\_Qx} = 3.3V +5\%$ ,  $V_{SS} = 0V$ ,  $T_A = -40^{\circ}C$  to  $85^{\circ}C$ ) [1][2][3][4]**

| Symbol          | Parameter                  |              | Test Condition   | Minimum | Typical | Maximum | Unit |
|-----------------|----------------------------|--------------|------------------|---------|---------|---------|------|
| $V_{OVS}^{[5]}$ | Output Voltage Swing       | Output Q [1] | SWING = 00 [6]   | 336     | 402     | 462     | mV   |
|                 |                            |              | SWING = 01       | 478     | 605     | 698     |      |
|                 |                            |              | SWING = 10       | 658     | 791     | 910     |      |
|                 |                            |              | SWING = 11       | 739     | 870     | 997     |      |
| $V_{CMR}^{[7]}$ | Output Common Mode Voltage | Output Q [1] | CENTER = 000 [8] | 0.86    | 0.95    | 1.07    | V    |
|                 |                            |              | CENTER = 001     | 0.98    | 1.14    | 1.28    |      |
|                 |                            |              | CENTER = 010     | 1.13    | 1.33    | 1.51    |      |
|                 |                            |              | CENTER = 011     | 1.30    | 1.53    | 1.73    |      |
|                 |                            |              | CENTER = 100     | 1.46    | 1.73    | 1.95    |      |
|                 |                            |              | CENTER = 101     | 1.63    | 1.93    | 2.17    |      |
|                 |                            |              | CENTER = 110     | 1.80    | 2.12    | 2.39    |      |
|                 |                            |              | CENTER = 111     | 1.96    | 2.30    | 2.59    |      |

1. For information on the signals referenced by this abbreviation, see [Table 3](#).
2. Terminated with  $100\Omega$  across Qx and nQx.
3. If LVDS operation is desired, select SWING = 00 and CENTER = 001 or 010.
4. If LVPECL operation is desired, select SWING = 10 and CENTER = 101 or 110 for 3.3V LVPECL, and SWING = 10 and CENTER = 001 or 010 for 2.5V LVPECL operation.
5.  $V_{OVS}$  is the single-ended amplitude of the output signal. The differential specs is  $2 * V_{OVS}$ .
6. Refers to the differential voltage swing setting programed into device registers for each output.
7. Not all  $V_{CMR}$  selections can be supported with particular  $V_{DDO\_Qx}$  and  $V_{OVS}$  settings.
8. Refers to the differential voltage crossing point (center voltage) setting programed into device registers for each output.

**Table 11. Differential Output DC Characteristics ( $V_{DDO\_Qx} = 2.5V +5\%$ ,  $V_{SS} = 0V$ ,  $T_A = -40^{\circ}C$  to  $85^{\circ}C$ ) [1][2][3][4]**

| Symbol                          | Parameter                  |                         | Test Condition              | Minimum       | Typical | Maximum | Unit |  |
|---------------------------------|----------------------------|-------------------------|-----------------------------|---------------|---------|---------|------|--|
| V <sub>OVS</sub> <sup>[5]</sup> | Output Voltage Swing       | Output Q <sup>[1]</sup> | SWING = 00 <sup>[6]</sup>   | 295           | 393     | 448     | mV   |  |
|                                 |                            |                         | SWING = 01                  | 457           | 591     | 677     |      |  |
|                                 |                            |                         | SWING = 10                  | 587           | 761     | 881     |      |  |
|                                 |                            |                         | SWING = 11                  | 733           | 835     | 943     |      |  |
| V <sub>CMR</sub> <sup>[7]</sup> | Output Common Mode Voltage | Output Q <sup>[1]</sup> | CENTER = 000 <sup>[8]</sup> | 0.85          | 0.93    | 1.03    | V    |  |
|                                 |                            |                         | CENTER = 001                | 0.94          | 1.10    | 1.23    |      |  |
|                                 |                            |                         | CENTER = 010                | 1.09          | 1.28    | 1.44    |      |  |
|                                 |                            |                         | CENTER = 011                | 1.24          | 1.46    | 1.65    |      |  |
|                                 |                            |                         | CENTER = 100                | 1.39          | 1.65    | 1.86    |      |  |
|                                 |                            |                         | CENTER = 101                | Not Supported |         |         |      |  |
|                                 |                            |                         | CENTER = 110                |               |         |         |      |  |
|                                 |                            |                         | CENTER = 111                |               |         |         |      |  |

1. For information on the signals referenced by this abbreviation, see [Table 3](#).
2. Terminated with  $100\Omega$  across Qx and nQx.
3. If LVDS operation is desired, select SWING = 00 and CENTER = 001 or 010.
4. If LVPECL operation is desired, select SWING = 10 and CENTER = 001 or 010 for 2.5V LVPECL operation. For  $V_{DDO} = 2.5V, 3.3V$  LVPECL levels cannot be generated.

5.  $V_{OVS}$  is the single-ended amplitude of the output signal. The differential specs is  $2 * V_{OVS}$ .
6. Refers to the differential voltage swing setting programed into device registers for each output.
7. Not all  $V_{CMR}$  selections can be supported with particular  $V_{DDO\_Qx}$  and  $V_{OVS}$  settings.
8. Refers to the differential voltage crossing point (center voltage) setting programed into device registers for each output.

**Table 12. Differential Output DC Characteristics ( $V_{DDO\_Qx} = 1.8V \pm 5\%$ ,  $V_{SS} = 0V$ ,  $T_A = -40^{\circ}C$  to  $85^{\circ}C$ ) [1][2][3]**

| Symbol               | Parameter                  |              | Test Condition   | Minimum       | Typical | Maximum | Unit |  |
|----------------------|----------------------------|--------------|------------------|---------------|---------|---------|------|--|
| V <sub>OVS</sub> [4] | Output Voltage Swing       | Output Q [1] | SWING = 00 [5]   | 299           | 411     | 485     | mV   |  |
|                      |                            |              | SWING = 01       | 470           | 586     | 700     |      |  |
|                      |                            |              | SWING = 10       | 582           | 713     | 852     |      |  |
|                      |                            |              | SWING = 11       | 612           | 750     | 899     |      |  |
| V <sub>CMR</sub> [6] | Output Common Mode Voltage | Output Q [1] | CENTER = 000 [7] | 0.84          | 0.91    | 0.99    | V    |  |
|                      |                            |              | CENTER = 001     | 0.91          | 1.05    | 1.18    |      |  |
|                      |                            |              | CENTER = 010     | 1.05          | 1.21    | 1.36    |      |  |
|                      |                            |              | CENTER = 011     | Not Supported |         |         |      |  |
|                      |                            |              | CENTER = 100     |               |         |         |      |  |
|                      |                            |              | CENTER = 101     |               |         |         |      |  |
|                      |                            |              | CENTER = 110     |               |         |         |      |  |
|                      |                            |              | CENTER = 111     |               |         |         |      |  |

1. For information on the signals referenced by this abbreviation, see [Table 3](#).
2. Terminated with  $100\Omega$  across  $Qx$  and  $nQx$ .
3. If LVDS operation is desired, select SWING = 00 and CENTER = 010.
4.  $V_{OVS}$  is the single-ended amplitude of the output signal. The differential specs is  $2 * V_{OVS}$ .
5. Refers to the differential voltage swing setting programed into device registers for each output.
6. Not all  $V_{CMR}$  selections can be supported with particular  $V_{DDO\_Qx}$  and  $V_{OVS}$  settings.
7. Refers to the differential voltage crossing point (center voltage) setting programed into device registers for each output.

Table 13. LVCMOS Clock Output DC Characteristics [1][2]

| Symbol           | Parameter           | Test Condition                 | TERM <sup>[3]</sup> = 00   |      |                            | TERM = 01                  |      |                            | TERM = 10                  |      |                            | TERM = 11                  |      |                            | Unit |
|------------------|---------------------|--------------------------------|----------------------------|------|----------------------------|----------------------------|------|----------------------------|----------------------------|------|----------------------------|----------------------------|------|----------------------------|------|
|                  |                     |                                | Min.                       | Typ. | Max.                       | Min.                       | Typ. | Max.                       | Min.                       | Typ. | Max.                       | Min.                       | Typ. | Max.                       |      |
| V <sub>OH</sub>  | Output High Voltage | V <sub>DDO_Qx</sub> = 3.3V ±5% | 0.74 × V <sub>DDO_Qx</sub> |      |                            | 0.75 × V <sub>DDO_Qx</sub> |      |                            | 0.75 × V <sub>DDO_Qx</sub> |      |                            | 0.75 × V <sub>DDO_Qx</sub> |      |                            | V    |
|                  |                     | V <sub>DDO_Qx</sub> = 2.5V ±5% | 0.70 × V <sub>DDO_Qx</sub> |      |                            | 0.75 × V <sub>DDO_Qx</sub> |      |                            | 0.75 × V <sub>DDO_Qx</sub> |      |                            | 0.75 × V <sub>DDO_Qx</sub> |      |                            |      |
|                  |                     | V <sub>DDO_Qx</sub> = 1.8V ±5% | 0.65 × V <sub>DDO_Qx</sub> |      |                            | 0.71 × V <sub>DDO_Qx</sub> |      |                            | 0.75 × V <sub>DDO_Qx</sub> |      |                            | 0.75 × V <sub>DDO_Qx</sub> |      |                            |      |
|                  |                     | V <sub>DDO_Qx</sub> = 1.5V ±5% | 0.61 × V <sub>DDO_Qx</sub> |      |                            | 0.66 × V <sub>DDO_Qx</sub> |      |                            | 0.70 × V <sub>DDO_Qx</sub> |      |                            | 0.72 × V <sub>DDO_Qx</sub> |      |                            |      |
|                  |                     | V <sub>DDO_Qx</sub> = 1.2V ±5% | 0.56 × V <sub>DDO_Qx</sub> |      |                            | 0.59 × V <sub>DDO_Qx</sub> |      |                            | 0.63 × V <sub>DDO_Qx</sub> |      |                            | 0.66 × V <sub>DDO_Qx</sub> |      |                            |      |
| V <sub>OL</sub>  | Output Low Voltage  | V <sub>DDO_Qx</sub> = 3.3V ±5% |                            |      | 0.29 × V <sub>DDO_Qx</sub> |                            |      | 0.25 × V <sub>DDO_Qx</sub> |                            |      | 0.25 × V <sub>DDO_Qx</sub> |                            |      | 0.25 × V <sub>DDO_Qx</sub> | V    |
|                  |                     | V <sub>DDO_Qx</sub> = 2.5V ±5% |                            |      | 0.32 × V <sub>DDO_Qx</sub> |                            |      | 0.27 × V <sub>DDO_Qx</sub> |                            |      | 0.25 × V <sub>DDO_Qx</sub> |                            |      | 0.25 × V <sub>DDO_Qx</sub> |      |
|                  |                     | V <sub>DDO_Qx</sub> = 1.8V ±5% |                            |      | 0.39 × V <sub>DDO_Qx</sub> |                            |      | 0.33 × V <sub>DDO_Qx</sub> |                            |      | 0.30 × V <sub>DDO_Qx</sub> |                            |      | 0.26 × V <sub>DDO_Qx</sub> |      |
|                  |                     | V <sub>DDO_Qx</sub> = 1.5V ±5% |                            |      | 0.44 × V <sub>DDO_Qx</sub> |                            |      | 0.38 × V <sub>DDO_Qx</sub> |                            |      | 0.35 × V <sub>DDO_Qx</sub> |                            |      | 0.31 × V <sub>DDO_Qx</sub> |      |
|                  |                     | V <sub>DDO_Qx</sub> = 1.2V ±5% |                            |      | 0.50 × V <sub>DDO_Qx</sub> |                            |      | 0.46 × V <sub>DDO_Qx</sub> |                            |      | 0.42 × V <sub>DDO_Qx</sub> |                            |      | 0.38 × V <sub>DDO_Qx</sub> |      |
| Z <sub>OUT</sub> | Output Impedance    | V <sub>DDO_Qx</sub> = 3.3V ±5% |                            | 35   |                            |                            | 25   |                            |                            | 21   |                            |                            | 18   |                            | Ω    |
|                  |                     | V <sub>DDO_Qx</sub> = 2.5V ±5% |                            | 31   |                            |                            | 23   |                            |                            | 20   |                            |                            | 17   |                            |      |
|                  |                     | V <sub>DDO_Qx</sub> = 1.8V ±5% |                            | 42   |                            |                            | 31   |                            |                            | 25   |                            |                            | 21   |                            |      |
|                  |                     | V <sub>DDO_Qx</sub> = 1.5V ±5% |                            | 71   |                            |                            | 47   |                            |                            | 35   |                            |                            | 29   |                            |      |
|                  |                     | V <sub>DDO_Qx</sub> = 1.2V ±5% |                            | 101  |                            |                            | 86   |                            |                            | 66   |                            |                            | 49   |                            |      |

1. V<sub>SS</sub> = 0V, T<sub>A</sub> = -40°C to 85°C.

2. V<sub>DDO\_Qx</sub> is used to refer to the appropriate V<sub>DDO\_Qx</sub> power supply voltage for each output. For more information, see [Table 3](#) and [Table 2](#).

3. This refers to the register settings for the LVCMOS output drive strength within the device.

Table 14. Input Frequency Characteristics [1]

| Symbol     | Parameter                           |                            | Test Condition                                       | Minimum | Typical | Maximum | Unit |
|------------|-------------------------------------|----------------------------|--|---------|---------|---------|------|
| $f_{IN}$   | Input Frequency                     | OSCI, OSCO                 | Using a Crystal [2]                                  | 25      |         | 54      | MHz  |
|            |                                     |                            | Over-driving Crystal Input Doubler Logic Enabled [3] | 25      |         | 62.5    |      |
|            |                                     |                            | Over-driving Crystal Input Doubler Logic Disabled    | 50      |         | 125     |      |
| $f_{SCLK}$ | Serial Port Clock SCLK (Slave mode) | I <sup>2</sup> C Operation |  | 100     |         | 1200    | kHz  |
|            |                                     | SPI Operation              |  | 0.1     |         | 50      | MHz  |

1.  $V_{SS} = 0V$ ,  $T_A = -40^{\circ}C$  to  $85^{\circ}C$ .

2. For crystal characteristics, see [Table 15](#).

3. Refer to [Overdriving the XTAL Interface](#).

Table 15. Crystal Characteristics [1]

| Parameter                          | Test Condition                                | Minimum     | Typical | Maximum | Unit     |
|------------------------------------|---|-------------|---------|---------|----------|
| Mode of Oscillation                |   | Fundamental |         |         |          |
| Frequency                          |   | 25          |         | 54      | MHz      |
| Equivalent Series Resistance (ESR) | $C_L = 18pF$ , crystal frequency $\leq 40MHz$ |             |         | 50      | $\Omega$ |
|                                    | $C_L = 18pF$ , crystal frequency $> 40MHz$    |             |         | 25      |          |
|                                    | $C_L = 12pF$                                  |             |         | 50      |          |
| Load Capacitance ( $C_L$ )         |   |             | 12      |         | pF       |

1.  $V_{SS} = 0V$ ,  $T_A = -40^{\circ}C$  to  $85^{\circ}C$ .

## 2.6 AC Electrical Characteristics

Table 16. AC Characteristics [1][2]

| Symbol           | Parameter                                     |                     | Test Condition                         | Minimum   | Typical | Maximum | Unit |
|------------------|---|---------------------|--|-----------|---------|---------|------|
| $f_{VCO}$        | Analog PLL VCO Operating Frequency            |                     | $V_{DDA\_X}^{[3]} = 3.3V \pm 5\%$      | 13.4      |         | 13.8    | GHz  |
|                  |   |                     | $V_{DDA\_X}^{[3]} = 2.5V \pm 5\%$      | 13.5      |         | 13.9    |      |
| $f_{FOD}$        | Fractional Output Divider Operating Frequency |                     | Measured with output divider set to /1 | 500       |         | 1000    | MHz  |
| $f_{OUT}$        | Output Frequency                              | Differential Output |  | 0.0000005 |         | 1000    | MHz  |
|                  |   | LVC MOS Output      |  | 0.0000005 |         | 250     |      |
| $\Delta f_{OUT}$ | Output Frequency Accuracy <sup>[4]</sup>      |                     |  |           | 0       |         | ppb  |



Table 16. AC Characteristics [1][2] (Cont.)

| Symbol             | Parameter                                     | Test Condition   |                                      | Minimum                                       | Typical                        | Maximum | Unit |       |    |                                |
|--------------------|---|--|--------------------------------------|---|--------------------------------|---------|------|-------|----|--------------------------------|
| t <sub>SK</sub>    | Output-to-Output Skew<br>[5][6]               | Any two differential outputs [7]   |                                      | V <sub>DDO_Qx</sub> = 3.3V ±5%                |                                | 65      | 150  | ps    |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 2.5V ±5%                |                                |         |      |       |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 1.8V ±5%                |                                |         |      |       |    |                                |
|                    |   | Any two outputs configured as LVCMOS in-phase [8]  |                                      | V <sub>DDO_Qx</sub> = 3.3V ±5%                |                                | 100     | 255  |       |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 2.5V ±5%                |                                |         |      |       |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 1.8V ±5%                |                                |         |      |       |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 1.5V ±5% <sup>[9]</sup> |                                |         |      |       |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 1.2V ±5% <sup>[9]</sup> |                                |         |      |       |    |                                |
|                    |   | Q to nQ of same output pair, configured as LVCMOS, in-phase [8]                                  |                                      | V <sub>DDO_Qx</sub> = 3.3V ±5%                |                                | 20      | 90   |       |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 2.5V ±5%                |                                | 20      | 130  |       |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 1.8V ±5%                |                                |         |      |       |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 1.5V ±5% <sup>[9]</sup> |                                |         |      |       |    |                                |
|                    | V <sub>DDO_Qx</sub> = 1.2V ±5% <sup>[9]</sup> |  |                                      |   |                                |         |      |       |    |                                |
| t <sub>SK(B)</sub> | Output-to-Output Skew within a Bank [10]      | Bank 1: Q0/nQ0(FOD0), Q1/nQ1(FOD0), Q2/nQ2(FOD1, FOD5), Q3/nQ3(FOD5), Q8/nQ8(FOD5), Q9/nQ9(FOD5) | Differential [7]                     | V <sub>DDO_Qx</sub> = 3.3V ±5%                |                                | 30      | 65   | ps    |    |                                |
|                    |   |  |                                      |   | V <sub>DDO_Qx</sub> = 2.5V ±5% |         | 30   |       | 72 |                                |
|                    |   |  |                                      |   | V <sub>DDO_Qx</sub> = 1.8V ±5% |         |      |       |    |                                |
|                    |   |  | LVCMOS [8]                           | V <sub>DDO_Qx</sub> = 3.3V ±5%                |                                | 75      | 150  |       |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 2.5V ±5%                |                                |         |      |       |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 1.8V ±5%                |                                |         |      |       |    |                                |
|                    |   |  | Bank 2: Q4/nQ4(FOD5), Q10/nQ10(FOD5) | Differential [7]                              | V <sub>DDO_Qx</sub> = 3.3V ±5% |         | 22   | 50    | ps |                                |
|                    |   |  |                                      |   |                                |         |      |       |    | V <sub>DDO_Qx</sub> = 2.5V ±5% |
|                    |   |  |                                      |   |                                |         |      |       |    | V <sub>DDO_Qx</sub> = 1.8V ±5% |
|                    |   | LVCMOS [8][9]  |                                      | V <sub>DDO_Qx</sub> = 3.3V ±5%                |                                | 45      | 130  |       |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 2.5V ±5%                |                                |         |      |       |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 1.8V ±5%                |                                |         |      |       |    |                                |
|                    |   | Bank 3: Q5/nQ5(FOD2, FOD3), Q6/nQ6(FOD2, FOD3), Q7/nQ7(FOD3, FOD7), Q11/nQ11(FOD7)               |                                      | Differential [7]                              | V <sub>DDO_Qx</sub> = 3.3V ±5% |         | 35   | 90    | ps |                                |
|                    |   |  |                                      |   |                                |         |      |       |    | V <sub>DDO_Qx</sub> = 2.5V ±5% |
|                    |   |  |                                      |   |                                |         |      |       |    | V <sub>DDO_Qx</sub> = 1.8V ±5% |
|                    |   |  | LVCMOS [8][9]                        | V <sub>DDO_Qx</sub> = 3.3V ±5%                |                                | 55      | 130  |       |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 2.5V ±5%                |                                |         |      |       |    |                                |
|                    |   |  |                                      | V <sub>DDO_Qx</sub> = 1.8V ±5%                |                                |         |      |       |    |                                |
| Δt <sub>SK</sub>   | Temperature Variation [11] Output-Output      |  |                                      |   |                                |         | 4    | ps/°C |    |                                |

Table 16. AC Characteristics [1][2] (Cont.)

| Symbol        | Parameter                             |                                  | Test Condition   |                                       | Minimum | Typical | Maximum | Unit    |
|---------------|---------------------------------------|----------------------------------|--|---------------------------------------|---------|---------|---------|---------|
| $t_R / t_F$   | Output Rise and Fall Times 20% to 80% | Differential Output [12][13]     | $V_{DDO\_Qx}^{[14]} = 3.3V \pm 5\%, 2.5V \pm 5\% \text{ or } 1.8V \pm 5\%$ | SWING <sup>[15]</sup> = 00            | 100     |         | 450     | ps      |
|               |                                       |                                  |  | SWING = 01                            |         |         |         |         |
|               |                                       |                                  |  | SWING = 10                            |         |         |         |         |
|               |                                       |                                  |  | SWING = 11                            |         |         |         |         |
|               |                                       | LVCMOS Output [16]               | $V_{DDO\_Qx} = 3.3V \pm 5\%$   | TERM <sup>[17]</sup> = 00             | 100     | 254     | 380     | ps      |
|               |                                       |                                  |  | TERM = 01                             | 100     | 262     | 400     |         |
|               |                                       |                                  |  | TERM = 10                             | 110     | 275     | 460     |         |
|               |                                       |                                  |  | TERM = 11                             | 115     | 268     | 510     |         |
|               |                                       |                                  | $V_{DDO\_Qx} = 2.5V \pm 5\%$   | TERM = 00                             | 115     | 285     | 405     | ps      |
|               |                                       |                                  |  | TERM = 01                             | 120     | 293     | 470     |         |
|               |                                       |                                  |  | TERM = 10                             | 120     | 315     | 525     |         |
|               |                                       |                                  |  | TERM = 11                             | 140     | 347     | 565     |         |
|               |                                       |                                  | $V_{DDO\_Qx} = 1.8V \pm 5\%$   | TERM = 00                             | 205     | 417     | 590     | ps      |
|               |                                       |                                  |  | TERM = 01                             | 205     | 458     | 715     |         |
|               |                                       |                                  |  | TERM = 10                             | 230     | 459     | 800     |         |
|               |                                       |                                  |  | TERM = 11                             | 235     | 482     | 880     |         |
|               |                                       |                                  | $V_{DDO\_Qx} = 1.5V \pm 5\%^{[18]}$  | TERM = 00                             | 415     | 558     | 730     | ps      |
|               |                                       |                                  |  | TERM = 01                             | 545     | 747     | 985     |         |
|               |                                       |                                  |  | TERM = 10                             | 615     | 890     | 1145    |         |
|               |                                       |                                  |  | TERM = 11                             | 690     | 1011    | 1305    |         |
|               |                                       |                                  | $V_{DDO\_Qx} = 1.2V \pm 5\%^{[18]}$  | TERM = 00                             | 800     | 986     | 1250    | ps      |
|               |                                       |                                  |  | TERM = 01                             | 1180    | 1416    | 1835    |         |
|               |                                       |                                  |  | TERM = 10                             | 1415    | 1715    | 2195    |         |
|               |                                       |                                  |  | TERM = 11                             | 1650    | 1980    | 2520    |         |
| odc           | Output Duty Cycle                     | Differential Output              | PULSE = 50%  | $f_{OUT} < 500MHz$                    | 47      | 50      | 53      | %       |
|               |                                       |                                  |  | $500MHz \leq f_{OUT} < 800MHz$        | 45      | 50      | 55      | %       |
|               |                                       |                                  |  | $f_{OUT} \geq 800MHz$                 | 40      | 50      | 60      | %       |
|               |                                       | LVCMOS                           | PULSE = 50%  | $V_{DDO\_Qx} = 3.3V \text{ or } 2.5V$ | 47      | 50      | 53      | %       |
|               |                                       |                                  |  | $V_{DDO\_Qx} = 1.8V \text{ or } 1.5V$ | 45      | 50      | 55      |         |
|               |                                       |                                  |  | $V_{DDO\_Qx} = 1.2V$                  | 42      | 50      | 58      |         |
| $t_{STARTUP}$ | Start-up Time <sup>[19]</sup>         | Regulators Ready <sup>[20]</sup> |  |                                       |         | 3       |         | $\mu s$ |
|               |                                       | Internal OTP Start-up            | Synthesizer mode   |                                       |         | 7       | 10      | ms      |

Table 16. AC Characteristics [1][2] (Cont.)

| Symbol | Parameter                                     | Test Condition  |         | Minimum | Typical | Maximum | Unit |
|--------|---|-----------------|---------|---------|---------|---------|------|
| PSNR   | Power Supply Noise Rejection [21][22][23][24] | VDDA_LC_BG      | 50mVpp  |         | -85     |         | dBc  |
|        |   |                 | 100mVpp |         | -80     |         |      |
|        |   | VDDA_PDCP_X TAL | 50mVpp  |         | -75     |         |      |
|        |   |                 | 100mVpp |         | -70     |         |      |
|        |   | VDDO_Qx         | 50mVpp  |         | -70     |         |      |
|        |   |                 | 100mVpp |         | -70     |         |      |

1.  $V_{SS} = 0V$ ,  $T_A = -40^{\circ}C$  to  $85^{\circ}C$ .
2. 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.
3.  $V_{DDA\_X}$  refers to  $V_{DDA\_PDCP}$ ,  $V_{DDA\_XTAL}$ ,  $V_{DDA\_LC}$ , and  $V_{DDA\_BG}$ .
5. Defined as the time between the rising edges of two outputs of the same frequency, configuration, loading, and supply voltage
6. This parameter is defined in accordance with JEDEC Standard 65.
7. Measured at the differential cross points.
8. Measured at  $V_{DDO\_Qx} / 2$ .
9. Using LVCMOS with  $V_{DDO\_Qx} = 1.5V$  or  $1.2V$  will result in much larger skews and is not recommended for skew-sensitive applications.
10. Banks are defined as a list of outputs driven by a specific FOD. Results do not apply if the output is driven by a different FOD.
11. This parameter is measured across the full operating temperature range and the difference between the slowest and fastest numbers is the variation.
12. Rise and fall times on differential outputs are independent of the power supply voltage on the output.
13. Measured with outputs terminated with  $50\Omega$  to GND.
14. For information on the signals referenced by this abbreviation, see [Table 3](#).
15. Refers to the differential voltage swing setting programed into device registers for each output.
16. Measured with outputs terminated with  $50\Omega$  to  $V_{DDO\_Qx} / 2$ .
17. Refers to the LVCMOS output drive strength (termination) setting programed into device registers for each output.
18. This parameter has been characterized with  $F_{OUT} = 50MHz$ .
19. Measured from the rising edge of nMR after all power supplies have reached  $> 80\%$  of nominal voltage to the first stable clock edge on the output. A stable clock is defined as one generated from a locked analog or digital PLL (as appropriate for the configuration listed) with no further perturbations in frequency expected.
20. At power-up, the nMR signal must be asserted for at least this period of time.
21. Noise spur amplitude measured relative to 156.25MHz carrier.
22. Typical PSNR values specified over the modulation frequency range of 10kHz to 1MHz.
23. Injected as sinusoidal noise to the specified power rail only.
24. 0.1uF capacitor placed on modulated power rail.

Table 17. Phase Jitter and Phase Noise

| Symbol           | Parameter   | Conditions   | Minimum | Typical | Maximum | Unit     |
|------------------|---|--|---------|---------|---------|----------|
| tjit( $\Phi$ )   | Random Phase Jitter (12kHz to 20MHz, 50MHz Crystal, Clock Generator Mode, 13750MHz APLL VCO Frequency)                              | 156.25MHz (IOD)  | -       | 107     | 130     | fs (RMS) |
|                  |   | 312.5MHz (IOD)   | -       | 103     | 120     |          |
|                  |   | 106.25MHz (FOD)  | -       | 147     | 165     |          |
|                  |   | 100MHz (FOD)   | -       | 176     | 192     |          |
| $\Phi$ SSB(1k)   | Single Sideband Phase Noise (50MHz Crystal, Clock Generator Mode, 13750MHz APLL VCO Frequency, one IOD output enabled at 156.25MHz) | 1kHz Offset  | -       | -129    | -       | dBc/Hz   |
| $\Phi$ SSB(10k)  |   | 10kHz Offset   | -       | -136    | -       |          |
| $\Phi$ SSB(100k) |   | 100kHz Offset  | -       | -145    | -       |          |
| $\Phi$ SSB(1M)   |   | 1MHz Offset  | -       | -153    | -       |          |
| $\Phi$ SSB(10M)  |   | 10MHz Offset   | -       | -157    | -       |          |
| $\Phi$ SSB(20M)  |   | 20MHz Offset   | -       | -158    | -       |          |
| $\Phi$ SSB(1k)   | Single Sideband Phase Noise (50MHz Crystal, Clock Generator Mode, 13750MHz APLL VCO Frequency, one FOD output enabled at 106.25MHz) | 1kHz Offset  | -       | -127    | -       | dBc/Hz   |
| $\Phi$ SSB(10k)  |   | 10kHz Offset   | -       | -134    | -       |          |
| $\Phi$ SSB(100k) |   | 100kHz Offset  | -       | -143    | -       |          |
| $\Phi$ SSB(1M)   |   | 1MHz Offset  | -       | -155    | -       |          |
| $\Phi$ SSB(10M)  |   | 10MHz Offset   | -       | -158    | -       |          |
| $\Phi$ SSB(20M)  |   | 20MHz Offset   | -       | -159    | -       |          |
| -                | Output-output Isolation   | Measured on 156.25MHz LVDS victim with 100MHz HCSL aggressor | -       | -75     | -       | dB       |

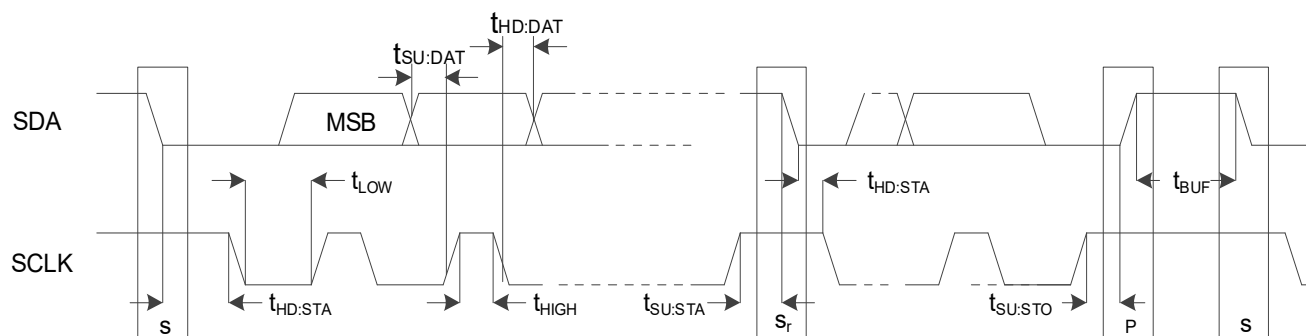
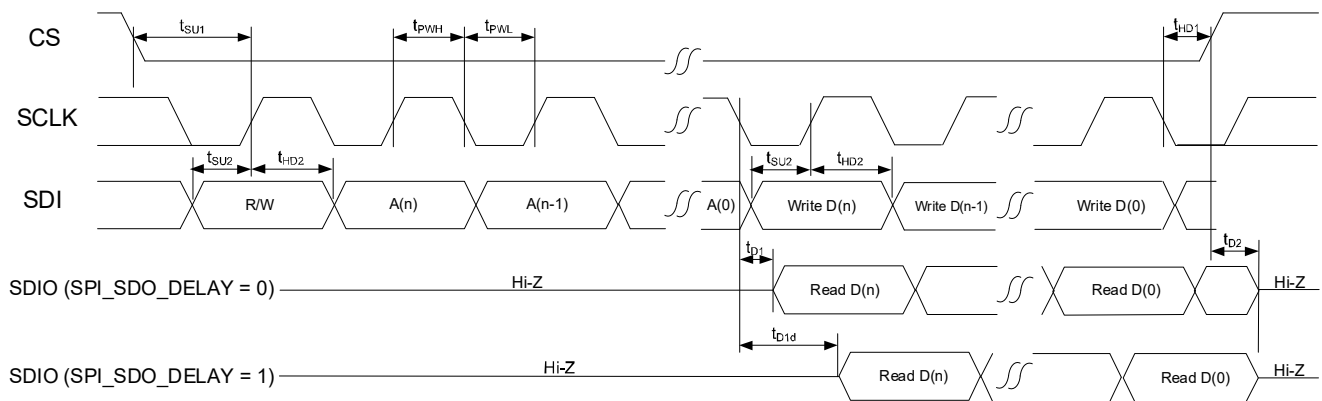


Figure 1. I²C Slave Timing Diagram

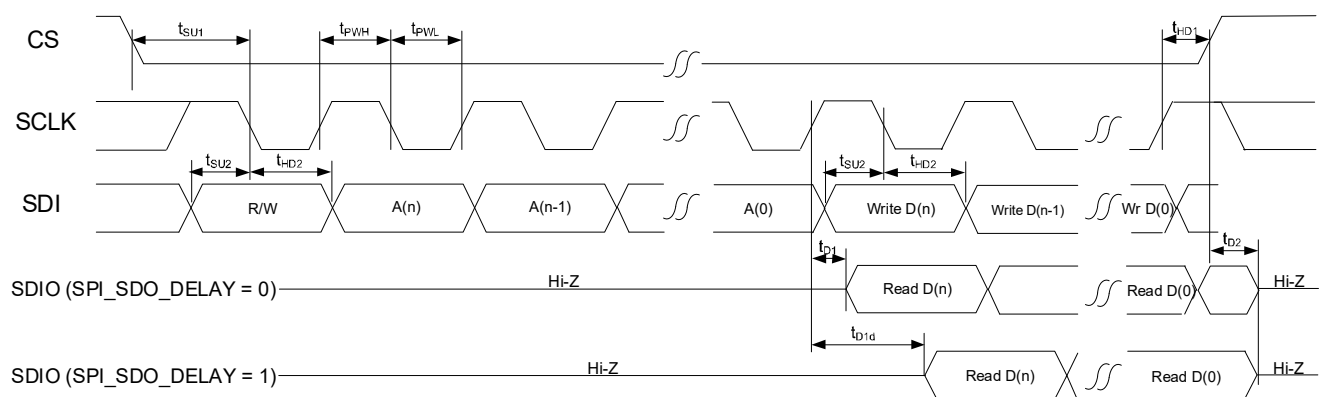
Table 18. I²C Slave Timing

| Parameter           | Description                               | Minimum | Typical | Maximum | Unit |
|---------------------|---|---------|---------|---------|------|
| $f_{\text{SCLK}}$   | SCLK Operating Frequency                  |         |         | 1       | MHz  |
| $t_{\text{LOW}}$    | SCLK Pulse Width Low                      |         | 130     |         | ns   |
| $t_{\text{HIGH}}$   | SCLK Pulse Width High                     |         | 9       |         | ns   |
| $t_{\text{SU:STA}}$ | Start or Repeat Start Setup Time to SCLK  |         | 6       |         | ns   |
| $t_{\text{HD:STA}}$ | Start or Repeat Start Hold Time from SCLK |         | 18      |         | ns   |
| $t_{\text{SU:DAT}}$ | Data Setup Time to SCLK rising edge       |         | 5       |         | ns   |
| $t_{\text{HD:DAT}}$ | Data Hold Time from SCLK rising edge      |         | 0       |         | ns   |
| $t_{\text{SU:STO}}$ | Stop Setup Time to SCLK                   |         | 12      |         | ns   |
| $t_{\text{BUF}}$    | Minimum Time from Stop to Next Start      |         | 0.5     |         | ns   |

**SPI\_CLOCK\_SELECTION = 0**



**SPI\_CLOCK\_SELECTION = 1**



**Figure 2. SPI Timing Diagram**

**Table 19. SPI Timing**

| Parameter      | Description  | Minimum           | Typical | Maximum | Unit |
|----------------|--|-------------------|---------|---------|------|
| $f_{MAX}$      | Maximum operating frequency when performing only writes                        |                   |         | 50      | MHz  |
| $t_{PWH}$      | SCLK Pulse Width High  | 9                 |         |         | ns   |
| $t_{PWL}$      | SCLK Pulse Width Low   | 9                 |         |         | ns   |
| $t_{SU1}$      | CS Setup Time to SCLK rising or falling edge                                   | 4.2               |         |         | ns   |
| $t_{HD1}$      | CS Hold Time from SCLK rising or falling edge                                  | 0                 |         |         | ns   |
| $t_{SU2}$      | SDIO Setup Time to SCLK rising or falling edge                                 | 0                 |         |         | ns   |
| $t_{HD2}$      | SDIO Hold Time from SCLK rising or falling edge                                | 0.6               |         |         | ns   |
| $t_{D1}^{[1]}$ | Read Data Valid Time from SCLK rising or falling edge with no data delay added | $V_{CCCS} = 3.3V$ |         | 7.2     | ns   |
|                |  | $V_{CCCS} = 2.5V$ |         | 7.3     | ns   |
|                |  | $V_{CCCS} = 1.8V$ |         | 8.6     | ns   |

1. Measurement performed approximately 1cm away from device pad. Observing at a greater distance on a heavily loaded trace may show slower edge rates and longer delays. This is highly dependent on PCB loading.

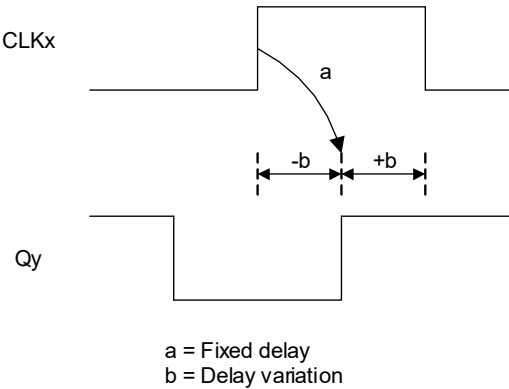


Figure 3. Input-Output Delay

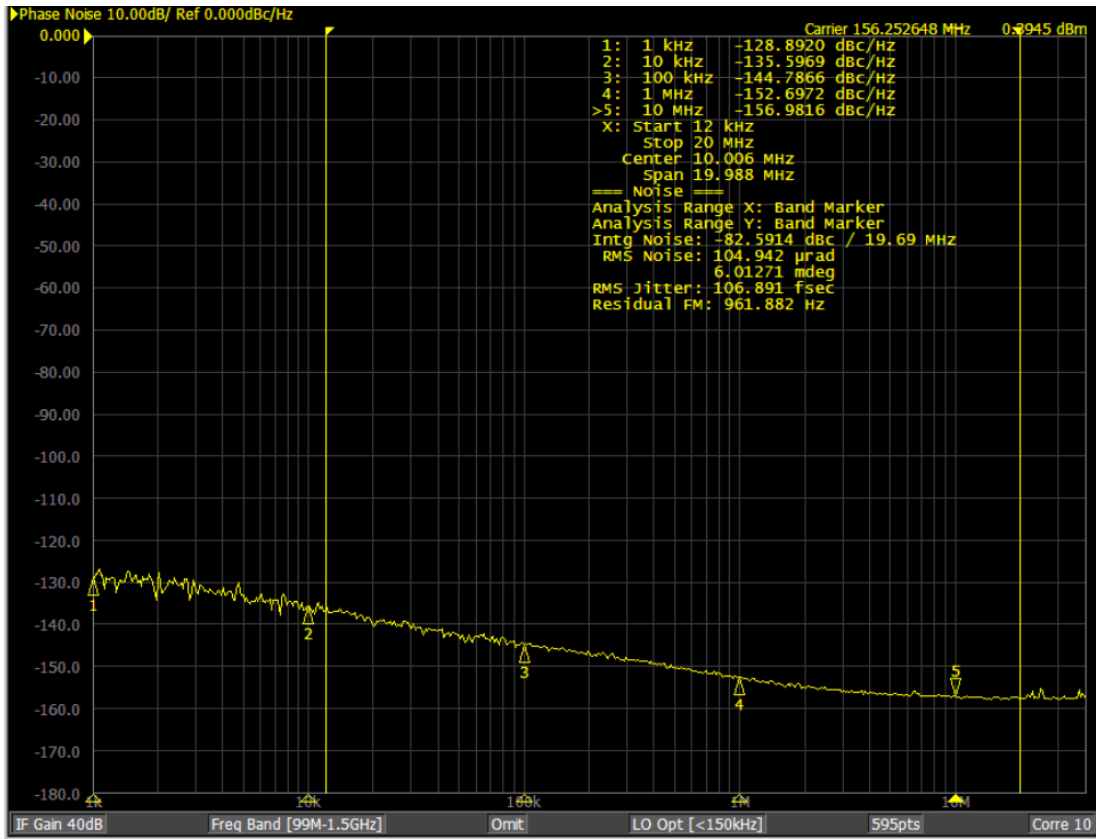


Figure 4. Phase Noise of 156.25MHz Output in Clock Generator Mode

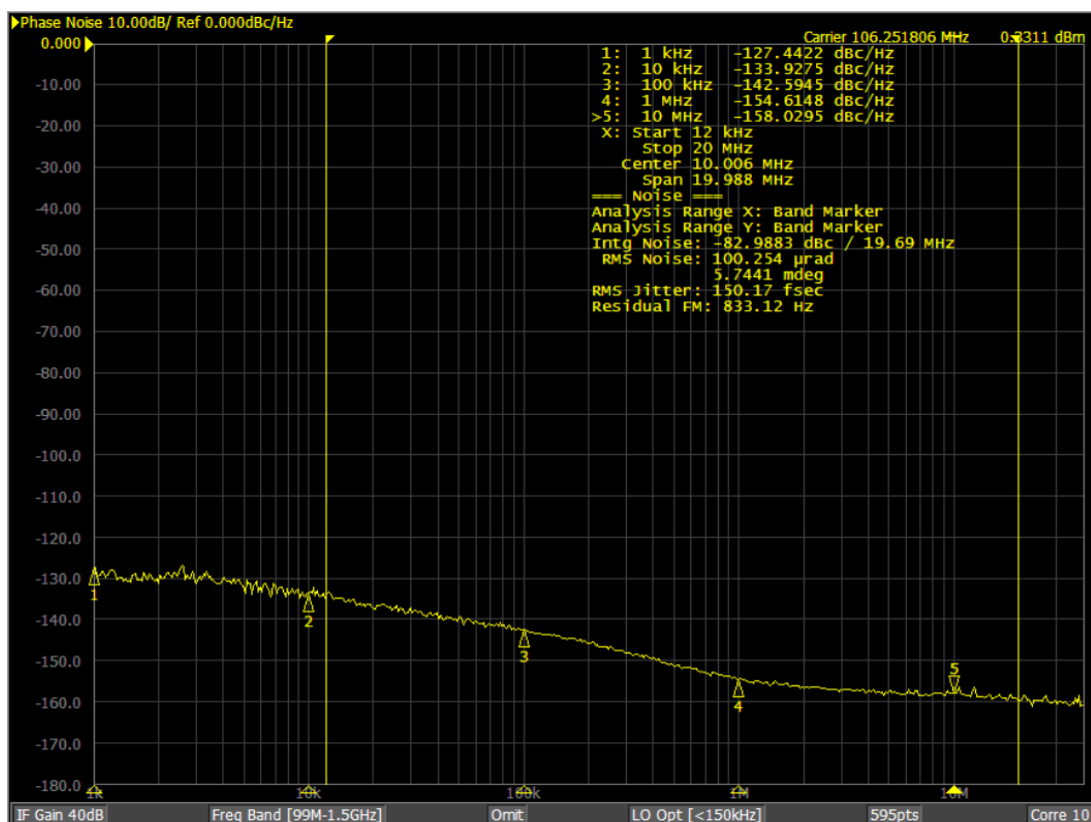


Figure 5. Phase Noise of 106.25MHz Output in Clock Generator Mode



### 3. Functional Description

The RC22112A is a fully integrated, low-power, high-performance frequency synthesizer. The device can be set up as a clock generator that is locked to the external crystal or oscillator and providing free-run clock outputs.

The device is optimized to deliver excellent phase noise as required for driving up to 28Gbps Ethernet PHYs, ASICs, or FPGAs in 10G, 25G, 40G, 100G, 200G, or 400G switch fabric cards.

#### 3.1 Clock Generator Mode

The RC22112A is set in Clock Generator mode by completing the following steps:

1. APLL is locked to external crystal or oscillator and provides high-frequency clocks to FOD\_0, FOD\_1, FOD\_2, FOD\_3, FOD\_5, and FOD\_7.
2. Free-run clock outputs are generated from FOD\_0, FOD\_1, FOD\_2, FOD\_3, FOD\_5, or FOD\_7, and each FOD can be independently set to integer or fractional divide values.

*Note:* Up to six unrelated clock frequency domains can be achieved.

#### 3.2 Power-Up, Configuration, and Serial Interfaces

The RC22112A can be powered up and configured in three ways:

- From internal non-volatile memory using OTP user configurations (UserCfgs)
- From its slave serial interface
- From an external I2C EEPROM

The RC22112A supports three slave serial interfaces: I2C, SPI, and SMBUS, and one serial master interface (I2C). These interfaces share the same pins, so only one is available at a time. Additionally, all of the device GPIO pins are sampled at the rising edge of the nMR (master reset) signal and some of them can be used in setting the initial configuration.

#### 3.3 Input Clocks

The RC22112A supports one crystal/reference input that is used as a reference to the analog PLL (APLL).

##### 3.3.1 Crystal/Oscillator Input

The crystal input supports crystal frequencies of 25 to 54 MHz with a recommended load capacitance of 12pF. The crystal input can be over-driven with differential or single-ended inputs with proper external terminations. The supported frequency range is 25 to 62.5 MHz when doubler logic for APLL is enabled, and 50 to 125 MHz when doubler logic for APLL is disabled. An available LOS monitor detects the loss of signal on crystal input.

#### 3.4 APLL

The APLL is an integer LC-VCO based PLL with an operating range from 13.4 to 13.9 GHz. The crystal or oscillator input clock is used to drive the APLL, and can be frequency doubled for increased performance. The APLL is temperature compensated for utmost frequency stability. The high-frequency clock output from the APLL is provided to each of the six fractional output dividers (FOD\_0, FOD\_1, FOD\_2, FOD\_3, FOD\_5, and FOD\_7).

##### 3.4.1 APLL Lock Detector

The APLL lock detector indicates whether the APLL is locked to a functioning crystal or reference input by monitoring the phase errors. Lock status is available on a GPIO pin or in the register map.

### 3.5 Output Dividers

The RC22112A provides six fractional output dividers (FODs) and 12 integer output dividers (IODs).

#### 3.5.1 Integer Output Dividers

All 12 IODs are identical and derive their input clock from the output of either of the six FODs. Each IOD uses a 32-bit divider to provide output frequencies from 0.5Hz to 1GHz. Changing IOD values results in an immediate change to the new frequency. Glitchless squelch and release of the IOD clock is supported. When enabled, this mimics a gapped clock behavior when an IOD frequency is changed.

#### 3.5.2 Fractional Output Dividers

There are six FODs. Each FOD can divide down the APLL VCO clock to provide frequencies of 500MHz to 1GHz. The fractional divide value involves two unsigned integer values, representing the integer (INT) and fraction (FRAC) portion of the divide ratio. The fraction portion is an integer representing the 43-bit numerator of a fraction, where the denominator of that fraction is fixed at  $2^{43}$ . The equation for the FOD output frequency is as follows.

$$f_{\text{FOD}} = \frac{f_{\text{APLL}}}{\left( \text{INT} + \frac{\text{FRAC}}{2^{43}} \right)}$$

*Note:* Fractions that approach 0, 1, or 1/2 can result in increased phase noise on the output signal due to integer-boundary spurs. It is recommended that APLL frequency and FOD divider settings be coordinated to avoid such fractions.

##### 3.5.2.1 Output Phase Adjustment

Fine phase adjustments of the FOD output can be performed by increasing or decreasing the frequency of operation of the FOD for a period of time. This results in the clock edges of the FOD output clock being advanced (increased FOD output frequency will move edges to the left as seen on an oscilloscope relative to some fixed reference point) or delayed (decreased FOD output frequency moves edges to the right) by some amount.

Coarse phase adjustments of the IOD output can be performed, and is the same as FOD phase adjustment but with a step size of one FOD output clock period.

##### 3.5.2.2 Numerically Controlled Oscillator (NCO) Mode

In NCO mode, each FOD can adjust its output clock frequency with a step size of  $(1/2^{43})/N$  where N is the nominal fractional output divide value, and is based on incrementing the numerator where the denominator of that fraction is fixed at  $2^{43}$ . This frequency change at the output clock is gradual without glitches.

### 3.6 Clock Outputs

The RC22112A supports up to 12 differential or 24 single-ended clock outputs or any combination of differential and single-ended clock outputs. Every differential clock output can be programmed as two single-ended clock outputs.

#### 3.6.1 Output Buffer in Single-Ended Mode

When used as a single-ended output buffer, two copies of the same output clock are created with LVCMOS output levels. Each clock will have the same frequency, phase, voltage, and current characteristics. The only exception is that the user can program the clock from the nQx output pad to be inverted in phase relative to the one coming from the Qx output pin. The non-inverted setting can result in greater noise on these outputs and increased coupling to other output clocks in the device, so it should be used with caution.

In this mode of operation, the output buffer supports 1.2V, 1.5V, 1.8V, 2.5V, or 3.3V  $V_{\text{DDO\_Qx}}$  voltages. For each output voltage, there are four impedance options that can be selected from. For actual voltage and impedance values under different conditions, see [Table 13](#).

### 3.6.2 Output Buffer in Differential Mode

When used as a differential output buffer, the user can control the output voltage swing ( $V_{OVS}$ ) and common mode voltage ( $V_{CMR}$ ) of the buffer. The  $V_{OVS}$  and  $V_{SWING}$  settings that can be used with a specific  $V_{DDO\_Qx}$  voltage are listed in Table 20. Note that  $V_{DDO\_Qx}$  options of 1.5V or 1.2V cannot be used in differential mode.

Table 20. Configurable Output Mode Options

| $V_{DDO\_Qx}$ | $V_{OVS}$ Options Supported | $V_{CMR}$ Options Supported                    |
|---------------|-----------------------------|--|
| 3.3V          | 410mV                       | 0.9V, 1.1V, 1.3V, 1.5V, 1.7V, 1.9V, 2.1V, 2.3V |
|               | 600mV                       | 0.9V, 1.1V, 1.3V, 1.5V, 1.7V, 1.9V, 2.1V, 2.3V |
|               | 750mV                       | 0.9V, 1.1V, 1.3V, 1.5V, 1.7V, 1.9V, 2.1V       |
|               | 900mV                       | 0.9V, 1.1V, 1.3V, 1.5V, 1.7V, 1.9V             |
| 2.5V          | 410mV                       | 0.9V, 1.1V, 1.3V, 1.5V, 1.7V                   |
|               | 600mV                       | 0.9V, 1.1V, 1.3V, 1.5V, 1.7V                   |
|               | 750mV                       | 0.9V, 1.1V, 1.3V, 1.5V                         |
|               | 900mV                       | 0.9V, 1.1V, 1.3V                               |
| 1.8V          | 410mV                       | 0.9V, 1.1V, 1.3V                               |
|               | 600mV                       | 0.9V, 1.1V, 1.3V                               |
|               | 750mV                       | 0.9V, 1.1V, 1.3V                               |
|               | 900mV                       | 0.9V, 1.1V                                     |

### 3.6.3 Output Banks

The RC22112A maps the internal and external frequency sources to output banks (that can be programmed in the register map) according to Table 21. There are up to 12 clock outputs that can be derived from each of the four FODs.

Table 21. Output Bank Assignment

| Output Pins   | FODs that can Drive this Stage    |
|---|-----------------------------------|
| Q0 / nQ0  | FOD_0                             |
| Q1 / nQ1  | FOD_0, FOD_1                      |
| Q2 / nQ2  | FOD_1, FOD_5                      |
| Q8 / nQ8  | FOD_5                             |
| Q3 / nQ3, Q4 / nQ4, Q5 / nQ5,<br>Q9 / nQ9, Q10 / nQ10 | FOD_0, FOD_1, FOD_2, FOD_3, FOD_5 |
| Q6 / nQ6  | FOD_2, FOD_3, FOD_7               |
| Q7 / nQ7  | FOD_3, FOD_7                      |
| Q11 / nQ11  | FOD_7                             |

### 3.7 General Purpose Input/Outputs (GPIOs)

The GPIO signals provide a flexible method to manage the control and status of the device via pins without providing dedicated pins for each possible function that may be wasted in a lot of applications. The GPIOs are fully configurable so that any GPIO can perform any function on any target logic block.

#### 3.7.1 GPIO Modes

Each GPIO pin can be individually configured to operate in one of the following modes. Note that these modes are effective only when the RC22112A has completed its reset sequence. During the reset sequence one or more of these pins may have different functions as outlined in [Use of GPIO Pins at Reset](#):

- General Purpose Input – In this operating mode, the GPIO pin will act as an input whose logic level will be monitored and reflected in an internal register that may be read over the serial port. This is the default mode if no other option is programmed in OTP or EEPROM.
- General Purpose Output – In this operating mode, the GPIO pin will act as an output that is driven to the logic level specified in an internal register. That register may be written over the serial port.
- Alarm output – In this operating mode, the GPIO pin will act as a single-purpose alarm or Alert (aggregated alarm) output. For information on when an alarm output will be asserted or released and alarm sources, see [Temperature Sensor](#). Note that each GPIO can be independently configured and so if multiple GPIOs are configured the same way, they will all have the same output values.
  - Loss-of-Lock status – In this operating mode, the GPIO pin will act as an active-high Loss-of-Lock output. When the GPIO output is asserted, that indicates the System APLL has lost lock. This is a latched or “sticky” signal and so must be cleared by register access to the sticky bit clear register to remove the alarm signal.
  - Alert (aggregated alarm) status – In this operating mode, the GPIO will act as the logical OR of all alarm indicators that are enabled to drive this output. Only “sticky” bits are available to drive the GPIO in this mode. This output will be asserted if any of the sticky bits are asserted and enabled to cause the Alert (aggregated alarm). To clear this output, all contributing sticky bits must be individually cleared. This output will be active-high to indicate one or more alarms are asserted.
- Output Disable control – In this operating mode, the GPIO pin will act as a control input. When the GPIO input is high, the selected output clock(s) will be disabled then placed in high-impedance state. When the GPIO pin is low, the selected output clock(s) will be enabled and will drive their outputs as configured. Selection of which output(s) are controlled by which GPIO(s) is configured via registers over the serial port or by OTP or EEPROM at reset. Each GPIO can be configured to control any or all outputs (or none). As such, all combinations can be set up from a single GPIO controlling all outputs, to all outputs responding to individual GPIO signals and any grouping in between.

#### 3.7.2 GPIO Pin Configuration

The GPIO pins are all powered off a single voltage supply that only supports 1.8V operation. An internal register must be set to indicate 1.8V. This setting is a global one for all GPIOs.

In addition, each GPIO can be enabled or disabled under register control. If enabled and configured in an operating mode that makes it an output, the user can choose if the GPIO output will behave as an open-drain output or a CMOS output. The open-drain output drives low but is pulled high by a pull-up resistor. There is a very weak pull-up internal to the RC22112A, but an external pull-up is strongly recommended. In CMOS mode, the output voltage will be driven actively both high and low as needed. Register control may also enable a pull-up (default) or pull-down.

### 3.8 Temperature Sensor

The RC22112A includes a temperature sensor. The accuracy of the sensor is  $\pm 2^{\circ}\text{C}$ . The temperature can be read in degrees Celsius from registers. The reading is updated once every 10 seconds.

### 3.9 Device Initial Configuration

During its reset sequence, the RC22112A will load its initial configuration, enable internal regulators, establish and enable internal clocks, perform initial calibration of the Analog PLL, and lock it to the reference on the OSCI / OSCO pins.

There are four mechanisms that can be used to establish the initial configuration during the reset sequence:

- State of certain GPIO pins (see Table 22) at the rising edge of the nMR signal
- Configuration previously stored in One-Time Programmable memory
- Configuration stored in an external I<sup>2</sup>C EEPROM
- Default values for internal registers

Each of these is discussed in the following sections and then integrated into the reset sequence.

#### 3.9.1 Use of GPIO Pins at Reset

Several of the device GPIO pins are sampled at the rising edge of the nMR (master reset) signal and used in setting the initial configuration. Table 22 shows which pins are used to control what aspects of the initial configuration. All of these register settings can be over-written later using serial port accesses.

**Table 22. GPIO Pin Usage at Start-Up**

| GPIO Number                           | Function  | Internal Pull-up or Pull-down |
|---------------------------------------|---|-------------------------------|
| 9                                     | 0 = Device uses SPI protocol<br>1 = Device uses I <sup>2</sup> C protocol   | Pull-up                       |
| 4 pins user selectable <sup>[1]</sup> | Identifies which stored configuration in OTP to use for initial configuration (has no effect with “-000” unprogrammed devices). <sup>[2]</sup>  | Pull-up                       |
| 1 pin user selectable <sup>[1]</sup>  | Disables EEPROM accesses during start-up sequence<br>By default, no GPIO is used for this purpose, so the device will attempt to find an external EEPROM to check for additional start-up information by default. <sup>[2]</sup>  | Pull-up                       |
| 1 pin user selectable <sup>[1]</sup>  | Provides pin control for I <sup>2</sup> C slave serial port (for serial port selected by GPIO[9] as I <sup>2</sup> C) default base address bit A2. Has no effect on serial port selected as SPI.<br>By default no GPIO is used for this purpose, so the default I <sup>2</sup> C slave port base address will have a 0 for bit A2. <sup>[2]</sup> | Pull-up                       |

1. Selection of this mode for a GPIO is performed using the Device Information block in the OTP memory, which is programmed by Renesas at the factory for dash codes that are non-zero. “-000” dash code devices are considered unprogrammed and so will have the default behavior indicated above.
2. For more information, see details below this table.

Any of the available GPIOs can be used as follows:

- I<sup>2</sup>C base address bit A2

This is for the serial port, whichever is selected as I<sup>2</sup>C during the start-up sequence using GPIO[9]. If no GPIOs are configured in this mode, bit A2 of the slave serial port base address will be zero. The value of the I<sup>2</sup>C base address and the serial port configuration can be over-written by SCSR configuration data or serial port accesses later in the start-up sequence. If more than one GPIO is programmed with this functionality, only the one with the highest index will be used.

- EEPROM Access Disable control

A high input value on a GPIO programmed with this function prevents the device from attempting to read device update information or SCSR configuration data from an external I<sup>2</sup>C EEPROM. This will speed up device reset time but will prevent access to updated information that may be stored in EEPROM. If no GPIOs are configured in this mode, then the device will attempt to locate an external EEPROM at the appropriate point in the start-up

sequence. If multiple GPIOs are configured to perform this function, then any one of them being active will disable EEPROM accesses, so it is recommended that no more than one GPIO be programmed for this function.

- Default Configuration Select control

If no GPIOs are selected then GPIO[3:0] will be assumed and the value on those pins at the rising edge of the nMR signal will be used to select which of the SCSR configurations in OTP memory is to be used. Note that since a GPIO is pulled-up by default, unless these pins are pulled or driven low during the reset period, this will select SCSR Configuration 15.

If one or more GPIOs are selected for this function, then the value on those pins at the rising edge of nMR will be used to select the SCSR configuration to be loaded. The Device Information block of the OTP can be configured to select any of up to four GPIO pins to be used for this purpose if the default GPIOs are not convenient. The GPIOs chosen do not have to be sequential, but whichever ones are chosen, the one with the lowest index number will be the LSB and so on in order of the index until the GPIO with the highest index is the MSB. No GPIO that appears elsewhere in this table should be used for this purpose.

If less than four GPIO pins are selected, then the selected GPIOs will be used as the least-significant bits of a 4-bit selection value, with the upper bits set to zero. If more than four GPIOs are programmed for this function, then the GPIOs will form a larger bit-length word for selection of internal configuration.

### 3.9.2 Default Values for Registers

All registers are defined so that the default state (without any configuration data from OTP or EEPROM being loaded) will cause the device to power-up with none of the outputs enabled and all GPIO signals in General-Purpose Input mode. Users can then program any desired configuration data over the serial port once the reset sequence has completed.

## 3.10 One-Time Programmable (OTP) Memory

The RC22112A contains a 32KB (OTP memory block that is factory programmable. The term “one-time programmable” refers to individual blocks within the memory structure. Different blocks can be programmed at different times, but each block can only be programmed once. The data structure within the OTP is designed to facilitate multiple updates and multiple configurations being stored, up to the limit of the physical memory space.

Access to OTP memory is via serial port through registers that communicate with an internal OTP controller state machine. The state machine protocol is handled via Timing Commander GUI software, which is the recommended access mechanism. For customers that wish to program OTP via another method, such as in their own production processes should contact [Renesas](#) for details on this state machine interface. Note that OTP programming is considered an “offline” function and should not be performed while the device is in an operational system.

After reset of the RC22112A, all internal registers are reset to their default values then OTP contents are loaded into the device's internal registers. A Device Information block programmed by Renesas at Final Test will always be loaded. This provides information that is specific to the device, including product ID codes and revision information. In addition, there are zero or more device configurations stored in the OTP by customer programming or by Renesas at the factory if a special dash-code part number is requested. Certain GPIO pins are sampled at the rising edge of the external nMR input signal. The state of those pins at that time will be used by the RC22112A to determine which of up to 16 configurations stored in the OTP to load into the device registers. For information on how to select a configuration, see [Use of GPIO Pins at Reset](#).

Storage of configuration data in OTP does not require having a value stored for every register in the device. Register default values are defined to ensure that most functions will be disabled or otherwise made as neutral as possible. This allows only features that are being used in any particular configuration (and their associated trigger registers as defined in the 8A3xxxx Family Programming Guide) to need to be stored in OTP for that configuration. The intent of this is to minimize the size a configuration takes in OTP to allow more configurations to be stored there. For this reason, the exact number of configurations storable in OTP cannot be predetermined. There will be a minimum of two configurations and a maximum of 16 configuration capacity in the OTP.



Part numbers with -000 as the dash code number are considered “unprogrammed” parts, but are shipped with at least a Device Information block pre-programmed with Renesas-proprietary information including parameters needed to successfully boot the device to the point where it can read its configuration data. One Device Update block can also be programmed if determined to be appropriate by Renesas.

Custom user configurations indicated with non-zero dash code part numbers will in addition have one or more SCSR Configuration sections pre-programmed as indicated in the datasheet addendum for that particular dash code part number.

A programmed configuration, Device Information block, or Device Update block, can be invalidated via the OTP programming interface and if sufficient OTP space remains a new one added to replace it. Note that this does not erase or remove the original data and the space it consumes. It just marks it to be ignored by the device. This allows for a limited ability to update a device in the field either from a device functional update or configuration data perspective. This is a purely software-driven process handled over the serial port. If this type of in-field upgrade / change is desired, contact [Renesas](#) for support. Note that the ability to perform this type of in-field update is highly dependent on the size of the change versus the remaining space in OTP, so will not be possible in all cases.

### 3.10.1 Configuration Data in OTP

Users can program multiple configurations into the internal One-Time Programmable memory. The Timing Commander GUI Software can perform this function. If this needs to be performed in another way by the end-user, contact [Renesas](#) for sample code. By using the GPIO pins at start-up as outlined in [Use of GPIO Pins at Reset](#), one of those configurations can be chosen for use as the initial values in the device registers after reset. Register values can be changed at any time over the serial port, but any such changes are not stored in OTP and will be lost on reset or power-down.

The OTP is organized so that only configuration data that changes from the register default values needs to be stored. This saves OTP space and allows the potential for more configurations to be stored in the OTP.

If the indicated configuration in OTP has a checksum error, it will not be loaded and registers will be left at their default values.

### 3.10.2 Configuration Data in External I<sup>2</sup>C EEPROM

As a final option, the initial configuration can be read from one or more external I<sup>2</sup>C EEPROMs. The Timing Commander GUI Software can generate the necessary EEPROM load information as an Intel HEX file for this purpose. The RC22112A will search each EEPROM for a valid configuration data block (valid header and checksum). The first valid block found will be loaded into internal registers after checksum validation. The search will terminate after the first valid block is found and loaded. This means that only a single valid configuration block can be stored via the EEPROM method.

The RC22112A will look for EEPROMs at I<sup>2</sup>C base addresses of 1010xxx (binary), and search each EEPROM from the lowest address to the highest. When the device searches for an EEPROM configuration, it will check for a valid block at address offsets 0x0000 and 0xF000 within an EEPROM. If using this configuration method, see the warning in [Step 5 – Search for Configuration in External EEPROM](#).

### 3.11 Reset Sequence

Figure 6 shows the relationship between the master reset signal (nMR) and the supply voltages for the RC22112A. There are no power sequencing requirements between the power rails, so  $V_{DD}$  in the diagram represents any of the supply voltages. To ensure there is no anomalous behavior from the device as it powers up, it is recommended that the nMR signal be asserted (low) before any voltage supply reaches the minimum voltage shown in the figure. nMR should remain asserted until a short hold time ( $t_{HOLD} \sim 10\text{nsec}$ ) after all supply voltages reach the operating window of 95% of nominal voltage. nMR must be asserted or the device will not function correctly after power-up.

One additional consideration is that once minimum voltage is reached on all voltage supplies, internal regulators and voltage references will take up to  $3\mu\text{sec}$  to reach stability. If the time  $t_{RAMP}$  shown in the figure is less than the voltage regulator startup time of  $3\mu\text{sec}$ , then release of nMR should be delayed.

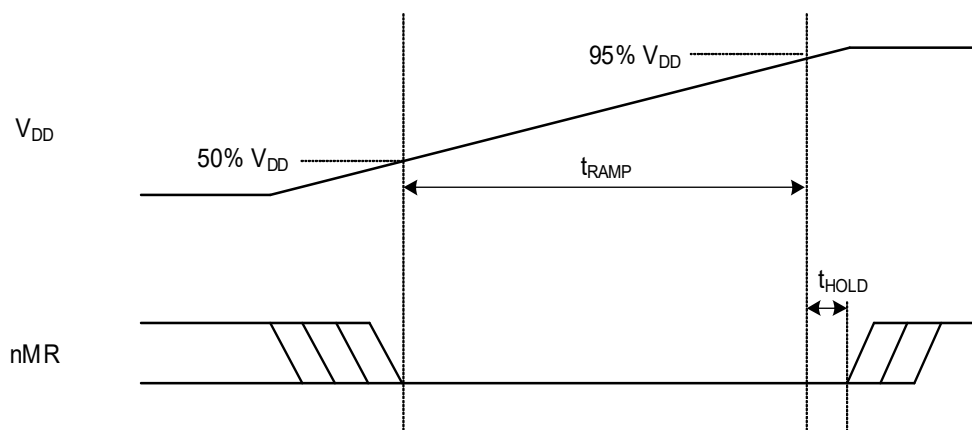


Figure 6. Power-Up Reset Sequencing

In cases where the device is not powering up and just being reset, a low pulse on nMR of 20ns will be sufficient to reset the device.

The following reset sequence will begin from the rising (negating) edge of the nMR (master reset) signal.

#### 3.11.1 Step 0 – Reset Sequence Starting Condition

When the power rails reach nominal values and the nMR signal has been asserted, the RC22112A will be in the following state:

- All Qx / nQx outputs will be in a high-impedance state.
- All GPIO pins will be set to General-Purpose Inputs, so none will be driving the output.
- The serial port protocols are not set at this point in the reset sequence, so the ports will not respond.
- OTP will be checked for any device patch information. If one is found, it will be loaded and the device reinitialized.
- Device Information block loaded from internal OTP to configure what GPIOs will be used for what start-up functions in Step 1.

#### 3.11.2 Step 1 – Negation of nMR (Rising Edge)

At the rising edge of the nMR signal, the state on the GPIO pins at that time is latched. After a short hold time, the GPIOs can release their reset levels and assume their normal operation modes. The latched values will be used in later stages of the reset sequence.

#### 3.11.3 Step 2 – Internally Set Default Conditions

An internal image of all the device registers will be created in internal RAM with all registers set to their default values. This will not result in any changes to the GPIO or output clock signals from their Step 0 condition.



Based on the serial port protocol selection made via the GPIO pin in Step 1, serial port configuration will be completed as indicated by the GPIO input pin. If SPI mode is selected by the GPIO, the register default values will configure it to use 4-wire SPI mode.

### 3.11.4 Step 3 – Scan for Device Updates in EEPROM

Unless a GPIO is configured to control this in Step 0 and in Step 1 is sampled in the state requesting no EEPROM read, this step will be performed by the RC22112A. The RC22112A will use the I<sup>2</sup>C Master port (if available) to check for device functional update information. If such information is found, it will be loaded, the device functionality updated and then the part will reinitialize to Step 0.

### 3.11.5 Step 4 – Read Configuration from OTP

Using the GPIO values latched in Step 1, the device will search the internal OTP memory for the indicated configuration number. If no such configuration is found or the configuration has an invalid checksum, the device will skip to Step 6. Any errors in this process will be reported. If loading from OTP was successful, which configuration number was loaded will be reported.

If the requested configuration is found and is valid, the device will load the registers indicated in the configuration data with the stored data values in the internal register image. Any register not included in the configuration data set will remain at its default value in the register image.

*Note:* Many register modules have explicitly defined trigger registers that when written will cause the other register settings in that module to take effect. Users must ensure that the configuration in OTP will cause a write to all applicable trigger registers, even if that register's contents would be all zero. Multi-byte register fields also require all bytes of the field to be written to ensuring triggering. Please refer to the *8A3xxxx Family Programming Guide* for indications of which trigger registers are associated with which other registers.

The contents of several of the registers will be used to guide the remainder of the reset sequence.

- If the APLL feedback divider value was programmed in this step, perform APLL calibration in parallel with remaining reset activities.
- Re-configure serial ports to use I<sup>2</sup>C or SPI protocols as indicated (for information, see [I2C Slave Operation](#) or [SPI Operation](#)).

### 3.11.6 Step 5 – Search for Configuration in External EEPROM

Unless a GPIO is configured to control this in Step 0 and in Step 1 is sampled in the state requesting no EEPROM read, this step will be performed by the RC22112A.

The device will use its I<sup>2</sup>C Master Port to attempt to access an external I<sup>2</sup>C EEPROM at base address 1010000 (binary) at an I<sup>2</sup>C frequency of 1MHz. If there is no response, this will be repeated at base address 1010001 (binary) at 1MHz. This will repeat up to address 1010111 (binary) at 1MHz. If there are still no responses, the search will be repeated at 400kHz and then again at 100kHz. If no response is received after this whole sequence, the device will proceed to Step 6. Any errors in the process will be reported in status registers.

If at any point in the above search sequence a response is received from an EEPROM, the device will read data from the EEPROM at address offsets 0x0000 and 0xF000 in the EEPROM. If a valid configuration data block is found, it will be read, its checksum validated and if that passes, loaded into internal the internal register image similarly to OTP configuration data described in Step 4. If the data found is not of the correct format or the data block fails a checksum comparison, it will be ignored. The search will continue through the EEPROM and on to the next EEPROM address until the whole range has been searched or a valid configuration block has been found and applied to the internal register image. Then the sequence will proceed to Step 6.

*Warning:* Since OTP and EEPROM configuration data rarely consists of a full register image, reading of configuration data from OTP and then from one or more configuration blocks stored in EEPROM may result in internal registers being loaded with conflicting settings drawn partially from each of the configuration data sets being loaded. It is strongly recommended that a configuration block placed in EEPROM only be used when no valid configuration is being pointed to in OTP by GPIO signals (or there is no valid configuration in OTP at all).

If multiple configurations are to be used then the user must ensure all registers are set to the desired values by the final configuration block to be loaded.

### 3.11.7 Step 6 – Complete Configuration

The RC22112A will complete the reset and initial configuration process at this point and begin normal operations. Completion steps include:

1. Calibrate the System APLL and lock it to the reference clock on the OSC1 input,
2. Perform a temperature sensor cycle to establish an initial value in internal registers,
3. Enable serial port operation as configured,
4. Apply configuration settings from the internal register image to the actual registers and enable output clocks and GPIOs as configured.
5. Enable alarm operation as configured.

Note that there are several scenarios in which the reset sequence will reach this point without retrieving any configuration data and with all registers in the default state. This may be intentional for users who wish to configure only via the serial port or the result of a problem in the loading of a configuration. Users may read appropriate status bits to determine what failures, if any, occurred during the reset sequence.

## 3.12 Clock Gating and Logic Power-Down Control

The RC22112A can disable the clocks to many logic blocks inside the device. It can also turn off internal power regulators, disabling individual power domains within the part. Because of the potentially complex interactions of the logic blocks within the device, logic within the part will handle the decision-making of what will be powered off versus clock-gated versus fully operational at any time. By default, the device will configure itself with functions in the lowest power-consuming state consistent with powering up the part and reading a user configuration. User configurations, whether stored in internal OTP, external EEPROM, or manually adjusted over the serial port, should make use of register bits to turn on functions only that are needed. Also, if a function is no longer needed, register bits should be used to indicate it is no longer required. Internal logic will reduce its power consumption state in reaction to these indicators to the greatest extent possible.

## 3.13 Serial Port Functions

The RC22112A supports one serial port. The signals on the port share the functions of an I<sup>2</sup>C Master port used for loading configuration data at reset and a configurable slave I<sup>2</sup>C or SPI port that can be used at any time after the reset sequence is complete to monitor and/or configure the device. Note that the I<sup>2</sup>C master port can only be used when the slave port is configured in I<sup>2</sup>C mode. Since I<sup>2</sup>C master operation only occurs immediately after reset, while configuration or other data is being loaded from an external I<sup>2</sup>C serial EEPROM, I<sup>2</sup>C mode for the serial port can be selected using GPIOs as indicated in [Use of GPIO Pins at Reset](#).

The operation of the serial port when in I<sup>2</sup>C master operation (during self-configuration only) is described in [I<sup>2</sup>C Master](#). The SCL and SDIO pins are used for this purpose. For information on the operation of the master I<sup>2</sup>C and slave I<sup>2</sup>C or SPI ports, see the appropriate section below.

A slave serial port can be reconfigured at any time by accessing the appropriate registers within a single burst write. This includes configuration options with each protocol or switching between protocols (I<sup>2</sup>C to SPI, or vice versa). However, it is recommended that the full operating mode configuration, including page sizes for registers, and for a serial port, be set in the initial configuration data read from OTP or external EEPROM (for information, see [Device Initial Configuration](#)).

### Note on Signal Naming in the Remainder of the Serial Port Sections

The pin names indicated in [Pin Descriptions](#) are meant to indicate the function of that signal when used in SPI mode and also the function when in I<sup>2</sup>C mode. In the remainder of the Serial Port Functions descriptions, the SPI descriptions will refer to the signals by their function in the selected mode, as shown in [Table 23](#).

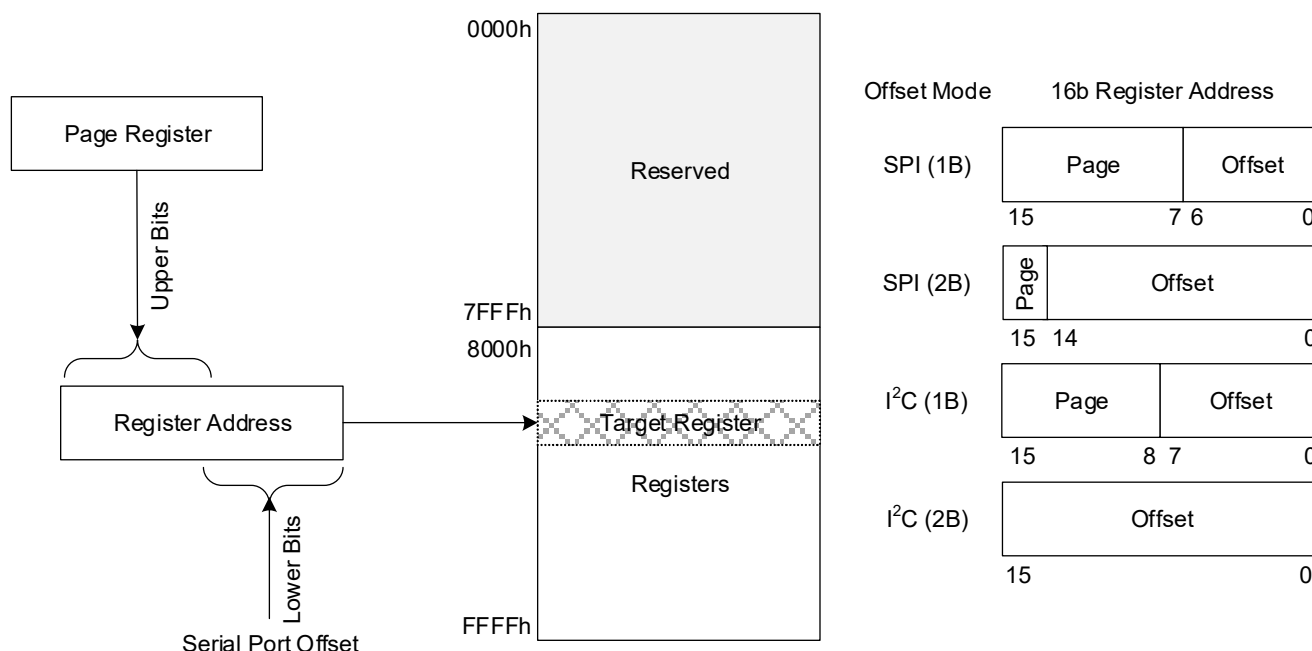
**Table 23. Serial Port Pin to Function Mapping**

| SPI Mode Signal Name | Function  | I <sup>2</sup> C Mode Signal Name | Function                             | Package Pin Name       |
|----------------------|---|-----------------------------------|--------------------------------------|------------------------|
| SCLK                 | SPI Clock Input   | SCLK                              | I <sup>2</sup> C Clock Input         | <a href="#">SCLK</a>   |
| CS                   | SPI Chip Select (active low)                                | A0                                | I <sup>2</sup> C Slave Address Bit 0 | <a href="#">CS_A0</a>  |
| SDI                  | SPI Data Input (unused in 3-wire mode)                      | A1                                | I <sup>2</sup> C Slave Address Bit 1 | <a href="#">SDI_A1</a> |
| SDIO                 | SPI Data Out (4-wire mode)<br>SPI Data In/Out (3-wire mode) | SDA                               | I <sup>2</sup> C Data In/Out         | <a href="#">SDIO</a>   |

### 3.13.1 Addressing Registers within the RC22112A

The address space that is externally accessible within the RC22112A is 64KB in size and so needs 16 bit of address offset information to be provided during slave serial port accesses. Of that 64KB, only the upper 32KB contains user accessible registers.

The user can choose to operate the serial port providing the full offset address within each burst, or to operate in a paged mode where part of the address offset is provided in each transaction and part comes from an internal page register in each serial port. [Figure 7](#) shows how page register and offset bytes from each serial transaction interact to address a register within the RC22112A.

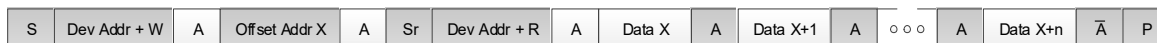


**Figure 7. Register Addressing Modes via Serial Port**

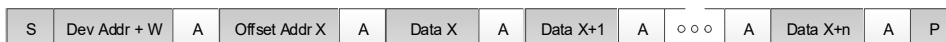
### 3.13.2 I<sup>2</sup>C Slave Operation

The I<sup>2</sup>C slave protocol of the RC22112A complies with Rev.6 of the I<sup>2</sup>C specification. Figure 8 shows the sequence of states on the I<sup>2</sup>C SDA signal for the supported modes of operation.

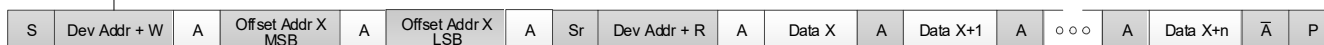
Sequential 8-bit Read



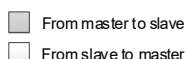
Sequential 8-bit Write



Sequential 16-bit Read



Sequential 16-bit Write



S = Start  
 Sr = Repeated start  
 A = Acknowledge  
 $\bar{A}$  = Non-acknowledge  
 P = Stop

Figure 8. I<sup>2</sup>C Slave Sequencing

The Dev Addr shown in the figure represents the base address of the RC22112A. This 7-bit value can be set in an internal register which can have a user-defined value loaded at reset from internal OTP memory or an external EEPROM. The default value is 1011000b if those methods are not used. Note that the levels on the A0 and A1 signals can be used to control Bit 0 and Bit 1 (respectively) of this address. There is also an option, as described in [Use of GPIO Pins at Reset](#), to designate the reset state of a GPIO pin to set the default value of the A2 bit of the I<sup>2</sup>C slave port base address. In I<sup>2</sup>C operation these inputs are expected to remain static. They have different functions when the part is in SPI mode. The resulting base address is the I<sup>2</sup>C bus address that this device will respond to.

When I<sup>2</sup>C operation is selected for a slave serial port, the selection of 1-byte (1B) or 2-byte (2B) offset addressing must also be configured. These offsets are used in conjunction with the page register for each serial port to access registers internal to the device. Because the I<sup>2</sup>C protocol already includes a read/write bit with the Dev Addr, all bits of the 1B or 2B offset field can be used to address internal registers.

- In 1B mode, the lower 8 bits of the register offset address come from the Offset Addr byte and the upper 8 bits come from the page register.

The page register can be accessed at any time using an offset byte value of FCh. This 4-byte register must be written in a single burst write transaction.

- In 2B mode, the full 16-bit register address can be obtained from the Offset Addr bytes, so the page register only needs to be set up once after reset using a 4-byte burst access at offset FFFCh.

**Note:** I<sup>2</sup>C burst mode operation is required to ensure data integrity of multi-byte registers. When accessing a multi-byte register, all data bytes must be written or read in a single I<sup>2</sup>C burst access. Bursts can be longer if desired, but must not extend beyond the end of the register page (offset Addr FFh in 1B mode, no limit in 2B mode). An internal address pointer is incremented automatically as each data byte is written or read.

### 3.13.2.1 I<sup>2</sup>C 1-byte (1B) Addressing Examples

RC22112A I<sup>2</sup>C 7-bit I<sup>2</sup>C address is 0x5B with LSB = R/W

Example write "0x50" to register 0xCBE4:

```
B6* FC 00 CB 10 20#Set Page Register, *I2C Address is left-shifted one bit.
B6 E4 50          #Write data 5B to CB E4
```

Example read from register 0xC024:

```
B6* FC 00 C0 10 20#Set Page Register, *I2C Address is left-shifted one bit.
B6 24*          #Set I2C pointer to 0xC024, *I2C instruction should use "No
Stop"
B7 <read back data>#Send address with Read bit set.
```

### 3.13.2.2 I<sup>2</sup>C 2-byte (2B) Addressing

RC22112A I<sup>2</sup>C 7-bit I<sup>2</sup>C address is 0x5B with LSB = R/W

Example write "50" to register 0xCBE4:

```
B6* FF FD 00 10 20#Set Page Register, *I2C Address is left-shifted one bit.
B6 CB E4 50          #Write data to CB E4
```

Example read from register 0xC024:

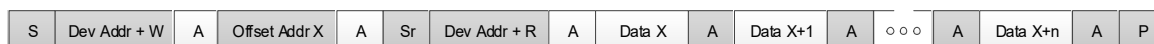
```
B6* FF FD 00 10 20#Set Page Register (*I2C Address is left-shifted one bit.)
B6 C0 24*          #Set I2C pointer to 0xC024, *I2C instruction should use "No
Stop"
B7 <read back data>#Send address with Read bit set.
```

### 3.13.3 I<sup>2</sup>C Master

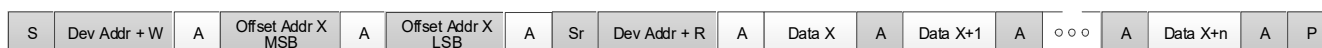
The RC22112A can load its register configuration from an external I<sup>2</sup>C EEPROM during its reset sequence, but only if the serial port is configured in I<sup>2</sup>C mode. For information on what accesses occur under what conditions, see [Reset Sequence](#).

As needed during the reset sequence, the RC22112A will arbitrate for the I<sup>2</sup>C bus and attempt to access an external I<sup>2</sup>C EEPROM using the access sequence shown in [Figure 9](#). The I<sup>2</sup>C master protocol of the RC22112A complies with Rev.6 of the I<sup>2</sup>C specification. As displayed in the figure, the I<sup>2</sup>C master port can be configured to support I<sup>2</sup>C EEPROMs with either 1-byte or 2-byte offset addressing. The I<sup>2</sup>C master logic will negotiate with any EEPROMs found to use the highest speed of 1MHz, 400kHz, or 100kHz.

Sequential Read (1-byte Offset Address)



Sequential Read (2-byte Offset Address)



- ☐ From master to slave  
☐ From slave to master

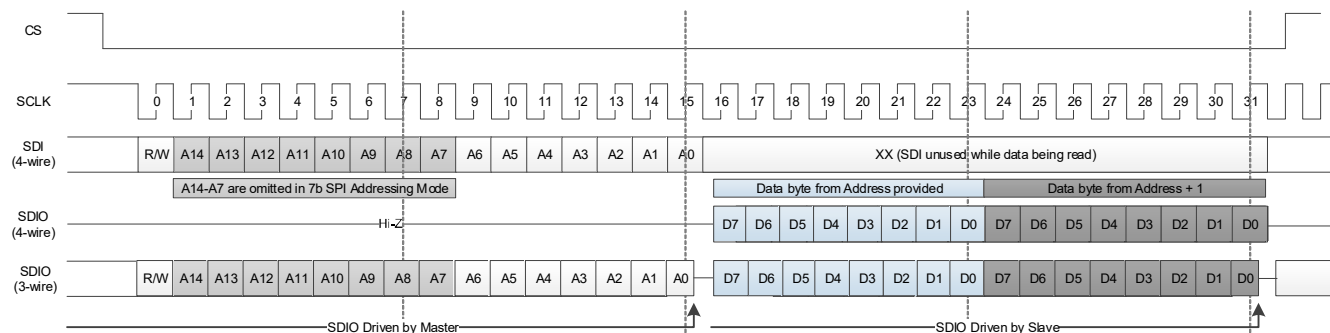
S = Start  
 Sr = Repeated start  
 A = Acknowledge  
 Ā = Non-acknowledge  
 P = Stop

Figure 9. I<sup>2</sup>C Master Sequencing

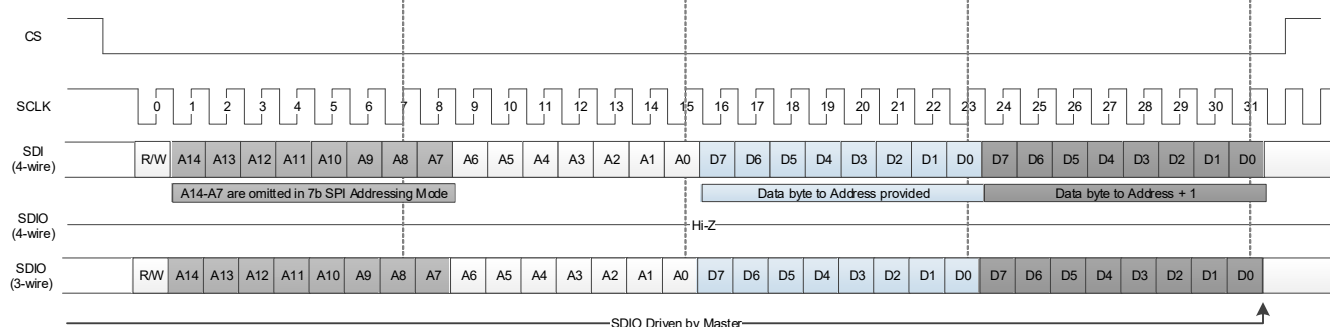
### 3.13.4 SPI Operation

The RC22112A supports SPI operation as a selectable protocol on the serial port. The port may be configured for either 3-wire or 4-wire operation. In 4-wire mode, there are separate data in (to the RC22112A) and data out (from the RC22112A) signals (SDI and SDIO respectively). In 3-wire mode, the SDIO signal is used as a single, bidirectional data signal. [Figure 10](#) shows the sequencing of address and data on the serial port in both 3-wire and 4-wire SPI mode. 4-wire SPI mode is the default. The R/W bit is high for Read Cycles and low for Write Cycles.

**SPI Read Sequence\***



**SPI Write Sequence\***



\* See the timing diagrams for exact timing relationships.

**Figure 10. SPI Sequencing**

A serial port can be configured for the following settings. These settings can come from register defaults or from an internal OTP or external EEPROM configuration loaded at reset:

- 1-byte (1B) or 2-byte (2B) offset addressing (see [Figure 7](#))
  - In 1B operation, the 16-bit register address is formed by using the 7 bits of address supplied in the SPI access and taking the upper 9 bits from the page register. The page register is accessed using an Offset Address of 7Ch with a 4-byte burst access.
  - In 2B operation, the 16-bit register address is formed by using the 15 bits of address supplied in the SPI access and taking the upper 1 bit from the page register. Note that this bit will always be 1 for register accesses, so the page register only needs to be set once in 2B operation. The page register can be accessed using a 3-byte burst access Offset Address of 7FFDh. It should be accessed in a single burst write transaction to set it.
- Data sampling on falling or rising edge of SCLK
- Output (read) data positioning relative to active SCLK edge
- 4-wire (SCLK, CS, SDIO, SDI) or 3-wire (SCLK, CS, SDIO) operation
- In 3-wire mode, SDIO is a bi-directional data pin
- Output signal protocol compatibility / drive strength and termination voltage

**Note:** SPI burst mode operation is required to ensure data integrity of multi-byte registers. When accessing a multi-byte register, all data bytes must be written or read in a single SPI burst access. Bursts can be longer if desired, but must not extend beyond the end of the register page. An internal address pointer is incremented automatically as each data byte is written or read.

### 3.13.4.1 SPI 1-byte (1B) Addressing Example

Example write to “50” to register 0xCBE4

```
7C 80 CB 10 20    #Set Page register
64* 50            #*MSB is 0 for write transactions
```

Example read from 0xC024:

```
7C 00 C0 10 20    #Set Page register
A4* 00            #*MSB is set, so this is a read command
```

### 3.13.4.2 SPI 2-byte (2B) Addressing Example

Example write to “50” to register 0xCBE4

```
7F FD 80 10 20    #Set Page register
4B E4* 50          #*MSB is 0 for write transactions
```

Example read from 0xC024:

```
7F FD 80 10 20    #Set Page register
C0* 24 00          #*MSB is set, so this is a read command
```

## 3.14 JTAG Interface

The RC22112A provides a JTAG interface that can be used in non-operational situations with the device when nTEST control pin is held low. The JTAG interface is compliant with IEEE-1149.1 and supports the IDCODE, BYPASS, EXTEST, SAMPLE, PRELOAD, HIGHZ, and CLAMP instructions. For information on the value the IDCODE instruction will return for the RC22112A, see the *RC22112A Programming Guide Addendum*.

JTAG port signals share five pins with GPIO functions as outlined in [Table 24](#). Assertion of the nTEST input (active low) will place those pins in JTAG mode.

**Table 24. JTAG Signal Mapping**

| Function with nTEST Active (Low) | Function when nTEST Inactive (High) |
|----------------------------------|-------------------------------------|
| TCK                              | GPIO[0]                             |
| TMS                              | GPIO[1]                             |
| TDI                              | GPIO[2]                             |
| TDO                              | GPIO[3]                             |
| TRSTn                            | GPIO[4]                             |

## 4. Applications Information

### 4.1 Recommendations for Unused Input and Output Pins

#### 4.1.1 Inputs

##### 4.1.1.1 LVCMOS Control Pins

LVCMOS control pins have internal pull-ups. Additional resistance is not required but can be added for additional protection. A 1k $\Omega$  resistor can be used.

#### 4.1.2 Outputs

##### 4.1.2.1 LVCMOS Outputs

Any LVCMOS output can be left floating if unused. There should be no trace attached. The mode of the output buffer should be set to tri-stated to avoid any noise being generated.

##### 4.1.2.2 Differential Outputs

All unused differential outputs can be left floating. Renesas recommends that there is no trace attached. Both sides of the differential output pair should be left floating or terminated.

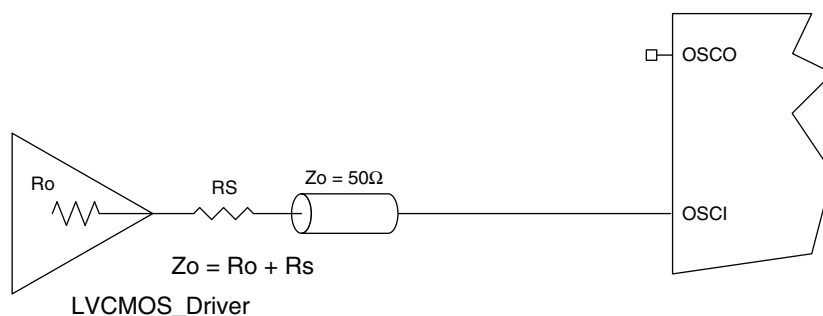
#### 4.1.3 Power Connections

The power connections of the RC22112A can be grouped as shown if all members of the groups use the same voltage level:

- $V_{DD\_DIG}$
- $V_{DDA\_FB}$
- $V_{DDO\_Qn}$  (can share supplies if output frequencies are the same, otherwise keep separated to avoid spur coupling)
  - If all outputs,  $Qn/nQn$ , associated with any particular  $V_{DDO\_Qn}$  pin are not used, the power pin can be left floating

### 4.2 Overdriving the XTAL Interface

The OSCI input can be overdriven by an LVCMOS driver or by one side of a differential driver through an AC coupling capacitor. The OSCI input is internally biased at 1V. The OSCO pin can be left floating. The amplitude of the input signal should be between 500mV and 1.8V and the slew rate should not be less than 0.2V/ns. For 1.8V LVCMOS, inputs can be DC-coupled into the device as shown in [Figure 11](#). For 3.3V LVCMOS inputs, the amplitude must be reduced from full swing to at least half the swing in order to prevent signal interference with the power rail and to reduce internal noise.



**Figure 11. 1.8V LVCMOS Driver to XTAL Input Interface**

[Figure 12](#) shows an example of the interface diagram for a high-speed 3.3V LVCMOS driver. This configuration requires that the sum of the output impedance of the driver ( $R_o$ ) and the series resistance ( $R_s$ ) equals the



transmission line impedance. In addition, matched termination at the crystal input will attenuate the signal in half. This can be done in one of two ways. First, R1 and R2 in parallel should equal the transmission line impedance. For most 50Ω applications, R1 and R2 can be 100Ω. This can also be done by removing R1 and changing R2 to 50Ω. The values of the resistors can be increased to reduce the loading for a slower and weaker LVCMOS driver.

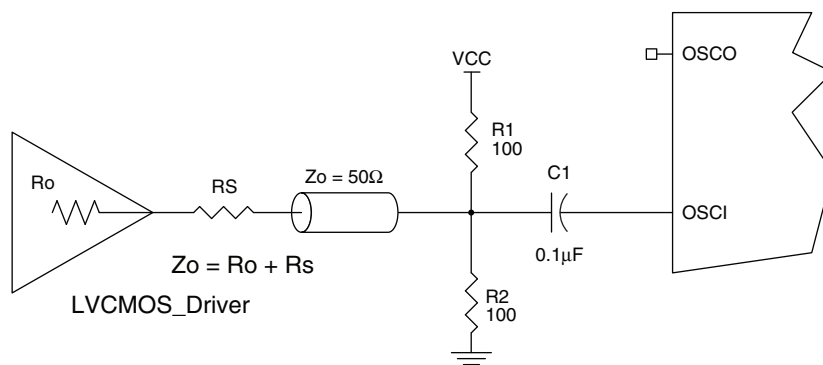


Figure 12. LVCMOS Driver to XTAL Input Interface

Figure 13 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 XTAL\_IN 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. The datasheet specifications are characterized and guaranteed using a quartz crystal as the input.

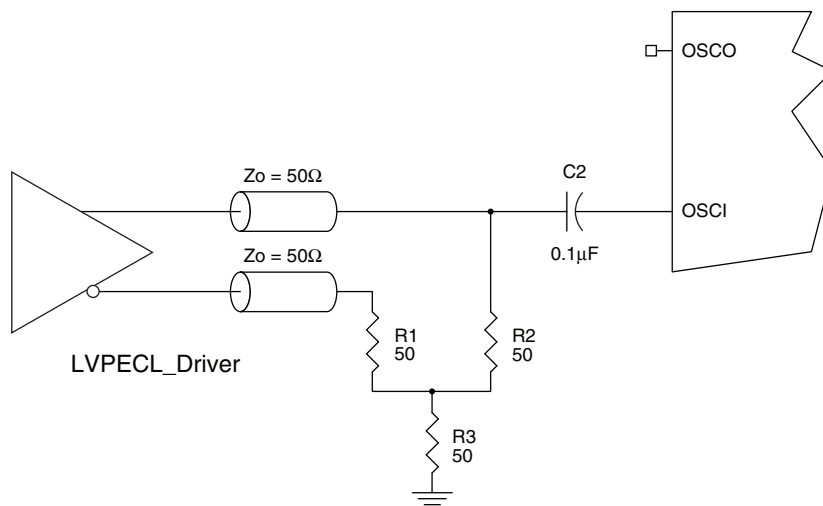


Figure 13. LVPECL Driver to XTAL Input Interface

### 4.3 Wiring the Differential Input to Accept Single-Ended Levels

For information, see [Differential Input to Accept Single-ended Levels Application Note \(AN-836\)](#).

### 4.4 Differential Output Termination

For all types of differential protocols, the same termination schemes are recommended (see [Figure 14](#) and [Figure 15](#)). These schemes are the same as normally used for an LVDS output type.

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 ( $Z_{Diff}$ ) 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. To avoid any transmission-line reflection issues, the components should be surface-mounted and must be placed as close to the receiver as possible.

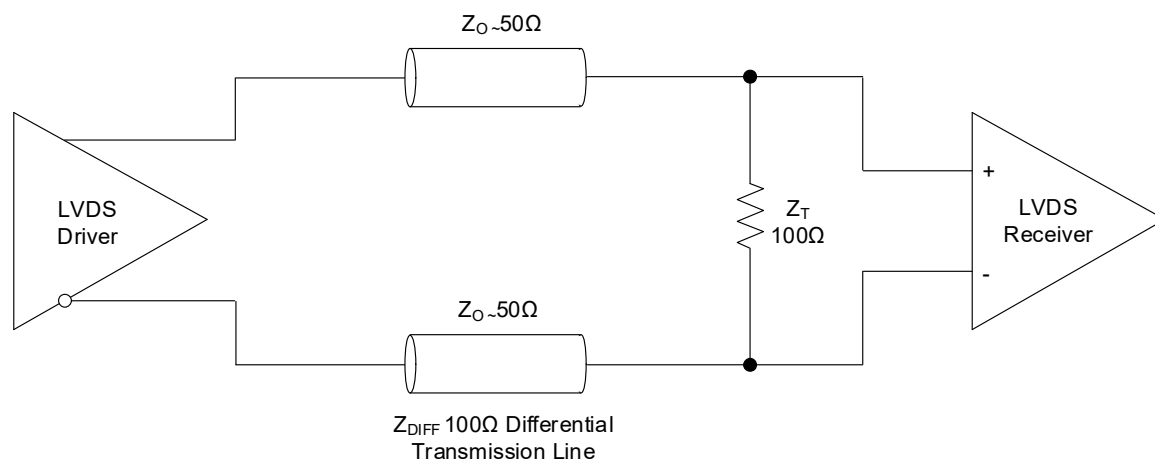


Figure 14. Standard LVDS Termination

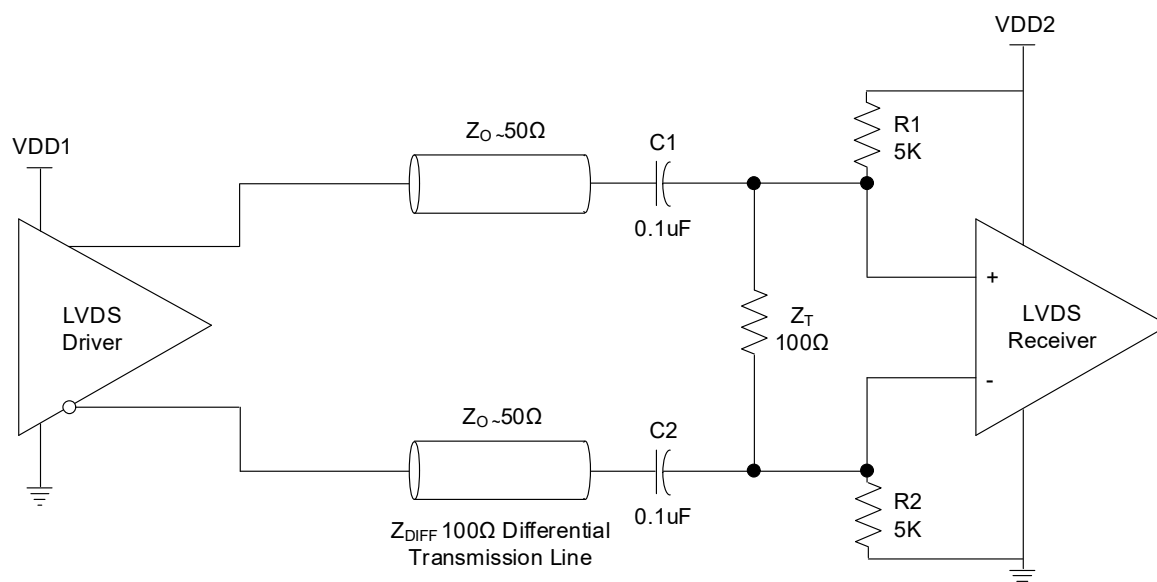


Figure 15. AC Coupled LVDS Termination

For alternate termination schemes, see “LVDS Termination” in [Quick Guide - Output Terminations \(AN-953\)](#), or contact [Renesas](#) for support.

## 4.5 External I<sup>2</sup>C Serial EEPROM Recommendation

An external I<sup>2</sup>C EEPROM can be used to store configuration data and/or to contain device update data. An EEPROM with 8Kbit capacity is sufficient to store a full configuration. However, the recommendation is to use an EEPROM with a 1Mbit capacity in order to support future device updates. Renesas has validated and recommends the use of the Microchip 24FC1025 or OnSemi CAT24M01 1Mbit EEPROM.

## 4.6 Schematic and Layout Information

The RC22112A requires external load capacitors to ensure the crystal will resonate at the proper frequency. For recommendations on crystal vendors, contact [Renesas](#). For recommended values for external tuning capacitors, see [Table 25](#).

Table 25. Recommended Tuning Capacitors for Crystal Input

| Crystal Nominal $C_L$ Value (pF) | Recommended Tuning Capacitor Value (pF) <sup>[1]</sup> |                     |
|----------------------------------|--|---------------------|
|                                  | OSCI Capacitor (pF)                                    | OSCO Capacitor (pF) |
| 8                                | 2.7  | 2.7                 |
| 10                               | 13   | 3.3                 |
| 12                               | 27   | 3.3                 |
| 18 <sup>[2]</sup>                | 27   | 3.3                 |

- Recommendations are based on 4pF stray capacitance on each leg of the crystal. Adjust according to the PCB capacitance.
- This will tune the crystal to a CL of 12pF, which is fine when channels are running in Jitter attenuator mode or referenced to an XO. It will present a positive ppm offset for channels running exclusively in Synthesizer mode and referenced only to the crystal.

## 4.7 Power Considerations

For power and current consumption calculations, see the Renesas [Timing Commander](#) tool.

## 5. Thermal Information

### 5.1 VFQFPN 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 16](#). 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 13 mils (0.30 to 0.33 mm) 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 more information, see the application note on the *Surface Mount Assembly of Amkor's Thermally/ Electrically Enhance Lead frame Base Package*, Amkor Technology.

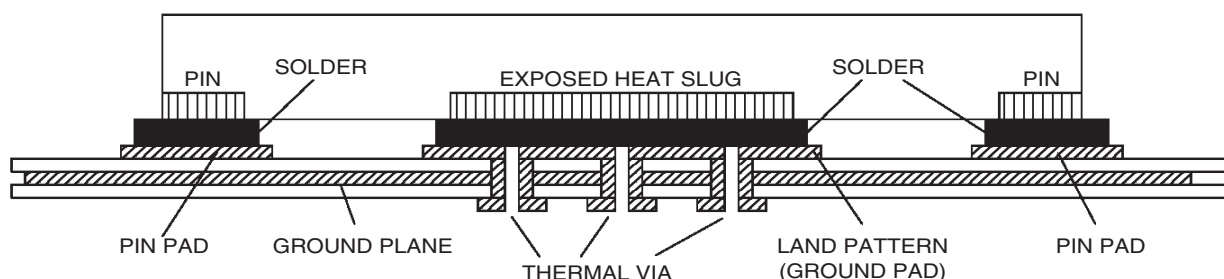


Figure 16. PC Assembly for Exposed Pad Thermal Release Path – Side View (Drawing not to Scale)

## 5.2 Thermal Characteristics

Table 26. Thermal Characteristics

| Symbol        | Parameter   |                | Value | Unit |
|---------------|---|----------------|-------|------|
| $\theta_{JA}$ | Theta $J_A$ . Junction to Ambient Air Thermal Coefficient <sup>[1][2]</sup> | 0 m/s air flow | 13.71 | °C/W |
|               |   | 1 m/s air flow | 10.67 | °C/W |
|               |   | 2 m/s air flow | 9.46  | °C/W |
| $\theta_{JB}$ | Theta $J_B$ . Junction to Board Thermal Coefficient <sup>[1]</sup>          |                | 0.702 | °C/W |
| $\theta_{JC}$ | Theta $J_C$ . Junction to Device Case Thermal Coefficient <sup>[1]</sup>    |                | 12.87 | °C/W |
| -             | Moisture Sensitivity Rating (Per J-STD-020)                                 |                | 3     |      |

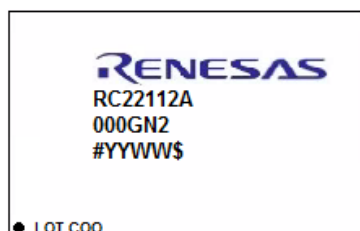
1. Multi-Layer PCB with two ground and two voltage planes.

2. Assumes ePAD is connected to a ground plane using a grid of 9 × 9 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 (see package links in Ordering Information). The package information is the most current data available and is subject to change without revision of this document.

## 7. Marking Diagram



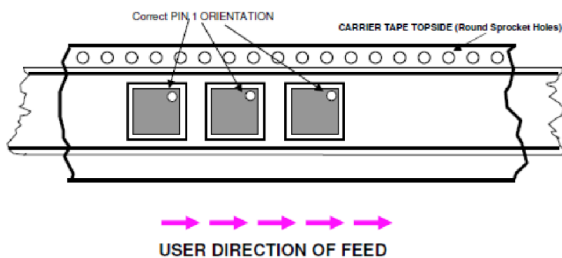
- Lines 2 and 3 indicate the part number.
- Line 4:
  - “#” denotes the stepping number.
  - “YYWW” denotes the last two digits of the year and the work week the part was assembled.
  - “\$” indicates the mark code.
- “LOT” denotes the lot number and “COO” the country of origin.

## 8. Ordering Information

| Part Number                       | Package Description                            | MSL Rating | Carrier Type                                   | Temperature Range |
|-----------------------------------|--|------------|--|-------------------|
| RC22112AdddGN2#BB0 <sup>[1]</sup> | 10 × 10 × 0.9 mm,<br><a href="#">72-VFQFPN</a> | 3          | Tray   | -40° to +85°C     |
| RC22112AdddGN2#HBO                | 10 × 10 × 0.9 mm,<br><a href="#">72-VFQFPN</a> | 3          | Tape and Reel, Pin 1<br>Orientation: EIA-481-D | -40° to +85°C     |

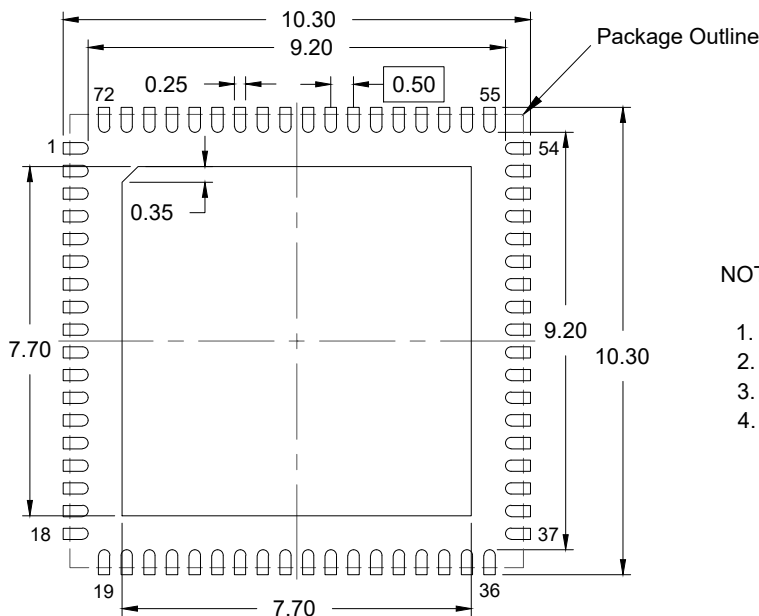
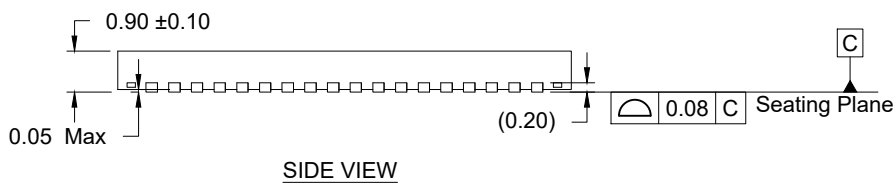
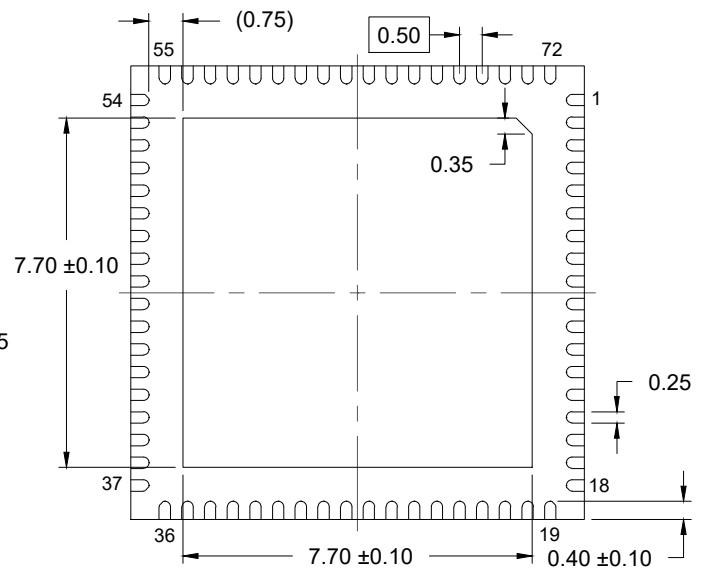
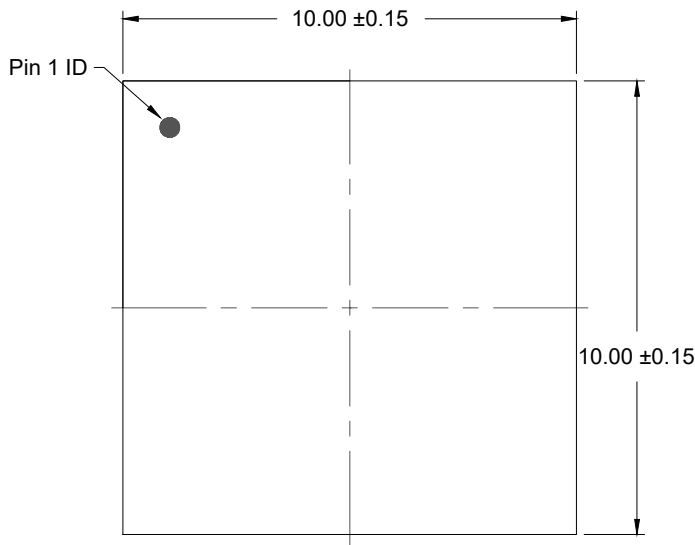
1. Replace “ddd” with the desired pre-programmed configuration code provided by Renesas in response to a custom configuration request or use “000” for unprogrammed parts.

**Table 27. Pin 1 Orientation in Tape and Reel Packaging**

| Part Number Suffix | Pin 1 Orientation      | Illustration   |
|--------------------|------------------------|--|
| NK#K               | Quadrant 2 (EIA-481-D) |  |

## 9. Revision History

| Revision | Date         | Description   |
|----------|--------------|---|
| 1.02     | Jan 10, 2025 | <ul style="list-style-type: none"> <li>Updated the second paragraph in <a href="#">Output Buffer in Single-Ended Mode</a>.</li> </ul>   |
| 1.01     | Oct 3, 2022  | <ul style="list-style-type: none"> <li>Updated <math>f_{MAX}</math> and <math>t_{HD1}</math> parameters in <a href="#">Table 19</a>.</li> <li>Removed <math>t_{D1d}</math> and <math>t_{D2}</math> parameters from <a href="#">Table 19</a>. Also deleted footnotes 2 and 3.</li> </ul> |
| 1.00     | May 24, 2022 | Initial release.  |



NOTES:

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

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### Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,  
Koto-ku, Tokyo 135-0061, Japan  
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### Contact Information

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