

RC32514A

FemtoClock[®]2 Sub-100fs Universal Frequency Translator

The RC32514A is a small, low-power timing component designed to be placed immediately adjacent to a PHY, switch, ASIC or FPGA that requires several reference clocks with jitter performance less than 100fs. The RC32514A can act as a frequency synthesizer to locally generate the reference clock, a jitter attenuator to perform local clean-up and/or frequency translation of a centrally-supplied reference or as a DCO for frequency margining or OTN clock applications.

The device is a member of Renesas' high-performance FemtoClock2 family.

Applications

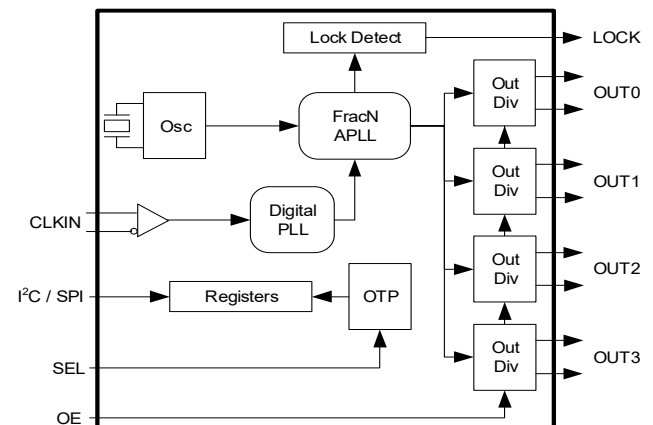
- Reference clock generator for 100Gbps / 400Gbps PHYs or switches
- Adjustable OTN clock reference for OTU3 / OTU4 mappers
- Reference clock for programmable FiberOptic Modules

Features

- Jitter below 100fs RMS maximum (10kHz to 20MHz)
- PLL core consists of fractional-feedback Analog PLL (APLL) which can optionally be steered by a Digital PLL (DPLL)
 - Operates from an integrated 60MHz crystal
 - APLL frequency independent of input / crystal frequency
 - Operates as a frequency synthesizer, jitter attenuator, or Digitally Controlled Oscillator (DCO)
 - DPLL loop filter programmable from 10Hz to 12kHz
 - DCO has tuning granularity of < 1ppb
- Programmable input buffer supports HCSL, LVDS, or two LVCMOS with no external terminations needed
 - Input frequencies: 1MHz to 800MHz (250MHz for LVCMOS)
 - Reference monitor qualifies/disqualifies input clock
- Programmable status output

- 4 differential / 8 LVCMOS outputs
 - Any frequency from 10MHz to 1GHz (180MHz for LVCMOS)
 - Programmable output buffer supports HCSL (DC-coupled), LVDS/LVPECL/CML (AC-coupled) or two LVCMOS
 - Differential output swing is selectable: 400mV to 800mV
 - Output Enable input with programmable effect
- Supports up to 1MHz I²C or up to 20MHz SPI serial processor port
- Can configure itself automatically after reset via internal customer-definable One-Time Programmable (OTP) memory with up to four different configurations
- 4 × 4 mm 28-QFN package

Block Diagram



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1. About this Document

1.1 Document Conventions

This document uses the following conventions.

1.1.1 Signal Notation

Signals are either active low or active high. An active-low signal has an active state of logic 0 (or the lower voltage level) and is denoted by a lowercase n prefix. An active-high signal has an active state of logic 1 (or the higher voltage level) and is not denoted by a special character. The following table illustrates the signal naming convention.

Table 1. Signal Naming Convention

| State | Signal Naming |
|-------------|---------------|
| Active low | nNAME |
| Active high | NAME |

1.1.2 Object Size Notation

- A byte is an 8-bit object.
- A half-word (hword) is a 16-bit object.
- A word is a 32-bit object.
- A double-word (dword) is a 64-bit object.

1.1.3 Numeric Notation

- Hexadecimal numbers are denoted by the prefix 0x (for example, 0x04).
- Binary numbers are denoted by the prefix 0b (for example, 0b010).
- Register blocks that have multiple iterations are denoted by [x:y] in their names; where x is first instance, and y is the last instance. For example, BLOCK[0:1] with a base address of 0x10 += 0x08 indicates there are two iterations of the registers defined for BLOCK, with instance 0 at a base address of 0x10 and instance 1 at a base address of 0x18.

1.1.4 Endianness

RC32514A uses little-endian notation.

The Least Significant Bit (LSB) in a data object is numbered with 0, and the Most Significant Bit (MSB) is numbered with the width of the object minus 1. For example, the LSB index of a word is 0 and the MSB is 31.

The least significant byte of a multi-byte register field is located at the base address of the register and subsequent bytes up to the most significant byte are located at increasing byte addresses. For example, given a half-word located at address 0x42, the least significant byte (bits 7:0) can be accessed at address 0x42, and the most significant byte (bits 15:8) can be accessed at address 0x43.

Some multi-byte register fields are updated atomically, where the values written to the lower order bytes are buffered but not applied to the internal logic until the most significant bits are written, which then triggers the entire new register field value to be applied to the internal logic at once. Atomic registers fields are noted in the description.

When a multi-byte register field is non-atomic (the default if not noted otherwise), the value written to any byte of the field is immediately applied to the internal logic.

2. Pin Information

2.1 Pin Assignments

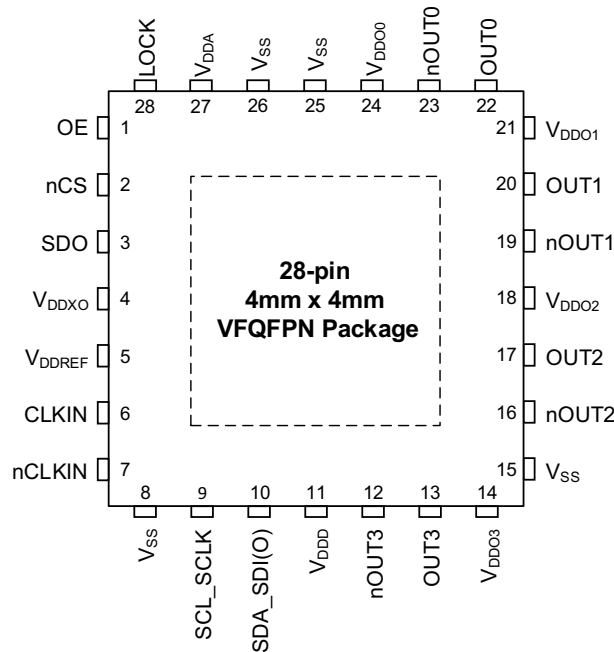


Figure 1. Pin Assignments – Top View

2.2 Pin Descriptions

Table 2. Pin Descriptions

| Number | Name | Type | | Description |
|--------|--------------------|-------|---------------------------|---|
| 1 | OE | I | Optional Pullup/ Pulldown | Output Enable signal for all clock outputs when <code>oe_sel</code> is set to 0. Polarity, pull-up enable and pull-down enable are controlled by the <code>oe_pol</code> , <code>oe_pu</code> , and <code>oe_pd</code> register fields, respectively. |
| 2 | nCS | I | | I ² C Mode: Unused SPI Mode: Chip Select |
| 3 | SDO | O | | I ² C Mode: Unused SPI Mode: Data Out (4-wire) and Unused (3-wire) |
| 4 | V _{DDXO} | Power | | Oscillator supply. 1.8V supported. |
| 5 | V _{DDREF} | Power | | Reference input supply. 1.8V supported. <code>CLKIN</code> and <code>nCLKIN</code> are referenced to this voltage supply. |
| 5 | CLKIN | I | | Non-inverting differential reference clock input/CMOS single-ended reference clock input. If the clock signal is AC-coupled, then <code>en_dc_bias</code> must be set to 1 for a differential input, or <code>en_selfbias_cmos</code> must be set to 1 for single-ended inputs. When in single-ended operation, the input supports the termination of a single leg of an LVDS clock (no additional external termination). Input buffer should be disabled if unused by setting <code>en_inbuff</code> to 0. For information on input buffer configuration and termination strategies, see Clock Input Interface . |
| 7 | nCLKIN | I | | Inverting differential reference clock input/CMOS single-ended reference clock input. |
| 8 | V _{SS} | Power | | Negative supply voltage. Connect to same supply as the EPAD. |

Table 2. Pin Descriptions (Cont.)

| Number | Name | Type | | Description |
|--------|-------------------|-------|------------------|--|
| 9 | SCL_SCLK | I | Optional Pull-up | I ² C Mode: I ² C interface bi-directional clock. SPI Mode: Serial Clock The pull-up enable is controlled by the scl_pu register field. |
| 10 | SDA_SDI(O) | I/O | Optional Pull-up | I ² C Mode: I ² C interface bi-directional data in open-drain mode. SPI Mode: Serial Data In and Out (3-wire)/Serial Data In (4-wire) The pull-up enable is controlled by the sda_pu register field. |
| 11 | V _{DD} | Power | | Core digital function supply. 1.8V or 3.3V supported. Note that the digital power consumption is increased when operating above 1.8V (for information, see Power Considerations). OE , nCS , SDO , SCL_SCLK , and SDA_SDI(O) are referenced to this voltage. |
| 12 | nOUT3 | O | | Output Clock 3 negative. |
| 13 | OUT3 | O | | Output Clock 3 positive. |
| 14 | V _{DDO3} | Power | | Supply voltage for output pair OUT3 and nOUT3 . 1.8V supported. This pin can be left unconnected if clock output 3 is unused and the corresponding out_pd bit is set to 1. |
| 15 | V _{SS} | Power | | Negative supply voltage. Connect to same supply as the Epad. |
| 16 | nOUT2 | O | | Output Clock 2 negative. |
| 17 | OUT2 | O | | Output Clock 2 positive. |
| 18 | V _{DDO2} | Power | | Supply voltage for output pair OUT2 and nOUT2 . 1.8V supported. This pin can be left unconnected if clock output 2 is unused and the corresponding out_pd bit is set to 1. |
| 19 | nOUT1 | O | | Output Clock 1 negative. |
| 20 | OUT1 | O | | Output Clock 1 positive. |
| 21 | V _{DDO1} | Power | | Supply voltage for output pair OUT1 and nOUT1 . 1.8V supported. This pin can be left unconnected if clock output 1 is unused and the corresponding out_pd bit is set to 1. |
| 22 | OUT0 | O | | Output Clock 0 positive. |
| 23 | nOUT0 | O | | Output Clock 0 negative. |
| 24 | V _{DDO0} | Power | | Supply voltage for output pair OUT0 and nOUT0 . 1.8V supported. This pin can be left unconnected if clock output 0 is unused and the corresponding out_pd bit is set to 1. |
| 25, 26 | V _{SS} | Power | | Negative supply voltage. Connect to same supply as the Epad. |
| 27 | V _{DDA} | Power | | Analog function supply for core analog functions. 1.8V supported. LOCK is referenced to this voltage. |
| 28 | LOCK | O | See description | PLL lock status or other status as selected by lock_sel . Polarity, pull-up enable and pull-down enable are controlled by the lock_pol , lock_pu , and lock_pd register fields, respectively. |
| EPAD | V _{SS} | Power | | Negative supply voltage. Epad must be connected before any positive supply voltage is applied. |

Table 3. Pin Characteristics

| Symbol | Parameter | Test Conditions | Minimum | Typical | Maximum | Units | |
|---------------------------------|---------------------------|-----------------|--------------------------|---------|---------|-------|----|
| C _{IN} | Input Capacitance | CLKIN | - | 2 | - | pF | |
| | | nCLKIN | - | 2 | - | pF | |
| | | OE | - | 4 | - | pF | |
| | | SCL_SCLK | - | 4 | - | pF | |
| | | SDA_SDI(O) | - | 4 | - | pF | |
| R _{PULLUP} | Input Pull-Up Resistor | OE | 51 | 54 | 57 | kΩ | |
| | | nCS | 51 | 53 | 57 | kΩ | |
| | | SCL_SCLK | 51 | 54 | 57 | kΩ | |
| | | SDA_SDI(O) | 51 | 54 | 57 | kΩ | |
| | Output Pull-Up Resistor | LOCK | 51 | 54 | 57 | kΩ | |
| | | SDO | 51 | 53 | 57 | kΩ | |
| R _{PULLDOWN} | Input Pull-Down Resistor | CLKIN | en_HCSL = 1 | 44 | 50 | 57 | kΩ |
| | | nCLKIN | | 44 | 50 | 57 | kΩ |
| | | OE | 51 | 53 | 57 | kΩ | |
| | Output Pull-Down Resistor | LOCK | 51 | 54 | 57 | kΩ | |
| | | SDO | 51 | 53 | 57 | kΩ | |
| | | SDO | 51 | 53 | 57 | kΩ | |
| R _{OUT} ^[1] | Output Impedance | LOCK | V _{DDA} = 1.89V | 30 | 43 | 70 | Ω |
| | | SDA_SDI(O) | V _{DDD} = 1.89V | 48 | 49 | 50 | Ω |
| | | SDO | | 30 | 43 | 70 | Ω |

[1] Output impedance for the clock outputs are provided in Table 20.

3. Specifications

3.1 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 RC32514A at absolute maximum ratings is not implied. Exposure to absolute maximum rating conditions can affect device reliability.

Table 4. Absolute Maximum Ratings

| Symbol | Parameter | Test Condition | Minimum | Maximum | Unit |
|-------------------|------------------------------|---|---------|---------|------|
| V _{DD33} | 3.3V power supplies | V _{DDD} | -0.5 | 3.63 | V |
| V _{DD18} | 1.8V power supplies | V _{DDREF} , V _{DDXO} , V _{DDA} , V _{DDO3} , V _{DDO2} , V _{DDO1} , V _{DDO0} | -0.5 | 1.98 | V |
| V _{IN} | Voltage on any input | CLKIN, nCLKIN | 0 | 1.98 | V |
| | | All other inputs | -0.5 | 3.63 | V |
| I _{IN} | Differential Input Current | CLKIN, nCLKIN | - | ±50 | mA |
| I _O | Output Current - Continuous | OUT0/1/2/3 | - | 30 | mA |
| | | LOCK, SDA_SDI(O), SDO | - | 25 | mA |
| | Output Current - Surge | OUT0/1/2/3 | - | 60 | mA |
| | | LOCK, SDA_SDI(O), SDO | - | 50 | mA |
| T _{JMAX} | Maximum Junction Temperature | | - | 150 | °C |
| T _S | Storage temperature | | -65 | 150 | °C |
| - | ESD - Human Body Model | | - | 2000 | V |
| - | ESD - Charged Device Model | | - | 500 | V |

3.2 Recommended Operating Conditions

Table 5. Recommended Operating Conditions^{[1][2]}

| Symbol | Parameter | Minimum | Typical | Maximum | Unit |
|----------------------------------|--|---------|---------|---------|------|
| T _J | Maximum Junction temperature | - | - | 125 | °C |
| T _A | Ambient air temperature | -40 | - | 85 | °C |
| V _{DDREF} | Supply Voltage for Input Clock Buffers and Dividers | 1.71 | 1.8 | 1.89 | V |
| V _{DDXO} | Supply Voltage for Crystal Oscillator | 1.71 | 1.8 | 1.89 | V |
| V _{DDA} | Supply Voltage for Analog Core | 1.71 | 1.8 | 1.89 | V |
| V _{DDD} | Supply Voltage for Digital Core ^[3] | 1.71 | 1.8/3.3 | 3.465 | V |
| V _{DDOx} ^[4] | Supply Voltage for Output Clock Driver and Divider ^[5] | 1.71 | 1.8 | 1.89 | V |
| t _{PU} | Power Up Time for V _{DDx} - for all supply voltages to reach minimum specified voltage (power ramps must be monotonic) ^[6] | 0.05 | - | 5 | ms |

[1] It is your responsibility to ensure that device junction temperature remains below the maximum allowed.

[2] All conditions in this table must be met to ensure device functionality.

[3] Supports 1.8V ±5% or 3.3V ±5% operation, not a continuous range.

[4] V_{DDOx} represents any of V_{DDO3}, V_{DDO2}, V_{DDO1}, or V_{DDO0}.

[5] Currents for the outputs are shown in Table 12 as appropriate for the mode the individual output is operating in.

[6] This implies all supply rails must reach their minimum voltage within maximum T_{PU}.

3.3 Reference Clock Phase Jitter and Phase Noise

Table 6. Output Phase Jitter Characteristics^{[1][2]}

| Symbol | Parameter | Test Condition | Typical | Maximum | Unit | |
|--------------------|--------------------------------|---|--|---------|------|--------|
| tjit(Φ) | Phase Jitter, RMS (Random) | 10kHz to 20MHz 60MHz Crystal ^[3] ; JA Mode Locked to 25MHz CLKIN | 156.25MHz | 105 | 130 | fs |
| | | | 245.76MHz | 104 | 130 | fs |
| | | | 312.5MHz | 101 | 130 | fs |
| | | | 322.265625MHz | 104 | 130 | fs |
| | | | 491.52MHz | 102 | 130 | fs |
| | | | 983.04MHz | 101 | 130 | fs |
| $\Phi_{SSB}(100)$ | Single Sideband Phase Noise | 100Hz | 60MHz Crystal, JA Mode with 25Hz loop bandwidth, 25MHz input from SMA-100; All outputs enabled at 156.25MHz | -103 | - | dBc/Hz |
| $\Phi_{SSB}(1k)$ | | 1kHz | | -113 | - | dBc/Hz |
| $\Phi_{SSB}(10k)$ | | 10kHz | | -132 | - | dBc/Hz |
| $\Phi_{SSB}(100k)$ | | 100kHz | | -140 | - | dBc/Hz |
| $\Phi_{SSB}(1M)$ | | 1MHz | | -154 | - | dBc/Hz |
| $\Phi_{SSB}(10M)$ | | 10MHz | | -164 | - | dBc/Hz |
| $\Phi_{SSB}(30M)$ | | ≥ 30 MHz | | -166 | - | dBc/Hz |

[1] $V_{DDX0} = V_{DDA} = V_{DDOx} = 1.8V \pm 5\%$, $V_{SS} = 0V$, $T_A = -40^\circ C$ to $85^\circ C$.

[2] Electrical parameters are ensured 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 meets specifications after thermal equilibrium has been reached under these conditions.

[3] APLL at 9.8304GHz for 245.76MHz, 491.52MHz and 983.04MHz. APLL at 10.3125GHz for 156.25MHz, 312.5MHz, and 322.265625MHz.

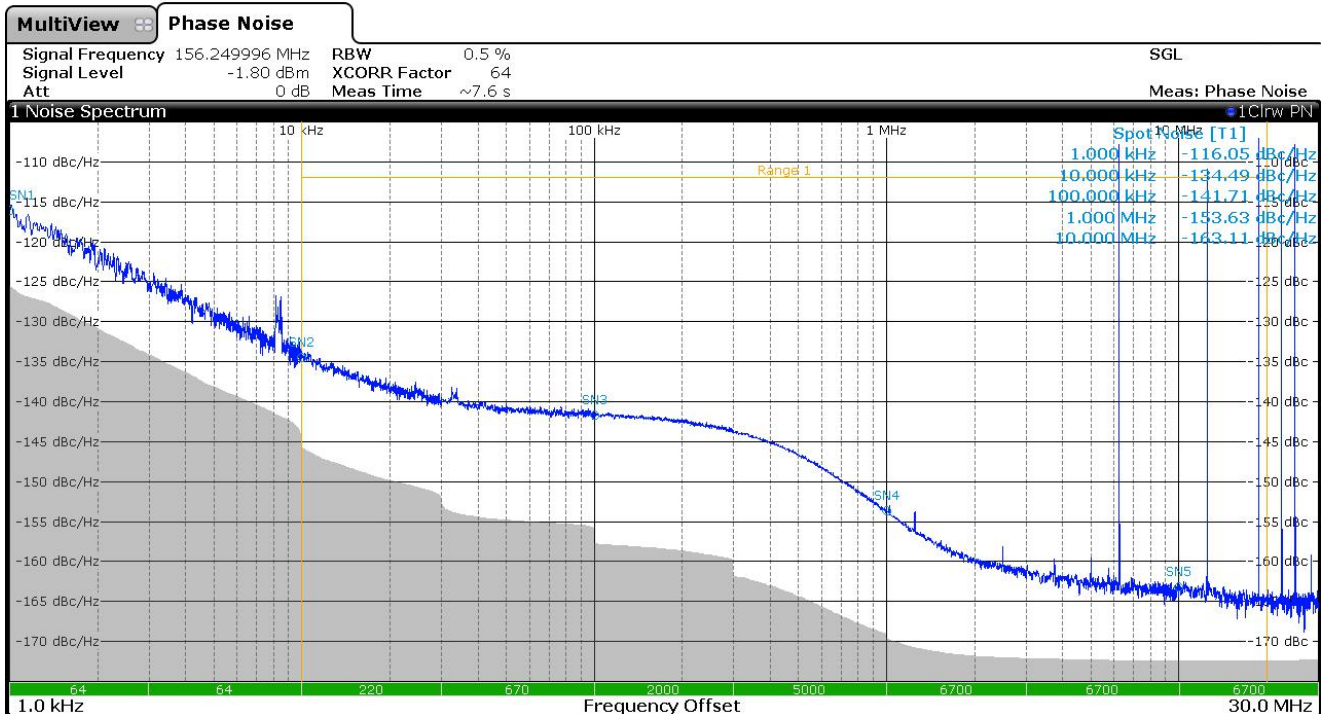


Figure 2. 156.25MHz Output Phase Noise – Fractional Jitter Attenuator Mode

Table 7. PCI Express Jitter Specifications^{[1][2]}

| Symbol | Parameter | Test Conditions | Typical | PCIe Industry Specification | Unit |
|--------------------|--|---|---------|-----------------------------|----------|
| $t_{jphPCIeG1-CC}$ | PCIe Phase Jitter (Common Clocked Architecture) | PCIe Gen 1 (2.5 GT/s) ^{[3][4]} | 0.836 | 86 | ps (p-p) |
| $t_{jphPCIeG2-CC}$ | | PCIe Gen 2 Lo Band (5.0 GT/s) ^{[3][4]} | 0.014 | 3 | ps (RMS) |
| | | PCIe Gen 2 Hi Band (5.0 GT/s) ^{[3][4]} | 0.055 | 3.1 | ps (RMS) |
| $t_{jphPCIeG3-CC}$ | | PCIe Gen 3 (8.0 GT/s) ^{[3][4]} | 0.022 | 1 | ps (RMS) |
| $t_{jphPCIeG4-CC}$ | | PCIe Gen 4 (16.0 GT/s) ^{[3][4][5]} | 0.029 | 0.5 | ps (RMS) |
| $t_{jphPCIeG5-CC}$ | | PCIe Gen 5 (32.0 GT/s) ^{[3][4][6]} | 0.008 | 0.15 | ps (RMS) |

[1] $V_{DDX0} = V_{DDA} = V_{DDOx} = 1.8V \pm 5\%$, $V_{SS} = 0V$, $T_A = -40^{\circ}C$ to $85^{\circ}C$.

[2] Electrical parameters are ensured 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 500 lfm. The device meets specifications after thermal equilibrium has been reached under these conditions.

[3] The Refclk jitter is measured after applying the filter functions found in the *PCI Express Base Specification 5.0, Revision 1.0*. For the exact measurement setup, see the Test Loads section of the datasheet. The worst case results for each data rate are summarized in this table.

[4] Jitter measurements should be made with a capture of at least 100,000 clock cycles captured by a Real-Time Oscilloscope (RTO) with a sample rate of 20GS/s or greater. Broadband oscilloscope noise must be minimized in the measurement. The measured PP jitter is used (no extrapolation) for RTO measurements. Alternately, jitter measurements can be used with a Phase Noise Analyzer (PNA) extending (flat) and integrating and folding the frequency content up to an offset from the carrier frequency of at least 200MHz (at 300MHz absolute frequency) below the Nyquist frequency. For PNA measurements for the 2.5GT/s data rate, the RMS jitter is converted to a peak-to-peak jitter using a multiplication factor of 8.83. In the case where real-time oscilloscope and PNA measurements have both been done and produce different results, the RTO result must be used.

[5] In channel simulations to account for additional noise in a real system, 0.7ps RMS must be used.

[6] In channel simulations to account for additional noise in a real system, 0.25ps RMS must be used.

3.4 AC Electrical Characteristics

Table 8. Input Frequency Characteristics^[1]

| Symbol | Parameter | | Test Condition | Minimum | Maximum | Unit |
|--------------------|--|----------------------------|--|---------|---------|------|
| f _{CLKIN} | Input Frequency for CLKIN ^[2] | | Clock Synthesizer Mode (Doubler Logic Disabled) | 50 | 312.5 | MHz |
| | | | Jitter Attenuator Mode - Differential Mode | 1 | 800 | MHz |
| | | | Jitter Attenuator Mode - Single- ended Mode | 1 | 250 | MHz |
| f _{SCLK} | Serial Port Clock SCL_SCLK | I ² C Operation | Slave Mode | 100 | 1200 | kHz |
| | | SPI Operation | Slave Mode | 0.1 | 20 | MHz |

[1] V_{DDXO} = 1.8V ±5%, V_{SS} = 0V, T_A = -40°C to 85°C

[2] For proper device operation, the input frequency must be divided down to f_{TDC} or less, see Table 9 for details.

Table 9. PLL Characteristics^{[1][2]}

| Symbol | Parameter | | Test Condition | Minimum | Typical | Maximum | Unit |
|----------------------|--|--------------------------|--|----------------------------------|---------|---------|------|
| f _{VCO} | Analog PLL VCO Operating Frequency | | | 9.7 | - | 10.7 | GHz |
| Δf _{OUT} | Output frequency tuning resolution | | DCO Mode | [2 ⁻⁴⁰ × 1e12] = 0.91 | | | ppt |
| f _{PFD} | Analog Phase/Frequency Detector (PFD) Operating Frequency | | Integer VCO feedback | 50 | - | 312.5 | MHz |
| f _{TDC} | Digital Phase Detector (TDC) Operating Frequency | | | 1 | - | 33 | MHz |
| f _{MON} | Reference Monitor Operating Frequency | CLKMON0/1 | | - | - | 33 | MHz |
| | | CLKMON2 | | - | - | 312.5 | MHz |
| t _{startup} | Start-up Time ^[3] | Internal OTP Start-up | Synthesizer mode | - | 7 | 10 | ms |
| | | | DPLL mode, with a loop bandwidth setting of 300Hz ^[4] | - | - | 1 | s |

[1] V_{DDXO} = V_{DDD} = V_{DDA} = V_{DDOX} = 1.8V ±5%, V_{SS} = 0V, T_A = -40°C to 85°C.

[2] Electrical parameters are ensured 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 meets specifications after thermal equilibrium has been reached under these conditions.

[3] Measured from when 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.

[4] Start-up time depends on the actual configuration used. For more information on estimating start-up time, contact REA technical support.

Table 10. Output Frequency Characteristics^{[1][2]}

| Symbol | Parameter | | Test Condition | | Minimum | Typical | Maximum | Unit |
|-----------------|--|---|--|-----------------------------|---------|---------|---------|-------|
| f_{OUT} | Output Frequency | Differential Output | | | 10 | - | 1000 | MHz |
| | | LVC MOS Output | | | 10 | - | 180 | MHz |
| t_{SK} | Output to Output Skew ^{[3][4]} | Differential ^[5] | Any two outputs | | - | 40 | 45 | ps |
| | | LVC MOS ^[6] | Any OUTx to any other OUTx or any nOUTx to any other nOUTx | | - | 80 | 90 | ps |
| | | | OUTx to nOUTx of the same output pair, configured in-phase | | - | 80 | 90 | ps |
| Δt_{SK} | Temperature Variation ^[7] Output-Output | | | | - | - | 1 | ps/°C |
| t_{PD} | Input to Output Skew ^[8] Differential ^[5] WRT CLKIN ^[9] | Delay for JA mode, integer DPLL feedback | | 760 | 860 | 960 | ps | |
| | | Delay for JA mode, fractional DPLL feedback | | 810 | 910 | 1010 | ps | |
| | | Delay for SYNTH mode | | 750 | 850 | 950 | ps | |
| Δt_{PD} | Input to Output Delay Variation Differential ^[5] | | Any mode | | - | - | ±200 | ps |
| t_R / t_F | Output Rise and Fall Times 20% to 80% | Differential Output ^[10] | HCSL Mode | SWING ^[11] = Any | - | - | 120 | ps |
| | | | LVDS Mode | SWING ^[12] = Any | - | - | 180 | ps |
| | | LVC MOS Output ^[13] | $V_{DDOx} = 1.8V \pm 5\%$ | - | - | 800 | ps | |
| odc | Output Duty Cycle | Differential Output | $f_{OUT} \leq f_{VCO} / N; N = 10, 12, \dots$ | | 48 | 50 | 52 | % |
| | | | $f_{OUT} \leq f_{VCO} / N; N = 39, 41, \dots$ | | 48 | 50 | 52 | % |
| | | | $f_{OUT} \leq f_{VCO} / N; N = 11, 13, \dots, 37$ | | 45 | 50 | 55 | % |
| | | LVC MOS | Any frequency | | 45 | 50 | 55 | % |
| $\Delta F/F$ | Frequency Stability (Free-run) | | Over 10 years. Inclusive of 25°C tolerance, operating temperature range, input voltage change, load change, aging, shock, and vibration. | | -40 | | 40 | PPM |

[1] $V_{DDXO} = V_{DDA} = V_{DDOx} = 1.8V \pm 5\%$, $V_{SS} = 0V$, $T_A = -40^\circ C$ 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 500lpm. The device meets specifications after thermal equilibrium has been reached under these conditions.

[3] Defined as the time between the rising edges of two outputs of the same frequency, configuration, loading, and supply voltage.

[4] This parameter is defined in accordance with JEDEC Standard 65.

[5] Measured at the differential cross points.

[6] Measured at $V_{DDOx} / 2$.

[7] This parameter is measured across the full operating temperature range and the difference between the slowest and fastest numbers is the variation.

[8] Defined as the time between the output rising edge and the input rising edge that caused it.

[9] Clkin was from Rhode and Schwarz SMA 100B Signal Generator.

[10] Measured with outputs terminated with 50Ω to GND.

[11] Refers to the output voltage (swing) setting programed into device registers for each output using the [ODRV_AMP_CNFG Register.out_cnf_hcs_lswing](#) field for each output.

[12] Refers to the output voltage (swing) setting programed into device registers for each output using the [ODRV_AMP_CNFG Register.out_cnf_lvds_amp](#) field for each output.

[13] Measured with outputs terminated with 50Ω to $V_{DDOx} / 2$.

Table 11. Power Supply Noise Rejection^{[1][2]}

| Symbol | Parameter | Test Condition | | Minimum | Typical | Maximum | Unit |
|---|--|---|---------------------------------------|---------|---------|---------|------|
| PSNR | Power Supply Noise Rejection ^{[3][4]} | $f_{\text{NOISE}} \leq 1\text{MHz}$ | $V_{\text{DDOx}} = 1.8\text{V}^{[5]}$ | -105 | -94 | - | dBc |
| | | | $V_{\text{DDXO}} = 1.8\text{V}$ | -95 | -87 | - | dBc |
| | | $f_{\text{NOISE}} \leq 100\text{kHz}$ | $V_{\text{DDREF}} = 1.8\text{V}$ | -95 | -86 | - | dBc |
| | | | $V_{\text{DD}} = 1.8\text{V}$ | -140 | -114 | - | dBc |
| | | $100\text{kHz} < f_{\text{NOISE}} \leq 600\text{kHz}$ | $V_{\text{DDREF}} = 1.8\text{V}$ | -140 | -109 | - | dBc |
| | | | $V_{\text{DD}} = 1.8\text{V}$ | -100 | -96 | - | dBc |
| $600\text{kHz} < f_{\text{NOISE}} \leq 1\text{MHz}$ | $V_{\text{DDREF}} = 1.8\text{V}$ | -155 | -143 | - | dBc | | |
| | $V_{\text{DD}} = 1.8\text{V}$ | -105 | -99 | - | dBc | | |

[1] $V_{\text{DDXO}} = V_{\text{DDREF}} = V_{\text{DDA}} = V_{\text{DDOx}} = 1.8\text{V} \pm 5\%$, $V_{\text{SS}} = 0\text{V}$, $T_{\text{A}} = -40^{\circ}\text{C}$ to 85°C .

[2] Electrical parameters are ensured 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 500fpm. The device meets specifications after thermal equilibrium has been reached under these conditions.

[3] 50mV peak-to-peak sine-wave noise signal injected on indicated power supply pin(s).

[4] Noise spur amplitude measured relative to 156.25MHz carrier.

[5] Excluding V_{DDOx} of the output being measured.

3.5 DC Electrical Characteristics

Table 12. Power Supply DC Characteristics - Supply Current^{[1][2][3]}

| Symbol | Parameter | Test Condition | | Current Consumption | | Unit |
|----------------------------------|--|--|------------------------------|---------------------|-----|------|
| | | | | Typ | Max | |
| I _{DDREF} | Supply Current for V _{DDREF} ^[4] | 1.8V LVCMOS input | | 8 | 13 | mA |
| | | HCSL input (P_N_Diff_Sel = 0, en_HCSL = 1) | | 10 | | mA |
| | | LVDS input (P_N_Diff_Sel = 1, en_LVDS = 1) | | 11 | | mA |
| | | AC-coupled differential input | | 5.5 | | mA |
| I _{DDXO} | Supply Current for V _{DDXO} | V _{DDXO} = 1.89V | | 5.5 | 10 | mA |
| I _{DDA} | Supply Current for V _{DDA} | V _{DDA} = 1.89V | | 129 | 150 | mA |
| I _{DDD} | Supply Current for V _{DDD} | V _{DDD} = 1.89V | | 25 | 30 | mA |
| | | V _{DDD} = 3.465V | | 26 | | mA |
| I _{DDOx} ^[5] | Supply Current for V _{DDOx} ^{[6][7]} | HCSL Mode | SWING ^[8] = 200mV | 31 | 50 | mA |
| | | | SWING = 250mV | 32 | | mA |
| | | | SWING = 300mV | 33 | | mA |
| | | | SWING = 350mV | 34 | | mA |
| | | | SWING = 400mV | 35 | | mA |
| | | | SWING = 450mV | 36 | | mA |
| | | | SWING = 500mV | 37 | | mA |
| | | | SWING = 550mV | 39 | | mA |
| | | | SWING = 600mV | 40 | | mA |
| | | | SWING = 650mV | 41 | | mA |
| | | | SWING = 700mV | 42 | | mA |
| | | | SWING = 750mV | 43 | | mA |
| | | | SWING = 800mV | 44 | | mA |
| | | | SWING = 850mV | 45 | | mA |
| | | SWING = 900mV | 46 | mA | | |
| | | LVDS Mode | AMP ^[9] = 350mV | 30 | 40 | mA |
| | | | AMP = 400mV | 31 | | mA |
| | | Output Disabled | | 28 | 50 | mA |
| | | Output Hi-Z | | 26 | 30 | mA |
| | | LVCMOS Mode | In phase | 34 | 45 | mA |
| Opposite phase | 34 | | mA | | | |
| nOUTx Disabled | 31 | | 40 | mA | | |
| OUTx Disabled | 31 | | | 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_{SS} = 0V, T_A = -40°C to 85°C.
 [4] Voltage of the input signal must be appropriate for the V_{DDREF} voltage supply level when using a DC-coupled connection.
 [5] I_{DDOx} denotes the current consumed by each V_{DDOx} supply.
 [6] V_{DDOx} = 1.89V.
 [7] Measured with outputs unloaded.

- [8] Refers to the output voltage (swing) setting programmed into device registers for each output using the [ODRV_AMP_CNFG Register.out_cnf_hcsl_swing](#) field for each output.
- [9] Refers to the output voltage (amplitude) setting programmed into device registers for each output using the [ODRV_AMP_CNFG Register.out_cnf_lvds_amp](#) field for each output.

Table 13. LVCMOS Status and Control Signal DC Characteristics^{[1][2][3]}

| Symbol | Parameter | Test Condition | Minimum | Typical | Maximum | Unit |
|-----------------|---------------------|--|------------------------|---------|------------------------|------|
| V _{IH} | Input High Voltage | V _{DD} = 3.3V ±5% | 2 | - | V _{DD} + 0.3 | V |
| | | V _{DD} = 1.8V ±5% | 0.65 × V _{DD} | - | V _{DD} + 0.3 | |
| V _{IL} | Input Low Voltage | V _{DD} = 3.3V ±5% | -0.3 | - | 0.8 | V |
| | | V _{DD} = 1.8V ±5% | -0.3 | - | 0.35 × V _{DD} | |
| I _{IH} | Input High Current | V _{IN} = V _{DD} = V _{DD} (max) | - | - | 5 | μA |
| I _{IL} | Input Low Current | V _{IN} = 0V, V _{DD} = V _{DD} (max) | -75 | - | - | μA |
| V _{OH} | Output High Voltage | V _{DD} = 3.3V ±5% or 1.8V ±5% I _{OH} = -100μA | V _{DD} - 0.2 | - | - | V |
| | | (LOCK Signal Only) V _{DDA} = 1.8V ±5% I _{OH} = -100μA | V _{DDA} - 0.2 | - | - | V |
| V _{OL} | Output Low Voltage | V _{DD} = 3.3V ±5% or 1.8V ±5% V _{DDA} = 1.8V ±5% I _{OL} = 100μA | - | - | 0.2 | V |

- [1] 3.3V characteristics in accordance with JESD8C-01, 1.8V characteristics in accordance with JESD8-7A.
- [2] V_{SS} = 0V, T_A = -40°C to 85°C.
- [3] Input specifications see signals [SCL_SCLK](#), [SDA_SDI\(O\)](#), [OE](#), [nCS](#). Output specifications see signals [LOCK](#), [SDO](#), [SDA_SDI\(O\)](#) (3-wire SPI).

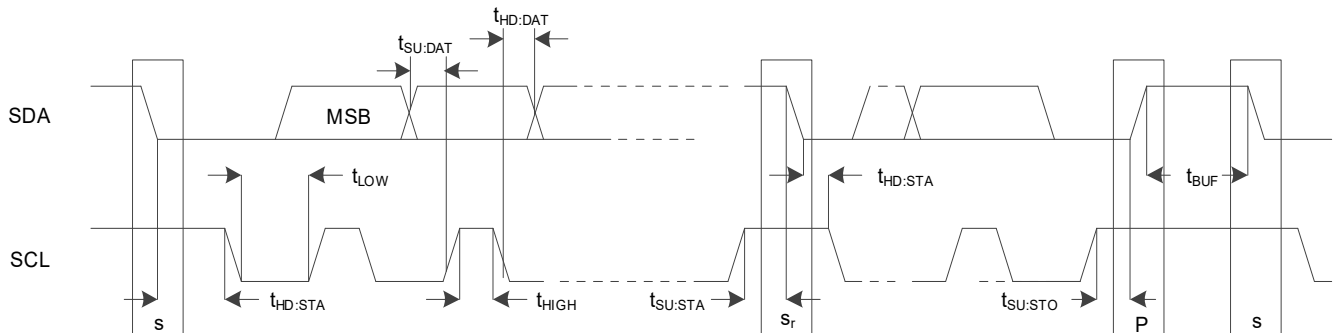


Figure 3. I²C Slave Timing Diagram

Table 14. I²C Slave Timing^[1]

| Parameter | Description | Standard Mode | | Fast Mode | | Fast Mode Plus | | Unit |
|---------------------|--|------------------|------------------|--------------------|------------------|----------------|---------|------|
| | | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | |
| f _{SCL} | SCL clock frequency | 0 | 100 | 0 | 400 | 0 | 1000 | kHz |
| t _{HD:STA} | Hold time (repeated) START condition | 4000 | - | 600 | - | 260 | - | ns |
| t _{LOW} | LOW period of the SCL clock | 4700 | - | 1300 | - | 500 | - | ns |
| t _{HIGH} | HIGH period of the SCL clock | 4000 | - | 600 | - | 260 | - | ns |
| t _{SU:STA} | Setup time for a repeated START condition | 4700 | - | 600 | - | 260 | - | ns |
| t _{HD:DAT} | Data hold time ^[2] | 0 ^[3] | - ^[4] | 0 ^[3] | - ^[4] | 0 | - | ns |
| t _{SU:DAT} | Data setup time | 250 | - | 100 ^[5] | - | 50 | - | ns |
| t _{SU:STO} | Setup time for STOP condition | 4000 | - | 600 | - | 260 | - | ns |
| t _{BUF} | Bus free time between a STOP and START condition | 4700 | - | 1300 | - | 500 | - | ns |

[1] All values referred to V_{IH} (minimum) and V_{IL} (maximum) levels (see Table 13).

[2] t_{HD:DAT} is the data hold time that is measured from the falling edge of SCL, and applies to data in transmission and the acknowledge.

[3] A device must internally provide a hold time of at least 300ns for the SDA signal (with respect to the V_{IH} (min) of the SCL signal) to bridge the undefined region of the falling edge of SCL.

[4] The maximum t_{HD:DAT} could be 3.45μs and 0.9μs for Standard mode and Fast mode, but must be less than the maximum of t_{VD:DAT} or t_{VD:ACK} by a transition time. This maximum must only be met if the device does not stretch the LOW period (t_{LOW}) of the SCL signal. If the clock stretches the SCL, the data must be valid by the setup time before it releases the clock.

[5] A Fast mode I²C-bus device can be used in a Standard mode I²C-bus system, but the requirement t_{SU:DAT} 250ns must then be met. This is automatically the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, it must output the next data bit to the SDA line t_{r(max)} + t_{SU:DAT} = 1000 + 250 = 1250ns (according to the Standard mode I²C-bus specification) before the SCL line is released. The acknowledge timing also must meet this setup time.

Table 15. I²C-Bus Characteristics

| Parameter | Description | Standard Mode | | Fast Mode | | Fast Mode Plus | | Unit |
|----------------|---|---------------|---------|--------------------------------|---------|---|--------------------|------|
| | | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | |
| t _r | Rise time of both SDA and SCL signals | - | 1000 | 20 | 300 | - | 120 | ns |
| t _f | Fall time of both SDA and SCL signals ^{[1][2][3][4]} | - | 300 | 20 × (V _{DD} / 5.5 V) | 300 | 20 × (V _{DD} / 5.5 V) ^[5] | 120 ^[4] | ns |
| C _D | Capacitive load for device on bus | - | 5 | - | 5 | - | 5 | pF |

[1] A device must internally provide a hold time of at least 300ns for the SDA signal (with respect to the V_{IH} (minimum) of the SCL signal) to bridge the undefined region of the falling edge of SCL.

[2] If mixed with Hs-mode devices, faster fall times are allowed.

[3] The maximum t_r for the SDA and SCL bus lines is specified at 300ns. The maximum fall time for the SDA output stage t_f is specified at 250ns, allowing series protection resistors to be connected in between the SDA and the SCL pins and the SDA/SCL bus lines without exceeding the maximum specified t_f.

[4] In Fast Mode Plus, fall time is specified the same for both output stage and bus timing. If series resistors are used, designers should allow for this when considering bus timing.

[5] Necessary to be backwards compatible to Fast mode.

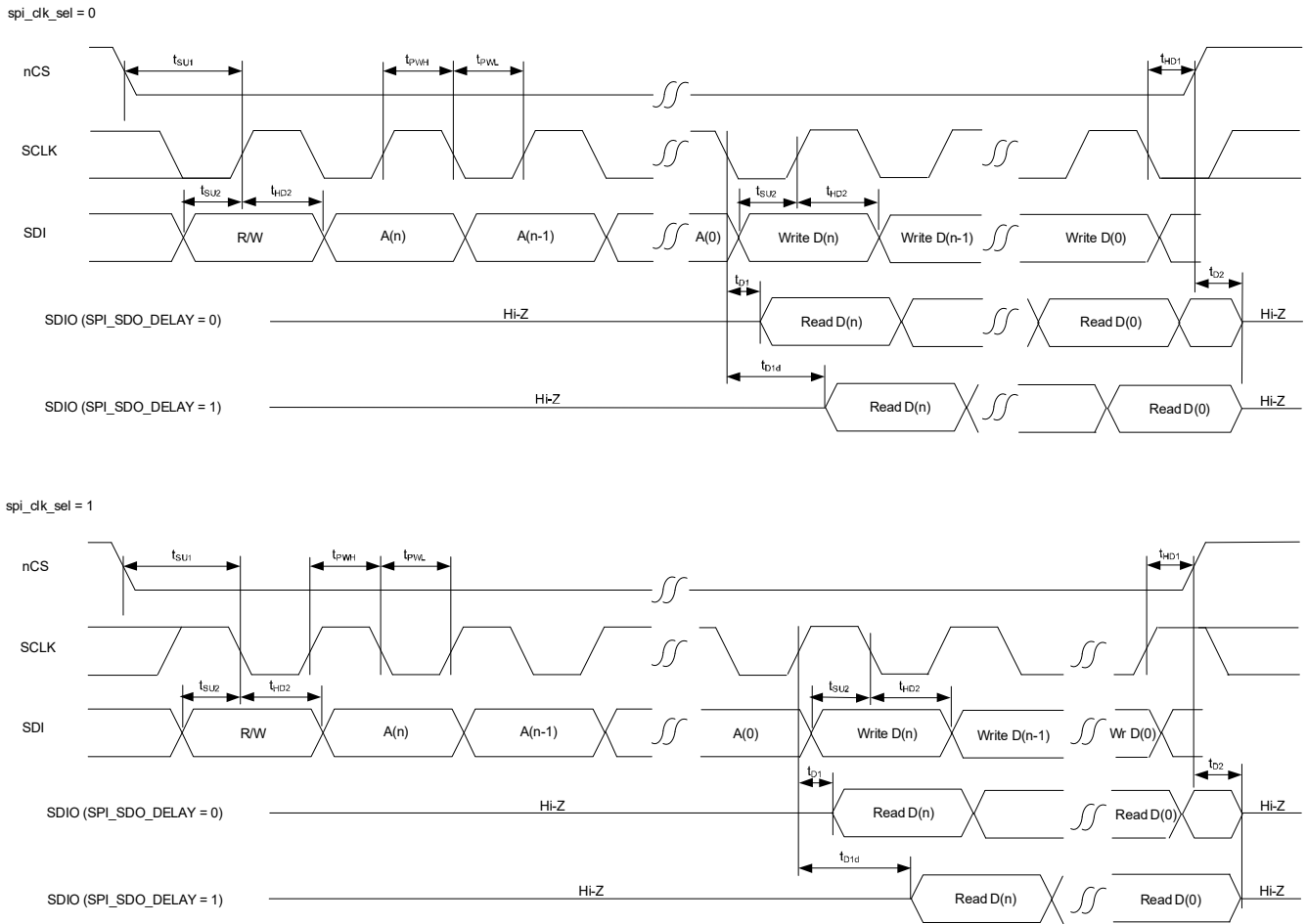


Figure 4. SPI Timing Diagram

Table 16. SPI Slave Timing

| Parameter | Description | Minimum | Typical | Maximum | Unit |
|------------------|---|------------------------------------|---------|---------|------|
| f _{MAX} | Maximum operating frequency | - | - | 20 | MHz |
| t _{PWH} | SCLK Pulse Width High | 25 | - | - | ns |
| t _{PWL} | SCLK Pulse Width Low | 25 | - | - | ns |
| t _{SU1} | nCS Setup Time to SCLK rising or falling edge | 10 | - | - | ns |
| t _{HD1} | nCS Hold Time from SCLK rising or falling edge | 10 | - | - | ns |
| t _{SU2} | SDIO Setup Time to SCLK rising or falling edge | 10 | - | - | ns |
| t _{HD2} | SDIO Hold Time from SCLK rising or falling edge | 10 | - | - | ns |
| t _{D1} | Read Data Valid Time from SCLK rising or falling edge with no data delay added | 4 | 5.6 | - | ns |
| t _{D1d} | Read Data Valid Time from SCLK rising or falling edge including half period of SCLK delay added to data timing ^[1] | t _{D1} + half SCLK period | - | - | ns |
| t _{D2} | SDIO Read Data Hi-Z Time from CS High ^[2] | - | 10 | - | ns |

[1] Adding the extra half period of delay is a register programming option to emulate read data being clocked out on the opposite edge of the SCLK to the write data.

[2] This is the time until the RC32514A releases the signal. Rise time to any specific voltage is dependent on pull-up resistor strength and PCB trace loading.

Table 17. Differential Clock Input DC Characteristics^[1]

| Symbol | Parameter | Test Condition | Minimum | Typical | Maximum | Unit | |
|--------------------|---|--|---|---------|---|------|----|
| I _{IH} | Input High Current | CLKIN | V _{IN} = V _{DDREF} = V _{DDREF} (max) | - | - | 100 | μA |
| | | nCLKIN | | - | - | 100 | μA |
| I _{IL} | Input Low Current | CLKIN | V _{IN} = 0V | -50 | - | - | μA |
| | | nCLKIN | | -50 | - | - | μA |
| V _{I(PP)} | Peak-to-Peak Voltage ^{[2][3][4]} | | 0.15 | - | 1.2 | V | |
| V _{CMR} | Common Mode Input Voltage ^{[2][4][5][6]} | PMOS input buffer (HCSL, P_N_Diff_Sel = 0) | V _{I(PP)} / 2 | 0.35 | V _{DDREF} - 1.2 | V | |
| | | NMOS input buffer (LVDS, P_N_Diff_Sel = 1) | 0.7 | 1.2 | V _{DDREF} - (V _{I(PP)} / 2) | V | |

[1] V_{DDREF} = 1.8V ±5%, V_{SS} = 0V, T_A = -40°C to 85°C.

[2] V^L should not be less than -0.3V.

[3] V_{PP} is the single-ended amplitude of the input signal. The differential specification is 2*V_{PP}.

[4] V_{DDREF} = 1.8V ±5%. Voltage of the input signal must be appropriate for the V_{DDREF} voltage supply level when using a DC-coupled connection.

[5] Common-mode voltage is defined as the cross-point.

[6] Voltage of the input signal must be appropriate for the V_{DDREF} voltage supply level when using a DC-coupled connection. For example, when supplying an LVDS input signal that is referenced to a 2.5V supply at its source, the V_{DDREF} supply must also be 2.5V nominal voltage.

Table 18. LVCMOS Clock Input DC Characteristics^{[1][2][3]}

| Symbol | Parameter | Test Condition | Minimum | Typical | Maximum | Unit |
|-----------------|--------------------|---|---------------------------|---------|---------------------------|------|
| V _{IH} | Input High Voltage | V _{DDREF} = 1.8V ±5% | 0.65 × V _{DDREF} | - | V _{DDREF} + 0.3 | V |
| V _{IL} | Input Low Voltage | V _{DDREF} = 1.8V ±5% | -0.3 | - | 0.35 × V _{DDREF} | V |
| I _{IH} | Input High Current | V _{IN} = V _{DDREF} = V _{DDREF} (max) | - | - | 150 | μA |
| I _{IL} | Input Low Current | V _{IN} = 0V | -150 | - | - | μA |

[1] 1.8V characteristics in accordance with JESD8-7A.

[2] V_{SS} = 0V, T_A = -40°C to 85°C.

[3] Input specifications see both CLKIN and nCLKIN.

Table 19. Differential Clock Output DC Characteristics^{[1][2][3]}

| Symbol | Parameter | Test Condition | Minimum | Typical | Maximum | Unit |
|---------------------|---|--------------------------|---------------------|---------|---------------------|------|
| V _{OUT} | Absolute Voltage on HCSL output | ^[4] | -125 ^[5] | - | 1150 ^[6] | mV |
| V _{CROSS} | Absolute Voltage Output Crossing | HCSL Mode ^[7] | 350 | - | 500 | mV |
| ΔV _{CROSS} | Total Variation on HCSL output crossing over all edges ^[8] | ^[9] | - | 30 | 100 | mV |

Table 19. Differential Clock Output DC Characteristics^{[1][2][3]} (Cont.)

| Symbol | Parameter | Test Condition | | Minimum | Typical | Maximum | Unit |
|----------------------------------|----------------------------|---------------------------|--------------------------------|---------|---------|---------|------|
| V _{OVS} ^[10] | Output Voltage Swing | HCSL Mode | SWING = 200mV ^[11] | 195 | - | 250 | mV |
| | | | SWING = 250mV | 245 | - | 315 | mV |
| | | | SWING = 300mV | 295 | - | 380 | mV |
| | | | SWING = 350mV | 345 | - | 450 | mV |
| | | | SWING = 400mV | 395 | - | 520 | mV |
| | | | SWING = 450mV | 445 | - | 585 | mV |
| | | | SWING = 500mV | 495 | - | 645 | mV |
| | | | SWING = 550mV | 545 | - | 725 | mV |
| | | | SWING = 600mV | 595 | - | 780 | mV |
| | | | SWING = 650mV | 645 | - | 820 | mV |
| | | | SWING = 700mV | 685 | - | 855 | mV |
| | | | SWING = 750mV | 725 | - | 880 | mV |
| | | | SWING = 800mV | 755 | - | 915 | mV |
| | | | SWING = 850mV | 785 | - | 960 | mV |
| | | SWING = 875mV | 810 | - | 1005 | mV | |
| | | SWING = 900mV | 825 | - | 1045 | mV | |
| | | LVDS Mode | AMP = 350mV ^[12] | 350 | - | 460 | mV |
| | | | AMP = 400mV | 365 | - | 500 | mV |
| V _{CMR} | Output Common Mode Voltage | LVDS Mode ^[13] | CENTER = 700mV ^[14] | 650 | - | 750 | mV |
| | | | CENTER = 800mV | 750 | - | 850 | mV |
| | | | CENTER = 900mV | 800 | - | 950 | mV |
| | | | CENTER = 1000mV | 900 | - | 1050 | mV |

[1] V_{DDOx} = 1.8V ±5%, V_{SS} = 0V, T_A = -40°C to 85°C.

[2] Terminated with 100Ω across OUTx and nOUTx.

[3] OUTx refers to any of the output pairs [OUT3/nOUT3](#), [OUT2/nOUT2](#), [OUT1/nOUT1](#) or [OUT0/nOUT0](#).

[4] Measurement taken from single-ended waveform.

[5] Defined as the minimum instantaneous voltage including undershoot.

[6] Defined as the maximum instantaneous voltage including overshoot.

[7] Terminated with 50Ω to GND on each of OUTx and nOUTx.

[8] Defined as the total variation of all crossing voltages of rising OUTx and falling nOUTx, This is the maximum allowed variance for any particular system.

[9] Measured at crossing point where the instantaneous voltage value of the rising edge of Qx equals the falling edge of nQx.

[10] V_{OVS} is the single-ended amplitude of the output signal. The differential specs is 2*V_{OVS}.

[11] Refers to the output voltage (swing) setting programed into device registers for each output using the [ODRV_AMP_CNFG Register.out_cnf_hcsl_swing](#) field for each output.

[12] Refers to the output voltage (swing) setting programed into device registers for each output using the [ODRV_AMP_CNFG Register.out_cnf_lvds_amp](#) field for each output.

[13] Terminated with 100Ω across OUTx and nOUTx.

[14] Refers to the differential voltage crossing point (center voltage) setting programed into device registers for each output using the [ODRV_MODE_CNFG Register.out_lvds_cm_voltage](#) field for each output.

Table 20. LVCMOS Clock Output DC Characteristics^{[1][2][3]}

| Symbol | Parameter | Test Condition | Minimum | Typical | Maximum | Unit |
|------------------|---------------------|----------------------------|-------------------------|---------|---------|------|
| V _{OH} | Output High Voltage | I _{DDOx} = ±100μA | V _{DDOx} - 0.2 | - | - | V |
| V _{OL} | Output Low Voltage | | - | - | 0.2 | V |
| Z _{OUT} | Output Impedance | | 41 | 51 | 67 | Ω |

[1] V_{DDOx} = 1.8V ±5%, V_{SS} = 0V, T_A = -40°C to 85°C.

[2] Applies to any of OUT3, nOUT3, OUT2, nOUT2, OUT1, nOUT1, nOUT0, or OUT0.

[3] Output voltages compliant with JESD8-7A, Normal Range.

4. Applications Information

4.1 Power Considerations

For power and current consumption calculations, see the Renesas Timing Commander tool.

4.2 Recommendations for Unused Input and Output Pins

4.2.1 CLKIN/nCLKIN Input

For applications that do not require the use of the reference clock input, both **CLKIN** and **nCLKIN** should be left floating. If the **CLKIN/CLKIN** input is connected but not used by the device, Renesas recommends that both **CLKIN** and **nCLKIN** are not driven with active signals.

4.2.2 LVCMOS Control Pins

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

4.2.3 LVCMOS Outputs

Any LVCMOS output must be left floating if unused. There should be no trace attached. Set the mode of the output buffer to a high-impedance state to avoid any noise being generated.

4.2.4 Differential Outputs

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

4.3 Clock Input Interface

The RC32514A provides a programmable input buffer for reference clock inputs, as shown in [Figure 5](#). This programmable buffer allows most standard signaling protocols to be supported with no need for external termination components at the receiver end of the transmission line.

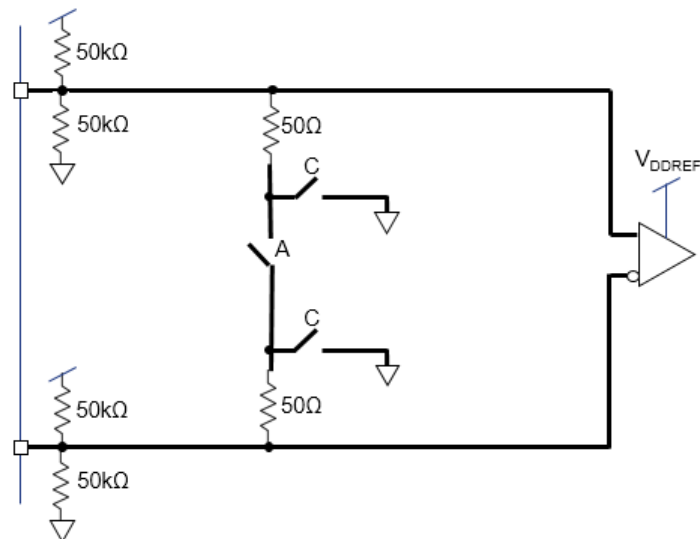


Figure 5. Programmable Input Buffer Logical Diagram

By making appropriate register selections, the switches labeled A and C in [Figure 5](#) can be closed as shown in [Table 21](#) to support the indicated protocols. With the switches closed as indicated, the input buffer behaves as shown in [Figure 6](#) for the various input reference signal protocols.

Note: HCSL is sometimes used in an 85 Ω transmission line environment and this input buffer supports that with no external terminations needed. However, this is not expected to be used often in RC32514A applications.

Table 21. Input Buffer Programming Options for Specific Signaling Protocols

| Input Signaling Protocol | Register Setting | Switches Closed | V _{DDREF} Voltage Required |
|---|---|-----------------|-------------------------------------|
| LVDS | REF_CLK_IN_CNFG Register.en_LVDS | A | 1.8V |
| HCSL | REF_CLK_IN_CNFG Register.en_HCSL | C | 1.8V ^[1] |
| 1.8V LVCMOS | REF_CLK_IN_CNFG Register.CMOS_Sel | - | 1.8V |
| Externally AC-coupled LVCMOS ^[2] | REF_CLK_IN_CNFG Register.en_selfbias_cmos | - | 1.8V |
| Externally AC-coupled ^[2] | REF_CLK_IN_CNFG Register.en_dc_bias | - | 1.8V |

[1] Only a 1.8V V_{DDREF} is supported. If a higher VDD is used by the transmitter, then External AC-coupling must be used.

[2] In this mode of operation, AC-coupling capacitors must isolate the voltage level of the transmitter from the receiver. The signal must be properly terminated on the transmitter side of the AC-coupling capacitors. No terminations are needed between the AC-coupling capacitors and the RC32514A.

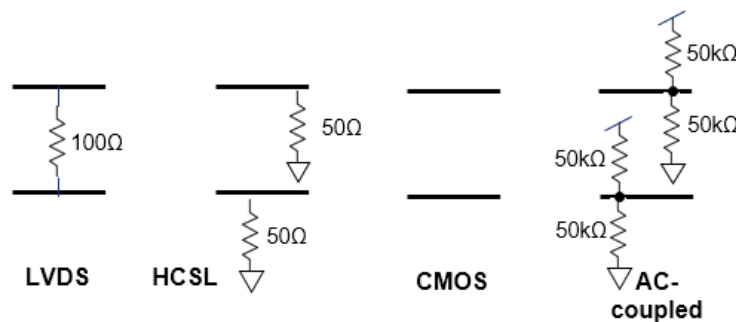


Figure 6. Input Buffer Behavior by Protocol

4.4 Differential Output Termination

The RC32514A provides a programmable output buffer for clock outputs. This buffer allows most standard signaling protocols to be supported with no need for external termination components at the transmitter side of the transmission line.

Note: Many receivers of the type expected to be used with a high-performance device like RC32514A are equipped with internal terminations that can include trace termination, voltage biasing, and even AC-coupling in some cases. Consult with the receiver specifications to determine if any or all of the following indicated external components are needed.

4.4.1 Direct-Coupled HCSL Termination

For HCSL differential protocol, the following termination scheme is recommended (see Figure 7). A typical HCSL design uses a 50Ω resistor to ground at the receiver. The RC32514A supports source termination (see Figure 7), with an internal 50Ω resistor to ground at the transmitter. This is enabled by setting `ODRV_MODE_CNFG Register.out_hcsl_term_en`.

For alternate termination schemes, see HCSL Terminations in *Quick Guide - Output Terminations (AN-953)* located on the RC32514A product page, or contact Renesas for support.

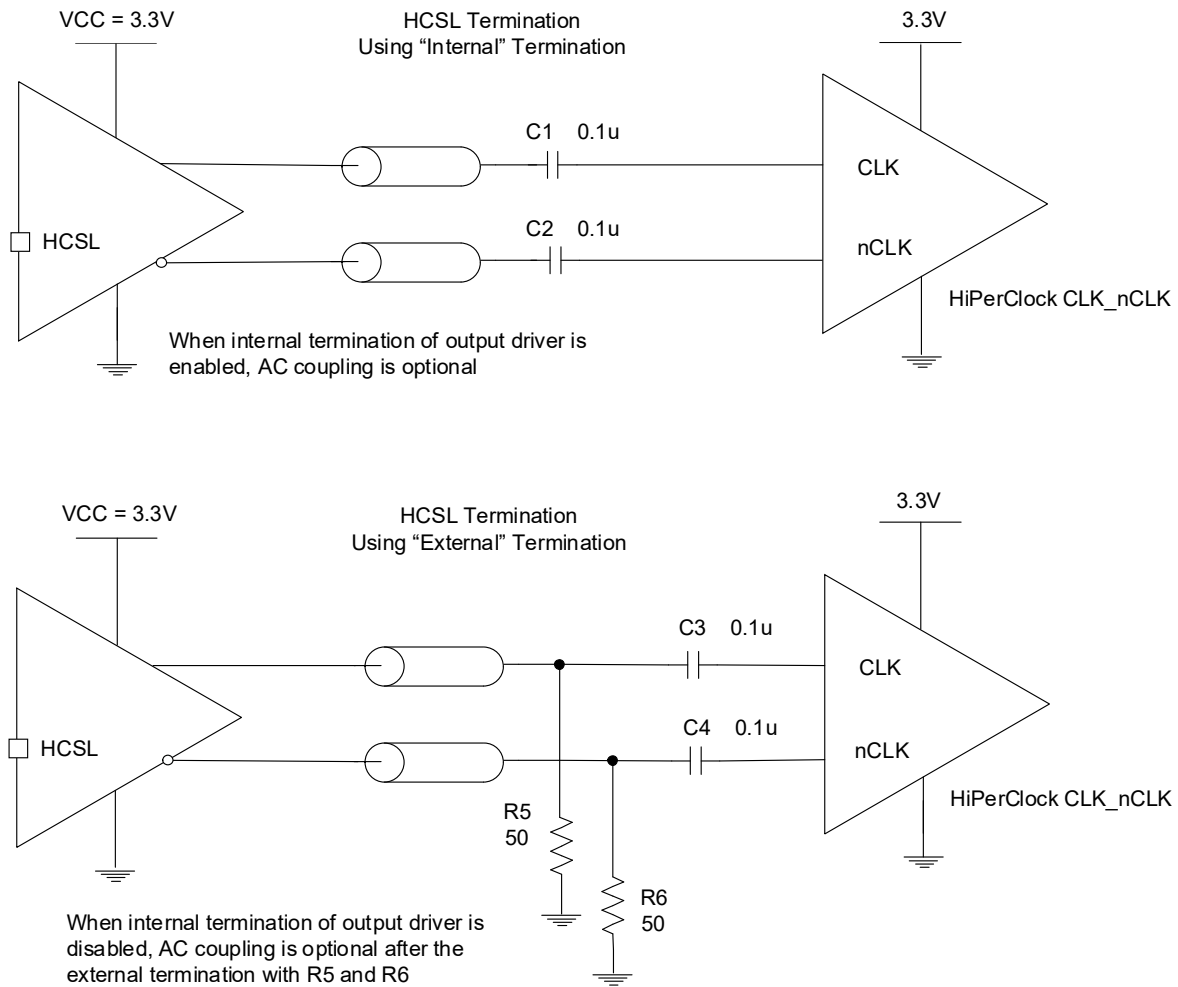


Figure 7. Standard HCSL Termination

4.4.2 Direct-Coupled LVDS Termination

For LVDS differential protocol, the following termination scheme is recommended (see Figure 8). The recommended value for the termination impedance (Z_T) is between 90Ω and 132Ω . The actual value should be selected to match the differential impedance (Z_0) of your transmission line. A typical point-to-point LVDS design uses a 100Ω parallel resistor at the receiver and a 100Ω differential transmission-line environment. To avoid any transmission-line reflection issues, the components should be surface-mounted and must be placed as close to the receiver as possible.

For alternate termination schemes, see LVDS Terminations in *Quick Guide - Output Terminations (AN-953)* located on the RC32514A product page, or contact Renesas for support.

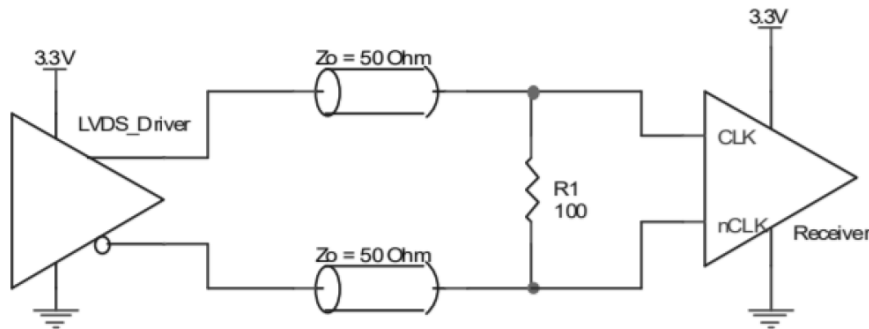


Figure 8. Standard LVDS Termination

4.4.3 AC-Coupled Differential Termination

For any other type of differential protocol, AC-coupling should be used as shown in Figure 9, which assumes a 100Ω differential transmission-line environment. The RC32514A should be programmed in HCSL mode when using AC-coupling, with an appropriate voltage swing selection for the receiver being driven. The device supports a wide range of programmable voltage swing options.

No terminations are needed between the RC32514A and the AC-coupling capacitors. Select the resistors on the receiver side of the AC-coupling capacitors to provide an appropriate voltage bias for the particular receiver. Consult receiver specifications for details. Finally, a 100Ω resistor across the differential pair, located near the receiver attenuates or prevents reflections that may corrupt the clock signal integrity.

It may also be useful to consult *Quick Guide - Output Terminations (AN-953)* located on the RC32514A product page, or contact Renesas for support.

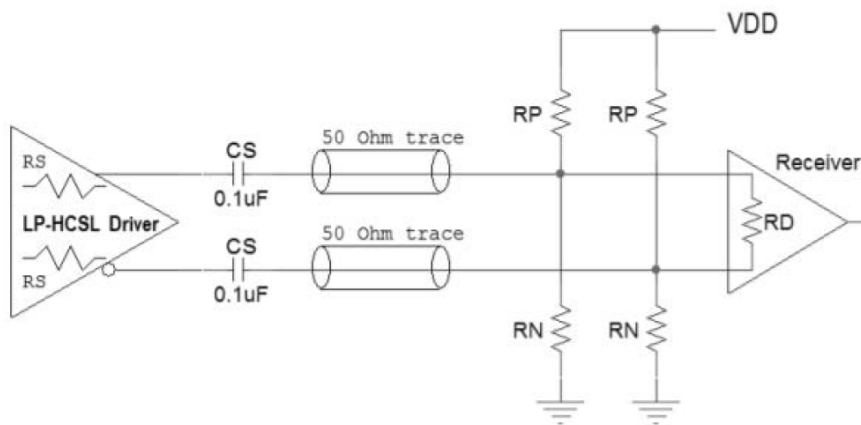


Figure 9. AC-Coupling Termination

5. Architecture

The RC32514A detailed block diagram is shown in Figure 10. Blocks are described in the following chapter. The crystal shown is internal to the package and so the ability to over-drive it is not supported in RC32514A.

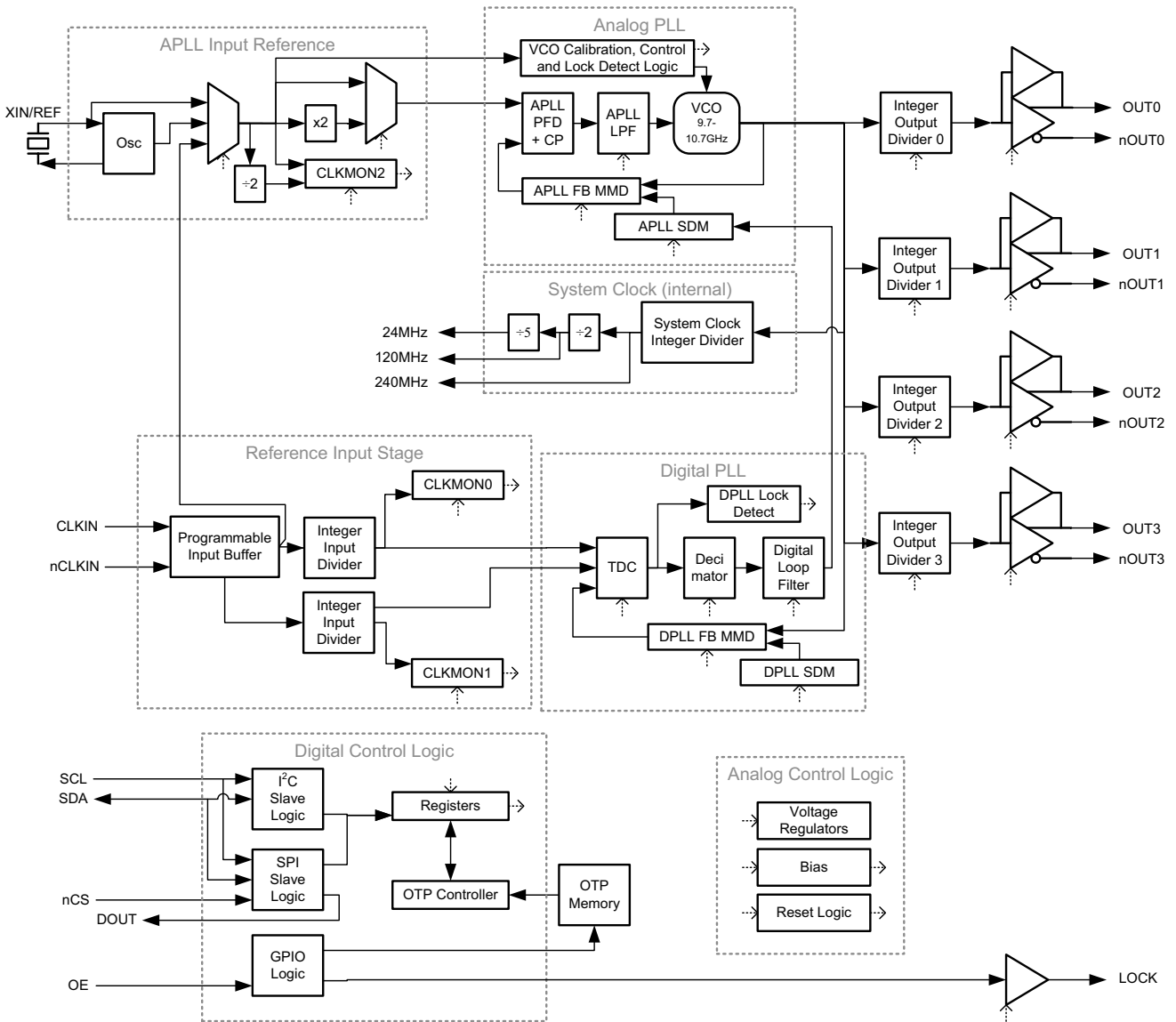


Figure 10. Detailed Block Diagram

5.1 Modes of Operation

5.1.1 Frequency Synthesizer/Digitally Controlled Oscillator (DCO)

When operating as a frequency synthesizer or DCO, the device receives its clock input from a crystal in the same package as the RC32514A die or from CLKIN and nCLKIN. The clock is multiplied-up internally to a high frequency using a fractional-feedback Analog PLL (APLL) that can generate a wide range of frequencies that are unrelated to the crystal frequency. The APLL frequency in turn is used by integer output dividers to generate several output frequencies that are related to each other, but unrelated to the crystal frequency.

In DCO mode, a frequency control word is passed directly from an external processor or FPGA to the fractional APLL. The frequency control word (specifying ppm offset) is written to the write_freq register. This value is scaled according to the APLL feedback divide ratio and then applied to the feedback divider.

A fixed frequency offset can be programmed to compensate for the initial frequency offset of the crystal, if known. This can be programmed in the OTP configuration during final test.

In these modes, the reference clock inputs are unused and the Digital PLL (DPLL) is bypassed. The DPLL logic can also be disabled to save power.

5.1.2 Jitter Attenuator

When operating as a Jitter Attenuator (JA) or frequency translator, the single input reference clock drives a DPLL that monitors the fractional APLL output frequency and generates a phase error. That phase error is filtered by a programmable low bandwidth filter and applied to the fractional APLL.

In this mode, the frequency control word is not available.

The register settings default to select Synthesizer/DCO mode. To enable JA mode, the following mode bits must be set appropriately:

- [en_inbuff](#)
- [out_startup](#)
- [lock_sel](#)
- [dpll_en](#)

6. Blocks

6.1 Device Reset Logic

The Reset Logic holds all internal logic in reset from the initial ramping of the power supply pins until the on-chip voltage regulators have stabilized. After that it controls the sequence of bringing the individual logic blocks out of reset. For information, see [Power-up Sequence](#).

6.1.1 Bias Calibration

The bias circuits provide precision reference voltages needed by other internal circuits. During the [Power-up Sequence](#) these undergo a calibration process. Completion of the calibration process sets [bias_cal_done](#). If in the unlikely event there is an issue, it sets [bias_cal_fail](#), and the startup sequence continues. You can read these bits using the serial port to confirm that the bias calibration succeeded. If bias calibration fails, contact Renesas for assistance.

6.2 Crystal Oscillator

The crystal oscillator (XO) supports a fundamental-mode parallel-resonant crystal that is integrated into the package.

6.3 Reference Clock Input

The reference clock input supports a differential clock supplied on the [CLKIN/nCLKIN](#) pins or a CMOS single-ended clock supplied on the [CLKIN](#) or [nCLKIN](#) pin. Differential vs single-ended operation is controlled by the [CMOS_Sel](#) register bit. When an externally AC-coupled clock is provided, the [en_dc_bias](#) register bit must be set to 1 for differential input or [en_selfbias_cmos](#) must be set to 1 for single-ended inputs. The input pad is disabled by default; when operating in Jitter Attenuator Clock Generator mode, it must be enabled by setting the [en_inbuff](#) register bit to 1.

In differential operation, the supported reference clock frequency range is 1MHz to 800MHz with a worst case duty cycle of 45/55%. In single-ended operation, the supported reference clock frequency range 1MHz to 250MHz.

6.4 Analog Phase Lock Loop

The Analog Phase Lock Loop (APLL) consists of a frequency doubler, a Phase-Frequency Detector (PFD), a Loop Filter (LPF), a Voltage-Controlled Oscillator (VCO), and a feedback divider. Renesas recommends using Renesas' Timing Commander software to provide optimized register setting recommendations for the APLL.

6.4.1 Frequency Doubler

The reference clock frequency is doubled using the frequency doubler before entering into the PFD, enabled by the [en_doubler](#) register bit. Reference clock selection to the frequency doubler, between the XO or [CLKIN](#), can be set by the [apll_ref_sel](#) register bit.

6.4.2 APLL Loop Filter (LPF)

The LPF is a lead-lag filter with the topology shown in Figure 11. This circuit accepts the current from the PFD/CP circuit and provides the filtered control voltage to adjust the frequency of the VCO.

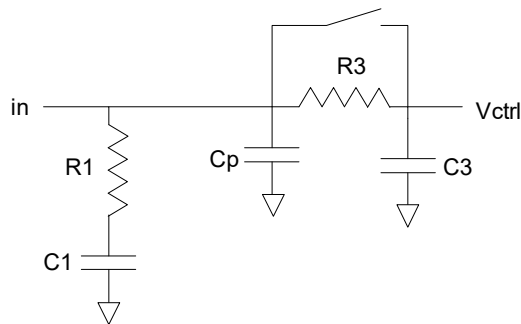


Figure 11. APLL LPF Topology

It is recommended for C1 to have a fixed nominal capacitance of 985pF. The values of R1, Cp, R3, and C3 can be adjusted using the `cnf_LPF_res`, `cnf_LPF_cp`, `cnf_LPF_R3`, and `cnf_LPF_C3` register fields, respectively. The switch bypassing the third pole is controlled by `byp_p3`, and can be enabled only when the APLL feedback divider is set to an integer value. All loop filter components are internal to the device.

The default effective bandwidth (BW) of the APLL with a 60MHz XTAL is 455.05kHz. This is based on an example filter circuit of R1 = 1.6kohm, Cp = 33.33pF, R3 = 1.6kohm, and C3 = 9pF.

6.4.3 Voltage-Controlled Oscillator (VCO)

The VCO is a quad-core LC VCO with a tunable frequency range of 9.7GHz to 10.7GHz across PVT. There is temperature compensation to allow the VCO frequency to remain stable across the operating temperature range regardless of the temperature at which calibration was performed.

6.4.4 APLL Feedback Divider

The APLL Feedback divider consists of two parts. The Multi-Modulus Divider (MMD) performs the actual division of the VCO frequency down to the nominal frequency needed to match the PFD input reference frequency (from frequency doubler). The MMD contains a number of integer divide ratios that are switched between under control of the Sigma-Delta Modulator (SDM) block. This allows a fractional divide ratio to be achieved while also providing noise shaping to minimize the spurs that switching would otherwise cause. The divide ratio is configured using the `apll_fb_div_frac` and `apll_fb_div_int` register fields. The fractional portion of the divide ratio is a 27-bit integer representing the numerator of an M/N fraction. The denominator is fixed at 2^{27} . It is recommended that fractions close to 0, 1, or 1/2 be avoided for best phase noise performance.

6.4.5 APLL Lock Detector

The analog lock detector indicates whether the APLL is locked to an input reference. The current lock status can be read in the `apll_lock_sts` register bit or reflected on one of the general purpose output pins (see GPIOs). The falling edge of the lock status sets the `apll_lol` event bit. This bit remains set until cleared by the user.

The `lck_detect_ref_sel` register field must be programmed according to the input reference frequency range.

6.4.6 Direct DCO Control

When the APLL is in Synthesizer mode, a frequency offset can be programmed using the `write_freq` register field. The frequency adjustment's LSB resolution is 2^{-40} , which translates to approximately 0.91ppt. An offset to compensate for the initial frequency offset of the internal crystal is pre-programmed by Renesas at the factory in `xtal_trim`.

6.5 Reference Clock Outputs

6.5.1 Integer Output Divider (IOD)

There are four independent integer output dividers (IOD0/1/2/3), corresponding to the four differential output clocks, which divide the VCO frequency to the desired output frequency. The integer divide ratio is programmed in the `outdiv_ratio` register field.

When operating in differential mode, the output clocks support a continuous frequency range from 1MHz to 1000MHz. When operating in LVCMOS mode, the output clocks support a continuous frequency range from 1MHz to 180MHz.

The output clock disable (from the `OE` pin or `out_dis`; for details, see [Clock Output Driver](#)) acts synchronously to avoid glitches or runt pulses when disabling or enabling the output.

The maximum skew between any outputs configured for the same output type is shown in [Table 10](#). This is achieved by:

- The output dividers and DPLL feedback divider are automatically synchronized after the PLL is configured on startup, and can be manually synchronized by writing the `divider_sync` register bit following reconfiguration. The output clocks are interrupted for 50µs to 300µs during synchronization, depending on the APLL re-lock time. On power-up, this interruption is hidden because the output drivers are not enabled until after it is complete. However, on a manual synchronization command, this interruption is visible if the outputs are enabled.
- The delay in the clock fanout from the VCO to each divider is balanced to minimize output-output skew.

6.5.2 Clock Output Driver

There are four independent differential clock output drivers supporting receiver-only termination schemes using termination values of 100Ω across OUTx and nOUTx. The output type (HCSL, LVDS, or LVCMOS) is selected by the `out_mode` register field. The output swing level is selected by the `out_cnf_hcsl_swing` or `out_cnf_lvds_amp` register field depending on the output type. In HCSL mode, internal termination of 50Ω resistor to ground on both of OUTx and nOUTx can be enabled as configured by `out_hcsl_term_en`. In CMOS mode, one or both of OUTx and nOUTx can be active as configured by `out_cmos_mode`.

When output x is disabled, OUTx and nOUTx are held low by default. The disabled state can be set to low/high or tristate by setting the `out_dis_state` register field. When output x is enabled, OUTx and nOUTx operate normally.

If a clock output is unused, the corresponding `out_pd` register bit can be set to 1 to power down the output driver logic and tristate the outputs. While powered down, the output cannot be enabled and its output enable is ignored. If a clock output is never used, it can be powered down and the corresponding V_{DDOx} pin can be left unconnected.

6.5.3 Output Enable Control

During the [Power-up Sequence](#), the clock output drivers are powered down (OUTx and nOUTx are tri-stated) until the power supplies have stabilized. Then the output drivers are powered up in the default disabled state (OUTx and nOUTx are both held low).

After the OTP configuration load completes, the clock output drivers can be held disabled until the APLL and/or DPLL locks according to the `out_startup` setting:

- Clock output drivers are disabled until APLL lock asserts
- Clock output drivers are disabled until DPLL lock asserts
- Clock output drivers are enabled immediately

The APLL/DPLL lock status no longer affects the clock output drivers, regardless of the `out_startup` setting.

After startup, the clock output drivers are then user-controllable using output enable control. When the `oe_sel` register bit is set to 1, each clock's output can be independently disabled by setting the corresponding `out_dis` register bit to 1, and enabled by setting `out_dis` to 0. When the `oe_sel` register bit is set to 0, de-assertion of the `OE` input pin disables all powered-up clock output drivers. Assertion of `OE` enables the powered-up clock output

drivers that are not disabled by their corresponding `out_dis` register bits. For more information on polarity and pull-up/pull-down control, see [Output Enable](#).

6.6 DPLL

In jitter attenuator mode, the DPLL and APLL are nested and form a fractional-N PLL architecture. The APLL locks to an input clock from the crystal and generates an output clock of approx. 10GHz. The APLL uses a fractional feedback divider to generate its feedback clock. The fractional feedback divide ratio is dynamically controlled by the DPLL. The DPLL also uses the APLL’s VCO clock to generate the fractional divided DPLL feedback clock. The DPLL fractional feedback clock divide ratio is static during normal operation. The DPLL must be enabled by setting the `dpll_en` register bit to 1.

In synthesizer/DCO modes, the unused DPLL logic may be disabled by setting the `dpll_en` register bit to 0. This saves power and avoids the creation of unnecessary noise within the device.

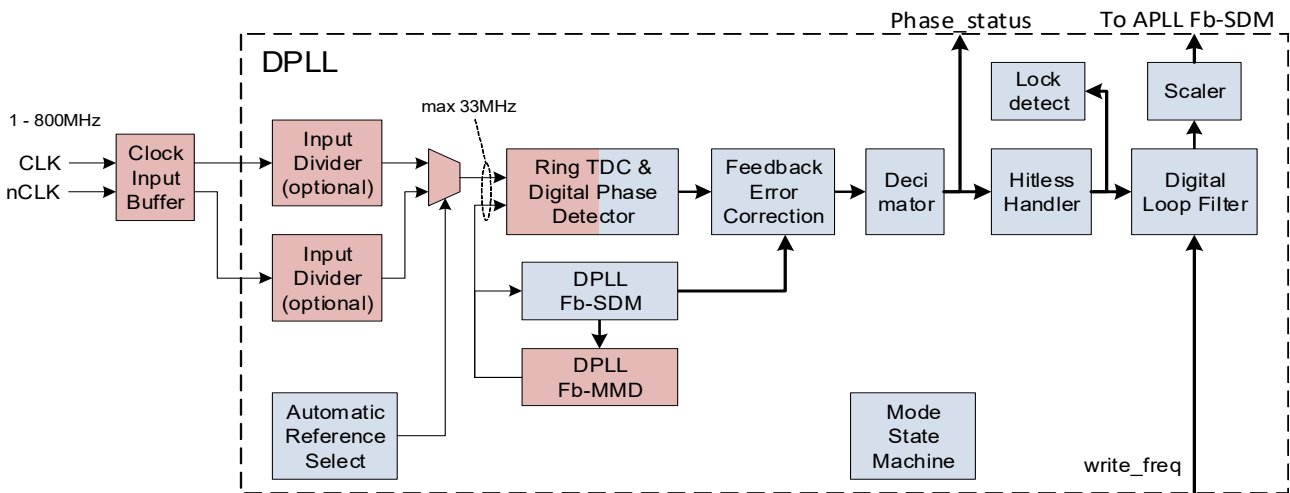


Figure 12. DPLL Block Diagram

6.6.1 Reference Clock Input Buffer

The `CLKIN` input buffer is designed to minimize or eliminate the need for external terminations and still support most common input clock signaling protocols. When operating in differential mode, it supports clocks up to 800MHz. When operating in single-ended LVCMOS mode, it supports clock rates up to 250MHz and the `nCLKIN` input can be used as a second reference clock.

6.6.2 Input Dividers

The TDC supports a maximum clock frequency of 33 MHz. If the reference clock frequency is higher than this limit, it must be divided down below the limit by the Input Divider. The integer divide ratio is controlled by the `id_ratio` register field, and the output is guaranteed to be 50/50 duty cycle.

6.6.3 DPLL Reference Selection

The DPLL can lock to the differential `CLKIN` input, or to either `CLKIN` or `nCLKIN` in single-ended mode. The reference selection can be either automatic or manual which is set by `dpll_ref_sel_mode`.

6.6.3.1 Manual Reference Selection

In manual mode, the reference is selected through the `dpll_ref_sel` field.

6.6.4 Digital Loop Filter

The digital loop filter is a Proportional - Integrator (PI) type filter as shown in Figure 13. It is programmable to a bandwidth of approximately 10Hz to 12kHz.

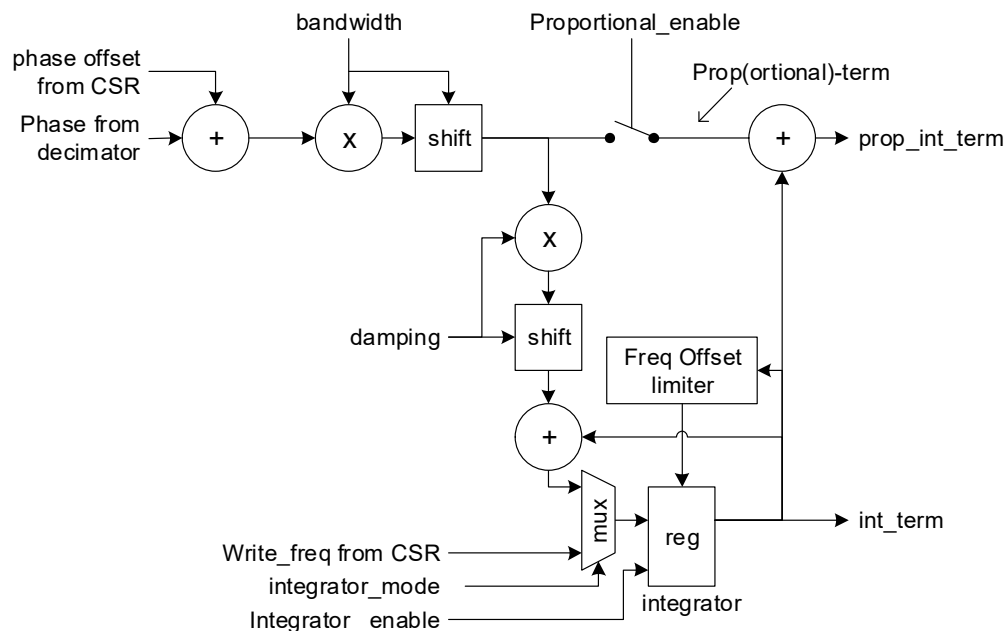


Figure 13. Loop Filter Block Diagram

The phase corrections are mainly done through the proportional path while the frequency offset is done in the integrator. The phase input can come from the phase detector/decimator and an offset from CSR. The phase value gets multiplied by a bandwidth factor. These are programmed in the [normal_bw_mult](#) and [normal_bw_shift](#) register fields. Renesas's Timing Commander software can simplify the settings of these registers based on a target loop bandwidth.

The damping is set by another shifter and multiplier that attenuates the input to the integrator. The damping is programmable such that the frequency domain peaking ranges between 0.02 to 2.0 dB. These are programmed in the [normal_damping_mult](#) and [normal_damping_shift](#) register fields. Renesas's RICBox software can simplify the settings of these registers based on a target maximum gain peaking.

The integrator selects its input from either the damping shifter (in Jitter Attenuator mode) or the programmable Write Frequency ([write_freq](#)) register field (in Synthesizer or DCO modes).

When the DPLL is in Synthesizer/DCO mode, the Write Frequency register input is selected, the Proportional path is disabled, and the output frequency offset is purely the user-programmed value.

In Jitter Attenuator mode, if the [Reference Monitors](#) detects the selected reference to be invalid, the DPLL enters holdover mode (either temporarily while waiting to switch to the other reference, or indefinitely while waiting for a reference to become re-qualified). The DPLL may be forced into holdover mode or freerun mode by writing the [dpll_mode](#) register field to the Holdover or Freerun setting.

When the DPLL enters holdover mode, the integrator is no longer updated and the proportional path is disabled. That way the output frequency is purely based on the integrator value which represents the averaged fractional frequency offset of the input clock while still valid. The integrator range is limited to ± 244 ppm.

When the DPLL enters freerun mode, the integrator is reset to zero and the proportional path is disabled. That way the output frequency is purely based on the APLL the [apll_fb_div_int](#) and [apll_fb_div_frac](#) registers.

Because of the lowest bandwidth of 10Hz, the required data width is 28 bits. The LSB resolution of the frequency adjustment is 2^{-40} , which translates to approximately 0.91ppt.

6.6.5 Lock Detector

The lock detector declares lock when the phase from the phase detector remains within a programmable range (`dppll_lock_thresh`) for a programmable time interval (`dppll_lock_timer`). This indicates that the DPLL is locked to the reference clock input. The current lock status may be read in the `dppll_lock_sts` register bit or reflected on one of the general purpose output pins (see [GPIOs](#)). The falling edge of the lock status sets the `dppll_loi` event bit. This bit remains set until cleared by you.

Two instances of the same scaler are used: one for the APLL feedback SDM and one for the system clock SDM.

6.6.6 DPLL Feedback Divider

The Feedback Divider is a multi-modulus divider which divides the APLL's output frequency of 9.7 to 10.7 GHz down to a frequency between 1MHz and 33MHz, to match the (pre-divided) reference clock. The divide ratio is dynamically controlled by the DPLL FB-SDM. The divided feedback clock has a phase error of up to 1 cycle of the APLL clock.

6.6.7 DPLL State Machine

The DPLL can work in 6 different states; Freerun, Acquire, Normal, Holdover, Hitless_switch, and Write_frequency. The state selection and transitions can either be manual or automatic which is set in register `dppll_mode`. In manual mode, the states Freerun, Holdover and Write_frequency can be forced in the register `dppll_mode`. If the automatic/normal mode is selected, the state machine follows the state transitions in [DPLL State Machine Diagram](#). The thick arrows in the state diagram indicate global state transitions that take priority over the thin state transition arrows.

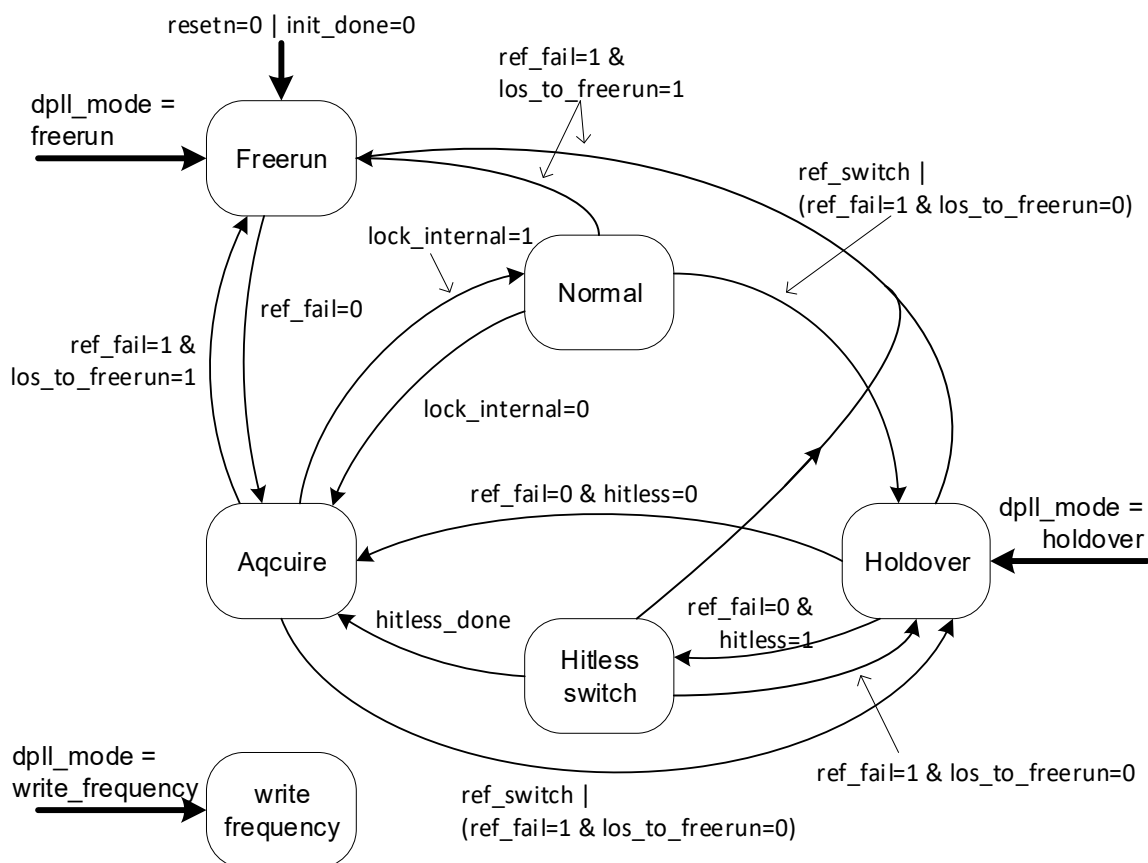


Figure 14. DPLL State Machine Diagram

6.6.7.1 Freerun

During power-up reset, VCO calibration or synthesizer mode, the DPLL is in the Freerun state. In this state, no reference clock is used and the output clocks are tracking the APLL reference clock (crystal). If `init_done` is low, the state machine goes in the Freerun state regardless of the value of `dppll_mode`.

6.6.7.2 Acquire

When there is at least one qualified reference, the DPLL is tracking the selected qualified reference clock with the acquisition bandwidth and damping settings.

If the reference clock is disqualified and no other qualified reference clock is available, the state machine goes either to the Freerun state or to the Holdover state dependent on the value of the CSR bit `los_to_holdover`.

When the lock-detector detects a lock, it reports the 'locked' status in the CSR and the state machine goes to the Normal state.

6.6.7.3 Normal

In this state, the DPLL is tracking the selected reference clock with the normal locking bandwidth and damping settings.

If the selected reference clock is disqualified or a reference switch occurs, state machine goes to the Holdover state.

6.6.7.4 Holdover

In this state, the DPLL frequency can be held at the instantaneous value or a value that is low pass filtered and/or restored from the holdover history registers. This can be selected through the CSR register

[DPLL_HOLDOVER_CNFG Register](#). The initial holdover accuracy is less than 1ppb.

6.6.7.5 Hitless Switch

At a hitless reference switch or a hitless transition from the Holdover state, the TDC of the DPLL measures the phase offset between the (newly) selected reference clock and the feedback clock. This offset is stored in the phase offset register. As a result, the output clocks experience a minimal phase transient because of the reference switch or coming out of Holdover. After the hitless switch procedure has finished, the state machine transitions to the Acquire state unless the reference clock fails.

6.6.7.6 Write Frequency

In this mode the DPLL is not tracking any reference clock. The DPLL output frequency offset is directly controlled by the value in the CSR [write_freq](#) register.

6.6.7.7 Manual Modes

The state machine can be forced to the Freerun, Holdover, and Write_frequency states by the CSR register [dppll_mode](#). These state transitions are indicated by the thick arrows in the state diagram.

6.7 Reference Monitors

There is one reference monitor core for each reference. The monitor core consists of a short-term (Loss Of Signal) monitor and a medium-term (Activity) monitor.

- The LOS monitor detects missing edges over a window of several reference clock periods. For the best accuracy, it is recommended to program the window to be equal to at least 8 times that of the measuring clock period. The measuring clock period for the LOS monitor is the system clock.
- The activity monitor measures the reference over a nominal 10ms time window to achieve ~1ppm granularity with a ~216MHz measurement clock.

There are short-term clock monitors on the post-Input Divider reference clock inputs (LOSMON0 and LOSMON1) and the crystal clock input (LOSMON2). There are activity monitors only on the post-Input Divider reference clock

inputs (ACTMON0 and ACTMON1). The implementation structure of the monitors are the same but with different configuration settings.

The LOS and Activity monitors nominal value should be programmed as follows:

- LOS monitor – $\text{sys_clk_2x} / \text{ref clock}$, where ref clock should be at least 8x less than sys_clk_2x for best results.
- Activity monitor – N / T , where N is the closest to 10ms that can be achieved with an integer number of monitored clock edges, and T is the period of the measuring clock. The resulting accuracy of the measurement is T / N (for a nominal window of 10ms and a system clock of 108MHz, this means the accuracy is 0.926ppm).

6.7.1 Comparator

All monitors have both reject and accept threshold values that are all programmable in CSRs ([los_nom_num](#), [los_acc_margin](#), [los_rej_margin](#), [act_nom_num](#), [act_acc_margin](#) and [act_rej_margin](#)). The nominal value is compared with the nominal value +/- [accept_margin](#) or [reject_margin](#).

When the counter value exceeds the reject threshold, the internal “failure counter” increments, and the internal “good counter” value resets it to 0. When the counter value is within the accept threshold, the “failure counter” resets to 0 and the “good counter” increments.

When the “good counter” reaches [los_good_times](#) for the LOS monitor, or the value of 1 for the Activity monitor, the monitor’s status ([los_sts](#) or [act_sts](#)) get cleared, indicating a valid reference.

When the “failure counter” reaches [los_fail_times](#) for the LOS monitor, or the value of 1 for the Activity monitor, the monitor’s status ([los_sts](#) or [act_sts](#)) get set, indicating an out-of-spec reference.

6.7.2 Alarm and Interrupt

The combinational OR of the LOS monitor’s [los_sts](#) and Activity monitor’s [act_sts](#) outputs are used to qualify/disqualify the reference, unless masked by [los_fail_mask](#) and [act_fail_mask](#) bits. It is also possible to force a reference to be disqualified by setting the [ref_disable](#) control bit.

When the status ([los_sts](#) or [act_sts](#)) changes from valid to invalid, the corresponding [los_evt](#) or [act_evt](#) bit gets set and can be cleared only by a CSR write, unless the underlying failing condition is still there, in which case the write does not take effect.

6.8 OTP

The RC32514A supports four user-definable, non-volatile start-up configurations stored in an internal OTP (one-time programmable) memory. Each configuration is capable of storing values for all write-able configuration registers. The configuration is selected by the values of the [Configuration Select Pins](#) latched at power-up. The serial interfaces are inactive until all register values specified in the selected configuration are written.

6.9 Serial Interfaces

I²C or SPI operation is selected by the `ssi_enable` register field which defaults to I²C mode. The serial interfaces are inactive until the OTP load completes during the power-up sequence.

6.9.1 Paging

You 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 another part comes from an internal page register in each serial port. Figure 15 shows how page register and offset bytes from each serial transaction interact to address a register within the RC32514A.

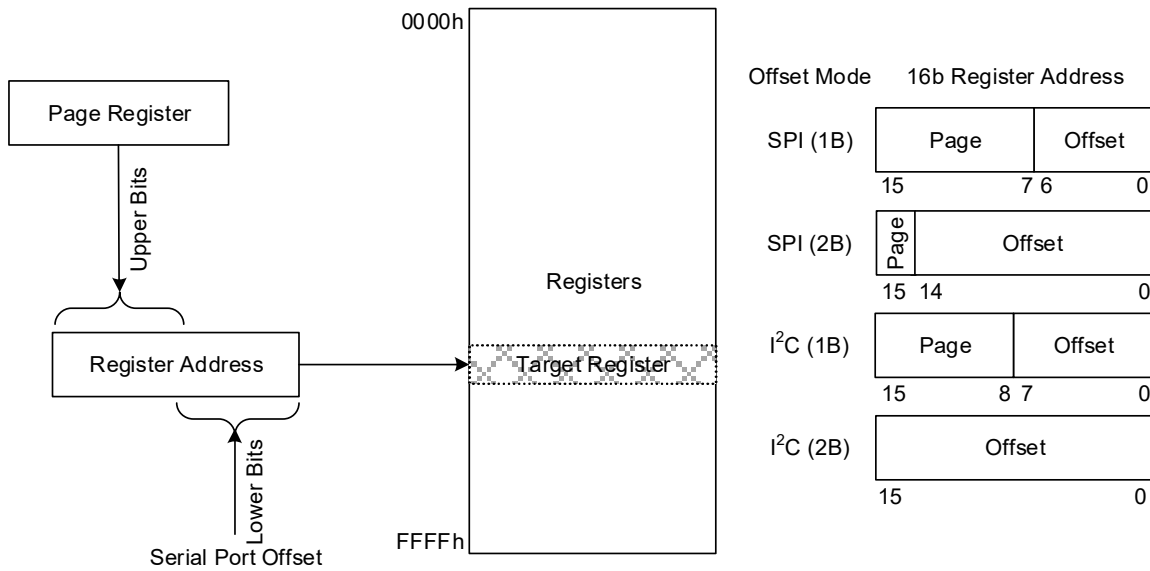


Figure 15. Register Addressing Modes Using Serial Port

6.9.2 I²C Slave

The I²C slave protocol of the RC32514A complies with the I²C specification, version UM10204 Rev.6 – 4 April 2014. In the following description, SCL refers to the `SCL_SCLK` pin and SDA refers to the `SDA_SDI(O)` pin.

Figure 16 shows the sequence of states on the I²C SDA signal for the supported modes of operation.

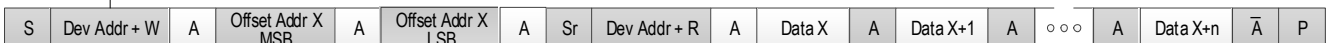
Sequential 8-bit Read



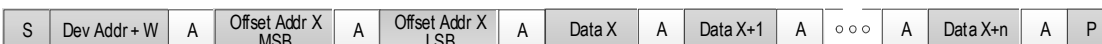
Sequential 8-bit Write



Sequential 16-bit Read



Sequential 16-bit Write



- From master to slave
- From slave to master
- S = Start
- Sr = Repeated start
- A = Acknowledge
- \bar{A} = Non-acknowledge
- P = Stop

Figure 16. I²C Slave Sequencing

The Dev Addr shown in the figure represents the I²C bus address that the device responds to. This 7-bit value in the `i2c_addr` register field defaults to 0x09 if not programmed using the OTP load, or controlled through pins, as per Table 22.

The selection of 1-byte (1B) or 2-byte (2B) offset addressing must also be configured using the `ssi_addr_size` register field. These offsets are used in conjunction with the page register to access registers internal to the device (see Figure 15). Because the I²C 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 0xFC. 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.

Note: I²C burst mode operation is recommended 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 I²C burst access. Bursts can be of greater length if required but must not extend beyond the end of the register page (Offset Addr 0xFF in 1B mode, no limit in 2B mode). An internal address pointer is incremented automatically as each data byte is written or read.

Figure 3 and Table 14 show the detailed timing on the interface. 100kHz (Standard mode), 400kHz (Fast mode), and 1MHz (Fast mode Plus) operation are supported. The output slew rate is set according to the speed selected by the `i2c_speed` register field.

The I²C interface operating at 1MHz supports a DCO update rate of approximately 16k updates per second.

6.9.2.1 I²C 1-byte (1B) Addressing Example

RC32514A I²C 7-bit I²C address is 0x09 with LSB = R/W

Example write 0x8003 to register 0x20:

```
12* FC 00 00 00 00      #Set Page Register, *I2C Address is left-shifted one bit.
12 20 03 80             #Write data 0x8003 to 0x20
```

Example read from register 0x168

```
12* FC 00 01 00 00      #Set Page Register, *I2C Address is left-shifted one bit.
12 68                   #Set I2C pointer to 0x168, I2C instruction should use "No Stop".
13 <read back data>     #Send address with Read bit set.
```

6.9.2.2 I²C 2-byte (2B) Addressing Example

RC32514A I²C 7-bit I²C address is 0x09 with LSB = R/W

Example write 0x8003 to register 0x20:

```
12 00 20 03 80          #Write data 0x8003 to 0x0020
```

Example read from register 0x168:

```
12 01 68                #Set I2C pointer to 0x0168, * I2C instruction should use "No Stop".
13 <read back data>     #Send address with Read bit set.
```

6.9.3 SPI Slave

In the following description, nCS refers to the nCS pin, SCLK refers to the SCL_SCLK pin, SDI SDIO refer to the SDA_SDI(O) pin, and SDO refers to the SDO pin.

The RC32514A supports 4-wire or 3-wire SPI operation as a selectable protocol on the serial port. The 3-wire or 4-wire mode is selected by the `spi_3wire` register bit. In 4-wire mode, there are separate data in (to the RC32514A) and data out signals (SDI and SDO respectively). In 3-wire mode, the SDIO signal is used as a single, bidirectional data signal.

When reading, a configurable number of dummy bytes can be read before the requested data byte(s) as controlled by the `spi_dummy_en` and `spi_dummy_size` register fields. When the SPI clock is faster than the system clock frequency divided by 4, at least 1 dummy byte must be enabled. Writes do not use dummy bytes.



Figure 17. SPI Sequencing

Figure 17 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. The read sequence is shown without dummy bytes (`spi_dummy_en` set to 0). If 1 dummy byte were enabled, then the data bits labeled Data byte from Address provided would be zero, the data bits labeled Data byte from Address + 1 would become Data byte from Address provided, and they would be followed by another 8 bits containing Data byte from Address + 1.

SPI operation can be configured for the following settings through register fields:

- 1-byte (1B) or 2-byte (2B) offset addressing (`ssi_addr_size`) (see Figure 15)
- 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 0x7C 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 the upper 1-bit is fixed to b'0.
- Data sampling on falling or rising edge of SCLK (`spi_clk_sel`)
- Output (read) data positioning relative to active SCLK edge (`spi_del_out`)

Note: SPI burst mode operation is recommended 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 of greater length 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.

SPI timing is shown in Figure 4 and Table 16.

The SPI interface operating at 20MHz supports a DCO update rate of approximately 400k updates per second.

6.9.3.1 SPI 1-byte (1B) Addressing Example

Example write “50” to register 0xE4:

```
7C 80 00 00 00      #Set Page register
64* 50              #*MSB is 0 for write transactions
```

Example read from 0x24:

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

6.9.3.2 SPI 2-byte (2B) Addressing Example

Example write “50” to register 0x124

```
01* 24 50          #*MSB is 0 for write transactions
```

Example read from 0xE4:

```
80* E4 00          #*MSB is set, so this is a read command
```

6.10 GPIOs

6.10.1 Lock Status

The **LOCK** output pin reflects one of these conditions as selected by the `lock_sel` register field:

- APLL lock
- DPLL lock
- Reference #0 loss-of-signal
- Crystal loss-of-signal
- Reference #0 activity monitor status
- Reference #0 ref_invalid status
- Device Interrupt (Refer to the `device_int_sts` register bit)
- Device ready (OTP load is complete and the serial port is active)
- Logic low
- Logic high

The polarity of **LOCK** is controlled by the `lock_pol` register bit. Internal pull-up resistors can be enabled by setting the `lock_pu` and the and pull-down resistors by enabling the `lock_pd` register bits. The output can be tri-stated by setting the `lock_hiz` register bit. **LOCK** can be configured as an open-drain output by setting the `lock_od` register bit.

The **LOCK** output driver is disabled until the OTP configuration load completes, allowing it to function as one of the [Configuration Select Pins](#).

6.10.2 Serial Data Out

When the serial port is configured for SPI 4-wire mode, the **SDO** pin is the data out. When the serial port is configured for either I²C mode or SPI 3-wire mode, the **SDO** pin reflects one of the following conditions as selected by the `sdo_sel` register field:

- APLL lock
- DPLL lock
- Reference #0 loss-of-signal
- Crystal loss-of-signal
- Reference #0 activity monitor status

- Reference #0 ref_invalid status
- Device Interrupt (Refer to the [device_int_sts](#) register bit)
- Device ready (OTP load is complete and the serial port is active)
- Logic low
- Logic high

The polarity of [SDO](#) is controlled by the [sdo_pol](#) register bit. Internal pull-up resistors can be enabled by setting the [sdo_pu](#) register bits and the pull-down resistors can be enabled by setting the [sdo_pd](#) register bits. The output can be tri-stated by setting the [sdo_hiz](#) register bit. [SDO](#) can be configured as an open-drain output by setting the [sdo_od](#) register bit.

In SPI 4-wire mode, the [sdo_pol](#), [sdo_pu](#), [sdo_pd](#), [sdo_hiz](#), and [sdo_od](#) register bits must be set to 0 (the default reset value).

The [SDO](#) output driver is disabled until the OTP configuration load completes, allowing it to function as one of the [Configuration Select Pins](#).

6.10.3 Output Enable

After the clock output drivers become user controllable during the startup sequence, the [OE](#) input pin controls the output enable of the output drivers if appropriately configured (for details, see [Output Enable Control](#)).

The polarity of the [OE](#) input is controlled by the [oe_pol](#) register bit. Internal pull-up resistors can be enabled by setting the [oe_pu](#) register bits and the pull-down resistors can be enabled by setting the [oe_pd](#) register bits.

The [OE](#) input also can function as one of the [Configuration Select Pins](#).

6.11 Power-up Sequence

There are no power-up/down sequencing requirements on the power supply pins, or between the power supply pins and input signals. There are no external reset sequencing requirements.

After VCO calibration, the output dividers, APLL feedback divider and DPLL feedback divider are synchronized. The VCO output clock is gated, the divider resets are de-asserted, and the VCO output clock is ungated. Each divider outputs a rising edge on the first cycle of the VCO clock.

After the APLL locks (generally within 200us), the reference clock monitors are enabled.

In synthesizer/DCO mode, the enabled output drivers are set to normal operation and the output clocks begin to toggle. The power-up sequence is complete.

In JA mode, the DPLL is allowed to move to the Acquire state (by [dpll_init_done](#)) once the reference clock is qualified. After the DPLL locks, the enabled output drivers are set to normal operation and the output clocks begin to toggle. The power-up sequence is complete.

Setting the [divider_sync](#) register bit triggers the divider synchronization sequence and waits for the APLL to relock. The output drivers are disabled during this time.

Setting the [apll_reinit](#) bit restarts the power-up sequence from the VCO calibration step. The output drivers are disabled and are re-enabled after the APLL or DPLL locks as in the regular power-up sequence.

6.11.1 Configuration Select Pins

When the power-on-reset de-asserts, the logic level of the following pins are latched into the [gpio_at_startup](#) register field:

- [LOCK](#)
- [OE](#)
- [SDA_SDI\(O\)](#)
- [SDO](#)

- **nCS**

A 2-bit index of the OTP user configuration is selected according to the `config_sel` register field (this field is intended to be written in the OTP Common Configuration), which determines the OTP user configuration to use. The `config_sel` register also determines how the lower two bits of the I²C address (according to the `i2c_addr` register field) are selected, if applicable.

Table 22. OTP and I²C Address User Configuration Selection

| <code>config_sel</code> [3:0] | Configuration Index [1] | Configuration Index [0] | I ² C Address [1] | I ² C Address [0] |
|-------------------------------|-------------------------|-------------------------|------------------------------|------------------------------|
| 0x0 | 0 | 0 | <code>i2c_addr</code> [1] | <code>i2c_addr</code> [0] |
| 0x1 | 0 | 1 | <code>i2c_addr</code> [1] | <code>i2c_addr</code> [0] |
| 0x2 | 1 | 0 | <code>i2c_addr</code> [1] | <code>i2c_addr</code> [0] |
| 0x3 | 1 | 1 | <code>i2c_addr</code> [1] | <code>i2c_addr</code> [0] |
| 0x4 (default) | OE | LOCK | nCS | SDO |
| 0x5 | SDO | LOCK | nCS | OE |
| 0x6 | SDO | OE | nCS | LOCK |
| 0x7 | SDA_SDI(O) | SCL_SCLK | <code>i2c_addr</code> [1] | <code>i2c_addr</code> [0] |
| 0x8 | nCS | LOCK | SDO | OE |
| 0x9 | nCS | OE | SDO | LOCK |
| 0xA | nCS | SDO | OE | LOCK |
| 0xB | nCS | SDA_SDI(O) | SDO | LOCK |
| 0xC | nCS | SCL_SCLK | OE | SDA_SDI(O) |
| 0xD | nCS | SDA_SDI(O) | OE | SCL_SCLK |
| 0xE | SDA_SDI(O) | LOCK | OE | nCS |
| 0xF | SDA_SDI(O) | SDO | OE | LOCK |

The **LOCK**, **SDA_SDI(O)**, **SDO**, **nCS**, and **OE** levels at power-up can be selected by connecting pull-up or pull-down resistors on the board. When I²C mode is selected, **SCL_SCLK** and **SDA_SDI(O)** must have a pull-up resistor and should not be used for OTP configuration or I²C address selection.

If only two pin selectable user configurations are required, any one of the five inputs can be used as the select by programming two pairs of user configurations to use the same blocks, such that the value of the uncontrolled input pin is irrelevant. For example, to use only the **LOCK** pin, `config_sel` can be set to 0x8 with user configurations 0 and 2 programmed equivalently and user configurations 1 and 3 programmed equivalently.

6.11.2 Divider Synchronization

The output dividers must be synchronized with each other to align the output clocks to the common multiple of their divide ratios. The DPLL feedback divider must be synchronized to provide a deterministic phase relationship between the input reference clock and the output clocks in JA mode; the input-to-output skew for a particular device configuration must be deterministic across PVT. Similarly, when the APLL reference is the input reference clock (selected by `apll_ref_sel`) in synthesizer mode, the APLL feedback divider must be synchronized to provide the deterministic input-to-output phase relationship. If the APLL reference is the crystal, synchronizing the APLL feedback divider is not necessary but causes the APLL to lose lock and re-lock; in JA mode, the DPLL also loses lock and relock.

6.11.2.1 Divider Synchronization Procedure

The Divider Sync Procedure is illustrated in [Figure 18](#).

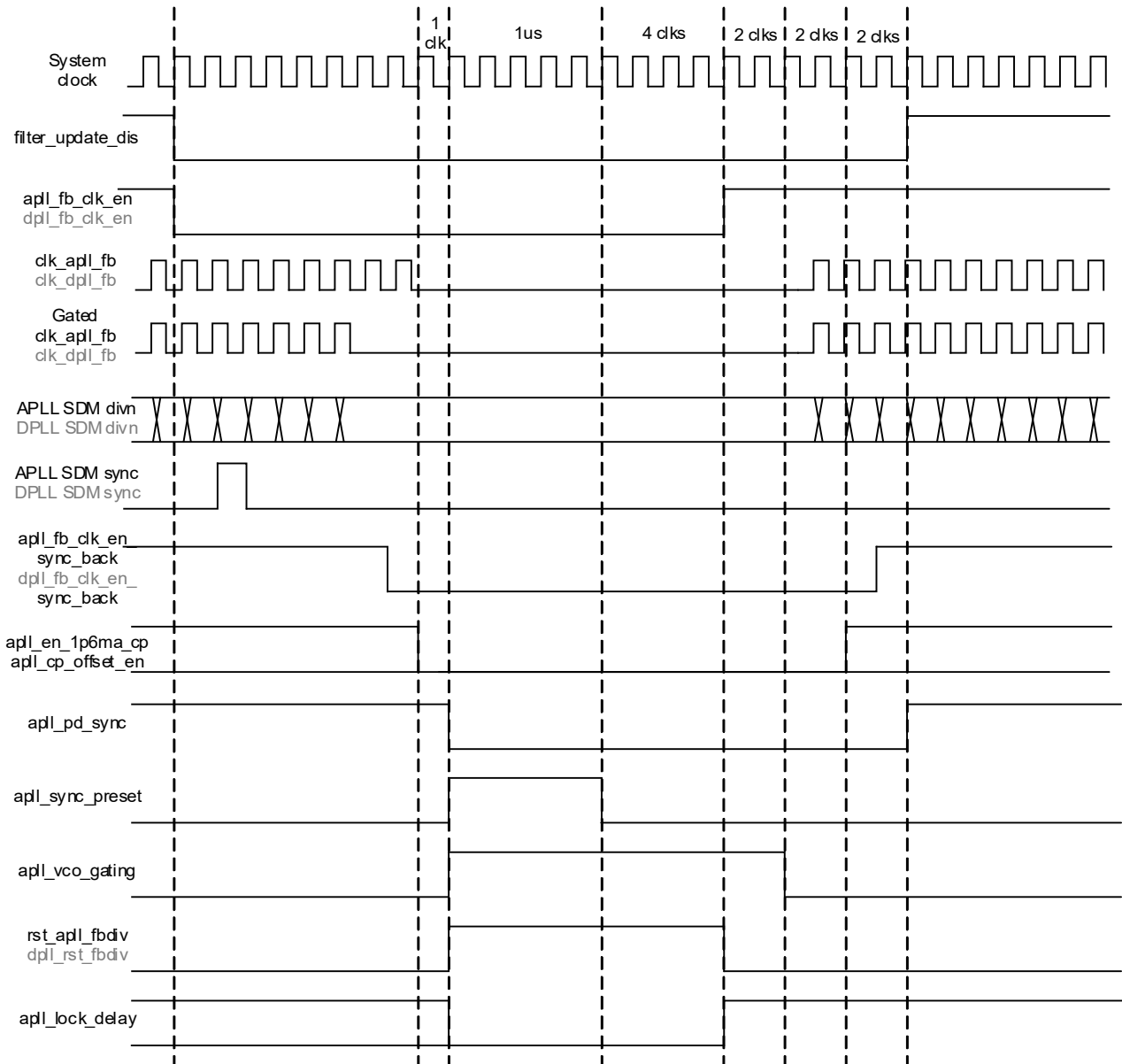


Figure 18. Divider Synchronization Procedure

6.11.3 Maximum PLL Lock Times

When operating in clock synthesizer mode, the maximum start-up and APLL lock time is 10ms. This is measured from the last voltage rail achieving nominal limits to the output clock being stable (no locking transients, no clock interruptions).

When in jitter attenuator mode, the maximum start-up and DPLL lock time is 1 second. This may be achieved by increasing the loop filter bandwidth while acquiring lock by setting [bw_damp_sw](#) to 1, and setting [acquire_bw_shift](#), [acquire_bw_mult](#), [acquire_damping_shift](#) and [acquire_damping_mult](#) to different values than [normal_bw_shift](#), [normal_bw_mult](#), [normal_damping_shift](#) and [normal_damping_mult](#). Faster lock times can also be achieved by disabling the activity monitor for the input reference qualification.

7. Register Organization

7.1 Register Block Offsets

Table 23. Register Block Offset

| Block Offsets | Block Name | Register Block Address Table Links | Register Block Description |
|---------------|------------|---|---------------------------------|
| 0x00 | GLOBAL | Global Block Register Offsets | GLOBAL Registers |
| 0x20 | INT | Interrupt Block Register Offsets | INT Registers |
| 0x30 | LOSMON[0] | LOS Monitor Block Register Offsets | LOSMON Registers |
| 0x40 | LOSMON[1] | LOS Monitor Block Register Offsets | LOSMON Registers ^[1] |
| 0x50 | LOSMON[2] | LOS Monitor Block Register Offsets | LOSMON Registers ^[1] |
| 0x60 | ACTMON[0] | ACT Monitor Block Register Offsets | ACTMON Registers |
| 0x80 | ACTMON[1] | ACT Monitor Block Register Offsets | ACTMON Registers ^[1] |
| 0xA0 | DPLL | DPLL Block Register Offsets | DPLL Registers |
| 0xE0 | TDC | TDC Block Register Offsets | TDC Registers |
| 0xF0 | SYSDIV | System Clock Divider Block Register Offsets | SYSDIV Registers |
| 0xF4 | BIAS | Bias Block Register Offsets | BIAS Registers |
| 0xF8 | XO | Crystal Block Register Offsets | XO Registers |
| 0x100 | OUT[0] | Clock Output Block Register Offsets | OUT Registers |
| 0x108 | OUT[1] | Clock Output Block Register Offsets | OUT Registers ^[1] |
| 0x110 | OUT[2] | Clock Output Block Register Offsets | OUT Registers ^[1] |
| 0x118 | OUT[3] | Clock Output Block Register Offsets | OUT Registers ^[1] |
| 0x120 | REF[0] | Clock Reference Addresses | REF Registers |
| 0x124 | REF[1] | Clock Reference Addresses | REF Registers ^[1] |
| 0x130 | GPIO | GPIO Block Register Offsets | GPIO Registers |
| 0x140 | SSI | SSI Block Register Offsets | SSI Registers |
| 0x150 | APLL | APLL Block Register Offsets | APLL Registers |
| 0x190 | INP | Clock Input Block Register Offsets | INP Registers |
| 0x1D0 | Rsvd | Reserved | - |

[1] Register block functionality is the same, so the description is not duplicated.

7.2 Register Block Address Maps

7.2.1 Global Register Block Address Map

The Global Register block has a base address of 0x00. The addresses shown in [Table 24](#) are offsets starting from this base address.

Table 24. Global Block Register Offsets

| Offset | Size | Register Name | Register Description |
|--------|-------|--------------------------------------|--|
| 0x00 | hword | VENDOR_ID Register | Device vendor identification code. Address map for this block of registers: Global Block Register Offsets. |
| 0x02 | hword | DEVICE_ID Register | Device-specific identification code. Address map for this block of registers: Global Block Register Offsets. |
| 0x04 | hword | DEVICE_REV Register | Device revision identification information. Address map for this block of registers: Global Block Register Offsets. |
| 0x06 | hword | DEVICE_PGM Register | Identifies any factory OTP pre-programmed configuration. Address map for this block of registers: Global Block Register Offsets. |
| 0x08 | byte | DEVICE_CNFG Register | Device overall configuration settings. Address map for this block of registers: Global Block Register Offsets. |
| 0x0A | byte | DEV_RESET Register | Device reset commands. Address map for this block of registers: Global Block Register Offsets. |
| 0x0C | hword | SW_RESET Register | Software reset command. Address map for this block of registers: Global Block Register Offsets. |
| 0x0E | hword | CLOCK_GATE Register | Clock gating control. Setting of any of the bits in this register stops the internal clocks to the indicated logic block(s). The Renesas Timing Commander Software automatically determines which logic can be disabled for a specific configuration. Contact Renesas if further details are needed. |
| 0x10 | byte | DEVICE_STS Register | Device status. Address map for this block of registers: Global Block Register Offsets. |

7.2.2 Interrupt Register Block Address Map

The Interrupt block has a base address of 0x20. The addresses shown below are offsets starting from this base address.

Table 25. Interrupt Block Register Offsets

| Offset | Size | Register Name | Register Description |
|--------|-------|----------------------------------|--|
| 0x00 | hword | INT_EN Register | Interrupt Enable control. Address map for this block of registers: Interrupt Block Register Offsets. |
| 0x02 | hword | INT_STS Register | Interrupt Status. Address map for this block of registers: Interrupt Block Register Offsets. |

7.2.3 Loss of Signal Monitor Register Block Address Map

The LOS Monitor 0 block has a base address of 0x30. The LOS Monitor 1 block has a base address of 0x40. The LOS Monitor 2 block has a base address of 0x50. The addresses shown below are offsets starting from this base address. Note that before reprogramming a Loss of Signal Monitor block, the corresponding [losmon0_sw_rst](#), [losmon1_sw_rst](#), or [losmon2_sw_rst](#) bit should be set. When programming is done, it should then be cleared.

Table 26. LOS Monitor Block Register Offsets

| Offset | Size | Register Name | Register Description |
|--------|-------|---|---|
| 0x00 | byte | LOSMON_STS Register | LOS Monitor Status. Address map for this block of registers: LOS Monitor Block Register Offsets. |
| 0x01 | byte | LOSMON_EVENT Register | LOS Monitor Event Status. Address map for this block of registers: LOS Monitor Block Register Offsets. |
| 0x02 | byte | LOSMON_QUAL Register | LOS Monitor Qualify Counter Configuration. Address map for this block of registers: LOS Monitor Block Register Offsets. |
| 0x04 | hword | LOSMON_WINDOW Register | LOS Monitor Window Configuration. Address map for this block of registers: LOS Monitor Block Register Offsets. |
| 0x08 | word | LOSMON_THRESH Register | LOS Monitor Threshold Configuration. Address map for this block of registers: LOS Monitor Block Register Offsets. |
| 0x0C | word | LOSMON_NOMINAL Register | LOS Monitor Nominal Number Configuration. Address map for this block of registers: LOS Monitor Block Register Offsets. |

7.2.4 Activity Monitor Register Block Address Map

The ACT Monitor 0 block has a base address of 0x60. The LOS Monitor 1 block has a base address of 0x80. The addresses shown below are offsets starting from this base address. Note that before reprogramming an Activity Monitor, the corresponding [actmon0_sw_rst](#) or [actmon1_sw_rst](#) bit should be set. Once programming is done, it should then be cleared.

Table 27. ACT Monitor Block Register Offsets

| Offset | Size | Register Name | Register Description |
|--------|-------|---|---|
| 0x00 | byte | ACTMON_STS Register | Activity Monitor Status. Address map for this block of registers: ACT Monitor Block Register Offsets. |
| 0x01 | byte | ACTMON_EVENT Register | Activity Monitor Event Status. Address map for this block of registers: ACT Monitor Block Register Offsets. |
| 0x04 | word | ACTMON_WINDOW Register | Activity Monitor Window Configuration. Address map for this block of registers: ACT Monitor Block Register Offsets. |
| 0x08 | dword | ACTMON_THRESH Register | Activity Monitor Threshold Configuration. Address map for this block of registers: ACT Monitor Block Register Offsets. |
| 0x10 | word | ACTMON_NOMINAL Register | Activity Monitor Nominal Number Configuration. Address map for this block of registers: ACT Monitor Block Register Offsets. |

7.2.5 DPLL Register Block Address Map

The Digital PLL block has a base address of 0xA0. The addresses shown below are offsets starting from this base address.

Table 28. DPLL Block Register Offsets

| Offset | Size | Register Name | Register Description |
|--------|-------|---|---|
| 0x00 | byte | DPLL_REF_FB_CNFG Register | DPLL Ref and Fb Clock Configuration. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x01 | byte | DPLL_MODE Register | Digital PLL mode control. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x02 | byte | DPLL_DECIMATOR Register | Decimator configuration control. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x03 | byte | DPLL_TRIM_OFFSET Register | DPLL Crystal trim offset. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x04 | hword | DPLL_HOLDOVER_CNFG Register | Holdover Configuration. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x06 | hword | DPLL_BANDWIDTH Register | DPLL Bandwidth configuration. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x08 | hword | DPLL_DAMPING Register | DPLL Damping control. Address map for this block of registers: DPLL Block Register Offsets |
| 0x0C | word | DPLL_PHASE_SLOPE_LIMIT Register | DPLL Phase Slope Limit control. Address map for this block of registers: DPLL Block Register Offsets |
| 0x10 | dword | DPLL_FB_DIV_NUM Register | DPLL Feedback Fraction Numerator value. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x18 | dword | DPLL_FB_DIV_DEN Register | DPLL Feedback Fraction Denominator value. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x20 | hword | DPLL_FB_DIV_INT Register | DPLL Feedback Integer value. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x22 | hword | DPLL_FB_CORR Register | DPLL Feedback Correction Configuration. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x24 | word | DPLL_PHASE_OFFSET Register | DPLL Phase Offset configuration. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x28 | word | DPLL_WRITE_FREQ Register | DPLL Write Frequency command. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x2C | word | DPLL_LOCK Register | DPLL Lock Detection control. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x30 | byte | DPLL_TDC_DELAY Register | DPLL TDC Delay Control. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x31 | byte | DPLL_STS Register | DPLL Status. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x32 | byte | DPLL_EVENT Register | DPLL Event status. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x33 | byte | DPLL_LOL_CNT Register | DPLL Loss-of-Lock Event Counter. Address map for this block of registers: DPLL Block Register Offsets. |
| 0x34 | word | Reserved | Reserved |
| 0x38 | word | Reserved | Reserved |
| 0x3C | byte | Reserved | Reserved |

7.2.6 TDC Register Block Address Map

The TDC block has a base address of 0xE0. The addresses shown below are offsets starting from this base address.

Table 29. TDC Block Register Offsets

| Offset | Size | Register Name | Register Description |
|--------|-------|---|---|
| 0x00 | hword | Reserved | Reserved |
| 0x02 | byte | TDC_REF_DIV_CNFG Register | TDC reference divider control. Address map for this block of registers: TDC Block Register Offsets. |
| 0x03 | byte | TDC_FB_SDM_CNFG Register | TDC internal APLL Feedback Divider SDM control. Address map for this block of registers: TDC Block Register Offsets. |
| 0x04 | byte | TDC_FB_DIV_INT Register | TDC internal APLL Feedback Divider Integer value. Address map for this block of registers: TDC Block Register Offsets. |
| 0x06 | hword | TDC_FB_DIV_FRAC Register | TDC internal APLL Feedback Divider Fraction value. Address map for this block of registers: TDC Block Register Offsets. |
| 0x0A | byte | TDC_DAC_CNFG Register | TDC internal APLL Digital to Analog Converter (DAC) control. Address map for this block of registers: TDC Block Register Offsets. |

7.2.7 System Clock Divider Register Block Address Map

The System Clock Divider block has a base address of 0xF0. The addresses shown below are offsets starting from this base address.

Table 30. System Clock Divider Block Register Offsets

| Offset | Size | Register Name | Register Description |
|--------|------|--------------------------------------|---|
| 0x00 | byte | SYS_DIV_INT Register | System Clock Divider Integer value. Address map for this block of registers: System Clock Divider Block Register Offsets. |

7.2.8 Bias Register Block Address Map

The Bias block has a base address of 0xF4. The addresses shown below are offsets starting from this base address.

Table 31. Bias Block Register Offsets

| Offset | Size | Register Name | Register Description |
|--------|-------|-----------------------------------|--|
| 0x00 | hword | Reserved | Reserved |
| 0x02 | hword | BIAS_STS Register | Bias circuit status. Address map for this block of registers: Bias Block Register Offsets. |

7.2.9 Crystal Register Block Address Map

The Crystal block has a base address of 0xF8. The addresses shown below are offsets starting from this base address.

Table 32. Crystal Block Register Offsets

| Offset | Size | Register Name | Register Description |
|--------|------|----------------------------------|--|
| 0x00 | word | XO_CNFG Register | Crystal oscillator circuit control. Address map for this block of registers: Crystal Block Register Offsets. For information on how to set up this interface, see Differential Output Termination. |

7.2.10 Clock Output Register Block Address Map

The Clock Output 0 block has a base address of 0x100.

The Clock Output 1 block has a base address of 0x108.

The Clock Output 2 block has a base address of 0x110.

The Clock Output 3 block has a base address of 0x118.

The addresses shown below are offsets starting from this base address.

Table 33. Clock Output Block Register Offsets

| Offset | Size | Register Name | Register Description |
|--------|-------|---|--|
| 0x00 | hword | OD_CNFG Register | Output Divider control. Address map for this block of registers: Clock Output Block Register Offsets. |
| 0x02 | byte | ODRV_EN Register | Output driver enable control. Address map for this block of registers: Clock Output Block Register Offsets. |
| 0x03 | byte | ODRV_MODE_CNFG Register | Output driver mode control. Address map for this block of registers: Clock Output Block Register Offsets. |
| 0x04 | byte | ODRV_AMP_CNFG Register | Output driver amplitude control. Address map for this block of registers: Clock Output Block Register Offsets. |

7.2.11 Clock Reference Register Block Address Map

The Clock Reference Register block has a base address of 0x120. The addresses shown below are offsets starting from this base address

Table 34. Clock Reference Addresses

| Offset | Size | Register Name | Register Description |
|--------|------|--------------------------------------|--|
| 0x00 | word | PREDIV_CNFG Register | Reference Clock Input Divider control. Address map for this block of registers: Clock Reference Addresses. |

7.2.12 GPIO Register Block Address Map

The GPIO Register block has a base address of 0x130. The addresses shown below are offsets starting from this base address.

Table 35. GPIO Block Register Offsets

| Offset | Size | Register Name | Register Description |
|--------|-------|--------------------------------------|--|
| 0x00 | byte | OE_CNFG Register | Configuration control for Output Enable input pin. Address map for this block of registers: GPIO Block Register Offsets. |
| 0x01 | byte | IO_CNFG Register | Miscellaneous Input/Output Configuration. Address map for this block of registers: GPIO Block Register Offsets. |
| 0x02 | hword | LOCK_CNFG Register | Lock output configuration control. Address map for this block of registers: GPIO Block Register Offsets. |
| 0x04 | hword | SDO_CNFG Register | SDO pin configuration control. Address map for this block of registers: GPIO Block Register Offsets. |
| 0x06 | byte | Reserved | Reserved |
| 0x07 | byte | STARTUP_STS Register | Start-up status. Address map for this block of registers: GPIO Block Register Offsets. |
| 0x08 | byte | GPIO_STS Register | GPIO status. Address map for this block of registers: GPIO Block Register Offsets. |
| 0x0C | word | SCRATCH0 Register | Software Scratch Register 0. Address map for this block of registers: GPIO Block Register Offsets. |

7.2.13 SSI Register Block Address Map

The SSI Register block has a base address of 0x140. The addresses shown below are offsets starting from this base address.

Table 36. SSI Block Register Offsets

| Offset | Size | Register Name | Register Description |
|--------|------|--|--|
| 0x00 | byte | SPI_CNFG Register | SPI mode configuration. Address map for this block of registers: SSI Block Register Offsets. |
| 0x01 | byte | I2C_FLTR_CNFG Register | I ² C mode configuration. Address map for this block of registers: SSI Block Register Offsets. |
| 0x02 | byte | I2C_TIMING_CNFG Register | I ² C mode timing configuration. Address map for this block of registers: SSI Block Register Offsets. |
| 0x03 | byte | I2C_ADDR_CNFG Register | I ² C mode device address configuration. Address map for this block of registers: SSI Block Register Offsets. |
| 0x04 | byte | SSI_GLOBAL_CNFG Register | Slave Serial Interface Global configuration. Address map for this block of registers: SSI Block Register Offsets. |

7.2.14 APLL Register Block Address Map

The Analog PLL block has a base address of 0x150. The addresses shown below are offsets starting from this base address.

Table 37. APLL Block Register Offsets

| Offset | Size | Register Name | Register Description |
|--------|-------|---|---|
| 0x00 | word | APLL_FB_DIV_FRAC Register | APLL Feedback Divider Fraction Numerator value. Address map for this block of registers: APLL Block Register Offsets. |
| 0x04 | hword | APLL_FB_DIV_INT Register | APLL Feedback Divider Integer value. Address map for this block of registers: APLL Block Register Offsets. |
| 0x06 | byte | APLL_FB_SDM_CNFG Register | APLL Feedback SDM control. Address map for this block of registers: APLL Block Register Offsets. |
| 0x07 | byte | APLL_CNFG Register | APLL Configuration control. Address map for this block of registers: APLL Block Register Offsets. |
| 0x08 | hword | Reserved | Reserved |
| 0x0A | byte | LPF_CNFG Register | APLL Loop Filter Configuration. Address map for this block of registers: APLL Block Register Offsets. |
| 0x0B | byte | LPF_3RD_CNFG Register | APLL Loop Filter 3rd Pole control. Address map for this block of registers: APLL Block Register Offsets. |
| 0x0C | byte | Reserved | Reserved |
| 0x0D | byte | Reserved | Reserved |
| 0x0E | byte | Reserved | Reserved |
| 0x0F | byte | Reserved | Reserved |
| 0x10 | byte | Reserved | Reserved |
| 0x12 | hword | Reserved | Reserved |
| 0x14 | hword | APLL_LOCK_CNFG Register | APLL Lock Detector control. Address map for this block of registers: APLL Block Register Offsets. |
| 0x16 | byte | APLL_LOCK_THRSH Register | APLL Precision Lock Detector Threshold control. Address map for this block of registers: APLL Block Register Offsets. |
| 0x17 | byte | VCO_CAL_STS Register | APLL VCO Calibration status. Address map for this block of registers: APLL Block Register Offsets. |

Table 37. APLL Block Register Offsets (Cont.)

| Offset | Size | Register Name | Register Description |
|--------|------|---------------------------------------|--|
| 0x18 | byte | APLL_STS Register | APLL Lock status. Address map for this block of registers: APLL Block Register Offsets. |
| 0x19 | byte | APLL_EVENT Register | APLL Event status. Address map for this block of registers: APLL Block Register Offsets. |
| 0x1A | byte | APLL_LOL_CNT Register | APLL Loss-of-Lock Event counter. Address map for this block of registers: APLL Block Register Offsets. |

7.2.15 Clock Input Register Block Address Map

The Clock Input block has a base address of 0x190. The addresses shown below are offsets starting from this base address.

Table 38. Clock Input Block Register Offsets

| Offset | Size | Register Name | Register Description |
|--------|-------|--|---|
| 0x00 | hword | REF_CLK_IN_CNFG Register | Reference Clock Input Pad configuration. Address map for this block of registers: Clock Input Block Register Offsets. |

8. Register Descriptions

8.1 GLOBAL Registers

8.1.1 VENDOR_ID Register

Device vendor identification code. Address map for this block of registers: [Global Block Register Offsets](#).

| Bit Field | Field Name | Type | Default | Description |
|-----------|-------------|------|---------|---|
| 15:12 | dev_id_type | RO | 0x1 | Device ID Block Type. A value of 0x1 indicates that this register is followed by a 16-bit Device ID register, a 16-bit Device Revision register, and a 16-bit Device Programming register. |
| 11 | reserved | RO | 0x0 | reserved. |
| 10:0 | vendor_id | RO | 0x33 | Vendor ID. Renesas JTAG ID. |

8.1.2 DEVICE_ID Register

Device-specific identification code. Address map for this block of registers: [Global Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|---|
| 15:0 | device_id | RW | 0x304A | Device ID. For default value refer to the Product Id in Table 42 . |

8.1.3 DEVICE_REV Register

Device revision identification information. Address map for this block of registers: [Global Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|---|
| 15:13 | reserved | RO | 0x0 | Reserved |
| 12:8 | font_id | RO | 0x2 | Font ID. Font ID to distinguish die variants. Decode as follows: <ul style="list-style-type: none"> • 0x0 = Font 0 (Font 0) • 0x1 = Font 1 (Font 1) • 0x2 = Font 2 (Font 2) |
| 7:4 | ana_rev | RO | 0x3 | Hardware analog revision. Decode as follows: <ul style="list-style-type: none"> • 0x1 = First revision (TV) • 0x2 = Second revision (RevA) • 0x3 = Third revision (RevB) |
| 3:0 | dig_rev | RO | 0x2 | Hardware digital revision. Decode as follows: <ul style="list-style-type: none"> • 0x1 = First revision (TV) • 0x2 = Second revision (RevA/B) |

8.1.4 DEVICE_PGM Register

Identifies any factory OTP pre-programmed configuration. Address map for this block of registers: [Global Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|--|
| 15:0 | dash_code | RW | 0x0 | Dash code. Decimal value assigned by Renesas to identify the user configuration loaded in OTP at the factory. This field is writeable and is configured from the OTP common configuration programmed at the factory. <ul style="list-style-type: none"> • 0x0 = No user configurations are programmed at the factory |

8.1.5 DEVICE_CNFG Register

Device overall configuration settings. Address map for this block of registers: [Global Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|---|
| 7 | digldo_cnf | RW | 0x0 | Digital LDO voltage select. Selects the digital LDO voltage level. This setting is intended for test purposes only. <ul style="list-style-type: none"> • 0x0 = 1.25V • 0x1 = 1.32V |
| 6:4 | xo_delay | RW | 0x0 | Crystal Startup Delay. Selects the wait time for the internal crystal oscillator circuit during the startup sequence. The default setting of 1ms should be sufficient for all crystals. This setting is intended for debug purposes only. <ul style="list-style-type: none"> • 0x0 = 1 ms • 0x1 = 2.5 ms • 0x2 = 5 ms • 0x3 = 7.5 ms • 0x4 = 10 ms • 0x5 = 0.5 ms • 0x6 = 15 ms • 0x7 = reserved |
| 3:0 | config_sel | RW | 0x4 | User Configuration Select. Controls the selection of the user configuration stored in OTP to read on start-up (for details, see OTP and I2C Address User Configuration Selection). |

8.1.6 DEV_RESET Register

Device reset commands. Address map for this block of registers: [Global Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-----------------------|------|---------------|--|
| 7:6 | reserved | RO | 0x0 | reserved. |
| 5 | input_div_global_setb | RW | 0x1 | Input Dividers Common Set. When cleared, both input dividers get held in set mode (bit is active low). This allows to set and release both dividers at roughly the same time. |
| 4 | out_global_oe | RW | 0x1 | Output Global OE. This bit allows manual CSR control of the output OE. |
| 3:2 | reserved | RO | 0x0 | reserved. |

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|--------------|------|---------------|--|
| 1 | divider_sync | RW | 0x0 | Divider synchronization. Writing this bit to 1 synchronizes the Output Dividers and the DPLL feedback divider (if the DPLL is enabled). The output clocks are squelched for approximately 10µs. <i>Note:</i> This bit must be written to 0 before it can be triggered again by writing it to 1. |
| 0 | apll_reinit | RW | 0x0 | APLL Reinitialization. Writing this bit to 1 restarts the startup sequence from the VCO calibration step, including divider synchronization. <i>Note:</i> This bit must be written to 0 before it can be triggered again by writing it to 1. |

8.1.7 SW_RESET Register

Software reset command. Address map for this block of registers: [Global Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|---------------------|------|---------------|---|
| 15:12 | reserved | RO | 0x0 | reserved. |
| 11 | reserved | RW | 0x0 | reserved |
| 10:9 | reserved | RO | 0x0 | reserved. |
| 8 | bias_cal_sw_rst | RW | 0x0 | Bias Cal Software reset. The bias calibration logic is held in reset while this bit is set to 1. |
| 7 | tdc_apll_dig_sw_rst | RW | 0x0 | TDC Software reset. The TDC logic is held in reset while this bit is set to 1. |
| 6 | dpll_sw_rst | RW | 0x0 | DPLL Software reset. The DPLL is held in reset while this bit is set to 1. |
| 5 | actmon1_sw_rst | RW | 0x0 | ACTMON1 Software reset. The Activity Monitor 1, which monitors the nCLKIN input, is held in reset while this bit is set to 1. |
| 4 | actmon0_sw_rst | RW | 0x0 | ACTMON0 Software reset. The Activity Monitor 0, which monitors the CLKIN input, is held in reset while this bit is set to 1. |
| 3 | losmon2_sw_rst | RW | 0x0 | LOSMON2 Software reset. The Loss-of-signal Monitor 2, which monitors the crystal input, is held in reset while this bit is set to 1. |
| 2 | losmon1_sw_rst | RW | 0x0 | LOSMON1 Software reset. The Loss-of-signal Monitor 1, which monitors the nCLKIN input, is held in reset while this bit is set to 1. |
| 1 | losmon0_sw_rst | RW | 0x0 | LOSMON0 Software reset. The Loss-of-signal Monitor 0, which monitors the CLKIN input, is held in reset while this bit is set to 1. |
| 0 | otp_sw_rst | RW | 0x0 | OTP Software reset. The OTP logic is held in reset while this bit is set to 1. |

8.1.8 CLOCK_GATE Register

Clock gating control. Setting of any of the bits in this register stops the internal clocks to the indicated logic block(s). The Renesas Timing Commander Software automatically determines which logic can be disabled for a specific configuration. Contact Renesas if further details are needed.

Address map for this block of registers: [Global Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|--|
| 15:12 | reserved | RO | 0x0 | reserved. |
| 11 | dig_cg | RW | 0x0 | Digital Logic Clock Gate. All digital clocks that do not have separate clock gating control bits in this register are gated while this bit is set to 1. Because this gates the register bus clock, no further register access is possible through the serial port. The device must be power cycled to recover. This bit is intended for test purposes only (shut down all digital logic during analog characterization or debug). |
| 10:9 | reserved | RO | 0x0 | reserved. |
| 8 | reserved | RW | 0x0 | reserved |
| 7 | reserved | RO | 0x0 | reserved. |
| 6 | reserved | RW | 0x0 | reserved |
| 5 | actmon1_cg | RW | 0x0 | ACTMON1 Clock Gate. The Activity Monitor 1 is clock gated while this bit is set to 1. |
| 4 | actmon0_cg | RW | 0x0 | ACTMON0 Clock Gate. The Activity Monitor 0 is clock gated while this bit is set to 1. |
| 3 | losmon2_cg | RW | 0x0 | LOSMON2 Clock Gate. The Loss-of-signal Monitor 2 is clock gated while this bit is set to 1. |
| 2 | losmon1_cg | RW | 0x0 | LOSMON1 Clock Gate. The Loss-of-signal Monitor 1 is clock gated while this bit is set to 1. |
| 1 | losmon0_cg | RW | 0x0 | LOSMON0 Clock Gate. The Loss-of-signal Monitor 0 is clock gated while this bit is set to 1. |
| 0 | reserved | RW | 0x0 | reserved. |

8.1.9 DEVICE_STS Register

Device status. Address map for this block of registers: [Global Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-----------------|------|---------------|---|
| 7:5 | startup_seq_sts | RO | 0x0 | Startup Sequence Status. Status related to the startup sequence. This field is intended for debug purposes only. bit [0] = Bias calibration timeout (2ms) bit [1] = OTP load timeout (10ms) bit [2] = APLL lock timeout (2ms) |
| 4 | osc_fallback | RO | 0x0 | Power-on-Reset Ring Oscillator Fallback. Set to 1 if the system clock divider output does not begin toggling during the startup sequence and the reset controller muxes the ring oscillator clock onto the system clock instead. |
| 3 | device_ready | RO | 0x0 | Device Ready. Set to 1 when the OTP load completes during the startup sequence. |
| 2 | reserved | RO | 0x0 | reserved. |
| 1:0 | config_loaded | RO | 0x0 | User Configuration Loaded. Indicates the user configuration loaded from OTP on start-up. Note that the common configuration is always loaded in addition to any user configurations are loaded. |

8.2 INT Registers

8.2.1 INT_EN Register

Interrupt Enable control. Address map for this block of registers: [Interrupt Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|----------------------|------|---------------|--|
| 15 | device_int_en | RW | 0x0 | Device interrupt enable. Overall device interrupt enable. When this field is set to 1, the device interrupt is asserted while device_int_sts is 1. |
| 14:12 | reserved | RO | 0x0 | reserved. |
| 11:9 | reserved | RW | 0x0 | reserved. |
| 8 | act1_int_en | RW | 0x0 | nCLKIN Activity Monitor interrupt enable. When this field is set to 1, the act1_int_sts bit contributes to the device interrupt |
| 7 | act0_int_en | RW | 0x0 | CLKIN Activity Monitor interrupt enable. When this field is set to 1, the act0_int_sts bit contributes to the device interrupt. |
| 6 | los2_int_en | RW | 0x0 | XTAL Monitor Loss-of-Signal interrupt enable. When this field is set to 1, the los2_int_sts bit contributes to the device interrupt. |
| 5 | los1_int_en | RW | 0x0 | nCLKIN Monitor Loss-of-Signal interrupt enable. When this field is set to 1, the los1_int_sts bit contributes to the device interrupt |
| 4 | los0_int_en | RW | 0x0 | CLKIN Monitor Loss-of-Signal interrupt enable. When this field is set to 1, the los0_int_sts bit contributes to the device interrupt. |
| 3 | dpll_state_ch_int_en | RW | 0x0 | DPLL State Change interrupt enable. When this field is set to 1, the dpll_state_ch_int_sts bit contributes to the device interrupt. |
| 2 | dpll_holdover_int_en | RW | 0x0 | DPLL Holdover interrupt enable. When this field is set to 1, the dpll_holdover_int_sts bit contributes to the device interrupt. |
| 1 | dpll_lol_int_en | RW | 0x0 | DPLL Loss-of-Lock interrupt enable. When this field is set to 1, the dpll_lol_int_sts bit contributes to the device interrupt. |
| 0 | apll_lol_int_en | RW | 0x0 | APLL Loss-of-Lock interrupt enable. When this field is set to 1, the apll_lol_int_sts bit contributes to the device interrupt. |

8.2.2 INT_STS Register

Interrupt Status. Address map for this block of registers: [Interrupt Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|----------------|------|---------------|---|
| 15 | device_int_sts | RO | 0x0 | Device interrupt status. Overall device interrupt status. This bit is the OR of all the other interrupt status bits in this register after masking by their respective interrupt enable bits in INT_EN Register . This bit is masked by device_int_en . The resulting signal is output on the LOCK pin when lock_sel selects the device interrupt. |
| 14:9 | reserved | RO | 0x0 | reserved. |
| 8 | act1_int_sts | RO | 0x0 | nCLKIN Activity Monitor interrupt status Mirrors the nCLKIN act_evt event bit |
| 7 | act0_int_sts | RO | 0x0 | CLKIN Activity Monitor interrupt status Mirrors the CLKIN act_evt event bit |
| 6 | los2_int_sts | RO | 0x0 | XTAL Monitor Loss-of-Signal interrupt status Mirrors the los_evt event bit |

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-----------------------|------|---------------|--|
| 5 | los1_int_sts | RO | 0x0 | nCLKIN Monitor Loss-of-Signal interrupt status Mirrors the nCLKIN los_evt event bit |
| 4 | los0_int_sts | RO | 0x0 | CLKIN Monitor Loss-of-Signal interrupt status Mirrors the CLKIN los_evt event bit |
| 3 | dpll_state_ch_int_sts | RO | 0x0 | DPLL State Change interrupt status Mirrors the dpll_state_ch event bit |
| 2 | dpll_holdover_int_sts | RO | 0x0 | DPLL Holdover interrupt status. Mirrors the dpll_holdover event bit. |
| 1 | dpll_loI_int_sts | RO | 0x0 | DPLL Loss-of-Lock interrupt status. Mirrors the dpll_loI event bit. |
| 0 | apll_loI_int_sts | RO | 0x0 | APLL Loss-of-Lock interrupt status. Mirrors the apll_loI event bit. |

8.3 LOSMON Registers

Before reprogramming a Loss of Signal Monitor block, the corresponding [losmon0_sw_rst](#), [losmon1_sw_rst](#), or [losmon2_sw_rst](#) bit should be set. When programming is done, it should then be cleared.

8.3.1 LOSMON_STS Register

LOS Monitor Status. Address map for this block of registers: [LOS Monitor Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-------------|------|---------------|---|
| 7:2 | reserved | RO | 0x0 | reserved. |
| 1 | ref_invalid | RO | 0x1 | Reference Clock Invalid status. Indicates whether this reference clock is currently considered to be invalid. This occurs if the clock is disqualified by one or more of the Loss-of-Signal and Activity monitors or ref_disable is set to 1. <ul style="list-style-type: none"> 0x0 = Clock is valid 0x1 = Clock is invalid |
| 0 | los_sts | RO | 0x1 | Loss-of-Signal status. Current value of the LOS status from the clock monitor: <ul style="list-style-type: none"> 0x0 = Clock meets the monitoring criteria 0x1 = Loss-of-signal detected |

8.3.2 LOSMON_EVENT Register

LOS Monitor Event Status. Address map for this block of registers: [LOS Monitor Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|--|
| 7:1 | reserved | RO | 0x0 | reserved. |
| 0 | los_evt | RW1C | 0x1 | Loss-of-Signal Event status. Set while the clock monitor asserts LOS. This bit cannot be cleared by software while the LOS condition persists. This bit is set when the block comes out of reset and needs to be cleared after proper programming. <ul style="list-style-type: none"> 0x0 = Loss-of-signal not detected since the last time the bit was cleared 0x1 = Loss-of-signal detected since the last time the bit was cleared |

8.3.3 LOSMON_QUAL Register

LOS Monitor Qualify Counter Configuration. Address map for this block of registers: [LOS Monitor Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|----------------|------|---------------|---|
| 7:4 | los_good_times | RW | 0x0 | LOS Monitor Qualification Count If this number of consecutive accepted clock LOS monitoring windows occur without a rejected window, then the clock is qualified and los_sts is set to 0. A value of 0 is the same as using the value 1. |
| 3:0 | los_fail_times | RW | 0x0 | LOS Monitor Disqualification Count If this number of rejected clock LOS monitoring windows occur without qualifying the clock, then the clock is disqualified and los_sts is set to 1. A value of 0 is the same as using the value 1. |

8.3.4 LOSMON_WINDOW Register

LOS Monitor Window Configuration. Address map for this block of registers: [LOS Monitor Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|---------------|------|---------------|--|
| 15:8 | reserved | RO | 0x0 | reserved. |
| 7:3 | los_div_ratio | RW | 0x0 | LOS Monitor Divide Ratio This divide ratio must be set such that the monitored clock nominal frequency divided by los_div_ratio is less than 1/8 of the system clock frequency to achieve 25% accuracy. One period of the divided clock is the monitoring window duration. A value of 0 or 1 means divide by 1. The value 0x1F is not supported. |
| 2 | reserved | RO | 0x0 | reserved. |
| 1 | ref_disable | RW | 0x0 | Reference Clock Selection Disable Controls whether this reference clock may be selected as the DPLL reference clock. Not applicable for LOSMON2 (XTAL monitor). <ul style="list-style-type: none"> • 0 = Reference clock may be selected, subject to qualification by the Loss-of-Signal, Activity and Frequency monitors, and prioritization according to ref_priority • 1 = Reference clock cannot be selected, ref_invalid is 1. |
| 0 | los_fail_mask | RW | 0x0 | LOS Monitor Failure Mask Masks the LOS monitor status los_sts contribution to ref_invalid . <ul style="list-style-type: none"> • 0 = los_sts contributes to ref_invalid • 1 = los_sts does not contribute to ref_invalid |

8.3.5 LOSMON_THRESH Register

LOS Monitor Threshold Configuration. Address map for this block of registers: [LOS Monitor Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|----------------|------|---------------|---|
| 31:29 | reserved | RO | 0x0 | reserved. |
| 28:16 | los_acc_margin | RW | 0x0 | LOS Monitor Accept Threshold An accepted clock monitoring window occurs when the final monitor counter value is within los_nom_num ± los_acc_margin . |
| 15:13 | reserved | RO | 0x0 | reserved. |
| 12:0 | los_rej_margin | RW | 0x0 | LOS Monitor Reject Threshold A rejected clock monitoring window occurs when the final monitor counter value is outside of los_nom_num ± los_rej_margin . |

8.3.6 LOSMON_NOMINAL Register

LOS Monitor Nominal Number Configuration. Address map for this block of registers: [LOS Monitor Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-------------|------|---------------|---|
| 31:13 | reserved | RO | 0x0 | reserved. |
| 12:0 | los_nom_num | RW | 0x0 | LOS Monitor Nominal Cycle Count Sets the expected number of system clock periods within one monitor window. Set to 0x0 to disable the LOS monitor. Disabling the monitor causes the los_sts to get asserted, therefore the los_fail_mask should also be set when this field is written to 0x0. |

8.4 ACTMON Registers

Note that before reprogramming an Activity Monitor, the corresponding [actmon0_sw_rst](#) or [actmon1_sw_rst](#) bit should be set. When programming is done, it should then be cleared.

8.4.1 ACTMON_STS Register

Activity Monitor Status. Address map for this block of registers: [ACT Monitor Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|---|
| 7:1 | reserved | RO | 0x0 | reserved. |
| 0 | act_sts | RO | 0x1 | Activity Monitor status. Current value of the qualification status from the activity monitor: <ul style="list-style-type: none"> • 0x0 = Clock meets the monitoring criteria, clock qualified • 0x1 = failure detected, clock disqualified |

8.4.2 ACTMON_EVENT Register

Activity Monitor Event Status. Address map for this block of registers: [ACT Monitor Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|---|
| 7:1 | reserved | RO | 0x0 | reserved. |
| 0 | act_evt | RW1C | 0x1 | Activity Monitor event status. Set while the activity monitor disqualifies the clock. This bit cannot be cleared by software while the disqualified condition persists. This bit is set when the block comes out of reset and needs to be cleared after proper programming. <ul style="list-style-type: none"> • 0x0 = Activity monitor has not disqualified the clock since the last time the bit was cleared • 0x1 = Activity monitor has disqualified the clock since the last time the bit was cleared |

8.4.3 ACTMON_WINDOW Register

Activity Monitor Window Configuration. Address map for this block of registers: [ACT Monitor Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|---------------|------|---------------|--|
| 31:21 | reserved | RO | 0x0 | reserved. |
| 20 | act_fail_mask | RW | 0x0 | Activity Monitor Failure Mask Masks the activity monitor status act_sts . <ul style="list-style-type: none"> • 0 = Status is not masked • 1 = Forces clock to be considered as qualified |
| 19 | reserved | RO | 0x0 | reserved. |
| 18:0 | act_div_ratio | RW | 0x0 | Activity Monitor Divide Ratio This divide ratio must be set such that the monitored clock nominal frequency divided by act_div_ratio is as close as possible to 100Hz, creating a 10ms monitoring window. A value of 0 means divide by 1. A value of 0x7FFFF is reserved. |

8.4.4 ACTMON_THRESH Register

Activity Monitor Threshold Configuration. Address map for this block of registers: [ACT Monitor Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|----------------|------|---------------|--|
| 63:54 | reserved | RO | 0x0 | reserved. |
| 53:32 | act_acc_margin | RW | 0x0 | Activity Monitor Accept Threshold An accepted clock monitoring window occurs when the final monitor counter value is within act_nom_num ± act_acc_margin . One accepted window qualifies the clock and act_sts is set to 0. |
| 31:22 | reserved | RO | 0x0 | reserved. |
| 21:0 | act_rej_margin | RW | 0x0 | Activity Monitor Reject Threshold A rejected clock monitoring window occurs when the final monitor counter value is outside of act_nom_num ± act_rej_margin . One rejected window disqualifies the clock and act_sts is set to 1. |

8.4.5 ACTMON_NOMINAL Register

Activity Monitor Nominal Number Configuration. Address map for this block of registers: [ACT Monitor Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-------------|------|---------------|---|
| 31:22 | reserved | RO | 0x0 | reserved. |
| 21:0 | act_nom_num | RW | 0x0 | Activity Monitor Nominal Cycle Count Sets the expected number of clock periods of the ring oscillator frequency divided by 4 (nominally 216MHz) within one monitor window. Set to 0x0 to disable the activity monitor. Disabling the monitor causes the act_sts to get asserted, therefore the act_fail_mask should also be set when this field gets written to 0x0. |

8.5 DPLL Registers

8.5.1 DPLL_REF_FB_CNFG Register

DPLL Ref and Fb Clock Configuration. Address map for this block of registers: [DPLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-------------------|------|---------------|---|
| 7:6 | dpll_ref_sel_mode | RW | 0x0 | DPLL reference clock selection mode <ul style="list-style-type: none"> • 0x0 = manual mode, reference selection is based on the setting of dpll_ref_sel • 0x2 = auto mode |
| 5 | reserved | RO | 0x0 | reserved. |
| 4 | dpll_ref_sel | RW | 0x0 | DPLL manual reference clock selection <ul style="list-style-type: none"> • 0x0 = clk0 • 0x1 = clk1 |
| 3:2 | reserved | RO | 0x0 | reserved. |
| 1 | dpll_revertive_en | RW | 0x0 | DPLL revertive reference switch <ul style="list-style-type: none"> • 0x0 = non-revertive • 0x1 = revertive |
| 0 | dpll_hitless_en | RW | 0x0 | DPLL hitless reference switch <ul style="list-style-type: none"> • 0x0 = hitless disabled • 0x1 = hitless enabled |

8.5.2 DPLL_MODE Register

Digital PLL mode control. Address map for this block of registers: [DPLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-------------------|------|---------------|---|
| 7 | bw_damp_sw | RW | 0x1 | Automatic bandwidth/damping switching. Enables the DPLL to switch to the Locking Loop Filter bandwidth and damping settings when the DPLL is in the Acquire state while locking. Refer to dpll_lock_timer . <ul style="list-style-type: none"> • 0x0 = always use Normal Operation settings. • 0x1 = use Locking settings when the DPLL is in the Acquire state. |
| 6 | los_to_freerun | RW | 0x0 | Reference Loss-of-Signal to Freerun. Controls whether the DPLL enters Freerun or Holdover mode when the current reference clock is invalid. <ul style="list-style-type: none"> • 0x0 = Holdover. • 0x1 = Freerun. |
| 5:4 | reserved | RW | 0x0 | reserved |
| 3 | filter_update_dis | RW | 0x0 | DPLL filter update disable. This bit must be set to 1 before reconfiguring any DPLL registers while the DPLL is enabled, and then must be cleared after the reconfiguration finishes. The exception is write_freq which may be controlled dynamically and automatically suppresses filter_update when written. |
| 2 | dpll_en | RW | 0x0 | DPLL Enable. Controls whether the DPLL is enabled. <ul style="list-style-type: none"> • 0x0 = Synthesizer/DCO mode. DPLL (except loop filter and scaler blocks) is disabled (clock gated to reduce power) • 0x1 = Jitter Attenuator mode. DPLL is enabled. |

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|--|
| 1:0 | dppl_mode | RW | 0x1 | DPLL mode selection. Selects DPLL mode: <ul style="list-style-type: none"> • 0x0 = Forces DPLL into Freerun state • 0x1 = Places the DPLL in Normal (automatic) mode. This is the normal setting for Jitter Attenuator mode • 0x2 = Forces DPLL into Holdover state. • 0x3 = Places DPLL in Write Frequency mode. This is the normal setting in DCO mode. |

8.5.3 DPLL_DECIMATOR Register

Decimator configuration control. Address map for this block of registers: [DPLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-----------------------|------|---------------|---|
| 7 | reserved | RO | 0x0 | reserved. |
| 6:4 | dec_histless_bw_shift | RW | 0x3 | Hitless Switch Decimator Bandwidth Shift to set the decimator bandwidth during a hitless reference switch or holdover-normal switch for measuring the phase offset. If dppl_histless_en is set to zero, this field is ignored. |
| 3:0 | dec_bw_shift | RW | 0x6 | Main Decimator Bandwidth. Shift to set the main decimator bandwidth. 0 puts the decimator in feed-through (infinite bandwidth). |

8.5.4 DPLL_TRIM_OFFSET Register

DPLL Crystal trim offset. Address map for this block of registers: [DPLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|---|
| 7:0 | xtal_trim | RW | 0x0 | Crystal Trim Offset. Crystal fractional frequency offset compensation. This is an 8-bit 2's complement value. Resolution = $2^{-20} \approx 1$ ppm, Range = $\pm 2^{-13} \approx \pm 122$ ppm. |

8.5.5 DPLL_HOLDOVER_CNFG Register

Holdover Configuration. Address map for this block of registers: [DPLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-----------------------|------|---------------|--|
| 15:11 | holdover_bw_shift | RW | 0x7 | Holdover Filter Bandwidth Shift. Coarse control of the holdover bandwidth. A value of zero disables the holdover filter (infinite bandwidth). The valid range is 0-20. Values larger than 20 are limited internally to 20. |
| 10:8 | holdover_bw_mult | RW | 0x0 | Holdover Filter Bandwidth Multiplier. Fine control of the holdover filter bandwidth. A value of zero disables the holdover filter (infinite bandwidth), which is also the default setting. |
| 7:4 | holdover_history | RW | 0x0 | Holdover history <ul style="list-style-type: none"> • 0x0 = instantaneous • 0x1 = 1 second • 0x2 = 2 seconds • 0x3 = 3 seconds • ... • 0x9 = 9 seconds • 0xA = 10 seconds |
| 3:0 | dpll_lo_l_cnt_thres_h | RW | 0x0 | DPLL Loss-of-Lock Counter Threshold. While the DPLL Loss-of-Lock counter (dpll_lo_l_cnt) exceeds this threshold, the dpll_lo_l_lmt bit is set. |

8.5.6 DPLL_BANDWIDTH Register

DPLL Bandwidth configuration. Address map for this block of registers: [DPLL Block Register Offsets](#).

Refer to [Digital Loop Filter](#) for details on configuring these settings. Or use Renesas's Timing Commander SW to provide appropriate settings.

This section supports separate settings for fast-lock acquisition (Acquire) and regular locked operation (Normal Operation).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------------|------|---------------|--|
| 15:11 | acquire_bw_shift | RW | 0xE | Acquire Loop Filter Bandwidth Shift. Coarse control of the DPLL loop filter bandwidth in the Acquire state while locking to the input clock. Default bandwidth = 1023 Hz. |
| 10:8 | acquire_bw_mult | RW | 0x0 | Acquire Loop Filter Bandwidth Multiplier. Fine control of the DPLL loop filter bandwidth in the Acquire state while locking to the input clock. Default bandwidth = 1023 Hz. |
| 7:3 | normal_bw_shift | RW | 0xB | Normal Operation Loop Filter Bandwidth Shift. Coarse control of the DPLL loop filter bandwidth in the Normal state when locked to the input clock. Default bandwidth = 127 Hz. |
| 2:0 | normal_bw_mult | RW | 0x0 | Normal Operation Loop Filter Bandwidth Multiplier. Fine control of the DPLL loop filter bandwidth in the Normal state when locked to the input clock. Default bandwidth = 127 Hz. |

8.5.7 DPLL_DAMPING Register

DPLL Damping control. Address map for this block of registers: [DPLL Block Register Offsets](#)

Refer to [Digital Loop Filter](#) for details on configuring these settings. Or use Renesas's Timing Commander SW to provide appropriate settings. This section supports separate settings for fast-lock acquisition (Acquire) and regular locked operation (Normal Operation).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-----------------------|------|---------------|--|
| 15:14 | reserved | RO | 0x0 | reserved. |
| 13:11 | acquire_damping_shift | RW | 0x5 | Acquire Loop Filter Damping Shift. Coarse control of the DPLL loop filter damping in the Acquire state while locking to the input clock. Default damping causes 1.1 dB peaking in the frequency domain jitter transfer function. |
| 10:8 | acquire_damping_mult | RW | 0x1 | Acquire Loop Filter Damping Multiplier. Fine control of the DPLL loop filter damping in the Acquire state while locking to the input clock. Default damping causes 1.1 dB peaking in the frequency domain jitter transfer function. |
| 7:6 | reserved | RO | 0x0 | reserved. |
| 5:3 | normal_damping_shift | RW | 0x0 | Normal Operation Loop Filter Damping Shift. Coarse control of the DPLL loop filter damping in the Normal state when locked to the input clock. Default damping causes 0.1 dB peaking in the frequency domain jitter transfer function. |
| 2:0 | normal_damping_mult | RW | 0x1 | Normal Operation Loop Filter Damping Multiplier. Fine control of the DPLL loop filter damping in the Normal state when locked to the input clock. Default damping causes 0.1 dB peaking in the frequency domain jitter transfer function. |

8.5.8 DPLL_PHASE_SLOPE_LIMIT Register

DPLL Phase Slope Limit control. Address map for this block of registers: [DPLL Block Register Offsets](#)

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-------------------|------|---------------|--|
| 31:29 | reserved | RO | 0x0 | reserved. |
| 28:0 | phase_slope_limit | RW | 0x1FFFFFF | Phase Slope Limit. Control of the phase slope limit of the output clocks. This represents the maximum instant relative frequency change of the output clock. This is an unsigned unitless number although it is often expressed as $\mu\text{s}/$ or ns/s . Renesas recommends programming a value that is approx. 10% smaller than the required limit to leave some room for the integrator to adjust to frequency offsets. The resolution of 1 LSB is $2^{-35} = 2.91\text{e-}11 = 29. \text{ps}/\text{s}$. |

8.5.9 DPLL_FB_DIV_NUM Register

DPLL Feedback Fraction Numerator value. Address map for this block of registers: [DPLL Block Register Offsets](#).

Refer to [DPLL Feedback Divider](#) for details on configuring these settings. Or use Renesas's Timing Commander SW to provide appropriate settings.

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|---|
| 63:48 | reserved | RO | 0x0 | reserved. |
| 47:0 | fb_div_num | RW | 0x0 | Feedback Divider Numerator. DPLL feedback divide numerator value. Refer to fb_div_int for details. This register is part of the atomic group consisting of DPLL_FB_DIV_NUM Register , DPLL_FB_DIV_DEN Register and DPLL_FB_DIV_INT Register . When the most significant byte (bits [47:40]) of fb_div_num or fb_div_den , is written, the value of both these fields, in addition to the one in fb_div_int is applied to the DPLL. |

8.5.10 DPLL_FB_DIV_DEN Register

DPLL Feedback Fraction Denominator value. Address map for this block of registers: [DPLL Block Register Offsets](#).

Refer to [DPLL Feedback Divider](#) for details on configuring these settings. Or use Renesas's Timing Commander SW to provide appropriate settings.

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|--|
| 63:48 | reserved | RO | 0x0 | reserved. |
| 47:0 | fb_div_den | RW | 0x80000 0 | Feedback Divider Denominator. DPLL feedback divide denominator value. Refer to fb_div_int for details. When the fb_div_num field is non-zero, the fraction has to be set such that the MSB of the fb_div_den is set (both fields should be shifted up by the same amount). This register is part of the atomic group consisting of DPLL_FB_DIV_NUM Register , DPLL_FB_DIV_DEN Register and DPLL_FB_DIV_INT Register . When the most significant byte (bits [47:40]) of fb_div_num or fb_div_den , is written, the value of both these fields, in addition to the one in fb_div_int is applied to the DPLL. |

8.5.11 DPLL_FB_DIV_INT Register

DPLL Feedback Integer value. Address map for this block of registers: [DPLL Block Register Offsets](#).

Refer to [DPLL Feedback Divider](#) for details on configuring these settings. Or use Renesas's Timing Commander SW to provide appropriate settings.

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|--|
| 15:14 | reserved | RO | 0x0 | reserved. |
| 13:0 | fb_div_int | RW | 0x190 | <p>DPLL Feedback Clock Divider Integer. DPLL feedback divide integer value. The DPLL feedback clock frequency must be no more than 33 MHz, and must be equal to the frequency of the reference clock divided by <code>id_ratio</code>, or equal to the reference clock when the input divider is bypassed by <code>id_byp_en</code>.</p> <p>This register is part of the atomic group consisting of DPLL_FB_DIV_NUM Register, DPLL_FB_DIV_DEN Register and DPLL_FB_DIV_INT Register. When this field is changed from its previous value, the value of this field, in addition to the values from <code>fb_div_num</code>, <code>fb_div_den</code> get applied to the DPLL.</p> |

8.5.12 DPLL_FB_CORR Register

DPLL Feedback Correction Configuration. Address map for this block of registers: [DPLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|---------------|------|---------------|--|
| 15:10 | reserved | RO | 0x0 | reserved. |
| 9 | fine_rev | RW | 0x0 | <p>TDC Fine Timestamp Bit Reversal. Selects the bit ordering of the fine timestamp signals from the TDC analog to digital. This setting is intended for debug purposes only.</p> <ul style="list-style-type: none"> • 0x0 = Analog 30:0 maps to digital 30:0 • 0x1 = Analog 0:30 maps to digital 30:0 |
| 8:7 | pec_delay | RW | 0x0 | <p>PEC Delay. Phase error correction delay. Intended for debug purposes only.</p> <ul style="list-style-type: none"> • 0x0 = sdm error no delay • 0x1 = sdm error delay one cycle • 0x2 = same as 0x0 • 0x3 = same as 0x0 |
| 6:0 | pec_corr_mult | RW | 0x0 | <p>Feedback Correction Multiplier. Multiplier to get the FB SDM remainder bits on the same resolution as the TDC phase bits (resolution ≈ 18.7 ps if TDC APLL runs at 864MHz). Should be set as follows: $pec_cor_mult = (Tvco/TDC_step) * (128/fb_div_den[47:41])$</p> |

8.5.13 DPLL_PHASE_OFFSET Register

DPLL Phase Offset configuration. Address map for this block of registers: [DPLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|--------------|------|---------------|---|
| 31:30 | reserved | RO | 0x0 | reserved. |
| 29:0 | phase_offset | RW | 0x0 | Phase Offset. Manually sets the phase offset between the reference and feedback clocks. This is a 30-bit 2's complement value. The resolution is the TDC resolution / 8 (≈ 2.3 ps) and the range is $\approx \pm 1.26$ ms. This allows all outputs to be adjusted in terms of their phase relationship to the input. All outputs move together using this precision setting. This field is not used when hitless switching is enabled. This register is atomic. When the most significant byte (bits [31:24]) is written, the new value is applied to the APLL. |

8.5.14 DPLL_WRITE_FREQ Register

DPLL Write Frequency command. Address map for this block of registers: [DPLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|--|
| 31:29 | reserved | RO | 0x0 | reserved. |
| 28:0 | write_freq | RW | 0x0 | Write Frequency. Frequency control word for synthesizer/DCO mode. This is a 29-bit 2's complement value. The units are $2^{-40} * 1e6$ [ppm]. This provides a maximum setting of ± 244 ppm. An update to this multi-byte register only takes effect when the most significant byte (bits [28:24]) are written, the new value is applied to the DPLL. |

8.5.15 DPLL_LOCK Register

DPLL Lock Detection control. Address map for this block of registers: [DPLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------------|------|---------------|--|
| 31:16 | dpll_lock_timer | RW | 0x00FF | DPLL lock timer. Specifies the time interval during which the absolute value of the phase detector error must remain below the DPLL lock threshold (dpll_lock_thresh) to declare lock. The DPLL switches from the Acquire state to the Normal state when the threshold has been met for half of this time interval. If enabled by bw_damp_sw , the loop filter bandwidth and damping settings revert at this time from the Acquire settings to the Normal settings. When the threshold has been met again for half of this time interval, the DPLL declares lock. The units are ms. |
| 15:0 | dpll_lock_thresh | RW | 0x0155 | DPLL lock threshold. Specifies the threshold that the absolute value of the phase detector error must remain below during the DPLL lock timer (dpll_lock_timer) to declare lock. The units are the $8 * \text{TDC resolution}$ (≈ 149 ps if TDC APLL runs at 864MHz). |

8.5.16 DPLL_TDC_DELAY Register

DPLL TDC Delay Control. Address map for this block of registers: [DPLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|---|
| 7:0 | tdc_delay | RW | 0x1F | TDC delay. Sets the TDC delay which goes to the DPLL, for debug purposes only. |

8.5.17 DPLL_STS Register

DPLL Status. Address map for this block of registers: [DPLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------------|------|---------------|--|
| 7 | reserved | RO | 0x0 | reserved. |
| 6:4 | dpll_state_sts | RO | 0x0 | DPLL state machine's current state. Decode as follows: <ul style="list-style-type: none"> • 0x0 = freerun • 0x1 = normal/locked • 0x2 = holdover • 0x3 = write_frequency • 0x4 = acquire • 0x5 = hitless switch |
| 3:2 | reserved | RO | 0x0 | reserved. |
| 1 | dpll_ref_sel_sts | RO | 0x0 | DPLL reference clock selection status Indicates the reference clock selected by the DPLL. <ul style="list-style-type: none"> • 0x0 = clkin0 • 0x1 = clkin1 |
| 0 | dpll_lock_sts | RO | 0x0 | DPLL lock status. Indicates the DPLL lock status: <ul style="list-style-type: none"> • 0x0 = unlocked • 0x1 = locked |

8.5.18 DPLL_EVENT Register

DPLL Event status. Address map for this block of registers: [DPLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|---------------|------|---------------|---|
| 7:4 | reserved | RO | 0x0 | reserved. |
| 3 | dpll_state_ch | RW1C | 0x0 | DPLL State Change event. Set to 1 when the DPLL state machine changes state. |
| 2 | dpll_holdover | RW1C | 0x0 | DPLL Holdover event. Set to 1 when the DPLL state machine enters the holdover state. When asserted, this bit remains asserted until cleared by a write of '1' to this bit position. |
| 1 | dpll_lo_lmt | RW1C | 0x0 | DPLL Loss-of-Lock Counter Threshold Exceeded status. Set while the DPLL Loss-of-Lock counter (dpll_lo_lmt_cnt) exceeds the threshold set in dpll_lo_lmt_cnt_thresh . This bit cannot be cleared by software while the condition persists. <ul style="list-style-type: none"> • 0x0 = Loss-of-lock counter has not exceeded the threshold since the last time the bit was cleared • 0x1 = Loss-of-lock counter exceeded the threshold since the last time the bit was cleared |

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|--|
| 0 | dppll_lol | RW1C | 0x0 | DPLL Loss-of-lock event. Set to 1 when the DPLL lock status transitions from locked to unlocked. When asserted, this bit remains asserted until cleared by a write of '1' to this bit position. |

8.5.19 DPLL_LOL_CNT Register

DPLL Loss-of-Lock Event Counter. Address map for this block of registers: [DPLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|---------------|------|---------------|--|
| 7:4 | reserved | RO | 0x0 | reserved. |
| 3:0 | dppll_lol_cnt | RW | 0x0 | DPLL Loss-of-Lock Counter. This counter increments each time the DPLL lock status de-asserts, and saturates at 0xF. It is cleared by writing it to 0x0, and may be preset by writing the desired value. Preset may be used either as a debug tool or to cause a threshold alarm to happen sooner because the alarm threshold is not configurable. This register can only be written if the block is not clock gated or held in reset (dppll_sw_rst). |

8.6 TDC Registers

8.6.1 TDC_REF_DIV_CNFG Register

TDC reference divider control. Address map for this block of registers: [TDC Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------------|------|---------------|--|
| 7:3 | reserved | RO | 0x0 | reserved. |
| 2:0 | tdc_ref_div_cnfg | RW | 0x1 | TDC Reference Divider Control. Controls the divide ratio of the TDC reference (either input or CLKIN input, selected by apll_ref_sel). This field should be programmed such that the reference to the TDC APLL is between 10MHz and 30MHz <ul style="list-style-type: none"> • 0x0 = bypass divider. • 0x1 = divide by 2 • 0x2 = divide by 4 • 0x3 = divide by 8 • 0x4 = divide by 16 |

8.6.2 TDC_FB_SDM_CNFG Register

TDC internal APLL Feedback Divider SDM control. Address map for this block of registers: [TDC Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|---------------|------|---------------|--|
| 7 | tdc_fb_sdm_en | RW | 0x1 | TDC APLL Feedback SDM Enable. Enables the SDM controlling the TDC APLL feedback divider. <ul style="list-style-type: none"> • 0x0 = SDM disabled, constant integer division by tdc_fb_div_int • 0x1 = SDM enabled, MMD mode |
| 6:2 | reserved | RO | 0x0 | reserved. |

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------------|------|---------------|---|
| 1:0 | tdc_fb_sdm_order | RW | 0x1 | TDC APLL Feedback SDM Order. Selects the order of the SDM controlling the feedback divider for the TDC APLL. <ul style="list-style-type: none"> • 0x0 = Integer • 0x1 = 1st order • 0x2 = 2nd order • 0x3 = reserved |

8.6.3 TDC_FB_DIV_INT Register

TDC internal APLL Feedback Divider Integer value. Address map for this block of registers: [TDC Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|----------------|------|---------------|---|
| 7:0 | tdc_fb_div_int | RW | 0x23 | TDC APLL Feedback Divider Integer. Integer portion of the TDC APLL feedback divider. |

8.6.4 TDC_FB_DIV_FRAC Register

TDC internal APLL Feedback Divider Fraction value. Address map for this block of registers: [TDC Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-----------------|------|---------------|--|
| 15:0 | tdc_fb_div_frac | RW | 0x2800 | TDC APLL Feedback Fraction. Fraction of the TDC APLL feedback divider. The fraction is calculated as follows: $tdc_fb_div_frac/2^{16}$. |

8.6.5 TDC_DAC_CNFG Register

TDC internal APLL Digital to Analog Converter (DAC) control. Address map for this block of registers: [TDC Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|-------------|
| 7:5 | reserved | RO | 0x0 | reserved. |

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-------------|------|---------------|--|
| 4:0 | tdc_dig_set | RW | 0x4 | <p>TDC APLL Set value.</p> <p>Increases the baseline APLL DCO voltage. The step size is 1/32nd of the full range (nominally 37.5 mV). The dynamic control signal generated by the DAC SDM (0-16) is added to this value to create the DAC input. Values 0x11 to 0x1F are reserved.</p> <ul style="list-style-type: none"> • 0x0 = no increase • 0x1 = 1/32 increase • 0x2 = 2/32 increase • 0x3 = 3/32 increase • 0x4 = 4/32 increase • 0x5 = 5/32 increase • 0x6 = 6/32 increase • 0x7 = 7/32 increase • 0x8 = 8/32 increase • 0x9 = 9/32 increase • 0xA = 10/32 increase • 0xB = 11/32 increase • 0xC = 12/32 increase • 0xD = 13/32 increase • 0xE = 14/32 increase • 0xF = 15/32 increase • 0x10 = 16/32 increase |

8.7 SYSDIV Registers

8.7.1 SYS_DIV_INT Register

System Clock Divider Integer value. Address map for this block of registers: [System Clock Divider Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-------------|------|---------------|--|
| 7:5 | reserved | RO | 0x0 | reserved. |
| 4:0 | sys_div_int | RW | 0xC | <p>System Clock Divide Integer.</p> <p>The system clock divide integer value must be set to produce a system frequency between 180MHz and 333MHz, divided down from the APLL VCO frequency divided by 4. The frequency picked has side effects on various calculations done in other blocks (LOSMON Registers). Normally expected to be between 210MHz and 240MHz. The minimum valid value for this field is 10 and the maximum is 15.</p> |

8.8 BIAS Registers

8.8.1 BIAS_STS Register

Bias circuit status. Address map for this block of registers: [Bias Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-------------|------|---------------|---|
| 15:9 | reserved | RO | 0x0 | reserved. |
| 8 | bias_cal_in | RO | 0x0 | <p>Bias Calibration comparator value.</p> <p>Raw bias_cal_in value.</p> |

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------------|------|---------------|---|
| 7:5 | cnf_bias_cal_eff | RO | 0x0 | Bias Calibration effective configuration value. Indicates the configuration value selected as sent to the bias control circuit. Valid when bias_cal_done is set to 1. |
| 4:2 | cnf_bias_cal | RO | 0x0 | Bias Calibration configuration value. Indicates the configuration value selected by the bias calibration logic. Valid when bias_cal_done is set to 1. |
| 1 | bias_cal_fail | RO | 0x0 | Bias Calibration failed. Indicates whether bias calibration completed successfully. Valid when bias_cal_done is set to 1. <ul style="list-style-type: none"> • 0x0 = Bias calibration succeeded • 0x1 = Bias calibration failed |
| 0 | bias_cal_done | RO | 0x0 | Bias Calibration done. Indicates whether bias calibration is running: <ul style="list-style-type: none"> • 0x0 = Bias calibration is in progress • 0x1 = Bias calibration is completed |

8.9 XO Registers

8.9.1 XO_CNFG Register

Crystal oscillator circuit control. Address map for this block of registers: [Crystal Block Register Offsets](#). For information on how to set up this interface, see [Differential Output Termination](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|---|
| 31:19 | Reserved | RO | 0x0 | reserved. |
| 18:17 | xo_cfg_res | RW | 0x0 | reserved. Not used. |
| 16 | en_ldo_xo | RW | 0x1 | XO LDO Enable. When set, enables the XO LDO. |
| 15:14 | en_gain | RW | 0x1 | XO gain boosting control. Selects the number of gain boosting amplifiers enabled during startup. <ul style="list-style-type: none"> • 0x0 = Gain boosting amplifiers are disabled • 0x1 = One parallel amplifier is enabled • 0x2 = Two parallel amplifiers are enabled • 0x3 = All three parallel amplifiers are enabled |
| 13:8 | Reserved | RW | 0x1F | reserved. |
| 7:6 | Reserved | RW | 0x0 | reserved. |
| 5:0 | Reserved | RW | 0x1F | reserved. |

8.10 OUT Registers

8.10.1 OD_CNFG Register

Output Divider control. Address map for this block of registers: [Clock Output Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|--|
| 15 | en_ldo_od | RW | 0x1 | Output Divider LDO Enable. When set, enables the corresponding output divider LDO. |
| 14 | reserved | RO | 0x0 | reserved. |

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|--------------|------|---------------|--|
| 13:0 | outdiv_ratio | RW | 0x69 | Output Divider ratio. Output divider ratio. The minimum divide value is 10 (decimal). |

8.10.2 ODRV_EN Register

Output driver enable control. Address map for this block of registers: [Clock Output Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|---------------|------|---------------|--|
| 7:4 | reserved | RO | 0x0 | reserved. |
| 3:2 | out_dis_state | RW | 0x0 | Output Driver disabled state. Controls the state of OUTx/nOUTx when the output driver is disabled. <ul style="list-style-type: none"> 0x0 = Held Low/Low (except LVDS mode is held Low/High) 0x1 = Held Low/High 0x2 = Held Hi-Z/Hi-Z 0x3 = Normal operation (not held static). This is intended for debug purposes only. |
| 1 | out_dis | RW | 0x0 | Output Driver disable. Forces the Output Driver to be disabled (for details, see Output Enable Control). <ul style="list-style-type: none"> 0 = Output Driver is enabled if not disabled by other means 1 = Output Driver is disabled |
| 0 | out_pd | RW | 0x0 | Output Driver power down. Powers down the Output Driver. When powered down, OUTx/nOUTx are tri-stated and the output enable control is ignored. <ul style="list-style-type: none"> 0 = Output Driver is powered up and can be enabled/disabled 1 = Output Driver is powered down |

8.10.3 ODRV_MODE_CNFG Register

Output driver mode control. Address map for this block of registers: [Clock Output Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|---------------------|------|---------------|---|
| 7:6 | out_cmos_mode | RW | 0x1 | Output Driver CMOS mode. Controls how OUTx and nOUTx are driven when CMOS mode is selected. <ul style="list-style-type: none"> 0x0 = OUTx, nOUTx are driven with the same phase 0x1 = OUTx, nOUTx are driven with the opposite phase 0x2 = Only OUTx is driven. nOUTx is held low. 0x3 = Only nOUTx is driven. OUTx is held low. |
| 5:4 | out_lvds_cm_voltage | RW | 0x2 | Output Driver LVDS common mode voltage control. Controls the common mode voltage of the output driver when LVDS mode is selected. <ul style="list-style-type: none"> 0x0 = 700mV 0x1 = 800mV 0x2 = 900mV 0x3 = 1000mV |
| 3 | out_hcsl_term_en | RW | 0x1 | Output Driver HCSL termination enable. Controls the internal HCSL termination. <ul style="list-style-type: none"> 0x0 = Internal HCSL termination is disabled. An external termination resistor to ground is required. 0x1 = Internal HCSL termination is enabled, providing an internal 50ohm resistor to ground. |

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-------------|------|---------------|---|
| 2 | en_out_bias | RW | 0x1 | Output Driver Bias Enable. When set, enables the output driver bias circuit. |
| 1:0 | out_mode | RW | 0x0 | Output Driver type. Selects the output driver type. <ul style="list-style-type: none"> • 0x0 = HCSL • 0x1 = reserved • 0x2 = LVDS • 0x3 = CMOS |

8.10.4 ODRV_AMP_CNFG Register

Output driver amplitude control. Address map for this block of registers: [Clock Output Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------------------|------|---------------|--|
| 7:4 | out_cnf_hcsl_sw ing | RW | 0xB | Output Driver HCSL amplitude control. Controls the amplitude of the output driver when CML mode is selected. Each value provides a 50mV increment. <ul style="list-style-type: none"> • 0x0 = 200mV • 0x1 = 250mV • 0x2 = 300mV • 0x3 = 350mV • 0x4 = 400mV • 0x5 = 450mV • 0x6 = 500mV • 0x7 = 550mV • 0x8 = 600mV • 0x9 = 650mV • 0xA = 700mV • 0xB = 750mV • 0xC = 800mV • 0xD = 850mV • 0xE = 875mV • 0xF = 900mV |
| 3 | out_cnf_lvds_amp | RW | 0x0 | Output Driver LVDS amplitude control. Controls the amplitude of the output driver when LVDS mode is selected. <ul style="list-style-type: none"> • 0 = 350mV • 1 = 400mV |
| 2:0 | reserved | RW | 0x4 | reserved. |

8.11 REF Registers

8.11.1 PREDIV_CNFG Register

Reference Clock Input Divider control. Address map for this block of registers: [Clock Reference Addresses](#).

Refer to [Input Dividers](#) for details on how to set up this interface. Or use the Renesas Timing Commander Software to provide correct settings.

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|-------------|
| 31:25 | reserved | RO | 0x0 | reserved. |

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|----------------|------|---------------|--|
| 24 | ref_priority | RW | 0x0 | Reference Clock Priority Sets the clock's priority for DPLL reference switching. If multiple clocks are set to the same priority level, they are prioritized from the lowest numbered (clkIn0) to the highest numbered (clkIn3). <ul style="list-style-type: none"> • 0x0 = first priority • 0x1 = second priority |
| 23 | reserved | RO | 0x0 | reserved. |
| 22 | input_div_setb | RW | 0x1 | Input Divider Set When cleared, the corresponding input divider gets held in set mode (bit is active low). |
| 21 | enb_input_div | RW | 0x0 | Input Divider Enable When cleared, enables the corresponding input divider (active low). |
| 20 | id_byp_en | RW | 0x1 | Input Divider Bypass. Allows the input divider to be bypassed and the reference clock input is passed directly to the DPLL and clock monitor. Bypass must be disabled if the reference clock frequency is greater than 33 MHz. <ul style="list-style-type: none"> • 0 = divided reference clock is selected, divide ratio is id_ratio • 1 = reference clock is selected, effective divide ratio is 1 |
| 19:0 | id_ratio | RW | 0x0 | Input Divider ratio. Input divider ratio. The reference clock frequency divided by this value must be no more than 33 MHz, and must be equal to the DPLL feedback clock frequency. The minimum divide value is 2. To divide by 1 (when the input reference clock frequency is no more than 33 MHz), bypass the divider by setting id_byp_en to 1. |

8.12 GPIO Registers

8.12.1 OE_CNFG Register

Configuration control for Output Enable input pin. Address map for this block of registers: [GPIO Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|---|
| 7:6 | reserved | RO | 0x0 | reserved. |
| 5 | oe_pd | RW | 0x0 | OE Pull-down Enable. Set to 1 to enable the internal pull-down resistor on the OE pin. |
| 4 | oe_pu | RW | 0x1 | OE Pull-up Enable. Set to 1 to enable the internal pull-up resistor on the OE pin. |
| 3 | oe_pol | RW | 0x0 | OE Input Polarity. Controls the active polarity of the OE input pin when oe_sel is set to 0. <ul style="list-style-type: none"> • 0x0 = Active high (1 = enable outputs, 0 = disable outputs) • 0x1 = Active low (0 = enable outputs, 1 = disable outputs) |
| 2:1 | reserved | RO | 0x0 | reserved. |
| 0 | oe_sel | RW | 0x0 | OE Select. Selects whether the OE input pin can control the output enable of the clock output drivers: <ul style="list-style-type: none"> • 0x0 = The OE input disables the clock output drivers when de-asserted. • 0x1 = The OE input does not affect the clock output drivers. |

8.12.2 IO_CNFG Register

Miscellaneous Input/Output Configuration. Address map for this block of registers: [GPIO Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-------------|------|---------------|--|
| 7:6 | out_startup | RW | 0x0 | Output Disable on startup until PLL locks. Controls whether the clock output drivers are disabled until the APLL or DPLL locks during the startup sequence. <ul style="list-style-type: none"> 0x0 = Clock output drivers are disabled until APLL lock asserts 0x1 = Clock output drivers are disabled until DPLL lock asserts 0x2 = Clock output drivers are not disabled by APLL or DPLL lock status 0x3 = Reserved |
| 5:4 | pp_drv | RW | 0x2 | Push-Pull Drive Strength <ul style="list-style-type: none"> Applies to pads LOCK, SDO, and SDA_SDI(O) (for 3-wire SPI only) when configured for push-pull mode. Drive strength increases as this setting increases. |
| 3:2 | od_drv | RW | 0x3 | Open-Drain Drive Strength <ul style="list-style-type: none"> Applies to pads LOCK and SDO when configured for open-drain mode. Drive strength increases as this setting increases. |
| 1 | sda_pu | RW | 0x1 | SDA Pull-up Enable. Set to 1 to enable the internal pull-up resistor on the SDA_SDI(O) pin. |
| 0 | scl_pu | RW | 0x1 | SCL Pull-up Enable. Set to 1 to enable the internal pull-up resistor on the SCL_SCLK pin. |

8.12.3 LOCK_CNFG Register

Lock output configuration control. Address map for this block of registers: [GPIO Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|--|
| 15:13 | reserved | RO | 0x0 | reserved. |
| 12 | lock_od | RW | 0x0 | LOCK Open-drain enable. Set to 1 to configure the LOCK pin as an open-drain output. When lock_pol is set to 0, LOCK is driven low when the value to output is 0 and LOCK is open-drain when the value to output is 1. When lock_pol is set to 1, LOCK is driven low when the value to output is 1 and LOCK is open-drain when the value to output is 0. |
| 11 | lock_hiz | RW | 0x0 | LOCK Tristate Enable. Set to 1 to place the LOCK pin in a high-impedance state. |
| 10 | lock_pd | RW | 0x0 | LOCK Pull-down Enable. Set to 1 to enable the internal pull-down resistor on the LOCK pin. This should not be used when lock_od is set to 1. |
| 9 | lock_pu | RW | 0x1 | LOCK Pull-up Enable. Set to 1 to enable the internal pull-up resistor on the LOCK pin. Note that this internal pull-up is weak, so an external pull-up, tied to the V_{DDA} voltage rail is recommended when lock_od is set to 1. |
| 8 | lock_pol | RW | 0x0 | LOCK Output Polarity. Selects the polarity of the signal driven on the LOCK pin. When set to active high, the true value of the signal is driven. When set to active low, the inverse of the signal is driven. For example, when lock_sel selects APLL lock, and lock_pol is set to active high, LOCK drives high when the APLL is locked, and drives low when the APLL is unlocked. When lock_pol is set to active low, LOCK drives low when the APLL is locked, and drives high when the APLL is unlocked. This setting is ignored when lock_sel is set to 0x1F. <ul style="list-style-type: none"> 0x0 = Active high 0x1 = Active low |

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|--|
| 7:5 | reserved | RO | 0x0 | reserved. |
| 4:0 | lock_sel | RW | 0x0 | <p>LOCK Output Mode Select. Selects the status/clock to output on the LOCK pin:</p> <ul style="list-style-type: none"> • 0x0 = APLL lock (apll_lock_sts) • 0x1 = DPLL lock (dpll_lock_sts) • 0x2 = Reference #0 loss-of-signal (LOSMON0_los_sts) • 0x4 = Crystal loss-of-signal (LOSMON2_los_sts) • 0x5 = Reference #0 activity monitor status (ACTMON0_act_sts) • 0x7 = Reference #0 ref_invalid status • 0x9 = Device Interrupt (device_int_sts & device_int_en) • 0xA = Device ready (startup sequence completed) • 0x1D: Logic low • 0x1E: Logic high • Others: reserved |

8.12.4 SDO_CNFG Register

SDO pin configuration control. Address map for this block of registers: [GPIO Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|---|
| 15:13 | reserved | RO | 0x0 | reserved. |
| 12 | sdo_od | RW | 0x0 | <p>SDO Open-drain enable. Set to 1 to configure the SDO pin as an open-drain output. When sdo_pol is set to 0, SDO is pulled low when the value to output is 0 and LOCK is open-drain when the value to output is 1. When sdo_pol is set to 1, SDO is pulled low when the value to output is 1 and LOCK is open-drain when the value to output is 0.</p> |
| 11 | sdo_hiz | RW | 0x0 | <p>SDO Tristate Enable. Set to 1 to tristate the SDO pin.</p> |
| 10 | sdo_pd | RW | 0x0 | <p>SDO Pull-down Enable. Set to 1 to enable the internal pull-down resistor on the SDO pin.</p> |
| 9 | sdo_pu | RW | 0x1 | <p>SDO Pull-up Enable. Set to 1 to enable the internal pull-up resistor on the SDO pin.</p> |
| 8 | sdo_pol | RW | 0x0 | <p>SDO Output Polarity.</p> <ul style="list-style-type: none"> • 0x0 = Active high (1 = locked, 0 = not locked) • 0x1 = Active low (0 = locked, 1 = not locked) |
| 7:4 | reserved | RO | 0x0 | reserved. |
| 3:0 | sdo_sel | RW | 0x0 | <p>SDO Output Select. Selects the status/clock to output on the SDO pin when the serial port is in either I2C mode or SPI 3-wire mode. In SPI 4-wire mode, SDO is the SPI data out.</p> <ul style="list-style-type: none"> • 0x0 = APLL lock (apll_lock_sts) • 0x4 = Crystal loss-of-signal (LOSMON2_los_sts) • 0x9 = Device Interrupt (device_int_sts & device_int_en) • 0xA = Device ready (startup sequence completed) • 0xD = Logic low • 0xE = Logic high • others = reserved |

8.12.5 STARTUP_STS Register

Start-up status. Address map for this block of registers: [GPIO Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-----------------|------|---------------|--|
| 7 | bond_id | RO | 0x0 | Bond ID value. Value of bond id die pad. |
| 6 | reserved | RO | 0x0 | Reserved |
| 5:0 | gpio_at_startup | RO | 0x0 | GPIO startup value. Value of pins latched at startup. bit [0] = LOCK bit [1] = SDA_SDI(O) bit [2] = SCL_SCLK bit [3] = SDO bit [4] = OE bit [5] = nCS |

8.12.6 GPIO_STS Register

GPIO status. Address map for this block of registers: [GPIO Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|---|
| 7:2 | reserved | RO | 0x0 | reserved. |
| 1 | lock_o | RO | 0x0 | LOCK Output value. Reflects the value driven on the LOCK pin when lock_sel is set to 0x0 through 0x4. This bit reads as 0 when lock_sel is set to any other value. |
| 0 | oe_j | RO | 0x0 | OE Input value. Reflects the value input on the OE pin when oe_sel is set to 0. This bit reads as 0 when oe_sel is set to 1. |

8.12.7 SCRATCH0 Register

Software Scratch Register 0. Address map for this block of registers: [GPIO Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|--|
| 31:0 | scratch0 | RW | 0x0 | Scratch register. This value can be stored in OTP on a per-configuration basis. It is not used by the device hardware for any purpose. Users can set this to any value. |

8.13 SSI Registers

The acronym SSI refers to items that are generic to the Slave Serial Interface in any mode of operation. SPI or I²C is used for features and functions that are specific to those operating modes.

8.13.1 SPI_CNFG Register

SPI mode configuration. Address map for this block of registers: [SSI Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|-------------|
| 7 | reserved | RO | 0x0 | reserved. |

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|----------------|------|---------------|--|
| 6:5 | spi_dummy_size | RW | 0x1 | SPI dummy read byte count. Number of dummy bytes shifted out before the read data when spi_dummy_en is 1. <ul style="list-style-type: none"> • 0x0 = reserved • 0x1 = 1 byte • 0x2 = 2 bytes • 0x3 = 3 bytes |
| 4 | spi_dummy_en | RW | 0x0 | SPI dummy read byte enable. Enables insertion of dummy read bytes. <ul style="list-style-type: none"> • 0x0 = Read data is immediately available (no dummy bytes) • 0x1 = spi_dummy_size number of bytes are shifted out before the read data |
| 3 | spi_del_out | RW | 0x0 | SDO driving edge selection. Selects the clock edge that drives SDO. <ul style="list-style-type: none"> • 0x0 = SDO is driven on opposite SCLK edge than the sampling edge • 0x1 = SDO is delayed one half cycle of SCLK |
| 2 | reserved | RO | 0x0 | reserved. |
| 1 | spi_clk_sel | RW | 0x0 | SDI sampling edge selection. Selects the clock edge that samples SDI. <ul style="list-style-type: none"> • 0x0 = SDI is sampled on rising SCLK edge • 0x1 = SDI is sampled on falling SCLK edge |
| 0 | spi_3wire | RW | 0x1 | Select SPI 3-wire mode. Selects 3-wire or 4-wire mode. <ul style="list-style-type: none"> • 0x0 = Normal 4-wire SPI • 0x1 = 3-wire SPI. Data is received and transmitted on SDA_SDI(O) |

8.13.2 I2C_FLTR_CNFG Register

I²C mode configuration. Address map for this block of registers: [SSI Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|---------------|------|---------------|---|
| 7:6 | reserved | RO | 0x0 | reserved. |
| 5:4 | i2c_speed | RW | 0x0 | I2C speed selection. Selects the operating speed of the I2C interface. Only the output driver slew rate is affected by this setting (higher setting means higher drive strength). The I2C master must provide the appropriate SCL frequency and other timing requirements according to the selected speed. <ul style="list-style-type: none"> • 0x0 = 1.8V Standard mode (100 kHz) or 3.3V Standard (100kHz) and Fast mode (400kHz) • 0x1 = 1.8V Fast mode (400 kHz) • 0x2 = reserved • 0x3 = 1.8V and 3.3V Fast mode plus (1 MHz) |
| 3:0 | i2c_spike_ftr | RW | 0x1 | I2C digital spike filter duration. Controls the duration of the digital spike filters on the SCL and SDA inputs, specified in number of system clock cycles. 0 disables filtering. |

8.13.3 I2C_TIMING_CNFG Register

I²C mode timing configuration. Address map for this block of registers: [SSI Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-------------------|------|---------------|--|
| 7:4 | i2c_sda_high_hold | RW | 0x4 | I2C/SMBus transmit one bit delay. Delays transmission of 1 value by 8x this number of system clock cycles. |
| 3:0 | i2c_sda_low_hold | RW | 0x4 | I2C/SMBus transmit zero bit delay. Delays transmission of 0 value by 8x this number of system clock cycles. |

8.13.4 I2C_ADDR_CNFG Register

I²C mode device address configuration. Address map for this block of registers: [SSI Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|--|
| 7 | reserved | RO | 0x0 | reserved. |
| 6:0 | i2c_addr | RW | 0x09 | I2C device address. Sets I2C device address that the SSI acknowledges and accepts accesses on. Bits[1:0] are set by OTP only and can be overridden by pins as per Table 22 . |

8.13.5 SSI_GLOBAL_CNFG Register

Slave Serial Interface Global configuration. Address map for this block of registers: [SSI Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|---------------|------|---------------|--|
| 7:3 | reserved | RO | 0x0 | reserved. |
| 2 | ssi_addr_size | RW | 0x0 | SSI address size. When 0 the SSI expects 1-byte CSR addresses; when 1 the SSI expects 2-byte CSR addresses. Upper address bits are taken from the SSI's page register to create a full 32-bit CSR address. <ul style="list-style-type: none"> • 0x0 = 1-byte address • 0x1 = 2-byte address |
| 1:0 | ssi_enable | RW | 0x1 | SSI mode. Selects the serial port mode: <ul style="list-style-type: none"> • 0x0 = SSI is disabled • 0x1 = SSI is in I2C mode • 0x2 = SSI is in SPI mode • 0x3 = Reserved |

8.14 APLL Registers

8.14.1 APLL_FB_DIV_FRAC Register

APLL Feedback Divider Fraction Numerator value. Address map for this block of registers: [APLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------------|------|---------------|---|
| 31:27 | reserved | RO | 0x0 | reserved. |
| 26:0 | apll_fb_div_frac | RW | 0x0 | APLL Feedback Divider Fraction Numerator. APLL feedback divider numerator value. The denominator is a fixed value of 2 ²⁷ . This register is atomic. When the most significant byte (bits [31:24]) is written, the new value is applied to the APLL. |

8.14.2 APLL_FB_DIV_INT Register

APLL Feedback Divider Integer value. Address map for this block of registers: [APLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-----------------|------|---------------|--|
| 15:10 | reserved | RO | 0x0 | reserved. |
| 9:0 | apll_fb_div_int | RW | 0x6C | APLL Feedback Divider Integer. APLL feedback divider integer value. This register is atomic. When the most significant byte (bits [15:8]) is written, the new value is applied to the APLL. |

8.14.3 APLL_FB_SDM_CNFG Register

APLL Feedback SDM control. Address map for this block of registers: [APLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|---------------------|------|---------------|--|
| 7:6 | reserved | RO | 0x0 | reserved. |
| 5 | apll_fb_dither_en | RW | 0x0 | APLL Feedback SDM Dither Enable. Dither enable for the SDM controlling the APLL feedback divider. <ul style="list-style-type: none"> • 0x0 = dither disabled • 0x1 = dither enabled |
| 4 | apll_fb_dither_ns | RW | 0x0 | APLL Feedback SDM Dither Noise shaping. Dither noise shaping enable for the SDM controlling the APLL feedback divider. <ul style="list-style-type: none"> • 0x0 = dither not shaped • 0x1 = dither shaped |
| 3:2 | apll_fb_dither_gain | RW | 0x0 | APLL Feedback SDM Dither Gain. Gain control for the SDM controlling the APLL feedback divider. <ul style="list-style-type: none"> • 0x0 = LSB • 0x1 = 2*LSB • 0x2 = 4*LSB • 0x3 = 8*LSB |
| 1:0 | apll_fb_sdm_order | RW | 0x3 | APLL Feedback SDM Order. Selects the order of the SDM controlling the feedback divider for the APLL. <ul style="list-style-type: none"> • 0x0 = Integer • 0x1 = 1st order • 0x2 = 2nd order • 0x3 = 3rd order |

8.14.4 APLL_CNFG Register

APLL Configuration control. Address map for this block of registers: [APLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|--------------|------|---------------|---|
| 7:2 | reserved | RO | 0x0 | reserved. |
| 1 | apll_ref_sel | RW | 0x0 | APLL Reference Selection Configuration. <ul style="list-style-type: none"> • 0x0 = Selects XO • 0x1 = Selects CLKIN |
| 0 | en_doubler | RW | 0x1 | Frequency doubler enable. Enables the frequency doubler. <ul style="list-style-type: none"> • 0 = Disable • 1 = Enable |

8.14.5 LPF_CNFG Register

APLL Loop Filter Configuration. Address map for this block of registers: [APLL Block Register Offsets](#).

See to [APLL Loop Filter \(LPF\)](#) for details. Use the Renesas Timing Commander Software to provide optimal setting recommendations for a specific device configuration.

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|-------------------------|------|---------------|---|
| 7 | apll_vco_filter_by p | RW | 0x0 | VCO current source filter bypass. <ul style="list-style-type: none"> • 0 = Filter active • 1 = Filter bypassed |
| 6:4 | cnf_LPF_cp | RW | 0x7 | Loop filter pole capacitor setting. <ul style="list-style-type: none"> • 0x0 = 33.3pF • 0x1 = 36pF • 0x2 = 38.7pF • 0x3 = 41.4pF • 0x4 = 44.1pF • 0x5 = 46.8pF • 0x6 = 49.5pF • 0x7 = 52.2pF |
| 3:0 | cnf_LPF_res | RW | 0x6 | Loop filter resistor setting. <ul style="list-style-type: none"> • 0x0 = 0Ohm • 0x1 = 400Ohm • 0x2 = 800Ohm • 0x3 = 1.2kOhm • 0x4 = 1.6kOhm • 0x5 = 2kOhm • 0x6 = 2.4kOhm • 0x7 = 2.8kOhm • 0x8 = 3.2kOhm • 0x9 = 3.6kOhm • 0xA = 4kOhm • 0xB = 4.4kOhm • 0xC = 4.8kOhm • 0xD = 5.2kOhm • 0xE = 5.6kOhm • 0xF = 6kOhm |

8.14.6 LPF_3RD_CNFG Register

APLL Loop Filter 3rd Pole control. Address map for this block of registers: [APLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------|------|---------------|---|
| 7 | byp_p3 | RW | 0x0 | Bypass 3rd pole. This bit can only be set to 1 when operating with an integer feedback divider. <ul style="list-style-type: none"> 0 = 3rd pole active 1 = 3rd pole bypassed |
| 6:4 | cnf_LPF_R3 | RW | 0x3 | Loop filter 3rd pole resistor setting. <ul style="list-style-type: none"> 0x0 = 0Ohm 0x1 = 800Ohm 0x2 = 1.6kOhm 0x3 = 2.4kOhm 0x4 = 3.2kOhm 0x5 = 4kOhm 0x6 = 4.8kOhm 0x7 = 5.6kOhm |
| 3 | reserved | RO | 0x0 | reserved. |
| 2:0 | cnf_LPF_C3 | RW | 0x7 | Loop filter 3rd pole capacitor setting. <ul style="list-style-type: none"> 0x0 = 2pF 0x1 = 3pF 0x2 = 4pF 0x3 = 5pF 0x4 = 6pF 0x5 = 7pF 0x6 = 8pF 0x7 = 9pF |

8.14.7 APLL_LOCK_CNFG Register

APLL Lock Detector control. Address map for this block of registers: [APLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------------------|------|---------------|--|
| 15:10 | reserved | RO | 0x0 | reserved. |
| 9 | use_raw_lock | RW | 0x0 | APLL Lock Status Select to Pin. When set, the raw selected lock (precision or original) is sent to the GPIO status pin (LOCK or SDO) |
| 8 | apll_precision_lock_en | RW | 0x1 | APLL Precision Lock Detector Enable. When set, enables the lock detector using the ranges controlled by apll_th_refl and apll_th_refh . |
| 7:6 | apll_lock_timer | RW | 0x2 | APLL Lock Timer. Controls the digital debounce interval for the lock indication for the APLL. This duration is a function of the system clock cycles. <ul style="list-style-type: none"> 0x0 = 0us 0x1 = 570 cycles of the system clock 0x2 = 5700 cycles of the system clock 0x3 = 57000 cycles of the system clock. |
| 5 | sel_1time_lock | RW | 0x0 | One time lock select. Controls whether lock detection occurs once or continuously. <ul style="list-style-type: none"> 0x0 = Real-time lock. 0x1 = One-time lock. When the lock signal asserts, it remains asserted even if the APLL loses lock. |

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------------------|------|---------------|--|
| 4 | lck_detect_cal_by p | RW | 0x0 | Lock detect during calibration enable. Selects when the lock detector is enabled. <ul style="list-style-type: none"> • 0x0 = Lock detector is enabled after VCO calibration completes • 0x1 = Lock detector is enabled during and after VCO calibration |
| 3 | lck_byp | RW | 0x0 | Lock detector disable. <ul style="list-style-type: none"> • 0x0 = Lock detector is enabled according to lck_detect_cal_byp and sel_1time_lock • 0x1 = Lock detector is disabled and the lock signal is asserted |
| 2:0 | lck_detect_ref_sel | RW | 0x0 | Analog Lock Detect RC filter resistor Selects the filter resistor. C=5pF. <ul style="list-style-type: none"> • 0x0 = 7.5kΩ • 0x1 = 15kΩ • 0x2 = 23kΩ • 0x3 = 30kΩ • 0x4 = 37.5kΩ • 0x5 = 45kΩ • 0x6 = 53kΩ • 0x7 = 60kΩ |

8.14.8 APLL_LOCK_THRSH Register

APLL Precision Lock Detector Threshold control. Address map for this block of registers: [APLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|--------------|------|---------------|---|
| 7:4 | apll_th_refh | RW | 0x8 | APLL Precision Lock High Threshold. Controls the high threshold voltage of the precision lock detector. The threshold is approximately $750\text{mV} + 20\text{mV} * \text{apll_th_refh}$. The default is around 900mV. |
| 3:0 | apll_th_refl | RW | 0x8 | APLL Precision Lock Low Threshold. Controls the low threshold voltage of the precision lock detector. The threshold is approximately $50\text{mV} + 18\text{mV} * \text{apll_th_refl}$. The default is around 200mV. |

8.14.9 VCO_CAL_STS Register

APLL VCO Calibration status. Address map for this block of registers: [APLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|--------------|------|---------------|---|
| 7 | vco_cal_fail | RO | 0x0 | VCO Calibration failed. Indicates whether VCO calibration was completed successfully. Valid when vco_cal_done is set to 1. <ul style="list-style-type: none"> • 0x0 = VCO calibration succeeded • 0x1 = VCO calibration failed |
| 6 | vco_cal_done | RO | 0x0 | VCO Calibration done. Indicates whether VCO calibration is running: <ul style="list-style-type: none"> • 0x0 = VCO calibration is in progress • 0x1 = VCO calibration is completed |
| 5:0 | vco_cap | RO | 0x0 | VCO Calibration frequency band. Indicates the frequency band selected by the VCO calibration logic. Valid when vco_cal_done is set to 1. |

8.14.10 APLL_STS Register

APLL Lock status. Address map for this block of registers: [APLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|--------------------|------|---------------|---|
| 7:3 | reserved | RO | 0x0 | reserved. |
| 2 | apll_rail_high_sts | RO | 0x0 | APLL rail high real-time status. When high, indicates that the APLL is railed high. |
| 1 | apll_rail_low_sts | RO | 0x0 | APLL rail low real-time status. When high, indicates that the APLL is railed low. |
| 0 | apll_lock_sts | RO | 0x0 | APLL lock real-time status. Indicates if the APLL is locked to its reference. <ul style="list-style-type: none"> • 0x0 = unlocked • 0x1 = locked |

8.14.11 APLL_EVENT Register

APLL Event status. Address map for this block of registers: [APLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|--------------------|------|---------------|--|
| 7:3 | reserved | RO | 0x0 | reserved. |
| 2 | apll_rail_high_evt | RW1C | 0x0 | APLL Rail High event. Set to 1 when the APLL lock detects a rail high status. When asserted, this bit remains asserted until cleared by a write of 1 to this bit position. |
| 1 | apll_rail_low_evt | RW1C | 0x0 | APLL Rail Low event. Set to 1 when the APLL lock detects a rail low status. When asserted, this bit remains asserted until cleared by a write of 1 to this bit position. |
| 0 | apll_lol | RW1C | 0x0 | APLL Loss-of-lock event. Set to 1 when the APLL lock status transitions from locked to unlocked. When asserted, this bit remains asserted until cleared by a write of 1 to this bit position. |

8.14.12 APLL_LOL_CNT Register

APLL Loss-of-Lock Event counter. Address map for this block of registers: [APLL Block Register Offsets](#).

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|--------------|------|---------------|--|
| 7:4 | reserved | RO | 0x0 | reserved. |
| 3:0 | apll_lol_cnt | RW | 0x0 | APLL Loss-of-Lock Counter. This counter increments each time the APLL lock status de-asserts, and saturates at 0xF. It is cleared by writing it to 0x0, and can be preset by writing the desired value. Preset can be used either as a debug tool or to cause a threshold alarm to happen sooner because the alarm threshold is not configurable. |

8.15 INP Registers

8.15.1 REF_CLK_IN_CNFG Register

Reference Clock Input Pad configuration. Address map for this block of registers: [Clock Input Block Register Offsets](#).

Refer to [Reference Clock Input Buffer](#) section for details on how to set up this interface. Or use the Renesas Timing Commander Software to provide correct settings.

| Bit Field | Field Name | Type | Default Value | Description |
|-----------|------------------|------|---------------|---|
| 15:10 | reserved | RO | 0x0 | reserved. |
| 9 | en_LVDS | RW | 0x0 | Reference Clock LVDS Enable. Enables compatible termination when the reference clock input signal is LVDS. <ul style="list-style-type: none"> • 0 = LVDS input termination is disabled • 1 = LVDS input termination is enabled |
| 8 | en_HCSL | RW | 0x0 | Reference Clock HCSL Enable. Enables compatible termination when the reference clock input signal is HCSL. <ul style="list-style-type: none"> • 0 = HCSL input termination is disabled • 1 = HCSL input termination is enabled |
| 7 | en_ldo_ib | RW | 0x1 | Reference Clock Input Pad LDO enable. When set, enables the input buffer LDO. |
| 6 | en_selfbias_cmos | RW | 0x0 | Reference Clock Input Pad internal self-bias enable. When the single-ended reference clock input signal is AC-coupled external to the device, the internal DC bias voltage must be enabled. <ul style="list-style-type: none"> • 0x0 = Internal self-bias is disabled (input signal is DC-coupled) • 0x1 = Internal self-bias is enabled (input signal is AC-coupled) |
| 5:4 | en_term | RW | 0x0 | Unused. No defined function. Reserved for future use. |
| 3 | en_dc_bias | RW | 0x0 | Reference Clock Input Pad internal DC bias enable. When the differential reference clock input signal is AC-coupled external to the device, the internal DC bias voltage must be enabled. <ul style="list-style-type: none"> • 0 = Internal DC bias is disabled (input signal is DC-coupled) • 1 = Internal DC bias is enabled (input signal is AC-coupled) |
| 2 | en_inbuff | RW | 0x0 | Reference Clock Input Pad enable. The reference clock input pad must be enabled in Jitter Attenuator mode and should be left disabled in synthesizer/DCO mode. <ul style="list-style-type: none"> • 0 = Input pad is disabled • 1 = Input pad is enabled |
| 1 | CMOS_Sel | RW | 0x0 | Reference Clock Input Pad CMOS/differential select. Configures the reference clock input pad for a single-ended CMOS or differential input signal. <ul style="list-style-type: none"> • 0 = Differential input is selected • 1 = CMOS input is selected |
| 0 | P_N_Diff_Sel | RW | 0x0 | Reference Clock Input Pad PMOS/NMOS select. Configures the reference clock input pad according to the common mode voltage of the provided input signal. <ul style="list-style-type: none"> • 0 = PMOS input pair is enabled (low common mode voltage) • 1 = NMOS input pair is enabled (higher common mode voltage) |

9. Package Information

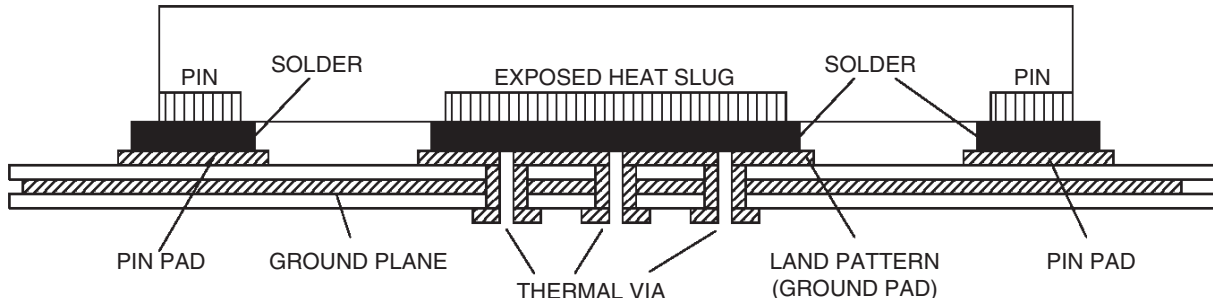
9.1 ePad Thermal Release Path

In order to maximize both the removal of heat from the package and the electrical performance, a land pattern must be incorporated on the Printed Circuit Board (PCB) within the footprint of the package corresponding to the exposed metal pad or exposed heat slug on the package, as shown in [Figure 19](#). 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 further information, please refer to the Application Note on the Surface Mount Assembly of Amkor’s Thermally/Electrically Enhance Lead frame Base Package, Amkor Technology.

Figure 19. P.C. Assembly for Exposed Pad Thermal Release Path – Side View (Drawing not to Scale)



9.2 Thermal Characteristics

Table 39. Thermal Characteristics

| Symbol | Parameter | Value | Unit |
|---------------|---|----------------|-----------|
| θ_{JA} | Theta J_A . Junction to Ambient Air Thermal Coefficient ^{[1][2]} | 0 m/s air flow | 49.6 °C/W |
| | | 1 m/s air flow | 46.6 °C/W |
| | | 2 m/s air flow | 43.9 °C/W |
| | | 3 m/s air flow | 42.8 °C/W |
| θ_{JB} | Theta J_B . Junction to Board Thermal Coefficient ^{[1][3]} | 9.7 | °C/W |
| θ_{JC} | Theta J_C . Junction to Device Case Thermal Coefficient ^[1] | 27.8 | °C/W |
| - | Moisture Sensitivity Rating (Per J-STD-020) | 3 | - |

[1] Multi-Layer PCB with 2 ground and 2 voltage planes.

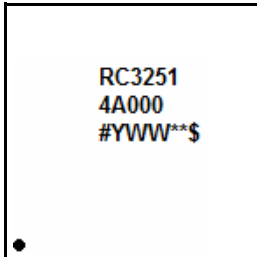
[2] Assumes ePad is connected to a ground plane using a grid of 9 × 9 thermal vias.

[3] Chip junction to ePad.

10. Package Outline Drawings

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

11. Marking Diagram



- Line 1 and 2 indicate the part number.
- Line 3 denotes the following:
 - “YWW” is the last digit of the year and week that the part was assembled.
 - “\$” denotes mark code
 - “#” denotes stepping

12. Ordering Information

| Part Number ^[1] | Package | MSL Rating | Carrier Type | Temperature Range |
|----------------------------|---|------------|---|-------------------|
| RC32514AdddGNL#BB0 | 4 × 4 × 1.5 mm, 28-VFQFPN | 3 | Tray | -40° to +85°C |
| RC32514AdddGNL#KB0 | 4 × 4 × 1.5 mm, 28-VFQFPN | 3 | Tape and Reel, Pin 1 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 40. Pin 1 Orientation in Tape and Reel Packaging

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

Table 41. Product Identification

| Part Number | Product ID |
|-------------|------------|
| RC32514A | 0x314A |

13. Glossary

| Term | Definition |
|------------------|--|
| 3-level | Describes an input structure that support a high, middle, and low logic level allowing one of three states to be selected. |
| ADC | Analog to Digital Converter – These devices require reference clock inputs with strict jitter budgets |
| AC-coupling | A method of connecting a transmitter to a receiver using series capacitors. This only transmits signal transitions, not DC voltage levels, so can be useful for constantly toggling signals like clocks, especially when trying to isolate the DC voltage levels. |
| APLL | Analog Phase Lock Loop – PLL technology that uses purely analog circuitry. Useful for low-noise applications without needs for low loop bandwidths or sophisticated switchover techniques. |
| ASIC | Application Specific Integrated Circuit – Custom chip design usually developed by a system vendor to meet the needs of a specific product family. Not available for general sale. Many ASICs include serial interfaces that need high-performance reference clock inputs |
| CDR | Clock/Data Recovery – Circuit that recovers a clock from a data stream and uses it to create a sampling clock for data recovery from the stream |
| C_L | Load Capacitance – A crystal parameter that affects the frequency accuracy of the crystal + oscillator circuit |
| CLKIN | Clock input signal (may be differential using pins CLKIN/nCLKIN or single-ended using CLKIN or nCLKIN) |
| CML | Current Mode Logic – A protocol for differential signaling between two chips. Referenced to V_{DD} . |
| CMOS | Complementary Metal-Oxide Semiconductor – Protocol for single-wire signaling between two chips. Referenced to Ground and VDD |
| CPLD | Complex Programmable Logic Device – Programmable IC with complexity less than an FPGA. Often used for power-up sequencing on printed circuit board designs |
| CPU | Central Processing Unit – A type of integrated circuit that executes software. Requires reference clocks with only time-domain jitter specifications. |
| CRC | Cyclic Redundancy Check – A method of determining if a block of data was stored or transmitted correctly. Involves the addition of one or more bytes of extra information to determine data integrity. One of several algorithms may be used. CCITT-16 is a commonly used algorithm. |
| DAC | Digital to Analog Converter – These devices require reference clock inputs with strict jitter budgets |
| DCO | Digitally Controlled Oscillator – An adjustable oscillator for generating frequencies that can be adjusted by writing a digital word to it |
| DPLL | Digital Phase Lock Loop – Type of PLL that uses at least a digital filter, if not a digital phase detector. Useful for implementing low loop bandwidths and/or complex switchover/holdover techniques |
| EEPROM | Electrically-Erasable Programmable Read-Only Memory – Commonly used non-volatile memory device. |
| ESR | Equivalent Series Resistance – A parameter for a quartz crystal indicating its ability to dissipate current from an oscillator circuit |
| FOD | Fractional Output Divider – Circuit that can divide down a clock frequency using non-integer ratios. Adds flexibility at a cost of increased size, complexity and power consumption and extra spurs |
| FPGA | Field-Programmable Gate Array – Highly complex custom programmed device that may include CPUs, serial interfaces, and other logic. Able to be re-programmed at will. Depending on what it contains, an FPGA may need reference clocks with low or high performance |
| GPI | General-Purpose Input – An input signal that can be programmed for many different purposes |
| GPIO | General-Purpose Input/Output – A signal that can be programmed for many different purposes as either an input or an output |
| GPO | General-Purpose Output – An output signal that may be programmed to be used for many different purposes |
| GUI | Graphical User Interface – A Timing Commander Personality that includes graphical elements to make device programming simpler |
| HCSL | High-speed Current Steering Logic – Differential signaling protocol usually associated with PCIe components |
| HSTL | High-speed Transceiver Logic – Low voltage-swing single-ended signaling protocol. Not often used. |
| I ² C | Inter-Integrated Circuit signaling protocol – A serial data transmission scheme originally created by Philips Semiconductor and released into the public domain. |
| IBIS | Input/output Buffer Information Specification – Standard for providing information for signal integrity simulation of an integrated circuit's inputs and outputs |

| Term | Definition |
|---------|--|
| IDT | Integrated Device Technology – A wholly owned subsidiary of Renesas |
| IOD | Integer Output Divider – Circuit for dividing down a clock signal using whole numbers only. |
| LAN | Local Area Network – Wired or wireless communication protocol between PC within a short distance |
| LGA | Land Grid Array – Type of integrated circuit package that has contact locations around the periphery of the package, but only on the bottom surface |
| LOL | Loss-of-Lock – A signal or register bit indicating that a PLL is not in the locked state |
| LOS | Loss-of-Signal – A signal or register bit indicating that a clock input is not receiving a valid input clock |
| LP-HCSL | Low-Power HCSL – Variant of an HCSL output buffer that includes the transmitter series termination internal to the part |
| LVDS | Low-Voltage Differential Signaling – Differential signaling protocol using a lower voltage swing. Referenced to VDD. |
| LVPECL | Low-Voltage Pseudo Emitter-Coupled Logic – Differential signaling protocol using a voltage swing similar to ECL logic, but uses a 2.5V or 3.3V positive reference voltage. |
| MMD | Multi-Modulus Divider - Clock divider circuit that applies one of several integer divide ratios under control of an SDM. |
| NTP | Network Time Protocol – Software based protocol that aligns real-time clocks across a wide-area network. Can align to less than 1 second of accuracy. |
| OCXO | Oven-Controlled Crystal Oscillator – A device that generates a highly stable clock frequency by using an internal oven to maintain the quartz crystal at an even internal temperature |
| OTN | Optical Transport Network – Asynchronous optical communication protocol defined in ITU-T G.709. Used for high-speed data communications. Able to carry many different protocols at the same time over large distances. |
| OTP | One-Time Programmable memory – Non-volatile storage medium that allows any individual memory bit to be programmed only once. |
| OTU3 | OTN line rate of approximately 40Gbps |
| OTU4 | OTN line rate of approximately 100Gbps |
| PCIe | Peripheral Component Interconnect Express – Interchip communication protocol primarily used in PC and datacenter equipment |
| PHY | Physical Layer Interconnection component. Integrated circuit that formats a signal for transmission over an inter-system interconnect medium. Requires reference clock inputs that may be strict if the interconnect medium is high speed |
| PLL | Phase Lock Loop – Integrated circuit that generates, cleans up, or translates clock signals |
| PSRR | Power Supply Rejection Ratio (sometimes referred to as Power Supply Noise Rejection) – Indicates the amount of noise energy received on the power pins of the PLL that appear on the output. May be expressed as a dB ratio of input to output power at the noise frequency or as an absolute value of the output power at the noise frequency |
| PVT | Process, Voltage, and Temperature – Three axes of stress that affect the performance of an integrated circuit |
| QFN | Quad Flat No-leads package – Type of integrated circuit package that has interconnection pads on all 4 sides of the package including on the bottom. Often has a heat-dissipation metal slug called an ePAD. |
| RAM | Random Access Memory – Type of integrated circuit that requires clock signals. |
| REA | Renesas Electronics America |
| RMS | Root-Mean-Square – Method of specifying the power content of an oscillating signal. |
| SD Card | Secure Digital memory card – Popular non-volatile storage medium that involves removable cards. Can provide firmware or software updates to a system. |
| SDM | Sigma-Delta Modulator - Control logic function that uses a sigma-delta algorithm to control an MMD to generate a fractional divide ratio that is dynamically adjustable to minimize noise contributions. |
| SPI | Serial Peripheral Interface – Serial communication protocol for inter-chip communication. Originally developed by Motorola Semiconductor. It is widely used in the industry but has never been standardized. |
| SSC | Spread Spectrum Clock – A clock signal that is modulated at a low rate to reduce electro-magnetic emissions from a system. Primarily used in data center equipment. |
| SSTL | Stub Series Terminated Logic – Signaling protocol commonly used with Dynamic RAMs |
| TCXO | Temperature Compensated Crystal Oscillator – Electronic component that uses a quartz crystal to generate a reference clock frequency and temperature-compensation logic to stabilize the frequency over temperature. Stability falls between XOs and OCXOs. |
| TDC | Time-to-Digital Converter - High precision sampling logic that detects the rising edges on its two input signals and converts the time difference between those two edges into a digital word. |

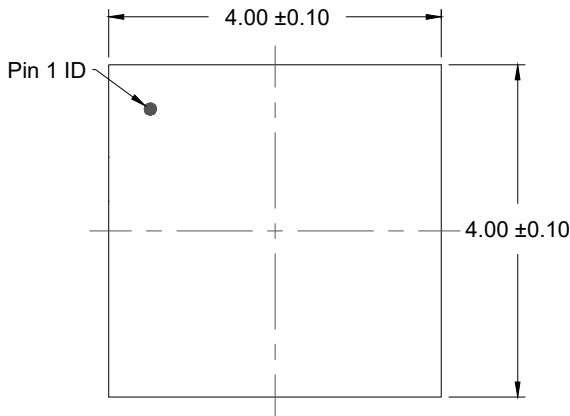
| Term | Definition |
|--------------------|--|
| USB | Universal Serial Bus – device-device interconnection protocol used for short-range wired communication. Is used in some systems to provide management access for software or firmware update. |
| VCO | Voltage Controlled Oscillator - an adjustable oscillator for generating frequencies that can be adjusted by changing the voltage on a control pin |
| V _{DD} | Generic term used for any power input reference or pin. |
| V _{DDO} | Power input pins that provide power and set a reference voltage for the output buffers. There are several such pins each associated with specific output buffers. |
| V _{DDREF} | Power input pin(s) that power and set a reference voltage for the input reference clocks |
| XO | Crystal Oscillator circuit – electronic component that generates a frequency reference by combining a quartz crystal and an oscillator circuit in a single package. Since the crystal is uncompensated, the frequency stability over temperature may be bad. |
| Xtal | Crystal – passive quartz crystal that provides a frequency reference when stimulated by an oscillator circuit |

14. Device Errata

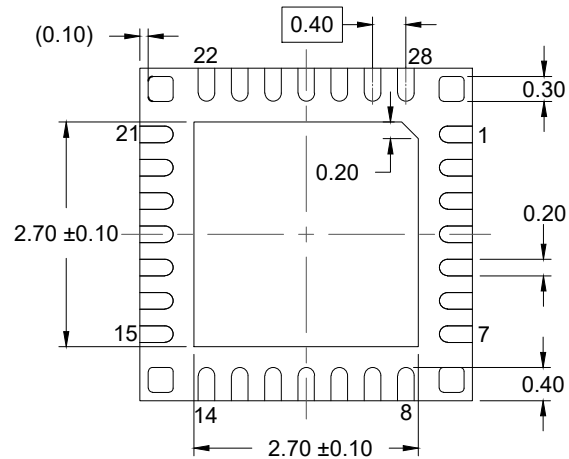
| # | Parameter/Function | Description | Work Around |
|----|--|---------------------------------------|--|
| A1 | odc, Output Duty Cycle in Table 10 . | Violation to max 55% for /11 and /13. | None. Please use a VCO frequency that allows for an even divide to achieve the desired output frequency. |

15. Revision History

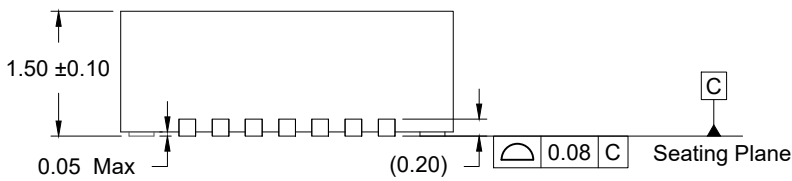
| Revision | Date | Description of Change |
|----------|--------------|--|
| 1.07 | Apr 4, 2024 | <ul style="list-style-type: none"> Completed several changes to APLL Loop Filter (LPF). |
| 1.06 | Nov 20, 2023 | <ul style="list-style-type: none"> Updated the typical values for C_{IN} in Table 3. Completed other minor changes. |
| 1.05 | Nov 11, 2022 | <ul style="list-style-type: none"> Updated Figure 7; Standard HCSL Termination. Updated the I²C slave addressing examples in the following: <ul style="list-style-type: none"> I2C 1-byte (1B) Addressing Example I2C 2-byte (2B) Addressing Example SPI 2-byte (2B) Addressing Example |
| 1.04 | Aug 4, 2022 | <ul style="list-style-type: none"> Updated the input capacitance for nCLKIN in Table 3. Updated the I2C slave addressing examples in I2C 1-byte (1B) Addressing Example and I2C 2-byte (2B) Addressing Example. Removed OTP information. Completed other minor changes. |
| 1.03 | Mar 18, 2022 | Updated the Ordering Information . |
| 1.02 | Nov 8, 2021 | Updated the Frequency Stability (Free-run) parameter and test condition in Table 10 . |
| 1.01 | Jun 4, 2021 | Updated the description of the HCSL internal resistor to 50Ω in Direct-Coupled HCSL Termination and Clock Output Driver . |
| 1.00 | May 12, 2021 | Initial release. |



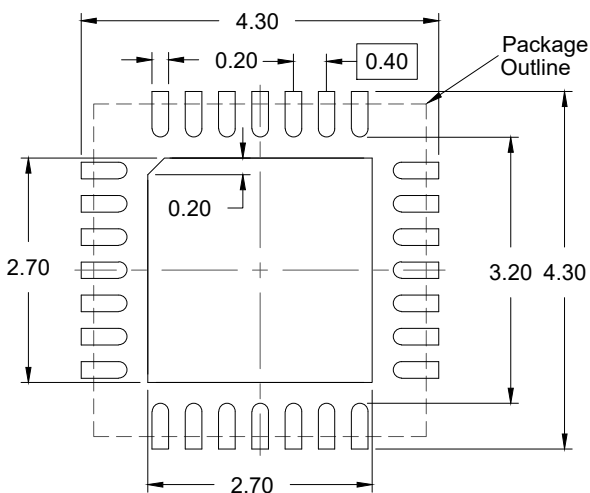
TOP VIEW



BOTTOM VIEW



SIDE VIEW



RECOMMENDED LAND PATTERN
(PCB Top View, NSMD Design)

NOTES:

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

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