# SLG47011

GreenPAK Programmable Mixed-Signal Matrix With Analog-to-Digital Data Acquisition System

The SLG47011 provides a small, low power solution for commonly used analog-to-digital conversion and mixed-signal functions. A flexible data acquisition system used in conjunction with configurable logic provides a way to implement a wide variety of functions with minimal cost. The user can create a circuit design by programming the one time programmable (OTP) Non-Volatile Memory (NVM), to configure the interconnect logic, the macrocells, and the IO pins.

## Features

- SAR ADC
  - 14-, 12-, 10-, 8-bit Selectable Resolution
  - Up to 2.35 Msps in 8-bit mode
  - Sampling up to Four Analog Channels
  - Output Options: Parallel, $I^2C$, SPI
- Programmable Gain Amplifier
  - 1x to 64x Gain Selection
  - Differential, Single-Ended Modes
- MathCore
  - Multiplier, Adder, Subtractor, Shifter Options
- Four Independent Data Buffers
  - Buffer Length up to Eight 16-bit Words
  - Oversampling Mode (Increasing ADC Resolution)
  - Moving Average Mode
  - Counter Capture Mode
- 4096 Words x 12-bit Memory Table Macrocell
  - Full Range Mode or Two Ranges Mode
  - ADC Data Linearization or Any y = F(x) Function
  - ADDR-to-DATA/Storage Modes
- 16-bit Multichannel Digital Comparator (MDCMP)
  - Sampling up to Four Independent Channels
  - Static or Dynamic Threshold
  - Hysteresis Option for Each Channel
- PWM Macrocell
  - 12-bit Resolution
  - Dynamic Duty Cycle Change (up to 4096 Duty Cycle Value)
- Width Converter Macrocell
  - 12-bit Parallel Data Output
  - Optional 12 x 1-bit, 6 x 2-bit, 3 x 4-bit Output
- 12-bit 333 ksps Digital-to-Analog Converter
- Selectable Current Source
- Integrated Voltage References ($V_{REF}$)
- High Speed Analog Comparator
  - Configurable Hysteresis and Reference
- Eighteen Combination Function Macrocells
  - Two 2-bit LUT or DFF/LATCH Macrocells
  - Eight 3-bit LUT or DFF/LATCH with Set/Reset
  - Six Selectable DFF/LATCH or 3-bit LUTs or Shift Registers
  - Two 4-bit LUT or DFF/LATCH with Set/Reset Macrocell
- Fourteen Multi-Function Macrocells
  - Ten Selectable DFF/LATCH or 3-bit LUTs + 12-bit Delay/Counters
  - Two Selectable DFF/LATCH or 4-bit LUT + 16-bit Delay/Counter/FSM
  - One Selectable DFF/LATCH or 3-bit LUTs + 12-bit Delay/Counter/FSM
  - 12-bit Memory Control Up/Down Counter
- Communication Interfaces
  - $I^2C$ Interface
  - SPI Interface
- Programmable Delay with Edge Detector Output
- Deglitch Filter or Edge Detector
- Two Oscillators (OSC)
  - 2 kHz/10 kHz Oscillator
  - 20 MHz/40 MHz Oscillator
- Analog Temperature Sensor
- Power-On Reset (POR) with CRC
- Read Back Protection (Read Lock)
- Power Supply
  - 1.71 V to 3.6 V
- Operating Temperature Range: -40 °C to 85 °C
- RoHS Compliant/Halogen-Free
- Available Package
  - 16-pin STQFN: 2.0 mm x 2.0 mm x 0.55 mm, 0.4 mm pitch

## Applications

- Consumer Electronics
- Handheld and Portable Electronics
- Industrial Automation and Process Control
- Personal Computers and Servers
- PC Peripherals
- Battery Voltage and Current Monitoring
- Power Monitors

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# 1. Overview

## 1.1 Block Diagram

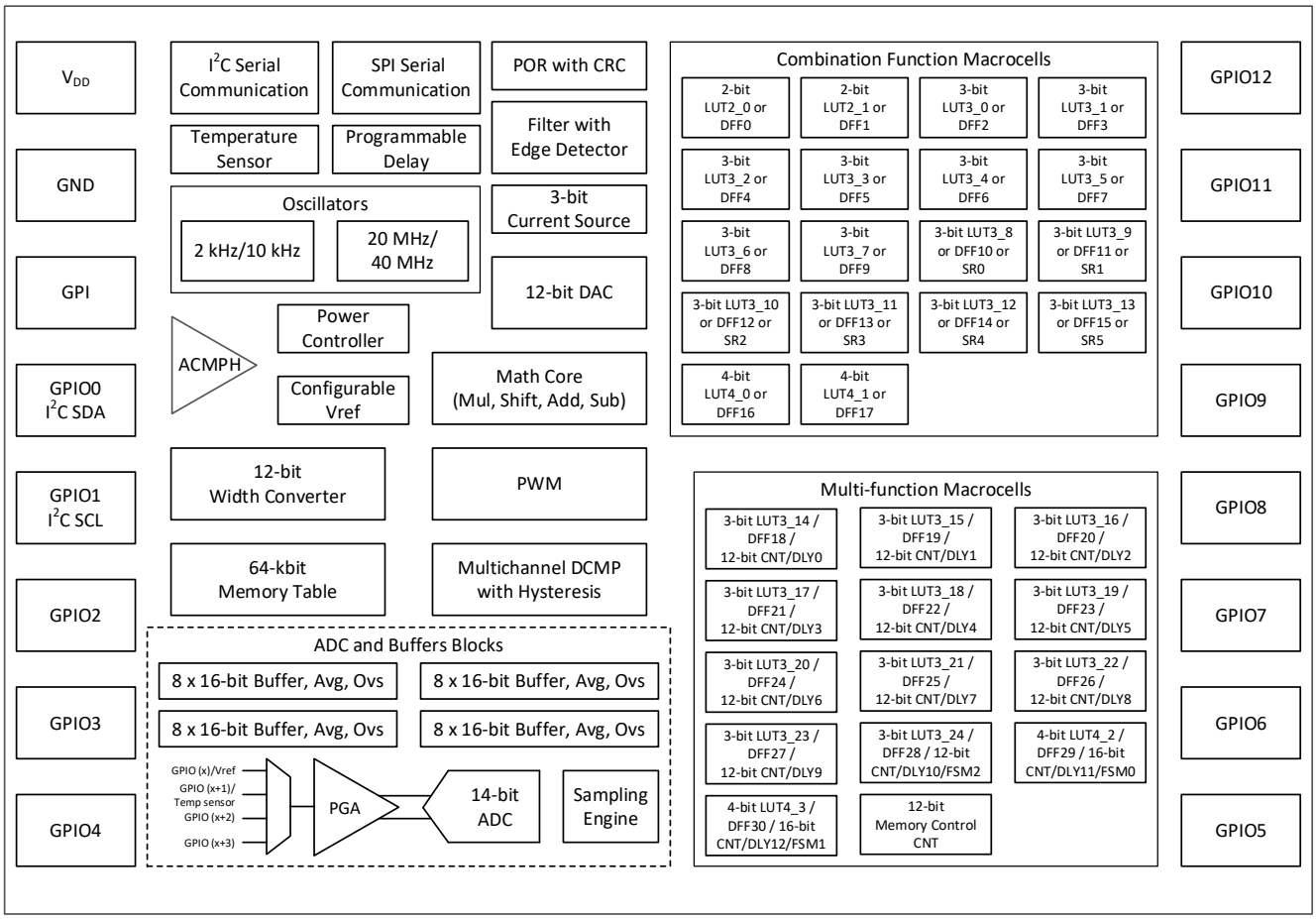



**Figure 1. Block Diagram**

## 1.2 Analog and Digital Blocks Interaction

Figure 2 shows the interconnect between combination function macrocells, multi-function macrocells, ADC, Data Buffers, Memory Table, DAC, DCMP, and other associated macrocells.

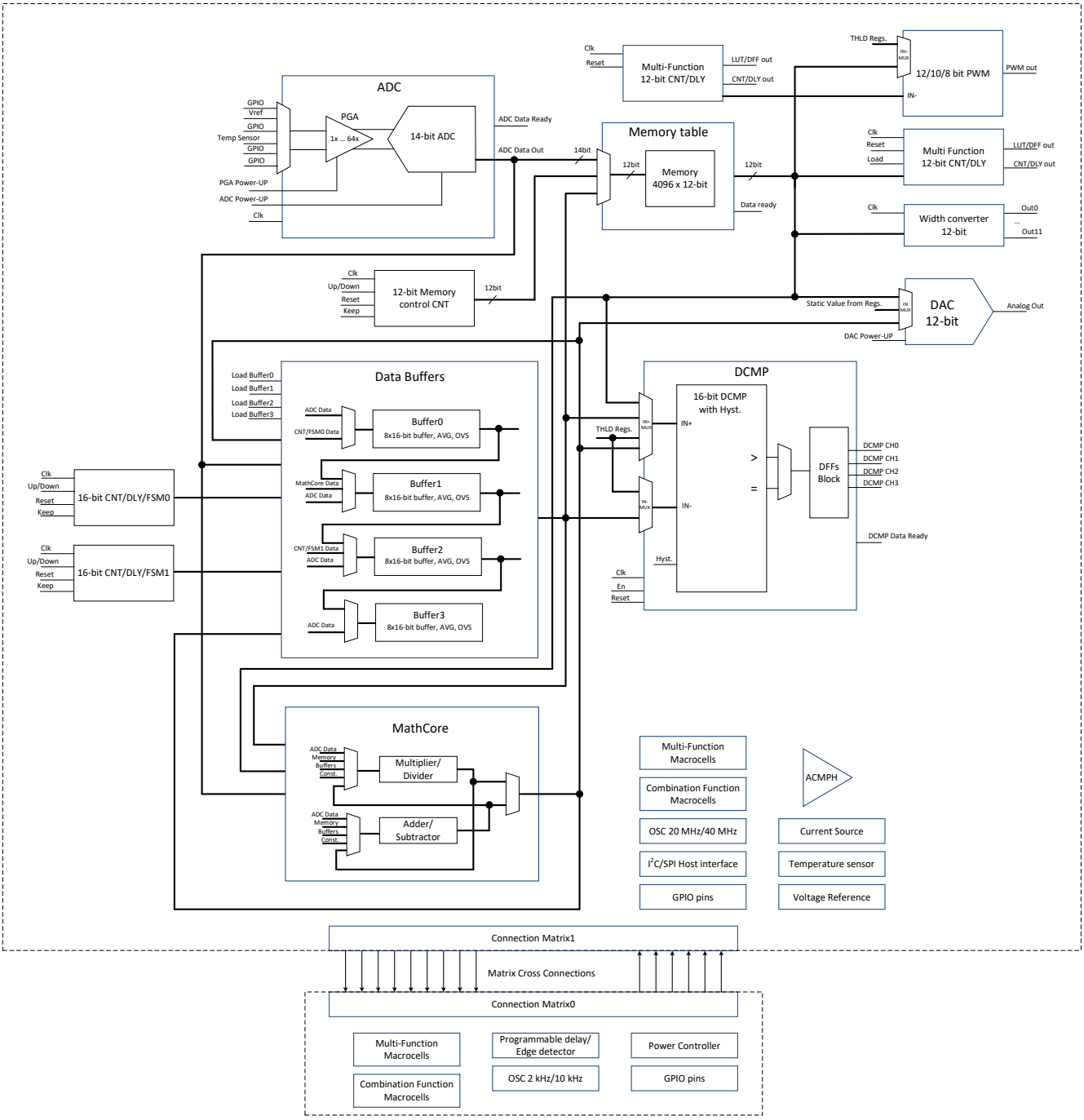



**Figure 2. Analog and Digital Blocks Combined Structure**

## 1.3 User Programmability and Customization

The SLG47011 is a user-programmable device with one time programmable (OTP) memory elements that can configure the connection matrix and macrocells. A programming development kit (Go Configure™ Software Hub) allows the user the ability to create initial designs. Once the design is finalized, the programming code (.aap file) is forwarded to Renesas Electronics Corporation to integrate into the production process.

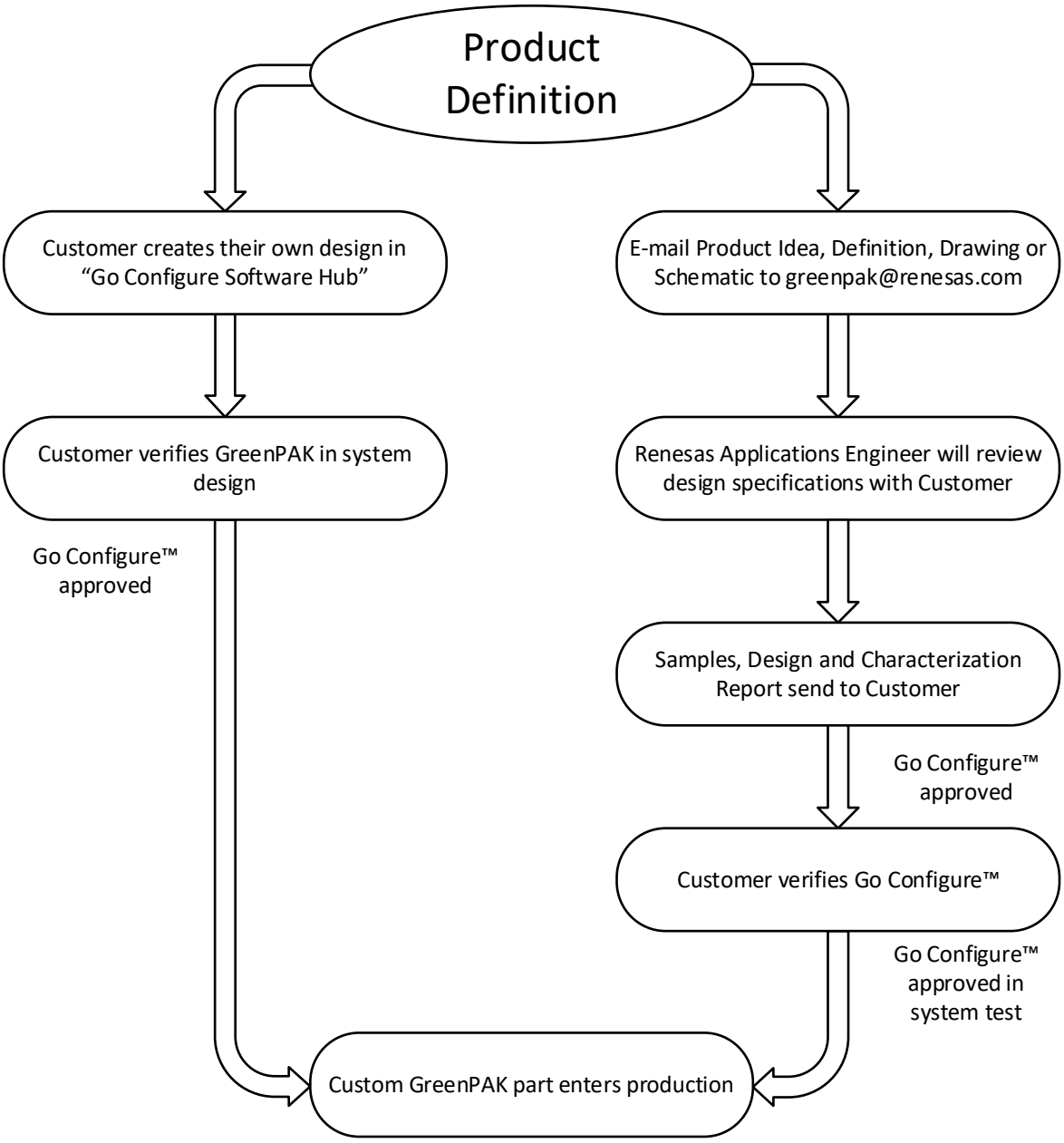



**Figure 3. Device Custom Design Procedure**

# 2. Pin Information

## 2.1 Pin Assignments

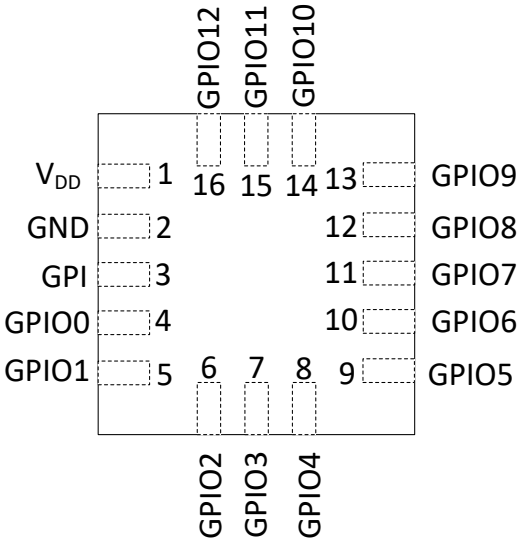



**Figure 4. Pin Assignments – STQFN 16L (Top View)**

**Table 1. Pin Assignments and Description**

| Pin Number | Pin Name | Pin Functions |
|---|---|---|
| 1 | $V_{DD}$ | Power Supply |
| 2 | GND | Ground |
| 3 | GPI | GPI, SPI nCS |
| 4 | GPIO0 | GPIO, $I^2C$ SDA, SPI MOSI |
| 5 | GPIO1 | GPIO, $I^2C$ SCL, SPI CLK |
| 6 | GPIO2 | GPIO, SPI MISO, SLA 0 |
| 7 | GPIO3 | GPIO, PGA In0+, EXT OSC1 |
| 8 | GPIO4 | GPIO, PGA In1+ |
| 9 | GPIO5 | GPIO, PGA In2+ |
| 10 | GPIO6 | GPIO, PGA In3+, SLA 1 |
| 11 | GPIO7 | GPIO, PGA In0-, CS out, ACMP In+, SLA 2 |
| 12 | GPIO8 | GPIO, PGA In1-, DAC out, SLA 3 |
| 13 | GPIO9 | GPIO, ACMP In+, PGA Out+ |
| 14 | GPIO10 | GPIO, ACMP In-, EXT OSC0, PGA Out- |
| 15 | GPIO11 | GPIO, ADC Ext $V_{REF}$ In, DAC Ext $V_{REF}$ in, DAC $V_{REF}$ Buffer out |
| 16 | GPIO12 | GPIO |

## 2.2 Pin Descriptions

**Table 2. Functional Pin Description**

| Pin Name | Signal Name | Function | Input Options | Output Options |
|---|---|---|---|---|
| $V_{DD}$ | $V_{DD}$ | Digital Power Supply | Power | - |
| GND | GND | Analog and Digital GND | - | - |
| GPI | GPI | General Purpose Input | Digital Input without Schmitt Trigger | - |
| | | | Digital Input with Schmitt Trigger | - |
| | | | Low Voltage Digital Input | - |
| | SPI nCS | SPI nCS | Digital | - |
| GPIO0 | GPIO0 | General Purpose Input/Open-Drain Output | Digital Input without Schmitt Trigger | Open-Drain NMOS |
| | | | Digital Input with Schmitt Trigger | - |
| | | | Low Voltage Digital Input | - |
| | $I^2C$_SDA | $I^2C$ Serial Data | Digital | Digital |
| | SPI MOSI | SPI MOSI | Digital | - |
| GPIO1 | GPIO1 | General Purpose Input/Open-Drain Output | Digital Input without Schmitt Trigger | Open-Drain NMOS |
| | | | Digital Input with Schmitt Trigger | - |
| | | | Low Voltage Digital Input | - |
| | $I^2C$_SCL | $I^2C$ Serial Clock | Digital | - |
| | SPI CLK | SPI CLK | Digital | - |
| GPIO2 | GPIO2 | General Purpose IO with OE | Digital Input without Schmitt Trigger | Push-Pull |
| | | | Digital Input with Schmitt Trigger | Open-Drain NMOS |
| | | | Low Voltage Digital Input | - |
| | SPI MISO | SPI MISO | - | Digital |
| | SLA 0 | $I^2C$ Slave Address Bit0 | Digital | - |
| GPIO3 | GPIO3 | General Purpose IO with OE | Digital Input without Schmitt Trigger | Push-Pull |
| | | | Digital Input with Schmitt Trigger | Open-Drain NMOS |
| | | | Low Voltage Digital Input | - |
| | PGA In0+ | PGA Positive Input0 | Analog | - |
| | EXT OSC1 | External CLK1 Input | Digital | - |

| Pin Name | Signal Name | Function | Input Options | Output Options |
|---|---|---|---|---|
| GPIO4 | GPIO4 | General Purpose IO with OE | Digital Input without Schmitt Trigger | Push-Pull |
| | | | Digital Input with Schmitt Trigger | Open-Drain NMOS |
| | | | Low Voltage Digital Input | - |
| | PGA In1+ | PGA Positive Input1 | Analog | - |
| GPIO5 | GPIO5 | General Purpose IO with OE | Digital Input without Schmitt Trigger | Push-Pull |
| | | | Digital Input with Schmitt Trigger | Open-Drain NMOS |
| | | | Low Voltage Digital Input | - |
| | PGA In2+ | PGA Positive Input2 | Analog | - |
| GPIO6 | GPIO6 | General Purpose IO with OE | Digital Input without Schmitt Trigger | Push-Pull |
| | | | Digital Input with Schmitt Trigger | Open-Drain NMOS |
| | | | Low Voltage Digital Input | - |
| | PGA In3+ | PGA Positive Input3 | Analog | - |
| | SLA 1 | $I^2C$ Slave Address Bit1 | Digital | - |
| GPIO7 | GPIO7 | General Purpose IO with OE | Digital Input without Schmitt Trigger | Push-Pull |
| | | | Digital Input with Schmitt Trigger | Open-Drain NMOS |
| | | | Low Voltage Digital Input | - |
| | PGA In0- | PGA Negative Input0 | Analog | - |
| | ACMP In+ | ACMP Positive Input | Analog | - |
| | CS Out | Current Source Output | - | Analog |
| | SLA 2 | $I^2C$ Slave Address Bit2 | Digital | - |
| GPIO8 | GPIO8 | General Purpose IO with OE | Digital Input without Schmitt Trigger | Push-Pull |
| | | | Digital Input with Schmitt Trigger | Open-Drain NMOS |
| | | | Low Voltage Digital Input | - |
| | PGA In1- | PGA Negative Input1 | Analog | - |
| | DAC out | DAC Output | - | Analog |
| | SLA 3 | $I^2C$ Slave Address Bit3 | Digital | - |
| GPIO9 | GPIO9 | General Purpose IO with OE | Digital Input without Schmitt Trigger | Push-Pull |
| | | | Digital Input with Schmitt Trigger | Open-Drain NMOS |
| | | | Low Voltage Digital Input | - |
| | ACMP In+ | ACMP Positive Input | Analog | - |
| | PGA Out+ | PGA Positive Output | - | Analog |

| Pin Name | Signal Name | Function | Input Options | Output Options |
|---|---|---|---|---|
| GPIO10 | GPIO10 | General Purpose IO with OE | Digital Input without Schmitt Trigger | Push-Pull |
| | | | Digital Input with Schmitt Trigger | Open-Drain NMOS |
| | | | Low Voltage Digital Input | - |
| | ACMP In- | ACMP Negative Input | Analog | - |
| | EXT OSC0 | External CLK0 Input | Digital | - |
| | PGA Out- | PGA Negative Output | - | Analog |
| GPIO11 | GPIO11 | General Purpose IO with OE | Digital Input without Schmitt Trigger | Push-Pull |
| | | | Digital Input with Schmitt Trigger | Open-Drain NMOS |
| | | | Low Voltage Digital Input | - |
| | ADC Ext $V_{REF}$ In | ADC External Voltage Reference Input | Analog | - |
| | DAC Ext $V_{REF}$ in | DAC External Voltage Reference Input | Analog | - |
| | DAC $V_{REF}$ Buffer out | DAC Voltage Reference Buffer Output | - | Analog |
| GPIO12 | GPIO12 | General Purpose IO with OE | Digital Input without Schmitt Trigger | Push-Pull |
| | | | Digital Input with Schmitt Trigger | Open-Drain NMOS |
| | | | Low Voltage Digital Input | - |

# 3. Specifications

## 3.1 Absolute Maximum Ratings

Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, so functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification are not implied. Exposure to the absolute maximum conditions for extended periods may affect the device reliability.

| Parameter | | Min | Max | Unit |
|---|---|---|---|---|
| $V_{DD}$ Voltage to GND | | - 0.3 | 4.5 | V |
| SDA/GPIO0 and SCL/GPIO1 Pin Voltage to GND | | - 0.3 | $V_{DD}$ + 0.3, up to 4.5 | V |
| GPIO2 – GPIO12, and GPI Pin Voltage to GND | | - 0.3 | $V_{DD}$ + 0.3, up to 4.5 | V |
| $V_{DD}$ DC Current | | -- | 90 | mA |
| GND DC Current | | -- | 90 | mA |
| GPIO DC Current | Push-Pull Output Mode | -- | 8 | mA |
| | Open-Drain Output Mode | -- | 8 | |
| Current at Input Pin | | -1.0 | 1.0 | mA |
| Continuous Power Dissipation (JESD51-7, $T_A$ = +85ºC) | STQFN 16L (Derate 16.7 mW/°C above $T_A$ = +85 ºC) | - | 1083 | mW |
| Junction Temperature | | -- | 150 | °C |
| Storage Temperature Range | | -65 | 150 | °C |
| Moisture Sensitive Level | | 1 | | |

## 3.2 ESD Ratings

| Parameter | Min | Max | Unit |
|---|---|---|---|
| ESD Protection (Human Body Model) | 2000 | -- | V |
| ESD Protection (Charged Device Model) | 500 | -- | V |

## 3.3 Recommended Operating Conditions

| Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $V_{DD}$ Supply Voltage Range | | 1.71 | 3.3 | 3.6 | V |
| SDA/GPIO0 and SCL/GPIO1 Pin Voltage to GND | | - 0.2 | -- | $V_{DD}$ + 0.2, up to 4.5 | V |
| GPIO2 – GPIO12, and GPI Pin Voltage to GND | | - 0.2 | -- | $V_{DD}$ + 0.2, up to 4.5 | V |
| Operating Ambient Temperature Range ($T_A$) | | -40 | -- | 85 | °C |
| Input Capacitor at $V_{DD}$ Pin | | 0.1 | -- | -- | µF |
| Analog Input Common Mode Range | Allowable Input Voltage at Analog Pins | -0.3 | -- | $V_{DD}$ | V |

## 3.4 Electrical Specifications

### 3.4.1. Logic IO Specifications

$V_{DD}$ = 1.71 V to 3.6 V, $T_A$ = -40 °C to +85 °C, typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| HIGH-Level Input Voltage | $V_{IH}$ | Logic Input [1] [3] | 0.7 x $V_{DD}$ | -- | -- | V |
| | | Logic Input with Schmitt Trigger | 0.7 x $V_{DD}$ | -- | -- | V |
| | | Low-voltage Logic Input [1] [3] | 0.9 | -- | -- | V |
| LOW-Level Input Voltage | $V_{IL}$ | Logic Input [1] [3] | -- | -- | 0.3 x $V_{DD}$ | V |
| | | Logic Input with Schmitt Trigger | -- | -- | 0.3 x $V_{DD}$ | V |
| | | Low-voltage Logic Input [1] [3] | -- | -- | 0.3 | V |
| Schmitt Trigger Hysteresis Voltage | $V_{HYS}$ | | 0.166 x $V_{DD}$ | 0.23 x $V_{DD}$ | 0.304 x $V_{DD}$ | V |
| HIGH-Level Output Voltage | $V_{OH}$ | Push-pull, $V_{DD}$ = 1.8 V ± 5 %, $I_{OH}$ = 100 µA | 0.994 x $V_{DD}$ | -- | -- | V |
| | | Push-pull, $V_{DD}$ = 1.8 V ± 5 %, $I_{OH}$ = 2 mA | 0.895 x $V_{DD}$ | -- | -- | V |
| | | Push-pull, $V_{DD}$ = 2.5 V ± 10 %, $I_{OH}$ = 100 µA | 0.996 x $V_{DD}$ | -- | -- | V |
| | | Push-pull, $V_{DD}$ = 2.5 V ± 10 %, $I_{OH}$ = 2 mA | 0.940 x $V_{DD}$ | -- | -- | V |
| | | Push-pull, $V_{DD}$ = 3.3 V ± 10 %, $I_{OH}$ = 100 µA | 0.998 x $V_{DD}$ | -- | -- | V |
| | | Push-pull, $V_{DD}$ = 3.3 V ± 10 %, $I_{OH}$ = 2 mA | 0.983 x $V_{DD}$ | -- | -- | V |
| LOW-Level Output Voltage | $V_{OL}$ | Push-pull, $V_{DD}$ = 1.8 V ± 5 %, $I_{OH}$ = 100 µA | -- | -- | 0.002 x $V_{DD}$ | V |
| | | Push-pull, $V_{DD}$ = 1.8 V ± 5 %, $I_{OH}$ = 2 mA | -- | -- | 0.047 x $V_{DD}$ | V |
| | | Push-pull, $V_{DD}$ = 2.5 V ± 10 %, $I_{OH}$ = 100 µA | -- | -- | 0.002 x $V_{DD}$ | V |
| | | Push-pull, $V_{DD}$ = 2.5 V ± 10 %, $I_{OH}$ = 2 mA | -- | -- | 0.028 x $V_{DD}$ | V |
| | | Push-pull, $V_{DD}$ = 3.3 V ± 10 %, $I_{OH}$ = 100 µA | -- | -- | 0.001 x $V_{DD}$ | V |
| | | Push-pull, $V_{DD}$ = 3.3 V ± 10 %, $I_{OH}$ = 2 mA | -- | -- | 0.019 x $V_{DD}$ | V |

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| LOW-Level Output Voltage | $V_{OL}$ | NMOS OD, $V_{DD}$ = 1.8 V ± 5 %, $I_{OH}$ = 100 µA | -- | -- | 0.004 x $V_{DD}$ | V |
| | | NMOS OD, $V_{DD}$ = 1.8 V ± 5 %, $I_{OH}$ = 2 mA | -- | -- | 0.077 x $V_{DD}$ | V |
| | | NMOS OD, $V_{DD}$ = 2.5 V ± 10 %, $I_{OH}$ = 100 µA | -- | -- | 0.002 x $V_{DD}$ | V |
| | | NMOS OD, $V_{DD}$ = 2.5 V ± 10 %, $I_{OH}$ = 2 mA | -- | -- | 0.045 x $V_{DD}$ | V |
| | | NMOS OD, $V_{DD}$ = 3.3 V ± 10 %, $I_{OH}$ = 100 µA | -- | -- | 0.002 x $V_{DD}$ | V |
| | | NMOS OD, $V_{DD}$ = 3.3 V ± 10 %, $I_{OH}$ = 2 mA | -- | -- | 0.029 x $V_{DD}$ | V |
| HIGH-Level Output Pulse Current [2] | $I_{OH}$ | Push-pull, $V_{DD}$ = 1.8 V ± 5 %, $V_{OH}$ = $V_{DD}$ x 0.8 | 2.96 | -- | -- | mA |
| | | Push-pull, $V_{DD}$ = 2.5 V ± 10 %, $V_{OH}$ = $V_{DD}$ x 0.8 | 5.13 | -- | -- | mA |
| | | Push-pull, $V_{DD}$ = 3.3 V ± 10 %, $V_{OH}$ = $V_{DD}$ x 0.8 | 8.41 | -- | -- | mA |
| LOW-Level Output Pulse Current [2] | $I_{OL}$ | Push-pull, $V_{DD}$ = 1.8 V ± 5 %, $V_{OL}$ = $V_{DD}$ x 0.2 | 5.27 | -- | -- | mA |
| | | Push-pull, $V_{DD}$ = 2.5 V ± 10 %, $V_{OL}$ = $V_{DD}$ x 0.2 | 9.09 | -- | -- | mA |
| | | Push-pull, $V_{DD}$ = 3.3 V ± 10 %, $V_{OL}$ = $V_{DD}$ x 0.2 | 14.48 | -- | -- | mA |
| | | NMOS OD, PINs 4-5, $V_{DD}$ = 1.8 V ± 5 %, $V_{OL}$ = $V_{DD}$ x 0.1 | 5.53 | -- | -- | mA |
| | | NMOS OD, PINs 4-5, $V_{DD}$ = 2.5 V ± 10 %, $V_{OL}$ = $V_{DD}$ x 0.1 | 9.14 | -- | -- | mA |
| | | NMOS OD, PINs 4-5, $V_{DD}$ = 3.3 V ± 10 %, $V_{OL}$ = $V_{DD}$ x 0.1 | 14.14 | -- | -- | mA |
| | | NMOS OD, PINs 6-16, $V_{DD}$ = 1.8 V ± 5 %, $V_{OL}$ = $V_{DD}$ x 0.1 | 3.81 | -- | -- | mA |
| | | NMOS OD, PINs 6-16, $V_{DD}$ = 2.5 V ± 10 %, $V_{OL}$ = $V_{DD}$ x 0.1 | 6.50 | -- | -- | mA |
| | | NMOS OD, PINs 6-16, $V_{DD}$ = 3.3 V ± 10 %, $V_{OL}$ = $V_{DD}$ x 0.1 | 10.28 | -- | -- | mA |

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Startup Time | $T_{SU}$ | From $V_{DD}$ rising past $PON_{THR}$ OTP load including SRAM | -- | 4.2 | 4.37 | ms |
| | | From $V_{DD}$ rising past $PON_{THR}$ OTP load excluding SRAM | -- | 1.7 | 1.93 | ms |
| | | Transition from SLEEP mode to All ON mode, OTP load including SRAM | -- | 3.8 | -- | ms |
| | | Transition from SLEEP mode to All ON mode, OTP load excluding SRAM | -- | 1.4 | -- | ms |
| | | Transition from RETENTION mode to All ON mode | -- | 0.4 | -- | ms |
| Power-On Threshold | $PON_{THR}$ | $V_{DD}$ level required to start up the chip | 1.44 | 1.5 | 1.56 | V |
| Power-Off Threshold | $POFF_{THR}$ | $V_{DD}$ level required to switch off the chip | 0.66 | 0.7 | 0.72 | V |
| Pull-Up or Pull-Down Resistance | $R_{PULL}$ | 50 k for pull-up: $V_{IN}$ = GND; for pull-down: $V_{IN}$ = $V_{DD}$ | 35 | 50 | 65 | kΩ |
| | | 10 k for pull-up: $V_{IN}$ = GND; for pull-down: $V_{IN}$ = $V_{DD}$ | 7 | 10 | 13 | kΩ |
| Input Capacitance | $C_{IN}$ | PIN 9, 12, 13, 14, 15, 16 Input Capacity on one PIN, $T_A$ = 25 °C | -- | 4.5 | -- | pF |
| | | PIN 3, 4, 5, 6, 8, 10 Input Capacity on one PIN, $T_A$ = 25 °C | -- | 6.8 | -- | pF |
| Input Leakage Current [4] | $I_{Leak}$ | Absolute Value | -- | -- | 500 | nA |

**[1]** No hysteresis.

**[2]** DC or average current through any pin should not exceed value given in Absolute Maximum Conditions.

**[3]** When using Logic Input without Schmitt Trigger the minimal slew rate of input signal is limited, please see section 4 IO Pins for details.

**[4]** Guaranteed by design, not tested in production.

## 3.4.2. I²C Specifications

$V_{DD}$ = 1.71 V to 3.6 V, $T_A$ = -40 °C to +85 °C, typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Conditions | Fast-Mode | | Fast-Mode Plus | | Unit |
|---|---|---|---|---|---|---|---|
| | | | Min | Max | Min | Max | |
| **IO Stage** | | | | | | | |
| LOW-Level Input Voltage | $V_{IL}$ | Logic Input with Schmitt Trigger | -- | 0.3 x $V_{DD}$ | -- | 0.3 x $V_{DD}$ | V |
| | | Low-voltage Logic Input [1] | -- | 0.3 | N/A | N/A | |

| Parameter | Symbol | Conditions | Fast-Mode | | Fast-Mode Plus | | Unit |
|---|---|---|---|---|---|---|---|
| | | | Min | Max | Min | Max | |
| HIGH-Level Input Voltage | $V_{IH}$ | Logic Input with Schmitt Trigger | 0.7 x $V_{DD}$ | -- | 0.7 x $V_{DD}$ | -- | V |
| | | Low-voltage Logic Input [1] | 0.9 | -- | N/A | N/A | |
| Hysteresis of Schmitt Trigger Inputs | $V_{HYS}$ | | 0.05 x $V_{DD}$ | -- | 0.05 x $V_{DD}$ | -- | V |
| LOW-Level Output Voltage 1 | $V_{OL1}$ | Open-drain at 3 mA sink current, $V_{DD}$ > 2 V | 0 | 0.4 | 0 | 0.4 | V |
| LOW-Level Output Voltage 2 | $V_{OL2}$ | Open-drain at 2 mA sink current, $V_{DD}$ ≤ 2 V | 0 | 0.2 x $V_{DD}$ | 0 | 0.2 x $V_{DD}$ | V |
| LOW-Level Output Current [2] | $I_{OL}$ | $V_{OL}$ = 0.4 V, $V_{DD}$ = 1.8 V | 3 | -- | 17 | -- | mA |
| | | $V_{OL}$ = 0.4 V, $V_{DD}$ = 2.5 V | 3 | -- | 20 | -- | mA |
| | | $V_{OL}$ = 0.4 V, $V_{DD}$ = 3.3 V | 3 | -- | 20 | -- | mA |
| | | $V_{OL}$= 0.6 V | 6 | -- | -- | -- | mA |
| Output Fall Time from $V_{IH(MIN)}$ to $V_{IL(MAX)}$ [2] | $t_{of}$ | | - | 250 | - | 120 | ns |
| Pulse Width of Spikes that must be suppressed by the Input Filter | $t_{SP}$ | | 0 | 10 [3] | 0 | 10 [3] | ns |
| Input Current Each IO Pin | $I_i$ | 0.1 x $V_{DD}$ < $V_I$ < 0.9 x $V_{DD(MAX)}$ | -10 | +10 | -10 | +10 | µA |
| Capacitance for Each IO Pin | $C_i$ | | -- | 10 | -- | 10 | pF |
| **Timing (See Figure 205 for Diagram)** | | | | | | | |
| Clock Frequency, SCL | $f_{SCL}$ | | -- | 400 | -- | 1000 | kHz |
| Clock Pulse Width Low | $t_{LOW}$ | | 1300 | -- | 500 | -- | ns |
| Clock Pulse Width High | $t_{HIGH}$ | | 600 | -- | 260 | -- | ns |
| Start Hold Time | $t_{HD\_STA}$ | | 600 | -- | 260 | -- | ns |
| Set-up Time for a Repeated START Condition | $t_{SU\_STA}$ | | 600 | -- | 260 | -- | ns |
| Data Hold Time | $t_{HD\_DAT}$ | Logic Input with Schmitt Trigger | 0 [4] | -- | 0 [4] | -- | ns |
| | | Low-voltage Logic Input | 70 [4] | -- | N/A | N/A | |
| Data Set-Up Time | $t_{SU\_DAT}$ | Logic Input with Schmitt Trigger | 100 | -- | 50 | -- | ns |
| | | Low-voltage Logic Input | 100 | -- | N/A | N/A | |
| Rise Time of both SDA and SCL Signals | $t_R$ | | -- | 300 | -- | 120 | ns |

| Parameter | Symbol | Conditions | Fast-Mode | | Fast-Mode Plus | | Unit |
|---|---|---|---|---|---|---|---|
| | | | Min | Max | Min | Max | |
| Fall Time of both SDA and SCL Signals | $t_F$ | | -- | 300 | -- | 120 | ns |
| Set-Up Time for STOP Condition | $t_{SU\_STO}$ | | 600 | -- | 260 | -- | ns |
| Bus Free Time between STOP and START Condition | $t_{BUF}$ | | 1300 | -- | 500 | -- | ns |
| Capacitive Load for Each Bus Line | $C_b$ | | -- | 400 | -- | 400 | pF |
| Data Valid Time | $t_{VD\_DAT}$ | | -- | 900 | -- | 450 | ns |
| Data Valid Acknowledge Time | $t_{VD\_ACK}$ | | -- | 900 | -- | 450 | ns |

**[1]** No hysteresis.
**[2]** Does not meet standard $I^2C$ specifications: $t_{OF(MIN)}$ = 20 x ($V_{DD}$/5.5 V); for Fast-Mode Plus, $I_{OL(MIN)}$ = 20 mA at $V_{OL}$ = 0.4 V.
**[3]** Does not meet standard $I^2C$ specifications: pulse width of spikes that must be suppressed by the input filter – 50 ns.
**[4]** Does not meet standard $I^2C$ specifications.

## 3.4.3. SPI Specifications

$V_{DD}$ = 1.71 V to 3.6 V, $T_A$ = -40 °C to +85 °C, typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| **IO Stage** | | | | | |
| LOW-Level Input Voltage | $V_{IL}$ | Schmitt Trigger Input | -- | 0.3 x $V_{DD}$ | V |
| | | Low-voltage Logic Input | -- | 0.3 | |
| HIGH-Level Input Voltage | $V_{IH}$ | Schmitt Trigger Input | 0.7 x $V_{DD}$ | -- | V |
| | | Low-voltage Logic Input | 0.9 | -- | |
| LOW-Level Output Voltage | $V_{OL}$ | $I_{OL}$ = 1 mA | 0 | 0.2 | V |
| HIGH-Level Output Voltage | $V_{OH}$ | $I_{OH}$ = -1 mA | $V_{DD}$ - 0.2 V | -- | V |
| **Timing (See Figure 216 for Diagram)** | | | | | |
| CLK Period | $t_{CP}$ | Receive only operation.<br>Logic Input with Schmitt Trigger<br>Cpol = 0, Cpha = 0 | 52 | -- | ns |
| | | Receive only operation.<br>Low-voltage Logic Input<br>Cpol = 0, Cpha = 0 | 95 | -- | |
| | | Receive and transmit operations<br>Logic Input with Schmitt Trigger<br>Cpha = 0 | 85 | -- | |

| Parameter | Symbol | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| CLK Period | $t_{CP}$ | Receive and transmit operations<br>Logic Input with Schmitt Trigger<br>Cpha = 1 | 205 | -- | ns |
| | | Receive and transmit operations<br>Low-voltage Logic Input<br>Cpol = 0, Cpha = 0 | 294 | -- | |
| CLK Pulse Width High | $t_{CH}$ | Logic Input with Schmitt Trigger | 52 | -- | ns |
| | | Low-voltage Logic Input | 10 | -- | |
| CLK Pulse Width Low | $t_{CL}$ | Logic Input with Schmitt Trigger | 21 | -- | ns |
| | | Low-voltage Logic Input | 95 | -- | |
| nCS Fall to CLK First Edge Setup | $t_{CSS}$ | Logic Input with Schmitt Trigger | 14 | -- | ns |
| | | Low-voltage Logic Input | 85 | -- | |
| CLK Last Edge to nCS Rise Hold | $t_{CSH}$ | | 25 | -- | ns |
| nCS Pulse Width High | $t_{CSW}$ | | 25 | -- | ns |
| Data Hold Time | $t_{DIH}$ | | 10 | -- | ns |
| Data Set-Up Time | $t_{DIS}$ | Logic Input with Schmitt Trigger | 0 | -- | ns |
| | | Low-voltage Logic Input | 91 | -- | |

## 3.4.4. Estimated Typical Current of Macrocell Specifications

Typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Conditions | $V_{DD}$ = 1.8 V | $V_{DD}$ = 2.5 V | $V_{DD}$ = 3.3 V | Unit |
|---|---|---|---|---|---|---|
| Current | $I_{DD}$ | Power Detector + Matrix 0 active (SLEEP mode) | 0.5 | 0.5 | 0.6 | µA |
| | | Power Detector + Matrix 0 active + Memory Table and Data Buffers retained (RETENTION mode) | 4.7 | 4.8 | 4.9 | µA |
| | | Power Detector + $I^2C$/SPI + Matrix 0 active + Matrix 1 active (All ON mode) | 30.1 | 30.4 | 30.7 | µA |
| | | Temperature Sensor | 17.6 | 17.8 | 18.0 | µA |
| | | OSC1 20 MHz, Pre-divider = 1 | 27.1 | 27.0 | 27.0 | µA |
| | | OSC1 20 MHz, Pre-divider = 4 | 30.0 | 29.9 | 29.9 | µA |
| | | OSC1 20 MHz, Pre-divider = 8 | 29.5 | 29.4 | 29.4 | µA |
| | | OSC1 40 MHz, Pre-divider = 1 | 49.8 | 49.7 | 49.7 | µA |
| | | OSC1 40 MHz, Pre-divider = 4 | 55.5 | 55.5 | 55.5 | µA |
| | | OSC1 40 MHz, Pre-divider = 8 | 54.5 | 54.5 | 54.5 | µA |
| | | OSC0 2 kHz, Pre-divider = 1 | 0.5 | 0.8 | 1.4 | µA |

| Parameter | Symbol | Conditions | $V_{DD}$ = 1.8 V | $V_{DD}$ = 2.5 V | $V_{DD}$ = 3.3 V | Unit |
|---|---|---|---|---|---|---|
| Current | $I_{DD}$ | OSC0 2 kHz, Pre-divider = 4 | 0.5 | 0.8 | 1.4 | µA |
| | | OSC0 2 kHz, Pre-divider = 8 | 0.5 | 0.8 | 1.4 | µA |
| | | OSC0 10 kHz, Pre-divider = 1 | 0.5 | 0.8 | 1.5 | µA |
| | | OSC0 10 kHz, Pre-divider = 4 | 0.5 | 0.8 | 1.5 | µA |
| | | OSC0 10 kHz, Pre-divider = 8 | 0.5 | 0.8 | 1.5 | µA |
| | | ACMP ($V_{REF}$ Source - Internal $V_{IN+}$ = 0 V; $V_{IN-}$ = 27 mV) | 5.8 | 5.8 | 5.9 | µA |
| | | PGA, Mode 2, Gain = 64, $V_{IN} = V_{DD}/64$ | 18.6 | 20.5 | 24.1 | µA |
| | | PGA, Mode 3, Gain = 64, $V_{IN(CM)} = V_{DD}/2$ , $V_{IN(DIFF)} = V_{DD}/64$ | 26.9 | 28.7 | 32.3 | µA |
| | | PGA, Mode 4, Gain = 64, $V_{IN+} = V_{DD}/32$, $V_{IN-} = V_{DD}/64$ | 16.1 | 17.9 | 21.5 | µA |
| | | PGA, Mode 5, Gain = 64, $V_{IN+} = V_{DD}/64$, $V_{IN-} = V_{DD}/128$, $V_{REF} = V_{DD}/2$ (ADC $V_{REF}$ buffer ON) | 873.4 | 878.8 | 887.5 | µA |
| | | PGA, Mode 5, Gain = 64, $V_{IN+} = V_{DD}/64$, $V_{IN-} = V_{DD}$ /128, Ext $V_{REF}$ (ADC $V_{REF}$ buffer OFF) | 37.2 | 39.1 | 42.8 | µA |
| | | PGA, Mode 6, $V_{IN} = V_{DD}/2$ | 19.1 | 20.5 | 23.9 | µA |
| | | ADC, 14-bit resolution, 40 MHz CLK, 1 Msps, continuous conversion operation, four input channels sampled, $V_{REF}$ = 1.62 V internal | 1180 | 1197 | 1222 | µA |
| | | ADC, 14-bit resolution, 40 MHz CLK, 1 Msps, continuous conversion operation, four input channels sampled, $V_{REF}$ = 1.62 V external | 331.7 | 346.5 | 367.2 | µA |
| | | ADC, 8-bit resolution, 40 MHz CLK, 2.35 Msps, continuous conversion operation, one input channel sampled, $V_{REF}$ = 1.62 V internal | 1214 | 1244 | 1285 | µA |
| | | ADC, 8-bit resolution, 40 MHz CLK, 2.35 Msps, continuous conversion operation, one input channel sampled, $V_{REF}$ = 1.62 V external | 348.9 | 377.2 | 416.2 | µA |
| | | DAC, static code = 7FFh, DAC buffer ON, $V_{REF}$ = 1.62 V internal | 869.5 | 902.9 | 940.0 | µA |
| | | DAC, static code = 000h, DAC buffer ON, $V_{REF}$ = 1.62 V internal | 791.4 | 842.6 | 882.9 | µA |
| | | DAC, static code = 7FFh, DAC buffer ON, $V_{REF}$ = 1.62 V external | 848.8 | 883.0 | 920.8 | µA |
| | | DAC, static code = 000h, DAC buffer ON, $V_{REF}$ = 1.62 V external | 787.8 | 835.2 | 876.0 | µA |

| Parameter | Symbol | Conditions | $V_{DD}$ = 1.8 V | $V_{DD}$ = 2.5 V | $V_{DD}$ = 3.3 V | Unit |
|---|---|---|---|---|---|---|
| Current | $I_{DD}$ | DAC, static code = 7FFh, DAC buffer OFF, $V_{REF}$ = 1.62 V internal | 118.1 | 118.3 | 118.7 | µA |
| | | DAC, static code = 7FFh, DAC buffer OFF, $V_{REF}$ = 1.62 V external | 107.1 | 107.2 | 107.4 | µA |
| | | DAC, code is incrementing by +1 from 0 to FFF, 1.042 MHz clock, DAC buffer ON, $V_{REF}$ = 1.62 V internal [1] | 879.8 | 914.3 | 951.4 | µA |
| | | DAC, code is incrementing by +1 from 0 to FFF, 1.042 MHz clock, DAC buffer ON, $V_{REF}$ = 1.62 V external [1] | 812.7 | 859.7 | 900.2 | µA |
| | | DAC, code is incrementing by +1 from 0 to FFF, 1.042 MHz clock, DAC buffer OFF, $V_{REF}$ = 1.62 V internal [1] | 139.4 | 139.6 | 140.0 | µA |
| | | DAC, code is incrementing by +1 from 0 to FFF, 1.042 MHz clock, DAC buffer OFF, $V_{REF}$ = 1.62 V external [1] | 85.1 | 85.2 | 85.4 | µA |
| | | Current Source. Setting 1 µA. | 9.3 | 9.3 | 9.4 | µA |

**[1]** Averaged value.

## 3.4.5. Estimated Typical Delay for Each Macrocell

Typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Conditions | $V_{DD}$ = 1.8 V | | $V_{DD}$ = 2.5 V | | $V_{DD}$ = 3.3 V | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Rising [1] | Falling [1] | Rising [1] | Falling [1] | Rising [1] | Falling [1] | |
| **GPI and GPIO Macrocell** | | | | | | | | | |
| Delay | $t_{PD}$ | Digital Input to PP (Matrix0) | 23 | 22 | 15 | 14 | 12 | 12 | ns |
| Delay | $t_{PD}$ | Digital Input to PP (Matrix0 to Matrix1) | 23 | 19 | 17 | 15 | 14 | 13 | ns |
| Delay | $t_{PD}$ | Digital Input to PP (Matrix1) | 19 | 17 | 15 | 13 | 13 | 12 | ns |
| Delay | $t_{PD}$ | Digital Input with Schmitt Trigger to PP (Matrix0) | 24 | 22 | 16 | 15 | 13 | 12 | ns |
| Delay | $t_{PD}$ | Digital Input with Schmitt Trigger to PP (Matrix1) | 20 | 18 | 16 | 14 | 14 | 12 | ns |
| Delay | $t_{PD}$ | Low Voltage Digital Input to PP (Matrix0) | 22 | 77 | 15 | 48 | 12 | 36 | ns |
| Delay | $t_{PD}$ | Low Voltage Digital Input to PP (Matrix1) | 18 | 72 | 14 | 47 | 13 | 37 | ns |
| Delay | $t_{PD}$ | Digital Input to NMOS (Matrix0) | -- | 22 | -- | 14 | -- | 12 | ns |
| Delay | $t_{PD}$ | Output Enable from Pin, OE Hi-Z to 1 (Matrix0) | 22 | -- | 15 | -- | 12 | -- | ns |
| Delay | $t_{PD}$ | Output Enable from Pin, OE Hi-Z to 0 (Matrix0) | -- | 21 | -- | 14 | -- | 12 | ns |

| Parameter | Symbol | Conditions | $V_{DD}$ = 1.8 V | | $V_{DD}$ = 2.5 V | | $V_{DD}$ = 3.3 V | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Rising [1] | Falling [1] | Rising [1] | Falling [1] | Rising [1] | Falling [1] | |
| Delay | $t_{PD}$ | PP 3 State Hi-Z to 1 (Matrix0) | 22 | -- | 15 | -- | 12 | -- | ns |
| Delay | $t_{PD}$ | PP 3 State Hi-Z to 0 (Matrix0) | -- | 21 | -- | 14 | -- | 12 | ns |
| **Combination Function Macrocell** | | | | | | | | | |
| Delay | $t_{PD}$ | LATCH Q (Matrix0) | 10 | 12 | 7 | 7 | 5 | 5 | ns |
| | | LATCH Q (Matrix1) | 3 | 3 | 3 | 3 | 3 | 3 | ns |
| Delay | $t_{PD}$ | LATCH nQ (Matrix 0) | 11 | 10 | 7 | 6 | 6 | 5 | ns |
| | | LATCH nQ (Matrix 1) | 5 | -- | 4 | -- | 4 | -- | ns |
| Delay | $t_{PD}$ | LATCH nRST High Q (Matrix 0) | 12 | 12 | 8 | 7 | 6 | 6 | ns |
| | | LATCH nRST High Q (Matrix 1) | 5 | -- | 4 | -- | 4 | -- | ns |
| Delay | $t_{PD}$ | LATCH nRST High nQ (Matrix 0) | 12 | 12 | 8 | 8 | 6 | 6 | ns |
| | | LATCH nRST High nQ (Matrix 1) | 3 | 3 | 3 | 3 | 3 | 3 | ns |
| Delay | $t_{PD}$ | LATCH nRST Low Q (Matrix 0) | 12 | 12 | 7 | 8 | 6 | 6 | ns |
| | | LATCH nRST Low Q (Matrix 1) | 3 | 3 | 3 | 3 | 3 | 3 | ns |
| Delay | $t_{PD}$ | LATCH nRST Low nQ (Matrix 0) | 12 | 11 | 8 | 7 | 6 | 5 | ns |
| | | LATCH nRST Low nQ (Matrix 1) | 5 | -- | 4 | -- | 4 | -- | ns |
| Delay | $t_{PD}$ | LATCH nSET High Q (Matrix 0) | 12 | 16 | 8 | 10 | 6 | 8 | ns |
| | | LATCH nSET High Q (Matrix 1) | 3 | 4 | 3 | 4 | 3 | 4 | ns |
| Delay | $t_{PD}$ | LATCH nSET High nQ (Matrix 0) | 16 | 12 | 10 | 7 | 8 | 6 | ns |
| | | LATCH nSET High nQ (Matrix 1) | 6 | -- | 6 | -- | 5 | -- | ns |
| Delay | $t_{PD}$ | LATCH nSET Low Q (Matrix 0) | 12 | 16 | 8 | 10 | 6 | 7 | ns |
| | | LATCH nSET Low Q (Matrix 1) | 5 | -- | 4 | -- | 4 | -- | ns |
| Delay | $t_{PD}$ | LATCH nSET Low nQ (Matrix 0) | 16 | 12 | 10 | 8 | 8 | 6 | ns |
| | | LATCH nSET Low nQ (Matrix 1) | 4 | 3 | 4 | 3 | 4 | 3 | ns |
| Delay | $t_{PD}$ | LATCH16 Second nRST High nQ (Matrix 0) | 13 | -- | 8 | -- | 6 | -- | ns |
| | | LATCH17 Second nRST High nQ (Matrix 1) | 3 | -- | 3 | -- | 3 | -- | ns |
| Delay | $t_{PD}$ | 2-bit LUT (Matrix 0) | 8 | 9 | 5 | 5 | 4 | 4 | ns |
| | | 2-bit LUT (Matrix 1) | 3 | 3 | 3 | 3 | 3 | 3 | ns |

| Parameter | Symbol | Conditions | $V_{DD}$ = 1.8 V | | $V_{DD}$ = 2.5 V | | $V_{DD}$ = 3.3 V | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Rising [1] | Falling [1] | Rising [1] | Falling [1] | Rising [1] | Falling [1] | |
| Delay | $t_{PD}$ | 3-bit LUT (Matrix 0) | 10 | 10 | 6 | 6 | 5 | 5 | ns |
| | | 3-bit LUT (Matrix 1) | 3 | 3 | 3 | 3 | 3 | 3 | ns |
| Delay | $t_{PD}$ | 4-bit LUT (Matrix 0) | 11 | 10 | 7 | 6 | 5 | 5 | ns |
| | | 4-bit LUT (Matrix 1) | 2 | 2 | 2 | 2 | 2 | 2 | ns |
| Delay | $t_{PD}$ | DFF Q (Matrix 0) | 13 | 13 | 8 | 8 | 6 | 6 | ns |
| | | DFF Q (Matrix 1) | 3 | -- | 3 | -- | 3 | -- | ns |
| Delay | $t_{PD}$ | DFF nQ (Matrix 0) | 13 | 13 | 8 | 8 | 6 | 6 | ns |
| | | DFF nQ (Matrix 1) | 3 | -- | 3 | -- | 3 | -- | ns |
| Delay | $t_{PD}$ | DFF nRST High Q (Matrix 0) | -- | 14 | -- | 8 | -- | 6 | ns |
| Delay | $t_{PD}$ | DFF nRST High nQ (Matrix 0) | 14 | -- | 9 | -- | 7 | -- | ns |
| | | DFF nRST High nQ (Matrix 1) | 3 | -- | 3 | -- | 3 | -- | ns |
| Delay | $t_{PD}$ | DFF nRST Low Q (Matrix 0) | -- | 14 | -- | 9 | -- | 7 | ns |
| | | DFF nRST Low Q (Matrix 1) | -- | 3 | -- | 3 | -- | 3 | ns |
| Delay | $t_{PD}$ | DFF nRST Low nQ (Matrix 0) | 14 | -- | 9 | -- | 7 | -- | ns |
| | | DFF nRST Low nQ (Matrix 1) | 5 | -- | 4 | -- | 4 | -- | ns |
| Delay | $t_{PD}$ | DFF nSET High Q (Matrix 0) | 14 | -- | 9 | -- | 7 | -- | ns |
| | | DFF nSET High Q (Matrix 1) | 3 | -- | 3 | -- | 3 | -- | ns |
| Delay | $t_{PD}$ | DFF nSET High nQ (Matrix 0) | -- | 14 | -- | 8 | -- | 6 | ns |
| Delay | $t_{PD}$ | DFF nSET Low Q (Matrix 0) | 14 | -- | 9 | -- | 7 | -- | ns |
| | | DFF nSET Low Q (Matrix 1) | 5 | -- | 5 | -- | 4 | -- | ns |
| Delay | $t_{PD}$ | DFF nSET Low nQ (Matrix 0) | -- | 14 | -- | 9 | -- | 7 | ns |
| | | DFF nSET Low nQ (Matrix 1) | -- | 4 | -- | 4 | -- | 4 | ns |
| Delay | $t_{PD}$ | Shift Register Transition (Matrix 0) | 19 | 17 | 12 | 11 | 9 | 8 | ns |
| | | Shift Register Transition (Matrix 1) | 4 | -- | 4 | -- | 4 | -- | ns |
| Delay | $t_{PD}$ | Shift Register Reset (Matrix 0) | 18 [2] | 18 [2] | 11 [2] | 11 [2] | 8 [2] | 8 [2] | ns |
| | | Shift Register Reset (Matrix 1) | -- | 4 [2] | -- | 4 [2] | -- | 4 [2] | ns |

| Parameter | Symbol | Conditions | $V_{DD}$ = 1.8 V | | $V_{DD}$ = 2.5 V | | $V_{DD}$ = 3.3 V | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Rising [1] | Falling [1] | Rising [1] | Falling [1] | Rising [1] | Falling [1] | |
| **Multi-Function Macrocell** | | | | | | | | | |
| Delay | $t_{PD}$ | Multi-function LATCH Q (Matrix 0) | 12 | 13 | 7 | 8 | 6 | 6 | ns |
| | | Multi-function LATCH Q (Matrix 1) | 3 | 3 | 3 | 3 | 3 | 3 | ns |
| Delay | $t_{PD}$ | Multi-function LATCH nQ (Matrix 0) | 12 | 11 | 8 | 7 | 6 | 5 | ns |
| | | Multi-function LATCH nQ (Matrix 1) | 5 | -- | 4 | -- | 4 | -- | ns |
| Delay | $t_{PD}$ | Multi-function LATCH nRST Q (Matrix 0) | 13 | 13 | 8 | 8 | 6 | 6 | ns |
| | | Multi-function LATCH nRST Q (Matrix 1) | 3 | 3 | 3 | 3 | 3 | 3 | ns |
| Delay | $t_{PD}$ | Multi-function LATCH nRST nQ (Matrix 0) | 13 | 13 | 8 | 8 | 6 | 6 | ns |
| | | Multi-function LATCH nRST nQ (Matrix 1) | 5 | -- | 4 | -- | 4 | -- | ns |
| Delay | $t_{PD}$ | Multi-function LATCH nSET Q (Matrix 0) | 13 | 17 | 9 | 10 | 7 | 8 | ns |
| | | Multi-function LATCH nSET Q (Matrix 1) | 5 | -- | 4 | -- | 4 | -- | ns |
| Delay | $t_{PD}$ | Multi-function LATCH nSET nQ (Matrix 0) | 17 | 13 | 11 | 8 | 8 | 6 | ns |
| | | Multi-function LATCH nSET nQ (Matrix 1) | 5 | 3 | 5 | 3 | 5 | 3 | ns |
| Delay | $t_{PD}$ | Multi-function 3-bit LUT (Matrix 0) | 11 | 11 | 7 | 7 | 5 | 5 | ns |
| | | Multi-function 3-bit LUT (Matrix 1) | 3 | 3 | 3 | 3 | 3 | 3 | ns |
| Delay | $t_{PD}$ | Multi-function 3-bit LUT, CNT Delay (Matrix 0) | 26 | 29 | 16 | 18 | 12 | 13 | ns |
| | | Multi-function 3-bit LUT, CNT Delay (Matrix 1) | 6 | 7 | 6 | 7 | 6 | 7 | ns |
| Delay | $t_{PD}$ | Multi-function Edge Detect (Matrix 0) | 13 [2] | 13 [2] | 8 [2] | 9 [2] | 6 [2] | 7 [2] | ns |
| | | Multi-function Edge Detect (Matrix 1) | 3 [2] | 5 [2] | 3 [2] | 5 [2] | 3 [2] | 4 [2] | ns |
| Width | $t_{PD}$ | Multi-function Edge Detect (Matrix 0) | 56 [2] | 57 [2] | 35 [2] | 35 [2] | 27 [2] | 27 [2] | ns |
| | | Multi-function Edge Detect (Matrix 1) | 22 [2] | 24 [2] | 23 [2] | 24 [2] | 23 [2] | 24 [2] | ns |
| Delay | $t_{PD}$ | Multi-function DFF Q (Matrix 0) | 13 | 13 | 8 | 8 | 6 | 6 | ns |
| | | Multi-function DFF Q (Matrix 1) | 4 | -- | 4 | -- | 4 | -- | ns |
| Delay | $t_{PD}$ | Multi-function DFF nQ (Matrix 0) | 13 | 13 | 8 | 8 | 6 | 6 | ns |
| | | Multi-function DFF nQ (Matrix 1) | 3 | -- | 3 | -- | 3 | -- | ns |
| Delay | $t_{PD}$ | Multi-function DFF nRST Q (Matrix 0) | -- | 14 | -- | 9 | -- | 7 | ns |
| | | Multi-function DFF nRST Q (Matrix 1) | -- | 3 | -- | 3 | -- | 3 | ns |

| Parameter | Symbol | Conditions | $V_{DD}$ = 1.8 V | | $V_{DD}$ = 2.5 V | | $V_{DD}$ = 3.3 V | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Rising [1] | Falling [1] | Rising [1] | Falling [1] | Rising [1] | Falling [1] | |
| Delay | $t_{PD}$ | Multi-function DFF nRST nQ (Matrix 0) | 14 | -- | 9 | -- | 7 | -- | ns |
| | | Multi-function DFF nRST nQ (Matrix 1) | 5 | -- | 5 | -- | 4 | -- | ns |
| Delay | $t_{PD}$ | Multi-function DFF nSET Q Matrix 0) | 14 | -- | 9 | -- | 7 | -- | ns |
| | | Multi-function DFF nSET Q (Matrix 1) | 5 | -- | 5 | -- | 4 | -- | ns |
| Delay | $t_{PD}$ | Multi-function DFF nSET nQ (Matrix 0) | -- | 14 | -- | 9 | -- | 7 | ns |
| | | Multi-function DFF nSET nQ (Matrix 1) | -- | 4 | -- | 4 | -- | 4 | ns |
| **Filter Macrocell** | | | | | | | | | |
| Delay | $t_{PD}$ | Filter Q | 11 | 11 | 11 | 11 | 11 | 11 | ns |
| Delay | $t_{PD}$ | Filter nQ | 9 | 13 | 10 | 13 | 10 | 12 | ns |
| **Edge Detector Macrocell** | | | | | | | | | |
| Delay | $t_{PD}$ | Edge Detector | 6 [2] | 8 [2] | 6 [2] | 7 [2] | 6 [2] | 7 [2] | ns |
| Width | $t_W$ | Edge Detector | 26 [2] | 26 [2] | 26 [2] | 26 [2] | 27 [2] | 27 [2] | ns |
| **Width Converter Macrocell** | | | | | | | | | |
| Delay | $t_{PD}$ | Width Converter Clock | 3 [2] | -- | 3 [2] | -- | 3 [2] | -- | ns |

**[1]** Edge at output.
**[2]** Edge at input.

## 3.4.6. Programmable Delay Typical Delays and Widths

Typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Note | $V_{DD}$ = 1.8 V | $V_{DD}$ = 2.5 V | $V_{DD}$ = 3.3 V | Unit |
|---|---|---|---|---|---|---|
| Pulse Width | tw | Mode (any) edge detect, edge detect output | 253 | 157 | 117 | ns |
| Delay | time1 | Mode (any) edge detect, edge detect output | 26 | 17 | 13 | ns |
| Delay | time2 | Mode: both edge delay, edge detect output | 277 | 173 | 129 | ns |

## 3.4.7. Typical Filter Rejection Pulse Width

Typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | $V_{DD}$ = 1.8 V | $V_{DD}$ = 2.5 V | $V_{DD}$ = 3.3 V | Unit |
|---|---|---|---|---|---|
| Filtered Pulse Width | $T_{BLOCK}$ | < 8 | < 11 | < 10 | ns |
| Filtered Pulse Width | $T_{PASS}$ | > 14 | > 13 | > 12 | ns |

# 3.5 Counter/Delay Specifications

## 3.5.1. Typical Counter/Delay Offset

Typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | OSC Frequency | OSC Power Control | $V_{DD}$ = 1.8 V | $V_{DD}$ = 2.5 V | $V_{DD}$ = 3.3 V | Unit |
|---|---|---|---|---|---|---|
| Maximum Power-On Time | 20 MHz | auto | 35 | 30 | 30 | ns |
| Maximum Power-On Time | 40 MHz | auto | 33 | 30 | 28 | ns |
| Maximum Power-On Time | 2 kHz | auto | 135 | 136 | 126 | µs |
| Maximum Power-On Time | 10 kHz | auto | 23 | 34 | 24 | µs |
| Frequency Settling Time (settle from 95 % to 105 % of target frequency) | 20 MHz | auto | 3 | 3 | 3 | Nominal CLK periods |
| Frequency Settling Time (settle from 95 % to 105 % of target frequency) | 40 MHz | auto | 5 | 5 | 5 | Nominal CLK periods |
| Frequency Settling Time (settle from 95 % to 105 % of target frequency) | 2 kHz | auto | 2 | 2 | 2 | Nominal CLK periods |
| Frequency Settling Time (settle from 95 % to 105 % of target frequency) | 10 kHz | auto | 3 | 2 | 2 | Nominal CLK periods |
| Variable (CLK period) | 20 MHz | forced | 0 - 1 | 0 - 1 | 0 - 1 | Nominal CLK periods |
| Variable (CLK period) | 40 MHz | forced | 0 - 1 | 0 - 1 | 0 - 1 | Nominal CLK periods |
| Variable (CLK period) | 2 kHz | forced | 0 - 1 | 0 - 1 | 0 - 1 | Nominal CLK periods |
| Variable (CLK period) | 10 kHz | forced | 0 - 1 | 0 - 1 | 0 - 1 | Nominal CLK periods |

# 3.6 Oscillator Specifications

## 3.6.1. Oscillators Frequency Limits

$V_{DD}$ = 1.71 V to 3.6 V, unless otherwise specified.

| Parameter | Temperature Range | | | | | |
|---|---|---|---|---|---|---|
| | +25 °C | | | -40 °C to +85 °C | | |
| | Min [kHz] | Max [kHz] | Error [%] | Min [kHz] | Max [kHz] | Error [%] |
| 2 kHz OSC0 | 1.948 | 2.033 | 1.65 | 1.889 | 2.058 | 2.90 |
| | | | -2.60 | | | -5.55 |
| 10 kHz OSC0 | 9.785 | 10.255 | 2.55 | 9.509 | 10.369 | 3.69 |
| | | | -2.15 | | | -4.91 |

| Parameter | Temperature Range | | | | | |
|---|---|---|---|---|---|---|
| | +25 °C | | | -40 °C to +85 °C | | |
| | Min [kHz] | Max [kHz] | Error [%] | Min [kHz] | Max [kHz] | Error [%] |
| 20 MHz OSC1 | 19462.6 | 20576.2 | 2.88 | 19096.3 | 21051.6 | 5.26 |
| | | | -2.69 | | | -4.52 |
| 40 MHz OSC1 | 39650 | 40350 | 0.88 | 38883.8 | 41318.0 | 3.30 |
| | | | -0.88 | | | -2.79 |

### 3.6.2. Oscillator0 2 kHz/10 kHz Power-On Delay

$T_A$ = 25 °C, OSC power setting: "Auto Power-on", unless otherwise specified.

| $V_{DD}$ Range [V] | OSC0 2 kHz | | OSC0 10 kHz | |
|---|---|---|---|---|
| | Typ [µs] | Max [µs] | Typ [µs] | Max [µs] |
| 1.71 | 129 | 159 | 19 | 28 |
| 1.8 | 124 | 135 | 17 | 23 |
| 2.5 | 122 | 136 | 24 | 34 |
| 3.0 | 117 | 129 | 20 | 27 |
| 3.3 | 114 | 126 | 18 | 24 |
| 3.6 | 112 | 124 | 16 | 21 |

### 3.6.3. Oscillator1 20 MHz/40 MHz Power-On Delay

$T_A$ = 25 °C, OSC power setting: "Auto Power-on", unless otherwise specified.

| $V_{DD}$ Range [V] | OSC1 20 MHz | | OSC1 40 MHz | |
|---|---|---|---|---|
| | Typ [cycle] | Max [cycle] | Typ [cycle] | Max [cycle] |
| 1.71 | 0.6 | 0.7 | 1.2 | 1.4 |
| 1.8 | 0.6 | 0.7 | 1.2 | 1.4 |
| 2.5 | 0.5 | 0.6 | 1.1 | 1.2 |
| 3.0 | 0.5 | 0.6 | 1.0 | 1.2 |
| 3.3 | 0.5 | 0.6 | 1.0 | 1.2 |
| 3.6 | 0.5 | 0.6 | 1.0 | 1.2 |

## 3.7 Analog Comparator Specifications

$V_{DD}$ = 1.71 V to 3.6 V, $T_A$ = -40 °C to +85 °C, typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Note | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| ACMP Input Voltage Range | $V_{ACMP}$ | Positive Input | | 0 | -- | $V_{DD}$ | V |
| | | Negative Input | | 0 | -- | $V_{DD}$ | V |
| ACMP Input Offset | $V_{OFFSET}$ | ACMP $V_{HYS}$ = 0 mV, Gain = 1, $V_{REF}$ = 27 mV to 1620 mV | $T_A$ = 25 °C | -6.95 | -- | 6.28 | mV |
| | | | $T_A$ = -40 °C to 85 °C | -9.89 | -- | 6.76 | mV |
| ACMP Built-In Hysteresis [1] | $V_{HYS}$ | Selectable hysteresis (Comparator threshold should be larger than hysteresis voltage when used) | $T_A$ = 25 °C | -- | 0.2 | --- | mV |
| | | | | -- | 25.6 | -- | |
| | | | | -- | 52.5 | -- | |
| | | | | -- | 160.7 | -- | |
| ACMP Startup Time | $t_{START}$ | ACMP Power-on delay, Minimal required wake time for the "Wake and Sleep function" | $V_{REF}$ auto power-on | -- | -- | 121.4 | µs |
| | | | $V_{REF}$ forced power-on | -- | -- | 19.2 | µs |
| Series Input Resistance | $R_{SIN}$ | Gain = 1x | | -- | 10 | -- | GΩ |
| | | Gain = 0.5x | | -- | 1.1 | -- | MΩ |
| | | Gain = 0.33x | | -- | 1.1 | -- | MΩ |
| Propagation Delay, Response Time | PROP | Gain = 1, $V_{REF}$ = 27 mV to 1620 mV, Overdrive = 10 mV (LOW to HIGH: $V_{REF}$ – 100 mV to $V_{REF}$ + Overdrive) (HIGH to LOW: $V_{REF}$ + 100 mV to $V_{REF}$ - Overdrive) | LOW to HIGH | -- | 1.52 | 3.19 | µs |
| | | | HIGH to LOW | -- | 2.11 | 6.71 | µs |
| | | Gain = 1, $V_{REF}$ = 27 mV to 1620 mV, Overdrive = 100 mV (LOW to HIGH: $V_{REF}$ - 100 mV to $V_{REF}$ + Overdrive) (HIGH to LOW: $V_{REF}$ + 100 mV to $V_{REF}$ - Overdrive) | LOW to HIGH | -- | 0.46 | 1.19 | µs |
| | | | HIGH to LOW | -- | 0.69 | 1.24 | µs |
| | | Gain = 1, $T_A$ = 25 °C, $V_{REF}$ = 27 mV, Overdrive = 10 mV (LOW to HIGH: $V_{REF}$ - 100 mV to $V_{REF}$ + Overdrive) (HIGH to LOW: $V_{REF}$ + 100mV to $V_{REF}$ - Overdrive) | LOW to HIGH | -- | 0.98 | -- | µs |
| | | | HIGH to LOW | -- | 1.79 | -- | µs |

| Parameter | Symbol | Note | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Propagation Delay, Response Time | PROP | Gain = 0.5, $T_A$ = 25 °C, $V_{REF}$ = 27 mV, Overdrive = 10 mV (LOW to HIGH: $V_{REF}$ -100 mV to $V_{REF}$ + Overdrive) (High to Low: $V_{REF}$ + 100 mV to $V_{REF}$ - Overdrive) | LOW to HIGH | -- | 1.42 | -- | µs |
| | | | HIGH to LOW | -- | 2.20 | -- | µs |
| | | Gain = 0.33, $T_A$ = 25 °C, $V_{REF}$ = 27 mV, Overdrive = 10 mV (LOW to HIGH: $V_{REF}$ - 100 mV to $V_{REF}$ + Overdrive) (HIGH to LOW: $V_{REF}$ + 100 mV to $V_{REF}$ - Overdrive) | LOW to HIGH | -- | 1.38 | -- | µs |
| | | | HIGH to LOW | -- | 2.11 | -- | µs |
| | | Gain = 1, $T_A$ = 25 °C, $V_{REF}$ = 27 mV, Overdrive = 100 mV (LOW to HIGH: $V_{REF}$ – 100 mV to $V_{REF}$ + Overdrive) (HIGH to LOW: $V_{REF}$ + 100 mV to $V_{REF}$ - Overdrive) | LOW to HIGH | -- | 0.34 | -- | µs |
| | | | HIGH to LOW | -- | 1.03 | -- | µs |
| | | Gain = 0.5, $T_A$ = 25 °C, $V_{REF}$ = 27 mV, Overdrive = 100 mV (LOW to HIGH: $V_{REF}$ - 100 mV to $V_{REF}$ + Overdrive) (HIGH to LOW: $V_{REF}$ + 100 mV to $V_{REF}$ - Overdrive) | LOW to HIGH | -- | 0.55 | -- | µs |
| | | | HIGH to LOW | -- | 1.44 | -- | µs |
| | | Gain = 0.33, $T_A$ = 25 °C, $V_{REF}$ = 27 mV, Overdrive = 100 mV (LOW to HIGH: $V_{REF}$ - 100 mV to $V_{REF}$ + Overdrive) (HIGH to LOW: $V_{REF}$ + 100 mV to $V_{REF}$ - Overdrive) | LOW to HIGH | -- | 0.53 | -- | µs |
| | | | HIGH to LOW | -- | 1.39 | -- | µs |
| Gain Error (Note: ACMP comparator offset is included) | G | G = 1 | | 1 | 1 | 1 | |
| | | G = 0.5 | | 0.481 | 0.501 | 0.519 | |
| | | G = 0.33 | | 0.317 | 0.332 | 0.344 | |

**[1]** $V_{IH}$ = Vin.

# 3.8 Programmable Gain Amplifier Specifications

## 3.8.1. PGA Specifications

$V_{DD}$ = 1.71 V to 3.6 V, $T_A$ = -40 °C to +85 °C, typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **Input Parameters** | | | | | | |
| Input Common-Mode Voltage Range [1], [2] | $V_{CMR}$ | Conditionally rail-to-rail depending on different modes | - 0.3 | -- | $V_{DD}$ | V |
| Common-Mode Rejection Ratio (Referred to Input) | CMRR (RTI) | PGA is configured as mode 5b, gain = 1 | -- | 57.7 | -- | dB |
| | | PGA is configured as mode 5b, gain = 2 | -- | 76.2 | -- | |
| | | PGA is configured as mode 5b, gain = 4 | -- | 80.2 | -- | |
| | | PGA is configured as mode 5b, gain = 8 | -- | 69.5 | -- | |
| | | PGA is configured as mode 5b, gain = 16 | -- | 70.1 | -- | |
| | | PGA is configured as mode 5b, gain = 32 | -- | 73.8 | -- | |
| | | PGA is configured as mode 5b, gain = 64 | -- | 79.7 | -- | |
| Power Supply Rejection Ratio | PSRR | PGA is configured as mode 3, gain = 1. Includes gain resister matrix. | -- | 111.2 | -- | dB |
| | | PGA is configured as mode 3, gain = 64. Includes gain resister matrix. | -- | 82.6 | -- | |
| | | PGA is configured as mode 5a, gain = 1. Includes gain resister matrix. | -- | 57.7 | -- | |
| | | PGA is configured as mode 5a, gain = 64. Includes gain resister matrix. | -- | 52.2 | -- | |
| Input Bias Current [3] (Including PIN Leakage Current) | $I_B$ | PGA is configured as mode 6, $T_A$ = 25 °C, $V_{DD}$ = 1.71 V to 2.5 V | -12 | 0.2 | 14 | nA |
| | | PGA is configured as mode 6, $T_A$ = 25°C, $V_{DD}$ = 3.3 V | -25 | 0.9 | 32 | |
| | | PGA is configured as mode 6, $T_A$ = -40 °C to +85 °C, $V_{DD}$ = 1.71 V to 2.5 V | -15 | 1.8 | 28 | |
| | | PGA is configured as mode 6, $T_A$ = -40 °C to +85 °C, $V_{DD}$ = 3.3 V | -34 | 2.8 | 72 | |
| | | PGA is configured as mode 6 $T_A$ = -40 °C to +85 °C, $V_{DD}$ = 1.71 V to 3.6 V | -41 | 3.0 | 96 | |
| **Noise Performance** | | | | | | |
| Input Voltage Noise Density | $V_n$ | f = 1 kHz, PGA is configured as mode 6 | -- | 53.9 | 62.30 | nV/√Hz |

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Input Noise Current Density [4] | $I_n$ | f = 1 kHz,<br>PGA is configured as mode 6 | -- | 105.5 | 173.5 | fA/√Hz |
| Input Voltage Noise | $e_n$ | f = 0.1 to 10 Hz,<br>PGA is configured as mode 6,<br>$V_{DD}$ = 2.5 V to 3.6 V | -- | 1.02 | 2.35 | µV p-p |
| Total Harmonic Distortion | THD | PGA is configured as mode 6,<br>Sin frequency = 0.1 kHz,<br>Harmonic frequency = 0.1 - 1 kHz | -- | 0.027 | 0.23 | % |
| | | PGA is configured as mode 6,<br>Sin frequency = 1kHz,<br>Harmonic frequency = 1 - 10 kHz | -- | 0.030 | 0.25 | |
| | | PGA is configured as mode 6,<br>Sin frequency = 10 kHz,<br>Harmonic frequency = 10 - 100kHz | -- | 0.356 | 0.71 | |
| Output Voltage Range | $V_{OUTRNG}$ | Without load, $R_{LOAD}$ = Hi-Z | GND + 0.035 | -- | $V_{DD}$ - 0.035 | V |
| -3 dB Signal Bandwidth | BW | PGA is configured as mode 2, gain = 2 | 194.25 | 265.7 | 331.92 | kHz |
| | | PGA is configured as mode 2, gain = 4 | 73.23 | 109.0 | 144.15 | |
| | | PGA is configured as mode 2, gain = 8 | 17.62 | 23.2 | 28.56 | |
| | | PGA is configured as mode 2, gain = 16 | 11.38 | 14.2 | 16.92 | |
| | | PGA is configured as mode 2, gain = 32 | 6.99 | 8.8 | 10.41 | |
| | | PGA is configured as mode 2, gain = 64 | 4.06 | 5.2 | 6.24 | |
| | | PGA is configured as mode 6 | 461.36 | 612.6 | 768.70 | |
| Quiescent Current | $I_Q$ | PGA is configured as mode 6,<br>$V_{DD}$ = 2.5 V, $V_{CM}$ = $V_{DD}$ /2 | -- | 20.5 | 34.1 | µA |
| **Shutdown Characteristics** | | | | | | |
| Amplifier Turn-On Time | $t_{ON}$ | PGA is configured as mode 6.<br>Turn-on time: PGA enable to 90 % of target output. $V_{DD}$ = 2.5 V, $V_{CM}$ = $V_{DD}$/2. | -- | 33 | 40 | µs |
| Amplifier Turn-Off Time | $t_{OFF}$ | PGA is configured as mode 6.<br>Turn-off time: PGA disable to 10 % target output. $V_{DD}$ = 2.5 V, $V_{CM}$ = $V_{DD}$/2. | -- | 273 | 306 | µs |

**[1]** Input voltage on pin should not exceed AbsMax value.

**[2]** Please see Figure 105 and Figure 106 for pin input leakage current at negative voltage applied to the pin.

**[3]** Guaranteed by design, not tested in production.

**[4]** Guaranteed by design simulation.

## 3.8.2. PGA Gain Specifications

$V_{DD}$ = 1.71 V to 3.6 V, $T_A$ = -40 °C to +85 °C, typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **PGA Mode Internal Gain Resistor Ratio** | | | | | | |
| Rb/Ra Internal Resistors Values in Mode 2 (Figure 90) | Rratio | Mode 2, Gain = 2 | -- | 800/800 | -- | kΩ/kΩ |
| | | Mode 2, Gain = 4 | -- | 2400/800 | -- | |
| | | Mode 2, Gain = 8 | -- | 3150/450 | -- | |
| | | Mode 2, Gain = 16 | -- | 3000/200 | -- | |
| | | Mode 2, Gain = 32 | -- | 3100/100 | -- | |
| | | Mode 2, Gain = 64 | -- | 3150/50 | -- | |
| Rb/Ra Internal Resistors Values in Mode 3 (Figure 90) | | Mode 3, Gain = 1 | -- | 0/800 | -- | |
| | | Mode 3, Gain = 2 | -- | 400/800 | -- | |
| | | Mode 3, Gain = 4 | -- | 1200/800 | -- | |
| | | Mode 3, Gain = 8 | -- | 2800/800 | -- | |
| | | Mode 3, Gain = 16 | -- | 3000/400 | -- | |
| | | Mode 3, Gain = 32 | -- | 3100/200 | -- | |
| | | Mode 3, Gain = 64 | -- | 3150/100 | -- | |
| Rb/Ra Internal Resistors Values in Mode 4/5 (Figure 90) | | Mode 4/5, Gain = 1 | -- | 800/800 | -- | |
| | | Mode 4/5, Gain = 2 | -- | 1600/800 | -- | |
| | | Mode 4/5, Gain = 4 | -- | 3200/800 | -- | |
| | | Mode 4/5, Gain = 8 | -- | 3200/400 | -- | |
| | | Mode 4/5, Gain = 16 | -- | 3200/200 | -- | |
| | | Mode 4/5, Gain = 32 | -- | 3200/100 | -- | |
| | | Mode 4/5, Gain = 64 | -- | 3200/50 | -- | |
| **PGA Gain** | | | | | | |
| Gain, Mode 2 [1] | Gain | Mode 2, Gain setting = 2 | 2.00 | 2.02 | 2.03 | V/V |
| | | Mode 2, Gain setting = 4 | 3.99 | 4.00 | 4.02 | |
| | | Mode 2, Gain setting = 8 | 7.98 | 8.01 | 8.06 | |
| | | Mode 2, Gain setting = 16 | 15.85 | 15.91 | 16.01 | |
| | | Mode 2, Gain setting = 32 | 31.45 | 31.68 | 31.90 | |
| | | Mode 2, Gain setting = 64 | 62.07 | 62.94 | 63.67 | |

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Gain, Mode 3 [2] | Gain | Mode 3, Gain setting = 1 | 1.00 | 1.00 | 1.01 | V/V |
| | | Mode 3, Gain setting = 2 | 2.00 | 2.01 | 2.03 | |
| | | Mode 3, Gain setting = 4 | 3.99 | 4.01 | 4.04 | |
| | | Mode 3, Gain setting = 8 | 7.95 | 8.01 | 8.07 | |
| | | Mode 3, Gain setting = 16 | 15.82 | 15.97 | 16.11 | |
| | | Mode 3, Gain setting = 32 | 31.30 | 31.77 | 32.25 | |
| | | Mode 3, Gain setting = 64 | 62.16 | 63.27 | 64.53 | |
| Gain, Mode 4 [2] | | Mode 4, Gain setting = 1 | 1.00 | 1.02 | 1.03 | |
| | | Mode 4, Gain setting = 2 | 2.00 | 2.01 | 2.02 | |
| | | Mode 4, Gain setting = 4 | 3.99 | 4.02 | 4.04 | |
| | | Mode 4, Gain setting = 8 | 7.94 | 7.99 | 8.04 | |
| | | Mode 4, Gain setting = 16 | 15.73 | 15.87 | 15.96 | |
| | | Mode 4, Gain setting = 32 | 30.99 | 31.47 | 31.73 | |
| | | Mode 4, Gain setting = 64 | 60.80 | 62.21 | 62.95 | |
| Gain, Mode 5a [3] | | Mode 5a, Gain setting = 1 | 1.00 | 1.02 | 1.03 | |
| | | Mode 5a, Gain setting = 2 | 2.00 | 2.01 | 2.02 | |
| | | Mode 5a, Gain setting = 4 | 3.99 | 4.02 | 4.04 | |
| | | Mode 5a, Gain setting = 8 | 7.93 | 7.99 | 8.04 | |
| | | Mode 5a, Gain setting = 16 | 15.73 | 15.87 | 15.96 | |
| | | Mode 5a, Gain setting = 32 | 30.98 | 31.47 | 31.73 | |
| | | Mode 5a, Gain setting = 64 | 60.80 | 62.26 | 62.98 | |

**[1]** $V_{IN}$ = 0.5/Gain.

**[2]** $V_{IN-}$ = $V_{DD}$/2 - (($V_{DD}$ - 0.2 V)/Gain)/2), $V_{CM}$ = $V_{DD}$ /2, $\Delta V_{IN}$ > ($V_{DD}$ - 0.2 V)/Gain)/2.

**[3]** $V_{IN-}$ = -0.5/Gain (at $V_{DD}$ < 2 V), $V_{IN-}$ = ($V_{DD}$ -1.9 V)/Gain (at $V_{DD}$ > 2 V), $V_{CM}$ = $V_{DD}$ /2, $\Delta V_{IN}$ > ($V_{DD}$ - 0.2 V)/Gain)/2.

### 3.8.3. PGA Offset Specifications

$T_A$ = -40 °C to +85 °C, $V_{DD}$ = 1.71 V to 3.6 V, typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Offset Referred to Output (Including All Error Sources), | $V_{OS\_OUT}$ | Mode 2, Gain setting = 2 | -2.093 | -0.378 | 2.506 | mV |
| | | Mode 2, Gain setting = 4 | -3.021 | -0.932 | 6.432 | |
| | | Mode 2, Gain setting = 8 | -3.734 | -1.654 | 2.803 | |
| | | Mode 2, Gain setting = 16 | -7.947 | -2.742 | 0.897 | |
| | | Mode 2, Gain setting = 32 | -15.933 | -4.788 | 2.918 | |
| | | Mode 2, Gain setting = 64 | -28.114 | -8.911 | 4.280 | |
| | | Mode 3, Gain setting = 1 | -0.008 | 0.161 | 0.295 | |
| | | Mode 3, Gain setting = 2 | -0.409 | -0.107 | 0.289 | |
| | | Mode 3, Gain setting = 4 | -0.940 | -0.098 | 0.463 | |
| | | Mode 3, Gain setting = 8 | -1.870 | -0.077 | 1.126 | |
| | | Mode 3, Gain setting = 16 | -2.362 | -0.076 | 1.920 | |
| | | Mode 3, Gain setting = 32 | -3.706 | -0.017 | 2.712 | |
| | | Mode 3, Gain setting = 64 | -5.763 | 0.036 | 4.699 | |
| | | Mode 4, Gain setting = 1 | -13.628 | -5.542 | 1.149 | |
| | | Mode 4, Gain setting = 2 | -9.294 | -3.010 | 2.337 | |
| | | Mode 4, Gain setting = 4 | -11.674 | -2.947 | 3.225 | |
| | | Mode 4, Gain setting = 8 | -9.180 | 1.287 | 10.126 | |
| | | Mode 4, Gain setting = 16 | -7.034 | 5.015 | 15.889 | |
| | | Mode 4, Gain setting = 32 | -6.362 | 6.922 | 19.195 | |
| | | Mode 4, Gain setting = 64 | -17.959 | 7.448 | 31.550 | |
| | | Mode 5a, Gain setting = 1 | -2.414 | -0.036 | 2.444 | |
| | | Mode 5a, Gain setting = 2 | -2.309 | -0.046 | 2.517 | |
| | | Mode 5a, Gain setting = 4 | -2.615 | 0.011 | 2.460 | |
| | | Mode 5a, Gain setting = 8 | -3.371 | 0.002 | 2.994 | |
| | | Mode 5a, Gain setting = 16 | -3.075 | 0.025 | 3.114 | |
| | | Mode 5a, Gain setting = 32 | -4.958 | -0.117 | 4.654 | |
| | | Mode 5a, Gain setting = 64 | -10.977 | 0.048 | 10.916 | |

## 3.9 Analog-to-Digital Converter Specifications

$V_{DD}$ = 1.71 V to 3.6 V, $T_A$ = -40 °C to +85 °C, typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Full-Scale Input Range | $V_{SR}$ | Differential mode | $V_{IN+} = V_{CM} - V_{REF}/4$ $V_{IN-} = V_{CM} + V_{REF}/4$ | -- | $V_{IN+} = V_{CM} + V_{REF}/4$ $V_{IN-} = V_{CM} - V_{REF}/4$ | V |
| | | Single-ended mode | GND | -- | $V_{REF}$ | |
| ADC Reference Voltage Allowable Range | $V_{REF}$ | | 1.5 | -- | 2 | V |
| Input Clock Frequency | $f_{CLK}$ | For optimized ENOB performance measurement | -- | -- | 40 | MHz |
| Input Clock Duty Cycle | Duty Cycle | For optimized ENOB performance measurement | 48 | 50 | 52 | % |
| Input Capacitance | $C_{IN}$ | | -- | 3.6 | -- | pF |
| Input Resistance [1] | $R_{IN}$ | | -- | 28.9 [2] | -- | KΩ |
| Reference Input Capacitance | $C_{IN\_REF}$ | | -- | 8.5 | -- | pF |
| Output Data Latency | Latency | 14-bit mode | -- | 40 | -- | Cycles |
| | | 12-bit mode | -- | 28 | -- | Cycles |
| | | 10-bit mode | -- | 20 | -- | Cycles |
| | | 8-bit mode | -- | 17 | -- | Cycles |
| Sample Rate | Sr | 14-bit mode, $f_{ADC\_CLK}$ = 40 MHz | -- | 1 | -- | Msps |
| | | 12-bit mode, $f_{ADC\_CLK}$ = 40 MHz | -- | 1.42 | -- | |
| | | 10-bit mode, $f_{ADC\_CLK}$ = 40 MHz | -- | 2 | -- | |
| | | 8-bit mode, $f_{ADC\_CLK}$ = 40 MHz | -- | 2.35 | -- | |
| Internal Calibration Period | $T_{CAL}$ | | -- | 6415 | -- | Cycles |
| Resolution | Res | No missing codes | -- | -- | 12 | Bits |
| Signal to (Noise + Distortion) Ratio | SINAD | 14-bit resolution, $f_{ADC\_CLK}$ = 10 MHz (external), $V_{REF}$ = 1.62 V (internal), $f_{IN}$ = 10 kHz sine wave | 61.83 | 65.5 | -- | dB |
| | | 12-bit resolution, $f_{ADC\_CLK}$ = 7 MHz (external), $V_{REF}$ = 1.62 V (internal), $f_{IN}$ = 10 kHz sine wave | 62.50 | 64.5 | -- | |
| | | 10-bit resolution, $f_{ADC\_CLK}$ = 5 MHz (external), $V_{REF}$ = 1.62 V (internal), $f_{IN}$ = 10 kHz sine wave | 56.52 | 59.2 | -- | |

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Signal to (Noise + Distortion) Ratio | SINAD | 8-bit resolution, $f_{ADC\_CLK}$ = 4.25 MHz (external), $V_{REF}$ = 1.62 V (internal), $f_{IN}$ = 10 kHz sine wave | 44.73 | 49.4 | -- | dB |
| Integral Non-Linearity Error | INL | 14-bit resolution, $V_{REF}$ = 1.62 V (internal)/1.5 V (external), $f_{ADC\_CLK}$ = 20 MHz/5 MHz (internal)/ 20 MHz (external) | -- | ±5 | -- | LSB |
| | | 12-bit resolution, $V_{REF}$ = 1.62 V (internal)/1.5 V (external), $f_{ADC\_CLK}$ = 10 MHz (external) | -2.9 | -- | 2.9 | |
| | | 12-bit resolution, $V_{REF}$ = 1.62 V (internal), $f_{ADC\_CLK}$ = 10 MHz/2.5 MHz (internal) | -2.8 | -- | 2.8 | |
| | | 10-bit resolution, $V_{REF}$ = 1.62 V (internal)/1.5 V (external), $f_{ADC\_CLK}$ = 10 MHz (external) | -1.0 | -- | 1.0 | |
| | | 10-bit resolution, $V_{REF}$ = 1.62 V (internal), $f_{ADC\_CLK}$ = 10 MHz (internal) | -0.9 | -- | 0.9 | |
| | | 8-bit resolution, $V_{REF}$ = 1.62 V (internal)/1.5 V (external), $f_{ADC\_CLK}$ = 10 MHz | -0.5 | -- | 0.5 | |
| Differential Non-Linearity Error | DNL | 14-bit resolution, $V_{REF}$ = 1.62 V (internal)/1.5 V (external), $f_{ADC\_CLK}$ = 20 MHz/5 MHz (internal)/20 MHz (external) | -- | ±1 | -- | LSB |
| | | 12-bit resolution, $V_{REF}$ = 1.62 V (internal)/1.5 V (external), $f_{ADC\_CLK}$ = 10 MHz (external) | -1.0 | - | 1.0 | |
| | | 12-bit resolution, $V_{REF}$ = 1.62 V (internal), $f_{ADC\_CLK}$ = 10 MHz/2.5 MHz (internal) | -1.0 | - | 1.1 | |
| | | 10-bit resolution, $V_{REF}$ = 1.62 V (internal)/1.5 V (external), $f_{ADC\_CLK}$ = 10 MHz (external) | -0.5 | - | 0.5 | |
| | | 10-bit resolution, $V_{REF}$ = 1.62 V (internal), $f_{ADC\_CLK}$ = 10 MHz (internal) | -0.5 | -- | 0.5 | |
| | | 8-bit resolution, $V_{REF}$ = 1.62 V (internal)/1.5 V (external), $f_{ADC\_CLK}$ = 10 MHz | -0.5 | -- | 0.5 | |

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Gain Error | Ge | 14-, 12-, 10-bit resolution, $V_{REF}$ = 1.62 V (internal)/1.5 V (external), $f_{ADC\_CLK}$ (14-bit) = 20 MHz (external), $f_{ADC\_CLK}$ (12-,10-bit) = 10 MHz (external) | -0.7 | -- | 0.4 | %FS |
| | | 14-, 12-, 10-bit resolution, $V_{REF}$ = 1.62 V (internal), $f_{ADC\_CLK}$ (14-bit) = 20 MHz/5 MHz (internal), $f_{ADC\_CLK}$ (12-,10-bit) = 10 MHz/2.5 MHz (internal) | -0.7 | -- | 0.4 | |
| | | 8-bit resolution, $V_{REF}$ = 1.62 V (internal)/1.5 V (external), $f_{ADC\_CLK}$ = 10 MHz | -- | ±0.4 | -- | |
| Offset Error | Offe | 14-, 12-, 10-bit resolution, $V_{REF}$ = 1.62 V (internal)/1.5 V (external), $f_{ADC\_CLK}$ (14-bit) = 20 MHz (external), $f_{ADC\_CLK}$ (12-,10-bit) = 10 MHz (external) | -0.5 | -- | 0.2 | %FS |
| | | 14-, 12-, 10-bit resolution, $V_{REF}$ = 1.62 V (internal), $f_{ADC\_CLK}$ (14-bit) = 20 MHz/5 MHz (internal), $f_{ADC\_CLK}$ (12-,10-bit) = 10 MHz/2.5 MHz (internal) | -0.2 | -- | 0.2 | |
| | | 8-bit resolution, $V_{REF}$ = 1.62 V (internal)/1.5 V (external), $f_{ADC\_CLK}$ = 10 MHz | -- | ±0.5 | -- | |
| Effective Number of Bits | ENOB | 14-bit resolution, $f_{ADC\_CLK}$ = 10 MHz (external), $V_{REF}$ = 1.62 V (internal), $f_{IN}$ = 10 kHz | 10.0 | 10.6 | -- | bits |
| | | 12-bit resolution, $f_{ADC\_CLK}$ 7 MHz (external), $V_{REF}$ = 1.62 V (internal), $f_{IN}$ = 10 kHz | 10.1 | 10.4 | -- | |
| | | 10-bit resolution, $f_{ADC\_CLK}$ = 5 MHz (external), $V_{REF}$ = 1.62 V (internal), $f_{IN}$ = 10 kHz | 9.1 | 9.4 | -- | |
| | | 8-bit resolution, $f_{ADC\_CLK}$ = 4.25 MHz (external), $V_{REF}$ = 1.62 V (internal), $f_{IN}$ = 10 kHz | 7.1 | 7.9 | -- | |

**[1]** Depends on the Input Clock Frequency ($f_{CLK}$) and the Input Capacitance ($C_{IN}$). Input Resistance of the ADC is calculated by the formula: $R_{IN} = 5/(f_{CLK} * C_{IN})$.

**[2]** Guaranted by design simulation.

## 3.10 Digital-to-Analog Converter Specifications

$V_{DD}$ = 1.71 V to 3.6 V, $T_A$ = -40 °C to +85 °C, typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Monotonicity | MN | | -- | 12 | -- | Bits |
| Resolution | Res | | -- | 12 | -- | Bits |
| Conversion time | $t_{CONV}$ | $V_{REF}$ = 1.62 V internal | -- | -- | 6 | µs |
| Integral Non-Linearity Error | INL | $V_{DD} \geq 2.7$ V, $V_{REF} = V_{DD}$, DAC output buffer ON | -- | -- | ±10.7 | LSB |
| | | $V_{DD} < 2.7$ V, $V_{REF} = V_{DD}$, DAC output buffer ON | -- | -- | ±15 | |
| | | $V_{REF}$ = 1.62 V internal, DAC output buffer ON | -- | -- | ±8.9 | |
| Differential Non-Linearity Error | DNL | $V_{DD} \geq 2.7$ V, $V_{REF} = V_{DD}$, DAC output buffer ON | -- | -- | ±1.3 | LSB |
| | | $V_{DD} < 2.7$ V, $V_{REF} = V_{DD}$, DAC output buffer ON | -- | -- | ±1.4 | |
| | | $V_{REF}$ = 1.62 V internal, DAC output buffer ON | -- | -- | ±4.4 | |
| Zero Offset Error | ZOE | $V_{DD} \geq 2.7$ V, $V_{REF} = V_{DD}$, DAC output buffer ON | -- | -- | ±24.2 | LSB |
| | | $V_{DD} < 2.7$ V, $V_{REF} = V_{DD}$, DAC output buffer ON | -- | -- | ±32.4 | |
| | | $V_{REF}$ = 1.62 V internal, DAC output buffer ON | -- | -- | ±36 | |
| Center Offset Error | COE | $V_{DD} \geq 2.7$ V, $V_{REF} = V_{DD}$, DAC output buffer ON | -- | -- | ±13.7 | LSB |
| | | $V_{DD} < 2.7$ V, $V_{REF} = V_{DD}$, DAC output buffer ON | -- | -- | ±21.4 | |
| | | $V_{REF}$ = 1.62 V internal, DAC output buffer ON | -- | -- | ±36 | |
| Offset Temperature Drift | OFD | $V_{REF}$ = 1.62 V internal, DAC output buffer ON | -- | -- | ±44.4 | µV/°C |
| Full Scale Gain Error | GE | $V_{REF}$ = 1.62 V internal, DAC output buffer ON | -- | -- | ±1.15 | % FS |
| **Output Characteristics** | | | | | | |
| DAC Output Resistance | $R_{OUT}$ | DAC output buffer OFF | -- | 8.9 | -- | kΩ |
| Power Supply Rejection Ratio | PSRR | Excluding Bandgap Error Contribution, DAC output buffer ON | -- | 69.4 | 120.64 | dB |
| Load Resistance | $R_{LOAD}$ | DAC output buffer OFF | -- | 2 | -- | MΩ |
| Load Capacitance | $C_{LOAD}$ | DAC output buffer OFF | -- | -- | 20 | pF |

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage Range | OVR | DAC output buffer OFF | GND | -- | $V_{REF}$ | V |
| Output Settling Time | STT | From 0 to 100% of Full Scale, accuracy 1 % | -- | -- | 3.7 | µs |
| | | From 0 to 100% of Full Scale, accuracy 1 LSB | -- | -- | 15.2 | µs |
| Total Harmonic Distortion | THD | f = 1 kHz, DAC output buffer OFF | -- | 0.3 | -- | % |
| DAC Input Code Range | $D_{IN}$ | DAC output buffer OFF | 0 | -- | 0xFFF | -- |
| | | DAC output buffer ON, $V_{REF}$ < 2.7 V [1] | 0x1F8 | -- | 0xE07 | |
| | | DAC output buffer ON, $V_{REF}$ ≥ 2.7 V [1] | 0x0E0 | -- | 0xF1F | |

**[1]** Beyond this range, buffer output voltage non-linearity may occur.

## 3.11 DAC Output Buffer Specifications

$V_{DD}$ = 1.71 V to 3.6 V, $T_A$ = -40 °C to +85 °C, typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Offset Voltage | $V_{DAC\_BUF\_Offset}$ | $T_A$ = 25 °C, $I_{LOAD}$ = 100 µA | -7.05 | -0.03 | 7.02 | mV |
| | | $T_A$ = -40 °C to +85 °C, $I_{LOAD}$ = 100 µA | -7.49 | -0.03 | 7.54 | |
| Maximum Voltage Swing | $V_{DAC\_BUF\_OH}$ | $T_A$ = -40 °C to +85 °C, $I_{LOAD}$ = 100 µA | $V_{DD}$ – 12 | -- | -- | mV |
| | $V_{DAC\_BUF\_OL}$ | $T_A$ = -40 °C to +85 °C, $I_{LOAD}$ = 100 µA | -- | -- | GND + 16.35 | mV |
| Short Circuit Current | $I_{SC}$ | $I_{SC}$ to $V_{DD}$ | -- | 47.4 | -- | mA |
| | | $I_{SC}$ to GND | -- | 47.8 | -- | mA |
| Quiescent Current | $I_{DAC\_BUF\_Q}$ | No load | -- | 821.4 | 1140.4 | µA |
| DAC Buffer Output Capacitive Loading | $V_{DAC\_BUF\_OUTCAP}$ | Connected to GPIO, Load Resistance = 5 kΩ | -- | -- | 50 [1] | pF |

**[1]** Guaranted by design.

## 3.12 Analog Temperature Sensor Characteristics

$V_{DD}$ = 1.71 V to 3.6 V, unless otherwise specified.

| $T_J$ [°C] | Target $V_{TS\_OUT}$ [V] | $V_{TS\_OUT}$ [V] | | Calculated $T_J$ [°C] | | $T_J$ Accuracy [°C] | |
|---|---|---|---|---|---|---|---|
| | | Min | Max | Min | Max | Min | Max |
| -40 | 0.827 | 0.819 | 0.832 | -42.6 | -35.5 | -2.6 | 4.5 |
| -30 | 0.809 | 0.801 | 0.814 | -32.7 | -25.7 | -2.7 | 4.3 |
| -20 | 0.79 | 0.783 | 0.796 | -22.8 | -15.8 | -2.8 | 4.2 |
| -10 | 0.772 | 0.765 | 0.778 | -13 | -6.1 | -3 | 3.9 |

| $T_J$ [°C] | Target $V_{TS\_OUT}$ [V] | $V_{TS\_OUT}$ [V] | | Calculated $T_J$ [°C] | | $T_J$ Accuracy [°C] | |
|---|---|---|---|---|---|---|---|
| | | Min | Max | Min | Max | Min | Max |
| 0 | 0.754 | 0.747 | 0.759 | -2.8 | 3.7 | -2.8 | 3.7 |
| 10 | 0.736 | 0.729 | 0.740 | 7.4 | 13.4 | -2.6 | 3.4 |
| 20 | 0.717 | 0.712 | 0.722 | 17.2 | 22.8 | -2.8 | 2.8 |
| 25 | 0.708 | 0.704 | 0.712 | 22.6 | 27.4 | -2.4 | 2.4 |
| 30 | 0.699 | 0.692 | 0.704 | 27 | 33.9 | -3 | 3.9 |
| 40 | 0.681 | 0.674 | 0.685 | 37.4 | 43.8 | -2.6 | 3.8 |
| 50 | 0.662 | 0.656 | 0.667 | 47.4 | 53.5 | -2.6 | 3.5 |
| 60 | 0.644 | 0.637 | 0.649 | 57.2 | 64 | -2.8 | 4 |
| 70 | 0.626 | 0.618 | 0.631 | 67 | 74.4 | -3 | 4.4 |
| 80 | 0.607 | 0.599 | 0.613 | 76.7 | 84.5 | -3.3 | 4.5 |
| 85 | 0.598 | 0.589 | 0.604 | 82.1 | 89.8 | -2.9 | 4.8 |

## 3.13 Internal $V_{REF}$ Specifications

$V_{DD}$ = 1.71 V to 3.6 V, $V_{REF}$ = 1.62 V, $T_A$ = -40 °C to +85 °C, typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **ACMP $V_{REF}$** | | | | | | |
| Internal ACMP $V_{REF}$ Accuracy | $V_{REF\_ACC}$ | $T_A$ = 25 °C, $V_{REF}$ = 1.62 V | -0.26 | -- | 0.31 | % |
| | | $T_A$ = -40 °C to +85 °C, $V_{REF}$ = 1.62 V | -1.19 | -- | 0.93 | |
| | | $T_A$ = -20 °C to +85 °C, $V_{REF}$ = 1.62 V | -0.88 | -- | 0.74 | |
| | | $T_A$ = 0 °C to +85 °C, $V_{REF}$ = 1.62 V | -0.88 | -- | 0.56 | |
| ACMP $V_{REF}$ Divider Accuracy | $V_{REF\_DIV\_ACC}$ | $T_A$ = 25 °C, $V_{REF}$ = 0.027 V | -0.49 | -- | 2.05 | mV |
| | | $T_A$ = 25 °C, $V_{REF}$ = 0.81 V | -5.64 | -- | 6.48 | |
| | | $T_A$ = 25 °C, $V_{REF}$ = 1.512 V | -7.37 | -- | 8.11 | |
| | | $T_A$ = -40 °C to +85 °C, $V_{REF}$ = 0.027 V | -1.00 | -- | 2.33 | |
| | | $T_A$ = -40 °C to +85 °C, $V_{REF}$ = 0.81 V | -16.88 | -- | 12.58 | |
| | | $T_A$ = -40 °C to +85 °C, $V_{REF}$ = 1.512 V | -28.28 | -- | 19.31 | |
| **ADC $V_{REF}$ Buffer** | | | | | | |
| ADC $V_{REF}$ Error | $V_{REF}$_ADC_err | $T_A$ = -40 °C to +85 °C, $V_{REF}$ = 1.62 V | -18.99 | -- | 14.40 | mV |
| | | $T_A$ = -20 °C to +85 °C, $V_{REF}$ = 1.62 V | -12.26 | -- | 11.69 | |

| Parameter | Symbol | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| **DAC $V_{REF}$ Buffer** | | | | | | | |
| DAC $V_{REF}$ Error | $V_{REF}$_DAC_err | $T_A$ = -40 °C to +85 °C, $V_{REF}$ = 1.62 V No Load. | | -19.20 | -0.27 | 16.20 | mV |
| | | $T_A$ = -20 °C to +85 °C, $V_{REF}$ = 1.62 V No Load. | | -13.55 | -0.27 | 12.95 | |
| DAC $V_{REF}$ Buffer Output Capacitive Loading | Cap_load_DAC_buff | Load resistance = 1 MΩ, $V_{REF}$ = 1.62 V | | -- | 10 | -- | pF |
| DAC $V_{REF}$ Buffer Output Current Capability | I_DAC_buf | $T_A$ = 25 °C (steady DC conditions due to circuit topology) | DAC is ON | -- | -- | 10 | µA |
| | | | DAC is OFF | -- | -- | 160 | µA |
| DAC $V_{REF}$ Buffer to Pin Switch Resistance | R_DAC_buff_SW | $T_A$ = 25 °C | | -- | 328 | -- | Ω |

## 3.14 Current Source Specifications

$V_{DD}$ = 1.71 V to 3.6 V, $T_A$ = -40 °C to +85 °C, typical values are at $T_A$ = +25 °C, unless otherwise specified.

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Headroom for Output Current Source | $V_{HEADROOM}$ | | -- | 0.34 | -- | V |
| Accuracy | CS_Accuracy | All settings | -- | 4.5 | -- | % |

# 4. IO Pins

The SLG47011 has one GPI and thirteen GPIO pins, which can function as either user-defined inputs or outputs.

In Matrix0, four GPI functions and three GPO functions are available. In Matrix1, fourteen GPI functions and ten GPO functions are available (see Figure 14).

Each input can be configured in three ways: Logic Input (Non-Schmitt Trigger Input), Logic Input with Schmitt Trigger (Schmitt Trigger Input), Low-voltage Logic Input. For general digital input, Schmitt Trigger Input is recommended. The Schmitt trigger provides hysteresis, which helps to ensure clean transitions. Non-Schmitt Trigger Input should only be used if a narrow $V_{IH}$ to $V_{IL}$ range is required. Note that the lack of hysteresis in this mode can cause a spurious chatter when signal transitions are too slow compared to internal propagation delays. To prevent such chatter when Non-Schmitt Trigger Input is used, the slew rate of the input source between $V_{IH}$ and $V_{IL}$ should exceed the values in Table 3.

**Table 3. Digital IO Input Transition Slew Rate Limitations**

| Parameter | Configuration | Minimal Value | Unit |
|---|---|---|---|
| Slew rate for low to high transition | Logic Input, Input Voltage between $V_{IL}$ and $V_{IH}$ | 65 | V/µs |
| | Low-voltage Logic Input, Input Voltage between $V_{IL}$ and $V_{IH}$ | 5 | |
| Slew rate for high to low transition | Logic Input, Input Voltage between $V_{IH}$ and $V_{IL}$ | 30 | V/µs |
| | Low-voltage Logic Input, Input Voltage between $V_{IH}$ and $V_{IL}$ | 11 | |

## 4.1 GPI Pin

The GPI pin serves as a general purpose input pin and is available for connections in Matrix 0 and Matrix 1 (see Figure 14).

### 4.1.1. GPI Structure

Registers abbreviations:
**GPI_INPUT_MODE [473:472] → INPUT_MODE [1:0]**
00b: Digital Input without Schmitt Trigger (WOSMT_EN = 1, OE = 0)
01b: Digital Input with Schmitt Trigger (SMT_EN = 1, OE = 0)
10b: Low-voltage Digital Input (LV_EN = 1, OE = 0)
11b: Reserved

**GPI_RES_SEL [478:477] → RES_SEL [1:0]**
00b: Floating
01b: 10 kΩ
10b: 50 kΩ

**GPI_PULLUP_EN [479] → PULLUP_EN [0]**
0b: Pull-Down
1b: Pull-Up

**Note:**
"Digital IN" is a Connection Matrix Input.

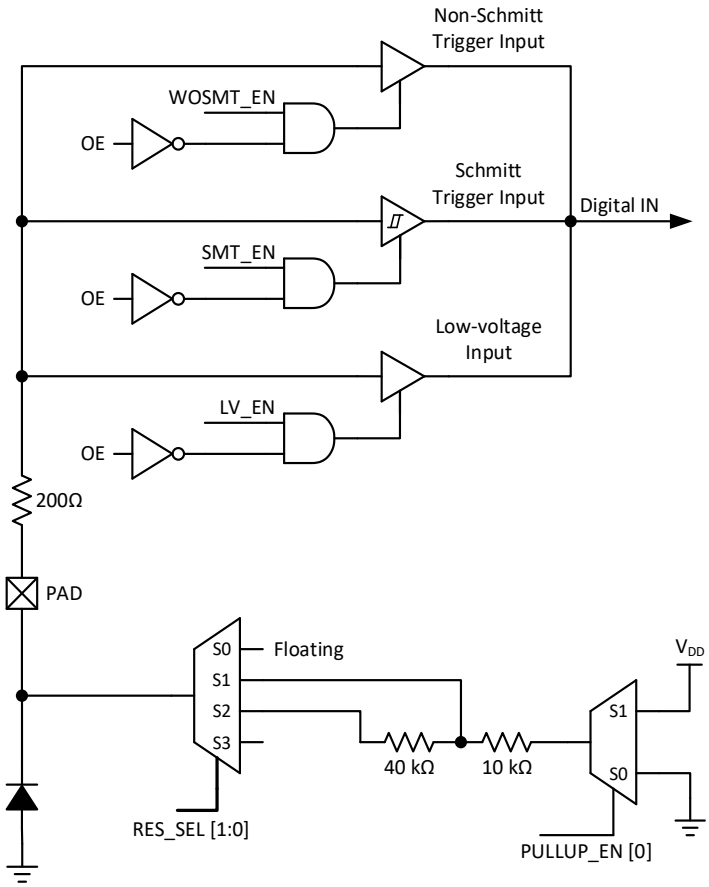



**Figure 5. GPI Structure Diagram**

## 4.2 GPIO Pins

GPIO0 to GPIO12 serve as General Purpose IO pins.

GPIO10 to GPIO12 digital inputs and outputs are available for connections in Matrix0.

GPIO0 to GPIO12 digital inputs and GPIO0 to GPIO9 digital outputs are available for connections in Matrix1 (see Figure 14).

### 4.2.1. GPIO with I²C Mode Structure (for GPIO0 and GPIO1)

Registers abbreviations:
**GPIOx_INPUT_MODE [1:0] → INPUT_MODE [1:0]**
00b: Digital Input without Schmitt Trigger (WOSMT_EN = 1)
01b: Digital Input with Schmitt Trigger (SMT_EN = 1)
10b: Low-voltage Digital Input (LV_EN = 1)
11b: Analog IO

**GPIOx_RES_SEL [1:0] → RES_SEL [1:0]**
00b: Floating
01b: 10 kΩ
10b: 50 kΩ

**GPIOx_PULLUP_EN [0] → PULLUP_EN [0]**
0b: Pull-Down
1b: Pull-Up

**GPIOx_FAST_MODE_EN [0] → FAST_MODE_EN [0]**
0: I²C fast-mode plus enable
1: I²C fast-mode plus disable

**GPIOx_OPEN_DRAIN_EN [0] → OD_EN [0]**
0: Open-drain mode disable, output = Hi-Z
1: Open-drain mode enable

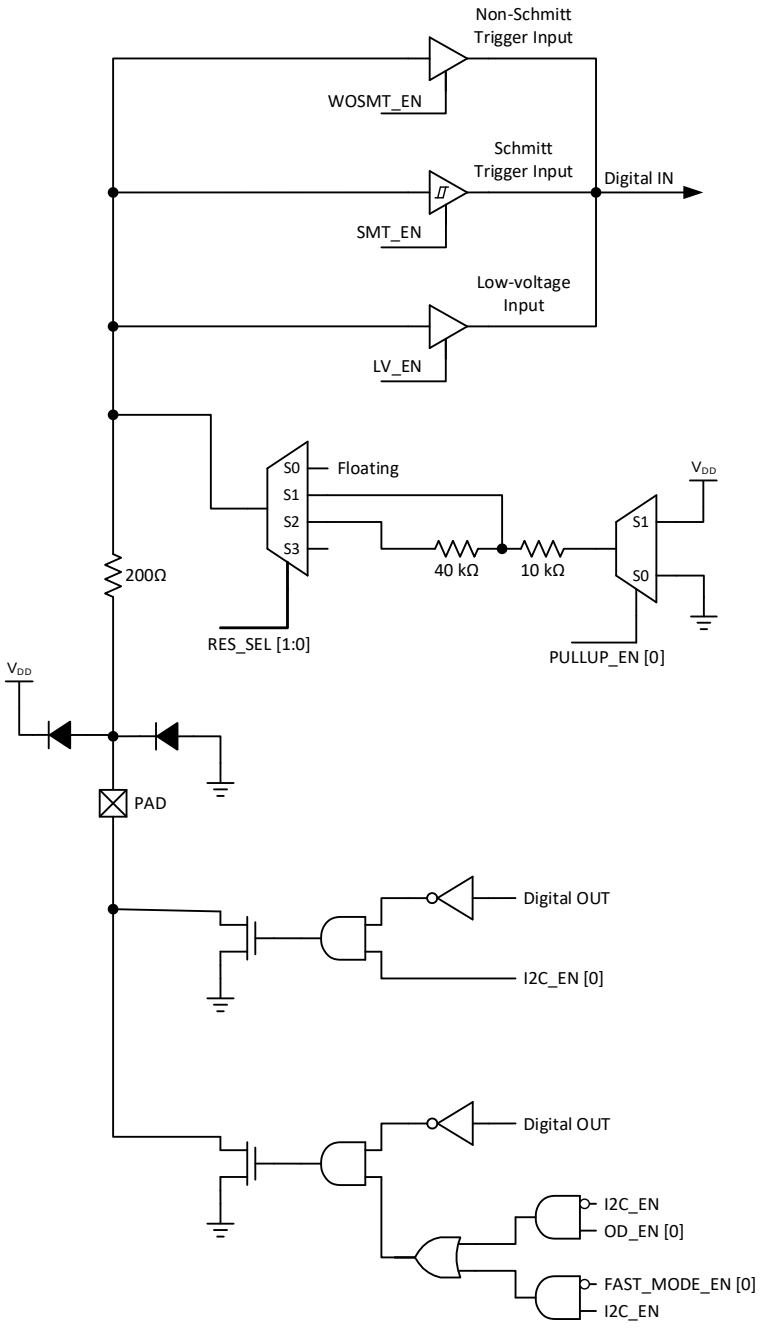



**Figure 6. GPIO with I²C Mode IO Structure Diagram**

## 4.2.2. Matrix OE IO Structure (for GPIO2 to GPIO9, GPIO11, GPIO12)

Registers abbreviations:
**GPIOx_INPUT_MODE [1:0] → INPUT_MODE [1:0]**
00b: Digital Input without Schmitt Trigger (WOSMT_EN = 1)
01b: Digital Input with Schmitt Trigger (SMT_EN = 1)
10b: Low-voltage Digital Input (LV_EN = 1)
11b: Analog IO

**GPIOx_RES_SEL [1:0] → RES_SEL [1:0]**
00b: Floating
01b: 10 kΩ
10b: 50 kΩ

**GPIOx_PULLUP_EN [0] → PULLUP_EN [0]**
0b: Pull-Down
1b: Pull-Up

**GPIOx_OUTPUT_MODE [0] → OUTPUT_MODE [0]**
0: Push-pull Mode (PP_EN = 1)
1: Open-drain NMOS Mode (OD_EN = 1)

**Note 1:**
- "Digital OUT" is Matrix Output
- "Digital IN" is a Matrix Input
- "OE" is Matrix Output.

**Note 2:**
Can be varied over PVT (for reference only).

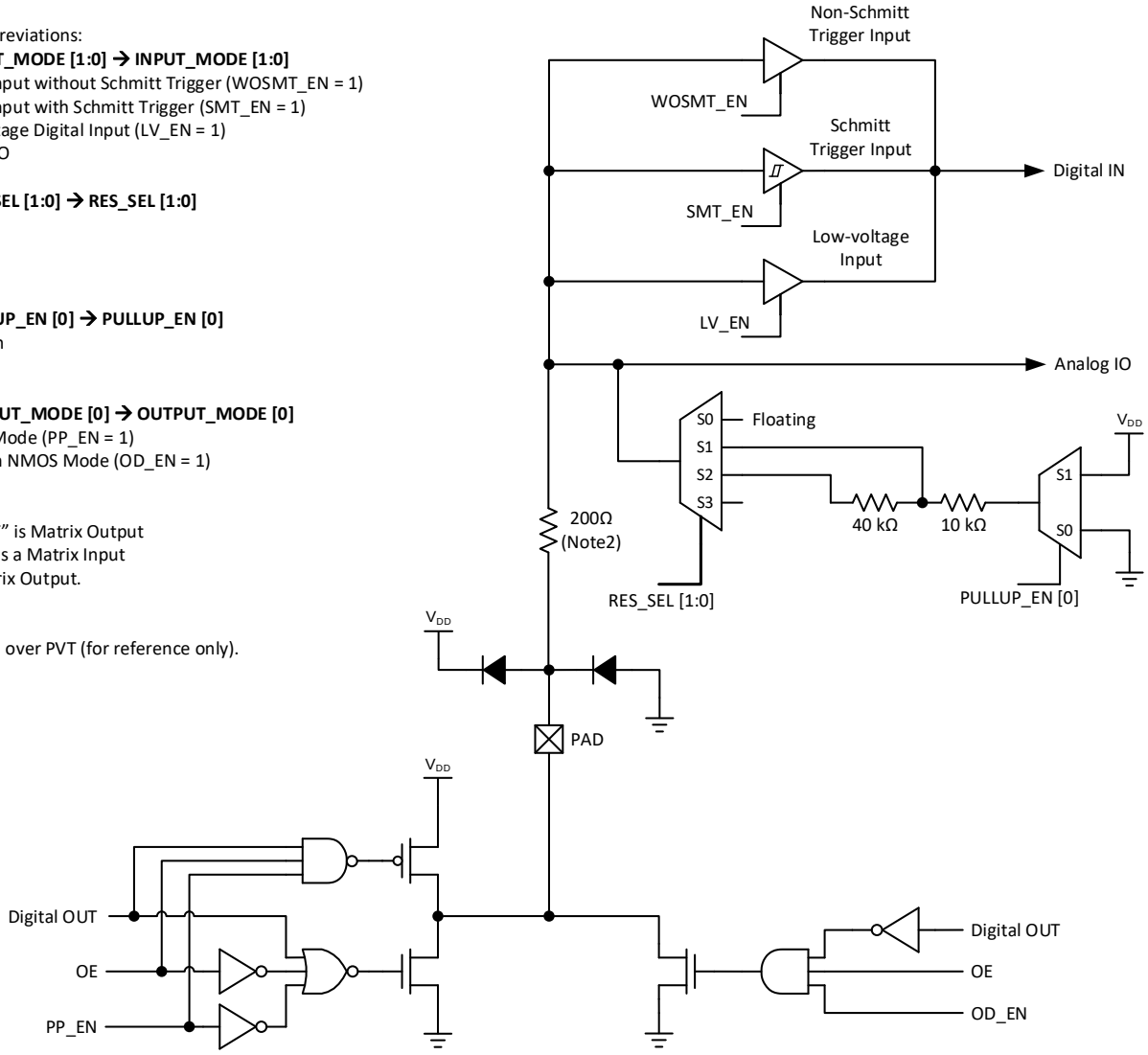



**Figure 7. Matrix OE IO Structure Diagram (with ESD Structure Type 1)**

### 4.2.3. Matrix OE IO Structure (for GPIO10)

Registers abbreviations:
**GPIO10_INPUT_MODE [481:480] → INPUT_MODE [1:0]**
00b: Digital Input without Schmitt Trigger (WOSMT_EN = 1)
01b: Digital Input with Schmitt Trigger (SMT_EN = 1)
10b: Low-voltage Digital Input (LV_EN = 1)
11b: Analog IO

**GPIO10_RES_SEL [486:485] → RES_SEL [1:0]**
00b: Floating
01b: 10 kΩ
10b: 50 kΩ

**GPIO10_PULLUP_EN [487] → PULLUP_EN [0]**
0b: Pull-Down
1b: Pull-Up

**GPIO10_OUTPUT_MODE [490] → OUTPUT_MODE [0]**
0: Push-pull Mode (PP_EN = 1)
1: Open-drain NMOS Mode (OD_EN = 1)

**Note 1:**
- "Digital OUT" is Matrix Output
- "Digital IN" is a Matrix Input
- "OE" is Matrix Output.

**Note 2:**
Can be varied over PVT (for reference only).

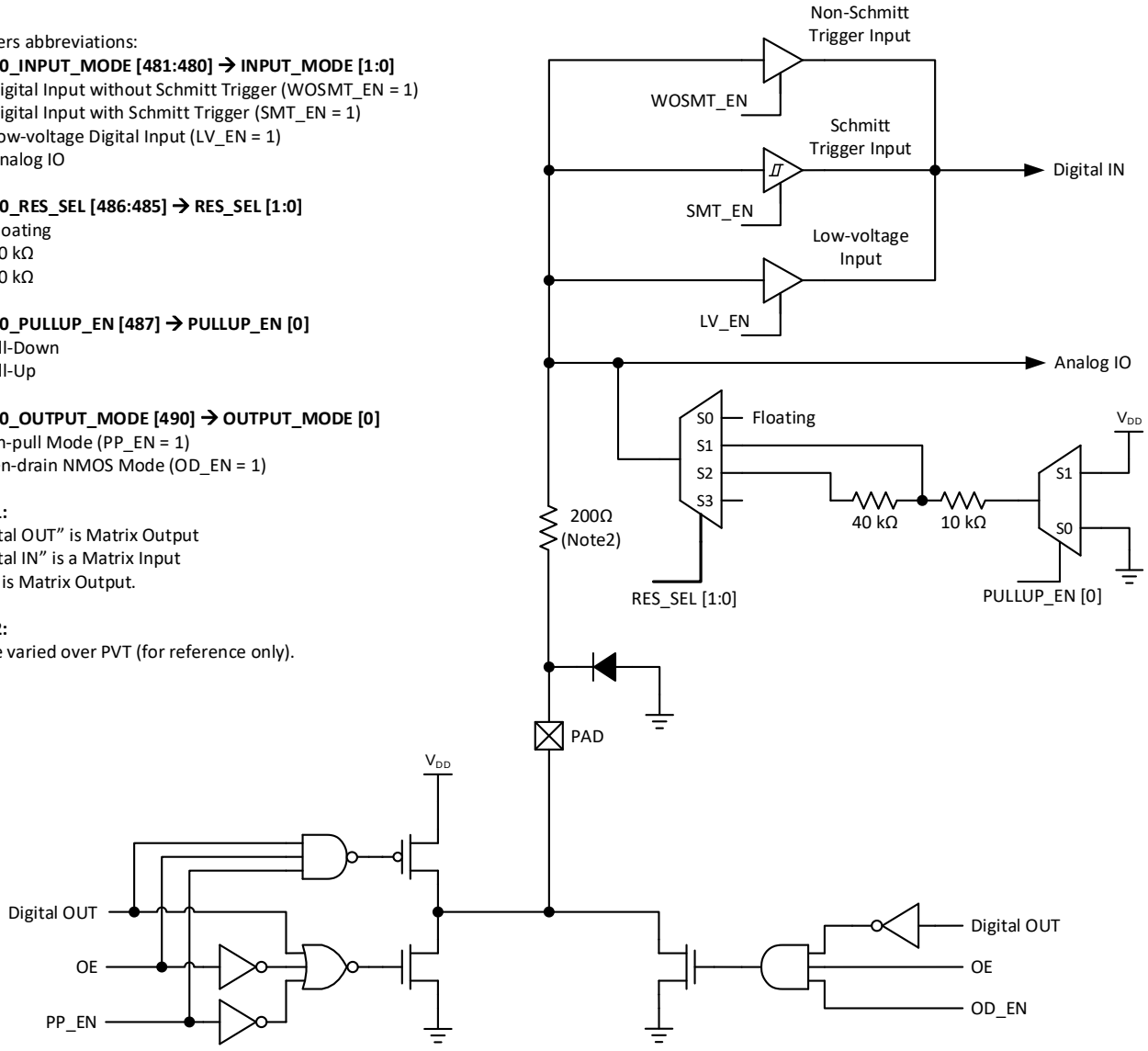



**Figure 8. Matrix OE IO Structure Diagram (with ESD Structure Type 2)**

## 4.3 Pull-Up/Pull-Down Resistors

All IO pins have the option for user-selectable resistors connected to the input structure. The selectable values of these resistors are 10 kΩ and 50 kΩ. The internal resistors can be configured as either pull-up or pull-down.

## 4.4 Fast Pull-Up/Pull-Down During Power-Up

During power-up, IO pull-up/down resistance will switch to 2.6 kΩ initially and then switch to its normal setting value. This function is enabled by register IO_QCHG_EN [504].

## 4.5 Typical Performance of IOs

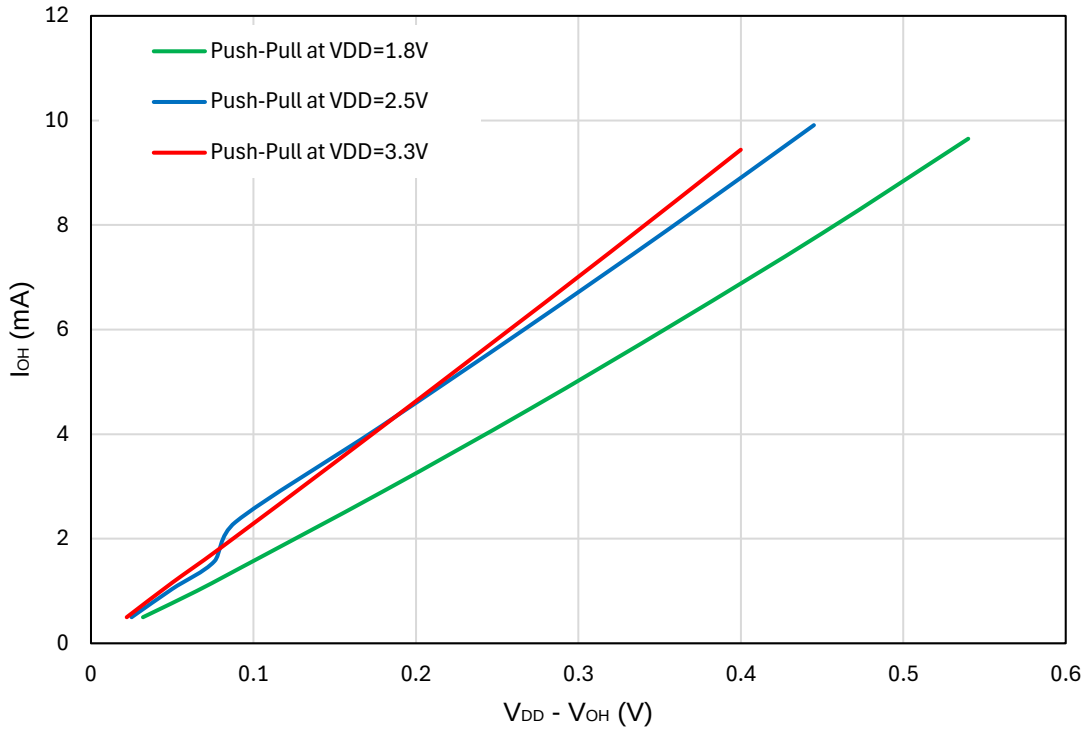



**Figure 9. Typical $I_{OH}$ vs. $V_{DD}$-$V_{OH}$ in Push-Pull Mode at $T_A$ = +25 °C**

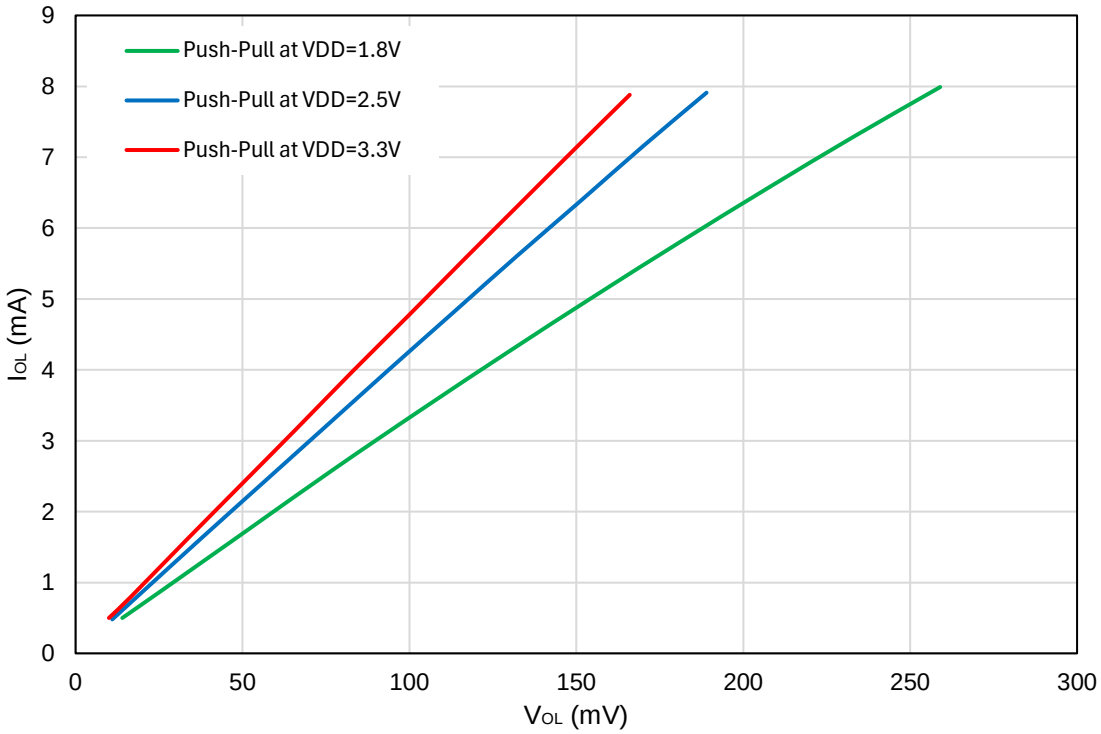



**Figure 10. Typical $I_{OL}$ vs. $V_{OL}$ in Push-Pull Mode at $T_A$ = +25 °C**

# 5. Power Architecture

## 5.1 Power Architecture General Description

The SLG47011 supports three power domains (PD) and can operate in three power modes. Two power domains can be powered on and off using matrix outputs, one power domain is always ON. The description of power domains is shown in Table 4.

**Table 4. Power Domains Description**

| Domain Name | Description |
|---|---|
| PD_Mx0 | Always powered ON domain. It comprises combination function and multi-function macrocells, configuration registers, and Connection Matrix0. |
| PD_Mx1 | Sleep power domain. It comprises ADC Sampling Engine, MathCore, Width Converter, Memory Table control, PWM, DCMP, combination function and multi-function macrocells, $I^2C$/SPI interfaces, and Connection Matrix1. |
| PD_RET | Retention power domain. It comprises Memory Table RAM, internal memory address counter (in Storage mode), and Data Buffers memory. |

The power architecture of the SLG47011 is shown in structural scheme in Figure 11.

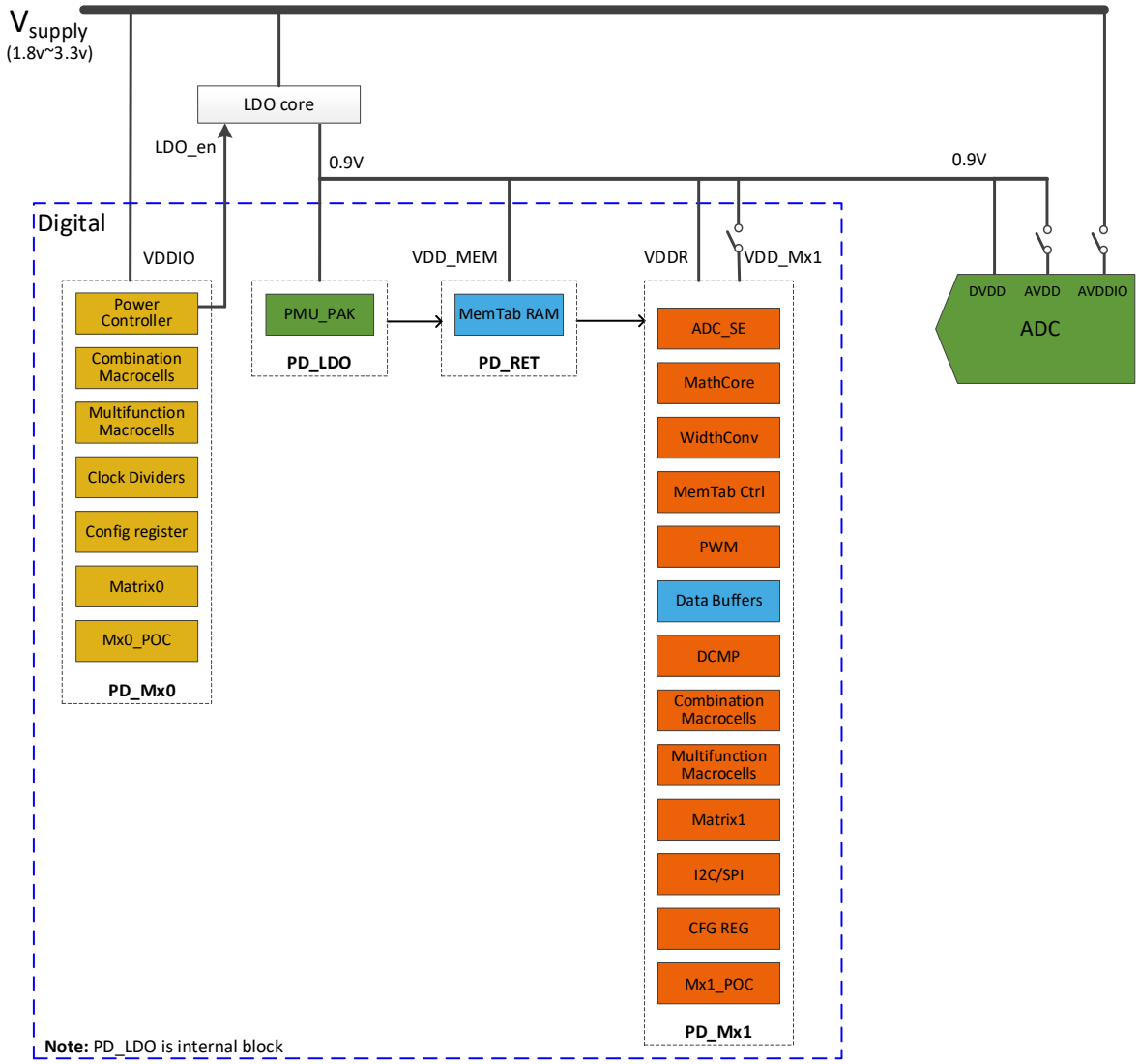



**Figure 11. Power Management Architecture of SLG47011**

The detailed list of digital macrocells powered by PD_Mx0, PD_Mx1, and PD_RET power domains is shown in Table 5.

**Table 5. Macrocells Powered by Power Domains PD_Mx0, PD_Mx1, and PD_RET**

| Matrix0 | Matrix1 | |
|---|---|---|
| **Always ON Domain (PD_Mx0)** | **Sleep Domain (PD_Mx1)** | **Retention Domain (PD_RET)** |
| LUT2_0/DFF0 | LUT2_1/DFF1 | Data Buffer0 |
| LUT3_0/DFF2 | LUT3_4/DFF6 | Data Buffer1 |
| LUT3_1/DFF3 | LUT3_5/DFF7 | Data Buffer2 |
| LUT3_2/DFF4 | LUT3_6/DFF8 | Data Buffer3 |
| LUT3_3/DFF5 | LUT3_7/DFF9 | Memory Table |
| LUT3_8/DFF10/Shift_Reg0 | LUT3_10/DFF12/Shift_Reg2 | |
| LUT3_9/DFF11/Shift_Reg1 | LUT3_11/DFF13/Shift_Reg3 | |
| LUT4_0/DFF16 | LUT3_12/DFF14/Shift_Reg4 | |
| LUT3_14/DFF18/CNT0 | LUT3_13/DFF15/Shift_Reg5 | |
| LUT3_15/DFF19/CNT1 | LUT4_1/DFF17 | |
| Programmable delay | LUT3_16/DFF20/CNT2 | |
| Oscillator0 | LUT3_17/DFF21/CNT3 | |
| | LUT3_18/DFF22/CNT4 | |
| | LUT3_19/DFF23/CNT5 | |
| | LUT3_20/DFF24/CNT6 | |
| | LUT3_21/DFF25/CNT7 | |
| | LUT3_22/DFF26/CNT8 | |
| | LUT3_23/DFF27/CNT9 | |
| | LUT3_24/DFF28/CNT10/FSM2 | |
| | LUT4_2/DFF29/CNT11/FSM0 | |
| | LUT4_3/DFF30/CNT12/FSM1 | |
| | Memory Table Control CNT | |
| | Width Converter | |
| | DCMP | |
| | ADC | |
| | PWM | |
| | MathCore | |

| Matrix0 | Matrix1 | |
|---|---|---|
| **Always ON Domain (PD_Mx0)** | **Sleep Domain (PD_Mx1)** | **Retention Domain (PD_RET)** |
| | DAC | |
| | Current source | |
| | Filter Edge detect | |
| | Temperature sensor | |
| | $I^2C$/SPI | |
| | Oscillator1 | |

**Note:** If PD_Mx1 is powered off, the outputs of all macrocells powered by this power domain are LOW. Internal states of macrocells powered by PD_Mx1 are reset after transition to Power-off mode.

There are three different power modes in the SLG47011:

**All ON:** device is active, all digital power domains and ADC are enabled.

**RETENTION:** Memory Table RAM, internal memory address counter (in Storage mode), and Data Buffers are retained while PD_Mx1 is powered off. ADC is powered off.

**SLEEP:** PD_Mx0 is active, PD_Mx1 and PD_RET are disabled. Memory Table RAM and configuration registers of macrocells powered by PD_Mx1 are powered off.

## 5.2 Power Controller

The SLG47011 has a Power Controller block that controls power modes. There are two user controlled matrix outputs SLP (CMO0 [44]) and RET (CMO0 [45]) that set the power mode.

The transition from SLEEP to RETENTION power mode is followed by the sequence: transition to All ON mode, loading the data from NVM to RAM, transition to RETENTION mode.

The transition times from SLEEP and RETENTION modes to All ON mode are shown in section 3.4.5 Estimated Typical Delay for Each Macrocell. All operations with the Memory Table or the Data Buffers should be completed 5 µs before entering SLEEP or RETENTION modes.

The configuration of matrix outputs, power domains state, and power consumption are shown in Table 6. The power consumption data is for static inputs and outputs, including all the leakages of all internal blocks, while all analog blocks are powered off, such as OSC and $V_{REF}$ generator at $T_A$ = 25 °C and $V_{DD}$ = 3.3 V.

**Table 6. Power Modes, Power Domains State, Power Consumption, and Mode Transition Delays**

| | Matrix Inputs Configuration | | Power Domains State | | | ADC (in Analog) | | Power Consumption | Mode Transition Delay |
|---|---|---|---|---|---|---|---|---|---|
| **Power Mode** | **SLP (from CMO0 [44])** | **RET (from CMO0 [45])** | **PD_Mx0** | **PD_RET** | **PD_Mx1** | **$CV_{DD}$** | **$AV_{DDIO}$, $AV_{DD}$, $V_{REF}$** | | |
| All ON | 0 | X | ON | ON | ON | ON | ON/OFF | 30.36 µA at $V_{DD}$ = 2.5 V | RETENTION to All ON 0.41 ms<br>SLEEP to All ON 1.37 ms |
| RETENTION | 1 | 1 | ON | ON | OFF | ON | OFF | 4.75 µA at $V_{DD}$ = 2.5 V | -- |
| SLEEP | 1 | 0 | ON | OFF | OFF | OFF | OFF | 0.50 µA at $V_{DD}$ = 2.5 V | -- |

During device loading and transition from SLEEP/RETENTION modes to All ON, the Memory Table data can be loaded from NVM to RAM or bypassed. Memory Table data loading is controlled by SKIP_NVM_MEM [541] register.

If SKIP_NVM_MEM [541] = 0 – the Memory Table data will be loaded from NVM to RAM during device loading and transition from SLEEP/RETENTION modes to All ON mode.

If SKIP_NVM_MEM [541] = 1 – the Memory Table data loading will be bypassed. If the Memory Table macrocell is not used in the design, then SKIP_NVM_MEM [541] must to be set to “1”.

# 6. Connection Matrix

The SLG47011 features two connection matrices, Matrix0 and Matrix1, that define the connectivity for internal digital signals. The output of each functional macrocell has a specific digital code assigned to it, that is either set to active (HIGH) or inactive (LOW), based on the user's design. Once all NVM bit registers are programmed, a fully custom circuit will be created.

Matrix0 is always ON, while Matrix1 can be powered on/off depending on the selected power mode (see section 5 Power Architecture)

Matrix0 has 32 inputs and 46 outputs. Matrix1 has 95 inputs and 124 outputs. Each Matrix input is hard-wired to the digital output of a particular source macrocell, including IO pins, LUTs, ADC, analog comparators, other digital macrocells, $V_{DD}$, and GND. The input to a digital macrocell uses a 5-bit register (Matrix0) and a 7-bit register (Matrix1) to select one of the 32 (Matrix0) and 95 (Matrix1) lines, respectively.

All macrocells associated with a particular matrix have both their inputs and outputs connected to that matrix. To make connections to macrocells associated with the other matrix, the user can utilize the matrix cross connection lines (see Figure 13).

Each matrix has dedicated output connections for connecting to the other matrix, known as the cross connection outputs. Matrix0 has 6 outputs to Matrix1, Matrix1 has 9 outputs to Matrix0 (see Figure 14). When using these cross connections, any macrocell can be connected to any other macrocell in the device by first connecting through the other matrix. Because there is a limited number of matrix cross connections, it is important to make connections between the outputs of macrocells to the inputs of other macrocells within the same matrix whenever possible. This will free up the matrix cross connection lines for digital connections to the resources associated with the other matrix.

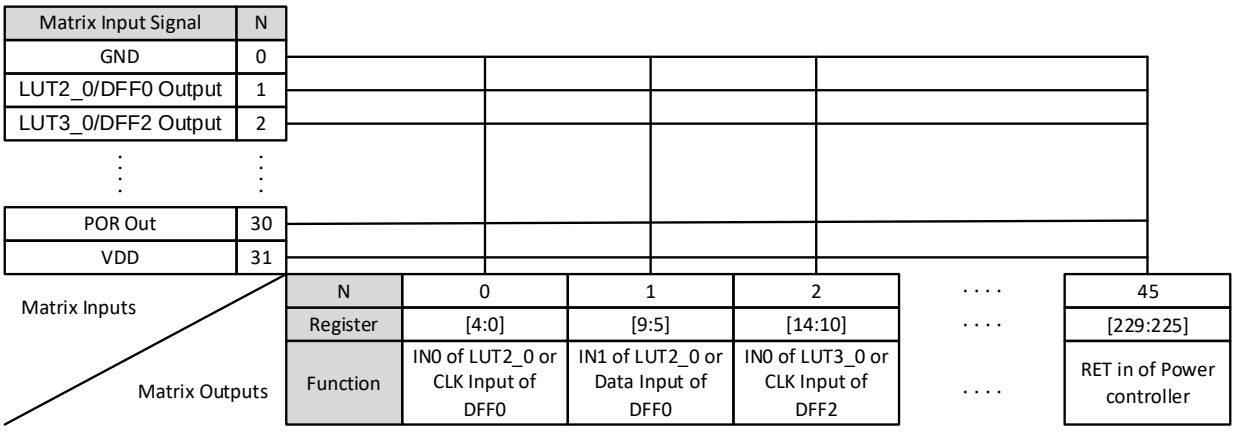



**Figure 12. Connection Matrix0**

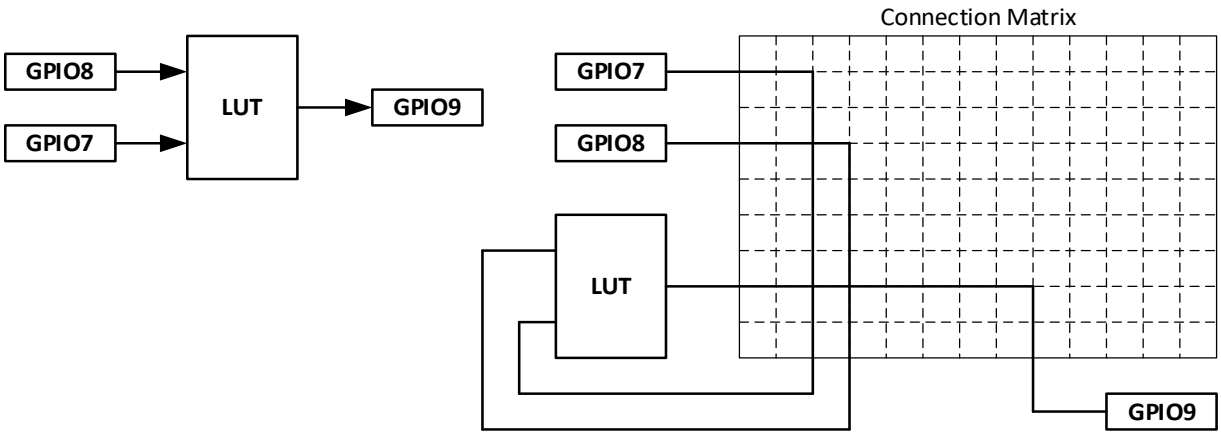



**Figure 13. Connection Matrix Usage Example**

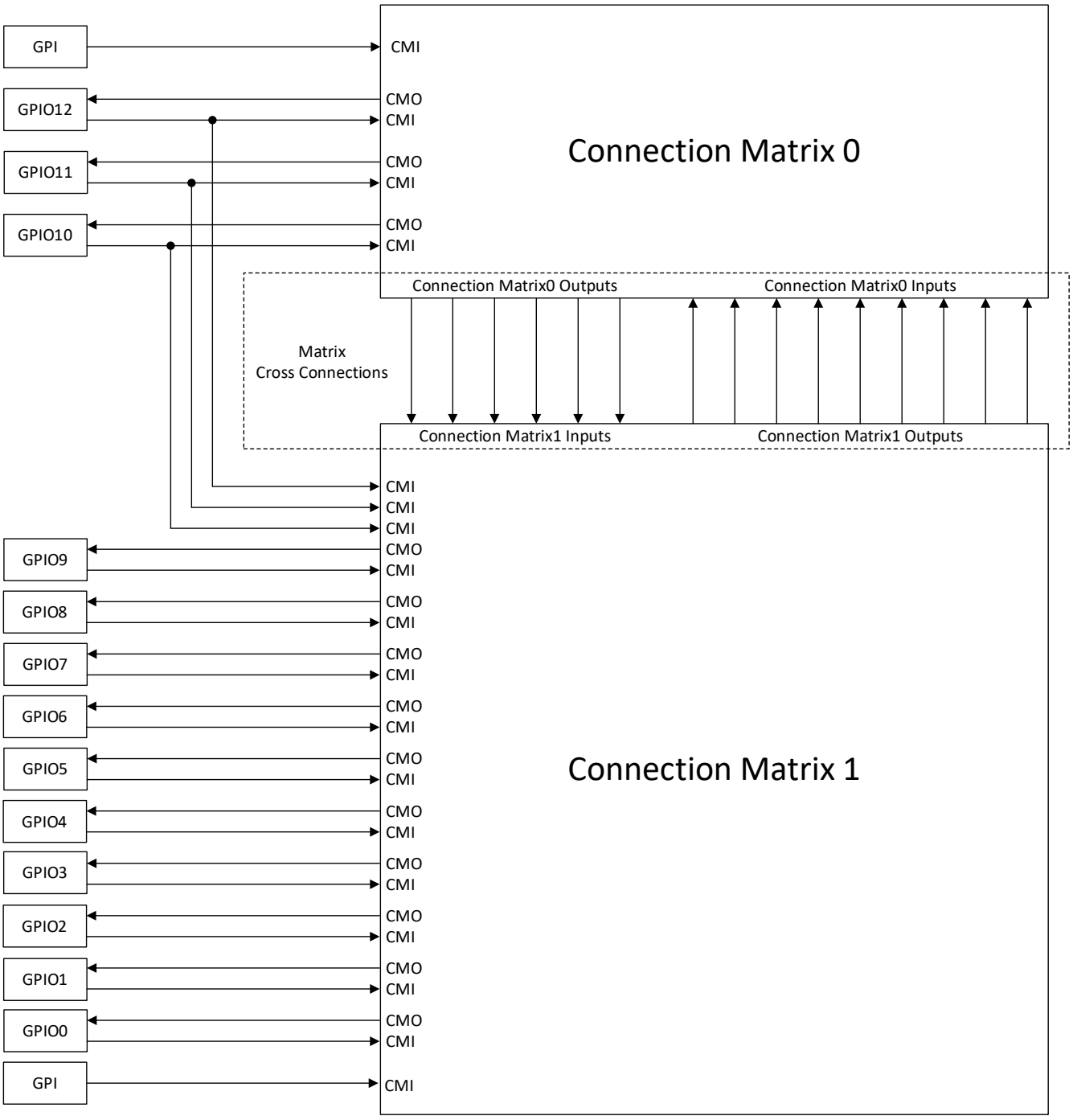



**Figure 14. Interconnection of Connection Matrices**

## 6.1 Connection Matrix0 Input and Output

**Table 7. Matrix0 Input Table**

| Matrix Input Number | Matrix Input Signal Function | Matrix Decode | | | | |
|---|---|---|---|---|---|---|
| | | 4 | 3 | 2 | 1 | 0 |
| 0 | GND | 0 | 0 | 0 | 0 | 0 |
| 1 | LUT2_0/DFF0 output | 0 | 0 | 0 | 0 | 1 |
| 2 | LUT3_0/DFF2 output | 0 | 0 | 0 | 1 | 0 |
| 3 | LUT3_1/DFF3 output | 0 | 0 | 0 | 1 | 1 |
| 4 | LUT3_2/DFF4 output | 0 | 0 | 1 | 0 | 0 |
| 5 | LUT3_3/DFF5 output | 0 | 0 | 1 | 0 | 1 |
| 6 | LUT3_8/DFF10 output/Shift_Reg0 output | 0 | 0 | 1 | 1 | 0 |
| 7 | LUT3_9/DFF11 output/Shift_Reg1 output | 0 | 0 | 1 | 1 | 1 |
| 8 | LUT4_0/DFF16 output | 0 | 1 | 0 | 0 | 0 |
| 9 | CNT0 output | 0 | 1 | 0 | 0 | 1 |
| 10 | MLT0_LUT3_14/DFF18_OUT | 0 | 1 | 0 | 1 | 0 |
| 11 | CNT1 output | 0 | 1 | 0 | 1 | 1 |
| 12 | MLT1_LUT3_15/DFF19_OUT | 0 | 1 | 1 | 0 | 0 |
| 13 | Programmable Delay/Edge Detector Output | 0 | 1 | 1 | 0 | 1 |
| 14 | GPI | 0 | 1 | 1 | 1 | 0 |
| 15 | GPIO10 | 0 | 1 | 1 | 1 | 1 |
| 16 | GPIO11 | 1 | 0 | 0 | 0 | 0 |
| 17 | GPIO12 | 1 | 0 | 0 | 0 | 1 |
| 18 | Oscillator0 output | 1 | 0 | 0 | 1 | 0 |
| 19 | In0 Input from Matrix1 | 1 | 0 | 0 | 1 | 1 |
| 20 | In1 Input from Matrix1 | 1 | 0 | 1 | 0 | 0 |
| 21 | In2 Input from Matrix1 | 1 | 0 | 1 | 0 | 1 |
| 22 | In3 Input from Matrix1 | 1 | 0 | 1 | 1 | 0 |
| 23 | In4 Input from Matrix1 | 1 | 0 | 1 | 1 | 1 |
| 24 | In5 Input from Matrix1 | 1 | 1 | 0 | 0 | 0 |
| 25 | In6 Input from Matrix1 | 1 | 1 | 0 | 0 | 1 |
| 26 | In7 Input from Matrix1 | 1 | 1 | 0 | 1 | 0 |
| 27 | In8 Input from Matrix1 | 1 | 1 | 0 | 1 | 1 |
| 28 | Reserved | 1 | 1 | 1 | 0 | 0 |
| 29 | Reserved | 1 | 1 | 1 | 0 | 1 |

| Matrix Input Number | Matrix Input Signal Function | Matrix Decode | | | | |
|---|---|---|---|---|---|---|
| | | 4 | 3 | 2 | 1 | 0 |
| 30 | POR | 1 | 1 | 1 | 1 | 0 |
| 31 | $V_{DD}$ | 1 | 1 | 1 | 1 | 1 |

**Table 8. Matrix0 Output Table**

| Register Bit Address | Matrix0 Output Signal Function | Matrix Output Number |
|---|---|---|
| [4:0] | IN0 of LUT2_0 or Clock Input of DFF0 | 0 |
| [9:5] | IN1 of LUT2_0 or Data Input of DFF0 | 1 |
| [14:10] | IN0 of LUT3_0 or CLK Input of DFF2 | 2 |
| [19:15] | IN1 of LUT3_0 or Data of DFF2 | 3 |
| [24:20] | IN2 of LUT3_0 or nRST (nSET) of DFF2 | 4 |
| [29:25] | IN0 of LUT3_1 or CLK Input of DFF3 | 5 |
| [34:30] | IN1 of LUT3_1 or Data of DFF3 | 6 |
| [39:35] | IN2 of LUT3_1 or nRST (nSET) of DFF3 | 7 |
| [44:40] | IN0 of LUT3_2 or CLK Input of DFF4 | 8 |
| [49:45] | IN1 of LUT3_2 or Data of DFF4 | 9 |
| [54:50] | IN2 of LUT3_2 or nRST (nSET) of DFF4 | 10 |
| [59:55] | IN0 of LUT3_3 or CLK Input of DFF5 | 11 |
| [64:60] | IN1 of LUT3_3 or Data of DFF5 | 12 |
| [69:65] | IN2 of LUT3_3 or nRST (nSET) of DFF5 | 13 |
| [74:70] | IN0 of LUT3_8 or CLK Input of DFF10 or Clock Input of Shift_Reg0 | 14 |
| [79:75] | IN1 of LUT3_8 or Data of DFF10 or Data Input of Shift_Reg0 | 15 |
| [84:80] | IN2 of LUT3_8 or nRST (nSET) of DFF10 or nRST (nSET) of Shift_Reg0 | 16 |
| [89:85] | IN0 of LUT3_9 or CLK Input of DFF11 or Clock Input of Shift_Reg1 | 17 |
| [94:90] | IN1 of LUT3_9 or Data of DFF11 or Data Input of Shift_Reg1 | 18 |
| [99:95] | IN2 of LUT3_9 or nRST (nSET) of DFF11 or nRST (nSET) of Shift_Reg1 | 19 |
| [104:100] | IN0 of LUT4_0 or CLK Input of DFF16 | 20 |
| [109:105] | IN1 of LUT4_0 or Data of DFF16 | 21 |
| [114:110] | IN2 of LUT4_0 or nRST (nSET) of DFF16 | 22 |
| [119:115] | IN3 of LUT4_0 | 23 |
| [124:120] | IN0 of LUT3_14 or CLK Input of DFF18 or Delay0 Input (or Counter0 nRST Input) | 24 |

| Register Bit Address | Matrix0 Output Signal Function | Matrix Output Number |
|---|---|---|
| [129:125] | IN1 of LUT3_14 or nRST (nSET) of DFF18 or Delay0 Input (or Counter0 nRST Input) | 25 |
| [134:130] | IN2 of LUT3_14 or Data of DFF18 or Delay0 Input (or Counter0 nRST Input) | 26 |
| [139:135] | IN0 of LUT3_15 or CLK Input of DFF19 or Delay1 Input (or Counter1 nRST Input) | 27 |
| [144:140] | IN1 of LUT3_15 or nRST (nSET) of DFF19 or Delay1 Input (or Counter1 nRST Input) | 28 |
| [149:145] | IN2 of LUT3_15 or Data of DFF19 or Delay1 Input (or Counter1 nRST Input) | 29 |
| [154:150] | Programmable Delay/Edge Detect Input | 30 |
| [159:155] | GPIO10 Digital Output OE | 31 |
| [164:160] | GPIO10 Digital Output | 32 |
| [169:165] | GPIO11 Digital Output OE | 33 |
| [174:170] | GPIO11 Digital Output | 34 |
| [179:175] | GPIO12, Digital Output OE | 35 |
| [184:180] | GPIO12, Digital Output | 36 |
| [189:185] | OSC0 Enable | 37 |
| [194:190] | Out0 output to Matrix1 | 38 |
| [199:195] | Out1 output to Matrix1 | 39 |
| [204:200] | Out2 output to Matrix1 | 40 |
| [209:205] | Out3 output to Matrix1 | 41 |
| [214:210] | Out4 output to Matrix1 | 42 |
| [219:215] | Out5 output to Matrix1 | 43 |
| [224:220] | SLP in of Power controller | 44 |
| [229:225] | RET in of Power controller | 45 |

## 6.2 Connection Matrix1 Input and Output

**Table 9. Matrix1 Input Table**

| Matrix Input Number | Matrix1 Input Signal Function | Matrix Decode | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | GND | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | LUT2_1/DFF1 output | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 2 | LUT3_4/DFF6 output | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 3 | LUT3_5/DFF7 output | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 4 | LUT3_6/DFF8 output | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

| Matrix Input Number | Matrix1 Input Signal Function | Matrix Decode | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 5 | LUT3_7/DFF9 output | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 6 | LUT3_10/DFF12 output/Shift_Reg2 output | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 7 | LUT3_11/DFF13 output/Shift_Reg3 output | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 8 | LUT3_12/DFF14 output/Shift_Reg4 output | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 9 | LUT3_13/DFF15 output/Shift_Reg5 output | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 10 | LUT4_1/DFF17 output | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 11 | CNT2 output | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 12 | MLT2_LUT3_16/DFF20_OUT | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 13 | CNT3 output | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| 14 | MLT3_LUT3_17/DFF21_OUT | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 15 | CNT4 output | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 16 | MLT4_LUT3_18/DFF22_OUT | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 17 | CNT5 output | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 18 | MLT5_LUT3_19/DFF23_OUT | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 19 | CNT6 output | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 20 | MLT6_LUT3_20/DFF24_OUT | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 21 | CNT7 output | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| 22 | MLT7_LUT3_21/DFF25_OUT | 0 | 0 | 1 | 0 | 1 | 1 | 0 |
| 23 | CNT8 output | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| 24 | MLT8_LUT3_22/DFF26_OUT | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 25 | CNT9 output | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| 26 | MLT9_LUT3_23/DFF27_OUT | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| 27 | CNT10 output | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| 28 | MLT10_LUT3_24/DFF28_OUT | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 29 | CNT10 PWM OUT0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 |
| 30 | CNT10 PWM OUT1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| 31 | 16-bit CNT11 output | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 32 | MLT11_LUT4_2/DFF29_OUT | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 33 | 16-bit CNT12 output | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 34 | MLT12_LUT4_3/DFF30_OUT | 0 | 1 | 0 | 0 | 0 | 1 | 0 |

| Matrix Input Number | Matrix1 Input Signal Function | Matrix Decode | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 35 | Memory control counter Out | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 36 | Edge Detect Filter Output | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 37 | Width Converter Output0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| 38 | Width Converter Output1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 39 | Width Converter Output2 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |
| 40 | Width Converter Output3 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 41 | Width Converter Output4 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| 42 | Width Converter Output5 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 43 | Width Converter Output6 | 0 | 1 | 0 | 1 | 0 | 1 | 1 |
| 44 | Width Converter Output7 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |
| 45 | Width Converter Output8 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
| 46 | Width Converter Output9 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |
| 47 | Width Converter Output10 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| 48 | Width Converter Output11 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 49 | Data Buffer0 ready | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| 50 | Data Buffer1 ready | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 51 | Data Buffer2 ready | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| 52 | Data Buffer3 ready | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| 53 | BufferX ready output | 0 | 1 | 1 | 0 | 1 | 0 | 1 |
| 54 | DCMP Output 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| 55 | DCMP Output 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| 56 | DCMP Output 2 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 57 | DCMP Output 3 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| 58 | DCMP Data ready output | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| 59 | Memory Table Data Ready output | 0 | 1 | 1 | 1 | 0 | 1 | 1 |
| 60 | ADC Data Ready output | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| 61 | MathCore Math_DR output | 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| 62 | ACMP_H Output | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 63 | $I^2C$/SPI virtual Input 0/I2C_Ack | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 64 | $I^2C$/SPI virtual Input 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

| Matrix Input Number | Matrix1 Input Signal Function | Matrix Decode | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 65 | $I^2C$/SPI virtual Input 2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 66 | $I^2C$/SPI virtual Input 3 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 67 | $I^2C$/SPI virtual Input 4 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 68 | $I^2C$/SPI virtual Input 5 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 69 | $I^2C$/SPI virtual Input 6 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| 70 | $I^2C$/SPI virtual Input 7 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| 71 | GPI Digital Input | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 72 | GPIO0 Digital Input or SDA | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 73 | GPIO1 Digital Input or SCL | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| 74 | GPIO2 Digital Input | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| 75 | GPIO3 Digital Input | 1 | 0 | 0 | 1 | 0 | 1 | 1 |
| 76 | GPIO4 Digital Input | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 77 | GPIO5 Digital Input | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| 78 | GPIO6 Digital Input | 1 | 0 | 0 | 1 | 1 | 1 | 0 |
| 79 | GPIO7 Digital Input | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| 80 | GPIO8 Digital Input | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 81 | GPIO9 Digital Input | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| 82 | GPIO10 Digital Input | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| 83 | GPIO11 Digital Input | 1 | 0 | 1 | 0 | 0 | 1 | 1 |
| 84 | GPIO12 Digital Input | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| 85 | Oscillator0 output | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 86 | Oscillator1 output | 1 | 0 | 1 | 0 | 1 | 1 | 0 |
| 87 | In0 Input from Matrix0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 |
| 88 | In1 Input from Matrix0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| 89 | In2 Input from Matrix0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 |
| 90 | In3 Input from Matrix0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| 91 | In4 Input from Matrix0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| 92 | In5 Input from Matrix0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| 93 | POR | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| 94 | $V_{DD}$ | 1 | 0 | 1 | 1 | 1 | 1 | 0 |

**Table 10. Matrix1 Output Table**

| Register Bit Address | Matrix1 Output Signal Function | Matrix Output Number |
|---|---|---|
| [830:824] | IN0 of LUT2_1 or Clock Input of DFF1 | 0 |
| [837:831] | IN1 of LUT2_1 or Data Input of DFF1 | 1 |
| [844:838] | IN0 of LUT3_4 or CLK Input of DFF6 | 2 |
| [851:845] | IN1 of LUT3_4 or Data of DFF6 | 3 |
| [858:852] | IN2 of LUT3_4 or nRST (nSET) of DFF6 | 4 |
| [865:859] | IN0 of LUT3_5 or CLK Input of DFF7 | 5 |
| [872:866] | IN1 of LUT3_5 or Data of DFF7 | 6 |
| [879:873] | IN2 of LUT3_5 or nRST (nSET) of DFF7 | 7 |
| [886:880] | IN0 of LUT3_6 or CLK Input of DFF8 | 8 |
| [893:887] | IN1 of LUT3_6 or Data of DFF8 | 9 |
| [900:894] | IN2 of LUT3_6 or nRST (nSET) of DFF8 | 10 |
| [907:901] | IN0 of LUT3_7 or CLK Input of DFF9 | 11 |
| [914:908] | IN1 of LUT3_7 or Data of DFF9 | 12 |
| [921:915] | IN2 of LUT3_7 or nRST (nSET) of DFF9 | 13 |
| [928:922] | IN0 of LUT3_10 or CLK Input of DFF12 or Clock Input of Shift_Reg2 | 14 |
| [935:929] | IN1 of LUT3_10 or Data of DFF12 or Data Input of Shift_Reg2 | 15 |
| [942:936] | IN2 of LUT3_10 or nRST (nSET) of DFF12 or nRST (nSET) of Shift_Reg2 | 16 |
| [949:943] | IN0 of LUT3_11 or CLK Input of DFF13 or Clock Input of Shift_Reg3 | 17 |
| [956:950] | IN1 of LUT3_11 or Data of DFF13 or Data Input of Shift_Reg3 | 18 |
| [963:957] | IN2 of LUT3_11 or nRST (nSET) of DFF13 or nRST (nSET) of Shift_Reg3 | 19 |
| [970:964] | IN0 of LUT3_12 or CLK Input of DFF14 or Clock Input of Shift_Reg4 | 20 |
| [977:971] | IN1 of LUT3_12 or Data of DFF14 or Data Input of Shift_Reg4 | 21 |
| [984:978] | IN2 of LUT3_12 or nRST (nSET) of DFF14 or nRST (nSET) of Shift_Reg4 | 22 |
| [991:985] | IN0 of LUT3_13 or CLK Input of DFF15 or Clock Input of Shift_Reg5 | 23 |
| [998:992] | IN1 of LUT3_13 or Data of DFF15 or Data Input of Shift_Reg5 | 24 |
| [1005:999] | IN2 of LUT3_13 or nRST (nSET) of DFF15 or nRST (nSET) of Shift_Reg5 | 25 |
| [1012:1006] | IN0 of LUT4_1 or CLK Input of DFF17 | 26 |
| [1019:1013] | IN1 of LUT4_1 or Data of DFF17 | 27 |
| [1026:1020] | IN2 of LUT4_1 or nRST (nSET) of DFF17 | 28 |
| [1033:1027] | IN3 of LUT4_1 | 29 |

| Register Bit Address | Matrix1 Output Signal Function | Matrix Output Number |
|---|---|---|
| [1040:1034] | IN0 of LUT3_16 or CLK Input of DFF20 or Delay2 Input (or Counter2 nRST Input) | 30 |
| [1047:1041] | IN1 of LUT3_16 or nRST (nSET) of DFF20 or Delay2 Input (or Counter2 nRST Input) | 31 |
| [1054:1048] | IN2 of LUT3_16 or Data of DFF20 or Delay2 Input (or Counter2 nRST Input) | 32 |
| [1061:1055] | IN0 of LUT3_17 or CLK Input of DFF21 or Delay3 Input (or Counter3 nRST Input) | 33 |
| [1068:1062] | IN1 of LUT3_17 or nRST (nSET) of DFF21 or Delay3 Input (or Counter3 nRST Input) | 34 |
| [1075:1069] | IN2 of LUT3_17 or Data of DFF21 or Delay3 Input (or Counter3 nRST Input) | 35 |
| [1082:1076] | IN0 of LUT3_18 or CLK Input of DFF22 or Delay4 Input (or Counter4 nRST Input) | 36 |
| [1089:1083] | IN1 of LUT3_18 or nRST (nSET) of DFF22 or Delay4 Input (or Counter4 nRST Input) | 37 |
| [1096:1090] | IN2 of LUT3_18 or Data of DFF22 or Delay4 Input (or Counter4 nRST Input) | 38 |
| [1103:1097] | IN0 of LUT3_19 or CLK Input of DFF23 or Delay5 Input (or Counter5 nRST Input) | 39 |
| [1110:1104] | IN1 of LUT3_19 or nRST (nSET) of DFF23 or Delay5 Input (or Counter5 nRST Input) | 40 |
| [1117:1111] | IN2 of LUT3_19 or Data of DFF23 or Delay5 Input (or Counter5 nRST Input) | 41 |
| [1124:1118] | IN0 of LUT3_20 or CLK Input of DFF24 or Delay6 Input (or Counter6 nRST Input) | 42 |
| [1131:1125] | IN1 of LUT3_20 or nRST (nSET) of DFF24 or Delay6 Input (or Counter6 nRST Input) | 43 |
| [1138:1132] | IN2 of LUT3_20 or Data of DFF24 or Delay6 Input (or Counter6 nRST Input) | 44 |
| [1145:1139] | IN0 of LUT3_21 or CLK Input of DFF25 or Delay7 Input (or Counter7 nRST Input) | 45 |
| [1152:1146] | IN1 of LUT3_21 or nRST (nSET) of DFF25 or Delay7 Input (or Counter7 nRST Input) | 46 |
| [1159:1153] | IN2 of LUT3_21 or Data of DFF25 or Delay7 Input (or Counter7 nRST Input) | 47 |
| [1166:1160] | IN0 of LUT3_22 or CLK Input of DFF26 or Delay8 Input (or Counter8 nRST Input) | 48 |
| [1173:1167] | IN1 of LUT3_22 or nRST (nSET) of DFF26 or Delay8 Input (or Counter8 nRST Input) | 49 |
| [1180:1174] | IN2 of LUT3_22 or Data of DFF26 or Delay8 Input (or Counter8 nRST Input) | 50 |
| [1187:1181] | IN0 of LUT3_23 or CLK Input of DFF27 or Delay9 Input (or Counter9 nRST Input) | 51 |
| [1194:1188] | IN1 of LUT3_23 or nRST (nSET) of DFF27 or Delay9 Input (or Counter9 nRST Input) | 52 |
| [1201:1195] | IN2 of LUT3_23 or Data of DFF27 or Delay9 Input (or Counter9 nRST Input) | 53 |
| [1208:1202] | Load of Delay9 or Counter9 | 54 |
| [1215:1209] | IN0 of LUT3_24 or CLK Input of DFF28 or Delay10 Input (or Counter10 nRST Input) or UP Input of FSM2 | 55 |
| [1222:1216] | IN1 of LUT3_24 or nRST (nSET) of DFF28 or Delay10 Input (or Counter10 nRST Input) or DLY/CNT10/FSM2 External CLK input | 56 |
| [1229:1223] | IN2 of LUT3_24 or Data of DFF28 or Delay10 Input (or Counter10 nRST Input) or FSM Reset/Set input | 57 |
| [1236:1230] | IN0 of LUT4_2 or CLK Input of DFF29 or Delay11 Input (or Counter11 nRST Input) | 58 |

| Register Bit Address | Matrix1 Output Signal Function | Matrix Output Number |
|---|---|---|
| [1243:1237] | IN1 of LUT4_2 or nRST of DFF29 or Delay11 Input (or Counter11 nRST Input) or Delay/Counter11 External CLK source | 59 |
| [1250:1244] | IN2 of LUT4_2 or nSET of DFF29 or Delay11 Input (or Counter11 nRST Input) or Delay/Counter11 External CLK source or KEEP Input of FSM0 | 60 |
| [1257:1251] | IN3 of LUT4_2 or Data of DFF29 or Delay11 Input (or Counter11 nRST Input) or UP Input of FSM0 | 61 |
| [1264:1258] | IN0 of LUT4_3 or CLK Input of DFF30 or Delay12 Input (or Counter12 nRST Input) | 62 |
| [1271:1265] | IN1 of LUT4_3 or nRST of DFF30 or Delay12 Input (or Counter12 nRST Input) or Delay/Counter12 External CLK source | 63 |
| [1278:1272] | IN2 of LUT4_3 or nSET of DFF30 or Delay12 Input (or Counter12 nRST Input) or Delay/Counter12 External CLK source or KEEP Input of FSM1 | 64 |
| [1285:1279] | IN3 of LUT4_3 or Data of DFF30 or Delay12 Input (or Counter12 nRST Input) or UP Input of FSM1 | 65 |
| [1292:1286] | Memory Control counter External Clock Input / Width Converter CLK input | 66 |
| [1299:1293] | Memory Control counter Reset/Set Input | 67 |
| [1306:1300] | Memory Control counter Up/Down Input | 68 |
| [1313:1307] | Memory Control counter Keep/Range Input | 69 |
| [1320:1314] | Filter/Edge Detect Input | 70 |
| [1327:1321] | ADC Conversion Start | 71 |
| [1334:1328] | ADC Start Calibration | 72 |
| [1341:1335] | ADC CLK input | 73 |
| [1348:1342] | MathCore Calc_EN | 74 |
| [1355:1349] | PGA Power-Up | 75 |
| [1362:1356] | Current source Power-up | 76 |
| [1369:1363] | DCMP Enable | 77 |
| [1376:1370] | DCMP Reset | 78 |
| [1383:1377] | ADC Power-up | 79 |
| [1390:1384] | Data Buffer0 Load | 80 |
| [1397:1391] | Data Buffer1 Load | 81 |
| [1404:1398] | Data Buffer2 Load | 82 |
| [1411:1405] | Data Buffer3 Load | 83 |
| [1418:1412] | PWM Power-up | 84 |
| [1425:1419] | DAC Power-up | 85 |
| [1432:1426] | ACMP_H Power-up | 86 |

| Register Bit Address | Matrix1 Output Signal Function | Matrix Output Number |
|---|---|---|
| [1439:1433] | GPIO0 Digital Output | 87 |
| [1446:1440] | GPIO1 Digital Output | 88 |
| [1453:1447] | GPIO2 Digital Output OE | 89 |
| [1460:1454] | GPIO2 Digital Output | 90 |
| [1467:1461] | GPIO3 Digital Output OE | 91 |
| [1474:1468] | GPIO3 Digital Output | 92 |
| [1481:1475] | GPIO4 Digital Output OE | 93 |
| [1488:1482] | GPIO4 Digital Output | 94 |
| [1495:1489] | GPIO5 Digital Output OE | 95 |
| [1502:1496] | GPIO5 Digital Output | 96 |
| [1509:1503] | GPIO6 Digital Output OE | 97 |
| [1516:1510] | GPIO6 Digital Output | 98 |
| [1523:1517] | GPIO7 Digital Output OE | 99 |
| [1530:1524] | GPIO7 Digital Output | 100 |
| [1537:1531] | GPIO8 Digital Output OE | 101 |
| [1544:1538] | GPIO8 Digital Output | 102 |
| [1551:1545] | GPIO9 Digital Output OE | 103 |
| [1558:1552] | GPIO9 Digital Output | 104 |
| [1565:1559] | Temperature sensor Power-up | 105 |
| [1572:1566] | OSC1 Enable | 106 |
| [1579:1573] | $I^2C$/SPI Virtual Output 7 (Signal Readback Input 7) | 107 |
| [1586:1580] | $I^2C$/SPI Virtual Output 6 (Signal Readback Input 6) | 108 |
| [1593:1587] | $I^2C$/SPI Virtual Output 5 (Signal Readback Input 5) | 109 |
| [1600:1594] | $I^2C$/SPI Virtual Output 4 (Signal Readback Input 4) | 110 |
| [1607:1601] | $I^2C$/SPI Virtual Output 3 (Signal Readback Input 3) | 111 |
| [1614:1608] | $I^2C$/SPI Virtual Output 2 (Signal Readback Input 2) | 112 |
| [1621:1615] | $I^2C$/SPI Virtual Output 1 (Signal Readback Input 1) | 113 |
| [1628:1622] | $I^2C$/SPI Virtual Output 0 (Signal Readback Input 0) | 114 |
| [1635:1629] | Out0 output to Matrix0 | 115 |
| [1642:1636] | Out1 output to Matrix0 | 116 |

| Register Bit Address | Matrix1 Output Signal Function | Matrix Output Number |
|---|---|---|
| [1649:1643] | Out2 output to Matrix0 | 117 |
| [1656:1650] | Out3 output to Matrix0 | 118 |
| [1663:1657] | Out4 output to Matrix0 | 119 |
| [1670:1664] | Out5 output to Matrix0 | 120 |
| [1677:1671] | Out6 output to Matrix0 | 121 |
| [1684:1678] | Out7 output to Matrix0 | 122 |
| [1691:1685] | Out8 output to Matrix0 | 123 |

## 6.3 Connection Matrix Virtual Inputs

Most connection matrix inputs come from the outputs of various digital macrocells on the device. Eight of the connection matrix inputs connect to a register that can be written via I²C/SPI by the user. This gives the user an access to the inputs of other macrocells through the connection matrix. The I²C/SPI address for reading and writing these register values is 0x0061.

Seven out of eight Connection Matrix Virtual Inputs are dedicated to this virtual input function. An I²C/SPI write command to this register bits will set the desired signal values of the connection matrix inputs.

One out of eight Connection Matrix Virtual Inputs is shared with I2C_Ack output (I²C/SPI virtual Input 0 or I2C_Ack). The register I2C_ACK_HV0_SEL [3435] selects whether the connection matrix input comes from the I2C_Ack output or from the I²C/SPI virtual Input 0. If the virtual input mode is selected, the I²C/SPI write command to this register bit will set the signal value going into the connection matrix to the desired state.

I²C/SPI virtual inputs are always available for read/write operation via I²C/SPI interfaces. Protection bits have no effect on I²C/SPI virtual inputs (see section 25.4 Chip Configuration Data Protection).

## 6.4 Connection Matrix Virtual Outputs (Signal Readback)

The digital outputs of the various macrocells are routed to the connection matrix to enable interconnections to the inputs of other macrocells. It is possible to read the state of any of the macrocell outputs through the Host Interface (I²C/SPI). This option, called Connection Matrix Virtual Outputs, allows the user to read the state of each macrocell outputs, which are connected to eight inputs of the Signal Readback block register: I²C/SPI Virtual Output 0 (CMO1 [114]) to I²C/SPI Virtual Output 7 (CMO1 [107]). The I²C/SPI address for reading this register is 0x0062. Write commands to these same register values will be ignored.

# 7. Combination Function Macrocells

The SLG47011 has 18 combination function macrocells that can perform more than one logic or timing function. Each macrocell can function as a Look Up Table (LUT) or another logic or timing function.

See the list below for the functions that can be implemented in these macrocells.

- Two macrocells that can serve as either 2-bit LUTs or DFFs.
- Eight macrocells that can serve as either 3-bit LUTs or DFFs with reset/set input.
- Six macrocells that can serve as either 3-bit LUTs, DFFs with reset/set input, or as Shift Register.
- Two macrocells that can serve as either 4-bit LUTs or DFF with reset/set input.

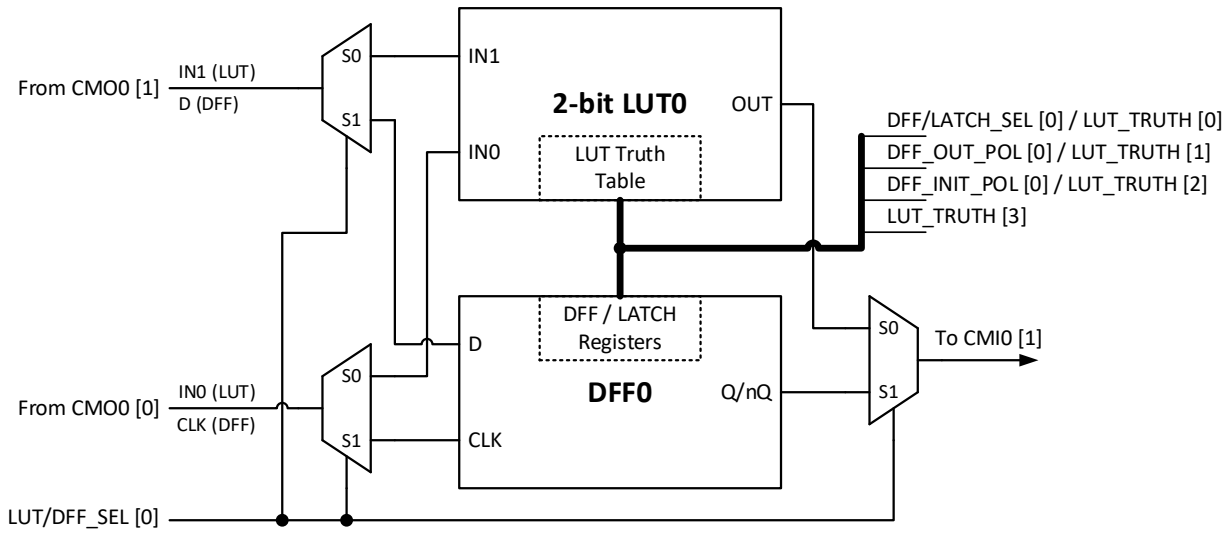
Inputs and outputs of those combination function macrocells are configured by the connection matrix with specific logic functions being defined by the state of configuration bits.

When the macrocell is used as a LUT to implement combinatorial logic functions, the outputs of the LUTs can be configured to any user-defined function, including the following standard digital logic functions: AND, NAND, OR, NOR, XOR, XNOR, buffer, inverter.

## 7.1 2-bit LUT or D Flip-Flop Macrocells

There are two macrocells that can serve as either 2-bit LUTs or DFFs. If the LUT function is selected, the 2-bit LUT will take two input signals from the connection matrix outputs (CMOs) and produce a single output, which will connect back to the connection matrix input (CMI). If DFF function is selected, the two input signals from the connection matrix will connect to data (D) and clock (CLK) inputs for the DFF with the output connecting back to the connection matrix input. The DFF/LATCH_SEL registers select either the DFF or LATCH function. The operations of DFF and LATCH functions are described below:

- **DFF:** Q = D at a rising edge of CLK (edge-triggered), otherwise Q retains its previous value.
- **LATCH:** Q = D when CLK is low (level-triggered), otherwise Q retains its previous value.




Registers abbreviations:

| | |
|---|---|
| LUT2_0_DFF0_LUT_DFF_SEL [320] | → LUT/DFF_SEL [0] |
| LUT2_0_DFF0_DFF_LATCH_SEL [232] | → DFF/LATCH_SEL [0] |
| LUT2_0_DFF0_OUT_POL [233] | → DFF_OUT_POL [0] |
| LUT2_0_DFF0_INIT_POL [234] | → DFF_INIT_POL [0] |
| LUT2_0_TRUTH [235:232] | → LUT_TRUTH [3:0] (for LUT function selected) |

**Figure 15. 2-bit LUT0 or DFF0**

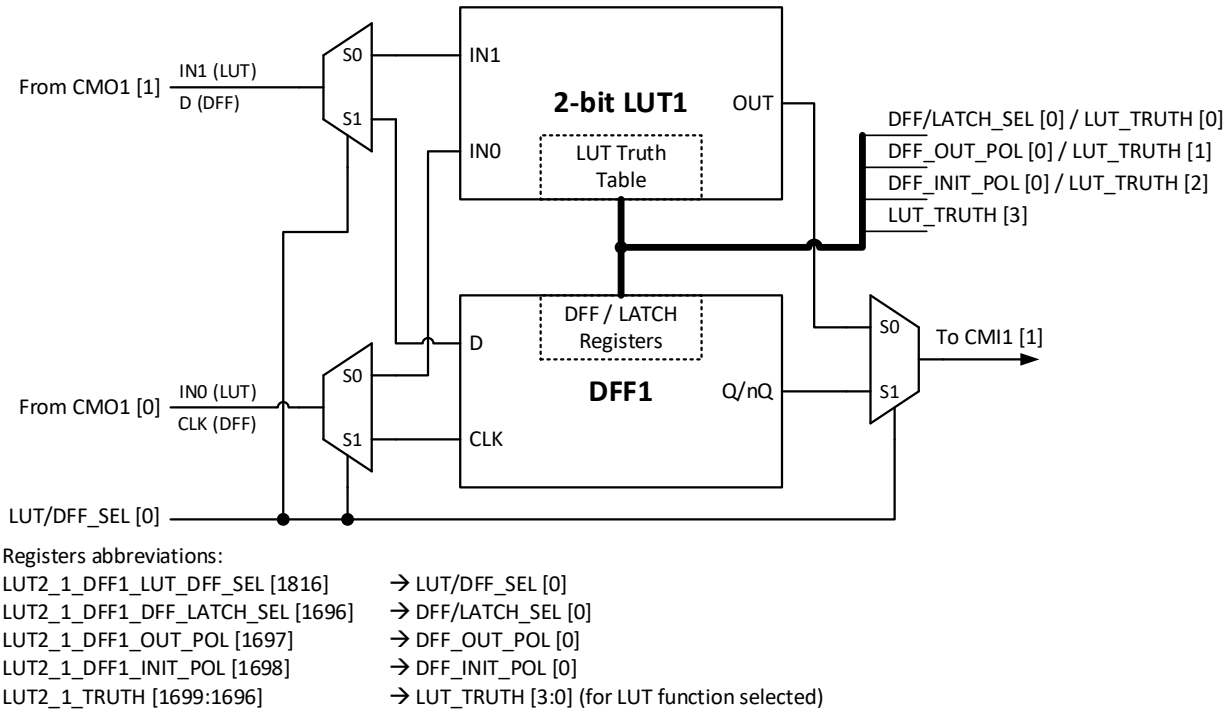



**Figure 16. 2-bit LUT1 or DFF1**

## 7.2 2-bit LUT or D Flip-Flop Macrocell Used as 2-bit LUT

When these macrocells are configured as LUT functions, 4-bit registers are used to define their output functions:

- 2-bit LUT0 is defined by registers Reg[235:232]
- 2-bit LUT1 is defined by registers Reg[1699:1696].

**Table 11. 2-bit LUT2_0 and 2-bit LUT2_1 Truth Table**

| IN1 | IN0 | OUT LUT0 | OUT LUT1 | |
|---|---|---|---|---|
| 0 | 0 | Reg[232] | Reg[1696] | LSB |
| 0 | 1 | Reg[233] | Reg[1697] | |
| 1 | 0 | Reg[234] | Reg[1698] | |
| 1 | 1 | Reg[235] | Reg[1699] | MSB |

Table 12 shows the register bits for the standard digital logic functions: AND, NAND, OR, NOR, XOR, XNOR, that can be created within each of the 2-bit LUT logic cells.

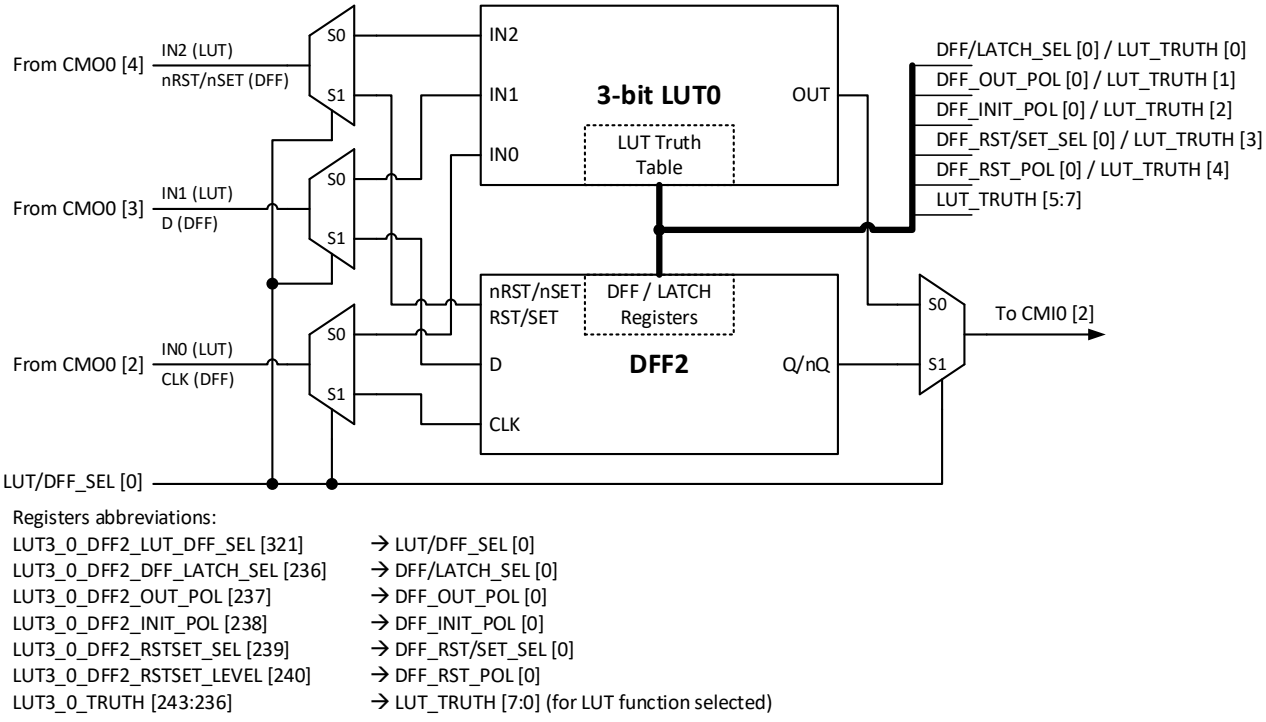
**Table 12. 2-bit LUT Standard Digital Functions**

| Function | MSB | | | LSB |
|---|---|---|---|---|
| AND-2 | 1 | 0 | 0 | 0 |
| NAND-2 | 0 | 1 | 1 | 1 |
| OR-2 | 1 | 1 | 1 | 0 |
| NOR-2 | 0 | 0 | 0 | 1 |
| XOR-2 | 0 | 1 | 1 | 0 |
| XNOR-2 | 1 | 0 | 0 | 1 |

## 7.3 3-bit LUT or D Flip-Flop with Reset/Set Macrocells

There are eight macrocells that can function as either 3-bit LUTs or DFFs with reset/set inputs. If the LUT function is selected, the 3-bit LUTs will each take three input signals from the connection matrix outputs (CMOs) and produce a single output, which will connect back to the connection matrix input (CMI). If the DFF function is selected, the three input signals from the connection matrix outputs will be connected to data (D), clock (CLK), and reset/set (nRST/nSET) inputs, and the output will connect back to the connection matrix input. It is possible to select the polarity of the reset/set input of DFF/LATCH macrocell. The DFF_RST_POL bit selects either active-high (RST/SET) or active-low (nRST/nSET) options. The DFF/LATCH_SEL registers select either DFF or LATCH function. The operations of DFF and LATCH functions are described below:

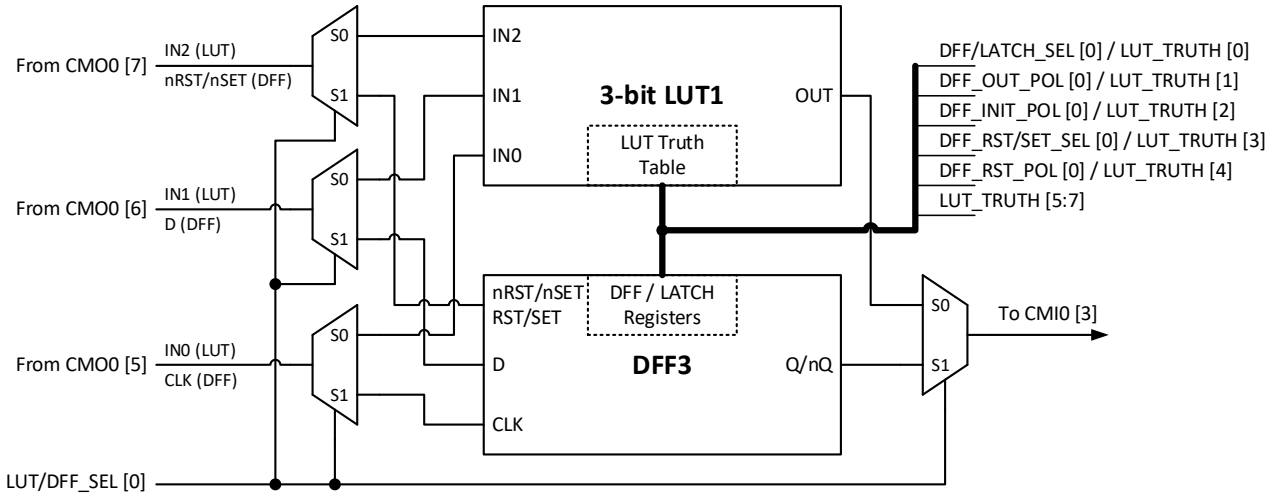
- **DFF**: Q = D at a rising edge of CLK (edge-triggered), otherwise Q retains its previous value.
- **LATCH**: Q = D when CLK is low (level-triggered), otherwise Q retains its previous value.




Registers abbreviations:

| | |
|---|---|
| LUT3_0_DFF2_LUT_DFF_SEL [321] | → LUT/DFF_SEL [0] |
| LUT3_0_DFF2_DFF_LATCH_SEL [236] | → DFF/LATCH_SEL [0] |
| LUT3_0_DFF2_OUT_POL [237] | → DFF_OUT_POL [0] |
| LUT3_0_DFF2_INIT_POL [238] | → DFF_INIT_POL [0] |
| LUT3_0_DFF2_RSTSET_SEL [239] | → DFF_RST/SET_SEL [0] |
| LUT3_0_DFF2_RSTSET_LEVEL [240] | → DFF_RST_POL [0] |
| LUT3_0_TRUTH [243:236] | → LUT_TRUTH [7:0] (for LUT function selected) |

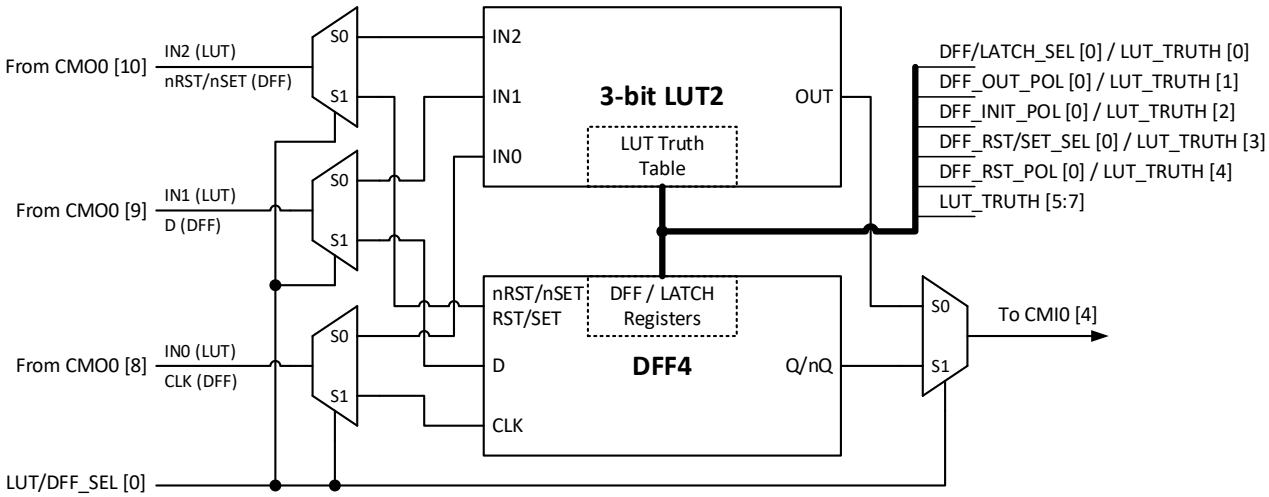
**Figure 17. 3-bit LUT0 or DFF2**




Registers abbreviations:

| | |
|---|---|
| LUT3_1_DFF3_LUT_DFF_SEL [322] | → LUT/DFF_SEL [0] |
| LUT3_1_DFF3_DFF_LATCH_SEL [244] | → DFF/LATCH_SEL [0] |
| LUT3_1_DFF3_OUT_POL [245] | → DFF_OUT_POL [0] |
| LUT3_1_DFF3_INIT_POL [246] | → DFF_INIT_POL [0] |
| LUT3_1_DFF3_RSTSET_SEL [247] | → DFF_RST/SET_SEL [0] |
| LUT3_1_DFF3_RSTSET_LEVEL [248] | → DFF_RST_POL [0] |
| LUT3_1_TRUTH [251:244] | → LUT_TRUTH [7:0] (for LUT function selected) |

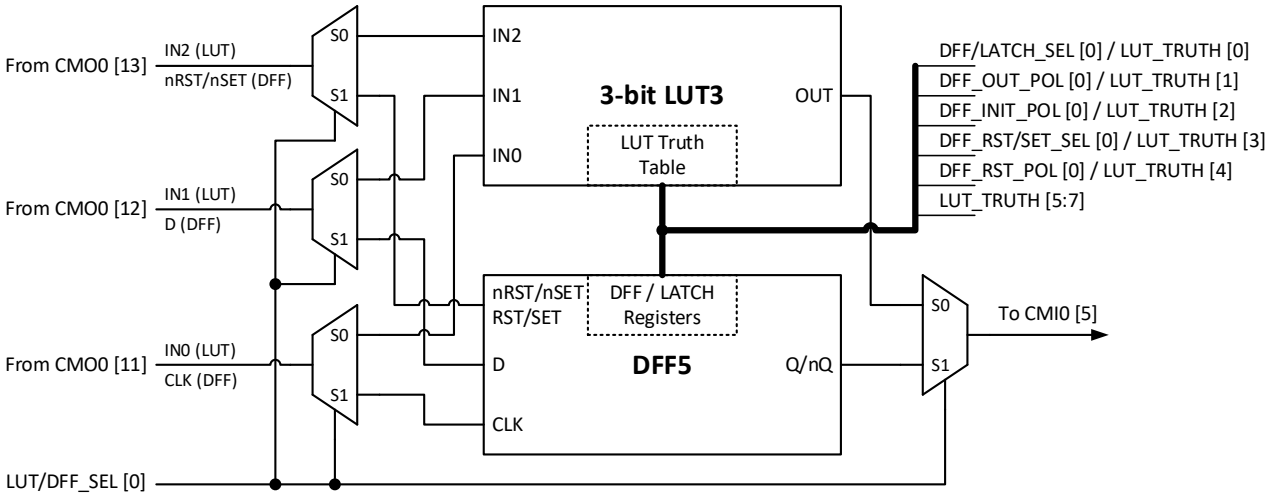
**Figure 18. 3-bit LUT1 or DFF3**




Registers abbreviations:

| | |
|---|---|
| LUT3_2_DFF4_LUT_DFF_SEL [323] | → LUT/DFF_SEL [0] |
| LUT3_2_DFF4_DFF_LATCH_SEL [252] | → DFF/LATCH_SEL [0] |
| LUT3_2_DFF4_OUT_POL [253] | → DFF_OUT_POL [0] |
| LUT3_2_DFF4_INIT_POL [254] | → DFF_INIT_POL [0] |
| LUT3_2_DFF4_RSTSET_SEL [255] | → DFF_RST/SET_SEL [0] |
| LUT3_2_DFF4_RSTSET_LEVEL [256] | → DFF_RST_POL [0] |
| LUT3_2_TRUTH [259:252] | → LUT_TRUTH [7:0] (for LUT function selected) |

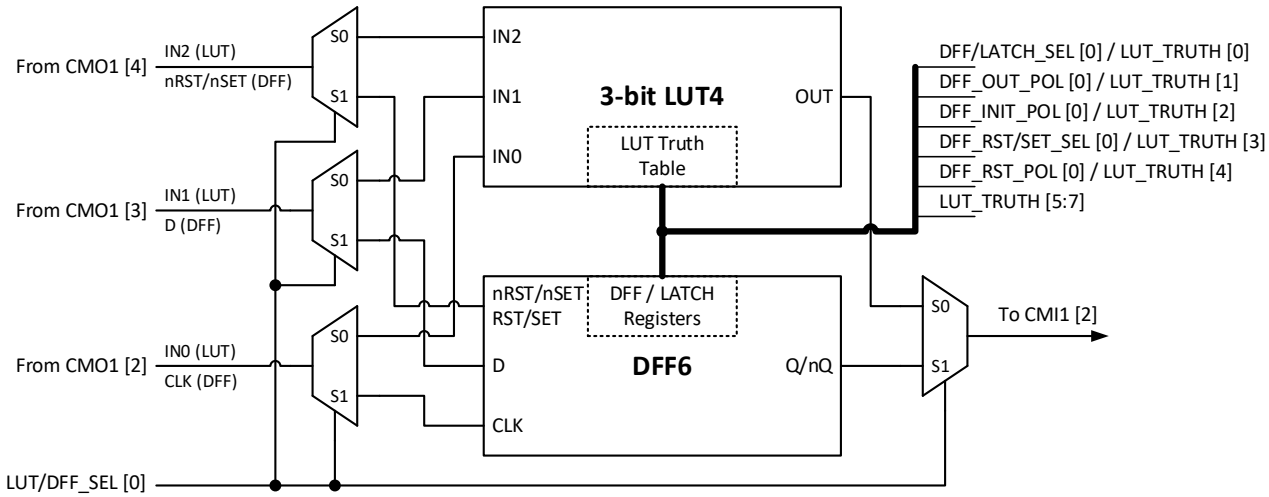
**Figure 19. 3-bit LUT2 or DFF4**




Registers abbreviations:

| | |
|---|---|
| LUT3_3_DFF5_LUT_DFF_SEL [324] | → LUT/DFF_SEL [0] |
| LUT3_3_DFF5_DFF_LATCH_SEL [260] | → DFF/LATCH_SEL [0] |
| LUT3_3_DFF5_OUT_POL [261] | → DFF_OUT_POL [0] |
| LUT3_3_DFF5_INIT_POL [262] | → DFF_INIT_POL [0] |
| LUT3_3_DFF5_RSTSET_SEL [263] | → DFF_RST/SET_SEL [0] |
| LUT3_3_DFF5_RSTSET_LEVEL [264] | → DFF_RST_POL [0] |
| LUT3_3_TRUTH [267:260] | → LUT_TRUTH [7:0] (for LUT function selected) |

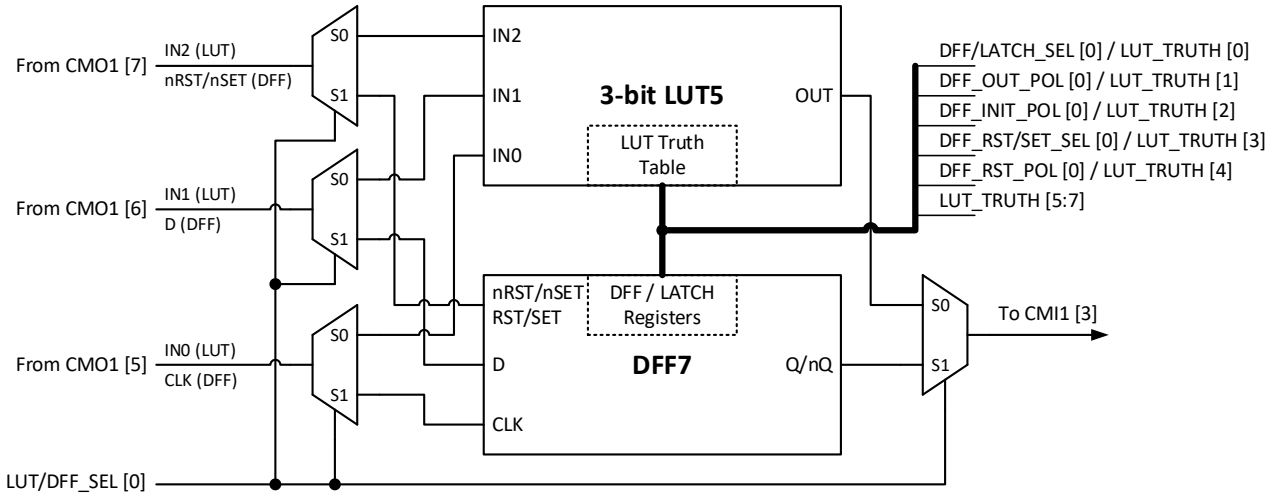
**Figure 20. 3-bit LUT3 or DFF5**




Registers abbreviations:

| | |
|---|---|
| LUT3_4_DFF6_LUT_DFF_SEL [1817] | → LUT/DFF_SEL [0] |
| LUT3_4_DFF6_DFF_LATCH_SEL [1700] | → DFF/LATCH_SEL [0] |
| LUT3_4_DFF6_OUT_POL [1701] | → DFF_OUT_POL [0] |
| LUT3_4_DFF6_INIT_POL [1702] | → DFF_INIT_POL [0] |
| LUT3_4_DFF6_RSTSET_SEL [1703] | → DFF_RST/SET_SEL [0] |
| LUT3_4_DFF6_RSTSET_LEVEL [1704] | → DFF_RST_POL [0] |
| LUT3_4_TRUTH [1707:1700] | → LUT_TRUTH [7:0] (for LUT function selected) |

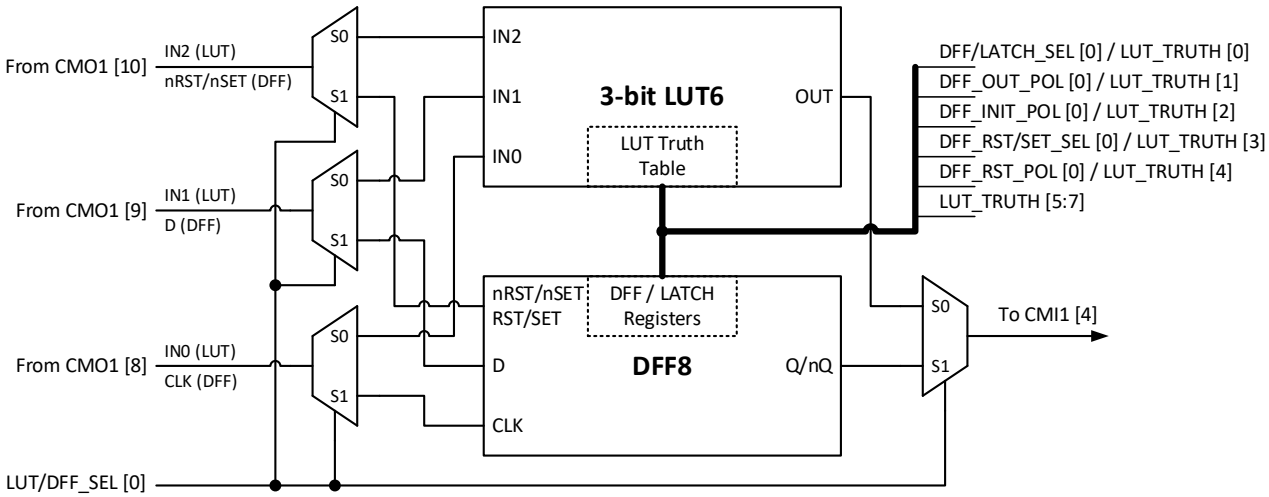
**Figure 21. 3-bit LUT4 or DFF6**




Registers abbreviations:

| | |
|---|---|
| LUT3_5_DFF7_LUT_DFF_SEL [1818] | → LUT/DFF_SEL [0] |
| LUT3_5_DFF7_DFF_LATCH_SEL [1708] | → DFF/LATCH_SEL [0] |
| LUT3_5_DFF7_OUT_POL [1709] | → DFF_OUT_POL [0] |
| LUT3_5_DFF7_INIT_POL [1710] | → DFF_INIT_POL [0] |
| LUT3_5_DFF7_RSTSET_SEL [1711] | → DFF_RST/SET_SEL [0] |
| LUT3_5_DFF7_RSTSET_LEVEL [1712] | → DFF_RST_POL [0] |
| LUT3_5_TRUTH [1715:1708] | → LUT_TRUTH [7:0] (for LUT function selected) |

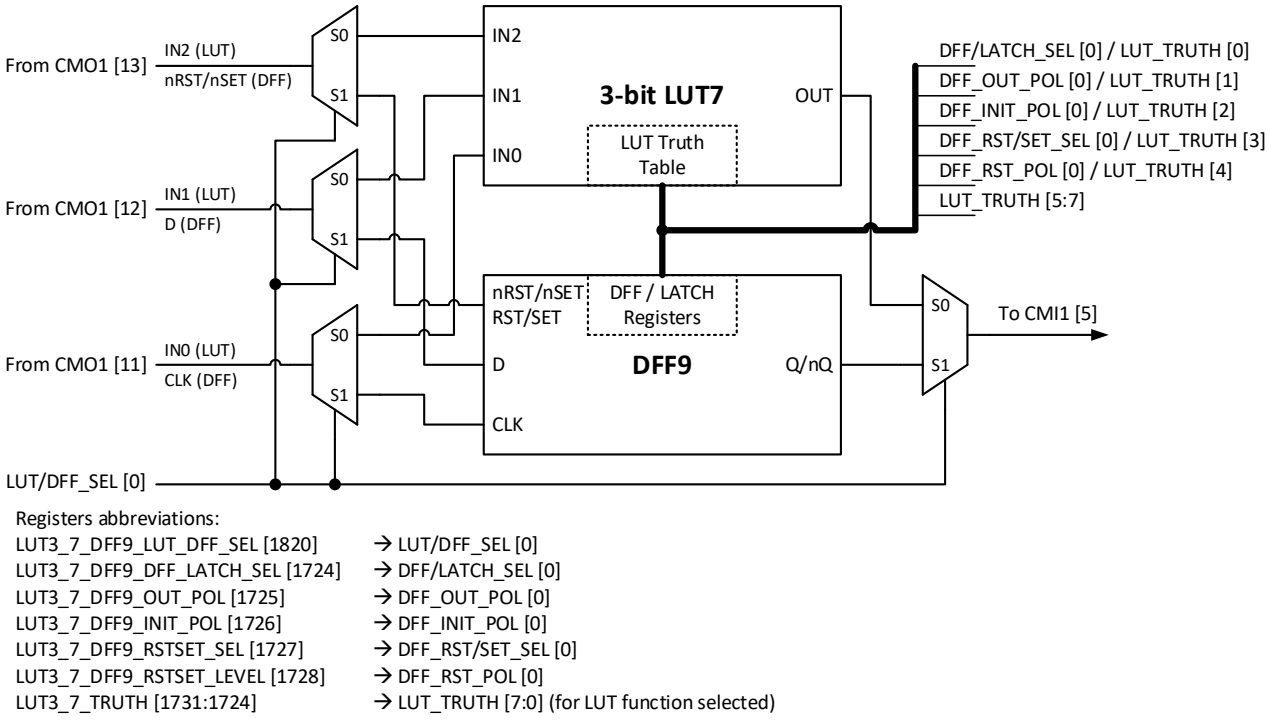
**Figure 22. 3-bit LUT5 or DFF7**




Registers abbreviations:

| | |
|---|---|
| LUT3_6_DFF8_LUT_DFF_SEL [1819] | → LUT/DFF_SEL [0] |
| LUT3_6_DFF8_DFF_LATCH_SEL [1716] | → DFF/LATCH_SEL [0] |
| LUT3_6_DFF8_OUT_POL [1717] | → DFF_OUT_POL [0] |
| LUT3_6_DFF8_INIT_POL [1718] | → DFF_INIT_POL [0] |
| LUT3_6_DFF8_RSTSET_SEL [1719] | → DFF_RST/SET_SEL [0] |
| LUT3_6_DFF8_RSTSET_LEVEL [1720] | → DFF_RST_POL [0] |
| LUT3_6_TRUTH [1723:1716] | → LUT_TRUTH [7:0] (for LUT function selected) |

**Figure 23. 3-bit LUT6 or DFF8**




Registers abbreviations:

| | |
|---|---|
| LUT3_7_DFF9_LUT_DFF_SEL [1820] | → LUT/DFF_SEL [0] |
| LUT3_7_DFF9_DFF_LATCH_SEL [1724] | → DFF/LATCH_SEL [0] |
| LUT3_7_DFF9_OUT_POL [1725] | → DFF_OUT_POL [0] |
| LUT3_7_DFF9_INIT_POL [1726] | → DFF_INIT_POL [0] |
| LUT3_7_DFF9_RSTSET_SEL [1727] | → DFF_RST/SET_SEL [0] |
| LUT3_7_DFF9_RSTSET_LEVEL [1728] | → DFF_RST_POL [0] |
| LUT3_7_TRUTH [1731:1724] | → LUT_TRUTH [7:0] (for LUT function selected) |

**Figure 24. 3-bit LUT7 or DFF9**

## 7.4 3-bit LUT or D Flip-Flop with Reset/Set or Shift Register Macrocells

There are six macrocells that can serve as 3-bit LUTs, DFFs/LATCH, or shift registers (SR). The user can select the functionality (LUT, DFF/LATCH, or SR) of the macrocell by writing to registers. LUTs of DFF/Shift Register are selected by registers LUT/DFF_SR_SEL. If the macrocell is configured as a LUT, it will take three input signals from the connection matrix outputs (CMOs) and produce a single output, which will connect back to the connection matrix input (CMI).

If DFF/LATCH function is selected, the three input signals from the connection matrix outputs will be connected to data (D), clock (CLK) and reset/set (nRST/nSET) inputs of the DFF/LATCH, and the output will connect back to the connection matrix input. The active function for the reset/set input is defined by register DFF_RST/SET_SEL. The user can select the polarity of the reset/set input of the DFF/LATCH macrocell. The register DFF_RST_POL selects either active-high (RST/SET) or active-low (nRST/nSET) options. The DFF/LATCH_SEL registers select either DFF or LATCH function. The operations of the DFF and LATCH functions are as follows:

- **DFF**: Q = D at a rising edge of CLK (edge-triggered), otherwise Q retains its previous value.
- **LATCH**: Q = D when CLK is low (level-triggered), otherwise Q retains its previous value.

The user can also define the active level, Q or nQ, for the macrocell output by using the register OUT_POL.

If the macrocell is configured as a SR, the three input signals from the connection matrix outputs will be connected to the data (D), the clock (CLK) and the reset/set (nRST/nSET) inputs of the SR and its output will be fed back to the connection matrix input.

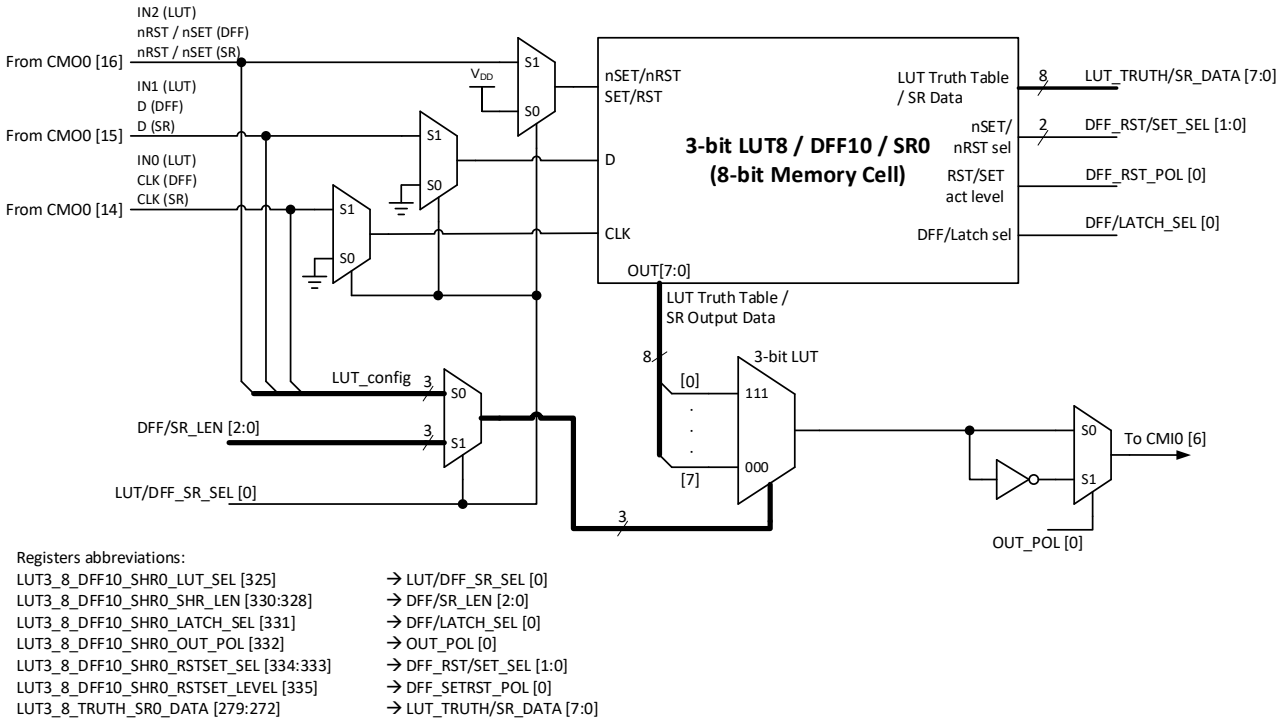
The user may select one of three options for the nSET/nRST input by registers DFF_RST/SET_SEL:

- Set the Shift Register to all ones (1).
- Set the Shift Register to the default value defined by the user.
- Reset the Shift Register to all zeros (0).

The user can select the polarity of the reset/set input of the SR macrocell by using the register DFF_RST_POL.

The input data (D) is written to the Shift Register input (starting from the LSB), and the length of the SR (up to 8 bits per memory cell) is selected by the DFF/SR_LEN [2:0] register. If the length of the SR is one, it will function as a DFF/LATCH.

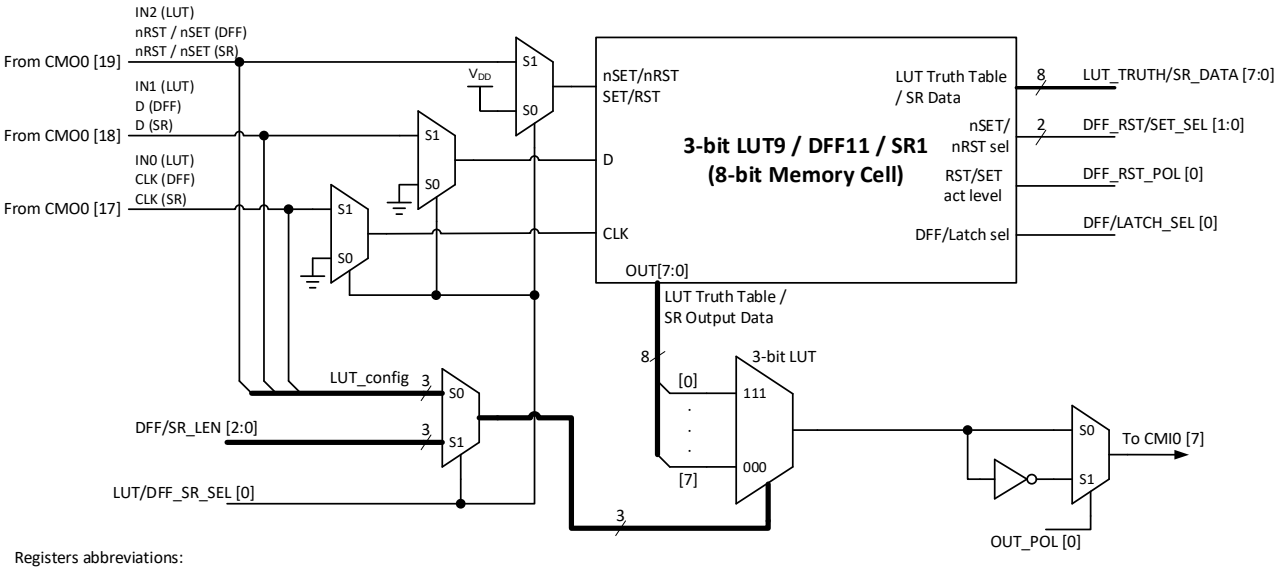
The Shift Registers can be read or written through the I²C/SPI interface. Note that the data (D) and the clock (CLK) inputs must remain unchanged while the I²C/SPI master is reading data from the Shift Register. Otherwise, the I²C/SPI master can read the wrong data. Signals at D and CLK inputs of the Shift Register will be ignored while I²C/SPI master is writing new data to the Shift Register macrocell. Also, note that the reset input of the Shift Register has higher priority to the Shift Register than the I²C/SPI write routine.




Registers abbreviations:

| | |
|---|---|
| LUT3_8_DFF10_SHR0_LUT_SEL [325] | → LUT/DFF_SR_SEL [0] |
| LUT3_8_DFF10_SHR0_SHR_LEN [330:328] | → DFF/SR_LEN [2:0] |
| LUT3_8_DFF10_SHR0_LATCH_SEL [331] | → DFF/LATCH_SEL [0] |
| LUT3_8_DFF10_SHR0_OUT_POL [332] | → OUT_POL [0] |
| LUT3_8_DFF10_SHR0_RSTSET_SEL [334:333] | → DFF_RST/SET_SEL [1:0] |
| LUT3_8_DFF10_SHR0_RSTSET_LEVEL [335] | → DFF_SETRST_POL [0] |
| LUT3_8_TRUTH_SR0_DATA [279:272] | → LUT_TRUTH/SR_DATA [7:0] |

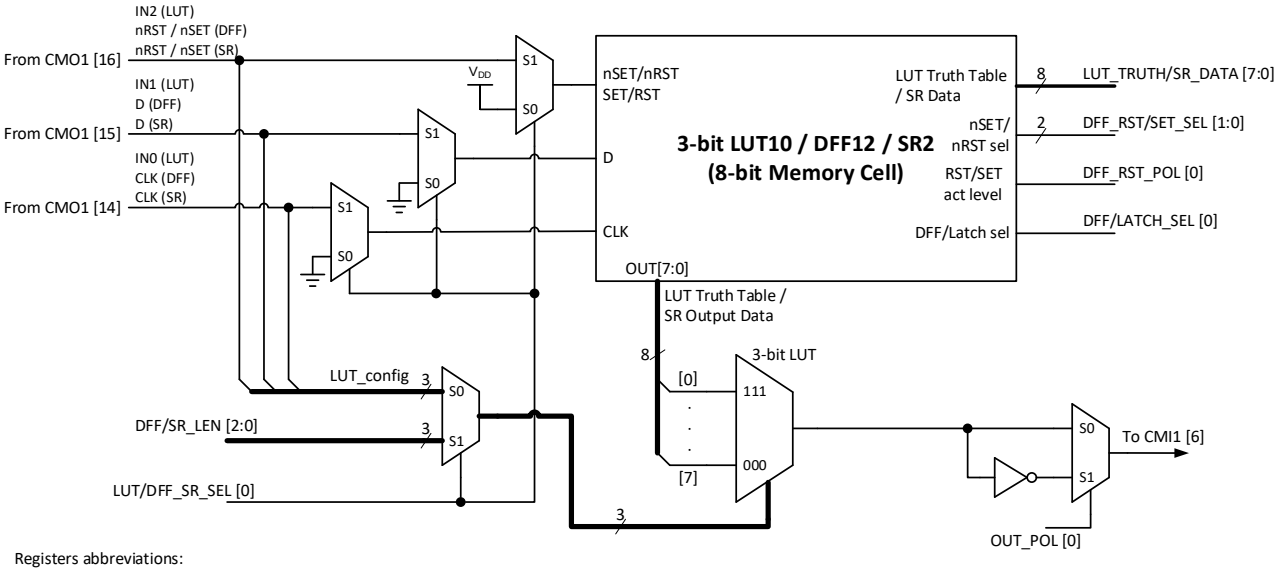
**Figure 25. 3-bit LUT8 or DFF10, or SR0**




Registers abbreviations:

| | |
|---|---|
| LUT3_9_DFF11_SHR1_LUT_SEL [336] | → LUT/DFF_SR_SEL [0] |
| LUT3_9_DFF11_SHR1_SHR_LEN [339:337] | → DFF/SR_LEN [2:0] |
| LUT3_9_DFF11_SHR1_LATCH_SEL [340] | → DFF/LATCH_SEL [0] |
| LUT3_9_DFF11_SHR1_OUT_POL [341] | → OUT_POL [0] |
| LUT3_9_DFF11_SHR1_RSTSET_SEL [343:342] | → DFF_RST/SET_SEL [1:0] |
| LUT3_9_DFF11_SHR1_RSTSET_LEVEL [344] | → DFF_SETRST_POL [0] |
| LUT3_9_TRUTH_SR1_DATA [295:288] | → LUT_TRUTH/SR_DATA [7:0] |

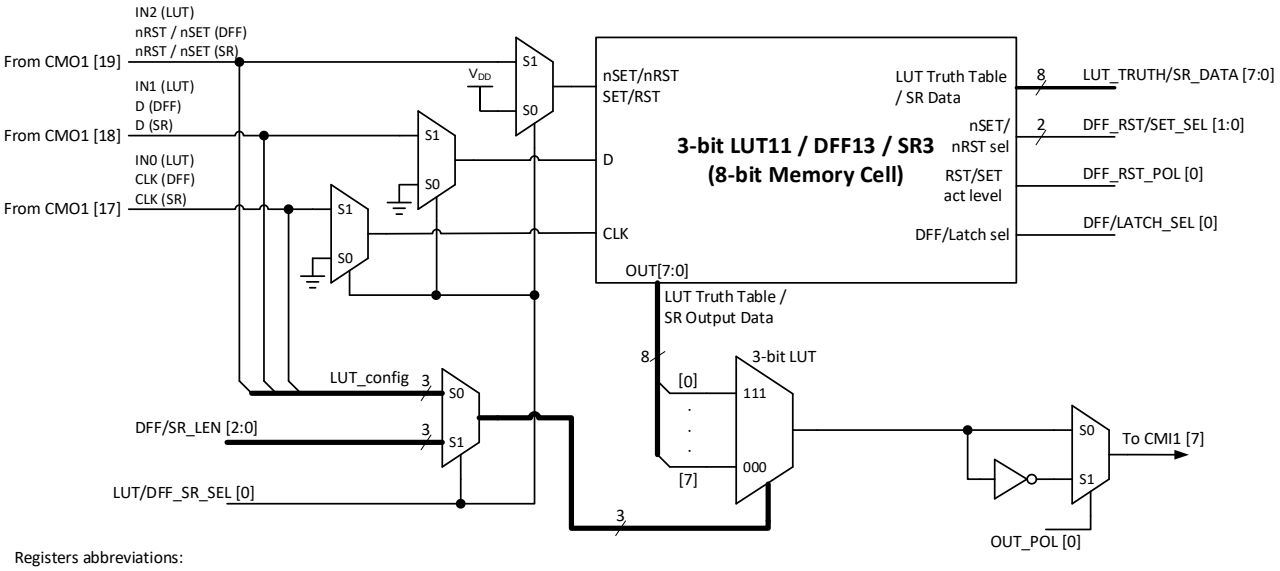
**Figure 26. 3-bit LUT9 or DFF11, or SR1**




Registers abbreviations:

| | |
|---|---|
| LUT3_10_DFF12_SHR2_LUT_SEL [1821] | → LUT/DFF_SR_SEL [0] |
| LUT3_10_DFF12_SHR2_SHR_LEN [1826:1824] | → DFF/SR_LEN [2:0] |
| LUT3_10_DFF12_SHR2_LATCH_SEL [1827] | → DFF/LATCH_SEL [0] |
| LUT3_10_DFF12_SHR2_OUT_POL [1828] | → OUT_POL [0] |
| LUT3_10_DFF12_SHR2_RSTSET_SEL [1830:1829] | → DFF_RST/SET_SEL [1:0] |
| LUT3_10_DFF12_SHR2_RSTSET_LEVEL [1831] | → DFF_SETRST_POL [0] |
| LUT3_10_TRUTH_SR1_DATA [1743:1736] | → LUT_TRUTH/SR_DATA [7:0] |

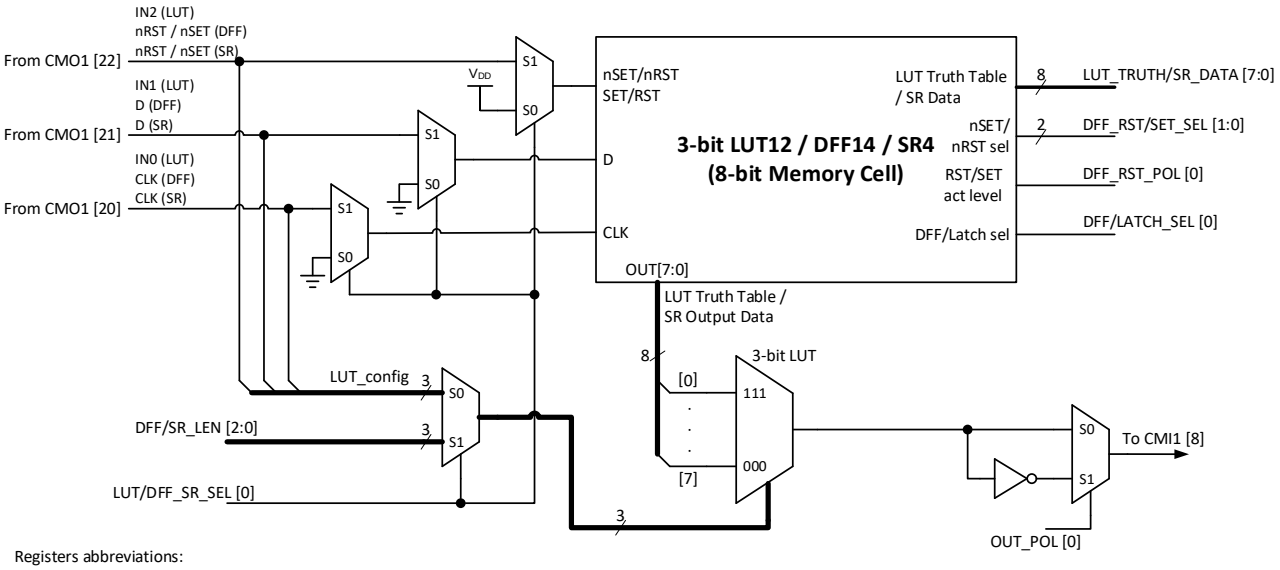
**Figure 27. 3-bit LUT10 or DFF12, or SR2**




Registers abbreviations:

| | |
|---|---|
| LUT3_11_DFF13_SHR3_LUT_SEL [1832] | → LUT/DFF_SR_SEL [0] |
| LUT3_11_DFF13_SHR3_SHR_LEN [1835:1833] | → DFF/SR_LEN [2:0] |
| LUT3_11_DFF13_SHR3_LATCH_SEL [1836] | → DFF/LATCH_SEL [0] |
| LUT3_11_DFF13_SHR3_OUT_POL [1837] | → OUT_POL [0] |
| LUT3_11_DFF13_SHR3_RSTSET_SEL [1839:1838] | → DFF_RST/SET_SEL [1:0] |
| LUT3_11_DFF13_SHR3_RSTSET_LEVEL [1840] | → DFF_SETRST_POL [0] |
| LUT3_11_TRUTH_SR3_DATA [1759:1752] | → LUT_TRUTH/SR_DATA [7:0] |

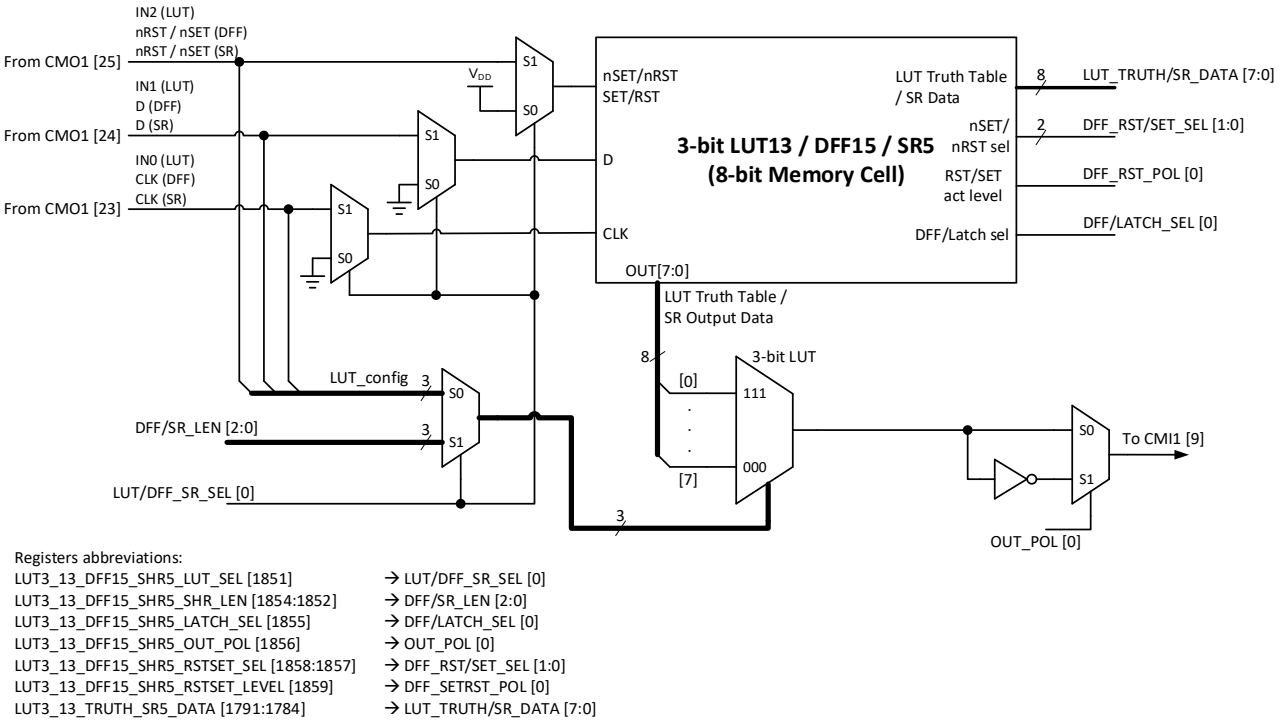
**Figure 28. 3-bit LUT11 or DFF13, or SR3**




Registers abbreviations:

| | |
|---|---|
| LUT3_12_DFF14_SHR4_LUT_SEL [1841] | → LUT/DFF_SR_SEL [0] |
| LUT3_12_DFF14_SHR4_SHR_LEN [1844:1842] | → DFF/SR_LEN [2:0] |
| LUT3_12_DFF14_SHR4_LATCH_SEL [1845] | → DFF/LATCH_SEL [0] |
| LUT3_12_DFF14_SHR4_OUT_POL [1846] | → OUT_POL [0] |
| LUT3_12_DFF14_SHR4_RSTSET_SEL [1849:1848] | → DFF_RST/SET_SEL [1:0] |
| LUT3_12_DFF14_SHR4_RSTSET_LEVEL [1850] | → DFF_SETRST_POL [0] |
| LUT3_12_TRUTH_SR4_DATA [1775:1768] | → LUT_TRUTH/SR_DATA [7:0] |

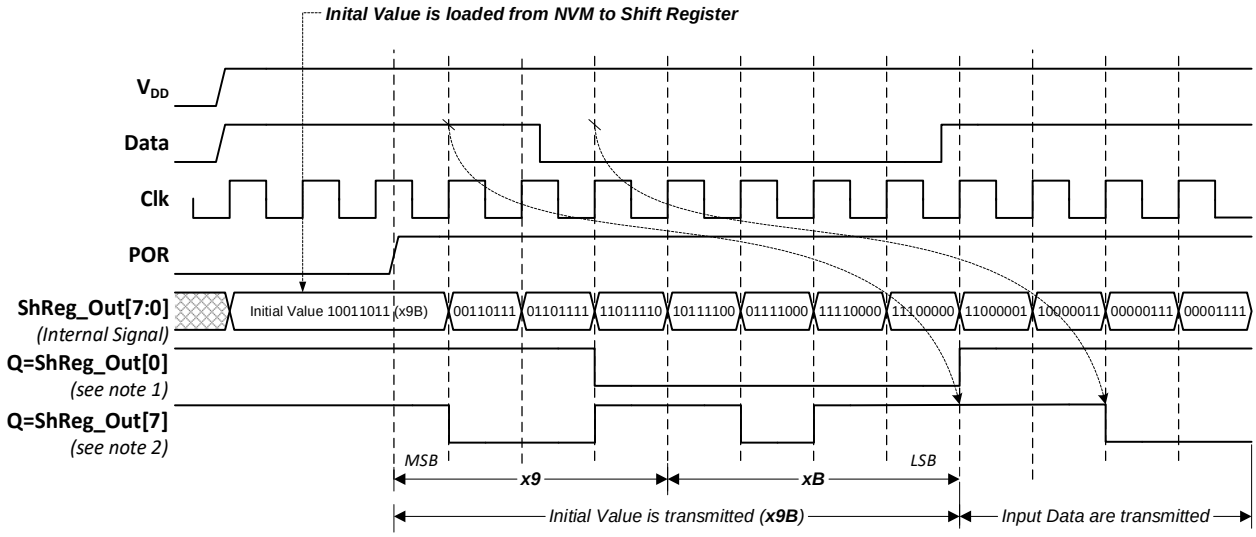
**Figure 29. 3-bit LUT12 or DFF14, or SR4**




Registers abbreviations:

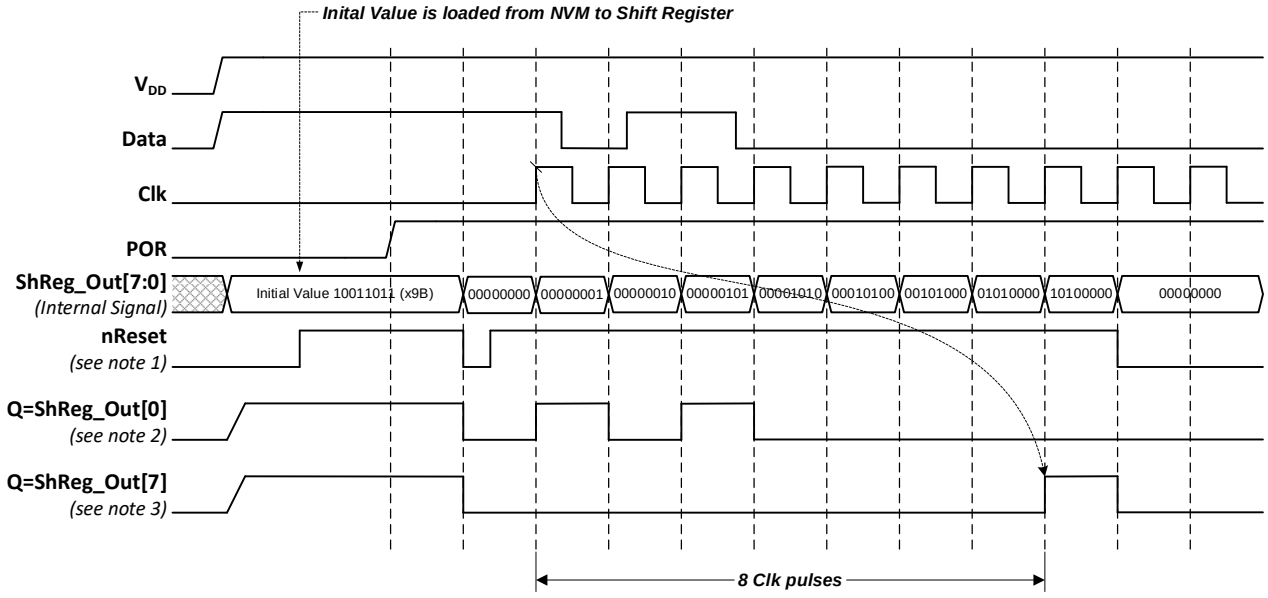
| | |
|---|---|
| LUT3_13_DFF15_SHR5_LUT_SEL [1851] | → LUT/DFF_SR_SEL [0] |
| LUT3_13_DFF15_SHR5_SHR_LEN [1854:1852] | → DFF/SR_LEN [2:0] |
| LUT3_13_DFF15_SHR5_LATCH_SEL [1855] | → DFF/LATCH_SEL [0] |
| LUT3_13_DFF15_SHR5_OUT_POL [1856] | → OUT_POL [0] |
| LUT3_13_DFF15_SHR5_RSTSET_SEL [1858:1857] | → DFF_RST/SET_SEL [1:0] |
| LUT3_13_DFF15_SHR5_RSTSET_LEVEL [1859] | → DFF_SETRST_POL [0] |
| LUT3_13_TRUTH_SR5_DATA [1791:1784] | → LUT_TRUTH/SR_DATA [7:0] |

**Figure 30. 3-bit LUT13 or DFF15, or SR5**



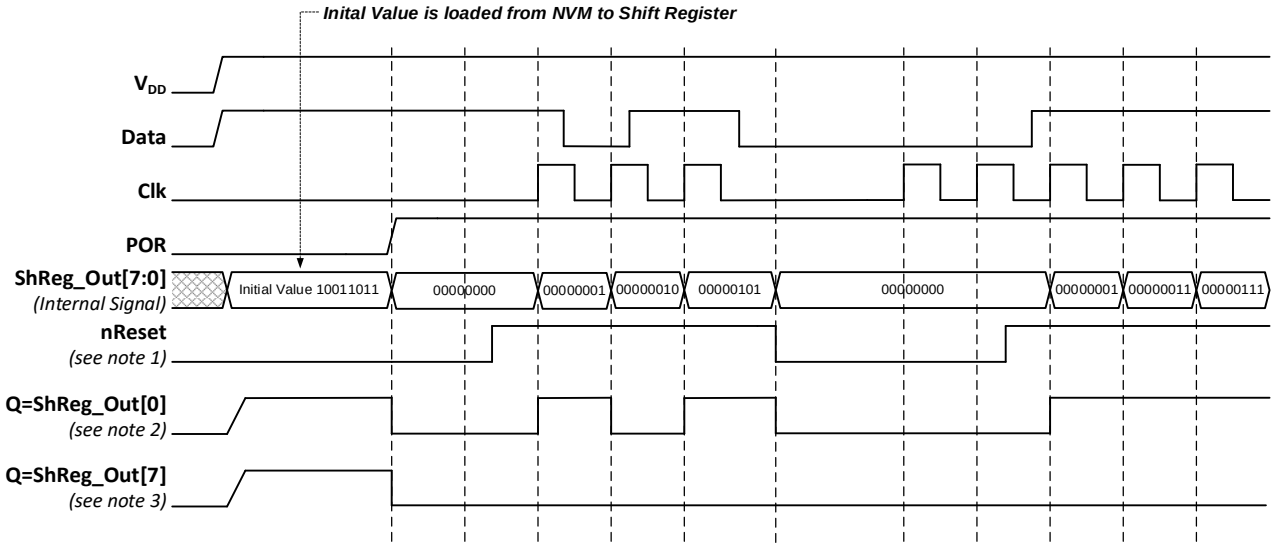

**Note 1:** Macrocell is configured as DFF.
**Note 2:** Macrocell is configured as 8-bit Shift Register.

**Figure 31. DFF10 to DFF15 or SR0 to SR5 Operation**



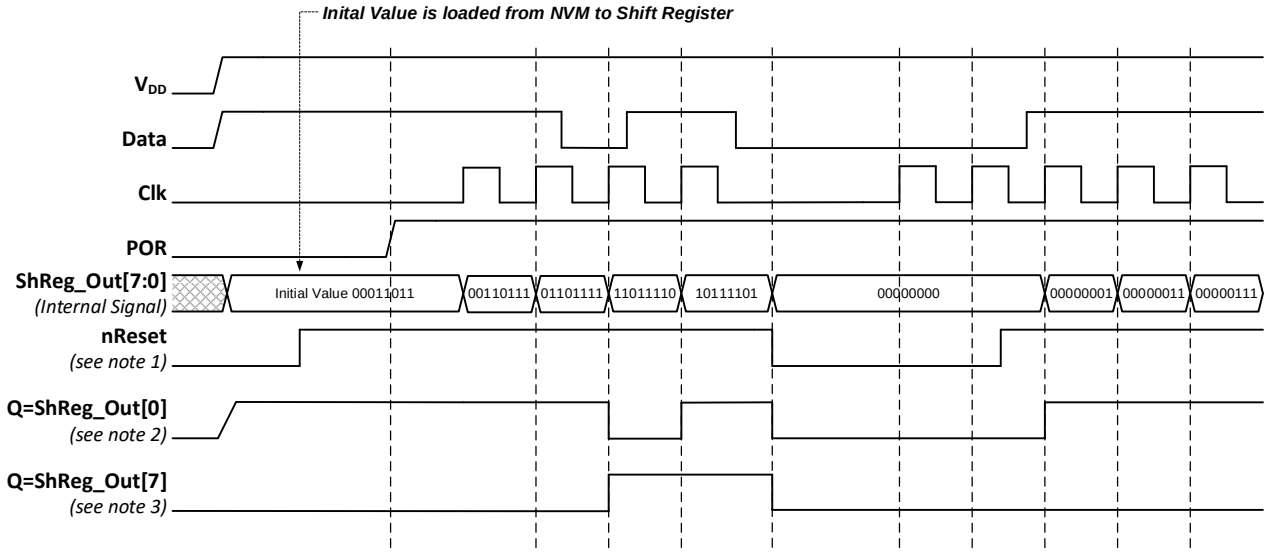

**Note 1:** DFF Setting "Initial Value = 1".
**Note 2:** Macrocell is configured as DFF.
**Note 3:** Macrocell is configured as 8-bits.

**Figure 32. DFF10 to DFF15 or SR0 to SR5 Operation, nRST Option**



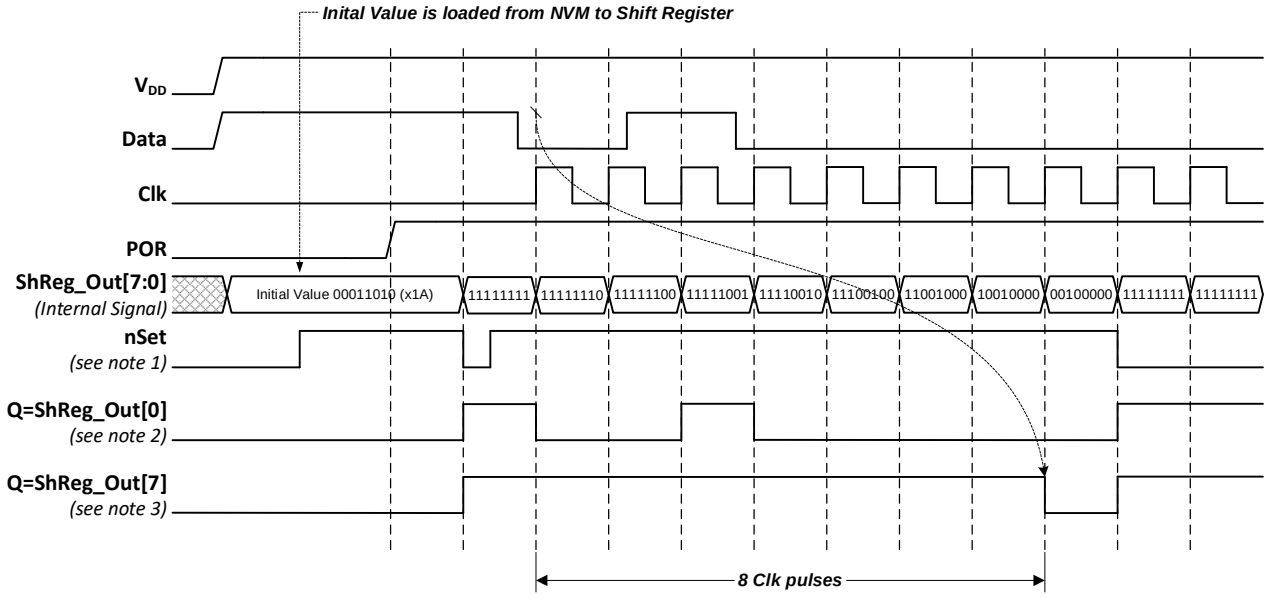

**Note 1:** DFF Setting "Initial Value = 1".
**Note 2:** Macrocell is configured as DFF.
**Note 3:** Macrocell is configured as 8-bits.

**Figure 33. DFF10 to DFF15 or SR0 to SR5 Operation, nRST Option, Case 1**



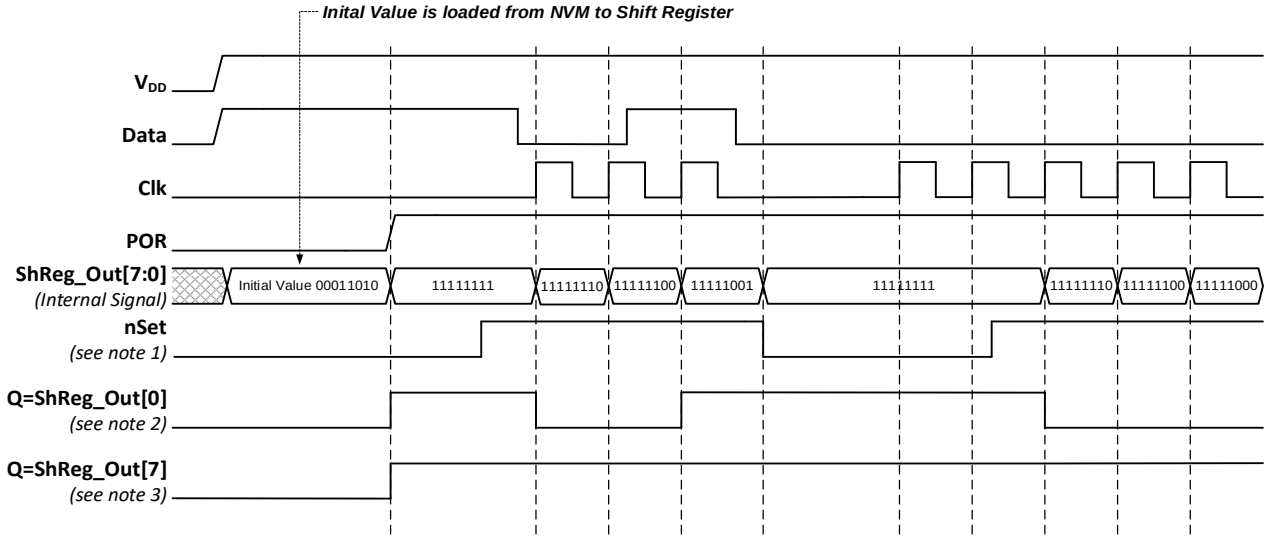

**Note 1:** DFF Setting "Initial Value = 1".
**Note 2:** Macrocell is configured as DFF.
**Note 3:** Macrocell is configured as 8-bits.

**Figure 34. DFF10 to DFF15 or SR0 to SR5 Operation, nRST Option, Case 2**



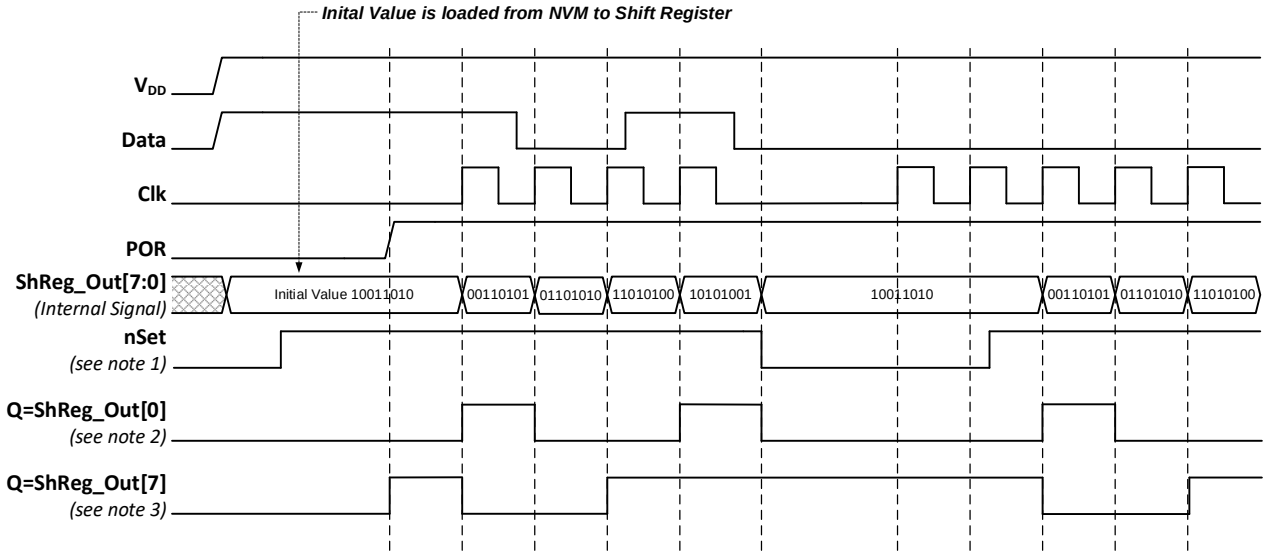

**Note 1:** DFF Setting "Initial Value = 0".
**Note 2:** Macrocell is configured as DFF.
**Note 3:** Macrocell is configured as 8-bits.

**Figure 35. DFF10 to DFF15 or SR0 to SR5 Operation, nSET to All '1' Option**




**Note 1:** DFF Setting “Initial Value = 0”.
**Note 2:** Macrocell is configured as DFF.
**Note 3:** Macrocell is configured as 8-bits.

**Figure 36. DFF10 to DFF15 or SR0 to SR5 Operation, nSET to All ‘1’ Option, Case 1**




**Note 1:** DFF Setting “Initial Value = 0”.
**Note 2:** Macrocell is configured as DFF.
**Note 3:** Macrocell is configured as 8-bits.

**Figure 37. DFF10 to DFF15 or SR0 to SR5 Operation, nSET to Default Value Option, Case 2**

## 7.4.1. 3-bit LUT or D Flip-Flop Macrocells Used as 3-bit LUTs

Each macrocell operating as LUT uses an 8-bit register to define its output function:

- 3-bit LUT3_0 is defined by Reg[243:236]
- 3-bit LUT3_1 is defined by Reg[251:244]
- 3-bit LUT3_2 is defined by Reg[259:252]
- 3-bit LUT3_3 is defined by Reg[267:260]
- 3-bit LUT3_4 is defined by Reg[1707:1700]
- 3-bit LUT3_5 is defined by Reg[1715:1708]

- 3-bit LUT3_6 is defined by Reg[1723:1716]
- 3-bit LUT3_7 is defined by Reg[1731:1724]
- 3-bit LUT3_8 is defined by Reg[279:272]
- 3-bit LUT3_9 is defined by Reg[295:288]
- 3-bit LUT3_10 is defined by Reg[1743:1736]
- 3-bit LUT3_11 is defined by Reg[1759:1752]
- 3-bit LUT3_12 is defined by Reg[1775:1768]
- 3-bit LUT3_13 is defined by Reg[1791:1784].

**Table 13. 3-bit LUT3_0 to 3-bit LUT3_13 Truth Table**

| IN2 | IN1 | IN0 | OUT LUT3_0 | OUT LUT3_1 | OUT LUT3_2 | OUT LUT3_3 | OUT LUT3_4 | OUT LUT3_5 | OUT LUT3_6 | OUT LUT3_7 | OUT LUT3_8 | OUT LUT3_9 | OUT LUT3_10 | OUT LUT3_11 | OUT LUT3_12 | OUT LUT3_13 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | Reg [236] | Reg [244] | Reg [252] | Reg [260] | Reg [1700] | Reg [1708] | Reg [1716] | Reg [1724] | Reg [272] | Reg [288] | Reg [1736] | Reg [1752] | Reg [1768] | Reg [1784] | LSB |
| 0 | 0 | 1 | Reg [237] | Reg [245] | Reg [253] | Reg [261] | Reg [1701] | Reg [1709] | Reg [1717] | Reg [1725] | Reg [273] | Reg [289] | Reg [1737] | Reg [1753] | Reg [1769] | Reg [1785] | |
| 0 | 1 | 0 | Reg [238] | Reg [246] | Reg [254] | Reg [262] | Reg [1702] | Reg [1710] | Reg [1718] | Reg [1726] | Reg [274] | Reg [290] | Reg [1738] | Reg [1754] | Reg [1770] | Reg [1786] | |
| 0 | 1 | 1 | Reg [239] | Reg [247] | Reg [255] | Reg [263] | Reg [1703] | Reg [1711] | Reg [1719] | Reg [1727] | Reg [275] | Reg [291] | Reg [1739] | Reg [1755] | Reg [1771] | Reg [1787] | |
| 1 | 0 | 0 | Reg [240] | Reg [248] | Reg [256] | Reg [264] | Reg [1704] | Reg [1712] | Reg [1720] | Reg [1728] | Reg [276] | Reg [292] | Reg [1740] | Reg [1756] | Reg [1772] | Reg [1788] | |
| 1 | 0 | 1 | Reg [241] | Reg [249] | Reg [257] | Reg [265] | Reg [1705] | Reg [1713] | Reg [1721] | Reg [1729] | Reg [277] | Reg [293] | Reg [1741] | Reg [1757] | Reg [1773] | Reg [1789] | |
| 1 | 1 | 0 | Reg [242] | Reg [250] | Reg [258] | Reg [266] | Reg [1706] | Reg [1714] | Reg [1722] | Reg [1730] | Reg [278] | Reg [294] | Reg [1742] | Reg [1758] | Reg [1774] | Reg [1790] | |
| 1 | 1 | 1 | Reg [243] | Reg [251] | Reg [259] | Reg [267] | Reg [1707] | Reg [1715] | Reg [1723] | Reg [1731] | Reg [279] | Reg [295] | Reg [1743] | Reg [1759] | Reg [1775] | Reg [1791] | MSB |

Table 14 shows the register bits for standard digital logic functions: AND, NAND, OR, NOR, XOR, XNOR, that can be utilized within each of the fourteen 3-bit LUT logic cells.

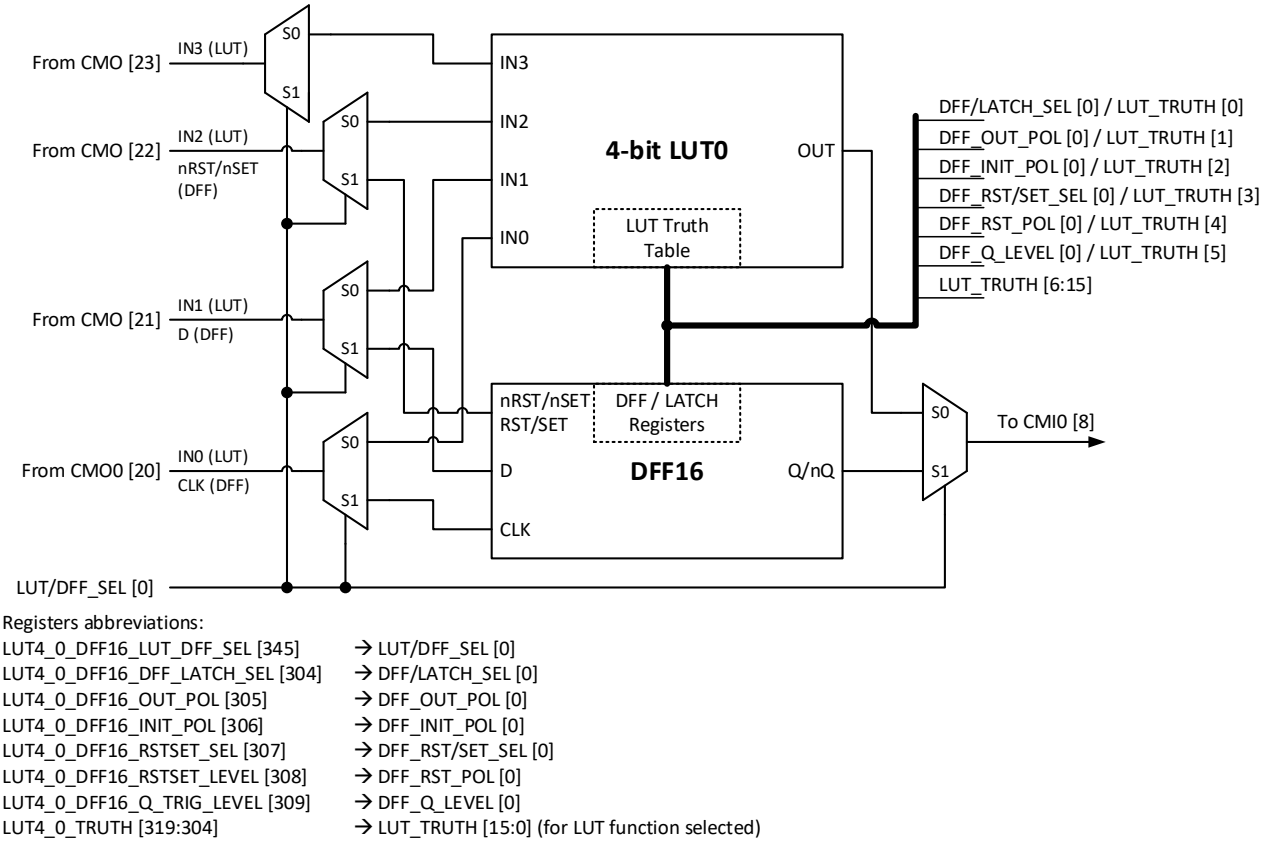
**Table 14. 3-bit LUT Standard Digital Functions**

| Function | MSB | | | | | | | LSB |
|---|---|---|---|---|---|---|---|---|
| AND-3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NAND-3 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| OR-3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| NOR-3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| XOR-3 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 |
| XNOR-3 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |

## 7.5 4-BIT LUT or D Flip-Flop with Reset/Set Macrocell

There are two macrocells that can function as either a 4-bit LUT or a DFF/LATCH with reset/set input. The 4-bit LUT takes four input signals from the connection matrix outputs (CMOs) and generates a single output, which connects back to the connection matrix input (CMI). For the DFF/LATCH function, the input signals from the connection matrix outputs are connected to data (D), clock (CLK), and reset/set (nRST/nSET) inputs, and the output connects back to the connection matrix input. The user can select the polarity of the reset/set input of DFF/LATCH macrocell. The DFFx_RST_POL bit selects either active-high (RST/SET) or active-low (nRST/nSET) options. The DFF/LATCH_SEL bit selects either DFF or LATCH function. The operations of the DFF and LATCH functions are described below:

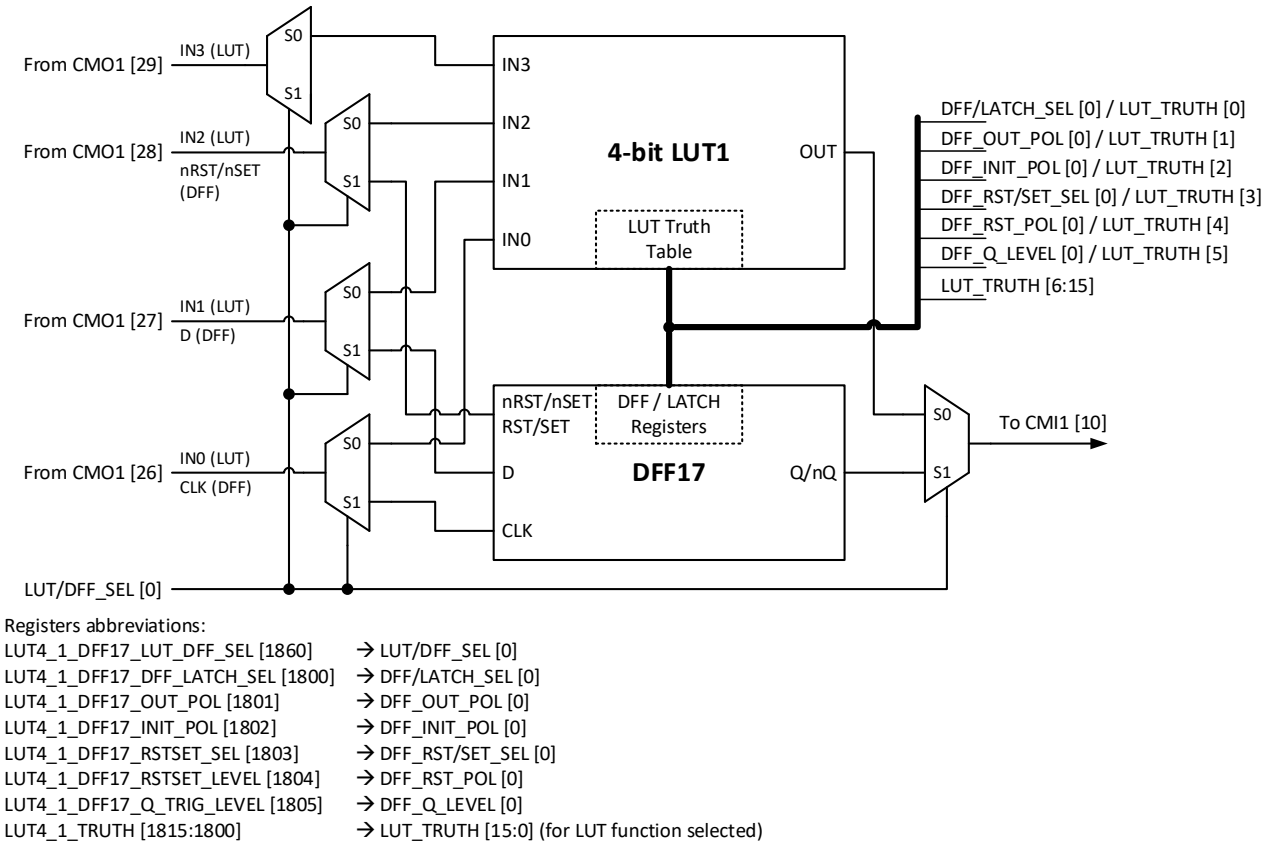
- **DFF**: Q = D at a rising edge of the CLK (edge-triggered), otherwise Q retains its previous value.
- **LATCH**: Q = D when CLK is low (level-triggered), otherwise Q retains its previous value.




Registers abbreviations:

| | |
|---|---|
| LUT4_0_DFF16_LUT_DFF_SEL [345] | → LUT/DFF_SEL [0] |
| LUT4_0_DFF16_DFF_LATCH_SEL [304] | → DFF/LATCH_SEL [0] |
| LUT4_0_DFF16_OUT_POL [305] | → DFF_OUT_POL [0] |
| LUT4_0_DFF16_INIT_POL [306] | → DFF_INIT_POL [0] |
| LUT4_0_DFF16_RSTSET_SEL [307] | → DFF_RST/SET_SEL [0] |
| LUT4_0_DFF16_RSTSET_LEVEL [308] | → DFF_RST_POL [0] |
| LUT4_0_DFF16_Q_TRIG_LEVEL [309] | → DFF_Q_LEVEL [0] |
| LUT4_0_TRUTH [319:304] | → LUT_TRUTH [15:0] (for LUT function selected) |

**Figure 38. 4-bit LUT0 or DFF16**




Registers abbreviations:

| | |
|---|---|
| LUT4_1_DFF17_LUT_DFF_SEL [1860] | → LUT/DFF_SEL [0] |
| LUT4_1_DFF17_DFF_LATCH_SEL [1800] | → DFF/LATCH_SEL [0] |
| LUT4_1_DFF17_OUT_POL [1801] | → DFF_OUT_POL [0] |
| LUT4_1_DFF17_INIT_POL [1802] | → DFF_INIT_POL [0] |
| LUT4_1_DFF17_RSTSET_SEL [1803] | → DFF_RST/SET_SEL [0] |
| LUT4_1_DFF17_RSTSET_LEVEL [1804] | → DFF_RST_POL [0] |
| LUT4_1_DFF17_Q_TRIG_LEVEL [1805] | → DFF_Q_LEVEL [0] |
| LUT4_1_TRUTH [1815:1800] | → LUT_TRUTH [15:0] (for LUT function selected) |

**Figure 39. 4-bit LUT1 or DFF17**

## 7.5.1. 4-bit LUT Macrocell Used as 4-bit LUT

This macrocell uses a 16-bit register to define the output function:

- 4-bit LUT0 is defined by Reg[319:304]
- 4-bit LUT1 is defined by Reg[1815:1800].

**Table 15. 4-bit LUT0 Truth Table**

| IN3 | IN2 | IN1 | IN0 | 4-bit LUT0 OUT | 4-bit LUT1 OUT | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | Reg[304] | Reg[1800] | LSB |
| 0 | 0 | 0 | 1 | Reg[305] | Reg[1801] | |
| 0 | 0 | 1 | 0 | Reg[306] | Reg[1802] | |
| 0 | 0 | 1 | 1 | Reg[307] | Reg[1803] | |
| 0 | 1 | 0 | 0 | Reg[308] | Reg[1804] | |
| 0 | 1 | 0 | 1 | Reg[309] | Reg[1805] | |
| 0 | 1 | 1 | 0 | Reg[310] | Reg[1806] | |
| 0 | 1 | 1 | 1 | Reg[311] | Reg[1807] | |
| 1 | 0 | 0 | 0 | Reg[312] | Reg[1808] | |
| 1 | 0 | 0 | 1 | Reg[313] | Reg[1809] | |

| IN3 | IN2 | IN1 | IN0 | 4-bit LUT0 OUT | 4-bit LUT1 OUT | |
|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | Reg[314] | Reg[1810] | |
| 1 | 0 | 1 | 1 | Reg[315] | Reg[1811] | |
| 1 | 1 | 0 | 0 | Reg[316] | Reg[1812] | |
| 1 | 1 | 0 | 1 | Reg[317] | Reg[1813] | |
| 1 | 1 | 1 | 0 | Reg[318] | Reg[1814] | |
| 1 | 1 | 1 | 1 | Reg[319] | Reg[1815] | MSB |

**Table 16. 4-bit LUT Standard Digital Functions**

| Function | MSB | | | | | | | | | | | | | | | LSB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AND-4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NAND-4 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| OR-4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| NOR-4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| XOR-4 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 |
| XNOR-4 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |

# 8. Multi-Function Macrocells

The SLG47011 features fourteen multi-function macrocells that can perform various logic or timing functions. Each multi-function macrocell can operate as a LUT, a DFF with flexible settings, or a counter/delay with multiple modes such as delay, reset counter, one-shot, frequency detection, edge detection, delayed edge detection. The multi-function macrocell is also capable of combining the LUT/DFF with the CNT/DLY function in a serial fashion, as shown in Figure 40.

See the list below for the functions that can be implemented in these macrocells:

- Ten macrocells that can function as 3-bit LUTs/DFFs and as 12-bit counter/delays.
- Two macrocells that can function as 4-bit LUTs/DFFs and as 16-bit counter/delays/FSM.
- One macrosell that can function as 3-bit LUT/DFF and as 12-bit counter/delay/FSM.
- One macrocell that can function as a 12-bit Up/Down Counter.

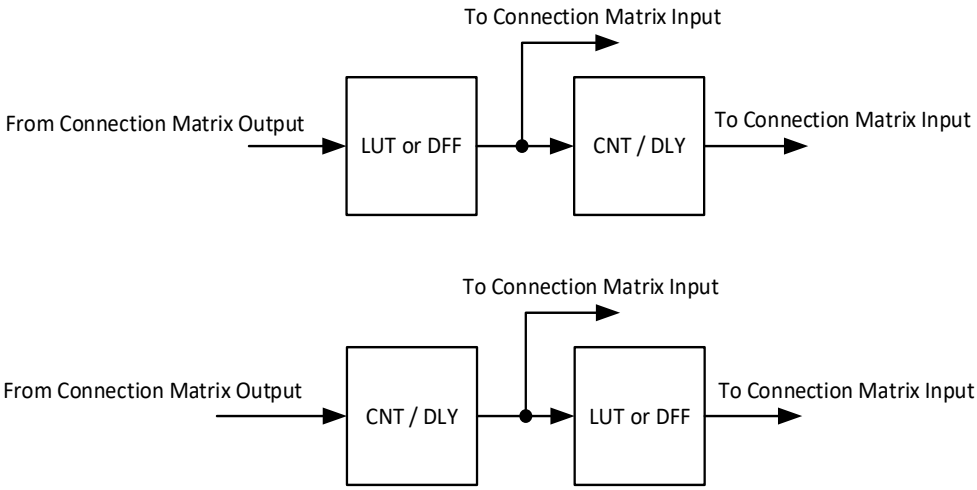



**Figure 40. Possible Connections Inside Multi-Function Macrocell**

The IOs of the multi-function macrocells are configured from the connection matrix with specific logic functions being defined by the state of the NVM bits.

If the LUT function is selected, the outputs of the LUTs can be configured to any user-defined function, including the following standard digital logic functions: AND, NAND, OR, NOR, XOR, XNOR, buffer, inverter.

## 8.1 3-BIT LUT or DFF/LATCH with Counter/Delay Macrocells

The SLG47011 features eleven macrocells that can function as 3-bit LUTs/DFFs and as 12-bit counter/delays.

If the LUT function is selected, the 3-bit LUTs take three input signals from the connection matrix outputs (CMOs) and produce a single output, which connects back to the connection matrix input (CMI) or can be connected to the input of CNT/DLY.

If the DFF function is selected, the three input signals from the connection matrix outputs are connected to data (D), clock (CLK), and reset/set (nRST/nSET) inputs, and the output connects back to the connection matrix input or to the input of CNT/DLY.

If the Counter/Delay function is selected, each macrocell has a dedicated matrix input connection. Each macrocell can be driven by a variety of internal and external clock sources. The user has also an option to use the output of the previous (N-1) CNT/DLY macrocell as a clock input, to implement larger/longer count/delay circuits. Counter end output signal can be routed to the next counter clock input, that can be used as a counter chain with twice as many bits as a single counter. All counters can be chained together.

These macrocells can also operate in a one-shot mode that generates an output pulse of user-defined width. They can also operate in a frequency detection or an edge detection mode.

All possible multi-function macrocell configurations (3-BIT LUT or DFF/LATCH with 12-bit CNT/DLY) and corresponding matrix outputs functions are shown in Table 17.

**Table 17. 3-BIT LUT or DFF/LATCH with Counter/Delay Macrocells Configuration**

| Function | LUT_DFF_SEL | MF_INT_CONN[1] | MF_INT_CONN[1] | MULTI_FUNC_SEL[1] | MULTI_FUNC_SEL[0] | In2 | In1 | In0 | D | nRST/nSET | CLK | DLY_IN | EXT_CLK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Single 3-bit LUT | 0 | 0 | 0 | 0 | 0 | Matrix A | Matrix B | Matrix C | 0 | 0 | 0 | 0 | 0 |
| Single DFF with RST and SET | 1 | 0 | 0 | 0 | 0 | Matrix A | Matrix B | Matrix C | Matrix A | Matrix B | Matrix C | 0 | 0 |
| Single CNT/DLY | 0 | 0 | 0 | 0 | 1 | DLY_OUT | DLY_OUT | DLY_OUT | 0 | 0 | 0 | Matrix A | Matrix B |
| CNT/DLY → LUT | 0 | 0 | 0 | 1 | 0 | DLY_OUT | Matrix B | Matrix C | 0 | 0 | 0 | Matrix A | 0 |
| | 0 | 0 | 1 | 1 | 0 | Matrix A | DLY_OUT | Matrix C | 0 | 0 | 0 | Matrix B | 0 |
| | 0 | 1 | 0 | 1 | 0 | Matrix A | Matrix B | DLY_OUT | 0 | 0 | 0 | Matrix C | 0 |
| CNT/DLY → DFF | 1 | 0 | 0 | 1 | 0 | DLY_OUT | Matrix B | Matrix C | DLY_OUT | Matrix B | Matrix C | Matrix A | 0 |
| | 1 | 0 | 1 | 1 | 0 | Matrix A | DLY_OUT | Matrix C | Matrix A | DLY_OUT | Matrix C | Matrix B | 0 |
| | 1 | 1 | 0 | 1 | 0 | Matrix A | Matrix B | DLY_OUT | Matrix A | Matrix B | DLY_OUT | Matrix C | 0 |
| LUT → CNT/DLY | 0 | 0 | 0 | 1 | 1 | Matrix A | Matrix B | Matrix C | 0 | 0 | 0 | LUT_OUT | 0 |
| DFF → CNT/DLY | 1 | 0 | 0 | 1 | 1 | Matrix A | Matrix B | Matrix C | Matrix A | Matrix B | Matrix C | DFF_OUT | 0 |

Each counter/delay macrocell is initialized with a default value, which is set during the power-up. It is possible to select either initial LOW or initial HIGH as the initial value defined by a Delay macrocell Input signal. For example, if the initial LOW option is used, the rising edge delay will start operation.

For timing diagrams refer to sections 7.1 2-bit LUT or D Flip-Flop Macrocells and 8.2 CNT/DLY Timing Diagrams.

**Note:** After two DFFs – counters initialize with counter data = 0 after POR.

- Initial state = 1 – counters initialize with counter data = 0 after POR.
- Initial state = 0 and after two DFFs are bypassed – counters initialize with counter data after POR.

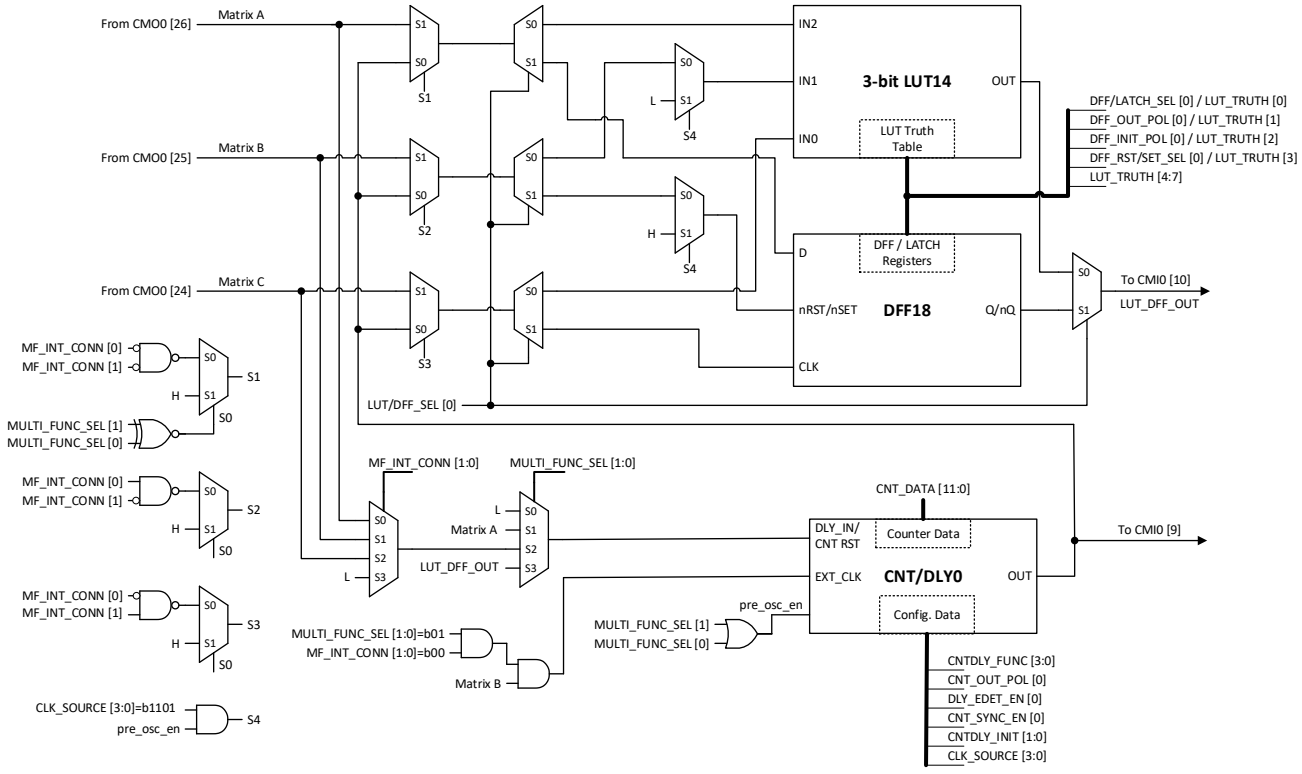
**Note:** If the counter's Rising Edge Reset option is used, it is recommended: 1) to use the "After two DFFs" setting for CNT mode synchronization; 2) spread the CNT clock and the Reset signals over time.

The user can read the counter states of 16-bit CNT11, 16-bit CNT12, and the 12-bit Memory Control Counter via $I^2C$/SPI. The user can also write any counter data using $I^2C$/SPI write commands. In counter/delay mode, it is possible to load the count data immediately (after two DFFs) or after the counter finishes counting. See section 25 Host Interface for further details.

The 12-bit CNT/DLY10/FSM2 macrocell can operate as a Pulse Width Modulation (PWM) period counter when the PWM macrocell is enabled. The counting direction of the 12-bit CNT/DLY10 macrocell in PWM mode is:

- from CNT Data to 0 if register PWM_CNT_UP [3157] = 0
- from 0 to CNT Data if register PWM_CNT_UP [3157] = 1.

The user can dynamically change the Counter data (CNT data) of the 12-bit CNT/DLY9 macrocell using the Memory Control Counter.

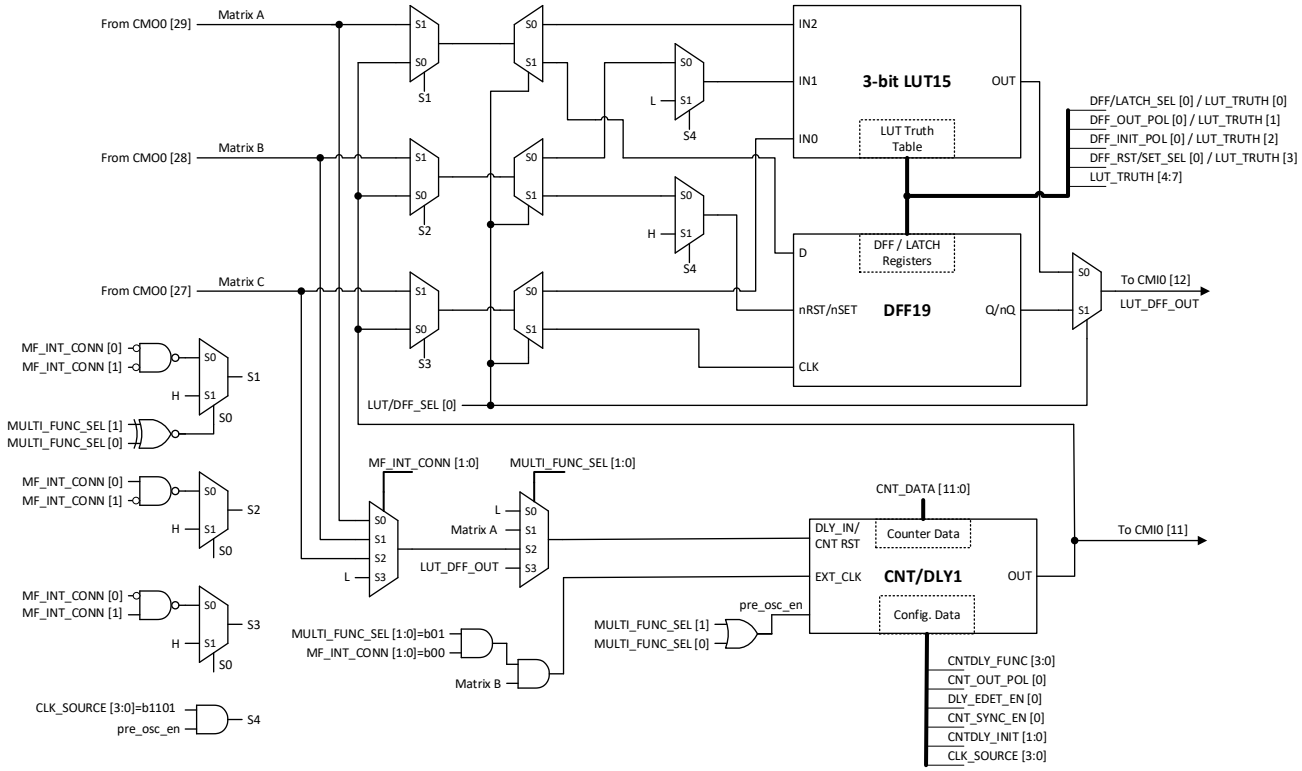



**Note:** H – High logic level; L – Low logic level.

Registers abbreviations:

| | | | |
|---|---|---|---|
| LUT3_14_DFF18_CNTDLY0_MF_SEL [369:368] | → MULTI_FUNC_SEL [1:0] | LUT3_14_DFF18_CNTDLY0_LUT_DFF_SEL [364] | → LUT/DFF_SEL [0] |
| LUT3_14_DFF18_CNTDLY0_INT_CONN [371:370] | → MF_INT_CONN [1:0] | LUT3_14_DFF18_CNTDLY0_DFF_LATCH_SEL [352] | → DFF/LATCH_SEL [0] |
| LUT3_14_DFF18_CNTDLY0_CLK_SEL [379:376] | → CLK_SOURCE [3:0] | LUT3_14_DFF18_CNTDLY0_DFF_OUT_POL [353] | → DFF_OUT_POL [0] |
| LUT3_14_DFF18_CNTDLY0_CNTDLY_FUNC [363:360] | → CNTDLY_FUNC [3:0] | LUT3_14_DFF18_CNTDLY0_INIT_POL [354] | → DFF_INIT_POL [0] |
| LUT3_14_DFF18_CNTDLY0_CNT_OUT_POL [365] | → CNT_OUT_POL [0] | LUT3_14_DFF18_CNTDLY0_RSTSET_SEL [355] | → DFF_RST/SET_SEL [0] |
| LUT3_14_DFF18_CNTDLY0_DLY_EDET_EN [366] | → DLY_EDET_EN [0] | LUT3_14_TRUTH [359:352] | → LUT_TRUTH [7:0] (for LUT function selected) |
| LUT3_14_DFF18_CNTDLY0_CNT_SYNC_EN [367] | → CNT_SYNC_EN [0] | | |
| LUT3_14_DFF18_CNTDLY0_CNTDLY_INIT [373:372] | → CNTDLY_INIT [1:0] | | |
| LUT3_14_DFF18_CNTDLY0_CNT_DATA [383:380, 391:384] | → CNT_DATA [11:0] | | |

**Figure 41. 12-bit Multi-Function Macrocells Block Diagram (3-bit LUT14/DFF18, CNT/DLY0)**

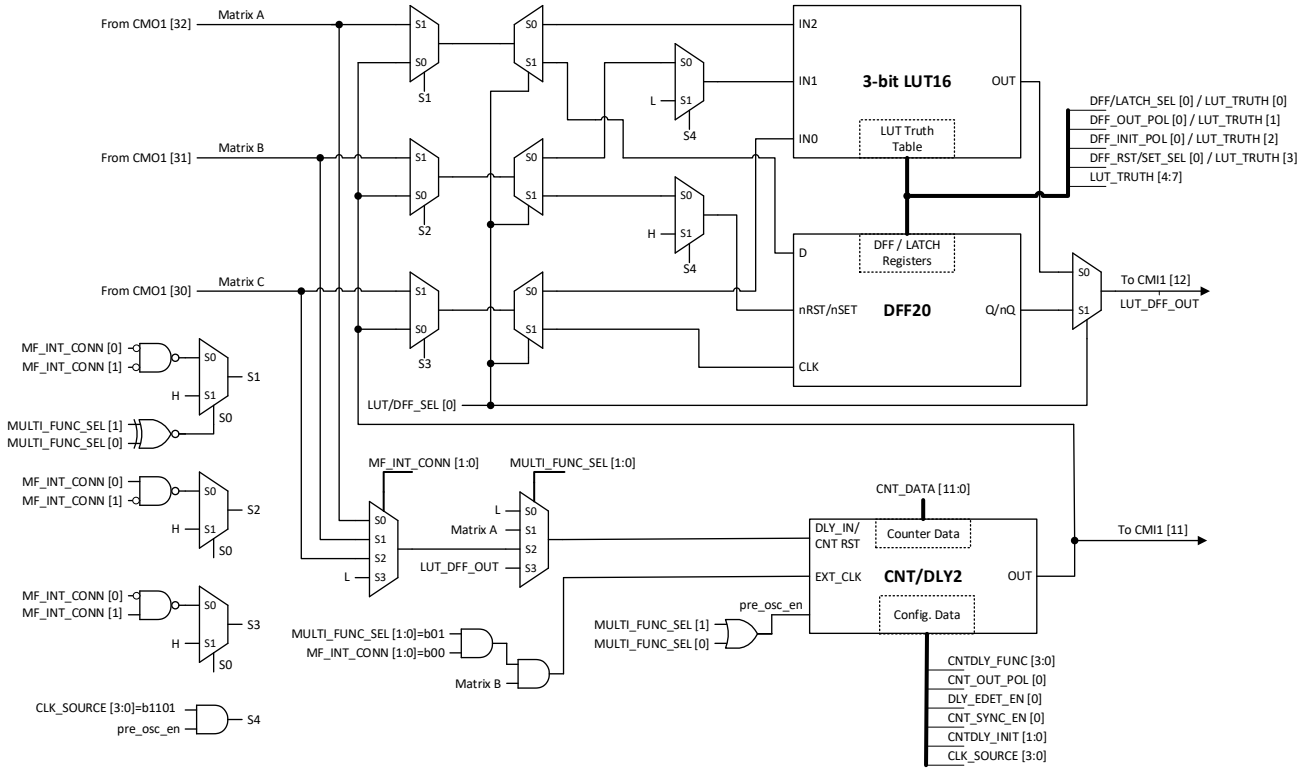



**Note:** H – High logic level; L – Low logic level.

Registers abbreviations:

| | |
|---|---|
| LUT3_15_DFF19_CNTDLY1_MF_SEL [425:424] | → MULTI_FUNC_SEL [1:0] |
| LUT3_15_DFF19_CNTDLY1_INT_CONN [427:426] | → MF_INT_CONN [1:0] |
| LUT3_15_DFF19_CNTDLY1_CLK_SEL [435:432] | → CLK_SOURCE [3:0] |
| LUT3_15_DFF19_CNTDLY1_CNTDLY_FUNC [419:416] | → CNTDLY_FUNC [3:0] |
| LUT3_15_DFF19_CNTDLY1_CNT_OUT_POL [421] | → CNT_OUT_POL [0] |
| LUT3_15_DFF19_CNTDLY1_DLY_EDET_EN [422] | → DLY_EDET_EN [0] |
| LUT3_15_DFF19_CNTDLY1_CNT_SYNC_EN [423] | → CNT_SYNC_EN [0] |
| LUT3_15_DFF19_CNTDLY1_CNTDLY_INIT [429:428] | → CNTDLY_INIT [1:0] |
| LUT3_15_DFF19_CNTDLY1_CNT_DATA [439:436, 447:440] | → CNT_DATA [11:0] |
| LUT3_15_DFF19_CNTDLY1_LUT_DFF_SEL [420] | → LUT/DFF_SEL [0] |
| LUT3_15_DFF19_CNTDLY1_DFF_LATCH_SEL [408] | → DFF/LATCH_SEL [0] |
| LUT3_15_DFF19_CNTDLY1_DFF_OUT_POL [409] | → DFF_OUT_POL [0] |
| LUT3_15_DFF19_CNTDLY1_INIT_POL [410] | → DFF_INIT_POL [0] |
| LUT3_15_DFF19_CNTDLY1_RSTSET_SEL [411] | → DFF_RST/SET_SEL [0] |
| LUT3_15_TRUTH [415:408] | → LUT_TRUTH [7:0] (for LUT function selected) |

**Figure 42. 12-bit Multi-Function Macrocells Block Diagram (3-bit LUT15/DFF19, CNT/DLY1)**

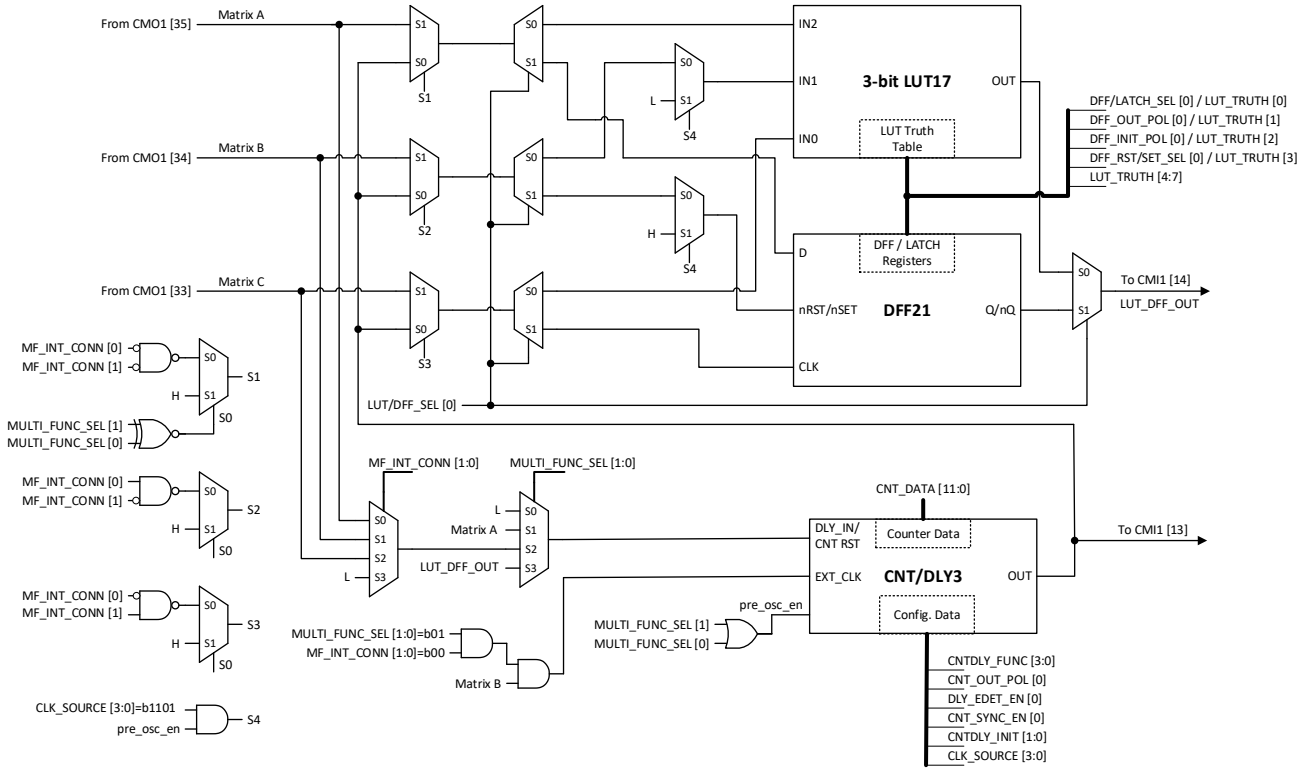



**Note:** H – High logic level; L – Low logic level.

Registers abbreviations:

| | | | |
|---|---|---|---|
| LUT3_16_DFF20_CNTDLY2_MF_SEL [1881:1880] | → MULTI_FUNC_SEL [1:0] | LUT3_16_DFF20_CNTDLY2_LUT_DFF_SEL [1876] | → LUT/DFF_SEL [0] |
| LUT3_16_DFF20_CNTDLY2_INT_CONN [1883:1882] | → MF_INT_CONN [1:0] | LUT3_16_DFF20_CNTDLY2_DFF_LATCH_SEL [1864] | → DFF/LATCH_SEL [0] |
| LUT3_16_DFF20_CNTDLY2_CLK_SEL [1891:1888] | → CLK_SOURCE [3:0] | LUT3_16_DFF20_CNTDLY2_DFF_OUT_POL [1865] | → DFF_OUT_POL [0] |
| LUT3_16_DFF20_CNTDLY2_CNTDLY_FUNC [1875:1872] | → CNTDLY_FUNC [3:0] | LUT3_16_DFF20_CNTDLY2_INIT_POL [1866] | → DFF_INIT_POL [0] |
| LUT3_16_DFF20_CNTDLY2_CNT_OUT_POL [1877] | → CNT_OUT_POL [0] | LUT3_16_DFF20_CNTDLY2_RSTSET_SEL [1867] | → DFF_RST/SET_SEL [0] |
| LUT3_16_DFF20_CNTDLY2_DLY_EDET_EN [1878] | → DLY_EDET_EN [0] | LUT3_16_TRUTH [1871:1864] | → LUT_TRUTH [7:0] (for LUT function selected) |
| LUT3_16_DFF20_CNTDLY2_CNT_SYNC_EN [1879] | → CNT_SYNC_EN [0] | | |
| LUT3_16_DFF20_CNTDLY2_CNTDLY_INIT [1885:1884] | → CNTDLY_INIT [1:0] | | |
| LUT3_16_DFF20_CNTDLY2_CNT_DATA [1895:1892, 1903:1896] | → CNT_DATA [11:0] | | |

**Figure 43. 12-bit Multi-Function Macrocells Block Diagram (3-bit LUT16/DFF20, CNT/DLY2)**

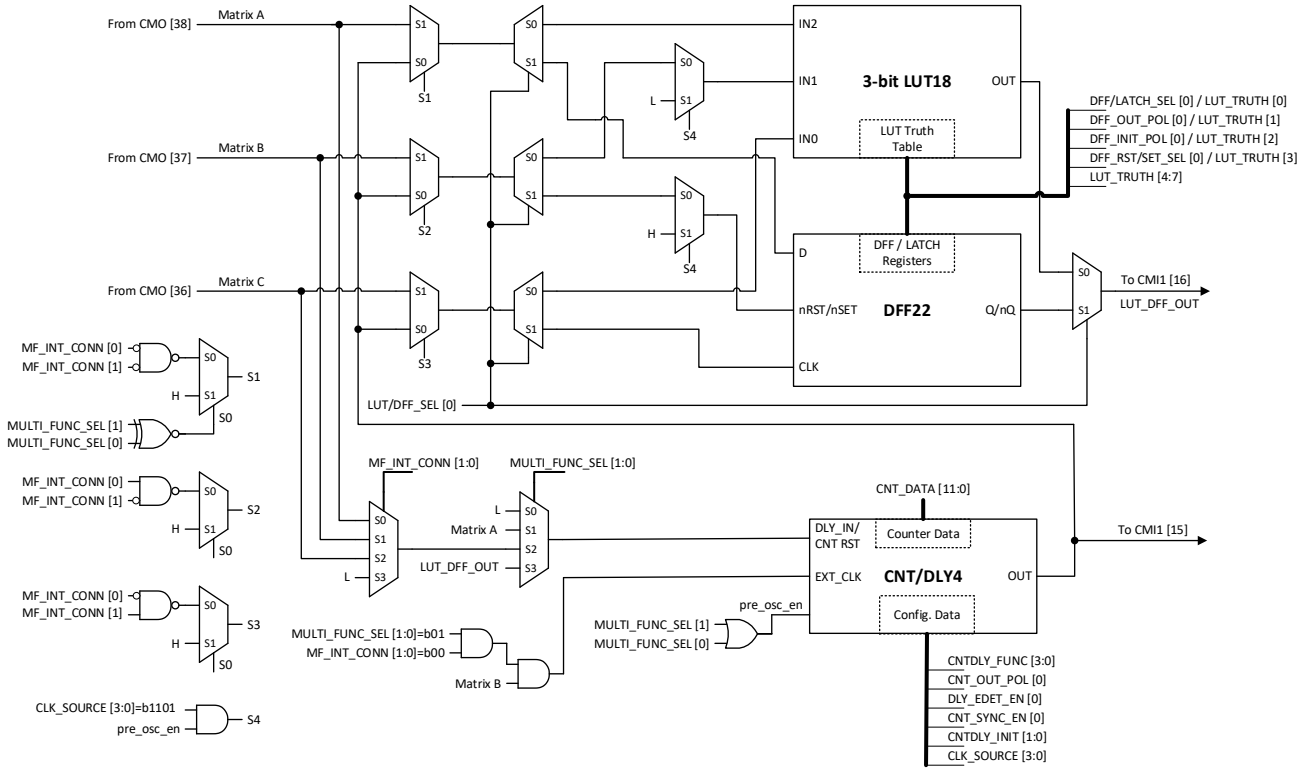



**Note:** H – High logic level; L – Low logic level.

Registers abbreviations:

| | | | |
|---|---|---|---|
| LUT3_17_DFF21_CNTDLY3_MF_SEL [1937:1936] | → MULTI_FUNC_SEL [1:0] | LUT3_17_DFF21_CNTDLY3_LUT_DFF_SEL [1932] | → LUT/DFF_SEL [0] |
| LUT3_17_DFF21_CNTDLY3_INT_CONN [1939:1938] | → MF_INT_CONN [1:0] | LUT3_17_DFF21_CNTDLY3_DFF_LATCH_SEL [1920] | → DFF/LATCH_SEL [0] |
| LUT3_17_DFF21_CNTDLY3_CLK_SEL [1947:1944] | → CLK_SOURCE [3:0] | LUT3_17_DFF21_CNTDLY3_DFF_OUT_POL [1921] | → DFF_OUT_POL [0] |
| LUT3_17_DFF21_CNTDLY3_CNTDLY_FUNC [1931:1928] | → CNTDLY_FUNC [3:0] | LUT3_17_DFF21_CNTDLY3_INIT_POL [1922] | → DFF_INIT_POL [0] |
| LLUT3_17_DFF21_CNTDLY3_CNT_OUT_POL [1933] | → CNT_OUT_POL [0] | LUT3_17_DFF21_CNTDLY3_RSTSET_SEL [1923] | → DFF_RST/SET_SEL [0] |
| LUT3_17_DFF21_CNTDLY3_DLY_EDET_EN [1934] | → DLY_EDET_EN [0] | LUT3_17_TRUTH [1927:1920] | → LUT_TRUTH [7:0] (for LUT function selected) |
| LUT3_17_DFF21_CNTDLY3_CNT_SYNC_EN [1935] | → CNT_SYNC_EN [0] | | |
| LUT3_17_DFF21_CNTDLY3_CNTDLY_INIT [1941:1940] | → CNTDLY_INIT [1:0] | | |
| LUT3_17_DFF21_CNTDLY3_CNT_DATA [1951:1948, 1959:1952] | → CNT_DATA [11:0] | | |

**Figure 44. 12-bit Multi-Function Macrocells Block Diagram (3-bit LUT17/DFF21, CNT/DLY3)**

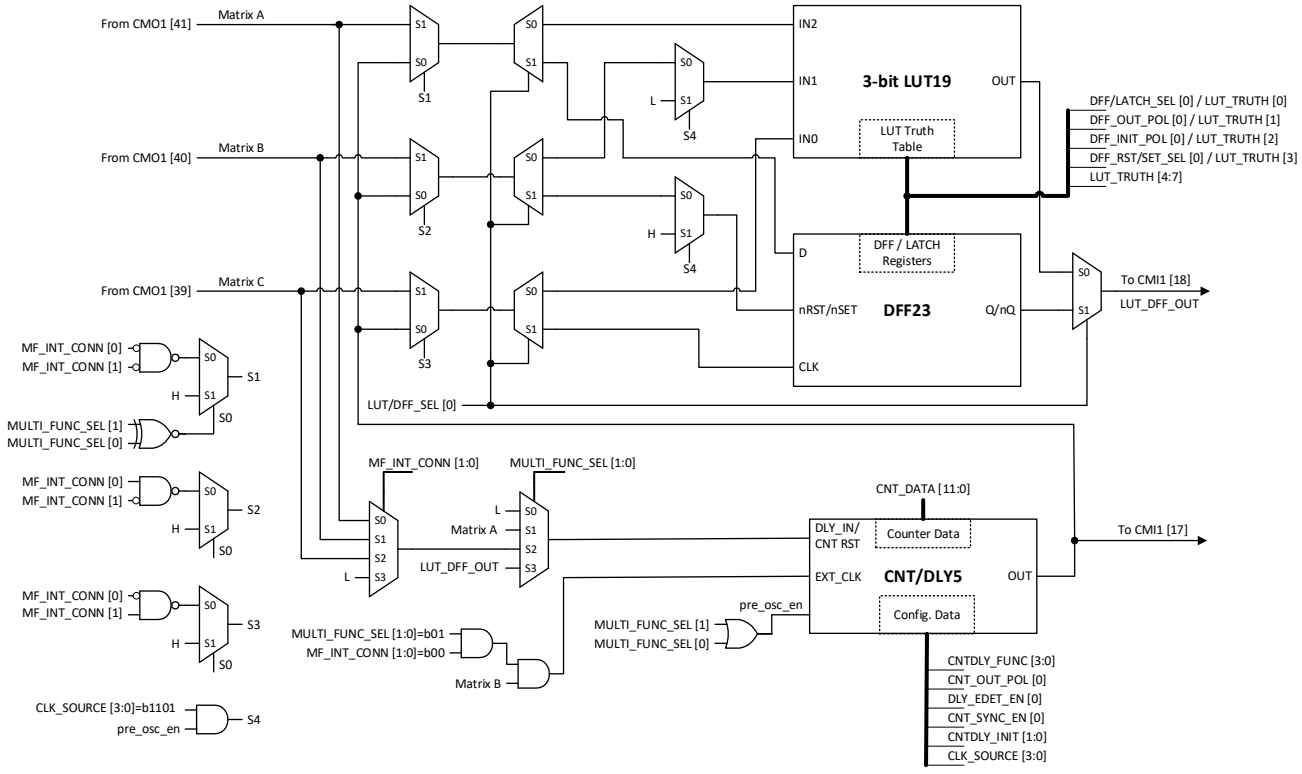



**Note:** H – High logic level; L – Low logic level.

Registers abbreviations:

| | |
|---|---|
| LUT3_18_DFF22_CNTDLY4_MF_SEL [1993:1192] | → MULTI_FUNC_SEL [1:0] |
| LUT3_18_DFF22_CNTDLY4_INT_CONN [1995:1994] | → MF_INT_CONN [1:0] |
| LUT3_18_DFF22_CNTDLY4_CLK_SEL [2003:2000] | → CLK_SOURCE [3:0] |
| LUT3_18_DFF22_CNTDLY4_CNTDLY_FUNC [1987:1987] | → CNTDLY_FUNC [3:0] |
| LUT3_18_DFF22_CNTDLY4_CNT_OUT_POL [1989] | → CNT_OUT_POL [0] |
| LUT3_18_DFF22_CNTDLY4_DLY_EDET_EN [1990] | → DLY_EDET_EN [0] |
| LUT3_18_DFF22_CNTDLY4_CNT_SYNC_EN [1991] | → CNT_SYNC_EN [0] |
| LUT3_18_DFF22_CNTDLY4_CNTDLY_INIT [1997:1996] | → CNTDLY_INIT [1:0] |
| LUT3_18_DFF22_CNTDLY4_CNT_DATA [2007:2004, 2015:2008] | → CNT_DATA [11:0] |
| LUT3_18_DFF22_CNTDLY4_LUT_DFF_SEL [1988] | → LUT/DFF_SEL [0] |
| LUT3_18_DFF22_CNTDLY4_DFF_LATCH_SEL [1976] | → DFF/LATCH_SEL [0] |
| LUT3_18_DFF22_CNTDLY4_DFF_OUT_POL [1977] | → DFF_OUT_POL [0] |
| LUT3_18_DFF22_CNTDLY4_INIT_POL [1978] | → DFF_INIT_POL [0] |
| LUT3_18_DFF22_CNTDLY4_RSTSET_SEL [1979] | → DFF_RST/SET_SEL [0] |
| LUT3_18_TRUTH [1983:1976] | → LUT_TRUTH [7:0] (for LUT function selected) |

**Figure 45. 12-bit Multi-Function Macrocells Block Diagram (3-bit LUT18/DFF22, CNT/DLY4)**

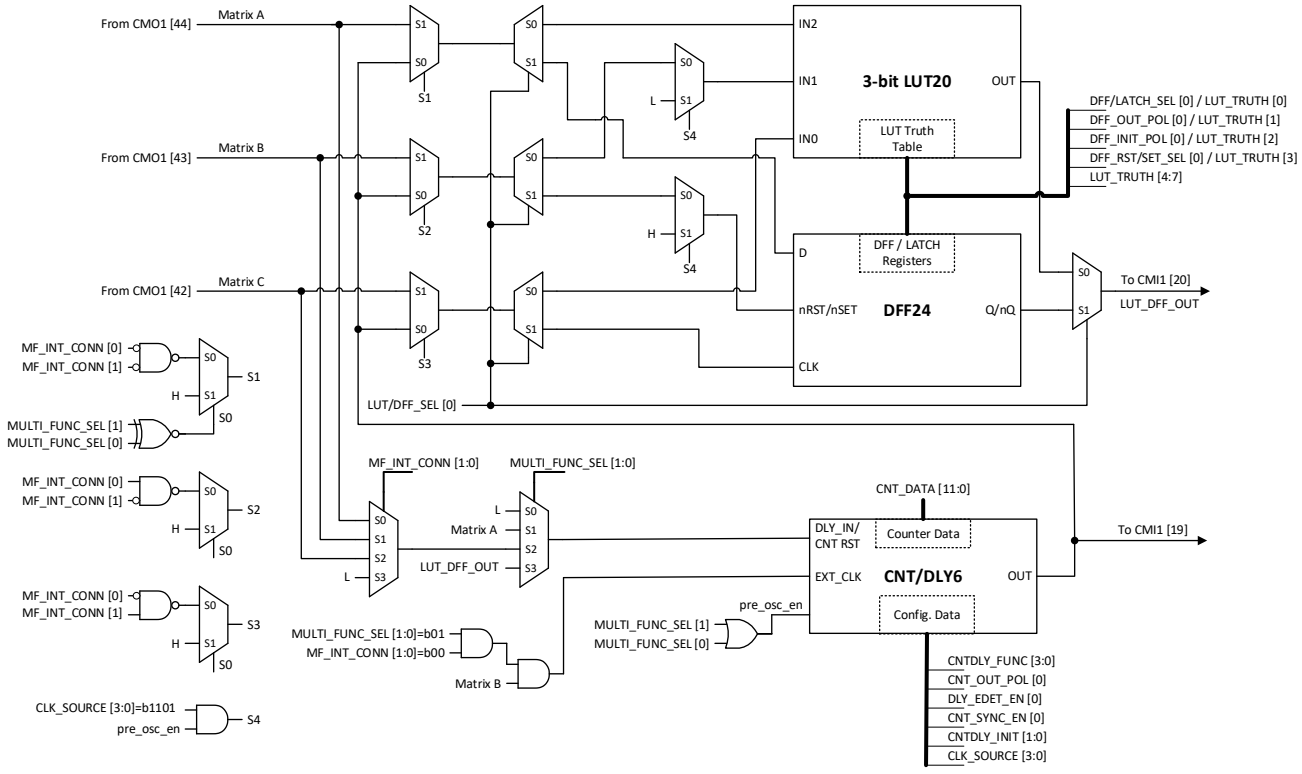



**Note:** H – High logic level; L – Low logic level.

Registers abbreviations:

| | |
|---|---|
| LUT3_19_DFF23_CNTDLY5_MF_SEL [2049:2048] | → MULTI_FUNC_SEL [1:0] |
| LUT3_19_DFF23_CNTDLY5_INT_CONN [2051:2050] | → MF_INT_CONN [1:0] |
| LUT3_19_DFF23_CNTDLY5_CLK_SEL [2059:2056] | → CLK_SOURCE [3:0] |
| LUT3_19_DFF23_CNTDLY5_CNTDLY_FUNC [2043:2040] | → CNTDLY_FUNC [3:0] |
| LUT3_19_DFF23_CNTDLY5_CNT_OUT_POL [2045] | → CNT_OUT_POL [0] |
| LUT3_19_DFF23_CNTDLY5_DLY_EDET_EN [2046] | → DLY_EDET_EN [0] |
| LUT3_19_DFF23_CNTDLY5_CNT_SYNC_EN [2047] | → CNT_SYNC_EN [0] |
| LUT3_19_DFF23_CNTDLY5_CNTDLY_INIT [2053:2052] | → CNTDLY_INIT [1:0] |
| LUT3_19_DFF23_CNTDLY5_CNT_DATA [2063:2060, 2071:2064] | → CNT_DATA [11:0] |
| LUT3_19_DFF23_CNTDLY5_LUT_DFF_SEL [2044] | → LUT/DFF_SEL [0] |
| LUT3_19_DFF23_CNTDLY5_DFF_LATCH_SEL [2032] | → DFF/LATCH_SEL [0] |
| LUT3_19_DFF23_CNTDLY5_DFF_OUT_POL [2033] | → DFF_OUT_POL [0] |
| LUT3_19_DFF23_CNTDLY5_INIT_POL [2034] | → DFF_INIT_POL [0] |
| LUT3_19_DFF23_CNTDLY5_RSTSET_SEL [2035] | → DFF_RST/SET_SEL [0] |
| LUT3_19_TRUTH [2039:2032] | → LUT_TRUTH [7:0] (for LUT function selected) |

**Figure 46. 12-bit Multi-Function Macrocells Block Diagram (3-bit LUT19/DFF23, CNT/DLY5)**

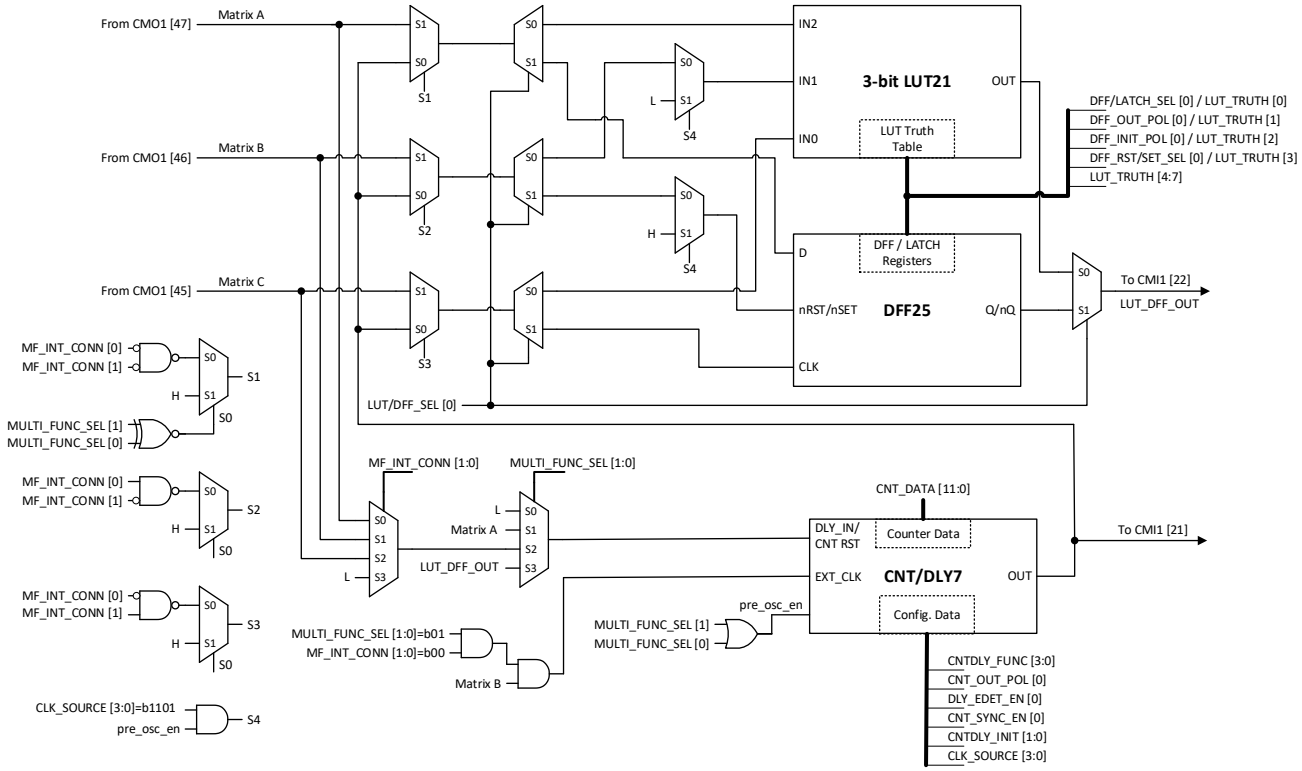



**Note:** H – High logic level; L – Low logic level.

Registers abbreviations:

| | | | |
|---|---|---|---|
| LUT3_20_DFF24_CNTDLY6_MF_SEL [2105:2104] | → MULTI_FUNC_SEL [1:0] | LUT3_20_DFF24_CNTDLY6_LUT_DFF_SEL [2100] | → LUT/DFF_SEL [0] |
| LUT3_20_DFF24_CNTDLY6_INT_CONN [2107:2106] | → MF_INT_CONN [1:0] | LUT3_20_DFF24_CNTDLY6_DFF_LATCH_SEL [2088] | → DFF/LATCH_SEL [0] |
| LUT3_20_DFF24_CNTDLY6_CLK_SEL [2115:2112] | → CLK_SOURCE [3:0] | LUT3_20_DFF24_CNTDLY6_DFF_OUT_POL [2089] | → DFF_OUT_POL [0] |
| LUT3_20_DFF24_CNTDLY6_CNTDLY_FUNC [2099:2096] | → CNTDLY_FUNC [3:0] | LUT3_20_DFF24_CNTDLY6_INIT_POL [2090] | → DFF_INIT_POL [0] |
| LUT3_20_DFF24_CNTDLY6_CNT_OUT_POL [2101] | → CNT_OUT_POL [0] | LUT3_20_DFF24_CNTDLY6_RSTSET_SEL [2091] | → DFF_RST/SET_SEL [0] |
| LUT3_20_DFF24_CNTDLY6_DLY_EDET_EN [2102] | → DLY_EDET_EN [0] | LUT3_20_TRUTH [2095:2088] | → LUT_TRUTH [7:0] (for LUT function selected) |
| LUT3_20_DFF24_CNTDLY6_CNT_SYNC_EN [2103] | → CNT_SYNC_EN [0] | | |
| LUT3_20_DFF24_CNTDLY6_CNTDLY_INIT [2109:2108] | → CNTDLY_INIT [1:0] | | |
| LUT3_20_DFF24_CNTDLY6_CNT_DATA [2119:2116, 2127:2120] | → CNT_DATA [11:0] | | |

**Figure 47. 12-bit Multi-Function Macrocells Block Diagram (3-bit LUT20/DFF24, CNT/DLY6)**

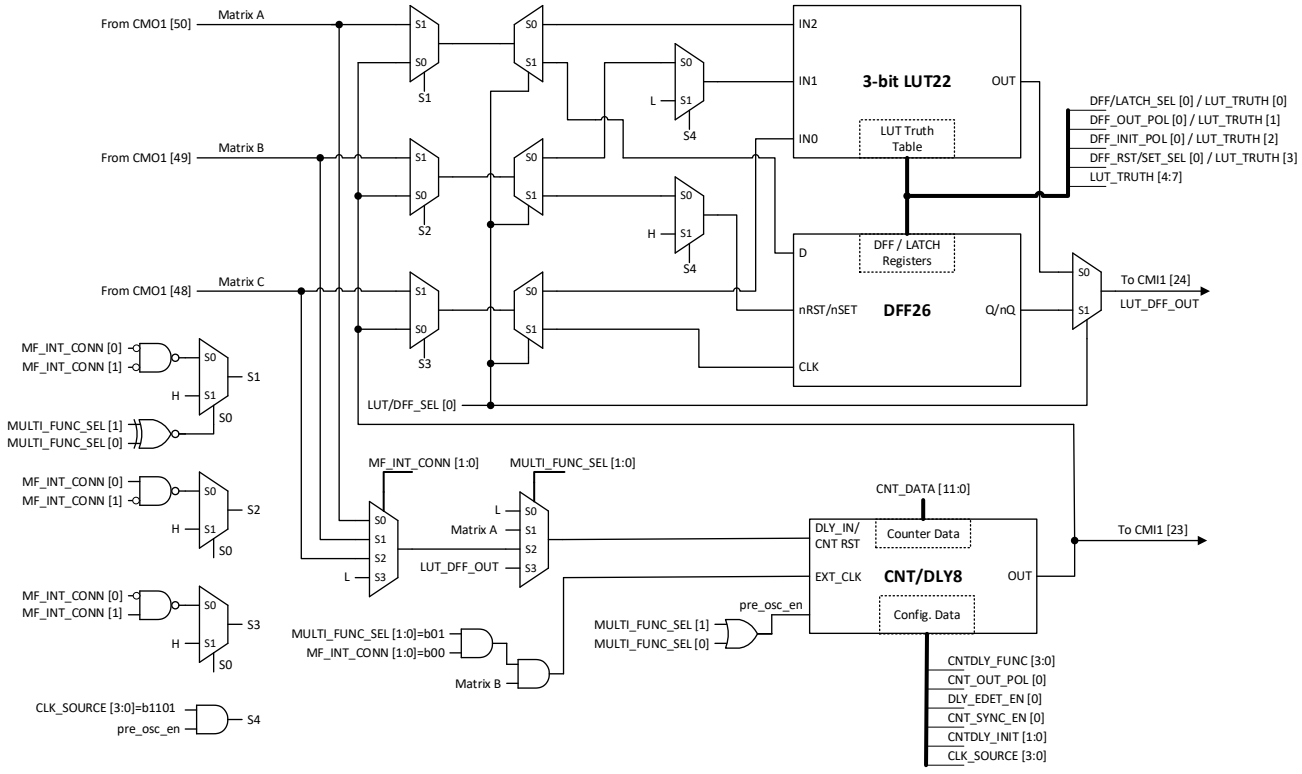



**Note:** H – High logic level; L – Low logic level.

Registers abbreviations:

| | | | |
|---|---|---|---|
| LUT3_21_DFF25_CNTDLY7_MF_SEL [2161:2160] | → MULTI_FUNC_SEL [1:0] | LUT3_21_DFF25_CNTDLY7_LUT_DFF_SEL [2156] | → LUT/DFF_SEL [0] |
| LUT3_21_DFF25_CNTDLY7_INT_CONN [2163:2162] | → MF_INT_CONN [1:0] | LUT3_21_DFF25_CNTDLY7_DFF_LATCH_SEL [2144] | → DFF/LATCH_SEL [0] |
| LUT3_21_DFF25_CNTDLY7_CLK_SEL [2171:2168] | → CLK_SOURCE [3:0] | LUT3_21_DFF25_CNTDLY7_DFF_OUT_POL [2145] | → DFF_OUT_POL [0] |
| LUT3_21_DFF25_CNTDLY7_CNTDLY_FUNC [2155:2152] | → CNTDLY_FUNC [3:0] | LUT3_21_DFF25_CNTDLY7_INIT_POL [2146] | → DFF_INIT_POL [0] |
| LUT3_21_DFF25_CNTDLY7_CNT_OUT_POL [2157] | → CNT_OUT_POL [0] | LUT3_21_DFF25_CNTDLY7_RSTSET_SEL [2147] | → DFF_RST/SET_SEL [0] |
| LUT3_21_DFF25_CNTDLY7_DLY_EDET_EN [2158] | → DLY_EDET_EN [0] | LUT3_21_TRUTH [2151:2144] | → LUT_TRUTH [7:0] (for LUT function selected) |
| LUT3_21_DFF25_CNTDLY7_CNT_SYNC_EN [2159] | → CNT_SYNC_EN [0] | | |
| LUT3_21_DFF25_CNTDLY7_CNTDLY_INIT [2165:2164] | → CNTDLY_INIT [1:0] | | |
| LUT3_21_DFF25_CNTDLY7_CNT_DATA [2175:2172, 2183:2176] | → CNT_DATA [11:0] | | |

**Figure 48. 12-bit Multi-Function Macrocells Block Diagram (3-bit LUT21/DFF25, CNT/DLY7)**

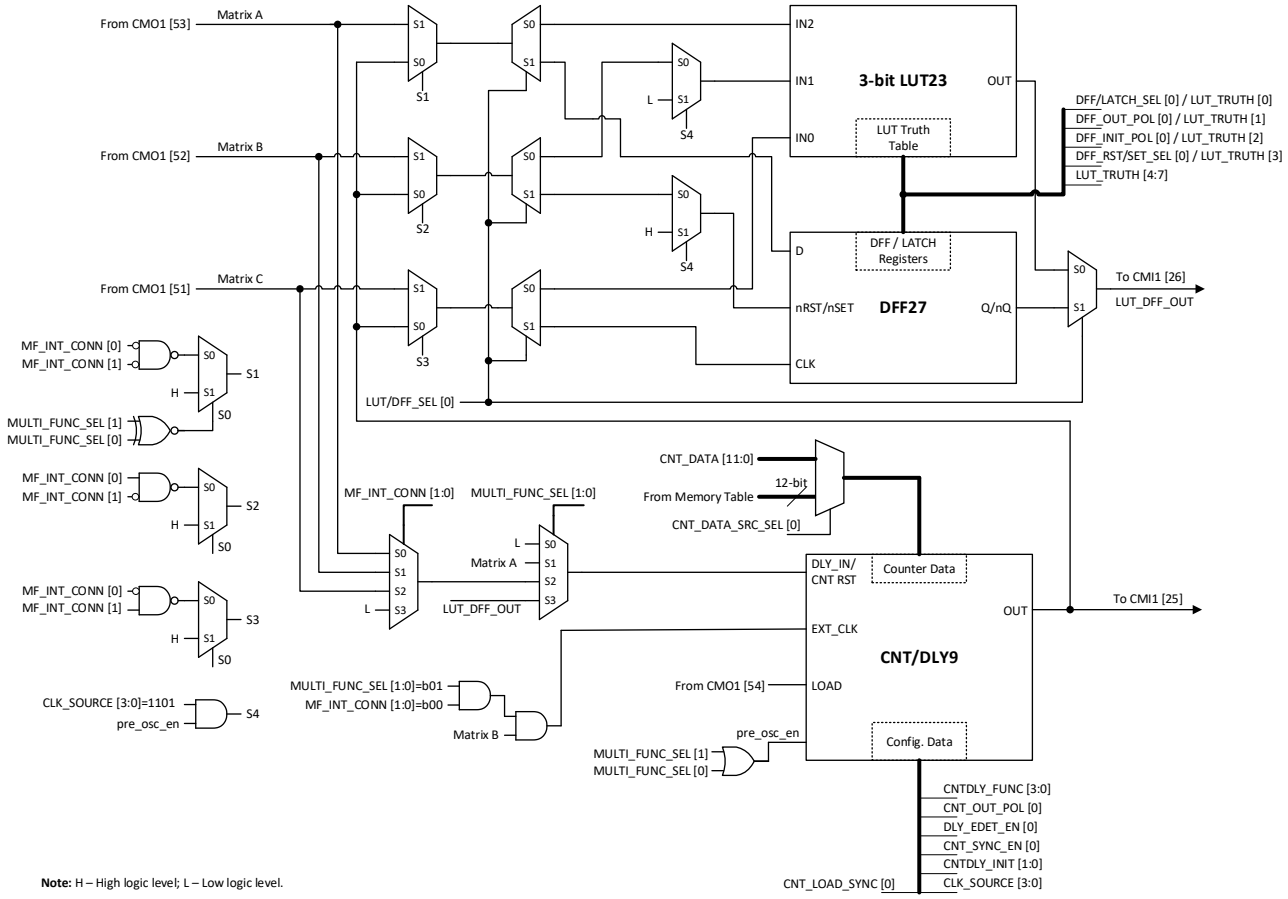



**Note:** H – High logic level; L – Low logic level.

Registers abbreviations:

| | | | |
|---|---|---|---|
| LUT3_22_DFF26_CNTDLY8_MF_SEL [2217:2216] | → MULTI_FUNC_SEL [1:0] | LUT3_22_DFF26_CNTDLY8_LUT_DFF_SEL [2212] | → LUT/DFF_SEL [0] |
| LUT3_22_DFF26_CNTDLY8_INT_CONN [2219:2218] | → MF_INT_CONN [1:0] | LUT3_22_DFF26_CNTDLY8_DFF_LATCH_SEL [2200] | → DFF/LATCH_SEL [0] |
| LUT3_22_DFF26_CNTDLY8_CLK_SEL [2227:2224] | → CLK_SOURCE [3:0] | LUT3_22_DFF26_CNTDLY8_DFF_OUT_POL [2201] | → DFF_OUT_POL [0] |
| LUT3_22_DFF26_CNTDLY8_CNTDLY_FUNC [2211:2208] | → CNTDLY_FUNC [3:0] | LUT3_22_DFF26_CNTDLY8_INIT_POL [2202] | → DFF_INIT_POL [0] |
| LUT3_22_DFF26_CNTDLY8_CNT_OUT_POL [2213] | → CNT_OUT_POL [0] | LUT3_22_DFF26_CNTDLY8_RSTSET_SEL [2203] | → DFF_RST/SET_SEL [0] |
| LUT3_22_DFF26_CNTDLY8_DLY_EDET_EN [2214] | → DLY_EDET_EN [0] | LUT3_22_TRUTH [2207:2200] | → LUT_TRUTH [7:0] (for LUT function selected) |
| LUT3_22_DFF26_CNTDLY8_CNT_SYNC_EN [2215] | → CNT_SYNC_EN [0] | | |
| LUT3_22_DFF26_CNTDLY8_CNTDLY_INIT [2221:2220] | → CNTDLY_INIT [1:0] | | |
| LUT3_22_DFF26_CNTDLY8_CNT_DATA [2231:2228, 2239:2232] | → CNT_DATA [11:0] | | |

**Figure 49. 12-bit Multi-Function Macrocells Block Diagram (3-bit LUT22/DFF26, CNT/DLY8)**

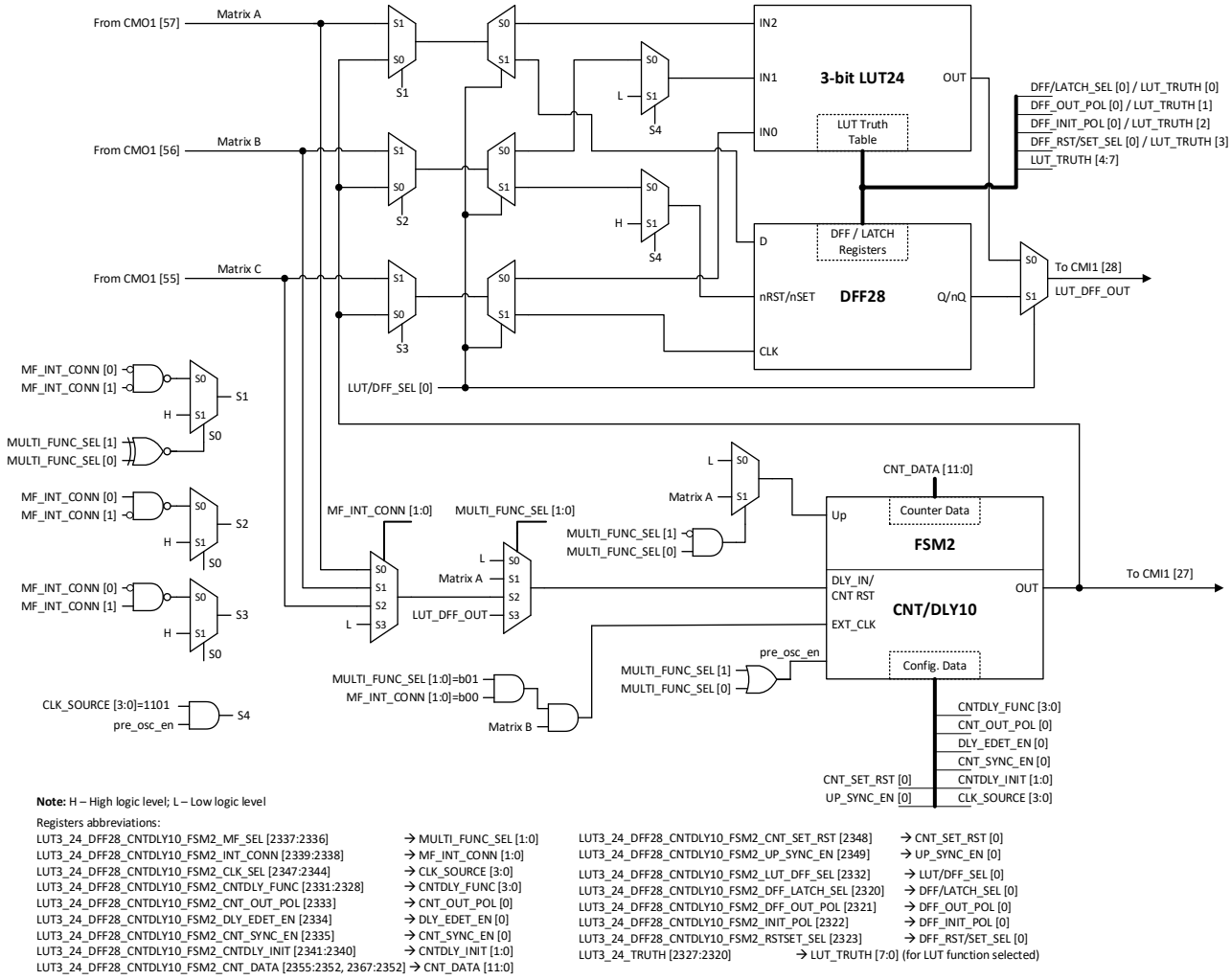



**Note:** H – High logic level; L – Low logic level.

Registers abbreviations:

| | | | |
|---|---|---|---|
| LUT3_23_DFF27_CNTDLY9_MF_SEL [2273:2272] | → MULTI_FUNC_SEL [1:0] | LUT3_23_DFF27_CNTDLY9_LUT_DFF_SEL [2268] | → LUT/DFF_SEL [0] |
| LUT3_23_DFF27_CNTDLY9_INT_CONN [2275:2274] | → MF_INT_CONN [1:0] | LUT3_23_DFF27_CNTDLY9_DFF_LATCH_SEL [2256] | → DFF/LATCH_SEL [0] |
| LUT3_23_DFF27_CNTDLY9_CLK_SEL [2283:2280] | → CLK_SOURCE [3:0] | LUT3_23_DFF27_CNTDLY9_DFF_OUT_POL [2257] | → DFF_OUT_POL [0] |
| LUT3_23_DFF27_CNTDLY9_CNTDLY_FUNC [2267:2264] | → CNTDLY_FUNC [3:0] | LUT3_23_DFF27_CNTDLY9_INIT_POL [2258] | → DFF_INIT_POL [0] |
| LUT3_23_DFF27_CNTDLY9_CNT_OUT_POL [2269] | → CNT_OUT_POL [0] | LUT3_23_DFF27_CNTDLY9_RSTSET_SEL [2259] | → DFF_RST/SET_SEL [0] |
| LUT3_23_DFF27_CNTDLY9_DLY_EDET_EN [2270] | → DLY_EDET_EN [0] | LUT3_23_DFF27_CNTDLY9_DATA_SRC_SEL [2284] | → CNT_DATA_SRC_SEL [0] |
| LUT3_23_DFF27_CNTDLY9_CNT_SYNC_EN [2271] | → CNT_SYNC_EN [0] | LUT3_23_DFF27_CNTDLY9_LOAD_SYNC [2285] | → CNT_LOAD_SYNC [0] |
| LUT3_23_DFF27_CNTDLY9_CNTDLY_INIT [2277:2276] | → CNTDLY_INIT [1:0] | LUT3_23_TRUTH [2263:2256] | → LUT_TRUTH [7:0] (for LUT function selected) |
| LUT3_23_DFF27_CNTDLY9_CNT_DATA [2291:2288, 2303:2296] | → CNT_DATA [11:0] | | |

**Figure 50. 12-bit Multi-Function Macrocells Block Diagram (3-bit LUT23/DFF27, CNT/DLY9)**




**Note:** H – High logic level; L – Low logic level

Registers abbreviations:

| | |
|---|---|
| LUT3_24_DFF28_CNTDLY10_FSM2_MF_SEL [2337:2336] | → MULTI_FUNC_SEL [1:0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_INT_CONN [2339:2338] | → MF_INT_CONN [1:0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_CLK_SEL [2347:2344] | → CLK_SOURCE [3:0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_CNTDLY_FUNC [2331:2328] | → CNTDLY_FUNC [3:0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_CNT_OUT_POL [2333] | → CNT_OUT_POL [0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_DLY_EDET_EN [2334] | → DLY_EDET_EN [0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_CNT_SYNC_EN [2335] | → CNT_SYNC_EN [0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_CNTDLY_INIT [2341:2340] | → CNTDLY_INIT [1:0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_CNT_DATA [2355:2352, 2367:2352] | → CNT_DATA [11:0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_CNT_SET_RST [2348] | → CNT_SET_RST [0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_UP_SYNC_EN [2349] | → UP_SYNC_EN [0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_LUT_DFF_SEL [2332] | → LUT/DFF_SEL [0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_DFF_LATCH_SEL [2320] | → DFF/LATCH_SEL [0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_DFF_OUT_POL [2321] | → DFF_OUT_POL [0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_INIT_POL [2322] | → DFF_INIT_POL [0] |
| LUT3_24_DFF28_CNTDLY10_FSM2_RSTSET_SEL [2323] | → DFF_RST/SET_SEL [0] |
| LUT3_24_TRUTH [2327:2320] | → LUT_TRUTH [7:0] (for LUT function selected) |

**Figure 51. 12-bit Multi-Function Macrocells Block Diagram (3-bit LUT24/DFF28, CNT/DLY10/FSM2)**

As shown in Figure 41-Figure 51, it is possibile to use LUT/DFF and CNT/DLY simultaneously.

**Note:** It is not possible to use LUT and DFF simultaneously. The user can consider following use cases involving LUT/DFF and CNT/DLY macrocells:

- **Case 1**: LUT/DFF in series with CNT/DLY.

  Three input signals from the connection matrix outputs are connected to the inputs of the LUT or DFF and produce a single output that connects to the input of CNT/DLY. The output of CNT/DLY connects back to the connection matrix input.

- **Case 2**: CNT/DLY in series with LUT/DFF.

  Two input signals, IN and CLK, from the connection matrix outputs are connected to the input of CNT/DLY macrocell. Its output signal can be connected to any input of LUT/DFF macrocell. The output of the LUT/DFF connects back to the connection matrix input.

- **Case 3**: Single LUT/DFF or CNT/DLY.

  The LUT/DFF or CNT/DLY function can be used as a standalone function. In this case, all inputs and output of the macrocell are connected to the connection matrix.

If the LUT function is used, an 8-bit register defines the output function:

- 3-bit LUT3_14 is defined by Reg[359:352]
- 3-bit LUT3_15 is defined by Reg[415:408]
- 3-bit LUT3_16 is defined by Reg[1871:1864]

- 3-bit LUT3_17 is defined by Reg[1927:1920]
- 3-bit LUT3_18 is defined by Reg[1983:1976]
- 3-bit LUT3_19 is defined by Reg[2039:2032]
- 3-bit LUT3_20 is defined by Reg[2095:2088]
- 3-bit LUT3_21 is defined by Reg[2151:2144]
- 3-bit LUT3_22 is defined by Reg[2207:2200]
- 3-bit LUT3_23 is defined by Reg[2263:2256]
- 3-bit LUT3_24 is defined by Reg[2327:2320].

**Table 18. 3-bit LUT8 to 3-bit LUT13 Truth Table**

| IN2 | IN1 | IN0 | OUT LUT 3_14 | OUT LUT 3_15 | OUT LUT 3_16 | OUT LUT 3_17 | OUT LUT 3_18 | OUT LUT 3_19 | OUT LUT 3_20 | OUT LUT 3_21 | OUT LUT 3_22 | OUT LUT 3_23 | OUT LUT 3_24 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | Reg [352] | Reg [408] | Reg [1864] | Reg [1920] | Reg [1976] | Reg [2032] | Reg [2088] | Reg [2144] | Reg [2200] | Reg [2256] | Reg [2320] | LSB |
| 0 | 0 | 1 | Reg [353] | Reg [409] | Reg [1865] | Reg [1921] | Reg [1977] | Reg [2033] | Reg [2089] | Reg [2145] | Reg [2201] | Reg [2257] | Reg [2321] | |
| 0 | 1 | 0 | Reg [354] | Reg [410] | Reg [1866] | Reg [1922] | Reg [1978] | Reg [2034] | Reg [2090] | Reg [2146] | Reg [2202] | Reg [2258] | Reg [2322] | |
| 0 | 1 | 1 | Reg [355] | Reg [411] | Reg [1867] | Reg [1923] | Reg [1979] | Reg [2035] | Reg [2091] | Reg [2147] | Reg [2203] | Reg [2259] | Reg [2323] | |
| 1 | 0 | 0 | Reg [356] | Reg [412] | Reg [1868] | Reg [1924] | Reg [1980] | Reg [2036] | Reg [2092] | Reg [2148] | Reg [2204] | Reg [2260] | Reg [2324] | |
| 1 | 0 | 1 | Reg [357] | Reg [413] | Reg [1869] | Reg [1925] | Reg [1981] | Reg [2037] | Reg [2093] | Reg [2149] | Reg [2205] | Reg [2261] | Reg [2325] | |
| 1 | 1 | 0 | Reg [358] | Reg [414] | Reg [1870] | Reg [1926] | Reg [1982] | Reg [2038] | Reg [2094] | Reg [2150] | Reg [2206] | Reg [2262] | Reg [2326] | |
| 1 | 1 | 1 | Reg [359] | Reg [415] | Reg [1871] | Reg [1927] | Reg [1983] | Reg [2039] | Reg [2095] | Reg [2151] | Reg [2207] | Reg [2263] | Reg [2327] | MSB |

## 8.2 CNT/DLY Timing Diagrams

### 8.2.1. Delay Mode (Edge Select: Both Edges, Counter Data: 3), CNT/DLY0 to CNT/DLY12

The macrocell shifts the respective edge to a set time and restarts by appropriate edge. If the time difference between rising and falling edge of the input signal is less than the programmed delay time of the macrocell, then no signal will appear at the delay cell output. Please note that because Input signal and Clock signal (OSC) are not synchronized, variable delays are added to the total delay time.

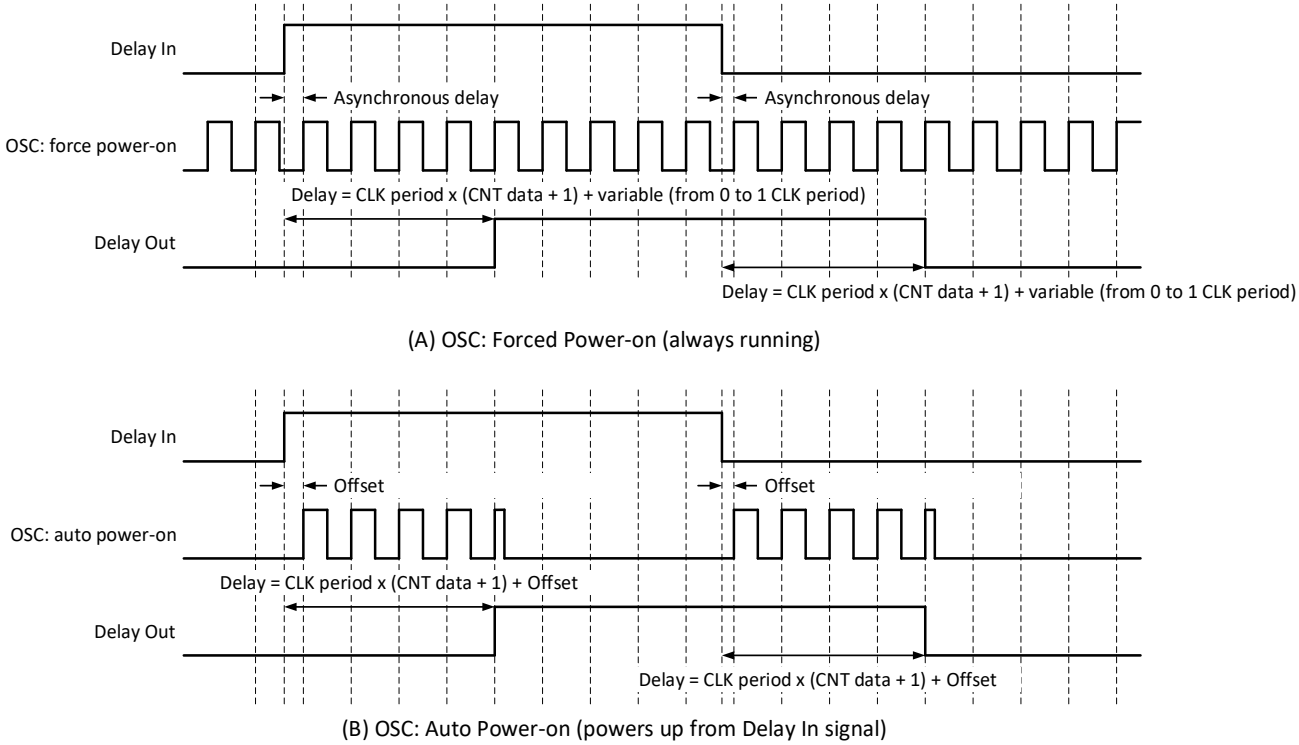



**Figure 52. Delay Macrocell Behavior with Different Oscillators Options (Edge Select: Both, CNT Data = 3)**

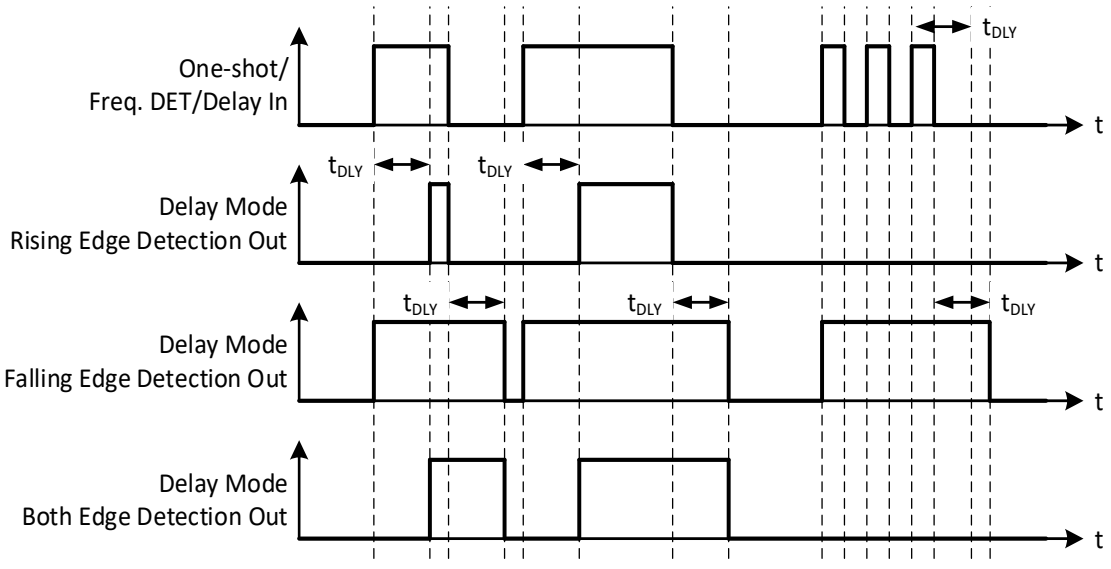



**Figure 53. Delay Mode Timing Diagram (Rising, Falling, and Both Edge Detection)**

The initial value of delay macrocell output defines what the delay macrocell output will be during a power-on. This setting is selected by register CNTDLY_INIT [1:0]:

- **Bypass the initial:** the delay cell is bypassed during startup and the DLY input is forwarded to output during startup.
- **Initial 0:** DLY output will be held LOW during startup.
- **Initial 1:** DLY output will be held HIGH during startup.

The output signals of a delay macrocell depends on the input signal and the initial value set by the register. See Figure 54, Figure 55, and Figure 56 for details and signal timing.

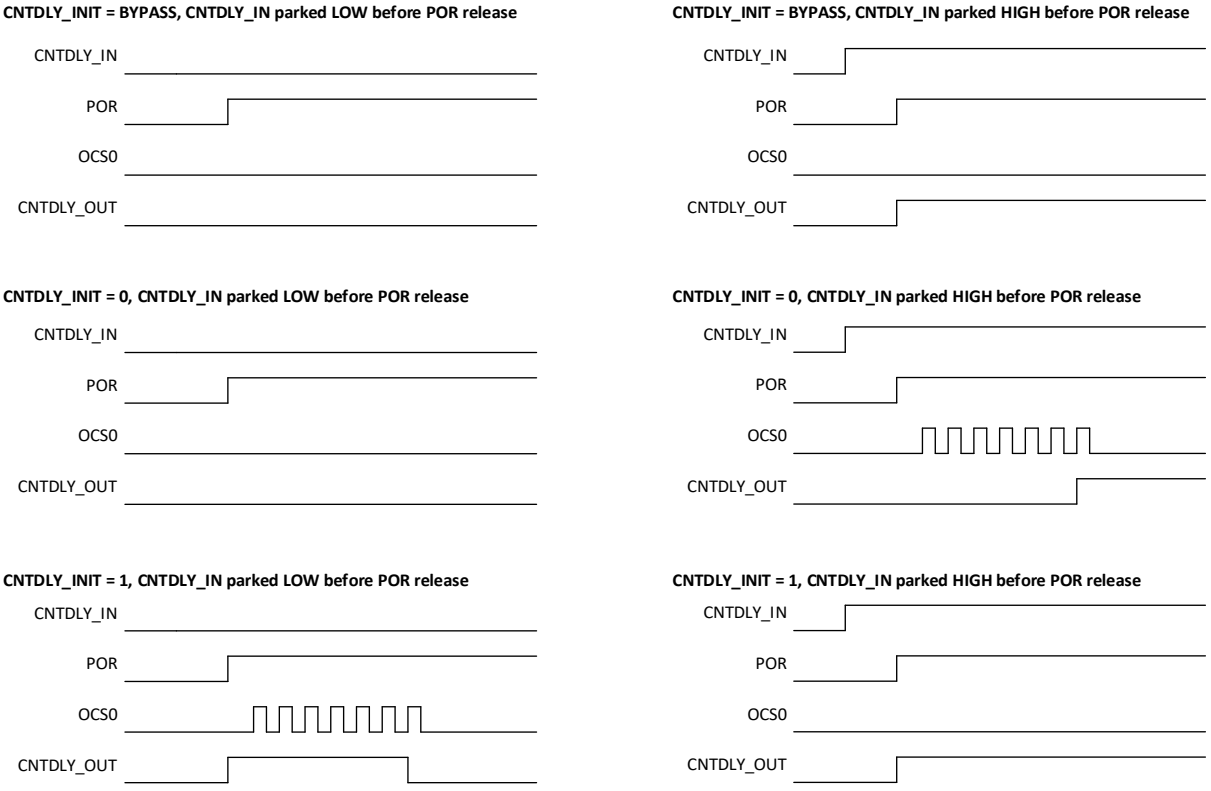



**Figure 54. Delay Mode (Both Edge Delay) Initial Value States**

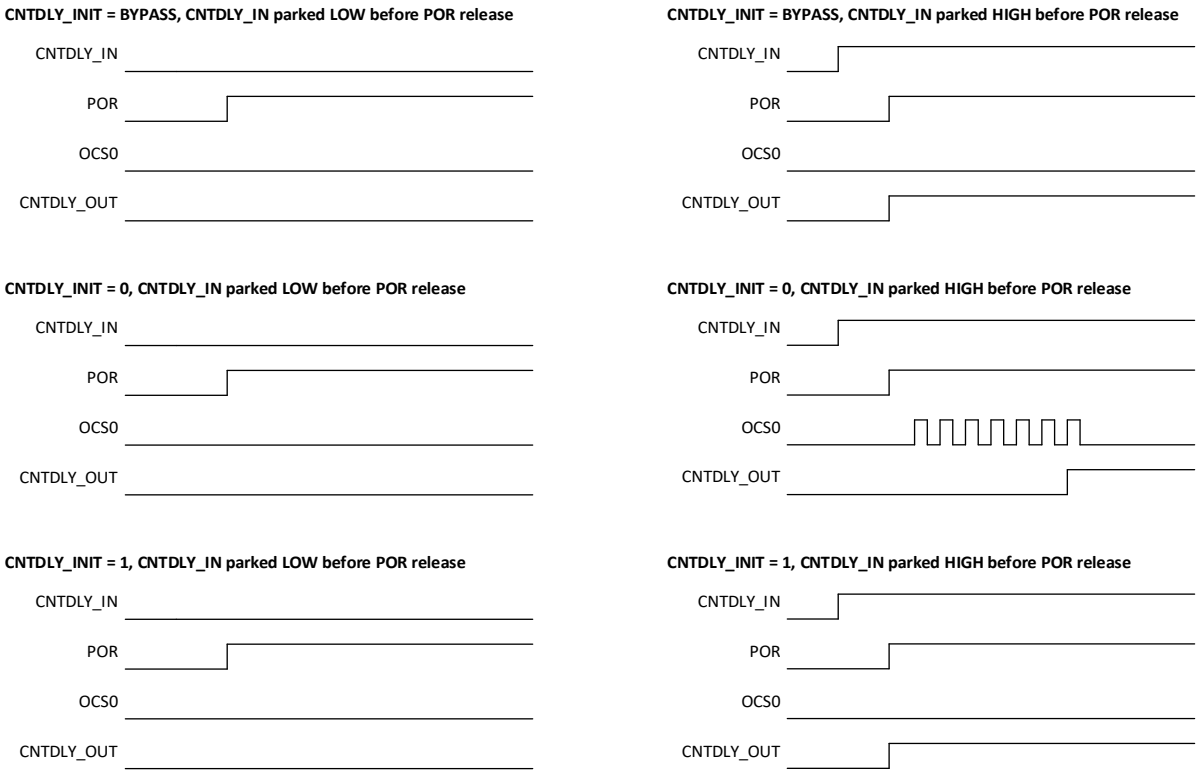



**Figure 55. Delay Mode (Rising Edge Delay) Initial Value States**

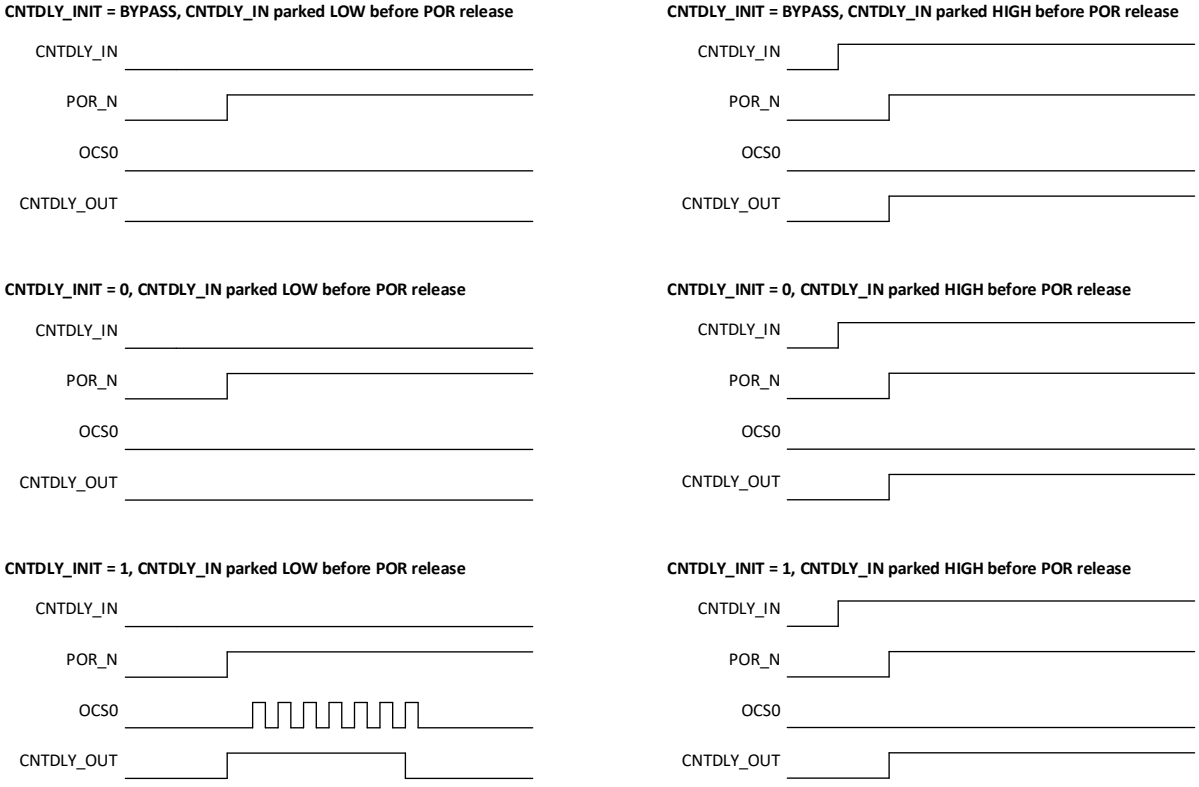



**Figure 56. Delay Mode (Falling Edge Delay) Initial Value States**

### 8.2.2. Count Mode (Count Data: 3), Counter Reset (Rising Edge Detect) CNT/DLY0 to CNT/DLY12

Counter mode timing diagrams with rising edge detection for CNT_DATA [11:0] = 3 are shown in Figure 57 (CNT_SYNC_EN = 0) and Figure 58 (CNT_SYNC_EN = 1).

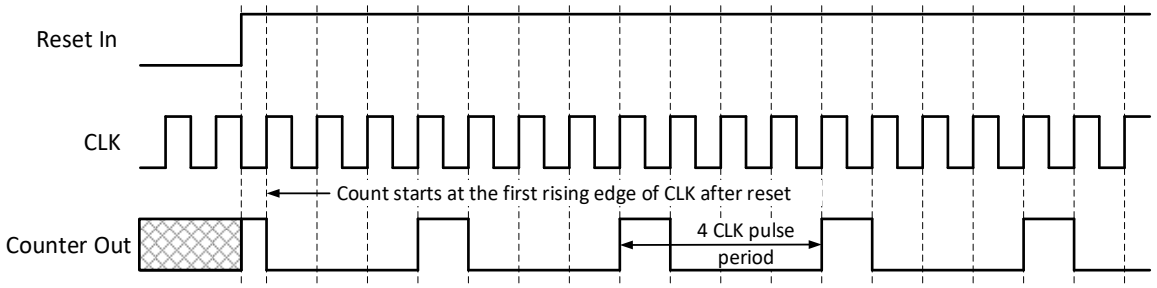



**Figure 57. Counter Mode Timing Diagram without Two DFFs Synced Up**

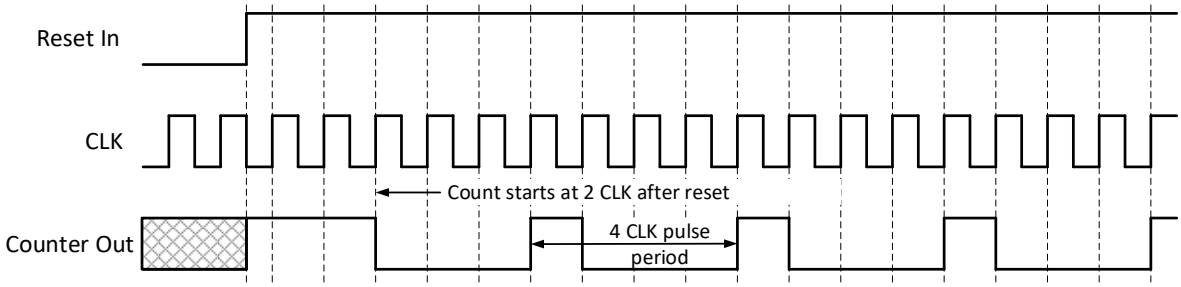



**Figure 58. Counter Mode Timing Diagram with Two DFFs Synced Up**

### 8.2.3. One-Shot Mode CNT/DLY0 to CNT/DLY12

This macrocell will generate a pulse whenever a selected edge is detected at its input. Register CNTDLY_FUNC [3:0] set the edge selection. The pulse width is determined by a counter data and clock selection properties. The output pulse polarity (non-inverted or inverted) is selected by register CNT_OUT_POL [0]. Any incoming edges will be ignored during the pulse generation. Figure 59 shows one-shot functions for non-inverted output.

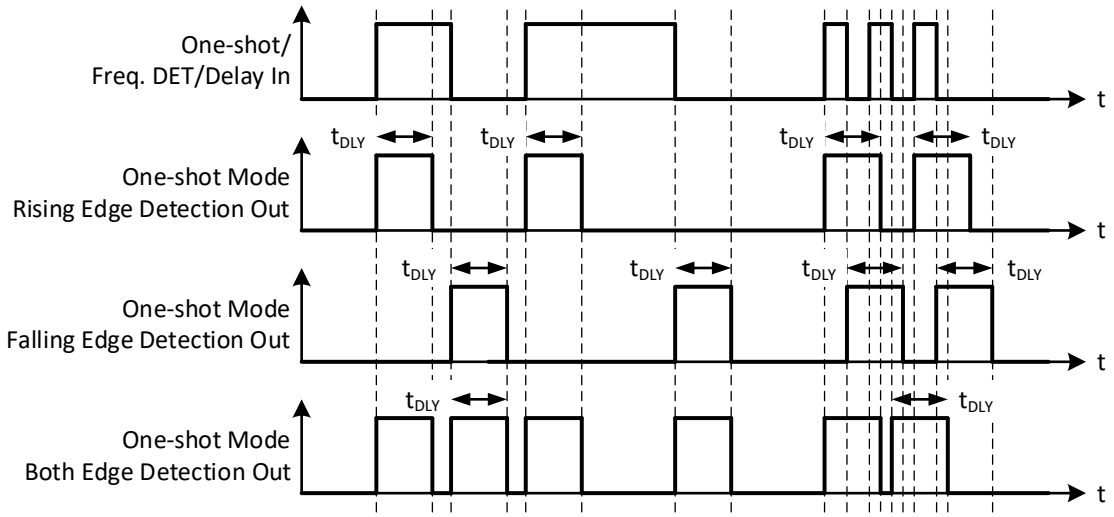



**Figure 59. One-Shot Function Timing Diagram**

### 8.2.4. Frequency Detection Mode CNT/DLY0 to CNT/DLY12

In frequency detection mode, the macrocell output transitions HIGH if the time between two respective edges selected by register CNTDLY_FUNC [3:0] is less than the specified delay. See Figure 60:

- **Rising Edge Detection**: the output transitions HIGH if the time between two successive edges is less than the specified delay. The output transitions LOW if the subsequent rising edge has not come after the last rising edge within the specified time.
- **Falling Edge Detection**: the output transitions HIGH if the time between two successive falling edges is less than the specified delay. The output transitions LOW if the second falling edge has not come after the last falling edge within the specified time.
- **Both Edge Detection**: the output transitions HIGH if the time between the rising and falling edges is less than the specified delay, which is equivalent to the length of the pulse. The output transitions LOW if the subsequent edge has not come after the last rising/falling edge within the specified time.

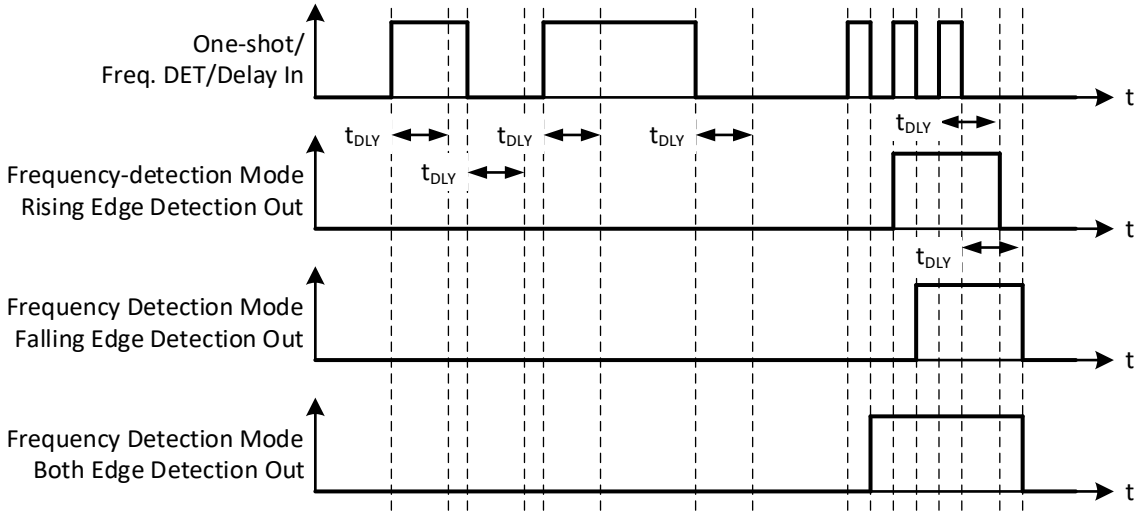



**Figure 60. Frequency Detection Mode Timing Diagram**

### 8.2.5. Edge Detection Mode CNT/DLY0 to CNT/DLY12

In edge detection mode, the macrocell generates a high-level short pulse when detecting the respective edge (see Figure 61).

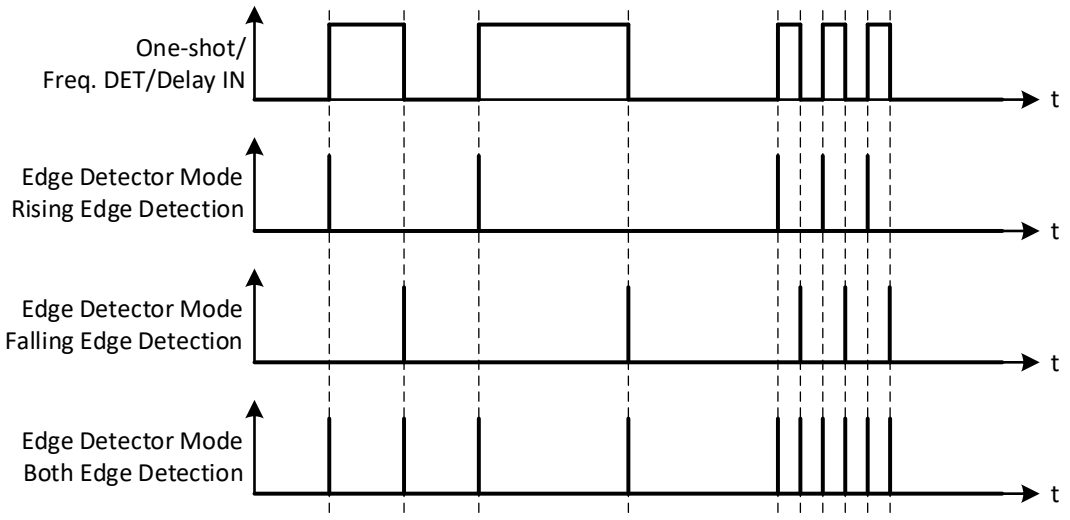



**Figure 61. Edge Detection Mode Timing Diagram**

### 8.2.6. Delayed Edge Detection Mode

In delayed edge detection mode, high-level short pulses are generated at the macrocell output after the configured delay time, if the specified edge was detected at the input.

If the input signal changes its state during the set delay time, the pulse will not be generated. See Figure 62:

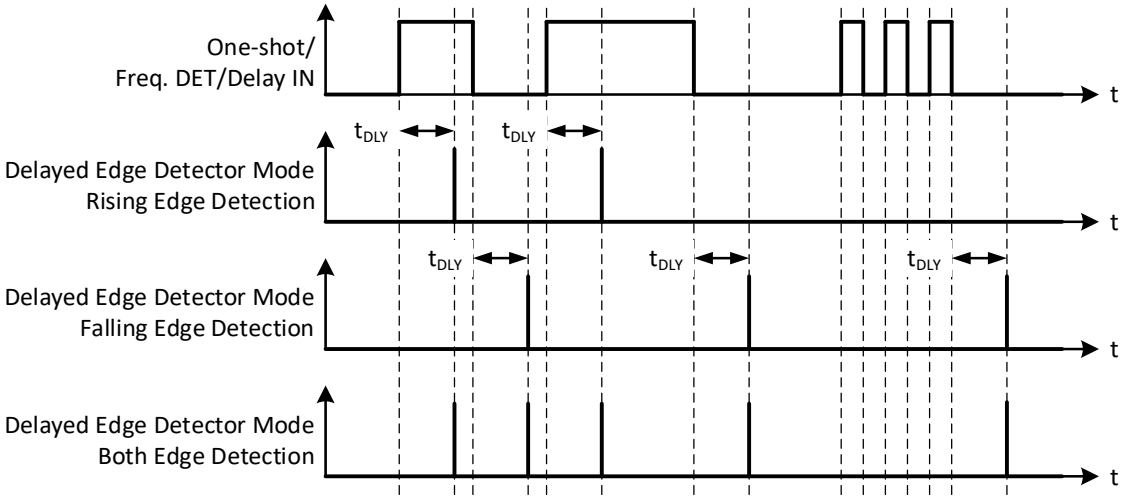



**Figure 62. Delayed Edge Detection Mode Timing Diagram**

### 8.2.7. Difference in Counter Value for Counter, Delay, One-Shot, and Frequency Detect Modes

There is a difference in counter value between counter and delay/one-shot/frequency detect modes. The counter value is shifted for two rising edges of the clock signal in delay/one-shot/frequency detect modes compared to counter mode. See Figure 63:

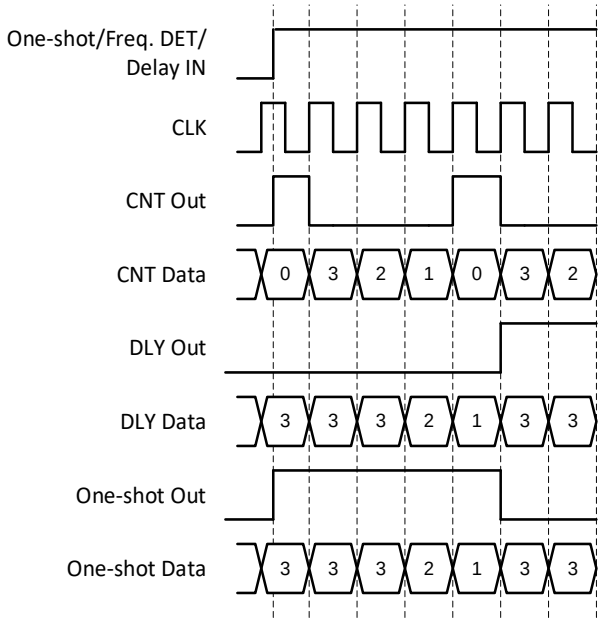



**Figure 63. Counter Value, Counter Data = 3**

## 8.3 Counter/Delay/FSM Macrocells

### 8.3.1. 4-bit LUT or DFF/LATCH with 16-bit CNT/DLY/FSM Macrocell General Description

The SLG47011 features two macrocells that can operate as either 4-bit LUT/DFFs or as 16-bit counter/delays.

For the LUT function, the 4-bit LUT takes in four input signals from the connection matrix and generates a single output that connects back into the connection matrix.

For the D Flip-flop function, the two input signals from the connection matrix connect to the data (D) and clock (CLK) inputs for the Flip-flop, with the output connecting back to the connection matrix.

For the 16-bit Counter/Delay function, two out of four input signals from the connection matrix connect to the external clock (EXT_CLK) and the reset (DLY_IN/CNT Reset) for the counter/delay, with the output connecting back to the connection matrix.

This macrocell has also an optional Finite State Machine (FSM) function. There are two additional matrix inputs for Up and Keep to control the FSM.

This macrocell can operate in the one-shot mode, which generates an output pulse of user-defined width.

This macrocell can also operate in the frequency detection or edge detection mode.

The current counter value of 16-bit CNT/DLY11 and CNT/DLY12 can be stored in the Data Buffer0 and Data Buffer2, respectively (CNT/DLY11 → Data Buffer0 and CNT/DLY12 → Data Buffer2).

All possible multi-function macrocell (4-bit LUT or DFF/LATCH with 16-bit CNT/DLY/FSM) configurations and corresponding matrix outputs functions are shown in Table 19.

**Table 19. 4-bit LUT or DFF/LATCH with 16-bit CNT/DLY/FSM Macrocells Configuration**

| Function | CNT_EXT_CLK_SEL[1] | CNT_EXT_CLK_SEL[0] | LUT_DFF_SEL | MF_INT_CONN[1] | MF_INT_CONN[0] | MULTI_FUNC_SEL[1] | MULTI_FUNC_SEL[0] | In3 | In2 | In1 | In0 | D | nSET | nRST | CLK | DLY_IN | EXT_CLK | UP | KEEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Single 4-bit LUT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Matrix A | Matrix B | Matrix C | Matrix D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Single DFF with RST and SET | 0 | 0 | 1 | 0 | 0 | 0 | 0 | Matrix A | Matrix B | Matrix C | Matrix D | Matrix A | Matrix B | Matrix C | Matrix D | 0 | 0 | 0 | 0 |
| Single CNT/DLY | 0 | 0 | 0 | 0 | 0 | 0 | 1 | DLY_OUT | DLY_OUT | DLY_OUT | DLY_OUT | 0 | 0 | 0 | 0 | Matrix D | Matrix C | Matrix A | Matrix B |
| CNT/DLY → LUT | 0 | 0 | 0 | 0 | 0 | 1 | 0 | DLY_OUT | Matrix B | Matrix C | Matrix D | 0 | 0 | 0 | 0 | Matrix A | 0 | 0 | 0 |
| | 0 | 1 | 0 | 0 | 0 | 1 | 0 | DLY_OUT | 0 | Matrix C | Matrix D | 0 | 0 | 0 | 0 | Matrix A | Matrix B | 0 | 0 |
| | 1 | 0 | 0 | 0 | 0 | 1 | 0 | DLY_OUT | Matrix B | 0 | Matrix D | 0 | 0 | 0 | 0 | Matrix A | Matrix C | 0 | 0 |
| | 0 | 0 | 0 | 0 | 1 | 1 | 0 | Matrix A | DLY_OUT | Matrix C | Matrix D | 0 | 0 | 0 | 0 | Matrix B | 0 | 0 | 0 |
| | 1 | 0 | 0 | 0 | 1 | 1 | 0 | Matrix A | DLY_OUT | 0 | Matrix D | 0 | 0 | 0 | 0 | Matrix B | Matrix C | 0 | 0 |
| | 0 | 0 | 0 | 1 | 0 | 1 | 0 | Matrix A | Matrix B | DLY_OUT | Matrix D | 0 | 0 | 0 | 0 | Matrix C | 0 | 0 | 0 |
| | 0 | 1 | 0 | 1 | 0 | 1 | 0 | Matrix A | 0 | DLY_OUT | Matrix D | 0 | 0 | 0 | 0 | Matrix C | Matrix B | 0 | 0 |
| | 0 | 0 | 0 | 1 | 1 | 1 | 0 | Matrix A | Matrix B | Matrix C | DLY_OUT | 0 | 0 | 0 | 0 | Matrix D | 0 | 0 | 0 |

| Function | CNT_EXT_CLK_SEL[1] | CNT_EXT_CLK_SEL[0] | LUT_DFF_SEL | MF_INT_CONN[1] | MF_INT_CONN[0] | MULTI_FUNC_SEL[1] | MULTI_FUNC_SEL[0] | In3 | In2 | In1 | In0 | D | nSET | nRST | CLK | DLY_IN | EXT_CLK | UP | KEEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CNT/DLY → LUT | 0 | 1 | 0 | 1 | 1 | 1 | 0 | Matrix A | 0 | Matrix C | DLY_OUT | 0 | 0 | 0 | 0 | Matrix D | Matrix B | 0 | 0 |
| | 1 | 0 | 0 | 1 | 1 | 1 | 0 | Matrix A | Matrix B | 0 | DLY_OUT | 0 | 0 | 0 | 0 | Matrix D | Matrix C | 0 | 0 |
| CNT/DLY → DFF | 0 | 0 | 1 | 0 | 0 | 1 | 0 | DLY_OUT | Matrix B | Matrix C | Matrix D | DLY_OUT | Matrix B | Matrix C | Matrix D | Matrix A | 0 | 0 | 0 |
| | 0 | 1 | 1 | 0 | 0 | 1 | 0 | DLY_OUT | 1 | Matrix C | Matrix D | DLY_OUT | 1 | Matrix C | Matrix D | Matrix A | Matrix B | 0 | 0 |
| | 1 | 0 | 1 | 0 | 0 | 1 | 0 | DLY_OUT | Matrix B | 1 | Matrix D | DLY_OUT | Matrix B | 1 | Matrix D | Matrix A | Matrix C | 0 | 0 |
| | 0 | 0 | 1 | 0 | 1 | 1 | 0 | Matrix A | DLY_OUT | Matrix C | Matrix D | Matrix A | DLY_OUT | Matrix C | Matrix D | Matrix B | 0 | 0 | 0 |
| | 1 | 0 | 1 | 0 | 1 | 1 | 0 | Matrix A | DLY_OUT | 1 | Matrix D | Matrix A | DLY_OUT | 1 | Matrix D | Matrix B | Matrix C | 0 | 0 |
| | 0 | 0 | 1 | 1 | 0 | 1 | 0 | Matrix A | Matrix B | DLY_OUT | Matrix D | Matrix A | Matrix B | DLY_OUT | Matrix D | Matrix C | 0 | 0 | 0 |
| | 0 | 1 | 1 | 1 | 0 | 1 | 0 | Matrix A | 1 | DLY_OUT | Matrix D | Matrix A | 1 | DLY_OUT | Matrix D | Matrix C | Matrix B | 0 | 0 |
| | 0 | 0 | 1 | 1 | 1 | 1 | 0 | Matrix A | Matrix B | Matrix C | DLY_OUT | Matrix A | Matrix B | Matrix C | DLY_OUT | Matrix D | 0 | 0 | 0 |
| | 0 | 1 | 1 | 1 | 1 | 1 | 0 | Matrix A | 1 | Matrix C | DLY_OUT | Matrix A | 1 | Matrix C | DLY_OUT | Matrix D | Matrix B | 0 | 0 |
| | 1 | 0 | 1 | 1 | 1 | 1 | 0 | Matrix A | 1 | 1 | DLY_OUT | Matrix A | 1 | 1 | DLY_OUT | Matrix D | Matrix C | 0 | 0 |
| LUT → CNT/DLY | 0 | 0 | 0 | 0 | 0 | 1 | 1 | Matrix A | Matrix B | Matrix C | Matrix D | 0 | 0 | 0 | 0 | LUT_OUT | 0 | 0 | 0 |
| | 0 | 1 | 0 | 0 | 0 | 1 | 1 | Matrix A | 0 | Matrix C | Matrix D | 0 | 0 | 0 | 0 | LUT_OUT | Matrix B | 0 | 0 |
| | 1 | 0 | 0 | 0 | 0 | 1 | 1 | Matrix A | Matrix B | 0 | Matrix D | 0 | 0 | 0 | 0 | LUT_OUT | Matrix C | 0 | 0 |
| DFF → CNT/DLY | 0 | 0 | 1 | 0 | 0 | 1 | 1 | Matrix A | Matrix B | Matrix C | Matrix D | Matrix A | Matrix B | Matrix C | Matrix D | DFF_OUT | 0 | 0 | 0 |
| | 0 | 1 | 1 | 0 | 0 | 1 | 1 | Matrix A | 1 | Matrix C | Matrix D | Matrix A | 1 | Matrix C | Matrix D | DFF_OUT | Matrix B | 0 | 0 |
| | 1 | 0 | 1 | 0 | 0 | 1 | 1 | Matrix A | Matrix B | 1 | Matrix D | Matrix A | Matrix B | 1 | Matrix D | DFF_OUT | Matrix C | 0 | 0 |

The user can optionally enable the Data Buffers synchronization (registers BUF0_LOAD_SYNC [2793:2792], BUF2_LOAD_SYNC [2797:2796]) to guarantee the correct counter data to be loaded into the Data Buffers. Please note that synchronization option will add a latency of one or two counter clocks to Data Buffer output (see Figure 64, Figure 65).

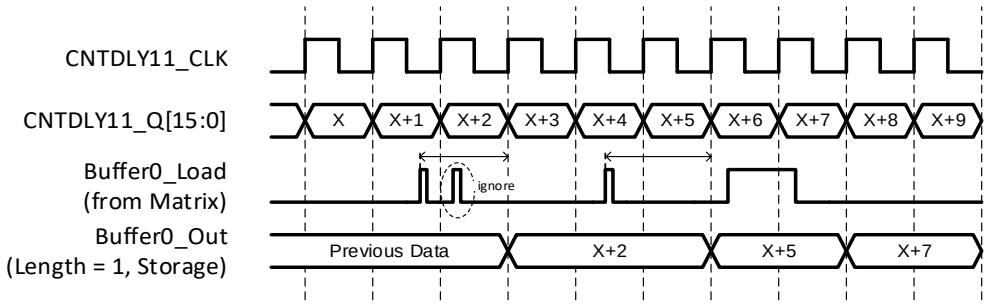



**Figure 64. Data Buffer0 Synchronization Option Enabled**

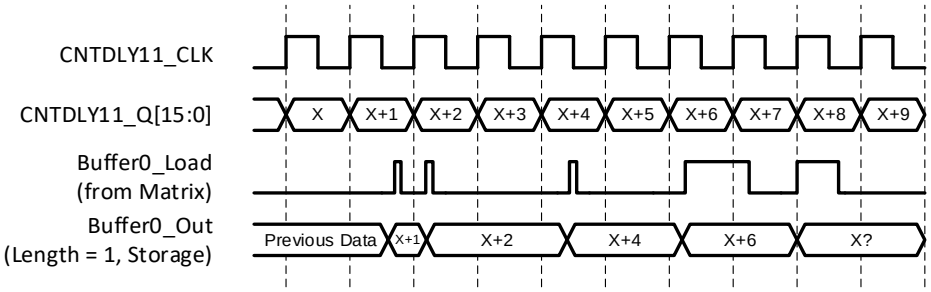



**Figure 65. Data Buffer0 Synchronization Option Disabled. X Data Options: (X + 7), (X + 8), Transition Data**

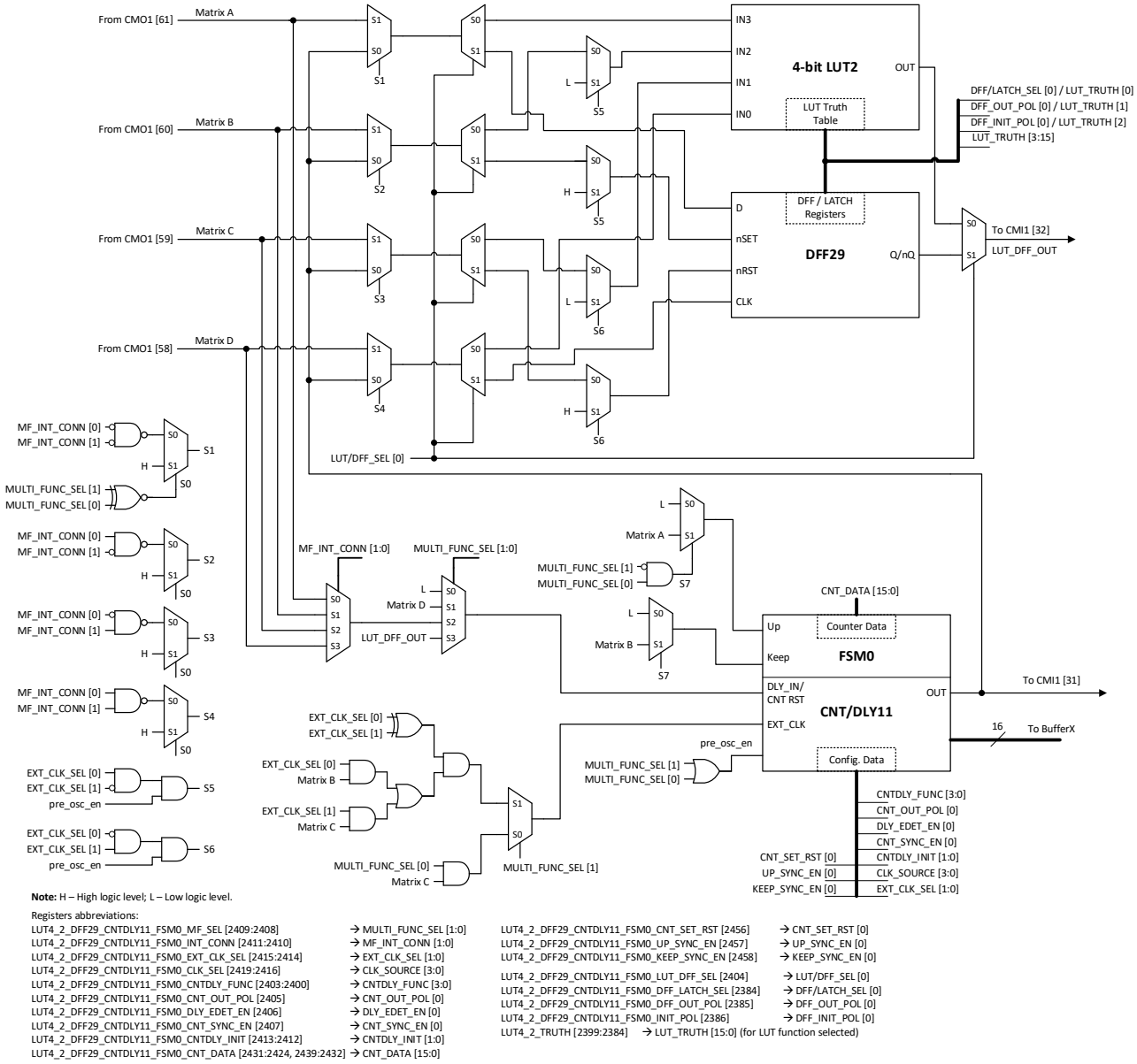
The user can read the CNT macrocell active count value via I²C/SPI. See section 25.2 Reading Current Counter Value via I2C/SPI for details.

**Note**: After two DFFs – counters initialize with counter data = 0 after POR.

Initial state = 1 – counters initialize with counter data = 0 after POR.

Initial state = 0 and after two DFFs are bypassed – counters initialize with counter data after POR.

**Note:** If counter Rising Edge Reset option is used, it is recommended: 1) to use “After two DFFs” setting of CNT mode synchronization; 2) spread CNT clock and Reset, Keep, Up signals over time.

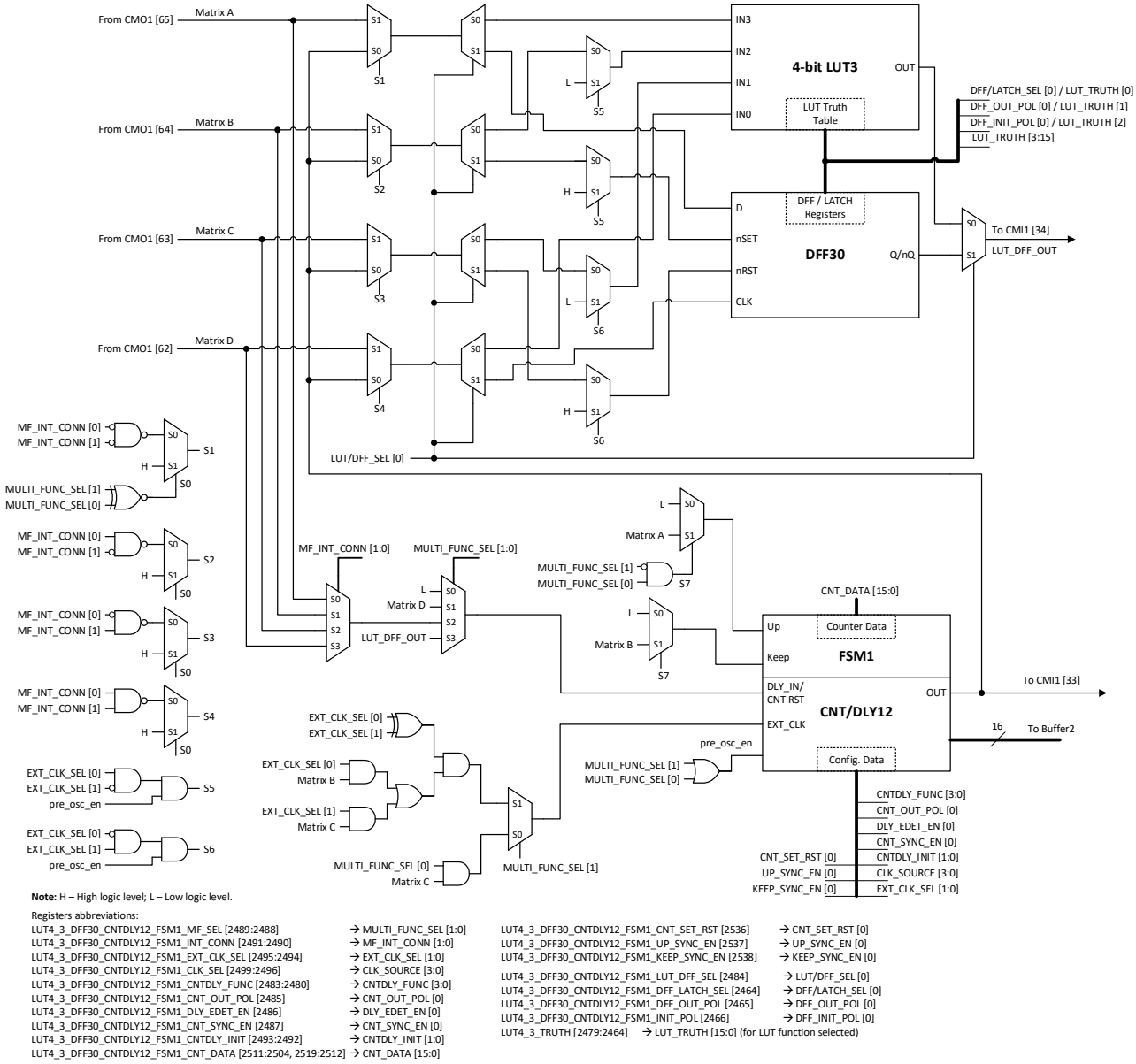



**Note:** H – High logic level; L – Low logic level.

Registers abbreviations:

| | |
|---|---|
| LUT4_2_DFF29_CNTDLY11_FSM0_MF_SEL [2409:2408] | → MULTI_FUNC_SEL [1:0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_INT_CONN [2411:2410] | → MF_INT_CONN [1:0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_EXT_CLK_SEL [2415:2414] | → EXT_CLK_SEL [1:0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_CLK_SEL [2419:2416] | → CLK_SOURCE [3:0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_CNTDLY_FUNC [2403:2400] | → CNTDLY_FUNC [3:0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_CNT_OUT_POL [2405] | → CNT_OUT_POL [0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_DLY_EDET_EN [2406] | → DLY_EDET_EN [0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_CNT_SYNC_EN [2407] | → CNT_SYNC_EN [0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_CNTDLY_INIT [2413:2412] | → CNTDLY_INIT [1:0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_CNT_DATA [2431:2424, 2439:2432] | → CNT_DATA [15:0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_CNT_SET_RST [2456] | → CNT_SET_RST [0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_UP_SYNC_EN [2457] | → UP_SYNC_EN [0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_KEEP_SYNC_EN [2458] | → KEEP_SYNC_EN [0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_LUT_DFF_SEL [2404] | → LUT/DFF_SEL [0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_DFF_LATCH_SEL [2384] | → DFF/LATCH_SEL [0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_DFF_OUT_POL [2385] | → DFF_OUT_POL [0] |
| LUT4_2_DFF29_CNTDLY11_FSM0_INIT_POL [2386] | → DFF_INIT_POL [0] |
| LUT4_2_TRUTH [2399:2384] | → LUT_TRUTH [15:0] (for LUT function selected) |

**Figure 66. 4-bit LUT2 or DFF29, or CNT/DLY11/FSM0 Macrocell**




**Note:** H – High logic level; L – Low logic level.

Registers abbreviations:

LUT4_3_DFF30_CNTDLY12_FSM1_MF_SEL [2489:2488] → MULTI_FUNC_SEL [1:0]
LUT4_3_DFF30_CNTDLY12_FSM1_INT_CONN [2491:2490] → MF_INT_CONN [1:0]
LUT4_3_DFF30_CNTDLY12_FSM1_EXT_CLK_SEL [2495:2494] → EXT_CLK_SEL [1:0]
LUT4_3_DFF30_CNTDLY12_FSM1_CLK_SEL [2499:2496] → CLK_SOURCE [3:0]
LUT4_3_DFF30_CNTDLY12_FSM1_CNTDLY_FUNC [2483:2480] → CNTDLY_FUNC [3:0]
LUT4_3_DFF30_CNTDLY12_FSM1_CNT_OUT_POL [2485] → CNT_OUT_POL [0]
LUT4_3_DFF30_CNTDLY12_FSM1_DLY_EDET_EN [2486] → DLY_EDET_EN [0]
LUT4_3_DFF30_CNTDLY12_FSM1_CNT_SYNC_EN [2487] → CNT_SYNC_EN [0]
LUT4_3_DFF30_CNTDLY12_FSM1_CNTDLY_INIT [2493:2492] → CNTDLY_INIT [1:0]
LUT4_3_DFF30_CNTDLY12_FSM1_CNT_DATA [2511:2504, 2519:2512] → CNT_DATA [15:0]
LUT4_3_DFF30_CNTDLY12_FSM1_CNT_SET_RST [2536] → CNT_SET_RST [0]
LUT4_3_DFF30_CNTDLY12_FSM1_UP_SYNC_EN [2537] → UP_SYNC_EN [0]
LUT4_3_DFF30_CNTDLY12_FSM1_KEEP_SYNC_EN [2538] → KEEP_SYNC_EN [0]
LUT4_3_DFF30_CNTDLY12_FSM1_LUT_DFF_SEL [2484] → LUT/DFF_SEL [0]
LUT4_3_DFF30_CNTDLY12_FSM1_DFF_LATCH_SEL [2464] → DFF/LATCH_SEL [0]
LUT4_3_DFF30_CNTDLY12_FSM1_DFF_OUT_POL [2465] → DFF_OUT_POL [0]
LUT4_3_DFF30_CNTDLY12_FSM1_INIT_POL [2466] → DFF_INIT_POL [0]
LUT4_3_TRUTH [2479:2464] → LUT_TRUTH [15:0] (for LUT function selected)

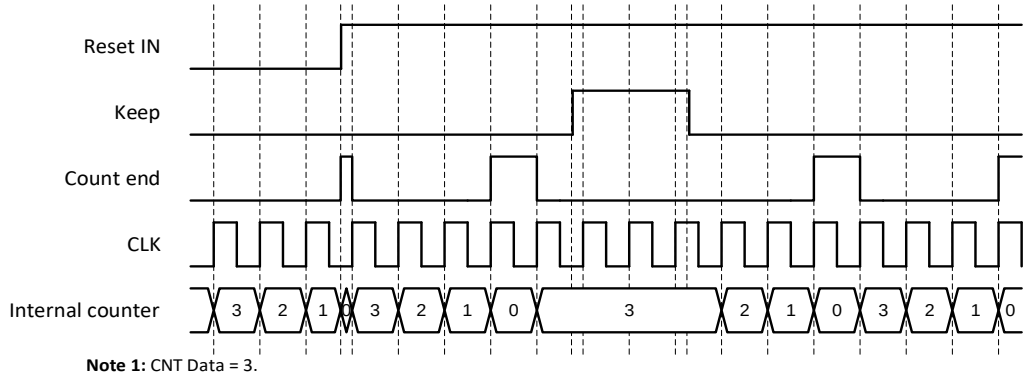
**Figure 67. 4-bit LUT3 or DFF30, or CNT/DLY12/FSM1 Macrocell**

## 8.3.2. 3-bit LUT or DFF/LATCH with 12-bit CNT/DLY/FSM Macrocell General Description

The SLG47011 features one multi-function macrocell that has a limited FSM functionality: 3-bit LUT24, DFF/LATCH28, CNT/DLY10/FSM2. This macrocell operates as the FSM macrocells described in section 8.3.1 4-bit LUT or DFF/LATCH with 16-bit CNT/DLY/FSM Macrocell General Description, with the exception that FSM2 macrocell has no Keep input (see Figure 51).

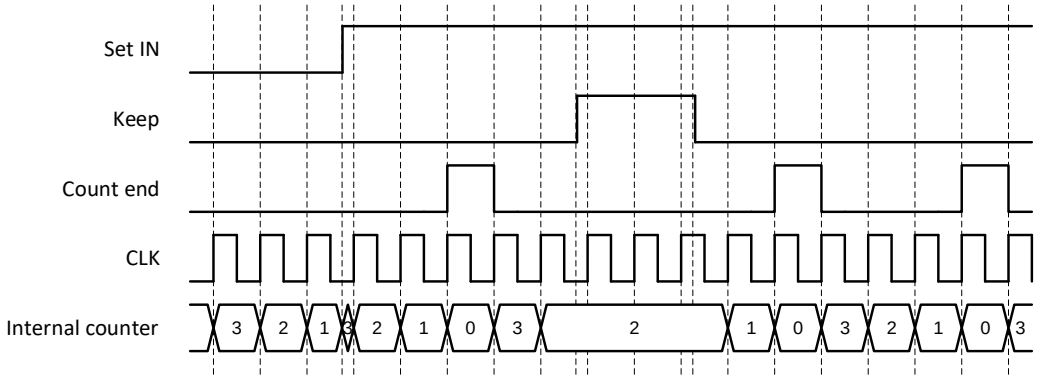
Also, CNT/DLY10/FSM2 macrocell is used as the PWM period counter. If PWM is enabled, the macrocell will be switched to the counter mode and the signals at the set/reset input of CNT/DLY10/FSM2 will be ignored.

## 8.4 CNT/FSM Mode (CNT/DLY10, CNT/DLY11, and CNT/DLY12) Timing Diagrams



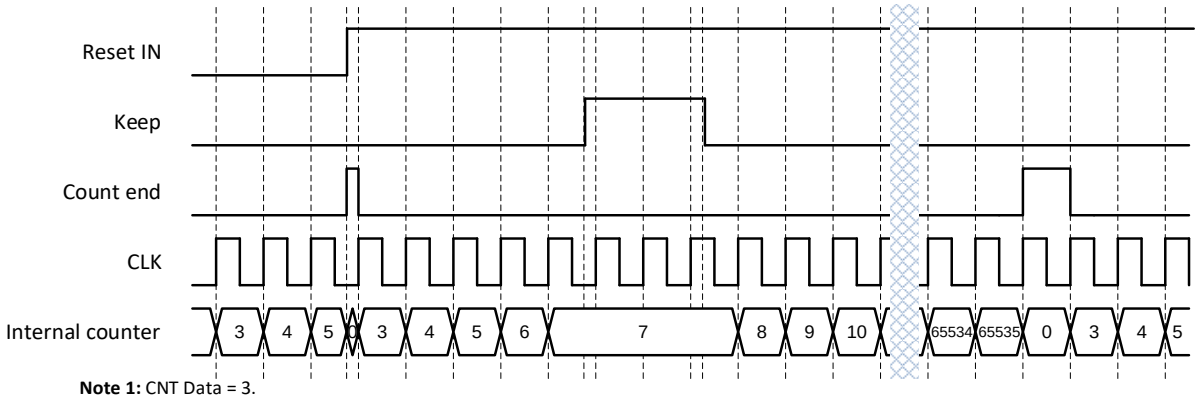

**Note 1:** CNT Data = 3.
**Note 2:** Q = current counter value.
**Note 3:** KEEP input is not available in FSM2.

**Figure 68. CNT/FSM Timing Diagram (Reset Rising Edge Mode, OSC is Forced On, UP = 0)**



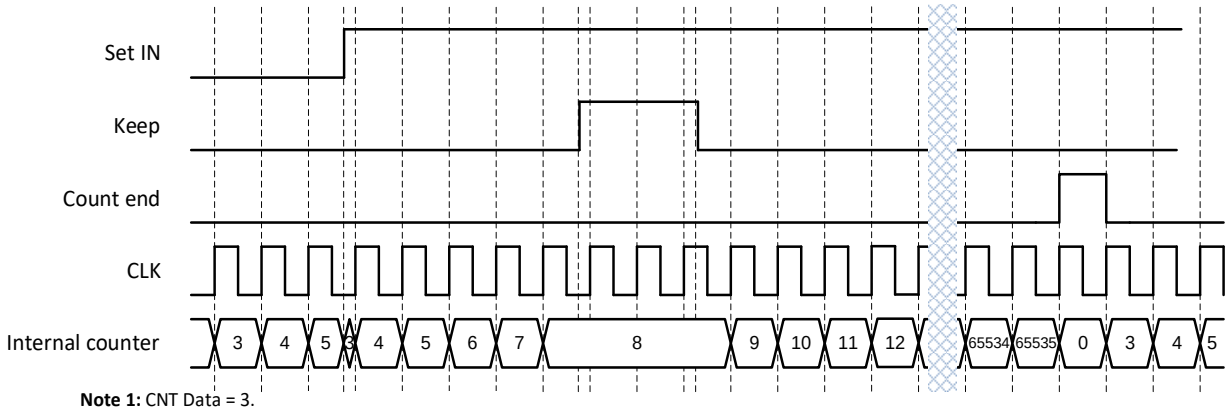

**Note 1:** CNT Data = 3.
**Note 2:** Q = current counter value.
**Note 3:** KEEP input is not available in FSM2.

**Figure 69. CNT/FSM Timing Diagram (Set Rising Edge Mode, OSC is Forced On, UP = 0)**



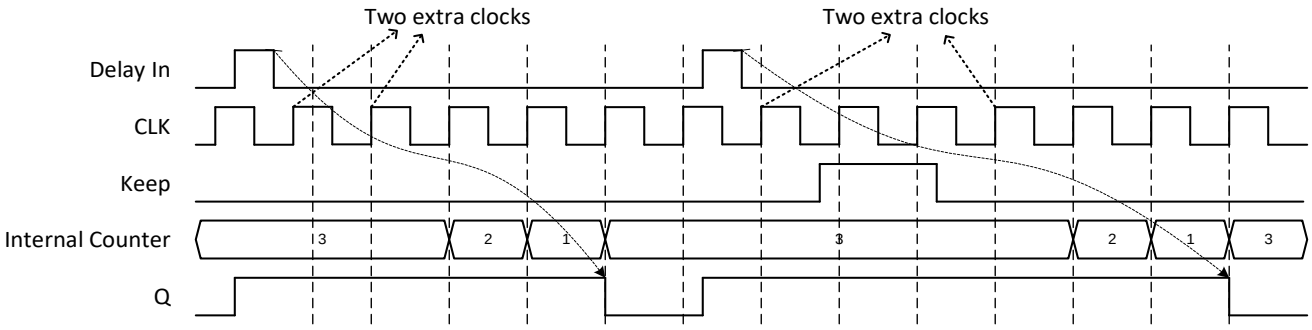

**Note 1:** CNT Data = 3.
**Note 2:** Q = current counter value.
**Note 3:** KEEP input is not available in FSM2.

**Figure 70. CNT/FSM Timing Diagram (Reset Rising Edge Mode, OSC is Forced On, UP = 1)**



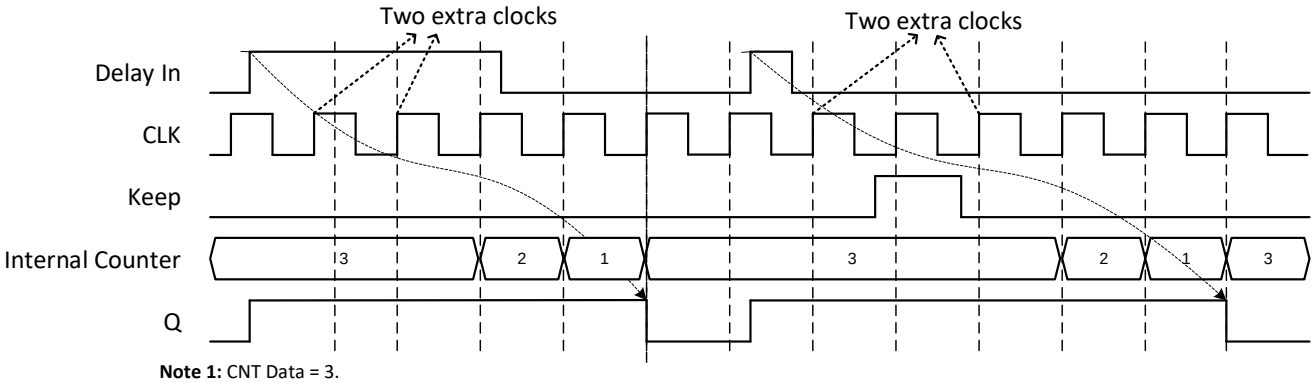

**Note 1:** CNT Data = 3.
**Note 2:** Q = current counter value.
**Note 3:** KEEP input is not available in FSM2.

**Figure 71. DLY/FSM Mode, Falling Edge Delay, OSC is Forced On, DFFs Synced Up, UP = 0**



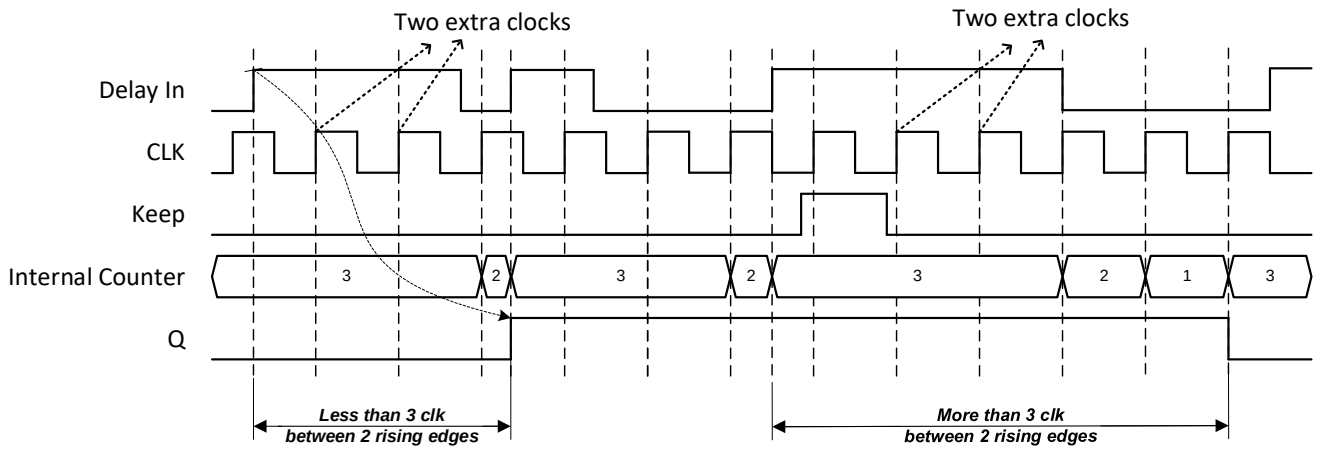

**Note 1:** CNT Data = 3.
**Note 2:** KEEP input is not available in FSM2.

**Figure 72. DLY/FSM Mode, Falling Edge Delay, OSC is Forced On, DFFs Synced Up, UP = 0**



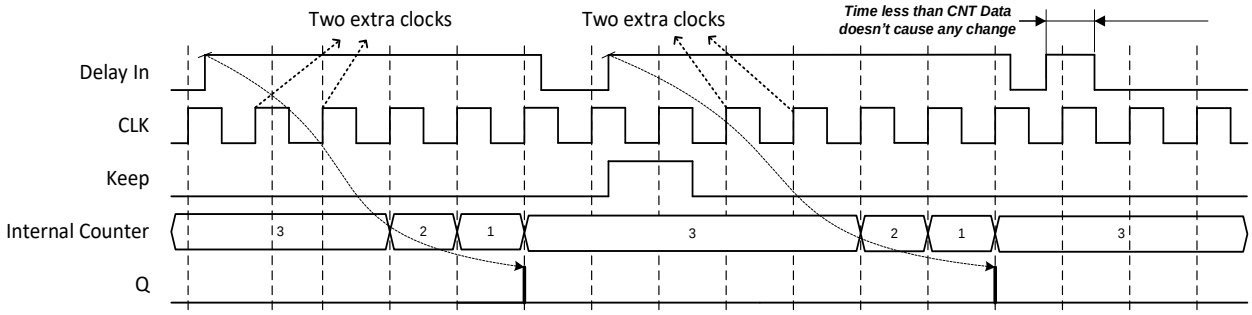

**Note 1:** CNT Data = 3.
**Note 2:** KEEP input is not available in FSM2.

**Figure 73. One-Shot/FSM Mode, Rising Edge, OSC is Forced On, DFFs Synced Up, UP = 0**




**Note 1:** CNT Data = 3.
**Note 2:** KEEP input is not available in FSM2.

**Figure 74. Frequency Detector/FSM Mode, Rising Edge, OSC is Forced On, DFFs Synced Up, UP = 0**




**Note 1:** CNT Data = 3.
**Note 2:** KEEP input is not available in FSM2.

**Figure 75. Delayed Edge Detector/FSM Mode, Rising Edge, OSC is Forced On, DFFs Synced Up, UP = 0**

## 8.5 12-bit Memory Control Counter

The SLG47011 features a macrocell that can operate as 12-bit Up/Down counter and provide an output signal to the connection matrix (see Figure 76). This macrocell can be used to control the address input of the Memory Table macrocell (see section 13 Memory Table Macrocell).

The Memory Control Counter inputs are as follows:

- **Clock**: Clock input to the macrocell. It can be an external signal (from the connection matrix) or the output signal from one of the internal oscillators.
- **Up/Down**: Controls if a CLK pulse either increments (Up/nDown = 1) or decrements (Up/nDown = 0) the current counter value of Memory Control Counter.
- **Reset/Set**: loads zero (Reset option) or default counter data (Set option) to the counter.
- **Keep/Range**: stops the counter (Keep option) or selects one of two operation ranges (Range option, when the Two Ranges mode is selected).

The counter value is readable via I²C/SPI. See section 25.2 Reading Current Counter Value via I2C/SPI for details.

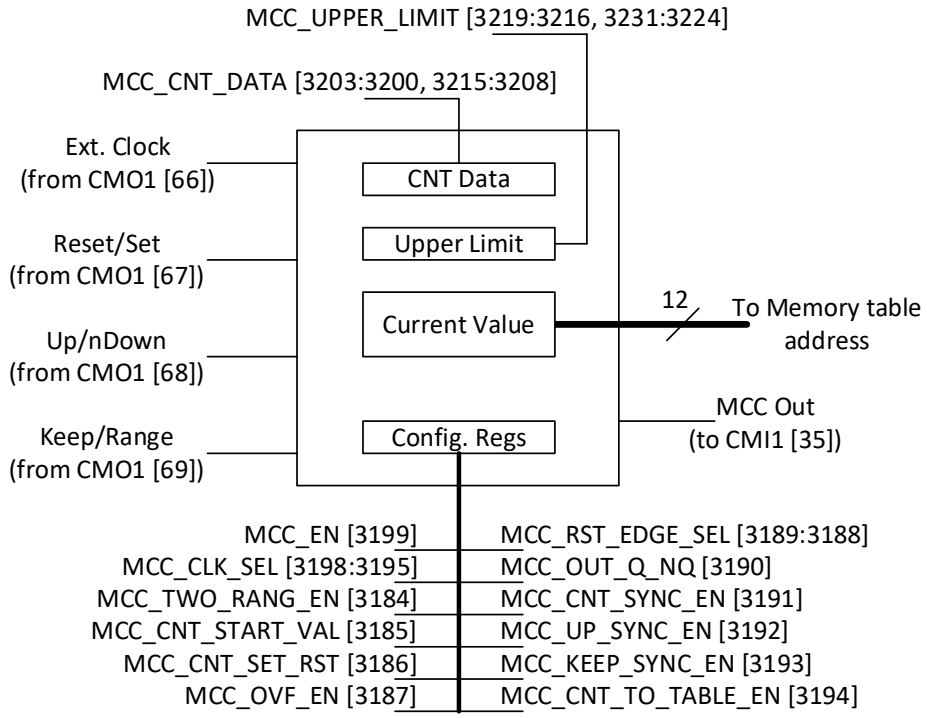



**Figure 76. 12-bit Memory Control Counter Macrocell**

### 8.5.1. Memory Control Counter Operation Modes

Every CLK pulse increments or decrements the Memory Control Counter. The Up/Down input is used to select between incrementing (HIGH) or decrementing (LOW) the counter.

The Memory Control Counter macrocell can operate in two basic modes:

- **Full Range Mode** (see Figure 79): set the register MCC_CNT_TWO_RANGES_EN [3184] = 0 to activate this mode. The counter value is ranged from 0 to the upper limit value defined by registers MCC_UPPER_LIMIT [3219:3216, 3231:3224]. The counter start value after power-up can be 0 or the CNT Data depending on register MCC_CNT_START_VAL [3185] (see Table 20). The Reset/Set input is used to either reset the current CNT value to 0 or set the current CNT value to CNT Data depending on register MCC_CNT_SET_RST [3186] setting. The CNT Data must not be larger than registers MCC_UPPER_LIMIT [3219:3216, 3231:3224].
- **Two Ranges Mode** (see Figure 82): to activate this mode, set the register MCC_CNT_TWO_RANGES_EN [3184] = 1. When this mode is active, the counter range is divided into two ranges. The 1st range is from 0 to CNT Data. The 2nd range ranges from (CNT Data + 1) to the upper limit defined by two registers MCC_UPPER_LIMIT [3219:3216] and MCC_UPPER_LIMIT[3231:3224]. In this mode the Keep/Range input is used to select the range. If Keep/Range is LOW, the counter will operate in the 1st range. If Keep/Range is HIGH, the counter will operate in the 2nd range. The counter start value after power-up is set by register MCC_CNT_START_VAL [3185] and the selected counter range (see Table 20).

If the Keep/Range input transitions from LOW to HIGH, the current counter value will be set to [CNT Data + 1] (if MCC_CNT_SET_RST [3186] = 0, Reset option) or set to the upper limit value (if MCC_CNT_SET_RST [3186] = 1, Set option), and the counter will operate in the 2nd range.

If Keep/Range goes from HIGH to LOW, the current counter value will be set to 0 (if MCC_CNT_SET_RST [3186] = 0, Reset option) or to CNT Data (if MCC_CNT_SET_RST [3186] = 1, Set option), and the counter will operate in the 1st range.

If the reset signal is sent to the Memory Control Counter macrocell and the “Reset to 0” option is chosen (MCC_CNT_SET_RST [3186] = 0), the current counter value loads 0 or (CNT Data + 1) depending on the operation range. If the reset signal comes to the Memory Control Counter macrocell and the “Set to CNT Data”

option is chosen (MCC_CNT_SET_RST [3186] = 1), the current counter value loads CNT Data or the upper limit value depending on the operation range.

The user has the option to select Overflow or Stop at Boundaries modes. If Overflow mode is selected (MCC_OVF_EN [3187] = 1), the counter will continue counting when reaching the boundaries.

**Table 20. Memory Control Counter Start Value**

| | Full Range Mode | Two Ranges Mode: Keep/Range = 0 (1st Range) | Two Ranges Mode: Keep/Range = 1 (2nd Range) |
|---|---|---|---|
| MCC_CNT_START_VAL [3185] = 0 | Initial value = 0 | Initial value = 0 | Initial value = (CNT Data + 1) [1] |
| MCC_CNT_START_VAL [3185] = 1 | Initial value = CNT Data | Initial value = CNT Data | Initial value = MCC_UPPER_LIMIT [3219:3216, 3231:3224] |

**[1]** Restrictred if MCC_OVF_EN [3187] = 1, MCC_CNT_TWO_RANGES_EN [3184] = 1, MCC_CNT_START_VAL [3185] = 1, and Keep/Range (CMO1[69]) = HIGH.

**[2]** The behavior of MCC first period after POR event will be different.

If Memory Control Counter is functioning in Two Ranges mode with Memory Table Macrocell, its operation is different from the case, when MCC is operating as standalone counter (see Table 21).

**Table 21. Memory Control Counter Operation in Two Ranges Mode with Memory Table**

| Up/Down | MCC_CNT_START_VAL | Keep/Range | MCC_OVF_EN = 1 | MCC_OVF_EN = 0 |
|---|---|---|---|---|
| 1 | 0 | 0 | 0, 1, 2, …, CNT_data, 0, 1, 2,… | 0, 1, 2, …, CNT_data |
| | | 1 | N/A | CNT_data+1, CNT_data+2,…, MCC_UPPER_LIMIT |
| | 1 | 0 | CNT_data, 0, 1, 2, …, CNT_data, 0, 1, 2,… | CNT_data |
| | | 1 | MCC_UPPER_LIMIT, CNT_data+1, CNT_data+2,…, MCC_UPPER_LIMIT-1, MCC_UPPER_LIMIT, CNT_data+1, … | MCC_UPPER_LIMIT |
| 0 | 0 | 0 | 0, CNT_data, CNT_data-1, …, 0, CNT_data, CNT_data-1, … | 0 |
| | | 1 | N/A | CNT_data+1 |
| | 1 | 0 | CNT_data, CNT_data-1, …, 0, CNT_data, CNT_data-1, … | CNT_data, CNT_data-1, …, 0 |
| | | 1 | MCC_UPPER_LIMIT, MCC_UPPER_LIMIT-1, …, CNT_data+1, MCC_UPPER_LIMIT, MCC_UPPER_LIMIT-1, … | MCC_UPPER_LIMIT, MCC_UPPER_LIMIT-1, …, CNT_data+1 |

**[1]** The behavior of MCC first period after POR event will be different.

Example: the counter operates in Two Ranges mode and the 2nd range is selected, CNT Data = 250, MCC_UPPER_LIMIT = 1000, MCC_CNT_START_VAL = 1 (starts from MCC_UPPER_LIMIT), MCC_OVF_EN [3187] = 1 (overflow). If the counter counts up, then the current counter value will be: 1000, 251, 252, …, 999, 1000, 251, 252, and others. If the counter counts down, the current counter value will be: 1000, 999, …, 251, 1000, 999, and others.

Example: the counter operates in Full Range mode, CNT Data = 250, MCC_UPPER_LIMIT = 1000, MCC_CNT_START_VAL [3185] = 0 (starts from 0), MCC_OVF_EN [3187] = 1 (overflow), MCC is operating with Memory Table macrocell. If the counter counts down, then the current counter value will be: 0, 1000, 999, …, 2, 1, 0, 1000, and others. If the counter counts up, then the current counter value will be 0, 1, …, 999, 1000, 0, 1, and others.

If Stop at Boundaries mode is selected (MCC_OVF_EN [3187] = 0) and the counter operates in Full Range mode, then the counter will stop at 0 or at the upper limit MCC_UPPER_LIMIT. If Stop at Boundaries mode is selected (MCC_OVF_EN [3187] = 0) and the counter operates in Two Ranges mode, then the counter will stop at 0 or CNT Data when operating in the 1st range. If Stop at Boundaries mode is selected (MCC_OVF_EN [3187] = 0) and the counter operates in Two Ranges mode, then the counter will stop at (CNT Data + 1) or the upper limit when operating in the 2nd range.

The Memory Control Counter output to the connection matrix is HIGH if:

- counter value reaches 0 (zero) in Full Range mode
- counter value reaches 0 when operating in the 1st range of Two Ranges mode
- counter value reaches (CNT Data + 1) when operating in the 2nd range of Two Ranges mode.

If the counter counts up and the overflow option is enabled (MCC_OVF_EN [3187] = 1), the connection matrix output MCC Out (CMI1 [35]) can be used to observe the counter overflow events.

Note that changing registers MCC_CNT_DATA [3203:3200, 3215:3208], MCC_UPPER_LIMIT [3219:3216, 3231:3224], MCC_CNT_TWO_RANGES_EN [3184], MCC_CNT_START_VAL [3185], or MCC_OVF_EN [3187] with I²C/SPI during the counter operation may lead to undefined counter behavior.

Maximum clock speed for the Memory Control Counter is 20 MHz when operating with the Memory Table.

The MCC function is enabled/disabled by the MCC_EN [3199] register. If MCC_en is set to 1, the MCC will start to request the corresponding clock. If the user does not want to use the MCC, this register should be set to 0 to save power.

### 8.5.2. Controlling the Memory Table Macrocell Address with the Memory Control Counter

The Memory Control Counter macrocell can be used to control the input address of the Memory Table macrocell (see Figure 77). To activate this mode, MEM_ADDR_SEL [2732:2729] must be set to 7h (see section 13 Memory Table Macrocell). In this mode, the current counter value of the Memory Control Counter macrocell is the input address to the Memory Table.

In memory control mode (MEM_ADDR_SEL [2732:2729] = 7h), the address range and, consequently, the current counter value can be a number in a range from 0 to the upper limit value defined by MCC_UPPER_LIMIT [3219:3216, 3231:3224]. For correct operation of the Memory Table, the maximum allowable value of MCC_UPPER_LIMIT [3219:3216, 3231:3224] is 4095 (0xFFF).

The timing diagram of the Memory Table Address controlled by the Memory Control Counter is shown in Figure 78.

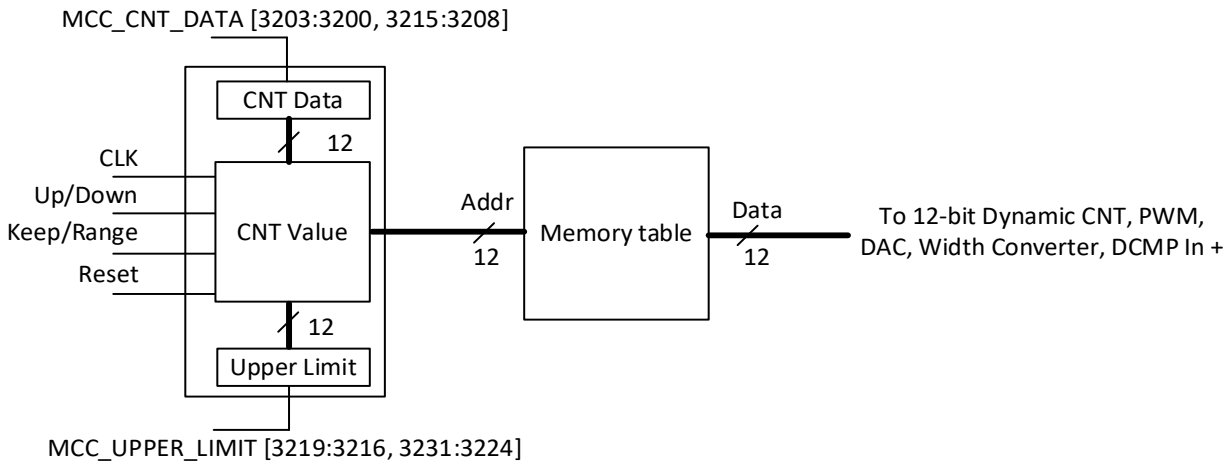



**Figure 77. Memory Control Counter Configuration to Control Memory Table**

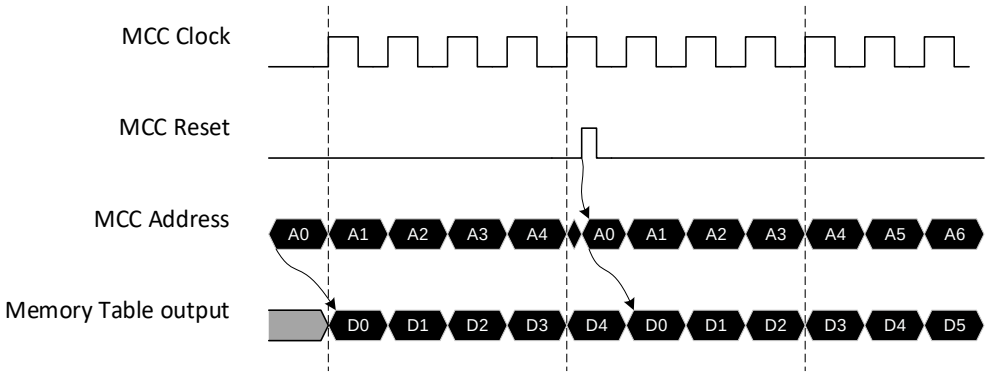
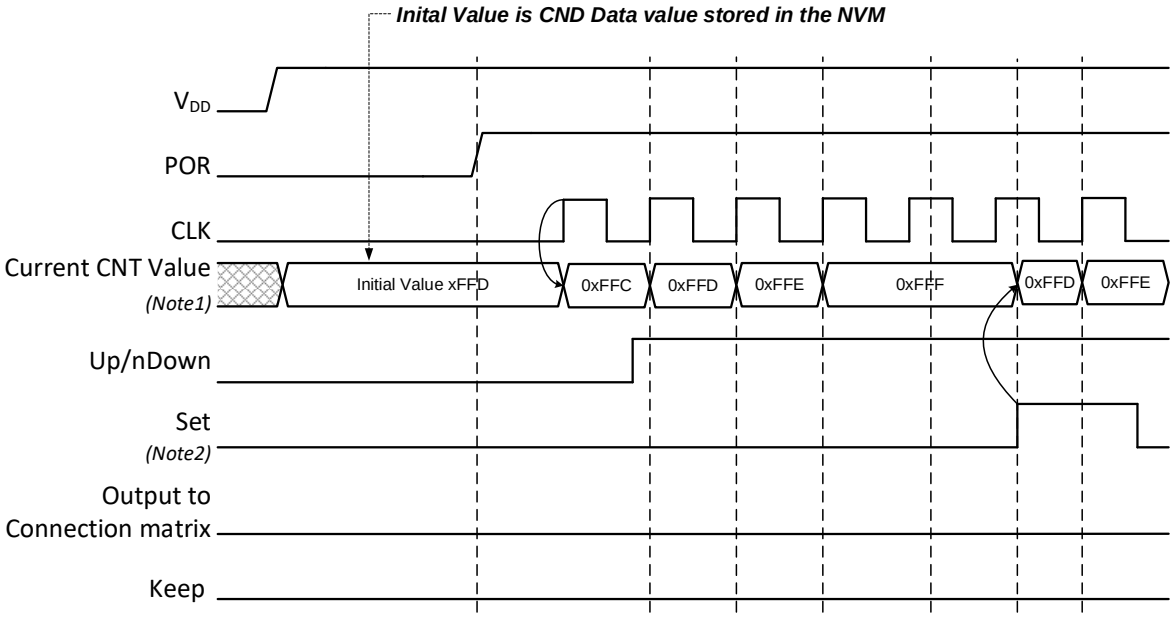



**Figure 78. Memory Table Address Controlling with Memory Control Counter**

## 8.5.3. Controlling the Width Converter Output

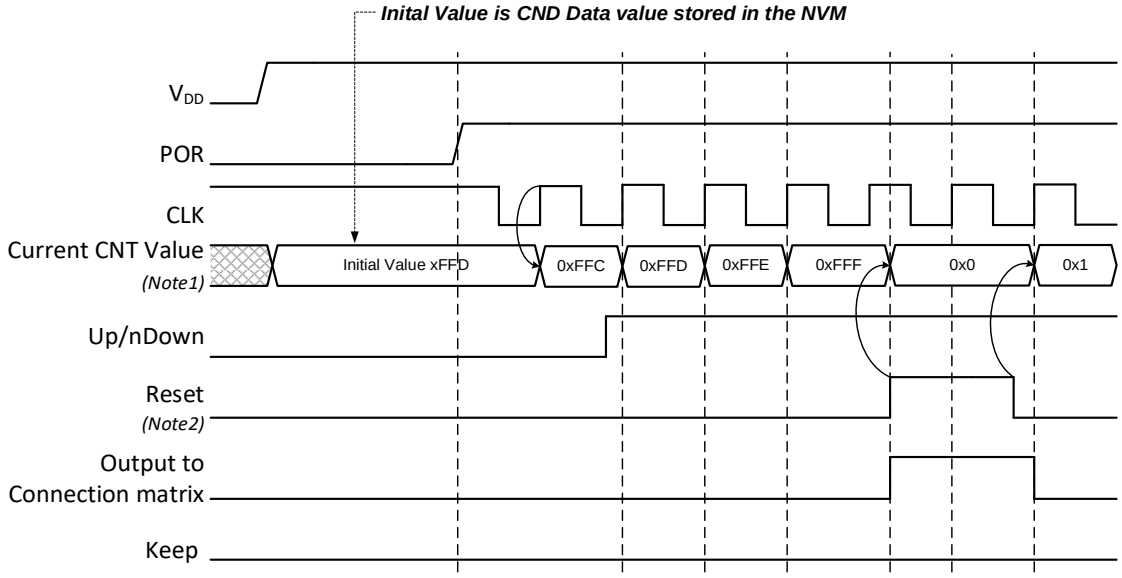
To control the Width Converter output, the Memory Control Counter is used in combination with the Memory Table. If the Width Converter is enabled, the clock for the Memory Control Counter will come from the Width Converter and will depend on the Width Converter setting (see section 18 Width Converter Macrocell). All other features and behavior of the Memory Control Counter remain the same in this mode.

## 8.5.4. Memory Control Counter Timing Diagrams



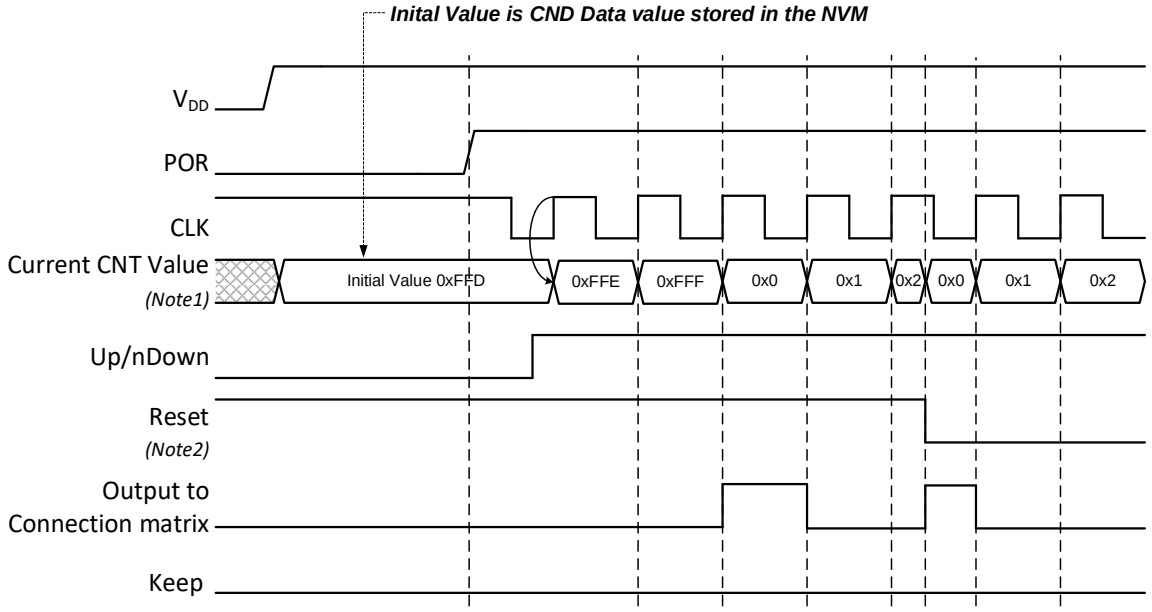

**Note 1:** Start from CNT Data. Full range mode. Stop at boundaries option enabled.
Start value is CNT Data = 0xFFD. Upper limit value = 0xFFF.
**Note 2:** Set to CNT Data option. Rising edge activated set signal.

**Figure 79. Memory Control Counter in Full Range Mode. Rising Edge Set Option**



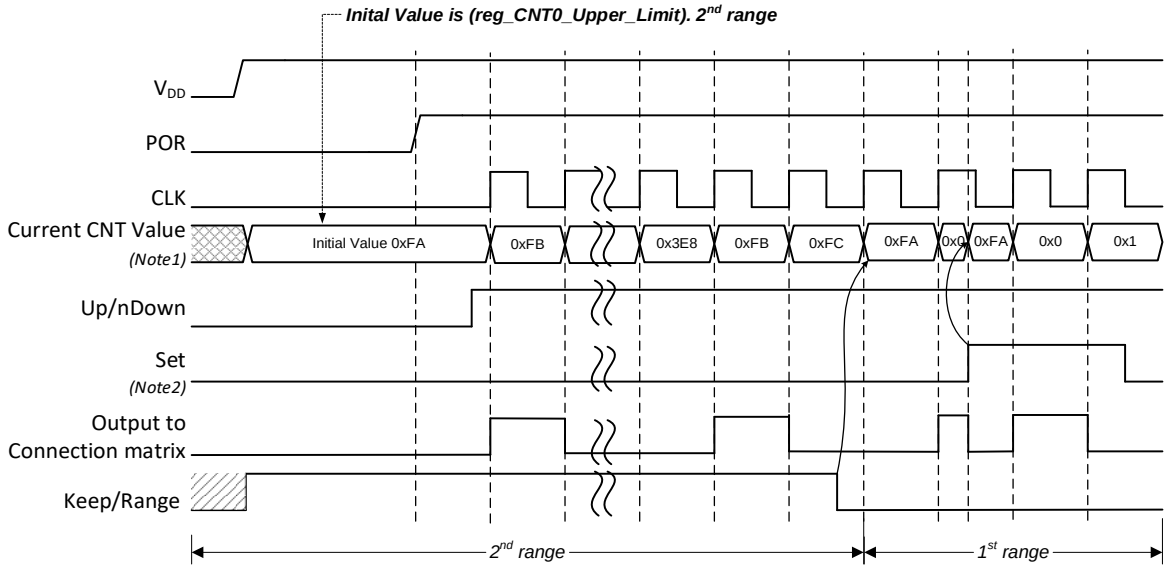

**Note 1:** Start from CNT Data. Full range mode. Stop at boundaries option enabled.
Start value is CNT Data = 0xFFD. Upper limit value = 0xFFF.
**Note 2:** Reset to 0 option. High level reset.

**Figure 80. Memory Control Counter in Full Range Mode. High Level Reset Option**




**Note 1:** Start from CNT Data. Full range mode. Stop at boundaries option disabled (overflow mode). Start value is CNT Data = 0xFFD. Upper limit value = 0xFFF.
**Note 2:** Reset to 0 option. Falling edge reset.

**Figure 81. Memory Control Counter in Full Range Mode, Operation with Memory Table. Falling Edge Reset Option**




**Note 1:** Two ranges mode. Stop at boundaries option disabled. Start from CNT Data option. CNT Data = 0xFA. Upper limit value = 0x3E8.
**Note 2:** Set to CNT Data option. Rising edge activated Set.

**Figure 82. Memory Control Counter in Two Ranges Mode. Rising Edge Set Option**

**Note:** The change of Memory Control Counter data during operation is prohibited. Counter data must be loaded before the start of operation.

## 8.6 12-bit CNT/DLY9 Macrocell Dynamic Counter Data Change

The counter data for the 12-bit CNT/DLY9 macrocell can be dynamically changed with the data from the Memory Table macrocell (see Figure 50). This mode is disabled by default and can be activated by setting register LUT3_23_DFF27_CNTDLY9_DATA_SRC_SEL [2284] = 1 (see Figure 83).

At power-up, 12-bit CNT/DLY9 always loads its default CNT Data value from the NVM (registers LUT3_23_DFF27_CNTDLY9_CNT_DATA [2291:2288, 2303:2296]). New data will be loaded from the Memory Table to the CNT data after each CLK pulse at the Load input (see Figure 84).

**Note:** If CNT/DLY9 is used in delay mode, OSC1 should be powered ON before the Load signal is applied.

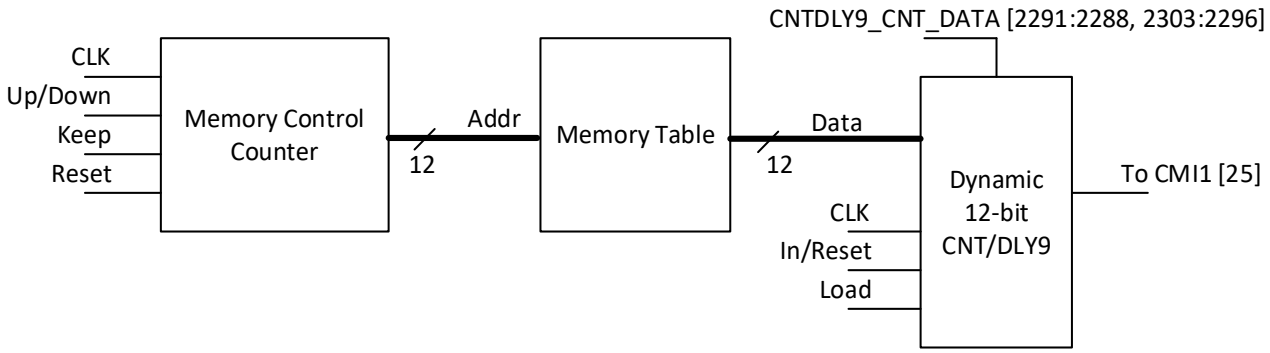



**Figure 83. Recommended Configuration for Dynamically Changed CNT Data Value**

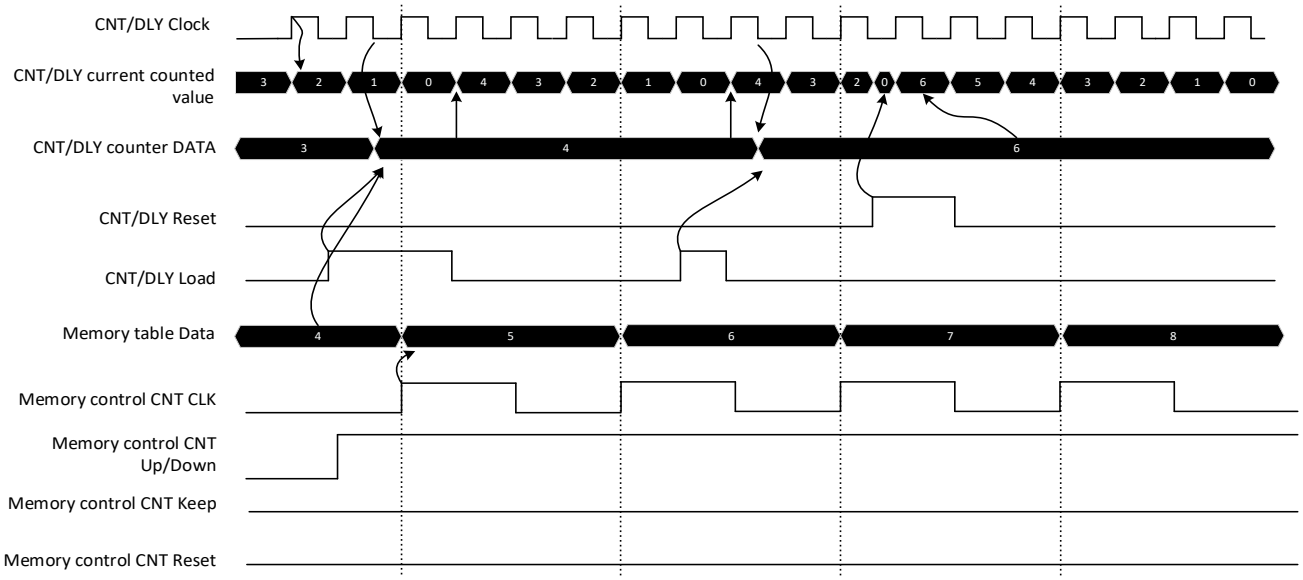



**Figure 84. Dynamic Counter Data Change Example**

# 9. Analog Comparator Macrocell

## 9.1 Analog Comparator General Description

The SLG47011 features a High Speed Rail-to-Rail General Purpose Analog Comparator (ACMP) macrocell. For the ACMP macrocell to be used in a GreenPAK design, the power-up signals (ACMPH PWR UP) need to be active. It is possible to have the ACMP be continuously ON, continuously OFF, or switched on periodically based on a digital signal coming from the connection matrix. If the ACMP is powered down (OFF), its output will be LOW.

The ACMP's positive input can be driven by a variety of external sources and can also have a selectable gain stage (1x, 0.5x, 0.33x, 0.25x) in its signal path. The gain divider is unbuffered and has input resistance (shown in section 3.7 Analog Comparator Specifications).

The ACMP's negative input is either driven by an internal $V_{REF}$ or provided by any external source (GPIO10). Note that the external $V_{REF}$ signal is filtered with a 2nd order low pass filter with 300 kHz typical bandwidth, see Figure 85.

The ACMP's Input bias current is less than 1 nA (typ). The PWR_UP signal determines the power state of the ACMP: if PWR_UP = 1, the ACMP will be powered up, if PWR_UP = 0, the ACMP will be powered down.

During power-up, the ACMP output will remain LOW, and then become valid after power-up signal transitions HIGH (see parameter $t_{start}$ in section 3.7 Analog Comparator Specifications).

Input LPF (Low Pass Filter) at the positive input, and Output LPF at the ACMP's output can be enabled using register ACMPH_INLPF_EN [3304] and register ACMPH_OUTLPF_EN [3305].

The possible ACMPH IN+ sources are GPIO, analog MUX GPIO9, $V_{DD}$, and temperature sensor.

The possible ACMPH IN- sources are GPIO, internal $V_{REF}$, and DAC Out.

Please allow for sufficient settling time when changing the ACMP input dynamicly.

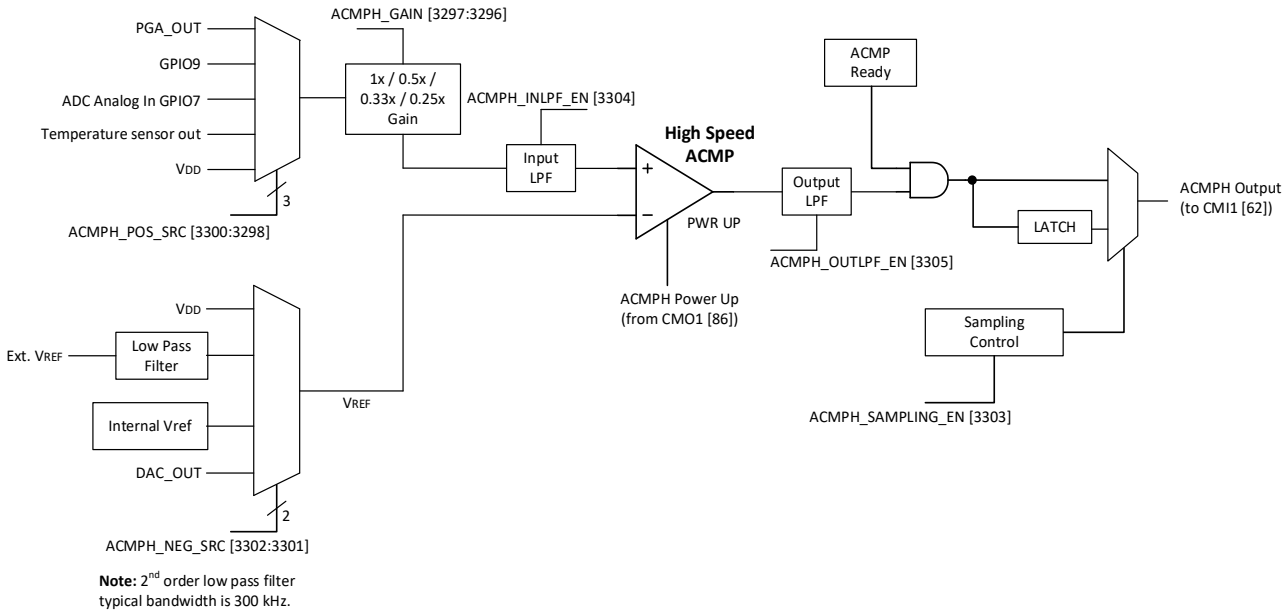



**Figure 85. ACMPH Block Diagram**

## 9.2 Analog Comparator Sampling Mode

The analog comparator features an optional Sampling mode. In this mode, the ACMP is enabled to process its analog inputs in the shortest amount of time after the rising edge at the power-up input. Then the ACMP latches its value and enters Power-Off mode (OFF) automatically.

Register ACMPH_SAMPLING_EN [3303] enables Sampling mode for the comparator.

## 9.3 ACMPH Typical Performance

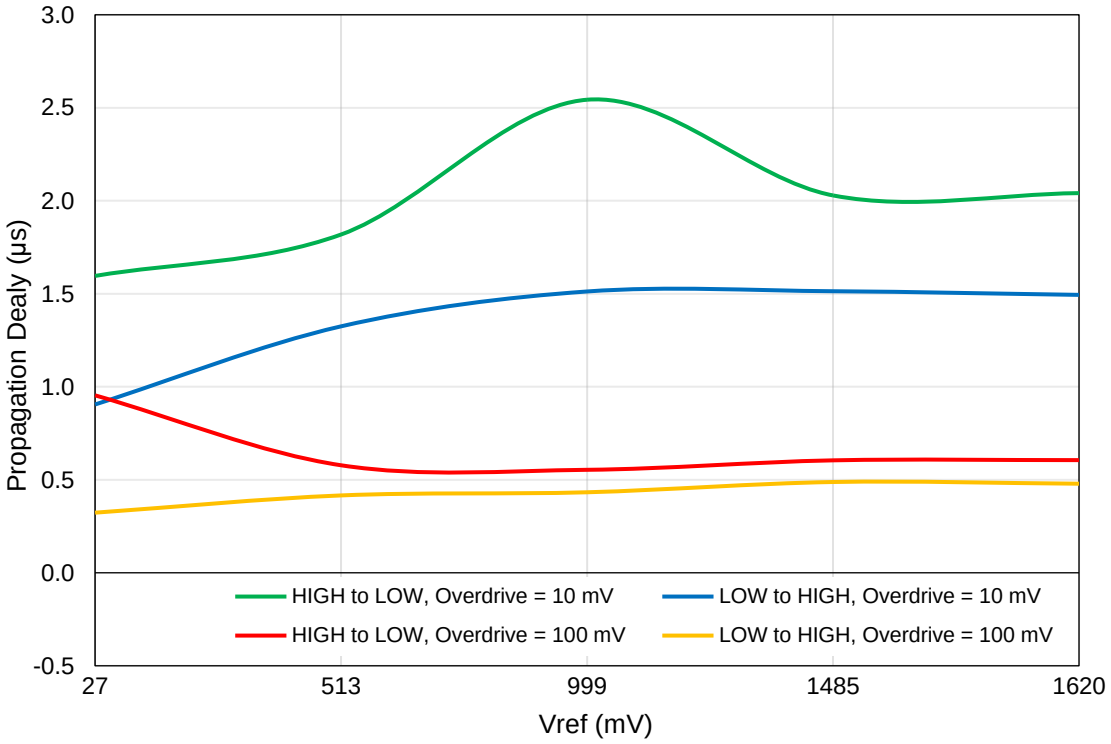



**Figure 86. Propagation Delay vs. $V_{REF}$ for ACMPH at $T_A$ = +25 °C, $V_{DD}$ = 1.71 V to 3.6 V**

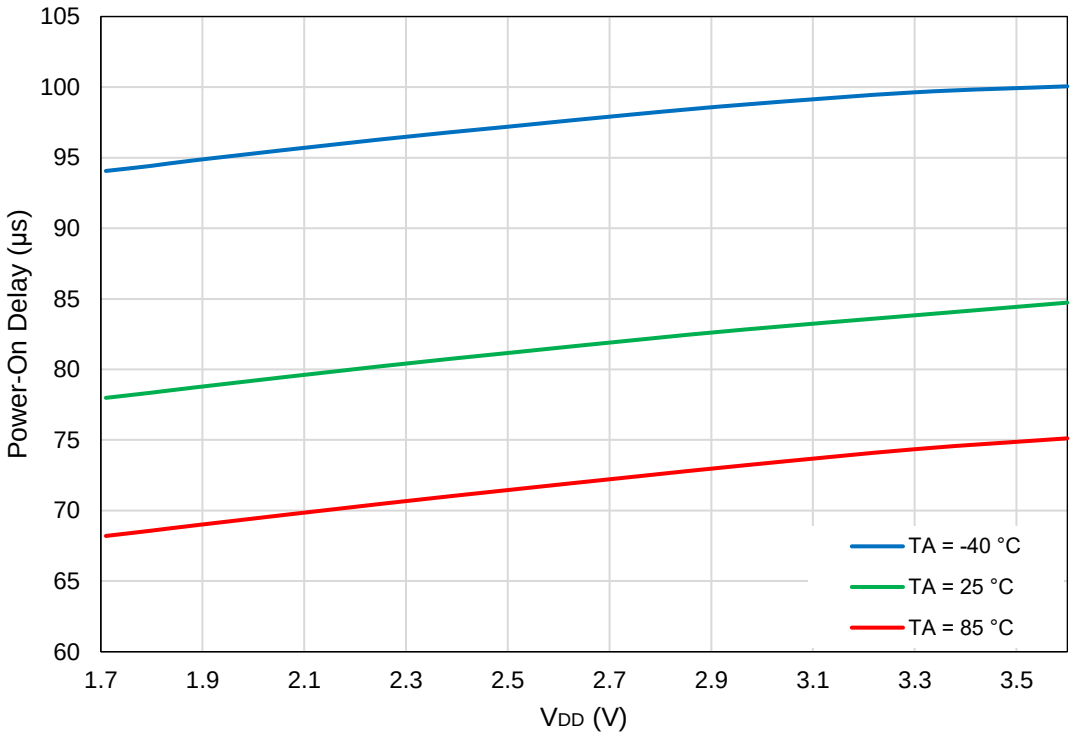



**Figure 87. ACMPH Power-On Delay vs. $V_{DD}$ at $V_{REF}$ – Forced OFF**

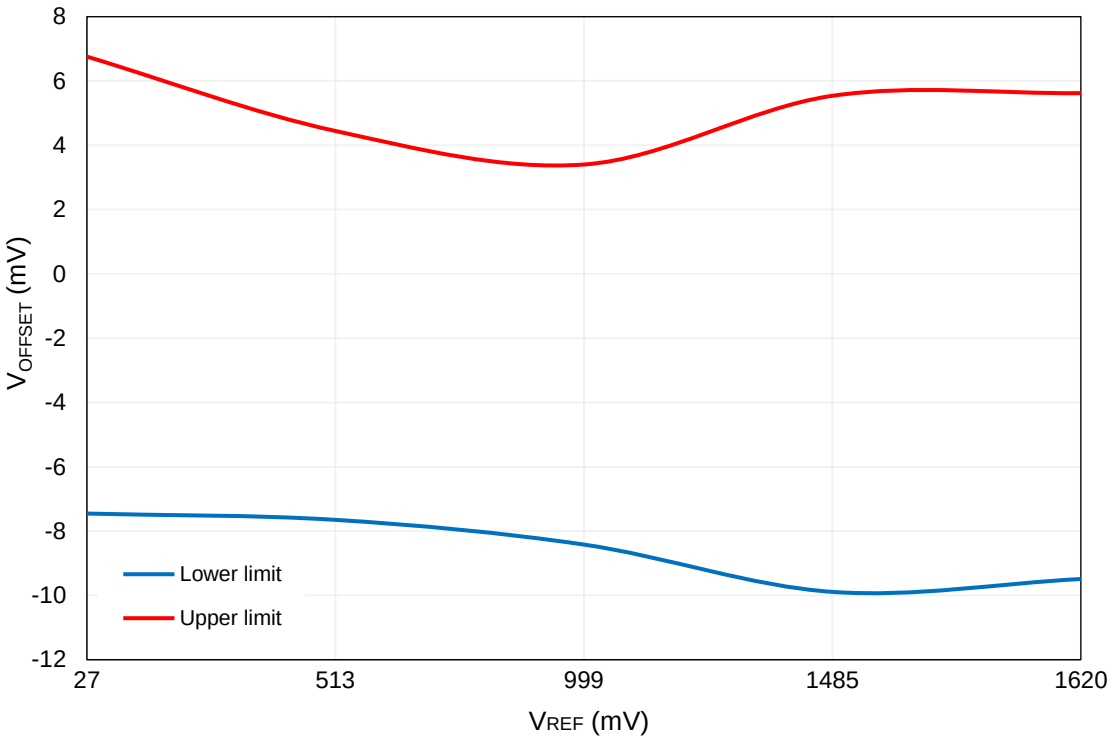



**Figure 88. ACMPH Input Offset Voltage vs. External $V_{REF}$ at $T_A$ = -40 °C to 85 °C, $V_{DD}$ = 1.71 V to 3.6 V**

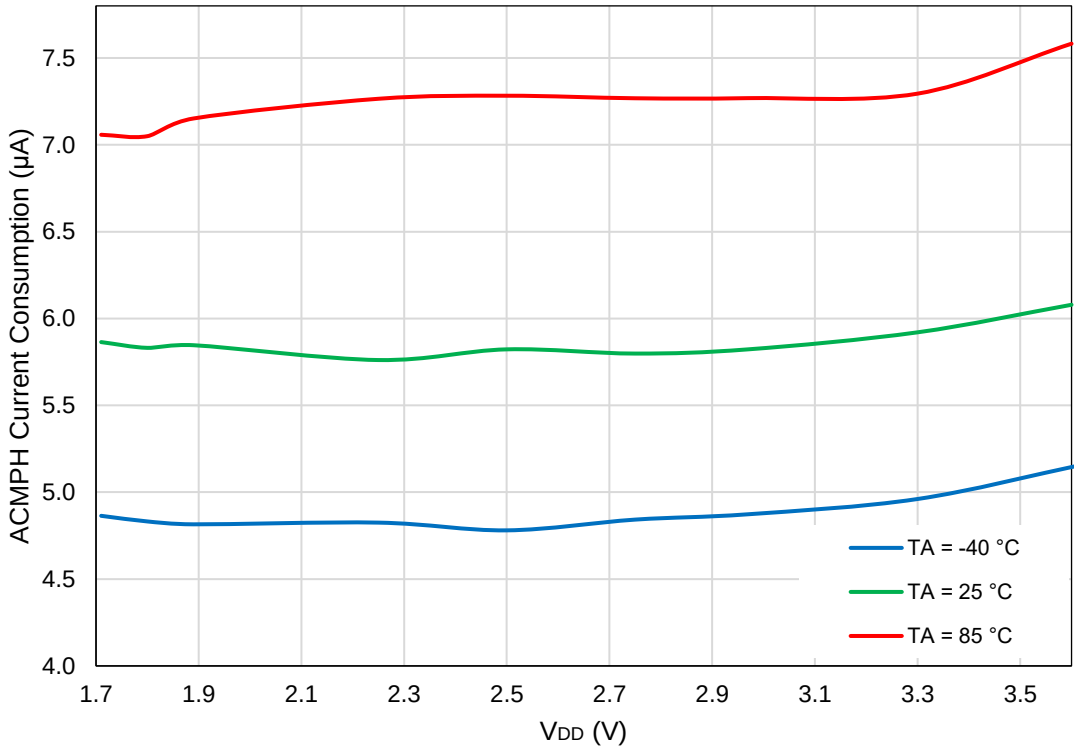



**Figure 89. ACMPH Current Consumption vs. $V_{DD}$**

# 10. Programmable Gain Amplifier Macrocell

## 10.1 PGA General Description

The Programmable Gain Amplifier (PGA) macrocell of the SLG47011 (see Figure 91 and Figure 107) allows to amplify signals or to interface a sensor with a high output impedance. The PGA has a 3-bit gain selection. Possible gain settings are PGA bypass, 1x, 2x, 4x, 8x, 16x, 32x, and 64x. PGA can by bypassed, and signals can be measured directly by ADC.

PGA allows to operate with up to 4 channels. PGA control registers are assigned for each channel, where numbers in control register names correspond directly to channel numbers.

The PGA Gain selection registers PGA_CHx_GAIN [2:0] (PGA_CH0_GAIN [2658:2656], PGA_CH1_GAIN [2661:2659], PGA_CH2_GAIN [2666:2664], PGA_CH3_GAIN [2669:2667]) can be written via I²C/SPI during the operation, and require a settling time for the PGA to stabilize.

The PGA has eight modes (see Figure 90) that share three input categories:

- **Differential** (mode 3 and mode 5): gain is applied to the difference between $V_{IN(P)}$ (positive input) and $V_{IN(N)}$ (negative input) (mode 3), and to the difference between $V_{IN(P)}$ and $V_{IN(N)}$ with an offset of ADC_$V_{REF}$/2 (mode 5). For example, in mode 5, the output is ADC_$V_{REF}$/2 when the input voltage difference is zero. $V_{IN(P)}$ can be above or below $V_{IN(N)}$.
- **Pseudo-differential** (mode 4): gain is applied to the difference between $V_{IN(P)}$ and $V_{IN(N)}$ with no offset. The output is 0 V when the input difference is zero. The operating range assumes $V_{IN(P)}$ is always above $V_{IN(N)}$.
- **Single-ended** (mode 2): with $V_{IN(N)}$ connected to the ground.

The PGA modes for channels 0 to 3 are configured by registers PGA_CHx_MODE [2:0] (PGA_CH0_MODE [2644:2642], PGA_CH1_MODE [2647:2645], PGA_CH2_MODE [2650:2648], PGA_CH3_MODE [2653:2651]).

**Table 22. PGA/ADC Input/Output Modes**

| Mode | PGA In/Out Configuration | | ADC input Configuration |
|---|---|---|---|
| | Input | Output | |
| 1a | Bypass | Bypass | Differential |
| 1b | Bypass | Bypass | Single-ended |
| 2 | Single-ended | Single-ended | Single-ended |
| 3 | Differential | Differential | Differential |
| 4 | Pseudo-differential | Single-ended | Single-ended |
| 5a | Differential | Single-ended | Single-ended |
| 5b | Differential | Differential | Differential |
| 6 | Buffer | Buffer | Single-ended |

**Mode 1a/1b:** The PGA is bypassed, and signals are passed directly to the ADC operating in differential or single-ended mode.

**Mode 2:** High input impedance non-inverting single-ended amplifier.

**Mode 3:** Instrumentation amplifier with common mode voltage limits and high input impedance.

**Mode 4:** Pseudo-differential amplifier with low input impedance and extended common mode voltage.

**Mode 5a:** Differential amplifier with low input impedance and $V_{REF}/2$ reference voltage, and single-ended output.

**Mode 5b:** The same as 5a, but the output is differential.

**Note:** Register [2557] ADC_HALF_DIVIDER_EN must be enabled when operating in mode 5a and 5b.

**Mode 6:** Single-ended voltage follower with high input impedance and single-ended output.

Individual analog gain settings are made through the PGA_CHx_GAIN [2:0] registers.

PGA positive and negative inputs can be configured for different GPIOs or internal signals (ACMP $V_{REF}$, Temperature Sensor).

**Table 23. PGA Gain and Input Resistance vs. PGA Mode**

| Mode | Mode Description | Gain | Output voltage | Input Resistance |
|---|---|---|---|---|
| 1a | Bypass, differential ADC in configuration | -- | $V_{OUT}(diff) = V_{IN(P)} – V_{IN(N)}$ | Determined by ADC input resistance $R_{IN} = 5/(F_{clk} * C_{IN})$ (see section 3.9 Analog-to-Digital Converter Specifications) |
| 1b | Bypass, single-ended ADC in configuration | -- | $V_{OUT} = V_{IN}$ | Determined by ADC input resistance $R_{IN} = 5/(F_{clk} * C_{IN})$ (see section 3.9 Analog-to-Digital Converter Specifications) |
| 2 | Non-inverting single-ended input, single-ended output | $Gain = 1 + (R_b/R_a)$ | $V_{OUT} = V_{IN} * Gain$ | Hi-Z |
| 3 | Instrumentation amplifier Differential input, differential output | $Gain = 1 + (2R_b/R_a)$ | $V_{OUT}(diff) = (V_{IN(P)} – V_{IN(N)}) * Gain$ | Hi-Z |
| 4 | Pseudo-differential input, single-ended output | $Gain = R_b/R_a$ | $V_{OUT} = (V_{IN(P)} – V_{IN(N)}) * Gain$ | $R_{in(p)} = R_a + R_b$ $R_{in(n)} = \frac{R_a}{1 - \frac{V_{in(p)}}{V_{in(n)}} \times \frac{R_b}{R_a + R_b}}$ |
| 5a | Differrential input, single-ended output | $Gain = R_b/R_a$ | $V_{OUT} = (V_{IN(P)} – V_{IN(N)}) * Gain + V_{REF}/2$ | $R_{in(p)} = \frac{V_{in(p)} \times (R_a + R_b)}{V_{in(p)} - V_{ref}/2}$ $R_{in(n)} = \frac{R_a}{1 - \frac{V_{in(p)} - V_{ref}/2}{V_{in(n)}} \times \frac{R_b}{R_a + R_b} + \frac{V_{ref}/2}{V_{in(n)}}}$ |
| 5b | Differential input, differential output | $Gain = R_b/R_a$ | $V_{OUT}(diff) = (V_{IN(P)} – V_{IN(N)}) * Gain$ | $R_{in(p)} = \frac{V_{in(p)} \times (R_a + R_b)}{V_{in(p)} - V_{ref}/2}$ $R_{in(n)} = \frac{R_a}{1 - \frac{V_{in(p)} - V_{ref}/2}{V_{in(n)}} \times \frac{R_b}{R_a + R_b} + \frac{V_{ref}/2}{V_{in(n)}}}$ (ADC effect is not considered) |
| 6 | Single-ended buffer | 1 | $V_{OUT} = V_{IN}$ | Hi-Z |

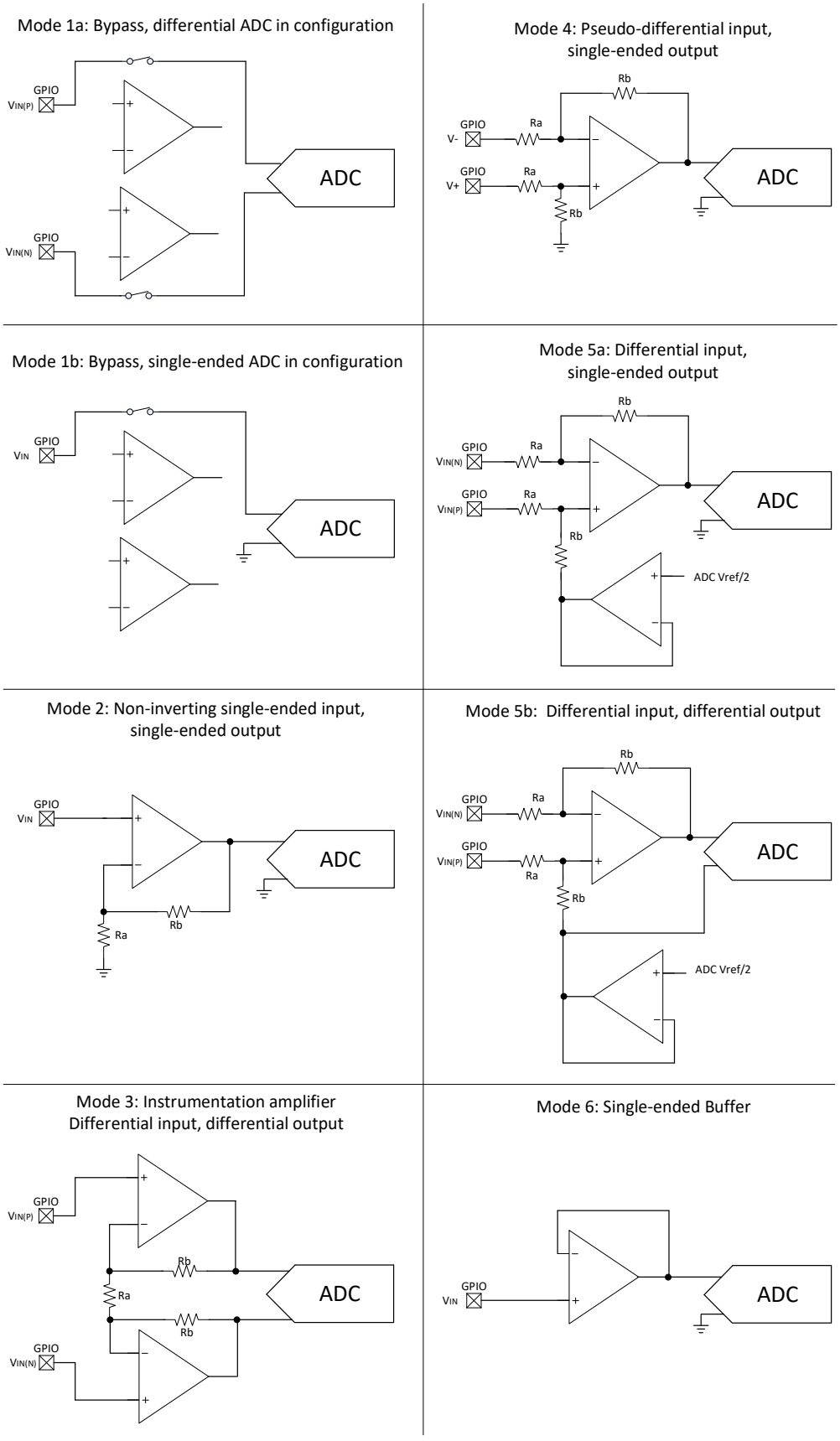



**Figure 90. PGA Configuration Modes**

Registers PGA_INN_SEL_CHx [2:0] (PGA_INN_SEL_CH0 [2674:2672], PGA_INN_SEL_CH1 [2677:2675], PGA_INN_SEL_CH2 [2682:2680], PGA_INN_SEL_CH3 [2685:2683]) are used to configure the negative input for channels 0 to 3.

Registers PGA_INP_SEL_CHx [2:0] (PGA_INP_SEL_CH0 [2679:2678], PGA_INP_SEL_CH1 [2687:2686], PGA_INP_SEL_CH2 [2689:2688], PGA_INP_SEL_CH3 [2691:2690]) are used to configure the positive input for channels 0 to 3.

The PGA can be used as a standalone amplifier with the single-ended or differential output connected to GPIO9 and GPIO10. Register PGA_OUT_N [2693] selects GPIO10 as a PGA negative output, and PGA_OUT_P [2692] selects GPIO9 as a PGA positive output, respectively. PGA outputs are connected to GPIO througt high-impedance switches. Therefore, the PGA should only be loaded with a high-impedance. When the PGA is powered down and the PGA output is routed to GPIO9, the PGA output is in a Hi-Z state.

When the PGA power-up signal is LOW or when the PGA is powered off by register PGA_POWERUP [2640], bypass switches connect the analog signal from the input MUXs to the ADC. This way, input signals can be sampled and converted without powering the PGA.

The PGA output can also be connected to the analog comparator’s non-inverting input multiplexer via register setting ACMPH_POS_SRC_SEL [3300:3298] = 1.

The PGA power-up signal can be controlled independently by PGA Power-Up signal (from CMO1 [75]).

After the PGA is powered up, its signals undergo a settling process and become valid after $t_{ON}$ time (see section 3.8.1 PGA Specifications).

## 10.2 Input Multiplexer Configuration

The input MUX and its connectivity is shown in Figure 91. The PGA has per-channel configuration registers that control mode/gain/MUX settings and the ADC has per-channel configuration registers that control the ADC mode. The ADC controller generates the curr_adc_ch[1:0] signal for channel selection. If register PGA_IMUX_SEL_EN [2641] = 1, the MUX configuration selection will be directly determined by the setting registers ADC_CH_SEL [2619:2618]. This allows the PGA to be controlled without the ADC enabled.

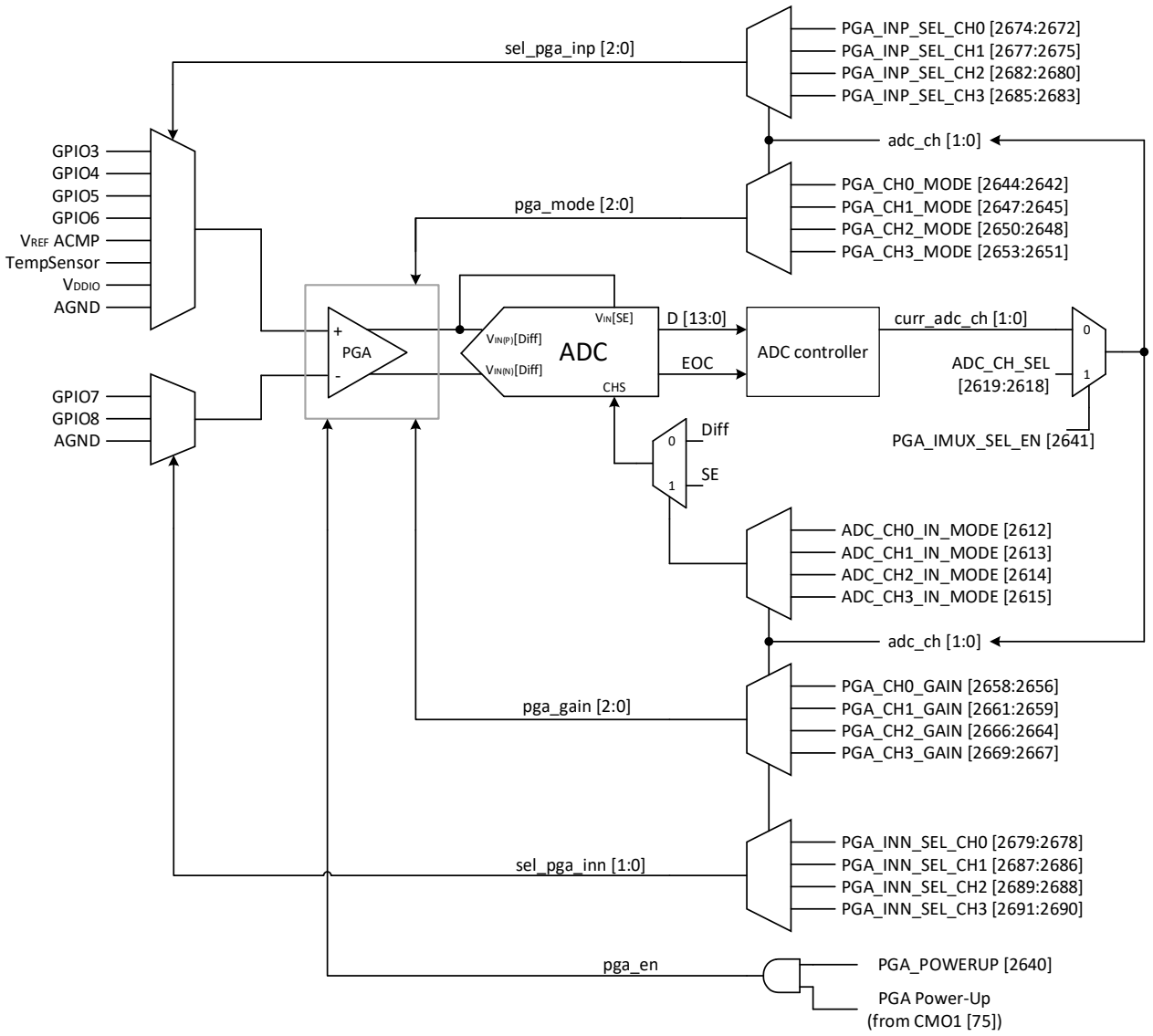



**Figure 91. Input MUX Configuration**

## 10.3 PGA Typical Performance

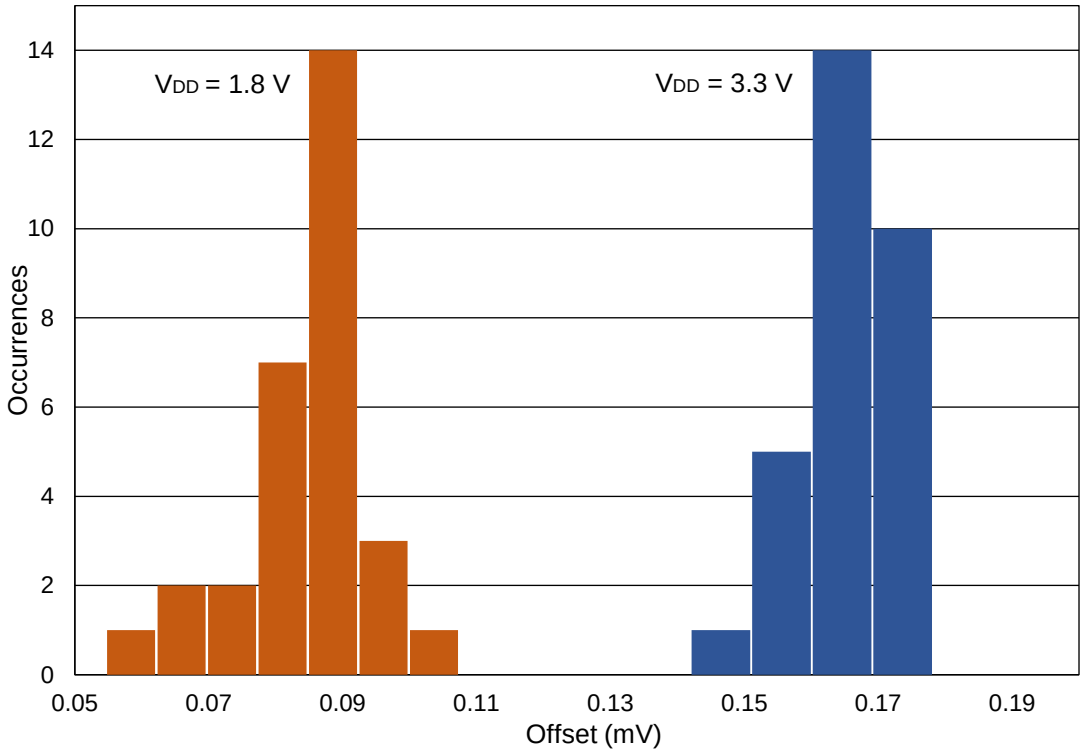



**Figure 92. Offset Voltage Referred to Output Distribution at $T_A$ = 25 °C, PGA Mode 3, Gain = 1**

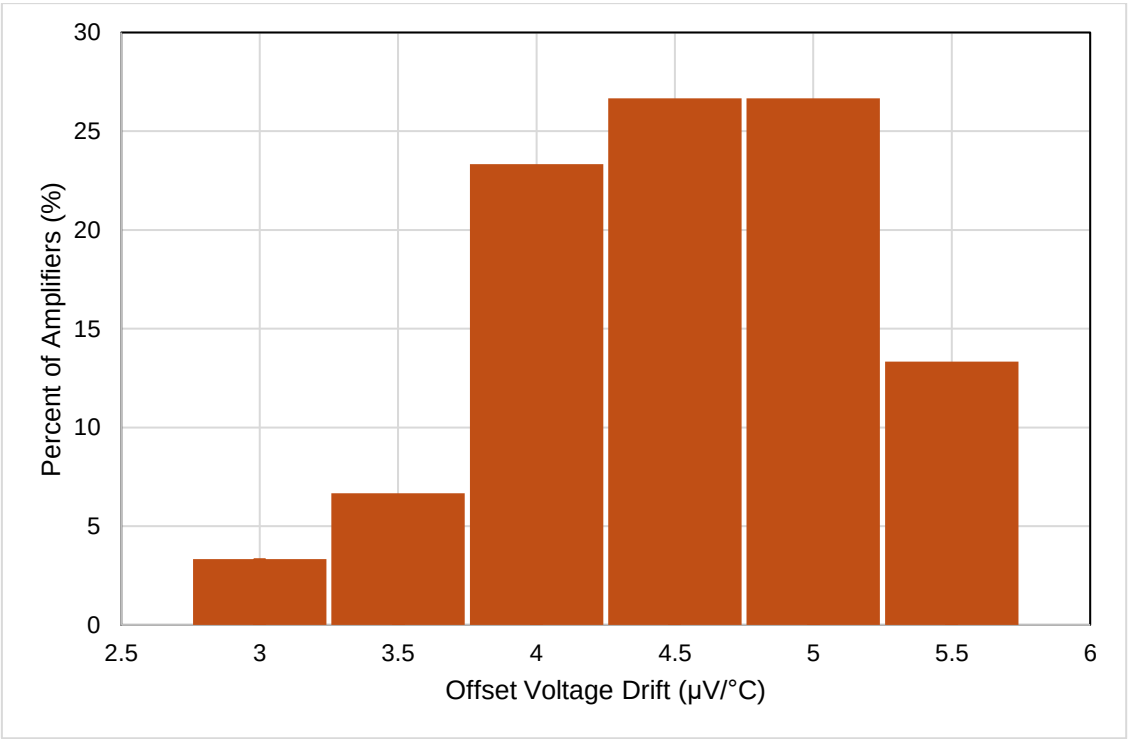



**Figure 93. Offset Voltage Referred to Output Drift Distribution at $T_A$ = -40 °C to +85 °C, $V_{DD}$ = 3.3 V, PGA Mode 3, Gain = 1**

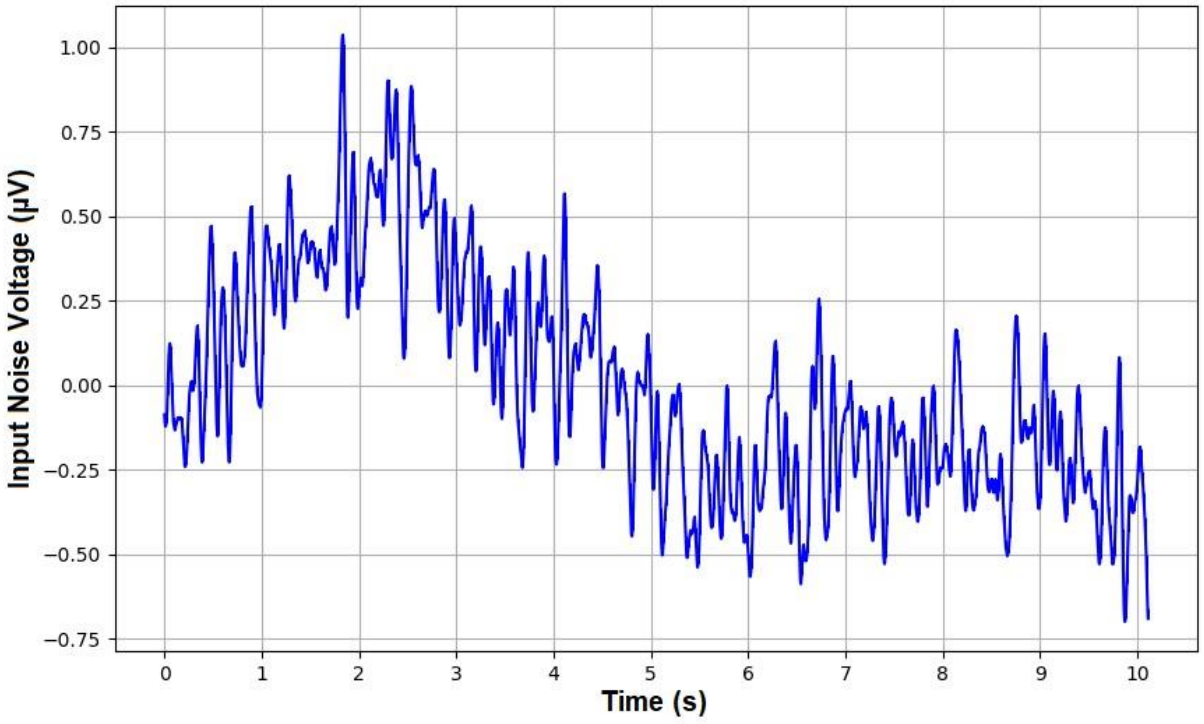



**Figure 94. 0.1 Hz to 10 Hz Noise (Oscillogram) at $T_A$ = +25 °C, $V_{DD}$ = 3.3 V, PGA Mode 6**

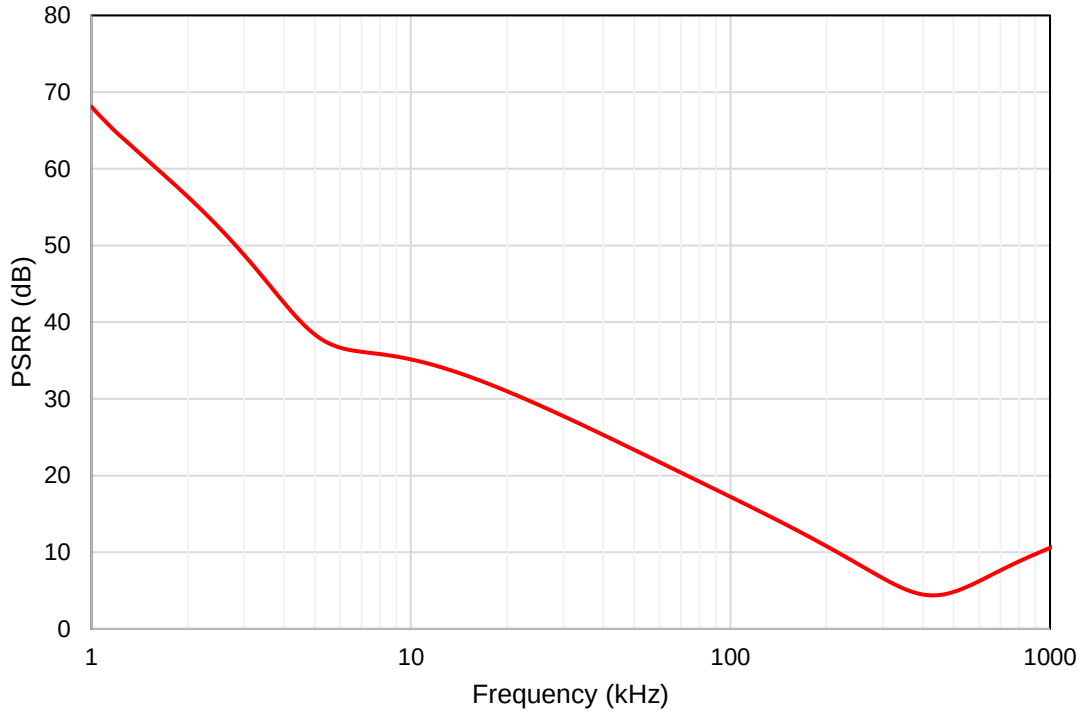



**Figure 95. PSRR vs. Frequency at $T_A$ = +25 °C, $V_{DD}$ = 1.71 V to 3.6 V, PGA Mode 6**

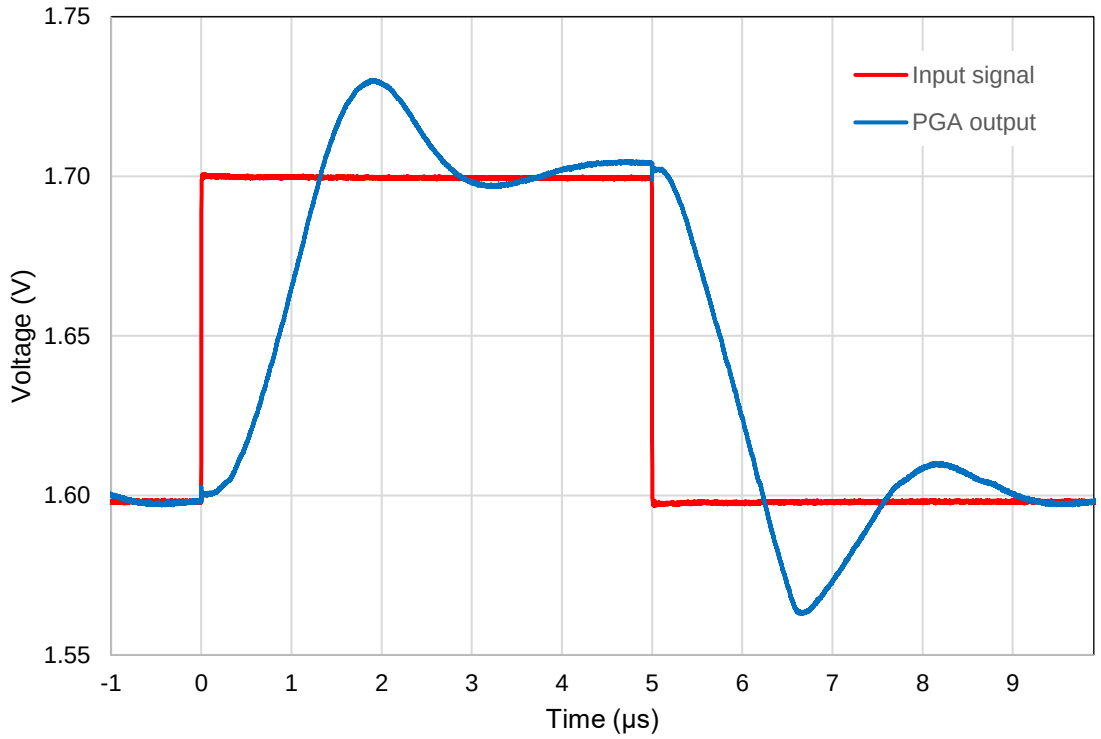



**Figure 96. Small-Signal Pulse Response at $T_A$ = +25 °C, $V_{DD}$ = 3.3 V, PGA Mode 6**

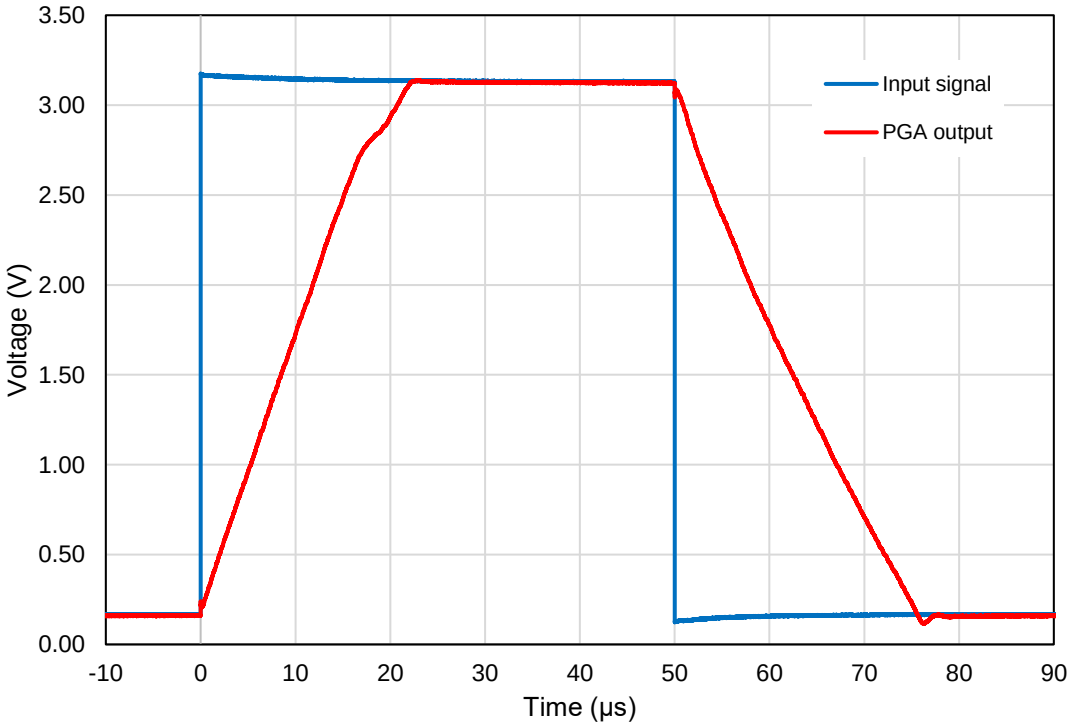



**Figure 97. Large-Signal Pulse Response at $T_A$ = +25 °C, $V_{DD}$ = 3.3 V, PGA Mode 6**

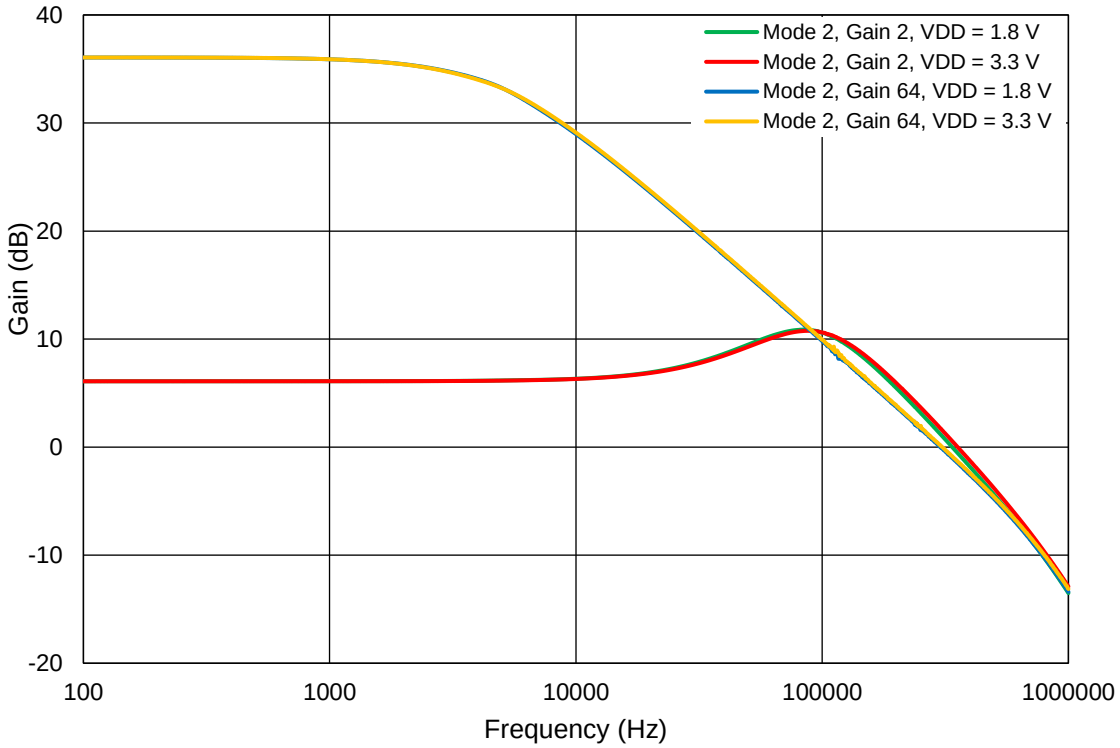



**Figure 98. Gain vs. Frequency at $T_A$ = +25 °C**

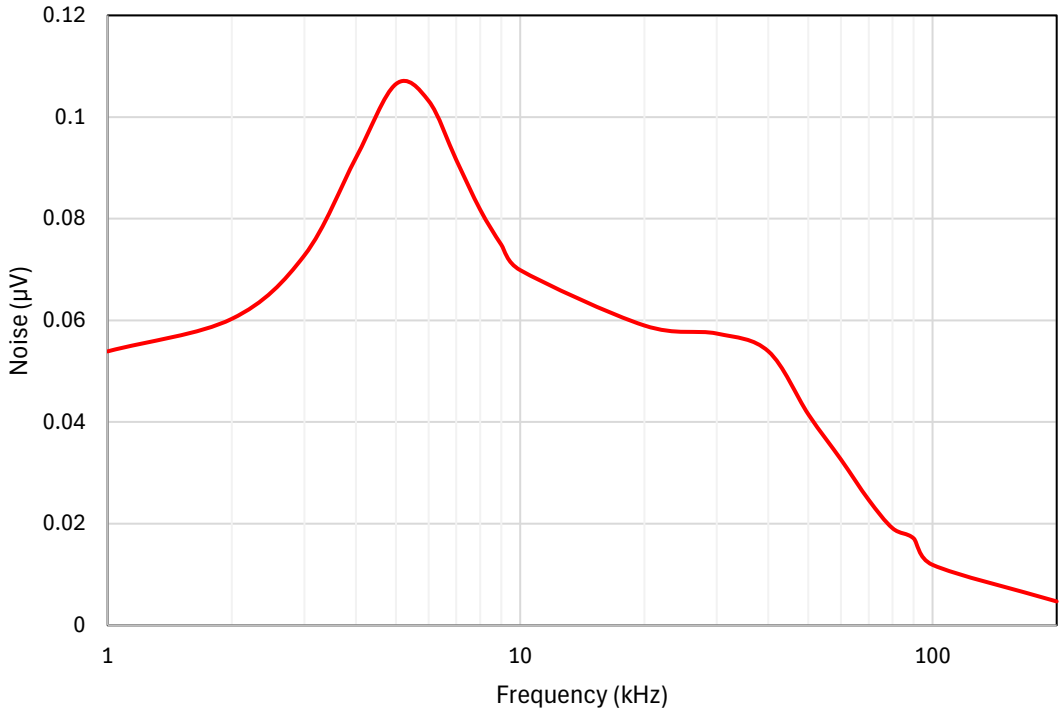



**Figure 99. Input Noise Voltage Density vs. Frequency at $T_A$ = +25 °C, $V_{DD}$ = 3.3 V, PGA Mode 6**

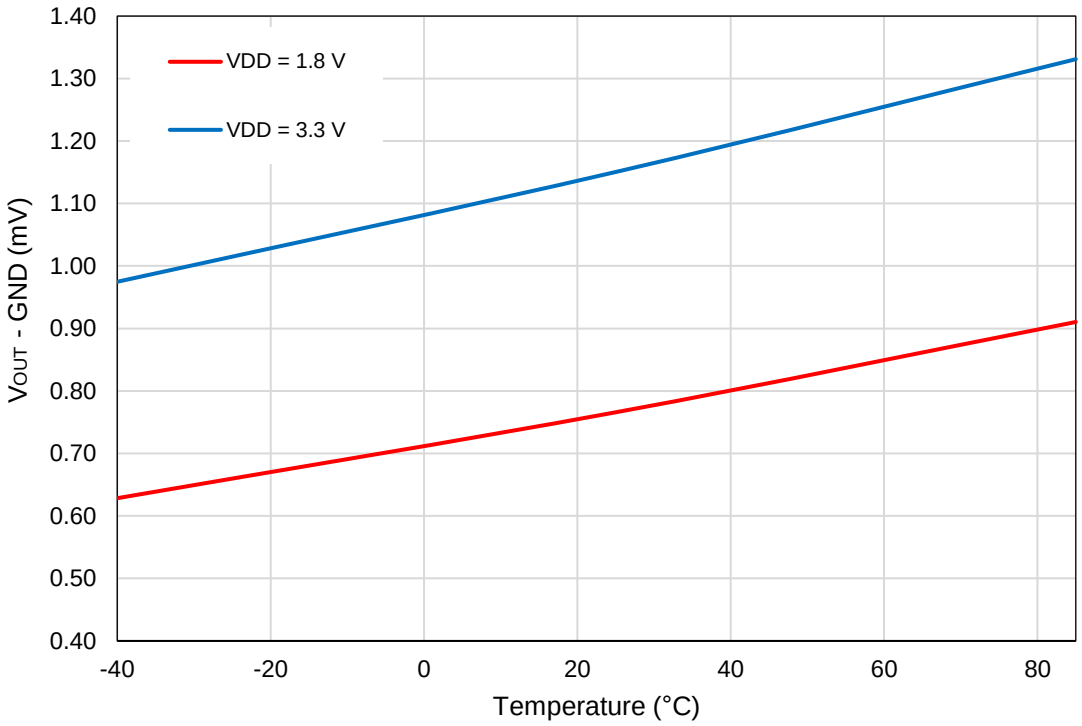



**Figure 100. Output Voltage Low ($V_{OUT}$ - GND) vs. Temperature at $T_A$ = +25 °C, PGA Mode 6, $R_{LOAD}$ = 1 MΩ (Including Output Swith Resistance)**

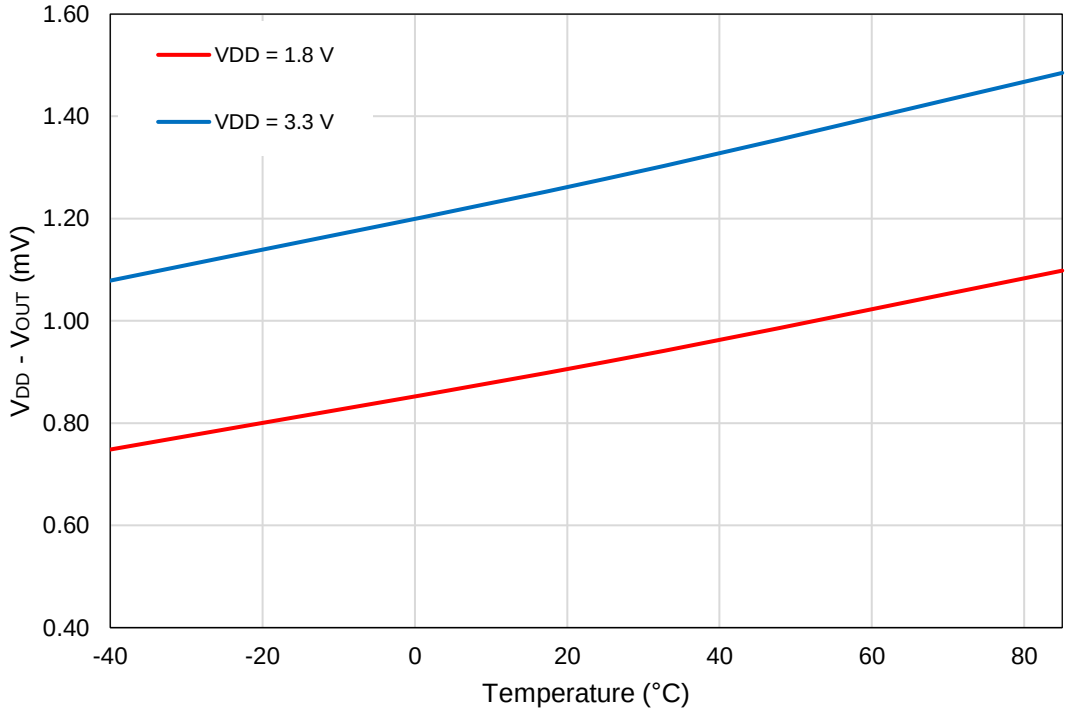



**Figure 101. Output Voltage High ($V_{DDA}$ - $V_{OUT}$) vs. Temperature at $T_A$ = 25 °C, PGA Mode 6, $R_{LOAD}$ = 1MΩ (Including Output Swith Resistance)**

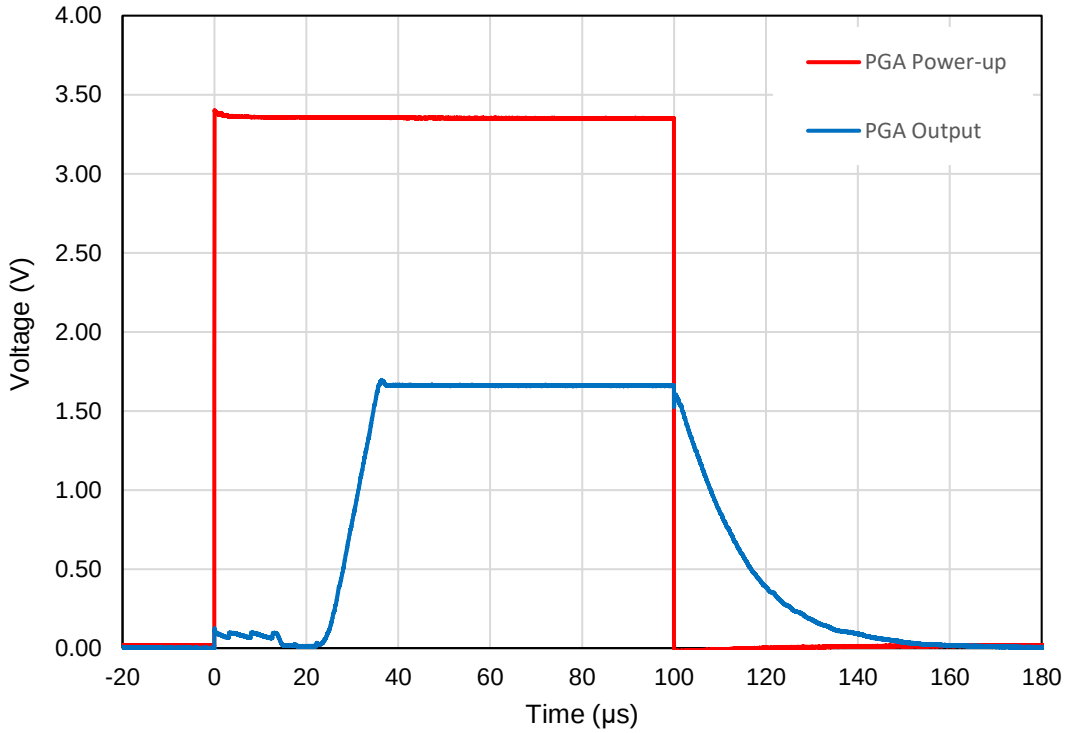



**Figure 102. Output Response to Power-Down Signal at $T_A$ = +25 °C, $V_{DD}$ = 3.3 V**

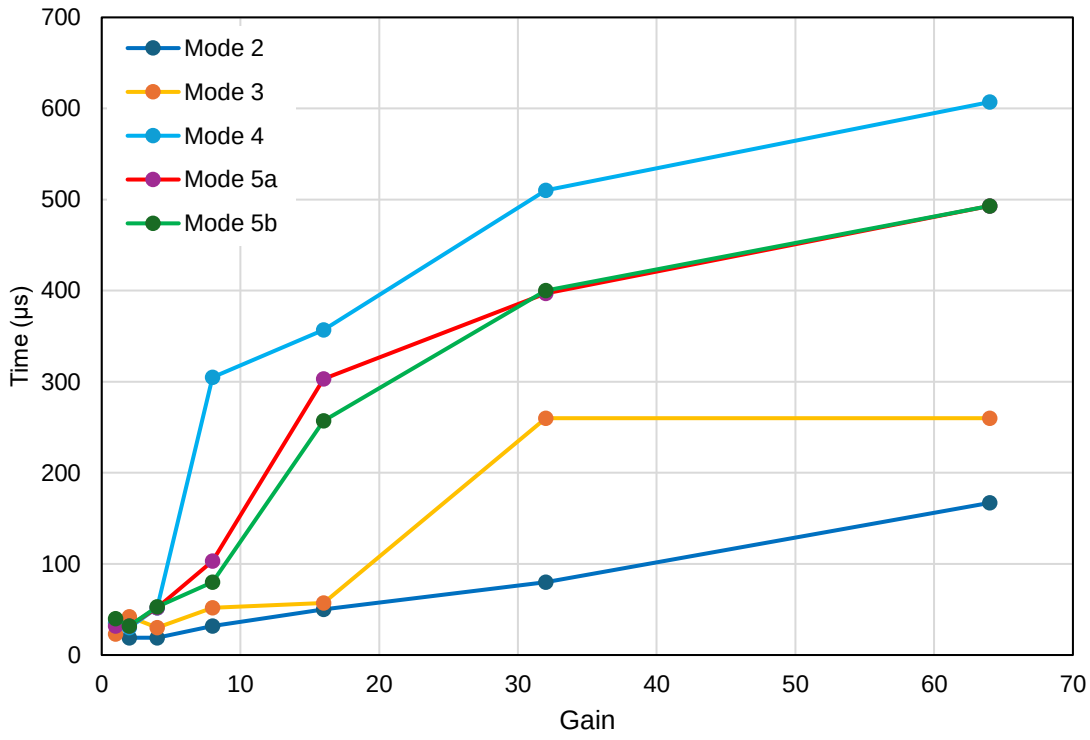



**Figure 103. Gain vs. Settling Time at $T_A$ = +25 °C, $V_{DD}$ = 1.8 V, Output Settling to 1 %**

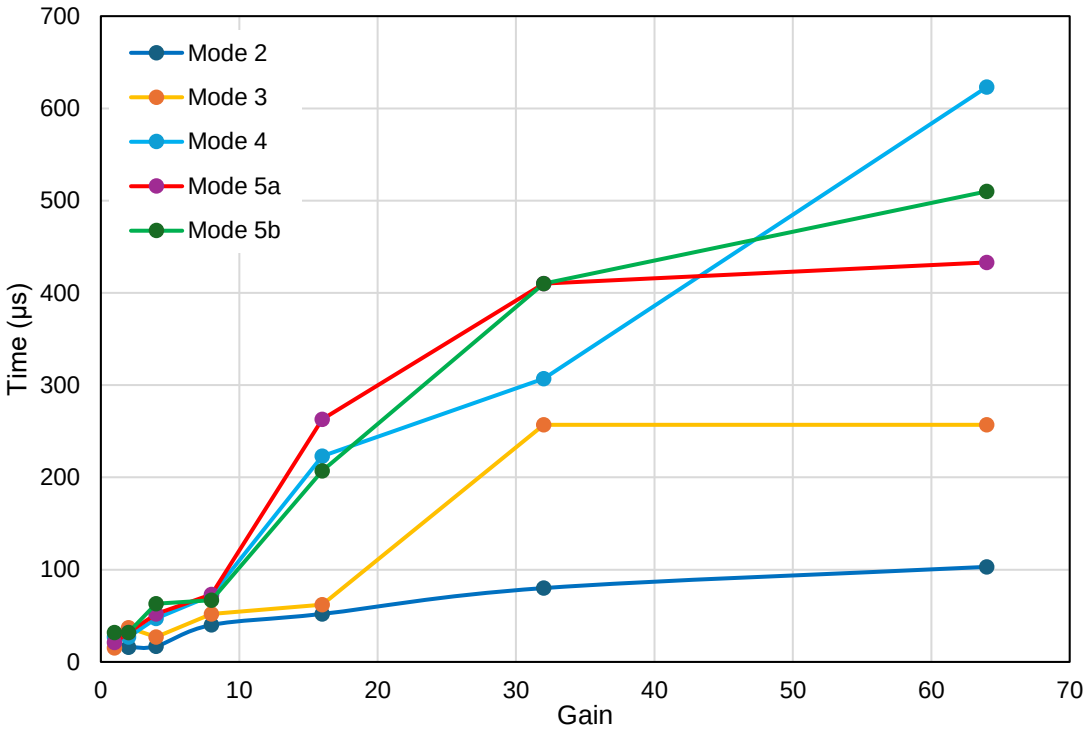



**Figure 104. Gain vs. Settling Time at $T_A$ = +25 °C, $V_{DD}$ = 3.3 V, Output Settling to 1 %**

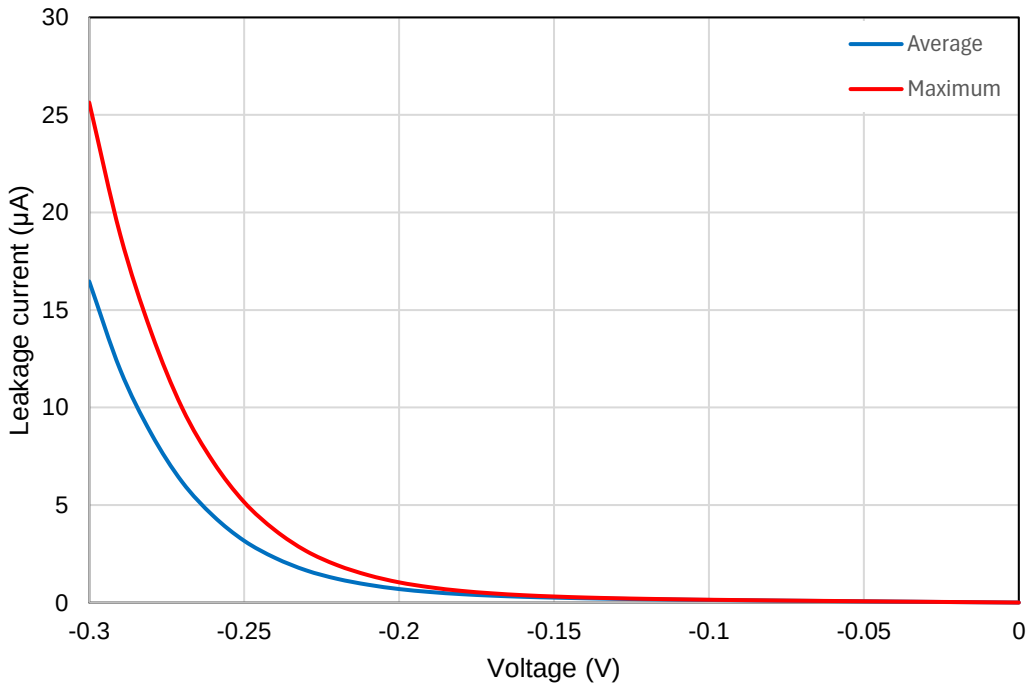



**Figure 105. Pin Input Leakage Current vs. Negative Voltage Applied to the Pin at $T_A$ = +25 °C, $V_{DD}$ = 3.3 V, PGA Mode 5a, 5b**

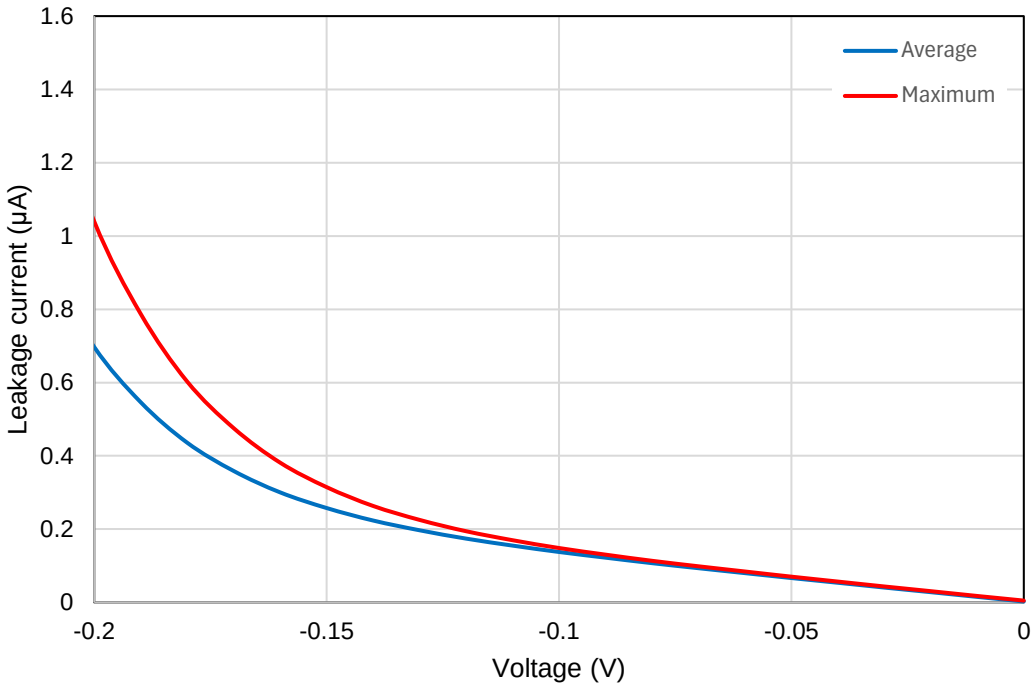
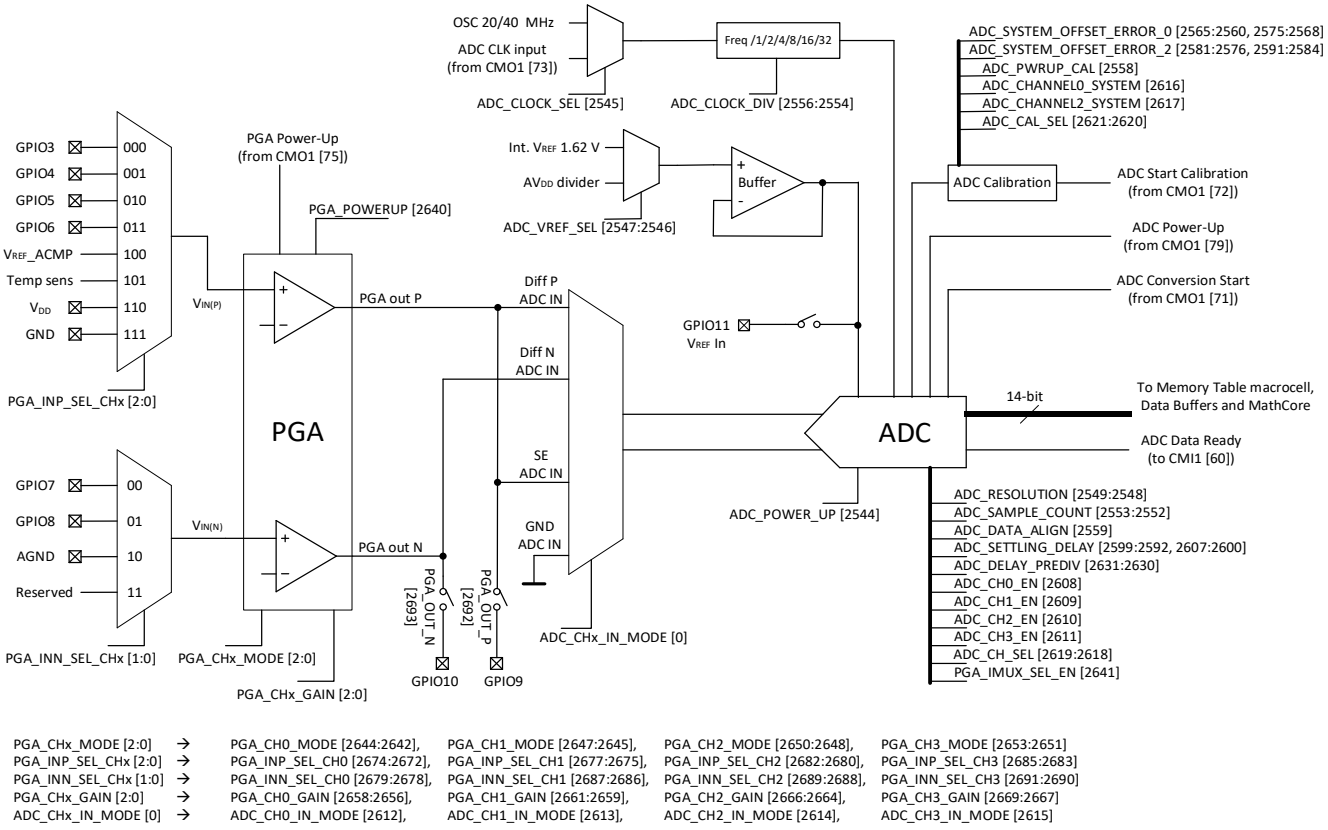



**Figure 106. Pin Input Leakage Current vs. Negative Voltage Applied to the Pin at $T_A$ = +25 °C, $V_{DD}$ = 3.3 V, PGA Mode 5a, 5b (Zoomed)**

# 11. Analog-to-Digital Converter Macrocell

The SLG47011 has a 14-bit successive approximation register Analog-to-Digital Converter (SAR ADC) macrocell, which samples an incoming signal that is amplified by Programmable Gain Amplifier or comes directly from GPIO pins (see Figure 107).




| | | | | |
|---|---|---|---|---|
| PGA_CHx_MODE [2:0] → | PGA_CH0_MODE [2644:2642], | PGA_CH1_MODE [2647:2645], | PGA_CH2_MODE [2650:2648], | PGA_CH3_MODE [2653:2651] |
| PGA_INP_SEL_CHx [2:0] → | PGA_INP_SEL_CH0 [2674:2672], | PGA_INP_SEL_CH1 [2677:2675], | PGA_INP_SEL_CH2 [2682:2680], | PGA_INP_SEL_CH3 [2685:2683] |
| PGA_INN_SEL_CHx [1:0] → | PGA_INN_SEL_CH0 [2679:2678], | PGA_INN_SEL_CH1 [2687:2686], | PGA_INN_SEL_CH2 [2689:2688], | PGA_INN_SEL_CH3 [2691:2690] |
| PGA_CHx_GAIN [2:0] → | PGA_CH0_GAIN [2658:2656], | PGA_CH1_GAIN [2661:2659], | PGA_CH2_GAIN [2666:2664], | PGA_CH3_GAIN [2669:2667] |
| ADC_CHx_IN_MODE [0] → | ADC_CH0_IN_MODE [2612], | ADC_CH1_IN_MODE [2613], | ADC_CH2_IN_MODE [2614], | ADC_CH3_IN_MODE [2615] |

**Figure 107. SAR ADC Block Diagram**

## 11.1 ADC Features

- Programable ADC resolution: 14, 12, 10, 8 bit.
- Sample rate up to 2.35 Msps in 8-bit mode.
- Differential or single-ended input modes.
- Selectable internal or external reference voltage.
- Selectable internal or external ADC clock source.
- Fixed internal voltage source can be connected to ADC input via input MUX.
- Parallel data output.
- Data ready signal indicates the end of the conversion process.
- Continuous or one-shot conversion operations.
- ADC System offset calibration procedure.
- ADC conversion data can be stored or processed in up to 4 buffers.
- Programmable channel count and sampling order.
- Programmable number of samples per channel (same for all channels).
- Optional ADC data output to Data Buffers, Memory Table macrocell or MathCore macrocell.
- Optional ADC access measurement bypassing PGA.
- Programable delay before sampling.

## 11.2 ADC General Description

The ADC has an internal Sampling Engine block that manages the analog MUX and the ADC data receivers (Data Buffers or Memory Table macrocell).

The signal can be amplified through the PGA, which has programmable gain and is configurable for each individual channel (see Section 10 Programmable Gain Amplifier).

The ADC can sample up to four channels. Each chanel is programmable to operate with any of possible analog inputs (see Section 10.2 Input Multiplexer Configuration).

ADC data destination options:

- Data Buffers
- Address input of Memory Table macrocell (ADDR-to-DATA mode)
- Data input of Memory Table macrocell (Storage mode)
- MathCore inputs
- Internal one-word buffer accessible via I²C/SPI Host Interface

ADC voltage reference sources:

- External source (GPIO11)
- Internal reference 1.62 V
- $AV_{DD}$ divider.

ADC clock sources:

- Internal OSC 20 MHz/40 MHz
- External clock via connection matrix
- Configurable clock divider.

The ADC's differential or single-ended input mode is configured by registers ADC_CHx_IN_MODE [0] for channels 0 to 3 independently (ADC_CH0_IN_MODE [2612], ADC_CH1_IN_MODE [2613], ADC_CH2_IN_MODE [2614], ADC_CH3_IN_MODE [2615]).

To power up the ADC, both registry setting ADC_POWER_UP [2544] must be set to 1 and matrix output ADC power-up (CMO1 [79]) must be asserted.

Please note that the ADC macrocell has to be powered off during any ADC configuration change via I²C/SPI.

## 11.3 ADC Offset Calibration

There are two types of offset calibration in the ADC:

- Internal Offset Calibration (inherent SAR ADC calibration).
- System Offset Calibration (specially designed customer calibration to simplify some differential mode measurements).

The Internal Calibration measures the ADC offset and then subtracts it from the ADC conversion data. Internal Calibration of the ADC is initiated automatically after the device power-up and after the transition from SLEEP to All ON mode (register ADC_PWRUP_CAL [2558]). The Internal Offset Calibration procedure requires 6415 ADC clock periods and should be considered in the user design (refer to Figure 108).

System Offset Calibration considers the entire signal path, including the external source, the internal input MUX, and the PGA. To initiate the system offset calibration, the external device or sensor must be in its zero signal state and the ADC Start Calibration (CMO1 [72]) signal must be set. The result of the System Offset Calibration will be saved as a system offset error value in the ADC_SYSTEM_OFFSET_ERROR_x [13:0] register using a 2's complement 14-bit word and subtracted from every ADC measurement. Register is allowable for read/write via I²C/SPI.

Two registers, ADC_CHANNEL0_SYSTEM [2616] (for channel 0, 1) and ADC_CHANNEL2_SYSTEM [2617] (for channel 2, 3) are used to configure which pair of differential GPIO ports will be calibrated and which differential channel will be corrected during operation. System Offset Calibration starts with a rising edge at the Start Calibration input (refer to Figure 109). While the conversion is running, the signal ADC Start Calibration (CMO1 [72]) will be blocked. Likewise, while the system calibration is running, the incoming CMO signal ADC Conversion Start (CMO1 [71]) will be ignored.

System Offset Calibration will be performed using the ADC and PGA register settings.

The System Offset Calibration time is defined by the following:

- **Single channel system calibration:**
  - If ADC_SETTLING_DELAY > 0:
    (D1 + ADC_Latency + 5) * ADC_T_CLK + (D1 + ADC_Latency) * 7 * ADC_T_CLK + 3 * ADC_T_CLK
  - If ADC_SETTLING_DELAY = 0:
    (7 + ADC_Latency + 5)*ADC_T_CLK + (7 + ADC_Latency) * 7 * ADC_T_CLK + 3 * ADC_T_CLK
- **Two channels system calibration:**
  - If ADC_SETTLING_DELAY > 0:
    [(D1 + ADC_Latency + 5) * ADC_T_CLK + (D1 + ADC_Latency) * 7 * ADC_T_CLK + 3 * ADC_T_CLK] * 2
  - If ADC_SETTLING_DELAY = 0:
    [(7 + ADC_Latency + 5) * ADC_T_CLK + (7 + ADC_Latency) * 7 * ADC_T_CLK + 3 * ADC_T_CLK] * 2,

where

D1 is the ADC_SETTLING_DELAY value set by register ADC_SETTLING_DELAY [2599:2592, 2607:2600],

ADC_Latency is the ADC Output data Latency (refer to section 3.9 Analog-to-Digital Converter Specifications),

ADC_T_CLK is the ADC clock period.

When the System Offset Calibration is complete, the system offset calibration value is stored in the ADC_SYSTEM_OFFSET_ERROR_x [13:0] register, and the ADC internal offset calibration value will be subtracted from the ADC conversion data.

The calibration register value can be written via $I^2C$/SPI and must be represented as 2's complement 14-bit word.

System Offset Calibration is available for both channels configured as differential inputs. Each input pair has its own system offset calibration registers (ADC_SYSTEM_OFFSET_ERROR_0 [2565:2560, 2575:2568] and ADC_SYSTEM_OFFSET_ERROR_2 [2581:2576, 2591:2584]). Registers are allowable for read/write via $I^2C$/SPI.

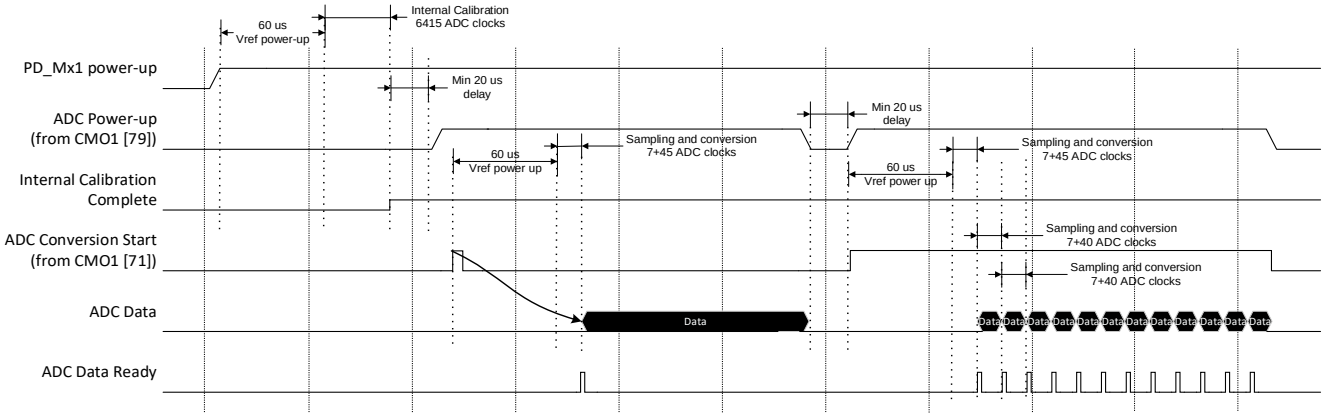
The ADC configuration registers should not be changed while the ADC is operating or in calibration mode.

If ADC is operating in combination with PGA, the ADC should wait for the PGA signal to settle after PGA power-up (see section 3.8.1 PGA Specifications).

If PGA differential mode (1a, 3, 5b, refer to Table 22) is selected, all measurements will be sampled from the voltage level $V_{REF}/2$. The ADC's zero output code is also half of its code range (8192 for 14-bit resolution, 2048 for 12-bit, 512 for 10-bit, and 128 for 8-bit, refer to Figure 112 and Figure 113). The system offset calibration result = ADC_data_after_Calibration_Start – Midscale_value.

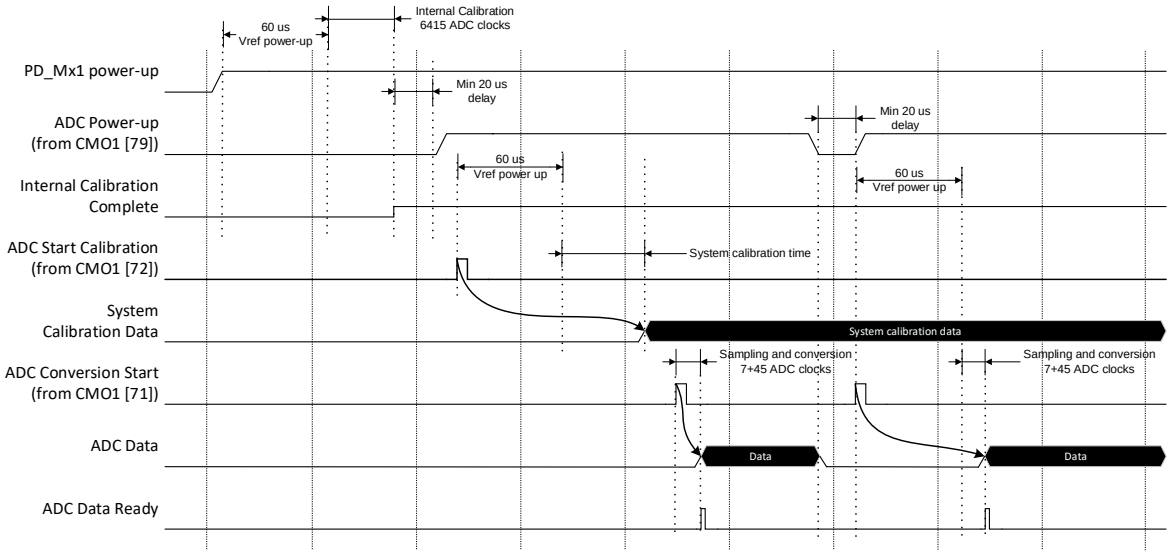
ADC_data_after_Calibration_Start is a sample specifically created after the ADC macrocell receives a pulse at ADC Start Calibration (CMO1 [72]).

For example, if the zero scale output code for 10-bit resolution is measured to be 500, the offset code will be 500 - 512 = -12. This value will be subtracted from the ADC raw data (ADC raw data - (-12), which will add 12 to the ADC raw data). The calibration registers can be used to subtract the desired values from each ADC sample.




**Note:** ADC_POWER_UP [2544] = 1, ADC_PWRUP_CAL [2558] = 1, ADC_SETTLING_DELAY [2599:2592, 2607:2600] = 0.

**Figure 108. ADC Internal Calibration Timing Diagram**




**Note:** ADC_POWER_UP [2544] = 1, ADC_PWRUP_CAL [2558] = 1, ADC_SETTLING_DELAY [2599:2592, 2607:2600] = 0.

**Figure 109. ADC System Calibration Timing Diagram**

## 11.4 ADC Output

The ADC output code from the ADC channel's differential analog input is shown in Figure 112. If the common mode voltage ($V_{CM}$) is applied to both inputs, the output code will be half of the selected code range.

The voltage swing of each positive and negative input will be limited to a $V_{REF}/2$ peak-to-peak amplitude.

Each ADC channel can be assigned to a specific Data Buffer, which can be selected by register BUFx_LOAD_SRC [2:0]. The ADC ready signal will also be connected to the selected Data Buffer.

In the 12-bit, 10-bit, and 8-bit ADC modes, the ADC's internal data bus can be aligned to the block output data bus shifted to the most significant bits or the least significant bits. This option is configured by the register ADC_DATA_ALIGN [2559]. Its default value is 1 (see Figure 110).

The ADC data can be read from register bytes 0x2201 and 0x2200 via $I^2C$/SPI Host Interface. Depending on the value of register ADC_DATA_ALIGN [2559], the ADC data in register bytes 0x2201 and 0x2200 is aligned as shown in Figure 111.

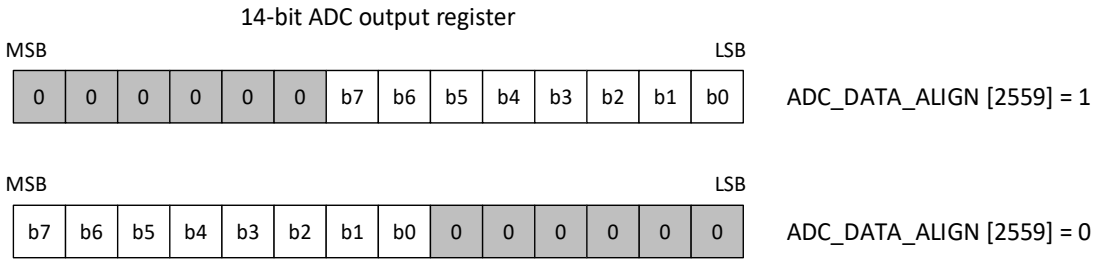



**Figure 110. Example of ADC Data Alignment (All Other Macrocells Except I²C/SPI) in 8-bit Mode**

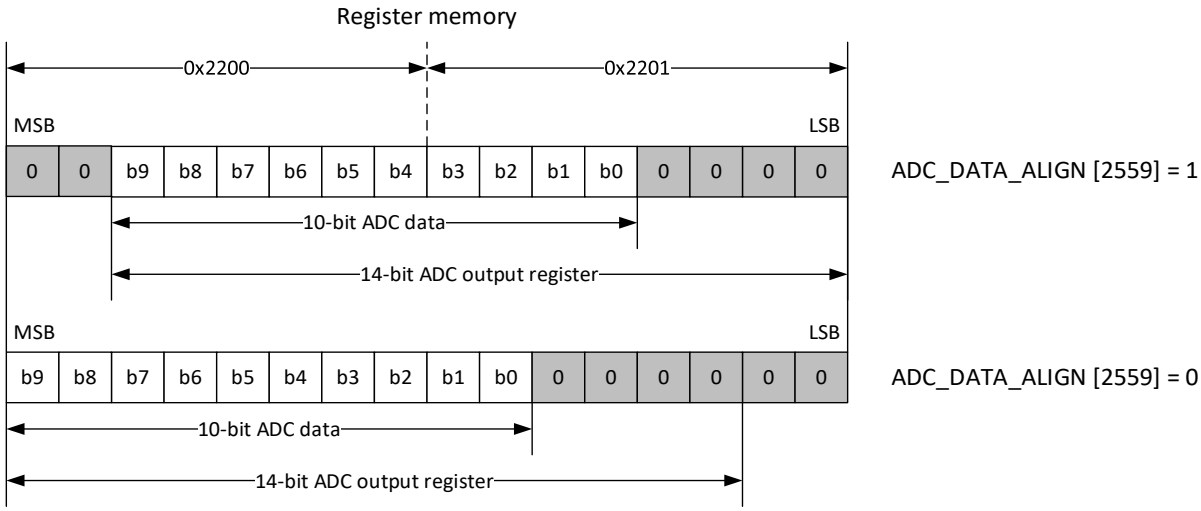



**Figure 111. Example of ADC Data Alignment in Register Memory (Bytes 0x2200 and 0x2201) in 10-bit Mode**

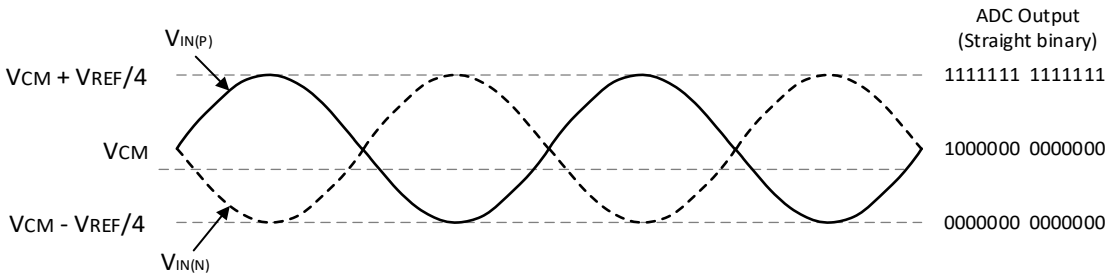



**Figure 112. Voltage $V_{IN(P)}$ and $V_{IN(N)}$ at ADC Inputs in Differential Mode**

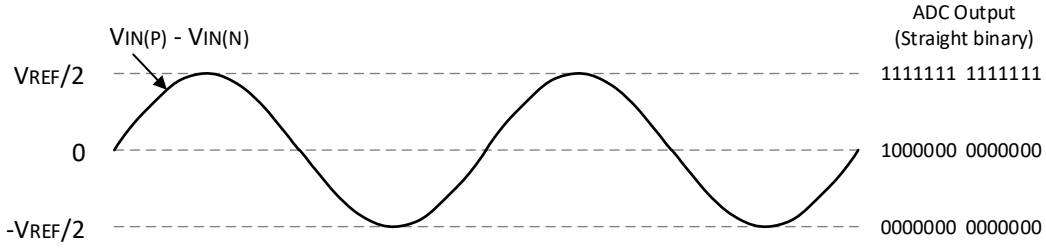



**Figure 113. Voltage ($V_{IN(P)}$-$V_{IN(N)}$) of ADC Inputs in Differential Mode**

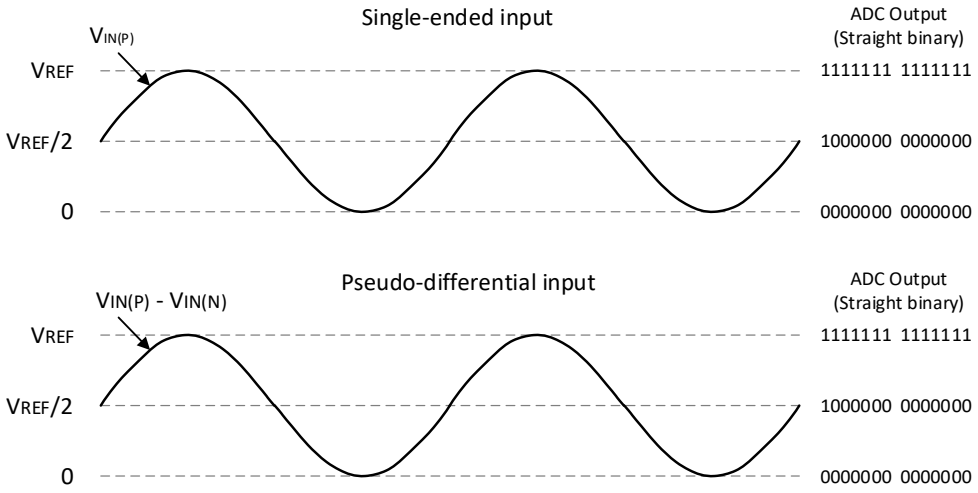



**Figure 114. Voltage of ADC Inputs in Single-Ended and Pseudo-Differential Mode**

## 11.5 Sampling and Conversion Process

The ADC starts operating when the rising edge is applied to the Conversion Start input.

An acquisition time ($t_{ACQ}$) is required for the input source to charge the sampling capacitor in the ADC's sample and hold circuit. After $t_{ACQ}$ and a conversion time ($t_{CONV}$) has passed, the ADC's conversion result is available to be transferred to other macrocells.

The ADC can sample up to four channels. Any channel can be excluded from a sampling sequence.

If the Conversion Start signal is a short pulse (shorter than conversion period, but no less than one clock cycle), the ADC samples all channels in the selected sequence. Each channel is sampled a defined number of times (once, twice, 4 times, or 8 times), as defined by ADC_SAMPLE_COUNT [2553:2552] register and then stops until the next pulse is applied to the Conversion Start input.

If the Conversion Start is asserted and remains HIGH beyond a single conversion, the ADC continues sampling all channels in the sequence a defined number of samples per channel, and then repeats the process (continuous conversion operation). The ADC continues sampling signals until the Conversion Start input becomes LOW. After the HIGH to LOW transition of the Conversion Start input, the ADC will finish the current sampling sequence and then stops.

The ADC has a Data Ready output (CMI1 [60]) that is set HIGH when the ADC is idle, set LOW when the conversion is in process, and is a high-level pulse when the ADC has finished sampling the current channel. The ADC Data ready pulse duration is at least one ADC clock cycle time in continuous conversion operation.

Figure 115 shows the timing diagram of the ADC in one-shot conversion operation, and Figure 116 shows the ADC timing diagram in continuous conversion operation, in which one analog input is converted continuously.

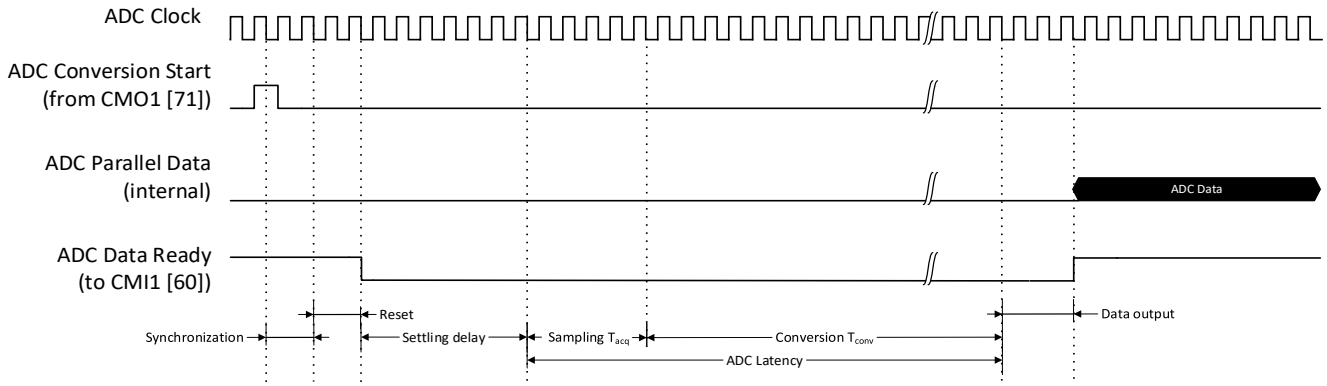



**Figure 115. ADC Timing Diagram. One-Shot Conversion Operation**

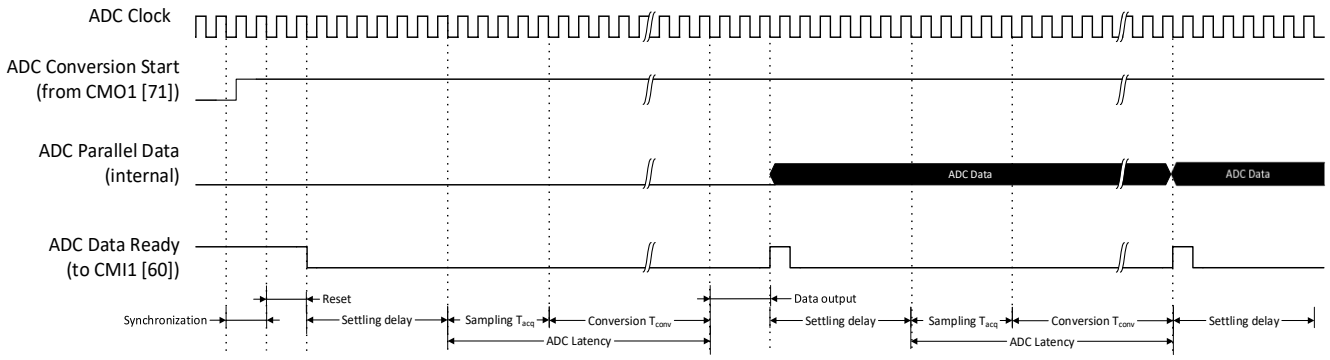



**Figure 116. ADC Timing Diagram. Continuous Conversion Operation**

For one-shot conversion operation, the ADC data ready time is described by the following:

- If ADC_SETTLING_DELAY = 0:
  One-shot ADC cycle = (7 + ADC_Latency + 5) * ADC_T_CLK.
- If ADC_SETTLING_DELAY > 0:
  One-shot ADC cycle = (D1 + ADC_Latency + 5) * ADC_T_CLK.

For continuous conversion operation, the ADC data ready time is described by the following:

- If ADC_SETTLING_DELAY = 0:
  Continuous conversion ADC cycle #1 = (7 + ADC_Latency + 5) * ADC_T_CLK, and
  continuous conversion ADC cycle #2, #3, #4, … = ADC_Latency * ADC_T_CLK.
- If ADC_SETTLING_DELAY > 0:
  Continuous conversion ADC cycle #1 = (D1 + ADC_Latency + 5) * ADC_T_CLK, and
  continuous conversion ADC cycle #2, #3, #4, … = (D1 + ADC_Latency) * ADC_T_CLK

Where:

D1 is ADC_SETTLING_DELAY value set by register ADC_SETTLING_DELAY [2599:2592, 2607:2600],

ADC_Latency is ADC Output data Latency (refer to section 3.9 Analog-to-Digital Converter Specifications),

ADC_T_CLK is ADC clock period.

ADC conversion data can be stored in any Data Buffer. This function can be configured using the BUFx_LOAD_SRC [2:0] register (see Section 14 Data Buffer). Channel sampling order is from channel 0 to channel 3. The Data Buffers can accept up to eight samples from each channel. Sample count per channel is defined by programming the ADC_SAMPLE_COUNT [2553:2552] register, and the sample count number is the same for all Data Buffers and channels. In continuous conversion operation, the new ADC's conversion result overwrites the previous data in the Data Buffers.

Optionally, samples from ADC can be routed to the Data Buffer for averaging before going to the Memory Table, as shown in Figure 117.

If the MathCore is utilized to process ADC conversion data, sampled channels will be assigned to the MathCore inputs by the corresponding MathCore register (see section 15 Mathematical Core).

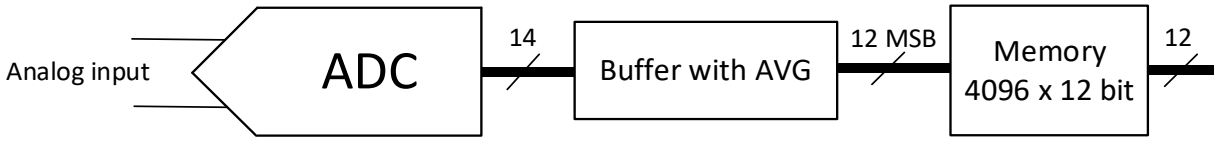



**Figure 117. Example of Averaging Mode Implementation**

## 11.6 One-Shot Conversion Operation

One-shot conversion operation is enabled by a single Conversion Start signal pulse that is shorter than a conversion period. One-shot conversion operation (see Figure 118) facilitates a single conversion event one or multiple samples, depending on the number of samples set by register, after the Conversion Start signal transitions from LOW to HIGH. After all the channels in the sequence are sampled and converted, the ADC Sampling Engine idles until the next rising edge at the Conversion Start input.

Figure 118 shows ADC operation in one-shot conversion operation. Two analog inputs are sampled and stored in the Data Buffers: GPIO3 data is stored in Data Buffer0 and temperature sensor data is stored in Data Buffer1. The Data Buffer length is two words and two samples are made per channel. The Data ready output is configured to indicate when the Data Buffers are filled.

Additional delay before each sampling cycle can be enabled to allow the PGA to settle out switching transients when transitioning between input channels. The delay period is set by ADC_SETTLING_DELAY [2599:2592, 2607:2600], where values can range from 0 to 65535 delay (in ADC clocks) and the default selection is “0” for seven ADC clock cycles delay.

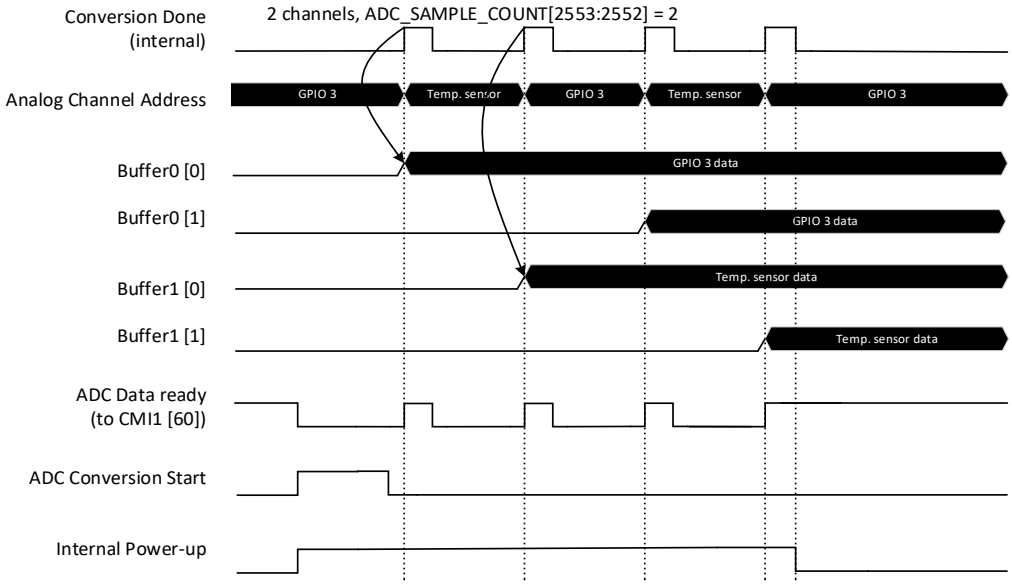



**Figure 118. ADC Functioning in One-Shot Conversion Operation**

## 11.7 Continuous Conversion Operation

Continuous conversion operation is enabled by setting and holding the Conversion Start signal HIGH. Connecting $V_{DD}$ or POR signal to ADC Conversion Start will not start the conversion because the ADC needs time to power up and calibrate after chip startup. The ADC starts sampling data after the Conversion Start signal’s LOW to HIGH transition. The ADC samples all channel sequence a defined number of times and then repeats the process by overwriting the previous data in the Data Buffers. If the ADC Conversion Start (CMO1 [71]) signal drops LOW five clocks before finishing the last sample of the sequence, the ADC finishes sampling the whole sequence of channels. If the ADC Conversion Start (CMO1 [71]) signal stays HIGH after the data ready signal arrives, the ADC starts a new sampling sequence and updates previously recorded data.The current sequence sampling procedure cannot be interrupted by a new pulse at the Conversion Start input.

**Note:** A LOW to HIGH transition of the ADC Conversion Start signal before the POR signal will be ignored.

Figure 119 shows ADC operation in continuous conversion operation. Two analog inputs are sampled and stored in the Data Buffers: GPIO3 data is stored in Data Buffer0 and Temperature Sensor data is stored in Data Buffer1. The Data Buffer length is two words and two conversions are performed per channel. The Conversion Start signal transitions LOW (on the 5$^{th}$ sample) after a new sampling sequence has started, so the sampling process stops only after an entire second sampling sequence is completed (eight samples in total). Only after the 8$^{th}$ sample is completed, the data ready output will transition HIGH, and the ADC will idle. If the ADC is

connected to the Memory Table in Storage mode, the sampling process will stop only after the entire Memory Table of the configured size is filled with ADC samples (MEMORY_TABLE_SIZE [2739:2736, 2751:2744] registers).

A delay before each sampling cycle can be enabled. This delay will help the PGA settle its output voltage in the transition process after switching between input channels. The delay time before sampling the next channel is set by ADC_SETTLING_DELAY [2599:2592, 2607:2600], where values can range from 0 to 65535 delay (in ADC clocks) and the default selection is “0” for seven ADC clock cycles delay.

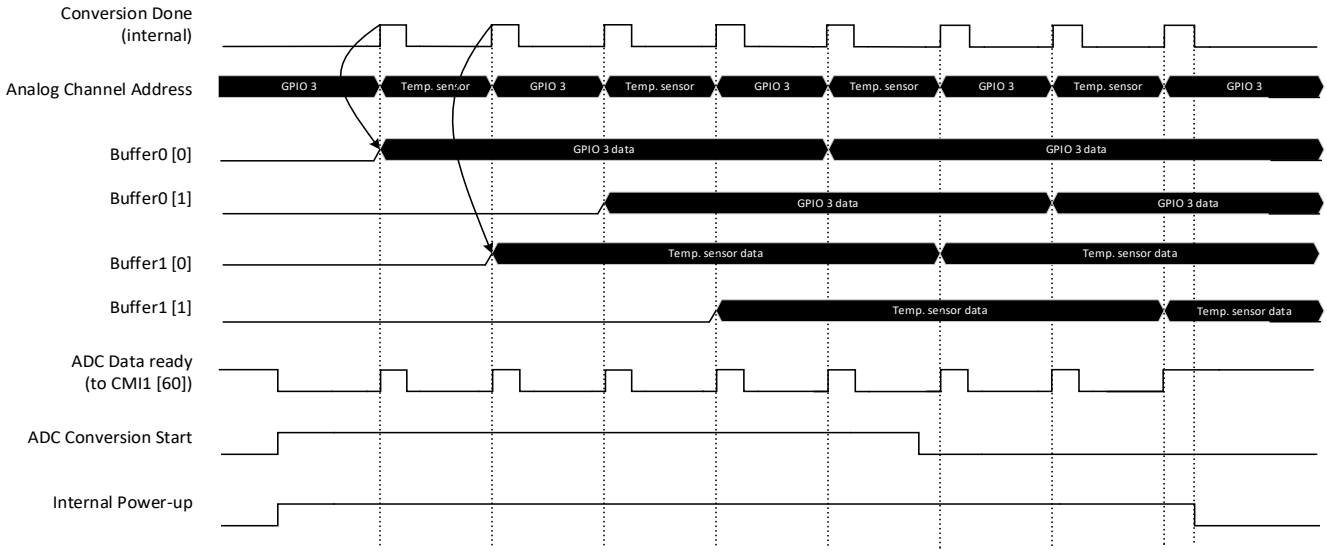



**Figure 119. ADC Functioning in Continuous Conversion Operation**

## 11.8 ADC $V_{REF}$

The user can supply the ADC’s reference voltage $V_{REF}$ from GPIO11. Alternatively, the SLG47011 features also an internal $V_{REF}$ source for the ADC. Two options are available: 1.62 V internal $V_{REF}$ source, or selectable divider from the $AV_{DD}$. These options are selected by the $V_{REF}$ MUX (registers ADC_VREF_SEL [2547:2546]). If an external reference is used for the ADC via the GPIO11 pin, the GPIO11 switch must be turned on and internal buffer must be turned off (ADC_VREF_TO_GPIO [2550] = 0). For details see section 22 Internal Voltage Reference.

## 11.9 Fast ADC Read I²C Command

The SLG47011 has sideband sequential read access path for I²C direct access to the ADC 14-bit output, which avoids repeated read request from host device. The sideband path for the I²C sequential read ADC output can be operated at up to 2 MHz speed.

To provide synchronization of I²C sideband sequential read with other macrocells, the I²C ACK signal is routed to the connection matrix input I²C_ACK (CMI1 [63]). I²C_ACK (CMI1 [63]) is synchronized with the ACK (nACK) bit. The synchronization of ADC Conversion Start and I²C readout can be implemented by GreenPAK logic cells. Figure 120 shows the I²C sideband sequential read protocol for ADC data readout. Register address 0xFFFF should be used for access to ADC data via I²C sideband sequential read.

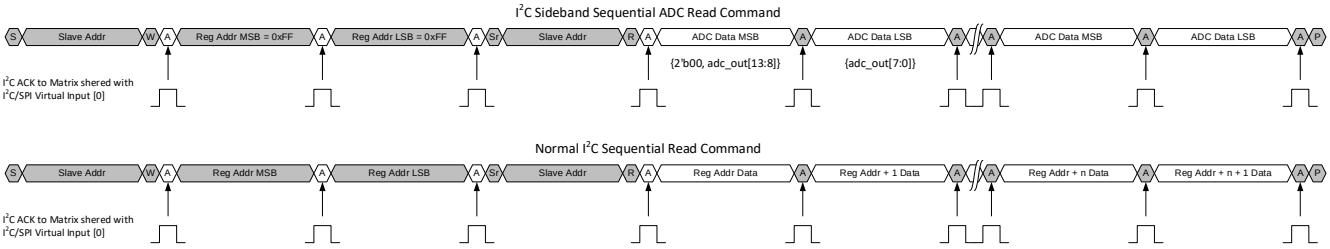



**Figure 120. I²C Sideband Sequential Read Protocol for ADC Data**

## 11.10 Data Flow and Alignment

The macrocells in the SLG47011 have different data bus width:

- ADC: 14 bit
- Data Buffers: 16 bit
- Memory Table: 12 bit
- MathCore: 16 bit
- DAC: 12 bit.
- Width Converter: 12 bit.

Different data alignment and truncation options are shown in Figure 121.

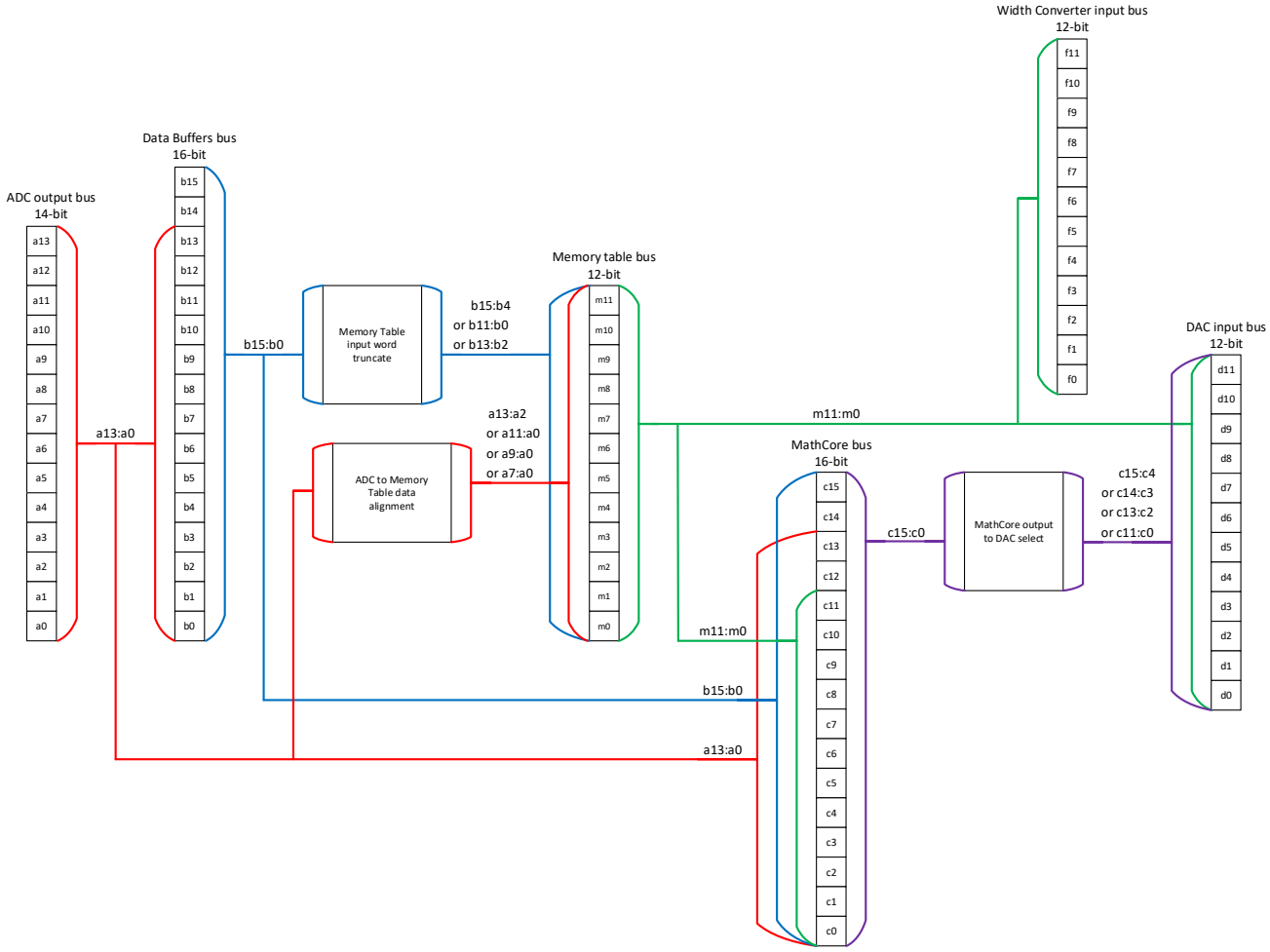



**Figure 121. Data Flow and Alignment**

## 11.11 ADC Typical Performance

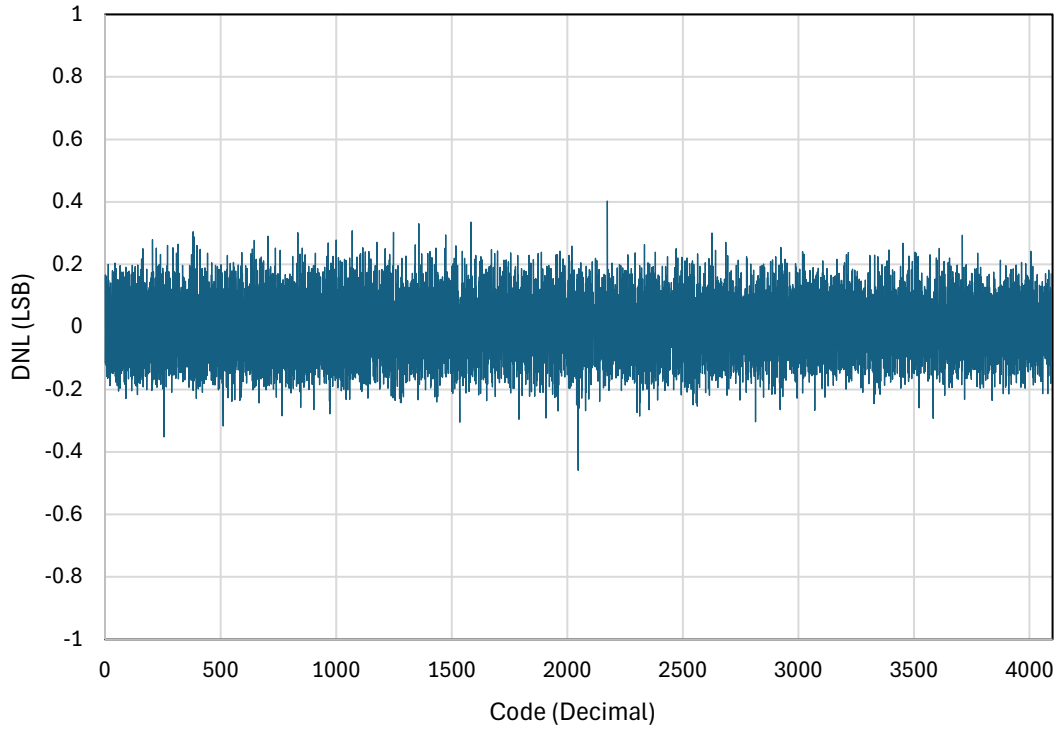



**Figure 122. Differential Non-Linearity (DNL) vs. Code at $T_A$ = +25 °C, $V_{DD}$ = 3.6 V, Resolution = 12 bit, $f_{sample}$ = 700 ksps, $V_{REF}$ = 1.62 V (Internal)**

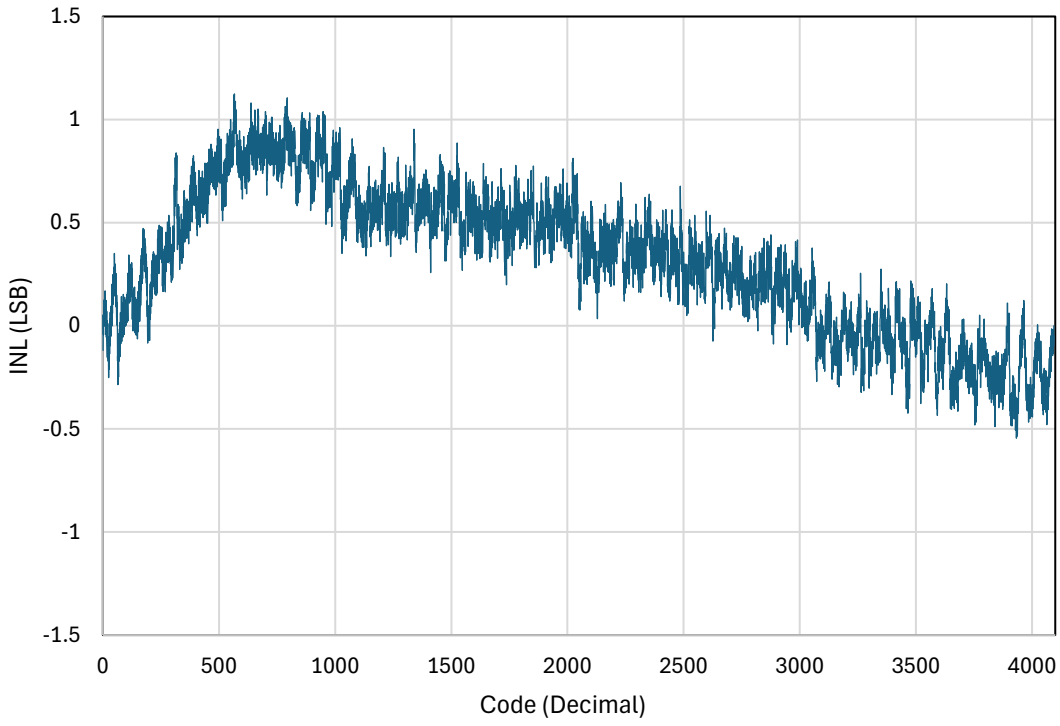



**Figure 123. Integral Non-Linearity (INL) vs. Code at $T_A$ = +25 °C, $V_{DD}$ = 3.6 V, Resolution = 12 bit, $f_{sample}$ = 700 ksps, $V_{REF}$ = 1.62 V (Internal)**

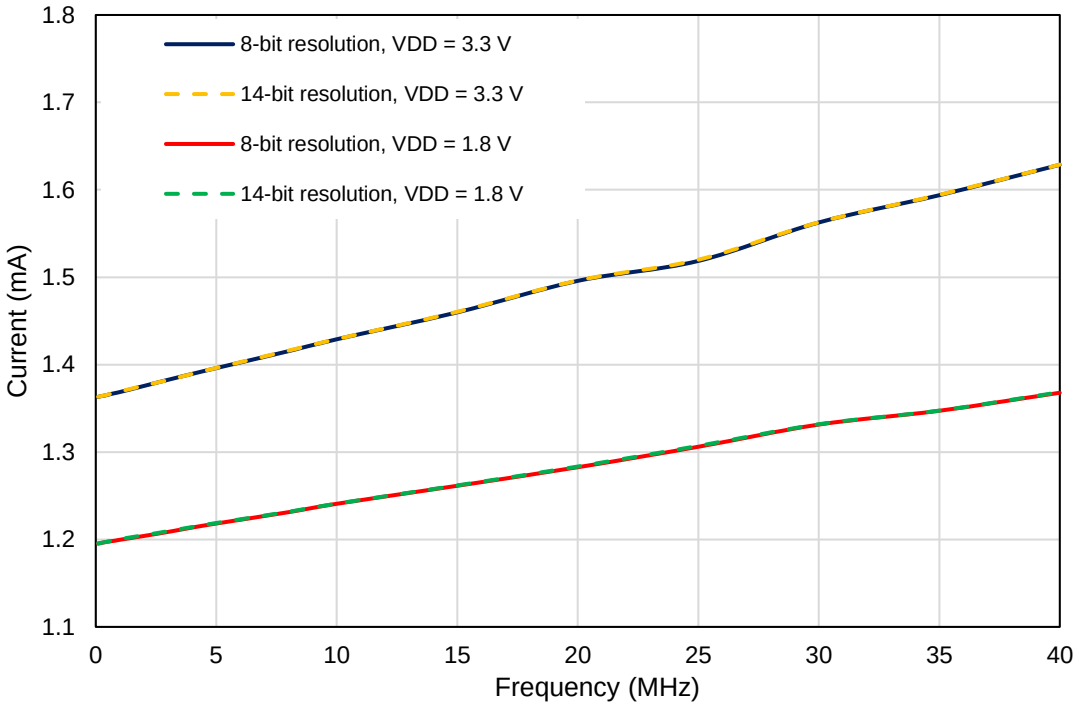



**Figure 124. Power Consumption vs. ADC Clock Frequency at $T_A$ = +25 °C**

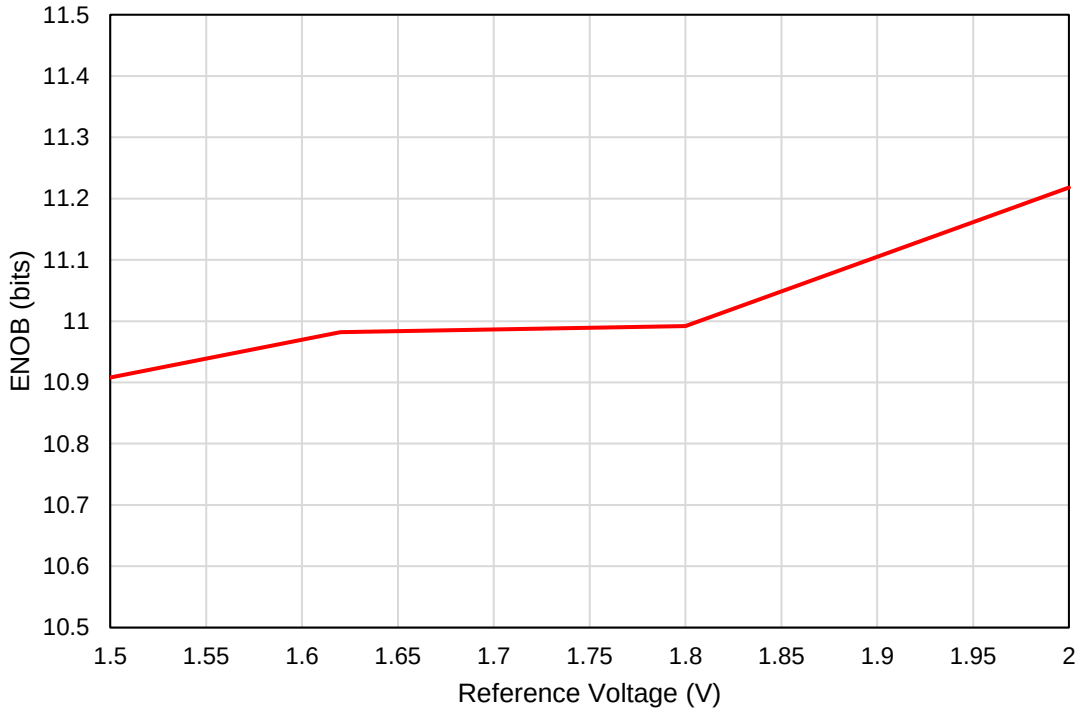



**Figure 125. ENOB vs. Reference Voltage at $T_A$ = +25 °C, $V_{DD}$ = 3.3 V, Resolution = 14 bit, $f_{sample}$ = 1 Msps, $V_{REF}$ - External, ADC Clock - External**

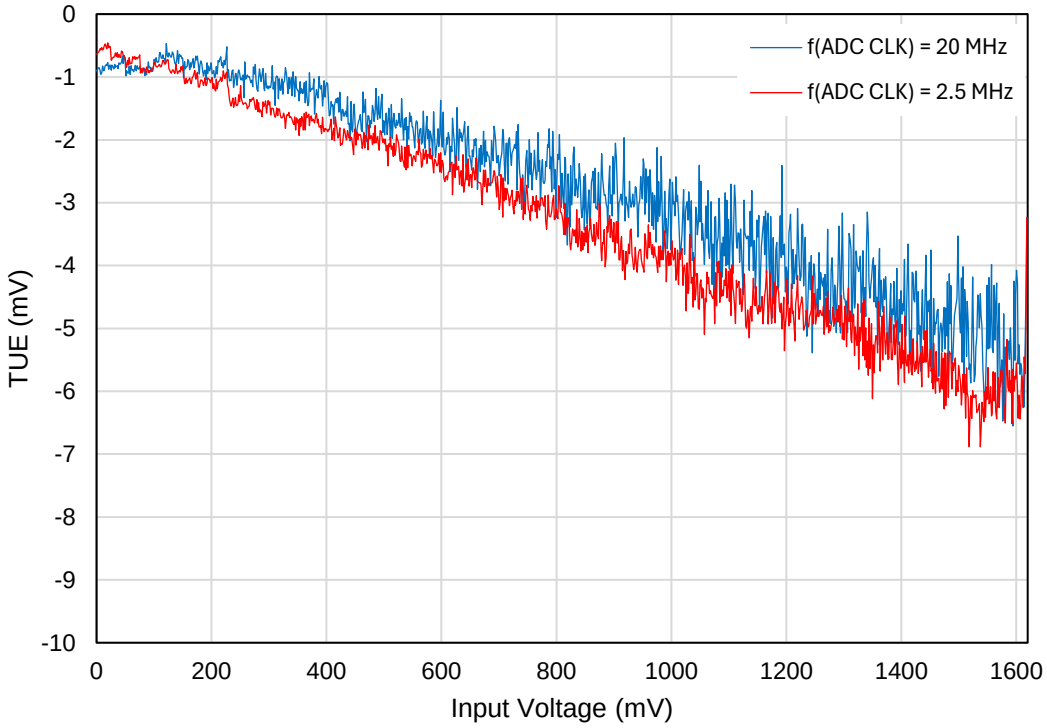



**Figure 126. Total Unadjusted Error (TUE) vs. Input Voltage at $T_A$ = +25 °C, $V_{DD}$ = 3.3 V, Resolution = 14 bit, $V_{REF}$ = 1.62 V (Internal)**

# 12. Digital-to-Analog Converter Macrocell

## 12.1 DAC General Description

The Digital-to-Analog Converter (DAC) macrocell outputs a voltage to the GPIO8 pin with a resolution of 12 bits. The DAC Power-up CMO1 [85] signal is used to control power-up/sleep state of the DAC. There are a variety of options available for the reference voltage $V_{REF}$ of the DAC. These options are shared with the ADC (see section 22 Internal Voltage Reference).

The DAC input can be a static value stored in registers DAC_VALUE [3251:3248, 3263:3256], Memory Table macrocell data, or MathCore output data. The static value can be changed via I²C/SPI interfaces.

The DAC input data from the MathCore is controlled by registers DAC_MATH_MSB_SEL [3269:3268] and has four data alignment options (see Figure 121).

The DAC has three output options: buffered output (inverting buffer), unbuffered output, or out to the ACMP (see Table 24). The output option is selected by DAC_EN_INV_BUF [3264] and DAC_BUF_OUT [3266] registers.

**Table 24. DAC Output Configuration**

| DAC_EN_INV_BUF [3264] | DAC_BUF_OUT [3266] | Mode Description | Output to GPIO | Output to ACMP |
|---|---|---|---|---|
| 0 | 0 | Unbuffered output to GPIO | Unbuffered | Open, Hi-Z |
| 0 | 1 | Unbuffered output to ACMP | Open, Hi-Z | Unbuffered |
| 1 | 0 | Buffered inverted output to GPIO | Buffered inverted | Open, Hi-Z |
| 1 | 1 | No output to GPIO or ACMP | Open, Hi-Z | Open, Hi-Z |

If the DAC output is buffered (inverting buffer), the output voltage is defined by the following equation:

$$V_{DACOUT} = V_{REF} – (\text{DAC input code}) * V_{REF}/4096$$

If DAC output is unbuffered or out to ACMP is selected, the output voltage is defined by the following equation:

$$V_{DACOUT} = (\text{DAC input code}) * V_{REF}/4096$$

The DAC startup time from DAC Power-up CMO1 [85] signal to DAC output ready is approximately 26 µs.

**Note:** Before issuing a DAC configuration change command via I²C/SPI, the DAC must be powered off.

The DAC has built-in offset correction. Offset is automatically measured at mid-scale and stored in 2's complement format in read-only registers DAC_OFFS_BUFF [3279:3272] and DAC_OFFS_UNBUFF [3287:3280].

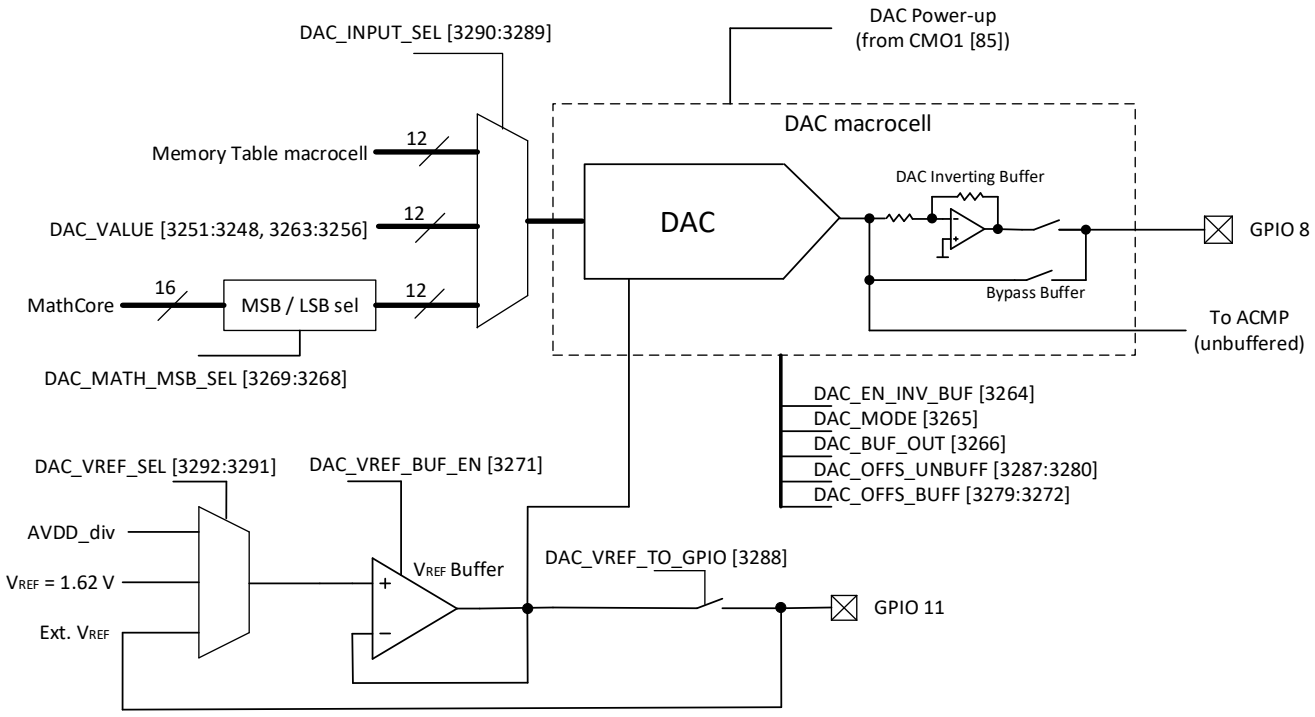



**Figure 127. DAC Structure**

## 12.2 DAC $V_{REF}$

There are three options for the DAC $V_{REF}$ source: 1.62 V internal $V_{REF}$ source, selectable divider of the $AV_{DD}$ voltage, and external $V_{REF}$ source via the GPIO11 pin. $V_{REF}$ options are selected by registers DAC_VREF_SEL [3292:3291].

To source the DAC $V_{REF}$ voltage from the GPIO11 pin, the GPIO11 switch must be turned on (DAC_VREF_TO_GPIO [3288] = 1).

For details see section 22 Internal Voltage Reference.

## 12.3 DAC Typical Performance

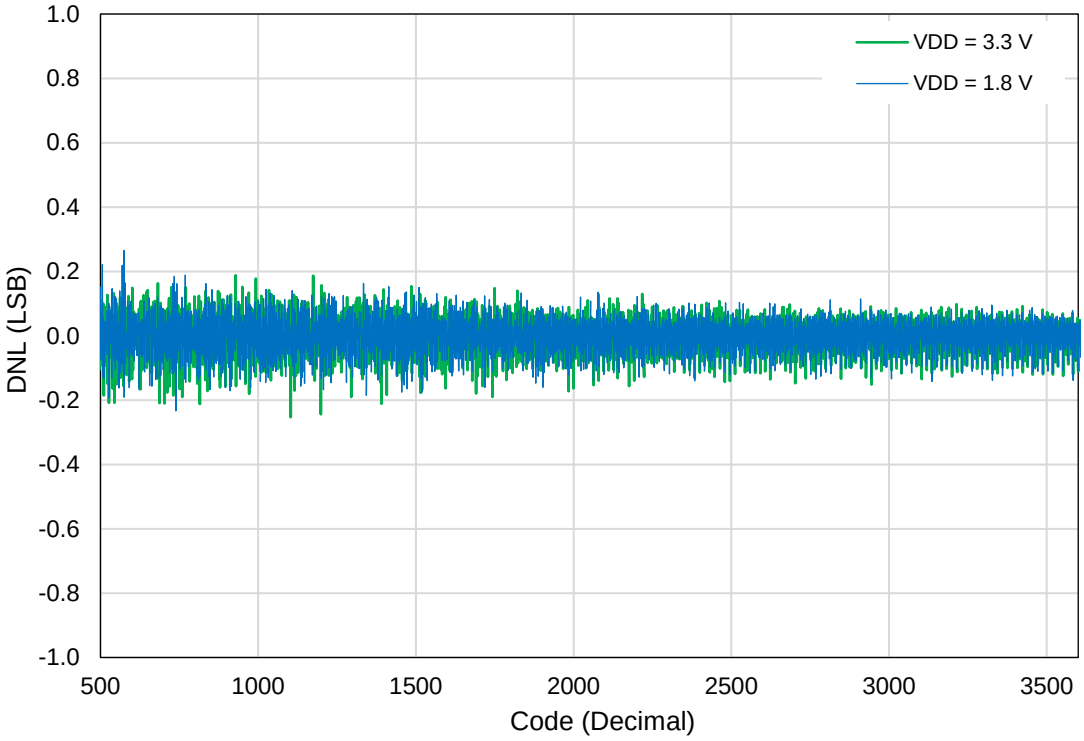



**Figure 128. Differential Non-Linearity (DNL) vs. Code at $T_A$ = +25 °C, $V_{REF}$ = 1.62 V (Internal), DAC Buffer ON**

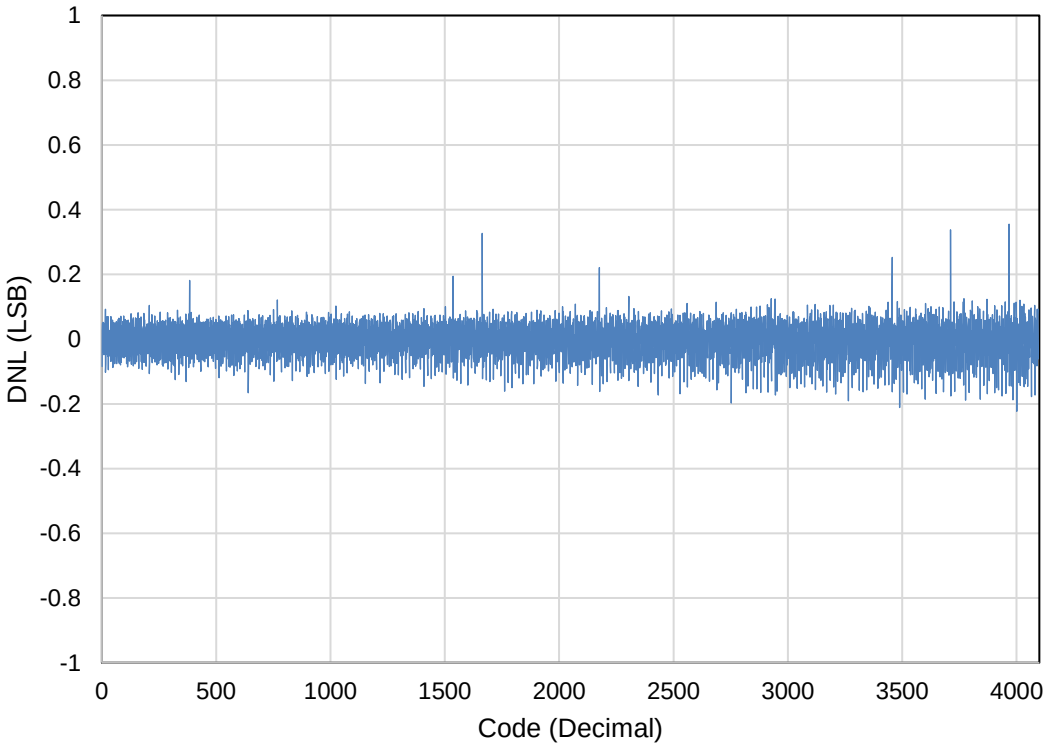



**Figure 129. Differential Non-Linearity (DNL) vs. Code at $T_A$ = +25 °C, $V_{REF}$ = 1.62 V (External), $V_{DD}$ = 3.3 V, DAC Buffer OFF**

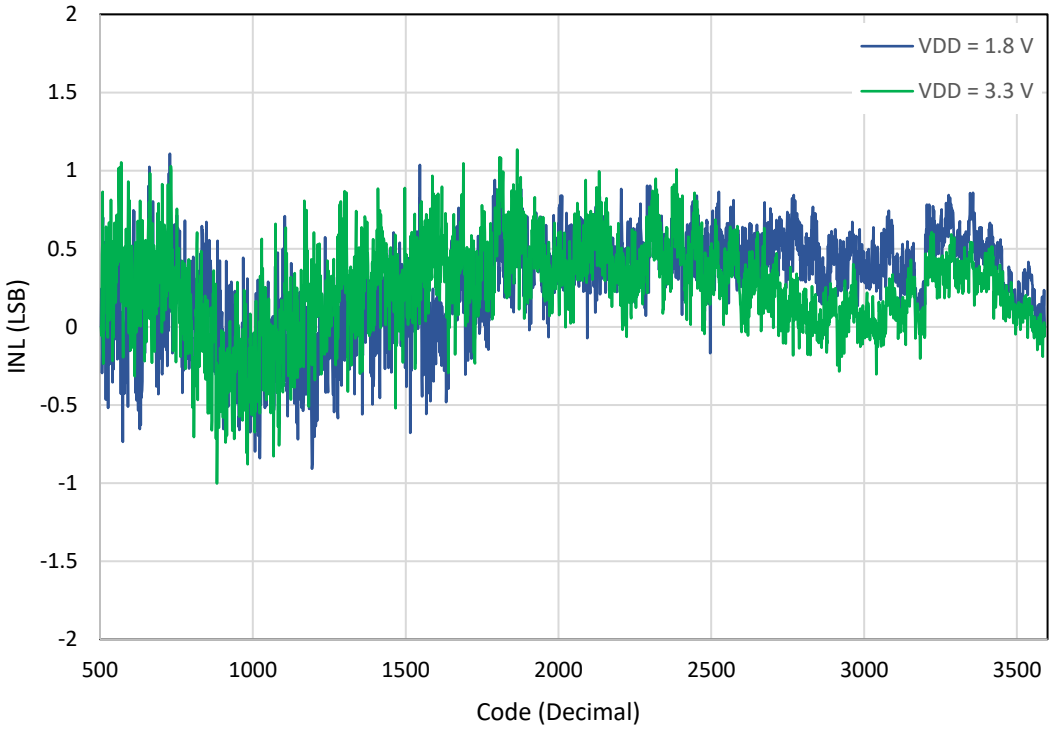



**Figure 130. Integral Non-Linearity (INL) vs. Code at $T_A$ = +25 °C, $V_{REF}$ = 1.62 V (Internal), DAC Buffer ON**

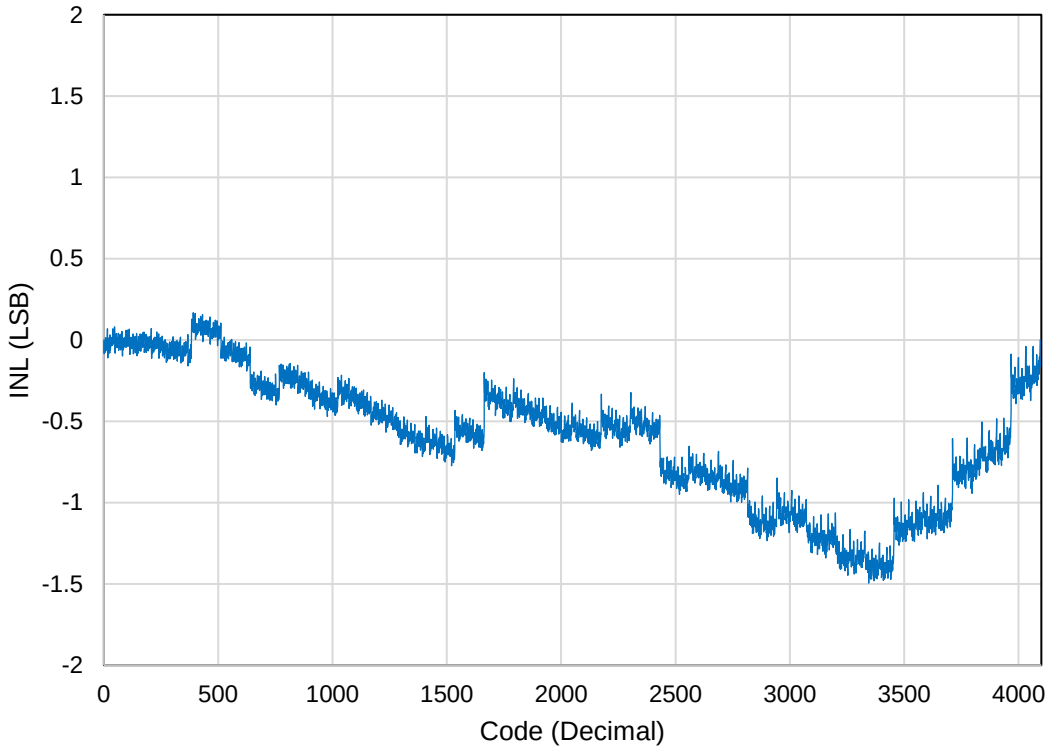



**Figure 131. Integral Non-Linearity (INL) vs. Code at $T_A$ = +25 °C, $V_{REF}$ = 1.62 V (External), $V_{DD}$ = 3.3 V, DAC Buffer OFF**

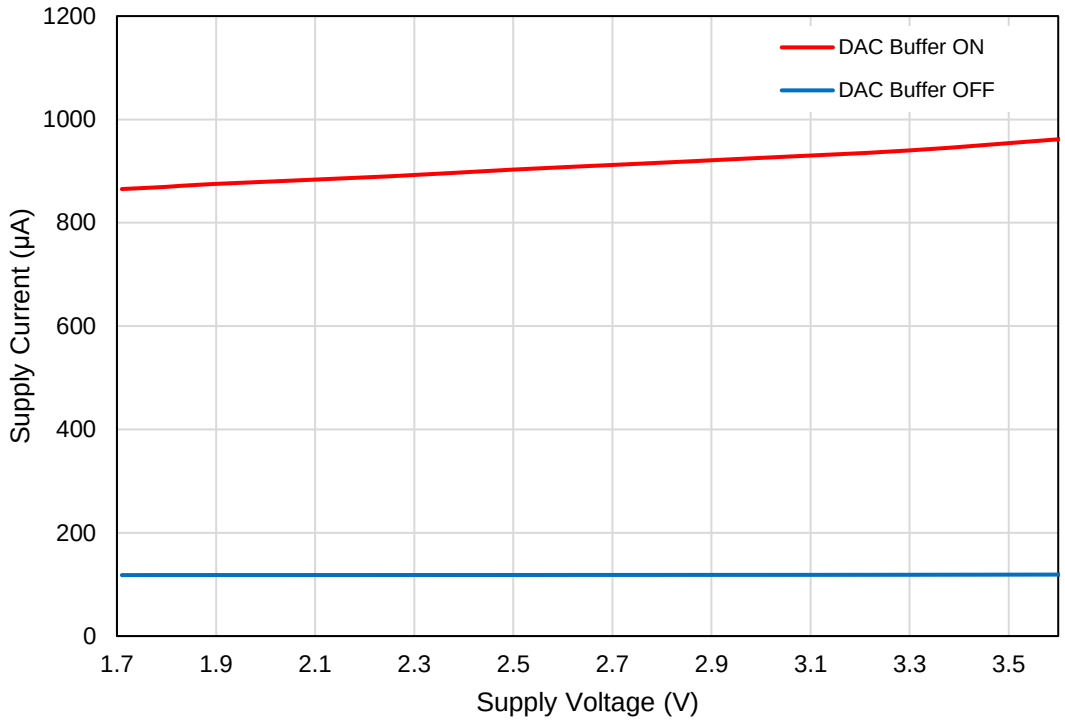



**Figure 132. Supply Current vs. Supply Voltage at $T_A$ = +25 °C**

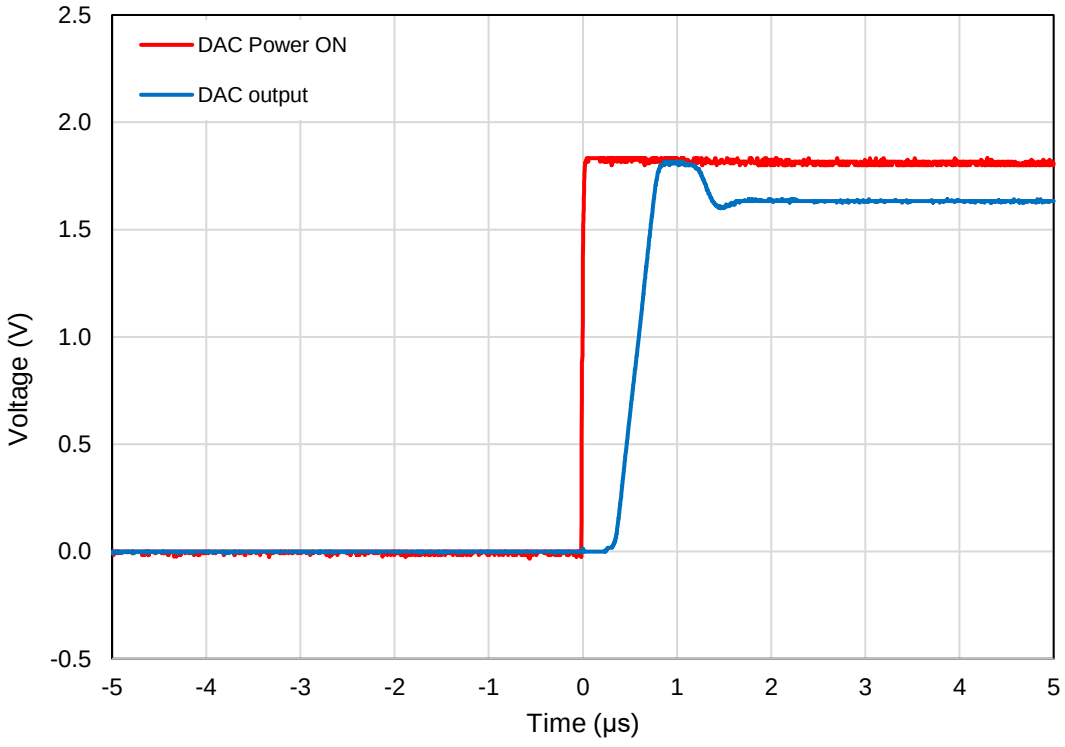



**Figure 133. Wake-Up Time/Full-Scale Settling Time at $T_A$ = +25 °C, $V_{DD}$ = 1.8 V, $V_{REF}$ = 1.62 V (Internal), DAC Buffer ON**

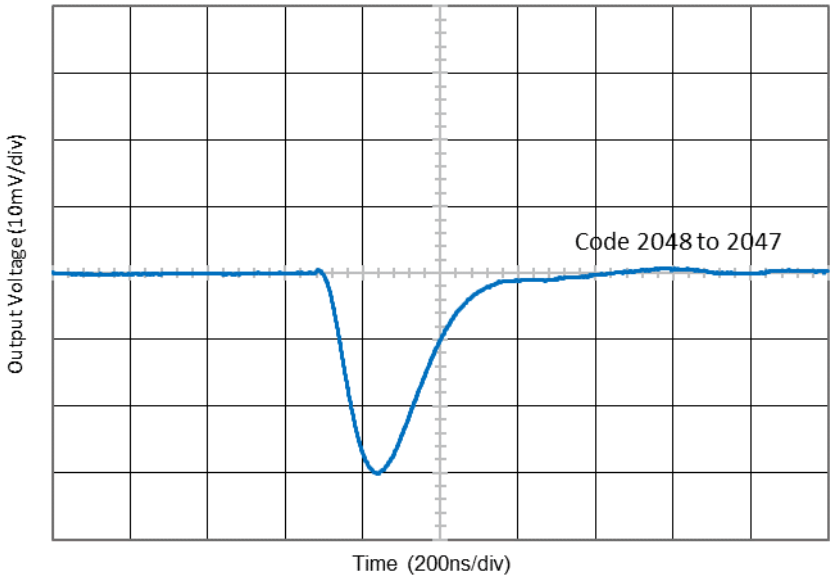



**Figure 134. Worst Case Glitch Response at $T_A$ = +25 °C, $V_{DD}$ = 1.8 V, $V_{REF}$ = 1.62 V (Internal), DAC Buffer ON**

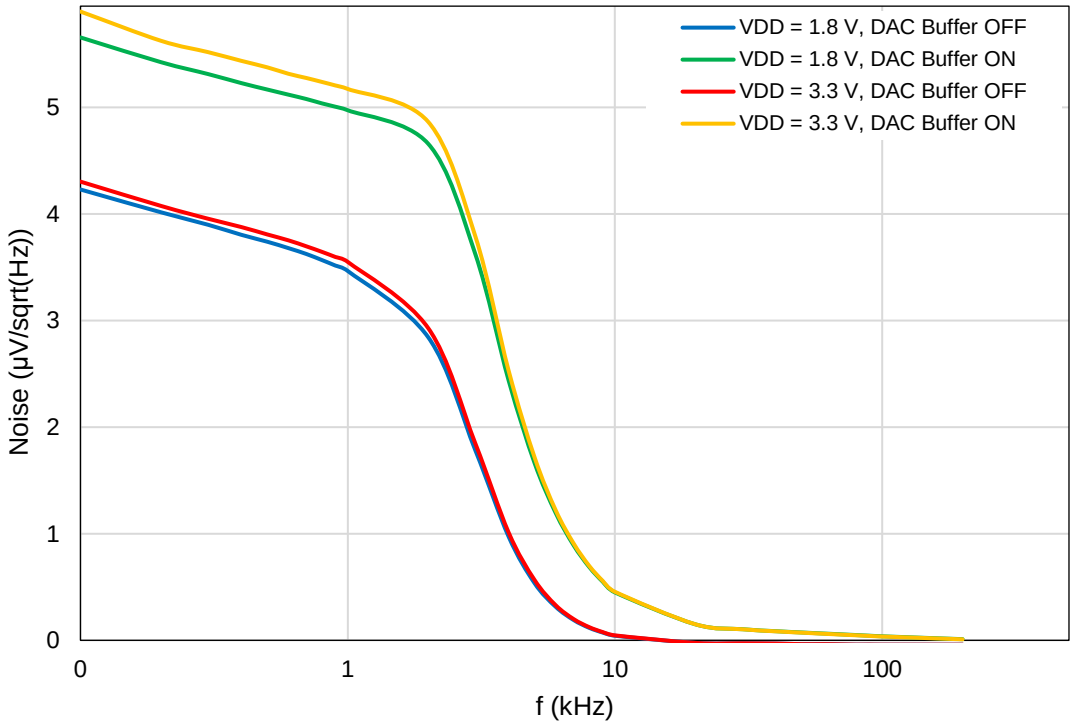



**Figure 135. Frequency vs. Output Noise Spectral Density at $T_A$ = +25 °C, $V_{REF}$ = 1.62 V (Internal)**

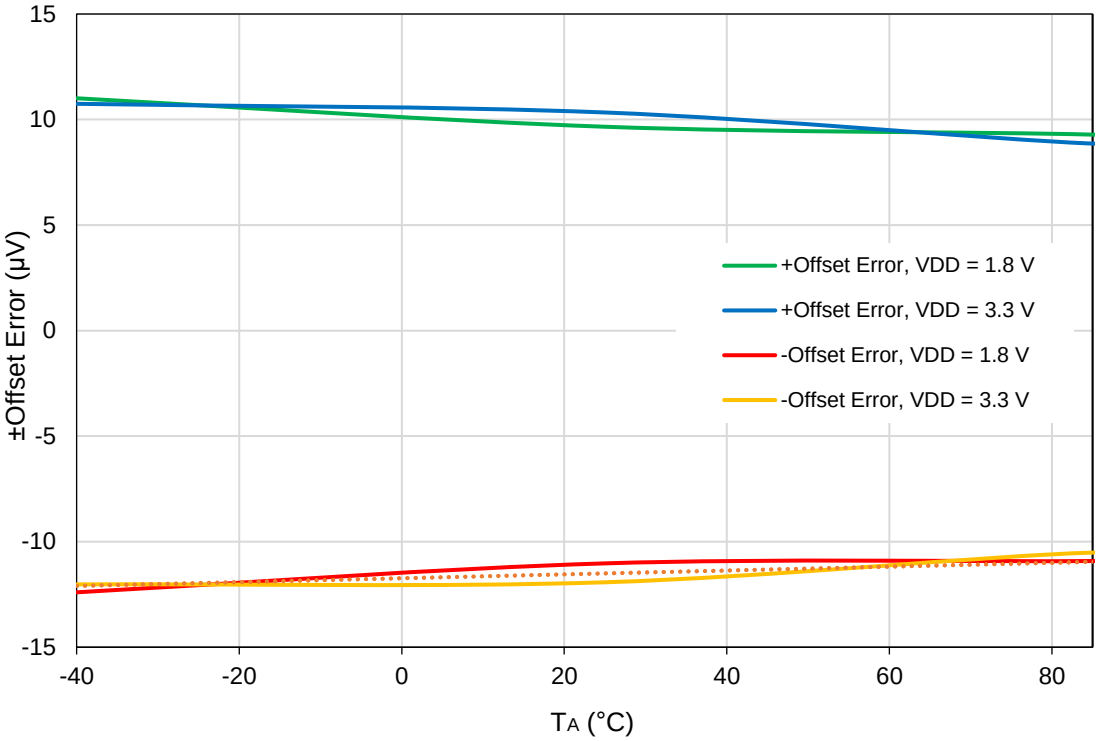



**Figure 136. Offset Error vs. Temperature at $T_A$ = +25 °C, $V_{REF}$ = 1.62 V (Internal), DAC Buffer ON**

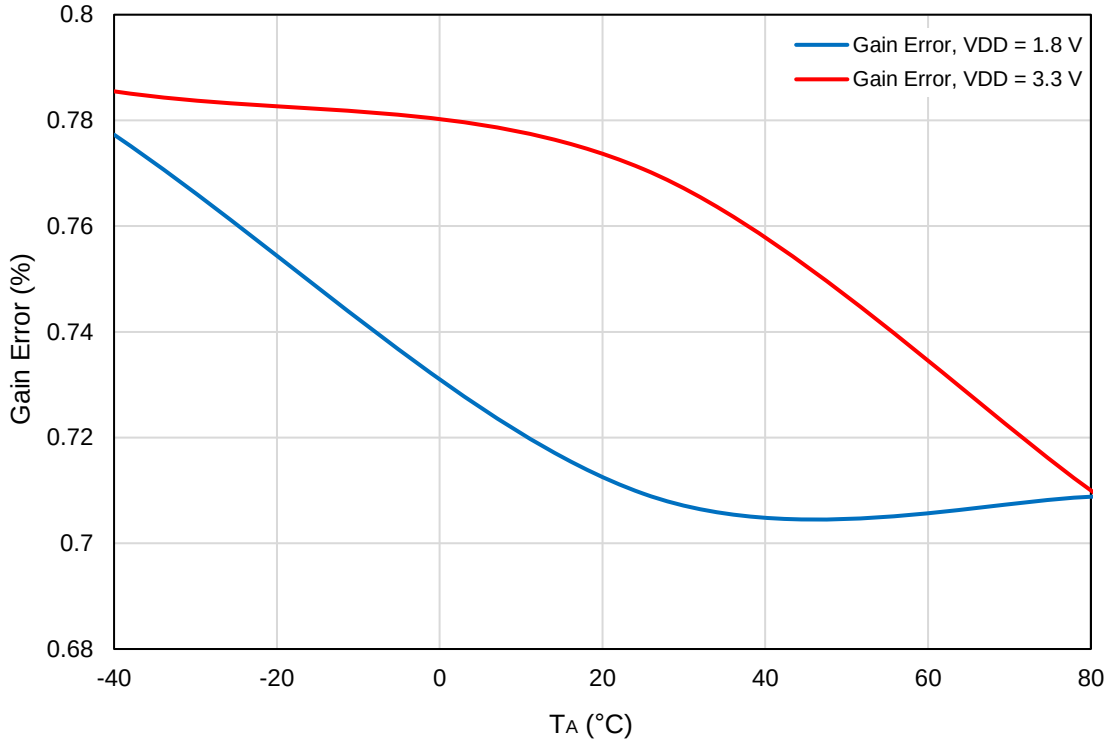



**Figure 137. Gain Error vs. Temperature at $T_A$ = +25 °C, $V_{REF}$ = 1.62 V (Internal), DAC Buffer ON**

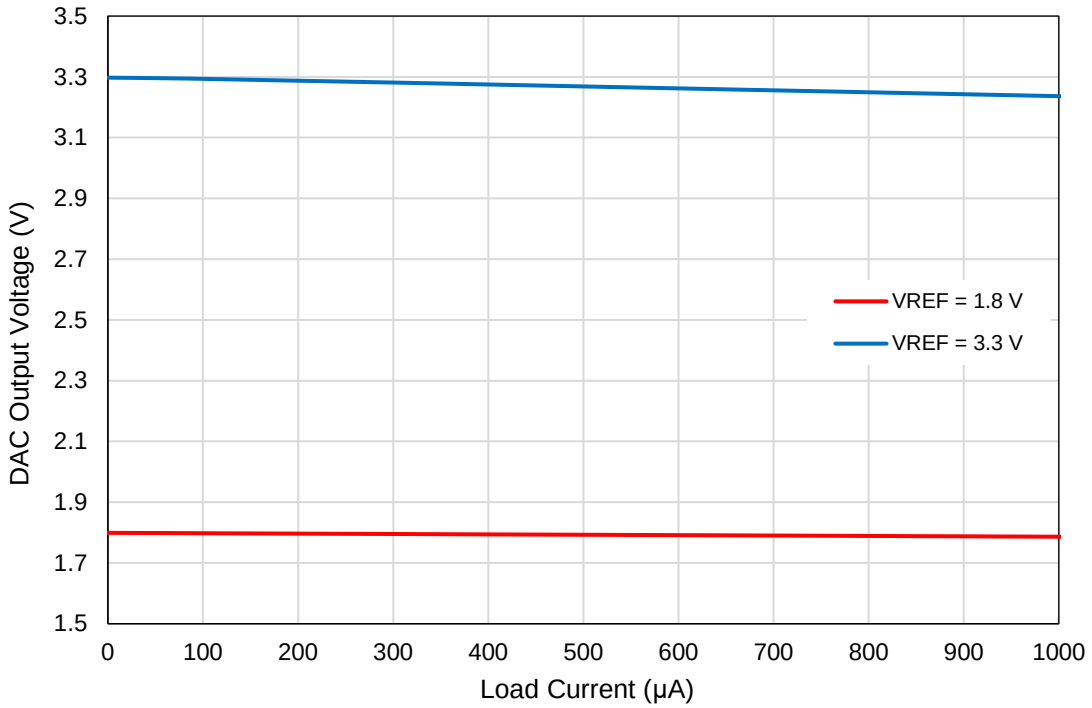



**Figure 138. DAC Output Voltage Drop vs. Load Current at $T_A$ = 25 °C, $V_{DD}$ = 3.3 V, DAC Buffer ON**

# 13. Memory Table Macrocell

## 13.1 Memory Table General Description

The Memory Table macrocell is a memory block that can hold 4096 12-bit words. It has a 12-bit address and a 12-bit data port. The structure diagram of the Memory Table Macrocell is shown in Figure 139.

The Memory Table can work in two modes selected by register MEM_MODE_SEL [2728]:

- ADDR-to-DATA mode (register MEM_MODE_SEL [2728] = 1): Memory Table output consists of the data pre-written in addressed cell.
- Storage mode (register MEM_MODE_SEL [2728] = 0): Memory Table works as a general purpose storage block, which can be read via I²C/SPI.

Data in all modes can be written via I²C/SPI interface.

The memory address input source is selected by registers MEM_ADDR_SEL [2732:2729]. The address input source for the Memory Table can be selected from:

- Data Buffer0
- Data Buffer1
- Internal counter (must be selected when operating in Storage mode only)
- ADC channels 0 to 3
- Memory Control Counter
- I²C/SPI Host Interface.

The data input source is selected by register MEM_DATA_SEL [2735]. The data input source for Memory Table can be selected from:

- Data Buffer0
- ADC channels 0 to 3
- NVM
- I²C/SPI Host Interface.

The data output can be sourced to:

- DAC
- PWM
- CNT/DLY 9
- MathCore
- DCMP
- Width Converter.

Maximum clock rate for the Memory Table is 20 MHz.

All operations with the Memory Table or Data Buffers should be completed 5 µs before entering SLEEP or RETENTION modes (see section 5 Power Architecture).

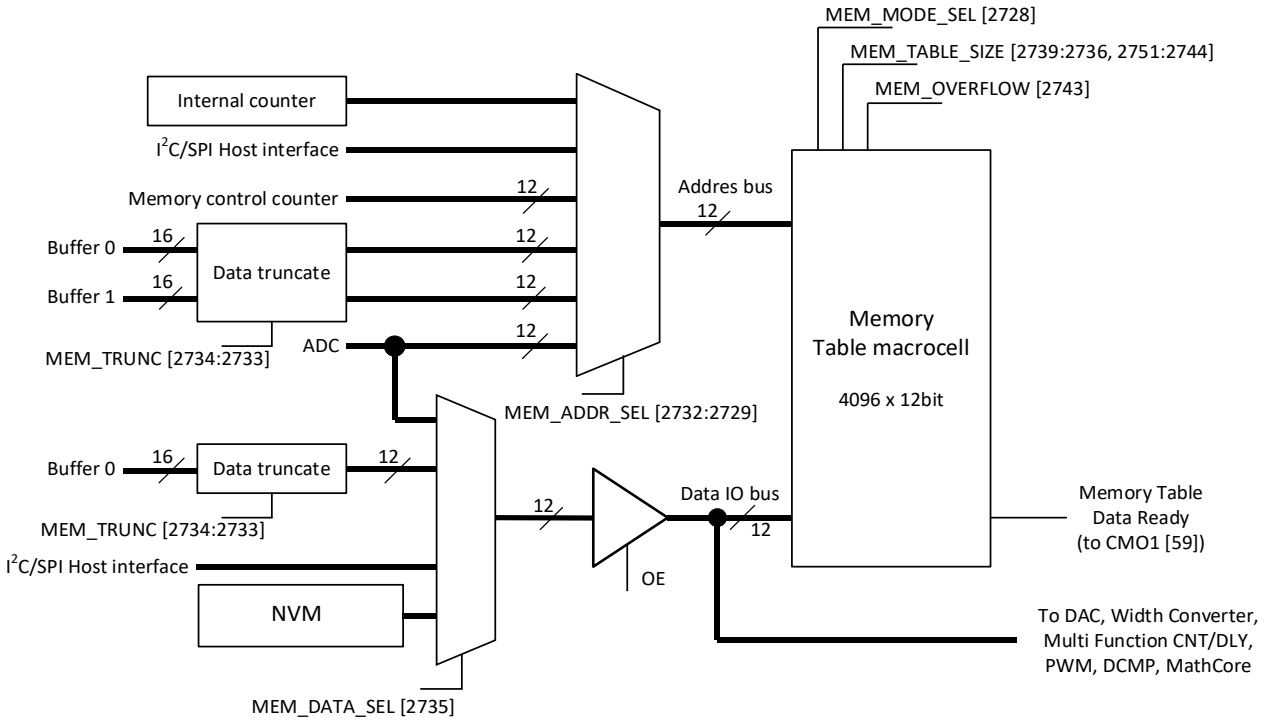



**Figure 139. Memory Table Macrocell Simplified Structure**

## 13.2 ADDR-to-DATA Mode

In ADDR-to-DATA mode, the Memory Table data is loaded from NVM at chip startup. If an address is applied to the address input, the corresponding data word will be available after some propagation delay and access time at the output port. ADDR-to-DATA mode is enabled by setting register MEM_MODE_SEL [2728] = 1.

The initial output value of the Memory Table macrocell can be the first SRAM address (0x200) after NVM load completed. This option is enabled by the MEM_INIT_OUT [3784] register. Otherwise, if register MEM_INIT_OUT [3784] = 0, the Memory Table output will be unpredictable after Power-up event.

The address source choices for the Memory Table (in ADDR-to-DATA mode) selected by MEM_ADDR_SEL [2732:2729] can be: Data Buffer0, Data Buffer1, ADC channels 0 to 3, Memory Control Counter, or I²C/SPI Host Interface.

If ADC channel 0 to 3 is selected as address source (registers MEM_ADDR_SEL [2732:2729] = 3 to 6), the ADC conversion data from selected channel will be used as the Memory Table address.

If the ADC is operating with a resolution other than 12-bit, address alignment rules are as follows. In case of 14-bit resolution, the MSB from the ADC will be aligned with the MSB of the Memory Table. In case of an 8-bit and 10-bit ADC resolution, LSB of the ADC code will align with the Memory Table, as shown in Figure 140.

If the Data Buffer (ADDR-to-DATA or Storage mode) is selected as the input source of the Memory Table address bus, only 12 bits of the 16 Data Buffer bits can be used as the Memory Table address. Registers MEM_TRUNC [2734:2733] are used to configure which 12 bits of the Data Buffer will be used as the memory address (MSB, LSB, middle part), see Figure 141. Setting the value to ‘0b00’ will use the MSB, while setting the value to ‘0b01’ will use the LSB, and setting the value to ‘0b10’ will use the middle part from bit 2 to bit 13. ‘0b00’ is the default setting of this register.

If the Memory Table is in ADDR-to-DATA mode and the user accesses its data via I²C/SPI, any macrocell that accesses the Memory Table (ADC, Memory Control Counter, Data Buffers) must be stopped or disabled via register settings and the Memory Table address input source should be changed to MEM_ADDR_SEL [2732:2729] = 0x8. After the host read/write operation, the Memory Table source setting should be reverted to the previous setting and the operation of the ADC, control counter, or Data Buffers can be resumed.

The Memory Table macrocell output can be connected to the DAC, 12-bit CNT/DLY9, Width Converter, PWM macrocell, as well as to the MUX of a positive input of the DCMP macrocell.

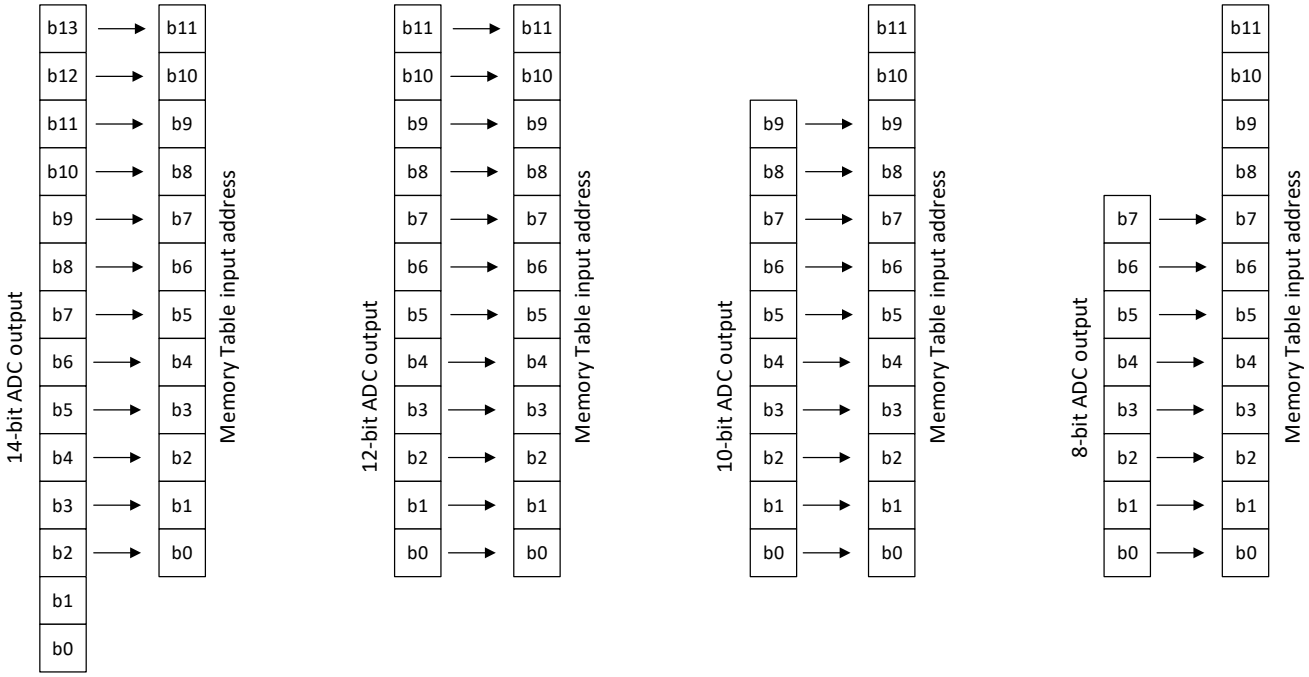



**Figure 140. Memory Table - ADC Bus Configuration**

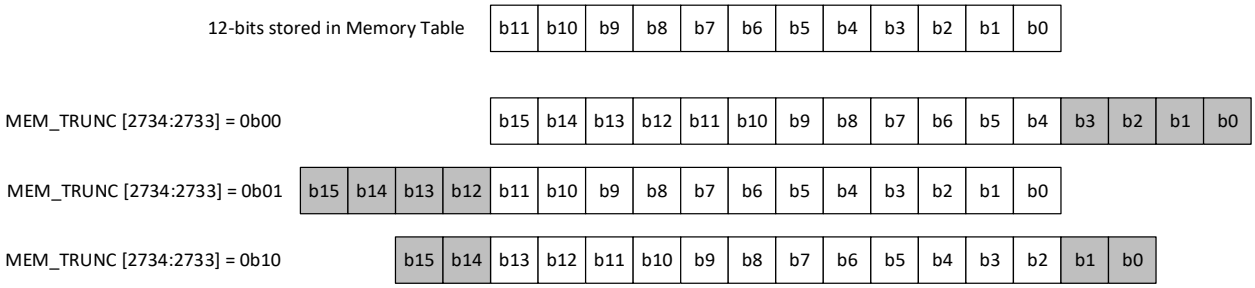



**Figure 141. Memory Table Input Word Truncate (Gray Truncated)**

## 13.3 Storage Mode

Storage mode is an operating mode that stores ADC conversion data in the Memory Table, acting as a buffer. Storage mode is enabled by setting register MEM_MODE_SEL [2728] = 0. In this mode, data input for the Memory Table macrocell is selected by the MEM_DATA_SEL [2735], options are: ADC output and Data Buffer0. The memory address is automatically incremented by an internal counter for every new data word that is available from the ADC.

If the Memory Table is connected to the ADC via Data Buffer0, the ADC sample count will be increased by the value stored in ADC_SAMPLE_COUNT [2553:2552] and divided by BUF0_RDY_DIV [2769:2768] (Data Buffer0 will output intermediate values of the averaging process into the memory). For example: MEM_TABLE_SIZE [2739:2736, 2751:2744] = N * (ADC_SAMPLE_COUNT [2553:2552] * ADC channel enable count/BUFx_RDY_DIV [1:0]) - 1,

where N is the number of conversion start pulses needed to fill the Memory Table size.

If the ADC is connected directly to the Memory Table without Data Buffer, the number of conversion start pulse needed to fill the Memory Table with N size words will be

MEM_TABLE_SIZE [2739:2736, 2751:2744] = N * (ADC_SAMPLE_COUNT [2553:2552] * ADC channel enable count) - 1.

Each channel will be sampled sequentially as many times as set by ADC_SAMPLE_COUNT [2553:2552] and written into the Memory Table. For example, if two channels are sampled and the sample count is also two, then two conversion start pulses will fill the Memory Table contents starting from a zero address with the following samples: Ch1 sample 1, Ch2 sample 1, Ch1 sample 2, Ch2 sample 2, Ch1 sample 3, Ch2 sample 3, Ch1 sample 4, Ch2 sample 4.

Internal counter overflow behavior is configured with the MEM_OVERFLOW [2743] register. Two available options are to continue from the start address (MEM_OVERFLOW [2743] = 1) or stop at the end address (MEM_OVERFLOW [2743] = 0).

Storage mode starts operating by loading ADC conversion data from each ADC channel selected after the ADC Conversion Start signal becomes active. Next, the Memory Table stores samples incrementally until the end of the buffer (4096 words maximum). The Memory Table size is defined by MEM_TABLE_SIZE [2739:2736, 2751:2744], and the value can range from 1 to 4096 data words.

The user can read the contents of the Memory Table via I²C/SPI interface.

If ADC Conversion Start (CMO [71]) remains asserted beyond five ADC clock cycles before the Memory Table is filled, and MEM_OVERFLOW [2743] = 1, the conversion procedure will continue writing samples to the Memory Table (continuous conversion operation) (see Figure 142). If the Memory Table starts from the zero address, the previous data in the Memory Table will be overwritten with new samples. If Conversion Start is de-asserted before Memory Table is filled (more than five ADC clock cycles before the Memory Table ready signal become active), then the Sampling Engine will finish sampling until the end address of the Memory Table, which is configured by MEM_TABLE_SIZE [2739:2736, 2751:2744] and sampling will stop. The Memory Table ready (CMI1 [59]) signal will appear when the last sample is transferred. For any subsequent ADC conversions and memory updates, the user should set the ADC Conversion Start (CMO1 [71]) active again. New samples of the ADC will overwrite prior data in the Memory Table.

After the last data word is stored in the Memory Table, a data ready output (CMI1 [59]) signal is asserted until a new ADC Conversion Start (CMO1 [71]) signal is received (it drops LOW on Conversion Start rising edge).

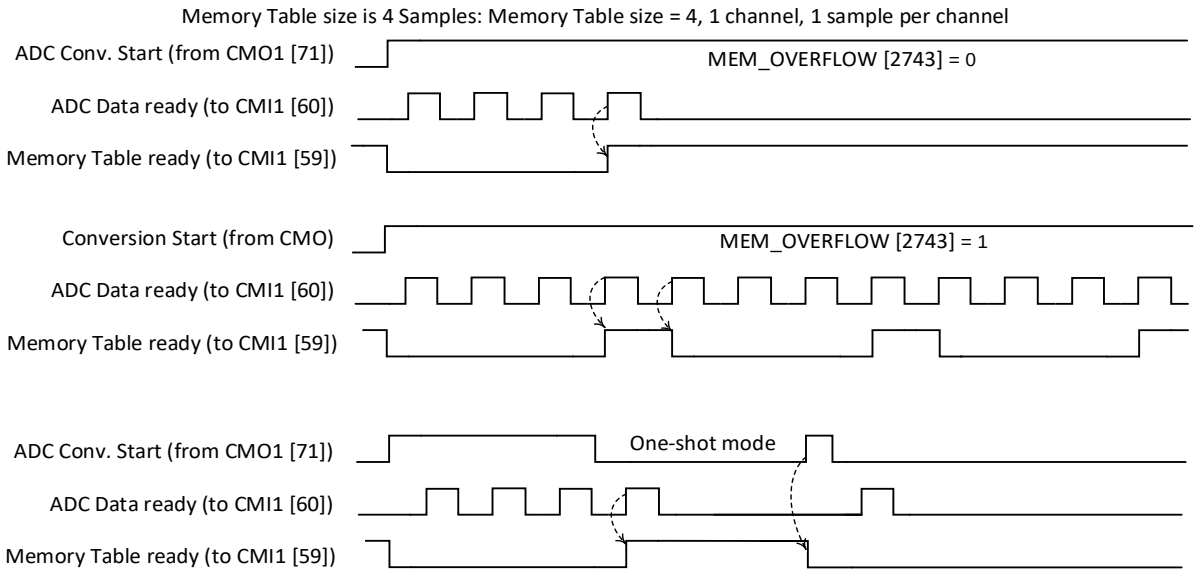



**Figure 142. Continuous and One-Shot Conversion Operation with Storage Mode Memory Table Diagram**

The order of input channels that are selected and loaded to the memory cells is from Channel 0 to Channel 3. That is, every new recording into the first memory cell starts with Channel 0 and is followed by Channel 1, and others (see Figure 143).

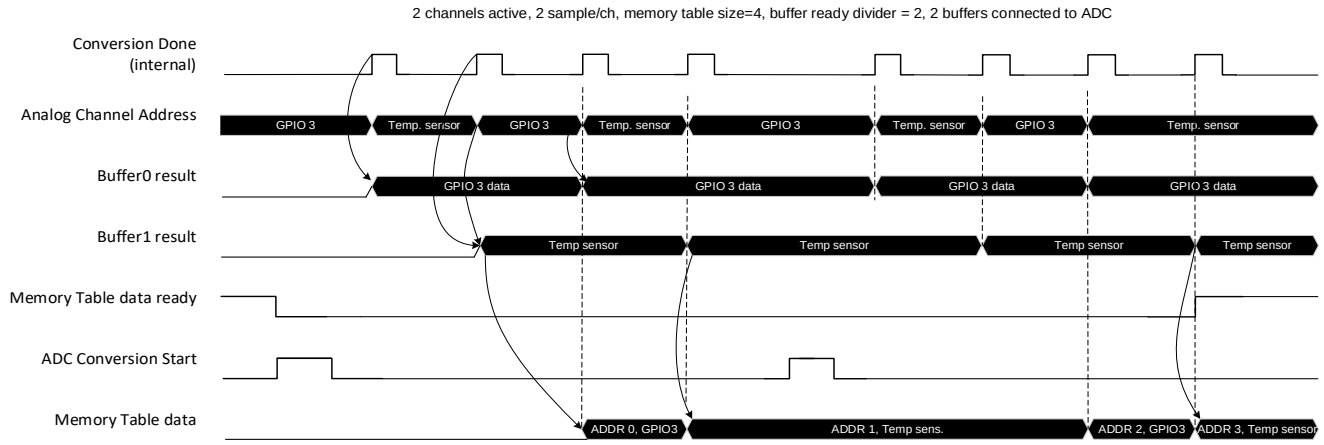



**Figure 143. One-Shot Conversion Operation with Storage Mode Memory Table Diagram**

Note that the Memory Table macrocell cannot perform read/write operations simultaneously. If the Memory Table is in Storage mode and the I²C/SPI communication requests to read data from the Memory Table, the ADC will pause for the I²C/SPI read operation to complete. After the I²C/SPI transaction is completed, the ADC will resume the suspended operation from the address where it was interrupted.

# 14. Data Buffer Macrocells

## 14.1 Data Buffers General Description

The SLG47011 has four Data Buffers designed to store or process data from the ADC or CNT/DLY. The input sources for a Data Buffer can be ADC conversion data (all Data Buffers), current value of CNT/DLY/FSM0 (Data Buffer0), current value of CNT/DLY/FSM1 (Data Buffer2), MathCore output (Data Buffer1), and also previous Data Buffer results in Daisy chain mode (Data Buffer1, Data Buffer2, Data Buffer3). A Data Buffer length of 1, 2, 4, or 8 words can be selected, as well as the initial data of the Data Buffers (0x0000 or 0xFFFF).

The operating modes for the Data Buffer are:

- Storage mode
- Moving Average mode
- Oversampling mode.

Every rising edge at the LOAD input of the Data Buffer loads data from the input. If the LOAD signal comes from an internal source, then the matrix output operates as LOAD_EN. If LOAD_EN is HIGH, it enables LOAD from an internal connection. If LOAD_EN is LOW, the internal LOAD is disabled. Note that if the Data Buffer is connected to the ADC, then the internal ADC Sampling Engine controls the LOAD signal. Each ADC channel can be assigned to a specific Data Buffer, which can be selected by registers BUFx_LOAD_SRC [2:0]. If data at the output of the Data Buffer is ready for reading, then the Buffer Ready output signal will transition HIGH. By setting registers BUFx_RDY_DIV [1:0] (BUF0_RDY_DIV [2769:2768], BUF1_RDY_DIV [2771:2770], BUF2_RDY_DIV [2773:2772], and BUF3_RDY_DIV [2775:2774]) the user can select how many samples are required to generate a BufferX Ready signal.

It is also possible to select one of the BufferX READY signals from one of four Data Buffers or one signal that indicates that all Data Buffers are READY by setting registers BUF_RD [2766:2764].

The Data Buffer latency from the arrival of the buffer LOAD signal to the buffer READY signal asserting is five oscillator OSC1 clock cycles when register DATABUFFER_BUFx_L_SYNC [1:0] = 0x0 (without sync), and five oscillator OSC1 clock + three sync clock cycles when syncronization option enabled (with ADC, FSM0, FSM1, or MathCore clock) by register DATABUFFER_BUFx_L_SYNC [1:0].

Both outputs of Data Buffer0 and Data Buffer1 (DATA or Result) can be routed to the Memory Table macrocell address input, while only Data Buffer0 (DATA or Result) can be routed to the Memory Table macrocell data input. Data stored in the Data Buffers can also be read directly via $I^2C$/SPI interfaces. Either 8x16-bit data from the DATA block or the 16-bit average value from the Result block can be read via $I^2C$/SPI.

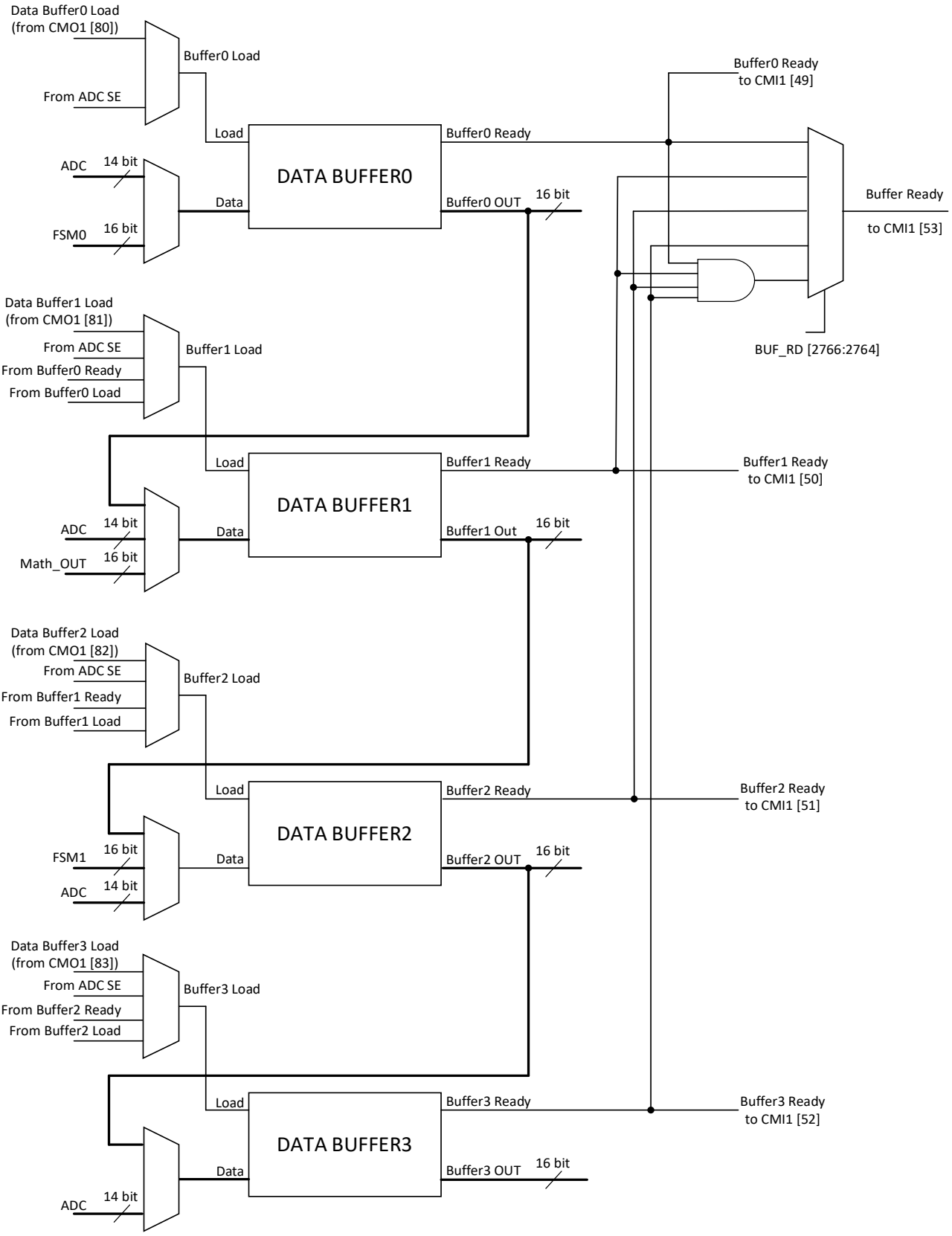



**Figure 144. Data Buffers Structure Diagram**

## 14.2 Storage Mode

Storage of data is implemented according to the FIFO (first in, first out) principle, where new data written to the Data Buffer is written over the oldest data in the Data Buffer. Data Buffers can be connected in a daisy chain. This way, if only one ADC channel is used, the length of the buffer can be increased from 8 to 32 words. If the daisy chain connection is used, the output of Data Buffer (for example, Data Buffer0) is connected to the input of the subsequent Data Buffer (for example, Data Buffer1). In the daisy chain connection, the internal BufferX signal can be connected to the LOAD signal of the subsequent Data Buffer using a direct internal connection, instead of connecting through the connection matrix (see Table 25 to Table 28).

## 14.3 Moving Average Mode

In Moving Average mode, N - the number of data words, are taken from the Data Buffer DATA, added together, and the result is divided by N, and written to the Buffer Result register. The result is updated with every new data word loaded into the Data Buffer. If four Data Buffers are connected in daisy chain (Figure 145), it is possible to average up to 4096 equivalent samples. In the daisy chain connection, the LOAD signal is sourced from the previous Data Buffer once every X clock cycles, where X is the length of the previous Data Buffer. In the daisy chain connection, the BufferX data READY signal of a Buffer is connected to the LOAD signal of the next Data Buffer using a direct internal connection, instead of connecting through the connection matrix (see Table 25 to Table 28).

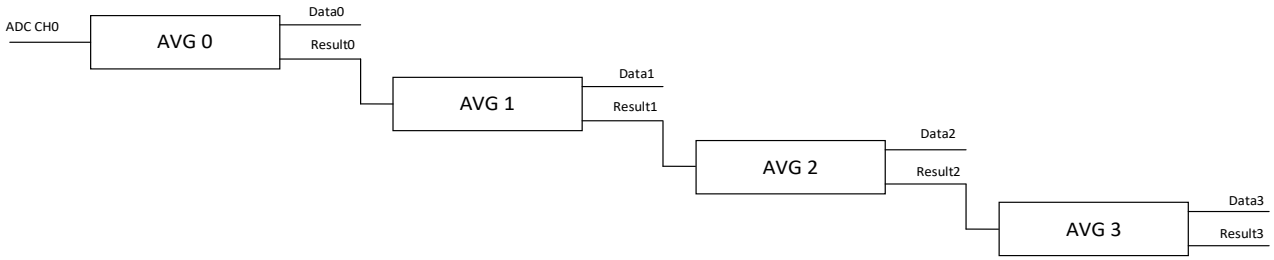



**Figure 145. Daisy Chain for Averaging 4096 Equivalent Samples**

Figure 146 shows an example of averaging 16 equivalent samples. Data Buffer0 with buffer length 4 words is connected to the Data Buffer1 with buffer length 4 words.

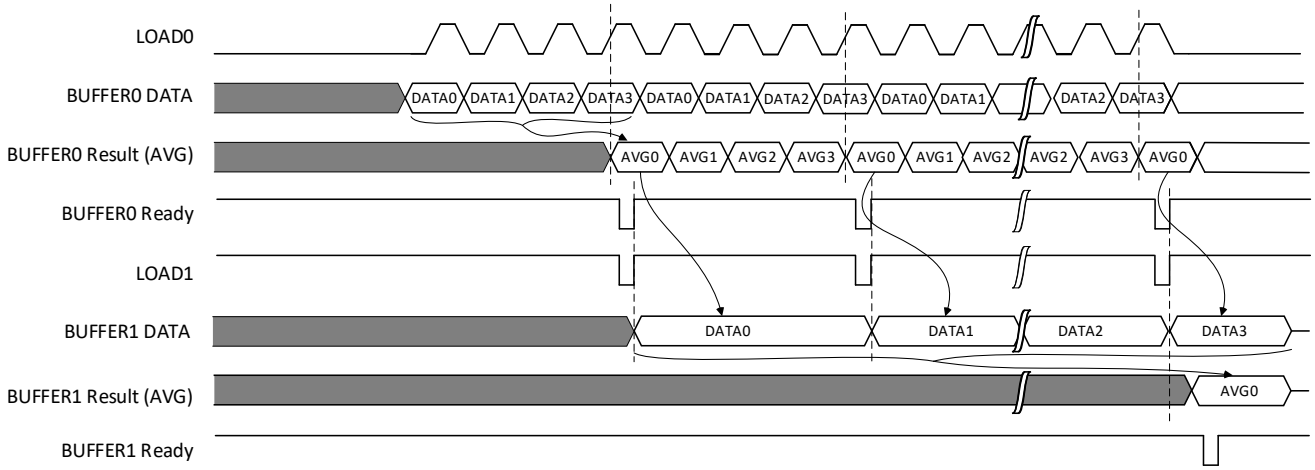



**Figure 146. Averaging 16 Equivalent Samples**

## 14.4 Oversampling Mode

Oversampling mode can be used to increase the effective resolution of the ADC. For example, if a 14-bit ADC is used and it is necessary to generate codes with 15-bits of resolution, oversampling can be used to get a 15-bit ADC result.

Oversampling is only available for buffer length of four or eight words. If buffer length is four words and Oversampling mode is activated, four samples are taken from the Data Buffer DATA, added together, and the result is divided by 2 and written to the Buffer Result. If buffer length is eight and Oversampling mode is active, eight samples are taken from the Data Buffer DATA, added together, and the result is divided by 4 and written to the Buffer Result register. If two Data Buffers are connected in a daisy chain, oversampling can increase the ADC resolution to 16 bits.

In the daisy chain connection, the BufferX Data READY signal of a Data Buffer can be connected to the LOAD signal of the next Data Buffer using a direct internal connection, instead of connecting through the connection matrix (see Table 25 to Table 28).

## 14.5 Data Buffers Structure

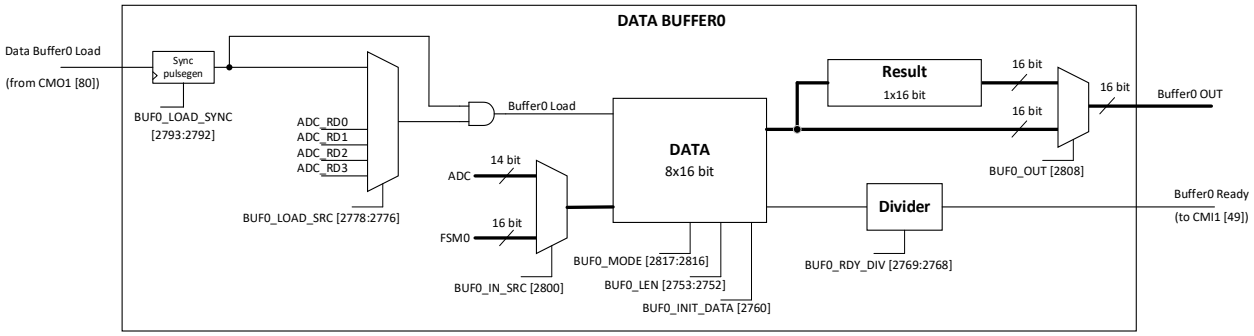



**Figure 147. Data Buffer0 Structure Diagram**

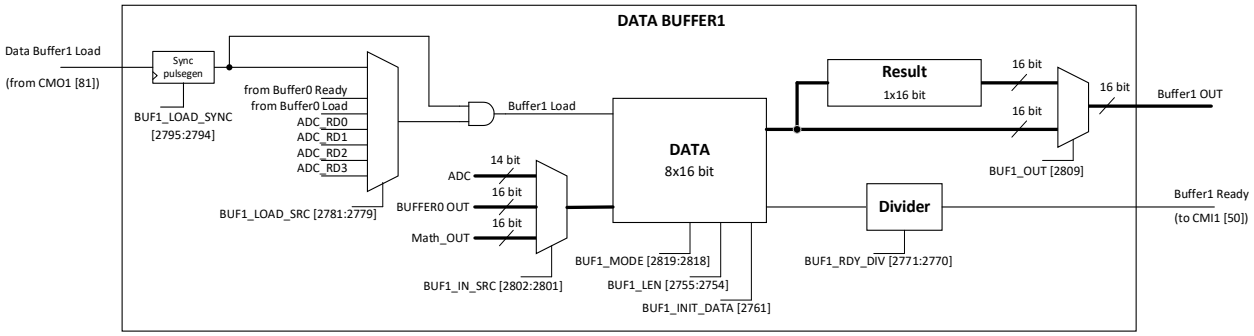



**Figure 148. Data Buffer1 Structure Diagram**

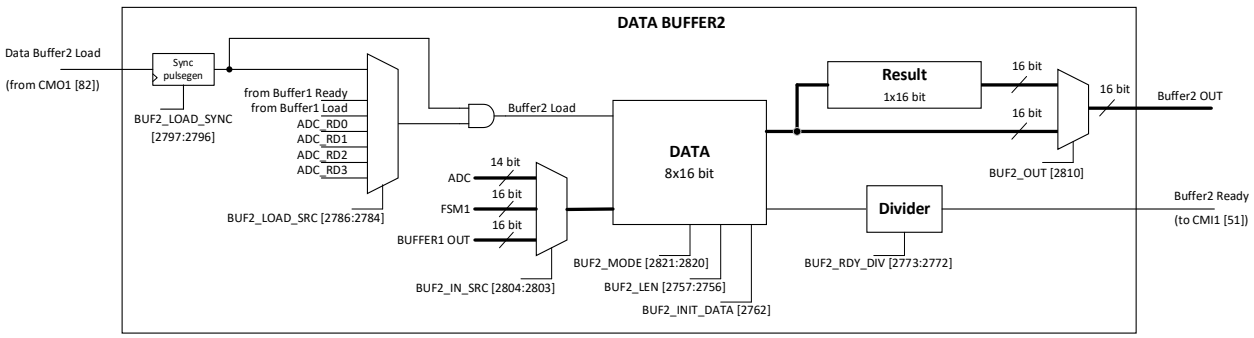



**Figure 149. Data Buffer2 Structure Diagram**

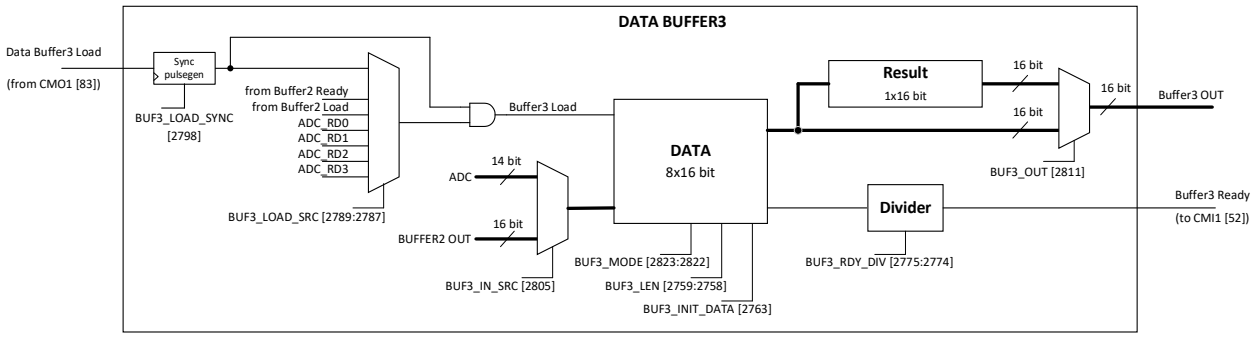



**Figure 150. Data Buffer3 Structure Diagram**

The LOAD/LOAD_EN Data Buffer input settings depend on the input data source selection (see Table 25 to Table 28).

**Table 25. Data Buffer0 LOAD or LOAD_EN**

| Data Input | CMO Option: LOAD or LOAD_EN | Load Signal Source | Mode of the Previous Data Buffer (Load Signal Source Selection Rule) | Sync Pulsegen Options |
|---|---|---|---|---|
| From ADC Ch0 | LOAD_EN | from ADC Data_rdy (from Sampling Engine) | --- | No, Syncronized with ADC CLK |
| From FSM0 | LOAD | from Matrix output | --- | No, Syncronized with FSM0 CLK |

**Table 26. Data Buffer1 LOAD or LOAD_EN**

| Data Input | CMO Option: LOAD or LOAD_EN | Load Signal Source | Mode of the Previous Data Buffer (Load Signal Source Selection Rule) | Sync Pulsegen Options |
|---|---|---|---|---|
| From ADC Ch1 | LOAD_EN | from ADC Data_rdy (from Sampling Engine) | --- | No, Syncronized with ADC CLK |
| From Buffer0 | LOAD_EN | from Buffer0_Load | if Buffer0 mode is Storage mode | No |
| | | from Buffer0_Ready | if Buffer0 mode is Moving Average mode or Oversampling mode | |
| From MathCore | LOAD_EN | from MathCore Data_rdy | --- | No, Syncronized with MathCore CLK |

**Table 27. Data Buffer2 LOAD or LOAD_EN**

| Data Input | CMO Option: LOAD or LOAD_EN | Load Signal Source | Mode of the Previous Data Buffer (Load Signal Source Selection Rule) | Sync Pulsegen Options |
|---|---|---|---|---|
| From ADC Ch2 | LOAD_EN | from ADC Data_rdy (from Sampling Engine) | --- | No, Syncronized with ADC CLK |
| From Buffer1 | LOAD_EN | from Buffer1_Load | if Buffer1 mode is Storage mode | No |
| | | from Buffer1_Ready | if Buffer1 mode is Moving Average mode or Oversampling mode | |
| From FSM1 | LOAD | from Matrix output | --- | No, Syncronized with FSM1 CLK |

**Table 28. Data Buffer3 LOAD or LOAD_EN**

| Data Input | CMO Option: LOAD or LOAD_EN | Load Signal Source | Mode of the Previous Data Buffer (Load Signal Source Selection Rule) | Sync Pulsegen Options |
|---|---|---|---|---|
| From ADC Ch3 | LOAD_EN | from ADC Data_rdy (from Sampling Engine) | --- | No, Syncronized with ADC CLK |
| From Buffer2 | LOAD_EN | from Buffer2_Load | if Buffer2 mode is Storage mode | No |
| | | from Buffer2_Ready | if Buffer2 mode is Moving Average mode or Oversampling mode | |

# 15. Mathematical Core Macrocell

## 15.1 MathCore General Description

The SLG47011 has a Mathematical Core (MathCore) macrocell, which can perform four mathematical operations: addition, subtraction, multiplication, division (cyclic shift), as well as their combinations. The function to be calculated by the MathCore can be selected according to one of the following operation modes:

- Multiplier and Shifter mode
- Adder/Subtractor mode
- Multiplier + Adder/Subtractor mode
- Adder/Subtractor + Multiplier mode.

MathCore input sources are:

- ADC channel 0 output
- ADC channel 1 output
- ADC channel 2 output
- ADC channel 3 output
- Memory Table macrocell output
- Data Buffer0 output
- Data Buffer1 output
- Data Buffer2 output
- Constant K (from register)
- Constant B (from register).

The structure of the MathCore is shown in Figure 151. The main components of the MathCore are two calculation units: Multiplier/Shifter and Adder/Subtractor, and a Math Control unit. The Multiplier/Shifter unit consists of a Multiplier and a Shifter/Divider, which are connected in series and provide a single result at the unit output. The Adder/Subtractor unit consists of an Adder and a Subtractor.

Each calculation unit has two data inputs. The input sources for the “k” and “x” inputs of the Multiplier/Shifter unit are selected by the value of MATH_K_SRC [2842:2840] and MATH_X_SRC [2845:2843] respectively (see Figure 151). The input sources for the “a” and “b” inputs of the Adder/Subtractor unit are selected by the value of MATH_A_SRC [2850:2848] and MATH_B_SRC [2853:2851] respectively. Detailed description of the input sources for the calculation units is listed below:

- ADC – 14-bit data from ADC output
- Data Buffer0 – 16-bit data from Data Buffer0 output
- Data Buffer1 – 16-bit data from Data Buffer1 output
- Data Buffer2 – 16-bit data from Data Buffer2 output
- Memory Table – 12-bit data from Memory Table output
- Const K – 16-bit coefficient from internal registers MATH_CONST_K [2863:2856, 2871:2864], which can be set by the user
- Const B – 16-bit coefficient from internal registers MATH_CONST_B [2879:2872, 2887:2880], which can be set by the user
- F out – 16-bit data from Multiplier/Shifter calculation unit output
- Y out – 16-bit data from Adder/Subtractor calculation unit output.

The Calc_EN (CMO1 [74]) (calculation enable) signal controls the start of calculation. The mathematical operation is performed by the calculation unit when the data on both inputs is ready and the calculation is enabled by the Math Control unit. Input data is latched into the input register of the calculation unit after receiving the Data Ready (DR) signals at the internal DR inputs of the Control Unit. After completing the operation, the

Data Ready signal is generated on the DR output of the calculation unit and the calculation result is stored in a 16-bit Storage register.

The MathCore has a single 16-bit output. Depending on the selected mode of the MathCore, the output Math_OUT switches between two calculation units selected by the out_sel signal. The MathCore output can be connected to the Data Buffer1 input, DAC, and DCMP. The MathCore data output Math_OUT is reset to 0x0000 during POR.

The output registers MATH_MULT_STORE [2895:2888, 2903:2896] and MATH_ADD_SUB_STORE [2911:2904, 2919:2912] of both the Multiplier/Shifter and the Adder/Subtractor blocks can be read via the $I^2C$/SPI interface.

The Math_DR (CMI1 [61]) signal is set to HIGH when the calculation is complete and the output data becomes available on the data bus. The latency from the last argument received to the Math_DR signal in different modes is as follows:

1. For Adder/Subtractor mode, the delay time from the latest argument (k or x) arrival to Math_DR assertion is around seven OSC1 clock cycles.
2. For Multiplier mode, the delay time from the latest argument (a or b) arrival to Math_DR assertion is around eight OSC1 clock cycles.
3. For Adder + Multiplier or Multiplier + Adder mode, the delay time from the latest argument arrival to Math_DR assertion is 8 + 7 =15 OSC1 clock cycles.

The delay time from Calc_EN arrival to MathCore starting to detect arguments is three OSC1 clock cycles.

Depending on the MATH_RESET [2827] register value, the Math_DR output:

- transitions LOW after Calc_EN rising edge (MATH_RESET [2827] = 0)
- transitions LOW after the last argument is received (MATH_RESET [2827] = 1).

The initial state of the Math_DR output during POR is set by MATH_DR_INIT [2830]. If MATH_DR_INIT [2830] = 0 – the Math_DR output is LOW until the first calculation is completed. If MATH_DR_INIT [2830] = 1 – the Math_DR output is HIGH until the first calculation is started.

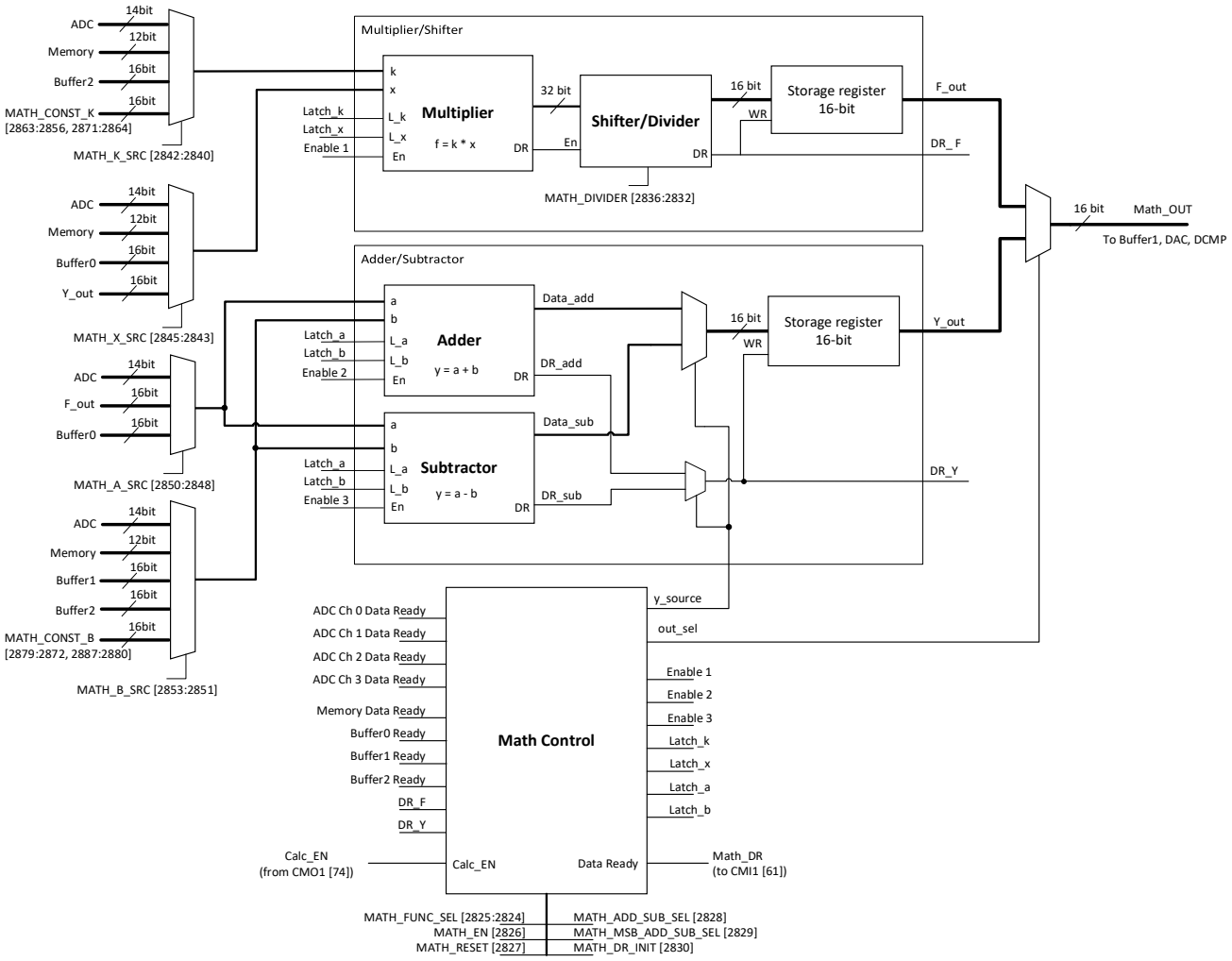



**Figure 151. Mathematical Core Structure Diagram**

## 15.2 MathCore Modes

The mathematical function to be performed by the MathCore is selected by setting the MATH_FUNC_SEL [2825:2824] register. There are four basic modes:

- Multiplier mode (f = k * x function)
- Adder/Subtractor mode (y = a + b or y = a - b function)
- Multiplier + Adder/Subtractor mode (y = k * x + b or y = k * x - b function)
- Adder/Subtractor + Multiplier mode (y = (a + b) * k or y = (a - b) *k function).

Mathematical operations (adding or subtraction) performed by the Adder/Subtractor unit are defined by MATH_ADD_SUB_SEL [2828] register.

Alternatively, the adding or subtraction operation can be defined by the MSB value of the input. This option is set by the MATH_MSB_ADD_SUB_SEL [2829] register. If MSB = 0, then the addition operation is performed; if MSB = 1, then the subtraction operation is performed. This option can be set only if MATH_ADD_SUB_SEL [2828] = 0 (Adder mode).

In Multiplier mode, the output is the result of multiplying two arguments received at the “k” and “x” inputs of the Multiplier/Shifter unit. Because multiplying two 16-bit input numbers results in a 32-bit number, the multiplication should be followed by a cyclic shift operation to generate a 16-bit result compatible with data bus width. The number of bits to be shifted is defined by the MATH_DIVIDER [2836:2832] register and should consider the maximal expected value of the multiplication result. The cyclic shift effectively provides a division function, and

the result of multiplication can be divided by a number $2^n$ (n = 1 to 32). The 'n' value is set by the MATH_DIVIDER [2836:2832] register value.

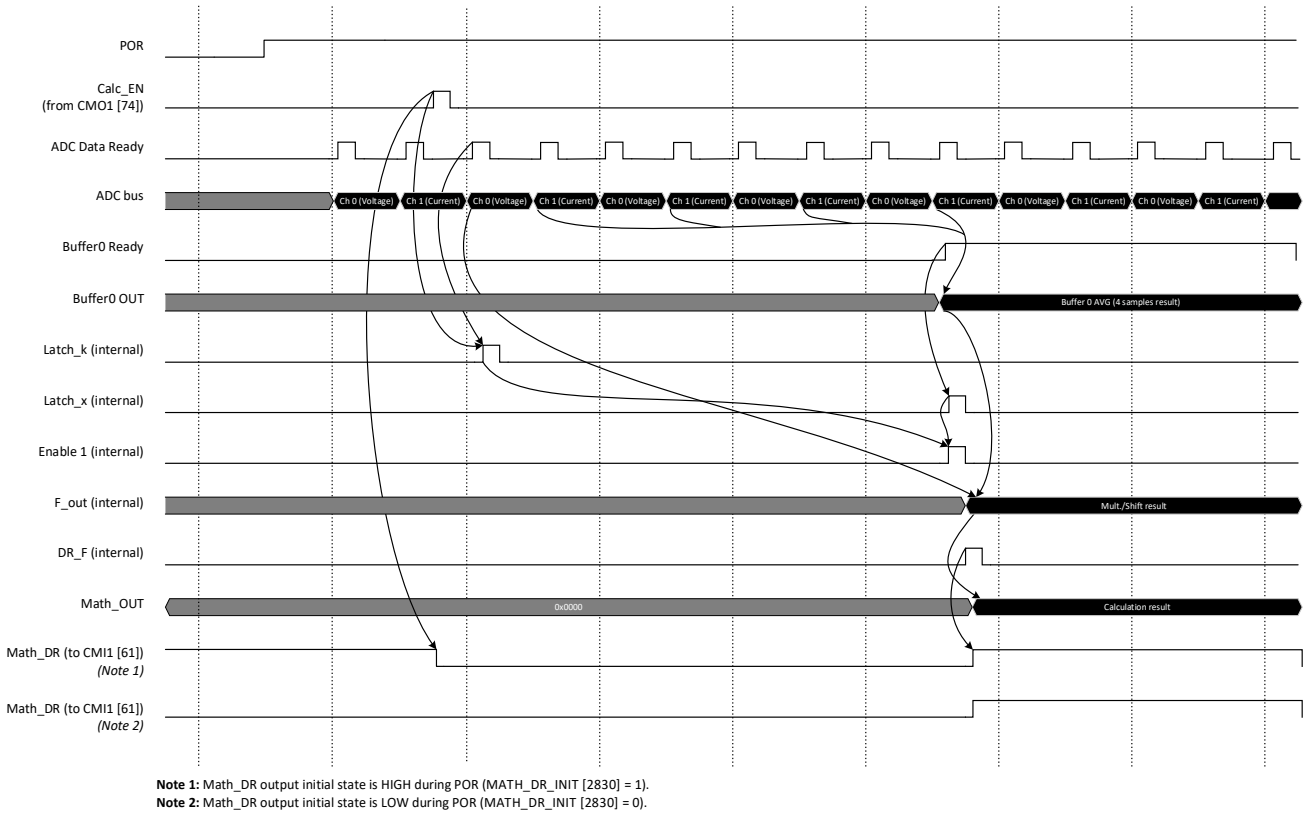
In Adder/Subtractor mode, the output is the result of adding/subtracting two arguments received at the "a" and "b" inputs of the Adder/Subtractor unit. If the sum of two arguments is larger than a maximal 16-bit number (0xFFFF), the output will be set to 0xFFFF. The MathCore does not operate with negative numbers. If the value "a" input of the Subtractor is less than the value "b", that is, the result of the subtraction is less than 0, then the output value will be 0x0000.

In Multiplier + Adder/Subtractor mode, a two-stage operation is performed. The first operation multiplies two arguments received at the "k" and "x" inputs of the Multiplier/Shifter. At the second stage, the calculation result F_out from the Multiplier/Shifter received at the "a" input of the Adder/Subtractor is added/subtracted with the argument at the "b" input. In this mode, the result of the Multiplier/Shifter output (F_out) unit is automatically selected as a source for the "a" input of the Adder/Subtractor unit. Similarly, in Multiplier + Adder/Subtractor mode, if the sum of two arguments is larger than a maximal 16-bit number (0xFFFF), the output will be set to 0xFFFF. If the result of the subtraction is less than 0, then the output value will be 0x0000.

The Adder/Subtractor + Multiplier mode is also a two-stage operation. The first operation adds/subtracts two arguments received at the "a" and "b" inputs of the Adder/Subtractor unit. The calculation result Y_out from the Adder/Subtractor is received at the "x" input of the Multiplier and then multiplied by the argument received at the "k" input. In this mode, of the Adder/Subtractor unit output (Y_out) is automatically selected as a source for the "x" input of the Multiplier/Shifter unit.

## 15.3 MathCore Timing Diagrams

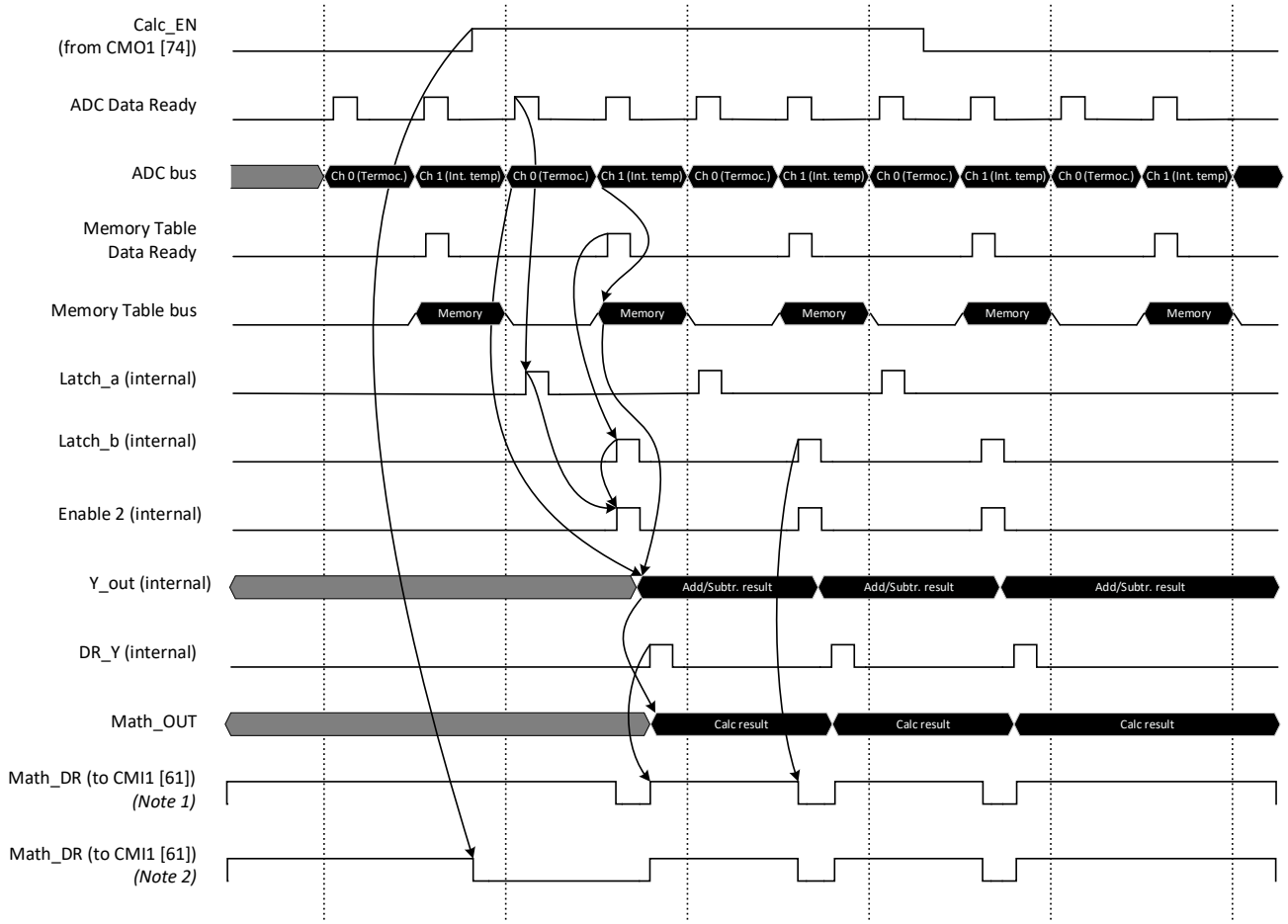
Timing diagrams for the MathCore operation in Multiplier mode (f = k * x function) are shown in Figure 152. The diagram shows the "k" input – ADC channel 0 conversion result, and the "x" input – Data Buffer0 average result from four samples of ADC channel 1. Calculation is run once after a Calc_EN signal pulse. Register MATH_RESET [2827] is set to 0 and the Math_DR output goes LOW after a Calc_EN rising edge.




**Note 1:** Math_DR output initial state is HIGH during POR (MATH_DR_INIT [2830] = 1).
**Note 2:** Math_DR output initial state is LOW during POR (MATH_DR_INIT [2830] = 0).

**Figure 152. MathCore Operation in Multiplier Mode (f = k * x Function)**

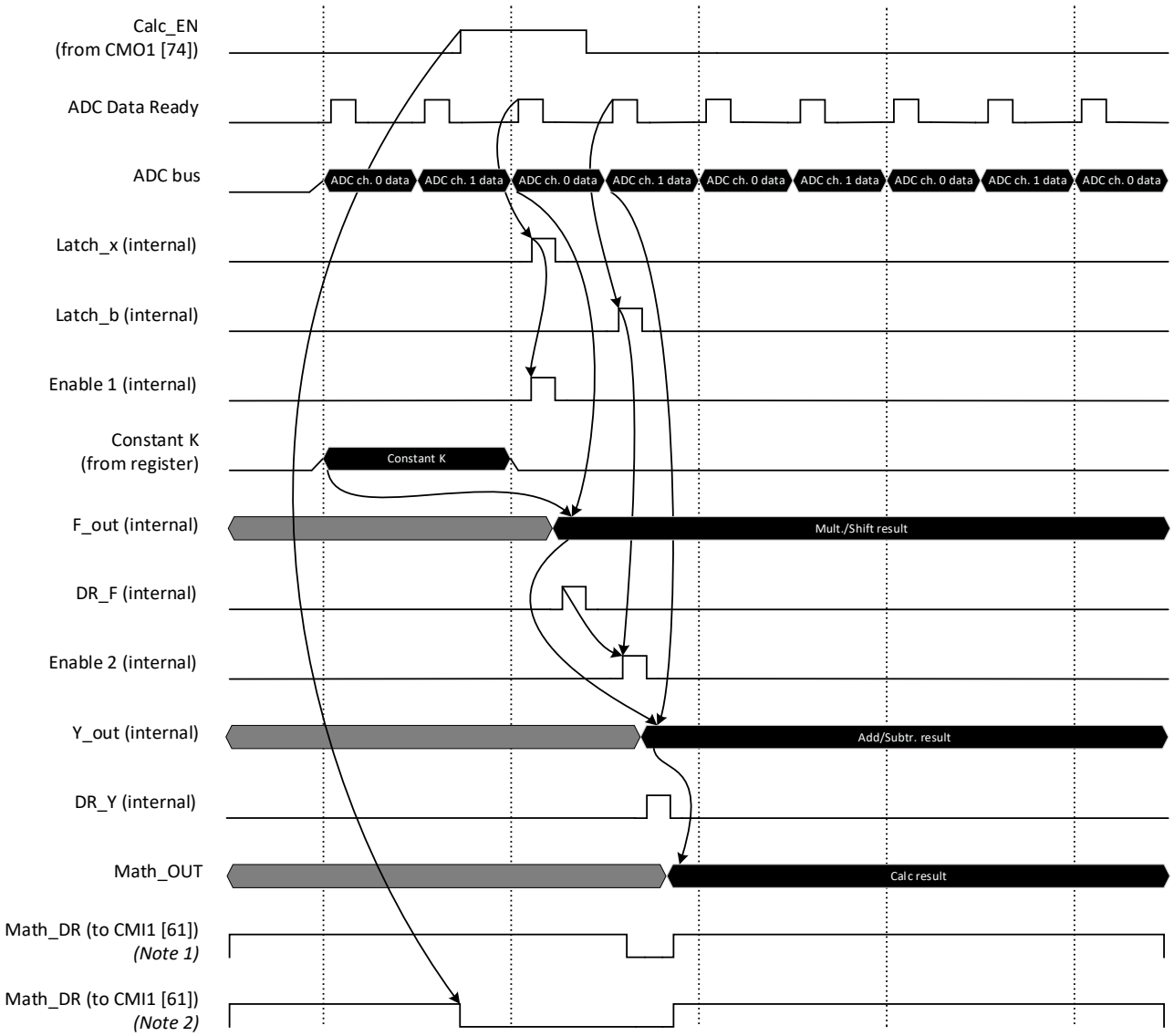
Timing diagrams for the MathCore operation in Adder mode (y = a + b function) are shown in Figure 153. The diagram shows the “a” input – ADC channel 0 conversion result, and the “b” input – Memory Table output at ADC channel 1 input. Calculation runs until the Calc_EN signal is HIGH.




**Note 1:** MathCore DR output goes LOW after last argument received (MATH_RESET [2827] = 1).
**Note 2:** MathCore DR output goes LOW after Calc_EN rising edge (MATH_RESET [2827] = 0).

**Figure 153. MathCore Operation in Adder Mode (y = a + b Function)**

Timing diagrams for the MathCore operation in Multiplier + Adder mode (f = k * x + b function) are shown in Figure 154. The diagram shows the “k” input – constant K (from register), the “x” input – ADC channel 0 conversion result, and the “b” input – ADC channel 1 conversion result. Calculation is performed once after a Calc_EN signal pulse.




**Note 1:** MathCore DR output goes LOW after last argument received (MATH_RESET [2827] = 1).
**Note 2:** MathCore DR output goes LOW after Calc_EN rising edge (MATH_RESET [2827] = 0).

**Figure 154. MathCore Operation in Multiplier + Adder Mode (f = k * x + b Function)**

# 16. Multichannel Digital Comparator Macrocell

## 16.1 Multichannel Digital Comparator General Description

The SLG47011 has a 16-bit multichannel digital comparator (DCMP) that can make periodic comparisons of up to four input channels, and latch the results at four outputs.

Selectable input sources for each of four positive inputs of the multichannel DCMP are:

- Memory Table output
- MathCore output
- Data Buffer0 output
- Data Buffer1 output
- Data Buffer2 output
- Data Buffer3 output
- Fixed value from registers (one static threshold per channel).

Selectable input sources for each of four negative inputs of the multichannel DCMP are:

- Data Buffer0 output
- Data Buffer1 output
- Data Buffer2 output
- Data Buffer3 output
- Fixed value from registers (one static threshold per channel).

**Note 1:** If the 12-bit Memory Table output is selected as the input of the 16-bit DCMP, the 12 least significant bits of the DCMP input consist of the 12-bit Memory Table data, and the four most significant bits are '0000', for example, {0000, memory_table_data [11:0]}.

**Note 2:** To prevent unexpected issues, changing the value of the threshold registers via $I^2C$/SPI must be performed only when the DCMP is disabled.

Up to four channels can be selected to be compared. For example, Channel0, Channel2, and Channel3. The active DCMP channels are selected by register DCMP_CHx_EN (DCMP_CH0_EN [2940], DCMP_CH1_EN [2941], DCMP_CH2_EN [2942], and DCMP_CH3_EN [2943]). Note that the channels are sampled in fixed order from 0 to 3.

It is possible to set a 16-bit hysteresis value for each channel. Depending on the register settings (DCMP_HYST_MODE [2923]), there are two hysteresis modes:

- **Regular hysteresis mode:** when active, the multichannel DCMP operates like an analog comparator with hysteresis.
  - LOW to HIGH transition of output '>' occurs when In+ > (In- + Hysteresis).
  - HIGH to LOW transition of output '>' occurs when In+ ≤ In-.
- **Offset adding mode:** in this mode, the In+ source is always compared with the value (In- + Hysteresis).
  - LOW to HIGH transition of output '>' occurs when In+ > (In- + Hysteresis).
  - HIGH to LOW transition of output '>' occurs when In+ ≤ (In- + Hysteresis).

The user can also select the 'equal' = DCMP output instead of 'greater than' > output. This option is selected with registers (COMPARE_SEL_CHx) for each channel. This function is only available in Offset adding mode, and the function is defined as follows:

- High logic level of output '>' occurs when In+ = (In- + Hysteresis).
- Low logic level of output '>' occurs when In+ < (In- + Hysteresis) or In+ > (In- + Hysteresis).

Basic modes for the multichannel DCMP are described by the following:

- **Continuous mode:** registers DCMP_MODE [2921:2920] = b00. In this mode, the multichannel DCMP continuously compares the data at the inputs. To start the comparison, the user must set HIGH level signal at an Enable input. After the high logic level is released (low logic level appears at the Enable input), the multichannel DCMP finishes comparison of the channel sequence and then turns off. The user can select a clock source for this mode.
- **Sequence conversion mode activated by an Enable signal:** registers DCMP_MODE [2921:2920] = b01. This mode is activated by the LOW to HIGH transition of the Enable signal. The multisampling DCMP performs the comparison of the channel sequence and then turns off. To start a new comparison, the user should reapply the signal at the Enable input. The user can select a clock source for this mode.
- **Sequence conversion mode activated by an internal Buffer Ready signal:** registers DCMP_MODE [2921:2920] = b10. The multisampling DCMP performs the comparison of the channel sequence once and then turns off. This mode is activated by the LOW to HIGH transition of the Buffer Ready or Memory Table Data Ready signal. The user can select any of four Buffer Ready signals or Memory Table Data Ready signal as a trigger to start the DCMP comparison. When this mode is active and the ADC is used as a source for Data Buffers or Memory Table, the DCMP will share clock source with the ADC.

Note that if the DCMP operates in continuous mode, the DCMP clock and the source data update rate synchronization must be controlled to avoid incorrect results.

The DCMP Enable input source is selected by the DCMP_EN_SRC_SEL [2929:2928] registers and the available options include: matrix output, BufferX ready, Memory Table Data Ready, MathCore Math_DR.

The multichannel DCMP uses a clock to switch between channels, make comparisons, and latch the results. The clock sources can come from OCS1 oscillator, OSC1 dividers, and the ADC clock. If the “Auto power-on” setting of the oscillator is selected, a logic HIGH (or rising edge, depending on setting) at the Enable input of the DCMP starts the internal oscillator.

**Note:** If the DCMP is enabled by the DCMP Enable signal, it will take two additional DCMP sampling clock pulses to generate the expected channel output.

The way the results appear at the outputs of the multichannel DCMP can be configured. In asynchronous mode (DCMP_SYNC_EN [2922] = 0), the results appear continuously after each channel is sampled. In synchronous mode (DCMP_SYNC_EN [2922] = 1), the results at the output appear simultaneously after the last selected channel has been sampled. The signal DCMP Sync Data Ready (CMI1 [58]) generates a pulse when the sequence of selected channels has been sampled.

The signal DCMP Data ready (CMI1 [58]) is set to HIGH when the sequence of selected channels has been sampled and the DCMP Data ready output goes LOW after Conversion Start is activated by the Enable signal.

The initial state of the DCMP Data ready output during power-up is set by DCMP_DR_INIT [2927] (see Figure 157). If DCMP_DR_INIT [2927] = 0, then the DCMP Data ready output is LOW until the 1st sequence of channels is sampled. If DCMP_DR_INIT [2927] = 1, then the DCMP Data ready output is HIGH until the 1st sequence of channels is started.

The latency of the DCMP from the DCMP Enable signal arrival to the DCMP Data ready signal asserting is as follows:

- 1st channel latency: 1 sampling clock period (if register MDCMP_EN_SYNC_SEL [3108] = 0), and 2 sync clock periods + 1 sampling clock period (if register MDCMP_EN_SYNC_SEL [3108] = 1).
- 2nd channel latency: 1st channel latency + 1 sampling clock period.
- 3rd channel latency: 2nd channel latency + 1 sampling clock period.
- 4th channel latency: 3rd channel latency + 1 sampling clock period.

**Note:** To guarantee the correct conversion result of the DCMP, it is not recommended to change the values at the DCMP inputs during operation.

The output values of the DCMP channels can be non-inverted (Q) or inverted (nQ). The type of output is selected by Q_nQ_SEL_CHx [0] (Q_NQ_SEL_CH0 [3104], Q_NQ_SEL_CH1 [3105], Q_NQ_SEL_CH2 [3106], Q_NQ_SEL_CH3 [3107]).

The rising edge at the Reset input of the DCMP (DCMP Reset) resets the state of OUT0-OUT3 and the Data ready outputs of the DCMP. If the DCMP reset occurs during DCMP operation, the current comparison is aborted and the DCMP outputs are reset. The state of OUT0-OUT3 and the Data ready outputs is not forced LOW while the high level at the Reset input is holding.

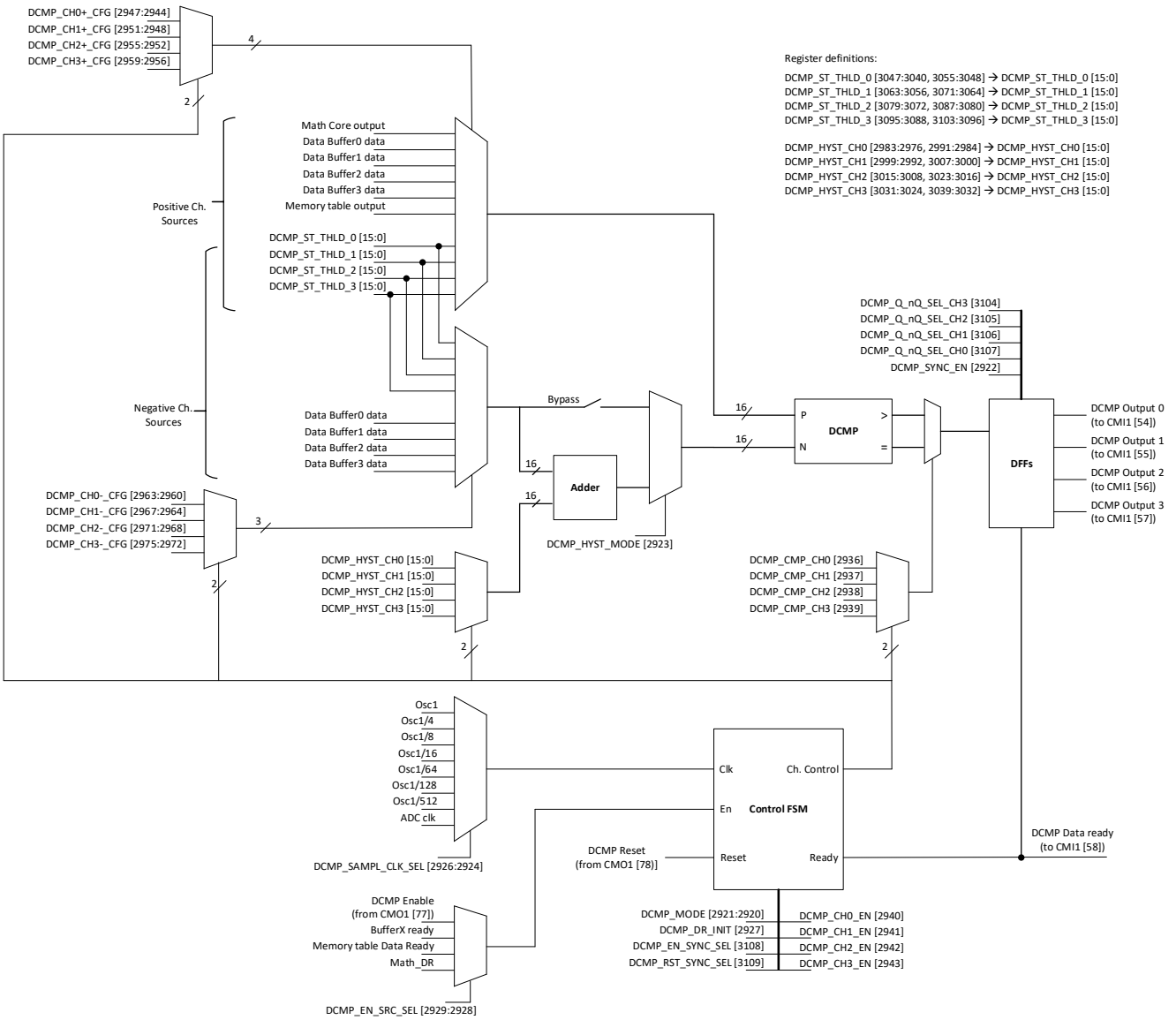



**Figure 155. Multichannel Digital Comparator Block Diagram**

## 16.2 Multichannel DCMP Timing Diagrams

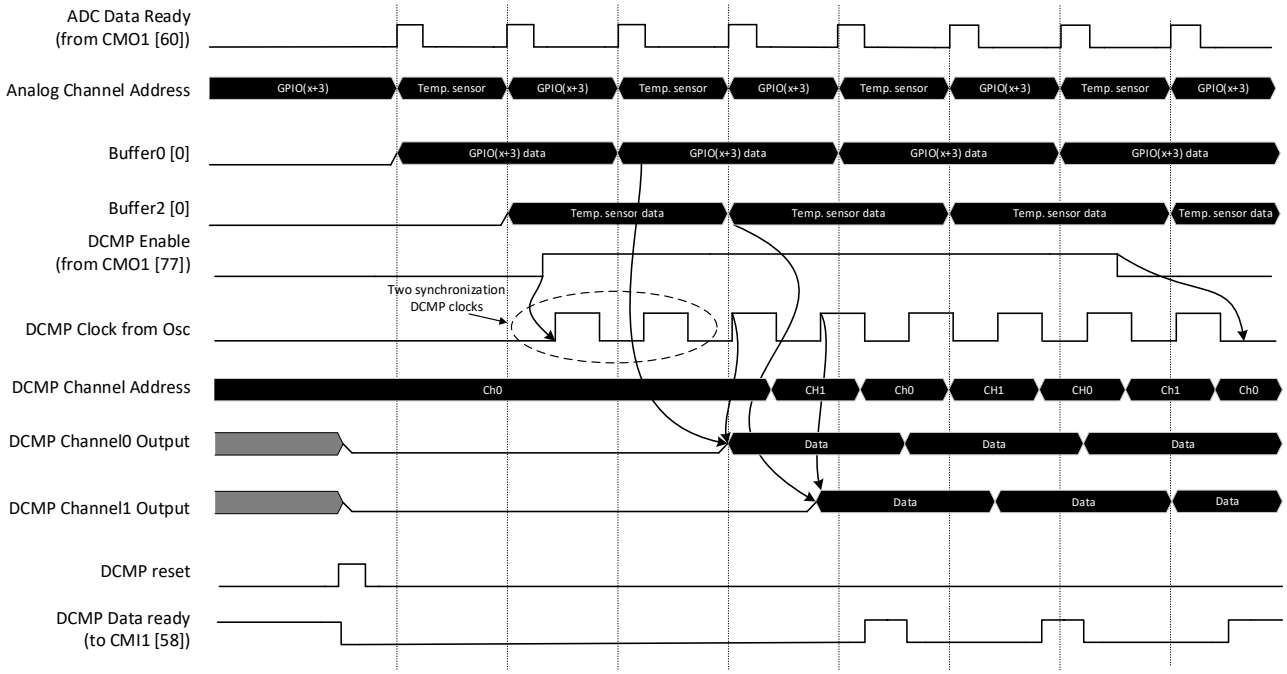
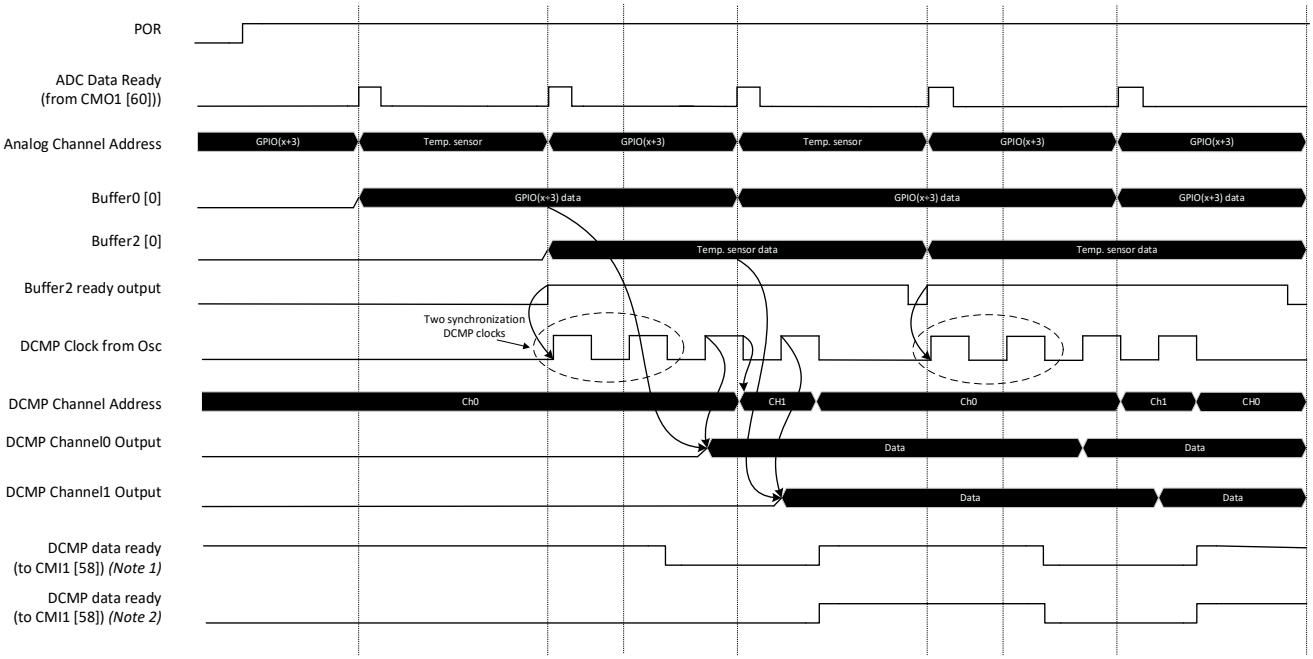
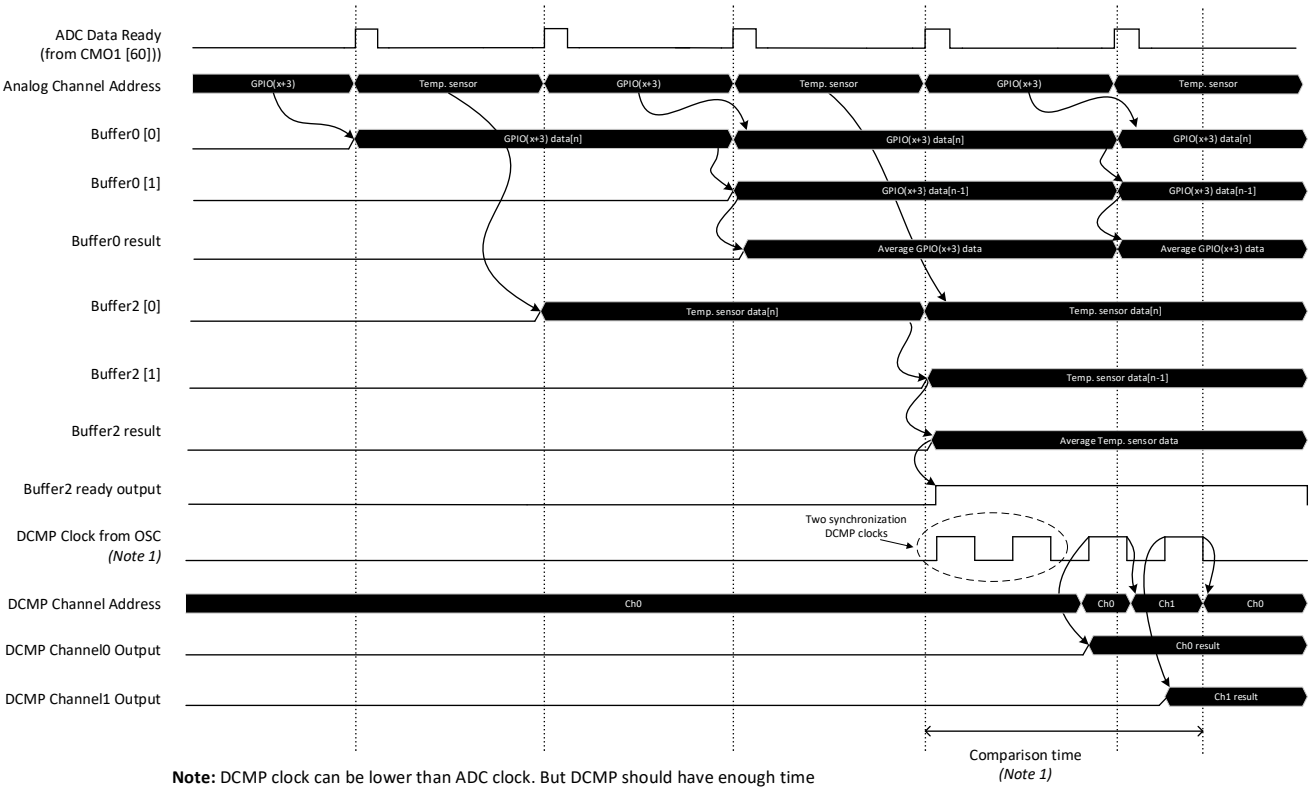



**Figure 156. Multichannel DCMP Operation in Continuous Mode**




**Note 1:** DCMP data ready output initial state is HIGH during POR (DCMP_DR_INIT [2927] = 1).
**Note 2:** DCMP data ready output initial state is LOW during POR (DCMP_DR_INIT [2927] = 0).

**Figure 157. Multichannel DCMP Operation in Sequence Conversion Mode Activated by Buffer2 Ready**




**Note:** DCMP clock can be lower than ADC clock. But DCMP should have enough time to make comparison of all channels before ADC change data in the data buffers.

**Figure 158. Multichannel DCMP Operation in Sequence Conversion Mode Activated by Buffer2 Ready. Buffer Length is Two Words**

# 17. Pulse Width Modulator Macrocell

The SLG47011 has a 12-bit pulse width modulator (PWM) logic macrocell (see Figure 159), which generates output signal with variable duty cycle. The PWM power-up is set by CMO1 [84] (if PWR_UP is LOW – PWM is OFF, if PWR_UP is HIGH – PWM is ON). The PWM has a positive (IN+) input and a negative (IN-) input. The signal input IN+ accepts 12-bit data from the Memory Table macrocell or a 12-bit user-defined signal value (PWM_THLD [3163:3160, 3175:3168]). The signal that goes through the IN- input takes 12-bit data from CNT10. The PWM reads new data from IN+ every rising edge of PWM power-up when CNT10 has counted to either 0 or to CNT data (at the end of each PWM period). If PWM power-up (CMO1 [84]) is HIGH, then CNT10 operates with the PWM.

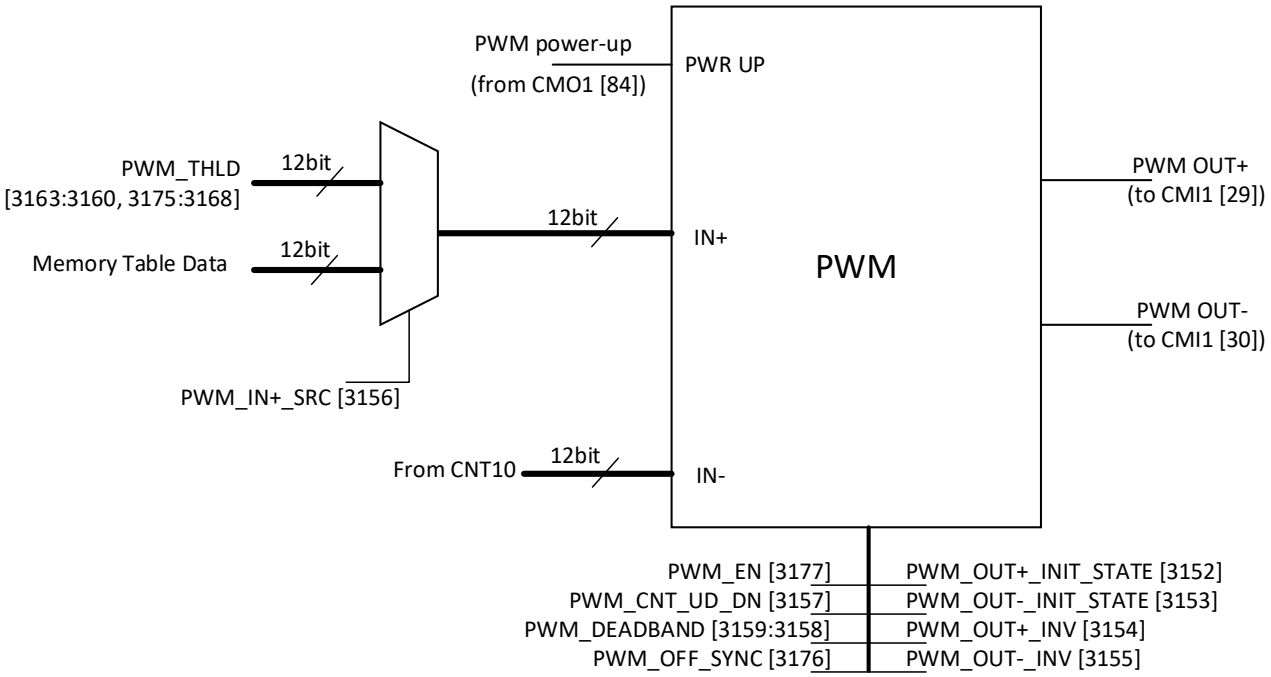



**Figure 159. PWM Functional Diagram**

## 17.1 PWM Output

The PWM output duty cycle can range from 0 % to 100 % and is determined by: Output Duty Cycle = IN+/IN- (IN+ = 0: output duty cycle = 0/IN- = 0 %; IN+ = IN-: output duty cycle = 100 %). The outputs of the PWM block can be inverted and are enabled by registers. Both OUT+ and OUT- have a separate register to select its inverted or non-inverted output option (PWM_OUT+_INV [3154] and PWM_OUT-_INV [3155]). Each output has also a separate register to select initial state output when PWM is OFF (PWM_OUT+_INIT_STATE [3152] and PWM_OUT+_INIT_STATE [3153]).

## 17.2 PWM DeadBand Control

The deadband interval can be set with NVM bits by setting PWM_DEADBAND [3159:3158]. It is possible to select no deadband time or deadband time equal to one, two, or three PWM period clock cycles.

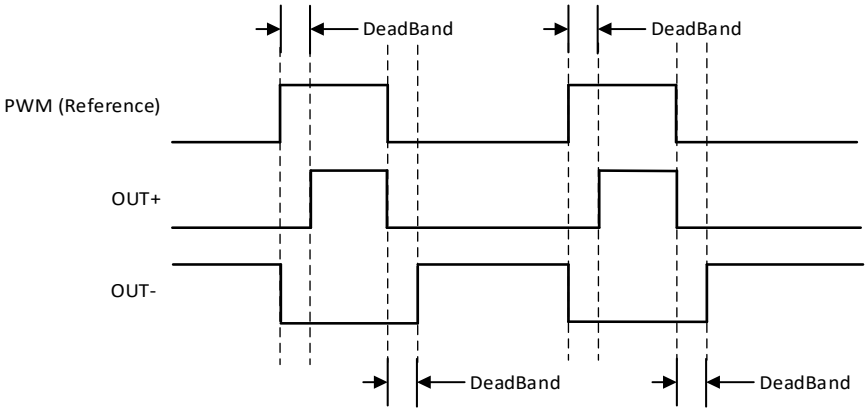



**Figure 160. PWM Output Waveforms (OUT+ and OUT-)**

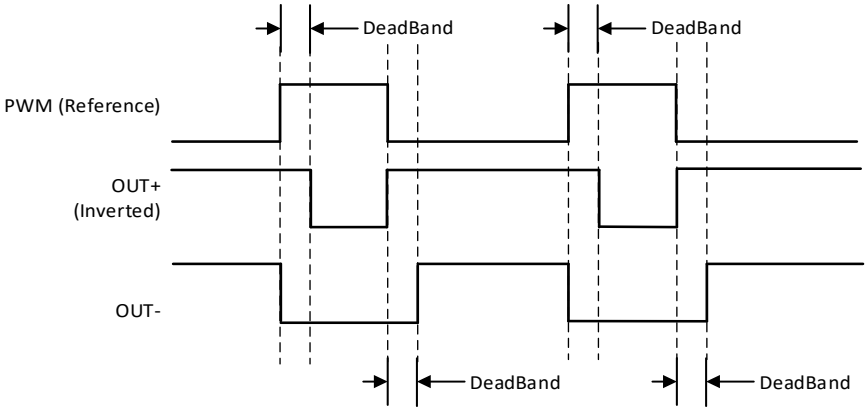



**Figure 161. PWM Output Waveforms (nOUT+ and OUT-)**

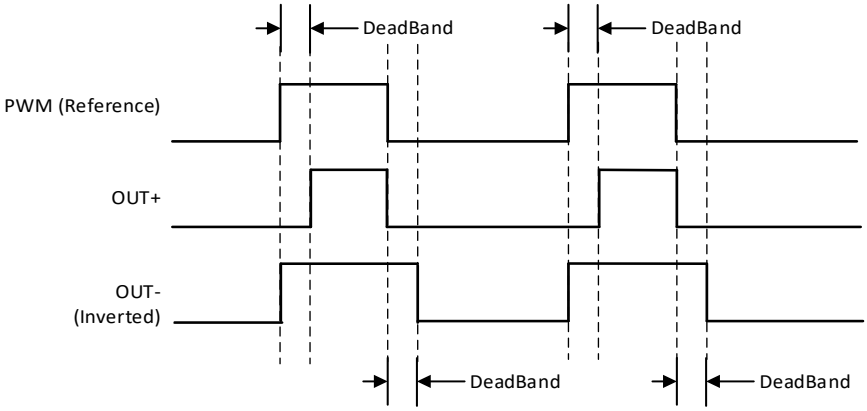



**Figure 162. PWM Output Waveforms (OUT+ and nOUT-)**

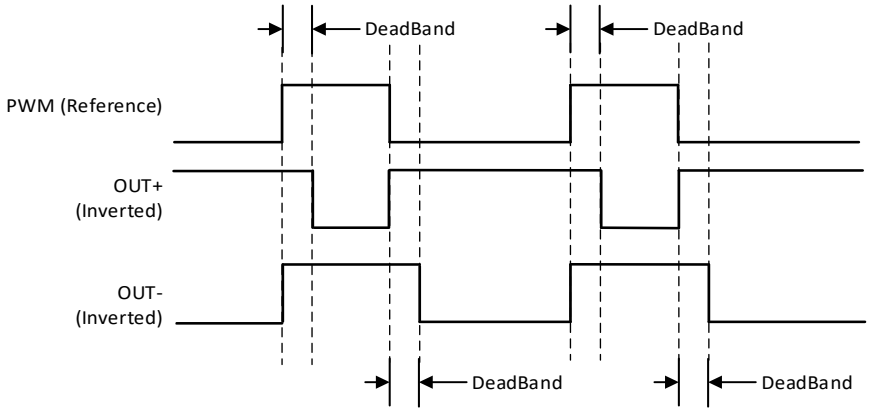



**Figure 163. PWM Output Waveforms (nOUT+ and nOUT-)**

# 18. Width Converter Macrocell

The SLG47011 has a 12-bit Width Converter (WCN) macrocell designed to provide data from the Memory Table macrocell to the connection matrix. The WCN converts a 12-bit parallel data word into a series of words of smaller width, effectively functioning as a parallel-to-serial converter with programmable bit width. The WCN takes 12-bit data from the Memory Table Output and is enabled by register WCONV_EN [3112]. The Width Converter clock is synchronized with the 12-bit Memory Control CNT block using internal synchronization, which functions as a frequency divider. The Width Converter initial value is defined by register WCONV_INIT_VAL_x [11:0]. This value appears at the output of the macrocell after power-up or after applying a LOW level at the Reset input of the Memory Control CNT. If the Memory Control Counter is configured in Two Ranges mode, then the Width Converter initial value for the first range is defined by registers WCONV_INIT_VAL_0 [3123:3120, 3135:3128], and for the second range - by registers WCONV_INIT_VAL_1 [3139:3136, 3151:3144].

The clock inputs of the Memory Control CNT and Width Converter are connected to the same matrix output through internal signal selection MUX, which is automatically controlled by WCN enable signal. When the Width Converter is enabled, the clock for the Memory Control CNT will be supplied from the Width Converter, whereas if the WCN is disabled, the matrix output will directly drive the clock input of the Memory Control CNT.

Basic modes for the Width Converter are selected by the registers WCONV_MODE [3114:3113] and are listed below:

- 12-to-12 mode (12-bit parallel output)
- 12-to-4 mode (12-bit word to three 4-bit words)
- 12-to-2 mode (12-bit word to six 2-bit words)
- 12-to-1 mode (12-bit word to serial bit stream).

If the Memory Control Counter operates with the WCN, the maximum clock frequency of the Memory Control Counter is the following:

- If the WCN is operating in the 12-to-12 mode, the maximum CLK frequency is 20 MHz.
- If the WCN is operating in the 12-to-4, 12-to-2, 12-to-1 mode, the maximum CLK frequency is 40 MHz.

The maximum clock frequency of 40 MHz is guaranteed.

## 18.1 12-to-12 Conversion Mode

In the 12-to-12 mode, the Width Converter converts data from Memory Table to 12 parallel outputs, as shown in Figure 164 and Figure 165.

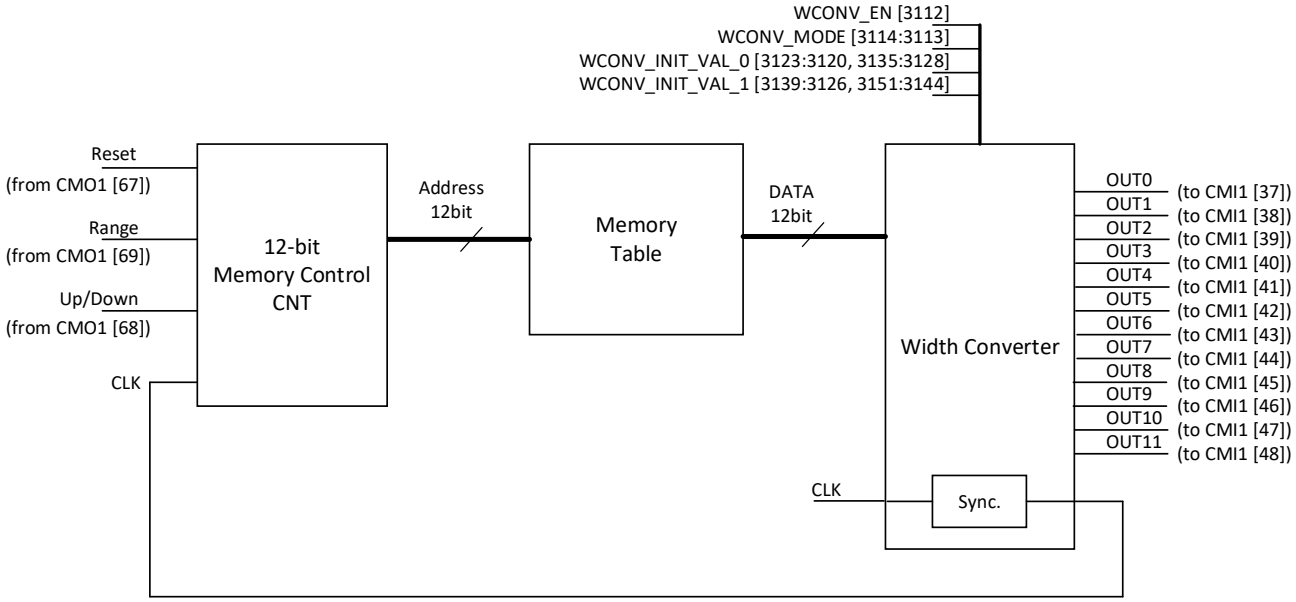



**Figure 164. Width Converter in 12-to-12 Mode Functional Diagram**

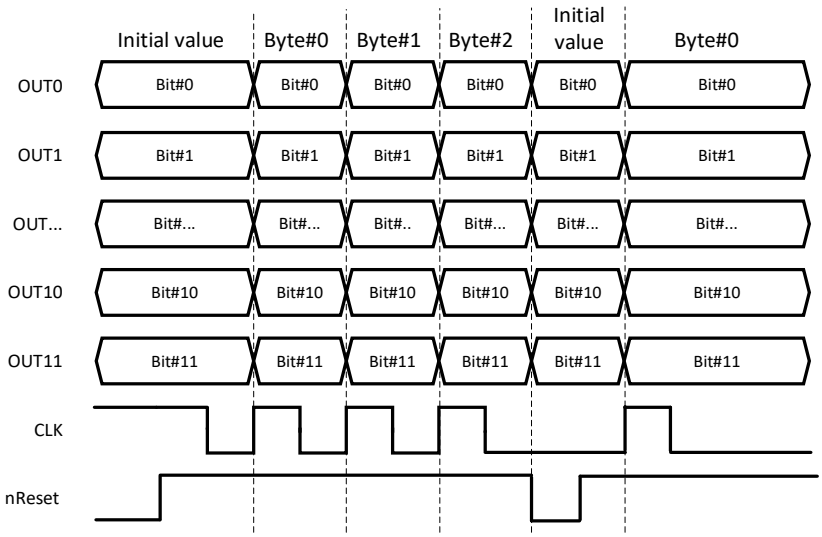



**Figure 165. Width Converter in 12-to-12 Mode Output Waveforms**

## 18.2 12-to-4 Conversion Mode

In the 12-to-4 mode, the Width Converter converts a 12-bit word from Memory Table into three 4-bit words to four parallel outputs, see Figure 166 and Figure 167.

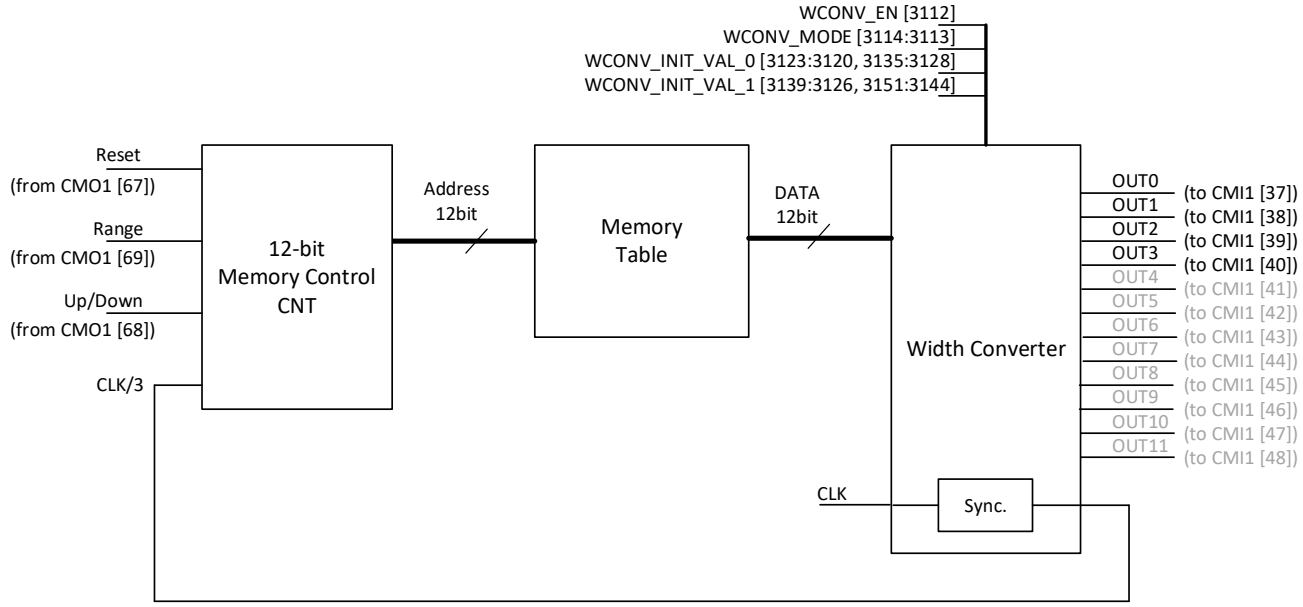



**Figure 166. Width Converter in 12-to-4 Mode Functional Diagram**

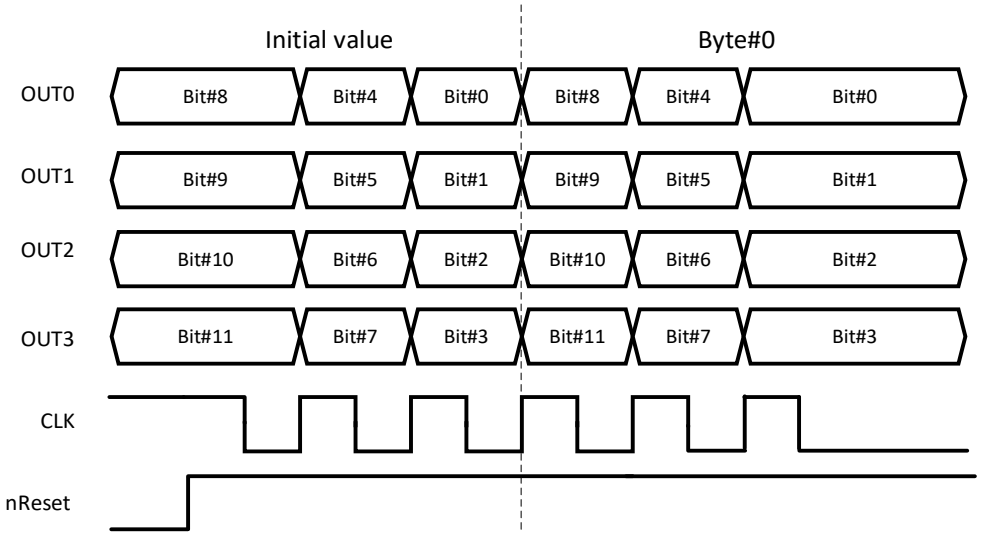



**Figure 167. Width Converter in 12-to-4 Mode (without Sync) Output Waveforms**

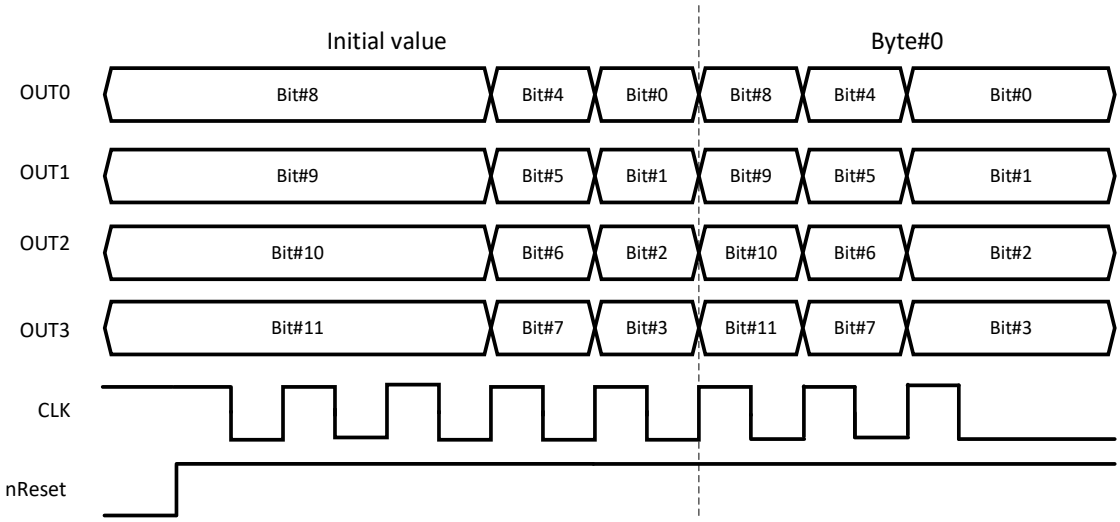



**Figure 168. Width Converter in 12-to-4 Mode (With Sync) Output Waveforms**

## 18.3 12-to-2 Conversion Mode

In the 12-to-2 mode, the Width Converter converts a 12-bit word from Memory Table into six 2-bit words to two parallel outputs, see Figure 169 and Figure 170.

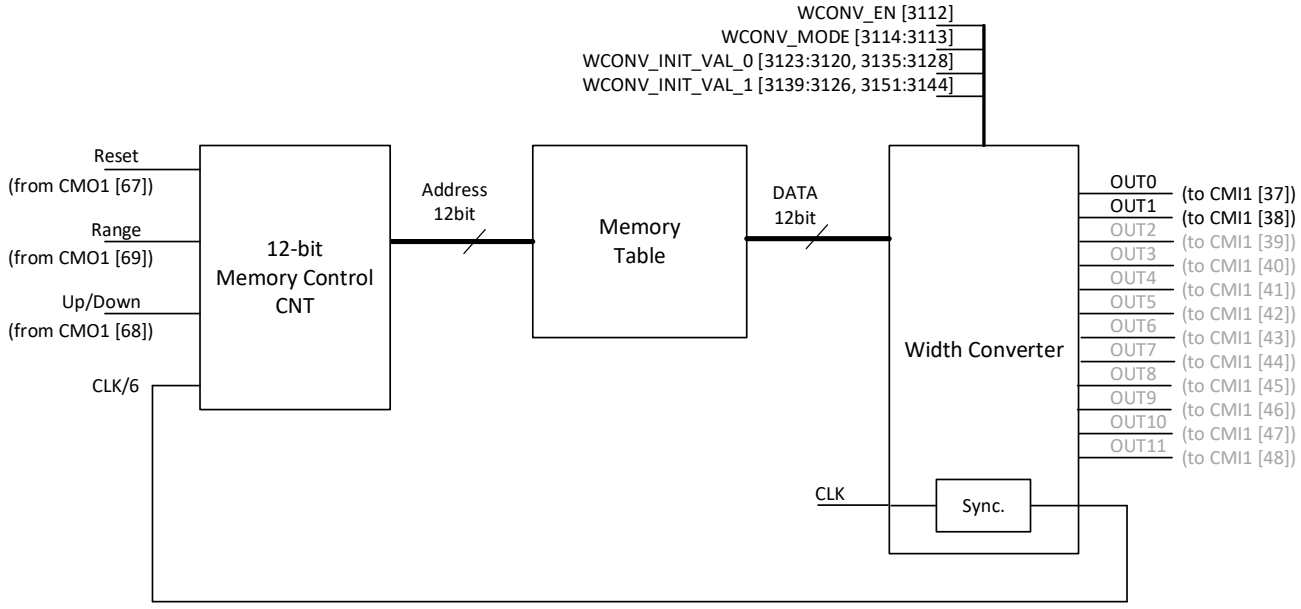



**Figure 169. Width Converter in 12-to-2 Mode Functional Diagram**

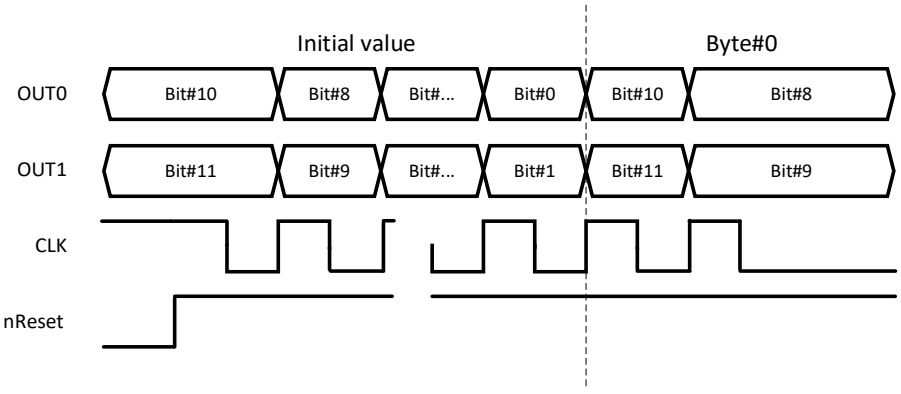



**Figure 170. Width Converter in 12-to-2 Mode Output Waveforms**

## 18.4 12-to-1 Conversion Mode

In the 12-to-1 mode, the Width Converter converts a 12-bit word from Memory Table into a single serial bit stream output, see Figure 171 and Figure 172.

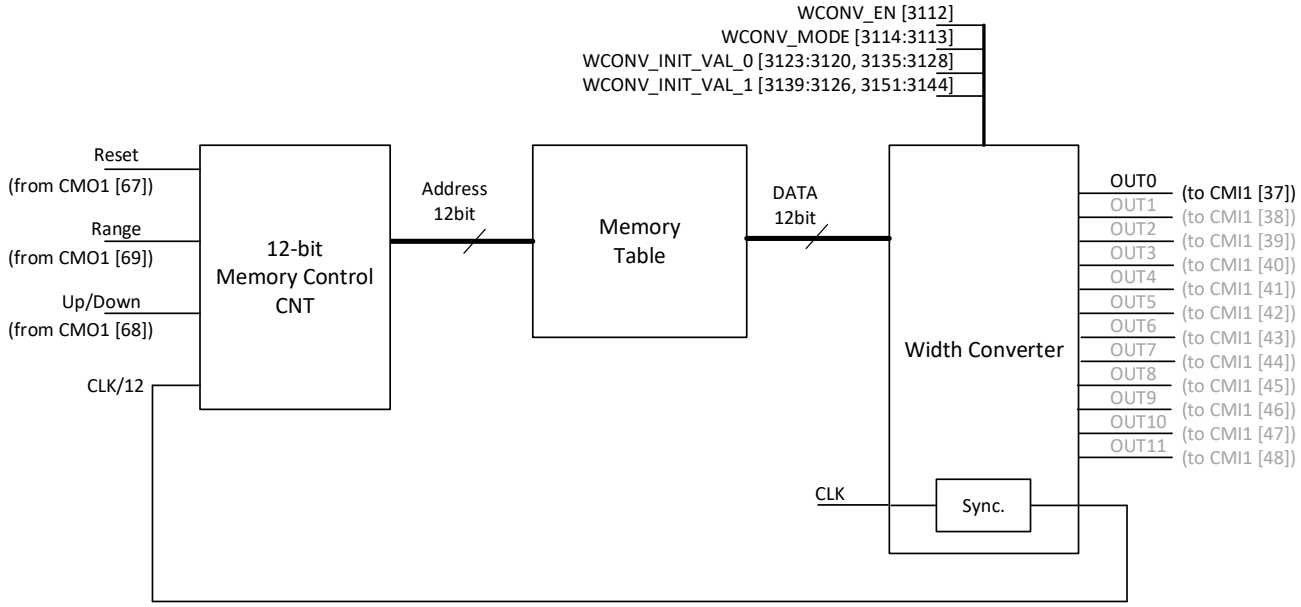



**Figure 171. Width Converter in 12-to-1 Mode Functional Diagram**

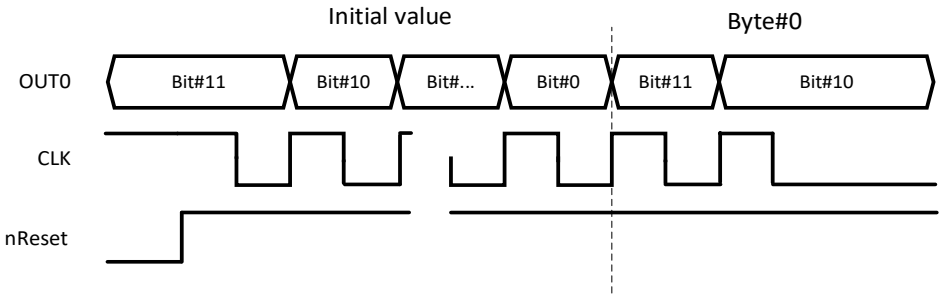



**Figure 172. Width Converter in 12-to-1 Mode Output Waveforms**

# 19. Programmable Delay/Edge Detector Macrocell

The SLG47011 has a programmable time delay macrocell that can generate a fixed time delay. The programmable time delay cell can generate one of four different delay patterns: rising edge detection, falling edge detection, both edge detection, and both edge delay. These four patterns can be further modified with the addition of delayed edge detection, which adds an extra unit of delay, as well as glitch rejection during the delay period. See Figure 173, Figure 174, and section 3.4.6 Programmable Delay Typical Delays and Widths for further information.

Note that the input signal must be longer than the delay, otherwise it will be filtered out.

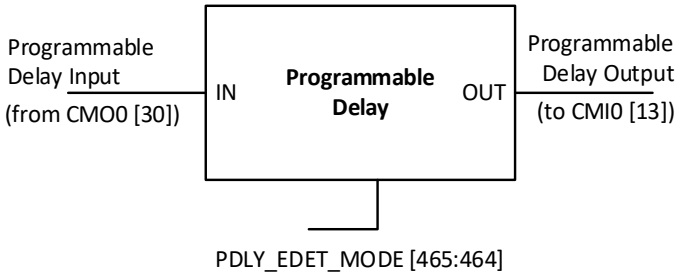



**Figure 173. Programmable Delay**

## 19.1 Programmable Delay Timing Diagram - Edge Detector Output

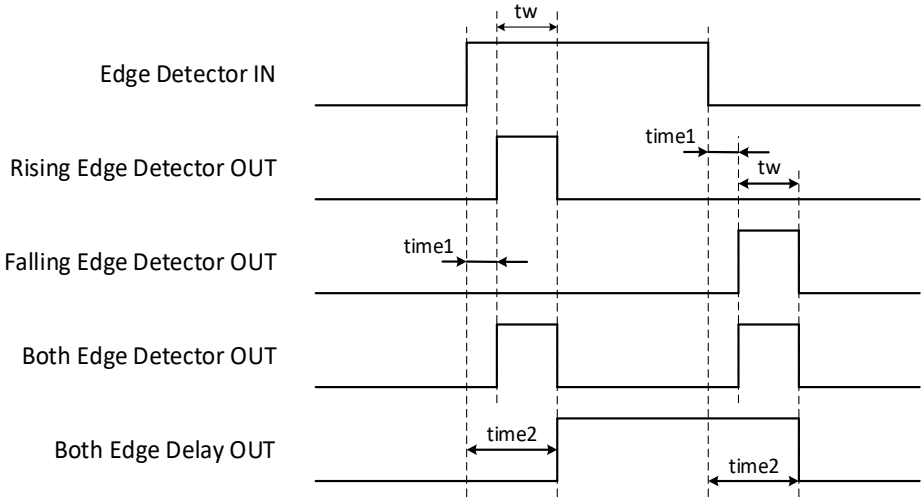



**Figure 174. Edge Detector Output**

# 20. Deglitch Filter Macrocell

The SLG47011 has a Deglitch Filter macrocell with inverter function. The filter blocks the input signal for pulse width < $t_{block}$ (at typical temperature 25 °C, see section 3.4.7 Typical Filter Rejection Pulse Width) and passes the input signal for pulse width > $t_{pass}$ (at typical temperature 25 °C). For pulse widths in between, the output pulse width will be reduced.

In addition, this macrocell can be configured as an Edge Detector, with the following settings:

- Rising Edge Detector
- Falling Edge Detector
- Both Edge Detector
- Both Edge Delay.

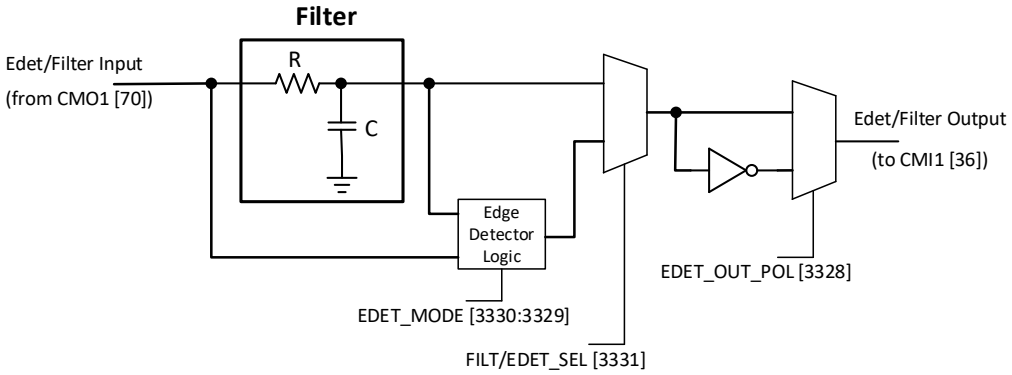



**Figure 175. Deglitch Filter/Edge Detector Simplified Structure**

# 21. Current Source Macrocell

The Current Source (CS) is a macrocell that outputs (sources) a constant current to the load connected to GPIO7 (Figure 176). The current value is selected by a register CS_CURRENT [3322:3320] and can range from 1 µA to 100 µA (1, 2, 5, 10, 20, 50, 100 µA).

The CS power-up signal CMO1 [76] provides power-up/sleep macrocell control capability. The output current is referenced to GND.

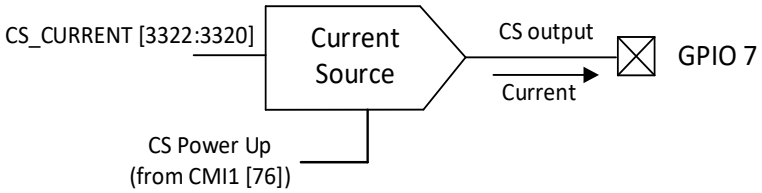



**Figure 176. Current Source Structure**

# 22. Internal Voltage Reference

## 22.1 Internal $V_{REF}$ General Description

The SLG47011 has a Voltage Reference ($V_{REF}$) to provide a fixed reference of 1.62 V to the ADC and DAC. The Analog Comparator (ACMP) has also an access to the Voltage Reference via a programmable voltage divider, see

Table 29. The ACMP Reference voltage can range from 27 mV to 1.62 V.

The DAC reference voltage also has the option to output on pin GPIO11 (see Table 1).

**Note 1:** The switch, which outputs the $V_{REF}$ voltage to GPIO11 has a resistance specified in section 3.13 Internal VREF Specifications. Please consider the switch resistance in the circuit design when using the $V_{REF}$ output to external pin.

**Note 2:** Excessive capacitance on GPIO11 may cause a DAC $V_{REF}$ buffer instability. Please consider the pin capacitance in the circuit design when using the $V_{REF}$ output to external pin.

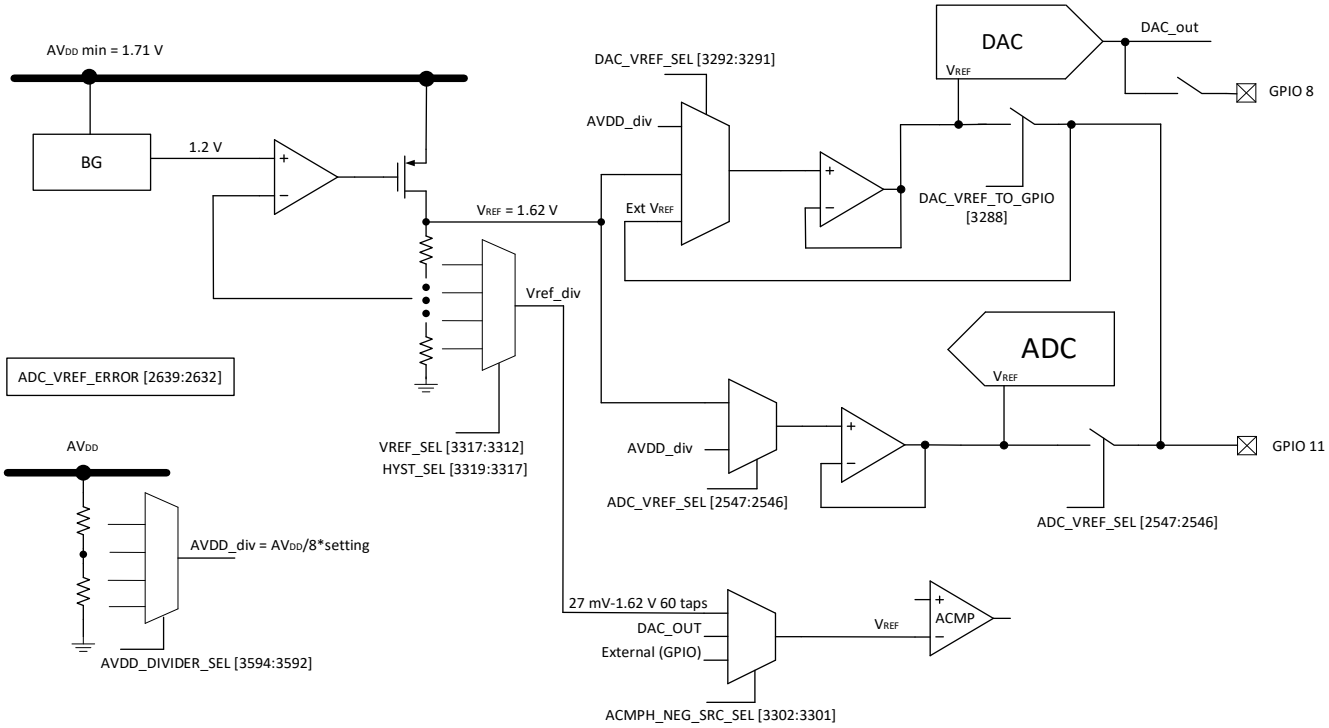



**Figure 177. $V_{REF}$ Structure**

**Table 29. Analog Comparator $V_{REF}$ Selection Table**

| VREF_SEL [3317:3312] | $V_{REF}$ [V] | VREF_SEL [3317:3312] | $V_{REF}$ [V] |
|---|---|---|---|
| 0 | 0.027 | 31 | 0.864 |
| 1 | 0.054 | 32 | 0.891 |
| 2 | 0.081 | 33 | 0.918 |
| 3 | 0.108 | 34 | 0.945 |
| 4 | 0.135 | 35 | 0.972 |
| 5 | 0.162 | 36 | 0.999 |

| VREF_SEL [3317:3312] | $V_{REF}$ [V] | VREF_SEL [3317:3312] | $V_{REF}$ [V] |
|---|---|---|---|
| 6 | 0.189 | 37 | 1.026 |
| 7 | 0.216 | 38 | 1.053 |
| 8 | 0.243 | 39 | 1.08 |
| 9 | 0.27 | 40 | 1.107 |
| 10 | 0.297 | 41 | 1.134 |
| 11 | 0.324 | 42 | 1.161 |
| 12 | 0.351 | 43 | 1.188 |
| 13 | 0.378 | 44 | 1.215 |
| 14 | 0.405 | 45 | 1.242 |
| 15 | 0.432 | 46 | 1.269 |
| 16 | 0.459 | 47 | 1.296 |
| 17 | 0.486 | 48 | 1.323 |
| 18 | 0.513 | 49 | 1.35 |
| 19 | 0.54 | 50 | 1.377 |
| 20 | 0.567 | 51 | 1.404 |
| 21 | 0.594 | 52 | 1.431 |
| 22 | 0.621 | 53 | 1.458 |
| 23 | 0.648 | 54 | 1.485 |
| 24 | 0.675 | 55 | 1.512 |
| 25 | 0.702 | 56 | 1.539 |
| 26 | 0.729 | 57 | 1.566 |
| 27 | 0.756 | 58 | 1.593 |
| 28 | 0.783 | 59 | 1.62 |
| 29 | 0.81 | 60 | N/A |
| 30 | 0.837 | 61 | N/A |

## 22.2 $V_{REF}$ Typical Performance

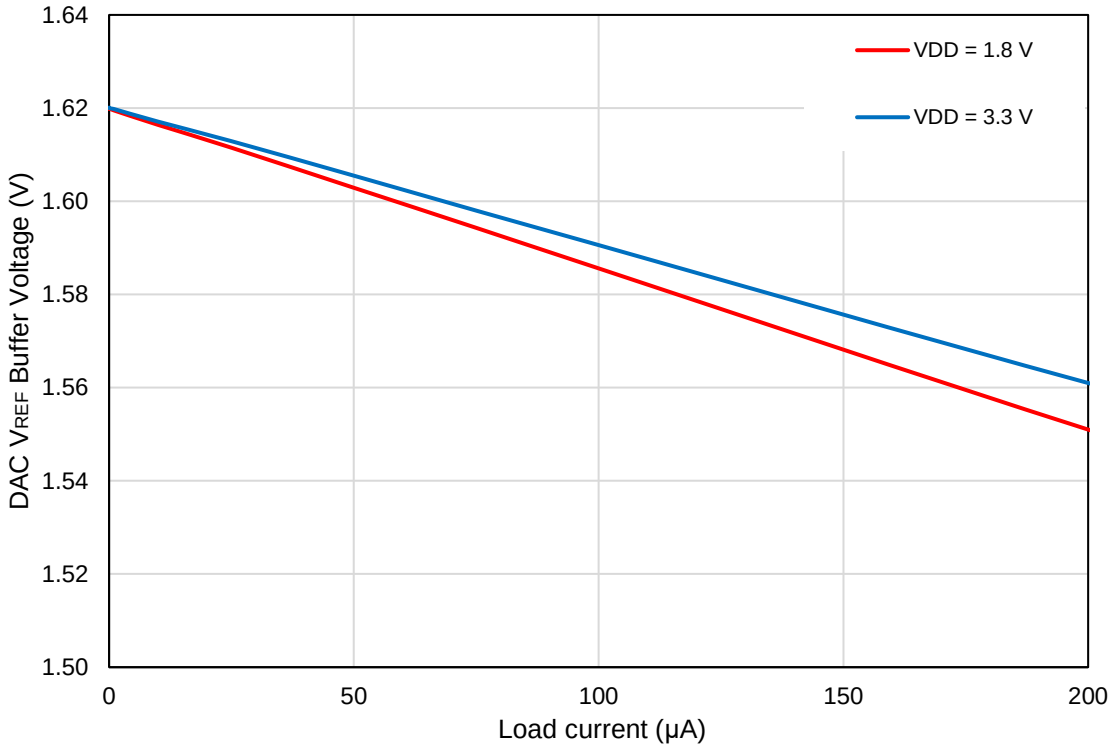



**Figure 178. DAC $V_{REF}$ Output Buffer Typical Load Regulation at $T_A$ = +25 °C, $V_{REF}$ = 1.62 V (Internal)**

# 23. Clocking

The SLG47011 has two internal oscillators to support a variety of applications:

- Oscillator0 (2 kHz or 10 kHz optional selection)
- Oscillator1 (20 MHz or 40 MHz optional selection).

Oscillator0 can operate in one of two modes (2 kHz or 10 kHz) selected by register OSC0_FREQ_SEL [531], and Oscillator1 can operate in one of two modes (20 MHz or 40 MHz) selected by register OSC1_FREQ_SEL [3447]. There are two divider stages for each oscillator that provides flexibility for introducing clock signals to the connection matrix, as well as various other macrocells. The pre-divider (first stage) for Oscillator0 is clock /1, /2, /4, or /8. The pre-divider (first stage) for Oscillator1 is clock /1, /2, /4, /8, /12, /24, /48, /96. The second stage divider has an input of frequency from the pre-divider and outputs one of eight different frequencies divided by /1, /2, /3, /4, /8, /12, /24, or /64 on connection matrix input lines CMO0 [18], CMO1 [85], and CMO1 [86]. Please see Figure 179, Figure 180, and Figure 181 for more details on the SLG47011 clock scheme.

The Matrix Power-down/Force On function switches off or forces on the oscillators using an external pin. The Matrix Power-down/Force On (CMO0 [37] and CMO1 [106]) signals have the highest priority. Exceptions are the ADC, MathCore, Memory Table, Data Buffer, DAC, and DCMP macrocells, which each can force OSC1 on internally, but makes the OSC1 output to the connection matrix unavailable.

The OSC operates according to Table 30:

**Table 30. Oscillator Operation Mode Configuration Settings**

| POR | External Clock Selection | Signal From Connection Matrix | Register: Power-Down or Force On by Matrix Input | Register: Auto Power-On or Force On | OSC Enable Signal from Macrocells | OSC Operation Mode |
|---|---|---|---|---|---|---|
| 0 | X | X | X | X | X | OFF |
| 1 | 1 | X | X | X | X | Internal OSC is OFF, logic is ON |
| 1 | 0 | 1 | 0 | X | X | OFF |
| 1 | 0 | 1 | 1 | X | X | ON |
| 1 | 0 | 0 | X | 1 | X | ON |
| 1 | 0 | 0 | X | 0 | CNT/DLY requires OSC | ON |
| 1 | 0 | 0 | X | 0 | CNT/DLY does not require OSC | OFF |
| 1 | 0 | X | X | X | ADC, MathCore, Memory Table, Data Buffer, DAC, and DCMP | ON, no output to connection matrix |

**[1]** The OSC will run only when any macrocell that uses OSC is powered on.

## 23.1 Oscillator0 (2 kHz, 10 kHz) Macrocell

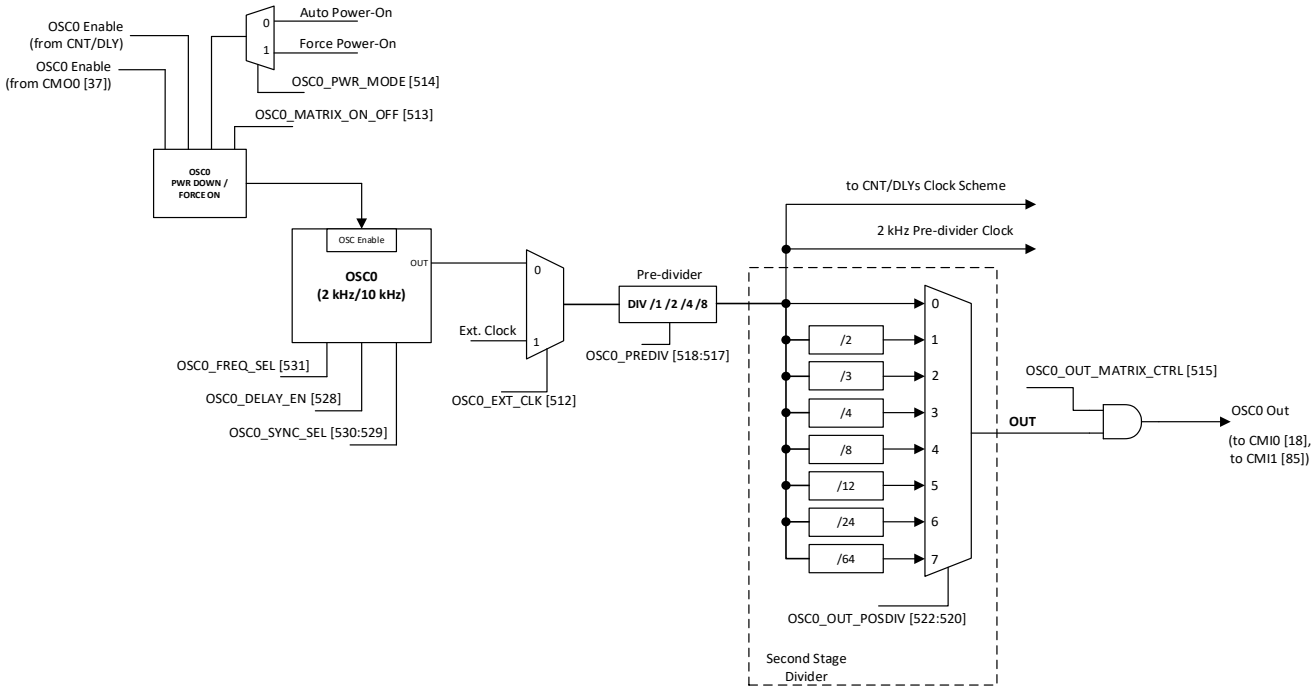



**Figure 179. Oscillator0 Block Diagram**

## 23.2 Oscillator1 (20 MHz, 40 MHz) Macrocell

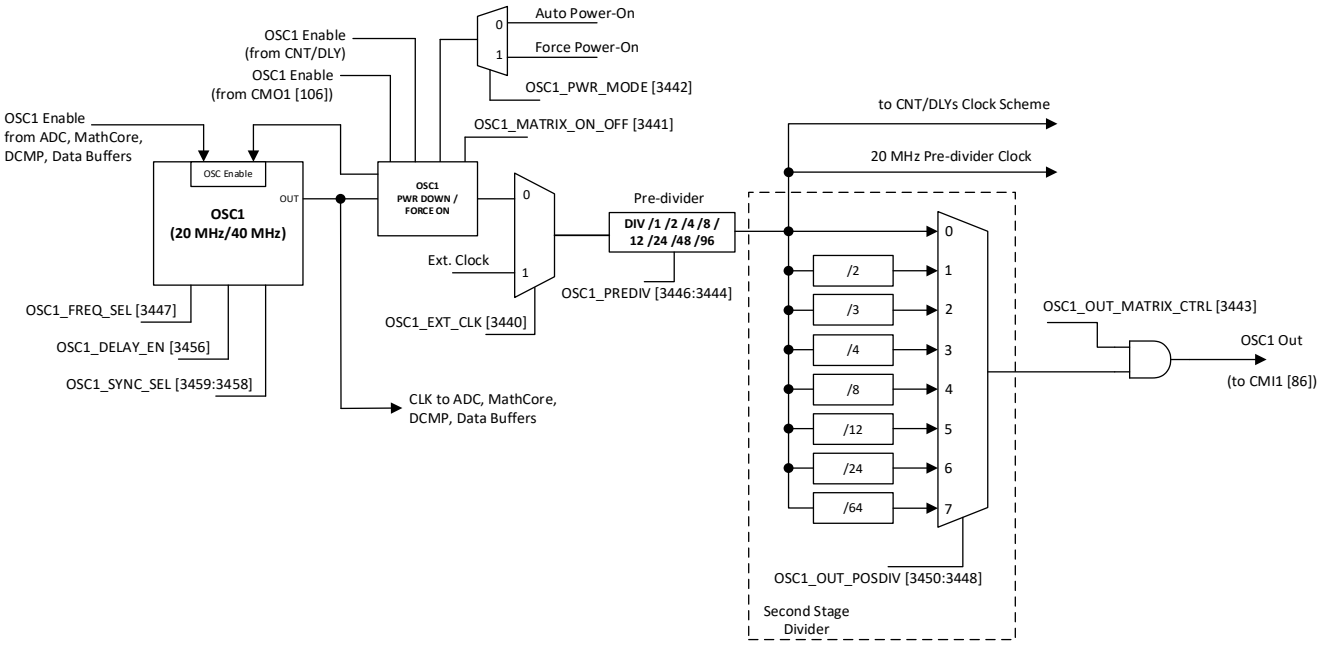



**Figure 180. Oscillator1 Block Diagram**

## 23.3 CNT/DLY Clock Scheme

The CNT/DLY within each multi-function macrocell and Memory Control Counter has its own additional clock divider fed from to the oscillators pre-divider. Available dividers are:

- OSC0/1, OSC0/8, OSC0/16, OSC0/32, OSC0/64, OSC0/512, OSC0/4096
- OSC1/1, OSC1/4, OSC1/8, OSC1/64, OSC1/512.

CNT0 and CNT1's input clock source is limited to OSC0 only.

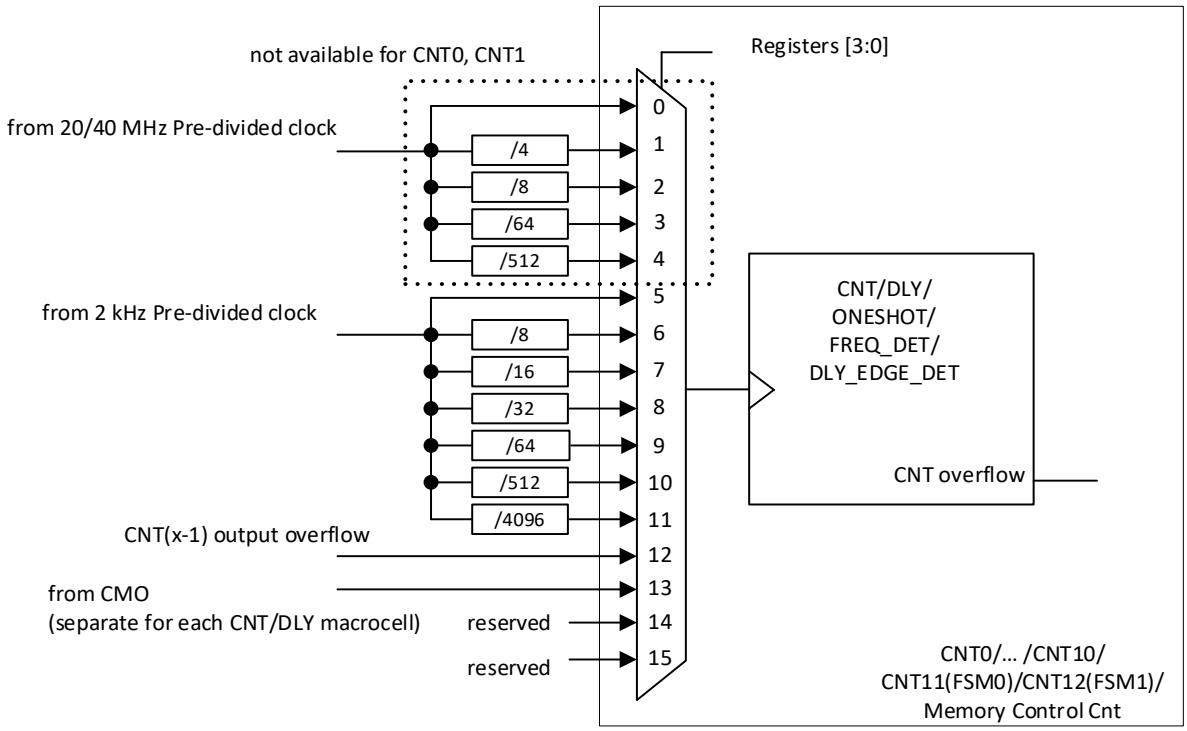



**Figure 181. Clock Scheme**

## 23.4 External Clocking

The SLG47011 supports several options to use an external, higher accuracy clock as a reference source for internal operations.

### 23.4.1. GPIO Source for Oscillator0 (2 kHz/10 kHz)

If register OSC0_EXT_CLK [512] is set to '1', the external clock signal applied to pin GPIO10 will replace the internal oscillator derived from the 2 kHz/10 kHz clock source (see Figure 179). The low and the high limits of the external frequency are 0 kHz and 10 kHz.

### 23.4.2. GPIO Source for Oscillator1 (20 MHz/40 MHz)

If register OSC1_EXT_CLK [3440] is set to '1', an external clock signal applied to pin GPIO3 will replace the internal oscillator derived from the 20 MHz clock source (see Figure 180). The external frequency ranges from 0 MHz to 235 MHz at $V_{DD}$ = 1.8 V, 286 MHz at $V_{DD}$ = 2.5 V, and 281 MHz at $V_{DD}$ = 3.3 V.

**Note:** Proper operation of internal blocks is guaranteed for a maximum clock frequency of 40 MHz.

## 23.5 Oscillators Power-On Delay

If "Auto Power-On" is selected, the "OSC enable" signal transitions HIGH if any macrocell that uses the OSC is powered on (see Figure 182). The values of Power-on Delay are in section 3.6.2 Oscillator0 2 kHz/10 kHz Power-On Delay.

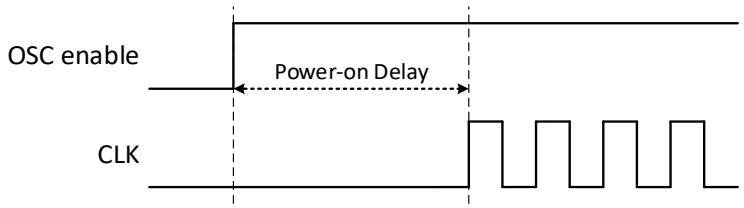



**Figure 182. Oscillator Startup Diagram**

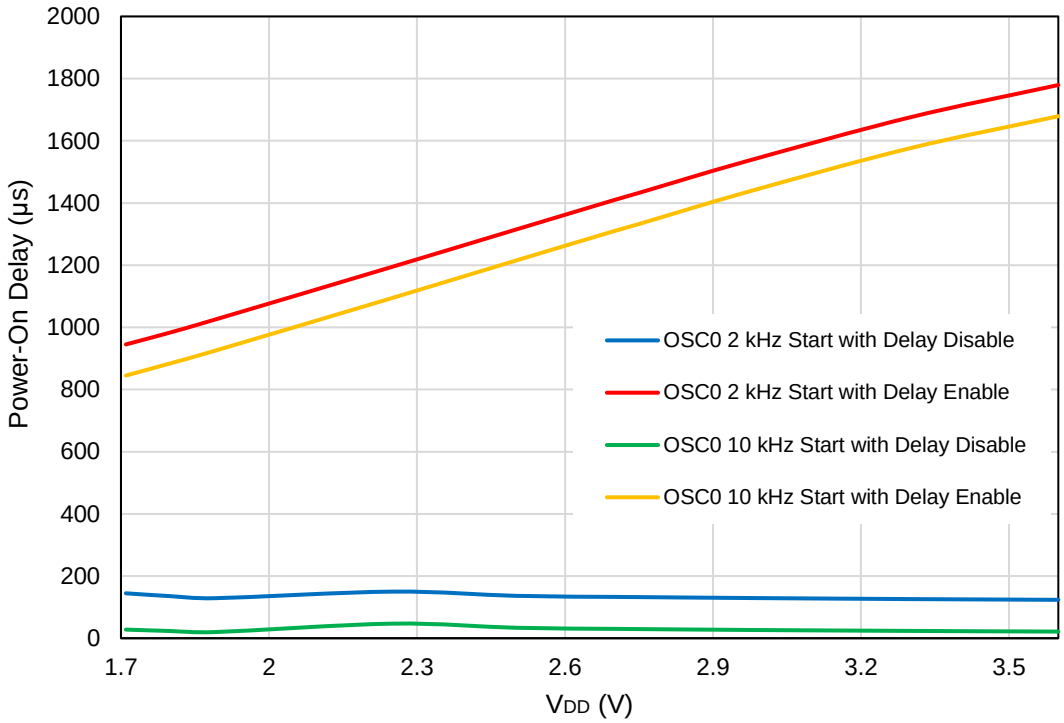



**Figure 183. RC Oscillator Maximum Power-On Delay vs. $V_{DD}$ at $T_A$ = +25 °C, OSC0 = 2 kHz/10 kHz**

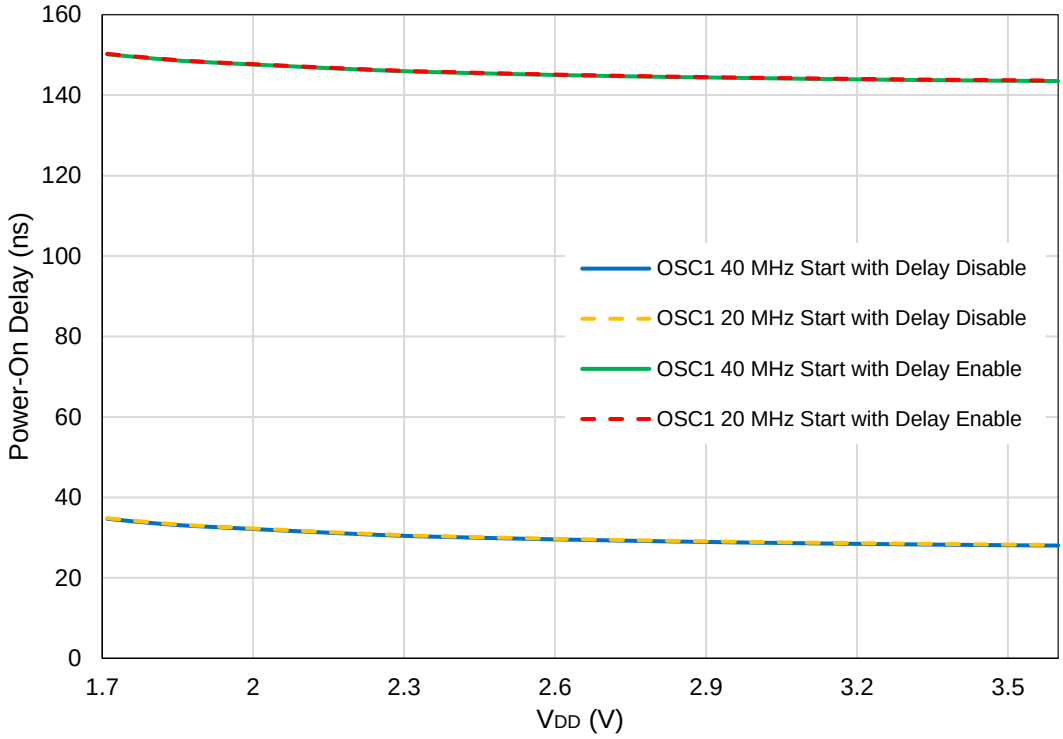



**Figure 184. RC Oscillator Maximum Power-On Delay vs. $V_{DD}$ at $T_A$ = +25 °C, OSC1 = 20 MHz/40 MHz**

## 23.6 Oscillators Accuracy

**Note**: OSC power setting: Force Power-on; clock to matrix input: enable; bandgap turned on by register: enable.

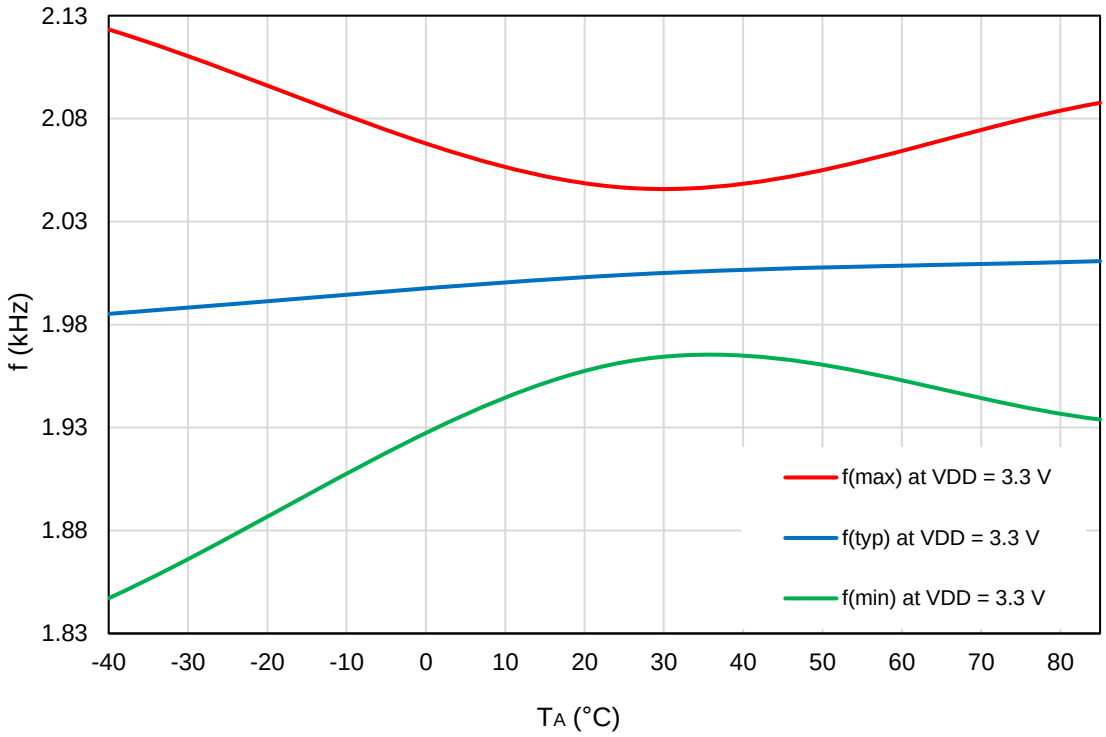



**Figure 185. Oscillator0 Frequency vs. Temperature, OSC0 = 2 kHz**

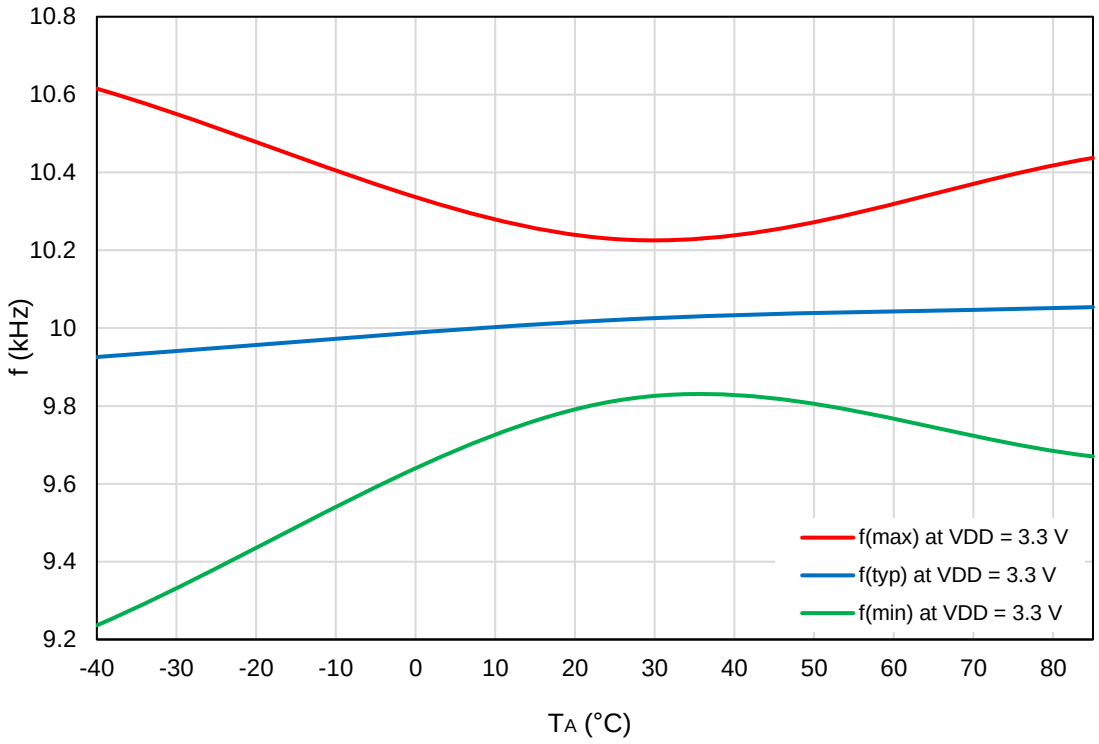



**Figure 186. Oscillator0 Frequency vs. Temperature, OSC0 = 10 kHz**

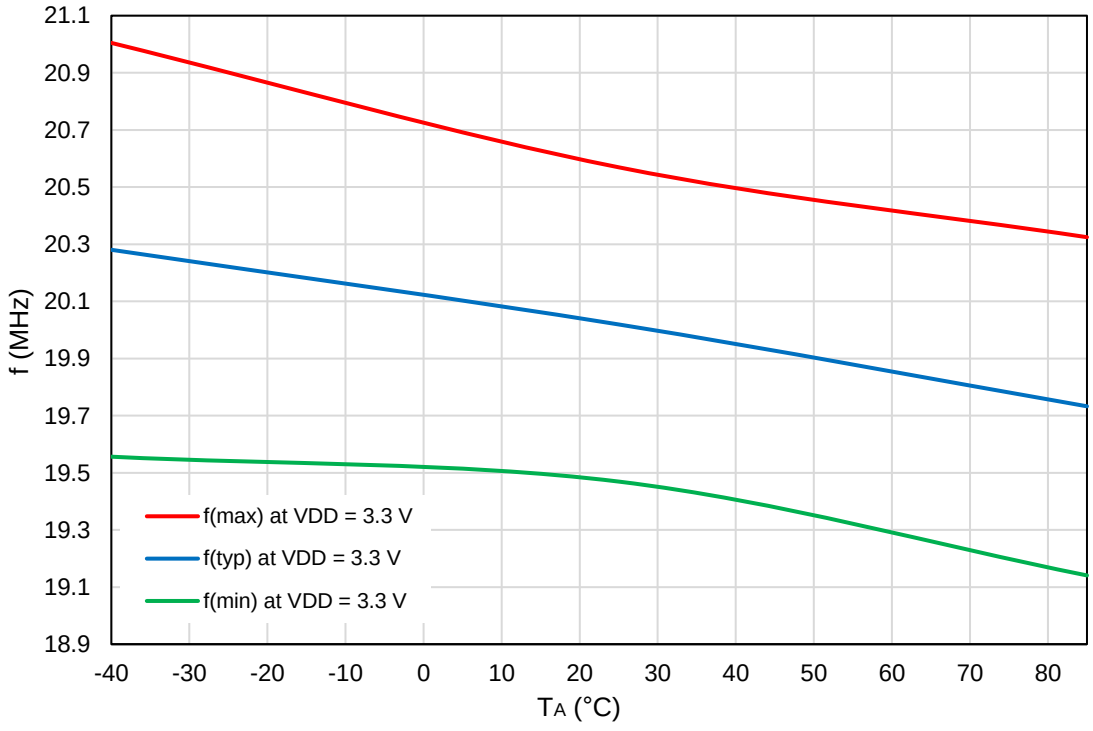



**Figure 187. Oscillator1 Frequency vs. Temperature, OSC1 = 20 MHz**

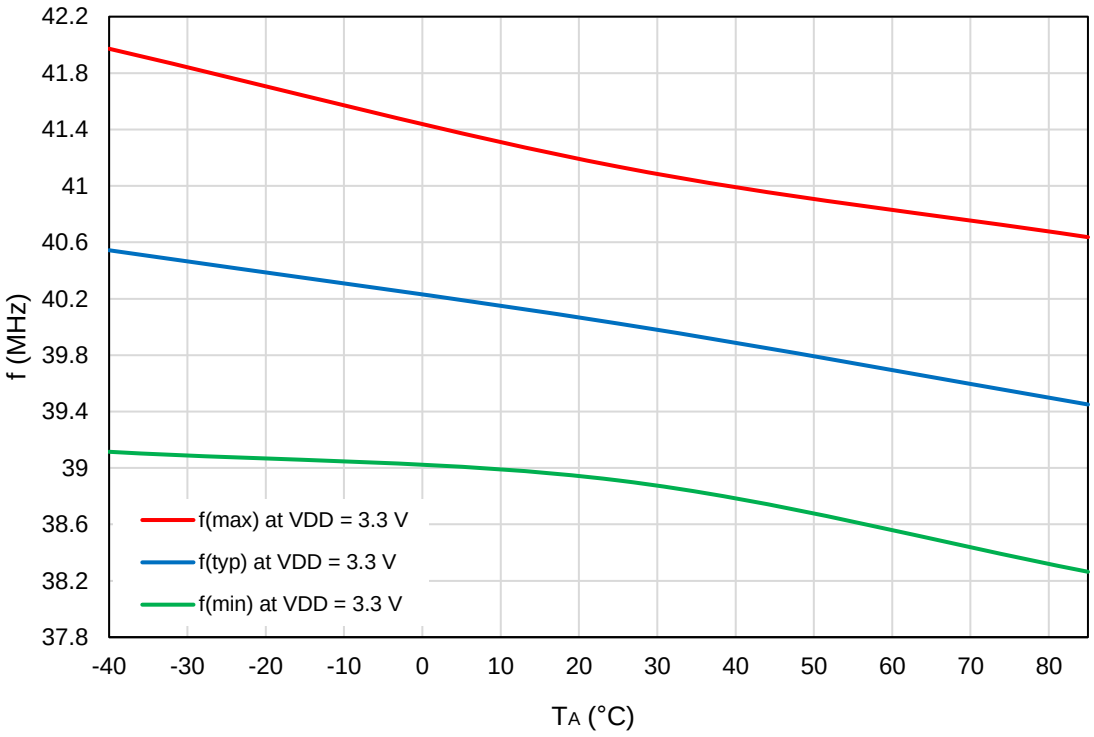



**Figure 188. Oscillator1 Frequency vs. Temperature, OSC1 = 40 MHz**

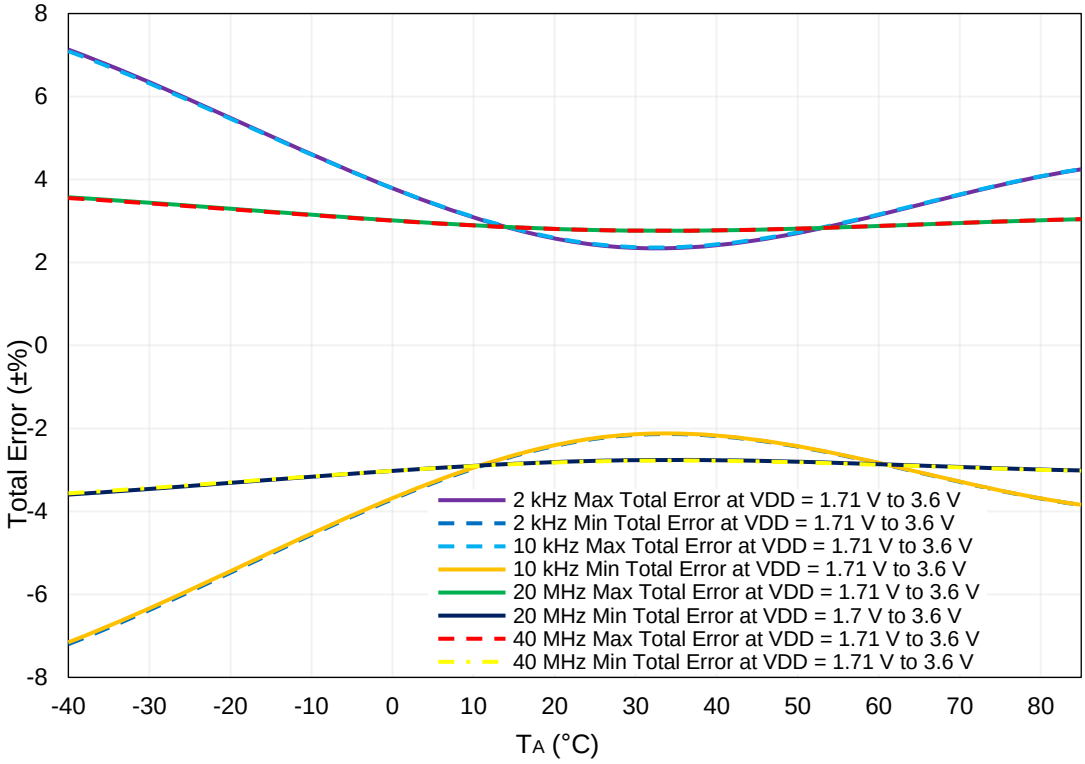



**Figure 189. Oscillators Total Error vs. Temperature**

## 23.7 Oscillator Settling Time

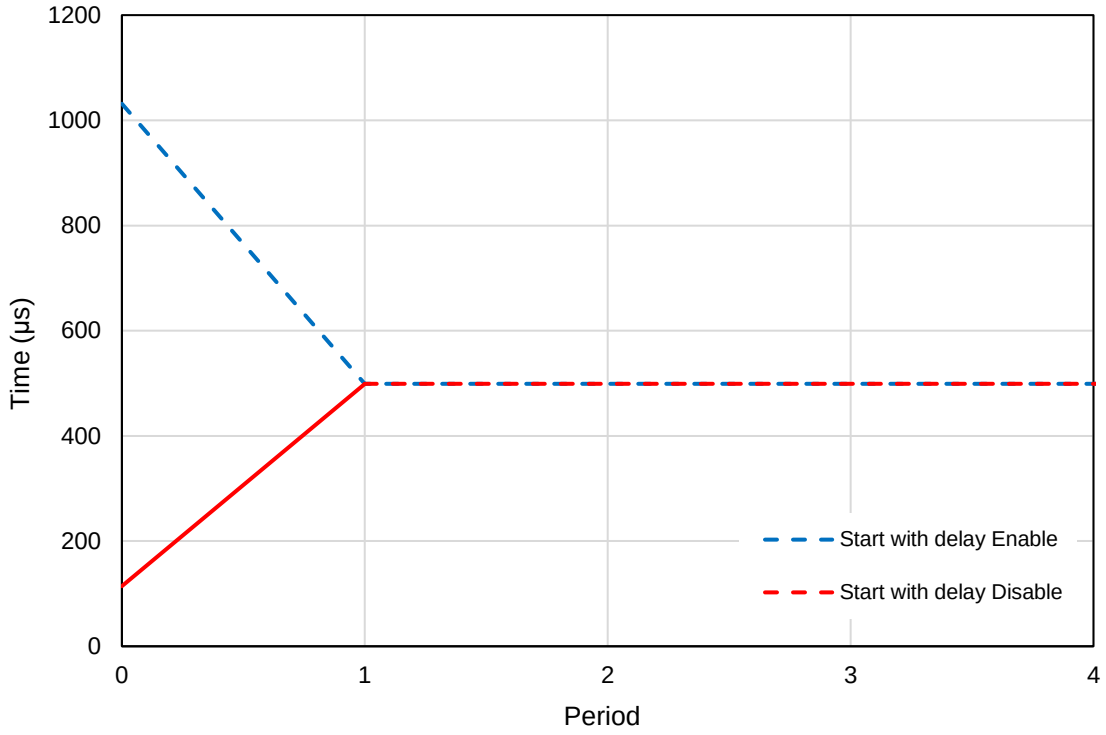



**Figure 190. Oscillator0 Settling Time, OSC0 = 2 kHz**

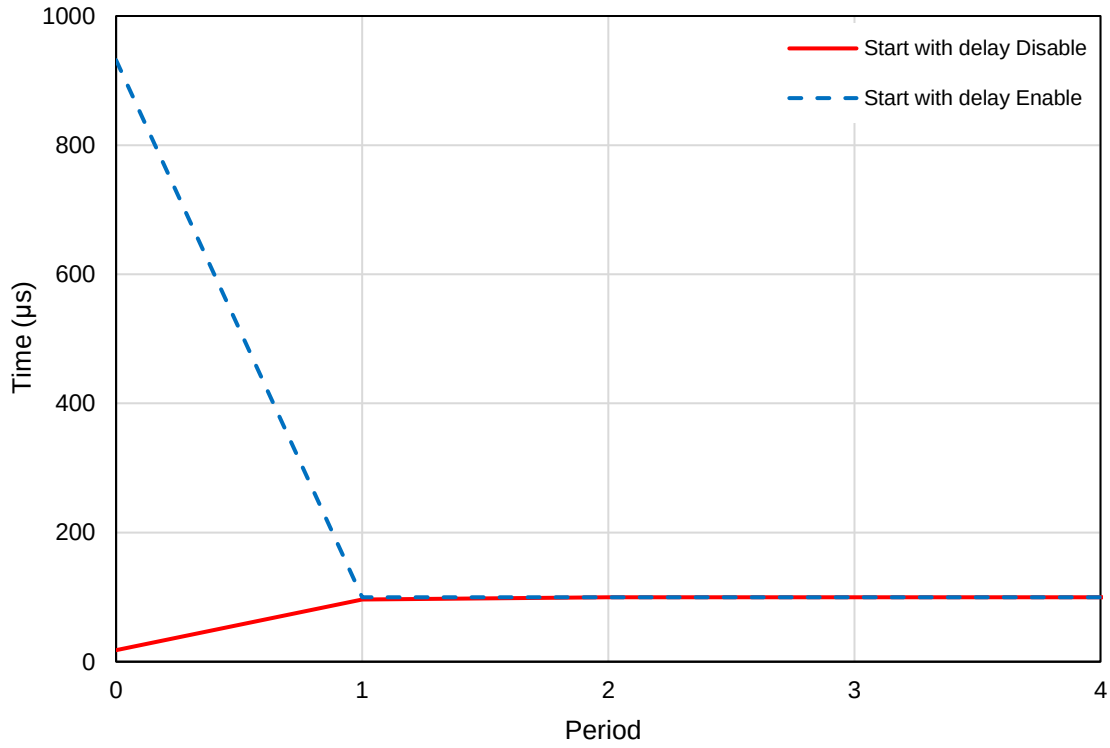



**Figure 191. Oscillator0 Settling Time, OSC0 = 10 kHz**

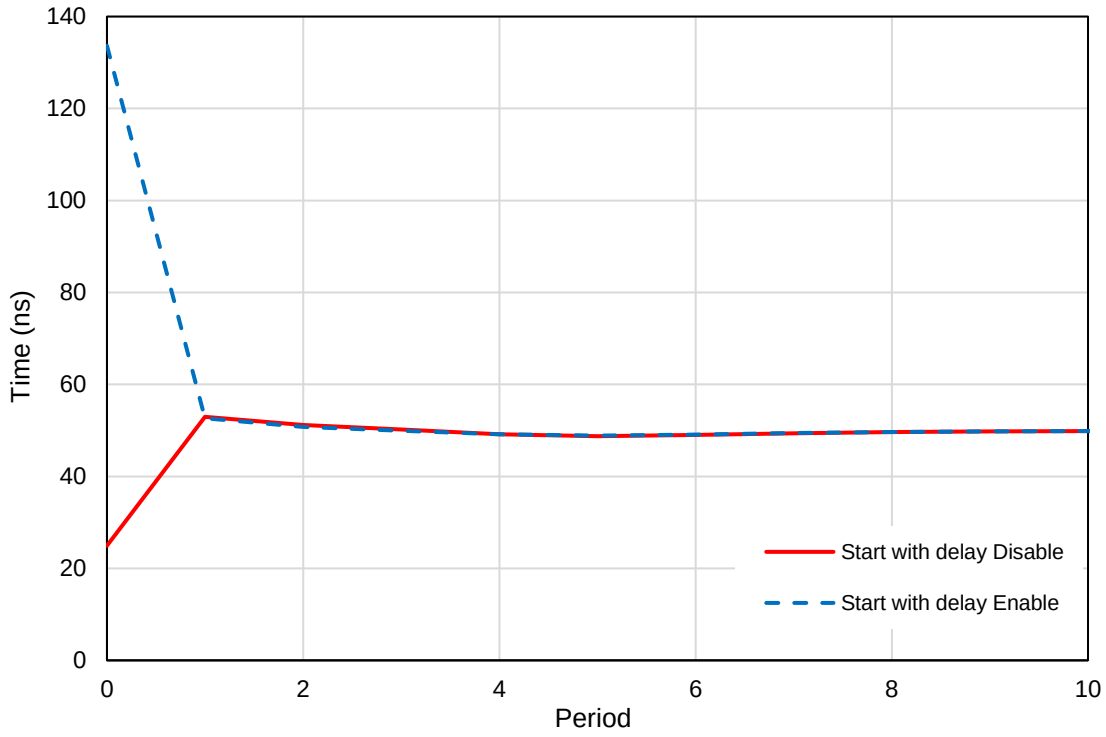



**Figure 192. Oscillator1 Settling Time, OSC1 = 20 MHz**

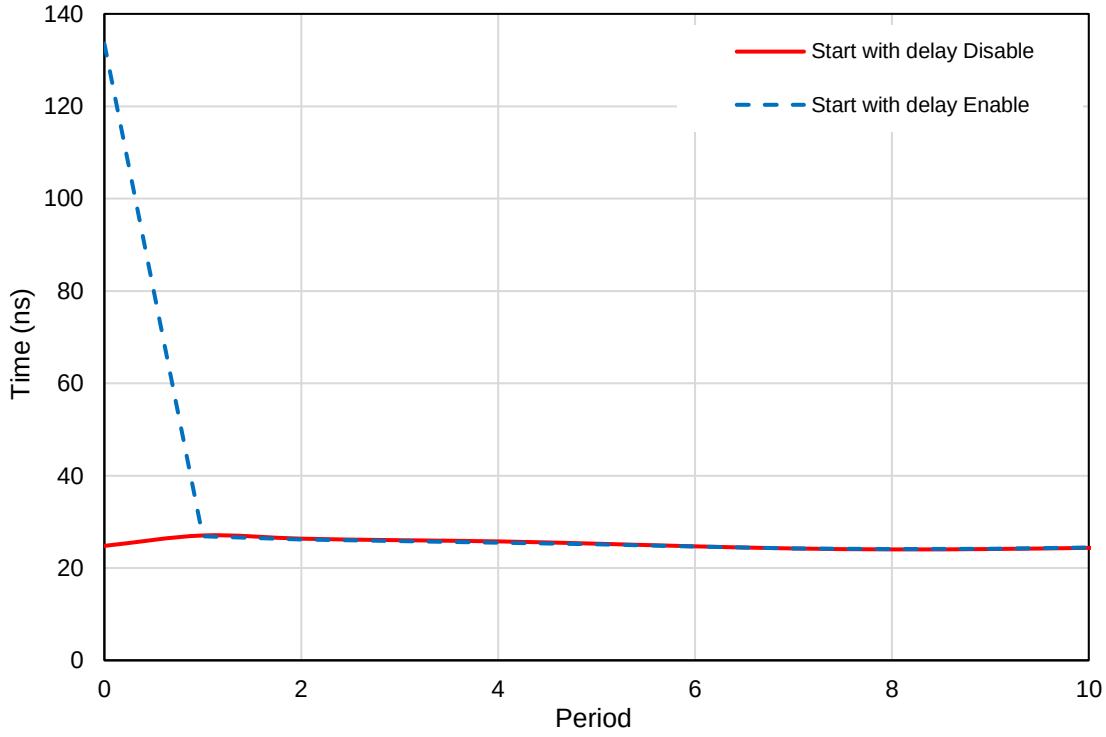



**Figure 193. Oscillator1 Settling Time, OSC1 = 40 MHz**

## 23.8 Oscillator Current Consumption

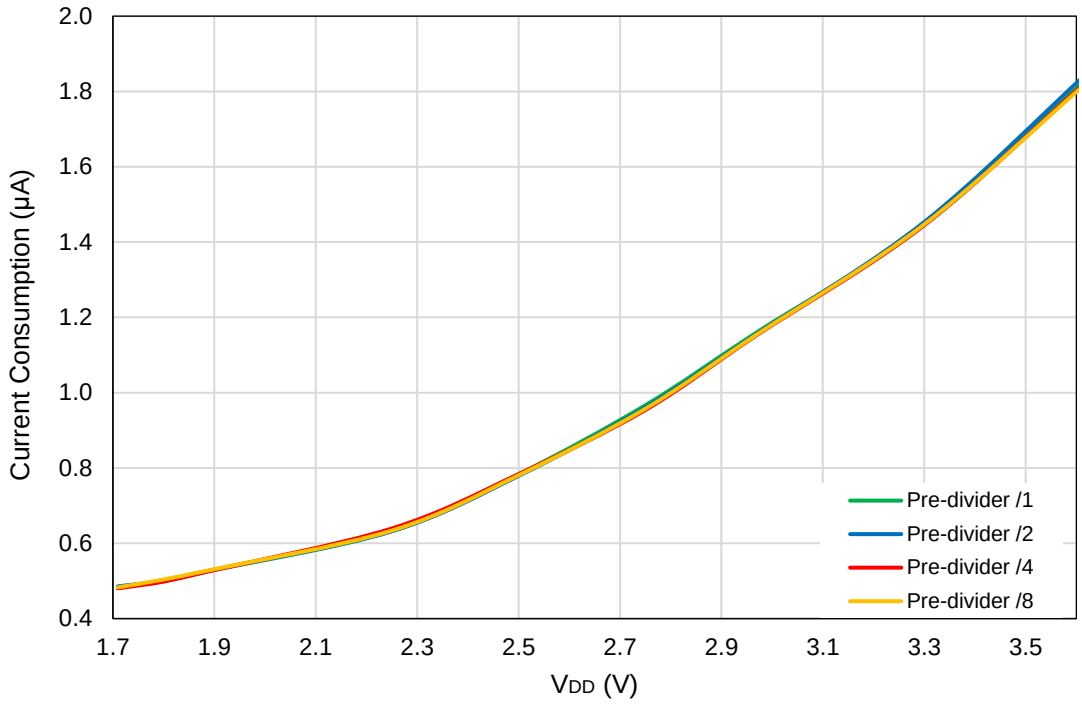



**Figure 194. OSC0 Current Consumption vs. $V_{DD}$ (All Pre-Dividers), OSC0 = 2 kHz**

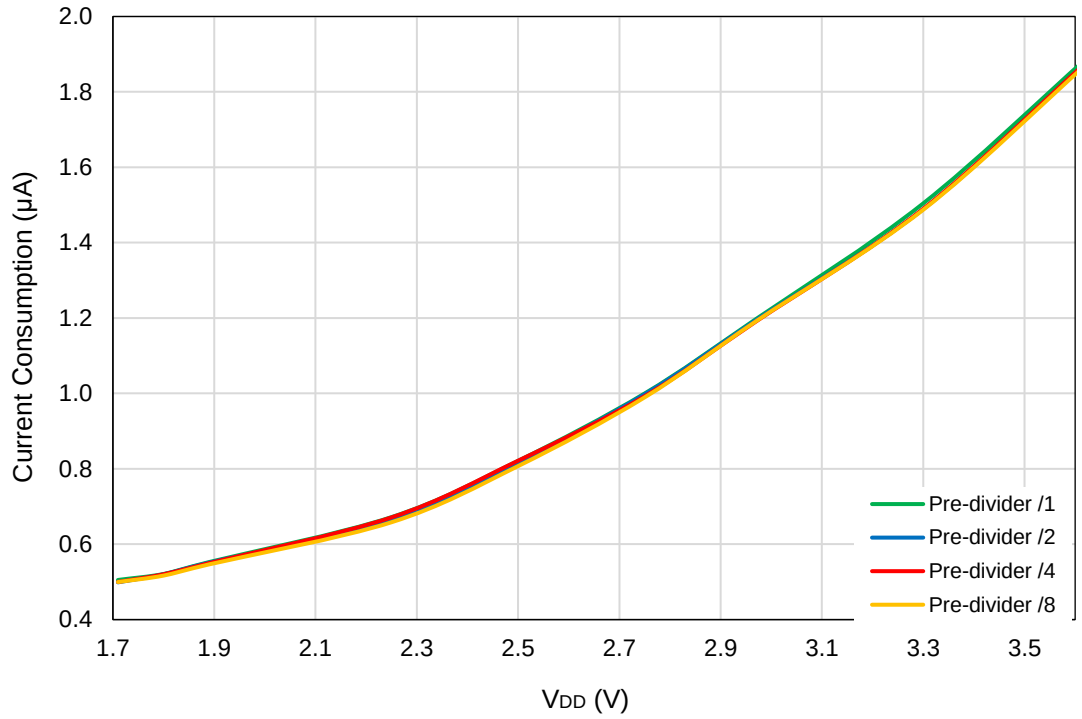



**Figure 195. OSC0 Current Consumption vs. $V_{DD}$ (All Pre-Dividers), OSC0 = 10 kHz**

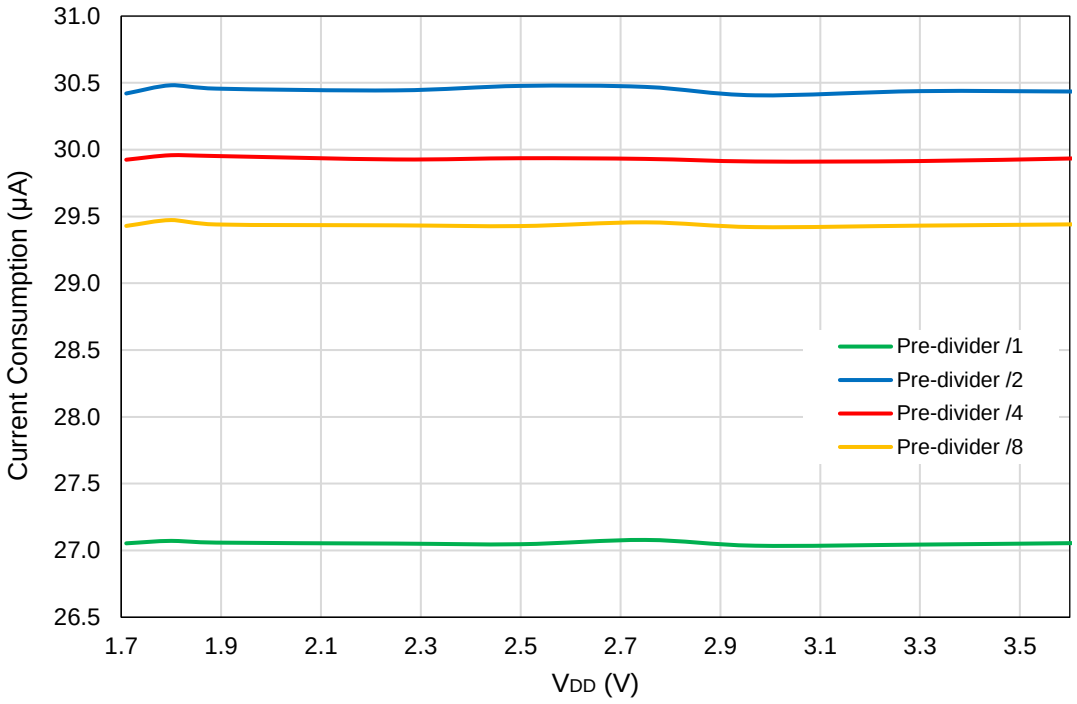



**Figure 196. OSC1 Current Consumption vs. $V_{DD}$ (All Pre-Dividers), OSC1 = 20 MHz**

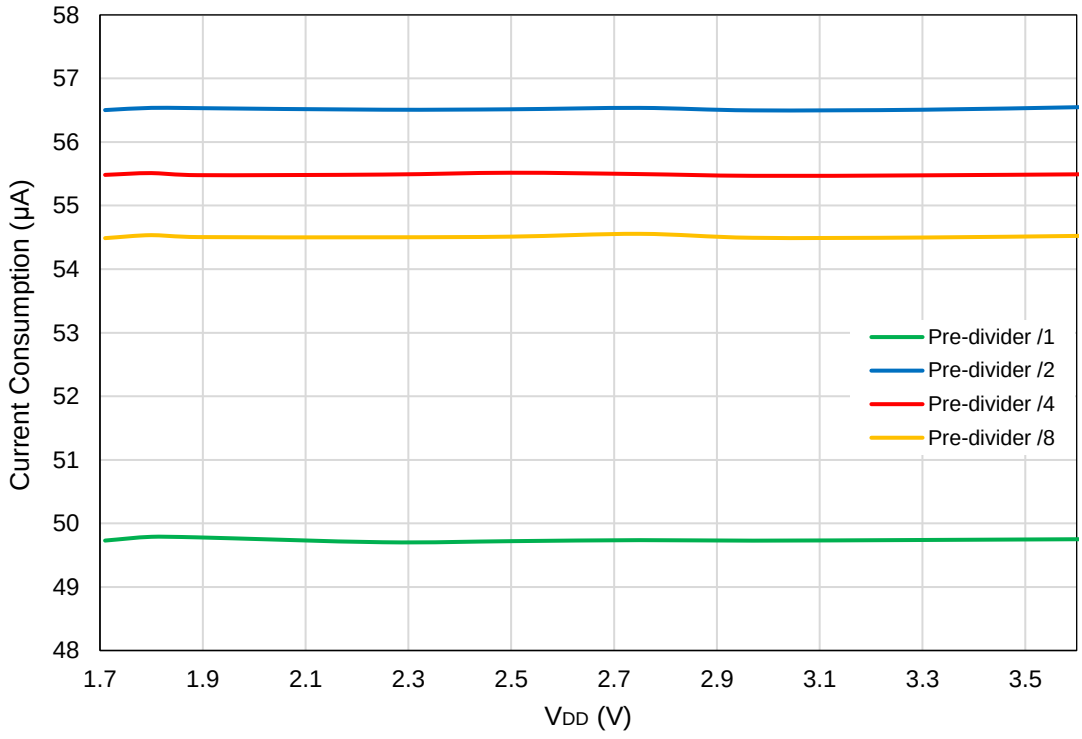



**Figure 197. OSC1 Current Consumption vs. $V_{DD}$ (All Pre-Dividers), OSC1 = 40 MHz**

# 24. Power-On Reset

The SLG47011 has a Power-on Reset (POR) macrocell to ensure correct device initialization and operation of all macrocells in the device. The purpose of the POR circuit is to have consistent behavior and predictable results when the $V_{DD}$ power is first ramping to the device, and while the $V_{DD}$ voltage is falling during power-down. To accomplish this goal, the POR drives a defined sequence of internal events that trigger changes to the states of different macrocells inside the device, and finally to the state of the IO pins.

## 24.1 POR General Operation

The SLG47011 is guaranteed to be powered down and non-operational if the $V_{DD}$ voltage (voltage on PIN1) is lower than the power-off threshold ($POFF_{THR}$), but not less than -0.6 V. Another essential condition for the device to be powered down is that no voltage higher than the $V_{DD}$ voltage is applied to any other pin. For example, if $V_{DD}$ voltage is 0.3 V, applying a voltage higher than 0.3 V to any other pin can lead to incorrect or unexpected device behavior.

**Note**: There is a 0.6 V margin due to forward drop voltage on the ESD protection diodes.

To initiate the POR sequence, the $V_{DD}$ needs to exceed the power-on threshold ($PON_{THR}$). The full operational $V_{DD}$ range for the SLG47011 is 1.71 V to 3.6 V. This means that the POR sequence will start before the $V_{DD}$ voltage reaches its operating voltage range. Once the POR sequence has initiated, the SLG47011 will need a certain time to go through all the steps in the POR sequence.

While the POR sequence is progressing, all the pins are in Hi-Z state. The last step in the POR sequence is the release of the IO pins from their Hi-Z state. The pin configuration at this point of time is defined by the design programmed into the device. Once the POR sequence is complete, the device will be completely operational.

To power down the device, the $V_{DD}$ voltage needs to be pulled below the power-off threshold. The power-off threshold and the power-on threshold are specified in section 3.4.1 Logic IO Specifications.

## 24.2 POR Sequence

The POR system generates a staggered sequence of POR signals that enable certain macrocells. The POR sequence depends on the selected power mode (All ON, RETENTION, SLEEP, refer to Table 6).

If the selected power mode is All ON, the POR sequence shown in Figure 198 incudes POR stages related to the PD_Mx0 and PD_Mx1 power domains (Case 1). If selected power mode is SLEEP, the POR sequence in Figure 198 incudes only the POR stages related to the PD_Mx0 power domain (Case 2) and the stages related to PD_Mx1 power domain are skipped.

The POR sequence for RETENTION mode, followed by the transition from RETENTION mode to All ON mode is shown in Figure 199. The POR sequence for SLEEP mode, followed by wakeup from SLEEP mode to All ON mode is shown in Figure 200.

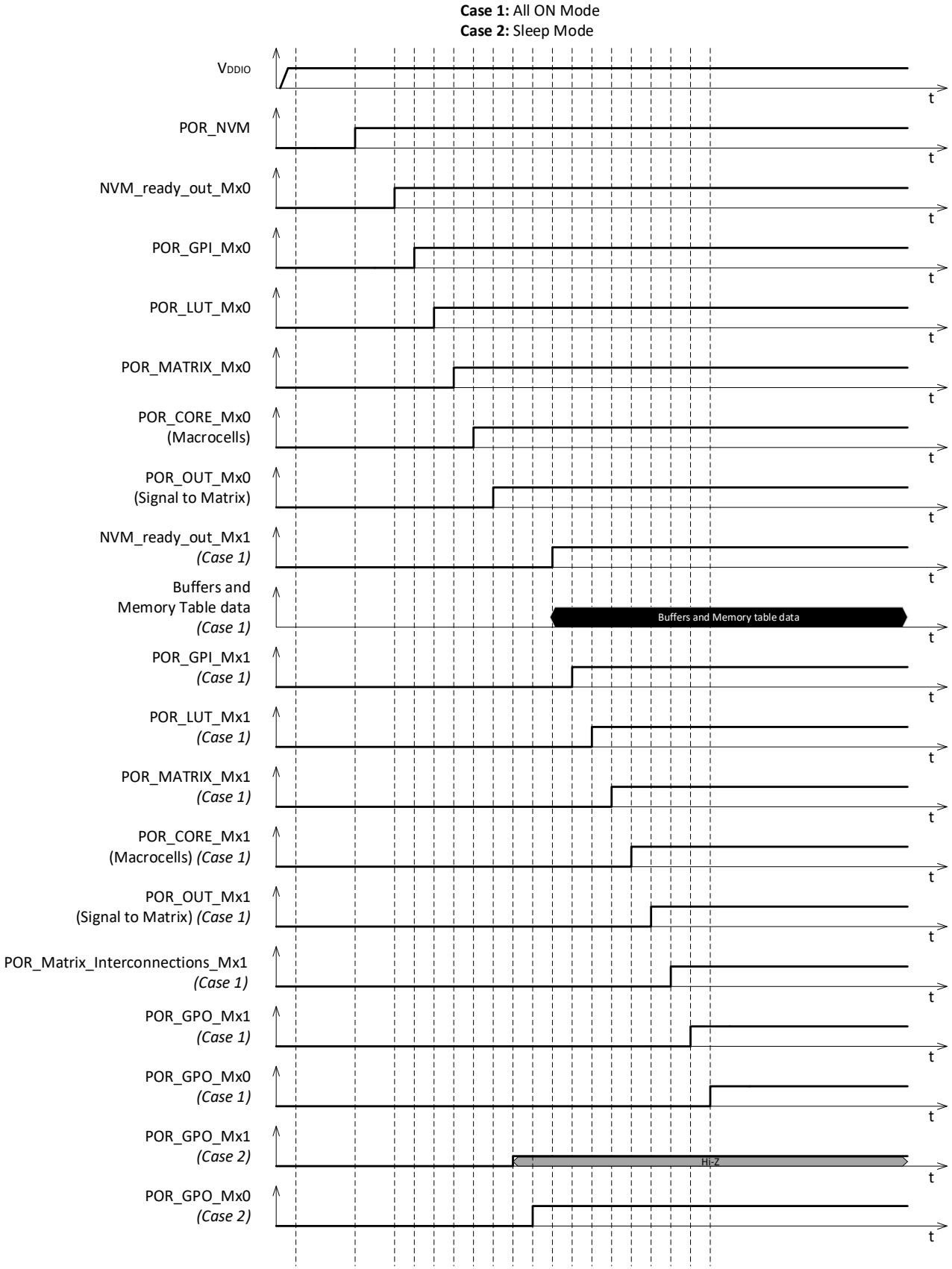



**Figure 198. POR Sequence at Transition from Power Off State to Power On State in Case 1 and Case 2**

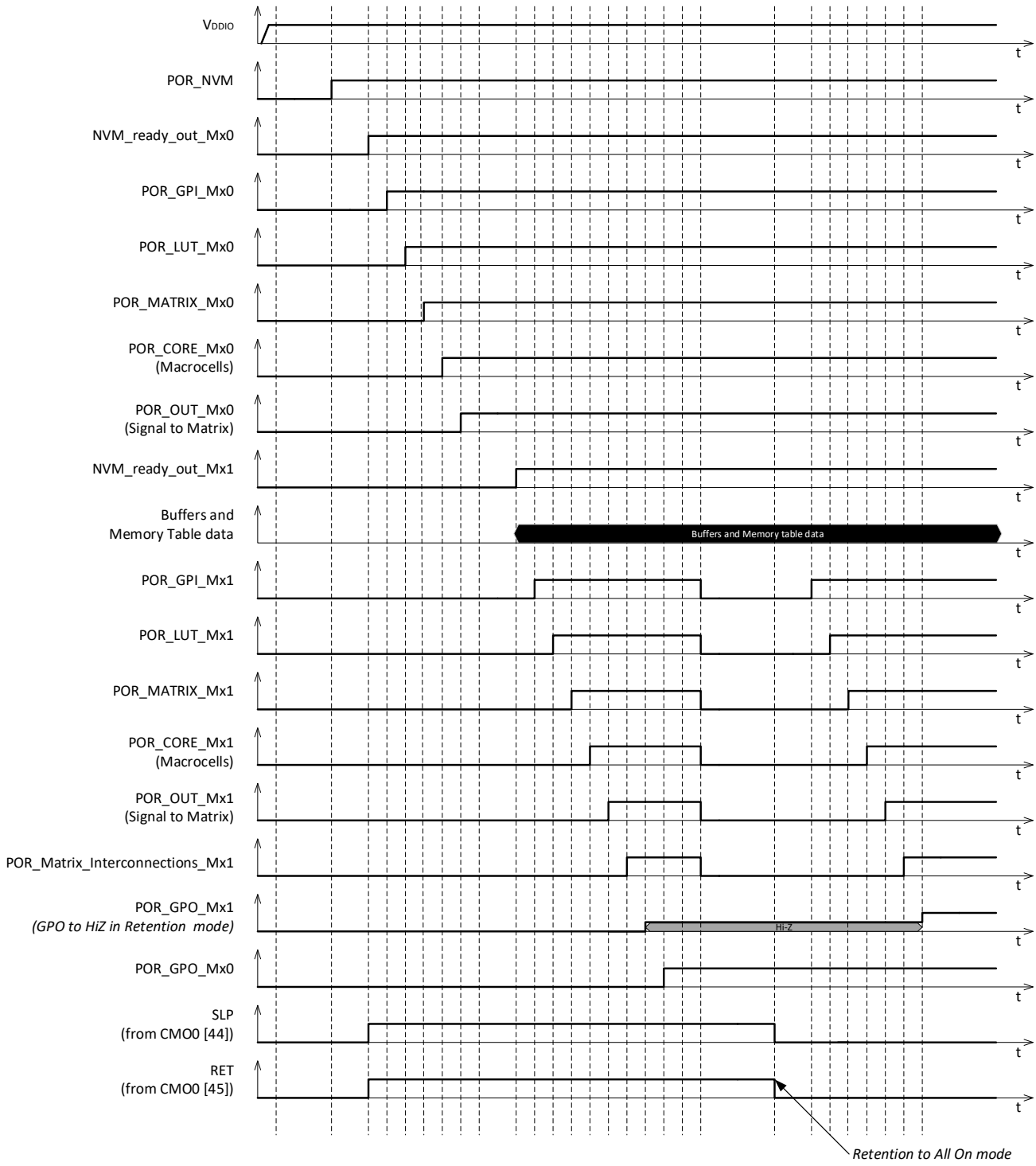



**Figure 199. POR Sequence in RETENTION Mode, Followed by Resumption from RETENTION Mode to All ON Mode**

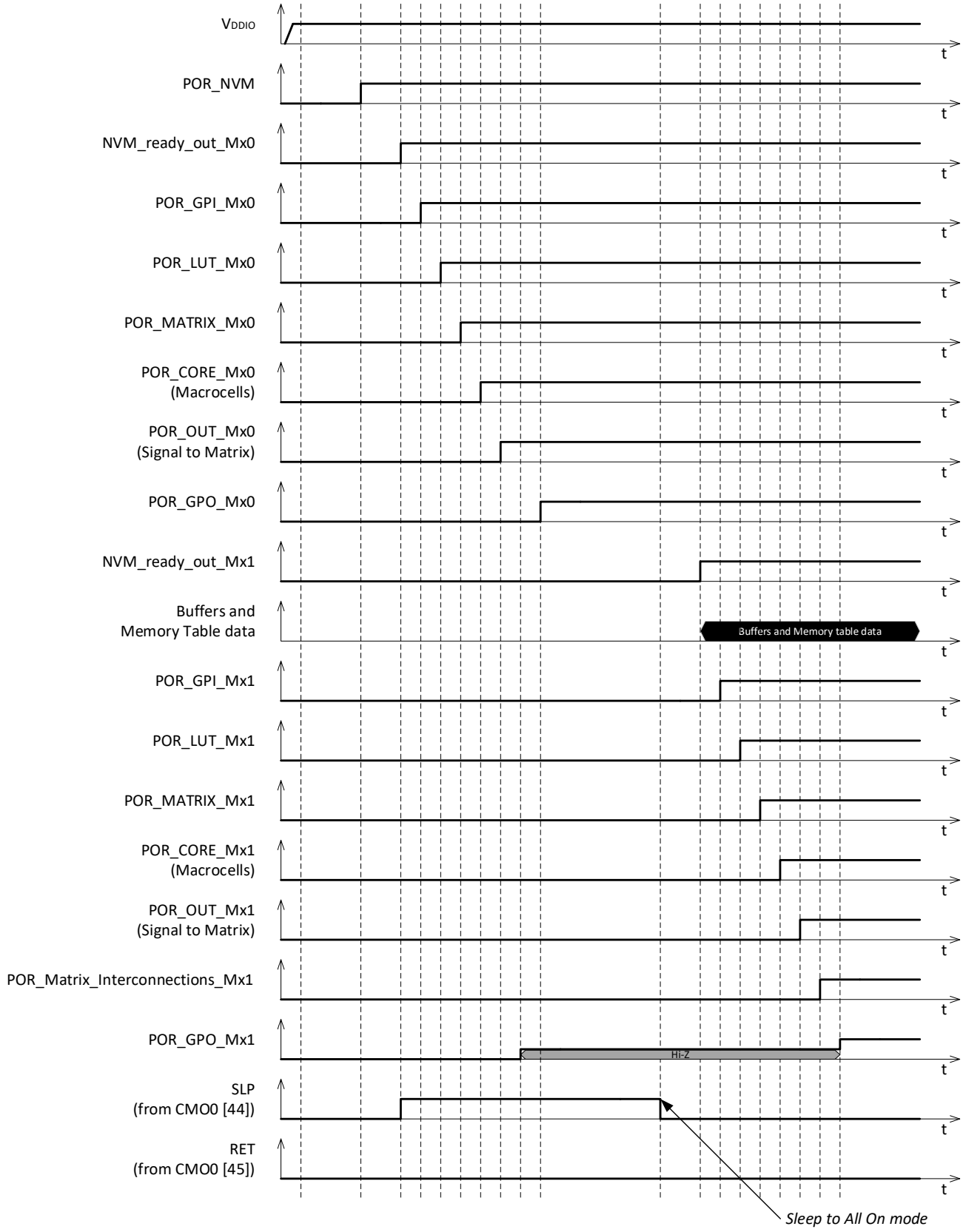



**Figure 200. POR Sequence in SLEEP Mode, Followed by Wakeup from SLEEP Mode to All ON Mode**

As shown in Figure 198, once the $V_{DD}$ voltage exceeds the POR (Power-on Reset) threshold, the on-die NVM controller gets reset first. Next, the device reads the data from the NVM and transfers this information to CMOS latches that configure each macrocell and the connection matrices. At the third stage, the input pins get reset and enabled. Then, the LUTs are reset and become active. After that, the delay cells, RC OSC, DFFs, and LATCHES are initialized. After all macrocells are initialized, the internal POR signal (POR macrocell output) transitions from LOW to HIGH. At the last step of the device initialization, the output pins transition from high impedance state to active.

The typical time that takes to complete the POR sequence varies by device type in the GreenPAK family. It also depends on many operating conditions, such as the $V_{DD}$ voltage and its slew-rate, temperature, and process variations.

## 24.3 Macrocells Output States During POR Sequence

Figure 201 describes the output states of all macrocells in the SLG47011 during the POR sequence.

Before the device has been reset, the outputs of all macrocells are set to logic-low, except for the output pins which are in Hi-Z state. Until the NVM is ready, the outputs of all macrocell are unpredictable, except for the output pins. At the next step, some macrocells start initialization:

- Output states of the input pins become low
- LUT outputs become low.

Only the programmable delay macrocell, which is configured as an edge detector, becomes active at this time. After that, input pins are enabled. Next, only LUTs are configured. Soon thereafter, all other macrocells are initialized. When all macrocells are initialized, the internal POR matrix signal switches from LOW to HIGH. At the last step, the output pins become active and their output states are determined by the input signals.

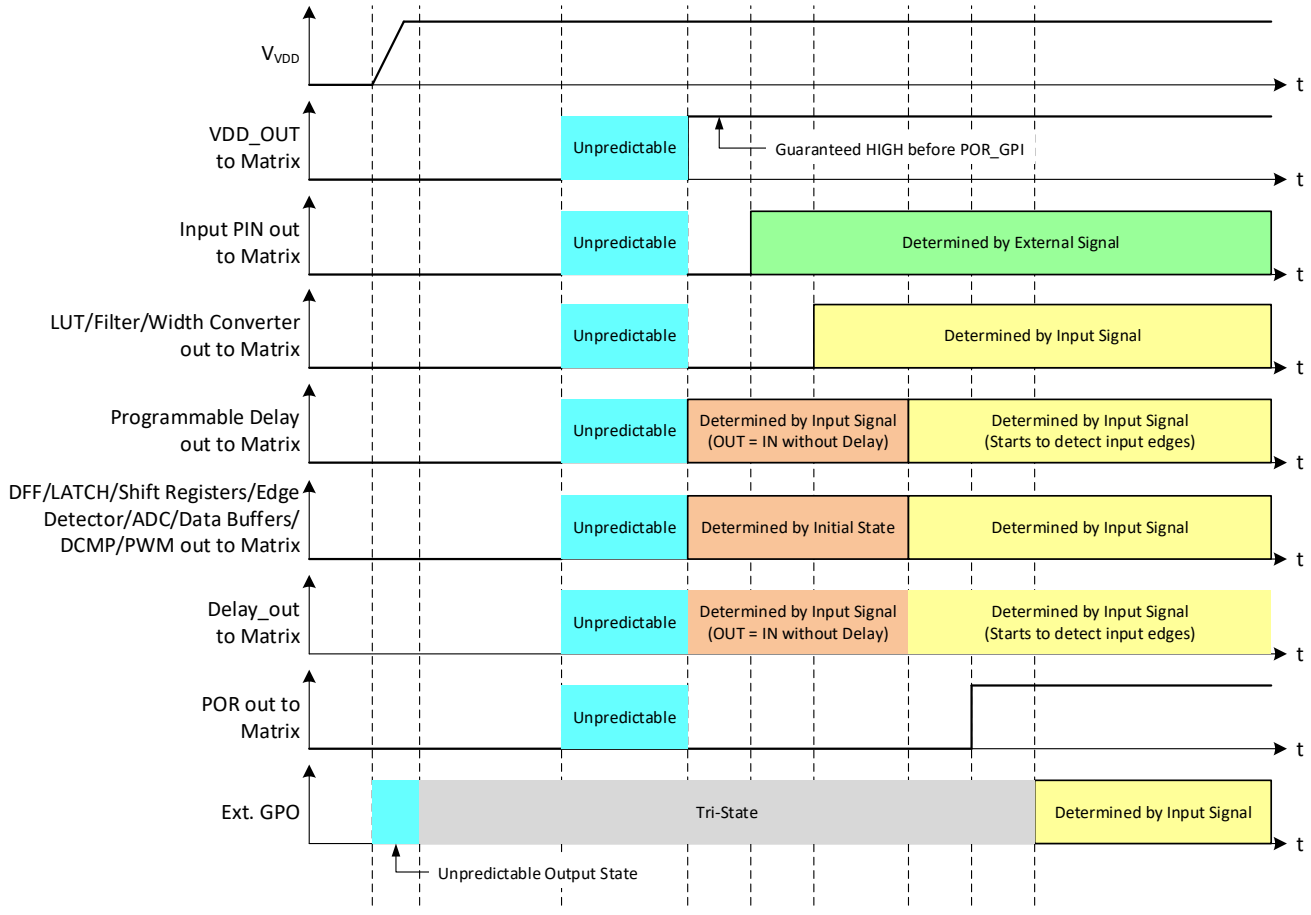



**Figure 201. Internal Macrocell States During POR Sequence**

### 24.3.1. Initialization

All macrocells have logic LOW as the initial state by default. After the indicated power-up time from the condition that the $V_{DD}$ voltage exceeds the power-on threshold ($PON_{THR}$, see section 3.4.1 Logic IO Specifications), all macrocells are powered on, while they are forced into a reset state. At this stage, all outputs are in Hi-Z state and the device starts loading the initial data from the NVM. After that, the reset signal is released for the macrocells to start initializing according to the following sequence:

1. Input pins, Pull-up/down.
2. LUTs, Width Converter.
3. DFFs, Delays/Counters, OSCs, ACMP, DCMP, ADC, and other macrocells.
4. POR output to matrix.
5. Output pins correspond to the internal logic.

The low-to-high transition of the POR signal indicates that the power-up sequence is complete.

**Note:** The maximum voltage applied to any pin should not be higher than the $V_{DD}$ level. There are ESD diodes between pin → $V_{DD}$ and pin → GND on each pin. So, if the input signal applied to pin is higher than $V_{DD}$, then current will sink through the diode to $V_{DD}$. Exceeding $V_{DD}$ results in leakage current on the input pin, and $V_{DD}$ will be pulled up, following the voltage on the input pin. There is no effect from input pin when input voltage is applied at the same time as $V_{DD}$.

### 24.3.2. Power-Down

When the $V_{DD}$ voltage drops below the power-off threshold ($POFF_{THR}$), the macrocells in the SLG47011 are powered off. In case the $V_{DD}$ voltage ramp-down is slow, the outputs can possibly switch states during power-down.

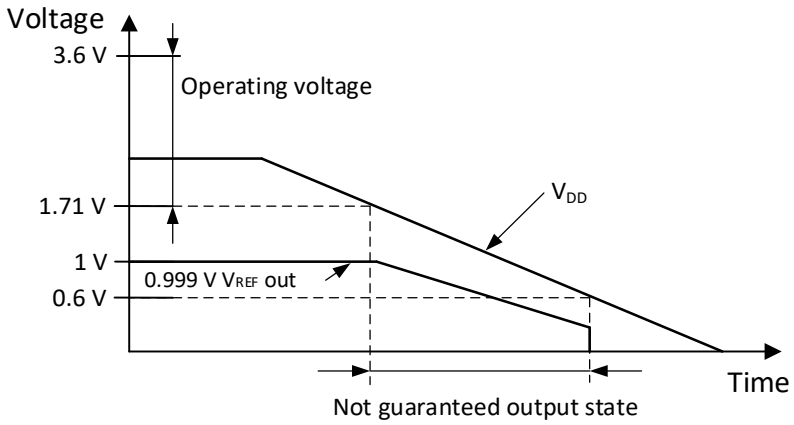



**Figure 202. Power-Down**

# 25. Host Interface

## 25.1 Host Interface General Description

The Host Interface block provides communication between the SLG47011 and the host device via the I²C/SPI communication interface. Only one interface (I²C or SPI) can be active in the design. The active interface selection is controlled by register HST_IF_SEL [801] and is enabled by register HST_IF_EN [800]. See section 26 I2C Communication Interface for I²C interface description 27 SPI Communication Interface for the SPI interface description

In the standard use case for GreenPAK devices, the desired configuration is stored in the Non-Volatile Memory (NVM). This information is transferred at startup time to the RAM registers that determine the configuration of the macrocells and the connection matrices. Other RAM registers in the device are responsible for setting the connections in the connection matrix in order to route signals in the manner most appropriate for the application.

The Host Interface allows an I²C/SPI bus Master to read and write configuration information via a serial channel directly to the RAM registers, allowing the remote re-configuration of macrocells and remote changes to signal chains being used.

The I²C/SPI bus Master is also able to read and write other register bits that are not associated with NVM memory. As an example, the input signals to the connection matrix can be read. These are the signal outputs for each of the macrocells in the device, giving the I²C/SPI bus Master the capability to remotely read the current value of any macrocell.

The user has the flexibility to control read access and write access via registers bits RPR [3657:3656] and WPR [3659:3658]. See section 25.5 I2C/SPI Command Register Map for more details on I²C/SPI read/write memory protection.

## 25.2 Reading Current Counter Value via I²C/SPI

The current count value of all counters in the device can be read via I²C/SPI.

## 25.3 I²C/SPI Byte Write Bit Masking

The SLG47011 supports the masking of individual bits within a byte that is written to the configuration registers in RAM memory space via I²C/SPI. This function is supported across the entire RAM memory space. To implement this function, the following Byte Write Commands are used (see section 26.3.1 Byte Write Command for details):

1. Byte Write Command on the I²C/SPI Byte Write Mask Register (address 0x0060) with the desired Bit Mask Pattern.
2. Byte Write Command on the target memory location (target register) with New Write Data.

This sets a bit mask pattern for the target memory location that will take effect on the next Byte Write Command to this register byte. If the mask bit is set to ‘1’, the corresponding bit in the target register isn’t changed. If the mask bit is set to ‘0’, the corresponding bit in the target register will be changed to the new value. If the next command received by the device is not the Byte Write Command, the bit mask will be kept in the I²C/SPI Byte Write Mask Register until a new bit mask is written into this register. Figure 203 shows an example of this function.

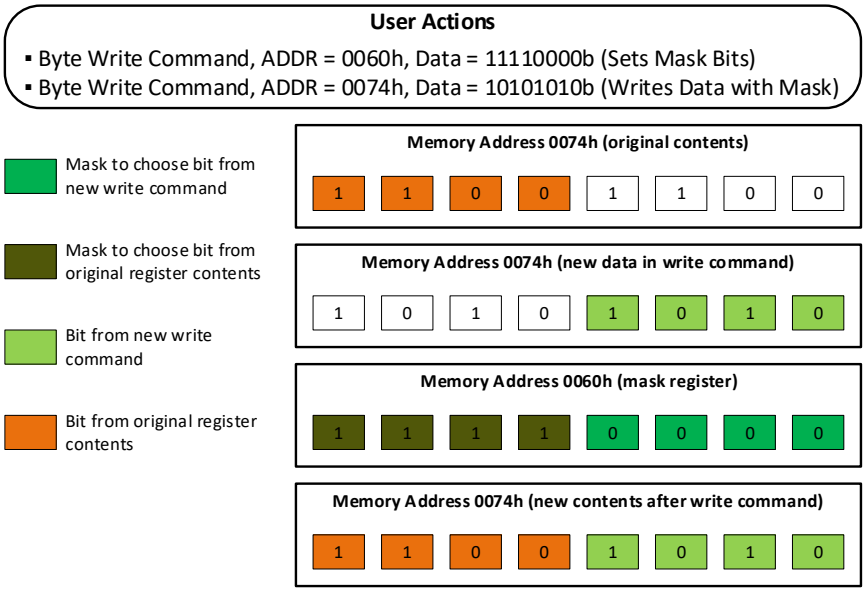



**Figure 203. Example of I²C Byte Write Bit Masking**

## 25.4 Chip Configuration Data Protection

The SLG47011 uses a function that allows a part of or the entire memory to be inhibited from being read or written. To enable this function the register PROTECT_EN [3663] bit must be set to '1'. Protection options are defined by registers RPR [3657:3656] (Registers Read Protection Register) and WPR [3659:3658] (Registers Write Protection Register).

RPR register options are:

- RPR [3657:3656] = 'b00': Register data is unprotected for read
- RPR [3657:3656] = 'b01': Register data is partly protected for read
- RPR [3657:3656] = 'b10': Register data is fully protected for read
- RPR [3657:3656] = 'b11': Register data is fully protected for read.

WPR register options are:

- WPR [3659:3658] = 'b00': Register data is unprotected for write
- WPR [3659:3658] = 'b01': Register data is partly protected for write
- WPR [3659:3658] = 'b10': Register data is fully protected for write
- WPR [3659:3658] = 'b11': Register data is fully protected for write.

The user can select one of the following schemes:

- RPR [3657:3656] = 'b00'; WPR [3659:3658] = 'b00': Unlock (all open read/write) (Mode 0)
- RPR [3657:3656] = 'b01'; WPR [3659:3658] = 'b00': Partly Lock Read (Mode 1)
- RPR [3657:3656] = 'b00'; WPR [3659:3658] = 'b01': Partly Lock Write (Mode 2)
- RPR [3657:3656] = 'b01'; WPR [3659:3658] = 'b01': Partly Lock Read/Write (Mode 3)
- RPR [3657:3656] = 'b01'; WPR [3659:3658] = 'b1x': Partly Lock Read and Lock Write (Mode 4)
- RPR [3657:3656] = 'b1x'; WPR [3659:3658] = 'b01': Lock Read and Partly Lock Write (Mode 5)
- RPR [3657:3656] = 'b1x'; WPR [3659:3658] = 'b00': Lock Read (Mode 6)
- RPR [3657:3656] = 'b00'; WPR [3659:3658] = 'b1x': Lock Write (Mode 7)
- RPR [3657:3656] = 'b1x'; WPR [3659:3658] = 'b1x': Lock Read/Write (Mode 8).

For more information see Table 31.

## 25.5 I²C/SPI Command Register Map

There are seven read/write protect modes for preventing the design sequence from being corrupted or copied. See Table 31 for details.

**Table 31. Read/Write Protection Options**

| Protection Modes Configuration | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Configurations** | **Unlock** | **Partly Lock Read** | **Partly Lock Write** | **Partly Lock Read/ Write** | **Partly Lock Read and Lock Write** | **Lock Read and Partly Lock Write** | **Lock Read** | **Lock Write** | **Lock Read/ Write** | **Register Address** |
| | **Mode 0** | **Mode 1** | **Mode 2** | **Mode 3** | **Mode 4** | **Mode 5** | **Mode 6** | **Mode 7** | **Mode 8** | |
| **RPR [3657:3656]** | **00** | **01** | **00** | **01** | **01** | **1x** | **1x** | **00** | **1x** | |
| **WPR [3659:3658]** | **00** | **00** | **01** | **01** | **1x** | **01** | **00** | **1x** | **1x** | |
| I²C/SPI Write Mask Control Register | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | 0x0060 |
| I²C/SPI Output (8-bit) to Matrix (Virtual Input) | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | 0x0061 |
| Macrocells Output Values (Virtual Output) | R | R | R | R | R | R | R | R | R | 0x0062 |
| I²C/SPI Reset Control Register | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | 0x0043, 0x0063 |
| I²C/SPI Configuration Register | R/W | R/W | R/W | R/W | R | R/W | R/W | R | R | 0x0064~0x0066 |
| Matrix Output Configuration | R/W | W | R | - | - | - | W | R | - | 0x0000~0x001C, 0x0067~0x00D3 |
| Combination Function Macrocell Configuration | R/W | W | R | - | - | - | W | R | - | 0x001D~0x002B, 0x00D4~0x00E8 |
| Multi-Function Macrocell Configuration | R/W | W | R | - | - | - | W | R | - | 0x002C~0x0039, 0x00E9~0x013D |
| Misc-function Macrocell Configuration | R/W | W | R | - | - | - | W | R | - | 0x003A, 0x013E~0x01A0 |
| IO Configuration | R/W | W | R | - | - | - | W | R | - | 0x003B~0x003F, 0x01A1~0x01AD |
| OSC ACMP $V_{REF}$ Configuration | R/W | W | R | - | - | - | W | R | - | 0x0040~0x0043, 0x01AE~0x01B0 |
| Data Buffer Content | R | - | R | - | - | - | - | R | - | 0x2200~0x2249 |
| Memory Table Content | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | 0x0200~0x21FF |
| MathCore Output | R | - | R | - | - | - | - | R | - | 0x0169~0x0172 |
| Protect Mode Configuration (RPR, WPR, NPR, Protection_Enable) | R | R | R | R | R | R | R | R | R | 0x01C9 |

| | |
|---|---|
| R/W | Allow Read and Write Data |
| W | Allow Write Data Only |
| R | Allow Read Data Only |
| - | The Data is protected for Read and Write |

It is possible to read certain data from the macrocells, such as counter current value, Data Buffers content, Memory Table macrocell content and output register, connection matrix inputs, and connection matrix virtual inputs. The $I^2C$/SPI write will not have any impact on data in case data comes from macrocell output, except for connection matrix virtual inputs. The silicon identification service bits are used for identifying silicon family, its revision, and others.

# 26. I²C Communication Interface

## 26.1 I²C Communications Device Addressing

Each command sent to the I²C Serial Communications macrocell begins with a Control Byte. The bits of this Control Byte are shown in Figure 204. After the START Bit, the first four bits represent the Control Code. Each bit in the Control Code can be set independently from the register or by value defined externally by GPIO2, GPIO6, GPIO7, or GPIO8. GPIO2 represents the LSB and GPIO8 represents the MSB. The address source (either register bit or pin) for each bit in the Control Code is defined by registers I2C_CONTROL_CODE_SEL [819:816]. This allows for flexibility on the device level addressing of this device and other devices on the same I²C bus. The last bit in the Control Byte is the R/W bit, which selects whether a read command or a write command is requested, with a “1” selecting for a Read command, and a “0” selecting for a Write command. This Control Byte will be followed by an Acknowledge bit (ACK), which is sent by this device to indicate successful communication of the Control Byte data.

The user can route I2C_ACK signal to CMI1 [63] (please refer to section 6 Connection Matrix).

In the read and write command address structure, there are a total of 16 address bits (two bytes), resulting in a total address space of 65536 bytes. The valid addresses accessible throuth the I²C macrocell ranges from 0 (0x0000) to 8777 (0x2249).

With the exception of the Current Address Read command, all commands will have the Control Byte followed by the Word Address. Figure 204 shows this basic command structure.

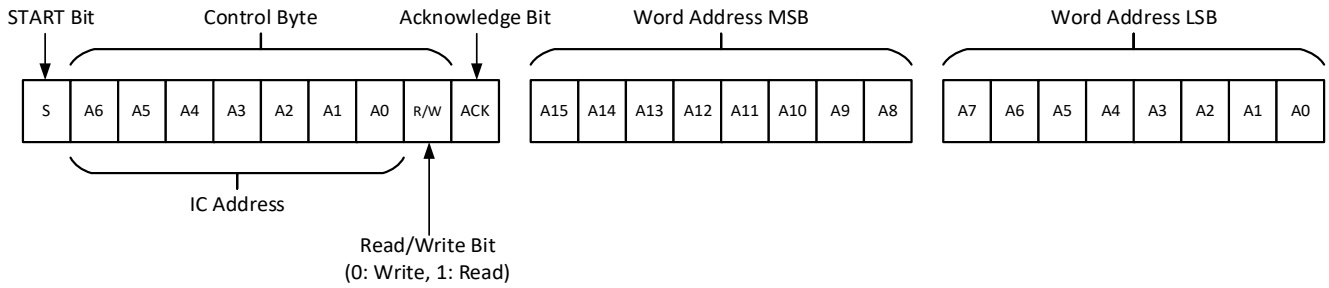



**Figure 204. Basic Command Structure**

## 26.2 I²C General Timing

The general timing characteristics for the I²C Serial Communications macrocell are shown in Figure 205. Timing specifications can be found in section 3.4.2 I2C Specifications.

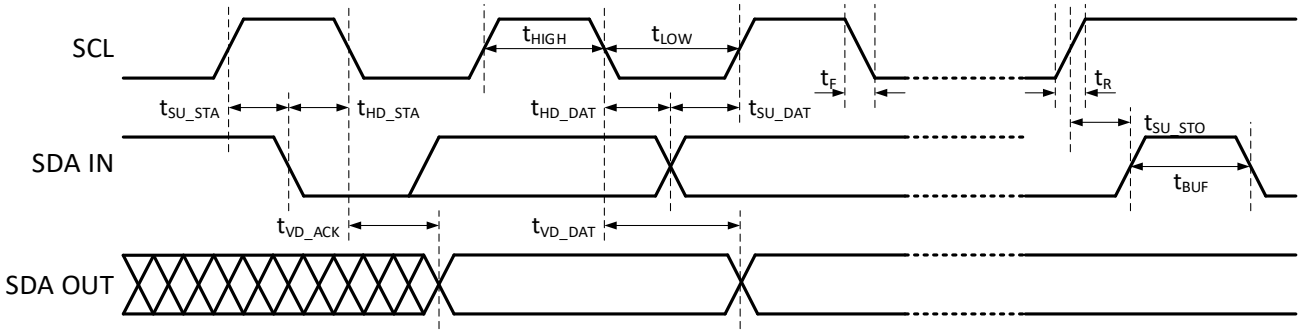



**Figure 205. I²C General Timing Characteristics**

# 26.3 I²C Communications Commands

## 26.3.1. Byte Write Command

Following the START Bit from the Master, the IC address [7 bits] and the R/W bit (set to “0”) are written to the I²C bus by the Master. After the SLG47011 sends an Acknowledge bit, the Master transmits the next two bytes (the Word Address). After the SLG47011 sends another Acknowledge bit, the Master will transmit the Data Byte to be written into the addressed memory location. The SLG47011 again provides an Acknowledge bit and then the Master generates a STOP Bit. The internal data write cycle will take place at the time that the SLG47011 generates the Acknowledge bit.

It is possible to latch all IOs during an I²C write command, IO_LATCH_EN [3433] = ‘1’ (Enable). It means that IOs will remain their state until the write command is done.

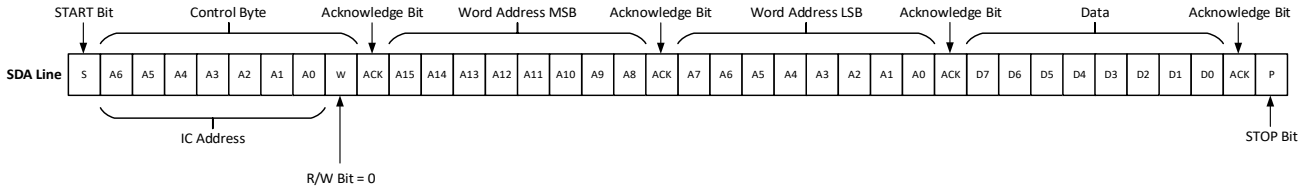



**Figure 206. Byte Write Command, R/W = 0**

## 26.3.2. Sequential Write Command

During a Sequential Write Command, the Control Byte, Word Address, and the first Data Byte are transmitted to the SLG47011 in the same way as in a Byte Write command. However, instead of generating the STOP Bit, the Bus Master continues to transmit data bytes to the SLG47011. Each subsequent Data Byte will increment the internal address counter and will be written into the next higher byte in the command addressing. As in the case of the Byte Write command, the internal write cycle will take place at the time that the SLG47011 generates the Acknowledge bit. See Figure 207.

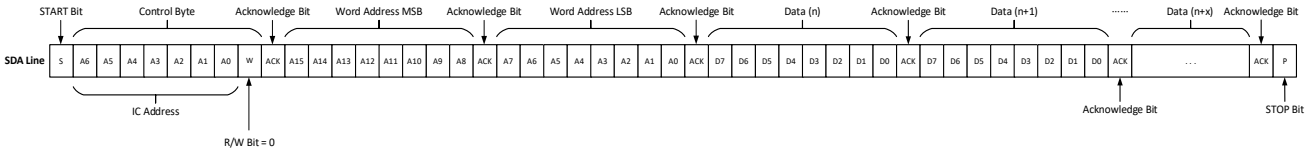



**Figure 207. Sequential Write Command**

## 26.3.3. Current Address Read Command

The Current Address Read Command reads from the current pointer address location. The address pointer is incremented at the first STOP Bit following any write Control Byte. For example, if the Sequential Read Command (which contains a write control byte) reads data up to address n, the address pointer will get incremented to n + 1 upon the STOP of that command. Subsequently, the Current Address Read Command that follows will start reading data at n + 1. The Current Address Read Command contains the Control Byte sent by the Master, with the R/W bit = ‘1’. The SLG47011 will issue the Acknowledge bit and then transmit eight data bits for the requested byte. The Master will not issue the Acknowledge bit and follow immediately with the STOP condition.

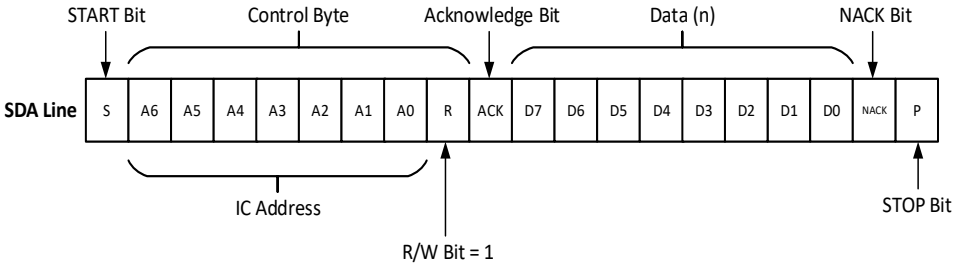



**Figure 208. Current Address Read Command, R/W = 1**

## 26.3.4. Random Address Read Command

The Random Read Command allows to read data at an arbitrary address. The Random Read Command starts with the Control Byte (with R/W bit set to “0”, indicating the write command), followed by a two byte Word Address to set the internal address, followed by a START Bit, and then the Control Byte for the read command (exactly the same as the Byte Write command). The START Bit in the middle of the command will halt the decoding of the Write command, but will set the internal address counter in preparation for the second half of the command. After the START Bit, the Bus Master issues a second Control Byte with the R/W bit set to ‘1’, after which the SLG47011 issues the Acknowledge bit, followed by the requested eight data bits.

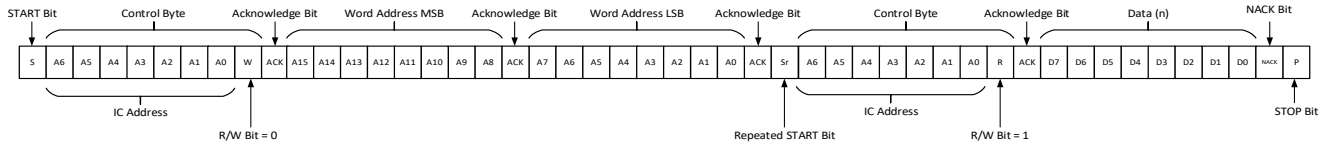



**Figure 209. Random Address Read Command**

## 26.3.5. Sequential Read Command

The Sequential Read Command is initiated in the same way as the Random Read Command, except that when the SLG47011 transmits the first data byte, the Bus Master issues the Acknowledge bit as opposed to the STOP Bit condition in a random read. The Bus Master continues reading sequential bytes of data and will terminate the command with the STOP Bit.

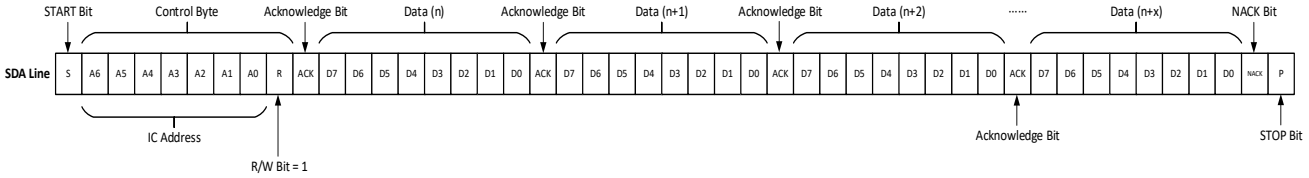



**Figure 210. Sequential Read Command**

## 26.3.6. I²C Serial Reset Command

If I²C serial communication is established with the device, it is possible to reset the device to its initial power-up conditions, including configuration of all macrocells, and all connections provided by the connection matrices. This is implemented by setting registers SW_RESET [536] and PAK_SW_RESET [792] I²C reset bit to ‘1’, which causes the device to re-enable the Power-on Reset (POR) sequence, including the reloading of all register data from the NVM. During the POR sequence, the outputs of the device will be in tri-state. After the reset is finished, the contents of registers SW_RESET [536] and PAK_SW_RESET [792] will be set to “0” automatically. Figure 211 illustrates the sequence of events for this reset function.

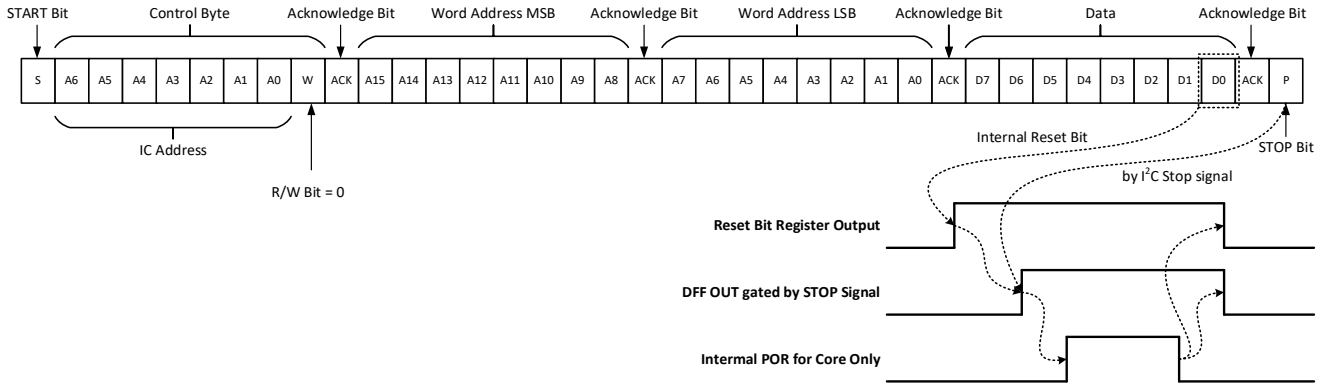



**Figure 211. Reset Command Timing**

## 26.3.7. I²C Additional Options

When latching output during I²C write, IO_LATCH_EN [3433] = '1', which allows the output value of all pins to be latched until I²C write is done. This protects the output from changing due to the configuration process during I²C write in case multiple register bytes are changed. Inputs and internal macrocells retain their status during I²C write.

If GPIO0 and GPIO1 functions are set to a selection other than SDA and SCL, all access via I²C will be disabled.

**Note**: Any write commands that are sent to the device via I²C that are not blocked based on the protection bits, will change the contents of the RAM register bits that mirror the NVM bits. These write commands will not change the NVM bits themselves, and a POR event will restore the register bits to their original programmed contents within the NVM.

# 27. SPI Communication Interface

The SPI macrocell uses the nCS, CLK, MOSI, and MISO signas.

- **nCS:** Inverted chip select line
- **CLK:** Clock signal from the SPI master
- **MOSI:** Master Output, Slave Input
- **MISO:** Master Input, Slave Output.

If the nCS signal is LOW, the SLG47011 will be selected for operation and will take control of the data bus. The maximum clock frequencies of the SPI are 19 MHz (write only) and 11 MHz (read and write). If the SPI is used to acces or program OTP memory, its clock speed will be limited to 400 kHz.

The SPI operates in Slave mode. If nCS is HIGH, the SPI is not active and both MOSI and MISO lines will be in the Hi-Z state.

All of the I²C functions are available via SPI: accessing internal control registers, NVM memory, and Data Buffers.

SPI can work in one of four combinations of clock and phase polarities CPOL = ‘1,0’, CPHA = ‘1,0’, and are configured by a register.

If CPOL = ‘0’ the base value of the clock will be zero.

- For CPHA = ‘0’, data is captured on the clock rising edge (LOW → HIGH transition) and is propagated on the falling edge (HIGH → LOW transition).
- For CPHA = ‘1’, data is captured on the clock falling edge and is propagated on the rising edge.

If CPOL = ‘1’ the base value of the clock will be one (inversion of CPOL = ‘0’).

- For CPHA = ‘0’, data is captured on the clock falling edge and is propagated on the rising edge.
- For CPHA = ‘1’, data is captured on the clock rising edge and is propagated on the falling edge.

CPHA = ‘0’ results in sampling on the leading (first) clock edge, while CPHA = ‘1’ results in sampling on the trailing (second) clock edge, regardless of whether that clock edge is rising or falling. Note that with CPHA = ‘0’ the data must be stable for a half cycle before the first clock cycle.

**Table 32. SPI Modes**

| SPI Mode | CPOL | CPHA | Clock Polarity at Idle State | Clock Phase Used to Sample and/or Shift Data |
|---|---|---|---|---|
| 0 | 0 | 0 | Logic Low | Data sampled on the rising edge and shifted out on the falling edge |
| 1 | 0 | 1 | Logic Low | Data sampled on the falling edge and shifted out on the rising edge |
| 2 | 1 | 0 | Logic High | Data sampled on the falling edge and shifted out on the rising edge |
| 3 | 1 | 1 | Logic High | Data sampled on the rising edge and shifted out on the falling edge |

The read procedure from the SLG47011 starts with a Chip Select (nCS) signal that goes LOW, and the master sending a clock signal to CLK. The first bit at the MOSI line is the R/nW bit and it must be HIGH for the read procedure. Next, the master sends 15 bits of address data starting with the most significant bit (MSB).

The slave device outputs a dummy byte (8-bits) on the MOSI line after an address is acquired.

After the dummy byte is received, the master receives 8 bits of data and keeps transmitting the next 8 bits while nCS stays LOW. Transmission of the data bits is completed when the nCS (Chip Select) line transitions HIGH. The master controls how many serial bits it receives from the slave by controlling the nCS signal. The clock can be active on the CLK line at this time. If nCS goes HIGH, the MOSI and MISO inputs of the SLG47011 will go into the Hi-Z state.

SPI Read Transaction: when reading data from the Memory Table macrocell, 12-bit words from the Memory Table will be sent as 16-bit words, as shown in Figure 213, with the last four MSB set to zero. If the nCS line stays LOW, the next data bytes will be sent to the MISO bus. When accessing registers, data will be sent as one byte, as shown in Figure 214.

SPI Write Transaction: when the master writes data to the SLG47011 by sending a logic LOW write bit followed by an address on the MOSI line. The slave is ready to receive data on the MISO line without a dummy byte (see Figure 215).

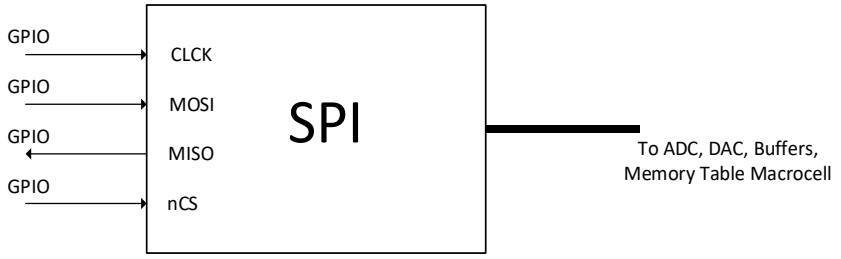



**Figure 212. SPI Block Scheme**

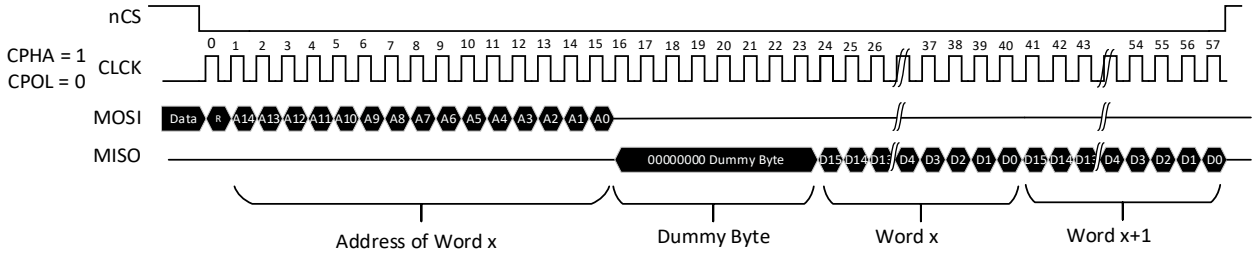



**Figure 213. Reading Memory Table Data in 16-bit Words from SLG47011 via SPI (CPOL = 0, CPHA = 1)**

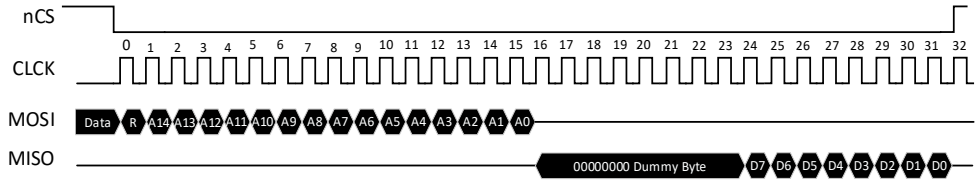



**Figure 214. Reading Register 8-bit Data from SLG47011 via SPI (CPOL = 0, CPHA = 1)**

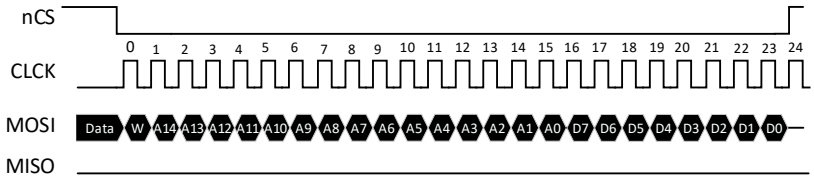



**Figure 215. Writing Configuration Register 8-bit Data to SLG47011 via SPI (CPOL = 0, CPHA = 1)**

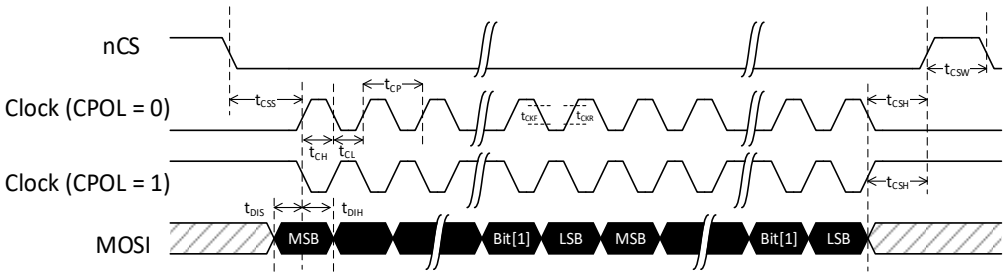



**Figure 216. SPI Timing Diagram (CPHA = 0)**

# 28. Analog Temperature Sensor

The SLG47011 features an Analog Temperature sensor (TS) with an output voltage linearly-proportional to the die temperature in degree Celsius (°C). The TS output can be selected as a signal source for the ADC or ACMP positive input. The TS is rated to operate over a -40 °C to 85 °C temperature range with error in the entire temperature range not exceeding ±4.8 °C. For more details refer to section 3.12 Analog Temperature Sensor Characteristics.

The equation below calculates the typical analog voltage passed from the TS to the ADC or ACMPs' IN+ source input.

$$V_{TS\_OUT} = – 1.83 \times T + 753.8$$

where:

$V_{TS\_OUT}$: TS Output Voltage in mV

$T_J$: Junction temperature in °C.

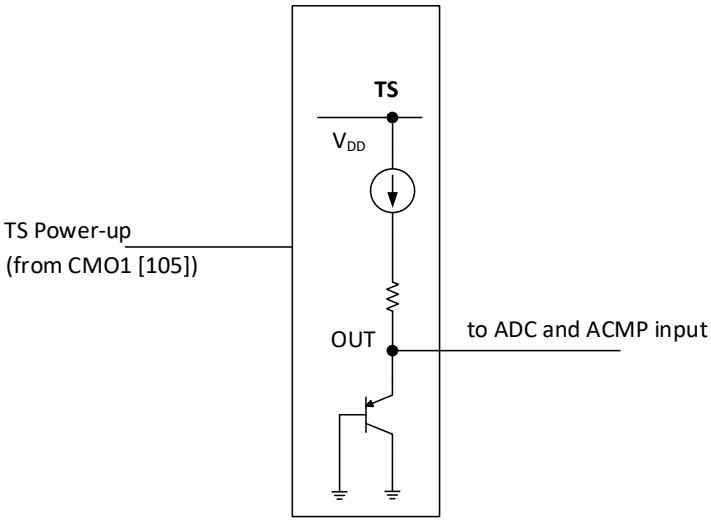



**Figure 217. Analog Temperature Sensor Structure Diagram**

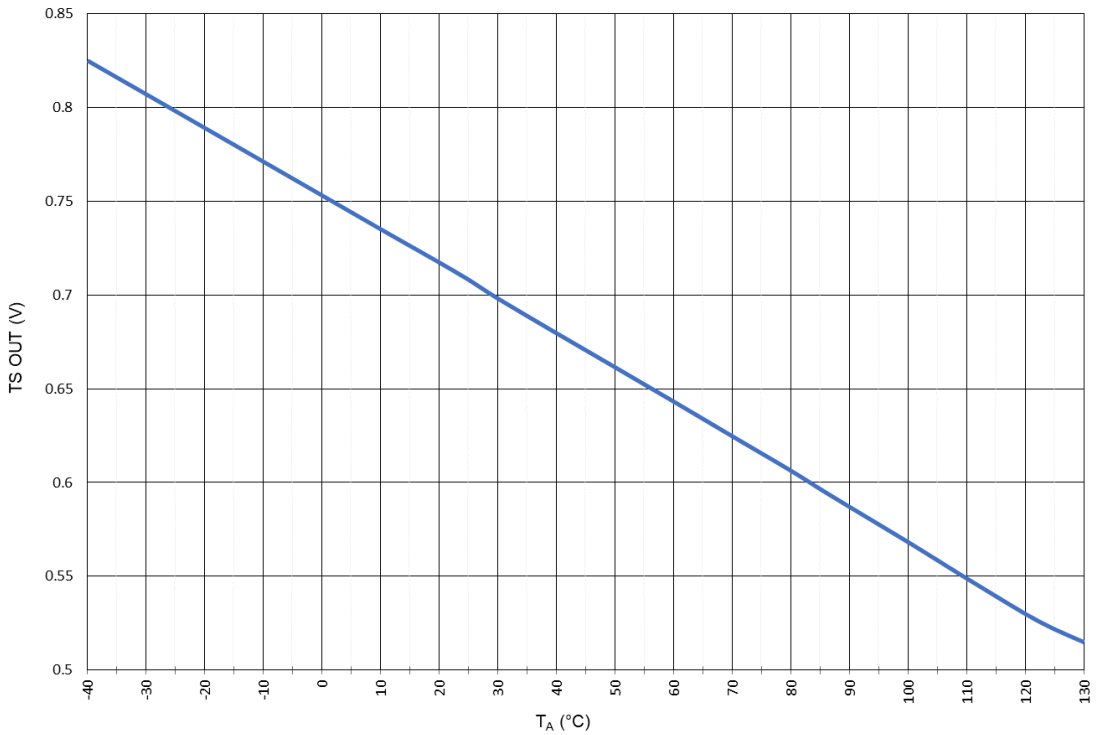
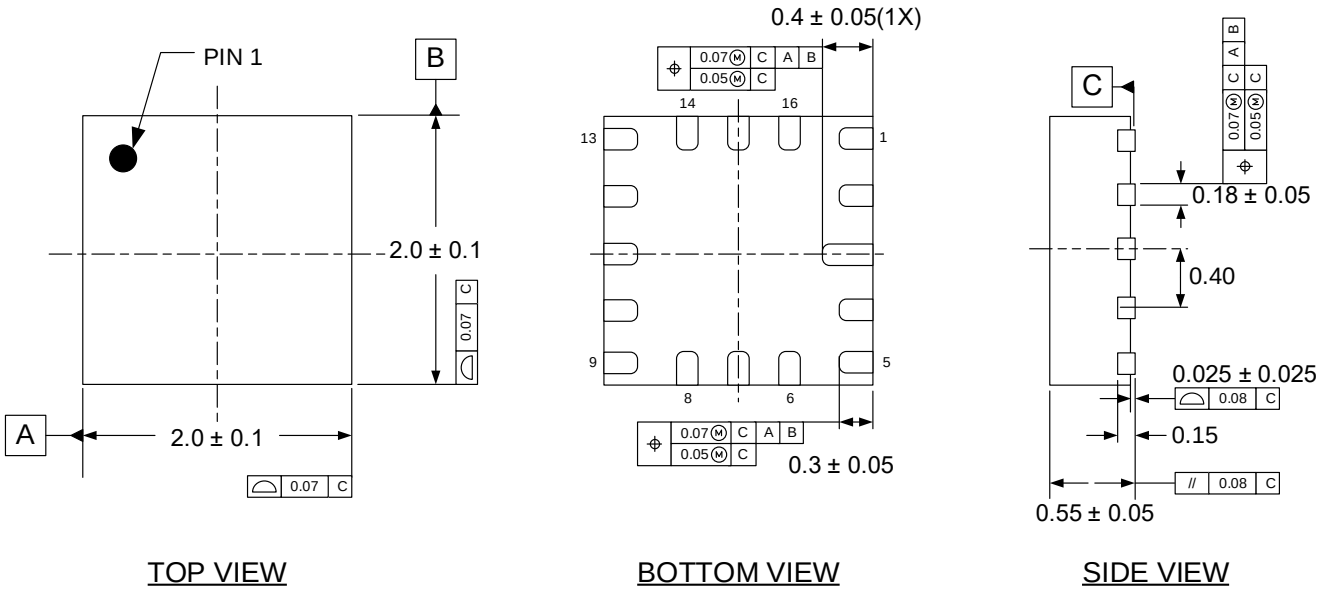



**Figure 218. TS Output vs. Temperature, $V_{DD}$ = 1.71 V to 3.6 V**

# 29. Package Information

## 29.1 Package Outline Drawings

### 29.1.1. STQFN 16L (2.0 mm x 2.0 mm x 0.55 mm, 0.4 mm Pitch) FC Package




**Note 1:** JEDEC compatible.

**Note 2:** All dimensions are in mm and angles are in degrees.

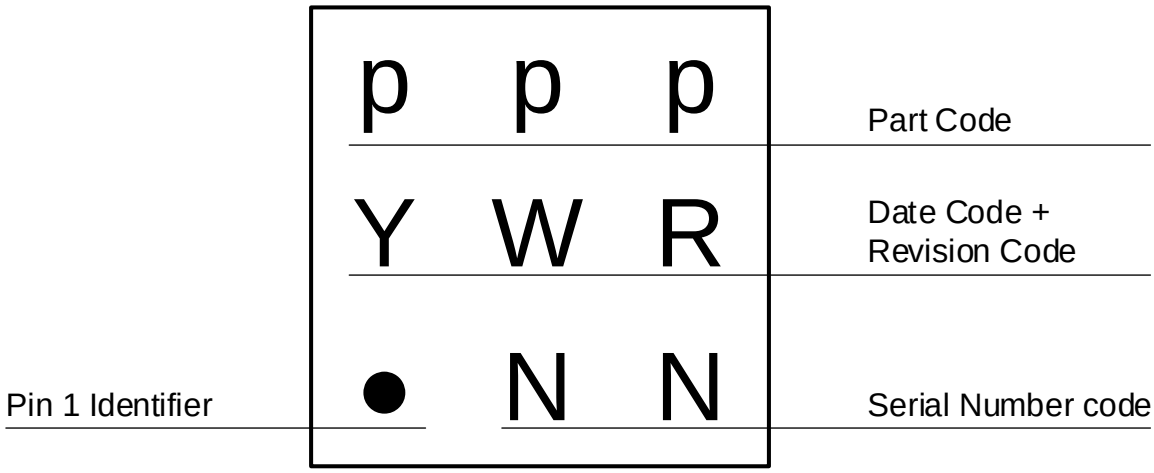
**Note 3:** Use ±0.05 mm for the non-toleranced dimensions.

**Note 4:** Numbers in ( ) are for references only.

**Figure 219. Package Outline Drawing**

## 29.2 Package Top Marking

### 29.2.1. STQFN 16L (2.0 mm x 2.0 mm x 0.55 mm, 0.4 mm Pitch) FC Package



## 29.3 Junction-to-Ambient Thermal Resistance ($\theta_{JA}$)

**Table 33. Junction-to-Ambient Thermal Resistance**

| Package Option | Thermal Resistance ($\theta_{JA}$) |
|---|---|
| STQFN 16L (SLG47011V) | 60.0 °C/W |

## 29.4 Moisture Sensitivity Level

The Moisture Sensitivity Level (MSL) is an indicator for the maximum allowable time period (floor lifetime) in which a moisture sensitive plastic device, once removed from the dry bag, can be exposed to an environment with a specified maximum temperature and a maximum relative humidity before the solder reflow process. The MSL classification is defined in Table 34.

For detailed information on MSL levels refer to the IPC/JEDEC standard J-STD-020, which can be downloaded from http://www.jedec.org.

The STQFN 16L package is qualified for MSL 1.

**Table 34. MSL Classification**

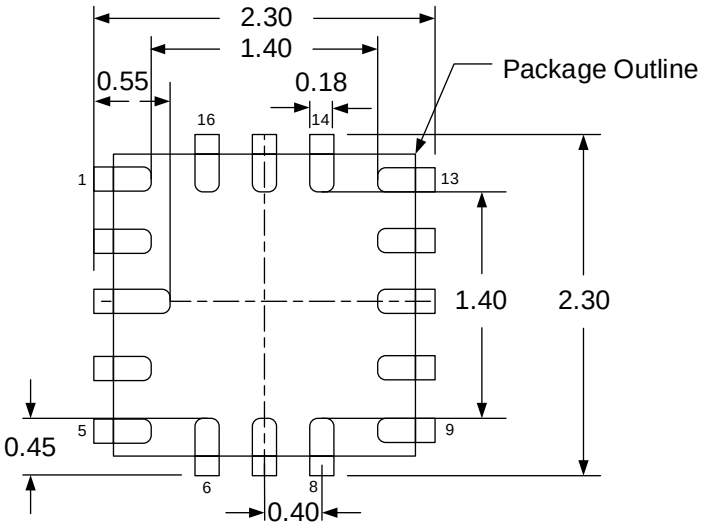
| MSL Level | Floor Lifetime | Conditions |
|---|---|---|
| MSL 4 | 72 hours | 30 °C / 60 % RH |
| MSL 3 | 168 hours | 30 °C / 60 % RH |
| MSL 2A | 4 weeks | 30 °C / 60 % RH |
| MSL 2 | 1 year | 30 °C / 60 % RH |
| MSL 1 | Unlimited | 30 °C / 85 % RH |

## 29.5 Soldering Information

Refer to the IPC/JEDEC standard J-STD-020 for relevant soldering information. This document can be downloaded from http://www.jedec.org.

# 30. PCB Layout Guidelines

## 30.1 STQFN 16L (2.0 mm x 2.0 mm x 0.55 mm, 0.4 mm Pitch) FC Package




RECOMMENDED LAND PATTERN
(PCB Top View, NSMD Design)

# 31. Ordering Information

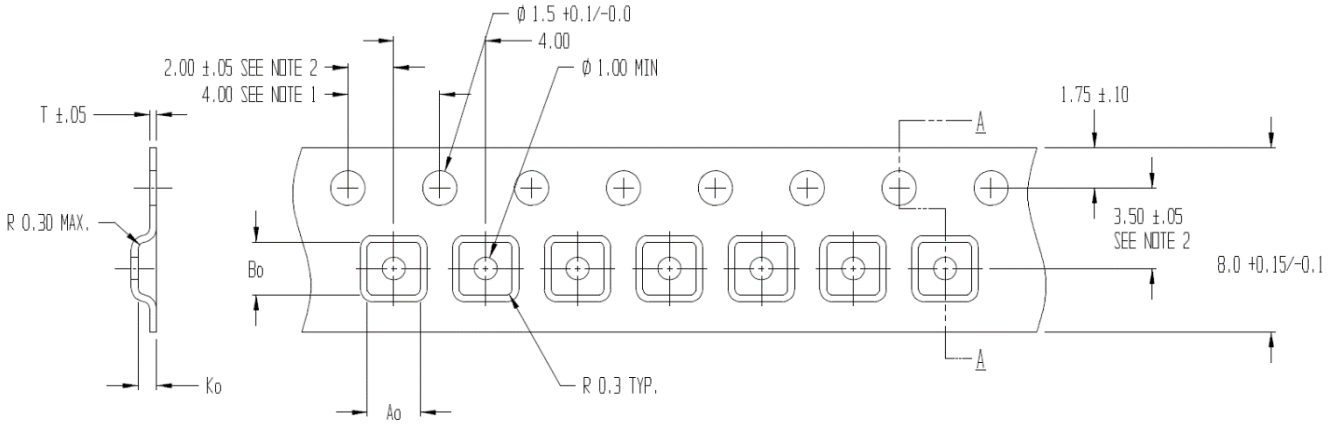
| Part Number | Package | Size (mm) | Shipment Form |
|---|---|---|---|
| SLG47011V | 16-pin STQFN | 2.0 mm x 2.0 mm x 0.55 mm, 0.4 mm pitch | Tape and Reel (3k units) |

## 31.1 Tape and Reel Specifications

| Package Type | # of Pins | Nominal Package Size (mm) | Max Units | Reel Dia. (mm) | Leader (min) | | Trailer (min) | | Tape Width (mm) | Part Pitch (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Per Reel | | Pockets | Length (mm) | Pockets | Length (mm) | | |
| STQFN 16L 2 mm x 2 mm 0.4P FC Green | 16 | 2 x 2 x 0.55 | 3000 | 178 | 100 | 400 | 100 | 400 | 8 | 4 |

## 31.2 Carrier Tape Drawing and Dimensions

| Package Type | Pocket BTM Length (mm) | Pocket BTM Width (mm) | Pocket Depth (mm) | Index Hole Pitch (mm) | Pocket Pitch (mm) | Index Hole Diameter (mm) | Index Hole to Tape Edge (mm) | Index Hole to Pocket Center (mm) | Tape Width (mm) |
|---|---|---|---|---|---|---|---|---|---|
| | A0 | B0 | K0 | P0 | P1 | D0 | E | F | W |
| STQFN 16L 2 mm x 2 mm 0.4P FC Green | 2.30 | 2.30 | 0.80 | 4.00 | 4.00 | 1.5 | 1.75 | 3.5 | 8 |




SECTION A - A

# Glossary

**A**

| | |
|---|---|
| ACK | Acknowledge Bit |

**B**

| | |
|---|---|
| BG | Bandgap |

**C**

| | |
|---|---|
| CLK | Clock |
| CMI | Connection Matrix Input |
| CMI0 | Connection Matrix 0 Input |
| CMI1 | Connection Matrix 1 Input |
| CMO | Connection Matrix Output |
| CMO0 | Connection Matrix 0 Output |
| CMO1 | Connection Matrix 1 Output |
| CNT | Counter |

**D**

| | |
|---|---|
| DFF | D Flip-Flop |
| DI | Digital Input |
| DILV | Low Voltage Digital Input |
| DLY | Delay |
| DNL | Differential Non-Linearity |

**E**

| | |
|---|---|
| ESD | Electrostatic Discharge |
| EV | End Value |

**F**

| | |
|---|---|
| FSM | Finite State Machine |
| FS | Full Scale |

**G**

| | |
|---|---|
| GPI | General Purpose Input |
| GPIO | General Purpose Input/Output |
| GPO | General Purpose Output |

**I**

| | |
|---|---|
| IN | Input |
| INL | Integral Non-Linearity |
| IO | Input/Output |

**L**

| | |
|---|---|
| LPF | Low Pass Filter |
| LSB | Least Significant Bit |
| LUT | Look Up Table |
| LV | Low Voltage |

**M**

| | |
|---|---|
| MS DCMP | Multichannel Sampling Digital Comparator |
| MSB | Most Significant Bit |
| MUX | Multiplexer |

**N**

| | |
|---|---|
| NPR | Non-Volatile Memory Read/Write/Erase Protection |
| nRST | Reset |
| NVM | Non-Volatile Memory |

**O**

| | |
|---|---|
| OD | Open-Drain |
| OE | Output Enable |
| OSC | Oscillator |
| OTP | One Time Programmable |
| OUT | Output |

**P**

| | |
|---|---|
| PD | Power-Down |
| POR | Power-on Reset |
| PP | Push-Pull |
| PWR | Power |
| P DLY | Programmable Delay |

**R**

| | |
|---|---|
| R/W | Read/Write |

**S**

| | |
|---|---|
| SCL | $I^2C$ Clock Input |
| SDA | $I^2C$ Data Input/Output |
| SLA | Slave Address |
| SMT | With Schmitt Trigger |
| SPI | Serial Peripheral Interface |
| SR | Shift Register |
| SV | nSET Value |

**T**

| | |
|---|---|
| TS | Temperature Sensor |

**V**

| | |
|---|---|
| $V_{REF}$ | Voltage Reference |

**W**

| | |
|---|---|
| WCN | Width Converter |
| WOSMT | Without Schmitt Trigger |

# Revision History

| Revision | Date | Description |
|---|---|---|
| 1.01 | Oct. 14, 2024 | Section Features: updated SAR ADC features<br>Section 3.1. Absolute Maximum Ratings: added Continuous Power Dissipation parameter.<br>Section 3.13. Internal $V_{REF}$ Specifications: added 'ADC $V_{REF}$ Error' and 'DAC $V_{REF}$ Error' at $T_A$ = -20 °C to +85 °C<br>Section 29. Package Information, section 30. PCB Layout Guidelines, section 31. Ordering Information: updated package height from 0.6 mm to 0.55 mm<br>Added section 29.3. Junction-to-Ambient Thermal Resistance ($\theta_{JA}$)<br>Updated document formatting.<br>Fixed typos. |
| 1.00 | Sep. 04, 2024 | Initial release |