

## AWR1843 Single-Chip 77 to 79GHz FMCW Radar Sensor

### 1 Features

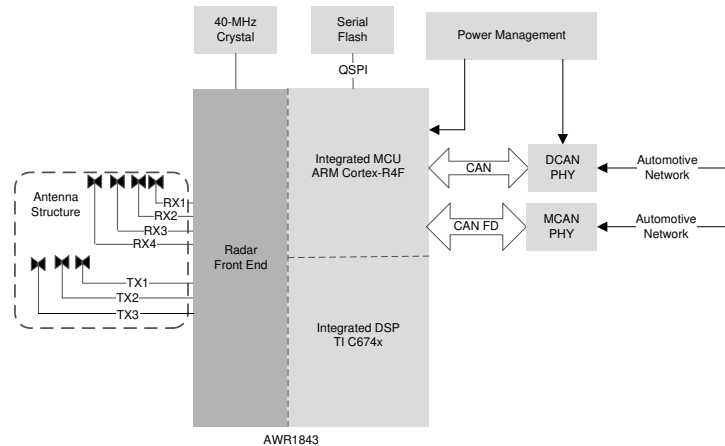
- FMCW transceiver
  - Integrated PLL, transmitter, receiver, Baseband, and ADC
  - 76 to 81GHz coverage with 4GHz available bandwidth
  - Four receive channels
  - Three transmit channels
  - Ultra-accurate chirp engine based on fractional-N PLL
  - TX power: 12dBm
  - RX noise figure:
    - 14dB (76 to 77GHz)
    - 15dB (77 to 81GHz)
  - Phase noise at 1MHz:
    - $-95\text{dBc/Hz}$  (76 to 77GHz)
    - $-93\text{dBc/Hz}$  (77 to 81GHz)
- Built-in calibration and self-test (monitoring)
  - Arm<sup>®</sup> Cortex<sup>®</sup>-R4F-based radio control system
  - Built-in firmware (ROM)
  - Self-calibrating system across process and temperature
- C674x DSP for FMCW signal processing
- On-chip Memory: 2MB
- Cortex-R4F microcontroller for object tracking and classification, AUTOSAR, and interface control
  - Supports autonomous mode (loading user application from QSPI flash memory)
- Integrated peripherals
  - Internal memories With ECC
- Host interface
  - CAN and CAN-FD
- Other interfaces available to user application
  - Up to 6 ADC channels
  - Up to 2 SPI channels
  - Up to 2 UARTs
  - I<sup>2</sup>C
  - GPIOs
  - 2-lane LVDS interface for raw ADC data and debug instrumentation
- Device Security (*on select part numbers*)
  - Secure authenticated and encrypted boot support
  - Customer programmable root keys, symmetric keys (256 bit), Asymmetric keys (up to RSA-2K) with Key revocation capability
  - Crypto software accelerators - PKA , AES (up to 256 bit), SHA (up to 256 bit), TRNG/DRGB
- **Functional Safety-Compliant**
  - Developed for functional safety applications
  - Documentation available to aid ISO 26262 functional safety system design up to ASIL-D
  - Hardware integrity up to ASIL-B
  - Safety-related certification
    - ISO 26262 certified upto ASIL B by TUV SUD
- AEC-Q100 qualified
- Device advanced features
  - Embedded self-monitoring with no host processor involvement
  - Complex baseband architecture
  - Embedded interference detection capability
  - Programmable phase rotators in transmit path to enable beam forming
- Power management
  - Built-in LDO network for enhanced PSRR
  - I/Os support dual voltage 3.3 V/1.8 V
- Clock source
  - Supports external oscillator at 40MHz
  - Supports externally driven clock (square/sine) at 40MHz
  - Supports 40MHz crystal connection with load capacitors
- Easy hardware design
  - 0.65mm pitch, 161-pin 10.4mm × 10.4 mm flip chip BGA package for easy assembly and low-cost PCB design
  - Small solution size
- Operating Conditions
  - Junction temp range:  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$



## 2 Applications

- Blind spot detection
- Lane change assistance
- Cross traffic alert

- Parking assistance
- Occupancy detection
- Gesture recognition



**Figure 2-1. Autonomous Radar Sensor For Automotive Applications**

## 3 Description

The AWR1843 device is an integrated single-chip FMCW radar sensor capable of operation in the 76 to 81GHz band. The device is built with TI's low-power 45nm RFCMOS process and enables unprecedented levels of integration in an extremely small form factor. The AWR1843 is an ideal solution for low-power, self-monitored, ultra-accurate radar systems in the automotive space.

The AWR1843 device is a self-contained FMCW radar sensor single-chip solution that simplifies the implementation of Automotive Radar sensors in the band of 76 to 81GHz. It is built on TI's low-power 45nm RFCMOS process, which enables a monolithic implementation of a 3TX, 4RX system with built-in PLL and ADC converters. It integrates the DSP subsystem, which contains TI's high-performance C674x DSP for the Radar Signal processing. The device includes a BIST processor subsystem, which is responsible for radio configuration, control, and calibration. Additionally the device includes a user programmable ARM R4F based for automotive interfacing. The Hardware Accelerator block (HWA) can perform radar processing and can help save MIPS on the DSP for higher level algorithms. Simple programming model changes can enable a wide variety of sensor implementation (Short, Mid, Long) with the possibility of dynamic reconfiguration for implementing a multimode sensor. Additionally, the device is provided as a complete platform solution including TI reference designs, software drivers, sample configurations, API guides, and user documentation.

### Device Information

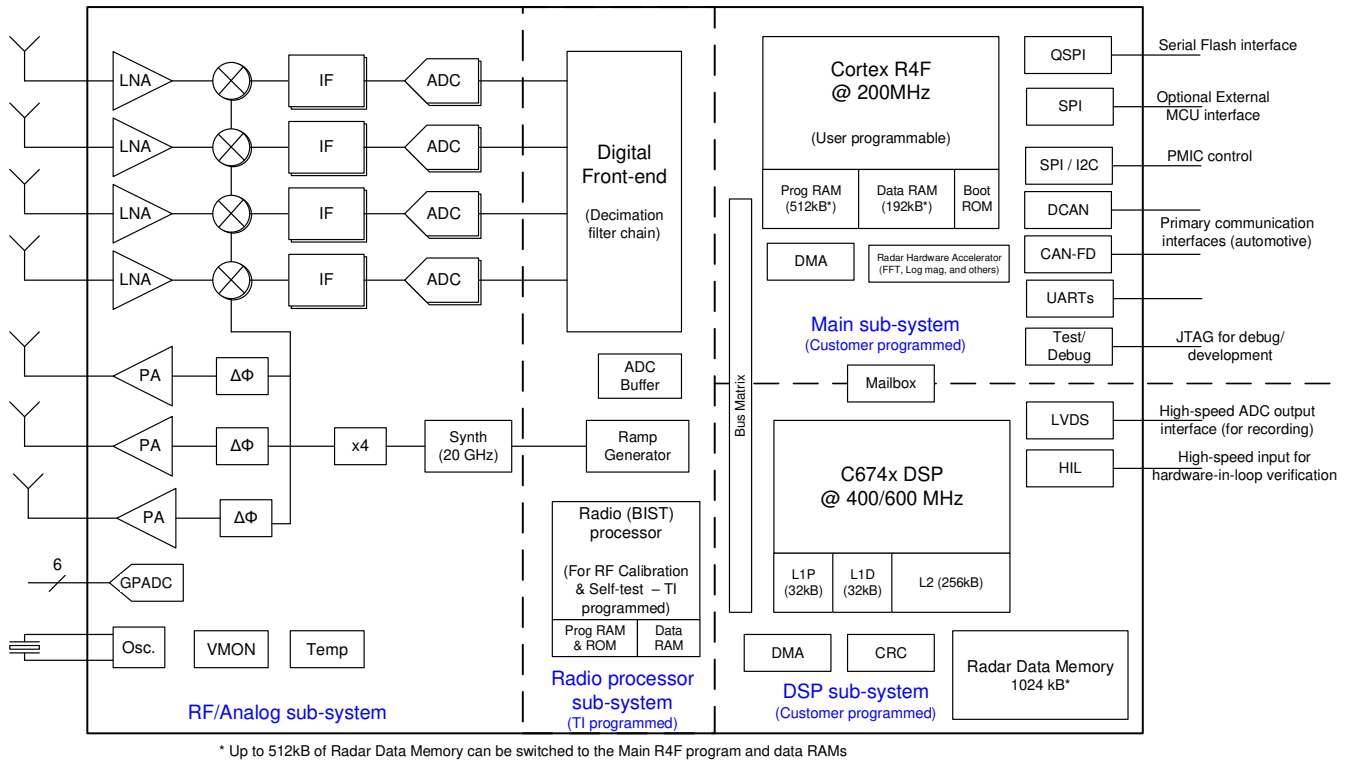
| PART NUMBER <sup>(2)</sup> | PACKAGE <sup>(1)</sup> | BODY SIZE        | TRAY / TAPE AND REEL |
|----------------------------|------------------------|------------------|----------------------|
| AWR1843ABGABLQ1            | ABL (FCBGA, 161)       | 10.4mm × 10.4 mm | Tray                 |
| AWR1843ABGABLRQ1           |                        |                  | Tape and Reel        |
| AWR1843ABSABLQ1            |                        |                  | Tray                 |
| AWR1843ABSABLRQ1           |                        |                  | Tape and Reel        |

(1) For more information, see [Section 13, Mechanical, Packaging, and Orderable Information](#).

(2) For more information, see [Section 11.1, Device Nomenclature](#).

## 4 Functional Block Diagram

Figure 4-1 shows the functional block diagram of the device.



**Figure 4-1. Functional Block Diagram**

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## 5 Device Comparison

| FUNCTION  | AWR1243   | AWR1443 | AWR1642 | AWR1843 <sup>(1)</sup> |
|---|---|---------|---------|------------------------|
| Number of receivers                                   | 4   | 4       | 4       | 4                      |
| Number of transmitters                                | 3   | 3       | 2       | 3                      |
| On-chip memory  | —   | 576KB   | 1.5MB   | 2MB                    |
| Max I/F (Intermediate Frequency) (MHz)                | 15  | 5       | 5       | 10                     |
| Max real/complex 2x sampling rate (Msps)              | 37.5  | 12.5    | 12.5    | 25                     |
| Max complex 1x sampling rate (Msps)                   | 18.75   | 6.25    | 6.25    | 12.5                   |
| Device Security <sup>(2)</sup>                        | —   | —       | Yes     | Yes                    |
| <b>Processor</b>                                      |   |         |         |                        |
| MCU (R4F)   | —   | Yes     | Yes     | Yes                    |
| DSP (C674x)   | —   | —       | Yes     | Yes                    |
| <b>Peripherals</b>                                    |   |         |         |                        |
| Serial Peripheral Interface (SPI) ports               | 1   | 1       | 2       | 2                      |
| Quad Serial Peripheral Interface (QSPI)               | —   | Yes     | Yes     | Yes                    |
| Inter-Integrated Circuit (I <sup>2</sup> C) interface | —   | 1       | 1       | 1                      |
| Controller Area Network (DCAN) interface              | —   | Yes     | Yes     | Yes                    |
| CAN-FD  | —   | —       | Yes     | Yes                    |
| Trace   | —   | —       | Yes     | Yes                    |
| PWM   | —   | —       | Yes     | Yes                    |
| Hardware In Loop (HIL/DMM)                            | —   | —       | Yes     | Yes                    |
| GPADC   | —   | Yes     | Yes     | Yes                    |
| LVDS/Debug <sup>(3)</sup>                             | Yes   | Yes     | Yes     | Yes                    |
| CSI2  | Yes   | —       | —       | —                      |
| Hardware accelerator                                  | —   | Yes     | —       | Yes                    |
| 1-V bypass mode                                       | Yes   | Yes     | Yes     | Yes                    |
| Cascade (20-GHz sync)                                 | —   | —       | —       | —                      |
| JTAG  | —   | Yes     | Yes     | Yes                    |
| Number of Tx that can be simultaneously used          | 2   | 2       | 2       | 3 <sup>(4)</sup>       |
| Per chirp configurable Tx phase shifter               | —   | —       | —       | Yes                    |
| Product status <sup>(5)</sup>                         | PRODUCT PREVIEW (PP),<br>ADVANCE INFORMATION (AI),<br>or PRODUCTION DATA (PD) | PD      | PD      | PD                     |

- (1) Developed for Functional Safety applications, the device supports hardware integrity upto ASIL-B. Refer to the related documentation for more details.
- (2) Device security features including Secure Boot and Customer Programmable Keys are available in select devices for only select part variants as indicated by the Device Type identifier in Section 3, Device Information table.
- (3) The LVDS interface is not a production interface and is only used for debug.
- (4) 3 Tx Simultaneous operation is supported only in AWR1843 with 1V LDO bypass and PA LDO disable mode. In this mode 1V supply needs to be fed on the VOUT PA pin. Rest of the other devices only support simultaneous operation of 2 Transmitters.
- (5) PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of the Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

## 5.1 Related Products

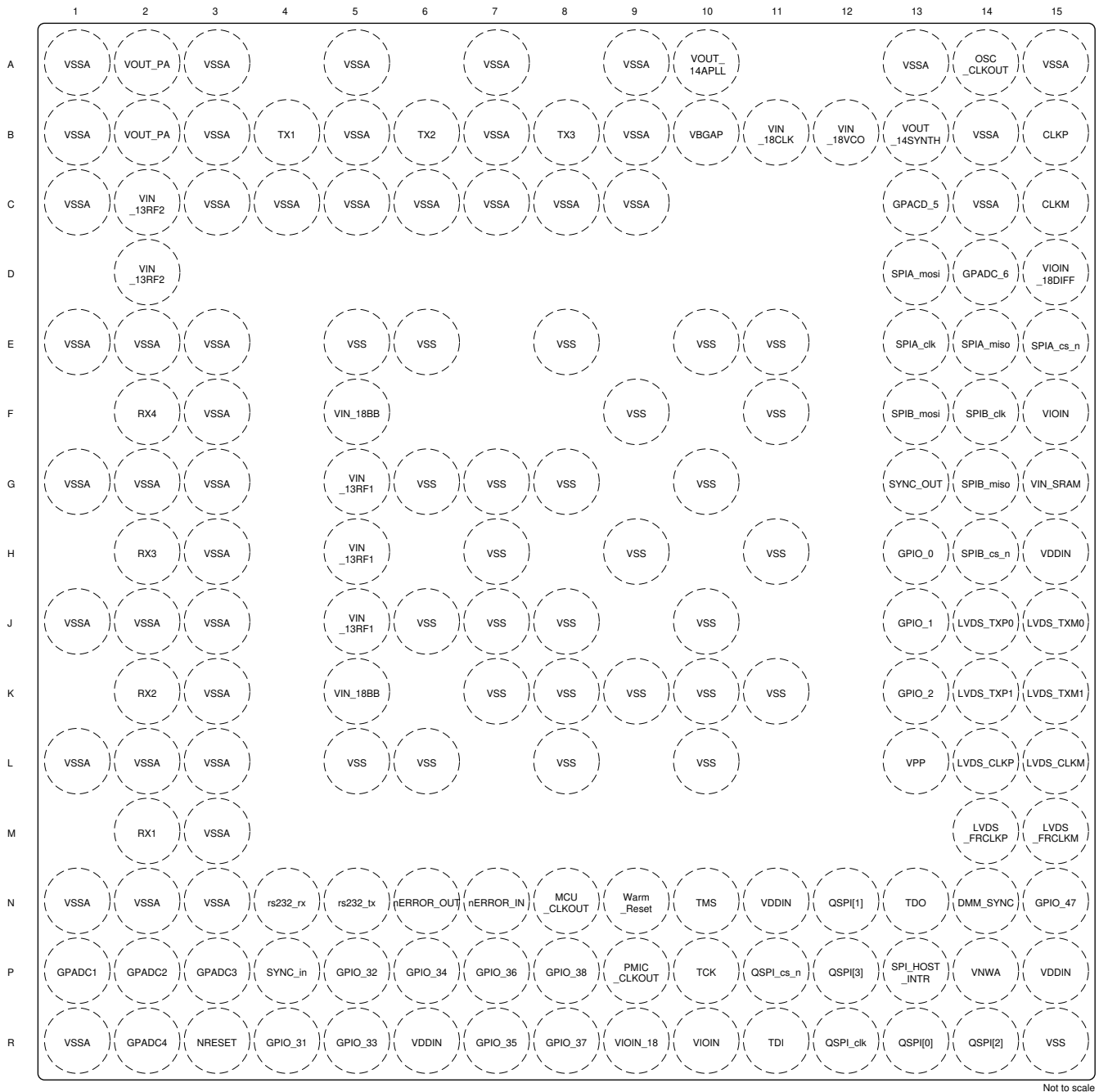
For information about other devices in this family of products or related products see the links that follow.

- mmWave sensors** TI's mmWave sensors rapidly and accurately sense range, angle and velocity with less power using the smallest footprint mmWave sensor portfolio for automotive applications.
- Automotive mmWave sensors** TI's automotive mmWave sensor portfolio offers high-performance radar front end to ultra-high resolution, small and low-power single-chip radar solutions. TI's scalable sensor portfolio enables design and development of ADAS system solution for every performance, application and sensor configuration ranging from comfort functions to safety functions in all vehicles.
- Companion products for AWR1843** Review products that are frequently purchased or used in conjunction with this product.
- Reference designs for AWR1843** TI Designs Reference Design Library is a robust reference design library spanning analog, embedded processor and connectivity. Created by TI experts to help you jump-start your system design, all TI Designs include schematic or block diagrams, BOMs, and design files to speed your time to market. Search and download designs at [ti.com/tidesigns](http://ti.com/tidesigns).

## 6 Terminal Configuration and Functions

### 6.1 Pin Diagram

Figure 6-1 shows the pin locations for the 161-pin FCBGA package. Figure 6-2, Figure 6-3, Figure 6-4, and Figure 6-5 show the same pins, but split into four quadrants.

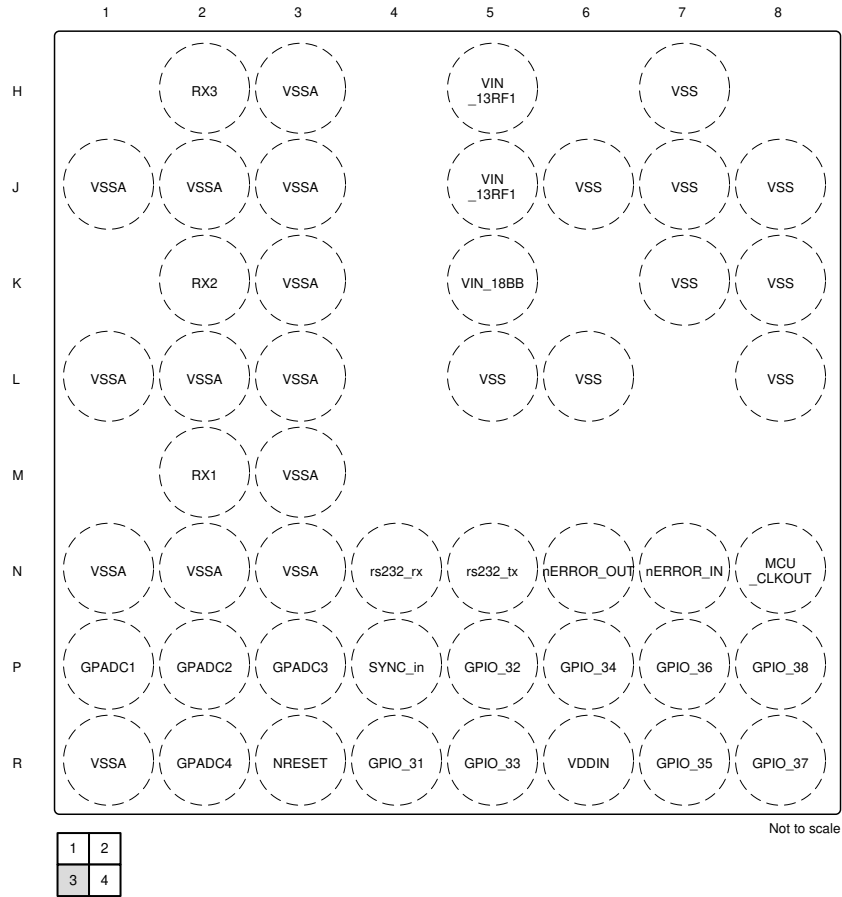


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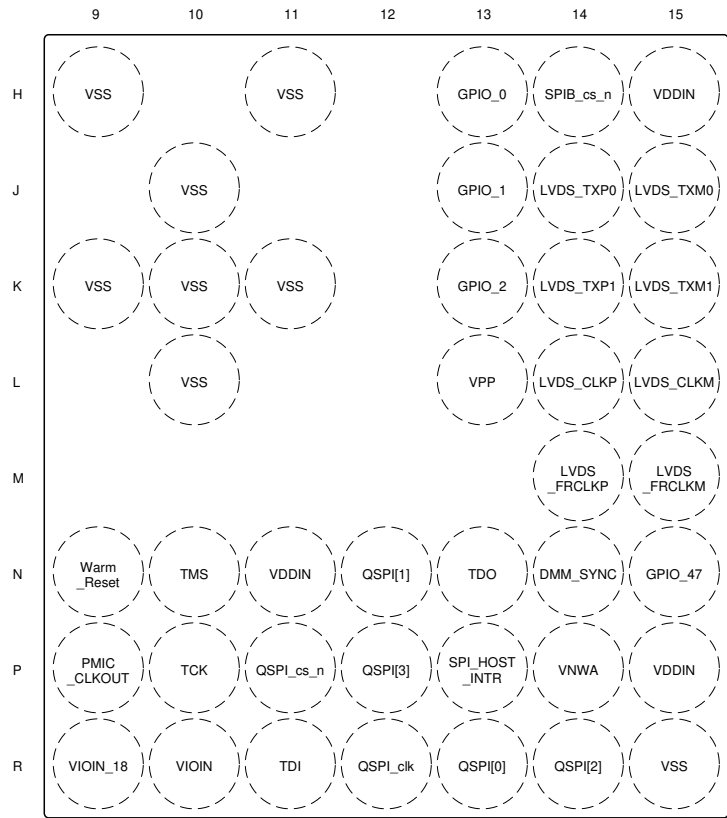
Figure 6-1. Pin Diagram







**Figure 6-4. Bottom Left Quadrant**



Not to scale

|   |   |
|---|---|
| 1 | 2 |
| 3 | 4 |

**Figure 6-5. Bottom Right Quadrant**

## 6.2 Signal Descriptions

### Note

All digital IO pins of the device (except NERROR\_IN, NERROR\_OUT, and WARM\_RESET) are non-failsafe; hence, care needs to be taken that they are not driven externally without the VIO supply being present to the device.

### Note

The GPIO state during the power supply ramp is not ensured. In case the GPIO is used in the application where the state of the GPIO is critical, even when NRESET is low, a tri-state buffer should be used to isolate the GPIO output from the radar device and a pull resistor used to define the required state in the application. The NRESET signal to the radar device could be used to control the output enable (OE) of the tri-state buffer.

### 6.2.1 Signal Descriptions - Digital

| SIGNAL NAME | PIN TYPE | DESCRIPTION   | BALL NO.                            |
|-------------|----------|---|-------------------------------------|
| ADC_VALID   | O        | When high, indicating valid ADC samples   | H13, J13, P13                       |
| BSS_UART_TX | O        | Debug UART Transmit [Radar Block]   | F14, H14, K13, N10, N13, N4, N5, R8 |
| CAN_FD_RX   | I        | CAN FD (MCAN) Receive Signal  | D13, F14, N10, N4, P12              |
| CAN_FD_TX   | O        | CAN FD (MCAN) Transmit Signal   | E14, H14, N5, P10, R14              |
| CAN_RX      | I        | CAN (DCAN) Receive Signal   | E13                                 |
| CAN_TX      | IO       | CAN (DCAN) Transmit Signal  | E15                                 |
| CHIRP_END   | O        | Pulse signal indicating the end of each chirp                                       | K13, N8, P9                         |
| CHIRP_START | O        | Pulse signal indicating the start of each chirp                                     | K13, N8, P9                         |
| DMM0        | I        | Debug Interface (Hardware In Loop) - Data Line                                      | R4                                  |
| DMM1        | I        | Debug Interface (Hardware In Loop) - Data Line                                      | P5                                  |
| DMM2        | I        | Debug Interface (Hardware In Loop) - Data Line                                      | R5                                  |
| DMM3        | I        | Debug Interface (Hardware In Loop) - Data Line                                      | P6                                  |
| DMM4        | I        | Debug Interface (Hardware In Loop) - Data Line                                      | R7                                  |
| DMM5        | I        | Debug Interface (Hardware In Loop) - Data Line                                      | P7                                  |
| DMM6        | I        | Debug Interface (Hardware In Loop) - Data Line                                      | R8                                  |
| DMM7        | I        | Debug Interface (Hardware In Loop) - Data Line                                      | P8                                  |
| DMM_CLK     | I        | Debug Interface (Hardware In Loop) - Clock  | N15                                 |
| DMM_MUX_IN  | I        | Debug Interface (Hardware In Loop) Mux Select between DMM1 and DMM2 (Two Instances) | G13, J13, P4                        |
| DMM_SYNC    | I        | Debug Interface (Hardware In Loop) - Sync   | N14                                 |
| DSS_UART_TX | O        | Debug UART Transmit [DSP]   | D13, E13, G14, P8, R12              |
| EPWM1A      | O        | PWM Module 1 - Output A   | N5, N8                              |
| EPWM1B      | O        | PWM Module 1 - Output B   | H13, N5, P9                         |
| EPWM1SYNCI  | I        | PWM Module 1 - Sync Input   | J13                                 |
| EPWM2A      | O        | PWM Module 2 - Output A   | H13, N4, N5, P9                     |
| EPWM2B      | O        | PWM Module 2 - Output B   | N4                                  |
| EPWM2SYNCO  | O        | PWM Module 2 - Sync Output  | R7                                  |
| EPWM3A      | O        | PWM Module 3 - Output A   | N4                                  |
| EPWM3SYNCO  | O        | PWM Module 3 - Sync Output  | P6                                  |
| FRAME_START | O        | Pulse signal indicating the start of each frame                                     | K13, N8, P9                         |
| GPIO_0      | IO       | General-purpose I/O   | H13                                 |

| SIGNAL NAME | PIN TYPE | DESCRIPTION                    | BALL NO. |
|-------------|----------|--------------------------------|----------|
| GPIO_1      | IO       | General-purpose I/O            | J13      |
| GPIO_2      | IO       | General-purpose I/O            | K13      |
| GPIO_3      | IO       | General-purpose I/O            | E13      |
| GPIO_4      | IO       | General-purpose I/O            | H14      |
| GPIO_5      | IO       | General-purpose I/O            | F14      |
| GPIO_6      | IO       | General-purpose I/O            | P11      |
| GPIO_7      | IO       | General-purpose I/O            | R12      |
| GPIO_8      | IO       | General-purpose I/O            | R13      |
| GPIO_9      | IO       | General-purpose I/O            | N12      |
| GPIO_10     | IO       | General-purpose I/O            | R14      |
| GPIO_11     | IO       | General-purpose I/O            | P12      |
| GPIO_12     | IO       | General-purpose I/O            | P13      |
| GPIO_13     | IO       | General-purpose I/O            | H13      |
| GPIO_14     | IO       | General-purpose I/O            | N5       |
| GPIO_15     | IO       | General-purpose I/O            | N4       |
| GPIO_16     | IO       | General-purpose I/O            | J13      |
| GPIO_17     | IO       | General-purpose I/O            | P10      |
| GPIO_18     | IO       | General-purpose I/O            | N10      |
| GPIO_19     | IO       | General-purpose I/O            | D13      |
| GPIO_20     | IO       | General-purpose I/O            | E14      |
| GPIO_21     | IO       | General-purpose I/O            | F13      |
| GPIO_22     | IO       | General-purpose I/O            | G14      |
| GPIO_23     | IO       | General-purpose I/O            | R11      |
| GPIO_24     | IO       | General-purpose I/O            | N13      |
| GPIO_25     | IO       | General-purpose I/O            | N8       |
| GPIO_26     | IO       | General-purpose I/O            | K13      |
| GPIO_27     | IO       | General-purpose I/O            | P9       |
| GPIO_28     | IO       | General-purpose I/O            | P4       |
| GPIO_29     | IO       | General-purpose I/O            | G13      |
| GPIO_30     | IO       | General-purpose I/O            | E15      |
| GPIO_31     | IO       | General-purpose I/O            | R4       |
| GPIO_32     | IO       | General-purpose I/O            | P5       |
| GPIO_33     | IO       | General-purpose I/O            | R5       |
| GPIO_34     | IO       | General-purpose I/O            | P6       |
| GPIO_35     | IO       | General-purpose I/O            | R7       |
| GPIO_36     | IO       | General-purpose I/O            | P7       |
| GPIO_37     | IO       | General-purpose I/O            | R8       |
| GPIO_38     | IO       | General-purpose I/O            | P8       |
| GPIO_47     | IO       | General-purpose I/O            | N15      |
| I2C_SCL     | IO       | I2C Clock                      | G14, N4  |
| I2C_SDA     | IO       | I2C Data                       | F13, N5  |
| LVDS_TXP[0] | O        | Differential data Out – Lane 0 | J14      |
| LVDS_TXM[0] | O        |                                | J15      |
| LVDS_TXP[1] | O        | Differential data Out – Lane 1 | K14      |
| LVDS_TXM[1] | O        |                                | K15      |

| SIGNAL NAME   | PIN TYPE | DESCRIPTION   | BALL NO.                        |
|---------------|----------|---|---------------------------------|
| LVDS_CLKP     | O        | Differential clock Out  | L14                             |
| LVDS_CLKM     | O        |   | L15                             |
| LVDS_FRCLKP   | O        | Differential Frame Clock  | M14                             |
| LVDS_FRCLKM   | O        |   | M15                             |
| MCU_CLKOUT    | O        | Programmable clock given out to external MCU or the processor   | N8                              |
| MSS_UARTA_RX  | I        | Main Subsystem - UART A Receive   | F14, N4, R11                    |
| MSS_UARTA_TX  | O        | Main Subsystem - UART A Transmit  | H14, N13, N5, R4                |
| MSS_UARTB_RX  | IO       | Main Subsystem - UART B Receive   | N4, P4                          |
| MSS_UARTB_TX  | O        | Main Subsystem - UART B Transmit  | F14, H14, K13, N13, N5, P10, P7 |
| NDMM_EN       | I        | Debug Interface (Hardware In Loop) Enable - Active Low Signal   | N13, N5                         |
| NERROR_IN     | I        | Failsafe input to the device. Nerror output from any other device can be concentrated in the error signaling monitor module inside the device and appropriate action can be taken by Firmware | N7                              |
| NERROR_OUT    | O        | Open drain fail safe output signal. Connected to PMIC/ Processor/MCU to indicate that some severe criticality fault has happened. Recovery would be through reset.                            | N6                              |
| PMIC_CLKOUT   | O        | Output Clock from AWR1843 device for PMIC   | H13, K13, P9                    |
| QSPI[0]       | IO       | QSPI Data Line #0 (Used with Serial Data Flash)   | R13                             |
| QSPI[1]       | IO       | QSPI Data Line #1 (Used with Serial Data Flash)   | N12                             |
| QSPI[2]       | I        | QSPI Data Line #2 (Used with Serial Data Flash)   | R14                             |
| QSPI[3]       | IO       | QSPI Data Line #3 (Used with Serial Data Flash)   | P12                             |
| QSPI_CLK      | IO       | QSPI Clock (Used with Serial Data Flash)  | R12                             |
| QSPI_CLK_EXT  | I        | QSPI Clock (Used with Serial Data Flash)  | H14                             |
| QSPI_CS_N     | IO       | QSPI Chip Select (Used with Serial Data Flash)  | P11                             |
| RS232_RX      | I        | Debug UART (Operates as Bus Main) - Receive Signal  | N4                              |
| RS232_TX      | O        | Debug UART (Operates as Bus Main) - Transmit Signal   | N5                              |
| SOP[0]        | I        | Sense On Power - Line#0   | N13                             |
| SOP[1]        | I        | Sense On Power - Line#1   | G13                             |
| SOP[2]        | I        | Sense On Power - Line#2   | P9                              |
| SPIA_CLK      | IO       | SPI Channel A - Clock   | E13                             |
| SPIA_CS_N     | IO       | SPI Channel A - Chip Select   | E15                             |
| SPIA_MISO     | IO       | SPI Channel A - Main In Slave Out   | E14                             |
| SPIA_MOSI     | IO       | SPI Channel A - Main Out Slave In   | D13                             |
| SPIB_CLK      | IO       | SPI Channel B - Clock   | F14, R12                        |
| SPIB_CS_N     | IO       | SPI Channel B Chip Select (Instance ID 0)   | H14, P11                        |
| SPIB_CS_N_1   | IO       | SPI Channel B Chip Select (Instance ID 1)   | G13, J13, P13                   |
| SPIB_CS_N_2   | IO       | SPI Channel B Chip Select (Instance ID 2)   | G13, J13, N12                   |
| SPIB_MISO     | IO       | SPI Channel B - Main In Slave Out   | G14, R13                        |
| SPIB_MOSI     | IO       | SPI Channel B - Main Out Slave In   | F13, N12                        |
| SPI_HOST_INTR | O        | Out of Band Interrupt to an external host communicating over SPI  | P13                             |
| SYNC_IN       | I        | Low frequency Synchronization signal input  | P4                              |
| SYNC_OUT      | O        | Low Frequency Synchronization Signal output   | G13, J13, K13, P4               |
| TCK           | I        | JTAG Test Clock   | P10                             |
| TDI           | I        | JTAG Test Data Input  | R11                             |
| TDO           | O        | JTAG Test Data Output   | N13                             |
| TMS           | I        | JTAG Test Mode Signal   | N10                             |
| TRACE_CLK     | O        | Debug Trace Output - Clock  | N15                             |

| SIGNAL NAME  | PIN TYPE | DESCRIPTION  | BALL NO. |
|--------------|----------|--|----------|
| TRACE_CTL    | O        | Debug Trace Output - Control   | N14      |
| TRACE_DATA_0 | O        | Debug Trace Output - Data Line   | R4       |
| TRACE_DATA_1 | O        | Debug Trace Output - Data Line   | P5       |
| TRACE_DATA_2 | O        | Debug Trace Output - Data Line   | R5       |
| TRACE_DATA_3 | O        | Debug Trace Output - Data Line   | P6       |
| TRACE_DATA_4 | O        | Debug Trace Output - Data Line   | R7       |
| TRACE_DATA_5 | O        | Debug Trace Output - Data Line   | P7       |
| TRACE_DATA_6 | O        | Debug Trace Output - Data Line   | R8       |
| TRACE_DATA_7 | O        | Debug Trace Output - Data Line   | P8       |
| WARM_RESET   | IO       | Open drain fail safe warm reset signal. Can be driven from PMIC for diagnostic or can be used as status signal that the device is going through reset. | N9       |

### 6.2.2 Signal Descriptions - Analog

| INTERFACE            | SIGNAL NAME  | PIN TYPE                      | DESCRIPTION  | BALL NO.          |
|----------------------|--------------|-------------------------------|--|-------------------|
| Transmitters         | TX1          | O                             | Single ended transmitter1 o/p  | B4                |
|                      | TX2          | O                             | Single ended transmitter2 o/p  | B6                |
|                      | TX3          | O                             | Single ended transmitter3 o/p  | B8                |
| Receivers            | RX1          | I                             | Single ended receiver1 i/p   | M2                |
|                      | RX2          | I                             | Single ended receiver2 i/p   | K2                |
|                      | RX3          | I                             | Single ended receiver3 i/p   | H2                |
|                      | RX4          | I                             | Single ended receiver4 i/p   | F2                |
| Reset                | NRESET       | I                             | Power on reset for chip. Active low  | R3                |
| Reference Oscillator | CLKP         | I                             | In XTAL mode: Input for the reference crystal<br>In External clock mode: Single ended input reference clock port | B15               |
|                      | CLKM         | I                             | In XTAL mode: : Feedback drive for the reference crystal<br>In External clock mode: Connect this port to ground  | C15               |
| Reference clock      | OSC_CLKOUT   | O                             | Reference clock output from clocking subsystem after cleanup PLL (1.4V output voltage swing).                    | A14               |
| Bandgap voltage      | VBGAP        | O                             | Device's Band Gap Reference Output   | B10               |
| Power supply         | VDDIN        | Power                         | 1.2V digital power supply  | H15, N11, P15, R6 |
|                      | VIN_SRAM     | Power                         | 1.2V power rail for internal SRAM  | G15               |
|                      | VNWA         | Power                         | 1.2V power rail for SRAM array back bias   | P14               |
|                      | VIOIN        | Power                         | I/O Supply (3.3V or 1.8V): All CMOS I/Os would operate on this supply  | R10, F15          |
|                      | VIOIN_18     | Power                         | 1.8V supply for CMOS IO  | R9                |
|                      | VIN_18CLK    | Power                         | 1.8V supply for clock module   | B11               |
|                      | VIOIN_18DIFF | Power                         | 1.8V supply for LVDS port  | D15               |
| VPP                  | Power        | Voltage supply for fuse chain | L13  |                   |

| INTERFACE   | SIGNAL NAME         | PIN TYPE | DESCRIPTION  | BALL NO.   |
|---|---------------------|----------|--|--|
| Power supply  | VIN_13RF1           | Power    | 1.3V Analog and RF supply, VIN_13RF1 and VIN_13RF2 could be shorted on the board   | G5, H5, J5   |
|   | VIN_13RF2           | Power    | 1.3V Analog and RF supply  | C2, D2   |
|   | VIN_18BB            | Power    | 1.8V Analog base band power supply   | K5, F5   |
|   | VIN_18VCO           | Power    | 1.8V RF VCO supply   | B12  |
|   | VSS                 | Ground   | Digital ground   | L5, L6, L8, L10, K7, K8, K9, K10, K11, J6, J7, J8, J10, H7, H9, H11, G6, G7, G8, G10, F9, F11, E5, E6, E8, E10, E11, R15   |
|   | VSSA                | Ground   | Analog ground  | A1, A3, A5, A7, A15, B1, B3, B5, B7, C1, C3, C4, C5, C6, C7, E1, E2, E3, F3, G1, G2, G3, H3, J1, J2, J3, K3, L1, L2, L3, M3, N1, N2, N3, R1, A13, C8, A9, B9, C9, B14, C14 |
| Internal LDO output/<br>inputs  | VOUT_14APLL         | O        | Internal LDO output  | A10  |
|   | VOUT_14SYNTH        | O        | Internal LDO output  | B13  |
|   | VOUT_PA             | IO       | When internal PA LDO is used this pin provides the output voltage of the LDO. When the internal PA LDO is bypassed and disabled 1V supply should be fed on this pin. This is mandatory in 3TX simultaneous use case. | A2, B2   |
| Test and Debug<br>output for pre-<br>production phase.<br>Can be pinned<br>out on production<br>hardware for field<br>debug | Analog Test1 / ADC1 | IO       | ADC Channel 1 <sup>(1)</sup>   | P1   |
|   | Analog Test2 / ADC2 | IO       | ADC Channel 2 <sup>(1)</sup>   | P2   |
|   | Analog Test3 / ADC3 | IO       | ADC Channel 3 <sup>(1)</sup>   | P3   |
|   | Analog Test4 / ADC4 | IO       | ADC Channel 4 <sup>(1)</sup>   | R2   |
|   | ANAMUX / ADC5       | IO       | ADC Channel 5 <sup>(1)</sup>   | C13  |
|   | VSENSE / ADC6       | IO       | ADC Channel 6 <sup>(1)</sup>   | D14  |

(1) For details, see [Section 8.4.1](#).

## 6.3 Pin Attributes

**Table 6-1. Pin Attributes (ABL0161 Package)**

| BALL NUMBER [1] | BALL NAME [2] | SIGNAL NAME [3] | PINCNTL ADDRESS[4] | MODE [5] [9] | TYPE [6]   | BALL RESET STATE [7] | PULL UP/DOWN TYPE [8] |            |                 |           |                 |           |
|-----------------|---------------|-----------------|--------------------|--------------|------------|----------------------|-----------------------|------------|-----------------|-----------|-----------------|-----------|
| H13             | GPIO_0        | GPIO_13         | 0xFFFFEA04         | 0            | IO         | Output Disabled      | Pull Down             |            |                 |           |                 |           |
|                 |               | GPIO_0          |                    | 1            | IO         |                      |                       |            |                 |           |                 |           |
|                 |               | PMIC_CLKOUT     |                    | 2            | O          |                      |                       |            |                 |           |                 |           |
|                 |               | ADC_VALID       |                    | 9            | O          |                      |                       |            |                 |           |                 |           |
|                 |               | ePWM1b          |                    | 10           | O          |                      |                       |            |                 |           |                 |           |
|                 |               | ePWM2a          |                    | 11           | O          |                      |                       |            |                 |           |                 |           |
| J13             | GPIO_1        | GPIO_16         | 0xFFFFEA08         | 0            | IO         | Output Disabled      | Pull Down             |            |                 |           |                 |           |
|                 |               | GPIO_1          |                    | 1            | IO         |                      |                       |            |                 |           |                 |           |
|                 |               | SYNC_OUT        |                    | 2            | O          |                      |                       |            |                 |           |                 |           |
|                 |               | ADC_VALID       |                    | 7            | O          |                      |                       |            |                 |           |                 |           |
|                 |               | DMM_MUX_IN      |                    | 12           | I          |                      |                       |            |                 |           |                 |           |
|                 |               | SPIB_cs_n_1     |                    | 13           | IO         |                      |                       |            |                 |           |                 |           |
|                 |               | SPIB_cs_n_2     |                    | 14           | IO         |                      |                       |            |                 |           |                 |           |
|                 |               | ePWM1SYNCl      |                    | 15           | I          |                      |                       |            |                 |           |                 |           |
|                 |               | K13             |                    | GPIO_2       | GPIO_26    |                      |                       | 0xFFFFEA64 | 0               | IO        | Output Disabled | Pull Down |
| GPIO_2          | 1             |                 | IO                 |              |            |                      |                       |            |                 |           |                 |           |
| OSC_CLKOUT      | 2             |                 | O                  |              |            |                      |                       |            |                 |           |                 |           |
| MSS_uartb_tx    | 7             |                 | O                  |              |            |                      |                       |            |                 |           |                 |           |
| BSS_uart_tx     | 8             |                 | O                  |              |            |                      |                       |            |                 |           |                 |           |
| SYNC_OUT        | 9             |                 | O                  |              |            |                      |                       |            |                 |           |                 |           |
| PMIC_CLKOUT     | 10            |                 | O                  |              |            |                      |                       |            |                 |           |                 |           |
| CHIRP_START     | 11            |                 | O                  |              |            |                      |                       |            |                 |           |                 |           |
| CHIRP_END       | 12            |                 | O                  |              |            |                      |                       |            |                 |           |                 |           |
| FRAME_START     | 13            |                 | O                  |              |            |                      |                       |            |                 |           |                 |           |
| R4              | GPIO_31       |                 | TRACE_DATA_0       |              | 0xFFFFEA7C | 0                    | O                     |            | Output Disabled | Pull Down |                 |           |
|                 |               |                 | GPIO_31            |              |            | 1                    | IO                    |            |                 |           |                 |           |
|                 |               |                 | DMM0               |              |            | 2                    | I                     |            |                 |           |                 |           |
|                 |               | MSS_uarta_tx    | 4                  | IO           |            |                      |                       |            |                 |           |                 |           |
| P5              | GPIO_32       | TRACE_DATA_1    | 0xFFFFEA80         | 0            | O          | Output Disabled      | Pull Down             |            |                 |           |                 |           |
|                 |               | GPIO_32         |                    | 1            | IO         |                      |                       |            |                 |           |                 |           |
|                 |               | DMM1            |                    | 2            | I          |                      |                       |            |                 |           |                 |           |
| R5              | GPIO_33       | TRACE_DATA_2    | 0xFFFFEA84         | 0            | O          | Output Disabled      | Pull Down             |            |                 |           |                 |           |
|                 |               | GPIO_33         |                    | 1            | IO         |                      |                       |            |                 |           |                 |           |
|                 |               | DMM2            |                    | 2            | I          |                      |                       |            |                 |           |                 |           |



**Table 6-1. Pin Attributes (ABL0161 Package) (continued)**

| BALL NUMBER [1] | BALL NAME [2] | SIGNAL NAME [3] | PINCNTL ADDRESS[4] | MODE [5] [9] | TYPE [6] | BALL RESET STATE [7] | PULL UP/DOWN TYPE [8] |
|-----------------|---------------|-----------------|--------------------|--------------|----------|----------------------|-----------------------|
| P6              | GPIO_34       | TRACE_DATA_3    | 0xFFFFEA88         | 0            | O        | Output Disabled      | Pull Down             |
|                 |               | GPIO_34         |                    | 1            | IO       |                      |                       |
|                 |               | DMM3            |                    | 2            | I        |                      |                       |
|                 |               | ePWM3SYNCO      |                    | 4            | O        |                      |                       |
| R7              | GPIO_35       | TRACE_DATA_4    | 0xFFFFEA8C         | 0            | O        | Output Disabled      | Pull Down             |
|                 |               | GPIO_35         |                    | 1            | IO       |                      |                       |
|                 |               | DMM4            |                    | 2            | I        |                      |                       |
|                 |               | ePWM2SYNCO      |                    | 4            | O        |                      |                       |
| P7              | GPIO_36       | TRACE_DATA_5    | 0xFFFFEA90         | 0            | O        | Output Disabled      | Pull Down             |
|                 |               | GPIO_36         |                    | 1            | IO       |                      |                       |
|                 |               | DMM5            |                    | 2            | I        |                      |                       |
|                 |               | MSS_uartb_tx    |                    | 5            | O        |                      |                       |
| R8              | GPIO_37       | TRACE_DATA_6    | 0xFFFFEA94         | 0            | O        | Output Disabled      | Pull Down             |
|                 |               | GPIO_37         |                    | 1            | IO       |                      |                       |
|                 |               | DMM6            |                    | 2            | I        |                      |                       |
|                 |               | BSS_uart_tx     |                    | 5            | O        |                      |                       |
| P8              | GPIO_38       | TRACE_DATA_7    | 0xFFFFEA98         | 0            | O        | Output Disabled      | Pull Down             |
|                 |               | GPIO_38         |                    | 1            | IO       |                      |                       |
|                 |               | DMM7            |                    | 2            | I        |                      |                       |
|                 |               | DSS_uart_tx     |                    | 5            | O        |                      |                       |
| N15             | GPIO_47       | TRACE_CLK       | 0xFFFFEABC         | 0            | O        | Output Disabled      | Pull Down             |
|                 |               | GPIO_47         |                    | 1            | IO       |                      |                       |
|                 |               | DMM_CLK         |                    | 2            | I        |                      |                       |
| N14             | DMM_SYNC      | TRACE_CTL       | 0xFFFFEAC0         | 0            | O        | Output Disabled      | Pull Down             |
|                 |               | DMM_SYNC        |                    | 2            | I        |                      |                       |
| N8              | MCU_CLKOUT    | GPIO_25         | 0xFFFFEA60         | 0            | IO       | Output Disabled      | Pull Down             |
|                 |               | MCU_CLKOUT      |                    | 1            | O        |                      |                       |
|                 |               | CHIRP_START     |                    | 2            | O        |                      |                       |
|                 |               | CHIRP_END       |                    | 6            | O        |                      |                       |
|                 |               | FRAME_START     |                    | 7            | O        |                      |                       |
|                 |               | ePWM1a          |                    | 12           | O        |                      |                       |
| N7              | nERROR_IN     | nERROR_IN       | 0xFFFFEA44         | 0            | I        | Input                |                       |
| N6              | nERROR_OUT    | nERROR_OUT      | 0xFFFFEA4C         | 0            | O        | Hi-Z (Open Drain)    |                       |

**Table 6-1. Pin Attributes (ABL0161 Package) (continued)**

| BALL NUMBER [1] | BALL NAME [2] | SIGNAL NAME [3] | PINCNTL ADDRESS[4] | MODE [5] [9]    | TYPE [6] | BALL RESET STATE [7] | PULL UP/DOWN TYPE [8] |
|-----------------|---------------|-----------------|--------------------|-----------------|----------|----------------------|-----------------------|
| P9              | PMIC_CLKOUT   | SOP[2]          | 0xFFFFEA68         | During Power Up | I        | Output Disabled      | Pull Down             |
|                 |               | GPIO_27         |                    | 0               | IO       |                      |                       |
|                 |               | PMIC_CLKOUT     |                    | 1               | O        |                      |                       |
|                 |               | CHIRP_START     |                    | 6               | O        |                      |                       |
|                 |               | CHIRP_END       |                    | 7               | O        |                      |                       |
|                 |               | FRAME_START     |                    | 8               | O        |                      |                       |
|                 |               | ePWM1b          |                    | 11              | O        |                      |                       |
|                 |               | ePWM2a          |                    | 12              | O        |                      |                       |
| R13             | QSPI[0]       | GPIO_8          | 0xFFFFEA2C         | 0               | IO       | Output Disabled      | Pull Down             |
|                 |               | QSPI[0]         |                    | 1               | IO       |                      |                       |
|                 |               | SPIB_miso       |                    | 2               | IO       |                      |                       |
| N12             | QSPI[1]       | GPIO_9          | 0xFFFFEA30         | 0               | IO       | Output Disabled      | Pull Down             |
|                 |               | QSPI[1]         |                    | 1               | IO       |                      |                       |
|                 |               | SPIB_mosi       |                    | 2               | IO       |                      |                       |
|                 |               | SPIB_cs_n_2     |                    | 8               | IO       |                      |                       |
| R14             | QSPI[2]       | GPIO_10         | 0xFFFFEA34         | 0               | IO       | Output Disabled      | Pull Down             |
|                 |               | QSPI[2]         |                    | 1               | I        |                      |                       |
|                 |               | CAN_FD_tx       |                    | 8               | O        |                      |                       |
| P12             | QSPI[3]       | GPIO_11         | 0xFFFFEA38         | 0               | IO       | Output Disabled      | Pull Down             |
|                 |               | QSPI[3]         |                    | 1               | IO       |                      |                       |
|                 |               | CAN_FD_rx       |                    | 8               | I        |                      |                       |
| R12             | QSPI_clk      | GPIO_7          | 0xFFFFEA3C         | 0               | IO       | Output Disabled      | Pull Down             |
|                 |               | QSPI_clk        |                    | 1               | IO       |                      |                       |
|                 |               | SPIB_clk        |                    | 2               | O        |                      |                       |
|                 |               | DSS_uart_tx     |                    | 6               | O        |                      |                       |
| P11             | QSPI_cs_n     | GPIO_6          | 0xFFFFEA40         | 0               | IO       | Output Disabled      | Pull Up               |
|                 |               | QSPI_cs_n       |                    | 1               | IO       |                      |                       |
|                 |               | SPIB_cs_n       |                    | 2               | IO       |                      |                       |
| N4              | rs232_rx      | GPIO_15         | 0xFFFFEA74         | 0               | IO       | Input Enabled        | Pull Up               |
|                 |               | rs232_rx        |                    | 1               | I        |                      |                       |
|                 |               | MSS_uarta_rx    |                    | 2               | I        |                      |                       |
|                 |               | BSS_uart_tx     |                    | 6               | IO       |                      |                       |
|                 |               | MSS_uartb_rx    |                    | 7               | IO       |                      |                       |
|                 |               | CAN_FD_rx       |                    | 8               | I        |                      |                       |
|                 |               | I2C_scl         |                    | 9               | IO       |                      |                       |
|                 |               | ePWM2a          |                    | 10              | O        |                      |                       |
|                 |               | ePWM2b          |                    | 11              | O        |                      |                       |
|                 |               | ePWM3a          |                    | 12              | O        |                      |                       |

**Table 6-1. Pin Attributes (ABL0161 Package) (continued)**

| BALL NUMBER [1] | BALL NAME [2] | SIGNAL NAME [3] | PINCNTL ADDRESS[4] | MODE [5] [9] | TYPE [6] | BALL RESET STATE [7] | PULL UP/DOWN TYPE [8] |
|-----------------|---------------|-----------------|--------------------|--------------|----------|----------------------|-----------------------|
| N5              | rs232_tx      | GPIO_14         | 0xFFFFFEA78        | 0            | IO       | Output Enabled       |                       |
|                 |               | rs232_tx        |                    | 1            | O        |                      |                       |
|                 |               | MSS_uarta_tx    |                    | 5            | IO       |                      |                       |
|                 |               | MSS_uartb_tx    |                    | 6            | IO       |                      |                       |
|                 |               | BSS_uart_tx     |                    | 7            | IO       |                      |                       |
|                 |               | CAN_FD_tx       |                    | 10           | O        |                      |                       |
|                 |               | I2C_sda         |                    | 11           | IO       |                      |                       |
|                 |               | ePWM1a          |                    | 12           | O        |                      |                       |
|                 |               | ePWM1b          |                    | 13           | O        |                      |                       |
|                 |               | NDMM_EN         |                    | 14           | I        |                      |                       |
|                 |               | ePWM2a          |                    | 15           | O        |                      |                       |
|                 |               | E13             |                    | SPIA_clk     | GPIO_3   |                      |                       |
| SPIA_clk        | 1             |                 | IO                 |              |          |                      |                       |
| CAN_rx          | 6             |                 | I                  |              |          |                      |                       |
| DSS_uart_tx     | 7             |                 | O                  |              |          |                      |                       |
| E15             | SPIA_cs_n     | GPIO_30         | 0xFFFFFEA18        | 0            | IO       | Output Disabled      | Pull Up               |
|                 |               | SPIA_cs_n       |                    | 1            | IO       |                      |                       |
|                 |               | CAN_tx          |                    | 6            | O        |                      |                       |
| E14             | SPIA_miso     | GPIO_20         | 0xFFFFFEA10        | 0            | IO       | Output Disabled      | Pull Up               |
|                 |               | SPIA_miso       |                    | 1            | IO       |                      |                       |
|                 |               | CAN_FD_tx       |                    | 2            | O        |                      |                       |
| D13             | SPIA_mosi     | GPIO_19         | 0xFFFFFEA0C        | 0            | IO       | Output Disabled      | Pull Up               |
|                 |               | SPIA_mosi       |                    | 1            | IO       |                      |                       |
|                 |               | CAN_FD_rx       |                    | 2            | I        |                      |                       |
|                 |               | DSS_uart_tx     |                    | 8            | O        |                      |                       |
| F14             | SPIB_clk      | GPIO_5          | 0xFFFFFEA24        | 0            | IO       | Output Disabled      | Pull Up               |
|                 |               | SPIB_clk        |                    | 1            | IO       |                      |                       |
|                 |               | MSS_uarta_rx    |                    | 2            | I        |                      |                       |
|                 |               | MSS_uartb_tx    |                    | 6            | O        |                      |                       |
|                 |               | BSS_uart_tx     |                    | 7            | O        |                      |                       |
|                 |               | CAN_FD_rx       |                    | 8            | I        |                      |                       |
| H14             | SPIB_cs_n     | GPIO_4          | 0xFFFFFEA28        | 0            | IO       | Output Disabled      | Pull Up               |
|                 |               | SPIB_cs_n       |                    | 1            | IO       |                      |                       |
|                 |               | MSS_uarta_tx    |                    | 2            | O        |                      |                       |
|                 |               | MSS_uartb_tx    |                    | 6            | O        |                      |                       |
|                 |               | BSS_uart_tx     |                    | 7            | IO       |                      |                       |
|                 |               | QSPI_clk_ext    |                    | 8            | I        |                      |                       |
|                 |               | CAN_FD_tx       |                    | 9            | O        |                      |                       |

**Table 6-1. Pin Attributes (ABL0161 Package) (continued)**

| BALL NUMBER [1] | BALL NAME [2] | SIGNAL NAME [3] | PINCNTL ADDRESS[4] | MODE [5] [9]    | TYPE [6] | BALL RESET STATE [7] | PULL UP/DOWN TYPE [8] |
|-----------------|---------------|-----------------|--------------------|-----------------|----------|----------------------|-----------------------|
| G14             | SPIB_miso     | GPIO_22         | 0xFFFFEA20         | 0               | IO       | Output Disabled      | Pull Up               |
|                 |               | SPIB_miso       |                    | 1               | IO       |                      |                       |
|                 |               | I2C_scl         |                    | 2               | IO       |                      |                       |
|                 |               | DSS_uart_tx     |                    | 6               | O        |                      |                       |
| F13             | SPIB_mosi     | GPIO_21         | 0xFFFFEA1C         | 0               | IO       | Output Disabled      | Pull Up               |
|                 |               | SPIB_mosi       |                    | 1               | IO       |                      |                       |
|                 |               | I2C_sda         |                    | 2               | IO       |                      |                       |
| P13             | SPI_HOST_INTR | GPIO_12         | 0xFFFFEA00         | 0               | IO       | Output Disabled      | Pull Down             |
|                 |               | SPI_HOST_INTR   |                    | 1               | O        |                      |                       |
|                 |               | ADC_VALID       |                    | 2               | O        |                      |                       |
|                 |               | SPIB_cs_n_1     |                    | 6               | IO       |                      |                       |
| P4              | SYNC_in       | GPIO_28         | 0xFFFFEA6C         | 0               | IO       | Output Disabled      | Pull Down             |
|                 |               | SYNC_IN         |                    | 1               | I        |                      |                       |
|                 |               | MSS_uartb_rx    |                    | 6               | IO       |                      |                       |
|                 |               | DMM_MUX_IN      |                    | 7               | I        |                      |                       |
|                 |               | SYNC_OUT        |                    | 9               | O        |                      |                       |
| G13             | SYNC_OUT      | SOP[1]          | 0xFFFFEA70         | During Power Up | I        | Output Disabled      | Pull Down             |
|                 |               | GPIO_29         |                    | 0               | IO       |                      |                       |
|                 |               | SYNC_OUT        |                    | 1               | O        |                      |                       |
|                 |               | DMM_MUX_IN      |                    | 9               | I        |                      |                       |
|                 |               | SPIB_cs_n_1     |                    | 10              | IO       |                      |                       |
|                 |               | SPIB_cs_n_2     |                    | 11              | IO       |                      |                       |
| P10             | TCK           | GPIO_17         | 0xFFFFEA50         | 0               | IO       | Input Enabled        | Pull Down             |
|                 |               | TCK             |                    | 1               | I        |                      |                       |
|                 |               | MSS_uartb_tx    |                    | 2               | O        |                      |                       |
|                 |               | CAN_FD_tx       |                    | 8               | O        |                      |                       |
| R11             | TDI           | GPIO_23         | 0xFFFFEA58         | 0               | IO       | Input Enabled        | Pull Up               |
|                 |               | TDI             |                    | 1               | I        |                      |                       |
|                 |               | MSS_uarta_rx    |                    | 2               | I        |                      |                       |
| N13             | TDO           | SOP[0]          | 0xFFFFEA5C         | During Power Up | I        | Output Enabled       |                       |
|                 |               | GPIO_24         |                    | 0               | IO       |                      |                       |
|                 |               | TDO             |                    | 1               | O        |                      |                       |
|                 |               | MSS_uarta_tx    |                    | 2               | O        |                      |                       |
|                 |               | MSS_uartb_tx    |                    | 6               | O        |                      |                       |
|                 |               | BSS_uart_tx     |                    | 7               | O        |                      |                       |
|                 |               | NDMM_EN         |                    | 9               | I        |                      |                       |

**Table 6-1. Pin Attributes (ABL0161 Package) (continued)**

| BALL NUMBER [1] | BALL NAME [2] | SIGNAL NAME [3] | PINCNTL ADDRESS[4] | MODE [5] [9] | TYPE [6] | BALL RESET STATE [7]    | PULL UP/DOWN TYPE [8] |
|-----------------|---------------|-----------------|--------------------|--------------|----------|-------------------------|-----------------------|
| N10             | TMS           | GPIO_18         | 0xFFFFEA54         | 0            | IO       | Input Enabled           | Pull Down             |
|                 |               | TMS             |                    | 1            | I        |                         |                       |
|                 |               | BSS_uart_tx     |                    | 2            | O        |                         |                       |
|                 |               | CAN_FD_rx       |                    | 6            | I        |                         |                       |
| N9              | Warm_Reset    | Warm_Reset      | 0xFFFFEA48         | 0            | IO       | Hi-Z Input (Open Drain) |                       |

The following list describes the table column headers:

- BALL NUMBER:** Ball numbers on the bottom side associated with each signal on the bottom.
- BALL NAME:** Mechanical name from package device (name is taken from muxmode 0).
- SIGNAL NAME:** Names of signals multiplexed on each ball (also notice that the name of the ball is the signal name in muxmode 0).
- PINCNTL ADDRESS:** MSS Address for PinMux Control
- MODE:** Multiplexing mode number: value written to PinMux Cntl register to select specific Signal name for this Ball number. Mode column has bit range value.
- TYPE:** Signal type and direction:
  - I = Input
  - O = Output
  - IO = Input or Output
- BALL RESET STATE:** The state of the terminal at power-on reset
- PULL UP/DOWN TYPE:** indicates the presence of an internal pullup or pulldown resistor. Pullup and pulldown resistors can be enabled or disabled via software.
  - Pull Up: Internal pullup
  - Pull Down: Internal pulldown
  - An empty box means No pull.
- Pin Mux Control Value maps to lower 4 bits of register.

IO MUX registers are available in the MSS memory map and the respective mapping to device pins is as follows:

**Table 6-2. PAD IO Control Registers**

| Default Pin/Ball Name | Package Ball /Pin (Address) | Pin Mux Config Register |
|-----------------------|-----------------------------|-------------------------|
| SPI_HOST_INTR         | P13                         | 0xFFFFEA00              |
| GPIO_0                | H13                         | 0xFFFFEA04              |
| GPIO_1                | J13                         | 0xFFFFEA08              |
| SPIA_MOSI             | D13                         | 0xFFFFEA0C              |
| SPIA_MISO             | E14                         | 0xFFFFEA10              |
| SPIA_CLK              | E13                         | 0xFFFFEA14              |
| SPIA_CN_EN            | E15                         | 0xFFFFEA18              |
| SPIB_MOSI             | F13                         | 0xFFFFEA1C              |
| SPIB_MISO             | G14                         | 0xFFFFEA20              |
| SPIB_CLK              | F14                         | 0xFFFFEA24              |
| SPIB_CS_N             | H14                         | 0xFFFFEA28              |
| QSPI[0]               | R13                         | 0xFFFFEA2C              |
| QSPI[1]               | N12                         | 0xFFFFEA30              |
| QSPI[2]               | R14                         | 0xFFFFEA34              |
| QSPI[3]               | P12                         | 0xFFFFEA38              |
| QSPI_CLK              | R12                         | 0xFFFFEA3C              |
| QSPI_CS_N             | P11                         | 0xFFFFEA40              |
| NERROR_IN             | N7                          | 0xFFFFEA44              |
| WARM_RESET            | N9                          | 0xFFFFEA48              |
| NERROR_OUT            | N6                          | 0xFFFFEA4C              |
| TCK                   | P10                         | 0xFFFFEA50              |
| TMS                   | N10                         | 0xFFFFEA54              |
| TDI                   | R11                         | 0xFFFFEA58              |
| TDO                   | N13                         | 0xFFFFEA5C              |
| MCU_CLKOUT            | N8                          | 0xFFFFEA60              |
| GPIO_2                | K13                         | 0xFFFFEA64              |
| PMIC_CLKOUT           | P9                          | 0xFFFFEA68              |
| SYNC_IN               | P4                          | 0xFFFFEA6C              |
| SYNC_OUT              | G13                         | 0xFFFFEA70              |
| RS232_RX              | N4                          | 0xFFFFEA74              |
| RS232_TX              | N5                          | 0xFFFFEA78              |

**Table 6-2. PAD IO Control Registers (continued)**

| Default Pin/Ball Name | Package Ball /Pin (Address) | Pin Mux Config Register |
|-----------------------|-----------------------------|-------------------------|
| GPIO_31               | R4                          | 0xFFFFEA7C              |
| GPIO_32               | P5                          | 0xFFFFEA80              |
| GPIO_33               | R5                          | 0xFFFFEA84              |
| GPIO_34               | P6                          | 0xFFFFEA88              |
| GPIO_35               | R7                          | 0xFFFFEA8C              |
| GPIO_36               | P7                          | 0xFFFFEA90              |
| GPIO_37               | R8                          | 0xFFFFEA94              |
| GPIO_38               | P8                          | 0xFFFFEA98              |
| GPIO_47               | N15                         | 0xFFFFEABC              |
| DMM_SYNC              | N14                         | 0xFFFFEAC0              |

The register layout is as follows:

**Table 6-3. PAD IO Register Bit Descriptions**

| BIT   | FIELD            | TYPE | RESET (POWER ON DEFAULT) | DESCRIPTION  |
|-------|------------------|------|--------------------------|--|
| 31-11 | NU               | RW   | 0                        | Reserved   |
| 10    | SC               | RW   | 0                        | IO slew rate control:<br>0 = Higher slew rate<br>1 = Lower slew rate   |
| 9     | PUPDSEL          | RW   | 0                        | Pullup/PullDown Selection<br>0 = Pull Down<br>1 = Pull Up (This field is valid only if Pull Inhibit is set as '0')   |
| 8     | PI               | RW   | 0                        | Pull Inhibit/Pull Disable<br>0 = Enable<br>1 = Disable   |
| 7     | OE_OVERRIDE      | RW   | 1                        | Output Override  |
| 6     | OE_OVERRIDE_CTRL | RW   | 1                        | Output Override Control:<br>(A '1' here overrides any o/p manipulation of this IO by any of the peripheral block hardware it is associated with for example a SPI Chip select) |
| 5     | IE_OVERRIDE      | RW   | 0                        | Input Override   |
| 4     | IE_OVERRIDE_CTRL | RW   | 0                        | Input Override Control:<br>(A '1' here overrides any i/p value on this IO with a desired value)  |
| 3-0   | FUNC_SEL         | RW   | 1                        | Function select for Pin Multiplexing (Refer to the Pin Mux Sheet)  |

## 7 Specifications

### 7.1 Absolute Maximum Ratings

| PARAMETERS <sup>(1) (2)</sup>  |   | MIN   | MAX                                    | UNIT |
|--------------------------------|---|-------|--|------|
| VDDIN                          | 1.2 V digital power supply  | -0.5  | 1.4                                    | V    |
| VIN_SRAM                       | 1.2 V power rail for internal SRAM  | -0.5  | 1.4                                    | V    |
| VNWA                           | 1.2 V power rail for SRAM array back bias   | -0.5  | 1.4                                    | V    |
| VIOIN                          | I/O supply (3.3 V or 1.8 V): All CMOS I/Os would operate on this supply.  | -0.5  | 3.8                                    | V    |
| VIOIN_18                       | 1.8 V supply for CMOS IO  | -0.5  | 2                                      | V    |
| VIN_18CLK                      | 1.8 V supply for clock module   | -0.5  | 2                                      | V    |
| VIOIN_18DIFF                   | 1.8 V supply for LVDS port  | -0.5  | 2                                      | V    |
| VIN_13RF1                      | 1.3 V Analog and RF supply, VIN_13RF1 and VIN_13RF2 could be shorted on the board.  | -0.5  | 1.45                                   | V    |
| VIN_13RF2                      |   |       |  |      |
| VIN_13RF1                      | 1-V Internal LDO bypass mode. Device supports mode where external Power Management block can supply 1 V on VIN_13RF1 and VIN_13RF2 rails. In this configuration, the internal LDO of the device would be kept bypassed. | -0.5  | 1.4                                    | V    |
| VIN_13RF2                      |   |       |  |      |
| VIN_18BB                       | 1.8-V Analog baseband power supply  | -0.5  | 2                                      | V    |
| VIN_18VCO supply               | 1.8-V RF VCO supply   | -0.5  | 2                                      | V    |
| RX1-4                          | Externally applied power on RF inputs   |       | 10                                     | dBm  |
| TX1-3                          | Externally applied power on RF outputs <sup>(3)</sup>   |       | 10                                     | dBm  |
| Input and output voltage range | Dual-voltage LVCMOS inputs, 3.3 V or 1.8 V (Steady State)   | -0.3V | VIOIN + 0.3                            | V    |
|                                | Dual-voltage LVCMOS inputs, operated at 3.3 V/1.8 V (Transient Overshoot/Undershoot) or external oscillator input   |       | VIOIN + 20% up to 20% of signal period |      |
| CLKP, CLKM                     | Input ports for reference crystal   | -0.5  | 2                                      | V    |
| Clamp current                  | Input or Output Voltages 0.3 V above or below their respective power rails. Limit clamp current that flows through the internal diode protection cells of the I/O.  | -20   | 20                                     | mA   |
| T <sub>J</sub>                 | Operating junction temperature range  | -40   | 125                                    | °C   |
| T <sub>STG</sub>               | Storage temperature range after soldered onto PC board  | -55   | 150                                    | °C   |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltage values are with respect to V<sub>SS</sub>, unless otherwise noted.
- (3) This value is for an externally applied signal level on the TX. Additionally, a reflection coefficient up to Gamma = 1 can be applied on the TX output.

### 7.2 ESD Ratings

|                    |                         | VALUE   | UNIT  |
|--------------------|-------------------------|---|-------|
| V <sub>(ESD)</sub> | Electrostatic discharge | Human-body model (HBM), per AEC Q100-002 <sup>(1)</sup>     | ±2000 |
|                    |                         | Charged-device model (CDM), per AEC Q100-011 <sup>(2)</sup> | ±500  |

- (1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.
- (2) Corner pins are rated as ±750 V



### 7.3 Power-On Hours (POH)

| JUNCTION TEMPERATURE (T <sub>J</sub> )<br>(1) (2) | OPERATING CONDITION | NOMINAL CVDD VOLTAGE (V) | POWER-ON HOURS [POH] (HOURS) |
|---|---------------------|--------------------------|------------------------------|
| -40°C   | 100% duty cycle     | 1.2                      | 600 (6%)                     |
| 75°C  |                     |                          | 2000 (20%)                   |
| 95°C  |                     |                          | 6500 (65%)                   |
| 125°C   |                     |                          | 900 (9%)                     |

- (1) This information is provided solely for your convenience and does not extend or modify the warranty provided under TI's standard terms and conditions for TI semiconductor products.
- (2) The specified POH are applicable with max Tx output power settings using the default firmware gain tables. The specified POH would not be applicable, if the Tx gain table is overwritten using an API.

### 7.4 Recommended Operating Conditions

|  |  | MIN         | NOM | MAX       | UNIT |
|--|--|-------------|-----|-----------|------|
| VDDIN  | 1.2 V digital power supply   | 1.14        | 1.2 | 1.32      | V    |
| VIN_SRAM                                       | 1.2 V power rail for internal SRAM   | 1.14        | 1.2 | 1.32      | V    |
| VNWA   | 1.2 V power rail for SRAM array back bias  | 1.14        | 1.2 | 1.32      | V    |
| VIOIN  | I/O supply (3.3 V or 1.8 V);<br>All CMOS I/Os would operate on this supply.          | 3.135       | 3.3 | 3.465     | V    |
|  |  | 1.71        | 1.8 | 1.89      |      |
| VIOIN_18                                       | 1.8 V supply for CMOS IO   | 1.71        | 1.8 | 1.9       | V    |
| VIN_18CLK                                      | 1.8 V supply for clock module  | 1.71        | 1.8 | 1.9       | V    |
| VIOIN_18DIFF                                   | 1.8 V supply for LVDS port   | 1.71        | 1.8 | 1.9       | V    |
| VIN_13RF1                                      | 1.3 V Analog and RF supply. VIN_13RF1 and VIN_13RF2<br>could be shorted on the board | 1.23        | 1.3 | 1.36      | V    |
| VIN_13RF2                                      |  |             |     |           |      |
| VIN_13RF1<br>(1-V Internal LDO<br>bypass mode) |  | 0.95        | 1   | 1.05      | V    |
| VIN_13RF2<br>(1-V Internal LDO<br>bypass mode) |  |             |     |           |      |
| VIN18BB  | 1.8-V Analog baseband power supply   | 1.71        | 1.8 | 1.9       | V    |
| VIN_18VCO                                      | 1.8V RF VCO supply   | 1.71        | 1.8 | 1.9       | V    |
| V <sub>IH</sub>                                | Voltage Input High (1.8 V mode)  | 1.17        |     |           | V    |
|  | Voltage Input High (3.3 V mode)  | 2.25        |     |           |      |
| V <sub>IL</sub>                                | Voltage Input Low (1.8 V mode)   |             |     | 0.3*VIOIN | V    |
|  | Voltage Input Low (3.3 V mode)   |             |     | 0.62      |      |
| V <sub>OH</sub>                                | High-level output threshold (I <sub>OH</sub> = 6 mA)                                 | VIOIN – 450 |     |           | mV   |
| V <sub>OL</sub>                                | Low-level output threshold (I <sub>OL</sub> = 6 mA)                                  | 450         |     |           | mV   |
| NRESET<br>SOP[2:0]                             | V <sub>IL</sub> (1.8V Mode)  |             |     | 0.2       | V    |
|  | V <sub>IH</sub> (1.8V Mode)  | 0.96        |     |           |      |
|  | V <sub>IL</sub> (3.3V Mode)  |             |     | 0.3       |      |
|  | V <sub>IH</sub> (3.3V Mode)  | 1.57        |     |           |      |

## 7.5 Power Supply Specifications

Table 7-1 describes the four rails from an external power supply block of the AWR1843 device.

**Table 7-1. Power Supply Rails Characteristics**

| SUPPLY  | DEVICE BLOCKS POWERED FROM THE SUPPLY   | RELEVANT IOS IN THE DEVICE  |
|---|---|---|
| 1.8 V   | Synthesizer and APLL VCOs, crystal oscillator, IF Amplifier stages, ADC, LVDS | Input: VIN_18VCO, VIN18CLK, VIN_18BB, VIOIN_18DIFF, VIOIN_18<br>LDO Output: VOUT_14SYNTH, VOUT_14APLL |
| 1.3 V (or 1 V in internal LDO bypass mode) <sup>(1)</sup> | Power Amplifier, Low Noise Amplifier, Mixers and LO Distribution              | Input: VIN_13RF2, VIN_13RF1<br>LDO Output: VOUT_PA  |
| 3.3 V (or 1.8 V for 1.8 V I/O mode)                       | Digital I/Os  | Input VIOIN   |
| 1.2 V   | Core Digital and SRAMs  | Input: VDDIN, VIN_SRAM  |

(1) Three simultaneous transmitter operation is supported only in 1-V LDO bypass and PA LDO disable mode. In this mode 1V supply needs to be fed on the VOUT PA pin.

The 1.3-V (1.0 V) and 1.8-V power supply ripple specifications mentioned in Table 7-2 are defined to meet a target spur level of  $-105$  dBc (RF Pin =  $-15$  dBm) at the RX. The spur and ripple levels have a dB-to-dB relationship, for example, a 1-dB increase in supply ripple leads to a  $\sim 1$  dB increase in spur level. Values quoted are rms levels for a sinusoidal input applied at the specified frequency.

**Table 7-2. Ripple Specifications**

| FREQUENCY (kHz) | RF RAIL   |                                      | VCO/IF RAIL                          |
|-----------------|---|--------------------------------------|--------------------------------------|
|                 | 1.0 V (INTERNAL LDO BYPASS)<br>( $\mu\text{V}_{\text{RMS}}$ ) | 1.3 V ( $\mu\text{V}_{\text{RMS}}$ ) | 1.8 V ( $\mu\text{V}_{\text{RMS}}$ ) |
| 137.5           | 7   | 648                                  | 83                                   |
| 275             | 5   | 76                                   | 21                                   |
| 550             | 3   | 22                                   | 11                                   |
| 1100            | 2   | 4                                    | 6                                    |
| 2200            | 11  | 82                                   | 13                                   |
| 4400            | 13  | 93                                   | 19                                   |
| 6600            | 22  | 117                                  | 29                                   |

## 7.6 Power Consumption Summary

Table 7-3 and Table 7-4 summarize the power consumption at the power terminals.

**Table 7-3. Maximum Current Ratings at Power Terminals**

| PARAMETER                          | SUPPLY NAME  | DESCRIPTION  | MIN | TYP | MAX  | UNIT |
|------------------------------------|--|--|-----|-----|------|------|
| Current consumption <sup>(1)</sup> | VDDIN, VIN_SRAM, VNWA                                  | Total current drawn by all nodes driven by 1.2V rail   |     |     | 1000 | mA   |
|                                    | VIN_13RF1, VIN_13RF2                                   | Total current drawn by all nodes driven by 1.3V or 1.0V rail (2TX, 4 RX simultaneously) <sup>(2)</sup> |     |     | 2000 |      |
|                                    | VIOIN_18, VIN_18CLK, VIOIN_18DIFF, VIN_18BB, VIN_18VCO | Total current drawn by all nodes driven by 1.8V rail   |     |     | 850  |      |
|                                    | VIOIN  | Total current drawn by all nodes driven by 3.3V rail <sup>(3)</sup>                                    |     | 50  |      |      |

- (1) The specified current values are at typical supply voltage level.
- (2) Simultaneous 3 Transmitter operation is supported only with 1-V LDO bypass and PA LDO disable mode. In this mode, the 1-V supply needs to be fed on the VOUT\_PA pin. In this case, the peak 1-V supply current goes up to 2500 mA. To enable the LDO bypass mode, see the *Interface Control* document in the [mmWave Device Firmware Package](#).
- (3) The exact VIOIN current depends on the peripherals used and their frequency of operation.

**Table 7-4. Average Power Consumption at Power Terminals**

| PARAMETER                 | CONDITION                      |                | DESCRIPTION | MIN   | TYP | MAX  | UNIT |
|---------------------------|--------------------------------|----------------|-------------|---|-----|------|------|
| Average power consumption | 1.0-V internal LDO bypass mode | 25% Duty Cycle | 1TX, 4RX    | Use Case: Regular mode, 6.4 MSps complex transceiver, 25-ms frame time, 128 chirps, 128 samples/chirp, 5- $\mu$ s idle time (25% duty cycle), 3 $\mu$ s ADC start time and excess ramp time, DSP and HWA active |     | 1.29 | W    |
|                           |                                |                | 2TX, 4RX    |   |     | 1.36 |      |
|                           |                                |                | 3TX, 4RX    |   |     | 1.43 |      |
|                           |                                | 50% Duty Cycle | 1TX, 4RX    |   |     | 1.82 |      |
|                           |                                |                | 2TX, 4RX    |   |     | 1.96 |      |
|                           |                                |                | 3TX, 4RX    |   |     | 2.08 |      |

## 7.7 RF Specification

over recommended operating conditions and with run time calibrations enabled (unless otherwise noted)

| PARAMETER          |   | MIN  | TYP  | MAX  | UNIT |        |
|--------------------|---|--|--|------|------|--------|
| Receiver           | Noise figure <sup>(2)</sup>   | 76 to 77 GHz   | 14   |      | dB   |        |
|                    |   | 77 to 81 GHz   | 15   |      |      |        |
|                    | 1-dB compression point (Out Of Band / Specified at 10 kHz) <sup>(1)</sup> |  |  | -8   |      | dBm    |
|                    | Maximum gain  |  |  | 48   |      | dB     |
|                    | Gain range  |  |  | 24   |      | dB     |
|                    | Gain step size  |  |  | 2    |      | dB     |
|                    | Image Rejection Ratio (IMRR)  |  |  | 30   |      | dB     |
|                    | IF bandwidth <sup>(3)</sup>   |  |  |      | 10   | MHz    |
|                    | ADC sampling rate (real/complex 2x)                                       |  |  |      | 25   | Msp/s  |
|                    | ADC sampling rate (complex 1x)  |  |  |      | 12.5 | Msp/s  |
|                    | ADC resolution  |  |  | 12   |      | Bits   |
|                    | Return loss (S11)   |  |  | <-10 |      | dB     |
|                    | Gain mismatch variation (over temperature)                                |  |  | ±0.5 |      | dB     |
|                    | Phase mismatch variation (over temperature)                               |  |  | ±3   |      | °      |
|                    | Receiver  | In-band IIP2   | RX gain = 30dB<br>IF = 1.5, 2 MHz at<br>-12 dBFS | 16   |      | dBm    |
| Out-of-band IIP2   |   | RX gain = 24dB<br>IF = 10 kHz at -10dBm,<br>1.9 MHz at -30 dBm | 24   |      | dBm  |        |
| Idle Channel Spurs |   |  | -90  |      | dBFS |        |
| Output power       |   |  | 12   |      | dBm  |        |
| Transmitter        | Amplitude noise   |  |  | -145 |      | dBc/Hz |
| Clock subsystem    | Frequency range   |  | 76   |      | 81   | GHz    |
|                    | Ramp rate   |  |  |      | 100  | MHz/μs |
|                    | Phase noise at 1-MHz offset   | 76 to 77 GHz   |  | -95  |      | dBc/Hz |
| 77 to 81 GHz       |   |  | -93  |      |      |        |

- (1) 1-dB Compression Point (Out Of Band) is measured by feed a Continuous wave Tone (10 kHz) well below the lowest HPF cut-off frequency.
- (2) Specification is quoted for complex 1x mode.
- (3) The analog IF stages include high-pass filtering, with two independently configurable first-order high-pass corner frequencies. The set of available HPF corners is summarized as follows:

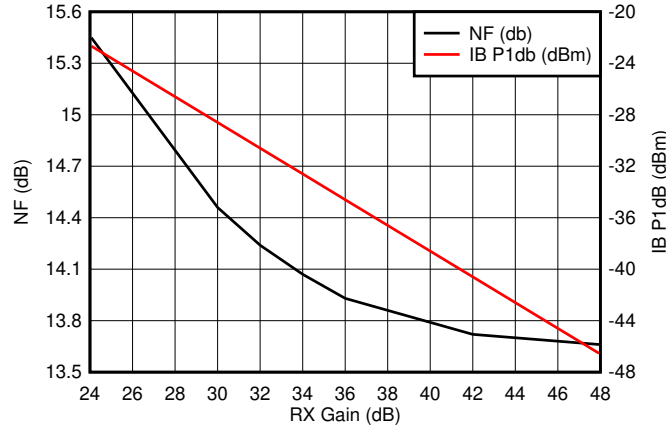
Available HPF Corner Frequencies (kHz)

| HPF1               | HPF2                 |
|--------------------|----------------------|
| 175, 235, 350, 700 | 350, 700, 1400, 2800 |

The filtering performed by the digital baseband chain is targeted to provide:

- Less than ±0.5 dB pass-band ripple/droop, and
- Better than 60 dB anti-aliasing attenuation for any frequency that can alias back into the pass-band.

Figure 7-1 shows variations of noise figure and in-band P1dB parameters with respect to receiver gain programmed.



**Figure 7-1. Noise Figure, In-band P1dB vs Receiver Gain**

### 7.8 CPU Specifications

over recommended operating conditions (unless otherwise noted)

| PARAMETER                   |                                      | MIN | TYP  | MAX | UNIT |
|-----------------------------|--------------------------------------|-----|------|-----|------|
| DSP Subsystem (C674 Family) | Clock Speed                          |     | 600  |     | MHz  |
|                             | L1 Code Memory                       |     | 32   |     | KB   |
|                             | L1 Data Memory                       |     | 32   |     | KB   |
|                             | L2 Memory                            |     | 256  |     | KB   |
| Main Subsystem (R4F Family) | Clock Speed                          |     | 200  |     | MHz  |
|                             | Tightly Coupled Memory - A (Program) |     | 512  |     | KB   |
|                             | Tightly Coupled Memory - B (Data)    |     | 192  |     | KB   |
| Shared Memory               | Shared L3 Memory                     |     | 1024 |     | KB   |

### 7.9 Thermal Resistance Characteristics for FCBGA Package [ABL0161]

| THERMAL METRICS <sup>(1)</sup> |                         | °C/W <sup>(2) (3)</sup> |
|--------------------------------|-------------------------|-------------------------|
| RO <sub>JC</sub>               | Junction-to-case        | 4.2                     |
| RO <sub>JB</sub>               | Junction-to-board       | 5.7                     |
| RO <sub>JA</sub>               | Junction-to-free air    | 20.9                    |
| RO <sub>JMA</sub>              | Junction-to-moving air  | 14.5 <sup>(4)</sup>     |
| Psi <sub>JT</sub>              | Junction-to-package top | 0.38                    |
| Psi <sub>JB</sub>              | Junction-to-board       | 5.6                     |

(1) For more information about traditional and new thermal metrics, see [Semiconductor and IC Package Thermal Metrics](#).

(2) °C/W = degrees Celsius per watt.

(3) These values are based on a JEDEC-defined 2S2P system (with the exception of the Theta JC [RO<sub>JC</sub>] value, which is based on a JEDEC-defined 1S0P system) and will change based on environment as well as application. For more information, see these EIA/JEDEC standards:

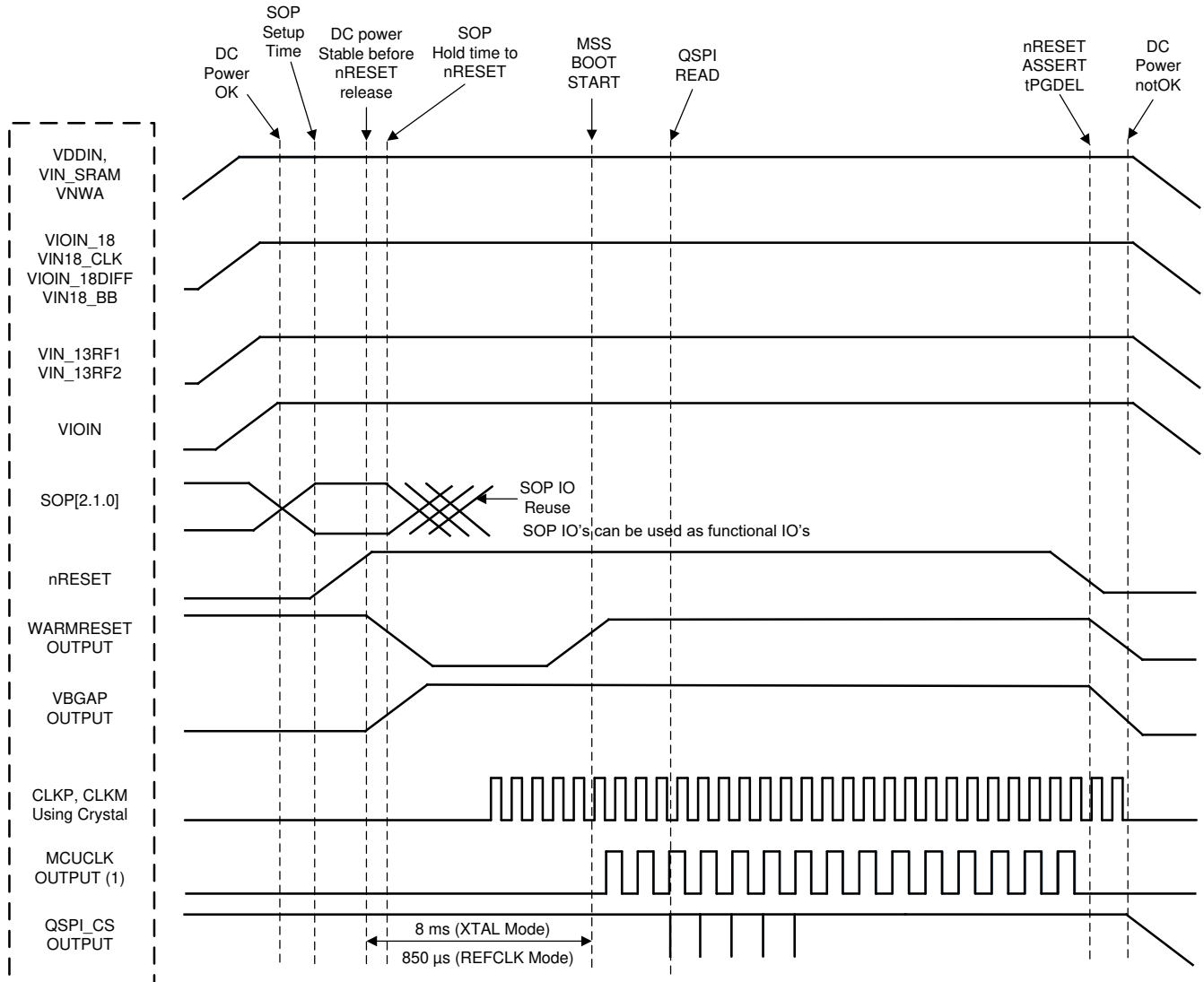
- JESD51-2, *Integrated Circuits Thermal Test Method Environmental Conditions - Natural Convection (Still Air)*
- JESD51-3, *Low Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-7, *High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-9, *Test Boards for Area Array Surface Mount Package Thermal Measurements*

(4) Air flow = 1 m/s

## 7.10 Timing and Switching Characteristics

### 7.10.1 Power Supply Sequencing and Reset Timing

The AWR1843 device expects all external voltage rails and SOP lines to be stable before reset is deasserted. Figure 7-2 describes the device wake-up sequence.



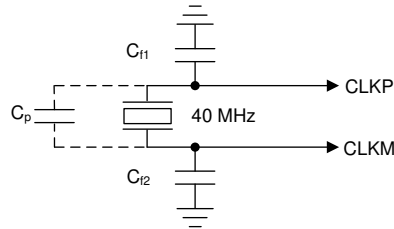
- A. MCU\_CLK\_OUT in autonomous mode, where AWR1843 application is booted from the serial flash, MCU\_CLK\_OUT is not enabled by default by the device bootloader.

**Figure 7-2. Device Wake-up Sequence**

## 7.10.2 Input Clocks and Oscillators

### 7.10.2.1 Clock Specifications

The AWR1843 requires external clock source (that is, a 40-MHz crystal) for initial boot and as a reference for an internal APLL hosted in the device. An external crystal is connected to the device pins. [Figure 7-3](#) shows the crystal implementation.



**Figure 7-3. Crystal Implementation**

#### Note

The load capacitors,  $C_{f1}$  and  $C_{f2}$  in [Figure 7-3](#), should be chosen such that [Equation 1](#) is satisfied.  $C_L$  in the equation is the load specified by the crystal manufacturer. All discrete components used to implement the oscillator circuit should be placed as close as possible to the associated oscillator CLKP and CLKM pins.

$$C_L = C_{f1} \times \frac{C_{f2}}{C_{f1} + C_{f2}} + C_P \quad (1)$$

[Table 7-5](#) lists the electrical characteristics of the clock crystal.

**Table 7-5. Crystal Electrical Characteristics (Oscillator Mode)**

| NAME                | DESCRIPTION                                    | MIN  | TYP | MAX | UNIT               |
|---------------------|--|------|-----|-----|--------------------|
| $f_P$               | Parallel resonance crystal frequency           |      | 40  |     | MHz                |
| $C_L$               | Crystal load capacitance                       | 5    | 8   | 12  | pF                 |
| ESR                 | Crystal ESR                                    |      |     | 50  | $\Omega$           |
| Temperature range   | Expected temperature range of operation        | -40  |     | 125 | $^{\circ}\text{C}$ |
| Frequency tolerance | Crystal frequency tolerance <sup>(1) (2)</sup> | -200 |     | 200 | ppm                |
| Drive level         |  |      | 50  | 200 | $\mu\text{W}$      |

(1) The crystal manufacturer's specification must satisfy this requirement.

(2) Includes initial tolerance of the crystal, drift over temperature, aging and frequency pulling due to incorrect load capacitance.

In the case where an external clock is used as the clock resource, the signal is fed to the CLKP pin only; CLKM is grounded. The phase noise requirement is very important when a 40-MHz clock is fed externally. [Table 7-6](#) lists the electrical characteristics of the external clock signal.

**Table 7-6. External Clock Mode Specifications**

| PARAMETER   |                        | SPECIFICATION |     |      | UNIT    |
|---|------------------------|---------------|-----|------|---------|
|   |                        | MIN           | TYP | MAX  |         |
| Input Clock:<br>External AC-coupled sine wave or DC-<br>coupled square wave<br>Phase Noise referred to 40 MHz | Frequency              |               | 40  |      | MHz     |
|   | AC-Amplitude           | 700           |     | 1200 | mV (pp) |
|   | Phase Noise at 1 kHz   |               |     | -132 | dBc/Hz  |
|   | Phase Noise at 10 kHz  |               |     | -143 | dBc/Hz  |
|   | Phase Noise at 100 kHz |               |     | -152 | dBc/Hz  |
|   | Phase Noise at 1 MHz   |               |     | -153 | dBc/Hz  |
|   | Duty Cycle             | 35            |     | 65   | %       |
|   | Freq Tolerance         | -100          |     | 100  | ppm     |



### 7.10.3 Multibuffered / Standard Serial Peripheral Interface (MibSPI)

#### 7.10.3.1 Peripheral Description

The SPI uses a MibSPI Protocol by TI.

The MibSPI/SPI is a high-speed synchronous serial input/output port that allows a serial bit stream of programmed length (2 to 16 bits) to be shifted into and out of the device at a programmed bit-transfer rate. The MibSPI/SPI is normally used for communication between the microcontroller and external peripherals or another microcontroller.

Standard and MibSPI modules have the following features:

- 16-bit shift register
- Receive buffer register
- 8-bit baud clock generator
- SPICLK can be internally-generated (controller mode) or received from an external clock source (peripheral mode)
- Each word transferred can have a unique format.
- SPI I/Os not used in the communication can be used as digital input/output signals

#### 7.10.3.2 MibSPI Transmit and Receive RAM Organization

The Multibuffer RAM is comprised of 256 buffers. Each entry in the Multibuffer RAM consists of 4 parts: a 16-bit transmit field, a 16-bit receive field, a 16-bit control field and a 16-bit status field. The Multibuffer RAM can be partitioned into multiple transfer group with variable number of buffers each.

[Section 7.10.3.2.2](#) and [Section 7.10.3.2.3](#) assume the operating conditions stated in [Section 7.10.3.2.1](#).

##### 7.10.3.2.1 SPI Timing Conditions

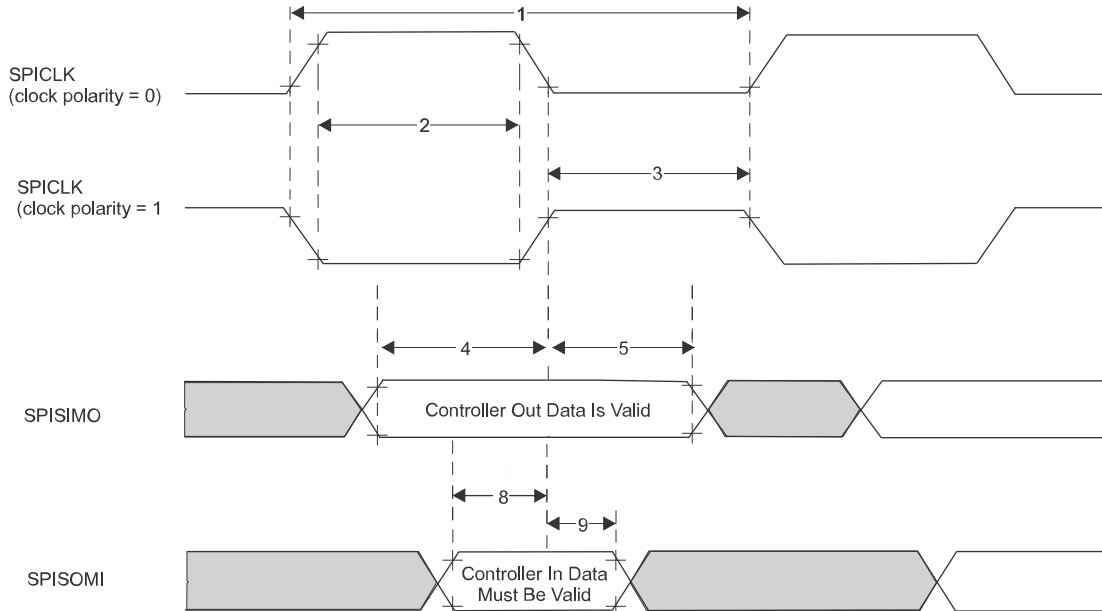
|                   |                         | MIN | TYP | MAX | UNIT |
|-------------------|-------------------------|-----|-----|-----|------|
| Input Conditions  |                         |     |     |     |      |
| $t_R$             | Input rise time         | 1   |     | 3   | ns   |
| $t_F$             | Input fall time         | 1   |     | 3   | ns   |
| Output Conditions |                         |     |     |     |      |
| $C_{LOAD}$        | Output load capacitance | 2   |     | 15  | pF   |

##### 7.10.3.2.2 SPI Controller Mode Switching Parameters (CLOCK PHASE = 0, SPICLK = output, SPISIMO = output, and SPISOMI = input) <sup>(1) (2) (3)</sup>

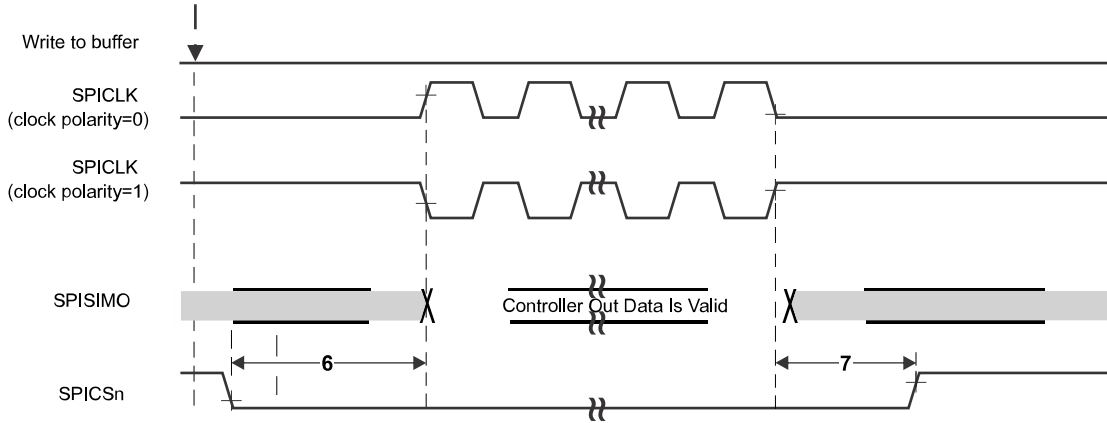
| NO.              | PARAMETER           |  | MIN                     | TYP | MAX                  | UNIT |
|------------------|---------------------|--|-------------------------|-----|----------------------|------|
| 1                | $t_{c(SPC)}M$       | Cycle time, SPICLK <sup>(4)</sup>                                      | 25                      |     | $256t_{c(VCLK)}$     | ns   |
| 2 <sup>(4)</sup> | $t_{w(SPCH)}M$      | Pulse duration, SPICLK high (clock polarity = 0)                       | $0.5t_{c(SPC)}M - 4$    |     | $0.5t_{c(SPC)}M + 4$ | ns   |
|                  | $t_{w(SPCL)}M$      | Pulse duration, SPICLK low (clock polarity = 1)                        | $0.5t_{c(SPC)}M - 4$    |     | $0.5t_{c(SPC)}M + 4$ |      |
| 3 <sup>(4)</sup> | $t_{w(SPCL)}M$      | Pulse duration, SPICLK low (clock polarity = 0)                        | $0.5t_{c(SPC)}M - 4$    |     | $0.5t_{c(SPC)}M + 4$ | ns   |
|                  | $t_{w(SPCH)}M$      | Pulse duration, SPICLK high (clock polarity = 1)                       | $0.5t_{c(SPC)}M - 4$    |     | $0.5t_{c(SPC)}M + 4$ |      |
| 4 <sup>(4)</sup> | $t_{d(SPCH-SIMO)}M$ | Delay time, SPISIMO valid before SPICLK low, (clock polarity = 0)      | $0.5t_{c(SPC)}M - 3$    |     |                      | ns   |
|                  | $t_{d(SPCL-SIMO)}M$ | Delay time, SPISIMO valid before SPICLK high, (clock polarity = 1)     | $0.5t_{c(SPC)}M - 3$    |     |                      |      |
| 5 <sup>(4)</sup> | $t_{v(SPCL-SIMO)}M$ | Valid time, SPISIMO data valid after SPICLK low, (clock polarity = 0)  | $0.5t_{c(SPC)}M - 10.5$ |     |                      | ns   |
|                  | $t_{v(SPCH-SIMO)}M$ | Valid time, SPISIMO data valid after SPICLK high, (clock polarity = 1) | $0.5t_{c(SPC)}M - 10.5$ |     |                      |      |

| NO.              | PARAMETER                              |  | MIN   | TYP  | MAX  | UNIT |
|------------------|--|--|---|--|--|------|
| 6 <sup>(5)</sup> | t <sub>C2TDELAY</sub>                  | Setup time CS active until SPICLK high (clock polarity = 0)          | CSHOLD = 0  | (C2TDELAY+2)*<br>t <sub>c(VCLK)</sub> - 7.5  | (C2TDELAY+2)<br>* t <sub>c(VCLK)</sub> + 7 | ns   |
|                  |  |  | CSHOLD = 1  | (C2TDELAY +3)<br>* t <sub>c(VCLK)</sub> - 7.5  | (C2TDELAY+3)<br>* t <sub>c(VCLK)</sub> + 7 |      |
|                  |  | Setup time CS active until SPICLK low (clock polarity = 1)           | CSHOLD = 0  | (C2TDELAY+2)*<br>t <sub>c(VCLK)</sub> - 7.5  | (C2TDELAY+2)<br>* t <sub>c(VCLK)</sub> + 7 |      |
|                  |  |  | CSHOLD = 1  | (C2TDELAY +3)<br>* t <sub>c(VCLK)</sub> - 7.5  | (C2TDELAY+3)<br>* t <sub>c(VCLK)</sub> + 7 |      |
| 7 <sup>(5)</sup> | t <sub>T2CDELAY</sub>                  | Hold time, SPICLK low until CS inactive (clock polarity = 0)         | 0.5*t <sub>c(SPC)<sub>M</sub></sub> +<br>(T2CDELAY +<br>1) * t <sub>c(VCLK)</sub> - 7 | 0.5*t <sub>c(SPC)<sub>M</sub></sub> +<br>(T2CDELAY +<br>1) * t <sub>c(VCLK)</sub> +<br>7.5 | ns   |      |
|                  |  | Hold time, SPICLK high until CS inactive (clock polarity = 1)        | 0.5*t <sub>c(SPC)<sub>M</sub></sub> +<br>(T2CDELAY +<br>1) * t <sub>c(VCLK)</sub> - 7 | 0.5*t <sub>c(SPC)<sub>M</sub></sub> +<br>(T2CDELAY +<br>1) * t <sub>c(VCLK)</sub> +<br>7.5 |  |      |
| 8 <sup>(4)</sup> | t <sub>SU(SOMI-SPCL)<sub>M</sub></sub> | Setup time, SPISOMI before SPICLK low (clock polarity = 0)           | 5   |  | ns   |      |
|                  | t <sub>SU(SOMI-SPCH)<sub>M</sub></sub> | Setup time, SPISOMI before SPICLK high (clock polarity = 1)          | 5   |  |  |      |
| 9 <sup>(4)</sup> | t <sub>H(SPCL-SOMI)<sub>M</sub></sub>  | Hold time, SPISOMI data valid after SPICLK low (clock polarity = 0)  | 3   |  | ns   |      |
|                  | t <sub>H(SPCH-SOMI)<sub>M</sub></sub>  | Hold time, SPISOMI data valid after SPICLK high (clock polarity = 1) | 3   |  |  |      |

- (1) The MASTER bit (SPIGRx.0) is set and the CLOCK PHASE bit (SPIFMTx.16) is cleared (where x = 0 or 1).
- (2) t<sub>c(MSS\_VCLK)</sub> = main subsystem clock time = 1 / f<sub>(MSS\_VCLK)</sub>. For more details, see the [Technical Reference Manual](#).
- (3) When the SPI is in Controller mode, the following must be true: For PS values from 1 to 255: t<sub>c(SPC)<sub>M</sub></sub> ≥ (PS + 1)t<sub>c(MSS\_VCLK)</sub> ≥ 25ns, where PS is the prescale value set in the SPIFMTx.[15:8] register bits. For PS values of 0: t<sub>c(SPC)<sub>M</sub></sub> = 2t<sub>c(MSS\_VCLK)</sub> ≥ 25ns.
- (4) The active edge of the SPICLK signal referenced is controlled by the CLOCK POLARITY bit (SPIFMTx.17).
- (5) C2TDELAY and T2CDELAY is programmed in the SPIDELAY register



**Figure 7-4. SPI Controller Mode External Timing (CLOCK PHASE = 0)**



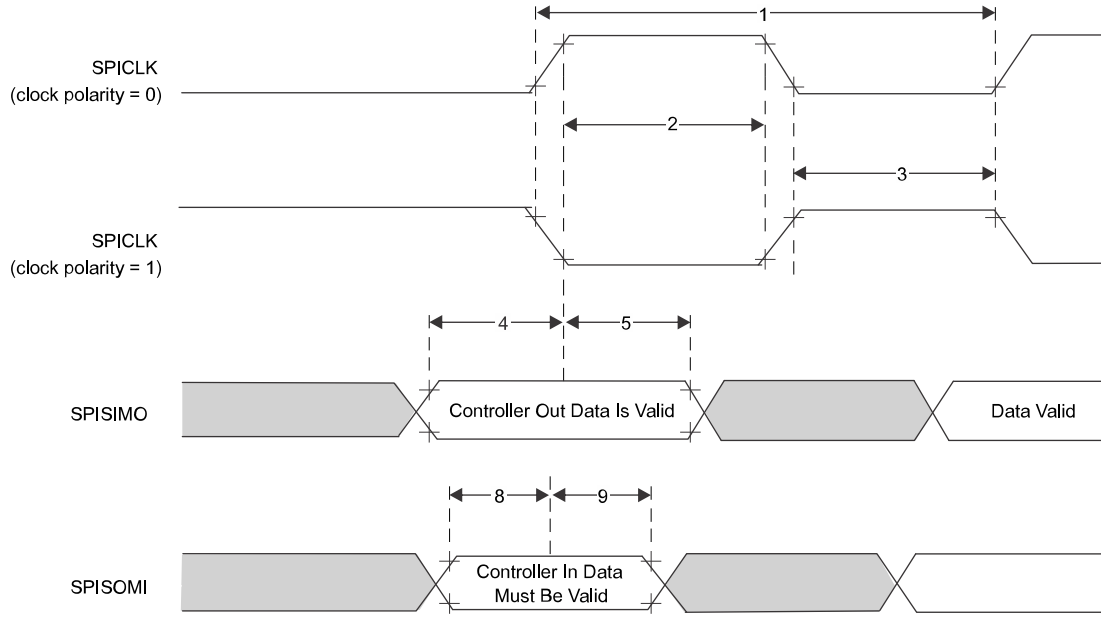
**Figure 7-5. SPI Controller Mode Chip Select Timing (CLOCK PHASE = 0)**

**7.10.3.2.3 SPI Controller Mode Switching Parameters (CLOCK PHASE = 1, SPICLK = output, SPISIMO = output, and SPISOMI = input) (1) (2) (3)**

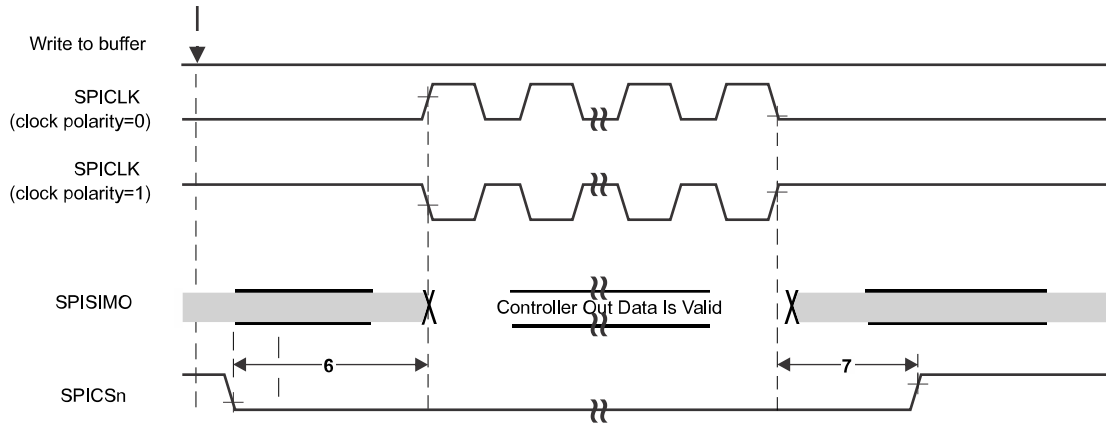
| NO.              | PARAMETER  |  | MIN  | TYP  | MAX  | UNIT |
|------------------|--|--|--|--|--|------|
| 1                | $t_{c(SPC)M}$  | Cycle time, SPICLK <sup>(4)</sup>                                      | 25   |  | $256t_{c(VCLK)}$   | ns   |
| 2 <sup>(4)</sup> | $t_{w(SPCH)M}$   | Pulse duration, SPICLK high (clock polarity = 0)                       | $0.5t_{c(SPC)M} - 4$                                   |  | $0.5t_{c(SPC)M} + 4$                                     | ns   |
|                  | $t_{w(SPCL)M}$   | Pulse duration, SPICLK low (clock polarity = 1)                        | $0.5t_{c(SPC)M} - 4$                                   |  | $0.5t_{c(SPC)M} + 4$                                     |      |
| 3 <sup>(4)</sup> | $t_{w(SPCL)M}$   | Pulse duration, SPICLK low (clock polarity = 0)                        | $0.5t_{c(SPC)M} - 4$                                   |  | $0.5t_{c(SPC)M} + 4$                                     | ns   |
|                  | $t_{w(SPCH)M}$   | Pulse duration, SPICLK high (clock polarity = 1)                       | $0.5t_{c(SPC)M} - 4$                                   |  | $0.5t_{c(SPC)M} + 4$                                     |      |
| 4 <sup>(4)</sup> | $t_{d(SPCH-SIMO)M}$  | Delay time, SPISIMO valid before SPICLK low, (clock polarity = 0)      | $0.5t_{c(SPC)M} - 3$                                   |  |  | ns   |
|                  | $t_{d(SPCL-SIMO)M}$  | Delay time, SPISIMO valid before SPICLK high, (clock polarity = 1)     | $0.5t_{c(SPC)M} - 3$                                   |  |  |      |
| 5 <sup>(4)</sup> | $t_{v(SPCL-SIMO)M}$  | Valid time, SPISIMO data valid after SPICLK low, (clock polarity = 0)  | $0.5t_{c(SPC)M} - 10.5$                                |  |  | ns   |
|                  | $t_{v(SPCH-SIMO)M}$  | Valid time, SPISIMO data valid after SPICLK high, (clock polarity = 1) | $0.5t_{c(SPC)M} - 10.5$                                |  |  |      |
| 6 <sup>(5)</sup> | $t_{C2TDELAY}$   | Setup time CS active until SPICLK high (clock polarity = 0)            | CSHOLD = 0   | $0.5 * t_{c(SPC)M} + (C2TDELAY + 2) * t_{c(VCLK)} - 7$   | $0.5 * t_{c(SPC)M} + (C2TDELAY + 2) * t_{c(VCLK)} + 7.5$ | ns   |
|                  |  |  | CSHOLD = 1   | $0.5 * t_{c(SPC)M} + (C2TDELAY + 2) * t_{c(VCLK)} - 7$   | $0.5 * t_{c(SPC)M} + (C2TDELAY + 2) * t_{c(VCLK)} + 7.5$ |      |
|                  | Setup time CS active until SPICLK low (clock polarity = 1) | CSHOLD = 0   | $0.5 * t_{c(SPC)M} + (C2TDELAY + 2) * t_{c(VCLK)} - 7$ | $0.5 * t_{c(SPC)M} + (C2TDELAY + 2) * t_{c(VCLK)} + 7.5$ |  |      |
|                  |  | CSHOLD = 1   | $0.5 * t_{c(SPC)M} + (C2TDELAY + 3) * t_{c(VCLK)} - 7$ | $0.5 * t_{c(SPC)M} + (C2TDELAY + 3) * t_{c(VCLK)} + 7.5$ |  |      |
| 7 <sup>(5)</sup> | $t_{T2CDELAY}$   | Hold time, SPICLK low until CS inactive (clock polarity = 0)           | $(T2CDELAY + 1) * t_{c(VCLK)} - 7.5$                   | $(T2CDELAY + 1) * t_{c(VCLK)} + 7$                       | ns   |      |
|                  |  | Hold time, SPICLK high until CS inactive (clock polarity = 1)          | $(T2CDELAY + 1) * t_{c(VCLK)} - 7.5$                   | $(T2CDELAY + 1) * t_{c(VCLK)} + 7$                       |  |      |

| NO.              | PARAMETER  | MIN | TYP | MAX | UNIT |
|------------------|--|-----|-----|-----|------|
| 8 <sup>(4)</sup> | $t_{su}(SOMI-SPCL)M$ Setup time, SPISOMI before SPICLK low (clock polarity = 0)        | 5   |     |     | ns   |
|                  | $t_{su}(SOMI-SPCH)M$ Setup time, SPISOMI before SPICLK high (clock polarity = 1)       | 5   |     |     |      |
| 9 <sup>(4)</sup> | $t_h(SPCL-SOMI)M$ Hold time, SPISOMI data valid after SPICLK low (clock polarity = 0)  | 3   |     |     | ns   |
|                  | $t_h(SPCH-SOMI)M$ Hold time, SPISOMI data valid after SPICLK high (clock polarity = 1) | 3   |     |     |      |

- (1) The MASTER bit (SPIGCRx.0) is set and the CLOCK PHASE bit (SPIFMTx.16) is set ( where x = 0 or 1 ).
- (2)  $t_{c(MSS\_VCLK)}$  = main subsystem clock time =  $1 / f_{(MSS\_VCLK)}$ . For more details, see the [Technical Reference Manual](#).
- (3) When the SPI is in Controller mode, the following must be true: For PS values from 1 to 255:  $t_{c(SPC)M} \geq (PS + 1)t_{c(MSS\_VCLK)} \geq 25$  ns, where PS is the prescale value set in the SPIFMTx.[15:8] register bits. For PS values of 0:  $t_{c(SPC)M} = 2t_{c(MSS\_VCLK)} \geq 25$  ns.
- (4) The active edge of the SPICLK signal referenced is controlled by the CLOCK POLARITY bit (SPIFMTx.17).
- (5) C2TDELAY and T2CDELAY is programmed in the SPIDELAY register



**Figure 7-6. SPI Controller Mode External Timing (CLOCK PHASE = 1)**



**Figure 7-7. SPI Controller Mode Chip Select Timing (CLOCK PHASE = 1)**

### 7.10.3.3 SPI Peripheral Mode I/O Timings

#### 7.10.3.3.1 SPI Peripheral Mode Switching Parameters (SPICLK = input, SPISIMO = input, and SPISOMI = output) <sup>(1)</sup> <sup>(2)</sup> <sup>(3)</sup>

| NO.              | PARAMETER            |  | MIN | TYP | MAX | UNIT |
|------------------|----------------------|--|-----|-----|-----|------|
| 1                | $t_{c(SPC)}S$        | Cycle time, SPICLK <sup>(4)</sup>  | 25  |     |     | ns   |
| 2 <sup>(5)</sup> | $t_w(SPCH)S$         | Pulse duration, SPICLK high (clock polarity = 0)   | 10  |     |     | ns   |
|                  | $t_w(SPCL)S$         | Pulse duration, SPICLK low (clock polarity = 1)  | 10  |     |     |      |
| 3 <sup>(5)</sup> | $t_w(SPCL)S$         | Pulse duration, SPICLK low (clock polarity = 0)  | 10  |     |     | ns   |
|                  | $t_w(SPCH)S$         | Pulse duration, SPICLK high (clock polarity = 1)   | 10  |     |     |      |
| 4 <sup>(5)</sup> | $t_d(SPCH-SOMI)S$    | Delay time, SPISOMI valid after SPICLK high (clock polarity = 0)   |     |     | 10  | ns   |
|                  | $t_d(SPCL-SOMI)S$    | Delay time, SPISOMI valid after SPICLK low (clock polarity = 1)  |     |     | 10  |      |
| 5 <sup>(5)</sup> | $t_h(SPCH-SOMI)S$    | Hold time, SPISOMI data valid after SPICLK high (clock polarity = 0)   | 2   |     |     | ns   |
|                  | $t_h(SPCL-SOMI)S$    | Hold time, SPISOMI data valid after SPICLK low (clock polarity = 1)  | 2   |     |     |      |
| 4 <sup>(5)</sup> | $t_d(SPCH-SOMI)S$    | Delay time, SPISOMI valid after SPICLK high (clock polarity = 0; clock phase = 0) OR (clock polarity = 1; clock phase = 1)     |     |     | 10  | ns   |
|                  | $t_d(SPCL-SOMI)S$    | Delay time, SPISOMI valid after SPICLK low (clock polarity = 1; clock phase = 0) OR (clock polarity = 0; clock phase = 1)      |     |     | 10  |      |
| 5 <sup>(5)</sup> | $t_h(SPCH-SOMI)S$    | Hold time, SPISOMI data valid after SPICLK high (clock polarity = 0; clock phase = 0) OR (clock polarity = 1; clock phase = 1) | 2   |     |     | ns   |
|                  | $t_h(SPCL-SOMI)S$    | Hold time, SPISOMI data valid after SPICLK low (clock polarity = 1; clock phase = 0) OR (clock polarity = 0; clock phase = 1)  | 2   |     |     |      |
| 6 <sup>(5)</sup> | $t_{su}(SIMO-SPCL)S$ | Setup time, SPISIMO before SPICLK low (clock polarity = 0; clock phase = 0) OR (clock polarity = 1; clock phase = 1)           | 3   |     |     | ns   |
|                  | $t_{su}(SIMO-SPCH)S$ | Setup time, SPISIMO before SPICLK high (clock polarity = 1; clock phase = 0) OR (clock polarity = 0; clock phase = 1)          | 3   |     |     |      |
| 7 <sup>(5)</sup> | $t_h(SPCL-SIMO)S$    | Hold time, SPISIMO data valid after SPICLK low (clock polarity = 0; clock phase = 0) OR (clock polarity = 1; clock phase = 1)  | 1   |     |     | ns   |
|                  | $t_h(SPCL-SIMO)S$    | Hold time, SPISIMO data valid after SPICLK high (clock polarity = 1; clock phase = 0) OR (clock polarity = 0; clock phase = 1) | 1   |     |     |      |

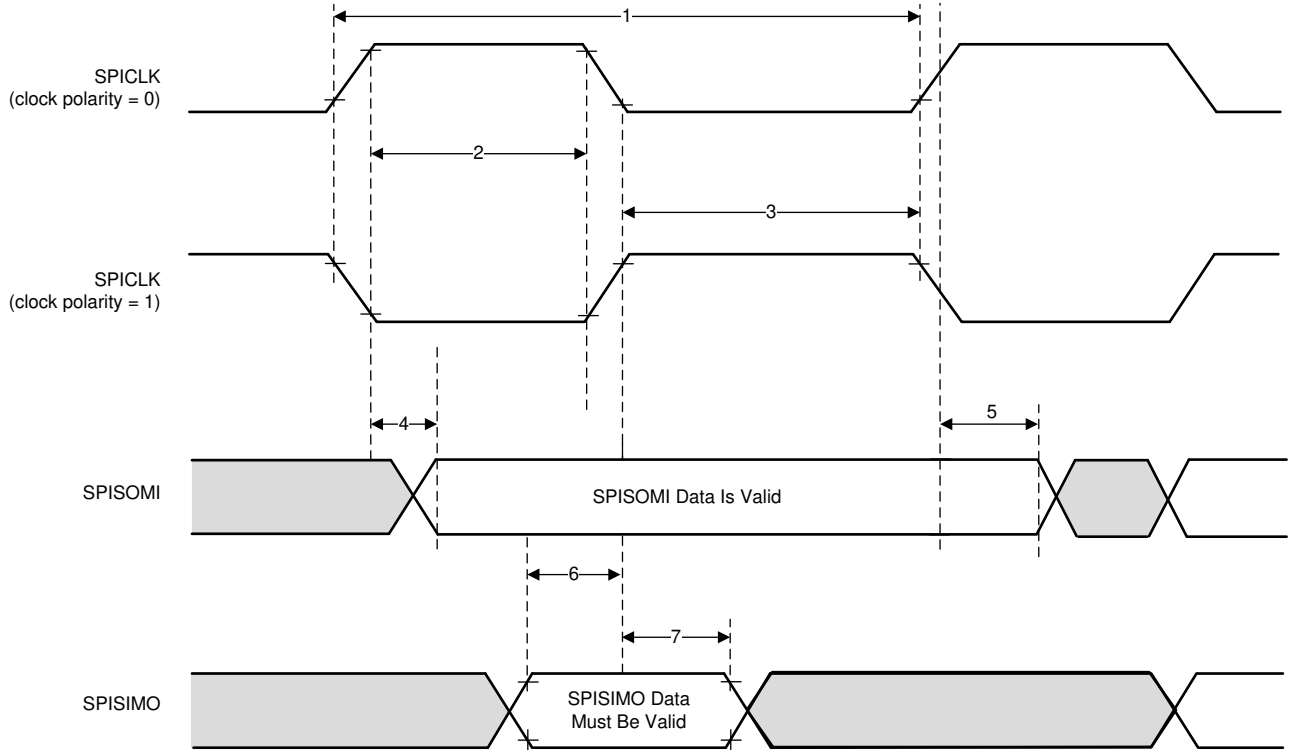
(1) The MASTER bit (SPIGCRx.0) is cleared ( where x = 0 or 1 ).

(2) The CLOCK PHASE bit (SPIFMTx.16) is either cleared or set for CLOCK PHASE = 0 or CLOCK PHASE = 1 respectively.

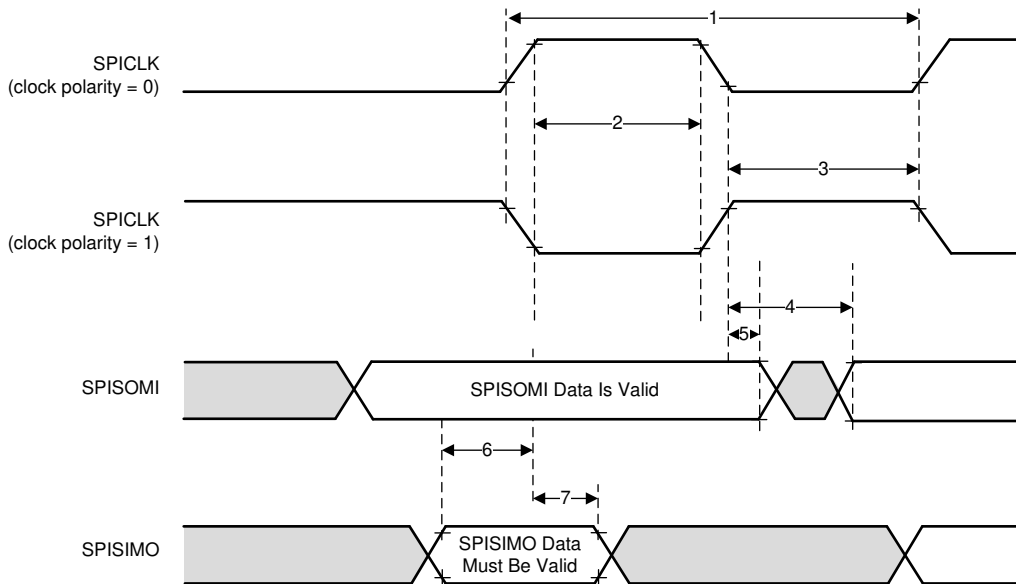
(3)  $t_{c(MSS\_VCLK)}$  = main subsystem clock time =  $1 / f_{(MSS\_VCLK)}$ . For more details, see the [Technical Reference Manual](#).

(4) When the SPI is in peripheral mode, the following must be true: For PS values from 1 to 255:  $t_{c(SPC)}S \geq (PS + 1)t_{c(MSS\_VCLK)} \geq 25$  ns, where PS is the prescale value set in the SPIFMTx.[15:8] register bits. For PS values of 0:  $t_{c(SPC)}S = 2t_{c(MSS\_VCLK)} \geq 25$  ns.

(5) The active edge of the SPICLK signal referenced is controlled by the CLOCK POLARITY bit (SPIFMTx.17).



**Figure 7-8. SPI peripheral Mode External Timing (CLOCK PHASE = 0)**

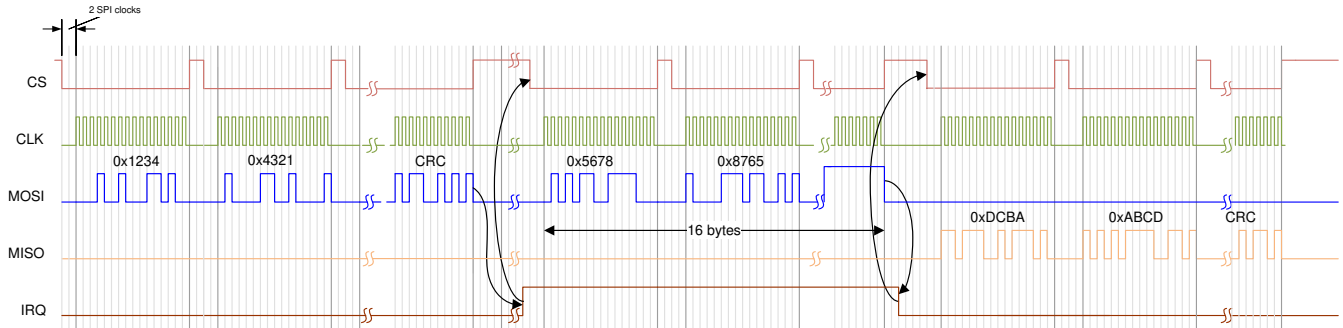


**Figure 7-9. SPI peripheral Mode External Timing (CLOCK PHASE = 1)**

**7.10.3.4 Typical Interface Protocol Diagram (Peripheral Mode)**

1. Host should ensure that there is a delay of two SPI clocks between CS going low and start of SPI clock.
2. Host should ensure that CS is toggled for every 16 bits of transfer through SPI.

Figure 7-10 shows the SPI communication timing of the typical interface protocol.



**Figure 7-10. SPI Communication**

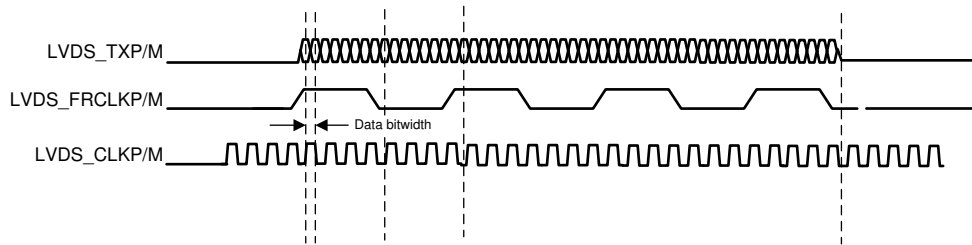


### 7.10.4 LVDS Interface Configuration

The supported AWR1843 LVDS lane configuration is two Data lanes (LVDS\_TXP/M), one Bit Clock lane (LVDS\_CLKP/M) and one Frame clock lane (LVDS\_FRCLKP/M). The LVDS interface is used for debugging. The LVDS interface supports the following data rates:

- 900 Mbps (450 MHz DDR Clock)
- 600 Mbps (300 MHz DDR Clock)
- 450 Mbps (225 MHz DDR Clock)
- 400 Mbps (200 MHz DDR Clock)
- 300 Mbps (150 MHz DDR Clock)
- 225 Mbps (112.5 MHz DDR Clock)
- 150 Mbps (75 MHz DDR Clock)

Note that the bit clock is in DDR format and hence the numbers of toggles in the clock is equivalent to data.

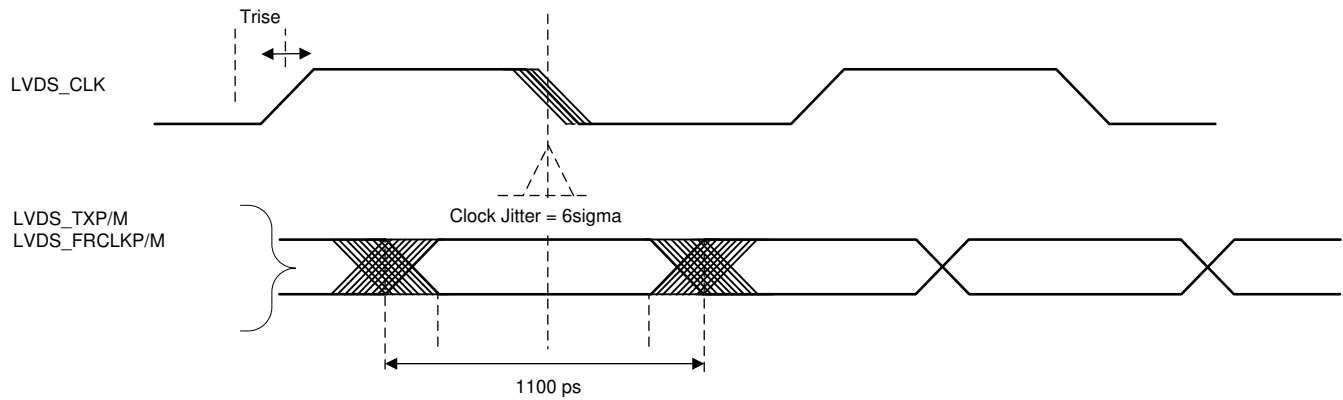


**Figure 7-11. LVDS Interface Lane Configuration And Relative Timings**

#### 7.10.4.1 LVDS Interface Timings

**Table 7-7. LVDS Electrical Characteristics**

| PARAMETER                   | TEST CONDITIONS  | MIN  | TYP | MAX  | UNIT |
|-----------------------------|--|------|-----|------|------|
| Duty Cycle Requirements     | max 1 pF lumped capacitive load on LVDS lanes                                  | 48%  |     | 52%  |      |
| Output Differential Voltage | peak-to-peak single-ended with 100 Ω resistive load between differential pairs | 250  |     | 450  | mV   |
| Output Offset Voltage       |  | 1125 |     | 1275 | mV   |
| Trise and Tfall             | 20%-80%, 900 Mbps  |      | 330 |      | ps   |
| Jitter (pk-pk)              | 900 Mbps   |      | 80  |      | ps   |



**Figure 7-12. Timing Parameters**

### 7.10.5 General-Purpose Input/Output

Section 7.10.5.1 lists the switching characteristics of output timing relative to load capacitance.

#### 7.10.5.1 Switching Characteristics for Output Timing versus Load Capacitance ( $C_L$ )

| PARAMETER <sup>(1) (2)</sup> |               | TEST CONDITIONS  | VIOIN = 1.8V  | VIOIN = 3.3V | UNIT |    |
|------------------------------|---------------|------------------|---------------|--------------|------|----|
| $t_r$                        | Max rise time | Slew control = 0 | $C_L = 20$ pF | 2.8          | 3.0  | ns |
|                              |               |                  | $C_L = 50$ pF | 6.4          | 6.9  |    |
|                              |               |                  | $C_L = 75$ pF | 9.4          | 10.2 |    |
| $t_f$                        | Max fall time | Slew control = 0 | $C_L = 20$ pF | 2.8          | 2.8  | ns |
|                              |               |                  | $C_L = 50$ pF | 6.4          | 6.6  |    |
|                              |               |                  | $C_L = 75$ pF | 9.4          | 9.8  |    |
| $t_r$                        | Max rise time | Slew control = 1 | $C_L = 20$ pF | 3.3          | 3.3  | ns |
|                              |               |                  | $C_L = 50$ pF | 6.7          | 7.2  |    |
|                              |               |                  | $C_L = 75$ pF | 9.6          | 10.5 |    |
| $t_f$                        | Max fall time | Slew control = 1 | $C_L = 20$ pF | 3.1          | 3.1  | ns |
|                              |               |                  | $C_L = 50$ pF | 6.6          | 6.6  |    |
|                              |               |                  | $C_L = 75$ pF | 9.6          | 9.6  |    |

- (1) Slew control, which is configured by PADxx\_CFG\_REG, changes behavior of the output driver (faster or slower output slew rate).
- (2) The rise/fall time is measured as the time taken by the signal to transition from 10% and 90% of VIOIN voltage.

### 7.10.6 Controller Area Network Interface (DCAN)

The DCAN supports the CAN 2.0B protocol standard and uses a serial, multi-commander communication protocol that efficiently supports distributed real-time control with robust communication rates of up to 1 Mbps. The DCAN is ideal for applications operating in noisy and harsh environments that require reliable serial communication or multiplexed wiring.

The DCAN has the following features:

- Supports CAN protocol version 2.0 part A, B
- Bit rates up to 1 Mbps
- Configurable Message objects
- Individual identifier masks for each message object
- Programmable FIFO mode for message objects
- Suspend mode for debug support
- Programmable loop-back modes for self-test operation
- Direct access to Message RAM in test mode
- Supports two interrupt lines - Level 0 and Level 1
- Automatic Message RAM initialization

#### 7.10.6.1 Dynamic Characteristics for the DCANx TX and RX Pins

| PARAMETER        |  | MIN | TYP | MAX | UNIT |
|------------------|--|-----|-----|-----|------|
| $t_{d(CAN\_tx)}$ | Delay time, transmit shift register to CAN_tx pin <sup>(1)</sup> |     |     | 15  | ns   |
| $t_{d(CAN\_rx)}$ | Delay time, CAN_rx pin to receive shift register <sup>(1)</sup>  |     |     | 10  | ns   |

(1) These values do not include rise/fall times of the output buffer.

### 7.10.7 Controller Area Network - Flexible Data-rate (CAN-FD)

The CAN-FD module supports both classic CAN and CAN FD (CAN with Flexible Data-Rate) specifications. CAN FD feature allows high throughput and increased payload per data frame. The classic CAN and CAN FD devices can coexist on the same network without any conflict.

The CAN-FD has the following features:

- Conforms with CAN Protocol 2.0 A, B and ISO 11898-1
- Full CAN FD support (up to 64 data bytes per frame)
- AUTOSAR and SAE J1939 support
- Up to 32 dedicated Transmit Buffers
- Configurable Transmit FIFO, up to 32 elements
- Configurable Transmit Queue, up to 32 elements
- Configurable Transmit Event FIFO, up to 32 elements
- Up to 64 dedicated Receive Buffers
- Two configurable Receive FIFOs, up to 64 elements each
- Up to 128 11-bit filter elements
- Internal Loopback mode for self-test
- Mask-able interrupts, two interrupt lines
- Two clock domains (CAN clock / Host clock)
- Parity / ECC support - Message RAM single error correction and double error detection (SECDED) mechanism
- Full Message Memory capacity (4352 words).

#### 7.10.7.1 Dynamic Characteristics for the CANx TX and RX Pins

| PARAMETER            |   | MIN | TYP | MAX | UNIT |
|----------------------|---|-----|-----|-----|------|
| $t_{d(CAN\_FD\_tx)}$ | Delay time, transmit shift register to CAN_FD_tx pin <sup>(1)</sup> |     |     | 15  | ns   |
| $t_{d(CAN\_FD\_rx)}$ | Delay time, CAN_FD_rx pin to receive shift register <sup>(1)</sup>  |     |     | 10  | ns   |

(1) These values do not include rise/fall times of the output buffer.

### 7.10.8 Serial Communication Interface (SCI)

The SCI has the following features:

- Standard universal asynchronous receiver-transmitter (UART) communication
- Standard non-return to zero (NRZ) format
- Double-buffered receive and transmit functions
- Asynchronous or iso-synchronous communication modes with no CLK pin
- Capability to use Direct Memory Access (DMA) for transmit and receive data
- Two external pins: RS232\_RX and RS232\_TX

#### 7.10.8.1 SCI Timing Requirements

|         |                              | MIN | TYP   | MAX | UNIT |
|---------|------------------------------|-----|-------|-----|------|
| f(baud) | Supported baud rate at 20 pF |     | 921.6 |     | kHz  |

### 7.10.9 Inter-Integrated Circuit Interface (I2C)

The inter-integrated circuit (I2C) module is a multicontroller communication module providing an interface between devices compliant with Philips Semiconductor I2C-bus specification version 2.1 and connected by an I<sup>2</sup>C-bus™. This module will support any target or controller I2C compatible device.

The I2C has the following features:

- Compliance to the Philips I2C bus specification, v2.1 (The I2C Specification, Philips document number 9398 393 40011)
  - Bit/Byte format transfer
  - 7-bit and 10-bit device addressing modes
  - General call
  - START byte
  - Multi-controller transmitter/ target receiver mode
  - Multi-controller receiver/ target transmitter mode
  - Combined controller transmit/receive and receive/transmit mode
  - Transfer rates of 100 kbps up to 400 kbps (Phillips fast-mode rate)
- Free data format
- Two DMA events (transmit and receive)
- DMA event enable/disable capability
- Module enable/disable capability
- The SDA and SCL are optionally configurable as general purpose I/O
- Slew rate control of the outputs
- Open drain control of the outputs
- Programmable pullup/pulldown capability on the inputs
- Supports Ignore NACK mode

---

#### Note

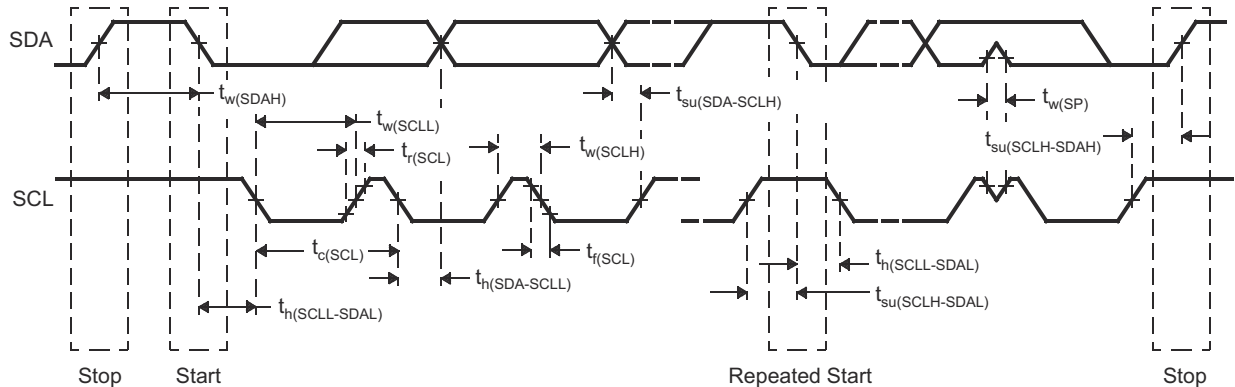
This I2C module does not support:

- High-speed (HS) mode
  - C-bus compatibility mode
  - The combined format in 10-bit address mode (the I2C sends the target address second byte every time it sends the target address first byte)
-

### 7.10.9.1 I2C Timing Requirements <sup>(1)</sup>

|                          |  | STANDARD MODE |                     | FAST MODE |     | UNIT          |
|--------------------------|--|---------------|---------------------|-----------|-----|---------------|
|                          |  | MIN           | MAX                 | MIN       | MAX |               |
| $t_{c(SCL)}$             | Cycle time, SCL  | 10            |                     | 2.5       |     | $\mu\text{s}$ |
| $t_{su(SCLH-SDAL)}$      | Setup time, SCL high before SDA low<br>(for a repeated START condition)          | 4.7           |                     | 0.6       |     | $\mu\text{s}$ |
| $t_{h(SCLL-SDAL)}$       | Hold time, SCL low after SDA low<br>(for a START and a repeated START condition) | 4             |                     | 0.6       |     | $\mu\text{s}$ |
| $t_{w(SCLL)}$            | Pulse duration, SCL low  | 4.7           |                     | 1.3       |     | $\mu\text{s}$ |
| $t_{w(SCLH)}$            | Pulse duration, SCL high   | 4             |                     | 0.6       |     | $\mu\text{s}$ |
| $t_{su(SDA-SCLH)}$       | Setup time, SDA valid before SCL high  | 250           |                     | 100       |     | $\mu\text{s}$ |
| $t_{h(SCLL-SDA)}$        | Hold time, SDA valid after SCL low   | 0             | 3.45 <sup>(1)</sup> | 0         | 0.9 | $\mu\text{s}$ |
| $t_{w(SDAH)}$            | Pulse duration, SDA high between STOP and START<br>conditions                    | 4.7           |                     | 1.3       |     | $\mu\text{s}$ |
| $t_{su(SCLH-SDAH)}$      | Setup time, SCL high before SDA high<br>(for STOP condition)                     | 4             |                     | 0.6       |     | $\mu\text{s}$ |
| $t_{w(SP)}$              | Pulse duration, spike (must be suppressed)                                       |               |                     | 0         | 50  | ns            |
| $C_b$ <sup>(2) (3)</sup> | Capacitive load for each bus line  |               | 400                 |           | 400 | pF            |

- (1) The I2C pins SDA and SCL do not feature fail-safe I/O buffers. These pins could potentially draw current when the device is powered down.
- (2) The maximum  $t_{h(SDA-SCLL)}$  for I2C bus devices has only to be met if the device does not stretch the low period ( $t_{w(SCLL)}$ ) of the SCL signal.
- (3)  $C_b$  = total capacitance of one bus line in pF. If mixed with fast-mode devices, faster fall-times are allowed.



**Figure 7-13. I2C Timing Diagram**

#### Note

- A device must internally provide a hold time of at least 300 ns for the SDA signal (referred to the  $V_{IHmin}$  of the SCL signal) to bridge the undefined region of the falling edge of SCL.
- The maximum  $t_{h(SDA-SCLL)}$  has only to be met if the device does not stretch the LOW period ( $t_{w(SCLL)}$ ) of the SCL signal. E.A Fast-mode I2C-bus device can be used in a Standard-mode I2C-bus system, but the requirement  $t_{su(SDA-SCLH)} \geq 250$  ns must then be met. This will automatically be the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, it must output the next data bit to the SDA line  $t_{rmax} + t_{su(SDA-SCLH)}$ .

### 7.10.10 Quad Serial Peripheral Interface (QSPI)

The quad serial peripheral interface (QSPI) module is a kind of SPI module that allows single, dual, or quad read access to external SPI devices. This module has a memory mapped register interface, which provides a direct interface for accessing data from external SPI devices and thus simplifying software requirements. The QSPI works as a controller only. The QSPI in the device is primarily intended for fast booting from quad-SPI flash memories.

The QSPI supports the following features:

- Programmable clock divider
- Six-pin interface
- Programmable length (from 1 to 128 bits) of the words transferred
- Programmable number (from 1 to 4096) of the words transferred
- Support for 3-, 4-, or 6-pin SPI interface
- Optional interrupt generation on word or frame (number of words) completion
- Programmable delay between chip select activation and output data from 0 to 3 QSPI clock cycles

Section 7.10.10.2 and Section 7.10.10.3 assume the operating conditions stated in Section 7.10.10.1.

#### 7.10.10.1 QSPI Timing Conditions

|                   |                         | MIN | TYP | MAX | UNIT |
|-------------------|-------------------------|-----|-----|-----|------|
| Input Conditions  |                         |     |     |     |      |
| $t_R$             | Input rise time         | 1   |     | 3   | ns   |
| $t_F$             | Input fall time         | 1   |     | 3   | ns   |
| Output Conditions |                         |     |     |     |      |
| $C_{LOAD}$        | Output load capacitance | 2   |     | 15  | pF   |

#### 7.10.10.2 Timing Requirements for QSPI Input (Read) Timings <sup>(1) (2)</sup>

|                  |   | MIN                    | TYP | MAX | UNIT |
|------------------|---|------------------------|-----|-----|------|
| $t_{su(D-SCLK)}$ | Setup time, d[3:0] valid before falling sclk edge (Q12)           | 7.3                    |     |     | ns   |
| $t_{h(SCLK-D)}$  | Hold time, d[3:0] valid after falling sclk edge (Q13)             | 1.5                    |     |     | ns   |
| $t_{su(D-SCLK)}$ | Setup time, final d[3:0] bit valid before final falling sclk edge | 7.3 – P <sup>(3)</sup> |     |     | ns   |
| $t_{h(SCLK-D)}$  | Hold time, final d[3:0] bit valid after final falling sclk edge   | 1.5 + P <sup>(3)</sup> |     |     | ns   |

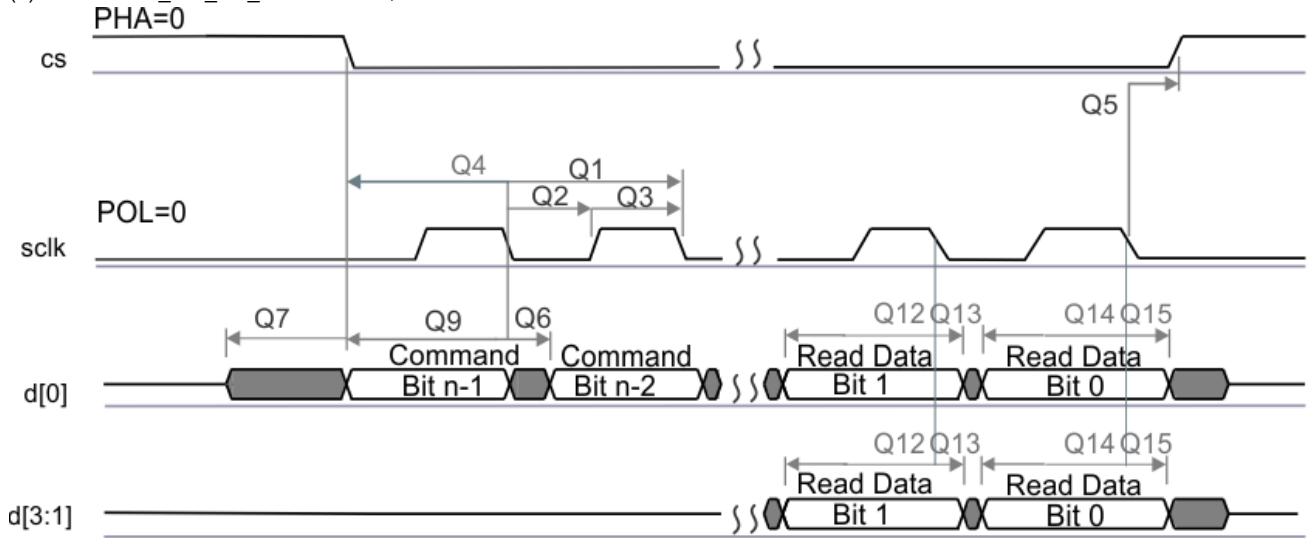
- (1) Clock Mode 0 (clk polarity = 0 ; clk phase = 0 ) is the mode of operation.
- (2) The Device captures data on the falling clock edge in Clock Mode 0, as opposed to the traditional rising clock edge. Although non-standard, the falling-edge-based setup and hold time timings have been designed to be compatible with standard SPI devices that launch data on the falling edge in Clock Mode 0.
- (3) P = SCLK period in ns.

**7.10.10.3 QSPI Switching Characteristics**

| NO. | PARAMETER          |   | MIN                 | TYP | MAX                  | UNIT |
|-----|--------------------|---|---------------------|-----|----------------------|------|
| Q1  | $t_{c(SCLK)}$      | Cycle time, sclk  | 25                  |     |                      | ns   |
| Q2  | $t_{w(SCLKL)}$     | Pulse duration, sclk low  | $0.5 * P - 3^{(1)}$ |     |                      | ns   |
| Q3  | $t_{w(SCLKH)}$     | Pulse duration, sclk high   | $0.5 * P - 3$       |     |                      | ns   |
| Q4  | $t_{d(CS-SCLK)}$   | Delay time, sclk falling edge to cs active edge                                 | $-M * P - 1^{(2)}$  |     | $-M * P + 2.5^{(2)}$ | ns   |
| Q5  | $t_{d(SCLK-CS)}$   | Delay time, sclk falling edge to cs inactive edge                               | $N * P - 1^{(2)}$   |     | $N * P + 2.5^{(2)}$  | ns   |
| Q6  | $t_{d(SCLK-D1)}$   | Delay time, sclk falling edge to d[0] transition                                | -3.5                |     | 7                    | ns   |
| Q7  | $t_{ena(CS-D1LZ)}$ | Enable time, cs active edge to d[0] driven (lo-z)                               | $-P - 4^{(2)}$      |     | $-P + 1^{(2)}$       | ns   |
| Q8  | $t_{dis(CS-D1Z)}$  | Disable time, cs active edge to d[0] tri-stated (hi-z)                          | $-P - 4^{(2)}$      |     | $-P + 1^{(2)}$       | ns   |
| Q9  | $t_{d(SCLK-D1)}$   | Delay time, sclk first falling edge to first d[1] transition (for PHA = 0 only) | $-3.5 - P^{(2)}$    |     | $7 - P^{(2)}$        | ns   |

(1) P = SCLK period in ns.

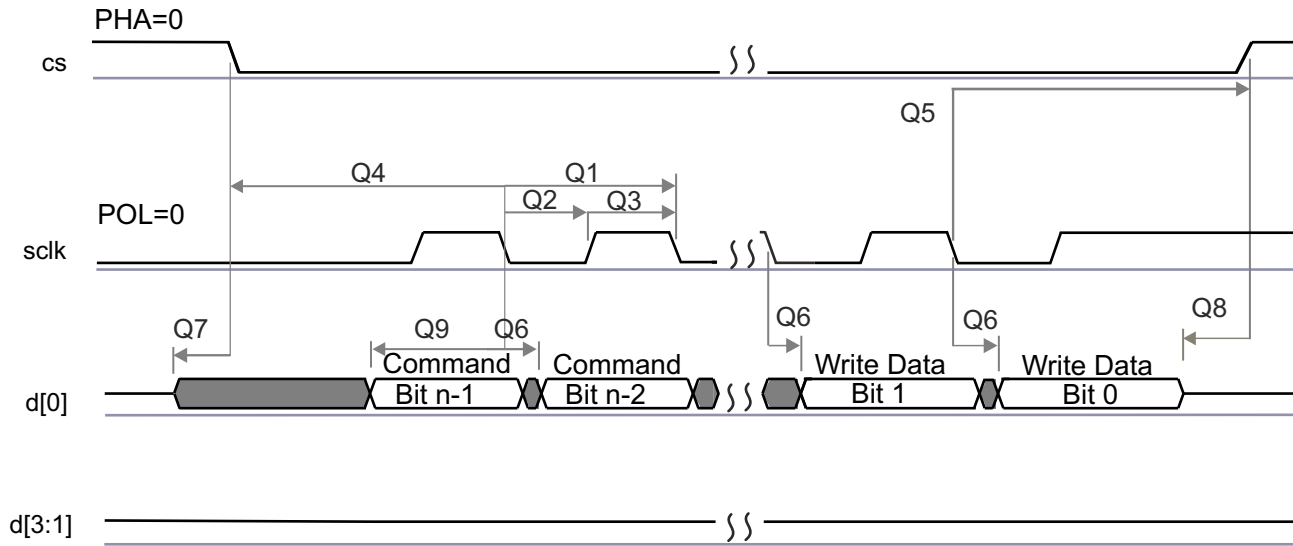
(2) M = QSPI\_SPI\_DC\_REG.DDx + 1, N = 2



SPRS85v TIMING OSPI1 02

**Figure 7-14. QSPI Read (Clock Mode 0)**





SPRS85v\_TIMING\_OSP11\_04

Figure 7-15. QSPI Write (Clock Mode 0)

### 7.10.11 ETM Trace Interface

Section 7.10.11.2 and 1 assume the recommended operating conditions stated in Section 7.10.11.1.

#### 7.10.11.1 ETMTRACE Timing Conditions

|                   |                         | MIN | TYP | MAX | UNIT |
|-------------------|-------------------------|-----|-----|-----|------|
| Output Conditions |                         |     |     |     |      |
| C <sub>LOAD</sub> | Output load capacitance | 2   |     | 20  | pF   |

#### 7.10.11.2 ETM TRACE Switching Characteristics

| NO. | PARAMETER   | MIN | TYP | MAX | UNIT |
|-----|---|-----|-----|-----|------|
| 1   | t <sub>cyc(ETM)</sub> Cycle time, TRACECLK period   | 20  |     |     | ns   |
| 2   | t <sub>h(ETM)</sub> Pulse Duration, TRACECLK High   | 9   |     |     | ns   |
| 3   | t <sub>l(ETM)</sub> Pulse Duration, TRACECLK Low  | 9   |     |     | ns   |
| 4   | t <sub>r(ETM)</sub> Clock and data rise time  |     |     | 3.3 | ns   |
| 5   | t <sub>f(ETM)</sub> Clock and data fall time  |     |     | 3.3 | ns   |
| 6   | t <sub>d(ETMTRACE CLKH-ETMDATAV)</sub> Delay time, ETM trace clock high to ETM data valid | 1   |     | 7   | ns   |
| 7   | t <sub>d(ETMTRACE CLKL-ETMDATAV)</sub> Delay time, ETM trace clock low to ETM data valid  | 1   |     | 7   | ns   |

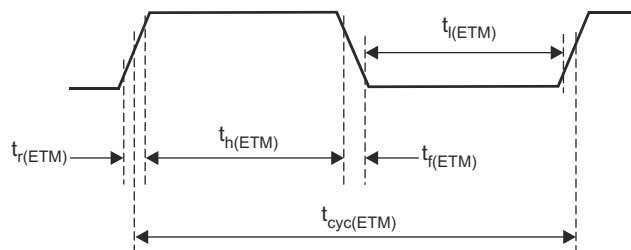


Figure 7-16. ETMTRACECLKOUT Timing

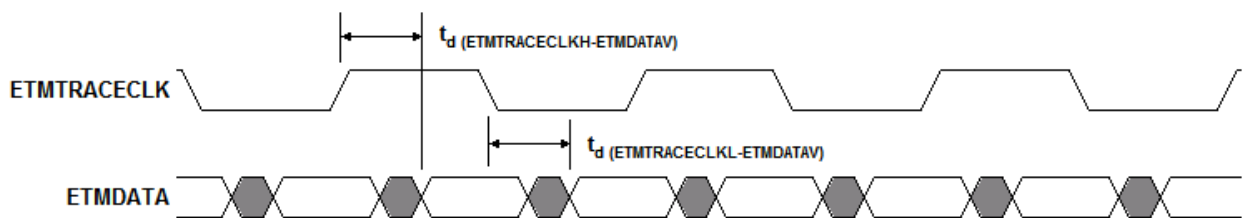


Figure 7-17. ETMDATA Timing

### 7.10.12 Data Modification Module (DMM)

A Data Modification Module (DMM) gives the ability to write external data into the device memory.

The DMM has the following features:

- Acts as a bus controller, thus enabling direct writes to the 4GB address space without CPU intervention
- Writes to memory locations specified in the received packet (leverages packets defined by trace mode of the RAM trace port [RTP] module)
- Writes received data to consecutive addresses, which are specified by the DMM (leverages packets defined by direct data mode of RTP module)
- Configurable port width (1, 2, 4, 8, 16 pins)
- Up to 65 Mbit/s pin data rate

#### 7.10.12.1 DMM Timing Requirements

|                |   | MIN  | TYP | MAX | UNIT |
|----------------|---|------|-----|-----|------|
| $t_{cyc(DMM)}$ | Clock period                                    | 15.4 |     |     | ns   |
| $t_R$          | Clock rise time                                 | 1    |     | 3   | ns   |
| $t_F$          | Clock fall time                                 | 1    |     | 3   | ns   |
| $t_h(DMM)$     | High pulse width                                | 6    |     |     | ns   |
| $t_l(DMM)$     | Low pulse width                                 | 6    |     |     | ns   |
| $t_{ssu(DMM)}$ | SYNC active to clk falling edge setup time      | 2    |     |     | ns   |
| $t_{sh(DMM)}$  | DMM clk falling edge to SYNC deactive hold time | 3    |     |     | ns   |
| $t_{dsu(DMM)}$ | DATA to DMM clk falling edge setup time         | 2    |     |     | ns   |
| $t_{dh(DMM)}$  | DMM clk falling edge to DATA hold time          | 3    |     |     | ns   |

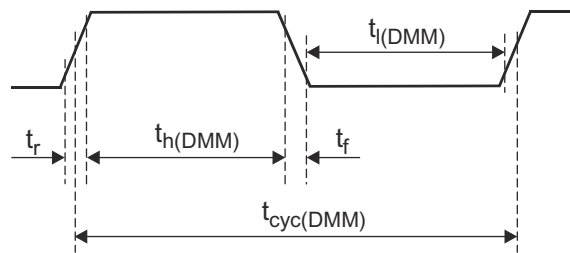


Figure 7-18. DMMCLK Timing

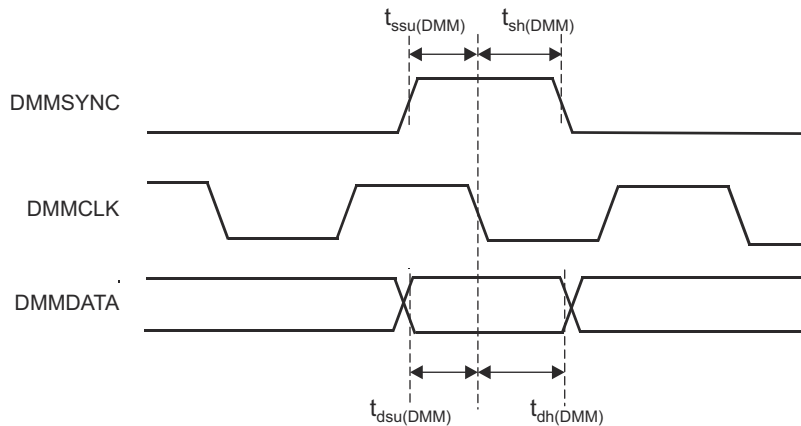


Figure 7-19. DMMDATA Timing

### 7.10.13 JTAG Interface

Section 7.10.13.2 and Section 7.10.13.3 assume the operating conditions stated in Section 7.10.13.1.

#### 7.10.13.1 JTAG Timing Conditions

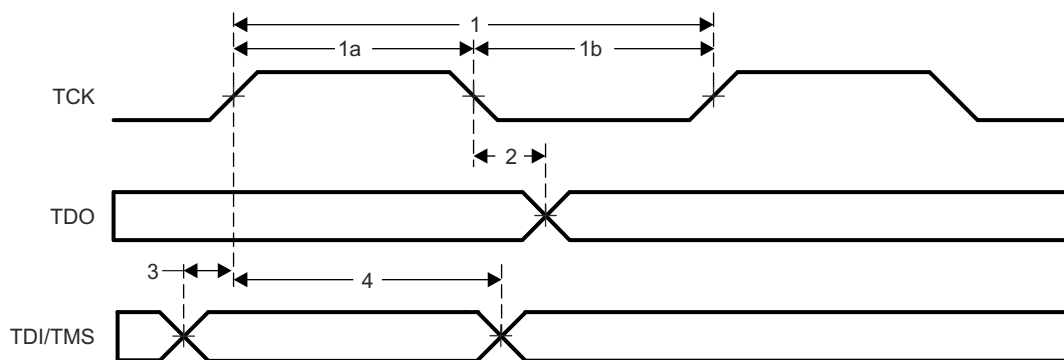
|                   |                         | MIN | TYP | MAX | UNIT |
|-------------------|-------------------------|-----|-----|-----|------|
| Input Conditions  |                         |     |     |     |      |
| $t_R$             | Input rise time         | 1   |     | 3   | ns   |
| $t_F$             | Input fall time         | 1   |     | 3   | ns   |
| Output Conditions |                         |     |     |     |      |
| $C_{LOAD}$        | Output load capacitance | 2   |     | 15  | pF   |

#### 7.10.13.2 Timing Requirements for IEEE 1149.1 JTAG

| NO. | PARAMETER         |   | MIN   | TYP | MAX | UNIT |
|-----|-------------------|---|-------|-----|-----|------|
| 1   | $t_c(TCK)$        | Cycle time TCK                          | 66.66 |     |     | ns   |
| 1a  | $t_w(TCKH)$       | Pulse duration TCK high (40% of $t_c$ ) | 26.67 |     |     | ns   |
| 1b  | $t_w(TCKL)$       | Pulse duration TCK low(40% of $t_c$ )   | 26.67 |     |     | ns   |
| 3   | $t_{su}(TDI-TCK)$ | Input setup time TDI valid to TCK high  | 2.5   |     |     | ns   |
|     | $t_{su}(TMS-TCK)$ | Input setup time TMS valid to TCK high  | 2.5   |     |     | ns   |
| 4   | $t_h(TCK-TDI)$    | Input hold time TDI valid from TCK high | 18    |     |     | ns   |
|     | $t_h(TCK-TMS)$    | Input hold time TMS valid from TCK high | 18    |     |     | ns   |

#### 7.10.13.3 Switching Characteristics Over Recommended Operating Conditions for IEEE 1149.1 JTAG

| NO. | PARAMETER        |                                  | MIN | TYP | MAX | UNIT |
|-----|------------------|----------------------------------|-----|-----|-----|------|
| 2   | $t_d(TCKL-TDOV)$ | Delay time, TCK low to TDO valid | 0   |     | 25  | ns   |



SPRS91v\_JTAG\_01

Figure 7-20. JTAG Timing

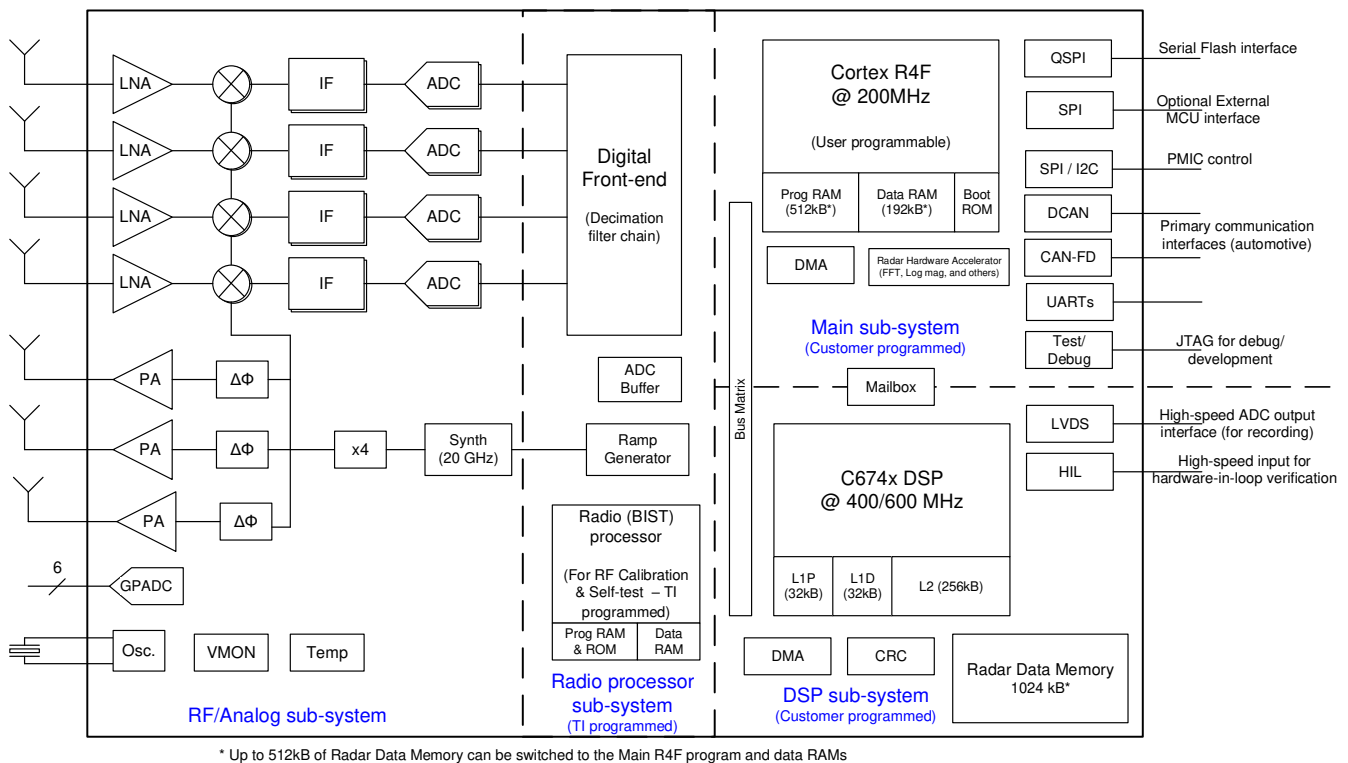
## 8 Detailed Description

### 8.1 Overview

The AWR1843 device includes the entire Millimeter Wave blocks and analog baseband signal chain for two transmitters and four receivers, as well as a customer-programmable MCU. This device is applicable as a radar-on-a-chip in use-cases with modest requirements for memory, processing capacity, and application code size. These could be cost-sensitive automotive applications that are evolving from 24 GHz narrowband implementation and some emerging simple ultra-short-range radar applications. Typical application examples for this device include basic Blind Spot Detect, Parking Assist, and so forth.

In terms of scalability, the AWR1843 device could be paired with a low-end external MCU, to address more complex applications that might require additional memory for larger application software footprint and faster interfaces. Because the AWR1843 device also provides high speed data interfaces like Serial-LVDS, it is suitable for interfacing with more capable external processing blocks. Here system designers can choose the AWR1843 to provide raw ADC data.

### 8.2 Functional Block Diagram



**Figure 8-1. Functional Block Diagram**

## 8.3 Subsystems

### 8.3.1 RF and Analog Subsystem

The RF and analog subsystem includes the RF and analog circuitry – namely, the synthesizer, PA, LNA, mixer, IF, and ADC. This subsystem also includes the crystal oscillator and temperature sensors. The three transmit channels can be operated up to a maximum of two at a time (simultaneously) for transmit beamforming purpose as required; whereas the four receive channels can all be operated simultaneously.

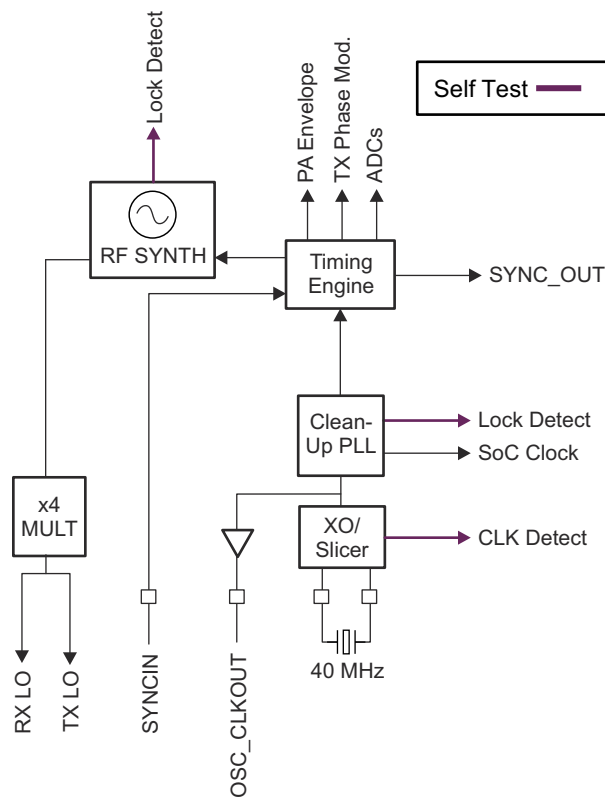
### 8.3.1.1 Clock Subsystem

The AWR1843 clock subsystem generates 76 to 81 GHz from an input reference of 40-MHz crystal. It has a built-in oscillator circuit followed by a clean-up PLL and a RF synthesizer circuit. The output of the RF synthesizer is then processed by an X4 multiplier to create the required frequency in the 76 to 81 GHz spectrum. The RF synthesizer output is modulated by the timing engine block to create the required waveforms for effective sensor operation.

The clean-up PLL also provides a reference clock for the host processor after system wakeup.

The clock subsystem also has built-in mechanisms for detecting the presence of a crystal and monitoring the quality of the generated clock.

Figure 8-2 describes the clock subsystem.



**Figure 8-2. Clock Subsystem**

### 8.3.1.2 Transmit Subsystem

The AWR1843 transmit subsystem consists of three parallel transmit chains, each with independent phase and amplitude control. All three transmitters can be used simultaneously. For AWR1843, additional phase shifters are associated with Tx channels, and these can be programmed on a per chirp basis.

Each transmit chain can deliver a maximum of 12 dBm at the antenna port on the PCB. The transmit chains also support programmable backoff for system optimization.

Figure 8-3 describes the transmit subsystem.

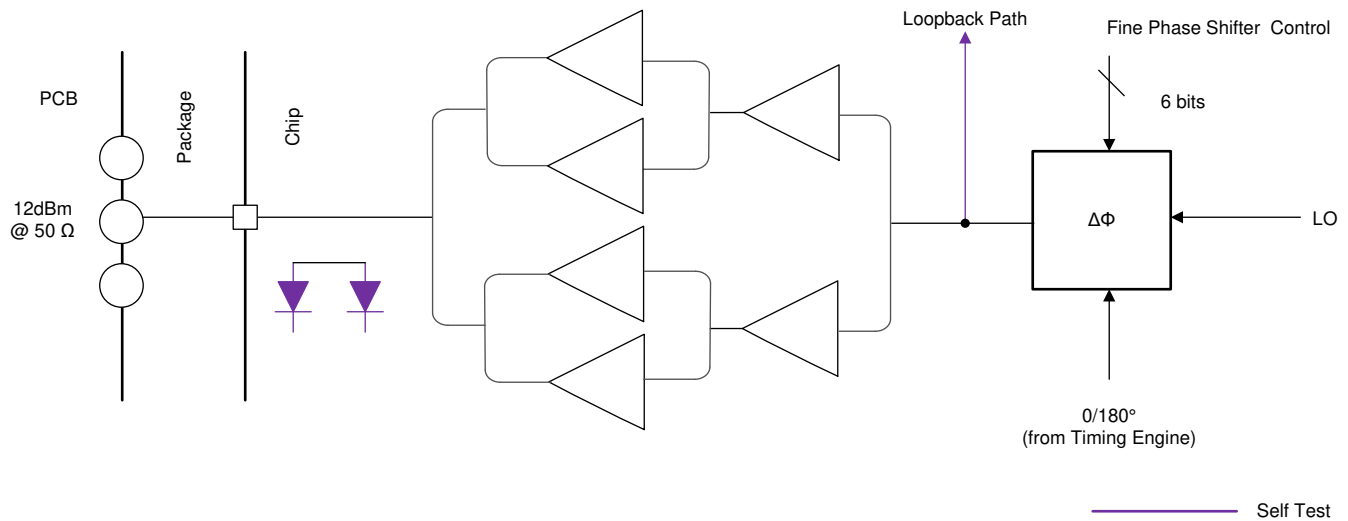


Figure 8-3. Transmit Subsystem (Per Channel)

### 8.3.1.3 Receive Subsystem

The AWR1843 receive subsystem consists of four parallel channels. A single receive channel consists of an LNA, mixer, IF filtering, ADC conversion, and decimation. All four receive channels can be operational at the same time an individual power-down option is also available for system optimization.

Unlike conventional real-only receivers, the AWR1843 device supports a complex baseband architecture, which uses quadrature mixer and dual IF and ADC chains to provide complex I and Q outputs for each receiver channel. The AWR1843 is targeted for fast chirp systems. The band-pass IF chain has configurable lower cutoff frequencies above 175 kHz and can support bandwidths up to 10 MHz.

Figure 8-4 describes the receive subsystem.

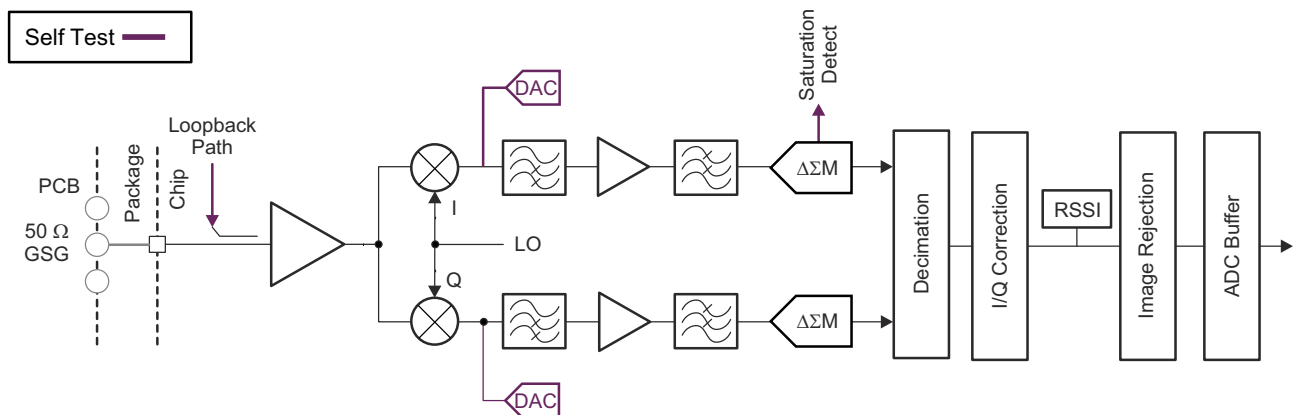
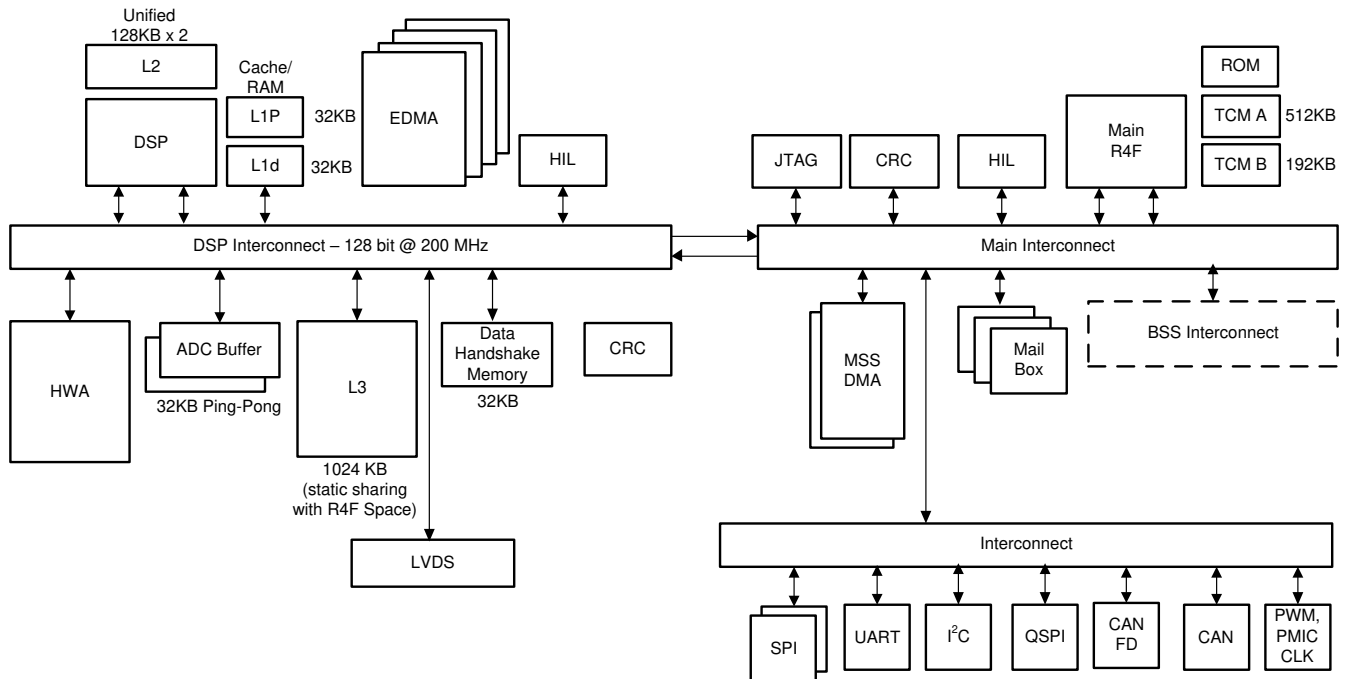


Figure 8-4. Receive Subsystem (Per Channel)



### 8.3.2 Processor Subsystem



**Figure 8-5. Processor Subsystem**

Figure 8-5 shows the block diagram for customer programmable processor subsystems in the AWR1843 device. At a high level there are two customer programmable subsystems, as shown separated by a dotted line in the diagram. Left hand side shows the DSP Subsystem which contains TI's high-performance C674x DSP, a high-bandwidth interconnect for high performance (128-bit, 200MHz), and associated peripherals – four DMAs for data transfer. LVDS interface for Measurement data output, L3 Radar data cube memory, ADC buffers, CRC engine, and data handshake memory (additional memory provided on interconnect).

The right side of the diagram shows the Main subsystem. Main subsystem as name suggests is the brain of the device and controls all the device peripherals and house-keeping activities of the device. Main subsystem contains Cortex-R4F (Main R4F) processor and associated peripherals and house-keeping components such as DMAs, CRC and Peripherals (I<sup>2</sup>C, UART, SPIs, CAN, PMIC clocking module, PWM, and others) connected to Main Interconnect through Peripheral Central Resource (PCR interconnect).

Details of the DSP CPU core can be found at <https://www.ti.com/product/TMS320C6748>.

HIL module is shown in both the subsystems and can be used to perform the radar operations feeding the captured data from outside into the device without involving the RF subsystem. HIL on Main SS is for controlling the configuration and HIL on DSPSS for high speed ADC data input to the device. Both HIL modules uses the same IOs on the device, one additional IO (DMM\_MUX\_IN) allows selecting either of the two.

### 8.3.3 Automotive Interface

The AWR1843 communicates with the automotive network over the following main interfaces:

- CAN and CAN-FD

### 8.3.4 Main Subsystem Cortex-R4F Memory Map

Table 8-1 shows the main subsystem, Cortex-R4F memory map.

**Note**

There are separate Cortex-R4F addresses and DMA MSS addresses for the main subsystem. See the [Technical Reference Manual](#) for a complete list.

**Table 8-1. Main Subsystem, Cortex-R4F Memory Map**

| NAME                                      | FRAME ADDRESS (HEX) |                                 | SIZE    | DESCRIPTION                                      |
|---|---------------------|---------------------------------|---------|--|
|   | START               | END                             |         |  |
| <b>CPU Tightly-Coupled Memories</b>       |                     |                                 |         |  |
| TCMA ROM                                  | 0x0000_0000         | 0x0001_FFFF                     | 128 KiB | Program ROM                                      |
| TCM RAM-A                                 | 0x0020_0000         | 0x0023_FFFF (or<br>0x0027_FFFF) | 512 KiB | 256/512KB based on variant                       |
| TCM RAM-B                                 | 0x0800_0000         | 0x0802_FFFF                     | 192 KB  | Data RAM   |
| <b>S/W Scratch Pad Memory</b>             |                     |                                 |         |  |
| SW_Buffer                                 | 0x0C20_0000         | 0x0C20_1FFF                     | 8 KB    | S/W Scratchpad memory                            |
| <b>System Peripherals</b>                 |                     |                                 |         |  |
| Mail Box<br>MSS<->RADARSS                 | 0xF060_1000         | 0xF060_17FF                     | 2 KB    | RADARSS to MSS mailbox memory space              |
|   | 0xF060_2000         | 0xF060_27FF                     |         | MSS to RADARSS mailbox memory space              |
|   | 0xF060_8000         | 0xF060_80FF                     | 188 B   | MSS to RADARSS mailbox Configuration registers   |
|   | 0xF060_8060         | 0xF060_86FF                     |         | RADARSS to MSS mailbox Configuration registers   |
| Mail Box<br>MSS<->DSPSS                   | 0xF060_4000         | 0xF060_47FF                     | 2 KB    | DSPSS to MSS mailbox memory space                |
|   | 0xF060_5000         | 0xF060_57FF                     |         | MSS to DSPSS mailbox memory space                |
|   | 0xF060_8400         | 0xF060_84FF                     | 188 B   | MSS to DSPSS mailbox Configuration registers     |
|   | 0xF060_8300         | 0xF060_83FF                     |         | DSPSS to MSS mailbox Configuration registers     |
| Mail Box<br>RADARSS<-><br>DSPSS           | 0xF060_6000         | 0xF060_67FF                     | 2 KB    | RADARSS to DSPSS mailbox memory space            |
|   | 0xF060_7000         | 0xF060_7FFF                     |         | DSPSS to RADARSS mailbox memory space            |
|   | 0xF060_8200         | 0xF060_82FF                     | 188 B   | RADARSS to DSPSS mailbox Configuration registers |
|   | 0xF060_8100         | 0xF060_81FF                     |         | DSPSS to RADARSS mailbox Configuration registers |
| PRCM and Control<br>Module                | 0xFFFF_E100         | 0xFFFF_E2FF                     | 756 B   | TOP Level Reset, Clock management registers      |
|   | 0xFFFF_FF00         | 0xFFFF_FFFF                     | 256 B   | MSS Reset, Clock management registers            |
|   | 0xFFFF_EA00         | 0xFFFF_EBFF                     | 512 KB  | IO Mux module registers                          |
|   | 0xFFFF_F800         | 0xFFFF_FBFF                     | 352 B   | General-purpose control registers                |
| GIO                                       | 0xFFF7_BC00         | 0xFFF7_BDFF                     | 180 B   | GIO module configuration registers               |
| DMA-1                                     | 0xFFFF_F000         | 0xFFFF_F3FF                     | 1 KB    | DMA-1 module configuration registers             |
| DMA-2                                     | 0xFCFF_F800         | 0xFCFF_FBFF                     | 1 KB    | DMA-2 module configuration registers             |
| DMM-1                                     | 0xFCFF_F700         | 0xFCFF_F7FF                     | 472 B   | DMM-1 module configuration registers             |
| DMM-2                                     | 0xFCFF_F600         | 0xFCFF_F6FF                     | 472 B   | DMM-2 module configuration registers             |
| VIM                                       | 0xFFFF_FD00         | 0xFFFF_FEFF                     | 512 B   | VIM module configuration registers               |
| RTI-AWD                                   | 0xFFFF_FC00         | 0xFFFF_FCFF                     | 192 B   | RTI-A module configuration registers             |
| RTI-B                                     | 0xFFFF_EE00         | 0xFFFF_EEFF                     | 192 B   | RTI-B module configuration registers             |
| <b>Serial Interfaces and Connectivity</b> |                     |                                 |         |  |
| QSPI                                      | 0xC000_0000         | 0xC07F_FFFF                     | 8 MB    | QSPI –flash memory space                         |
|   | 0xC080_0000         | 0xC0FF_FFFF                     | 116 B   | QSPI module configuration registers              |
| MIBSPI-A                                  | 0xFFF7_F400         | 0xFFF7_F5FF                     | 512 B   | MIBSPI-A module configuration registers          |
| MIBSPI-B                                  | 0xFFF7_F600         | 0xFFF7_F7FF                     | 512 B   | MIBSPI-B module configuration registers          |
| SCI-A                                     | 0xFFF7_E500         | 0xFFF7_E5FF                     | 148 B   | SCI-A module configuration registers             |
| SCI-B                                     | 0xFFF7_E700         | 0xFFF7_E7FF                     | 148 B   | SCI-B module configuration registers             |

**Table 8-1. Main Subsystem, Cortex-R4F Memory Map (continued)**

| NAME  | FRAME ADDRESS (HEX) |              | SIZE                | DESCRIPTION                                  |
|---|---------------------|--------------|---------------------|--|
|   | START               | END          |                     |  |
| CAN   | 0xFFFF7_DC00        | 0xFFFF7_DDFF | 512 B               | CAN module configuration registers           |
| CAN_FD(MCAN)                                      | 0xFFFF7_C800        | 0xFFFF7_CFFF | 768 B               | CAN-FD module configuration registers        |
|   | 0xFFFF7_A000        | 0xFFFF7_A1FF | 452 B               | MCAN ECC module registers                    |
| I2C   | 0xFFFF7_D400        | 0xFFFF7_D4FF | 112 B               | I2C module configuration registers           |
| <b>Interconnects</b>                              |                     |              |                     |  |
| PCR-1   | 0xFFFF7_8000        | 0xFFFF7_87FF | 1 KiB               | PCR-1 interconnect configuration port        |
| PCR-2   | 0xFCFF_1000         | 0xFCFF_17FF  | 1 KiB               | PCR-2 interconnect configuration port        |
| <b>Safety Modules</b>                             |                     |              |                     |  |
| CRC   | 0xFE00_0000         | 0xFEFF_FFFF  | 16 KiB              | CRC module configuration registers           |
| PBIST   | 0xFFFF_E400         | 0xFFFF_E5FF  | 464 B               | PBIST module configuration registers         |
| STC   | 0xFFFF_E600         | 0xFFFF_E7FF  | 284 B               | STC module configuration registers           |
| DCC-A   | 0xFFFF_EC00         | 0xFFFF_ECFF  | 44 B                | DCC-A module configuration registers         |
| DCC-B   | 0xFFFF_F400         | 0xFFFF_F4FF  | 44 B                | DCC-B module configuration registers         |
| ESM   | 0xFFFF_F500         | 0xFFFF_F5FF  | 156 B               | ESM module configuration registers           |
| CCMR4   | 0xFFFF_F600         | 0xFFFF_F6FF  | 136 B               | CCMR4 module configuration registers         |
| <b>Security Modules</b>                           |                     |              |                     |  |
| Crypto  | 0xFD00_0000         | 0xFDFF_FFFF  | 3 KiB               | Crypto module configuration registers        |
| <b>Other Subsystems</b>                           |                     |              |                     |  |
| DSS_TPTC0   | 0x5000 0000         | 0x5000 0317  | 792 B               | TPTC0 module configuration space             |
| DSS_REG   | 0x5000 0400         | 0x5000 075F  | 864 B               | DSPSS control module registers               |
| DSS_TPTC1   | 0x5000 0800         | 0x5000 0B17  | 792 B               | TPTC1 module configuration space             |
| DSS_REG2  | 0x5000 0C00         | 0x5000 0EA3  | 676 B               | DSPSS control module registers               |
| DSS_TPCC0   | 0x5001 0000         | 0x5001 3FFF  | 16 KB               | TPCC0 module configuration space             |
| DSS_RTIA/WDT                                      | 0x5002 0000         | 0x5002 00BF  | 192 B               | DSS_RTIA/WDT configuration space             |
| DSS_SCI   | 0x5003 0000         | 0x5003 0093  | 148 B               | SCI memory space                             |
| DSS_STC   | 0x5004 0000         | 0x5004 011B  | 284 B               | STC module configuration space               |
| DSS_CBUFF   | 0x5007 0000         | 0x5007 0233  | 564 B               | Common Buffer module configuration registers |
| DSS_TPTC2   | 0x5009 0000         | 0x5009 0317  | 792 B               | TPTC2 module configuration space             |
| DSS_TPTC3   | 0x5009 0400         | 0x5009 0717  | 792 B               | TPTC3 module configuration space             |
| DSS_TPCC1   | 0x500A 0000         | 0x500A 3FFF  | 16 KB               | TPCC1 module configuration space             |
| DSS_ESM   | 0x500D 0000         | 0x500D 005B  | 92 B                | ESM module configuration registers           |
| DSS_RTIB  | 0x500F 0000         | 0x500F 00BF  | 192 B               | RTI-B module configuration registers         |
| DSS_L3RAM Shared memory                           | 0x5100 0000         | 0x511F FFFF  | 2 MB <sup>(1)</sup> | L3 shared memory space                       |
| DSS_ADCBUF Buffer                                 | 0x5200 0000         | 0x5200 7FFF  | 32 KB               | ADC buffer memory space                      |
| DSS_CBUFF_FIFO                                    | 0x5202 0000         | 0x5202 3FFF  | 16 KB               | Common buffer FIFO space                     |
| DSS_HSRAM1  | 0x5208 0000         | 0x5208 7FFF  | 32 KB               | Handshake memory space                       |
| DSS_DSP_L2_UMA P1                                 | 0x577E 0000         | 0x577F FFFF  | 128 KB              | L2 RAM space                                 |
| DSS_DSP_L2_UMA P0                                 | 0x5780 0000         | 0x5781 FFFF  | 128 KB              | L2 RAM space                                 |
| DSS_DSP_L1P                                       | 0x57E0 0000         | 0x57E0 7FFF  | 32 KB               | L1 program memory space                      |
| DSS_DSP_L1D                                       | 0x57F0 0000         | 0x57F0 7FFF  | 32 KB               | L1 data memory space                         |
| <b>Peripheral Memories (System and Nonsystem)</b> |                     |              |                     |  |
| CAN RAM   | 0xFF1E_0000         | 0xFF1F_FFFF  | 128 KB              | CAN RAM memory space                         |

**Table 8-1. Main Subsystem, Cortex-R4F Memory Map (continued)**

| NAME                 | FRAME ADDRESS (HEX) |              | SIZE   | DESCRIPTION                                |
|----------------------|---------------------|--------------|--------|--|
|                      | START               | END          |        |  |
| CAN-FD RAM           | 0xFF50_0000         | 0xFF51_FFFF  | 68 KB  | CAN-FD RAM memory space                    |
| DMA1 RAM             | 0xFFFF8_0000        | 0xFFFF8_0FFF | 4 KB   | DMA1 RAM memory space                      |
| DMA2 RAM             | 0xFCF8_1000         | 0xFCF8_0FFF  | 4 KB   | DMA2 RAM memory space                      |
| VIM RAM              | 0xFFFF8_2000        | 0xFFFF8_2FFF | 2 KB   | VIM RAM memory space                       |
| MIBSPIB-TX RAM       | 0xFF0C_0000         | 0xFF0C_01FF  | 0.5 KB | MIBSPIB-TX RAM memory space                |
| MIBSPIB-RX RAM       | 0xFF0C_0200         | 0xFF0C_03FF  | 0.5 KB | MIBSPIB-RX RAM memory space                |
| MIBSPIA-TX RAM       | 0xFF0E_0000         | 0xFF0E_01FF  | 0.5 KB | MIBSPIA-TX RAM memory space                |
| MIBSPIA- RX RAM      | 0xFF0E_0200         | 0xFF0E_03FF  | 0.5 KB | MIBSPIA- RX RAM memory space               |
| <b>Debug Modules</b> |                     |              |        |  |
| Debug subsystem      | 0xFFA0_0000         | 0xFFAF_FFFF  | 244 KB | Debug subsystem memory space and registers |

(1) 768 KB memory within 2 MB memory space

### 8.3.5 DSP Subsystem Memory Map

Table 8-2 shows the DSP C674x memory map.

**Table 8-2. DSP C674x Memory Map**

| Name                            | Frame Address (Hex) |             | Size    | Description                      |
|---------------------------------|---------------------|-------------|---------|----------------------------------|
|                                 | Start               | End         |         |                                  |
| <b>DSP Memories</b>             |                     |             |         |                                  |
| DSP_L1D                         | 0x00F0_0000         | 0x00F0_7FFF | 32 KiB  | L1 data memory space             |
| DSP_L1P                         | 0x00E0_0000         | 0x00E0_7FFF | 32 KiB  | L1 program memory space          |
| DSP_L2_UMAP0                    | 0x0080_0000         | 0x0081_FFFF | 128 KiB | L2 RAM space                     |
| DSP_L2_UMAP1                    | 0x007E_0000         | 0x007F_FFFF | 128 KiB | L2 RAM space                     |
| <b>EDMA</b>                     |                     |             |         |                                  |
| TPCC0                           | 0x0201_0000         | 0x0201_3FFF | 16 KiB  | TPCC0 module configuration space |
| TPCC1                           | 0x020A_0000         | 0x020A_3FFF | 16 KiB  | TPCC1 module configuration space |
| TPTC0                           | 0x0200_0000         | 0x0200_03FF | 1 KiB   | TPTC0 module configuration space |
| TPTC1                           | 0x0200_0800         | 0x0200_0BFF | 1 KiB   | TPTC1 module configuration space |
| TPTC2                           | 0x0209_0000         | 0x0209_03FF | 1 KiB   | TPTC2 module configuration space |
| TPTC3                           | 0x0209_0400         | 0x0209_07FF | 1 KiB   | TPTC3 module configuration space |
| <b>Control Registers</b>        |                     |             |         |                                  |
| DSS_REG                         | 0x0200_0400         | 0x0200_07FF | 864 B   | DSPSS control module registers   |
| DSS_REG2                        | 0x0200_0C00         | 0x0200_0FFF | 624 B   | DSPSS control module registers   |
| <b>System Memories</b>          |                     |             |         |                                  |
| ADC Buffer                      | 0x2100_0000         | 0x2100_7FFC | 32 KiB  | ADC buffer memory space          |
| CBUFF-FIFO                      | 0x2102_0000         | 0x2102_3FFC | 16 KiB  | Common buffer FIFO space         |
| L3-Shared memory <sup>(1)</sup> | 0x2000_0000         | 0x201F_FFFF | 2 MB    | L3 shared memory space           |
| HS-RAM                          | 0x2108_0000         | 0x2108_7FFC | 32 KiB  | Handshake memory space           |

**Table 8-2. DSP C674x Memory Map (continued)**

| Name                         | Frame Address (Hex) |             | Size  | Description                                      |
|------------------------------|---------------------|-------------|-------|--|
|                              | Start               | End         |       |  |
| <b>System Peripherals</b>    |                     |             |       |  |
| RTI-A/WD                     | 0x0202_0000         | 0x0202_00FF | 192 B | RTI-A module configuration registers             |
| RTI-B                        | 0x020F_0000         | 0x020F_00FF | 192 B | RTI-B module configuration registers             |
| CBUFF                        | 0x0207_0000         | 0x0207_03FF | 564 B | Common Buffer module Configuration registers     |
| Mail Box<br>MSS<->RADARSS    | 0x5060_1000         | 0x5060_17FF | 2 KiB | RADARSS to MSS mailbox memory space              |
|                              | 0x5060_2000         | 0x5060_27FF |       | MSS to RADARSS mailbox memory space              |
|                              | 0x0460_8000         | 0x0460_80FF | 188 B | MSS to RADARSS mailbox Configuration registers   |
|                              | 0x0460_8060         | 0x0460_86FF |       | RADARSS to MSS mailbox Configuration registers   |
| Mail Box<br>MSS<->DSPSS      | 0x5060_4000         | 0x5060_47FF | 2 KiB | DSPSS to MSS mailbox memory space                |
|                              | 0x5060_5000         | 0x5060_57FF |       | MSS to DSPSS mailbox memory space                |
|                              | 0x0460_8400         | 0x0460_84FF | 188 B | MSS to DSPSS mailbox Configuration registers     |
|                              | 0x0460_8300         | 0x0460_83FF |       | DSPSS to MSS mailbox Configuration registers     |
| Mail Box<br>RADARSS<->DSPSS  | 0x5060_6000         | 0x5060_67FF | 2 KiB | RADARSS to DSPSS mailbox memory space            |
|                              | 0x5060_7000         | 0x5060_7FFF |       | DSPSS to RADARSS mailbox memory space            |
|                              | 0x0460_8200         | 0x0460_82FF | 188 B | RADARSS to DSPSS mailbox Configuration registers |
|                              | 0x0460_8100         | 0x0460_81FF |       | DSPSS to RADARSS mailbox Configuration registers |
| <b>Safety Modules</b>        |                     |             |       |  |
| ESM                          | 0x020D_0000         |             | 92 B  | ESM module Configuration registers               |
| CRC                          | 0x2200_0000         | 0x2200_03FF | 1 KiB | CRC module Configuration registers               |
| STC                          | 0x0204_0000         | 0x0204_01FF | 284 B | STC module Configuration registers               |
| <b>Nonsystem Peripherals</b> |                     |             |       |  |
| SCI                          | 0x0203_0000         | 0x0203_00FF | 148 B | SCI module Configuration registers               |

(1) 768 KB memory within 2 MB memory space

## 8.4 Other Subsystems

### 8.4.1 ADC Channels (Service) for User Application

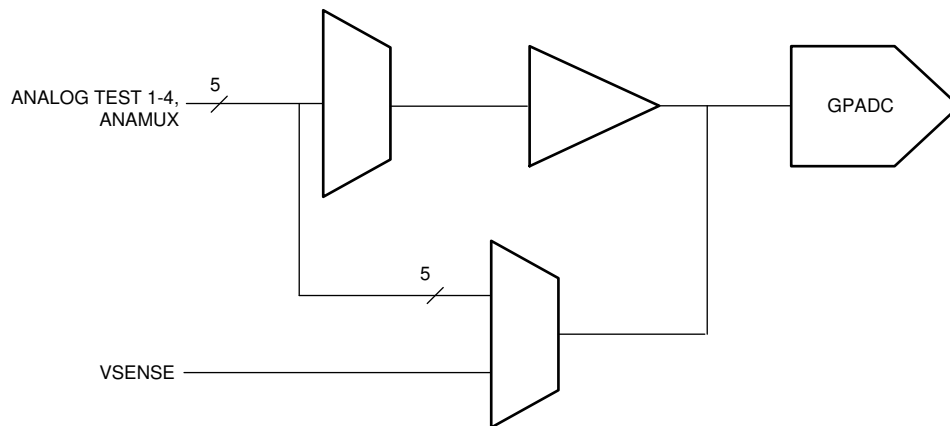
The AWR1843 device includes provision for an ADC service for user application, where the

GPADC engine present inside the device can be used to measure up to six external voltages. The ADC1, ADC2, ADC3, ADC4, ADC5, and ADC6 pins are used for this purpose.

- ADC itself is controlled by TI firmware running inside the BIST subsystem and access to it for customer's external voltage monitoring purpose is via 'monitoring API' calls routed to the BIST subsystem. This API could be linked with the user application running on MSS R4F.
- BIST subsystem firmware will internally schedule these measurements along with other RF and Analog monitoring operations. The API allows configuring the settling time (number of ADC samples to skip) and number of consecutive samples to take. At the end of a frame, the minimum, maximum and average of the readings will be reported for each of the monitored voltages.

GPADC Specifications:

- 625 Ksps SAR ADC
- 0 to 1.8V input range
- 10-bit resolution
- For 5 out of the 6 inputs, an optional internal buffer is available. Without the buffer, the ADC has a switched capacitor input load modeled with 5pF of sampling capacitance and 12pF parasitic capacitance (GPADC channel 6, the internal buffer is not available).



A. GPADC structures are used for measuring the output of internal temperature sensors. The accuracy of these measurements is  $\pm 7^\circ\text{C}$ .

**Figure 8-6. ADC Path**

#### 8.4.1.1 GP-ADC Parameter

over operating free-air temperature range (unless otherwise noted)

| PARAMETER                                       | TYP       | UNIT |
|---|-----------|------|
| ADC supply                                      | 1.8       | V    |
| ADC unbuffered input voltage range              | 0 – 1.8   | V    |
| ADC buffered input voltage range <sup>(1)</sup> | 0.4 – 1.3 | V    |
| ADC resolution                                  | 10        | bits |
| ADC offset error                                | $\pm 5$   | LSB  |
| ADC gain error                                  | $\pm 5$   | LSB  |
| ADC DNL   | $-1/+2.5$ | LSB  |
| ADC INL   | $\pm 2.5$ | LSB  |
| ADC sample rate <sup>(2)</sup>                  | 625       | Ksps |
| ADC sampling time <sup>(2)</sup>                | 400       | ns   |
| ADC internal cap                                | 10        | pF   |
| ADC buffer input capacitance                    | 2         | pF   |

over operating free-air temperature range (unless otherwise noted)

| PARAMETER                 | TYP | UNIT |
|---------------------------|-----|------|
| ADC input leakage current | 3   | uA   |

- (1) Outside of given range, the buffer output will become nonlinear.
- (2) ADC itself is controlled by TI firmware running inside the BIST subsystem. For more details please refer to the API calls.

## 9 Monitoring and Diagnostics

### 9.1 Monitoring and Diagnostic Mechanisms

Table 9-1 is a list of the main monitoring and diagnostic mechanisms available in the Functional Safety-Compliant devices

**Table 9-1. Monitoring and Diagnostic Mechanisms for Functional Safety-Compliant Devices**

| NO | FEATURE   | DESCRIPTION   |
|----|---|---|
| 1  | Boot time LBIST For MSS R4F Core and associated VIM | Device architecture supports hardware logic BIST (LBIST) engine self-test Controller (STC). This logic is used to provide a very high diagnostic coverage (>90%) on the MSS R4F CPU core and Vectored Interrupt Module (VIM) at a transistor level. LBIST for the CPU and VIM need to be triggered by application code before starting the functional safety application. CPU stays there in while loop and does not proceed further if a fault is identified.  |
| 2  | Boot time PBIST for MSS R4F TCM Memories            | MSS R4F has three Tightly coupled Memories (TCM) memories TCMA, TCMB0 and TCMB1. Device architecture supports a hardware programmable memory BIST (PBIST) engine. This logic is used to provide a very high diagnostic coverage (March-13n) on the implemented MSS R4F TCMs at a transistor level. PBIST for TCM memories is triggered by Bootloader at the boot time before starting download of application from Flash or peripheral interface. CPU stays there in while loop and does not proceed further if a fault is identified.  |
| 3  | End to End ECC for MSS R4F TCM Memories             | TCMs diagnostic is supported by Single error correction double error detection (SECCDED) ECC diagnostic. An 8-bit code word is used to store the ECC data as calculated over the 64-bit data bus. ECC evaluation is done by the ECC control logic inside the CPU. This scheme provides end-to-end diagnostics on the transmissions between CPU and TCM. CPU can be configured to have predetermined response (Ignore or Abort generation) to single and double bit error conditions.  |
| 4  | MSS R4F TCM bit multiplexing                        | Logical TCM word and its associated ECC code is split and stored in two physical SRAM banks. This scheme provides an inherent diagnostic mechanism for address decode failures in the physical SRAM banks. Faults in the bank addressing are detected by the CPU as an ECC fault. Further, bit multiplexing scheme implemented such that the bits accessed to generate a logical (CPU) word are not physically adjacent. This scheme helps to reduce the probability of physical multi-bit faults resulting in logical multi-bit faults; rather they manifest as multiple single bit faults. As the SECCDED TCM ECC can correct a single bit fault in a logical word, this scheme improves the usefulness of the TCM ECC diagnostic. Both these features are hardware features and cannot be enabled or disabled by application software.   |
| 5  | Clock Monitor                                       | Device architecture supports Three Digital Clock Comparators (DCCs) and an internal RCOSC. Dual functionality is provided by these modules – Clock detection and Clock Monitoring. DCCint is used to check the availability/range of Reference clock at boot otherwise the device is moved into limp mode (Device still boots but on 10MHz RCOSC clock source. This provides debug capability). DCCint is only used by boot loader during boot time. It is disabled once the APLL is enabled and locked. DCC1 is dedicated for APLL lock detection monitoring, comparing the APLL output divided version with the Reference input clock of the device. Initially (before configuring APLL), DCC1 is used by bootloader to identify the precise frequency of reference input clock against the internal RCOSC clock source. Failure detection for DCC1 would cause the device to go into limp mode. DCC2 module is one which is available for user software. From the list of clock options given in detailed spec, any two clocks can be compared. One example usage is to compare the CPU clock with the Reference or internal RCOSC clock source. Failure detection is indicated to the MSS R4F CPU via Error Signaling Module (ESM). |
| 7  | RTI/WD for MSS R4F                                  | Device architecture supports the use of an internal watchdog that is implemented in the real-time interrupt (RTI) module. The internal watchdog has two modes of operation: digital watchdog (DWD) and digital windowed watchdog (DWWDD). The modes of operation are mutually exclusive; the designer can elect to use one mode or the other but not both at the same time. Watchdog can issue either an internal (warm) system reset or a CPU non-mask able interrupt upon detection of a failure. The Watchdog is enabled by the bootloader in DWD mode at boot time to track the boot process. Once the application code takes up the control, Watchdog can be configured again for mode and timings based on specific customer requirements.  |



**Table 9-1. Monitoring and Diagnostic Mechanisms for Functional Safety-Compliant Devices (continued)**

| NO | FEATURE  | DESCRIPTION   |
|----|--|---|
| 8  | MPU for MSS R4F  | Cortex-R4F CPU includes an MPU. The MPU logic can be used to provide spatial separation of software tasks in the device memory. Cortex-R4F MPU supports 12 regions. It is expected that the operating system controls the MPU and changes the MPU settings based on the needs of each task. A violation of a configured memory protection policy results in a CPU abort.  |
| 9  | PBIST for Peripheral interface SRAMs - SPIs, CANs          | Device architecture supports a hardware programmable memory BIST (PBIST) engine for Peripheral SRAMs as well. PBIST for peripheral SRAM memories can be triggered by the application. User can elect to run the PBIST on one SRAM or on groups of SRAMs based on the execution time, which can be allocated to the PBIST diagnostic. The PBIST tests are destructive to memory contents, and as such are typically run only at boot time. However, the user has the freedom to initiate the tests at any time if peripheral communication can be hindered. Any fault detected by the PBIST results in an error indicated in PBIST status registers.   |
| 10 | ECC for Peripheral interface SRAMs – SPIs, CANs            | Peripheral interface SRAMs diagnostic is supported by Single error correction double error detection (SECDED) ECC diagnostic. When a single or double bit error is detected the MSS R4F is notified via ESM (Error Signaling Module). This feature is disabled after reset. Software must configure and enable this feature in the peripheral and ESM module. ECC failure (both single bit corrected and double bit uncorrectable error conditions) is reported to the MSS R4F as an interrupt via ESM module.  |
| 11 | Configuration registers protection for Main SS peripherals | All the Main SS peripherals (SPIs, CANs, I2C, DMAs, RTI/WD, DCCs, IOMUX etc.) are connected to interconnect via Peripheral Central resource (PCR). This provides two diagnostic mechanisms that can limit access to peripherals. Peripherals can be clock gated per peripheral chip select in the PCR. This can be utilized to disable unused features such that they cannot interfere. In addition, each peripheral chip select can be programmed to limit access based on privilege level of transaction. This feature can be used to limit access to entire peripherals to privileged operating system code only. These diagnostic mechanisms are disabled after reset. Software must configure and enable these mechanisms. Protection violation also generates an 'error' that result in abort to MSS R4F or error response to other peripherals such as DMAs. |
| 12 | Cyclic Redundancy Check – Main SS                          | Device architecture supports hardware CRC engine on Main SS implementing the below polynomials. <ul style="list-style-type: none"> <li>• CRC16 CCITT – 0x10</li> <li>• CRC32 Ethernet – 0x04C11DB7</li> <li>• CRC64</li> <li>• CRC 32C – CASTAGNOLI – 0x1EDC6F4</li> <li>• CRC32P4 – E2E Profile4 – 0xF4ACFB1</li> <li>• CRC-8 – H2F Autosar – 0x2F</li> <li>• CRC-8 – VDA CAN – 0x1D</li> </ul> The read operation of the SRAM contents to the CRC can be done by CPU or by DMA. The comparison of results, indication of fault, and fault response are the responsibility of the software managing the test.  |
| 13 | MPU for DMAs   | Device architecture supports MPUs on Main SS DMAs. Failure detection by MPU is reported to the MSS R4F CPU core as an interrupt via ESM. DSPSS's high performance EDMAs also includes MPUs on both read and write ports. EDMA MPUs supports 8 regions. Failure detection by MPU is reported to the DSP core as an interrupt via local ESM.  |
| 14 | Boot time LBIST For BIST R4F Core and associated VIM       | Device architecture supports hardware logic BIST (LBIST) even for BIST R4F core and associated VIM module. This logic provides very high diagnostic coverage (>90%) on the BIST R4F CPU core and VIM. This is triggered by MSS R4F boot loader at boot time and it does not proceed further if the fault is detected.   |
| 15 | Boot time PBIST for BIST R4F TCM Memories                  | Device architecture supports a hardware programmable memory BIST (PBIST) engine for BIST R4F TCMs which provide a very high diagnostic coverage (March-13n) on the BIST R4F TCMs. PBIST is triggered by MSS R4F Bootloader at the boot time and it does not proceed further if the fault is detected.   |

**Table 9-1. Monitoring and Diagnostic Mechanisms for Functional Safety-Compliant Devices (continued)**

| NO | FEATURE  | DESCRIPTION   |
|----|--|---|
| 16 | End to End ECC for BIST R4F TCM Memories         | BIST R4F TCMs diagnostic is supported by Single error correction double error detection (SECDED) ECC diagnostic. Single bit error is communicated to the BIST R4FCPU while double bit error is communicated to MSS R4F as an interrupt so that application code becomes aware of this and takes appropriate action.   |
| 17 | BIST R4F TCM bit multiplexing                    | Logical TCM word and its associated ECC code is split and stored in two physical SRAM banks. This scheme provides an inherent diagnostic mechanism for address decode failures in the physical SRAM banks and helps to reduce the probability of physical multi-bit faults resulting in logical multi-bit faults.   |
| 18 | RTI/WD for BIST R4F                              | Device architecture supports an internal watchdog for BIST R4F. Timeout condition is reported via an interrupt to MSS R4F and rest is left to application code to either go for SW reset for BIST SS or warm reset for the device to come out of faulty condition.  |
| 19 | Boot time PBIST for L1P, L1D, L2 and L3 Memories | Device architecture supports a hardware programmable memory BIST (PBIST) engine for DSPSS's L1P, L1D, L2 and L3 memories which provide a very high diagnostic coverage (March-13n). PBIST is triggered by MSS R4F Bootloader at the boot time and it does not proceed further if the fault is detected.   |
| 20 | Parity on L1P                                    | Device architecture supports Parity diagnostic on DSP's L1P memory. Parity error is reported to the CPU as an interrupt.<br>Note:- L1D memory is not covered by parity or ECC and need to be covered by application level diagnostics.  |
| 21 | ECC on DSP's L2 Memory                           | Device architecture supports both Parity Single error correction double error detection (SECDED) ECC diagnostic on DSP's L2 memory. L2 Memory is a unified 256KB of memory used to store program and Data sections for the DSP. A 12-bit code word is used to store the ECC data as calculated over the 256-bit data bus (logical instruction fetch size). The ECC logic for the L2 access is located in the DSP and evaluation is done by the ECC control logic inside the DSP. This scheme provides end-to-end diagnostics on the transmissions between DSP and L2. Byte aligned Parity mechanism is also available on L2 to take care of data section. |
| 22 | ECC on Radar Data Cube (L3) Memory               | L3 memory is used as Radar data section in Device. Device architecture supports Single error correction double error detection (SECDED) ECC diagnostic on L3 memory. An 8-bit code word is used to store the ECC data as calculated over the 64-bit data bus. Failure detection by ECC logic is reported to the MSS R4F CPU core as an interrupt via ESM.   |
| 23 | RTI/WD for DSP Core                              | Device architecture supports the use of an internal watchdog for BIST R4F that is implemented in the real-time interrupt (RTI) module – replication of same module as used in Main SS. This module supports same features as that of RTI/WD for MSS/BIST R4F. This watchdog is enabled by customer application code and Timeout condition is reported via an interrupt to MSS R4F and rest is left to application code in MSS R4F to either go for SW reset for DSP SS or warm reset for the device to come out of faulty condition.  |
| 24 | CRC for DSP Sub-System                           | Device architecture supports dedicated hardware CRC on DSPSS implementing the below polynomials. <ul style="list-style-type: none"> <li>• CRC16 CCITT - 0x10</li> <li>• CRC32 Ethernet - 0x04C11DB7</li> <li>• CRC64</li> </ul> The read of SRAM contents to the CRC can be done by DSP CPU or by DMA. The comparison of results, indication of fault, and fault response are the responsibility of the software managing the test.   |
| 25 | MPU for DSP                                      | Device architecture supports MPUs for DSP memory accesses (L1D, L1P, and L2). L2 memory supports 64 regions and 16 regions for L1P and L1D each. Failure detection by MPU is reported to the DSP core as an abort.  |
| 26 | Temperature Sensors                              | Device architecture supports various temperature sensors all across the device (next to power hungry modules such as PAs, DSP etc) which is monitored during the inter-frame period. <sup>(1)</sup>   |
| 27 | Tx Power Monitors                                | Device architecture supports power detectors at the Tx output. <sup>(2)</sup>   |

**Table 9-1. Monitoring and Diagnostic Mechanisms for Functional Safety-Compliant Devices (continued)**

| NO | FEATURE   | DESCRIPTION  |
|----|---|--|
| 28 | Error Signaling<br>Error Output                           | When a diagnostic detects a fault, the error must be indicated. The device architecture provides aggregation of fault indication from internal monitoring/diagnostic mechanisms using a peripheral logic known as the Error Signaling Module (ESM). The ESM provides mechanisms to classify errors by severity and to provide programmable error response. ESM module is configured by customer application code and specific error signals can be enabled or masked to generate an interrupt (Low/High priority) for the MSS R4F CPU. device supports Nerror output signal (IO) which can be monitored externally to identify any kind of high severity faults in the design which could not be handled by the R4F. |
| 29 | Synthesizer (Chirp) frequency monitor                     | Monitors Synthesizer's frequency ramp by counting (divided-down) clock cycles and comparing to ideal frequency ramp. Excess frequency errors above a certain threshold, if any, are detected and reported.   |
| 30 | Ball break detection for TX ports (TX Ball break monitor) | Device architecture supports a ball break detection mechanism based on Impedance measurement at the TX output(s) to detect and report any large deviations that can indicate a ball break. Monitoring is done by TI's code running on BIST R4F and failure is reported to the MSS R4F via Mailbox. It is completely up to customer SW to decide on the appropriate action based on the message from BIST R4F.  |
| 31 | RX loopback test  | Built-in TX to RX loopback to enable detection of failures in the RX path(s), including Gain, inter-RX balance, etc.   |
| 32 | IF loopback test  | Built-in IF (square wave) test tone input to monitor IF filter's frequency response and detect failure.  |
| 33 | RX saturation detect                                      | Provision to detect ADC saturation due to excessive incoming signal level and/or interference.   |
| 34 | Boot time LBIST for DSP core                              | Device supports boot time LBIST for the DSP Core. LBIST can be triggered by the MSS R4F application code during boot time.   |

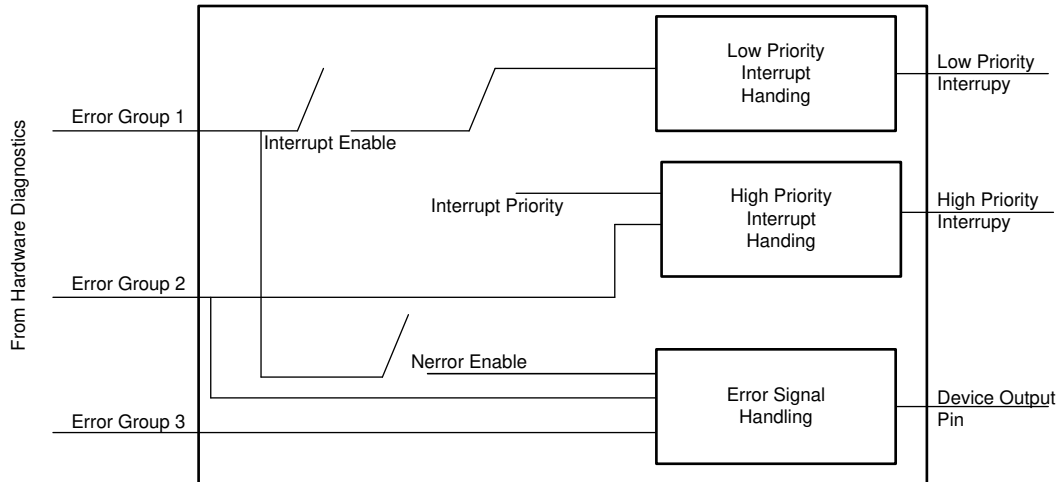
- (1) Monitoring is done by TI's code running on BIST R4F.  
There are two modes in which it could be configured to report the temperature sensed via API by customer application.
- a. Report the temperature sensed after every N frames
  - b. Report the condition once the temperature crosses programmed threshold.
- It is completely up to customer SW to decide on the appropriate action based on the message from BIST R4F via Mailbox.
- (2) Monitoring is done by the TI's code running on BIST R4F.  
There are two modes in which it could be configured to report the detected output power via API by customer application.
- a. Report the power detected after every N frames
  - b. Report the condition once the output power degrades by more than configured threshold from the configured.
- It is completely up to customer SW to decide on the appropriate action based on the message from BIST R4F.

**Note**

Refer to the Device Safety Manual or other relevant collaterals for more details on applicability of all diagnostics mechanisms. For Certification details, refer to the Device product folder.

### 9.1.1 Error Signaling Module

When a diagnostic detects a fault, the error must be indicated. AWR1843 architecture provides aggregation of fault indication from internal diagnostic mechanisms using a peripheral logic known as the error signaling module (ESM). The ESM provides mechanisms to classify faults by severity and allows programmable error response. Below is the high level block diagram for ESM module.



**Figure 9-1. ESM Module Diagram**

## 10 Applications, Implementation, and Layout

### Note

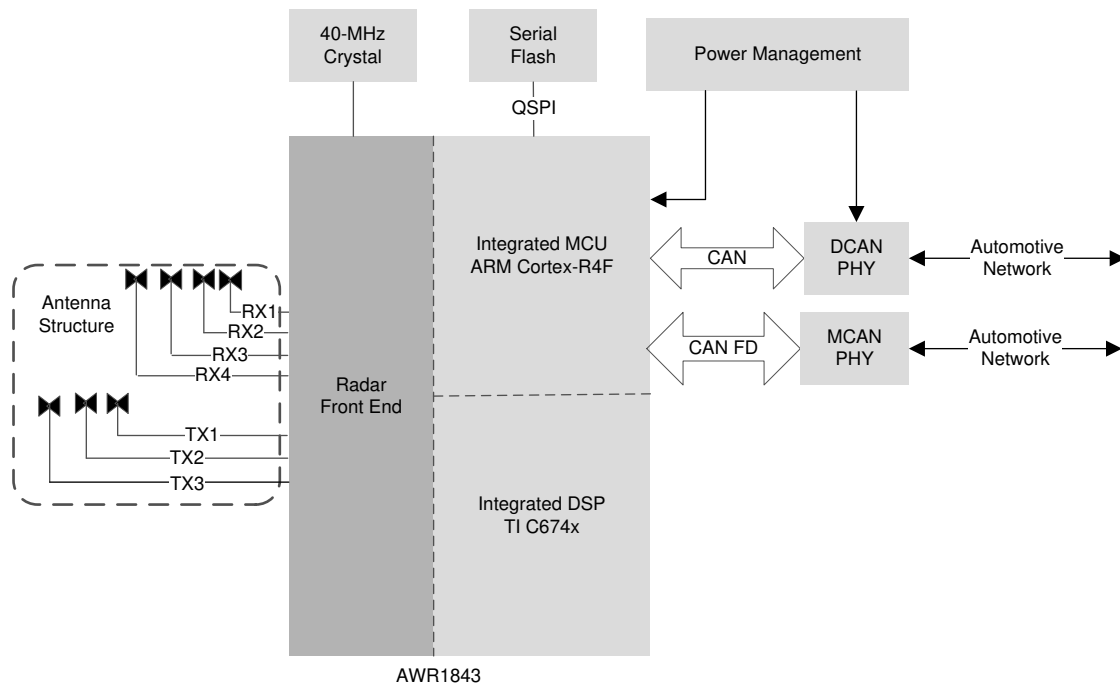
Information in the following Applications section is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

### 10.1 Application Information

Key device features driving the following applications are:

- Integration of Radar Front End and Programmable MCU
- Flexible boot modes: Autonomous Application boot using a serial flash or external boot over SPI.

### 10.2 Short- and Medium-Range Radar



**Figure 10-1. Short- and Medium-Range Radar**

### 10.3 Reference Schematic

The reference schematic and power supply information can be found in the [AWR1843 EVM Documentation](#).

Listed for convenience are: Design Files, Schematics, Layouts, and Stack up for PCB.

- [Altium AWR1843 EVM Design Files](#)
- [AWR1843 EVM Schematic Drawing, Assembly Drawing, and Bill of Materials](#)

## 11 Device and Documentation Support

TI offers an extensive line of development tools. Tools and software to evaluate the performance of the device, generate code, and develop solutions follow.

### 11.1 Device Nomenclature

To designate the stages in the product development cycle, TI assigns prefixes to the part numbers of all microprocessors (MPUs) and support tools. Each device has one of three prefixes: X, P, or null (no prefix) (for example, *AWR1843*). Texas Instruments recommends two of three possible prefix designators for its support tools: TMDX and TMDS. These prefixes represent evolutionary stages of product development from engineering prototypes (TMDX) through fully qualified production devices and tools (TMDS).

Device development evolutionary flow:

- X** Experimental device that is not necessarily representative of the final device's electrical specifications and may not use production assembly flow.
- P** Prototype device that is not necessarily the final silicon die and may not necessarily meet final electrical specifications.
- null** Production version of the silicon die that is fully qualified.

Support tool development evolutionary flow:

- TMDX** Development-support product that has not yet completed Texas Instruments internal qualification testing.
- TMDS** Fully-qualified development-support product.

X and P devices and TMDX development-support tools are shipped against the following disclaimer:

"Developmental product is intended for internal evaluation purposes."

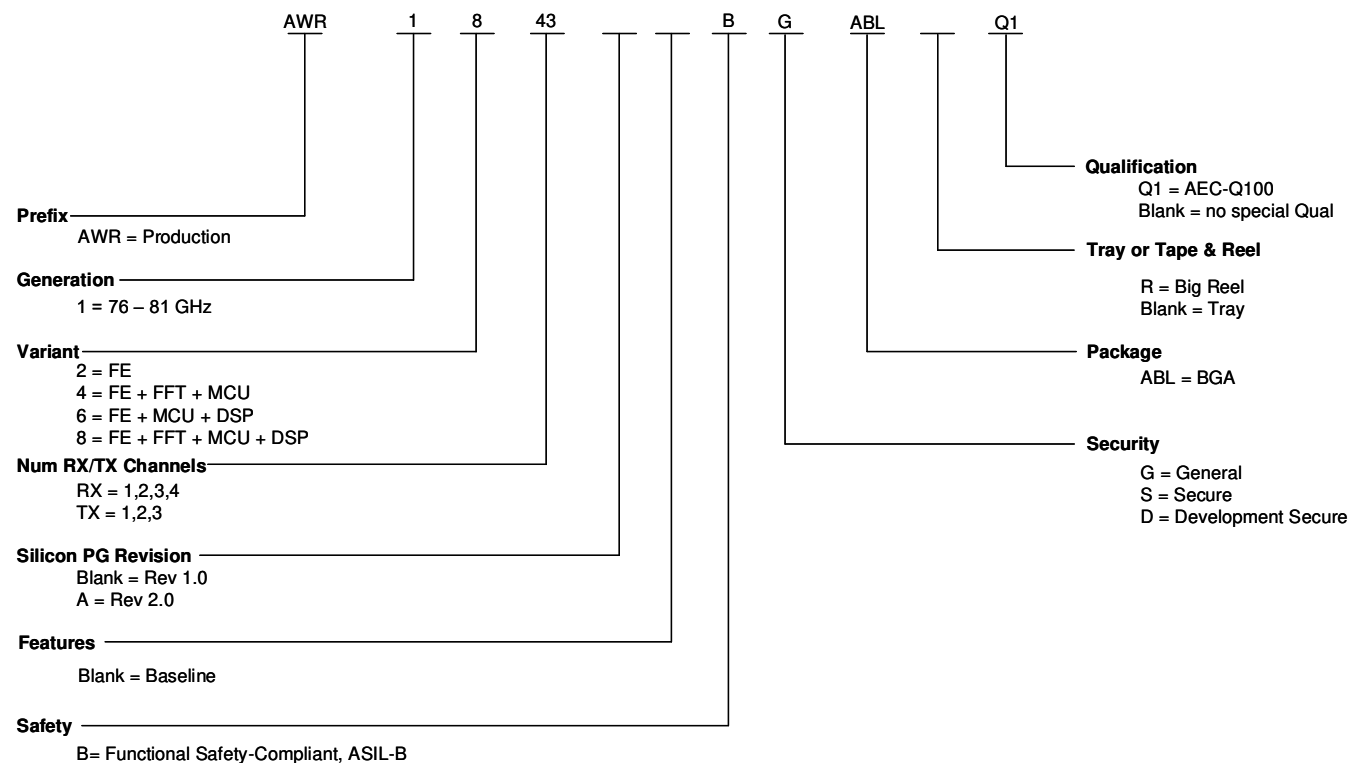
Production devices and TMDS development-support tools have been characterized fully, and the quality and reliability of the device have been demonstrated fully. TI's standard warranty applies.

Predictions show that prototype devices (X or P) have a greater failure rate than the standard production devices. Texas Instruments recommends that these devices not be used in any production system because their expected end-use failure rate still is undefined. Only qualified production devices are to be used.

TI device nomenclature also includes a suffix with the device family name. This suffix indicates the package type (for example, ABL0161 ALB0161), the temperature range (for example, blank is the default commercial temperature range). [Figure 11-1](#) provides a legend for reading the complete device name for any *AWR1843* device.

For orderable part numbers of *AWR1843* devices in the ABL0161 package types, see the Package Option Addendum of this document, the TI website ([www.ti.com](http://www.ti.com)), or contact your TI sales representative.

For additional description of the device nomenclature markings on the die, see the [AWR1843 Device Errata](#).



**Figure 11-1. Device Nomenclature**

## 11.2 Tools and Software

### Models

[AWR1843 BSDL model](#) Boundary scan database of testable input and output pins for IEEE 1149.1 of the specific device.

[AWR1843 IBIS model](#) IO buffer information model for the IO buffers of the device. For simulation on a circuit board, see IBIS Open Forum.

### 11.3 Documentation Support

To receive notification of documentation updates, navigate to the device product folder on [ti.com](https://www.ti.com). Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

The current documentation that describes the DSP, related peripherals, and other technical collateral follows.

### Errata

[AWR1843 device errata](#) Describes known advisories, limitations, and cautions on silicon and provides workarounds.

### 11.4 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

### 11.5 Trademarks

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## 11.6 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## 11.7 Glossary

### [TI Glossary](#)

This glossary lists and explains terms, acronyms, and definitions.

## 12 Revision History

Changes from December 31, 2021 to September 11, 2024 (from Revision C (December 2021) to Revision D (September 2024))

Page

- 
- *(RF Specification)*: Updated Noise Figure, In-band P1dB vs Receiver Gain.....28
-

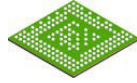
**Changes from May 1, 2020 to December 31, 2021 (from Revision B (May 2020) to Revision C (December 2021))**

|  | <b>Page</b> |
|--|-------------|
| • <i>Global</i> : Updated to reflect Functional Safety-Compliance.....   | 1           |
| • <i>Global</i> : Replaced "A2D" with "ADC"; Changed Masters Subsystem and Masters R4F to Main Subsystem and Main R4F; Shift to more inclusive language made in terms of Master/Slave terminology.....                 | 1           |
| • <i>(Features)</i> : Updated Functional-Safety Compliance Certification Collateral; Mentioned the specific operating temperature range for the mmWave Sensor; Additional information on Device Security updated. .... | 1           |
| • <i>(Device Information)</i> : Additional Secure production parts added for the mmWave Sensor.....  | 2           |
| • Updated/Changed Functional Block Diagram for inclusive terminology.....  | 3           |
| • <i>(Device Comparison)</i> : Removed a row on Functional-Safety compliance and instead added a table-note for this and LVDS Interface; Additional information on Device security added.....                          | 5           |
| • <i>(Signal Descriptions)</i> :Updated/Changed CLKP and CLKM descriptions.....  | 14          |
| • <i>(Absolute Maximum Ratings)</i> : Added entries for externally supplied power on the RF inputs (TX and RX) and a table-note for the signal level applied on TX.....  | 24          |
| • <i>(Average Power Consumption at Power Terminals)</i> : Updated/Changed the typical average power numbers.....   | 27          |
| • <i>(RF Specifications)</i> : Added lead-in paragraph and "Noise Figure, In-band P1dB vs Receiver Gain" image....   | 28          |
| • <i>(Clock Specifications)</i> : Updated/Changed <a href="#">Table 7-5</a> to reflect correct device operating temperature range...   | 31          |
| • <i>(Table. External Clock Mode Specifications)</i> : Revised frequency tolerance specs from +/-50 to +/-100 ppm.   | 31          |
| • Added a footnote for L3-Shared memory in <i>DSP C674x Memory Map</i> .....   | 60          |
| • <i>(Monitoring and Diagnostic Mechanisms)</i> : Updated/Changed table header and description to reflect Functional Safety-Compliance; added a note for reference to safety related collateral.....                   | 64          |
| • <i>(Reference Schematics)</i> : Added weblinks to device EVM documentation collateral .....  | 70          |
| • <i>(Device Nomenclature)</i> :Updated/changed <i>Device Nomenclature</i> .....   | 71          |

## 13 Mechanical, Packaging, and Orderable Information

### 13.1 Packaging Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

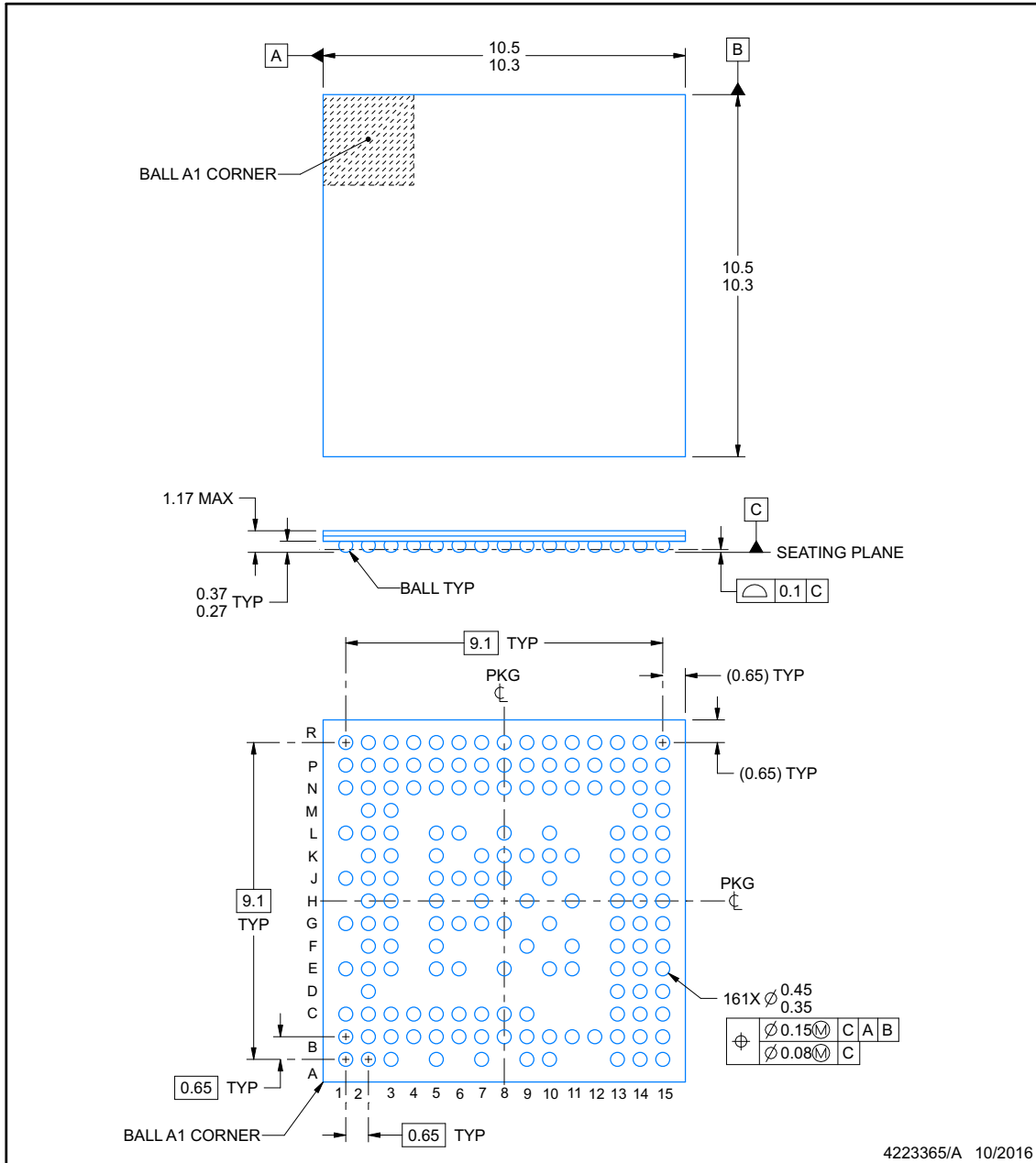


# ABL0161B

# PACKAGE OUTLINE

## FCBGA - 1.17 mm max height

PLASTIC BALL GRID ARRAY



**NOTES:**

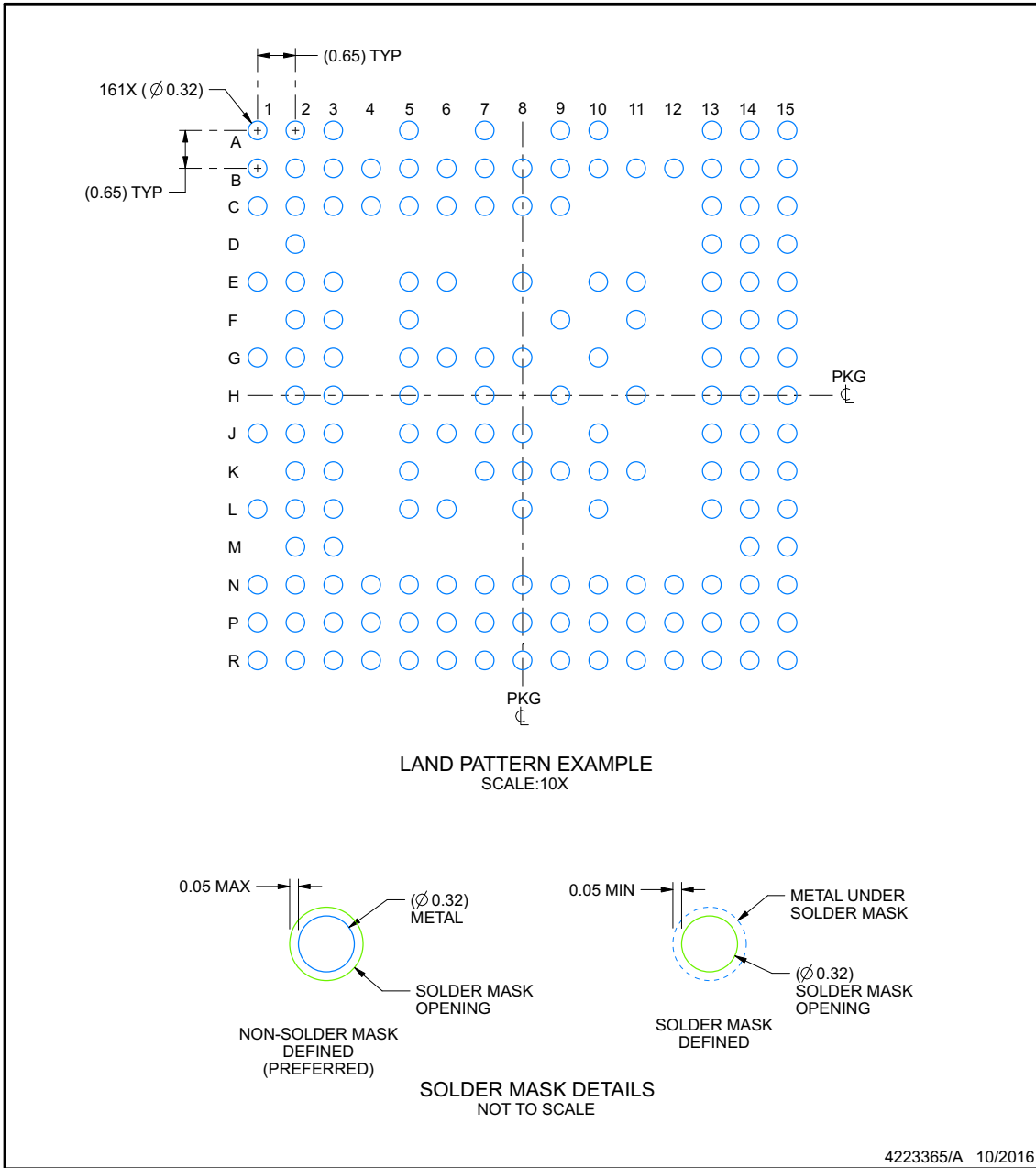
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

# EXAMPLE BOARD LAYOUT

## ABL0161B

## FCBGA - 1.17 mm max height

PLASTIC BALL GRID ARRAY



NOTES: (continued)

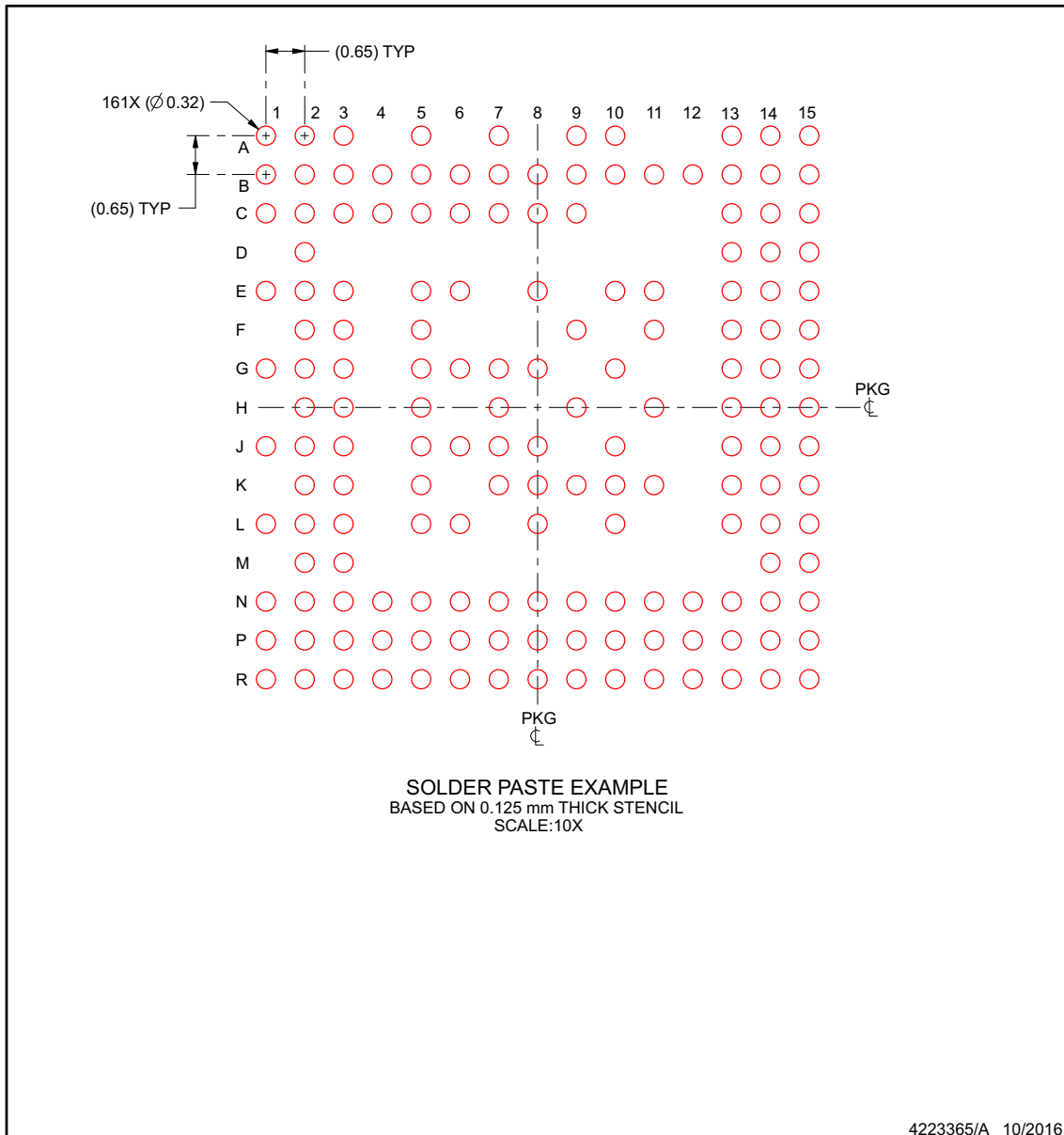
- 3. Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. For information, see Texas Instruments literature number SPRAA99 ([www.ti.com/lit/spraa99](http://www.ti.com/lit/spraa99)).

## EXAMPLE STENCIL DESIGN

**ABL0161B**

**FCBGA - 1.17 mm max height**

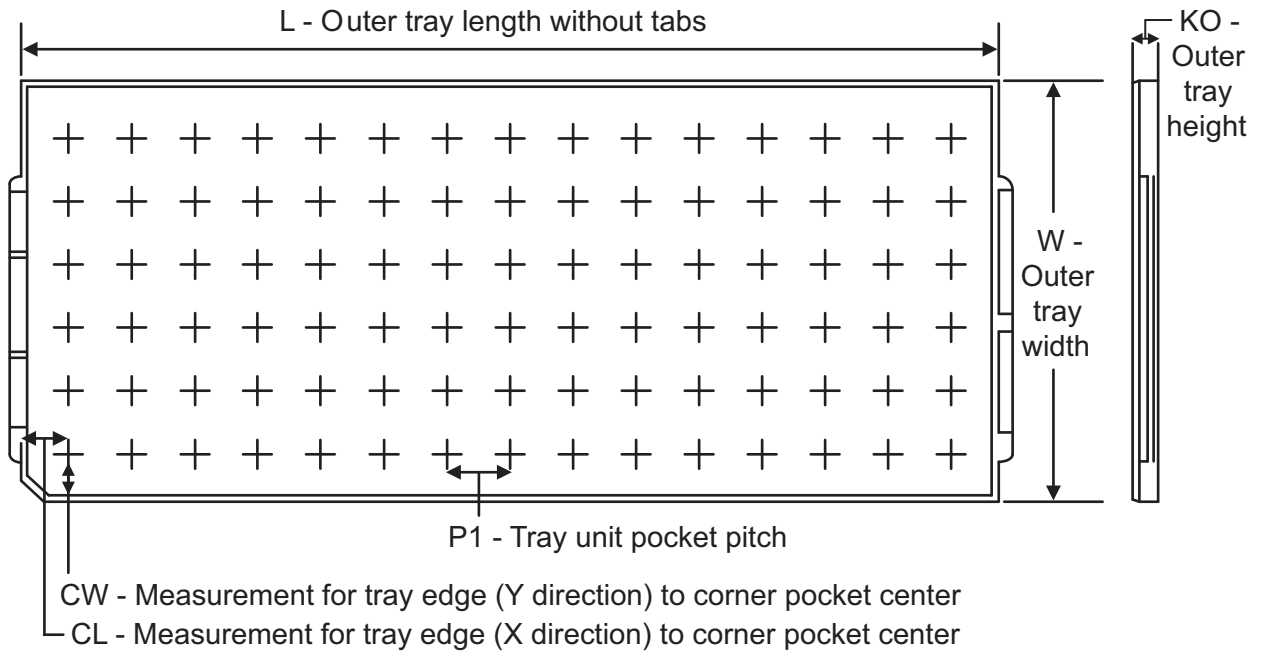
PLASTIC BALL GRID ARRAY



NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

### 13.2 Tray Information for



Chamfer on Tray corner indicates Pin 1 orientation of packed units.



**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan<br>(2) | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5)     | Samples                 |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-----------------------------|-------------------------|
| AWR1843ABGABLQ1  | ACTIVE        | FCCSP        | ABL             | 161  | 176         | RoHS & Green    | Call TI                              | Level-3-260C-168 HR  | -40 to 125   | AWR1843<br>IG<br>502AD      | <a href="#">Samples</a> |
| AWR1843ABGABLRQ1 | ACTIVE        | FCCSP        | ABL             | 161  | 1000        | RoHS & Green    | Call TI                              | Level-3-260C-168 HR  | -40 to 125   | AWR1843<br>IG<br>502AD<br>D | <a href="#">Samples</a> |
| AWR1843ABSABLQ1  | ACTIVE        | FCCSP        | ABL             | 161  | 176         | RoHS & Green    | Call TI                              | Level-3-260C-168 HR  | -40 to 125   | AWR1843<br>IS<br>502AD      | <a href="#">Samples</a> |
| AWR1843ABSABLRQ1 | ACTIVE        | FCCSP        | ABL             | 161  | 1000        | RoHS & Green    | Call TI                              | Level-3-260C-168 HR  | -40 to 125   | AWR1843<br>IS<br>502AD      | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSELETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

<sup>(6)</sup> Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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