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## General Description

PSoC® 4 is a scalable and reconfigurable platform architecture for a family of programmable embedded system controllers with an ARM® Cortex™-M0 CPU. It combines programmable and reconfigurable analog and digital blocks with flexible automatic routing. The PSoC 4XX8 BLE 4.2 product family, based on this platform, is a combination of a microcontroller with an integrated Bluetooth Low Energy (BLE), also known as Bluetooth Smart, radio and subsystem (BLESS). The other features include digital programmable logic, high-performance analog-to-digital conversion (ADC), opamps with Comparator mode, and standard communication and timing peripherals. The programmable analog and digital subsystems allow flexibility and in-field tuning of the design.

## Features

### 32-bit MCU Subsystem

- 48-MHz ARM Cortex-M0 CPU with single-cycle multiply and DMA
- Up to 256 KB of flash with Read Accelerator
- Up to 32 KB of SRAM

### BLE Radio and Subsystem

- BLE 4.2 support
- 2.4-GHz RF transceiver with 50-Ω antenna drive
- Digital PHY
- Link-Layer engine supporting master and slave modes
- RF output power: -18 dBm to +3 dBm
- RX sensitivity: -92 dBm
- RX current: 18.7 mA
- TX current: 16.5 mA at 0 dBm
- RSSI: 1-dB resolution

### Programmable Analog

- Four opamps with reconfigurable high-drive external and high-bandwidth internal drive, Comparator modes, and ADC input buffering capability. Can operate in Deep Sleep mode.
- 12-bit, 1-Msps SAR ADC with differential and single-ended modes; Channel Sequencer with signal averaging
- Two current DACs (IDACs) for general-purpose or capacitive sensing applications on any pin
- Two low-power comparators that operate in Deep Sleep mode

### Programmable Digital

- Four programmable logic blocks called universal digital blocks, (UDBs), each with eight macrocells and data path
- Cypress-provided peripheral component library, user-defined state machines, and Verilog input

### Power Management

- Active mode: 1.7 mA at 3-MHz flash program execution
- Deep Sleep mode: 1.5 μA with watch crystal oscillator (WCO) on
- Hibernate mode: 150 nA with RAM retention
- Stop mode: 60 nA

### Capacitive Sensing

- Cypress Capacitive Sigma-Delta (CSD) provides best-in-class SNR (>5:1) and liquid tolerance
- Cypress-supplied software component makes capacitive sensing design easy
- Automatic hardware tuning algorithm (SmartSense™)

### Segment LCD Drive

- LCD drive supported on all pins (common or segment)
- Operates in Deep Sleep mode with four bits per pin memory

### Serial Communication

- Two independent run-time reconfigurable serial communication blocks (SCBs) with reconfigurable I<sup>2</sup>C, SPI, or UART functionality

### Timing and Pulse-Width Modulation

- Four 16-bit timer/counter pulse-width modulator (TCPWM) blocks
- Center-aligned, Edge, and Pseudo-random modes
- Comparator-based triggering of Kill signals for motor drive and other high-reliability digital logic applications

### Up to 36 Programmable GPIOs

- 7 mm × 7 mm 56-pin QFN package
- 76-ball CSP package
- Any GPIO pin can be CapSense, LCD, analog, or digital
- Two overvoltage-tolerant (OVT) pins; drive modes, strengths, and slew rates are programmable

### PSoC Creator™ Design Environment

- Integrated Design Environment (IDE) provides schematic design entry and build (with analog and digital automatic routing)
- API components for all fixed-function and programmable peripherals

### Industry-Standard Tool Compatibility

- After schematic entry, development can be done with ARM-based industry-standard development tools



**More Information**

Cypress provides a wealth of data at <http://www.cypress.com> to help you to select the right PSoC device for your design, and to help you to quickly and effectively integrate the device into your design. For a comprehensive list of resources, see the introduction page for [Bluetooth® Low Energy \(BLE\) Products](#). Following is an abbreviated list for PSoC BLE:

- Overview: PSoC Portfolio, PSoC Roadmap
- Product Selectors: PSoC 1, PSoC 3, PSoC 4, PSoC BLE, PSoC 4 BLE, PSoC 5LP In addition, PSoC Creator includes a device selection tool.
- Application Notes: Cypress offers a large number of PSoC application notes covering a broad range of topics, from basic to advanced level. Recommended application notes for getting started with PSoC BLE are:
  - [AN94020](#): Getting Started with PSoC BLE
  - [AN97060](#): PSoC 4 BLE and PSoC BLE - Over-The-Air (OTA) Device Firmware Upgrade (DFU) Guide
  - [AN91184](#): PSoC 4 BLE - Designing BLE Applications
  - [AN91162](#): Creating a BLE Custom Profile
  - [AN91445](#): Antenna Design and RF Layout Guidelines
  - [AN96841](#): Getting Started With EZ-BLE Module
  - [AN85951](#): PSoC 4 CapSense Design Guide

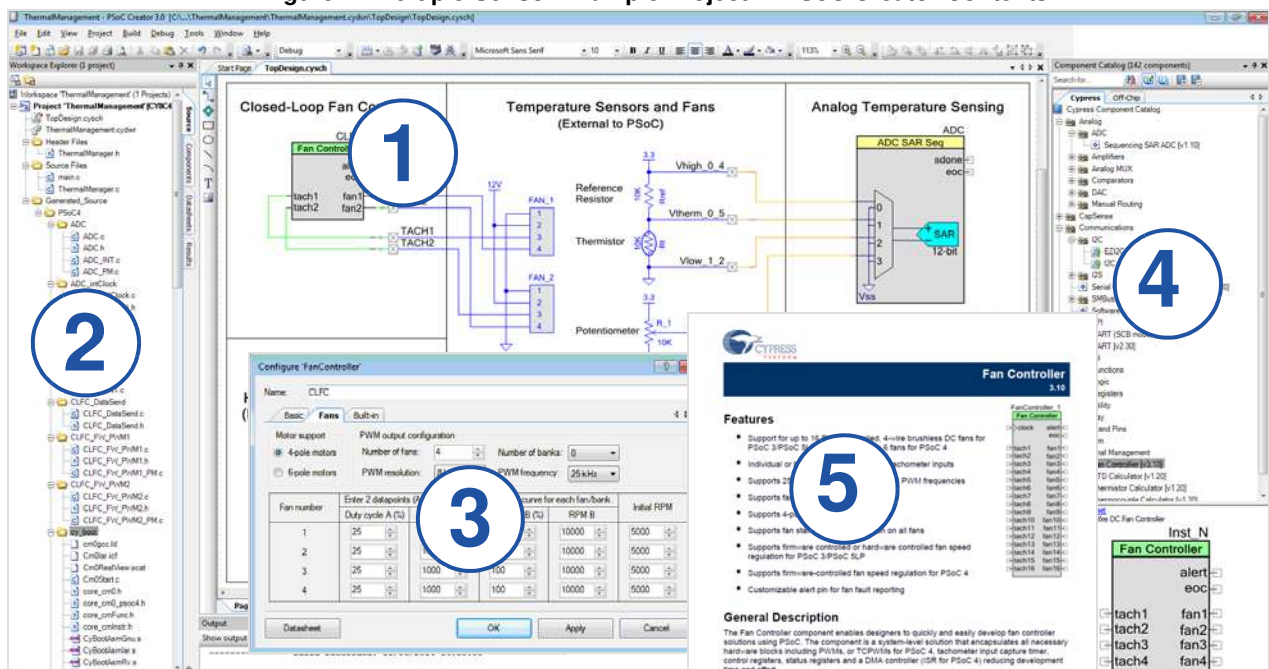
- [AN95089](#): PSoC 4/PRoC BLE Crystal Oscillator Selection and Tuning Techniques
- [AN92584](#): Designing for Low Power and Estimating Battery Life for BLE Applications
- Technical Reference Manual (TRM) is in two documents:
  - [Architecture TRM](#) details each PSoC BLE functional block
  - [Registers TRM](#) describes each of the PSoC BLE registers
- Development Kits:
  - [CY8CKIT-042-BLE](#) Pioneer Kit, is a flexible, Arduino-compatible, Bluetooth LE development kit for PSoC 4 BLE and PSoC BLE.
  - [CY5676](#), PSoC BLE 256KB Module, features a PSoC BLE 256KB device, two crystals for the antenna matching network, a PCB antenna and other passives, while providing access to all GPIOs of the device.
  - [CY8CKIT-142](#), PSoC 4 BLE Module, features a PSoC 4 BLE device, two crystals for the antenna matching network, a PCB antenna and other passives, while providing access to all GPIOs of the device.
  - [CY8CKIT-143](#), PSoC 4 BLE 256KB Module, features a PSoC 4 BLE 256KB device, two crystals for the antenna matching network, a PCB antenna and other passives, while providing access to all GPIOs of the device.
  - The [MiniProg3](#) device provides an interface for flash programming and debug.

**PSoC Creator**

**PSoC Creator** is a free Windows-based Integrated Design Environment (IDE). It enables concurrent hardware and firmware design of PSoC 3, PSoC 4, and PSoC 5LP based systems. Create designs using classic, familiar schematic capture supported by over 100 pre-verified, production-ready PSoC Components; see the [list of component datasheets](#). With PSoC Creator, you can:

1. Drag and drop component icons to build your hardware system design in the main design workspace
2. Codesign your application firmware with the PSoC hardware, using the PSoC Creator IDE C compiler
3. Configure components using the configuration tools
4. Explore the library of 100+ components
5. Review component datasheets

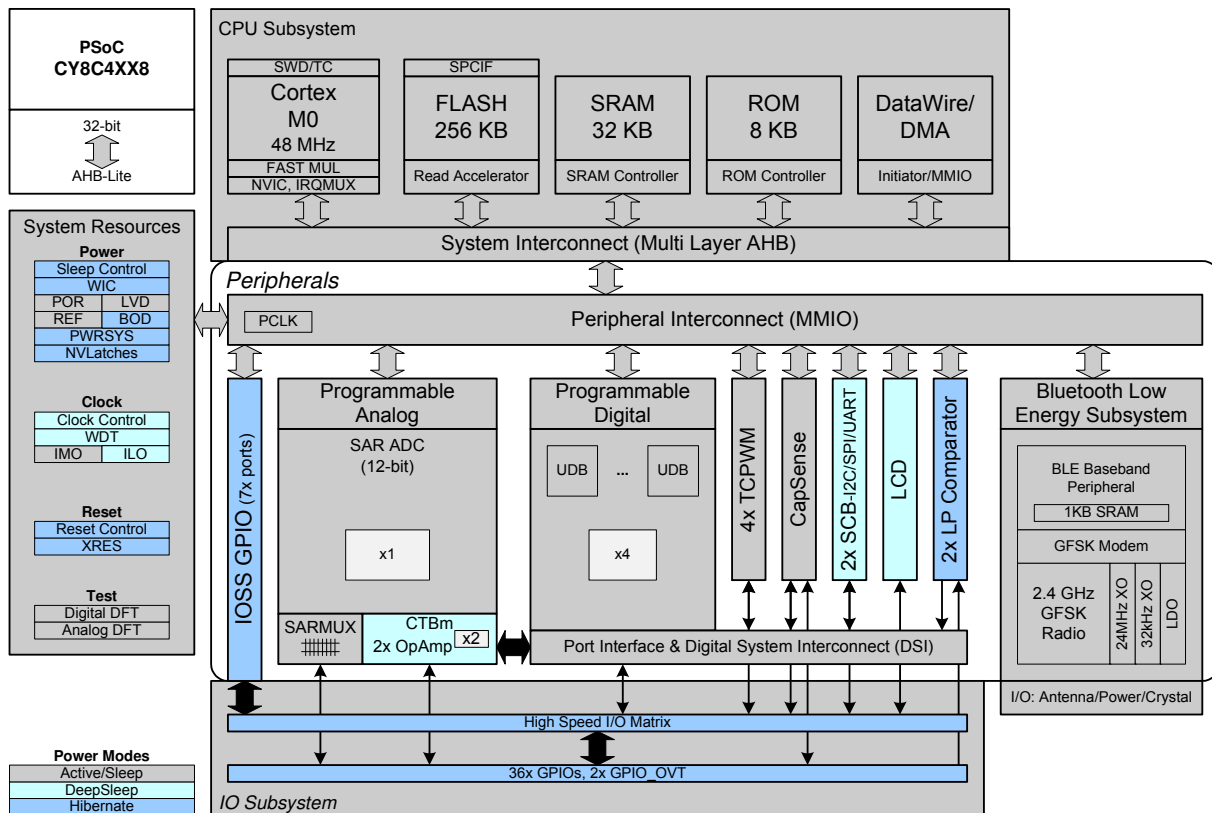
**Figure 1. Multiple-Sensor Example Project in PSoC Creator Contents**



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**Figure 2. Block Diagram**



The PSoC 4XX8 BLE 4.2 devices include extensive support for programming, testing, debugging, and tracing both hardware and firmware.

The ARM SWD interface supports all programming and debug features of the device.

Complete debug-on-chip functionality enables full-device debugging in the final system using the standard production device. It does not require special interfaces, debugging pods, simulators, or emulators. Only the standard programming connections are required to fully support debugging.

The PSoC Creator IDE provides fully integrated programming and debugging support for the PSoC 4XX8 BLE 4.2 devices. The SWD interface is fully compatible with industry-standard third-party tools. With the ability to disable debug features, very robust flash protection, and allowing customer-proprietary functionality to be implemented in on-chip programmable blocks, the PSoC 4XX8 BLE 4.2 family provides a level of security not possible with multi-chip application solutions or with microcontrollers.

Debug circuits are enabled by default and can only be disabled in firmware. If not enabled, the only way to re-enable them is to erase the entire device, clear flash protection, and reprogram the device with the new firmware that enables debugging.

Additionally, all device interfaces can be permanently disabled (device security) for applications concerned about phishing attacks due to a maliciously reprogrammed device or attempts to defeat security by starting and interrupting flash programming sequences. Because all programming, debug, and test interfaces are disabled when maximum device security is enabled, PSoC 4XX8 BLE 4.2 with device security enabled may not be returned for failure analysis. This is a trade-off the PSoC 4XX8 BLE 4.2 allows the customer to make.

## Functional Definition

### CPU and Memory Subsystem

#### CPU

The Cortex-M0 CPU in PSoC 4XX8 BLE 4.2 is part of the 32-bit MCU subsystem, which is optimized for low-power operation with extensive clock gating. It mostly uses 16-bit instructions and executes a subset of the Thumb-2 instruction set. This enables fully compatible binary upward migration of the code to higher-performance processors such as Cortex-M3 and M4. The Cypress implementation includes a hardware multiplier that provides a 32-bit result in one cycle. It includes a nested vectored interrupt controller (NVIC) block with 32 interrupt inputs and a wakeup interrupt controller (WIC). The WIC can wake the processor up from the Deep Sleep mode, allowing power to the main processor to be switched off when the chip is in the Deep Sleep mode. The Cortex-M0 CPU provides a nonmaskable interrupt (NMI) input, which is made available to the user when it is not in use for system functions requested by the user.

The CPU also includes an SWD interface, which is a 2-wire form of JTAG; the debug configuration used for PSoC 4XX8 BLE 4.2 has four break-point (address) comparators and two watchpoint (data) comparators.

#### Flash

The PSoC 4XX8 BLE 4.2 device has a flash module with either 128 KB or 256 KB of flash memory, tightly coupled to the CPU to improve average access times from the flash block. The flash block is designed to deliver 2 wait-state (WS) access time at 48 MHz and with 1-WS access time at 24 MHz. The flash accelerator delivers 85% of single-cycle SRAM access performance on average. Part of the flash module can be used to emulate EEPROM operation if required. Maximum erase and program time is 20 ms per row (256 bytes). This also applies to the emulated EEPROM.

#### SRAM

SRAM memory is retained during Hibernate.

#### SROM

The 8-KB supervisory ROM contains a library of executable functions for flash programming. These functions are accessed through supervisory calls (SVC) and enable in-system programming of the flash memory.

#### DMA

A DMA engine, with eight channels, is provided that can do 32-bit transfers and has chainable ping-pong descriptors.

### System Resources

#### Power System

The power system is described in detail in the section [Power on page 16](#). It provides an assurance that the voltage levels are as required for the respective modes, and can either delay the mode entry (on power-on reset (POR), for example) until voltage levels are as required or generate resets (brownout detect (BOD)) or interrupts when the power supply reaches a particular programmable level between 1.8 and 4.5 V (low voltage detect (LVD)).

PSoC 4XX8 BLE 4.2 operates with a single external supply (1.71 to 5.5 V without radio, and 1.9 V to 5.5 V with radio). The device has five different power modes; transitions between these modes are managed by the power system. PSoC 4XX8 BLE 4.2 provides Sleep, Deep Sleep, Hibernate, and Stop low-power modes. Refer to the *Technical Reference Manual* for more details.

#### Clock System

The PSoC 4XX8 BLE 4.2 clock system is responsible for providing clocks to all subsystems that require clocks and for switching between different clock sources without glitching. In addition, the clock system ensures that no metastable conditions occur.

The clock system for PSoC 4XX8 BLE 4.2 consists of the internal main oscillator (IMO), the internal low-speed oscillator (ILO), the 24-MHz external crystal oscillator (ECO) and the 32-kHz watch crystal oscillator (WCO). In addition, an external clock may be supplied from a pin.

#### IMO Clock Source

The IMO is the primary source of internal clocking in PSoC 4XX8 BLE 4.2. It is trimmed during testing to achieve the specified accuracy. Trim values are stored in nonvolatile latches (NVL). Additional trim settings from flash can be used to compensate for changes. The IMO default frequency is 24 MHz and it can be adjusted between 3 to 48 MHz in steps of 1 MHz. The IMO tolerance with Cypress-provided calibration settings is  $\pm 2\%$ .

#### ILO Clock Source

The ILO is a very low-power oscillator, which is primarily used to generate clocks for the peripheral operation in the Deep Sleep mode. ILO-driven counters can be calibrated to the IMO to improve accuracy. Cypress provides a software component, which does the calibration.

#### External Crystal Oscillator (ECO)

The ECO is used as the active clock for the BLE subsystem to meet the  $\pm 50$ -ppm clock accuracy of the Bluetooth 4.2 Specification. PSoC 4XX8 BLE 4.2 includes a tunable load capacitor to tune the crystal clock frequency by measuring the actual clock frequency. The high-accuracy ECO clock can also be used as a system clock.

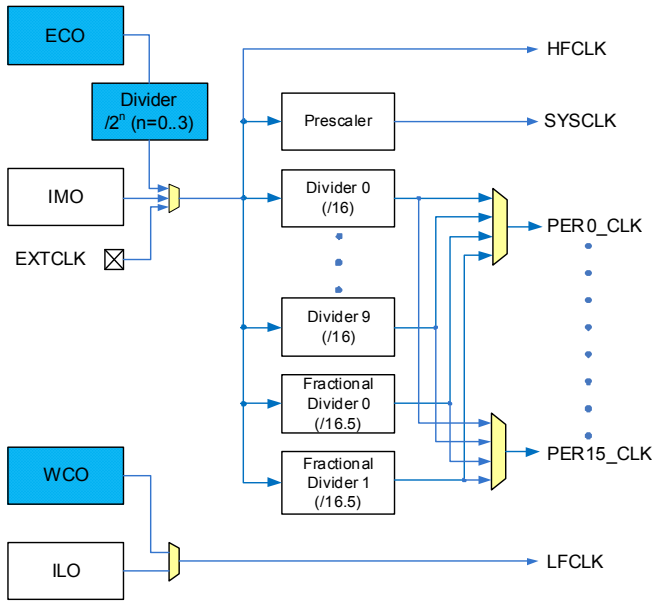
#### Watch Crystal Oscillator (WCO)

The WCO is used as the sleep clock for the BLE subsystem to meet the  $\pm 500$ -ppm clock accuracy for the Bluetooth 4.2 Specification. The sleep clock provides an accurate sleep timing and enables wakeup at the specified advertisement and connection intervals. The WCO output can be used to realize the real-time clock (RTC) function in firmware.

#### Watchdog Timer

A watchdog timer is implemented in the clock block running from the ILO or from the WCO; this allows the watchdog operation during Deep Sleep and generates a watchdog reset if not serviced before the timeout occurs. The watchdog reset is recorded in the Reset Cause register. With the WCO and firmware, an accurate real-time clock (within the bounds of the 32-kHz crystal accuracy) can be realized.

**Figure 3. PSoC 4XX8 BLE 4.2 MCU Clocking Architecture**



The HFCLK signal can be divided down (see Figure 3) to generate synchronous clocks for the UDBs, and the analog and digital peripherals. There are a total of 12 clock dividers for PSoC 4XX8 BLE 4.2: ten with 16-bit divide capability and two with 16.5-bit divide capability. This allows the generation of 16 divided clock signals, which can be used by peripheral blocks. The analog clock leads the digital clocks to allow analog events to occur before the digital clock-related noise is generated. The 16-bit and 16.5-bit dividers allow a lot of flexibility in generating fine-grained frequency values and are fully supported in PSoC Creator.

#### Reset

PSoC 4XX8 BLE 4.2 device can be reset from a variety of sources including a software reset. Reset events are asynchronous and guarantee reversion to a known state. The reset cause is recorded in a register, which is sticky through resets and allows the software to determine the cause of the reset. An XRES pin is reserved for an external reset to avoid complications with the configuration and multiple pin functions during power-on or reconfiguration. The XRES pin has an internal pull-up resistor that is always enabled.

#### Voltage Reference

The PSoC 4XX8 BLE 4.2 reference system generates all internally required references. A one-percent voltage reference spec is provided for the 12-bit ADC. To allow better signal-to-noise ratios (SNR) and better absolute accuracy, it is possible to bypass the internal reference using a GPIO pin or use an external reference for the SAR. Refer to Table 19, “SAR ADC AC Specifications,” on page 26 for details.

### BLE Radio and Subsystem

PSoC 4XX8 BLE 4.2 incorporates a Bluetooth Smart subsystem that contains the Physical Layer (PHY) and Link Layer (LL) engines with an embedded AES-128 security engine. The physical layer consists of the digital PHY and the RF transceiver that transmits and receives GFSK packets at 1 Mbps over a 2.4-GHz ISM band, which is compliant with Bluetooth Smart Bluetooth Specification 4.2. The baseband controller is a composite hardware and firmware implementation that supports both master and slave modes. Key protocol elements, such as HCI and link control, are implemented in firmware. Time-critical functional blocks, such as encryption, CRC, data whitening, and access code correlation, are implemented in hardware (in the LL engine).

The RF transceiver contains an integrated balun, which provides a single-ended RF port pin to drive a 50-Ω antenna via a matching/filtering network. In the receive direction, this block converts the RF signal from the antenna to a digital bit stream after performing GFSK demodulation. In the transmit direction, this block performs GFSK modulation and then converts a digital baseband signal to a radio frequency before transmitting it to air through the antenna.

The Bluetooth Smart Radio and Subsystem (BLESS) requires a 1.9-V minimum supply (the range varies from 1.9 V to 5.5 V).

Key features of BLESS are as follows:

- Master and slave single-mode protocol stack with logical link control and adaptation protocol (L2CAP), attribute (ATT), and security manager (SM) protocols
- API access to generic attribute profile (GATT), generic access profile (GAP), and L2CAP
- L2CAP connection-oriented channel
- GAP features
  - Broadcaster, Observer, Peripheral, and Central roles
  - Security mode 1: Level 1, 2, 3, and 4
  - Security mode 2: Level 1 and 2
  - User-defined advertising data
  - Multiple bond support
- GATT features
  - GATT client and server
  - Supports GATT sub-procedures
  - 32-bit universally unique identifier (UUID)
- Security Manager (SM)
  - Pairing methods: Just works, Passkey Entry, Out of Band and Numeric Comparison
  - Authenticated man-in-the-middle (MITM) protection and data signing
  - LE Secure Connections (Bluetooth 4.2 feature)
- Link Layer (LL)
  - Master and Slave roles
  - 128-bit AES engine
  - Encryption
  - Low-duty cycle advertising
  - LE Ping
  - LE Data Packet Length Extension (Bluetooth 4.2 feature)
  - Link Layer Privacy (with extended scanning filter policy, Bluetooth 4.2 feature)
- Supports all SIG-adopted BLE profiles



**Analog Blocks**

*12-bit SAR ADC*

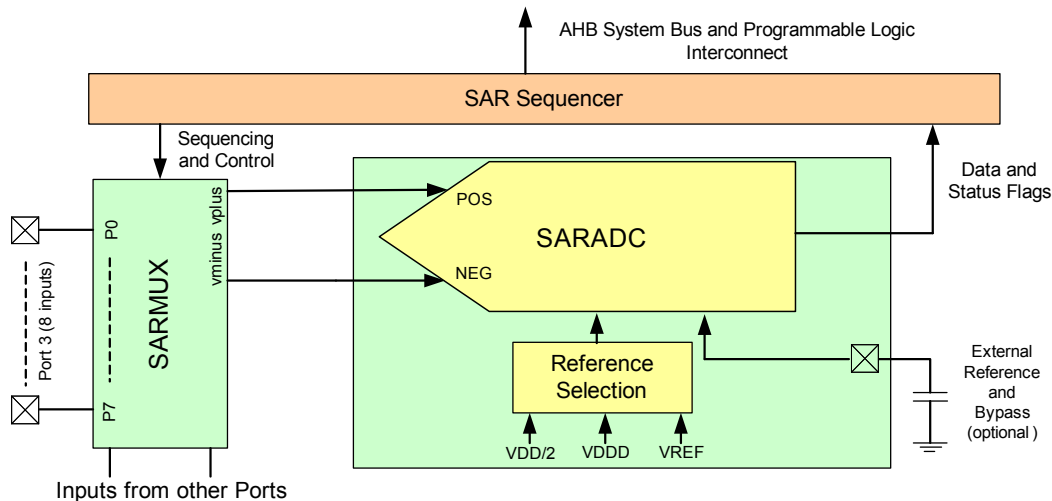
The 12-bit, 1-Msps SAR ADC can operate at a maximum clock rate of 18 MHz and requires a minimum of 18 clocks at that frequency to do a 12-bit conversion (up to 806 Ksps for the PSoC 41X8\_BLE derivatives).

The block functionality is augmented for the user by adding a reference buffer to it (trimmable to ±1%) and by providing the choice of three internal voltage references,  $V_{DD}$ ,  $V_{DD}/2$ , and  $V_{REF}$  (nominally 1.024 V), as well as an external reference through a GPIO pin. The Sample-and-Hold (S/H) aperture is programmable; it allows the gain bandwidth requirements of the amplifier driving the SAR inputs, which determine its settling time, to be relaxed if required. System performance will be 65 dB for true 12-bit precision provided appropriate references are used and system noise levels permit it. To improve the performance in noisy conditions, it is possible to provide an external bypass (through a fixed pin location) for the internal reference amplifier.

The SAR is connected to a fixed set of pins through an 8-input sequencer. The sequencer cycles through the selected channels autonomously (sequencer scan) and does so with zero switching overhead (that is, the aggregate sampling bandwidth is equal to 1 Msps whether it is for a single channel or distributed over several channels). The sequencer switching is effected through a state machine or through firmware-driven switching. A feature provided by the sequencer is the buffering of each channel to reduce CPU interrupt-service requirements. To accommodate signals with varying source impedances and frequencies, it is possible to have different sample times programmable for each channel. Also, the signal range specification through a pair of range registers (low and high range values) is implemented with a corresponding out-of-range interrupt if the digitized value exceeds the programmed range; this allows fast detection of out-of-range values without having to wait for a sequencer scan to be completed and the CPU to read the values and check for out-of-range values in software.

The SAR is able to digitize the output of the on-chip temperature sensor for calibration and other temperature-dependent functions. The SAR is not available in Deep Sleep and Hibernate modes as it requires a high-speed clock (up to 18 MHz). The SAR operating range is 1.71 to 5.5 V.

**Figure 4. SAR ADC System Diagram**



*Opamps (CTBm Block)*

PSoC 42X8\_BLE has four opamps with Comparator modes, which allow most common analog functions to be performed on-chip, eliminating external components. PGAs, voltage buffers, filters, transimpedance amplifiers, and other functions can be realized with external passives saving power, cost, and space. The on-chip opamps are designed with enough bandwidth to drive the sample-and-hold circuit of the ADC without requiring external buffering.

*Temperature Sensor*

PSoC 4XX8 BLE 4.2 has an on-chip temperature sensor. This consists of a diode, which is biased by a current source that can be disabled to save power. The temperature sensor is connected

to the ADC, which digitizes the reading and produces a temperature value by using a Cypress-supplied software that includes calibration and linearization.

*Low-Power Comparators*

PSoC 4XX8 BLE 4.2 has a pair of low-power comparators, which can also operate in Deep Sleep and Hibernate modes. This allows the analog system blocks to be disabled while retaining the ability to monitor external voltage levels during low-power modes. The comparator outputs are normally synchronized to avoid metastability unless operating in an asynchronous power mode (Hibernate) where the system wake-up circuit is activated by a comparator-switch event.

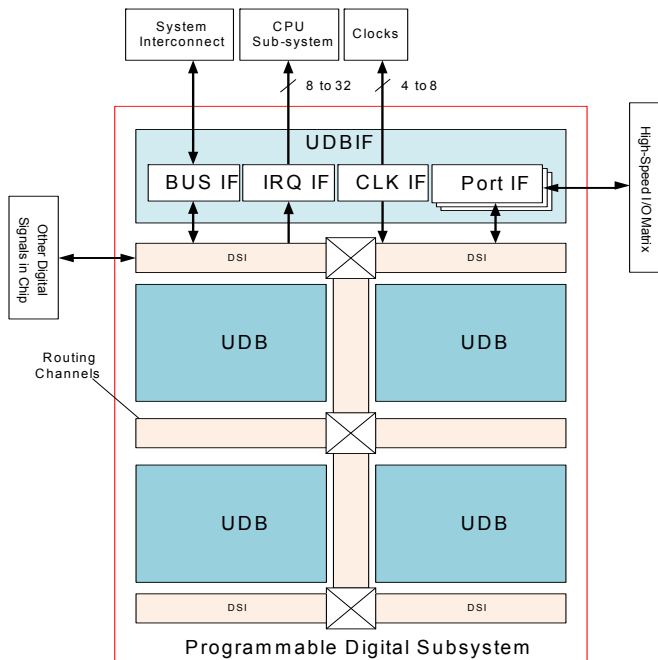


**Programmable Digital**

*Universal Digital Blocks (UDBs) and Port Interfaces*

The PSoc 4XX8 BLE 4.2 has four UDBs; the UDB array also provides a switched Digital System Interconnect (DSI) fabric that allows signals from peripherals and ports to be routed to and through the UDBs for communication and control.

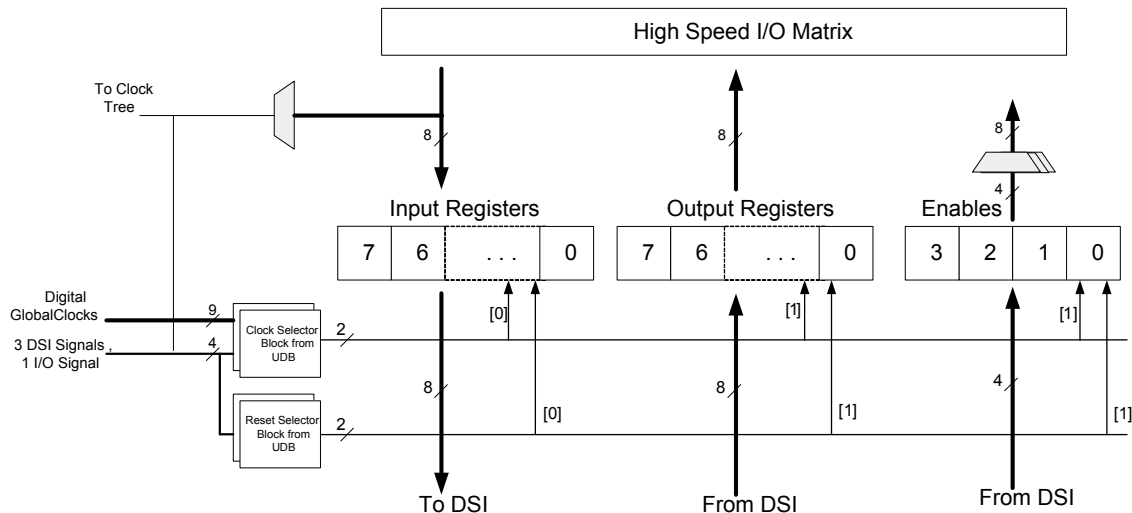
**Figure 5. UDB Array**



UDBs can be clocked from a clock-divider block, from a port interface (required for peripherals such as SPI), and from the DSI network directly or after synchronization.

A port interface is defined, which acts as a register that can be clocked with the same source as the PLDs inside the UDB array. This allows a faster operation because the inputs and outputs can be registered at the port interface close to the I/O pins and at the edge of the array. The port interface registers can be clocked by one of the I/Os from the same port. This allows interfaces such as SPI to operate at higher clock speeds by eliminating the delay for the port input to be routed over DSI and used to register other inputs (see Figure 6).

**Figure 6. Port Interface**



UDBs can generate interrupts (one UDB at a time) to the interrupt controller. UDBs retain the ability to connect to any pin on the chip through the DSI.

## Fixed-Function Digital

### Timer/Counter/PWM Block

The timer/counter/PWM block consists of four 16-bit counters with user-programmable period length. There is a Capture register to record the count value at the time of an event (which may be an I/O event), a period register which is used to either stop or auto-reload the counter when its count is equal to the period register, and compare registers to generate compare value signals which are used as PWM duty cycle outputs. The block also provides true and complementary outputs with programmable offset between them to allow the use as deadband programmable complementary PWM outputs. It also has a Kill input to force outputs to a predetermined state; for example, this is used in motor-drive systems when an overcurrent state is indicated and the PWMs driving the FETs need to be shut off immediately with no time for software intervention.

### Serial Communication Blocks (SCB)

PSoC 4XX8 BLE 4.2 has two SCBs, each of which can implement an I<sup>2</sup>C, UART, or SPI interface.

**I<sup>2</sup>C Mode:** The hardware I<sup>2</sup>C block implements a full multi-master and slave interface (it is capable of multimaster arbitration). This block is capable of operating at speeds of up to 1 Mbps (Fast Mode Plus) and has flexible buffering options to reduce the interrupt overhead and latency for the CPU. It also supports EzI<sup>2</sup>C that creates a mailbox address range in the memory of PSoC 4XX8 BLE 4.2 and effectively reduces the I<sup>2</sup>C communication to reading from and writing to an array in the memory. In addition, the block supports an 8-deep FIFO for receive and transmit, which, by increasing the time given for the CPU to read the data, greatly reduces the need for clock stretching caused by the CPU not having read the data on time. The FIFO mode is available in all channels and is very useful in the absence of DMA.

The I<sup>2</sup>C peripheral is compatible with I<sup>2</sup>C Standard-mode, Fast-mode, and Fast-Mode Plus devices as defined in the NXP I<sup>2</sup>C-bus specification and user manual (UM10204). The I<sup>2</sup>C bus I/O is implemented with GPIO in open-drain modes.

SCB1 is fully compliant with Standard mode (100 kHz), Fast mode (400 kHz), and Fast-Mode Plus (1 MHz) I<sup>2</sup>C signaling specifications when routed to GPIO pins P5[0] and P5[1], except for hot-swap capability during I<sup>2</sup>C active communication. The remaining GPIOs do not meet the hot-swap specification ( $V_{DD}$  off; draw < 10- $\mu$ A current) for Fast mode and Fast-Mode Plus,  $I_{OL}$  Spec (20 mA) for Fast-Mode Plus, hysteresis spec (0.05  $V_{DD}$ ) for Fast mode and Fast-Mode Plus, and minimum fall time spec for Fast mode and Fast-Mode Plus.

- GPIO cells, including P5.0 and P5.1, cannot be hot-swapped or powered up independent of the rest of the I<sup>2</sup>C system.
- The GPIO pins P5.0 and P5.1 are over-voltage tolerant but cannot be hot-swapped or powered up independent of the rest of the I<sup>2</sup>C system
- Fast-Mode Plus has an  $I_{OL}$  specification of 20 mA at a  $V_{OL}$  of 0.4 V. The GPIO cells can sink a maximum of 8 mA  $I_{OL}$  with a  $V_{OL}$  maximum of 0.6 V.
- Fast-mode and Fast-Mode Plus specify minimum Fall times, which are not met with the GPIO cell; the Slow-Strong mode can help meet this spec depending on the bus load.

**UART Mode:** This is a full-feature UART operating at up to 1 Mbps. It supports automotive single-wire interface (LIN), infrared interface (IrDA), and SmartCard (ISO7816) protocols, all of which are minor variants of the basic UART protocol. In addition, it supports the 9-bit multiprocessor mode that allows the addressing of peripherals connected over common RX and TX lines. Common UART functions such as parity error, break detect, and frame error are supported. An 8-deep FIFO allows much greater CPU service latencies to be tolerated. Note that hardware handshaking is not supported. This is not commonly used and can be implemented with a UDB-based UART in the system, if required.

**SPI Mode:** The SPI mode supports full Motorola SPI, TI Secure Simple Pairing (SSP) (essentially adds a start pulse that is used to synchronize SPI Codecs), and National Microwire (half-duplex form of SPI). The SPI block can use the FIFO and supports an EzSPI mode in which the data interchange is reduced to reading and writing an array in memory.

## GPIO

PSoC 4XX8 BLE 4.2 has 36 GPIOs. The GPIO block implements the following:

- Eight drive strength modes:
  - Analog input mode (input and output buffers disabled)
  - Input only
  - Weak pull-up with strong pull-down
  - Strong pull-up with weak pull-down
  - Open drain with strong pull-down
  - Open drain with strong pull-up
  - Strong pull-up with strong pull-down
  - Weak pull-up with weak pull-down
- Input threshold select (CMOS or LVTTTL)
- Pins 0 and 1 of Port 5 are overvoltage-tolerant pins
- Individual control of input and output buffer enabling/disabling in addition to drive-strength modes
- Hold mode for latching previous state (used for retaining the I/O state in Deep Sleep and Hibernate modes)
- Selectable slew rates for dV/dt-related noise control to improve EMI

The pins are organized in logical entities called ports, which are 8-bit in width. During power-on and reset, the blocks are forced to the disable state so as not to crowbar any inputs and/or cause excess turn-on current. A multiplexing network known as a high-speed I/O matrix (HSIOM) is used to multiplex between various signals that may connect to an I/O pin. Pin locations for fixed-function peripherals are also fixed to reduce internal multiplexing complexity (these signals do not go through the DSI network). DSI signals are not affected by this and any pin may be routed to any UDB through the DSI network.

Data output and pin-state registers store, respectively, the values to be driven on the pins and the states of the pins themselves.

Every I/O pin can generate an interrupt if so enabled and each I/O port has an interrupt request (IRQ) and interrupt service routine (ISR) vector associated with it (5 for PSoC 4XX8 BLE 4.2).

## Special-Function Peripherals

### *LCD Segment Drive*

PSoC 4XX8 BLE 4.2 has an LCD controller, which can drive up to four commons and up to 32 segments. It uses full digital methods to drive the LCD segments requiring no generation of internal LCD voltages. The two methods used are referred to as digital correlation and PWM.

The digital correlation method modulates the frequency and levels of the common and segment signals to generate the highest RMS voltage across a segment to light it up or to keep the RMS signal zero. This method is good for STN displays but may result in reduced contrast with TN (cheaper) displays.

The PWM method drives the panel with PWM signals to effectively use the capacitance of the panel to provide the integration of the modulated pulse-width to generate the desired LCD voltage. This method results in higher power consumption but can result in better results when driving TN displays. LCD operation is supported during Deep Sleep mode, refreshing a small display buffer (four bits; one 32-bit register per port).

### *CapSense*

CapSense is supported on all pins in PSoC 4XX8 BLE 4.2 through a CapSense Sigma-Delta (CSD) block that can be connected to any pin through an analog mux bus that any GPIO pin can be connected to via an Analog switch. CapSense function can thus be provided on any pin or group of pins in a system under software control. A Component is provided for the CapSense block to make it easy for the user.

The shield voltage can be driven on another mux bus to provide liquid-tolerance capability. Liquid tolerance is provided by driving the shield electrode in phase with the sense electrode to keep the shield capacitance from attenuating the sensed input.

The CapSense block has two IDACs which can be used for general purposes if CapSense is not being used (both IDACs are available in that case) or if CapSense is used without liquid tolerance (one IDAC is available).



## Pinouts

Table 1 shows the pin list for the PSoC 4XX8 BLE 4.2 device. Port 3 consists of the high-speed analog inputs for the SAR mux. All pins support CSD CapSense and analog mux bus connections.

**Table 1. PSoC 4XX8 BLE 4.2 Pin List (QFN Package)**

Pin	Name	Type	Description
1	VDDD	POWER	1.71-V to 5.5-V digital supply
2	XTAL32O/P6.0	CLOCK	32.768-kHz crystal
3	XTAL32I/P6.1	CLOCK	32.768-kHz crystal or external clock input
4	XRES	RESET	Reset, active LOW
5	P4.0	GPIO	Port 4 Pin 0, lcd, csd
6	P4.1	GPIO	Port 4 Pin 1, lcd, csd
7	P5.0	GPIO	Port 5 Pin 0, lcd, csd
8	P5.1	GPIO	Port 5 Pin 1, lcd, csd
9	VSSD	GROUND	Digital ground
10	VDDR	POWER	1.9-V to 5.5-V radio supply
11	GANT1	GROUND	Antenna shielding ground
12	ANT	ANTENNA	Antenna pin
13	GANT2	GROUND	Antenna shielding ground
14	VDDR	POWER	1.9-V to 5.5-V radio supply
15	VDDR	POWER	1.9-V to 5.5-V radio supply
16	XTAL24I	CLOCK	24-MHz crystal or external clock input
17	XTAL24O	CLOCK	24-MHz crystal
18	VDDR	POWER	1.9-V to 5.5-V radio supply
19	P0.0	GPIO	Port 0 Pin 0, lcd, csd
20	P0.1	GPIO	Port 0 Pin 1, lcd, csd
21	P0.2	GPIO	Port 0 Pin 2, lcd, csd
22	P0.3	GPIO	Port 0 Pin 3, lcd, csd
23	VDDD	POWER	1.71-V to 5.5-V digital supply
24	P0.4	GPIO	Port 0 Pin 4, lcd, csd
25	P0.5	GPIO	Port 0 Pin 5, lcd, csd
26	P0.6	GPIO	Port 0 Pin 6, lcd, csd
27	P0.7	GPIO	Port 0 Pin 7, lcd, csd
28	P1.0	GPIO	Port 1 Pin 0, lcd, csd
29	P1.1	GPIO	Port 1 Pin 1, lcd, csd
30	P1.2	GPIO	Port 1 Pin 2, lcd, csd
31	P1.3	GPIO	Port 1 Pin 3, lcd, csd
32	P1.4	GPIO	Port 1 Pin 4, lcd, csd
33	P1.5	GPIO	Port 1 Pin 5, lcd, csd
34	P1.6	GPIO	Port 1 Pin 6, lcd, csd
35	P1.7	GPIO	Port 1 Pin 7, lcd, csd
36	VDDA	POWER	1.71-V to 5.5-V analog supply
37	P2.0	GPIO	Port 2 Pin 0, lcd, csd
38	P2.1	GPIO	Port 2 Pin 1, lcd, csd
39	P2.2	GPIO	Port 2 Pin 2, lcd, csd

**Table 1. PSoC 4XX8 BLE 4.2 Pin List (QFN Package) (continued)**

Pin	Name	Type	Description
40	P2.3	GPIO	Port 2 Pin 3, lcd, csd
41	P2.4	GPIO	Port 2 Pin 4, lcd, csd
42	P2.5	GPIO	Port 2 Pin 5, lcd, csd
43	P2.6	GPIO	Port 2 Pin 6, lcd, csd
44	P2.7	GPIO	Port 2 Pin 7, lcd, csd
45	VREF	REF	1.024-V reference
46	VDDA	POWER	1.71-V to 5.5-V analog supply
47	P3.0	GPIO	Port 3 Pin 0, lcd, csd
48	P3.1	GPIO	Port 3 Pin 1, lcd, csd
49	P3.2	GPIO	Port 3 Pin 2, lcd, csd
50	P3.3	GPIO	Port 3 Pin 3, lcd, csd
51	P3.4	GPIO	Port 3 Pin 4, lcd, csd
52	P3.5	GPIO	Port 3 Pin 5, lcd, csd
53	P3.6	GPIO	Port 3 Pin 6, lcd, csd
54	P3.7	GPIO	Port 3 Pin 7, lcd, csd
55	VSSA	GROUND	Analog ground
56	VCCD	POWER	Regulated 1.8-V supply, connect to 1.3- $\mu$ F capacitor.
57	EPAD	GROUND	Ground paddle for the QFN package

**Table 2. PSoC 4XX8 BLE 4.2 Pin List (WLCSP Package)**

Pin	Name	Type	Description
A1	NC	NC	Do not connect
A2	VREF	REF	1.024-V reference
A3	VSSA	GROUND	Analog ground
A4	P3.3	GPIO	Port 3 Pin 3, analog/digital/lcd/csd
A5	P3.7	GPIO	Port 3 Pin 7, analog/digital/lcd/csd
A6	VSSD	GROUND	Digital ground
A7	VSSA	GROUND	Analog ground
A8	VCCD	POWER	Regulated 1.8-V supply, connect to 1- $\mu$ F capacitor
A9	VDDD	POWER	1.71-V to 5.5-V digital supply
B1	NB	NO BALL	No Ball
B2	P2.3	GPIO	Port 2 Pin 3, analog/digital/lcd/csd
B3	VSSA	GROUND	Analog ground
B4	P2.7	GPIO	Port 2 Pin 7, analog/digital/lcd/csd
B5	P3.4	GPIO	Port 3 Pin 4, analog/digital/lcd/csd
B6	P3.5	GPIO	Port 3 Pin 5, analog/digital/lcd/csd
B7	P3.6	GPIO	Port 3 Pin 6, analog/digital/lcd/csd
B8	XTAL32I/P6.1	CLOCK	32.768-kHz crystal or external clock input
B9	XTAL32O/P6.0	CLOCK	32.768-kHz crystal
C1	NC	NC	Do not connect

**Table 2. PSoC 4XX8 BLE 4.2 Pin List (WLCSP Package) (continued)**

Pin	Name	Type	Description
C2	VSSA	GROUND	Analog ground
C3	P2.2	GPIO	Port 2 Pin 2, analog/digital/lcd/csd
C4	P2.6	GPIO	Port 2 Pin 6, analog/digital/lcd/csd
C5	P3.0	GPIO	Port 3 Pin 0, analog/digital/lcd/csd
C6	P3.1	GPIO	Port 3 Pin 1, analog/digital/lcd/csd
C7	P3.2	GPIO	Port 3 Pin 2, analog/digital/lcd/csd
C8	XRES	RESET	Reset, active LOW
C9	P4.0	GPIO	Port 4 Pin 0, analog/digital/lcd/csd
D1	NC	NC	Do not connect
D2	P1.7	GPIO	Port 1 Pin 7, analog/digital/lcd/csd
D3	VDDA	POWER	1.71-V to 5.5-V analog supply
D4	P2.0	GPIO	Port 2 Pin 0, analog/digital/lcd/csd
D5	P2.1	GPIO	Port 2 Pin 1, analog/digital/lcd/csd
D6	P2.5	GPIO	Port 2 Pin 5, analog/digital/lcd/csd
D7	VSSD	GROUND	Digital ground
D8	P4.1	GPIO	Port 4 Pin 1, analog/digital/lcd/csd
D9	P5.0	GPIO	Port 5 Pin 0, analog/digital/lcd/csd
E1	NC	NC	Do not connect
E2	P1.2	GPIO	Port 1 Pin 2, analog/digital/lcd/csd
E3	P1.3	GPIO	Port 1 Pin 3, analog/digital/lcd/csd
E4	P1.4	GPIO	Port 1 Pin 4, analog/digital/lcd/csd
E5	P1.5	GPIO	Port 1 Pin 5, analog/digital/lcd/csd
E6	P1.6	GPIO	Port 1 Pin 6, analog/digital/lcd/csd
E7	P2.4	GPIO	Port 2 Pin 4, analog/digital/lcd/csd
E8	P5.1	GPIO	Port 5 Pin 1, analog/digital/lcd/csd
E9	VSSD	GROUND	Digital ground
F1	NC	NC	Do not connect
F2	VSSD	GROUND	Digital ground
F3	P0.7	GPIO	Port 0 Pin 7, analog/digital/lcd/csd
F4	P0.3	GPIO	Port 0 Pin 3, analog/digital/lcd/csd
F5	P1.0	GPIO	Port 1 Pin 0, analog/digital/lcd/csd
F6	P1.1	GPIO	Port 1 Pin 1, analog/digital/lcd/csd
F7	VSSR	GROUND	Radio ground
F8	VSSR	GROUND	Radio ground
F9	VDDR	POWER	1.9-V to 5.5-V radio supply
G1	NC	NC	Do not connect
G2	P0.6	GPIO	Port 0 Pin 6, analog/digital/lcd/csd
G3	VDDD	POWER	1.71-V to 5.5-V digital supply
G4	P0.2	GPIO	Port 0 Pin 2, analog/digital/lcd/csd
G5	VSSD	GROUND	Digital ground



**Table 2. PSoC 4XX8 BLE 4.2 Pin List (WLCSP Package) (continued)**

Pin	Name	Type	Description
G6	VSSR	GROUND	Radio ground
G7	VSSR	GROUND	Radio ground
G8	GANT	GROUND	Antenna shielding ground
G9	VSSR	GROUND	Radio ground
H1	NC	NC	Do not connect
H2	P0.5	GPIO	Port 0 Pin 5, analog/digital/lcd/csd
H3	P0.1	GPIO	Port 0 Pin 1, analog/digital/lcd/csd
H4	XTAL24O	CLOCK	24-MHz crystal
H5	XTAL24I	CLOCK	24-MHz crystal or external clock input
H6	VSSR	GROUND	Radio ground
H7	VSSR	GROUND	Radio ground
H8	ANT	ANTENNA	Antenna pin
J1	NC	NC	Do not connect
J2	P0.4	GPIO	Port 0 Pin 4, analog/digital/lcd/csd
J3	P0.0	GPIO	Port 0 Pin 0, analog/digital/lcd/csd
J4	VDDR	POWER	1.9-V to 5.5-V radio supply
J7	VDDR	POWER	1.9-V to 5.5-V radio supply
J8	NO CONNECT	–	–

High-speed I/O matrix (HSIOM) is a group of high-speed switches that routes GPIOs to the resources inside the device. These resources include CapSense, TCPWMs, I<sup>2</sup>C, SPI, UART, and LCD. HSIOM\_PORT\_SELx are 32-bit-wide registers that control the routing of GPIOs. Each register controls one port; four dedicated bits are assigned to each GPIO in the port. This provides up to 16 different options for GPIO routing as shown in [Table 3](#).

**Table 3. HSIOM Port Settings**

Value	Description
0	Firmware-controlled GPIO
1	Output is firmware-controlled, but Output Enable (OE) is controlled from DSI.
2	Both output and OE are controlled from DSI.
3	Output is controlled from DSI, but OE is firmware-controlled.
4	Pin is a CSD sense pin
5	Pin is a CSD shield pin
6	Pin is connected to AMUXA
7	Pin is connected to AMUXB
8	Pin-specific Active function #0
9	Pin-specific Active function #1
10	Pin-specific Active function #2

**Table 3. HSIOM Port Settings (continued)**

Value	Description
11	Reserved
12	Pin is an LCD common pin
13	Pin is an LCD segment pin
14	Pin-specific Deep-Sleep function #0
15	Pin-specific Deep-Sleep function #1

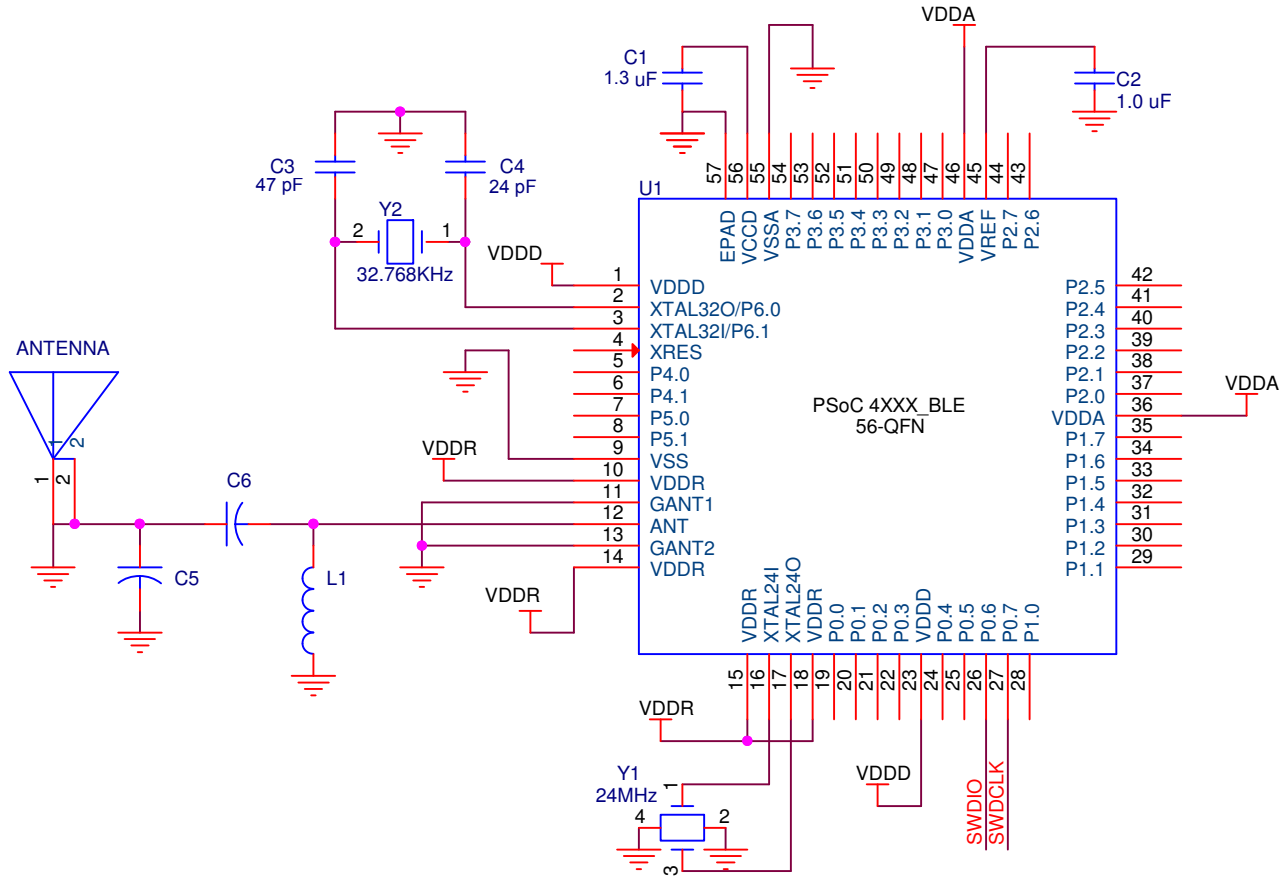
The selection of peripheral function for different GPIO pins is given in [Table 4](#).

**Table 4. Port Pin Connections**

Name	Analog	Digital					
		GPIO	Active #0	Active #1	Active #2	Deep Sleep #0	Deep Sleep #1
P0.0	COMP0_INP	GPIO	TCPWM0_P[3]	SCB1_UART_RX[1]	-	SCB1_I2C_SDA[1]	SCB1_SPI_MOSI[1]
P0.1	COMP0_INN	GPIO	TCPWM0_N[3]	SCB1_UART_TX[1]	-	SCB1_I2C_SCL[1]	SCB1_SPI_MISO[1]
P0.2	-	GPIO	TCPWM1_P[3]	SCB1_UART_RTS[1]	-	COMP0_OUT[0]	SCB1_SPI_SS0[1]
P0.3	-	GPIO	TCPWM1_N[3]	SCB1_UART_CTS[1]	-	COMP1_OUT[0]	SCB1_SPI_SCLK[1]
P0.4	COMP1_INP	GPIO	TCPWM1_P[0]	SCB0_UART_RX[1]	EXT_CLK[0]/ ECO_OUT[0]	SCB0_I2C_SDA[1]	SCB0_SPI_MOSI[1]
P0.5	COMP1_INN	GPIO	TCPWM1_N[0]	SCB0_UART_TX[1]	-	SCB0_I2C_SCL[1]	SCB0_SPI_MISO[1]
P0.6	-	GPIO	TCPWM2_P[0]	SCB0_UART_RTS[1]	-	SWDIO[0]	SCB0_SPI_SS0[1]
P0.7	-	GPIO	TCPWM2_N[0]	SCB0_UART_CTS[1]	-	SWDCLK[0]	SCB0_SPI_SCLK[1]
P1.0	CTBm1_OA0_INP	GPIO	TCPWM0_P[1]	-	-	COMP0_OUT[1]	WCO_OUT[2]
P1.1	CTBm1_OA0_INN	GPIO	TCPWM0_N[1]	-	-	COMP1_OUT[1]	SCB1_SPI_SS1
P1.2	CTBm1_OA0_OUT	GPIO	TCPWM1_P[1]	-	-	-	SCB1_SPI_SS2
P1.3	CTBm1_OA1_OUT	GPIO	TCPWM1_N[1]	-	-	-	SCB1_SPI_SS3
P1.4	CTBm1_OA1_INN	GPIO	TCPWM2_P[1]	SCB0_UART_RX[0]	-	SCB0_I2C_SDA[0]	SCB0_SPI_MOSI[1]
P1.5	CTBm1_OA1_INP	GPIO	TCPWM2_N[1]	SCB0_UART_TX[0]	-	SCB0_I2C_SCL[0]	SCB0_SPI_MISO[1]
P1.6	CTBm1_OA0_INP	GPIO	TCPWM3_P[1]	SCB0_UART_RTS[0]	-	-	SCB0_SPI_SS0[1]
P1.7	CTBm1_OA1_INP	GPIO	TCPWM3_N[1]	SCB0_UART_CTS[0]	-	-	SCB0_SPI_SCLK[1]
P2.0	CTBm0_OA0_INP	GPIO	-	-	-	-	SCB0_SPI_SS1
P2.1	CTBm0_OA0_INN	GPIO	-	-	-	-	SCB0_SPI_SS2
P2.2	CTBm0_OA0_OUT	GPIO	-	-	-	WAKEUP	SCB0_SPI_SS3
P2.3	CTBm0_OA1_OUT	GPIO	-	-	-	-	WCO_OUT[1]
P2.4	CTBm0_OA1_INN	GPIO	-	-	-	-	-
P2.5	CTBm0_OA1_INP	GPIO	-	-	-	-	-
P2.6	CTBm0_OA0_INP	GPIO	-	-	-	-	-
P2.7	CTBm0_OA1_INP	GPIO	-	-	EXT_CLK[1]/ECO_OUT[1]	-	-
P3.0	SARMUX_0	GPIO	TCPWM0_P[2]	SCB0_UART_RX[2]	-	SCB0_I2C_SDA[2]	-
P3.1	SARMUX_1	GPIO	TCPWM0_N[2]	SCB0_UART_TX[2]	-	SCB0_I2C_SCL[2]	-
P3.2	SARMUX_2	GPIO	TCPWM1_P[2]	SCB0_UART_RTS[2]	-	-	-
P3.3	SARMUX_3	GPIO	TCPWM1_N[2]	SCB0_UART_CTS[2]	-	-	-
P3.4	SARMUX_4	GPIO	TCPWM2_P[2]	SCB1_UART_RX[2]	-	SCB1_I2C_SDA[2]	-
P3.5	SARMUX_5	GPIO	TCPWM2_N[2]	SCB1_UART_TX[2]	-	SCB1_I2C_SCL[2]	-
P3.6	SARMUX_6	GPIO	TCPWM3_P[2]	SCB1_UART_RTS[2]	-	-	-
P3.7	SARMUX_7	GPIO	TCPWM3_N[2]	SCB1_UART_CTS[2]	-	-	WCO_OUT[0]
P4.0	CMOD	GPIO	TCPWM0_P[0]	SCB1_UART_RTS[0]	-	-	SCB1_SPI_MOSI[0]
P4.1	CTANK	GPIO	TCPWM0_N[0]	SCB1_UART_CTS[0]	-	-	SCB1_SPI_MISO[0]
P5.0	-	GPIO	TCPWM3_P[0]	SCB1_UART_RX[0]	EXTPA_EN	SCB1_I2C_SDA[0]	SCB1_SPI_SS0[0]
P5.1	-	GPIO	TCPWM3_N[0]	SCB1_UART_TX[0]	EXT_CLK[2]/ECO_OUT[2]	SCB1_I2C_SCL[0]	SCB1_SPI_SCLK[0]
P6.0_XTAL320	-	GPIO	-	-	-	-	-
P6.1_XTAL321	-	GPIO	-	-	-	-	-

The possible pin connections are shown for all analog and digital peripherals (except the radio, LCD, and CSD blocks, which were shown in Table 1). A typical system application connection diagram is shown in Figure 7.

**Figure 7. System Application Connection Diagram**



## Power

The PSoC 4XX8 BLE 4.2 device can be supplied from batteries with a voltage range of 1.9 V to 5.5 V by directly connecting to the digital supply (VDDD), analog supply (VDDA), and radio supply (VDDR) pins. Internal LDOs in the device regulate the supply voltage to the required levels for different blocks. The device has one regulator for the digital circuitry and separate regulators for radio circuitry for noise isolation. Analog circuits run directly from the analog supply (VDDA) input. The device uses separate regulators for Deep Sleep and Hibernate (lowered power supply and retention) modes to minimize the power consumption. The radio stops working below 1.9 V, but the device continues to function down to 1.71 V without RF.

Bypass capacitors must be used from VDDx (x = A, D, or R) to ground. The typical practice for systems in this frequency range is to use a capacitor in the 1- $\mu$ F range in parallel with a smaller capacitor (for example, 0.1  $\mu$ F). Note that these are simply rules of thumb and that, for critical applications, the PCB layout, lead inductance, and the bypass capacitor parasitic should be simulated to design and obtain optimal bypassing.

Power Supply	Bypass Capacitors
VDDD	The internal bandgap may be bypassed with a 1- $\mu$ F to 10- $\mu$ F.
VDDA	0.1- $\mu$ F ceramic at each pin plus bulk capacitor 1- $\mu$ F to 10- $\mu$ F.
VDDR	0.1- $\mu$ F ceramic at each pin plus bulk capacitor 1- $\mu$ F to 10- $\mu$ F.
VCCD	1.3- $\mu$ F ceramic capacitor at the VCCD pin.
VREF (optional)	The internal bandgap may be bypassed with a 1- $\mu$ F to 10- $\mu$ F capacitor.



## Development Support

The PSoC 4XX8 BLE 4.2 family has a rich set of documentation, development tools, and online resources to assist you during your development process. Visit [www.cypress.com/go/psoc4ble](http://www.cypress.com/go/psoc4ble) to find out more.

### Documentation

A suite of documentation supports the PSoC 4XX8 BLE 4.2 family to ensure that you can find answers to your questions quickly. This section contains a list of some of the key documents.

**Software User Guide:** A step-by-step guide for using PSoC Creator. The software user guide shows you how the PSoC Creator build process works in detail, how to use source control with PSoC Creator, and much more.

**Component Datasheets:** The flexibility of PSoC allows the creation of new peripherals (Components) long after the device has gone into production. Component datasheets provide all of the information needed to select and use a particular Component, including a functional description, API documentation, example code, and AC/DC specifications.

**Application Notes:** PSoC application notes discuss a particular application of PSoC in depth; examples include creating standard and custom BLE profiles. Application notes often include example projects in addition to the application note document.

**Technical Reference Manual:** The Technical Reference Manual (TRM) contains all the technical detail you need to use a PSoC device, including a complete description of all PSoC registers. The TRM is available in the Documentation section at [www.cypress.com/psoc4](http://www.cypress.com/psoc4).

### Online

In addition to print documentation, the Cypress PSoC forums connect you with fellow PSoC users and experts in PSoC from around the world, 24 hours a day, 7 days a week.

### Tools

With industry standard cores, programming, and debugging interfaces, the PSoC 4XX8 BLE 4.2 family is part of a development tool ecosystem. Visit us at [www.cypress.com/go/psoccreator](http://www.cypress.com/go/psoccreator) for the latest information on the revolutionary, easy to use PSoC Creator IDE, supported third party compilers, programmers, debuggers, and development kits.

## Electrical Specifications

### Absolute Maximum Ratings

**Table 5. Absolute Maximum Ratings<sup>[1]</sup>**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/ Conditions
SID1	V <sub>DDD_ABS</sub>	Analog, digital, or radio supply relative to V <sub>SS</sub> (V <sub>S5D</sub> = V <sub>SSA</sub> )	-0.5	-	6	V	Absolute max
SID2	V <sub>CCD_ABS</sub>	Direct digital core voltage input relative to V <sub>SSD</sub>	-0.5	-	1.95	V	Absolute max
SID3	V <sub>GPIO_ABS</sub>	GPIO voltage	-0.5	-	V <sub>DD</sub> + 0.5	V	Absolute max
SID4	I <sub>GPIO_ABS</sub>	Maximum current per GPIO	-25	-	25	mA	Absolute max
SID5	I <sub>GPIO_injection</sub>	GPIO injection current, Max for V <sub>IH</sub> > V <sub>DDD</sub> , and Min for V <sub>IL</sub> < V <sub>SS</sub>	-0.5	-	0.5	mA	Absolute max, current injected per pin
BID57	ESD_HBM	Electrostatic discharge human body model	2200	-	-	V	-
BID58	ESD_CDM	Electrostatic discharge charged device model	500	-	-	V	-
BID61	LU	Pin current for latch-up	-200	-	200	mA	-

### Device-Level Specifications

All specifications are valid for -40 °C ≤ T<sub>A</sub> ≤ 85 °C and T<sub>J</sub> ≤ 100 °C, except where noted. Specifications are valid for 1.71 V to 5.5 V, except where noted.

**Table 6. DC Specifications**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/ Conditions
SID6	V <sub>DD</sub>	Power supply input voltage (V <sub>D5A</sub> = V <sub>DDD</sub> = V <sub>DD</sub> )	1.8	-	5.5	V	With regulator enabled
SID7	V <sub>DD</sub>	Power supply input voltage unregulated (V <sub>D5A</sub> = V <sub>DDD</sub> = V <sub>DD</sub> )	1.71	1.8	1.89	V	Internally unregulated Supply
SID8	V <sub>DDR</sub>	Radio supply voltage (Radio ON)	1.9	-	5.5	V	-
SID8A	V <sub>DDR</sub>	Radio supply voltage (Radio OFF)	1.71	-	5.5	V	-
SID9	V <sub>CCD</sub>	Digital regulator output voltage (for core logic)	-	1.8	-	V	-
SID10	C <sub>VCCD</sub>	Digital regulator output bypass capacitor	1	1.3	1.6	μF	X5R ceramic or better
<b>Active Mode, V<sub>DD</sub> = 1.71 V to 5.5 V</b>							-
SID13	I <sub>DD3</sub>	Execute from flash; CPU at 3 MHz	-	2.1	-	mA	T = 25 °C, V <sub>DD</sub> = 3.3 V
SID14	I <sub>DD4</sub>	Execute from flash; CPU at 3 MHz	-	-	-	mA	T = -40 °C to 85 °C
SID15	I <sub>DD5</sub>	Execute from flash; CPU at 6 MHz	-	2.5	-	mA	T = 25 °C, V <sub>DD</sub> = 3.3 V
SID16	I <sub>DD6</sub>	Execute from flash; CPU at 6 MHz	-	-	-	mA	T = -40 °C to 85 °C
SID17	I <sub>DD7</sub>	Execute from flash; CPU at 12 MHz	-	4	-	mA	T = 25 °C, V <sub>DD</sub> = 3.3 V
SID18	I <sub>DD8</sub>	Execute from flash; CPU at 12 MHz	-	-	-	mA	T = -40 °C to 85 °C

**Note**

- Usage above the absolute maximum conditions listed in Table 5 may cause permanent damage to the device. Exposure to absolute maximum conditions for extended periods of time may affect device reliability. The maximum storage temperature is 150 °C in compliance with JEDEC Standard JESD22-A103, High Temperature Storage Life. When used below absolute maximum conditions but above normal operating conditions, the device may not operate to specification.

**Table 6. DC Specifications (continued)**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/ Conditions
SID19	I <sub>DD9</sub>	Execute from flash; CPU at 24 MHz	–	7.1	–	mA	T = 25 °C, V <sub>DD</sub> = 3.3 V
SID20	I <sub>DD10</sub>	Execute from flash; CPU at 24 MHz	–	–	–	mA	T = –40 °C to 85 °C
SID21	I <sub>DD11</sub>	Execute from flash; CPU at 48 MHz	–	13.4	–	mA	T = 25 °C, V <sub>DD</sub> = 3.3 V
SID22	I <sub>DD12</sub>	Execute from flash; CPU at 48 MHz	–	–	–	mA	T = –40 °C to 85 °C
<b>Sleep Mode, V<sub>DD</sub> = 1.8 to 5.5 V</b>							
SID23	I <sub>DD13</sub>	IMO on	–	–	–	mA	T = 25 °C, V <sub>DD</sub> = 3.3 V, SYSCLK = 3 MHz
<b>Sleep Mode, V<sub>DD</sub> and V<sub>DDR</sub> = 1.9 to 5.5 V</b>							
SID24	I <sub>DD14</sub>	ECO on	–	–	–	mA	T = 25 °C, V <sub>DD</sub> = 3.3 V, SYSCLK = 3 MHz
<b>Deep Sleep Mode, V<sub>DD</sub> = 1.8 to 3.6 V</b>							
SID25	I <sub>DD15</sub>	WDT with WCO on	–	1.5	–	µA	T = 25 °C, V <sub>DD</sub> = 3.3 V
SID26	I <sub>DD16</sub>	WDT with WCO on	–	–	–	µA	T = –40 °C to 85 °C
<b>Deep Sleep Mode, V<sub>DD</sub> = 3.6 to 5.5 V</b>							
SID27	I <sub>DD17</sub>	WDT with WCO on	–	–	–	µA	T = 25 °C, V <sub>DD</sub> = 5 V
SID28	I <sub>DD18</sub>	WDT with WCO on	–	–	–	µA	T = –40 °C to 85 °C
<b>Deep Sleep Mode, V<sub>DD</sub> = 1.71 to 1.89 V (Regulator Bypassed)</b>							
SID29	I <sub>DD19</sub>	WDT with WCO on	–	–	–	µA	T = 25 °C
SID30	I <sub>DD20</sub>	WDT with WCO on	–	–	–	µA	T = –40 °C to 85 °C
<b>Deep Sleep Mode, V<sub>DD</sub> = 1.8 to 3.6 V</b>							
SID31	I <sub>DD21</sub>	Opamp on	–	–	–	µA	T = 25 °C, V <sub>DD</sub> = 3.3 V
SID32	I <sub>DD22</sub>	Opamp on	–	–	–	µA	T = –40 °C to 85 °C
<b>Deep Sleep Mode, V<sub>DD</sub> = 3.6 to 5.5 V</b>							
SID33	I <sub>DD23</sub>	Opamp on	–	–	–	µA	T = 25 °C, V <sub>DD</sub> = 5 V
SID34	I <sub>DD24</sub>	Opamp on	–	–	–	µA	T = –40 °C to 85 °C
<b>Deep Sleep Mode, V<sub>DD</sub> = 1.71 to 1.89 V (Regulator Bypassed)</b>							
SID35	I <sub>DD25</sub>	Opamp on	–	–	–	µA	T = 25 °C
SID36	I <sub>DD26</sub>	Opamp on	–	–	–	µA	T = –40 °C to 85 °C
<b>Hibernate Mode, V<sub>DD</sub> = 1.8 to 3.6 V</b>							
SID37	I <sub>DD27</sub>	GPIO and reset active	–	150	–	nA	T = 25 °C, V <sub>DD</sub> = 3.3V
SID38	I <sub>DD28</sub>	GPIO and reset active	–	–	–	nA	T = –40 °C to 85 °C
<b>Hibernate Mode, V<sub>DD</sub> = 3.6 to 5.5 V</b>							
SID39	I <sub>DD29</sub>	GPIO and reset active	–	–	–	nA	T = 25 °C, V <sub>DD</sub> = 5 V
SID40	I <sub>DD30</sub>	GPIO and reset active	–	–	–	nA	T = –40 °C to 85 °C
<b>Hibernate Mode, V<sub>DD</sub> = 1.71 to 1.89 V (Regulator Bypassed)</b>							



**Table 6. DC Specifications** (continued)

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/ Conditions
SID41	I <sub>DD31</sub>	GPIO and reset active	–	–	–	nA	T = 25 °C
SID42	I <sub>DD32</sub>	GPIO and reset active	–	–	–	nA	T = –40 °C to 85 °C
<b>Stop Mode, V<sub>DD</sub> = 1.8 to 3.6 V</b>							
SID43	I <sub>DD33</sub>	Stop mode current (V <sub>DD</sub> )	–	20	–	nA	T = 25 °C, V <sub>DD</sub> = 3.3 V
SID44	I <sub>DD34</sub>	Stop mode current (V <sub>DDR</sub> )	–	40	–	nA	T = 25 °C, V <sub>DDR</sub> = 3.3 V
SID45	I <sub>DD35</sub>	Stop mode current (V <sub>DD</sub> )	–	–	–	nA	T = –40 °C to 85 °C
SID46	I <sub>DD36</sub>	Stop mode current (V <sub>DDR</sub> )	–	–	–	nA	T = –40 °C to 85 °C, V <sub>DDR</sub> = 1.9 V to 3.6 V
<b>Stop Mode, V<sub>DD</sub> = 3.6 to 5.5 V</b>							
SID47	I <sub>DD37</sub>	Stop mode current (V <sub>DD</sub> )	–	–	–	nA	T = 25 °C, V <sub>DD</sub> = 5 V
SID48	I <sub>DD38</sub>	Stop mode current (V <sub>DDR</sub> )	–	–	–	nA	T = 25 °C, V <sub>DDR</sub> = 5 V
SID49	I <sub>DD39</sub>	Stop mode current (V <sub>DD</sub> )	–	–	–	nA	T = –40 °C to 85 °C
SID50	I <sub>DD40</sub>	Stop mode current (V <sub>DDR</sub> )	–	–	–	nA	T = –40 °C to 85 °C
<b>Stop Mode, V<sub>DD</sub> = 1.71 to 1.89 V (Regulator Bypassed)</b>							
SID51	I <sub>DD41</sub>	Stop mode current (V <sub>DD</sub> )	–	–	–	nA	T = 25 °C
SID52	I <sub>DD42</sub>	Stop mode current (V <sub>DD</sub> )	–	–	–	nA	T = –40 °C to 85 °C

**Table 7. AC Specifications**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/ Conditions
SID53	F <sub>CPU</sub>	CPU frequency	DC	–	48	MHz	1.71 V ≤ V <sub>DD</sub> ≤ 5.5 V
SID54	T <sub>SLEEP</sub>	Wakeup from Sleep mode	–	0	–	μs	Guaranteed by characterization
SID55	T <sub>DEEPSLEEP</sub>	Wakeup from Deep Sleep mode	–	–	25	μs	24-MHz IMO. Guaranteed by characterization.
SID56	T <sub>HIBERNATE</sub>	Wakeup from Hibernate mode	–	–	0.7	ms	Guaranteed by characterization
SID57	T <sub>STOP</sub>	Wakeup from Stop mode	–	–	2.2	ms	Guaranteed by characterization

**GPIO**

**Table 8. GPIO DC Specifications**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/ Conditions
SID58	V <sub>IH</sub>	Input voltage HIGH threshold	0.7 × V <sub>DD</sub>	–	–	V	CMOS input
SID59	V <sub>IL</sub>	Input voltage LOW threshold	–	–	0.3 × V <sub>DD</sub>	V	CMOS input
SID60	V <sub>IH</sub>	LVTTL input, V <sub>DD</sub> < 2.7 V	0.7 × V <sub>DD</sub>	–	–	V	–
SID61	V <sub>IL</sub>	LVTTL input, V <sub>DD</sub> < 2.7 V	–	–	0.3 × V <sub>DD</sub>	V	–
SID62	V <sub>IH</sub>	LVTTL input, V <sub>DD</sub> ≥ 2.7 V	2.0	–	–	V	–
SID63	V <sub>IL</sub>	LVTTL input, V <sub>DD</sub> ≥ 2.7 V	–	–	0.8	V	–
SID64	V <sub>OH</sub>	Output voltage HIGH level	V <sub>DD</sub> – 0.6	–	–	V	I <sub>oh</sub> = 4-mA at 3.3-V V <sub>DD</sub>
SID65	V <sub>OH</sub>	Output voltage HIGH level	V <sub>DD</sub> – 0.5	–	–	V	I <sub>oh</sub> = 1-mA at 1.8-V V <sub>DD</sub>
SID66	V <sub>OL</sub>	Output voltage LOW level	–	–	0.6	V	I <sub>ol</sub> = 8-mA at 3.3-V V <sub>DD</sub>
SID67	V <sub>OL</sub>	Output voltage LOW level	–	–	0.6	V	I <sub>ol</sub> = 4-mA at 1.8-V V <sub>DD</sub>
SID68	V <sub>OL</sub>	Output voltage LOW level	–	–	0.4	V	I <sub>ol</sub> = 3-mA at 3.3-V V <sub>DD</sub>
SID69	R <sub>pullup</sub>	Pull-up resistor	3.5	5.6	8.5	kΩ	–
SID70	R <sub>pulldown</sub>	Pull-down resistor	3.5	5.6	8.5	kΩ	–
SID71	I <sub>IL</sub>	Input leakage current (absolute value)	–	–	2	nA	25 °C, V <sub>DD</sub> = 3.3 V
SID72	I <sub>IL_CTBM</sub>	Input leakage on CTBm input pins	–	–	4	nA	–
SID73	C <sub>IN</sub>	Input capacitance	–	–	7	pF	–
SID74	V <sub>hystttl</sub>	Input hysteresis LVTTL	25	40	–	mV	V <sub>DD</sub> > 2.7 V
SID75	V <sub>hyscmos</sub>	Input hysteresis CMOS	0.05 × V <sub>DD</sub>	–	–	mV	–
SID76	I <sub>diode</sub>	Current through protection diode to V <sub>DD</sub> /V <sub>SS</sub>	–	–	100	μA	–
SID77	I <sub>TOT_GPIO</sub>	Maximum total source or sink chip current	–	–	200	mA	–

**Table 9. GPIO AC Specifications**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/ Conditions
SID78	T <sub>RISEF</sub>	Rise time in Fast-Strong mode	2	–	12	ns	3.3-V V <sub>DDD</sub> , C <sub>LOAD</sub> = 25-pF
SID79	T <sub>FALLF</sub>	Fall time in Fast-Strong mode	2	–	12	ns	3.3-V V <sub>DDD</sub> , C <sub>LOAD</sub> = 25-pF
SID80	T <sub>RISES</sub>	Rise time in Slow-Strong mode	10	–	60	–	3.3-V V <sub>DDD</sub> , C <sub>LOAD</sub> = 25-pF
SID81	T <sub>FALLS</sub>	Fall time in Slow-Strong mode	10	–	60	–	3.3-V V <sub>DDD</sub> , C <sub>LOAD</sub> = 25-pF
SID82	F <sub>GPIOUT1</sub>	GPIO Fout; 3.3 V ≤ V <sub>DD</sub> ≤ 5.5 V. Fast-Strong mode	–	–	33	MHz	90/10%, 25-pF load, 60/40 duty cycle

**Note**

- V<sub>IH</sub> must not exceed V<sub>DD</sub> + 0.2 V.

**Table 9. GPIO AC Specifications (continued)**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/Conditions
SID83	F <sub>GPIOOUT2</sub>	GPIO F <sub>OUT</sub> ; 1.7 V ≤ V <sub>DD</sub> ≤ 3.3 V. Fast-Strong mode	–	–	16.7	MHz	90/10%, 25-pF load, 60/40 duty cycle
SID84	F <sub>GPIOOUT3</sub>	GPIO F <sub>OUT</sub> ; 3.3 V ≤ V <sub>DD</sub> ≤ 5.5 V. Slow-Strong mode	–	–	7	MHz	90/10%, 25-pF load, 60/40 duty cycle
SID85	F <sub>GPIOOUT4</sub>	GPIO F <sub>OUT</sub> ; 1.7 V ≤ V <sub>DD</sub> ≤ 3.3 V. Slow-Strong mode	–	–	3.5	MHz	90/10%, 25-pF load, 60/40 duty cycle
SID86	F <sub>GPIOIN</sub>	GPIO input operating frequency; 1.71 V ≤ V <sub>DD</sub> ≤ 5.5 V	–	–	48	MHz	90/10% V <sub>IO</sub>

**Table 10. OVT GPIO DC Specifications (P5\_0 and P5\_1 Only)**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/Conditions
SID71A	I <sub>IL</sub>	Input leakage current (absolute value), V <sub>IH</sub> > V <sub>DD</sub>	–	–	10	μA	25 °C, V <sub>DD</sub> = 0 V, V <sub>IH</sub> = 3.0 V
SID66A	V <sub>OL</sub>	Output voltage LOW level	–	–	0.4	V	I <sub>OL</sub> = 20-mA, V <sub>DD</sub> > 2.9-V

**Table 11. OVT GPIO AC Specifications (P5\_0 and P5\_1 Only)**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/Conditions
SID78A	T <sub>RISE_OVFS</sub>	Output rise time in Fast-Strong mode	1.5	–	12	ns	25-pF load, 10%–90%, V <sub>DD</sub> =3.3-V
SID79A	T <sub>FALL_OVFS</sub>	Output fall time in Fast-Strong mode	1.5	–	12	ns	25-pF load, 10%–90%, V <sub>DD</sub> =3.3-V
SID80A	T <sub>RISSS</sub>	Output rise time in Slow-Strong mode	10	–	60	ns	25-pF load, 10%–90%, V <sub>DD</sub> =3.3-V
SID81A	T <sub>FALLSS</sub>	Output fall time in Slow-Strong mode	10	–	60	ns	25-pF load, 10%–90%, V <sub>DD</sub> =3.3-V
SID82A	F <sub>GPIOOUT1</sub>	GPIO F <sub>OUT</sub> ; 3.3 V ≤ V <sub>DD</sub> ≤ 5.5 V Fast-Strong mode	–	–	24	MHz	90/10%, 25-pF load, 60/40 duty cycle
SID83A	F <sub>GPIOOUT2</sub>	GPIO F <sub>OUT</sub> ; 1.71 V ≤ V <sub>DD</sub> ≤ 3.3 V Fast-Strong mode	–	–	16	MHz	90/10%, 25-pF load, 60/40 duty cycle

**XRES**

**Table 12. XRES DC Specifications**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/Conditions
SID87	V <sub>IH</sub>	Input voltage HIGH threshold	0.7 × V <sub>DDD</sub>	–	–	V	CMOS input
SID88	V <sub>IL</sub>	Input voltage LOW threshold	–	–	0.3 × V <sub>DDD</sub>	V	CMOS input
SID89	R <sub>pullup</sub>	Pull-up resistor	3.5	5.6	8.5	kΩ	–
SID90	C <sub>IN</sub>	Input capacitance	–	3	–	pF	–
SID91	V <sub>HYSXRES</sub>	Input voltage hysteresis	–	100	–	mV	–
SID92	I <sub>DIODE</sub>	Current through protection diode to V <sub>DDD</sub> /V <sub>SS</sub>	–	–	100	μA	–

**Table 13. XRES AC Specifications**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/Conditions
SID93	T <sub>RESETWIDTH</sub>	Reset pulse width	1	–	–	µs	–

**Analog Peripherals**

*Opamp*

**Table 14. Opamp Specifications**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/Conditions
<b>I<sub>DD</sub> (Opamp Block Current. V<sub>DD</sub> = 1.8 V. No Load)</b>							
SID94	I <sub>DD_HI</sub>	Power = high	–	1000	1850	µA	–
SID95	I <sub>DD_MED</sub>	Power = medium	–	500	950	µA	–
SID96	I <sub>DD_LOW</sub>	Power = low	–	250	350	µA	–
<b>GBW (Load = 20 pF, 0.1 mA. V<sub>DDA</sub> = 2.7 V)</b>							
SID97	GBW_HI	Power = high	6	–	–	MHz	–
SID98	GBW_MED	Power = medium	4	–	–	MHz	–
SID99	GBW_LO	Power = low	–	1	–	MHz	–
<b>I<sub>OUT_MAX</sub> (V<sub>DDA</sub> ≥ 2.7 V, 500 mV From Rail)</b>							
SID100	I <sub>OUT_MAX_HI</sub>	Power = high	10	–	–	mA	–
SID101	I <sub>OUT_MAX_MID</sub>	Power = medium	10	–	–	mA	–
SID102	I <sub>OUT_MAX_LO</sub>	Power = low	–	5	–	mA	–
<b>I<sub>OUT</sub> (V<sub>DDA</sub> = 1.71 V, 500 mV From Rail)</b>							
SID103	I <sub>OUT_MAX_HI</sub>	Power = high	4	–	–	mA	–
SID104	I <sub>OUT_MAX_MID</sub>	Power = medium	4	–	–	mA	–
SID105	I <sub>OUT_MAX_LO</sub>	Power = low	–	2	–	mA	–
SID106	V <sub>IN</sub>	Charge pump on, V <sub>DDA</sub> ≥ 2.7 V	–0.05	–	V <sub>DDA</sub> – 0.2	V	–
SID107	V <sub>CM</sub>	Charge pump on, V <sub>DDA</sub> ≥ 2.7 V	–0.05	–	V <sub>DDA</sub> – 0.2	V	–
<b>V<sub>OUT</sub> (V<sub>DDA</sub> ≥ 2.7 V)</b>							
SID108	V <sub>OUT_1</sub>	Power = high, I <sub>LOAD</sub> =10 mA	0.5	–	V <sub>DDA</sub> – 0.5	V	–
SID109	V <sub>OUT_2</sub>	Power = high, I <sub>LOAD</sub> =1 mA	0.2	–	V <sub>DDA</sub> – 0.2	V	–
SID110	V <sub>OUT_3</sub>	Power = medium, I <sub>LOAD</sub> =1 mA	0.2	–	V <sub>DDA</sub> – 0.2	V	–
SID111	V <sub>OUT_4</sub>	Power = low, I <sub>LOAD</sub> =0.1 mA	0.2	–	V <sub>DDA</sub> – 0.2	V	–
SID112	V <sub>OS_TR</sub>	Offset voltage, trimmed	1	±0.5	1	mV	High mode
SID113	V <sub>OS_TR</sub>	Offset voltage, trimmed	–	±1	–	mV	Medium mode
SID114	V <sub>OS_TR</sub>	Offset voltage, trimmed	–	±2	–	mV	Low mode
SID115	V <sub>OS_DR_TR</sub>	Offset voltage drift, trimmed	–10	±3	10	µV/C	High mode
SID116	V <sub>OS_DR_TR</sub>	Offset voltage drift, trimmed	–	±10	–	µV/C	Medium mode
SID117	V <sub>OS_DR_TR</sub>	Offset voltage drift, trimmed	–	±10	–	µV/C	Low mode
SID118	CMRR	DC	70	80	–	dB	V <sub>DD</sub> = 3.6-V
SID119	PSRR	At 1 kHz, 100-mV ripple	70	85	–	dB	V <sub>DD</sub> = 3.6-V
<b>Noise</b>							
SID120	V <sub>N1</sub>	Input referred, 1 Hz–1 GHz, power = high	–	94	–	µVrms	–
SID121	V <sub>N2</sub>	Input referred, 1-kHz, power = high	–	72	–	nV/rtHz	–



**Table 14. Opamp Specifications (continued)**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/ Conditions
SID122	V <sub>N3</sub>	Input referred, 10-kHz, power = high	–	28	–	nV/rtHz	–
SID123	V <sub>N4</sub>	Input referred, 100-kHz, power = high	–	15	–	nV/rtHz	–
SID124	C <sub>LOAD</sub>	Stable up to maximum load. Performance specs at 50 pF	–	–	125	pF	–
SID125	Slew_rate	Cload = 50 pF, Power = High, V <sub>DDA</sub> ≥ 2.7 V	6	–	–	V/μsec	–
SID126	T <sub>op_wake</sub>	From disable to enable, no external RC dominating	–	300	–	μsec	–
<b>Comp_mode (Comparator Mode; 50-mV Drive, T<sub>RISE</sub> = T<sub>FALL</sub> (Approx.))</b>							
SID127	T <sub>PD1</sub>	Response time; power = high	–	150	–	nsec	–
SID128	T <sub>PD2</sub>	Response time; power = medium	–	400	–	nsec	–
SID129	T <sub>PD3</sub>	Response time; power = low	–	2000	–	nsec	–
SID130	V <sub>hyst_op</sub>	Hysteresis	–	10	–	mV	–
<b>Deep Sleep (Deep Sleep mode operation is only guaranteed for V<sub>DDA</sub> &gt; 2.5 V)</b>							
SID131	GBW_DS	Gain bandwidth product	–	50	–	kHz	–
SID132	IDD_DS	Current	–	15	–	μA	–
SID133	V <sub>os_DS</sub>	Offset voltage	–	5	–	mV	–
SID134	V <sub>os_dr_DS</sub>	Offset voltage drift	–	20	–	μV/°C	–
SID135	V <sub>out_DS</sub>	Output voltage	0.2	–	V <sub>DD</sub> –0.2	V	–
SID136	V <sub>cm_DS</sub>	Common mode voltage	0.2	–	V <sub>DD</sub> –1.8	V	–

**Table 15. Comparator DC Specifications<sup>[3]</sup>**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/ Conditions
SID140	V <sub>OFFSET1</sub>	Input offset voltage, Factory trim	–	–	±10	mV	–
SID141	V <sub>OFFSET2</sub>	Input offset voltage, Custom trim	–	–	±6	mV	–
SID141A	V <sub>OFFSET3</sub>	Input offset voltage, ultra-low-power mode	–	±12	–	mV	V <sub>DDD</sub> ≥ 2.6 V for Temp < 0°C, V <sub>DDD</sub> ≥ 1.8 V for Temp > 0°C
SID142	V <sub>HYST</sub>	Hysteresis when enabled. Common Mode voltage range from 0 to V <sub>DD</sub> –1	–	10	35	mV	–
SID143	V <sub>ICM1</sub>	Input common mode voltage in normal mode	0	–	V <sub>DDD</sub> –0.1	V	Modes 1 and 2
SID144	V <sub>ICM2</sub>	Input common mode voltage in low power mode	0	–	V <sub>DDD</sub>	V	–
SID145	V <sub>ICM3</sub>	Input common mode voltage in ultra low power mode	0	–	V <sub>DDD</sub> –1.15	V	V <sub>DDD</sub> ≥ 2.6 V for Temp < 0°C, V <sub>DDD</sub> ≥ 1.8 V for Temp > 0°C
SID146	CMRR	Common mode rejection ratio	50	–	–	dB	V <sub>DDD</sub> ≥ 2.7 V
SID147	CMRR	Common mode rejection ratio	42	–	–	dB	V <sub>DDD</sub> ≤ 2.7 V
SID148	I <sub>CMP1</sub>	Block current, normal mode	–	–	400	μA	–
SID149	I <sub>CMP2</sub>	Block current, low power mode	–	–	100	μA	–

**Note**

3. ULP LCOMP operating conditions:  
 - V<sub>DDD</sub> 2.6 V-5.5 V for datasheet temp range < 0 °C  
 - V<sub>DDD</sub> 1.8 V-5.5 V for datasheet temp range ≥ 0 °C

**Table 15. Comparator DC Specifications<sup>[3]</sup> (continued)**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/Conditions
SID150	I <sub>CMP3</sub>	Block current in ultra low-power mode	–	6	–	μA	V <sub>DDD</sub> ≥ 2.6 V for Temp < 0 °C, V <sub>DDD</sub> ≥ 1.8 V for Temp > 0 °C
SID151	Z <sub>CMP</sub>	DC input impedance of comparator	35	–	–	MΩ	–

**Table 16. Comparator AC Specifications<sup>[4]</sup>**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/Conditions
SID152	T <sub>RESP1</sub>	Response time, normal mode, 50-mV overdrive	–	38	–	ns	50-mV overdrive
SID153	T <sub>RESP2</sub>	Response time, low power mode, 50-mV overdrive	–	70	–	ns	50-mV overdrive
SID154	T <sub>RESP3</sub>	Response time, ultra-low-power mode, 50-mV overdrive	–	2.3	–	μs	200-mV overdrive. V <sub>DDD</sub> ≥ 2.6 V for Temp < 0 °C, V <sub>DDD</sub> ≥ 1.8 V for Temp > 0 °C

*Temperature Sensor*

**Table 17. Temperature Sensor Specifications**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/Conditions
SID155	T <sub>SENSACC</sub>	Temperature sensor accuracy	–5	±1	5	°C	–40 to +85 °C

*SAR ADC*

**Table 18. SAR ADC DC Specifications**

Spec ID#	Parameter	Description	Min	Typ	Max	Units	Details/Conditions
SID156	A_RES	Resolution	–	–	12	bits	–
SID157	A_CHNIS_S	Number of channels - single-ended	–	–	8	–	8 full-speed
SID158	A-CHNKS_D	Number of channels - differential	–	–	4	–	Diff inputs use neighboring I/O
SID159	A-MONO	Monotonicity	–	–	–	–	Yes
SID160	A_GAINERR	Gain error	–	–	±0.1	%	With external reference.
SID161	A_OFFSET	Input offset voltage	–	–	2	mV	Measured with 1-V V <sub>REF</sub>
SID162	A_ISAR	Current consumption	–	–	1	mA	–
SID163	A_VINS	Input voltage range - single-ended	V <sub>SS</sub>	–	V <sub>DDA</sub>	V	–
SID164	A_VIND	Input voltage range - differential	V <sub>SS</sub>	–	V <sub>DDA</sub>	V	–
SID165	A_INRES	Input resistance	–	–	2.2	kΩ	–
SID166	A_INCAP	Input capacitance	–	–	10	pF	–
SID312	VREFSAR	Trimmed internal reference to SAR	–1	–	1	%	Percentage of V <sub>bg</sub> (1.024-V)

**Note**

4. ULP LCOMP operating conditions:
  - V<sub>DDD</sub> 2.6 V-5.5 V for datasheet temp range < 0 °C
  - V<sub>DDD</sub> 1.8 V-5.5 V for datasheet temp range ≥ 0 °C