

Features

- High-performance, Low-power 32-bit Atmel® AVR® Microcontroller
 - Compact Single-cycle RISC Instruction Set Including DSP Instructions
 - Read-modify-write Instructions and Atomic Bit Manipulation
 - Performance
 - Up to 64DMIPS Running at 50MHz from Flash (1 Flash Wait State)
 - Up to 36DMIPS Running at 25MHz from Flash (0 Flash Wait State)
 - Memory Protection Unit (MPU)
 - Secure Access Unit (SAU) providing User-defined Peripheral Protection
- picoPower® Technology for Ultra-low Power Consumption
- Multi-hierarchy Bus System
 - High-performance Data Transfers on Separate Buses for Increased Performance
 - 12 Peripheral DMA Channels improve Speed for Peripheral Communication
- Internal High-speed Flash
 - 256Kbytes, 128Kbytes, and 64Kbytes Versions
 - Single-cycle Access up to 25MHz
 - FlashVault Technology Allows Pre-programmed Secure Library Support for End User Applications
 - Prefetch Buffer Optimizing Instruction Execution at Maximum Speed
 - 100,000 Write Cycles, 15-year Data Retention Capability
 - Flash Security Locks and User-defined Configuration Area
- Internal High-speed SRAM, Single-cycle Access at Full Speed
 - 32Kbytes (256Kbytes and 128Kbytes Flash) and 16Kbytes (64Kbytes Flash)
- Interrupt Controller (INTC)
 - Autovector Low-latency Interrupt Service with Programmable Priority
- External Interrupt Controller (EIC)
- Peripheral Event System for Direct Peripheral to Peripheral Communication
- System Functions
 - Power and Clock Manager
 - SleepWalking Power Saving Control
 - Internal System RC Oscillator (RCSYS)
 - 32 KHz Oscillator
 - Multipurpose Oscillator, Phase Locked Loop (PLL), and Digital Frequency Locked Loop (DFLL)
- Windowed Watchdog Timer (WDT)
- Asynchronous Timer (AST) with Real-time Clock Capability
 - Counter or Calendar Mode Supported
- Frequency Meter (FREQM) for Accurate Measuring of Clock Frequency
- Universal Serial Bus (USBC)
 - Full Speed and Low Speed USB Device Support
 - Multi-packet Ping-pong Mode
- Six 16-bit Timer/Counter (TC) Channels
 - External Clock Inputs, PWM, Capture, and Various Counting Capabilities
- 36 PWM Channels (PWMA)
 - 12-bit PWM with a Source Clock up to 150MHz
- Four Universal Synchronous/Asynchronous Receiver/Transmitters (USART)
 - Independent Baudrate Generator, Support for SPI
 - Support for Hardware Handshaking



32-bit Atmel AVR Microcontroller

ATUC256L3U
ATUC128L3U
ATUC64L3U
ATUC256L4U
ATUC128L4U
ATUC64L4U

Summary



- **One Master/Slave Serial Peripheral Interface (SPI) with Chip Select Signals**
 - Up to 15 SPI Slaves can be Addressed
- **Two Master and Two Slave Two-wire Interfaces (TWI), 400kbit/s I²C-compatible**
- **One 8-channel Analog-to-digital Converter (ADC) with up to 12 Bits Resolution**
 - Internal Temperature Sensor
- **Eight Analog Comparators (AC) with Optional Window Detection**
- **Capacitive Touch (CAT) Module**
 - Hardware-assisted Atmel® AVR® QTouch® and Atmel® AVR® QMatrix Touch Acquisition
 - Supports QTouch and QMatrix Capture from Capacitive Touch Sensors
- **QTouch Library Support**
 - Capacitive Touch Buttons, Sliders, and Wheels
 - QTouch and QMatrix Acquisition
- **Audio Bitstream DAC (ABDACB) Suitable for Stereo Audio**
- **Inter-IC Sound (IIS) Controller**
 - Compliant with Inter-IC Sound (I²S) Specification
- **On-chip Non-intrusive Debug System**
 - Nexus Class 2+, Runtime Control, Non-intrusive Data and Program Trace
 - aWire Single-pin Programming Trace and Debug Interface, Muxed with Reset Pin
 - NanoTrace Provides Trace Capabilities through JTAG or aWire Interface
- **64-pin TQFP/QFN (51 GPIO Pins), 48-pin TQFP/QFN/TLLGA (36 GPIO Pins)**
- **Six High-drive I/O Pins (64-pin Packages), Four High-drive I/O Pins (48-pin Packages)**
- **Single 1.62-3.6V Power Supply**

1. Description

The Atmel® AVR® ATUC64/128/256L3/4U is a complete system-on-chip microcontroller based on the AVR32 UC RISC processor running at frequencies up to 50MHz. AVR32 UC is a high-performance 32-bit RISC microprocessor core, designed for cost-sensitive embedded applications, with particular emphasis on low power consumption, high code density, and high performance.

The processor implements a Memory Protection Unit (MPU) and a fast and flexible interrupt controller for supporting modern and real-time operating systems. The Secure Access Unit (SAU) is used together with the MPU to provide the required security and integrity.

Higher computation capability is achieved using a rich set of DSP instructions.

The ATUC64/128/256L3/4U embeds state-of-the-art picoPower technology for ultra-low power consumption. Combined power control techniques are used to bring active current consumption down to 174µA/MHz, and leakage down to 220nA while still retaining a bank of backup registers. The device allows a wide range of trade-offs between functionality and power consumption, giving the user the ability to reach the lowest possible power consumption with the feature set required for the application.

The Peripheral Direct Memory Access (DMA) controller enables data transfers between peripherals and memories without processor involvement. The Peripheral DMA controller drastically reduces processing overhead when transferring continuous and large data streams.

The ATUC64/128/256L3/4U incorporates on-chip Flash and SRAM memories for secure and fast access. The FlashVault technology allows secure libraries to be programmed into the device. The secure libraries can be executed while the CPU is in Secure State, but not read by non-secure software in the device. The device can thus be shipped to end customers, who will be able to program their own code into the device to access the secure libraries, but without risk of compromising the proprietary secure code.

The External Interrupt Controller (EIC) allows pins to be configured as external interrupts. Each external interrupt has its own interrupt request and can be individually masked.

The Peripheral Event System allows peripherals to receive, react to, and send peripheral events without CPU intervention. Asynchronous interrupts allow advanced peripheral operation in low power sleep modes.

The Power Manager (PM) improves design flexibility and security. The Power Manager supports SleepWalking functionality, by which a module can be selectively activated based on peripheral events, even in sleep modes where the module clock is stopped. Power monitoring is supported by on-chip Power-on Reset (POR), Brown-out Detector (BOD), and Supply Monitor (SM). The device features several oscillators, such as Phase Locked Loop (PLL), Digital Frequency Locked Loop (DFLL), Oscillator 0 (OSC0), and system RC oscillator (RCSYS). Either of these oscillators can be used as source for the system clock. The DFLL is a programmable internal oscillator from 20 to 150MHz. It can be tuned to a high accuracy if an accurate reference clock is running, e.g. the 32KHz crystal oscillator.

The Watchdog Timer (WDT) will reset the device unless it is periodically serviced by the software. This allows the device to recover from a condition that has caused the system to be unstable.

The Asynchronous Timer (AST) combined with the 32KHz crystal oscillator supports powerful real-time clock capabilities, with a maximum timeout of up to 136 years. The AST can operate in counter or calendar mode.

The Frequency Meter (FREQM) allows accurate measuring of a clock frequency by comparing it to a known reference clock.

The Full-speed USB 2.0 device interface (USBC) supports several USB classes at the same time, thanks to the rich end-point configuration.

The device includes six identical 16-bit Timer/Counter (TC) channels. Each channel can be independently programmed to perform frequency measurement, event counting, interval measurement, pulse generation, delay timing, and pulse width modulation.

The Pulse Width Modulation controller (PWMA) provides 12-bit PWM channels which can be synchronized and controlled from a common timer. 36 PWM channels are available, enabling applications that require multiple PWM outputs, such as LCD backlight control. The PWM channels can operate independently, with duty cycles set individually, or in interlinked mode, with multiple channels changed at the same time.

The ATUC64/128/256L3/4U also features many communication interfaces, like USART, SPI, and TWI, for communication intensive applications. The USART supports different communication modes, like SPI Mode and LIN Mode.

A general purpose 8-channel ADC is provided, as well as eight analog comparators (AC). The ADC can operate in 10-bit mode at full speed or in enhanced mode at reduced speed, offering up to 12-bit resolution. The ADC also provides an internal temperature sensor input channel. The analog comparators can be paired to detect when the sensing voltage is within or outside the defined reference window.

The Capacitive Touch (CAT) module senses touch on external capacitive touch sensors, using the QTouch technology. Capacitive touch sensors use no external mechanical components, unlike normal push buttons, and therefore demand less maintenance in the user application. The CAT module allows up to 17 touch sensors, or up to 16 by 8 matrix sensors to be interfaced. All touch sensors can be configured to operate autonomously without software interaction, allowing wakeup from sleep modes when activated.

Atmel offers the QTouch library for embedding capacitive touch buttons, sliders, and wheels functionality into AVR microcontrollers. The patented charge-transfer signal acquisition offers robust sensing and includes fully debounced reporting of touch keys as well as Adjacent Key Suppression® (AKS®) technology for unambiguous detection of key events. The easy-to-use QTouch Suite toolchain allows you to explore, develop, and debug your own touch applications.

The Audio Bitstream DAC (ABDACB) converts a 16-bit sample value to a digital bitstream with an average value proportional to the sample value. Two channels are supported, making the ABDAC particularly suitable for stereo audio.

The Inter-IC Sound Controller (IISC) provides a 5-bit wide, bidirectional, synchronous, digital audio link with external audio devices. The controller is compliant with the Inter-IC Sound (I2S) bus specification.

The ATUC64/128/256L3/4U integrates a class 2+ Nexus 2.0 On-chip Debug (OCD) System, with non-intrusive real-time trace and full-speed read/write memory access, in addition to basic runtime control. The NanoTrace interface enables trace feature for aWire- or JTAG-based debuggers. The single-pin aWire interface allows all features available through the JTAG interface to be accessed through the RESET pin, allowing the JTAG pins to be used for GPIO or peripherals.

2.2 Configuration Summary

Table 2-1. Configuration Summary

| Feature | ATUC256L3U | ATUC128L3U | ATUC64L3U | ATUC256L4U | ATUC128L4U | ATUC64L4U |
|-------------------------|--|------------|-----------|----------------------|------------|-----------|
| Flash | 256 KB | 128 KB | 64 KB | 256 KB | 128 KB | 64 KB |
| SRAM | 32 KB | | 16 KB | 32 KB | | 16 KB |
| GPIO | 51 | | | 36 | | |
| High-drive pins | 6 | | | 4 | | |
| External Interrupts | 6 | | | | | |
| TWI | 2 | | | | | |
| USART | 4 | | | | | |
| Peripheral DMA Channels | 12 | | | | | |
| Peripheral Event System | 1 | | | | | |
| SPI | 1 | | | | | |
| Asynchronous Timers | 1 | | | | | |
| Timer/Counter Channels | 6 | | | | | |
| PWM channels | 36 | | | | | |
| Frequency Meter | 1 | | | | | |
| Watchdog Timer | 1 | | | | | |
| Power Manager | 1 | | | | | |
| Secure Access Unit | 1 | | | | | |
| Glue Logic Controller | 1 | | | | | |
| Oscillators | Digital Frequency Locked Loop 20-150MHz (DFLL) Phase Locked Loop 40-240MHz (PLL) Crystal Oscillator 0.45-16MHz (OSC0) Crystal Oscillator 32KHz (OSC32K) RC Oscillator 120MHz (RC120M) RC Oscillator 115kHz (RCSYS) RC Oscillator 32kHz (RC32K) | | | | | |
| ADC | 8-channel 12-bit | | | | | |
| Temperature Sensor | 1 | | | | | |
| Analog Comparators | 8 | | | | | |
| Capacitive Touch Module | 1 | | | | | |
| JTAG | 1 | | | | | |
| aWire | 1 | | | | | |
| USB | 1 | | | | | |
| Audio Bitstream DAC | 1 | | | 0 | | |
| IIS Controller | 1 | | | 0 | | |
| Max Frequency | 50MHz | | | | | |
| Packages | TQFP64/QFN64 | | | TQFP48/QFN48/TLLGA48 | | |

3. Package and Pinout

3.1 Package

The device pins are multiplexed with peripheral functions as described in [Section 3.2](#).

Figure 3-1. ATUC64/128/256L4U TQFP48/QFN48 Pinout

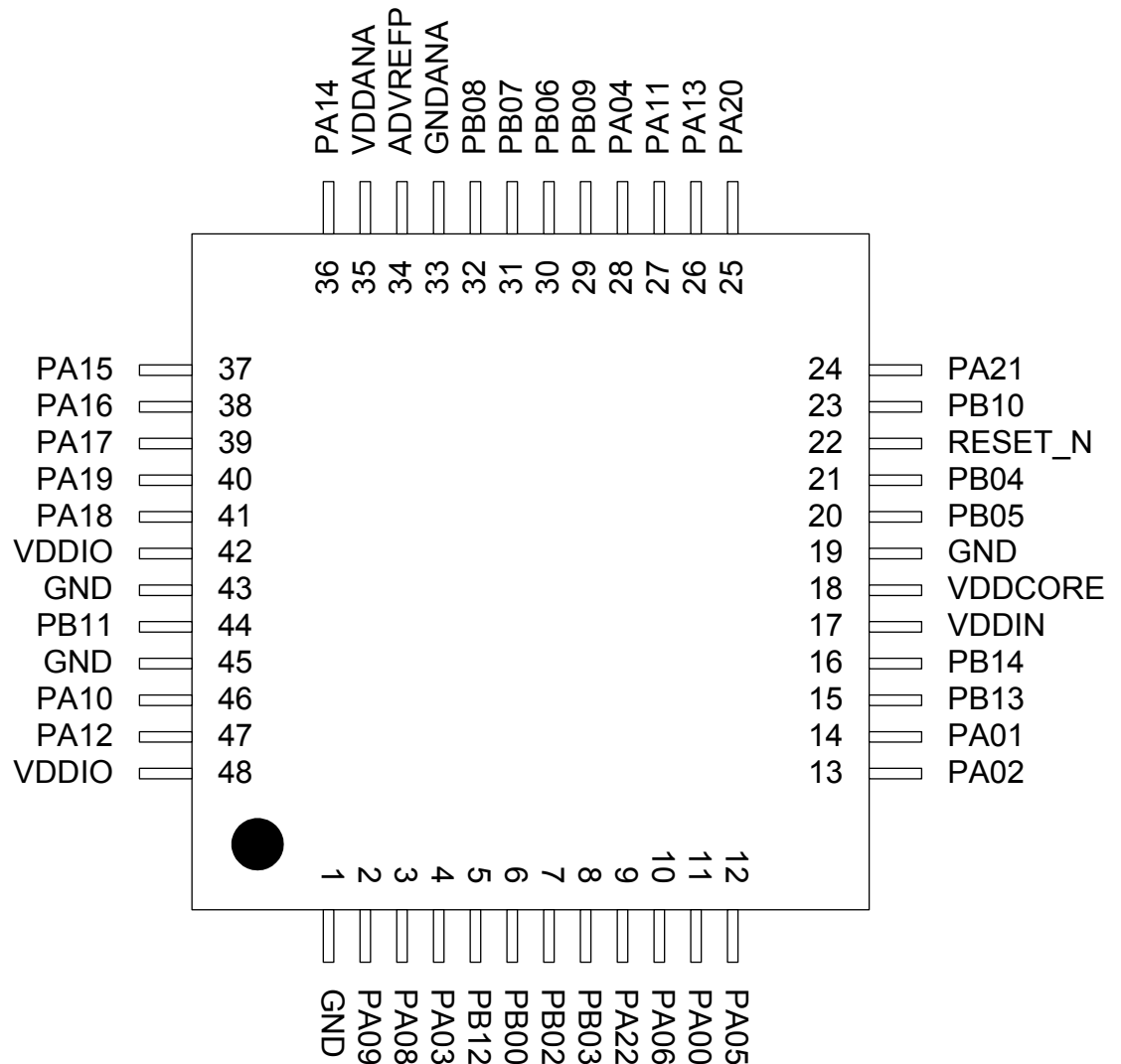


Figure 3-2. ATUC64/128/256L4U TLLGA48 Pinout

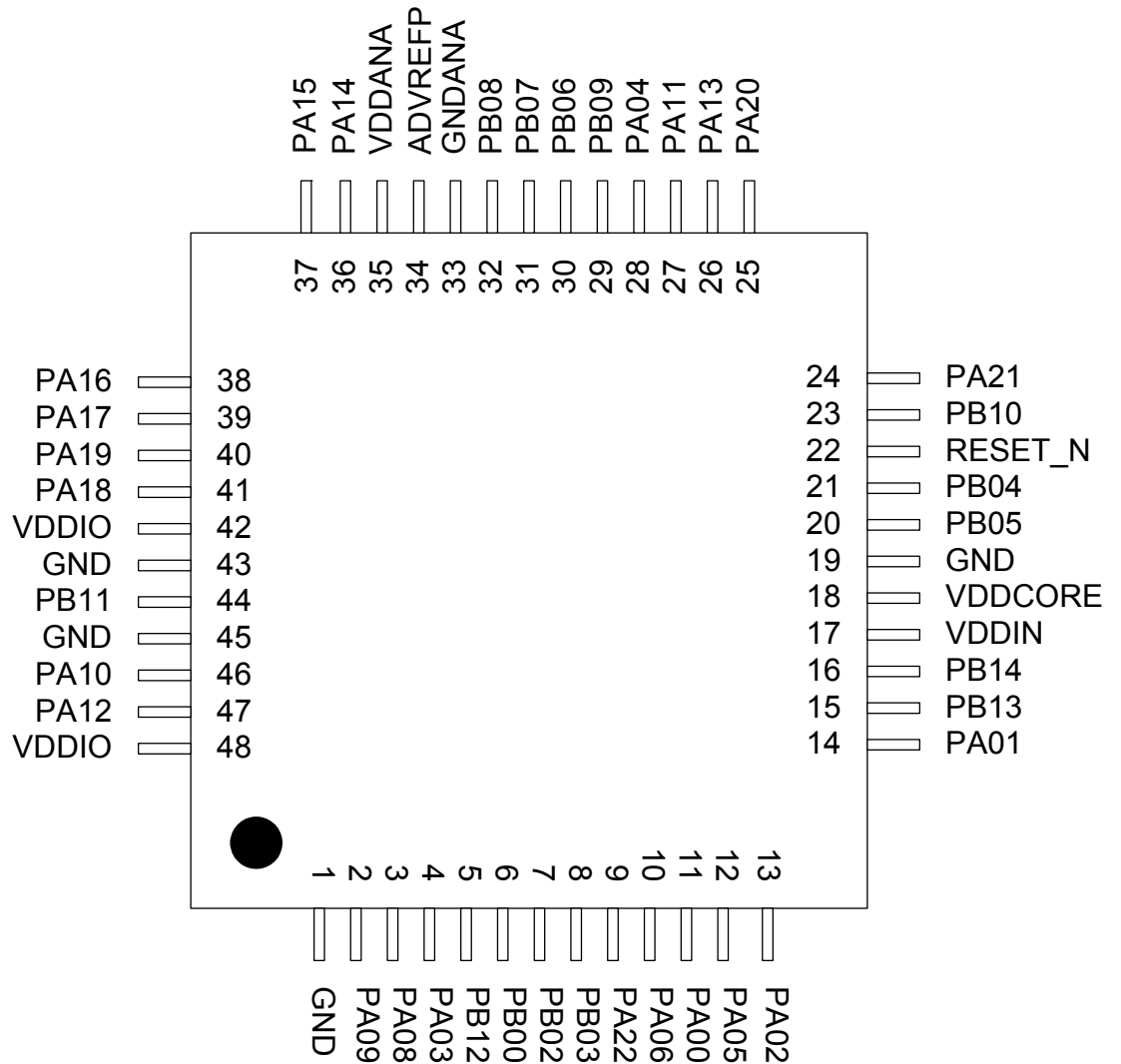
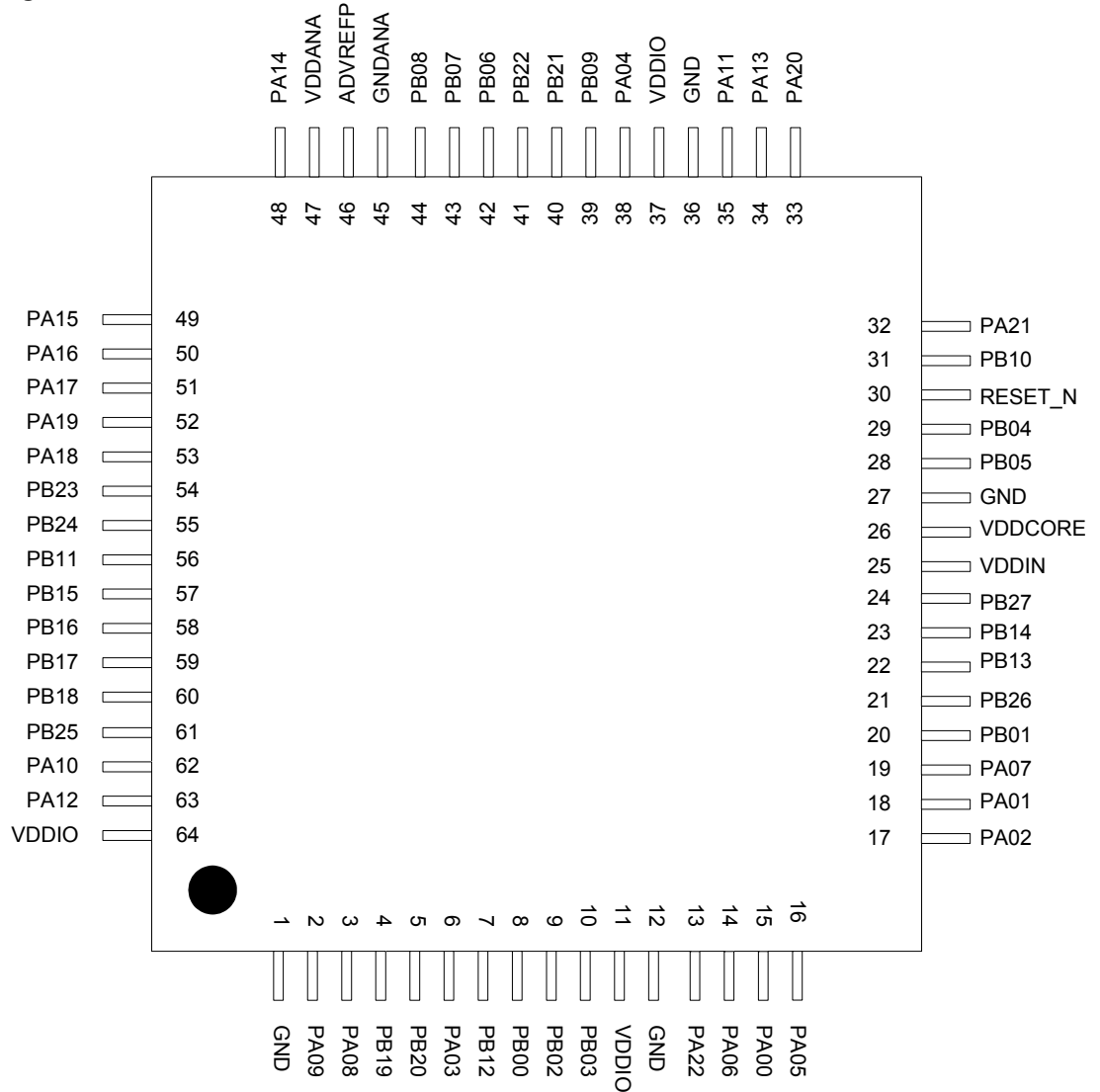


Figure 3-3. ATUC64/128/256L3U TQFP64/QFN64 Pinout



3.2 Peripheral Multiplexing on I/O lines

3.2.1 Multiplexed Signals

Each GPIO line can be assigned to one of the peripheral functions. The following table describes the peripheral signals multiplexed to the GPIO lines.

Table 3-1. GPIO Controller Function Multiplexing

| 48-pin | 64-pin | Pin Name | GPIO | Supply | Pad Type | GPIO Function | | | | | | | |
|--------|--------|----------|------|--------|------------|---------------|------------|-------------|------------|--------------|---------------|--------------|------------|
| | | | | | | A | B | C | D | E | F | G | H |
| 11 | 15 | PA00 | 0 | VDDIO | Normal I/O | USART0-TXD | USART1-RTS | SPI-NPCS[2] | | PWMA-PWMA[0] | | SCIF-GCLK[0] | CAT-CSA[2] |
| 14 | 18 | PA01 | 1 | VDDIO | Normal I/O | USART0-RXD | USART1-CTS | SPI-NPCS[3] | USART1-CLK | PWMA-PWMA[1] | ACIFB-ACAP[0] | TWIM0-TWALM | CAT-CSA[1] |

Table 3-1. GPIO Controller Function Multiplexing

| | | | | | | | | | | | | | |
|----|----|------|----|-------|--------------------------------------|--------------|----------------|--------------|----------------|---------------|-----------------|---------------------|-------------|
| 13 | 17 | PA02 | 2 | VDDIO | High-drive I/O | USART0-RTS | ADCIFB-TRIGGER | USART2-TXD | TC0-A0 | PWMA-PWMA[2] | ACIFB-ACBP[0] | USART0-CLK | CAT-CSA[3] |
| 4 | 6 | PA03 | 3 | VDDIO | Normal I/O | USART0-CTS | SPI-NPCS[1] | USART2-TXD | TC0-B0 | PWMA-PWMA[3] | ACIFB-ACBN[3] | USART0-CLK | CAT-CSB[3] |
| 28 | 38 | PA04 | 4 | VDDIO | Normal I/O | SPI-MISO | TWIMS0-TWCK | USART1-RXD | TC0-B1 | PWMA-PWMA[4] | ACIFB-ACBP[1] | | CAT-CSA[7] |
| 12 | 16 | PA05 | 5 | VDDIO | Normal I/O (TWI) | SPI-MOSI | TWIMS1-TWCK | USART1-TXD | TC0-A1 | PWMA-PWMA[5] | ACIFB-ACBN[0] | TWIMS0-TWD | CAT-CSB[7] |
| 10 | 14 | PA06 | 6 | VDDIO | High-drive I/O, 5V tolerant | SPI-SCK | USART2-TXD | USART1-CLK | TC0-B0 | PWMA-PWMA[6] | EIC-EXTINT[2] | SCIF-GCLK[1] | CAT-CSB[1] |
| | 19 | PA07 | 7 | VDDIO | Normal I/O (TWI) | SPI-NPCS[0] | USART2-RXD | TWIMS1-TWALM | TWIMS0-TWCK | PWMA-PWMA[7] | ACIFB-ACAN[0] | EIC-NMI (EXTINT[0]) | CAT-CSB[2] |
| 3 | 3 | PA08 | 8 | VDDIO | High-drive I/O | USART1-TXD | SPI-NPCS[2] | TC0-A2 | ADCIFB-ADP[0] | PWMA-PWMA[8] | | | CAT-CSA[4] |
| 2 | 2 | PA09 | 9 | VDDIO | High-drive I/O | USART1-RXD | SPI-NPCS[3] | TC0-B2 | ADCIFB-ADP[1] | PWMA-PWMA[9] | SCIF-GCLK[2] | EIC-EXTINT[1] | CAT-CSB[4] |
| 46 | 62 | PA10 | 10 | VDDIO | Normal I/O | TWIMS0-TWD | | TC0-A0 | | PWMA-PWMA[10] | ACIFB-ACAP[1] | SCIF-GCLK[2] | CAT-CSA[5] |
| 27 | 35 | PA11 | 11 | VDDIN | Normal I/O | | | | | PWMA-PWMA[11] | | | |
| 47 | 63 | PA12 | 12 | VDDIO | Normal I/O | | USART2-CLK | TC0-CLK1 | CAT-SMP | PWMA-PWMA[12] | ACIFB-ACAN[1] | SCIF-GCLK[3] | CAT-CSB[5] |
| 26 | 34 | PA13 | 13 | VDDIN | Normal I/O | GLOC-OUT[0] | GLOC-IN[7] | TC0-A0 | SCIF-GCLK[2] | PWMA-PWMA[13] | CAT-SMP | EIC-EXTINT[2] | CAT-CSA[0] |
| 36 | 48 | PA14 | 14 | VDDIO | Normal I/O | ADCIFB-AD[0] | TC0-CLK2 | USART2-RTS | CAT-SMP | PWMA-PWMA[14] | | SCIF-GCLK[4] | CAT-CSA[6] |
| 37 | 49 | PA15 | 15 | VDDIO | Normal I/O | ADCIFB-AD[1] | TC0-CLK1 | | GLOC-IN[6] | PWMA-PWMA[15] | CAT-SYNC | EIC-EXTINT[3] | CAT-CSB[6] |
| 38 | 50 | PA16 | 16 | VDDIO | Normal I/O | ADCIFB-AD[2] | TC0-CLK0 | | GLOC-IN[5] | PWMA-PWMA[16] | ACIFB-ACREFN | EIC-EXTINT[4] | CAT-CSA[8] |
| 39 | 51 | PA17 | 17 | VDDIO | Normal I/O (TWI) | | TC0-A1 | USART2-CTS | TWIMS1-TWD | PWMA-PWMA[17] | CAT-SMP | CAT-DIS | CAT-CSB[8] |
| 41 | 53 | PA18 | 18 | VDDIO | Normal I/O | ADCIFB-AD[4] | TC0-B1 | | GLOC-IN[4] | PWMA-PWMA[18] | CAT-SYNC | EIC-EXTINT[5] | CAT-CSB[0] |
| 40 | 52 | PA19 | 19 | VDDIO | Normal I/O | ADCIFB-AD[5] | | TC0-A2 | TWIMS1-TWALM | PWMA-PWMA[19] | SCIF-GCLK_IN[0] | CAT-SYNC | CAT-CSA[10] |
| 25 | 33 | PA20 | 20 | VDDIN | Normal I/O | USART2-TXD | | TC0-A1 | GLOC-IN[3] | PWMA-PWMA[20] | SCIF-RC32OUT | | CAT-CSA[12] |
| 24 | 32 | PA21 | 21 | VDDIN | Normal I/O (TWI, 5V tolerant, SMBus) | USART2-RXD | TWIMS0-TWD | TC0-B1 | ADCIFB-TRIGGER | PWMA-PWMA[21] | PWMA-PWMAOD[21] | SCIF-GCLK[0] | CAT-SMP |
| 9 | 13 | PA22 | 22 | VDDIO | Normal I/O | USART0-CTS | USART2-CLK | TC0-B2 | CAT-SMP | PWMA-PWMA[22] | ACIFB-ACBN[2] | | CAT-CSB[10] |
| 6 | 8 | PB00 | 32 | VDDIO | Normal I/O | USART3-TXD | ADCIFB-ADP[0] | SPI-NPCS[0] | TC0-A1 | PWMA-PWMA[23] | ACIFB-ACAP[2] | TC1-A0 | CAT-CSA[9] |
| | 20 | PB01 | 33 | VDDIO | High-drive I/O | USART3-RXD | ADCIFB-ADP[1] | SPI-SCK | TC0-B1 | PWMA-PWMA[24] | | TC1-A1 | CAT-CSB[9] |

Table 3-1. GPIO Controller Function Multiplexing

| | | | | | | | | | | | | | |
|----|----|------|----|-------|--------------------------------------|----------------|------------|--------------|----------------|---------------|-----------------|---------------------|-------------|
| 7 | 9 | PB02 | 34 | VDDIO | Normal I/O | USART3-RTS | USART3-CLK | SPI-MISO | TC0-A2 | PWMA-PWMA[25] | ACIFB-ACAN[2] | SCIF-GCLK[1] | CAT-CSB[11] |
| 8 | 10 | PB03 | 35 | VDDIO | Normal I/O | USART3-CTS | USART3-CLK | SPI-MOSI | TC0-B2 | PWMA-PWMA[26] | ACIFB-ACBP[2] | TC1-A2 | CAT-CSA[11] |
| 21 | 29 | PB04 | 36 | VDDIN | Normal I/O (TWI, 5V tolerant, SMBus) | TC1-A0 | USART1-RTS | USART1-CLK | TWIMS0-TWALM | PWMA-PWMA[27] | PWMA-PWMAOD[27] | TWIMS1-TWCK | CAT-CSA[14] |
| 20 | 28 | PB05 | 37 | VDDIN | Normal I/O (TWI, 5V tolerant, SMBus) | TC1-B0 | USART1-CTS | USART1-CLK | TWIMS0-TWCK | PWMA-PWMA[28] | PWMA-PWMAOD[28] | SCIF-GCLK[3] | CAT-CSB[14] |
| 30 | 42 | PB06 | 38 | VDDIO | Normal I/O | TC1-A1 | USART3-TXD | ADCIFB-AD[6] | GLOC-IN[2] | PWMA-PWMA[29] | ACIFB-ACAN[3] | EIC-NMI (EXTINT[0]) | CAT-CSB[13] |
| 31 | 43 | PB07 | 39 | VDDIO | Normal I/O | TC1-B1 | USART3-RXD | ADCIFB-AD[7] | GLOC-IN[1] | PWMA-PWMA[30] | ACIFB-ACAP[3] | EIC-EXTINT[1] | CAT-CSA[13] |
| 32 | 44 | PB08 | 40 | VDDIO | Normal I/O | TC1-A2 | USART3-RTS | ADCIFB-AD[8] | GLOC-IN[0] | PWMA-PWMA[31] | CAT-SYNC | EIC-EXTINT[2] | CAT-CSB[12] |
| 29 | 39 | PB09 | 41 | VDDIO | Normal I/O | TC1-B2 | USART3-CTS | USART3-CLK | | PWMA-PWMA[32] | ACIFB-ACBN[1] | EIC-EXTINT[3] | CAT-CSB[15] |
| 23 | 31 | PB10 | 42 | VDDIN | Normal I/O | TC1-CLK0 | USART1-TXD | USART3-CLK | GLOC-OUT[1] | PWMA-PWMA[33] | SCIF-GCLK_IN[1] | EIC-EXTINT[4] | CAT-CSB[16] |
| 44 | 56 | PB11 | 43 | VDDIO | Normal I/O | TC1-CLK1 | USART1-RXD | | ADCIFB-TRIGGER | PWMA-PWMA[34] | CAT-VDIVEN | EIC-EXTINT[5] | CAT-CSA[16] |
| 5 | 7 | PB12 | 44 | VDDIO | Normal I/O | TC1-CLK2 | | TWIMS1-TWALM | CAT-SYNC | PWMA-PWMA[35] | ACIFB-ACBP[3] | SCIF-GCLK[4] | CAT-CSA[15] |
| 15 | 22 | PB13 | 45 | VDDIN | USB I/O | USBC-DM | USART3-TXD | | TC1-A1 | PWMA-PWMA[7] | ADCIFB-ADP[1] | SCIF-GCLK[5] | CAT-CSB[2] |
| 16 | 23 | PB14 | 46 | VDDIN | USB I/O | USBC-DP | USART3-RXD | | TC1-B1 | PWMA-PWMA[24] | | SCIF-GCLK[5] | CAT-CSB[9] |
| | 57 | PB15 | 47 | VDDIO | High-drive I/O | ABDACB-CLK | IISC-IMCK | SPI-SCK | TC0-CLK2 | PWMA-PWMA[8] | | SCIF-GCLK[3] | CAT-CSB[4] |
| | 58 | PB16 | 48 | VDDIO | Normal I/O | ABDACB-DAC[0] | IISC-ISCK | USART0-TXD | | PWMA-PWMA[9] | | SCIF-GCLK[2] | CAT-CSA[5] |
| | 59 | PB17 | 49 | VDDIO | Normal I/O | ABDACB-DAC[1] | IISC-IWS | USART0-RXD | | PWMA-PWMA[10] | | | CAT-CSB[5] |
| | 60 | PB18 | 50 | VDDIO | Normal I/O | ABDACB-DACN[0] | IISC-ISDI | USART0-RTS | | PWMA-PWMA[12] | | | CAT-CSA[0] |
| | 4 | PB19 | 51 | VDDIO | Normal I/O | ABDACB-DACN[1] | IISC-ISDO | USART0-CTS | | PWMA-PWMA[20] | | EIC-EXTINT[1] | CAT-CSA[12] |
| | 5 | PB20 | 52 | VDDIO | Normal I/O | TWIMS1-TWD | USART2-RXD | SPI-NPCS[1] | TC0-A0 | PWMA-PWMA[21] | USART1-RTS | USART1-CLK | CAT-CSA[14] |
| | 40 | PB21 | 53 | VDDIO | Normal I/O | TWIMS1-TWCK | USART2-TXD | SPI-NPCS[2] | TC0-B0 | PWMA-PWMA[28] | USART1-CTS | USART1-CLK | CAT-CSB[14] |
| | 41 | PB22 | 54 | VDDIO | Normal I/O | TWIMS1-TWALM | | SPI-NPCS[3] | TC0-CLK0 | PWMA-PWMA[27] | ADCIFB-TRIGGER | SCIF-GCLK[0] | CAT-CSA[8] |
| | 54 | PB23 | 55 | VDDIO | Normal I/O | SPI-MISO | USART2-RTS | USART2-CLK | TC0-A2 | PWMA-PWMA[0] | CAT-SMP | SCIF-GCLK[6] | CAT-CSA[4] |
| | 55 | PB24 | 56 | VDDIO | Normal I/O | SPI-MOSI | USART2-CTS | USART2-CLK | TC0-B2 | PWMA-PWMA[1] | ADCIFB-ADP[1] | SCIF-GCLK[7] | CAT-CSA[2] |

Table 3-1. GPIO Controller Function Multiplexing

| | | | | | | | | | | | | | |
|--|----|------|----|-------|------------|-------------|------------|--|----------|--------------|-----------------|---------------------|------------|
| | 61 | PB25 | 57 | VDDIO | Normal I/O | SPI-NPCS[0] | USART1-RXD | | TC0-A1 | PWMA-PWMA[2] | SCIF-GCLK_IN[2] | SCIF-GCLK[8] | CAT-CSA[3] |
| | 21 | PB26 | 58 | VDDIO | Normal I/O | SPI-SCK | USART1-TXD | | TC0-B1 | PWMA-PWMA[3] | ADCIFB-ADP[0] | SCIF-GCLK[9] | CAT-CSB[3] |
| | 24 | PB27 | 59 | VDDIN | Normal I/O | | USART1-RXD | | TC0-CLK1 | PWMA-PWMA[4] | ADCIFB-ADP[1] | EIC-NMI (EXTINT[0]) | CAT-CSA[9] |

See [Section 3.3](#) for a description of the various peripheral signals.

Refer to ["Electrical Characteristics" on page 45](#) for a description of the electrical properties of the pin types used.

3.2.2 TWI, 5V Tolerant, and SMBUS Pins

Some normal I/O pins offer TWI, 5V tolerance, and SMBUS features. These features are only available when either of the TWI functions or the PWMAOD function in the PWMA are selected for these pins.

Refer to the ["Electrical Characteristics" on page 45](#) for a description of the electrical properties of the TWI, 5V tolerance, and SMBUS pins.

3.2.3 Peripheral Functions

Each GPIO line can be assigned to one of several peripheral functions. The following table describes how the various peripheral functions are selected. The last listed function has priority in case multiple functions are enabled on the same pin.

Table 3-2. Peripheral Functions

| Function | Description |
|---------------------------------------|---|
| GPIO Controller Function multiplexing | GPIO and GPIO peripheral selection A to H |
| Nexus OCD AUX port connections | OCD trace system |
| aWire DATAOUT | aWire output in two-pin mode |
| JTAG port connections | JTAG debug port |
| Oscillators | OSC0, OSC32 |

3.2.4 JTAG Port Connections

If the JTAG is enabled, the JTAG will take control over a number of pins, irrespectively of the I/O Controller configuration.

Table 3-3. JTAG Pinout

| 48-pin | 64-pin | Pin name | JTAG pin |
|--------|--------|----------|----------|
| 11 | 15 | PA00 | TCK |
| 14 | 18 | PA01 | TMS |
| 13 | 17 | PA02 | TDO |
| 4 | 6 | PA03 | TDI |

3.2.5 Nexus OCD AUX Port Connections

If the OCD trace system is enabled, the trace system will take control over a number of pins, irrespective of the I/O Controller configuration. Two different OCD trace pin mappings are possible, depending on the configuration of the OCD AXS register. For details, see the AVR32 UC Technical Reference Manual.

Table 3-4. Nexus OCD AUX Port Connections

| Pin | AXS=1 | AXS=0 |
|---------|-------|-------|
| EVTI_N | PA05 | PB08 |
| MDO[5] | PA10 | PB00 |
| MDO[4] | PA18 | PB04 |
| MDO[3] | PA17 | PB05 |
| MDO[2] | PA16 | PB03 |
| MDO[1] | PA15 | PB02 |
| MDO[0] | PA14 | PB09 |
| EVTO_N | PA04 | PA04 |
| MCKO | PA06 | PB01 |
| MSEO[1] | PA07 | PB11 |
| MSEO[0] | PA11 | PB12 |

3.2.6 Oscillator Pinout

The oscillators are not mapped to the normal GPIO functions and their muxings are controlled by registers in the System Control Interface (SCIF). Please refer to the SCIF chapter for more information about this.

Table 3-5. Oscillator Pinout

| 48-pin | 64-pin | Pin Name | Oscillator Pin |
|--------|--------|----------|----------------|
| 3 | 3 | PA08 | XIN0 |
| 46 | 62 | PA10 | XIN32 |
| 26 | 34 | PA13 | XIN32_2 |

Table 3-5. Oscillator Pinout

| | | | |
|----|----|------|----------|
| 2 | 2 | PA09 | XOUT0 |
| 47 | 63 | PA12 | XOUT32 |
| 25 | 33 | PA20 | XOUT32_2 |

3.2.7 Other Functions

The functions listed in [Table 3-6](#) are not mapped to the normal GPIO functions. The aWire DATA pin will only be active after the aWire is enabled. The aWire DATAOUT pin will only be active after the aWire is enabled and the 2_PIN_MODE command has been sent. The WAKE_N pin is always enabled. Please refer to [Section 6.1.4.2 on page 44](#) for constraints on the WAKE_N pin.

Table 3-6. Other Functions

| 48-pin | 64-pin | Pin Name | Function |
|--------|--------|----------|---------------|
| 27 | 35 | PA11 | WAKE_N |
| 22 | 30 | RESET_N | aWire DATA |
| 11 | 15 | PA00 | aWire DATAOUT |

3.3 Signal Descriptions

The following table gives details on signal name classified by peripheral.

Table 3-7. Signal Descriptions List

| Signal Name | Function | Type | Active Level | Comments |
|---|--------------------------------------|--------|--------------|----------|
| Audio Bitstream DAC - ABDACB | | | | |
| CLK | D/A Clock out | Output | | |
| DAC1 - DAC0 | D/A Bitstream out | Output | | |
| DACN1 - DACN0 | D/A Inverted bitstream out | Output | | |
| Analog Comparator Interface - ACIFB | | | | |
| ACAN3 - ACAN0 | Negative inputs for comparators "A" | Analog | | |
| ACAP3 - ACAP0 | Positive inputs for comparators "A" | Analog | | |
| ACBN3 - ACBN0 | Negative inputs for comparators "B" | Analog | | |
| ACBP3 - ACBP0 | Positive inputs for comparators "B" | Analog | | |
| ACREFN | Common negative reference | Analog | | |
| ADC Interface - ADCIFB | | | | |
| AD8 - AD0 | Analog Signal | Analog | | |
| ADP1 - ADP0 | Drive Pin for resistive touch screen | Output | | |
| TRIGGER | External trigger | Input | | |
| aWire - AW | | | | |
| DATA | aWire data | I/O | | |
| DATAOUT | aWire data output for 2-pin mode | I/O | | |
| Capacitive Touch Module - CAT | | | | |
| CSA16 - CSA0 | Capacitive Sense A | I/O | | |
| CSB16 - CSB0 | Capacitive Sense B | I/O | | |
| DIS | Discharge current control | Analog | | |
| SMP | SMP signal | Output | | |
| SYNC | Synchronize signal | Input | | |
| VDIVEN | Voltage divider enable | Output | | |
| External Interrupt Controller - EIC | | | | |
| NMI (EXTINT0) | Non-Maskable Interrupt | Input | | |
| EXTINT5 - EXTINT1 | External interrupt | Input | | |
| Glue Logic Controller - GLOC | | | | |
| IN7 - IN0 | Inputs to lookup tables | Input | | |
| OUT1 - OUT0 | Outputs from lookup tables | Output | | |
| Inter-IC Sound (I2S) Controller - IISC | | | | |

Table 3-7. Signal Descriptions List

| | | | | |
|---|---|--------------------|-----|--|
| IMCK | I2S Master Clock | Output | | |
| ISCK | I2S Serial Clock | I/O | | |
| ISDI | I2S Serial Data In | Input | | |
| ISDO | I2S Serial Data Out | Output | | |
| IWS | I2S Word Select | I/O | | |
| JTAG module - JTAG | | | | |
| TCK | Test Clock | Input | | |
| TDI | Test Data In | Input | | |
| TDO | Test Data Out | Output | | |
| TMS | Test Mode Select | Input | | |
| Power Manager - PM | | | | |
| RESET_N | Reset | Input | Low | |
| Pulse Width Modulation Controller - PWMA | | | | |
| PWMA35 - PWMA0 | PWMA channel waveforms | Output | | |
| PWMAOD35 - PWMAOD0 | PWMA channel waveforms, open drain mode | Output | | Not all channels support open drain mode |
| System Control Interface - SCIF | | | | |
| GCLK9 - GCLK0 | Generic Clock Output | Output | | |
| GCLK_IN2 - GCLK_IN0 | Generic Clock Input | Input | | |
| RC32OUT | RC32K output at startup | Output | | |
| XIN0 | Crystal 0 Input | Analog/ Digital | | |
| XIN32 | Crystal 32 Input (primary location) | Analog/ Digital | | |
| XIN32_2 | Crystal 32 Input (secondary location) | Analog/ Digital | | |
| XOUT0 | Crystal 0 Output | Analog | | |
| XOUT32 | Crystal 32 Output (primary location) | Analog | | |
| XOUT32_2 | Crystal 32 Output (secondary location) | Analog | | |
| Serial Peripheral Interface - SPI | | | | |
| MISO | Master In Slave Out | I/O | | |
| MOSI | Master Out Slave In | I/O | | |
| NPCS3 - NPCS0 | SPI Peripheral Chip Select | I/O | Low | |
| SCK | Clock | I/O | | |
| Timer/Counter - TC0, TC1 | | | | |
| A0 | Channel 0 Line A | I/O | | |
| A1 | Channel 1 Line A | I/O | | |
| A2 | Channel 2 Line A | I/O | | |

Table 3-7. Signal Descriptions List

| | | | | |
|---|--------------------------------|--------|-----|--|
| B0 | Channel 0 Line B | I/O | | |
| B1 | Channel 1 Line B | I/O | | |
| B2 | Channel 2 Line B | I/O | | |
| CLK0 | Channel 0 External Clock Input | Input | | |
| CLK1 | Channel 1 External Clock Input | Input | | |
| CLK2 | Channel 2 External Clock Input | Input | | |
| Two-wire Interface - TWIM0, TWIM1 | | | | |
| TWALM | SMBus SMBALERT | I/O | Low | |
| TWCK | Two-wire Serial Clock | I/O | | |
| TWD | Two-wire Serial Data | I/O | | |
| Universal Synchronous Asynchronous Receiver Transmitter - USART0, USART1, USART2, USART3 | | | | |
| CLK | Clock | I/O | | |
| CTS | Clear To Send | Input | Low | |
| RTS | Request To Send | Output | Low | |
| RXD | Receive Data | Input | | |
| TXD | Transmit Data | Output | | |

Note: 1. ADCIFB: AD3 does not exist.

Table 3-8. Signal Description List, Continued

| Signal Name | Function | Type | Active Level | Comments |
|-----------------------------|--|--------------------|--------------|---|
| Power | | | | |
| VDDCORE | Core Power Supply / Voltage Regulator Output | Power Input/Output | | 1.62V to 1.98V |
| VDDIO | I/O Power Supply | Power Input | | 1.62V to 3.6V. VDDIO should always be equal to or lower than VDDIN. |
| VDDANA | Analog Power Supply | Power Input | | 1.62V to 1.98V |
| ADVREFP | Analog Reference Voltage | Power Input | | 1.62V to 1.98V |
| VDDIN | Voltage Regulator Input | Power Input | | 1.62V to 3.6V ⁽¹⁾ |
| GNDANA | Analog Ground | Ground | | |
| GND | Ground | Ground | | |
| Auxiliary Port - AUX | | | | |
| MCKO | Trace Data Output Clock | Output | | |
| MDO5 - MDO0 | Trace Data Output | Output | | |

Table 3-8. Signal Description List, Continued

| Signal Name | Function | Type | Active Level | Comments |
|--------------------------------|------------------------------------|--------|--------------|----------|
| MSEO1 - MSEO0 | Trace Frame Control | Output | | |
| EVTI_N | Event In | Input | Low | |
| EVTO_N | Event Out | Output | Low | |
| General Purpose I/O pin | | | | |
| PA22 - PA00 | Parallel I/O Controller I/O Port 0 | I/O | | |
| PB27 - PB00 | Parallel I/O Controller I/O Port 1 | I/O | | |

Note: 1. See [Section 6. on page 39](#)

3.4 I/O Line Considerations

3.4.1 JTAG Pins

The JTAG is enabled if TCK is low while the RESET_N pin is released. The TCK, TMS, and TDI pins have pull-up resistors when JTAG is enabled. The TCK pin always has pull-up enabled during reset. The TDO pin is an output, driven at VDDIO, and has no pull-up resistor. The JTAG pins can be used as GPIO pins and multiplexed with peripherals when the JTAG is disabled. Please refer to [Section 3.2.4 on page 12](#) for the JTAG port connections.

3.4.2 PA00

Note that PA00 is multiplexed with TCK. PA00 GPIO function must only be used as output in the application.

3.4.3 RESET_N Pin

The RESET_N pin is a schmitt input and integrates a permanent pull-up resistor to VDDIN. As the product integrates a power-on reset detector, the RESET_N pin can be left unconnected in case no reset from the system needs to be applied to the product.

The RESET_N pin is also used for the aWire debug protocol. When the pin is used for debugging, it must not be driven by external circuitry.

3.4.4 TWI Pins PA21/PB04/PB05

When these pins are used for TWI, the pins are open-drain outputs with slew-rate limitation and inputs with spike filtering. When used as GPIO pins or used for other peripherals, the pins have the same characteristics as other GPIO pins. Selected pins are also SMBus compliant (refer to [Section 3.2 on page 9](#)). As required by the SMBus specification, these pins provide no leakage path to ground when the ATUC64/128/256L3/4U is powered down. This allows other devices on the SMBus to continue communicating even though the ATUC64/128/256L3/4U is not powered.

After reset a TWI function is selected on these pins instead of the GPIO. Please refer to the GPIO Module Configuration chapter for details.

3.4.5 TWI Pins PA05/PA07/PA17

When these pins are used for TWI, the pins are open-drain outputs with slew-rate limitation and inputs with spike filtering. When used as GPIO pins or used for other peripherals, the pins have the same characteristics as other GPIO pins.

After reset a TWI function is selected on these pins instead of the GPIO. Please refer to the GPIO Module Configuration chapter for details.

3.4.6 GPIO Pins

All the I/O lines integrate a pull-up resistor. Programming of this pull-up resistor is performed independently for each I/O line through the GPIO Controllers. After reset, I/O lines default as inputs with pull-up resistors disabled, except PA00 which has the pull-up resistor enabled. PA20 selects SCIF-RC32OUT (GPIO Function F) as default enabled after reset.

3.4.7 High-drive Pins

The six pins PA02, PA06, PA08, PA09, PB01, and PB15 have high-drive output capabilities. Refer to [Section 7. on page 45](#) for electrical characteristics.

3.4.8 USB Pins PB13/PB14

When these pins are used for USB, the pins are behaving according to the USB specification. When used as GPIO pins or used for other peripherals, the pins have the same behaviour as other normal I/O pins, but the characteristics are different. Refer to [Section 7. on page 45](#) for electrical characteristics.

To be able to use the USB I/O the VDDIN power supply must be 3.3V nominal.

3.4.9 RC32OUT Pin**3.4.9.1 Clock output at startup**

After power-up, the clock generated by the 32kHz RC oscillator (RC32K) will be output on PA20, even when the device is still reset by the Power-On Reset Circuitry. This clock can be used by the system to start other devices or to clock a switching regulator to rise the power supply voltage up to an acceptable value.

The clock will be available on PA20, but will be disabled if one of the following conditions are true:

- PA20 is configured to use a GPIO function other than F (SCIF-RC32OUT)
- PA20 is configured as a General Purpose Input/Output (GPIO)
- The bit FRC32 in the Power Manager PPCR register is written to zero (refer to the Power Manager chapter)

The maximum amplitude of the clock signal will be defined by VDDIN.

Once the RC32K output on PA20 is disabled it can never be enabled again.

3.4.9.2 XOUT32_2 function

PA20 selects RC32OUT as default enabled after reset. This function is not automatically disabled when the user enables the XOUT32_2 function on PA20. This disturbs the oscillator and may result in the wrong frequency. To avoid this, RC32OUT must be disabled when XOUT32_2 is enabled.

3.4.10 ADC Input Pins

These pins are regular I/O pins powered from the VDDIO. However, when these pins are used for ADC inputs, the voltage applied to the pin must not exceed 1.98V. Internal circuitry ensures that the pin cannot be used as an analog input pin when the I/O drives to VDD. When the pins are not used for ADC inputs, the pins may be driven to the full I/O voltage range.

4. Processor and Architecture

Rev: 2.1.2.0

This chapter gives an overview of the AVR32UC CPU. AVR32UC is an implementation of the AVR32 architecture. A summary of the programming model, instruction set, and MPU is presented. For further details, see the *AVR32 Architecture Manual* and the *AVR32UC Technical Reference Manual*.

4.1 Features

- **32-bit load/store AVR32A RISC architecture**
 - 15 general-purpose 32-bit registers
 - 32-bit Stack Pointer, Program Counter and Link Register reside in register file
 - Fully orthogonal instruction set
 - Privileged and unprivileged modes enabling efficient and secure operating systems
 - Innovative instruction set together with variable instruction length ensuring industry leading code density
 - DSP extension with saturating arithmetic, and a wide variety of multiply instructions
- **3-stage pipeline allowing one instruction per clock cycle for most instructions**
 - Byte, halfword, word, and double word memory access
 - Multiple interrupt priority levels
- **MPU allows for operating systems with memory protection**
- **Secure State for supporting FlashVault technology**

4.2 AVR32 Architecture

AVR32 is a new, high-performance 32-bit RISC microprocessor architecture, designed for cost-sensitive embedded applications, with particular emphasis on low power consumption and high code density. In addition, the instruction set architecture has been tuned to allow a variety of microarchitectures, enabling the AVR32 to be implemented as low-, mid-, or high-performance processors. AVR32 extends the AVR family into the world of 32- and 64-bit applications.

Through a quantitative approach, a large set of industry recognized benchmarks has been compiled and analyzed to achieve the best code density in its class. In addition to lowering the memory requirements, a compact code size also contributes to the core's low power characteristics. The processor supports byte and halfword data types without penalty in code size and performance.

Memory load and store operations are provided for byte, halfword, word, and double word data with automatic sign- or zero extension of halfword and byte data. The C-compiler is closely linked to the architecture and is able to exploit code optimization features, both for size and speed.

In order to reduce code size to a minimum, some instructions have multiple addressing modes. As an example, instructions with immediates often have a compact format with a smaller immediate, and an extended format with a larger immediate. In this way, the compiler is able to use the format giving the smallest code size.

Another feature of the instruction set is that frequently used instructions, like add, have a compact format with two operands as well as an extended format with three operands. The larger format increases performance, allowing an addition and a data move in the same instruction in a

single cycle. Load and store instructions have several different formats in order to reduce code size and speed up execution.

The register file is organized as sixteen 32-bit registers and includes the Program Counter, the Link Register, and the Stack Pointer. In addition, register R12 is designed to hold return values from function calls and is used implicitly by some instructions.

4.3 The AVR32UC CPU

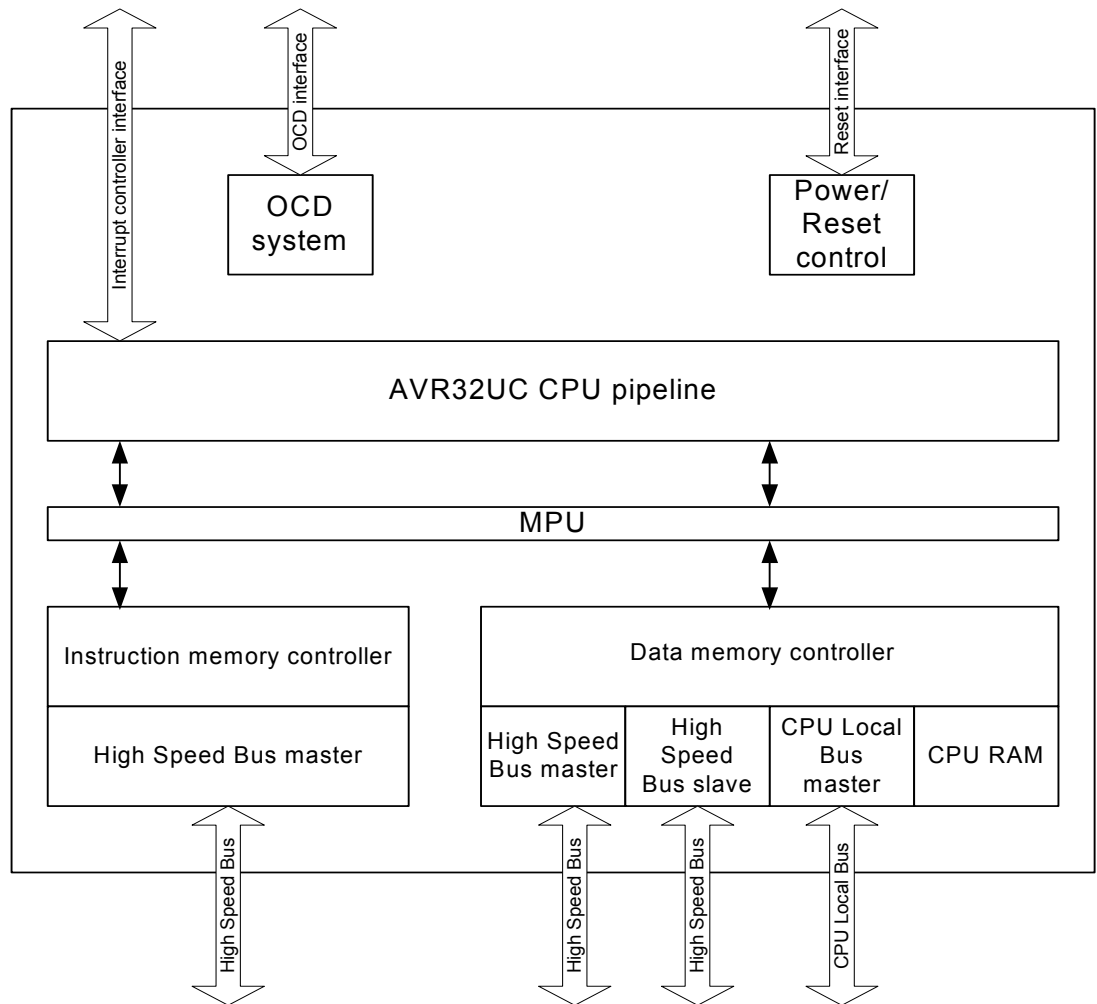
The AVR32UC CPU targets low- and medium-performance applications, and provides an advanced On-Chip Debug (OCD) system, no caches, and a Memory Protection Unit (MPU). Java acceleration hardware is not implemented.

AVR32UC provides three memory interfaces, one High Speed Bus master for instruction fetch, one High Speed Bus master for data access, and one High Speed Bus slave interface allowing other bus masters to access data RAMs internal to the CPU. Keeping data RAMs internal to the CPU allows fast access to the RAMs, reduces latency, and guarantees deterministic timing. Also, power consumption is reduced by not needing a full High Speed Bus access for memory accesses. A dedicated data RAM interface is provided for communicating with the internal data RAMs.

A local bus interface is provided for connecting the CPU to device-specific high-speed systems, such as floating-point units and I/O controller ports. This local bus has to be enabled by writing a one to the LOCEN bit in the CPU_CR system register. The local bus is able to transfer data between the CPU and the local bus slave in a single clock cycle. The local bus has a dedicated memory range allocated to it, and data transfers are performed using regular load and store instructions. Details on which devices that are mapped into the local bus space is given in the CPU Local Bus section in the Memories chapter.

[Figure 4-1 on page 23](#) displays the contents of AVR32UC.

Figure 4-1. Overview of the AVR32UC CPU



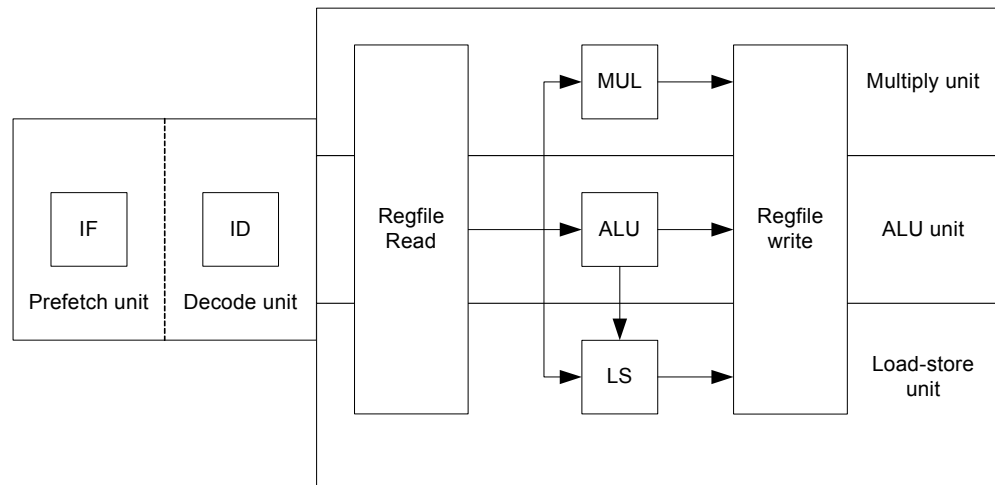
4.3.1 Pipeline Overview

AVR32UC has three pipeline stages, Instruction Fetch (IF), Instruction Decode (ID), and Instruction Execute (EX). The EX stage is split into three parallel subsections, one arithmetic/logic (ALU) section, one multiply (MUL) section, and one load/store (LS) section.

Instructions are issued and complete in order. Certain operations require several clock cycles to complete, and in this case, the instruction resides in the ID and EX stages for the required number of clock cycles. Since there is only three pipeline stages, no internal data forwarding is required, and no data dependencies can arise in the pipeline.

Figure 4-2 on page 24 shows an overview of the AVR32UC pipeline stages.

Figure 4-2. The AVR32UC Pipeline



4.3.2 AVR32A Microarchitecture Compliance

AVR32UC implements an AVR32A microarchitecture. The AVR32A microarchitecture is targeted at cost-sensitive, lower-end applications like smaller microcontrollers. This microarchitecture does not provide dedicated hardware registers for shadowing of register file registers in interrupt contexts. Additionally, it does not provide hardware registers for the return address registers and return status registers. Instead, all this information is stored on the system stack. This saves chip area at the expense of slower interrupt handling.

4.3.2.1 Interrupt Handling

Upon interrupt initiation, registers R8-R12 are automatically pushed to the system stack. These registers are pushed regardless of the priority level of the pending interrupt. The return address and status register are also automatically pushed to stack. The interrupt handler can therefore use R8-R12 freely. Upon interrupt completion, the old R8-R12 registers and status register are restored, and execution continues at the return address stored popped from stack.

The stack is also used to store the status register and return address for exceptions and *scall*. Executing the *rete* or *rets* instruction at the completion of an exception or system call will pop this status register and continue execution at the popped return address.

4.3.2.2 Java Support

AVR32UC does not provide Java hardware acceleration.

4.3.2.3 Memory Protection

The MPU allows the user to check all memory accesses for privilege violations. If an access is attempted to an illegal memory address, the access is aborted and an exception is taken. The MPU in AVR32UC is specified in the AVR32UC Technical Reference manual.

4.3.2.4 Unaligned Reference Handling

AVR32UC does not support unaligned accesses, except for doubleword accesses. AVR32UC is able to perform word-aligned *st.d* and *ld.d*. Any other unaligned memory access will cause an

address exception. Doubleword-sized accesses with word-aligned pointers will automatically be performed as two word-sized accesses.

The following table shows the instructions with support for unaligned addresses. All other instructions require aligned addresses.

Table 4-1. Instructions with Unaligned Reference Support

| Instruction | Supported Alignment |
|-------------|---------------------|
| ld.d | Word |
| st.d | Word |

4.3.2.5 Unimplemented Instructions

The following instructions are unimplemented in AVR32UC, and will cause an Unimplemented Instruction Exception if executed:

- All SIMD instructions
- All coprocessor instructions if no coprocessors are present
- retj, incjosp, popjc, pushjc
- tlbr, tlbs, tlbw
- cache

4.3.2.6 CPU and Architecture Revision

Three major revisions of the AVR32UC CPU currently exist. The device described in this datasheet uses CPU revision 3.

The Architecture Revision field in the CONFIG0 system register identifies which architecture revision is implemented in a specific device.

AVR32UC CPU revision 3 is fully backward-compatible with revisions 1 and 2, ie. code compiled for revision 1 or 2 is binary-compatible with revision 3 CPUs.

4.4 Programming Model

4.4.1 Register File Configuration

The AVR32UC register file is shown below.

Figure 4-3. The AVR32UC Register File

| Application | Supervisor | INT0 | INT1 | INT2 | INT3 | Exception | NMI | Secure | | | |
|-------------|------------|--------|--------|--------|--------|-----------|--------|--------|--------|--------|--------|
| Bit 31 | Bit 0 | Bit 31 | Bit 0 | Bit 31 | Bit 0 | Bit 31 | Bit 0 | Bit 31 | Bit 0 | Bit 31 | Bit 0 |
| PC | PC | PC | PC | PC | PC | PC | PC | PC | PC | PC | PC |
| LR | LR | LR | LR | LR | LR | LR | LR | LR | LR | LR | LR |
| SP_APP | SP_SYS | SP_SYS | SP_SYS | SP_SYS | SP_SYS | SP_SYS | SP_SYS | SP_SYS | SP_SEC | SP_SEC | SP_SEC |
| R12 | R12 | R12 | R12 | R12 | R12 | R12 | R12 | R12 | R12 | R12 | R12 |
| R11 | R11 | R11 | R11 | R11 | R11 | R11 | R11 | R11 | R11 | R11 | R11 |
| R10 | R10 | R10 | R10 | R10 | R10 | R10 | R10 | R10 | R10 | R10 | R10 |
| R9 | R9 | R9 | R9 | R9 | R9 | R9 | R9 | R9 | R9 | R9 | R9 |
| R8 | R8 | R8 | R8 | R8 | R8 | R8 | R8 | R8 | R8 | R8 | R8 |
| R7 | R7 | R7 | R7 | R7 | R7 | R7 | R7 | R7 | R7 | R7 | R7 |
| R6 | R6 | R6 | R6 | R6 | R6 | R6 | R6 | R6 | R6 | R6 | R6 |
| R5 | R5 | R5 | R5 | R5 | R5 | R5 | R5 | R5 | R5 | R5 | R5 |
| R4 | R4 | R4 | R4 | R4 | R4 | R4 | R4 | R4 | R4 | R4 | R4 |
| R3 | R3 | R3 | R3 | R3 | R3 | R3 | R3 | R3 | R3 | R3 | R3 |
| R2 | R2 | R2 | R2 | R2 | R2 | R2 | R2 | R2 | R2 | R2 | R2 |
| R1 | R1 | R1 | R1 | R1 | R1 | R1 | R1 | R1 | R1 | R1 | R1 |
| R0 | R0 | R0 | R0 | R0 | R0 | R0 | R0 | R0 | R0 | R0 | R0 |
| SR | SR | SR | SR | SR | SR | SR | SR | SR | SR | SR | SR |
| | | | | | | | | | | | |
| SS_STATUS | | | | | | | | | | | |
| SS_ADRF | | | | | | | | | | | |
| SS_ADDR | | | | | | | | | | | |
| SS_ADR0 | | | | | | | | | | | |
| SS_ADR1 | | | | | | | | | | | |
| SS_SP_SYS | | | | | | | | | | | |
| SS_SP_APP | | | | | | | | | | | |
| SS_RAR | | | | | | | | | | | |
| SS_RSR | | | | | | | | | | | |

4.4.2 Status Register Configuration

The Status Register (SR) is split into two halfwords, one upper and one lower, see [Figure 4-4](#) and [Figure 4-5](#). The lower word contains the C, Z, N, V, and Q condition code flags and the R, T, and L bits, while the upper halfword contains information about the mode and state the processor executes in. Refer to the *AVR32 Architecture Manual* for details.

Figure 4-4. The Status Register High Halfword

| Bit 31 | | | | | | | | | | | | | | | | Bit 16 | Bit name |
|--------|---|---|---|----|---|---|----|----|----|----|-----|-----|-----|-----|----|--------|---------------|
| SS | - | - | - | DM | D | - | M2 | M1 | M0 | EM | I3M | I2M | I1M | I0M | GM | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | | Initial value |

Global Interrupt Mask

Interrupt Level 0 Mask

Interrupt Level 1 Mask

Interrupt Level 2 Mask

Interrupt Level 3 Mask

Exception Mask

Mode Bit 0

Mode Bit 1

Mode Bit 2

Reserved

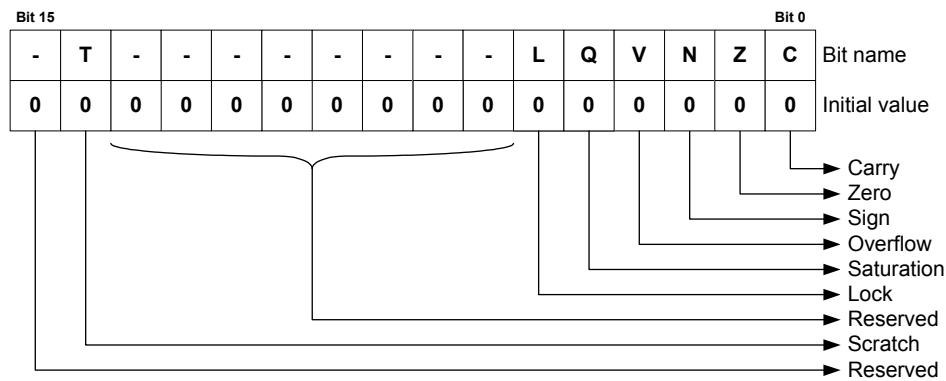
Debug State

Debug State Mask

Reserved

Secure State

Figure 4-5. The Status Register Low Halfword



4.4.3 Processor States

4.4.3.1 Normal RISC State

The AVR32 processor supports several different execution contexts as shown in [Table 4-2](#).

Table 4-2. Overview of Execution Modes, their Priorities and Privilege Levels.

| Priority | Mode | Security | Description |
|----------|------------------------|--------------|---|
| 1 | Non Maskable Interrupt | Privileged | Non Maskable high priority interrupt mode |
| 2 | Exception | Privileged | Execute exceptions |
| 3 | Interrupt 3 | Privileged | General purpose interrupt mode |
| 4 | Interrupt 2 | Privileged | General purpose interrupt mode |
| 5 | Interrupt 1 | Privileged | General purpose interrupt mode |
| 6 | Interrupt 0 | Privileged | General purpose interrupt mode |
| N/A | Supervisor | Privileged | Runs supervisor calls |
| N/A | Application | Unprivileged | Normal program execution mode |

Mode changes can be made under software control, or can be caused by external interrupts or exception processing. A mode can be interrupted by a higher priority mode, but never by one with lower priority. Nested exceptions can be supported with a minimal software overhead.

When running an operating system on the AVR32, user processes will typically execute in the application mode. The programs executed in this mode are restricted from executing certain instructions. Furthermore, most system registers together with the upper halfword of the status register cannot be accessed. Protected memory areas are also not available. All other operating modes are privileged and are collectively called System Modes. They have full access to all privileged and unprivileged resources. After a reset, the processor will be in supervisor mode.

4.4.3.2 Debug State

The AVR32 can be set in a debug state, which allows implementation of software monitor routines that can read out and alter system information for use during application development. This implies that all system and application registers, including the status registers and program counters, are accessible in debug state. The privileged instructions are also available.

All interrupt levels are by default disabled when debug state is entered, but they can individually be switched on by the monitor routine by clearing the respective mask bit in the status register.

Debug state can be entered as described in the *AVR32UC Technical Reference Manual*.

Debug state is exited by the *retd* instruction.

4.4.3.3 Secure State

The AVR32 can be set in a secure state, that allows a part of the code to execute in a state with higher security levels. The rest of the code can not access resources reserved for this secure code. Secure State is used to implement FlashVault technology. Refer to the *AVR32UC Technical Reference Manual* for details.

4.4.4 System Registers

The system registers are placed outside of the virtual memory space, and are only accessible using the privileged *mfsr* and *mtsr* instructions. The table below lists the system registers specified in the AVR32 architecture, some of which are unused in AVR32UC. The programmer is responsible for maintaining correct sequencing of any instructions following a *mtsr* instruction. For detail on the system registers, refer to the *AVR32UC Technical Reference Manual*.

Table 4-3. System Registers

| Reg # | Address | Name | Function |
|-------|---------|----------|--|
| 0 | 0 | SR | Status Register |
| 1 | 4 | EVBA | Exception Vector Base Address |
| 2 | 8 | ACBA | Application Call Base Address |
| 3 | 12 | CPUCR | CPU Control Register |
| 4 | 16 | ECR | Exception Cause Register |
| 5 | 20 | RSR_SUP | Unused in AVR32UC |
| 6 | 24 | RSR_INT0 | Unused in AVR32UC |
| 7 | 28 | RSR_INT1 | Unused in AVR32UC |
| 8 | 32 | RSR_INT2 | Unused in AVR32UC |
| 9 | 36 | RSR_INT3 | Unused in AVR32UC |
| 10 | 40 | RSR_EX | Unused in AVR32UC |
| 11 | 44 | RSR_NMI | Unused in AVR32UC |
| 12 | 48 | RSR_DBG | Return Status Register for Debug mode |
| 13 | 52 | RAR_SUP | Unused in AVR32UC |
| 14 | 56 | RAR_INT0 | Unused in AVR32UC |
| 15 | 60 | RAR_INT1 | Unused in AVR32UC |
| 16 | 64 | RAR_INT2 | Unused in AVR32UC |
| 17 | 68 | RAR_INT3 | Unused in AVR32UC |
| 18 | 72 | RAR_EX | Unused in AVR32UC |
| 19 | 76 | RAR_NMI | Unused in AVR32UC |
| 20 | 80 | RAR_DBG | Return Address Register for Debug mode |
| 21 | 84 | JECR | Unused in AVR32UC |
| 22 | 88 | JOSP | Unused in AVR32UC |
| 23 | 92 | JAVA_LV0 | Unused in AVR32UC |

Table 4-3. System Registers (Continued)

| Reg # | Address | Name | Function |
|-------|---------|----------|--|
| 24 | 96 | JAVA_LV1 | Unused in AVR32UC |
| 25 | 100 | JAVA_LV2 | Unused in AVR32UC |
| 26 | 104 | JAVA_LV3 | Unused in AVR32UC |
| 27 | 108 | JAVA_LV4 | Unused in AVR32UC |
| 28 | 112 | JAVA_LV5 | Unused in AVR32UC |
| 29 | 116 | JAVA_LV6 | Unused in AVR32UC |
| 30 | 120 | JAVA_LV7 | Unused in AVR32UC |
| 31 | 124 | JTBA | Unused in AVR32UC |
| 32 | 128 | JBCR | Unused in AVR32UC |
| 33-63 | 132-252 | Reserved | Reserved for future use |
| 64 | 256 | CONFIG0 | Configuration register 0 |
| 65 | 260 | CONFIG1 | Configuration register 1 |
| 66 | 264 | COUNT | Cycle Counter register |
| 67 | 268 | COMPARE | Compare register |
| 68 | 272 | TLBEHI | Unused in AVR32UC |
| 69 | 276 | TLBELO | Unused in AVR32UC |
| 70 | 280 | PTBR | Unused in AVR32UC |
| 71 | 284 | TLBEAR | Unused in AVR32UC |
| 72 | 288 | MMUCR | Unused in AVR32UC |
| 73 | 292 | TLBARLO | Unused in AVR32UC |
| 74 | 296 | TLBARHI | Unused in AVR32UC |
| 75 | 300 | PCCNT | Unused in AVR32UC |
| 76 | 304 | PCNT0 | Unused in AVR32UC |
| 77 | 308 | PCNT1 | Unused in AVR32UC |
| 78 | 312 | PCCR | Unused in AVR32UC |
| 79 | 316 | BEAR | Bus Error Address Register |
| 80 | 320 | MPUAR0 | MPU Address Register region 0 |
| 81 | 324 | MPUAR1 | MPU Address Register region 1 |
| 82 | 328 | MPUAR2 | MPU Address Register region 2 |
| 83 | 332 | MPUAR3 | MPU Address Register region 3 |
| 84 | 336 | MPUAR4 | MPU Address Register region 4 |
| 85 | 340 | MPUAR5 | MPU Address Register region 5 |
| 86 | 344 | MPUAR6 | MPU Address Register region 6 |
| 87 | 348 | MPUAR7 | MPU Address Register region 7 |
| 88 | 352 | MPUPSR0 | MPU Privilege Select Register region 0 |
| 89 | 356 | MPUPSR1 | MPU Privilege Select Register region 1 |

Table 4-3. System Registers (Continued)

| Reg # | Address | Name | Function |
|---------|----------|-----------|---|
| 90 | 360 | MPUPSR2 | MPU Privilege Select Register region 2 |
| 91 | 364 | MPUPSR3 | MPU Privilege Select Register region 3 |
| 92 | 368 | MPUPSR4 | MPU Privilege Select Register region 4 |
| 93 | 372 | MPUPSR5 | MPU Privilege Select Register region 5 |
| 94 | 376 | MPUPSR6 | MPU Privilege Select Register region 6 |
| 95 | 380 | MPUPSR7 | MPU Privilege Select Register region 7 |
| 96 | 384 | MPUCRA | Unused in this version of AVR32UC |
| 97 | 388 | MPUCRB | Unused in this version of AVR32UC |
| 98 | 392 | MPUBRA | Unused in this version of AVR32UC |
| 99 | 396 | MPUBRB | Unused in this version of AVR32UC |
| 100 | 400 | MPUAPRA | MPU Access Permission Register A |
| 101 | 404 | MPUAPRB | MPU Access Permission Register B |
| 102 | 408 | MPUCR | MPU Control Register |
| 103 | 412 | SS_STATUS | Secure State Status Register |
| 104 | 416 | SS_ADRF | Secure State Address Flash Register |
| 105 | 420 | SS_ADRR | Secure State Address RAM Register |
| 106 | 424 | SS_ADR0 | Secure State Address 0 Register |
| 107 | 428 | SS_ADR1 | Secure State Address 1 Register |
| 108 | 432 | SS_SP_SYS | Secure State Stack Pointer System Register |
| 109 | 436 | SS_SP_APP | Secure State Stack Pointer Application Register |
| 110 | 440 | SS_RAR | Secure State Return Address Register |
| 111 | 444 | SS_RSR | Secure State Return Status Register |
| 112-191 | 448-764 | Reserved | Reserved for future use |
| 192-255 | 768-1020 | IMPL | IMPLEMENTATION DEFINED |

4.5 Exceptions and Interrupts

In the AVR32 architecture, events are used as a common term for exceptions and interrupts. AVR32UC incorporates a powerful event handling scheme. The different event sources, like Illegal Op-code and interrupt requests, have different priority levels, ensuring a well-defined behavior when multiple events are received simultaneously. Additionally, pending events of a higher priority class may preempt handling of ongoing events of a lower priority class.

When an event occurs, the execution of the instruction stream is halted, and execution is passed to an event handler at an address specified in [Table 4-4 on page 34](#). Most of the handlers are placed sequentially in the code space starting at the address specified by EVBA, with four bytes between each handler. This gives ample space for a jump instruction to be placed there, jumping to the event routine itself. A few critical handlers have larger spacing between them, allowing the entire event routine to be placed directly at the address specified by the EVBA-relative offset generated by hardware. All interrupt sources have autovectorized interrupt service routine (ISR) addresses. This allows the interrupt controller to directly specify the ISR address as an address

relative to EVBA. The autovector offset has 14 address bits, giving an offset of maximum 16384 bytes. The target address of the event handler is calculated as (EVBA | event_handler_offset), not (EVBA + event_handler_offset), so EVBA and exception code segments must be set up appropriately. The same mechanisms are used to service all different types of events, including interrupt requests, yielding a uniform event handling scheme.

An interrupt controller does the priority handling of the interrupts and provides the autovector offset to the CPU.

4.5.1 System Stack Issues

Event handling in AVR32UC uses the system stack pointed to by the system stack pointer, SP_SYS, for pushing and popping R8-R12, LR, status register, and return address. Since event code may be timing-critical, SP_SYS should point to memory addresses in the IRAM section, since the timing of accesses to this memory section is both fast and deterministic.

The user must also make sure that the system stack is large enough so that any event is able to push the required registers to stack. If the system stack is full, and an event occurs, the system will enter an UNDEFINED state.

4.5.2 Exceptions and Interrupt Requests

When an event other than *scall* or debug request is received by the core, the following actions are performed atomically:

1. The pending event will not be accepted if it is masked. The I3M, I2M, I1M, I0M, EM, and GM bits in the Status Register are used to mask different events. Not all events can be masked. A few critical events (NMI, Unrecoverable Exception, TLB Multiple Hit, and Bus Error) can not be masked. When an event is accepted, hardware automatically sets the mask bits corresponding to all sources with equal or lower priority. This inhibits acceptance of other events of the same or lower priority, except for the critical events listed above. Software may choose to clear some or all of these bits after saving the necessary state if other priority schemes are desired. It is the event source's responsibility to ensure that their events are left pending until accepted by the CPU.
2. When a request is accepted, the Status Register and Program Counter of the current context is stored to the system stack. If the event is an INT0, INT1, INT2, or INT3, registers R8-R12 and LR are also automatically stored to stack. Storing the Status Register ensures that the core is returned to the previous execution mode when the current event handling is completed. When exceptions occur, both the EM and GM bits are set, and the application may manually enable nested exceptions if desired by clearing the appropriate bit. Each exception handler has a dedicated handler address, and this address uniquely identifies the exception source.
3. The Mode bits are set to reflect the priority of the accepted event, and the correct register file bank is selected. The address of the event handler, as shown in [Table 4-4 on page 34](#), is loaded into the Program Counter.

The execution of the event handler routine then continues from the effective address calculated.

The *rete* instruction signals the end of the event. When encountered, the Return Status Register and Return Address Register are popped from the system stack and restored to the Status Register and Program Counter. If the *rete* instruction returns from INT0, INT1, INT2, or INT3, registers R8-R12 and LR are also popped from the system stack. The restored Status Register contains information allowing the core to resume operation in the previous execution mode. This concludes the event handling.

4.5.3 Supervisor Calls

The AVR32 instruction set provides a supervisor mode call instruction. The *scall* instruction is designed so that privileged routines can be called from any context. This facilitates sharing of code between different execution modes. The *scall* mechanism is designed so that a minimal execution cycle overhead is experienced when performing supervisor routine calls from time-critical event handlers.

The *scall* instruction behaves differently depending on which mode it is called from. The behaviour is detailed in the instruction set reference. In order to allow the *scall* routine to return to the correct context, a return from supervisor call instruction, *rets*, is implemented. In the AVR32UC CPU, *scall* and *rets* uses the system stack to store the return address and the status register.

4.5.4 Debug Requests

The AVR32 architecture defines a dedicated Debug mode. When a debug request is received by the core, Debug mode is entered. Entry into Debug mode can be masked by the DM bit in the status register. Upon entry into Debug mode, hardware sets the SR.D bit and jumps to the Debug Exception handler. By default, Debug mode executes in the exception context, but with dedicated Return Address Register and Return Status Register. These dedicated registers remove the need for storing this data to the system stack, thereby improving debuggability. The Mode bits in the Status Register can freely be manipulated in Debug mode, to observe registers in all contexts, while retaining full privileges.

Debug mode is exited by executing the *retd* instruction. This returns to the previous context.

4.5.5 Entry Points for Events

Several different event handler entry points exist. In AVR32UC, the reset address is 0x80000000. This places the reset address in the boot flash memory area.

TLB miss exceptions and *scall* have a dedicated space relative to EVBA where their event handler can be placed. This speeds up execution by removing the need for a jump instruction placed at the program address jumped to by the event hardware. All other exceptions have a dedicated event routine entry point located relative to EVBA. The handler routine address identifies the exception source directly.

AVR32UC uses the ITLB and DTLB protection exceptions to signal a MPU protection violation. ITLB and DTLB miss exceptions are used to signal that an access address did not map to any of the entries in the MPU. TLB multiple hit exception indicates that an access address did map to multiple TLB entries, signalling an error.

All interrupt requests have entry points located at an offset relative to EVBA. This autovector offset is specified by an interrupt controller. The programmer must make sure that none of the autovector offsets interfere with the placement of other code. The autovector offset has 14 address bits, giving an offset of maximum 16384 bytes.

Special considerations should be made when loading EVBA with a pointer. Due to security considerations, the event handlers should be located in non-writeable flash memory, or optionally in a privileged memory protection region if an MPU is present.

If several events occur on the same instruction, they are handled in a prioritized way. The priority ordering is presented in [Table 4-4 on page 34](#). If events occur on several instructions at different locations in the pipeline, the events on the oldest instruction are always handled before any events on any younger instruction, even if the younger instruction has events of higher priority.

than the oldest instruction. An instruction B is younger than an instruction A if it was sent down the pipeline later than A.

The addresses and priority of simultaneous events are shown in [Table 4-4 on page 34](#). Some of the exceptions are unused in AVR32UC since it has no MMU, coprocessor interface, or floating-point unit.

Table 4-4. Priority and Handler Addresses for Events

| Priority | Handler Address | Name | Event source | Stored Return Address |
|----------|------------------------|-----------------------------|----------------|---------------------------------|
| 1 | 0x80000000 | Reset | External input | Undefined |
| 2 | Provided by OCD system | OCD Stop CPU | OCD system | First non-completed instruction |
| 3 | EVBA+0x00 | Unrecoverable exception | Internal | PC of offending instruction |
| 4 | EVBA+0x04 | TLB multiple hit | MPU | PC of offending instruction |
| 5 | EVBA+0x08 | Bus error data fetch | Data bus | First non-completed instruction |
| 6 | EVBA+0x0C | Bus error instruction fetch | Data bus | First non-completed instruction |
| 7 | EVBA+0x10 | NMI | External input | First non-completed instruction |
| 8 | Autovectored | Interrupt 3 request | External input | First non-completed instruction |
| 9 | Autovectored | Interrupt 2 request | External input | First non-completed instruction |
| 10 | Autovectored | Interrupt 1 request | External input | First non-completed instruction |
| 11 | Autovectored | Interrupt 0 request | External input | First non-completed instruction |
| 12 | EVBA+0x14 | Instruction Address | CPU | PC of offending instruction |
| 13 | EVBA+0x50 | ITLB Miss | MPU | PC of offending instruction |
| 14 | EVBA+0x18 | ITLB Protection | MPU | PC of offending instruction |
| 15 | EVBA+0x1C | Breakpoint | OCD system | First non-completed instruction |
| 16 | EVBA+0x20 | Illegal Opcode | Instruction | PC of offending instruction |
| 17 | EVBA+0x24 | Unimplemented instruction | Instruction | PC of offending instruction |
| 18 | EVBA+0x28 | Privilege violation | Instruction | PC of offending instruction |
| 19 | EVBA+0x2C | Floating-point | UNUSED | |
| 20 | EVBA+0x30 | Coprocessor absent | Instruction | PC of offending instruction |
| 21 | EVBA+0x100 | Supervisor call | Instruction | PC(Supervisor Call) +2 |
| 22 | EVBA+0x34 | Data Address (Read) | CPU | PC of offending instruction |
| 23 | EVBA+0x38 | Data Address (Write) | CPU | PC of offending instruction |
| 24 | EVBA+0x60 | DTLB Miss (Read) | MPU | PC of offending instruction |
| 25 | EVBA+0x70 | DTLB Miss (Write) | MPU | PC of offending instruction |
| 26 | EVBA+0x3C | DTLB Protection (Read) | MPU | PC of offending instruction |
| 27 | EVBA+0x40 | DTLB Protection (Write) | MPU | PC of offending instruction |
| 28 | EVBA+0x44 | DTLB Modified | UNUSED | |

5. Memories

5.1 Embedded Memories

- Internal high-speed flash
 - 256Kbytes (ATUC256L3U, ATUC256L4U)
 - 128Kbytes (ATUC128L3U, ATUC128L4U)
 - 64Kbytes (ATUC64L3U, ATUC64L4U)
 - 0 wait state access at up to 25MHz in worst case conditions
 - 1 wait state access at up to 50MHz in worst case conditions
 - Pipelined flash architecture, allowing burst reads from sequential flash locations, hiding penalty of 1 wait state access
 - Pipelined flash architecture typically reduces the cycle penalty of 1 wait state operation to only 8% compared to 0 wait state operation
 - 100 000 write cycles, 15-year data retention capability
 - Sector lock capabilities, bootloader protection, security bit
 - 32 fuses, erased during chip erase
 - User page for data to be preserved during chip erase
- Internal high-speed SRAM, single-cycle access at full speed
 - 32Kbytes (ATUC256L3U, ATUC256L4U, ATUC128L3U, ATUC128L4U)
 - 16Kbytes (ATUC64L3U, ATUC64L4U)

5.2 Physical Memory Map

The system bus is implemented as a bus matrix. All system bus addresses are fixed, and they are never remapped in any way, not even during boot. Note that AVR32 UC CPU uses unsegmented translation, as described in the AVR32 Architecture Manual. The 32-bit physical address space is mapped as follows:

Table 5-1. ATUC64/128/256L3/4U Physical Memory Map

| Memory | Start Address | Size | | |
|-----------------|---------------|------------------------|------------------------|----------------------|
| | | ATUC256L3U, ATUC256L4U | ATUC128L3U, ATUC128L4U | ATUC64L3U, ATUC64L4U |
| Embedded SRAM | 0x00000000 | 32Kbytes | 32Kbytes | 16Kbytes |
| Embedded Flash | 0x80000000 | 256Kbytes | 128Kbytes | 64Kbytes |
| SAU Channels | 0x90000000 | 256 bytes | 256 bytes | 256 bytes |
| HSB-PB Bridge B | 0xFFFFE0000 | 64Kbytes | 64Kbytes | 64Kbytes |
| HSB-PB Bridge A | 0xFFFFF0000 | 64Kbytes | 64Kbytes | 64Kbytes |

Table 5-2. Flash Memory Parameters

| Device | Flash Size (<i>FLASH_PW</i>) | Number of Pages (<i>FLASH_P</i>) | Page Size (<i>FLASH_W</i>) |
|---------------------------|--------------------------------|------------------------------------|------------------------------|
| ATUC256L3U, ATUC256L4U | 256Kbytes | 512 | 512 bytes |
| ATUC128L3U, ATUC128L4U | 128Kbytes | 256 | 512 bytes |
| ATUC64L3U, ATUC64L4U | 64Kbytes | 128 | 512 bytes |

5.3 Peripheral Address Map

Table 5-3. Peripheral Address Mapping

| Address | | Peripheral Name |
|------------|----------|--|
| 0xFFFE0000 | FLASHCDW | Flash Controller - FLASHCDW |
| 0xFFFE0400 | HMATRIX | HSB Matrix - HMATRIX |
| 0xFFFE0800 | SAU | Secure Access Unit - SAU |
| 0xFFFE1000 | USBC | USB 2.0 Interface - USBC |
| 0xFFFF0000 | PDCA | Peripheral DMA Controller - PDCA |
| 0xFFFF1000 | INTC | Interrupt controller - INTC |
| 0xFFFF1400 | PM | Power Manager - PM |
| 0xFFFF1800 | SCIF | System Control Interface - SCIF |
| 0xFFFF1C00 | AST | Asynchronous Timer - AST |
| 0xFFFF2000 | WDT | Watchdog Timer - WDT |
| 0xFFFF2400 | EIC | External Interrupt Controller - EIC |
| 0xFFFF2800 | FREQM | Frequency Meter - FREQM |
| 0xFFFF2C00 | GPIO | General-Purpose Input/Output Controller - GPIO |
| 0xFFFF3000 | USART0 | Universal Synchronous Asynchronous Receiver Transmitter - USART0 |
| 0xFFFF3400 | USART1 | Universal Synchronous Asynchronous Receiver Transmitter - USART1 |
| 0xFFFF3800 | USART2 | Universal Synchronous Asynchronous Receiver Transmitter - USART2 |
| 0xFFFF3C00 | USART3 | Universal Synchronous Asynchronous Receiver Transmitter - USART3 |
| 0xFFFF4000 | SPI | Serial Peripheral Interface - SPI |

Table 5-3. Peripheral Address Mapping

| | | |
|------------|--------|--|
| 0xFFFF4400 | TWIM0 | Two-wire Master Interface - TWIM0 |
| 0xFFFF4800 | TWIM1 | Two-wire Master Interface - TWIM1 |
| 0xFFFF4C00 | TWIS0 | Two-wire Slave Interface - TWIS0 |
| 0xFFFF5000 | TWIS1 | Two-wire Slave Interface - TWIS1 |
| 0xFFFF5400 | PWMA | Pulse Width Modulation Controller - PWMA |
| 0xFFFF5800 | TC0 | Timer/Counter - TC0 |
| 0xFFFF5C00 | TC1 | Timer/Counter - TC1 |
| 0xFFFF6000 | ADCIFB | ADC Interface - ADCIFB |
| 0xFFFF6400 | ACIFB | Analog Comparator Interface - ACIFB |
| 0xFFFF6800 | CAT | Capacitive Touch Module - CAT |
| 0xFFFF6C00 | GLOC | Glue Logic Controller - GLOC |
| 0xFFFF7000 | AW | aWire - AW |
| 0xFFFF7400 | ABDACB | Audio Bitstream DAC - ABDACB |
| 0xFFFF7800 | IISC | Inter-IC Sound (I2S) Controller - IISC |

5.4 CPU Local Bus Mapping

Some of the registers in the GPIO module are mapped onto the CPU local bus, in addition to being mapped on the Peripheral Bus. These registers can therefore be reached both by accesses on the Peripheral Bus, and by accesses on the local bus.

Mapping these registers on the local bus allows cycle-deterministic toggling of GPIO pins since the CPU and GPIO are the only modules connected to this bus. Also, since the local bus runs at CPU speed, one write or read operation can be performed per clock cycle to the local bus-mapped GPIO registers.

The following GPIO registers are mapped on the local bus:

Table 5-4. Local Bus Mapped GPIO Registers

| Port | Register | Mode | Local Bus Address | Access |
|------|--------------------------------------|--------|-------------------|------------|
| 0 | Output Driver Enable Register (ODER) | WRITE | 0x40000040 | Write-only |
| | | SET | 0x40000044 | Write-only |
| | | CLEAR | 0x40000048 | Write-only |
| | | TOGGLE | 0x4000004C | Write-only |
| | Output Value Register (OVR) | WRITE | 0x40000050 | Write-only |
| | | SET | 0x40000054 | Write-only |
| | | CLEAR | 0x40000058 | Write-only |
| | | TOGGLE | 0x4000005C | Write-only |
| | Pin Value Register (PVR) | - | 0x40000060 | Read-only |
| 1 | Output Driver Enable Register (ODER) | WRITE | 0x40000140 | Write-only |
| | | SET | 0x40000144 | Write-only |
| | | CLEAR | 0x40000148 | Write-only |
| | | TOGGLE | 0x4000014C | Write-only |
| | Output Value Register (OVR) | WRITE | 0x40000150 | Write-only |
| | | SET | 0x40000154 | Write-only |
| | | CLEAR | 0x40000158 | Write-only |
| | | TOGGLE | 0x4000015C | Write-only |
| | Pin Value Register (PVR) | - | 0x40000160 | Read-only |

6. Supply and Startup Considerations

6.1 Supply Considerations

6.1.1 Power Supplies

The ATUC64/128/256L3/4U has several types of power supply pins:

- VDDIO: Powers I/O lines. Voltage is 1.8 to 3.3V nominal.
- VDDIN: Powers I/O lines, the USB pins, and the internal regulator. Voltage is 1.8 to 3.3V nominal if USB is not used, and 3.3V nominal when USB is used.
- VDDANA: Powers the ADC. Voltage is 1.8V nominal.
- VDDCORE: Powers the core, memories, and peripherals. Voltage is 1.8V nominal.

The ground pins GND are common to VDDCORE, VDDIO, and VDDIN. The ground pin for VDDANA is GNDANA.

When VDDCORE is not connected to VDDIN, the VDDIN voltage must be higher than 1.98V.

Refer to [Section 7. on page 45](#) for power consumption on the various supply pins.

For decoupling recommendations for the different power supplies, please refer to the schematic checklist.

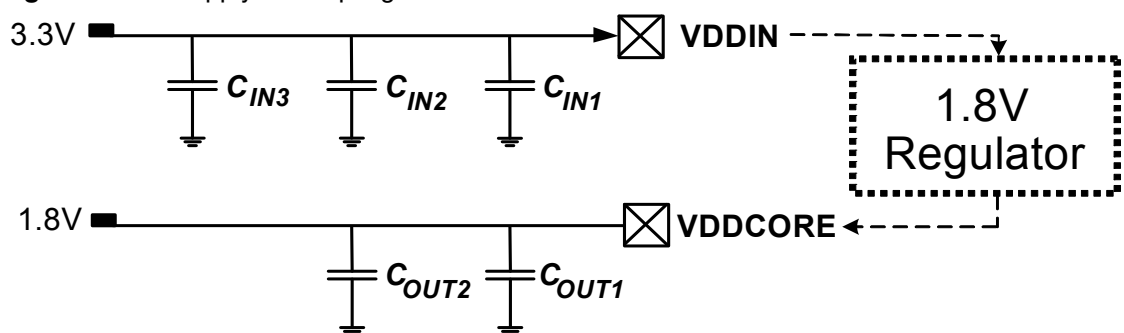
Refer to [Section 3.2 on page 9](#) for power supply connections for I/O pins.

6.1.2 Voltage Regulator

The ATUC64/128/256L3/4U embeds a voltage regulator that converts from 3.3V nominal to 1.8V with a load of up to 60 mA. The regulator supplies the output voltage on VDDCORE. The regulator may only be used to drive internal circuitry in the device. VDDCORE should be externally connected to the 1.8V domains. See [Section 6.1.3](#) for regulator connection figures.

Adequate output supply decoupling is mandatory for VDDCORE to reduce ripple and avoid oscillations. The best way to achieve this is to use two capacitors in parallel between VDDCORE and GND as close to the device as possible. Please refer to [Section 7.8 on page 59](#) for decoupling capacitors values and regulator characteristics.

Figure 6-1. Supply Decoupling.



The voltage regulator can be turned off in the shutdown mode to power down the core logic and keep a small part of the system powered in order to reduce power consumption. To enter this mode the 3.3V supply mode, with 1.8V regulated I/O lines power supply configuration must be used.

6.1.3 Regulator Connection

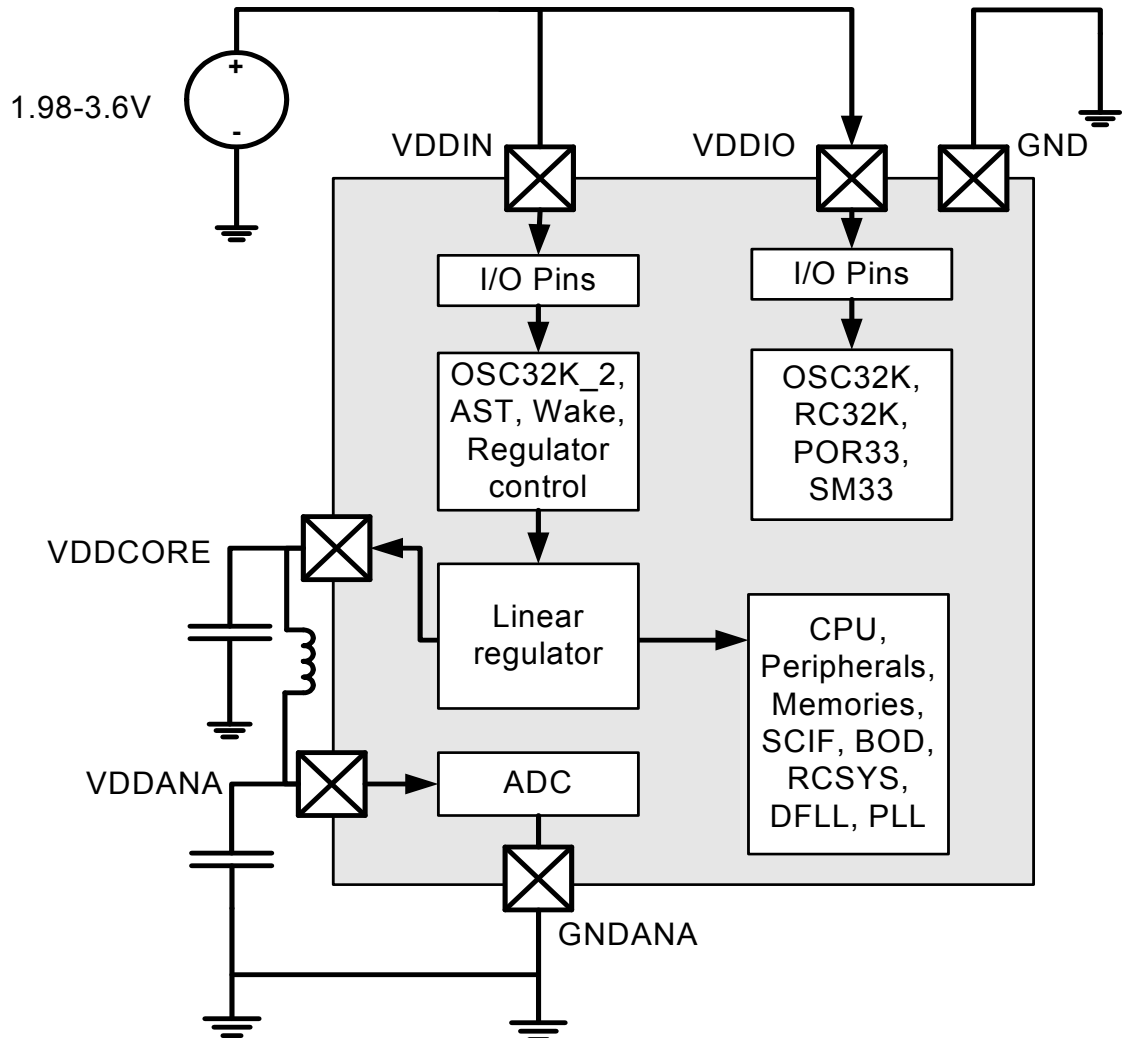
The ATUC64/128/256L3/4U supports three power supply configurations:

- 3.3V single supply mode
 - Shutdown mode is not available
- 1.8V single supply mode
 - Shutdown mode is not available
- 3.3V supply mode, with 1.8V regulated I/O lines
 - Shutdown mode is available

6.1.3.1 3.3V Single Supply Mode

In 3.3V single supply mode the internal regulator is connected to the 3.3V source (VDDIN pin) and its output feeds VDDCORE. Figure 6-2 shows the power schematics to be used for 3.3V single supply mode. All I/O lines will be powered by the same power (VDDIN=VDDIO).

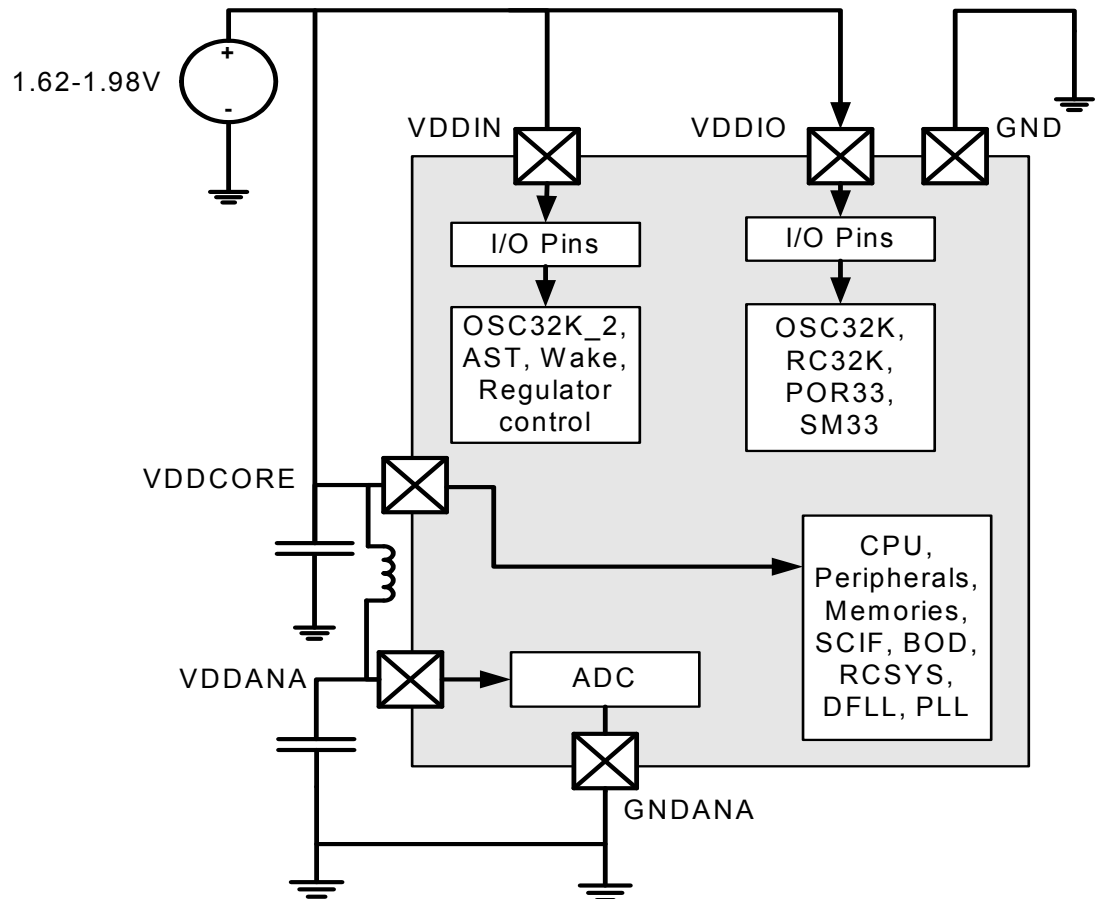
Figure 6-2. 3.3V Single Supply Mode



6.1.3.2 1.8V Single Supply Mode

In 1.8V single supply mode the internal regulator is not used, and VDDIO and VDDCORE are powered by a single 1.8V supply as shown in [Figure 6-3](#). All I/O lines will be powered by the same power ($VDDIN = VDDIO = VDDCORE$).

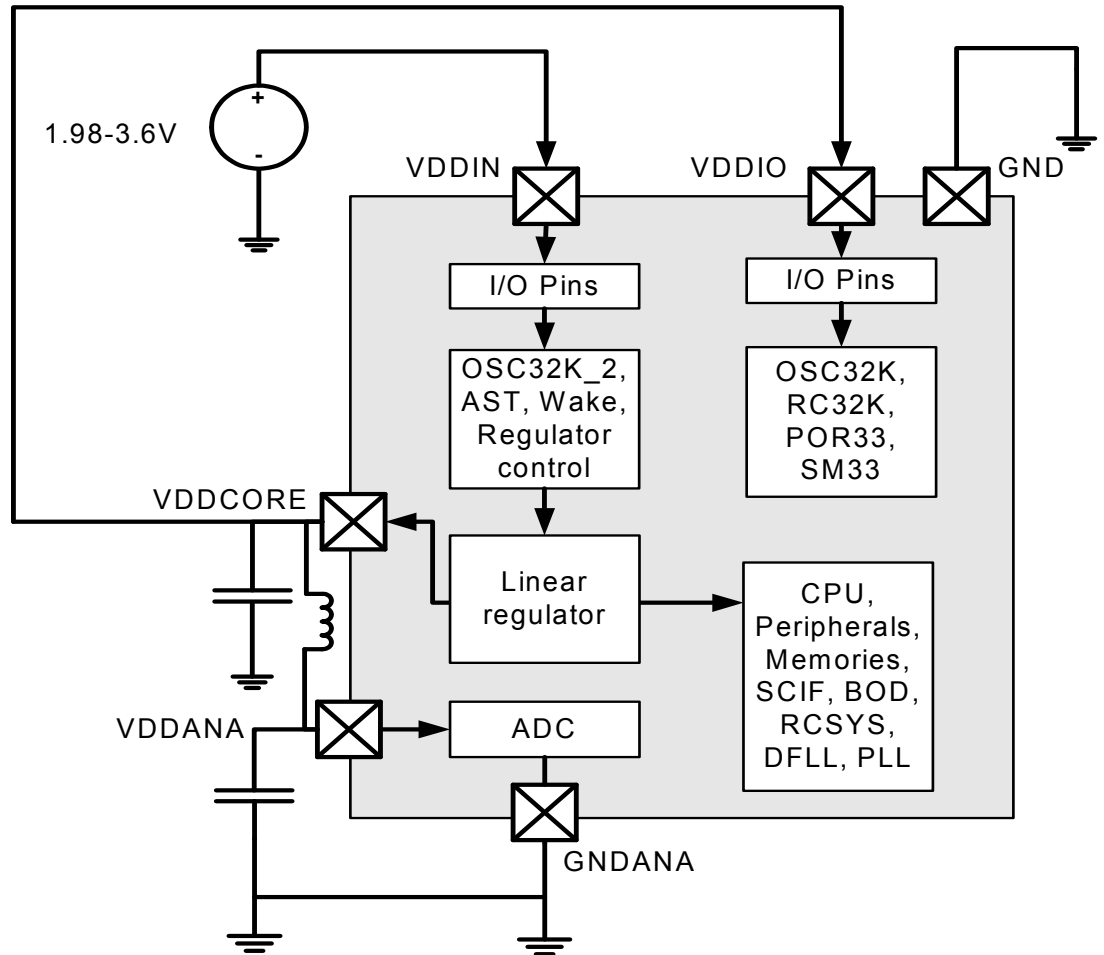
Figure 6-3. 1.8V Single Supply Mode



6.1.3.3 3.3V Supply Mode with 1.8V Regulated I/O Lines

In this mode, the internal regulator is connected to the 3.3V source and its output is connected to both VDDCORE and VDDIO as shown in [Figure 6-4](#). This configuration is required in order to use Shutdown mode.

Figure 6-4. 3.3V Supply Mode with 1.8V Regulated I/O Lines



In this mode, some I/O lines are powered by VDDIN while other I/O lines are powered by VDDIO. Refer to [Section 3.2 on page 9](#) for description of power supply for each I/O line.

Refer to the Power Manager chapter for a description of what parts of the system are powered in Shutdown mode.

Important note: As the regulator has a maximum output current of 60 mA, this mode can only be used in applications where the maximum I/O current is known and compatible with the core and peripheral power consumption. Typically, great care must be used to ensure that only a few I/O lines are toggling at the same time and drive very small loads.

6.1.4 Power-up Sequence

6.1.4.1 Maximum Rise Rate

To avoid risk of latch-up, the rise rate of the power supplies must not exceed the values described in [Table 7-3 on page 46](#).

Recommended order for power supplies is also described in this chapter.

6.1.4.2 Minimum Rise Rate

The integrated Power-on Reset (POR33) circuitry monitoring the VDDIN powering supply requires a minimum rise rate for the VDDIN power supply.

See [Table 7-3 on page 46](#) for the minimum rise rate value.

If the application can not ensure that the minimum rise rate condition for the VDDIN power supply is met, one of the following configurations can be used:

- A logic “0” value is applied during power-up on pin PA11 (WAKE_N) until VDDIN rises above 1.2V.
- A logic “0” value is applied during power-up on pin RESET_N until VDDIN rises above 1.2V.

6.2 Startup Considerations

This chapter summarizes the boot sequence of the ATUC64/128/256L3/4U. The behavior after power-up is controlled by the Power Manager. For specific details, refer to the Power Manager chapter.

6.2.1 Starting of Clocks

After power-up, the device will be held in a reset state by the Power-on Reset (POR18 and POR33) circuitry for a short time to allow the power to stabilize throughout the device. After reset, the device will use the System RC Oscillator (RCSYS) as clock source. Please refer to [Table 7-17 on page 58](#) for the frequency for this oscillator.

On system start-up, all high-speed clocks are disabled. All clocks to all modules are running. No clocks have a divided frequency; all parts of the system receive a clock with the same frequency as the System RC Oscillator.

When powering up the device, there may be a delay before the voltage has stabilized, depending on the rise time of the supply used. The CPU can start executing code as soon as the supply is above the POR18 and POR33 thresholds, and before the supply is stable. Before switching to a high-speed clock source, the user should use the BOD to make sure the VDDCORE is above the minimum level (1.62V).

6.2.2 Fetching of Initial Instructions

After reset has been released, the AVR32 UC CPU starts fetching instructions from the reset address, which is 0x80000000. This address points to the first address in the internal Flash.

The code read from the internal flash is free to configure the clock system and clock sources. Please refer to the PM and SCIF chapters for more details.

7. Electrical Characteristics

7.1 Absolute Maximum Ratings*

Table 7-1. Absolute Maximum Ratings

| | |
|---|--------------------------------|
| Operating temperature..... | -40°C to +85°C |
| Storage temperature..... | -60°C to +150°C |
| Voltage on input pins (except for 5V pins) with respect to ground | -0.3V to $V_{VDD}^{(2)}$ +0.3V |
| Voltage on 5V tolerant ⁽¹⁾ pins with respect to ground | -0.3V to 5.5V |
| Total DC output current on all I/O pins - VDDIO, 64-pin package | 141 mA |
| Total DC output current on all I/O pins - VDDIN, 64-pin package | 42 mA |
| Total DC output current on all I/O pins - VDDIO, 48-pin package | 120mA |
| Total DC output current on all I/O pins - VDDIN, 48-pin package | 39 mA |
| Maximum operating voltage VDDCORE..... | 1.98V |
| Maximum operating voltage VDDIO, VDDIN | 3.6V |

*NOTICE: Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

- Notes: 1. 5V tolerant pins, see [Section 3.2 “Peripheral Multiplexing on I/O lines” on page 9](#)
2. V_{VDD} corresponds to either V_{VDDIN} or V_{VDDIO} , depending on the supply for the pin. Refer to [Section 3.2 on page 9](#) for details.

7.2 Supply Characteristics

The following characteristics are applicable to the operating temperature range: $T_A = -40^{\circ}\text{C}$ to 85°C , unless otherwise specified and are valid for a junction temperature up to $T_J = 100^{\circ}\text{C}$. Please refer to [Section 6. “Supply and Startup Considerations” on page 39](#).

Table 7-2. Supply Characteristics

| Symbol | Parameter | Voltage | | |
|---------------|--|---------|------|------|
| | | Min | Max | Unit |
| V_{VDDIO} | DC supply peripheral I/Os | 1.62 | 3.6 | V |
| V_{VDDIN} | DC supply peripheral I/Os, 1.8V single supply mode | 1.62 | 1.98 | V |
| | DC supply peripheral I/Os and internal regulator, 3.3V supply mode | 1.98 | 3.6 | V |
| $V_{VDDCORE}$ | DC supply core | 1.62 | 1.98 | V |
| V_{VDDANA} | Analog supply voltage | 1.62 | 1.98 | V |

Table 7-3. Supply Rise Rates and Order⁽¹⁾

| Symbol | Parameter | Rise Rate | | | |
|----------------------|--|-----------|-----|------|--|
| | | Min | Max | Unit | Comment |
| V _{VDDIO} | DC supply peripheral I/Os | 0 | 2.5 | V/μs | |
| V _{VDDIN} | DC supply peripheral I/Os and internal regulator | 0.002 | 2.5 | V/μs | Slower rise time requires external power-on reset circuit. |
| V _{VDDCORE} | DC supply core | 0 | 2.5 | V/μs | Rise before or at the same time as VDDIO |
| V _{VDDANA} | Analog supply voltage | 0 | 2.5 | V/μs | Rise together with VDDCORE |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

7.3 Maximum Clock Frequencies

These parameters are given in the following conditions:

- V_{VDDCORE} = 1.62V to 1.98V
- Temperature = -40°C to 85°C

Table 7-4. Clock Frequencies

| Symbol | Parameter | Description | Min | Max | Units |
|--------------------|-----------------------|---|-----|-----|-------|
| f _{CPU} | CPU clock frequency | | | 50 | MHz |
| f _{PBA} | PBA clock frequency | | | 50 | |
| f _{PBB} | PBB clock frequency | | | 50 | |
| f _{GCLK0} | GCLK0 clock frequency | DPLLIF main reference, GCLK0 pin | | 50 | |
| f _{GCLK1} | GCLK1 clock frequency | DPLLIF dithering and SSG reference, GCLK1 pin | | 50 | |
| f _{GCLK2} | GCLK2 clock frequency | AST, GCLK2 pin | | 20 | |
| f _{GCLK3} | GCLK3 clock frequency | PWMA, GCLK3 pin | | 140 | |
| f _{GCLK4} | GCLK4 clock frequency | CAT, ACIFB, GCLK4 pin | | 50 | |
| f _{GCLK5} | GCLK5 clock frequency | GLOC and GCLK5 pin | | 80 | |
| f _{GCLK6} | GCLK6 clock frequency | ABDACB, IISC, and GCLK6 pin | | 50 | |
| f _{GCLK7} | GCLK7 clock frequency | USBC and GCLK7 pin | | 50 | |
| f _{GCLK8} | GCLK8 clock frequency | PLL0 source clock and GCLK8 pin | | 50 | |
| f _{GCLK9} | GCLK9 clock frequency | FREQM, GCLK0-8, GCLK9 pin | | 150 | |

7.4 Power Consumption

The values in [Table 7-5](#) are measured values of power consumption under the following conditions, except where noted:

- Operating conditions, internal core supply ([Figure 7-1](#)) - this is the default configuration
 - V_{VDDIN} = 3.0V

- $V_{VDDCORE} = 1.62V$, supplied by the internal regulator
- Corresponds to the 3.3V supply mode with 1.8V regulated I/O lines, please refer to the Supply and Startup Considerations section for more details
 - Equivalent to the 3.3V single supply mode
 - Consumption in 1.8V single supply mode can be estimated by subtracting the regulator static current
- Operating conditions, external core supply ([Figure 7-2](#)) - used only when noted
 - $V_{VDDIN} = V_{VDDCORE} = 1.8V$
 - Corresponds to the 1.8V single supply mode, please refer to the Supply and Startup Considerations section for more details
- $T_A = 25^{\circ}C$
- Oscillators
 - OSC0 (crystal oscillator) stopped
 - OSC32K (32KHz crystal oscillator) running with external 32KHz crystal
 - DFLL running at 50MHz with OSC32K as reference
- Clocks
 - DFLL used as main clock source
 - CPU, HSB, and PBB clocks undivided
 - PBA clock divided by 4
 - The following peripheral clocks running
 - PM, SCIF, AST, FLASHCDW, PBA bridge
 - All other peripheral clocks stopped
- I/Os are inactive with internal pull-up
- Flash enabled in high speed mode
- POR18 enabled
- POR33 disabled

Table 7-5. Power Consumption for Different Operating Modes

| Mode | Conditions | Measured on | Consumption Typ | Unit |
|------------------------|--|-------------|-----------------|--------------------------|
| Active ⁽¹⁾ | CPU running a recursive Fibonacci algorithm | Amp0 | 300 | $\mu\text{A}/\text{MHz}$ |
| | CPU running a division algorithm | | 174 | |
| Idle ⁽¹⁾ | | | 96 | |
| Frozen ⁽¹⁾ | | | 57 | |
| Standby ⁽¹⁾ | | | 46 | |
| Stop | | | 38 | μA |
| DeepStop | | | 25 | |
| Static | -OSC32K and AST stopped -Internal core supply | | 14 | |
| | -OSC32K running -AST running at 1 KHz -External core supply (Figure 7-2) | | 7.3 | |
| | -OSC32K and AST stopped -External core supply (Figure 7-2) | | 6.7 | |
| | | | | |
| Shutdown | -OSC32K running -AST running at 1 KHz | | 800 | nA |
| | AST and OSC32K stopped | | 220 | |

Note: 1. These numbers are valid for the measured condition only and must not be extrapolated to other frequencies.

Figure 7-1. Measurement Schematic, Internal Core Supply

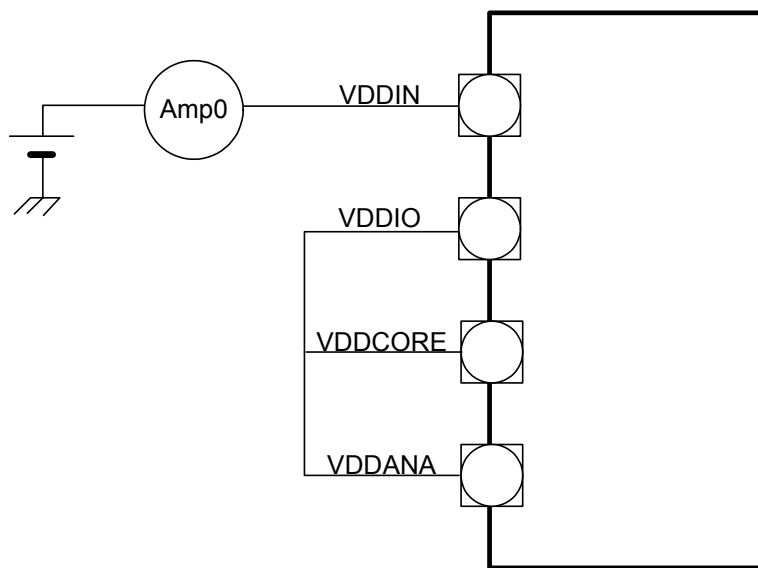
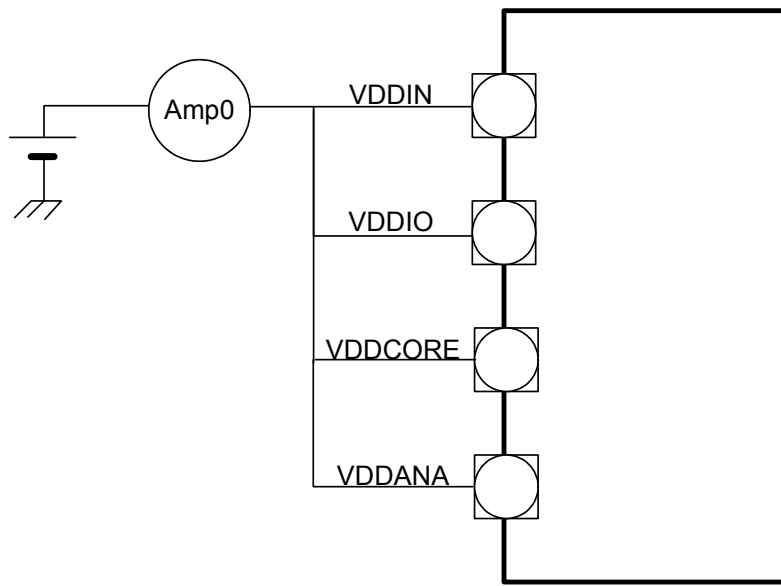


Figure 7-2. Measurement Schematic, External Core Supply



7.5 I/O Pin Characteristics

Table 7-6. Normal I/O Pin Characteristics⁽¹⁾

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|--------------|--|--------------------------------------|-----------------|-----|-----------------|---------|
| R_{PULLUP} | Pull-up resistance | | 75 | 100 | 145 | kOhm |
| V_{IL} | Input low-level voltage | $V_{VDD} = 3.0V$ | -0.3 | | $0.3 * V_{VDD}$ | V |
| | | $V_{VDD} = 1.62V$ | -0.3 | | $0.3 * V_{VDD}$ | |
| V_{IH} | Input high-level voltage | $V_{VDD} = 3.6V$ | $0.7 * V_{VDD}$ | | $V_{VDD} + 0.3$ | V |
| | | $V_{VDD} = 1.98V$ | $0.7 * V_{VDD}$ | | $V_{VDD} + 0.3$ | |
| V_{OL} | Output low-level voltage | $V_{VDD} = 3.0V, I_{OL} = 3mA$ | | | 0.4 | V |
| | | $V_{VDD} = 1.62V, I_{OL} = 2mA$ | | | 0.4 | |
| V_{OH} | Output high-level voltage | $V_{VDD} = 3.0V, I_{OH} = 3mA$ | $V_{VDD} - 0.4$ | | | V |
| | | $V_{VDD} = 1.62V, I_{OH} = 2mA$ | $V_{VDD} - 0.4$ | | | |
| f_{MAX} | Output frequency ⁽²⁾ | $V_{VDD} = 3.0V, \text{load} = 10pF$ | | | 45 | MHz |
| | | $V_{VDD} = 3.0V, \text{load} = 30pF$ | | | 23 | |
| t_{RISE} | Rise time ⁽²⁾ | $V_{VDD} = 3.0V, \text{load} = 10pF$ | | | 4.7 | ns |
| | | $V_{VDD} = 3.0V, \text{load} = 30pF$ | | | 11.5 | |
| t_{FALL} | Fall time ⁽²⁾ | $V_{VDD} = 3.0V, \text{load} = 10pF$ | | | 4.8 | |
| | | $V_{VDD} = 3.0V, \text{load} = 30pF$ | | | 12 | |
| I_{LEAK} | Input leakage current | Pull-up resistors disabled | | | 1 | μA |
| C_{IN} | Input capacitance, all normal I/O pins except PA05, PA07, PA17, PA20, PA21, PB04, PB05 | TQFP48 package | | 1.4 | | pF |
| | | QFN48 package | | 1.1 | | |
| | | TLLGA48 package | | 1.1 | | |
| | | TQFP64 package | | 1.5 | | |
| | | QFN64 package | | 1.1 | | |
| C_{IN} | Input capacitance, PA20 | TQFP48 package | | 2.7 | | |
| | | QFN48 package | | 2.4 | | |
| | | TLLGA48 package | | 2.4 | | |
| | | TQFP64 package | | 2.8 | | |
| | | QFN64 package | | 2.4 | | |
| C_{IN} | Input capacitance, PA05, PA07, PA17, PA21, PB04, PB05 | TQFP48 package | | 3.8 | | |
| | | QFN48 package | | 3.5 | | |
| | | TLLGA48 package | | 3.5 | | |
| | | TQFP64 package | | 3.9 | | |
| | | QFN64 package | | 3.5 | | |

- Notes: 1. V_{VDD} corresponds to either V_{VDDIN} or V_{VDDIO} , depending on the supply for the pin. Refer to [Section 3.2 on page 9](#) for details.
2. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

Table 7-7. High-drive I/O Pin Characteristics⁽¹⁾

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|---------------------|--|---|------------------------|-----|------------------------|-------|
| R _{PULLUP} | Pull-up resistance | PA06 | 30 | 50 | 110 | kOhm |
| | | PA02, PB01, RESET | 75 | 100 | 145 | |
| | | PA08, PA09 | 10 | 20 | 45 | |
| V _{IL} | Input low-level voltage | V _{VDD} = 3.0V | -0.3 | | 0.3 * V _{VDD} | V |
| | | V _{VDD} = 1.62V | -0.3 | | 0.3 * V _{VDD} | |
| V _{IH} | Input high-level voltage | V _{VDD} = 3.6V | 0.7 * V _{VDD} | | V _{VDD} + 0.3 | V |
| | | V _{VDD} = 1.98V | 0.7 * V _{VDD} | | V _{VDD} + 0.3 | |
| V _{OL} | Output low-level voltage | V _{VDD} = 3.0V, I _{OL} = 6mA | | | 0.4 | V |
| | | V _{VDD} = 1.62V, I _{OL} = 4mA | | | 0.4 | |
| V _{OH} | Output high-level voltage | V _{VDD} = 3.0V, I _{OH} = 6mA | V _{VDD} - 0.4 | | | V |
| | | V _{VDD} = 1.62V, I _{OH} = 4mA | V _{VDD} - 0.4 | | | |
| f _{MAX} | Output frequency, all High-drive I/O pins, except PA08 and PA09 ⁽²⁾ | V _{VDD} = 3.0V, load = 10pF | | | 45 | MHz |
| | | V _{VDD} = 3.0V, load = 30pF | | | 23 | |
| t _{RISE} | Rise time, all High-drive I/O pins, except PA08 and PA09 ⁽²⁾ | V _{VDD} = 3.0V, load = 10pF | | | 4.7 | ns |
| | | V _{VDD} = 3.0V, load = 30pF | | | 11.5 | |
| t _{FALL} | Fall time, all High-drive I/O pins, except PA08 and PA09 ⁽²⁾ | V _{VDD} = 3.0V, load = 10pF | | | 4.8 | |
| | | V _{VDD} = 3.0V, load = 30pF | | | 12 | |
| f _{MAX} | Output frequency, PA08 and PA09 ⁽²⁾ | V _{VDD} = 3.0V, load = 10pF | | | 54 | MHz |
| | | V _{VDD} = 3.0V, load = 30pF | | | 40 | |
| t _{RISE} | Rise time, PA08 and PA09 ⁽²⁾ | V _{VDD} = 3.0V, load = 10pF | | | 2.8 | ns |
| | | V _{VDD} = 3.0V, load = 30pF | | | 4.9 | |
| t _{FALL} | Fall time, PA08 and PA09 ⁽²⁾ | V _{VDD} = 3.0V, load = 10pF | | | 2.4 | |
| | | V _{VDD} = 3.0V, load = 30pF | | | 4.6 | |
| I _{LEAK} | Input leakage current | Pull-up resistors disabled | | | 1 | μA |
| C _{IN} | Input capacitance, all High-drive I/O pins, except PA08 and PA09 | TQFP48 package | | 2.2 | | pF |
| | | QFN48 package | | 2.0 | | |
| | | TLLGA48 package | | 2.0 | | |
| | | TQFP64 package | | 2.3 | | |
| | | QFN64 package | | 2.0 | | |
| C _{IN} | Input capacitance, PA08 and PA09 | TQFP48 package | | 7.0 | | |
| | | QFN48 package | | 6.7 | | |
| | | TLLGA48 package | | 6.7 | | |
| | | TQFP64 package | | 7.1 | | |
| | | QFN64 package | | 6.7 | | |

Notes: 1. V_{VDD} corresponds to either V_{VDDIN} or V_{VDDIO}, depending on the supply for the pin. Refer to [Section 3.2 on page 9](#) for details.

2. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

Table 7-8. High-drive I/O, 5V Tolerant, Pin Characteristics⁽¹⁾

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|--------------|---------------------------------|--------------------------------------|-----------------|-----|-----------------|---------|
| R_{PULLUP} | Pull-up resistance | | 30 | 50 | 110 | kOhm |
| V_{IL} | Input low-level voltage | $V_{VDD} = 3.0V$ | -0.3 | | $0.3 * V_{VDD}$ | V |
| | | $V_{VDD} = 1.62V$ | -0.3 | | $0.3 * V_{VDD}$ | |
| V_{IH} | Input high-level voltage | $V_{VDD} = 3.6V$ | $0.7 * V_{VDD}$ | | 5.5 | V |
| | | $V_{VDD} = 1.98V$ | $0.7 * V_{VDD}$ | | 5.5 | |
| V_{OL} | Output low-level voltage | $V_{VDD} = 3.0V, I_{OL} = 6mA$ | | | 0.4 | V |
| | | $V_{VDD} = 1.62V, I_{OL} = 4mA$ | | | 0.4 | |
| V_{OH} | Output high-level voltage | $V_{VDD} = 3.0V, I_{OH} = 6mA$ | $V_{VDD} - 0.4$ | | | V |
| | | $V_{VDD} = 1.62V, I_{OH} = 4mA$ | $V_{VDD} - 0.4$ | | | |
| f_{MAX} | Output frequency ⁽²⁾ | $V_{VDD} = 3.0V, \text{load} = 10pF$ | | | 87 | MHz |
| | | $V_{VDD} = 3.0V, \text{load} = 30pF$ | | | 58 | |
| t_{RISE} | Rise time ⁽²⁾ | $V_{VDD} = 3.0V, \text{load} = 10pF$ | | | 2.3 | ns |
| | | $V_{VDD} = 3.0V, \text{load} = 30pF$ | | | 4.3 | |
| t_{FALL} | Fall time ⁽²⁾ | $V_{VDD} = 3.0V, \text{load} = 10pF$ | | | 1.9 | |
| | | $V_{VDD} = 3.0V, \text{load} = 30pF$ | | | 3.7 | |
| I_{LEAK} | Input leakage current | 5.5V, pull-up resistors disabled | | | 10 | μA |
| C_{IN} | Input capacitance | TQFP48 package | | 4.5 | | pF |
| | | QFN48 package | | 4.2 | | |
| | | TLLGA48 package | | 4.2 | | |
| | | TQFP64 package | | 4.6 | | |
| | | QFN64 package | | 4.2 | | |

Notes: 1. V_{VDD} corresponds to either V_{VDDIN} or V_{VDDIO} , depending on the supply for the pin. Refer to [Section 3.2 on page 9](#) for details.

2. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

Table 7-9. TWI Pin Characteristics⁽¹⁾

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|--------------|--|-------------------|-----------------|-----|-----------------|-------|
| R_{PULLUP} | Pull-up resistance | | 25 | 35 | 60 | kOhm |
| V_{IL} | Input low-level voltage | $V_{VDD} = 3.0V$ | -0.3 | | $0.3 * V_{VDD}$ | V |
| | | $V_{VDD} = 1.62V$ | -0.3 | | $0.3 * V_{VDD}$ | |
| V_{IH} | Input high-level voltage | $V_{VDD} = 3.6V$ | $0.7 * V_{VDD}$ | | $V_{VDD} + 0.3$ | V |
| | | $V_{VDD} = 1.98V$ | $0.7 * V_{VDD}$ | | $V_{VDD} + 0.3$ | |
| | Input high-level voltage, 5V tolerant SMBUS compliant pins | $V_{VDD} = 3.6V$ | $0.7 * V_{VDD}$ | | 5.5 | V |
| | | $V_{VDD} = 1.98V$ | $0.7 * V_{VDD}$ | | 5.5 | |

Table 7-9. TWI Pin Characteristics⁽¹⁾

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|------------|--------------------------|--|-----|-----|-----|---------------|
| V_{OL} | Output low-level voltage | $I_{OL} = 3\text{mA}$ | | | 0.4 | V |
| I_{LEAK} | Input leakage current | Pull-up resistors disabled | | | 1 | μA |
| I_{IL} | Input low leakage | | | | 1 | |
| I_{IH} | Input high leakage | | | | 1 | |
| C_{IN} | Input capacitance | TQFP48 package | | 3.8 | | pF |
| | | QFN48 package | | 3.5 | | |
| | | TLLGA48 package | | 3.5 | | |
| | | TQFP64 package | | 3.9 | | |
| | | QFN64 package | | 3.5 | | |
| t_{FALL} | Fall time | $C_{bus} = 400\text{pF}$, $V_{DD} > 2.0\text{V}$ | | 250 | | ns |
| | | $C_{bus} = 400\text{pF}$, $V_{DD} > 1.62\text{V}$ | | 470 | | |
| f_{MAX} | Max frequency | $C_{bus} = 400\text{pF}$, $V_{DD} > 2.0\text{V}$ | 400 | | | kHz |

Note: 1. V_{DD} corresponds to either V_{DDIN} or V_{DDIO} , depending on the supply for the pin. Refer to [Section 3.2 on page 9](#) for details.

7.6 Oscillator Characteristics

7.6.1 Oscillator 0 (OSC0) Characteristics

7.6.1.1 Digital Clock Characteristics

The following table describes the characteristics for the oscillator when a digital clock is applied on XIN.

Table 7-10. Digital Clock Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---------------|-------------------------------------|-----------------|-----|-----|-----|--------|
| f_{CPXIN} | XIN clock frequency | | | | 50 | MHz |
| t_{CPXIN} | XIN clock duty cycle ⁽¹⁾ | | 40 | | 60 | % |
| $t_{STARTUP}$ | Startup time | | | 0 | | cycles |
| C_{IN} | XIN input capacitance | TQFP48 package | | 7.0 | | pF |
| | | QFN48 package | | 6.7 | | |
| | | TLLGA48 package | | 6.7 | | |
| | | TQFP64 package | | 7.1 | | |
| | | QFN64 package | | 6.7 | | |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

7.6.1.2 Crystal Oscillator Characteristics

The following table describes the characteristics for the oscillator when a crystal is connected between XIN and XOUT as shown in [Figure 7-3](#). The user must choose a crystal oscillator where the crystal load capacitance C_L is within the range given in the table. The exact value of C_L

can be found in the crystal datasheet. The capacitance of the external capacitors (C_{LEXT}) can then be computed as follows:

$$C_{LEXT} = 2(C_L - C_i) - C_{PCB}$$

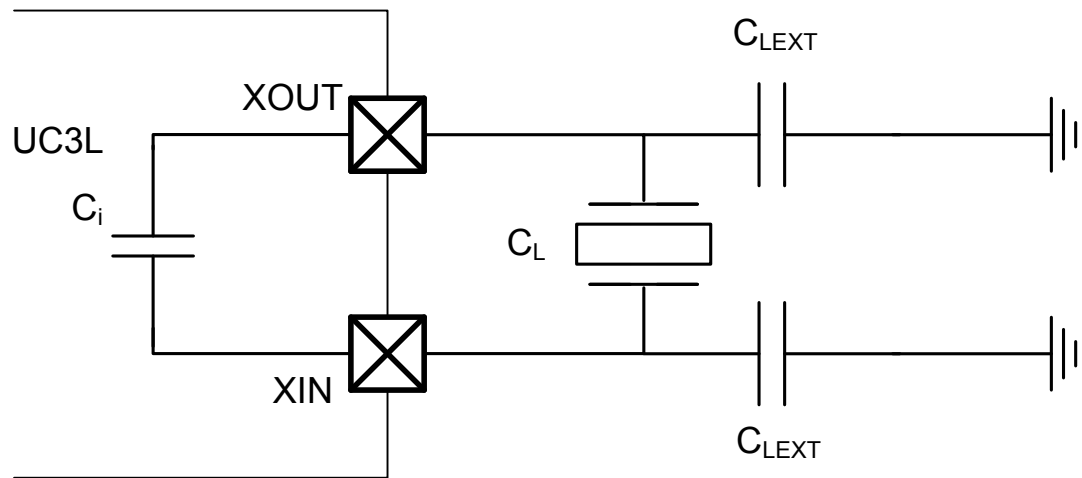
where C_{PCB} is the capacitance of the PCB and C_i is the internal equivalent load capacitance.

Table 7-11. Crystal Oscillator Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---------------|---|--|------|-----------------------|-----|---------------|
| f_{OUT} | Crystal oscillator frequency ⁽³⁾ | | 0.45 | 10 | 16 | MHz |
| C_L | Crystal load capacitance ⁽³⁾ | | 6 | | 18 | pF |
| C_i | Internal equivalent load capacitance | | | 2 | | |
| $t_{STARTUP}$ | Startup time | SCIF.OSCCTRL.GAIN = 2 ⁽¹⁾ | | 30 000 ⁽²⁾ | | cycles |
| I_{OSC} | Current consumption | Active mode, $f = 0.45\text{MHz}$, SCIF.OSCCTRL.GAIN = 0 | | 30 | | μA |
| | | Active mode, $f = 10\text{MHz}$, SCIF.OSCCTRL.GAIN = 2 | | 220 | | |

- Notes:
1. Please refer to the SCIF chapter for details.
 2. Nominal crystal cycles.
 3. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

Figure 7-3. Oscillator Connection



7.6.2 32 KHz Crystal Oscillator (OSC32K) Characteristics

Figure 7-3 and the equation above also applies to the 32 KHz oscillator connection. The user must choose a crystal oscillator where the crystal load capacitance C_L is within the range given in the table. The exact value of C_L can then be found in the crystal datasheet.

Table 7-12. 32 KHz Crystal Oscillator Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---------------|---|---------------------------------|-----|-----------------------|------|------------|
| f_{OUT} | Crystal oscillator frequency | | | 32 768 | | Hz |
| $t_{STARTUP}$ | Startup time | $R_S = 60k\Omega$, $C_L = 9pF$ | | 30 000 ⁽¹⁾ | | cycles |
| C_L | Crystal load capacitance ⁽²⁾ | | 6 | | 12.5 | pF |
| C_i | Internal equivalent load capacitance | | | 2 | | |
| I_{OSC32} | Current consumption | | | 0.6 | | μA |
| R_S | Equivalent series resistance ⁽²⁾ | 32 768Hz | 35 | | 85 | k Ω |

- Notes:
1. Nominal crystal cycles.
 2. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

7.6.3 Phase Locked Loop (PLL) Characteristics

Table 7-13. Phase Locked Loop Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---------------|---|------------------|-----|-----|-----|-------------|
| f_{OUT} | Output frequency ⁽¹⁾ | | 40 | | 240 | MHz |
| f_{IN} | Input frequency ⁽¹⁾ | | 4 | | 16 | |
| I_{PLL} | Current consumption | | | 8 | | $\mu A/MHz$ |
| $t_{STARTUP}$ | Startup time, from enabling the PLL until the PLL is locked | $f_{IN} = 4MHz$ | | 200 | | μs |
| | | $f_{IN} = 16MHz$ | | 155 | | |

- Note:
1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

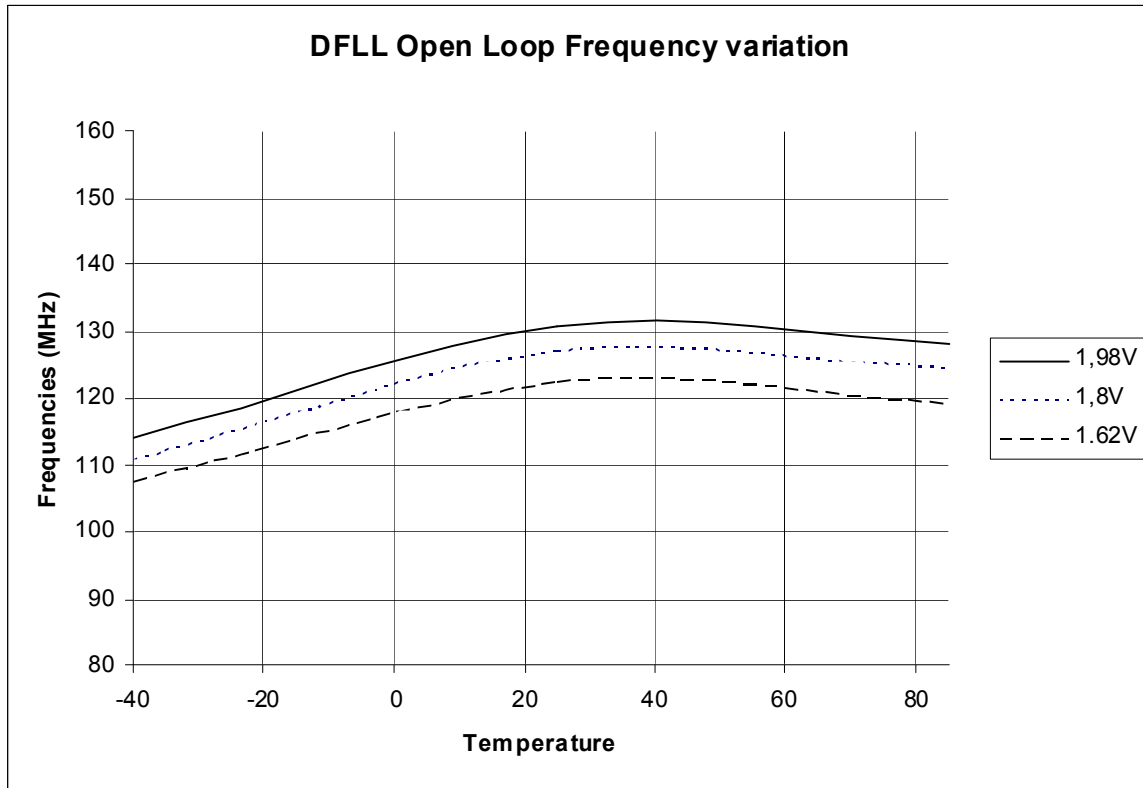
7.6.4 Digital Frequency Locked Loop (DFLL) Characteristics

Table 7-14. Digital Frequency Locked Loop Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---------------|--|--|-----|----------------|-----|-------------------|
| f_{OUT} | Output frequency ⁽²⁾ | | 20 | | 150 | MHz |
| f_{REF} | Reference frequency ⁽²⁾ | | 8 | | 150 | kHz |
| | FINE resolution step | FINE > 100, all COARSE values ⁽³⁾ | | 0.38 | | % |
| | Frequency drift over voltage and temperature | Open loop mode | | See Figure 7-4 | | |
| | Accuracy ⁽²⁾ | FINE lock, $f_{REF} = 32\text{kHz}$, SSG disabled | | 0.1 | 0.5 | % |
| | | ACCURATE lock, $f_{REF} = 32\text{kHz}$, dither clk RCSYS/2, SSG disabled | | 0.06 | 0.5 | |
| | | FINE lock, $f_{REF} = 8\text{-}150\text{kHz}$, SSG disabled | | 0.2 | 1 | |
| | | ACCURATE lock, $f_{REF} = 8\text{-}150\text{kHz}$, dither clk RCSYS/2, SSG disabled | | 0.1 | 1 | |
| I_{DFLL} | Power consumption | | | 25 | | $\mu\text{A/MHz}$ |
| $t_{STARTUP}$ | Startup time ⁽²⁾ | Within 90% of final values | | | 100 | μs |
| t_{LOCK} | Lock time | $f_{REF} = 32\text{kHz}$, FINE lock, SSG disabled | | 8 | | ms |
| | | $f_{REF} = 32\text{kHz}$, ACCURATE lock, dithering clock = RCSYS/2, SSG disabled | | 28 | | |

- Notes:
1. Spread Spectrum Generator (SSG) is disabled by writing a zero to the EN bit in the DFLL0SSG register.
 2. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.
 3. The FINE and COARSE values are selected by writing to the DFLL0VAL.FINE and DFLL0VAL.COARSE field respectively.

Figure 7-4. DFLL Open Loop Frequency Variation⁽¹⁾⁽²⁾



- Notes:
1. The plot shows a typical open loop mode behavior with COARSE= 99 and FINE= 255.
 2. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

7.6.5 120MHz RC Oscillator (RC120M) Characteristics

Table 7-15. Internal 120MHz RC Oscillator Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---------------|---------------------------------|----------------------|-----|-----|-----|---------|
| f_{OUT} | Output frequency ⁽¹⁾ | | 88 | 120 | 152 | MHz |
| I_{RC120M} | Current consumption | | | 1.2 | | mA |
| $t_{STARTUP}$ | Startup time ⁽¹⁾ | $V_{VDDCORE} = 1.8V$ | | 3 | | μs |

- Note:
1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

7.6.6 32kHz RC Oscillator (RC32K) Characteristics

Table 7-16. 32kHz RC Oscillator Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---------------|---------------------------------|------------|-----|-----|-----|---------|
| f_{OUT} | Output frequency ⁽¹⁾ | | 20 | 32 | 44 | kHz |
| I_{RC32K} | Current consumption | | | 0.7 | | μA |
| $t_{STARTUP}$ | Startup time ⁽¹⁾ | | | 100 | | μs |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

7.6.7 System RC Oscillator (RCSYS) Characteristics

Table 7-17. System RC Oscillator Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|-----------|------------------|--------------------|-------|-----|-------|------|
| f_{OUT} | Output frequency | Calibrated at 85°C | 111.6 | 115 | 118.4 | kHz |

7.7 Flash Characteristics

Table 7-18 gives the device maximum operating frequency depending on the number of flash wait states and the flash read mode. The FSW bit in the FLASHCDW FSR register controls the number of wait states used when accessing the flash memory.

Table 7-18. Maximum Operating Frequency

| Flash Wait States | Read Mode | Maximum Operating Frequency |
|-------------------|----------------------|-----------------------------|
| 1 | High speed read mode | 50MHz |
| 0 | | 25MHz |
| 1 | Normal read mode | 30MHz |
| 0 | | 15MHz |

Table 7-19. Flash Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|-----------|-----------------------------------|-------------------------|-----|-----|-----|------|
| t_{FPP} | Page programming time | $f_{CLK_HSB} = 50MHz$ | | 5 | | ms |
| t_{FPE} | Page erase time | | | 5 | | |
| t_{FFP} | Fuse programming time | | | 1 | | |
| t_{FEA} | Full chip erase time (EA) | | | 6 | | |
| t_{FCE} | JTAG chip erase time (CHIP_ERASE) | $f_{CLK_HSB} = 115kHz$ | | 310 | | |

Table 7-20. Flash Endurance and Data Retention

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---------------------|---|------------|------|-----|-----|--------|
| N_{FARRAY} | Array endurance (write/page) | | 100k | | | cycles |
| N_{FFUSE} | General Purpose fuses endurance (write/bit) | | 10k | | | |
| t_{RET} | Data retention | | 15 | | | years |

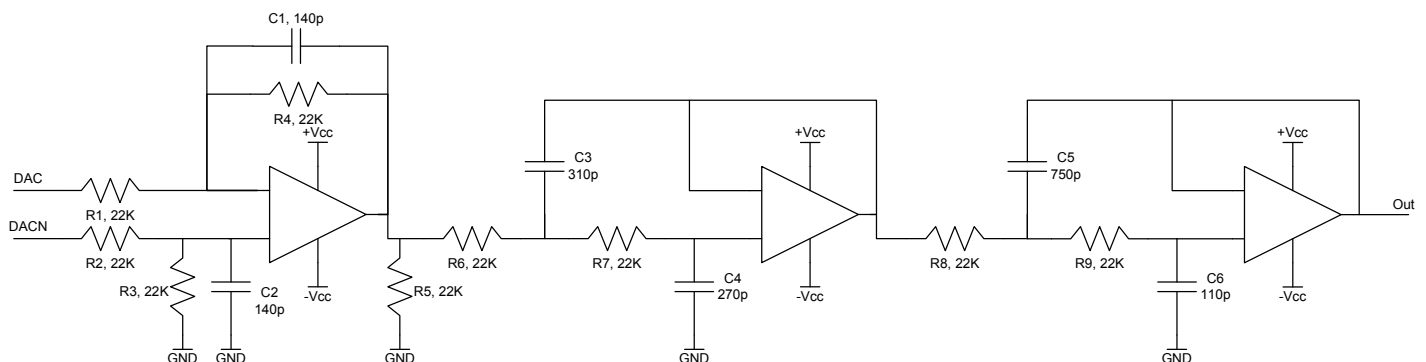
7.8 ABDACB Electrical Characteristics.

Table 7-21. ABDACB Electrical Characteristics

| Symbol | Parameter | Conditions | MIN | TYP | MAX | Unit |
|--------|------------------------------------|---|--------|--|-----|------|
| | Resolution | | | 16 | | Bits |
| | Dynamic range ⁽¹⁾⁽²⁾⁽³⁾ | $F_S = 48.000\text{kHz}$ | > 76 | | | dB |
| | SNR ⁽¹⁾⁽²⁾⁽³⁾ | $F_S = 48.000\text{kHz}$ | > 46 | | | dB |
| | THD ⁽¹⁾⁽²⁾⁽³⁾ | $F_S = 48.000\text{kHz}$ | < 0.02 | | | % |
| | PSRR | | | 0 | | dB |
| | V_{Out} maximum | CR.CMOC = 0 | | $97/128 * V_{\text{DDIO}}$ | | V |
| | V_{Out} minimum | CR.CMOC = 0 | | $31/128 * V_{\text{DDIO}}$ | | V |
| | Common mode | CR.CMOC = 0 CR.CMOC = 1, DAC_0 and DAC_1 pins CR.CMOC = 1, DACN_0 and DACN_1 pins | | $64/128 * V_{\text{DDIO}}$ $80/128 * V_{\text{DDIO}}$ $48/128 * V_{\text{DDIO}}$ | | V |

- Notes:
1. Test Condition: Common Mode Offset Control disabled (CR.CMOC = 0). Alternative Upsampling Ratio disabled (CR.ALTUPR = 0). Volume at maximum level (VCR0.VOLUME = 0x7FFF and VCR1.VOLUME = 0x7FFF). Device is battery powered (9V) through an LDO, VDDIO at 3.3V. Analog low pass filter as shown in [Figure 7-5](#)(1. order differential low pass filter followed by a 4. order low-pass), +VCC at +9V and -VCC at -9V. Test signal stored on a SD card and read by the SPI Interface.
 2. Performance numbers for dynamic range, SNR, and THD performance are very dependent on the application and circuit board design. Since the design has 0dB Power Supply Rejection Ratio (PSRR), noise on the IO power supply will couple directly through to the output and be present in the audio signal. To get the best performance one should reduce toggling of other IO pins as much as possible and make sure the device has sufficient decoupling on the IO supply pins.
 3. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

Figure 7-5. Differential Analog Low-pass Filter



7.9 Analog Characteristics

7.9.1 Voltage Regulator Characteristics

Table 7-22. VREG Electrical Characteristics

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|---------------|--|--|------|-----|-----|---------|
| V_{VDDIN} | Input voltage range | | 1.98 | 3.3 | 3.6 | V |
| $V_{VDDCORE}$ | Output voltage, calibrated value | $V_{VDDIN} \geq 1.98V$ | | 1.8 | | |
| | Output voltage accuracy ⁽¹⁾ | $I_{OUT} = 0.1mA \text{ to } 60mA,$ $V_{VDDIN} > 1.98V$ | | 2 | | % |
| | | $I_{OUT} = 0.1mA \text{ to } 60mA,$ $V_{VDDIN} < 1.98V$ | | 4 | | |
| I_{OUT} | DC output current ⁽¹⁾ | Normal mode | | | 60 | mA |
| | | Low power mode | | | 1 | |
| I_{VREG} | Static current of internal regulator | Normal mode | | 13 | | μA |
| | | Low power mode | | 4 | | |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

Table 7-23. Decoupling Requirements

| Symbol | Parameter | Condition | Typ | Techno. | Units |
|------------|------------------------------|-----------|-----|-------------------------------------|---------|
| C_{IN1} | Input regulator capacitor 1 | | 33 | | nF |
| C_{IN2} | Input regulator capacitor 2 | | 100 | | |
| C_{IN3} | Input regulator capacitor 3 | | 10 | | μF |
| C_{OUT1} | Output regulator capacitor 1 | | 100 | | nF |
| C_{OUT2} | Output regulator capacitor 2 | | 2.2 | Tantalum $0.5 < ESR < 10 \Omega$ | μF |

Note: 1. Refer to [Section 6.1.2 on page 39](#).

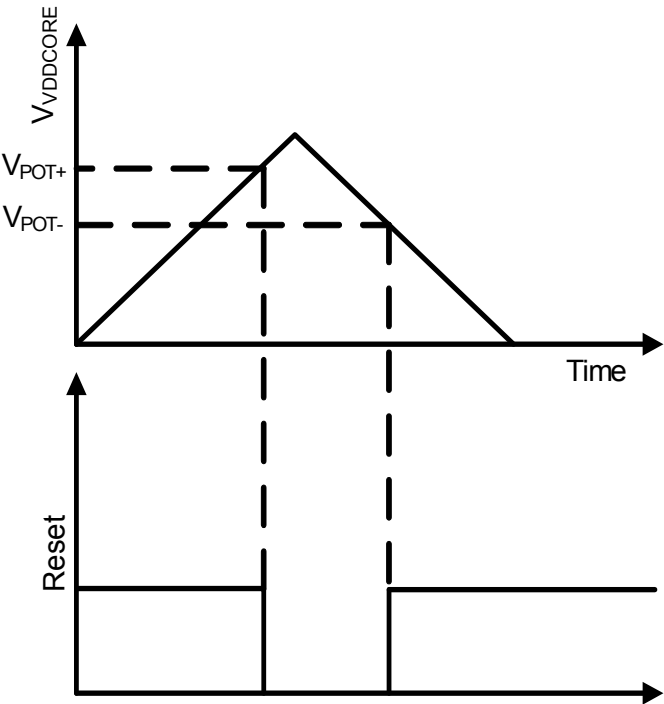
7.9.2 Power-on Reset 18 Characteristics

Table 7-24. POR18 Characteristics

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|---------------|---|--|-----|------|------|---------|
| V_{POT+} | Voltage threshold on V_{DDCORE} rising | | | 1.45 | 1.58 | V |
| V_{POT-} | Voltage threshold on V_{DDCORE} falling | | 1.2 | 1.32 | | |
| t_{DET} | Detection time ⁽¹⁾ | Time with $V_{DDCORE} < V_{POT-}$ necessary to generate a reset signal | | 460 | | μs |
| I_{POR18} | Current consumption | | | 4 | | μA |
| $t_{STARTUP}$ | Startup time ⁽¹⁾ | | | 6 | | μs |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

Figure 7-6. POR18 Operating Principle



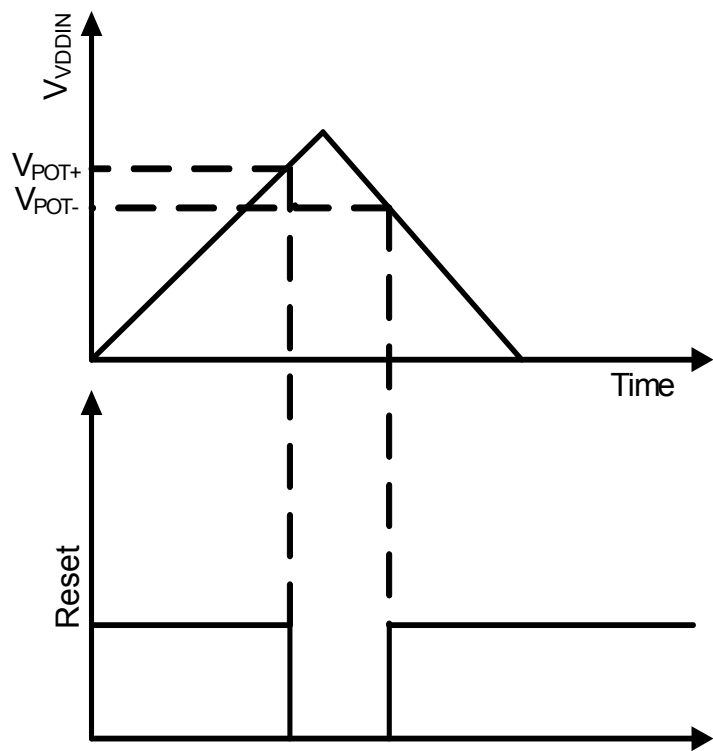
7.9.3 Power-on Reset 33 Characteristics

Table 7-25. POR33 Characteristics

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|---------------|---|--|-----|------|------|---------|
| V_{POT+} | Voltage threshold on V_{DDIN} rising | | | 1.49 | 1.58 | V |
| V_{POT-} | Voltage threshold on V_{DDIN} falling | | 1.3 | 1.45 | | |
| t_{DET} | Detection time ⁽¹⁾ | Time with $V_{DDIN} < V_{POT-}$ necessary to generate a reset signal | | 460 | | μs |
| I_{POR33} | Current consumption | | | 20 | | μA |
| $t_{STARTUP}$ | Startup time ⁽¹⁾ | | | 400 | | μs |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

Figure 7-7. POR33 Operating Principle



7.9.4 Brown Out Detector Characteristics

The values in [Table 7-26](#) describe the values of the BODLEVEL in the flash General Purpose Fuse register.

Table 7-26. BODLEVEL Values

| BODLEVEL Value | Min | Typ | Max | Units |
|-------------------------|-----|------|-----|-------|
| 011111 binary (31) 0x1F | | 1.60 | | V |
| 100111 binary (39) 0x27 | | 1.69 | | |

Table 7-27. BOD Characteristics

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|---------------|---------------------|---|-----|-----|-----|---------------|
| V_{HYST} | BOD hysteresis | $T = 25^{\circ}\text{C}$ | | 10 | | mV |
| t_{DET} | Detection time | Time with $V_{DDCORE} < \text{BODLEVEL}$ necessary to generate a reset signal | | 1 | | μs |
| I_{BOD} | Current consumption | | | 7 | | μA |
| $t_{STARTUP}$ | Startup time | | | 5 | | μs |

7.9.5 Supply Monitor 33 Characteristics

Table 7-28. SM33 Characteristics

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|---------------|--|--|-------|------|-------|---------------|
| V_{TH} | Voltage threshold | Calibrated ⁽¹⁾ , $T = 25^{\circ}\text{C}$ | 1.675 | 1.75 | 1.825 | V |
| | Step size, between adjacent values in SCIF.SM33.CALIB ⁽²⁾ | | | 11 | | mV |
| V_{HYST} | Hysteresis ⁽²⁾ | | | 30 | | |
| t_{DET} | Detection time | Time with $V_{DDIN} < V_{TH}$ necessary to generate a reset signal | | 280 | | μs |
| I_{SM33} | Current consumption | Normal mode | | 17 | | μA |
| $t_{STARTUP}$ | Startup time | Normal mode | | 140 | | μs |

- Notes:
1. Calibration value can be read from the SM33.CALIB field. This field is updated by the flash fuses after a reset. Refer to SCIF chapter for details.
 2. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

7.9.6 Analog to Digital Converter Characteristics

Table 7-29. ADC Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|----------------------|--|--|------|-----|------|---------------|
| f_{ADC} | ADC clock frequency | 12-bit resolution mode | | | 6 | MHz |
| | | 10-bit resolution mode | | | 6 | |
| | | 8-bit resolution mode | | | 6 | |
| t_{STARTUP} | Startup time | Return from Idle Mode | | 15 | | μs |
| t_{CONV} | Conversion time (latency) | $f_{\text{ADC}} = 6\text{MHz}$ | 11 | | 26 | cycles |
| | Throughput rate | $V_{\text{VDD}} > 3.0\text{V}$, $f_{\text{ADC}} = 6\text{MHz}$, 12-bit resolution mode, low impedance source | | | 28 | kSPS |
| | | $V_{\text{VDD}} > 3.0\text{V}$, $f_{\text{ADC}} = 6\text{MHz}$, 10-bit resolution mode, low impedance source | | | 460 | |
| | | $V_{\text{VDD}} > 3.0\text{V}$, $f_{\text{ADC}} = 6\text{MHz}$, 8-bit resolution mode, low impedance source | | | 460 | |
| V_{ADVREFP} | Reference voltage range | $V_{\text{ADVREFP}} = V_{\text{VDDANA}}$ | 1.62 | | 1.98 | V |
| I_{ADC} | Current consumption on V_{VDDANA} | ADC Clock = 6MHz | | 350 | | μA |
| I_{ADVREFP} | Current consumption on ADVREFP pin | $f_{\text{ADC}} = 6\text{MHz}$ | | 150 | | |

Note: These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

7.9.6.1 Inputs and Sample and Hold Acquisition Times

Table 7-30. Analog Inputs

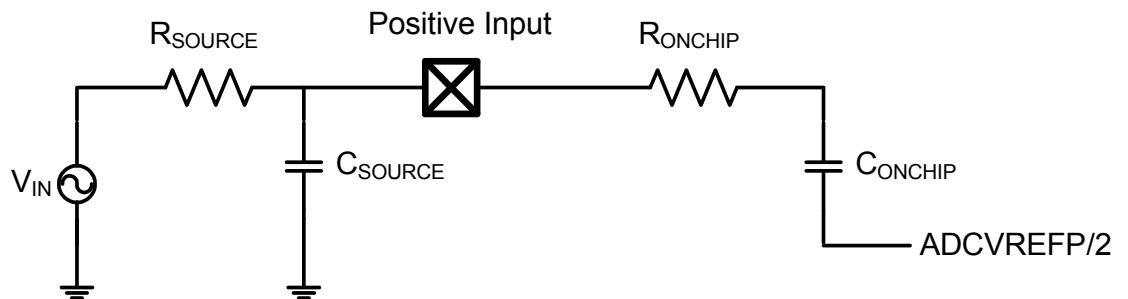
| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---------------------|-------------------------------------|--|-----|-----|----------------------|-------|
| V_{ADn} | Input Voltage Range | 12-bit mode | 0 | | V_{ADVREFP} | V |
| | | 10-bit mode | | | | |
| | | 8-bit mode | | | | |
| C_{ONCHIP} | Internal Capacitance ⁽¹⁾ | | | | 22.5 | pF |
| R_{ONCHIP} | Internal Resistance ⁽¹⁾ | $V_{\text{VDDIO}} = 3.0\text{V to } 3.6\text{V}$, $V_{\text{VDDCORE}} = 1.8\text{V}$ | | | 3.15 | kOhm |
| | | $V_{\text{VDDIO}} = V_{\text{VDDCORE}} = 1.62\text{V to } 1.98\text{V}$ | | | 55.9 | |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

The analog voltage source must be able to charge the sample and hold (S/H) capacitor in the ADC in order to achieve maximum accuracy. Seen externally the ADC input consists of a resistor (R_{ONCHIP}) and a capacitor (C_{ONCHIP}). In addition, the resistance (R_{SOURCE}) and capacitance

(C_{SOURCE}) of the PCB and source must be taken into account when calculating the required sample and hold time. Figure 7-8 shows the ADC input channel equivalent circuit.

Figure 7-8. ADC Input



The minimum sample and hold time (in ns) can be found using this formula:

$$t_{SAMPLEHOLD} \geq (R_{ONCHIP} + R_{SOURCE}) \times (C_{ONCHIP} + C_{SOURCE}) \times \ln(2^{n+1})$$

Where n is the number of bits in the conversion. $t_{SAMPLEHOLD}$ is defined by the SHTIM field in the ADCIFB ACR register. Please refer to the ADCIFB chapter for more information.

7.9.6.2 Applicable Conditions and Derating Data

Table 7-31. Transfer Characteristics 12-bit Resolution Mode⁽¹⁾

| Parameter | Conditions | Min | Typ | Max | Units |
|----------------------------|---|------|------|-----|-------|
| Resolution | | | 12 | | Bit |
| Integral non-linearity | ADC clock frequency = 6MHz, Input Voltage Range = 0 - $V_{ADVREFP}$ | | +/-4 | | LSB |
| | ADC clock frequency = 6MHz, Input Voltage Range = (10% $V_{ADVREFP}$) - (90% $V_{ADVREFP}$) | | +/-2 | | |
| Differential non-linearity | | -1.5 | | 1.5 | |
| Offset error | ADC clock frequency = 6MHz | | +/-3 | | |
| Gain error | | | +/-5 | | |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

Table 7-32. Transfer Characteristics, 10-bit Resolution Mode⁽¹⁾

| Parameter | Conditions | Min | Typ | Max | Units |
|----------------------------|----------------------------|------|------|-----|-------|
| Resolution | | | 10 | | Bit |
| Integral non-linearity | ADC clock frequency = 6MHz | | +/-1 | | LSB |
| Differential non-linearity | | -1.0 | | 1.0 | |
| Offset error | | | +/-1 | | |
| Gain error | | | +/-2 | | |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

Table 7-33. Transfer Characteristics, 8-bit Resolution Mode⁽¹⁾

| Parameter | Conditions | Min | Typ | Max | Units |
|----------------------------|----------------------------|------|--------|-----|-------|
| Resolution | | | 8 | | Bit |
| Integral non-linearity | ADC clock frequency = 6MHz | | +/-0.5 | | LSB |
| Differential non-linearity | | -0.3 | | 0.3 | |
| Offset error | | | +/-1 | | |
| Gain error | | | +/-1 | | |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

7.9.7 Temperature Sensor Characteristics

Table 7-34. Temperature Sensor Characteristics⁽¹⁾

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|----------------------|---------------------|-----------|-----|-----|-----|-------|
| | Gradient | | | 1 | | mV/°C |
| I _{TS} | Current consumption | | | 1 | | μA |
| t _{STARTUP} | Startup time | | | 0 | | μs |

Note: 1. The Temperature Sensor is not calibrated. The accuracy of the Temperature Sensor is governed by the ADC accuracy.

7.9.8 Analog Comparator Characteristics

Table 7-35. Analog Comparator Characteristics

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|---------------|---|--|------|--|-------------------|----------------------------|
| | Positive input voltage range ⁽³⁾ | | -0.2 | | $V_{VDDIO} + 0.3$ | V |
| | Negative input voltage range ⁽³⁾ | | -0.2 | | $V_{VDDIO} - 0.6$ | |
| | Statistical offset ⁽³⁾ | $V_{ACREFN} = 1.0V$, $f_{AC} = 12MHz$, filter length = 2, hysteresis = 0 ⁽¹⁾ | | 20 | | mV |
| f_{AC} | Clock frequency for GCLK4 ⁽³⁾ | | | | 12 | MHz |
| | Throughput rate ⁽³⁾ | $f_{AC} = 12MHz$ | | | 12 000 000 | Comparisons per second |
| | Propagation delay | Delay from input change to Interrupt Status Register Changes | | $\left(\left\lceil \frac{1}{t_{CLKACIFB} \times f_{AC}} \right\rceil + 3 \right) \times t_{CLKACIFB}$ | | ns |
| I_{AC} | Current consumption ⁽³⁾ | All channels, $V_{DDIO} = 3.3V$, $f_A = 3MHz$ | | 420 | | μA |
| $t_{STARTUP}$ | Startup time | | | 3 | | cycles |
| | Input current per pin ⁽³⁾ | | | 0.2 | | $\mu A/MHz$ ⁽²⁾ |

- Notes:
1. AC.CONFN.FLEN and AC.CONFN.HYS fields, refer to the Analog Comparator Interface chapter.
 2. Referring to f_{AC} .
 3. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

7.9.9 Capacitive Touch Characteristics

7.9.9.1 Discharge Current Source

Table 7-36. DICS Characteristics

| Symbol | Parameter | Min | Typ | Max | Unit |
|-----------|-------------------------------|-----|-----|-----|------|
| R_{REF} | Internal resistor | | 170 | | kOhm |
| k | Trim step size ⁽¹⁾ | | 0.7 | | % |

- Note:
1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

7.9.9.2 Strong Pull-up Pull-down

Table 7-37. Strong Pull-up Pull-down

| Parameter | Min | Typ | Max | Unit |
|--------------------|-----|-----|-----|------|
| Pull-down resistor | | 1 | | kOhm |
| Pull-up resistor | | 1 | | |

7.9.10 USB Transceiver Characteristics

The USB on-chip buffers comply with the Universal Serial Bus (USB) v2.0 standard. All AC parameters related to these buffers can be found within the USB 2.0 electrical specifications.

7.9.10.1 Electrical Characteristics

Table 7-38. Electrical Parameters

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|------------------|--|--|-----|-----|-----|------|
| R _{EXT} | Recommended external USB series resistor | In series with each USB pin with $\pm 5\%$ | | 39 | | Ohm |

7.10 Timing Characteristics

7.10.1 Startup, Reset, and Wake-up Timing

The startup, reset, and wake-up timings are calculated using the following formula:

$$t = t_{CONST} + N_{CPU} \times t_{CPU}$$

Where t_{CONST} and N_{CPU} are found in [Table 7-39](#). t_{CPU} is the period of the CPU clock. If a clock source other than RCSYS is selected as the CPU clock, the oscillator startup time, $t_{OSCSTART}$, must be added to the wake-up time from the stop, deepstop, and static sleep modes. Please refer to the source for the CPU clock in the ["Oscillator Characteristics" on page 53](#) for more details about oscillator startup times.

Table 7-39. Maximum Reset and Wake-up Timing⁽¹⁾

| Parameter | | Measuring | Max t_{CONST} (in μs) | Max N_{CPU} |
|---|----------|--|-------------------------------|---------------|
| Startup time from power-up, using regulator | | Time from VDDIN crossing the V_{POT+} threshold of POR33 to the first instruction entering the decode stage of CPU. VDDCORE is supplied by the internal regulator. | 2210 | 0 |
| Startup time from power-up, no regulator | | Time from VDDIN crossing the V_{POT+} threshold of POR33 to the first instruction entering the decode stage of CPU. VDDCORE is connected to VDDIN. | 1810 | 0 |
| Startup time from reset release | | Time from releasing a reset source (except POR18, POR33, and SM33) to the first instruction entering the decode stage of CPU. | 170 | 0 |
| Wake-up | Idle | From wake-up event to the first instruction of an interrupt routine entering the decode stage of the CPU. | 0 | 19 |
| | Frozen | | 0 | 110 |
| | Standby | | 0 | 110 |
| | Stop | | $27 + t_{OSCSTART}$ | 116 |
| | Deepstop | | $27 + t_{OSCSTART}$ | 116 |
| | Static | | $97 + t_{OSCSTART}$ | 116 |
| Wake-up from shutdown | | From wake-up event to the first instruction entering the decode stage of the CPU. | 1180 | 0 |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

7.10.2 RESET_N Timing

Table 7-40. RESET_N Waveform Parameters⁽¹⁾

| Symbol | Parameter | Conditions | Min | Max | Units |
|-------------|------------------------------|------------|-----|-----|-------|
| t_{RESET} | RESET_N minimum pulse length | | 10 | | ns |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

7.10.3 USART in SPI Mode Timing

7.10.3.1 Master mode

Figure 7-9. USART in SPI Master Mode with (CPOL= CPHA= 0) or (CPOL= CPHA= 1)

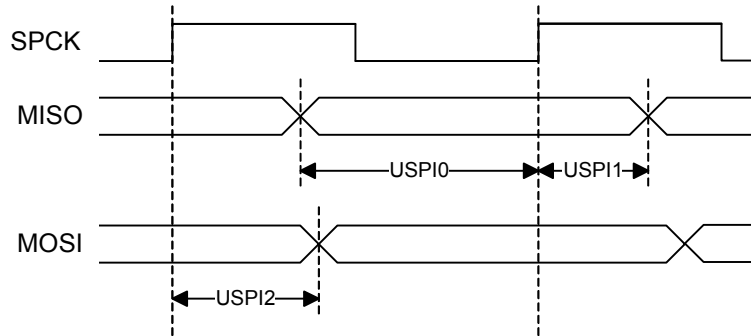


Figure 7-10. USART in SPI Master Mode with (CPOL= 0 and CPHA= 1) or (CPOL= 1 and CPHA= 0)

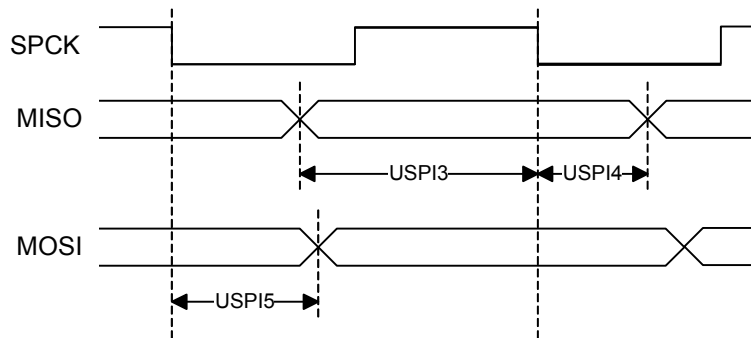


Table 7-41. USART in SPI Mode Timing, Master Mode⁽¹⁾

| Symbol | Parameter | Conditions | Min | Max | Units |
|--------|-----------------------------------|---|---------------------------|-------|-------|
| USPI0 | MISO setup time before SPCK rises | V_{DDIO} from 3.0V to 3.6V, maximum external capacitor = 40pF | $28.7 + t_{SAMPLE}^{(2)}$ | | ns |
| USPI1 | MISO hold time after SPCK rises | | 0 | | |
| USPI2 | SPCK rising to MOSI delay | | | 16.5 | |
| USPI3 | MISO setup time before SPCK falls | | $25.8 + t_{SAMPLE}^{(2)}$ | | |
| USPI4 | MISO hold time after SPCK falls | | 0 | | |
| USPI5 | SPCK falling to MOSI delay | | | 21.19 | |

Notes: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

2. Where: $t_{SAMPLE} = t_{SPCK} - \left(\left\lfloor \frac{t_{SPCK}}{2 \times t_{CLKUSART}} \right\rfloor \times t_{CLKUSART} \right)$

Maximum SPI Frequency, Master Output

The maximum SPI master output frequency is given by the following formula:

$$f_{SPCKMAX} = \min(f_{PINMAX}, \frac{1}{SPI_{in}}, \frac{f_{CLKSPI} \times 2}{9})$$

Where SPI_{in} is the MOSI delay, USPI2 or USPI5 depending on CPOL and NCPHA. f_{PINMAX} is the maximum frequency of the SPI pins. Please refer to the I/O Pin Characteristics section for the maximum frequency of the pins. f_{CLKSPI} is the maximum frequency of the CLK_SPI. Refer to the SPI chapter for a description of this clock.

Maximum SPI Frequency, Master Input

The maximum SPI master input frequency is given by the following formula:

$$f_{SPCKMAX} = \min(\frac{1}{SPI_{in} + t_{VALID}}, \frac{f_{CLKSPI} \times 2}{9})$$

Where SPI_{in} is the MISO setup and hold time, USPI0 + USPI1 or USPI3 + USPI4 depending on CPOL and NCPHA. t_{VALID} is the SPI slave response time. Please refer to the SPI slave datasheet for t_{VALID} . f_{CLKSPI} is the maximum frequency of the CLK_SPI. Refer to the SPI chapter for a description of this clock.

7.10.3.2 Slave mode

Figure 7-11. USART in SPI Slave Mode with (CPOL= 0 and CPHA= 1) or (CPOL= 1 and CPHA= 0)

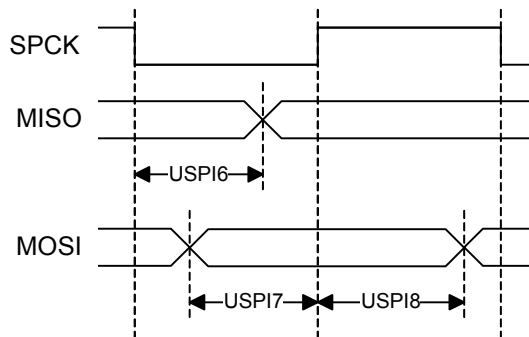


Figure 7-12. USART in SPI Slave Mode with (CPOL= CPHA= 0) or (CPOL= CPHA= 1)

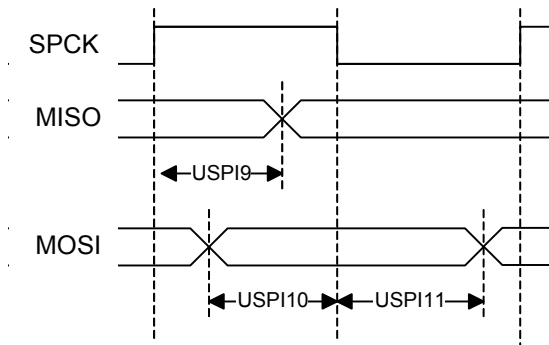


Figure 7-13. USART in SPI Slave Mode, NPCS Timing

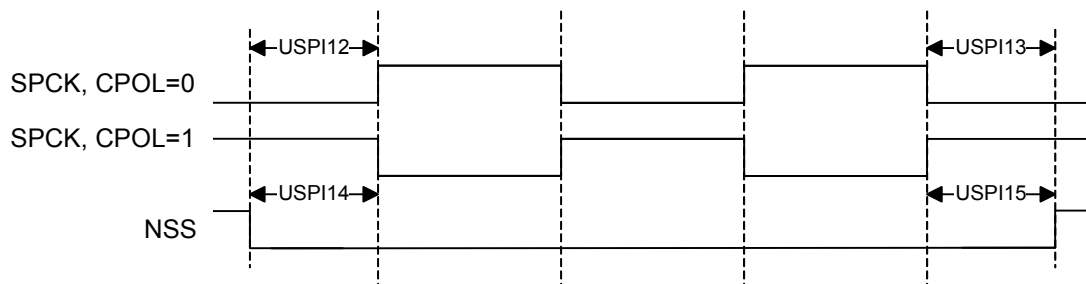


Table 7-42. USART in SPI mode Timing, Slave Mode⁽¹⁾

| Symbol | Parameter | Conditions | Min | Max | Units |
|--------|-----------------------------------|---|---|------|-------|
| USPI6 | SPCK falling to MISO delay | V_{DDIO} from 3.0V to 3.6V, maximum external capacitor = 40pF | | 37.3 | ns |
| USPI7 | MOSI setup time before SPCK rises | | $2.6 + t_{SAMPLE}^{(2)} + t_{CLK_USART}$ | | |
| USPI8 | MOSI hold time after SPCK rises | | 0 | | |
| USPI9 | SPCK rising to MISO delay | | | 37.0 | |
| USPI10 | MOSI setup time before SPCK falls | | $2.6 + t_{SAMPLE}^{(2)} + t_{CLK_USART}$ | | |
| USPI11 | MOSI hold time after SPCK falls | | 0 | | |
| USPI12 | NSS setup time before SPCK rises | | 27.2 | | |
| USPI13 | NSS hold time after SPCK falls | | 0 | | |
| USPI14 | NSS setup time before SPCK falls | | 27.2 | | |
| USPI15 | NSS hold time after SPCK rises | | 0 | | |

Notes: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

2. Where: $t_{SAMPLE} = t_{SPCK} - \left(\left\lceil \frac{t_{SPCK}}{2 \times t_{CLK_USART}} \right\rceil + \frac{1}{2} \right) \times t_{CLK_USART}$

Maximum SPI Frequency, Slave Input Mode

The maximum SPI slave input frequency is given by the following formula:

$$f_{SPCKMAX} = \text{MIN}\left(\frac{f_{CLKSPI} \times 2}{9}, \frac{1}{SPI_{In}}\right)$$

Where SPI_{In} is the MOSI setup and hold time, USPI7 + USPI8 or USPI10 + USPI11 depending on CPOL and NCPHA. f_{CLKSPI} is the maximum frequency of the CLK_SPI. Refer to the SPI chapter for a description of this clock.

Maximum SPI Frequency, Slave Output Mode

The maximum SPI slave output frequency is given by the following formula:

$$f_{SPCKMAX} = \text{MIN}\left(\frac{f_{CLKSPI} \times 2}{9}, f_{PINMAX} \frac{1}{SPI_{In} + t_{SETUP}}\right)$$

Where SPI_{In} is the MISO delay, USPI6 or USPI9 depending on CPOL and NCPHA. T_{SETUP} is the SPI master setup time. Please refer to the SPI master datasheet for $T_{SETUP} \cdot f_{CLKSPI}$ is the maximum frequency of the CLK_SPI. Refer to the SPI chapter for a description of this clock. f_{PINMAX} is the maximum frequency of the SPI pins. Please refer to the I/O Pin Characteristics section for the maximum frequency of the pins.

7.10.4 SPI Timing

7.10.4.1 Master mode

Figure 7-14. SPI Master Mode with (CPOL= NCPHA= 0) or (CPOL= NCPHA= 1)

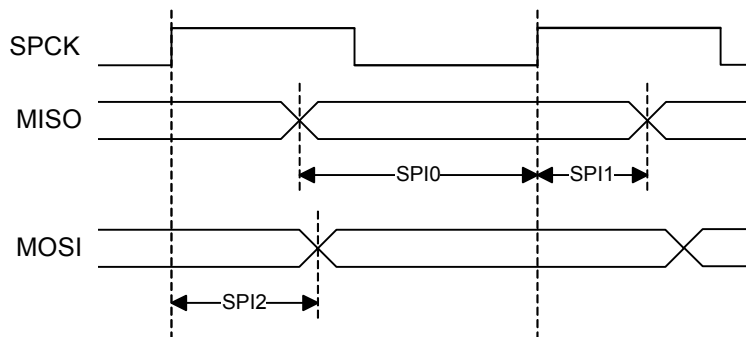


Figure 7-15. SPI Master Mode with (CPOL= 0 and NCPHA= 1) or (CPOL= 1 and NCPHA= 0)

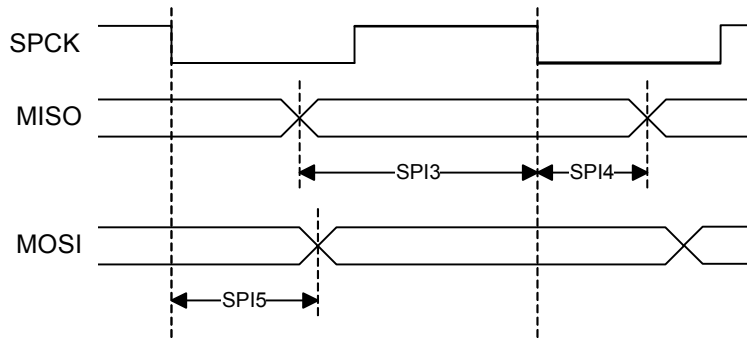


Table 7-43. SPI Timing, Master Mode⁽¹⁾

| Symbol | Parameter | Conditions | Min | Max | Units |
|--------|-----------------------------------|---|----------------------------------|------|-------|
| SPI0 | MISO setup time before SPCK rises | V _{VDDIO} from 3.0V to 3.6V, maximum external capacitor = 40pF | 33.4 + (t _{CLK_SPI})/2 | | ns |
| SPI1 | MISO hold time after SPCK rises | | 0 | | |
| SPI2 | SPCK rising to MOSI delay | | | 7.1 | |
| SPI3 | MISO setup time before SPCK falls | | 29.2 + (t _{CLK_SPI})/2 | | |
| SPI4 | MISO hold time after SPCK falls | | 0 | | |
| SPI5 | SPCK falling to MOSI delay | | | 8.63 | |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

Maximum SPI Frequency, Master Output

The maximum SPI master output frequency is given by the following formula:

$$f_{SPCKMAX} = \min(f_{PINMAX}, \frac{1}{SPI_n})$$

Where SPI_n is the MOSI delay, SPI2 or SPI5 depending on CPOL and NCPHA. f_{PINMAX} is the maximum frequency of the SPI pins. Please refer to the I/O Pin Characteristics section for the maximum frequency of the pins.

Maximum SPI Frequency, Master Input

The maximum SPI master input frequency is given by the following formula:

$$f_{SPCKMAX} = \frac{1}{SPI_n + t_{VALID}}$$

Where SPI_n is the MISO setup and hold time, SPI0 + SPI1 or SPI3 + SPI4 depending on CPOL and NCPHA. t_{VALID} is the SPI slave response time. Please refer to the SPI slave datasheet for t_{VALID} .

7.10.4.2 Slave mode

Figure 7-16. SPI Slave Mode with (CPOL= 0 and NCPHA= 1) or (CPOL= 1 and NCPHA= 0)

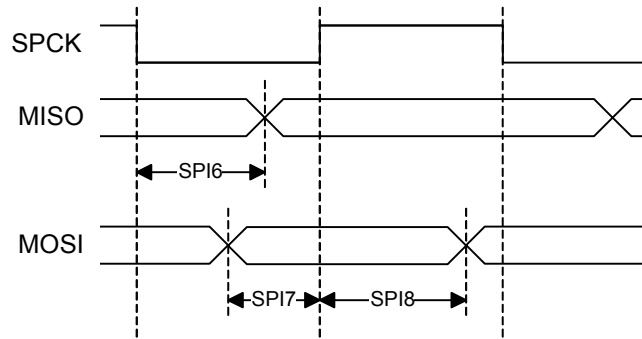


Figure 7-17. SPI Slave Mode with (CPOL= NCPHA= 0) or (CPOL= NCPHA= 1)

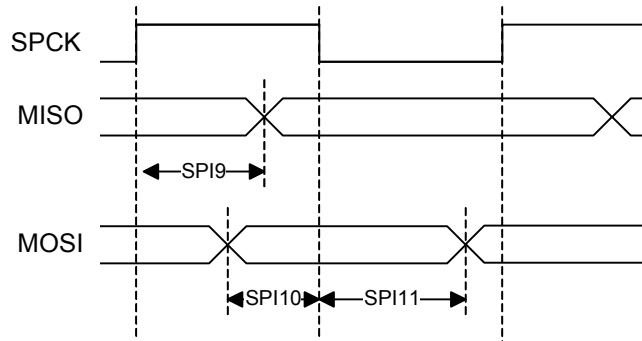


Figure 7-18. SPI Slave Mode, NPCS Timing

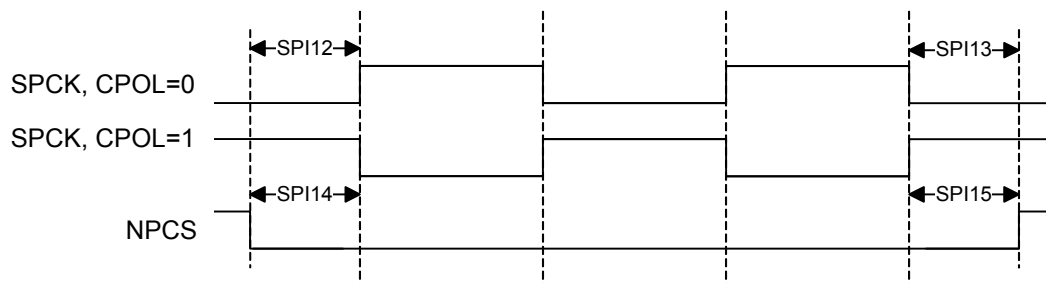


Table 7-44. SPI Timing, Slave Mode⁽¹⁾

| Symbol | Parameter | Conditions | Min | Max | Units |
|--------|-----------------------------------|---|-----|------|-------|
| SPI6 | SPCK falling to MISO delay | V_{DDIO} from 3.0V to 3.6V, maximum external capacitor = 40pF | | 29.4 | ns |
| SPI7 | MOSI setup time before SPCK rises | | 0 | | |
| SPI8 | MOSI hold time after SPCK rises | | 6.0 | | |
| SPI9 | SPCK rising to MISO delay | | | 29.0 | |
| SPI10 | MOSI setup time before SPCK falls | | 0 | | |
| SPI11 | MOSI hold time after SPCK falls | | 5.5 | | |
| SPI12 | NPCS setup time before SPCK rises | | 3.4 | | |
| SPI13 | NPCS hold time after SPCK falls | | 1.1 | | |
| SPI14 | NPCS setup time before SPCK falls | | 3.3 | | |
| SPI15 | NPCS hold time after SPCK rises | | 0.7 | | |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

Maximum SPI Frequency, Slave Input Mode

The maximum SPI slave input frequency is given by the following formula:

$$f_{SPCKMAX} = MIN(f_{CLKSPI}, \frac{1}{SPI_{In}})$$

Where SPI_{In} is the MOSI setup and hold time, SPI7 + SPI8 or SPI10 + SPI11 depending on CPOL and NCPHA. f_{CLKSPI} is the maximum frequency of the CLK_SPI. Refer to the SPI chapter for a description of this clock.

Maximum SPI Frequency, Slave Output Mode

The maximum SPI slave output frequency is given by the following formula:

$$f_{SPCKMAX} = MIN(f_{PINMAX}, \frac{1}{SPI_{In} + t_{SETUP}})$$

Where SPI_{In} is the MISO delay, SPI6 or SPI9 depending on CPOL and NCPHA. t_{SETUP} is the SPI master setup time. Please refer to the SPI master datasheet for $t_{SETUP} \cdot f_{PINMAX}$ is the maximum frequency of the SPI pins. Please refer to the I/O Pin Characteristics section for the maximum frequency of the pins.

7.10.5 TWIM/TWIS Timing

Figure 7-45 shows the TWI-bus timing requirements and the compliance of the device with them. Some of these requirements (t_r and t_f) are met by the device without requiring user intervention. Compliance with the other requirements (t_{HD-STA} , t_{SU-STA} , t_{SU-STO} , t_{HD-DAT} , $t_{SU-DAT-TWI}$, $t_{LOW-TWI}$, t_{HIGH} , and t_{TWCK}) requires user intervention through appropriate programming of the relevant

TWIM and TWIS user interface registers. Please refer to the TWIM and TWIS sections for more information.

Table 7-45. TWI-Bus Timing Requirements

| Symbol | Parameter | Mode | Minimum | | Maximum | | Unit |
|-------------------------|------------------------------|-------------------------|------------------------|---------------------|---------------------|---|------|
| | | | Requirement | Device | Requirement | Device | |
| t _r | TWCK and TWD rise time | Standard ⁽¹⁾ | - | | 1000 | | ns |
| | | Fast ⁽¹⁾ | 20 + 0.1C _b | | 300 | | |
| t _f | TWCK and TWD fall time | Standard | - | | 300 | | ns |
| | | Fast | 20 + 0.1C _b | | 300 | | |
| t _{HD-STA} | (Repeated) START hold time | Standard | 4 | t _{clkpb} | - | | μs |
| | | Fast | 0.6 | | | | |
| t _{SU-STA} | (Repeated) START set-up time | Standard | 4.7 | t _{clkpb} | - | | μs |
| | | Fast | 0.6 | | | | |
| t _{SU-STO} | STOP set-up time | Standard | 4.0 | 4t _{clkpb} | - | | μs |
| | | Fast | 0.6 | | | | |
| t _{HD-DAT} | Data hold time | Standard | 0.3 ⁽²⁾ | 2t _{clkpb} | 3.45 ⁽¹⁾ | 15t _{prescaled} + t _{clkpb} | μs |
| | | Fast | | | 0.9 ⁽¹⁾ | | |
| t _{SU-DAT-TWI} | Data set-up time | Standard | 250 | 2t _{clkpb} | - | | ns |
| | | Fast | 100 | | | | |
| t _{SU-DAT} | | - | - | t _{clkpb} | - | | - |
| t _{LOW-TWI} | TWCK LOW period | Standard | 4.7 | 4t _{clkpb} | - | | μs |
| | | Fast | 1.3 | | | | |
| t _{LOW} | | - | - | t _{clkpb} | - | | - |
| t _{HIGH} | TWCK HIGH period | Standard | 4.0 | 8t _{clkpb} | - | | μs |
| | | Fast | 0.6 | | | | |
| f _{TWCK} | TWCK frequency | Standard | - | | 100 | $\frac{1}{12t_{clkpb}}$ | kHz |
| | | Fast | | | 400 | | |

- Notes: 1. Standard mode: $f_{TWCK} \leq 100$ kHz ; fast mode: $f_{TWCK} > 100$ kHz .
2. A device must internally provide a hold time of at least 300 ns for TWD with reference to the falling edge of TWCK.

Notations:

C_b = total capacitance of one bus line in pF

t_{clkpb} = period of TWI peripheral bus clock

$t_{prescaled}$ = period of TWI internal prescaled clock (see chapters on TWIM and TWIS)

The maximum $t_{HD;DAT}$ has only to be met if the device does not stretch the LOW period ($t_{LOW-TWI}$) of TWCK.

7.10.6 JTAG Timing

Figure 7-19. JTAG Interface Signals

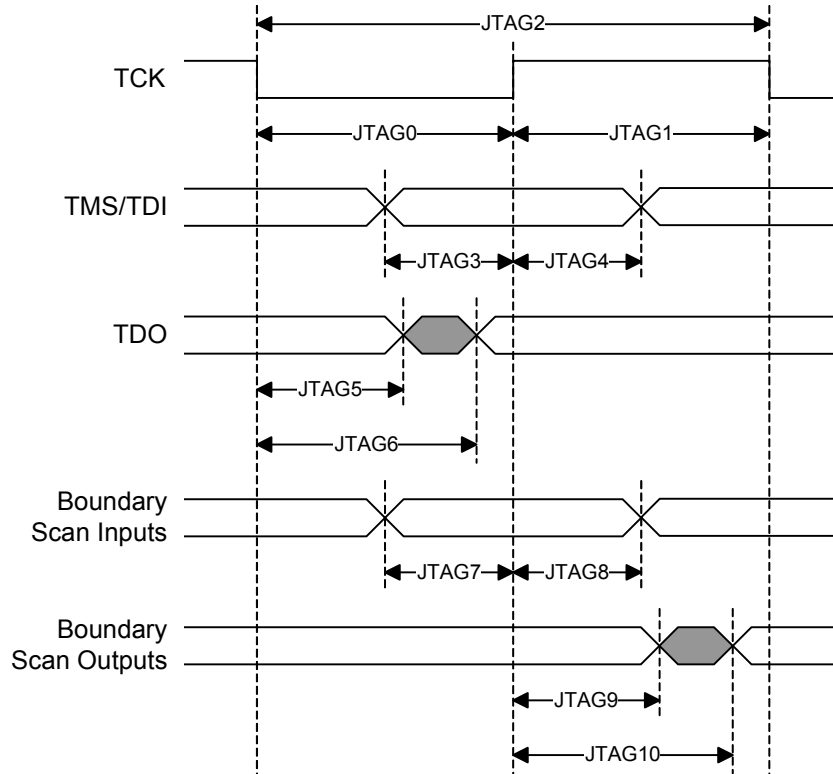


Table 7-46. JTAG Timings⁽¹⁾

| Symbol | Parameter | Conditions | Min | Max | Units |
|--------|------------------------------------|---|------|------|-------|
| JTAG0 | TCK Low Half-period | V_{DDIO} from 3.0V to 3.6V, maximum external capacitor = 40pF | 21.8 | | ns |
| JTAG1 | TCK High Half-period | | 8.6 | | |
| JTAG2 | TCK Period | | 30.3 | | |
| JTAG3 | TDI, TMS Setup before TCK High | | 2.0 | | |
| JTAG4 | TDI, TMS Hold after TCK High | | 2.3 | | |
| JTAG5 | TDO Hold Time | | 9.5 | | |
| JTAG6 | TCK Low to TDO Valid | | | 21.8 | |
| JTAG7 | Boundary Scan Inputs Setup Time | | 0.6 | | |
| JTAG8 | Boundary Scan Inputs Hold Time | | 6.9 | | |
| JTAG9 | Boundary Scan Outputs Hold Time | | 9.3 | | |
| JTAG10 | TCK to Boundary Scan Outputs Valid | | | 32.2 | |

Note: 1. These values are based on simulation and characterization of other AVR microcontrollers manufactured in the same process technology. These values are not covered by test limits in production.

8. Mechanical Characteristics

8.1 Thermal Considerations

8.1.1 Thermal Data

Table 8-1 summarizes the thermal resistance data depending on the package.

Table 8-1. Thermal Resistance Data

| Symbol | Parameter | Condition | Package | Typ | Unit |
|---------------|--|-----------|---------|------|------|
| θ_{JA} | Junction-to-ambient thermal resistance | Still Air | TQFP48 | 54.4 | °C/W |
| θ_{JC} | Junction-to-case thermal resistance | | TQFP48 | 15.7 | |
| θ_{JA} | Junction-to-ambient thermal resistance | Still Air | QFN48 | 26.0 | °C/W |
| θ_{JC} | Junction-to-case thermal resistance | | QFN48 | 1.6 | |
| θ_{JA} | Junction-to-ambient thermal resistance | Still Air | TLLGA48 | 25.4 | °C/W |
| θ_{JC} | Junction-to-case thermal resistance | | TLLGA48 | 12.7 | |
| θ_{JA} | Junction-to-ambient thermal resistance | Still Air | TQFP64 | 52.9 | °C/W |
| θ_{JC} | Junction-to-case thermal resistance | | TQFP64 | 15.5 | |
| θ_{JA} | Junction-to-ambient thermal resistance | Still Air | QFN64 | 22.9 | °C/W |
| θ_{JC} | Junction-to-case thermal resistance | | QFN64 | 1.6 | |

8.1.2 Junction Temperature

The average chip-junction temperature, T_J , in °C can be obtained from the following:

1. $T_J = T_A + (P_D \times \theta_{JA})$
2. $T_J = T_A + (P_D \times (\theta_{HEATSINK} + \theta_{JC}))$

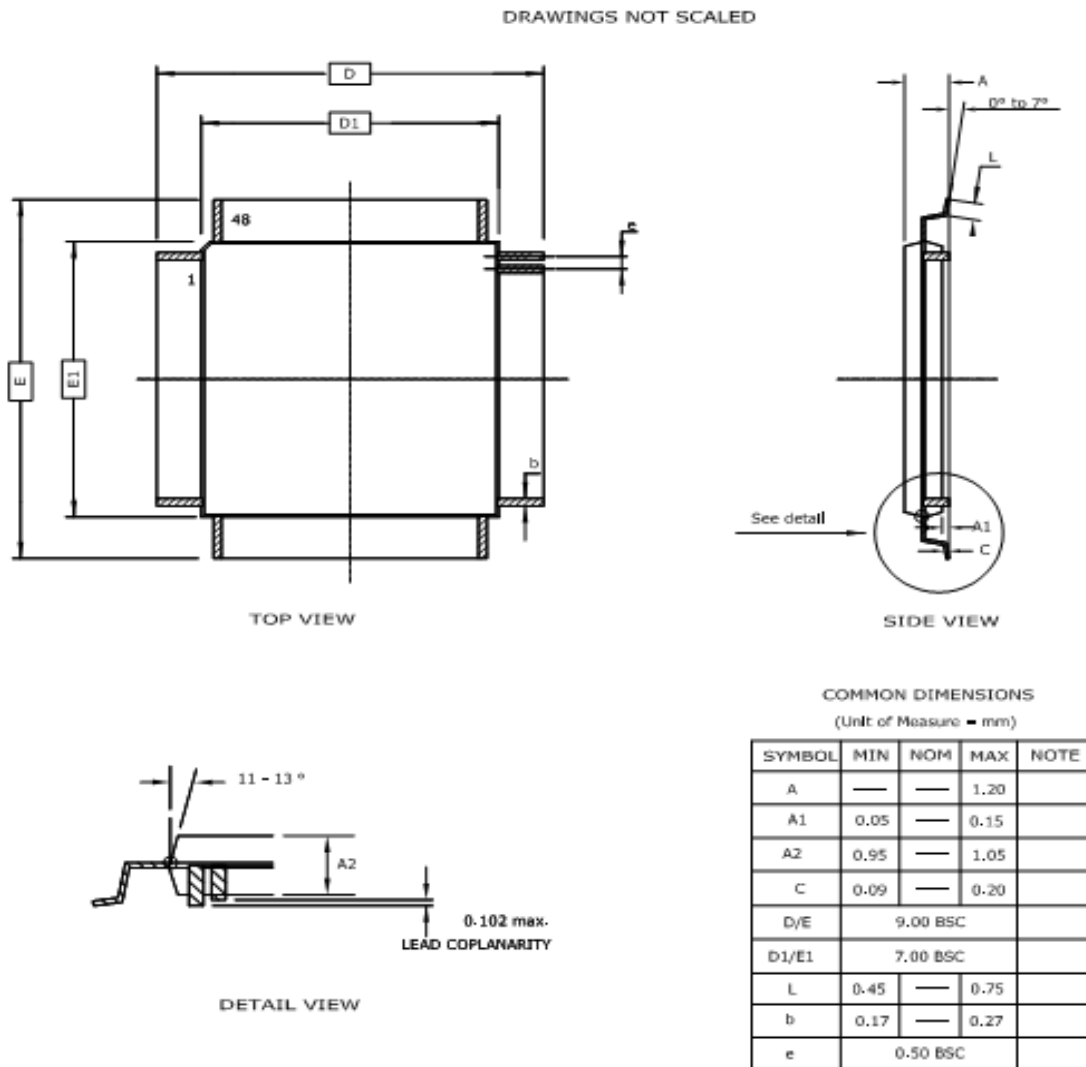
where:

- θ_{JA} = package thermal resistance, Junction-to-ambient (°C/W), provided in Table 8-1.
- θ_{JC} = package thermal resistance, Junction-to-case thermal resistance (°C/W), provided in Table 8-1.
- $\theta_{HEAT SINK}$ = cooling device thermal resistance (°C/W), provided in the device datasheet.
- P_D = device power consumption (W) estimated from data provided in Section 7.4 on page 46.
- T_A = ambient temperature (°C).

From the first equation, the user can derive the estimated lifetime of the chip and decide if a cooling device is necessary or not. If a cooling device is to be fitted on the chip, the second equation should be used to compute the resulting average chip-junction temperature T_J in °C.

8.2 Package Drawings

Figure 8-1. TQFP-48 Package Drawing



- Notes : 1. This drawing is for general information only. Refer to JEDEC Drawing MS-026, Variation ABC.
 2. Dimensions D1 and E1 do not include mold protrusion. Allowable protrusion is 0.25mm per side. Dimensions D1 and E1 are maximum plastic body size dimensions including mold mismatch.
 3. Lead coplanarity is 0.10mm maximum.

10/04/2011

Table 8-2. Device and Package Maximum Weight

| | |
|-----|----|
| 140 | mg |
|-----|----|

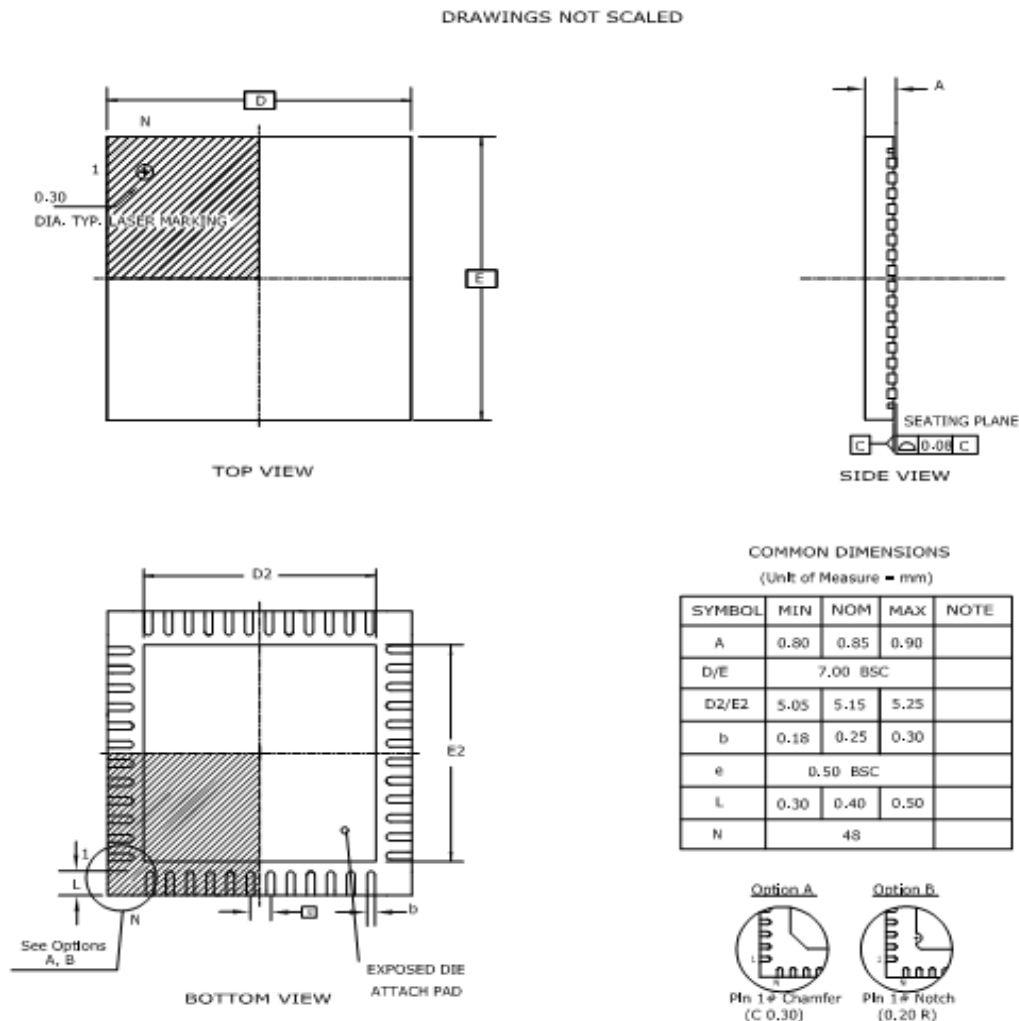
Table 8-3. Package Characteristics

| | |
|----------------------------|------|
| Moisture Sensitivity Level | MSL3 |
|----------------------------|------|

Table 8-4. Package Reference

| | |
|-------------------------|--------|
| JEDEC Drawing Reference | MS-026 |
| JESD97 Classification | E3 |

Figure 8-2. QFN-48 Package Drawing



Notes : 1. This drawing is for general information only. Refer to JEDEC Drawing MO-220, Variation VKKD-4, for proper dimensions, tolerances, datums, etc.
2. Dimension b applies to metallized terminal and is measured between 0.15mm and 0.30mm from the terminal tip.
If the terminal has the optical radius on the other end of the terminal, the dimension should not be measured in that radius area.

07/27/2011

Note: The exposed pad is not connected to anything internally, but should be soldered to ground to increase board level reliability.

Table 8-5. Device and Package Maximum Weight

| | |
|-----|----|
| 140 | mg |
|-----|----|

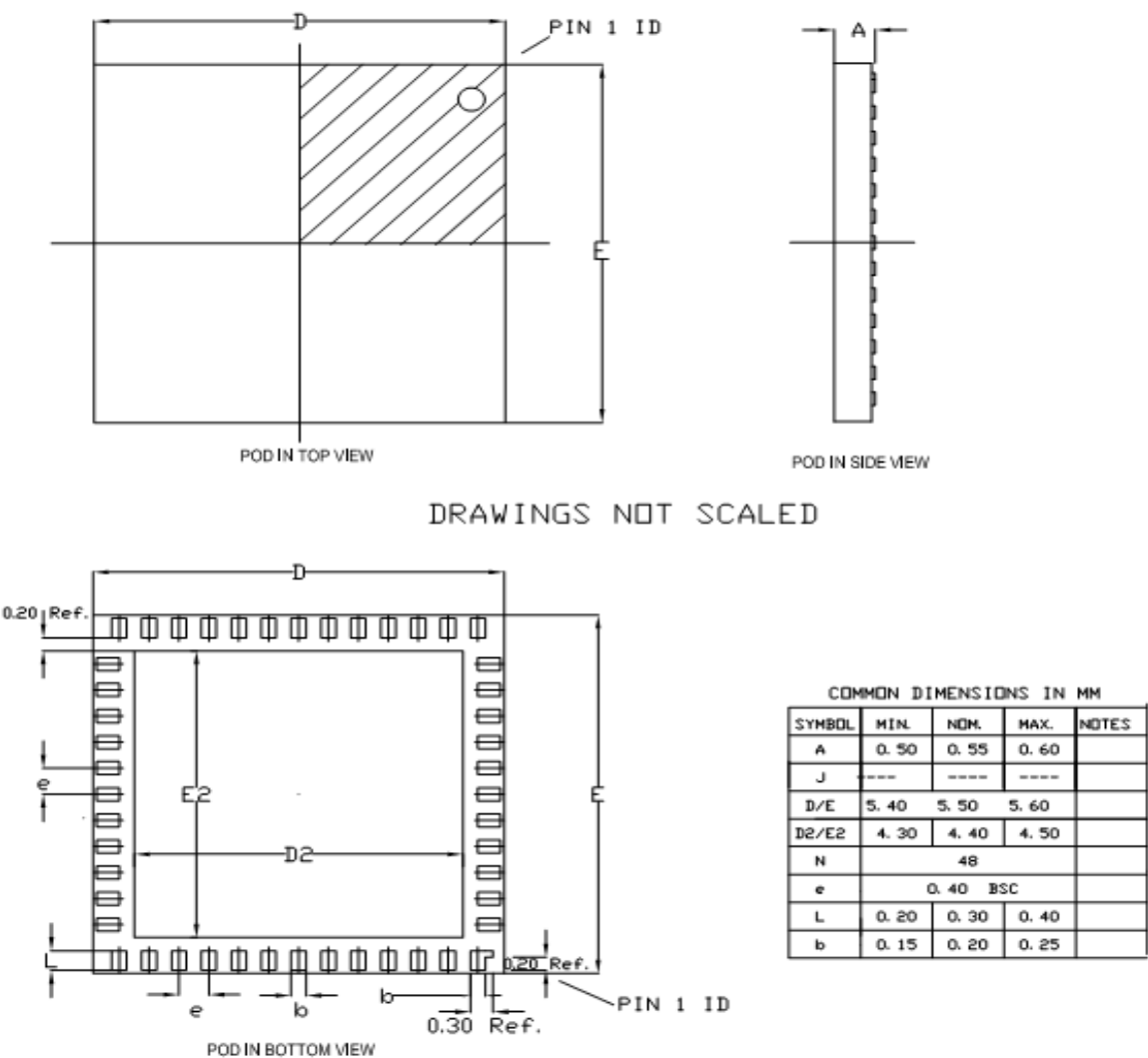
Table 8-6. Package Characteristics

| | |
|----------------------------|------|
| Moisture Sensitivity Level | MSL3 |
|----------------------------|------|

Table 8-7. Package Reference

| | |
|-------------------------|--------|
| JEDEC Drawing Reference | M0-220 |
| JESD97 Classification | E3 |

Figure 8-3. TLLGA-48 Package Drawing



19/05/08

Table 8-8. Device and Package Maximum Weight

| | |
|------|----|
| 39.3 | mg |
|------|----|

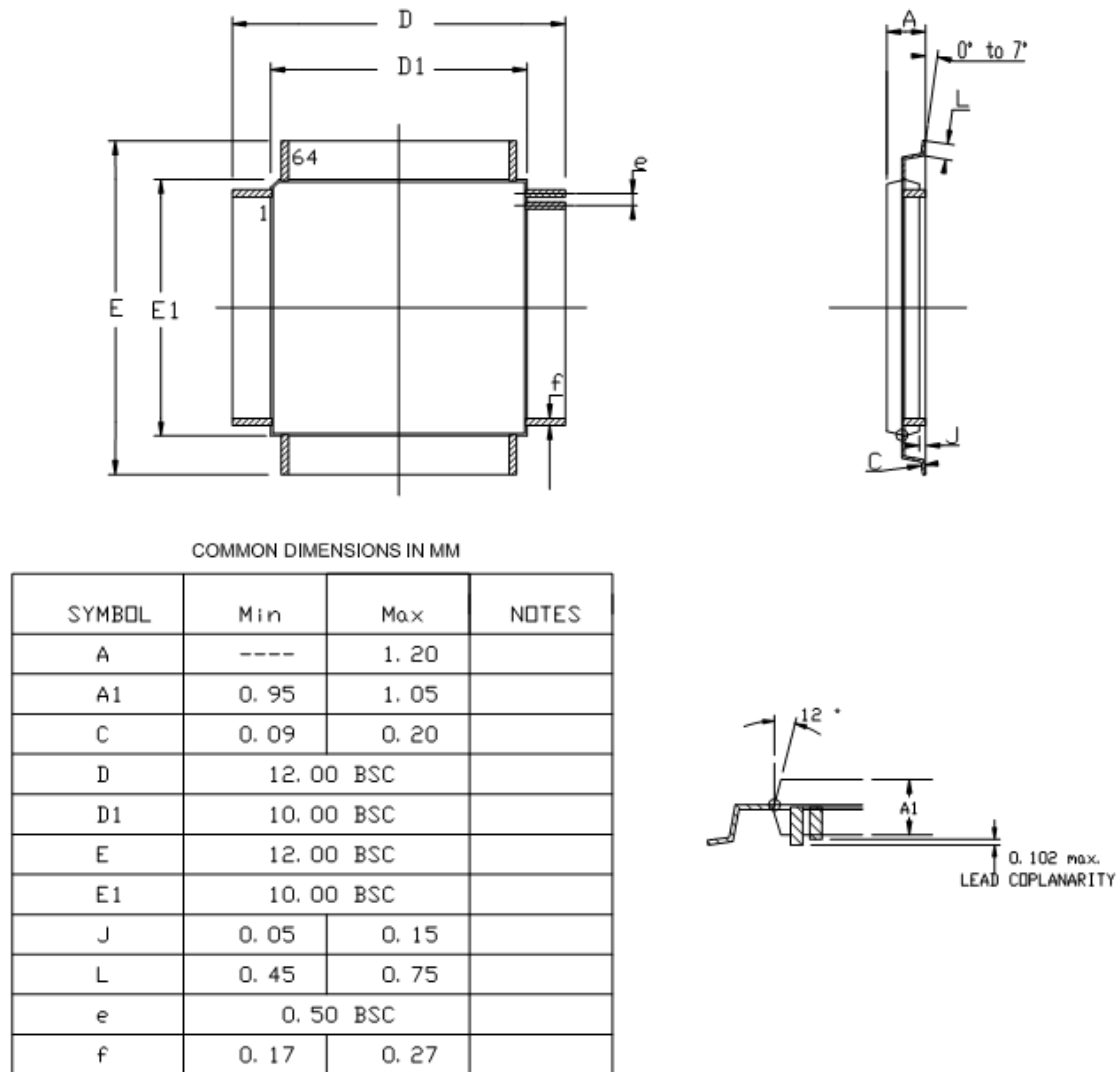
Table 8-9. Package Characteristics

| | |
|----------------------------|------|
| Moisture Sensitivity Level | MSL3 |
|----------------------------|------|

Table 8-10. Package Reference

| | |
|-------------------------|-----|
| JEDEC Drawing Reference | N/A |
| JESD97 Classification | E4 |

Figure 8-4. TQFP-64 Package Drawing



04/07/2010

Table 8-11. Device and Package Maximum Weight

| | |
|-----|----|
| 300 | mg |
|-----|----|

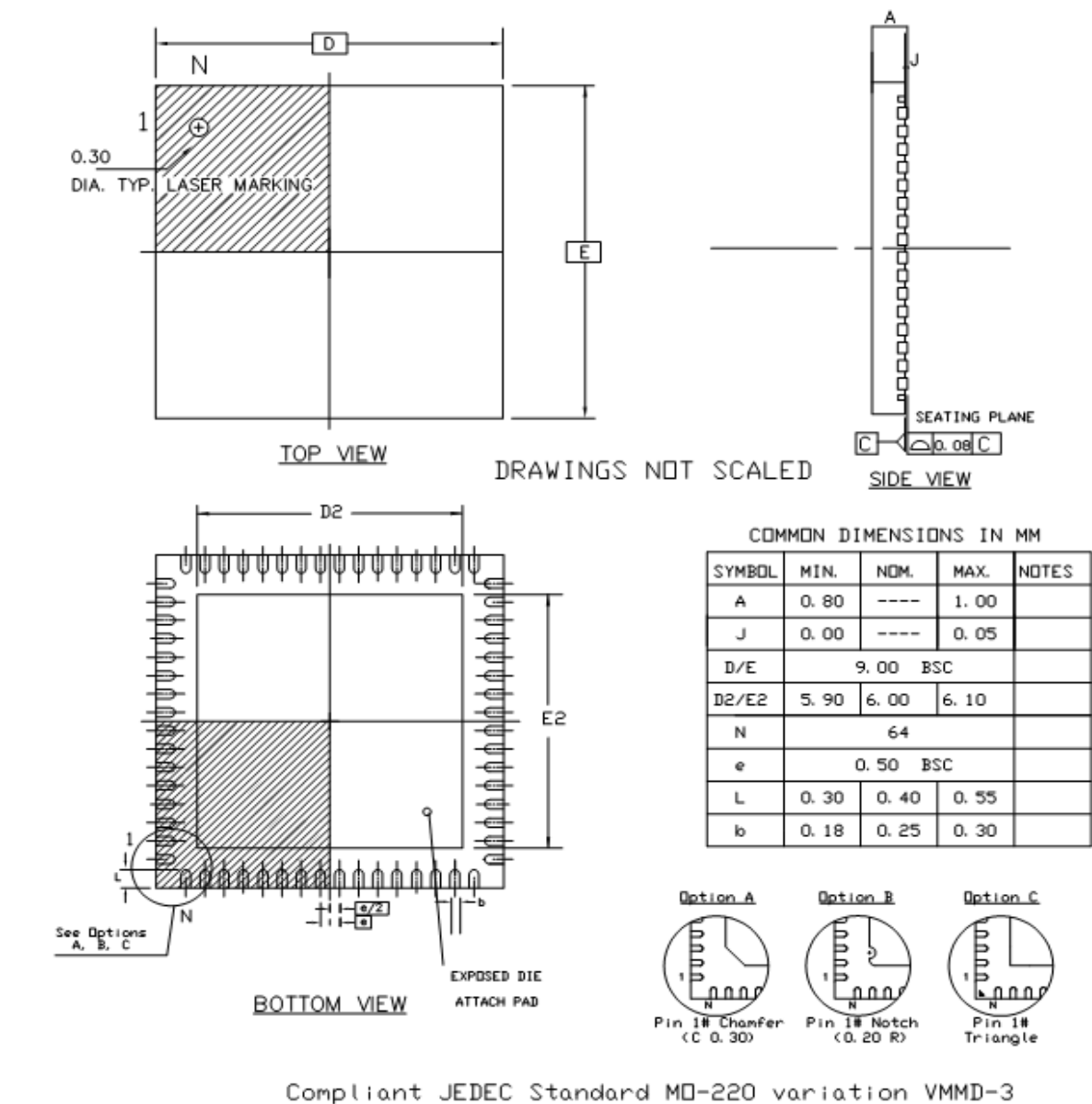
Table 8-12. Package Characteristics

| | |
|----------------------------|------|
| Moisture Sensitivity Level | MSL3 |
|----------------------------|------|

Table 8-13. Package Reference

| | |
|-------------------------|--------|
| JEDEC Drawing Reference | MS-026 |
| JESD97 Classification | E3 |

Figure 8-5. QFN-64 Package Drawing



28/11/2008

Note: The exposed pad is not connected to anything internally, but should be soldered to ground to increase board level reliability.

Table 8-14. Device and Package Maximum Weight

| | |
|-----|----|
| 200 | mg |
|-----|----|

Table 8-15. Package Characteristics

| | |
|----------------------------|------|
| Moisture Sensitivity Level | MSL3 |
|----------------------------|------|

Table 8-16. Package Reference

| | |
|-------------------------|--------|
| JEDEC Drawing Reference | MO-220 |
| JESD97 Classification | E3 |

8.3 Soldering Profile

Table 8-17 gives the recommended soldering profile from J-STD-20.

Table 8-17. Soldering Profile

| Profile Feature | Green Package |
|--|---------------|
| Average Ramp-up Rate (217°C to Peak) | 3°C/s max |
| Preheat Temperature 175°C ±25°C | 150-200°C |
| Time Maintained Above 217°C | 60-150 s |
| Time within 5°C of Actual Peak Temperature | 30 s |
| Peak Temperature Range | 260°C |
| Ramp-down Rate | 6°C/s max |
| Time 25°C to Peak Temperature | 8 minutes max |

A maximum of three reflow passes is allowed per component.

9. Ordering Information

Table 9-1. Ordering Information

| Device | Ordering Code | Carrier Type | Package | Package Type | Temperature Operating Range |
|------------|-------------------|--------------|---------|--------------------------|-----------------------------|
| ATUC256L3U | ATUC256L3U-AUTES | ES | TQFP 64 | JESD97 Classification E3 | N/A |
| | ATUC256L3U-AUT | Tray | | | Industrial (-40°C to 85°C) |
| | ATUC256L3U-AUR | Tape & Reel | | | |
| | ATUC256L3U-Z3UTES | ES | N/A | | |
| | ATUC256L3U-Z3UT | Tray | | | Industrial (-40°C to 85°C) |
| | ATUC256L3U-Z3UR | Tape & Reel | | | |
| ATUC128L3U | ATUC128L3U-AUT | Tray | TQFP 64 | JESD97 Classification E3 | |
| | ATUC128L3U-AUR | Tape & Reel | | | |
| | ATUC128L3U-Z3UT | Tray | QFN 64 | | |
| | ATUC128L3U-Z3UR | Tape & Reel | | | |
| ATUC64L3U | ATUC64L3U-AUT | Tray | TQFP 64 | JESD97 Classification E3 | Industrial (-40°C to 85°C) |
| | ATUC64L3U-AUR | Tape & Reel | | | |
| | ATUC64L3U-Z3UT | Tray | QFN 64 | | |
| | ATUC64L3U-Z3UR | Tape & Reel | | | |

Table 9-1. Ordering Information

| Device | Ordering Code | Carrier Type | Package | Package Type | Temperature Operating Range |
|------------|-------------------|--------------|----------|--------------------------|-----------------------------|
| ATUC256L4U | ATUC256L4U-AUTES | ES | TQFP 48 | JESD97 Classification E3 | N/A |
| | ATUC256L4U-AUT | Tray | | | Industrial (-40°C to 85°C) |
| | ATUC256L4U-AUR | Tape & Reel | | | |
| | ATUC256L4U-ZAUTES | ES | QFN 48 | | |
| | ATUC256L4U-ZAUT | Tray | | | Industrial (-40°C to 85°C) |
| | ATUC256L4U-ZAUR | Tape & Reel | | | |
| | ATUC256L4U-D3HES | ES | TLLGA 48 | JESD97 Classification E4 | |
| | ATUC256L4U-D3HT | Tray | | | |
| | ATUC256L4U-D3HR | Tape & Reel | | | |
| ATUC128L4U | ATUC128L4U-AUT | Tray | TQFP 48 | JESD97 Classification E3 | Industrial (-40°C to 85°C) |
| | ATUC128L4U-AUR | Tape & Reel | | | |
| | ATUC128L4U-ZAUT | Tray | QFN 48 | | |
| | ATUC128L4U-ZAUR | Tape & Reel | | | |
| | ATUC128L4U-D3HT | Tray | TLLGA 48 | JESD97 Classification E4 | |
| | ATUC128L4U-D3HR | Tape & Reel | | | |
| ATUC64L4U | ATUC64L4U-AUT | Tray | TQFP 48 | JESD97 Classification E3 | |
| | ATUC64L4U-AUR | Tape & Reel | | | |
| | ATUC64L4U-ZAUT | Tray | QFN 48 | | |
| | ATUC64L4U-ZAUR | Tape & Reel | | | |
| | ATUC64L4U-D3HT | Tray | TLLGA 48 | JESD97 Classification E4 | |
| | ATUC64L4U-D3HR | Tape & Reel | | | |

10. Errata

10.1 Rev. C

10.1.1 SCIF

1. The RC32K output on PA20 is not always permanently disabled

The RC32K output on PA20 may sometimes re-appear.

Fix/Workaround

Before using RC32K for other purposes, the following procedure has to be followed in order to properly disable it:

- Run the CPU on RCSYS
- Disable the output to PA20 by writing a zero to PM.PPCR.RC32OUT
- Enable RC32K by writing a one to SCIF.RC32KCR.EN, and wait for this bit to be read as one
- Disable RC32K by writing a zero to SCIF.RC32KCR.EN, and wait for this bit to be read as zero.

2. PLLCOUNT value larger than zero can cause PLEN glitch

Initializing the PLLCOUNT with a value greater than zero creates a glitch on the PLEN signal during asynchronous wake up.

Fix/Workaround

The lock-masking mechanism for the PLL should not be used.

The PLLCOUNT field of the PLL Control Register should always be written to zero.

3. Writing 0x5A5A5A5A to the SCIF memory range will enable the SCIF UNLOCK feature

The SCIF UNLOCK feature will be enabled if the value 0x5A5A5A5A is written to any location in the SCIF memory range.

Fix/Workaround

None.

10.1.2 SPI

1. SPI data transfer hangs with CSR0.CSAAT==1 and MR.MODFDIS==0

When CSR0.CSAAT==1 and mode fault detection is enabled (MR.MODFDIS==0), the SPI module will not start a data transfer.

Fix/Workaround

Disable mode fault detection by writing a one to MR.MODFDIS.

2. Disabling SPI has no effect on the SR.TDRE bit

Disabling SPI has no effect on the SR.TDRE bit whereas the write data command is filtered when SPI is disabled. Writing to TDR when SPI is disabled will not clear SR.TDRE. If SPI is disabled during a PDCA transfer, the PDCA will continue to write data to TDR until its buffer is empty, and this data will be lost.

Fix/Workaround

Disable the PDCA, add two NOPs, and disable the SPI. To continue the transfer, enable the SPI and PDCA.

3. SPI disable does not work in SLAVE mode

SPI disable does not work in SLAVE mode.

Fix/Workaround

Read the last received data, then perform a software reset by writing a one to the Software Reset bit in the Control Register (CR.SWRST).

4. **SPI bad serial clock generation on 2nd chip_select when SCBR=1, CPOL=1, and NCPHA=0**

When multiple chip selects (CS) are in use, if one of the baudrates equal 1 while one (CSRn.SCBR=1) of the others do not equal 1, and CSRn.CPOL=1 and CSRn.NCPHA=0, then an additional pulse will be generated on SCK.

Fix/Workaround

When multiple CS are in use, if one of the baudrates equals 1, the others must also equal 1 if CSRn.CPOL=1 and CSRn.NCPHA=0.

5. **SPI mode fault detection enable causes incorrect behavior**

When mode fault detection is enabled (MR.MODFDIS==0), the SPI module may not operate properly.

Fix/Workaround

Always disable mode fault detection before using the SPI by writing a one to MR.MODFDIS.

6. **SPI RDR.PCS is not correct**

The PCS (Peripheral Chip Select) field in the SPI RDR (Receive Data Register) does not correctly indicate the value on the NPCS pins at the end of a transfer.

Fix/Workaround

Do not use the PCS field of the SPI RDR.

10.1.3 TWI

1. **SMBALERT bit may be set after reset**

The SMBus Alert (SMBALERT) bit in the Status Register (SR) might be erroneously set after system reset.

Fix/Workaround

After system reset, clear the SR.SMBALERT bit before commencing any TWI transfer.

2. **Clearing the NAK bit before the BTF bit is set locks up the TWI bus**

When the TWIS is in transmit mode, clearing the NAK Received (NAK) bit of the Status Register (SR) before the end of the Acknowledge/Not Acknowledge cycle will cause the TWIS to attempt to continue transmitting data, thus locking up the bus.

Fix/Workaround

Clear SR.NAK only after the Byte Transfer Finished (BTF) bit of the same register has been set.

10.1.4 TC

1. **Channel chaining skips first pulse for upper channel**

When chaining two channels using the Block Mode Register, the first pulse of the clock between the channels is skipped.

Fix/Workaround

Configure the lower channel with RA = 0x1 and RC = 0x2 to produce a dummy clock cycle for the upper channel. After the dummy cycle has been generated, indicated by the SR.CPCS bit, reconfigure the RA and RC registers for the lower channel with the real values.

10.1.5 CAT

1. **CAT QMatrix sense capacitors discharged prematurely**

At the end of a QMatrix burst charging sequence that uses different burst count values for different Y lines, the Y lines may be incorrectly grounded for up to n-1 periods of the periph-

eral bus clock, where n is the ratio of the PB clock frequency to the GCLK_CAT frequency. This results in premature loss of charge from the sense capacitors and thus increased variability of the acquired count values.

Fix/Workaround

Enable the 1 kOhm drive resistors on all implemented QMatrix Y lines (CSA 1, 3, 5, 7, 9, 11, 13, and/or 15) by writing ones to the corresponding odd bits of the CSARES register.

2. Autonomous CAT acquisition must be longer than AST source clock period

When using the AST to trigger CAT autonomous touch acquisition in sleep modes where the CAT bus clock is turned off, the CAT will start several acquisitions if the period of the AST source clock is larger than one CAT acquisition. One AST clock period after the AST trigger, the CAT clock will automatically stop and the CAT acquisition can be stopped prematurely, ruining the result.

Fix/Workaround

Always ensure that the ATCFG1.max field is set so that the duration of the autonomous touch acquisition is greater than one clock period of the AST source clock.

10.1.6 aWire

1. aWire MEMORY_SPEED_REQUEST command does not return correct CV

The aWire MEMORY_SPEED_REQUEST command does not return a CV corresponding to the formula in the aWire Debug Interface chapter.

Fix/Workaround

Issue a dummy read to address 0x100000000 before issuing the MEMORY_SPEED_REQUEST command and use this formula instead:

$$f_{sab} = \frac{7f_{aw}}{CV-3}$$

10.2 Rev. B

10.2.1 SCIF

1. The RC32K output on PA20 is not always permanently disabled

The RC32K output on PA20 may sometimes re-appear.

Fix/Workaround

Before using RC32K for other purposes, the following procedure has to be followed in order to properly disable it:

- Run the CPU on RCSYS
- Disable the output to PA20 by writing a zero to PM.PPCR.RC32OUT
- Enable RC32K by writing a one to SCIF.RC32KCR.EN, and wait for this bit to be read as one
- Disable RC32K by writing a zero to SCIF.RC32KCR.EN, and wait for this bit to be read as zero.

2. PLLCOUNT value larger than zero can cause PLEN glitch

Initializing the PLLCOUNT with a value greater than zero creates a glitch on the PLEN signal during asynchronous wake up.

Fix/Workaround

The lock-masking mechanism for the PLL should not be used.

The PLLCOUNT field of the PLL Control Register should always be written to zero.

3. Writing 0x5A5A5A5A to the SCIF memory range will enable the SCIF UNLOCK feature

The SCIF UNLOCK feature will be enabled if the value 0x5A5A5A5A is written to any location in the SCIF memory range.

Fix/Workaround

None.

10.2.2 WDT

1. WDT Control Register does not have synchronization feedback

When writing to the Timeout Prescale Select (PSEL), Time Ban Prescale Select (TBAN), Enable (EN), or WDT Mode (MODE) fields of the WDT Control Register (CTRL), a synchronizer is started to propagate the values to the WDT clock domain. This synchronization takes a finite amount of time, but only the status of the synchronization of the EN bit is reflected back to the user. Writing to the synchronized fields during synchronization can lead to undefined behavior.

Fix/Workaround

-When writing to the affected fields, the user must ensure a wait corresponding to 2 clock cycles of both the WDT peripheral bus clock and the selected WDT clock source.

-When doing writes that changes the EN bit, the EN bit can be read back until it reflects the written value.

10.2.3 SPI

1. SPI data transfer hangs with CSR0.CSAAT==1 and MR.MODFDIS==0

When CSR0.CSAAT==1 and mode fault detection is enabled (MR.MODFDIS==0), the SPI module will not start a data transfer.

Fix/Workaround

Disable mode fault detection by writing a one to MR.MODFDIS.

2. Disabling SPI has no effect on the SR.TDRE bit

Disabling SPI has no effect on the SR.TDRE bit whereas the write data command is filtered when SPI is disabled. Writing to TDR when SPI is disabled will not clear SR.TDRE. If SPI is disabled during a PDCA transfer, the PDCA will continue to write data to TDR until its buffer is empty, and this data will be lost.

Fix/Workaround

Disable the PDCA, add two NOPs, and disable the SPI. To continue the transfer, enable the SPI and PDCA.

3. SPI disable does not work in SLAVE mode

SPI disable does not work in SLAVE mode.

Fix/Workaround

Read the last received data, then perform a software reset by writing a one to the Software Reset bit in the Control Register (CR.SWRST).

4. SPI bad serial clock generation on 2nd chip_select when SCBR=1, CPOL=1, and NCPHA=0

When multiple chip selects (CS) are in use, if one of the baudrates equal 1 while one (CSRn.SCBR=1) of the others do not equal 1, and CSRn.CPOL=1 and CSRn.NCPHA=0, then an additional pulse will be generated on SCK.

Fix/Workaround

When multiple CS are in use, if one of the baudrates equals 1, the others must also equal 1 if CSRn.CPOL=1 and CSRn.NCPHA=0.

5. SPI mode fault detection enable causes incorrect behavior

When mode fault detection is enabled (MR.MODFDIS==0), the SPI module may not operate

properly.

Fix/Workaround

Always disable mode fault detection before using the SPI by writing a one to MR.MODFDIS.

6. SPI RDR.PCS is not correct

The PCS (Peripheral Chip Select) field in the SPI RDR (Receive Data Register) does not correctly indicate the value on the NPCS pins at the end of a transfer.

Fix/Workaround

Do not use the PCS field of the SPI RDR.

10.2.4 TWI

1. TWIS may not wake the device from sleep mode

If the CPU is put to a sleep mode (except Idle and Frozen) directly after a TWI Start condition, the CPU may not wake upon a TWIS address match. The request is NACKed.

Fix/Workaround

When using the TWI address match to wake the device from sleep, do not switch to sleep modes deeper than Frozen. Another solution is to enable asynchronous EIC wake on the TWIS clock (TWCK) or TWIS data (TWD) pins, in order to wake the system up on bus events.

2. SMBALERT bit may be set after reset

The SMBus Alert (SMBALERT) bit in the Status Register (SR) might be erroneously set after system reset.

Fix/Workaround

After system reset, clear the SR.SMBALERT bit before commencing any TWI transfer.

3. Clearing the NAK bit before the BTF bit is set locks up the TWI bus

When the TWIS is in transmit mode, clearing the NAK Received (NAK) bit of the Status Register (SR) before the end of the Acknowledge/Not Acknowledge cycle will cause the TWIS to attempt to continue transmitting data, thus locking up the bus.

Fix/Workaround

Clear SR.NAK only after the Byte Transfer Finished (BTF) bit of the same register has been set.

10.2.5 PWMA

1. The SR.READY bit cannot be cleared by writing to SCR.READY

The Ready bit in the Status Register will not be cleared when writing a one to the corresponding bit in the Status Clear register. The Ready bit will be cleared when the Busy bit is set.

Fix/Workaround

Disable the Ready interrupt in the interrupt handler when receiving the interrupt. When an operation that triggers the Busy/Ready bit is started, wait until the ready bit is low in the Status Register before enabling the interrupt.

10.2.6 TC

1. Channel chaining skips first pulse for upper channel

When chaining two channels using the Block Mode Register, the first pulse of the clock between the channels is skipped.

Fix/Workaround

Configure the lower channel with RA = 0x1 and RC = 0x2 to produce a dummy clock cycle for the upper channel. After the dummy cycle has been generated, indicated by the SR.CPCS bit, reconfigure the RA and RC registers for the lower channel with the real values.

10.2.7 CAT

1. CAT QMatrix sense capacitors discharged prematurely

At the end of a QMatrix burst charging sequence that uses different burst count values for different Y lines, the Y lines may be incorrectly grounded for up to n-1 periods of the peripheral bus clock, where n is the ratio of the PB clock frequency to the GCLK_CAT frequency. This results in premature loss of charge from the sense capacitors and thus increased variability of the acquired count values.

Fix/Workaround

Enable the 1 kOhm drive resistors on all implemented QMatrix Y lines (CSA 1, 3, 5, 7, 9, 11, 13, and/or 15) by writing ones to the corresponding odd bits of the CSARES register.

2. Autonomous CAT acquisition must be longer than AST source clock period

When using the AST to trigger CAT autonomous touch acquisition in sleep modes where the CAT bus clock is turned off, the CAT will start several acquisitions if the period of the AST source clock is larger than one CAT acquisition. One AST clock period after the AST trigger, the CAT clock will automatically stop and the CAT acquisition can be stopped prematurely, ruining the result.

Fix/Workaround

Always ensure that the ATCFG1.max field is set so that the duration of the autonomous touch acquisition is greater than one clock period of the AST source clock.

3. CAT consumes unnecessary power when disabled or when autonomous touch not used

A CAT prescaler controlled by the ATCFG0.DIV field will be active even when the CAT module is disabled or when the autonomous touch feature is not used, thereby causing unnecessary power consumption.

Fix/Workaround

If the CAT module is not used, disable the CLK_CAT clock in the PM module. If the CAT module is used but the autonomous touch feature is not used, the power consumption of the CAT module may be reduced by writing 0xFFFF to the ATCFG0.DIV field.

10.2.8 aWire

1. aWire MEMORY_SPEED_REQUEST command does not return correct CV

The aWire MEMORY_SPEED_REQUEST command does not return a CV corresponding to the formula in the aWire Debug Interface chapter.

Fix/Workaround

Issue a dummy read to address 0x100000000 before issuing the MEMORY_SPEED_REQUEST command and use this formula instead:

$$f_{sab} = \frac{7f_{aw}}{CV-3}$$

10.3 Rev. A

10.3.1 Device

1. **JTAGID is wrong**
The JTAGID reads 0x021DF03F for all devices.
Fix/Workaround
None.

10.3.2 FLASHCDW

1. **General-purpose fuse programming does not work**
The general-purpose fuses cannot be programmed and are stuck at 1. Please refer to the Fuse Settings chapter in the FLASHCDW for more information about what functions are affected.
Fix/Workaround
None.
2. **Set Security Bit command does not work**
The Set Security Bit (SSB) command of the FLASHCDW does not work. The device cannot be locked from external JTAG, aWire, or other debug accesses.
Fix/Workaround
None.
3. **Flash programming time is longer than specified**
The flash programming time is now:

Table 10-1. Flash Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|------------------|-----------------------------------|-------------------------------|-----|-----|-----|------|
| T _{FPP} | Page programming time | f _{CLK_HSB} = 50MHz | | 7.5 | | ms |
| T _{FPE} | Page erase time | | | 7.5 | | |
| T _{FFP} | Fuse programming time | | | 1 | | |
| T _{FEA} | Full chip erase time (EA) | | | 9 | | |
| T _{FCE} | JTAG chip erase time (CHIP_ERASE) | f _{CLK_HSB} = 115kHz | | 250 | | |

Fix/Workaround
None.

10.3.3 Power Manager

1. **Clock Failure Detector (CFD) can be issued while turning off the CFD**
While turning off the CFD, the CFD bit in the Status Register (SR) can be set. This will change the main clock source to RCSYS.
Fix/Workaround
Solution 1: Enable CFD interrupt. If CFD interrupt is issues after turning off the CFD, switch back to original main clock source.
Solution 2: Only turn off the CFD while running the main clock on RCSYS.
2. **Sleepwalking in idle and frozen sleep mode will mask all other PB clocks**

If the CPU is in idle or frozen sleep mode and a module is in a state that triggers sleep walking, all PB clocks will be masked except the PB clock to the sleepwalking module.

Fix/Workaround

Mask all clock requests in the PM.PPCR register before going into idle or frozen mode.

2. Unused PB clocks are running

Three unused PBA clocks are enabled by default and will cause increased active power consumption.

Fix/Workaround

Disable the clocks by writing zeroes to bits [27:25] in the PBA clock mask register.

10.3.4 SCIF

1. The RC32K output on PA20 is not always permanently disabled

The RC32K output on PA20 may sometimes re-appear.

Fix/Workaround

Before using RC32K for other purposes, the following procedure has to be followed in order to properly disable it:

- Run the CPU on RCSYS
- Disable the output to PA20 by writing a zero to PM.PPCR.RC32OUT
- Enable RC32K by writing a one to SCIF.RC32KCR.EN, and wait for this bit to be read as one
- Disable RC32K by writing a zero to SCIF.RC32KCR.EN, and wait for this bit to be read as zero.

2. PLL lock might not clear after disable

Under certain circumstances, the lock signal from the Phase Locked Loop (PLL) oscillator may not go back to zero after the PLL oscillator has been disabled. This can cause the propagation of clock signals with the wrong frequency to parts of the system that use the PLL clock.

Fix/Workaround

PLL must be turned off before entering STOP, DEEPSTOP or STATIC sleep modes. If PLL has been turned off, a delay of 30us must be observed after the PLL has been enabled again before the SCIF.PLL0LOCK bit can be used as a valid indication that the PLL is locked.

3. PLLCOUNT value larger than zero can cause PLEN glitch

Initializing the PLLCOUNT with a value greater than zero creates a glitch on the PLEN signal during asynchronous wake up.

Fix/Workaround

The lock-masking mechanism for the PLL should not be used.

The PLLCOUNT field of the PLL Control Register should always be written to zero.

4. RCSYS is not calibrated

The RCSYS is not calibrated and will run faster than 115.2kHz. Frequencies around 150kHz can be expected.

Fix/Workaround

If a known clock source is available the RCSYS can be runtime calibrated by using the frequency meter (FREQM) and tuning the RCSYS by writing to the RCCR register in SCIF.

5. Writing 0x5A5A5A5A to the SCIF memory range will enable the SCIF UNLOCK feature

The SCIF UNLOCK feature will be enabled if the value 0x5A5A5A5A is written to any location in the SCIF memory range.

Fix/Workaround

None.

10.3.5 WDT

1. Clearing the Watchdog Timer (WDT) counter in second half of timeout period will issue a Watchdog reset

If the WDT counter is cleared in the second half of the timeout period, the WDT will immediately issue a Watchdog reset.

Fix/Workaround

Use twice as long timeout period as needed and clear the WDT counter within the first half of the timeout period. If the WDT counter is cleared after the first half of the timeout period, you will get a Watchdog reset immediately. If the WDT counter is not cleared at all, the time before the reset will be twice as long as needed.

2. WDT Control Register does not have synchronization feedback

When writing to the Timeout Prescale Select (PSEL), Time Ban Prescale Select (TBAN), Enable (EN), or WDT Mode (MODE) fields of the WDT Control Register (CTRL), a synchronizer is started to propagate the values to the WDT clock domain. This synchronization takes a finite amount of time, but only the status of the synchronization of the EN bit is reflected back to the user. Writing to the synchronized fields during synchronization can lead to undefined behavior.

Fix/Workaround

-When writing to the affected fields, the user must ensure a wait corresponding to 2 clock cycles of both the WDT peripheral bus clock and the selected WDT clock source.

-When doing writes that changes the EN bit, the EN bit can be read back until it reflects the written value.

10.3.6 GPIO

1. Clearing Interrupt flags can mask other interrupts

When clearing interrupt flags in a GPIO port, interrupts on other pins of that port, happening in the same clock cycle will not be registered.

Fix/Workaround

Read the PVR register of the port before and after clearing the interrupt to see if any pin change has happened while clearing the interrupt. If any change occurred in the PVR between the reads, they must be treated as an interrupt.

10.3.7 SPI

1. SPI data transfer hangs with CSR0.CSAAT==1 and MR.MODFDIS==0

When CSR0.CSAAT==1 and mode fault detection is enabled (MR.MODFDIS==0), the SPI module will not start a data transfer.

Fix/Workaround

Disable mode fault detection by writing a one to MR.MODFDIS.

2. Disabling SPI has no effect on the SR.TDRE bit

Disabling SPI has no effect on the SR.TDRE bit whereas the write data command is filtered when SPI is disabled. Writing to TDR when SPI is disabled will not clear SR.TDRE. If SPI is disabled during a PDCA transfer, the PDCA will continue to write data to TDR until its buffer is empty, and this data will be lost.

Fix/Workaround

Disable the PDCA, add two NOPs, and disable the SPI. To continue the transfer, enable the SPI and PDCA.

3. SPI disable does not work in SLAVE mode

SPI disable does not work in SLAVE mode.

Fix/Workaround

Read the last received data, then perform a software reset by writing a one to the Software Reset bit in the Control Register (CR.SWRST).

4. SPI bad serial clock generation on 2nd chip_select when SCBR=1, CPOL=1, and NCPHA=0

When multiple chip selects (CS) are in use, if one of the baudrates equal 1 while one (CSRn.SCBR=1) of the others do not equal 1, and CSRn.CPOL=1 and CSRn.NCPHA=0, then an additional pulse will be generated on SCK.

Fix/Workaround

When multiple CS are in use, if one of the baudrates equals 1, the others must also equal 1 if CSRn.CPOL=1 and CSRn.NCPHA=0.

5. SPI mode fault detection enable causes incorrect behavior

When mode fault detection is enabled (MR.MODFDIS==0), the SPI module may not operate properly.

Fix/Workaround

Always disable mode fault detection before using the SPI by writing a one to MR.MODFDIS.

6. SPI RDR.PCS is not correct

The PCS (Peripheral Chip Select) field in the SPI RDR (Receive Data Register) does not correctly indicate the value on the NPCS pins at the end of a transfer.

Fix/Workaround

Do not use the PCS field of the SPI RDR.

10.3.8 TWI

1. TWIS may not wake the device from sleep mode

If the CPU is put to a sleep mode (except Idle and Frozen) directly after a TWI Start condition, the CPU may not wake upon a TWIS address match. The request is NACKed.

Fix/Workaround

When using the TWI address match to wake the device from sleep, do not switch to sleep modes deeper than Frozen. Another solution is to enable asynchronous EIC wake on the TWIS clock (TWCK) or TWIS data (TWD) pins, in order to wake the system up on bus events.

2. SMBALERT bit may be set after reset

The SMBus Alert (SMBALERT) bit in the Status Register (SR) might be erroneously set after system reset.

Fix/Workaround

After system reset, clear the SR.SMBALERT bit before commencing any TWI transfer.

3. Clearing the NAK bit before the BTF bit is set locks up the TWI bus

When the TWIS is in transmit mode, clearing the NAK Received (NAK) bit of the Status Register (SR) before the end of the Acknowledge/Not Acknowledge cycle will cause the TWIS to attempt to continue transmitting data, thus locking up the bus.

Fix/Workaround

Clear SR.NAK only after the Byte Transfer Finished (BTF) bit of the same register has been set.

4. TWIS stretch on Address match error

When the TWIS stretches TWCK due to a slave address match, it also holds TWD low for the same duration if it is to be receiving data. When TWIS releases TWCK, it releases TWD at the same time. This can cause a TWI timing violation.

Fix/Workaround

None.

5. TWIM TWALM polarity is wrong

The TWALM signal in the TWIM is active high instead of active low.

Fix/Workaround

Use an external inverter to invert the signal going into the TWIM. When using both TWIM and TWIS on the same pins, the TWALM cannot be used.

10.3.9 PWMA

1. The SR.READY bit cannot be cleared by writing to SCR.READY

The Ready bit in the Status Register will not be cleared when writing a one to the corresponding bit in the Status Clear register. The Ready bit will be cleared when the Busy bit is set.

Fix/Workaround

Disable the Ready interrupt in the interrupt handler when receiving the interrupt. When an operation that triggers the Busy/Ready bit is started, wait until the ready bit is low in the Status Register before enabling the interrupt.

10.3.10 TC

1. Channel chaining skips first pulse for upper channel

When chaining two channels using the Block Mode Register, the first pulse of the clock between the channels is skipped.

Fix/Workaround

Configure the lower channel with RA = 0x1 and RC = 0x2 to produce a dummy clock cycle for the upper channel. After the dummy cycle has been generated, indicated by the SR.CPCS bit, reconfigure the RA and RC registers for the lower channel with the real values.

10.3.11 ADCIFB

1. ADCIFB DMA transfer does not work with divided PBA clock

DMA requests from the ADCIFB will not be performed when the PBA clock is slower than the HSB clock.

Fix/Workaround

Do not use divided PBA clock when the PDCA transfers from the ADCIFB.

10.3.12 CAT

1. CAT QMatrix sense capacitors discharged prematurely

At the end of a QMatrix burst charging sequence that uses different burst count values for different Y lines, the Y lines may be incorrectly grounded for up to n-1 periods of the peripheral bus clock, where n is the ratio of the PB clock frequency to the GCLK_CAT frequency. This results in premature loss of charge from the sense capacitors and thus increased variability of the acquired count values.

Fix/Workaround

Enable the 1 kOhm drive resistors on all implemented QMatrix Y lines (CSA 1, 3, 5, 7, 9, 11, 13, and/or 15) by writing ones to the corresponding odd bits of the CSARES register.

2. Autonomous CAT acquisition must be longer than AST source clock period

When using the AST to trigger CAT autonomous touch acquisition in sleep modes where the CAT bus clock is turned off, the CAT will start several acquisitions if the period of the AST source clock is larger than one CAT acquisition. One AST clock period after the AST trigger, the CAT clock will automatically stop and the CAT acquisition can be stopped prematurely, ruining the result.

Fix/Workaround

Always ensure that the ATCFG1.max field is set so that the duration of the autonomous touch acquisition is greater than one clock period of the AST source clock.

3. CAT consumes unnecessary power when disabled or when autonomous touch not used

A CAT prescaler controlled by the ATCFG0.DIV field will be active even when the CAT module is disabled or when the autonomous touch feature is not used, thereby causing unnecessary power consumption.

Fix/Workaround

If the CAT module is not used, disable the CLK_CAT clock in the PM module. If the CAT module is used but the autonomous touch feature is not used, the power consumption of the CAT module may be reduced by writing 0xFFFF to the ATCFG0.DIV field.

4. CAT module does not terminate QTouch burst on detect

The CAT module does not terminate a QTouch burst when the detection voltage is reached on the sense capacitor. This can cause the sense capacitor to be charged more than necessary. Depending on the dielectric absorption characteristics of the capacitor, this can lead to unstable measurements.

Fix/Workaround

Use the minimum possible value for the MAX field in the ATCFG1, TG0CFG1, and TG1CFG1 registers.

10.3.13 aWire

1. aWire MEMORY_SPEED_REQUEST command does not return correct CV

The aWire MEMORY_SPEED_REQUEST command does not return a CV corresponding to the formula in the aWire Debug Interface chapter.

Fix/Workaround

Issue a dummy read to address 0x100000000 before issuing the MEMORY_SPEED_REQUEST command and use this formula instead:

$$f_{sab} = \frac{7f_{aw}}{CV-3}$$

10.3.14 I/O Pins

1. PA05 is not 3.3V tolerant.

PA05 should be grounded on the PCB and left unused if VDDIO is above 1.8V.

Fix/Workaround

None.

2. No pull-up on pins that are not bonded

PB13 to PB27 are not bonded on UC3L0256/128, but has no pull-up and can cause current consumption on VDDIO/VDDIN if left undriven.

Fix/Workaround

Enable pull-ups on PB13 to PB27 by writing 0x0FFFE000 to the PUERS1 register in the GPIO.

3. PA17 has low ESD tolerance

PA17 only tolerates 500V ESD pulses (Human Body Model).

Fix/Workaround

Care must be taken during manufacturing and PCB design.

11. Datasheet Revision History

Please note that the referring page numbers in this section are referred to this document. The referring revision in this section are referring to the document revision.

11.1 Rev. C – 01/2012

1. Description: DFLL frequency is 20 to 150MHz, not 40 to 150MHz.
2. Block Diagram: GCLK_IN is input, not output. CAT SMP corrected from I/O to output. SPI NPCS corrected from output to I/O.
3. Package and Pinout: EXTINT0 in Signal Descriptions table is NMI.
4. Supply and Startup Considerations: In 1.8V single supply mode figure, the input voltage is 1.62-1.98V, not 1.98-3.6V. "On system start-up, the DFLL is disabled" is replaced by "On system start-up, all high-speed clocks are disabled".
5. ADCIFB: PRND signal removed from block diagram.
6. Electrical Characteristics: Added 64-pin package information to I/O Pin Characteristics tables and Digital Clock Characteristics table.
7. Mechanical Characteristics: QFN48 Package Drawing updated. Note that the package drawing for QFN48 is correct in datasheet rev A, but wrong in rev B. Added notes to package drawings.
8. Summary: Removed Programming and Debugging chapter, added Processor and Architecture chapter.

11.2 Rev. B – 12/2011

1. JTAG Data Registers subchapter added in the Programming and Debugging chapter, containing JTAG IDs.

11.3 Rev. A – 12/2011

1. Initial revision.

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