JN516x Integrated Peripherals API User Guide

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Contents

About this Manual

This manual describes the use of the JN516x Integrated Peripherals Application Programming Interface (API) to interact with the peripherals on a wireless microcontroller from the NXP JN516x family. The manual explains the basic operation of each peripheral and indicates how to use the relevant API functions to control the peripheral from the application which runs on the JN516x device. The C functions and associated resources of the API are fully detailed.

Organisation

This manual is divided into three parts:

- Part I: Concept and Operational Information comprises 17 chapters:
  - Chapter 1 presents a functional overview of the JN516x Integrated Peripherals API.
  - Chapter 2 describes use of the **General functions** of the API, including the API initialisation function.
  - Chapter 3 describes use of the **System Controller functions**, including functions that configure the system clock and sleep operations.
  - Chapter 4 describes use of the **Analogue Peripheral functions**, used to control the ADC and comparator.
  - Chapter 5 describes use of the **DIO functions**, used to control the general-purpose digital input/output pins.
  - Chapter 6 describes use of the **UART functions**, used to control the 16550-compatible UARTs.
  - Chapter 7 describes use of the **Timer functions**, used to control the general-purpose timers.
  - Chapter 8 describes use of the **Wake Timer functions**, used to control the wake timers that can be employed to time sleep periods.
  - Chapter 9 describes use of the **Tick Timer functions**, used to control the high-precision hardware timer.
  - Chapter 10 describes use of the **Watchdog Timer functions**, used to control the watchdog that allows software lock-ups to be avoided.
  - Chapter 11 describes use of the **Pulse Counter functions**, used to control the two pulse counters.
  - Chapter 12 describes use of the **Infra-Red Transmitter functions**, used to control the infra-red transmission feature of Timer 2.
  - Chapter 13 describes use of the **Serial Interface (SI) functions**, used to control a 2-wire SI master and SI slave.
  - Chapter 14 describes use of the **Serial Peripheral Interface (SPI) Master functions**, used to control the master interface to the SPI bus.

- Chapter 15 describes use of the **Serial Peripheral Interface (SPI) Slave functions**, used to control the slave interface to the SPI bus.
- Chapter 16 describes use of the **Flash Memory functions**, used to manage the Flash memory.
- Chapter 17 describes use of the **EEPROM functions**, used to access the on-chip EEPROM device.

- Part II: Reference Information comprises 16 chapters:
  - Chapter 18 details the **General functions** of the API, including the API initialisation function.
  - Chapter 19 details the **System Controller functions**, including functions that configure the system clock and sleep operations.
  - Chapter 20 details the **Analogue Peripheral functions**, used to control the ADC and comparator.
  - Chapter 21 details the **DIO functions**, used to control the general-purpose digital input/output pins.
  - Chapter 22 details the **UART functions**, used to control the 16550-compatible UARTs.
  - Chapter 23 details the **Timer functions**, used to control the general-purpose timers.
  - Chapter 24 details the **Wake Timer functions**, used to control the wake timers that can be employed to time sleep periods.
  - Chapter 25 details the **Tick Timer functions**, used to control the high-precision hardware timer.
  - Chapter 26 details the **Watchdog Timer functions**, used to control the watchdog that allows software lock-ups to be avoided.
  - Chapter 27 details the **Pulse Counter functions**, used to control the two pulse counters.
  - Chapter 28 details the **Infra-Red Transmitter functions**, used to control infra-red transmission.
  - Chapter 29 details the **Serial Interface (SI) functions**, used to control a 2-wire SI master and SI slave.
  - Chapter 30 details the **Serial Peripheral Interface (SPI) Master functions**, used to control the master interface to the SPI bus.
  - Chapter 31 details the **Serial Peripheral Interface (SPI) Slave functions**, used to control the slave interface to the SPI bus.
  - Chapter 32 details the **Flash Memory functions**, used to manage the Flash memory.
  - Chapter 33 details the **EEPROM functions**, used to access the on-chip EEPROM device.
- Part III: Appendices provides information on handling interrupts from the peripheral devices.

Conventions

Files, folders, functions and parameter types are represented in **bold** type.

Function parameters are represented in *italics* type.

Code fragments are represented in the `Courier New` typeface.

This is a **Tip**. It indicates useful or practical information.

This is a **Note**. It highlights important additional information.

*This is a **Caution**. It warns of situations that may result in equipment malfunction or damage.*

Acronyms and Abbreviations

ADC	Analogue-to-Digital Converter
AES	Advanced Encryption Standard
AHI	Application Hardware Interface
API	Application Programming Interface
CPU	Central Processing Unit
CTS	Clear-To-Send
DAC	Digital-to-Analogue Converter
DAI	Digital Audio Interface
DIO	Digital Input/Output
EIRP	Equivalent Isotropically Radiated Power
FIFO	First In, First Out (queue)
GPIO	General Purpose Input/Output
LPRF	Low-Power Radio Frequency
MAC	Medium Access Control

NVM	Non-Volatile Memory
PWM	Pulse Width Modulation
RAM	Random Access Memory
RTS	Ready-To-Send
SI	Serial Interface
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver-Transmitter
VBO	Voltage Brownout

Related Documents

JN-DS-JN516x	JN516x Data Sheet

Support Resources

To access online support resources such as SDKs, Application Notes and User Guides, visit the Wireless Connectivity TechZone:

www.nxp.com/techzones/wireless-connectivity

All NXP resources referred to in this manual can be found at the above address, unless otherwise stated.

Trademarks

Part I:
Concept and Operational Information

1. Overview

This chapter introduces the JN516x Integrated Peripherals Application Programming Interface (API) that is used to interact with peripherals on a wireless microcontroller from the NXP JN516x family. The chips of this family have the same peripherals but different memory sizes:

- JN5168 (32KB RAM, 4KB EEPROM, 256KB Flash memory)
- JN5164 (32KB RAM, 4KB EEPROM, 160KB Flash memory)
- JN5161 (8KB RAM, 4KB EEPROM, 64KB Flash memory)

1.1 JN516x Integrated Peripherals

The JN516x microcontrollers each feature a number of on-chip peripherals that can be used by a user application which runs on the CPU of the microcontroller. These 'integrated peripherals' are listed below.

- System Controller
- Analogue Peripherals:
  - Analogue-to-Digital Converter (ADC)
  - Comparator
- Digital Inputs/Outputs (DIOs)
- Universal Asynchronous Receiver-Transmitters (UARTs)
- Timers
- Wake Timers
- Tick Timer
- Watchdog Timer
- Pulse Counters
- Serial Interface (2-wire):
  - SI Master
  - SI Slave
- Serial Peripheral Interface (SPI):
  - SPI Master
  - SPI Slave
- Interface to external Flash memory

The above peripherals are illustrated in Figure 1.

For hardware details of these peripherals, refer to the relevant chip data sheet - see "Related Documents" on page 18.

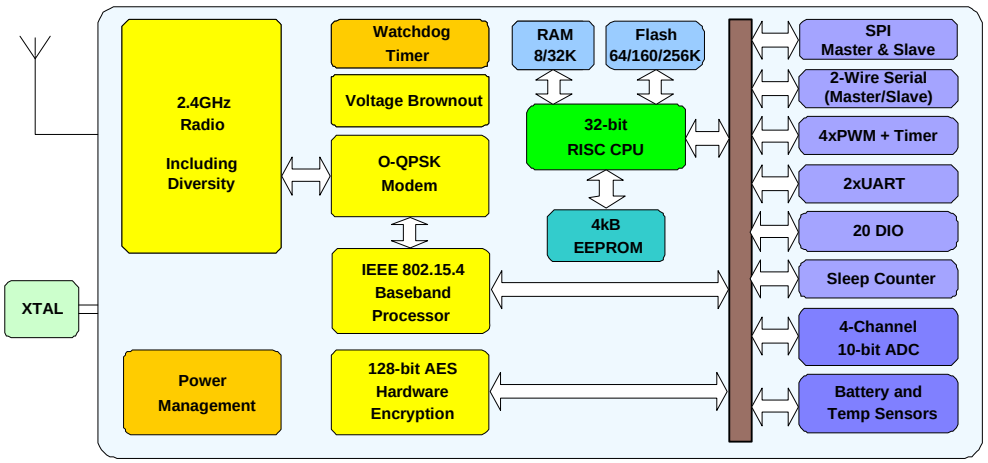


Figure 1: JN516x Block Diagram

1.2 JN516x Integrated Peripherals API

The JN516x Integrated Peripherals API is a collection of C functions that can be incorporated in application code that runs on a JN516x wireless microcontroller in order to control the on-chip peripherals listed in Section 1.1. This API (sometimes referred to as the AHI) is defined in the header file **AppHardwareApi.h**, which is included in the NXP Software Developer's Kits (SDKs) for the JN516x devices. The software that is invoked by this API is located in the on-chip ROM.

This API provides a thin software layer above the on-chip registers used to control the integrated peripherals. By encapsulating several register accesses into one function call, the API simplifies use of the peripherals without the need for a detailed knowledge of their operation.

Caution: *The JN516x Integrated Peripherals API functions are not re-entrant. A function must be allowed to complete before the function is called again, otherwise unexpected results may occur.*

Note that the Integrated Peripherals API does NOT include functions to control the:

- IEEE 802.15.4 Baseband Processor built into the JN516x device - this is controlled by the wireless network protocol stack software (which may be an IEEE 802.15.4, ZigBee, JenNet or JenNet-IP stack), and APIs for this purpose are provided with the appropriate stack software product.
- 128-bit AES Hardware Encryption core built into the JN516x device - this is controlled using the functions described in the *AES Coprocessor API Reference Manual (JN-RM-2013)*
- EEPROM - this is controlled using the Persistent Data Manager resident in the Jennic Operating System (JenOS). For further details, please refer to the *JenOS User Guide (JN-UG-3075)*
- resources of the JN516x evaluation kit boards, such as sensors and display panels (although the buttons and LEDs on the evaluation kit boards are connected to the DIO pins of the JN516x device) - a special function library, called the LPRF Board API, is provided by NXP for this purpose and is described in the *LPRF Board API Reference Manual (JN-RM-2003)*.

1.3 Using this Manual

The remainder of this manual is largely organised as one chapter per peripheral block. You should use the manual as follows:

1. First study Chapter 2 which describes the general functions that are not associated with one particular peripheral block. This chapter explains how to initialise the Integrated Peripherals API for use in your application code.
2. Next study Chapter 3 which describes the range of features associated with the System Controller. You may need to use one or more of these features in your application.
3. Then study those chapters in Part I: Concept and Operational Information which correspond to the particular peripherals that you wish to use in your application.

For full details of the referenced API functions, refer to Part II: Reference Information. Also note that interrupt handling is described in Part III: Appendices.

2. General Functions

This chapter describes use of the 'general functions' that are not associated with any of the peripheral blocks but may be needed in your application code (the API initialisation function will definitely be needed).

These functions cover the following areas:

- API initialisation (Section 2.1)
- Configuration of the radio transmission power (Section 2.2)
- Use of the random number generator (Section 2.4)
- Accessing the JN516x internal Non-Volatile Memory (Section 2.5)

2.1 API Initialisation

Before calling any other function from the JN516x Integrated Peripherals API, the function **u32AHI_Init()** must be called to initialise the API. This function must be called after every reset and wake-up (from sleep) of the JN516x microcontroller.

***Caution:** If you are using JenOS (Jennic Operating System), you must not call **u32AHI_Init()** explicitly in your code, as this function is called internally by JenOS. This applies principally to users who are developing ZigBee PRO applications.*

2.2 Radio Transmission Power

The radio transmission power of a JN516x device can be varied. A standard JN516x module has a transmission power range of -32 to +2.5 dBm. To set the transmission power, you can use the function **eAppApiPlmeSet()** from the NXP 802.15.4 Stack API (supplied in **AppApi.h** in all the JN516x SDKs). The required function call is:

```
eAppApiPlmeSet(PHY_PIB_ATTR_TX_POWER, x);
```

where `x` is a 6-bit two's complement power level, yielding a range of -32 to 31 dBm - in practice, this value is mapped to one of the four levels -32, -20, -9 and 0 dBm.

Note: The function **bAHI_PhyRadioSetPower()** has been removed from the JN516x Integrated Peripherals API. If updating existing code that previously used the function call `bAHI_PhyRadioSetPower(y)` then `x` in the above call to **eAppApiPlmeSet()** can be calculated as `34+10*y`.

2.3 Antenna Diversity

The JN516x device provides an antenna diversity facility, allowing two antennae to be connected to the device. If this feature is implemented and the transmit and/or receive performance through the current antenna is deemed poor, a switch to the alternative antenna is automatically initiated.

If antenna diversity is to be used, two antennas must be connected to the JN516x device via a 2-state switch which is controlled by the device using a complementary pair of signals output on pins DIO12 and DIO13. In one position (e.g. DIO12-13 = 10), the switch connects the RF_IN pin of the JN516x device to one antenna and in the other position (e.g. DIO12-13 = 01) the switch connects this pin to the other antenna. This connection is illustrated in Figure 2 below.

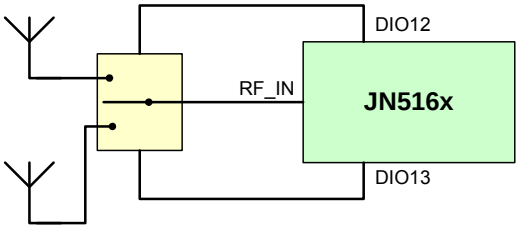


Figure 2: Connections for Antenna Diversity

The DIO12 and DIO13 pins must first be enabled for antenna diversity use by calling the function **vAHI_AntennaDiversityOutputEnable()**.

Antenna diversity is enabled in the application by calling the function **vAHI_AntennaDiversityEnable()**. This function allows antenna diversity to be enabled individually for the transmit and receive paths (or for both paths). The operation of antenna diversity for the transmit and receive cases is outlined below:

- **Transmit:** For a transmission, the decision of whether to switch antennae is dependent on the use of IEEE 802.15.4 MAC acknowledgments. Once an IEEE 802.15.4 packet has been transmitted, the radio transceiver will enter receive mode and wait for an acknowledgment from the target node. If no acknowledgment is received, the device will retry the transmission on the alternative antenna (the number of retries is configurable in the IEEE 802.15.4 MAC). The selected antenna is switched for each subsequent retry.
- **Receive:** For reception, the JN516x device measures the received energy in the relevant radio channel every 40µs. The measured energy level is compared with a pre-set energy threshold. The JN516x device will automatically switch the antenna if the measurement is below this threshold and all the following conditions hold:
  - The radio is not in the process of receiving a packet
  - A preamble symbol having a signal quality above a minimum specified threshold has not been detected in the last 40µs
  - The radio is not waiting for an acknowledgment from a previous transmission

The signal energy and signal quality thresholds can be set by the application using the function **vAHI_AntennaDiversityControl()**.

The current antenna diversity status can be obtained using the function **u8AHI_AntennaDiversityStatus()**. This function returns the antenna used for the last packet transmitted, the antenna used for the last packet received and the antenna that is currently selected.

The currently selected antenna can be manually switched by calling the function **vAHI_AntennaDiversitySwitch()**. Calling this function will generally not be required because it is expected that most applications will make use of the automatic transmit and/or receive antenna diversity control features that are enabled by calling **vAHI_AntennaDiversityEnable()**.

2.4 Random Number Generator

The JN516x devices feature a random number generator which can produce 16-bit random numbers in one of two modes:

- **Single-shot mode:** The generator produces one random number and stops.
- **Continuous mode:** The generator runs continuously and generates a new random number every 256µs.

The random number generator can be started in either of the above modes using the function **vAHI_StartRandomNumberGenerator()**. This function also allows an interrupt to be enabled which is produced when a random number becomes available - this is handled as a System Controller interrupt by the callback function registered using the function **vAHI_SysCtrlRegisterCallback()** (see Section 3.5).

A randomly generated value can subsequently be read using the function **u16AHI_ReadRandomNumber()**. The availability of a new random number, and therefore the need to call the 'read' function, can be determined using either of the following methods:

- Waiting for a random number generator interrupt, if enabled (see above)
- Periodically calling the function **bAHI_RndNumPoll()** to poll for the availability of a new random value

When running in Continuous mode, the random number generator can be stopped using the function **vAHI_StopRandomNumberGenerator()**.

Note: The random number generator uses the 32kHz clock domain (see Section 3.1) and will not operate properly if a high-precision external 32kHz clock source is used. Therefore, if generating random numbers in your application, you are advised to use the internal RC oscillator or a low-precision external clock source. You may also generate random numbers in your application before switching to a high-precision external clock.

2.5 Accessing Internal NVM

The JN516x device contains a small block of Non-Volatile Memory (NVM) which is organised as four 32-bit words numbered 0, 1, 2 and 3. This memory can be used to preserve important data (e.g. counter values) at times when the JN516x RAM is not powered - for example, during periods of sleep without RAM held.

Two functions are provided to access this memory:

- **vAHI_WriteNVData()** can be used to write a 32-bit word of data to one of the four memory locations
- **u32AHI_ReadNVData()** can be used to read a 32-bit word of data from one of the four memory locations

Caution: *The contents of this JN516x NVM are not maintained when the microcontroller is completely powered off. However, they are maintained through a device reset.*

3. System Controller

This chapter describes use of the functions that control features of the System Controller.

These functions cover the following areas:

- Clock management (Section 3.1)
- Power management (Section 3.2)
- Supply voltage monitoring (Section 3.3)
- Chip reset (Section 3.4)
- Interrupts (Section 3.5)

3.1 Clock Management

The System Controller provides clocks to the JN516x microcontroller and is divided into four main blocks - a system clock domain, a peripheral clock domain, a CPU clock domain and a 32kHz clock domain.

System Clock Domain

The system clock is a high-speed reference clock from which the peripheral clock and CPU clock are derived when the chip is fully operational. The clock for this domain is sourced from one of the following:

- External 32MHz crystal oscillator
- Internal high-speed RC oscillator

The crystal oscillator is driven from a 32MHz external crystal connected to device pins 4 and 5. The domain will produce a 32MHz system clock when sourced from the crystal oscillator.

The uncalibrated RC oscillator runs at 27MHz nominally, but can be calibrated to run at approximately 32MHz. The RC oscillator is mainly provided for a quick start-up following sleep, since the RC oscillator can start much more quickly than the crystal oscillator.

The radio transceiver and some peripherals should not be used when sourcing the system clock from the RC oscillator. System clock start-up and source selection is described in described in Section 3.1.1 and Section 3.1.2.

Peripheral Clock Domain

The peripheral clock is derived from the system clock and is used as the clock reference for the on-chip peripherals including the modem and baseband processor. The peripheral clock operates at half the system clock frequency - the peripheral clock runs at 16MHz when the system clock is sourced from the external 32MHz crystal oscillator.

CPU Clock Domain

The CPU clock is a divided down version of the system clock and is used as the clock reference for the microprocessor and memory subsystem. The CPU clock frequency selection is described in Section 3.1.3.

32kHz Clock Domain

The 32kHz clock domain is mainly used during low-power sleep states (but also for the random number generator on the JN516x device - see Section 2.4). While in Sleep mode (see Section 3.2.3), the CPU does not run and relies on an interrupt to wake it. The interrupt can be generated by an on-chip wake timer (see Chapter 8) or alternatively from an external source via a DIO pin (see Chapter 5), an on-chip comparator (see Section 4.3) or an on-chip pulse counter (see Chapter 11). The wake timers are driven from the 32kHz domain. The 32kHz clock for this domain can be sourced from one of the following:

- Internal RC oscillator
- External crystal
- External clock module

The crystal oscillator is driven from an external 32kHz crystal connected to DIO9 and DIO10. If used, the external clock module is connected to DIO9.

Source clock selection for this domain is described in Section 3.1.4.

The 32kHz domain is still active when the chip is operating normally and can be calibrated against the peripheral clock to improve timing accuracy - see Section 8.2.

3.1.1 System Clock Start-up and Source Selection

As stated in the introduction to Section 3.1, there are two possible sources for the system clock on the JN516x device:

- Internal high-speed RC oscillator
- External crystal oscillator

where the crystal oscillator provides a more accurate clock than the RC oscillator.

Following a reset, the JN516x device takes its system clock from the internal high-speed RC oscillator. By default, an automatic switch to the external 32MHz crystal oscillator is performed once the crystal oscillator has stabilised (this can take up to 1ms). Application code is executed immediately following a reset.

Once the device and system clock are fully up and running, the system clock source can be changed using the function **vAHI_SelectClockSource()**. The identity of the current source clock can be obtained by calling the function **bAHI_GetClkSource()**.

The RC Oscillator may be calibrated to improve its frequency accuracy by calling the function **bAHI_TrimHighSpeedRCOsc()**.

It is important to note the following limitations while using the RC oscillator:

- Uncalibrated, the RC oscillator will produce a system clock frequency to an accuracy of ±18% (or ±5% if calibrated)
- The full system cannot be run while using the RC oscillator - it is possible to execute code but it is not possible to successfuly transmit or receive radio signals. Also, the peripheral clock may not be sufficiently accurate to support certain peripheral functions, such as UART communication.

Therefore, while using the RC oscillator, use of the radio transceiver should not be attempted, and the JN516x peripherals should be used with special care.

3.1.2 System Clock Start-up Following Sleep

By default, following sleep, the JN516x device takes its system clock from the internal high-speed RC oscillator, but performs an automatic switch to the external 32MHz crystal oscillator once the crystal oscillator has stabilised (can take up to 1ms). Thus, application code is executed immediately following sleep.

It is possible to continue using the internal high-speed RC oscillator (without the automatic switch). In this case, before going to sleep, it is necessary to call the function **vAHI_EnableFastStartUp()** with the manual switch option selected - this cancels the automatic switch to the crystal oscillator.

3.1.3 CPU Clock Frequency Selection

A range of CPU clock frequencies are available on the JN516x device. By default, the source clock frequency is halved to produce the CPU clock. Thus:

- Using the external crystal oscillator, the 32MHz source frequency will produce a CPU clock frequency of 16MHz
- Using the uncalibrated internal high-speed RC oscillator, the 27MHz source frequency will produce a CPU clock frequency of 13.5MHz (±18%).

Note: The frequency of the high-speed RC oscillator can be adjusted to a calibrated 32MHz by calling **bAHI_TrimHighSpeedRCOsc()**.

However, alternative CPU clock frequencies can be configured using the function **bAHI_SetClockRate()**. A division factor must be specified for dividing down the source clock to produce the CPU clock. The possible division factors are 1, 2, 4, 8, 16 and 32:

- For a source clock of 32MHz, the possible CPU clock frequencies are then 1, 2, 4, 8, 16 and 32 MHz
- For a source clock of 27MHz, the possible CPU clock frequencies are then 0.84, 1.17, 3.38, 6.75, 13.5 and 27 MHz.

3.1.4 32kHz Clock Selection

As stated in the introduction to Section 3.1, a choice of source for the 32kHz clock is available on the JN516x device. The selection of this source clock is detailed below.

Note: The default clock source is the internal 32kHz RC oscillator. The functions described below only need to be called if an external 32kHz clock source is required. Once an external source has been selected, it is not possible to switch back to the internal RC oscillator.

The 32kHz clock can be optionally sourced from an external crystal or clock module. If one of these external clock sources is required, the function **bAHI_Set32KhzClockMode()** must be called. If required, this function should be called near the start of the application. More information is provided below on using this function to select an external crystal.

If selecting the external crystal oscillator then **bAHI_Set32KhzClockMode()** must be called before Timer 0 and any Wake Timers are used by the application, since these timers are used by the function when switching the clock source to the external crystal. This function starts the external crystal, which can take up to 1 second to stabilise, and the function waits for the crystal to become ready before returning.

If selecting the external crystal oscillator, alternatively the function **vAHI_Init32KhzXtal()** can first be called in order to start the external crystal. This function returns immediately, allowing the application to do other processing or to put the JN516x device into sleep mode while waiting for the crystal to become stable - in the case of sleep, the application should typically set a wake timer to wake the device after 1 second. **bAHI_Set32KhzClockMode()** must then be called in order to switch the 32kHz clock source to the external crystal.

If selecting the external clock module (RC circuit), the accuracy of the clock frequency produced can be chosen by setting the current consumption of the circuit using the function **vAHI_Trim32KhzRC()**.

The connections to the external clock source must be made as follows:

- The external clock module must be supplied on DIO9. You must first disable the pull-up on DIO9 using the function **vAHI_DioSetPullup()**.
- The external crystal oscillator must be attached on DIO9 and DIO10. The pull-ups on DIO9 and DIO10 are disabled automatically.

Note that there is no need to explicitly configure DIO9 or DIO10 as an input, as this is done automatically by **bAHI_Set32KhzClockMode()** and by **vAHI_Init32KhzXtal()**.

3.2 Power Management

This section describes how to control the power to a JN516x microcontroller using the Integrated Peripherals API. This includes control of the power regulator that supplies certain on-chip peripherals and the management of low-power sleep modes.

3.2.1 Power Domains

A JN516x microcontroller has a number of power domains, as follows:

- **Digital Logic domain:** This domain supplies the CPU and digital peripherals as well as the wireless transceiver (including encryption coprocessor and baseband controller). The clock from this domain to the wireless transceiver can be enabled/disabled by the application (see Section 3.2.2). The domain is always unpowered during sleep.
- **Analogue domain:** This domain supplies the ADC. The domain is switched on when the function **vAHI_ApConfigure()** is called to configure the analogue peripherals - see Chapter 4. The domain is always unpowered during sleep.
- **RAM domain:** This domain supplies the on-chip RAM. The domain may be powered or unpowered during sleep.
- **Radio domain:** This domain supplies the radio transceiver. The domain is always unpowered during sleep.
- **VDD Supply domain:** This domain supplies the wake timers, DIO blocks, comparator and 32kHz oscillators. The domain is driven from the external supply (battery) and is always powered. However, the wake timers and 32kHz oscillators may be powered or unpowered during sleep.

Separate voltage regulators for the CPU (Digital Logic domain) and on-chip RAM provide flexibility in implementing different low-power sleep modes, allowing the memory to be either powered (and its contents maintained) or unpowered while the CPU is powered down - for further information on sleep modes, refer to Section 3.2.3.

3.2.2 Wireless Transceiver Clock

The clock to the wireless transceiver can be enabled/disabled using the function **vAHI_ProtocolPower()**. However, disabling this clock outside of a reset or sleep cycle must be done with caution. The following points should be noted:

- Disabling this clock leaves the clock powered but disabled (gated).
- Disabling the clock causes the IEEE 802.15.4 MAC settings to be lost. Therefore, you must save the current MAC settings before disabling the clock. On re-enabling the clock, the MAC settings must be restored from the saved settings. You can save and restore the MAC settings using functions of the 802.15.4 Stack API, described in the *IEEE 802.15.4 Stack User Guide (JN-UG-3024)*:
  - To save the MAC settings, use the function **vAppApiSaveMacSettings()**.
  - To restore the saved MAC settings, use the function **vAppApiRestoreMacSettings()** - the clock is automatically re-enabled, since this function calls **vAHI_ProtocolPower()**.
- Do not call **vAHI_ProtocolPower()** to disable the clock while the 802.15.4 MAC layer is active, otherwise the microcontroller may freeze.
- While the clock is disabled, do not make any calls into the stack, as this may result in the stack attempting to access the associated hardware (which is disabled) and therefore cause an exception.

3.2.3 Low-Power Modes

The JN516x microcontroller is able to enter a number of low-power modes in order to conserve power during periods when the device does not need to be fully active. Generally, there are two low-power modes, Sleep mode (including Deep Sleep) and Doze mode, described below.

Sleep and Deep Sleep Modes

In Sleep mode, most of the internal chip functions are shut down to save power, including the CPU and the majority of on-chip peripherals. However, the states of the DIO pins are retained, including the output values and pull-up enables, which preserves any interface to the outside world. The on-chip RAM, the 32kHz oscillator, the comparator and the pulse counter can optionally remain active during sleep.

Sleep mode is started using the function **vAHI_Sleep()**, when one of four sleep modes can be selected which depend on whether RAM and the 32kHz oscillator are to be powered off. The significance of the 32kHz oscillator and RAM during sleep is outlined below:

- **32kHz Oscillator:** The 32kHz oscillator (internal RC, external clock or external crystal) can, in theory, be either left running or stopped for the duration of sleep. However, this oscillator is used by the wake timers and must be left running if a wake timer will be used to wake the device from sleep. Also, if an external source is used for this oscillator, it is not recommended that the oscillator is stopped on entering sleep mode.

Note: If the pulse counter is to be run with debounce while the device is asleep, the 32kHz oscillator must be left running - see Chapter 11.

- **On-chip RAM:** Power to on-chip RAM can be either maintained or removed during sleep. The application program, stack context data and application data are all held in on-chip RAM while the microcontroller is fully active, but are lost if the power to RAM is switched off.
  - If the power to RAM is removed during sleep, the application is re-loaded into RAM from on-chip Flash memory on exiting sleep mode. Stack context and application data may also be re-loaded by the application, if they were saved to the on-chip EEPROM before entering sleep mode.
  - If the power to RAM is maintained during sleep, the application and data will be preserved. This option is useful for short sleep periods, when the time taken on waking to re-load the application and data into RAM is significant compared with the sleep duration.

A further low-power option is Deep Sleep mode in which the CPU, RAM and both the system and 32kHz clock domains are powered down. In addition, any external Flash memory is also powered down during Deep Sleep mode. This option obviously provides a bigger power saving than Sleep mode.

Note: External NVM is not powered down during normal Sleep mode. If required, you can power down an external Flash memory device using the function **vAHI_FlashPowerDown()**, which must be called before **vAHI_Sleep()**, provided you are using a compatible Flash device. For full details, refer to Section 16.4.

The microcontroller can be woken from Sleep mode by one of the following:

- DIO interrupt (see Chapter 5)
- Wake timer interrupt (needs 32kHz oscillator to be running - see Chapter 8)
- Comparator interrupt (see Section 4.3)
- Pulse counter interrupt (see Chapter 11)

The device can only be woken from Deep Sleep mode by its reset line being pulled low or by an external event which triggers a change on a DIO pin.

When the device restarts, it will begin processing at the cold start or warm start entry point, depending on the sleep mode from which the device is waking.

Doze Mode

Doze mode is a low-power mode in which the CPU, RAM, radio transceiver and digital peripherals remain powered but the clock to the CPU is stopped (all other clocks continue as normal). This mode provides less of a power saving than Sleep mode but allows a quicker recovery back to full working mode. Doze mode is useful for very short periods of low power consumption - for example, while waiting for a timer event or for a transmission to complete.

The CPU can be put into Doze mode by calling the function **vAHI_CpuDoze()**. It is subsequently brought out of Doze mode by any interrupt.

3.2.4 Power Status

The power status of the JN516x microcontroller can be obtained using the function **u16AHI_PowerStatus()**. This function returns a bitmap which indicates whether:

- The device has completed a sleep-wake cycle
- RAM contents were retained during sleep
- The analogue power domain is switched on
- The protocol logic is operational - clock is enabled
- Watchdog timeout was responsible for the last device restart
- 32kHz clock is ready (e.g. following a reset or wake-up)
- Device has just come out of Deep Sleep mode (rather than a reset)

For further details of the bitmap, refer to the function descriptions in Chapter 19.

3.3 Supply Voltage Monitor (SVM)

A 'brownout' is a fall in the supply voltage to a device or system below a pre-defined level, which may hinder or be harmful to the operation of the device/system. The JN516x microcontroller is equipped with a Supply Voltage Monitor (SVM) to detect the brownout condition. SVM can be configured and monitored through functions of the Integrated Peripherals API.

3.3.1 Configuring SVM

By default on the JN516x device, the SVM feature is automatically enabled and the brownout voltage is set to 2.0V. On detection of a brownout, the chip will be automatically reset.

The SVM settings can be changed from the default values by calling the function **vAHI_BrownOutConfigure()**, which allows the configuration of the following:

- **SVM enable/disable:** The SVM feature can be enabled/disabled - if the configuration function is called and SVM is required, the feature must be explicitly enabled in the function.
- **Brownout level:** The brownout voltage level can be set to one of the following values: 1.95V, 2.0V (default), 2.1V, 2.2V, 2.3V, 2.4V, 2.7V or 3.0V
- **Reset on brownout:** The automatic reset on the occurrence of a brownout can be enabled/disabled.
- **Brownout interrupts:** Two separate interrupts relating to brownout can be enabled/disabled:
  - An interrupt can be generated when the device enters the brownout state (supply voltage falls below the brownout voltage level).
  - An interrupt can be generated when the device leaves the brownout state (supply voltage rises above the brownout voltage level).

After the return of the configuration function, there will be a delay before the new settings take effect - this delay is up to 3.3µs.

Note: Following a device reset or sleep, the default SVM settings are re-instated.

3.3.2 Monitoring Voltage

Provided that SVM is enabled (see Section 3.3.1), the brownout status of the JN516x device can be monitored in one of three ways: automatic reset, interrupts or polling. These options are described below.

Automatic Reset on Brownout

An automatic reset on a brownout is enabled by default, but can also be enabled/disabled through the function **vAHI_BrownOutConfigure()**. Following a chip reset, the application can check whether a brownout was the cause of the reset by calling the function **bAHI_BrownOutEventResetStatus()**.

Brownout Interrupts

Interrupts can be generated when the device enters the brownout state and/or when it exits the brownout state. These two interrupts can be individually enabled/disabled through the function **vAHI_BrownOutConfigure()**. Brownout interrupts are System Controller interrupts and are handled by the callback function registered using the function **vAHI_SysCtrlRegisterCallback()** - see Section 3.5.

Polling for Brownout

If brownout interrupts and automatic reset are disabled (but SVM is still enabled), the brownout state of the device can be obtained by manually polling via the function **u32AHI_BrownOutPoll()**. This function will indicate whether the supply voltage is currently above or below the brownout level.

3.4 Resets

The JN516x microcontroller can be reset from the application using the function **vAHI_SwReset()**. This function initiates the full reset sequence for the chip and is the equivalent of pulling the external RESETN line low. Note that during a chip reset, the contents of on-chip RAM are likely to be lost.

One or more external devices may also be connected to the RESETN line. Thus, any external devices connected to this line may be affected.

Note: An external RC circuit can be connected to the RESETN line in order to generate a reset. The required resistance and capacitance values are specified in the data sheet for the microcontroller.

3.5 System Controller Interrupts

System Controller interrupts cover a number of on-chip peripherals that do not have their own interrupts:

- Comparator
- DIOs
- Wake Timers
- Pulse Counter
- Random Number Generator
- Brownout detector

Interrupts for these peripherals can be individually enabled using their own functions from the Integrated Peripherals API.

The handling of interrupts from these sources must be incorporated in a user-defined callback function, registered using the function **vAHI_SysCtrlRegisterCallback()**. The registered callback function is automatically invoked when an interrupt of the type E_AHI_DEVICE_SYSCTRL occurs. The exact source of the interrupt (from the peripherals listed above) can then be identified from a bitmap that is passed into the function. Note that the interrupt will be automatically cleared before the callback function is invoked.

Note: The callback function prototype is detailed in Appendix A.1. The interrupt source information is provided in Appendix B.

***Caution:** The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.*

4. Analogue Peripherals

This chapter describes control of the analogue peripherals using functions of the Integrated Peripherals API.

The are two types of analogue peripheral on the JN516x microcontroller:

- Analogue-to-Digital Converter [ADC] (Section 4.1)
- Comparator (Section 4.3)

Analogue peripheral interrupts are described in Section 4.4.

4.1 ADC

The JN516x microcontroller includes a 10-bit Analogue-to-Digital Converter (ADC). The ADC samples an analogue input signal to produce a digital representation of the input voltage. It samples the input voltage at one instant in time and holds this voltage (in a capacitor) while converting it to a 10-bit binary value - the total sample/convert duration is called the conversion time.

The ADC may sample periodically to produce a sequence of digital values representing the behaviour of the input voltage over time. The rate at which the sampling events take place is called the sampling frequency. According to the Nyquist sampling theorem, the sampling frequency must be at least twice the highest frequency to be measured in the input signal. If the input signal contains frequencies of more than half the sampling frequency, these frequencies will be aliased. To prevent aliasing, a low-pass filter should be applied to the ADC input in order to remove frequencies greater than half the sampling frequency.

The ADC can take its analogue input from an external source, an on-chip temperature sensor and an internal voltage monitor (see below). The input voltage range is also selectable as between zero and a reference voltage, or between zero and twice this reference voltage (see below).

Note: When an ADC input which is shared with a DIO is used, the associated DIO should be configured as an input with the pull-up disabled (refer to Section 5.1.1 and Section 5.1.3).

When using the ADC, the first analogue peripheral function to be called must be **vAHI_ApConfigure()**, which allows the following properties to be configured:

- **Clock:**

  The clock input for the ADC is provided by the peripheral clock, normally 16MHz (see Section 3.1 for system clock options), which is divided down. The target frequency is selected using **vAHI_ApConfigure()**. The recommended target frequency for the ADC is 500kHz.

- **Sampling interval and conversion time:**

  The sampling interval determines the time over which the ADC will integrate the analogue input voltage before performing the conversion - in fact, the integration occurs over three times this interval (see Figure 3). This interval is set as a multiple of the ADC clock period (2x, 4x, 6x or 8x), where this multiple is selected using **vAHI_ApConfigure()**. Normally, it should be set to 2x - for details, refer to the data sheet for the microcontroller.

  The time allowed to perform the subsequent conversion is 13 clock periods. Thus, the total time to sample and convert (the conversion time) is given by:

  [(3 x *sampling interval)* + 13] x *clock period*

  For a visual illustration, refer to Figure 3.

- **Reference voltage:**

  The permissible range for the analogue input voltage is defined relative to a reference voltage V_{ref}, which can be sourced internally or externally. The source of V_{ref} is selected using **vAHI_ApConfigure()**.

  The input voltage range can be selected as either 0 to V_{ref} or 0 to $2V_{ref}$, which is selected the **vAHI_AdcEnable()** function - see later.

- **Voltage regulator:**

  In order to minimise the amount of digital noise in the ADC, the device is powered from a voltage regulator, sourced from the analogue supply VDD1. The regulator (and therefore power) can be enabled/disabled using **vAHI_ApConfigure()**. Once enabled, it is necessary to wait for the regulator to stabilise - the function **bAHI_APRegulatorEnabled()** can be used to check whether the regulator is ready.

- **Interrupt:**

  Interrupts can be enabled such that an interrupt (of the type E_AHI_DEVICE_ANALOGUE) is generated after each individual conversion. This is particularly useful for ADC continuous (periodic) conversion. Interrupts can be enabled/disabled using **vAHI_ApConfigure()**. Analogue peripheral interrupt handling is described in Section 4.4.

The ADC must then be further configured and enabled (but not started) using the function **vAHI_AdcEnable()**. This function allows the following properties to be configured.

- **Input source:**

  The ADC can take its input from one of six multiplexed sources, comprising four external pins (DIOs), an on-chip temperature sensor and an internal voltage monitor. The input is selected using **vAHI_AdcEnable()**.

- **Input voltage range:**

  The permissible range for the analogue input voltage is defined relative to the reference voltage V_{ref}. The input voltage range can be selected as either 0 to V_{ref} or 0 to $2V_{ref}$ (an input voltage outside this range results in a saturated digital output). The analogue voltage range is selected using **vAHI_AdcEnable()**.

- **Conversion mode:**

  The ADC can be configured to perform conversions in the following modes:

  - **Single-shot:** A single conversion is performed (see Section 4.1.1).
  - **Continuous:** Conversions are performed repeatedly (see Section 4.1.2).
  - **Accumulation:** A fixed number of conversions are performed and the results are added together (see Section 4.1.3).

  Single-shot mode or continuous mode can be selected using **vAHI_AdcEnable()**. In all three cases, the conversion time for an individual conversion is given by [(3 x *sampling interval)* + 13] x *clock period*, which is illustrated in Figure 3. In the cases of continuous mode and accumulation mode, after this time the next conversion will start and the sampling frequency will be the reciprocal of the conversion time.

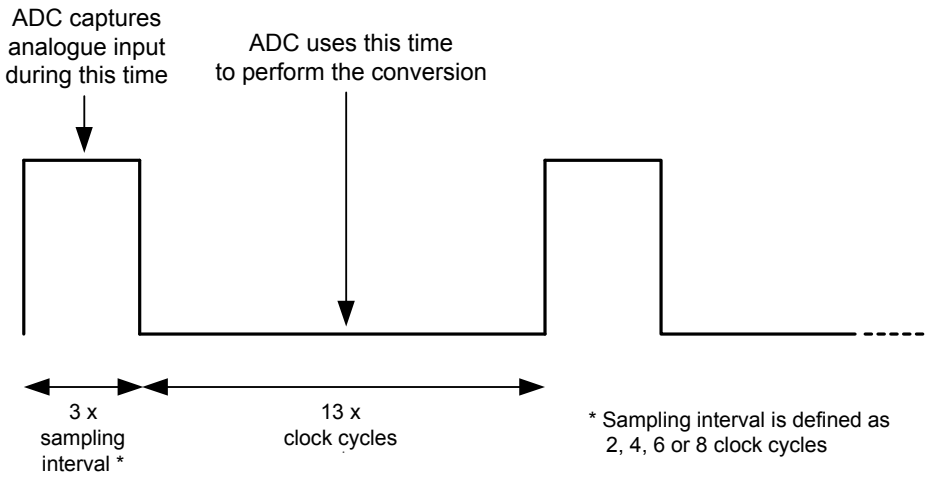


Figure 3: ADC Sampling

Once the ADC has been configured using first **vAHI_ApConfigure()** and then **vAHI_AdcEnable()**, conversion can be started in one of the available modes. Operation of the ADC in these modes is described in the subsections below:

- Single-shot mode: Section 4.1.1
- Continuous mode: Section 4.1.2
- Accumulation mode: Section 4.1.3

Note that only the ADC can generate analogue peripheral interrupts (of the type E_AHI_DEVICE_ANALOGUE) - these interrupts are handled by a user-defined callback function registered via **vAHI_APRegisterCallback()**. Refer to Section 4.4 for more information on analogue peripheral interrupt handling.

4.1.1 Single-Shot Mode

In single-shot mode, the ADC performs one conversion and then stops. To operate in this way, single-shot mode must have been selected when the ADC was enabled using **vAHI_AdcEnable()**. The conversion can then be started using the function **vAHI_AdcStartSample()**.

Completion of the conversion can be detected in one of two ways:

- An interrupt can be generated on completion - in this case, analogue peripheral interrupts must have been enabled in the function **vAHI_ApConfigure()**.
- The function **bAHI_AdcPoll()** can be used to check whether the conversion has completed.

Once the conversion has been performed, the result can be obtained using the function **u16AHI_AdcRead()**.

4.1.2 Continuous Mode

In continuous mode, the ADC performs repeated conversions indefinitely (until stopped). To operate in this way, continuous mode must have been selected when the ADC was enabled using **vAHI_AdcEnable()**. The conversions can then be started using the function **vAHI_AdcStartSample()**.

The sampling frequency in continuous mode is given by the reciprocal of the conversion time, where:

$$\textit{Conversion time} = [(3 \times \textit{sampling interval}) + 13] \times \textit{clock period}$$

Completion of an individual conversion can be detected in one of two ways:

- An interrupt can be generated on completion - in this case, analogue peripheral interrupts must have been enabled in the function **vAHI_ApConfigure()**.
- The function **bAHI_AdcPoll()** can be used to check whether the conversion has completed.

Once an individual conversion has been performed, the result can be obtained using the function **u16AHI_AdcRead()**. The result remains available to be read by this function until the next conversion has completed.

The conversions can be stopped using the function **vAHI_AdcDisable()**.

4.1.3 Accumulation Mode

In accumulation mode, the ADC performs a fixed number of conversions and then stops. The results of these conversions are added together to allow them to be averaged. To operate in this mode, the conversions must be started using the function **vAHI_AdcStartAccumulateSamples()**. The number of conversions is selected in this function as 2, 4, 8 or 16.

Note: When the ADC is started in accumulation mode, the conversion mode selected in **vAHI_AdcEnable()** is ignored.

The sampling frequency in accumulation mode is given by the reciprocal of the conversion time, where:

Conversion time = [(3 x *sampling interval)* + 13] x *clock period*

Completion of ALL the conversions can be detected in one of two ways:

- An interrupt can be generated on completion - in this case, analogue peripheral interrupts must have been enabled in the function **vAHI_ApConfigure()**.
- The function **bAHI_AdcPoll()** can be used to check whether the conversions have completed.

Once the conversions have been performed, the cumulative result can be obtained using the function **u16AHI_AdcRead()**. Note that this function delivers the sum of the results for individual conversions - the averaging calculation must be performed by the application (by dividing by the number of conversions).

The conversions can be stopped at any time using the function **vAHI_AdcDisable()**.

4.2 ADC with DMA Engine (Sample Buffer Mode)

This section describes an operational mode of the ADC in which it is used in conjunction with the DMA (Direct Memory Access) engine on the JN516x device. In this mode:

- ADC 10-bit data samples are produced at regular intervals and transferred into a buffer in RAM as 16-bit samples, where this data transfer and storage is performed by the DMA engine independently of the CPU
- The CPU can perform other tasks while the data transfer and storage is being managed by the DMA engine - the CPU only needs to initiate the ADC conversions and deal with the results in the buffer (when an interrupt occurs)
- ADC sampling can be multiplexed between different analogue sources

This method of using the ADC is called ‘sample buffer mode’.

The ADC samples are produced at a configurable rate and are timed using one of the on-chip timers (Timer 0, 1, 2, 3 or 4).

The application running on the CPU can service the buffer when the latter has collected sufficient data to cause an interrupt. The application must register a callback function to service this interrupt.

4.2.1 Preparing for Sample Buffer Mode

Before sample buffer mode can be enabled and started (see Section 4.2.2), the following preparations must be carried out:

- The function **vAHI_ApConfigure()** must be called to perform the initial configuration of the ADC (including clock frequency for conversion, sampling interval for conversion, reference voltage for input, use of voltage regulator and use of interrupts), as described for other ADC modes in Section 4.2.
- A JN516x timer to trigger the repeated conversions must be set up and started, as described in Chapter 7. Note the following:
  - This timer can be any one of Timers 0 to 4 (the required timer is specified later when sample buffer mode is enabled and started - see Section 4.2.2)
  - DIOs are not needed by this timer and may be released for other uses (see Section 7.2.1)
  - Timer interrupts are not required and should be disabled for this timer when **vAHI_TimerEnable()** is called (see Section 7.2.2)
  - The timer must be configured and started in 'Timer repeat' mode using **vAHI_TimerStartRepeat()** (see Section 7.3.1)
- A user-defined callback function to handle the interrupts generated in sample buffer mode must be registered using **vAHI_APRegisterCallback()**, as described in Section 4.4 (the required interrupt mode is specified later when sample buffer mode is enabled and started - see Section 4.2.2).

4.2.2 Sample Buffer Mode Operation

Once sample buffer mode has been prepared as described in Section 4.2.1 (ADC configuration, timer started, callback function registered), operation in this mode can be further configured and started using **bAHI_AdcEnableSampleBuffer()**. The following configuration must be carried out in this function call:

- The required JN516x timer must be specified as one of Timers 0 to 4
- The input voltage range must be specified as either 0 to V_{ref} or 0 to $2V_{ref}$, where the reference voltage V_{ref} has been specified in the call to **vAHI_ApConfigure()**
- A bitmap must be provided which specifies the analogue input sources that will be multiplexed in this ADC mode - the possible sources include four external pins (DIOs), an on-chip temperature sensor and an internal voltage monitor
- The RAM buffer to receive the data must be fully specified, as follows:
  - A pointer to the start of the buffer
  - The size of the buffer (in 16-bit samples, up to a maximum of 2047)

- Whether the buffer will wrap around to the start (when it becomes full)

- The DMA interrupt mode to be used must be specified as one of:
  - Interrupt when the buffer fills to its mid-point
  - Interrupt when the buffer is full
  - Interrupt when the buffer has wrapped around to its start

If operation in this mode is continuous (the buffer wraps around), it can be stopped using the function **vAHI_AdcDisableSampleBuffer()**.

Notes on various aspects of sample buffer mode operation (input multiplexing, buffer wrap and DMA interrupts) are provided below.

Input Multiplexing

Sample buffer mode allows up to six analogue inputs to be multiplexed. These inputs comprise four external inputs (ADC1-4, corresponding to DIO pins), an on-chip temperature sensor and an internal voltage monitor. The required multiplexed inputs are specified through a bitmap in the call to **bAHI_AdcEnableSampleBuffer()**.

16-bit samples from all the selected inputs will be produced on each timer trigger. These samples will be produced (and stored in the buffer) in the following order:

1. External input ADC1
2. External input ADC2
3. External input ADC3
4. External input ADC4
5. Temperature sensor
6. Voltage monitor

Buffer Wrap

In the call to **bAHI_AdcEnableSampleBuffer()**, the RAM buffer can be configured to wrap around - that is, when the buffer is full, data will continue to be written from the start of the buffer again (and an interrupt will be generated, if configured).

If the buffer wrap is not selected, conversions will automatically stop once the buffer is full (and an interrupt will be generated, if configured).

DMA Interrupts

DMA interrupts are used to notify the application of the status of the RAM buffer. These interrupts can be generated in the following circumstances:

- The buffer has been half-filled
- The buffer has been completely filled
- The buffer has been completely filled, and a new sample is available and cannot be stored (assumes that the buffer wrap option has been disabled)

One or more of the above interrupt conditions can be selected in the call to **bAHI_AdcEnableSampleBuffer()**. These interrupts must be serviced by the user-defined callback function registered using **vAHI_APRegisterCallback()**.

4.3 Comparator

The JN516x microcontroller includes one comparator (numbered 1).

The comparator can be used to compare two analogue inputs. It changes its two-state digital output (high to low or low to high) when the arithmetic difference between the inputs changes sense (positive to negative or negative to positive). The comparator can be used as a basis for measuring the frequency of a time-varying analogue input when compared with a constant reference input.

One analogue input carries the externally sourced signal to be monitored - the input voltage must always remain within the range 0V to V_{dd} (the chip supply voltage). This external signal can be supplied on the comparator's 'positive' pin (COMP1P) or 'negative' pin (COMP1M). It will be compared with a reference signal, which can be sourced internally or externally as follows:

- externally from the other comparator pin (COMP1P or COMP1M) that is not being used for the monitored input signal
- internally from the reference voltage V_{ref} (the source of V_{ref} is selected using the function **vAHI_ApConfigure()**)

The input and reference signals are selected from the above options via the function **vAHI_ComparatorEnable()**, which is used to configure and enable the comparator.

Note 1: By default, the comparator is enabled in low-power mode. Refer to Section 4.3.2 for more details.

Note 2: Calling **vAHI_ComparatorEnable()** while the ADC is operating may lead to corruption of the ADC results. Therefore, if required, this function should be called before starting the ADC.

Note 3: When a comparator pin is used, the associated DIO should be configured as an input with the pull-up disabled (refer to Section 5.1.1 and Section 5.1.3).

The comparator has two possible states - high or low. The comparator state is determined by the relative values of the two analogue input voltages - that is, by the instantaneous voltages of the signal under analysis, V_{sig}, and the reference signal, V_{refsig}. The relationships are as follows:

$$V_{sig} > V_{refsig} \Rightarrow \text{high}$$

$$V_{sig} < V_{refsig} \Rightarrow \text{low}$$

or in terms of differences:

$$V_{sig} - V_{refsig} > 0 \Rightarrow \text{high}$$

$$V_{sig} - V_{refsig} < 0 \Rightarrow \text{low}$$

Thus, as the signal levels vary with time, when V_{sig} rises above V_{refsig} or falls below V_{refsig}, the state of the comparator result changes. In this way, V_{refsig} is used as the threshold against which V_{sig} is assessed.

In reality, this method of functioning is sensitive to noise in the analogue input signals causing spurious changes in the comparator state. This situation can be improved by using two different thresholds:

- An upper threshold, V_{upper}, for low-to-high transitions
- A lower threshold, V_{lower}, for high-to-low transitions

The thresholds V_{upper} and V_{lower} are defined such that they are above and below the reference signal voltage V_{refsig} by the same amount, where this amount is called the hysteresis voltage, V_{hyst}.

That is:

$$V_{upper} = V_{refsig} + V_{hyst}$$
$$V_{lower} = V_{refsig} - V_{hyst}$$

The hysteresis voltage is selected using the **vAHI_ComparatorEnable()** function. It can be set to 0, 5, 10 or 20 mV. The selected hysteresis level should be larger than the noise level in the input signal.

The comparator two-threshold mechanism is illustrated in Figure 4 below for the case when the reference signal voltage V_{refsig} is constant.

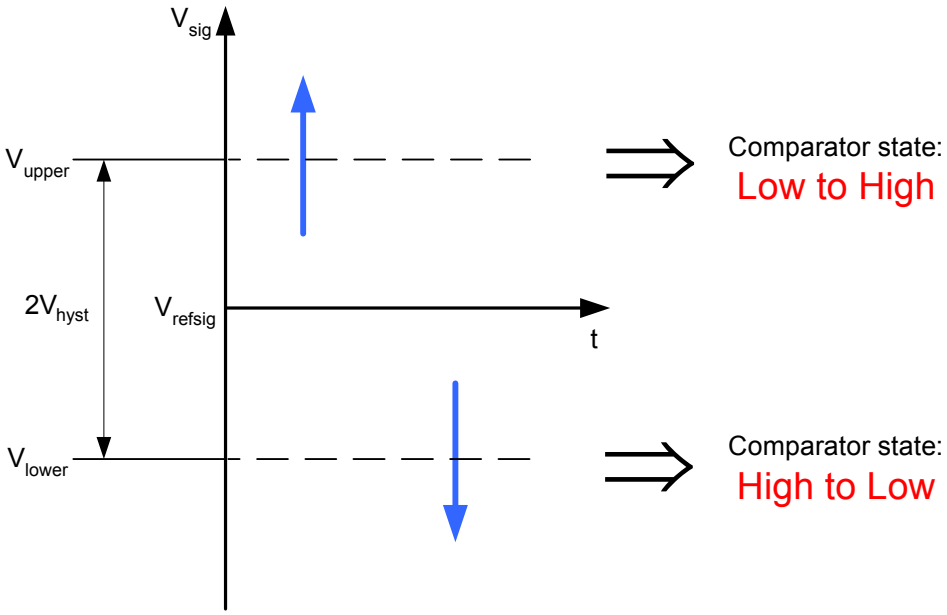


Figure 4: Upper and Lower Thresholds of Comparator

Note that there is a time delay between a change in the comparator inputs and the resulting state reported by the comparator.

As well as configuring the comparator, **vAHI_ComparatorEnable()** also starts operation of the comparator. The current state of the comparator (high or low) can be obtained at any time using the function **u8AHI_ComparatorStatus()**. The comparator can be stopped at any time using the function **vAHI_ComparatorDisable()**.

4.3.1 Comparator Interrupts and Wake-up

The comparator allows an interrupt to be generated on either a low-to-high or high-to-low transition. Interrupts can only be produced on transitions in one direction (and not both). Interrupts can be enabled using the function **vAHI_ComparatorIntEnable()**. The function is used to both enable/disable comparator interrupts and select the direction of the transitions that will trigger the interrupts.

Important: Comparator interrupts are System Controller interrupts and not analogue peripheral interrupts. They must therefore be handled by a callback function that is registered via **vAHI_SysCtrlRegisterCallback()**.

A comparator interrupt can be used as a signal to wake a node from sleep - this is then referred to as a 'wake-up interrupt'. To use this feature, interrupts must be configured and enabled using **vAHI_ComparatorIntEnable()**, as described above. Note that during sleep, the reference signal V_{refsig} is taken from an external source via the 'negative' pin COMP1M or the 'positive' pin COMP1P, whichever is used during wake periods. The wake-up interrupt status can be checked using the function **u8AHI_ComparatorWakeStatus()**.

4.3.2 Comparator Low-Power Mode

The comparator is able to operate in a low-power mode, in which it draws only 0.8µA of current, compared with 73µA when operating in standard-power mode. Comparator low-power mode can be enabled/disabled using the function **vAHI_ComparatorLowPowerMode()**.

When a comparator is configured and started using **vAHI_ComparatorEnable()**, it operates in standard-power mode. To operate the comparator in low-power mode, the function **vAHI_ComparatorLowPowerMode()** must then be called.

Low-power mode is beneficial in helping to minimise the current drawn by a device that employs energy harvesting. It is also automatically enabled during sleep in order to optimise the energy conserved. The disadvantage of low-power mode is a slower response time for the comparator - that is, a longer delay between a change in the comparator inputs and the resulting state reported by the comparator. However, if the response time is not important, low-power mode should normally be used.

4.4 Analogue Peripheral Interrupts

Analogue peripheral interrupts (of the type E_AHI_DEVICE_ANALOGUE) are only generated by the ADC (the comparator generates System Controller interrupts). The analogue peripheral interrupts are enabled in the function **vAHI_ApConfigure()** and are handled by a user-defined callback function registered using the function **vAHI_APRegisterCallback()**. For details of the callback function prototype, refer to Appendix A.1. The interrupt is automatically cleared when the callback function is invoked.

Caution: *The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling* ***u32AHI_Init()*** *on waking.*

The exact interrupt source depends on the ADC operating mode (single-shot, continuous, accumulation):

- In single-shot and continuous modes, a ‘capture’ interrupt will be generated after each individual conversion.
- In accumulation mode, an ‘accumulation’ interrupt will be generated when the final accumulated result is available.

Once an ADC result becomes available, it can be obtained by calling the function **u16AHI_AdcRead()** within the callback function.

5. Digital Inputs/Outputs (DIOs)

This chapter describes control of the Digital Inputs/Outputs (DIOs) using functions of the Integrated Peripherals API.

The JN516x microcontroller has 20 DIO lines, numbered 0 to 19. Each pin can be individually configured as an input or output. However, the DIO pins are shared with the following on-chip peripherals/features:

- ADC
- Comparator
- UARTs
- Timers
- 2-wire Serial Interface (SI)
- Serial Peripheral Interface (SPI)
- Antenna Diversity
- Pulse Counter

A shared DIO is not available when the corresponding peripheral/feature is enabled. For details of the shared pins, refer to the data sheet for the microcontroller.

From reset, all peripherals are disabled and the DIOs are configured as inputs.

In addition to normal operation, when configured as inputs, the DIOs can be used to generate interrupts and wake the device from sleep - see Section 5.2. Note that the interrupts triggered by the DIOs are System Controller interrupts and are handled by a callback function registered via **vAHI_SysCtrlRegisterCallback()** - see Section 3.5.

Note: In addition to the DIOs, the JN516x device has two digital outputs (DO0 and DO1). The configuration of these outputs is described in Section 5.3.

5.1 Using the DIOs

This section describes how to use the Integrated Peripherals API functions to configure and access the DIOs.

5.1.1 Setting the Directions of the DIOs

The DIOs can be individually configured as inputs and outputs using the function **vAHI_DioSetDirection()** - by default, they are all inputs. If a DIO is shared with an on-chip peripheral and is being used by this peripheral when **vAHI_DioSetDirection()** is called, the specified input/output setting for the DIO will not take immediate effect but will take effect once the peripheral has been disabled.

5.1.2 Setting DIO Outputs

The DIOs configured as outputs can then be individually set to on (high) and off (low) using the function **vAHI_DioSetOutput()**. The output states are set in a 32-bit bitmap, where each DIO is represented by a bit (bits 0-19 for DIO0-19). Note that:

- DIOs configured as inputs will not be affected by this function unless they are later set as outputs via a call to **vAHI_DioSetDirection()** - they will then adopt the output states set in **vAHI_DioSetOutput()**.
- If a shared DIO is in use by an on-chip peripheral when **vAHI_DioSetOutput()** is called, the specified on/off setting for the DIO will not take immediate effect but will take effect once the peripheral has been disabled.

A set of 8 consecutive DIOs can be used to output a byte in parallel - set DIO0-7 or DIO8-15 can be used for this purpose, where bit 0 or 8 is used for the least significant bit of the byte. The DIO set and the output byte can be specified using the function **vAHI_DioSetByte()**. All DIOs in the selected set must have been previously configured as outputs - see Section 5.1.1.

5.1.3 Setting DIO Pull-ups

Each DIO has an associated pull-up resistor. The purpose of the 'pull-up' is to prevent the state of the pin from 'floating' when there is no external load connected to the DIO - that is, when enabled, the pull-up ties the pin to the high (on) state in the absence of an external load (or in the presence a weak external load). The pull-ups for all the DIOs can be enabled/disabled using the function **vAHI_DioSetPullup()** - by default, all pull-ups are enabled. Again, if a shared DIO is in use by an on-chip peripheral when **vAHI_DioSetPullup()** is called, the specified pull-up setting for the DIO will be applied except when it is connected to an external 32kHz crystal (see Section 3.1.4).

Note: DIO pull-up settings are maintained through sleep. A power saving can be made by disabling DIO pull-ups (during sleep or normal operation) if they are not required.

5.1.4 Reading the DIOs

The states of the DIOs can be obtained using the function **u32AHI_DioReadInput()**. This function will return the states of all the DIOs, irrespective of whether they have been configured as inputs or outputs, or are in use by peripherals.

A set of 8 consecutive DIOs can be used to input a byte in parallel - set DIO0-7 or DIO8-15 can be used for this purpose, where bit 0 or 8 is used for the least significant bit of the byte. The input byte on a DIO set can be obtained using the function **u8AHI_DioReadByte()**. All DIOs in the set must have been previously configured as inputs - see Section 5.1.1.

5.2 DIO Interrupts and Wake-up

The DIOs configured as inputs can be used to generate System Controller interrupts. These interrupts can be used to wake the microcontroller, if it is sleeping. The Integrated Peripherals API includes a set of 'DIO interrupt' functions and a set of 'DIO wake' functions, but these functions are identical in their effect (as they access the same register bits in hardware). Use of these two function-sets is described in the subsections below.

Caution: *Since the 'DIO interrupt' and 'DIO wake' functions access the same JN516x register bits, you must ensure that the two sets of functions do not conflict in your application code.*

5.2.1 DIO Interrupts

A change of state on an input DIO can be used to trigger an interrupt.

First, the input signal transition (low-to-high or high-to-low) that will trigger the interrupt should be selected for individual DIOs using the function **vAHI_DioInterruptEdge()** - the default is a low-to-high transition. Interrupts can then be enabled for the relevant DIO pins using the function **vAHI_DioInterruptEnable()**.

The interrupt status of the DIO pins can subsequently be obtained using the function **u32AHI_DioInterruptStatus()** - that is, this function can be used to determine if one of the DIOs caused an interrupt. This function is useful for polling the interrupt status of the DIOs when DIO interrupts are disabled and therefore not generated.

Note: If DIO interrupts are enabled, you should include DIO interrupt handling in the callback function registered via **vAHI_SysCtrlRegisterCallback()**.

5.2.2 DIO Wake-up

The DIOs can be used to wake the microcontroller from Sleep (including Deep Sleep) or Doze mode. Any DIO pin configured as an input can be used for wake-up - a change of state of the DIO will trigger a wake interrupt.

First, the input signal transition (low-to-high or high-to-low) that will trigger the wake interrupt should be selected for individual DIOs using the function **vAHI_DioWakeEdge()** - the default is a low-to-high transition. Wake interrupts can then be enabled for the relevant DIO pins using the function **vAHI_DioWakeEnable()**.

The wake status of the DIO pins can subsequently be obtained using the function **u32AHI_DioWakeStatus()** - that is, this function can be used to determine if one of the DIOs caused a wake-up event. Note that on waking, you must call this function before **u32AHI_Init()**, as the latter function will clear any pending interrupts.

Note 1: As an alternative to calling the function **u32AHI_DioWakeStatus()**, you can determine the wake interrupt source in the callback function registered via **vAHI_SysCtrlRegisterCallback()**.

Note 2: When waking from deep sleep, the function **u32AHI_DioWakeStatus()** will not indicate a DIO wake source because the device will have completed a full reset. When waking from sleep, this function may indicate more than one wake source if multiple DIO events occurred while the device was booting.

Note 3: If using the JenNet protocol, do not call **u32AHI_DioWakeStatus()** to obtain the DIO interrupt status on waking from sleep. At wake-up, JenNet calls **u32AHI_Init()** internally and clears the interrupt status before passing control to the application. The System Controller callback function must be used to obtain the interrupt status, if required.

5.3 Configuring Digital Outputs (DOs)

The JN516x device has two pins, DO0 and DO1, that may be used as general-purpose digital outputs while the device is awake. The DO pins are shared with the SPI Master, and Timers 2 and 3.

These pins can be configured as follows:

- **bAHI_DoEnableOutputs()** can be used to enable (or disable) the DO pins as general-purpose digital outputs - by default, the DO pins are disabled as general-purpose digital outputs at power-up
- **vAHI_DoSetDataOut()** can be used to set the output states of the DO pins to on or off, in any combination - by default, the output states are on at power-up
- **vAHI_DoSetPullup()** can be used to set the pull-up states of the DO pins to on or off, in any combination - by default, the pull-ups are enabled at power-up

The DO pins do not preserve their status through sleep and may not be used to wake the device from sleep. From reset, during sleep and on waking from sleep the DO pins revert to being disabled as general-purpose outputs with pull-ups enabled.

6. UARTs

This chapter describes control of the UARTs (Universal Asynchronous Receiver Transmitters) using functions of the Integrated Peripherals API.

The JN516x microcontroller has two UARTs, denoted UART0 and UART1, which can be independently enabled. These UARTs are 16550-compatible and can be used for the input/output of serial data at a programmable baud-rate of up to 4Mbps.

Note: The UART operation described here assumes that the peripheral clock runs at 16MHz and is derived from an external crystal oscillator - see Section 3.1. You are not advised to run a UART from any other clock.

6.1 UART Signals and Pins

A UART employs the following signals to interface with an external device:

- Transmit Data (TxD) output - connected to RxD on external device
- Receive Data (RxD) input - connected to TxD on external device
- Request-To-Send (RTS) output - connected to CTS on external device
- Clear-To-Send (CTS) input - connected to RTS on external device

If a UART just uses signals RxD and TxD, it is said to operate in 2-wire mode (see Section 6.2.1). If it uses all four of the above signals, it is said to operate in 4-wire mode and implements flow control (see Section 6.2.2). On the JN516x device:

- UART0 can operate in 4-wire mode (default) or in 2-wire mode
- UART1 can operate in 2-wire mode (default) or in 1-wire (transmit only) mode

The default pins used for the above signals are shared with the DIOs, as shown below:

Signal	DIOs for UART0 *	DIOs for UART1
CTS	DIO4	-
RTS	DIO5	-
TxD	DIO6	DIO14
RxD	DIO7	DIO15

Table 1: Default DIOs Used for UART Signals

* The pins used by UART0 can alternatively be used to connect a JTAG emulator for debugging

The UART0 signals can be moved from DIO4-7 to DIO12-15 using the function **vAHI_UartSetLocation()**. The UART1 signals can be moved from DIO14 and DIO15 to DIO11 and DIO9, respectively, using the same function. If this function is required, it must be called before the UART is enabled.

6.2 UART Operation

The transmit and receive paths of a UART each have a FIFO buffer, which allows multiple-byte serial transfers to be performed with an external device:

- The TxD pin is connected to the Transmit FIFO
- The RxD pin is connected to the Receive FIFO

The FIFOs are contained in RAM and are defined by the application. The size of each FIFO can be from 16 bytes up to 2047 bytes.

On the local device, the CPU can write/read data to/from a FIFO either one byte or a block of data at a time. The two paths are independent, so transmission and reception occur independently. The movement of data between the FIFOs and the TxD/RxD lines is handled by a DMA (Direct Memory Access) engine, with no CPU involvment.

The basic UART set-up is illustrated in Figure 5 below.

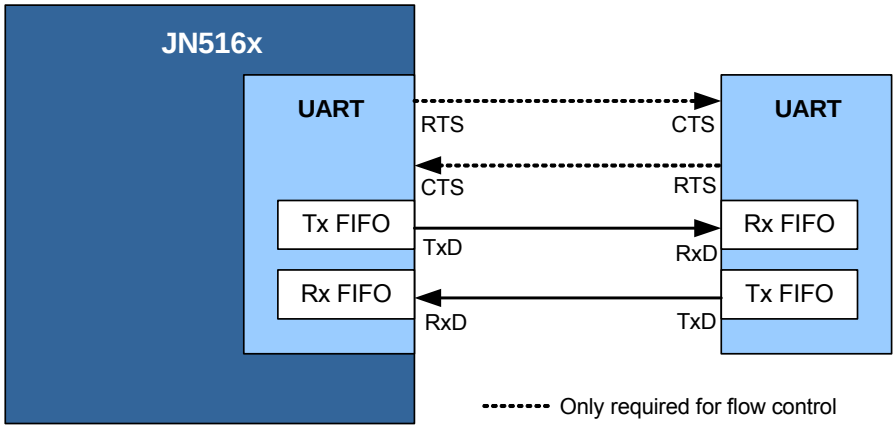


Figure 5: UART Connections

Both UARTs can operate in 2-wire mode, UART0 can also operate in 4-wire mode and UART1 can also operate in 1-wire mode. These modes are introduced in the sub-sections below.

6.2.1 2-wire Mode

In 2-wire mode, the UART only uses signal lines TxD and RxD. Data is transmitted unannounced, at the convenience of the sending device (e.g. when the Transmit FIFO contains some data). Data is also received unannounced and at the convenience of the sending device. This can cause problems and the loss of data - for example, if the receiving device has insufficient space in its Receive FIFO to accept the sent data.

6.2.2 4-wire Mode (with Flow Control) [UART0 Only]

In 4-wire mode, UART0 uses the signal lines TxD, RxD, RTS and CTS. This allows flow control to be implemented, which ensures that sent data can always be accepted. The general principle of flow control is described below.

The RTS and CTS lines are flags that are used to indicate when it is safe to transfer data between the devices. The RTS line on one device is connected to the CTS line on the other device.

The destination device dictates when the source device should send data to it, as follows:

- When the destination device is ready to receive data, it asserts its RTS line to request the source device to send data. This may be when the Receive FIFO fill-level on the destination device falls below a pre-defined level and the FIFO becomes able to receive more data.
- The assertion of the RTS line on the destination device is seen by the source device as the assertion of its CTS line. The source device is then able to send data from its Transmit FIFO.

Flow control operation is illustrated in Figure 6 below.

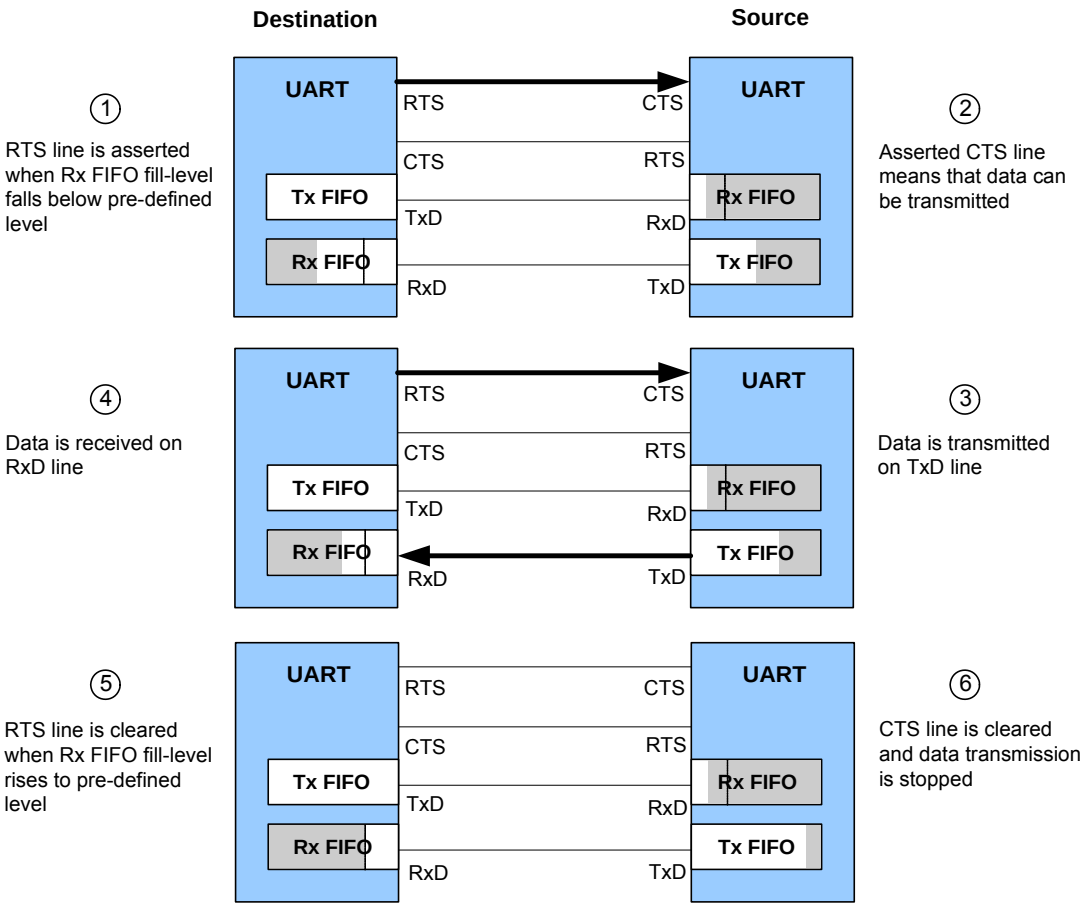


Figure 6: Example of UART Flow Control (UART0 Only)

The Integrated Peripherals API provides functions for controlling and monitoring the RTS/CTS lines, allowing the application to implement the flow control algorithm manually. In practice, manual flow control can be a burden for a busy CPU, particularly when the UART is operating at a high baud-rate. For this reason, the API provides an Automatic Flow Control option in which the state of the RTS line is controlled directly by the Receive FIFO fill-level on the destination device. The implementations of manual and automatic flow control using the functions of Integrated Peripherals API are described in Section 6.5.

6.2.3 1-Wire Mode [UART1 Only]

In 1-wire mode, UART1 uses the TxD line to transmit data unannounced, at the convenience of the sending device. In this mode, data is not received and the RxD line is unused (so the associated DIO pin is available for another purpose).

6.3 Configuring the UARTs

This section describes the various aspects of configuring a UART before using it to transfer serial data.

6.3.1 Enabling a UART

A UART is enabled using the function **bAHI_UartEnable()**, which enables UART0 in 4-wire mode or UART1 in 2-wire mode, by default. This must be the first UART function called, unless you wish to use the UART in its non-default mode:

- If you wish to use UART0 in 2-wire mode (without flow control), you will first need to call **vAHI_UartSetRTSCTS()** in order to release control of the DIOs used for the flow control RTS and CTS lines.
- If you wish to use UART1 in 1-wire mode (transmit only), you will first need to call **vAHI_UartTxOnly()** in order to release control of the pin used for RxD.

The function **bAHI_UartEnable()** also allows the FIFO buffers for the UART transmit and receive paths to be configured. Each buffer is defined by the application as a section of RAM, and the start address and size (in bytes) of each buffer must be specified. The maximum possible buffer size is 2047 bytes and the minimum possible buffer size is 16 bytes.

Note: The function **vAHI_UartEnable()** (returns void rather than boolean) is also available for backward compatibility with application code developed for the JN514x microcontrollers.

6.3.2 Setting the Baud-rate

The following functions are provided for setting the baud-rate of a UART:

- **vAHI_UartSetBaudRate()**

  This function allows one of the following standard baud-rates to be set: 4800, 9600, 19200, 38400, 76800 or 115200 bps.

- **vAHI_UartSetBaudDivisor()**

  This function allows a 16-bit integer divisor (*Divisor*) to be specified which will be used to derive the baud-rate from a 1MHz frequency, given by:

$$\frac{1 \times 10^6}{Divisor}$$

- **vAHI_UartSetClocksPerBit()**

  This function can be used to obtain a more refined baud-rate than can be achieved using **vAHI_UartSetBaudDivisor()** alone. The divisor from the latter function is used in conjunction with an 8-bit integer parameter (*Cpb*) from **vAHI_UartSetClocksPerBit()** to derive a baud-rate from the 16MHz peripheral clock, given by:

$$\frac{16 \times 10^6}{Divisor \times (Cpb + 1)}$$

  Based on the above formula, the highest recommended baud-rate that can be achieved is 4Mbps (*Divisor*=1, *Cpb*=3).

Note: Either **vAHI_UartSetBaudRate()** or **vAHI_UartSetBaudDivisor()** must be called, but not both. If used, **vAHI_UartSetClocksPerBit()** must be called after **vAHI_UartSetBaudDivisor()**.

6.3.3 Setting Other UART Properties

In addition to setting the baud-rate of a UART, as described in Section 6.3.2, it is also necessary to configure a number of other properties of the UART. These properties are set using the function **vAHI_UartSetControl()** and include the following:

- Parity checks can be optionally applied to the transferred data and the type of parity (odd or even) can be selected.
- The length of a word of data can be set to 5, 6, 7 or 8 bits - this is the number of bits per transmitted ‘character’ and should normally be set to 8 (a byte).
- The number of stop bits can be set to 1 or 1.5 / 2.
- The initial state of the RTS line can be configured (set or cleared) - this is only implemented if using UART0 in 4-wire mode (see Section 6.3.1).

6.3.4 Enabling Interrupts

UART interrupts can be generated under a variety of conditions. The interrupts can be enabled and configured using the function **vAHI_UartSetInterrupt()**. The possible interrupt conditions are as follows:

- **Transmit FIFO empty:** The Transmit FIFO has become empty (and therefore requires more data).
- **Receive data available:** The Receive FIFO has filled with data to a pre-defined level, which can be set to 1, 4, 8 or 14 bytes. This interrupt is cleared when the FIFO fill-level falls below the pre-defined level again.
- **Timeout:** This interrupt is enabled when the 'receive data available' interrupt is enabled and is generated if all the following conditions exist:
  - At least one character is in the FIFO.
  - No character has entered the FIFO during a time interval in which at least four characters could potentially have been received.
  - Nothing has been read from the FIFO during a time interval in which at least four characters could potentially have been read.

  A timeout interrupt is cleared and the timer is reset by reading a character from the Receive FIFO.
- **Receive line status:** An error condition has occurred on the RxD line, such as a break indication, framing error, parity error or over-run.
- **Modem status:** A change in the CTS line has been detected (for example, it has been asserted to indicate that the remote device is ready to accept data) in the case of UART0 operating 4-wire mode.

UART interrupts are handled by a callback function which must be registered using the function **vAHI_Uart0RegisterCallback()** or **vAHI_Uart1RegisterCallback()**, depending on the UART (0 or 1). For more information on UART interrupt handling, refer to Section 6.8.

6.4 Transferring Serial Data in 2-wire Mode

In 2-wire mode, a UART only uses signals RxD and TxD, and does not implement flow control. Data transmission and reception are covered separately below.

Note 1: For UART1, 2-wire mode is the default mode.

Note 2: In order to operate UART0 in 2-wire mode, the function **vAHI_UartSetRTSCTS()** must first be called to release control of the DIOs used for flow control. This function must be called before **vAHI_UartEnable()**.

6.4.1 Transmitting Data (2-wire Mode)

Data is transmitted via a UART by calling one of the following functions:

- **vAHI_UartWriteData()**: This function can be used to write a single byte of data to the Transmit FIFO. If used, this function may be called multiple times to queue data bytes for transmission.
- **u16AHI_UartBlockWriteData()**: This function is used to write a block of data bytes to the Transmit FIFO. The function will return the number of bytes that have been successfully written to the FIFO.

Once in the FIFO, a data byte starts to be transmitted as soon as it reaches the head of the FIFO (and provided that the TxD line is idle). The transfer of data from the FIFO to the TxD line is handled automatically by the DMA engine.

The following methods can be used to prompt the application to call the **vAHI_UartWriteData()** or **u16AHI_UartBlockWriteData()** function:

- The function **u16AHI_UartReadTxFifoLevel()** can be called to check the number of characters currently waiting in the Transmit FIFO (more data could then be written to the FIFO, if there is sufficient free space).
- The function **u16AHI_UartReadLineStatus()** can be used to check whether the Transmit FIFO is empty.
- An interrupt can be generated when the Transmit FIFO becomes empty (that is, when the last data byte in the FIFO starts to be transmitted) - this interrupt is enabled using the function **vAHI_UartSetInterrupt()**.
- A timer can be used to schedule periodic transmissions (provided that data is available to be transmitted).

6.4.2 Receiving Data (2-wire Mode)

Data is received on the RxD line as and when the source device sends it. The local transfer of data from the RxD line to the Receive FIFO is handled automatically by the DMA engine. The destination application can read data from the FIFO using one of the following functions:

- **u8AHI_UartReadData()**: This function can be used to read a single byte of data from the Receive FIFO.
- **u16AHI_UartBlockReadData()**: This function can be used to read a block of data bytes from the Receive FIFO.

The following methods can be used to prompt the application to call the **u8AHI_UartReadData()** or **u16AHI_UartBlockReadData()** function:

- The function **u16AHI_UartReadRxFifoLevel()** can be called to check the number of characters currently in the Receive FIFO.
- The function **u8AHI_UartReadLineStatus()** can be used to check whether the Receive FIFO contains data that can be read (or is empty).
- An interrupt can be generated when the Receive FIFO contains a certain number of data bytes - this interrupt is enabled using the function **vAHI_UartSetInterrupt()**, in which the trigger level for the interrupt must be specified as 1, 4, 8 or 14 bytes.
- A timer can be used to schedule periodic reads of the Receive FIFO. Before each timed read, the presence of data in the FIFO can be checked using either **u8AHI_UartReadLineStatus()** or **u16AHI_UartReadRxFifoLevel()**.

Note: When the 'receive data available' interrupt is enabled (described above), a 'timeout' interrupt is also enabled for the Receive FIFO. For more details of this interrupt, refer to Section 6.3.4.

6.5 Transferring Serial Data in 4-wire Mode (UART0 Only)

In 4-wire mode, UART0 uses the signals RTS and CTS to implement flow control (see Section 6.2.2), as well as RxD and TxD. Flow control can be implemented manually by the application or automatically. The implementation of manual flow control is described below for transmission and reception separately, and then automatic flow control is described.

Note 1: 4-wire mode is the default mode on UART0. Therefore, the UART will automatically have control of the DIOs used for the RTS and CTS lines as soon as **vAHI_UartEnable()** is called.

Note 2: 4-wire mode is not available on UART1.

6.5.1 Transmitting Data (4-wire Mode, Manual Flow Control)

In the flow control protocol, the source device should only transmit data when the destination device is ready to receive (see Section 6.5.2). The readiness of the destination device to accept data is indicated on the source device by its CTS line being asserted. The status of the CTS line can be monitored in either of the following ways:

- The source device can check the status of its CTS line using the function **u8AHI_UartReadModemStatus()**.
- An interrupt can be generated when a change in status of the CTS line occurs - this interrupt is enabled using the function **vAHI_UartSetInterrupt()**.

Once a change in the state of the CTS line (to asserted) has been detected, one of the following functions can be called:

- **vAHI_UartWriteData()**: This function can be used to write a single byte of data to the Transmit FIFO. If used, this function may be called multiple times to queue data bytes for transmission.
- **u16AHI_UartBlockReadData()**: This function can be used to read a block of data bytes from the Receive FIFO. The function will return the number of bytes that have been successfully written to the FIFO.

Once in the FIFO, a data byte starts to be transmitted as soon as it reaches the head of the FIFO (and provided that the TxD line is idle). The transfer of data from the FIFO to the TxD line is handled automatically by the DMA engine.

Note that before calling **vAHI_UartWriteData()** to write data to the Transmit FIFO, the application may check whether there is already data in the FIFO (left over from a previous transfer) using the function **u16AHI_UartReadTxFifoLevel()** or **u8AHI_UartReadLineStatus()**.

The CTS line is de-asserted when the RTS line is de-asserted on the destination device - see Section 6.5.2.

6.5.2 Receiving Data (4-wire Mode, Manual Flow Control)

In the flow control protocol, the destination device should only receive data when it is ready. This is normally when its Receive FIFO has sufficient free space to accept more data. The application can check the fill status of its Receive FIFO using the function **u16AHI_UartReadRxFifoLevel()** or **u8AHI_UartReadLineStatus()**.

Once the application on the destination device has decided that it is ready to receive data, it must request the data from the source device by asserting the RTS line (which asserts the CTS line on the source device - see Section 6.5.1). The RTS line can be asserted using the function **vAHI_UartSetRTS()** or **vAHI_UartSetControl()**.

The source device may then send data, which is received on the RxD line on the destination device. The local transfer of data from the RxD line to the Receive FIFO is handled automatically by the DMA engine. The received data can be read from the Receive FIFO using one of the following functions:

- **u8AHI_UartReadData()**: This function can be used to read a single byte of data from the Receive FIFO.
- **u16AHI_UartBlockReadData()**: This function can be used to read a block of data bytes from the Receive FIFO.

The application may subsequently make a decision to stop the transfer from the source device, which is achieved by de-asserting the RTS line using the function **vAHI_UartSetRTS()** or **vAHI_UartSetControl()**. This decision is based on the fill-level of the Receive FIFO - when the amount of data in the FIFO reaches a certain level, the application will start to read the data and may also stop the transfer if it cannot read from the FIFO quickly enough to prevent an overflow condition. The current fill-level of the Receive FIFO can be monitored using either of the following mechanisms:

- The function **u16AHI_UartReadRxFifoLevel()** can be called to check the number of data bytes currently in the Receive FIFO.
- A ‘receive data available’ interrupt can be generated when the number of data bytes in the Receive FIFO rises to a certain level - this interrupt is enabled using the function **vAHI_UartSetInterrupt()**, in which the trigger-level for the interrupt must be specified as 1, 4, 8 or 14 bytes.

Note: When the ‘receive data available’ interrupt is enabled (described above), a ‘timeout’ interrupt is also enabled for the Receive FIFO. For more details of this interrupt, refer to Section 6.3.4.

6.5.3 Automatic Flow Control (4-wire Mode)

Flow control can be implemented automatically in UART0 4-wire mode, rather than manually (as described in Section 6.5.1 and Section 6.5.2). Automatic flow control can be used on the destination device and/or on the source device:

- On the destination device, automatic flow control avoids the need for the application to monitor the Receive FIFO fill-level and to assert/de-assert the RTS line.
- On the source device, automatic flow control avoids the need for the application to monitor the CTS line before transmitting data.

Automatic flow control is configured and enabled using the function **vAHI_UartSetAutoFlowCtrl()** which, if used, must be called after enabling the UART and before starting the data transfer.

The **vAHI_UartSetAutoFlowCtrl()** function allows:

- A Receive FIFO trigger-level to be specified on the destination device (as 8, 11, 13 or 15 bytes), so that:
  - The local RTS line is asserted when the fill-level is below the trigger-level, indicating the readiness of the destination device to accept more data.
  - The local RTS line is de-asserted when the fill-level is at or above the trigger-level, indicating that the destination device is not in a position to accept more data.

  Thus, as the destination Receive FIFO fill-level rises and falls (as data is received and read), the local RTS line is automatically manipulated to control the arrival of further data from the source device.
- Automatic monitoring of the CTS line to be enabled on the source device - when this line is asserted, any data in the Transmit FIFO is transmitted automatically.

This function also allows the RTS/CTS signals to be configured as active-high or active-low.

Automatic flow control can be set up between the two devices either for data transfers in only one direction or for data transfers in both directions.

Although much of the data transfer is automatic, the application on the source device must write data into its Transmit FIFO and the application on the destination device must read data from its Receive FIFO. These operations are described below.

Transmitting Data

To transmit data, the sending application can use one of the following functions:

- **vAHI_UartWriteData()**: This function can be used to write a single byte of data to the Transmit FIFO. If used, this function may be called multiple times to queue data bytes for transmission.
- **u16AHI_UartBlockReadData()**: This function can be used to read a block of data bytes from the Receive FIFO. The function will return the number of bytes that have been successfully written to the FIFO.

Once in the FIFO, the data is automatically transmitted (via the TxD line) as soon as the CTS line indicates that the destination device is ready to receive. The transfer of data from the FIFO to the TxD line is handled automatically by the DMA engine.

Note that before calling **vAHI_UartWriteData()** or **u16AHI_UartBlockReadData()** to write data to the Transmit FIFO, the application may check whether there is already data in the FIFO (left over from a previous transfer) using the function **u8AHI_UartReadTxFifoLevel()** or **u8AHI_UartReadLineStatus()**.

Receiving Data

Data is received on the RxD line on the destination device. The local transfer of data from the RxD line to the Receive FIFO is handled automatically by the DMA engine. The received data can be read from the Receive FIFO using one of the following functions:

- **u8AHI_UartReadData()**: This function can be used to read a single byte of data from the Receive FIFO.
- **u16AHI_UartBlockReadData()**: This function can be used to read a block of data bytes from the Receive FIFO.

The application can decide when to start and stop reading data from the Receive FIFO, based on either of the following mechanisms:

- The function **u16AHI_UartReadRxFifoLevel()** can be called to check the number of characters currently in the Receive FIFO. Thus, the application may decide to start reading data when the FIFO fill-level is at or above a certain threshold. It may decide to stop reading data when the FIFO fill-level is at or below another threshold, or when the FIFO is empty.
- A ‘receive data available’ interrupt can be generated when the Receive FIFO contains a certain number of data bytes - this interrupt is enabled using the function **vAHI_UartSetInterrupt()**, in which the trigger-level for the interrupt must be specified as 1, 4, 8 or 14 bytes. Thus, the application may decide to start reading data from the Receive FIFO when this interrupt occurs and to stop reading data when all the received bytes have been extracted from the FIFO.

Note: When the ‘receive data available’ interrupt is enabled (described above), a ‘timeout’ interrupt is also enabled for the Receive FIFO. For more details of this interrupt, refer to Section 6.3.4.

6.6 Transmitting Serial Data in 1-wire Mode (UART1 Only)

In 1-wire mode, UART1 uses only the TxD line and can only transmit serial data. This transmission is performed at the convenience of the sending device (so no flow control is implemented).

For this mode, the function **vAHI_UartTxOnly()** must be called to release control of the pin used for RxD before the UART is enabled using **bAHI_UartEnable()**. Since the RxD line is not used and the Receive FIFO buffer is therefore not needed, in **bAHI_UartEnable()** you are advised to set the pointer to the start of this buffer in RAM to NULL - this avoids allocating RAM space to this buffer.

6.7 Break Condition

During a data transfer, if the application on this source device becomes aware of an error, it can convey this error status to the destination device by setting a break condition using the function **vAHI_UartSetBreak()**. When this break condition is issued, the data byte that is currently being transmitted is corrupted and the transmission is stopped.

If a JN516x device receives a break condition (as the destination device), this results in a 'receive line status' interrupt (E_AHI_UART_INT_RXLINE) being generated on the device, provided that UART interrupts are enabled on this device. UART interrupts are described in Section 6.3.4 and UART interrupt handling in Section 6.8.

The **vAHI_UartSetBreak()** function can also be used to clear the break condition (from the source device). In this case, the transmission will restart in order to transfer the data remaining in the Transmit FIFO.

6.8 UART Interrupt Handling

Interrupts can be employed in a number of ways in controlling UART operation. The various uses of UART interrupts are introduced in Section 6.3.4 and are further covered in the sections on transferring data (Section 6.4 and Section 6.5).

UART interrupts are handled by a user-defined callback function, which must be registered using **vAHI_Uart0RegisterCallback()** or **vAHI_Uart1RegisterCallback()**, depending on the UART (0 or 1). The relevant callback function is automatically invoked when an interrupt of the type E_AHI_DEVICE_UART0 (for UART 0) or E_AHI_DEVICE_UART1 (for UART 1) occurs. For details of the callback function prototype, refer to Appendix A.1.

Caution: *The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling* ***u32AHI_Init()*** *on waking.*

The exact nature of the UART interrupt (from those listed in Section 6.3.4) can then be identified from an enumeration that is passed into the callback function. For details of these enumerations, refer to Appendix B.2.

Note that the handling of UART interrupts differs from the handling of other interrupts in the following ways:

- The exact cause of an interrupt is normally indicated to the callback function by means of a bitmap, but not in the case of a UART interrupt - instead, an enumeration is used to indicate the nature of a UART interrupt. The reported enumeration corresponds to the currently active interrupt condition with the highest priority.
- An interrupt is normally automatically cleared before the callback function is invoked, but the UARTs are the exception to this rule. When generating a 'receive data available' or 'timeout' interrupt, the UART will only clear the interrupt once the data has been read from the Receive FIFO. It is therefore vital that the callback function handles the UART 'receive data available' and 'timeout' interrupts by reading the data from the Receive FIFO before returning.

Note: If the Application Queue API is being used, the above issue with the UART interrupts is handled by this API, so the application does not need to deal with it. For more information on this API, refer to the *Application Queue API Reference Manual (JN-RM-2025)*.

7. Timers

This chapter describes control of the on-chip timers using functions of the Integrated Peripherals API. On the JN516x device, there are five timers: Timer 0, Timer 1, Timer 2, Timer 3 and Timer 4.

Note: These timers are distinct from the wake timers described in Chapter 8 and tick timer described in Chapter 9.

The timers offer a range of operating modes:

- Timer mode
- Pulse Width Modulation (PWM) mode
- Counter mode
- Capture mode
- Delta-Sigma mode

However, not all the timers can operate in all modes. Timers 1-4 do not support modes that require external inputs - these are Counter mode and Capture mode. The timer modes are outlined in Section 7.1.

To use a timer in one of the above modes:

1. First refer to Section 7.2 on setting up a timer.
2. Then refer to Section 7.3 on operating a timer (you should refer to the sub-section which corresponds to your chosen mode of operation).

For information on Timer interrupts, refer to Section 7.4.

7.1 Modes of Timer Operation

The following timer modes are available on the JN516x microcontrollers: Timer, Pulse Width Modulation (PWM), Counter, Capture and Delta-Sigma. These modes are summarised in the table below, along with the functions needed for each mode (following a call to **vAHI_TimerEnable()**). A mode is supported by all JN516x timers unless otherwise stated.

Mode	Description	Functions
Timer	The source clock is used to produce a pulse cycle defined by the number of clock cycles until a positive pulse edge and until a negative pulse edge. Interrupts can be generated on either or both edges. The pulse cycle can be produced just once in 'single-shot' mode or continuously in 'repeat' mode. Timer mode is described further in Section 7.3.1.	**vAHI_TimerConfigureOutputs()** **vAHI_TimerStartSingleShot()** or **vAHI_TimerStartRepeat()**
PWM	As for Timer mode, except the Pulse Width Modulated signal is output on a DIO pin (which depends on the specific timer used - see Section 7.2.1). PWM mode is described further in Section 7.3.1.	**vAHI_TimerConfigureOutputs()** **vAHI_TimerStartSingleShot()** or **vAHI_TimerStartRepeat()**
Counter	The timer is used to count edges on an external input signal, selected as an external clock input. The timer can count just rising edges or both rising and falling edges. Counter mode is described further in Section 7.3.4. **Supported by Timer 0 but not by Timers 1-4**	**vAHI_TimerClockSelect()** **vAHI_TimerConfigureInputs()** **vAHI_TimerStartSingleShot()** or **vAHI_TimerStartRepeat()** **u16AHI_TimerReadCount()**
Capture	An external input signal is sampled on every tick of the source clock. The results of the capture allow the period and pulse width of the sampled signal to be calculated. If required, the results can be read without stopping the timer. Capture mode is described further in Section 7.3.3. **Supported by Timer 0 but not by Timers 1-4**	**vAHI_TimerConfigureInputs()** **vAHI_TimerStartCapture()** **vAHI_TimerReadCapture()** or **vAHI_TimerReadCaptureFreeRunning()**
Delta-Sigma	The timer is used as a low-rate DAC. The converted signal is output on a DIO pin (which depends on the specific timer used - see Section 7.2.1) and requires simple filtering to give the analogue signal. Delta-Sigma mode is available in two options, NRZ and RTZ, and is described further in Section 7.3.2.	**vAHI_TimerStartDeltaSigma()**

Table 2: Modes of Timer Operation

7.2 Setting up a Timer

This section describes how to use the Integrated Peripherals API functions to set up a timer before the timer is started (starting and operating a timer are described in Section 7.3).

7.2.1 Selecting DIOs

The timers may use certain DIO pins, as indicated in the table below

Timer 0 DIO *	Timer 1 DIO *	Timer 2 DIO *	Timer 3 DIO *	Timer 4 DIO *	Function
8	Not Applicable**	Not Applicable**	Not Applicable**	Not Applicable**	Clock or gate input (used in Counter mode)
9	Not Applicable**	Not Applicable**	Not Applicable**	Not Applicable**	Capture mode input
10	11	12	13	17	PWM and Delta-Sigma mode output

Table 3: DIO Usage with JN516x Timers

* **vAHI_TimerSetLocation()** can be used to move the Timer 0 signals from DIO8-10 to DIO2-4 or to move the Timer 1-4 signals from DIO11-13 and 17 to DIO5-8. Alternatively, this function can be used to put the Timer 2 and 3 signals on DO0 and DO1 (Digital Outputs) respectively.

** Timers 1-4 have no inputs

By default, a DIO pin associated with an enabled timer is reserved for use by the timer but becomes available for General Purpose Input/Output (GPIO) when the timer is disabled. The DIO pin(s) assigned to a timer can also be released for GPIO use by calling the function **vAHI_TimerDIOControl()**. Alternatively, the function **vAHI_TimerFineGrainDIOControl()** can be used to configure the DIO usage for all the timers at the same time - this function can also be used to individually release the three DIO pins associated with Timer 0.

***Caution:** The above DIO configuration should be performed before a timer is enabled using **vAHI_TimerEnable()**, in order to avoid glitching on the GPIOs during timer operation.*

7.2.2 Enabling a Timer

Before a timer can be started, it must be configured and enabled using the function **vAHI_TimerEnable()**.

Caution: *You must enable a timer before attempting any other operation on it, otherwise an exception may result.*

The **vAHI_TimerEnable()** function contains certain configuration parameters, which are outlined below.

- **Clock Divisor:**

  To obtain the timer frequency, the peripheral clock is divided by a factor of $2^{prescale}$, where *prescale* is a user-configurable integer value in the range 0 to 16 (note that the value 0 leaves the clock frequency unchanged). For example, for a 16MHz peripheral clock and a *prescale* value of 3, a division factor of 8 is used to give a timer frequency of 2MHz. A system clock sourced from the external crystal oscillator will give the most stable timer frequency (for system clock options, refer to Section 3.1).

- **Interrupts:**

  Each timer can be configured to generate interrupts on either or both of the following conditions:

  - On the rising edge of the timer output (at end of low period)
  - On the falling edge of the timer output (at the end of full timer period)

  Timer interrupts are further described in Section 7.4.

- **External Output:**

  The timer signal can be output externally, but this output must be explicitly enabled. This output is required for Delta-Sigma mode and PWM mode. It is this option which distinguishes between Timer mode (output disabled) and PWM mode (output enabled). The DIO pin on which the timer signal is output depends on the device type:

  - For Timer 0, DIO10 is used
  - For Timer 1, DIO11 is used
  - For Timer 2, DIO12 is used
  - For Timer 3, DIO13 is used
  - For Timer 4, DIO17 is used

Once a timer has been enabled using **vAHI_TimerEnable()**, an external clock input can be selected (if required - see Section 7.2.3) and then the timer can be started in the desired mode using the relevant start function (see Section 7.3.1 to Section 7.3.4).

Note: An enabled timer can be disabled using the function **vAHI_TimerDisable()**. This stops the timer (if running) and powers down the timer block - this is useful to reduce power consumption when the timer is not needed. The application must not attempt to access a disabled timer, otherwise an exception may occur.

7.2.3 Selecting Clocks

Each timer requires a source clock, which is provided by the peripheral clock. This source clock is divided down to produce the timer's clock. The division factor is specified when the timer is enabled using **vAHI_TimerEnable()** - see Section 7.2.2. A system clock sourced from the external crystal oscillator gives the most stable timer frequency (for system clock options, refer to Section 3.1).

When Timer 0 is operating in Counter mode (see Section 7.3.4), an external clock is monitored by the timer. This signal is input on the DIO8 pin and this input must be enabled using the function **vAHI_TimerClockSelect()**, which must be called after **vAHI_TimerEnable()**.

7.3 Starting and Operating a Timer

This section describes how to use the Integrated Peripherals API functions to start and operate a timer that has been set up as described in Section 7.2. A timer can be started in the following modes:

- Timer or PWM mode - see Section 7.3.1
- Delta-Sigma mode - see Section 7.3.2
- Capture mode (Timer 0 only) - see Section 7.3.3
- Counter mode (Timer 0 only) - see Section 7.3.4

7.3.1 Timer and PWM Modes

Timer mode allows a timer to produce a rectangular waveform of a specified period, where this waveform starts low and then goes high after a specified time. These times are specified when the timer is started (see below), in terms of the following parameters:

- **Time to rise (*u16Hi*):** This is the number of clock cycles between starting the timer and the (first) low-to-high transition. An interrupt can be generated at this transition.
- **Time to fall (*u16Lo*):** This is the number of clock cycles between starting the timer and the (first) high-to-low transition (effectively the period of one pulse cycle). An interrupt can be generated at this transition.

These times and the timer signal are illustrated below in Figure 7.

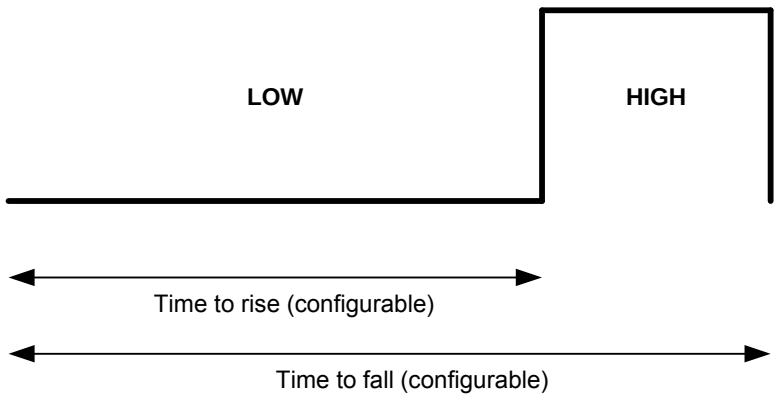


Figure 7: Timer Mode Signal

Within Timer mode, there are two sub-modes and the timer is started in these modes using different functions:

- **Single-shot mode:** The timer produces a single pulse cycle (as depicted in Figure 7) and then stops. The timer can be started in this mode using **vAHI_TimerStartSingleShot()**.
- **Repeat mode:** The timer produces a train of pulses (where the repetition rate is determined by the configured 'time to fall' period - see above). The timer can be started in this mode using **vAHI_TimerStartRepeat()**.

Once started, the timer can be stopped using the function **vAHI_TimerStop()**.

PWM (Pulse Width Modulation) mode is identical to Timer mode except the produced waveform is output on a DIO pin - see Section 7.2.1 for the relevant DIOs. This output can be enabled in **vAHI_TimerEnable()**. The output can also be inverted using the function **vAHI_TimerConfigureOutputs()**.

7.3.2 Delta-Sigma Mode (NRZ and RTZ)

Delta-Sigma mode allows a timer to be used as a simple low-rate DAC. This requires the timer output on a DIO pin to be enabled in the call to **vAHI_TimerEnable()** - see Section 7.2.1 for the relevant DIOs. An RC (Resistor-Capacitor) circuit must be inserted between this pin and Ground (see Figure 8).

A timer is started in Delta-Sigma mode using **vAHI_TimerStartDeltaSigma()**. The value to be converted is digitally encoded by the timer as a pseudo-random waveform in which:

- the total number of clock cycles that make up one period of the waveform is fixed (at 2^{16} for NRZ and at 2^{17} for RTZ - see below)
- the number of high clock cycles during one period is set to a number which is proportional to the value to be converted
- the high clock cycles are distributed randomly throughout a complete period

Thus, the capacitor will charge in proportion to the specified value such that, at the end of the period, the voltage produced is an analogue representation of the digital value. The output voltage requires calibration - for example, you could determine the maximum possible voltage by measuring the voltage across the capacitor after a conversion with the high period set to the whole pulse period (less one clock cycle).

Two Delta-Sigma mode options are available, NRZ and RTZ:

- **NRZ (Non Return-to-Zero):** Delta-Sigma NRZ mode uses the 16MHz peripheral clock and the period of the waveform is fixed at 2^{16} clock cycles. The NRZ option means that clock cycles are implemented without gaps between them (see RTZ option below). You must define the number of clock cycles spent in the high state during the pulse cycle such that this high period is proportional to the value to be converted. This number is set when the timer is started using the function **vAHI_TimerStartDeltaSigma()**. For example, if you wish to convert values in the range 0-100 then 2^{16} clock cycles would correspond to 100, and to convert the value 25 you must set the number of high

clock cycles to 2^{14} (a quarter of the pulse cycle). For an illustration, refer to Figure 8.

- **RTZ (Return-to-Zero):** Delta-Sigma RTZ mode is similar to the NRZ option, described above, except that after every clock cycle, a blank (low) clock cycle is inserted. Thus, each pulse cycle takes twice as many clock cycles - that is, 2^{17}. Note that this does not affect the required number of high clock cycles to represent the digital value being converted. This mode doubles the conversion period but improves linearity if the rise and fall times of the outputs are different from each other.

Note: For more information on 'Delta-Sigma' mode, refer to the data sheet for your microcontroller.

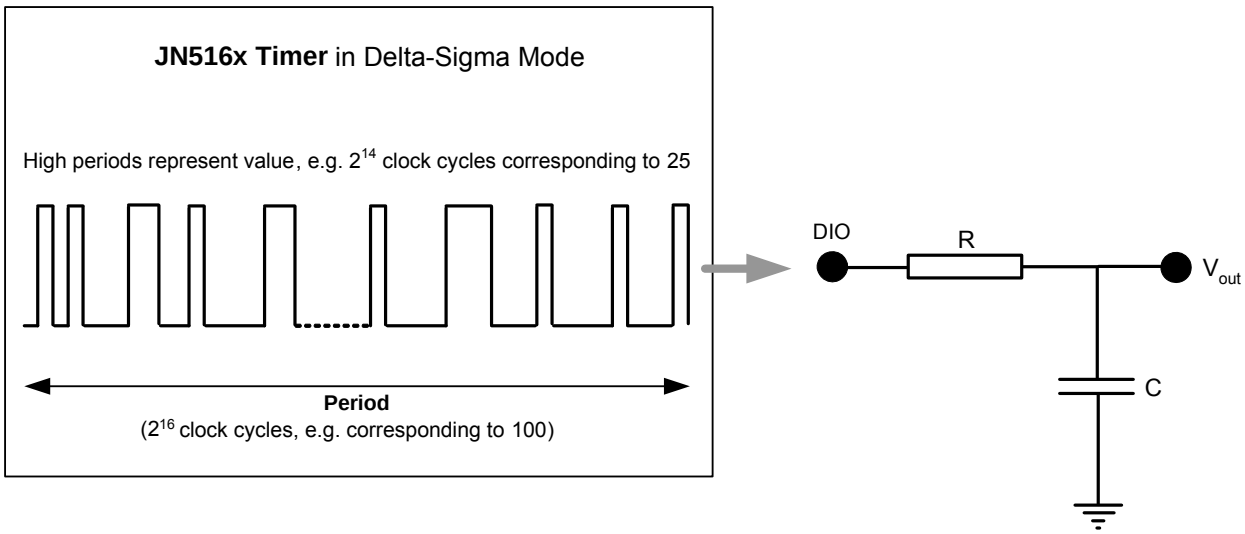


Figure 8: Delta-Sigma NRZ Mode Operation

7.3.3 Capture Mode

Capture mode is available on Timer 0 only (and not on Timers 1-4). In this mode, the timer can be used to measure the pulse width of an external input. The external signal must be provided on a DIO pin - see Section 7.2.1 for the relevant DIOs. The timer measures the number of clock cycles in the input signal from the start of capture to the next low-to-high transition and also to next the high-to-low transition. The number of clock cycles in the last pulse is then the difference between these measured values (see Figure 9). The pulse width in units of time is then given by:

Pulse width (in units of time) = Number of clock cycles in pulse X Clock cycle period

A timer is started in Capture mode using the function **vAHI_TimerStartCapture()**. The timer can be stopped and the most recent measurements obtained using the function

vAHI_TimerReadCapture(). These measurements can alternatively be obtained without stopping the timer by calling **vAHI_TimerReadCaptureFreeRunning()**.

Note: Only the measurements for the last low-to-high and high-to-low transitions are stored, and then returned when the above 'read capture' functions are called. Therefore, it is important not to call these functions during a pulse, as in this case the measurements will not give sensible results. To ensure that you obtain the capture results after a pulse has completed, you should enable interrupts on the falling edge when the timer is configured using **vAHI_TimerEnable()**.

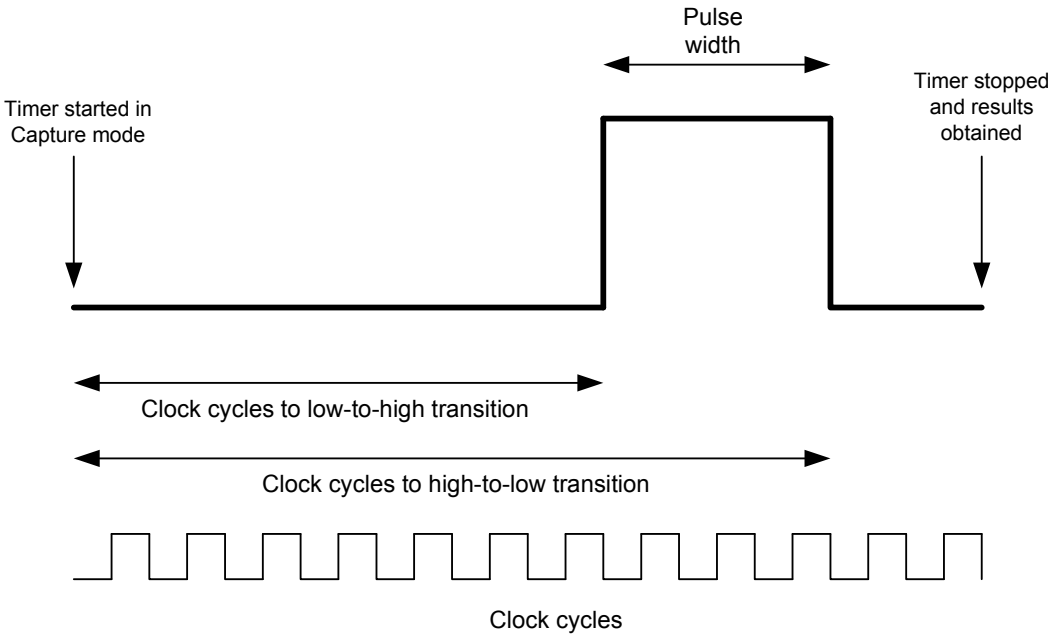


Figure 9: Capture Mode Operation

The input signal for Capture mode can be inverted. This option is configured using the function **vAHI_TimerConfigureInputs()** and allows the low-pulse width (instead of the high-pulse width) of the input signal to be measured.

7.3.4 Counter Mode

Counter mode is available on Timer 0 only (and not on Timers 1-4). In this mode, the timer counts edges on an external clock signal, which must be provided on a DIO pin - see Section 7.2.1 for the relevant DIOs. Counter mode is enabled by selecting an external clock input in a call to **vAHI_TimerClockSelect()**.

The timer can count rising edges only or both rising and falling edges. This must be configured using the function **vAHI_TimerConfigureInputs()**. Edges must be at least 100ns apart, i.e. pulses must be wider than 100ns.

Like Timer/PWM mode, the timer can then be started in one of two sub-modes:

- **Single-shot mode:** The timer can be started in this mode using the function **vAHI_TimerStartSingleShot()** and will stop at a specified count value (*u16Lo*).
- **Repeat mode:** The timer can be started in this mode using the function **vAHI_TimerStartRepeat()**. The timer operates continuously and the counter resets to zero each time the specified count value (*u16Lo*) is reached.

The above start functions each allow two counts to be specified at which interrupts will be generated (timer interrupts must also have been enabled in **vAHI_TimerEnable()**).

The current count of a running timer can be obtained at any time using the function **u16AHI_TimerReadCount()**. The timer can be stopped using **vAHI_TimerStop()**.

7.4 Timer Interrupts

A timer can be configured in **vAHI_TimerEnable()** to generate interrupts on either or both of the following conditions:

- On the rising edge of the timer output (at end of low period)
- On the falling edge of the timer output (at the end of full timer period)

The handling of timer interrupts must be incorporated in a user-defined callback function for the particular timer. These callback functions are registered using dedicated registration functions for the individual timers:

- **vAHI_Timer0RegisterCallback()** for Timer 0
- **vAHI_Timer1RegisterCallback()** for Timer 1
- **vAHI_Timer2RegisterCallback()** for Timer 2
- **vAHI_Timer3RegisterCallback()** for Timer 3
- **vAHI_Timer4RegisterCallback()** for Timer 4

The relevant callback function is automatically invoked when an interrupt of the type E_AHI_DEVICE_TIMER0, E_AHI_DEVICE_TIMER1, E_AHI_DEVICE_TIMER2, E_AHI_DEVICE_TIMER3 or E_AHI_DEVICE_TIMER4 occurs. The exact nature of the interrupt (from the two conditions listed above) can then be identified from a bitmap that is passed into the function. Note that the interrupt will be automatically cleared before the callback function is invoked.

Note: The callback function prototype is detailed in Appendix A.1. The interrupt source information is provided in Appendix B.

***Caution:** A registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.*

8. Wake Timers

This chapter describes control of the on-chip wake timers using functions of the Integrated Peripherals API.

The JN516x microcontroller includes two wake timers, denoted Wake Timer 0 and Wake Timer 1, where each is a 41-bit counter. The wake timers are based on the 32kHz clock (which can be sourced internally or externally, as described in Section 3.1.4) and can run while the device is in sleep mode (and while the CPU is running). They are generally used to time the sleep duration and wake the device at the end of the sleep period. A wake timer counts down from a programmed value and wakes the device when the count reaches zero by generating an interrupt or wake-up event.

8.1 Using a Wake Timer

This section describes how to use the Integrated Peripherals API functions to operate a wake timer.

8.1.1 Enabling and Starting a Wake Timer

A wake timer is enabled using the function **vAHI_WakeTimerEnable()**. This function allows the interrupt to be enabled/disabled that is generated when the counter reaches zero. Note that wake timer interrupts are handled by the callback function registered using the function **vAHI_SysCtrlRegisterCallback()** - see Section 3.5.

A wake timer can then be started using the function **vAHI_WakeTimerStartLarge()**. This function takes as a parameter the starting value for the countdown - this value must be specified in 32kHz clock periods (thus, 32 corresponds to 1 millisecond).

On reaching zero, the timer ‘fires’, rolls over to 0x1FFFFFFFFF and continues to count down. If enabled, the wake timer interrupt is generated on reaching zero.

Note: If the 32kHz clock is sourced from the (default) internal 32kHz RC oscillator, the wake timers may run up to 18% fast or slow. For more accurate timings, you are advised to first calibrate the clock and adjust the specified count value accordingly, as described in Section 8.2.

8.1.2 Stopping a Wake Timer

A wake timer can be stopped at any time using the function **vAHI_WakeTimerStop()**. The counter will then remain at the value at which it was stopped and will not generate an interrupt.

8.1.3 Reading a Wake Timer

The current count of a wake timer can be obtained using the function **u64AHI_WakeTimerReadLarge()**. This function does not stop the wake timer.

8.1.4 Obtaining Wake Timer Status

The states of the wake timers can be obtained using the following functions:

- **u8AHI_WakeTimerStatus()** can be used to find out which wake timers are currently running.
- **u8AHI_WakeTimerFiredStatus()** can be used to find out which wake timers have fired (passed zero). The 'fired' status of a wake timer is also cleared by this function.

Note 1: If using **u8AHI_WakeTimerFiredStatus()** to check whether a wake timer caused a wake-up event, you must call this function before **u32AHI_Init()**.

Note 2: If using the JenNet protocol, do not call **u8AHI_WakeTimerFiredStatus()** to obtain the wake timer interrupt status on waking from sleep. At wake-up, JenNet calls **u32AHI_Init()** internally and clears the interrupt status before passing control to the application. The System Controller callback function must be used to obtain the interrupt status, if required.

8.2 Clock Calibration

The wake timers are driven by the JN516x microcontroller's 32kHz clock. If this clock is sourced from the internal 32kHz RC oscillator, it may run up to 18% fast or slow, depending on temperature, supply voltage and manufacturing tolerance. To achieve more accurate timings in this case, the self-calibration facility should be used that compares the 32kHz clock against the faster and more accurate peripheral clock, which should be running at 16MHz with the system clock sourced from the external crystal oscillator (for system clock information, refer to Section 3.1). This test is performed using Wake Timer 0. The result of this calibration allows you to calculate the required number of 32kHz clock cycles to achieve the desired timer duration when starting a wake timer with the function **vAHI_WakeTimerStart()** or **vAHI_WakeTimerStartLarge()**.

The calibration is performed using the function **u32AHI_WakeTimerCalibrate()**, as described below.

1. Wake Timer 0 must be disabled (using **vAHI_WakeTimerStop()**, if required).
2. The status of both wake timers (0 and 1) must be cleared by calling the function **u8AHI_WakeTimerFiredStatus()**.
3. The calibration is started using **u32AHI_WakeTimerCalibrate()**.

   This causes Wake Timer 0 to start counting down 20 clock periods of the internal 32kHz clock. At the same time, a reference counter starts counting up from zero using the 16MHz peripheral clock.
4. When the wake timer reaches zero, **u32AHI_WakeTimerCalibrate()** returns the number of 16MHz clock cycles registered by the reference counter. Let this value be *n*.
   - If the clock is running at 32kHz, *n* = 10000
   - If the clock is running slower than 32kHz, *n* > 10000
   - If the clock is running faster than 32kHz, *n* < 10000
5. You can then calculate the required number of 32kHz clock periods (for **vAHI_WakeTimerStart()** or **vAHI_WakeTimerStartLarge()**) to achieve the desired timer duration. If *T* is the required duration in seconds, the appropriate number of 32kHz clock periods, *N*, is given by:

$$N = \left(\frac{10000}{n}\right) \times 32000 \times T$$

   For example, if a value of 9000 is obtained for *n*, this means that the 32kHz clock is running fast. Therefore, to achieve a 2 second timer duration, instead of requiring 64000 clock periods, you will need (10000/9000) x 32000 x 2 clock periods; that is, 71111 (rounded down).

Tip: To ensure that the device wakes in time for a scheduled event, it is better to under-estimate the required number of 32kHz clock periods than to over-estimate them.

9. Tick Timer

This chapter describes control of the Tick Timer using functions of the Integrated Peripherals API.

The Tick Timer is a hardware timer derived from the peripheral clock and can be used to implement:

- timing interrupts to software
- regular events, such as ticks for software timers or an operating system
- a high-precision timing reference
- system monitor timeouts, as used in a watchdog timer

Note: For high-precision Tick Timer operation, the peripheral clock should run at 16MHz with the system clock sourced from the external crystal oscillator. For system clock information, refer to Section 3.1.

9.1 Tick Timer Operation

The Tick Timer counts upwards until the count matches a pre-defined reference value (the starting value can be specified). The timer can be operated in one of three modes, which determine what the timer will do once the reference count has been reached. The options are:

- Continue counting upwards
- Restart the count from zero
- Stop counting (single-shot mode)

An interrupt can also be enabled which is generated on reaching the reference count.

9.2 Using the Tick Timer

This section describes how to use the Integrated Peripherals API functions to set up and run the Tick Timer.

9.2.1 Setting Up the Tick Timer

On device power-up/reset, the Tick Timer is disabled. However, before setting up the Tick Timer, you are advised to call the function **vAHI_TickTimerConfigure()** and specify the disable option. The starting count and reference count can then be set as follows:

1. The starting count is set (in the range 0 to 0xFFFFFFFF) using the function **vAHI_TickTimerWrite()**. Note that if this function is called while the timer is enabled, the timer will immediately start counting from the specified value.
2. The reference count is set (in the range 0 to 0x0FFFFFFF) using the function **vAHI_TickTimerInterval()**.

9.2.2 Running the Tick Timer

Once the timer has been set up (as described in Section 9.2.1), it can be started by calling the function **vAHI_TickTimerConfigure()** again but, this time, specifying one of the three operational modes listed in Section 9.1.

The current count of the Tick Timer can be obtained at any time by calling the function **u32AHI_TickTimerRead()**.

Note that if the Tick Timer is started in single-shot mode, once it has stopped (on reaching the reference count), it can be started again simply by setting another starting value using **vAHI_TickTimerWrite()**.

9.3 Tick Timer Interrupts

An interrupt can be enabled that will be generated when the Tick Timer reaches its reference count. This interrupt is enabled using the function **vAHI_TickTimerIntEnable()**.

The Tick Timer interrupt is handled by a user-defined callback function which is registered using the function **vAHI_TickTimerRegisterCallback()**.

The registered callback function is automatically invoked when an interrupt of the type E_AHI_DEVICE_TICK_TIMER occurs. For details of the callback function prototype, refer to Appendix A.1.

Caution: *The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling* ***u32AHI_Init()*** *on waking.*

The following functions are also provided to deal with the status of the Tick Timer interrupt:

- **bAHI_TickTimerIntStatus()** obtains the current interrupt status of the Tick Timer.
- **vAHI_TickTimerIntPendClr()** clears a pending Tick Timer interrupt.

10. Watchdog Timer

This chapter describes control of the Watchdog Timer on the JN516x device using functions of the Integrated Peripherals API.

The Watchdog Timer is provided to allow the JN516x device to recover from software lock-ups. Note that a watchdog can also be implemented using the Tick Timer, described in Chapter 9.

10.1 Watchdog Operation

The Watchdog Timer implements a timeout period and is derived from the internal high-speed RC oscillator (which runs at 27MHz or 32MHz).

On reaching the timeout period, the JN516x device is automatically reset. Therefore, to avoid a chip reset, the application must regularly reset the Watchdog Timer (to the start of the timeout period) in order to prevent the timer from expiring and to indicate that the application still has control of the JN516x device. If the timer is allowed to expire, the assumption is that the application has lost control of the chip and, thus, a hardware reset of the chip is automatically initiated.

Note that the Watchdog Timer continues to run during Doze mode but not during Sleep or Deep Sleep mode, or when the hardware debugger has taken control of the CPU (it will, however, automatically restart when the debugger un-stalls the CPU).

Note 1: Following a power-up, reset or wake-up from sleep, the Watchdog Timer is enabled with the maximum possible timeout period of 16392ms (regardless of its state before any sleep or reset).

Note 2: The Watchdog Timer can be configured to invoke an exception on timeout. This allows debugging of the situation that led to the timeout during application development. For more information, refer to Section 10.2.3.

10.2 Using the Watchdog Timer

This section describes how to use the Integrated Peripherals API functions to start and reset the Watchdog Timer.

10.2.1 Starting the Timer

The Watchdog Timer is started by default on the JN516x device. It is started with the maximum possible timeout of 16392ms.

- If the Watchdog Timer is required with a shorter timeout period, the timer must be restarted with the desired period. To do this, first call the function **vAHI_WatchdogRestart()** to restart the timer from the beginning of the timeout period and then call the function **vAHI_WatchdogStart()** to specify the new timeout period (see below).
- If the Watchdog Timer is not required in the application, call the function **vAHI_WatchdogStop()** at the start of your code to stop the timer.

In the function **vAHI_WatchdogStart()**, the timeout period must be specified via an index, *Prescale* (in the range 0 to 12), which the function uses to calculate the timeout period, in milliseconds, according to the following formulae:

Timeout Period = 8ms if *Prescale* = 0

Timeout Period = $[2^{(Prescale - 1)} + 1] \times 8ms$ if $1 \leq Prescale \leq 12$

This gives timeout periods in the range 8 to 16392ms.

Note that if the Watchdog Timer is sourced from an internal RC oscillator, the actual timeout period obtained may be up to 18% less than the calculated value due to variations in the oscillator.

Note: If called while the Watchdog Timer is in a stopped state, **vAHI_WatchdogStart()** will start the timer with the specified timeout period. If this function is called while the timer is running, the timer will continue to run but with the newly specified timeout period.

***Caution:** Be sure to set the Watchdog timeout period to be greater than the worst-case Flash memory read-write cycle. If the Watchdog times out during a Flash memory access, the JN516x microcontroller will enter programming mode. For information on read-write cycle times, refer to the relevant Flash memory data sheet.*

The current count of a running Watchdog Timer can be obtained using the function **u16AHI_WatchdogReadValue()**.

10.2.2 Resetting the Timer

A running Watchdog Timer should be reset by the application before the pre-set timeout period is reached. This is done using the function **vAHI_WatchdogRestart()**, which restarts the timer from the beginning of the timeout period. When applying this reset, the application should take into account the fact that the true timeout period may be up to 18% shorter than the calculated timeout period (if the timer is sourced from an internal RC oscillator - see Section 10.2.1).

If the application fails to prevent a Watchdog timeout, the chip will be automatically reset. The function **bAHI_WatchdogResetEvent()** can be used following a chip reset to find out whether the last hardware reset was caused by a Watchdog Timer expiry event.

Note that it is also possible to stop the Watchdog Timer and freeze its count by using the function **vAHI_WatchdogStop()**.

10.2.3 Exception Handler for Debug

By default, the expiry of the Watchdog Timer will cause a reset of the JN516x device. Alternatively, an exception can be invoked on expiry of the timer. The exception is serviced by the stack overflow exception handler, which can call the function **bAHI_WatchdogResetEvent()** to determine if a Watchdog exception occurred. This may help to debug the situation which led to the Watchdog timeout. Therefore, this option is designed for use only during application development.

The exception option is enabled by calling the function **vAHI_WatchdogException()**. The stack overflow exception handler function should be developed before enabling the Watchdog exception option.

Note: The stack overflow exception handler function should have the following prototype definition:

PUBLIC void vException_StackOverflow(void);

We would not expect an exception handler written in C to return - once it has performed any actions, it should either sit in a loop or reset the device.

11. Pulse Counters

This chapter describes control of the pulse counters on the JN516x device using functions of the Integrated Peripherals API.

Two pulse counters are provided on the JN516x device, Pulse Counter 0 and Pulse Counter 1. A pulse counter detects and counts pulses in an external signal that is input on an associated DIO pin.

11.1 Pulse Counter Operation

The two pulse counters, Pulse Counter 0 and Pulse Counter 1, are each 16-bit counters which, by default, receive their input signals on pins DIO1 and DIO8, respectively (alternatively, Pulse Counter 0 can take its input from DIO4 and Pulse Counter 1 can take its input from DIO5). The two counters can be combined together to form a single 32-bit counter, if desired - in this case, the DIO on which the input signal is taken can be selected from the input pins for the two counters.

The pulse counters can operate in all power modes of the JN516x device, including sleep, and with input signals of up to 100kHz. An increment of the counter can be configured to occur on a rising or falling edge of the relevant input. Each pulse counter has an associated user-defined reference value. An interrupt (or wake-up event, if asleep) can be generated when the counter passes its pre-configured reference value - that is, when the count reaches *(reference value + 1)*. The counters do not saturate at their maximum count values, but wrap around to zero.

Note: Pulse Counter interrupts are handled by the callback function for the System Controller interrupts, registered using **vAHI_SysCtrlRegisterCallback()** - see Section 11.3.

Debounce

The input pulses can be debounced using the 32kHz clock, to avoid false counts on slow or noisy edges. The debounce feature requires a number of identical consecutive input samples (2, 4 or 8) before a change in the input signal is recognised. Depending on the debounce setting, a pulse counter can work with input signals up to the following frequencies:

- 100kHz, if debounce disabled
- 3.7kHz, if debounce enabled to operate with 2 consecutive samples
- 2.2kHz, if debounce enabled to operate with 4 consecutive samples
- 1.2kHz, if debounce enabled to operate with 8 consecutive samples

The required debounce setting is selected when the pulse counter is configured, as described in Section 11.2.1.

When using debounce, the 32kHz clock must be active - therefore, for minimum sleep current, the debounce feature should not be used.

11.2 Using a Pulse Counter

This section describes how to use the Integrated Peripherals API functions to configure, start/stop and monitor a pulse counter.

11.2.1 Configuring a Pulse Counter

A pulse counter must first be configured using the **bAHI_PulseCounterConfigure()** function. This function call must specify:

- if the two 16-bit pulse counters are to be combined into a single 32-bit pulse counter and, if so, the pin on which the combined counter will take its input
- if the pulse count is to be incremented on the rising edge or falling edge of a pulse in the input signal
- if the debounce feature is to be enabled and, if so, the number of consecutive samples (2, 4 or 8) with which it will operate (see Section 11.1)
- if an interrupt is to be enabled which is generated when the pulse count passes the reference value (see below)

When a pulse counter is selected using this function, the input signal will automatically be taken from the relevant pin: DIO1 for Pulse Counter 0, DIO8 for Pulse Counter 1 (the combined pulse counter can take its input from either of these DIOs). However, the input can be moved to another pin using **vAHI_PulseCounterSetLocation()**:

- For Pulse Counter 0, the input can be moved from DIO1 to DIO4
- For Pulse Counter 1, the input can be moved from DIO8 to DIO5

The configuration of the pulse counter is completed by calling the function **bAHI_SetPulseCounterRef()** in order to set the reference count. Note that the pulse counter will continue to count beyond the specified reference value, but will wrap around to zero on reaching the maximum possible count value.

11.2.2 Starting and Stopping a Pulse Counter

A configured pulse counter is started using the function **bAHI_StartPulseCounter()**. Note that the count may increment by one when this function is called (even though no pulse has been detected).

The pulse counter will continue to count until stopped using the function **bAHI_StopPulseCounter()**, at which point the count will be frozen. The count can then be cleared to zero using one of the following functions:

- **bAHI_Clear16BitPulseCounter()** for Pulse Counter 0 or 1
- **bAHI_Clear32BitPulseCounter()** for the combined pulse counter

11.2.3 Monitoring a Pulse Counter

The application can detect whether a running pulse counter has reached its reference count in either of the following ways:

- An interrupt can be enabled which is triggered when the reference count is passed (see Section 11.3).
- The application can use the function **u32AHI_PulseCounterStatus()** to poll the pulse counters - this function returns a bitmap which includes all running pulse counters and indicates whether each counter has reached its reference value.

Functions are also provided that allow the current count of a pulse counter to be read without stopping the pulse counter or clearing its count. The required function depends on the pulse counter:

- **bAHI_Read16BitCounter()** for Pulse Counter 0 or 1
- **bAHI_Read32BitCounter()** for the combined pulse counter

When a pulse counter reaches its reference count, it continues counting beyond this value. If required, a new reference count can then be set (while the counter is running) using the function **bAHI_SetPulseCounterRef()**.

11.3 Pulse Counter Interrupts

A pulse counter can optionally generate an interrupt when its count passes the pre-set reference value - that is, when the count reaches *(reference value + 1)*. This interrupt can be enabled as part of the call to the function **bAHI_PulseCounterConfigure()**.

Note: A pulse counter continues to run during sleep. A pulse counter interrupt can be used to wake the JN516x device from sleep.

The pulse counter interrupt is handled as a System Controller interrupt and must therefore be incorporated in the user-defined callback function registered using the function **vAHI_SysCtrlRegisterCallback()** - see Section 3.5.

The registered callback function is automatically invoked when an interrupt of the type E_AHI_DEVICE_SYSCTRL occurs. If the source of the interrupt is Pulse Counter 0 or Pulse Counter 1, this will be indicated in the bitmap that is passed into the callback function (if the combined pulse counter is in use, this counter will be shown as Pulse Counter 0 for the purpose of interrupts). Note that the interrupt will be automatically cleared before the callback function is invoked.

Once a pulse counter interrupt has occurred, the pulse counter will continue to count beyond its reference value. If required, a new reference count can then be set (while the counter is running) using the function **bAHI_SetPulseCounterRef()**.

12. Infra-Red Transmitter

This chapter describes control of the infra-red transmitter on the JN516x device using functions of the Integrated Peripherals API.

Infra-red transmission is a special feature of Timer 2 in which the timer is used to generate waveforms for infra-red remote control applications.

12.1 Infra-Red Transmitter Operation

Remote control protocols, such as Philips RC-6, apply On-Off Key (OOK) modulation to a carrier signal using an encoded bit stream. The infra-red transmitter is able to accommodate a variety of remote control protocols that have different carrier frequency, carrier duty-cycle and data bit encoding requirements. The infra-red transmitter uses Timer 2 to produce a programmable carrier waveform that is OOK modulated by a programmable bit sequence stored in RAM. The resultant waveform is output to the associated Timer 2 output pin.

Caution: *A typical infra-red LED requires at least 15mA of drive current. An external transistor or LED driver will be required to supply this current because the standard digital outputs do not have this drive strength capability.*

Example Waveform

An example of an OOK modulated waveform is shown in Figure 10.

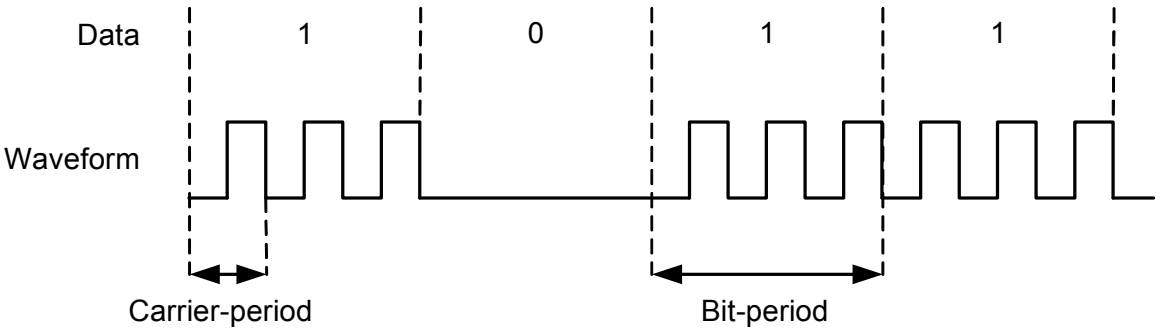


Figure 10: Example OOK Modulated Waveform

In this example, the resultant OOK modulated waveform is generated from the logical AND of a periodic carrier signal and the binary bit pattern 1011, where the period of each data bit is exactly equal to three times the carrier-period.

12.2 Using the Infra-Red Transmitter

This section describes how to use the Integrated Peripherals API functions to configure, start and monitor an infra-red transmission.

Note: When using the infra-red transmission feature of Timer 2, none of the common Timer functions described in Chapter 7 and listed in Chapter 23 should be called for Timer 2 except **vAHI_TimerSetLocation()** and **vAHI_TimerFineGrainDIOControl()**, if required.

12.2.1 Configuring the Infra-Red Transmitter

The infra-red transmitter must first be enabled and configured using the **bAHI_InfraredEnable()** function. This function call must specify:

- the clock prescale value used to divide down the peripheral clock and produce the timer clock
- the number of timer clock periods after starting the timer before the carrier goes high - this defines the carrier low duration
- the number of timer clock periods after starting the timer before the carrier goes low again - this defines the carrier period
- the bit-period in units of the carrier period
- the output signal polarity
- if an interrupt is to be enabled that indicates the end of transmission

Example Configuration

The Philips RC-6 protocol requires a carrier signal of 36kHz ±10% with a duty cycle between 25% and 50%. In this example we will use a duty cycle of 30%.

The RC-6 protocol encodes logic ‘0’ as bits ‘01’, logic ‘1’ as bits ‘10’ and the leader symbol as bits ‘11111100’. Each individual bit has a duration of 16 times the carrier period (i.e. 16x1/36kHz ≈ 444µs). These waveform timing requirements can be satisfied by calling **bAHI_InfraredEnable()** with the following input parameter values:

- *u8Prescale*: 2 (timer clock period = $2^{u8Prescale}$/16MHz = 4/16MHz = 250ns)
- *u16Hi*: 78 (carrier low duration = 78x250ns = 19.5µs)
- *u16Lo*: 111 (carrier period = 111x250ns = 27.75µs, i.e. frequency = 36.036kHz)
- *u16BitPeriodInCarrierPeriods*: 16 (bit period = 16x27.75µs = 444µs)
- *bInvertOutput*: TRUE or FALSE as required by the external transistor
- *bInterruptEnable*: TRUE or FALSE as required by the application

Note: To guarantee accurate waveform timings the user is advised to ensure that the peripheral clock operates at 16MHz with the system clock sourced from the external crystal oscillator - see Section 3.1.

12.2.2 Starting an Infra-Red Transmission

Having configured the waveform timing requirements for the remote control protocol by calling **bAHI_InfraredEnable()**, the user can start the waveform generation for the infra-red transmission by calling the function **bAHI_InfraredStart()**. This function call must specify:

- the start address in RAM of a 32-bit wide array containing the encoded bits to be transmitted (maximum array size of 128 words)
- the number of encoded bits from the array to be transmitted (1 to 4096 bits)

Prior to calling **bAHI_InfraredStart()**, the user should populate the data array with the required encoded bit pattern to be transmitted. The MSB of each 32-bit word will be transmitted first. For example, a transmission of 35 bits will require the user to program all 32 bits in the first 32-bit word followed by the upper 3 bits in the second 32-bit word.

Note: The data array should contain an encoded bit sequence. It is the responsibility of the application to perform this encoding as required by the protocol.

On calling **bAHI_InfraredStart()**, waveform generation will start - the device will automatically read the specified number of bits from the data array using a DMA mechanism and produce an OOK modulated carrier waveform using the pre-configured timing requirements.

By default, the generated waveform will be output to pin DIO12 (i.e. the default output pin of Timer 2). If required, the Timer 2 output can be moved to pin DIO6 or pin DO0 by calling the function **vAHI_TimerSetLocation()** - see Section 7.2.1.

Note: To prevent glitches from occurring on the output pins associated with Timer 2, we recommend that the application calls **vAHI_TimerSetLocation()** before **bAHI_InfraredEnable()**.

12.2.3 Monitoring an Infra-Red Transmission

The application can detect when an infra-red transmission has completed in either of the following ways:

- An interrupt can be enabled which is triggered when the transmission completes (see Section 12.3)
- The application can use the function **bAHI_InfraredStatus()** to poll the infra-red transmission status - this function returns TRUE if a transmission is in progress and FALSE otherwise

12.2.4 Disabling the Infra-Red Transmitter

If enabled, the infra-red transmitter may be subsequently disabled by calling the function **vAHI_InfraredDisable()**. After calling this function, **bAHI_InfraredEnable()** must first be called before attempting to call any other infra-red function.

12.3 Infra-Red Transmitter Interrupt

The infra-red transmitter can optionally generate an interrupt when the infra-red transmission has completed. This interrupt can be enabled as part of the call to the function **bAHI_InfraredEnable()**.

The interrupt is handled as an Infra-Red Transmitter interrupt and must be incorporated in the user-defined callback function registered using the function **vAHI_InfraredRegisterCallback()**.

The registered callback function is automatically invoked when an interrupt of the type E_AHI_DEVICE_INFRARED occurs. The source of the interrupt will be indicated in the bitmap that is passed into the callback function. Note that the interrupt will be automatically cleared before the callback function is invoked.

13. Serial Interface (SI)

This chapter describes control of the 2-wire Serial Interface (SI) using functions of the Integrated Peripherals API.

The JN516x microcontroller includes an industry-standard 2-wire synchronous Serial Interface that provides a simple and efficient method of data exchange between devices. The Serial Interface is similar to an I^2C interface and comprises two lines:

- Serial data line on DIO15
- Serial clock line on DIO14

These signals can be moved to DIO17 and DIO16, respectively.

The SI peripheral on a JN516x device can act as a master or a slave of the Serial Interface bus:

- SI master functionality is described in Section 13.1
- SI slave functionality is described in Section 13.2

Tip: The protocol used by the Serial Interface is detailed in the I^2C Specification (available from www.nxp.com).

13.1 SI Master

The SI master can implement communication in either direction with a slave device on the Serial Interface bus. This section describes how to implement a data transfer.

Note: The Serial Interface bus on the JN516x device can have more than one master, but multiple masters cannot use the bus at the same time. To avoid this, an arbitration scheme is provided on to resolve conflicts caused by competing masters attempting to take control of the Serial Interface bus. If a master loses arbitration, it must wait and try again later.

13.1.1 Enabling the SI Master

The SI master has its own set of functions in the Integrated Peripherals API (and the SI slave has a separate set of functions). Before using any of the SI master functions, the SI peripheral must be enabled using the function **vAHI_SiMasterConfigure()**.

When enabled, this interface uses the DIO14 pin as the clock line and the DIO15 pin as the bi-directional data line. However, these signals can be moved to DIO16 and DIO17, respectively, using the function **vAHI_SiSetLocation()**.

As a bus master, the microcontroller provides the clock (on the clock line) for synchronous data transfers (on the data line), where the clock is scaled from the peripheral clock which must run at 16MHz (the system clock must be sourced from an external crystal oscillator - for system clock information, refer to Section 3.1). The clock scaling factor, *PreScaler*, is specified when the interface is enabled - the final operating frequency of the interface is given by:

Operating frequency = 16/[(*PreScaler* + 1) x 5] MHz

The SI enable functions also allow SI interrupts (of the type E_AHI_DEVICE_SI) to be enabled, which are handled by the user-defined callback function registered using the function **vAHI_SiRegisterCallback()**. For details of the callback function prototype, refer to Appendix A.1.

Caution: *The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling* ***u32AHI_Init()*** *on waking.*

vAHI_SiMasterConfigure() also allows a pulse suppression filter to be enabled, which suppresses any spurious pulses (high or low) with a pulse width less than 62.5ns on the clock and data lines. Also note that an SI master enabled using this function can later be disabled using **vAHI_SiMasterDisable()**.

13.1.2 Writing Data to SI Slave

The procedure below describes how the SI master can write data to an SI slave which has a 7-bit or 10-bit address. It is assumed that the SI master has been enabled as described in Section 13.1.1. The data can comprise one or more bytes.

Step 1 **Take control of SI bus and write slave address to bus**

The SI master must first take control of the SI bus and transmit the address of the target slave for the data transfer. The required method is different for 7-bit and 10-bit slave addresses, as outlined below:

For 7-bit slave address:

a) Call the function **vAHI_SiMasterWriteSlaveAddr()** to specify the 7-bit slave address. Also specify through this function that a write operation will be performed on the slave. This function will put the specified slave address in the SI master's buffer, but will not transmit it on the SI bus.

b) Call the function **bAHI_SiMasterSetCmdReg()** to issue Start and Write commands, in order to take control of the SI bus and transmit the slave address specified above.

c) Wait for an indication of success (slave address sent and target slave responded) by polling or waiting for an interrupt - for details of this stage, refer to Section 13.1.4.

For 10-bit slave address:

a) Call the function **vAHI_SiMasterWriteSlaveAddr()** to indicate that 10-bit slave addressing will be used and to specify the two most significant bits of the relevant slave address (when specified, these bits must be bitwise ORed with 0x78). Also specify through this function that a write operation will be performed on the slave. This function will put the specified information in the SI master's buffer, but will not transmit it on the SI bus.

b) Call the function **bAHI_SiMasterSetCmdReg()** to issue Start and Write commands, in order to take control of the SI bus and transmit the slave address information specified above.

c) Wait for an indication of success (slave address information sent and at least one matching slave responded) by polling or waiting for an interrupt - for details of this stage, refer to Section 13.1.4.

d) Call the function **vAHI_SiMasterWriteData8()** to specify the eight remaining bits of the slave address. This function will put the specified information in the SI master's buffer, but will not transmit it on the SI bus.

e) Call the function **bAHI_SiMasterSetCmdReg()** to issue a Write command, in order to transmit the slave address information specified above.

f) Wait for an indication of success (slave address information sent and target slave responded) by polling or waiting for an interrupt - for details of this stage, refer to Section 13.1.4.

Step 2 **Send data byte to slave**

If only one data byte or the final data byte is to be sent to the slave then go directly to Step 3, otherwise follow the instructions below:

a) Call the function **vAHI_SiMasterWriteData8()** to specify the data byte to be sent. This function will put the specified data in the SI master's buffer, but will not transmit it on the SI bus.

b) Call the function **bAHI_SiMasterSetCmdReg()** to issue a Write command, in order to transmit the data byte specified above.

c) Wait for an indication of success (data byte sent and target slave responded) by polling or waiting for an interrupt - for details of this stage, refer to Section 13.1.4.

Repeat the above instructions (Step 2a-c) for all subsequent data bytes except the final byte to be sent (which is covered in Step 3).

Step 3 **Send final data byte to slave**

Send the final (or only) data byte to the slave as follows:

a) Call the function **vAHI_SiMasterWriteData8()** to specify the data byte to be sent. This function will put the specified data in the SI master's buffer, but will not transmit it on the SI bus.

b) Call the function **bAHI_SiMasterSetCmdReg()** to issue Write and Stop commands, in order to transmit the data byte specified above and release control of the SI bus.

c) Wait for an indication of success (data byte sent and target slave responded) by polling or waiting for an interrupt - for details of this stage, refer to Section 13.1.4.

13.1.3 Reading Data from SI Slave

The procedure below describes how the SI master can read data sent from an SI slave which has a 7-bit or 10-bit address. It is assumed that the SI master has been enabled as described in Section 13.1.1. The data can comprise one or more bytes.

Step 1 **Take control of SI bus and write slave address to bus**

The SI Master must first take control of the SI bus and transmit the address of the slave which is to be the source of the data transfer. The required method is different for 7-bit and 10-bit slave addresses, as outlined below:

For 7-bit slave address:

a) Call the function **vAHI_SiMasterWriteSlaveAddr()** to specify the 7-bit slave address. Also specify through this function that a read operation will be performed on the slave. This function will put the specified slave address in the SI master's buffer, but will not transmit it on the SI bus.

b) Call the function **bAHI_SiMasterSetCmdReg()** to issue Start and Write commands, in order to take control of the SI bus and transmit the slave address specified above.

c) Wait for an indication of success (slave address sent and target slave responded) by polling or waiting for an interrupt - for details of this stage, refer to Section 13.1.4.

For 10-bit slave address:

a) Call the function **vAHI_SiMasterWriteSlaveAddr()** to indicate that 10-bit slave addressing will be used and to specify the two most significant bits of the relevant slave address. Also, initially specify through this function that a write operation will be performed. This function will put the specified information in the SI master's buffer, but will not transmit it on the SI bus.

b) Call the function **bAHI_SiMasterSetCmdReg()** to issue Start and Write commands, in order to take control of the SI bus and transmit the slave address information specified above.

c) Wait for an indication of success (slave address information sent and at least one matching slave responded) by polling or waiting for an interrupt - for details of this stage, refer to Section 13.1.4.

d) Call the function **vAHI_SiMasterWriteData8()** to specify the eight remaining bits of the slave address. This function will put the specified information in the SI master's buffer, but will not transmit it on the SI bus.

e) Call the function **bAHI_SiMasterSetCmdReg()** to issue a Write command, in order to transmit the slave address information specified above.

f) Wait for an indication of success (slave address information sent and target slave responded) by polling or waiting for an interrupt - for details of this stage, refer to Section 13.1.4.

g) Call the function **vAHI_SiMasterWriteSlaveAddr()** again, indicating that 10-bit slave addressing will be used and specifying the two most significant bits of the relevant slave address. This time, specify through this function that a read operation will be performed on the slave. This function will put the specified information in the SI master's transmit buffer, but will not transmit it on the SI bus.

h) Call the function **bAHI_SiMasterSetCmdReg()** to issue Start and Write commands, in order to take control of the SI bus and transmit the slave address information specified above.

i) Wait for an indication of success by polling or waiting for an interrupt - for details of this stage, refer to Section 13.1.4.

Step 2 **Read data byte from slave**

If only one data byte or the final data byte is to be read from the slave then go directly to Step 3, otherwise follow the instructions below:

a) Call the function **bAHI_SiMasterSetCmdReg()** to issue a Read command, in order to request a data byte from the slave. Also use this function to enable an ACK (acknowledgement) to be sent to the slave once the byte has been received.

b) Wait for an indication of success (read request sent and data received) by polling or waiting for an interrupt - for details of this stage, refer to Section 13.1.4.

c) Call the function **u8AHI_SiMasterReadData8()** to read the received data byte from the SI master's buffer.

Repeat the above instructions (Step 2a-c) for all subsequent data bytes except the final byte to be read (which is covered in Step 3).

Step 3 **Read final data byte from slave**

Read the final (or only) data byte from the slave as follows:

a) Call the function **bAHI_SiMasterSetCmdReg()** to issue Read and Stop commands, in order to request a data byte from the slave and release control of the SI bus. Also use this function to enable a NACK to be sent to the slave once the byte has been received (to indicate that no more data is required).

b) Wait for an indication of success (read request sent and data received) by polling or waiting for an interrupt - for details of this stage, refer to Section 13.1.4.

c) Call the function **u8AHI_SiMasterReadData8()** to read the received data byte from the SI master's buffer.

13.1.4 Waiting for Completion

At various points in the write and read procedures of Section 13.1.2 and Section 13.1.3, it is necessary to wait for an indication of the success of an operation before continuing. The application can use either interrupts or polling to determine when to continue:

- **Interrupts:** SI interrupts can be enabled when **vAHI_SiConfigure()** or **vAHI_SiMasterConfigure()** is called, as described in Section 13.1.1. An SI interrupt (of the type E_AHI_DEVICE_SI) can be generated on a variety of conditions of the Serial Interface. The interrupt is handled by a user-defined callback function registered using the function **vAHI_SiRegisterCallback()**. This interrupt handler should identify the exact source of the SI interrupt and act on it. For more details on the callback function and interrupt sources, refer to Appendix A.1 and Appendix B.2, respectively. In the above write and read procedures, the SI master interrupt source of interest is the one which indicates the completion of a byte transfer or loss of arbitration.
- **Polling:** To determine when the transfer of a byte has finished, the application can regularly call **bAHI_SiMasterPollTransferInProgress()**, which indicates whether a transfer is in progress on the SI bus.

Once an interrupt or polling has indicated that the transfer of a byte has completed, further checks must be made to determine whether the master should stop the data transfer and release the SI bus:

1. In the case of a write to the slave, the application should call the function **bAHI_SiMasterCheckRxNack()** which indicates whether an ACK or a NACK has been received from the slave following the byte transfer:
   - An ACK indicates that the slave can accept more data and therefore further byte transfers can be initiated.
   - A NACK indicates that the slave cannot accept any more data, and that the data transfer must be stopped and the SI bus released.
2. Provided that the SI bus has not already been released, the application should call the function **bAHI_SiMasterPollArbitrationLost()** to check whether the SI master has lost the arbitration of the SI bus. If this is the case, the data transfer must be stopped and the SI bus released.

The data transfer is stopped and the SI bus released by calling the function **bAHI_SiMasterSetCmdReg()** in order to issue the Stop command.

13.2 SI Slave

The SI peripheral on the JN516x device can act as an SI master or an SI slave (but not as both at the same time). This section describes what must be done to allow the SI slave to participate in a data transfer initiated by a remote SI master.

13.2.1 Enabling the SI Slave and its Interrupts

The SI slave must first be configured and enabled using the function **vAHI_SiSlaveConfigure()**. This function requires the address size of the SI slave to be specified as 7-bit or 10-bit, and the SI slave address itself to be specified. The function also allows the generation of SI slave interrupts to be configured - interrupts can be triggered on the following conditions:

- Data buffer requires data byte for transmission to SI master
- Byte in data buffer sent to SI master and so buffer free for next byte
- Data buffer contains data byte from SI master, available to be read by SI slave
- Final data byte received from SI master (end of data transfer)
- I^2C protocol error

SI interrupts (of the type E_AHI_DEVICE_SI) are handled by the user-defined callback function registered using the function **vAHI_SiRegisterCallback()**. This is the same registration function as used for the SI master. For details of the callback function prototype, refer to Appendix A.1.

Caution: *The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling* ***u32AHI_Init()*** *on waking.*

vAHI_SiSlaveConfigure() also allows a pulse suppression filter to be enabled, which suppresses any spurious pulses (high or low) with a pulse width less than 62.5ns on the clock and data lines. Also note that an SI slave enabled using this function can later be disabled using **vAHI_SiSlaveDisable()**.

When enabled, this interface uses the DIO14 pin as the clock line and the DIO15 pin as the bi-directional data line (but does not supply the clock). These signals can be moved to DIO16 and DIO17, respectively, using the function **vAHI_SiSetLocation()**.

13.2.2 Receiving Data from the SI Master

An SI master indicates that it needs to send data to a particular SI slave as described in Section 13.1.2. The SI slave automatically responds to the SI master according to the protocol for this request, but the application associated with the slave must deal with the data that arrives from the master.

The data transfer on the SI bus consists of a sequence of data bytes, where each byte must be received and then read from the SI slave before the next byte can be received. Interrupts are used to signal the arrival of a data byte from the SI master:

- An interrupt can be generated when a data byte has arrived from the SI master and is available to be read from the SI slave's buffer.
- An interrupt can also be generated when the final data byte of the transfer has arrived from the SI master and is available to be read from the SI slave's buffer.

To use these interrupts, they must have been enabled when the function **vAHI_SiSlaveConfigure()** was called. The registered SI interrupt handler must also deal with them - see Section 13.2.1.

Once a received data byte is available in the SI slave's buffer, it can be read from the buffer by the application using the function **u8AHI_SiSlaveReadData8()**.

13.2.3 Sending Data to the SI Master

An SI master indicates that it needs to obtain data from a particular SI slave as described in Section 13.1.3. The SI slave automatically responds to the SI master according to the protocol for this request, but the application associated with the slave must supply the data that is to be sent to the master.

The data transfer on the SI bus consists of a sequence of data bytes, where each byte must be written to the SI slave's buffer and transmitted before the next byte can be written to the buffer. Interrupts are used to signal when the next data byte is needed in the buffer. To use these interrupts, they must have been enabled when the function **vAHI_SiSlaveConfigure()** was called. The registered SI interrupt handler must deal with them - see Section 13.2.1.

Once a new data byte is required in the SI slave's buffer, it can be written to the buffer by the application using the function **vAHI_SiSlaveWriteData8()**.

14. Serial Peripheral Interface (SPI) Master

This chapter describes control of the Serial Peripheral Interface (SPI) Master on the JN516x microcontroller using functions of the Integrated Peripherals API.

The Serial Peripheral Interface on the JN516x microcontroller allows high-speed synchronous data transfers between the microcontroller and peripheral devices, without software intervention. When the microcontroller operates as the master on the SPI bus, all other devices connected to the bus are expected to be slave devices under the control of the master's CPU.

The SPI Master device on the JN516x device supports up to three slaves.

Note: On a JN516x device, the SPI Master is disabled by default and shares its pins with other functions - this is unlike a JN514x device that uses dedicated pins for the SPI Master, which is enabled from reset in order to boot from an external Flash device.

14.1 SPI Bus Lines

The SPI Master uses pins DO0 to output the Clock (SPICLK), DO1 for Data In (SPIMISO) and DIO18 for Data Out (SPIMOSI) - these signals are shared on the SPI bus.

Up to three slave-select output lines can be used: SPISEL0, SPISEL1 and SPISEL2. If enabled, they appear on DIO19, DIO0 and DIO1, respectively. However, lines SPISEL1 and SPISEL2 can be moved to DIO14 and DIO15 using the function **vAHI_SpiSelSetLocation()**.

14.2 Data Transfers

Data transfer is full-duplex, so data is transmitted by both communicating devices at the same time. Data to be transmitted is stored in a FIFO buffer (shift register) in the device. Any data transaction size between 1 and 32 bits (inclusive) can be used. The data transfer order can be configured as LSB (least significant bit) first or MSB (most significant bit) first.

Since the data transfer is synchronous, both transmitting and receiving devices use the same clock, provided by the SPI master. The SPI device uses the peripheral clock (for system clock options, see Section 3.1), which may be divided down and allows bit rates of up to 16Mbps.

An interrupt can be enabled, which is generated when the data transfer completes.

14.3 SPI Modes

The clock edge on which data is latched is determined by the SPI mode of operation used (0, 1, 2 or 3), which is determined by two boolean parameters, clock polarity and phase, as indicated in the table below.

SPI Mode	Polarity	Phase	Description
0	0	0	Data latched on rising edge of clock
1	0	1	Data latched on falling edge of clock
2	1	0	Clock inverted and data latched on falling edge of clock
3	1	1	Clock inverted and data latched on rising edge of clock

Table 4: SPI Modes of Operation

14.4 Slave Selection

Before transferring data, the SPI master must select the slave(s) with which it wishes to communicate. Thus, the relevant slave-select line(s) must be asserted. It is usual for the SPI master to communicate with a single slave at a time, so not to receive data from multiple slaves simultaneously (unless the slave devices can be inhibited from transmitting data). An ‘Automatic Slave Selection’ feature is provided, which only asserts the chosen slave-select line(s) during a data transfer.

Manual slave selection is preferred over ‘Automatic Slave Selection’ when a number of consecutive data transfers are to be performed with a particular slave device, avoiding the need for the slave to be deselected and then reselected between adjacent transfers.

14.5 Using the Serial Peripheral Interface

This section describes how to use the Integrated Peripherals API functions to operate the Serial Peripheral Interface.

14.5.1 Performing a Data Transfer

A SPI data transfer is performed as follows:

1. The SPI master must first be configured and enabled using the function **vAHI_SpiConfigure()**. This function allows the configuration of:
   - Number of SPI slaves
   - Clock divisor (for peripheral clock)
   - Data transfer order (LSB first or MSB first)
   - Clock polarity (unchanged or inverted)
   - Phase (latch data on leading edge or trailing edge of clock)
   - Automatic Slave Selection
   - SPI interrupts

   If SPI interrupts are enabled, a corresponding callback function must be registered using the function **vAHI_SpiRegisterCallback()** - see Section 14.6.
2. The SPI slaves must be selected using the function **vAHI_SpiSelect()**. If 'Automatic Slave Selection' is off, the relevant slave-select line(s) will be asserted immediately, otherwise the line(s) will only be asserted during a subsequent data transfer.
3. A data transfer is implemented using **vAHI_SpiStartTransfer()**. A transaction size between 1 and 32 bits can be specified.
4. The transfer is allowed to complete by waiting for a SPI interrupt (if enabled) to indicate completion, or by calling **vAHI_SpiWaitBusy()** which returns when the transfer has completed, or by periodically calling **bAHI_SpiPollBusy()** to check whether the SPI master is still busy.
5. Data received from a slave is read using **u32AHI_SpiReadTransfer32()**. The read data is aligned to the right (lower bits) of the returned 32-bit value.
6. If another transfer is required then Steps 3 to 5 must be repeated for the next data. Otherwise, if 'Automatic Slave Selection' is off, the SPI slaves must be de-selected by calling **vAHI_SpiSelect(0)** or **vAHI_SpiStop()**.

A number of other SPI functions exist in the Integrated Peripherals API. The current SPI configuration can be obtained and saved using **vAHI_SpiReadConfiguration()**. If necessary, this saved configuration can later be restored in the SPI using the function **vAHI_SpiRestoreConfiguration()**.

14.5.2 Performing a Continuous Transfer

Continuous SPI transfers can be initiated by calling the function **vAHI_SpiContinuous()** instead of **vAHI_SpiStartTransfer()**. This mode facilitates back-to-back reads of the received data, with the incoming data transfers automatically controlled by hardware - data is received and the hardware then waits for this data to be read by the software before allowing the next incoming data transfer.

In this case, Steps 1-2 of the procedure in Section 14.5.1 remain the same but Steps 3 and onwards are replaced by the following:

3. A continuous data transfer is started using **vAHI_SpiContinuous()**, which requires the data length (1 to 32 bits) of an individual transfer to be specified.
4. **bAHI_SpiPollBusy()** must be called periodically to check whether the SPI master is still busy with an individual transfer.
5. Once the latest transfer has completed (the SPI master is no longer busy), the the received data from this transfer must be read by calling the function **u32AHI_SpiReadTransfer32()** - the read data is aligned to the right (lower bits) of the returned 32-bit value.
6. Once the data has been read, the next transfer will automatically occur and the transferred data must be read as detailed in Steps 4-5 above. However, a continuous transfer can be stopped at any time by calling the function **vAHI_SpiContinuous()** again, this time to disable continuous mode (after this function call, there will be one more transfer before the transfers are stopped).
7. If 'Automatic Slave Selection' is off, after stopping a continuous transfer the SPI slaves must be de-selected by calling **vAHI_SpiSelect(0)**.

14.6 SPI Interrupts

A SPI interrupt can be used to indicate when a data transfer initiated by the SPI master has completed. This interrupt is enabled in **vAHI_SpiConfigure()**.

SPI interrupts are handled by a user-defined callback function, which must be registered using **vAHI_SpiRegisterCallback()**. The relevant callback function is automatically invoked when an interrupt of the type E_AHI_DEVICE_SPIM occurs. For details of the callback function prototype, refer to Appendix A.1.

***Caution:** The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.*

15. Serial Peripheral Interface (SPI) Slave

This chapter describes control of the Serial Peripheral Interface (SPI) Slave on the JN516x microcontroller using functions of the Integrated Peripherals API.

The Serial Peripheral Interface on the JN516x microcontroller allows high-speed synchronous data transfers between the microcontroller and peripheral devices, without software intervention.

Note: The SPI Master device on the JN516x microcontroller is described in Chapter 14.

15.1 SPI Slave Operation

The SPI Slave is used for high-speed data exchanges between the JN516x microcontroller and a 'remote' processor, which may be a separate processor contained in the wireless network node. The remote processor must contain a SPI Master device, which initiates the data transfers. The data exchanges then require minimal CPU usage. Data transfer is full-duplex, so data is simultaneously transmitted and received by both communicating devices.

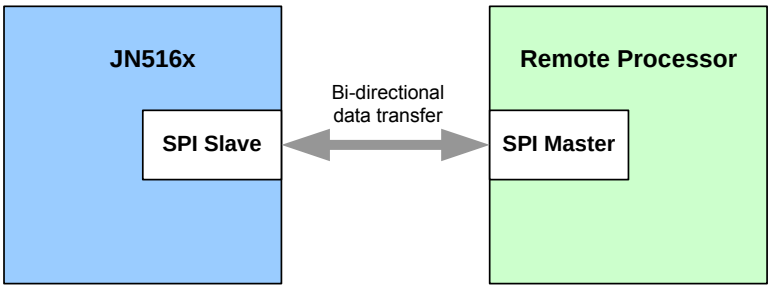


Figure 11: JN516x SPI Slave

The SPI Slave uses separate configurable FIFO buffers located in system RAM to store data bytes for transmission and reception.

Caution: *Only SPI mode 0 is supported. At both ends of the data link, the data to be transmitted is changed on a negative clock edge and received data is sampled on a positive clock edge.*

15.1.1 SPI Bus Lines and DIO Usage

The SPI Slave uses the following bus lines:

- Slave Clock Input, SPISCLK
- Slave Data Output, SPISMISO
- Slave Data Input, SPISMOSI
- Slave-select Input, SPISSEL

These signals use the following DIO pins:

- SPISCLK uses DIO15
- SPISMOSI and SPISMISO use DIO12-13 or alternatively DIO16-17
- SPISSEL uses DIO14

The DIO pins used for SPISMOSI and SPISMISO are configured when calling **bAHI_SpiSlaveEnable()**.

15.1.2 SPI Slave FIFOs and Interrupts

The Data In (Receive) and Data Out (Transmit) paths of the SPI Slave device contain FIFO buffers which are located in RAM. The exact locations and sizes of these buffers are defined by the application when the SPI Slave is initialised using the function **bAHI_SpiSlaveEnable()**. Each buffer can be up to 255 bytes in size.

Fill-level thresholds (in bytes) must also be specified that are used to prompt the application to write data to the Transmit buffer and read data from the Receive buffer.

- For the Transmit FIFO, this threshold is the fill-level which is considered low enough for more data to be written into the buffer - if interrupts are enabled, an interrupt will be generated when the amount of data in the buffer falls below this level
- For the Receive FIFO, this threshold is the fill-level which is considered high enough for data to be read from the buffer - if interrupts are enabled, an interrupt will be generated when the amount of data in the buffer rises above this level

A Receive timeout duration (in microseconds) must also be specified in the above function call. Following the end of a SPI transfer, if the Receive FIFO remains not empty for this duration then a timeout interrupt will be generated (if enabled) to prompt the application to read data from the buffer. This prevents received data from remaining in the buffer for too long without being read.

SPI Slave interrupts must be enabled in order to use the buffer thresholds and Receive timeout described above. Again, interrupts can be enabled when the device is configured using **bAHI_SpiSlaveEnable()**. If they are enabled, a user-defined callback function to handle SPI Slave interrupts must be registered using the function **vAHI_SpiSlaveRegisterCallback()**. The callback function is automatically invoked when an interrupt of the type E_AHI_DEVICE_SPIS occurs. For details of the callback function prototype, refer to Appendix A.1.

Caution: *The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling* ***u32AHI_Init()*** *on waking.*

15.2 Using the SPI Slave

A data transfer is conducted via the SPI Slave as follows (this procedure assumes that SPI Slave interrupts will be enabled):

1. The SPI Slave must first be initialised and configured using the function **bAHI_SpiSlaveEnable()**. This function allows the following to be configured:
   - Bit-order for transmission/reception of SPI data (LSB first or MSB first)
   - DIO pins used for SPISMISO and SPISMOSI
   - Transmit FIFO buffer, including start address in RAM, size (in bytes) and write threshold (in bytes) - see Section 15.1.2
   - Receive FIFO buffer, including start address in RAM, size (in bytes), read threshold (in bytes) and timeout (in microseconds) - see Section 15.1.2
   - SPI Slave interrupts (which should be enabled)
2. A user-defined callback function to handle SPI Slave interrupts must now be registered using **vAHI_SpiSlaveRegisterCallback()**.
3. The application can now load transmission data into the Transmit FIFO (data will be transmitted when a transfer is initiated by the remote SPI Master):
   a) The initial data must be written to the Transmit FIFO using the function **vAHI_SpiSlaveTxWriteByte()**. The number of bytes written must not exceed the size of the buffer. By default, if the Transmit FIFO is empty and a transfer is initiated by the remote SPI Master, the SPI Slave will transmit the data byte 0x00.
   b) Subsequently, the application must wait for a write threshold interrupt to prompt further writes to the Transmit FIFO. When this interrupt occurs, the user-defined callback function will be invoked to handle the interrupt and **vAHI_SpiSlaveTxWriteByte()** should be called within this callback function. The number of bytes written should not exceed the size of the buffer minus the write threshold for the buffer.
4. The application can now also read any received data from the Receive FIFO. To do this, it should wait for a read threshold interrupt or a read timeout interrupt. When one of these interrupts occurs, the user-defined callback function will be invoked to handle the interrupt and the function **u8AHI_SpiSlaveRxReadByte()** should be called within this callback function.

The functions **u8AHI_SpiSlaveTxFillLevel()**, **u8AHI_SpiSlaveRxFillLevel()** and **u8AHI_SpiSlaveStatus()** are provided to enable an application to monitor the SPI Slave in a non-interrupt driven manner.

Tip: Although the data transfer is full-duplex, a simplex transfer can be achieved by transferring dummy data in the unwanted direction.

16. Flash Memory

This chapter describes control of Flash memory using functions of the Integrated Peripherals API.

The JN516x microcontroller has on-chip Flash memory. This non-volatile memory is used to store the binary application and associated application data. The JN516x device can also be optionally connected to an external Flash memory device.

The Integrated Peripherals API includes functions that allow the application to erase, programme and read a sector of Flash memory. Normally, these functions are used to store and retrieve application data - this might include data to be preserved in non-volatile memory before going to sleep without RAM held.

16.1 Flash Memory Organisation and Types

Flash memory is partitioned into sectors. The number of sectors depends on the Flash device type, but the application binary is normally stored from the start of the first sector, denoted Sector 0, and the application data is stored in the final sector. A Flash memory sector which is blank (no data) comprises entirely of binary 1s. When data is written to the sector, the relevant bits are changed from 1 to 0.

The following tables provide details of the on-chip Flash memory and supported external Flash devices for the JN516x family of microcontrollers..

JN516x Chip	Number of Sectors	Sector Size (Kbytes)	Total Size (Kbytes)
JN5168	8	32	256
JN5164	5	32	160
JN5161	2	32	64

Table 5: On-chip Flash Memory

Manufacturer	Flash Device	Number of Sectors	Sector Size (Kbytes)	Total Size (Kbytes)
Atmel	AT25F512	2	32	64
STMicroelectronics	M25P05A	2	32	64
Microchip	SST25VF010A	4	32	128
STMicroelectronics	M25P10A	4	32	128
STMicroelectronics	M25P20	4	64	256
Winbond	W25X20B	4	64	256
STMicroelectronics	M25P40	8	64	512

Table 6: Supported External Flash Devices

16.2 API Functions

The supplied Flash Memory functions can be used to interact with the on-chip Flash device and any compatible external Flash device (detailed in Section 16.1). The functions are able to access any sector of Flash memory - the application is stored from the first sector (0) and application data is normally stored in the final sector - you should refer to the data sheet for the Flash device to obtain the necessary sector details. The Flash Memory functions are fully detailed in Chapter 32.

16.3 Operating on Flash Memory

This section describes how to use the Flash Memory functions to erase, read from and write to a sector of Flash memory.

The first Flash memory function called must be the initialisation function **bAHI_FlashInit()**. In the case of external Flash memory, this function requires the attached Flash device type to be specified.

A custom external Flash device can also be specified. In this case, a set of custom functions must be provided that will be used by the API to access the Flash device.

Note 1: If you wish to use both internal (on-chip) and external Flash memory devices, you will need to call **bAHI_FlashInit()** when switching between them.

Note 2: The **bAHI_FlashEECerrorInterruptSet()** function can be used to enable interrupts that are generated when an error occurs in the on-chip Flash device. A user-defined callback function is also registered which is invoked when a Flash memory interrupt occurs.

16.3.1 Erasing Data from Flash Memory

Erasing a portion of Flash memory involves setting any 0 bits to 1. The function **bAHI_FlashEraseSector()** can be used to erase an entire sector of Flash memory. Any sector can be erased.

***Caution:** Be careful not to erase essential data such as the application code. The application is stored from the start of the on-chip Flash memory (starting in Sector 0).*

Note: The internal Flash memory of the JN516x device has a sector-erase time of approximately 100ms.

16.3.2 Reading Data from Flash Memory

The function **bAHI_FullFlashRead()** can be used to read data from any sector of Flash memory. This function can be used to read a portion of data starting at any point within the sector.

16.3.3 Writing Data to Flash Memory

Before writing the first data to a sector of Flash memory, the sector must be blank (consisting entirely of binary 1s), as the write operation will only change 1s to 0s (where relevant). Therefore, it may be necessary to erase the relevant sector, as described in Section 16.3.1, before writing the first data to it.

The function **bAHI_FullFlashProgram()** can be used to write data to any sector of Flash memory. This function can be used to write a portion of data containing a multiple of 16 bytes starting on a 16-byte boundary within the sector. When adding data to existing data in a sector, you must be sure that the relevant portion of the sector is already blank (comprising all binary 1s).

One way to ensure that data is added successfully to a sector is as follows:

1. Read the entire sector into RAM (see Section 16.3.2).
2. Erase the entire sector in Flash memory (see Section 16.3.1).
3. Add the new data to the existing data in RAM.
4. Write all of this data back to the sector in Flash memory.

Caution 1: *Each sector of the internal Flash memory in the JN516x device is divided into 16-byte pagewords. A write to a non-blank pageword must not be performed - the sector containing the non-blank pageword should first be erased using* ***bAHI_FlashEraseSector()*** *before writing to the pageword. If the user omits the sector-erase operation, a subsequent error will likely result when reading from the pageword - this read-error will trigger an interrupt and execute the callback function registered using* ***bAHI_FlashEECerrorInterruptSet()****.*

Caution 2: *The internal Flash memory of the JN516x device has an endurance limit of 10000 write/erase cycles per sector. Refer to the device-specific data sheet for the endurance limit of the external Flash memory.*

Note: The internal Flash memory of the JN516x device has a sector write-time of approximately 1ms.

16.4 Controlling Power to External Flash Memory

Any external Flash memory can be optionally powered off while the JN516x microcontroller is in a sleep mode (including Deep Sleep). An unpowered Flash device during sleep allows greater power savings and extends battery life.

Two functions (see below) are provided for controlling power to an external Flash device, but these are only applicable to the following STMicroelectronics devices:

- STM25P05A
- STM25P10A
- STM25P20
- STM25P40

Calling these functions for other Flash devices will have no effect.

Caution: *These functions must not be called when using JN516x on-chip Flash memory device (selected in* ***bAHI_FlashInit()****). Note that when using the JenOS Persistent Data Manager (PDM), the on-chip Flash memory device is automatically selected by default.*

The necessary function calls before and after sleep are outlined as follows.

Before Sleep

The above external Flash memory devices can be powered down before entering sleep mode by calling the function **vAHI_FlashPowerDown()**. This function must be called before **vAHI_Sleep()** is called.

After Sleep

If a Flash memory device was powered down using **vAHI_FlashPowerDown()** before entering sleep, on waking from sleep the function **vAHI_FlashPowerUp()** must be called to power on the Flash memory device again.

Tip: In order to conserve power, you may wish to power down the external Flash memory device at JN516x start-up and only power up the Flash device when required.

17. EEPROM

This chapter describes access to the JN516x on-chip EEPROM using functions of the Integrated Peripherals API. This non-volatile memory is used to store data that must be preserved while the JN516x device is not powered or during sleep without RAM held. Functions are provided for writing to, reading from and erasing the EEPROM.

Although the functions referenced in this chapter provide direct access to the EEPROM device, *it is recommended that they are not used or are used with caution*, for the following reasons:

- JenNet-IP and ZigBee nodes normally use the JenOS Persistent Data Manager (PDM), which also accesses the EEPROM. PDM is supplied in the NXP JenNet-IP and ZigBee SDKs, and is described in the *JenOS User Guide (JN-UG-3075)*. The advantages of using PDM include:
  - 'Wear levelling' to achieve the uniform use of the EEPROM
  - Record IDs to avoid the use of memory addresses

  If PDM and the EEPROM direct-access function set are both to be used, it is important to avoid conflicts between the two - therefore, they must never access the same part of the EEPROM. To achieve this, PDM must be initialised with a specific configuration to limit the number of segments used, and a limited address range must be used for direct EEPROM access.
- ZigBee RF4CE uses the EEPROM direct-access functions itself so, again, conflicts must be avoided.

17.1 Initialisation

In order to access the EEPROM from the application, the initialisation function **u16AHI_InitialiseEEP()** must first be called.

The 4-Kbyte EEPROM is organised in terms of segments and the above function returns the following information about the available segments:

- Number of segments
- Number of bytes in each segment

The segments are indexed from 0.

17.2 Writing to the EEPROM

A block of data can be written to a specified EEPROM segment using the function **iAHI_WriteDataIntoEEPROMsegment()**. The data can be written starting at any (byte) offset from the beginning of the segment. The function will not allow a segment to overflow - if the length of the data block to be written is greater than the memory space up to the end of the segment, the function will return an error and will not write any data.

17.3 Reading from the EEPROM

A block of data can be read from a specified EEPROM segment using the function **iAHI_ReadDataFromEEPROMsegment()**. The data can be read starting at any (byte) offset from the beginning of the segment. If the length of the data block to be read is greater than the memory space up to the end of the segment, the function will return an error and will not read any data.

17.4 Erasing the EEPROM

The EEPROM can be erased a whole segment at a time. The function **iAHI_EraseEEPROMsegment()** can be used to erase a specified segment.

Part II:
Reference Information

18. General Functions

This chapter describes various functions of the Integrated Peripherals API that are not associated with any of the main peripheral blocks on a JN516x microcontroller.

The functions in this chapter include:

- API initialisation function
- Functions to implement antenna diversity
- Functions to control the random number generator
- Processor stack overflow function
- Functions for accessing on-chip Non-Volatile Memory

Note that the random number generator can produce interrupts which are treated as System Controller interrupts. For more information on interrupt handling, refer to Appendix A.

Note: For guidance on using these functions in JN516x application code, refer to Chapter 2.

The functions are listed below, along with their page references:

u32AHI_Init

```
uint32 u32AHI_Init(void);
```

Description

This function initialises the Integrated Peripherals API. It should be called after every reset and wake-up, and before any other Integrated Peripherals API functions are called.

Caution: *If you are using JenOS (Jennic Operating System), you must not call this function explicitly in your code, as the function is called internally by JenOS. This applies principally to users who are developing ZigBee PRO applications.*

Note: This function must be called before initialising the Application Queue API (if used). For more information on the latter, refer to the *Application Queue API Reference Manual (JN-RM-2025)*.

Parameters

None

Returns

0 if initialisation failed, otherwise a 32-bit version number for the API (most significant 16 bits are main revision, least significant 16 bits are minor revision).

vAHI_HighPowerModuleEnable

```
void vAHI_HighPowerModuleEnable(bool_t bRFTXEn,
                                bool_t bRFRXEn);
```

Description

This function allows control for transmission and reception on a JN516x high-power module to be enabled or disabled. Control for transmission and reception must both be enabled or disabled at the same time (enabling only one of them is not supported). The function should be called before using the radio transceiver on a JN516x high-power module.

Note 1: This function should only be used with a JN516x high-power module manufactured by NXP.

Note 2: Instead of using this function to enable/disable a high-power module, you are advised to use the function **vAppApiSetHighPowerMode()** from the NXP 802.15.4 Stack API (supplied in the file **AppApi.h** in all the JN516x SDKs).

Caution: *This function must not be used to enable a JN516x high-power module which will operate in channel 26 of the 2.4GHz band, since emission regulations will be breached. The function* ***vAppApiSetHighPowerMode()*** *should be used instead (see Note 2 above), which enables a mechanism to reduce the output power on channel 26 so that the emission regulations are met.*

Parameters

bRFTXEn	Enable/disable control for high-power module transmission (must be same setting as for *bRFRXEn*): TRUE - enable control for high-power module transmission FALSE - disable control for high-power module transmission
bRFRXEn	Enable/disable control for high-power module reception (must be same setting as for *bRFTXEn*): TRUE - enable control for high-power module reception FALSE - disable control for high-power module reception

Returns

None

vAHI_AntennaDiversityOutputEnable

```
void vAHI_AntennaDiversityOutputEnable(
                                        bool_t bOddOutEn,
                                        bool_t bEvenOutEn);
```

Description

This function can be used to individually enable or disable the use of DIO12 and DIO13 for the control of antenna diversity. The use of antenna diversity requires two antennas to be connected to the JN516x device via a switch controlled by DIO12 and DIO13.

Parameters

bOddOutEn	Enable/disable setting for DIO12: TRUE - enable antenna diversity control output on pin FALSE - disable antenna diversity control output on pin
bEvenOutEn	Enable/disable setting for DIO13: TRUE - enable antenna diversity control output on pin FALSE - disable antenna diversity control output on pin

Returns

None

vAHI_AntennaDiversityEnable

```
void vAHI_AntennaDiversityEnable(
                                    bool_t bRxDiversity,
                                    bool_t bTxDiversity);
```

Description

This function can be used to independently enable/disable antenna diversity on the transmit and receive paths. The use of antenna diversity requires two antennae to be connected to the JN516x device via a switch controlled by DIO12 and DIO13 - pins are enabled for antenna diversity use by calling the function **vAHI_AntennaDiversityOutputEnable()**.

Parameters

bRxDiversity	Enable/disable antenna diversity on receive path: TRUE - enable FALSE - disable
bTxDiversity	Enable/disable antenna diversity on transmit path: TRUE - enable FALSE - disable

Returns

None

u8AHI_AntennaDiversityStatus

```
uint8 u8AHI_AntennaDiversityStatus(void);
```

Description

This function can be used to obtain the latest antenna diversity status (when two antennae are connected to the JN516x device and antenna diversity has been enabled through a call to **vAHI_AntennaDiversityEnable()**). The use of antenna diversity requires two antennas to be connected to the JN516x device via a switch controlled by DIO12 and DIO13 - pins are enabled for antenna diversity use by calling the function **vAHI_AntennaDiversityOutputEnable()**.

The function returns a bitmap containing the following information:

- Antenna used for the last transmit (bit 0)
- Antenna used for the last receive (bit 1)
- Currently selected antenna (bit 2)

A bit is set to 0 or 1 according to the antenna used where the value corresponds to the state of the antenna control signal output on DIO12 - the state of the antenna control signal output on DIO13 will be the complement of this value.

Parameters

None

Returns

Result is a bitmap which can be bitwise ANDed with the following masks:
E_AHI_ANTDIV_STAT_TX_MASK (0x1) - extracts antenna used for last Tx
E_AHI_ANTDIV_STAT_RX_MASK (0x2) - extracts antenna used for last Rx
E_AHI_ANTDIV_STAT_ANT_MASK (0x4) - extracts antenna currently selected

vAHI_AntennaDiversityControl

```
void vAHI_AntennaDiversityControl(
                                uint8 u8RxRssiThreshold,
                                uint8 u8RxCorrThreshold);
```

Description

This function can be used for application control of antenna diversity (enabled through a call to **vAHI_AntennaDiversityEnable()**), in the following ways:

- Receive diversity RSSI threshold can be set which determines the minimum acceptable receive signal strength below which the antenna may be switched (also subject to other conditions - see Section 2.3)
- Receive diversity Correlation threshold can be set which determines the minimum acceptable receive signal quality below which the antenna may be switched (also subject to other conditions - see Section 2.3)

Parameters

u8RxRssiThreshold	Receive diversity RSSI threshold, in 1dB steps from 0 to 31 (default value is 25 - it not recommended to use values less than 25)
u8RxCorrThreshold	Receive diversity Correlation threshold, from 0 to 63 (default value is 25 - it is not recommended to use values less than 25 or greater than 40)

Returns

None

vAHI_AntennaDiversitySwitch

```
void vAHI_AntennaDiversitySwitch(void);
```

Description

This function can be used by an application to manually switch the currently selected antenna for the control of antenna diversity. Note, calling this function will generally not be required because it is expected that most applications will make use of the automatic transmit and/or receive antenna diversity control features that are enabled by calling **vAHI_AntennaDiversityEnable()**.

The use of antenna diversity requires two antennas to be connected to the JN516x device via a switch controlled by DIO12 and DIO13 - pins are enabled for antenna diversity use by calling the function **vAHI_AntennaDiversityOutputEnable()**.

Parameters

None

Returns

None

vAHI_StartRandomNumberGenerator

```
void vAHI_StartRandomNumberGenerator(
                                    bool_t const bMode,
                                    bool_t const bIntEn);
```

Description

This function starts the random number generator on the JN516x device, which produces 16-bit random values. The generator can be started in one of two modes:

- **Single-shot mode:** Stop generator after one random number
- **Continuous mode:** Run generator continuously - this will generate a random number every 256µs

A randomly generated value can subsequently be read using the function **u16AHI_ReadRandomNumber()**. The availability of a new random number, and therefore the need to call the 'read' function, can be determined using either interrupts or polling:

- When random number generator interrupts are enabled, an interrupt will occur each time a new random value is generated. These interrupts are handled by the callback function registered with **vAHI_SysCtrlRegisterCallback()** - also refer to Appendix A.
- Alternatively, when random number generator interrupts are disabled, the function **bAHI_RndNumPoll()** can be used to poll for the availability of a new random value.

When running continuously, the random number generator can be stopped using the function **vAHI_StopRandomNumberGenerator()**.

Note that the random number generator uses the 32kHz clock domain (see Section 3.1) and will not operate properly if a high-precision external 32kHz clock source is used. Therefore, if generating random numbers in your application, you are advised to use the internal RC oscillator or a low-precision external clock source.

Parameters

bMode	Generator mode: E_AHI_RND_SINGLE_SHOT (single-shot mode) E_AHI_RND_CONTINUOUS (continuous mode)
bIntEn	Enable/disable interrupts setting: E_AHI_INTS_ENABLED(enable) E_AHI_INTS_DISABLED(disable)

Returns

None

vAHI_StopRandomNumberGenerator

```
void vAHI_StopRandomNumberGenerator(void);
```

Description

This function stops the random number generator on the JN516x device, if it has been started in continuous mode using **vAHI_StartRandomNumberGenerator()**.

Parameters

None

Returns

None

u16AHI_ReadRandomNumber

```
uint16 u16AHI_ReadRandomNumber(void);
```

Description

This function obtains the last 16-bit random value produced by the random number generator on the JN516x device. The function can only be called once the random number generator has generated a new random number.

The availability of a new random number, and therefore the need to call **u16AHI_ReadRandomNumber()**, is determined using either interrupts or polling:

- When random number generator interrupts are enabled, an interrupt will occur each time a new random value is generated.
- Alternatively, when random number generator interrupts are disabled, the function **bAHI_RndNumPoll()** can be used to poll for the availability of a new random value.

Interrupts are enabled or disabled when the random number generator is started using **vAHI_StartRandomNumberGenerator()**.

Parameters

None

Returns

16-bit random integer

bAHI_RndNumPoll

```
bool_t bAHI_RndNumPoll(void);
```

Description

This function can be used to poll the random number generator on the JN516x device - that is, to determine whether the generator has produced a new random value.

Note that this function does not obtain the random value, if one is available - the function **u16AHI_ReadRandomNumber()** must be called to read the value.

Parameters

None

Returns

Availability of new random value, one of:
TRUE - random value available
FALSE - no random value available

vAHI_SetStackOverflow

void vAHI_SetStackOverflow(bool_t *bStkOvfEn*,
uint32 *u32Addr*);

Description

This function allows processor stack overflow detection to be enabled/disabled on the JN516x device and a threshold to be set for the generation of a stack overflow exception.

The JN516x processor has a stack for temporary storage of data during code execution, such as local variables and return addresses from functions. The base address of RAM is 0x04000000 for the JN516x. The stack begins at the highest location in RAM (e.g. 0x04008000 for the JN5168) and grows downwards through RAM, as required. Thus, the stack size is dynamic, typically growing when a function is called and shrinking when returning from a function. It is difficult to determine by code inspection exactly how large the stack may grow. The lowest memory location currently used by the stack is stored in the stack pointer.

Applications occupy the bottom region of RAM and the memory space required by the applications is fixed at build time. Above the applications is the heap, which is used to store data. The heap grows upwards through RAM as data is added. Since the actual space needed by the processor stack is not known at build time, it is possible for the processor stack to grow downwards into the heap space while the application is running. This condition is called a stack overflow and results in the processor stack corrupting the heap (and potentially the application).

This function allows a threshold RAM address to be set, such that a stack overflow exception is generated if and when the stack pointer falls below this threshold address. The threshold address is specified as a 17-bit offset from the base of RAM (i.e. from 0x04000000). For example, the threshold address offset for the JN5168 can take a value up to 0x07FFC, so a good starting point is 0x07800. Note, the stack pointer is word-aligned, so the bottom 2 bits of the address are always 0.

The stack overflow exception handler function should first be developed before enabling stack overflow detection.

Note 1: If a stack overflow is detected, the detection mechanism is automatically disabled and this function must be called to re-enable it.

Note 2: The stack overflow exception handler function should have the following prototype definition:

PUBLIC void vException_StackOverflow(void);

We would not expect an exception handler written in C to return - once it has performed any actions, it should either sit in a loop or reset the device.

Parameters

bStkOvfEn	Enable/disable stack overflow detection: TRUE - enable detection FALSE - disable detection (default)
u32Addr	17-bit stack overflow threshold

Returns

None

vAHI_WriteNVData

```
void vAHI_WriteNVData(uint8 u8Location,
                      uint32 u32WriteData);
```

Description

This function writes the specified 32-bit word to the specified location in the JN516x internal 4-word NVM (Non-Volatile Memory). The JN516x internal NVM contains four 32-bit locations, numbered 0 to 3.

Parameters

u8Location	Number of NVM location to which word is to be written: 0, 1, 2 or 3
u32WriteData	32-bit word to be written to NVM

Returns

None

u32AHI_ReadNVData

uint32 u32AHI_ReadNVData(uint8 *u8Location***);**

Description

This function reads the 32-bit word from the specified location in the JN516x internal 4-word NVM (Non-Volatile Memory). The JN516x internal NVM contains four 32-bit locations, numbered 0 to 3.

Parameters

u8Location	Number of NVM location from which word is to be read: 0, 1, 2 or 3

Returns

32-bit word read from NVM

vAHI_InterruptSetPriority

```
void vAHI_InterruptSetPriority(uint16 u16Mask,
                               uint8 u8Level);
```

Description

This function can be used to configure a set of interrupt sources to have the specified interrupt priority level.

The priority level is set in the range 0 to 15, where 0 represents interrupts disabled and 15 is the highest interrupt priority level (the default priority level is 8). The interrupt sources to which this priority level will be applied are specified in a bitmap - each bit of the bitmap represents an interrupt source and should be set to '1' to include this interrupt. To help construct this bitmap, enumerations of the form MICRO_ISR_MASK_xxx are supplied in the file **MicroSpecific.h**.

The function can be called multiple times to set different priorities for different interrupt sources.

Parameters

u16Mask	Bitmap specifying the interrupt sources to which the priority level will be applied
u8Level	Interrupt priority level (in the range 0 to 15)

Returns

None

19. System Controller Functions

This chapter describes the functions that interface to the System Controller on the JN516x microcontroller.

The functions detailed in this chapter cover the following areas:

- Power management
- Clock management
- Supply voltage monitoring (Voltage brownout)
- Chip reset

Note: For information on the above chip features and guidance on using the System Controller functions in JN516x application code, refer to Chapter 3.

The System Controller functions are listed below, along with their page references:

u16AHI_PowerStatus

```
uint16 u16AHI_PowerStatus(void);
```

Description

This function returns power domain status information for the JN516x microcontroller - in particular, whether:

- Device has completed a sleep-wake cycle
- RAM contents were retained during sleep
- Analogue power domain is switched on
- Protocol logic is operational (clock is enabled)
- Watchdog timeout was responsible for the last device restart
- 32kHz clock is ready (e.g. following a reset or wake-up)
- Device has just come out of Deep Sleep mode (rather than a reset)

Note that you must check whether the 32kHz clock is ready before starting a wake timer.

Parameters

None

Returns

Returns the power domain status information in bits 0-3, 7 and 10-11 of the 16-bit return value:

Bit	Reads a '1' if...
0	Device has completed a sleep-wake cycle
1	RAM contents were retained during sleep
2	Analogue power domain is switched on
3	Protocol logic is operational
4-6	Unused
7	Watchdog caused last device restart
8-9	Unused
10	32kHz clock is ready
11	Device has just come out of Deep Sleep mode
12-15	Unused

vAHI_CpuDoze

```
void vAHI_CpuDoze(void);
```

Description

This function puts the device into Doze mode by stopping the clock to the CPU (other on-chip components are not affected by this function and so will continue to operate normally, e.g. on-chip RAM will remain powered and so retain its contents). The CPU will cease operating until an interrupt occurs to re-start normal operation. Disabling the CPU clock in this way reduces the power consumption of the device during inactive periods.

The function returns when the CPU re-starts.

Parameters

None

Returns

None

vAHI_Sleep

void vAHI_Sleep(teAHI_SleepMode *sSleepMode***);**

Description

This function puts the JN516x device into Sleep mode, being one of four 'normal' Sleep modes or Deep Sleep mode. The normal sleep modes are distinguished by whether on-chip RAM remains powered and whether the 32kHz oscillator is left running during sleep (see parameter description below).

Note 1: If an external source is used for the 32kHz oscillator on the JN516x device (see page 147), it is not recommended that the oscillator is stopped on entering Sleep mode.

Note 2: Registered callback functions are only preserved during Sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, any callback functions must be re-registered before calling **u32AHI_Init()** on waking. Alternatively, a DIO wake source can be resolved using **u32AHI_DioWakeStatus()**.

- In a normal sleep mode, the device can be woken by a reset or one of the following interrupts:
  - DIO interrupt
  - Wake timer interrupt (needs 32kHz oscillator to be left running during sleep)
  - Comparator interrupt
  - Pulse counter interrupt

  External Flash memory is not powered down during normal sleep mode. If required, you can power down the Flash memory device using the function **vAHI_FlashPowerDown()**, which must be called before **vAHI_Sleep()**, provided you are using a compatible Flash memory device - refer to the description of **vAHI_FlashPowerDown()** on page 378.
- In Deep Sleep mode, all components of the chip are powered down and the device can only be woken by the device's reset line being pulled low or an external event which triggers a change on a DIO pin (the relevant DIO must be configured as an input and DIO interrupts must be enabled).

When the device restarts, it will begin processing at the cold start or warm start entry point, depending on the Sleep mode from which the device is waking (see below). This function does not return.

Parameters

sSleepMode	Required Sleep mode, one of: E_AHI_SLEEP_OSCON_RAMON 32kHz oscillator on and RAM on (warm restart) E_AHI_SLEEP_OSCON_RAMOFF 32kHz oscillator on and RAM off (cold restart) E_AHI_SLEEP_OSCOFF_RAMON 32kHz oscillator off and RAM on (warm restart) E_AHI_SLEEP_OSCOFF_RAMOFF 32kHz oscillator off and RAM off (cold restart) E_AHI_SLEEP_DEEP Deep Sleep (all components off - cold restart)

Returns

None

vAHI_ProtocolPower

void vAHI_ProtocolPower(bool_t *bOnNotOff***);**

Description

This function is used to enable or disable the clock to the wireless transceiver - the clock is simply disabled (gated) while the domain remains powered.

If you intend to switch the clock off and then back on again, without performing a reset or going through a sleep cycle, you must first save the current IEEE 802.15.4 MAC settings before switching off the clock. Upon switching the clock on again, the MAC settings must be restored from the saved settings. You can save and restore the MAC settings using functions of the 802.15.4 Stack API:

- To save the MAC settings, use the function **vAppApiSaveMacSettings()**.
- Switching the clock back on can then be achieved by restoring the MAC settings using the function **vAppApiRestoreMacSettings()** (this function automatically calls **vAHI_ProtocolPower()** to switch on the clock)

The MAC settings save and restore functions are described in the *802.15.4 Stack API Reference Manual (JN-RM-2002)*.

While this clock is off, you must not make any calls into the stack, as this may result in the stack attempting to access the associated hardware (which is disabled) and therefore cause an exception.

***Caution:** Do not call **vAH_ProtocolPower(FALSE)** while the 802.15.4 MAC layer is active, otherwise the device may freeze.*

Parameters

bOnNotOff	Setting for clock to wireless transceiver: TRUE to switch the clock ON FALSE to switch the clock OFF

Returns

None

bAHI_Set32KhzClockMode

bool_t bAHI_Set32KhzClockMode(uint8 const *u8Mode*);

Description

This function selects an external source for the 32kHz clock for the JN516x device (the function is used to move from the internal source to an external source). The selected clock can be either of the following options:

- **External module (RC circuit):** This clock must be supplied on DIO9
- **External crystal:** This circuit must be attached on DIO9 and DIO10

If the external crystal is selected and is not already running, it will be started and this function will not return until the crystal has stabilised (which can take up to 1 second).

If this function is not called, the internal 32kHz RC oscillator is used by default. Note that once an external 32kHz clock source has been selected using this function, it is not possible to switch back to the internal RC oscillator.

If required, this function should be called near the start of the application. In particular, if selecting the external crystal, the function must be called before Timer 0 and any wake timers are used by the application, since these timers are used by the function when switching the clock source to the external crystal.

Note that there is no need to explicitly configure DIO9 or DIO10 as an input, as this is done automatically by the function.

When selecting an external module, you must disable the pull-up on DIO9 using the function **vAHI_DioSetPullup()**. However, when selecting the external crystal, the pull-ups on DIO9 and DIO10 are disabled automatically.

Parameters

u8Mode	External 32kHz clock source: E_AHI_EXTERNAL_RC (external module) E_AHI_XTAL (external crystal)

Returns

TRUE - valid clock source specified
FALSE - invalid clock source specified

vAHI_Init32KhzXtal

```
void vAHI_Init32KhzXtal(void);
```

Description

This function starts an external crystal that may later be selected as the source for the 32kHz clock on the JN516x device (the function does not switch the clock to this source). The external crystal must be connected to the device via DIO9 (pin 32) and DIO10 (pin 33).

The external crystal that has been started needs time to stabilise before it can be used as a clock source. The function returns immediately, allowing the application to do other processing or to put the JN516x device into sleep mode while waiting for the crystal to become ready - it takes up to 1 second to stabilise. Therefore, in the case of sleep, the application should typically set a wake timer to wake the device after 1 second. The function **bAHI_Set32KhzClockMode()** can then be called to select the external crystal as the source for the 32kHz clock.

Parameters

None

Returns

None

vAHI_Trim32KhzRC

void vAHI_Trim32KhzRC(uint8 *u8Value***);**

Description

This function sets the electrical current consumption of the 32kHz RC oscillator (external module), which determines the accuracy of the clock frequency produced - the higher the current, the more accurate the generated clock frequency.

Presently, two current settings are available; 0.53µA and 0.35µA, with corresponding frequency calibration errors of ±300ppm and ±600ppm, respectively.

Parameters

u8Value	Current consumption to be set: 0: Reserved 1: Reserved 2: 0.53µA (default) 3: 0.35µA 4-7: No effect

Returns

None

vAHI_SelectClockSource

```
void vAHI_SelectClockSource(bool_t bClkSource,
                            bool_t bPowerDown);
```

Description

This function selects the clock source for the system clock on the JN516x device. The clock options are:

- Crystal oscillator (XTAL) of frequency 32MHz, derived from external crystal
- Internal high-speed RC oscillator of frequency 27MHz (uncalibrated), but can be adjusted to 32MHz (calibrated) using the function **bAHI_TrimHighSpeedRCOsc()**

If used, the external crystal is connected to pins 4 and 5.

The CPU clock and peripheral clock are divided down versions of this clock source. The CPU clock divisor is controlled using the function **bAHI_SetClockRate()**. The peripheral clock is produced by dividing this clock source by two. Thus, the crystal oscillator will produce a 16MHz peripheral clock and the RC oscillator will produce a peripheral clock of 13.5MHz (±18%, uncalibrated) or 16MHz (±5% calibrated).

Caution: *You will not be able to run the full system while using the RC oscillator. It is possible to execute code while using this clock source, but it is not possible to transmit or receive. Further, timing intervals for the timers may need to be based on a frequency of 13.5MHz.*

When the RC oscillator is selected, the function allows the crystal oscillator to be powered down, in order to save power.

If the crystal oscillator is selected using this function but the oscillator is not already running when the function is called (see **vAHI_EnableFastStartUp()**), typically 1ms will be required for the oscillator to become stable once it has powered up. The function will not return until the oscillator has stabilised.

Parameters

bClkSource	System clock source: TRUE - RC oscillator FALSE - crystal oscillator
bPowerDown	Power down crystal oscillator: TRUE - power down when not needed FALSE - leave powered up (when not in Sleep mode)

Returns

None

bAHI_GetClkSource

```
bool_t bAHI_GetClkSource(void);
```

Description

This function obtains the identity of the clock source for the system clock on the JN516x device. The clock options are:

- Crystal oscillator (XTAL) of frequency 32MHz, derived from external crystal
- Internal high-speed RC oscillator of frequency 27MHz (uncalibrated), but can be adjusted to 32MHz (calibrated) using the function **bAHI_TrimHighSpeedRCOsc()**

If the high-speed RC oscillator is the system clock source, **bAHI_GetClkSource()** does not indicate the operating frequency of the oscillator.

Parameters

None

Returns

Clock source, one of:
TRUE - RC oscillator
FALSE - Crystal oscillator

bAHI_SetClockRate

bool_t bAHI_SetClockRate(uint8 *u8Speed***);**

Description

This function is used to select a CPU clock rate on the JN516x device by setting the divisor used to derive the CPU clock from the system source clock.

The system clock source is selected using the function **vAHI_SelectClockSource()** as one of:

- 32MHz external crystal oscillator
- High-speed internal RC oscillator of frequency 27MHz (uncalibrated), but can be adjusted to 32MHz (calibrated) using the function **bAHI_TrimHighSpeedRCOsc()**

The possible divisors are 1, 2, 4,8, 16 and 32.

Irrespective of the setting made with this function, the CPU clock rate will default to 16MHz or 13.5MHz (clock divisor of 2) following sleep - that is, the clock divisor configured before sleep is not automatically re-applied after sleep.

Parameters

u8Speed Divisor for desired CPU clock frequency:

u8Speed	Clock Divisor	Resulting Frequency (MHz)	
		From 32MHz	From 27MHz
000	8	4	3.38
001	4	8	6.75
010	2	16	13.5
011	1	32	27
100	Invalid		
101			
110	16	2	1.69
111	32	1	0.84

Note: When the RC oscillator is used as the source, the resulting CPU clock frequency is dictated by the actual RC oscillator frequency, which can be 27MHz (±18%) or 32MHz (±5% when calibrated).

Returns

TRUE - successful
FALSE - invalid divisor value specified

u8AHI_GetSystemClkRate

```
uint8 u8AHI_GetSystemClkRate(void);
```

Description

This function obtains the divisor used to divide down the source clock to produce the CPU clock on the JN516x device.

The system clock source is selected using the function **vAHI_SelectClockSource()** as one of:

- 32MHz external crystal oscillator
- High-speed internal RC oscillator of frequency 27MHz (uncalibrated), but can be adjusted to 32MHz using the function **bAHI_TrimHighSpeedRCOsc()**

The current clock source can be obtained using the function **bAHI_GetClkSource()**, but this function does not indicate the operating frequency of the RC oscillator (if used).

The divisor for the CPU clock is configured using **bAHI_SetClockRate()**.

The possible divisors are 1, 2, 4, 8, 16 and 32. The CPU clock frequency can be calculated by dividing the source clock frequency by the divisor returned by this function. The results are summarised in the table below.

Returned Value	Clock Divisor	Resulting Frequency (MHz)	
		From 32MHz	From 27MHz
0	8	4	3.38
1	4	8	6.75
2	2	16	13.5
3	1	32	27
4	Invalid		
5			
6	16	2	1.69
7	32	1	0.84

Note: When the RC oscillator is used as the source, the resulting system clock frequency is dictated by the actual RC oscillator frequency, which can be 27MHz (±18%) or 32MHz (±5% when calibrated).

Parameters

None

Returns

0: Divisor of 8
1: Divisor of 4
2: Divisor of 2
3: Divisor of 1 (source frequency untouched)
6: Divisor of 16
7: Divisor of 32

bAHI_Clock32MHzStable

```
bool_t bAHI_Clock32MHzStable(void);
```

Description

This function can be used to check whether the 32MHz crystal oscillator (sourced externally) is running and stable.

Parameters

None

Returns

TRUE - oscillator is stable

FALSE - oscillator is not stable

vAHI_ClockXtalPull

void vAHI_ClockXtalPull(uint8 *u8PullValue***);**

Description

This function can be used to decrease (pull) the frequency of the 32MHz crystal oscillator by increasing the crystal load capacitance in the oscillator tuning circuit. If the JN516x device operates at temperatures in excess of 90°C, it may be necessary to call this function to maintain the frequency tolerance of the clock to within the 40ppm limit specified by the IEEE 802.15.4 standard.

The crystal pulling coefficient specifies the sensitivity of the crystal frequency with respect to the crystal load capacitance. Crystals suitable for use with the JN516x will typically have a crystal pulling coefficient value in the range of 15 to 25 ppm/pF. Although the crystal pulling coefficient has a positive value, it should be noted that the crystal frequency will decrease with increasing crystal load capacitance.

The formula for calculating the crystal pulling coefficient *(Δf)* is given by:

$$\Delta f = \frac{C_m \times 10^6}{2 \times (C_L + C_S)^2} \qquad ppm/F$$

where,

C_m is the crystal motional capacitance (e.g. 4.4fF)
C_L is the crystal load capacitance (e.g. 9pF)
C_S is the crystal shunt or package capacitance (e.g. 1pF)

The example crystal capacitance values quoted above yield a crystal pulling coefficient of 22ppm/pF. Therefore, an increase of the crystal load capacitance *(C_L)* by 1pF will reduce the crystal oscillating frequency by 22ppm.

Note: Please refer to the JN516x data sheet and the crystal manufacturer data sheet for specific details of the crystal capacitances. Also refer to the Application Note *JN516x Temperature-dependent Operating Guidelines (JN-AN-1186)* for details of the crystal oscillator frequency compensation over temperature.

Parameters

u8PullValue Pull-value controls the additional crystal load capacitance:

0: No additional crystal load capacitance (default)
1: 1pF additional crystal load capacitance (as below)
2: 1pF additional crystal load capacitance (as above)
3: 2pF additional crystal load capacitance

Returns

None

vAHI_EnableFastStartUp

```
void vAHI_EnableFastStartUp(bool_t bMode,
                            bool_t bPowerDown);
```

Description

This function can be used to modify the (default) fast start-up following sleep. If required, the function must be called before entering sleep mode.

The external 32MHz crystal oscillator is powered down during sleep and takes some time to become available again when the JN516x device wakes. A more rapid start-up from sleep can be achieved by using the internal high-speed RC oscillator immediately on waking and then switching to the crystal oscillator when it becomes available. This allows initial processing at wake-up to proceed before the crystal oscillator is ready. This rapid start-up following sleep occurs automatically by default.

This function can be used to configure the switch to the crystal oscillator to be either automatic or manual (selected through the *bMode* parameter):

- **Automatic switch:** The crystal oscillator starts immediately on waking from sleep (irrespective of the setting of the *bPowerDown* parameter - see below), allowing it to warm up and stabilise while the boot code is running. The crystal oscillator is then automatically and seamlessly switched to when ready. To determine whether the switch has taken place, you can use the function **bAHI_GetClkSource()**.
- **Manual switch:** The switch to the crystal oscillator takes place at any time the application chooses, using the function **vAHI_SelectClockSource()**. If the crystal oscillator is not already running when this manual switch is initiated, the oscillator will be automatically started. Depending on the oscillator's progress towards stabilisation at the time of the switch request, there may be a delay of up to 1ms before the crystal oscillator is stable and the switch takes place.

It is also possible to use this function to configure the device to keep the RC oscillator as the source for the system clock when re-starting from sleep. To do this, it is necessary to select a manual switch (through the *bMode* parameter) but not perform any switch.

While the internal high-speed RC oscillator is being used, you should not attempt to transmit or receive, and you can only use the JN516x peripherals with special care - see Section 3.1.3.

To conserve power, you can use the *bPowerDown* parameter to keep the crystal oscillator powered down until it is needed.

Parameters

bMode	Automatic/manual switch to 32MHz crystal oscillator: TRUE - automatic switch FALSE - manual switch
bPowerDown	Power down crystal oscillator: TRUE - power down when not needed FALSE - leave powered up (when not in sleep mode)

Returns

None

bAHI_TrimHighSpeedRCOsc

```
bool_t bAHI_TrimHighSpeedRCOsc(void);
```

Description

This function can be used on the JN516x device to adjust the frequency of the internal high-speed RC oscillator from 27MHz uncalibrated to 32MHz calibrated.

Parameters

None

Returns

TRUE - RC oscillator frequency successfully changed

FALSE - Unable to change RC oscillator frequency

vAHI_OptimiseWaitStates

```
void vAHI_OptimiseWaitStates(void);
```

Description

This function recalculates the wait-state settings for the internal Flash memory and EEPROM devices after the system clock source or CPU clock frequency has been changed to minimise the Flash access time. The function is automatically called after calling **vAHI_SelectClockSource()** or **bAHI_SetClockRate()** but should preferably be called by the application in either of the following circumstances:

- at the start of an application (cold start or warm restart) with the system clock running from the internal high-speed RC oscillator
- after switching from the internal high-speed RC oscillator to the external 32MHz crystal

Note: By default, following a reset or on waking from sleep, the device will automatically switch from using the internal high-speed RC oscillator to the external 32MHz crystal as the system clock source once the crystal oscillator has stabilised.

Parameters

None

Returns

None

vAHI_BrownOutConfigure

```
void vAHI_BrownOutConfigure(unit8 u8VboSelect,
                            bool_t bVboRestEn,
                            bool_t bVboEn,
                            bool_t bVboIntEnFalling,
                            bool_t bVboIntEnRising);
```

Description

This function configures and enables the Supply Voltage Monitor (SVM), which can be used to detect a brownout condition on the JN516x device.

Brownout is the point at which the chip supply voltage falls to (or below) a pre-defined level. The default brownout level is set to 2.0 V in the JN516x device during manufacture. This function can be used to temporarily over-ride the default brownout voltage with one of several voltage levels. Before the new setting takes effect, there is a delay of up to 3.3µs.

The occurrence of the brownout condition is tracked by an internal 'brownout bit' in the device, which is set to:

- '1' when the brownout state is entered - that is, when the supply voltage crosses the brownout voltage from above (decreasing supply voltage)
- '0' when the brownout state is exited - that is, when the supply voltage crosses the brownout voltage from below (increasing supply voltage)

When SVM is enabled, the occurrence of a brownout event can be detected by the application in one of three ways:

- An automatic device reset (if configured using this function) - the function **bAHI_BrownOutEventResetStatus()** is used to check if a brownout caused a reset
- A brownout interrupt (if configured using this function) - see below
- Manual polling using the function **u32AHI_BrownOutPoll()**

Note: Following a device reset or sleep, 'reset on brownout' will be re-enabled and the default setting for the brownout voltage threshold will be re-instated.

Interrupts can be individually enabled that are generated when the chip goes into and out of brownout. Brownout interrupts are handled by the System Controller callback function, which is registered using the function **vAHI_SysCtrlRegisterCallback()**.

Parameters

u8VboSelect	Voltage threshold for brownout: 0: 1.95 V 1: 2.0 V (default) 2: 2.1 V 3: 2.2 V 4: 2.3 V 5: 2.4 V 6: 2.7 V 7: 3.0 V
bVboRestEn	Enable/disable 'reset on brownout': TRUE to enable reset FALSE to disable reset
bVboEn	Enable/disable SVM: TRUE to enable SVM FALSE to disable SVM
bVboIntEnFalling	Enable/disable interrupt generated when the brownout bit falls, indicating that the device has come out of the brownout state: TRUE to enable interrupt FALSE to disable interrupt
bVboIntEnRising	Enable/disable interrupt generated when the brownout bit rises, indicating that the device has entered the brownout state: TRUE to enable interrupt FALSE to disable interrupt

Returns

None

bAHI_BrownOutStatus

```
bool_t bAHI_BrownOutStatus(void);
```

Description

This function can be used to check whether the current supply voltage to the JN516x device is above or below the brownout voltage setting (the default value or the value configured using the function **vAHI_BrownOutConfigure()**).

The function is useful when deciding on a suitable brownout voltage to configure.

There may be a delay before **bAHI_BrownOutStatus()** returns, if the brownout configuration has recently changed - this delay is up to 3.3µs.

Parameters

None

Returns

TRUE - supply voltage is below brownout voltage

FALSE - supply voltage is above brownout voltage

bAHI_BrownOutEventResetStatus

```
bool_t bAHI_BrownOutEventResetStatus(void);
```

Description

This function can be called following a JN516x device reset to determine whether the reset event was caused by a brownout. This allows the application to then take any necessary action following a confirmed brownout.

Note that by default, a brownout will trigger a reset event. However, if **vAHI_BrownOutConfigure()** was called, the 'reset on brownout' option must have been explicitly enabled during this call.

Parameters

None

Returns

TRUE if brownout caused reset, FALSE otherwise

u32AHI_BrownOutPoll

```
uint32 u32AHI_BrownOutPoll(void);
```

Description

This function can be used to poll for a brownout on the JN516x device - that is, to check whether a brownout has occurred. The returned value will indicate whether the chip supply voltage has fallen below or risen above the brownout voltage (or both). Polling using this function clears the brownout status, so that a new and valid result will be obtained the next time the function is called.

Polling in this way is useful when brownout interrupts and 'reset on brownout' have been disabled through **vAHI_BrownOutConfigure()**. However, to successfully poll, brownout detection must still have been enabled through the latter function.

Parameters

None

Returns

32-bit value containing brownout status:

- Bit 24 is set (to '1') if the chip has come out of brownout - that is, an increasing supply voltage has crossed the brownout voltage from below. If the 32-bit return value is bitwise ANDed with the bitmask E_AHI_SYSCTRL_VFEM_MASK, a non-zero result indicates this brownout condition.
- Bit 25 is set (to '1') if the chip has gone into brownout - that is, a decreasing supply voltage has crossed the brownout voltage from above. If the 32-bit return value is bitwise ANDed with the bitmask E_AHI_SYSCTRL_VREM_MASK, a non-zero result indicates this brownout condition.

vAHI_SwReset

```
void vAHI_SwReset(void);
```

Description

This function generates an internal reset which completely re-starts the system through the full reset sequence.

Caution: *This reset has the same effect as pulling the external RESETN line low and is likely to result in the loss of the contents of on-chip RAM.*

Parameters

None

Returns

None

vAHI_SetJTAGdebugger

```
void vAHI_SetJTAGdebugger(bool_t bEnable,
                          bool_t bLocation);
```

Description

This function can be used to enable or disable the JTAG debugger hardware, and to select the set of DIOs on which the JTAG signals will be located (DIO15-12 or DIO7-4). The pin location option allows DIO usage conflicts between the JTAG debugger and any enabled peripheral to be more easily avoided. The JTAG debugger has the highest priority for controlling these DIO pins.

This function will typically not be required in an application because the debugger will be automatically configured by the bootloader depending on makefile build options.

Note: The bootloader will automatically enable the debugger hardware if the makefile build option variable HARDWARE_DEBUG_ENABLED is set to 1. The bootloader will also configure the DIO pins for the enabled debugger as directed by the makefile build option variable DEBUG_PORT, which should be set to UART0 (for DIO7-4) or UART1 (for DIO15-12).

Parameters

bEnable	Enable or disable debugger: TRUE - enable FALSE - disable
bLocation	Set of DIOs on which JTAG signals are located: TRUE - JTAG on DIO15-12 FALSE - JTAG on DIO7-4

Returns

None

vAHI_ClearSystemEventStatus

void vAHI_ClearSystemEventStatus(uint32 *u32BitMask*);

Description

This function clears the specified System Controller interrupt sources on a JN516x device. A bitmask indicating the interrupt sources to be cleared must be passed into the function.

Parameters

u32BitMask	Bitmask of the System Controller interrupt sources to be cleared. To clear an interrupt, the corresponding bit must be set to 1 - for bit numbers, refer to Table 9 on page 394

Returns

None

vAHI_SysCtrlRegisterCallback

```
void vAHI_SysCtrlRegisterCallback(
                PR_HWINT_APPCALLBACK prSysCtrlCallback);
```

Description

This function registers a user-defined callback function that will be called when a System Control interrupt is triggered. The source of this interrupt could be the wake timer, a comparator, a DIO event, a brownout event, a pulse counter or the random number generator.

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.

Note that the System Controller interrupt handler will clear the interrupt before invoking the callback function to deal with the interrupt.

Interrupt handling is described in Appendix A.

Parameters

prSysCtrlCallback	Pointer to callback function to be registered

Returns

None

20. Analogue Peripheral Functions

This chapter describes the functions that are used to control the analogue peripherals of the JN516x microcontroller. These are the on-chip peripheral types with analogue inputs or outputs: Analogue-to-Digital Converter (ADC) and comparator.

The analogue peripheral functions are divided into the following sections:

- Common analogue peripheral functions, described in Section 20.1
- ADC functions, described in Section 20.2
- ADC with DMA Engine functions, described in Section 20.3
- Comparator functions, described in Section 20.4

Note: For information on the analogue peripherals and guidance on using these functions in JN516x application code, refer to Chapter 4.

20.1 Common Analogue Peripheral Functions

This section describes functions used to configure functionality shared by the on-chip analogue peripherals - the ADC and comparator.

The functions are listed below, along with their page references:

vAHI_ApConfigure

```
void vAHI_ApConfigure(bool_t bAPRegulator,
                      bool_t bIntEnable,
                      uint8 u8SampleSelect,
                      uint8 u8ClockDivRatio,
                      bool_t bRefSelect);
```

Description

This function configures common parameters for all on-chip analogue resources.

- The regulator used to power the analogue peripherals must be enabled for the remaining input parameters to take effect and for the ADC to operate. The regulator minimises digital noise and is sourced from the analogue supply pin VDD1.
- Interrupts can be enabled that are generated after each ADC conversion.
- The divisor is specified to obtain the ADC clock from the peripheral clock.
- The 'sampling interval' is specified as a number of clock periods.
- The source of the reference voltage, V_{ref}, is specified.

The peripheral clock runs at 16MHz when the system clock is sourced from the external 32MHz crystal. The supplied clock divisor enumerations (see the parameter *u8ClockDivRatio* below) for producing the ADC clock are based on a 16MHz peripheral clock. If the peripheral clock frequency is not exactly 16MHz, the resultant ADC clock frequency will be scaled accordingly.

For the ADC, the input signal is integrated over *3 x sampling interval,* where *sampling interval* is defined as 2, 4, 6 or 8 clock cycles. The total conversion period (for a single value) is given by

[(3 x *sampling interval*) + 13] x *clock period*

Parameters

bAPRegulator	Enable/disable the regulator used to power the analogue peripherals: E_AHI_AP_REGULATOR_ENABLE E_AHI_AP_REGULATOR_DISABLE
bIntEnable	Enable/disable interrupt when ADC conversion completes: E_AHI_AP_INT_ENABLE E_AHI_AP_INT_DISABLE
u8SampleSelect	Sampling interval in terms of divided clock periods: E_AHI_AP_SAMPLE_2 (2 clock periods) E_AHI_AP_SAMPLE_4 (4 clock periods) E_AHI_AP_SAMPLE_6 (6 clock periods) E_AHI_AP_SAMPLE_8 (8 clock periods)
u8ClockDivRatio	Clock divisor (frequencies based on16MHz peripheral clock): E_AHI_AP_CLOCKDIV_2MHZ (divisor of 8) E_AHI_AP_CLOCKDIV_1MHZ (divisor of 16) E_AHI_AP_CLOCKDIV_500KHZ (divisor of 32) E_AHI_AP_CLOCKDIV_250KHZ (divisor of 64) (500kHz is recommended for ADC)

bRefSelect	Source of reference voltage, V_{ref}: E_AHI_AP_EXTREF (external from VREF pin) E_AHI_AP_INTREF (internal)

Returns

None

vAHI_ApSetBandGap

void vAHI_ApSetBandGap(bool_t *bBandGapEnable***);**

Description

This function allows the device's internal band-gap cell to be routed to the VREF pin, in order to provide internal reference voltage de-coupling.

Note that:

- Before calling **vAHI_ApSetBandGap()**, you must ensure that protocol power is enabled, by calling **vAHI_ProtocolPower()** if necessary, otherwise an exception will occur. Also, subsequently disabling protocol power will cause the band-gap cell setting to be lost.
- A call to **vAHI_ApSetBandGap()** is only valid if an internal source for V_{ref} has been selected through the function **vAHI_ApConfigure()**.

Caution: *Never call this function to enable the use of the internal band-gap cell after selecting an external source for V_{ref} through **vAHI_ApConfigure()**, otherwise damage to the device may result.*

Parameters

bBandGapEnable	Enable/disable routing of band-gap cell to VREF: E_AHI_AP_BANDGAP_ENABLE (enable routing) E_AHI_AP_BANDGAP_DISABLE (disable routing)

Returns

None

bAHI_APRegulatorEnabled

```
bool_t bAHI_APRegulatorEnabled(void);
```

Description

This function enquires whether the regulator used to power the analogue peripherals has powered up. The function should be called after enabling the regulator through **vAHI_ApConfigure()**. When the regulator is enabled, it will take a little time to start - this period is 16µs.

Parameters

None

Returns

TRUE if powered up, FALSE if still waiting

vAHI_APRegisterCallback

```
void vAHI_APRegisterCallback(
                    PR_HWINT_APPCALLBACK prApCallback);
```

Description

This function registers a user-defined callback function that will be called when an analogue peripheral interrupt is triggered.

Note: Among the analogue peripherals, only the ADC generates Analogue peripheral interrupts. The comparator generates System Controller interrupts (see Section 3.5).

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.

Interrupt handling is described in Appendix A. Analogue peripheral interrupt handling is further described in Section 4.4.

Parameters

prApCallback	Pointer to callback function to be registered

Returns

None

20.2 ADC Functions

This section describes the functions that can be used to control the on-chip 10-bit ADC (Analogue-to-Digital Converter). The ADC can be switched between 6 different sources - 4 pins on the device, an on-chip temperature sensor and a voltage monitor. The ADC can be configured to perform a single conversion or convert continuously (until stopped). It is also possible to operate the ADC in accumulation mode, in which a number of consecutive samples are added together for averaging.

The ADC functions are listed below, along with their page references:

Note 1: In order to use the ADC, the regulator used to power the analogue peripherals must first be enabled using the function **vAHI_ApConfigure()**. You must also check that the regulator has started, using the function **bAHI_APRegulatorEnabled()**.

Note 2: When an ADC input which is shared with a DIO is used, the associated DIO should be configured as an input with the pull-up disabled (using DIO functions detailed in Chapter 21).

vAHI_AdcEnable

```
void vAHI_AdcEnable(bool_t bContinuous,
                    bool_t bInputRange,
                    uint8 u8Source);
```

Description

This function configures and enables the ADC. Note that this function does not start the conversions (this is done using the function **vAHI_AdcStartSample()** or, in the case of accumulation mode, using **vAHI_AdcStartAccumulateSamples()**).

The function allows the ADC mode of operation to be set to one of:

- **Single-shot mode:** ADC will perform a single conversion and then stop
- **Continuous mode:** ADC will perform conversions repeatedly until stopped using the function **vAHI_AdcDisable()**

If using the ADC in accumulation mode then the mode set here is ignored.

The function also allows the input source for the ADC to be selected as one of four pins, the on-chip temperature sensor or the internal voltage monitor. The voltage range for the analogue input to the ADC can also be selected as 0 to V_{ref} or 0 to $2V_{ref}$.

Note that:

- The source of V_{ref} is defined using **vAHI_ApConfigure()**.
- The internal voltage monitor measures the voltage on the pin VDD1.

Before enabling the ADC, the regulator used to power the analogue peripherals must have been enabled using the function **vAHI_ApConfigure()**. You must also check that the regulator has started, using the function **bAHI_APRegulatorEnabled()**.

Parameters

bContinuous	Conversion mode of ADC: E_AHI_ADC_CONTINUOUS (continous mode) E_AHI_ADC_SINGLE_SHOT (single-shot mode)
bInputRange	Input voltage range: E_AHI_AP_INPUT_RANGE_1 (0 to V_{ref}) E_AHI_AP_INPUT_RANGE_2 (0 to $2V_{ref}$)
u8Source	Source for conversions: E_AHI_ADC_SRC_ADC_1 (ADC1 input) E_AHI_ADC_SRC_ADC_2 (ADC2 input) E_AHI_ADC_SRC_ADC_3 (ADC3 input) E_AHI_ADC_SRC_ADC_4 (ADC4 input) E_AHI_ADC_SRC_TEMP (on-chip temperature sensor) E_AHI_ADC_SRC_VOLT (internal voltage monitor)

Returns

None

vAHI_AdcStartSample

```
void vAHI_AdcStartSample(void);
```

Description

This function starts the ADC sampling in single-shot or continuous mode, depending on which mode has been configured using **vAHI_AdcEnable()**.

If analogue peripheral interrupts have been enabled in **vAHI_ApConfigure()**, an interrupt will be triggered when a result becomes available. Alternatively, if interrupts are disabled, you can use **bAHI_AdcPoll()** to check for a result. Once a conversion result becomes available, it should be read with **u16AHI_AdcRead()**.

Once sampling has been started in continuous mode, it can be stopped at any time using the function **vAHI_AdcDisable()**.

Note: If you wish to use the ADC in accumulation mode, start sampling using **vAHI_AdcStartAccumulateSamples()** instead.

Parameters

None

Returns

None

vAHI_AdcStartAccumulateSamples

```
void vAHI_AdcStartAccumulateSamples(
                                    uint8 u8AccSamples);
```

Description

This function starts the ADC sampling in accumulation mode, which allows a specified number of consecutive samples to be added together to facilitate the averaging of output samples. Note that before calling this function, the ADC must be configured and enabled using **vAHI_AdcEnable()**.

In accumulation mode, the output will become available after the specified number of consecutive conversions (2, 4, 8 or 16), where this output is the sum of these conversion results. Conversion will then stop. The cumulative result can be obtained using the function **u16AHI_AdcRead()**, but the application must then perform the averaging calculation itself (by dividing the result by the appropriate number of samples).

If analogue peripheral interrupts have been enabled in **vAHI_ApConfigure()**, an interrupt will be triggered when the accumulated result becomes available. Alternatively, if interrupts are disabled, you can use the function **bAHI_AdcPoll()** to check whether the conversions have completed.

In this mode, conversion can be stopped at any time using the function **vAHI_AdcDisable()**.

Parameters

u8AccSamples	Number of samples to add together: E_AHI_ADC_ACC_SAMPLE_2 (2 samples) E_AHI_ADC_ACC_SAMPLE_4 (4 samples) E_AHI_ADC_ACC_SAMPLE_8 (8 samples) E_AHI_ADC_ACC_SAMPLE_16 (16 samples)

Returns

None

bAHI_AdcPoll

```
bool_t bAHI_AdcPoll(void);
```

Description

This function can be used when the ADC is operating in single-shot mode, continuous mode or accumulation mode, to check whether the ADC is still busy performing a conversion:

- In single-shot mode, the poll result indicates whether the sample has been taken and is ready to be read.
- In continuous mode, the poll result indicates whether a new sample is ready to be read.
- In accumulation mode, the poll result indicates whether the final sample for the accumulation has been taken.

You may wish to call this function before attempting to read the conversion result using **u16AHI_AdcRead()**, particularly if you are not using the analogue peripheral interrupts.

Parameters

None

Returns

TRUE if ADC is busy, FALSE if conversion complete

u16AHI_AdcRead

```
uint16 u16AHI_AdcRead(void);
```

Description

This function reads the most recent ADC conversion result.

- If sampling was started using the function **vAHI_AdcStartSample()**, the most recent ADC conversion will be returned.
- If sampling was started using the function **vAHI_AdcStartAccumulateSamples()**, the last accumulated conversion result will be returned.

If analogue peripheral interrupts have been enabled in **vAHI_ApConfigure()**, you must call this read function from a callback function invoked when an interrupt has been generated to indicate that an ADC result is ready (this user-defined callback function is registered using the function **vAHI_APRegisterCallback()**). Alternatively, if interrupts have not been enabled, before calling the read function, you must first check whether a result is ready using the function **bAHI_AdcPoll()**.

Parameters

None

Returns

Most recent single conversion result or accumulated conversion result:

- A single conversion result is contained in the least significant 10 bits of the 16-bit returned value
- An accumulated conversion result is contained in the least significant 14 bits of the 16-bit returned value

vAHI_AdcDisable

```
void vAHI_AdcDisable(void);
```

Description

This function disables the ADC. It can be used to stop the ADC when operating in continuous mode or accumulation mode.

Parameters

None

Returns

None

20.3 ADC with DMA Engine Functions

This section describes the functions that can be used to control the on-chip 10-bit ADC (Analogue-to-Digital Converter) when used in conjunction with the DMA engine, in 'sample buffer mode'. In this mode, ADC data samples are produced at regular intervals and transferred into a buffer in RAM as 16-bit samples, where this data transfer and storage is performed by the DMA engine independently of the CPU.

The ADC with DMA Engine functions are listed below, along with their page references:

Note 1: In order to use the ADC, the regulator used to power the analogue peripherals must first be enabled using the function **vAHI_ApConfigure()**. You must also check that the regulator has started, using the function **bAHI_APRegulatorEnabled()**.

Note 2: When an ADC input which is shared with a DIO is used, the associated DIO should be configured as an input with the pull-up disabled (using DIO functions detailed in Chapter 21).

bAHI_AdcEnableSampleBuffer

```
bool_t bAHI_AdcEnableSampleBuffer(
                                  bool_t bInputRange,
                                  uint8 u8Timer,
                                  uint8 u8SourceBitmap,
                                  uint16 *pu16Buffer,
                                  uint16 u16BufferSize,
                                  bool_t bBufferWrap,
                                  uint8 u8InterruptModes);
```

Description

This function configures and starts the ADC in sample buffer mode, in which 10-bit samples are produced repeatedly by the ADC and are transferred into a RAM buffer by the DMA engine as 16-bit samples.

Sampling is triggered by a JN516x timer, which must be specified through this function as Timer 0, 1, 2, 3 or 4. The chosen timer must have been configured and started in 'Timer repeat' mode before this function is called.

The function allows the input source(s) for the ADC to be selected from four external input pins (DIOs), the on-chip temperature sensor and the internal voltage monitor. Sample buffer mode allows multiple inputs to be selected (through a bitmap) and multiplexed - in this case, on each timer trigger, samples will be produced from each of the selected inputs, in turn, and written to the buffer. The inputs are sampled in the following order: ADC1 input, ADC2 input, ADC3 input, ADC4 input, temperature sensor, voltage monitor. Note that the internal voltage monitor measures the voltage on the pin VDD1.

The RAM buffer must be specified in terms of a pointer to the start of the buffer and the size of the buffer (in 16-bit samples, up to a maximum of 2047). The option for buffer to wrap around can also be selected - in this case, once the buffer is full, data will be written to the start of the buffer again. If this option is not selected, conversions will stop once the buffer is full.

The condition(s) on which DMA interrupts will be generated can also be selected. These interrupts reflect the state of the RAM buffer and at least one must be selected:

- Buffer is half-full
- Buffer is full
- Buffer is full and has wrapped around

These interrupts must be serviced by the user-defined callback function registered using **vAHI_APRegisterCallback()**.

The voltage range for the analogue input to the ADC can also be selected as 0 to V_{ref} or 0 to $2V_{ref}$. Note that the source of V_{ref} is defined using **vAHI_ApConfigure()**.

Before starting the ADC using this function, the regulator used to power the analogue peripherals must have been enabled using the function **vAHI_ApConfigure()**. You must also check that the regulator has started, using the function **bAHI_APRegulatorEnabled()**.

Parameters

bInputRange	Input voltage range: E_AHI_AP_INPUT_RANGE_1 (0 to V_{ref}) E_AHI_AP_INPUT_RANGE_2 (0 to $2V_{ref}$)
u8Timer	Identity of timer to use for trigger: E_AHI_TIMER_0 (Timer 0) E_AHI_TIMER_1 (Timer 1) E_AHI_TIMER_2 (Timer 2) E_AHI_TIMER_3 (Timer 3) E_AHI_TIMER_4 (Timer 4)
u8Source	Source(s) for conversions - any combination of: E_AHI_ADC_SRC_ADC_1 (ADC1 input) E_AHI_ADC_SRC_ADC_2 (ADC2 input) E_AHI_ADC_SRC_ADC_3 (ADC3 input) E_AHI_ADC_SRC_ADC_4 (ADC4 input) E_AHI_ADC_SRC_TEMP (on-chip temperature sensor) E_AHI_ADC_SRC_VOLT (internal voltage monitor)
**pu16Buffer*	Pointer to start of RAM buffer in which samples will be stored
u16BufferSize	Size of RAM buffer, in 16-bit samples (valid range is 1-2047)
bBufferWrap	Indicates whether buffer will wrap around: TRUE - Buffer wrap enabled FALSE - Buffer wrap disabled
u8InterruptModes	DMA interrupt(s) to be generated (must select at least one): E_AHI_AP_INT_DMA_OVER_MASK (buffer wrapped) E_AHI_AP_INT_DMA_END_MASK (buffer full) E_AHI_AP_INT_DMA_MID_MASK (buffer half-full)

Returns

TRUE - conversions successfully started

FALSE - conversions not successfully started (e.g. parameter error)

vAHI_AdcDisableSampleBuffer

```
void vAHI_AdcDisableSampleBuffer(void);
```

Description

This function can be used to stop the ADC operation when it has been started in sample buffer mode using the function **bAHI_AdcEnableSampleBuffer()**. In particular, the function can be used to stop the ADC when buffer wrap has been enabled and, therefore, the ADC will otherwise operate indefinitely.

Parameters

None

Returns

None

u16AHI_AdcSampleBufferOffset

```
uint16 u16AHI_AdcSampleBufferOffset(void);
```

Description

This function can be used in sample buffer mode to obtain the location in the RAM buffer where the next sample will be written. The function is primarily intended to be used as a diagnostic tool during application development to determine the progress of the DMA transfer to the buffer.

The location is returned as an offset (in 16-bit samples) from the start of the buffer. Note that when the buffer is full:

- if buffer wrap is not enabled, the returned value will be 2047
- if buffer wrap is enabled, the returned value will be 0

Parameters

None

Returns

Offset of next free location from start of buffer (range of possible values is 0 to 2047)

20.4 Comparator Functions

This section describes the functions that can be used to control the on-chip comparator.

A comparator compares its signal input with a reference input, and can be programmed to provide an interrupt when the difference between its inputs changes sense. It can also be used to wake the chip from sleep. The inputs to the comparator use dedicated pins on the chip. The signal input is provided on the comparator '+' pin and the reference input is provided on the comparator '-' pin or by the internal reference voltage V_{ref}.

Note 1: If the comparator is to be used to wake the device from sleep mode then only the comparator '+' and '-' pins can be used. The internal reference voltage cannot be used.

Note 2: The analogue peripherals regulator must be enabled while configuring a comparator, although it can be disabled once configuration is complete.

Note 3: When a comparator pin is used, the associated DIO should be configured as an input with the pull-up disabled (using DIO functions detailed in Chapter 21).

The Comparator functions are listed below, along with their page references:

vAHI_ComparatorEnable

```
void vAHI_ComparatorEnable(uint8 u8Comparator,
                           uint8 u8Hysteresis,
                           uint8 u8SignalSelect);
```

Description

This function configures and enables the comparator. The input signal, reference signal and hysteresis setting must be specified.

The external input signal to be monitored can be provided on the comparator '+' pin (COMP1P) or '-' pin (COMP1M). This signal is compared with a reference signal which is either an external input on the other comparator pin or the internal reference voltage (V_{ref}). The input and reference signals are selected through a single parameter (*u8SignalSelect*) using one of following enumerations:

Input Signal	Reference Signal	Enumeration (*u8SignalSelect*)
COMP1P	COMP1M	E_AHI_COMP_SEL_EXT
COMP1P	V_{ref}	E_AHI_COMP_SEL_BANDGAP
COMP1M	COMP1M	E_AHI_COMP_SEL_EXT_INVERSE
COMP1M	V_{ref}	E_AHI_COMP_SEL_BANDGAP_INVERSE

The hysteresis voltage selected should be greater than:

- the noise level in the input signal (on the comparator '+' or '-' pin, as selected), if comparing the signal on this pin with the internal reference voltage or DAC output
- the differential noise between the signals on the comparator '+' and '-' pins, if comparing the signals on these two pins

Note: This function puts the comparator into standard-power mode in which it draws 73µA of current. The comparator can subsequently be put into low-power mode, in which it draws 0.8µA of current, by calling the function **vAHI_ComparatorLowPowerMode()**.

Once enabled using this function, the comparator can be disabled using the function **vAHI_ComparatorDisable()**.

Parameters

u8Comparator	Identity of comparator: E_AHI_AP_COMPARATOR_1
u8Hysteresis	Hysteresis setting (controllable from 0 to 40mV) E_AHI_COMP_HYSTERESIS_0MV (0mV) E_AHI_COMP_HYSTERESIS_10MV (10mV) E_AHI_COMP_HYSTERESIS_20MV (20mV) E_AHI_COMP_HYSTERESIS_40MV (40mV)
u8SignalSelect	Selection of input and reference signals (see table above): E_AHI_COMP_SEL_EXT E_AHI_COMP_SEL_BANDGAP E_AHI_COMP_SEL_EXT_INVERSE E_AHI_COMP_SEL_BANDGAP_INVERSE

Returns

None

vAHI_ComparatorDisable

void vAHI_ComparatorDisable(uint8 *u8Comparator***);**

Description

This function disables the comparator.

Parameters

u8Comparator	Identity of comparator: E_AHI_AP_COMPARATOR_1

Returns

None

vAHI_ComparatorLowPowerMode

```
void vAHI_ComparatorLowPowerMode(
                                    bool_t bLowPowerEnable);
```

Description

This function can be used to enable or disable low-power mode on the comparator.

In low-power mode, a comparator draws 0.8µA of current, compared with 73µA when operating in standard-power mode. Low-power mode is ideal for energy harvesting. The mode is also automatically enabled when the device is sleeping.

When the comparator is enabled using **vAHI_ComparatorEnable()**, it is put into standard-power mode by default. Therefore, to use the comparator in low-power mode, you must call **vAHI_ComparatorLowPowerMode()** to enable this mode.

Parameters

bLowPowerEnable	Enable/disable low-power mode: TRUE - enable FALSE - disable

Returns

None

vAHI_ComparatorIntEnable

```
void vAHI_ComparatorIntEnable(uint8 u8Comparator,
                              bool_t bIntEnable,
                              bool_t bRisingNotFalling);
```

Description

This function enables interrupts for the comparator. An interrupt can be used to wake the device from sleep or as a normal interrupt.

If enabled, an interrupt is generated on one of the following conditions (which must be configured):

- The input signal rises above the reference signal (plus hysteresis level, if non-zero)
- The input signal falls below the reference signal (minus hysteresis level, if non-zero)

Comparator interrupts are handled by the System Controller callback function, registered using the function **vAHI_SysCtrlRegisterCallback()**.

Parameters

u8Comparator	Identity of comparator: E_AHI_AP_COMPARATOR_1
bIntEnable	Enable/disable interrupts: TRUE to enable interrupts FALSE to disable interrupts
bRisingNotFalling	Triggering condition for interrupt: TRUE for interrupt when input signal rises above reference FALSE for interrupt when input signal falls below reference

Returns

None

u8AHI_ComparatorStatus

```
uint8 u8AHI_ComparatorStatus(void);
```

Description

This function obtains the status of the comparator.

To obtain the status of the comparator, the returned value must be bitwise ANDed with the mask E_AHI_AP_COMPARATOR_MASK_1.

The result is interpreted as follows:

- **0** indicates that the input signal is lower than the reference signal
- **1** indicates that the input signal is higher than the reference signal

Parameters

None

Returns

Value containing the status of comparator (see above)

u8AHI_ComparatorWakeStatus

```
uint8 u8AHI_ComparatorWakeStatus(void);
```

Description

This function returns the wake-up interrupt status of the comparator. The value is cleared after reading.

To obtain the wake-up interrupt status of the comparator, the returned value must be bitwise ANDed with the mask E_AHI_AP_COMPARATOR_MASK_1.

The result is interpreted as follows:

- **Zero** indicates that a wake-up interrupt has not occurred
- **Non-zero** value indicates that a wake-up interrupt has occurred

Note: If you wish to use this function to check whether the comparator caused a wake-up event, you must call it before **u32AHI_Init()**. Alternatively, you can determine the wake source as part of your System Controller callback function.

Note 2: If using the JenNet protocol, do not call this function to obtain the comparator interrupt status on waking from sleep. At wake-up, JenNet calls **u32AHI_Init()** internally and clears the interrupt status before passing control to the application. The System Controller callback function must be used to obtain the interrupt status, if required.

Parameters

None

Returns

Value containing wake-up interrupt status of comparator (see above)

21. DIO and DO Functions

This chapter describes the functions that can be used to control the digital input/output lines, referred to as DIOs, and the digital output lines, referred to as DOs. The JN516x microcontroller has:

- 20 DIOs, numbered DIO0 to DIO19
- 2 DOs, numbered DO0 and DO1

Each DIO/DO can be individually configured. However, the pins for the DIO/DO lines are shared with other peripherals (see Chapter 5) and are not available when those peripherals are enabled. For details of the shared pins, refer to the data sheet for your microcontroller.

In addition to normal operation, when configured as inputs, the DIOs can be used to generate interrupts and wake the device from sleep.

Note: For guidance on using the DIO functions in JN516x application code, refer to Chapter 5.

The DIO/DO functions are listed below, along with their page references:

In some of the above functions, a 32-bit bitmap is used to represent the set of DIOs. In the bitmap, each of bits 0 to 19 represents a DIO pin, where bit 0 represents DIO0 and bit 19 represents DIO19 (bits 20-31 are unused).

vAHI_DioSetDirection

```
void vAHI_DioSetDirection(uint32 u32Inputs,
                          uint32 u32Outputs);
```

Description

This function sets the direction for the DIO pins individually as either input or output (note that they are set as inputs, by default, on reset). This is done through two bitmaps for inputs and outputs, *u32Inputs* and *u32Outputs* respectively. In these values, each bit represents a DIO pin, as described on page 203. Setting a bit in one of these bitmaps configures the corresponding DIO as an input or output, depending on the bitmap.

Note that:

- Not all DIO pins must be defined (in other words, *u32Inputs* bitwise ORed with *u32Outputs* does not need to produce all ones for the DIO bits).
- Any DIO pins that are not defined by a call to this function (the relevant bits being cleared in both bitmaps) will be left in their previous states.
- If a bit is set in both *u32Inputs* and *u32Outputs*, it will default to becoming an input.
- If a DIO is assigned to another peripheral which is enabled, this function call will not immediately affect the relevant pin. However, the DIO setting specified by this function will take effect if/when the relevant peripheral is subsequently disabled.
- This function does not change the DIO pull-up status - this must be done separately using **vAHI_DioSetPullup()**.

Parameters

u32Inputs	Bitmap of inputs - a bit set means that the corresponding DIO pin will become an input
u32Outputs	Bitmap of outputs - a bit set means that the corresponding DIO pin will become an output

Returns

None

vAHI_DioSetOutput

void vAHI_DioSetOutput(uint32 *u32On*, **uint32** *u32Off*);

Description

This function sets individual DIO outputs on or off, driving an output high or low, respectively. This is done through two bitmaps for on-pins and off-pins, *u32On* and *u32Off* respectively. In these values, each bit represents a DIO pin, as described on page 203. Setting a bit in one of these bitmaps configures the corresponding DIO output as on or off, depending on the bitmap.

Note that:

- Not all DIO pins must be defined (in other words, *u32On* bitwise ORed with *u32Off* does not need to produce all ones for the DIO bits).
- Any DIO pins that are not defined by a call to this function (the relevant bits being cleared in both bitmaps) will be left in their previous states.
- If a bit is set in both *u32On* and *u32Off*, the DIO pin will default to off.
- This call has no effect on DIO pins that are not defined as outputs (see **vAHI_DioSetDirection()**), until a time when they are re-configured as outputs.
- If a DIO is assigned to another peripheral which is enabled, this function call will not affect the relevant DIO, until a time when the relevant peripheral is disabled.

Parameters

u32On	Bitmap of on-pins - a bit set means that the corresponding DIO pin will be set to on
u32Off	Bitmap of off-pins - a bit set means that the corresponding DIO pin will be set to off

Returns

None

u32AHI_DioReadInput

```
uint32 u32AHI_DioReadInput (void);
```

Description

This function returns the value of each of the DIO pins (irrespective of whether the pins are used as inputs, as outputs or by other enabled peripherals).

Parameters

None

Returns

Bitmap representing set of DIOs, as described on page 203 - a bit is set to 1 if the correponding DIO pin is high or to 0 if the pin is low (unused bits are always 0).

vAHI_DioSetPullup

void vAHI_DioSetPullup(uint32 *u32On*, **uint32** *u32Off*);

Description

This function sets the pull-ups on individual DIO pins as on or off. A pull-up can be set irrespective of whether the pin is an input or output. This is done through two bitmaps for 'pull-ups on' and 'pull-ups off', *u32On* and *u32Off* respectively. In these values, each bit represents a DIO pin, as described on page 203.

Note that:

- By default, the pull-ups are enabled (on) at power-up.
- Not all DIO pull-ups must be set (in other words, *u32On* bitwise ORed with *u32Off* does not need to produce all ones for the DIO bits).
- Any DIO pull-ups that are not set by a call to this function (the relevant bits being cleared in both bitmaps) will be left in their previous states.
- If a bit is set in both *u32On* and *u32Off*, the corresponding DIO pull-up will default to off.
- If a DIO is assigned to another peripheral which is enabled, this function call will still apply to the relevant pin, except in the case of a DIO connected to an external 32kHz crystal.

Parameters

u32On	Bitmap of 'pull-ups on' - a bit set means that the corresponding pull-up will be enabled
u32Off	Bitmap of 'pull-ups off' - a bit set means that the corresponding pull-up will be disabled

Returns

None

vAHI_DioSetByte

void vAHI_DioSetByte(bool_t *bDIOSelect*, **uint8** *u8DataByte*);

Description

This function can be used to output a byte on either DIO0-7 or DIO8-15, where bit 0 or 8 is used for the least significant bit of the byte.

Before calling this function, the relevant DIOs must be configured as outputs using the function **vAHI_DioSetDirection()**.

Parameters

bDIOSelect	Set of DIO lines on which to output the byte: FALSE selects DIO0-7 TRUE selects DIO8-15
u8DataByte	Byte to output on the DIO pins

Returns

None

u8AHI_DioReadByte

uint8 u8AHI_DioReadByte(bool_t *bDIOSelect***);**

Description

This function can be used to read a byte input on either DIO0-7 or DIO8-15, where bit 0 or 8 is used for the least significant bit of the byte.

Before calling this function, the relevant DIOs must be configured as inputs using the function **vAHI_DioSetDirection()**.

Parameters

bDIOSelect	Set of DIO lines on which to read the input byte: FALSE selects DIO0-7 TRUE selects DIO8-15

Returns

The byte read from DIO0-7 or DIO8-15

vAHI_DioInterruptEnable

```
void vAHI_DioInterruptEnable(uint32 u32Enable,
                             uint32 u32Disable);
```

Description

This function enables/disables interrupts on the DIO pins - that is, whether the signal on a DIO pin will generate an interrupt. This is done through two bitmaps for 'interrupts enabled' and 'interrupts disabled', *u32Enable* and *u32Disable* respectively. In these values, each bit represents a DIO pin, as described on page 203. Setting a bit in one of these bitmaps enables/disables interrupts on the corresponding DIO, depending on the bitmap (by default, all DIO interrupts are disabled).

Note that:

- Not all DIO interrupts must be defined (in other words, *u32Enable* bitwise ORed with *u32Disable* does not need to produce all ones for bits 0-20).
- Any DIO interrupts that are not defined by a call to this function (the relevant bits being cleared in both bitmaps) will be left in their previous states.
- If a bit is set in both *u32Enable* and *u32Disable*, the corresponding DIO interrupt will default to disabled.
- This call has no effect on DIO pins that are not defined as inputs (see **vAHI_DioSetDirection()**).
- DIOs assigned to enabled JN516x peripherals are affected by this function.
- The DIO interrupt settings made with this function are retained during sleep.

The signal edge on which each DIO interrupt is generated can be configured using the function **vAHI_DioInterruptEdge()** (the default is 'rising edge').

DIO interrupts are handled by the System Controller callback function, registered using the function **vAHI_SysCtrlRegisterCallback()**.

Caution: *This function has the same effect as* ***vAHI_DioWakeEnable()*** *- both functions access the same JN516x register bits. Therefore, do not allow the two functions to conflict in your code.*

Parameters

u32Enable	Bitmap of DIO interrupts to enable - a bit set means that interrupts on the corresponding DIO will be enabled
u32Disable	Bitmap of DIO interrupts to disable - a bit set means that interrupts on the corresponding DIO will be disabled

Returns

None

vAHI_DioInterruptEdge

```
void vAHI_DioInterruptEdge(uint32 u32Rising,
                           uint32 u32Falling);
```

Description

This function configures enabled DIO interrupts by controlling whether individual DIOs will generate interrupts on a rising or falling edge of the DIO signal. This is done through two bitmaps for 'rising edge' and 'falling edge', *u32Rising* and *u32Falling* respectively. In these values, each bit represents a DIO pin, as described on page 203. Setting a bit in one of these bitmaps configures interrupts on the corresponding DIO to occur on a rising or falling edge, depending on the bitmap (by default, all DIO interrupts are 'rising edge').

Note that:

- Not all DIO interrupts must be configured (in other words, *u32Rising* bitwise ORed with *u32Falling* does not need to produce all ones for the DIO bits).
- Any DIO interrupts that are not configured by a call to this function (the relevant bits being cleared in both bitmaps) will be left in their previous states.
- If a bit is set in both *u32Rising* and *u32Falling*, the corresponding DIO interrupt will default to 'rising edge'.
- This call has no effect on DIO pins that are not defined as inputs (see **vAHI_DioSetDirection()**).
- DIOs assigned to enabled JN516x peripherals are affected by this function.
- The DIO interrupt settings made with this function are retained during sleep.

The DIO interrupts can be individually enable/disabled using the function **vAHI_DioInterruptEnable()**.

Caution: *This function has the same effect as* ***vAHI_DioWakeEdge()*** *- both functions access the same JN516x register bits. Therefore, do not allow the two functions to conflict in your code.*

Parameters

u32Rising	Bitmap of DIO interrupts to configure - a bit set means that interrupts on the corresponding DIO will be generated on a rising edge
u32Falling	Bitmap of DIO interrupts to configure - a bit set means that interrupts on the corresponding DIO will be generated on a falling edge

Returns

None

u32AHI_DioInterruptStatus

```
uint32 u32AHI_DioInterruptStatus(void);
```

Description

This function obtains the interrupt status of all the DIO pins. It is used to poll the DIO interrupt status when DIO interrupts are disabled (and therefore not generated).

Tip: If you wish to generate DIO interrupts instead of using this function to poll, you must enable DIO interrupts using **vAHI_DioInterruptEnable()** and incorporate DIO interrupt handling in the System Controller callback function registered using **vAHI_SysCtrlRegisterCallback()**.

The returned value is a bitmap in which a bit is set if an interrupt has occurred on the corresponding DIO pin (see below). In addition, this bitmap reports other DIO events that have occurred. After reading, the interrupt status and any other reported DIO events are cleared.

The results are valid irrespective of whether the pins are used as inputs, as outputs or by other enabled peripherals. They are also valid immediately following sleep.

Note: This function has the same effect as **vAHI_DioWakeStatus()** - both functions access the same JN516x register bits.

Parameters

None

Returns

Bitmap representing set of DIOs, as described in page 203 - a bit is set to 1 if the corresponding DIO interrupt has occurred or to 0 if the interrupt has not occurred (unused bits are always 0).

vAHI_DioWakeEnable

```
void vAHI_DioWakeEnable(uint32 u32Enable,
                        uint32 u32Disable);
```

Description

This function enables/disables wake interrupts on the DIO pins - that is, whether activity on a DIO input will be able to wake the device from Sleep or Doze mode. This is done through two bitmaps for 'wake enabled' and 'wake disabled', *u32Enable* and *u32Disable* respectively. In these values, each bit represents a DIO pin, as described on page 203. Setting a bit in one of these bitmaps enables/disables wake interrupts on the corresponding DIO, depending on the bitmap.

Note that:

- Not all DIO wake interrupts must be defined (in other words, *u32Enable* bitwise ORed with *u32Disable* does not need to produce all ones for the DIO bits).
- Any DIO wake interrupts that are not defined by a call to this function (the relevant bits being cleared in both bitmaps) will be left in their previous states.
- If a bit is set in both *u32Enable* and *u32Disable*, the corresponding DIO wake interrupt will default to disabled.
- This call has no effect on DIO pins that are not defined as inputs (see **vAHI_DioSetDirection()**).
- DIOs assigned to enabled JN516x peripherals are affected by this function.
- The DIO wake interrupt settings made with this function are retained during sleep.

The signal edge on which each DIO wake interrupt is generated can be configured using the function **vAHI_DioWakeEdge()** (the default is 'rising edge').

DIO wake interrupts are handled by the System Controller callback function, registered using the function **vAHI_SysCtrlRegisterCallback()**.

***Caution:** This function has the same effect as **vAHI_DioInterruptEnable()** - both functions access the same JN516x register bits. Therefore, do not allow the two functions to conflict in your code.*

Parameters

u32Enable	Bitmap of DIO wake interrupts to enable - a bit set means that wake interrupts on the corresponding DIO will be enabled
u32Disable	Bitmap of DIO wake interrupts to disable - a bit set means that wake interrupts on the corresponding DIO will be disabled

Returns

None

vAHI_DioWakeEdge

```
void vAHI_DioWakeEdge(uint32 u32Rising,
                      uint32 u32Falling);
```

Description

This function configures enabled DIO wake interrupts by controlling whether individual DIOs will generate wake interrupts on a rising or falling edge of the DIO input. This is done through two bitmaps for 'rising edge' and 'falling edge', *u32Rising* and *u32Falling* respectively. In these values, each bit represents a DIO pin, as described on page 203. Setting a bit in one of these bitmaps configures wake interrupts on the corresponding DIO to occur on a rising or falling edge, depending on the bitmap (by default, all DIO wake interrupts are 'rising edge').

Note that:

- Not all DIO wake interrupts must be configured (in other words, *u32Rising* bitwise ORed with *u32Falling* does not need to produce all ones for the DIO bits).
- Any DIO wake interrupts that are not configured by a call to this function (the relevant bits being cleared in both bitmaps) will be left in their previous states.
- If a bit is set in both *u32Rising* and *u32Falling*, the corresponding DIO wake interrupt will default to 'rising edge'.
- This call has no effect on DIO pins that are not defined as inputs (see **vAHI_DioSetDirection()**).
- DIOs assigned to enabled JN516x peripherals are affected by this function.
- The DIO wake interrupt settings made with this function are retained during sleep.

The DIO wake interrupts can be individually enable/disabled using the function **vAHI_DioWakeEnable()**.

Caution: *This function has the same effect as* ***vAHI_DioInterruptEdge()*** *- both functions access the same JN516x register bits. Therefore, do not allow the two functions to conflict in your code.*

Parameters

u32Rising	Bitmap of DIO wake interrupts to configure - a bit set means that wake interrupts on the corresponding DIO will be generated on a rising edge
u32Falling	Bitmap of DIO wake interrupts to configure - a bit set means that wake interrupts on the corresponding DIO will be generated on a falling edge

Returns

None

u32AHI_DioWakeStatus

```
uint32 u32AHI_DioWakeStatus(void);
```

Description

This function returns the wake status of all the DIO input pins - that is, whether the DIO pins were used to wake the device from sleep.

Note 1: If you wish to use this function to check whether a DIO caused a wake-up event, you must call it before **u32AHI_Init()**. Alternatively, you can determine the wake source as part of your System Controller callback function.

Note 2: When waking from deep sleep, this function will not indicate a DIO wake source because the device will have completed a full reset. When waking from sleep, the function may indicate more than one wake source if multiple DIO events occurred while the device was booting.

Note 3: If using the JenNet protocol, do not call this function to obtain the DIO interrupt status on waking from sleep. At wake-up, JenNet calls **u32AHI_Init()** internally and clears the interrupt status before passing control to the application. The System Controller callback function must be used to obtain the interrupt status, if required.

The returned value is a bitmap in which a bit is set if a wake interrupt has occurred on the corresponding DIO input pin (see below). In addition, this bitmap reports other DIO events that have occurred. After reading, the wake status and any other reported DIO events are cleared.

The results are not valid for DIO pins that are configured as outputs or assigned to other enabled peripherals.

Note: This function has the same effect as **vAHI_DioInterruptStatus()** - both functions access the same JN516x register bits.

Parameters

None

Returns

Bitmap representing set of DIOs, as described on page 203 - a bit is set to 1 if the corresponding DIO wake interrupt has occurred or to 0 if the interrupt has not occurred (unused bits are always 0).

bAHI_DoEnableOutputs

bool_t bAHI_DoEnableOutputs(bool_t *bEnable***);**

Description

This function can be used to enable both digital output pins (DO0 and DO1) for general-purpose use.

When enabled for general-purpose use, these pins cannot be used by the SPI Master, and Timers 2 and 3.

Note: From reset, during sleep and on waking from sleep, the DO pins revert to being disabled as general-purpose outputs with pull-ups enabled.

Parameters

bEnable	Enable or disable digital outputs: TRUE - enable FALSE - disable

Returns

TRUE - DO(s) successfully enabled

FALSE - DO(s) used by SPI Master, so not available to be driven

vAHI_DoSetDataOut

void vAHI_DoSetDataOut(uint8 *u8On*, **uint8** *u8Off*);

Description

This function sets individual digital outputs (DO0 and DO1) on or off, driving an output high or low, respectively. This is done through two bitmaps for on-pins and off-pins, *u8On* and *u8Off* respectively. In these values, bit 0 represents the DO0 pin and bit 1 represents the DO1 pin. Setting a bit in one of these bitmaps configures the corresponding digital output as on or off, depending on the bitmap.

Note that:

- By default, the digital outputs are high (on) at power-up.
- Both DO pins do not need to be defined (in other words, *u8On* bitwise ORed with *u8Off* does not need to produce all ones for the DO bits).
- A DO pin that is not defined by a call to this function (the relevant bit being cleared in both bitmaps) will be left in its previous state.
- If a bit is set in both *u8On* and *u8Off*, the DO pin will default to off.
- If a DO is assigned to another peripheral which is enabled, this function call will not affect the relevant DO, until a time when the relevant peripheral is disabled.

Before this function is called, the function **bAHI_DoEnableOutputs()** must have been called to enable the relevant DO(s) and must have returned TRUE.

Note: From reset, during sleep and on waking from sleep, the DO pins revert to being disabled as general-purpose outputs with pull-ups enabled.

Parameters

u8On	Bitmap of on-pins (only bits 0 and 1 are relevant) - a bit set means that the corresponding DO pin will be set to on
u8Off	Bitmap of off-pins (only bits 0 and 1 are relevant) - a bit set means that the corresponding DO pin will be set to off

Returns

None

vAHI_DoSetPullup

void vAHI_DoSetPullup(uint8 *u8On*, **uint8** *u8Off*);

Description

This function sets the pull-ups on individual DO pins (DO0 and DO1) as on or off. This is done through two bitmaps for 'pull-ups on' and 'pull-ups off', *u8On* and *u8Off* respectively. In these values, bit 0 represents the DO0 pull-up and bit 1 represents the DO1 pull-up. Setting a bit in one of these bitmaps configures the corresponding DO pull-up as on or off, depending on the bitmap.

Note that:

- By default, the pull-ups are enabled (on) at power-up.
- Both DO pull-ups do not need to be set (in other words, *u8On* bitwise ORed with *u8Off* does not need to produce all ones for the DIO bits).
- A DO pull-ups that is not set by a call to this function (the relevant bit being cleared in both bitmaps) will be left in its previous state.
- If a bit is set in both *u8On* and *u8Off*, the corresponding DIO pull-up will default to off.

Before this function is called, the function **bAHI_DoEnableOutputs()** must have been called to enable the relevant DO(s) and must have returned TRUE. In addition, the SPI Master should not be subsequently enabled.

Note: From reset, during sleep and on waking from sleep, the DO pins revert to being disabled as general-pupose outputs with pull-ups enabled.

Parameters

u8On	Bitmap of 'pull-ups on' (only bits 0 and 1 are relevant) - a bit set means that the corresponding pull-up will be enabled
u8Off	Bitmap of 'pull-ups off' (only bits 0 and 1 are relevant) - a bit set means that the corresponding pull-up will be disabled

Returns

None

22. UART Functions

This chapter details the functions for controlling the 16550-compatible UARTs (Universal Asynchronous Receiver Transmitters). The JN516x microcontroller has two UARTs, denoted UART0 and UART1, which can be independently enabled.

- UART0 uses four pins (shared with the DIOs) for the following signals: Transmit Data (TxD) output, Receive Data (RxD) input, Request-To-Send (RTS) output and Clear-To-Send (CTS) input. This UART can be used in 4-wire mode (using all four signals) or 2-wire mode (using only the TxD and RxD signals). 4-wire mode is used to implement flow control and is the default mode.
- UART1 uses two pins (shared with the DIOs) for the following signals: Transmit Data (TxD) output and Receive Data (RxD) input. This UART can be used in 2-wire mode (using both signals) or 1-wire mode (using only the TxD signal). 2-wire mode is the default mode.

Note: For information on the UARTs and guidance on using the UART functions in JN516x application code, refer to Chapter 6.

The UART functions are listed below, along with their page references:

bAHI_UartEnable

```
bool_t bAHI_UartEnable(uint8 u8Uart,
                       uint8 *pu8TxBufAd,
                       uint16 u16TxBufLen,
                       uint8 *pu8RxBufAd,
                       uint16 u16RxBufLen);
```

Description

This function enables the specified UART and configures the FIFO Transmit and Receive buffers for the UART. It must be the first UART function called, except when using UART0 in 2-wire mode or UART1 in 1-wire mode (see below).

Be sure to enable the UART using this function before writing to the UART using the function **vAHI_UartWriteData()**, otherwise an exception will result.

The UARTs should be operated from a peripheral clock which runs at 16MHz (i.e. the system clock should be sourced from an external crystal oscillator). Therefore, this system clock must be set up before calling this function (for clock set-up, refer to Section 3.1).

The function specifies the size (in bytes) and location in RAM of the Transmit and Receive FIFOs. The size of each buffer can be set between 16 and 2047 bytes (inclusive). A valid size and pointer value for the Transmit FIFO must always be set. If the Receive FIFO is not required (e.g. in 1-wire mode for UART1) then its pointer value should be set to NULL (its size will be ignored in this case).

The UARTs use the following sets of DIO lines (primary and alternative sets):

UART Signal	DIOs for UART0		DIOs for UART1	
CTS	DIO4	DIO12	-	-
RTS	DIO5	DIO13	-	-
TxD	DIO6	DIO14	DIO14	DIO11
RxD	DIO7	DIO15	DIO15	DIO9

The UART signals can be moved from the default DIO4-7 to DIO12-15 for UART0, and from the default DIO14-15 to DIO11 /DIO9 for UART1. In both cases, this is done using **vAHI_UartSetLocation()** which must be called before **bAHI_UartEnable()**.

- UART0 may use all four signals (CTS, RTS, TxD, RxD), in which case it is said to operate in 4-wire mode in which flow control is implemented
- UART0 and UART1 may use just two signals (TxD and RxD), in which case they are said to operate in 2-wire mode (in which no flow control is implemented)
- UART1 may alternatively use just one signal (TxD), in which case it is said to operate in 1-wire mode

For UART0, 4-wire mode (with flow control) is enabled by default when **bAHI_UartEnable()** is called. If you wish to implement 2-wire mode, you will need to

call **vAHI_UartSetRTSCTS()** before calling **bAHI_UartEnable()** in order to release control of the DIOs used for RTS and CTS.

For UART1, 2-wire mode is enabled by default when **bAHI_UartEnable()** is called. If you wish to implement 1-wire mode, you will need to call **vAHI_UartTxOnly()** before calling **bAHI_UartEnable()** in order to release control of the DIO used for RxD.

When **bAHI_UartEnable()** is called to enable UART0, the JTAG debugger on the JN516x device is automatically disabled (as it uses the same pins as UART0).

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)
**pu8TxBufAd*	Pointer to start of Transmit FIFO
u16TxBufLen	Size of Transmit FIFO, in range 16 to 2047 bytes
**pu8RxBufAd*	Pointer to start of Receive FIFO (if this FIFO is not needed, set to NULL)
u16RxBufLen	Size of Receive FIFO, in range 16 to 2047 bytes (this parameter is ignored when *pu8RxBufAd* is set to NULL)

Returns

TRUE if UART was successfully intialised, FALSE if UART was not successfully initialised (e.g. UART specified via *u8Uart* is invalid, *pu8TxBufAd* is set to NULL or *u16TxBufLen* is outside valid range)

vAHI_UartEnable

void vAHI_UartEnable(uint8 *u8Uart***);**

Description

This function enables the specified UART. It must be the first UART function called.

Note: This function is provided only for backward compatibility with application code developed for the JN514x microcontrollers. New code for the JN516x microcontrollers should use the function **bAHI_UartEnable()** instead, described on page 221.

Be sure to enable the UART using this function before writing to the UART using the function **vAHI_UartWriteData()**, otherwise an exception will result.

The UARTs should be operated from a peripheral clock which runs at 16MHz (i.e. the system clock should be sourced from an external crystal oscillator). Therefore, this system clock must be set up before calling this function (for clock set-up, refer to Section 3.1).

The UARTs use the following sets of DIO lines (primary and alternative sets):

UART Signal	DIOs for UART0		DIOs for UART1	
CTS	DIO4	DIO12	-	-
RTS	DIO5	DIO13	-	-
TxD	DIO6	DIO14	DIO14	DIO11
RxD	DIO7	DIO15	DIO15	DIO9

The UART signals can be moved from the default DIO4-7 to DIO12-15 for UART0, and from the default DIO14-15 to DIO11 /DIO9 for UART1. In both cases, this is done using **vAHI_UartSetLocation()** which must be called before **vAHI_UartEnable()**.

- UART0 may use all four signals (CTS, RTS, TxD, RxD), in which case it is said to operate in 4-wire mode in which flow control is implemented
- UART0 and UART1 may use just two signals (TxD and RxD), in which case they are said to operate in 2-wire mode (in which no flow control is implemented)
- UART1 may alternatively use just one signal (TxD), in which case it is said to operate in 1-wire mode

For UART0, 4-wire mode (with flow control) is enabled by default when **vAHI_UartEnable()** is called. If you wish to implement 2-wire mode, you will need to

call **vAHI_UartSetRTSCTS()** before calling **vAHI_UartEnable()** in order to release control of the DIOs used for RTS and CTS.

For UART1, 2-wire mode is enabled by default when **vAHI_UartEnable()** is called. If you wish to implement 1-wire mode, you will need to call **vAHI_UartTxOnly()** before calling **vAHI_UartEnable()** in order to release control of the DIO used for RxD.

When **vAHI_UartEnable()** is called to enable UART0, the JTAG debugger on the JN516x device is automatically disabled (as it uses the same pins as UART0).

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)

Returns

None

vAHI_UartDisable

void vAHI_UartDisable(uint8 *u8Uart***);**

Description

This function disables the specified UART by powering it down.

Be sure to re-enable the UART using **bAHI_UartEnable()** before attempting to write to the UART using the function **vAHI_UartWriteData()**, otherwise an exception will result.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)

Returns

None

vAHI_UartSetLocation

void vAHI_UartSetLocation(uint8 *u8Uart***, bool_t** *bLocation***);**

Description

This function can be used to select the set of DIOs on which the specified UART will operate:

- For UART0, DIO4-7 (default) or DIO12-15
- For UART1, DIO14-15 (default) or DIO11 and DIO9

The function only needs to be called if the alternative DIOs are to be used.

If required, this function must be called before **bAHI_UartEnable()** is called.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)
bLocation	DIOs on which UART will operate: TRUE - DIO12-15 (UART0) or DIO11/DIO9 (UART1) FALSE - DIO4-7 (UART0) or DIO14-15 (UART1)

Returns

None

vAHI_UartSetBaudRate

```
void vAHI_UartSetBaudRate(uint8 u8Uart,
                          uint8 u8BaudRate);
```

Description

This function sets the baud-rate for the specified UART to one of a number of standard rates.

The possible baud-rates are:

- 4800 bps
- 9600 bps
- 19200 bps
- 38400 bps
- 76800 bps
- 115200 bps

To set the baud-rate to other values, use the function **vAHI_UartSetBaudDivisor()**.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)
u8BaudRate	Desired baud-rate: E_AHI_UART_RATE_4800 (4800 bps) E_AHI_UART_RATE_9600 (9600 bps) E_AHI_UART_RATE_19200 (19200 bps) E_AHI_UART_RATE_38400 (38400 bps) E_AHI_UART_RATE_76800 (76800 bps) E_AHI_UART_RATE_115200 (115200 bps)

Returns

None

vAHI_UartSetBaudDivisor

```
void vAHI_UartSetBaudDivisor(uint8 u8Uart,
                             uint16 u16Divisor);
```

Description

This function sets an integer divisor to derive the baud-rate from a 1MHz frequency for the specified UART. The function allows baud-rates to be set that are not available through the function **vAHI_UartSetBaudRate()**.

The baud-rate produced is defined by:

baud-rate = 1000000/*u16Divisor*

For example:

u16Divisor	Baud-rate (bits/s)
1	1000000
2	500000
9	115200 (approx.)
26	38400 (approx.)

Note that other baud-rates (including higher baud-rates) can be achieved by subsequently calling the function **vAHI_UartSetClocksPerBit()**.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)
u16Divisor	Integer divisor

Returns

None

vAHI_UartSetClocksPerBit

void vAHI_UartSetClocksPerBit(uint8 *u8Uart*, **uint8** *u8Cpb*);

Description

This function sets the baud-rate used by the specified UART to a value derived from a 16MHz peripheral clock. The function allows higher baud-rates to be set than those available through **vAHI_UartSetBaudRate()** and **vAHI_UartSetBaudDivisor()**.

The obtained baud-rate, in Mbits/s, is given by:

$$\frac{16}{Divisor \times (Cpb + 1)}$$

where *Cpb* is set in this function and *Divisor* is set in **vAHI_UartSetBaudDivisor()**. Therefore, the function **vAHI_UartSetBaudDivisor()** must be called to set *Divisor* before calling **vAHI_UartSetClocksPerBit()**.

Example baud-rates that can be achieved are listed below:

Divisor	*Cpb*	Baud-rate (Mbits/s)
1	3	4.000
1	4	3.200
1	5	2.667
1	6	2.286
1	7	2.000
1	15	1.000
2	11	0.667
2	15	0.500
3	15	0.333

Note that 4 Mbits/s is the highest baud rate that is recommended.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)
u8Cpb	*Cpb* value in above formula, in range 0-15 (note that values 0-2 are not recommended)

Returns

None

vAHI_UartSetControl

```
void vAHI_UartSetControl(uint8 u8Uart,
                         bool_t bEvenParity,
                         bool_t bEnableParity,
                         uint8 u8WordLength,
                         bool_t bOneStopBit,
                         bool_t bRtsValue);
```

Description

This function sets various control bits for the specified UART.

Note that RTS for UART0 cannot be controlled automatically - it can only be set/ cleared under software control (this setting will be ignored for UART1).

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)
bEvenParity	Type of parity to be applied (if enabled): E_AHI_UART_EVEN_PARITY (even parity) E_AHI_UART_ODD_PARITY (odd parity)
bEnableParity	Enable/disable parity check: E_AHI_UART_PARITY_ENABLE E_AHI_UART_PARITY_DISABLE
u8WordLength	Word length (in bits): E_AHI_UART_WORD_LEN_5 (word is 5 bits) E_AHI_UART_WORD_LEN_6 (word is 6 bits) E_AHI_UART_WORD_LEN_7 (word is 7 bits) E_AHI_UART_WORD_LEN_8 (word is 8 bits)
bOneStopBit	Number of stop bits - 1 stop bit, or 1.5 or 2 stop bits (depending on word length), enumerated as: E_AHI_UART_1_STOP_BIT (TRUE - 1 stop bit) E_AHI_UART_2_STOP_BITS (FALSE - 1.5 or 2 stop bits)
bRtsValue	Set/clear RTS signal (UART0 only): E_AHI_UART_RTS_HIGH (TRUE - set RTS to high) E_AHI_UART_RTS_LOW (FALSE - clear RTS to low)

Returns

None

vAHI_UartSetInterrupt

```
void vAHI_UartSetInterrupt(uint8 u8Uart,
                           bool_t bEnableModemStatus,
                           bool_t bEnableRxLineStatus,
                           bool_t bEnableTxFifoEmpty,
                           bool_t bEnableRxData,
                           uint8 u8FifoLevel);
```

Description

This function enables or disables the interrupts generated by the specified UART and sets the Receive FIFO trigger-level - that is, the number of bytes required in the Receive FIFO to trigger a 'receive data available' interrupt.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)
bEnableModemStatus	Enable/disable 'modem status' interrupt (e.g. CTS change detected for UART0): TRUE to enable FALSE to disable
bEnableRxLineStatus	Enable/disable 'receive line status' interrupt (break indication, framing error, parity error or over-run): TRUE to enable FALSE to disable
bEnableTxFifoEmpty	Enable/disable 'Transmit FIFO empty' interrupt: TRUE to enable FALSE to disable
bEnableRxData	Enable/disable 'receive data available' interrupt: TRUE to enable FALSE to disable
u8FifoLevel	Number of bytes in Receive FIFO required to trigger a 'receive data available' interrupt: E_AHI_UART_FIFO_LEVEL_1 (1 byte) E_AHI_UART_FIFO_LEVEL_4 (4 bytes) E_AHI_UART_FIFO_LEVEL_8 (8 bytes) E_AHI_UART_FIFO_LEVEL_14 (14 bytes)

Returns

None

vAHI_UartTxOnly

void vAHI_UartTxOnly(uint8 *u8Uart*, **bool_t** *bEnable*);

Description

This function enables or disables 1-wire mode on the specified UART. In this mode, the UART can only transmit - only the TxD pin is used and the RxD is released for other uses.

Note: Currently, 1-wire mode is supported on UART1 only and this function will have no effect if UART0 is specified.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)
bEnable	Enable/disable 1-wire mode: TRUE to enable FALSE to disable

Returns

None

vAHI_UartSetRTSCTS

```
void vAHI_UartSetRTSCTS(uint8 u8Uart,
                        bool_t bRTSCTSEn);
```

Description

This function instructs UART0 to take or release control of the DIO lines used for RTS and CTS in flow control (depending on the DIOs selected):

- DIO4 (default) or DIO12 for CTS
- DIO5 (default) or DIO13 for RTS

The function must be called before **vAHI_UartEnable()** is called.

UART0 operates by default in 4-wire mode. If you wish to use this UART in 2-wire mode, it will be necessary to call **vAHI_UartSetRTSCTS()** before calling **bAHI_UartEnable()** in order to release control of the RTS and CTS lines.

Parameters

u8Uart	Identity of UART: set to E_AHI_UART_0
bRTSCTSEn	Take/release control of DIO lines for RTS and CTS: TRUE to take control FALSE to release control (allow use for other operations)

Returns

None

vAHI_UartSetRTS

void vAHI_UartSetRTS(uint8 *u8Uart***, bool_t** *bRtsValue***);**

Description

This function instructs UART0 to set or clear its RTS signal in 4-wire mode.

In order to use this function, the UART must be in 4-wire mode without automatic flow control enabled.

The function must be called after **bAHI_UartEnable()** is called.

Parameters

u8Uart	Identity of UART: set to E_AHI_UART_0
bRtsValue	Set/clear RTS signal: E_AHI_UART_RTS_HIGH (TRUE - set RTS to high) E_AHI_UART_RTS_LOW (FALSE - clear RTS to low)

Returns

None

vAHI_UartSetAutoFlowCtrl

```
void vAHI_UartSetAutoFlowCtrl(uint8 u8Uart,
                              uint8 u8RxFifoLevel,
                              bool_t bFlowCtrlPolarity,
                              bool_t bAutoRts,
                              bool_t bAutoCts);
```

Description

This function allows Automatic Flow Control (AFC) to be configured and enabled for UART0 operating in 4-wire mode. The function parameters allow the following to be selected/set:

- **Automatic RTS** (*bAutoRts*): This is the automatic control of the outgoing RTS signal based on the Receive FIFO fill-level. RTS is de-asserted when the Receive FIFO fill-level is greater than or equal to the specified trigger level (*u8RxFifoLevel*). RTS is then re-asserted as soon as Receive FIFO fill-level falls below the trigger level.
- **Automatic CTS** (*bAutoCts*): This is the automatic control of transmissions based on the incoming CTS signal. The transmission of a character is only started if the CTS input is asserted.
- **Receive FIFO Automatic RTS trigger level** (*u8RxFifoLevel*): This is the level at which the outgoing RTS signal is de-asserted when the Automatic RTS feature is enabled (using *bAutoRts*). If using a USB/FTDI cable to connect to the UART, use a setting of 13 bytes or lower (otherwise the Receive FIFO will overflow and data will be lost, as the FTDI device sends up to 3 bytes of data even once RTS has been de-asserted).
- **Flow Control Polarity** (*bFlowCtrlPolarity*): This is the active level (active-low or active-high) of the RTS and CTS hardware flow control signals when using the AFC feature. This setting has no effect when not using AFC (in this case, the software decides the active level, sets the outgoing RTS value and monitors the incoming CTS value).

In order to use the RTS and CTS lines, UART0 must be enabled in 4-wire mode, which is its default mode.

Parameters

u8Uart	Identity of UART: set to E_AHI_UART_0
u8RxFifoLevel	Receive FIFO automatic RTS trigger level: E_AHI_UART_FIFO_ARTS_LEVEL_8: 8 bytes E_AHI_UART_FIFO_ARTS_LEVEL_11: 11 bytes E_AHI_UART_FIFO_ARTS_LEVEL_13: 13 bytes E_AHI_UART_FIFO_ARTS_LEVEL_15: 15 bytes
bFlowCtrlPolarity	Active level (low or high) of RTS and CTS flow control: FALSE: RTS and CTS are active-low TRUE: RTS and CTS are active-high
bAutoRts	Enable/disable Automatic RTS feature: TRUE to enable FALSE to disable
bAutoCts	Enable/disable Automatic CTS feature: TRUE to enable FALSE to disable

Returns

None

vAHI_UartSetBreak

void vAHI_UartSetBreak(uint8 *u8Uart***, bool_t** *bBreak***);**

Description

This function instructs the specified UART to initiate or clear a transmission break.

On setting the break condition using this function, the data byte that is currently being transmitted is corrupted and transmission then stops. On clearing the break condition, transmission resumes to transfer the data remaining in the Transmit FIFO.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)
bBreak	Instruction for UART: TRUE to initiate break (no data) FALSE to clear break (and resume data transmission)

Returns

None

vAHI_UartReset

```
void vAHI_UartReset(uint8 u8Uart,
                    bool_t bTxReset,
                    bool_t bRxReset);
```

Description

This function resets the Transmit and Receive FIFOs of the specified UART. The character currently being transferred is not affected. The Transmit and Receive FIFOs can be reset individually or together.

The function also sets the FIFO trigger-level to single-byte trigger. The Receive FIFO interrupt trigger-level can be set via **vAHI_UartSetInterrupt()**.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)
bTxReset	Transmit FIFO reset: TRUE to reset the Transmit FIFO FALSE not to reset the Transmit FIFO
bRxReset	Receive FIFO reset: TRUE to reset the Receive FIFO FALSE not to reset the Receive FIFO

Returns

None

u16AHI_UartReadRxFifoLevel

uint16 u16AHI_UartReadRxFifoLevel(uint8 *u8Uart***);**

Description

This function obtains the fill-level of the Receive FIFO of the specified UART - that is, the number of characters currently in the FIFO.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)

Returns

Number of characters in the specified Receive FIFO

u16AHI_UartReadTxFifoLevel

uint16 u16AHI_UartReadTxFifoLevel(uint8 *u8Uart***);**

Description

This function obtains the fill-level of the Transmit FIFO - that is, the number of characters currently in the FIFO.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)

Returns

Number of characters in the specified Transmit FIFO

u8AHI_UartReadRxFifoLevel

```
uint8  u8AHI_UartReadRxFifoLevel(uint8 u8Uart);
```

Description

This function obtains the fill-level of the Receive FIFO of the specified UART on the JN516x device - that is, the number of characters currently in the FIFO.

Note: This function is provided only for backward compatibility with application code developed for the JN514x microcontrollers. New code for the JN516x microcontrollers should use the function **u16AHI_UartReadRxFifoLevel()** instead, described on page 239.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)

Returns

Number of characters in the specified Receive FIFO

u8AHI_UartReadTxFifoLevel

uint8 u8AHI_UartReadTxFifoLevel(uint8 *u8Uart***);**

Description

This function obtains the fill-level of the Transmit FIFO of the specified UART on the JN516x device - that is, the number of characters currently in the FIFO.

Note: This function is provided only for backward compatibility with application code developed for the JN514x microcontrollers. New code for the JN516x microcontrollers should use the function **u16AHI_UartReadTxFifoLevel()** instead, described on page 240.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)

Returns

Number of characters in the specified Transmit FIFO

u8AHI_UartReadLineStatus

uint8 u8AHI_UartReadLineStatus(uint8 *u8Uart*);

Description

This function returns line status information in a bitmap for the specified UART.

Note that the following bits are cleared after reading:

E_AHI_UART_LS_ERROR
E_AHI_UART_LS_BI
E_AHI_UART_LS_FE
E_AHI_UART_LS_PE
E_AHI_UART_LS_OE

Parameters

u8Uart Identity of UART:
E_AHI_UART_0 (UART0)
E_AHI_UART_1 (UART1)

Returns

Bitmap:

Bit	Description
E_AHI_UART_LS_ERROR	This bit will be set if a parity error, framing error or break indication has been received
E_AHI_UART_LS_TEMT	This bit will be set if the Transmit Shift Register is empty
E_AHI_UART_LS_THRE	This bit will be set if the Transmit FIFO is empty
E_AHI_UART_LS_BI	This bit will be set if a break indication has been received (line held low for a whole character)
E_AHI_UART_LS_FE	This bit will be set if a framing error has been received
E_AHI_UART_LS_PE	This bit will be set if a parity error has been received
E_AHI_UART_LS_OE	This bit will be set if a receive over-run has occurred, i.e. the receive buffer is full but another character arrives
E_AHI_UART_LS_DR	This bit will be set if there is data in the Receive FIFO

u8AHI_UartReadModemStatus

uint8 u8AHI_UartReadModemStatus(uint8 *u8Uart***);**

Description

This function obtains modem status information from UART0 as a bitmap which includes the CTS and 'CTS has changed' status (which can be extracted as described below).

Parameters

u8Uart	Identity of UART: set to E_AHI_UART_0

Returns

Bitmap in which:

- CTS input status is bit 4 ('1' indicates CTS is high, '0' indicates CTS is low).
- 'CTS has changed' status is bit 0 ('1' indicates that CTS input has changed). If the return value bitwise ANDed with E_AHI_UART_MS_DCTS is non-zero, the CTS input has changed.

u8AHI_UartReadInterruptStatus

uint8 u8AHI_UartReadInterruptStatus(uint8 *u8Uart***);**

Description

This function returns a pending interrupt for the specified UART as a bitmap.

Interrupts are returned one at a time, according to their priorities, so there may need to be multiple calls to this function. If interrupts are enabled, the interrupt handler processes this activity and posts each interrupt to the queue or to a callback function.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)

Returns

Bitmap:

Bit range	Value/Enumeration	Description
Bit 0	0	More interrupts pending
	1	No more interrupts pending
Bits 1-3	E_AHI_UART_INT_RXLINE (3)	Receive line status interrupt (highest prioritry)
	E_AHI_UART_INT_RXDATA (2)	Receive data available interrupt (next highest priority)
	E_AHI_UART_INT_TIMEOUT (6)	Timeout interrupt (next highest priority)
	E_AHI_UART_INT_TX (1)	Transmit FIFO empty interrupt (next highest priority)
	E_AHI_UART_INT_MODEM (0)	Modem status interrupt (lowest priority)

The above table lists the UART interrupts (bits 1-3) from highest to lowest priority.

vAHI_UartWriteData

void vAHI_UartWriteData(uint8 *u8Uart***, uint8** *u8Data***);**

Description

This function writes a data byte to the Transmit FIFO of the specified UART. The data byte will start to be transmitted as soon as it reaches the head of the FIFO.

If no flow control or manual flow control is being implemented for data transmission, the data in the Transmit FIFO will be transmitted as soon as possible (irrespective of the state of the local CTS line). Therefore, the function **vAHI_UartWriteData()** should be called only when the destination device is able to receive the data.

For UART0, if automatic flow control has been enabled for the local CTS line using the function **vAHI_UartSetAutoFlowCtrl()**, the data in the Transmit FIFO will only be transmitted once the CTS line has been asserted. In this case, **vAHI_UartWriteData()** can be called at any time to load data into the Transmit FIFO, provided that there is enough free space in the FIFO.

Refer to the description of **u16AHI_UartReadTxFifoLevel()** or **u8AHI_UartReadLineStatus()** for details of how to determine whether the Transmit FIFO already contains data.

Before this function is called, the UART must be enabled using the function **bAHI_UartEnable()**, otherwise an exception will result.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)
u8Data	Byte to transmit

Returns

None

u8AHI_UartReadData

uint8 u8AHI_UartReadData (uint8 *u8Uart***);**

Description

This function returns a single byte read from the Receive FIFO of the specified UART. If the FIFO is empty, the returned value is not valid.

Refer to the description of **u16AHI_UartReadRxFifoLevel()** or **u8AHI_UartReadLineStatus()** for details of how to determine whether the Receive FIFO is empty.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)

Returns

Received byte

u16AHI_UartBlockWriteData

```
uint16 u16AHI_UartBlockWriteData(uint8 u8Uart,
                                 uint8 *pu8Data,
                                 uint16 u16DataLength);
```

Description

This function writes a block of data to the Transmit FIFO of the specified UART. The transmission of the data will then be handled by the on-chip DMA engine.

If no flow control or manual flow control is being implemented for data transmission, the data in the Transmit FIFO will be transmitted as soon as possible (irrespective of the state of the local CTS line). Therefore, **u16AHI_UartBlockWriteData()** should be called only when the destination device is able to receive the data.

For UART0, if automatic flow control has been enabled for the local CTS line using the function **vAHI_UartSetAutoFlowCtrl()**, the data in the Transmit FIFO will only be transmitted once the CTS line has been asserted. In this case, **u16AHI_UartBlockWriteData()** can be called at any time to load data into the Transmit FIFO, provided that there is enough free space in the FIFO.

Refer to the description of **u16AHI_UartReadTxFifoLevel()** or **u8AHI_UartReadLineStatus()** for details of how to determine whether the Transmit FIFO already contains data.

Before this function is called, the UART must be enabled using the function **bAHI_UartEnable()**, otherwise an exception will result.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)
**pu8Data*	Pointer to start of data block to be written to Transmit FIFO
u16DataLength	Size of data block, in bytes

Returns

Number of bytes of data successfully written to the Transmit FIFO

u16AHI_UartBlockReadData

```
uint16 u16AHI_UartBlockReadData(
                                uint8 u8Uart,
                                uint8 *pu8DataBuffer,
                                uint16 u16DataBufferLength);
```

Description

This function reads a block of data from the Receive FIFO of the specified UART. If the FIFO is empty, the returned value is not valid.

A data buffer in RAM to receive the read data block must be specified.

Refer to the description of **u16AHI_UartReadRxFifoLevel()** or **u8AHI_UartReadLineStatus()** for details of how to determine whether the Receive FIFO is empty.

Parameters

u8Uart	Identity of UART: E_AHI_UART_0 (UART0) E_AHI_UART_1 (UART1)
**pu8DataBuffer*	Pointer to data buffer in RAM to receive read data block
u16DataBufferLength	Size of data buffer, in bytes

Returns

Number of bytes of data successfully read from Receive FIFO

vAHI_Uart0RegisterCallback

```
void vAHI_Uart0RegisterCallback(
                PR_HWINT_APPCALLBACK prUart0Callback);
```

Description

This function registers a user-defined callback function that will be called when the UART0 interrupt is triggered.

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.

Interrupt handling is described in Appendix A.

Parameters

prUart0Callback	Pointer to callback function to be registered

Returns

None

vAHI_Uart1RegisterCallback

```
void vAHI_Uart1RegisterCallback(
                PR_HWINT_APPCALLBACK prUart1Callback);
```

Description

This function registers a user-defined callback function that will be called when the UART1 interrupt is triggered.

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.

Interrupt handling is described in Appendix A.

Parameters

prUart1Callback	Pointer to callback function to be registered

Returns

None

23. Timer Functions

This chapter describes the functions that can be used to control the on-chip timers. The JN516x device has five times: Timer 0, Timer 1, Timer 2, Timer 3 and Timer 4 (Timers 1-4 have no external inputs and only support modes without inputs)

They are distinct from the wake timers described in Chapter 8 and tick timer described in Chapter 9.

Note: For information on the timers and guidance on using the timer functions in JN516x application code, refer to Chapter 7.

The Timer functions are listed below, along with their page references:

vAHI_TimerEnable

```
void vAHI_TimerEnable(uint8 u8Timer,
                      uint8 u8Prescale,
                      bool_t bIntRiseEnable,
                      bool_t bIntPeriodEnable,
                      bool_t bOutputEnable);
```

Description

This function configures and enables the specified timer, and must be the first timer function called. The timer is derived from the peripheral clock, which can be divided down to produce the timer clock (a system clock sourced from the external crystal oscillator gives the most stable results). The timer can be used in various modes, introduced in Section 7.1 (note that Timers 1-4 have no external inputs and therefore only support modes without inputs).

The parameters of this enable function cover the following features:

- **Prescaling** (*u8Prescale*): The timer's source clock is divided down to produce a slower clock for the timer, the divisor being $2^{u8Prescale}$. Therefore:

  Timer clock frequency = Source clock frequency / $2^{u8Prescale}$

- **Interrupts** (*bIntRiseEnable* and *bIntPeriodEnable*): Interrupts can be generated:
  - in Timer or PWM mode, on a low-to-high transition (rising output) and/or on a high-to-low transition (end of the timer period)
  - in Counter mode, on reaching target counts

  You can register a user-defined callback function for timer interrupts using the function **vAHI_Timer0RegisterCallback()** for Timer 0, **vAHI_Timer1RegisterCallback()** for Timer 1, **vAHI_Timer2RegisterCallback()** for Timer 2, **vAHI_Timer3RegisterCallback()** for Timer 3 or **vAHI_Timer4RegisterCallback()** for Timer 4. Alternatively, timer interrupts can be disabled.
- **Timer output** (*bOutputEnable*): When operating in PWM mode or Delta-Sigma mode, the timer's signal is output on a DIO pin (see Section 7.2.1), which must be enabled. If this option is enabled, the other DIOs associated with the timer cannot be used for general-purpose input/output.

Parameters

u8Timer	Identity of timer: E_AHI_TIMER_0 (Timer 0) E_AHI_TIMER_1 (Timer 1) E_AHI_TIMER_2 (Timer 2) E_AHI_TIMER_3 (Timer 3) E_AHI_TIMER_4 (Timer 4)
u8Prescale	Prescale index, in range 0 to 16, used in dividing down source clock (divisor is $2^{u8Prescale}$)
bIntRiseEnable	Enable/disable interrupt on rising output (low-to-high): TRUE to enable FALSE to disable
bIntPeriodEnable	Enable/disable interrupt at end of timer period (high-to-low): TRUE to enable FALSE to disable

bOutputEnable	Enable/disable output of timer signal on DIO: TRUE to enable (PWM or Delta-Sigma mode) FALSE to disable (Timer mode)

Returns

None

vAHI_TimerClockSelect

```
void vAHI_TimerClockSelect(uint8 u8Timer,
                           bool_t bExternalClock,
                           bool_t bInvertClock);
```

Description

This function can be used to enable/disable an external clock input for Timer 0. If enabled, the external input is taken from the DIO8 pin.

Note the following:

- This function should only be called when using the timer in Counter mode - in this mode, the timer is used to count edges on an input clock or pulse train.
- Output gating can be enabled when the internal clock is used.

If required, this function must be called after **vAHI_TimerEnable()**.

Parameters

u8Timer	Identity of timer: set to E_AHI_TIMER_0
bExternalClock	Clock source: TRUE to use an external source (Counter mode only) FALSE to use the internal 16MHz clock
bInvertClock	TRUE to gate the output pin when the gate input is high and invert the clock FALSE to gate the output pin when the gate input is low and not invert the clock

Returns

None

vAHI_TimerConfigureOutputs

```
void vAHI_TimerConfigureOutputs(uint8 u8Timer,
                                bool_t bInvertPwmOutput,
                                bool_t bGateDisable);
```

Description

This function configures certain parameters relating to the operation of the specified timer in the following modes (introduced in Section 7.1):

- **Timer mode:** The internal peripheral clock drives the timer's counter in order to produce a pulse cycle in either 'single shot' or 'repeat' mode. The clock may be temporarily interrupted by a gating input on a DIO (see Section 7.2.1 for the relevant DIOs). Clock gating can be enabled/disabled using this function for Timer 0 only (there are no gating inputs for Timers 1-4).
- **Pulse Width Modulation (PWM) mode:** The PWM signal produced in Timer mode (see above) is output, where this output can be enabled in **vAHI_TimerEnable()**. The signal is output on a DIO which depends on the timer selected (see Section 7.2.1 for the relevant DIOs). If required, the output signal can be inverted using this function on any of the timers operating in PWM mode.

This function must be called after the specified timer has been enabled through **vAHI_TimerEnable()** and before the timer is started.

Parameters

u8Timer	Identity of timer: E_AHI_TIMER_0 (Timer 0) E_AHI_TIMER_1 (Timer 1) E_AHI_TIMER_2 (Timer 2) E_AHI_TIMER_3 (Timer 3) E_AHI_TIMER_4 (Timer 4)
bInvertPwmOutput	Enable/disable inversion of PWM output: TRUE to enable inversion FALSE to disable inversion
bGateDisable	Enable/disable external gating input for Timer mode: TRUE to disable clock gating input FALSE to enable clock gating input (for Timers 1-4, set to TRUE)

Returns

None

vAHI_TimerConfigureInputs

```
void vAHI_TimerConfigureInputs(uint8 u8Timer,
                               bool_t bInvCapt,
                               bool_t bEventEdge);
```

Description

This function configures certain parameters relating to the operation of Timer 0 (there are no external signal inputs for Timers 1-4) in the following modes (introduced in Section 7.1):

- **Capture mode:** An external signal is sampled on every tick of the timer. The results of the capture allow the period and pulse width of the sampled signal to be obtained. The input signal can be inverted using this function, allowing the low-pulse width to be measured (instead of the high-pulse width). This external signal is input on the DIO9 pin.
- **Counter mode:** The timer is used to count the number of transitions on an external input (selected using **vAHI_TimerClockSelect()**). This configure function allows selection of the transitions on which the count will be performed - on low-to-high transitions, or on both low-to-high and high-to-low transitions.

This function must be called after the timer has been enabled through **vAHI_TimerEnable()** and before the timer is started.

Parameters

u8Timer	Identity of timer: set to E_AHI_TIMER_0
bInvCapt	Enable/disable inversion of the capture input signal: TRUE to enable inversion FALSE to disable inversion
bEventEdge	Determines the edge(s) of the external input on which the count will be incremented in counter mode: TRUE - on both low-to-high and high-to-low transitions FALSE - on low-to-high transition

Returns

None

vAHI_TimerSetLocation

```
void vAHI_TimerSetLocation(
                uint8 u8Timer,
                bool_t bLocation,
                bool_t bLocationOverridePWM3andPWM2);
```

Description

This function can be used to select the set of pins on which the specified timer(s) will operate. The affected timers can be Timer 0 alone or the other four timers (1, 2, 3 and 4) collectively:

- Timer 0 can use DIO8-10 (default) or alternatively DIO2-4
- Timers 1, 2, 3 and 4 can use DIO11-13 and 17 (default) or alternatively DIO5-8

Note that specifying any one of Timers 1-4 in the *bLocation* parameter will relocate the DIOs for all four of these timers. However, it is possible to relocate Timer 3 onto DO1 and Timer 2 onto DO0 (Digital Output 1 and Digital Output 0, and not DIOs) using the *bLocationOverridePWM3andPWM2* parameter, which over-rides the *bLocation* setting for these two timers.

The function only needs to be called if the alternative DIOs are preferred.

Parameters

u8Timer — Timer(s) to which DIO re-location will be applied:
E_AHI_TIMER_0 (Timer 0)
E_AHI_TIMER_1 (Timers 1-4)
E_AHI_TIMER_2 (Timers 1-4)
E_AHI_TIMER_3 (Timers 1-4)
E_AHI_TIMER_4 (Timers 1-4)

bLocation — DIOs on which specified timer(s) will operate:
TRUE - DIO2-4 (Timer 0) or DIO5-8 (Timers 1-4)
FALSE - DIO8-10 (Timer 0) or DIO11-13 & 17 (Timers 1-4)

bLocationOverridePWM3andPWM2

Relocate Timers 3 and 2 onto DO1 and DO0:
TRUE - relocate to DO1 and DO0
FALSE - relocate as specified by *bLocation*

Returns

None

vAHI_TimerStartSingleShot

```
void vAHI_TimerStartSingleShot(uint8 u8Timer,
                               uint16 u16Hi,
                               uint16 u16Lo);
```

Description

This function starts the specified timer in 'single-shot' mode. The function relates to Timer mode, PWM mode and Counter mode (introduced in Section 7.1).

In **Timer** or **PWM mode**, during one pulse cycle produced, the timer signal starts low and then goes high:

1. The output is low until *u16Hi* clock periods have passed, when it goes high.
2. The output remains high until *u16Lo* clock periods have passed since the timer was started and then goes low again (marking the end of the pulse cycle).

If enabled through **vAHI_TimerEnable()**, an interrupt can be triggered at the low-high transition and/or the high-low transition.

In **Counter mode**, this function is used differently:

- At a count of *u16Hi*, an interrupt (E_AHI_TIMER_RISE_MASK) will be generated (if enabled).
- At a count of *u16Lo*, another interrupt (E_AHI_TIMER_PERIOD_MASK) will be generated (if enabled) and the timer will stop.

Again, interrupts are enabled through **vAHI_TimerEnable()**.

Note that Counter mode is only available for Timer 0.

Parameters

u8Timer	Identity of timer: E_AHI_TIMER_0 (Timer 0) E_AHI_TIMER_1 (Timer 1) E_AHI_TIMER_2 (Timer 2) E_AHI_TIMER_3 (Timer 3) E_AHI_TIMER_4 (Timer 4)
u16Hi	Number of clock periods after starting a timer before the output goes high (Timer or PWM mode) or count at which first interrupt generated (Counter mode)
u16Lo	Number of clock periods after starting a timer before the output goes low again (Timer or PWM mode) or count at which second interrupt generated and timer stops (Counter mode)

Returns

None

vAHI_TimerStartRepeat

```
void vAHI_TimerStartRepeat(uint8 u8Timer,
                           uint16 u16Hi,
                           uint16 u16Lo);
```

Description

This function starts the specified timer in 'repeat' mode. The function relates to Timer mode, PWM mode and Counter mode (introduced in Section 7.1).

In **Timer** or **PWM mode**, during each pulse cycle produced, the timer signal starts low and then goes high:

1. The output is low until *u16Hi* clock periods have passed, when it goes high.
2. The output remains high until *u16Lo* clock periods have passed since the timer was started and then goes low again.

The above process repeats until the timer is stopped using **vAHI_TimerStop()**.

If enabled through **vAHI_TimerEnable()**, an interrupt can be triggered at the low-high transition and/or the high-low transition.

In **Counter mode**, this function is used differently:

- At a count of *u16Hi*, an interrupt (E_AHI_TIMER_RISE_MASK) will be generated (if enabled).
- At a count of *u16Lo*, another interrupt (E_AHI_TIMER_PERIOD_MASK) will be generated (if enabled) and the count will then be re-started from zero.

Again, interrupts are enabled through **vAHI_TimerEnable()**.

The current count can be read at any time using **u16AHI_TimerReadCount()**.

Note that Counter mode is only available for Timer 0.

Parameters

u8Timer	Identity of timer: E_AHI_TIMER_0 (Timer 0) E_AHI_TIMER_1 (Timer 1) E_AHI_TIMER_2 (Timer 2) E_AHI_TIMER_3 (Timer 3) E_AHI_TIMER_4 (Timer 4)
u16Hi	Number of clock periods after starting a timer before the output goes high (Timer or PWM mode) or count at which first interrupt generated (Counter mode)
u16Lo	Number of clock periods after starting a timer before the output goes low again (Timer or PWM mode) or count at which second interrupt generated (Counter mode)

Returns

None

vAHI_TimerStartCapture

void vAHI_TimerStartCapture(uint8 *u8Timer***);**

Description

This function starts Timer 0 in Capture mode (Timers 1-4 cannot operate in Capture mode). This mode must first be configured using the function **vAHI_TimerConfigureInputs()**.

An input signal must be provided on the DIO9 pin. The incoming signal is timed and the captured measurements are:

- number of clock cycles to the last low-to-high transition of the input signal
- number of clock cycles to the last high-to-low transition of the input signal

These values are placed in registers to be read later using the function **vAHI_TimerReadCapture()** or **vAHI_TimerReadCaptureFreeRunning()**. They allow the input pulse width to be determined.

Parameters

u8Timer	Identity of timer: set to E_AHI_TIMER_0

Returns

None

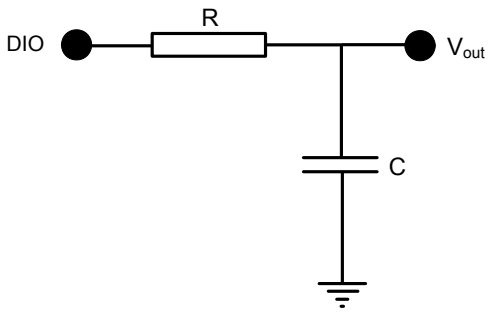
vAHI_TimerStartDeltaSigma

```
void vAHI_TimerStartDeltaSigma(uint8 u8Timer,
                               uint16 u16Hi,
                               uint16 0x0000,
                               bool_t bRtzEnable);
```

Description

This function starts the specified timer in Delta-Sigma mode, which allows the timer to be used as a low-rate DAC.

To use this mode, the DIO output for the timer (see Section 7.2.1 for the relevant DIOs) must be enabled through **vAHI_TimerEnable()**. In addition, an RC circuit must be inserted on the DIO output pin in the arrangement shown below (also see Note below).



The 16MHz peripheral clock is used as the timer source and the conversion period of the 'DAC' is 65536 clock cycles. In Delta-Sigma mode, the timer outputs a number of randomly spaced clock pulses as specified by the value being converted. When RC-filtered, this produces an analogue voltage proportional to the conversion value.

If the RTZ (Return-to-Zero) option is enabled, a low clock cycle is inserted after every clock cycle, so that there are never two consecutive high clock cycles. This doubles the conversion period, but improves linearity if the rise and fall times of the outputs are different from one another.

Note: For more information on 'Delta-Sigma' mode, refer to the data sheet for your microcontroller.

Parameters

u8Timer	Identity of timer: E_AHI_TIMER_0 (Timer 0) E_AHI_TIMER_1 (Timer 1) E_AHI_TIMER_2 (Timer 2) E_AHI_TIMER_3 (Timer 3) E_AHI_TIMER_4 (Timer 4)
u16Hi	Number of 16MHz clock cycles for which the output will be high during a conversion period, in the range 0 to 65535 (full period is 65536 clock cycles)
0x0000	Fixed null value
bRtzEnable	Enable/disable RTZ (Return-to-Zero) option: TRUE to enable FALSE to disable

Returns

None

u16AHI_TimerReadCount

uint16 u16AHI_TimerReadCount(uint8 *u8Timer***);**

Description

This function obtains the current count value of the specified timer.

Parameters

u8Timer	Identity of timer: E_AHI_TIMER_0 (Timer 0) E_AHI_TIMER_1 (Timer 1) E_AHI_TIMER_2 (Timer 2) E_AHI_TIMER_3 (Timer 3) E_AHI_TIMER_4 (Timer 4)

Returns

Current count value of timer

vAHI_TimerReadCapture

```
void vAHI_TimerReadCapture(uint8 u8Timer,
                           uint16 *pu16Hi,
                           uint16 *pu16Lo);
```

Description

This function stops Timer 0 and then obtains the results from a 'capture' started using the function **vAHI_TimerStartCapture()**.

The values returned are offsets from the start of capture, as follows:

- number of clock cycles to the last low-to-high transition of the input signal
- number of clock cycles to the last high-to-low transition of the input signal

The width of the last pulse can be calculated from the difference of these results, provided that the results were requested during a low period. However, since it is not possible to be sure of this, the results obtained from this function may not always be valid for calculating the pulse width.

If you wish to measure the pulse period of the input signal, you should use the function **vAHI_TimerReadCaptureFreeRunning()**, which does not stop the timer.

Capture mode and this function are relevant to Timer 0 only.

Parameters

u8Timer	Identity of timer: set to E_AHI_TIMER_0
**pu16Hi*	Pointer to location which will receive clock period at which last low-high transition occurred
**pu16Lo*	Pointer to location which will receive clock period at which last high-low transition occurred

Returns

None

vAHI_TimerReadCaptureFreeRunning

```
void vAHI_TimerReadCaptureFreeRunning(uint8 u8Timer,
                                      uint16 *pu16Hi,
                                      uint16 *pu16Lo);
```

Description

This function obtains the results from a 'capture' started on Timer 0 using the function **vAHI_TimerStartCapture()**. This function does not stop the timer.

Alternatively, the function **vAHI_TimerReadCapture()** can be used, which stops the timer before reporting the capture measurements.

The values returned are offsets from the start of capture, as follows:

- number of clock cycles to the last low-to-high transition of the input signal
- number of clock cycles to the last high-to-low transition of the input signal

The width of the last pulse can be calculated from the difference of these results, provided that the results were requested during a low period. However, since it is not possible to be sure of this, the results obtained from this function may not always be valid for calculating the pulse width.

If you wish to measure the pulse period of the input signal, you should call this function twice during consecutive pulse cycles. For example, a call to this function could be triggered by an interrupt generated on a particular type of transition (low-to-high or high-to-low). The pulse period can then be obtained by calculating the difference between the results for consecutive low-to-high transitions or the difference between the results for consecutive high-to-low transitions.

Caution: *Since it is not possible to be sure of the state of the input signal when capture started, the results of the first call to this function after starting capture should be discarded.*

Capture mode and this function are relevant to Timer 0 only.

Parameters

u8Timer	Identity of timer: set to E_AHI_TIMER_0
**pu16Hi*	Pointer to location which will receive clock period at which last low-high transition occurred
**pu16Lo*	Pointer to location which will receive clock period at which last high-low transition occurred

Returns

None

vAHI_TimerStop

void vAHI_TimerStop (uint8 *u8Timer***);**

Description

This function stops the specified timer.

Parameters

u8Timer	Identity of timer: E_AHI_TIMER_0 (Timer 0) E_AHI_TIMER_1 (Timer 1) E_AHI_TIMER_2 (Timer 2) E_AHI_TIMER_3 (Timer 3) E_AHI_TIMER_4 (Timer 4)

Returns

None

vAHI_TimerDisable

void vAHI_TimerDisable (uint8 *u8Timer***);**

Description

This function disables the specified timer. As well as stopping the timer from running, the clock to the timer block is switched off in order to reduce power consumption. This means that any subsequent attempt to access the timer will be unsuccessful until **vAHI_TimerEnable()** is called to re-enable the block.

Caution: *An attempt to access the timer while it is disabled will result in an exception.*

Parameters

u8Timer	Identity of timer: E_AHI_TIMER_0 (Timer 0) E_AHI_TIMER_1 (Timer 1) E_AHI_TIMER_2 (Timer 2) E_AHI_TIMER_3 (Timer 3) E_AHI_TIMER_4 (Timer 4)

Returns

None

vAHI_TimerDIOControl

```
void vAHI_TimerDIOControl(uint8 u8Timer,
                          bool_t bDIOEnable);
```

Description

This function enables/disables DIO usage for any one of the timers on the JN516x device. The function configures the DIO(s) for the specified timer:

- DIO8, DIO9 and DIO10 for Timer 0
- DIO11 for Timer 1
- DIO12 for Timer 2
- DIO13 for Timer 3
- DIO17 for Timer 4

Refer to Section 7.2.1 for the timer signals on these DIOs.

By default, the above DIOs are enabled for timer use. If disabled, a DIO can be used as a GPIO (General Purpose Input/Output). You should perform this configuration before the timers are enabled using **vAHI_TimerEnable()**, in order to avoid glitching on the GPIOs during timer operation.

You can alternatively use the function **AHI_TimerFineGrainDIOControl()** to configure the use of the DIOs for all the timers (0-4) at the same time and to enable/disable individual DIOs for Timer 0.

Parameters

u8Timer	Identity of timer: E_AHI_TIMER_0 (Timer 0) E_AHI_TIMER_1 (Timer 1) E_AHI_TIMER_2 (Timer 2) E_AHI_TIMER_3 (Timer 3) E_AHI_TIMER_4 (Timer 4)
bDIOEnable	Enable/disable use of associated DIO(s) by timer: TRUE to enable FALSE to disable (so available for GPIO)

Returns

None

vAHI_TimerFineGrainDIOControl

void vAHI_TimerFineGrainDIOControl(uint8 *u8BitMask***);**

Description

This function allows the DIOs associated with the timers to be enabled/disabled for timer use, permitting the DIOs for all five timers (Timers 0 to 4) to be configured in one call. It also allows the individual configuration of the three DIOs allocated to Timer 0.

By default, all these DIOs are enabled for timer use. Therefore, you can use this function to release those DIOs that you do not wish to use for the timers. The released DIOs will then be available as GPIOs (General Purpose Inputs/Outputs). You should perform this configuration before the timers are enabled using **vAHI_TimerEnable()**, in order to avoid glitching on the GPIOs during timer operation.

The DIO configuration information is passed into the function as an 8-bit bitmap. The bit interpretations in this bitmap are detailed in the table below. A bit is set to 0 to enable the corresponding DIO for timer use and is set to 1 to release the DIO from timer use.

Bit	Timer Input/Output
0	Timer 0 external gate/event input
1	Timer 0 capture input
2	Timer 0 PWM output
3	Timer 1 PWM output
4	Timer 2 PWM output
5	Timer 3 PWM output
6	Timer 4 PWM output
7	Reserved

Parameters

u8BitMask Bitmap containing DIO configuration information for all timers

Returns

None

u8AHI_TimerFired

uint8 u8AHI_TimerFired(uint8 *u8Timer***);**

Description

This function obtains the interrupt status of the specified timer. The function also clears interrupt status after reading it.

Caution: *This function should not be called within a Timer callback function which is invoked as the result of a Timer event, since the interrupt status of the timer is cleared before entering the callback function. The function should only be used when polling for the interrupt status of a timer.*

Parameters

u8Timer	Identity of timer: E_AHI_TIMER_0 (Timer 0) E_AHI_TIMER_1 (Timer 1) E_AHI_TIMER_2 (Timer 2) E_AHI_TIMER_3 (Timer 3) E_AHI_TIMER_4 (Timer 4)

Returns

Bitmap:

Returned value bitwise ANDed with E_AHI_TIMER_RISE_MASK - will be non-zero if interrupt for low-to-high transition (output rising) has been set

Returned value bitwise ANDed with E_AHI_TIMER_PERIOD_MASK - will be non-zero if interrupt for high-to-low transition (end of period) has been set

vAHI_Timer0RegisterCallback

```
void vAHI_Timer0RegisterCallback(
                PR_HWINT_APPCALLBACK PrTimer0Callback);
```

Description

This function registers a user-defined callback function that will be called when the Timer 0 interrupt is triggered.

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.

Note: The function **u8AHI_TimerFired()** should not be called within the Timer callback function - for more information, refer to the function description on page 272.

Interrupt handling is described in Appendix A.

Parameters

PrTimer0Callback Pointer to callback function to be registered

Returns

None

vAHI_Timer1RegisterCallback

```
void vAHI_Timer1RegisterCallback(
                PR_HWINT_APPCALLBACK PrTimer1Callback);
```

Description

This function registers a user-defined callback function that will be called when the Timer 1 interrupt is triggered.

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.

Note: The function **u8AHI_TimerFired()** should not be called within the Timer callback function - for more information, refer to the function description on page 272.

Interrupt handling is described in Appendix A.

Parameters

PrTimer1Callback Pointer to callback function to be registered

Returns

None

vAHI_Timer2RegisterCallback

```
void vAHI_Timer2RegisterCallback(
                PR_HWINT_APPCALLBACK PrTimer2Callback);
```

Description

This function registers a user-defined callback function that will be called when the Timer 2 interrupt is triggered.

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.

Note: The function **u8AHI_TimerFired()** should not be called within the Timer callback function - for more information, refer to the function description on page 272.

Interrupt handling is described in Appendix A.

Parameters

PrTimer2Callback Pointer to callback function to be registered

Returns

None

vAHI_Timer3RegisterCallback

```
void vAHI_Timer3RegisterCallback(
                PR_HWINT_APPCALLBACK PrTimer3Callback);
```

Description

This function registers a user-defined callback function that will be called when the Timer 3 interrupt is triggered.

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.

Note: The function **u8AHI_TimerFired()** should not be called within the Timer callback function - for more information, refer to the function description on page 272.

Interrupt handling is described in Appendix A.

Parameters

PrTimer3Callback Pointer to callback function to be registered

Returns

None

vAHI_Timer4RegisterCallback

```
void vAHI_Timer4RegisterCallback(
                PR_HWINT_APPCALLBACK PrTimer4Callback);
```

Description

This function registers a user-defined callback function that will be called when the Timer 4 interrupt is triggered.

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.

Note: The function **u8AHI_TimerFired()** should not be called within the Timer callback function - for more information, refer to the function description on page 272.

Interrupt handling is described in Appendix A.

Parameters

PrTimer4Callback Pointer to callback function to be registered

Returns

None

24. Wake Timer Functions

This chapter details the functions for controlling the wake timers. The JN516x microcontroller includes two wake timers, denoted Wake Timer 0 and Wake Timer 1, where each is a 41-bit counter.

The wake timers are normally used to time sleep periods and can be programmed to generate interrupts when the timeout period is reached. They can also be used outside of sleep periods, while the CPU is running (although there is another set of timers with more functionality that can operate only while the CPU is running - see Chapter 7).

The wake timers run at a nominal 32kHz, being driven from the 32kHz clock. This clock can be sourced internally or externally, as described in Section 3.1.4 (this clock selection is preserved during sleep). If sourced from the internal RC oscillator, the wake timers may run up to 18% fast or slow, depending on temperature, supply voltage and manufacturing tolerance. To achieve more accurate timings in this case, the self-calibration facility should be used to measure the 32kHz clock against the peripheral clock, which should be running at 16MHz with the system clock sourced from the external crystal oscillator.

Note: For guidance on using the Wake Timer functions in JN516x application code, refer to Chapter 8.

The Wake Timer functions are listed below, along with their page references:

vAHI_WakeTimerEnable

```
void vAHI_WakeTimerEnable(uint8 u8Timer,
                          bool_t bIntEnable);
```

Description

This function allows the wake timer interrupt (which is generated when the timer fires) to be enabled/disabled. If this function is called for a wake timer that is already running, it will stop the wake timer.

The interrupt configuration specified using this function will take effect the next time the wake timer is started. The wake timer can be started using the function **vAHI_WakeTimerStart()**.

Note that:

- If the wake timer interrupt is enabled and the timer is started, the device will be woken if the wake timer expires during sleep
- If the wake timer interrupt is disabled and the timer is started, the device will not be woken if the wake timer expires during sleep

Wake timer interrupts are handled by the System Controller callback function, registered using the function **vAHI_SysCtrlRegisterCallback()**.

Parameters

u8Timer	Identity of timer: E_AHI_WAKE_TIMER_0 (Wake Timer 0) E_AHI_WAKE_TIMER_1 (Wake Timer 1)
bIntEnable	Interrupt enable/disable: TRUE to enable interrupt when wake timer fires FALSE to disable interrupt

Returns

None

vAHI_WakeTimerStartLarge

```
void vAHI_WakeTimerStartLarge(uint8 u8Timer,
                              uint64 u64Count);
```

Description

This function starts the specified wake timer with the specified count value. The wake timer will count down from this value, which is set according to the desired timer duration. On reaching zero, the timer 'fires', rolls over to 0x1FFFFFFFFF and continues to count down.

The count value, *u64Count*, is set as the required number of 32kHz periods. Thus:

Timer duration (in seconds) = *u64Count* / 32000

If the 32kHz clock, which drives the wake timer, is sourced from the internal 32kHz RC oscillator then the wake timer may run up to 18% fast or slow. For accurate timings in this case, you are advised to first calibrate the clock using the function **u32AHI_WakeTimerCalibrate()** and adjust the specified count value accordingly.

If you wish to enable interrupts for the wake timer, you must call **vAHI_WakeTimerEnable()** before calling **vAHI_WakeTimerStartLarge()**. The wake timer can be subsequently stopped using **vAHI_WakeTimerStop()** and can be read using **u64AHI_WakeTimerReadLarge()**. Stopping the timer does not affect interrupts that have been set using **vAHI_WakeTimerEnable()**.

Parameters

u8Timer	Identity of timer: E_AHI_WAKE_TIMER_0 (Wake Timer 0) E_AHI_WAKE_TIMER_1 (Wake Timer 1)
u64Count	Count value in 32kHz periods, i.e. 32 is 1 millisecond (this value must not exceed 0x1FFFFFFFFF, and the values 0 and 1 must not be used)

Returns

None

vAHI_WakeTimerStop

void vAHI_WakeTimerStop(uint8 *u8Timer***);**

Description

This function stops the specified wake timer.

Note that no interrupt will be generated.

Parameters

u8Timer	Identity of timer: E_AHI_WAKE_TIMER_0 (Wake Timer 0) E_AHI_WAKE_TIMER_1 (Wake Timer 1)

Returns

None

u64AHI_WakeTimerReadLarge

uint64 u64AHI_WakeTimerReadLarge(uint8 *u8Timer***);**

Description

This function obtains the current value of the specified wake timer counter (which counts down), without stopping the counter.

Note that on reaching zero, the timer 'fires', rolls over to 0x1FFFFFFFFF and continues to count down. The count value obtained using this function then allows the application to calculate the time that has elapsed since the wake timer fired.

Parameters

u8Timer	Identity of timer: E_AHI_WAKE_TIMER_0 (Wake Timer 0) E_AHI_WAKE_TIMER_1 (Wake Timer 1)

Returns

Current value of wake timer counter

u8AHI_WakeTimerStatus

```
uint8 u8AHI_WakeTimerStatus(void);
```

Description

This function determines which wake timers are active. It is possible to have more than one wake timer active at the same time. The function returns a bitmap where the relevant bits are set to show which wake timers are active.

Note that a wake timer remains active after its countdown has reached zero (when the timer rolls over to 0x1FFFFFFFFF and continues to count down).

Parameters

None

Returns

Bitmap:

Returned value bitwise ANDed with E_AHI_WAKE_TIMER_MASK_0 will be non-zero if Wake Timer 0 is active

Returned value bitwise ANDed with E_AHI_WAKE_TIMER_MASK_1 will be non-zero if Wake Timer 1 is active

u8AHI_WakeTimerFiredStatus

```
uint8 u8AHI_WakeTimerFiredStatus(void);
```

Description

This function determines which wake timers have fired (by having passed zero). The function returns a bitmap where the relevant bits are set to show which timers have fired. Any fired timer status is cleared as a result of this call.

Note 1: If you wish to use this function to check whether a wake timer caused a wake-up event, you must call it before **u32AHI_Init()**. Alternatively, you can determine the wake source as part of your System Controller callback function. For more information, refer to Appendix A.

Note 2: If using the JenNet protocol, do not call this function to obtain the wake timer interrupt status on waking from sleep. At wake-up, JenNet calls **u32AHI_Init()** internally and clears the interrupt status before passing control to the application. The System Controller callback function must be used to obtain the interrupt status, if required.

Parameters

None

Returns

Bitmap:

Returned value bitwise ANDed with E_AHI_WAKE_TIMER_MASK_0 will be non-zero if Wake Timer 0 has fired
Returned value bitwise ANDed with E_AHI_WAKE_TIMER_MASK_1 will be non-zero if Wake Timer 1 has fired

u32AHI_WakeTimerCalibrate

```
uint32 u32AHI_WakeTimerCalibrate(void);
```

Description

This function requests a calibration of the 32kHz clock (on which the wake timers run) against the more accurate peripheral clock which must be running at 16MHz (i.e. the system clock is sourced from the external crystal oscillator). This calibration may be required if the 32kHz clock is sourced from the internal 32kHz RC oscillator, which has a tolerance of ±18% (uncalibrated).

The function uses Wake Timer 0 and takes twenty 32kHz clock periods to complete the calibration.

The returned result, n, is interpreted as follows:

- n = 10000 ⇒ clock running at 32kHz
- n > 10000 ⇒ clock running slower than 32kHz
- n < 10000 ⇒ clock running faster than 32kHz

The returned value can be used to adjust the time interval value used to program a wake timer. If the required timer duration is T seconds, the count value N that must be specified in **vAHI_WakeTimerStart()** or **vAHI_WakeTimerStartLarge()** is given by N = (10000/n) x 32000 x T.

Parameters

None

Returns

Calibration measurement, n (see above)

25. Tick Timer Functions

This chapter details the functions for controlling the Tick Timer on the JN516x microcontrollers - this is a hardware timer, derived from the peripheral clock. It can be used to generate timing interrupts to software.

The Tick Timer can be used to implement:

- regular events, such as ticks for software timers or an operating system
- a high-precision timing reference
- system monitor timeouts, as used in a watchdog timer

Note 1: For guidance on using the Tick Timer functions in JN516x application code, refer to Chapter 9.

Note 2: For high-precision Tick Timer operation, the peripheral clock should run at 16MHz with the system clock sourced from the external crystal oscillator. For system clock information, refer to Section 3.1.

The Tick Timer functions are listed below, along with their page references:

vAHI_TickTimerConfigure

void vAHI_TickTimerConfigure(uint8 *u8Mode***);**

Description

This function configures the operating mode of the Tick Timer and enables the timer. It can also be used to disable the timer.

The Tick Timer counts upwards until the count matches a pre-defined reference value. This function determines what the timer will do once the reference count has been reached. The options are:

- Continue counting upwards
- Restart the count from zero
- Stop counting (single-shot mode)

The reference count is set using the function **vAHI_TickTimerInterval()**. An interrupt can be enabled which is generated on reaching the reference count - see the description of **vAHI_TickTimerIntEnable()**.

The Tick Timer will start running as soon as **vAHI_TickTimerConfigure()** enables it in one of the above modes, irrespective of the state of its counter. In practice, to use the Tick Timer:

1. Call **vAHI_TickTimerConfigure()** to disable the Tick Timer.
2. Call **vAHI_TickTimerWrite()** to set an appropriate starting value for the count.
3. Call **vAHI_TickTimerInterval()** to set the reference count.
4. Call **vAHI_TickTimerConfigure()** again to start the Tick Timer in the desired mode.

On device power-up/reset, the Tick Timer is disabled. However, you are advised to always follow the above sequence of function calls to start the timer.

If the Tick Timer is enabled in single-shot mode, once it has stopped (on reaching the reference count), it can be started again simply by setting another starting value using **vAHI_TickTimerWrite()**.

Parameters

u8Mode	Tick Timer operating mode Action to take on reaching reference count: E_AHI_TICK_TIMER_CONT (continue counting) E_AHI_TICK_TIMER_RESTART (restart from zero) E_AHI_TICK_TIMER_STOP (stop timer) Disable timer: E_AHI_TICK_TIMER_DISABLE (disable timer)

Returns

None

vAHI_TickTimerInterval

void vAHI_TickTimerInterval(uint32 *u32Interval***);**

Description

This function sets the 28-bit reference count for the Tick Timer.

This is the value with which the actual count of the Tick Timer is compared. The action taken when the count reaches this reference value is determined using the function **vAHI_TickTimerConfigure()**. An interrupt can be also enabled which is generated on reaching the reference count - see the function **vAHI_TickTimerIntEnable()**.

Parameters

u32Interval	Tick Timer reference count (in the range 0 to 0x0FFFFFFF)

Returns

None

vAHI_TickTimerWrite

```
void vAHI_TickTimerWrite(uint32 u32Count);
```

Description

This function sets the initial count of the Tick Timer. If the timer is enabled, it will immediately start counting from this value.

By specifying a count of zero, the function can be used to reset the Tick Timer count to zero at any time.

Parameters

u32Count	Tick Timer count (in the range 0 to 0xFFFFFFFF)

Returns

None

u32AHI_TickTimerRead

```
uint32 u32AHI_TickTimerRead(void);
```

Description

This function obtains the current value of the Tick Timer counter.

Parameters

None

Returns

Value of the Tick Timer counter

vAHI_TickTimerIntEnable

```
void vAHI_TickTimerIntEnable(bool_t bIntEnable);
```

Description

This function can be used to enable Tick Timer interrupts, which are generated when the Tick Timer count reaches the reference count specified using the function **vAHI_TickTimerInterval()**.

A user-defined callback function, which is invoked when the interrupt is generated, can be registered using the function **vAHI_TickTimerRegisterCallback()**.

Note that Tick Timer interrupts can be used to wake the CPU from Doze mode.

Parameters

bIntEnable	Enable/disable interrupts: TRUE to enable interrupts FALSE to disable interrupts

Returns

None

bAHI_TickTimerIntStatus

```
bool_t bAHI_TickTimerIntStatus(void);
```

Description

This function obtains the current interrupt status of the Tick Timer.

Parameters

None

Returns

TRUE if an interrupt is pending, FALSE otherwise

vAHI_TickTimerIntPendClr

```
void vAHI_TickTimerIntPendClr(void);
```

Description

This function clears any pending Tick Timer interrupt.

Parameters

None

Returns

None

vAHI_TickTimerRegisterCallback

```
void vAHI_TickTimerRegisterCallback(
        PR_HWINT_APPCALLBACK prTickTimerCallback);
```

Description

This function registers a user-defined callback function that will be called when the Tick Timer interrupt is triggered.

Note that the callback function will be executed in interrupt context. You must therefore ensure that it returns to the main program in a timely manner.

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.

Interrupt handling is described in Appendix A.

Parameters

prTickTimerCallback	Pointer to callback function to be registered

Returns

None

26. Watchdog Timer Functions

This chapter describes the functions for configuring and controlling the Watchdog Timer on the JN516x microcontroller.

Note: For information on the Watchdog Timer and guidance on using the Watchdog Timer functions in JN516x application code, refer to Chapter 10.

The Watchdog Timer functions are listed below, along with their page references:

vAHI_WatchdogStart

void vAHI_WatchdogStart(uint8 *u8Prescale***);**

Description

This function starts the Watchdog Timer and sets the timeout period. Note that the Watchdog Timer is enabled by default and is run with the maximum possible timeout period of 16392ms. If this function is called while the Watchdog Timer is running, it allows the timer to continue uninterrupted but modifies the timeout period.

The timeout period of the Watchdog Timer is determined by an index, specified through the parameter *u8Prescale*, and is calculated according to the formulae:

Timeout Period = 8ms if *u8Prescale* = 0

Timeout Period = $[2^{(Prescale - 1)} + 1] \times 8ms$ if $1 \leq u8Prescale \leq 12$

If the Watchdog Timer is sourced from an internal RC oscillator, the actual timeout period obtained may be up to 18% less than the calculated value due to variations in the oscillator.

Be sure to set the Watchdog timeout period to be greater than the worst-case Flash memory read-write cycle. If the Watchdog times out during a Flash memory access, the JN516x microcontroller will enter programming mode. For information on read-write cycle times, refer to the relevant Flash memory data sheet.

Note that the Watchdog Timer will continue to run during Doze mode but not during Sleep or Deep Sleep mode, or when the hardware debugger has taken control of the CPU (it will, however, automatically restart using the same prescale value when the debugger un-stalls the CPU).

Parameters

u8Prescale	Index in the range 0 to 12, which determines the Watchdog timeout period (see above formulae) - gives timeout periods in the range 8 to 16392ms

Returns

None

vAHI_WatchdogStop

```
void vAHI_WatchdogStop(void);
```

Description

This function stops the Watchdog Timer and freezes the timer count.

Parameters

None

Returns

None

vAHI_WatchdogRestart

```
void vAHI_WatchdogRestart(void);
```

Description

This function re-starts the Watchdog Timer from the beginning of the timeout period.

Parameters

None

Returns

None

u16AHI_WatchdogReadValue

```
uint16 u16AHI_WatchdogReadValue(void);
```

Description

This function obtains an indication of the progress of the Watchdog Timer towards its timeout period.

The returned value is an integer in the range 0 to 255, where:

- 0 indicates that the timer has just started a new count
- 255 indicates that the timer has almost reached the timeout period

Thus, each increment of the returned value represents 1/256 of the Watchdog period - for example, a reported value of 128 indicates that the timer is about half-way through its count.

If this function is called on a transition (increment) of the Watchdog counter, the result will be unreliable. You are therefore advised to call this function repeatedly until two consecutive results are the same.

Tip: This function is useful during code development and debug to ensure that the application does not reset the Watchdog Timer too close to the Watchdog timeout period. The function should not be needed in the final application.

Parameters

None

Returns

Integer value in the range 0 to 255, indicating the progress of the Watchdog Timer

bAHI_WatchdogResetEvent

```
bool_t bAHI_WatchdogResetEvent(void);
```

Description

This function determines whether the last device reset was caused by a Watchdog Timer expiry event.

Parameters

None

Returns

TRUE if a reset occurred due to a Watchdog event, FALSE otherwise

vAHI_WatchdogException

void vAHI_WatchdogException(bool_t *bEnable***);**

Description

This function can be used to enable (or disable) an exception that will be invoked when the Watchdog Timer expires. The Watchdog exception is serviced by the stack overflow exception handler, which can call **bAHI_WatchdogResetEvent()** to determine if the Watchdog exception occurred.

If Watchdog exception handling is not enabled using this function, then the JN516x will be reset when the Watchdog Timer expires. The exception handling option is provided to allow debug on a Watchdog timeout during application development.

The stack overflow exception handler function should first be developed before enabling the Watchdog exception option.

Note: The stack overflow exception handler function should have the following prototype definition:

PUBLIC void vException_StackOverflow(void);

We would not expect an exception handler written in C to return - once it has performed any actions, it should either sit in a loop or reset the device.

Parameters

bEnable	Enable/disable exception handling: TRUE to enable FALSE to disable (default)

Returns

None

27. Pulse Counter Functions

This chapter details the functions for controlling and monitoring the pulse counters on the JN516x device. A pulse counter detects and counts pulses on an external signal that is input on an associated DIO pin.

Two 16-bit pulse counters are provided on the JN516x device, Pulse Counter 0 and Pulse Counter 1. The two counters can be combined together to provide a single 32-bit counter, if desired.

Note: For information on the pulse counters and guidance on using the Pulse Counter functions in JN516x application code, refer to Chapter 11.

The Pulse Counter functions are listed below, along with their page references:

bAHI_PulseCounterConfigure

```
bool_t bAHI_PulseCounterConfigure(uint8 u8Counter,
                                  bool_t bEdgeType,
                                  uint8 u8Debounce,
                                  uint8 u8Combine,
                                  bool_t bIntEnable);
```

Description

This function configures the specified pulse counter. The input signal will automatically be taken from the DIO associated with the specified counter: DIO1 for Pulse Counter 0 and DIO8 for Pulse Counter 1 (the input signal for the combined pulse counter can be taken from either of these DIOs).

Note: The input for Pulse Counter 0 can be moved from DIO1 to DIO4 and for Pulse Counter 1 can be moved from DIO8 to DIO5 using the function **vAHI_PulseCounterSetLocation()**.

The following features are configured:

- **Edge detected** (*bEdgeType*): The counter can be configured to detect a pulse on its rising edge (low-to-high transition) or falling edge (high-to-low transition).
- **Debounce** (*u8Debounce*): This feature can be enabled so that a number of identical consecutive input samples are required before a change in the input signal is recognised. When disabled, the device can sleep with the 32kHz oscillator off.
- **Combined counter** (*u8Combine*): The two 16-bit pulse counters can be combined into a single 32-bit pulse counter. The combined counter is configured according to the Pulse Counter 0 settings (the Pulse Counter 1 settings are ignored) but the input signal can be taken from the input pin for either counter.
- **Interrupts** (*bIntEnable*): Interrupts can be configured to occur when the count passes a reference value, specified using **bAHI_SetPulseCounterRef()**. These interrupts are handled as System Controller interrupts by the callback function registered with **vAHI_SysCtrlRegisterCallback()** - also refer to Appendix A.

Parameters

u8Counter	Identity of pulse counter: E_AHI_PC_0 (Pulse Counter 0 or combined counter) E_AHI_PC_1 (Pulse Counter 1)
bEdgeType	Edge type on which pulse detected (and count incremented): 0: Rising edge (low-to-high transition) 1: Falling edge (high-to-low transition)
u8Debounce	Debounce setting - number of identical consecutive input samples before change in input value is recognised: 0: No debounce (maximum input frequency of 100kHz) 1: 2 samples (maximum input frequency of 3.7kHz) 2: 4 samples (maximum input frequency of 2.2kHz) 3: 8 samples (maximum input frequency of 1.2kHz)

u8Combine	Enable/disable combined 32-bit counter: E_AHI_PC_COMBINE_OFF (0 - Pulse counters not combined) E_AHI_PC_COMBINE_ON0 (1 - Counters combined using PC0 input) E_AHI_PC_COMBINE_ON1 (2 - Counters combined using PC1 input)
bIntEnable	Enable/disable pulse counter interrupts: TRUE - Enable interrupts FALSE - Disable interrrupts

Returns

TRUE if valid pulse counter specified, FALSE otherwise

vAHI_PulseCounterSetLocation

```
void vAHI_PulseCounterSetLocation(uint8 u8Counter,
                                  bool_t bLocation);
```

Description

This function can be used to select the DIO on which the specified pulse counter will operate:

- Pulse Counter 0 can take its input from DIO1 or DIO4 - by default, DIO1 is used, so the function only needs to be called if DIO4 is preferred
- Pulse Counter 1 can take its input from DIO8 or DIO5 - by default, DIO8 is used, so the function only needs to be called if DIO5 is preferred

For the combined pulse counter, the input can be taken from the input pin used by Pulse Counter 0 or Pulse Counter 1, as configured in the call to **bAHI_PulseCounterConfigure()**.

Parameters

u8Counter	Identity of pulse counter: E_AHI_PC_0 (Pulse Counter 0) E_AHI_PC_1 (Pulse Counter 1)
bLocation	DIO on which pulse counter will operate: TRUE - DIO4 (Pulse Counter 0) or DIO5 (Pulse Counter 1) FALSE - DIO1 (Pulse Counter 0) or DIO8 (Pulse Counter 1)

Returns

None

bAHI_SetPulseCounterRef

```
bool_t bAHI_SetPulseCounterRef(uint8 u8Counter,
                               uint32 u32RefValue);
```

Description

This function can be used to set the reference value for the specified pulse counter.

If pulse counter interrupts are enabled through **bAHI_PulseCounterConfigure()**, an interrupt will be generated when the counter passes the reference value - that is, when the count reaches *(reference value + 1)*. This value is retained during sleep and, when generated, the pulse counter interrupt can wake the device from sleep.

The reference value must be 16-bit when specified for the individual pulse counters, but can be a 32-bit value when specified for the combined counter (enabled through **bAHI_PulseCounterConfigure()**). The reference value can be modified at any time.

The pulse counter can increment beyond its reference value and when it reaches its maximum value (65535, or 4294967295 for the combined counter), it will wrap around to zero.

Parameters

u8Counter	Identity of pulse counter: E_AHI_PC_0 (Pulse Counter 0 or combined counter) E_AHI_PC_1 (Pulse Counter 1)
u32RefValue	Reference value to be set - as a 16-bit value, it must be specified in the lower 16 bits of this 32-bit parameter, unless for the combined counter when a full 32-bit value should be specified

Returns

TRUE if valid pulse counter and reference count

FALSE if invalid pulse counter or reference count (>16 bits for single counter)

bAHI_StartPulseCounter

bool_t bAHI_StartPulseCounter(uint8 *u8Counter***);**

Description

This function starts the specified pulse counter.

Note that the count may increment by one when this function is called (even though no pulse has been detected).

Parameters

u8Counter	Identity of pulse counter: E_AHI_PC_0 (Pulse Counter 0 or combined counter) E_AHI_PC_1 (Pulse Counter 1)

Returns

TRUE if valid pulse counter has been specified and started, FALSE otherwise

bAHI_StopPulseCounter

bool_t bAHI_StopPulseCounter(uint8 *u8Counter***);**

Description

This function stops the specified pulse counter.

Note that the count will freeze when this function is called. Thus, this count can subsequently be read using **bAHI_Read16BitCounter()** or **bAHI_Read32BitCounter()** for the combined counter.

Parameters

u8Counter	Identity of pulse counter: E_AHI_PC_0 (Pulse Counter 0 or combined counter) E_AHI_PC_1 (Pulse Counter 1)

Returns

TRUE if valid pulse counter has been specified and stopped, FALSE otherwise

u32AHI_PulseCounterStatus

```
uint32 u32AHI_PulseCounterStatus(void);
```

Description

This function obtains the status of the pulse counters. It can be used to check whether the pulse counters have reached their reference values (set using the function **bAHI_SetPulseCounterRef()**).

The status of each pulse counter is returned by this function in a 32-bit bitmap value - bit 22 for Pulse Counter 0 and bit 23 for Pulse Counter 1. If the combined pulse counter is in use, its status is returned through bit 22.

If a pulse counter has reached its reference value then once the function has returned this status, the internal status bit is cleared for the corresponding pulse counter.

The function can be used to poll the pulse counters. Alternatively, interrupts can be enabled (through **bAHI_PulseCounterConfigure()**) that are generated when the pulse counters pass their reference values.

Parameters

None

Returns

32-bit value in which bit 23 indicates the status of Pulse Counter 1 and bit 22 indicates the status of Pulse Counter 0 or the combined counter. The bit values are interpreted as follows:

1 - pulse counter has reached its reference value
0 - pulse counter is still counting or is not in use

bAHI_Read16BitCounter

```
bool_t bAHI_Read16BitCounter(uint8 u8Counter,
                             uint16 *pu16Count);
```

Description

This function obtains the current count of the specified 16-bit pulse counter, without stopping the counter or clearing the count.

Note that this function can only be used to read the value of an individual 16-bit counter (Pulse Counter 0 or Pulse Counter 1) and cannot read the value of the combined 32-bit counter. If the combined counter is in use, its count value can be obtained using the function **bAHI_Read32BitCounter()**.

Parameters

u8Counter	Identity of pulse counter: E_AHI_PC_0 (Pulse Counter 0) E_AHI_PC_1 (Pulse Counter 1)
**pu16Count*	Pointer to location to receive 16-bit count

Returns

TRUE if valid pulse counter specified, FALSE otherwise

bAHI_Read32BitCounter

bool_t bAHI_Read32BitCounter(uint32 ****pu32Count*);**

Description

This function obtains the current count of the combined 32-bit pulse counter, without stopping the counter or clearing the count.

Note that this function can only be used to read the value of the combined 32-bit pulse counter and cannot read the value of a 16-bit pulse counter used in isolation. The returned Boolean value of this function indicates if the pulse counters have been combined. If the combined counter is not use, the count value of an individual 16-bit pulse counter can be obtained using the function **bAHI_Read16BitCounter()**.

Parameters

**pu32Count*	Pointer to location to receive 32-bit count

Returns

TRUE if combined 32-bit counter in use, FALSE otherwise

bAHI_Clear16BitPulseCounter

bool_t bAHI_Clear16BitPulseCounter(uint8 const *u8Counter***);**

Description

This function clears the count of the specified 16-bit pulse counter.

Note that this function can only be used to clear the count of an individual 16-bit counter (Pulse Counter 0 or Pulse Counter 1) and cannot clear the count of the combined 32-bit counter. To clear the latter, use the function **bAHI_Clear32BitPulseCounter()**.

Parameters

u8Counter	Identity of pulse counter: E_AHI_PC_0 (Pulse Counter 0) E_AHI_PC_1 (Pulse Counter 1)

Returns

TRUE if valid pulse counter specified, FALSE otherwise

bAHI_Clear32BitPulseCounter

```
bool_t bAHI_Clear32BitPulseCounter(void);
```

Description

This function clears the count of the combined 32-bit pulse counter.

Note that this function can only be used to clear the count of the combined 32-bit pulse counter and cannot clear the count of a 16-bit pulse counter used in isolation. To clear the latter, use the function **bAHI_Clear16BitPulseCounter()**.

Parameters

None

Returns

TRUE if combined 32-bit counter in use, FALSE otherwise

28. Infra-Red Transmitter Functions

This chapter details the functions for controlling and monitoring the infra-red transmitter on the JN516x device. Infra-red transmission is a special feature of Timer 2 in which the timer is used to generate a carrier waveform that is modulated by a programmable bit sequence and output on the associated Timer 2 output pin.

Note: For information and guidance on using the infra-red transmitter functions in JN516x application code, refer to Chapter 12.

The Infra-Red Transmitter functions are listed below, along with their page references:

bAHI_InfraredEnable

```
bool_t bAHI_InfraredEnable(
                        uint8 u8Prescale,
                        uint16 u16Hi,
                        uint16 u16Lo,
                        uint16 u16BitPeriodInCarrierPeriods,
                        bool_t bInvertOutput,
                        bool_t bInterruptEnable);
```

Description

This function enables Timer 2 for infra-red transmission and configures the carrier waveform, data-bit period, output polarity and interrupt behaviour. The function must be initially called before any of the other functions is this chapter.

Note: If enabling infra-red transmission, none of the Timer functions listed in Chapter 23 should be called for Timer 2 except **vAHI_TimerSetLocation()** and **vAHI_TimerFineGrainDIOControl()**.

A single interrupt can be enabled to indicate the end of transmission. This interrupt is handled as an Infra-Red Transmitter interrupt by the callback function registered with **vAHI_InfraredRegisterCallback()** - also refer to Appendix A.

Parameters

u8Prescale	Prescale index (0 to 16) used to divide down the peripheral clock to produce the timer clock (divider is $2^{u8Prescale}$)
u16Hi	Number of clock periods after starting the timer before the carrier goes high (i.e. carrier low duration)
u16Lo	Number of clock periods after starting the timer before the carrier goes low again (i.e. carrier period)
u16BitPeriodsInCarrierPeriods	Bit-period in units of the carrier period (1 to 256)
bInvertOutput	Output polarity: TRUE - Output polarity is inverted FALSE - Output polarity is non-inverted
bInterruptEnable	Enable/disable infra-red transmitter interrupt: TRUE - Enable interrupt FALSE - Disable interrrupt

Returns

TRUE if parameters valid, FALSE otherwise

vAHI_InfraredDisable

```
void vAHI_InfraredDisable(void);
```

Description

This function can be used to disable Timer 2 from infra-red transmission. If required, this function must be called after **bAHI_InfraredEnable()**.

Parameters

None

Returns

None

bAHI_InfraredStart

```
bool_t bAHI_InfraredStart(
                          uint32 *pu32BufferAddress,
                          uint16 u16TransmissionLengthInBits);
```

Description

This function is used to start the infra-red transmission of a programmed bit-sequence stored in a 32-bit wide data array (i.e. transmit buffer). This function should be called after **bAHI_InfraredEnable()**.

Parameters

**pu32BufferAddress*	Pointer to start of transmit buffer in RAM
u16TransmissionLengthInBits	Length of transmission sequence in bits (1 to 4096)

Returns

TRUE if transmission will start (due to valid input parameter values)

FALSE if transmission will not start (due to invalid input parameter values)

bAHI_InfraredStatus

```
bool_t bAHI_InfraredStatus(void);
```

Description

This function can be used to check the status of the infra-red transmission. If required, this function must be called after **bAHI_InfraredEnable()**.

Parameters

None

Returns

TRUE if a transmission is in progress

FALSE if a transmission is not (or no-longer) in progress

vAHI_InfraredRegisterCallback

```
void vAHI_InfraredRegisterCallback(
                PR_HWINT_APPCALLBACK prInfraredCallback);
```

Description

This function registers a user-defined callback function that will be called when the Infra-Red Transmitter interrupt is triggered.

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.

Interrupt handling is described in Appendix A.

Parameters

prInfraredCallback	Pointer to callback function to be registered

Returns

None

29. Serial Interface (2-wire) Functions

This chapter details the functions for controlling the 2-wire Serial Interface (SI) on the JN516x microcontroller. The Serial Interface is logic-compatible with similar interfaces such as I^2C and SMbus.

Two sets of functions are described in this chapter, one set for an SI master and another set for an SI slave:

- Functions for controlling the SI master are described in Section 29.1.
- Functions for controlling the SI slave are described in Section 29.2.

General functions that apply to both SI master and SI slave modes are described in Section 29.3.

Tip: The protocol used by the Serial Interface is detailed in the I^2C Specification (available from www.nxp.com).

Note: For guidance on using the SI functions in JN516x application code, refer to Chapter 13.

29.1 SI Master Functions

This section details the functions for controlling a 2-wire Serial Interface (SI) master on a JN516x microcontroller.

The SI master can implement bi-directional communication with a slave device on the SI bus (SI slave functions are also provided and are described in Section 29.2). Note that the SI bus on the JN516x device can have more than one master, but multiple masters cannot use the bus at the same time - to avoid this, an arbitration scheme is provided.

When enabled, this interface uses DIO14 as a clock and DIO15 as a bi-directional data line, but these signals can be moved to DIO16 and DIO17, respectively. The clock is scaled from the peripheral clock, which must run at 16MHz with the system clock sourced from the external crystal oscillator (for system clock information, refer to Section 3.1).

The SI Master functions are listed below, along with their page references:

vAHI_SiMasterConfigure

```
void vAHI_SiMasterConfigure(
                        bool_t bPulseSuppressionEnable,
                        bool_t bInterruptEnable,
                        uint8 u8PreScaler);
```

Description

This function is used to configure and enable the 2-wire Serial Interface (SI) master. This function must be called to enable the SI block before any other SI Master function is called. To later disable the interface, the function **vAHI_SiMasterDisable()** must be used.

The operating frequency, derived from the 16MHz peripheral clock using the specified prescaler *u8PreScaler*, is given by:

Operating frequency = 16/[(*PreScaler* + 1) x 5] MHz

The prescaler is an 8-bit value.

A pulse suppression filter can be enabled to suppress any spurious pulses (high or low) with a pulse width less than 62.5ns on the clock and data lines.

Parameters

bPulseSuppressionEnable	Enable/disable pulse suppression filter: TRUE - enable FALSE - disable
bInterruptEnable	Enable/disable Serial Interface interrupt: TRUE - enable FALSE - disable
u8PreScaler	8-bit clock prescaler (see above)

Returns

None

vAHI_SiMasterDisable

```
void vAHI_SiMasterDisable(void);
```

Description

This function disables (and powers down) the SI master, if it has been previously enabled using the function **vAHI_SiMasterConfigure()**.

Parameters

None

Returns

None

bAHI_SiMasterSetCmdReg

```
bool_t bAHI_SiMasterSetCmdReg(bool_t bSetSTA,
                              bool_t bSetSTO,
                              bool_t bSetRD,
                              bool_t bSetWR,
                              bool_t bSetAckCtrl,
                              bool_t bSetIACK);
```

Description

This function configures the combination of I^2C-protocol commands for a transfer on the SI bus and starts the transfer of the data held in the SI master's transmit buffer.

Up to four commands can be used to perform an I^2C-protocol transfer - Start, Stop, Write, Read. This function allows these commands to be combined to form a complete or partial transfer sequence. The valid command combinations that can be specified are summarised below.

Start	Stop	Read	Write	Resulting Instruction to SI Bus
0	0	0	0	No active command (idle)
1	0	0	1	Start followed by Write
1	1	0	1	Start followed by Write followed by Stop
0	1	1	0	Read followed by Stop
0	1	0	1	Write followed by Stop
0	0	0	1	Write only
0	0	1	0	Read only
0	1	0	0	Stop only

The above command combinations will result in the function returning TRUE, while command combinations that are not in the above list are invalid and will result in a FALSE return code.

The function must be called immediately after **vAHI_SiMasterWriteSlaveAddr()**, which puts the destination slave address (for the subsequent data transfer) into the transmit buffer. It must then be called immediately after **vAHI_SiMasterWriteData()** to start the transfer of data (from the transmit buffer).

For more details of implementing a data transfer on the SI bus, refer to Section 13.1.

***Caution:** If interrupts are enabled, this function should not be called from the user-defined callback function registered via **vAHI_SiRegisterCallback()**.*

Note: This function replaces **vAHI_SiMasterSetCmdReg()**, which returns no value. However, the previous function is still available in the API for backward compatibility.

Parameters

bSetSTA	Generate START bit to gain control of the SI bus (must not be enabled with STOP bit): E_AHI_SI_START_BIT E_AHI_SI_NO_START_BIT
bSetSTO	Generate STOP bit to release control of the SI bus (must not be enabled with START bit): E_AHI_SI_STOP_BIT E_AHI_SI_NO_STOP_BIT
bSetRD	Read from slave (cannot be enabled with slave write): E_AHI_SI_SLAVE_READ E_AHI_SI_NO_SLAVE_READ
bSetWR	Write to slave (cannot be enabled with slave read): E_AHI_SI_SLAVE_WRITE E_AHI_SI_NO_SLAVE_WRITE
bSetAckCtrl	Send ACK or NACK to slave after each byte read: E_AHI_SI_SEND_ACK (to indicate ready for next byte) E_AHI_SI_SEND_NACK (to indicate no more data required)
bSetIACK	Generate interrupt acknowledge (should not normally be required as interrupt is cleared by the interrupt handler): E_AHI_SI_IRQ_ACK E_AHI_SI_NO_IRQ_ACK (normally the required setting)

Returns

TRUE if specified command combination is legal
FALSE if specified command combination is illegal (will result in no action by device)

vAHI_SiMasterWriteSlaveAddr

```
void vAHI_SiMasterWriteSlaveAddr(uint8 u8SlaveAddress,
                                 bool_t bReadStatus);
```

Description

This function is used in setting up communication with a slave device. In this function, you must specify the address of the slave (see below) and the operation (read or write) to be performed on the slave. The function puts this information in the SI master's transmit buffer, but the information will be not transmitted on the SI bus until the function **bAHI_SiMasterSetCmdReg()** is called.

A slave address can be 7-bit or 10-bit, where this address size is set using the function **vAHI_SiSlaveConfigure()** called on the slave device. **vAHI_SiMasterWriteSlaveAddr()** is used differently for the two slave addressing modes:

- For 7-bit addressing, the parameter *u8SlaveAddress* must be set to the 7-bit slave address.
- For 10-bit addressing, the parameter *u8SlaveAddress* must be set to the binary value 011110xx, where xx are the 2 most significant bits of the 10-bit slave address - the code 011110 indicates to the SI bus slaves that 10-bit addressing will be used in the next communication. The remaining 8 bits of the slave address must subsequently be specified in a call to **vAHI_SiMasterWriteData8()**.

For more details of implementing a data transfer on the SI bus, refer to Section 13.1.

Parameters

u8SlaveAddress	Slave address (see above)
bReadStatus	Operation to perform on slave (read or write): TRUE - configure a read FALSE - configure a write

Returns

None

vAHI_SiMasterWriteData8

```
void vAHI_SiMasterWriteData8(uint8 u8Out);
```

Description

This function writes a single data-byte to the transmit buffer of the SI master.

The contents of the transmit buffer will not be transmitted on the SI bus until the function **bAHI_SiMasterSetCmdReg()** is called.

Parameters

u8Out	8 bits of data to transmit

Returns

None

u8AHI_SiMasterReadData8

```
uint8 u8AHI_SiMasterReadData8(void);
```

Description

This function obtains a data-byte received over the SI bus.

Parameters

None

Returns

Data read from receive buffer of SI master

bAHI_SiMasterPollBusy

```
bool_t bAHI_SiMasterPollBusy(void);
```

Description

This function checks whether the SI bus is busy (could be in use by another master).

Parameters

None

Returns

TRUE if busy, FALSE otherwise

bAHI_SiMasterPollTransferInProgress

```
bool_t bAHI_SiMasterPollTransferInProgress(void);
```

Description

This function checks whether a transfer is in progress on the SI bus.

Parameters

None

Returns

TRUE if a transfer is in progress, FALSE otherwise

bAHI_SiMasterCheckRxNack

```
bool_t bAHI_SiMasterCheckRxNack(void);
```

Description

This function checks whether a NACK or an ACK has been received from the slave device. If a NACK has been received, this indicates that the SI master should stop sending data to the slave.

Parameters

None

Returns

TRUE if NACK has occurred

FALSE if ACK has occurred

bAHI_SiMasterPollArbitrationLost

```
bool_t bAHI_SiMasterPollArbitrationLost(void);
```

Description

This function checks whether arbitration has been lost (by the local master) on the SI bus.

Parameters

None

Returns

TRUE if arbitration loss has occurred, FALSE otherwise

29.2 SI Slave Functions

This section details the functions for controlling a 2-wire Serial Interface (SI) slave on the JN516x microcontroller.

As in the case of an SI master, the SI slave uses DIO14 as a clock and DIO15 as a bi-directional data line (but does not supply the clock). These signals can be moved to DIO16 and DIO17, respectively.

The SI Slave functions are listed below, along with their page references:

vAHI_SiSlaveConfigure

```
void vAHI_SiSlaveConfigure(
                    uint16 u16SlaveAddress,
                    bool_t bExtendAddr,
                    bool_t bPulseSuppressionEnable,
                    uint8 u8InMaskEnable,
                    bool_t bFlowCtrlMode);
```

Description

This function is used to configure and enable the 2-wire Serial Interface (SI) slave. This function must be called before any other SI Slave function. To later disable the interface, the function **vAHI_SiSlaveDisable()** must be used.

You must specify the address of the slave to be configured and enabled. A 7-bit or 10-bit slave address can be used. The address size must also be specified through *bExtendAddr*.

The function allows SI slave interrupts to be enabled on an individual basis using an 8-bit bitmask specified through *u8InMaskEnable*. The SI slave interrupts are enumerated as follows:

Bit	Enumeration	Interrupt Description
0	E_AHI_SIS_DATA_RR_MASK	Data buffer must be written with data to be read by SI master
1	E_AHI_SIS_DATA_RTKN_MASK	Data taken from buffer by SI master - buffer free for next data
2	E_AHI_SIS_DATA_WA_MASK	Data buffer contains data from SI master to be read by SI slave
3	E_AHI_SIS_LAST_DATA_MASK	Last data transferred (end of burst)
4	E_AHI_SIS_ERROR_MASK	I^2C protocol error

To obtain the bitmask for *u8InMaskEnable*, the enumerations for the interrupts to be enabled can be bitwise ORed together.

A pulse suppression filter can be enabled to suppress any spurious pulses (high or low) with a pulse width less than 62.5ns on the clock and data lines.

Parameters

u16SlaveAddress	Slave address (7-bit or 10-bit, as defined by *bExtendAdd*)
bExtendAddr	Size of slave address (specified through *u16SlaveAddress*): TRUE - 10-bit address FALSE - 7-bit address

bPulseSuppressionEnable	Enable/disable pulse suppression filter: TRUE - enable FALSE - disable
u8InMaskEnable	Bitmask of SI slave interrupts to be enabled (see above)
bFlowCtrlMode	Flow control mode: TRUE - not valid (reserved for future use) FALSE - NACK (default)

Returns

None

vAHI_SiSlaveDisable

```
void vAHI_SiSlaveDisable(void);
```

Description

This function disables (and powers down) the SI slave, if it has been previously enabled using the function **vAHI_SiSlaveConfigure()**.

Parameters

None

Returns

None

vAHI_SiSlaveWriteData8

void vAHI_SiSlaveWriteData8(uint8 *u8Out***);**

Description

This function writes a single byte of output data to the data buffer of the SI slave, ready to be read by the SI master.

Parameters

u8Out	8 bits of output data

Returns

None

u8AHI_SiSlaveReadData8

```
uint8 u8AHI_SiSlaveReadData8(void);
```

Description

This function reads a single byte of input data from the buffer of the SI slave (where this data byte has been received from the SI master).

Parameters

None

Returns

Input data-byte read from buffer of SI slave

29.3 General SI Functions

This section describes the General SI functions that can be used for both an SI master and SI slave on the JN516x microcontroller.

The functions are listed below, along with their page references:

vAHI_SiSetLocation

void vAHI_SiSetLocation(bool_t *bLocation***);**

Description

This function can be used to select the pair of DIOs on which the Serial Interface (SI) will operate: either DIO14-15 or DIO16-17. By default, DIO14-15 are used, so the function only needs to be called if DIO16-17 are preferred.

The function can be used on an SI master or an SI slave.

Parameters

bLocation	DIOs on which interface will operate: TRUE - DIO16-17 FALSE - DIO14-15 (default)

Returns

None

vAHI_SiRegisterCallback

```
void vAHI_SiRegisterCallback(
                    PR_HWINT_APPCALLBACK prSiCallback);
```

Description

This function registers a user-defined callback function that will be called when a Serial Interface interrupt is triggered on an SI master or on an SI slave.

Note that this function can be used to register the callback function for the SI master or for a SI slave, but both callback functions cannot exist in the application at the same time.

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.

Interrupt handling is described in Appendix A.

Parameters

prSiCallback	Pointer to callback function to be registered

Returns

None

30. SPI Master Functions

This chapter details the functions for controlling the Serial Peripheral Interface (SPI) master on the JN516x microcontroller. The SPI allows high-speed synchronous data transfer between the microcontroller and peripheral devices. When JN516x device operates as the master on the SPI bus, all other devices connected to the bus are expected to be slave devices under the control of the microcontroller's CPU.

Note 1: For information on the SPI master and guidance on using the SPI Master functions in JN516x application code, refer to Chapter 14.

Note 2: SPI Slave functions are detailed in Chapter 31.

Note 3: On a JN516x device, the SPI Master is disabled by default and shares its pins with other functions - this is unlike a JN514x device that uses dedicated pins for the SPI Master, which is enabled from reset in order to boot from an external Flash device.

The SPI Master functions are listed below, along with their page references:

vAHI_SpiConfigure

```
void vAHI_SpiConfigure(uint8 u8SlaveEnable,
                       bool_t bLsbFirst,
                       bool_t bPolarity,
                       bool_t bPhase,
                       uint8 u8ClockDivider,
                       bool_t bInterruptEnable,
                       bool_t bAutoSlaveSelect);
```

Description

This function configures and enables the SPI master.

The function allows the number of SPI slaves (of the master) to be set. Up to three slave-select lines can be set, which use DIO19, DIO0 and DIO1 (but the last two lines can be moved to DIO14 and DIO15, respectively). Note that once reserved for SPI use, DIO lines cannot be subsequently released by calling this function again (and specifying a smaller number of SPI slaves).

The following features are also configurable using this function:

- Data transfer order - whether the least significant bit is transferred first or last
- Clock polarity and phase, which together determine the SPI mode (0, 1, 2 or 3) and therefore the clock edge on which data is latched:
  - SPI Mode 0: polarity=0, phase=0
  - SPI Mode 1: polarity=0, phase=1
  - SPI Mode 2: polarity=1, phase=0
  - SPI Mode 3: polarity=1, phase=1
- Clock divisor - the value used to derive the SPI clock from the peripheral clock
- SPI interrupt - generated when an API transfer has completed (note that interrupts are only worth using if the SPI clock frequency is much less than 16MHz)
- Automatic slave selection - enable the programmed slave-select line or lines (see **vAHI_SpiSelect()**) to be automatically asserted at the start of a transfer and de-asserted when the transfer completes. If not enabled, the slave-select lines will reflect the value set by **vAHI_SpiSelect()** directly.

Parameters

u8SlaveEnable	Number of SPI slaves to control. Valid values are 0-3 (higher values are truncated to 3)
bLsbFirst	Enable/disable data transfer with the least significant bit (LSB) transferred first: TRUE - enable FALSE - disable
bPolarity	Clock polarity: FALSE - unchanged TRUE - inverted

bPhase	Phase: FALSE - latch data on leading edge of clock TRUE - latch data on trailing edge of clock
u8ClockDivider	Clock divisor in the range 0 to 63. Peripheral clock is divided by 2 x *u8ClockDivider,* but 0 is a special value used when no clock division is required
bInterruptEnable	Enable/disable interrupt when an SPI transfer has completed: TRUE - enable FALSE - disable
bAutoSlaveSelect	Enable/disable automatic slave selection: TRUE - enable FALSE - disable

Note that the parameters *bPolarity* and *bPhase* are named differently in the library header file.

Returns

None

vAHI_SpiReadConfiguration

```
void vAHI_SpiReadConfiguration(
                    tSpiConfiguration *ptConfiguration);
```

Description

This function obtains the current configuration of the SPI bus.

This function is intended to be used in a system where the SPI bus is used in multiple configurations to allow the state to be restored later using the function **vAHI_SpiRestoreConfiguration()**. Therefore, no knowledge is needed of the configuration details.

Parameters

**ptConfiguration*	Pointer to location to receive obtained SPI configuration

Returns

None

vAHI_SpiRestoreConfiguration

```
void vAHI_SpiRestoreConfiguration(
                    tSpiConfiguration *ptConfiguration);
```

Description

This function restores the SPI bus configuration using the configuration previously obtained using **vAHI_SpiReadConfiguration()**.

Parameters

**ptConfiguration*	Pointer to SPI configuration to be restored

Returns

None

vAHI_SpiSelSetLocation

```
void vAHI_SpiSelSetLocation(uint8 u8SpiSel,
                            bool_t bLocation);
```

Description

This function can be used to select the DIO on which the specified SPI slave select line will operate. The DIO for slave select line SPISEL1 or SPISEL2 can be configured using this function:

- SPISEL1 can use DIO0 (default) or alternatively DIO14
- SPISEL2 can use DIO1 (default) or alternatively DIO15

The function only needs to be called if the alternative DIO is preferred.

Parameters

u8SpiSel	Slave select line to be configured: E_AHI_SPISEL_1 - Slave select 1 E_AHI_SPISEL_2 - Slave select 2
bLocation	DIO on which specified slave select line will operate: TRUE - DIO14 (SPISEL1) or DIO15 (SPISEL2) FALSE - DIO0 (SPISEL1) or DIO1 (SPISEL2)

Returns

None

vAHI_SpiSelect

void vAHI_SpiSelect(uint8 *u8SlaveMask***);**

Description

This function sets the active slave-select line(s) to use.

The slave-select lines are asserted immediately if “automatic slave selection” is disabled, or otherwise only during data transfers. The number of valid bits in *u8SlaveMask* depends on the setting of *u8SlaveEnable* in a previous call to **vAHI_SpiConfigure()**, as follows:

u8SlaveEnable	**Valid bits in *u8SlaveMask***
0	Bit 0
1	Bits 0, 1
2	Bits 0, 1, 2
3	Bits 0, 1, 2, 3
4	Bits 0, 1, 2, 3, 4

Parameters

u8SlaveMask Bitmap - one bit per slave-select line

Returns

None

vAHI_SpiStop

```
void vAHI_SpiStop(void);
```

Description

This function clears any active slave-select lines. It has the same effect as **vAHI_SpiSelect(0)**.

Parameters

None

Returns

None

vAHI_SpiDisable

```
void vAHI_SpiDisable(void);
```

Description

This function disables the SPI Master.

Parameters

None

Returns

None

vAHI_SpiStartTransfer

void vAHI_SpiStartTransfer(uint8 *u8CharLen*, **uint32** *u32Out*);

Description

This function can be used to start a data transfer to selected slave(s). The data length for the transfer can be specified in the range 1 to 32 bits.

It is assumed that **vAHI_SpiSelect()** has been called to set the slave(s) to communicate with. If interrupts are enabled for the SPI master, an interrupt will be generated when the transfer has completed.

The function **u32AHI_SpiReadTransfer32()** should be used to read the transferred data, with the data aligned to the right (lower bits).

Parameters

u8CharLen	Value in range 0-31 indicating data length for transfer: 0 - 1-bit data 1 - 2-bit data 2 - 3-bit data : 31 - 32-bit data
u32Out	Data to transmit, aligned to the right (e.g. for an 8-bit transfer, store the data in bits 0-7)

Returns

None

u32AHI_SpiReadTransfer32

```
uint32 u32AHI_SpiReadTransfer32(void);
```

Description

This function obtains the received data after a SPI transfer has completed that was started using **vAHI_SpiStartTransfer()** or **vAHI_SpiSetContinuous()**. The read data is aligned to the right (lower bits).

Parameters

None

Returns

Received data (32 bits)

u16AHI_SpiReadTransfer16

```
uint16 u16AHI_SpiReadTransfer16(void);
```

Description

This function obtains the received data after a 16-bit SPI transfer has completed.

Parameters

None

Returns

Received data (16 bits)

u8AHI_SpiReadTransfer8

```
uint8 u8AHI_SpiReadTransfer8(void);
```

Description

This function obtains the received data after a 8-bit SPI transfer has completed.

Parameters

None

Returns

Received data (8 bits)

vAHI_SpiContinuous

```
void vAHI_SpiContinuous(bool_t bEnable,
                        uint8 u8CharLen);
```

Description

This function can be used to enable/disable continuous read mode. The function allows continuous data transfers to the SPI master and facilitates back-to-back reads of the received data. In this mode, incoming data transfers are automatically controlled by hardware - data is received and the hardware then waits for this data to be read by the software before allowing the next data transfer.

The data length for an individual transfer can be specified in the range 1 to 32 bits.

If used to enable continuous mode, the function will start the transfers (so there is no need to call a SPI start transfer function. If used to disable continuous mode, the function will stop any existing transfers (following the function call, one more transfer is made before the transfers are stopped).

To determine when data is ready to be read, the application should check whether the interface is busy by calling the function **bAHI_SpiPollBusy()**. If it is not busy receiving data, the data from the previous transfer can be read by calling **u32AHI_SpiReadTransfer32()**, with the data aligned to the right (lower bits). Once the data has been read, the next transfer will automatically occur.

Parameters

bEnable	Enable/disable continuous read mode and start/stop transfers: TRUE - enable mode and start transfers FALSE - stop transfers and disable mode
u8CharLen	Value in range 0-31 indicating data length for transfer: 0 - 1-bit data 1 - 2-bit data 2 - 3-bit data : 31 - 32-bit data

Returns

None

bAHI_SpiPollBusy

```
bool_t bAHI_SpiPollBusy(void);
```

Description

This function polls the SPI master to determine whether it is currently busy performing a data transfer.

Parameters

None

Returns

TRUE if the SPI master is performing a transfer, FALSE otherwise

vAHI_SpiWaitBusy

```
void vAHI_SpiWaitBusy(void);
```

Description

This function waits for the SPI master to complete a transfer and then returns.

Parameters

None

Returns

None

vAHI_SetDelayReadEdge

void vAHI_SpiSetDelayReadEdge(bool_t *bSetDreBit***);**

Description

This function can be used to introduce a delay to the SCLK edge used to sample received data. The delay is by half a SCLK period relative to the normal position (so is the same edge used by the slave device to transmit the next data bit).

The function should be used when the round-trip delay of SCLK out to MISO IN is large compared with half a SCLK period (e.g. fast SCLK, low voltage, slow slave device), to allow a faster transfer rate to be used than would otherwise be possible.

Parameters

bSetDreBit	Enable/disable read edge delay: TRUE - enable FALSE - disable

Returns

None

vAHI_SpiRegisterCallback

```
void vAHI_SpiRegisterCallback(
        PR_HWINT_APPCALLBACK prSpiCallback);
```

Description

This function registers an application callback that will be called when the SPI interrupt is triggered.

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.

Interrupt handling is described in Appendix A.

Parameters

prSpiCallback	Pointer to callback function to be registered

Returns

None

31. SPI Slave Functions

This chapter details the functions for controlling the Serial Peripheral Interface (SPI) slave on the JN516x microcontroller.

Note 1: For information on the SPI slave and guidance on using the SPI Slave functions in JN516x application code, refer to Chapter 15.

Note 2: SPI Master functions are detailed in Chapter 30.

Note 3: For more details of the data message format, refer to the data sheet for your microcontroller.

The SPI Slave functions are listed below, along with their page references:

bAHI_SpiSlaveEnable

```
bool_t bAHI_SpiSlaveEnable(
                    bool_t  bPinLocation,
                    bool_t  bLsbFirst,
                    uint8   *pu8TxBuffer,
                    uint8   u8TxBufferLength,
                    uint8   u8TxBufferThreshold,
                    uint8   *pu8RxBuffer,
                    uint8   u8RxBufferLength,
                    uint8   u8RxBufferThreshold,
                    uint16  u16RxTimeOut,
                    uint16  u16InterruptEnableMask);
```

Description

This function initialises and configures the SPI Slave.

Parameters

bPinLocation	Configures pin location of SPISMISO and SPISMOSI: TRUE - SPISMISO : DIO17, SPISMOSI : DIO16 FALSE - SPISMISO : DIO13, SPISMOSI : DIO12
bLsbFirst	Configures serial bit-order: TRUE - SPI data byte transferred LSB first FALSE - SPI data byte transferred MSB first
**pu8TxBuffer*	Pointer to start of Transmit buffer in RAM
u8TxBufferLength	Length of Transmit buffer, in bytes (1 to 255)
u8TxBufferThreshold	Fill threshold of Transmit buffer, in bytes (0 to 255)
**pu8RxBuffer*	Pointer to start of Receive buffer in RAM
u8RxBufferLength	Length of Receive buffer, in bytes (1 to 255)
u8RxBufferThreshold	Fill threshold of Receive buffer, in bytes (0 to 255)
u16RxTimeOut	Receive timeout duration, in microseconds (0 to 4095)
u16InterruptEnableMask	Interrupt enable mask (bit): † E_AHI_SPIS_INT_RX_FIRST_MASK (0) E_AHI_SPIS_INT_TX_LAST_MASK (1) E_AHI_SPIS_INT_RX_CLIMB_MASK (2) E_AHI_SPIS_INT_TX_FALL_MASK (3) E_AHI_SPIS_INT_RX_OVER_MASK (4) E_AHI_SPIS_INT_TX_OVER_MASK (5) E_AHI_SPIS_INT_RX_UNDER_MASK (6) E_AHI_SPIS_INT_TX_UNDER_MASK (7) E_AHI_SPIS_INT_RX_TIMEOUT_MASK (8)

† Refer to Table 17 in Appendix B.2 for a description of each mask bit enumeration.

Returns

TRUE if successfully configured, FALSE otherwise (i.e. invalid input parameters)

vAHI_SpiSlaveDisable

```
void vAHI_SpiSlaveDisable(void);
```

Description

This function can be used to disable the SPI Slave.

Parameters

None

Returns

None

vAHI_SpiSlaveReset

```
void vAHI_SpiSlaveReset(bool_t bTxReset,
                        bool_t bRxReset);
```

Description

This function can be used to reset the Transmit and/or Receive FIFO buffers. Following a reset, the internal buffer pointers are re-initialised, the fill-level is reset to zero and the buffer contents remain unchanged.

Parameters

bTxReset	Transmit buffer reset: TRUE - Reset buffer FALSE - Do not reset buffer
bRxReset	Receive buffer reset: TRUE - Reset buffer FALSE - Do not reset buffer

Returns

None

vAHI_SpiSlaveTxWriteByte

void vAHI_SpiSlaveTxWriteByte(uint8 *u8Byte***);**

Description

This function writes a byte of data to the Transmit FIFO buffer of the SPI Slave.

Parameters

u8Byte	Data byte to write to the Transmit FIFO buffer

Returns

None

u8AHI_SpiSlaveRxReadByte

```
uint8 u8AHI_SpiSlaveRxReadByte(void);
```

Description

This function reads a byte of data from the Receive FIFO of the SPI Slave.

Parameters

None

Returns

Data byte read from the Receive FIFO buffer

u8AHI_SpiSlaveTxFillLevel

```
uint8 u8AHI_SpiSlaveTxFillLevel(void);
```

Description

This function returns the fill-level of the Transmit FIFO buffer of the SPI Slave.

Parameters

None

Returns

Fill-level of Transmit FIFO buffer

u8AHI_SpiSlaveRxFillLevel

```
uint8 u8AHI_SpiSlaveRxFillLevel(void);
```

Description

This function returns the fill-level of the Receive FIFO buffer of the SPI Slave.

Parameters

None

Returns

Fill-level of Receive FIFO buffer

u8AHI_SpiSlaveStatus

```
uint8 u8AHI_SpiSlaveStatus(void);
```

Description

This function returns a bitmap indicating the status of the SPI Slave.

Parameters

None

Returns

SPI Slave status bitmap which can be bitwise ANDed with the following masks:

E_AHI_SPIS_STAT_RX_AVAIL_MASK (0x1)	Receive buffer not empty
E_AHI_SPIS_STAT_TX_PENDING_MASK (0x2)	Transmit buffer not empty
E_AHI_SPIS_STAT_RX_ABOVE_MASK (0x4)	Receive buffer fill-level above threshold
E_AHI_SPIS_STAT_TX_ABOVE_MASK (0x8)	Transmit buffer fill-level above threshold

vAHI_SpiSlaveRegisterCallback

```
void vAHI_SpiSlaveRegisterCallback(
        PR_HWINT_APPCALLBACK prSpiCallback);
```

Description

This function registers an application callback that will be called when the SPI Slave interrupt is triggered.

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered before calling **u32AHI_Init()** on waking.

Interrupt handling is described in Appendix A.

Parameters

prSpiCallback	Pointer to callback function to be registered

Returns

None

32. Flash Memory Functions

This chapter describes functions for erasing and programming a sector of a Flash memory device. The Flash memory can be the on-chip device or an external device.

Functions are supplied that can be used to interact with any compatible Flash device (detailed in Section 16.1). They are able to access any sector of Flash memory - the application is stored from the first sector (0) and application data is normally stored in the final sector.

Note 1: To access sectors other than the final sector, you should refer to the data sheet for the Flash device to obtain the necessary sector details. However, be careful not to erase essential data such as application code. The application is stored from Sector 0 of the on-chip Flash memory.

Note 2: For guidance on using the Flash memory functions in JN516x application code, refer to Chapter 16.

The Flash Memory functions are listed below, along with their page references:

bAHI_FlashInit

```
bool_t bAHI_FlashInit(
                    teFlashChipType flashType,
                    tSPIflashFncTable *pCustomFncTable);
```

Description

This function selects the type of Flash memory device to be used.

The Flash memory device can be one of the supported device types or a custom device. In the latter case, a custom table of functions must be supplied for interaction with the device.

For information on the Flash memory devices supported by each JN516x microcontroller, refer to Section 16.1.

Note: If you wish to use both internal (on-chip) and external Flash memory devices, you will need to call **bAHI_FlashInit()** when switching between them.

Parameters

flashType	Type of Flash memory device, one of: E_FL_CHIP_ATMEL_AT25F512 (Atmel AT25F512) E_FL_CHIP_ST_M25P05_A (ST M25P05A) E_FL_CHIP_ST_M25P10_A (ST M25P10A) E_FL_CHIP_ST_M25P20_A (ST M25P20 / Winbond W25X20B) † E_FL_CHIP_ST_M25P40_A (ST M25P40) E_FL_CHIP_SST_25VF010 (Microchip SST25VF010A) †† E_FL_CHIP_CUSTOM (custom external device) E_FL_CHIP_INTERNAL (on-chip Flash memory) E_FL_CHIP_AUTO (on-chip Flash memory)
**pCustomFncTable*	Pointer to the function table for a custom Flash device (E_FL_CHIP_CUSTOM). If a supported Flash device is used, set to NULL.

† The Winbond W25X20B device is similar to the ST M25P20 device and should be specified as the latter (E_FL_CHIP_ST_M25P20_A).

†† The Microchip SST25VF010A device is supported using 4x32KB overlay blocks instead of 32x4KB sectors.

Returns

TRUE if initialisation was successful

FALSE if failed

bAHI_FlashEraseSector

bool_t bAHI_FlashEraseSector(uint8 *u8Sector***);**

Description

This function erases the specified sector of Flash memory by setting all bits to 1.

The function can be used with any compatible Flash memory device with up to 8 sectors. Refer to the data sheet of the Flash memory device for details of its sectors.

Caution: *Be careful not to erase essential data such as application code. The application is stored from the start of the on-chip Flash memory (starting in Sector 0).*

Parameters

u8Sector	Number of the sector to be erased (in the range 2 to 7)

Returns

TRUE if sector erase was successful, FALSE if erase failed

bAHI_FullFlashProgram

```
bool_t bAHI_FullFlashProgram(uint32 u32Addr,
                             uint16 u16Len,
                             uint8 *pu8Data);
```

Description

This function programs a block of Flash memory by clearing the appropriate bits from 1 to 0. The function can be used to access any sector of a compatible Flash memory device. This function must only be used to write a block of data containing a multiple of 16 bytes and this block must be written to a 16-byte boundary.

This mechanism does not allow bits to be set from 0 to 1. It is only possible to set bits to 1 by erasing the entire sector - therefore, before using this function, you must call the function **bAHI_FlashEraseSector()**.

Caution: *Each sector of the internal Flash memory in the JN516x device is divided into 16-byte pagewords. A write to a non-blank pageword must not be performed - the sector containing the non-blank pageword should first be erased using* ***bAHI_FlashEraseSector()*** *before writing to the pageword. If the user omits the sector-erase operation, a subsequent error will likely result when reading from the pageword - this read-error will trigger an interrupt and execute the callback function registered using* ***bAHI_FlashEECerrorInterruptSet()****.*

Caution: *The internal Flash memory of the JN516x device has an endurance limit of 10000 write/erase cycles per sector. Refer to the device-specific data sheet for the endurance limit of the external Flash memory.*

Parameters

u32Addr	Address of first Flash memory byte to be programmed (must be on a 16-byte boundary)
u16Len	Number of bytes to be programmed (must be a multiple of 16 up to 0x8000)
**pu8Data*	Pointer to start of data block to be written to Flash memory

Returns

TRUE if write was successful

FALSE if write failed

bAHI_FullFlashRead

```
bool_t bAHI_FullFlashRead(uint32 u32Addr,
                          uint16 u16Len,
                          uint8 *pu8Data);
```

Description

This function reads data from the application data area of Flash memory. The function can be used to access any sector of a compatible Flash memory device.

If the function parameters are invalid (e.g. by trying to read beyond end of sector), the function returns without reading anything.

Parameters

u32Addr	Address of first Flash memory byte to be read
u16Len	Number of bytes to be read: integer in range 1 to 0x8000
**pu8Data*	Pointer to start of buffer to receive read data.

Returns

TRUE (always)

vAHI_FlashPowerDown

```
void vAHI_FlashPowerDown(void);
```

Description

This function sends a 'power down' command to an external Flash memory device attached to the JN516x device. This allows further power savings to be made when the microcontroller is put into a sleep mode (including Deep Sleep).

The following Flash devices are supported by this function:

- STM25P05A
- STM25P10A
- STM25P20
- STM25P40

If the function is called for an unsupported Flash device, the function will return without doing anything.

The application on a JN516x device is responsible for managing the power to external Flash memory for all sleep modes (including Deep Sleep). If the external Flash device is to be unpowered while the JN516x device is sleeping, this function must be called before **vAHI_Sleep()** is called to put the CPU into Sleep mode. You must subsequently power up the device using **vAHI_FlashPowerUp()** after waking and before attempting to access the Flash memory.

Caution: *This function must not be called when using the JN516x on-chip Flash memory device - that is, when* ***bAHI_FlashInit()*** *has been called with the Flash device type E_FL_CHIP_INTERNAL or E_FL_CHIP_AUTO specified. Note that when using the JenOS Persistent Data Manager (PDM), the E_FL_CHIP_AUTO option is used by default, in which case the on-chip Flash memory device will be detected.*

Parameters

None

Returns

None

vAHI_FlashPowerUp

```
void vAHI_FlashPowerUp(void);
```

Description

This function sends a 'power up' command to an external Flash memory device attached to the JN516x device.

The following Flash devices are supported by this function:

- STM25P05A
- STM25P10A
- STM25P20
- STM25P40

If the function is called for an unsupported Flash device, the function will return without doing anything.

The application on a JN516x device is responsible for managing the power to external Flash memory for all sleep modes (including Deep Sleep). This function must be called when the JN516x device wakes from sleep if the Flash device was powered down using **vAHI_FlashPowerDown()** before the device entered Sleep mode.

Caution: *This function must not be called when using the JN516x on-chip Flash memory device - that is, when* ***bAHI_FlashInit()*** *has been called with the Flash device type E_FL_CHIP_INTERNAL or E_FL_CHIP_AUTO specified. Note that when using the JenOS Persistent Data Manager (PDM), the E_FL_CHIP_AUTO option is used by default, in which case the on-chip Flash memory device will be detected.*

Parameters

None

Returns

None

bAHI_FlashEECerrorInterruptSet

```
bool_t bAHI_FlashEECerrorInterruptSet(
        bool_t bEnable,
        PR_HWINT_APPCALLBACK prFlashEECCallback);
```

Description

This function can be used to enable or disable interrupts that are generated when an error occurs in the on-chip Flash memory device. A user-defined callback function must be specified which will be invoked when an interrupt of this type occurs.

Note that the callback function will be executed in interrupt context. You must therefore ensure that it returns to the main program in a timely manner.

The registered callback function is only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, the callback function must be re-registered and the interrupts re-enabled before calling **u32AHI_Init()** on waking.

Interrupt handling is described in Appendix A.

Parameters

bEnable	Enable or disable internal Flash memory interrupts: TRUE - enable FALSE - disable
prFlashEECCallback	Pointer to callback function to be registered

Returns

None

33. EEPROM Functions

This chapter describes functions for accessing the EEPROM device on the JN516x microcontroller - that is, to read from, write to and erase a segment of EEPROM.

Note 1: Although the functions described in this chapter provide direct access to the EEPROM device, it is recommended that the JenOS Persistent Data Manager (PDM) is normally used to access this memory. PDM is supplied in the NXP JenNet-IP and ZigBee SDKs, and is described in the *JenOS User Guide (JN-UG-3075)*.

Note 2: For guidance on using the EEPROM functions in JN516x application code, refer to Chapter 17.

The EEPROM functions are listed below, along with their page references:

u16AHI_InitialiseEEP

uint16 u16AHI_InitialiseEEP(uint8 ****pu8SegmentDatalength*);**

Description

This function initialises the EEPROM for access and returns the following values:

- The number of bytes in each memory segment is returned in the location pointed to by *pu8SegmentDatalength*
- The number of available memory segments in the device is the return value of the function

Parameters

***pu8SegmentDatalength**	Pointer to a location to receive the number of bytes per segment

Returns

Number of available memory segments in the device

iAHI_WriteDataIntoEEPROMsegment

```
int iAHI_WriteDataIntoEEPROMsegment(
                                uint16 u16SegmentIndex,
                                uint8 u8SegmentByteAddress,
                                uint8 *pu8DataBuffer,
                                uint8  u8Datalength);
```

Description

This function can be used to write a block of data into a segment of EEPROM.

The data block can be written starting at any point (byte address) within the segment. The data length must not be greater than the amount of memory space up to the end of the segment. The function will not allow an attempt to write data beyond the end of the segment (an overflow) and will return a 'failure' status.

Parameters

u16SegmentIndex	Index of EEPROM segment to be written to (segments are numbered from zero)
u8SegmentByteAddress	Byte address within the segment of the start location for writing data (offset from beginning of segment)
***pu8DataBuffer*	Pointer to start of data block in RAM to be written to EEPROM
u8Datalength	Length of data block to be written, in bytes

Returns

0 - Success

1 - Failure (parameter values were out of range)

iAHI_ReadDataFromEEPROMsegment

```
int iAHI_ReadDataFromEEPROMsegment(
                                uint16 u16SegmentIndex,
                                uint8 u8SegmentByteAddress,
                                uint8 *pu8DataBuffer,
                                uint8 u8Datalength);
```

Description

This function can be used to read a block of data from a segment of EEPROM.

The data block to be read can start at any point (byte address) within the segment. The length of the data block must be specified and must not be greater than the amount of memory space up to the end of the segment. The function will not allow an attempt to read data beyond the end of the segment and will return a 'failure' status.

Parameters

u16SegmentIndex	Index of EEPROM segment to be read (segments are numbered from zero)
u8SegmentByteAddress	Byte address within the segment of the start location for reading data (offset from beginning of segment)
***pu8DataBuffer*	Pointer to start location in RAM where the read data is to be written
u8Datalength	Length of data block to be read, in bytes

Returns

0 - Success

1 - Failure (parameter values were out of range)

iAHI_EraseEEPROMsegment

int iAHI_EraseEEPROMsegment(uint16 *u16SegmentIndex***);**

Description

This function can be used to erase the specified segment of EEPROM.

Parameters

u16SegmentIndex	Index of segment to erase (segments are numbered from zero)

Returns

0 - Success

1 - Failure (parameter values were out of range)

Part III: Appendices

A. Interrupt Handling

Interrupts from the on-chip peripherals are handled by a set of peripheral-specific callback functions. These user-defined functions can be introduced using the appropriate callback registration functions of the Integrated Peripherals API. For example, you can write your own interrupt handler for UART0 and then register this callback function using the **vAHI_Uart0RegisterCallback()** function. The full list of peripheral interrupt sources and the corresponding callback registration functions is provided in the table below.

Interrupt Source	Callback Registration Function
System Controller *	**vAHI_SysCtrlRegisterCallback()**
Analogue Peripherals (ADC)	**vAHI_APRegisterCallback()**
UART 0	**vAHI_Uart0RegisterCallback()**
UART 1	**vAHI_Uart1RegisterCallback()**
Timer 0	**vAHI_Timer0RegisterCallback()**
Timer 1	**vAHI_Timer1RegisterCallback()**
Timer 2	**vAHI_Timer2RegisterCallback()**
Timer 3	**vAHI_Timer3RegisterCallback()**
Timer 4	**vAHI_Timer4RegisterCallback()**
Tick Timer	**vAHI_TickTimerRegisterCallback()**
Serial Interface (2-wire)	**vAHI_SiRegisterCallback() ****
SPI Master	**vAHI_SpiRegisterCallback()**
SPI Slave	**vAHI_SpiSlaveRegisterCallback()**
Internal Flash Memory	**bAHI_FlashEECerrorInterruptSet()**
Infra-Red Transmitter	**vAHI_InfraredRegisterCallback()**
Encryption Engine	*Refer to AES Coprocessor API Reference Manual (JN-RM-2013)*

Table 7: Interrupt Sources and Callback Registration Functions

* Includes DIO, comparator, wake timer, pulse counter, random number and brownout interrupts

** Used for both SI master and SI slave interrupts

Note 1: A callback function is executed in interrupt context. You must therefore ensure that the function returns to the main program in a timely manner.

Note 2: The priorities of interrupts from the various interrupt sources can be set using the function **vAHI_InterruptSetPriority()**.

Caution: *Registered callback functions are only preserved during sleep modes in which RAM remains powered. If RAM is powered off during sleep and interrupts are required, any callback functions must be re-registered before calling* ***u32AHI_Init()*** *on waking.*

A.1 Callback Function Prototype and Parameters

The user-defined callback functions for all peripherals must be designed according to the following prototype:

```
void vHwDeviceIntCallback(uint32 u32DeviceId,
                          uint32 u32ItemBitmap);
```

The parameters of this function prototype are as follows:

- *u32DeviceId* identifies the peripheral that generated the interrupt. The list of possible sources is given in Table 7. Enumerations for these sources are provided in the API and are detailed in Appendix B.1.
- *u32ItemBitmap* is a bitmap that identifies the specific cause of the interrupt within the peripheral block identified through *u32DeviceId* above. Masks are provided in the API that allow particular interrupt causes to be checked for. The UART interrupts are an exception as, in their case, an enumerated value is passed via this parameter instead of a bitmap. The masks and enumerations are detailed in Appendix B.2.

A.2 Callback Behaviour

Before invoking one of the callback functions, the API clears the source of the interrupt, so that there is no danger of the same interrupt causing the processor to enter a state of permanently trying to handle the same interrupt (due to a poorly written callback function). This also means that it is possible to have a NULL callback function.

The UARTs are the exception to this rule. When generating a 'receive data available' or 'time-out indication' interrupt, the UARTs will only clear the interrupt once the data has been read from the UART receive buffer. It is therefore vital that if UART interrupts are to be enabled, the callback function handles the 'receive data available' and 'time-out indication' interrupts by reading the data from the UART before returning.

Note: If the Application Queue API is being used, the above issue with the UART interrupts is handled by this API, so the application does not need to deal with it. For more information on this API, refer to the *Application Queue API Reference Manual (JN-RM-2025)*.

A.3 Handling Wake Interrupts

A JN516x microcontroller can be woken from sleep by any of the following sources:

- Wake timer
- DIO
- Comparator
- Pulse counter

For the device to be woken by one of the above wake sources, interrupts must be enabled for that source at some point before the device goes to sleep.

Interrupts from all of the above sources are handled by the user-defined System Controller callback function which is registered using the function **vAHI_SysCtrlRegisterCallback()**. The callback function must be registered before the device goes to sleep. However, in the case of sleep without RAM held, the registered callback function will be lost during sleep and must therefore be re-registered on waking, as part of the cold start routine before the initialisation function **u32AHI_Init()** is called. If there are any System Controller interrupts pending, the call to **u32AHI_Init()** will result in the callback function being invoked and the interrupts being cleared. An interrupt bitmap *u32ItemBitmap* is passed into the callback function and the particular source of the interrupt (DIO, wake timer, etc) can be obtained from this bitmap by bitwise ANDing it with masks provided in the API and detailed in Appendix A.1.

Note 1: As an alternative, for some wake sources 'Status' functions are available which can be used to determine whether a particular source was responsible for a wake-up event (see below). However, if used, these functions must be called before any pending interrupts are cleared and therefore before **u32AHI_Init()** is called.

Note 2: If using the JenNet protocol, do not call these functions to obtain the interrupt status on waking from sleep. At wake-up, JenNet calls **u32AHI_Init()** internally and clears the interrupt status before passing control to the application. The System Controller callback function must be used to obtain the interrupt status, if required.

The above wake sources are outlined below.

Wake Timer

There are two wake timers (0 and 1) on the JN516x microcontroller. These timers run at a nominal 32kHz and are able to operate during sleep periods. When a running wake timer expires during sleep, an interrupt can be generated which wakes the device. Control of the wake timers is described in Chapter 8.

Interrupts for a wake timer can be enabled using **vAHI_WakeTimerEnable()**. The timed period for a wake timer is set when the wake timer is started.

The function **u8AHI_WakeTimerFiredStatus()** is provided to indicate whether a particular wake timer has fired. If used to determine whether a wake timer caused a wake-up event, this function must be called before **u32AHI_Init()** - see Note above.

DIO

There are 20 DIO lines (0-19) on the JN516x microcontroller. A JN516x device can be woken from sleep on the change of state of any DIOs that have been configured as inputs and as wake sources. Control of the DIOs is described in Chapter 5.

The directions of the DIOs (input or output) are configured using the function **vAHI_DioSetDirection()**. Wake interrupts can then be enabled on DIO inputs using the function **vAHI_DioWakeEnable()**. The change of state (rising or falling edge) on which each DIO interrupt will be generated is configured using the function **vAHI_DioWakeEdge()**.

The function **u32AHI_DioWakeStatus()** is provided to indicate whether a DIO caused a wake-up event. If used, this function must be called before **u32AHI_Init()** - see Note above.

Comparator

There is one comparator (numbered 1) on the JN516x microcontroller. A JN516x device can be woken from sleep by a comparator interrupt when either of the following events occurs:

- The comparator's input voltage rises above the reference voltage.
- The comparator's input voltage falls below the reference voltage.

Control of the comparator is described in Section 4.3.

Interrupts for a comparator are configured and enabled using the function **vAHI_ComparatorIntEnable()**.

A function **u8AHI_ComparatorWakeStatus()** is provided to indicate whether a comparator caused a wake-up event. If used, this function must be called before **u32AHI_Init()** - see Note above.

Pulse Counter

There are two pulse counters (0 and 1) on the JN516x microcontroller. These counters are able to run during sleep periods. When a running pulse counter reaches its reference count during sleep, an interrupt can be generated which wakes the device. Control of the pulse counters is described in Chapter 11.

Interrupts for a pulse counter can be enabled when the pulse counter is configured using the function **bAHI_PulseCounterConfigure()**.

B. Interrupt Enumerations and Masks

This appendix details the enumerations and masks used in the parameters of the interrupt callback function described in Appendix A.1.

B.1 Peripheral Interrupt Enumerations (u32DeviceId)

The device ID, *u32DeviceId*, is an enumerated value indicating the peripheral that generated the interrupt. The enumerations are detailed in Table 8 below.

Enumeration	Interrupt Source	Callback Registration Function
E_AHI_DEVICE_SYSCTRL	System Controller	**vAHI_SysCtrlRegisterCallback()**
E_AHI_DEVICE_ANALOGUE	Analogue Peripherals	**vAHI_APRegisterCallback()**
E_AHI_DEVICE_UART0	UART 0	**vAHI_Uart0RegisterCallback()**
E_AHI_DEVICE_UART1	UART 1	**vAHI_Uart1RegisterCallback()**
E_AHI_DEVICE_TIMER0	Timer 0	**vAHI_Timer0RegisterCallback()**
E_AHI_DEVICE_TIMER1	Timer 1	**vAHI_Timer1RegisterCallback()**
E_AHI_DEVICE_TIMER2	Timer 2	**vAHI_Timer2RegisterCallback()**
E_AHI_DEVICE_TIMER3	Timer 3	**vAHI_Timer3RegisterCallback()**
E_AHI_DEVICE_TIMER4	Timer 4	**vAHI_Timer4RegisterCallback()**
E_AHI_DEVICE_TICK_TIMER	Tick Timer	**vAHI_TickTimerRegisterCallback()** **vAHI_TickTimerInit()**
E_AHI_DEVICE_SI *	Serial Interface (2-wire)	**vAHI_SiRegisterCallback() ***
E_AHI_DEVICE_SPIM	SPI Master	**vAHI_SpiRegisterCallback()**
E_AHI_DEVICE_SPIS	SPI Slave	**vAHI_SpiSlaveRegisterCallback()**
E_AHI_DEVICE_FEC	Internal Flash Memory	**bAHI_FlashEECerrorInterruptSet()**
E_AHI_DEVICE_INFRARED	Infra-Red Transmitter	**vAHI_InfraredRegisterCallback()**
E_AHI_DEVICE_AES	Encryption Engine	Refer to *AES Coprocessor API Reference Manual (JN-RM-2013)*

Table 8: u32DeviceId Enumerations

* Used for both SI master and SI slave interrupts

B.2 Peripheral Interrupt Sources (u32ItemBitmap)

The parameter *u32ItemBitmap* is a 32-bit bitmask indicating the individual interrupt source within the peripheral (except for the UARTs, for which the parameter returns an enumerated value). The bits and their meanings are detailed in the tables below.

Mask (Bit)	Description
E_AHI_SYSCTRL_CKEM_MASK (31)	System clock source has been changed
E_AHI_SYSCTRL_RNDEM_MASK (30)	A new value has been generated by the Random Number Generator
E_AHI_SYSCTRL_COMP1_MASK (29) E_AHI_SYSCTRL_COMP0_MASK (28)	Comparator (0 and 1) events
E_AHI_SYSCTRL_WK1_MASK (27) E_AHI_SYSCTRL_WK0_MASK (26)	Wake Timer events
E_AHI_SYSCTRL_VREM_MASK (25) E_AHI_SYSCTRL_VFEM_MASK (24)	Brownout condition entered Brownout condition exited
E_AHI_SYSCTRL_PC1_MASK (23) E_AHI_SYSCTRL_PC0_MASK (22)	Pulse Counter (0 or 1) has reached its pre-configured reference value
E_AHI_DIO20_INT (20) E_AHI_DIO19_INT (19) E_AHI_DIO18_INT (18) E_AHI_DIO17_INT (17) . . . E_AHI_DIO0_INT (0)	Digital IO (DIO) events

Table 9: System Controller

Mask (Bit)	Description
E_AHI_AP_ACC_INT_STATUS_MASK (1 and 0)	Asserted in ADC accumulation mode to indicate that conversion is complete and the accumulated sample is available
E_AHI_AP_CAPT_INT_STATUS_MASK (0)	Asserted in all ADC modes to indicate that an individual conversion is complete and the resulting sample is available

Table 10: Analogue Peripherals

Mask (Bit)	Description
E_AHI_TIMER_RISE_MASK (1)	Interrupt status, generated on timer rising edge (low-to-high transition) - will be non-zero if interrupt for timer rising output has been set
E_AHI_TIMER_PERIOD_MASK (0)	Interrupt status, generated on end of timer period (high-to-low transition) - will be non-zero if interrupt for end of timer period has been set

Table 11: Timers (identical for all timers)

Mask (Bit)	Description
0	Single source for Tick-timer interrupt, therefore returns 1 every time

Table 12: Tick Timer

Mask (Bit)	Description
E_AHI_INFRARED_TX_MASK (0)	Asserted to indicate transmission complete

Table 13: Infra-Red Transmitter

Mask (Bit)	Description
E_AHI_SIM_RXACK_MASK (7)	Asserted if no acknowledgement is received from the addressed slave
E_AHI_SIM_BUSY_MASK (6)	Asserted if a START signal is detected Cleared if a STOP signal is detected
E_AHI_SIM_AL_MASK (5)	Asserted to indicate loss of arbitration
E_AHI_SIM_ICMD_MASK (2)	Asserted to indicate invalid command
E_AHI_SIM_TIP_MASK (1)	Asserted to indicate transfer in progress
E_AHI_SIM_INT_STATUS_MASK (0)	Interrupt status - interrupt indicates loss of arbitration or that byte transfer has completed

Table 14: Serial Interface (2-wire) Master

Mask (Bit)	Description
E_AHI_SIS_ERROR_MASK (4)	I^2C protocol error
E_AHI_SIS_LAST_DATA_MASK (3)	Last data transferred (end of burst)
E_AHI_SIS_DATA_WA_MASK (2)	Buffer contains data to be read by SI slave
E_AHI_SIS_DATA_RTKN_MASK (1)	Data taken from buffer by SI master (buffer free for next data to be loaded)
E_AHI_SIS_DATA_RR_MASK (0)	Buffer needs loading with data for SI master

Table 15: Serial Interface (2-wire) Slave

Mask (Bit)	Description
E_AHI_SPIM_TX_MASK (0)	Transfer has completed

Table 16: SPI Master

Mask (Bit)	Description
E_AHI_SPIS_INT_RX_FIRST_MASK (0)	Data has been received in the Receive FIFO, which was previously empty
E_AHI_SPIS_INT_TX_LAST_MASK (1)	Last remaining byte in Transmit FIFO has been transmitted, leaving the buffer empty
E_AHI_SPIS_INT_RX_CLIMB_MASK (2)	Fill-level of Receive FIFO has risen beyond the configured threshold level
E_AHI_SPIS_INT_TX_FALL_MASK (3)	Fill-level of Transmit FIFO has fallen below the configured threshold level
E_AHI_SPIS_INT_RX_OVER_MASK (4)	Data was received but Receive FIFO was full or busy (so data was discarded)
E_AHI_SPIS_INT_TX_OVER_MASK (5)	Transmit FIFO was written to but was full
E_AHI_SPIS_INT_RX_UNDER_MASK (6)	Receive FIFO was read but was empty
E_AHI_SPIS_INT_TX_UNDER_MASK (7)	Transmission was attempted but Transmit FIFO was empty or not ready (so 0x00 was transmitted over the SPI bus)
E_AHI_SPIS_INT_RX_TIMEOUT_MASK (8)	A Receive timeout has occurred (no further data has been received within this period)

Table 17: SPI Slave

For the UART interrupts, *u32ItemBitmap* returns the following enumerated values:

Enumerated Value	Description (and Priority)
E_AHI_UART_INT_RXLINE (3)	Receive line status (highest priority)
E_AHI_UART_INT_RXDATA (2)	Receive data available (next highest priority)
E_AHI_UART_INT_TIMEOUT (6)	Time-out indication (next highest priority)
E_AHI_UART_INT_TX (1)	Transmit FIFO empty (next highest priority)
E_AHI_UART_INT_MODEM (0)	Modem status (lowest priority)

Table 18: UART (identical for both UARTs)

Table 18 lists the UART interrupts from highest priority to lowest priority.

Revision History

Version	Date	Comments
1.0	22-Nov-2012	First release
1.1	22-Aug-2013	EEPROM functions added and various other modifications/corrections made

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