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"Embedded - Microcontrollers" refer to small, integrated circuits designed to perform specific tasks within larger systems. These microcontrollers are essentially compact computers on a single chip, containing a processor core, memory, and programmable input/output peripherals. They are called "embedded" because they are embedded within electronic devices to control various functions, rather than serving as standalone computers. Microcontrollers are crucial in modern electronics, providing the intelligence and control needed for a wide range of applications.

Applications of "Embedded - Microcontrollers"

Details	
Product Status	Active
Core Processor	ARM® Cortex®-M0+
Core Size	32-Bit Single-Core
Speed	48MHz
Connectivity	I²C, LINbus, SCI, SPI, UART/USART, USB
Peripherals	DMA, POR, PWM, WDT
Number of I/O	37
Program Memory Size	64KB (64K x 8)
Program Memory Type	FLASH
EEPROM Size	-
RAM Size	8K x 8
Voltage - Supply (Vcc/Vdd)	1.62V ~ 3.63V
Data Converters	A/D 14x12b; D/A 2x12b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 105°C (TA)
Mounting Type	Surface Mount
Package / Case	48-TQFP
Supplier Device Package	48-TQFP (7x7)
Purchase URL	https://www.e-xfl.com/product-detail/microchip-technology/atsaml21g16b-ant

Bit 3 – OSCCTRL: Peripheral OSCCTRL Write Protection Status

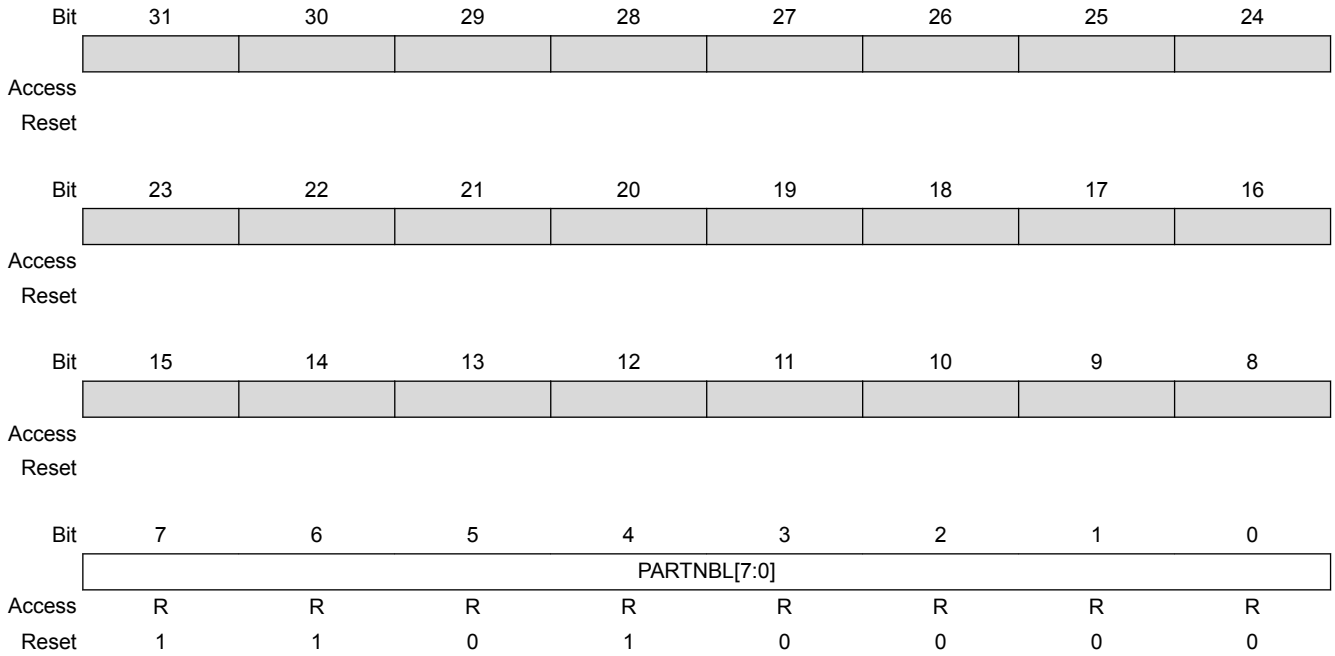
Bit 2 – RSTC: Peripheral RSTC Write Protection Status

Bit 1 – MCLK: Peripheral MCLK Write Protection Status

Bit 0 – PM: Peripheral ATW Write Protection Status

15.13.15. Peripheral Identification 0

Name: PID0
Offset: 0x1FE0
Reset: 0x000000D0
Property: -



Bit	31	30	29	28	27	26	25	24
Access								
Reset								

Bit	23	22	21	20	19	18	17	16
Access								
Reset								

Bit	15	14	13	12	11	10	9	8
Access								
Reset								

Bit	7	6	5	4	3	2	1	0
	PARTNBL[7:0]							
Access	R	R	R	R	R	R	R	R
Reset	1	1	0	1	0	0	0	0

Bits 7:0 – PARTNBL[7:0]: Part Number Low
These bits will always return 0xD0 when read, indicating that this device implements a DSU module instance.

17.8.3. Generator Control

GENCTRLn controls the settings of Generic Generator n (n=0..8).

Name: GENCTRLn
Offset: 0x20 + n*0x04 [n=0..8]
Reset: 0x00000106 for Generator n=0, else 0x00000000
Property: PAC Write-Protection, Write-Synchronized

Bit	31	30	29	28	27	26	25	24
	DIV[15:8]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bit	23	22	21	20	19	18	17	16
	DIV[7:0]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8
			RUNSTDBY	DIVSEL	OE	OOV	IDC	GENEN
Access								
Reset								

Bit	7	6	5	4	3	2	1	0
				SRC[4:0]				
Access				R/W	R/W	R/W	R/W	R/W
Reset				0	0	0	0	0

Bits 31:16 – DIV[15:0]: Division Factor

These bits represent a division value for the corresponding Generator. The actual division factor is dependent on the state of DIVSEL. The number of relevant DIV bits for each Generator can be seen in this table. Written bits outside of the specified range will be ignored.

Table 17-3. Division Factor Bits

Generic Clock Generator	Division Factor Bits
Generator 0	8 division factor bits - DIV[7:0]
Generator 1	16 division factor bits - DIV[15:0]
Generator 2 - 8	8 division factor bits - DIV[7:0]

Bit 13 – RUNSTDBY: Run in Standby

This bit is used to keep the Generator running in Standby as long as it is configured to output to a dedicated GCLK_IO pin. If GENCTRLn.OE is zero, this bit has no effect and the generator will only be running if a peripheral requires the clock.

interrupt sources, the user must read the INTFLAG register to determine which interrupt condition is present.

Related Links

Overview on page 52

PM – Power Manager on page 192

Sleep Mode Controller on page 198

18.6.5. Events

Not applicable.

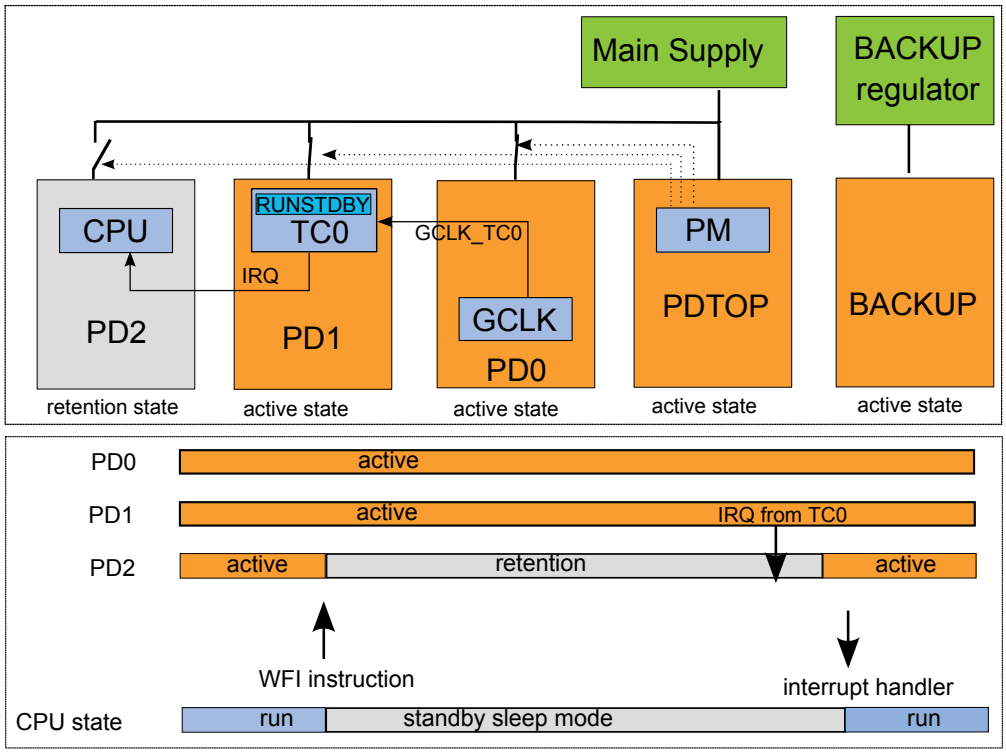
18.6.6. Sleep Mode Operation

In IDLE sleep mode, the MCLK is still running on the selected main clock.

In STANDBY sleep mode, the MCLK is frozen if no synchronous clock is required.

– In this case, the VDDCORE voltage is still supplied by the main voltage regulator, refer to Regulator Automatic Low Power Mode for details. Thus, global wake-up time is not affected by the regulator.

Figure 20-7. TC0 SleepWalking with Static PD Gating



EIC SleepWalking with Static PD Gating

In this example, EIC peripheral is used to detect an edge condition to generate interrupt to the CPU. An External interrupt pin is filtered by the CLK_ULP32K clock, GCLK peripheral is not used. Refer to Chapter EIC – External Interrupt Controller for details. The EIC peripheral is located in the power domain PDTOP (which is not switchable), and there is no RUNSTDBY bit in the EIC peripheral.

- Entering standby mode: As shown in Figure 20-8, all the switchable power domains are set in retention state by the Power Manager peripheral. The low power regulator supplies the VDDCORE voltage level.
- Exiting standby mode: When conditions are met, the EIC peripheral generates an interrupt to wake the device up. Successively, the PM peripheral sets PD0, PD1, and PD2 to active state, and the main voltage regulator restarts. Once PD2 is in active state and the main voltage regulator is ready, the CPU is able to operate normally and execute the EIC interrupt handler accordingly.
- Wake-up time:
  - The required time to set the switchable power domains to active state has to be considered for the global wake-up time, refer to Wake-Up Time for details.
  - When in standby sleep mode, the GCLK peripheral is not used, allowing the VDDCORE to be supplied by the low power regulator to reduce consumption, see Regulator Automatic Low Power Mode. Consequently, main voltage regulator wake-up time has to be considered for the global wake-up time as shown in Figure 20-8.

21.8.11. DPLL Control A

Name: DPLLCTRLA
Offset: 0x28
Reset: 0x80
Property: PAC Write-Protection, Write-Synchronized (ENABLE)

Bit	7	6	5	4	3	2	1	0
	ONDEMAND	RUNSTDBY					ENABLE	
Access	R/W	R/W					R/W	
Reset	1	0					0	

Bit 7 – ONDEMAND: On Demand Clock Activation
The On Demand operation mode allows the DPLL to be enabled or disabled depending on peripheral clock requests.

If the ONDEMAND bit has been previously written to '1', the DPLL will only be running when requested by a peripheral. If there is no peripheral requesting the DPLL's clock source, the DPLL will be in a disabled state.

If On Demand is disabled the DPLL will always be running when enabled.

In standby sleep mode, the On Demand operation is still active.

Value	Description
0	The DPLL is always on, if enabled.
1	The DPLL is enabled when a peripheral is requesting the DPLL to be used as a clock source. The DPLL is disabled if no peripheral is requesting the clock source.

Bit 6 – RUNSTDBY: Run in Standby
This bit controls how the DPLL behaves during standby sleep mode:

Value	Description
0	The DPLL is disabled in standby sleep mode if no peripheral requests the clock.
1	The DPLL is not stopped in standby sleep mode. If ONDEMAND=1, the DPLL will be running when a peripheral is requesting the clock. If ONDEMAND=0, the clock source will always be running in standby sleep mode.

Bit 1 – ENABLE: DPLL Enable
The software operation of enabling or disabling the DPLL takes a few clock cycles, so the DPLLSYNCBUSY.ENABLE status bit indicates when the DPLL is successfully enabled or disabled.

Value	Description
0	The DPLL is disabled.
1	The DPLL is enabled.

CPU Mode	XOSC32KCTRL.RUNSTDBY	XOSC32KCTRL.ONDEMAND	Sleep Behavior
Standby	1	1	Run if requested by peripheral
Standby	0	-	Run if requested by peripheral

As a crystal oscillator usually requires a very long start-up time, the 32KHz External Crystal Oscillator will keep running across resets when XOSC32K.ONDEMAND=0, except for power-on reset (POR). After a reset or when waking up from a sleep mode where the XOSC32K was disabled, the XOSC32K will need a certain amount of time to stabilize on the correct frequency. This start-up time can be configured by changing the Oscillator Start-Up Time bit group (XOSC32K.STARTUP) in the 32KHz External Crystal Oscillator Control register. During the start-up time, the oscillator output is masked to ensure that no unstable clock propagates to the digital logic.

Once the external clock or crystal oscillator is stable and ready to be used as a clock source, the XOSC32K Ready bit in the Status register is set (STATUS.XOSC32KRDY=1). The transition of STATUS.XOSC32KRDY from '0' to '1' generates an interrupt if the XOSC32K Ready bit in the Interrupt Enable Set register is set (INTENSET.XOSC32KRDY=1).

The XOSC32K can be used as a source for Generic Clock Generators (GCLK) or for the Real-Time Counter (RTC). Before enabling the GCLK or the RTC module, the corresponding oscillator output must be enabled (XOSC32K.EN32K or XOSC32K.EN1K) in order to ensure proper operation. In the same way, the GCLK or RTC modules must be disabled before the clock selection is changed. For details on RTC clock configuration, refer also to Real-Time Counter Clock Selection.

Related Links

GCLK - Generic Clock Controller on page 133
RTC – Real-Time Counter on page 347

22.6.3. 32KHz Internal Oscillator (OSC32K) Operation

The OSC32K provides a tunable, low-speed, and low-power clock source.

At reset, the OSC32K is disabled. It can be enabled by setting the Enable bit in the 32KHz Internal Oscillator Control register (OSC32K.ENABLE=1). The OSC32K is disabled by clearing the Enable bit in the 32KHz Internal Oscillator Control register (OSC32K.ENABLE=0).

The frequency of the OSC32K oscillator is controlled by OSC32K.CALIB, which is a calibration value in the 32KHz Internal Oscillator Calibration bits in the 32KHz Internal Oscillator Control register. The CALIB value must be must be loaded with production calibration values from the NVM Software Calibration Area. When writing the Calibration bits, the user must wait for the STATUS.OSC32KRDY bit to go high before the new value is committed to the oscillator.

The OSC32K has a 32.768kHz output which is enabled by setting the 32KHz Output Enable bit in the 32KHz Internal Oscillator Control register (OSC32K.EN32K=1). The OSC32K also has a 1.024kHz clock output. This is enabled by setting the 1KHz Output Enable bit in the 32KHz Internal Oscillator Control register (OSC32K.EN1K).

The OSC32K will behave differently in different sleep modes based on the settings of OSC32K.RUNSTDBY, OSC32K.ONDEMAND, and OSC32K.ENABLE. If OSC32KCTRL.ENABLE=0, the OSC32K will be always stopped. For OS32KCTRL.ENABLE=1, this table is valid:

Value	Name	Description
0x4	DIV32	Divide clock by 32
0x5	DIV64	Divide clock by 64
0x6	DIV128	Divide clock by 128
0x7	DIV256	Divide clock by 256
0x8	DIV512	Divide clock by 512
0x9	DIV1024	Divide clock by 1024
0xA	DIV2048	Divide clock by 2048
0xB	DIV4096	Divide clock by 4096
0xC	DIV8192	Divide clock by 8192
0xD	DIV16384	Divide clock by 16384
0xE	DIV32768	Divide clock by 32768
0xF	DIV65536	Divide clock by 65536

Bit 10 – VMON: Voltage Monitored in Active and Standby Mode
This bit is not synchronized.

Value	Description
0	The BOD33 monitors the VDD power pin in active and standby mode.
1	The BOD33 monitors the VBAT power pin in active and standby mode.

Bit 8 – ACTCFG: BOD33 Configuration in Active Sleep Mode
This bit is not synchronized.

Value	Description
0	In active mode, the BOD33 operates in continuous mode.
1	In active mode, the BOD33 operates in sampling mode.

Bit 7 – RUNBKUP: BOD33 Configuration in Backup Sleep Mode
This bit is not synchronized.

Value	Description
0	In backup sleep mode, the BOD33 is disabled.
1	In backup sleep mode, the BOD33 is enabled and configured in sampling mode.

Bit 6 – RUNSTDBY: Run in Standby
This bit is not synchronized.

Value	Description
0	In standby sleep mode, the BOD33 is disabled.
1	In standby sleep mode, the BOD33 is enabled.

Table 24-1. WDT Operating Modes

CTRLA.ENABLE	CTRLA.WEN	Interrupt Enable	Mode
0	x	x	Stopped
1	0	0	Normal mode
1	0	1	Normal mode with Early Warning interrupt
1	1	0	Window mode
1	1	1	Window mode with Early Warning interrupt

24.6.2. Basic Operation

24.6.2.1. Initialization

The following bits are enable-protected, meaning that they can only be written when the WDT is disabled (CTRLA.ENABLE=0):

- Control A register (CTRLA), except the Enable bit (CTRLA.ENABLE)
- Configuration register (CONFIG)
- Early Warning Interrupt Control register (EWCTRL)

Enable-protected bits in the CTRLA register can be written at the same time as CTRLA.ENABLE is written to '1', but not at the same time as CTRLA.ENABLE is written to '0'.

The WDT can be configured only while the WDT is disabled. The WDT is configured by defining the required Time-Out Period bits in the Configuration register (CONFIG.PER). If Window mode operation is desired, the Window Enable bit in the Control A register must be set (CTRLA.WEN=1) and the Window Period bits in the Configuration register (CONFIG.WINDOW) must be defined.

Enable-protection is denoted by the "Enable-Protected" property in the register description.

24.6.2.2. Configurable Reset Values

After a Power-on Reset, some registers will be loaded with initial values from the NVM User Row.

This includes the following bits and bit groups:

- Enable bit in the Control A register, CTRLA.ENABLE
- Always-On bit in the Control A register, CTRLA.ALWAYSON
- Watchdog Timer Windows Mode Enable bit in the Control A register, CTRLA.WEN
- Watchdog Timer Windows Mode Time-Out Period bits in the Configuration register, CONFIG.WINDOW
- Time-Out Period bits in the Configuration register, CONFIG.PER
- Early Warning Interrupt Time Offset bits in the Early Warning Interrupt Control register, EWCTRL.EWOFFSET

Related Links

NVM User Row Mapping on page 47

24.6.2.3. Enabling, Disabling, and Resetting

The WDT is enabled by writing a '1' to the Enable bit in the Control A register (CTRLA.ENABLE). The WDT is disabled by writing a '0' to CTRLA.ENABLE.

The WDT can be disabled only if the Always-On bit in the Control A register (CTRLA.ALWAYSON) is '0'.

27.6.2. Basic Operation

27.6.2.1. Initialization

The EIC must be initialized in the following order:

1. Enable CLK_EIC_APB
2. If required, configure the NMI by writing the Non-Maskable Interrupt Control register (NMICTRL)
3. When the NMI is used or synchronous edge detection or filtering are required, enable GCLK_EIC or CLK_ULP32K.
   GCLK_EIC is used when a frequency higher than 32KHz is required for filtering, CLK_ULP32K is recommended when power consumption is the priority. For CLK_ULP32K write a '1' to the Clock Selection bit in the Control A register (CTRLA.CKSEL). Optionally, enable the asynchronous mode.
4. Configure the EIC input sense and filtering by writing the Configuration n register (CONFIG0, CONFIG1).
5. Enable the EIC.

The following bits are enable-protected, meaning that it can only be written when the EIC is disabled (CTRLA.ENABLE=0):

- Clock Selection bit in Control A register (CTRLA.CKSEL)

The following registers are enable-protected:

- Event Control register (EVCTRL)
- Configuration n register (CONFIG0, CONFIG1...)
- External Interrupt Asynchronous Mode register (ASYNCH)

Enable-protected bits in the CTRLA register can be written at the same time when setting CTRLA.ENABLE to '1', but not at the same time as CTRLA.ENABLE is being cleared.

Enable-protection is denoted by the "Enable-Protected" property in the register description.

27.6.2.2. Enabling, Disabling, and Resetting

The EIC is enabled by writing a '1' the Enable bit in the Control A register (CTRLA.ENABLE). The EIC is disabled by writing CTRLA.ENABLE to '0'.

The EIC is reset by setting the Software Reset bit in the Control register (CTRLA.SWRST). All registers in the EIC will be reset to their initial state, and the EIC will be disabled.

Refer to the CTRLA register description for details.

27.6.3. External Pin Processing

Each external pin can be configured to generate an interrupt/event on edge detection (rising, falling or both edges) or level detection (high or low). The sense of external interrupt pins is configured by writing the Input Sense x bits in the Config n register (CONFIGn.SENSEx). The corresponding interrupt flag (INTFLAG.EXTINT[x]) in the Interrupt Flag Status and Clear register (INTFLAG) is set when the interrupt condition is met.

When the interrupt flag has been cleared in edge-sensitive mode, INTFLAG.EXTINT[x] will only be set if a new interrupt condition is met. In level-sensitive mode, when interrupt has been cleared, INTFLAG.EXTINT[x] will be set immediately if the EXTINTx pin still matches the interrupt condition.

Each external pin can be filtered by a majority vote filtering, clocked by GCLK_EIC or CLK_ULP32K. Filtering is enabled if bit Filter Enable x in the Configuration n register (CONFIGn.FILTENx) is written to '1'. The majority vote filter samples the external pin three times with GCLK_EIC or CLK_ULP32K and outputs the value when two or more samples are equal.

28. NVMCTRL – Non-Volatile Memory Controller

28.1. Overview

Non-Volatile Memory (NVM) is a reprogrammable Flash memory that retains program and data storage even with power off. It embeds a main array and a separate smaller array intended for EEPROM emulation (RWWEE) that can be programmed while reading the main array. The NVM Controller (NVMCTRL) connects to the AHB and APB bus interfaces for system access to the NVM block. The AHB interface is used for reads and writes to the NVM block, while the APB interface is used for commands and configuration.

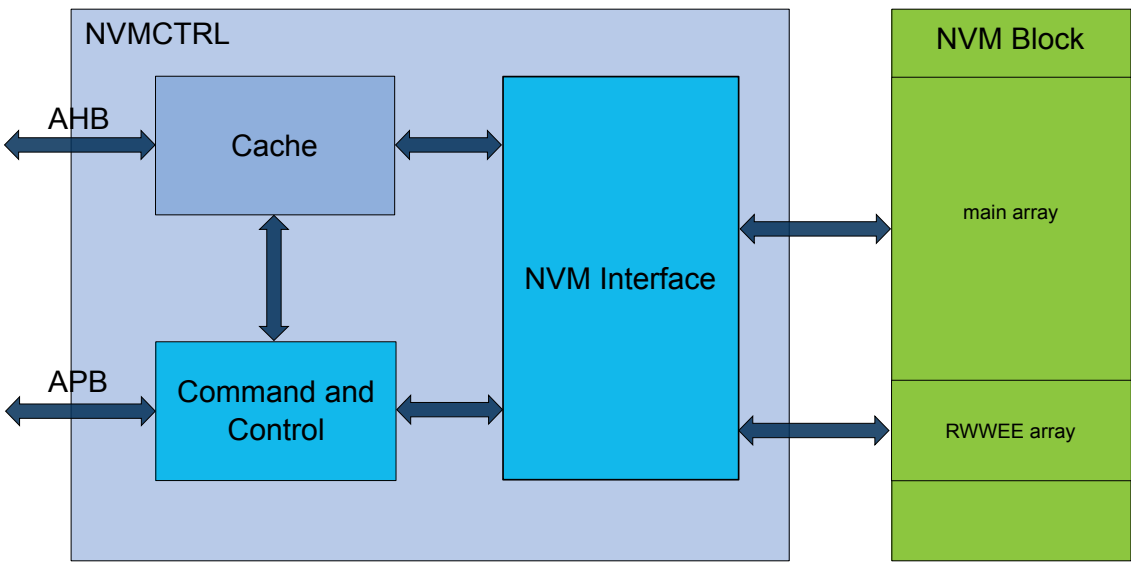
28.2. Features

- 32-bit AHB interface for reads and writes
- Read While Write EEPROM emulation area
- All NVM sections are memory mapped to the AHB, including calibration and system configuration
- 32-bit APB interface for commands and control
- Programmable wait states for read optimization
- 12 regions can be individually protected or unprotected
- Additional protection for boot loader
- Supports device protection through a security bit
- Interface to Power Manager for power-down of Flash blocks in sleep modes
- Can optionally wake up on exit from sleep or on first access
- Direct-mapped cache

Note: A register with property "Enable-Protected" may contain bits that are *not* enable-protected.

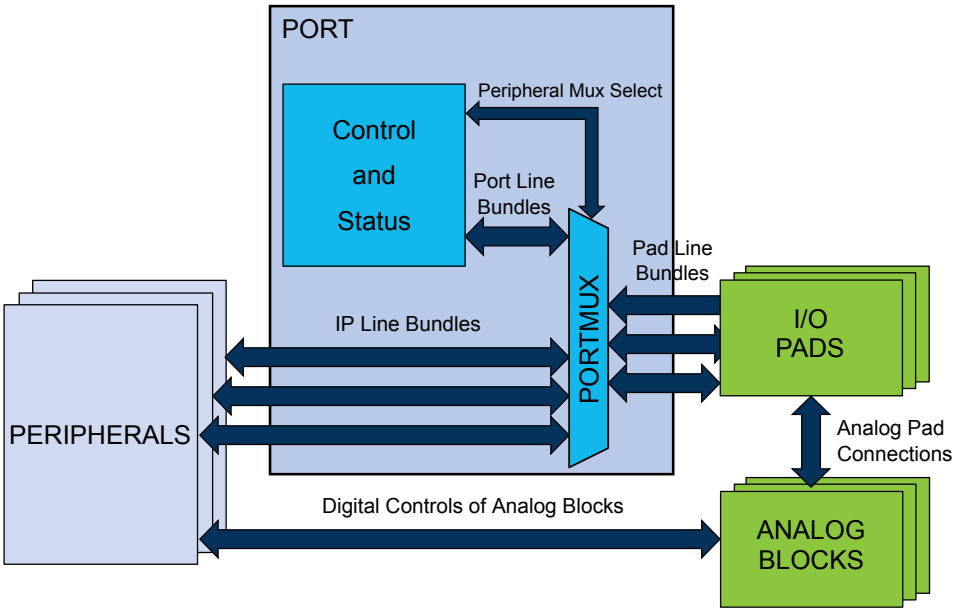
28.3. Block Diagram

Figure 28-1. Block Diagram



29.3. Block Diagram

Figure 29-1. PORT Block Diagram



29.4. Signal Description

Table 29-1. Signal description for PORT

Signal name	Type	Description
Pxy	Digital I/O	General-purpose I/O pin y in group x

Refer to the *I/O Multiplexing and Considerations* for details on the pin mapping for this peripheral. One signal can be mapped on several pins.

Related Links

I/O Multiplexing and Considerations on page 30

29.5. Product Dependencies

In order to use this peripheral, other parts of the system must be configured correctly as following.

29.5.1. I/O Lines

The I/O lines of the PORT are mapped to pins of the physical device. The following naming scheme is used:

Each line bundle with up to 32 lines is assigned an identifier 'xy', with letter x=A, B, C… and two-digit number y=00, 01, …31. Examples: A24, C03.

PORT pins are labeled 'Pxy' accordingly, for example PA24, PC03. This identifies each pin in the device uniquely.

Each pin may be controlled by one or more peripheral multiplexer settings, which allow the pad to be routed internally to a dedicated peripheral function. When the setting is enabled, the selected peripheral

29.8.1. Data Direction

This register allows the user to configure one or more I/O pins as an input or output. This register can be manipulated without doing a read-modify-write operation by using the Data Direction Toggle (DIRTGL), Data Direction Clear (DIRCLR) and Data Direction Set (DIRSET) registers.

Name: DIR
Offset: 0x00
Reset: 0x00000000
Property: PAC Write-Protection

Bit	31	30	29	28	27	26	25	24
	DIR[31:24]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bit	23	22	21	20	19	18	17	16
	DIR[23:16]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8
	DIR[15:8]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bit	7	6	5	4	3	2	1	0
	DIR[7:0]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bits 31:0 – DIR[31:0]: Port Data Direction

These bits set the data direction for the individual I/O pins in the PORT group.

Value	Description
0	The corresponding I/O pin in the PORT group is configured as an input.
1	The corresponding I/O pin in the PORT group is configured as an output.

This bit is not write-synchronized.

Value	Description
0	Group command is disabled.
1	Group command is enabled.

Bit 8 – SMEN: Smart Mode Enable
When smart mode is enabled, data is acknowledged automatically when DATA.DATA is read.

This bit is not write-synchronized.

Value	Description
0	Smart mode is disabled.
1	Smart mode is enabled.

34.9. Register Summary - I2C Master

Offset	Name	Bit Pos.								
0x00	CTRLA	7:0	RUNSTDBY			MODE[2:0]			ENABLE	SWRST
0x01		15:8								
0x02		23:16	SEXTTOEN	MEXTTOEN	SDAHOLD[1:0]					PINOUT
0x03		31:24		LOWTOUT	INACTOUT[1:0]		SCLSM		SPEED[1:0]	
0x04	CTRLB	7:0								
0x05		15:8							QCEN	SMEN
0x06		23:16						ACKACT	CMD[1:0]	
0x07		31:24								
0x08 ... 0x0B	Reserved									
0x0C	BAUD	7:0	BAUD[7:0]							
0x0D		15:8	BAUDLOW[7:0]							
0x0E		23:16	HSBAUD[7:0]							
0x0F		31:24	HSBAUDLOW[7:0]							
0x10 ... 0x13	Reserved									
0x14	INTENCLR	7:0	ERROR						SB	MB
0x15	Reserved									
0x16	INTENSET	7:0	ERROR						SB	MB
0x17	Reserved									
0x18	INTFLAG	7:0	ERROR						SB	MB
0x18	DATA	7:0	DATA[7:0]							
0x19		15:8								
0x1A	STATUS	7:0	CLKHOLD	LOWTOUT	BUSSTATE[1:0]			RXNACK	ARBLOST	BUSERR
0x1B		15:8						LENERR	SEXTTOUT	MEXTTOUT
0x1C	SYNCBUSY	7:0						SYSOP	ENABLE	SWRST
0x1D		15:8								
0x1E		23:16								
0x1F		31:24								
0x21 ... 0x23	Reserved									
0x24	ADDR	7:0								
0x25		15:8	TENBITEN	HS	LENEN			ADDR[2:0]		
0x26		23:16	LEN[7:0]							
0x27		31:24								
0x28 ... 0x2F	Reserved									
0x30	DBGCTRL	7:0								DBGSTOP

Signal	Description	Type
OA1NEG	OPAMP1 negative input	Analog input
OA2POS	OPAMP2 positive input	Analog input
OA2NEG	OPAMP2 negative input	Analog input
OA0OUT	OPAMP0 output	Analog output
OA1OUT	OPAMP1 output	Analog output
OA2OUT	OPAMP2 output	Analog output

One signal can be mapped on several pins.

Important:
When an analog peripheral is enabled, the analog output of the peripheral will interfere with the alternative functions of the output pads. This is also true even when the peripheral is used for internal purposes.

Analog inputs do not interfere with alternative pad functions.

Related Links

I/O Multiplexing and Considerations on page 30

41.5. Product Dependencies

In order to use this peripheral, other parts of the system must be configured correctly, as described below.

41.5.1. I/O Lines

Using the OPAMP I/O lines requires the I/O pins to be configured. Refer to the *PORT - I/O Pin Controller* chapter for details.

41.5.2. Power Management

The OPAMP can operate in idle and standby sleep mode, according to the settings of the Run in Standby and On Demand bits in the OPAMP Control x registers (OPAMPCTRLx.RUNSTDBY and OPAMPCTRLx.ONDEMAND), as well as the Enable bit in the Control A register (CTRLA.ENABLE). Refer to *PM – Power Manager* for details on the different sleep modes.

Related Links

PM – Power Manager on page 192

41.5.3. Clocks

The OPAMP bus clock (CLK_OPAMP_APB) can be enabled and disabled in the Power Manager, and the default state of CLK_OPAMP_APB can be found in the *Peripheral Clock Masking*.

A clock (CLK_ULP32K) is required by the voltage doubler for low voltage operation (VCC < 2.5V). The CLK_ULP32K is a 32KHz clock which is provided by the OSCULP32K oscillator in the OSC32KCTRL module.

Related Links

Peripheral Clock Masking on page 157

production tests. These calibration values are read by software to infer the most accurate temperature readings possible.

The Temperature Log Row basically contains the following parameter set for two different temperatures ("ROOM" and "HOT"):

- Calibration temperatures in °C. One at room temperature $temp_R$, one at a higher temperature $temp_H$:
  - ROOM_TEMP_VAL_INT and ROOM_TEMP_VAL_DEC contain the measured temperature at room insertion, $temp_R$, in °C, separated in integer and decimal value.
    Example: For ROOM_TEMP_VAL_INT=0x19=25 and ROOM_TEMP_VAL_DEC=2, the measured temperature at room insertion is 25.2°C.
  - HOT_TEMP_VAL_INT and HOT_TEMP_VAL_DEC contain the measured temperature at hot insertion, $temp_H$, in °C. The integer and decimal value are also separated.
- For each temperature, the corresponding sensor value at the ADC in 12-bit, ADC_R and ADC_H:
  - ROOM_ADC_VAL contains the 12-bit ADC value, ADC_R, corresponding to $temp_R$. Its conversion to Volt is denoted V_{ADCR}.
  - HOT_ADC_VAL contains the 12-bit ADC value, ADC_H, corresponding to $temp_H$. Its conversion to Volt is denoted V_{ADCH}.
- Actual reference voltages at each calibration temperature in Volt, $INT1V_R$ and $INT1V_H$, respectively:
  - ROOM_INT1V_VAL is the 2's complement of the internal 1V reference value at $temp_R$: $INT1V_R$.
  - HOT_INT1V_VAL is the 2's complement of the internal 1V reference value at $temp_H$: $INT1V_H$.
  - Both ROOM_INT1V_VAL and HOT_INT1V_VAL values are centered around 1V with a 0.001V step. In other words, the range of values [0,127] corresponds to [1V, 0.873V] and the range of values [-1, -127] corresponds to [1.001V, 1.127V]. INT1V == 1 - (VAL/1000) is valid for both ranges.

Calculating the Temperature by Linear Interpolation

Using the data pairs ($temp_R$, V_{ADCR}) and ($temp_H$, V_{ADCH}) for a linear interpolation, we have the following equation:

$$\left(\frac{V_{ADC} - V_{ADCR}}{temp - temp_R}\right) = \left(\frac{V_{ADCH} - V_{ADCR}}{temp_H - temp_R}\right)$$

The voltages V_x are acquired as 12-bit ADC values ADC_x, with respect to an internal reference voltage $INT1V_x$:

[Equation 1]

$$V_{ADCx} = ADC_x \cdot \frac{\mathrm{INT1V}_x}{2^{12} - 1}$$

For the measured value of the temperature sensor, ADC_m, the reference voltage is assumed to be perfect, i.e., $INT1V_m$=$INT1V_c$=1V. These substitutions yield a coarse value of the measured temperature $temp_C$:

[Equation 2]

$$temp_C = temp_R + \left[\frac{\left\{\left(ADC_m \cdot \frac{\mathrm{INT1V}_c}{\left(2^{12}-1\right)}\right) - \left(ADC_R \cdot \frac{\mathrm{INT1V}_R}{\left(2^{12}-1\right)}\right)\right\} \cdot \left(temp_H - temp_R\right)}{\left(ADC_H \cdot \frac{\mathrm{INT1V}_H}{\left(2^{12}-1\right)}\right) - \left(ADC_R \cdot \frac{\mathrm{INT1V}_R}{\left(2^{12}-1\right)}\right)}\right]$$

Nested Vector Interrupt Controller on page 52

43.6.13. Events

The AC can generate the following output events:

- Comparator (COMP0, COMP1): Generated as a copy of the comparator status
- Window (WIN0): Generated as a copy of the window inside/outside status

Writing a one to an Event Output bit in the Event Control Register (EVCTRL.xxEO) enables the corresponding output event. Writing a zero to this bit disables the corresponding output event. Refer to the Event System chapter for details on configuring the event system.

The AC can take the following action on an input event:

- Start comparison (START0, START1): Start a comparison.

Writing a one to an Event Input bit into the Event Control register (EVCTRL.COMPEIx) enables the corresponding action on input event. Writing a zero to this bit disables the corresponding action on input event. Note that if several events are connected to the AC, the enabled action will be taken on any of the incoming events. Refer to the Event System chapter for details on configuring the event system.

When EVCTRL.COMPEIx is one, the event will start a comparison on COMPx after the start-up time delay. In normal mode, each comparator responds to its corresponding input event independently. For a pair of comparators in window mode, either comparator event will trigger a comparison on both comparators simultaneously.

43.6.14. Sleep Mode Operation

The Run in Standby bits in the Comparator x Control registers (COMPCTRLx.RUNSTDBY) control the behavior of the AC during standby sleep mode. Each RUNSTDBY bit controls one comparator. When the bit is zero, the comparator is disabled during sleep, but maintains its current configuration. When the bit is one, the comparator continues to operate during sleep. Note that when RUNSTDBY is zero, the analog blocks are powered off for the lowest power consumption. This necessitates a start-up time delay when the system returns from sleep.

For Window Mode operation, both comparators in a pair must have the same RUNSTDBY configuration.

When RUNSTDBY is one, any enabled AC interrupt source can wake up the CPU. The AC can also be used during sleep modes where the clock used by the AC is disabled, provided that the AC is still powered (not in shutdown). In this case, the behavior is slightly different and depends on the measurement mode, as listed in Table 43-1.

Table 43-1. Sleep Mode Operation

COMPCTRLx.MODE	RUNSTDBY=0	RUNSTDBY=1
0 (Continuous)	COMPx disabled	GCLK_AC stopped, COMPx enabled
1 (Single-shot)	COMPx disabled	GCLK_AC stopped, COMPx enabled only when triggered by an input event

43.6.14.1. Continuous Measurement during Sleep

When a comparator is enabled in continuous measurement mode and GCLK_AC is disabled during sleep, the comparator will remain continuously enabled and will function asynchronously. The current state of the comparator is asynchronously monitored for changes. If an edge matching the interrupt condition is found, GCLK_AC is started to register the interrupt condition and generate events. If the interrupt is enabled in the Interrupt Enable registers (INTENCLR/SET), the AC can wake up the device;

43.8.5. Interrupt Enable Set

This register allows the user to enable an interrupt without doing a read-modify-write operation. Changes in this register will also be reflected in the Interrupt Enable Clear register (INTENCLR).

Name: INTENSET
Offset: 0x05
Reset: 0x00
Property: PAC Write-Protection

Bit	7	6	5	4	3	2	1	0
				WIN0			COMP1	COMP0
Access				R/W			R/W	R/W
Reset				0			0	0

Bit 4 – WIN0: Window 0 Interrupt Enable
Reading this bit returns the state of the Window 0 interrupt enable.

Writing a '0' to this bit has no effect.

Writing a '1' to this bit enables the Window 0 interrupt.

Value	Description
0	The Window 0 interrupt is disabled.
1	The Window 0 interrupt is enabled.

Bits 1,0 – COMPx: Comparator x Interrupt Enable
Reading this bit returns the state of the Comparator x interrupt enable.

Writing a '0' to this bit has no effect.

Writing a '1' to this bit will set the Ready interrupt bit and enable the Ready interrupt.

Value	Description
0	The Comparator x interrupt is disabled.
1	The Comparator x interrupt is enabled.

49. Schematic Checklist

49.1. Introduction

This chapter describes a common checklist which should be used when starting and reviewing the schematics for a SAM L21 design. This chapter illustrates recommended power supply connections, how to connect external analog references, programmer, debugger, oscillator and crystal.

49.1.1. Operation in Noisy Environment

If the device is operating in an environment with much electromagnetic noise it must be protected from this noise to ensure reliable operation. In addition to following best practice EMC design guidelines, the recommendations listed in the schematic checklist sections must be followed. In particular placing decoupling capacitors very close to the power pins, a RC-filter on the $\overline{\text{RESET}}$ pin, and a pull-up resistor on the SWCLK pin is critical for reliable operations. It is also relevant to eliminate or attenuate noise in order to avoid that it reaches supply pins, I/O pins and crystals.

49.2. Power Supply

The SAM L21 supports a single or dual power supply from 1.62V to 3.63V. The same voltage must be applied to both VDDIN and VDDANA.

The internal voltage regulator has four different modes:

- Linear mode: this mode does not require any external inductor. This is the default mode when CPU and peripherals are running
- Switching mode (Buck): the most efficient mode when the CPU and peripherals are running.
- Low Power (LP) mode: This is the default mode used when the chip is in standby mode
- Shutdown mode: When the chip is in backup mode, the internal regulator is turned off

Selecting between switching mode and linear mode can be done by software on the fly, but the power supply must be designed according to which mode is to be used.

49.2.1. Power Supply Connections

The following figures shows the recommended power supply connections for switched/linear mode, linear mode only and with battery backup.