SN32F100 Series

USER'S MANUAL

SN32F107
SN32F108
SN32F109

SONiX 32-Bit Cortex-M0 Micro-Controller

AMENDENT HISTORY

Version	Date	Description
1.0	2013/03/18	First version released.
1.1	2013/03/29	1. Update Codec Spec. 2. Update DAC Setting 3 Register. 3. Update Sigma-delta DAC Power-Up Sequence.
1.2	2013/04/02	1. Update Codec Spec. 2. Update ADC Setting 23 Register. 3. Update DAC Setting 1 Register and DAC Setting 2 Register.
1.3	2013/06/04	1. Add SN32F100 Start Kit V1.1 description. 2. Add Comparator Output Debounce Time. 3. Update supply current. 4. Add Operation Mode Comparison Table. 5. Update System Block Diagram. 6. Update System Tick Timer description. 7. Update LQFP 64 Pin Package Information. 8. Update Comparator description. 9. Modify ADC's SEL_MIC definition.
1.4	2013/07/16	1. Update I2S's Status register default value. 2. Update ADC's SEL_MIC register default value. 3. Update Code Security diagram. 4. Update Code Option Table. 5. Update High-level and Low-level input voltage Spec. 6. Update P0.14/DPDWAKEUP pin description.
1.5	2014/02/27	1. Update Electrical characteristics. 2. Update Code Security table in Code Security section. 3. Add Note for I/O open-drain function. 4. Add descriptions of I2C events which trigger I2C interrupt for I2Cn_STAT register. 5. Update SN-LINK description in Chap 17. Development Tool. 6. Add Notice for BOOT pin in Chap 16. SWD. 7. Add WAKEUP sections. 8. Fix typing error.
1.6	2014/06/04	1. Update SN-LINK-V2 photos. 2. Fix typing errors.
1.7	2015/05/29	1. Update UART baud rate sample.
1.8	2016/07/22	1. Fix typing errors. 2. Add Notice: HCLK MUST be equal or less than 24MHz during Flash program and erase operations. 3. Add SSPn Data Fetch (SSPn_DF) register. 4. Update LQFP48 package information.
1.9	2018/02/02	1. Fix typing errors. 2. Remove SYSTICKPRE[1:0] 3. Remove SYS0_ANTIEFT register. 4. Update WDTPRE[2:0] bits description in SYS1_APBCP1 register. 5. Update TO[15:0] bits description in I2Cn_TOCTRL register. 6. Add Note for setting the pins which are not pin-out.

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1 PRODUCT OVERVIEW

1.1 FEATURES

- **Memory configuration**
  64KB on-chip Flash programming memory.
  8KB SRAM.
  4KB Boot ROM

- **Operation Frequency up to 50MHz**

- **Interrupt sources**
  ARM Cortex-M0 built-in Nested Vectored Interrupt Controller (NVIC).

- **I/O pin configuration**
  Up to 62 General Purpose I/O (GPIO) pins with Configurable pull-up/pull-down resistors.
  GPIO pins can be used as edge and level sensitive interrupt sources.
  High-current source driver (20 mA)
  Comparator input pin: CM0~CM23.
  Comparator output pin: CMO.

- **Programmable Watchdog Timer (WDT)**
  Programmable watchdog frequency with watchdog Clock source and divider.

- **System tick timer**
  24-bit timer.
  The system tick timer clock is fixed to the frequency of the system clock.
  The SysTick timer is intended to generate a fixed 10-ms interrupt.

- **Real-Time Clock (RTC)**

- **LVD with separate thresholds**
  Reset: 1.65V for V_{CORE} 1.8V, 2.0/2.4/2.7V for VDD
  Interrupt: 2.0/2.4/2.7/3.0V for VDD

- **Fcpu (Instruction cycle)**
  $F_{CPU} = F_{HCLK} = F_{SYSCLK}/1$, $F_{SYSCLK}/2$, $F_{SYSCLK}/4$, …, $F_{SYSCLK}/512$.

- **Working voltage 1.8V ~ 3.6V**

- **Operating modes**
  Normal, Sleep, Deep-sleep, and Deep power-down

- **Serial Wire Debug (SWD)**

- **In-System Programming (ISP) supported**

- **Timer**
  Two 16-bit and two 32-bit general purpose timers with a total of four capture inputs, 6PWMs

- **DAC**
  16-bit Sigma-delta DAC for Audio.
  Can drive the L/R Channel Earphone.
  SNR 90dB.
  THD+N -75dB.

- **ADC**
  16-bit Sigma-delta ADC for Audio.
  AGC function.
  Differential Microphone input.
  Build-in Microphone Bias Voltage support.
  SNR 94dB.
  THD+N -80dB.

- **24-channel Comparator.**

- **Interface**
  -Two I2C controllers supporting I2C-bus specification with multiple address recognition and monitor mode.
  -Two UART controllers with fractional baud rate generation.
  -Two SPI controllers with SSP features and multi-protocol capabilities.
  -I2S Function with mono and stereo audio data supported, MSB justified data format supported, and can operate as either master or slave.

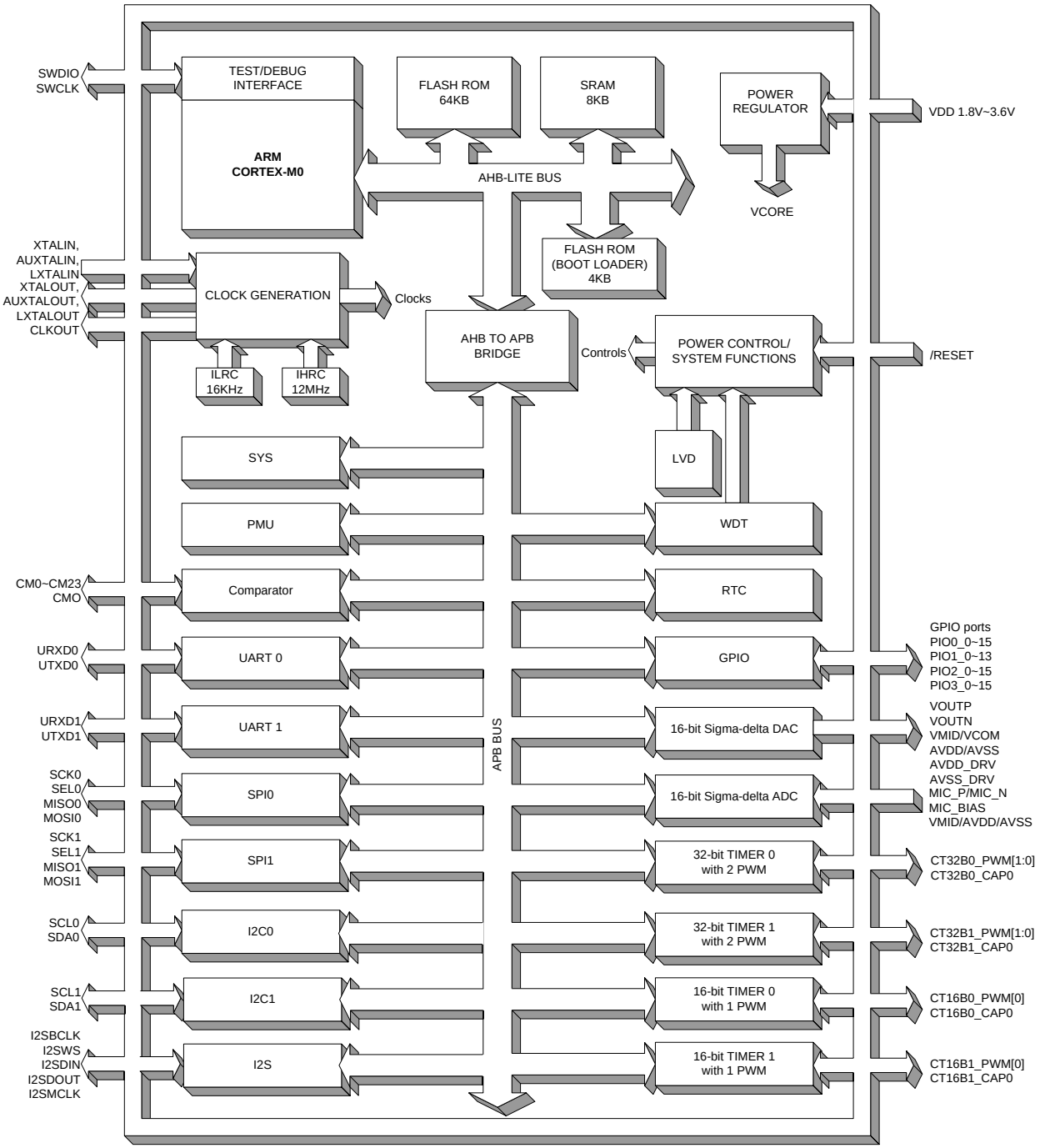
- **System clocks**
  -External high clock: Crystal type 10MHz~25MHz
  -External Audio high clock: Crystal type 16.384MHz
  -External low clock: Crystal type 32.768 KHz
  -Internal high clock: RC type 12 MHz
  -Internal low clock: RC type 16 KHz
  -PLL allows CPU operation up to the maximum CPU rate without the need for a high-frequency crystal. May be run from the external high clock or the internal high RC oscillator.
  -Clock output function which can reflect the internal high/low RC oscillator, HCLK, PLL output, and external high/low clock.

- **Package (Chip form support)**
  LQFP 80 pin
  LQFP 64 pin
  LQFP 48 pin

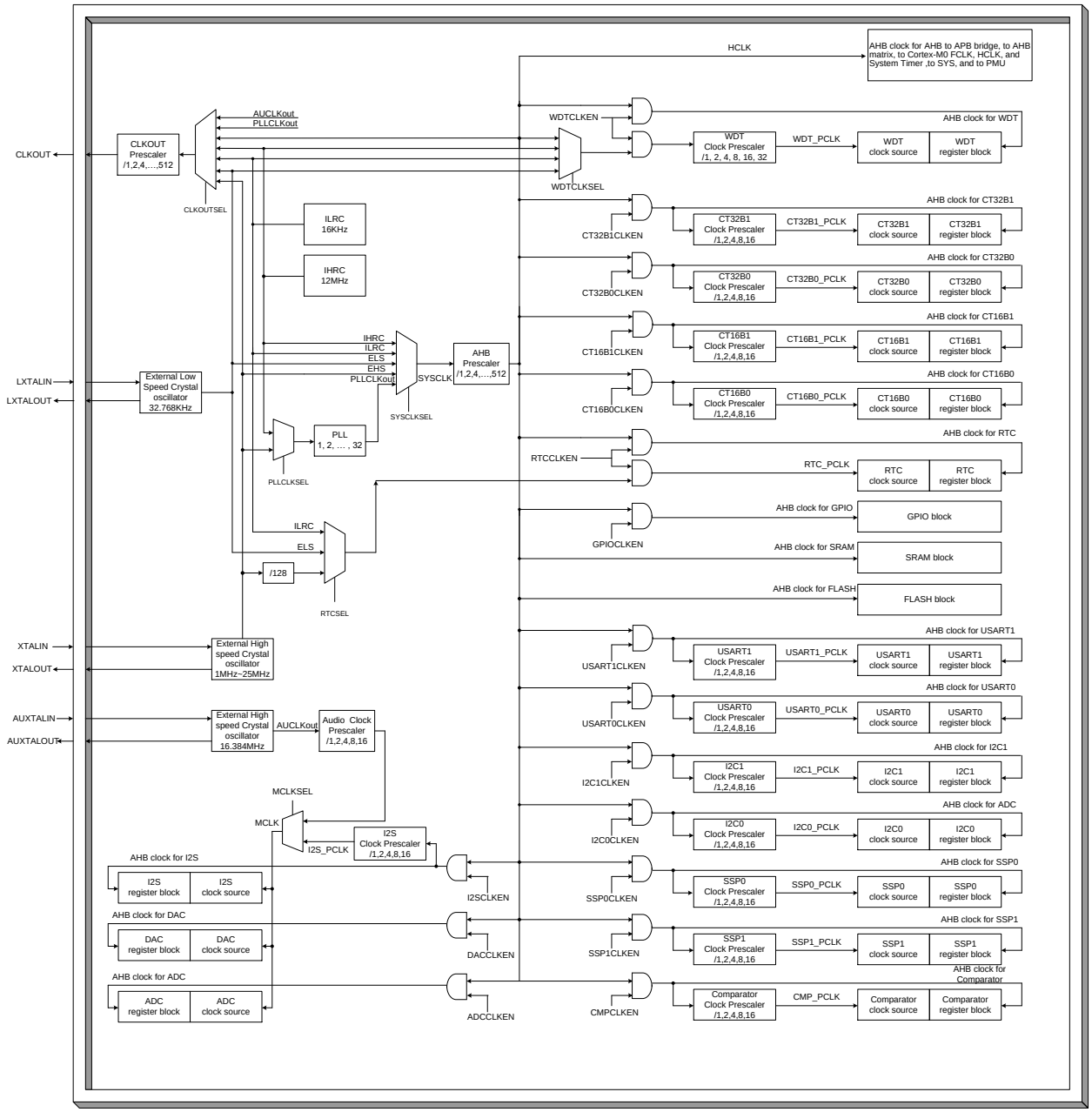
☞ **Features Selection Table**

Chip	ROM	RAM	Boot Loader	F_{CPU} (Max MHz)	UART	SPI	I2C	I2S	TIMER	PWM	16-bit Σ-δ ADC	16-bit Σ-δ DAC	CMP	GPIO with Wakeup	Package
SN32F107F	64KB	8KB	4KB	50	1	1	2	-	16-bit x 2 32-bit x 2	4	1	1	8	32	LQFP48
SN32F108F	64KB	8KB	4KB	50	2	1	2	-	16-bit x 2 32-bit x 2	6	1	1	17	46	LQFP64
SN32F109F	64KB	8KB	4KB	50	2	2	2	1	16-bit x 2 32-bit x 2	6	1	1	24	62	LQFP80

1.2 SYSTEM BLOCK DIAGRAM

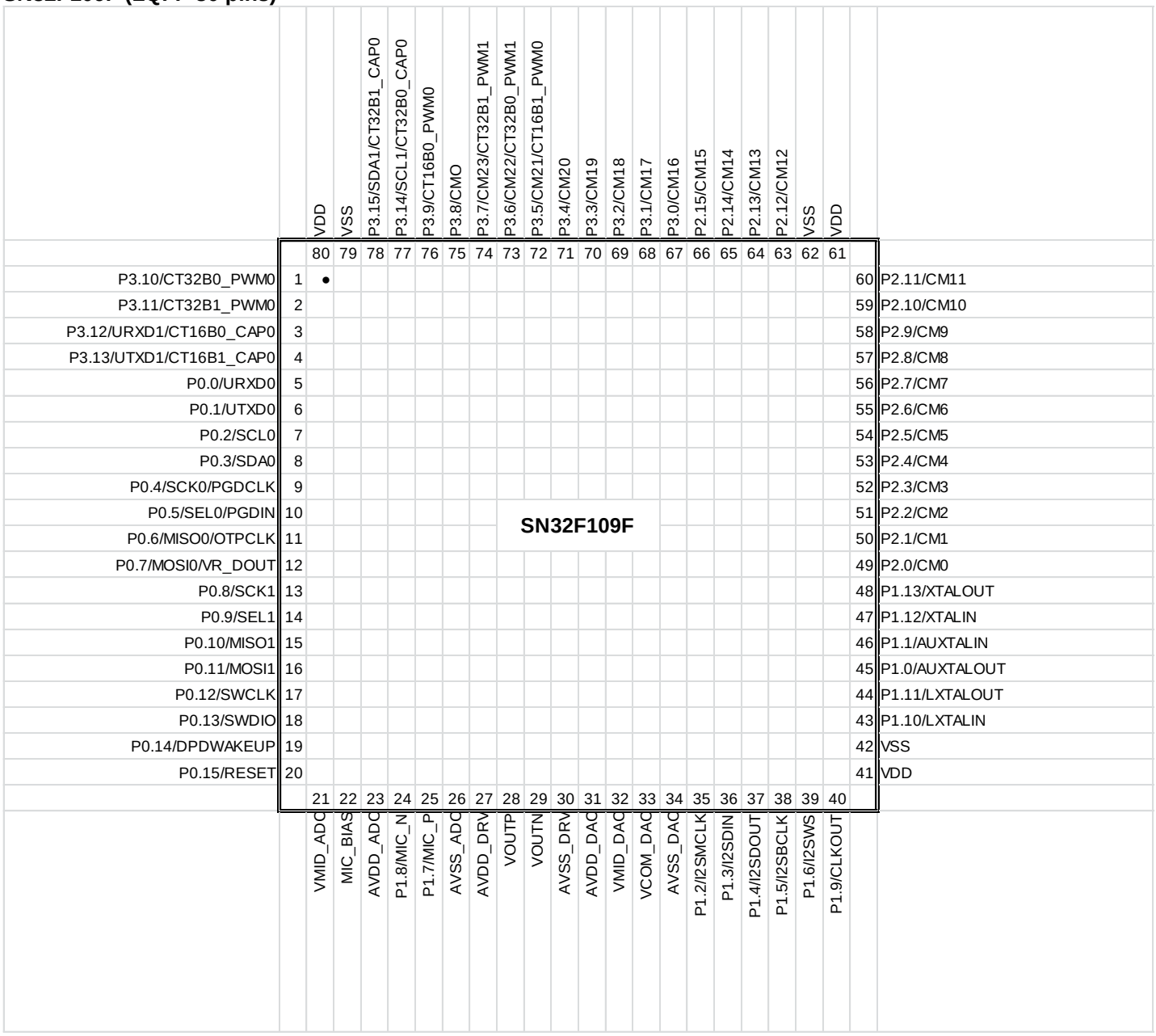


1.3 CLOCK GENERATION BLOCK DIAGRAM

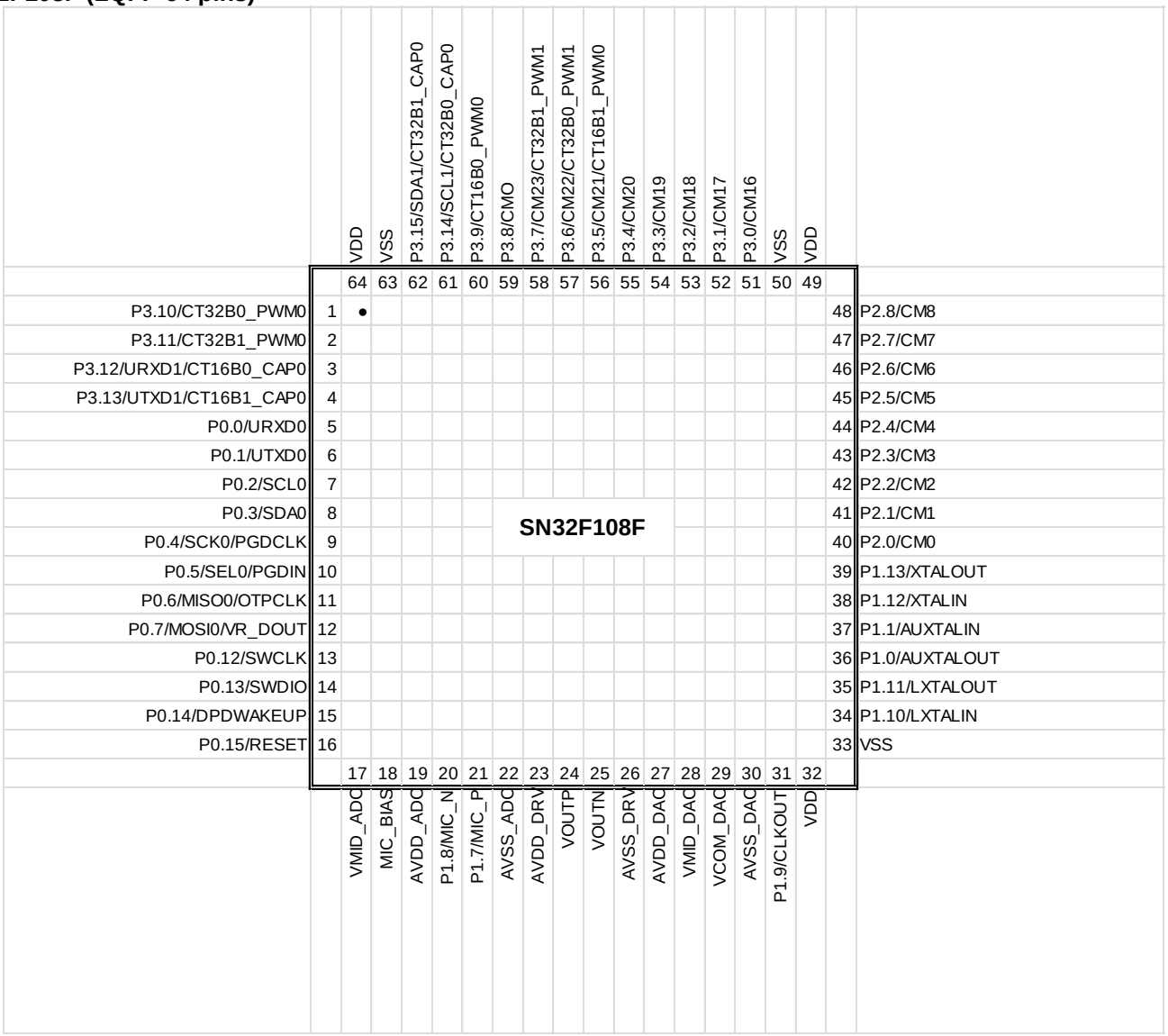


1.4 PIN ASSIGNMENT

SN32F109F (LQFP 80 pins)

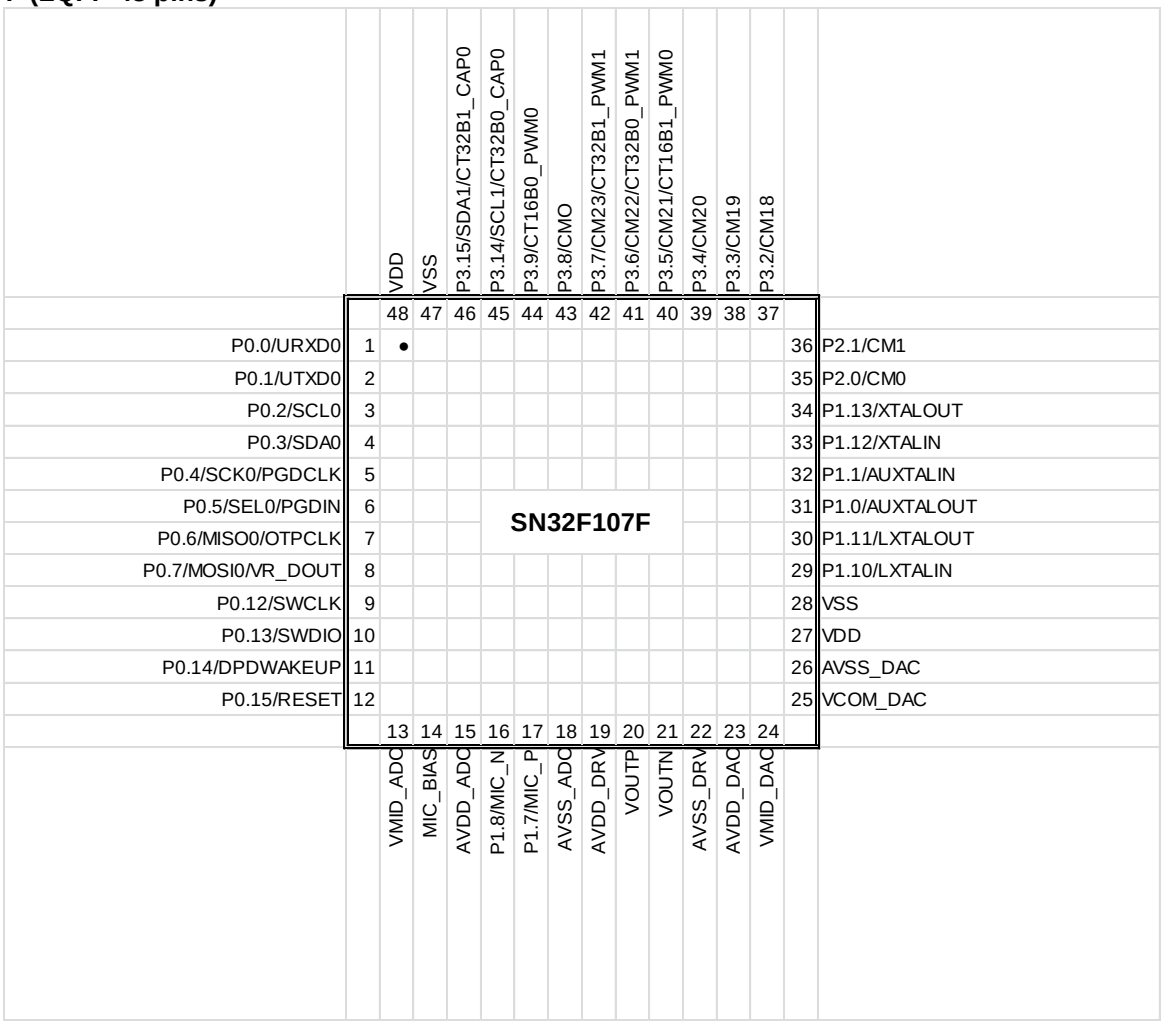


SN32F108F (LQFP 64 pins)



✸ ***Note: The pins which are not pin-out shall be set correctly to decrease power consumption in low-power modes. Strongly recommended to set these pins as input pull-up.***

SN32F107F (LQFP 48 pins)



✸ ***Note: The pins which are not pin-out shall be set correctly to decrease power consumption in low-power modes. Strongly recommended to set these pins as input pull-up.***

1.5 PIN DESCRIPTIONS

PIN NAME	TYPE	DESCRIPTION
VDD, VSS	P	Power supply input pins for digital circuit.
AVDD_DAC, AVSS_DAC	P	Power supply input pins for Sigma-delta DAC.
AVDD_ADC, AVSS_ADC	P	Power supply input pins for Sigma-delta ADC.
AVDD_DRV, AVSS_DRV	P	Power supply input pins for Sigma-delta DAC Driver.
VCOM_DAC	P	Sigma-delta DAC Common mode output.
VMID_DAC	P	Sigma-delta DAC VMID output.
VMID_ADC	P	Sigma-delta ADC VMID output.
MIC_BIAS	P	Sigma-delta ADC Microphone Bias Voltage output.
P0.0/URXD0	I/O	**P0.0 —** General purpose digital input/output pin with high-current sink driver.
		URXD0 — Receiver input for UART0.
P0.1/UTXD0	I/O	**P0.1 —** General purpose digital input/output pin with high-current sink driver.
		UTXD0 — Transmitter output for UART0.
P0.2/SCL0	I/O	**P0.2 —** General purpose digital input/output pin with high-current sink driver.
		SCL0 — I2C clock input/output.
P0.3/SDA0	I/O	**P0.3 —** General purpose digital input/output pin with high-current sink driver.
		SDA0 — I2C data input/output.
P0.4/SCK0	I/O	**P0.4 —** General purpose digital input/output pin.
		SCK0— Serial clock for SSP0.
P0.5/SEL0	I/O	**P0.5 —** General purpose digital input/output pin.
		SEL0 —Slave Select for SSP0.
P0.6/MISO0	I/O	**P0.6 —** General purpose digital input/output pin.
		MISO0— Master In Slave Out for SSP0.
P0.7/MOSI0	I/O	**P0.7 —** General purpose digital input/output pin with high-current sink driver.
		MOSI0 — Master Out Slave In for SSP0.
P0.8/SCK1	I/O	**P0.8 —** General purpose digital input/output pin.
		SCK1 — Serial clock for SSP1.

P0.9/SEL1	I/O	**P0.9 —** General purpose digital input/output pin.
		SEL1 — Slave Select for SSP1.
P0.10/MISO1	I/O	**P0.10 —** General purpose digital input/output pin.
		MISO1 — Master In Slave Out for SSP1.
P0.11/MOSI1	I/O	**P0.11 —** General purpose digital input/output pin.
		MOSI1 — Master Out Slave In for SSP1.
P0.12/SWCLK	I/O	**P0.12 —** General purpose digital input/output pin.
		SWCLK — Serial wire clock.
P0.13/SWDIO	I/O	**P0.13 —** General purpose digital input/output pin.
		SWDIO — Serial wire debug input/output.
P0.14/DPDWAKEUP	I	**P0.14 —** General purpose digital input pin.
		DPDWAKEUP — Deep power-down mode wake-up pin.
P0.15/RESET	I/O	**P0.15 —** General purpose digital input/output pin.
		RESET — external Reset input.
P1.0/AUXTALOUT	I/O	**P1.0 —** General purpose digital input/output pin.
		AUXTALOUT — External high-speed X'tal output pin for audio.
P1.1/AUXTALIN	I/O	**P1.1 —** General purpose digital input/output pin.
		AUXTALIN — External high-speed X'tal input pin for audio.
P1.2/I2SMCLK	I/O	**P1.2 —** General purpose digital input/output pin.
		I2SMCLK — MCLK for I2S.
P1.3/I2SDIN	I/O	**P1.3 —** General purpose digital input/output pin.
		I2SDIN — Serial data in for I2S.
P1.4/I2SDOUT	I/O	**P1.4 —** General purpose digital input/output pin.
		I2SDOUT — Serial data out for I2S.
P1.5/I2SBCLK	I/O	**P1.5 —** General purpose digital input/output pin.
		I2SBCLK — BCLK for I2S.
P1.6/I2SWS	I/O	**P1.6 —** General purpose digital input/output pin.
		I2SWS — WS for I2S.
P1.7/MIC_P	I/O	**P1.7 —** General purpose digital input/output pin.
		MIC_P — Sigma-delta ADC MIC difference input (+).
P1.8/MIC_N	I/O	**P1.8 —** General purpose digital input/output pin.
		MIC_N — Sigma-delta ADC MIC difference input (-).

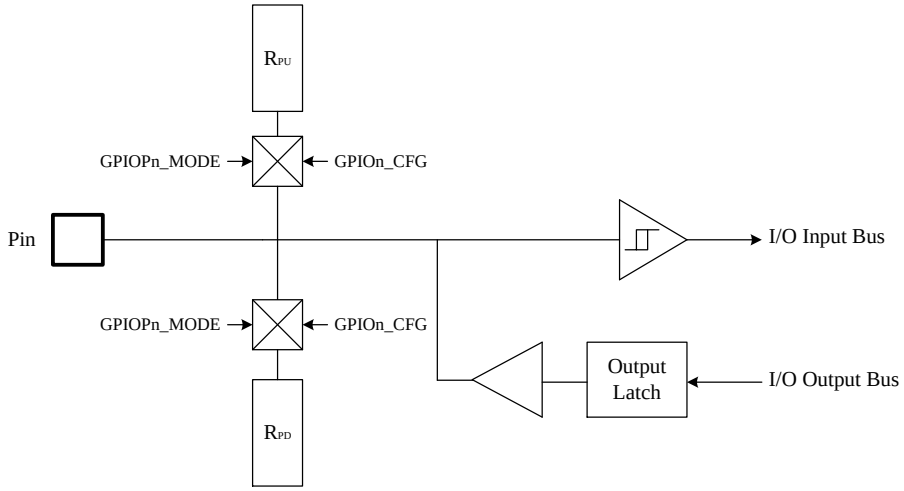
VOUTP	O	**VOUTP —** Sigma-delta DAC output (+).
VOUTN	O	**VOUTN —** Sigma-delta DAC output (-).
P1.9/CLKOUT	I/O	**P1.9 —** General purpose digital input/output pin.
		CLKOUT — Clockout pin.
P1.10/LXTALIN	I/O	**P1.10 —** General purpose digital input/output pin.
		LXTALIN — External low-speed X'tal input pin.
P1.11/LXTALOUT	I/O	**P1.11 —** General purpose digital input/output pin.
		LXTALOUT — External low-speed X'tal output pin.
P1.12/XTALIN	I/O	**P1.12 —** General purpose digital input/output pin.
		XTALIN — External high-speed X'tal input pin.
P1.13/XTALOUT	I/O	**P1.13 —** General purpose digital input/output pin.
		XTALOUT — External high-speed X'tal output pin.
P2.0/CMP	I/O	**P2.0 —** General purpose digital input/output pin.
		CMP — Comparator channel 0.
P2.1/CM1	I/O	**P2.1 —** General purpose digital input/output pin.
		CM1 — Comparator channel 1.
P2.2/CM2	I/O	**P2.2 —** General purpose digital input/output pin.
		CM2 — Comparator channel 2.
P2.3/CM3	I/O	**P2.3 —** General purpose digital input/output pin.
		CM3 — Comparator channel 3.
P2.4/CM4	I/O	**P2.4 —** General purpose digital input/output pin.
		CM4 — Comparator channel 4.
P2.5/CM5	I/O	**P2.5 —** General purpose digital input/output pin.
		CM5 — Comparator channel 5.
P2.6/CM6	I/O	**P2.6 —** General purpose digital input/output pin.
		CM6 — Comparator channel 6.
P2.7/CM7	I/O	**P2.7 —** General purpose digital input/output pin.
		CM7 — Comparator channel 7.
P2.8/CM8	I/O	**P2.8 —** General purpose digital input/output pin.
		CM8 — Comparator channel 8.
P2.9/CM9	I/O	**P2.9 —** General purpose digital input/output pin.
		CM9 — Comparator channel 9.

P2.10/CM10	I/O	**P2.10 —** General purpose digital input/output pin.
		CM10 — Comparator channel 10.
P2.11/CM11	I/O	**P2.11 —** General purpose digital input/output pin.
		CM11 — Comparator channel 11.
P2.12/CM12	I/O	**P2.12 —** General purpose digital input/output pin.
		CM12 — Comparator channel 12.
P2.13/CM13	I/O	**P2.13 —** General purpose digital input/output pin.
		CM13 — Comparator channel 13.
P2.14/CM14	I/O	**P2.14 —** General purpose digital input/output pin.
		CM14 — Comparator channel 14.
P2.15/CM15	I/O	**P2.15 —** General purpose digital input/output pin.
		CM15 — Comparator channel 15.
P3.0/CM16	I/O	**P3.0 —** General purpose digital input/output pin.
		CM16 — Comparator channel 16.
P3.1/CM17	I/O	**P3.1 —** General purpose digital input/output pin.
		CM17 — Comparator channel 17.
P3.2/CM18	I/O	**P3.2 —** General purpose digital input/output pin.
		CM18 — Comparator channel 18.
P3.3/CM19	I/O	**P3.3 —** General purpose digital input/output pin.
		CM19 — Comparator channel 19.
P3.4/CM20	I/O	**P3.4 —** General purpose digital input/output pin.
		CM20 — Comparator channel 20.
P3.5/CM21/ CT16B1_PWM0	I/O	**P3.5 —** General purpose digital input/output pin.
		CM21 — Comparator channel 21.
		CT16B1_PWM0 — PWM output 0 for CT16B1.
P3.6/CM22/ CT32B0_PWM1	I/O	**P3.6 —** General purpose digital input/output pin.
		CM22 — Comparator channel 22.
		CT32B0_PWM1 — PWM output 1 for CT32B0.
P3.7/CM23/ CT32B1_PWM1	I/O	**P3.7 —** General purpose digital input/output pin.
		CM23 — Comparator channel 23.
		CT32B1_PWM1 — PWM output 1 for CT32B1.
P3.8/CMO	I/O	**P3.8 —** General purpose digital input/output pin.

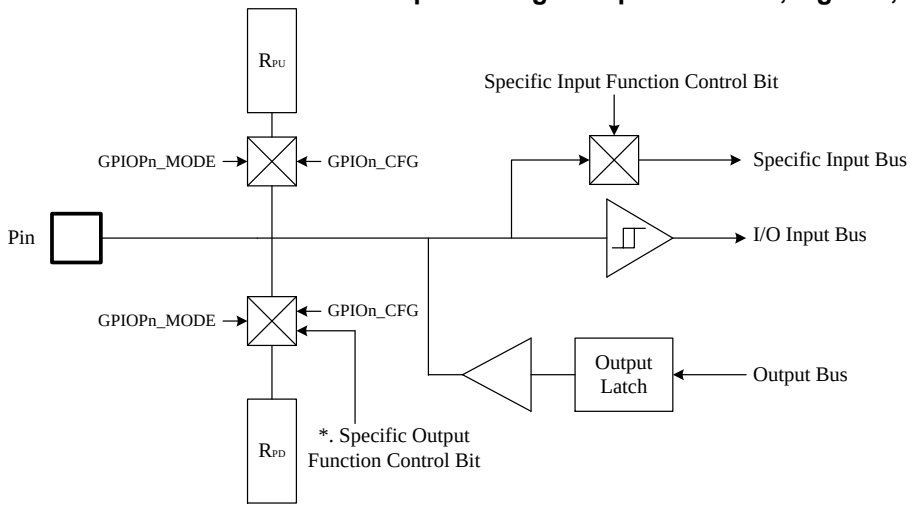
		CMO — Comparator output pin.
P3.9/CT16B0_PWM0	I/O	**P3.9 —** General purpose digital input/output pin.
		CT16B0_PWM0 — PWM output 0 for CT16B0.
P3.10/CT32B0_PWM0	I/O	**P3.10 —** General purpose digital input/output pin.
		CT32B0_PWM0 — PWM output 0 for CT32B0.
P3.11/CT32B1_PWM0	I/O	**P3.11 —** General purpose digital input/output pin.
		CT32B1_PWM0 — PWM output 0 for CT32B1.
P3.12/URXD1/ CT16B0_CAP0	I/O	**P3.12 —** General purpose digital input/output pin with high-current sink driver.
		URXD1 — Receiver data input for UART1.
		CT16B0_CAP0 — Capture input 0 for CT16B0.
P3.13/UTXD1/ CT16B1_CAP0	I/O	**P3.13 —** General purpose digital input/output pin with high-current sink driver.
		UTXD1 — Transmitter data output for UART1.
		CT16B1_CAP0 — Capture input 0 for CT16B1.
P3.14/SCL1/ CT32B0_CAP0	I/O	**P3.14 —** General purpose digital input/output pin with high-current sink driver.
		SCL1— I2C clock input/output.
		CT32B0_CAP0 — Capture input 0 for CT32B0.
P3.15/SDA1/ CT32B1_CAP0	I/O	**P3.15 —** General purpose digital input/output pin with high-current sink driver.
		SDA1 — I2C data input/output.
		CT32B1_CAP0 — Capture input 0 for CT32B1.

1.6 PIN CIRCUIT DIAGRAMS

- **Normal Bi-direction I/O Pin.**

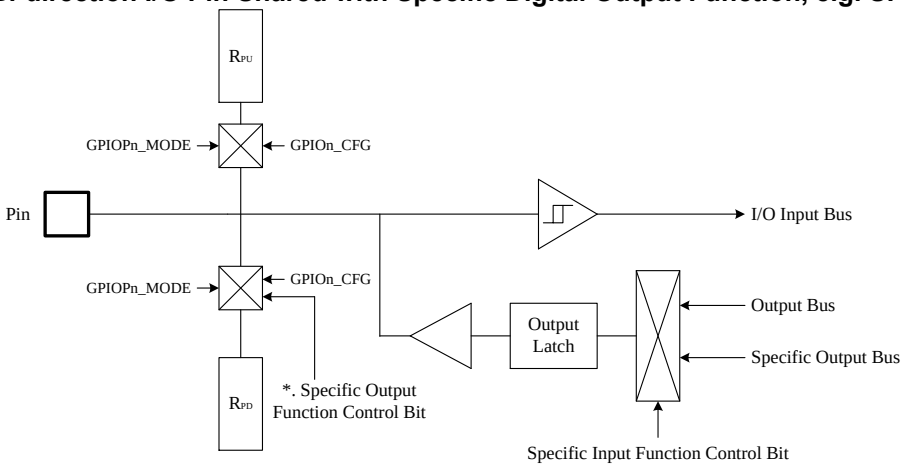


- **Bi-direction I/O Pin Shared with Specific Digital Input Function, e.g. SPI, I2C…**



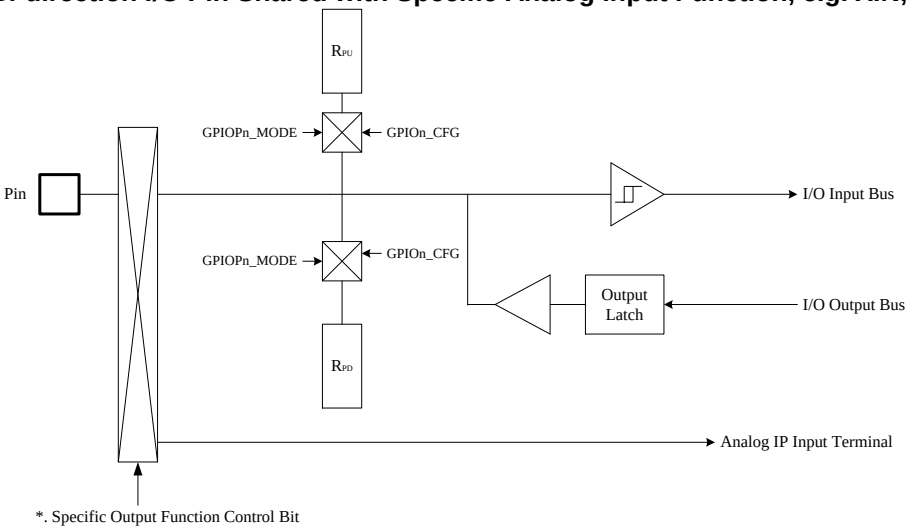
***. Some specific functions switch I/O direction directly, not through GPIOn_MODE register.**

- **Bi-direction I/O Pin Shared with Specific Digital Output Function, e.g. SPI, I2C…**



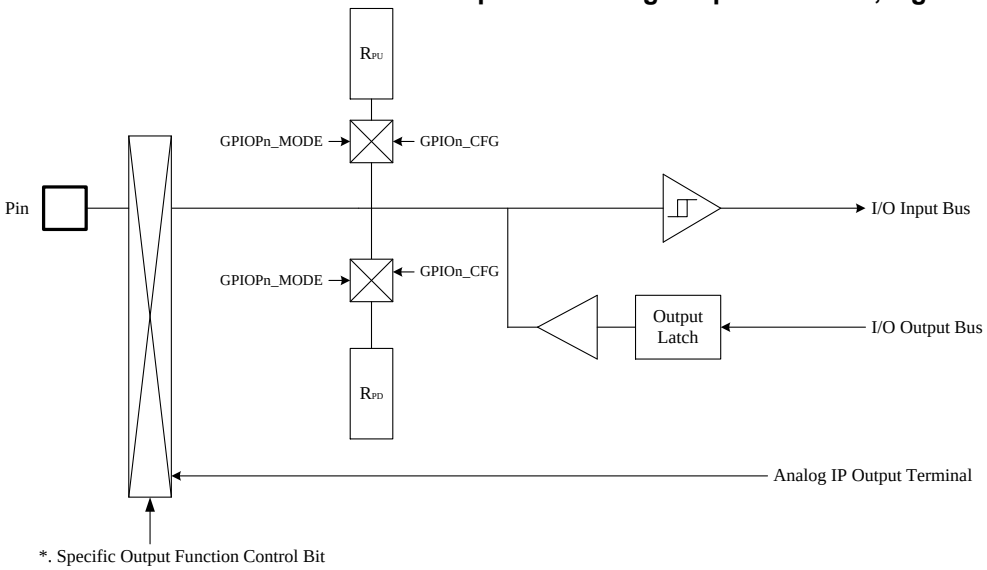
***. Some specific functions switch I/O direction directly, not through GPIOn_MODE register.**

- **Bi-direction I/O Pin Shared with Specific Analog Input Function, e.g. XIN, ADC…**



***. Some specific functions switch I/O direction directly, not through GPIOn_MODE register.**

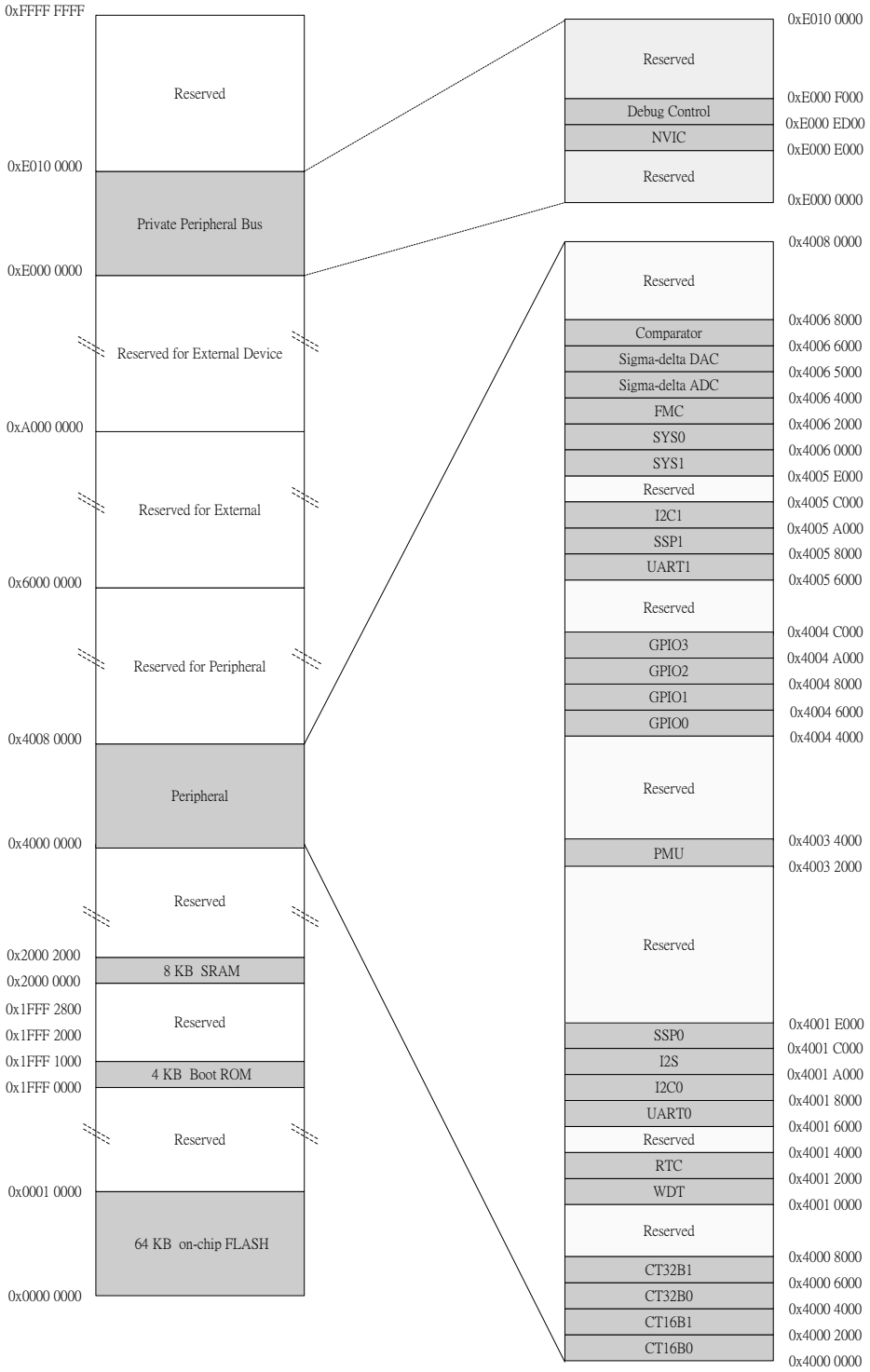
- **Bi-direction I/O Pin Shared with Specific Analog Output Function, e.g. XOUT…**



***. Some specific functions switch I/O direction directly, not through GPIOn_MODE register.**

2 CENTRAL PROCESSOR UNIT (CPU)

2.1 MEMORY MAP



2.2 SYSTEM TICK TIMER

The SysTick timer is an integral part of the Cortex-M0. The SysTick timer is intended to generate a fixed 10-ms interrupt for use by an operating system or other system management software.

Since the SysTick timer is a part of the Cortex-M0, it facilitates porting of software by providing a standard timer that is available on Cortex-M0 based devices.

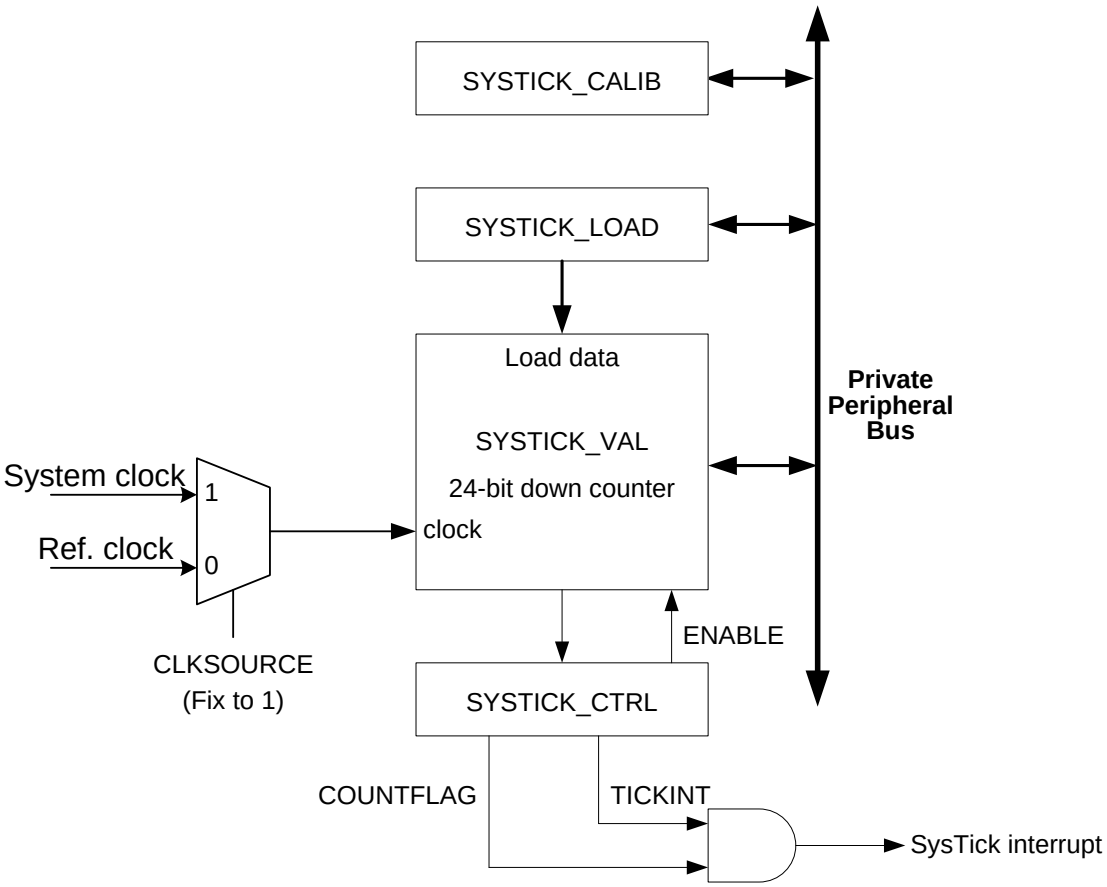
Refer to the *Cortex-M0 User Guide* for details.

2.2.1 OPERATION

The SysTick timer is a 24-bit timer that counts down to zero and generates an interrupt.

The intent is to provide a fixed 10-ms time interval between interrupts. The system tick timer is enabled through the SysTick control register. The system tick timer clock is fixed to the frequency of the system clock.

The block diagram of the SysTick timer:



When SysTick timer is enabled, the timer counts down from the current value (SYST_VAL) to zero, reloads to the value in the SysTick Reload Value Register (SYST_LOAD) on the next clock edge, then decrements on subsequent clocks. When the counter transitions to zero, the COUNTFLAG status bit is set to 1. The COUNTFLAG bit clears on reads.

✸ ***Note: When the processor is halted for debugging the counter does not decrease.***

2.2.2 SYSTICK USAGE HINTS AND TIPS

The interrupt controller clock updates the SysTick counter. Some implementations stop this clock signal for low power mode. If this happens, the SysTick counter stops.

Ensure SW uses word accesses to access the SysTick registers.

The SysTick counter reload and current value are not initialized by HW. This means the correct initialization sequence for the SysTick counter is:

1. Program the reload value in SYSTICK_LOAD register.
2. Clear the current value by writing any value to SYSTICK_VAL register.
3. Program the Control and Status (SYSTICK_CTRL) register.

2.2.3 SYSTICK REGISTERS

2.2.3.1 System Tick Timer Control and Status register (SYSTICK_CTRL)

Address: 0xE000 E010 (Refer to Cortex-M0 Spec)

Bit	Name	Description	Attribute	Reset
31:17	Reserved		R	0
16	COUNTFLAG	This flag is set when the System Tick counter counts down to 0, and is cleared by reading this register.	R/W	0
15:3	Reserved		R	0
2	CLKSOURCE	Selects the SysTick timer clock source. 0: reference clock. 1: system clock. (Fixed)	R	1
1	TICKINT	System Tick interrupt enable. 0: Disable the System Tick interrupt 1: Enable the System Tick interrupt, the interrupt is generated when the System Tick counter counts down to 0.	R/W	0
0	ENABLE	System Tick counter enable. 0: Disable 1: Enable	R/W	0

2.2.3.2 System Tick Timer Reload value register (SYSTICK_LOAD)

Address: 0xE000 E014 (Refer to Cortex-M0 Spec)

The RELOAD register is set to the value that will be loaded into the SysTick timer whenever it counts down to zero. This register is set by software as part of timer initialization. The SYST_CALIB register may be read and used as the value for RELOAD if the CPU or external clock is running at the frequency intended for use with the SYST_CALIB value.
The following example illustrates selecting the SysTick timer reload value to obtain a 10 ms time interval with the system clock set to 50 MHz.
The SysTick clock = system clock = 50 MHz
RELOAD = (system tick clock frequency × 10 ms) −1 = (50 MHz × 10 ms) −1
= 0x0007A11F.

Bit	Name	Description	Attribute	Reset
31:24	Reserved		R	0
23:0	RELOAD	Value to load into the SYST_CVR when the counter is enabled and when it reaches 0.	R/W	0x5F7F9B

2.2.3.3 System Tick Timer Current Value register (SYSTICK_VAL)

Address: 0xE000 E018 (Refer to Cortex-M0 Spec)

Bit	Name	Description	Attribute	Reset
31:24	Reserved		R	0
23:0	CURRENT	Reading this register returns the current value of the System Tick counter. Writing any value clears the System Tick counter and the COUNTFLAG bit in SYST_CSR.	R/W	0x7E7F35

2.2.3.4 System Tick Timer Calibration Value register (SYST_CALIB)

Address: 0xE000 E01C (Refer to Cortex-M0 Spec)

Bit	Name	Description	Attribute	Reset
31	NOREF	Indicates the reference clock to M0 is provided or not. 1: No reference clock provided.	R	1
30	SKEW	Indicates whether the TENMS value is exact, an inexact TENMS value can affect the suitability of SysTick as a software real time clock. 0: TENMS value is exact 1: TENMS value is inexact, or not given.	R	0
29:24	Reserved		R	0
23:0	TENMS	Reload value for 10ms timing, subject to system clock skew errors. If the value reads as zero, the calibration value is not known.	R/W	0xA71FF

2.3 NESTED VECTORED INTERRUPT CONTROLLER (NVIC)

All interrupts including the core exceptions are managed by the NVIC. NVIC has the following Features:

- The NVIC supports 32 vectored interrupts.
- 4 programmable interrupt priority levels with hardware priority level masking.
- Low-latency exception and interrupt handling.
- Efficient processing of late arriving interrupts.
- Implementation of System Control Registers
- Software interrupt generation.

2.3.1 INTERRUPT AND EXCEPTION VECTORS

2.3.2 NVIC REGISTERS

Execution No.	Priority	Function	Description	Address Offset
0	-	-	Reserved	0x0000 0000
1	-3	Reset	Reset	0x0000 0004
2	-2	NMI_Handler	Non maskable interrupt.	0x0000 0008
3	-1	HardFault_Handler	All class of fault	0x0000 000C
4~10	Reserved	Reserved	Reserved	-
11	Settable	SVCCall		0x0000 002C
12~13	Reserved	Reserved	Reserved	-
14	Settable	PendSV		0x0000 0038
15	Settable	SysTick		0x0000 003C
16	Settable	IRQ0/P0IRQ	GPIO interrupt status of port 0	0x0000 0040
17	Settable	IRQ1/P1IRQ	GPIO interrupt status of port 1	0x0000 0044
18	Settable	IRQ2/P2IRQ	GPIO interrupt status of port 2	0x0000 0048
19	Settable	IRQ3/P3IRQ	GPIO interrupt status of port 3	0x0000 004C
20~32	Reserved	Reserved	Reserved	-
33	Settable	IRQ17/CMPIRQ	CMP	0x0000 0084
34	Settable	IRQ18/CT16B0IRQ	CT16B0	0x0000 0088
35	Settable	IRQ19/CT16B1IRQ	CT16B1	0x0000 008C
36	Settable	IRQ20/CT32B0IRQ	CT32B0	0x0000 0090
37	Settable	IRQ21/CT32B1IRQ	CT32B1	0x0000 0094
38	Settable	IRQ22/I2SIRQ	I2S	0x0000 0098
39	Settable	IRQ23/SSP0IRQ	SSP0	0x0000 009C
40	Settable	IRQ24/SSP1IRQ	SSP1	0x0000 00A0
41	Settable	IRQ25/UART0IRQ	UART0	0x0000 00A4
42	Settable	IRQ26/UART1IRQ	UART1	0x0000 00A8

43	Settable	IRQ27/I2C0IRQ	I2C0	0x0000 00AC
44	Settable	IRQ28/I2C1IRQ	I2C1	0x0000 00B0
45	Settable	IRQ29/WDTIRQ	WDT	0x0000 00B4
46	Settable	IRQ30/LVDIRQ	LVD	0x0000 00B8
47	Settable	IRQ31/RTCIRQ	RTC	0x0000 00BC

2.3.2.1 IRQ0~31 Interrupt Set-Enable Register (NVIC_ISER)

Address: 0xE000 E100 (Refer to Cortex-M0 Spec.)

The ISER enables interrupts, and shows the interrupts that are enabled.

Bit	Name	Description	Attribute	Reset
31:0	SETENA[31:0]	Interrupt set-enable bits. Write→ 0: No effect 1: Enable interrupt. Read→ 0: Interrupt disabled 1: Interrupt enabled.	R/W	0

2.3.2.2 IRQ0~31 Interrupt Clear-Enable Register (NVIC_ICER)

Address: 0xE000 E180 (Refer to Cortex-M0 Spec.)

The ICER disables interrupts, and shows the interrupts that are enabled.

Bit	Name	Description	Attribute	Reset
31:0	CLRENA[31:0]	Interrupt clear-enable bits. Write→ 0: No effect 1: Disable interrupt. Read→ 0: Interrupt disabled 1: Interrupt enabled.	R/W	0

2.3.2.3 IRQ0~31 Interrupt Set-Pending Register (NVIC_ISPR)

Address: 0xE000 E200 (Refer to Cortex-M0 Spec.)

The ISPR forces interrupts into the pending state, and shows the interrupts that are pending.

Note: Writing 1 to the ISPR bit corresponding to
- an interrupt that is pending has no effect
- a disabled interrupt sets the state of that interrupt to pending.

Bit	Name	Description	Attribute	Reset
31:0	SETPEND[31:0]	Interrupt set-pending bits. Write→ 0: No effect 1: Change interrupt state to pending Read→ 0: Interrupt is not pending 1: Interrupt is pending	R/W	0

2.3.2.4 IRQ0~31 Interrupt Clear-Pending Register (NVIC_ICPR)

Address: 0xE000 E280 (Refer to Cortex-M0 Spec.)

The ICPR removes the pending state from interrupts, and shows the interrupts that are pending.
Note: Writing 1 to an ICPR bit does not affect the active state of the corresponding interrupt.

Bit	Name	Description	Attribute	Reset
31:0	CLRPEND[31:0]	Interrupt clear-pending bits. Write→ 0: No effect 1: Removes pending state of an interrupt Read→ 0: Interrupt is not pending 1: Interrupt is pending	R/W	0

2.3.2.5 IRQ0~31 Interrupt Priority Register (NVIC_IPRn) (n=0~7)

Address: 0xE000 E400 + 0x4 * n (Refer to Cortex-M0 Spec.)

The interrupt priority registers provide an 8-bit priority field for each interrupt, and each register holds four priority fields. This means the number of registers is implementation-defined, and corresponds to the number of implemented interrupts.

Bit	Name	Description	Attribute	Reset
31:24	PRI_(4*n+3)	Each priority field holds a priority value, 0-192. The lower the value, the greater the priority of the corresponding interrupt. The processor implements only bits[31:30] of each field, bits [29:24] read as zero and ignore writes. This means writing 255 to a priority register saves value 192 to the register.	R/W	0
23:16	PRI_(4*n+2)	Each priority field holds a priority value, 0-192. The lower the value, the greater the priority of the corresponding interrupt. The processor implements only bits[23:22] of each field, bits [21:16] read as zero and ignore writes. This means writing 255 to a priority register saves value 192 to the register.	R/W	0
15:8	PRI_(4*n+1)	Each priority field holds a priority value, 0-192. The lower the value, the greater the priority of the corresponding interrupt. The processor implements only bits[15:14] of each field, bits [13:8] read as zero and ignore writes. This means writing 255 to a priority register saves value 192 to the register.	R/W	0
7:0	PRI_4*n	Each priority field holds a priority value, 0-192. The lower the value, the greater the priority of the corresponding interrupt. The processor implements only bits[7:6] of each field, bits [5:0] read as zero and ignore writes. This means writing 255 to a priority register saves value 192 to the register.	R/W	0

2.4 APPLICATION INTERRUPT AND RESET CONTROL (AIRC)

Address: 0xE000 ED0C (Refer to Cortex-M0 Spec)

The entire MCU, including the core, can be reset by SW by setting the SYSRESREQ bit in the AIRC register in Cortex-M0 spec.

✷ ***Note: To write to this register, user must write 0x05FA to the VECTKEY field at the same time, otherwise the processor ignores the write.***

Bit	Name	Description	Attribute	Reset
31:16	VECTKEY	Register key. Read as unknown. Write 0x05FA to VECTKEY, otherwise the write is ignored.	R/W	0
15	ENDIANESS	Data endianness implemented 0: Little-endian 1: Big-endian	R	0
14:3	Reserved		R	0
2	SYSRESETREQ	System reset request. This bit read as 0. 0: No effect 1: Requests a system level reset.	W	0
1	VECTCLRACTIVE	Reserved for debug use. This bit read as 0. When writing to the register you must write 0 to this bit, otherwise behavior is Unpredictable.	W	0

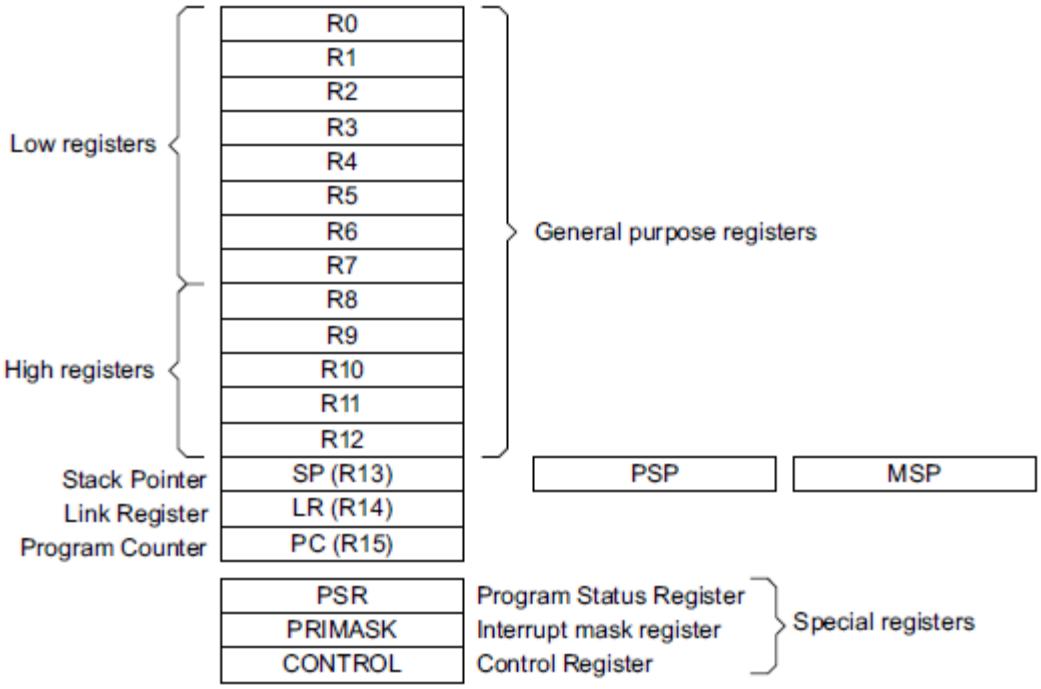
0	Reserved		R	0

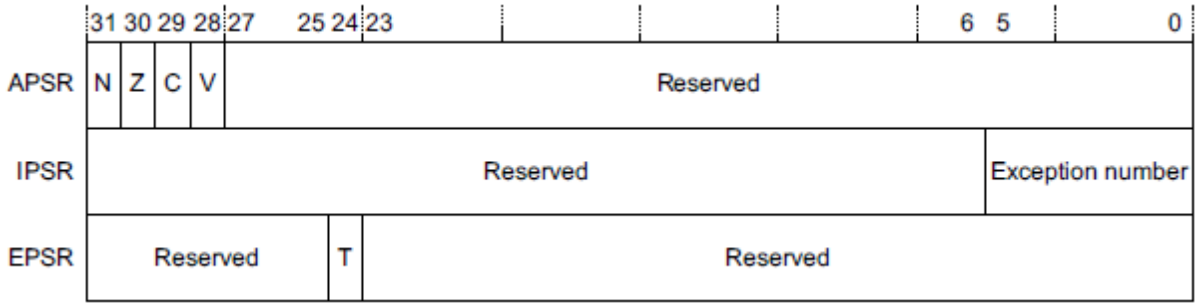
2.5 CODE OPTION TABLE

Address: 0x1FFF 2000

Bit	Name	Description	Attribute	Reset
31:16	Code Security[15:0]	Code Security 0xFFFF: CS0 0x5A5A: CS1 0xA5A5: CS2 0x55AA: CS3	R/W	0xFFFF
15:4	Reserved		R	1
3:1	Reserved		R	0
0	Reserved		R	1

2.6 CORE REGISTER OVERVIEW



Register	Description (Refer to Cortex-M0 Spec)
R0~R12	General-purpose registers for data operations.
SP (R13)	The Stack Pointer (SP). In Thread mode, the CONTROL register indicates the stack pointer to use, Main Stack Pointer (MSP) or Process Stack Pointer (PSP) On reset, the processor loads the MSP with the value from address 0x00000000.
LR (R14)	The Link Register (LR). It stores the return information for subroutines, function calls, and exceptions.
PC (R15)	The Program Counter (PC). It contains the current program address. On reset, the processor loads the PC with the value of the reset vector, at address 0x00000004.
PSR	The Program Status Register (PSR) combines: • Application Program Status Register (APSR) • Interrupt Program Status Register (IPSR) • Execution Program Status Register (EPSR). These registers are mutually exclusive bit fields in the 32-bit PSR. 
PRIMASK	The PRIMASK register prevents activation of all exceptions with configurable priority.
CONTROL	The CONTROL register controls the stack used when the processor is in Thread mode.

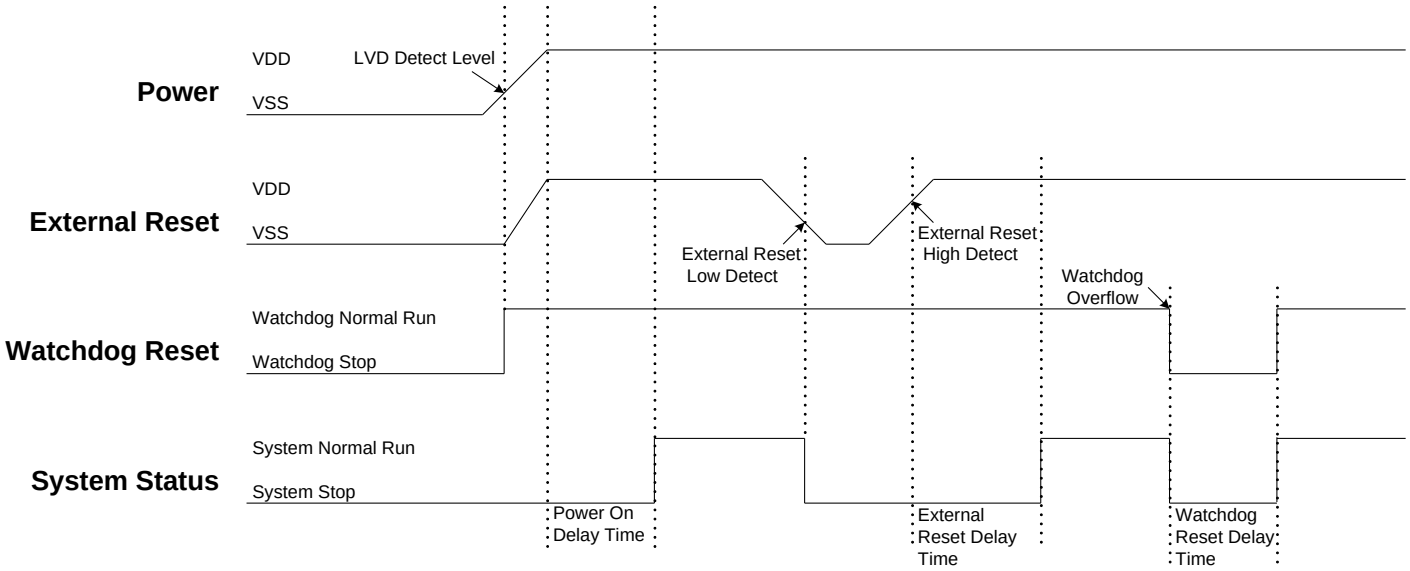
3 SYSTEM CONTROL

3.1 RESET

A system reset is generated when one of the following events occurs:
1. A low level on the RST pin (external reset).
2. Power-on reset (POR reset)
3. LVD reset
4. Watchdog Timer reset (WDT reset)
5. Software reset (SW reset)
6. DPDWAKEUP reset when exiting Deep power-down mode by DPDWAKEUP pin

The reset source can be identified by checking the reset flags in System Reset Status register (SYS0_RSTST). These sources act on the RST pin and it is always kept low during the delay phase. The RESET service routine vector is fixed at address 0x00000004 in the memory map. For more details, refer to Interrupt and Exception Vectors.

Finishing any reset sequence needs some time. The system provides complete procedures to make the power on reset successful. For different oscillator types, the reset time is different. That causes the VDD rise rate and start-up time of different oscillator is not fixed. RC type oscillator's start-up time is very short, but the crystal type is longer. Under client terminal application, users have to take care of the power on reset time for the master terminal requirement. The reset timing diagram is as following.



3.1.1 POWER-ON RESET (POR)

The power on reset depends on LVD operation for most power-up situations. The power supplying to system is a rising curve and needs some time to achieve the normal voltage. Power on reset sequence is as following:

- **Power-up:** System detects the power voltage up and waits for power stable.
- **External reset (only external reset pin enable):** System checks external reset pin status. If external reset pin is not high level, the system keeps reset status and waits external reset pin released.
- **System initialization:** All system registers is set as initial conditions and system is ready.
- **Oscillator warm up:** Oscillator operation is successfully and supply to system clock.
- **Program executing:** Power on sequence is finished and program executes from Boot loader.

3.1.2 WATCHDOG RESET (WDT RESET)

Watchdog reset is a system protection. In normal condition, system works well and clears watchdog timer by program. Under error condition, system is in unknown situation and watchdog can't be clear by program before watchdog timer overflow. Watchdog timer overflow occurs and the system is reset. After watchdog reset, the system restarts and returns normal mode. Watchdog reset sequence is as following.

- **Watchdog timer status:** System checks watchdog timer overflow status. If watchdog timer overflow occurs, the system is reset.
- **System initialization:** All system registers is set as initial conditions and system is ready.
- **Oscillator warm up:** Oscillator operation is successfully and supply to system clock.
- **Program executing:** Power on sequence is finished and program executes from 0x0.

Watchdog timer application note is as following.

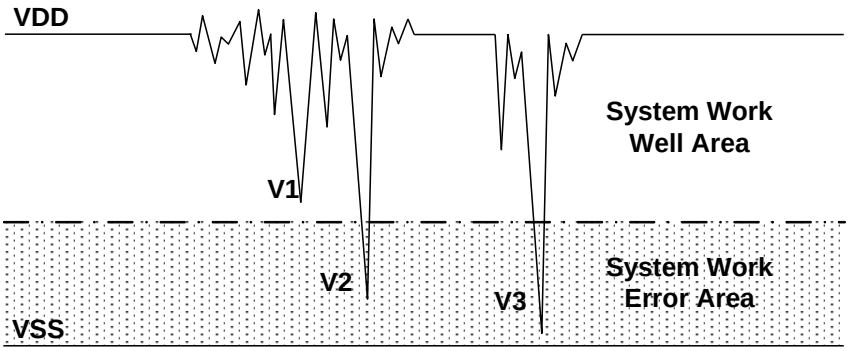
- Before clearing watchdog timer, check I/O status and check RAM contents can improve system error.
- Don't clear watchdog timer in interrupt vector and interrupt service routine. That can improve main routine fail.
- Clearing watchdog timer program is only at one part of the program. This way is the best structure to enhance the watchdog timer function.

✸ ***Note: Please refer to the "WATCHDOG TIMER" about watchdog timer detail information.***

3.1.3 BROWN-OUT RESET

3.1.3.1 BROWN OUT DESCRIPTION

The brown-out reset is a power dropping condition. The power drops from normal voltage to low voltage by external factors (e.g. EFT interference or external loading changed). The brown out reset would make the system not work well or executing program error.



Brown-Out Reset Diagram

The power dropping might through the voltage range that's the system dead-band. The dead-band means the power range can't offer the system minimum operation power requirement. The above diagram is a typical brown out reset diagram. There is a serious noise under the VDD, and VDD voltage drops very deep. There is a dotted line to separate the system working area. The above area is the system work well area. The below area is the system work error area called dead-band. V1 doesn't touch the below area and not affect the system operation. But the V2 and V3 is under the below area and may induce the system error occurrence. Let system under dead-band includes some conditions.

DC application:
The power source of DC application is usually using battery. When low battery condition and MCU drive any loading, the power drops and keeps in dead-band. Under the situation, the power won't drop deeper and not touch the system reset voltage. That makes the system under dead-band.

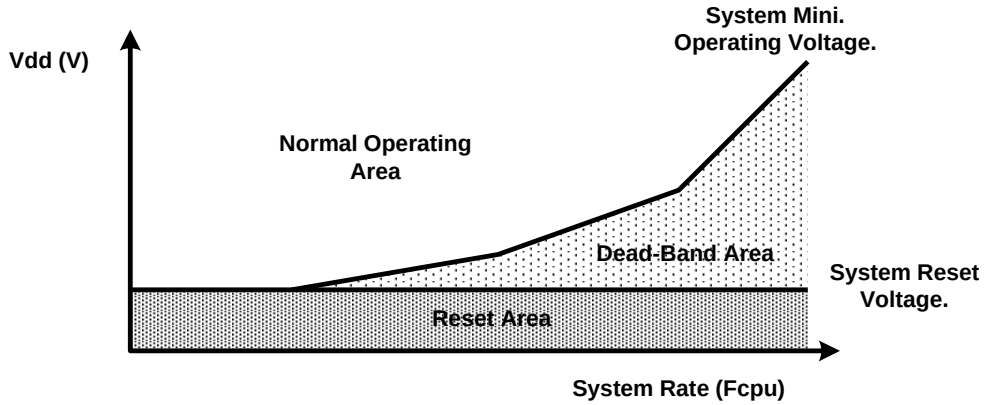
AC application:

In AC power application, the DC power is regulated from AC power source. This kind of power usually couples with AC noise that makes the DC power dirty. Or the external loading is very heavy, e.g. driving motor. The loading operating induces noise and overlaps with the DC power. VDD drops by the noise, and the system works under unstable power situation.

The power on duration and power down duration are longer in AC application. The system power on sequence protects the power on successful, but the power down situation is like DC low battery condition. When turn off the AC power, the VDD drops slowly and through the dead-band for a while.

3.1.3.2 THE SYSTEM OPERATING VOLTAGE DECSRIPTION

To improve the brown out reset needs to know the system minimum operating voltage which is depend on the system executing rate and power level. Different system executing rates have different system minimum operating voltage. The electrical characteristic section shows the system voltage to executing rate relationship.



Normally the system operation voltage area is higher than the system reset voltage to VDD, and the reset voltage is decided by LVD detect level. The system minimum operating voltage rises when the system executing rate upper even higher than system reset voltage. The dead-band definition is the system minimum operating voltage above the system reset voltage.

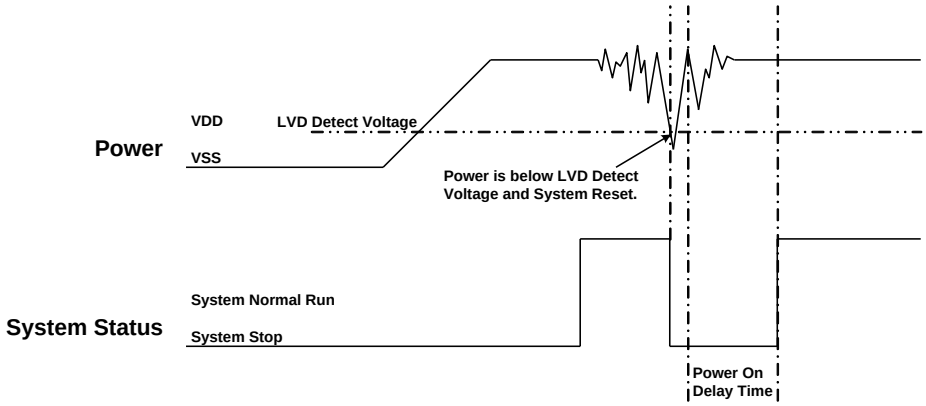
3.1.3.3 BROWN-OUT RESET IMPROVEMENT

How to improve the brown reset condition? There are some methods to improve brown out reset as following.

- **LVD reset**
- **Watchdog reset**
- **Reduce the system executing rate**
- **External reset circuit. (Zener diode reset circuit, Voltage bias reset circuit, External reset IC)**

✷ ***Note: The "Zener diode reset circuit", "Voltage bias reset circuit" and "External reset IC" can completely improve the brown out reset, DC low battery and AC slow power down conditions.***

LVD reset:



The LVD (low voltage detector) is built-in SONiX 32-bit MCU to be brown out reset protection. When the VDD drops and is below LVD detect voltage, the LVD asserts an interrupt signal to the NVIC. This signal can be enabled for interrupt in the Interrupt Enable Register in the NVIC in order to cause a CPU interrupt; if not, SW can monitor the signal by reading a dedicated status register. An additional threshold level can be selected to cause a forced reset of the chip. The LVD detect level is different by each MCU. The LVD voltage level is a point of voltage and not easy to cover all dead-band range. Using LVD to improve brown out reset is dependent on application requirement and environment. If the power variation is very deep, violent and trigger the LVD, the LVD can be the protection. If the power variation can touch the LVD detect level and make system work error, the LVD can't be the protection and need to other reset methods. More detail LVD information is in the electrical characteristic section.

Watchdog reset:
The watchdog timer is a protection to make sure the system executes well. Normally the watchdog timer would be clear at one point of program. Don't clear the watchdog timer in several addresses. The system executes normally and the watchdog won't reset system. When the system is under dead-band and the execution error, the watchdog timer can't be clear by program. The watchdog is continuously counting until overflow occurrence. The overflow signal of watchdog timer triggers the system to reset and return to normal mode after reset sequence. This method also can improve brown out reset condition and make sure the system to return normal mode.
If the system reset by watchdog and the power is still in dead-band, the system reset sequence won't be successful and the system stays in reset status until the power return to normal range.

Reduce the system executing rate:
If the system rate is fast and the dead-band exists, to reduce the system executing rate can improve the dead-band. The lower system rate is with lower minimum operating voltage. Select the power voltage that's no dead-band issue and find out the mapping system rate. Adjust the system rate to the value and the system exits the dead-band issue. This way needs to modify whole program timing to fit the application requirement.

External reset circuit:
The external reset methods also can improve brown out reset and is the complete solution. There are three external reset circuits to improve brown out reset including "Zener diode reset circuit", "Voltage bias reset circuit" and "External reset IC". These three reset structures use external reset signal and control to make sure the MCU be reset under power dropping and under dead-band. The external reset information is described in the next section.

3.1.4 EXTERNAL RESET

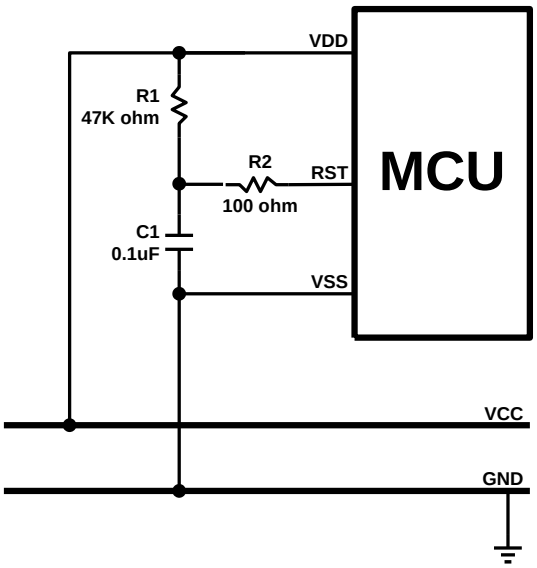
External reset function is controlled by External RESET pin control (SYS0_EXRSTCTRL) register. Default value is 1, which means external reset function is enabled. External reset pin is Schmitt Trigger structure and low level active. The system is running when reset pin is high level voltage input. The reset pin receives the low voltage and the system is reset. The external reset operation actives in power on and normal running mode. During system power-up, the external reset pin must be high level input, or the system keeps in reset status. External reset sequence is as following.

- **External reset (only external reset pin enable):** System checks external reset pin status. If external reset pin is not high level, the system keeps reset status and waits external reset pin released.
- **System initialization:** All system registers is set as initial conditions and system is ready.
- **Oscillator warm up:** Oscillator operation is successfully and supply to system clock.

- **Program executing:** Power on sequence is finished and program executes from Boot loader.

The external reset can reset the system during power on duration, and good external reset circuit can protect the system to avoid working at unusual power condition, e.g. brown out reset in AC power application.

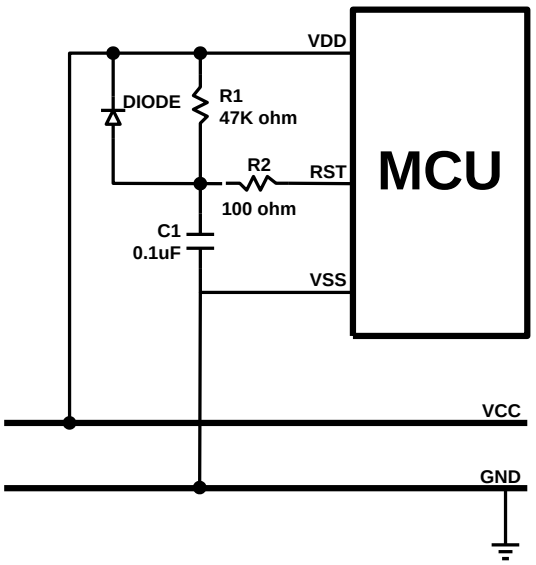
3.1.4.1 SIMPLY RC RESET CIRCUIT



This is the basic reset circuit, and only includes R1 and C1. The RC circuit operation makes a slow rising signal into reset pin as power up. The reset signal is slower than VDD power up timing, and system occurs a power on signal from the timing difference.

✷ ***Note: The reset circuit is no any protection against unusual power or brown out reset.***

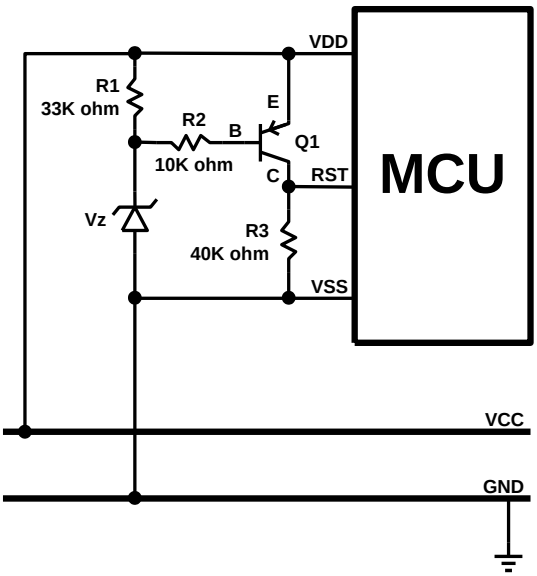
3.1.4.2 DIODE & RC RESET CIRCUIT



This is the better reset circuit. The R1 and C1 circuit operation is like the simply reset circuit to make a power on signal. The reset circuit has a simply protection against unusual power. The diode offers a power positive path to conduct higher power to VDD. It is can make reset pin voltage level to synchronize with VDD voltage. The structure can improve slight brown out reset condition.

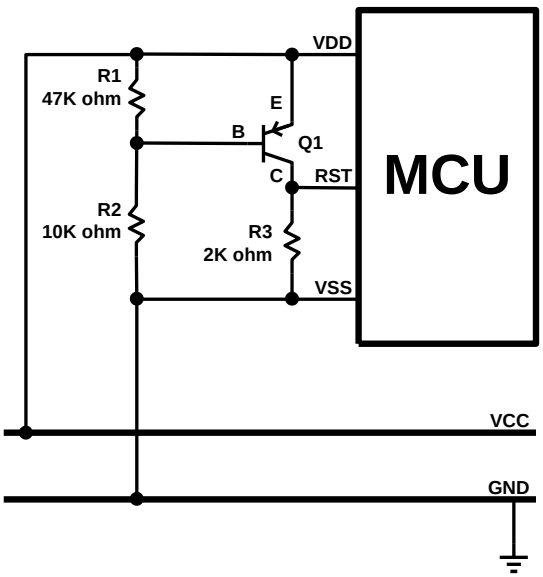
✷ ***Note: The R2 100 ohm resistor of "Simply reset circuit" and "Diode & RC reset circuit" is necessary to limit any current flowing into reset pin from external capacitor C in the event of reset pin breakdown due to Electrostatic Discharge (ESD) or Electrical Over-stress (EOS).***

3.1.4.3 ZENER DIODE RESET CIRCUIT



The Zener diode reset circuit is a simple low voltage detector and can **improve brown out reset condition completely**. Use Zener voltage to be the active level. When VDD voltage level is above "Vz + 0.7V", the C terminal of the PNP transistor outputs high voltage and MCU operates normally. When VDD is below "Vz + 0.7V", the C terminal of the PNP transistor outputs low voltage and MCU is in reset mode. Decide the reset detect voltage by Zener specification. Select the right Zener voltage to conform the application.

3.1.4.4 VOLTAGE BIAS RESET CIRCUIT

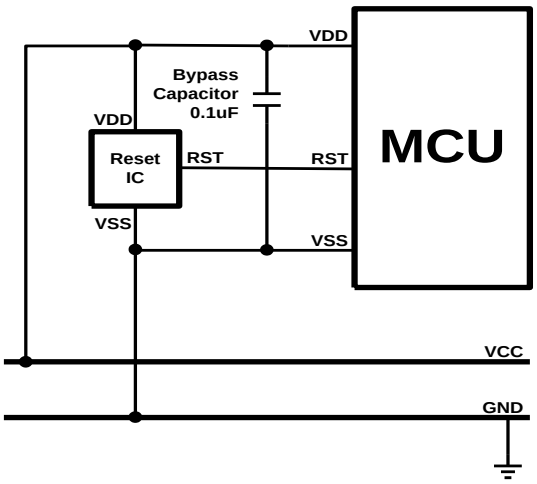


The voltage bias reset circuit is a low cost voltage detector and can **improve brown out reset condition completely**. The operating voltage is not accurate as Zener diode reset circuit. Use R1, R2 bias voltage to be the active level. When VDD voltage level is above or equal to "0.7V x (R1 + R2) / R1", the C terminal of the PNP transistor outputs high voltage and MCU operates normally. When VDD is below "0.7V x (R1 + R2) / R1", the C terminal of the PNP transistor

outputs low voltage and MCU is in reset mode.
Decide the reset detect voltage by R1, R2 resistances. Select the right R1, R2 value to conform the application. In the circuit diagram condition, the MCU's reset pin level varies with VDD voltage variation, and the differential voltage is 0.7V. If the VDD drops and the voltage lower than reset pin detect level, the system would be reset. If want to make the reset active earlier, set the R2 > R1 and the cap between VDD and C terminal voltage is larger than 0.7V. The external reset circuit is with a stable current through R1 and R2. For power consumption issue application, e.g. DC power system, the current must be considered to whole system power consumption.

✸ ***Note: Under unstable power condition as brown out reset, "Zener diode reset circuit" and "Voltage bias reset circuit" can protects system no any error occurrence as power dropping. When power drops below the reset detect voltage, the system reset would be triggered, and then system executes reset sequence. That makes sure the system work well under unstable power situation.***

3.1.4.5 EXTERNAL RESET IC



The external reset circuit also uses external reset IC to enhance MCU reset performance. This is a high cost and good effect solution. By different application and system requirement to select suitable reset IC. The reset circuit can improve all power variation.

3.1.5 SOFTWARE RESET

The entire MCU, including the core, can be reset by software by setting the SYSRESREQ bit in the AIRC (Application Interrupt and Reset Control) register in Cortex-M0 spec.

The software-initiated system reset sequence is as follows:
1. A software reset is initiated by setting the SYSRESREQ bit.
2. An internal reset is asserted.
3. The internal reset is deasserted and the MCU loads from memory the initial stack pointer, the initial program counter, and then begins execution.

3.2 SYSTEM CLOCK

Different clock sources can be used to drive the system clock (SYSCLK):
- 12 MHz internal high speed RC (IHRC)
- 16 KHz internal low speed RC (ILRC)
- PLL clock
- High speed external (EHS) crystal clock
- Low speed external (ELS) 32.768 KHz crystal

One clock sources can be used to drive the audio (I2S/Codec) clock (I2SMCLK):
- Audio High speed external (AUEHS) crystal clock for audio

Each clock source can be switched on or off independently when it is not used, to optimize power consumption.

The micro-controller is a dual clock system. There are high-speed clock and low-speed clock. The high-speed clock is generated from the external oscillator & on-chip PLL circuit. The low-speed clock is generated from on-chip low-speed RC oscillator circuit (ILRC 16 KHz).

3.2.1 INTERNAL RC CLOCK SOURCE

3.2.1.1 Internal High-speed RC Oscillator (IHRC)

The internal high-speed oscillator is 12MHz RC type. The accuracy is ±2% under commercial condition.
The IHRC can be switched on and off using the IHRCEN bit in Analog Block Control register (SYS0_ANBCTRL).

3.2.1.2 Internal Low-speed RC Oscillator (ILRC)

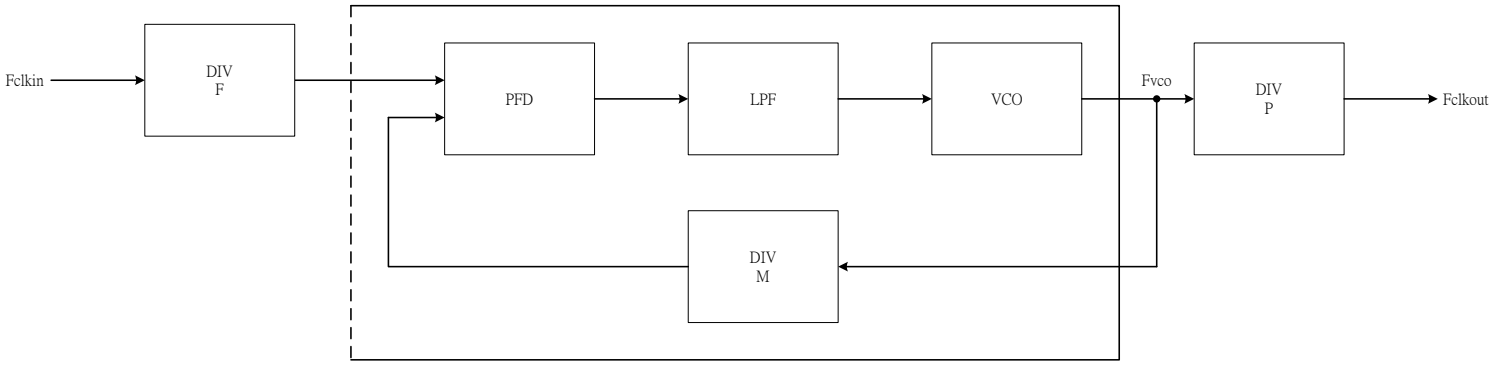
The system low clock source is the internal low-speed oscillator built in the micro-controller. The low-speed oscillator uses RC type oscillator circuit. The frequency is affected by the voltage and temperature of the system. In common condition, the frequency of the RC oscillator is about 16 KHz.

✸ ***Note: The ILRC can ONLY be switched on and off by HW.***

3.2.2 PLL

SN32F100 series MCU uses the PLL to create the clocks for the core and peripherals. The input frequency range is 10MHz to 25MHz. The input clock is divided down and fed to the Phase-Frequency Detector (PFD). This block compares the phase and frequency of its inputs, and generates a control signal when phase and/ or frequency do not match. The loop filter filters these control signals and drives the voltage controlled oscillator (VCO), which generates the main clock and optionally two additional phases. The VCO frequency range is 156MHz to 320MHz. These clocks are divided by P by the programmable post divider to create the output clock(s). The VCO output clock is then divided by M by the programmable feedback divider to generate the feedback clock. The output signal of the phase-frequency detector is also monitored by the lock detector, to signal when the PLL has locked on to the input clock.

The PLL settling time is 100 µs.



3.2.2.1 PLL Frequency selection

The PLL frequency equations:

$$F_{VCO} = F_{CLKIN} / F * M$$

$$F_{CLKOUT} = F_{VCO} / P$$

The PLL frequency is determined by the following parameters:

- F_{CLKIN}: Frequency from the PLLCLKSEL multiplexer.
- F_{VCO}: Frequency of the Voltage Controlled Oscillator (VCO); 156 to 320 MHz.
- F_{CLKOUT}: Frequency of PLL output.
- P: System PLL post divider ratio, controlled by PSEL bits in PLL control register (SYS0_PLLCTRL).
- F: System PLL front divider ratio, controlled by FSEL bits in PLL control register (SYS0_PLLCTRL).
- M: System PLL feedback divider ratio, controlled by MSEL bits in PLL control register (SYS0_PLLCTRL).

To select the appropriate values for M, P, and F, it is recommended to follow these constraints:

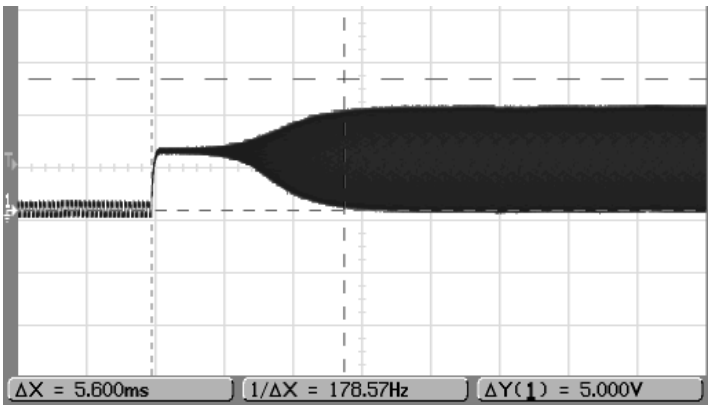
1. 10MHz ≤ F_{CLKIN} ≤ 25MHz
2. 150MHz ≤ F_{VCO} ≤ 330MHz
3. 2 < M ≤31
4. F = 1, or 2
5. P = 6, 8, 10, 12, or 14 (duty 50% +/- 2.5%)
6. F_{CLKOUT} = 20MHz, 30MHz, 40MHz, 50MHz, 24MHz, 36MHz, 48MHz, 32MHz, 22MHz, 24MHz, 50MHz with jitter < ±500 ps

3.2.3 EXTERNAL CLOCK SOURCE

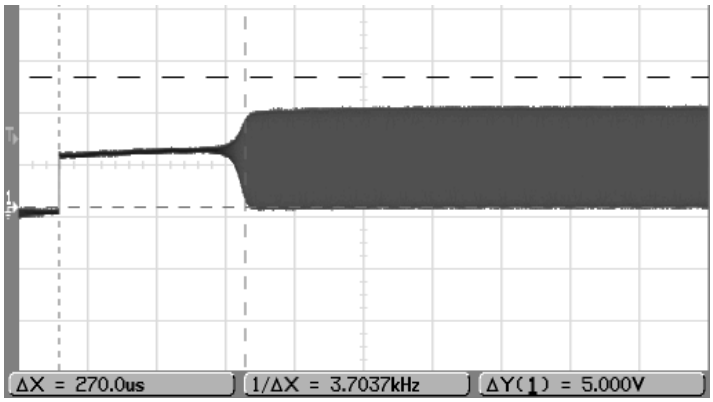
3.2.3.1 External High-speed (EHS) Clock

External high clock includes Crystal/Ceramic modules. The startup time of is longer. The oscillator start-up time decides reset time length.

4MHz Crystal

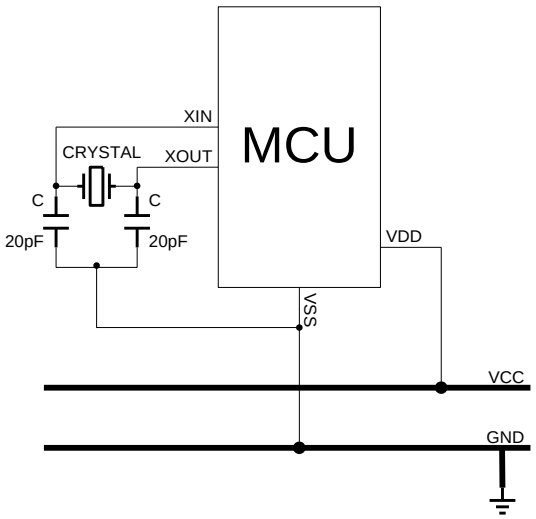


4MHz Ceramic



3.2.3.2 CRYSTAL/CERAMIC

Crystal/Ceramic devices are driven by XIN, XOUT pins. For high/normal/low frequency, the driving currents are different.



✷ ***Note: Connect the Crystal/Ceramic and C as near as possible to the XIN/XOUT/VSS pins of MCU.***

- **Structure:** 1MHz~25MHz EHS external crystal/ceramic resonator
- **Main Purpose:** System high clock source, RTC clock source, and PLL clock source.
- **Warm-up Time:** 2048*F_{EHS}
- **XIN/XOUT Shared Pin Selection:**

Oscillator Mode	XTALIN pin	XTALOUT pin
IHRC	GPIO	GPIO
EHS X'TAL	Crystal/Ceramic	Crystal/Ceramic

The resonator and the load capacitors have to be placed as close as possible to the oscillator pins in order to minimize output distortion and startup stabilization time. The loading capacitance values must be adjusted according to the selected oscillator.

The EHS crystal is switched on and off using the EHSEN bit in Analog Block Control register (SYS0_ANBCTRL).

3.2.3.3 Audio External High-speed (AUEHS) Clock

✸ ***Note: Connect the Crystal/Ceramic and C as near as possible to the AUXTALIN/AUXTALOUT/VSS pins of MCU.***

- **Structure:** 1MHz~25MHz AUEHS external crystal/ceramic resonator
- **Main Purpose:** Audio high clock source.
- **Warm-up Time:** 2048*F_{AUEHS}
- **AUXTALIN/AUXTALOUT Shared Pin Selection:**

Oscillator Mode	AUXTALIN pin	AUXTALOUT pin
--	GPIO	GPIO
AUEHS X'TAL	Crystal/Ceramic	Crystal/Ceramic

The resonator and the load capacitors have to be placed as close as possible to the oscillator pins in order to minimize output distortion and startup stabilization time. The loading capacitance values must be adjusted according to the selected oscillator.

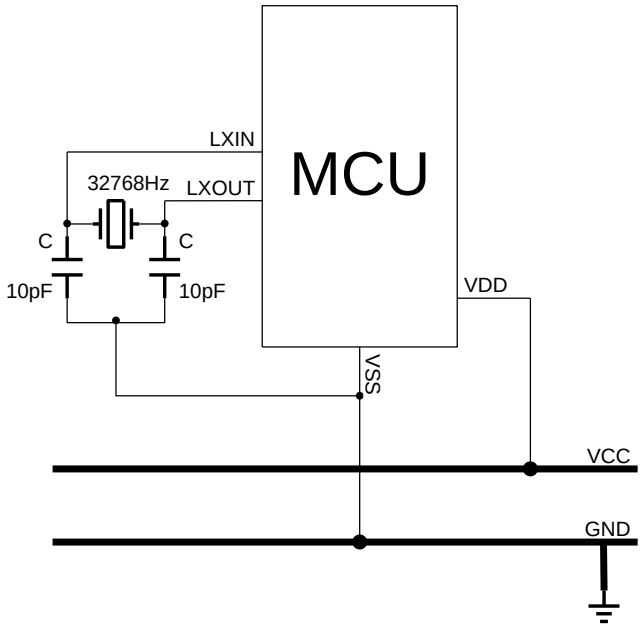
The AUEHS crystal is switched on and off using the AUEHSEN bit in Analog Block Control register (SYS0_ANBCTRL).

3.2.3.4 External Low-speed (ELS) Clock

The low-speed oscillator can use 32768 crystal oscillator circuit.

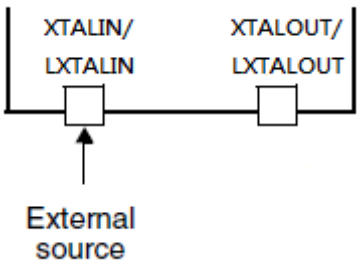
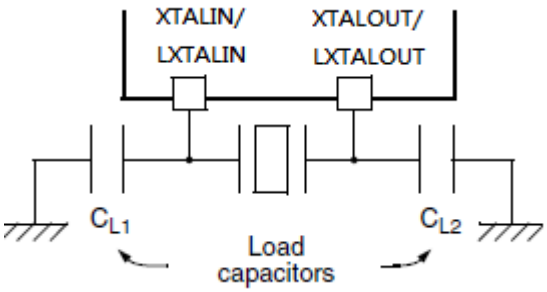
3.2.3.5 CRYSTAL

Crystal devices are driven by LXIN, LXOUT pins. The 32768 crystal and 10pF capacitor must be as near as possible to MCU. The ELS crystal is switched on and off using the ELSEN bit in Analog Block Control register (SYS0_ANBCTRL).



✸ ***Note: Connect the Crystal/Ceramic and C as near as possible to the LXIN/LXOUT/VSS pins of MCU. The capacitor between LXIN/LXOUT and VSS must be 10pF.***

3.2.3.6 Bypass Mode

Clock Source	H/W Configuration	Description
External clock source (Bypass)		In Bypass mode, the external clock signal (square, sinus or triangle) with ~50% duty cycle must be provided to drive the XTALIN/ LXTALIN pin while the XTALOUT/ LXTALOUT pin should be the inverse of the input clock signal. EHS X'tal can have a frequency of up to 25 MHz. Select this mode by setting EHSEN bit in Analog Block Control register (SYS0_ANBCTRL). ELS X'TAL must have a frequency of 32.768 KHz. You select this mode by setting ELSEN bit in Analog Block Control register (SYS0_ANBCTRL).
External X'TAL (EHS/ELS X'TAL)		The 1 to 25 MHz EHS X'TAL has the advantage of producing a very accurate rate on the main clock ELS X'TAL must have a frequency of 32.768 KHz.

3.2.4 SYSTEM CLOCK (SYSCLK) SELECTION

After a system reset, the IHRC is selected as system clock. When a clock source is used directly or through the PLL as system clock, it is not possible to stop it.

A switch from one clock source to another occurs only if the target clock source is ready (clock stable after startup delay or PLL locked). If a clock source which is not yet ready is selected, the switch will occur when the clock source is ready.

Ready bits in SYS0_CSST register indicate which clock(s) is (are) ready and SYSCLKST bits in SYS0_CLKCFG register indicate which clock is currently used as system clock.

3.2.5 CLOCK-OUT CAPABITITY

The MCU clock output (CLKOUT) capability allows the clock to be output onto the external CLKOUT pin. The configuration registers of the corresponding GPIO port must be programmed in alternate function mode.

One of 6 clock signals can be selected as clock output:
1. HCLK
2. IHRC
3. ILRC
4. PLL clock output
5. ELS X'TAL
6. EHS X'TAL
7. AUEHS X'TAL

The selection is controlled by the CLKOUTSEL bits in SYS1_AHBCLKEN register.

3.3 SYSTEM CONTROL REGISTERS 0

Base Address: 0x4006 0000

3.3.1 Analog Block Control register (SYS0_ANBCTRL)

Address Offset: 0x00

Reset value: 0x0000 0001

✸ ***Note: EHSEN / ELSEN / IHRCEN bit can NOT be cleared if the EHS X'tal / ELS X'tal / IHRC is selected as system clock or is selected to become the system clock.***

Bit	Name	Description	Attribute	Reset
31:10	Reserved		R	0
9	AUEHSFREQ	Frequency range of AUEHS X'TAL 0: <=12MHz 1: >12MHz	R/W	0
8	AUEHSEN	Audio external high-speed clock enable 0: Disable AUEHS X'TAL. 1: Enable AUEHS X'TAL.	R/W	0
7:6	Reserved		R	0
5	EHSFREQ	Frequency range (driving ability) of EHS X'TAL 0: <=12MHz 1: >12MHz	R/W	0
4	EHSEN	External high-speed clock enable 0: Disable EHS X'TAL. 1: Enable EHS X'TAL.	R/W	0
3	Reserved		R	0
2	ELSEN	External low-speed oscillator enable 0: Disable External 32.768 KHz oscillator 1: Enable External 32.768 KHz oscillator	R/W	0
1	Reserved		R	0
0	IHRCEN	Internal high-speed clock enable 0: Disable internal 12 MHz RC oscillator. 1: Enable internal 12 MHz RC oscillator.	R/W	1

3.3.2 PLL control register (SYS0_PLLCTRL)

Address Offset: 0x04

✸ ***Note: PLLEN bit can NOT be cleared if the PLL is selected as system clock or is selected to become the system clock.***

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15	PLLEN	PLL enable 0: Disable 1: Enable	R/W	0
14	Reserved		R	0

13:12	PLLCLKSEL[1:0]	System PLL clock source 00: IHRC 12 MHz oscillator 01: EHS X'TAL 10 MHz ~ 25 MHz Other: Reserved	R/W	0
11:9	Reserved		R	0
8	FSEL	Front divider value. The division value F is the programmed 2^{FSEL} 0: F = 1 1: F = 2	R/W	0
7:5	PSEL[2:0]	Post divider value. P= PSEL[2:0]*2 000~010: Reserved 011: P = 6 100: P = 8 101: P = 10 110: P = 12 111: P = 14	R/W	011b
4:0	MSEL[4:0]	Feedback divider value. M: 3~31	R/W	0x3

To select the appropriate values for M, P, and F, it is recommended to follow these constraints:

1. 10MHz ≤ F_{CLKIN} ≤ 25MHz
2. 150MHz ≤ F_{VCO} ≤ 330MHz
3. 2 < M ≤31
4. F = 1, or 2
5. P = 6, 8, 10, 12, or 14 **(duty 50% +/- 2.5%)**
6. F_{CLKOUT} = 20MHz, 30MHz, 40MHz, 50MHz, 24MHz, 36MHz, 48MHz, 32MHz, 22MHz, 24MHz, 50MHz with jitter < ±500 ps

Fclkin \ Fclkout	10MHz	12MHz	16MHz	20MHz	22MHz	24MHz	25MHz	30MHz	32MHz	36MHz	40MHz	44MHz	48MHz	50MHz
10MHz				V				V			V			V
12MHz						V				V			V	
16MHz									V				V	
22MHz												V		
24MHz													V	
25MHz														V

3.3.2.1 RECOMMEND FREQUENCY SETTING

$F_{VCO} = F_{CLKIN} / F * M$
$F_{CLKOUT} = F_{VCO} / P$

F_{CLKIN} (MHz)	FSEL	$F=2^{FEL}$	MSEL[4:0]=M	F_{VCO} (MHz) $=F_{CLKIN}$ /F*M	PSEL[2:0]	P= PSEL[2:0]*2	F_{CLKOUT} (MHz)
10	0	1	20	200	5	10	20
10	0	1	22	220	5	10	22
10	0	1	18	180	3	6	30
10	0	1	24	240	3	6	40
10	0	1	30	300	3	6	50
12	0	1	16	192	4	8	24
12	0	1	18	216	3	6	36
12	0	1	24	288	3	6	48
16	0	1	16	256	4	8	32
16	0	1	18	288	3	6	48
20	1	2	30	300	3	6	50
22	0	1	12	264	3	6	44
24	0	1	12	288	3	6	48
25	0	1	12	300	3	6	50

3.3.3 Clock Source Status register (SYS0_CSST)

Address Offset: 0x08

Bit	Name	Description	Attribute	Reset
31:9	Reserved		R	0
8	AUEHSRDY	Audio external high-speed clock ready flag 0: AUEHS oscillator not ready 1: AUEHS oscillator ready	R	0
7	Reserved		R	0
6	PLLRDY	PLL clock ready flag 0: PLL unlocked 1: PLL locked	R	0
5	Reserved		R	0
4	EHSRDY	External high-speed clock ready flag 0: EHS oscillator not ready 1: EHS oscillator ready	R	0
3	Reserved		R	0
2	ELSRDY	External low-speed clock ready flag 0: EHS oscillator not ready 1: EHS oscillator ready	R	0
1	Reserved		R	0
0	IHRCRDY	IHRC ready flag 0: IHRC not ready 1: IHRC ready	R	1

3.3.4 System Clock Configuration register (SYS0_CLKCFG)

Address Offset: 0x0C

Bit	Name	Description	Attribute	Reset
31:7	Reserved		R	0
6:4	SYSCLKST[2:0]	System clock switch status Set and cleared by HW to indicate which clock source is used as system clock. 000: IHRC is used as system clock 001: ILRC is used as system clock 010: EHS X'TAL is used as system clock 011: ELS X'TAL is used as system clock 100: PLL is used as system clock Other: Reserved	R	0
3	Reserved		R	0
2:0	SYSCLKSEL[2:0]	System clock switch Set and cleared by SW. 000: IHRC 001: ILRC 010: EHS X'TAL 011: ELS X'TAL 100: PLL output Other: Reserved	R/W	0

3.3.5 AHB Clock Prescale register (SYS0_AHBCP)

Address Offset: 0x10

Bit	Name	Description	Attribute	Reset
31:4	Reserved		R	0

3:0	AHBPRE[3:0]	AHB clock source prescale value 0000: SYSCLK / 1 0001: SYSCLK / 2 0010: SYSCLK / 4 0011: SYSCLK / 8 0100: SYSCLK / 16 0101: SYSCLK / 32 0110: SYSCLK / 64 0111: SYSCLK / 128 1000: SYSCLK / 256 1001: SYSCLK / 512 Other: Reserved	R/W	0

3.3.6 System Reset Status register (SYS0_RSTST)

Address Offset: 0x14

This register contains the reset source except DPDWAKEUP reset, since the LPFLAG bit in PMU_CTRL register had presented this case.

Bit	Name	Description	Attribute	Reset
31:5	Reserved		R	0
4	PORRSTF	POR reset flag Set by HW when a POR reset occurs. 0: Read→No POR reset occurred Write→Clear this bit 1: POR reset occurred.	R/W	1
3	EXTRSTF	External reset flag Set by HW when a reset from the RESET pin occurs. 0: Read→No reset from RESET pin occurred Write→Clear this bit 1: Reset from RESET pin occurred.	R/W	0
2	LVDRSTF	LVD reset flag Set by HW when a LVD reset occurs. 0: Read→No LVD reset occurred Write→Clear this bit 1: LVD reset occurred.	R/W	0
1	WDTRSTF	WDT reset flag Set by HW when a WDT reset occurs. 0: Read→No watchdog reset occurred Write→Clear this bit 1: Watchdog reset occurred.	R/W	0
0	SWRSTF	Software reset flag Set by HW when a software reset occurs. 0: Read→No software reset occurred Write→Clear this bit 1: Software reset occurred.	R/W	1

3.3.7 LVD Control register (SYS0_LVDCTRL)

Address Offset: 0x18

The LVD control register selects four separate threshold values for generating a LVD interrupt to the NVIC or LVD reset.

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15	LVDEN	LVD enable 0: Disable 1: Enable	R/W	0
14	LVDRSTEN	LVD Reset enable 0: Disable 1: Enable	R/W	0

13:6	Reserved		R	0
5:4	LVDINTLVL[1:0]	LVD interrupt level 00: The interrupt assertion threshold voltage is 2.00V 01: The interrupt assertion threshold voltage is 2.40V 10: The interrupt assertion threshold voltage is 2.70V 11: The interrupt assertion threshold voltage is 3.00V	R/W	0
3:2	Reserved		R	0
1:0	LVDRSTLVL[1:0]	LVD reset level 00: The reset assertion threshold voltage is 2.00V 01: The reset assertion threshold voltage is 2.40V 10: The reset assertion threshold voltage is 2.70V 11: Reserved	R/W	0

3.3.8 External RESET Pin Control register (SYS0_EXRSTCTRL)

Address Offset: 0x1C

Bit	Name	Description	Attribute	Reset
31:1	Reserved		R	0
0	RESETDIS	External RESET pin disable bit. 0: Enable external RESET pin. (P0.15 acts as RESET pin) 1: Disable. (P0.15 acts as GPIO pin)	R/W	0

3.3.9 SWD Pin Control register (SYS0_SWDCTRL)

Address Offset: 0x20

Bit	Name	Description	Attribute	Reset
31:1	Reserved		R	0
0	SWDDIS	SWD pin disable bit. 0: Enable SWD pin. (P0.13 acts as SWDIO pin, P0.12 acts as SWCLK pin) 1: Disable. (P0.13 and P0.12 act as GPIO pins)	R/W	0

3.4 SYSTEM CONTROL REGISTERS 1

Base Address: 0x4005 E000

3.4.1 AHB Clock Enable register (SYS1_AHBCLKEN)

Address Offset: 0x00

The SYS_AHBCLKEN register enables the AHB clock to individual system and peripheral blocks.

✸ ***Note:***
- ***1. When the clock is disabled, the peripheral register values may not be readable by SW and the value returned is always 0x0.***
- ***2. HW will replace GPIO with CLKOUT function directly if CLKOUTSEL is Not 0.***

Bit	Name	Description	Attribute	Reset
31	Reserved		R	0
30:28	CLKOUTSEL[2:0]	Clock output source 000: Disable 001: HCLK 010: PLL clock output 011: ILRC clock 100: IHRC clock 101: ELS clock 110: EHS clock 111: AUEHS clock	R/W	0
27:25	Reserved		R	0
24	WDTCLKEN	Enables clock for WDT. 0: Disable 1: Enable	R/W	1
23	RTCCLKEN	Enables clock for RTC. 0: Disable 1: Enable	R/W	0
22	I2SCLKEN	Enables clock for I2S. 0: Disable 1: Enable	R/W	0
21	I2C0CLKEN	Enables clock for I2C0. 0: Disable 1: Enable	R/W	0
20	I2C1CLKEN	Enables clock for I2C1. 0: Disable 1: Enable	R/W	0
19:18	Reserved		R	0
17	UART1CLKEN	Enables clock for UART1. 0: Disable 1: Enable	R/W	0
16	UART0CLKEN	Enables clock for UART0. 0: Disable 1: Enable	R/W	0
15:14	Reserved		R	0
13	SSP1CLKEN	Enables clock for SSP1. 0: Disable 1: Enable	R/W	0
12	SSP0CLKEN	Enables clock for SSP0. 0: Disable 1: Enable	R/W	0
11	CMPCLKEN	Enables clock for Comparator. 0: Disable 1: Enable	R/W	0

10	Reserved		R	0
9	CT32B1CLKEN	Enables clock for CT32B1. 0: Disable 1: Enable	R/W	0
8	CT32B0CLKEN	Enables clock for CT32B0. 0: Disable 1: Enable	R/W	0
7	CT16B1CLKEN	Enables clock for CT16B1. 0: Disable 1: Enable	R/W	0
6	CT16B0CLKEN	Enables clock for CT16B0. 0: Disable 1: Enable	R/W	0
5:4	Reserved		R	0
3	GPIOCLKEN	Enables clock for GPIO. 0: Disable 1: Enable	R/W	1
2:0	Reserved		R	0

3.4.2 APB Clock Prescale register 0 (SYS1_APBCP0)

Address Offset: 0x04

✸ ***Note: Must reset the corresponding peripheral with SYS1_PRST register after changing the prescale value.***

Bit	Name	Description	Attribute	Reset
31	Reserved		R	0
30:28	AUEHSPRE[2:0]	Audio external high clock source prescale value 000: AUEHS / 1 001: AUEHS / 2 010: AUEHS / 4 011: AUEHS / 8 100: AUEHS / 16 Other: Reserved	R/W	0
27	Reserved		R	0
26:24	SSP1PRE[2:0]	SSP1 clock source prescale value 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0
23	Reserved		R	0
22:20	SSP0PRE[2:0]	SSP0 clock source prescale value 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0
19	Reserved		R	0
18:16	CMPPRE[2:0]	Comparator clock source prescale value 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0
15	Reserved		R	0

14:12	CT32B1PRE[2:0]	CT32B1 clock source prescale value 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0
11	Reserved		R	0
10:8	CT32B0PRE[2:0]	CT32B0 clock source prescale value. 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0
7	Reserved		R	0
6:4	CT16B1PRE[2:0]	CT16B1 clock source prescale value 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0
3	Reserved		R	0
2:0	CT16B0PRE[2:0]	CT16B0 clock source prescale value 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0

3.4.3 APB Clock Prescale register 1 (SYS1_APBCP1)

Address Offset: 0x08

✷ ***Note: Must reset the corresponding peripheral with SYS1_PRST register after changing the prescale value.***

Bit	Name	Description	Attribute	Reset
31:28	CLKOUTPRE[3:0]	Clock-out source prescale value 0000: Clock-out source / 1 0001: Clock-out source / 2 0010: Clock-out source / 4 0011: Clock-out source / 8 0100: Clock-out source / 16 0101: Clock-out source / 32 0110: Clock-out source / 64 0111: Clock-out source / 128 1000: Clock-out source / 256 1001: Clock-out source / 512 Other: Reserved	R/W	0
27	Reserved		R	0
26:24	I2C1PRE[2:0]	I2C1 clock source prescale value 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0
23	Reserved		R	0

22:20	WDTPRE[2:0]	WDT clock source prescale value 000: WDT_PCLK = WDT clock source / 1 001: WDT_PCLK = WDT clock source / 2 010: WDT_PCLK = WDT clock source / 4 011: WDT_PCLK = WDT clock source / 8 100: WDT_PCLK = WDT clock source / 16 101: WDT_PCLK = WDT clock source / 32 Other: Reserved	R/W	0
19:15	Reserved		R	0
14:12	I2SPRE[2:0]	I2S clock source prescale value 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0
11	Reserved		R	0
10:8	I2C0PRE[2:0]	I2C0 clock source prescale value 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0
7	Reserved		R	0
6:4	UART1PRE[2:0]	UART1 clock source prescale value 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0
3	Reserved		R	0
2:0	UART0PRE[2:0]	UART0 clock source prescale value 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0

3.4.4 Peripheral Reset register (SYS1_PRST)

Address Offset: 0x0C

All bits are cleared by HW automatically after setting as “1”.

Bit	Name	Description	Attribute	Reset
31:27	Reserved		R	0
26	CODECADRST	Codec ADC reset 0: No effect 1: Reset Codec ADC	R/W	0
25	CODECDARST	Codec DAC reset 0: No effect 1: Reset Codec DAC	R/W	0
24	WDTRST	WDT reset 0: No effect 1: Reset WDT	R/W	0
23	RTCRST	RTC reset 0: No effect 1: Reset RTC	R/W	0
22	I2SRST	I2S reset 0: No effect 1: Reset I2S	R/W	0

21	I2C0RST	I2C0 reset 0: No effect 1: Reset I2C0	R/W	0
20	I2C1RST	I2C1 reset 0: No effect 1: Reset I2C1	R/W	0
19:18	Reserved		R	0
17	UART1RST	UART1 reset 0: No effect 1: Reset UART1	R/W	0
16	UART0RST	UART0 reset 0: No effect 1: Reset UART0	R/W	0
15:14	Reserved		R	0
13	SSP1RST	SSP1 reset 0: No effect 1: Reset SSP1	R/W	0
12	SSP0RST	SSP0 reset 0: No effect 1: Reset SSP0	R/W	0
11	CMPRST	Comparator reset 0: No effect 1: Reset Comparator	R/W	0
10	Reserved		R	0
9	CT32B1RST	CT32B1 reset 0: No effect 1: Reset CT32B1	R/W	0
8	CT32B0RST	CT32B0 reset 0: No effect 1: Reset CT32B0	R/W	0
7	CT16B1RST	CT16B1 reset 0: No effect 1: Reset CT16B1	R/W	0
6	CT16B0RST	CT16B0 reset 0: No effect 1: Reset CT16B0	R/W	0
5:4	Reserved		R	0
3	GPIOP3RST	GPIO port 3 reset 0: No effect 1: Reset GPIO port 3	R/W	0
2	GPIOP2RST	GPIO port 2 reset 0: No effect 1: Reset GPIO port 2	R/W	0
1	GPIOP1RST	GPIO port 1 reset 0: No effect 1: Reset GPIO port 1	R/W	0
0	GPIOP0RST	GPIO port 0 reset 0: No effect 1: Reset GPIO port 0	R/W	0

4 SYSTEM OPERATION MODE

4.1 OVERVIEW

The chip builds in four operating mode for difference clock rate and power saving reason. These modes control oscillators, op-code operation and analog peripheral devices' operation.

- Normal mode
- Sleep mode
- Deep sleep mode
- Deep Power-down mode

4.2 NORMAL MODE

In Normal mode, the ARM Cortex-M0 core, memories, and peripherals are clocked by the system clock. The SYS1_AHBCLKEN register controls which peripherals are running.

Selected peripherals have individual peripheral clocks with their own clock dividers in addition to the system clock. The peripheral clocks can be disabled respectively.

The power to various analog blocks (IHRC, EHS X'TAL, ELS X'TAL, PLL, Flash, LVD, Codec, Comparator) can be controlled at any time individually through the enable bit of all blocks.

4.3 LOW-POWER MODES

There are three special modes of processor power reduction: Sleep mode, Deep-sleep mode, and Deep power-down mode. The PMU_CTRL register controls which mode is going to entered.

The CPU clock rate may also be controlled as needed by changing clock sources, re-configuring PLL values, and/or altering the system clock divider value. This allows a trade-off of power versus processing speed based on application requirements.

Run-time power control allows disable the clocks to individual on-chip peripherals, allowing fine tuning of power consumption by eliminating all dynamic power use in any peripherals that are not required for the application. Selected peripherals have their own clock divider for power control.

✸ ***Note: 1. The debug mode is not supported in Deep-sleep and Deep Power-down mode.***

2. The pins which are not pin-out shall be set correctly to decrease power consumption in low-power modes. Strongly recommended to set these pins as input pull-up.

4.3.1 SLEEP MODE

In Sleep mode, the system clock to the ARM Cortex-M0 core is stopped and execution of instructions is suspended.

Peripheral functions, if selected to be clocked in SYS1_AHBCLKEN register, continue operation during Sleep mode and may generate interrupts to cause the processor to resume execution. Sleep mode eliminates dynamic power used by the processor itself, memory systems and related controllers, and internal buses.

The power state of the analog blocks (IHRC, EHS X'TAL, ELS X'TAL, PLL, Flash, LVD, Codec, Comparator) is

determined by the enable bit of all blocks.

The processor state and registers, peripheral registers, and internal SRAM values are maintained and the logic levels of the pins remain static.

Wake up the chip from Sleep mode by an interrupt occurs.

The RESET pin has keep functionality in Sleep mode.

The Sleep mode is entered by using the following steps:
1. Write 1 to SLEEPEN bit in PMU_CTRL register.
2. Execute ARM Cortex-M0 WFI instruction.

4.3.2 DEEP-SLEEP MODE

In Deep-sleep mode, the system clock to the ARM Cortex-M0 core is stopped, and execution of instructions is suspended.

The clock to the peripheral functions are stopped because the power state of oscillators are powered down, the clock source are stopped, except RTC low speed clock source (ELS X'TAL, ILRC) if used.

✷ ***Note: User SHALL decide to power down RTC low speed clock source (ELS X'TAL, ILRC oscillator) or not if RTC is enabled.***

The processor state and registers, peripheral registers, and internal SRAM values are maintained and the logic levels of the pins remain static.

Wake up the chip from Deep-sleep mode by anyone of GPIO port pins (P0~P3) interrupt trigger or RTC interrupt.

The RESET pin has keep functionality in Deep-sleep mode.

The Deep-sleep mode is entered by using the following steps:
1. Write 1 to DSLEEPEN bit in PMU_CTRL register.
2. Execute ARM WFI instruction.

The advantage of the Deep-sleep mode is that can power down clock generating blocks such as oscillators and PLL, thereby gaining far greater dynamic power savings over Sleep mode. In addition, the Flash can be powered down in Deep-sleep mode resulting in savings in static leakage power, however at the expense of longer wake-up times for the Flash memory.

4.3.3 DEEP POWER-DOWN (DPD) MODE

In Deep power-down mode, power (Turn off the on-chip voltage regulator) and clocks are shut off to the entire chip with the exception of the DPDWAKEUP pin. DPDWAKEUP pin must be pulled HIGH externally to enter Deep power-down mode and pulled LOW to exit Deep power-down mode.

The processor state and registers, peripheral registers, and internal SRAM values are not retained. However, the chip can retain data in four BACKUP registers.

Wakes up the chip from Deep power-down mode by pulling the DPDWAKEUP pin LOW (Turn on the on-chip voltage regulator. When the core voltage reaches the power-on-reset (POR) trip point, a system reset will be triggered and the chip re-boots).

The RESET pin has no functionality in Deep power-down mode.

4.3.3.1 Entering Deep power-down mode

Follow these steps to enter Deep power-down mode from Normal mode:

1. Pull the DPDWAKEUP pin externally HIGH (Please confirm pull-up time to ensure that the DPDWAKEUP pin already in the pull-up state).
2. (Optional) Save data to be retained during Deep power-down to the DATA bits in Backup registers.
3. Write 1 to DPDEN bit in PMU_CTRL register to enable Deep power-down mode.
4. Time spent between step 1 and step 5 shall longer than 20 us.
5. Execute ARM Cortex-M0 WFI instruction.

After step 5, the PMU turns off the on-chip voltage regulator and waits for a wake-up signal from the DPDWAKEUP pin.

4.3.3.2 Exiting Deep power-down mode

Follow these steps to wake up the chip from Deep power-down mode:

1. DPDWAKEUP pin transition from HIGH to LOW.
   – The PMU will turn on the on-chip voltage regulator. When the core voltage reaches the power-on-reset (POR) Trigger point, a system reset will be triggered and the chip reboots.
   – All registers except the PMU_BKP0 to PMU_BKP 15 and PMU_CTRL will be reset.
2. Once the chip has rebooted, read DPDEN bit in PMU_CTRL register to verify that the reset was caused by a wake-up event from Deep power-down and was not a cold reset.
3. Clear the DPDEN bit in PMU_CTRL register.
4. (Optional) Read the stored data in the backup registers.
5. Setup the PMU for the next Deep power-down cycle.

4.4 WAKEUP INTERRUPT

System will exit Deep-sleep mode when GPIO indicates a GPIO interrupt to the ARM core. The all GPIO port pins are served as wakeup pins. The user must program the registers for each pin to set the appropriate edge polarity for the corresponding wakeup event. Only edge sensitive is supported to wakeup MCU. Furthermore, the interrupts corresponding to each input must be enabled in the NVIC.

4.5 WAKEUP

4.5.1 OVERVIEW

Under low power mode, program doesn't execute. The wakeup trigger can wake the system up to normal mode. The wakeup function builds in interrupt operation and trigger system executing interrupt service routine as system wakeup occurrence.

- The wakeup trigger sources of the Sleep mode are all interrupts and the RESET pin.
- The wakeup trigger sources of the Deep-sleep mode are the GPIO interrupt, RTC interrupt, and the RESET pin.
- The wakeup trigger source of the Deep Power-down mode is DPDWAKEUP pin which is input pull-up before entering DPD mode.

4.5.2 WAKEUP TIME

When the system is in Sleep mode, the high clock is enabled or disabled by F/W. If the high clock stops and MCU is waken up from Sleep mode, MCU waits for 2048 external high-speed oscillator clocks and 32 internal high-speed oscillator clocks as the wakeup time to stable the oscillator circuit. After the wakeup time, the system goes into the normal mode.

✸ ***Note: Wakeup from Sleep mode spends NO wakeup time if the clock doesn't stop.***

When the system is in Deep-sleep mode, the high clock will stop. When MCU is waken up from Deep-sleep mode, MCU waits for 2048 external high-speed oscillator clocks and 32 IHRC clocks as the wakeup time to stable the oscillator circuit. After the wakeup time, the system goes into the normal mode.

The value of the external high clock oscillator wakeup time is as the following.

The total Wakeup time of EHS X'tal = 1/F_{EHS} * 2048 (sec) + high clock start-up time

➢ Example: F_{EHS}=20MHz, the wakeup time is as the following.

The total Wakeup time = 1/F_{EHS} * 2048 + oscillator start-up time

= 102.4 us + oscillator start-up time (F_{EHS} = 20MHz)

The value of the IHRC wakeup time is as the following.

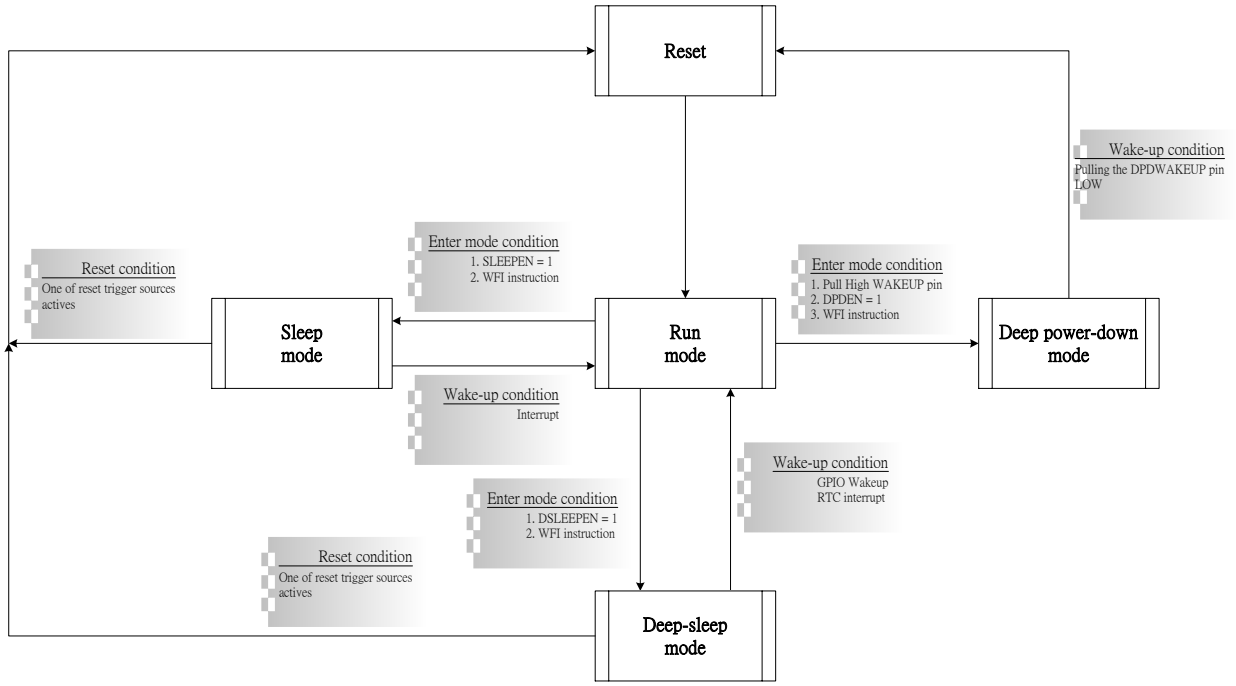
The total Wakeup time of IHRC = 1/F_{IHRC} * 32 (sec)

➢ Example: F_{IHRC}=12MHz, the wakeup time is as the following.

The total Wakeup time = 1/F_{IHRC} * 32 = 2.67 us (F_{IHRC} = 12MHz)

✸ ***Note: The high clock start-up time is depended on the VDD and oscillator type of high clock.***

4.6 STATE MACHINE OF PMU



4.7 OPERATION MODE COMPARSION TABLE

	Normal Mode	Low-Power Mode		
		Sleep Mode	Deep-Sleep Mode	Deep Power-down Mode
IHRC	By IHRCEN		Disable	OFF
ILRC	ON		***	OFF
EHS X'TAL	By EHSEN		Disable	OFF
AUEHS X'TAL	By AUEHSEN		Disable	OFF
ELS X'TAL	By ELSEN		***	OFF
PLL	By PLLEN		Disable	OFF
Cortex-M0 core	Running	Stop	Stop	Stop
Flash ROM	Enable	Disable	Disable	OFF
RAM	Enable	Maintain	Maintain	OFF
LVD	By LVDEN		Disable	OFF
RTC	By RTCEN		By RTCEN	OFF
Peripherals	By Enable bit of each peripherals		Disable HCLK	OFF
Wakeup Source	N/A	All interrupts, RESET pin	GPIO interrupt, RTC interrupt, RESET pin	DPDWAKEUP pin

***

RTCENB	RTC_CLKS	ILRC*	ELS*
0	---	X	X
1	0 (ILRC)	O	X
	1 (ELS)	X	O

4.8 PMU REGISTERS

Base Address: 0x4003 2000

4.8.1 Backup registers 0 to 15 (PMU_BKP0~15)

Address Offset: 0x0, 0x04, 0x08, 0x0C, 0x10, 0x14, 0x18, 0x1C, 0x20, 0x24, 0x28, 0x2C, 0x30, 0x34, 0x38, 0x3C

The backup registers retain data through the Deep power-down mode when power is still applied to the VDD pin but the chip has entered Deep power-down mode.

✸ ***Note: Backup registers will be reset only when all power has been completely removed from the chip.***

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	BACKUPDATA[7:0]	BACKUPDATA Data retained during Deep power-down mode.	R/W	0

4.8.2 Power control register (PMU_CTRL)

Address Offset: 0x40

The power control register selects whether one of the ARM Cortex-M0 controlled power-down modes (Sleep mode or Deep-sleep mode) or the Deep power-down mode is entered and provides the flags for Sleep or Deep-sleep modes and Deep power-down modes respectively.

✸ ***Note: 1. The PMU_CTRL register retains data through the Deep power-down mode when power is still applied to the VDD pin, and will be reset only when all power has been completely removed from the chip.***
2. The pins which are not pin-out shall be set correctly to decrease power consumption in low-power modes. Strongly recommended to set these pins as input pull-up.

Bit	Name	Description	Attribute	Reset
31:3	Reserved		R	0
2	SLEEPEN	Sleep mode enable 0: Disable. 1: Enable. WFI instruction will make MCU enter Sleep mode.	R/W	0
1	DSLEEPEN	Deep sleep mode enable 0: Disable. 1: Enable. WFI instruction will make MCU enter Deep-sleep mode.	R/W	0
0	DPDEN	Deep power-down mode enable 0: Disable. 1: Enable. WFI instruction will make MCU enter Deep power-down mode.	R/W	0

5 GENERAL PURPOSE I/O PORT (GPIO)

5.1 OVERVIEW

Digital ports can be configured input/output by SW
- Each individual port pin can serve as external interrupt input pin.
- Interrupts can be configured on single falling or rising edges and on both edges.
- The I/O configuration registers control the electrical characteristics of the pads.
- Internal pull-up/pull-down resistor.
- Most of the I/O pins are mixed with analog pins and special function pins.

5.2 GPIO MODE

The MODE bits in the GPIOn_CFG (n=0,1,2,3) register allow the selection of on-chip pull-up or pull-down resistors for each pin or select the repeater mode.

The repeater mode enables the pull-up resistor if the pin is logic HIGH and enables the pull-down resistor if the pin is logic LOW. This causes the pin to retain its last known state if it is configured as an input and is not driven externally. The state retention is not applicable to the Deep power-down mode.

- ***Note: HW will switch P1.7 and P1.8 to Microphone differential input if SEL_MIC=1 in ADC_SET23 register. Setting SEL_MIC=0 before P1.7 and P1.8 as GPIO function.***

- ***Note: P0.14 is the input pin only, please don't set it to the output function in GPIO0_MODE register.***

5.3 GPIO REGISTERS

Base Address: 0x4004 4000 (GPIO 0)
0x4004 6000 (GPIO 1)
0x4004 8000 (GPIO 2)
0x4004 A000 (GPIO 3)

5.3.1 GPIO Port n Data register (GPIOn_DATA) (n=0,1,2,3)

Address offset: 0x00

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	DATA[15:0]	Input data (read) or output data (write) for Pn.0 to Pn.15	R/W	0

5.3.2 GPIO Port n Mode register (GPIOn_MODE) (n=0,1,2,3)

Address offset: 0x04

✸ ***Note: HW will switch I/O Mode directly when Specific function (Peripheral) is enabled, not through GPIOn_MODE register.***

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	MODE[15:0]	Selects pin x as input or output (x = 0 to 15, ***n = 0 and x = 14 is input only***) 0: Pn.x is configured as input 1: Pn.x is configured as output.	R/W	0

✸ ***Note: HW will switch P1.7 and P1.8 to Microphone differential input if SEL_MIC=1 in ADC_SET23 register. Setting SEL_MIC=0 before P1.7 and P1.8 as GPIO function.***
✸ ***Note: P0.14 is the input pin only, please don't set it to the output function in GPIO0_MODE register.***

5.3.3 GPIO Port n Configuration register (GPIOn_CFG) (n=0,1,2,3)

Address offset: 0x08
Reset value: 0xAAAAAAAA

✸ ***Note: HW will switch I/O Mode directly when Specific function (Peripheral) is enabled, not through GPIOn_MODE register.***

Bit	Name	Description	Attribute	Reset
31:30	CFG15[1:0]	Configuration of Pn.15 00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.	R/W	10b
29:28	CFG14[1:0]	Configuration of Pn.14 00: Pull-up resistor enabled. 01: Pull-down resistor enabled.	R/W	10b

		10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.		
27:26	CFG13[1:0]	Configuration of Pn.13 00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.	R/W	10b
25:24	CFG12[1:0]	Configuration of Pn.12 00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.	R/W	10b
23:22	CFG11[1:0]	Configuration of Pn.11 00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.	R/W	10b
21:20	CFG10[1:0]	Configuration of Pn.10 00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.	R/W	10b
19:18	CFG9[1:0]	Configuration of Pn.9 00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.	R/W	10b
17:16	CFG8[1:0]	Configuration of Pn.8 00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.	R/W	10b
15:14	CFG7[1:0]	Configuration of Pn.7 00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.	R/W	10b
13:12	CFG6[1:0]	Configuration of Pn.6 00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.	R/W	10b
11:10	CFG5[1:0]	Configuration of Pn.5 00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.	R/W	10b
9:8	CFG4[1:0]	Configuration of Pn.4 00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.	R/W	10b
7:6	CFG3[1:0]	Configuration of Pn.3 00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.	R/W	10b
5:4	CFG2[1:0]	Configuration of Pn.2 00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.	R/W	10b
3:2	CFG1[1:0]	Configuration of Pn.1 00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.	R/W	10b
1:0	CFG0[1:0]	Configuration of Pn.0	R/W	10b

		00: Pull-up resistor enabled. 01: Pull-down resistor enabled. 10: Inactive (no pull-down/pull-up resistor enabled). 11: Repeater mode.		

- ***Note: HW will switch P1.7 and P1.8 to Microphone differential input if SEL_MIC=1 in ADC_SET23 register. Setting SEL_MIC=0 before P1.7 and P1.8 as GPIO function.***
- ***Note: P0.14 is the input pin only, please don't set it to the output function in GPIO0_MODE register.***

5.3.4 GPIO Port n Interrupt Sense register (GPIOn_IS) (n=0,1,2,3)

Address offset: 0x0C

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	IS[15:0]	Selects interrupt on pin x as level or edge sensitive (x = 0 to 15). 0: Interrupt on Pn.x is configured as edge sensitive. 1: Interrupt on Pn.x is configured as event sensitive.	R/W	0

5.3.5 GPIO Port n Interrupt Both-edge Sense register (GPIOn_IBS) (n=0,1,2,3)

Address offset: 0x10

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	IBS[15:0]	Selects interrupt on Pn.x to be triggered on both edges (x = 0 to 15). 0: Interrupt on Pn.x is controlled through register GPIOn_IEV. 1: Both edges on Pn.x trigger an interrupt.	R/W	0

5.3.6 GPIO Port n Interrupt Event register (GPIOn_IEV) (n=0,1,2,3)

Address offset: 0x14

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	IEV[15:0]	Selects interrupt on pin x to be triggered rising or falling edges (x = 0 to 15). 0: Depending on setting in register GPIOn_IS, Rising edges or HIGH level on Pn.x trigger an interrupt. 1: Depending on setting in register GPIOn_IS, Falling edges or LOW level on Pn.x trigger an interrupt.	R/W	0

5.3.7 GPIO Port n Interrupt Enable register (GPIOn_IE) (n=0,1,2,3)

Address offset: 0x18

Bits set to HIGH in the GPIOn_IE register allow the corresponding pins to trigger their individual interrupts. Clearing a bit disables interrupt triggering on that pin.

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	IE[15:0]	Selects interrupt on pin x to be enabled (x = 0 to 15). 0: Disable Interrupt on Pn.x 1: Enable Interrupt on Pn.x	R/W	0

5.3.8 GPIO Port n Raw Interrupt Status register (GPIOn_RIS) (n=0,1,2,3)

Address offset: 0x1C

This register indicates the status for GPIO control raw interrupts. A GPIO interrupt is sent to the interrupt controller if the corresponding bit in GPIOn_IE register is set.

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	IF[15:0]	GPIO raw interrupt flag (x = 0 to 15). 0: No interrupt on Pn.x 1: Interrupt requirements met on Pn.x.	R	0

5.3.9 GPIO Port n Interrupt Clear register (GPIOn_IC) (n=0,1,2,3)

Address offset: 0x20

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	IC[15:0]	Selects interrupt flag on pin x to be cleared (x = 0 to 15). 0: No effect 1: Clear interrupt flag on Pn.x	W	0

5.3.10 GPIO Port n Bits Set Operation register (GPIOn_BSET) (n=0,1,2,3)

Address offset: 0x24

In order for SW to set GPIO bits without affecting any other pins in a single write operation, the GPIO bit is set if the corresponding bit in the GPIOn_BSET register is set.

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	BSET[15:0]	Bit Set enable (x = 0 to 15) 0: No effect on Pn.x 1: Set Pn.x to “1”	W	0

5.3.11 GPIO Port n Bits Clear Operation register (GPIOn_BCLR) (n=0,1,2,3)

Address offset: 0x28

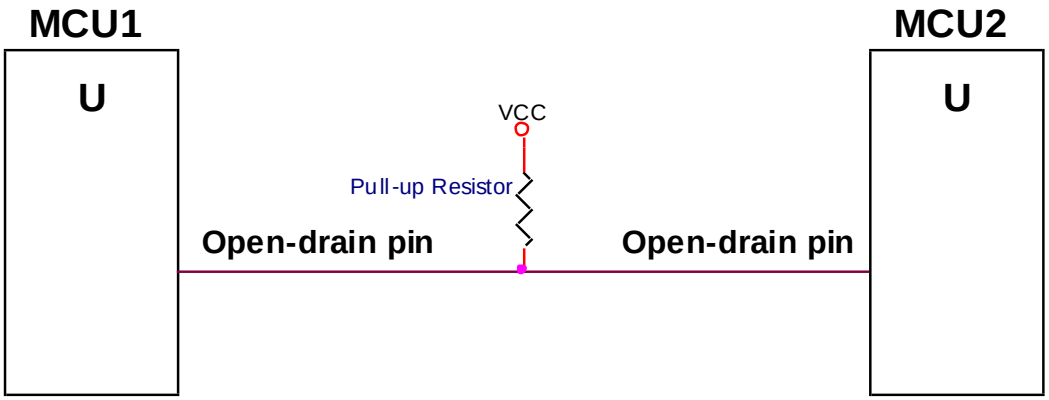
In order for SW to clear GPIO bits without affecting any other pins in a single write operation, the GPIO bit is cleared if the corresponding bit in this register is set.

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	BCLR[15:0]	Bit clear enable (x = 0 to 15) 0: No effect on Pn.x 1: Clear Pn.x.	W	0

5.3.12 GPIO Port n Open-Drain Control register (GPIOn_ODCTRL) (n=0,1,2,3)

Address offset: 0x2C

Several I/Os have built-in open-drain function and must be set as output mode when enable open-drain function. Open-drain external circuit is as following.



The external pull-up resistor is necessary. The digital output function of I/O only supports sink current capability, so the open-drain output high is driven by pull-up resistor, and output low is sunken by MCU's pin.

✸ ***Note: VCC shall be less than or equal to VDD of MCU1 and MCU2.***

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15	Pn15OC	n = 3 P3.15 open-drain control bit. 0: Disable 1: Enable. HW set P3.15 as output mode automatically.	R/W	0
		n=0~2 Reserved	R	
14	Pn14OC	n = 3 P3.14 open-drain control bit. 0: Disable 1: Enable. HW set P3.14 as output mode automatically.	R/W	0
		n=0~2 Reserved	R	
13	Pn13OC	n = 3 P3.13 open-drain control bit. 0: Disable 1: Enable. HW set P3.13 as output mode automatically.	R/W	0
		n=0~2 Reserved	R	
12	Pn12OC	n = 3 P3.12 open-drain control bit. 0: Disable 1: Enable. HW set P3.12 as output mode automatically.	R/W	0
		n=0~2 Reserved	R	
11:4	Reserved		R	0
3	Pn3OC	n = 0 P0.3 open-drain control bit. 0: Disable 1: Enable. HW set P0.3 as output mode automatically.	R/W	0
		n=1~3 Reserved	R	
2	Pn2OC	n = 0 P0.2 open-drain control bit. 0: Disable 1: Enable. HW set P0.2 as output mode automatically.	R/W	0
		n=1~3 Reserved	R	
1	Pn1OC	n = 0 P0.1 open-drain control bit. 0: Disable 1: Enable. HW set P0.1 as output mode automatically.	R/W	0
		n=1~3 Reserved	R	

0	Pn0OC	n = 0 P0.0 open-drain control bit. 0: Disable 1: Enable. HW set P0.0 as output mode automatically.	R/W	0
		n=1~3 Reserved	R	

6 16-BIT TIMER WITH CAPTURE FUNCTION

6.1 OVERVIEW

Each Counter/timer is designed to count cycles of the peripheral clock (PCLK) or an externally supplied clock and can optionally generate interrupts or perform other actions at specified timer values based on four match registers. Each counter/timer also includes one capture input to trap the timer value when an input signal transitions, optionally generating an interrupt.

In PWM mode, one match register can be used to provide a single-edge controlled PWM output on the match output pins.

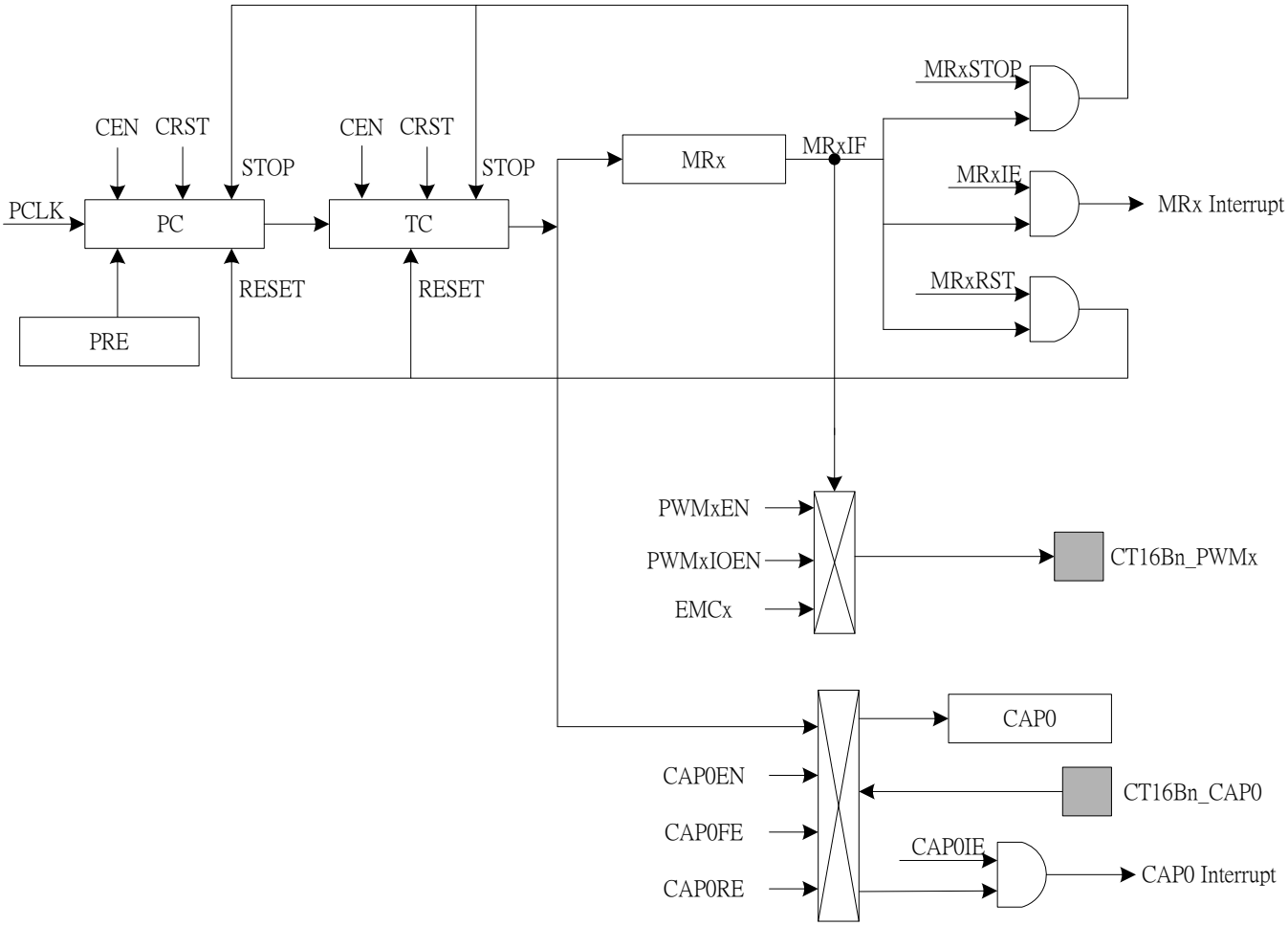
6.2 FEATURES

- Two 16-bit counter/timers with a programmable 16-bit prescale value.
- Counter or timer operation
- Two 16-bit capture channels that can take a snapshot of the timer value when an input signal transitions. A capture event may also optionally generate an interrupt.
- The timer and the prescale value may be configured to be cleared on a designated capture event. This feature permits easy pulse-width measurement by clearing the timer on the leading edge of an input pulse and capturing the timer value on the trailing edge.
- For each timer, four 16-bit match registers that allow:
  - Continuous operation with optional interrupt generation on match.
  - Stop timer on match with optional interrupt generation.
  - Reset timer on match with optional interrupt generation.
  - **C**onfigured as PWM allowing using up to one match outputs as single edge controlled PWM outputs.
- For each timer, up to one PWM output corresponding to match register with the following capabilities:
  - Set LOW on match.
  - Set HIGH on match.
  - Toggle on match.
  - Do nothing on match.

6.3 PIN DESCRIPTION

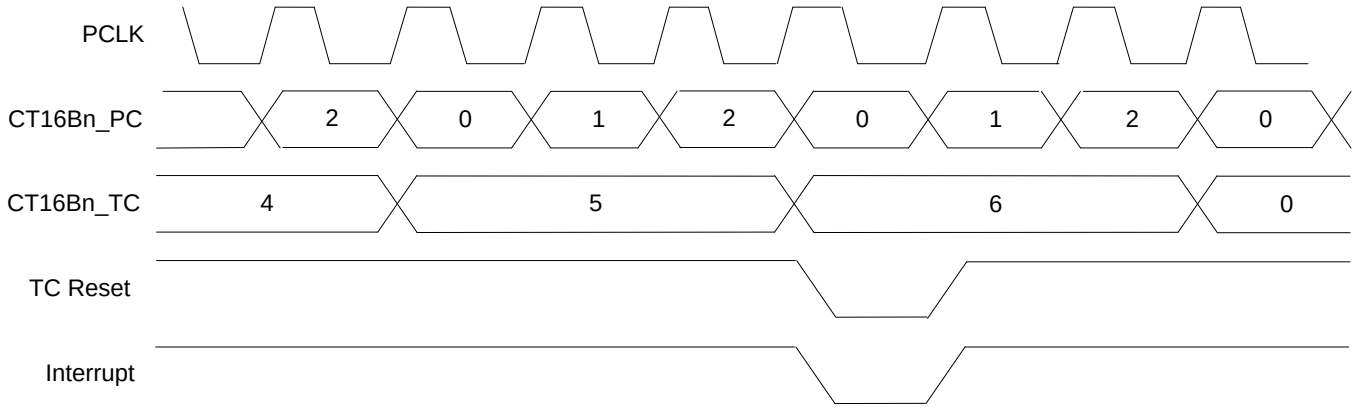
Pin Name	Type	Description	GPIO Configuration
CT16Bn_CAP0	I	Capture channel input 0	Depends on GPIOn_CFG
CT16Bn_PWMx	O	Output channel x of Match/PWM output.	

6.4 BLOCK DIAGRAM

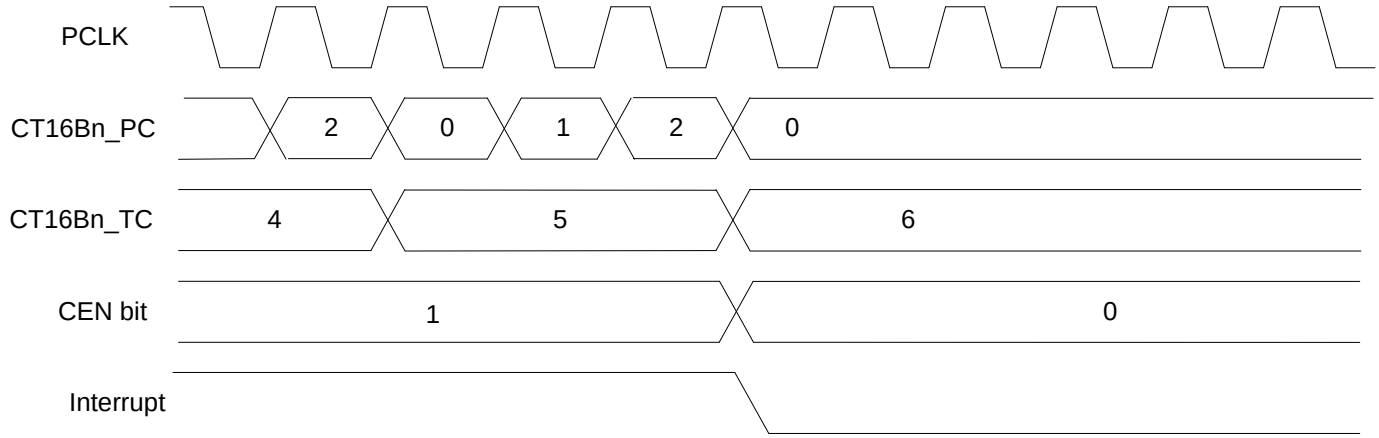


6.5 TIMER OPERATION

The following figure shows a timer configured to reset the count and generate an interrupt on match. The CT16Bn_PRE register is set to 2, and the CT16Bn_MRx register is set to 6. At the end of the timer cycle where the match occurs, the timer count is reset. The interrupt indicating that a match occurred is generated after the timer reached the match value.

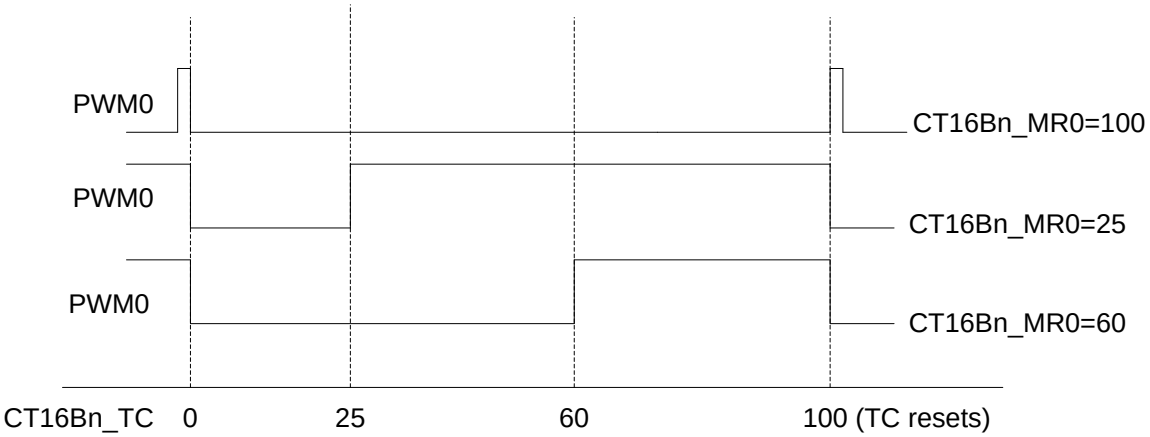


The following figure shows a timer configured to stop and generate an interrupt on match. The CT16Bn_PRE register is set to 2, and the CT16Bn_MRx register is set to 6. After the timer reaches the match value, the CEN bit in CT16Bn_TMRCTRL register is cleared, and the interrupt indicating that a match occurred is generated.



6.6 PWM

1. All single edge controlled PWM outputs go LOW at the beginning of each PWM cycle (timer is set to zero) unless their match value in CT16Bn_MR0~3 registers is equal to zero.
2. Each PWM output will go HIGH when its match value is reached. If no match occurs, the PWM output remains continuously LOW.
3. If a match value larger than the PWM cycle length is written to the CT16Bn_MR0~3 registers, and the PWM signal is HIGH already, then the PWM signal will be cleared on the next start of the next PWM cycle.
4. If a match register contains the same value as the timer reset value (the PWM cycle length), then the PWM output will be reset to LOW on the next clock tick. Therefore, the PWM output will always consist of a one clock tick wide positive pulse with a period determined by the PWM cycle length.
5. If a match register is set to zero, then the PWM output will go to HIGH the first time the timer goes back to zero and will stay HIGH continuously.



✷ ***Note: When the match outputs are selected to perform as PWM outputs, the timer reset (MRnRST) and timer stop (MRnSTOP) bits in CT16Bn_MCTRL register must be set to zero except for the match register setting the PWM cycle length. For this register, set the MRnR bit to one to enable the timer reset when the timer value matches the value of the corresponding match register.***

6.7 CT16Bn REGISTERS

Base Address: 0x4000 0000 (CT16B0)
0x4000 2000 (CT16B1)

6.7.1 CT16Bn Timer Control register (CT16Bn_TMRCTRL) (n=0,1)

Address Offset: 0x00

✸ ***Note: CEN bit shall be set at last!***

Bit	Name	Description	Attribute	Reset
31:2	Reserved		R	0
1	CRST	Counter Reset. 0: Disable counter reset. 1: Timer Counter and the Prescale Counter are synchronously reset on the next positive edge of PCLK. This is cleared by HW when the counter reset operation finishes.	R/W	0
0	CEN	Counter Enable 0: Disable Counter. 1: Enable Timer Counter and Prescale Counter for counting.	R/W	0

6.7.2 CT16Bn Timer Counter register (CT16Bn_TC) (n=0,1)

Address Offset: 0x04

The 16-bit Timer Counter is incremented when the Prescale Counter reaches its terminal count. Unless it is reset before reaching its upper limit, the TC will count up to the value 0x0000FFFF and then wrap back to the value 0x00000000. This event does not cause an interrupt, but a Match register can be used to detect an overflow if needed.

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	TC[15:0]	Timer Counter	R/W	0

6.7.3 CT16Bn Prescale register (CT16Bn_PRE) (n=0,1)

Address Offset: 0x08

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	PR[15:0]	Prescale max value.	R/W	0

6.7.4 CT16Bn Prescale Counter register (CT16Bn_PC) (n=0,1)

Address Offset: 0x0C

The 16-bit Prescale Counter controls division of PCLK by some constant value before it is applied to the Timer Counter. This allows control of the relationship between the resolution of the timer and the maximum time before the timer overflows. The Prescale Counter is incremented on every PCLK. When it reaches the value stored in the Prescale Register, the Timer Counter is incremented, and the Prescale Counter is reset on the next PCLK. This causes the TC to increment on every PCLK when PR = 0, every 2 PCLKs when PR = 1, etc.

Bit	Name	Description	Attribute	Reset

31:16	Reserved		R	0
15:0	PC[15:0]	Prescale Counter	R/W	0

6.7.5 CT16Bn Count Control register (CT16Bn_CNTCTRL) (n=0,1)

Address Offset: 0x10

This register is used to select between Timer and Counter mode, and in Counter mode to select the pin and edges for counting.

When Counter Mode is chosen as a mode of operation, the CAP input (selected by the CIS bits) is sampled on every rising edge of the PCLK clock. After comparing two consecutive samples of this CAP input, one of the following four events is recognized: rising edge, falling edge, either of edges or no changes in the level of the selected CAP input. Only if the identified event occurs, and the event corresponds to the one selected by CTM bits in this register, will the Timer Counter register be incremented.

Effective processing of the externally supplied clock to the counter has some limitations. Since two successive rising edges of the PCLK clock are used to identify only one edge on the CAP selected input, the frequency of the CAP input cannot exceed one half of the PCLK clock. Consequently, the duration of the HIGH/LOW levels on the same CAP input in this case cannot be shorter than 1/ (2 x PCLK).

✷ ***Note: If Counter mode is selected in the CNTCTRL register, Capture Control (CAPCTRL) register must be programmed as 0x0.***

Bit	Name	Description	Attribute	Reset
31:4	Reserved		R	0
3:2	CIS[1:0]	Count Input Select. In counter mode (when CTM[1:0] are not 00), these bits select which CAP0 pin is sampled for clocking. 00: CT16Bn_CAP0 Other: Reserved.	R/W	0
1:0	CTM[1:0]	Counter/Timer Mode. This field selects which rising PCLK edges can increment Timer's Prescale Counter (PC), or clear PC and increment Timer Counter (TC). 00: Timer Mode: every rising PCLK edge 01: Counter Mode: TC is incremented on rising edges on the CAP0 input selected by CIS bits. 10: Counter Mode: TC is incremented on falling edges on the CAP0 input selected by CIS bits. 11: Counter Mode: TC is incremented on both edges on the CAP0 input selected by CIS bits.	R/W	0

6.7.6 CT16Bn Match Control register (CT16Bn_MCTRL) (n=0,1)

Address Offset: 0x14

Bit	Name	Description	Attribute	Reset
31:12	Reserved		R	0
11	MR3STOP	Stop MR3: TC and PC will stop and CEN bit will be cleared if MR3 matches TC. 0: Disable 1: Enable	R/W	0
10	MR3RST	Enable reset TC when MR3 matches TC. 0: Disable 1: Enable	R/W	0
9	MR3IE	Enable generating an interrupt when MR3 matches the value in the TC. 0: Disable 1: Enable	R/W	0

8	MR2STOP	Stop MR2: TC and PC will stop and CEN bit will be cleared if MR2 matches TC. 0: Disable 1: Enable	R/W	0
7	MR2RST	Enable reset TC when MR2 matches TC. 0: Disable 1: Enable	R/W	0
6	MR2IE	Enable generating an interrupt when MR2 matches the value in the TC. 0: Disable 1: Enable	R/W	0
5	MR1STOP	Stop MR1: TC and PC will stop and CEN bit will be cleared if MR1 matches TC. 0: Disable 1: Enable	R/W	0
4	MR1RST	Enable reset TC when MR1 matches TC. 0: Disable 1: Enable	R/W	0
3	MR1IE	Enable generating an interrupt when MR1 matches the value in the TC. 0: Disable 1: Enable	R/W	0
2	MR0STOP	Stop MR0: TC and PC will stop and CEN bit will be cleared if MR0 matches TC. 0: Disable 1: Enable	R/W	0
1	MR0RST	Enable reset TC when MR0 matches TC. 0: Disable 1: Enable	R/W	0
0	MR0IE	Enable generating an interrupt when MR0 matches the value in the TC. 0: Disable 1: Enable	R/W	0

6.7.7 CT16Bn Match register 0~3 (CT16Bn_MR0~3) (n=0,1)

Address Offset: 0x18, 0x1C, 0x20, 0x24

The Match register values are continuously compared to the Timer Counter (TC) value. When the two values are equal, actions can be triggered automatically. The action possibilities are to generate an interrupt, reset the Timer Counter, or stop the timer. Actions are controlled by the settings in the CT16Bn_MCTRL register.

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	MR[15:0]	Timer counter match value	R/W	0

6.7.8 CT16Bn Capture Control register (CT16Bn_CAPCTRL) (n=0,1)

Address Offset: 0x28

The Capture Control register is used to control whether the Capture register is loaded with the value in the Counter/timer when the capture event occurs, and whether an interrupt is generated by the capture event. Setting both the rising and falling bits at the same time is a valid configuration, resulting in a capture event for both edges.

✸ ***Note: HW will switch I/O Configuration directly when CAP0EN=1.***

Bit	Name	Description	Attribute	Reset
31:7	Reserved		R	0
6:5	CAP0EN	Capture 0 function enable bit 0: Disable 1: Enable Capture 0 function for external Capture pin. 2~3: Reserved.	R/W	0

4	CAP0IE	Interrupt on CT16Bn_CAP0 signal event: a CAP0 load due to a CT16Bn_CAP0 signal event will generate an interrupt. 0: Disable 1: Enable	R/W	0
3:2	CAP0FE	Capture/Reset on CT16Bn_CAP0 signal falling edge. 0: Disable 1: Enable a sequence of 1 then 0 on CT16Bn_CAP0 signal will cause CAP0 to be loaded with the contents of TC. 2: Enable a sequence of 1 then 0 on CT16Bn_CAP0 signal will reset the TC. 3: Reserved.	R/W	0
1:0	CAP0RE	Capture/Reset on CT16Bn_CAP0 signal rising edge. 0: Disable 1: Enable a sequence of 0 then 1 on CT16Bn_CAP0 signal will cause CAP0 to be loaded with the contents of TC. 2: Enable a sequence of 0 then 1 on CT16Bn_CAP0 signal will reset the TC. 3: Reserved.	R/W	0

6.7.9 CT16Bn Capture 0 register (CT16Bn_CAP0) (n=0,1)

Address Offset: 0x2C

Each Capture register is associated with a device pin and may be loaded with the counter/timer value when a specified event occurs on that pin. The settings in the Capture Control register determine whether the capture function is enabled, and whether a capture event happens on the rising edge of the associated pin, the falling edge, or on both edges.

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	CAP0[15:0]	Timer counter capture value	R	0

6.7.10 CT16Bn External Match register (CT16Bn_EM) (n=0,1)

Address Offset: 0x30

The External Match register provides both control and status of CT16Bn_PWM[0]. If the match outputs are configured as PWM output, the function of the external match registers is determined by the PWM rules.

Bit	Name	Description	Attribute	Reset
31:6	Reserved		R	0
5:4	EMC0[1:0]	Determines the functionality of CT16Bn_PWM0. 00: Do Nothing. 01: CT16Bn_PWM0 pin is LOW 10: CT16Bn_PWM0 pin is HIGH 11: Toggle CT16Bn_PWM0.	R/W	0
3:1	Reserved		R	0
0	EM0	When the TC and MR0 are equal, this bit will act according to EMC0 bits, and also drive the state of CT16Bn_PWM0 output.	R/W	0

6.7.11 CT16Bn PWM Control register (CT16Bn_PWMCTRL) (n=0,1)

Address Offset: 0x34

The PWM Control register is used to configure the match outputs as PWM outputs. Each match output can be in-dependently set to perform either as PWM output or as match output whose function is controlled by CT16Bn_EM register.

For each timer, a maximum of three single edge controlled PWM outputs can be selected on the CT16Bn_PWMCTRL [0] outputs. One additional match register determines the PWM cycle length. When a match occurs in any of the other match registers, the PWM output is set to HIGH. The timer is reset by the match register that is configured to set the PWM cycle length. When the timer is reset to zero, all currently HIGH match outputs configured as PWM outputs are cleared.

Bit	Name	Description	Attribute	Reset
31:21	Reserved		R	0
20	PWM0IOEN	CT16Bn_PWM0/GPIO selection bit 0: CT16Bn_PWM0 pin act as GPIO 1: CT16Bn_PWM0 pin act as match output, and output signal depends on PWM0EN bit.	R/W	0
19:1	Reserved		R	0
0	PWM0EN	PWM0 enable 0: CT16Bn_PWM0 is controlled by EM0. 1: PWM mode is enabled for CT16Bn_PWM0.	R/W	0

6.7.12 CT16Bn Timer Raw Interrupt Status register (CT16Bn_RIS) (n=0,1)

Address Offset: 0x38

This register indicates the raw status for Timer/PWM interrupts. A Timer/PWM interrupt is sent to the interrupt controller if the corresponding bit in the CT16Bn_IE register is set.

Bit	Name	Description	Attribute	Reset
31:5	Reserved		R	0
4	CAP0IF	Interrupt flag for capture channel 0. 0: No interrupt on CAP0 1: Interrupt requirements met on CAP0.	R	0
3	MR3IF	Interrupt flag for match channel 3. 0: No interrupt on match channel 3 1: Interrupt requirements met on match channel 3.	R	0
2	MR2IF	Interrupt flag for match channel 2. 0: No interrupt on match channel 2 1: Interrupt requirements met on match channel 2.	R	0
1	MR1IF	Interrupt flag for match channel 1. 0: No interrupt on match channel 1 1: Interrupt requirements met on match channel 1.	R	0
0	MR0IF	Interrupt flag for match channel 0. 0: No interrupt on match channel 0 1: Interrupt requirements met on match channel 0.	R	0

6.7.13 CT16Bn Timer Interrupt Clear register (CT16Bn_IC) (n=0,1)

Address Offset: 0x3C

Bit	Name	Description	Attribute	Reset
31:5	Reserved		R	0
4	CAP0IC	0: No effect 1: Clear CAP0IF bit	W	0
3	MR3IC	0: No effect 1: Clear MR3IF bit	W	0
2	MR2IC	0: No effect 1: Clear MR2IF bit	W	0
1	MR1IC	0: No effect 1: Clear MR1IF bit	W	0
0	MR0IC	0: No effect 1: Clear MR0IF bit	W	0

7 32-BIT TIMER WITH CAPTURE FUNCTION

7.1 OVERVIEW

Each Counter/timer is designed to count cycles of the peripheral clock (PCLK) or an externally supplied clock and can optionally generate interrupts or perform other actions at specified timer values based on four match registers. Each counter/timer also includes one capture input to trap the timer value when an input signal transitions, optionally generating an interrupt.

In PWM mode, up to two match registers can be used to provide a single-edge controlled PWM output on the match output pins.

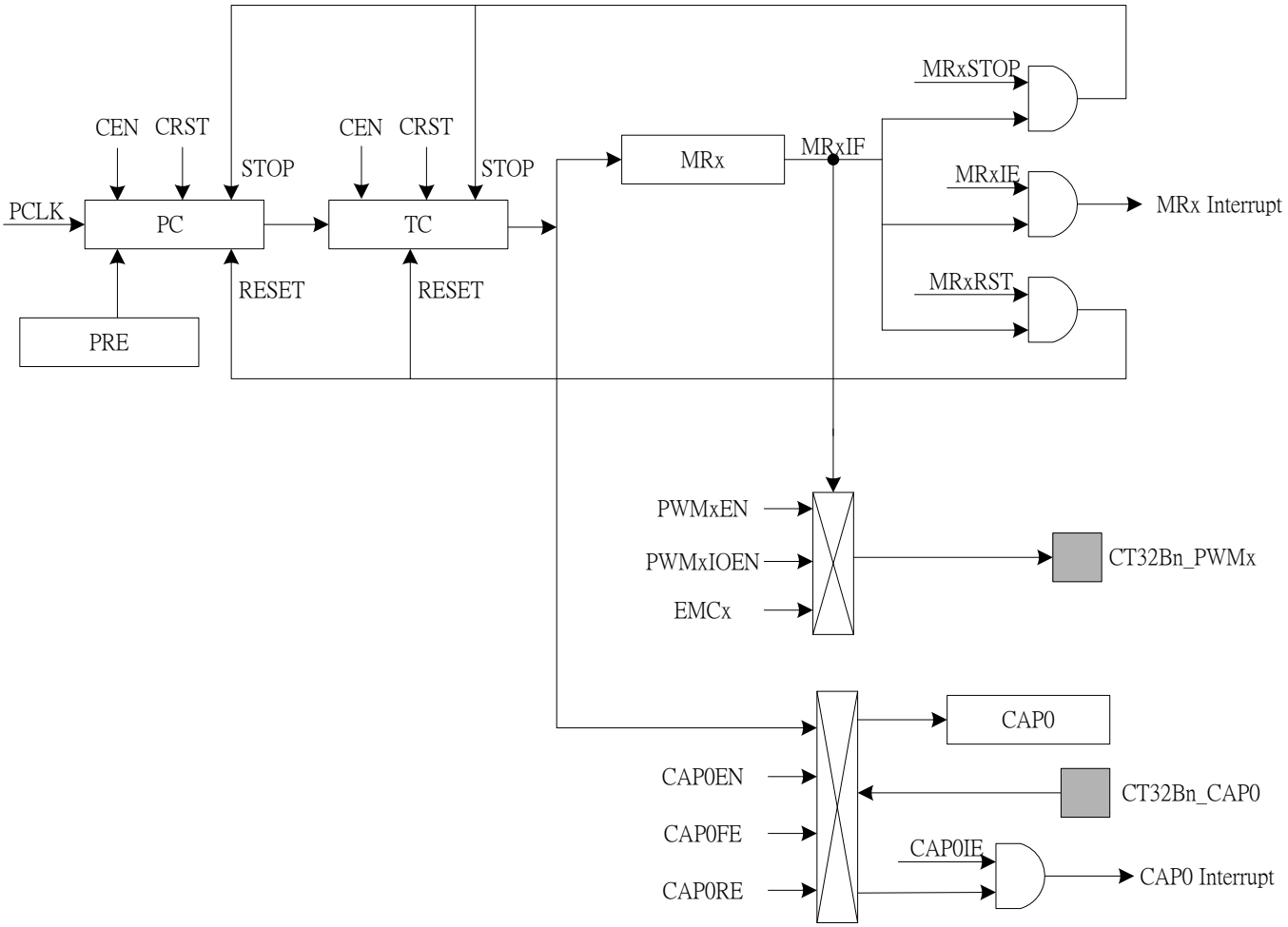
7.2 FEATURES

- Two 32-bit counter/timers with a programmable 16-bit prescale value.
- Counter or timer operation
- Two 32-bit capture channels that can take a snapshot of the timer value when an input signal transitions. A capture event may also optionally generate an interrupt.
- The timer and the prescale value may be configured to be cleared on a designated capture event. This feature permits easy pulse-width measurement by clearing the timer on the leading edge of an input pulse and capturing the timer value on the trailing edge.
- For each timer, four 32-bit match registers that allow:
  - Continuous operation with optional interrupt generation on match.
  - Stop timer on match with optional interrupt generation.
  - Reset timer on match with optional interrupt generation.
  - Configured as PWM allowing using up to two match outputs as single edge controlled PWM outputs.
- For each timer, up to two PWM outputs corresponding to match registers with the following capabilities:
  - Set LOW on match.
  - Set HIGH on match.
  - Toggle on match.
  - Do nothing on match.

7.3 PIN DESCRIPTION

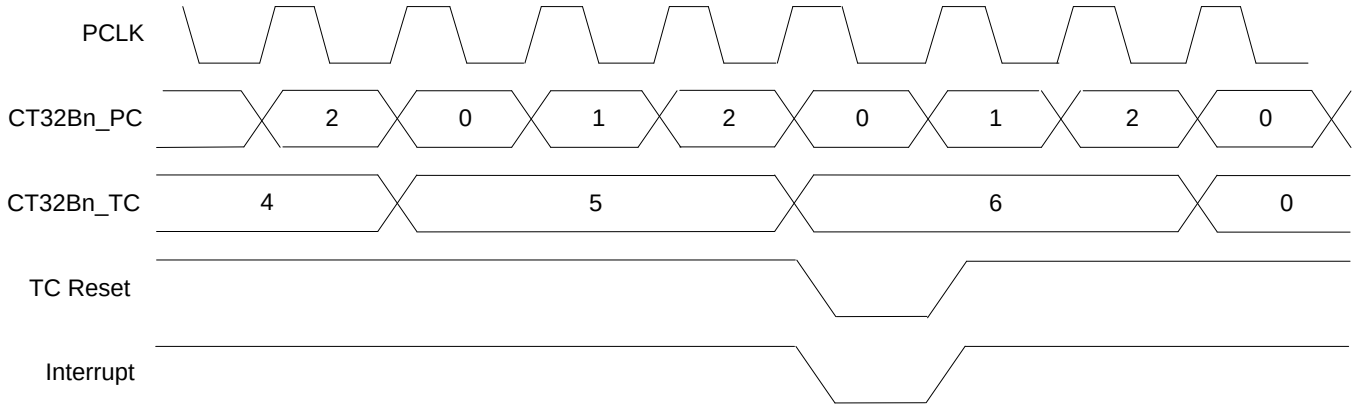
Pin Name	Type	Description	GPIO Configuration
CT32Bn_CAP0	I	Capture channel input 0	Depends on GPIOn_CFG
CT32Bn_PWMx	O	Output channel x of Match/PWM output.	

7.4 BLOCK DIAGRAM

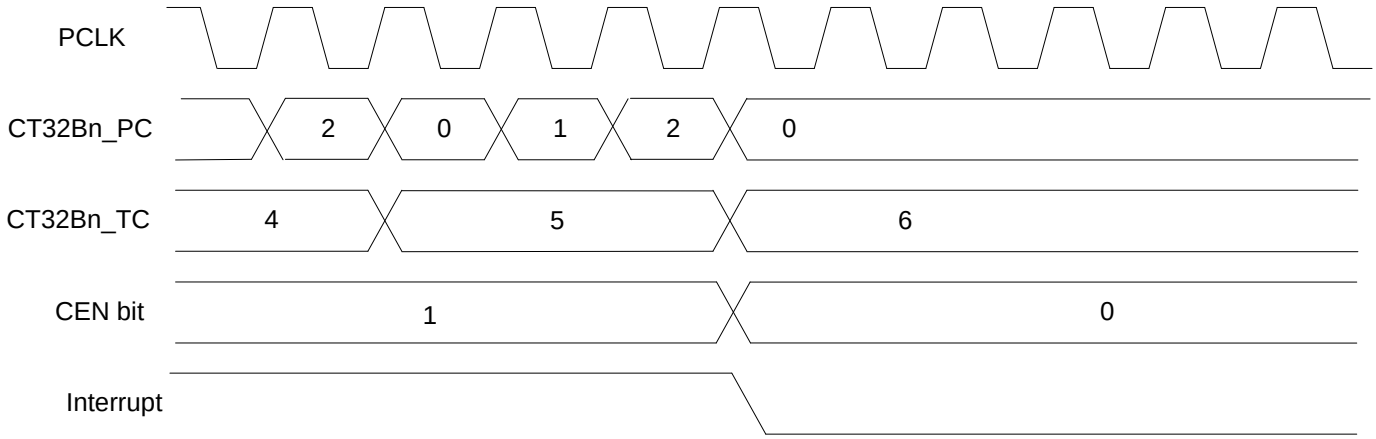


7.5 TIMER OPERATION

The following figure shows a timer configured to reset the count and generate an interrupt on match. The CT32Bn_PRE register is set to 2, and the CT32Bn_MRx register is set to 6. At the end of the timer cycle where the match occurs, the timer count is reset. This gives a full length cycle to the match value. The interrupt indicating that a match occurred is generated in the next clock after the timer reached the match value.

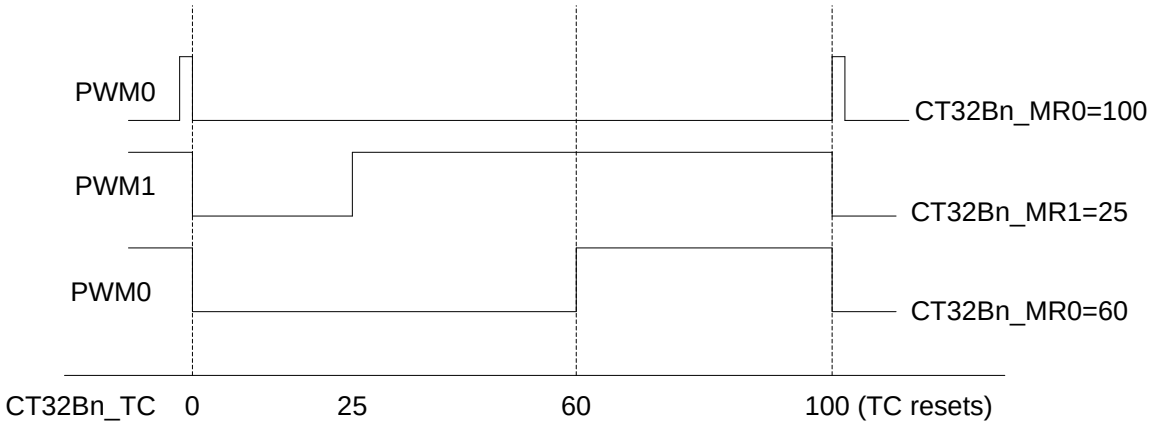


The following figure shows a timer configured to stop and generate an interrupt on match. The CT32Bn_PRE register is set to 2, and the CT32Bn_MRx register is set to 6. In the next clock after the timer reaches the match value, the CEN bit in CT32Bn_TMRCTRL register is cleared, and the interrupt indicating that a match occurred is generated.



7.6 PWM

1. All single edge controlled PWM outputs go LOW at the beginning of each PWM cycle (timer is set to zero) unless their match value in CT32Bn_MR0~3 registers is equal to zero.
2. Each PWM output will go HIGH when its match value is reached. If no match occurs, the PWM output remains continuously LOW.
3. If a match value larger than the PWM cycle length is written to the CT32Bn_MR0~3 registers, and the PWM signal is HIGH already, then the PWM signal will be cleared on the next start of the next PWM cycle.
4. If a match register contains the same value as the timer reset value (the PWM cycle length), then the PWM output will be reset to LOW on the next clock tick. Therefore, the PWM output will always consist of a one clock tick wide positive pulse with a period determined by the PWM cycle length.
5. If a match register is set to zero, then the PWM output will go to HIGH the first time the timer goes back to zero and will stay HIGH continuously.



✷ ***Note: When the match outputs are selected to perform as PWM outputs, the timer reset (MRnRST) and timer stop (MRnSTOP) bits in CT32Bn_MCTRL register must be set to zero except for the match register setting the PWM cycle length. For this register, set the MRnR bit to one to enable the timer reset when the timer value matches the value of the corresponding match register.***

7.7 CT32Bn REGISTERS

Base Address: 0x4000 4000 (CT32B0)
0x4000 6000 (CT32B1)

7.7.1 CT32Bn Timer Control register (CT32Bn_TMRCTRL) (n=0,1)

Address Offset: 0x00

✷ ***Note: CEN bit shall be set at last!***

Bit	Name	Description	Attribute	Reset
31:2	Reserved		R	0
1	CRST	Counter Reset. 0: Disable counter reset. 1: Timer Counter and the Prescale Counter are synchronously reset on the next positive edge of PCLK. This is cleared by HW when the counter reset operation finishes.	R/W	0
0	CEN	Counter Enable 0: Disable Counter. 1: Enable Timer Counter and Prescale Counter for counting.	R/W	0

7.7.2 CT32Bn Timer Counter register (CT32Bn_TC) (n=0,1)

Address Offset: 0x04

The 32-bit Timer Counter is incremented when the Prescale Counter reaches its terminal count. Unless it is reset before reaching its upper limit, the TC will count up through the value 0xFFFFFFFF and then wrap back to the value 0x00000000. This event does not cause an interrupt, but a Match register can be used to detect an overflow if needed.

Bit	Name	Description	Attribute	Reset
31:0	TC[31:0]	Timer Counter	R/W	0

7.7.3 CT32Bn Prescale register (CT32Bn_PRE) (n=0,1)

Address Offset: 0x08

Bit	Name	Description	Attribute	Reset
31:0	PR[31:0]	Prescale max value.	R/W	0

7.7.4 CT32Bn Prescale Counter register (CT32Bn_PC) (n=0,1)

Address Offset: 0x0C

The 32-bit Prescale Counter controls division of PCLK by some constant value before it is applied to the Timer Counter. This allows control of the relationship between the resolution of the timer and the maximum time before the timer overflows. The Prescale Counter is incremented on every PCLK. When it reaches the value stored in the Prescale Register, the Timer Counter is incremented, and the Prescale Counter is reset on the next PCLK. This causes the TC to increment on every PCLK when PR = 0, every 2 PCLKs when PR = 1, etc.

Bit	Name	Description	Attribute	Reset
31:0	PC[31:0]	Prescale Counter	R/W	0

7.7.5 CT32Bn Count Control register (CT32Bn_CNTCTRL) (n=0,1)

Address Offset: 0x10

This register is used to select between Timer and Counter mode, and in Counter mode to select the pin and edges for counting.

When Counter Mode is chosen as a mode of operation, the CAP input (selected by CIS bits) is sampled on every rising edge of the PCLK clock. After comparing two consecutive samples of this CAP input, one of the following four events is recognized: rising edge, falling edge, either of edges or no changes in the level of the selected CAP input. Only if the identified event occurs, and the event corresponds to the one selected by CTM bits in this register, will the Timer Counter register be incremented.

Effective processing of the externally supplied clock to the counter has some limitations. Since two successive rising edges of the PCLK clock are used to identify only one edge on the CAP selected input, the frequency of the CAP input cannot exceed one half of the PCLK clock. Consequently, the duration of the HIGH/LOW levels on the same CAP input in this case cannot be shorter than 1/ (2 x PCLK).

✸ ***Note: If Counter mode is selected in the CNTCTRL register, Capture Control (CAPCTRL) register must be programmed as 0x0.***

Bit	Name	Description	Attribute	Reset
31:4	Reserved		R	0
3:2	CIS[1:0]	Count Input Select. In counter mode (when CTM[1:0] are not 00), these bits select which CAP pin is sampled for clocking. 00: CT32Bn_CAP0 Other: Reserved.	R/W	0
1:0	CTM[1:0]	Counter/Timer Mode. This field selects which rising PCLK edges can increment Timer's Prescale Counter (PC), or clear PC and increment Timer Counter (TC). 00: Timer Mode: every rising PCLK edge 01: Counter Mode: TC is incremented on rising edges on the CAP input selected by CIS bits. 10: Counter Mode: TC is incremented on falling edges on the CAP input selected by CIS bits. 11: Counter Mode: TC is incremented on both edges on the CAP input selected by CIS bits.	R/W	0

7.7.6 CT32Bn Match Control register (CT32Bn_MCTRL) (n=0,1)

Address Offset: 0x14

Bit	Name	Description	Attribute	Reset
31:12	Reserved		R	0
11	MR3STOP	Stop MR3: TC and PC will stop and CEN bit will be cleared if MR3 matches TC. 0: Disable 1: Enable	R/W	0
10	MR3RST	Enable reset TC when MR3 matches TC. 0: Disable 1: Enable	R/W	0
9	MR3IE	Enable generating an interrupt when MR3 matches the value in the TC. 0: Disable 1: Enable	R/W	0
8	MR2STOP	Stop MR2: TC and PC will stop and CEN bit will be cleared if MR2 matches TC. 0: Disable 1: Enable	R/W	0
7	MR2RST	Enable reset TC when MR2 matches TC. 0: Disable 1: Enable	R/W	0

6	MR2IE	Enable generating an interrupt when MR2 matches the value in the TC. 0: Disable 1: Enable	R/W	0
5	MR1STOP	Stop MR1: TC and PC will stop and CEN bit will be cleared if MR1 matches TC. 0: Disable 1: Enable	R/W	0
4	MR1RST	Enable reset TC when MR1 matches TC. 0: Disable 1: Enable	R/W	0
3	MR1IE	Enable generating an interrupt when MR1 matches the value in the TC. 0: Disable 1: Enable	R/W	0
2	MR0STOP	Stop MR0: TC and PC will stop and CEN bit will be cleared if MR0 matches TC. 0: Disable 1: Enable	R/W	0
1	MR0RST	Enable reset TC when MR0 matches TC. 0: Disable 1: Enable	R/W	0
0	MR0IE	Enable generating an interrupt when MR0 matches the value in the TC. 0: Disable 1: Enable	R/W	0

7.7.7 CT32Bn Match register 0~3 (CT32Bn_MR0~3) (n=0,1)

Address Offset: 0x18, 0x1C, 0x20, 0x24

The Match register values are continuously compared to the Timer Counter (TC) value. When the two values are equal, actions can be triggered automatically. The action possibilities are to generate an interrupt, reset the Timer Counter, or stop the timer. Actions are controlled by the settings in the CT32Bn_MCTRL register.

Bit	Name	Description	Attribute	Reset
31:0	MR[31:0]	Timer counter match value	R/W	0

7.7.8 CT32Bn Capture Control register (CT32Bn_CAPCTRL) (n=0,1)

Address Offset: 0x28

The Capture Control register is used to control whether the Capture register is loaded with the value in the Counter/timer when the capture event occurs, and whether an interrupt is generated by the capture event. Setting both the rising and falling bits at the same time is a valid configuration, resulting in a capture event for both edges.

✸ ***Note: HW will switch I/O Configuration directly when CAP0EN =1.***

Bit	Name	Description	Attribute	Reset
31:7	Reserved		R	0
6:5	CAP0EN	Capture 0 function enable bit 0: Disable 1: Enable Capture 0 function for external Capture pin. 2~3: Reserved.	R/W	0
4	CAP0IE	Interrupt on CT32Bn_CAP0 signal event: a CAP0 load due to a CT32Bn_CAP0 signal event will generate an interrupt. 0: Disable 1: Enable	R/W	0
3:2	CAP0FE	Capture/Reset on CT32Bn_CAP0 signal falling edge. 0: Disable 1: Enable a sequence of 1 then 0 on CT32Bn_CAP0 signal will cause CAP0 to be loaded with the contents of TC. 2: Enable a sequence of 1 then 0 on CT32Bn_CAP0 signal will reset the TC. 3: Reserved.	R/W	0

1:0	CAP0RE	Capture/Reset on CT32Bn_CAP0 signal rising edge. 0: Disable 1: Enable a sequence of 0 then 1 on CT32Bn_CAP0 signal will cause CAP0 to be loaded with the contents of TC. 2: Enable a sequence of 0 then 1 on CT32Bn_CAP0 signal will reset the TC. 3: Reserved.	R/W	0

7.7.9 CT32Bn Capture 0 register (CT32Bn_CAP0) (n=0,1)

Address Offset: 0x2C

Each Capture register is associated with a device pin and may be loaded with the counter/timer value when a specified event occurs on that pin. The settings in the Capture Control register determine whether the capture function is enabled, and whether a capture event happens on the rising edge of the associated pin, the falling edge, or on both edges.

Bit	Name	Description	Attribute	Reset
31:0	CAP0[31:0]	Timer counter capture value	R	0

7.7.10 CT32Bn External Match register (CT32Bn_EM) (n=0,1)

Address Offset: 0x30

The External Match register provides both control and status of the external match pins CT32Bn_PWMCTRL[1:0]. If the match outputs are configured as PWM output, the function of the external match registers is determined by the PWM rules.

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:6	EMC1[1:0]	Determines the functionality of CT32Bn_PWM1. 00: Do Nothing. 01: CT32Bn_PWM1 pin is LOW 10: CT32Bn_PWM1 pin is HIGH. 11: Toggle CT32Bn_PWM1.	R/W	0
5:4	EMC0[1:0]	Determines the functionality of CT32Bn_PWM0. 00: Do Nothing. 01: CT32Bn_PWM0 pin is LOW 10: CT32Bn_PWM0 pin is HIGH 11: Toggle CT32Bn_PWM0.	R/W	0
3:2	Reserved		R	0
1	EM1	When the TC and MR1 are equal, this bit will act according to EMC1 bits, and also drive the state of CT32Bn_PWM1 output.	R/W	0
0	EM0	When the TC and MR0 are equal, this bit will act according to EMC0 bits, and also drive the state of CT32Bn_PWM0 output.	R/W	0

7.7.11 CT32Bn PWM Control register (CT32Bn_PWMCTRL) (n=0,1)

Address Offset: 0x34

The PWM Control register is used to configure the match outputs as PWM outputs. Each match output can be independently set to perform either as PWM output or as match output whose function is controlled by CT32Bn_EM register.

For each timer, a maximum of three single edge controlled PWM outputs can be selected on the CT32Bn_PWMCTRL[3:0] outputs. One additional match register determines the PWM cycle length. When a match occurs in any of the other match registers, the PWM output is set to HIGH. The timer is reset by the match register that is configured to set the PWM cycle length. When the timer is reset to zero, all currently HIGH match outputs configured as PWM outputs are cleared.

Bit	Name	Description	Attribute	Reset
31:22	Reserved		R	0
21	PWM1IOEN	CT32Bn_PWM1/GPIO selection bit	R/W	0

		0: CT32Bn_PWM1 pin act as GPIO 1: CT32Bn_PWM1 pin act as match output, and output signal depends on PWM1EN bit.		
20	PWM0IOEN	CT32Bn_PWM0/GPIO selection bit 0: CT32Bn_PWM0 pin act as GPIO 1: CT32Bn_PWM0 pin act as match output, and output signal depends on PWM0EN bit.	R/W	0
19:2	Reserved		R	0
1	PWM1EN	PWM1 enable 0: CT32Bn_PWM1 is controlled by EM1. 1: PWM mode is enabled for CT32Bn_PWM1.	R/W	0
0	PWM0EN	PWM0 enable 0: CT32Bn_PWM0 is controlled by EM0. 1: PWM mode is enabled for CT32Bn_PWM0.	R/W	0

7.7.12 CT32Bn Timer Raw Interrupt Status register (CT32Bn_RIS) (n=0,1)

Address Offset: 0x38

This register indicates the raw status for Timer/PWM interrupts. A Timer/PWM interrupt is sent to the interrupt controller if the corresponding bit in the CT16Bn_IE register is set.

Bit	Name	Description	Attribute	Reset
31:5	Reserved		R	0
4	CAP0IF	Interrupt flag for capture channel 0. 0: No interrupt on CAP0 1: Interrupt requirements met on CAP0.	R	0
3	MR3IF	Interrupt flag for match channel 3. 0: No interrupt on match channel 3 1: Interrupt requirements met on match channel 3.	R	0
2	MR2IF	Interrupt flag for match channel 2. 0: No interrupt on match channel 2 1: Interrupt requirements met on match channel 2.	R	0
1	MR1IF	Interrupt flag for match channel 1. 0: No interrupt on match channel 1 1: Interrupt requirements met on match channel 1.	R	0
0	MR0IF	Interrupt flag for match channel 0. 0: No interrupt on match channel 0 1: Interrupt requirements met on match channel 0.	R	0

7.7.13 CT32Bn Timer Interrupt Clear register (CT32Bn_IC) (n=0,1)

Address Offset: 0x3C

Bit	Name	Description	Attribute	Reset
31:5	Reserved		R	0
4	CAP0IC	0: No effect 1: Clear CAP0IF bit	W	0
3	MR3IC	0: No effect 1: Clear MR3IF bit	W	0
2	MR2IC	0: No effect 1: Clear MR2IF bit	W	0
1	MR1IC	0: No effect 1: Clear MR1IF bit	W	0
0	MR0IC	0: No effect 1: Clear MR0IF bit	W	0

8 WATCHDOG TIMER (WDT)

8.1 OVERVIEW

The purpose of the Watchdog is to reset the MCU within a reasonable amount of time if it enters an erroneous state. When enabled, the Watchdog will generate a system reset or interrupt if the user program fails to "feed" (or reload) the Watchdog within a predetermined amount of time.

The Watchdog consists of a divide by 128 fixed pre-scaler and an 8-bit counter. The clock is fed to the timer via a pre-scaler. The timer decrements when clocked. The minimum value from which the counter decrements is 0x01. Hence the minimum Watchdog interval is (T_{WDT_PCLK} × 128 × 1) and the maximum Watchdog interval is (T_{WDT_PCLK} × 128 × 256).

The Watchdog should be used in the following manner:
1. Select the clock source for the watchdog timer with WDTCLKSEL register.
2. Set the prescale value for the watchdog clock with WDTPRE bits in APB Clock Prescale register 1 (SYS1_APBCP1) register.
3. Set the Watchdog timer constant reload value in WDT_TC register.
4. Enable the Watchdog and setup the Watchdog timer operating mode in WDT_CFG register.
5. The Watchdog should be fed again by writing 0x55AA to WDT_FEED register before the Watchdog counter underflows to prevent reset or interrupt.

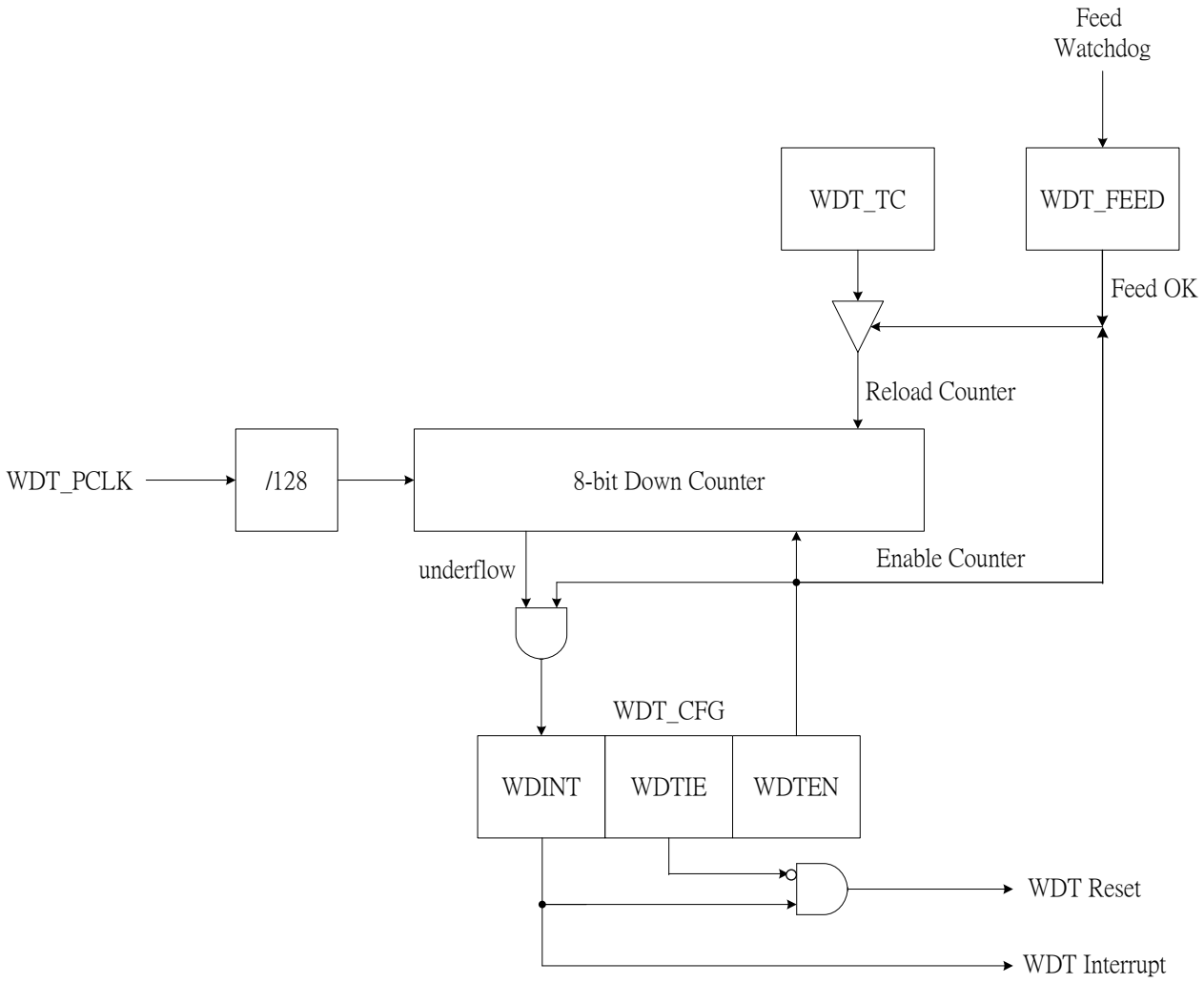
When the watchdog is started by setting the WDTEN in WDT_CFG register, the time constant value is loaded in the watchdog counter and the counter starts counting down. When the Watchdog is in the reset mode and the counter underflows, the CPU will be reset, loading the stack pointer and program counter from the vector table as in the case of external reset. Whenever the value 0x55AA is written in WDT_FEED register, the WDT_TC value is reloaded in the watchdog counter and the watchdog reset or interrupt is prevented.

The watchdog timer block uses two clocks: HCLK and WDT_PCLK. HCLK is used for the AHB accesses to the watchdog registers and is derived from the system clock. The WDT_PCLK is used for the watchdog timer counting. Several clocks can be used as a clock source for WDT_PCLK clock: IHRC, ILRC, ELS X'tal, and HCLK.

The clock to the watchdog register block can be disabled in AHB Clock Enable register (SYS1_AHBCLKEN) register for power savings.

Watchdog reset or interrupt will occur any time the watchdog is running and has an operating clock source.

8.2 BLOCK DIAGRAM



8.3 WDT REGISTERS

Base Address: 0x4001 0000

8.3.1 Watchdog Configuration register (WDT_CFG)

Address Offset: 0x00

The WDT_CFG register controls the operation of the Watchdog through the combination of WDTEN and WDTIE bits. This register indicates the raw status for Watchdog Timer interrupts. A WDT interrupt is sent to the interrupt controller if both the WDINT bit and the WDTIE bit are set.

Bit	Name	Description	Attribute	Reset
31:16	WDKEY	Watchdog register key. Read as 0. When writing to the register you must write 0x5AFA to WDKEY, otherwise behavior of writing to the register is ignored.	W	0
15:3	Reserved		R	0
2	WDTINT	Watchdog interrupt flag <Read> 0: Watchdog does not cause an interrupt. 1: Watchdog timeout and causes an interrupt (Only when WDTIE =1). <Write> 0: Clear this flag. SW shall feed Watchdog before clearing.	R/W	0
1	WDTIE	Watchdog interrupt enable 0: Watchdog timeout will cause a chip reset. (Watchdog reset mode) Watchdog counter underflow will reset the MCU, and will clear the WDINT flag. 1: Watchdog timeout will cause an interrupt. (Watchdog interrupt mode)	R/W	0
0	WDTEN	Watchdog enable 0: Disable 1: Enable. When enable the watchdog, the WDT_TC value is loaded in the watchdog counter.	R/W	0

8.3.2 Watchdog Clock Source register (WDT_CLKSOURCE)

Address Offset: 0x04

Bit	Name	Description	Attribute	Reset
31:16	WDKEY	Watchdog register key. Read as 0. When writing to the register you must write 0x5AFA to WDKEY, otherwise behavior of writing to the register is ignored.	W	0
15:2	Reserved		R	0
1:0	CLKSEL[1:0]	Selected Watchdog clock source. 00: IHRC oscillator 01: HCLK 10: ILRC oscillator 11: ELS X'TAL	R/W	0

8.3.3 Watchdog Timer Constant register (WDT_TC)

Address Offset: 0x08

The WDT_TC register determines the time-out value. Every time a feed sequence occurs the WDT_TC content is reloaded in to the Watchdog timer. It's an 8-bit counter. Thus the time-out interval is T_{WDT_PCLK} × 128 x 1 ~ T_{WDT_PCLK} × 128 x 256.

Watchdog overflow time = (0.02us x 1) x 128 x 1 ~ (0.0625ms x 32) x 128 x 256
= 2.56us ~ 65536ms

Bit	Name	Description	Attribute	Reset
31:16	WDKEY	Watchdog register key. Read as 0. When writing to the register you must write 0x5AFA to WDKEY, otherwise behavior of writing to the register is ignored.	W	0

15:8	Reserved		R	0
7:0	TC[7:0]	Watchdog timer constant reload value = TC[7:0]+1 0000 0000 : Timer constant = 1 0000 0001 : Timer constant = 2 ……. ……. 1111 1110 : Timer constant = 255 1111 1111 : Timer constant = 256	R/W	0xFF

8.3.4 Watchdog Feed register (WDT_FEED)

Address Offset: 0x0C

Bit	Name	Description	Attribute	Reset
31:16	WDKEY	Watchdog register key. Read as 0. When writing to the register you must write 0x5AFA to WDKEY, otherwise behavior of writing to the register is ignored.	W	0
15:0	FV[15:0]	Feed value (Read as 0x0) 0x55AA: The watchdog is fed, and the WDT_TC value is reloaded in the watchdog counter.	W	0

9 REAL-TIME CLOCK (RTC)

9.1 OVERVIEW

The RTC is an independent timer. The RTC provides a set of continuously running counters which can be used to provide a clock-calendar function with suitable software.
The counter values can be written to set the current time/date of the system.

9.2 FEATURES

- Programmable prescale value: division factor up to 2^{20}
- 32-bit programmable counter for long-term measurement
- The RTC clock source could be any of the following:
  - EHS XTAL clock divided by 128
  - ELS X'TA
  - ILRC
- Reset sources of the RTC Core (Prescale value, Alarm, Counter and Divider):
  - "Cold" boot
  - DPDWAKEUP
- Three dedicated enabled interrupt lines:
  - Alarm interrupt: generating a software programmable alarm interrupt.
  - Seconds interrupt: generating a periodic interrupt signal with a programmable period length (up to 1 second).
  - Overflow interrupt: to detect when the internal programmable counter rolls over to zero.

9.3 FUNCTIONAL DESCRIPTION

9.3.1 INTRODUCTION

RTC core includes a 20-bit preload value (RTC SECCNTV). Every TR_CLK period, the RTC generates an interrupt (Second Interrupt) if it is enabled in RTC_IE register. The second block is a 32-bit programmable counter that can be initialized to the current system time. The system time is incremented at the TR_CLK rate and compared with a programmable date (stored in the RTC_ALR register) in order to generate an alarm interrupt, if enabled in RTC_IE register.

9.3.2 RESET RTC REGISTERS

The RTC_SECCNTV, RTC_ALMCNTV, RTC_SECCNT, and RTC_ALMCNT registers are reset by "cold" boot or DPDWAKEUP reset.

9.3.3 RTC FLAG ASSERTION

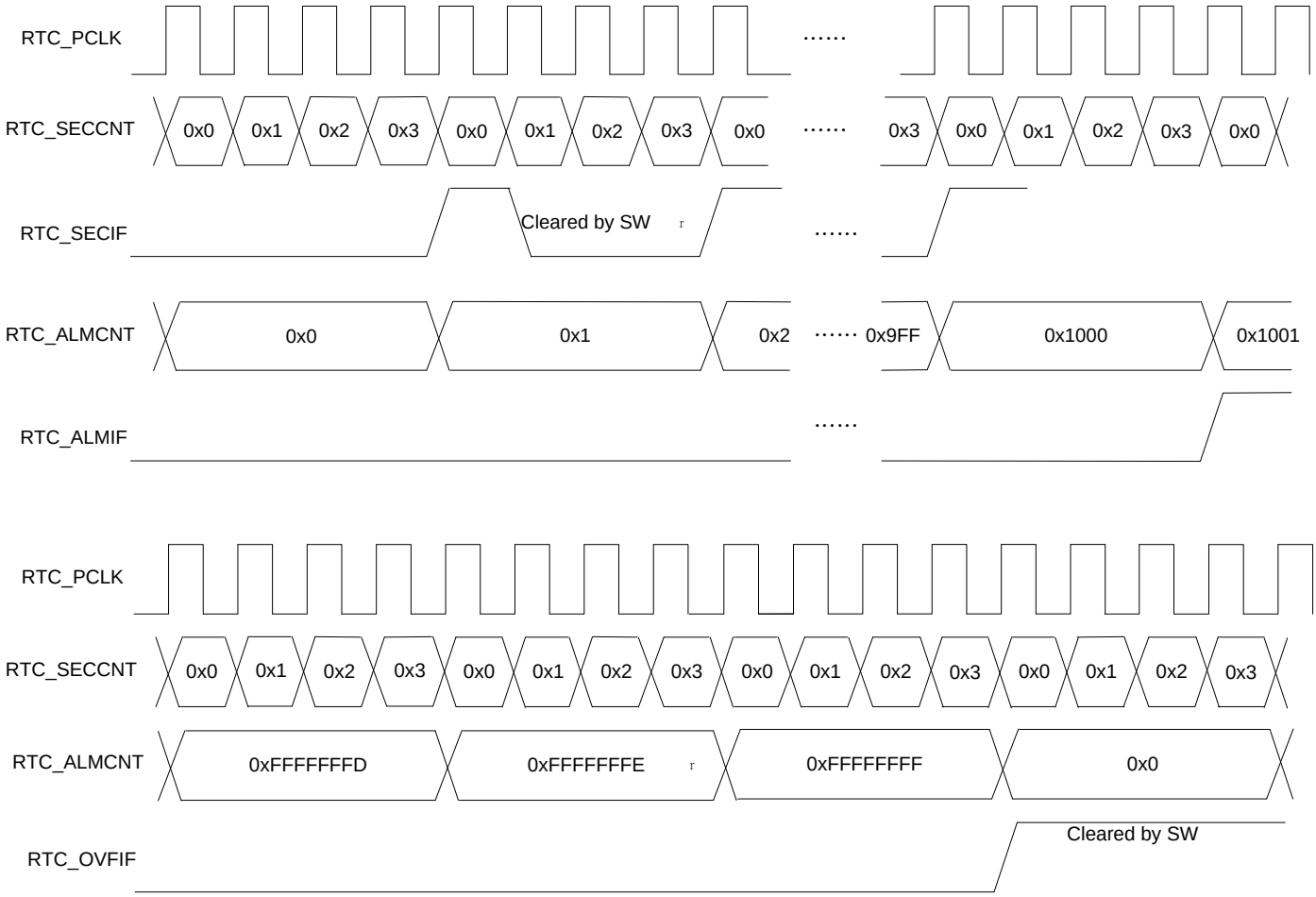
The RTC Second interrupt flag (SECIF) is asserted on each RTC Core clock cycle before the update of the RTC Counter.

The RTC Overflow interrupt flag (OVFIF) is asserted on the last RTC Core clock cycle before the counter reaches 0x0.

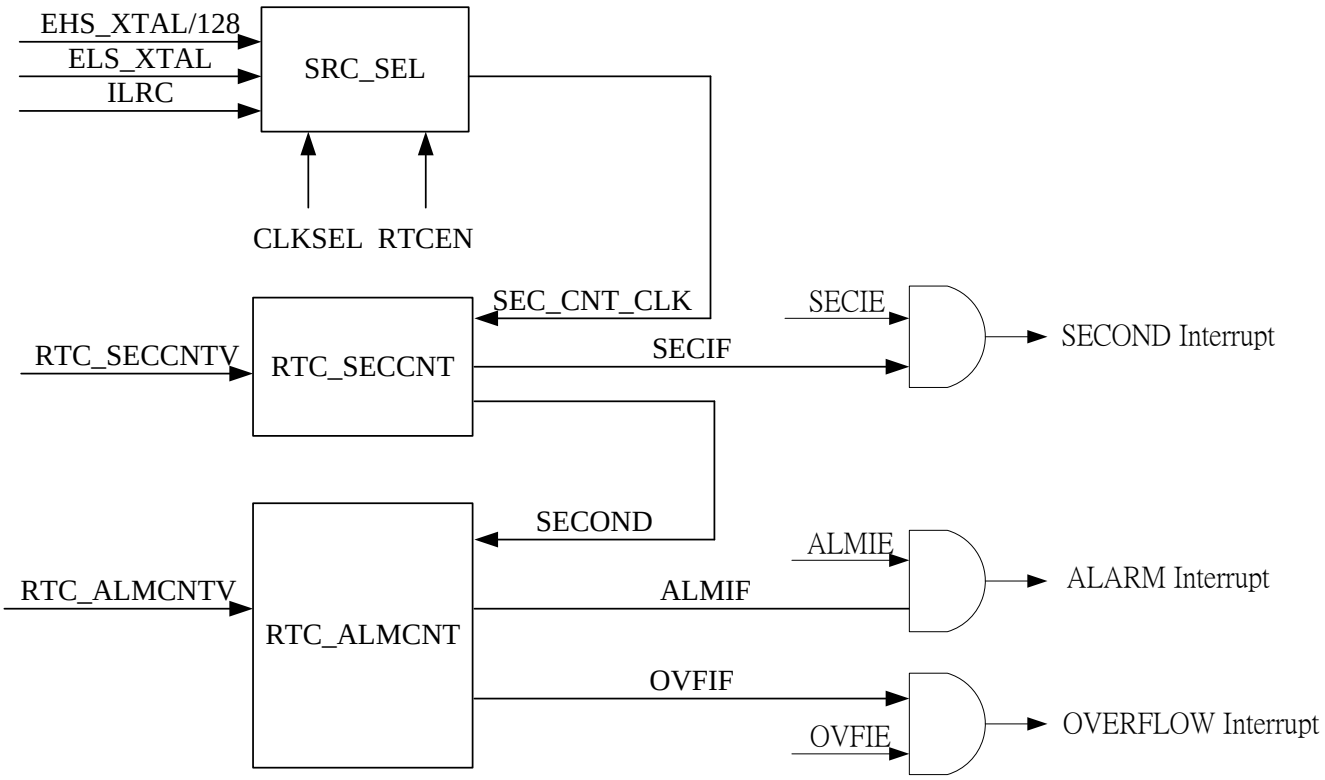
The RTC Alarm interrupt flag (ALMIF) are asserted on the last RTC Core clock cycle before the counter reaches the RTC Alarm counter reload value stored in the Alarm register.

9.3.4 RTC OPERATION

The following figure shows the RTC waveform when it is configured with RTC_SECCNTV=3, RTC_ALMCNTV=0x1000.



9.4 BLOCK DIAGRAM



9.5 RTC REGISTERS

Base Address: 0x4001 2000

9.5.1 RTC Control register (RTC_CTRL)

Address offset: 0x00

✸ ***Note: RTCEN bit shall be set at last!***

Bit	Name	Description	Attribute	Reset
31:1	Reserved		R	0
0	RTCEN	RTC enable bit 0: Disable 1: Enable. Reset SEC_CNT and ALM_CNT.	R/W	0

9.5.2 RTC Clock Source Select register (RTC_CLKS)

Address offset: 0x04

✸ ***Note: SW shall disable RTC (RTCEN=0) when changing the value of this register.***

Bit	Name	Description	Attribute	Reset
31:2	Reserved		R	0
1:0	CLKSEL[1:0]	RTC clock source selection. HW will reset SEC_CNT and ALM_CNT when changing the value. 00: ILRC 01: ELS X'TAL 10: Reserved 11: EHS X'TAL clock / 128	R/W	0

9.5.3 RTC Interrupt Enable register (RTC_IE)

Address offset: 0x08

Bit	Name	Description	Attribute	Reset
31:3	Reserved		R	0
2	OVFIE	Overflow interrupt enable 0: Disable 1: Enable	R/W	0
1	ALMIE	Alarm interrupt enable 0: Disable 1: Enable	R/W	0
0	SECIE	Second interrupt enable 0: Disable 1: Enable	R/W	0

9.5.4 RTC Raw Interrupt Status register (RTC_RIS)

Address offset: 0x0C

Bit	Name	Description	Attribute	Reset
31:3	Reserved		R	0
2	OVFIF	Overflow interrupt flag This bit is set by HW when ALM_CNT overflows (ALM_CNT counts from 0xFFFFFFFF to 0x0). An interrupt is generated if OVFIE=1. 0: Overflow not detected 1: 32-bit programmable counter overflow occurred.	R	0

1	ALMIF	Alarm interrupt flag This bit is set by HW when ALM_CNT=ALM_CNTV. An interrupt is generated if ALRIE=1. 0: Alarm not detected 1: Alarm detected.	R	0
0	SECIF	Second interrupt flag This bit is set by HW when SEC_CNT=SEC_CNTV. An interrupt is generated if SECIE=1. 0: Second flag condition not met. 1: Second flag condition met.	R	0

9.5.5 RTC Interrupt Clear register (RTC_IC)

Address offset: 0x10

Bit	Name	Description	Attribute	Reset
31:3	Reserved		R	0
2	OVFIC	0: No effect 1: Clear OVFIF bit	W	0
1	ALMIC	0: No effect 1: Clear ALMIF bit	W	0
0	SECIC	0: No effect 1: Clear SECIF bit	W	0

9.5.6 RTC Second Counter Reload Value register (RTC_SECCNTV)

Address offset: 0x14
Reset value: 0x8000

Bit	Name	Description	Attribute	Reset
31:20	Reserved		R	0
19:0	SECCNTV[19:0]	RTC second counter reload value. Update this register will reset RTC_SECCNT and RTC_ALMCNT registers. The zero value is not recommended, and will be replaced with default value (0x8000) by HW.	R/W	0x8000

9.5.7 RTC Second Count register (RTC_SECCNT)

Address offset: 0x18

The RTC core has one 32-bit programmable counter, and this register keeps the current counting value of this counter.

Bit	Name	Description	Attribute	Reset
31:0	SECCNT[31:0]	RTC second counter The current value of the RTC counter.	R	0

9.5.8 RTC Alarm Counter Reload Value register (RTC_ALMCNTV)

Address offset: 0x1C
Reset value: 0xFFFFFFFF

Bit	Name	Description	Attribute	Reset
31:0	ALMCNTV[31:0]	RTC alarm counter reload value. Update this register will reset ALMCNT. The zero value is not recommended, and will be replaced with default value (0xFFFFFFFF) by HW.	R/W	0xFFFFFFFF

9.5.9 RTC Alarm Count register (RTC_ALMCNT)

Address offset: 0x20

Bit	Name	Description	Attribute	Reset
31:0	ALMCNT[31:0]	RTC alarm counter The current value of the RTC alarm counter.	R	0x0

10 SPI/SSP

10.1 OVERVIEW

The SSP is a Synchronous Serial Port controller capable of operation on a SPI, and 4-wire SSI bus. It can interact with multiple masters and slaves on the bus. Only a single master and a single slave can communicate on the bus during a given data transfer. Data transfers are in principle full duplex, with frames of 4 to 16 bits of data flowing from the master to the slave and from the slave to the master. In practice it is often the case that only one of these data flows carries meaningful data.

10.2 FEATURES

- Compatible with Motorola SPI, and 4-wire TI SSI bus.
- Synchronous Serial Communication.
- Supports master or slave operation.
- 8-frame FIFO for both transmitter and receiver.
- 4-bit to 16-bit frame.
- Maximum SPI speed of 25 Mbps (master) or 6 Mbps (slave) in SSP mode.
- Data transfer format is from MSB or LSB controlled by register.
- The start phase of data sampling location selection is 1^{st}-phase or 2^{nd}-phase controlled register.

10.3 PIN DESCRIPTION

Pin Name	Type	Description	GPIO Configuration
SCKn	O	SSP Serial clock (Master)	
	I	SSP Serial clock (Slave)	Depends on GPIOn_CFG
SELn	O	SPI Slave Select/SSI Frame Sync (Master)	
	I	SSP Slave Select (Slave)	Depends on GPIOn_CFG
MISOn	I	Master In Slave Out (Master)	Depends on GPIOn_CFG
	O	Master In Slave Out (Slave)	
MOSIn	O	Master Out Slave In (Master)	
	I	Master Out Slave In (Slave)	Depends on GPIOn_CFG

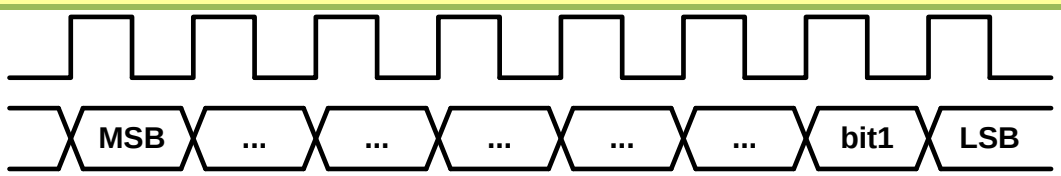
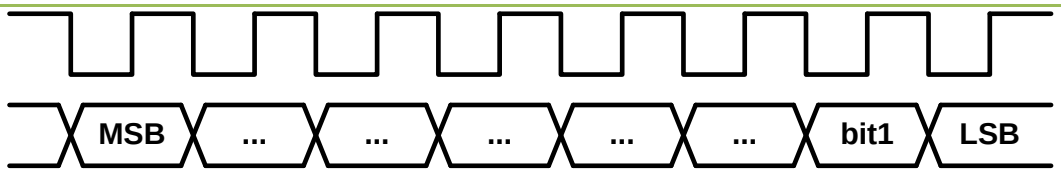
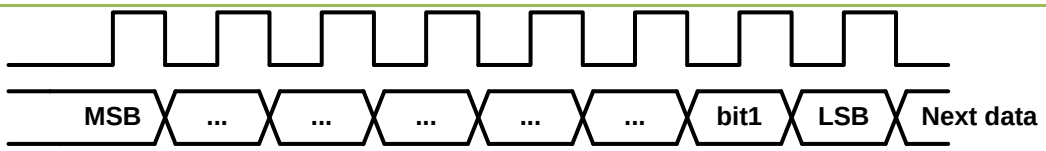
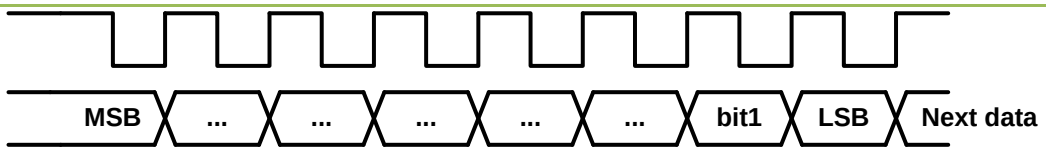
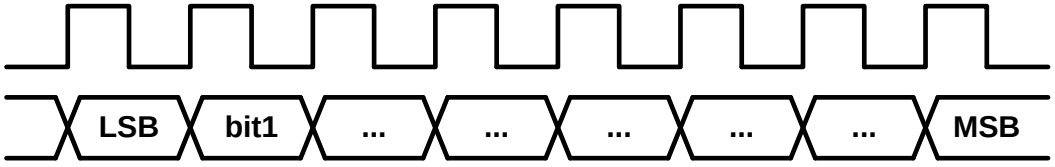
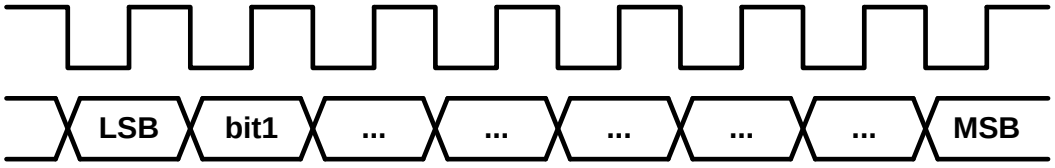
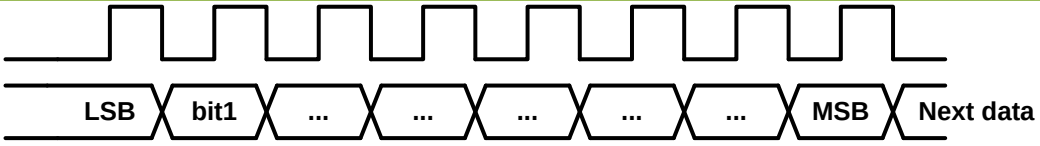
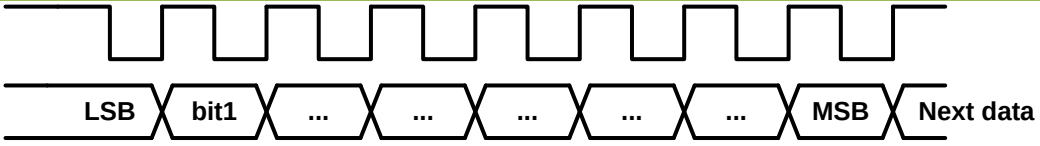
10.4 INTERFACE DESCRIPTION

10.4.1 SPI

The SPI interface is a 4-wire interface where the SEL signal behaves as a slave select. The main feature of the SPI format is that the inactive state and phase of the SCK signal are programmable through the CPOL and CPHA bits in SSPn_CTRL1 register.

When the “CPOL” clock polarity control bit is LOW, it produces a steady state low value on the SCK pin. If the CPOL clock polarity control bit is HIGH, a steady state high value is placed on the CLK pin when data is not being transferred. The “CPHA” clock phase bit controls the phase of the clock on which data is sampled. When CPHA=1, the SCK first edge is for data transition, and receive and transmit data is at SCK 2nd edge. When CPHA=0, the 1st bit is fixed already, and the SCK first edge is to receive and transmit data.

The SPI data transfer timing as following figure:

MLSB	CPOL	CPHA	SCK Idle Status	Diagrams
0	0	1	Low	
0	1	1	High	
0	0	0	Low	
0	1	0	High	
1	0	1	Low	
1	1	1	High	
1	0	0	Low	
1	1	0	High	

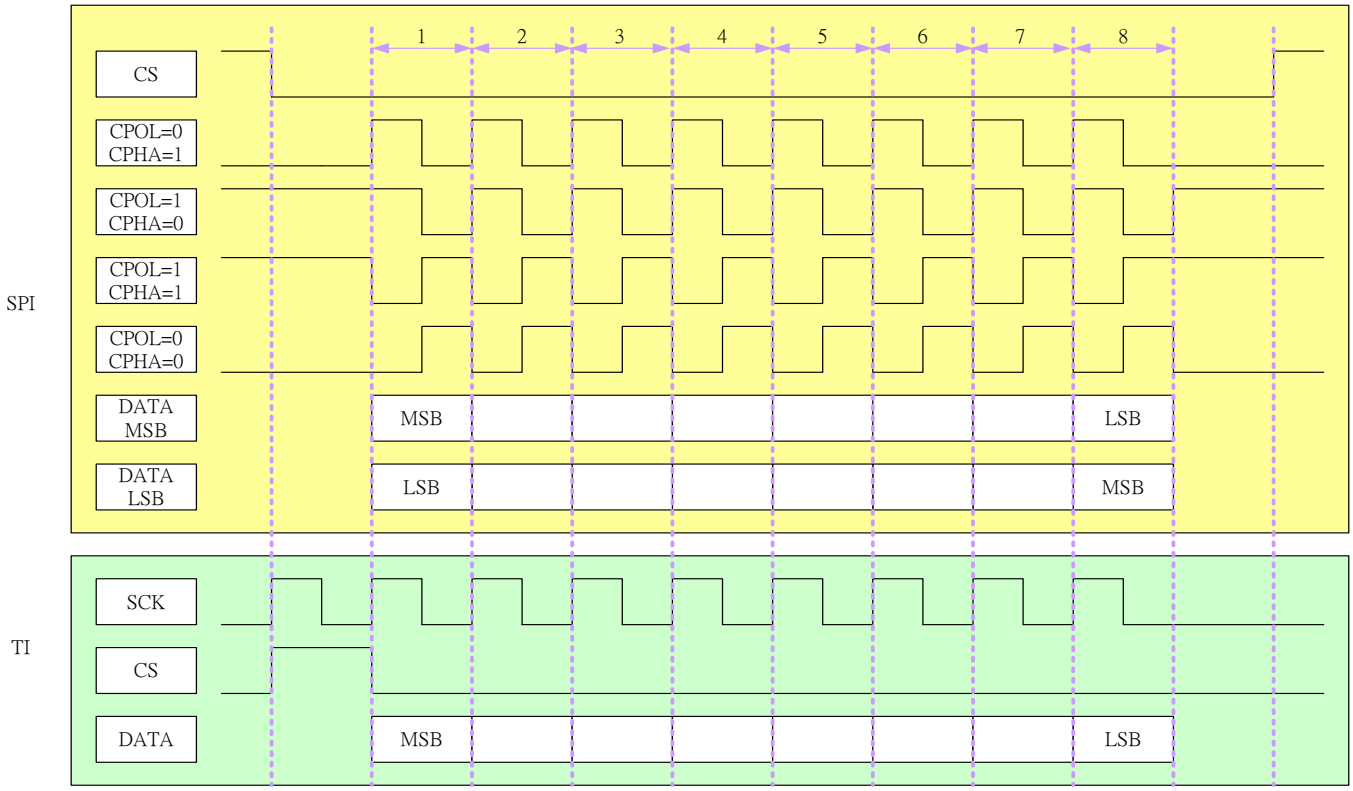
10.4.2 SSI

For device configured as a master in this mode, SCK and CS are forced LOW, and the transmit data line DATA is in 3-state mode whenever the SSP hardware is idle.

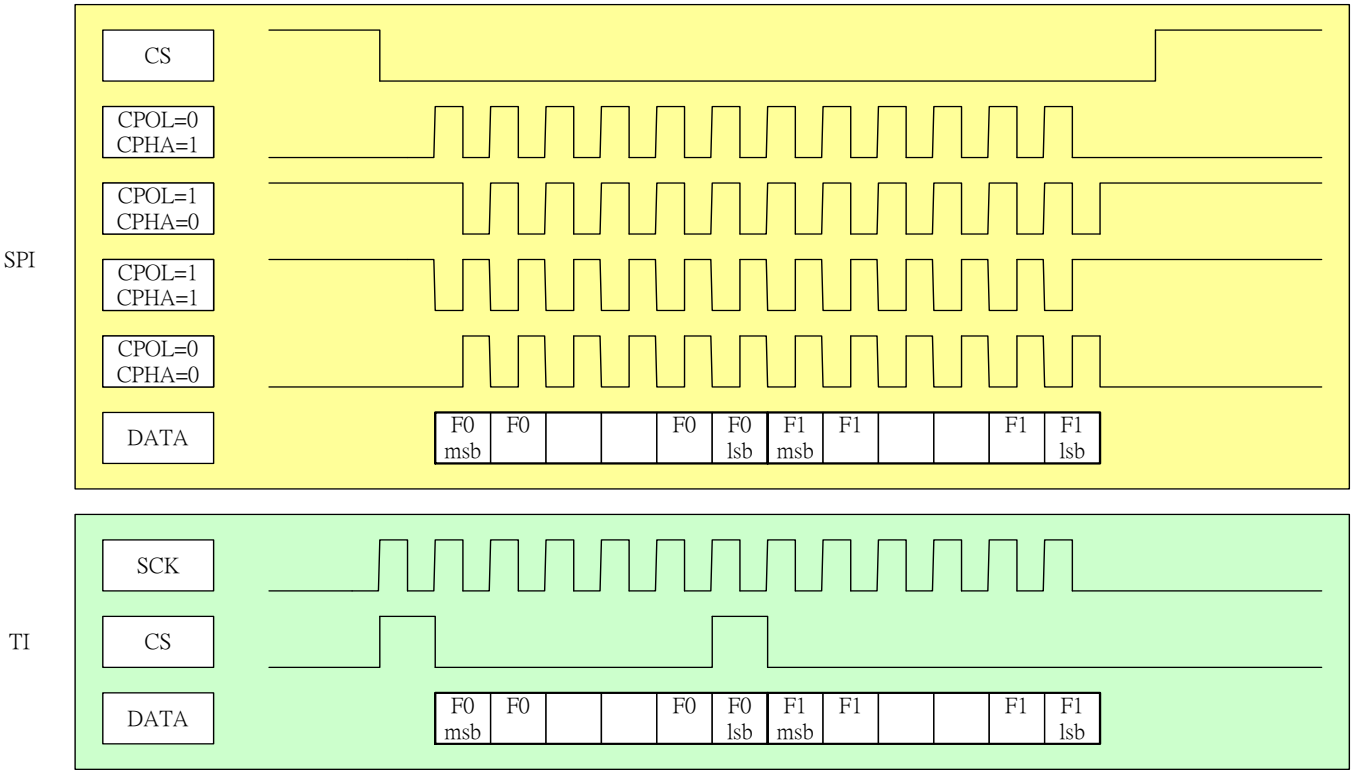
Once the bottom entry of the transmit FIFO contains data, CS is pulsed HIGH for one SCK period. The value to be transmitted is also transferred from the transmit FIFO to the serial shift register of the shifted out on the DATA pin. Likewise, the MSB of the received data is shifted onto the DATA pin by the off-chip serial slave device.
Both the SSP hardware and the off-chip serial slave device then clock each data bit into their serial shifter on the falling edge of each SCK. The received data is transferred from the serial shifter to the receive FIFO on the first rising edge of SCK after the LSB has been latched.

10.4.3 COMMUNICATION FLOW

10.4.3.1 SINGLE-FRAME



10.4.3.2 MULTI-FRAME



10.5 Auto-SEL (Auto-CS)

The Auto-SEL function is enabled by default, and Auto-SEL data flow is controlled by hardware. If Auto-SEL function is enabled, the SPI's hardware controls the SEL output of the SPI.

If Auto-SEL function is disabled by setting the SELDIS bit, the SELCTRL bit controls the SEL output of the SPI. If Auto-SEL function is enabled, hardware controls the SEL output, and the actual value of SEL will be copied in the SELCTRL Control bit of the SPI. As long as Auto-SEL is enabled, the value of the SELCTRL Control bit is read-only for software.

10.6 SSP REGISTERS

Base Address: 0x4001 C000 (SSP0)
0x4005 8000 (SSP1)

10.6.1 SSP n Control register 0 (SSPn_CTRL0) (n=0, 1)

Address Offset:0x00

✸ ***Note:***
- ***1. Must reset SSP FSM with FRESET[1:0] after changing any configuration of SSP when SSPEN = 1.***
- ***2. HW will switch I/O configurations refer to FORMAT bit directly when SSPEN = 1.***

Bit	Name	Description	Attribute	Reset
31:20	Reserved		R	0
19	SELCTRL	Source for SEL pin. For SPI mode only. 0: SEL pin is low level. 1: SEL pin is high level.	R/W	1
18	SELDIS	Auto-SEL disable bit. For SPI mode only. 0: Enable Auto-SEL flow control. 1: Disable Auto-SEL flow control.	R/W	0
17:15	RXFIFOTH[2:0]	RX FIFO Threshold level 0: RX FIFO threshold level = 0 1: RX FIFO threshold level = 1 … … n: RX FIFO threshold level = n	R/W	000b
14:12	TXFIFOTH[2:0]	TX FIFO Threshold level 0: TX FIFO threshold level = 0 1: TX FIFO threshold level = 1 … … n: TX FIFO threshold level = n	R/W	000b
11:8	DL[3:0]	Data length = DL[3:0] + 1 0000~0001: Reversed 0010: data length = 3 … … 1110: data length = 15 1111: data length = 16	R/W	1111b
7:6	FRESET[1:0]	SSP FSM and FIFO Reset bit 00: No effect 01: Reserved 10: Reserved 11: Reset finite state machine and FIFO. (BUF_BUSY = 0, data in shift BUF is cleared, TX_EMPTY = 1, TX_FULL = 0, RX_EMPTY = 1, RX_FULL = 0, and data in FIFO is cleared). This bit will be cleared by HW automatically.	W	0
5	Reserved		R	0
4	FORMAT	Interface format. 0: SPI 1: SSI	R/W	0
3	MS	Master/Slave selection bit 0: Act as Master. 1: Act as Slave.	R/W	0
2	SDODIS	Slave data output disable bit (ONLY used in slave mode) 0: Enable slave data output. 1: Disable slave data output. (MISO=0)	R/W	0
1	LOOPBACK	Loop back mode enable 0: Disable 1: Data input from data output	R/W	0

0	SSPEN	SSP enable bit 0: Disable 1: Enable.	R/W	0

10.6.2 SSP n Control register 1 (SSPn_CTRL1) (n=0, 1)

Address Offset: 0x04

Bit	Name	Description	Attribute	Reset
31:3	Reserved		R	0
2	CPHA	Clock phase for edge sampling. 0: Data changes at clock falling edge, latches at clock rising edge when CPOL = 0; Data changes at clock rising edge, latches at clock falling edge when CPOL = 1. 1: Data changes at clock rising edge, latches at clock falling edge when CPOL = 0; Data changes at clock falling edge, latches at clock rising edge when CPOL = 1.	R/W	0
1	CPOL	Clock polarity selection bit 0: SCK idles at Low level. 1: SCK idles at High level.	R/W	0
0	MLSB	MSB/LSB selection bit 0: MSB transmit first. 1: LSB transmit first.	R/W	0

10.6.3 SSP n Clock Divider register (SSPn_CLKDIV) (n=0, 1)

Address Offset: 0x08

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	DIV[7:0]	SSPn clock divider 0: SCK = SSPn_PCLK / 2 1: SCK = SSPn_PCLK / 4 2: SCK = SSPn_PCLK / 6 X: SCK = SSPn_PCLK / (2X+2)	R/W	0

10.6.4 SSP n Status register (SSPn_STAT) (n=0, 1)

Address Offset: 0x0C

Bit	Name	Description	Attribute	Reset
31:7	Reserved		R	0
6	RXFIFOTHF	RX FIFO threshold flag 0: Data in RX FIFO ≤ RXFIFOTH 1: Data in RX FIFO > RXFIFOTH	R	0
5	TXFIFOTHF	TX FIFO threshold flag 0: Data in TX FIFO > TXFIFOTH 1: Data in TX FIFO ≤ TXFIFOTH	R	1
4	BUSY	Busy flag. 0: SSP controller is idle. 1: SSP controller is transferring.	R	0
3	RX_FULL	RX FIFO full flag. 0: RX FIFO is NOT full. 1: RX FIFO is full.	R	0
2	RX_EMPTY	RX FIFO empty flag 0: RX FIFO is NOT empty. 1: RX FIFO is empty.	R	1
1	TX_FULL	TX FIFO full flag. 0: TX FIFO is NOT full. 1: TX FIFO is full.	R	0
0	TX_EMPTY	TX FIFO empty flag 0: TX FIFO is NOT empty. In Master mode, the transmitter will begin to transmit automatically. 1: TX FIFO is empty.	R	1

10.6.5 SSP n Interrupt Enable register (SSPn_IE) (n=0, 1)

Address Offset: 0x10

This register controls whether each of the four possible interrupt conditions in the SSP controller is enabled.

Bit	Name	Description	Attribute	Reset
31:4	Reserved		R	0
3	TXFIFOTHIE	TX FIFO threshold interrupt enable 0: Disable 1: Enable	R/W	0
2	RXFIFOTHIE	RX FIFO threshold interrupt enable 0: Disable 1: Enable	R/W	0
1	RXTOIE	RX time-out interrupt enable 0: Disable 1: Enable	R/W	0
0	RXOVFIE	RX Overflow interrupt enable 0: Disable 1: Enable	R/W	0

10.6.6 SSP n Raw Interrupt Status register (SSPn_RIS) (n=0, 1)

Address Offset: 0x14

This register contains the status for each interrupt condition, regardless of whether or not the interrupt is enabled in SSPn_IE register.

This register indicates the status for SSP control raw interrupts. An SSP interrupt is sent to the interrupt controller if the corresponding bit in the SSPn_IE register is set.

Bit	Name	Description	Attribute	Reset
31:4	Reserved		R	0
3	TXFIFOTHIF	TX FIFO threshold interrupt flag 0: No TX FIFO threshold interrupt 1: TX FIFO threshold triggered.	R	0
2	RXFIFOTHIF	RX FIFO threshold interrupt flag 0: No RX FIFO threshold interrupt 1: RX FIFO threshold triggered.	R	0
1	RXTOIF	RX time-out interrupt flag RXTO occurs when the RX FIFO is not empty, and has not been read for a time-out period (32*SSPn_PCLK). The time-out period is the same for master and slave modes. 0: RXTO doesn't occur. 1: RXTO occurs.	R	0
0	RXOVFIF	RX Overflow interrupt flag RXOVF occurs when the RX FIFO is full and another frame is completely received. The ARM spec implies that the preceding frame data is overwritten by the new frame data when this occurs. 0: RXOVF doesn't occur. 1: RXOVF occurs.	R	0

10.6.7 SSP n Interrupt Clear register (SSPn_IC) (n=0, 1)

Address Offset: 0x18

Bit	Name	Description	Attribute	Reset
31:4	Reserved		R	0
3	TXFIFOTHIC	0: No effect 1: Clear TXFIFOTHIF bit.	W	0
2	RXFIFOTHIC	0: No effect 1: Clear RXFIFOTHIF bit.	W	0

1	RXTOIC	0: No effect 1: Clear RXTOIF bit.	W	0
0	RXOVFIC	0: No effect 1: Clear RXOVFIF bit.	W	0

10.6.8 SSP n Data register (SSPn_DATA) (n=0, 1)

Address Offset: 0x1C

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	DATA[15:0]	Write SW can write data to be sent in a future frame to this register when TX_FULL = 0 in SSPn_STAT register (TX FIFO is not full). If the TX FIFO was previously empty and the SSP controller is not busy on the bus, transmission of the data will begin immediately. Otherwise the data written to this register will be sent as soon as all previous data has been sent (and received). Read SW can read data from this register when RX_EMPTY=0 in SSPn_STAT register (Rx FIFO is not empty). When SW reads this register, the SSP controller returns data from the least recent frame in the RX FIFO. If the data length is less than 16 bit, the data is right-justified in this field with higher order bits filled with 0s.	R/W	0

10.6.9 SSP n Data Fetch register (SSPn_DF) (n=0, 1)

Address Offset: 0x20

Bit	Name	Description	Attribute	Reset
31:1	Reserved		R	0
0	DF	SSP data fetch control bit 0: Disable 1: Enable when SCKn frequency > 6MHz	R/W	0

11 I2C

11.1 OVERVIEW

The I2C bus is bidirectional for inter-IC control using only two wires: Serial Clock Line (SCL) and Serial Data line (SDA). Each device is recognized by a unique address and can operate as either a receiver-only device (e.g., an LCD driver) or a transmitter with the capability to both receive and send information (such as memory). Transmitters and/or receivers can operate in either master or slave mode, depending on whether the chip has to initiate a data transfer or is only addressed. The I2C is a multi-master bus and can be controlled by more than one bus master connected to it. It is also SMBus 2.0 compatible.

Depending on the state of the direction bit (R/W), two types of data transfers are possible on the I2C bus:

- Data transfer from a master transmitter to a slave receiver.
  The first byte transmitted by the master is the slave address. Next follows a number of data bytes. The slave returns an acknowledge bit after each received byte.
- Data transfer from a slave transmitter to a master receiver.
  The first byte (the slave address) is transmitted by the master. The slave then returns an acknowledge bit. Next follows the data bytes transmitted by the slave to the master. The master returns an acknowledge bit after all received bytes other than the last byte. At the end of the last received byte, a “not acknowledge” is returned. The master device generates all of the serial clock pulses and the START and STOP conditions. A transfer is ended with a STOP condition or with a Repeated START condition. Since a Repeated START condition is also the beginning of the next serial transfer, the I2C bus will not be released.

The I2C interface is byte oriented and has four operating modes:

- Master transmitter mode
- Master receiver mode
- Slave transmitter mode
- Slave receiver mode

11.2 FEATURES

The I2C interface complies with the entire I2C specification, supporting the ability to turn power off to the ARM Cortex-M0 without interfering with other devices on the same I2C-bus.

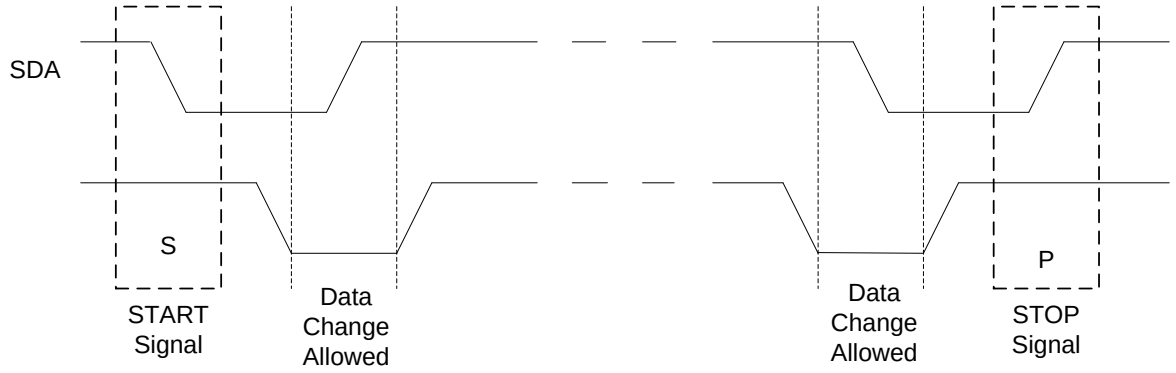
- Standard I2C-compliant bus interfaces may be configured as Master or Slave.
- I2C Master features:
  - Clock generation
  - Start and Stop generation
- I2C Slave features:
  - Programmable I2C Address detection
  - Optional recognition of up to four distinct slave addresses
  - Stop bit detection
- Supports different communication speeds:
  - Standard Speed (up to 100KHz)
  - Fast Speed (up to 400 KHz)
- Arbitration is handled between simultaneously transmitting masters without corruption of serial data on the bus.
- Programmable clock allows adjustment of I2C transfer rates.
- Data transfer is bidirectional between masters and slaves.
- Serial clock synchronization allows devices with different bit rates to communicate via one serial bus.
- Serial clock synchronization is used as a handshake mechanism to suspend and resume serial transfer.

- Monitor mode allows observing all I2C-bus traffic, regardless of slave address.
- I2C-bus can be used for test and diagnostic purposes.
- Generation and detection of 7-bit/10-bit addressing and General Call.

11.3 PIN DESCRIPTION

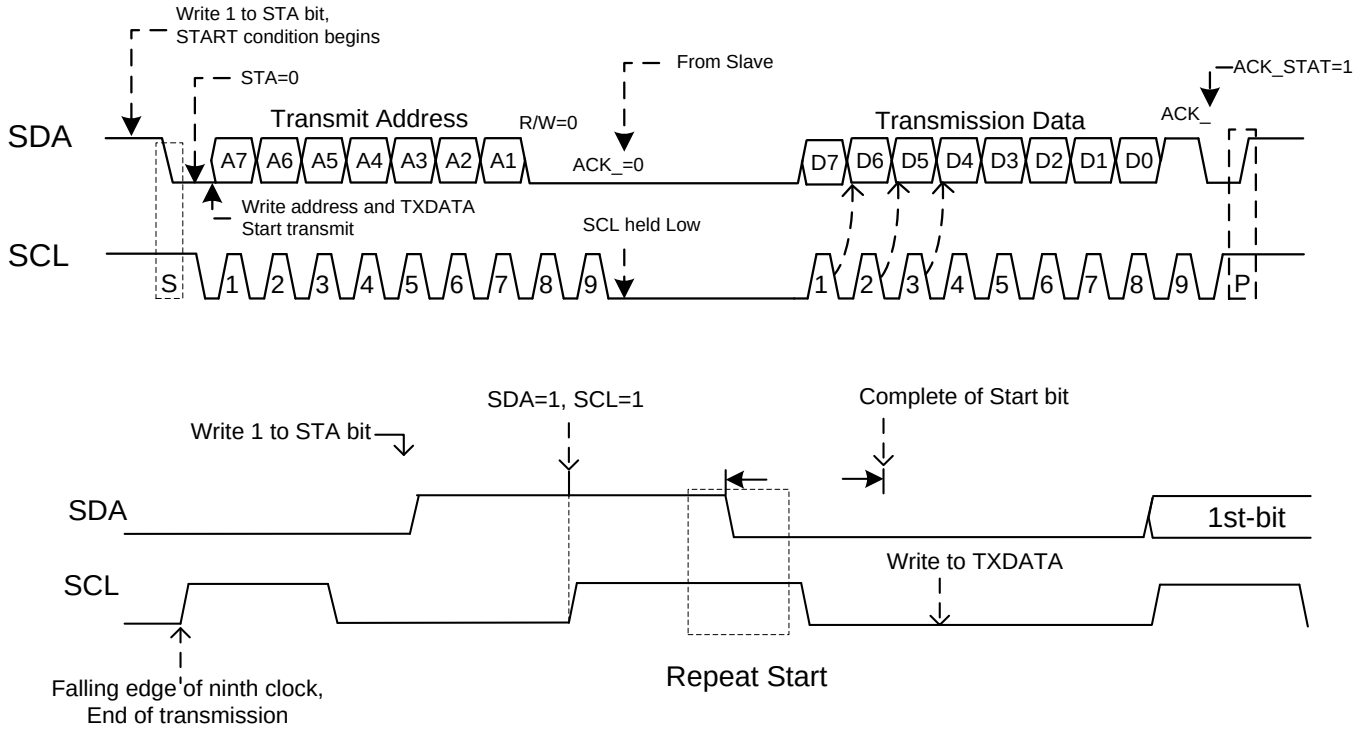
Pin Name	Type	Description	GPIO Configuration
SCLn	I/O	I2C Serial clock	Output with Open-drain Input depends on GPIOn_CFG
SDAn	I/O	I2C Serial data	Output with Open-drain Input depends on GPIOn_CFG

11.4 WAVE CHARACTERISTICS

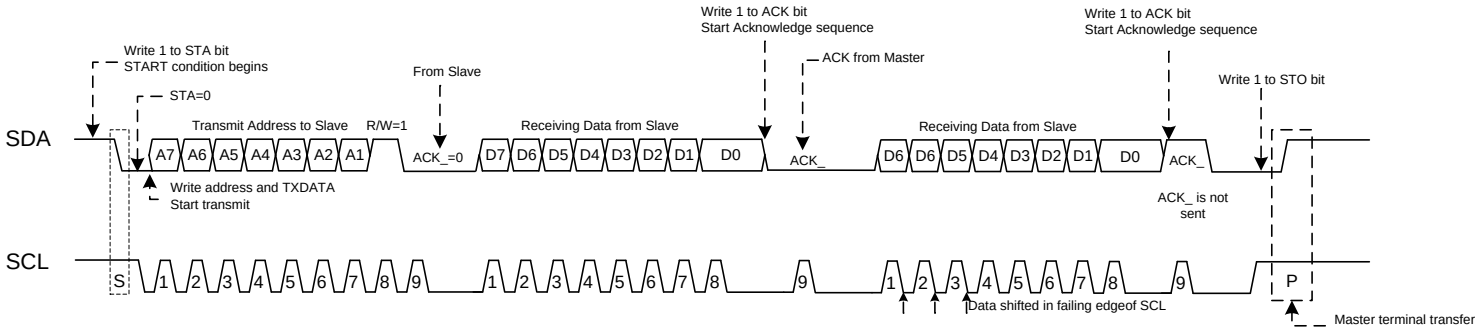


11.5 I2C MASTER MODES

11.5.1 MASTER TRANSMITTER MODE



11.5.2 MASTER RECEIVER MODE



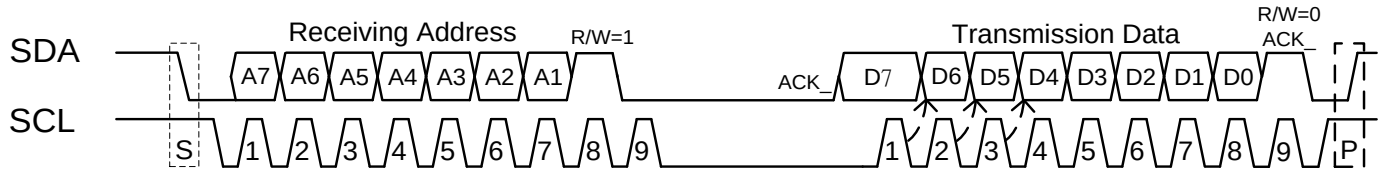
11.5.3 ARBITRATION

In the master transmitter mode, the arbitration logic checks that every transmitted logic 1 actually appears as logic 1 on the I2C bus. If another device on the bus overrules a logic 1 and pulls the SDA line low, arbitration is lost, and the I2C block immediately changes from master transmitter to slave receiver. The I2C block will continue to output clock pulses (on SCL) until transmission of the current serial byte is complete.

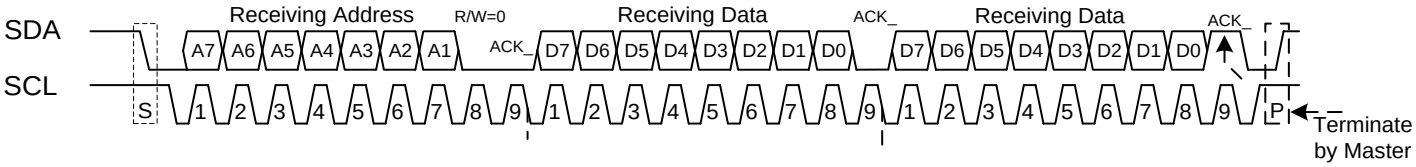
Arbitration may also be lost in the master receiver mode. Loss of arbitration in this mode can only occur while the I2C block is returning a “not acknowledge” to the bus. Arbitration is lost when another device on the bus pulls this signal low. Since this can occur only at the end of a serial byte, the I2C block generates no further clock pulses.

11.6 I2C SLAVE MODES

11.6.1 SLAVE TRANSMITTER MODE



11.6.2 SLAVE RECEIVER MODE



11.7 MONITOR MODE

11.7.1 INTERRUPT

All interrupts will occur as normal when the module is in monitor mode. This means that the first interrupt will occur when an address-match is detected (any address received if the MATCH_ALL bit is set, otherwise an address matching one of the four address registers).

Subsequent to an address-match detection, interrupts will be generated after each data byte is received for a slave-write transfer, or after each byte that the module “thinks” it has transmitted for a slave-read transfer. In this second case, the data register will actually contain data transmitted by some other slave on the bus which was actually addressed by the master.

Following all of these interrupts, the processor may read the data register to see what was actually transmitted on the bus.

11.7.2 LOSS of ARBITRATION

In monitor mode, the I2C module will not be able to respond to a request for information by the bus master or issue an ACK). Some other slave on the bus will respond instead. This will most probably result in a lost-arbitration state as far as our module is concerned. Software should be aware of the fact that the module is in monitor mode and should not respond to any loss of arbitration state that is detected. In addition, hardware may be designed into the module to block some/all loss of arbitration states from occurring if those state would either prevent a desired interrupt from occurring or cause an unwanted interrupt to occur. Whether any such hardware will be added is still to be determined.

11.8 I2C REGISTERS

Base Address: 0x4001 8000 (I2C0)
0x4005 A000 (I2C1)

11.8.1 I2C n Control register (I2Cn_CTRL) (n=0,1)

Address Offset: 0x00

The I2Cn_CTRL registers control setting of bits that controls operation of the I2C interface.

When STA =1 and the I2C interface is not already in master mode, it enters master mode, checks the bus and generates a START condition if the bus is free. If the bus is not free, it waits for a STOP condition (which will free the bus) and generates a START condition after a delay of a half clock period of the internal clock generator. If the I2C interface is already in master mode and data has been transmitted or received, it transmits a Repeated START condition. STA may be set at any time, including when the I2C interface is in an addressed slave mode.

When STO = 1 in master mode, a STOP condition is transmitted on the I2C bus. When the bus detects the STOP condition, STO is cleared automatically. In slave mode, setting STO bit can recover from an error condition. In this case, no STOP condition is transmitted to the bus. The HW behaves as if a STOP condition has been received and it switches to “not addressed” slave receiver mode.

If STA and STO are both set, then a STOP condition is transmitted on the I2C bus if it the interface is in master mode, and transmits a START condition thereafter. If the I2C interface is in slave mode, an internal STOP condition is generated, but is not transmitted on the bus.

✷ ***Note:***
- ***1. I2CEN shall be set at last.***
- ***2. HW will assign SCL0/SCL1 and SDA0/SDA1 pins as output pins with open-drain function instead of GPIO automatically, and HW will assign SCL0/SCL1 and SDA0/SDA1 pins as 20mA high-sinking current if I2CMODE =1.***
- ***3. ACK and NACK bits can’t both be “1” when receiving data.***
- ***4. User has to write 1 to ACK or NACK bit in Master mode to continue next RX process.***

Bit	Name	Description	Attribute	Reset
31:9	Reserved		R	0
8	I2CEN	I2C Interface enable bit 0: Disable. The STO bit is forced to “0”. 1: Enable. I2EN shall not be used to temporarily release the I2C bus since the bus status is lost when I2CEN resets. The ACK flag should be used instead.	R/W	0
7:6	Reserved		R	0
5	STA	START bit. 0: No START condition or Repeated START condition will be generated. 1: Cause the I2C interface to enter master mode and transmit a START or a Repeated START condition. Automatically cleared by HW.	R/W	0
4	STO	STOP flag 0: Stop condition idle. 1: Cause the I2C interface to transmit a STOP condition in master mode, or recover from an error condition in slave mode. Automatically cleared by HW.	R/W	0
3	Reserved		R	0
2	ACK	Assert ACK (Low level to SDA) flag. 0: Master mode→ No function Slave mode→Return a NACK after receiving address or data. 1: An ACK will be returned during the acknowledge clock pulse on SCLn when ➢ The address in the Slave Address register has been received. ➢ The General Call address has been received while the General Call bit (GC) in the ADR register is set.	R/W	0

		➢ A data byte has been received while the I2C is in the master receiver mode. ➢ A data byte has been received while the I2C is in the addressed slave receiver mode. HW will clear after issuing ACK automatically.		
1	NACK	Assert NACK (HIGH level to SDA) flag. 0: No function 1: An NACK will be returned during the acknowledge clock pulse on SCLn when ➢ A data byte has been received while the I2C is in the master receiver mode. HW will clear after issuing NACK automatically.	R/W	0
0	Reserved		R	0

11.8.2 I2C n Status register (I2Cn_STAT) (n=0,1)

Address Offset: 0x04

Check this register when I2C interrupt occurs, and all status will be cleared automatically by writing I2Cn_CTRL or I2Cn_TXDATA register.

While I2CIF =1, the low period of the serial clock on the SCL line is stretched, and the serial transfer is suspended. When SCL is HIGH, it is unaffected by the state of I2CIF.

Following events will trigger I2C interrupt if I2C interrupt is enabled in NVIC interrupt controller.

- **START/Repeat START condition**
- **STOP condition**
- **Timeout**
- **Data byte transmitted or received**
- **ACK Transmit or received**
- **NACK Transmit or received**

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15	I2CIF	I2C Interrupt flag. 0: I2C status doesn't change. 1: Read→I2C status changes. Write→Clear this flag.	R/W	0
14:10	Reserved		R	0
9	TIMEOUT	Time-out status 0: No Timeout 1: Timeout	R	0
8	LOST_ARB	Lost arbitration 0: Not lost arbitration 1: Lost arbitration	R	0
7	SLV_TX_HIT	0: No matched slave address. 1: Slave address hit, and is called for TX in slave mode.	R	0
6	SLV_RX_HIT	0: No matched slave address. 1: Slave address hit, and is called for RX in slave mode.	R	0
5	MST	Master/Slave status 0: I2C is in Slave state. 1: I2C is in Master state.	R	0
4	START_DN	Start done status 0: No START bit. 1: MASTER mode→ a START bit was issued. SLAVE mode→a START bit was received.	R	0
3	STOP_DN	Stop done status 0: No STOP bit. 1: MASTER mode→a STOP condition was issued. SLAVE mode→a STOP condition was received.	R	0
2	NACK_STAT	NACK done status 0 : Not received a NACK 1 : Received a NACK	R	0
1	ACK_STAT	ACK done status 0 : Not received an ACK	R	0

		1 : Received an ACK		
0	RX_DN	RX done status 0: No RX with ACK/NACK transfer. 1: 8-bit RX with ACK/NACK transfer is done.	R	0

11.8.3 I2C n TX Data register (I2Cn_TXDATA) (n=0,1)

Address Offset: 0x08

This register contains the data to be transmitted.
In Master TX mode, CPU writes this register will trigger a TX function. In Slave TX mode, CPU has to write this register before next TX procedure.

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	DATA[7:0]	Data to be transmitted.	R/W	0x00

11.8.4 I2C n RX Data register (I2Cn_RXDATA) (n=0,1)

Address Offset: 0x0C

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	DATA[7:0]	Contains the data received. Read this register when RX_DN = 1.	R	0x00

11.8.5 I2C n Slave Address 0 register (I2Cn_SLVADDR0) (n=0,1)

Address Offset: 0x10

Only used in slave mode. In master mode, this register has no effect.
If this register contains 0x00, the I2C will not acknowledge any address on the bus. Register ADR0 to ADR3 will be cleared to this disabled state on reset.

Bit	Name	Description	Attribute	Reset
31	ADD_MODE	Slave address mode. 0 : 7-bit address mode 1: 10-bit address mode	RW	0
30	GCEN	General call address enable bit. 0: Disable 1: Enable general call address (0x0)	RW	0
29:10	Reserved		R	0
9:0	ADDR[9:0]	The I2C slave address. ADD[9:0] is valid when ADD_MODE = 1 ADD[7:1] is valid when ADD_MODE = 0	R/W	0

11.8.6 I2C n Slave Address 1~3 register (I2Cn_SLVADDR1~3) (n=0,1)

Address Offset: 0x14, 0x18, 0x1C

Bit	Name	Description	Attribute	Reset
31:10	Reserved		R	0
9:0	ADDR[9:0]	The I2C slave address. ADD[9:0] is valid when ADD_MODE = 1 ADD[7:1] is valid when ADD_MODE = 0	R/W	0

11.8.7 I2C n SCL High Time register (I2Cn_SCLHT) (n=0,1)

Address Offset: 0x20

✸ ***Note: I2C Bit Frequency = I2Cn_PCLK / (I2Cn_SCLHT+I2Cn_SCLLT)***

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	SCLH[7:0]	Count for SCL High Period time SCL High Period Time = (SCLH+1) * I2C0_PCLK cycle	R/W	0x04

11.8.8 I2C n SCL Low Time register (I2Cn_SCLLT) (n=0,1)

Address Offset: 0x24

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	SCLL[7:0]	Count for SCL Low Period time SCL Low Period Time = (SCLL+1) * I2C0_PCLK cycle	R/W	0x04

11.8.9 I2C n Timeout Control register (I2Cn_TOCTRL) (n=0,1)

Address Offset: 0x2C

Timeout happens when Master/Slave SCL remained LOW for:
TO * 32 * I2C0_PCLK cycle.

When I2C timeout occurs, the I2C transfer will return to “IDLE” state, and issue a TO interrupt to inform user. That means SCL/SDA will be released by HW after timeout. User can issue a STOP after timeout interrupt occurred in Master mode.
Time-out status will be cleared automatically by writing I2Cn_CTRL or I2Cn_TXDATA register.

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	TO[15:0]	Count for checking Timeout. 0: Disable Timeout checking N: Timeout period time = N*32*I2Cn_PCLK cycle	R/W	0x0

11.8.10 I2C n Monitor Mode Control register (I2Cn_MMCTRL) (n=0,1)

Address Offset: 0x30

This register controls the Monitor mode which allows the I2C module to monitor traffic on the I2C bus without actually participating in traffic or interfering with the I2C bus.

In Monitor mode, SDA output will be forced high to prevent the I2C module from outputting data of any kind (including ACK) onto the I2C data bus. Depending on the state of the SCLOEN bit, the SCL output may be also forced high to prevent the module from having control over the I2C clock line.

✷ ***Note: The SCLOEN and MATCH_ALL bits have no effect if MMEN bit is ‘0’ (i.e. if the module is NOT in monitor mode).***

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
2	MATCH_ALL	Match address selection 0: Interrupt will only be generated when the address matches one of the values in I2Cn_SLVADDR0~3 register. 1: If I2C is in monitor mode, an interrupt will be generated on ANY address received. This will enable the part to monitor all traffic on the bus.	R/W	0
1	SCLOEN	SCL output enable bit. 0: SCL output will be forced high. 1: I2C module may act as a slave peripheral just like in normal operation, the I2C holds the clock line low until it has had time to respond to an I2C	R/W	0

		interrupt.		
0	MMEN	Monitor mode enable bit. 0: Disable 1: Enable.	R/W	0

12 UNIVERSAL ASYNCHRONOUS RECEIVER AND TRANSMITTER (UART)

12.1 OVERVIEW

The UART offers a flexible means of full-duplex data exchange with external equipment requiring an industry standard NRZ asynchronous serial data format. The serial interface is applied to low speed data transfer and communicate with low speed peripheral devices.

The UART offers a very wide range of baud rates using a fractional baud rate generator.

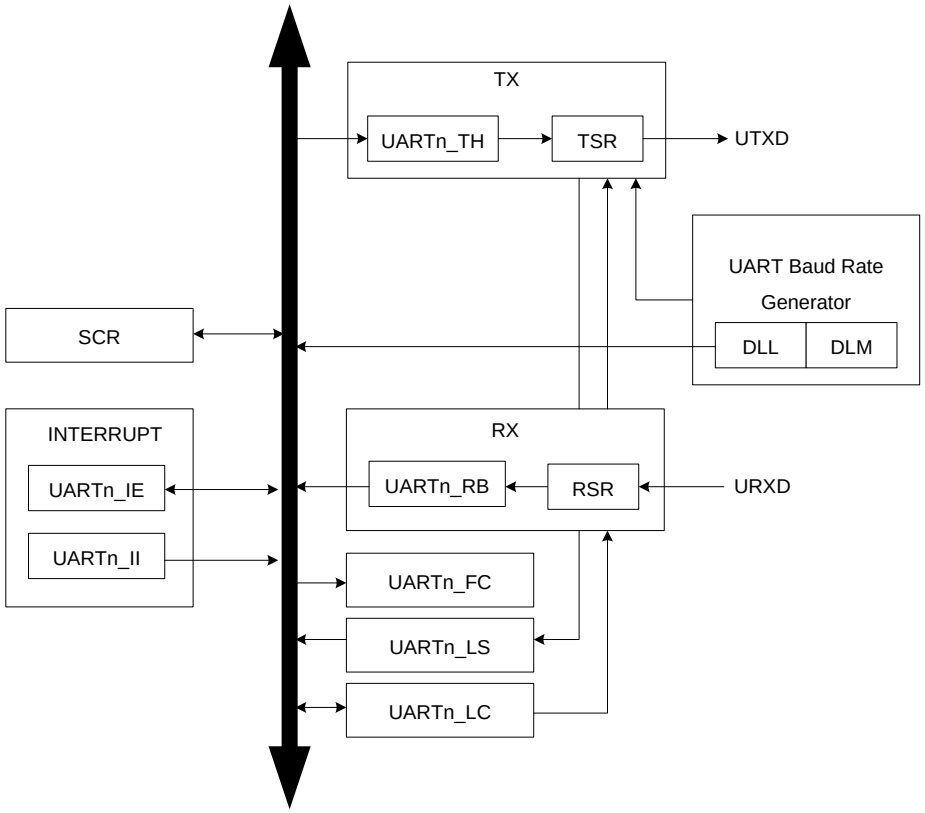
12.2 FEATURES

- Full-duplex, 2-wire asynchronous data transfer.
- Single-wire half-duplex communication
- 16-byte receive and transmit FIFOs
- Register locations conform to 16550 industry standard.
- Receiver FIFO trigger points at 1, 4, 8, and 14 bytes.
- Built-in baud rate generator.
- Software or hardware flow control.

12.3 PIN DESCRIPTION

Pin Name	Type	Description	GPIO Configuration
UTXDn	O	Serial Transmit data.	
URXDn	I	Serial Receive data.	Depends on GPIOn_CFG

12.4 BLOCK DIAGRAM



12.5 BAUD RATE CALCULATION

The UART baud rate is calculated as:

$$UART_{BAUDRATE} = \frac{UARTn\_PCLK}{Oversampling \times (256 \times DLM + DLL) \times (1 + DIVADDVAL / MULVAL)}$$

Where UARTn_PCLK is the peripheral clock, UARTn_DLM and UARTn_DLL are the standard UART baud rate divider registers, and DIVADDVAL and MULVAL are UART fractional baud rate generator specific parameters in UARTn_FD register.

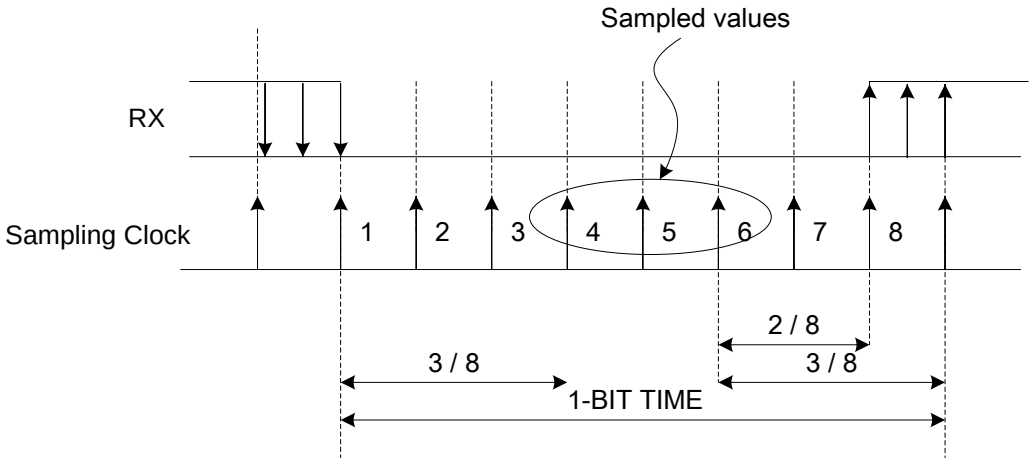
The value of MULVAL and DIVADDVAL should comply with the following conditions:

1. 1 ≤ MULVAL ≤ 15
2. 0 ≤ DIVADDVAL ≤ 14
3. DIVADDVAL< MULVAL
4. Oversampling is 8 or 16

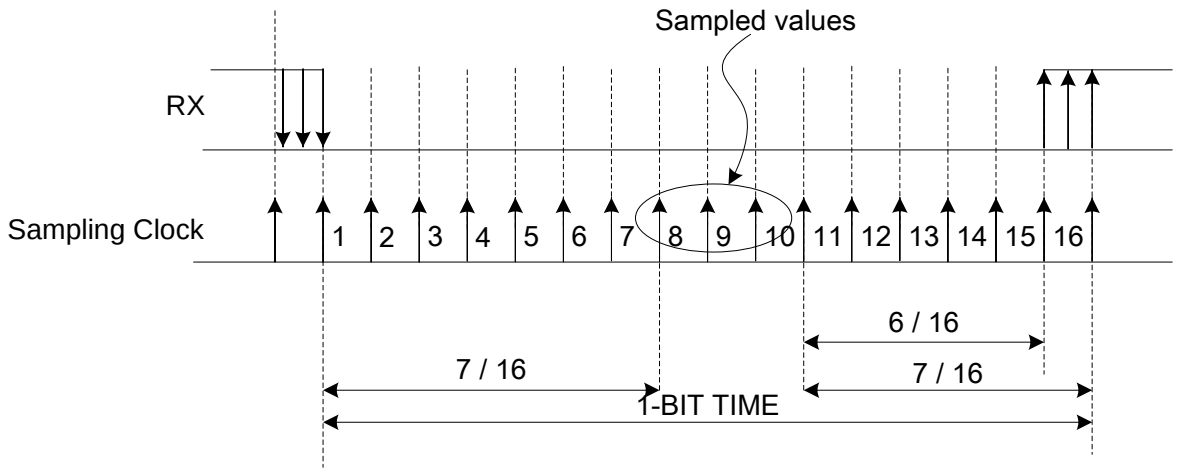
The value of the UARTn_FD register should not be modified while transmitting/receiving data or data may be lost or corrupted.

The oversampling method can be selected by programming the OVER8 bit in UARTn_FD register and can be either 16 or 8 times the baud rate clock.

● OVER8=1: Oversampling by 8 to achieve higher speed (up to UARTn_PCLK/8). In this case the maximum receiver tolerance to clock deviation is reduced.



● OVER8=0: Oversampling by 16 to increase the tolerance of the receiver to clock deviations. In this case, the maximum speed is limited to maximum UARTn_PCLK/16



If the UARTn_FD register value does not comply with these two requests, then the fractional divider output is undefined. If DIVADDVAL is zero then the fractional divider is disabled, and the clock will not be divided.

UART can operate with or without using the Fractional Divider. The desired baud rate can be achieved using several different Fractional Divider settings. The following algorithm illustrates one way of finding a set of DLM, DLL, MULVAL, and DIVADDVAL values. Such set of parameters yields a baud rate with a relative error of less than 1.1% from the desired one.

The following example illustrates selecting the DIVADDVAL, MULVAL, DLM, and DLL to generate BR = 115200 when UARTn_PCLK = 12 MHz, and Oversampling = 16.

$$UART_{BAUDRATE} = \frac{UARTn\_PCLK}{Oversampling \times (256 \times DLM + DLL) \times (1 + DIVADDVAL / MULVAL)}$$

$$115200 = \frac{12000000}{16 \times (256 \times DLM + DLL) \times (1 + DIVADDVAL / MULVAL)}$$

$$(256 \times DLM + DLL) \times (1 + DIVADDVAL / MULVAL) = 6.51$$

Since the value of MULVAL and DIVADDVAL should comply with the following conditions:

1. 1 ≤ MULVAL ≤ 15
2. 0 ≤ DIVADDVAL ≤ 14
3. DIVADDVAL< MULVAL

Thus, the suggested UART settings would be: DLM = 0, DLL = 4, DIVADDVAL = 5, and MULVAL = 8 (fill in 7 in the MULVAL bits). The baud rate generated is 115384, and has a relative error of 0.16% from the originally specified 115200.

12.6 AUTO-BAUD FLOW

12.6.1 AUTO-BAUD

The UART auto-baud function can be used to measure the incoming baud rate based on the “AT” protocol (Hayes command). If enabled the auto-baud feature will measure the bit time of the receive data stream and set the divisor latch registers UARTn_DLM and UARTn_DLL accordingly.

Auto-baud function is started by setting the START bit in UARTn_ABCTRL register, and can be stopped by clearing the START bit. The START bit will clear once auto-baud has finished and reading the bit will return the status of auto-baud (pending/finished). When auto-baud function is started, FIFO will be cleared, not available to write the TX FIFO, and the transmitter will stop transmitting until auto-baud function finishes or be stopped.

Two auto-baud measuring modes are available which can be selected by the MODE bit in UARTn_ABCTRL register. In Mode 0 the baud rate is measured on two subsequent falling edges of the UART RX pin (the falling edge of the start bit and the falling edge of the least significant bit). In Mode 1 the baud rate is measured between the falling edge and the subsequent rising edge of the UART RX pin (the length of the start bit).

The AUTORESTART bit in UARTn_ABCTRL register can be used to automatically restart baud rate measurement if a timeout occurs (the rate measurement counter overflows). If this bit is set, the rate measurement will restart at the next falling edge of the URXD pin.

The auto-baud function can generate two interrupts.

- The ABTOINT interrupt in UARTn_II register will get set if the interrupt is enabled (ABTOIE bit in UARTn_IE register is set and the auto-baud rate measurement counter overflows).
- The ABEOINT interrupt in UARTn_II register will get set if the interrupt is enabled (ABTOIE bit in UARTn_IE register is set and the auto-baud has completed successfully).

The auto-baud interrupts have to be cleared by setting the corresponding ABTOINTCLR and ABEOIE bits in

UARTn_IE register.

The fractional baud rate generator must be disabled (DIVADDVAL = 0) during auto-baud. Also, when auto-baud is used, any write to UARTn_DLM and UARTn_DLL registers should be done before UARTn_ABCCTRL register write. The minimum and the maximum baud rates supported by UART are a function of UARTn_PCLK and the number of data bits, stop bits and parity bits.

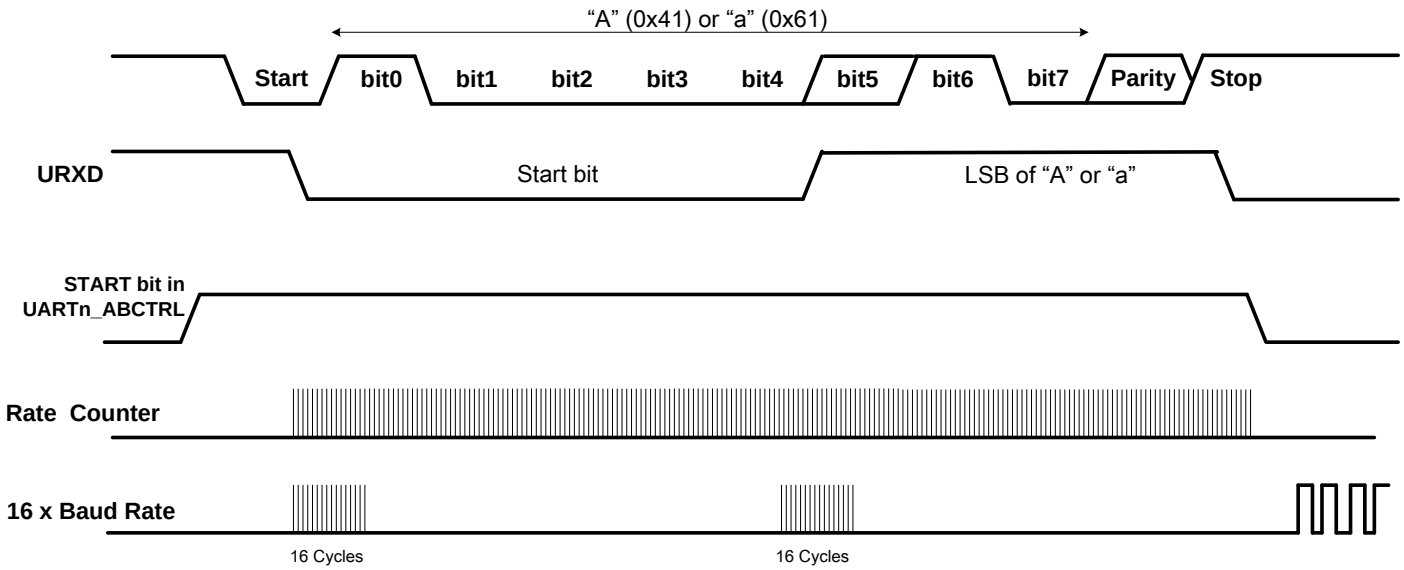
$$ratemin = \frac{2 \times PCLK}{16 \times 2^{15}} \leq UART_{baudrate} \leq \frac{PCLK}{16 \times (2 + databits + paritybits + stopbits)} = ratemax$$

12.6.2 AUTO-BAUD MODES

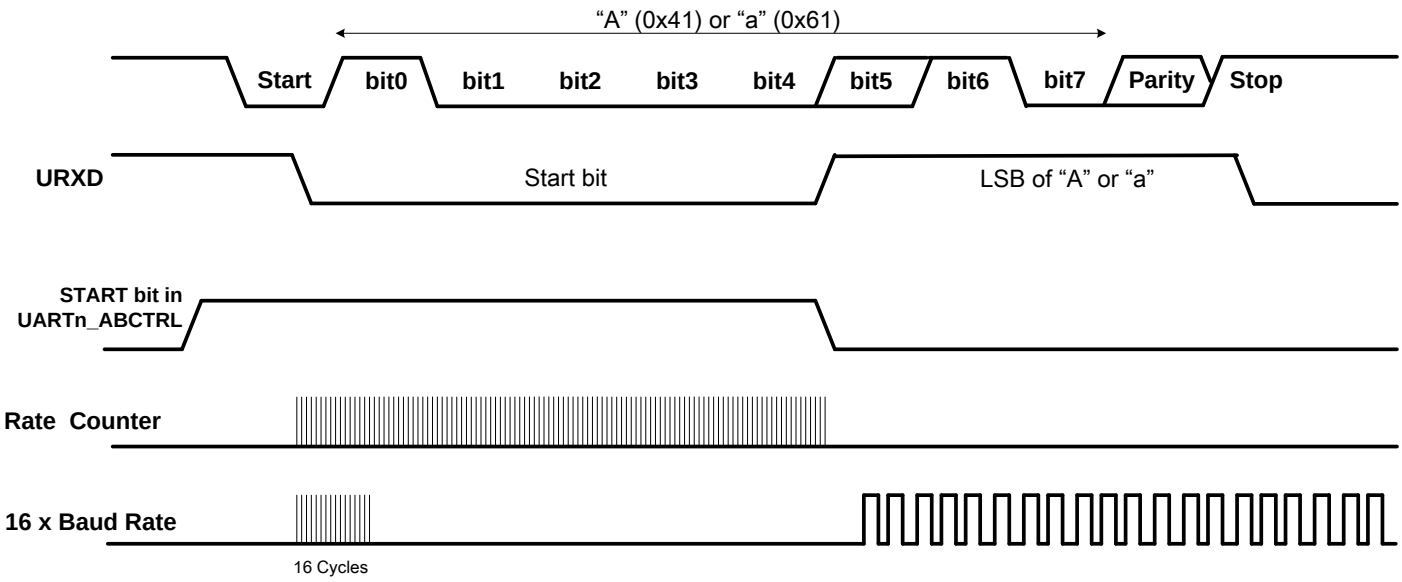
When the SW is expecting an “AT” command, it configures the UART with the expected character format and sets the ACR Start bit. The initial values in the divisor latches DLM and DLM don‘t care. Because of the “A” or “a” ASCII coding (“A” = 0x41, “a” = 0x61), the UART Rx pin sensed start bit and the LSB of the expected character are delimited by two falling edges. When the ACR Start bit is set, the auto-baud protocol will execute the following phases:

1. On START bit setting, the baud rate measurement counter is reset and the RSR is reset. The RSR baud rate is switched to the highest rate.
2. A falling edge on URXD pin triggers the beginning of the start bit. The rate measuring counter will start counting UARTn_PCLK cycles.
3. During the receipt of the start bit, 16 pulses are generated on the RSR baud input with the frequency of the UART input clock, guaranteeing the start bit is stored in the RSR.
4. During the receipt of the start bit (and the character LSB for MODE = 0 in UARTn_ABCTRL register), the rate counter will continue incrementing with the pre-scaled UART input clock (UARTn_PCLK).
5. If MODE = 0, the rate counter will stop on next falling edge of the UART RX pin. If MODE = 1, the rate counter will stop on the next rising edge of the URXD pin.
6. The rate counter is loaded into UARTn_DLM/UARTn_DLL and the baud rate will be switched to normal operation. After setting the DLM/DLL, the end of auto-baud interrupt ABEOINT in UARTn_II register will be set, if enabled. The RSR will now continue receiving the remaining bits of the character.

➢ **AUTO-BAUD RATE MODE 0 Waveform**



➢ **AUTO-BAUD RATE MODE 1 Waveform**


"A" (0x41) or "a" (0x61)
Start
bit0
bit1
bit2
bit3
bit4
bit5
bit6
bit7
Parity
Stop
URXD
Start bit
LSB of "A" or "a"
START bit in
UARTn_ABCTRL
Rate Counter
16 x Baud Rate
16 Cycles

12.7 UART REGISTERS

Base Address: 0x4001 6000 (UART0)
0x4005 6000 (UART1)

12.7.1 UART n Receiver Buffer register (UARTn_RB) (n=0, 1)

Address Offset: 0x00

This register is the top byte of the UART RX FIFO, and contains the oldest character received and can be read via the bus interface. The LSB (bit 0) contains the first-received data bit. If the character received is less than 8 bits, the unused MSBs are padded with zeros.
The Divisor Latch Access Bit (DLAB) in the UARTn_LC register must be zero in order to access this register.
Since PE, FE and BI bits correspond to the byte on the top of the UART RX FIFO (i.e. the one that will be read in the next read from this register), the right approach for fetching the valid pair of received byte and its status bits is first to read the content of the UARTn_LS register, and then to read a byte from this register.

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	RB[7:0]	Contains the oldest received byte in the UART RX FIFO.	R	0

12.7.2 UART n Transmitter Holding register (UARTn_TH) (n=0, 1)

Address Offset: 0x00

This register is the top byte of the UART TX FIFO. The top byte is the newest character in the TX FIFO and can be written via the bus interface. The LSB represents the first bit to transmit.
The Divisor Latch Access Bit (DLAB) in UARTn_LC register must be zero in order to access this register.

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	TH[7:0]	The byte will be sent when it is the oldest byte in TX FIFO and the transmitter is available.	W	0

12.7.3 UART n Divisor Latch LSB registers (UARTn_DLL) (n =0, 1)

Address Offset: 0x00

The UART Divisor Latch is part of the UART Baud Rate Generator and holds the value used (optionally with the Fractional Divider) to divide the UARTn_PCLK clock in order to produce the baud rate clock, which must be the multiple of the desired baud rate that is specified by the Oversampling Register (typically 16X).

The UARTn_DLL and UARTn_DLM registers together form a 16-bit divisor, and DLAB bit in UARTn_LC register must be one in order to access these registers.
DLL contains the lower 8 bits of the divisor and DLM contains the higher 8 bits. A zero value is treated like 0x0001.

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	DLL[7:0]	The UART Divisor Latch LSB Register, along with the DLM register, determines the baud rate of the UART.	R/W	0

12.7.4 UART n Divisor Latch MSB register (UARTn_DLM) (n=0,1)

Address Offset: 0x04

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	DLM[7:0]	The UART Divisor Latch MSB Register, along with the DLL register, determines the baud rate of the UART.	R/W	0

12.7.5 UART n Interrupt Enable register (UARTn_IE) (n=0, 1)

Address Offset: 0x04

The DLAB bit in UARTn_LC register must be zero in order to access this register.

Bit	Name	Description	Attribute	Reset
31:10	Reserved		R	0
9	ABTOIE	Enables the auto-baud time-out interrupt enable bit. 0: Disable 1: Enable	R/W	0
8	ABEOIE	End of auto-baud interrupt enable bit. 0: Disable 1: Enable	R/W	0
7:5	Reserved		R	0
4	TEMTIE	TEMT interrupt enable bit. The status of this interrupt can be read from TEMT bit in UARTn_LS register. 0: Disable 1: Enable	R/W	0
3	Reserved		R	0
2	RLSIE	Receive Line Status (RLS) interrupt enable bit. The status of this interrupt can be read from UARTn_LS[4:1]. 0: Disable 1: Enable	R/W	0
1	THREIE	THRE interrupt enable bit. The status of this interrupt can be read from THRE bit in UARTn_LS register. 0: Disable 1: Enable	R/W	0
0	RDAIE	RDA interrupt enable bit. Enables the Receive Data Available interrupt. It also controls the Character Receive Time-out interrupt. 0: Disable 1: Enable	R/W	0

12.7.6 UART n Interrupt Identification register (UARTn_II) (n=0,1)

Address Offset: 0x08

This register provides a status code that denotes the priority and source of a pending interrupt.
The interrupts are frozen during a UARTn_II register access. If an interrupt occurs during a UARTn_II register access, the interrupt is recorded for the next UARTn_II register access.

Bit	Name	Description	Attribute	Reset
31:10	Reserved		R	0
9	ABTOIF	Auto-baud time-out interrupt flag. 0: Auto-baud has not timed-out 1: Auto-baud has timed out and interrupt is enabled.	R	0
8	ABEOIF	End of auto-baud interrupt flag 0: Auto-baud has not finished. 1: Auto-baud has finished successfully and interrupt is enabled.	R	0
7:6	FIFOEN	Equivalent to FIFOEN bit in UARTn_FIFOCTRL register.	R	1
5:4	Reserved		R	0
3:1	INTID[2:0]	Interrupt identification which identifies an interrupt corresponding to the UARTn RX FIFO. 0x3: 1 - Receive Line Status (RLS).	R	0

		0x2: 2a - Receive Data Available (RDA). 0x6: 2b - Character Time-out Indicator (CTI). 0x1: 3a - THRE Interrupt. 0x7: 3b – TEMT Interrupt Other: Reserved		
0	INTSTATUS	Interrupt status. The pending interrupt can be determined by evaluating UARTn_II[3:1]. 0: At least one interrupt is pending. 1: No interrupt is pending.	R	1

Bits UARTn_II[9:8] are set by the auto-baud function and signal a time-out or end of auto-baud condition. The auto-baud interrupt conditions are cleared by setting the corresponding Clear bits in the Auto-baud Control Register.

Given the status of UARTn_II[3:0], an interrupt handler routine can determine the cause of the interrupt and how to clear the active interrupt. The UARTn_II register must be read in order to clear the interrupt prior to exiting the Interrupt service routine.

Interrupt	UARTn_II [3:0]	Priority	Interrupt Source	Interrupt Reset
RLS	0110	Highest	Overrun error (OE), Parity error (PE), Framing error (FE) or Break interrupt (BI)	Read UARTn_LS register
RDA	0100	2nd	RX data in FIFO reached trigger level (FCR0=1)	Read UARTn_RB register or UART FIFO drops below trigger level
CTI	1100	2nd	Minimum of one character in the RX FIFO and no character input or removed during a time period depending on how many characters are in FIFO and what the trigger level is set at 3.5 to 4.5 character times.	Read UARTn_RB register
THRE	0010	3rd	THRE	Read UARTn_II register (if source of interrupt) or Write THR register
TEMT	1110	3rd	TEMT	Read UARTn_II register (if source of interrupt) or Write THR register

12.7.7 UART n FIFO Control register (UARTn_FIFOCTRL) (n=0,1)

Address Offset: 0x08

This register controls the operation of the UART RX and TX FIFOs.

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:6	RXTL[1:0]	RX Trigger Level. These two bits determine how many receiver UART FIFO characters must be written before an interrupt is activated. 00: Trigger level 0 (1 character) 01: Trigger level 1 (4 characters) 10: Trigger level 2 (8 characters) 11: Trigger level 3 (14 characters)	W	0
5:3	Reserved		R	0
2	TXFIFORST	TX FIFO Reset bit. 0: No impact on either of UART FIFOs. 1: Writing a logic 1 to reset the pointer logic in UART TX FIFO. HW shall clear this bit automatically.	W	0
1	RXFIFORST	RX FIFO Reset bit. 0: No impact on either of UART FIFOs. 1: Writing a logic 1 to reset the pointer logic in UART RX FIFO. HW shall clear this bit automatically.	W	0
0	FIFOEN	FIFO enable 0: No effect 1: Enable for both UART Rx and TX FIFOs and UARTn_FIFOCTRL [7:1] access. This bit must be set for proper UART operation.	W	1

12.7.8 UART n Line Control register (UARTn_LC) (n=0,1)

Address Offset: 0x0C

This register determines the format of the data character that is to be transmitted or received.

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7	DLAB	Divisor Latch Access bit 0: Disable access to Divisor Latches. 1: Enable access to Divisor Latches.	R/W	0
6	BC	Break Control bit 0: Disable break transmission. 1: Enable break transmission. Output pin UART TXD is forced to logic 0.	R/W	0
5:4	PS[1:0]	Parity Select bits 00: Odd parity. Number of 1s in the transmitted character and the attached parity bit will be odd. 01: Even Parity. Number of 1s in the transmitted character and the attached parity bit will be even. 10: Forced 1 stick parity. 11: Forced 0 stick parity.	R/W	0
3	PE	Parity Enable bit 0: Disable parity generation and checking. 1: Enable parity generation and checking.	R/W	0
2	SBS	Stop Bit Select bit 0: 1 stop bit. 1: 2 stop bits (1.5 if WLS bits=00).	R/W	0
1:0	WLS[1:0]	Word Length Select bits 00: 5-bit character length. 01: 6-bit character length. 10: 7-bit character length. 11: 8-bit character length.	R/W	0

12.7.9 UART n Line Status register (UARTn_LS) (n=0,1)

Address Offset: 0x14

✸ ***Note:***
- ***1. The break interrupt (BI) is associated with the character at the top of the UARTn_RB FIFO.***
- ***2. The framing error (FE) is associated with the character at the top of the UARTn_RB FIFO.***
- ***3. The parity error (PE) is associated with the character at the top of the UARTn_RB FIFO.***

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7	RXFE	Error in RX FIFO flag. RXFE =1 when a character with a RX error such as framing error, parity error, or break interrupt, is loaded into the UARTn_RB register. This bit is cleared when the UARTn_LS register is read and there are no subsequent errors in the UART FIFO. 0: UARTn_RB register contains no UART RX errors or FIFOEN=0 1: UARTn_RB register contains at least one UART RX error.	R	0
6	TEMT	Transmitter Empty flag TEMT=1 when both THR and TSR are empty; TEMT is cleared when either the TSR or the THR contain valid data. 0: THR and/or TSR contains valid data. 1: THR and TSR are empty.	R	1
5	THRE	Transmitter Holding Register Empty flag THRE indicates that the UART is ready to accept a new character for transmission. In addition, this bit causes the UART to issue THRE interrupt to if THREIE=1. THRE=1 when a character is transferred from the THR into the TSR. The bit is reset to logic 0 concurrently with the loading of the Transmitter Holding Register by the CPU. 0: THR contains valid data. 1: THR (TX FIFO) is empty.	R	1
4	BI	Break Interrupt flag. When RXD1 is held in the spacing state (all zeros) for one full character transmission (start, data, parity, stop), a break interrupt occurs. Once the break condition has been detected, the receiver goes idle until RXD1 goes to marking state (all ones). A UARTn_LS register read clears BI bit. The time of break detection is dependent on FIFOEN bit in UARTn_FIFOCTRL register. 0: Break interrupt status is inactive. 1: Break interrupt status is active.	R	0
3	FE	Framing Error flag. When the stop bit of a received character is a logic 0, a framing error occurs. A UARTn_LS register read clears FE bit. The time of the framing error detection is dependent on FIFOEN bit in UARTn_FIFOCTRL register. Upon detection of a framing error, the RX will attempt to re-synchronize to the data and assume that the bad stop bit is actually an early start bit. However, it cannot be assumed that the next received byte will be correct even if there is no Framing Error. 0: Framing error status is inactive. 1: Framing error status is active.	R	0
2	PE	Parity Error flag. When the parity bit of a received character is in the wrong state, a parity error occurs. A UARTn_LS register read clears PE bit. Time of parity error detection is dependent on FIFOEN bit in UARTn_FIFOCTRL register. 0: Parity error status is inactive. 1: Parity error status is active.	R	0
1	OE	Overrun Error flag. The overrun error condition is set as soon as it occurs. A UARTn_LS register read clears OE bit. OE=1 when UART RSR has a new character assembled and the UARTn_RB FIFO is full. In this case, the UARTn_RB FIFO will not be overwritten and the character in the UARTn_RS register will be lost. 0: Overrun error status is inactive. 1: Overrun error status is active.	R	0
0	RDR	Receiver Data Ready flag RDR=1 when the UARTn_RB FIFO holds an unread character and is	R	0

		cleared when the UARTn_RB FIFO is empty. 0: UARTn_RB FIFO is empty. 1: UARTn_RB FIFO contains valid data.		

12.7.10 UART n Scratch Pad register (UARTn_SP) (n=0, 1)

Address Offset: 0x1C

This register has no effect on the UART operation. This register can be written and/or read at user's discretion. There is no provision in the interrupt interface that would indicate to the host that a read or write of this register has occurred.

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	PAD[7:0]	A readable, writable byte.	R/W	0

12.7.11 UART n Auto-baud Control register (UARTn_ABCTRL) (n=0, 1)

Address Offset: 0x20

This register controls the process of measuring the incoming clock/data rate for the baud rate generation and can be read and written at user's discretion. Besides, it also controls the clock pre-scaler for the baud rate generation. The reset value of the register keeps the fractional capabilities of UART disabled making sure that UART is fully SW and HW compatible with UARTs not equipped with this feature.

Bit	Name	Description	Attribute	Reset
31:10	Reserved		R	0
9	ABTOIFC	Auto-baud time-out interrupt flag clear bit 0: No effect 1: Clear ABTOIF bit. This bit is automatically cleared by HW.	W	0
8	ABEOIFC	End of auto-baud interrupt flag clear bit 0: No effect. 1: Clear ABEOIF bit. This bit is automatically cleared by HW.	W	0
7:3	Reserved		R	0
2	AUTORESTART	Restart mode 0: No restart 1: Restart in case of timeout (counter restarts at next UART RX falling edge)	R/W	0
1	MODE	Auto-baud mode select bit. 0: Mode 0. 1: Mode 1.	R/W	0
0	START	This bit is automatically cleared after auto-baud completion. 0: Auto-baud stop (auto-baud is not running). 1: Auto-baud start (auto-baud is running). Auto-baud run bit. This bit is automatically cleared by HW after auto-baud completion.	R/W	0

12.7.12 UART n Fractional Divider register (UARTn_FD) (n=0, 1)

Address Offset: 0x28

This register controls the clock prescaler for the baud rate generation and can be read and written at the user's discretion. This prescaler takes the APB clock and generates an output clock according to the specified fractional requirements.

In most applications, the UART samples received data 16 times in each nominal bit time, and sends bits that are 16 input clocks wide. OVER8 bit allows software to control the ratio between the input clock and bit clock. This is required for smart card mode, and provides an alternative to fractional division for other modes.

✷ ***Note: If the fractional divider is active (DIVADDVAL>0) and UARTn_DLM=0, the value of the UARTn_DLL register must ≥ 3.***

Bit	Name	Description	Attribute	Reset
31:9	Reserved		R	0
8	OVER8	Oversampling value 0: Oversampling by 16 1: Oversampling by 8	R/W	0
7:4	MULVAL[3:0]	Baud rate pre-scaler multiplier value = MULVAL[3:0] +1 0000: Baud rate pre-scaler multiplier value is 1 for HW 0001: Baud rate pre-scaler multiplier value is 2 for HW … … 1111: Baud rate pre-scaler multiplier value is 16 for HW.	R/W	0
3:0	DIVADDVAL[3:0]	Baud rate generation pre-scaler divisor value. If this field is 0, fractional baud rate generator will not impact the UART baud rate	R/W	0

12.7.13 UART n Control register (UARTn_CTRL) (n=0, 1)

Address Offset: 0x30

In addition to HW flow control, this register enables implementation of SW flow control.

When TXEN = 1, the UART transmitter will keep sending data as long as they are available. As soon as TXEN bit becomes 0, UART transmission will stop.

It is strongly suggested to let the UART HW implemented auto flow control features take care of limit the scope of TXEN to SW flow control.

✷ ***Note: It is advised that TXEN and RXEN are set in the same instruction if needed in order to minimize the setup and the hold time of the receiver.***

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7	TXEN	When this bit is 1, data written to the UARTn_TH register is output on the TXD pin as soon as any preceding data has been sent. If this bit is cleared to 0 while a character is being sent, the transmission of that character is completed, but no further characters are sent until this bit is set again. In other words, a 0 in this bit blocks the transfer of characters from the UARTn_TH register or TX FIFO into the transmit shift register.	R/W	1
6	RXEN	0: Disable RX related function 1: Enable RX	R/W	1
5:1	Reserved		R	0
0	UARTEN	UART enable 0: Disable . All UART shared pins act as GPIO. 1: Enable. HW switches GPIO to UART pin automatically.	R/W	0

12.7.14 UART n Half-duplex Enable register (UARTn_HDEN) (n=0, 1)

Address Offset: 0x34

After reset the UART will be in full-duplex mode, meaning that both TX and RX work independently. After setting the HDEN bit, the UART will be in half-duplex mode. In this mode, the UART ensures that the receiver is locked when idle, or will enter a locked state after having received a complete ongoing character reception. Line conflicts must be handled in SW.

The behavior of the UART is unpredictable when data is presented for reception while data is being transmitted. For this reason, the value of the HDEN register should not be modified while sending or receiving data, or data may be lost or corrupted.

Bit	Name	Description	Attribute	Reset
31:1	Reserved		R	0
0	HDEN	Half-duplex mode enable bit 0: Disable 1: Enable	R/W	0

13 AUDIO (I2S/CODEC)

13.1 OVERVIEW

13.1.1 I2S Description

The I2S bus specification defines a 5-wire serial bus, having one data in, one data out, one MCLK clock, one BCLK clock, and one word select signal. The basic I2S connection has one master, which is always the master, and one slave.

13.1.2 Codec Description

The SN32F100 mono Codec offers fundamental features suitable for system applications, which contains 16-Bit Sigma-delta ADC and DAC for audio in and audio out respectively.

The ADC supports a set of differential MIC input and the microphone input path includes a programmable gain amplifier (PGA) and MIC boost to adjust the analog volume. Also, there is a digital volume attenuation control after ADC, which can adjust the volume of digital output by bit shift. Besides, Audio Gain Controller (AGC) is programmable to monitor the input and further adjust the volume properly.

The DAC includes a power supply input for DAC driver, a power supply input pins for DAC, a DAC VMID output, and a DAC Common mode output.

The Codec circuit requires a 2.7~3.6 V operating voltage supply.

13.2 FEATURES

13.2.1 I2S Features

- I2S can operate as either master or slave.
- Capable of handling 8/16/24/32-bit data length.
- Mono and stereo audio data supported.
- I2S and MSB justified data format supported.
- 8 word (32-bit) FIFO data buffers are provided.
- Generate interrupt requests when buffer levels cross a programmable boundary.
- Controls include reset, stop and mute options separately for I2S input and I2S output.

13.2.2 Codec Features

- Mono Codec.
- Audio sample rates: 8K, 16K, 32K, and 48KHz.
- ADC.
  - SNR: 94dB (-120dBr, A-W).
  - DR: 94dB (-60dBr, A-W).
  - THD+N: -80dB (+0dBr)
- DAC.
  - SNR: 90dB (-120dBr, A-W).
  - DR: 90dB (-60dBr, A-W).
  - THD+N: -75dB (+0dBr).
- Differential microphone interface.
  - Programmable gain amplifier (PGA) -12dB~+33dB.
  - MIC boost gain 0,+12,+20,+30dB.
  - Auto Gain Control (AGC).
- Common mode output interface.
  - Mute on/off.

✸ ***Note: The Codec circuit requires a 2.7V~3.6V operating voltage supply.***

13.3 PIN DESCRIPTION

13.3.1 I2S Pin Description

Pin Name	Type	Description	GPIO Configuration
I2SBCLK	O	I2S Bit clock (Master)	
	I	I2S Bit clock (Slave)	Depends on GPIOn_CFG
I2SWS	O	I2S Word Select (Master)	
	I	I2S Word Select (Slave)	Depends on GPIOn_CFG
I2SDIN	I	I2S Received Serial data	Depends on GPIOn_CFG
I2SDOUT	O	I2S Transmitted Serial data	Depends on GPIOn_CFG
I2SMCLK	O	I2S Master clock output	
	I	I2S Master clock input from GPIO	Depends on GPIOn_CFG

13.3.2 Codec Pin Description

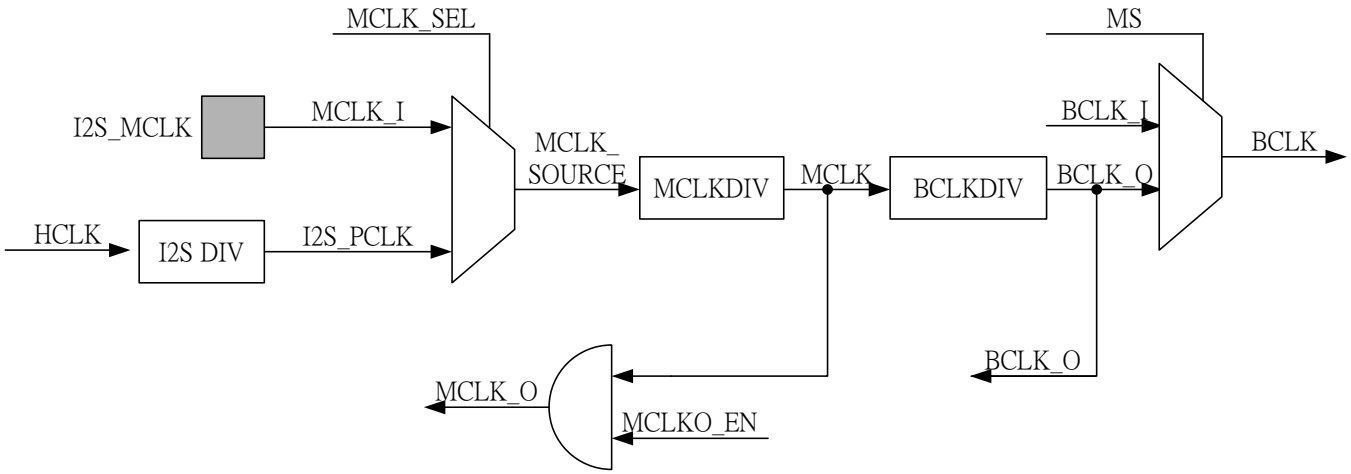
Pin Name	Type	Description	GPIO Configuration
AVDD_ADC, AVSS_ADC	P	Power supply input pins for Sigma-delta ADC.	
VMID_ADC	P	Sigma-delta ADC VMID output.	
MIC_BIAS	P	Sigma-delta ADC Microphone Bias Voltage output.	
MIC_P	I/O	Sigma-delta ADC MIC difference input (+).	Depends on GPIOn_CFG
MIC_N	I/O	Sigma-delta ADC MIC difference input (-).	Depends on GPIOn_CFG
AVDD_DAC, AVSS_DAC	P	Power supply input pins for Sigma-delta DAC.	
AVDD_DRV, AVSS_DRV	P	Power supply input pins for Sigma-delta DAC Driver.	
VCOM_DAC	P	Sigma-delta DAC Common mode output.	
VMID_DAC	P	Sigma-delta DAC VMID output.	
VOUTP	I/O	Sigma-delta DAC output (+).	
VOUTN	I/O	Sigma-delta DAC output (-).	

13.3.3 Audio Clock Pin Description

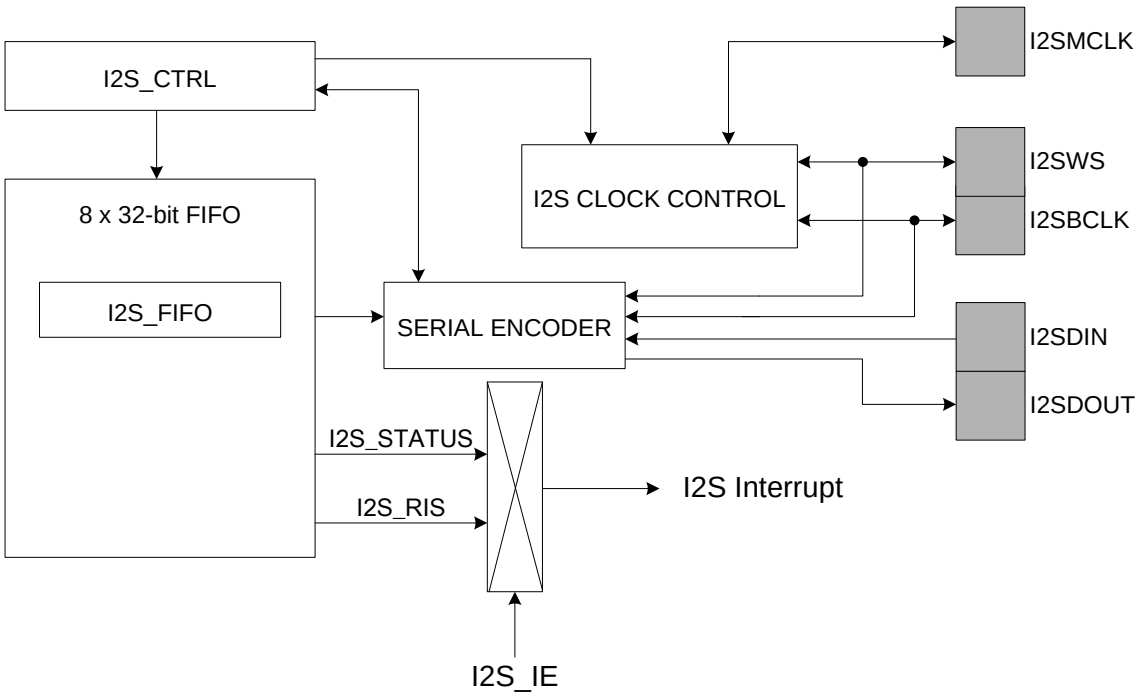
Pin Name	Type	Description	GPIO Configuration
AUXTALOUT	I/O	External high-speed X'tal output pin for audio.	Depends on GPIOn_CFG
AUXTALIN	I/O	External high-speed X'tal input pin for audio.	Depends on GPIOn_CFG

13.4 BLOCK DIAGRAM

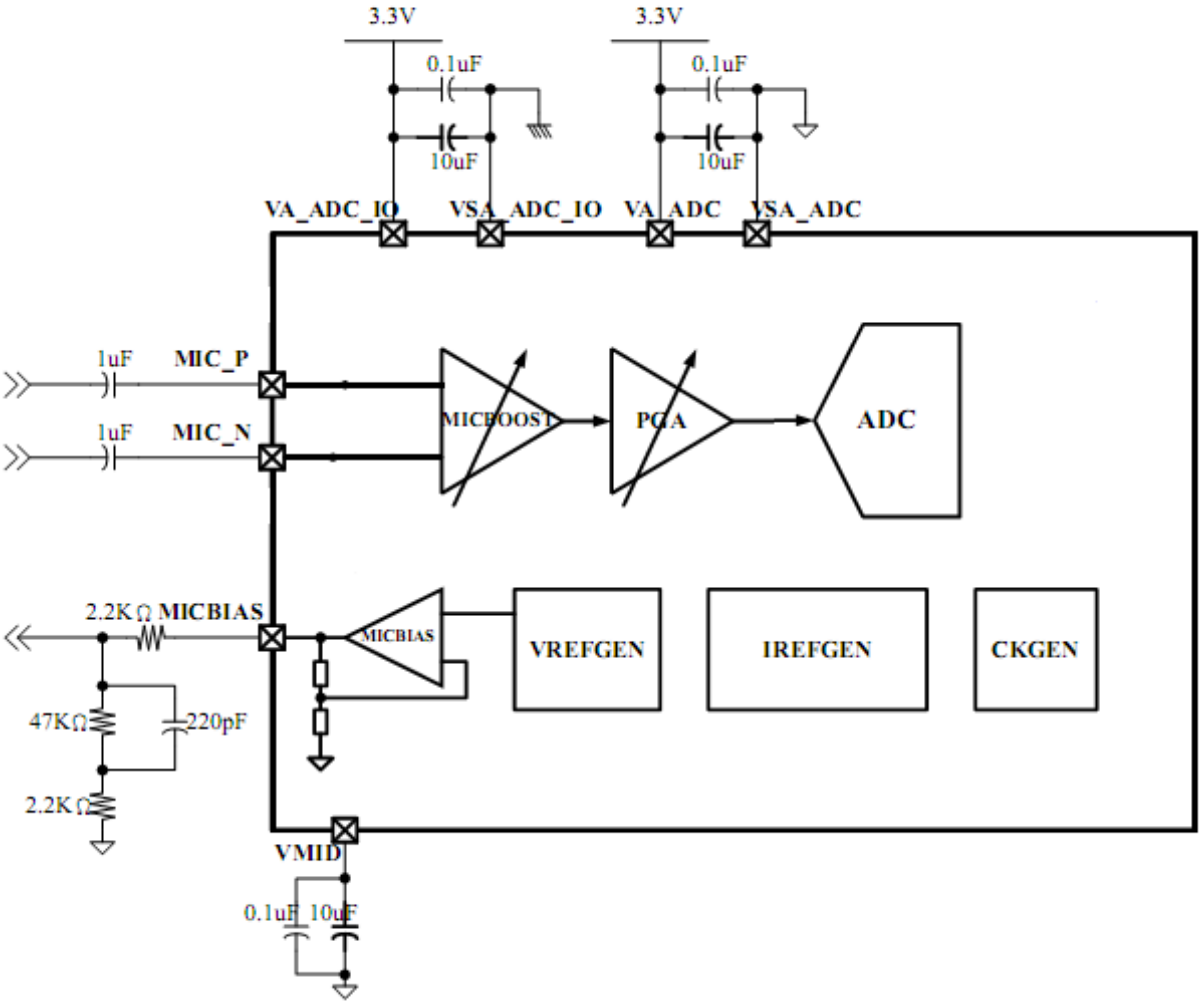
13.4.1 I2S CLCOK CONTROL



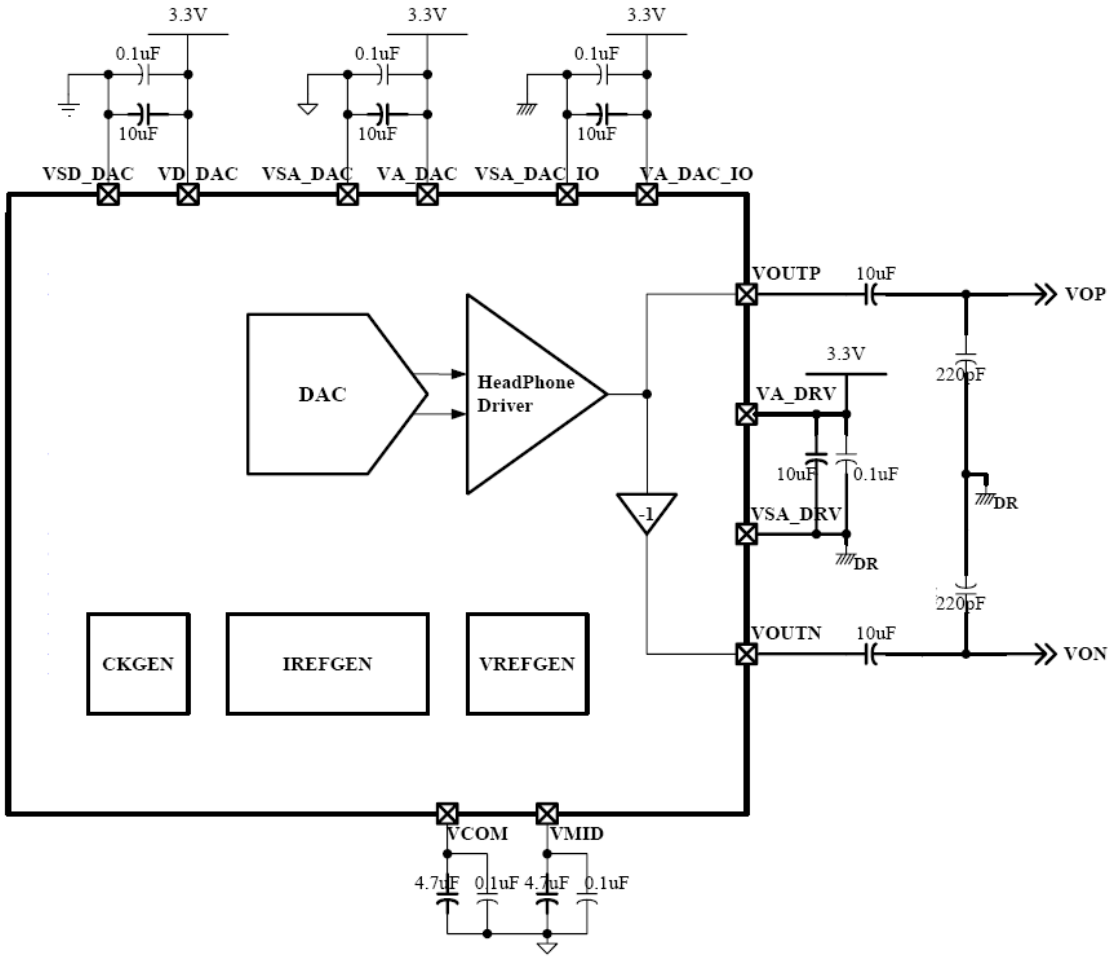
13.4.2 I2S BLOCK DIAGRAM



13.4.3 16-Bit Sigma-Delta ADC BLOCK DIAGRAM



13.4.4 16-Bit Sigma-Delta DAC BLOCK DIAGRAM

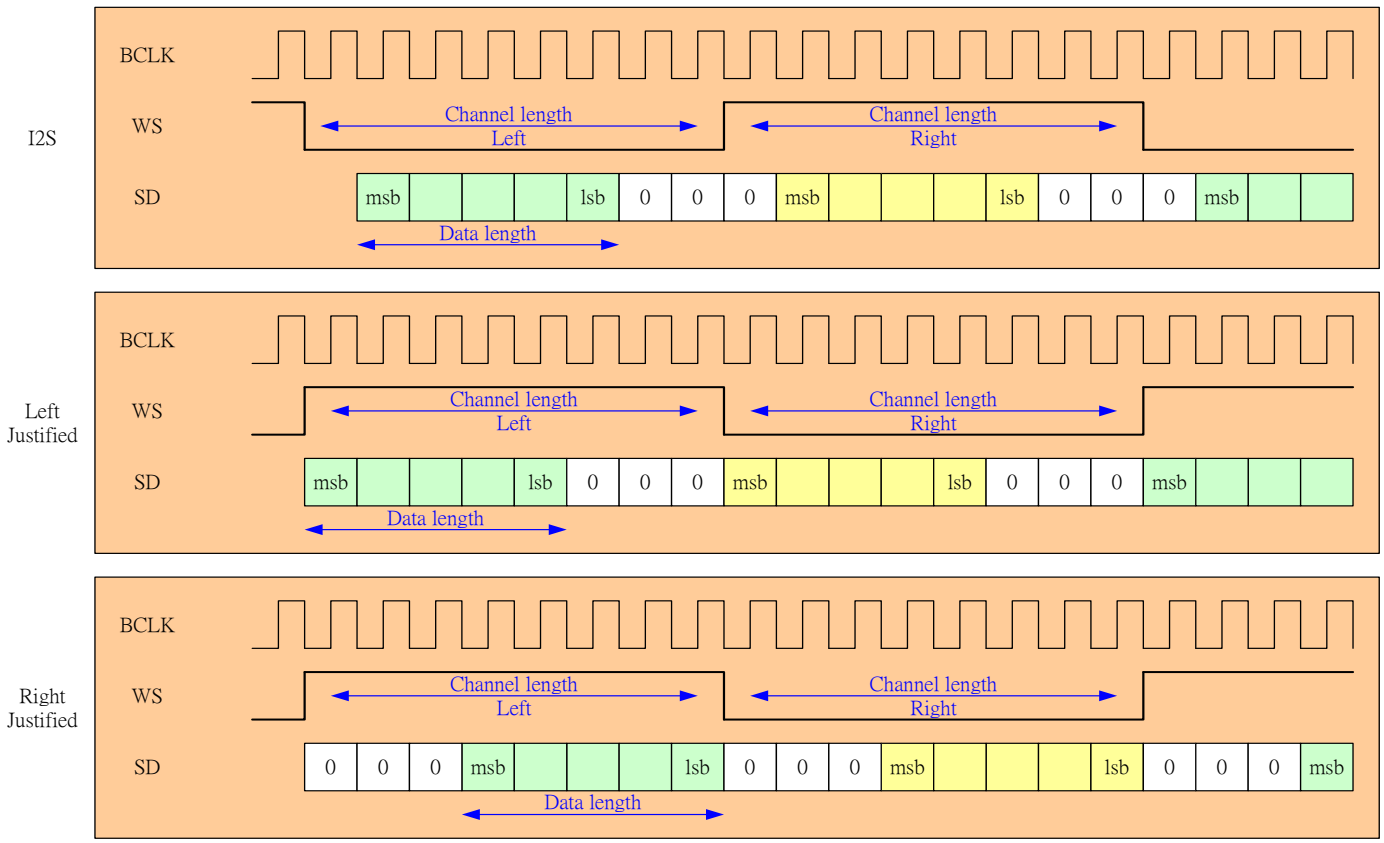


13.5 FUNCTIONAL DESCRIPTION

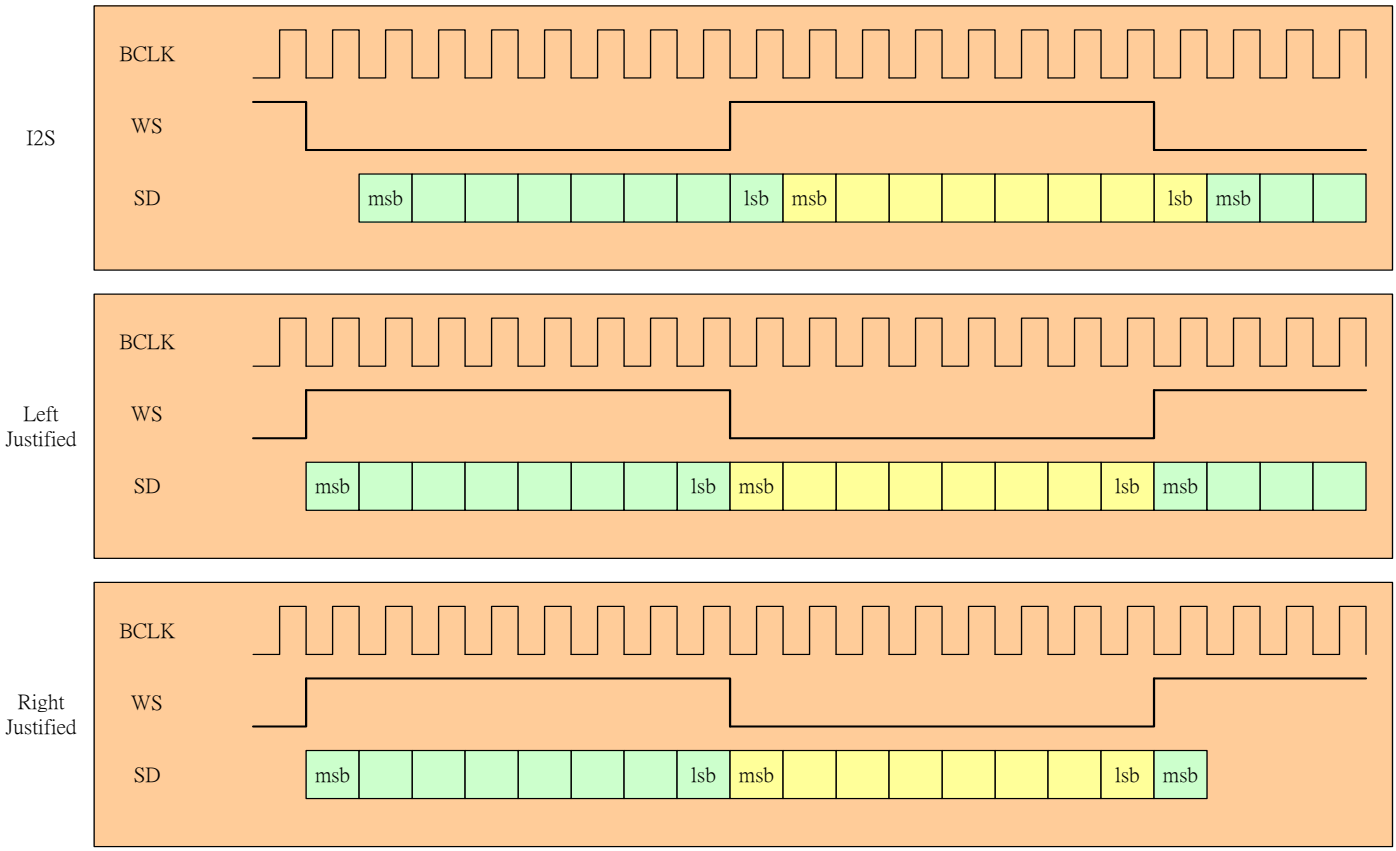
13.5.1 I2S OPERATION

- Standard I2S
- Right-justified Data Format
- MSB (Left)-justified Data Format

Channel Length > Data Length:



Channel Length = Data Length



13.5.2 I2S FIFO OPERAION

13.5.2.1 MONO

8bit

N+3	N+2	N+1	N
N+7	N+6	N+5	N+4

16bit

N+1	N
N+3	N+2

24 bit

	N
	N+1

32 bit

N
N+1

13.5.2.2 STEREO

8bit

RIGHT +1	LEFT +1	RIGHT	LEFT
RIGHT +3	LEFT +3	RIGHT +2	LEFT +2

16bit

RIGHT	LEFT
RIGHT +1	LEFT+1

24 bit

	LEFT
	RIGHT

32 bit

LEFT
RIGHT

13.6 I2S REGISTERS

Base Address: 0x4001 A000

13.6.1 I2S Control register (I2S_CTRL)

Address Offset: 0x00

✸ ***Note: START bit shall be set at last.***

Bit	Name	Description	Attribute	Reset
31	I2SEN	I2S enable bit 0: Disable 1: Enable I2S.	R/W	0
30	I2SMOD	I2S mode select bit 0: I2S mode for external I2S interface. (If I2SEN=1 and I2SMOD=0, HW will switch GPIO to DIN, DOUT, MCLK, BCLK, and WS.) 1: Codec mode for internal I2S interface connected to ADC and DAC. (If I2SEN=1 and I2SMOD=1, HW will switch channel length=32bits, BCLK=MCLK/4, Standard I2S format, I2S master, and I2S mono mode)	R/W	0
29:25	Reserved		R	0
24:20	CHLENGTH[4:0]	Bit number of single channel = CHLENGTH[4:0]+1. 0~6: Reserved 7: 8 bits 8: 9 bits … … 31: 32bits (Max) (If I2SEN=1, and I2SMOD=1, HW will switch channel length=32bits)	R/W	0x1F
19	Reserved		R	0
18:16	RXFIFOTH[2:0]	RX FIFO Threshold level 0: RX FIFO threshold level = 0 1: RX FIFO threshold level = 1 … … n: RX FIFO threshold level = n	R/W	0x3
15	Reserved		R	0
14:12	TXFIFOTH[2:0]	TX FIFO Threshold level 0: TX FIFO threshold level = 0 1: TX FIFO threshold level = 1 … … n: TX FIFO threshold level = n	R/W	0x3
11:10	DL[1:0]	Data Length 00: 8 bits 01: 16 bits 10: 24 bits 11: 32 bits	R/W	0x1
9	CLRRXFIFO	Clear I2S RX FIFO 0: No effect. 1: Reset RX FIFO (RXFIFOLV bit becomes 0, RXFIFOEMPTY bit becomes 1, Data in RX FIFO will be cleared). This bit returns “0” automatically	W	0
8	CLRTXFIFO	Clear I2S TX FIFO 0: No effect. 1: Reset TX FIFO (TXFIFOLV bit becomes 0, TXFIFOEMPTY bit becomes 1, Data in TX FIFO will be cleared). This bit returns “0” automatically	W	0
7	RXEN	Receiver enable bit 0: Disable 1: Enable	R/W	0
6	TXEN	Transmit enable bit	R/W	0

		0: Disable 1: Enable		
5:4	FORMAT[1:0]	I2S operation format. 00: Standard I2S format 01: Left-justified format 10: Right(MSB)-justified format 11: Reserved (If I2SEN=1 and I2SMOD=1, HW will switch Standard I2S format)	R/W	0
3	MS	Master/Slave selection bit 0: Act as Master using internally generated BCLK and WS signals. 1: Act as Slave using externally BCLK and WS signals. (If I2SEN=1 and I2SMOD=1, HW will switch Master mode)	R/W	0
2	MONO	Mono/Stereo selection bit 0: Stereo 1: Mono (If I2SEN=1 and I2SMOD=1, HW will switch Mono mode)	R/W	0
1	MUTE	Mute enable bit 0: Disable Mute 1: Enable. I2SSDA Output = 0	R/W	0
0	START	Start Transmit/Receive bit. 0: Stop Transmit/Receive 1: Start Transmit/Receive	R/W	0

13.6.2 I2S Clock register (I2S_CLK)

Address Offset: 0x04

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:8	BCLKDIV[7:0]	BCLK divider 0: BCLK = MCLK / 2 1: BCLK = MCLK / 4 2: BCLK = MCLK / 6 3: BCLK = MCLK / 8 … … n: BCLK = MCLK / (2*n +2) (If I2SEN=1, and I2SMOD=1, HW will switch BCLK=MCLK/4)	R/W	1
7:5	Reserved		R	0
4	MCLKSEL	MCLK source selection bit 0: MCLK source of master is from I2S_PCLK 1: MCLK source of master is from External high-speed X'tal for audio(AUXTALOUT/AUXTALIN) and Audio Clock Prescaler out(AUEHSPRE[2:0])	R/W	0
3	MCLKOEN	MCLK output enable bit 0: Disable 1: Enable	R/W	0
2:0	MCLKDIV[2:0]	MCLK divider 0: MCLK = MCLK source 1: MCLK = MCLK source / 2 2: MCLK = MCLK source / 4 … … n: MCLK = MCLK source / (2*n), n>0	R/W	0

13.6.3 I2S Status register (I2S_STATUS)

Address Offset: 0x08

Bit	Name	Description	Attribute	Reset
31:21	Reserved		R	0

20:17	RXFIFOLV[3:0]	RX FIFO used level 0000: 0/8 RX FIFO is used (Empty) 0001: 1/8 RX FIFO is used 0010: 2/8 RX FIFO is used … … 1000: 8/8 RX FIFO is used (Full) Other: Reserved	R	0
16	Reserved		R	0
15:12	TXFIFOLV[3:0]	TX FIFO used level 0000: 0/8 TX FIFO is used (Empty) 0001: 1/8 TX FIFO is used 0010: 2/8 TX FIFO is used … … 1000: 8/8 TX FIFO is used (Full) Other: Reserved	R	0
11	RXFIFOEMPTY	RX FIFO empty flag 0: RX FIFO is not empty. 1: RX FIFO is empty. Data read from RX FIFO will be zero.	R	1
10	TXFIFOEMPTY	TX FIFO empty flag 0: TX FIFO is not empty. 1: TX FIFO is empty.	R	1
9	RXFIFOFULL	RX FIFO full flag 0: RX FIFO is not full. 1: RX FIFO is full.	R	0
8	TXFIFOFULL	TX FIFO full flag 0: TX FIFO is not full. 1: TX FIFO is full. Write operation to TX FIFO will be ignored.	R	0
7	RXFIFOTHF	RX FIFO threshold flag 0: RXFIFOLV ≦ RXFIFOTH 1: RXFIFOLV > RXFIFOTH	R	0
6	TXFIFOTHF	TX FIFO threshold flag 0: TXFIFOLV ≧ TXFIFOTH 1: TXFIFOLV < TXFIFOTH	R	1
5:2	Reserved		R	0
1	RIGHTCH	Current channel status 0: Current channel is Left channel 1: Current channel is Right channel	R	1
0	I2SINT	I2S interrupt flag 0: No I2S interrupt 1: I2S interrupt occurs.	R	0

13.6.4 I2S Interrupt Enable register (I2S_IE)

Address Offset: 0x0C

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7	RXFIFOTHIEN	RX FIFO threshold interrupt enable bit 0: Disable 1: Enable	R/W	0
6	TXFIFOTHIEN	TX FIFO threshold interrupt enable bit 0: Disable 1: Enable	R/W	0
5	RXFIFOUDFIEN	RX FIFO underflow interrupt enable bit 0: Disable 1: Enable	R/W	0
4	TXFIFOOVFIEN	TX FIFO overflow interrupt enable bit 0: Disable 1: Enable	R/W	0
3:0	Reserved		R	0

13.6.5 I2S Raw Interrupt Status register (I2S_RIS)

Address Offset: 0x10

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7	RXFIFOTHIF	RX FIFO threshold interrupt flag 0: No RX FIFO threshold interrupt 1: RX FIFO threshold triggered.	R	0
6	TXFIFOTHIF	TX FIFO threshold interrupt flag 0: No TX FIFO threshold interrupt 1: TX FIFO threshold triggered.	R	0
5	RXFIFOUDIF	RX FIFO underflow interrupt flag 0: No RX FIFO underflow 1: RX FIFO underflow (RX FIFO is empty and still being read).	R	0
4	TXFIFOOVIF	TX FIFO overflow interrupt flag 0: No TX FIFO overflow 1: TX FIFO overflow (TX FIFO is full and still being written).	R	0
3:0	Reserved		R	0

13.6.6 I2S Interrupt Clear register (I2S_IC)

Address Offset: 0x14

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7	RXFIFOTHIC	0: No effect 1: Clear RXFIFOTHIF bit	W	0
6	TXFIFOTHIC	0: No effect 1: Clear TXFIFOTHIF bit	W	0
5	RXFIFOUDIC	0: No effect 1: Clear RXFIFOOUDIF bit	W	0
4	TXFIFOOVIC	0: No effect 1: Clear TXFIFOOVIF bit	W	0
3:0	Reserved		R	0

13.6.7 I2S RX FIFO register (I2S_RXFIFO)

Address Offset: 0x18

Bit	Name	Description	Attribute	Reset
31:0	RXFIFO[31:0]	8 x 32-bit RX FIFO	R	0

13.6.8 I2S TX FIFO register (I2S_TXFIFO)

Address Offset: 0x1C

Bit	Name	Description	Attribute	Reset
31:0	TXFIFO[31:0]	8 x 32-bit TX FIFO	W	0

13.7 CODEC ADC REGISTERS

Base Address: 0x4006 4000

✸ ***Note: Codec ADC Registers are available only when codec mode is selected by I2SMOD=1.***

13.7.1 ADC Setting 1 register (ADC_SET1)

Address Offset: 0x540

Bit	Name	Description	Attribute	Reset

31:8	Reserved		R	0
7:0	LB_H	AGC Control. Low bound setting for output amplitude of ADC: High byte	R/W	0x40

13.7.2 ADC Setting 2 register (ADC_SET2)

Address Offset: 0x550

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	LB_L	AGC Control. Low bound setting for output amplitude of ADC: Low byte	R/W	0x00

13.7.3 ADC Setting 3 register (ADC_SET3)

Address Offset: 0x560

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	HB_H	AGC Control. High bound setting for output amplitude of ADC: High byte	R/W	0x60

13.7.4 ADC Setting 4 register (ADC_SET4)

Address Offset: 0x570

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	HB_L	AGC Control. High bound setting for output amplitude of ADC: Low byte	R/W	0x00

13.7.5 ADC Setting 5 register (ADC_SET5)

Address Offset: 0x580

Bit	Name	Description	Attribute	Reset
31:4	Reserved		R	0
3:0	NOR_POD	AGC Control. The period of gain update at normal mode when AGC is enabled. Fs : Audio sampling rate 0000: 1/Fs x 2^(0) 0001: 1/Fs x 2^(1) ……. 1110: 1/Fs x 2^(14) 1111: 1/Fs x 2^(15)	R/W	0x05

13.7.6 ADC Setting 6 register (ADC_SET6)

Address Offset: 0x590

Bit	Name	Description	Attribute	Reset
31:4	Reserved		R	0
3:0	MUTE_POD	AGC Control. The period of gain update at mute mode when AGC is enabled. Fs : Audio sampling rate 0000: 1/Fs x 2^(0) 0001: 1/Fs x 2^(1) ……. 1110: 1/Fs x 2^(14) 1111: 1/Fs x 2^(15)	R/W	0x0B

13.7.7 ADC Setting 7 register (ADC_SET7)

Address Offset: 0x5A0

Bit	Name	Description	Attribute	Reset

31:8	Reserved		R	0
7:0	SEARCH_TH_H	AGC Control. Threshold for activating AGC. High byte. Once ADC output is larger than the threshold, AGC will update internal digital gain until the output amplitude is between high bound and low bound.	R/W	0x03

13.7.8 ADC Setting 8 register (ADC_SET8)

Address Offset: 0x5B0

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	SEARCH_TH_L	AGC Control. Threshold for activating AGC. Low byte.	R/W	0x00

13.7.9 ADC Setting 9 register (ADC_SET9)

Address Offset: 0x5C0

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	MUTE_TH_H	AGC Control. Threshold for inactivating AGC. High byte Once ADC output is lower than the threshold *(the check period setting is MUTE_CAL_POD in ADC_SET11)*, AGC will update internal digital gain until the PGA and Boost setting are equal to the setting in ADC_SET19. Then the internal digital gain is adjusted to default value. Finally, the AGC is entering mute mode until the ADC output is over search threshold in ADC_SET7 & ADC_SET8.	R/W	0x10

13.7.10 ADC Setting 10 register (ADC_SET10)

Address Offset: 0x5D0

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	MUTE_TH_L	AGC Control. Threshold for inactivating AGC. Low byte	R/W	0x00

13.7.11 ADC Setting 11 register (ADC_SET11)

Address Offset: 0x5E0

Bit	Name	Description	Attribute	Reset
31:4	Reserved		R	0
3:0	MUTE_CAL_POD	AGC Control. The calculating period for inactivating AGC. Fs : Audio sampling rate 0000: 256/Fs x 2^(0) 0001: 256/Fs x 2^(1) ……. 1110: 256/Fs x 2^(14) 1111: 256/Fs x 2^(15) AGC will check whether entering mute mode or not according to mute threshold per (MUTE_CAL_POD) seconds.	R/W	0x09

13.7.12 ADC Setting 12 register (ADC_SET12)

Address Offset: 0x5F0

Bit	Name	Description	Attribute	Reset
31:4	Reserved		R	0
3:0	SAT_TH	AGC Control. Threshold for ADC saturation condition. The saturation condition is for sigma-delta ADC, if there are more than	R/W	0x03

		(SAT_TH) bit streams are saturating, then the internal gain will be adjusted rapidly to avoid the ADC output saturation.		

13.7.13 ADC Setting 13 register (ADC_SET13)

Address Offset: 0x600

Bit	Name	Description	Attribute	Reset
31:4	Reserved		R	0
3:0	SAT_POD	AGC Control. The detection period for ADC saturation condition. Fs : Sampling rate 0000: 1/Fs x 2^(0) 0001: 1/Fs x 2^(1) ……. 1110: 1/Fs x 2^(14) 1111: 1/Fs x 2^(15)	R/W	0x0A

13.7.14 ADC Setting 14 register (ADC_SET14)

Address Offset: 0x610

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7	AGC_OFF	AGC Control AGC function 0: Enable 1: Disable	R/W	0x01
6:5	BOOST_SET_VAL	AGC Control Boost setting value at normal mode when AGC is on. 00: +0dB 01:+12dB 10: +20dB 11:+30dB	R/W	0x03
4:0	PGA_SET_VAL	AGC Control. PGA setting value at normal mode when AGC is on (1.5dB/step). 00000: Mute 00001: -12dB 01001: 0dB …… 11110: +31.5dB 11111: +33dB	R/W	0x10

13.7.15 ADC Setting 15 register (ADC_SET15)

Address Offset: 0x620

Bit	Name	Description	Attribute	Reset
31:3	Reserved		R	0
2	ACTIVE	Digital Audio Interface Control. 0: Disable 1: Enable	R/W	0x01
1:0	IWL	Word length of DA interface. 00: 16-bits 01: 18-bits 10: 20-bits 11: 24-bits	R/W	0x03

13.7.16 ADC Setting 16 register (ADC_SET16)

Address Offset: 0x630

Bit	Name	Description	Attribute	Reset
31:7	Reserved		R	0
6:5	BOOST	Boost setting value when AGC is off 00: +0dB 01: +12dB	R/W	0x00

		10: +20dB 11: +30dB		
4:0	PGA	PGA setting value when AGC is off 00000: Mute 00001: -12dB …… 01001: 0dB …… 11110: +31.5dB 11111: +33dB	R/W	0x09

13.7.17 ADC Setting 18 register (ADC_SET18)

Address Offset: 0x650

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:4	VOL_CTRL	Digital Volume attenuation control. At the normal mode when AGC is on or off. 0000: 0dB 0001: -3dB 0010: -6dB 0011: -9dB 0100: -12dB 0101: -15dB 0110: -18dB 0111: -21dB 1000: -24dB 1001: -27dB 1010: -30dB 1011: -36dB 1100: -42dB 1101: -48dB 1110: -54dB 1111: -78dB	R/W	0x00
3:0	MUTE_CTRL	Digital Volume attenuation control. At the mute mode when AGC is on. 0000: 0dB 0001: -3dB 0010: -6dB 0011: -9dB 0100: -12dB 0101: -15dB 0110: -18dB 0111: -21dB 1000: -24dB 1001: -27dB 1010: -30dB 1011: -36dB 1100: -42dB 1101: -48dB 1110: -54dB 1111: -78dB	R/W	0x00

13.7.18 ADC Setting 19 register (ADC_SET19)

Address Offset: 0x660

Bit	Name	Description	Attribute	Reset
31:7	Reserved		R	0
6:5	BOOST_MUTE_VAL	AGC Control. Boost setting value at mute mode when AGC is enabled. 00: +0dB 01: +12dB 10: +20dB 11: +30dB	R/W	0x03
4:0	PGA_MUTE_VAL	AGC Control. PGA setting value at mute mode when AGC is enabled. 00000: Mute	R/W	0x10

		00001: -12dB …… 01001: 0dB …… 11110: +31.5dB 11111: +33dB		

13.7.19 ADC Setting 20 register (ADC_SET20)

Address Offset: 0x670

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	VOL_MUTE_POD	The updating period for Digital Volume attenuation at the normal/mute mode when AGC is on. Bit[7:4]: for normal mode. Bit[3:0]: for mute mode. Fs : Sampling rate 0000: 1/Fs x 2^(0) 0001: 1/Fs x 2^(1) ……. 1110: 1/Fs x 2^(14) 1111: 1/Fs x 2^(15) The volume update when mode transition. This is mainly for avoiding large variation of analog gain setting during the transition of normal mode and mute mode.	R/W	0x12

13.7.20 ADC Setting 21 register (ADC_SET21)

Address Offset: 0x6B0

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7	ADC_EN	ADC power-on enable, active High	R/W	0
6	Reserved		R	0
5	MICBT_EN	MICBOOST power-on enable, active High	R/W	0
4	PGA_EN	PGA power-on enable, active High	R/W	0
3:0	Reserved		R	0

13.7.21 ADC Setting 22 register (ADC_SET22)

Address Offset: 0x6C0

Bit	Name	Description	Attribute	Reset
31:4	Reserved		R	0
3	IREF_EN	IREF circuit enable, active High	R/W	0
2	VREF_EN	VREF circuit enable, active High	R/W	0
1	MICB_EN	Microphone bias enable, active High	R/W	0
0	CK_EN	CKGEN enable, active High	R/W	0

13.7.22 ADC Setting 23 register (ADC_SET23)

Address Offset: 0x6D0

Bit	Name	Description	Attribute	Reset
31:5	Reserved		R	0
4	SEL_MICB	Microphone Bias Output select 0: 0.8*VA 1: 0.9*VA	R/W	0
3	Reserved		R	0
2	SEL_MIC	P1.7/MIC_P and P1.8/MIC_N function selection 0: General purpose IO 1: Microphone Differential input when ADC is enabled	R/W	0
1	Reserved		R	0
0	SEL_MIX_MIC	Microphone input path to mixer enable	R/W	1

		0: Disable 1: Enable		

13.7.23 ADC Setting 24 register (ADC_SET24)

Address Offset: 0x6E0

Bit	Name	Description	Attribute	Reset
31:7	Reserved		R	0
6:5	BOOST_AGC	Boost setting value when AGC is on.	R	-
4:0	PGA_AGC	PGA setting value when AGC is on.	R	-

13.8 CODEC DAC REGISTERS

Base Address: 0x4006 5000

> ✸ ***Note: Codec DAC Registers are available only when codec mode is selected by I2SMOD=1.***

13.8.1 DAC Setting 1 register (DAC_SET1)

Address Offset: 0x000

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7	PD_DAC	DAC Power-down, active High	R/W	1
6	PD_CLK	CKGEN Power-down, active High	R/W	1
5	PD_IREF	IREF Circuit Power-down, active High	R/W	1
4:3	Reserved		R	0
2	PD_VREF	VREF Circuit Power-down, active High	R/W	1
1	VMIDSEL	Normal mode/Fast Start-up select 0 : Normal mode 1 : Fast Start-up mode	R/W	0
0	Reserved		R	0

13.8.2 DAC Setting 2 register (DAC_SET2)

Address Offset: 0x010

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:6	RMP[1:0]	Attenuation ramp rate T= LRCK clock RMP = 00 1T RMP = 01 2T RMP = 10 4T RMP = 11 8T If VOL[7:0] in DAC_SET3 is changed, then after (RMP) seconds, the DAC output will start updating the volume.	R/W	0
5:3	Reserved		R	0
2	MUTX	Mute ON/OFF 1: Mute on 0 : Mute off	R/W	1
1	DAC_EN_IN	DAC Enable 1: Enable 0: Disable	R/W	0
0	SOFT_RSTN	Software reset digital circuit . low reset . one MCLK pulse trigger	R/W	1

13.8.3 DAC Setting 3 register (DAC_SET3)

Address Offset: 0x020

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	VOL[7:0]	Digital volume attenuation, -0.5dB/step 0x00: 0dB 0x01: -0.5dB 0x02: -1dB ……. 0x7E: -63dB 0x7F: -63.5dB	R/W	0

13.8.4 DAC Setting 4 register (DAC_SET4)

Address Offset: 0x030

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7	PD_DRV	DAC driver power down	R/W	1
6:3	Reserved		R	0
2:1	DEMS[1:0]	Select the DAC de-emphasis response curve 0: Reserved 1: De-emphasis for 48 kHz 2: De-emphasis for 44.1 kHz 3: De-emphasis for 32 kHz	R/W	0
0	INI_RAM_EN	Initialize DAC RAM, Set 1, until Ini_RAM_Ready =1, then clear this bit.	R/W	0

13.8.5 DAC Status register (DAC_STATUS)

Address Offset: 0x040

Bit	Name	Description	Attribute	Reset
31:1	Reserved		R	0
0	Ini_RAM_Ready	Status for checking whether the ram initialization is ready or not.	R	0

13.9 Sigma-delta ADC Control Flow

13.9.1 Sigma-delta ADC Power-up Sequence

Step1: IREF_EN = 1

Step2: VREF_EN = 1

Step3: MICBOOST_EN = 1

Step4: PGA_EN = 1

Step5: ADC_EN = 1

Step6: CK_EN = 1

Step7: MICB_EN = 1

13.9.2 Sigma-delta ADC Power-down Sequence

Step1: ADC_EN = 0

Step2: PGA_EN = 0

Step3: MICBOOST_EN = 0

Step4: MICB_EN = 0

Step5: VREF_EN = 0

Step6: IREF_EN = 0

Step7: CK_EN = 0

13.9.3 Sigma-delta ADC Enable Sequence

Step1: ADC Analog Enable (Sigma-delta ADC Power-Up Sequence)

Step2: ADC Digital Enable (ACTIVE = 1)

Step3: Delay 21us for ADC setup time

Step4: MCLK Output Enable (MCLKOEN = 1 and I2S Enable)

13.10 Sigma-delta DAC Control Flow

13.10.1 Sigma-delta DAC Power-up Sequence

Step1: PD_IREF = 0

Step2: VMIDSEL = 1

Step3: PD_VREF = 0

Step4: VMIDSEL = 0

Step5: PD_DAC = 0

Step6: PD_CLK = 0

Step7: After PD_CLK, delay 6.3us

Step8: After I2S data ready, delay 125ms

Step9: PD_DRV = 0

13.10.2 Sigma-delta DAC Power-down Sequence

Step1: PD_DRV = 1

Step2: PD_DAC = 1

Step3: VMIDSEL = 0

Step4: PD_VREF = 1

Step5: PD_IREF = 1

Step6: PD_CLK = 1

13.10.3 Sigma-delta DAC Enable Sequence

Step1: DAC Digital Enable (DAC_EN_IN = 1)

Step2: MCLK Output Enable (MCLKOEN = 1 and I2S Enable)

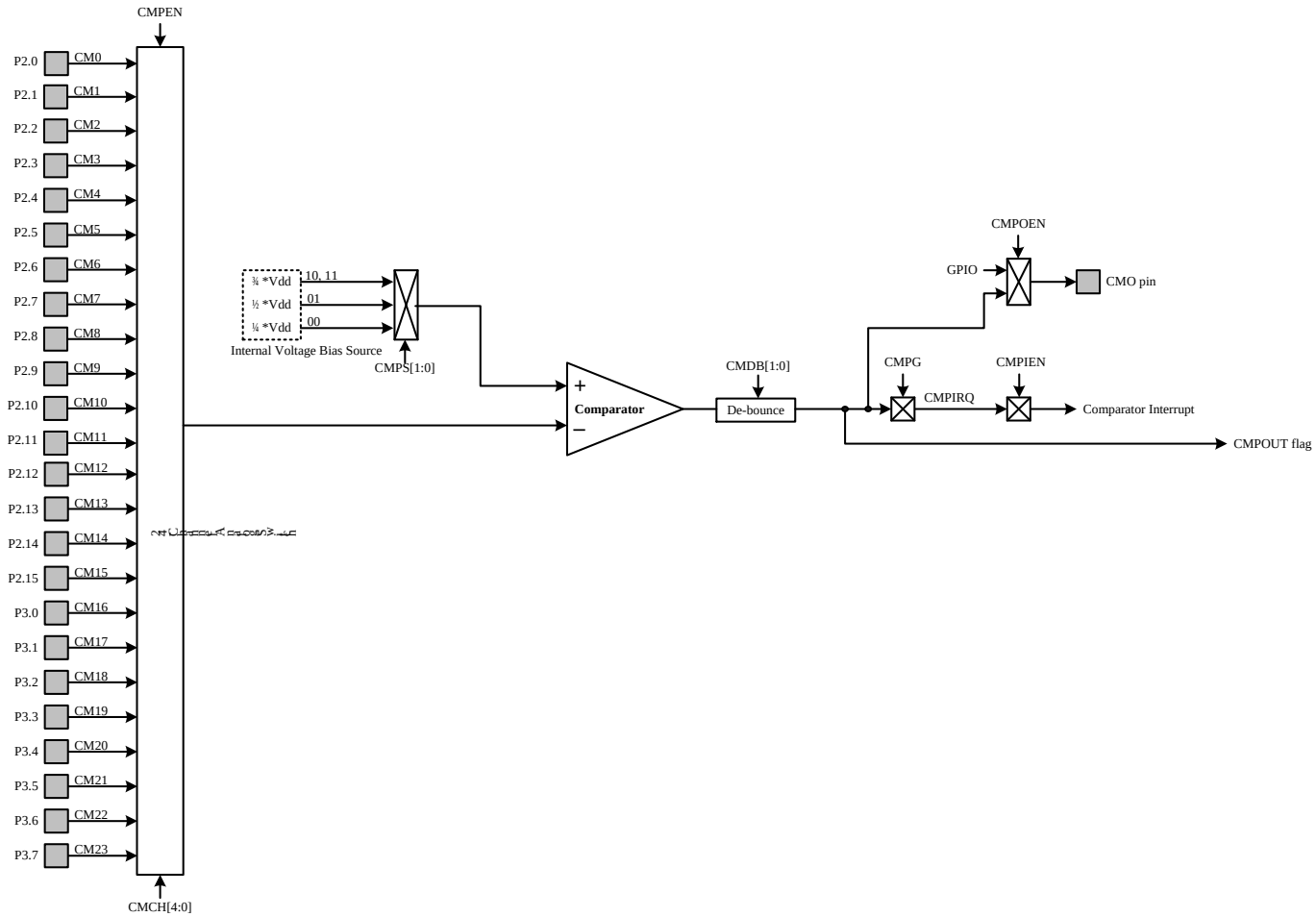
Step3: DAC Analog Enable (Sigma-delta DAC Power-Up Sequence)

14 24-CHANNEL COMPARATOR

14.1 OVERVIEW

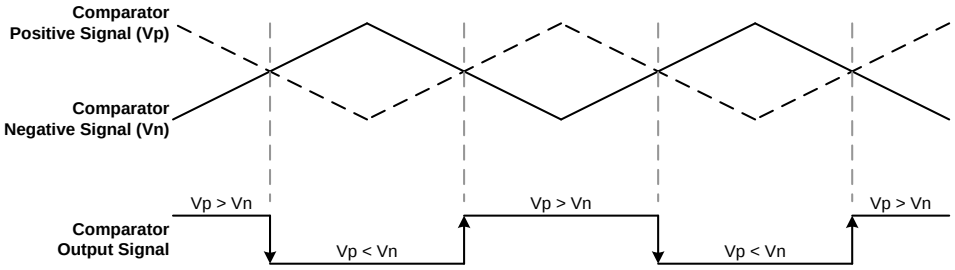
The analog comparator compares negative input voltage, and then output the result to comparator output terminal. The comparator has multi-input selection for different applications. The comparator negative input terminal is up to 24-channel controlled by CMCH[4:0]. The comparator positive input terminal has three selections controlled by CMPS[1:0] bits. The comparator output terminal connects to external pin CMO and connects to internal path. There is a programmable direction function to decide comparator trigger edge for indicator function. The comparator has flag indicator, interrupt function and sleep mode weak-up function for different application.

- 24-channel negative input selection.
- Comparator output function.
- Programmable internal reference voltage connected to comparator's positive terminal.
- Comparator unit with programmable output de-bounce
- Programmable trigger direction.
- Interrupt function.
- Sleep mode wake-up function.



14.2 COMPARATOR OPERATION

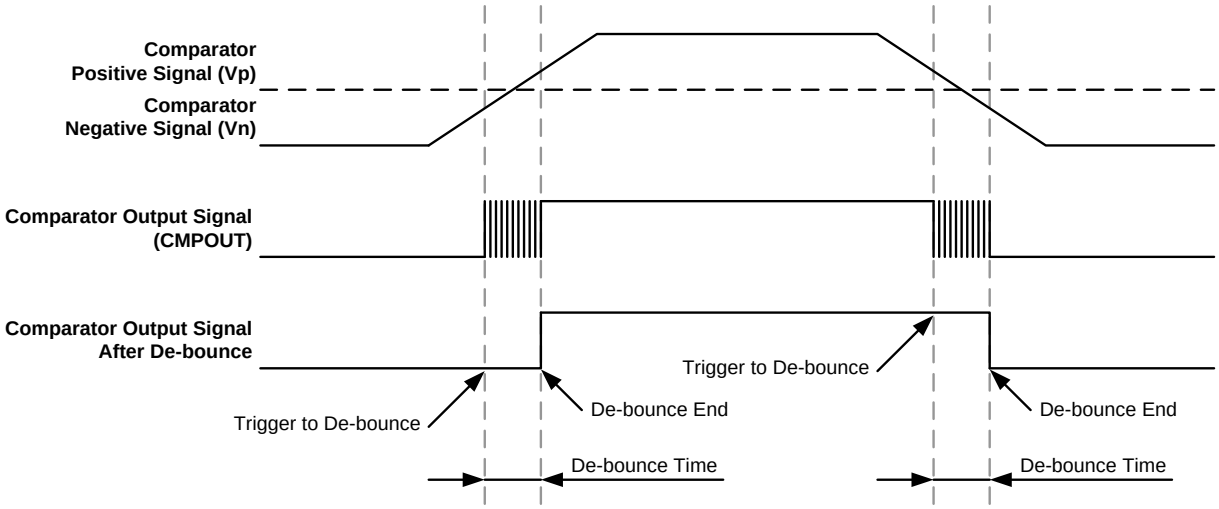
The comparator operation is to compare the voltage between comparator positive input and negative input terminals. When the positive input voltage is greater than the negative input voltage, the comparator output is high status. When the positive input voltage is smaller than the negative input voltage, the comparator output is low status.



The comparator builds in interrupt function. The interrupt function trigger edge is selected by CMPG. The trigger edge supports rising edge (CMPG=0), falling edge (CMPG=1). If the trigger edge condition is found, the CMPIRQ is set as “1”. If the comparator interrupt function enables, the system will execute interrupt routine. The CMPIRQ must be cleared by program.

The comparator builds in sleep mode wake-up function. The comparator sleep mode wake-up trigger edge is bi-direction. The comparator’s wake-up function only supports sleep mode, not deep-sleep mode and deep-power down mode. If the trigger edge condition (comparator output status exchanging) is found, the system will be wake-up from sleep mode. If the trigger edge direction is interrupt trigger condition, the CMPIRQ is set as “1”. Of course the interrupt routine is executed if the interrupt function enabled. When the wake-up trigger edge direction is equal to interrupt trigger condition, the system will execute interrupt operation after sleep mode wake-up immediately.

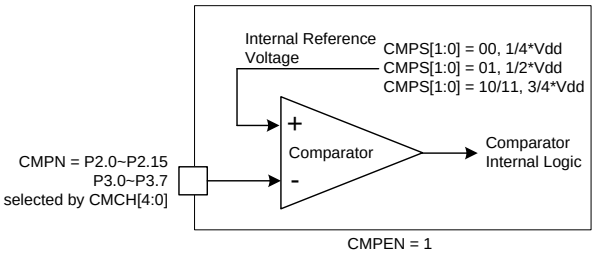
The critical condition is comparator positive voltage equal to comparator negative voltage, and the voltage range is decided comparator offset parameter of input common mode. In the voltage range, the comparator output signal is unstable and keeps oscillating until the differential voltage exits the range. In the condition, the comparator flag (CMPIRQ) latches the first exchanging and issue the status, but the status is a transient, not a stable condition. So the comparator builds in a filter to de-bounce the transient condition. The comparator output signal is through a de-bounce circuit to filter comparator transient status. The de-bounce time is controlled by CMDB[1:0] bits that means the comparator minimum response time is zero, 1*CMP_PCLK, 2*CMP_PCLK or 3*CMP_PCLK. The de-bounce time depends on the signal slew rate and selected by program.



The comparator positive input terminal includes internal reference voltage source. The internal reference voltage source supports three levels which are 1/4*Vdd (CMPS[1:0] = 00), 1/2*Vdd (CMPS[1:0] = 01) and 3/4*Vdd (CMPS[1:0] = 10,11).

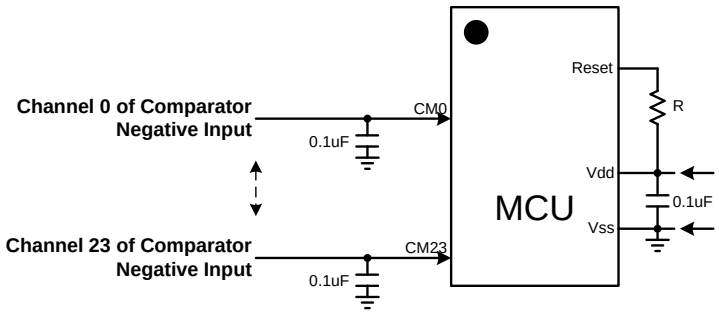
The comparator negative input terminal supports maximum 24-channel controlled by CMCH [4:0]. 00000 = P2.0. 00001 = P2.1. 00010 = P2.2. 00011 = P2.3. 00100 = P2.4. 00101 = P2.5. 00110 = P2.6. 00111 = P2.7. 01000 = P2.8. 01001 = P2.9. 01010 = P2.10. 01011 = P2.11. 01100 = P2.12. 01101 = P2.13. 01110 = P2.14. 01111 = P2.15. 10000 = P3.0. 10001 = P3.1. 10010 = P3.2. 10011 = P3.3. 10100 = P3.4. 10101 = P3.5. 10110 = P3.6. 10111 = P3.7. These channels selected is only when the comparator enables (CMPEN=1), the 24-channel analog switch works, or not workable. If one pin is selected to be comparator negative input pin, the pin is switched to input mode and connected to comparator negative input terminal. When the system selects to other pin or comparator disables, the original channel will returns to last GPIO mode automatically.

The comparator output status can output to CMO pin controlled by CMPOEN bit. When CMPOEN=0, the comparator output pin is GPIO mode. If CMPOEN=1, CMO pin outputs comparator output status and isolates GPIO mode. The comparator output terminal connects to internal path. The CMPOUT flag is the CMPOUT shows the comparator result immediately, but the CMPIRQ only indicates the event of the comparator result. The comparator output terminal through de-bounce circuit generates the comparator trigger edge controlled by CMPG. The even condition is controlled by register and includes rising edge (CMPOUT changes from low to high), falling edge (CMPOUT changes from high to low) controlled by CMPG bit. The CMPIRQ = 1 condition makes the comparator interrupt service executed when CMPGIE (comparator interrupt control bit) set.



14.3 COMPARATOR APPLICATION NOTICE

The comparator is to compares the positive voltage and negative voltage to output result. The positive used internal reference and negative sources are analog signal. In hardware application circuit, the comparator input pins must be connected a 0.1uF capacitance to reduce power noise and make the input signal more stable. The application circuit is as following.



14.4 COMPARATOR CONTROL REGISTERS

Base Address: 0x4006 6000

14.4.1 Comparator Control register (CMPM)

Address Offset: 0x00

Bit	Name	Description	Attribute	Reset
31	CMPEN	Comparator control bit.	R/W	0

		0: Disable. P2[15:0], P3[7:0] are GPIO mode. 1 : Enable. Comparator negative input pins are controlled by CMCH[4:0] bits.		
30:15	Reserved		R	0
14	CMPOUT	Comparator output flag bit. **The comparator output status is "1" as comparator disabled.** 0 : Comparator internal reference voltage is less than CMPN voltage. 1 : Comparator internal reference voltage is larger than CMPN voltage.	R	1
13:12	Reserved		R	0
11:10	CMDB[1:0]	Comparator output debounce time select bit. 00 : 1* CMP_PCLK. 01 : 2* CMP_PCLK. 10 : 3* CMP_PCLK. 11 : No de-bounce.	R/W	0
9	CMPOEN	Comparator output pin control bit. 0 : Disable. CMO pin is GPIO mode. 1 : Enable comparator output pin. P3.8 pin exchanges to comparator output pin (CMO pin), and GPIO function is isolated.	R/W	0
8	CMPG	Comparator interrupt trigger direction control bit. 0 : Rising edge trigger. CMPP > CMPN or comparator internal reference voltage. 1 : Falling edge trigger. CMPP < CMPN or comparator internal reference voltage.	R/W	0
7	Reserved		R	0
6:5	CMPS[1:0]	Comparator positive input voltage control bit. **If TCHEN=1, CMPS[1:0] bits are useless, and the internal reference switches automatically.** 00 : Internal 1/4*Vdd and enable internal reference voltage generator. 01 : Internal 1/2*Vdd and enable internal reference voltage generator. 10,11 : Internal 3/4*Vdd and enable internal reference voltage generator.	R/W	0
4:0	CMCH[4:0]	Comparator negative input pin control bit. **CMPEN must be "1".** 00000 : Comparator negative input pin is P2.0. 00001 : Comparator negative input pin is P2.1. 00010 : Comparator negative input pin is P2.2. 00011 : Comparator negative input pin is P2.3. 00100 : Comparator negative input pin is P2.4. 00101 : Comparator negative input pin is P2.5. 00110 : Comparator negative input pin is P2.6. 00111 : Comparator negative input pin is P2.7. 01000 : Comparator negative input pin is P2.8. 01001 : Comparator negative input pin is P2.9. 01010 : Comparator negative input pin is P2.10. 01011 : Comparator negative input pin is P2.11. 01100 : Comparator negative input pin is P2.12. 01101 : Comparator negative input pin is P2.13. 01110 : Comparator negative input pin is P2.14. 01111 : Comparator negative input pin is P2.15. 10000 : Comparator negative input pin is P3.0. 10001 : Comparator negative input pin is P3.1. 10010 : Comparator negative input pin is P3.2. 10011 : Comparator negative input pin is P3.3. 10100 : Comparator negative input pin is P3.4. 10101 : Comparator negative input pin is P3.5. 10110 : Comparator negative input pin is P3.6. 10111 : Comparator negative input pin is P3.7. 11000~11111 : Reserved.	R/W	0

14.4.2 Comparator Interrupt Enable register (CMP_IE)

Address Offset: 0x10

This register controls whether the interrupt condition in the Comparator controller is enabled.

Bit	Name	Description	Attribute	Reset
31:1	Reserved		R	0
0	CMPGIE	Comparator edge trigger interrupt enable. (Comparator interrupt trigger direction refer to CMPG) 0: Disable 1: Enable	R/W	0

14.4.3 Comparator Interrupt Status register (CMP_RIS)

Address Offset: 0x14

This register contains the status for interrupt condition, regardless of whether or not the interrupt is enabled in CMP_IE register.

This register indicates the status for Comparator control raw interrupts. A Comparator interrupt is sent to the interrupt controller if the corresponding bit in the CMP_IE register is set.

Bit	Name	Description	Attribute	Reset
31:1	Reserved		R	0
0	CMPGIF	Comparator edge trigger interrupt flag 0: Comparator edge trigger doesn't occur. 1: Comparator edge trigger occurs.	R	0

14.4.4 Comparator Interrupt Clear register (CMP_IC)

Address Offset: 0x18

Bit	Name	Description	Attribute	Reset
31:1	Reserved		R	0
0	CMPGIC	0: No effect 1: Clear CMPGIF bit.	W	0

15 FLASH

15.1 OVERVIEW

The SN32F100 series MCU integrated device feature in-system programmable (ISP) FLASH memory for convenient, upgradeable code storage. The FLASH memory may be programmed via the SONiX 32-bit MCU programming interface or by application code for maximum flexibility. The SN32F100 series MCU provides security options at the disposal of the designer to prevent unauthorized access to information stored in FLASH memory.

- The MCU is stalled during Flash program and erase operations, although peripherals (Timers, WDT, I/O, PWM, etc.) remain active.
- Watchdog timer should be cleared if enabled before the Flash write or erase operation.
- The erase operation sets all the bits in the Flash page to logic 1.
- HW will hold system clock and automatically move out data from RAM and do programming, after programming finished, HW will release system clock and let MCU execute the next instruction.

✸ ***Note: HCLK MUST be equal or less than 24MHz during Flash program and erase operations.***

15.2 EMBEDDED FLASH MEMORY

The Flash memory is organized as 32-bit wide memory cells that can be used for storing both code and data constants, and is located at a specific base address in the memory map of chip.

The high-performance Flash memory module in chip has the following key features:

- Memory organization: the Flash memory is organized as a User ROM, Boot ROM.

User ROM	Up to 16K × 32 bits divided into 64 pages of 1024 Bytes
Boot ROM	Up to 1K × 32 bits divided into 4 pages of 1024 Bytes

The Flash interface implements instruction access and data access based on the AHB protocol. It implements the logic necessary to carry out Flash memory operations (Program/Erase). Program/Erase operations can be performed over the whole product voltage range.

15.3 FEATURES

- Read interface (32-bit)
- Flash Program / Erase operation
- Code Option includes Code Security (CS)

Write operations to the main memory block and the code options are managed by an embedded Flash Memory Controller (FMC). The high voltage needed for Program/Erase operations is internally generated. The main Flash memory can be read/write protected against different levels of Code Security (CS).

During a write operation to the Flash memory, any attempt to read the Flash memory will stall the bus. The read operation will proceed correctly once the write operation has completed. This means that code or data fetches cannot be made while a write/erase operation is ongoing.

For write and erase operations on the Flash memory, the IHRC will be turn ON by FMC. The Flash memory can be programmed and erased using ICP and ISP.

15.4 ORGANIZATION

Block	Name	Base Address	Size (Byte)
User ROM	Page 0	0x00000000 ~ 0x000003FF	1024
	Page 1	0x00000400 ~ 0x000007FF	1024
	. . .	. . .	. . .
	Page 63	0x0000FC00 ~ 0x0000FFFF	1024
Boot Loader	Page 0	0x1FFF0000 ~ 0x1FFF03FF	1024
	Page 1	0x1FFF0400 ~ 0x1FFF07FF	1024
	Page 2	0x1FFF0800 ~ 0x1FFF0BFF	1024
	Page 3	0x1FFF0C00 ~ 0x1FFF0FFF	1024

15.5 READ

The embedded Flash module can be addressed directly, as a common memory space. Any data read operation accesses the content of the Flash module through dedicated read senses and provides the requested data.

The read interface consists of a read controller on one side to access the Flash memory, and an AHB interface on the other side to interface with the CPU. The main task of the read interface is to generate the control signals to read from the Flash memory as required by the CPU.

15.6 PROGRAM/ERASE

The Flash memory erase operation can be performed at page level.

To ensure that there is no over-programming, the Flash programming and erase controller blocks are clocked by IHRC.

15.7 EMBEDDED BOOT LOADER

The embedded boot loader is used to reprogram the Flash memory using the UART0 serial interface. This program is located in the Boot ROM and is programmed by SONiX during production.

15.8 FLASH MEMORY CONTROLLER (FMC)

The FMC handles the program and erase operations of the Flash memory.

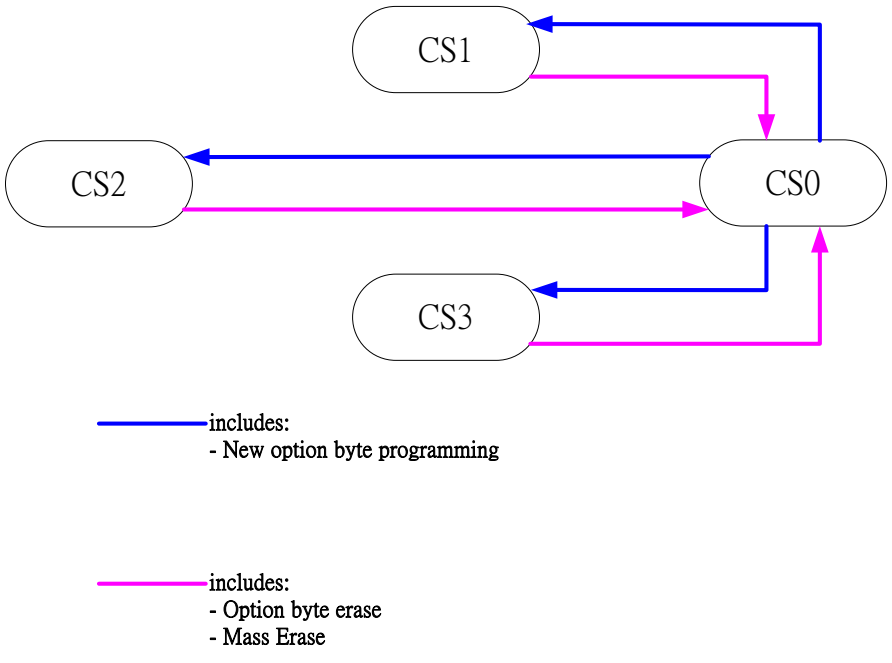
15.8.1 CODE SECURITY (CS)

Code Security is a mechanism that allows the user to enable different levels of security in the system so that access to the on-chip Flash and use of the ISP can be restricted.

✸ ***Note: Any Code Security change becomes effective only after the MCU has been Reboot.***

User ROM		CS0	CS1	CS2	CS3	Description
WRITER	Read	O	X	X	X	
	Erase	O	O(*)	O(*)	O(*)	(*) WRITER will change the CS level to CS0.
	Program	O	O	O	O	
FW (EEPROM emulation)	Read	O	O	O	O	
	Erase	O	O	O	X	
	Program	O	O	O	X	
SWD	Read	O	X	X	X	
	Erase	O	X	X	X	
	Program	O	X	X	X	

✸ ***Note: User may try to change security level from CS3 to CS0, from CS2 to CS0, or from CS1 to CS0. HW shall:***
1. ***Mass erase the User ROM first. User shall NOT execute this operation in debug mode, since the SWD communication may fail during the mass erase procedure.***
2. ***Update security level.***



15.8.2 PROGRAM FLASH MEMORY

The Flash memory can be programmed 32 bits at a time. CPU can program the main Flash memory by performing standard word write operations. The PG bit in the FLASH_CTRL register must be set. FMC preliminarily reads the value at the addressed main Flash memory location and checks that it has been erased. If not, the program operation is skipped and a warning is issued by the PGERR bit in FLASH_STATUS register. The end of the program operation is indicated by the EOP bit in the FLASH_STATUS register.

The main Flash memory programming sequence in standard mode is as follows:
- Set the PG bit in the FLASH_CTRL register.
- Perform the data write at the desired address.
- Wait for the BUSY bit to be reset.
- Read the programmed value and verify.

15.8.3 ERASE

The Flash memory can be erased page by page or completely (Mass Erase).

15.8.3.1 PAGE ERASE

A page of the Flash memory can be erased using the Page Erase feature of the FMC. To erase a page, the procedure below should be followed:
- Set the PER bit in the FLASH_CTRL register
- Program the FLASH_ADDR register to select a page to erase
- Set the STRT bit in the FLASH_CTRL register
- Wait for the BUSY bit to be reset
- Read the erased page and verify

15.8.3.2 MASS ERASE

When the Flash memory read protection is changed from protected to unprotected, a Mass Erase of the User ROM is performed by HW before reprogramming the read protection option.

15.9 READ PROTECTION

The read protection is activated by setting the Code Security bytes in Code option.

When the Flash memory read protection is changed from protected to unprotected, a Mass Erase of the User ROM is performed by HW before reprogramming the read protection option.

15.10 FMC REGISTERS

Base Address: 0x4006 2000

15.10.1 Flash Status register (FLASH_STATUS)

Address offset: 0x04
Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31:6	Reserved		R	0
5	EOP	End of operation flag 0: Flash operation (programming/erase) is not completed. 1: Set by HW when a Flash operation (programming/erase) is completed, and is cleared on the beginning of a Flash operation.	R	1
4:3	Reserved		R	0
2	PGERR	Programming error flag 0: Read→No error. Write→Clear this flag. 1: Set by HW when the address to be programmed contains a value different from 0xFFFFFFFF before programming.	R/W	0
1	Reserved		R	0
0	BUSY	Busy flag 0: Flash operation is not busy. 1: Flash operation is in progress. This is set on the beginning of a Flash operation (clear EOP bit at the same time) and reset when the operation finishes or when an error occurs by HW.	R	0

15.10.2 Flash Control register (FLASH_CTRL)

Address offset: 0x08

✸ ***Note: HCLK MUST be equal or less than 24MHz during Flash program and erase operations.***

Bit	Name	Description	Attribute	Reset
31:7	Reserved		R	0
6	STARTE	Start Erase operation 1: Triggers an ERASE operation when set. This bit is set only by SW and resets when the BUSY bit resets. PER bit shall also be 1 when setting this bit.	R/W	0
5:2	Reserved		R	0
1	PER	Page Erase chosen. This bit is set only by SW and reset when the BUSY bit resets.	R/W	0
0	PG	Flash Programming chosen. This bit is set only by SW and reset when the BUSY bit resets.	R/W	0

15.10.3 Flash Data register (FLASH_DATA)

Address offset: 0x0C

For Page Program operations, this should be updated by SW to indicate the data to be programmed.

Bit	Name	Description	Attribute	Reset
31:0	DATA[31:0]	Data to be programmed.	R/W	0

15.10.4 Flash Address register (FLASH_ADDR)

Address offset: 0x10

The Flash address to be erased or programmed should be updated by SW, and the PG bit or PER bit shall be set before filling in the Flash address.

✸ ***Note: Write access to this register is blocked when the BUSY bit in the FLASH_STATUS register is set.***

Bit	Name	Description	Attribute	Reset
31:0	FAR[31:0]	Flash Address Choose the Flash address to erase when Page Erase is selected, or to program when Page Program is selected.	R/W	0

16 SERIAL-WIRE DEBUG (SWD)

16.1 OVERVIEW

SWD functions are integrated into the ARM Cortex-M0. The ARM Cortex-M0 is configured to support up to four breakpoints and two watch points.

16.2 FEATURES

- Supports ARM Serial Wire Debug (SWD) mode.
- Direct debug access to all memories, registers, and peripherals.
- No target resources are required for the debugging session.
- Up to four breakpoints.
- Up to two data watch points that can also be used as triggers.

16.3 PIN DESCRIPTION

Pin Name	Type	Description	GPIO Configuration
SWCLK	I	Serial Wire Clock pin in SWD mode.	
SWDIO	I/O	Serial Wire Data Input/Output pin in SWD mode.	

16.4 DEBUG NOTE

16.4.1 LIMITATIONS

Debug mode changes the way in which reduced power modes work internal to the ARM Cortex-M0 CPU, and this ripples through the entire system. These differences mean that power measurements should not be made while debugging, the results will be higher than during normal operation in an application.

During a debugging session, the SysTick Timer is automatically stopped whenever the CPU is stopped. Other peripherals are not affected.

16.4.2 DEBUG RECOVERY

User code may disable SWD function in order to use P0.12 and P0.13 as GPIO, and may not debug by SWD function to debug or download FW any more.

SONiX provide Boot loader to check the status of P0.2 (BOOT pin) during boot procedure. If P0.2 is Low during Boot procedure, MCU will execute code in Boot loader instead of User code, so SWD function is not disabled.

Exit Boot loader, user code can still configure P0.2 as other functions such as GPIO.

✷ ***Note: We strongly recommended NOT using BOOT pin as output pin to drive the LED, otherwise, the BOOT pin status may be low during boot procedure.***

16.4.3 INTERNAL PULL-UP/DOWN RESISTORS on SWD PINS

To avoid any uncontrolled IO levels, the device embeds internal pull-up and pull-down resistor on the SWD input pins:

- NJTRST: Internal pull-up
- SWDIO/JTMS: Internal pull-up
- SWCLK/JTCK: Internal pull-down

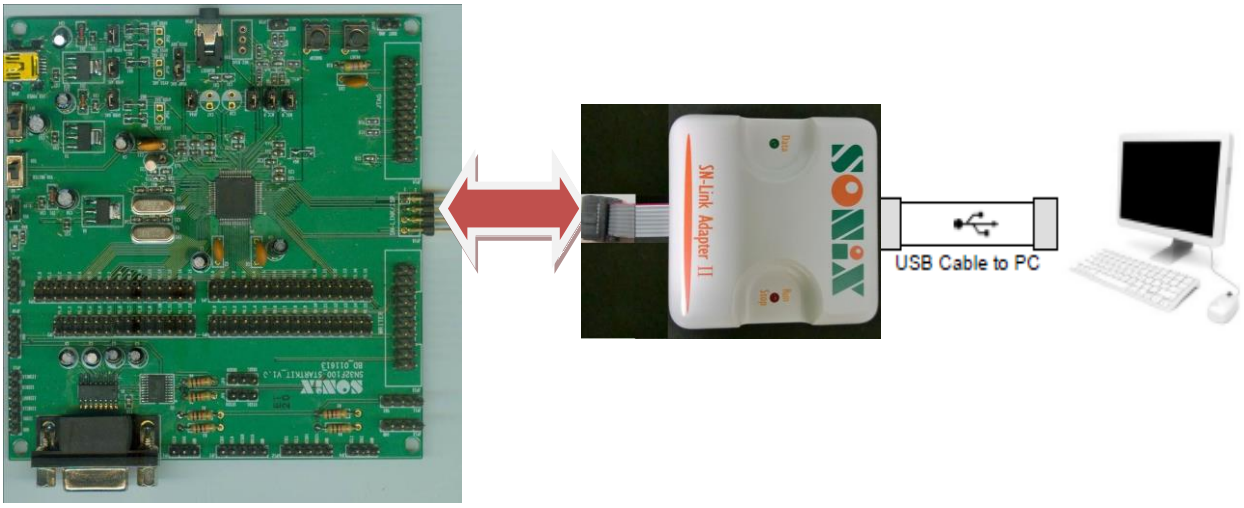
Once a SWD function is disabled by SW, the GPIO controller takes control again.

17 DEVELOPMENT TOOL

SONIX provides an Embedded ICE emulator system to offer SN32F100 series MCU firmware development.

SN32F100 Embedded ICE Emulator System includes:

- SN32F100 Starter-Kit.
- SN-LINK-V2
- USB cable to provide communications between the SN-LINK-V2 and PC.
- IDE Tools (KEIL RVMDK)



SN32F100 Starter-Kit. SN-LINK-V2 IDE Tools

SONiX 32-bit series Embedded ICE Emulator Feature:

- Target's Operating Voltage: 1.8V~3.6V.
- Up to 4 hardware break points.
- System clock rate up to 50MHz.
- Oscillator supports IHRC, ILRC, EHS/ELS X'tal.

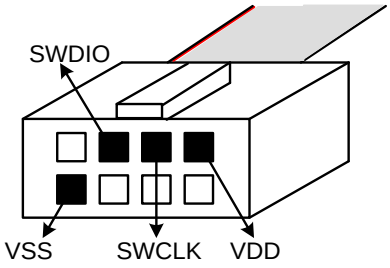
SONiX 32-bit series Embedded ICE Emulator Limitation:

- SWCLK and SWDIO pins are shared with GPIO pins. In embedded ICE mode, the shared GPIO function can't work.

17.1 SN-LINK-V2

SN-LINK-V2 is a high speed emulator for SONiX 32-bit MCU. It debugs and programs based on SWD protocol. In addition to debugger functions, the SN-LINK-V2 also may be used as a programmer to load firmware from PC to MCU for engineering production, even mass production.

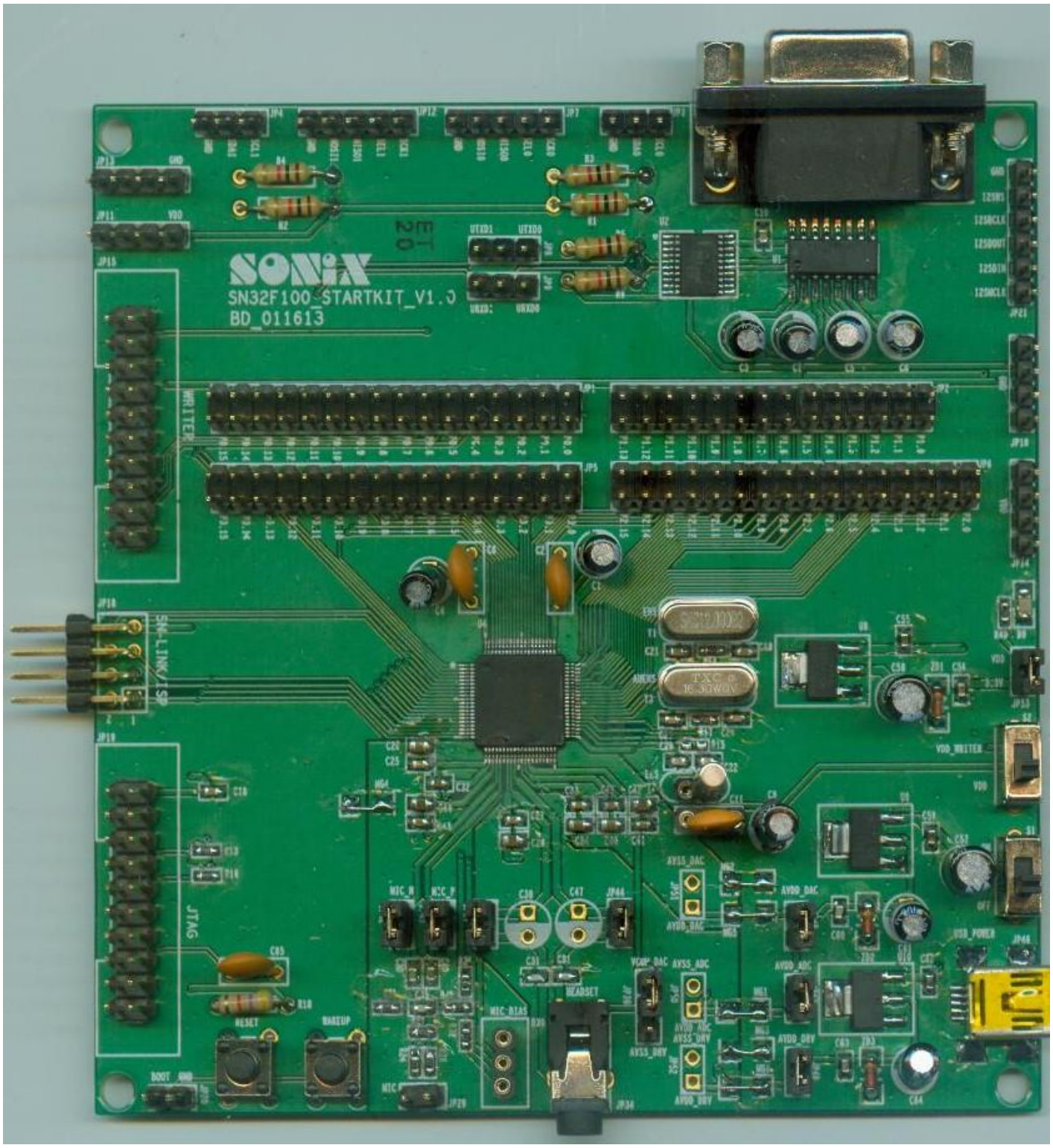
SN-LINK-V2 communicates with SONiX 32-bit MCU through SWD interface. The pin definition of the Modular cable is as following:



17.2 SN32F100 STARTER-KIT

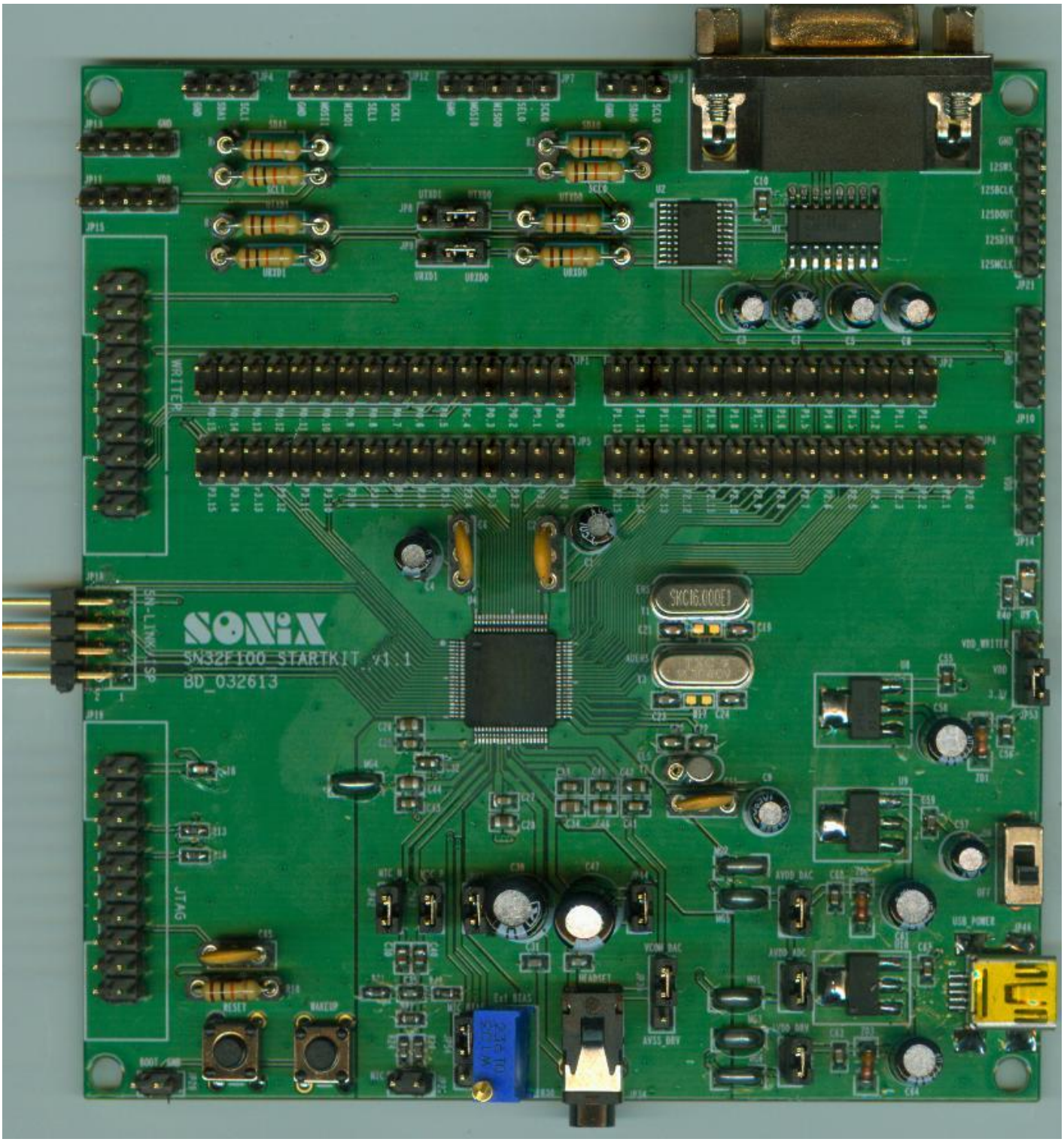
SN32F100 Starter-kit is an easy-development platform. It includes SN32F109 real chip and I/O connectors to input signal or drive extra device of user's application. It is a simple platform to develop application as target board not ready. The starter-kit can be replaced by target board because of SN32F100 series MCU integrates SWD debugger circuitry.

17.2.1 SN32F100 Start Kit V1.0



- JP46: Mini USB connector for power supply.
- S1: USB power on/off.
- S2: MCU power source is VDD or Writer.
- JP53: VDD power source is 3.3V from board or external power. Do not short if External power source is used.
- U4: SN32F109F real chip.
- D9: Power LED.
- RESET button: External reset trigger source.
- WAKEUP button: Trigger source to wake up from deep power-down mode.
- Y1: External high-speed X'tal
- Y2: External low-speed 32.768KHz X'tal
- Y3: External high-speed X'tal for Audio.
- JP18: SN-LINK connector
- JP15: Writer connector
- JP20: Short to force MCU stay in Boot loader.
- JP21: I2S connector.
- JP3/JP4: I2C0/I2C1 connector.
- JP7/JP12: SPI0/SPI1 connector.
- JP8/JP9: UART0/UART1 connector.
- R1: SCL0 pull-up resistor.
- R3: SDA0 pull-up resistor.
- R2: SCL1 pull-up resistor.
- R4: SDA1 pull-up resistor.
- R5: UTXD0 or UTXD1 pull-up resistor.
- R6: URXD0 or URXD1 pull-up resistor.
- JP47: Codec ADC power connector.
- JP48: Codec DAC power connector.
- JP49: Codec Driver power connector.
- JP34: Headset connector.
- JP29: Microphone connector.
- JP42: MIC_N connector.
- JP43: MIC_P connector.
- R30: MIC_BIAS from external bias adjust.

17.2.2 SN32F100 Start Kit V1.1/V1.2



- JP46: Mini USB connector for power supply.
- S1: USB power on/off.
- JP53: VDD power source is 3.3V from board, Writer, or external power. Open if External power source is used.
- U4: SN32F109F real chip.
- D9: Power LED.
- RESET button: External reset trigger source.
- WAKEUP button: Trigger source to wake up from deep power-down mode.
- Y1: External high-speed X'tal

- Y2: External low-speed 32.768KHz X'tal
- Y3: External high-speed X'tal for Audio.
- JP18: SN-LINK connector
- JP15: Writer connector
- JP20: Short to force MCU stay in Boot loader.
- JP21: I2S connector.
- JP3/JP4: I2C0/I2C1 connector.
- JP7/JP12: SPI0/SPI1 connector.
- JP8/JP9: UART0/UART1 connector.
- R1: SCL0 pull-up resistor.
- R3: SDA0 pull-up resistor.
- R2: SCL1 pull-up resistor.
- R4: SDA1 pull-up resistor.
- R5: UTXD0 pull-up resistor.
- R6: URXD0 pull-up resistor.
- R41: UTXD1 pull-up resistor.
- R42: URXD1 pull-up resistor.
- JP47: Codec ADC power connector.
- JP48: Codec DAC power connector.
- JP49: Codec Driver power connector.
- JP34: Headset connector.
- JP29: Microphone connector.
- JP42: MIC_N connector.
- JP43: MIC_P connector.
- JP54: MIC_BIAS from chip supply or external bias.
- R30: MIC_BIAS from external bias adjust.

18 ELECTRICAL CHARACTERISTIC

18.1 ABSOLUTE MAXIMUM RATING

Supply voltage (Vdd)..... - 0.3V ~ 3.6V
Input in voltage (Vin)..... Vss – 0.2V ~ Vdd + 0.2V
Operating ambient temperature (Topr)
SN32F107, SN32F108, SN32F109 ..... -40°C ~ + 85°C
Storage ambient temperature (Tstor) ..... –40°C ~ + 125°C

18.2 ELECTRICAL CHARACTERISTIC

Standard Operating Conditions (Typical temperature Ta = 25℃)
Operating Temperature -40℃ ≦ Ta ≦ +85℃ for Industrial Class
The below data covers process corner range (SS~TT~FF).

PARAMETER	SYM.	DESCRIPTION		MIN.	TYP.	MAX.	UNIT
Operating Voltage	Vdd	Supply voltage for core and external rail		1.8	3.3	3.6	V
VDD rise rate	V_{POR}	VDD rise rate to ensure internal power-on reset		0.05	-	-	V/ms
Power Consumption							
Supply Current	Idd1	Normal mode	System clock = 12MHz [1][3][4]	-	7	8 [2]	mA
			System clock = 50MHz [1][3][5]	-	20	30 [2]	mA
	Idd2	Sleep Mode	System clock = 12MHz [1][3][4][7]	-	2.4	2.65 [2]	mA
			System clock = 16KHz [1][3][6][7]	-	500	700 [2]	uA
	Idd3	Deep-sleep Mode	Vdd=3.3V [1][3][7]	-	7	110 [2]	uA
	Idd4	Deep power-down Mode	Vdd=3.3V [8]	-	200	8000 [2]	nA
Port Pins, RESET pin							
High-level input voltage	V_{IH}			0.8Vdd	-	Vdd	V
Low-level input voltage	V_{IL}			Vss	-	0.2Vdd	V
Input voltage	V_i			0	-	Vdd	V
Output voltage	V_o			0	-	Vdd	V
I/O port pull-up resistor	R_{PU}	Vin = Vss , Vdd = 3.3V		40	60	80	KΩ
I/O port pull-down resistor	R_{PD}	Vin = 3.3V		40	60	80	KΩ
I/O port input leakage current	Ilekg	Pull-up resistor disable, Vin = Vdd		-	-	2	uA
		I2C-bus pins (P0.2, P0.3, P3.14 and P3.15), Vin = Vdd		-	2	4	uA
I/O High-level output source current	I_{OH}	Standard port and RESET pins	V_{OP} = Vdd – 0.5V;	5	10	-	mA
		High-drive output pin (P0.0~P0.3, P3.12~P3.15)	V_{OP} = Vdd – 0.5V	12	20	-	mA
I/O Low-level output sink current	I_{OL}	Standard port and RESET pins	V_{OP} = Vss + 0.5V	5	10	-	mA
Codec							
ADC Analog Power	AVDD_ ADC			2.7	3.3	3.6	V

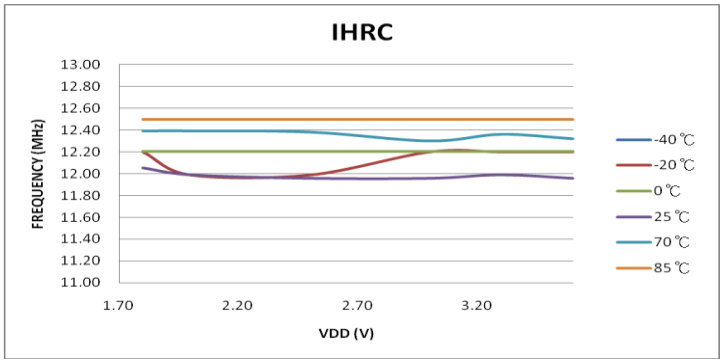
Microphone Bias	MIC_BIAS	Microphone Bias Voltage SEL_MICB=0	-5%	2.64	+5%	V
		Microphone Bias Voltage SEL_MICB=1	-5%	2.97	+5%	V
ADC Analog Reference Levels	VMID_ADC	Middle reference voltage AVDD_ADC=3.3V, VDD=1.8V AVSS_ADC=VSS=0V CL=10uF	-5%	1.65	+5%	V
Analog Input to ADC Output	SNR	Signal-to-Noise Ratio 1KHz input, -120dBr, A-weighted		94		dB
	THD+N	Total Harmonic Distortion 1KHz input, -6dBr		-80		dB
DAC Analog Power	AVDD_DAC		2.7	3.3	3.6	V
Headphone Driver Power	AVDD_DRV		2.7	3.3	3.6	V
DAC Analog Reference Levels	VMID_DAC	Middle reference voltage AVDD_DAC=AVDD_DRV=3.3V, VDD=1.8V AVSS_DAC=AVSS_DRV=VSS=0V CL=4.7uF	-5%	1.65	+5%	V
	VCOM_DAC	Common-mode voltage AVDD_DAC=AVDD_DRV=3.3V, VDD=1.8V AVSS_DAC=AVSS_DRV=VSS=0V CL=4.7uF	-5%	1.65	+5%	V
Headphone Driver Analog Output	SNR	Signal-to-Noise Ratio AVDD_DAC=AVDD_DRV=3.3V, VDD=1.8V AVSS_DAC=AVSS_DRV=VSS=0V 1KHz input, RL=16Ω, -120dBr, A-weighted		90		dB
	THD+N	Total Harmonic Distortion AVDD_DAC=AVDD_DRV=3.3V, VDD=1.8V AVSS_DAC=AVSS_DRV=VSS=0V 1KHz input, RL=16Ω, Po=20mW, -6dBr		-75		dB
FLASH						
Supply Voltage	Vdd1		1.8		Vdd	V
Endurance time	T_{EN}	Erase + Program	20K	*100K	-	Cycle
Page erase time	T_{PE}	1-Page (1024 bytes).	-	25	30	ms
1-Word Programming time	T_{PG}	1-Word (32 bits).	-	60	70	us
MISC						
Low Voltage Detector	LVD	Interrupt, Level 0	1.90	2.00	2.10	V
		Interrupt, Level 1	2.30	2.40	2.50	V
		Interrupt, Level 2	2.60	2.70	2.80	V
		Interrupt, Level 3	2.90	3.00	3.10	V
		Reset, Level 0	1.90	2.00	2.10	V
		Reset, Level 1	2.30	2.40	2.50	V
		Reset, Level 2	2.60	2.70	2.80	V
IHRC Freq.	F_{IHRC}	*T=25℃*, Vdd=1.8V~ 3.6V	11.76	12	12.24	MHz
		T=-40℃~85℃, Vdd=1.8V~3.6V	11.4	12	12.6	MHz

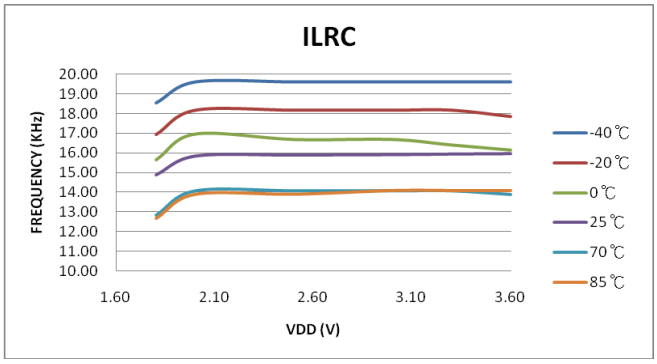
*** These parameters are for design reference, not tested.**

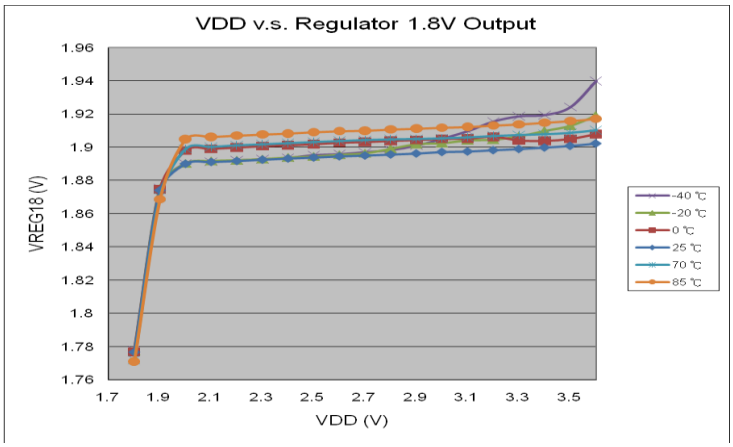
[1] IDD measurements were performed with all pins configured as GPIO outputs driven LOW and pull-up resistors disabled and VDD = 3.3V.
[2] IDD measurements were performed with operating temperature = +85°C. For more details, refer to “Supply Current V.S. Operating Temperature” in the **CHARACTERISTIC GRAPHS** section.
[3] LVD and all peripherals are disabled.
[4] IHRC and ILRC are enabled, external X’tal is disabled, and PLL is disabled.
[5] IHRC is disabled, external high X’tal is enabled, and PLL is enabled.
[6] ILRC is enabled, IHRC and external X’tal are disabled, and PLL is disabled.
[7] All oscillators and analog blocks are turned off.
[8] DPDWAKEUP pin is pulled HIGH internally.

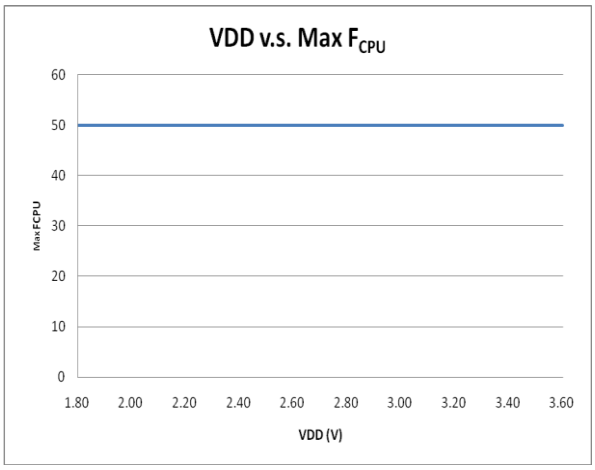
18.3 CHARACTERISTIC GRAPHS

The Graphs in this section are for design guidance, not tested or guaranteed. In some graphs, the data presented are outside specified operating range. This is for information only and devices are guaranteed to operate properly only within the specified range.

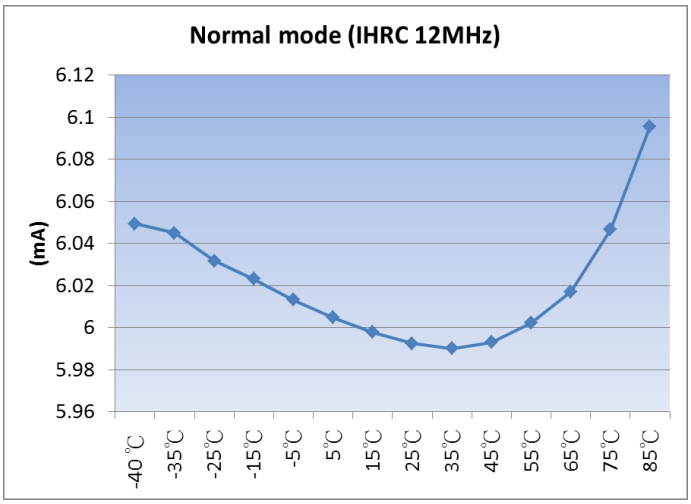


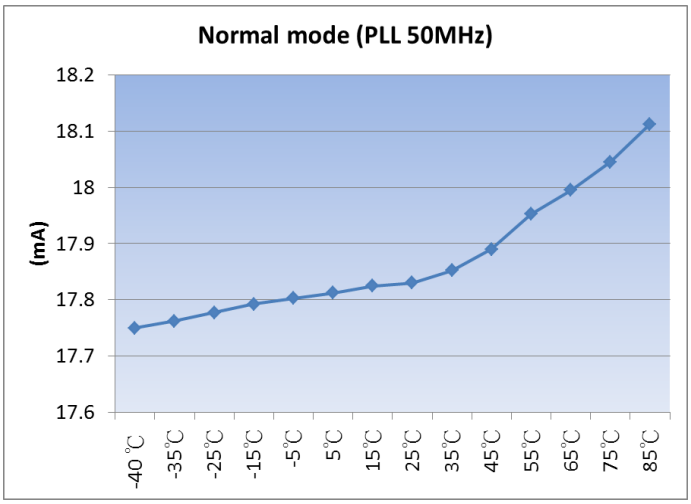


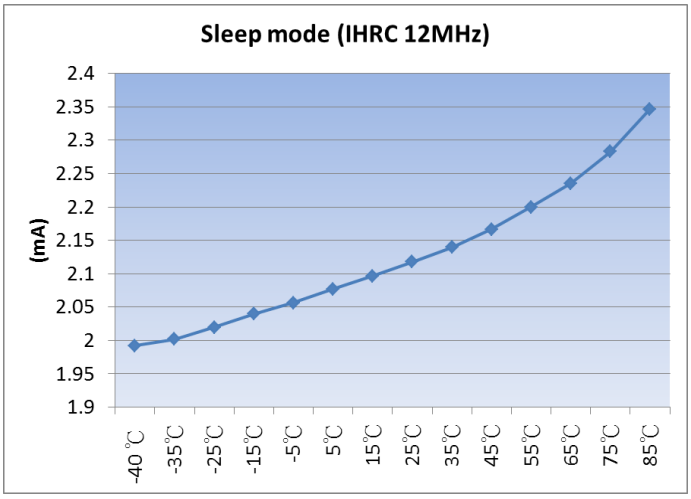


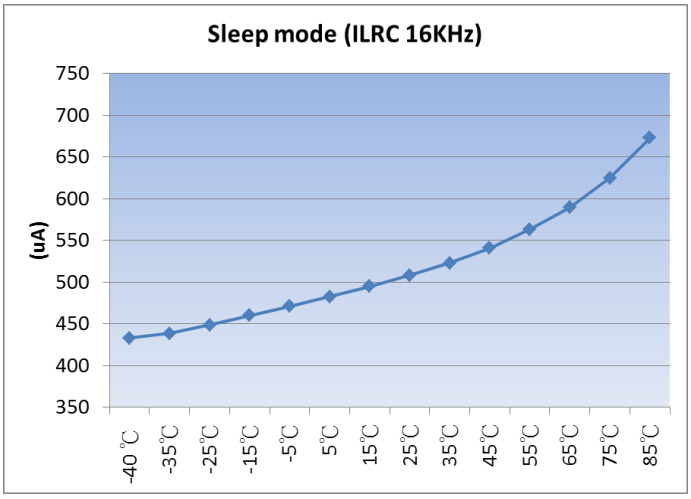


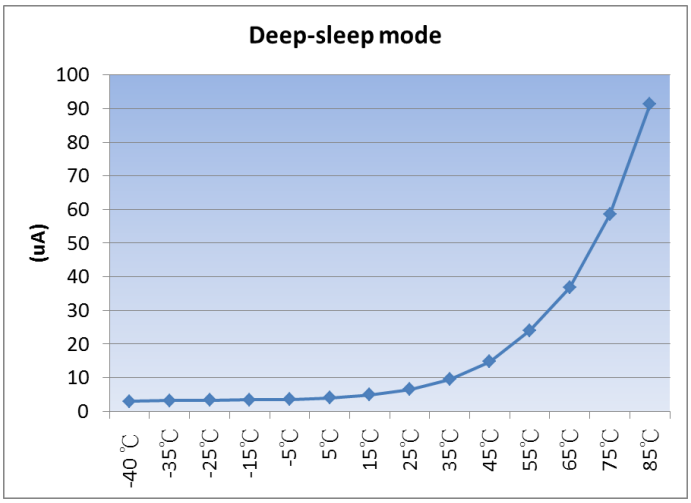
*Supply Current V.S. Operating Temperature (Operating Conditions : All pins configured as GPIO outputs driven Low and pull-up resistors disabled and VDD = 3.3V)

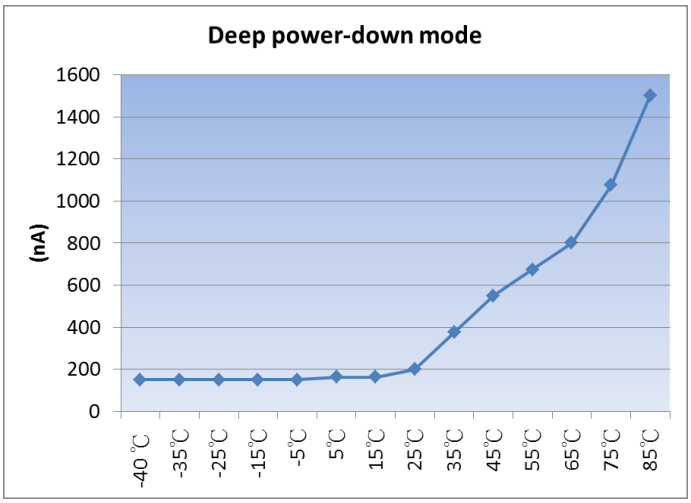










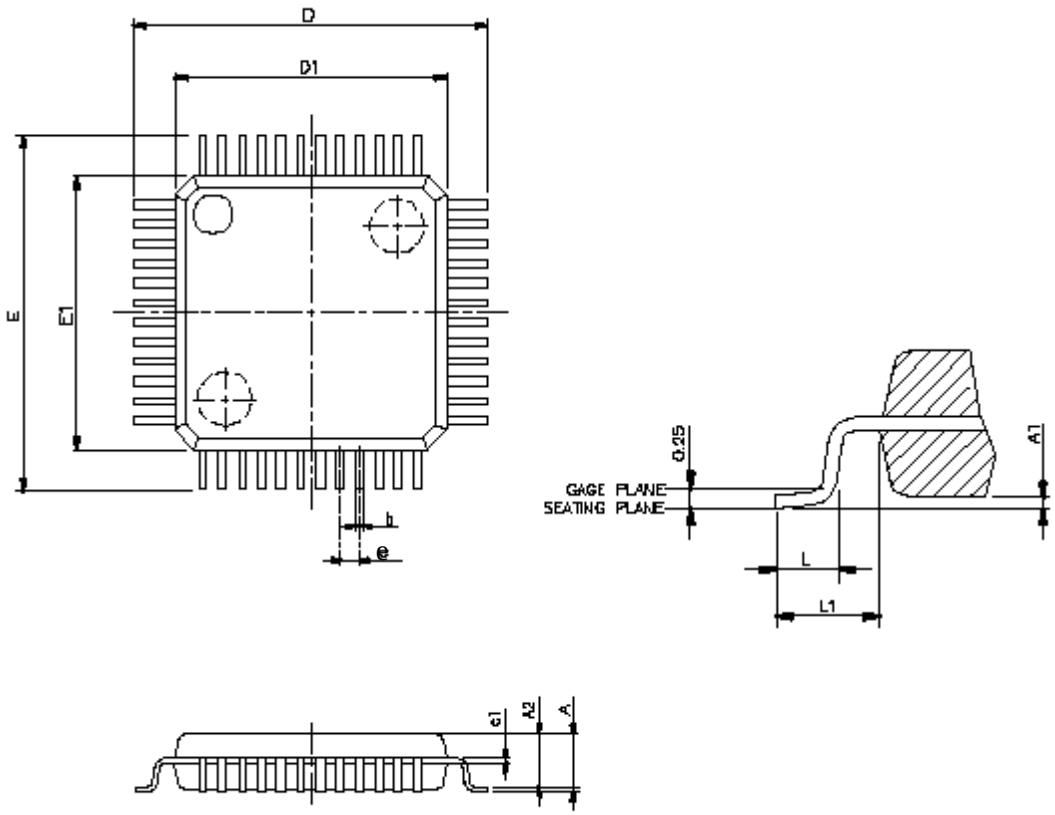


19 FLASH ROM PROGRAMMING PIN

Programming Information of SN32F100 Series											
Chip Name		SN32F109F		SN32F108F		SN32F107F					
MP PRO Writer Connector		Flash IC / JP3 Pin Assignment									
Number	Name	Number	Pin	Number	Pin	Number	Pin	Number	Pin	Number	Pin
1	VDD	41 61 80	VDD	32 49 64	VDD	27 48	VDD				
2	GND	42 62 79	VSS	33 50 63	VSS	28 47	VSS				
3	PGDCLK (CLK)	9	P0.4	9	P0.4	5	P0.4				
4	CE										
5	OTPCLK (PGM)	11	P0.6	11	P0.6	7	P0.6				
6	PGDIN (OE)	10	P0.5	10	P0.5	6	P0.5				
7	D1										
8	D0										
9	D3										
10	D2										
11	D5										
12	D4										
13	D7										
14	D6										
15	VDD										
16	-										
17	HLS										
18	RST										
19	-										
20	VR_DOUT (ALSB/PDB)	12	P0.7	12	P0.7	8	P0.7				

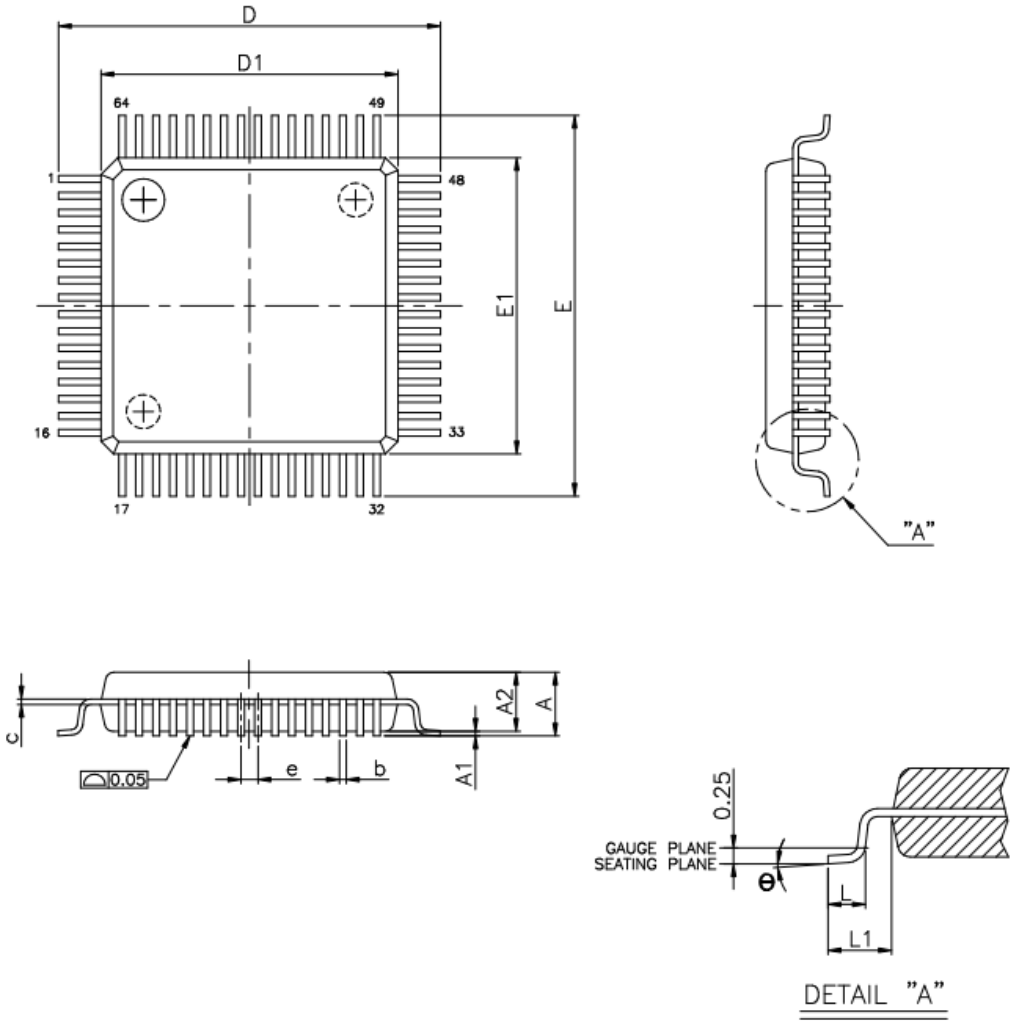
20 PACKAGE INFORMATION

20.1 LQFP 48 PIN



SYMBOLS	MIN	NOR	MAX
	(mm)		
A	-	-	1.6
A1	0.05	-	0.15
A2	1.35	-	1.45
c1	0.09	-	0.16
D	9.00 BSC		
D1	7.00 BSC		
E	9.00 BSC		
E1	7.00 BSC		
e	0.5 BSC		
b	0.17	-	0.27
L	0.45	-	0.75
L1	1 REF		

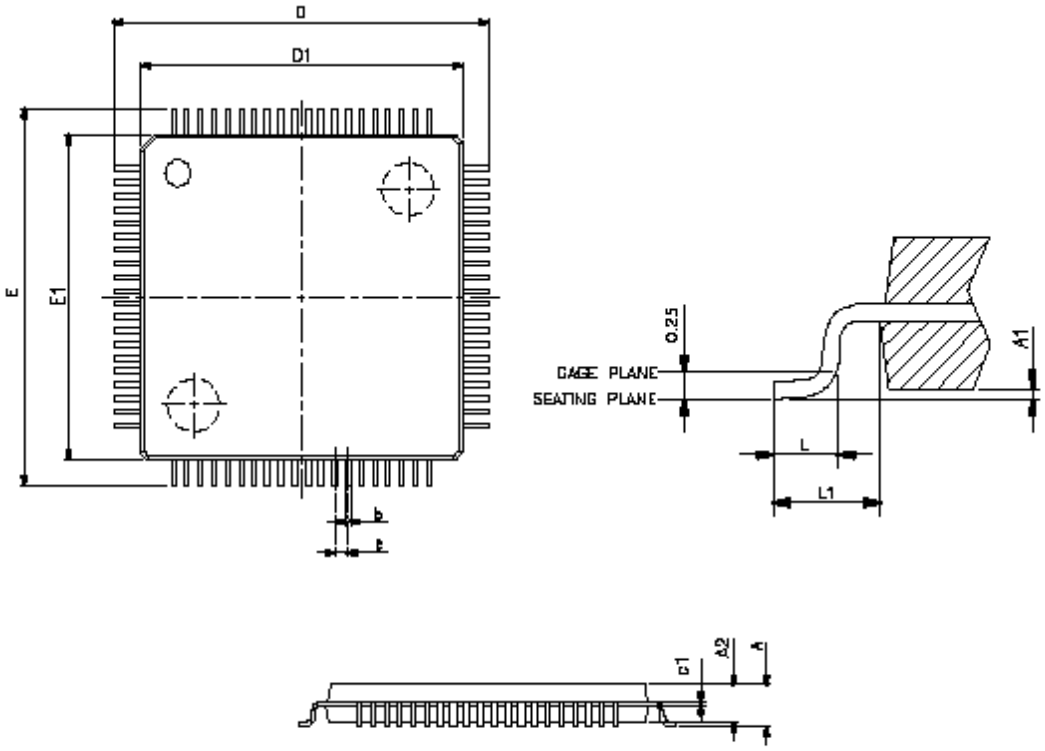
20.2 LQFP 64 PIN



VARIATIONS (ALL DIMENSIONS SHOWN IN MM)

SYMBOLS	MIN.	NOM.	MAX.
A	—	—	1.60
A1	0.05	—	0.15
A2	1.35	1.40	1.45
b	0.13	0.18	0.23
c	0.09	—	0.20
D		9.00 BSC	
D1		7.00 BSC	
e		0.40 BSC	
E		9.00 BSC	
E1		7.00 BSC	
L	0.45	0.60	0.75
L1		1.00 REF	
θ	0°	3.5°	7°

20.3 LQFP 80 PIN



VARIATIONS (ALL DIMENSIONS SHOWN IN MM)

SYMBOLS	MIN.	MAX.
A	--	1.6
A1	0.05	0.15
A2	1.35	1.45
c1	0.09	0.16
D	12 BSC	
D1	10 BSC	
E	12 BSC	
E1	10 BSC	
e	0.4 BSC	
b	0.17	0.27
L	0.45	0.75
L1	1 REF	

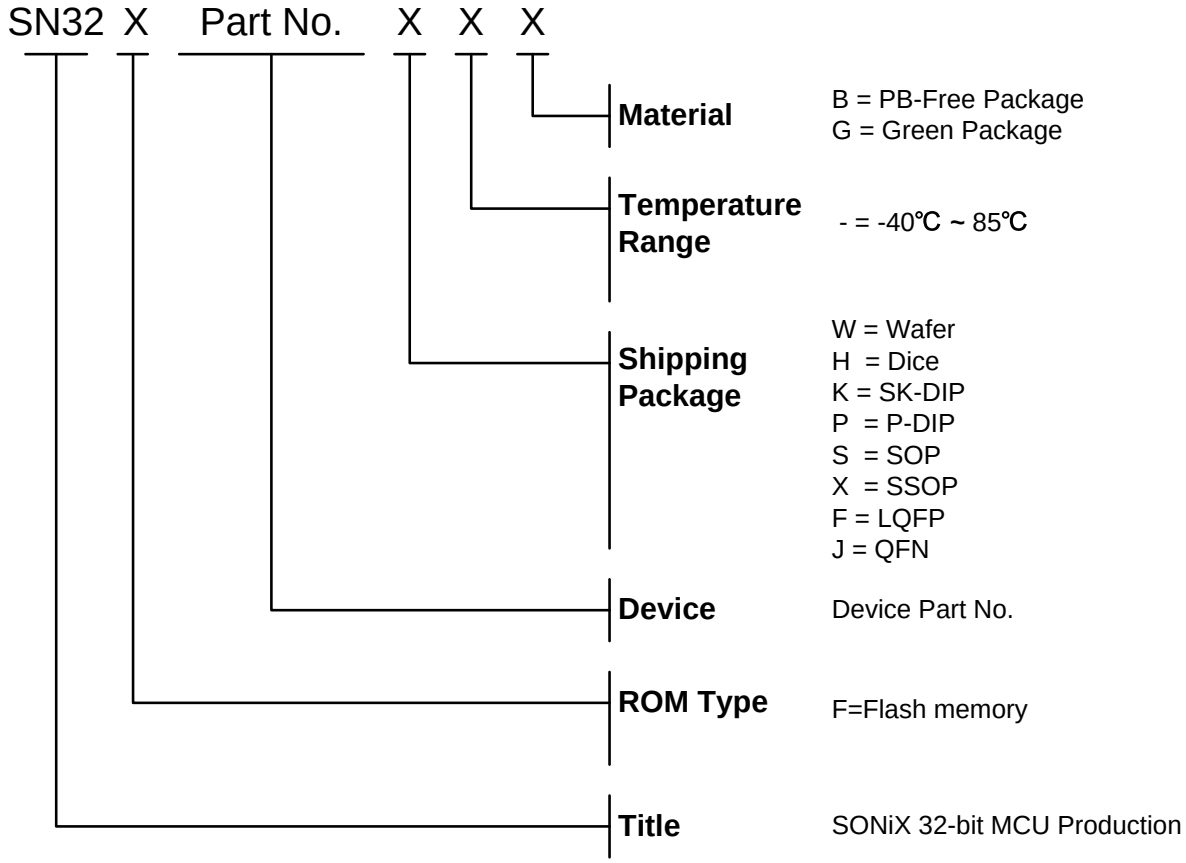
21 MARKING DEFINITION

21.1 INTRODUCTION

There are many different types in SONiX 32-bit MCU production line.

This note lists the marking definitions of all 32-bit MCU for order or obtaining information.

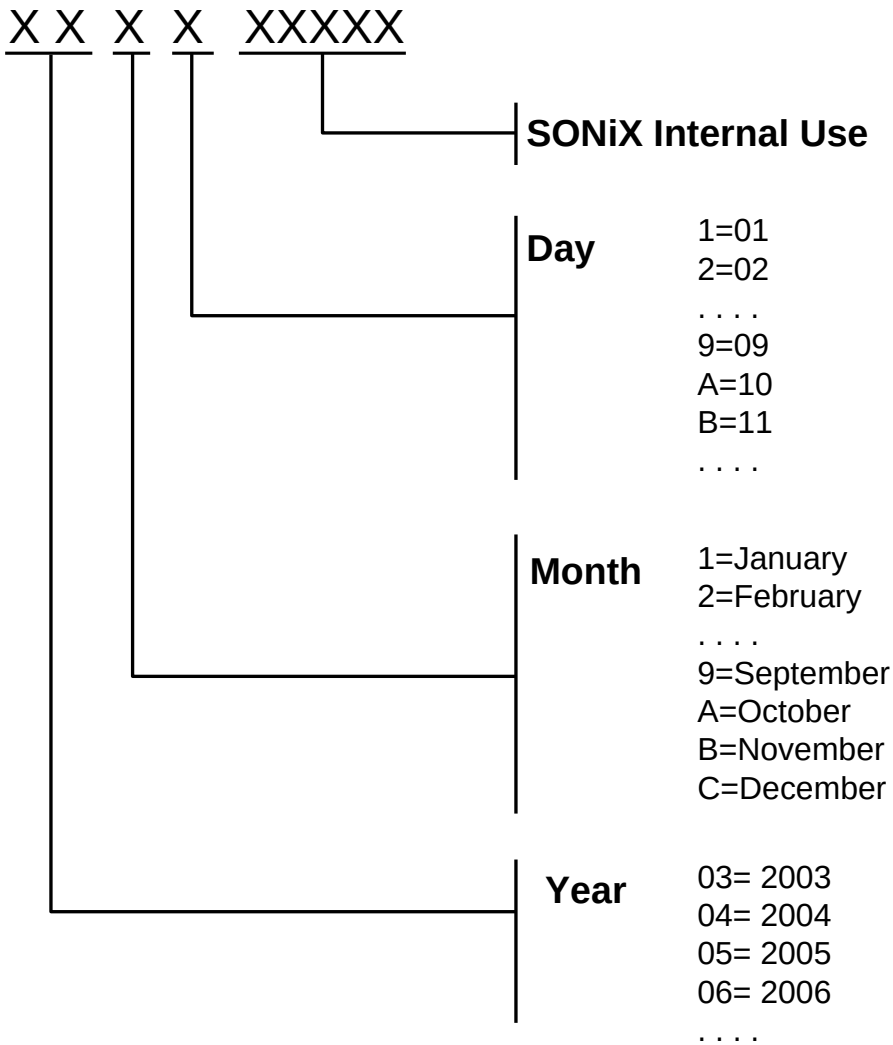
21.2 MARKING INDETIFICATION SYSTEM



21.3 MARKING EXAMPLE

Name	ROM Type	Device	Package	Temperature	Material
SN32F109FG	Flash memory	109	LQFP	-40℃~85℃	Green Package
SN32F109W	Flash memory	109	Wafer	-40℃~85℃	-
SN32F109H	Flash memory	109	Dice	-40℃~85℃	-
SN32F108FG	Flash memory	109	LQFP	-40℃~85℃	Green Package
SN32F107FG	Flash memory	109	LQFP	-40℃~85℃	Green Package

21.4 DATECODE SYSTEM



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