SN32F240/230/220 Series

USER'S MANUAL

SN32F249/239/229
SN32F248/238/228
SN32F247/237/227
SN32F246/236/226
SN32F245/235/225

SONiX 32-Bit Cortex-M0 Micro-Controller

AMENDENT HISTORY

Version	Date	Description
1.0	2014/02/27	First version released.

Table of Content

1 PRODUCT OVERVIEW

1.1 FEATURES

- **Memory configuration**
  Up to 64KB on-chip Flash programming memory.
  Up to 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 64 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)

- **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.

- **Hardware divider**

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

- **LVD with separate thresholds**
  Reset: 1.65V for V_{CORE}
  Reset: 1.8V/2.0V/2.4V/2.7V/3.0V/3.6V for VDD
  Interrupt: 1.8V/2.0V/2.4V/2.7V/3.0V/3.6V for VDD

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

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

- **Serial Wire Debug (SWD)**

- **Timers**
  Three 16-bit and three 32-bit general purpose timers with a total of 6 capture inputs and 21 PWMs.

- **Working voltage 1.8V ~ 5.5V**

- **ADC**
  14-channel 12-bit SAR ADC
  Temperature sensor inside

- **Interface**
  -Two I2C controllers supporting I2C-bus specification with multiple address recognition and monitor mode.
  - USART controller with fractional baud rate generation, and EIA-485 support.
  - UART controller 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 low clock: Crystal type 32.768 KHz
  -Internal high clock: RC type 12 MHz
  -Internal low clock: RC type 32 KHz
  -PLL allows CPU operation up to the maximum CPU rate without the need for a high-frequency crystal.
  -Clock output function which can reflect the internal high/low RC oscillator, HCLK, PLL output, and external high/low clock.

- **Full Speed USB 2.0**
  Conforms to USB specification version 2.0.
  3.3v regulator output for USB D+ pin internal 1.5k pull-up resistor.
  Supports one Full speed USB device address.
  One control endpoint and 6 configurable Isochronous/interrupt/bulk endpoints
  Total 7 endpoints share 512B USB SRAM.

- **LCD driver**
  Support both R-type and C-type
  4 common x 32 segment
  1/3 or 1/2 bias voltage
  Multiple C-type LCD Voltage: 2.7 ~5.0V
  R-type optional-bias resistor: 400K, 200K, 100K, 35K
  Support 1/2 duty, 1/3 duty, 1/4 duty

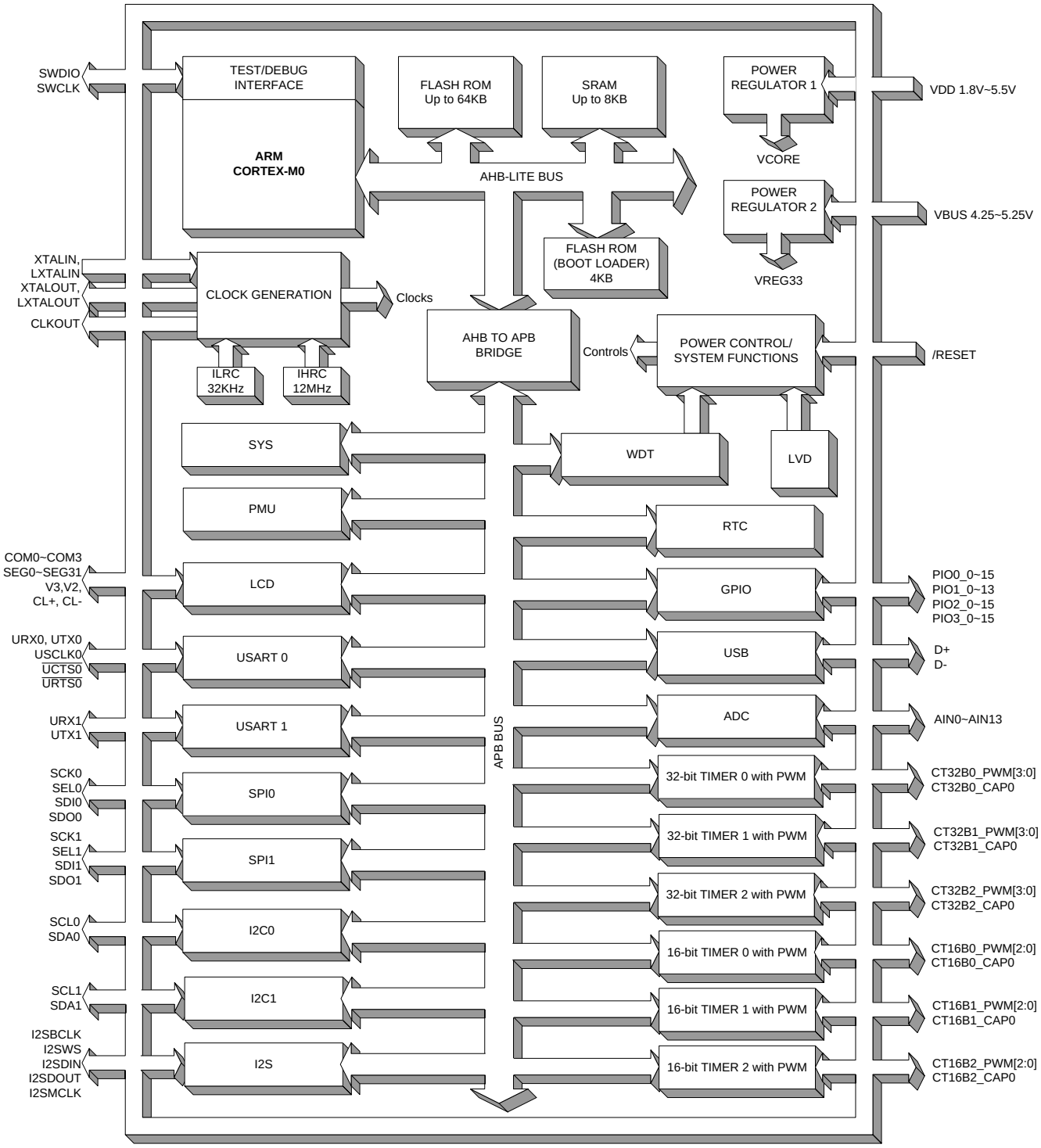
- **In-System Programming (ISP) supported**

- **Package (Chip form support)**
  LQFP 80/64/48 pin
  QFN 46/33 pin

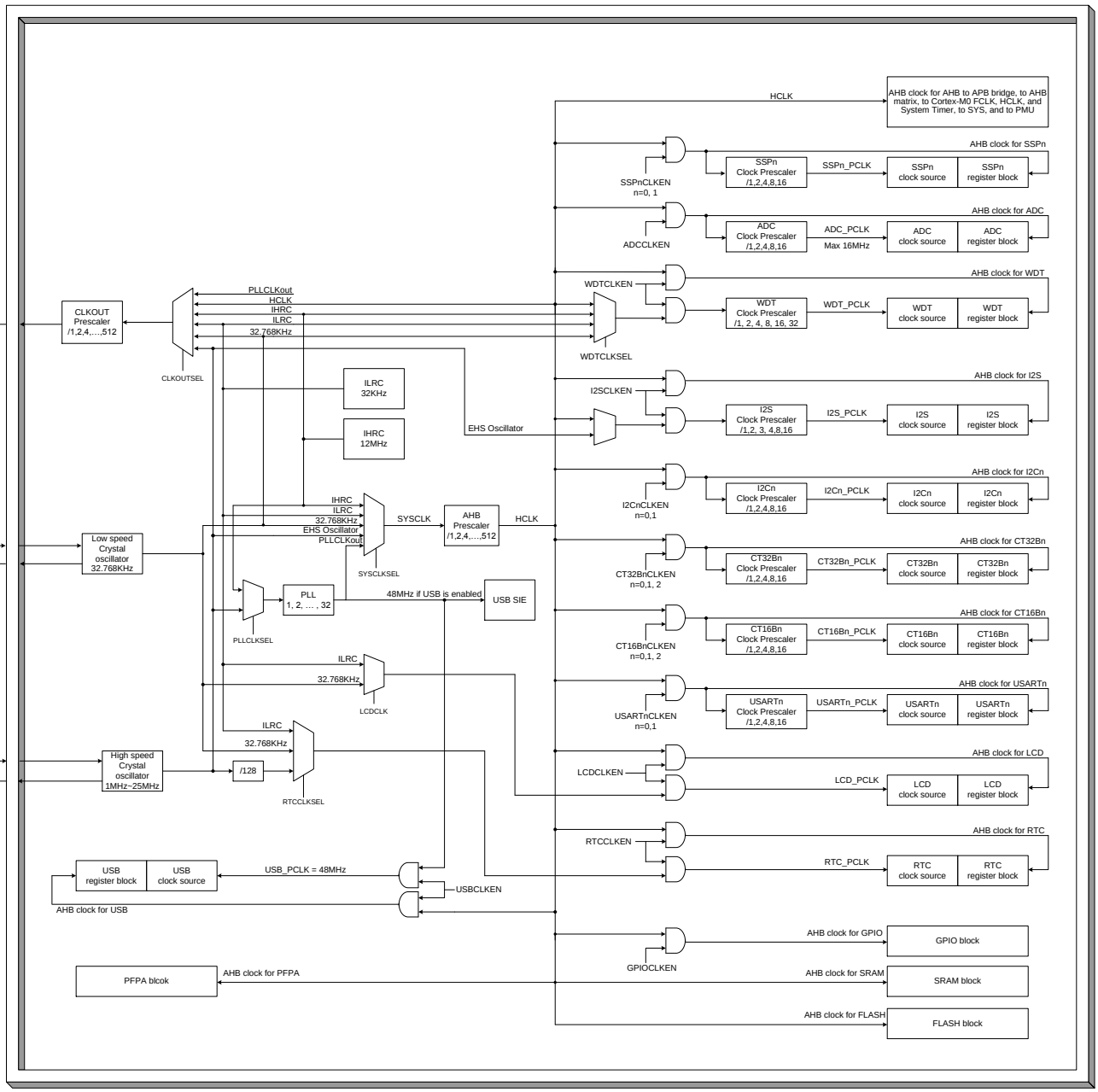
☞ Features Selection Table

Chip	ROM	RAM	Boot Loader	F_{CPU} (Max MHz)	TIMER	USART	SPI	I2C	I2S	PWM	12-bit ADC	LCD	GPIO with Wakeup	Package
SN32F249F	64KB	8KB	4KB	50 MHz	16-bitx3 32-bitx3	USARTx1 UARTx1	2	2	1	21	14CH	4x32	64	LQFP80
SN32F248F	64KB	8KB	4KB	50 MHz	16-bitx3 32-bitx3	UARTx2	2	2	1	21	11CH	4x28	55	LQFP64
SN32F247F	64KB	8KB	4KB	50 MHz	16-bitx3 32-bitx3	UARTx2	2	2	1	21	8CH	4x15	39	LQFP48
SN32F246J	64KB	8KB	4KB	50 MHz	16-bitx3 32-bitx3	UARTx2	2	2	1	21	6CH	4x15	37	QFN46
SN32F245J	64KB	8KB	4KB	50 MHz	16-bitx3 32-bitx3	UARTx2	2	2	-	21	4CH	-	23	QFN33
SN32F239F	32KB	4KB	4KB	50 MHz	16-bitx3 32-bitx3	USARTx1 UARTx1	2	2	1	21	14CH	4x32	64	LQFP80
SN32F238F	32KB	4KB	4KB	50 MHz	16-bitx3 32-bitx3	UARTx2	2	2	1	21	11CH	4x28	55	LQFP64
SN32F237F	32KB	4KB	4KB	50 MHz	16-bitx3 32-bitx3	UARTx2	2	2	1	21	8CH	4x15	39	LQFP48
SN32F236J	32KB	4KB	4KB	50 MHz	16-bitx3 32-bitx3	UARTx2	2	2	1	21	6CH	4x15	37	QFN46
SN32F235J	32KB	4KB	4KB	50 MHz	16-bitx3 32-bitx3	UARTx2	2	2	-	21	4CH	-	23	QFN33
SN32F229F	16KB	2KB	4KB	50 MHz	16-bitx3 32-bitx3	USARTx1 UARTx1	2	2	1	21	14CH	4x32	64	LQFP80
SN32F228F	16KB	2KB	4KB	50 MHz	16-bitx3 32-bitx3	UARTx2	2	2	1	21	11CH	4x28	55	LQFP64
SN32F227F	16KB	2KB	4KB	50 MHz	16-bitx3 32-bitx3	UARTx2	2	2	1	21	8CH	4x15	39	LQFP48
SN32F226J	16KB	2KB	4KB	50 MHz	16-bitx3 32-bitx3	UARTx2	2	2	1	21	6CH	4x15	37	QFN46
SN32F225J	16KB	2KB	4KB	50 MHz	16-bitx3 32-bitx3	UARTx2	2	2	-	21	4CH	-	23	QFN33

1.2 SYSTEM BLOCK DIAGRAM

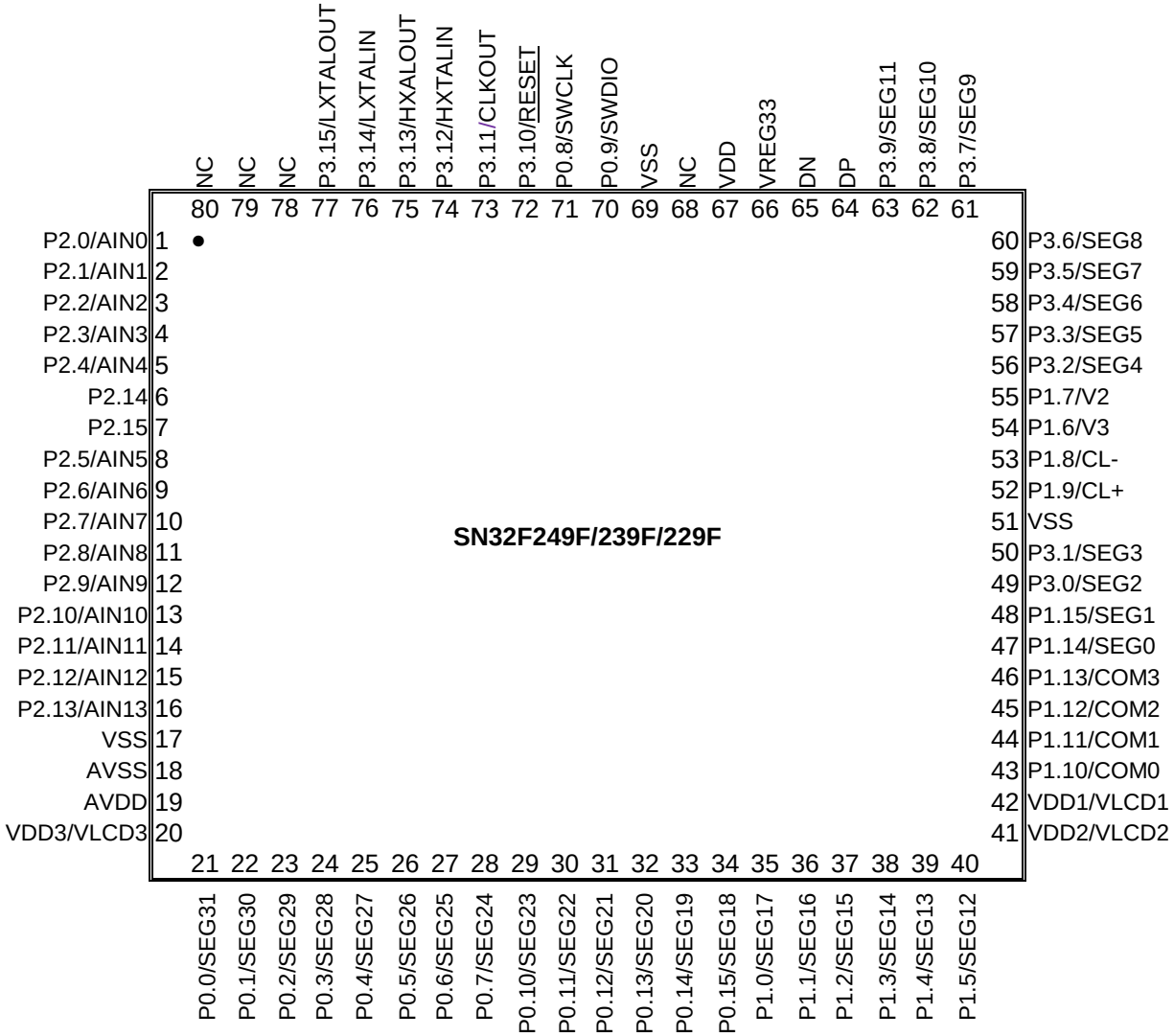


1.3 CLOCK GENERATION BLOCK DIAGRAM

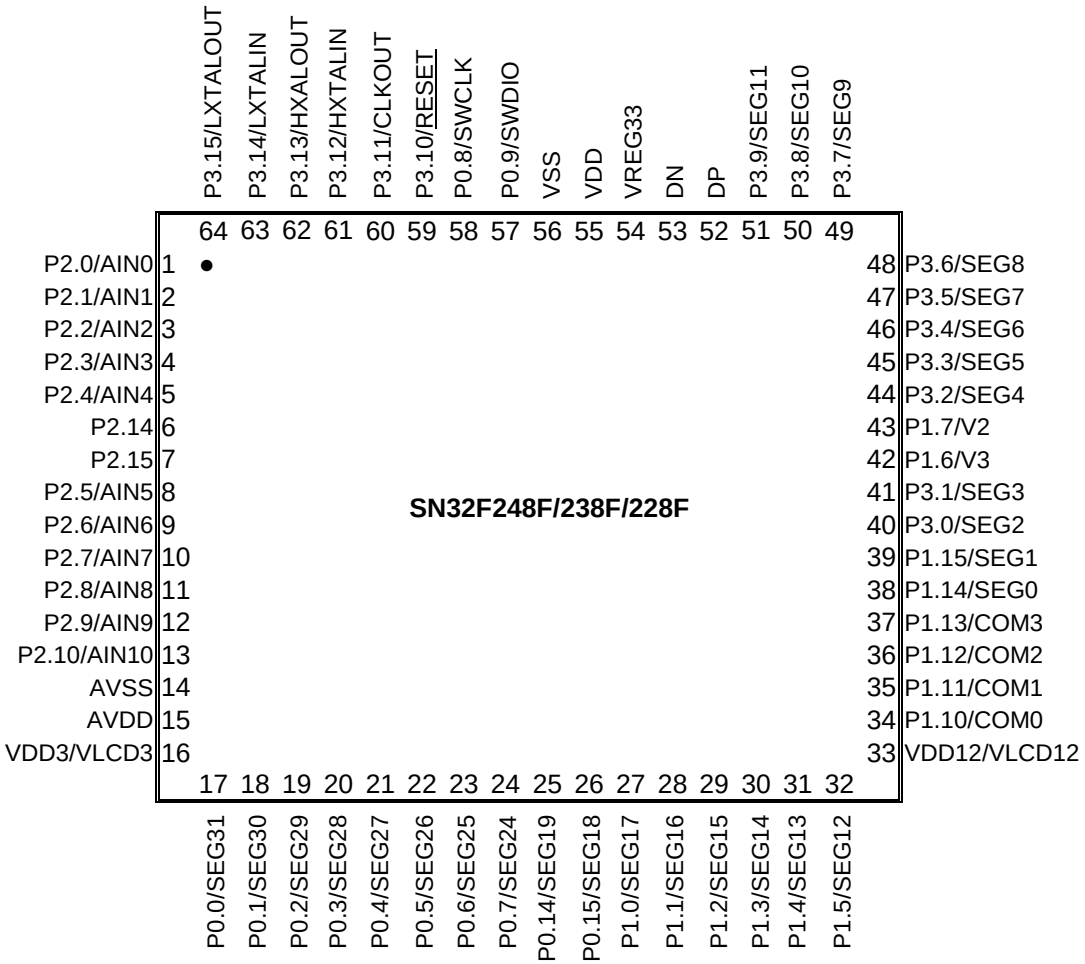


1.4 PIN ASSIGNMENT

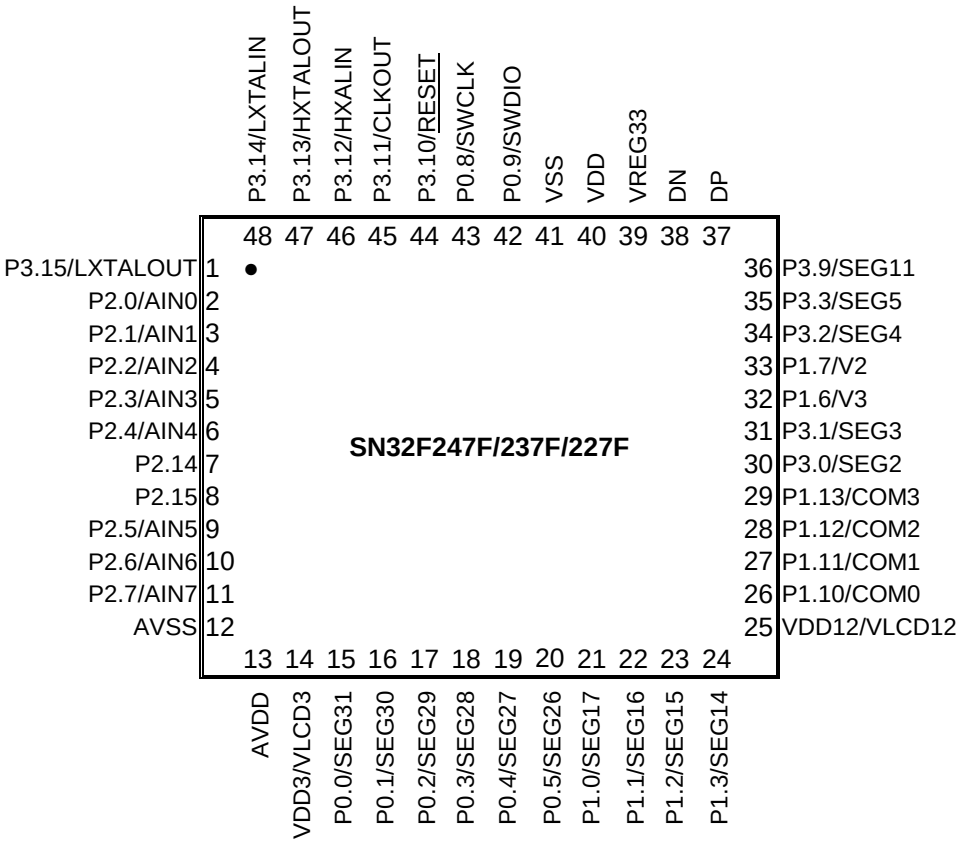
SN32F249F/239F/229F (LQFP 80 pins)



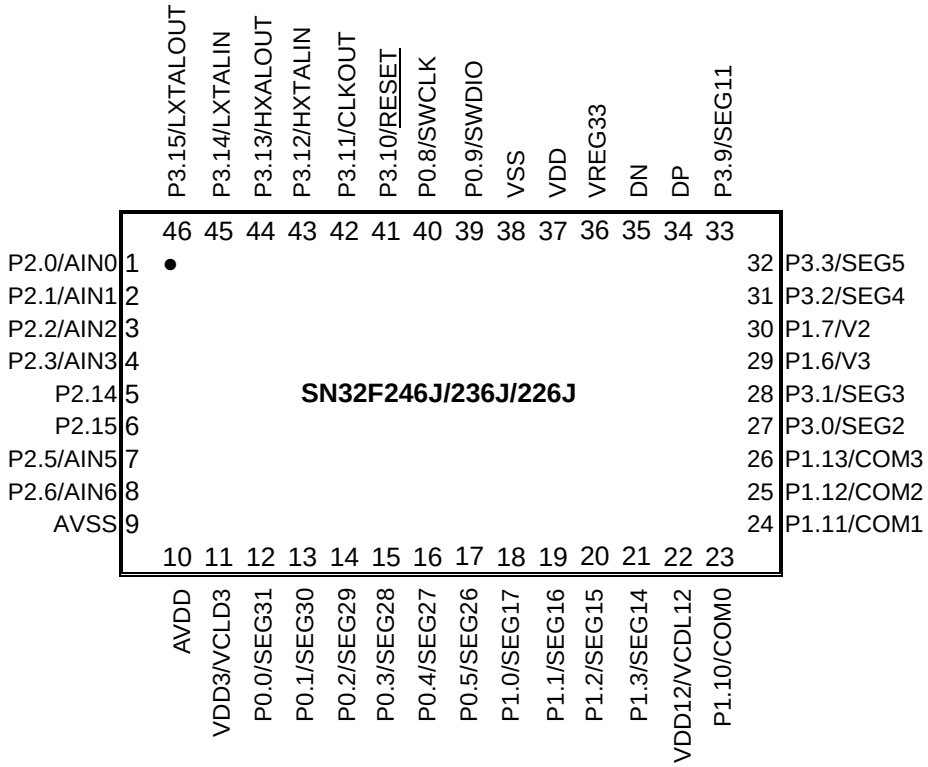
SN32F248F/238F/228F (LQFP 64 pins)



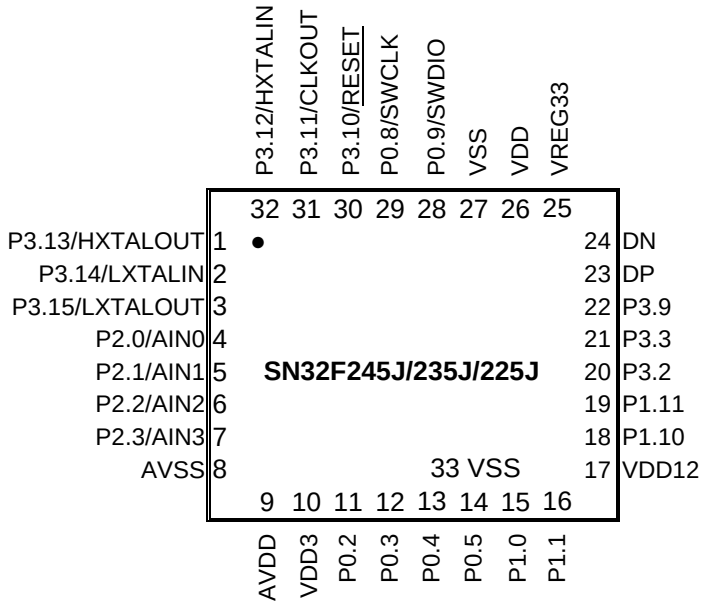
SN32F247F/237F/227F (LQFP 48 pins)



SN32F246J/236J/226J (QFN 46 pins)



SN32F245J/235J/225J (QFN 33 pins)



1.5 PIN DESCRIPTIONS

PIN NAME	TYPE	DESCRIPTION
VDD, VSS	P	Power supply input pins for digital circuit.
AVDD, AVSS	P	Power supply input pins for analog circuit.
VREG33	O	3.3v voltage output from USB 3.3v regulator.
DP, DN	I/O	USB differential data line.
VDD1/VLCD1	P	I/O and LCD driver power input pins for P1.6~P1.15 and P3.0~P3.9. This power input used for I/O power must be equal to VDD.
VDD2/VLCD2	P	I/O and LCD driver power input pins for P0.10~P0.15 and P1.0~P1.5.
VDD12/VLCD12	P	Double bonding pins with VDD1 and VDD2. This power input used for I/O power must be equal to VDD.
VDD3/VLCD3	P	I/O and LCD driver power input pins for P0.0~P0.7. If VDD3 voltage is lower than VDD, user should manually force to set the I/O port P1.6 and P1.7 as input pull-down state in case of internal power collision.
P1.8/CL-, P1.9/CL+	I/O, P	**P1.8, P1.9 —** Port 1.8, P1.9 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function. **CL+, CL- —** C-Type LCD charge pump capacitor
P1.6/V3, P1.7/V2	I/O, P	**P1.6, P1.7 —** Port 1.6, P1.7 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function. **V3 —** 2/3 VLCD bias voltage. **V2 —** 1/3 VLCD bias voltage.
P0.0~P0.7	I/O	**P0.0~P0.7 —** Port 0 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode.
P0.8/SWCLK	I/O	**P0.8 —** Port 0.8 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function. **SWCLK —** Serial Wire Clock pin.
P0.9/SWDIO	I/O	**P0.9 —** Port 0.9 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function. **SWDIO —** Serial Wire Data input/output pin.
P0.10~P0.15	I/O	**P0.0~P0.15 —** Port 0 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function.
P1.0~P1.5, P1.10~P1.15	I/O	**P1.0~P1.5, P1.10~P1.15 —** Port 1 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function.
P2.0~P2.13/AIN0~13	I/O	**P2.0~P2.13 —** Port 2 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function. **AIN0~AIN13 —** ADC channel input 0~13 pins.
P2.14	I/O	**P2.14 —** Port 2.14 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function.
P2.15	I/O	**P2.15 —** Port 2.15 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function.
P3.0~P3.9	I/O	**P3.0~P3.9 —** Port 3 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function.

P3.10/RESET	I/O	**P3.10 —** Port 3.10 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function. **RESET —** External Reset input. Schmitt trigger structure, active “Low”, normally stay “High”.
P3.11/CLKOUT	I/O	**P3.11 —** Port 3.11 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function. **CLKOUT —** Clockout pin.
P3.12/HXTALIN	I/O	**P3.12 —** Port 3.12 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function. **HXTALIN —** External high-speed X’tal input pin.
P3.13/HXTALOUT	I/O	**P3.13 —** Port 3.13 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function. **HXTALOUT —** External high-speed X’tal output pin.
P3.14/LXTALIN	I/O	**P3.14 —** Port 3.14 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function. **LXTALIN —** External low-speed X’tal input pin.
P3.15/LXTALOUT	I/O	**P3.15 —** Port 3.15 bi-direction pin. Schmitt trigger structure and built-in pull-up/pull-down resistors as input mode. Built-in wakeup function. **LXTALOUT —** External low-speed X’tal output pin.

Please refer to Peripheral Function Pin Assignment (PFPA) chapters for setting of each GPIOs.

Pin Name	Shared pins
P0.0	SEG31 / URXD0 / CT32B0_CAP0 / SCL1 / MISO0
	CT16B0_PWM0 / CT16B2_PWM1 / CT32B2_PWM2
P0.1	SEG30 / UTXD0 / SDA1 / MOSI0
	CT16B0_PWM1 / CT16B2_PWM2 / CT32B1_PWM0
P0.2	SEG29 / SCL0 / MISO0 / SEL1
	CT16B0_CAP0 / CT32B1_CAP0 / CT16B2_PWM0/CT32B2_PWM1
P0.3	SEG28 / SDA0 / MOSI0 /
	CT16B2_CAP0 / CT32B2_PWM2 / CT32B0_PWM3 / CT32B2_PWM0
P0.4	SEG27 / URXD0 / SCK0 / MISO1
	CT16B0_PWM1 / CT32B0_PWM0 / CT32B1_PWM1
P0.5	SEG26 / UTXD0 / SEL0 / MOSI1
	CT16B1_PWM0 / CT32B0_PWM2 / CT32B1_PWM2
P0.6	SEG25 / UTXD1 / SCL1 / MISO0
	CT16B1_PWM2 / CT32B1_PWM3 / C32B2_PWM3
P0.7	SEG24 / URXD1 / SDA1 / MOSI0 / SCK1
	CT16B1_CAP0 / CT32B0_PWM3 / CT32B1_PWM3
P0.8	SWCLK / CT16B0_CAP0 / CT32B1_CAP0
	CT16B1_PWM1 / CT32B0_PWM1 / CT32B1_PWM2 / CT32B2_PWM0

P0.9	SWDIO / CT32B0_CAP0 / CT32B2_CAP0
	CT16B0_PWM2 / CT16B2_PWM1 / CT32B0_PWM2 / CT32B1_PWM0 / CT32B2_PWM2
P0.10	SEG23 / I2SDIN / SDA0 / SEL0 / MISO1
	CT16B0_PWM1 / CT16B1_PWM0 / CT32B2_CAP0
P0.11	SEG22 / I2SDOUT / SCK0
	CT16B0_PWM2 / CT32B0_PWM0 / CT16B1_PWM1 /CT32B1_PWM2
P0.12	SEG21 / URXD1 / SEL0 / MOSI1 / I2SMCLK
	CT16B1_PWM1 / CT16B1_CAP0
P0.13	SEG20 / UTXD1 / SCK0 / SEL1 / I2SBCLK
	CT16B2_CAP0 / CT32B2_PWM0
P0.14	SEG19 / MOSI0 / SCK1 / I2SWS
	CT32B2_PWM1 / CT16B2_PWM0 / CT32B0_PWM1
P0.15	SEG18 / SCL0 / MISO0
	CT32B1_PWM1 / CT16B1_PWM2 / CT32B0_PWM3 / CT32B2_PWM1 / CT32B1_CAP0
P1.0	SEG17 / URXD1 / SDA1 / MISO0 / SEL1
	CT16B0_CAP0 / CT16B2_PWM2 / CT32B2_PWM3
P1.1	SEG16 / UTXD1 / SCL1 / MOSI0 / SCK1
	CT16B0_PWM0 / CT32B2_PWM0 / CT32B0_CAP0
P1.2	SEG15 / UTXD0 / SDA0 / MOSI1
	CT16B1_PWM2 / CT32B1_PWM1 / CT32B0_PWM3 / CT32B1_PWM3
P1.3	SEG14 / URXD0 / SCL0 / MISO1
	CT32B1_CAP0 / CT16B1_PWM1 / CT32B1_PWM0
P1.4	SEG13 / UTXD1 / SDA0 / SCK0 / SEL1
	CT16B2_PWM1 / CT16B2_PWM0 / CT32B2_CAP0
P1.5	SEG12 / URXD1 / SCL0 / SEL0
	CT16B2_CAP0 / CT32B0_PWM1 / CT32B2_PWM1
P1.6	V3 / UCTS0 / I2SDIN / MOSI1
	CT16B0_PWM2 / CT32B1_PWM2 / CT32B2_PWM2 / CT32B1_CAP0
P1.7	V2 / USCLK0 / I2SDOUT / SEL1
	CT16B1_CAP0 / CT32B1_PWM3 / CT32B2_PWM0 / CT32B2_PWM3
P1.8	CL- / URTS0 / SDA1 / I2SMCLK
	CT16B0_PWM0 / CT16B2_CAP0 / CT32B0_PWM0
P1.9	CL+ / SCL1 / I2SBCLK
	CT16B1_PWM2 / CT16B1_PWM0 / CT32B0_PWM2
P1.10	COM0 / MISO1 / I2SWS
	CT16B1_PWM3 / CT16B1_PWM1 / CT32B1_PWM1
P1.11	COM1 / SEL0 / SCK1
	CT16B1_CAP0 / CT16B2_PWM1 / CT32B0_PWM1
P1.12	COM2 / SCK0
	CT16B0_PWM0 / CT16B0_PWM2 / CT16B2_PWM2 / CT32B0_PWM3
P1.13	COM3 / URXD1 / SDA0 / MOSI1
	CT16B0_PWM1 / CT32B1_PWM0 / CT32B2_CAP0

P1.14	SEG0 / UTXD1 / SCL0 / MISO0 / SEL1
	CT16B1_PWM2 / CT32B0_PWM0 / CT32B0_PWM2
P1.15	SEG1 / URXD1 / MOSI0 / SCK1
	CT16B1_PWM0 / CT32B0_PWM0 / CT32B2_PWM0
P2.0	AIN0 / I2SDIN / SEL0 / MOSI1
	CT16B0_CAP0 / CT16B1_PWM0 / CT32B0_PWM2
P2.1	AIN1 / MISO0 / MISO1 / SEL1 / I2SWS
	CT16B1_CAP0/ CT16B2_PWM1 / CT32B1_PWM1
P2.2	AIN2 / MOSI0 / SCK1 / I2SMCLK
	CT16B2_CAP0 / CT16B0_PWM1 / CT32B0_PWM3
P2.3	AIN3 / SCK0
	CT16B0_PWM0 / CT16B1_PWM2 / CT32B0_PWM0 / CT32B2_PWM3 / CT32B0_CAP0
P2.4	AIN4 / CT32B1_CAP0
	CT16B0_PWM2 / CT16B1_PWM1 / CT16B2_PWM2 / CT32B0_PWM1 / CT32B1_PWM3
P2.5	AIN5 / I2SDIN
	CT16B2_PWM0 / CT32B1_PWM2 / CT32B2_CAP0
P2.6	AIN6 / I2SMCLK
	CT16B2_PWM1 / CT32B1_PWM0
P2.7	AIN7 / I2SWS
	CT16B1_PWM2 / CT32B2_PWM1
P2.8	AIN8 / I2SDOUT
	CT16B1_PWM1 / CT32B1_PWM1 / CT32B2_PWM3
P2.9	AIN9 / I2SWS
	CT16B1_CAP0 / CT16B2_PWM0 / CT32B2_PWM3
P2.10	AIN10 / I2SBCLK
	CT16B0_PWM2 / CT16B2_PWM2 / CT32B1_CAP0
P2.11	AIN11 / I2SBCLK
	CT16B0_PWM1 / CT32B0_PWM2 / CT32B2_PWM0
P2.12	AIN12 / MISO0 / MISO1 / I2SDOUT
	CT16B1_PWM0 / CT32B0_PWM3 / CT32B1_PWM2 / CT32B2_CAP0
P2.13	AIN13 / MOSI0 / SCK1
	CT16B0_CAP0 / CT32B0_PWM1 / CT32B1_PWM3 / CT32B2_PWM1
P2.14	SCK0 / SEL1
	CT16B2_CAP0 / CT32B0_PWM0 / CT32B1_PWM2 / CT32B2_PWM2
P2.15	SEL0 / MOSI1
	CT16B0_PWM0 / CT32B1_PWM0 / CT32B2_PWM0 / CT32B2_PWM3 / CT32B0_CAP0
P3.0	SEG2 / URXD0 / I2SDIN / SCL1 / MISO1
	CT16B0_CAP0 / CT16B2_PWM2 / CT32B2_PWM1
P3.1	SEG3 / I2SDOUT / UTXD0 / SEL0
	CT16B2_PWM2 / CT16B2_PWM0 / CT32B2_PWM2 / CT32B0_CAP0
P3.2	SEG4 / UTXD0 / SDA1 / I2SMCLK / SCK0 / MOSI1
	CT16B0_CAP0 / CT32B1_PWM0
P3.3	SEG5 / URXD0 / SCL1 / MISO0 / SCK1 / I2SBCLK
	CT16B0_PWM0 / CT32B0_CAP0
P3.4	SEG6 / UTXD0 / SDA1 / MOSI0 / MISO1 / I2SWS
	CT16B0_PWM1 / CT32B0_PWM3
P3.5	SEG7 / URXD0 / SDA1 / SEL0
	CT16B1_CAP0 / CT16B2_PWM0 / CT16B2_PWM1 / CT32B1_PWM1

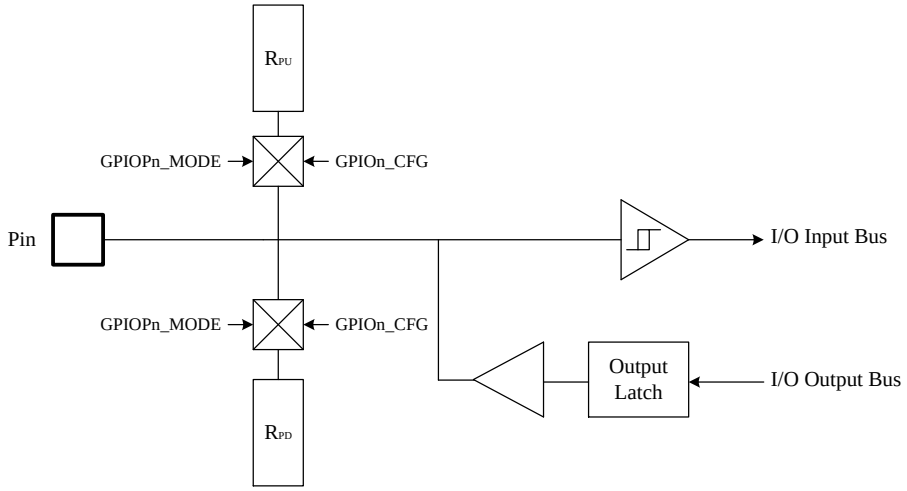
P3.6	SEG8 / URXD1 / SCL1 / SEL1 / SCK0 / I2SBCLK
	CT16B2_CAP0 / CT16B0_PWM2
P3.7	SEG9 / SDA0 / SCK1 / I2SMCLK
	CT16B1_PWM0 / CT32B0_PWM2 / CT32B2_PWM1 / CT32B2_CAP0
P3.8	SEG10 / UTXD1 / I2SDOUT / MOSI1
	CT16B1_PWM2 / CT32B0_PWM1 / CT32B1_CAP0
P3.9	SEG11 / I2SDIN / MISO1 / SCL0
	CT16B1_PWM1 / CT32B0_PWM0 / CT32B1_PWM3 / CT32B0_CAP0
P3.10	RESET / UTXD0 / UTXD1 / SEL0
	CT16B0_CAP0 / CT16B2_PWM0 / CT32B1_PWM1 / CT32B2_PWM3
P3.11	CLKOUT / URXD0 / SCL0 / SCK0 / SEL1
	CT16B0_PWM0 / CT16B2_PWM2 / CT32B1_PWM3
P3.12	HXTALIN / URXD1 / SDA1 / MISO1
	CT16B0_PWM1 / CT16B2_CAP0 / CT32B1_PWM2
P3.13	HXALOUT / UTXD1 / SCL1 / SDA0 / MOSI1
	CT16B1_CAP0 / CT32B0_PWM2 / CT32B2_PWM2
P3.14	LXTALIN / URXD0 / SCL0 / MOSI0 / SCK1
	CT16B1_PWM0 / CT32B0_PWM1 / CT32B2_CAP0
P3.15	LXTALOUT / UTXD0 / SDA0 / MISO0
	CT16B0_PWM2 / CT16B2_PWM1 / CT32B1_PWM0 / CT32B2_PWM2

✸ ***Note:***

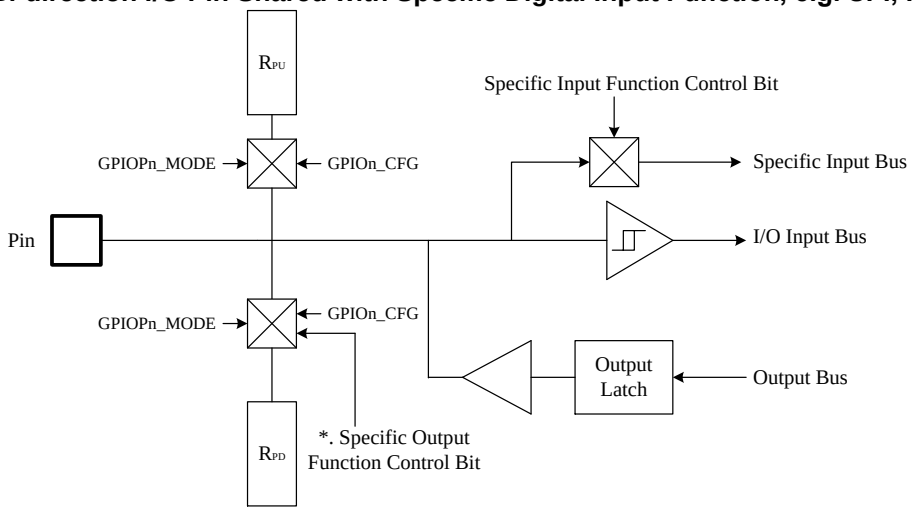
1. ***VDD1/VLCD1 is the*** **I/O and LCD driver power input pin for P1.6~P1.15 and P3.0~P3.9. This power input used for I/O power must be equal to VDD.**
2. **VDD12/VLCD12 is the double bonding pin with VDD1 and VDD2. This power input used for I/O power must be equal to VDD.**
3. ***VDD3/VLCD3 is the*** **I/O and LCD driver power input pin for P0.0~P0.7. If VDD3 voltage is lower than VDD, user should manually force to set the I/O port P1.6 and P1.7 as input pull-down state in case of internal power collision.**

1.6 PIN CIRCUIT DIAGRAMS

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

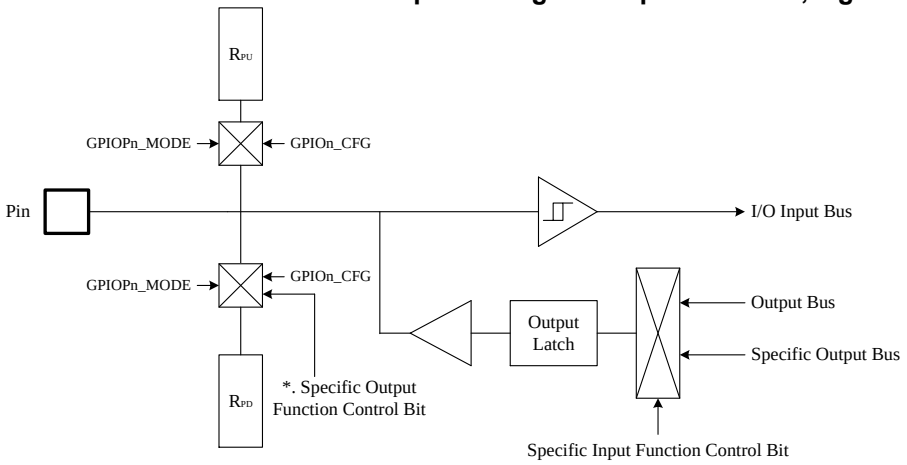


- **Bi-direction I/O Pin Shared with Specific Digital Input Function, e.g. SPI, I2C…**



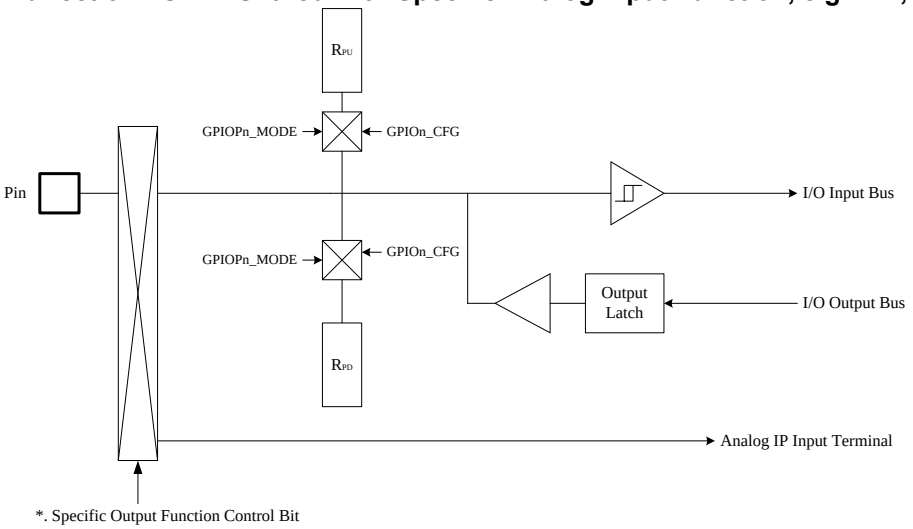
***. Some specific functions switch I/O direction directly, not through GPIOn_MODE register.**

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



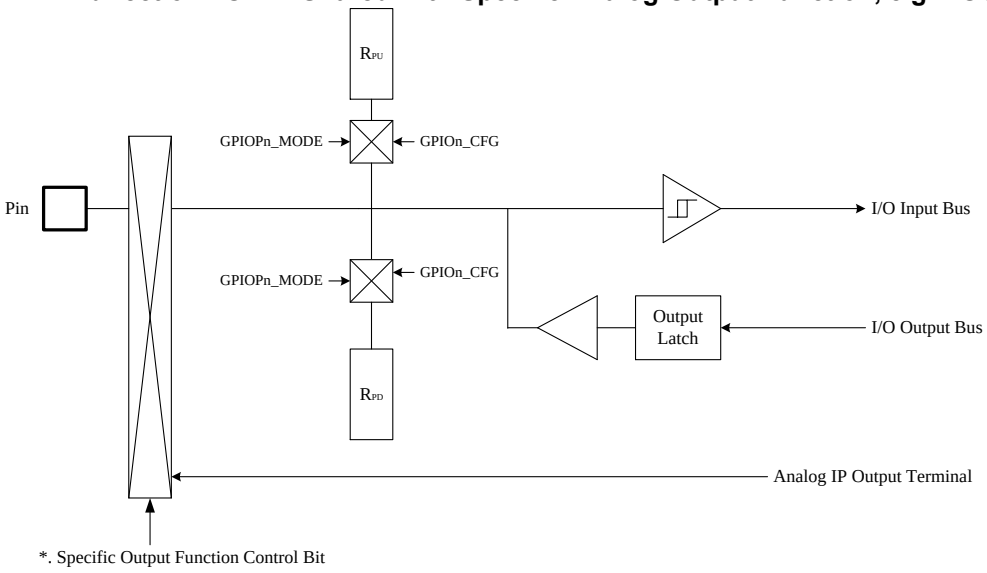
***. Some specific functions switch I/O direction directly, not through GPIOn_MODE register.**

- **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.**

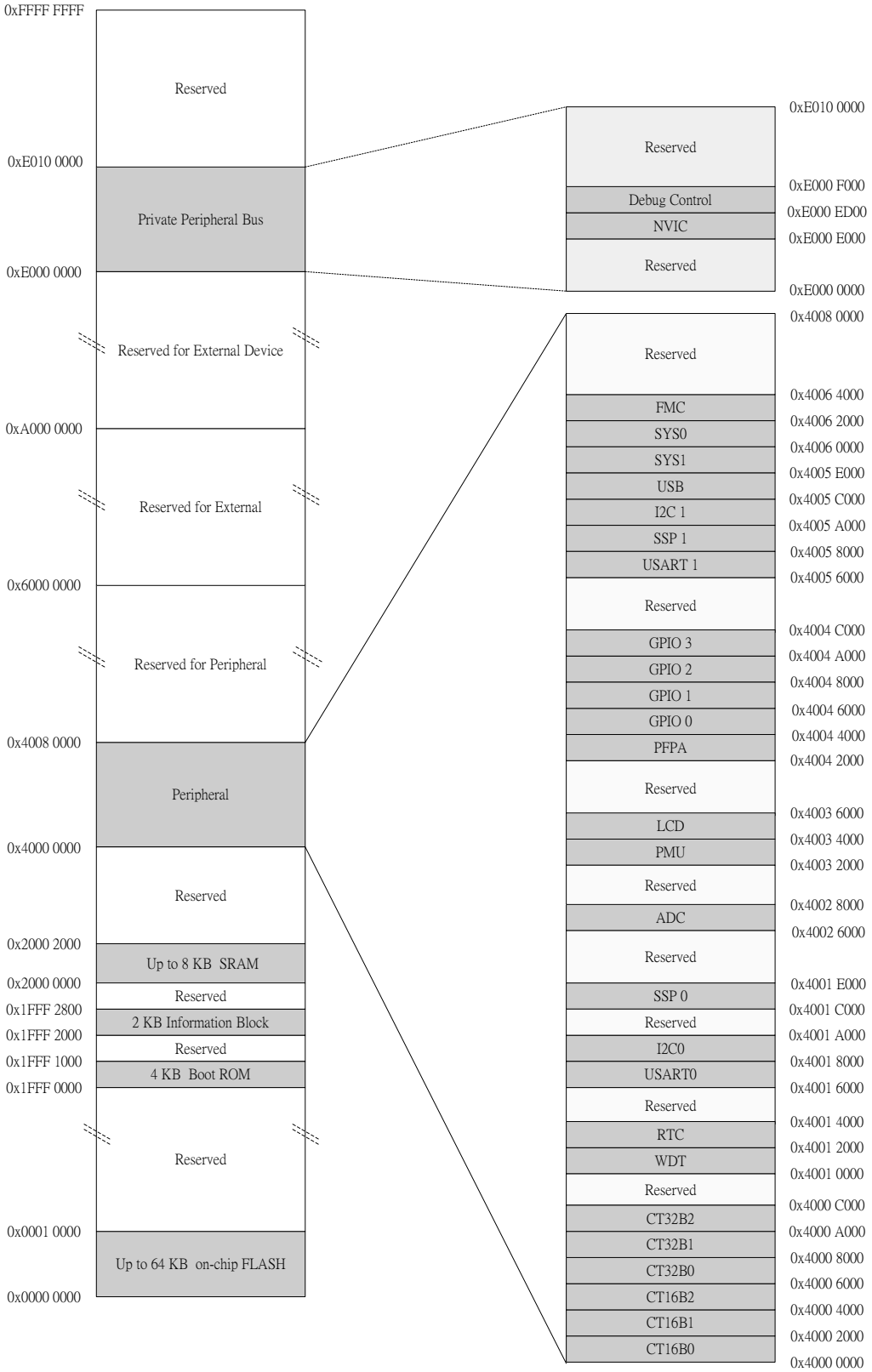
- **Bi-direction I/O Pin Shared with Specific Analog Output Function, e.g. XOUT…**



***. 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.

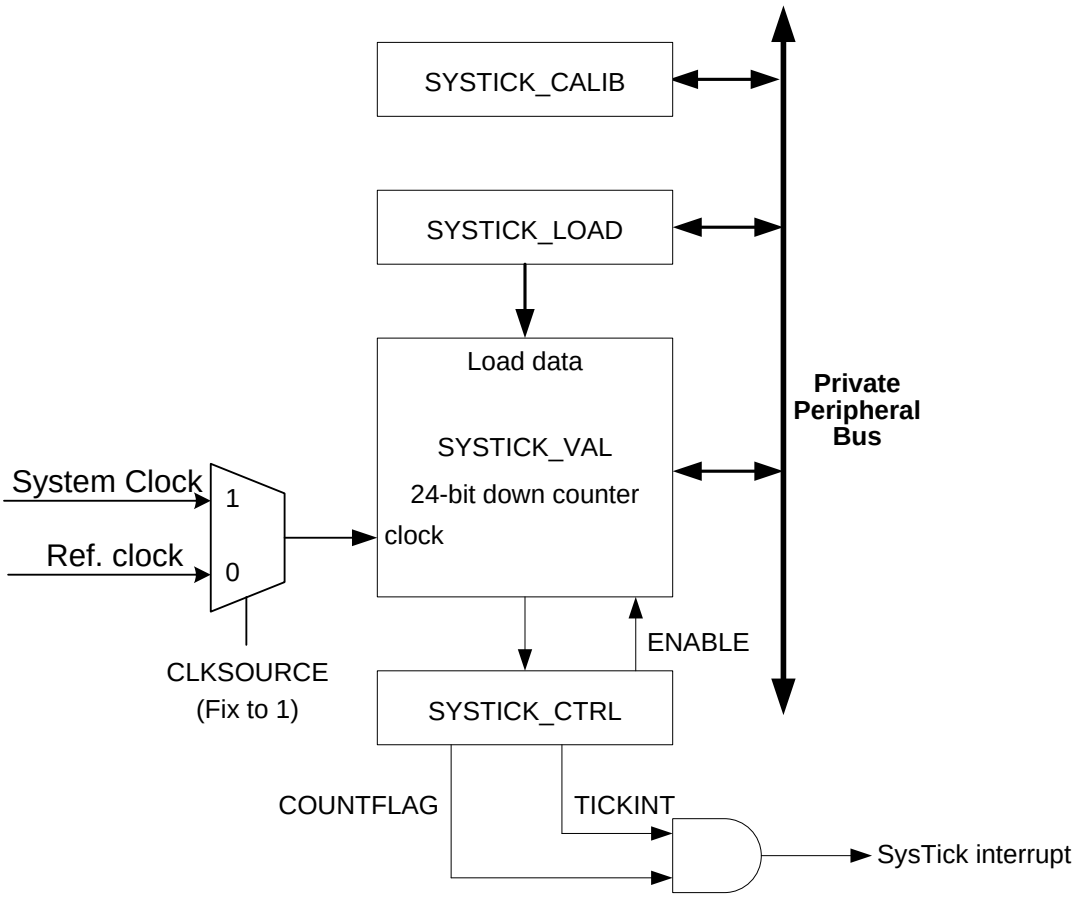
Refer to the *Cortex-M0 User Guide* for details.

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 (SYSTICK_VAL) to zero, reloads to the value in the SysTick Reload Value Register (SYSTICK_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 SYSTICK_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 SYSTICK_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 SYSTICK_VAL 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 SYSTICK_CTRL.	R/W	0x7E7F35

2.2.3.4 System Tick Timer Calibration Value register (SYSTICK_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

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	SVCCalll		0x0000 002C
12~13	Reserved	Reserved	Reserved	-
14	Settable	PendSV		0x0000 0038
15	Settable	SysTick		0x0000 003C
16	Settable	IRQ0/NDTIRQ	NDT	0x0000 0040
17	Settable	IRQ1/USBIRQ	USB	0x0000 0044
18	Settable	IRQ2/LCDIRQ	LCD	0x0000 0048
19	Settable	IRQ3/I2SIRQ	I2S	0x0000 004C
20	Settable	IRQ4/		0x0000 0050
21	Settable	IRQ5/		0x0000 0054
22	Settable	IRQ6/SSP0IRQ	SSP0	0x0000 0058
23	Settable	IRQ7/SSP1IRQ	SSP1	0x0000 005C
24	Settable	IRQ8/		0x0000 0060
25	Settable	IRQ9/		0x0000 0064
26	Settable	IRQ10/I2C0IRQ	I2C0	0x0000 0068
27	Settable	IRQ11/I2C1IRQ	I2C1	0x0000 006C
28	Settable	IRQ12/		0x0000 0070
29	Settable	IRQ13/USART0IRQ	USART0	0x0000 0074
30	Settable	IRQ14/USART1IRQ	USART1	0x0000 0078

31	Settable	IRQ15/CT16B0IRQ	CT16B0	0x0000 007C
32	Settable	IRQ16/CT16B1IRQ	CT16B1	0x0000 0080
33	Settable	IRQ17/CT16B2IRQ	CT16B2	0x0000 0084
34	Settable	IRQ18/		0x0000 0088
35	Settable	IRQ19/CT32B0IRQ	CT32B0	0x0000 008C
36	Settable	IRQ20/CT32B1IRQ	CT32B1	0x0000 0090
37	Settable	IRQ21/CT32B2IRQ	CT32B2	0x0000 0094
38	Settable	IRQ22/		0x0000 0098
39	Settable	IRQ23/RTCIRQ	RTC	0x0000 009C
40	Settable	IRQ24/ADCIRQ	ADC	0x0000 00A0
41	Settable	IRQ25/WDTIRQ	WDT	0x0000 00A4
42	Settable	IRQ26/LVDIRQ	LVD	0x0000 00A8
43	Settable	IRQ27/		0x0000 00AC
44	Settable	IRQ28/P3IRQ	GPIO interrupt status of port 3	0x0000 00B0
45	Settable	IRQ29/P2IRQ	GPIO interrupt status of port 2	0x0000 00B4
46	Settable	IRQ30/P1IRQ	GPIO interrupt status of port 1	0x0000 00B8
47	Settable	IRQ31/P0IRQ	GPIO interrupt status of port 0	0x0000 00BC

2.3.2 NVIC REGISTERS

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	R/W	0

		1: Interrupt enabled.		

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***
1. ***an interrupt that is pending has no effect***
2. ***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	R/W	0

		means writing 255 to a priority register saves value 192 to the register.		
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.***

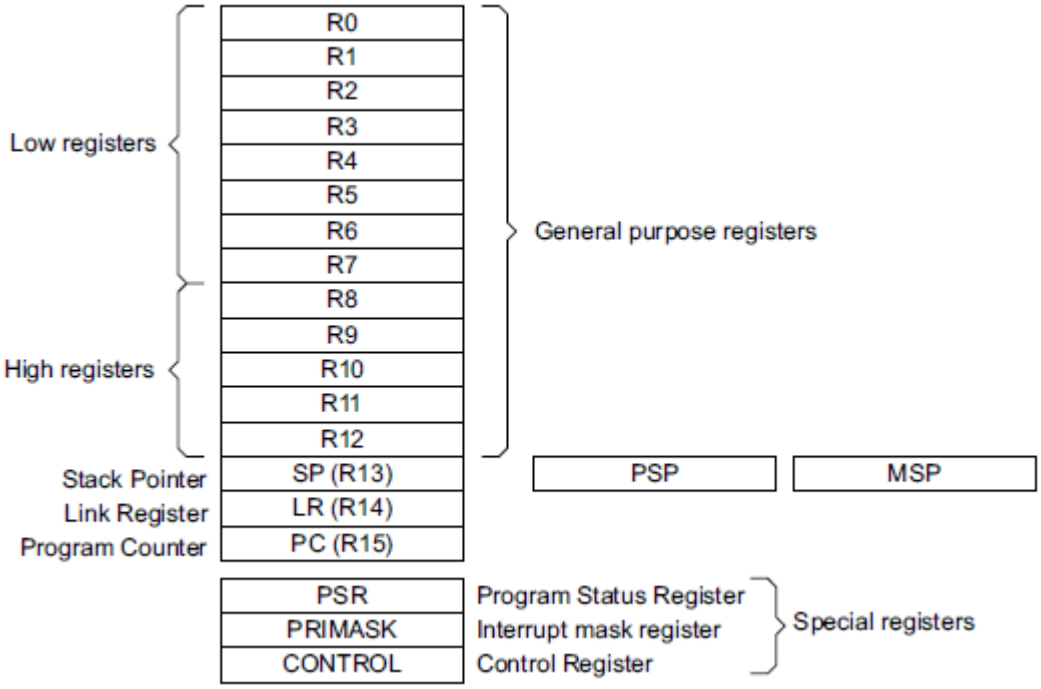
Bit	Name	Description	Attribute	Reset
31:16	VECTKEY	Register key. Read as unknown. Write 0x05FA to VECTKEY, otherwise the write is ignored.	R/W	0
15	ENDIANESS	Data endianness implemented 0: Little-endian 1: Big-endian	R	0
14:3	Reserved		R	0
2	SYSRESETREQ	System reset request. This bit read as 0. 0: No 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

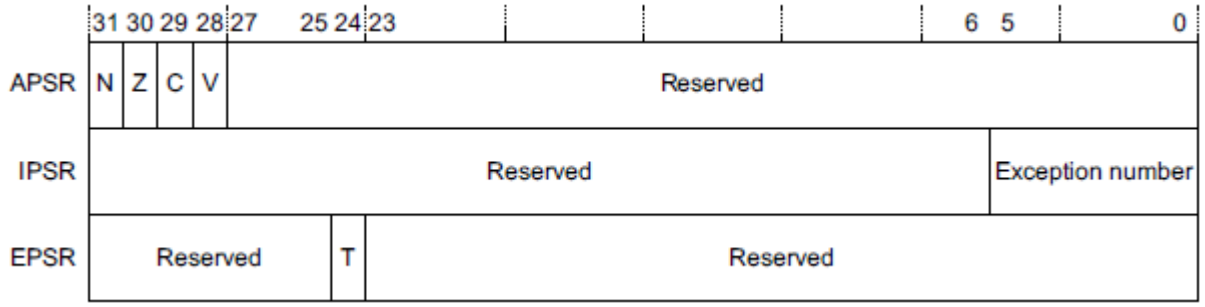
2.5 CODE OPTION TABLE

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
15:0	Reserved		R	All 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.

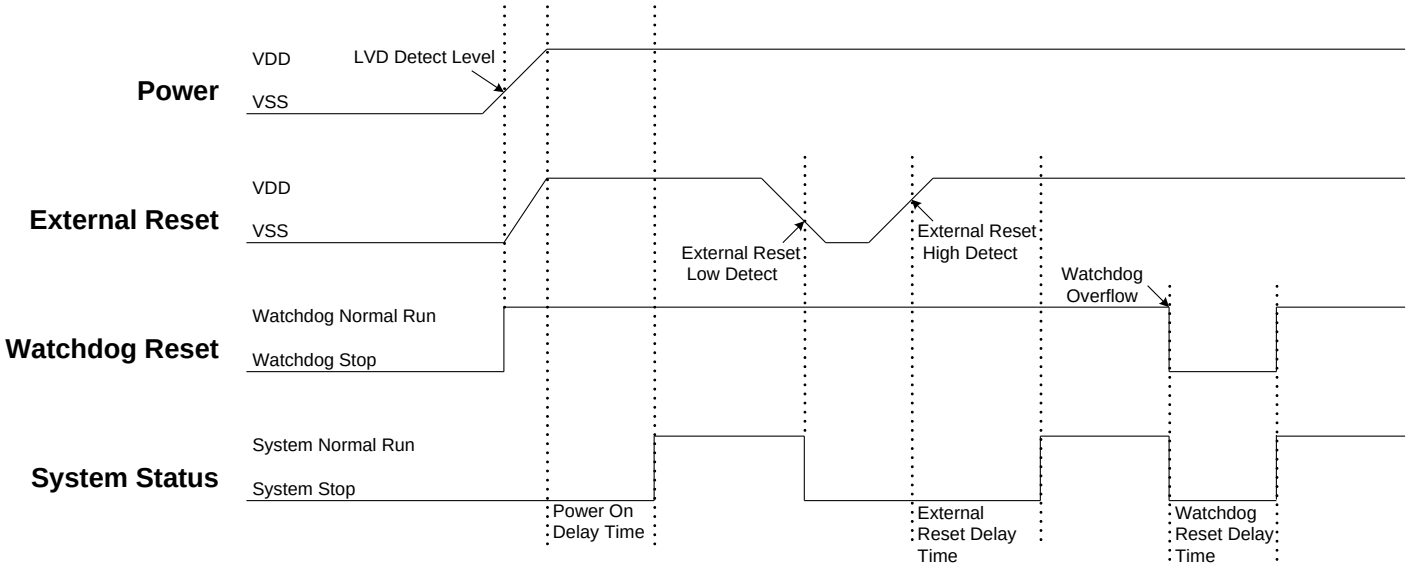
3 SYSTEM CONTROL

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.

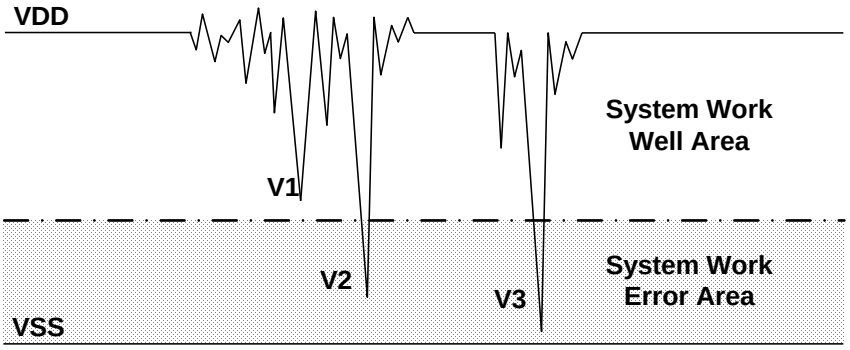
- Before clearing watchdog timer, check I/O status and check RAM contents can improve system error.
- Don't clear watchdog timer in interrupt vector and interrupt service routine. That can improve main routine fail.
- Clearing watchdog timer program is only at one part of the program. This way is the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

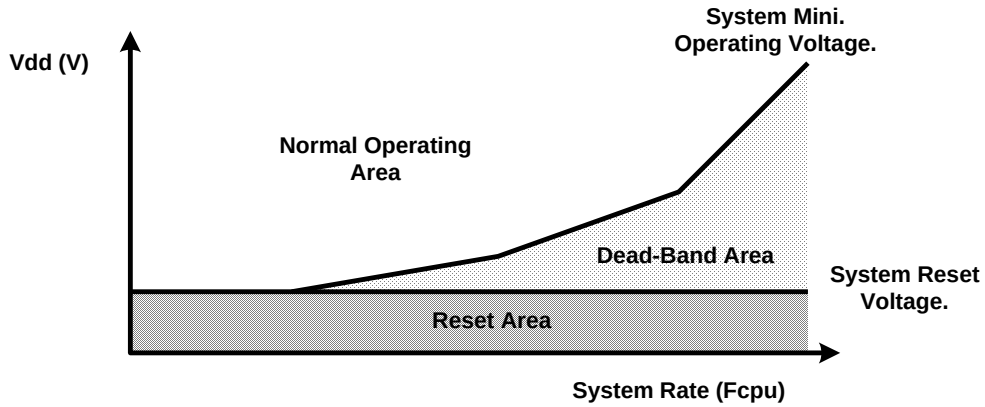
DC application:
The power source of DC application is usually using battery. When low battery condition and MCU drive any loading, the power drops and keeps in dead-band. Under the situation, the power won't drop deeper and not touch the system reset voltage. That makes the system under dead-band.

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.

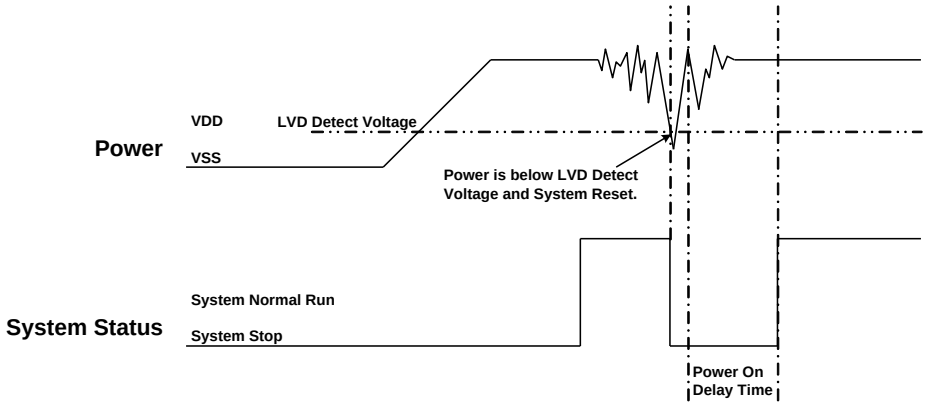
3.1.3.3 BROWN-OUT RESET IMPROVEMENT

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

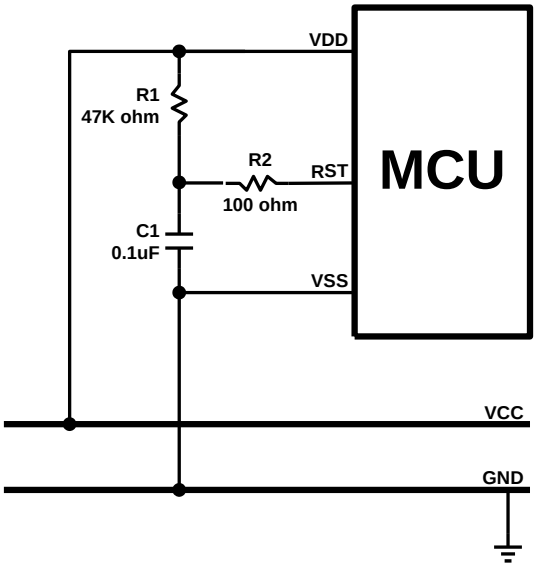
External reset function is controlled by External RESET pin control (SYS0_EXRSTCTRL) register. Default value is 1, which means external reset function is enabled. External reset pin is Schmitt Trigger structure and low level active. The system is running when reset pin is high level voltage input. The 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.

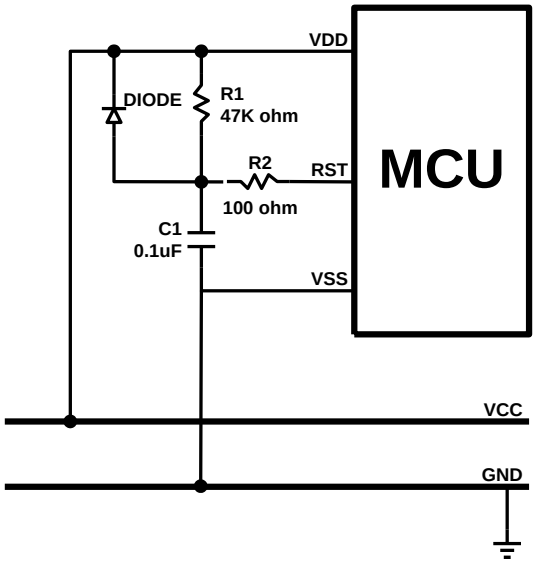
3.1.4.1 SIMPLY RC RESET CIRCUIT



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

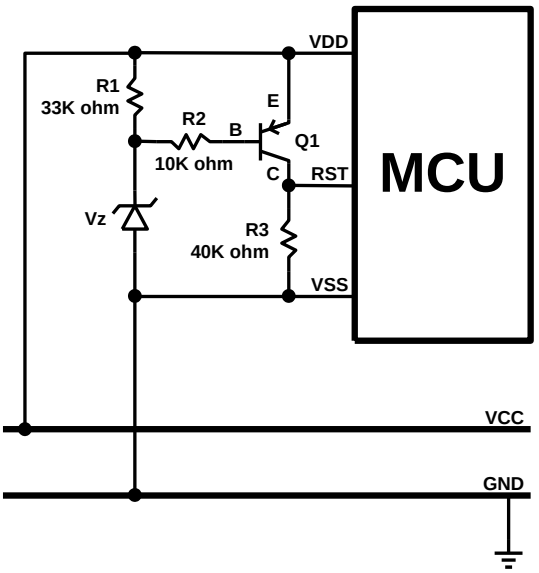


This is the better reset circuit. The R1 and C1 circuit operation is like the simply reset circuit to make a power on signal.

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.

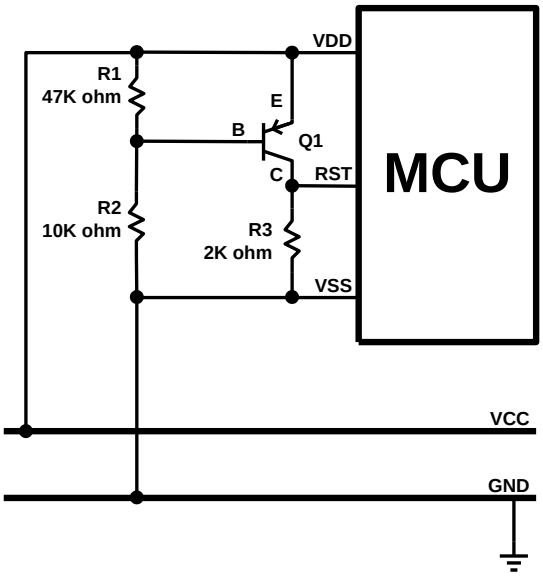
✸ ***Note: The R2 100 ohm resistor of "Simply reset circuit" and "Diode & RC reset circuit" is necessary to limit any current flowing into reset pin from external capacitor C in the event of reset pin breakdown due to Electrostatic Discharge (ESD) or Electrical Over-stress (EOS).***

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.

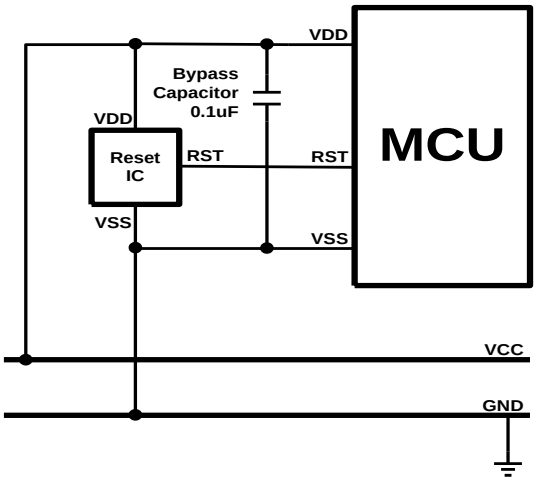
3.1.4.4 VOLTAGE BIAS RESET CIRCUIT



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 the first instruction designated by the 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)
- 32 KHz internal low speed RC (ILRC)
- PLL clock
- High speed external (EHS) crystal clock
- Low speed external (ELS) 32.768 KHz crystal

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 32KHz).

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)

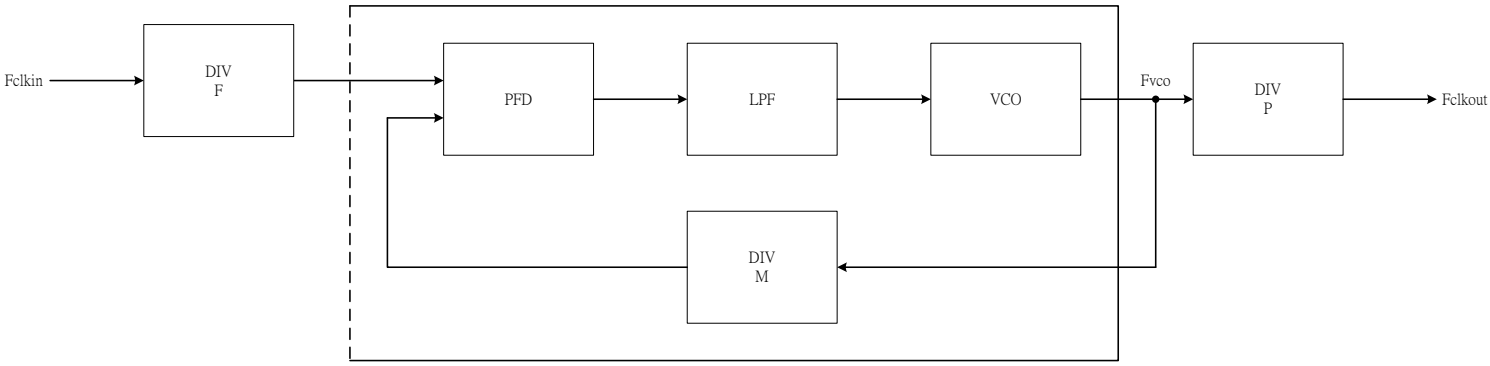
The system low clock source is the internal low-speed oscillator built in the micro-controller. The low-speed oscillator uses RC type oscillator circuit. The frequency is affected by the voltage and temperature of the system. In common condition, the frequency of the RC oscillator is about 32 KHz.

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

3.2.2 PLL

SONiX 32-bit 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:

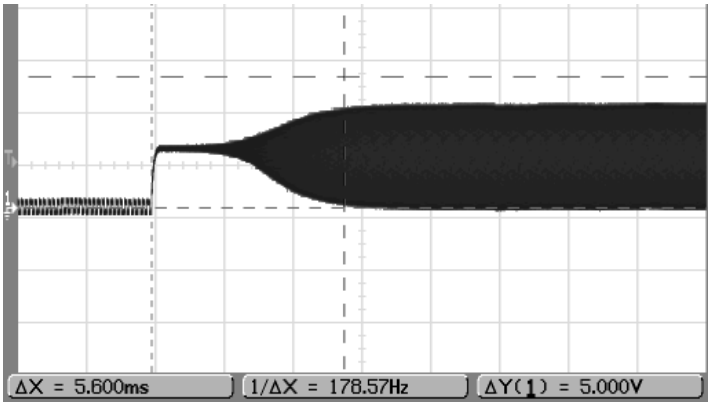
1. 10MHz ≤ F_{CLKIN} ≤ 25MHz
2. 150MHz ≤ F_{VCO} ≤ 330MHz
3. 2 < M ≤31
4. F = 1, or 2
5. P = 6, 8, 10, 12, or 14 (duty 50% +/- 2.5%)
6. F_{CLKOUT} = 20MHz, 30MHz, 40MHz, 50MHz, 24MHz, 36MHz, 48MHz, 32MHz, 22MHz, 24MHz, 50MHz with jitter < ±500 ps

3.2.3 EXTERNAL CLOCK SOURCE

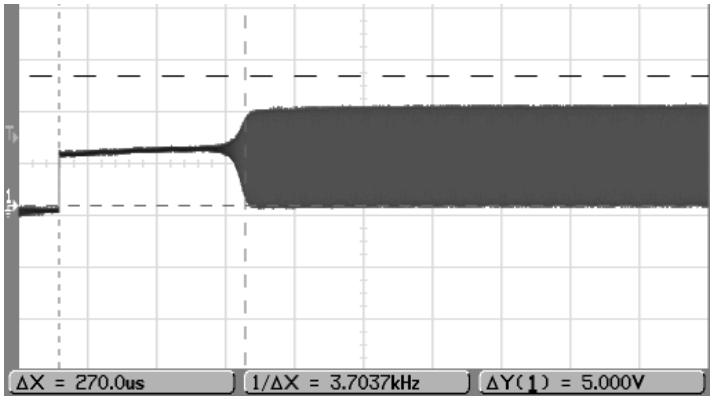
3.2.3.1 External High-speed (EHS) Clock

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

4MHz Crystal

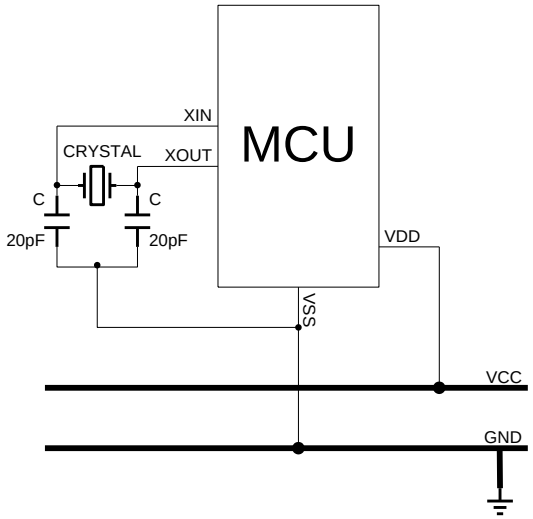


4MHz Ceramic



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.

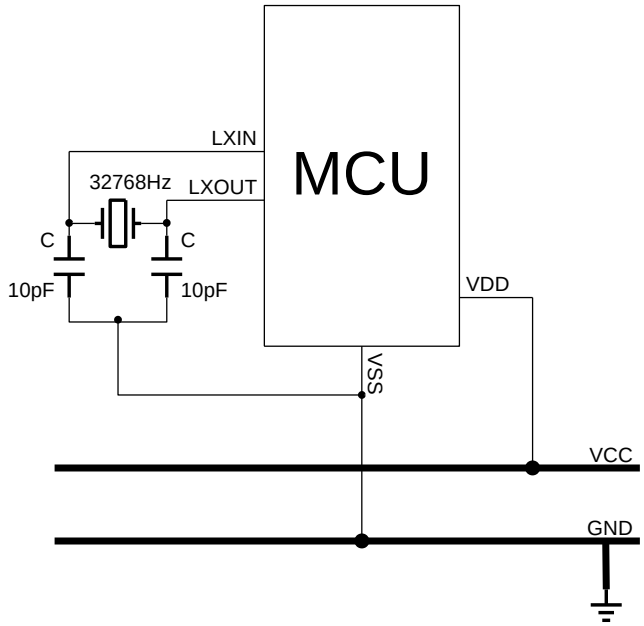
The EHS crystal is switched on and off using the EHSEN bit in Analog Block Control register (SYS0_ANBCTRL).

3.2.3.3 External Low-speed (ELS) Clock

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

3.2.3.4 CRYSTAL

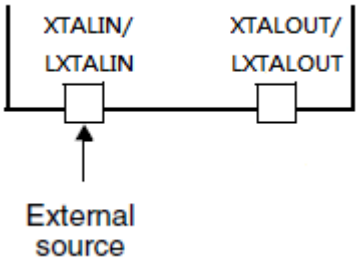
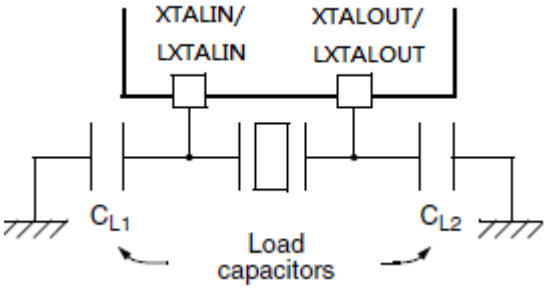
Crystal devices are driven by LXIN, LXOUT pins. The 32768 crystal and 10pF capacitor must be as near as possible to MCU. The ELS crystal is switched on and off using the ELSEN bit in Analog Block Control register (SYS0_ANBCTRL).



✸ ***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.***

3.2.3.5 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 10 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

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
31:6	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	R/W	0

		1: F = 2		
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

Fclkout / Fclkin	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
31:7	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	R/W	0

		0110: SYSCLK / 64 0111: SYSCLK / 128 1000: SYSCLK / 256 1001: SYSCLK / 512 Other: Reserved		

3.3.6 System Reset Status register (SYS0_RSTST)

Address Offset: 0x14

This register contains the reset source except DPDWAKEUP reset, since the MODE bits 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

13:7	Reserved		R	0
6:4	LVDINTLVL[2:0]	LVD interrupt level 000: 1.80V 001: 2.00V 010: 2.40V 011: 2.70V 100: 3.00V 101: 3.60V Other: Reserved	R/W	0
3	Reserved		R	0
2:0	LVDRSTLVL[2:0]	LVD reset level 000: 1.80V 001: 2.00V 010: 2.40V 011: 2.70V 100: 3.00V 101: 3.60V Other: 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. (P3.10 acts as RESET pin) 1: Disable. (P3.10 acts as GPIO pin)	R/W	1

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. (P0.9 acts as SWDIO pin, P0.8 acts as SWCLK pin) 1: Disable. (P0.8 and P0.9 act as GPIO pins)	R/W	0

3.3.10 Noise Detect Control register (SYS0_NDTCTRL)

Address Offset: 0x28

Bit	Name	Description	Attribute	Reset
31:2	Reserved		R	0
1	NDT2_IE	NDT2 for VDD interrupt enable bit 0: Disable 1: Enable (The noise detected on VDD will trigger NDT interrupt).	R/W	0
0	NDT1_IE	NDT1 for V_{CORE} interrupt enable bit 0: Disable 1: Enable (The noise detected on V_{CORE} will trigger NDT interrupt).	R/W	0

3.3.11 Noise Detect Status register (SYS0_NDTSTS)

Address Offset: 0x2C

Bit	Name	Description	Attribute	Reset
31:2	Reserved		R	0
1	NDT2_DET	Power noise status of NDT2 0: No power noise is detected. 1: Read→Power noise is detected. Write→Clear this bit.	R/W	0
0	NDT1_DET	Power noise status of NDT1 0: No power noise is detected. 1: Read→Power noise is detected. Write→Clear this bit.	R/W	0

3.3.12 Anti-EFT Ability Control register (SYS0_ANTIEFT)

Address Offset: 0x30

This register decides the HW anti-EFT ability.

Bit	Name	Description	Attribute	Reset
31:3	Reserved		R	0
2:0	AEFT[2:0]	HW anti-EFT ability. 000: No 010: Low 011: Medium 100: Strong	R/W	000

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: ILRC clock 010: ELS clock 100: HCLK 101: IHRC clock 110: EHS clock 111: PLL clock output	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	USART1CLKEN	Enables clock for USART1. 0: Disable 1: Enable	R/W	0
16	USART0CLKEN	Enables clock for USART0. 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	ADCCLKEN	Enables clock for ADC.	R/W	0

		0: Disable 1: Enable		
10	CT32B2CLKEN	Enables clock for CT32B2. 0: Disable 1: Enable	R/W	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	CT16B2CLKEN	Enables clock for CT16B2. 0: Disable 1: Enable	R/W	0
6	CT16B1CLKEN	Enables clock for CT16B1. 0: Disable 1: Enable	R/W	0
5	CT16B0CLKEN	Enables clock for CT16B0. 0: Disable 1: Enable	R/W	0
4:3	Reserved		R	0
2	LCDCLKEN	Enables clock for LCD 0: Disable 1: Enable	R/W	0
1	USBCLKEN	Enable clock for USB 0: Disable 1: Enable	R/W	0
0	GPIOCLKEN	Enables clock for GPIO. 0: Disable 1: Enable	R/W	1

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	CT32B2PRE[2:0]	CT32B2 clock source prescaler 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0
27	Reserved		R	0
26:24	SSP1PRE[2:0]	SSP1 clock source prescaler 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 prescaler 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	ADCPRE[2:0]	ADC clock source prescaler 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 prescaler 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 prescaler. 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 prescaler 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 prescaler 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	Reserved		R	0
30:28	CT16B2PRE[2:0]	CT16B2 clock source prescaler 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0
27	Reserved		R	0
26:24	I2C1PRE[2:0]	I2C1 clock source prescaler 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 prescaler 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 101: HCLK / 32 Other: Reserved	R/W	0
19:18	Reserved		R	0
17:16	SYSTICKPRE[1:0]	SysTick clock source prescaler 00: HCLK / 1 01: HCLK / 2 10: HCLK / 4 11: HCLK / 8	R/W	0
15	Reserved		R	0
14:12	I2SPRE[2:0]	I2S clock source prescaler 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 111: HCLK / 3 Other: Reserved	R/W	0
11	Reserved		R	0
10:8	I2C0PRE[2:0]	I2C0 clock source prescaler 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	USART1PRE[2:0]	USART1 clock source prescaler 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	USART0PRE[2:0]	USART0 clock source prescaler 000: HCLK / 1 001: HCLK / 2 010: HCLK / 4 011: HCLK / 8 100: HCLK / 16 Other: Reserved	R/W	0

3.4.4 APB Clock Prescale register 2 (SYS1_APBCP2)

Address Offset: 0x0C

Bit	Name	Description	Attribute	Reset
31:4	Reserved		R	0
3:0	CLKOUTPRE[3:0]	Clock-out source prescaler 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

3.4.5 Peripheral Reset register (SYS1_PRST)

Address Offset: 0x10

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

Bit	Name	Description	Attribute	Reset
31:25	Reserved		R	0
25	USBRST	USB reset 0: No effect 1: Reset USB	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	USART1RST	USART1 reset 0: No effect 1: Reset UART1	R/W	0
16	USART0RST	USART0 reset 0: No effect 1: Reset UART0	R/W	0
15	LCDRST	LCD reset 0: No effect 1: Reset LCD	R/W	0
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	ADCRST	ADC reset 0: No effect 1: Reset ADC	R/W	0
10	CT32B2RST	CT32B2 reset 0: No effect 1: Reset CT32B2	R/W	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	CT16B2RST	CT16B2 reset 0: No effect 1: Reset CT16B2	R/W	0
6	CT16B1RST	CT16B1 reset 0: No effect 1: Reset CT16B1	R/W	0
5	CT16B0RST	CT16B0 reset 0: No effect 1: Reset CT16B0	R/W	0
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

3.4.6 Divider Dividend register (SYS1_DIVIDEND)

Address Offset: 0x20

Bit	Name	Description	Attribute	Reset

31:0	Dividend[31:0]	Unsigned integer Dividend	R/W	0

3.4.7 Divider Divisor register (SYS1_DIVISOR)

Address Offset: 0x24

✸ ***Note: Quotient is 0xFFFFFFFF when Divisor is 0x0, instead of occurring Hard Fault, since FW shall be able to handle this case.***

Bit	Name	Description	Attribute	Reset
31:0	Divisor[31:0]	Unsigned integer Divisor	R/W	0

3.4.8 Divider Quotient register (SYS1_QUOTIENT)

Address Offset: 0x28

✸ ***Note: Quotient is 0xFFFFFFFF when Divisor is 0x0, instead of occurring Hard Fault, since FW shall be able to handle this case.***

Bit	Name	Description	Attribute	Reset
31:0	Quotient[31:0]	Unsigned integer Quotient	R/W	0

3.4.9 Divider Remainder register (SYS1_REMAINDER)

Address Offset: 0x2C

Bit	Name	Description	Attribute	Reset
31:0	Remainder[31:0]	Unsigned integer Remainder	R/W	0

3.4.10 Divider Control register (SYS1_DIVCTRL)

Address Offset: 0x30

Bit	Name	Description	Attribute	Reset
31:1	Reserved		R	0

0	DIVS	Divider start control bit. 0: Divider stops/finishes operation. 1: Start to execute Dividing. DIVS is cleared by HW automatically when the operation of dividing finishes.	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, and ADC) 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 desired.

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, and ADC) 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 4 to 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 or LCD low speed clock source (ELS X'TAL, ILRC) if used.

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

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

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

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

The Deep-sleep mode is entered by using the following steps:
1. Write 2 to 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 GPIO pins.

The processor state and registers, peripheral registers, and internal SRAM values are not retained. However, the chip can retain data in four BACKUP registers, and the status of all GPIO pins can also be latched.

All GPIO pins can be served as DPDWAKEUP pins. However, the DPDWAKEUP pins which are used to wake up MCU shall be set as input pull-up and keep in HIGH level before entering Deep power-down mode. The user must program the GPIO registers for each pin to set the appropriate GPIO status (input pull-up, input pull-down, input floating, output high, and output low, open-drain) and then program PMU_LATCHCTRL1 register to latch the status of all GPIO pins.

When any of the DPDWAKEUP pins is pulled LOW, MCU wakes up from Deep power-down mode. The on-chip voltage regulator will be turned on, and when the core voltage reaches the power-on-reset (POR) trip point, a system reset will be triggered and the chip re-boots.

Once the chip has rebooted, the user can read 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. If MCU wakes up from Deep power-down mode, the user must program GPIO registers with the same settings (input pull-up, input pull-down, input floating, output high, and output low) and then program PMU_LATCHCTRL2 register to release the status of all GPIO pins.

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. Disable analog IP (ADC, LCD, HXTAL and LXTAL), External reset, and SWD.
2. Setup the desired GPIO status of all GPIO pins. The DPDWAKEUP pins which are used to wake up MCU shall be set as input-pull up and keep in HIGH level. (Strongly recommended to set output high first, and then set as input pull-up to reduce pull-up time)
3. (Optional) Save data to be retained during Deep power-down to the DATA bits in Backup registers.
4. Write 0x5A5A0001 to PMU_LATCHCTRL1 register to latch the status of all GPIO pins.
5. Write 1 to PMU_CTRL register.
6. Time spent between step 1 and step 5 shall longer than 20 us.
7. Execute ARM Cortex-M0 WFI/WFE instruction.

After step 7, the PMU turns off the on-chip voltage regulator and waits for a wake-up signal from the DPDWAKEUP pins.

4.3.3.2 Exiting Deep power-down mode

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

1. Any of the DPDWAKEUP pins level is 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 will be reset, except the Backup registers and PMU_CTRL register.
2. Read the 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 PMU_CTRL register.
4. (Optional) Read the stored data in the backup registers.
5. Setup the same GPIO status of all GPIO pins as step 2 of 4.3.3.1.
6. Write 0x5A5A0001 to PMU_LATCHCTRL2 register to release the status of all GPIO pins.
7. Setup the PMU for the next Deep power-down cycle.

4.4 WAKEUP

4.4.1 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, LCD interrupt, and the RESET pin.
- The wakeup trigger sources of the Deep Power-down mode are DPDWAKEUP pins which are input pull-up and latched before entering DPD mode.

4.4.2 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.

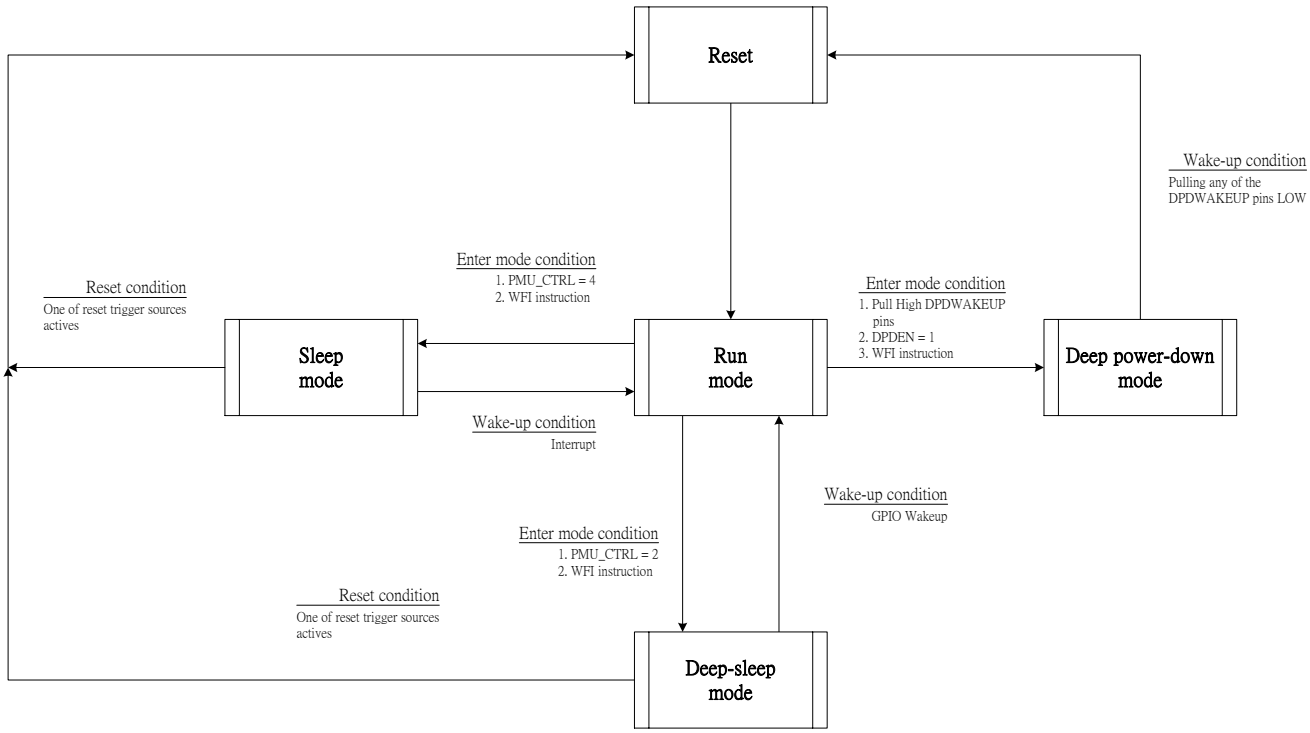
The total Wakeup time of IHRC = 1/F_{IHRC} * 32 (sec)

- 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.***

4.5 STATE MACHINE OF PMU



4.6 OPERATION MODE COMPARSION TABLE

Operation Mode	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
ELS X'TAL	By ELSEN		***	OFF
PLL	By PLLEN		Disable	OFF
Cortex-M0	Running	Stop	Stop	Stop
Flash ROM	Enable	Disable	Disable	OFF
RAM	Enable	Maintain	Maintain	OFF
ADC	By ADENB		Disable	Disable
LVD	By LVDEN		Disable	OFF
USB	By SIE_EN		Disable	OFF
LCD	By LCDENB		***	OFF
RTC	By RTCEN		By RTCEN	OFF
Peripherals	By Enable bit of each peripherals		Disable HCLK	OFF
IO status	-	Maintained	Maintained	Latched
Wakeup Source	N/A	All interrupts, RESET pin	GPIO interrupt, RTC interrupt, LCD interrupt, RESET pin	DPDWAKEUP pins (which are input pull-up)

***

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

4.7 PMU REGISTERS

Base Address: 0x4003 2000

4.7.1 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

4.7.2 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: 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.***

Bit	Name	Description	Attribute	Reset
31:3	Reserved		R	0
2:0	MODE[2:0]	Low power mode selection 000: Disable. 001: WFI instruction will make MCU enter Deep-power down mode. 010: WFI instruction will make MCU enter Deep-sleep mode. 100: WFI instruction will make MCU enter Sleep mode. Other: Disable	R/W	0

4.7.3 I/O Latch Control register 1 (PMU_LATCHCTRL1)

Address Offset: 0x44

Bit	Name	Description	Attribute	Reset

31:16	LATCHKEY	Latch register key. Read as 0. When writing to the register you must write 0x5A5A to LATCHKEY, otherwise behaviour of writing to the register is ignored.	W	0
15:1	Reserved		R	0
0	LATCHEN	Latch enable bit 0: No effect 1: Enable GPIO latch function	R/W	0

4.7.4 I/O Latch Control register 2 (PMU_LATCHCTRL2)

Address Offset: 0x48

Bit	Name	Description	Attribute	Reset
31:16	LATCHKEY	Latch register key. Read as 0. When writing to the register you must write 0x5A5A to LATCHKEY, otherwise behaviour of writing to the register is ignored.	W	0
15:1	Reserved		R	0
0	LATCHDIS	Latch disable bit 0: No effect 1: Disable GPIO latch function	R/W	0

4.7.5 I/O Latch Status register (PMU_LATCHST)

Address Offset: 0x4C

Bit	Name	Description	Attribute	Reset
31:1	Reserved		R	0
0	LATCH	Latch status bit 0: Not Latch yet 1: GPIO status is Latched.	R	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

All GPIO pins are inputs and floating by default. 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.

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, ADC) is enabled, not through GPIOn_MODE register.***

Bit	Name	Description	Attribute	Reset
31:16	CURRENT[15:0]	Driving/Sinking current selection (x = 0 to 15) 0: Typical 10mA 1: Typical 20mA	R/W	0
15:0	MODE[15:0]	Selects pin x as input or output (x = 0 to 15) 0: Pn.x is configured as input 1: Pn.x is configured as output.	R/W	0

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, ADC) 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 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

5.3.4 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

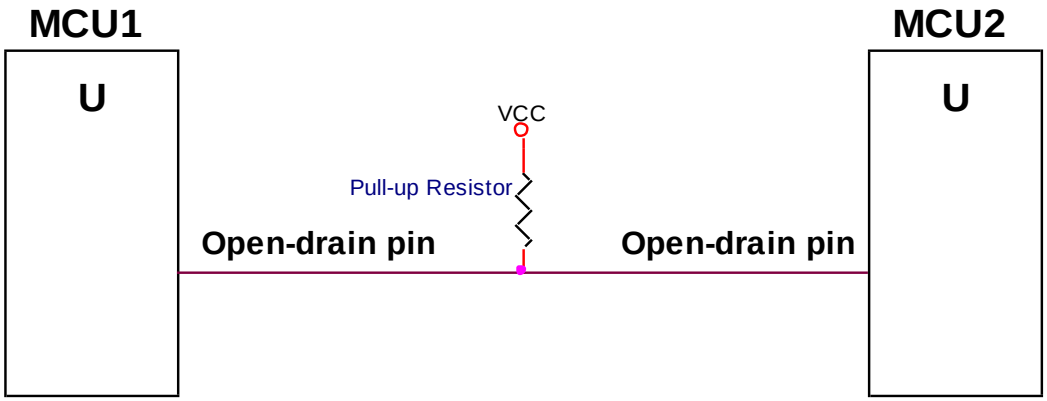
In order for SW to clear GPIO bits without affecting any other pins in a single write operation, the GPIO bit is cleared if the corresponding bit in this register is set.

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:***
1. VCC shall be less than or equal to VDD of MCU1 and MCU2.
2. Only P0, P1, and P3 support Open-drain.

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	OC[15:0]	Open-drain control bit (x = 0 to 15) 0: Disable. 1: Enable open-drain function of Pn.x. HW also set Pn.x as output mode automatically.	W/R	0

6 PERIPHERAL FUNCTION PIN ASSIGNMENT (PFPA)

6.1 OVERVIEW

PFPA registers are used to provide flexible assignment of digital peripheral functions to desired external pins of different packages.

6.2 FEATURES

- Flexible assignment of digital peripheral functions to desired pins.
- Supported functions are USART, I2C, SSP, I2S, Capture, and PWM.

6.3 PIN ASSIGNMENT LIST

Peripheral	Pin Name	PA0	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9
UART0	URXD0	P0.0	P0.4	P1.3	P3.0	P3.3	P3.5	P3.11	P3.14		
	UTXD0	P0.1	P0.5	P1.2	P3.1	P3.2	P3.4	P3.10	P3.15		
UART1	URXD1	P1.0	P0.7	P0.12	P1.5	P1.13	P1.15	P3.6	P3.12		
	UTXD1	P1.1	P0.6	P0.13	P1.4	P1.14	P3.8	P3.10	P3.13		
SSP0	SCK0	P0.4	P0.11	P0.13	P1.4	P1.12	P3.2	P3.6	P3.11	P2.3	P2.14
	SEL0	P0.5	P0.10	P0.12	P1.5	P1.11	P3.1	P3.5	P3.10	P2.0	P2.15
	MISO0	P0.2	P0.0	P0.6	P0.15	P1.0	P1.14	P3.3	P3.15	P2.1	P2.12
	MOSI0	P0.3	P0.1	P0.7	P0.14	P1.1	P1.15	P3.4	P3.14	P2.2	P2.13
SSP1	SCK1	P3.7	P0.7	P0.14	P1.1	P1.11	P1.15	P3.3	P3.14	P2.2	P2.13
	SEL1	P3.6	P0.2	P0.13	P1.0	P1.4	P1.7	P1.14	P3.11	P2.1	P2.14
	MISO1	P3.9	P0.4	P0.10	P1.3	P1.10	P3.0	P3.4	P3.12	P2.1	P2.12
	MOSI1	P3.8	P0.5	P0.12	P1.2	P1.6	P1.13	P3.2	P3.13	P2.0	P2.15
I2C0	SCL0	P1.5	P0.2	P0.15	P1.3	P1.14	P3.9	P3.11	P3.14		
	SDA0	P1.4	P0.3	P0.10	P1.2	P1.13	P3.7	P3.13	P3.15		
I2C1	SCL1	P0.6	P0.0	P1.1	P1.9	P3.0	P3.3	P3.6	P3.13		
	SDA1	P0.7	P0.1	P1.0	P1.8	P3.2	P3.4	P3.5	P3.12		
I2S	MCLK	P3.2	P0.12	P1.8	P3.7	P2.2	P2.6				
	BCLK	P3.3	P0.13	P1.9	P3.6	P2.10	P2.11				
	WS	P3.4	P0.14	P1.10	P2.1	P2.7	P2.9				
	DOUT	P3.1	P0.11	P1.7	P3.8	P2.8	P2.12				
	DIN	P3.0	P0.10	P1.6	P3.9	P2.0	P2.5				

CT16B0	CAP0	P0.2	P0.8	P1.0	P3.0	P3.2	P3.10	P2.0	P2.13		
	PWM0	P0.0	P1.1	P1.8	P1.12	P3.3	P3.11	P2.3	P2.15		
	PWM1	P0.1	P0.4	P0.10	P1.13	P3.4	P3.12	P2.2	P2.11		
	PWM2	P1.12	P0.9	P0.11	P1.6	P3.6	P3.15	P2.4	P2.10		
CT16B1	CAP0	P0.12	P0.7	P1.7	P1.11	P3.5	P3.13	P2.1	P2.9		
	PWM0	P0.10	P0.5	P1.9	P1.15	P3.7	P3.14	P2.0	P2.12		
	PWM1	P0.11	P0.8	P0.12	P1.3	P1.10	P3.9	P2.4	P2.8		
	PWM2	P1.9	P0.6	P0.15	P1.2	P1.14	P3.8	P2.3	P2.7		
CT16B2	CAP0	P1.8	P0.3	P0.13	P1.5	P3.6	P3.12	P2.2	P2.14		
	PWM0	P3.5	P0.2	P0.14	P1.4	P3.1	P3.10	P2.5	P2.9		
	PWM1	P1.4	P0.0	P0.9	P1.11	P3.5	P3.15	P2.1	P2.6		
	PWM2	P3.1	P0.1	P1.0	P1.12	P3.0	P3.11	P2.4	P2.10		
CT32B0	CAP0	P3.9	P0.0	P0.9	P1.1	P3.1	P3.3	P2.3	P2.15		
	PWM0	P1.15	P0.4	P0.11	P1.8	P1.14	P3.9	P2.3	P2.14		
	PWM1	P3.8	P0.8	P0.14	P1.5	P1.11	P3.14	P2.4	P2.13		
	PWM2	P1.14	P0.5	P0.9	P1.9	P3.7	P3.13	P2.0	P2.11		
	PWM3	P1.2	P0.3	P0.7	P0.15	P1.12	P3.4	P2.2	P2.12		
CT32B1	CAP0	P1.3	P0.2	P0.8	P0.15	P1.6	P3.8	P2.4	P2.10		
	PWM0	P1.13	P0.1	P0.9	P1.3	P3.2	P3.15	P2.6	P2.15		
	PWM1	P0.15	P0.4	P1.2	P1.10	P3.5	P3.10	P2.1	P2.8		
	PWM2	P1.6	P0.5	P0.8	P0.11	P3.12	P2.5	P2.12	P2.14		
	PWM3	P1.7	P0.6	P0.7	P1.2	P3.9	P3.11	P2.4	P2.13		
CT32B2	CAP0	P3.7	P0.9	P0.10	P1.4	P1.13	P3.14	P2.5	P2.12		
	PWM0	P0.13	P0.3	P0.8	P1.1	P1.7	P1.15	P2.11	P2.15		
	PWM1	P0.14	P0.2	P0.15	P1.5	P3.0	P3.7	P2.7	P2.13		
	PWM2	P0.3	P0.0	P0.9	P1.6	P3.1	P3.13	P3.15	P2.14		
	PWM3	P0.6	P1.0	P1.7	P3.10	P2.3	P2.8	P2.9	P2.15		

6.4 PFPA REGISTERS

Base Address: 0x4004 2000

6.4.1 PFPA for UART register (PFPA_UART)

Address offset: 0x00

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:12	URXD1[3:0]	Pin to be assigned as URXD1. 0000: P1.0 0001: P0.7 0010: P0.12	R/W	0000b

		0011: P1.5 0100: P1.13 0101: P1.15 0110: P3.6 0111: P3.12 Other: Reserved		
11:8	UTXD1[3:0]	Pin to be assigned as UTXD1. 0000: P1.1 0001: P0.6 0010: P0.13 0011: P1.4 0100: P1.14 0101: P3.8 0110: P3.10 0111: P3.13 Other: Reserved	R/W	0000b
7:4	URXD0[3:0]	Pin to be assigned as URXD0. 0000: P0.0 0001: P0.4 0010: P1.3 0011: P3.0 0100: P3.3 0101: P3.5 0110: P3.11 0111: P3.14 Other: Reserved	R/W	0000b
3:0	UTXD0[3:0]	Pin to be assigned as UTXD0. 0000: P0.1 0001: P0.5 0010: P1.2 0011: P3.1 0100: P3.2 0101: P3.4 0110: P3.10 0111: P3.15 Other: Reserved	R/W	0000b

6.4.2 PFPA for I2C register (PFPA_I2C)

Address offset: 0x04

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:12	SCL1[3:0]	Pin to be assigned as SCL1. 0000: P0.6 0001: P0.0 0010: P1.1 0011: P1.9 0100: P3.0 0101: P3.3 0110: P3.6 0111: P3.13 Other: Reserved	R/W	0000b
11:8	SDA1[3:0]	Pin to be assigned as SDA1. 0000: P0.7 0001: P0.1 0010: P1.0 0011: P1.8 0100: P3.2 0101: P3.4 0110: P3.5 0111: P3.12 Other: Reserved	R/W	0000b

7:4	SCL0[3:0]	Pin to be assigned as SCL0. 0000: P1.5 0001: P0.2 0010: P0.15 0011: P1.3 0100: P1.14 0101: P3.9 0110: P3.11 0111: P3.14 Other: Reserved	R/W	0000b
3:0	SDA0[3:0]	Pin to be assigned as SDA0. 0000: P1.4 0001: P0.3 0010: P0.10 0011: P1.2 0100: P1.13 0101: P3.7 0110: P3.13 0111: P3.15 Other: Reserved	R/W	0000b

6.4.3 PFPA for SSP register (PFPA_SSP)

Address offset: 0x08

Bit	Name	Description	Attribute	Reset
31:28	SEL1[3:0]	Pin to be assigned as SEL1. 0000: P3.6 0001: P0.2 0010: P0.13 0011: P1.0 0100: P1.4 0101: P1.7 0110: P1.14 0111: P3.11 1000: P2.1 1001: P2.14 Other: Reserved	R/W	0000b
27:24	SCK1[3:0]	Pin to be assigned as SCK1. 0000: P3.7 0001: P0.7 0010: P0.14 0011: P1.1 0100: P1.11 0101: P1.15 0110: P3.3 0111: P3.14 1000: P2.2 1001: P2.13 Other: Reserved	R/W	0000b
23:20	MOSI1[3:0]	Pin to be assigned as MOSI1. 0000: P3.8 0001: P0.5 0010: P0.12 0011: P1.2 0100: P1.6 0101: P1.13 0110: P3.2 0111: P3.13 1000: P2.0 1001: P2.15 Other: Reserved	R/W	0000b
19:16	MISO1[3:0]	Pin to be assigned as MISO1. 0000: P3.9	R/W	0000b

		0001: P0.4 0010: P0.10 0011: P1.3 0100: P1.10 0101: P3.0 0110: P3.4 0111: P3.12 1000: P2.1 1001: P2.12 Other: Reserved		
15:12	SEL0[3:0]	Pin to be assigned as SEL0. 0000: P0.5 0001: P0.10 0010: P0.12 0011: P1.5 0100: P1.11 0101: P3.1 0110: P3.5 0111: P3.10 1000: P2.0 1001: P2.15 Other: Reserved	R/W	0000b
11:8	SCK0[3:0]	Pin to be assigned as SCK0. 0000: P0.4 0001: P0.11 0010: P0.13 0011: P1.4 0100: P1.12 0101: P3.2 0110: P3.6 0111: P3.11 1000: P2.3 1001: P2.14 Other: Reserved	R/W	0000b
7:4	MOSI0[3:0]	Pin to be assigned as MOSI0. 0000: P0.3 0001: P0.1 0010: P0.7 0011: P0.14 0100: P1.1 0101: P1.15 0110: P3.4 0111: P3.14 1000: P2.2 1001: P2.13 Other: Reserved	R/W	0000b
3:0	MISO0[3:0]	Pin to be assigned as MISO0. 0000: P0.2 0001: P0.0 0010: P0.6 0011: P0.15 0100: P1.0 0101: P1.14 0110: P3.3 0111: P3.15 1000: P2.1 1001: P2.12 Other: Reserved	R/W	0000b

6.4.4 PFPA for I2S register (PFPA_I2S)

Address offset: 0x0C

Bit	Name	Description	Attribute	Reset

31:20	Reserved		R	0
19:16	DIN[3:0]	Pin to be assigned as I2SDIN. 0000: P3.0 0001: P0.10 0010: P1.6 0011: P3.9 0100: P2.0 0101: P2.5 Other: Reserved	R/W	0000b
15:12	DOUT[3:0]	Pin to be assigned as I2SDOUT. 0000: P3.1 0001: P0.11 0010: P1.7 0011: P3.8 0100: P2.8 0101: P2.12 Other: Reserved	R/W	0000b
11:8	WS[3:0]	Pin to be assigned as I2SWS. 0000: P3.4 0001: P0.14 0010: P1.10 0011: P2.1 0100: P2.7 0101: P2.9 Other: Reserved	R/W	0000b
7:4	BCLK[3:0]	Pin to be assigned as I2SBCLK. 0000: P3.3 0001: P0.13 0010: P1.9 0011: P3.6 0100: P2.10 0101: P2.11 Other: Reserved	R/W	0000b
3:0	MCLK[3:0]	Pin to be assigned as I2SMCLK. 0000: P3.2 0001: P0.12 0010: P1.8 0011: P3.7 0100: P2.2 0101: P2.6 Other: Reserved	R/W	0000b

6.4.5 PFPA for CT16B0 register (PFPA_CT16B0)

Address offset: 0x10

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:12	PWM2[3:0]	Pin to be assigned as CT16B0_PWM2. 0000: P1.12 0001: P0.9 0010: P0.11 0011: P1.6 0100: P3.6 0101: P3.15 0110: P2.4 0111: P2.10 Other: Reserved	R/W	0000b
11:8	PWM1[3:0]	Pin to be assigned as CT16B0_PWM1. 0000: P0.1 0001: P0.4 0010: P0.10	R/W	0000b

		0011: P1.13 0100: P3.4 0101: P3.12 0110: P2.2 0111: P2.11 Other: Reserved		
7:4	PWM0[3:0]	Pin to be assigned as CT16B0_PWM0. 0000: P0.0 0001: P1.1 0010: P1.8 0011: P1.12 0100: P3.3 0101: P3.11 0110: P2.3 0111: P2.15 Other: Reserved	R/W	0000b
3:0	CAP0[3:0]	Pin to be assigned as CT16B0_CAP0. 0000: P0.2 0001: P0.8 0010: P1.0 0011: P3.0 0100: P3.2 0101: P3.10 0110: P2.0 0111: P2.13 Other: Reserved	R/W	0000b

6.4.6 PFPA for CT16B1 register (PFPA_CT16B1)

Address offset: 0x14

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:12	PWM2[3:0]	Pin to be assigned as CT16B1_PWM2. 0000: P1.9 0001: P0.6 0010: P0.15 0011: P1.2 0100: P1.14 0101: P3.8 0110: P2.3 0111: P2.7 Other: Reserved	R/W	0000b
11:8	PWM1[3:0]	Pin to be assigned as CT16B1_PWM1. 0000: P0.11 0001: P0.8 0010: P0.12 0011: P1.3 0100: P1.10 0101: P3.9 0110: P2.4 0111: P2.8 Other: Reserved	R/W	0000b
7:4	PWM0[3:0]	Pin to be assigned as CT16B1_PWM0. 0000: P0.10 0001: P0.5 0010: P1.9 0011: P1.15 0100: P3.7 0101: P3.14 0110: P2.0 0111: P2.12 Other: Reserved	R/W	0000b

3:0	CAP0[3:0]	Pin to be assigned as CT16B1_CAP0. 0000: P0.12 0001: P0.7 0010: P1.7 0011: P1.11 0100: P3.5 0101: P3.13 0110: P2.1 0111: P2.9 Other: Reserved	R/W	0000b

6.4.7 PFPA for CT16B2 register (PFPA_CT16B2)

Address offset: 0x18

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:12	PWM2[3:0]	Pin to be assigned as CT16B2_PWM2. 0000: P3.1 0001: P0.1 0010: P1.0 0011: P1.12 0100: P3.0 0101: P3.11 0110: P2.4 0111: P2.10 Other: Reserved	R/W	0000b
11:8	PWM1[3:0]	Pin to be assigned as CT16B2_PWM1. 0000: P1.4 0001: P0.0 0010: P0.9 0011: P1.11 0100: P3.5 0101: P3.15 0110: P2.1 0111: P2.6 Other: Reserved	R/W	0000b
7:4	PWM0[3:0]	Pin to be assigned as CT16B2_PWM0. 0000: P3.5 0001: P0.2 0010: P0.14 0011: P1.4 0100: P3.1 0101: P3.10 0110: P2.5 0111: P2.9 Other: Reserved	R/W	0000b
3:0	CAP0[3:0]	Pin to be assigned as CT16B2_CAP0. 0000: P1.8 0001: P0.3 0010: P0.13 0011: P1.5 0100: P3.6 0101: P3.12 0110: P2.2 0111: P2.14 Other: Reserved	R/W	0000b

6.4.8 PFPA for CT32B0 register (PFPA_CT32B0)

Address offset: 0x20

Bit	Name	Description	Attribute	Reset
31:20	Reserved		R	0
19:16	PWM3[3:0]	Pin to be assigned as CT32B0_PWM3. 0000: P1.2 0001: P0.3 0010: P0.7 0011: P0.15 0100: P1.12 0101: P3.4 0110: P2.2 0111: P2.12 Other: Reserved	R/W	0000b
15:12	PWM2[3:0]	Pin to be assigned as CT32B0_PWM2. 0000: P1.14 0001: P0.5 0010: P0.9 0011: P1.9 0100: P3.7 0101: P3.13 0110: P2.0 0111: P2.11 Other: Reserved	R/W	0000b
11:8	PWM1[3:0]	Pin to be assigned as CT32B0_PWM1. 0000: P3.8 0001: P0.8 0010: P0.14 0011: P1.5 0100: P1.11 0101: P3.14 0110: P2.4 0111: P2.13 Other: Reserved	R/W	0000b
7:4	PWM0[3:0]	Pin to be assigned as CT32B0_PWM0. 0000: P1.15 0001: P0.4 0010: P0.11 0011: P1.8 0100: P1.14 0101: P3.9 0110: P2.3 0111: P2.14 Other: Reserved	R/W	0000b
3:0	CAP0[3:0]	Pin to be assigned as CT32B0_CAP0. 0000: P3.9 0001: P0.0 0010: P0.9 0011: P1.1 0100: P3.1 0101: P3.3 0110: P2.3 0111: P2.15 Other: Reserved	R/W	0000b

6.4.9 PFPA for CT32B1 register (PFPA_CT32B1)

Address offset: 0x24

Bit	Name	Description	Attribute	Reset
31:20	Reserved		R	0
19:16	PWM3[3:0]	Pin to be assigned as CT32B1_PWM3. 0000: P1.7 0001: P0.6 0010: P0.7 0011: P1.2 0100: P3.9 0101: P3.11 0110: P2.4 0111: P2.13 Other: Reserved	R/W	0000b
15:12	PWM2[3:0]	Pin to be assigned as CT32B1_PWM2. 0000: P1.6 0001: P0.5 0010: P0.8 0011: P0.11 0100: P3.12 0101: P2.5 0110: P2.12 0111: P2.14 Other: Reserved	R/W	0000b
11:8	PWM1[3:0]	Pin to be assigned as CT32B1_PWM1. 0000: P0.15 0001: P0.4 0010: P1.2 0011: P1.10 0100: P3.5 0101: P3.10 0110: P2.1 0111: P2.8 Other: Reserved	R/W	0000b
7:4	PWM0[3:0]	Pin to be assigned as CT32B1_PWM0. 0000: P1.13 0001: P0.1 0010: P0.9 0011: P1.3 0100: P3.2 0101: P3.15 0110: P2.6 0111: P2.15 Other: Reserved	R/W	0000b
3:0	CAP0[3:0]	Pin to be assigned as CT32B1_CAP0. 0000: P1.3 0001: P0.2 0010: P0.8 0011: P0.15 0100: P1.6 0101: P3.8 0110: P2.4 0111: P2.10 Other: Reserved	R/W	0000b

6.4.10 PFPA for CT32B2 register (PFPA_CT32B2)

Address offset: 0x28

Bit	Name	Description	Attribute	Reset
31:20	Reserved		R	0
19:16	PWM3[3:0]	Pin to be assigned as CT32B2_PWM3. 0000: P0.6	R/W	0000b

		0001: P1.0 0010: P1.7 0011: P3.10 0100: P2.3 0101: P2.8 0110: P2.9 0111: P2.15 Other: Reserved		
15:12	PWM2[3:0]	Pin to be assigned as CT32B2_PWM2. 0000: P0.3 0001: P0.0 0010: P0.9 0011: P1.6 0100: P3.1 0101: P3.13 0110: P3.15 0111: P2.14 Other: Reserved	R/W	0000b
11:8	PWM1[3:0]	Pin to be assigned as CT32B2_PWM1. 0000: P0.14 0001: P0.2 0010: P0.15 0011: P1.5 0100: P3.0 0101: P3.7 0110: P2.7 0111: P2.13 Other: Reserved	R/W	0000b
7:4	PWM0[3:0]	Pin to be assigned as CT32B2_PWM0. 0000: P0.13 0001: P0.3 0010: P0.8 0011: P1.1 0100: P1.7 0101: P1.15 0110: P2.11 0111: P2.15 Other: Reserved	R/W	0000b
3:0	CAP0[3:0]	Pin to be assigned as CT32B2_CAP0. 0000: P3.7 0001: P0.9 0010: P0.10 0011: P1.4 0100: P1.13 0101: P3.14 0110: P2.5 0111: P2.12 Other: Reserved	R/W	0000b

7 14+1 CHANNEL ANALOG TO DIGITAL CONVERTOR (ADC)

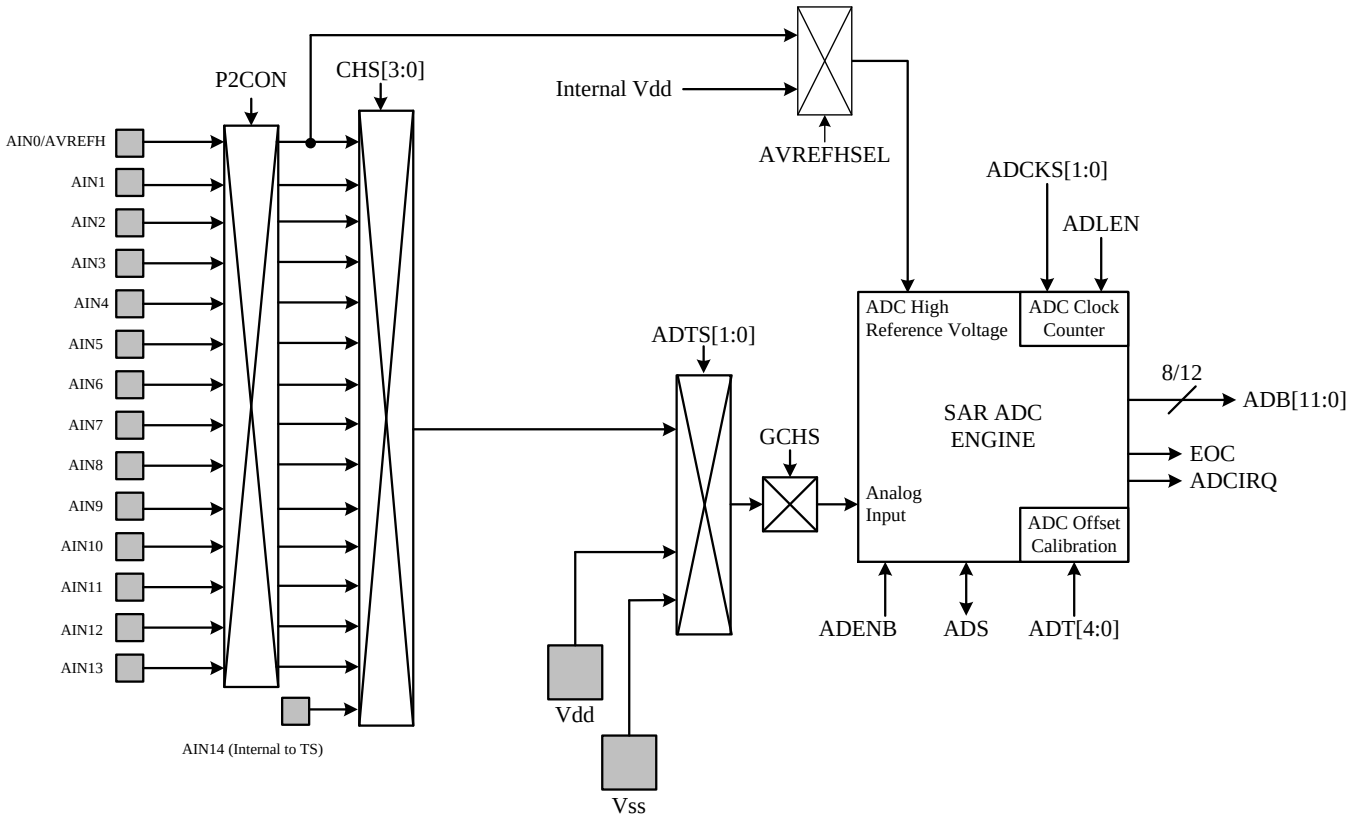
7.1 OVERVIEW

This analog to digital converter has 14 external channels and 1 internal channel to Temperature sensor, with up to 4096-step resolution to transfer analog signal into 12-bits digital data. The sequence of ADC operation is to select input source (AIN0 ~ AIN13) at first, then set GCHS and ADS bit to “1” to start conversion. When the conversion is complete, the ADC circuit will set EOC bit to “1” and final value output in ADB register.

Use CHS[3:0] to select AIN pin and GCHS enables global ADC channel, the analog signal inputs to ADC engine.

The ADC reference high voltage includes two source, one is internal Vdd (AVREFHSEL=0), and the other one is external reference voltage input pin from P2.0 pin (AVREFHSEL=1).

The ADC resolution can be selected 8-bit or 12-bit through ADLEN bit in ADR register. The ADC converting rate can be selected by ADCKS[1:0] bits. The two parameters decide ADC converting time.



✷ ***Note:***

1. ***For 8-bit resolution the conversion time is 12 steps. For 12-bit resolution the conversion time is 16 steps***
2. ***ADC_PCLK shall be less than 16MHz.***

3. *The analog input level must be between the AVREFH and AVREFL.*
4. *The AVREFH level must be between the AVDD and AVREFL + 2.0V.*
5. *ADC programming notice*
   - *Disable ADC (set ADENB = "0") before enter low-power (Sleep/Deep-sleep/Deep power-power-down) mode to save power consumption.*
   - *Delay 100us after enable ADC (set ADENB = "1") to wait ADC circuit ready for conversion.*

7.2 ADC CONVERTING TIME

The ADC converting time is from ADS=1 (Start to ADC convert) to EOC=1 (End of ADC convert). The converting time duration is depend on ADC resolution and ADC clock rate.
ADC clock source is controlled by ADCKS[2:0] bits. The ADC converting time affects ADC performance. If input high rate analog signal, it is necessary to select a high ADC converting rate. If the ADC converting time is slower than analog signal variation rate, the ADC result would be error. So to select a correct ADC clock rate and ADC resolution to decide a right ADC converting rate is very important.

12-bit ADC conversion time = 1/(ADC clock /4)*16 sec

ADLEN	ADCKS [2:0]	ADC Clock	ADC_PCLK = 4 MHz		ADC_PCLK = 16 MHz	
			ADC Conversion Time (us)	ADC Conversion Rate (KHz)	ADC Conversion Time (us)	ADC Conversion Rate (KHz)
1	000	ADC_PCLK	16	62.5	4	250
	001	ADC_PCLK/2	32	31.25	8	125
	010	ADC_PCLK/4	64	15.625	16	62.5
	011	ADC_PCLK/8	128	7.813	32	31.25
	100	ADC_PCLK/16	256	3.906	64	15.625
	101	ADC_PCLK/32	512	1.953	128	7.813

8-bit ADC conversion time = 1/(ADC clock /4)*12 sec

ADLEN	ADCKS [2:0]	ADC Clock	ADC_PCLK = 4 MHz		ADC_PCLK = 16 MHz	
			ADC Conversion Time (us)	ADC Conversion Rate (KHz)	ADC Conversion Time (us)	ADC Conversion Rate (KHz)
0	000	ADC_PCLK	12	83.333	3	333.333
	001	ADC_PCLK/2	24	41.667	6	166.667
	010	ADC_PCLK/4	48	20.83	12	83.333
	011	ADC_PCLK/8	96	10.416	24	41.667
	100	ADC_PCLK/16	192	5.208	48	20.83
	101	ADC_PCLK/32	384	2.604	96	10.416

7.3 ADC CONTROL NOTICE

7.3.1 ADC SIGNAL

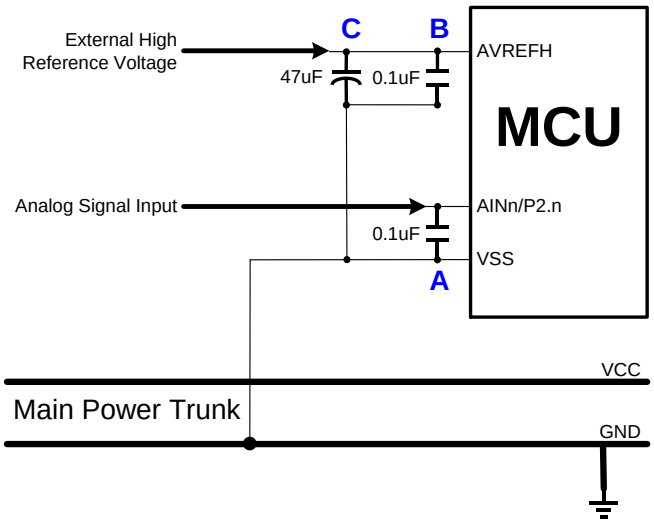
The ADC high reference voltage is internal Vdd or external voltage source. The ADC low reference voltage is ground.
The ADC input signal voltage range must be from high reference voltage to low reference voltage.
The external high reference voltage from P2.0 must be higher than "Low reference voltage + 2V". The low reference voltage is ground. So the external reference voltage range must be under 2V~Vdd.

7.3.2 ADC PROGRAM

The first step of ADC execution is to setup ADC configuration. The ADC program setup sequence and notices are as following.

- **Step 1:** Enable ADC. ADENB is ADC control bit to control. ADENB = 1 is to enable ADC. ADENB = 0 is to disable ADC. ***When ADENB is enabled, the system must be delay 100us to be the ADC warm-up time by program, and then set ADS to do ADC converting. The 100us delay time is necessary after ADENB setting (not ADS setting), or the ADC converting result would be error.*** Normally, the ADENB is set one time when the system under normal run condition, and do the delay time only one time.
- **Step 2:** If the ADC high reference voltage is from external voltage source, set the AVREFHSEL = 1. The ADC external high reference voltage inputs from P2.0 pin. ***It is necessary to set P2.0 as input mode without pull-up resistor.***
- **Step 3:** Select the ADC input pin by CHS[3:0], and enable ADC global input. **When one AIN pin is selected to be analog signal input pin, it is necessary to setup the pin as input mode and disable the pull-up resistor by program.**
- **Step 4:** Start to execute ADC conversion by setting ADS = 1.
- **Step 5:** Wait the end of ADC converting through checking EOC = 1 or ADCIF = 1. If ADC interrupt function is enabled, the program executes ADC interrupt service when ADC interrupt occurrence. ***ADS is cleared when the end of ADC converting automatically. EOC bit indicates ADC processing status immediately and is cleared when ADS = 1. Users needn't to clear it by program.***

7.4 ADC CIRCUIT



The analog signal is inputted to ADC input pin "AINn/P2.n". The ADC input signal must be through a 0.1uF capacitor "A". The 0.1uF capacitor is set between ADC input pin and VSS pin, and must be on the side of the ADC input pin as possible. Don't connect the capacitor's ground pin to ground plain directly, and must be through VSS pin. The capacitor can reduce the power noise effective coupled with the analog signal.

If the ADC high reference voltage is from external voltage source, the external high reference is connected to AVREFH pin (P2.0). The external high reference source must be through a 47uF ”C” capacitor first, and then 0.1uF capacitor “B”. These capacitors are set between AVREFH pin and VSS pin, and must be on the side of the AVREFH pin as possible. Don’t connect the capacitor’s ground pin to ground plain directly, and must be through VSS pin.

7.5 TEMPERATURE SENSOR (TS)

In applications, sensor characteristic might change in different temperature also. To get the temperature information, a temperature senor (TS) is built-in for temperature measurement, and is internally connected to the AIN14 input channel which is used to convert the sensor output voltage into a digital value.

If TSENB = 1, the temperature sensor is enabled. When not in use, this sensor can be put in power down mode if TSENB = 0.

✸ ***Note: The Temperature Sensor was just a reference data not real air temperature. For precision application, please use external thermistor sensor.***

In 25C, V(TS) will be about 1V typically, and if the temperature rises 10℃, V(TS) will increase about 35mV (V_{TS} =1.035V); if the temperature drops 10℃ , V(TS) will decrease about 35mV (V_{TS} =0.965V).

Example:

Temperature	V(TS)	AVrefH	ADC output (12-Bit)
15℃	0.965	3.0V	1250
25℃	1.000V	3.0V	1306
35℃	1.035V	3.0V	1352

By ADC output of V(TS), can get temperature information and compensation the system.

✸ ***Note 1: The V(TS) voltage and temperature curve of each chip might different. Calibration in room temperature is necessary when temperature sensor is used.***

✸ ***Note 2: 3.53mV/℃ is only the typical temperature parameter, every single chip is different to each other.***

7.6 ADC REGISTERS

Base Address: 0x4002 6000

7.6.1 ADC Management register (ADC_ADM)

Address Offset: 0x00

- ***Note 1: When ADC is enabled (ADENB=1) and global channel is enabled (GCHS=1), the ADC shared pins transfers to ADC purpose and disable GPIO function and disable pull-up/pull-down resistor by HW automatically, the P2.n/AINn's digital I/O function including pull-up is isolated.***
- ***Note 2: When ADC is disabled (ADENB=0) or global channel is disabled (GCHS=0) , the ADC pins returns to last GPIO status.***

Bit	Name	Description	Attribute	Reset
31:18	Reserved		R	0
17	TSENB	Temperature sensor enable bit 0: Disable 1: Enable	R/W	0
16:13	Reserved		R	0
12	AVREFHSEL	ADC high reference voltage source select bit 0: Internal VDD. (P2.0 is GPIO or AIN0 pin) 1: Enable external reference voltage from P2.0	R/W	0
11	ADENB	ADC Enable bit 0: Disable 1: Enable	R/W	0
10:8	ADCKS[2:0]	ADC Clock source divider 000: ADC_PCLK / 1 001: ADC_PCLK / 2 010: ADC_PCLK / 4 011: ADC_PCLK / 8 101: ADC_PCLK / 16 110: ADC_PCLK / 32 Other: Reversed	R/W	0
7	ADLEN	ADC resolution control bit. 0: 8-bit ADC. 1:12-bit ADC.	R/W	0
6	ADS	ADC start control bit. 0: ADC converting stops. 1: Start to execute ADC converting. ADS is cleared when the end of ADC converting automatically.	R/W	0
5	EOC	ADC status bit Indicates ADC processing status immediately and is cleared when ADS = 1. 0: ADC progressing. 1: End of converting and reset ADS bit.	R/W	0
4	GCHS	ADC global channel select bit. 0: Disable AIN channel 1: Enable AIN channel	R/W	0
3:0	CHS[3:0]	ADC input channels select bit. 0000: AIN0 0001: AIN1 0010: AIN2 0011: AIN3 0100: AIN4 0101: AIN5 0110: AIN6 0111: AIN7	R/W	0

		1000: AIN8 1001: AIN9 1010: AIN10 1011: AIN11 1100: AIN12 1101: AIN13 1110: AIN14 (Temperature Sensor) Other: Reserved		

7.6.2 ADC Data register (ADC_ADB)

Address Offset: 0x04

ADB is ADC data buffer to store AD converter result.

✸ ***Note: The initial value of ADC buffer (ADB) after reset is unknown.***

Bit	Name	Description	Attribute	Reset
31:12	Reserved		R	0
11:0	ADB[11:0]	ADB11~ADB4 bits for 8-bit ADC ADB11~ADB0 bits for 12-bit ADC	R	0

The AIN's input voltage v.s. ADB's output data

AIN n	ADB11	ADB10	ADB9	ADB8	ADB7	ADB6	ADB5	ADB4	ADB3	ADB2	ADB1	ADB0
0/4096*VREFH	0	0	0	0	0	0	0	0	0	0	0	0
1/4096*VREFH	0	0	0	0	0	0	0	0	0	0	0	1
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
4094/4096*VREFH	1	1	1	1	1	1	1	1	1	1	1	0
4095/4096*VREFH	1	1	1	1	1	1	1	1	1	1	1	1

For different applications, users maybe need more than 8-bit resolution but less than 12-bit ADC converter. First, the AD resolution must be set 12-bit mode and then to execute ADC converter routine. Then delete the LSB of ADC data and get the new resolution result. The table is as following.

	ADB11	ADB10	ADB9	ADB8	ADB7	ADB6	ADB5	ADB4	ADB3	ADB2	ADB1	ADB0
8-bit	O	O	O	O	O	O	O	O	X	X	X	X
9-bit	O	O	O	O	O	O	O	O	O	X	X	X
10-bit	O	O	O	O	O	O	O	O	O	O	X	X
11-bit	O	O	O	O	O	O	O	O	O	O	O	X
12-bit.	O	O	O	O	O	O	O	O	O	O	O	O
O = Selected, X = Delete												

7.6.3 Port 2 Control register (ADC_P2CON)

Address Offset: 0x08

The Port 2 is shared with ADC input function. Only one pin of port 2 can be configured as ADC input in the same time by ADM register. The other pins of port 2 are digital I/O pins.
Connect an analog signal to COMS digital input pin, especially, the analog signal level is about 1/2 VDD will cause extra current leakage. In the power down mode, the above leakage current will be a big problem. Unfortunately, if users connect more than one analog input signal to port 2 will encounter above current leakage situation.
P2CON is Port2 Configuration status register. When ADC is enabled, HW will configure P2CON [15:0] to make related port 2 pin as pure analog input pin to avoid current leakage.

Bit	Name	Description	Attribute	Reset

31:16	Reserved		R	0
15:0	P2CON[15:0]	P2.x configuration control bits. (x=0 to 15) 0: P2.x can be an analog input (ADC input) or digital I/O pins. 1: P2.x is pure analog input, can't be a digital I/O pin.	R	0

7.6.4 ADC Interrupt Enable register (ADC_IE)

Address offset: 0x0C

This register allows control over which A/D channels generate an interrupt when a conversion is complete. For example, it may be desirable to use some A/D channels to monitor sensors by continuously performing conversions on them. The most recent results are read by the application program whenever they are needed. In this case, an interrupt is not desirable at the end of each conversion for some A/D channels.

Bit	Name	Description	Attribute	Reset
31:15	Reserved		R	0
14:0	IE[14:0]	These bits allow control over which A/D channels generate interrupts for conversion completion. When bit x is one, completion of a conversion on AIN x will generate an interrupt.	R/W	0

7.6.5 ADC Raw Interrupt Status register (ADC_RIS)

Address offset: 0x10

Bit	Name	Description	Attribute	Reset
31:15	Reserved		R	0
14:0	IF[14:0]	ADC raw interrupt flag. (x = 0 to 14). 0: Read→No interrupt on AINx Write→Write "0" to the corresponding bit will clear the bit and reset the Interrupt if the corresponding IE bit is set. 1: Interrupt requirements met on AINx ADC conversion.	R/W	0

8 16-BIT TIMER WITH CAPTURE FUNCTION

8.1 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 three match registers can be used to provide a single-edge controlled PWM output on the match output pins.

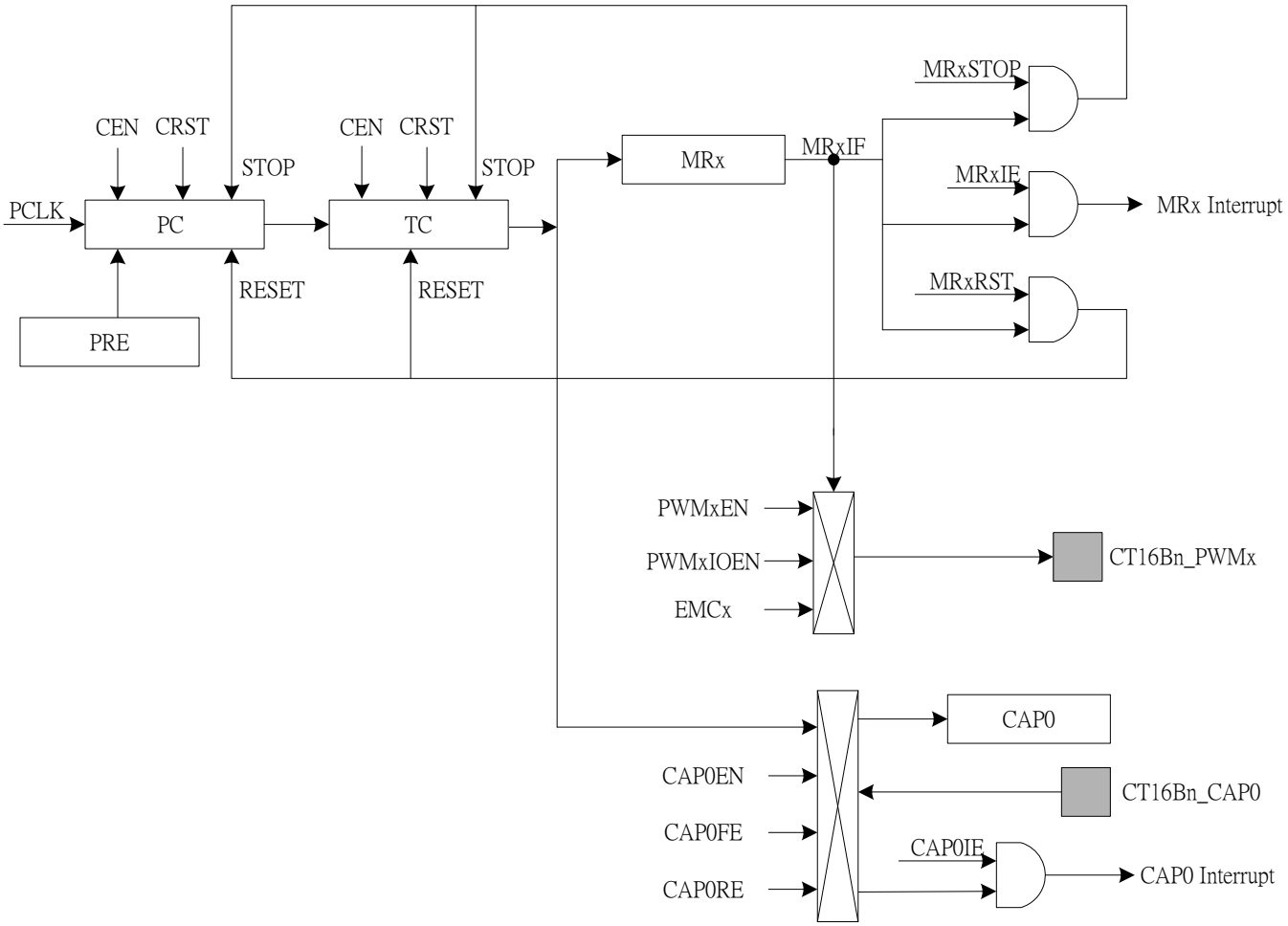
8.2 FEATURES

- Three 16-bit counter/timers with a programmable 16-bit prescaler.
- Counter or timer operation
- Three 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 prescaler 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.
  - Configured as PWM allowing to use up to three match outputs as single edge controlled PWM outputs.
- For each timer, up to three 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.

8.3 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.	

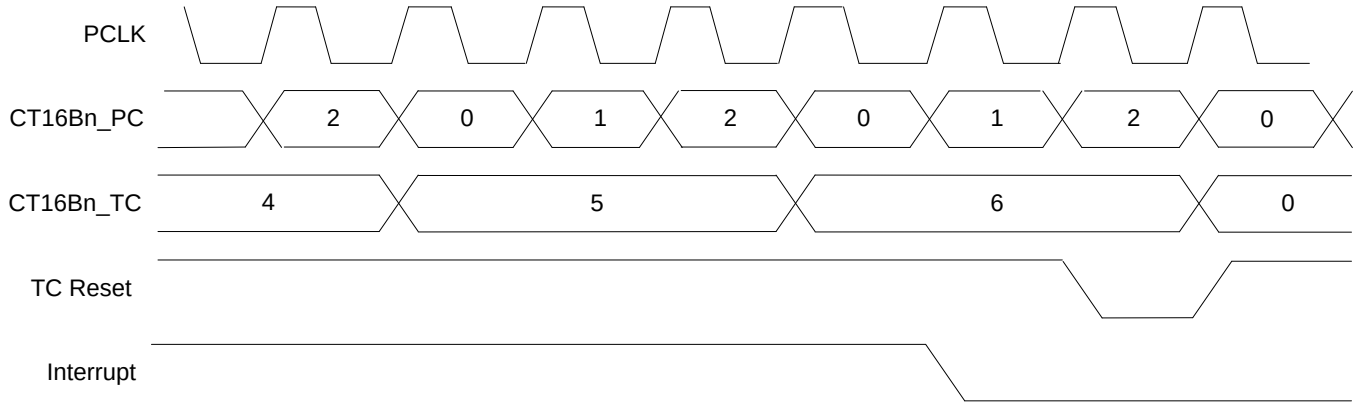
8.4 BLOCK DIAGRAM



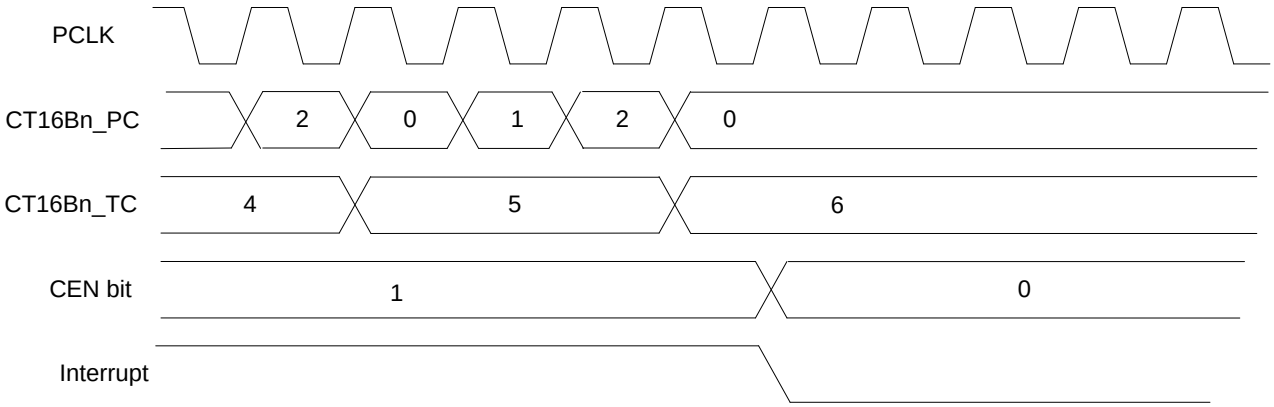
8.5 TIMER OPERATION

8.5.1 Edge-aligned Up-counting Mode

The following figure shows a timer configured to reset the count and generate an interrupt on match in Edge-aligned up-counting mode. 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. 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.



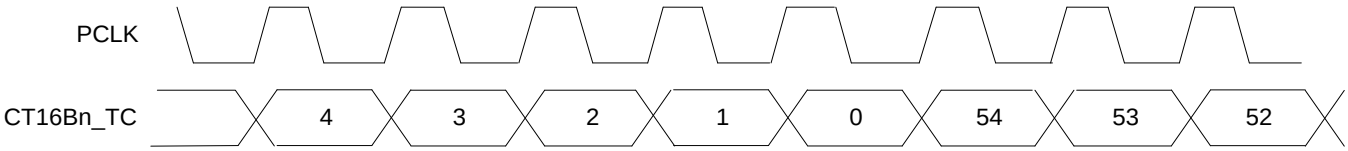
The following figure shows a timer configured to stop and generate an interrupt on match in Edge-aligned up-counting mode. The CT16Bn_PRE register is set to 2, and the CT16Bn_MRx register is set to 6. In the next clock after the timer reaches the match value, the CEN bit in CT16Bn_TMRCTRL register is cleared, and the interrupt indicating that a match occurred is generated.



8.5.2 Edge-aligned Down-counting Mode

The timer count TC[15:0] will be reset to the value of CT16Bn_MR3 after resetting counter or TC reaches 0. Besides, TC is blocked while the value of CT16Bn_MR3 is zero.

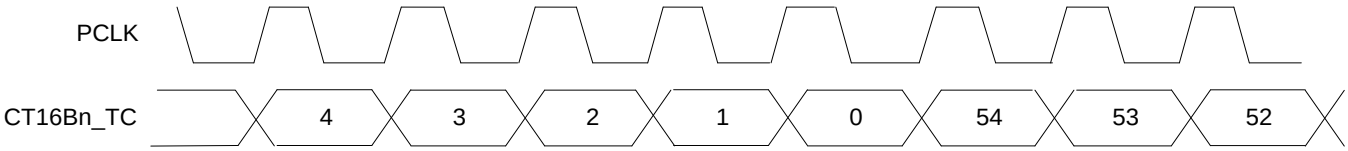
The following figure shows a timer configured to reset the count in Edge-aligned down-counting mode. The CT16Bn_PRE register is set to 0, and the CT16Bn_MR3 register is set to 54. After TC reaches 0, the timer count is reset and loaded from the value of CT16Bn_MR3.



8.5.3 Center-aligned Counting Mode

In Center-aligned counting mode, TC counts up from 0 to the value of CT16Bn_MR3, and then counts down to 0 alternatively. Besides, TC is blocked while the value of CT16Bn_MR3 is zero.

The following figure shows a timer in Center-aligned counting mode. The CT16Bn_PRE register is set to 0, and the CT16Bn_MR3 register is set to 5.



8.6 PWM

8.6.1 PWM Mode 1

- PWMn is 0 when TC<MRn during Up-counting period
- PWMn is 0 when TC≤MRn during Down-counting period

Take Edge-aligned Up-counting Mode as example,

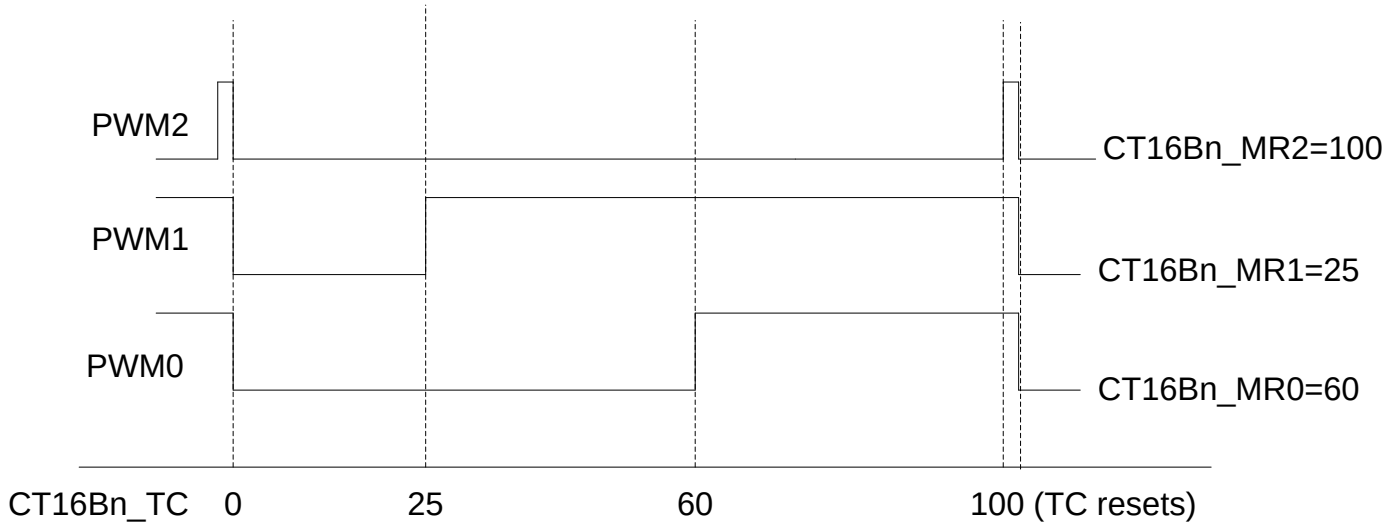
1. All single edge controlled PWM outputs go LOW at the beginning of each PWM cycle (timer is set to zero) unless their match value in CT16Bn_MR0~3 registers is equal to zero.

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.

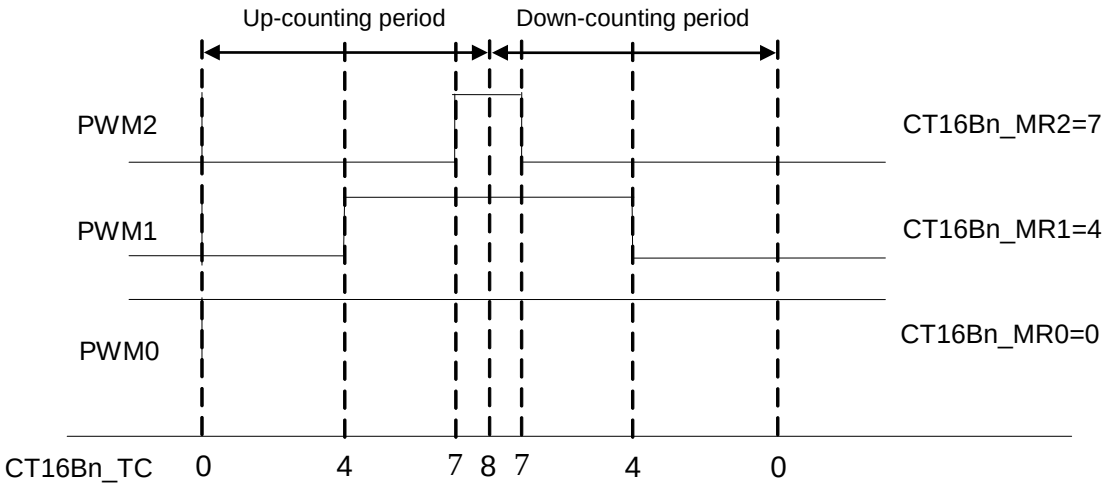
5. If a match register is set to zero, then the PWM output will go to HIGH the first time the timer goes back to zero and will stay HIGH continuously.



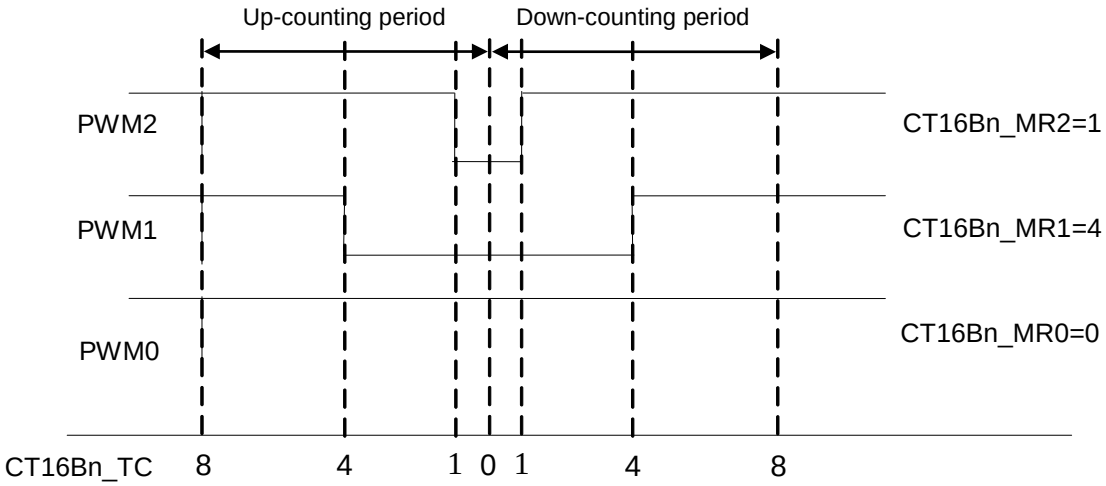
✷ ***Note: When the match outputs are selected to perform as PWM outputs, the timer reset (MRnRST) and timer stop (MRnSTOP) bits in CT16Bn_MCTRL register must be set to zero except for the match register setting the PWM cycle length. For this register, set the MRnR bit to one to enable the timer reset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

The following figure shows the PWM mode 1 wave form in Center-aligned counting mode.

Case1: The CT16Bn_PRE register is set to 0, the CT16Bn_MR3 register is set to 8, the CT16Bn_MR2 register is set to 7, the CT16Bn_MR1 register is set to 4, and the CT16Bn_MR0 register is set to 0.



Case 2: The CT16Bn_PRE register is set to 0, the CT16Bn_MR3 register is set to 8, the CT16Bn_MR2 register is set to 1, the CT16Bn_MR1 register is set to 4, and the CT16Bn_MR0 register is set to 0.



8.6.2 PWM Mode 2

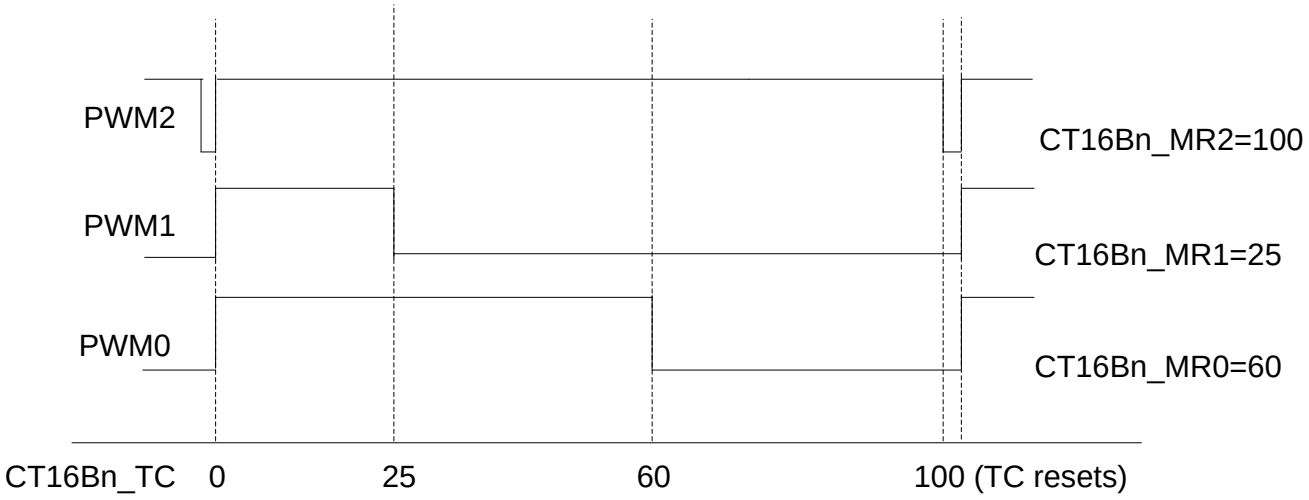
- PWMn is 1 when TC<MRn during Up-counting period
- PWMn is 1 when TC≤MRn during Down-counting period
- Not support in Center-aligned counting mode

Take Edge-aligned up-counting Mode as example,

1. All single edge controlled PWM outputs go HIGH 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 LOW when its match value is reached. If no match occurs, the PWM output remains continuously HIGH.
3. If a match value larger than the PWM cycle length is written to the CT16Bn_MR0~3 registers, and the PWM signal is LOW already, then the PWM signal will go HIGH 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 HIGH on the next clock tick. Therefore, the PWM output will always consist of a one clock tick wide low 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 LOW the first time the timer goes back to zero and will stay LOW 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.***

8.7 CT16Bn REGISTERS

Base Address: 0x4000 0000 (CT16B0)
0x4000 2000 (CT16B1)
0x4000 4000 (CT16B2)

8.7.1 CT16Bn Timer Control register (CT16Bn_TMRCTRL) (n=0,1,2)

Address Offset: 0x00

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

Bit	Name	Description	Attribute	Reset
31:7	Reserved		R	0
6:4	CM[2:0]	Counting mode selection 000: Edge-aligned Up-counting mode (ST32F80A) 001: Edge-aligned Down-counting mode 010: Center-aligned mode 1. The match interrupt flag is set during the down-counting period 100: Center-aligned mode 2. The match interrupt flag is set during the up-counting period 110: Center-aligned mode 3. The match interrupt flag is set during both up-counting and down-counting period Other: Reserved	R/W	000b
3:2	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

8.7.2 CT16Bn Timer Counter register (CT16Bn_TC) (n=0,1,2)

Address Offset: 0x04

In Edge-aligned up-counting mode (CM[2:0]=000b), 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.

In Edge-aligned down-counting mode (CM[2:0]=001b) , the TC[15:0] should be reset to the value of CT16Bn_MR3 after resetting counter (SW set CRST to 1).

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

8.7.3 CT16Bn Prescale register (CT16Bn_PRE) (n=0,1, 2)

Address Offset: 0x08

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

8.7.4 CT16Bn Prescale Counter register (CT16Bn_PC) (n=0,1, 2)

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

8.7.5 CT16Bn Count Control register (CT16Bn_CNTCTRL) (n=0,1,2)

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

8.7.6 CT16Bn Match Control register (CT16Bn_MCTRL) (n=0,1,2)

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 based on CM[2:0] 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 based on CM[2:0] 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 based on CM[2:0] 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 based on CM[2:0] when MR0 matches the value in the TC. 0: Disable 1: Enable	R/W	0

8.7.7 CT16Bn Match register 0~3 (CT16Bn_MR0~3) (n=0,1,2)

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

8.7.8 CT16Bn Capture Control register (CT16Bn_CAPCTRL) (n=0,1,2)

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
31:4	Reserved		R	0
3	CAP0EN	Capture 0 function enable bit 0: Disable 1: Enable.	R/W	0
2	CAP0IE	Interrupt on CT16Bn_CAP0 event: a CAP0 load due to a CT16Bn_CAP0 event will generate an interrupt. 0: Disable 1: Enable	R/W	0
1	CAP0FE	Capture on CT16Bn_CAP0 falling edge: a sequence of 1 then 0 on CT16Bn_CAP0 will cause CAP0 to be loaded with the contents of TC. 0: Disable 1: Enable	R/W	0
0	CAP0RE	Capture on CT16Bn_CAP0 rising edge: a sequence of 0 then 1 on CT16Bn_CAP0 will cause CAP0 to be loaded with the contents of TC. 0: Disable 1: Enable	R/W	0

8.7.9 CT16Bn Capture 0 register (CT16Bn_CAP0) (n=0,1,2)

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

8.7.10 CT16Bn External Match register (CT16Bn_EM) (n=0,1,2)

Address Offset: 0x30

The External Match register provides both control and status of CT16Bn_PWM[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
31:10	Reserved		R	0
9:8	EMC2[1:0]	Determines the functionality of CT16Bn_PWM2. 00: Do Nothing. 01: CT16Bn_PWM2 pin is LOW 10: CT16Bn_PWM2 pin is HIGH 11: Toggle CT16Bn_PWM2 pin.	R/W	0
7:6	EMC1[1:0]	Determines the functionality of CT16Bn_PWM1. 00: Do Nothing. 01: CT16Bn_PWM1 pin is LOW 10: CT16Bn_PWM1 pin is HIGH. 11: Toggle CT16Bn_PWM1.	R/W	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	Reserved		R	0
2	EM2	When the TC and MR2 are equal, this bit will act according to EMC2 bits, and also drive the state of CT16Bn_PWM2 output.	R/W	0
1	EM1	When the TC and MR1 are equal, this bit will act according to EMC1 bits, and also drive the state of CT16Bn_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 CT16Bn_PWM0 output.	R/W	0

8.7.11 CT16Bn PWM Control register (CT16Bn_PWMCTRL) (n=0,1,2)

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 [2:0] 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
31:23	Reserved		R	0
22	PWM2IOEN	CT16Bn_PWM2/GPIO selection bit 0: CT16Bn_PWM2 pin act as GPIO 1: CT16Bn_PWM2 pin act as match output, and output signal depends on PWM2EN bit.	R/W	0
21	PWM1IOEN	CT16Bn_PWM1/GPIO selection bit 0: CT16Bn_PWM1 pin act as GPIO 1: CT16Bn_PWM1 pin act as match output, and output signal depends on PWM1EN bit.	R/W	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
19:10	Reserved		R	0
9:8	PWM2M0DE[1:0]	PWM2 output mode 00: PWM mode 1 01: PWM mode 2 10: PWM2 is forced to 0. 11: PWM2 is forced to 1.	R/W	0
7:6	PWM1M0DE[1:0]	PWM1 output mode 00: PWM mode 1 01: PWM mode 2 10: PWM1 is forced to 0. 11: PWM1 is forced to 1.	R/W	0
5:4	PWM0M0DE[1:0]	PWM0 output mode 00: PWM mode 1 01: PWM mode 2 10: PWM0 is forced to 0. 11: PWM0 is forced to 1.	R/W	0
3	Reserved		R	0
2	PWM2EN	PWM2 enable 0: CT16Bn_PWM2 is controlled by EM2. 1: PWM mode is enabled for CT16Bn_PWM2.	R/W	0
1	PWM1EN	PWM1 enable 0: CT16Bn_PWM1 is controlled by EM1. 1: PWM mode is enabled for CT16Bn_PWM1.	R/W	0
0	PWM0EN	PWM0 enable 0: CT16Bn_PWM0 is controlled by EM0. 1: PWM mode is enabled for CT16Bn_PWM0.	R/W	0

8.7.12 CT16Bn Timer Raw Interrupt Status register (CT16Bn_RIS) (n=0,1,2)

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

8.7.13 CT16Bn Timer Interrupt Clear register (CT16Bn_IC) (n=0,1,2)

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

9 32-BIT TIMER WITH CAPTURE FUNCTION

9.1 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 four match registers can be used to provide a single-edge controlled PWM output on the match output pins.

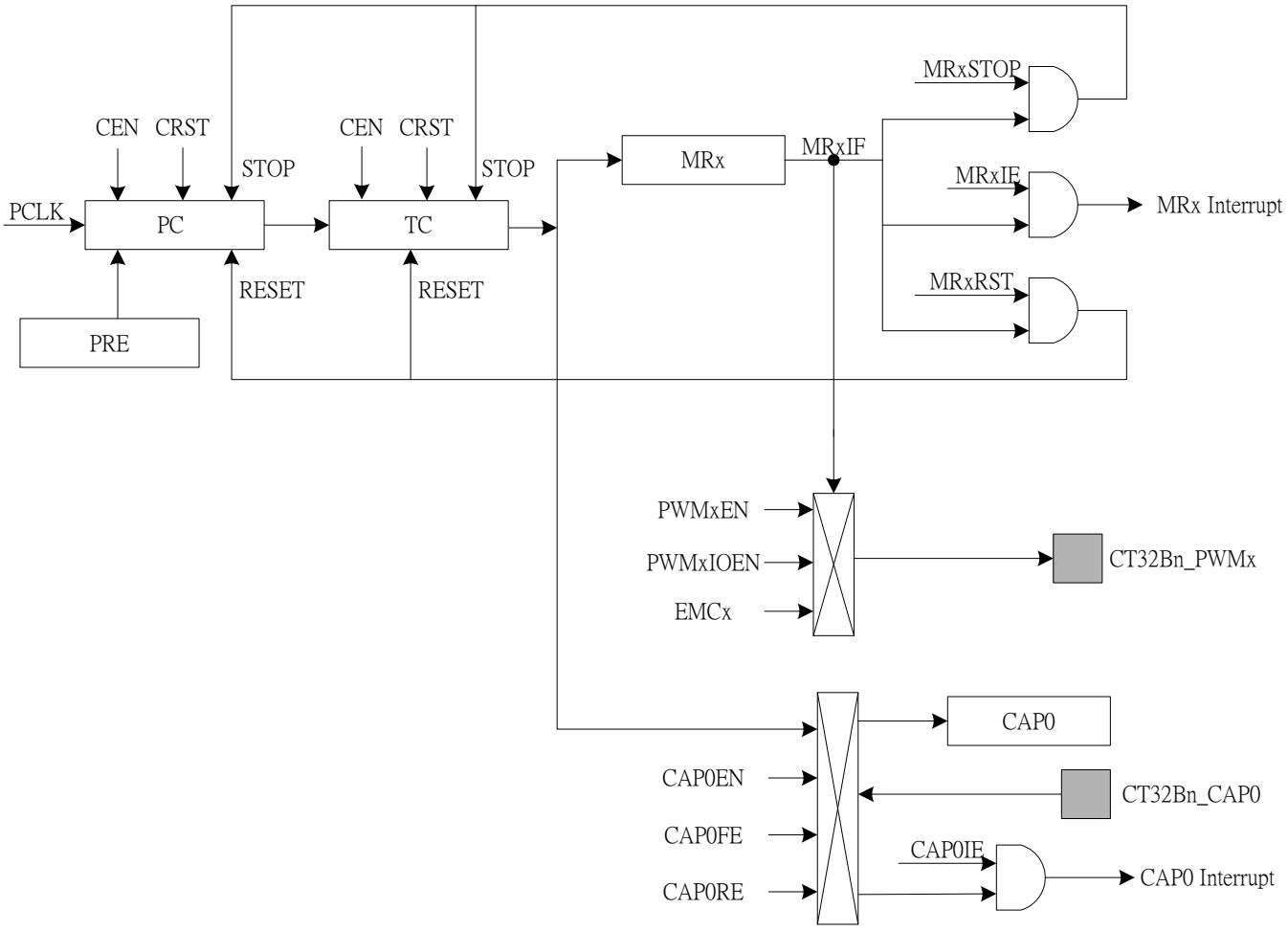
9.2 FEATURES

- Three 32-bit counter/timers with a programmable 32-bit prescaler.
- Counter or timer operation
- Three 32-bit capture channel 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 prescaler 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 to use up to four match outputs as single edge controlled PWM outputs.
- For each timer, up to four 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.

9.3 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.	

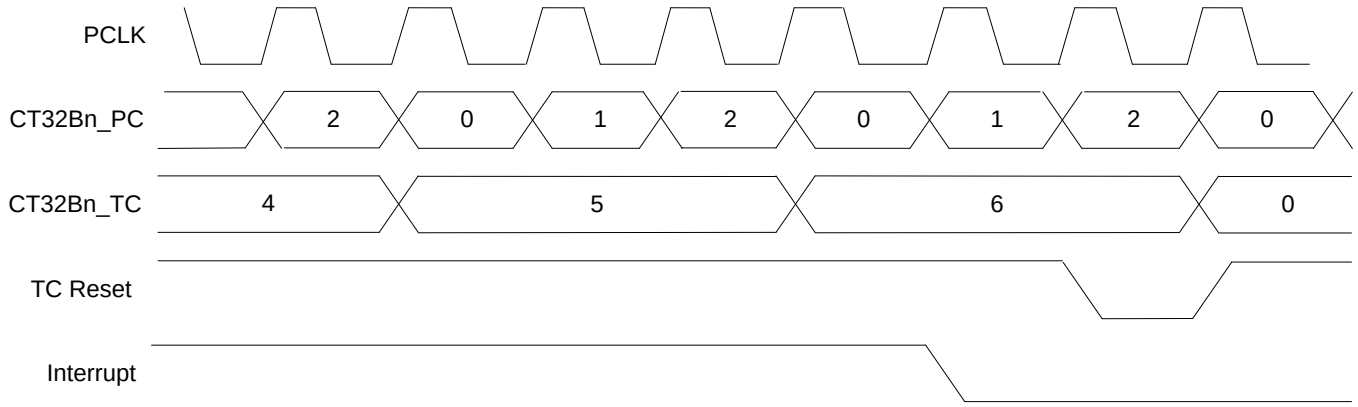
9.4 BLOCK DIAGRAM



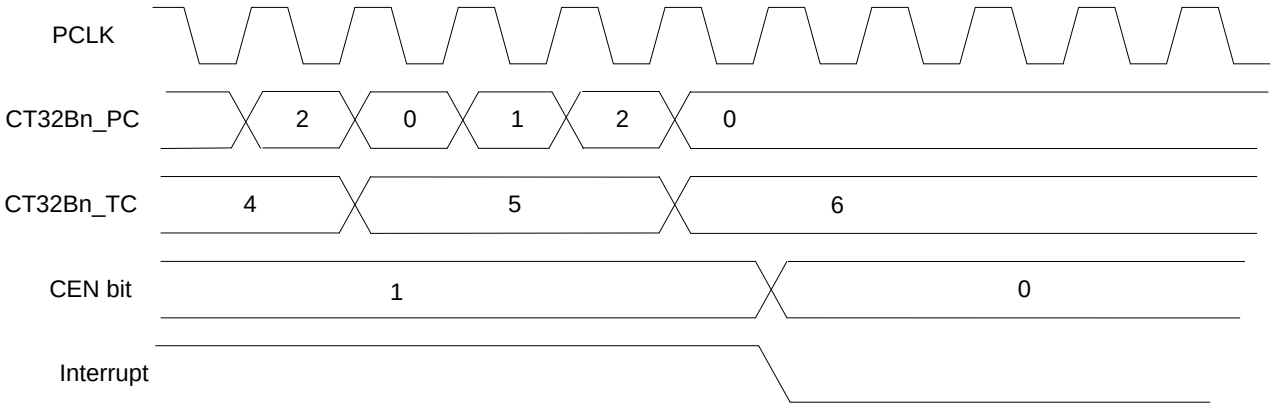
9.5 TIMER OPERATION

9.5.1 Edge-aligned Up-counting Mode

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.



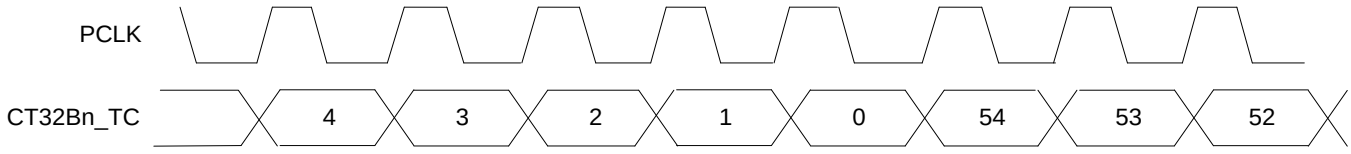
The following figure shows a timer configured to stop and generate an interrupt on match. The CT32Bn_PRE register is set to 2, and the CT32Bn_MRx register is set to 6. In the next clock after the timer reaches the match value, the CEN bit in CT32Bn_TMRCTRL register is cleared, and the interrupt indicating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



9.5.2 Edge-aligned Down-counting Mode

The timer count TC[31:0] will be reset to the value of CT32Bn_MR3 after resetting counter or TC reaches 0. Besides, TC is blocked while the value of CT132Bn_MR3 is zero.

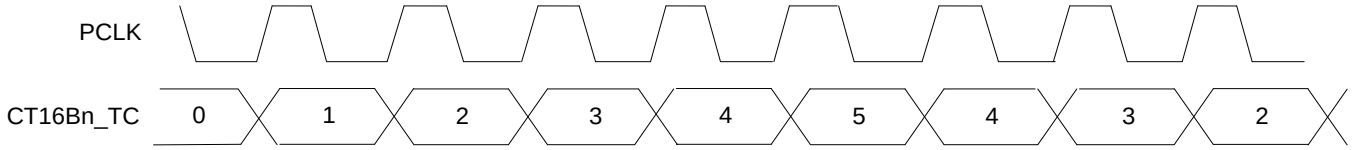
The following figure shows a timer configured to reset the count in Edge-aligned down-counting mode. The CT32Bn_PRE register is set to 0, and the CT32Bn_MR3 register is set to 54. After TC reaches 0, the timer count is reset and loaded from the value of CT32Bn_MR3.



9.5.3 Center-aligned Counting Mode

In Center-aligned counting mode, TC counts up from 0 to the value of CT32Bn_MR3, and then counts down to 0 alternatively. Besides, TC is blocked while the value of CT32Bn_MR3 is zero.

The following figure shows a timer in Center-aligned counting mode. The CT32Bn_PRE register is set to 0, and the CT32Bn_MR3 register is set to 5.



9.6 PWM

9.6.1 PWM Mode 1

- PWMn is 0 when TC<MRn during Up-counting period
- PWMn is 0 when TC≤MRn during Down-counting period

Take Edge-aligned Up-counting Mode as example,

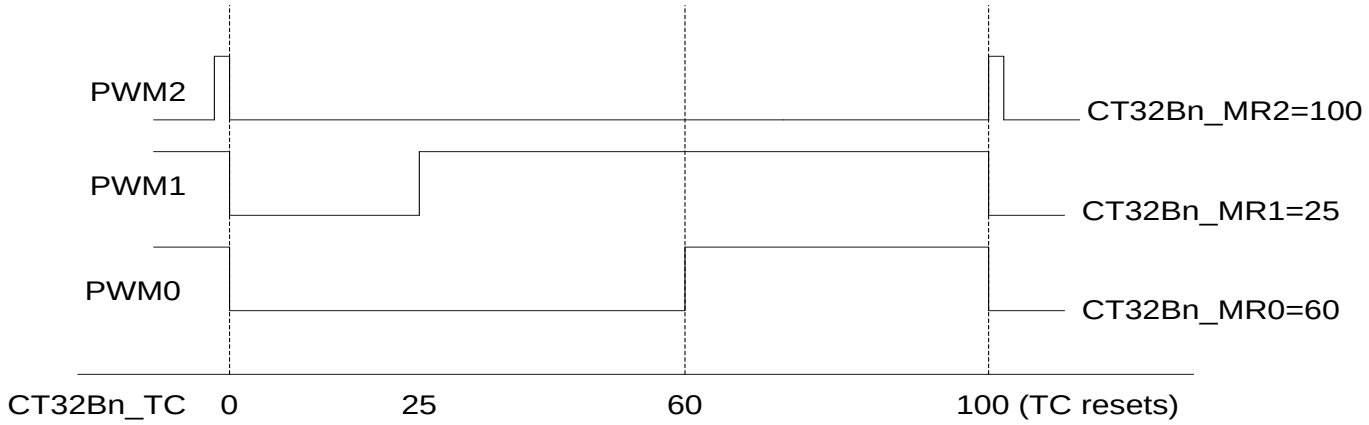
1. All single edge controlled PWM outputs go LOW at the beginning of each PWM cycle (timer is set to zero) unless their match value in CT32Bn_MR0~3 registers is equal to zero.

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.

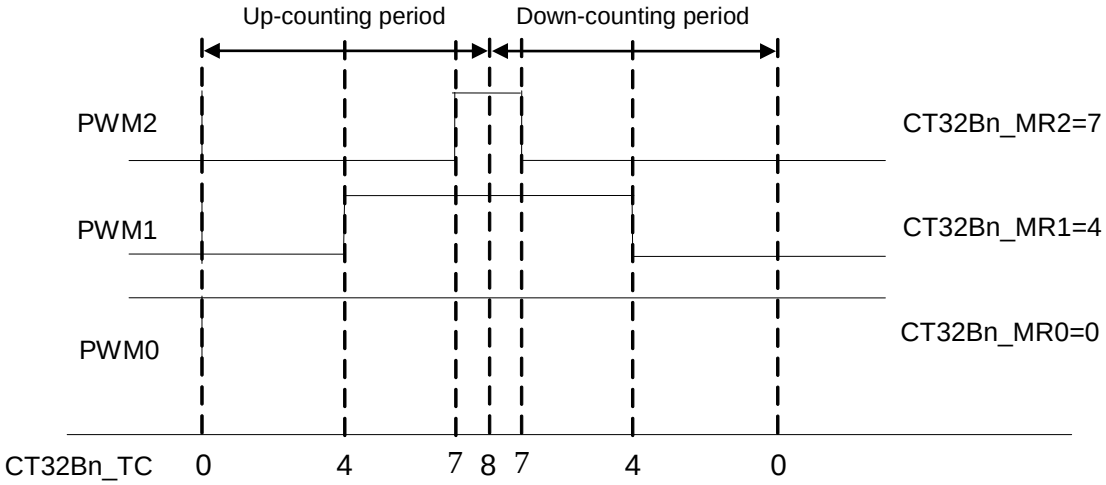
5. If a match register is set to zero, then the PWM output will go to HIGH the first time the timer goes back to zero and will stay HIGH continuously.



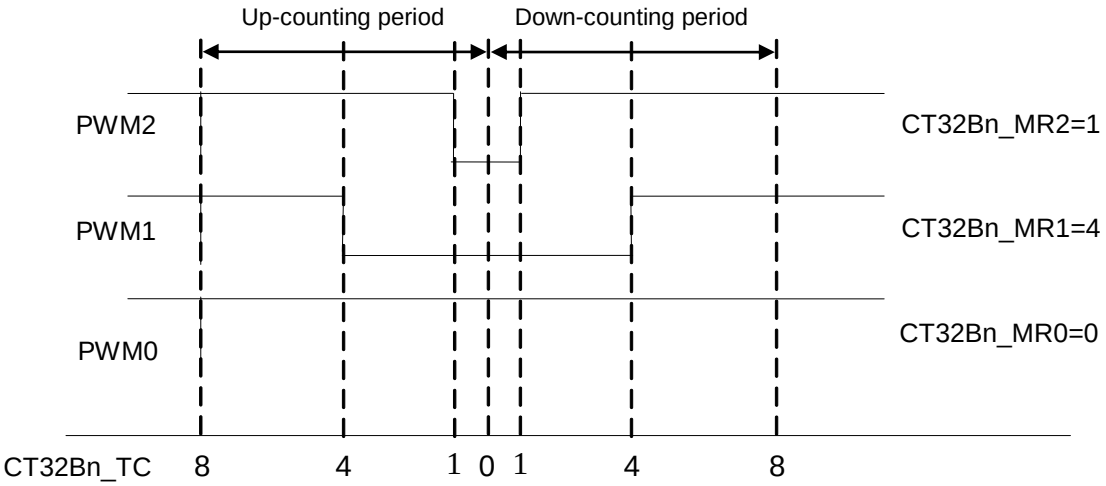
✸ ***Note: When the match outputs are selected to perform as PWM outputs, the timer reset (MRnRST) and timer stop (MRnSTOP) bits in CT32Bn_MCTRL register must be set to zero except for the match register setting the PWM cycle length. For this register, set the MRnR bit to one to enable the timer reset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

The following figure shows the PWM mode 1 wave form in Center-aligned counting mode.

Case 1: The CT32Bn_PRE register is set to 0, the CT32Bn_MR3 register is set to 8, the CT32Bn_MR2 register is set to 7, the CT32Bn_MR1 register is set to 4, and the CT32Bn_MR0 register is set to 0.



Case 2: The CT32Bn_PRE register is set to 0, the CT32Bn_MR3 register is set to 8, the CT32Bn_MR2 register is set to 1, the CT32Bn_MR1 register is set to 4, and the CT32Bn_MR0 register is set to 0.



9.6.2 PWM Mode 2

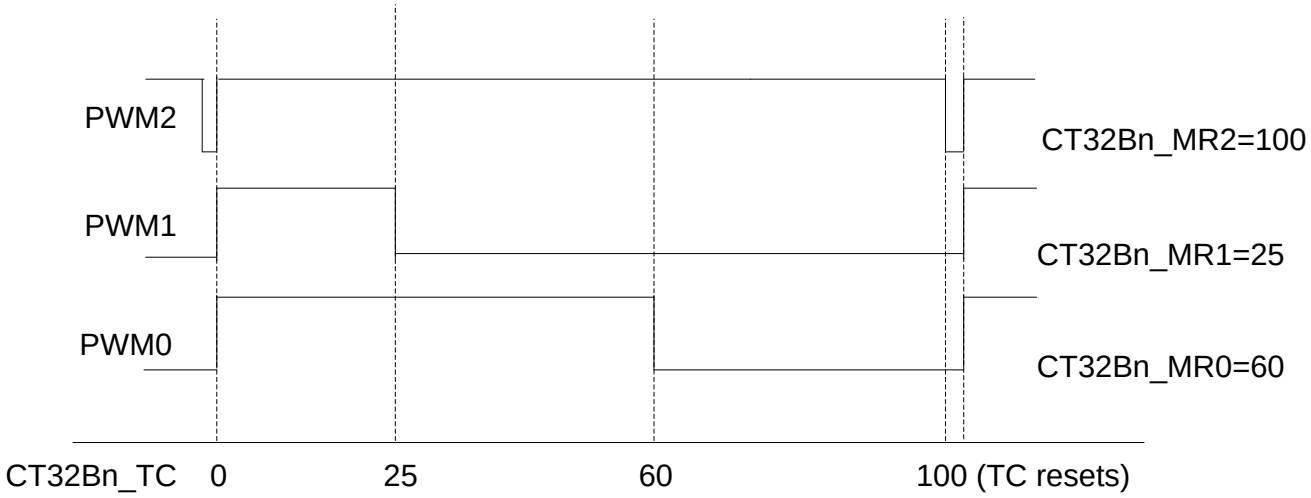
- PWMn is 1 when TC<MRn during Up-counting period
- PWMn is 1 when TC≤MRn during Down-counting period
- Not support in Center-aligned counting mode

Take Edge-aligned up-counting Mode as example,

1. All single edge controlled PWM outputs go HIGH 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 LOW when its match value is reached. If no match occurs, the PWM output remains continuously HIGH.
3. If a match value larger than the PWM cycle length is written to the CT32Bn_MR0~3 registers, and the PWM signal is LOW already, then the PWM signal will go HIGH 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 HIGH on the next clock tick. Therefore, the PWM output will always consist of a one clock tick wide low 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 LOW the first time the timer goes back to zero and will stay LOW 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.***

9.7 CT32Bn REGISTERS

Base Address: 0x4000 6000 (CT32B0)
0x4000 8000 (CT32B1)
0x4000 A000 (CT32B2)

9.7.1 CT32Bn Timer Control register (CT32Bn_TMRCTRL) (n=0,1,2)

Address Offset: 0x00

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

Bit	Name	Description	Attribute	Reset
31:7	Reserved		R	0
6:4	CM[2:0]	Counting mode selection 000: Edge-aligned Up-counting mode. 001: Edge-aligned Down-counting mode 010: Center-aligned mode 1. The match interrupt flag is set during the down-counting period 100: Center-aligned mode 2. The match interrupt flag is set during the up-counting period 110: Center-aligned mode 3. The match interrupt flag is set during both up-counting and down-counting period Other: Reserved	R/W	000b
3:2	Reserved		R	0
1	CRST	Counter Reset. 0: Disable counter reset. 1: Timer Counter is 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 for counting.	R/W	0

9.7.2 CT32Bn Timer Counter register (CT32Bn_TC) (n=0,1,2)

Address Offset: 0x04

In Edge-aligned up-counting mode (CM[2:0]=000b), unless it is reset before reaching its upper limit, the TC will count up to 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.

In Edge-aligned down-counting mode (CM[2:0]=001b) , the TC[31:0] should be reset to the value of CT32Bn_MR3 after resetting counter (SW set CRST to 1).

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

9.7.3 CT32Bn Prescale register (CT32Bn_PRE) (n=0,1,2)

Address Offset: 0x08

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

9.7.4 CT32Bn Prescale Counter register (CT32Bn_PC) (n=0,1,2)

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

9.7.5 CT32Bn Count Control register (CT16Bn_CNTCTRL) (n=0,1,2)

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), 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

9.7.6 CT32Bn Match Control register (CT32Bn_MCTRL) (n=0,1,2)

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 based on CM[2:0] 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 based on CM[2:0] 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 based on CM[2:0] 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 based on CM[2:0] when MR0 matches the value in the TC. 0: Disable 1: Enable	R/W	0

9.7.7 CT32Bn Match register 0~3 (CT32Bn_MR0~3) (n=0,1,2)

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

9.7.8 CT32Bn Capture Control register (CT32Bn_CAPCTRL) (n=0,1,2)

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
31:4	Reserved		R	0
3	CAP0EN	Capture 0 function enable bit 0: Disable 1: Enable..	R/W	0
2	CAP0IE	Interrupt on CT32Bn_CAP0 event: a CAP0 load due to a CT32Bn_CAP0 event will generate an interrupt. 0: Disable 1: Enable	R/W	0
1	CAP0FE	Capture on CT32Bn_CAP0 falling edge: a sequence of 1 then 0 on CT32Bn_CAP0 will cause CAP0 to be loaded with the contents of TC. 0: Disable 1: Enable	R/W	0
0	CAP0RE	Capture on CT32Bn_CAP0 rising edge: a sequence of 0 then 1 on CT32Bn_CAP0 will cause CAP0 to be loaded with the contents of TC. 0: Disable 1: Enable	R/W	0

9.7.9 CT32Bn Capture 0 register (CT32Bn_CAP0) (n=0,1,2)

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

9.7.10 CT32Bn External Match register (CT32Bn_EM) (n=0,1,2)

Address Offset: 0x30

The External Match register provides both control and status of the external match pins CT32Bn_PWMCTRL[3:0].
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
31:12	Reserved		R	0
11:10	EMC3[1:0]	Determines the functionality of CT32Bn_PWM3. 00: Do Nothing.	R/W	0

		01: CT32Bn_PWM3 pin is LOW 10: CT32Bn_PWM3 pin is HIGH 11: Toggle CT32Bn_PWM3 pin.		
9:8	EMC2[1:0]	Determines the functionality of CT32Bn_PWM2. 00: Do Nothing. 01: CT32Bn_PWM2 pin is LOW 10: CT32Bn_PWM2 pin is HIGH 11: Toggle CT32Bn_PWM2 pin.	R/W	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	EM3	When the TC and MR3 are equal, this bit will act according to EMC3 bits, and also drive the state of CT32Bn_PWM3 output.	R/W	0
2	EM2	When the TC and MR2 are equal, this bit will act according to EMC2 bits, and also drive the state of CT32Bn_PWM2 output.	R/W	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

9.7.11 CT32Bn PWM Control register (CT32Bn_PWMCTRL) (n=0,1,2)

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
31:24	Reserved		R	0
23	PWM3IOEN	CT32Bn_PWM3/GPIO selection bit 0: CT32Bn_PWM3 pin act as GPIO 1: CT32Bn_PWM3 pin act as match output, and output signal depends on PWM3EN bit.	R/W	0
22	PWM2IOEN	CT32Bn_PWM2/GPIO selection bit 0: CT32Bn_PWM2 pin act as GPIO 1: CT32Bn_PWM2 pin act as match output, and output signal depends on PWM2EN bit.	R/W	0
21	PWM1IOEN	CT32Bn_PWM1/GPIO selection bit 0: CT32Bn_PWM1 pin act as GPIO 1: CT32Bn_PWM1 pin actn_atch output, and output signal depends on PWM1EN bit.	R/W	0
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
19:12	Reserved		R	0

11:10	PWM3M0DE[1:0]	PWM3 output mode 00: PWM mode 1 01: PWM mode 2 10: PWM3 is forced to 0. 11: PWM3 is forced to 1.	R/W	0
9:8	PWM2M0DE[1:0]	PWM2 output mode 00: PWM mode 1 01: PWM mode 2 10: PWM2 is forced to 0. 11: PWM2 is forced to 1.	R/W	0
7:6	PWM1M0DE[1:0]	PWM1 output mode 00: PWM mode 1 01: PWM mode 2 10: PWM1 is forced to 0. 11: PWM1 is forced to 1.	R/W	0
5:4	PWM0M0DE[1:0]	PWM0 output mode 00: PWM mode 1 01: PWM mode 2 10: PWM0 is forced to 0. 11: PWM0 is forced to 1.	R/W	0
3	PWM3EN	PWM3 enable 0: CT32Bn_PWM3 is controlled by EM3. 1: PWM mode is enabled for CT32Bn_PWM3.	R/W	0
2	PWM2EN	PWM2 enable 0: CT32Bn_PWM2 is controlled by EM2. 1: PWM mode is enabled for CT32Bn_PWM2.	R/W	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

9.7.12 CT32Bn Timer Raw Interrupt Status register (CT32Bn_RIS) (n=0,1,2)

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

9.7.13 CT32Bn Timer Interrupt Clear register (CT32Bn_IC) (n=0,1,2)

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

10 WATCHDOG TIMER (WDT)

10.1 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 a 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 0 (SYS1_APBCP0) 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.

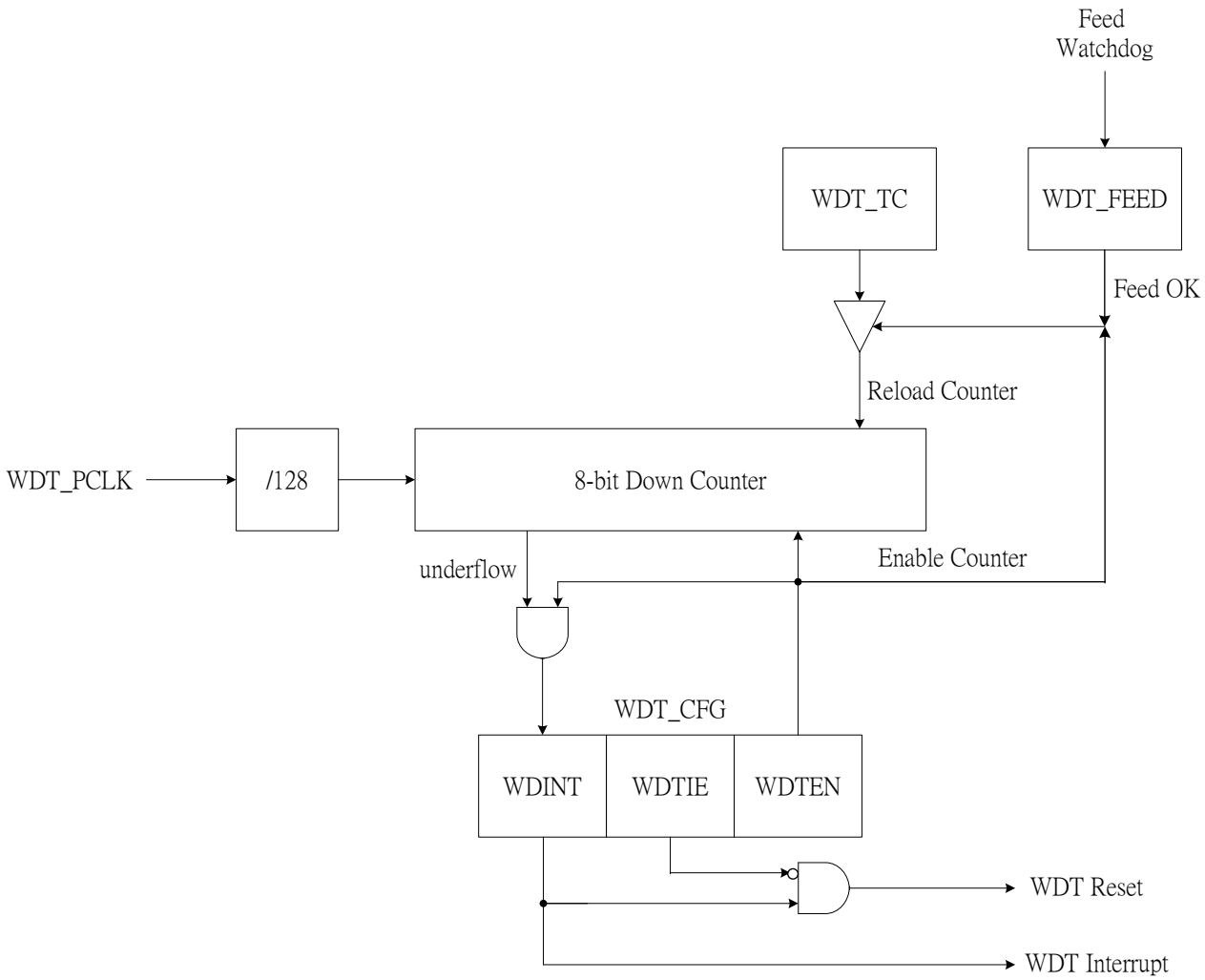
When the watchdog is started by setting the WDTEN in WDT_CFG register, the time constant value is loaded in the watchdog counter and the counter starts counting down. When the Watchdog is in the reset mode and the counter underflows, the CPU will be reset, loading the stack pointer and program counter 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.

10.2 BLOCK DIAGRAM



10.3 WDT REGISTERS

Base Address: 0x4001 0000

10.3.1 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 0: Read→Watchdog does not cause an interrupt. Writ→ Clear this flag. SW shall feed Watchdog before clearing. 1: Watchdog timeout and causes an interrupt (Only when WDTIE =1).	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

10.3.2 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

10.3.3 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 $T_{WDT\_PCLK} \times 128 \times 1 \sim T_{WDT\_PCLK} \times 128 \times 256$.

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

10.3.4 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

11 REAL-TIME CLOCK (RTC)

11.1 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.

11.2 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.

11.3 FUNCTIONAL DESCRIPTION

11.3.1 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.

11.3.2 RESET RTC REGISTERS

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

11.3.3 RTC FLAG ASSERTION

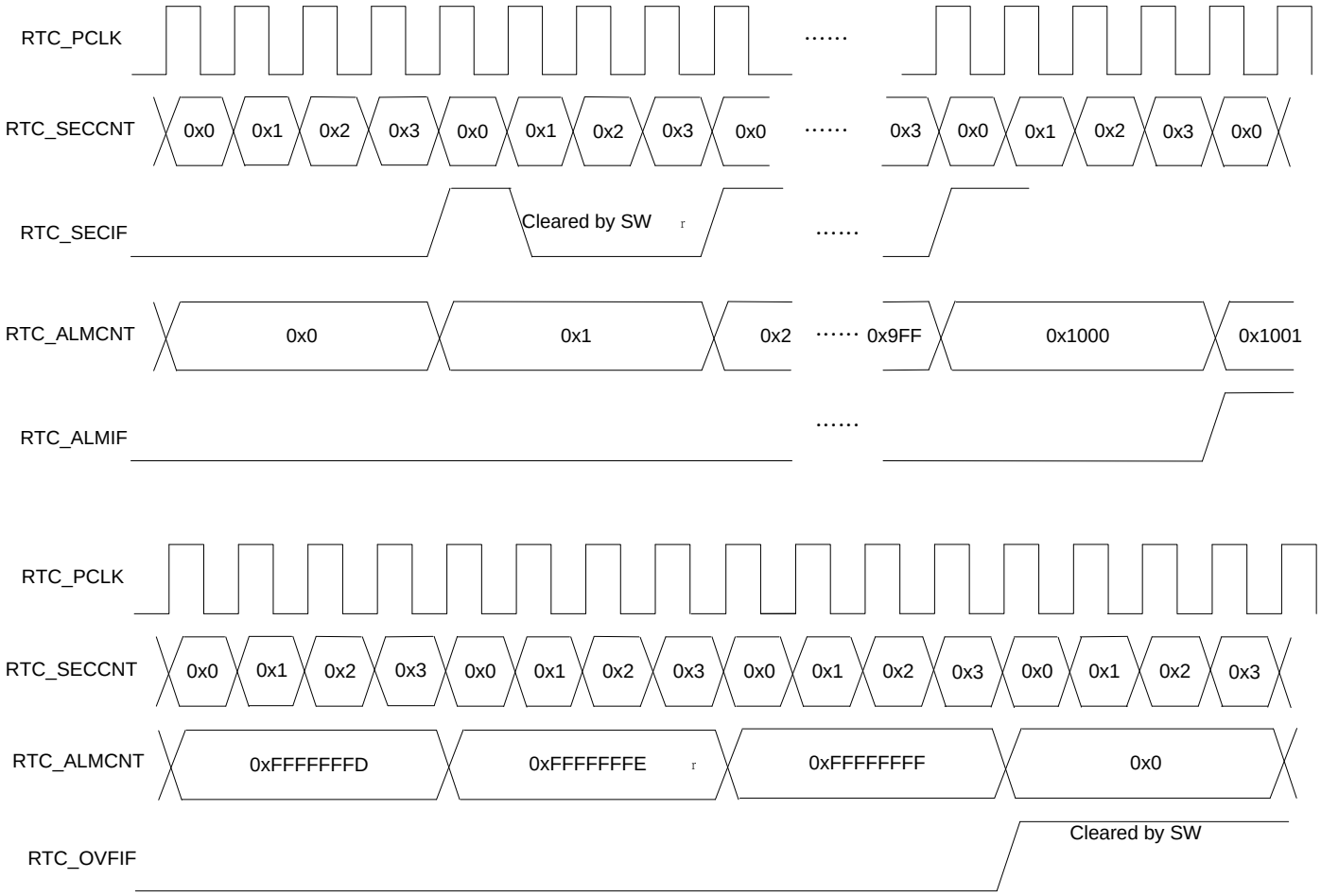
The RTC Second interrupt flag (SECIF) is asserted on each RTC Core clock cycle before the update of the RTC Counter.

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

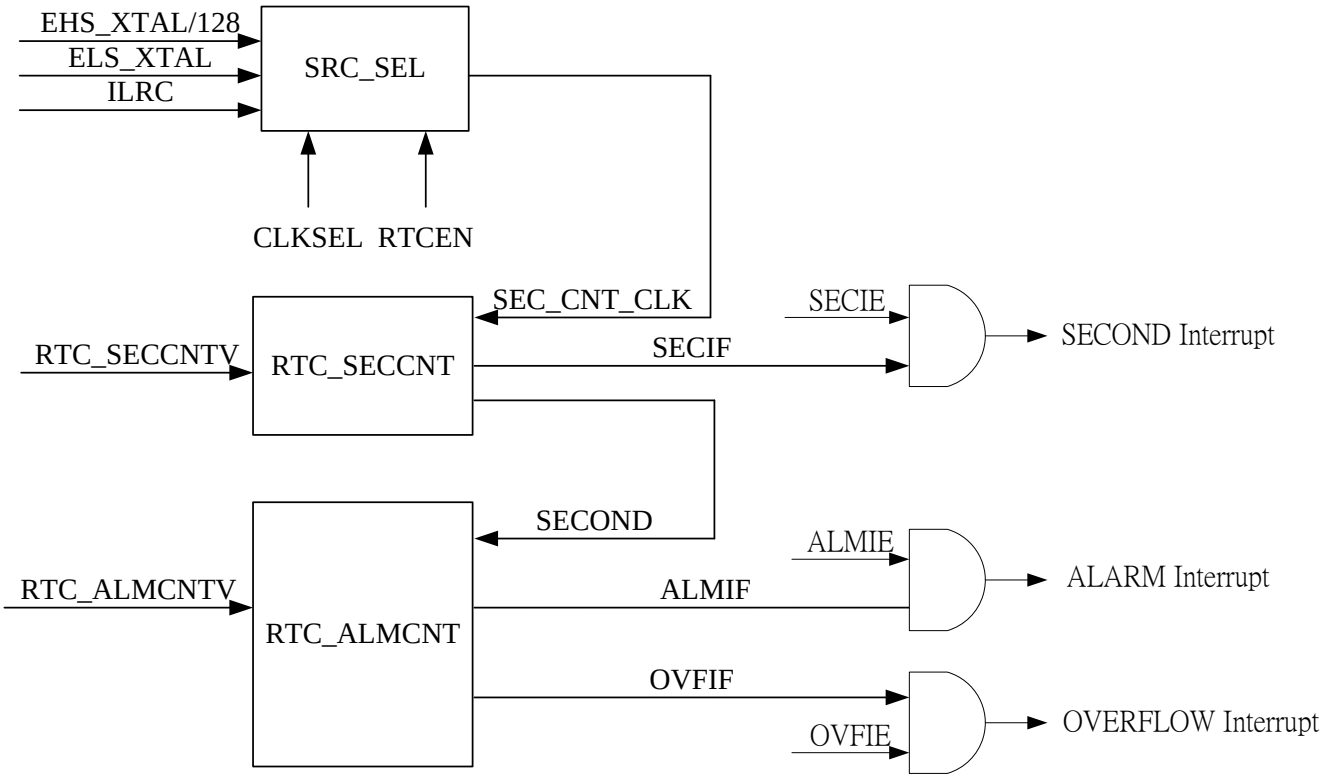
The RTC Alarm interrupt flag (ALMIF) are asserted on the last RTC Core clock cycle before the counter reaches the RTC Alarm counter reload value stored in the Alarm register.

11.3.4 RTC OPERATION

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



11.4 BLOCK DIAGRAM



11.5 RTC REGISTERS

Base Address: 0x4001 2000

11.5.1 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

11.5.2 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

11.5.3 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

11.5.4 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

11.5.5 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

11.5.6 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

11.5.7 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

11.5.8 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

11.5.9 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	0

12 SPI/SSP

12.1 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.

12.2 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 1st-phase or 2nd-phase controlled register.

12.3 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

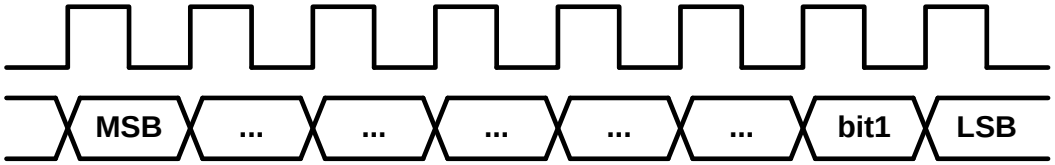
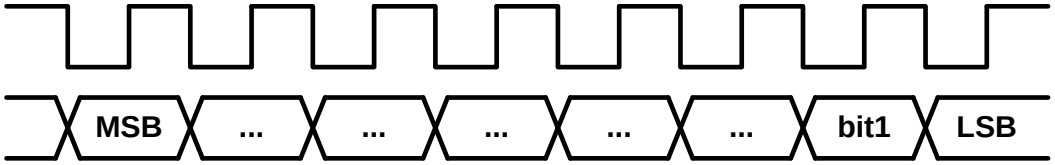
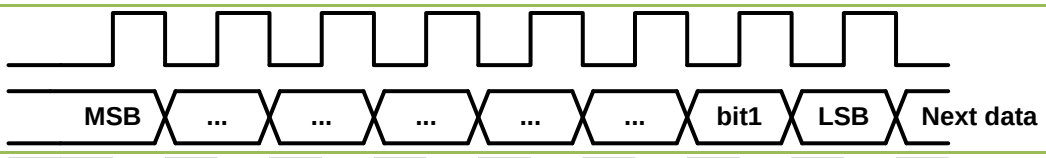
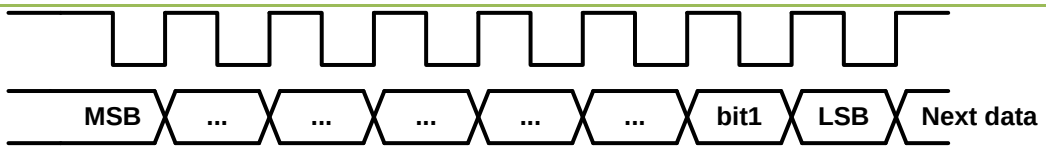
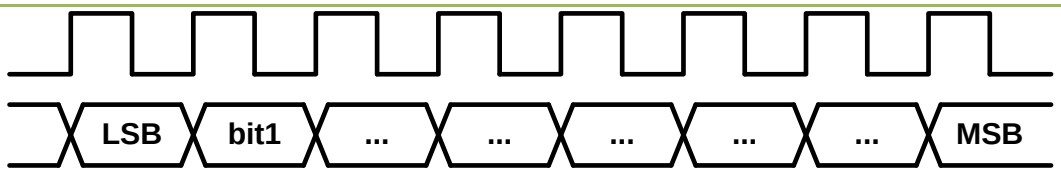
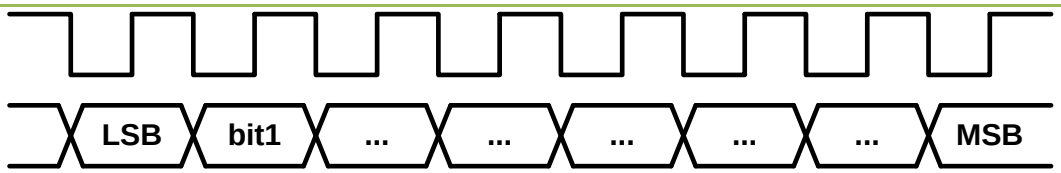
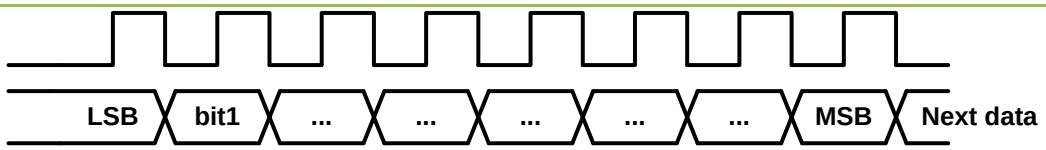
12.4 INTERFACE DESCRIPTION

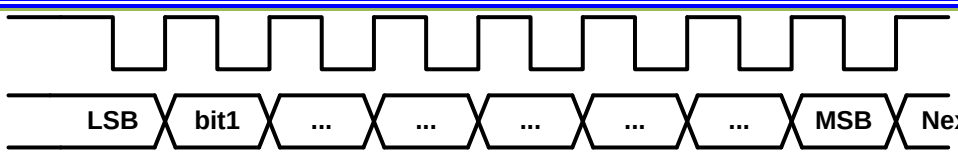
12.4.1 SPI

The SPI interface is a 4-wire interface where the SSEL 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	

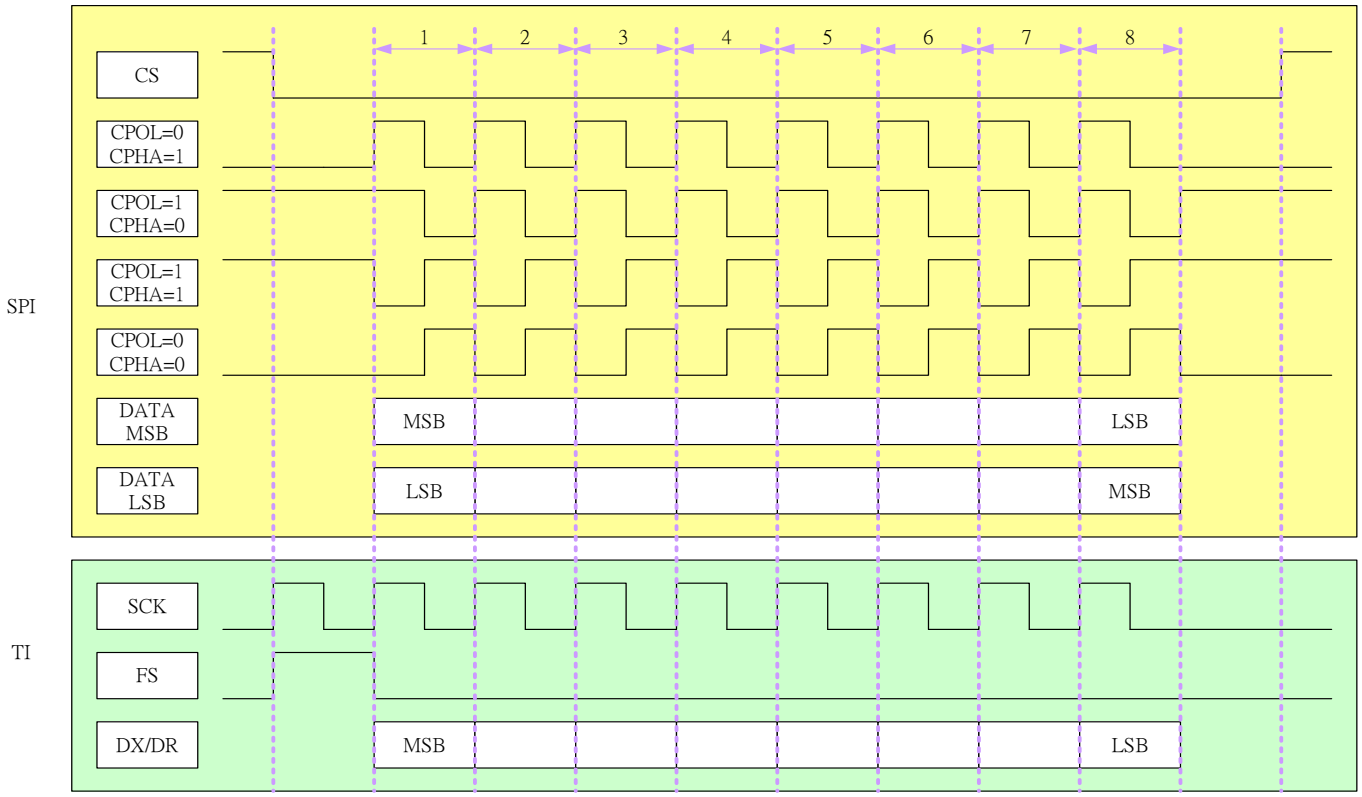
12.4.2 SSI

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

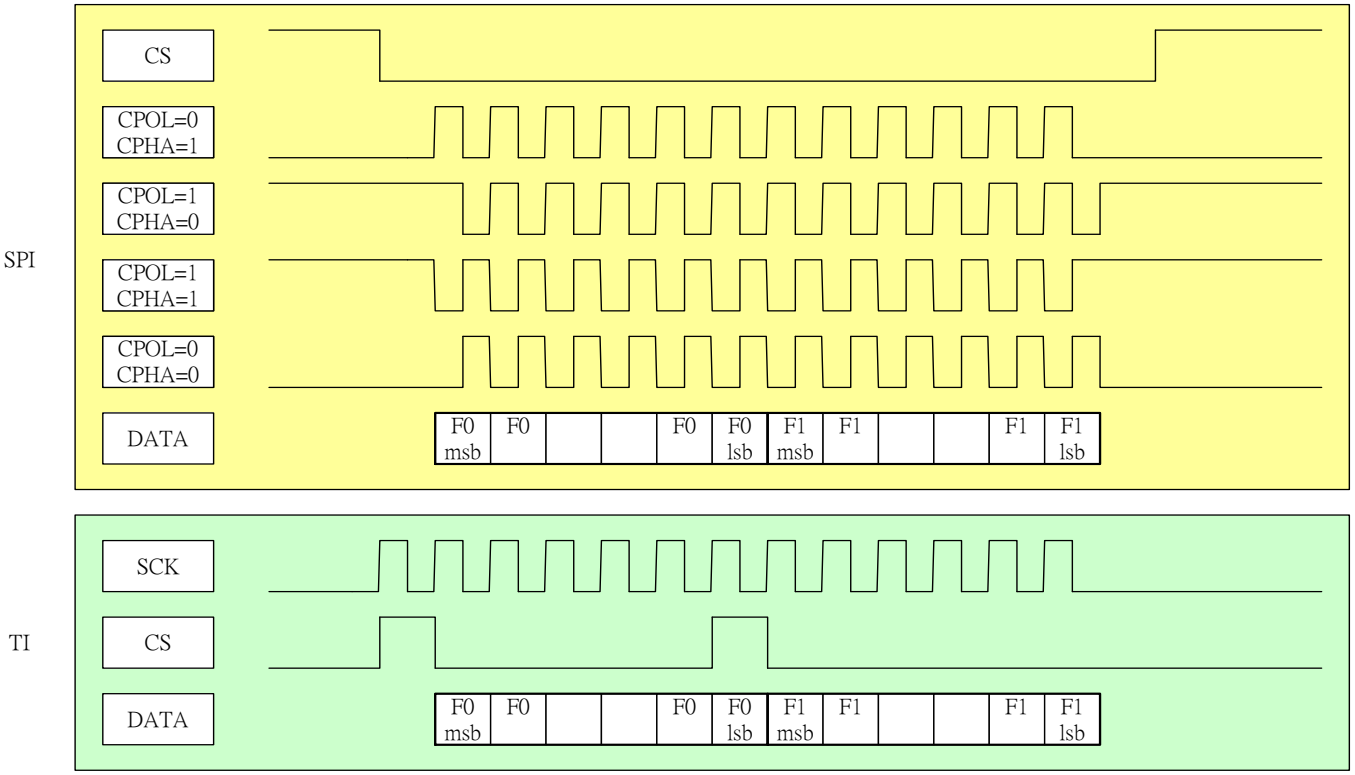
Once the bottom entry of the transmit FIFO contains data, CS is pulsed HIGH for one SCK period. The value to be transmitted is also transferred from the transmit FIFO to the serial shift register of the shifted out on the DX pin. Likewise, the MSB of the received data is shifted onto the DR pin by the 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.

12.4.3 COMMUNICATION FLOW

12.4.3.1 SINGLE-FRAME



12.4.3.2 MULTI-FRAME



12.5 AUTO-SEL

The Auto-SEL function is disabled (SELDIS = 1) by default, HW does NOT control SELn pin at all, and SELn pin is GPIO. If Auto-SEL function is enabled (SELDIS = 0), SPI HW controls the SELn activity, and SELn is assigned by PFPA_SSP register.

12.6 SSP REGISTERS

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

12.6.1 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
31:19	Reserved		R	0
18	SELDIS	Auto-SEL disable bit. For SPI mode only. 0: Enable Auto-SEL flow control. 1: Disable Auto-SEL flow control.	R/W	1
17:15	RXFIFOTH[2:0]	RX FIFO Threshold level 000: RX FIFO threshold level = 0 001: RX FIFO threshold level = 1 … … 111: RX FIFO threshold level = 7	R/W	000b
14:12	TXFIFOTH[2:0]	TX FIFO Threshold level 000: TX FIFO threshold level = 0 001: TX FIFO threshold level = 1 … … 111: TX FIFO threshold level = 7	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

12.6.2 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

12.6.3 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

12.6.4 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

12.6.5 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

12.6.6 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

12.6.7 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 effet 1: Clear RXTOIF bit.	W	0
0	RXOVFIC	0: No effet 1: Clear RXOVFIF bit.	W	0

12.6.8 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 registe (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

12.6.9 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

13 I2C

13.1 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

13.2 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.

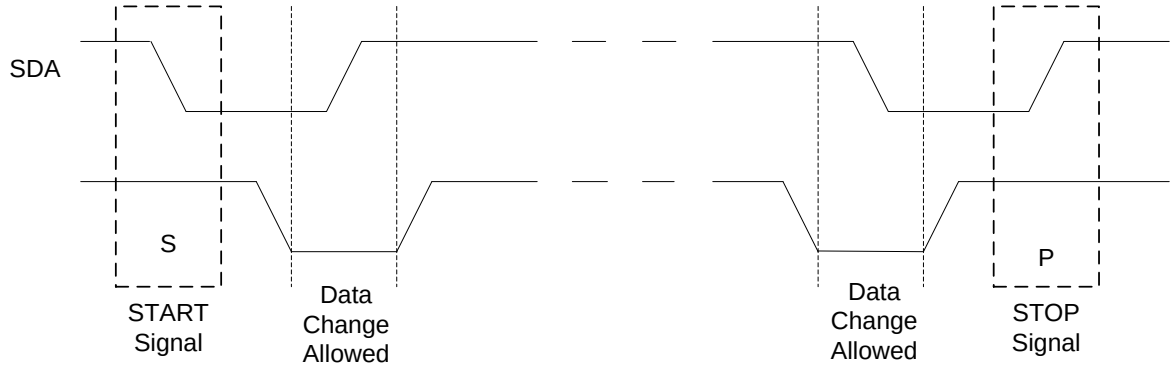
- Standard I2C-compliant bus interfaces may be configured as Master or Slave.
- I2C Master features:
  - Clock generation
  - Start and Stop generation
- I2C Slave features:
  - Programmable I2C Address detection
  - Optional recognition of up to four distinct slave addresses
  - Stop bit detection
- 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.

13.3 PIN DESCRIPTION

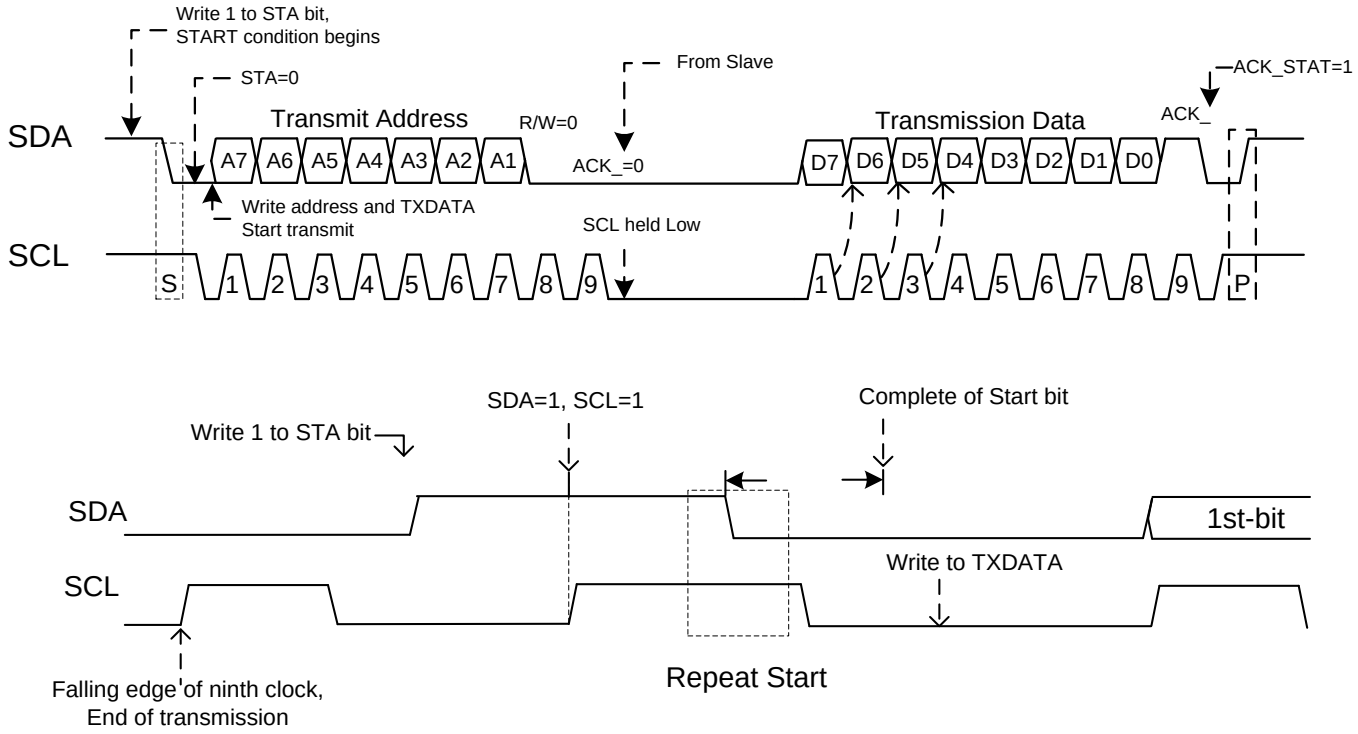
Pin Name	Type	Description	GPIO Configuration
SCLn	I/O	I2C Serial clock	Output with Open-drain Input depends on GPIOn_CFG
SDAn	I/O	I2C Serial data	Output with Open-drain Input depends on GPIOn_CFG

13.4 WAVE CHARACTERISTICS

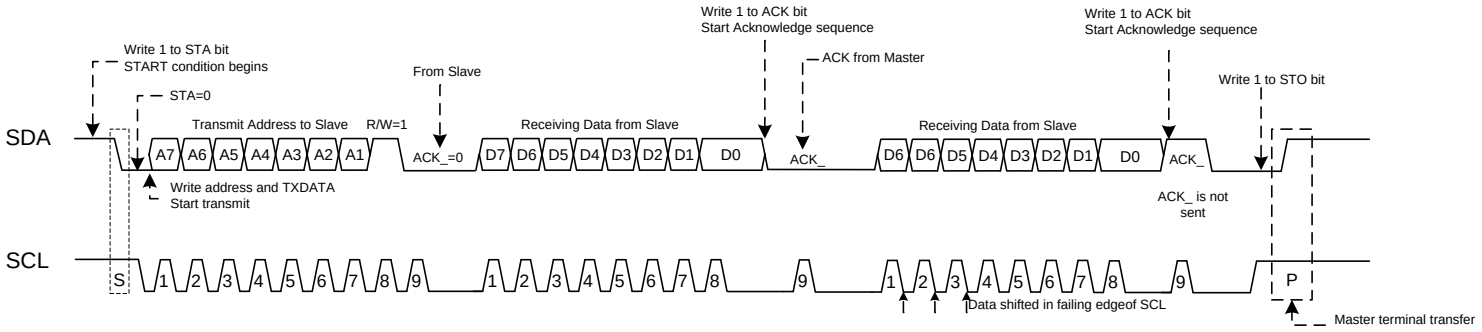


13.5 I2C MASTER MODES

13.5.1 MASTER TRANSMITTER MODE



13.5.2 MASTER RECEIVER MODE



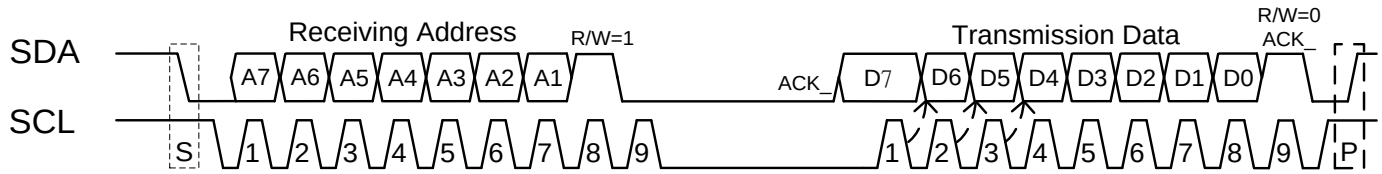
13.5.3 ARBITRATION

In the master transmitter mode, the arbitration logic checks that every transmitted logic 1 actually appears as a 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.

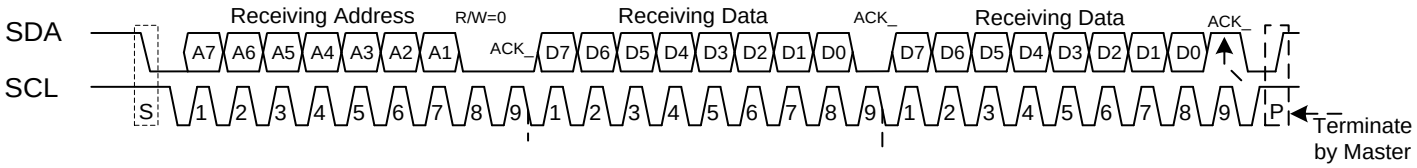
Arbitration may also be lost in the master receiver mode. Loss of arbitration in this mode can only occur while the I2C block is returning a “not acknowledge” to the bus. Arbitration is lost when another device on the bus pulls this signal low. Since this can occur only at the end of a serial byte, the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

13.6 I2C SLAVE MODES

13.6.1 SLAVE TRANSMITTER MODE



13.6.2 SLAVE RECEIVER MODE



13.7 MONITOR MODE

13.7.1 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.

13.7.2 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.

13.8 I2C REGISTERS

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

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

Address Offset: 0x00

Setting of the bits in this register 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.***
- ***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.	R/W	0

		➢ The General Call address has been received while the General Call bit (GC) in the ADR register is set. ➢ 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

13.8.2 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 1 : Received an ACK	R	0
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

13.8.3 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

13.8.4 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

13.8.5 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

13.8.6 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

13.8.7 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

13.8.8 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

13.8.9 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*I2Cn_PCLK cycle	R/W	0x0

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

14 UNIVERSAL SYNCHRONOUS AND ASYNCHRONOUS SERIAL RECEIVER AND TRANSMITTER (USART)

14.1 OVERVIEW

The USART 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 USART offers a very wide range of baud rates using a fractional baud rate generator. It supports both synchronous one-way communication and single wire communication. It also supports the LIN (local interconnection network), Smartcard Protocol, and modem operations (CTS/RTS).

14.2 FEATURES

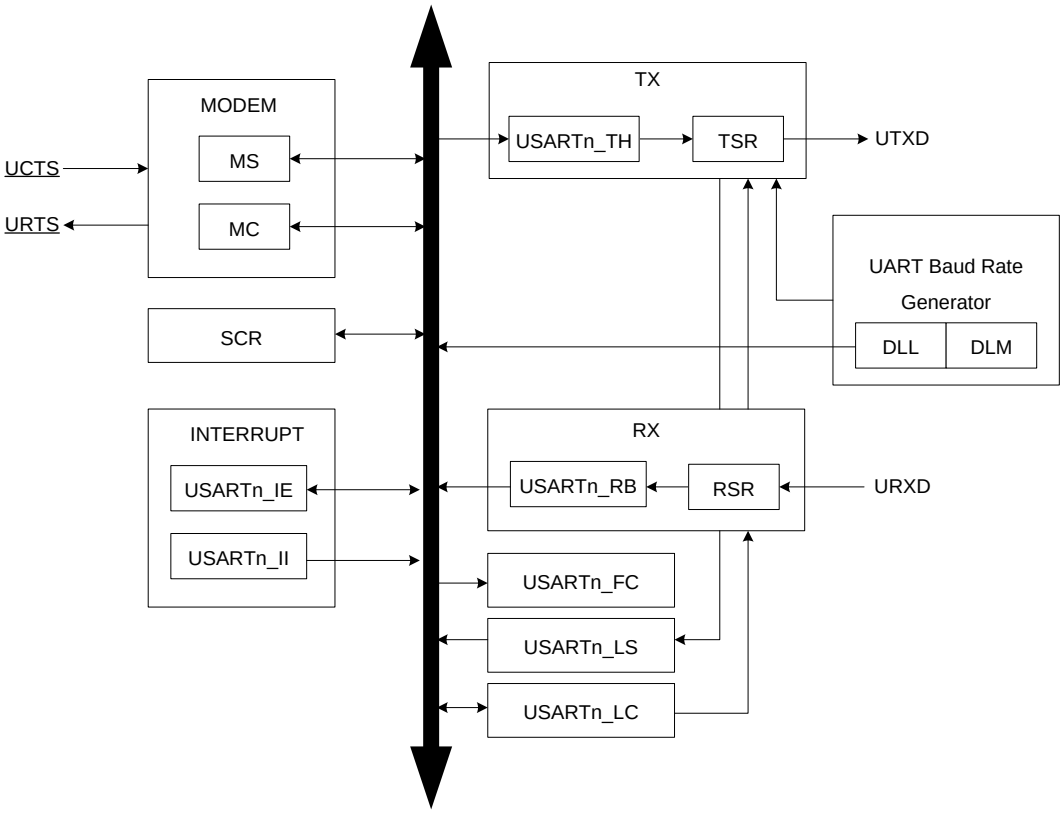
- Full-duplex, 2-wire asynchronous data transfer.
- Single-wire half-duplex communication
- Transmitter clock output for synchronous transmission
- 16-byte receive and transmit FIFOs
- Register locations conform to 16550 industry standard.
- Receiver FIFO trigger points at 1, 4, 8, and 14 bytes.
- Built-in baud rate generator.
- Software or hardware flow control.
- EIA-485 9-bit mode support with output enable.
- Modem control signals (CTS/RTS).
- ISO 7816-3 compliant Smartcard interface.

14.3 PIN DESCRIPTION

Pin Name	Type	Description	GPIO Configuration
UTXDn	O	Serial Transmit data.	
URXDn	I	Serial Receive data.	Depends on GPIOn_CFG
USCKn	O	Serial clock of Synchronous mode (Master)	
UCTSn	I	Clear to Send. When low, this indicates that the MODEM or data set is ready to exchange data. The CTS signal is a MODEM status input whose conditions can be tested by reading bit 4 (CTS) of USARTn_MS register.	Depends on GPIOn_CFG
URTSn	O	Request to Send. RS-485 direction control pin. When low, this informs the MODEM or data set that the UART is ready to exchange data. The RTS output signal can be set to an active low by programming bit 1 (RTS) of USARTn_MC register. Loop mode operation holds this signal	

		in its inactive state.	

14.4 BLOCK DIAGRAM



14.5 EIA-485/RS-485 MODES

The RS-485/EIA-485 feature allows the USART to be configured as an addressable slave receiver. The addressable slave receiver is one of multiple slaves receivers controlled by a single master.

The USART master transmitter will identify an address character by setting the parity (9th) bit to '1'. For data characters, the parity bit is set to '0'.

Each USART slave receiver can be assigned a unique address. The slave can be programmed to either manually or automatically reject data following an address which is not theirs.

In RS-485 mode, PS bits in USARTn_LC register shall be selected as forced 1 stick parity (Address), or forced stick 0 parity (Data) by SW. In addition, the word length shall be 8 bits by setting WLS bits in USARTn_LC register to 11b by SW.

14.5.1 RS-485/EIA-485 NORMAL MULTIDROP MODE (NMM)

Setting the NMMEN bit in USARTn_RS485CTRL register enables this mode. In this mode, an address is detected when a received byte causes the USART to set the parity error and generate an interrupt.

If the receiver is disabled (RXEN = 0 in USARTn_RS485CTRL register), any received data bytes will be ignored and will not be stored in the RXFIFO. When an address byte is detected (parity bit = '1') it will be placed into the RXFIFO and a parity error (PE) Interrupt will be generated. The processor can then read the address byte and decide whether or not to enable the receiver to accept the following data.

While the receiver is enabled (RXEN = 1 in USARTn_RS485CTRL register), all received bytes will be accepted and stored in the RXFIFO regardless of whether they are data or address. When an address character is received a parity error interrupt will be generated and the processor can decide whether or not to disable the receiver.

14.5.2 RS-485/EIA-485 AUTO ADDRESS DETECTION (AAD) MODE

When both NMMEN (9-bit mode enable) bit and AADEN (AAD mode enable) bit in USARTn_RS485CTRL register are set, the USART is in auto address detect mode.

In this mode, the receiver will compare any address byte received (parity = '1') to the 8-bit value programmed into the USARTn_RS485ADRMATCH register.

If the receiver is disabled (RXEN = 0 in USARTn_RS485CTRL register), any received byte will be discarded if it is either a data byte or an address byte which is different from the value in USARTn_RS485ADRMATCH register.

When a matching address character is detected it will be pushed onto the RXFIFO along with the parity bit, and the receiver will be automatically enabled (RXEN bit will be set by HW). The receiver will also generate an RX Data Available (RDA) Interrupt.

While the receiver is enabled (RXEN = 1 in USARTn_RS485CTRL register), all bytes received will be accepted and stored in the RXFIFO until an address byte which is different from the MATCH value is received. When this occurs, the receiver will be automatically disabled by HW (RXEN bit will be cleared by HW), the received non-matching address character will not be stored in the RXFIFO.

14.5.3 RS-485/EIA-485 AUTO DIRECTION CONTROL (ADC)

RS485/EIA-485 mode includes the option of allowing the transmitter to automatically control the state of the DIR pin as a direction control output signal. Set ADCEN bit in USARTn_RS485CTRL register to enable this feature.

The ADCEN bit takes precedence over all other mechanisms controlling the direction control pin with the exception of

loopback mode.

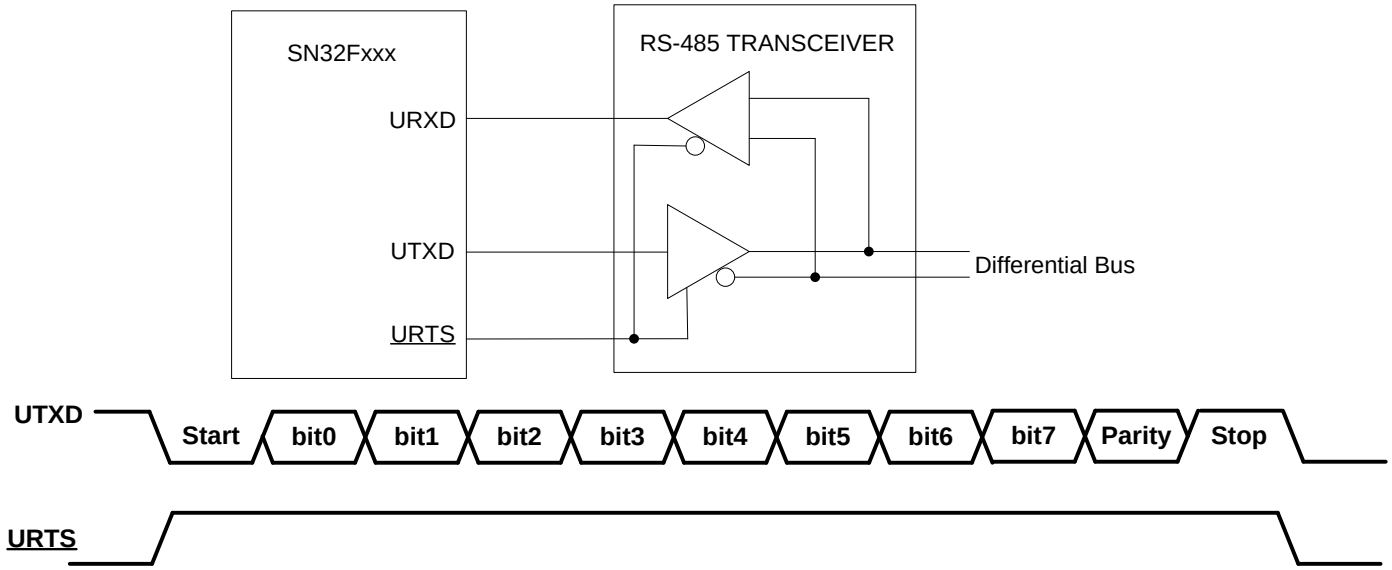
14.5.4 RS485/EIA-485 DRIVER DELAY TIME

The driver delay time is the delay between the last stop bit leaving the TXFIFO and the de-assertion of URTS. This delay time can be programmed in the 8-bit USARTn_RS485DLYV register. The delay time is in periods of the baud clock. Any delay time from 0 to 255 bit times may be used.

14.5.5 RS485/EIA-485 OUTPUT INVERSION

The polarity of the direction control signal on the URTS pin can be reversed by programming OINV bit in USARTn_RS485CTRL register. When OINV bit is set, the direction control pin will be driven to logic 1 (driven LOW) when the transmitter has data waiting to be sent. The direction control pin will be driven to logic 0 (driven High) once the last bit of data has been transmitted.

14.5.6 RS485/EIA-485 FRAME STRUCTURE



14.6 BAUD RATE CALCULATION

The USART baud rate is calculated as:

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

Where USARTn_PCLK is the peripheral clock, USARTn_DLM and USARTn_DLL are the standard UART baud rate divider registers, and DIVADDVAL and MULVAL are USART fractional baud rate generator specific parameters in USARTn_FD register.

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

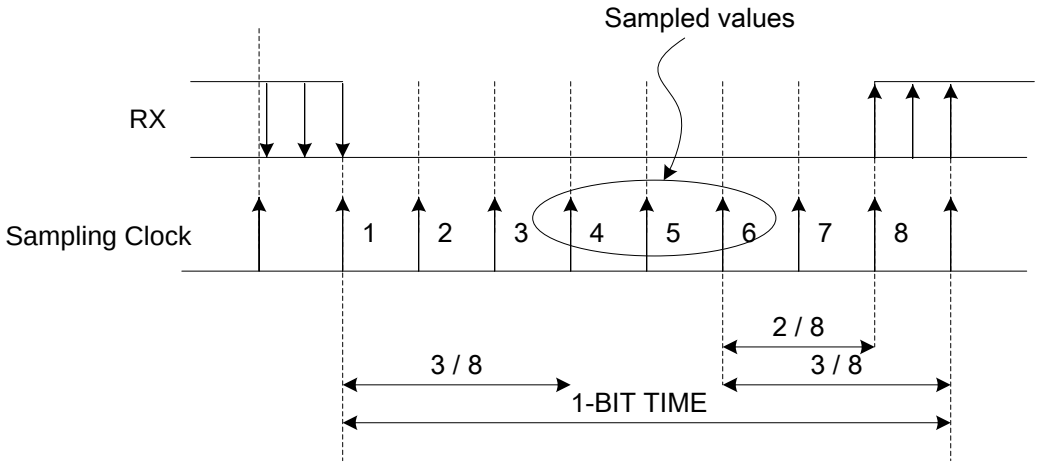
1. 1 ≤ MULVAL ≤ 15
2. 0 ≤ DIVADDVAL ≤ 14
3. DIVADDVAL< MULVAL

4. Oversampling is 8 or 16

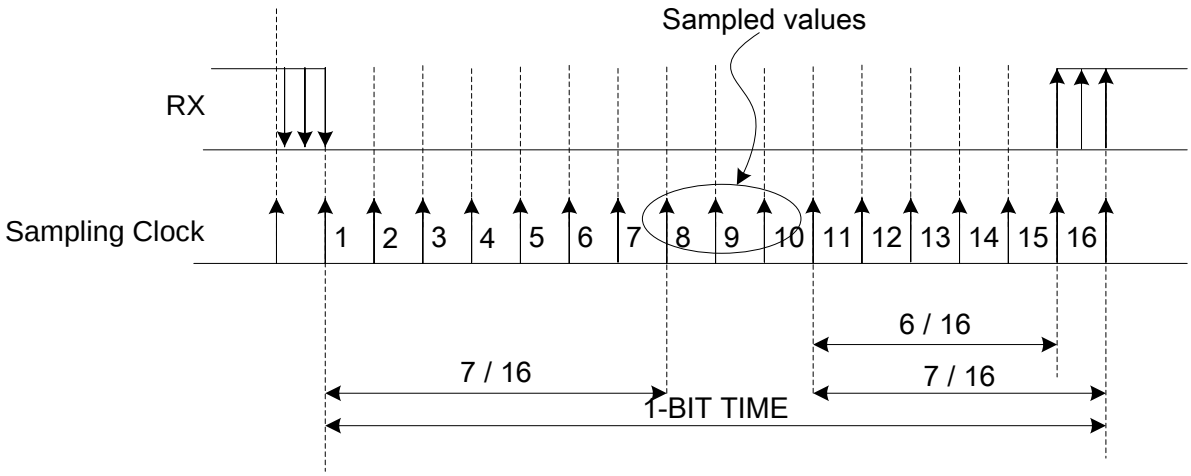
The value of the USARTn_FD register should not be modified while transmitting/receiving data or data may be lost or corrupted.

The oversampling method can be selected by programming the OVER8 bit in USARTn_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 USARTn_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 USARTn_PCLK/16



If the USARTn_FD register value does not comply to 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.

USART 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 USARTn_PCLK = 12 MHz, and Oversampling = 16.

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

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

(256 x DLM + DLL) x (1 + DIVADDVAL / MULVAL) = 6.51

Since the value of MULVAL and DIVADDVAL should comply to 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 = 7. The baud rate generated is 115384, and has a relative error of 0.16% from the originally specified 115200.

14.7 MODEM CONTROL (MC)

If Auto-RTS mode is enabled, the USART's receiver FIFO hardware controls the URTS output of the USART. If the auto-CTS mode is enabled, the USART's transmitter will only start sending if the UCTS pin is low.

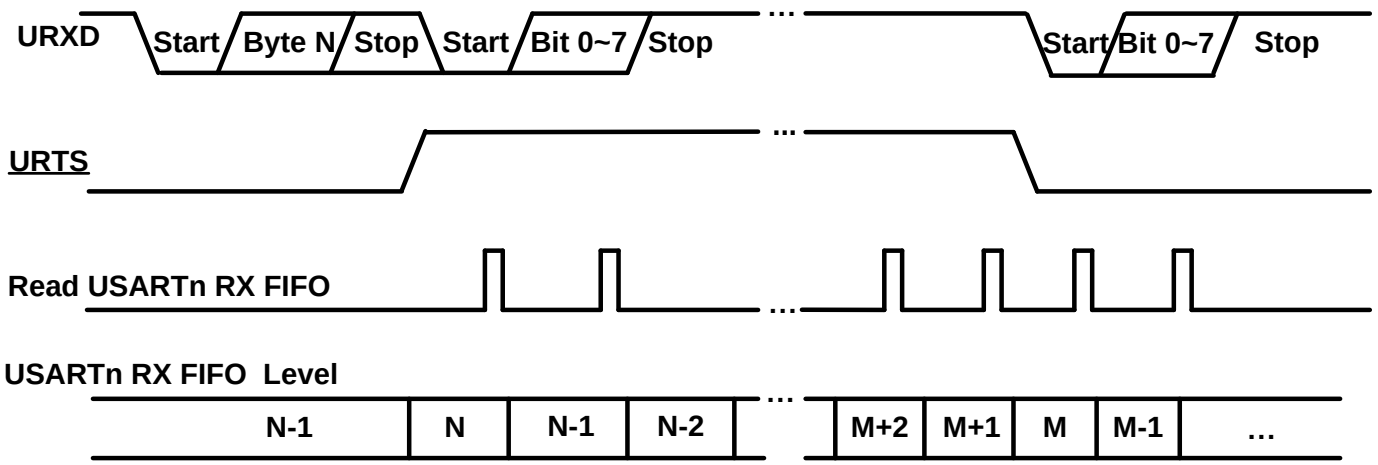
14.7.1 AUTO-RTS

The Auto-RTS function is enabled by setting the RTSEN bit. Auto-RTS data flow control originates in the USARTn_RB module and is linked to the programmed receiver FIFO trigger level. If auto-RTS is enabled, the data-flow is controlled as follows:

When the receiver FIFO level reaches the programmed trigger level, URTS is deasserted (to a high value). It is possible that the sending USART sends an additional byte after the trigger level is reached (assuming the sending USART has another byte to send) because it might not recognize the deassertion of URTS until after it has begun sending the additional byte. URTS is automatically reasserted (to a low value) once the receiver FIFO has reached the previous trigger level. The reassertion of URTS signals the sending USART to continue transmitting data.

If Auto-RTS mode is disabled, the RTSEN bit controls the URTS output of the USART. If Auto-RTS mode is enabled, hardware controls the RTS output, and the actual value of URTS will be copied in the URTS Control bit of the USART. As long as Auto-RTS is enabled, the value of the RTS Control bit is read-only for software.

Example: Suppose the USART operating in type 16550 mode has the trigger level in USARTn_FIFOCTRL register set to 0x2, then, if Auto-RTS is enabled, the USART will deassert the URTS output as soon as the receive FIFO contains 8 bytes. The URTS output will be reasserted as soon as the receive FIFO hits the previous trigger level: 4 bytes.

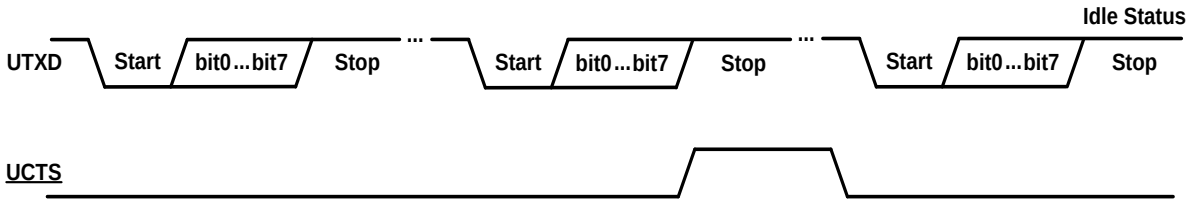


14.7.2 AUTO-CTS

The Auto-CTS function is enabled when CTSEN=1. If Auto-CTS is enabled, the transmitter circuitry checks the UCTS input before sending the next data byte. When UCTS is active (low), the transmitter sends the next byte. To stop the transmitter from sending the following byte, UCTS must be released before the middle of the last stop bit that is currently being sent. In Auto-CTS mode, a change of the UCTS signal does not trigger a modem status interrupt unless the CTS Interrupt Enable bit is set, but the DCTS bit in the USARTn_MS register will be set.

MSIE	CTSEN	Delta CTS (DCTS)	MODEM status interrupt
0	X	X	X
1	0	1	O
1	1	0	X
1	1	1	O

The Auto-CTS function typically eliminates the need for CTS interrupts. When flow control is enabled, a UCTS state change does not trigger host interrupts because the device automatically controls its own transmitter. Without Auto-CTS, the transmitter sends any data present in the transmit FIFO and a receiver overrun error can result.



During transmission of the second character the UCTS signal is negated. The third character is not sent thereafter. The USART maintains 1 on UTXD as long as UCTS is negated (high). As soon as UCTS is asserted, transmission resumes and a start bit is sent followed by the data bits of the next character.

14.8 AUTO-BAUD FLOW

14.8.1 AUTO-BAUD

The USART 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 USARTn_DLM and USARTn_DLL accordingly.

Auto-baud function is started by setting the START bit in USARTn_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 USARTn_ABCTRL register. In Mode 0 the baud rate is measured on two subsequent falling edges of the USART 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 USART RX pin (the length of the start bit).

The AUTORESTART bit in USARTn_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 USARTn_II register will get set if the interrupt is enabled (ABTOIE bit in USARTn_IE

register is set and the auto-baud rate measurement counter overflows).
- The ABEOINT interrupt in USARTn_II register will get set if the interrupt is enabled (ABTOIE bit in USARTn_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 USARTn_IE register.

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

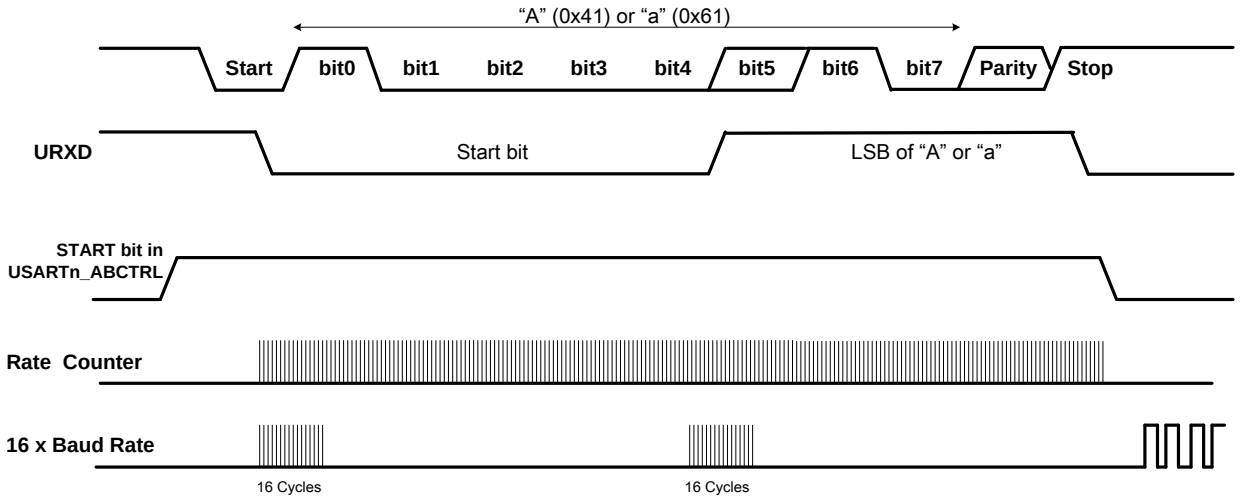
$$ratemin = \frac{2 \times PCLK}{16 \times 2^{15}} \leq UART_{baudrate} \leq \frac{PCLK}{16 \times (2 + databits + paritybits + stopbits)} = ratemax$$

14.8.2 AUTO-BAUD MODES

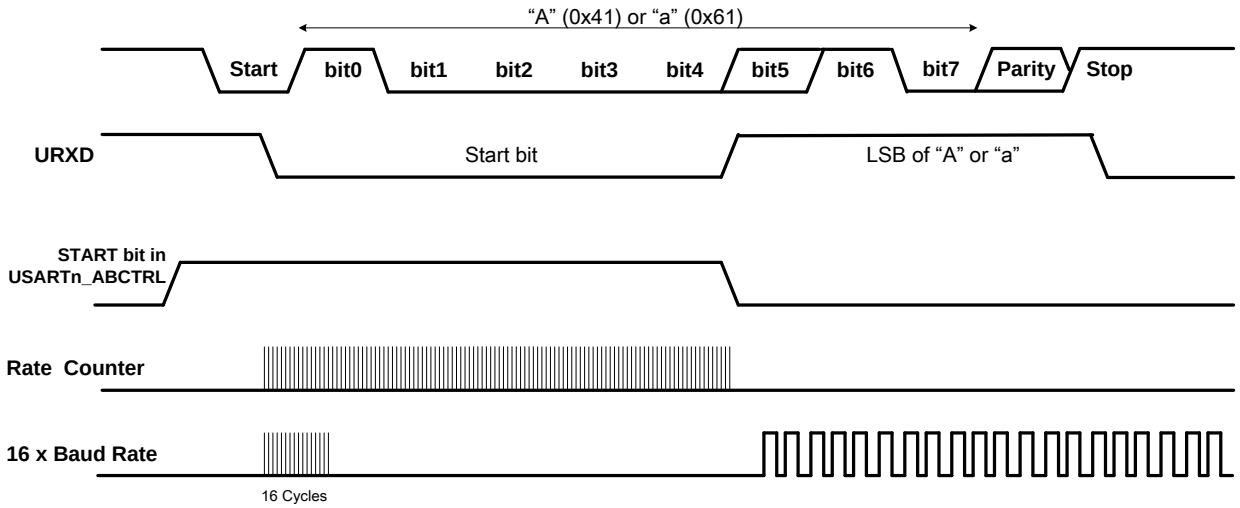
When the SW is expecting an “AT” command, it configures the USART with the expected character format and sets the ACR Start bit. The initial values in the divisor latches DLM and DLM don‘t care. Because of the “A” or “a” ASCII coding (“A” = 0x41, “a” = 0x61), the USART Rx pin sensed start bit and the 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 USARTn_PCLK cycles.
3. During the receipt of the start bit, 16 pulses are generated on the RSR baud input with the frequency of the USART 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 USARTn_ABCTRL register), the rate counter will continue incrementing with the pre-scaled USART input clock (USARTn_PCLK).
5. If MODE = 0, the rate counter will stop on next falling edge of the USART 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 USARTn_DLM/USARTn_DLL and the baud rate will be switched to normal operation. After setting the DLM/DLL, the end of auto-baud interrupt ABEOINT in USARTn_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**



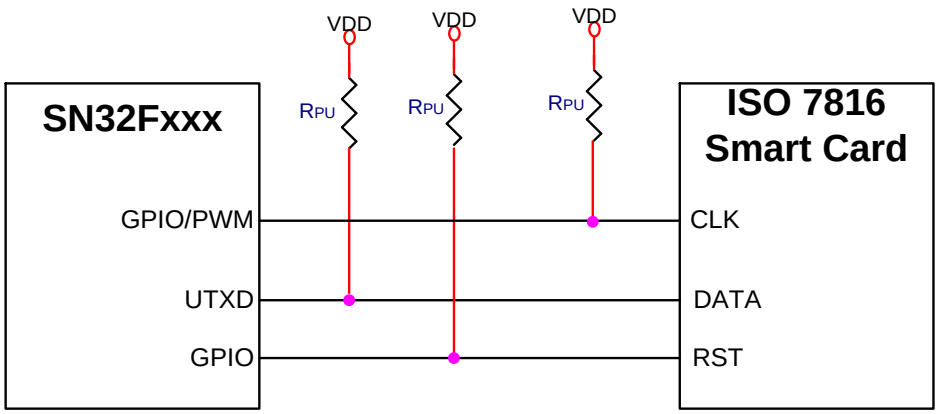
➢ **AUTO-BAUD RATE MODE 1 Waveform**



14.9 SMART CARD MODE

The Smart card mode is enabled by setting the USARTEN bit to 1 and MODE[2:0] = 011b in USARTn_CTRL register, the USART provides bidirectional serial data on the open-drain UTXD pin. No URXD pin is used in this mode. If a clock source is needed as an oscillator source into the Smart card, a timer match or PWM output can be used in cases when a higher frequency clock is needed that is not synchronous with the data bit rate.

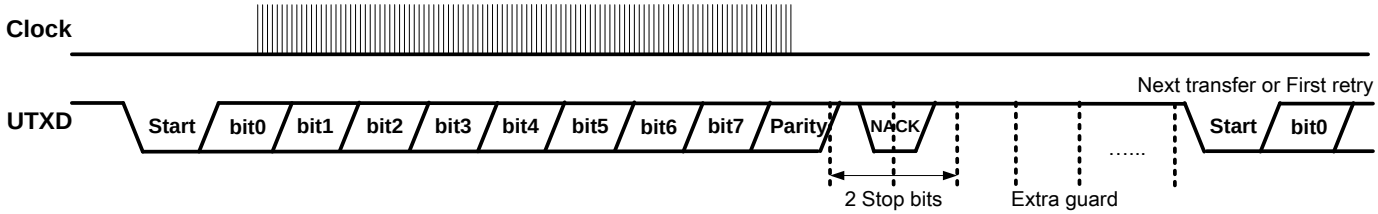
The USCLK pin may not be adequate for most asynchronous cards since it will output synchronously with the data and the data bit rate. SW must use timers to implement character and block waiting times instead.



14.9.1 SMART CARD SETUP PROCEDURE

A T = 0 protocol transfer consists of 8-bits of data, an even parity bit, and two stop bits t that allow for the receiver of the particular transfer to flag parity errors through the NACK response. Extra guard bits may be added according to card requirements.

If no NACK is sent, the next byte may be transmitted immediately after the last guard bit. If the NACK is sent, the transmitter will retry sending the byte until successfully received or until the SCICTRL retry limit has been met.



The smart card must be set up with the following considerations:

- Program SYS1_PRST register so that the USART is not continuously reset.
- Program USARTnPRE bits in SYS1_APBCP1 register for an initial USART frequency of 3.58 MHz.
- If necessary, program the USARTn_DLM and USARTn_DLL to 00 and 01 respectively, to pass the USART clock through without division.
- Program the USARTn_LC register for 8-bit characters, parity enabled, even parity.
- Program USARTn_SCICTRL register to enable the smart card feature with the desired options, and HW enables a USART TXD function automatically.
- Set up one or more timer(s) to provide timing as needed for ISO-7816 startup.
- Program USARTnCLKEN bit in SYS1_AHBCLKEN register to enable the USART clock.

Thereafter, SW should monitor card insertion, handle activation, wait for answer to reset as described in ISO7816-3.

14.10 SYNCHRONOUS MODE

The synchronous mode is selected by writing the MODE bits to 100b in USARTn_CTRL register.

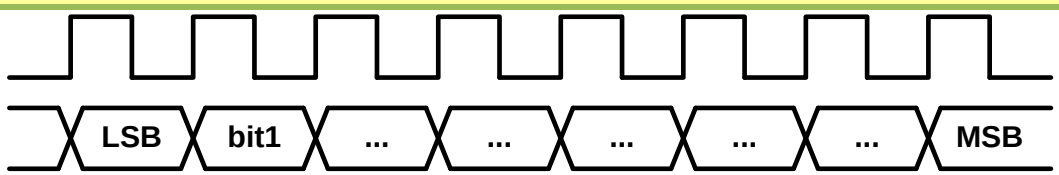
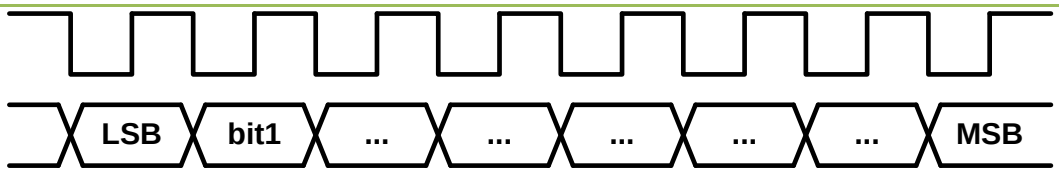
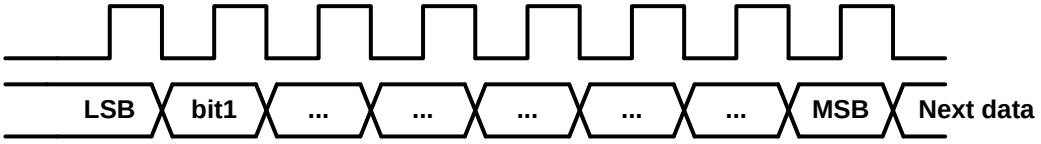
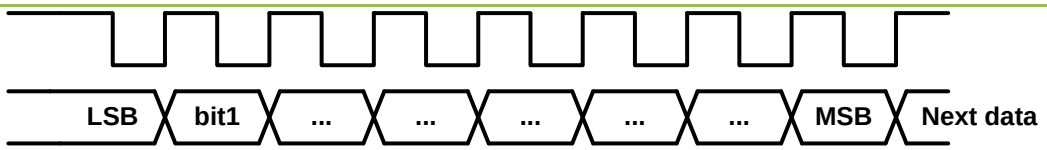
The USART allows the user to control a bidirectional synchronous serial communications in master mode. The SCLK pin is the output of the USART transmitter clock. No clock pulses are sent to the SCLK pin during start bit and stop bit.

The CPOL bit in USARTn_CTRL register allows the user to select the clock polarity, and the CPHA bit allows the user to select the phase of the clock.

During the Idle state, preamble and send break, the external SCLK clock is not activated. In synchronous mode the USART transmitter works exactly like in asynchronous mode. But as SCLK is synchronized with TX (according to CPOL and CPHA), the data on TX is synchronous.

In synchronous mode, the USART receiver works in a different manner compared to the asynchronous mode. If Receiver is enabled (RXEN=1), the data is sampled on SCLK (depending on CPOL and CPHA) without any oversampling. A setup and a hold time must be respected (which depends on the baud rate: 1/16 bit time).

- ***Note 1: The SCLK pin works in conjunction with the UTXD pin, so the clock is provided only if TXEN=1 in USARTn_CTRL register, and a data is being transmitted (the data register USART_DR has been written). This means that it is not possible to receive a synchronous data without transmitting data.***
- ***Note 2: The CPOL and CPHA bits in USARTn_SYNCCTRL register have to be selected when both the transmitter and the receiver are disabled (TXEN=0 and RXEN=0) to ensure that the clock pulses function correctly. These bits should not be changed while the transmitter or the receiver is enabled (TXEN=1 and RXEN=1).***
- ***Note 3: The Synchronous mode supports master mode only, it can NOT receive or send data related to an input clock (SCLK is always an output).***

CPOL	CPHA	SCLK Idle Status	Diagrams
0	1	Low	
1	1	High	
0	0	Low	
1	0	High	

14.11 USART REGISTERS

Base Address: 0x4001 6000 (USART0)
0x4005 6000 (USART1)

14.11.1 USART n Receiver Buffer register (USARTn_RB) (n=0, 1)

Address Offset: 0x00

This register is the top byte of the USART 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 USARTn_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 USART 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 USARTn_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 USART RX FIFO.	R	0

14.11.2 USART n Transmitter Holding register (USARTn_TH) (n=0, 1)

Address Offset: 0x00

This register is the top byte of the USART 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 USARTn_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

14.11.3 USART n Divisor Latch LSB registers (USARTn_DLL) (n =0, 1)

Address Offset: 0x00

The USART Divisor Latch is part of the USART Baud Rate Generator and holds the value used (optionally with the Fractional Divider) to divide the USARTn_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 USARTn_DLL and USARTn_DLM registers together form a 16-bit divisor, and DLAB bit in USARTn_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 USART Divisor Latch LSB Register, along with the DLM register, determines the baud rate of the USART.	R/W	0

14.11.4 USART n Divisor Latch MSB register (USARTn_DLM) (n=0,1)

Address Offset: 0x04

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

14.11.5 USART n Interrupt Enable register (USARTn_IE) (n=0, 1)

Address Offset: 0x04

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

Bit	Name	Description	Attribute	Reset
31:11	Reserved		R	0
10	TXERRIE	TXERR interrupt enable bit The status of this interrupt can be read from TXERR bit in USARTn_LS register. 0: Disable 1: Enable	R/W	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 USARTn_LS register. 0: Disable 1: Enable	R/W	0
3	MSIE	Modem Status interrupt enable bit. The components of this interrupt can be read from USARTn_MS register. 0: Disable 1: Enable	R/W	0
2	RLSIE	Receive Line Status (RLS) interrupt enable bit. The status of this interrupt can be read from USARTn_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 USARTn_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

14.11.6 USART n Interrupt Identification register (USARTn_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 USARTn_II register access. If an interrupt occurs during a USARTn_II register

access, the interrupt is recorded for the next USARTn_II register access.

Bit	Name	Description	Attribute	Reset
31:11	Reserved		R	0
10	TXERRIF	TXERR interrupt flag 0: TXERR has not occurred. 1: TXERR has occurred and interrupt is enabled.	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 USARTn_FIFOCTRL register.	R	1
5:4	Reserved		R	0
3:1	INTID[2:0]	Interrupt identification which identifies an interrupt corresponding to the USARTn RX FIFO. 0x3: 1 - Receive Line Status (RLS). 0x2: 2a - Receive Data Available (RDA). 0x6: 2b - Character Time-out Indicator (CTI). 0x1: 3a - THRE Interrupt. 0x0: 4 - Modem status 0x7: 3b – TEMT Interrupt Other: Reserved	R	0
0	INTSTATUS	Interrupt status. The pending interrupt can be determined by evaluating USARTn_II[3:1]. 0: At least one interrupt is pending. 1: No interrupt is pending.	R	1

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

Interrupt	USARTn_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 USARTn_LS register
RDA	0100	2nd	RX data in FIFO reached trigger level (FCR0=1)	Read USARTn_RB register or USART 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 USARTn_RB register
THRE	0010	3rd	THRE	Read USARTn_II register (if source of interrupt) or Write THR register
MS	0000	Lowest	CTS, DSR, RI, or DCD.	MSR Read

TEMT	1110	3rd	TEMT	Read USARTn_II register (if source of interrupt) or Write THR register

14.11.7 USART n Line Status register (USARTn_LS) (n=0,1)

Address Offset: 0x14

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

Bit	Name	Description	Attribute	Reset
31:9	Reserved		R	0
8	TXERR	TX Error flag. (Only available iIn smart card T=0 operation) 0: No TX Error. 1: Smart card has NACKed a transmitted character, one more than the number of times indicated by the TXRETRY field.	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 USARTn_RB register. This bit is cleared when the USARTn_LS register is read and there are no subsequent errors in the USART FIFO. 0: USARTn_RB register contains no USART RX errors or FIFOEN=0 1: USARTn_RB register contains at least one USART 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 USART is ready to accept a new character for transmission. In addition, this bit causes the USART 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 USARTn_LS register read clears BI bit. The time of break detection is dependent on FIFOEN bit in USARTn_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 USARTn_LS register read clears FE bit. The time of the framing error detection is dependent on FIFOEN bit in USARTn_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 USARTn_LS register read clears PE bit. Time of parity error detection is dependent on FIFOEN bit in USARTn_FIFOCTRL register. 0: Parity error status is inactive.	R	0

		1: Parity error status is active.		
1	OE	Overrun Error flag. The overrun error condition is set as soon as it occurs. A USARTn_LS register read clears OE bit. OE=1 when USART RSR has a new character assembled and the USARTn_RB FIFO is full. In this case, the USARTn_RB FIFO will not be overwritten and the character in the USARTn_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 USARTn_RB FIFO holds an unread character and is cleared when the USARTn_RB FIFO is empty. 0: USARTn_RB FIFO is empty. 1: USARTn_RB FIFO contains valid data.	R	0

14.11.8 USART n FIFO Control register (USARTn_FIFOCTRL) (n=0,1)

Address Offset: 0x08

This register controls the operation of the USART 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 USART 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 USART FIFOs. 1: Writing a logic 1 to reset the pointer logic in USART TX FIFO. HW shall clear this bit automatically.	W	0
1	RXFIFORST	RX FIFO Reset bit. 0: No impact on either of USART FIFOs. 1: Writing a logic 1 to reset the pointer logic in USART RX FIFO. HW shall clear this bit automatically.	W	0
0	FIFOEN	FIFO enable 0: No effect 1: Enable for both USART Rx and TX FIFOs and USARTn_FIFOCTRL [7:1] access. This bit must be set for proper USART operation.	W	1

14.11.9 USART n Line Control register (USARTn_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 USART 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). Must be 1 in Smart card mode.	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

14.11.10 USART n Modem Control register (USARTn_MC) (n=0,1)

Address Offset: 0x10

This register enables the modem loopback mode and controls the modem output signals.

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7	CTSEN	CTS enable bit 0: Disable Auto-CTS flow control. 1: Enable Auto-CTS flow control.	R/W	0
6	RTSEN	RTS enable bit 0: Disable Auto-RTS flow control. 1: Enable Auto-RTS flow control.	R/W	0
5:2	Reserved		R	0
1	RTSCTRL	Source for modem output pin RTS.	R/W	0
0	Reserved		R	0

14.11.11 USART n Modem Status register (USARTn_MS) (n=0,1)

Address Offset: 0x18

This register is a read-only register that provides status information on USART input signals.

✸ ***Note: Whenever the CTS bit changes state, an interrupt is generated if the MODEM Status Interrupt is enabled.***

Bit	Name	Description	Attribute	Reset
31:5	Reserved		R	0
4	CTS	Clear To Send State. Complement of input signal CTS. This bit is connected to USARTn_MC[1] in modem loopback mode.	R	0
3:1	Reserved		R	0
0	DCTS	Delta CTS. Set upon state change of input CTS. Cleared after reading this register. 0: No change detected on modem input CTS. 1: State change detected on modem input CTS.	R	0

14.11.12 USART n Scratch Pad register (USARTn_SP) (n=0, 1)

Address Offset: 0x1C

This register has no effect on the USART 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

14.11.13 USART n Auto-baud Control register (USARTn_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 USART disabled making sure that USART is fully SW and HW compatible with USARTs 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 USART 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

14.11.14 USART n Fractional Divider register (USARTn_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 USART 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 USARTn_DLM=0, the value of the USARTn_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 (Not supported for IrDA mode)	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 USART baud rate	R/W	0

14.11.15 USART n Control register (USARTn_CTRL) (n=0, 1)

Address Offset: 0x30

In addition to HW flow control (Auto-CTS and Auto-RTS mechanisms), this register enables implementation of SW flow control.

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

It is strongly suggested to let the USART 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 USARTn_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 USARTn_TH register or TX FIFO into the transmit shift register. SW can clear this bit when it detects that the HW-handshaking TX-permit signal (CTS) has gone false, or with SW handshaking, when it receives an XOFF character (DC3). SW can set this bit again when it detects that the TX-permit signal has gone true, or when it receives an XON (DC1) character.	R/W	1
6	RXEN	0: Disable RX related function 1: Enable RX	R/W	1
5:4	Reserved		R	0
3:1	MODE[2:0]	USARTn Mode 000: UART mode. HW will switch GPIO to UTXDn and URXDn. 001: Modem mode. HW will switch GPIO to UTXDn, URXDn, UDSRn, UCTSn, UDCDn, URIn, UDTRn and URTSn. 010: Reserved 011: Smart Card mode. HW will switch GPIO to UTXDn, and enable UTXDn pin with open-drain. 100: Synchronous mode. HW will switch GPIO to UTXDn, URXDn , and USCLK pin.	R/W	0

		101:RS-485 mode. HW will switch GPIO to UTXDn, URXDn pin.		
0	USARTEN	USART enable 0: Disable . All USART shared pins act as GPIO. 1: Enable. HW switches GPIO to USART pin according to MODE bits automatically.	R/W	0

14.11.16 USART n Half-duplex Enable register (USARTn_HDEN) (n=0, 1)

Address Offset: 0x34

After reset the USART will be in full-duplex mode, meaning that both TX and RX work independently. After setting the HDEN bit, the USART will be in half-duplex mode. In this mode, the USART 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 USART 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.

✷ ***Note: This register should be disabled when in smart card mode or IrDA mode (Smartcard and IrDA by default run in half-duplex mode).***

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

14.11.17 USART n Smart card Interface Control register (USARTn_SCICTRL) (n=0, 1)

Address Offset: 0x38

Bit	Name	Description	Attribute	Reset
31:24	Reserved		R	0
23:16	TC[7:0]	Count for SCLK clock cycle when SCLKEN=1. SCLK will toggle every (TC[7:0]+1) * USARTn_PCLK cycle	R/W	0x0
15:8	XTRAGUARD	When the protocol selection T= 0, this field indicates the number of bit times (ETUs) by which the guard time after a character transmitted by the USART should exceed the nominal 2 bit times. 0xFF in this field may indicate that there is just a single bit after a character and 11 bit times/character	R/W	N/A
7:5	TXRETRY[2:0]	When the protocol selection T = 0, the field controls the maximum number of retransmissions that the USART will attempt if the remote device signals NACK. When NACK has occurred this number of times plus one, the TX Error (TXERR) bit in USARTn_LS register is set, an interrupt is requested if enabled, and the USART is locked until the FIFO is cleared.	R/W	N/A
4	Reserved		R	0
3	SCLKEN	SCLK enable Enable if the smart card to be communicated with requires a clock. 0: Disable 1: Enable. HW will switch GPIO to UnSCLK pin.	R/W	0
2	PROTSEL	Protocol selection as defined in the ISO7816-3 standard. 0: T = 0 1: T = 1	R/W	0
1	NACKDIS	NACK response disable bit. Only applicable in T=0. 0: A NACK response is enabled.	R/W	0

		1: A NACK response is inhibited.		
0	Reserved		R	0

14.11.18 USART n RS485 Control register (USARTn_RS485CTRL) (n=0, 1)

Address Offset: 0x3C

Bit	Name	Description	Attribute	Reset
31:6	Reserved		R	0
5	OINV	Polarity control. This bit reverses the polarity of the direction control signal on the RTS pin. 0: The direction control pin will be driven to logic 0 when the transmitter has data to be sent. It will be driven to logic 1 after the last bit of data has been transmitted. 1: The direction control pin will be driven to logic 1 when the transmitter has data to be sent. It will be driven to logic 0 after the last bit of data has been transmitted.	R/W	0
4	ADCEN	Auto Direction control enable bit. 0: Disable 1: Enable. RTS pin is used for direction control. HW will switch GPIO to URTSn) pin automatically.	R/W	0
3	Reserved		R	0
2	AADEN	Auto Address Detect (AAD) enable bit. 0: Disable 1: Enable	R/W	0
1	RXEN	RS-485/EIA-485 Receiver enable bit. (Only work when NMMEN = 1) 0: Disable 1: Enable	R/W	0
0	NMMEN	RS-485/EIA-485 Normal Multidrop Mode (NMM) enable bit. 0: Disable 1: Enable. In this mode, an address is detected when a received byte causes the USART to set the parity error and generate an interrupt.	R/W	0

14.11.19 USART n RS485 Address Match register (USARTn_RS485ADRMATCH) (n=0, 1)

Address Offset: 0x40

This register contains the address match value for RS-485/EIA-485 mode.

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	MATCH[7:0]	The address value to be matched.	R/W	0

14.11.20 USART n RS485 Delay Value register (USARTn_RS485DLYV)(n=0, 1)

Address Offset: 0x44

The user may program this register with a delay between the last stop bit leaving the TXFIFO and the de-assertion of RTS. This delay time is in periods of the baud clock. Any delay time from 0 to 255 bit times may be programmed.

Bit	Name	Description	Attribute	Reset
31:8	Reserved		R	0
7:0	DLY[7:0]	The direction control (RTS) delay value. This register works in conjunction with an 8-bit counter.	R/W	0

14.11.21 USART n Synchronous Mode Control Register (USARTn_SYNCCTRL) (n=0,1)

Address Offset: 0x48

This register controls the synchronous mode. When this mode is in effect, the USART generates or receives a bit clock on the SCLK pin and applies it to transmit and receive shift registers.
Synchronous mode should not be used with smartcard mode.

Bit	Name	Description	Attribute	Reset
31:3	Reserved		R	0
2	CPHA	Clock phase for edge sampling. 0: Sample on the rising edge of SCLK 1: Sample on the falling edge of SCLK	R/W	0
1	CPOL	Clock polarity selection bit 0: SCLK idles at Low level. 1: SCLK idles at High level.	R/W	0
0	Reserved		R	0

15 I2S

15.1 OVERVIEW

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

15.2 FEATURES

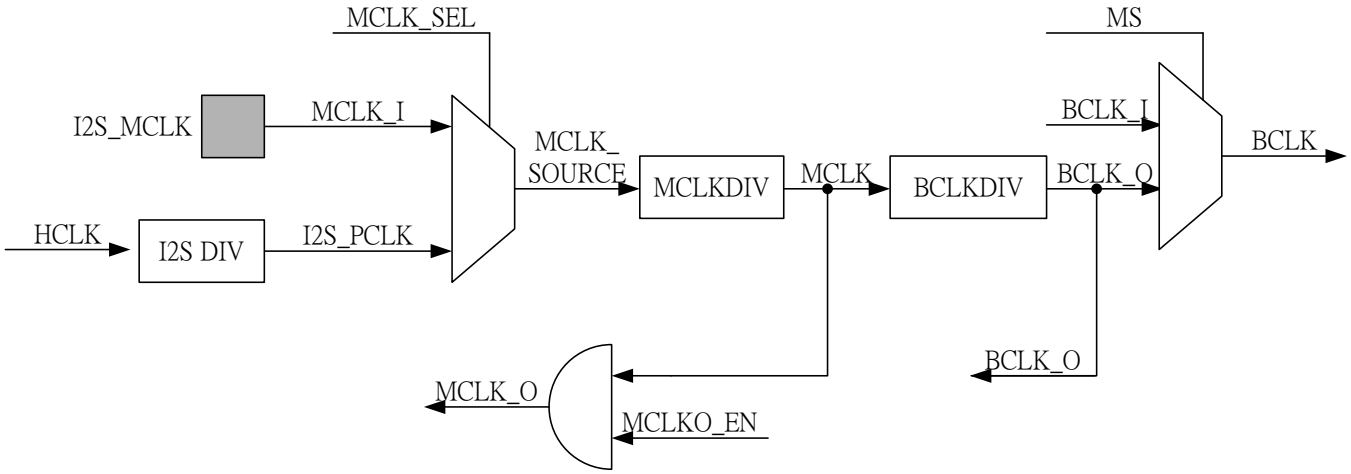
- I2S can operate as either master or slave.
- Capable of handling 8/16/24/32-bit data length.
- Mono and stereo audio data supported.
- I2S and MSB justified data format supported.
- 8 word (32-bit) FIFO data buffers are provided.
- Generate interrupt requests when buffer levels cross a programmable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

15.3 PIN DESCRIPTION

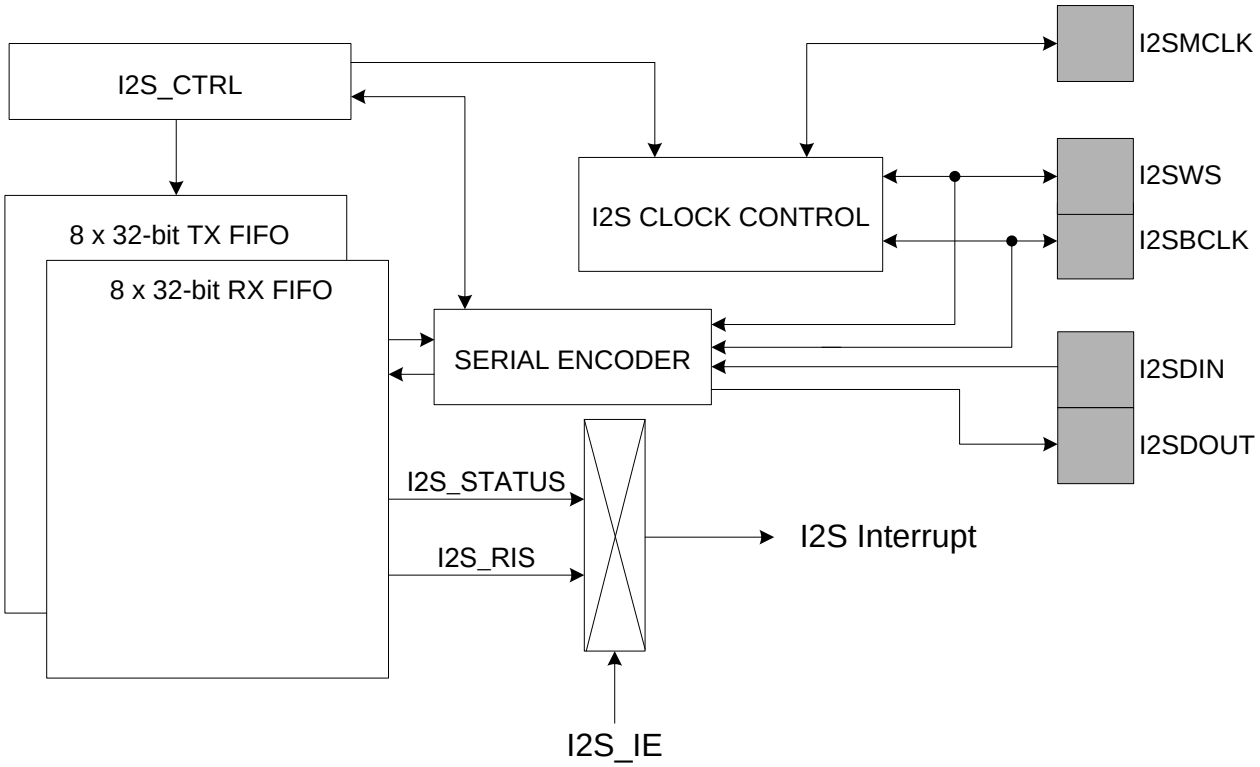
Pin Name	Type	Description	GPIO Configuration
I2SBCLK	O	I2S Bit clock (Master)	
	I	I2S Bit clock (Slave)	Depends on GPIOn_CFG
I2SWS	O	I2S Word Select (Master)	
	I	I2S Word Select (Slave)	Depends on GPIOn_CFG
I2SDIN	I	I2S Received Serial data	Depends on GPIOn_CFG
I2SDOUT	O	I2S Transmitted Serial data	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

15.4 BLOCK DIAGRAM

15.4.1 I2S CLCOK CONTROL



15.4.2 I2S BLOCK DIAGRAM

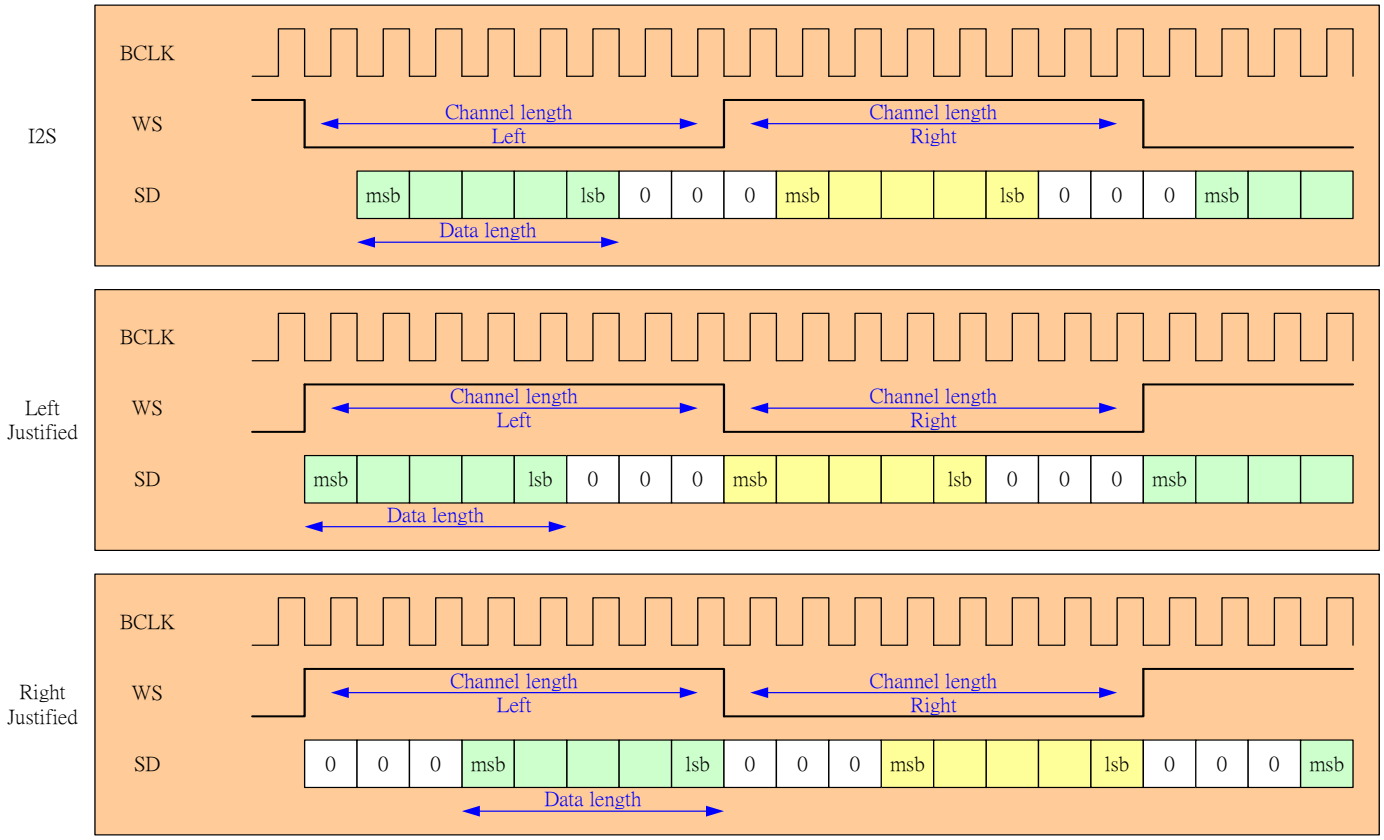


15.5 FUNCTIONAL DESCRIPTION

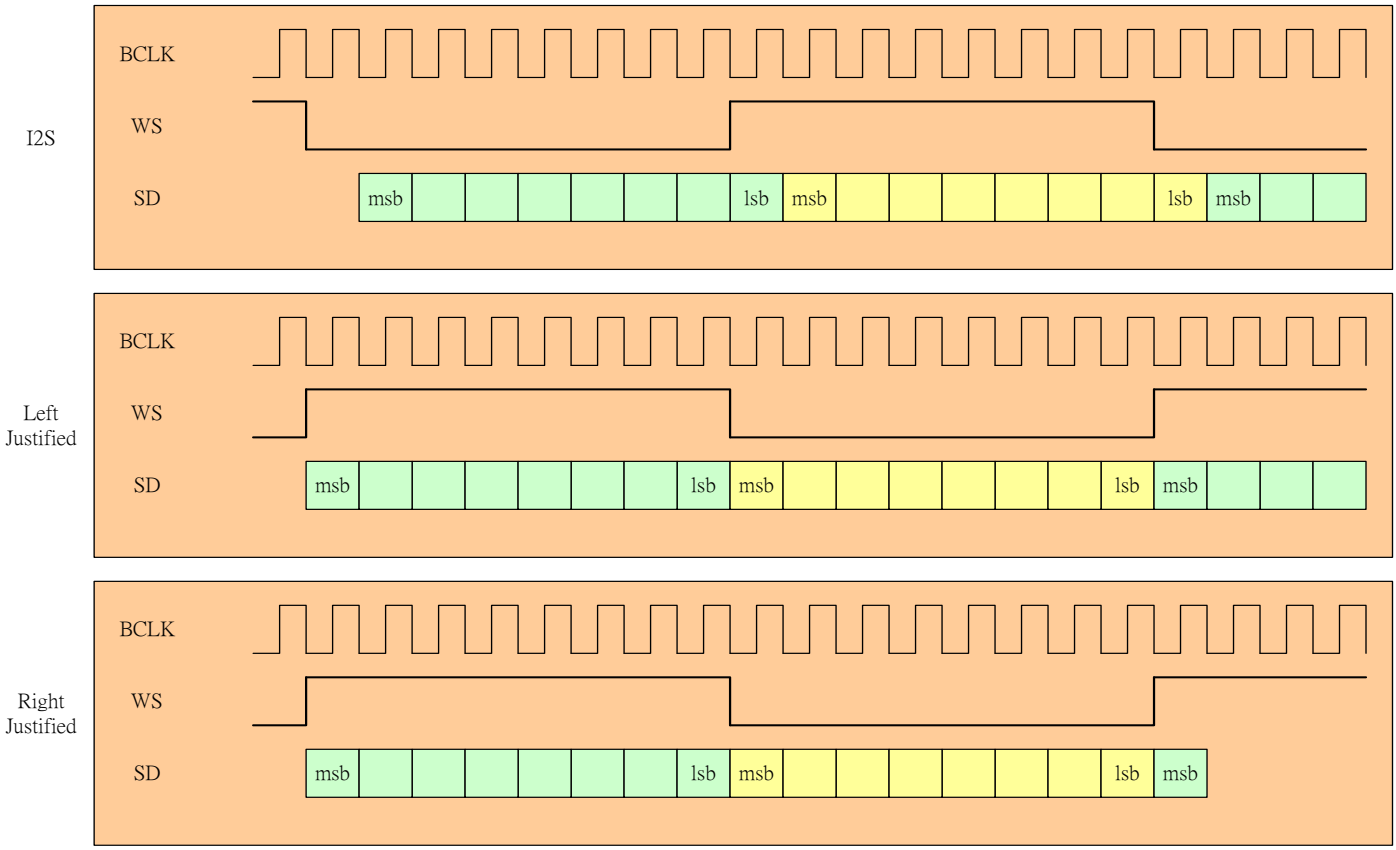
15.5.1 I2S OPERATION

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

Channel Length > Data Length:



Channel Length = Data Length



15.5.2 I2S FIFO OPERAION

15.5.2.1 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

15.5.2.2 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

15.6 I2S REGISTERS

Base Address: 0x4001 A000

15.6.1 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	R/W	0
30:25	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)	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 bit 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 0: Disable 1: Enable	R/W	0

5:4	FORMAT[1:0]	I2S operation format. 00: Standard I2S format 01: Left-justified format 10: Right(MSB)-justified format 11: Reserved	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.	R/W	0
2	MONO	Mono/Stereo selection bit 0: Stereo 1: Mono	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: Disable 1: Start Transmit/Receive	R/W	0

15.6.2 I2S Clock register (I2S_CLK)

Address Offset: 0x04

Bit	Name	Description	Attribute	Reset
31:17	Reserved		R	0
16	CLKSEL	I2S clock source selection 0: HCLK 1: EHS XTAL	R/W	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)	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 GPIO	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

15.6.3 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	R	0

		… … 1000: 8/8 RX FIFO is used (Full) Other: Reserved		
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

15.6.4 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

15.6.5 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

15.6.6 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

15.6.7 I2S RXFIFO register (I2S_RXFIFO)

Address Offset: 0x18

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

15.6.8 I2S TXFIFO register (I2S_TXFIFO)

Address Offset: 0x1C

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

16 4x32 LCD DRIVER

16.1 OVERVIEW

The MCU builds in 4x32 (4 commons and up to 32 segments, 128 dots) LCD driver, includes R type and C type (1C and 4C) structures with 4 common pins and up to 32 segment pins. The LCD scan timing can support 1/2 duty, 1/3 duty, and 1/4 duty, besides, 1/2 bias or 1/3 bias structure are supported. Of these pins, all common and segment pins are shared with GPIO, and can be selected by programming LCD_CTRL register. R type is using internal or external bias circuit to adjust LCD power and bias voltage. C type is using internal charge pump to adjust LCD power and bias voltage.

16.2 FEATURES

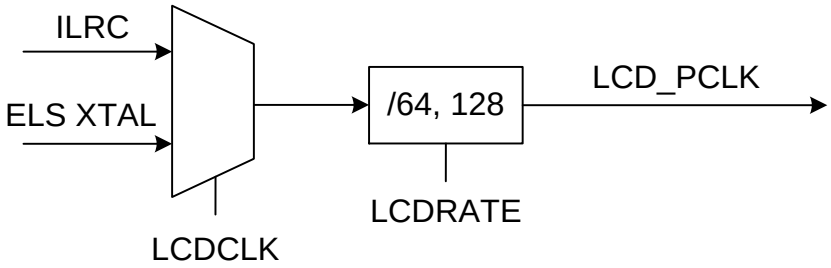
- Support R/C-type
- Support up to 128 (4 x 32) dots
- Common 0~3 and Segment 0~31, V3, V2, CL+, CL- are all shared with GPI/O pins
- Support 1/2 bias and 1/3 bias voltage
- Support 1/2 duty, 1/3 duty, 1/4 duty
- Configurable frame frequency
- Internal Charge pump, adjustable contrast adjustment , and configurable charge pump frequency
- Embedded LCD bias reference ladder (R-Type)
- LCD frame interrupt

16.3 PIN DESCRIPTION

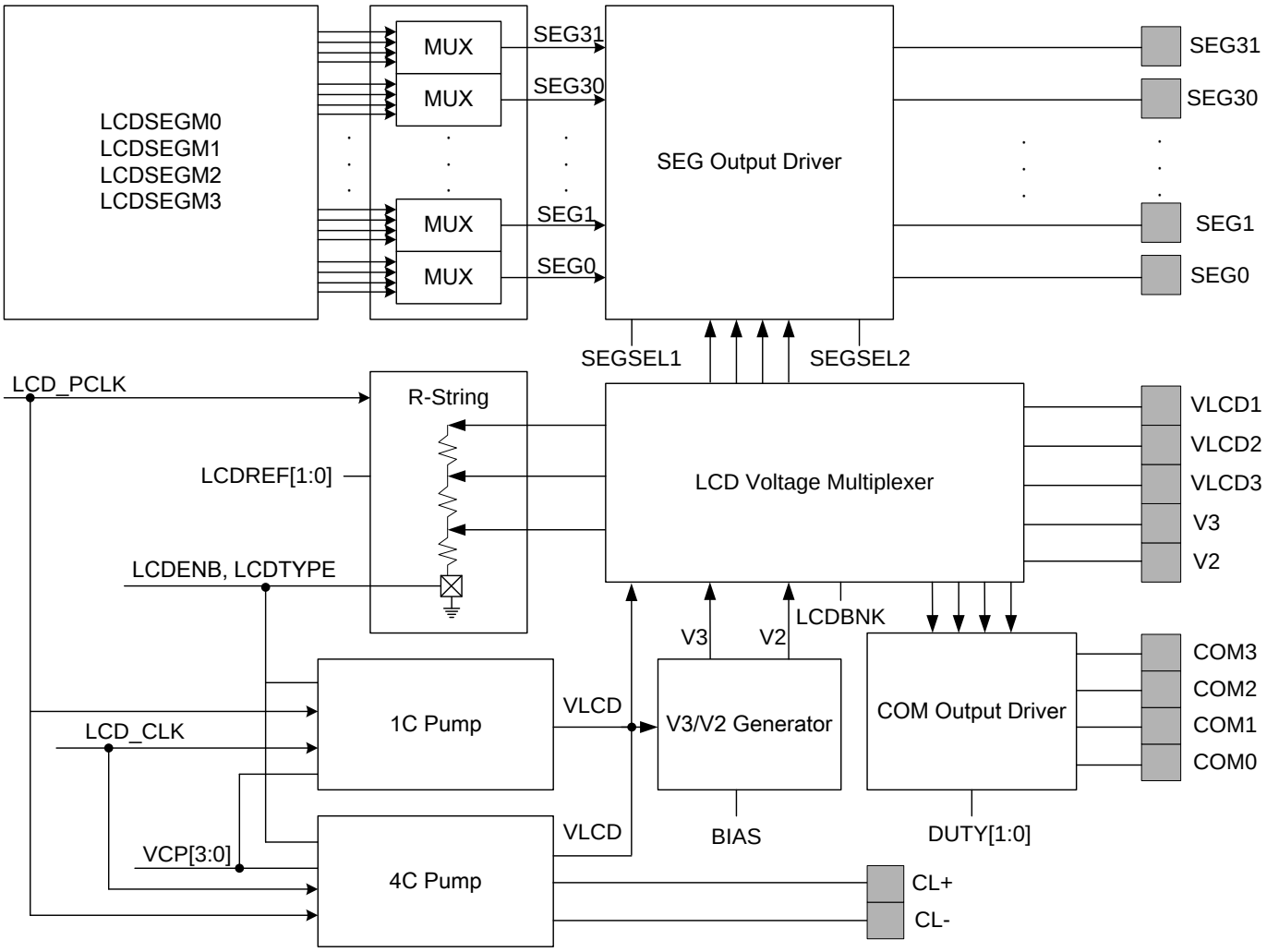
Pin Name	Type	Description	GPIO Configuration
SEGx	O	LCD driver segment pins	
COMx	O	LCD driver common pins	
CL+	P	C-Type LCD charge pump capacitor	
CL-	P	C-Type LCD charge pump capacitor	
VLCD1	P	LCD driver power input pin for COM0~3, SEG0~11	
VLCD2	P	LCD driver power input pin for SEG12~23	
VLCD3	P	LCD driver power pin for SEG24~31	
V3	P	2/3 VLCD bias voltage	
V2	P	1/3 VLCD bias voltage	

16.4 BLOCK DIAGRAM

16.4.1 LCD CLOCK CONTROL



16.4.2 LCD BLOCK DIAGRAM

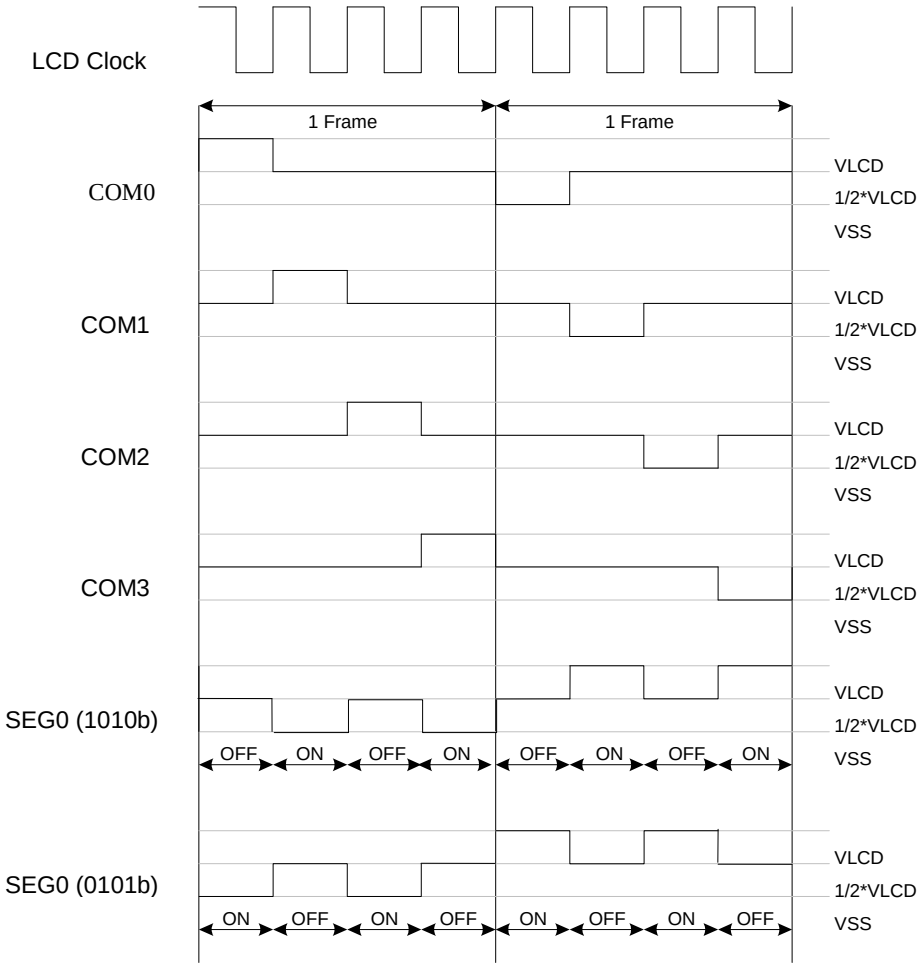


16.5 LCD TIMING

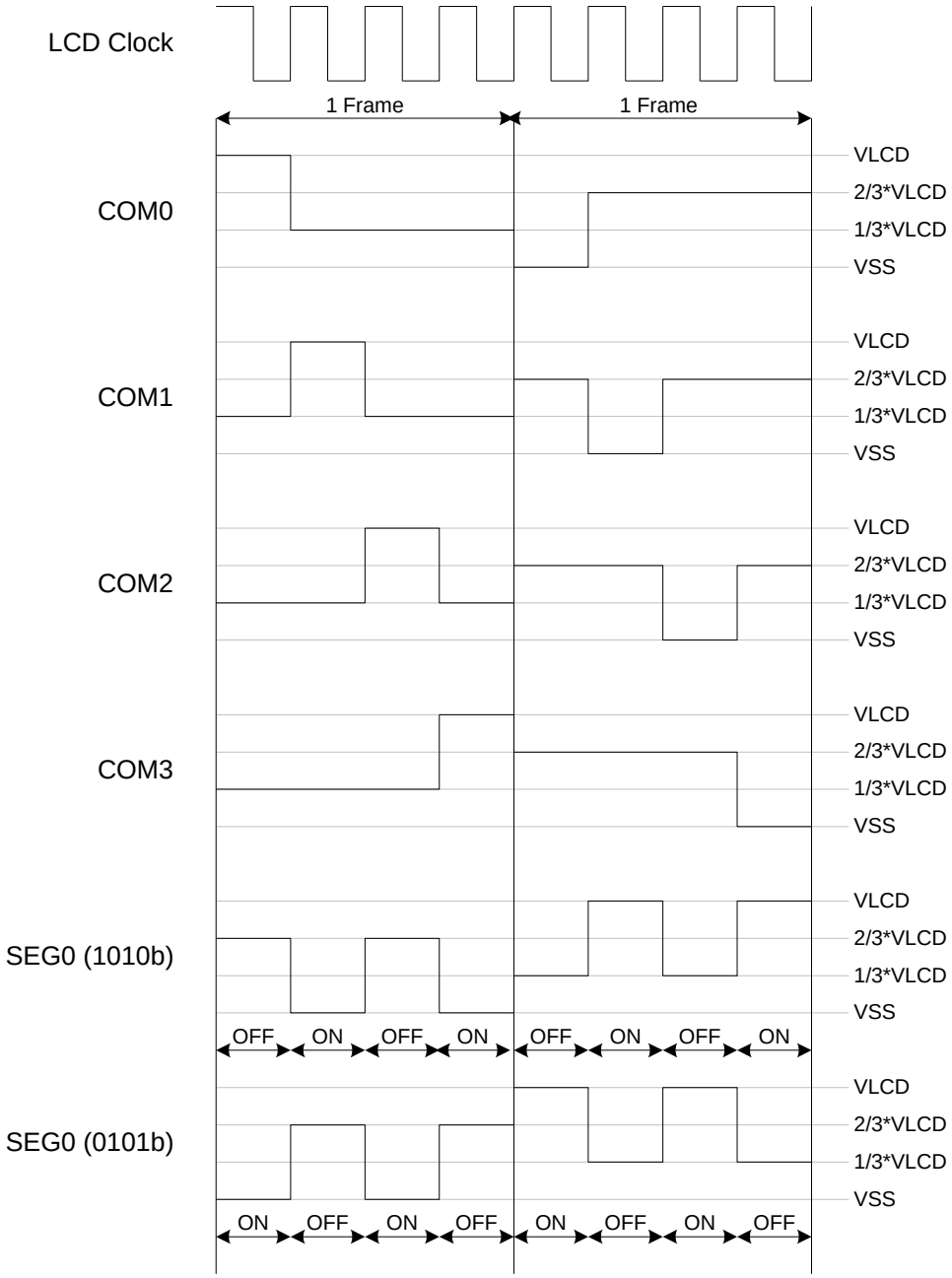
16.5.1 LCD Timing Table

LCDCLK	LCD Clock Source	LCDRATE	LCD Clock Rate (LCD_PCLK)	Duty	Frame Rate = LCD clock rate * Duty
0	ILRC 32KHz	0	32KHz / 64 = 500Hz	1/4	500Hz / 4 = 125Hz
		1	32KHz / 128 = 250Hz	1/2	250Hz / 2 = 125Hz
		1	32KHz / 128 = 250Hz	1/4	250Hz / 4 = 62.5Hz
1	ELS XTAL 32768Hz	0	32768Hz / 64 = 512Hz	1/4	512Hz / 4 = 128Hz
		1	32768Hz / 128 = 256Hz	1/4	256Hz / 4 = 64Hz

16.5.2 LCD Driver Waveform



1/4 duty, 1/2 bias



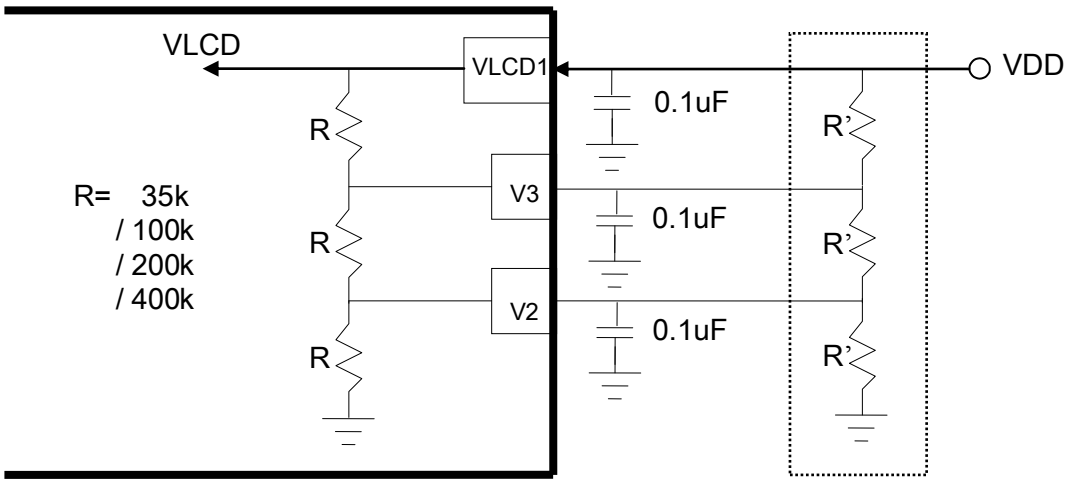
1/4 duty, 1/3 bias

16.6 R-TYPE LCD APPLICATION CIRCUIT

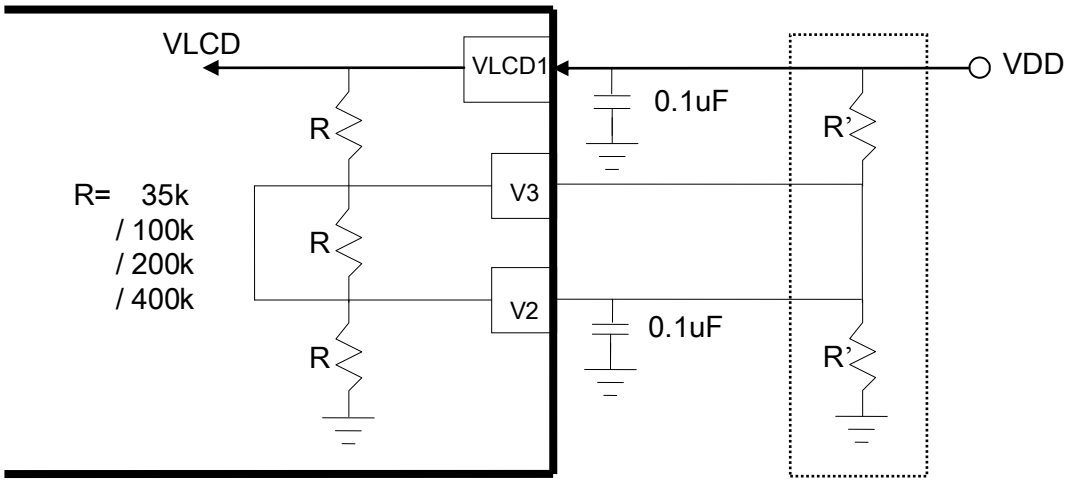
When R-type LCD is enabled (LCDENB=1, LCDTYPE[1:0]=00b in LCD_CTRL register), LCD power source (VLCD) is from external power via VLCD1 pad, and shall be connected to VDD with PCB layout, not internal short to VDD. HW will assign COM0~3 (refer to DUTY[1:0]), SEG0~11, V3, V2 pin as LCD pins instead of GPIO automatically.

V3 and V2 bias voltage is sourced by internal resistor voltage division, and the internal selective 35k, 100k, 200k, 400k resistor are selected by REF[1:0] bits in LCD_CTRL1 register. User can connect additional external resistance between VLCD1/V3/V2 for more driving current.

➢ **1/3 Bias (V3= 2/3*VLCD, V2 = 1/3*VLCD)**



➢ **1/2 Bias (V3 = V2 = 1/2*VLCD)**



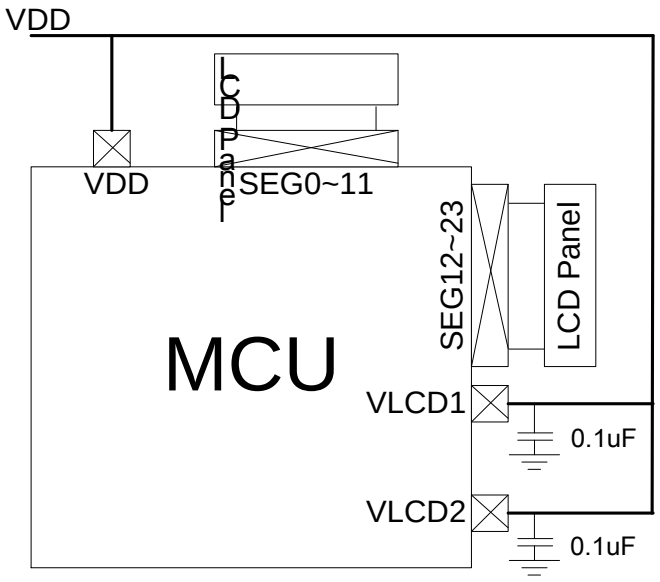
✷ ***Note: The 0.1uF capacitors of VLCD1/V3/V2 pins are necessary for power stable, and please put close to VLCD1/V3/V2 pins.***

Segment 12~Segment 23 pins are shared with P0.10~P0.15 and P1.0~P1.5. When these pins are used as LCD pins, the SEG1SEL bit shall be set as "1", and VLCD2 shall also be connected to VDD with PCB layout.

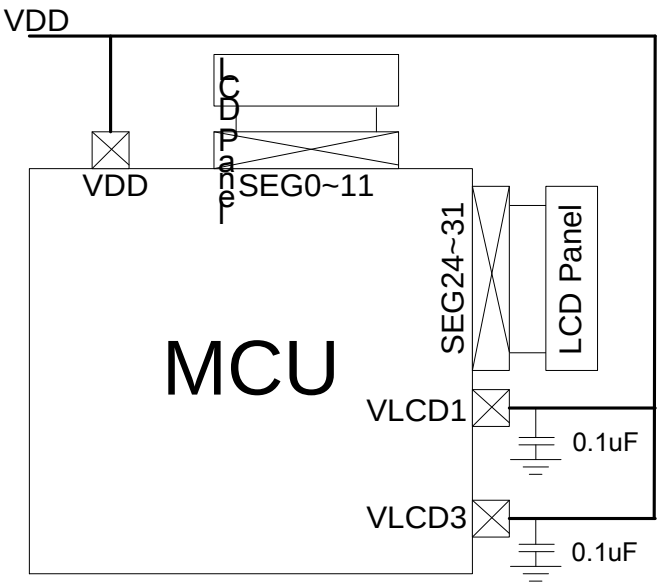
Segment 24~Segment 31 pins are shared with P0.0~P0.7. When these pins are used as LCD pins, the SEG2SEL bit

shall be set as “1”, and VLCD3 shall also be connected to VDD with PCB layout.

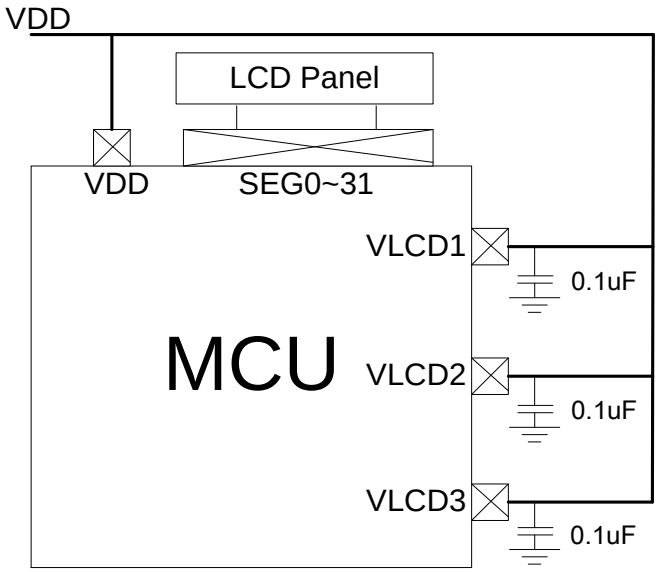
SEG1SEL = 1



SEG2SEL = 1



SEG1SEL = 1 & SEG2SEL = 1



16.7 C-TYPE LCD APPLICATION CIRCUIT

When C-type LCD is enabled (LCDENB=1, LCDTYPE[1:0]=01b or 10b) in LCD_CTRL register), The LCD power (VLCD) is supplied by internal LCD charge-pump, and is internal short to VLCD1. HW will assign COM0~3, SEG0~11, V3, V2, CL+, CL- pin as LCD pins instead of GPIO automatically.

The charge-pump voltage VLCD level is controlled by VCP[3:0] bits in LCD_CCTRL1 register. In 1/3 bias condition, V2 is the charge pump output voltage which level is 1/3*VLCD. V3 is 2 times of V2 by charge-pump which level is 2/3*VLCD; in 1/2 bias condition, V2 is the charge-pump output voltage which level is 1/2*VLCD, the voltage level of V3 is equal to V2.

Segment 12~Segment 23 pins are shared with P0.10~P0.15 and P1.0~P1.5. When these pins are used as LCD pins, the SEG1SEL bit shall be set as “1”, and VLCD2 shall also be connected to VLCD1 with PCB layout.

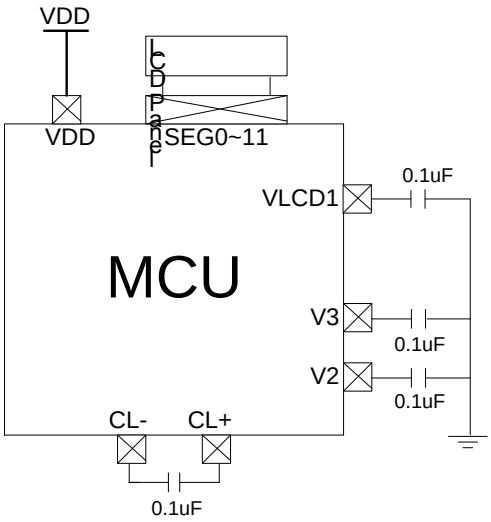
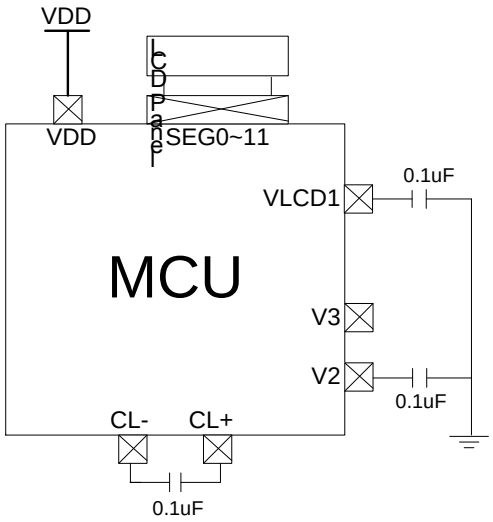
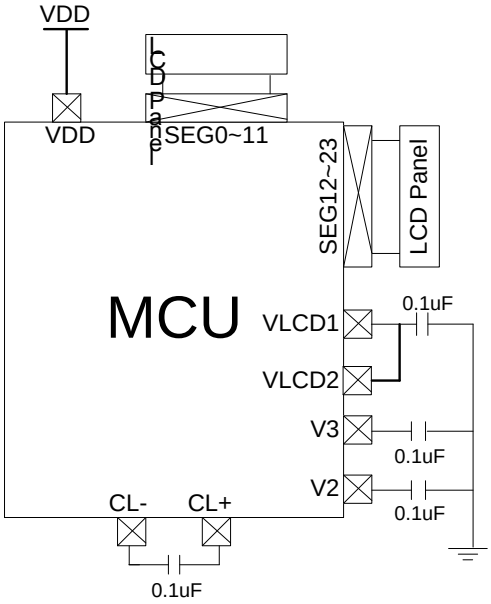
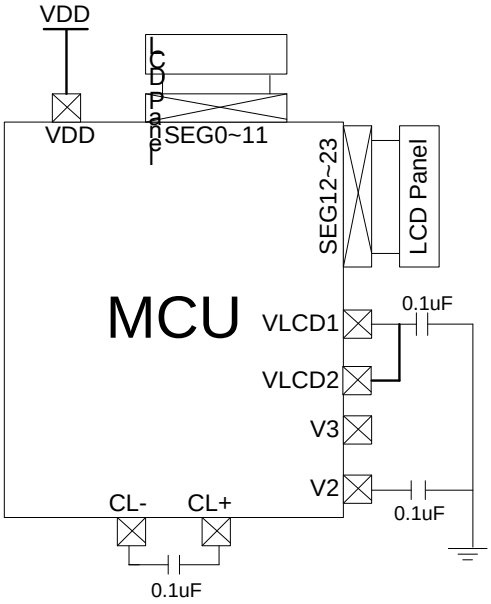
Segment 24~Segment 31 pins are shared with P0.0~P0.7. When these pins are used as LCD pins, the SEG2SEL bit shall be set as “1”, and VLCD3 shall also be connected to VLCD1 with PCB layout.

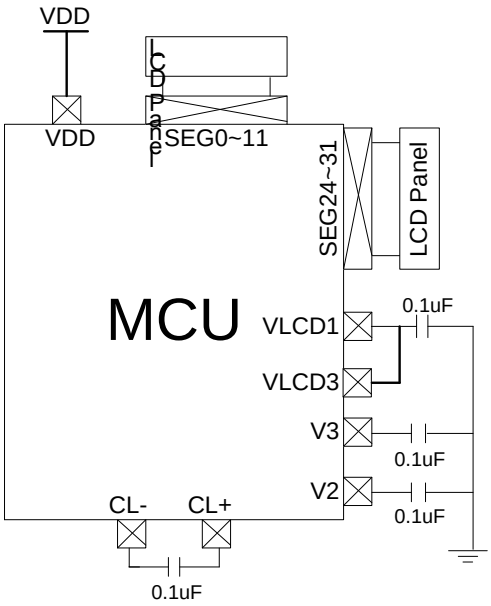
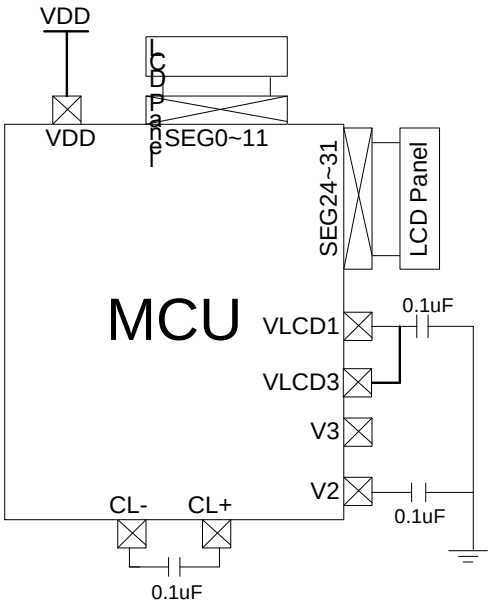
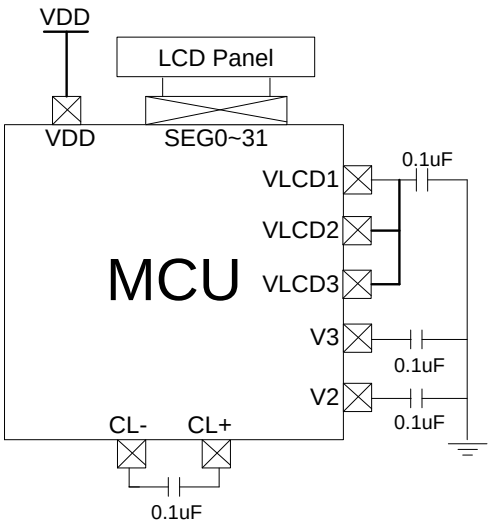
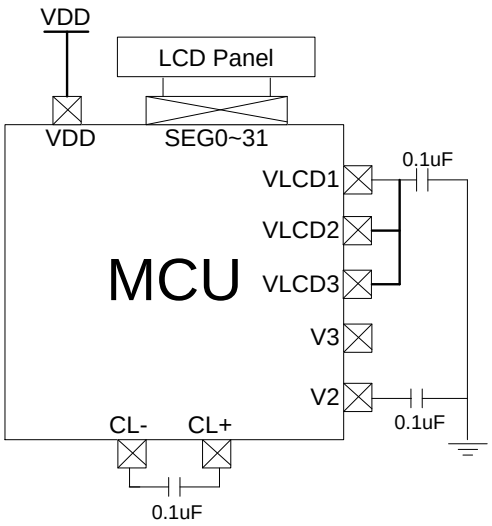
✷ ***Note: V2 voltage is charge-pump output voltage.***

16.7.1 4C-TYPE

✷ ***Note:***

1. ***Charge-pump voltage for VLCD is 2.7V~5.0V***
   - ***In 1/2 bias condition, VDD shall be larger than V3.***
   - ***In 1/3 bias condition, VDD shall be larger than V3-0.3V if VLCD > 3.6V***
2. ***Connect a 0.1uF or 0.47uF capacitor between CL+ and CL- pins. Users can adjust the capacitor value depend on the LCD panel size.***
3. ***The 0.1uF capacitors of VLCD1/V3/V2 pins are necessary for power stable. Users can adjust the capacitor value depend on the LCD panel size. Besides, please put close to VLCD1/V3/V2 pins.***

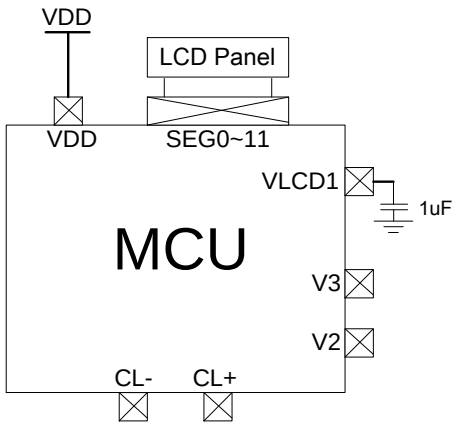
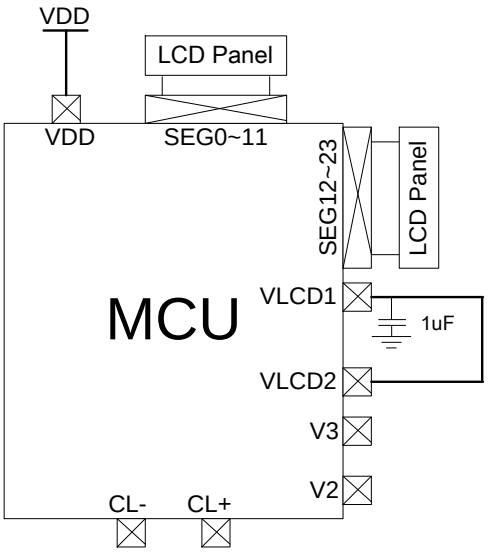
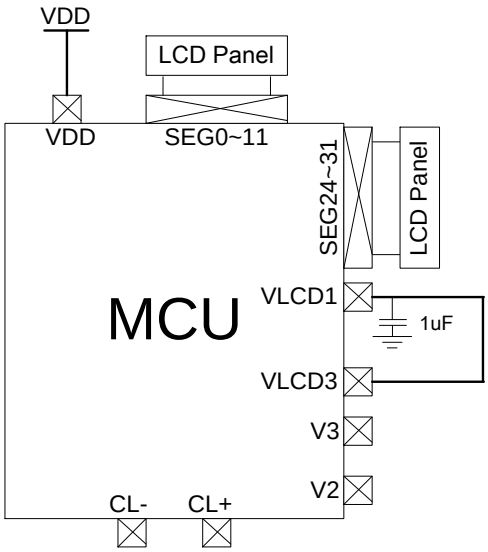
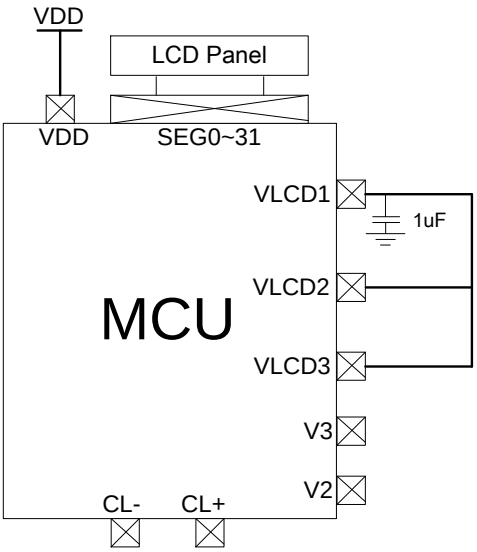
	1/3Bias (V3= 2/3*VLCD, V2 = 1/3*VLCD)	1/2Bias (V3 = V2 = 1/2*VLCD)
SEG1SEL = 0 **SEG2SEL = 0**		
SEG1SEL = 1		

SEG2SEL = 1		
SEG1SEL = 1 **SEG2SEL = 1**		

16.7.2 1C-Type

✷ ***Note:***

1. ***Maximal charge-pump voltage is 3.4V***
2. ***NOT necessary to connect capacitors between CL+ and CL- pins.***
3. ***NOT necessary to connect capacitors for V3/V2 pins.***
4. ***The 1uF capacitors of VLCD1 pin is necessary for power stable. Users can adjust the capacitor value depend on the LCD panel size. Besides, please put close to VLCD1 pin.***

SEG1SEL = 0 & SEG2SEL = 0	SEG1SEL = 1
	
SEG2SEL = 1	**SEG1SEL = 1 & SEG2SEL = 1**
	

16.8 LCD DISPLAY MEMORY MAP

Bit	LCD_SEGM3	LCD_SEGM2	LCD_SEGM1	LCD_SEGM0	
31	SEG31	SEG23	SEG15	SEG7	COM3
30					COM2
29					COM1
28					COM0
27	SEG31	SEG22	SEG14	SEG6	COM3
26					COM2
25					COM1
24					COM0
23	SEG29	SEG21	SEG13	SEG5	COM3
22					COM2
21					COM1
20					COM0
19	SEG28	SEG20	SEG12	SEG4	COM3
18					COM2
17					COM1
16					COM0
15	SEG27	SEG19	SEG11	SEG3	COM3
14					COM2
13					COM1
12					COM0
11	SEG26	SEG18	SEG10	SEG2	COM3
10					COM2
9					COM1
8					COM0
7	SEG25	SEG17	SEG9	SEG1	COM3
6					COM2
5					COM1
4					COM0
3	SEG24	SEG16	SEG8	SEG0	COM3
2					COM2
1					COM1
0					COM0

16.9 LCD REGISTERS

Base Address: 0x4003 4000

16.9.1 LCD Control register (LCD_CTRL)

Address Offset: 0x00

Reset value: 0x1000 0302

✸ ***Note:***

1. ***Segment 24~Segment 31 pins are shared with P0.0~P0.7.***
   - ***When these pins are used as general purpose I/O mode, the SEG2SEL bit shall be set as "0", and VDD3 shall be connected to VDD with PCB layout.***
   - ***When these pins are used as LCD pins, the SEG2SEL bit shall be set as "1", and please refer to R-type LCD application circuit or C-type LCD application circuit.***
2. ***Segment 12~Segment 23 pins are shared with P0.10~P0.15 and P1.0~P1.5.***
   - ***When these pins are used as general purpose I/O mode, the SEG1SEL bit shall be set as "0", and VDD2 shall be connected to VDD with PCB layout.***
   - ***When these pins are used as LCD pins, the SEG1SEL bit shall be set as "1", and please refer to R-type LCD application circuit or C-type LCD application circuit.***

Bit	Name	Description	Attribute	Reset
31:30	Reserved	-	R	0
29:28	DRIVEP[1:0]	LCD panel driving ability 00: Strong (Larger panel) 01: Medium (Medium panel) 10: Reserved 11: Low (Smaller panel)	R/W	01b
27:12	Reserved		R/W	0
11	LCDRATE	LCD clock rate (LCD_PCLK) 0: LCD clock source / 64 1: LCD clock source / 128	R/W	0
10	LCDCLK	LCD clock source selection 0: ILRC 1: ELS XTAL	R/W	0
9:8	DUTY[1:0]	Duty selection 00: Reserved 01: 1/2 duty. HW will assign COM0~1 as LCD pins instead of GPIO. P1.13, P1.12 is still available to be used as GPIO in R-type. 10: 1/3 duty. HW will assign COM0~2 as LCD pins instead of GPIO. P1.13 is still available to be used as GPIO in R-type. 11: 1/4 duty. HW will assign COM0~3 as LCD pins instead of GPIO.	R/W	11b
7	Reserved		R/W	0
6	SEGSEL2	SEG24~31 enable bit 0: Disable. SEG24~31 pins are GPIO. 1: Enable. HW will assign SEG24~31 pins as LCD pins instead of GPIO.	R/W	0
5	SEGSEL1	SEG12~23 enable bit 0: Disable. SEG12~23 pins are GPIO. 1: Enable. HW will assign SEG12~23 pins as LCD pins instead of GPIO.	R/W	0
4	BIAS	LCD Bias selection 0: 1/3 Bias 1: 1/2 Bias	R/W	0

3:2	LCDTYPE[1:0]	LCD type control bit 00: R-Type 01: 4C Type. HW will assign CL+, CL- pins as LCD pins instead of GPIO. 10: 1C Type. HW will assign CL+, CL- pins as LCD pins instead of GPIO. 11: Reserved	R/W	00b
1	ITB	Used for internal testing and the only value “1” is allowed.	R/W	1
0	LCDENB	LCD driver enable bit. 0: Disable 1: Enable HW will assign SEG0~11, V3, V2 pin as LCD pins instead of GPIO.	R/W	0

16.9.2 LCD Control register 1 (LCD_CTRL1)

Address Offset: 0x04

Reset value: 0x1000 0000

Bit	Name	Description	Attribute	Reset
31:29	Reserved		R/W	0
28	ITB	Used for internal testing and the only value “1” is allowed	R/W	1
27:3	Reserved		R/W	0
2:1	REF[1:0]	Resistance selection for LCD Bias Voltage-division. 00: 400K 01: 200K 10: 100K 11: 35K	R/W	00b
0	LCDBNK	LCD blank control bit 0: Normal display 1: All LCD dots off.	R/W	0

16.9.3 LCD C-Type Control register 1 (LCD_CCTRL1)

Address Offset: 0x08

Reset value: 0x6002 0003

LCD_CCTRL1 is available for C-Type LCD, and the charge pump clock source is controlled by LCDCLK bit in LCD_CTRL register.

LCDCLK	Charge-pump Clock Source
0	**ILRC 32KHz**
1	**ELS XTAL 32.768KHz**

Bit	Name	Description	Attribute	Reset
31:30	Reserved	The only value “01b” is allowed.	R/W	01b
29:28	IT1[1:0]	Used for internal testing and the only value “00b” is allowed.	R/W	10b

27:24	IT2[3:0]	Used for internal testing and the only value “0010b” is allowed.	R/W	00b
25:4	Reserved		R/W	0
3:0	VCP[3:0]	C-type VLCD output voltage	R/W	0011b

1C Type				
VCP[3:0]	VLCD	1/3 Bias		1/2 Bias
		V2	V3	V2 = V3
0000	2.70V	0.90V	1.80V	1.35V
0001	2.80V	0.94V	1.87V	1.40V
0010	2.90V	0.98V	1.96V	1.45V
0011	3.00V	1.00V	2.00V	1.50V
0100	3.10V	1.04V	2.08V	1.53V
0101	3.20V	1.08V	2.14V	1.57V
0110	3.30V	1.10V	2.20V	1.61V
0111	3.40V	1.14V	2.28V	1.66V
Reserved	N/A	N/A	N/A	N/A

4C Type				
VCP[3:0]	VLCD	1/3 Bias		1/2 Bias
		V2	V3	V2 = V3
0000	2.70V	0.90V	1.80V	1.35V
0001	2.80V	0.93V	1.86V	1.40V
0010	2.90V	0.96V	1.93V	1.45V
0011	3.00V	1.00V	2.00V	1.50V
0100	3.06V	1.02V	2.04V	1.53V
0101	3.14V	1.05V	2.10V	1.57V
0110	3.20V	1.07V	2.14V	1.61V
0111	3.30V	1.10V	2.20V	1.66V
1000	3.40V	1.13V	2.26V	1.70V
1001	3.60V	1.20V	2.40V	1.80V
1010	3.80V	1.27V	2.54V	1.90V
1011	4.00V	1.33V	2.67V	2.00V
1100	4.20V	1.40V	2.80V	2.12V
1101	4.40V	1.49V	2.98V	2.23V
1110	4.70V	1.57V	3.14V	2.35V
1111	5.00V	1.66V	3.32V	2.50V

16.9.4 LCD C-Type Control register 2 (LCD_CCTRL2)

Address Offset: 0x0C

LCD_CCTRL2 register is for internal testing, and the only value “0x00000004” is allowed.

16.9.5 LCD Frame Counter Control register (LCD_FCC)

Address offset: 0x10

Reset value: 0x0000 0002

The frame counter (FC) will start to count up from 0x0 when FCENB = 1, and add 1 when a frame is updated. When the counter value reaches FCT[5:0], FC will reset as 0x0 by HW, the LCD frame interrupt flag will become 1. If LCD

frame interrupt is enabled (FCIE =1), the LCD frame interrupt is generated and sent to the interrupt controller.

Bit	Name	Description	Attribute	Reset
31:10	Reserved		R	0
7	FCIE	LCD frame interrupt enable bit 0: Disable 1: Enable	R/W	0
6:1	FCT[5:0]	LCD frame counter threshold value	R/W	00001b
0	FCENB	LCD frame counter enable bit 0: Disable 1: Enable	R/W	0

16.9.6 LCD Raw Interrupt Status register (LCD_RIS)

Address offset: 0x14

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31:1	Reserved		R	0
0	FCIF	LCD frame interrupt flag. 0: Read→No interrupt Write→Write “0” to clear this bit and reset the interrupt if FCIE=1. 1: FC interrupt requirements met.	R/W	0

16.9.7 LCD SEG Memory register 0 (LCD_SEGM0)

Address Offset: 0x20

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31:28	SEG7[3:0]	SEG7 data for COM0~COM3	R/W	0
27:24	SEG6[3:0]	SEG6 data for COM0~COM3	R/W	0
23:20	SEG5[3:0]	SEG5 data for COM0~COM3	R/W	0
19:16	SEG4[3:0]	SEG4 data for COM0~COM3	R/W	0
15:12	SEG3[3:0]	SEG3 data for COM0~COM3	R/W	0
11:8	SEG2[3:0]	SEG2 data for COM0~COM3	R/W	0
7:4	SEG1[3:0]	SEG1 data for COM0~COM3	R/W	0
3:0	SEG0[3:0]	SEG0 data for COM0~COM3	R/W	0

16.9.8 LCD SEG Memory register 1 (LCD_SEGM1)

Address Offset: 0x24

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31:28	SEG15[3:0]	SEG15 data for COM0~COM3	R/W	0
27:24	SEG14[3:0]	SEG14 data for COM0~COM3	R/W	0
23:20	SEG13[3:0]	SEG13 data for COM0~COM3	R/W	0
19:16	SEG12[3:0]	SEG12 data for COM0~COM3	R/W	0
15:12	SEG11[3:0]	SEG11 data for COM0~COM3	R/W	0
11:8	SEG10[3:0]	SEG10 data for COM0~COM3	R/W	0
7:4	SEG9[3:0]	SEG9 data for COM0~COM3	R/W	0
3:0	SEG8[3:0]	SEG8 data for COM0~COM3	R/W	0

16.9.9 LCD SEG Memory register 2 (LCD_SEGM2)

Address Offset: 0x28

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31:28	SEG23[3:0]	SEG23 data for COM0~COM3	R/W	0
27:24	SEG22[3:0]	SEG22 data for COM0~COM3	R/W	0
23:20	SEG21[3:0]	SEG21 data for COM0~COM3	R/W	0
19:16	SEG20[3:0]	SEG20 data for COM0~COM3	R/W	0
15:12	SEG19[3:0]	SEG19 data for COM0~COM3	R/W	0
11:8	SEG18[3:0]	SEG18 data for COM0~COM3	R/W	0
7:4	SEG17[3:0]	SEG17 data for COM0~COM3	R/W	0
3:0	SEG16[3:0]	SEG16 data for COM0~COM3	R/W	0

16.9.10 LCD SEG Memory register 3 (LCD_SEGM3)

Address Offset: 0x2C

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31:28	SEG31[3:0]	SEG31 data for COM0~COM3	R/W	0
27:24	SEG30[3:0]	SEG30 data for COM0~COM3	R/W	0
23:20	SEG29[3:0]	SEG29 data for COM0~COM3	R/W	0
19:16	SEG28[3:0]	SEG28 data for COM0~COM3	R/W	0
15:12	SEG27[3:0]	SEG27 data for COM0~COM3	R/W	0
11:8	SEG26[3:0]	SEG26 data for COM0~COM3	R/W	0
7:4	SEG25[3:0]	SEG25 data for COM0~COM3	R/W	0
3:0	SEG24[3:0]	SEG24 data for COM0~COM3	R/W	0

17 USB FS DEVICE INTERFACE

17.1 OVERVIEW

The USB is the answer to connectivity for the PC architecture. A fast, bi-directional interrupt pipe, low-cost, dynamically attachable serial interface is consistent with the requirements of the PC platform of today and tomorrow. The SONIX USB microcontrollers are optimized for human-interface computer peripherals such as a mouse, keyboard, joystick, and game pad.

USB Specification Compliance

— Conforms to USB specifications, Version 2.0.

— Supports 1 Full-speed USB device address.

— Supports 1 control endpoint and 6 configurable endpoints for isochronous/interrupt/bulk transfer.

— Integrated USB transceiver.

— 5V to 3.3V regulator output for D+ 1.5K ohm internal resistor pull up.

✸ ***Note: HCLK must be at least ≧3MHz under USB active mode (except USB Suspend).***

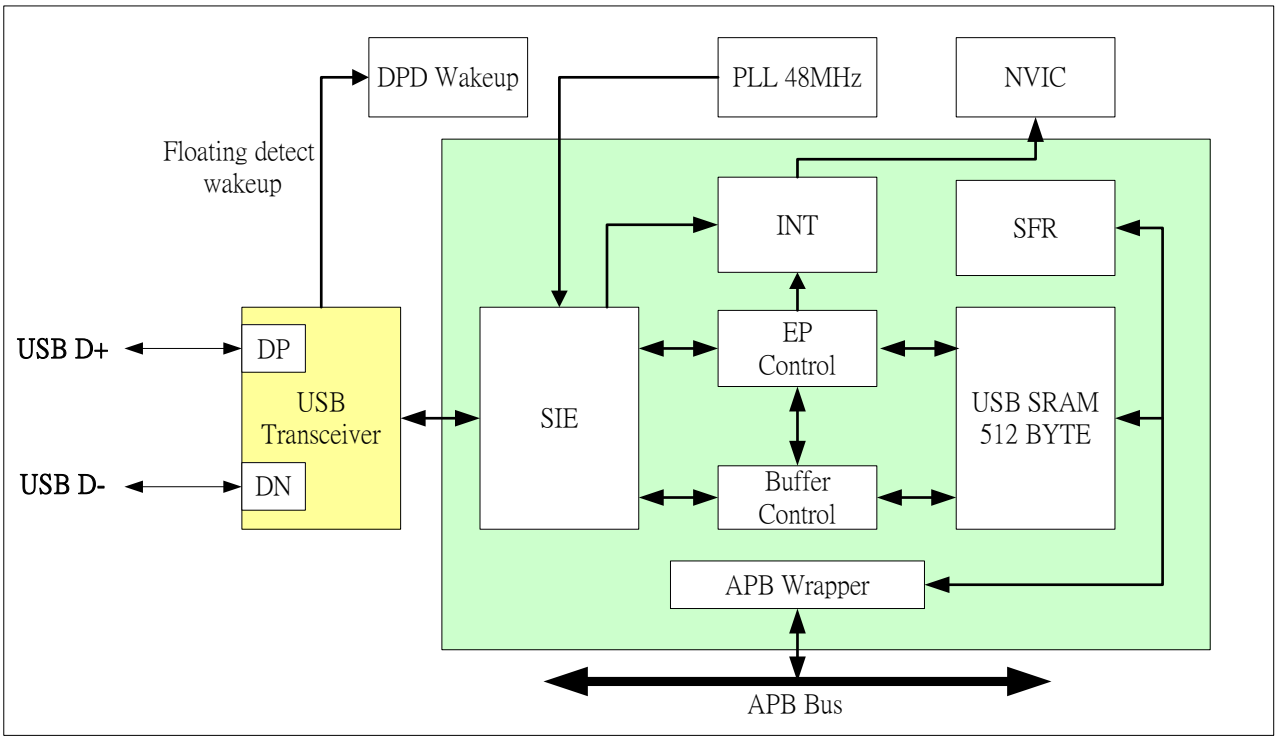
17.2 FEATURES

- Conforms to USB specifications, Version 2.0.
- Supports 1 Full-speed USB device address.
- Supports 1 control endpoint with maximum packet size 8 bytes, 16 bytes, 32 bytes, or 64 bytes.
- Supports 6 endpoints configurable for isochronous/interrupt/bulk transfer.
- Supports USB SRAM size 512 bytes shared by all 7 endpoints.
- Flexible data FIFO offset setting for endpoints except endpoint 0.
- 5V to 3.3V regulator output for D+ 1.5K ohm internal resistor pull up.
- Integrated USB transceiver.
- Floating detect wakeup from deep-power down mode.

17.3 PIN DESCRIPTION

Pin Name	Type	Description	GPIO Configuration
DP	I/O	USB differential signal D+	N/A
DN	I/O	USB differential signal D-	N/A

17.4 BLOCK DIAGRAM



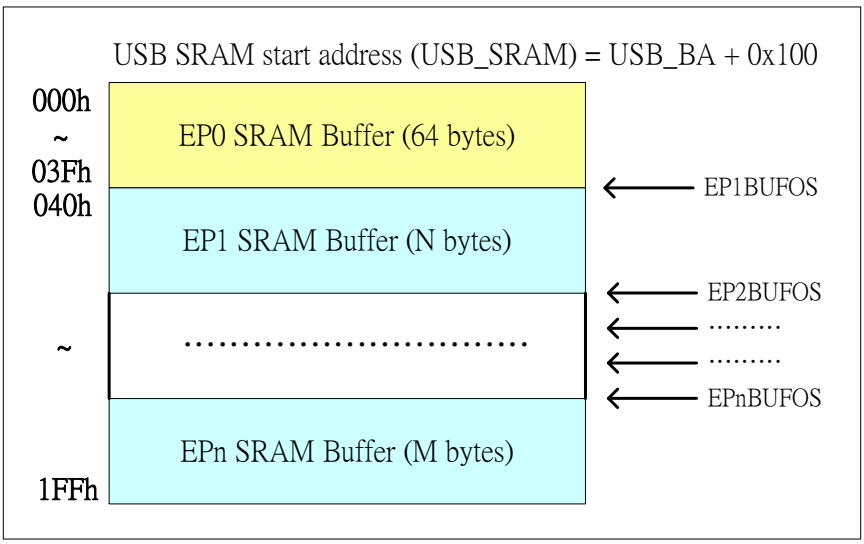
17.5 USB SRAM ACCESS

USB SRAM 512 bytes is shared by EP0~EP6, total 7 endpoints. The USB SRAM start address (USB_SRAM) is at (USB_BA + 0x100). EP0 SRAM buffer start address is fixed to range from offset 000h to 03Fh, and EP1~EP6 SRAM buffer start address are configurable by EPnBUFOS register.

The principles to access USB SRAM are as below.

– Each EPnBUFOS setting must be word-aligned, with 2 LSB bits equal to '0'.

– The maximum length of EPn SRAM buffer is defined by user. However, each endpoint should have its own EPn SRAM buffer without overlapping each other.



17.6 USB MACHINE

The USB machine allows the microcontroller to communicate with the USB host. The hardware handles the following USB bus activity independently of the microcontroller.

The USB machine will do:

– Translate the encoded received data and format the data to be transmitted on the bus.
– CRC checking and generation by hardware. If CRC is not correct, hardware will not send any response to USB host.
– Send and update the data toggle bit (Data1/0) automatically by hardware.
– Send appropriate ACK/NAK/STALL handshakes.
– SETUP, IN, or OUT Token type identification. Set the appropriate bit once a valid token is received.
– Place valid received data in the appropriate endpoint FIFOs.
– Bit stuffing/unstuffing.
– Address checking. Ignore the transactions not addressed to the device.
– Endpoint checking. Check the endpoint's request from USB host, and set the appropriate bit of registers.

Firmware is required to handle the rest of the following tasks:

– Coordinate enumeration by decoding USB device requests.
– Fill and empty the FIFOs.
– Reset/Suspend/Resume coordination.
– Remote wake up function.
– Determine the right interrupt request of USB communication

17.7 USB INTERRUPT

The USB function will accept the USB host command and generate the relative interrupts, and enter USB_IRQ_Handler. Firmware is required to check the USB status bit to realize what request comes from the USB host.

The USB function interrupt is generated when:

– The endpoint 0 is set to accept a SETUP token.
– The device receives an ACK handshake after a successful read transaction (IN) from the host.
– If the endpoint is in ACK OUT modes, an interrupt is generated when data is received.
– The USB host sends USB suspend request to the device.
– USB bus reset/resume event occurs.
– The USB endpoints interrupt after a USB transaction complete is on the bus.
– The NAK handshaking when the NAK interrupt enables.

17.8 USB ENUMERATION

A typical USB enumeration sequence is shown below.

1. The host computer sends a SETUP packet followed by a DATA packet to USB address 0 requesting the Device descriptor.
2. Firmware decodes the request and retrieves its Device descriptor from the program memory tables.
3. The host computer performs a control read sequence and firmware responds by sending the Device descriptor over the USB bus, via the on-chip USB SRAM.
4. After receiving the descriptor, the host sends a SETUP packet followed by a DATA packet to address 0 assigning a new USB address to the device.
5. Firmware stores the new address in its USB Device Address Register after the no-data control sequence completes.
6. The host sends a request for the Device descriptor using the new USB address.
7. Firmware decodes the request and retrieves the Device descriptor from program memory tables.
8. The host performs a control read sequence and firmware responds by sending its Device descriptor over the USB bus.
9. The host generates control reads from the device to request the Configuration and Report descriptors.
10. Once the device receives a Set Configuration request, its functions may now be used.
11. Firmware should take appropriate action for Endpoint 0~N transactions, which may occur from this point.

17.9 USB REGISTERS

Base Address: 0x4005 C000

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
USB_INTEN	0x00	R/W	USB Interrupt Enable Register	0x0000_0000
USB_INSTS	0x04	R	USB Interrupt Event Status Register	0x0000_0000
USB_INSTSC	0x08	W	USB Interrupt Event Status Clear Register	0x0000_0000
USB_ADDR	0x0C	R/W	USB Device Address Register	0x0000_0000
USB_CFG	0x10	R/W	USB Configuration Register	0x0000_0000
USB_SGCTL	0x14	R/W	USB Signal Control Register	0x0000_0000
USB_EP0CTL	0x18	R/W	USB Endpoint 0 Control Register	0x0000_0000
USB_EP1CTL	0x1C	R/W	USB Endpoint 1 Control Register	0x0000_0000
USB_EP2CTL	0x20	R/W	USB Endpoint 2 Control Register	0x0000_0000
USB_EP3CTL	0x24	R/W	USB Endpoint 3 Control Register	0x0000_0000
USB_EP4CTL	0x28	R/W	USB Endpoint 4 Control Register	0x0000_0000
USB_EP5CTL	0x2C	R/W	USB Endpoint 5 Control Register	0x0000_0000
USB_EP6CTL	0x30	R/W	USB Endpoint 6 Control Register	0x0000_0000
USB_EPTOGGLE	0x3C	R/W	USB Endpoint Data Toggle Register	0x0000_003F
USB_EP1BUFOS	0x48	R/W	USB Endpoint 1 Buffer Offset Register	0x0000_0000
USB_EP2BUFOS	0x4C	R/W	USB Endpoint 2 Buffer Offset Register	0x0000_0000
USB_EP3BUFOS	0x50	R/W	USB Endpoint 3 Buffer Offset Register	0x0000_0000
USB_EP4BUFOS	0x54	R/W	USB Endpoint 4 Buffer Offset Register	0x0000_0000
USB_EP5BUFOS	0x58	R/W	USB Endpoint 5 Buffer Offset Register	0x0000_0000
USB_EP6BUFOS	0x5C	R/W	USB Endpoint 6 Buffer Offset Register	0x0000_0000
USB_FRMNO	0x60	R	USB Frame Number Register	0x0000_0000
USB_PHYPRM	0x64	R/W	USB PHY Parameter Register	0x0000_0000
USB_SRAM	0x100	R/W	USB 512 byte SRAM	Undefined

17.9.1 USB Interrupt Enable Register (USB_INTEN)

Address Offset: 0x00

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31	BUS_IE	Bus Event Interrupt Enable 0: Disable BUS event interrupt 1: Enable Bus event interrupt. Any bus event including BUS_RESET, BUS_SUSPEND, and BUS_RESUME triggers USB interrupt.	R/W	0
30	USB_SOF_IE	USB SOF Interrupt Enable 0: Disable USB SOF interrupt. 1: Enable USB SOF interrupt.	R/W	0
29	USB_IE	USB Event Interrupt Enable 0: Disable USB event interrupt. 1: Enable USB event interrupt. Any USB event except EP1~EP6's NAK triggers USB interrupt.	R/W	0
28:6	Reserved		R	0
5	EP6_NAK_EN	EP6 NAK Interrupt Enable 0: Disable EP6 NAK interrupt function. 1: Enable EP6 NAK interrupt function.	R/W	0
4	EP5_NAK_EN	EP5 NAK Interrupt Enable 0: Disable EP5 NAK interrupt function. 1: Enable EP5 NAK interrupt function.	R/W	0
3	EP4_NAK_EN	EP4 NAK Interrupt Enable 0: Disable EP4 NAK interrupt function. 1: Enable EP4 NAK interrupt function.	R/W	0

2	EP3_NAK_EN	EP3 NAK Interrupt Enable 0: Disable EP3 NAK interrupt function. 1: Enable EP3 NAK interrupt function.	R/W	0
1	EP2_NAK_EN	EP2 NAK Interrupt Enable 0: Disable EP2 NAK interrupt function. 1: Enable EP2 NAK interrupt function.	R/W	0
0	EP1_NAK_EN	EP1 NAK Interrupt Enable 0: Disable EP1 NAK interrupt function. 1: Enable EP1 NAK interrupt function.	R/W	0

17.9.2 USB Interrupt Event Status Register (USB_INSTS)

Address Offset: 0x04

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31	BUS_RESET	USB Bus Reset signal flag. 0: No bus reset signal is detected.. 1: Bus reset signal is detected. Cleared by write 1 to USB_INSTSC[31].	R	0
30	BUS_SUSPEND	USB Bus Suspend signal flag. This flag will be automatically cleared as 0 by H/W once USB bus leaves suspend state. And it cannot be cleared as 0 by firmware. 0: No bus suspend is detected. 1: Bus suspend is detected.	R	0
29	BUS_RESUME	USB Bus Resume signal flag 0: No bus resume signal is detected. 1: Bus resume signal from suspend mode is detected. Cleared by write 1 to USB_INSTSC[29].	R	0
28:27	Reserved		-	0
26	USB_SOF	USB SOF packet received flag. 0: No USB SOF packet. 1: USB SOF packet is received. Cleared by write 1 to USB_INSTSC[26].	R	0
25	BUS_WAKEUP	USB Bus wakeup flag. 0: No wakeup from suspend mode. 1: Wakeup from suspend mode. Cleared by write 1 to USB_INSTSC[25]	R	0
24	EP0_PRESETUP	EP0 Setup token packet flag. This flag will not trigger USB interrupt. 0: No EP0 Setup token packet. 1: EP0 Setup token packet is received. Cleared by write 1 to USB_INSTSC[24]	R	0
23	EP0_SETUP	EP0 Setup transaction flag. 0: No EP0 Setup transaction. 1: EP0 Setup transaction is completed. Cleared by write 1 to USB_INSTSC[23].	R	0
22	EP0_IN	EP0 IN ACK transaction flag. 0: No EP0 IN ACK Transaction. 1: EP0 IN ACK transaction is completed. Cleared by write 1 to USB_INSTSC[22].	R	0
21	EP0_OUT	EP0 OUT ACK transaction flag. 0: No EP0 OUT ACK transaction. 1: EP0 OUT ACK transaction is completed. Cleared by write 1 to USB_INSTSC[21].	R	0
20	EP0_IN_STALL	EP0 IN STALL transaction flag. 0: No EP0 IN STALL transaction. 1: EP0 IN STALL transaction is completed. Cleared by write 1 to USB_INSTSC[20].	R	0
19	EP0_OUT_STALL	EP0 OUT STALL transaction flag. 0: No EP0 OUT STALL transaction.. 1: EP0 OUT STALL transaction is completed. Cleared by write 1 to USB_INSTSC[19].	R	0

18	ERR_SETUP	Wrong Setup data received. This flag will not trigger USB interrupt. 0: Normal 8-byte Setup DATA0 is received. 1: Setup data is not 8-byte or is not DATA0. Cleared by write 1 to USB_INSTSC[18].	R	0
17	ERR_TIMEOUT	Timeout status. This flag will not trigger USB interrupt. 0: No timeout. 1: Host ACK response timeout after IN data packet is sent. Cleared by write 1 to USB_INSTSC[17].	R	0
16:14	Reserved		-	0
13	EP6_ACK	Endpoint 6 ACK transaction flag. If USB_CFG[13] = 1, EP6_ACK will be set 1 by H/W once EP6 ISO transaction completes. 0: No EP6 ACK transaction. 1: EP6 ACK transaction completes. Cleared by write 1 to USB_INSTSC[13].	R	0
12	EP5_ACK	Endpoint 5 ACK transaction flag. If USB_CFG[12] = 1, EP5_ACK will be set 1 by H/W once EP5 ISO transaction completes. 0: No EP5 ACK transaction. 1: EP5 ACK transaction completes. Cleared by write 1 to USB_INSTSC[12].	R	0
11	EP4_ACK	Endpoint 4 ACK transaction flag. If USB_CFG[11] = 1, EP4_ACK will be set 1 by H/W once EP4 ISO transaction completes. 0: No Endpoint 4 ACK transaction. 1: EP4 ACK transaction completes. Cleared by write 1 to USB_INSTSC[11].	R	0
10	EP3_ACK	Endpoint 3 ACK transaction flag. If USB_CFG[10] = 1, EP3_ACK will be set 1 by H/W once EP3 ISO transaction completes. 0: No EP3 ACK transaction. 1: EP3 ACK transaction completes. Cleared by write 1 to USB_INSTSC[10].	R	0
9	EP2_ACK	Endpoint 2 ACK transaction flag. If USB_CFG[9] = 1, EP2_ACK will be set 1 by H/W once EP2 ISO transaction completes. 0: No EP2 ACK transaction. 1: EP2 ACK transaction completes. Cleared by write 1 to USB_INSTSC[9].	R	0
8	EP1_ACK	Endpoint 1 ACK transaction flag. If USB_CFG[8] = 1, EP1_ACK will be set 1 by H/W once EP1 ISO transaction completes. 0: No EP1 1 ACK transaction. 1: EP1 ACK transaction completes. Cleared by write 1 to USB_INSTSC[8].	R	0
7:6	Reserved		-	0
5	EP6_NAK	Endpoint 6 NAK transaction flag. 0: No EP6 NAK transaction. 1: EP6 NAK transaction completes. Cleared by write 1 to USB_INSTSC[5].	R	0
4	EP5_NAK	Endpoint 5 NAK transaction flag. 0: No Endpoint 5 NAK transaction. 1: EP5 NAK transaction completes. Cleared by write 1 to USB_INSTSC[4].	R	0
3	EP4_NAK	Endpoint 4 NAK transaction flag. 0: No EP4 NAK transaction. 1: EP4 NAK transaction completes. Cleared by write 1 to USB_INSTSC[3].	R	0
2	EP3_NAK	Endpoint 3 NAK transaction flag. 0: No Endpoint 3 NAK transaction. 1: EP3 NAK transaction completes. Cleared by write 1 to USB_INSTSC[2].	R	0
1	EP2_NAK	Endpoint 2 NAK transaction flag. 0: No EP2 NAK transaction. 1: EP2 NAK transaction completes. Cleared by write 1 to USB_INSTSC[1].	R	0
0	EP1_NAK	Endpoint 1 NAK transaction flag. 0: No EP1 NAK transaction. 1: EP1 NAK transaction completes. Cleared by write 1 to USB_INSTSC[0].	R	0

17.9.3 USB Interrupt Event Status Clear Register (USB_INSTSC)

Address Offset: 0x08

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31	BUS_RESETC	0: No effect. 1: Clear BUS_RESET bit.	W	0
30	Reserved		R	-
29	BUS_RESUMEC	0: No effect. 1: Clear BUS_RESUME bit.	W	0
28:27	Reserved		R	-
26	USB_SOFC	0: No effect. 1: Clear USB_SOF bit.	W	0
25	BUS_WAKEUPC	0: No effect. 1: Clear BUS_WAKEUP bit.	W	0
24	EP0_PRESETUPC	0: No effect 1: Clear EP0_PRESETUP bit.	W	0
23	EP0_SETUPC	0: No effect 1: Clear EP0_SETUP bit.	W	0
22	EP0_INC	0: No effect. 1: Clear EP0_IN bit.	W	0
21	EP0_OUTC	0:.No effect. 1: Clear EP0_OUT bit.	W	0
20	EP0_IN_STALLC	0: No effect. 1: Clear EP0_IN_STALL bit.	W	0
19	EP0_OUT_STALLC	0: No effect. 1: Clear EP0_OUT_STALL bit.	W	0
18	ERR_SETUPC	0: No effect. 1: Clear ERR_SETUP bit.	W	0
17	ERR_TIMEOUTC	0: No effect. 1: Clear ERR_TIMEOUT bit..	W	0
16:14	Reserved		R	-
13	EP6_ACKC	0: No effect. 1: Clear EP6_ACK bit.	W	0
12	EP5_ACKC	0: No effect. 1: Clear EP5_ACK bit..	W	0
11	EP4_ACKC	0: No effect. 1: Clear EP4_ACK bit.	W	0
10	EP3_ACKC	0: No effect. 1: Clear EP3_ACK bit.	W	0
9	EP2_ACKC	0: No effect. 1: Clear EP2_ACK bit.	W	0
8	EP1_ACKC	0: No effect. 1: Clear EP1_ACK bit.	W	0
7:6	Reserved		R	-
5	EP6_NAKC	0: No effect. 1: Clear EP6_NAK bit.	W	0
4	EP5_NAKC	0: No effect. 1: Clear EP5_NAK bit.	W	0
3	EP4_NAKC	0: No effect. 1: Clear EP4_NAK bit.	W	0
2	EP3_NAKC	0: No effect. 1: Clear EP3_NAK bit.	W	0
1	EP2_NAKC	0: No effect. 1: Clear EP2_NAK bit.	W	0
0	EP1_NAKC	0: No effect. 1: Clear EP1_NAK bit.	W	0

17.9.4 USB Device Address Register (USB_ADDR)

Address Offset: 0x0C

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31:7	Reserved		R	0
6:0	UADDR	USB device's address.	R/W	0

17.9.5 USB Configuration Register (USB_CFG)

Address offset: 0x10

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31	VREG33_EN	Internal VREG33 output function. If VREG33_EN is disabled, VREG33 will be switched to IC_VDD. 0: Disable 1: Enable	R/W	0
30	PHY_EN	PHY transceiver function. PHY will be automatically disabled if entering sleep mode, deep-sleep mode, and deep-power down mode. 0: Disable PHY transceiver function. 1: Enable PHY transceiver function.	R/W	0
29	DPPU_EN	Internal D+ 1.5k pull-up resistor function. 0: Disable internal D+ pull-up resistor. 1: Enable internal D+ pull-up resistor.	R/W	0
28	SIE_EN	USB serial interface engine enable. 0: Disable USB SIE function. 1: Enable USB SIE function.	R/W	0
27	EMC_EN	USB EMC protection enable. 0: Disable EMC protection. 1: Enable EMC protection.	R/W	0
26	FLTDET_PUEN	Enable internal high pull-up resistor on both D+ and D-. 0: Enable. 1: Disable.	R/W	0
25	USBRAM_EN	Enable USB 512-byte RAM function. 0: Disable 1: Enable	R/W	0
24	VREG33DIS_EN	Enable the VREG33 discharge path to GND. 0: Disable 1: Enable	R/W	0
23:14	Reserved		R	0
13	EP6_ISO	Endpoint 6 ISO mode setting. 0: Enable interrupt/bulk mode. 1: Enable ISO mode.	R/W	0
12	EP5_ISO	Endpoint 5 ISO mode setting. 0: Enable interrupt/bulk mode. 1: Enable ISO mode	R/W	0
11	EP4_ISO	Endpoint 4 ISO mode setting. 0: Enable interrupt/bulk mode. 1: Enable ISO mode	R/W	0
10	EP3_ISO	Endpoint 3 ISO mode setting. 0: Enable interrupt/bulk mode. 1: Enable ISO mode	R/W	0

9	EP2_ISO	Endpoint 2 ISO mode setting. 0: Enable interrupt/bulk mode. 1: Enable ISO mode	R/W	0
8	EP1_ISO	Endpoint 1 ISO mode setting. 0: Enable interrupt/bulk mode. 1: Enable ISO mode	R/W	0
7:6	Reserved		R	0
5	EP6_DIR	Endpoint 6 IN/OUT direction setting. 0: EP6 only handshakes to IN token packet. 1: EP6 only handshakes to OUT token packet.	R/W	0
4	EP5_DIR	Endpoint 5 IN/OUT direction setting. 0: EP5 only handshakes to IN token packet. 1: EP5 only handshakes to OUT token packet.	R/W	0
3	EP4_DIR	Endpoint 4 IN/OUT direction setting. 0: EP4 only handshakes to IN token packet. 1: EP4 only handshakes to OUT token packet.	R/W	0
2	EP3_DIR	Endpoint 3 IN/OUT direction setting. 0: EP3 only handshakes to IN token packet. 1: EP3 only handshakes to OUT token packet.	R/W	0
1	EP2_DIR	Endpoint 2 IN/OUT direction setting. 0: EP2 only handshakes to IN token packet. 1: EP2 only handshakes to OUT token packet.	R/W	0
0	EP1_DIR	Endpoint 1 IN/OUT direction setting. 0: EP1 only handshakes to IN token packet. 1: EP1 only handshakes to OUT token packet.	R/W	0

17.9.6 USB Signal Control Register (USB_SGCTL)

Address offset: 0x14

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31:3	Reserved		R	0
2	BUS_DRVEN	Enable to drive USB bus. 0: Not drive USB bus. Write operation to BUS_DP or BUS_DN has no effect. 1: Drive USB bus. The D+/D- bus state can be set by set BUS_DP and BUS_DN.	R/W	0
1	BUS_DP	USB D+ state 0: D+ state is low. 1: D+ state is high.	R/W	0
0	BUS_DN	USB D- state. 0: D- state is low. 1: D- state is high.	R/W	0

17.9.7 USB Endpoint 0 Control Register (USB_EP0CTL)

Address Offset: 0x18

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31	ENDP_EN	Enable Endpoint 0 function. 0: Disable endpoint 0 function. No handshake to endpoint0 SETUP/IN/ OUT token. 1: Enable endpoint 0 function.	R/W	0

30:29	ENDP_STATE[1:0]	Endpoint Handshake State 00: NAK. 01: ACK. For IN transaction, device will handshake data0/1 to IN transaction. For OUT transaction, device will handshake ACK to OUT token and the following data0/1. After IN/OUT ACK transaction completes, the ENDP_STATE will automatically return to NAK state. 10/11: INOUT_STALL: Device will handshake STALL to both IN or OUT token. ENDP_STATE will automatically return to NAK state after USB Setup transaction has completed.	R/W	00
28	IN_STALL_EN	Enable EP0 to handshake STALL to EP0 IN transaction. 0: Disable 1: Enable IN_STALL_EN enable is only effective to EP0 IN token. The EP0 handshake for EP0 OUT transaction depends on OUT_STALL_EN and ENDP_STATE setting. This bit will be automatically cleared to '0' after USB setup transaction has completed.	R/W	0
27	OUT_STALL_EN	Enable EP0 to handshake STALL to EP0 OUT transaction. 0: Disable 1: Enable OUT_STALL_EN enable is only effective to EP0 OUT token. The EP0 handshake state to EP0 IN transaction depends on IN_STALL_EN and ENDP_STATE setting. This bit will be automatically cleared to '0' after USB setup transaction has completed.	R/W	0
26:9	Reserved	-	R	0
5:0	ENDP_CNT[6:0]	Endpoint Byte Count For IN transaction, the ENDP_CNT indicates the byte count to be uploaded to host. The maximum count for IN transaction should depend on the bMaximumPacketSize0 declaration in USB Device Descriptor and cannot exceed 64 bytes for USB FS device. For OUT transaction, the ENDP_CNT indicates the byte count received from host.	R/W	0

17.9.8 USB Endpoint n Control Register (USB_EPnCTL, n = 1 ~ 6)

Address Offset: 0x1C, 0x20, 0x24, 0x28, 0x2C, 0x30

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31	ENDP_EN	EPn function enable bit 0: Disable EPn function. No handshake to EPn IN/OUT token. 1: Enable EPn function.	R/W	0
30:29	ENDP_STATE[1:0]	Endpoint Handshake State 00: NAK For IN direction usage, device will handshake NAK to IN token. For OUT direction usage, device will handshake NAK to OUT token. 01: ACK: For IN direction usage, device will handshake data0/1 to IN token. For OUT direction usage, device will handshake ACK to OUT token and the following data0/1. After IN/OUT ACK transaction completes, the ENDP_STATE will automatically return to NAK state. 10/11: STALL For IN direction usage, device will handshake STALL to IN token. For OUT direction usage, device will handshake STALL to OUT token and the following data0/1.	R/W	0
28:9	Reserved	-	-	0
8:0	ENDP_CNT[8:0]	Endpoint Byte Count For IN direction usage, the ENDP_CNT indicates the byte count to be uploaded to host. For OUT direction usage, the ENDP_CNT indicates the byte count	R/W	0

		received from host.		

17.9.9 USB Endpoint Data Toggle Register (USB_EPTOGGLE)

Address Offset: 0x3C

Reset value: 0x0000 003F

Bit	Name	Description	Attribute	Reset
31:6	Reserved		R	0
5	EP6_DATA01	0: Clear EP6's toggle bit to DATA0. 1: HW sets toggle bit automatically.	R/W	1
4	EP5_DATA01	0: Clear EP5's toggle bit to DATA0. 1: HW sets toggle bit automatically.	R/W	1
3	EP4_DATA01	0: Clear EP4's toggle bit to DATA0. 1: HW sets toggle bit automatically.	R/W	1
2	EP3_DATA01	0: Clear EP3's toggle bit to DATA0. 1: HW sets toggle bit automatically.	R/W	1
1	EP2_DATA01	0: Clear EP2's toggle bit to DATA0. 1: HW sets toggle bit automatically.	R/W	1
0	EP1_DATA01	0: Clear EP1's toggle bit to DATA0. 1: HW sets toggle bit automatically.	R/W	1

17.9.10 USB Endpoint n Buffer Offset Register (USB_EPnBUFOS, n = 1 ~ 6)

Address Offset: 0x48, 0x4C, 0x50, 0x54, 0x58, 0x5C

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31:9	Reserved		R	0
8:2	OFFSET[6:0]	The offset address for each endpoint data buffer. The effective offset address is: USB_SRAM address + {EPnBUFOS[8:2], 2'b00} Where USB_SRAM address = USB_BA + 0x100 For endpoint 0, the offset address is fixed as USB_SRAM address.	R/W	0
1:0	Reserved		R	0

17.9.11 USB Frame Number Register (USB_FRMNO)

Address Offset: 0x60

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31:11	Reserved		R	0
10:0	FRAME_NO[10:0]	The 11-bit frame number of the Start-Of-Frame(SOF) packet. This number is updated by H/W automatically when SOF packet is received.	R	0

17.9.12 USB PHY Parameter Register (USB_PHYPRM)

Address Offset: 0x64

Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31:26	PHY_PARAM[5:0]	The USB PHY parameter value. The suggested settings would be 0x20.	R/W	0
25:0	Reserved		R	0

18 FLASH

18.1 OVERVIEW

SONiX 32-bit 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. SONiX 32-bit 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.

18.2 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.

18.3 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.

18.4 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	
	Page 3	0x1FFF0C00 ~ 0x1FFF0FFF	1024

18.5 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.

18.6 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.

18.7 EMBEDDED BOOT LOADER

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

18.8 FLASH MEMORY CONTROLLER (FMC)

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

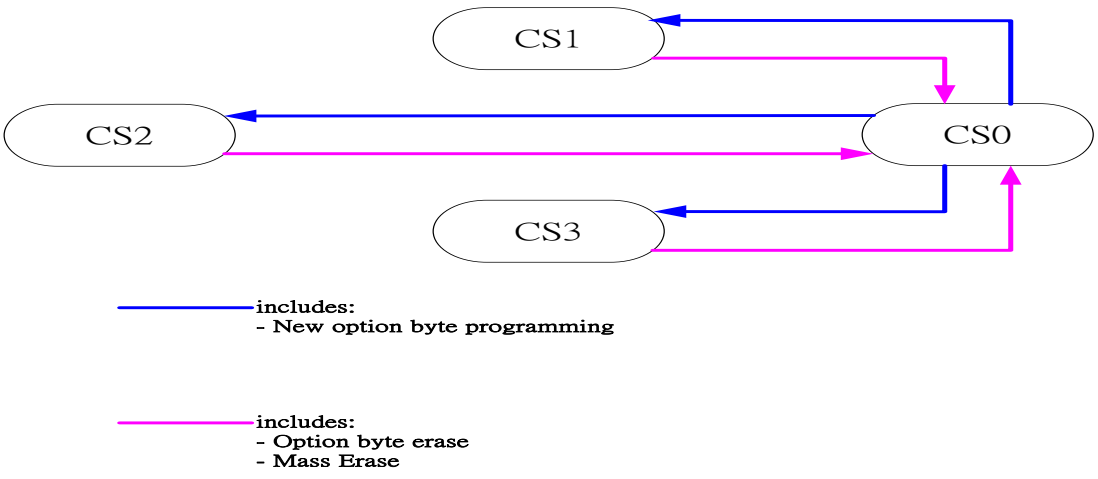
18.8.1 CODE SECURITY (CS)

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	If CS level is not CS0, it will become CS0 after Erasing procedure.
	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.



18.8.2 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:
1. Set the PG bit in the FLASH_CTRL register.
2. Perform the data write at the desired address.
3. Wait for the BUSY bit to be reset.
4. (Optional) Read the programmed value and verify.

18.8.3 ERASE

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

18.8.3.1 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:
1. Set the PER bit in the FLASH_CTRL register
2. Program the FLASH_ADDR register to select a page to be erased
3. Set the STARTE bit in the FLASH_CTRL register
4. Wait for the BUSY bit to be reset
5. (Optional) Read the erased page and verify

18.8.3.2 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.

18.9 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.

18.10 HW CHECKSUM

HW checksum is the checksum of User ROM. If the read protection is enabled, the users can still readout the HW checksum through Writer or ISP AP.

18.11 FMC REGISTERS

Base Address: 0x4006 2000

18.11.1 Flash Low Power Control register (FLASH_LPCTRL)

Address offset: 0x00

Bit	Name	Description	Attribute	Reset
31:16	FMCKEY	FMC verify key. Read as 0. When writing to the register you must write 0x5AFA to FMCKEY, otherwise behavior of writing to the register is ignored.	W	0
15:2	Reserved		R	0
1:0	LPMODE[1:0]	Flash Low Power mode enable bit 00b: Disable 01b: Reserved 10b: Slow mode power saving (HCLK ≤ 32KHz) 11b: Reserved	R/W	0

18.11.2 Flash Status register (FLASH_STATUS)

Address offset: 0x04
Reset value: 0x0000 0000

Bit	Name	Description	Attribute	Reset
31:3	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. - The address to be programmed is illegal.	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 and reset when the operation finishes or when an error occurs by HW.	R	0

18.11.3 Flash Control register (FLASH_CTRL)

Address offset: 0x08

Bit	Name	Description	Attribute	Reset
31:7	Reserved		R	0
7	CHK	Checksum calculation chosen This bit is set only by SW and reset when the BUSY bit resets.	R/W	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

18.11.4 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

18.11.5 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

18.11.6 Flash Checksum register (FLASH_CHKSUM)

Address offset: 0x14

Bit	Name	Description	Attribute	Reset
31:16	Reserved		R	0
15:0	CHKSUM[15:0]	Checksum of User ROM.	R	0

19 SERIAL-WIRE DEBUG (SWD)

19.1 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.

19.2 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.

19.3 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.	

19.4 DEBUG NOTE

19.4.1 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.

19.4.2 DEBUG RECOVERY

User code may disable SWD function in order to use P0.8 and P0.9 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 P2.2 (BOOT pin) during boot procedure. If P2.2 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 P2.2 as other functions such as GPIO.

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

19.4.3 INTERNAL PULL-UP/DOWN RESITIORS 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.

20 DEVELOPMENT TOOL

SONiX provides an Embedded ICE emulator system to offer 32-bit series MCU firmware development.

SONiX 32-bit series Embedded ICE Emulator System includes:

- SONiX 32-bit MCU Starter-Kit.
- SN-LINK-V2.0
- USB cable to provide communications between the SN-LINK-V2.0 and PC.
- IDE Tools (KEIL RVMDK)

SONiX 32-bit MCU Starter-Kit. SN-LINK-V2.0 IDE Tools

SONiX 32-bit series Embedded ICE Emulator Feature:

- Target's Operating Voltage: 1.8V~5.5V.
- Up to 4 hardware break points.
- System clock rate up to 50MHz.
- Oscillator supports IHRC, ILRC, EHS/ELS X'tal.

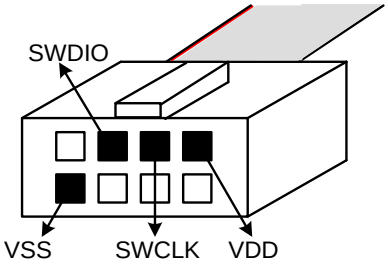
SONiX 32-bit series Embedded ICE Emulator Limitation:

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

20.1 SN-LINK

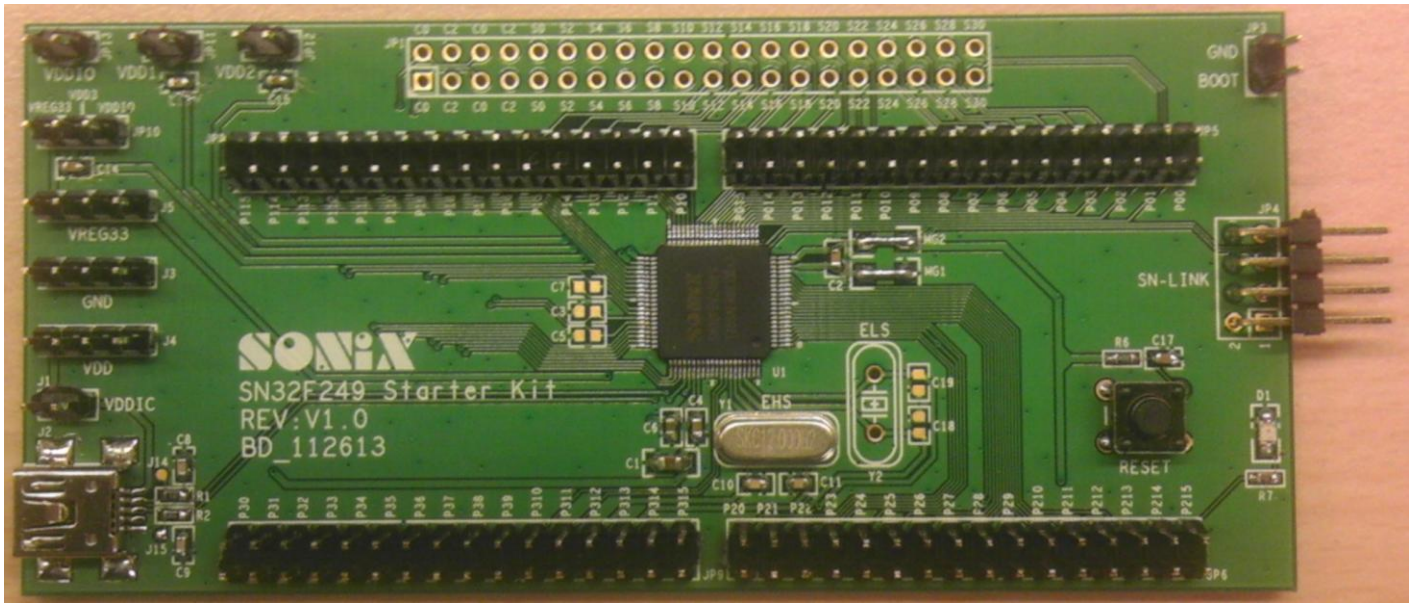
SN-LINK is a high speed emulator for SONiX 32-bit series MCU. It debugs and programs based on SWD protocol. In addition to debugger functions, the SN-LINK also may be used as a programmer to load firmware from PC to MCU for engineering production, even mass production.

SN-LINK-V2.0 communicates with SONiX 32-bit MCU through SWD interface. The pin definition of the Modular cable is as following:



20.2 SN32F249 STARTER-KIT

SONiX 32-bit MCU Starter-kit is an easy-development platform. It includes 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 integrated SWD debugger circuitry.



21 ELECTRICAL CHARACTERISTIC

21.1 ABSOLUTE MAXIMUM RATING

Supply voltage (Vdd)..... - 0.3V ~ 5.5V
Input in voltage (Vin)..... Vss – 0.2V ~ Vdd + 0.2V
Operating ambient temperature (Topr)..... -0°C ~ + 70°C
Storage ambient temperature (Tstor) ..... –40°C ~ + 125°C

21.2 ELECTRICAL CHARACTERISTIC

All of voltages refer to Vss, Typical Vdd = 5.0V, Fosc = 12MHz, ambient temperature is 25℃ unless otherwise note.

PARAMETER	SYM.	DESCRIPTION		MIN.	TYP.	MAX.	UNIT
Operating Voltage	Vdd1	Supply voltage for core and external rail		1.8	5	5.5	V
	Vdd2	USB mode		4.25	5	5.25	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][2][3]		5		mA
			System clock = 50MHz [1][3][4]		16		mA
	Idd2	Sleep Mode	System clock = 12MHz [1][2][3][5]		1		mA
	Idd3	Sleep Mode	System clock = 32KHz [1][3][5][7]		100		uA
	Idd4	Deep-sleep Mode	Vdd=5V [1][3][5]		5		uA
	Idd5	Deep power-down Mode	Vdd=5V [6]		150		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 = 5.0V		50	75	100	KΩ
I/O port pull-down resistor	R_{PD}	Vin = 5.0V		50	75	100	KΩ
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	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
		High-sinking output pin	V_{OP} = Vdd – 0.5V	12	20	-	mA
ADC							
ADC Operating Voltage	V_{ADC}			2.5		5.5	V
AIN0 ~ AIN13 input voltage	V_{ani}			0	-	Avrefh	V
ADC reference Voltage	V_{ref}			2.5	-	-	V
*ADC enable time	T_{ast}	Ready to start convert after set ADENB = “1”		100	-	-	us
*ADC current consumption	I_{ADC}	Vdd=5V, ADS=0		-	220	-	uA
ADC Clock Frequency	F_{ADCLK}	Vdd=5V		-	-	5	MHz
ADC Conversion Cycle Time	F_{ADCYL}	VDD=2.5V~5.5V		64	-	-	$1/F_{ADCLK}$
ADC Sampling Rate	F_{ADSMP}	Vdd=5V			-	250	KHz
Differential Nonlinearity	DNL	Vdd=5.5V , AVREFH=2.4V		-1	-	+1	LSB

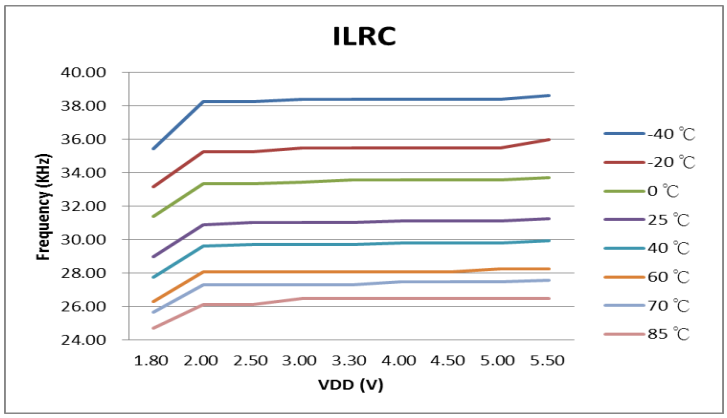
Integral Nonlinearity	INL	Vdd=5.5V , AVREFH=2.4V	-1	-	+1	LSB
No Missing Code	NMC	Vdd=5.5V , AVREFH=2.4V	10	-	12	Bits
ADC offset Voltage	$V_{ADCoffset}$		-5		+5	mV
Temperature sensor Range	TR	Temperature Sensor Operation Range	-10	-	+70	℃
Temperature Sensitivity	TS	Temperature Sensor Sensitivity.		3.53		mV/℃
Temperature Sensor Accuracy	ETS	One Temperature point Calibration.	-10	-	+10	%
		Two Temperature points Calibration	-1		+1	%
FLASH						
Supply Voltage	Vdd1		1.8		Vdd	V
Endurance time	T_{EN}	Erase + Program	20K	*100K	-	Cycle
Page erase time	T_{PE}	Vdd = 2.5V, 1-Page (1024 bytes).	-	25	30	ms
1-Word Programming time	T_{PG}	Vdd = 2.5V, 1-Word (32 bits).	-	60	70	us
LCD						
R-Type LCD Operation Current	I_{RLCD}	Vdd = 3.3V, 1/3 bias, 400k,bias resistor, No panel	-	3	5	uA
		Vdd = 3.3V, 1/3 bias, 35k,bias resistor, No panel		30	45	uA
	$I_{RLCD'}$	Vdd = 3.3V, 1/3 bias, 400k,bias resistor, LCD all dots ON, LCD rate=ILRC/64, 1/4 duty, MCU in Deep sleep mode	-	10	15	uA
1C-Type LCD Operation Current	I_{1CLCD}	Vdd = 3.3V, 1/3 bias, No panel	-	18	25	uA
	$I_{1CLCD'}$	Vdd = 3.3V, 1/3 bias, LCD all dots ON, LCD rate=ILRC/64, 1/4 duty, MCU in Deep sleep mode	-	50	65	uA
4C-Type LCD Operation Current	I_{4CLCD}	dd = 3.3V, 1/3 bias, No panel	-	7	15	uA
	$I_{4CLCD'}$	Vdd = 3.3V, 1/3 bias, LCD all dots ON, LCD rate=ILRC/64, 1/4 duty, MCU in Deep sleep mode	-	20	32	uA
C-Type VLCD Output Voltage	V_{LCD1}	Vdd = 1.8~5.5V. VCP[3:0] = 0011b	2.85	3.0	3.15	V
MISC						
Low Voltage Detector	LVD	Interrupt Level 0	1.70	1.80	1.90	V
		Interrupt Level 1	1.90	2.00	2.10	V
		Interrupt Level 2	2.30	2.40	2.50	V
		Interrupt Level 3	2.60	2.70	2.80	V
		Interrupt Level 4	2.90	3.00	3.10	V
		Interrupt Level 5	3.50	3.60	3.70	V
		Reset Level 0	1.70	1.80	1.90	V
		Reset Level 1	1.90	2.00	2.10	V
		Reset Level 2	2.30	2.40	2.50	V
		Reset Level 3	2.60	2.70	2.80	V
		Reset Level 4	2.90	3.00	3.10	V
		Reset Level 5	3.50	3.60	3.70	V
3.3V Regulator Output voltage	Vreg33	V_{CC} ≧ 3.60V, I_{VREG33} >= 60 mA	3.0		3.6	V
IHRC Freq.	F_{IHRC}	*T=25℃*, Vdd=1.8V~ 5.5V	11.88	12	12.12	MHz
		T=-40℃~85℃, Vdd=1.8V~5.5V	11.70	12	12.30	MHz

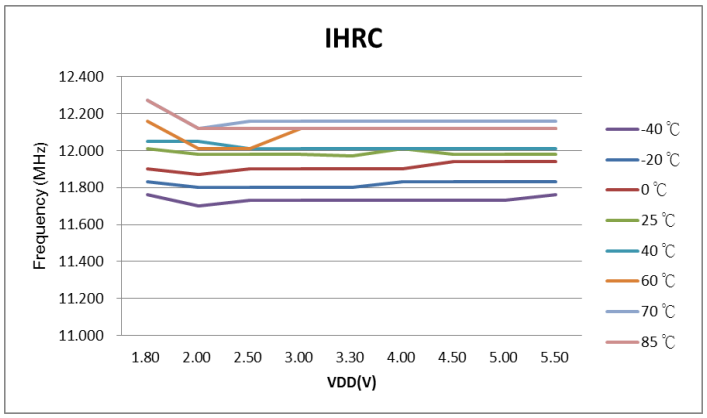
*** These parameters are for design reference, not tested.**

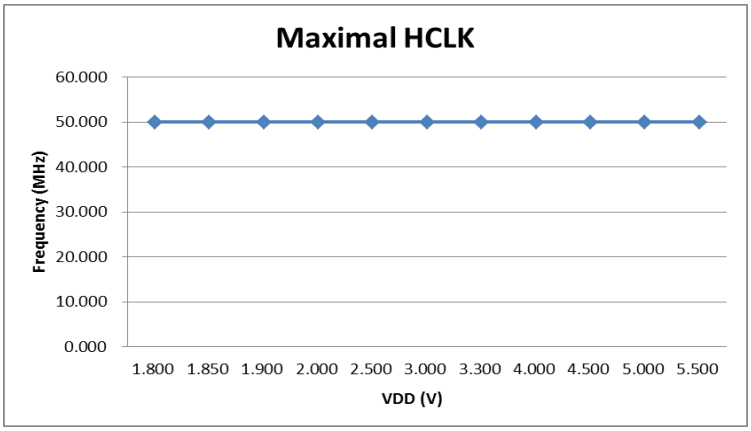
[1] I_{DD} measurements were performed with all pins configured as GPIO outputs driven LOW and pull-up resistors disabled and VDD=5V
[2] IHRC and ILRC are enabled, external X'tal are disabled, and PLL is disabled.
[3] LVD and all peripherals are disabled.
[4] IHRC is disabled, external high X'tal is enabled, and PLL is enabled.
[5] All oscillators and analog blocks are turned off.
[6] DPDWAKEUP pin is pulled HIGH internally.
[7] ILRC is enabled, IHRC and external X'tal are disabled, and PLL is disabled.

21.3 CHARACTERISTIC GRAPHS

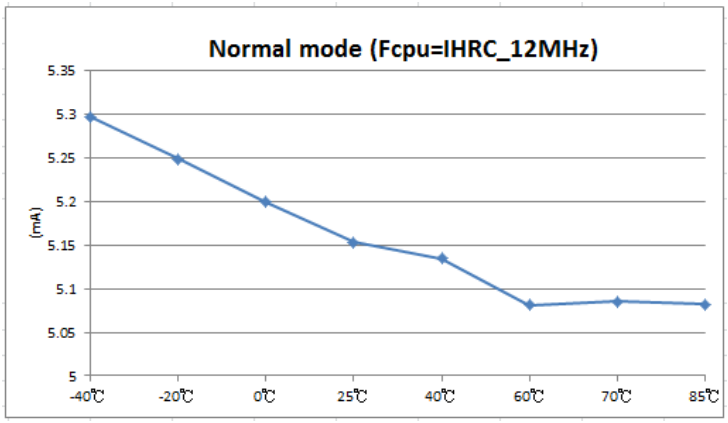
The Graphs in this section are for design guidance, not tested or guaranteed. In some graphs, the data presented are outside specified operating range. This is for information only and devices are guaranteed to operate properly only within the specified range.

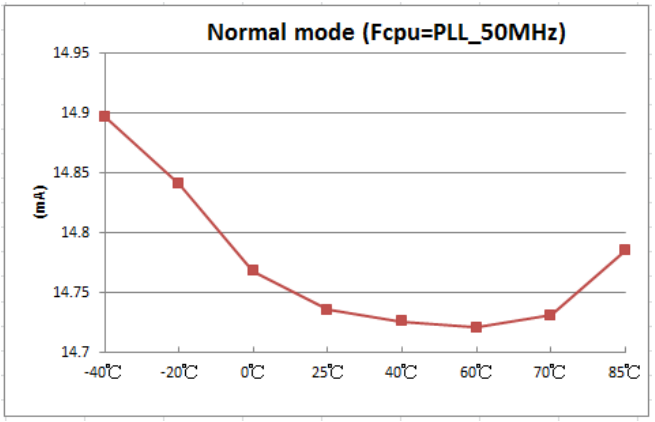


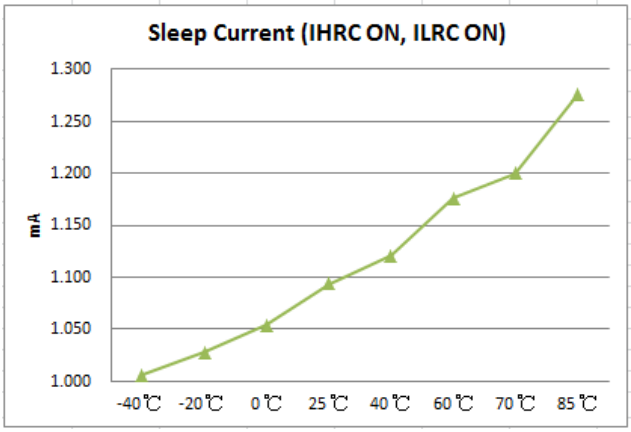


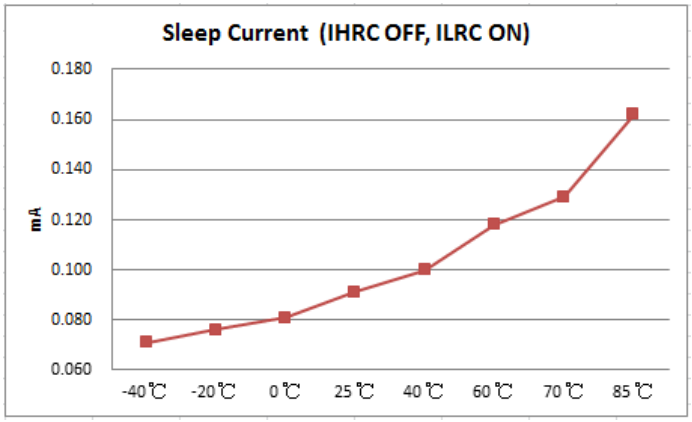


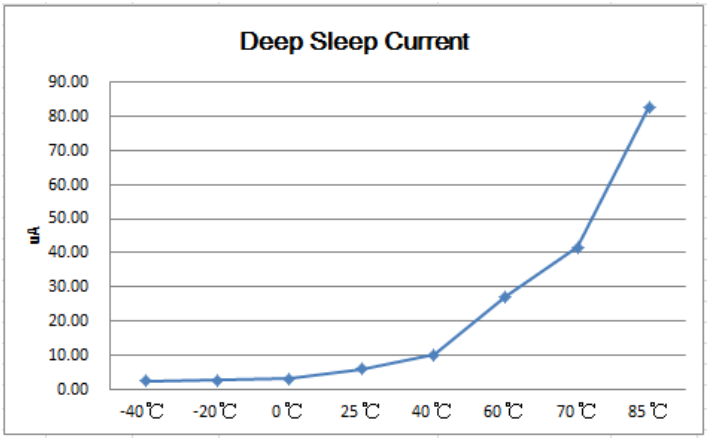
*Supply Current V.S. Operating Temperature (Operating Conditions: All pins configured as GPIO outputs driven Low and pull-up resistors disabled and VDD = 3.3V)

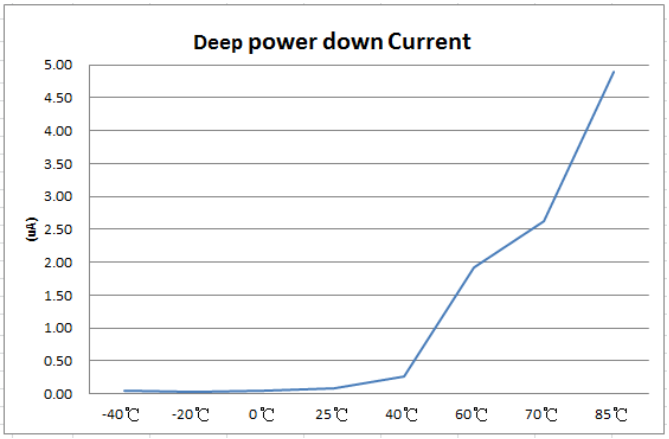










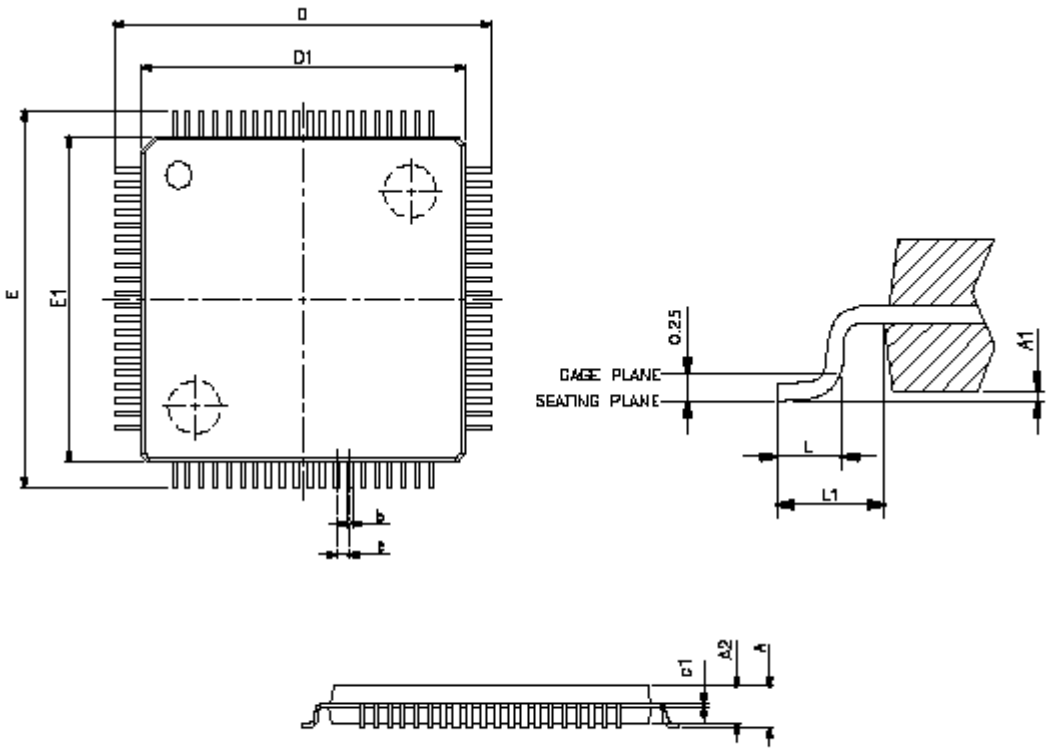


22 FLASH ROM PROGRAMMING PIN

Programming Information of SN32F240/230/220 Series											
Chip Name		SN32F249F SN32F239F SN32F229F		SN32F248F SN32F238F SN32F228F		SN32F247F SN32F237F SN32F227F		SN32F246J SN32F236J SN32F226J		SN32F245J SN32F235J SN32F225J	
MP PRO Writer Connector		Flash IC / JP3 Pin Assignment									
Number	Name	Number	Pin	Number	Pin	Number	Pin	Number	Pin	Number	Pin
1	VDD	*67*	VDD	*55*	VDD	*40*	VDD	*37*	VDD	*26*	VDD
2	GND	*69*	VSS	*56*	VSS	*41*	VSS	*38*	VSS	*27*	VSS
3	CLK	*74*	P3.12	*61*	P3.12	*46*	P3.12	*43*	P3.12	*32*	P3.12
4	CE										
5	PGM	*71*	P0.8	*58*	P0.8	*43*	P0.8	*40*	P0.8	*29*	P0.8
6	OE	*70*	P0.9	*57*	P0.9	*42*	P0.9	*39*	P0.9	*28*	P0.9
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	ALSB/PDB	*73*	P3.11	*60*	P3.11	*45*	P3.11	*42*	P3.11	*31*	P3.11

23 PACKAGE INFORMATION

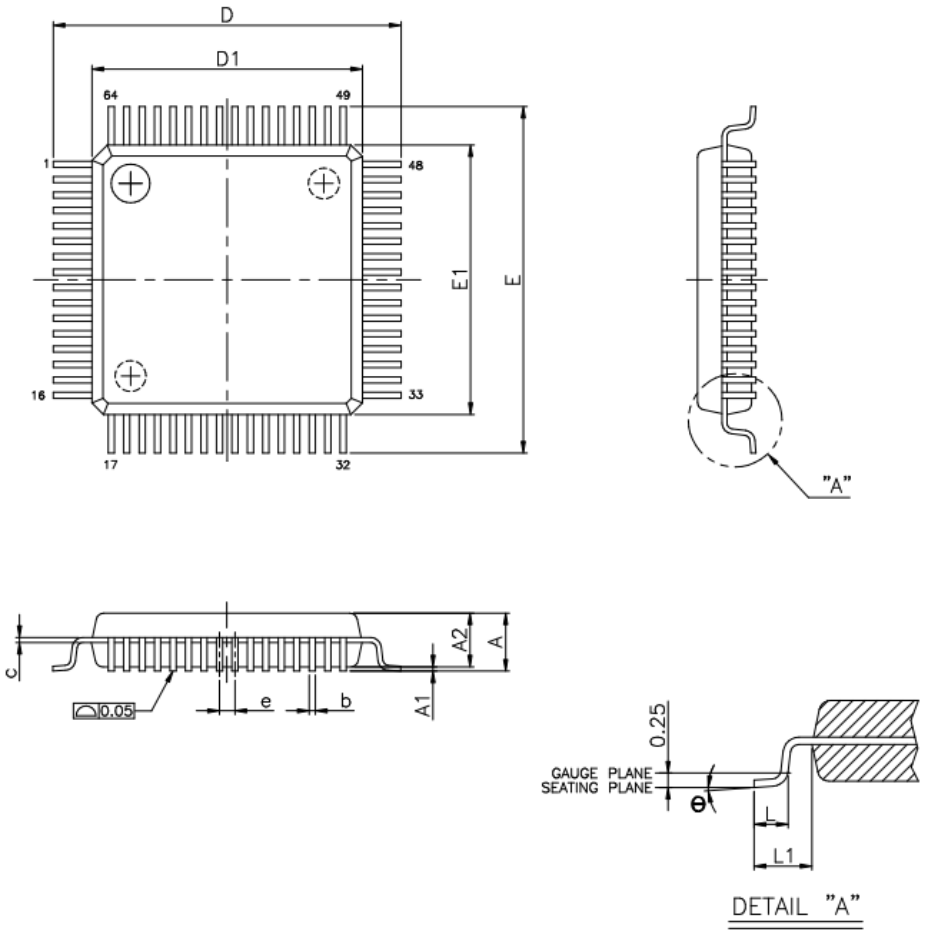
23.1 LQFP 80 PIN



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	

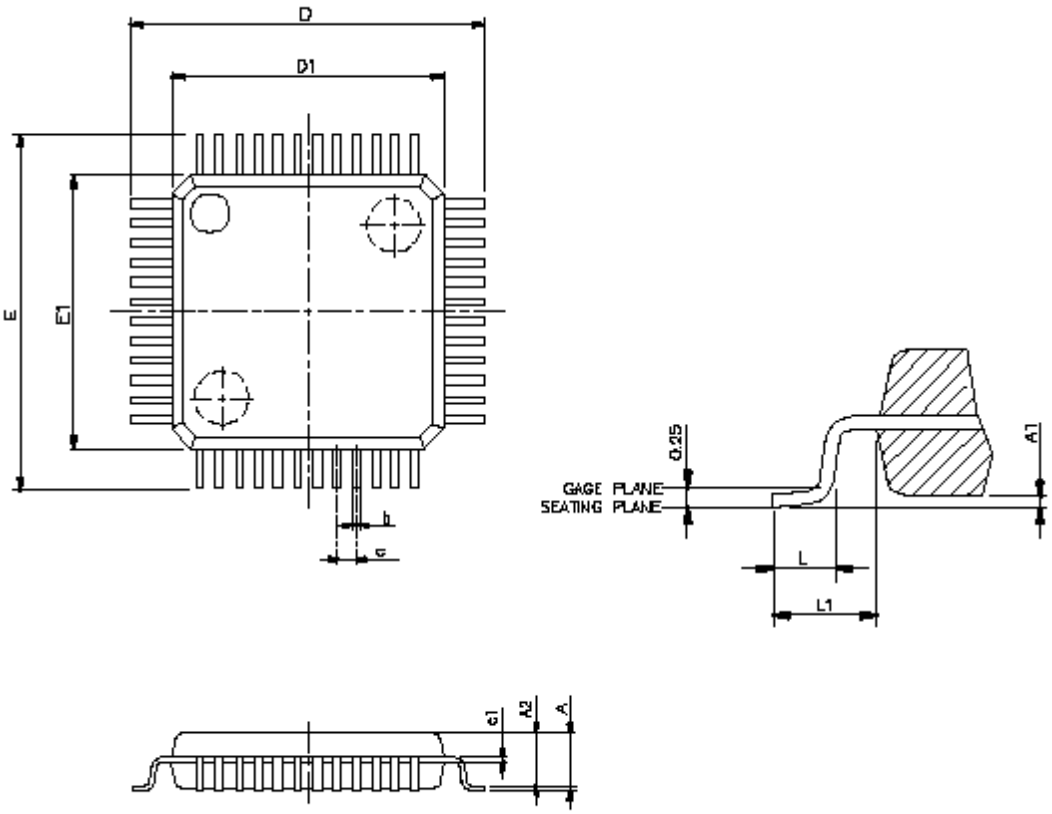
23.2 LQFP 64 PIN



VARIATIONS (ALL DIMENSIONS SHOWN IN MM)

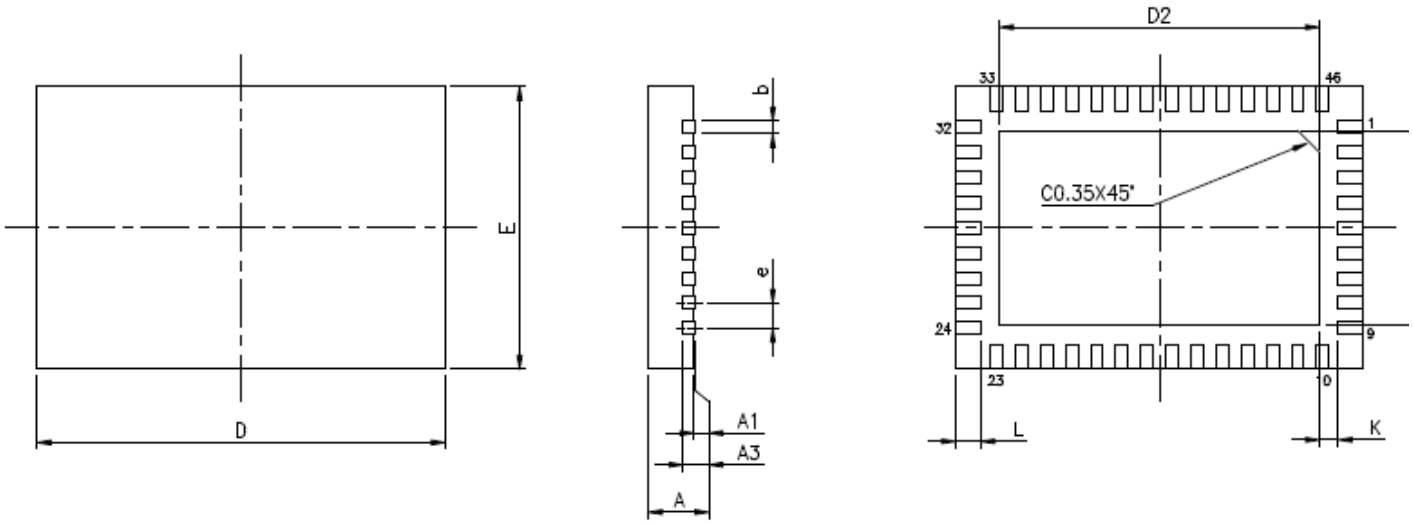
SYMBOLS	MIN.	NOM.	MAX.
A	—	—	1.60
A1	0.05	—	0.15
A2	1.35	1.40	1.45
b	0.13	0.18	0.23
c	0.09	—	0.20
D		9.00 BSC	
D1		7.00 BSC	
e		0.40 BSC	
E		9.00 BSC	
E1		7.00 BSC	
L	0.45	0.60	0.75
L1		1.00 REF	
θ	0°	3.5°	7°

23.3 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		

23.4 QFN 46 PIN

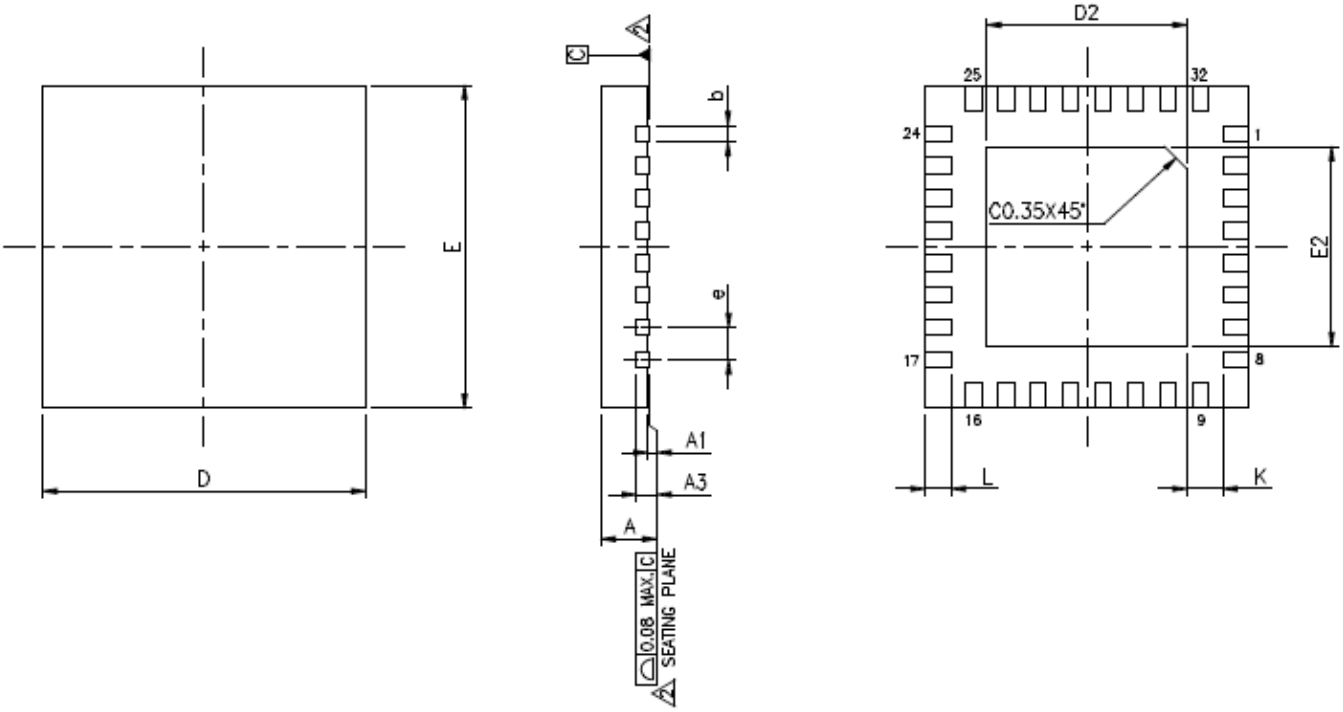


SYMBOLS	MIN.	NOM.	MAX.
A	0.70	0.75	0.80
A1	0.00	0.02	0.05
⚠ A3		0.203 REF.	
b	0.18	0.25	0.30
D	6.40	6.50	6.60
E	4.40	4.50	4.60
e		0.40 BSC.	
D2	5.00	5.10	5.20
E2	3.00	3.10	3.20
L	0.35	0.40	0.45
K	0.20	—	—

UNIT : mm

NOTES :
1. JEDEC OUTLINE : N/A.
2. DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.15mm AND 0.30mm FROM THE TERMINAL TIP. IF THE TERMINAL HAS THE OPTIONAL RADIUS ON THE OTHER END OF THE TERMINAL, THE DIMENSION b SHOULD NOT BE MEASURED IN THAT RADIUS AREA.
3. THE MINIMUM "K" VALUE OF 0.20mm APPLIES.
4. BILATERAL COPLANARITY ZONE APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.

23.5 QFN 33 PIN



SYMBOLS	MIN.	NOM.	MAX.
A	0.70	0.75	0.80
A1	0.00	0.02	0.05
A3		0.203 REF.	
b	0.18	0.25	0.30
D	4.90	5.00	5.10
E	4.90	5.00	5.10
e		0.50 BSC.	
L	0.35	0.40	0.45
K	0.20	—	—

UNIT : mm

	D2			E2		
EXPOSED PAD	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
2.7X2.7	2.60	2.70	2.80	2.60	2.70	2.80
3.2X3.2	3.10	3.20	3.30	3.10	3.20	3.30

UNIT : mm

NOTES :
1. JEDEC OUTLINE : N/A.
2. DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.15mm AND 0.30mm FROM THE TERMINAL TIP. IF THE TERMINAL HAS THE OPTIONAL RADIUS ON THE OTHER END OF THE TERMINAL, THE DIMENSION b SHOULD NOT BE MEASURED IN THAT RADIUS AREA.
3. THE MINIMUM "K" VALUE OF 0.20mm APPLIES.
4. BILATERAL COPLANARITY ZONE APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.

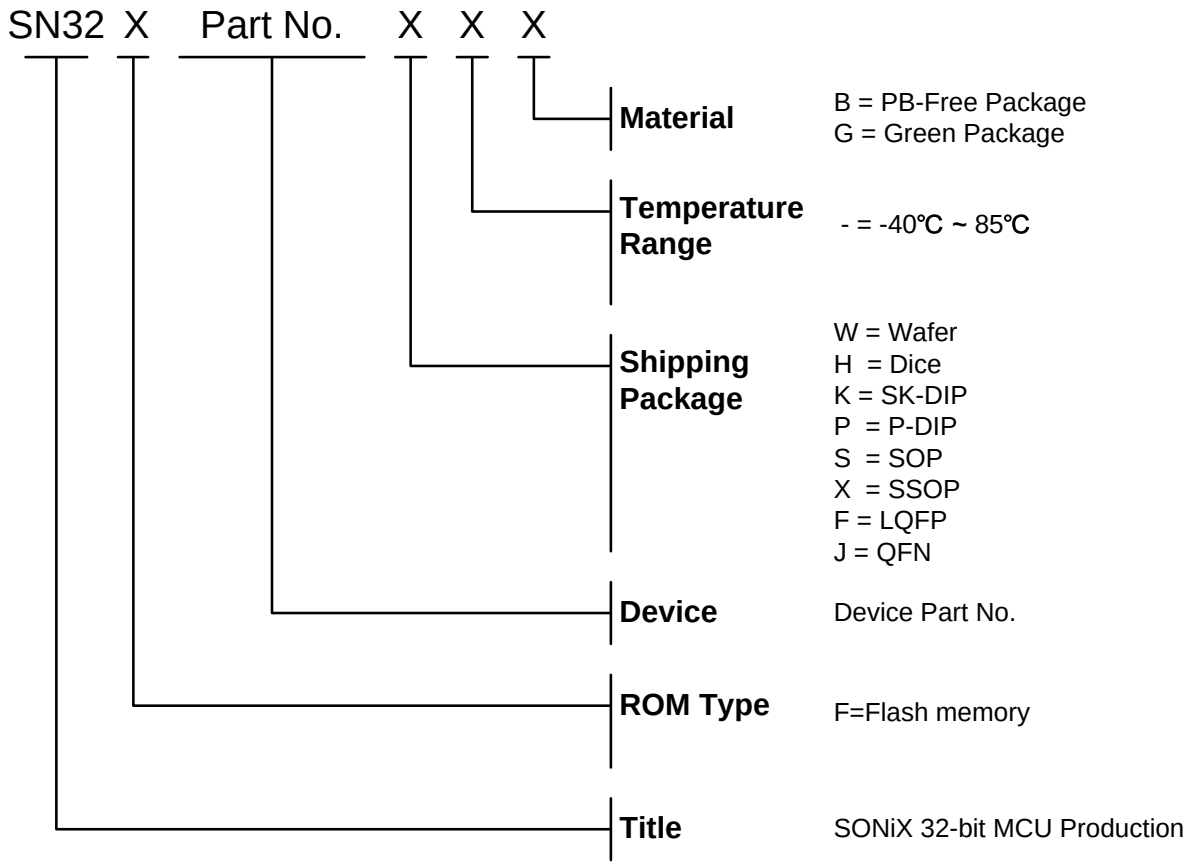
24 MARKING DEFINITION

24.1 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.

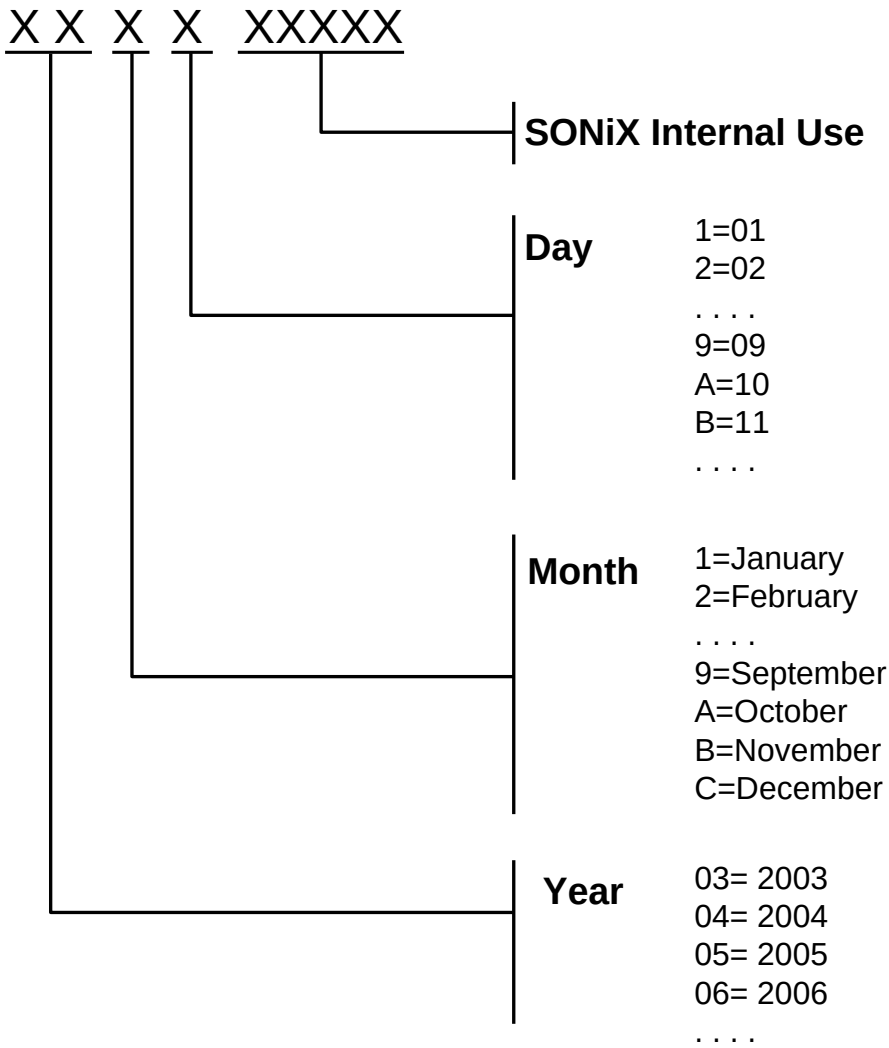
24.2 MARKING INDETIFICATION SYSTEM



24.3 MARKING EXAMPLE

Name	ROM Type	Device	Package	Temperature	Material
SN32F249FG	Flash memory	249	LQFP	0℃~70℃	Green Package
SN32F248FG	Flash memory	249	LQFP	0℃~70℃	Green Package
SN32F247FG	Flash memory	249	LQFP	0℃~70℃	Green Package
SN32F246JG	Flash memory	249	QFN	0℃~70℃	Green Package
SN32F249W	Flash memory	249	Wafer	0℃~70℃	-
SN32F249H	Flash memory	249	Dice	0℃~70℃	-

24.4 DATECODE SYSTEM



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