R-Sensor Blood Pressure Meter Flash MCU with LCD

BH67F2260/BH67F2270

Revision: V1.10 Date: August 17, 2017

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Features

CPU Features

- Operating voltage
  - f_{SYS}=4MHz: 2.2V~5.5V
  - f_{SYS}=8MHz: 2.2V~5.5V
  - f_{SYS}=12MHz: 2.7V~5.5V
  - f_{SYS}=16MHz: 3.3V~5.5V
- Up to 0.25μs instruction cycle with 16MHz system clock at V_{DD}=5V
- Power down and wake-up functions to reduce power consumption
- Oscillator types
  - External High Speed Crystal – HXT
  - External Low Speed 32.768kHz Crystal – LXT
  - Internal High Speed RC – HIRC
  - Internal Low Speed 32kHz RC – LIRC
- Multi-mode operation: FAST, SLOW, IDLE and SLEEP
- Fully integrated internal 4/8/12MHz oscillator requires no external components
- All instructions executed in 1~3 instruction cycles
- Table read instructions
- 115 powerful instructions
- 8-level subroutine nesting
- Bit manipulation instruction

Peripheral Features

- Flash Program Memory: 16K×16~32K×16
- Data Memory: 512×8~1024×8
- True EEPROM Memory: 64×8
- In Application Programming function – IAP
- Watchdog Timer function
- Up to 45 bidirectional I/O lines
- 2 pin-shared external interrupts
- Multiple Timer Modules for time measurement, input capture, compare match output or PWM output or single pulse output function
  - 1 Standard type 16-bit Timer Module − STM
  - 3 Periodic type 10-bit Timer Modules – PTM0~PTM2
- Serial Interface Module – SIM for SPI or I^2C
- Single Serial SPI Interface – SPIA
- Up to two fully-duplex Universal Asynchronous Receiver and Transmitter Interface – UART0 and UART1
- Dual Time-Base functions for generation of fixed time interrupt signals

- R-type Sensor Blood Pressure AFE
  - 4 external channels 12-bit resolution A/D converter
  - PGA and OPA modules
  - Constand Current Control
  - Battery Voltage Detection
- 16-bit Multiplication Division Unit
- LCD COM driver with 1/3 or 1/4 bias
- Low voltage reset function
- Low voltage detect function
- Internal 3.3V LDO
- Package types: 64/80-pin LQFP

General Description

This series of devices are Flash Memory A/D type 8-bit high performance RISC architecture microcontroller, specifically designed for Blood-Pressure Meter applications. Offering users the convenience of Flash Memory multi-programming features, these devices also include a wide range of functions and features. Other memory includes an area of RAM Data Memory as well as an area of true EEPROM memory for storage of non-volatile data such as serial numbers, calibration data etc.

Analog features include a multi-channel 12-bit A/D converter, PGA and OPA functions. Multiple and extremely flexible Timer Modules provide timing, pulse generation and PWM generation functions. Communication with the outside world is catered for by including fully integrated SPI, I^2C, SPIA and UART interface functions, popular interfaces which provide designers with a means of easy communication with external peripheral hardware. In addition, an internal LDO function provides various power options to the internal modules and external devices. Protective features such as an internal Watchdog Timer, Low Voltage Reset and Low Voltage Detector coupled with excellent noise immunity and ESD protection ensure that reliable operation is maintained in hostile electrical environments.

A full choice of external, internal high and low oscillators is provided including two fully integrated system oscillators which require no external components for their implementation. The ability to operate and switch dynamically between a range of operating modes using different clock sources gives users the ability to optimize microcontroller operation and minimize power consumption.

The inclusion of flexible I/O programming features, a fully integrated LCD driver, a 16-bit MDU and Time-Base funcitons along with many other features enhance the versatility of these devices to enable quick and cost efficient Blood-Pressure Meter applicaitons.

Selection Table

Most features are common to all devices. The main features distinguishing them are Memory capacity I/O count, UART, LCD and package types. The following table summarises the main features of each device.

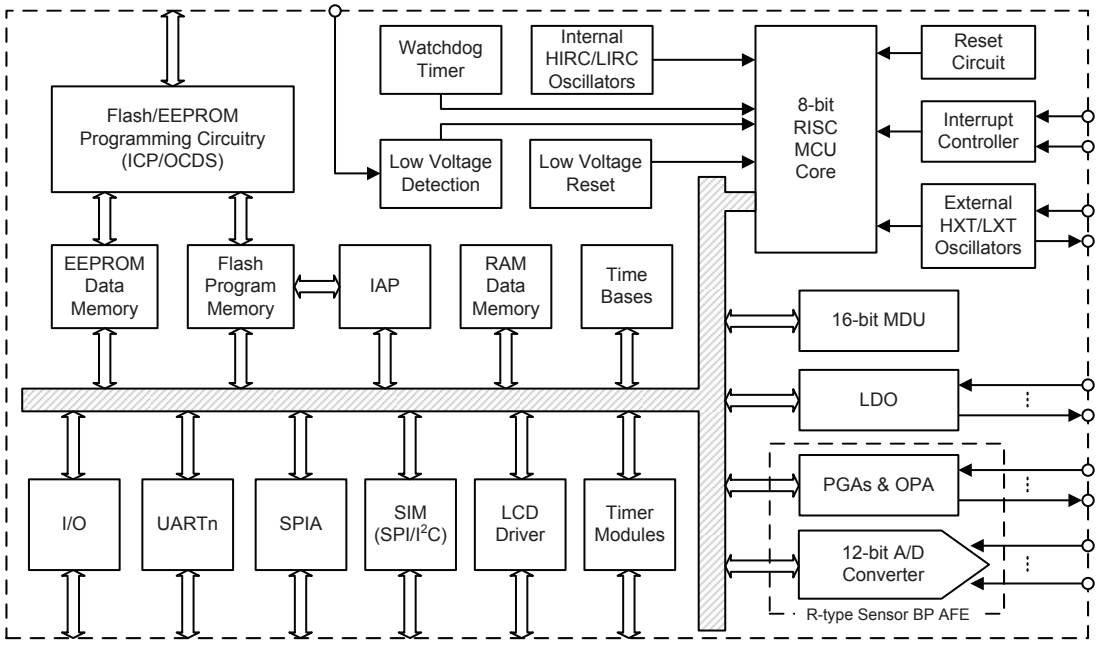
Part No.	V_{DD}	Program Memory	Data Memory	Data EEPROM	I/O	External Interrupt	A/D
BH67F2260	2.2V~5.5V	16K×16	512×8	64×8	32	2	12-bit×4
BH67F2270	2.2V~5.5V	32K×16	1024×8	64×8	45	2	12-bit×4

Part No.	Timer Module	Time base	SPIA	SIM	UART	MDU	LDO
BH67F2260	16-bit STM×1 10-bit PTM×3	2	√	√	1	16-bit MDU×1	√
BH67F2270	16-bit STM×1 10-bit PTM×3	2	√	√	2	16-bit MDU×1	√

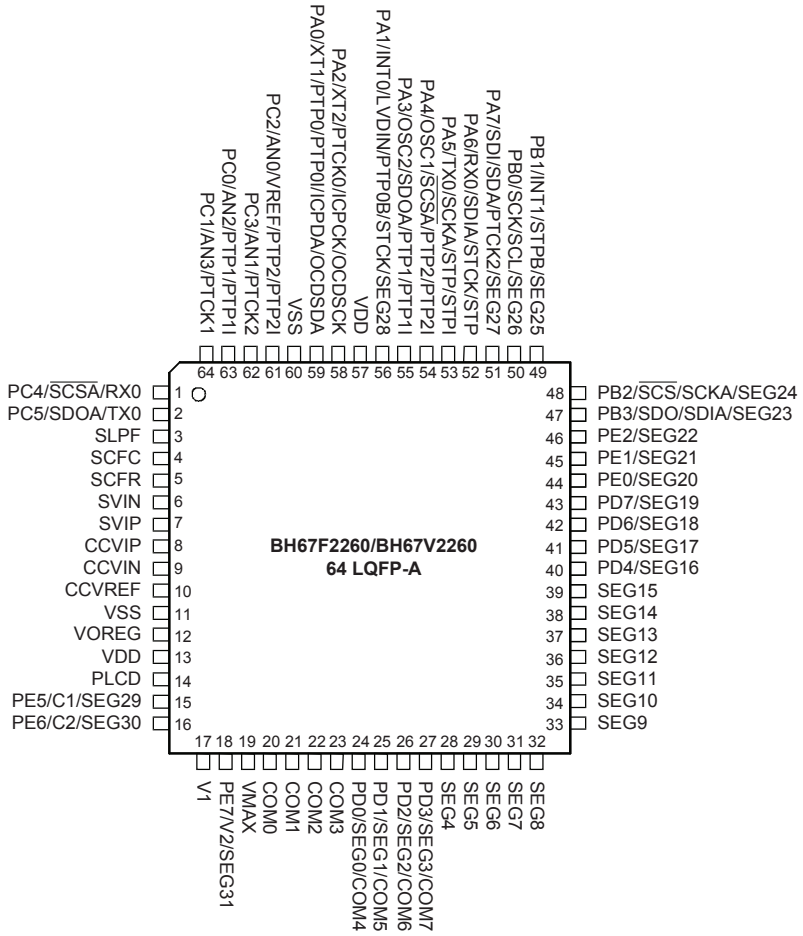
Part No.	Constant Current	PGA	OPA	LCD	Stacks	Package
BH67F2260	√	3	1	4×32 / 6×30 / 8×28	8	64LQFP
BH67F2270	√	3	1	4×46 / 6×44 / 8×42	8	64/80LQFP

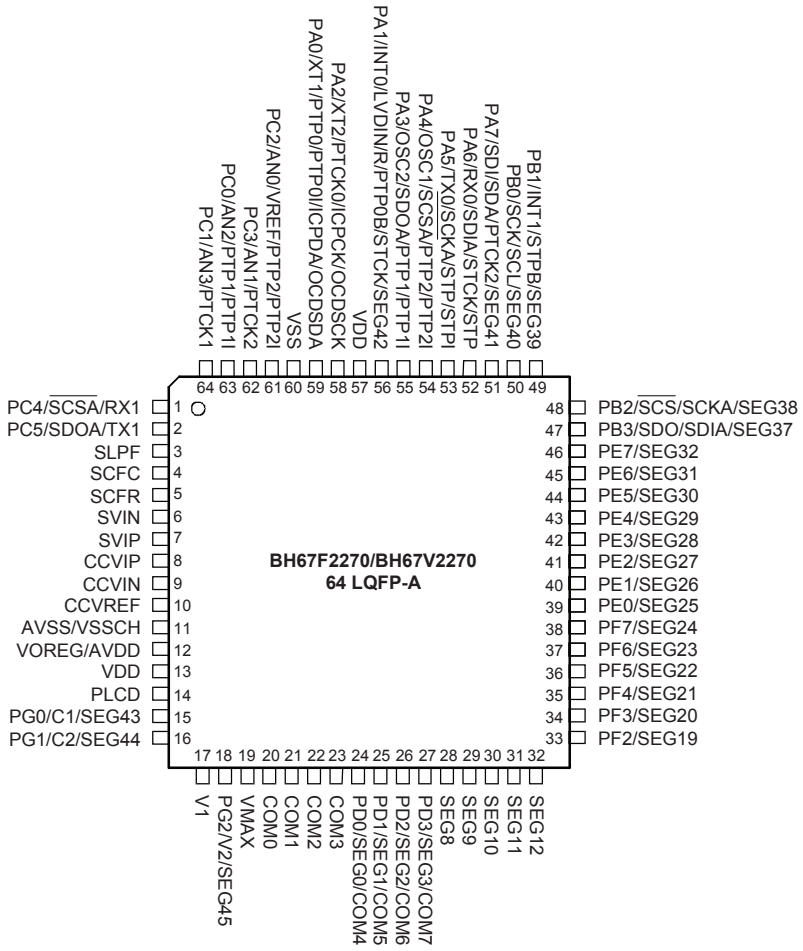
Note: As devices exist in more than one package format, the table reflects the situation for the package with the most pins.

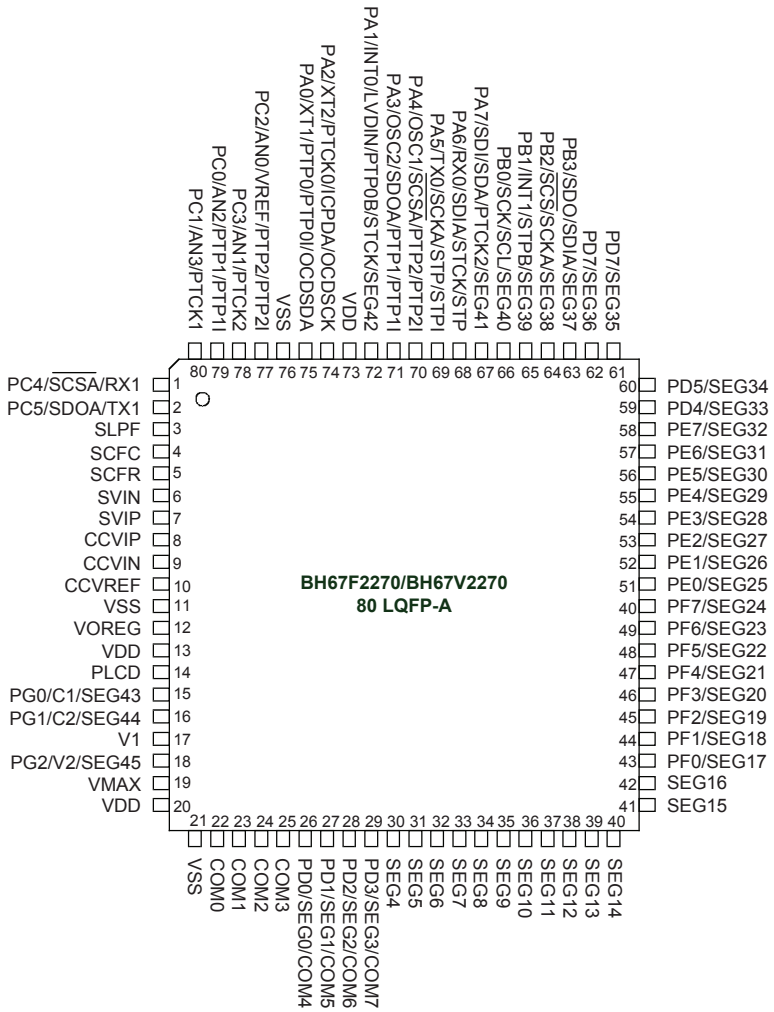
Block Diagram



Pin Assignment




BH67F2270/BH67V2270
64 LQFP-A
1 PC4/SCSA/RX1
2 PC5/SDOA/TX1
3 SLPF
4 SCFC
5 SCFR
6 SVIN
7 SVIP
8 CCVIP
9 CCVIN
10 CCVREF
11 AVSS/VSSCH
12 VOREG/AVDD
13 VDD
14 PLCD
15 PG0/C1/SEG43
16 PG1/C2/SEG44
17 V1
18 PG2/V2/SEG45
19 VMAX
20 COM0
21 COM1
22 COM2
23 COM3
24 PD0/SEG0/COM4
25 PD1/SEG1/COM5
26 PD2/SEG2/COM6
27 PD3/SEG3/COM7
28 SEG8
29 SEG9
30 SEG10
31 SEG11
32 SEG12
33 PF2/SEG19
34 PF3/SEG20
35 PF4/SEG21
36 PF5/SEG22
37 PF6/SEG23
38 PF7/SEG24
39 PE0/SEG25
40 PE1/SEG26
41 PE2/SEG27
42 PE3/SEG28
43 PE4/SEG29
44 PE5/SEG30
45 PE6/SEG31
46 PE7/SEG32
47 PB3/SDO/SDIA/SEG37
48 PB2/SCS/SCKA/SEG38
49 PB1/INT1/STPB/SEG39
50 PB0/SCK/SCL/SEG40
51 PA7/SDI/SDA/PTCK2/SEG41
52 PA6/RX0/SDIA/STCK/STP
53 PA5/TX0/SCKA/STP/STPI
54 PA4/OSC1/SCSA/PTP2/PTP2I
55 PA3/OSC2/SDOA/PTP1/PTP1I
56 PA1/INT0/LVDIN/R/PTP0B/STCK/SEG42
57 VDD
58 PA2/XT2/PTCK0/ICPCK/OCDSCK
59 PA0/XT1/PTP0/PTP0I/ICPDA/OCDSDA
60 VSS
61 PC2/AN0/VREF/PTP2/PTP2I
62 PC3/AN1/PTCK2
63 PC0/AN2/PTP1/PTP1I
64 PC1/AN3/PTCK1



Note: 1. If the pin-shared pin functions have multiple outputs simultaneously, the desired pin-shared function is determined by the corresponding software control bits.

2. The OCDSDA and OCDSCK pins are supplied for the OCDS dedicated pins and as such only available for the BH67V22x0 device which is the OCDS EV chip for the BH67F22x0 device.

Pin Description

With the exception of power pins and some LCD COM and SEG pins, all pins on these devices can be referenced by its Port name, e.g. PA0, PA1 etc., which refer to the digital I/O function of the pins. However these Port pins are also shared with other functions such as the Analog to Digital Converter, Timer Modules etc. The function of each pin is listed in the following table, however the details behind how each pin is configured is contained in other sections of the datasheet.

As the Pin Description Summary table applies to the package type with the most pins, not all of the above listed pins may be present on package types with smaller numbers of pins.

BH67F2260

Pin Name	Function	OPT	I/T	O/T	Description
PA0/XT1/PTP0/ PTP0I/ICPDA/ OCDSDA	PA0	PAPU PAWU PAS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	XT1	PAS0	LXT	—	LXT oscillator input
	PTP0	PAS0	—	CMOS	PTM0 ouput
	PTP0I	PAS0	ST	—	PTM0 capture input
	ICPDA	—	ST	CMOS	ICP Address/Data
	OCDSDA	—	ST	CMOS	OCDS data/address pin, for EV chip only.
PA1/INT0/LVDIN/ PTP0B/STCK/SEG28	PA1	PAPU PAWU PAS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	INT0	PAS0 INTEG INTC0	ST	—	External interrupt 0 input
	LVDIN	PAS0	AN	—	LVD input
	PTP0B	PAS0	—	CMOS	PTM0 inverted ouput
	STCK	PAS0 IFS0	ST	—	STM clock input
	SEG28	PAS0	—	SEG	LCD segment output
PA2/XT2/PTCK0/ ICPCK/OCDSCK	PA2	PAPU PAWU PAS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	XT2	PAS0	—	LXT	LXT oscillator output
	PTCK0	PAS0	ST	—	PTM0 clock input
	ICPCK	—	ST	—	ICP clock
	OCDSCK	—	ST	—	OCDS clock pin, for EV chip only
PA3/OSC2/SDOA/ PTP1/PTP1I	PA3	PAPU PAWU PAS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	OSC2	PAS0	—	HXT	HXT oscillator output
	SDOA	PAS0	—	CMOS	SPIA serial data output
	PTP1	PAS0	—	CMOS	PTM1 ouput
	PTP1I	PAS0 IFS0	ST	—	PTM1 capture input

Pin Name	Function	OPT	I/T	O/T	Description
PA4/OSC1/$\overline{SCSA}$/PTP2/PTP2I	PA4	PAPU PAWU PAS1	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	OSC1	PAS1	HXT	—	HXT oscillator input
	$\overline{SCSA}$	PAS1 IFS1	ST	CMOS	SPIA slave select
	PTP2	PAS1	—	CMOS	PTM2 ouput
	PTP2I	PAS1 IFS0	ST	—	PTM2 capture input
PA5/TX0/SCKA/STP/STPI	PA5	PAPU PAWU PAS1	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	TX0	PAS1	—	CMOS	UART0 TX serial data output
	SCKA	PAS1 IFS1	ST	CMOS	SPIA serial clock
	STP	PAS1	—	CMOS	STM ouput
	STPI	PAS1	ST	—	STM capture input
PA6/RX0/SDIA/STCK/STP	PA6	PAPU PAWU PAS1	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	RX0	PAS1 IFS1	ST	—	UART0 RX serial data input
	SDIA	PAS1 IFS1	ST	—	SPIA serial data input
	STCK	PAS1 IFS0	ST	—	STM clock input
	STP	PAS1	—	CMOS	STM ouput
PA7/SDI/SDA/PTCK2/SEG27	PA7	PAPU PAWU PAS1	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	SDI	PAS1	ST	—	SPI serial data input
	SDA	PAS1	ST	NMOS	I^2C data line
	PTCK2	PAS1 IFS1	ST	—	PTM2 clock input
	SEG27	PAS1	—	SEG	LCD segment output
PB0/SCK/SCL/SEG26	PB0	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	SCK	PBS0	ST	CMOS	SPI serial clock
	SCL	PBS0	ST	NMOS	I^2C clock line
	SEG26	PBS0	—	SEG	LCD segment output
PB1/INT1/STPB/SEG25	PB1	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	INT1	PBS0 INTEG INTC0	ST	—	External interrupt 1 input
	STPB	PBS0	—	CMOS	STM inverted ouput
	SEG25	PBS0	—	SEG	LCD segment output
PB2/$\overline{SCS}$/SCKA/SEG24	PB2	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	$\overline{SCS}$	PBS0	ST	CMOS	SPI slave select
	SCKA	PBS0 IFS1	ST	CMOS	SPIA serial clock
	SEG24	PBS0	—	SEG	LCD segment output

Pin Name	Function	OPT	I/T	O/T	Description
PB3/SDO/SDIA/SEG23	PB3	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	SDO	PBS0	—	CMOS	SPI serial data output
	SDIA	PBS0 IFS1	ST	—	SPIA serial data input
	SEG23	PBS0	—	SEG	LCD segment output
PC0/AN2/PTP1/PTP1I	PC0	PCPU PCS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	AN2	PCS0	AN	—	A/D Converter external input 2
	PTP1	PCS0	—	CMOS	PTM1 ouput
	PTP1I	PCS0 IFS0	ST	—	PTM1 capture input
PC1/AN3/PTCK1	PC1	PCPU PCS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	AN3	PCS0	AN	—	A/D Converter external input 3
	PTCK1	PCS0	ST	—	PTM1 clock input
PC2/AN0/VREF/PTP2/PTP2I	PC2	PCPU PCS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	AN0	PCS0	AN	—	A/D Converter external input 0
	VREF	PCS0	AN	—	A/D Converter external reference voltage input
	PTP2	PCS0	—	CMOS	PTM2 ouput
	PTP2I	PCS0 IFS0	ST	—	PTM2 capture input
PC3/AN1/PTCK2	PC3	PCPU PCS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	AN1	PCS0	AN	—	A/D Converter external input 1
	PTCK2	PCS0 IFS0	ST	—	PTM2 clock input
PC4/$\overline{\text{SCSA}}$/RX0	PC4	PCPU PCS1	ST	CMOS	General purpose I/O. Register enabled pull-up
	$\overline{\text{SCSA}}$	PCS1 IFS1	ST	CMOS	SPIA slave select
	RX0	PCS1 IFS1	ST	—	UART0 RX serial data input
PC5/SDOA/TX0	PC5	PCPU PCS1	ST	CMOS	General purpose I/O. Register enabled pull-up
	SDOA	PCS1	—	CMOS	SPIA serial data output
	TX0	PCS1	—	CMOS	UART0 TX serial data output
PD0/SEG0/COM4	PD0	PDPU PDS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	SEG0	PDS0	—	SEG	LCD segment output
	COM4	PDS0	—	COM	LCD common output
PD1/SEG1/COM5	PD1	PDPU PDS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	SEG1	PDS0	—	SEG	LCD segment output
	COM5	PDS0	—	COM	LCD common output
PD2/SEG2/COM6	PD2	PDPU PDS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	SEG2	PDS0	—	SEG	LCD segment output
	COM6	PDS0	—	COM	LCD common output

Pin Name	Function	OPT	I/T	O/T	Description
PD3/SEG3/COM7	PD3	PDPU PDS0	ST	CMOS	General purpose I/O. Register enabled pull-up
	SEG3	PDS0	—	SEG	LCD segment output
	COM7	PDS0	—	COM	LCD common output
PD4/SEG16	PD4	PDPU PDS1	ST	CMOS	General purpose I/O. Register enabled pull-up
	SEG16	PDS1	—	SEG	LCD segment output
PD5/SEG17	PD5	PDPU PDS1	ST	CMOS	General purpose I/O. Register enabled pull-up
	SEG17	PDS1	—	SEG	LCD segment output
PD6/SEG18	PD6	PDPU PDS1	ST	CMOS	General purpose I/O. Register enabled pull-up
	SEG18	PDS1	—	SEG	LCD segment output
PD7/SEG19	PD7	PDPU PDS1	ST	CMOS	General purpose I/O. Register enabled pull-up
	SEG19	PDS1	—	SEG	LCD segment output
PE0/SEG20	PE0	PEPU PES0	ST	CMOS	General purpose I/O. Register enabled pull-up
	SEG20	PES0	—	SEG	LCD segment output
PE1/SEG21	PE1	PEPU PES0	ST	CMOS	General purpose I/O. Register enabled pull-up
	SEG21	PES0	—	SEG	LCD segment output
PE2/SEG22	PE2	PEPU PES0	ST	CMOS	General purpose I/O. Register enabled pull-up
	SEG22	PES0	—	SEG	LCD segment output
PE5/C1/SEG29	PE5	PEPU PES1	ST	CMOS	General purpose I/O. Register enabled pull-up
	C1	PES1	AN	—	LCD voltage pump
	SEG29	PES1	—	SEG	LCD segment output
PE6/C2/SEG30	PE6	PEPU PES1	ST	CMOS	General purpose I/O. Register enabled pull-up
	C2	PES1	AN	—	LCD voltage pump
	SEG30	PES1	—	SEG	LCD segment output
PE7/V2/SEG31	PE7	PEPU PES1	ST	CMOS	General purpose I/O. Register enabled pull-up
	V2	PES1	—	AN	LCD voltage pump
	SEG31	PES1	—	SEG	LCD segment output
COM0~COM3	COMn	—	—	COM	LCD common output
SEG4~SEG15	SEGn	—	—	SEG	LCD segment output
VMAX	VMAX	—	PWR	—	IC maximum voltage, connected to VDD or V1
PLCD	PLCD	—	PWR	—	LCD power supply
V1	V1	—	AN	—	LCD voltage pump
SLPF	SLPF	—	AN	—	PGA2 input
SCFR	SCFR	—	—	AN	PGA1 output
SCFC	SCFC	—	AN	—	SCF input
SVIN	SVIN	—	AN	—	Pressure sensor negative input
SVIP	SVIP	—	AN	—	Pressure sensor positive input
CCVIP	CCVIP	—	—	AN	OPA output
CCVIN	CCVIN	—	AN	—	OPA inverting input
CCVREF	CCVREF	—	—	AN	V_{CCREF} output pin, a capacitor is connected between this pin and VSS.

Pin Name	Function	OPT	I/T	O/T	Description
VOREG	VOREG	—	PWR	—	LDO regulator output
VDD	VDD	—	PWR	—	Positive power supply
VSS	VSS	—	PWR	—	Negative power supply, ground.

Legend: I/T: Input type; O/T: Output type; PWR: Power;
OPT: Optional by register option; ST: Schmitt Trigger input; CMOS: CMOS output;
NMOS: NMOS output; AN: Analog signal; SEG: LCD SEG output;
COM: LCD COM output; HXT: High frequency crystal oscillator;
LXT: Low frequency crystal oscillator

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Pin Name	Function	OPT	I/T	O/T	Description
PA0/XT1/PTP0/PTP0I/ ICPDA/OCDSDA	PA0	PAPU PAWU PAS0	ST	CMOS	General purpose I/O. Register enabled pull-high and wake-up
	XT1	PAS0	LXT	—	LXT oscillator input
	PTP0	PAS0	—	CMOS	PTM0 output
	PTP0I	PAS0	ST	—	PTM0 capture input
	ICPDA	—	ST	CMOS	ICP data/address
	OCDSDA	—	ST	CMOS	OCDS data/address, for EV chip only
PA1/INT0/LVDIN/PTP0B/ STCK/ SEG42	PA1	PAPU PAWU PAS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	INT0	PAS0 INTEG INTC0	ST	—	External Interrupt 0 input
	LVDIN	PAS0	AN	—	LVD input
	PTP0B	PAS0	—	CMOS	PTM0 inverted output
	STCK	PAS0 IFS0	ST	—	STM clock input
	SEG42	PAS0	—	SEG	LCD Segment Output
PA2/XT2/PTCK0/ ICPCK / OCDSCK	PA2	PAPU PAWU PAS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	XT2	PAS0	—	LXT	LXT oscillator output
	PTCK0	PAS0	ST	—	PTM0 clock input
	ICPCK	—	ST	—	ICP clock
	OCDSCK	—	ST	—	OCDS clock pin, for EV chip only
PA3/OSC2/SDOA/PTP1/ PTP1I	PA3	PAPU PAWU PAS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	OSC2	PAS0	—	HXT	HXT Oscillator output
	SDOA	PAS0	—	CMOS	SPIA serial data output
	PTP1	PAS0	—	CMOS	PTM1 output
	PTP1I	PAS0 IFS0	ST	—	PTM1 capture input

Pin Name	Function	OPT	I/T	O/T	Description
PA4/OSC1/$\overline{SCSA}$/PTP2/PTP2I	PA4	PAPU PAWU PAS1	ST	CMOS	General purpose I/O. Register enabled pull-high and wake-up
	OSC1	PAS1	HXT	—	HXT Oscillator input
	$\overline{SCSA}$	PAS1 IFS1	ST	CMOS	SPIA slave select
	PTP2	PAS1	—	CMOS	PTM2 output
	PTP2I	PAS1 IFS0	ST	—	PTM2 capture input
PA5/TX0/SCKA/STP/STPI	PA5	PAPU PAWU PAS1	ST	CMOS	General purpose I/O. Register enabled pull-high and wake-up
	TX0	PAS1	—	CMOS	UART0 TX serial data output
	SCKA	PAS1 IFS1	ST	CMOS	SPIA serial clock
	STP	PAS1	—	CMOS	STM output
	STPI	PAS1	ST	—	STM capture input
PA6/RX0/SDIA/STCK/STP	PA6	PAPU PAWU PAS1	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	RX0	PAPU IFS1	ST	—	UART0 RX serial data input
	SDIA	PAWU IFS1	ST	—	SPIA serial data input
	STCK	PAS1 IFS0	AN	—	STM clock input
	STP	PAS1	—	CMOS	STM output
PA7/SDI/SDA/PTCK2/SEG41	PA7	PAPU PAWU PAS1	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	SDI	PAS1	ST	—	SPI serial data input
	SDA	PAS1	ST	NMOS	I^2C data line
	PTCK2	PAS1	ST	—	PTM2 clock input
	SEG41	PAS1	—	SEG	LCD Segment Output
PB0/SCK/SCL/SEG40	PB0	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	SCK	PBS0	ST	CMOS	SPI serial clock
	SCL	PBS0	ST	—	I^2C clock line
	SEG40	PBS0	—	SEG	LCD Segment Output
PB1/INT1/STPB/SEG39	PB1	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	INT1	PBS0 INTEG INTC0	ST	—	External interrupt 1input
	STPB	PBS0	—	CMOS	STM inverting output
	SEG39	PBS0	—	SEG	LCD Segment Output
PB2/$\overline{SCS}$/SCKA/SEG38	PB2	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	$\overline{SCS}$	PBS0	ST	CMOS	SPI slave select
	SCKA	PBS0 IFS1	ST	CMOS	SPIA serial clock
	SEG38	PBS0	—	SEG	LCD Segment Output

Pin Name	Function	OPT	I/T	O/T	Description
PB3/SDO/SDIA/SEG37	PB3	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	SDO	PBS0	—	CMOS	SPI serial data output
	SDIA	PBS0 IFS1	ST	—	SPIA serial data input
	SEG37	PBS0	—	SEG	LCD Segment Output
PC0/AN2/PTP1/PTP1I	PC0	PCPU PCS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	AN2	PCS0	AN	—	A/D Converter external input 2
	PTP1	PCS0	—	CMOS	PTM1 output
	PTP1I	PCS0	ST	—	PTM1 capture input
PC1/AN3/PTCK1	PC1	PCPU PCS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	AN3	PCS0	AN	—	A/D Converter external input 3
	PTCK1	PCS0	ST	—	PTM1 clock input
PC2/AN0/VREF/PTP2/ PTP2I	PC2	PCPU PCS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	AN0	PCS0	AN	—	A/D Converter external input 0
	VREF	PCS0	AN	—	A/D Converter external reference voltage input
	PTP2	PCS0	—	CMOS	PTM2 output
	PTP2I	PCS0	ST	—	PTM2 capture input
PC3/AN1/PTCK2	PC3	PCPU PCS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	AN1	PCS0	AN	—	A/D Converter external input 1
	PTCK2	PCS0	ST	—	PTM2 clock input
PC4/$\overline{\text{SCSA}}$/RX1	PC4	PCPU PCS1	ST	CMOS	General purpose I/O. Register enabled pull-high
	$\overline{\text{SCSA}}$	PCS1	ST	CMOS	SPIA slave select
	RX1	PCS1	ST	—	UART1 RX serial data input
PC5/SDOA/TX1	PC5	PCPU PCS1	ST	CMOS	General purpose I/O. Register enabled pull-high
	SDOA	PCS1	—	CMOS	SPIA serial data output
	TX1	PCS1	—	CMOS	UART1 TX serial data output
PD0/SEG0/COM4	PD0	PDPU PDS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG0	PDS0	—	SEG	LCD Segment output
	COM4	PDS0	—	COM	LCD Common output
PD1/SEG1/COM5	PD1	PDPU PDS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG1	PDS0	—	SEG	LCD Segment output
	COM5	PDS0	—	COM	LCD Common output
PD2/SEG2/COM6	PD2	PDPU PDS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG2	PDS0	—	SEG	LCD Segment output
	COM6	PDS0	—	COM	LCD Common output
PD3/SEG3/COM7	PD3	PDPU PDS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG3	PDS0	—	SEG	LCD Segment output
	COM7	PDS0	—	COM	LCD Common output

Pin Name	Function	OPT	I/T	O/T	Description
PD4/SEG33	PD4	PDPU PDS1	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG33	PDS1	—	SEG	LCD Segment output
PD5/SEG34	PD5	PDPU PDS1	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG34	PDS1	—	SEG	LCD Segment output
PD6/SEG35	PD6	PDPU PDS1	ST	CMOS	General purpose I/O. Register enabled pull-high.
	SEG35	PDS1	—	SEG	LCD Segment output
PD7/SEG36	PD7	PDPU PDS1	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG36	PDS1	—	SEG	LCD Segment output
PE0/SEG25	PE0	PEPU PES0	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG25	PES0	—	SEG	LCD Segment output
PE1/SEG26	PE1	PEPU PES0	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG26	PES0	—	SEG	LCD Segment output
PE2/SEG27	PE2	PEPU PES0	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG27	PES0	—	SEG	LCD Segment output
PE3/SEG28	PE3	PEPU PES0	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG28	PES0	—	SEG	LCD Segment output
PE4/SEG29	PE4	PEPU PES1	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG29	PES1	—	SEG	LCD Segment output
PE5/SEG30	PE5	PEPU PES1	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG30	PES1	—	SEG	LCD Segment output
PE6/SEG31	PE6	PEPU PES1	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG31	PES1	—	SEG	LCD Segment output
PE7/SEG32	PE7	PEPU PES1	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG32	PES1	—	SEG	LCD Segment output
PF0/SEG17	PF0	PFPU PFS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG17	PFS0	—	SEG	LCD Segment output
PF1/SEG18	PF1	PFPU PFS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG18	PFS0	—	SEG	LCD Segment output
PF2/SEG19	PF2	PFPU PFS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG19	PFS0	—	SEG	LCD Segment output
PF3/SEG20	PF3	PFPU PFS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG20	PFS0	—	SEG	LCD Segment output
PF4/SEG21	PF4	PFPU PFS1	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG21	PFS1	—	SEG	LCD Segment output

Pin Name	Function	OPT	I/T	O/T	Description
PF5/SEG22	PF5	PFPU PFS1	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG22	PFS1	—	SEG	LCD Segment output
PF6/SEG23	PF6	PFPU PFS1	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG23	PFS1	—	SEG	LCD Segment output
PF7/SEG24	PF7	PFPU PFS1	ST	CMOS	General purpose I/O. Register enabled pull-high
	SEG24	PFS1	—	SEG	LCD Segment output
PG0/C1/SEG43	PG0	PGPU PGS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	C1	PGS0	AN	—	LCD voltage pump
	SEG43	PGS0	—	SEG	LCD Segment output
PG1/C2/SEG44	PG1	PGPU PGS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	C2	PGS0	AN	—	LCD voltage pump
	SEG44	PGS0	—	SEG	LCD Segment output
PG2/V2/SEG45	PG2	PGPU PGS0	ST	CMOS	General purpose I/O. Register enabled pull-high
	V2	PGS0	—	AN	LCD voltage pump
	SEG45	PGS0	—	SEG	LCD Segment output
VMAX	VMAX	—	PWR	—	IC maximum voltage, connect to VDD or V1
PLCD	PLCD	—	PWR	—	LCD power supply
V1	V1	—	AN	—	LCD voltage pump
COM0~ COM3	COMn	—	—	COM	LCD Common output
SEG4 ~ SEG16	SEGn	—	—	SEG	LCD Segment output
SLPF	SLPF	—	AN	—	PGA2 input
SCFR	SCFR	—	—	AN	PGA1 output
SCFC	SCFC	—	AN	—	SCF input
SVIN	SVIN	—	AN	—	Pressure sensor negative input
SVIP	SVIP	—	AN	—	Pressure sensor positive input
CCVIP	CCVIP	—	—	AN	OPA Output
CCVIN	CCVIN	—	AN	—	OPA inverting input
CCVREF	CCVREF	—	—	AN	Constant current reference voltage output pin – capacitor connected between this pin and VSS
VOREG	VOREG	—	PWR	—	Regulator output
VDD	VDD	—	PWR	—	Digital positive power supply
VSS	VSS	—	PWR	—	Digital negative power supply

Legend: I/T: Input type; O/T: Output type; PWR: Power;
OPT: Optional by register option; ST: Schmitt Trigger input; CMOS: CMOS output;
NMOS: NMOS output; AN: Analog signal; SEG: LCD SEG output;
COM: LCD COM output; HXT: High frequency crystal oscillator;
LXT: Low frequency crystal oscillator

Absolute Maximum Ratings

Supply Voltage ..... V_{SS}-0.3V~V_{SS}+6.0V

Input Voltage ..... V_{SS}-0.3V to V_{DD}+0.3V

Storage Temperature..... -50°C to 125°C

Operating Temperature..... -40°C to 85°C

I_{OH} Total..... -80mA

I_{OL} Total 80mA

Total Power Dissipation 500mW

Note: These are stress ratings only. Stresses exceeding the range specified under "Absolute Maximum Ratings" may cause substantial damage to these devices. Functional operation of these devices at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect devices reliability.

D.C. Characteristics

For data in the following tables, note that factors such as oscillator type, operating voltage, operating frequency, pin load conditions, temperature and program instruction type, etc., can all exert an influence on the measured values.

Operating Voltage Characteristics

Ta=-40˚C~85˚C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Operating Voltage – HXT	—	$f_{SYS}=f_{HXT}$=4MHz	2.2	—	5.5	V
			$f_{SYS}=f_{HXT}$=8MHz	2.2	—	5.5	
			$f_{SYS}=f_{HXT}$=12MHz	2.7	—	5.5	
			$f_{SYS}=f_{HXT}$=16MHz	3.3	—	5.5	
	Operating Voltage – HIRC	—	$f_{SYS}=f_{HIRC}$=4MHz	2.2	—	5.5	V
			$f_{SYS}=f_{HIRC}$=8MHz	2.2	—	5.5	
			$f_{SYS}=f_{HIRC}$=12MHz	2.7	—	5.5	
	Operating Voltage – LXT	—	$f_{SYS}=f_{LXT}$=32.768kHz	2.2	—	5.5	V
	Operating Voltage – LIRC	—	$f_{SYS}=f_{LIRC}$=32kHz	2.2	—	5.5	V

Standby Current Characteristics

Ta=25°C

Symbol	Standby Mode	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
I_{STB}	SLEEP Mode	3V	WDT off	—	0.2	0.8	μA
		5V		—	0.5	1.0	
		3V	WDT on	—	1.5	3.0	μA
		5V		—	3.0	5.0	
	IDLE0 Mode	3V	f_{SUB} on	—	1.5	3.0	μA
		5V		—	3.0	5.0	
	IDLE1 Mode – HIRC	3V	f_{SUB} on, f_{SYS} = 4MHz	—	250	360	μA
		5V		—	450	720	
		3V	f_{SUB} on, f_{SYS} = 8MHz	—	420	600	μA
		5V		—	800	1200	
		3V	f_{SUB} on, f_{SYS} = 12MHz	—	600	900	μA
		5V		—	1200	1800	
	IDLE1 Mode – HXT	3V	f_{SUB} on, f_{SYS} = 4MHz	—	250	360	μA
		5V		—	450	720	
		3V	f_{SUB} on, f_{SYS} = 8MHz	—	420	600	μA
		5V		—	800	1200	
		3V	f_{SUB} on, f_{SYS} = 12MHz	—	600	900	μA
		5V		—	1200	1800	
		5V	f_{SUB} on, f_{SYS} = 16MHz	—	1.8	2.4	mA

Notes: When using the characteristic table data, the following notes should be taken into consideration:

1. Any digital inputs are setup in a non-floating condition.
2. All measurements are taken under conditions of no load and with all peripherals in an off state.
3. There are no DC current paths.
4. All Standby Current values are taken after a HALT instruction execution thus stopping all instruction execution.

Operating Current Characteristics

Ta=25°C

Symbol	Operating Mode	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
I_{DD}	Operating Current – LIRC	3V	f_{SYS}=32kHz	—	10	20	μA
		5V		—	30	50	
	Operating Current – LXT	3V	f_{SYS}=32768Hz	—	10	20	μA
		5V		—	30	50	
	Operating Current – HIRC	3V	f_{SYS}=4MHz	—	0.4	0.6	mA
		5V		—	0.8	1.2	
		3V	f_{SYS}=8MHz	—	0.8	1.2	mA
		5V		—	1.6	2.4	
		3V	f_{SYS}=12MHz	—	1.2	1.8	mA
		5V		—	2.4	3.6	
	Operating Current – HXT	3V	f_{SYS}=4MHz	—	0.5	0.75	mA
		5V		—	1.0	1.5	
		3V	f_{SYS}=8MHz	—	1.0	1.5	mA
		5V		—	2.0	3.0	
		3V	f_{SYS}=12MHz	—	1.5	2.75	mA
		5V		—	3.0	4.5	
		5V	f_{SYS}=16MHz	—	4.0	6.0	mA

Notes: When using the characteristic table data, the following notes should be taken into consideration:

1. Any digital inputs are setup in a non-floating condition.
2. All measurements are taken under conditions of no load and with all peripherals in an off state.
3. There are no DC current paths.
4. All Operating Current values are measured using a continuous NOP instruction program loop.

A.C. Characteristics

For data in the following tables, note that factors such as oscillator type, operating voltage, operating frequency and temperature etc., can all exert an influence on the measured values.

High Speed Internal Oscillator – HIRC – Frequency Accuracy

During the program writing operation the writer will trim the HIRC oscillator at a user selected HIRC frequency and user selected voltage of either 3V or 5V.

4/8/12MHz

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Temp.				
f_{HIRC}	4MHz Writer Trimmed HIRC Frequency	3V/5V	Ta=25˚C	-1%	4	+1%	MHz
			Ta=-40˚C~85˚C	-2%	4	+2%	
		2.2V~5.5V	Ta=25˚C	-2.5%	4	+2.5%	
			Ta=-40˚C~85˚C	-3%	4	+3%	
	8MHz Writer Trimmed HIRC Frequency	3V/5V	Ta=25˚C	-1%	8	+1%	MHz
			Ta=-40˚C~85˚C	-2%	8	+2%	
		2.2V~5.5V	Ta=25˚C	-2.5%	8	+2.5%	
			Ta=-40˚C~85˚C	-3%	8	+3%	
	12MHz Writer Trimmed HIRC Frequency	3V/5V	Ta=25˚C	-1%	12	+1%	MHz
			Ta=-40˚C~85˚C	-2%	12	+2%	
		2.7V~5.5V	Ta=25˚C	-2.5%	12	+2.5%	
			Ta=-40˚C~85˚C	-3%	12	+3%	

Notes: 1. The 3V/5V values for V_{DD} are provided as these are the two selectable fixed voltages at which the HIRC frequency is trimmed by the writer.

2. The row below the 3V/5V trim voltage row is provided to show the values for the full V_{DD} range operating voltage. It is recommended that the trim voltage is fixed at 3V for application voltage ranges from 2.2V to 3.6V and fixed at 5V for application voltage ranges from 3.3V to 5.5V.

3. The minimum and maximum tolerance values provided in the table are only for the frequency at which the writer trims the HIRC oscillator. After trimming at this chosen specific frequency any change in HIRC oscillator frequency using the oscillator register control bits by the application program will give a frequency tolerance to within ±20%.

Low Speed Internal Oscillator Characteristics – LIRC

Ta=25˚C, unless otherwise specified

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
f_{LIRC}	Oscillator Frequency	2.2V~5.5V	Ta=25˚C	-5%	32	+5%	kHz
			Ta=-40˚C~85˚C	-10%	32	+10%	
t_{START}	LIRC Start Up Time	—	—	—	—	100	μs

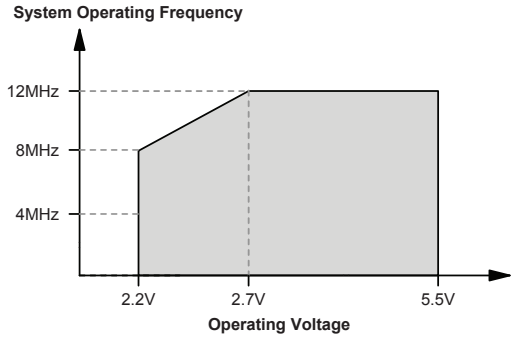
Low Speed Crystal Oscillator Characteristics – LXT

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
f_{LXT}	Oscillator Frequency	2.2~5.5V	$f_{SYS}=f_{LXT}$=32.768kHz	-10%	32.768	+10%	kHz
Duty Cycle	Duty Cycle	—	—	45	50	55	%
t_{START}	LXT Start Up Time	—	—	—	—	500	ms
R_{NEG}	Negative Resistance (Note)	2.2V	—	3×ESR	—	—	Ω

Note: C1, C2 and R_P are external components. C1=C2=10pF. R_P=10MΩ. C_L=7pF, ESR=30kΩ.

Operating Frequency Characteristic Curves



System Start-up Time Characteristics

Ta=-40°C~85°C

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
t_{SST}	System Start-up Time. Wake-up from Condition where f_{SYS} is off	$f_{SYS}=f_H$~$f_H/64$, $f_H=f_{HXT}$	—	128	—	t_{HXT}
		$f_{SYS}=f_H$~$f_H/64$, $f_H=f_{HIRC}$	—	16	—	t_{HIRC}
		$f_{SYS}=f_{SUB}=f_{LXT}$	—	1024	—	t_{LXT}
		$f_{SYS}=f_{SUB}=f_{LIRC}$	—	2	—	t_{LIRC}
	System Start-up Time. Wake-up from Condition where f_{SYS} is on.	$f_{SYS}=f_H$~$f_H/64$, $f_H=f_{HXT}$ or f_{HIRC}	—	2	—	t_H
		$f_{SYS}=f_{SUB}=f_{LXT}$ or f_{LIRC}	—	2	—	t_{SUB}
	System Speed Switch Time. FAST to SLOW Mode or SLOW to FAST Mode	f_{HXT} off → on	—	1024	—	t_{HXT}
		f_{HIRC} off → on	—	16	—	t_{HIRC}
		f_{LXT} off → on	—	1024	—	t_{LXT}
t_{RSTD}	System Reset Delay Time. Reset source from Power-on Reset or LVR Hardware Reset	RR_{POR}=5V/ms	42	48	54	ms
	System Reset Delay Time. LVRC/WDTC/RSTC Software Reset	—				
	System Reset Delay Time. Reset Source from WDT Overflow	—	14	16	18	ms
t_{SRESET}	Minimum Software Reset Width to Reset	—	45	90	123	μs

Notes: 1. For the System Start-up time values, whether f_{SYS} is on or off depends upon the mode type and the chosen f_{SYS} system oscillator. Details are provided in the System Operating Modes section.
2. The time units, shown by the symbols t_{HXT}, t_{HIRC} etc. are the inverse of the corresponding frequency values as provided in the frequency tables. For example $t_{HIRC}=1/f_{HIRC}$, $t_{HIRC}=1/f_{HIRC}$ etc.
3. If the LIRC is used as the system clock and if it is off when in the SLEEP Mode, then an additional LIRC start up time, t_{START}, as provided in the LIRC frequency table, must be added to the t_{SST} time in the table above.
4. The System Speed Switch Time is effectively the time taken for the newly activated oscillator to start up.

Input/Output Characteristics

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{IL}	Input Low Voltage for I/O Ports	5V	—	0	—	1.5	V
		—	—	0	—	$0.2V_{DD}$	
V_{IH}	Input High Voltage for I/O Ports	5V	—	3.5	—	5.0	V
		—	—	$0.8V_{DD}$	—	V_{DD}	
V_{OL}	Output Low Voltage for I/O Ports	3V	I_{OL}=16mA	—	—	0.3	V
		5V	I_{OL}=32mA	—	—	0.5	
V_{OH}	Output High Voltage for I/O Ports	3V	I_{OH}=-0.7mA, SLEDCn[m+1:m]=00, (n=0, 1, 2, 3; m=0, 2, 4, 6)	2.7	—	—	V
		5V	I_{OH}=-1.5mA, SLEDCn[m+1:m]=00, (n=0, 1, 2, 3; m=0, 2, 4, 6)	4.5	—	—	
		3V	I_{OH}=-1.3mA, SLEDCn[m+1:m]=01, (n=0, 1, 2, 3; m=0, 2, 4, 6)	2.7	—	—	
		5V	I_{OH}=-2.5mA, SLEDCn[m+1:m]=01, (n=0, 1, 2, 3; m=0, 2, 4, 6)	4.5	—	—	
		3V	I_{OH}=-1.8mA, SLEDCn[m+1:m]=10, (n=0, 1, 2, 3; m=0, 2, 4, 6)	2.7	—	—	
		5V	I_{OH}=-3.6mA, SLEDCn[m+1:m]=10, (n=0, 1, 2, 3; m=0, 2, 4, 6)	4.5	—	—	
		3V	I_{OH}=-4mA, SLEDCn[m+1:m]=11, (n=0, 1, 2, 3; m=0, 2, 4, 6)	2.7	—	—	
		5V	I_{OH}=-8mA, SLEDCn[m+1:m]=11, (n=0, 1, 2, 3; m=0, 2, 4, 6)	4.5	—	—	
I_{OL}	Sink Current for I/O Pins	3V	V_{OL}=0.1V_{DD}	16	32	—	mA
		5V		32	65	—	
I_{OH}	Source Current for I/O Pins	3V	V_{OH}=0.9V_{DD}, SLEDCn[m+1:m]=00, (n=0, 1, 2, 3; m=0, 2, 4, 6)	-0.7	-1.5	—	mA
		5V		-1.5	-2.9	—	
		3V	V_{OH}=0.9V_{DD}, SLEDCn[m+1:m]=01, (n=0, 1, 2, 3; m=0, 2, 4, 6)	-1.3	-2.5	—	
		5V		-2.5	-5.1	—	
		3V	V_{OH}=0.9V_{DD}, SLEDCn[m+1:m]=10, (n=0, 1, 2, 3; m=0, 2, 4, 6)	-1.8	-3.6	—	
		5V		-3.6	-7.3	—	
		3V	V_{OH}=0.9V_{DD}, SLEDCn[m+1:m]=11, (n=0, 1, 2, 3; m=0, 2, 4, 6)	-4	-8	—	
		5V		-8	-16	—	
R_{PH}	Pull-high Resistance for I/O Ports(Note)	3V	—	20	60	100	kΩ
		5V	—	10	30	50	
I_{LEAK}	Input Leakage Current	3V	V_{IN}=V_{DD} or V_{IN}=V_{SS}	—	—	±1	μA
		5V		—	—	±1	
t_{TPI}	TM Capture Input Minimum Pulse Width	—	—	0.3	—	—	μs
t_{TCK}	TM Clock Input Minimum Pulse Width	—	—	0.3	—	—	μs
t_{INT}	Interrupt Input Pin Minimum Pulse Width	—	—	10	—	—	μs

Note: The R_{PH} internal pull high resistance value is calculated by connecting to ground and enabling the input pin with a pull-high resistor and then measuring the input sink current at the specified supply voltage level. Dividing the voltage by this measured current provides the R_{PH} value.

Memory Characteristics

Ta=-40˚C~85˚C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{RW}	V_{DD} for Read/Write	—	—	V_{DDmin}	—	V_{DDmax}	V
Program Flash / Data EEPROM Memory							
t_{DEW}	Erase/Write cycle time	—	—	2.2	2.5	2.8	ms
I_{DDPGM}	Programming/Erase current on V_{DD}	—	—	—	—	5.0	mA
E_P	Cell Endurance	—	—	100K	—	—	E/W
t_{RETD}	ROM Data Retention time	—	Ta=25˚C	—	40	—	Year
RAM Data Memory							
V_{DR}	RAM Data Retention voltage	—	Device in SLEEP Mode	1.0	—	—	V

A/D Converter Electrical Characteristics

Ta=-40°C~85°C, unless otherwise specify

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Operating Voltage	—	—	2.4	–	5.5	V
V_{ADI}	Input Voltage	—	—	0	–	V_{REF}	V
V_{REF}	Reference Voltage	—	—	2	–	V_{DD}	V
DNL	Differential Non-linearity	3V	V_{REF}=V_{DD}, t_{ADCK}=0.5μs	—	—	±3	LSB
		5V					
		3V	V_{REF}=V_{DD}, t_{ADCK}=10μs				
		5V					
INL	Integral Non-linearity	3V	V_{REF}=V_{DD}, $_{ADCK}$=0.5μs	—	–	±4	LSB
		5V					
		3V	V_{REF}=V_{DD}, t_{ADCK}=10μs				
		5V					
I_{ADC}	Additional Current Consumption for A/D Converter Enable	3V	No load, t_{ADCK}=0.5μs	—	1	2	mA
		5V		—	1.5	3	
t_{ADCK}	Clock Period	—	—	0.5	—	10	μs
t_{ON2ST}	A/D Converter On-to-Start Time	—	—	4	—	—	μs
t_{ADC}	Conversion Time (Including A/D Sample and Hold Time)	—	ADACCM=0	—	16	—	t_{ADCK}

LVR/LVD Electrical Characteristics

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Operating Voltage	—	—	2.2	—	5.5	V
V_{LVR}	Low Voltage Reset Voltage	—	LVR enable, voltage select 2.1V	-5%	2.1	+5%	V
		—	LVR enable, voltage select 2.55V		2.55		
		—	LVR enable, voltage select 3.15V		3.15		
		—	LVR enable, voltage select 3.8V		3.8		
V_{LVD}	Low Voltage Detection Voltage	—	LVD enable, voltage select 1.04V	-10%	1.04	+10%	V
		—	LVD enable, voltage select 2.2V	-5%	2.2	+5%	
		—	LVD enable, voltage select 2.4V		2.4		
		—	LVD enable, voltage select 2.7V		2.7		
		—	LVD enable, voltage select 3.0V		3.0		
		—	LVD enable, voltage select 3.3V		3.3		
		—	LVD enable, voltage select 3.6V		3.6		
		—	LVD enable, voltage select 4.0V		4.0		
$I_{LVRLVDBG}$	Operating Current	3V	LVD enable, LVR enable, VBGEN=0	—	—	18	μA
		5V		—	20	25	
		3V	LVD enable, LVR enable, VBGEN=1	—	—	150	μA
		5V		—	180	200	
I_{LVR}	Additional Current for LVR Enable	—	LVD disable, VBGEN=0	—	—	24	μA
I_{LVD}	Additional Current for LVD Enable	—	LVR disable, VBGEN=0	—	—	24	μA
t_{LVDS}	LVDO Stable Time	—	For LVR enable, VBGEN=0, LVD off → on	—	—	15	μs
		—	For LVR disable, VBGEN=0, LVD off → on	—	—	150	μs
t_{LVR}	Minimum Low Voltage Width to Reset	—	—	120	240	480	μs
t_{LVD}	Minimum Low Voltage Width to Interrupt	—	—	60	120	240	μs

Note: If V_{LVD}=1.04V, it is used to detect the LVDIN pin input voltage. Other V_{LVD} choices are used to detect the power supply V_{DD}.

OPA Electrical Characteristics

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Operating Voltage	—	—	2.4	—	5.5	V
I_{OPA}	OPA Operating Current (all OPA and PGA)	3.3V	V_P=V_N=1/2 V_{DD}	—	—	650	μA
V_{CM}	PGA1 Common Mode Voltage Range	3.3V	—	0.4	—	V_{DD} -1.0	V
	PGA2/OPA Commun Mode Voltage Range	3.3V	—	0.2	—	V_{DD} -1.0	V
V_{OR}	PGA Maximum Output Voltage Range	3.3V	—	V_{SS} +0.1	—	V_{DD} -0.1	V

LDO Electrical Characteristics

V_{DD}=V_{IN}, V_{IN}=V_{OUT}+0.4V, C_{LOAD}=10μF, Ta=25°C

Symbol	Parameter	Test Condition		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{OUT}	Output Voltage	–	No load	3.0	3.3	3.6	V
I_Q	Quiescent Current	5V	No load	–	350	–	μA
I_{OUT}	Output Current	–	ΔV_{OUT}=0.1V	10	13.5	–	mA

Note: Load regulation is measured at a constant junction temperature, using pulse testing with a low ON time and is guaranteed up to the maximum power dissipation. Power dissipation is determined by the input/output differential voltage and the output current. Guaranteed maximum power dissipation will not be available over the full input/output range. The maximum allowable power dissipation at any ambient temperature is P_D=($T_{J(MAX)}$-Ta)/θ_{JA}

LCD Electrical Characteristics

Ta=25°C

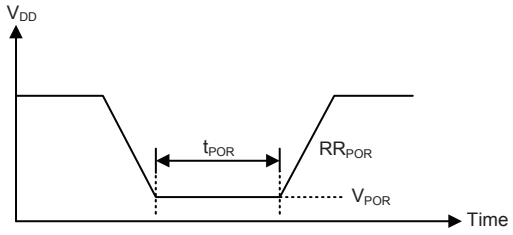
Symbol	Parameter	Test Condition		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{IN}	LCD Operating Voltage	—	Power supply from PLCD pin (for R type)	3.0	—	5.5	V
		—	Power supply from PLCD pin (for C type)	2.0	—	3.7	
		—	Power supply from V1 pin (for C type)	3.0	—	5.5	
		—	Power supply from V2 pin (for C type)	1.0	—	1.8	
		—	Power supply from VA (for C type)	3.0	—	5.5	
		3.3V~ 5.5V	Power supply from VB (for C type)	-10%	3.0	+10%	
		2.2V~ 5.5V	Power supply from VC (for C type)	-10%	1.08	+10%	
V_{LCD}	Power Supply Comes from Charge Pump	2.2V~ 5.5V	RCT=0, LCDPR=1, CPVS[1:0]=00b	-10%	3.3	+10%	V
			RCT=0, LCDPR=1, CPVS[1:0]=01b		3.0		
			RCT=0, LCDPR=1, CPVS[1:0]=10b		2.7		
			RCT=0, LCDPR=1, CPVS[1:0]=11b		4.5		

Symbol	Parameter	Test Condition		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
I_{LCD}	Additional Current for LCD Enable (R type), LCD Clock=4kHz	5V	No load, VA=PLCD=V_{DD}, 1/3 Bias, RCT=0, LCDPR=0, LCDIS[1:0]=00b	—	25	37.5	μA
			No load, VA=PLCD=V_{DD}, 1/4 Bias, RCT=0, LCDPR=0, LCDIS[1:0]=00b	—	18	28	μA
			No load, VA=PLCD=V_{DD}, 1/3 Bias, RCT=0, LCDPR=0, LCDIS[1:0]=01b	—	50	75	μA
			No load, VA=PLCD=V_{DD}, 1/4 Bias, RCT=0, LCDPR=0, LCDIS[1:0]=01b	—	37.5	56	μA
			No load, VA=PLCD=V_{DD}, 1/3 Bias, RCT=0, LCDPR=0, LCDIS[1:0]=10b	—	100	150	μA
			No load, VA=PLCD=V_{DD}, 1/4 Bias, RCT=0, LCDPR=0, LCDIS[1:0]=10b	—	75.0	112.5	μA
			No load, VA=PLCD=V_{DD}, 1/3 Bias, RCT=0, LCDPR=0, LCDIS[1:0]=11b	—	200	300	μA
			No load, VA=PLCD=V_{DD}, 1/4 Bias, RCT=0, LCDPR=0, LCDIS[1:0]=11b	—	150	225	μA
	Additional Current for LCD Enable (C type)	3V	No load, VA=V1=V_{DD}, 1/3 Bias	—	10	15	μA
		5V		—	13.5	20	
I_{LCDOL}	LCD Common and Segment Sink Current	3V	V_{OL}=0.1V_{DD}	210	420	—	μA
		5V		350	700	—	
I_{LCDOH}	LCD Common and Segment Source Current	3V	V_{OH}=0.9V_{DD}	-80	-160	—	μA
		5V		-180	-360	—	

Power-on Reset Characteristics

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{POR}	V_{DD} Start Voltage to Ensure Power-on Reset	—	—	—	—	100	mV
RR_{POR}	V_{DD} Rising Rate to Ensure Power-on Reset	—	—	0.035	—	—	V/ms
t_{POR}	Minimum Time for V_{DD} Stays at V_{POR} to Ensure Power-on Reset	—	—	1	—	—	ms



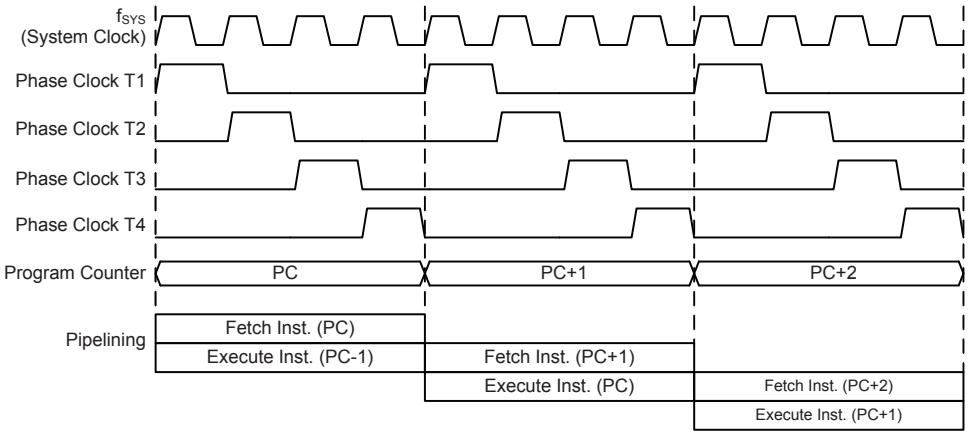
System Architecture

A key factor in the high-performance features of the Holtek range of microcontrollers is attributed to their internal system architecture. The range of these devices take advantage of the usual features found within RISC microcontrollers providing increased speed of operation and enhanced performance. The pipelining scheme is implemented in such a way that instruction fetching and instruction execution are overlapped, hence instructions are effectively executed in one or two cycles for most of the standard or extended instructions respectively, with the exception of branch or call instructions which need one more cycle. An 8-bit wide ALU is used in practically all instruction set operations, which carries out arithmetic operations, logic operations, rotation, increment, decrement, branch decisions, etc. The internal data path is simplified by moving data through the Accumulator and the ALU. Certain internal registers are implemented in the Data Memory and can be directly or indirectly addressed. The simple addressing methods of these registers along with additional architectural features ensure that a minimum of external components is required to provide a functional I/O and A/D control system with maximum reliability and flexibility. This makes these devices suitable for low-cost, high-volume production for controller applications.

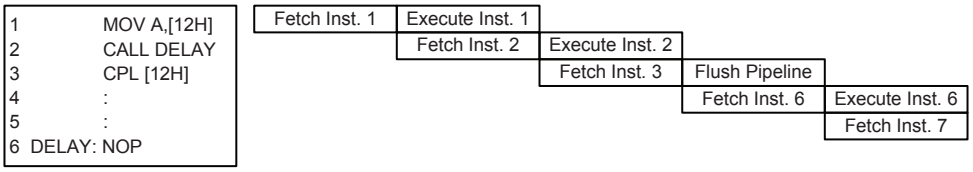
Clocking and Pipelining

The main system clock, derived from either a HXT, LXT, HIRC or LIRC oscillator is subdivided into four internally generated non-overlapping clocks, T1~T4. The Program Counter is incremented at the beginning of the T1 clock during which time a new instruction is fetched. The remaining T2~T4 clocks carry out the decoding and execution functions. In this way, one T1~T4 clock cycle forms one instruction cycle. Although the fetching and execution of instructions takes place in consecutive instruction cycles, the pipelining structure of the microcontroller ensures that instructions are effectively executed in one instruction cycle. The exception to this are instructions where the contents of the Program Counter are changed, such as subroutine calls or jumps, in which case the instruction will take one more instruction cycle to execute.

For instructions involving branches, such as jump or call instructions, two machine cycles are required to complete instruction execution. An extra cycle is required as the program takes one cycle to first obtain the actual jump or call address and then another cycle to actually execute the branch. The requirement for this extra cycle should be taken into account by programmers in timing sensitive applications.



System Clocking and Pipelining



Instruction Fetching

Program Counter

During program execution, the Program Counter is used to keep track of the address of the next instruction to be executed. It is automatically incremented by one each time an instruction is executed except for instructions, such as "JMP" or "CALL" that demand a jump to a non-consecutive Program Memory address. As the devices memory capacity is greater than 8K words, the Program Memory address may be located in a certain program memory bank which is selected by the program memory bank pointer bit, PBP0. Only the lower 8 bits, known as the Program Counter Low Register, are directly addressable by the application program.

When executing instructions requiring jumps to non-consecutive addresses such as a jump instruction, a subroutine call, interrupt or reset, etc., the microcontroller manages program control by loading the required address into the Program Counter. For conditional skip instructions, once the condition has been met, the next instruction, which has already been fetched during the present instruction execution, is discarded and a dummy cycle takes its place while the correct instruction is obtained.

Device	Program Counter	
	Program Counter High Byte	PCL Register
BH67F2260	PBP0, PC12~PC8	PCL7~PCL0
BH67F2270	PBP1~PBP0, PC12~PC8	PCL7~PCL0

Program Counter

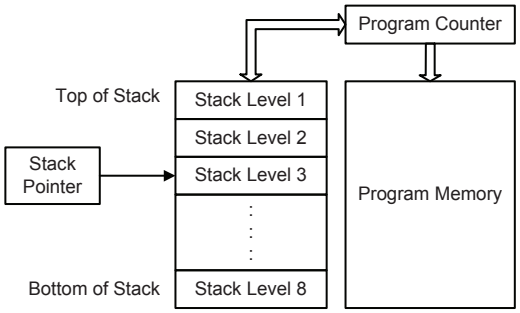
The lower byte of the Program Counter, known as the Program Counter Low register or PCL, is available for program control and is a readable and writeable register. By transferring data directly into this register, a short program jump can be executed directly; however, as only this low byte is available for manipulation, the jumps are limited to the present page of memory that is 256 locations. When such program jumps are executed it should also be noted that a dummy cycle will be inserted. Manipulating the PCL register may cause program branching, so an extra cycle is needed to pre-fetch.

Stack

This is a special part of the memory which is used to save the contents of the Program Counter only. The stack is organized into 8 levels and neither part of the data nor part of the program space, and is neither readable nor writeable. The activated level is indexed by the Stack Pointer, and is neither readable nor writeable. At a subroutine call or interrupt acknowledge signal, the contents of the Program Counter are pushed onto the stack. At the end of a subroutine or an interrupt routine, signaled by a return instruction, RET or RETI, the Program Counter is restored to its previous value from the stack. After a device reset, the Stack Pointer will point to the top of the stack.

If the stack is full and an enabled interrupt takes place, the interrupt request flag will be recorded but the acknowledge signal will be inhibited. When the Stack Pointer is decremented, by RET or RETI, the interrupt will be serviced. This feature prevents stack overflow allowing the programmer to use the structure more easily. However, when the stack is full, a CALL subroutine instruction can still be executed which will result in a stack overflow. Precautions should be taken to avoid such cases which might cause unpredictable program branching.

If the stack is overflow, the first Program Counter save in the stack will be lost.



Arithmetic and Logic Unit – ALU

The arithmetic-logic unit or ALU is a critical area of the microcontroller that carries out arithmetic and logic operations of the instruction set. Connected to the main microcontroller data bus, the ALU receives related instruction codes and performs the required arithmetic or logical operations after which the result will be placed in the specified register. As these ALU calculation or operations may result in carry, borrow or other status changes, the status register will be correspondingly updated to reflect these changes. The ALU supports the following functions:

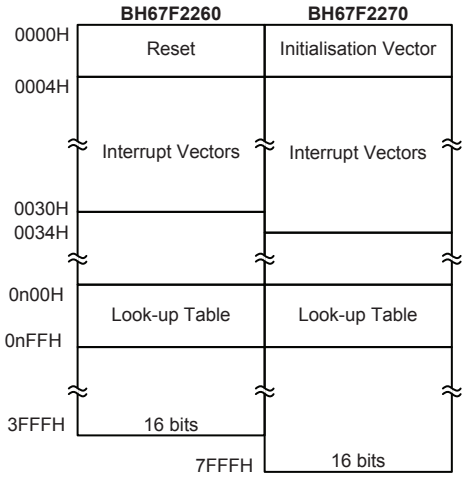
- Arithmetic operations
  ADD, ADDM, ADC, ADCM, SUB, SUBM, SBC, SBCM, DAA,
  LADD, LADDM, LADC, LADCM, LSUB, LSUBM, LSBC, LSBCM, LDAA
- Logic operations
  AND, OR, XOR, ANDM, ORM, XORM, CPL, CPLA,
  LAND, LANDM, LOR, LORM, LXOR, LXORM, LCPL, LCPLA
- Rotation:
  RRA, RR, RRCA, RRC, RLA, RL, RLCA, RLC,
  LRR, LRRA, LRRCA, LRRC, LRLA, LRL, LRLCA, LRLC
- Increment and Decrement
  INCA, INC, DECA, DEC,
  LINCA, LINC, LDECA, LDEC
- Branch decision
  JMP, SZ, SZA, SNZ, SIZ, SDZ, SIZA, SDZA, CALL, RET, RETI,
  LSNZ, LSZ, LSZA, LSIZ, LSIZA, LSDZ, LSDZA

Flash Program Memory

The Program Memory is the location where the user code or program is stored. For the devices the Program Memory is Flash type, which means it can be programmed and re-programmed a large number of times, allowing the user the convenience of code modification on the same device. By using the appropriate programming tools, the Flash device offers users the flexibility to conveniently debug and develop their applications while also offering a means of field programming and updating.

Structure

The Program Memory has a capacity of 16K×16 to 32K×16 bits. The Program Memory is addressed by the Program Counter and also contains data, table information and interrupt entries. Table data, which can be setup in any location within the Program Memory, is addressed by a separate table pointer register.



Program Memory Structure

Special Vectors

Within the Program Memory, certain locations are reserved for the reset and interrupts. The location 0000H is reserved for use by these devices reset for program initialisation. After a device reset is initiated, the program will jump to this location and begin execution.

Look-up Table

Any location within the Program Memory can be defined as a look-up table where programmers can store fixed data. To use the look-up table, the table pointer must first be setup by placing the address of the look up data to be retrieved in the table pointer register, TBLP and TBHP. These registers define the total address of the look-up table.

After setting up the table pointer, the table data can be retrieved from the Program Memory using the corresponding table read instruction such as "TABRD [m]" or "TABRDL [m]" respectively when the memory [m] is located in sector 0. If the memory [m] is located in other sectors, the data can be retrieved from the program memory using the corresponding extended table read instruction such as "LTABRD [m]" or "LTABRDL [m]" respectively. When the instruction is executed, the lower order table byte from the Program Memory will be transferred to the user defined Data Memory register [m] as specified in the instruction. The higher order table data byte from the Program Memory will be transferred to the TBLH special register.

The accompanying diagram illustrates the addressing data flow of the look-up table.

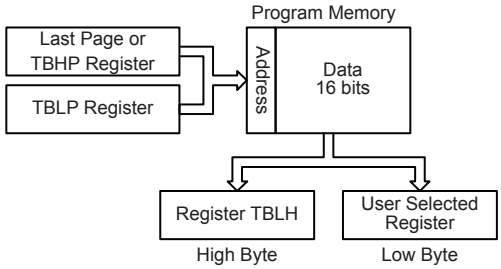


Table Program Example

The following example shows how the table pointer and table data is defined and retrieved from the microcontroller. This example uses raw table data located in the Program Memory which is stored there using the ORG statement. The value at this ORG statement is "1F00H" which is located in ROM Bank 1 and refers to the start address of the last page within the 16K words Program Memory of the BH67F2260 device. The table pointer low byte register is setup here to have an initial value of "06H". This will ensure that the first data read from the data table will be at the Program Memory address "3F06H" or 6 locations after the start of the last page. Note that the value for the table pointer is referenced to the first address specified by TBLP and TBHP if the "TABRD [m]" or "LTABRD [m]" instruction is being used. The high byte of the table data which in this case is equal to zero will be transferred to the TBLH register automatically when the "TABRD [m]" or "LTABRD [m]" instruction is executed.

Because the TBLH register is a read/write register and can be restored, care should be taken to ensure its protection if both the main routine and Interrupt Service Routine use table read instructions. If using the table read instructions, the Interrupt Service Routines may change the value of the TBLH and subsequently cause errors if used again by the main routine. As a rule it is recommended that simultaneous use of the table read instructions should be avoided. However, in situations where simultaneous use cannot be avoided, the interrupts should be disabled prior to the execution of any main routine table-read instructions. Note that all table related instructions require two instruction cycles to complete their operation.

Table Read Program Example

```
rombank 1 code1
ds .section 'data'
tempreg1 db?          ; temporary register #1
tempreg2 db?          ; temporary register #2
code0 .section 'code'
mov a,06h             ; initialise table pointer - note that this address is referenced
mov tblp,a            ; to the last page or the page that tbhp pointed
mov a,03fh            ; initialise high table pointer
mov tbhp,a            ; it is not necessary to set tbhp if executing tabrdl
:
:
tabrd tempreg1        ; transfers value in table referenced by table pointer
                      ; register pair to tempreg1
tabrdl tempreg1       ; data at program memory address "3F06H" transferred to
                      ; tempreg1 and TBLH
dec tblp              ; reduce value of table pointer by one
tabrd tempreg2        ; transfers value in table referenced by table pointer
                      ; register pair to tempreg2
tabrdl tempreg2       ; data at program memory address "3F05H" transferred to
                      ; tempreg2 and TBLH
                      ; in this example the data "1AH" is transferred to
                      ; tempreg1 and data "0FH" to tempreg2
                      ; the value "00H" will be transferred to the high byte register TBLH
:
:
code1 .section 'code'
org 1F00h             ; sets initial address of last page
dc 00Ah,00Bh,00Ch,00Dh,00Eh,00Fh,01Ah,01Bh
```

In Circuit Programming – ICP

The provision of Flash type Program Memory provides the user with a means of convenient and easy upgrades and modifications to their programs on the same device.

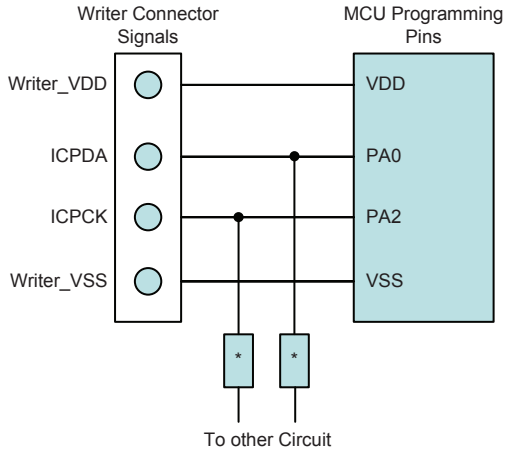
As an additional convenience, Holtek has provided a means of programming the microcontroller in-circuit using a 4-pin interface. This provides manufacturers with the possibility of manufacturing their circuit boards complete with a programmed or un-programmed microcontroller, and then programming or upgrading the program at a later stage. This enables product manufacturers to easily keep their manufactured products supplied with the latest program releases without removal and re-insertion of these devices.

The Holtek Flash MCU to Writer Programming Pin correspondence table is as follows:

Holtek Writer Pins	MCU Programming Pins	Pin Description
ICPDA	PA0	Programming Serial Data/Address
ICPCK	PA2	Programming Clock
VDD	VDD	Power Supply
VSS	VSS	Ground

The Program Memory and EEPROM Data Memory can be programmed serially in-circuit using this 4-wire interface. Data is downloaded and uploaded serially on a single pin with an additional line for the clock. Two additional lines are required for the power supply and one line for the reset. The technical details regarding the in-circuit programming of these devices is beyond the scope of this document and will be supplied in supplementary literature.

During the programming process, the user must take care of the ICPDA and ICPCK pins for data and clock programming purposes to ensure that no other outputs are connected to these two pins.



Note: * may be resistor or capacitor. The resistance of * must be greater than 1kΩ or the capacitance of * must be less than 1nF.

On-Chip Debug Support – OCDS

There is an EV chip named BH67V22x0 which is used to emulate the BH67F22x0 device. The EV chip device also provides an "On-Chip Debug" function to debug the real MCU device during the development process. The EV chip and the real MCU device are almost functionally compatible except for "On-Chip Debug" function. Users can use the EV chip device to emulate the real chip device behavior by connecting the OCDSDA and OCDSCK pins to the Holtek HT-IDE development tools. The OCDSDA pin is the OCDS Data/Address input/output pin while the OCDSCK pin is the OCDS clock input pin. When users use the EV chip for debugging, other functions which are shared with the OCDSDA and OCDSCK pins in these devices will have no effect in the EV chip. However, the two OCDS pins which are pin-shared with the ICP programming pins are still used as the Flash Memory programming pins for ICP. For more detailed OCDS information, refer to the corresponding document named "Holtek e-Link for 8-bit MCU OCDS User's Guide".

Holtek e-Link Pins	EV Chip Pins	Pin Description
OCDSDA	OCDSDA	On-Chip Debug Support Data/Address input/output
OCDSCK	OCDSCK	On-Chip Debug Support Clock input
VDD	VDD	Power Supply
VSS	VSS	Ground

In Application Programming – IAP

These devices offer IAP function to update data or application program to Flash ROM. Users can define any ROM location for IAP, but there are some features which user must notice in using IAP function.

- Erase Page: 64 words/page
- Writing Word: 64 words/time
- Reading Word: 1 word/time

In Application Programming Control Registers

The Address registers, FARL and FARH, and the Data registers, FD0L/FD0H, FD1L/FD1H, FD2L/FD2H, FD3L/FD3H, together with the Control registers, FC0, FC1 and FC2, located in Data Memory Sector 1, are the corresponding Flash access registers for IAP. If using indirect addressing to access all these registers, all read and write operations to the registers must be performed using the Indirect Addressing Register, IAR1 or IAR2, and the Memory Pointer pair, MP1L/MP1H or MP2L/MP2H. Because the data, address and control registers are located at the address of 43H~4FH in Data Memory Sector 1, the desired value ranged from 43H~4FH must be written into the MP1L or MP2L Memory Pointer low byte and the value "01H" must also be written into the MP1H or MP2H Memory Pointer high byte.

Register Name	Bit							
	7	6	5	4	3	2	1	0
FC0	CFWEN	FMOD2	FMOD1	FMOD0	FWPEN	FWT	FRDEN	FRD
FC1	D7	D6	D5	D4	D3	D2	D1	D0
FC2	—	—	—	—	—	—	—	CLWB
FARL	A7	A6	A5	A4	A3	A2	A1	A0
FARH (BH67F2260)	—	—	A13	A12	A11	A10	A9	A8
FARH (BH67F2270)	—	A14	A13	A12	A11	A10	A9	A8
FD0L	D7	D6	D5	D4	D3	D2	D1	D0
FD0H	D15	D14	D13	D12	D11	D10	D9	D8
FD1L	D7	D6	D5	D4	D3	D2	D1	D0
FD1H	D15	D14	D13	D12	D11	D10	D9	D8
FD2L	D7	D6	D5	D4	D3	D2	D1	D0
FD2H	D15	D14	D13	D12	D11	D10	D9	D8
FD3L	D7	D6	D5	D4	D3	D2	D1	D0
FD3H	D15	D14	D13	D12	D11	D10	D9	D8

IAP Registers List

- **FC0 Register**

Bit	7	6	5	4	3	2	1	0
Name	CFWEN	FMOD2	FMOD1	FMOD0	FWPEN	FWT	FRDEN	FRD
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7 **CFWEN**: Flash Memory Write enable control
0: Flash Memory write function is disabled
1: Flash Memory write function has been successfully enabled
When this bit is cleared to 0 by application program, the Flash Memory write function is disabled. Note that writing a "1" into this bit results in no action. This bit is used to indicate that the Flash Memory write function status. When this bit is set to 1 by hardware, it means that the Flash Memory write function is enabled successfully. Otherwise, the Flash Memory write function is disabled as the bit content is zero.

Bit 6~4 **FMOD2~FMOD0**: Mode selection
000: Write Program Memory
001: Page erase Program Memory
010: Reserved
011: Read Program Memory
100: Reserved
101: Reserved
110: FWEN mode – Flash Memory write function enable mode
111: Reserved

Bit 3 **FWPEN**: Flash Memory Write procedure enable control
0: Disable
1: Enable
When this bit is set to 1 and the FMOD field is set to "110", the IAP controller will execute the "Flash memory write function enable" procedure. Once the Flash memory write function is successfully enabled, it is not necessary to set the FWPEN bit any more.

Bit 2 **FWT**: Flash ROM write control bit
0: Do not initiate Flash Memory write or Flash Memory write process is completed
1: Initiate Flash Memory write process
This bit can be set by software only, when the write process is completed, hardware will clear the FWT bit.

Bit 1 **FRDEN**: Flash Memory read enabled bit
0: Flash Memory read disable
1: Flash Memory read enable

Bit 0 **FRD**: Flash Memory read control bit
0: Do not initiate Flash Memory read or Flash Memory read process is completed
1: Initiate Flash Memory read process
This bit can be set by software only, when the read process is completed, hardware will clear the FRD bit.

- **FC1 Register**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: whole chip reset
When user writes 55H to this register, it will generate a reset signal to reset whole chip.

- **FC2 Register**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	—	CLWB
R/W	—	—	—	—	—	—	—	R/W
POR	—	—	—	—	—	—	—	0

Bit 7~1 Unimplemented, read as "0"

Bit 0 **CLWB**: Flash Memory Write buffer clear control
0: Do not initiate Write Buffer Clear or Write Buffer Clear process is completed
1: Initiate Write Buffer Clear process
This bit can be set by software only, when the clear write buffer process is completed, hardware will clear the CLWB bit.

- **FARL Register**

Bit	7	6	5	4	3	2	1	0
Name	A7	A6	A5	A4	A3	A2	A1	A0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **A7~A0**: Flash Memory Address [7:0]

- **FARH Register – BH67F2260**

Bit	7	6	5	4	3	2	1	0
Name	—	—	A13	A12	A11	A10	A9	A8
R/W	—	—	R/W	R/W	R/W	R/W	R/W	R/W
POR	—	—	0	0	0	0	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5~0 **A13~A8**: Flash Memory Address [13:8]

- **FARH Register – BH67F2270**

Bit	7	6	5	4	3	2	1	0
Name	—	A14	A13	A12	A11	A10	A9	A8
R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	—	0	0	0	0	0	0	0

Bit 7 Unimplemented, read as "0"

Bit 6~0 **A14~A8**: Flash Memory Address [14:8]

- **FD0L Register**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: The first Flash Memory data [7:0]

Note that the data written into the low byte data register FD0L will only be stored in the FD0L register and not loaded into the lower 8-bit write buffer.

- **FD0H Register**

Bit	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D15~D8**: The first Flash Memory data [15:8]

Note that when the 8-bit data is written into the high byte data register FD0H, the whole 16-bit data stored in the FD0H and FD0L registers will simultaneously be loaded into the 16-bit write buffer and then the content of the Flash Memory address register pair, FARH and FARL, will be incremented by one.

- **FD1L Register**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: The second Flash Memory data [7:0]

- **FD1H Register**

Bit	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D15~D8**: The second Flash Memory data [15:8]

- **FD2L Register**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: The third Flash Memory data [7:0]

- **FD2H Register**

Bit	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D15~D8**: The third Flash Memory data [15:8]

- **FD3L Register**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: The fourth Flash Memory data [7:0]

- **FD3H Register**

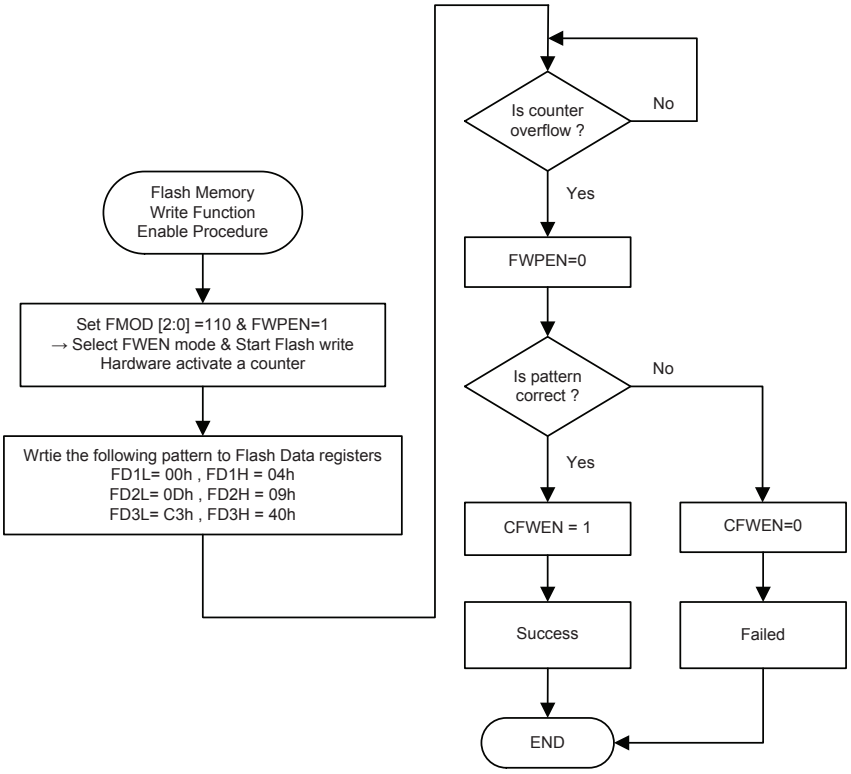
Bit	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D15~D8**: The third Flash Memory data [15:8]

Flash Memory Write Function Enable Procedure

In order to allow users to change the Flash Memory data through the IAP control registers, users must first enable the Flash Memory write operation by the following procedure:

1. Write “110” into the FMOD2~FMOD0 bits to select the FWEN mode.
2. Set the FWPEN bit to “1”. The step 1 and step 2 can be executed simultaneously.
3. The pattern data with a sequence of 00H, 04H, 0DH, 09H, C3H and 40H must be written into the FD1L, FD1H, FD2L, FD2H, FD3L and FD3H registers respectively.
4. A counter with a time-out period of 300μs will be activated to allow users writing the correct pattern data into the FD1L/FD1H~FD3L/FD3H register pairs. The counter clock is derived from the LIRC oscillator.
5. If the counter overflows or the pattern data is incorrect, the Flash Memory write operation will not be enabled and users must again repeat the above procedure. Then the FWPEN bit will automatically be cleared to “0” by hardware.
6. If the pattern data is correct before the counter overflows, the Flash Memory write operation will be enabled and the FWPEN bit will automatically be cleared to “0” by hardware. The CFWEN bit will also be set to “1” by hardware to indicate that the Flash Memory write operation is successfully enabled.
7. Once the Flash Memory write operation is enabled, the user can change the Flash ROM data through the Flash control register.
8. To disable the Flash Memory write operation, the user can clear the CFWEN bit to “0”.



Flash Memory Write Function Enable Procedure

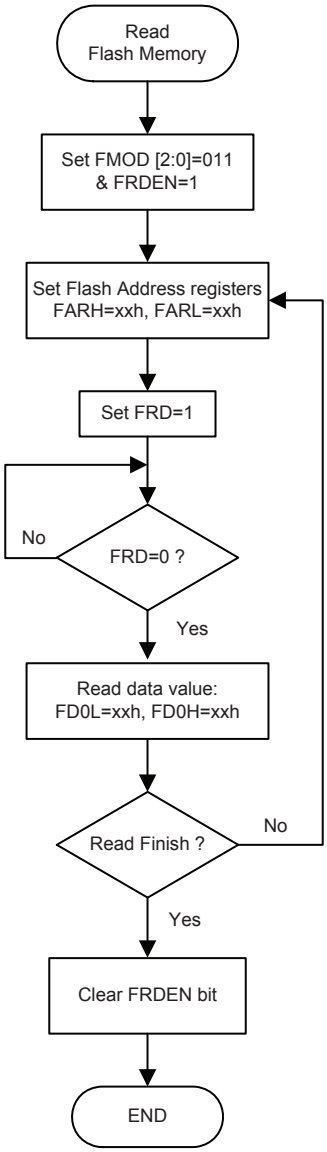
Flash Memory Read/Write Procedure

After the Flash Memory write function is successfully enabled through the preceding IAP procedure, users must first erase the corresponding Flash Memory page and then initiate the Flash Memory write operation. For these devices the number of the page erase operation is 64 words per page, the available page erase address is only specified by FARH register and the content of the FARL[7:6] bit field.

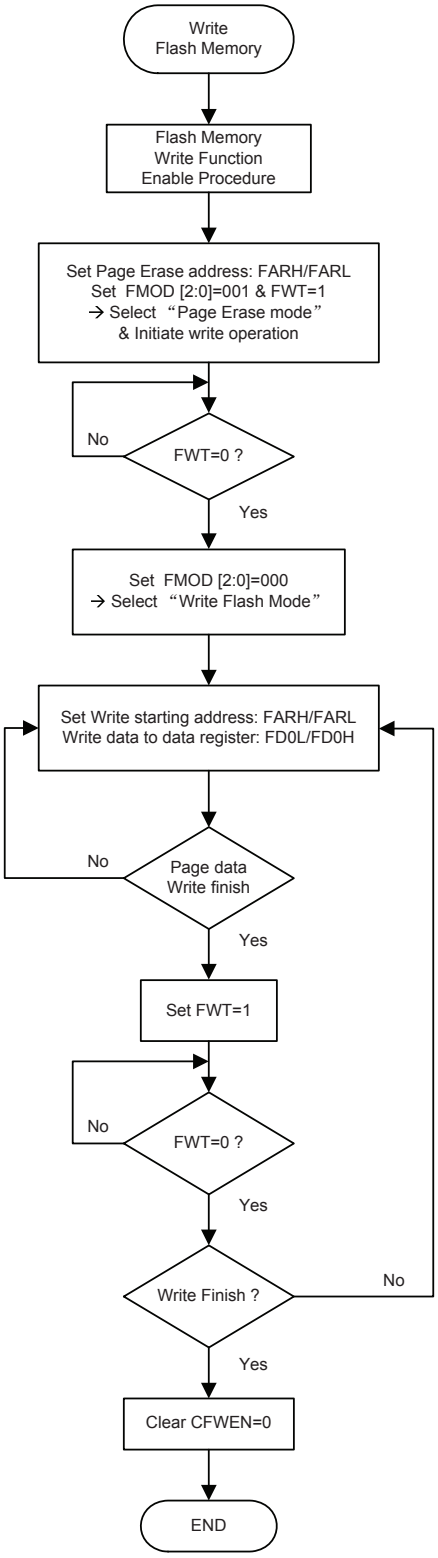
Erase Page	FARH	FARL[7:6]	FARL[5:0]
0	0000 0000	00	xx xxxx
1	0000 0000	01	xx xxxx
2	0000 0000	10	xx xxxx
3	0000 0000	11	xx xxxx
4	0000 0001	00	xx xxxx
5	0000 0001	01	xx xxxx
:	:	:	:
126	0001 1111	10	xx xxxx
127	0001 1111	11	xx xxxx
:	:	:	:
254	0011 1111	10	xx xxxx
255	0011 1111	11	xx xxxx

"x": don't care

Erase Page Number and Selection



Read Flash Memory Procedure



Write Flash Memory Procedure

Note: When the FWT or FRD bit is set to 1, the MCU is stopped.

Data Memory

The Data Memory is a volatile area of 8-bit wide RAM internal memory and is the location where temporary information is stored.

Categorized into two types, the first of these is an area of RAM, known as the Special Function Data Memory. These registers have fixed locations and are necessary for correct operation of these devices. Many of these registers can be read from and written to directly under program control, however, some remain protected from user manipulation. The second area of Data Memory is known as the General Purpose Data Memory, which is reserved for general purpose use. All locations within this area are read and write accessible under program control.

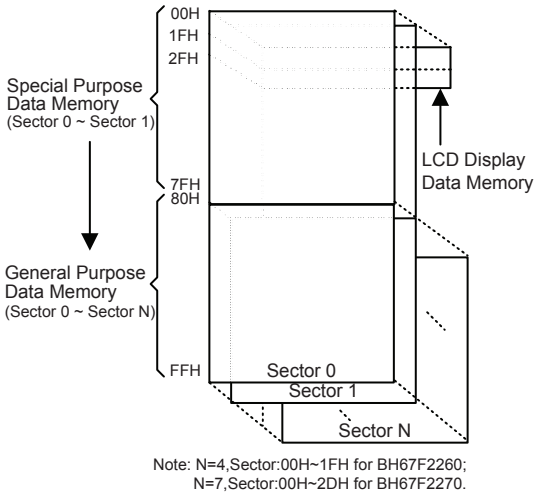
Switching between the different Data Memory sectors is achieved by properly setting the Memory Pointers to correct value.

Structure

The Data Memory is subdivided into several sectors, all of which are implemented in 8-bit wide RAM. Each of the Data Memory Sector is categorized into two types, the special Purpose Data Memory and the General Purpose Data Memory. The address range of the Special Purpose Data Memory for these devices is from 00H to 7FH while the General Purpose Data Memory address range is from 80H to FFH except the LCD Display Data Memory. The BH67F2260 LCD Display Data memory is located from 00H to 1FH in Sector 4. The BH67F2270 LCD Display Data memory is located from 00H to 2DH in Sector 4.

Device	Special Purpose Data Memory	General Purpose Data Memory		LCD Display Memory
	Located Sectors	Capacity	Sector: Address	Sector: Address
BH67F2260	0, 1	512×8	0: 80H~FFH 1: 80H~FFH 2: 80H~FFH 3: 80H~FFH	4: 00H~1FH
BH67F2270	0, 1	1024×8	0: 80H~FFH 1: 80H~FFH ⋮ 6: 80H~FFH 7: 80H~FFH	4: 00H~2DH

Data Memory Summary



Note: N=4,Sector:00H~1FH for BH67F2260;
N=7,Sector:00H~2DH for BH67F2270.

Data Memory Structure

Data Memory Addressing

For these devices that supports the extended instructions, there is no Bank Pointer for Data Memory. The Bank Pointer, PBP, is only available for Program Memory. For Data Memory the desired Sector is pointed by the MP1H or MP2H register and the certain Data Memory address in the selected sector is specified by the MP1L or MP2L register when using indirect addressing access.

Direct Addressing can be used in all sectors using the extended instructions which can address all available data memory space. For the accessed data memory which is located in any data memory sectors except sector 0, the extended instructions can be used to access the data memory instead of using the indirect addressing access. The main difference between standard instructions and extended instructions is that the data memory address "m" in the extended instructions can be has up to 11 valid bits, the high byte indicates a sector and the low byte indicates a specific address.

General Purpose Data Memory

All microcontroller programs require an area of read/write memory where temporary data can be stored and retrieved for use later. It is this area of RAM memory that is known as General Purpose Data Memory. This area of Data Memory is fully accessible by the user programing for both reading and writing operations. By using the bit operation instructions individual bits can be set or reset under program control giving the user a large range of flexibility for bit manipulation in the Data Memory.

Special Purpose Data Memory

This area of Data Memory is where registers, necessary for the correct operation of the microcontroller, are stored. Most of the registers are both readable and writeable but some are protected and are readable only, the details of which are located under the relevant Special Function Register section. Note that for locations that are unused, any read instruction to these addresses will return the value "00H".

	Sector 0	Sector 1
00H	IAR0	
01H	MP0	
02H	IAR1	
03H	MP1L	
04H	MP1H	
05H	ACC	
06H	PCL	
07H	TBLP	
08H	TBLH	
09H	TBHP	
0AH	STATUS	
0BH	PBP	
0CH	IAR2	
0DH	MP2L	
0EH	MP2H	
0FH	RSTFC	
10H	SCC	
11H	HIRC	
12H	HXTC	
13H	LXTC	
14H	PA	
15H	PAC	
16H	PAPU	
17H	PAWU	
18H	RSTC	
19H	LVRC	
1AH	LVDC	
1BH	MFI0	
1CH	MFI1	
1DH	MFI2	
1EH	WDTC	
1FH	INTEG	
20H	INTC0	PTM1C0
21H	INTC1	PTM1C1
22H	INTC2	PTM1DL
23H	INTC3	PTM1DH
24H	PB	PTM1AL
25H	PBC	PTM1AH
26H	PBPU	PTM1RPL
27H	PC	PTM1RPH
28H	PCC	PTM2C0
29H	PCPU	PTM2C1
2AH		PTM2DL
2BH		PTM2DH
2CH	PSCR	PTM2AL
2DH	TB0C	PTM2AH
2EH	TB1C	PTM2RPL
2FH	U0SR	PTM2RPH
30H	U0CR1	
31H	U0CR2	
32H	TXR_RXR0	
33H	BRG0	
34H	SIMC0	
35H	SIMC1	
36H	SIMD	
37H	SIMA/SIMC2	
38H	SIMTOC	
39H		
3AH	SPIAC0	
3BH	SPIAC1	
3CH	SPIAD	
3DH		
3EH		
3FH		

	Sector 0	Sector 1
40H		EEC
41H	EEA	
42H	EED	
43H		FC0
44H		FC1
45H		FC2
46H		FARL
47H		FARH
48H		FD0L
49H	STMC0	FD0H
4AH	STMC1	FD1L
4BH	STMDL	FD1H
4CH	STMDH	FD2L
4DH	STMAL	FD2H
4EH	STMAH	FD3L
4FH	STMRP	FD3H
50H	PTM0C0	IFS0
51H	PTM0C1	IFS1
52H	PTM0DL	
53H	PTM0DH	PAS0
54H	PTM0AL	PAS1
55H	PTM0AH	PBS0
56H	PTM0RPL	
57H	PTM0RPH	PCS0
58H		PCS1
59H	MDUWR0	PDS0
5AH	MDUWR1	PDS1
5BH	MDUWR2	PES0
5CH	MDUWR3	PES1
5DH	MDUWR4	SLEDC0
5EH	MDUWR5	SLEDC1
5FH	MDUWCTRL	SLEDC2
60H		
61H	REGC	
62H		
63H	PGAC0	
64H	PGAC1	
65H	PGAC2	
66H	PGAC3	
67H	SCFC0	
68H	SCFC1	
69H	SCFCKD	
6AH	CCVREFC	
6BH	SADOL	
6CH	SADOH	
6DH	SADC0	
6EH	SADC1	
6FH		
70H	LCDC0	
71H	LCDCP	
72H	LCDC2	
73H		
74H	PD	
75H	PDC	
76H	PDPU	
77H	PE	
78H	PEC	
79H	PEPU	
7AH		
7BH		
7CH		
7DH		
7EH		
7FH		

: Unused, read as 00H

Special Purpose Data Memory Structure – BH67F2260

	Sector 0	Sector 1
00H	IAR0	
01H	MP0	
02H	IAR1	
03H	MP1L	
04H	MP1H	
05H	ACC	
06H	PCL	
07H	TBLP	
08H	TBLH	
09H	TBHP	
0AH	STATUS	
0BH	PBP	
0CH	IAR2	
0DH	MP2L	
0EH	MP2H	
0FH	RSTFC	
10H	SCC	
11H	HIRCC	
12H	HXTC	
13H	LXTC	
14H	PA	
15H	PAC	
16H	PAPU	
17H	PAWU	
18H	RSTC	
19H	LVRC	
1AH	LVDC	
1BH	MFI0	
1CH	MFI1	
1DH	MFI2	
1EH	WDTC	
1FH	INTEG	
20H	INTC0	PTM1C0
21H	INTC1	PTM1C1
22H	INTC2	PTM1DL
23H	INTC3	PTM1DH
24H	PB	PTM1AL
25H	PBC	PTM1AH
26H	PBPU	PTM1RPL
27H	PC	PTM1RPH
28H	PCC	PTM2C0
29H	PCPU	PTM2C1
2AH		PTM2DL
2BH		PTM2DH
2CH	PSCR	PTM2AL
2DH	TB0C	PTM2AH
2EH	TB1C	PTM2RPL
2FH	U0SR	PTM2RPH
30H	U0CR1	
31H	U0CR2	
32H	TXR_RXR0	
33H	BRG0	
34H	SIMC0	
35H	SIMC1	
36H	SIMD	
37H	SIMA/SIMC2	
38H	SIMTOC	
39H		
3AH	SPIAC0	
3BH	SPIAC1	
3CH	SPIAD	
3DH		
3EH		
3FH		

	Sector 0	Sector 1
40H		EEC
41H	EEA	
42H	EED	
43H		FC0
44H	U1SR	FC1
45H	U1CR1	FC2
46H	U1CR2	FARL
47H	TXR_RXR1	FARH
48H	BRG1	FD0L
49H	STMC0	FD0H
4AH	STMC1	FD1L
4BH	STMDL	FD1H
4CH	STMDH	FD2L
4DH	STMAL	FD2H
4EH	STMAH	FD3L
4FH	STMRP	FD3H
50H	PTM0C0	IFS0
51H	PTM0C1	IFS1
52H	PTM0DL	
53H	PTM0DH	PAS0
54H	PTM0AL	PAS1
55H	PTM0AH	PBS0
56H	PTM0RPL	
57H	PTM0RPH	PCS0
58H		PCS1
59H	MDUWR0	PDS0
5AH	MDUWR1	PDS1
5BH	MDUWR2	PES0
5CH	MDUWR3	PES1
5DH	MDUWR4	PFS0
5EH	MDUWR5	PFS1
5FH	MDUWCTRL	PGS0
60H		SLEDC0
61H	REGC	SLEDC1
62H		SLEDC2
63H	PGAC0	SLEDC3
64H	PGAC1	
65H	PGAC2	
66H	PGAC3	
67H	SCFC0	
68H	SCFC1	
69H	SCFCKD	
6AH	CCVREFC	
6BH	SADOL	
6CH	SADOH	
6DH	SADC0	
6EH	SADC1	
6FH		
70H	LCDC0	
71H	LCDCP	
72H	LCDC2	
73H		
74H	PD	
75H	PDC	
76H	PDPU	
77H	PE	
78H	PEC	
79H	PEPU	
7AH	PF	
7BH	PFC	
7CH	PFPU	
7DH	PG	
7EH	PGC	
7FH	PGPU	

: Unused, read as 00H

Special Purpose Data Memory Structure – BH67F2270

Special Function Register Description

Most of the Special Function Register details will be described in the relevant functional section; however several registers require a separate description in this section.

Indirect Addressing Registers – IAR0, IAR1, IAR2

The Indirect Addressing Registers, IAR0, IAR1 and IAR2, although having their locations in normal RAM register space, do not actually physically exist as normal registers. The method of indirect addressing for RAM data manipulation uses these Indirect Addressing Registers and Memory Pointers, in contrast to direct memory addressing, where the actual memory address is specified. Actions on the IAR0, IAR1 and IAR2 registers will result in no actual read or write operation to these registers but rather to the memory location specified by their corresponding Memory Pointers, MP0, MP1L/MP1H or MP2L/MP2H. Acting as a pair, IAR0 and MP0 can together access data only from Sector 0 while the IAR1 register together with the MP1L/MP1H register pair and IAR2 register together with the MP2L/MP2H register pair can access data from any Data Memory Sector. As the Indirect Addressing Registers are not physically implemented, reading the Indirect Addressing Registers will return a result of "00H" and writing to the registers will result in no operation.

Memory Pointers – MP0, MP1L, MP1H, MP2L, MP2H

Five Memory Pointers, known as MP0, MP1L, MP1H, MP2L, MP2H, are provided. These Memory Pointers are physically implemented in the Data Memory and can be manipulated in the same way as normal registers providing a convenient way with which to address and track data. When any operation to the relevant Indirect Addressing Registers is carried out, the actual address that the microcontroller is directed to is the address specified by the related Memory Pointer. MP0, together with Indirect Addressing Register, IAR0, are used to access data from Sector 0, while MP1L/MP1H together with IAR1 and MP2L/MP2H together with IAR2 are used to access data from all sectors according to the corresponding MP1H or MP2H register. Direct Addressing can be used in all sectors using the extended instructions which can address all available data memory space.

The following example shows how to clear a section of four Data Memory locations already defined as locations adres1 to adres4.

Indirect Addressing Program Example 1

```
data .section ´data´
adres1   db ?
adres2   db ?
adres3   db ?
adres4   db ?
block    db ?
code .section at 0 ´code´
org 00h
start:
     mov a, 04h              ; setup size of block
     mov block, a
     mov a, offset adres1    ; Accumulator loaded with first RAM address
     mov mp0, a              ; setup memory pointer with first RAM address
loop:
     clr IAR0                ; clear the data at address defined by MP0
     inc mp0                 ; increment memory pointer
     sdz block               ; check if last memory location has been cleared
     jmp loop
continue:
```

Indirect Addressing Program Example 2

```
data .section ´data´
adres1   db ?
adres2   db ?
adres3   db ?
adres4   db ?
block    db ?
code .section at 0 ´code´
org 00h
start:
     mov a, 04h              ; setup size of block
     mov block, a
     mov a, 01h              ; setup the memory sector
     mov mp1h, a
     mov a, offset adres1    ; Accumulator loaded with first RAM address
     mov mp1l, a             ; setup memory pointer with first RAM address
loop:
     clr IAR1                ; clear the data at address defined by MP1L
     inc mp1l                ; increment memory pointer MP1L
     sdz block               ; check if last memory location has been cleared
     jmp loop
continue:
```

The important point to note here is that in the examples shown above, no reference is made to specific Data Memory addresses.

Direct Addressing Program Example using extended instructions

```
data .section ´data´
temp  db ?
code .section at 0 ´code´
org 00h
start:
     lmov a, [m]             ; move [m] data to acc
     lsub a, [m+1]           ; compare [m] and [m+1] data
     snz c                   ; [m]>[m+1]?
     jmp continue            ; no
     lmov a, [m]             ; yes, exchange [m] and [m+1] data
     mov temp, a
     lmov a, [m+1]
     lmov [m], a
     mov a, temp
     lmov [m+1], a
continue:
```

Note: Here “m” is a data memory address located in any data memory sectors. For example, m=1F0H, it indicates address 0F0H in Sector 1.

Program Memory Bank Pointer – PBP

For these devices the Program Memory is divided into several banks. Selecting the required Program Memory area is achieved using the Program Memory Bank Pointer, PBP. The PBP register should be properly configured before these devices execute the "Branch" operation using the "JMP" or "CALL" instruction. After that a jump to a non-consecutive Program Memory address which is located in a certain bank selected by the program memory bank pointer bits will occur.

PBP Register – BH67F2260

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	—	PBP0
R/W	—	—	—	—	—	—	—	R/W
POR	—	—	—	—	—	—	—	0

Bit 7~1 Unimplemented, read as "0"

Bit 0 **PBP0**: Program Memory Bank Pointer bit 0
0: Bank 0
1: Bank 1

PBP Register – BH67F2270

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	PBP1	PBP0
R/W	—	—	—	—	—	—	R/W	R/W
POR	—	—	—	—	—	—	0	0

Bit 7~2 Unimplemented, read as "0"

Bit 1~0 **PBP1~PBP0**: Program Memory Bank Pointer bit 1~ bit 0
00: Bank 0
01: Bank 1
10: Bank 2
11: Bank 3

Accumulator – ACC

The Accumulator is central to the operation of any microcontroller and is closely related with operations carried out by the ALU. The Accumulator is the place where all intermediate results from the ALU are stored. Without the Accumulator it would be necessary to write the result of each calculation or logical operation such as addition, subtraction, shift, etc., to the Data Memory resulting in higher programming and timing overheads. Data transfer operations usually involve the temporary storage function of the Accumulator; for example, when transferring data between one user-defined register and another, it is necessary to do this by passing the data through the Accumulator as no direct transfer between two registers is permitted.

Program Counter Low Register – PCL

To provide additional program control functions, the low byte of the Program Counter is made accessible to programmers by locating it within the Special Purpose area of the Data Memory. By manipulating this register, direct jumps to other program locations are easily implemented. Loading a value directly into this PCL register will cause a jump to the specified Program Memory location, however, as the register is only 8-bit wide, only jumps within the current Program Memory page are permitted. When such operations are used, note that a dummy cycle will be inserted.

Look-up Table Registers – TBLP, TBHP, TBLH

These three special function registers are used to control operation of the look-up table which is stored in the Program Memory. TBLP and TBHP are the table pointers and indicate the location where the table data is located. Their value must be setup before any table read commands are executed. Their value can be changed, for example using the "INC" or "DEC" instructions, allowing for easy table data pointing and reading. TBLH is the location where the high order byte of the table data is stored after a table read data instruction has been executed. Note that the lower order table data byte is transferred to a user defined location.

Status Register – STATUS

This 8-bit register contains the SC flag, CZ flag, zero flag (Z), carry flag (C), auxiliary carry flag (AC), overflow flag (OV), power down flag (PDF), and watchdog time-out flag (TO). These arithmetic/logical operation and system management flags are used to record the status and operation of the microcontroller.

With the exception of the TO and PDF flags, bits in the status register can be altered by instructions like most other registers. Any data written into the status register will not change the TO or PDF flag. In addition, operations related to the status register may give different results due to the different instruction operations. The TO flag can be affected only by a system power-up, a WDT time-out or by executing the "CLR WDT" or "HALT" instruction. The PDF flag is affected only by executing the "HALT" or "CLR WDT" instruction or during a system power-up.

The Z, OV, AC, C, SC and CZ flags generally reflect the status of the latest operations.

- C is set if an operation results in a carry during an addition operation or if a borrow does not take place during a subtraction operation; otherwise C is cleared. C is also affected by a rotate through carry instruction.
- AC is set if an operation results in a carry out of the low nibbles in addition, or no borrow from the high nibble into the low nibble in subtraction; otherwise AC is cleared.
- Z is set if the result of an arithmetic or logical operation is zero; otherwise Z is cleared.
- OV is set if an operation results in a carry into the highest-order bit but not a carry out of the highest-order bit, or vice versa; otherwise OV is cleared.
- PDF is cleared by a system power-up or executing the "CLR WDT" instruction. PDF is set by executing the "HALT" instruction.
- TO is cleared by a system power-up or executing the "CLR WDT" or "HALT" instruction. TO is set by a WDT time-out.
- CZ is the operational result of different flags for different instructions. Refer to register definitions for more details.
- SC is the result of the "XOR" operation which is performed by the OV flag and the MSB of the current instruction operation result.

In addition, on entering an interrupt sequence or executing a subroutine call, the status register will not be pushed onto the stack automatically. If the contents of the status registers are important and if the subroutine can corrupt the status register, precautions must be taken to correctly save it.

STATUS Register

Bit	7	6	5	4	3	2	1	0
Name	SC	CZ	TO	PDF	OV	Z	AC	C
R/W	R	R	R	R	R/W	R/W	R/W	R/W
POR	x	x	0	0	x	x	x	x

"x": unknown

Bit 7 **SC**: The result of the "XOR" operation which is performed by the OV flag and the MSB of the instruction operation result.

Bit 6 **CZ**: The operational result of different flags for different instructions.

For SUB/SUBM/LSUB/LSUBM instructions, the CZ flag is equal to the Z flag.

For SBC/SBCM/LSBC/LSBCM instructions, the CZ flag is the "AND" operation result which is performed by the previous operation CZ flag and current operation zero flag.

For other instructions, the CZ flag will not be affected.

Bit 5 **TO**: Watchdog Time-out flag
0: After power up or executing the "CLR WDT" or "HALT" instruction
1: A watchdog time-out occurred.

Bit 4 **PDF**: Power down flag
0: After power up or executing the "CLR WDT" instruction
1: By executing the "HALT" instruction

Bit 3 **OV**: Overflow flag
0: No overflow
1: An operation results in a carry into the highest-order bit but not a carry out of the highest-order bit or vice versa.

Bit 2 **Z**: Zero flag
0: The result of an arithmetic or logical operation is not zero
1: The result of an arithmetic or logical operation is zero

Bit 1 **AC**: Auxiliary flag
0: No auxiliary carry
1: An operation results in a carry out of the low nibbles in addition, or no borrow from the high nibble into the low nibble in subtraction

Bit 0 **C**: Carry flag
0: No carry-out
1: An operation results in a carry during an addition operation or if a borrow does not take place during a subtraction operation

The "C" flag is also affected by a rotate through carry instruction.

EEPROM Data Memory

these devices contain an area of internal EEPROM Data Memory. EEPROM, which stands for Electrically Erasable Programmable Read Only Memory, is by its nature a non-volatile form of re-programmable memory, with data retention even when its power supply is removed. By incorporating this kind of data memory, a whole new host of application possibilities are made available to the designer. The availability of EEPROM storage allows information such as product identification numbers, calibration values, specific user data, system setup data or other product information to be stored directly within the product microcontroller. The process of reading and writing data to the EEPROM memory has been reduced to a very trivial affair.

EEPROM Data Memory Structure

The EEPROM Data Memory capacity is 64×8 bits for these devices. Unlike the Program Memory and RAM Data Memory, the EEPROM Data Memory is not directly mapped into memory space and is therefore not directly addressable in the same way as the other types of memory. Read and Write operations to the EEPROM are carried out in single byte operations using an address and a data register in Sector 0 and a single control register in Sector 1.

EEPROM Registers

Three registers control the overall operation of the internal EEPROM Data Memory. These are the address register, EEA, the data register, EED and a single control register, EEC. As both the EEA and EED registers are located in Sector 0, they can be directly accessed in the same way as any other Special Function Register. The EEC register however, being located in Sector 1, can be read from or written to indirectly using the MP1L/MP1H or MP2L/MP2H Memory Pointer and Indirect Addressing Register, IAR1/IAR2. Because the EEC control register is located at address 40H in Sector 1, the MP1L or MP2L Memory Pointer must first be set to the value 40H and the MP1H or MP2H Memory Pointer high byte set to the value, 01H, before any operations on the EEC register are executed.

Register Name	Bit							
	7	6	5	4	3	2	1	0
EEA	—	—	EEA5	EEA4	EEA3	EEA2	EEA1	EEA0
EED	EED7	EED6	EED5	EED4	EED3	EED2	EED1	EED0
EEC	—	—	—	—	WREN	WR	RDEN	RD

EEPROM Registers List

EEA Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	EEA5	EEA4	EEA3	EEA2	EEA1	EEA0
R/W	—	—	R/W	R/W	R/W	R/W	R/W	R/W
POR	—	—	0	0	0	0	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5~0 **EEA5~EEA0**: Data EEPROM address bit 5~bit 0

EED Register

Bit	7	6	5	4	3	2	1	0
Name	EED7	EED6	EED5	EED4	EED3	EED2	EED1	EED0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **EED7~EED0**: Data EEPROM data bit 7~bit 0

EEC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	WREN	WR	RDEN	RD
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	0	0	0

Bit 7~4 Unimplemented, read as "0"

Bit 3 **WREN**: Data EEPROM Write Enable
0: Disable
1: Enable
This is the Data EEPROM Write Enable Bit which must be set high before Data EEPROM write operations are carried out. Clearing this bit to zero will inhibit Data EEPROM write operations.

Bit 2 **WR**: EEPROM Write Control
0: Write cycle has finished
1: Activate a write cycle
This is the Data EEPROM Write Control Bit and when set high by the application program will activate a write cycle. This bit will be automatically reset to zero by the hardware after the write cycle has finished. Setting this bit high will have no effect if the WREN has not first been set high.

Bit 1 **RDEN**: Data EEPROM Read Enable
0: Disable
1: Enable
This is the Data EEPROM Read Enable Bit which must be set high before Data EEPROM read operations are carried out. Clearing this bit to zero will inhibit Data EEPROM read operations.

Bit 0 **RD**: EEPROM Read Control
0: Read cycle has finished
1: Activate a read cycle
This is the Data EEPROM Read Control Bit and when set high by the application program will activate a read cycle. This bit will be automatically reset to zero by the hardware after the read cycle has finished. Setting this bit high will have no effect if the RDEN has not first been set high.

Note: The WREN, WR, RDEN and RD cannot be set high at the same time in one instruction. The WR and RD cannot be set high at the same time.

Reading Data from the EEPROM

To read data from the EEPROM, the read enable bit, RDEN, in the EEC register must first be set high to enable the read function. The EEPROM address of the data to be read must then be placed in the EEA register. If the RD bit in the EEC register is now set high, a read cycle will be initiated. Setting the RD bit high will not initiate a read operation if the RDEN bit has not been set. When the read cycle terminates, the RD bit will be automatically cleared to zero, after which the data can be read from the EED register. The data will remain in the EED register until another read or write operation is executed. The application program can poll the RD bit to determine when the data is valid for reading.

Writing Data to the EEPROM

The EEPROM address of the data to be written must first be placed in the EEA register and the data placed in the EED register. To write data to the EEPROM, the write enable bit, WREN, in the EEC register must first be set high to enable the write function. After this, the WR bit in the EEC register must be immediately set high to initiate a write cycle. These two instructions must be executed consecutively. The global interrupt bit EMI should also first be cleared before implementing any write operations, and then set again after the write cycle has started. Note that setting the WR bit high will not initiate a write cycle if the WREN bit has not been set. As the EEPROM write cycle is controlled using an internal timer whose operation is asynchronous to microcontroller system clock, a certain time will elapse before the data will have been written into the EEPROM. Detecting when the write cycle has finished can be implemented either by polling the WR bit in the EEC register or by using the EEPROM interrupt. When the write cycle terminates, the WR bit will be automatically cleared to zero by the microcontroller, informing the user that the data has been written to the EEPROM. The application program can therefore poll the WR bit to determine when the write cycle has ended.

Write Protection

Protection against inadvertent write operation is provided in several ways. After these devices are powered-on the Write Enable bit in the control register will be cleared preventing any write operations. Also at power-on the Memory Pointer high byte register, MP1H or MP2H, will be reset to zero, which means that Data Memory Sector 0 will be selected. As the EEPROM control register is located in Sector 1, this adds a further measure of protection against spurious write operations. During normal program operation, ensuring that the Write Enable bit in the control register is cleared will safeguard against incorrect write operations.

EEPROM Interrupt

The EEPROM write interrupt is generated when an EEPROM write cycle has ended. The EEPROM interrupt must first be enabled by setting the DEE bit in the relevant interrupt register. However as the EEPROM is contained within a Multi-function Interrupt, the associated multi-function interrupt enable bit must also be set. When an EEPROM write cycle ends, the DEF request flag and its associated multi-function interrupt request flag will both be set. If the global, EEPROM and Multi-function interrupts are enabled and the stack is not full, a jump to the associated Multi-function Interrupt vector will take place. When the interrupt is serviced only the Multi-function interrupt flag will be automatically reset, the EEPROM interrupt flag must be manually reset by the application program. More details can be obtained in the Interrupt section.

Programming Considerations

Care must be taken that data is not inadvertently written to the EEPROM. Protection can be enhanced by ensuring that the Write Enable bit is normally cleared to zero when not writing. Also the Memory Pointer high byte register, MP1H or MP2H, could be normally cleared to zero as this would inhibit access to Sector 1 where the EEPROM control register exists. Although certainly not necessary, consideration might be given in the application program to the checking of the validity of new write data by a simple read back process.

When writing data the WR bit must be set high immediately after the WREN bit has been set high, to ensure the write cycle executes correctly. The global interrupt bit EMI should also be cleared before a write cycle is executed and then re-enabled after the write cycle starts. Note that these devices should not enter the IDLE or SLEEP mode until the EEPROM read or write operation is totally complete. Otherwise, the EEPROM read or write operation will fail.

Programming Examples

- **Reading data from the EEPROM - polling method**

```
MOV  A, EEPROM_ADRES      ; user defined address
MOV  EEA, A
MOV  A, 40H               ; setup memory pointer MP1L
MOV  MP1L, A              ; MP1 points to EEC register
MOV  A, 01H               ; setup memory pointer MP1H
MOV  MP1H, A
SET  IAR1.1               ; set RDEN bit, enable read operations
SET  IAR1.0               ; start Read Cycle - set RD bit
BACK:
SZ   IAR1.0               ; check for read cycle end
JMP  BACK
CLR  IAR1                 ; disable EEPROM read/write
CLR  MP1H
MOV  A, EED               ; move read data to register
MOV  READ_DATA, A
```

- **Writing Data to the EEPROM - polling method**

```
MOV  A, EEPROM_ADRES      ; user defined address
MOV  EEA, A
MOV  A, EEPROM_DATA       ; user defined data
MOV  EED, A
MOV  A, 40H               ; setup memory pointer MP1L
MOV  MP1L, A              ; MP1 points to EEC register
MOV  A, 01H               ; setup memory pointer MP1H
MOV  MP1H, A
CLR  EMI
SET  IAR1.3               ; set WREN bit, enable write operations
SET  IAR1.2               ; start Write Cycle - set WR bit - executed immediately
                          ; after set WREN bit
SET  EMI
BACK:
SZ   IAR1.2               ; check for write cycle end
JMP  BACK
CLR  IAR1                 ; disable EEPROM read/write
CLR  MP1H
```

Oscillators

Various oscillator options offer the user a wide range of functions according to their various application requirements. The flexible features of the oscillator functions ensure that the best optimisation can be achieved in terms of speed and power saving. Oscillator selections and operation are selected through the application program and relevant control registers.

Oscillator Overview

In addition to being the source of the main system clock the oscillators also provide clock sources for the Watchdog Timer and Time Base Interrupts. External oscillators requiring some external components as well as fully integrated internal oscillators, requiring no external components, are provided to form a wide range of both fast and slow system oscillators. All oscillator options are selected through the relevant control registers. The higher frequency oscillators provide higher performance but carry with it the disadvantage of higher power requirements, while the opposite is of course true for the lower frequency oscillators. With the capability of dynamically switching between fast and slow system clock, these devices have the flexibility to optimize the performance/power ratio, a feature especially important in power sensitive portable applications.

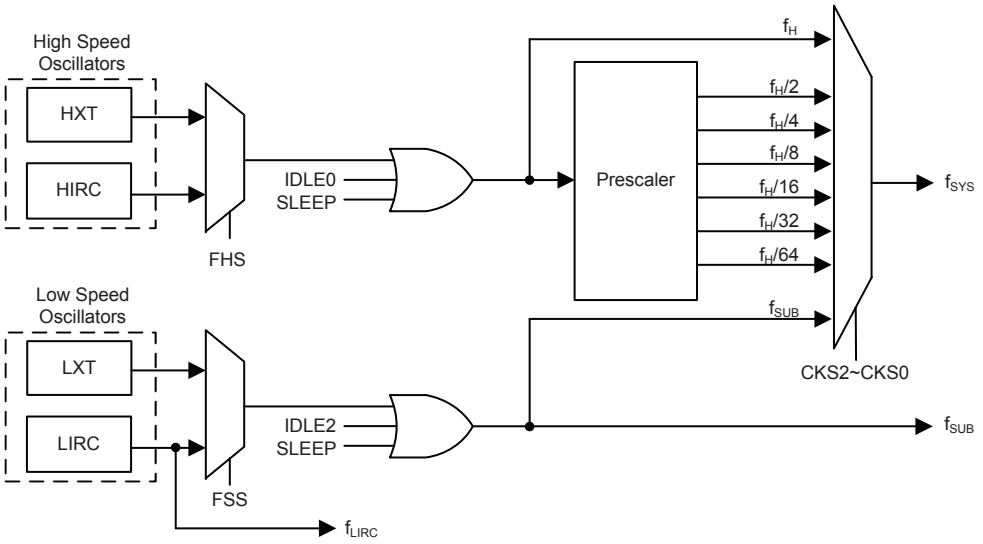
Type	Name	Frequency	Pins
External High Speed Crystal	HXT	400kHz~16MHz	OSC1/OSC2
Internal High Speed RC	HIRC	4/8/12MHz	—
External Low Speed Crystal	LXT	32.768kHz	XT1/XT2
Internal Low Speed RC	LIRC	32kHz	—

Oscillator Types

System Clock Configurations

There are several oscillator sources, two high speed oscillators and two low speed oscillators. The high speed system clocks are sourced from the external crystal/ceramic oscillator, HXT, and the internal 4/8/12MHz RC oscillator, HIRC. The low speed oscillators are the external 32.768kHz crystal oscillator, LXT, and the internal 32kHz RC oscillator, LIRC. Selecting whether the low or high speed oscillator is used as the system oscillator is implemented using the CKS2~CKS0 bits in the SCC register and as the system clock can be dynamically selected.

The actual source clock used for the low speed oscillators is chosen via the FSS bit in the SCC register while for the high speed oscillator the source clock is selected by the FHS bit in the SCC register. The frequency of the slow speed or high speed system clock is also determined using the CKS2~CKS0 bits in the SCC register. Note that two oscillator selections must be made namely one high speed and one low speed system oscillators. It is not possible to choose a no-oscillator selection for either the high or low speed oscillator.

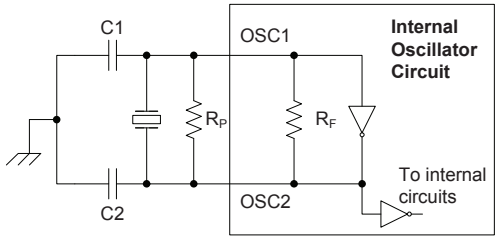


System Clock Configurations

External Crystal/Ceramic Oscillator – HXT

The External Crystal/Ceramic System Oscillator is one of the high frequency oscillators. For most crystal oscillator configurations, the simple connection of a crystal across OSC1 and OSC2 will create the necessary phase shift and feedback for oscillation, without requiring external capacitors. However, for some crystal types and frequencies, to ensure oscillation, it may be necessary to add two small value capacitors, C1 and C2. Using a ceramic resonator will usually require two small value capacitors, C1 and C2, to be connected as shown for oscillation to occur. The values of C1 and C2 should be selected in consultation with the crystal or resonator manufacturer's specification.

For oscillator stability and to minimise the effects of noise and crosstalk, it is important to ensure that the crystal and any associated resistors and capacitors along with interconnecting lines are all located as close to the MCU as possible.



Note: 1. R_P is normally not required. C1 and C2 are required.
2. Although not shown OSC1/OSC2 pins have a parasitic capacitance of around 7pF.

Crystal/Resonator Oscillator – HXT

Crystal Oscillator C1 and C2 Values		
Crystal Frequency	C1	C2
16MHz	0pF	0pF
12MHz	0pF	0pF
8MHz	0pF	0pF
6MHz	0pF	0pF
4MHz	0pF	0pF
1MHz	100pF	100pF
Note: C1 and C2 values are for guidance only.		

Crystal Recommended Capacitor Values

Internal High Speed RC Oscillator – HIRC

The internal RC oscillator is a fully integrated system oscillator requiring no external components. The internal RC oscillator has three fixed frequencies of 4MHz, 8MHz and 12MHz. Device trimming during the manufacturing process and the inclusion of internal frequency compensation circuits are used to ensure that the influence of the power supply voltage, temperature and process variations on the oscillation frequency are minimised. Note that if this internal system clock option is selected, as it requires no external pins for its operation, I/O pins PA3 and PA4 are free for use as normal I/O pins.

External 32.768kHz Crystal Oscillator – LXT

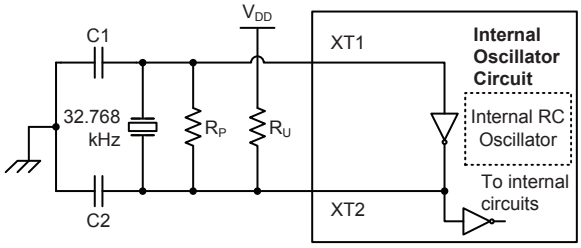
The External 32.768 kHz Crystal System Oscillator is one of the low frequency oscillator choices, which is selected via a software control bit, FSS. This clock source has a fixed frequency of 32.768kHz and requires a 32.768kHz crystal to be connected between pins XT1 and XT2. The external resistor and capacitor components connected to the 32.768kHz crystal are necessary to provide oscillation. For applications where precise frequencies are essential, these components may be required to provide frequency compensation due to different crystal manufacturing tolerances. After the LXT oscillator is enabled by setting the LXTEN bit to 1, there is a time delay associated with the LXT oscillator waiting for it to start-up.

However, for some crystals, to ensure oscillation and accurate frequency generation, it is necessary to add two small value external capacitors, C1 and C2. The exact values of C1 and C2 should be selected in consultation with the crystal or resonator manufacturer's specification. The external parallel feedback resistor, R_P, and the pull high resistor, R_U, are required.

The pin-shared software control bits determine if the XT1/XT2 pins are used for the LXT oscillator or as I/O or other pin-shared functional pins.

- If the LXT oscillator is not used for any clock source, the XT1/XT2 pins can be used as normal I/O or other pin-shared functional pins.
- If the LXT oscillator is used for any clock source, the 32.768 kHz crystal should be connected to the XT1/XT2 pins.

For oscillator stability and to minimise the effects of noise and crosstalk, it is important to ensure that the crystal and any associated resistors and capacitors along with interconnecting lines are all located as close to the MCU as possible.



Note: 1. R_P, R_U, C1 and C2 are required.
2. Although not shown XT1/XT2 pins have a parasitic capacitance of around 7pF.

External LXT Oscillator

LXT Oscillator C1 and C2 Values		
Crystal Frequency	**C1**	**C2**
32.768kHz	10pF	10pF
Note: 1. C1 and C2 values are for guidance only. 2. R_P=5M~10MΩ is recommended. 2. R_U=10MΩ is recommended.		

32.768kHz Crystal Recommended Capacitor Values

Internal 32kHz Oscillator – LIRC

The Internal 32kHz System Oscillator is one of the low frequency oscillator choices, which is selected via a software control bit, FSS. It is a fully integrated RC oscillator with a typical frequency of 32kHz at 5V, requiring no external components for its implementation. Device trimming during the manufacturing process and the inclusion of internal frequency compensation circuits are used to ensure that the influence of the power supply voltage, temperature and process variations on the oscillation frequency are minimised.

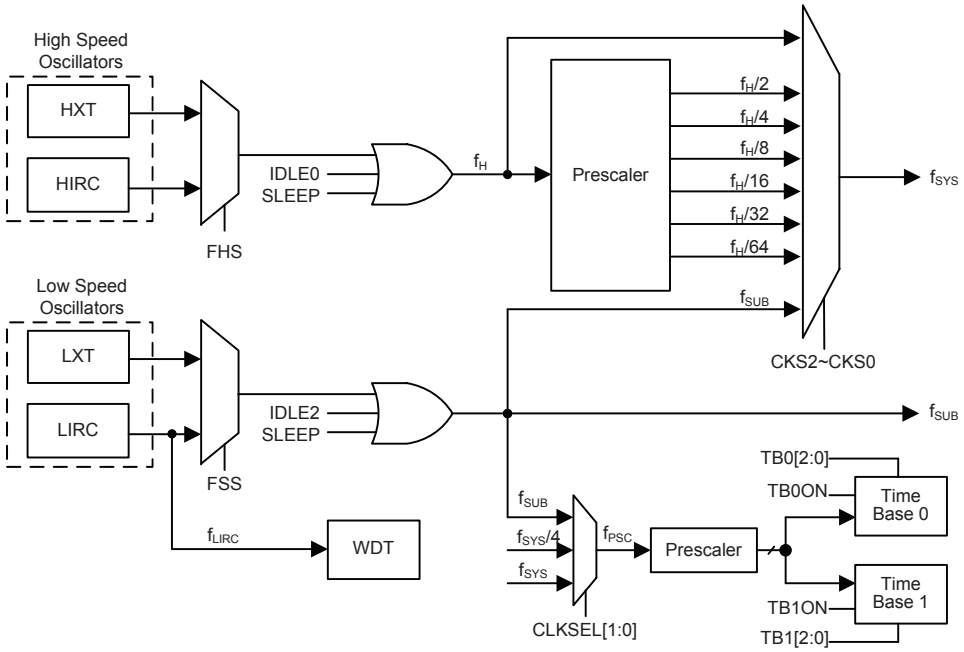
Operating Modes and System Clocks

Present day applications require that their microcontrollers have high performance but often still demand that they consume as little power as possible, conflicting requirements that are especially true in battery powered portable applications. The fast clocks required for high performance will by their nature increase current consumption and of course vice versa, lower speed clocks reduce current consumption. As Holtek has provided these devices with both high and low speed clock sources and the means to switch between them dynamically, the user can optimise the operation of their microcontroller to achieve the best performance/power ratio.

System Clocks

These devices have many different clock sources for both the CPU and peripheral function operation. By providing the user with a wide range of clock options using register programming, a clock system can be configured to obtain maximum application performance.

The main system clock, can come from a high frequency, f_H, or low frequency, f_{SUB}, source, and is selected using the CKS2~CKS0 bits in the SCC register. The high speed system clock can be sourced from an HXT or HIRC oscillator, selected via configuring the FHS bit in the SCC register. The low speed system clock source can be sourced from the internal clock f_{SUB}. If f_{SUB} is selected then it can be sourced by either the LXT or LIRC oscillators, selected via configuring the FSS bit in the SCC register. The other choice, which is a divided version of the high speed system oscillator has a range of $f_H/2$~$f_H/64$.



Device Clock Configurations

Note: When the system clock source f_{SYS} is switched to f_{SUB} from f_H, the high speed oscillator will stop to conserve the power or continue to oscillate to provide the clock source, f_H~$f_H/64$, for peripheral circuit to use, which is determined by configuring the corresponding high speed oscillator enable control bit.

System Operation Modes

There are six different modes of operation for the microcontroller, each one with its own special characteristics and which can be chosen according to the specific performance and power requirements of the application. There are two modes allowing normal operation of the microcontroller, the FAST Mode and SLOW Mode. The remaining four modes, the SLEEP, IDLE0, IDLE1 and IDLE2 Mode are used when the microcontroller CPU is switched off to conserve power.

Operation Mode	CPU	Register Setting			f_{SYS}	f_H	f_{SUB}	f_{LIRC}
		FHIDEN	FSIDEN	CKS2~CKS0				
FAST	On	x	x	000~110	f_H~f_H/64	On	On	On
SLOW	On	x	x	111	f_{SUB}	On/Off (1)	On	On
IDLE0	Off	0	1	000~110	Off	Off	On	On
				111	On			
IDLE1	Off	1	1	xxx	On	On	On	On
IDLE2	Off	1	0	000~110	On	On	Off	On
				111	Off			
SLEEP	Off	0	0	xxx	Off	Off	Off	On/Off (2)

"x": Don't care

Note: 1. The f_H clock will be switched on or off by configuring the corresponding oscillator enable bit in the SLOW mode.

2. The f_{LIRC} clock can be switched on or off which is controlled by the WDT function being enabled or disabled in the SLEEP mode.

FAST Mode

As the name suggests this is one of the main operating modes where the microcontroller has all of its functions operational and where the system clock is provided by one of the high speed oscillators. This mode operates allowing the microcontroller to operate normally with a clock source will come from one of the high speed oscillators, either the HXT or HIRC oscillators. The high speed oscillator will however first be divided by a ratio ranging from 1 to 64, the actual ratio being selected by the CKS2~CKS0 bits in the SCC register. Although a high speed oscillator is used, running the microcontroller at a divided clock ratio reduces the operating current.

SLOW Mode

This is also a mode where the microcontroller operates normally although now with a slower speed clock source. The clock source used will be from f_{SUB}. The f_{SUB} clock is derived from either the LIRC or LXT oscillator determined by the FSS bit in the SCC register.

SLEEP Mode

The SLEEP Mode is entered when an HALT instruction is executed and when the FHIDEN and FSIDEN bit are low. In the SLEEP mode the CPU will be stopped. The f_{SUB} clock provided to the peripheral function will also be stopped, too. However the f_{LIRC} clock can continues to operate if the WDT function is enabled.

IDLE0 Mode

The IDLE0 Mode is entered when an HALT instruction is executed and when the FHIDEN bit in the SCC register is low and the FSIDEN bit in the SCC register is high. In the IDLE0 Mode the CPU will be switched off but the low speed oscillator will be turned on to drive some peripheral functions.

IDLE1 Mode

The IDLE1 Mode is entered when an HALT instruction is executed and when the FHIDEN bit in the SCC register is high and the FSIDEN bit in the SCC register is high. In the IDLE1 Mode the CPU will be switched off but both the high and low speed oscillators will be turned on to provide a clock source to keep some peripheral functions operational.

IDLE2 Mode

The IDLE2 Mode is entered when an HALT instruction is executed and when the FHIDEN bit in the SCC register is high and the FSIDEN bit in the SCC register is low. In the IDLE2 Mode the CPU will be switched off but the high speed oscillator will be turned on to provide a clock source to keep some peripheral functions operational.

Control Registers

The registers, SCC, HIRCC, HXTC and LXTC, are used to control the system clock and the corresponding oscillator configurations.

Register Name	Bit							
	7	6	5	4	3	2	1	0
SCC	CKS2	CKS1	CKS0	—	FHS	FSS	FHIDEN	FSIDEN
HIRCC	—	—	—	—	HIRC1	HIRC0	HIRCF	HIRCEN
HXTC	—	—	—	—	—	HXTM	HXTF	HXTEN
LXTC	—	—	—	—	—	—	LXTF	LXTEN

System Operating Mode Control Registers List

SCC Register

Bit	7	6	5	4	3	2	1	0
Name	CKS2	CKS1	CKS0	—	FHS	FSS	FHIDEN	FSIDEN
R/W	R/W	R/W	R/W	—	R/W	R/W	R/W	R/W
POR	0	0	0	—	0	0	0	0

Bit 7~5 **CKS2~CKS0**: System clock selection
000: f_H
001: $f_H/2$
010: $f_H/4$
011: $f_H/8$
100: $f_H/16$
101: $f_H/32$
110: $f_H/64$
111: f_{SUB}
These three bits are used to select which clock is used as the system clock source. In addition to the system clock source directly derived from f_H or f_{SUB}, a divided version of the high speed system oscillator can also be chosen as the system clock source.

Bit 4 Unimplemented, read as "0"

Bit 3 **FHS**: High Frequency clock selection
0: HIRC
1: HXT

Bit 2 **FSS**: Low Frequency clock selection
0: LIRC
1: LXT

Bit 1 **FHIDEN**: High Frequency oscillator control when CPU is switched off
0: Disable
1: Enable
This bit is used to control whether the high speed oscillator is activated or stopped when the CPU is switched off by executing an "HALT" instruction.

Bit 0 **FSIDEN**: Low Frequency oscillator control when CPU is switched off
0: Disable
1: Enable
This bit is used to control whether the low speed oscillator is activated or stopped when the CPU is switched off by executing an "HALT" instruction. The LIRC oscillator is controlled by this bit together with the WDT function enable control. If this bit is cleared to 0 but the WDT function is enabled, the f_{LIRC} clock will also be enabled.

HIRCC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	HIRC1	HIRC0	HIRCF	HIRCEN
R/W	—	—	—	—	R/W	R/W	R	R/W
POR	—	—	—	—	0	0	0	1

Bit 7~4 Unimplemented, read as "0"

Bit 3~2 **HIRC1~HIRC0**: HIRC frequency selection
00: 4MHz
01: 8MHz
10: 12MHz
11: 4MHz

Bit 1 **HIRCF**: HIRC oscillator stable flag
0: HIRC unstable
1: HIRC stable
This bit is used to indicate whether the HIRC oscillator is stable or not. When the HIRCEN bit is set to 1 to enable the HIRC oscillator, the HIRCF bit will first be cleared to 0 and then set to 1 after the HIRC oscillator is stable.

Bit 0 **HIRCEN**: HIRC oscillator enable control
0: Disable
1: Enable

HXTC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	HXTM	HXTF	HXTEN
R/W	—	—	—	—	—	R/W	R	R/W
POR	—	—	—	—	—	0	0	0

Bit 7~3 Unimplemented, read as "0"

Bit 2 **HXTM**: HXT mode selection
0: HXT frequency ≤ 10MHz
1: HXT frequency > 10MHz
This bit is used to select the HXT oscillator operating mode. Note that this bit must be properly configured before the HXT is enabled. When the HXTEN bit is set to 1 to enable the HXT oscillator, it is invalid to change the value of this bit.

Bit 1 **HXTF**: HXT oscillator stable flag
0: HXT unstable
1: HXT stable
This bit is used to indicate whether the HXT oscillator is stable or not. When the HXTEN bit is set to 1 to enable the HXT oscillator, the HXTF bit will first be cleared to 0 and then set to 1 after the HXT oscillator is stable.

Bit 0 **HXTEN**: HXT oscillator enable control
0: Disable
1: Enable

LXTC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	LXTF	LXTEN
R/W	—	—	—	—	—	—	R	R/W
POR	—	—	—	—	—	—	0	0

Bit 7~2 Unimplemented, read as "0"

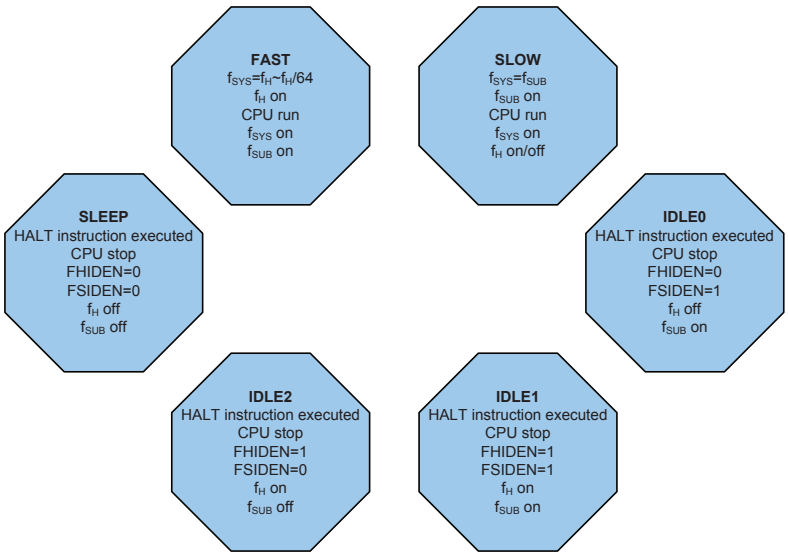
Bit 1 **LXTF**: LXT oscillator stable flag
0: LXT unstable
1: LXT stable
This bit is used to indicate whether the LXT oscillator is stable or not. When the LXTEN bit is set to 1 to enable the LXT oscillator, the LXTF bit will first be cleared to 0 and then set to 1 after the LXT oscillator is stable.

Bit 0 **LXTEN**: LXT oscillator enable control
0: Disable
1: Enable

Operating Mode Switching

These devices can switch between operating modes dynamically allowing the user to select the best performance/power ratio for the present task in hand. In this way microcontroller operations that do not require high performance can be executed using slower clocks thus requiring less operating current and prolonging battery life in portable applications.

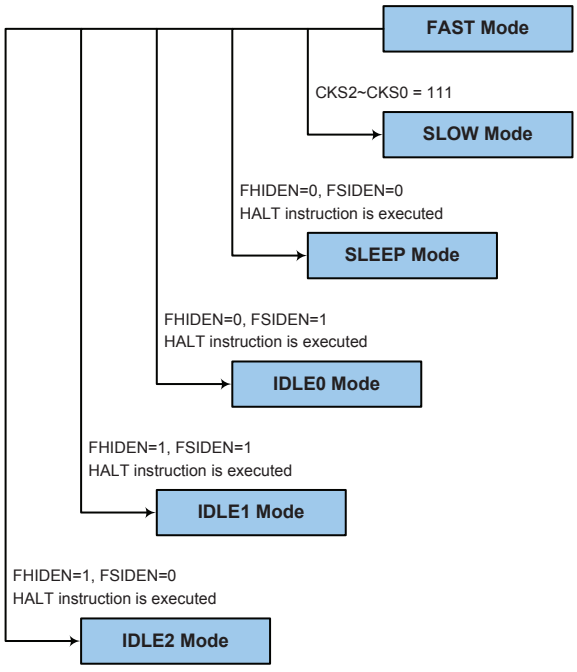
In simple terms, Mode Switching between the FAST Mode and SLOW Mode is executed using the CKS2~CKS0 bits in the SCC register while Mode Switching from the FAST/SLOW Modes to the SLEEP/IDLE Modes is executed via the HALT instruction. When an HALT instruction is executed, whether these devices enter the IDLE Mode or the SLEEP Mode is determined by the condition of the FHIDEN and FSIDEN bits in the SCC register.



FAST Mode to SLOW Mode Switching

When running in the FAST Mode, which uses the high speed system oscillator, and therefore consumes more power, the system clock can switch to run in the SLOW Mode by set the CKS2~CKS0 bits to "111" in the SCC register. This will then use the low speed system oscillator which will consume less power. Users may decide to do this for certain operations which do not require high performance and can subsequently reduce power consumption.

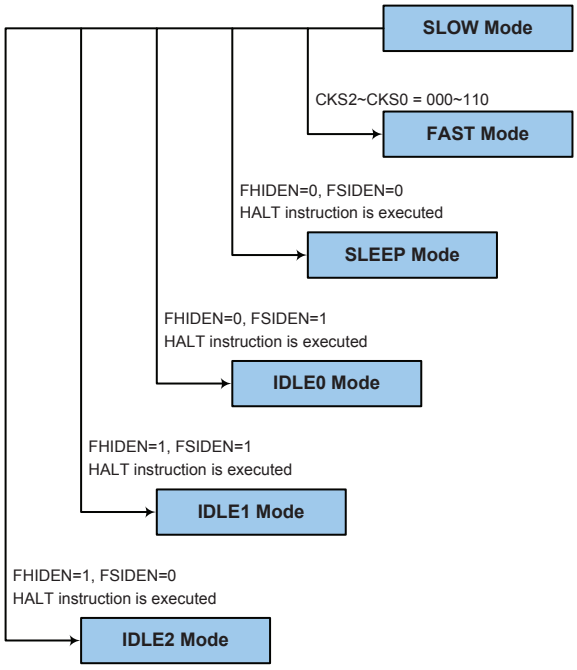
The SLOW Mode is sourced from the LXT or LIRC oscillator determined by the FSS bit in the SCC register and therefore requires this oscillator to be stable before full mode switching occurs.



SLOW Mode to FAST Mode Switching

In SLOW mode the system clock is derived from f_{SUB}. When system clock is switched back to the FAST mode from f_{SUB}, the CKS2~CKS0 bits should be set to "000"~"110" and then the system clock will respectively be switched to f_H~f_H/64.

However, if f_H is not used in SLOW mode and thus switched off, it will take some time to re-oscillate and stabilise when switching to the FAST mode from the SLOW Mode. This is monitored using the HXTF bit in the HXTC register or the HIRCF bit in the HIRCC register. The time duration required for the high speed system oscillator stabilization is specified in the System Start Up Time Characteristics.



Entering the SLEEP Mode

There is only one way for these devices to enter the SLEEP Mode and that is to execute the "HALT" instruction in the application program with both the FHIDEN and FSIDEN bits in the SCC register equal to "0". In this mode all the clocks and functions will be switched off except the WDT function. When this instruction is executed under the conditions described above, the following will occur:

- The system clock will be stopped and the application program will stop at the "HALT" instruction.
- The Data Memory contents and registers will maintain their present condition.
- The I/O ports will maintain their present conditions.
- In the status register, the Power Down flag, PDF, will be set and the Watchdog time-out flag, TO, will be cleared.
- The WDT will be cleared and resume counting if the WDT function is enabled. If the WDT function is disabled, the WDT will be cleared and then stopped.

Entering the IDLE0 Mode

There is only one way for these devices to enter the IDLE0 Mode and that is to execute the "HALT" instruction in the application program with the FHIDEN bit in the SCC register equal to "0" and the FSIDEN bit in the SCC register equal to "1". When this instruction is executed under the conditions described above, the following will occur:

- The f_H clock will be stopped and the application program will stop at the "HALT" instruction, but the f_{SUB} clock will be on.
- The Data Memory contents and registers will maintain their present condition.
- The I/O ports will maintain their present conditions.
- In the status register, the Power Down flag, PDF, will be set and the Watchdog time-out flag, TO, will be cleared.
- The WDT will be cleared and resume counting if the WDT function is enabled. If the WDT function is disabled, the WDT will be cleared and then stopped.

Entering the IDLE1 Mode

There is only one way for these devices to enter the IDLE1 Mode and that is to execute the "HALT" instruction in the application program with both the FHIDEN and FSIDEN bits in the SCC register equal to "1". When this instruction is executed under the conditions described above, the following will occur:

- The f_H and f_{SUB} clocks will be on but the application program will stop at the "HALT" instruction.
- The Data Memory contents and registers will maintain their present condition.
- The I/O ports will maintain their present conditions.
- In the status register, the Power Down flag, PDF, will be set and the Watchdog time-out flag, TO, will be cleared.
- The WDT will be cleared and resume counting if the WDT function is enabled. If the WDT function is disabled, the WDT will be cleared and then stopped.

Entering the IDLE2 Mode

There is only one way for these devices to enter the IDLE2 Mode and that is to execute the "HALT" instruction in the application program with the FHIDEN bit in the SCC register equal to "1" and the FSIDEN bit in the SCC register equal to "0". When this instruction is executed under the conditions described above, the following will occur:

- The f_H clock will be on but the f_{SUB} clock will be off and the application program will stop at the "HALT" instruction.
- The Data Memory contents and registers will maintain their present condition.
- The I/O ports will maintain their present conditions.
- In the status register, the Power Down flag, PDF, will be set and the Watchdog time-out flag, TO, will be cleared.
- The WDT will be cleared and resume counting if the WDT function is enabled. If the WDT function is disabled, the WDT will be cleared and then stopped.

Standby Current Considerations

As the main reason for entering the SLEEP or IDLE Mode is to keep the current consumption of these devices to as low a value as possible, perhaps only in the order of several micro-amps except in the IDLE1 and IDLE2 Mode, there are other considerations which must also be taken into account by the circuit designer if the power consumption is to be minimised. Special attention must be made to the I/O pins on these devices. All high-impedance input pins must be connected to either a fixed high or low level as any floating input pins could create internal oscillations and result in increased current consumption. This also applies to these devices which has different package types, as there may be unbonded pins. These must either be setup as outputs or if setup as inputs must have pull-high resistors connected.

Care must also be taken with the loads, which are connected to I/O pins, which are setup as outputs. These should be placed in a condition in which minimum current is drawn or connected only to external circuits that do not draw current, such as other CMOS inputs. Also note that additional standby current will also be required if the LXT or LIRC oscillator has enabled.

In the IDLE1 and IDLE2 Mode the high speed oscillator is on, if the peripheral function clock source is derived from the high speed oscillator, the additional standby current will also be perhaps in the order of several hundred micro-amps.

Wake-up

To minimise power consumption these devices can enter the SLEEP or any IDLE Mode, where the CPU will be switched off. However, when these devices are woken up again, it will take a considerable time for the original system oscillator to restart, stabilise and allow normal operation to resume.

After the system enters the SLEEP or IDLE Mode, it can be woken up from one of various sources listed as follows:

- An external falling edge on Port A
- A system interrupt
- A WDT overflow

When these devices execute the “HALT” instruction, it will enter the Power down mode and the PDF flag will be set to 1. The PDF flag will be cleared to 0 if these devices experience a system power-up or execute the clear Watchdog Timer instruction. If the system is woken up by a WDT overflow, a Watchdog Timer reset will be initiated and the TO flag will be set to 1. The TO flag is set if a WDT time-out occurs and causes a wake-up that only resets the Program Counter and Stack Pointer, other flags remain in their original status.

Each pin on Port A can be setup using the PAWU register to permit a negative transition on the pin to wake-up the system. When a pin wake-up occurs, the program will resume execution at the instruction following the “HALT” instruction. If the system is woken up by an interrupt, then two possible situations may occur. The first is where the related interrupt is disabled or the interrupt is enabled but the stack is full, in which case the program will resume execution at the instruction following the “HALT” instruction. In this situation, the interrupt which woke-up these devices will not be immediately serviced, but will rather be serviced later when the related interrupt is finally enabled or when a stack level becomes free. The other situation is where the related interrupt is enabled and the stack is not full, in which case the regular interrupt response takes place. If an interrupt request flag is set high before entering the SLEEP or IDLE Mode, the wake-up function of the related interrupt will be disabled.

Watchdog Timer

The Watchdog Timer is provided to prevent program malfunctions or sequences from jumping to unknown locations, due to certain uncontrollable external events such as electrical noise.

Watchdog Timer Clock Source

The Watchdog Timer clock source is provided by the internal clock, f_{LIRC} which is sourced from the LIRC oscillator. The LIRC internal oscillator has an approximate frequency of 32kHz and this specified internal clock period can vary with V_{DD}, temperature and process variations. The Watchdog Timer source clock is then subdivided by a ratio of 2^8 to 2^{18} to give longer timeouts, the actual value being chosen using the WS2~WS0 bits in the WDTC register.

Watchdog Timer Control Register

A single register, WDTC, controls the required time-out period as well as the enable/disable and reset MCU operation.

WDTC Register

Bit	7	6	5	4	3	2	1	0
Name	WE4	WE3	WE2	WE1	WE0	WS2	WS1	WS0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	1	0	1	0	0	1	1

Bit 7~3 **WE4~WE0**: WDT function software control
10101: Disable
01010: Enable
Other values: Reset MCU
When these bits are changed to any other values due to environmental noise the microcontroller will be reset; this reset operation will be activated after a delay time, t_{SRESET}, and the WRF bit in the RSTFC register will be set high.

Bit 2~0 **WS2~WS0**: WDT time-out period selection
000: $2^8/f_{LIRC}$
001: $2^{10}/f_{LIRC}$
010: $2^{12}/f_{LIRC}$
011: $2^{14}/f_{LIRC}$
100: $2^{15}/f_{LIRC}$
101: $2^{16}/f_{LIRC}$
110: $2^{17}/f_{LIRC}$
111: $2^{18}/f_{LIRC}$
These three bits determine the division ratio of the Watchdog Timer source clock, which in turn determines the timeout period.

RSTFC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	RSTF	LVRF	LRF	WRF
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	x	0	0

"x": unknown

Bit 7~4 Unimplemented, read as "0"

Bit 3 **RSTF**: Reset control register software reset flag
Describe elsewhere.

Bit 2 **LVRF**: LVR function reset flag
Described elsewhere.

Bit 1 **LRF**: LVR control register software reset flag
Described elsewhere.

Bit 0 **WRF**: WDT control register software reset flag
0: Not occurred
1: Occurred
This bit is set to 1 by the WDT Control register software reset and cleared by the application program. Note that this bit can only be cleared to 0 by the application program.

Watchdog Timer Operation

The Watchdog Timer operates by providing a device reset when its timer overflows. This means that in the application program and during normal operation the user has to strategically clear the Watchdog Timer before it overflows to prevent the Watchdog Timer from executing a reset. This is done using the clear watchdog instructions. If the program malfunctions for whatever reason, jumps to an unknown location, or enters an endless loop, these clear instructions will not be executed in the correct manner, in which case the Watchdog Timer will overflow and reset these devices. There are five bits, WE4~WE0, in the WDTC register to offer the enable/disable control and reset control of the Watchdog Timer. The WDT function will be disabled when the WE4~WE0 bits are set to a value of 10101B while the WDT function will be enabled if the WE4~WE0 bits are equal to 01010B. If the WE4~WE0 bits are set to any other values, other than 01010B and 10101B, it will reset these devices after a delay time, t_{SRESET}. After power on these bits will have a value of 01010B.

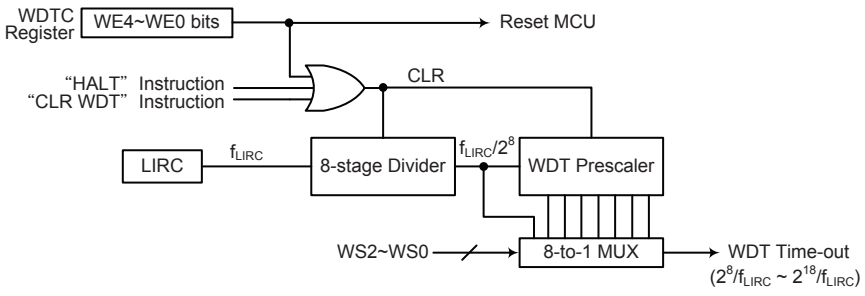
WE4~WE0 Bits	WDT Function
10101B	Disable
01010B	Enable
Any other value	Reset MCU

Watchdog Timer Enable/Disable Control

Under normal program operation, a Watchdog Timer time-out will initialise a device reset and set the status bit TO. However, if the system is in the SLEEP or IDLE Mode, when a Watchdog Timer time-out occurs, the TO bit in the status register will be set and only the Program Counter and Stack Pointer will be reset. Three methods can be adopted to clear the contents of the Watchdog Timer. The first is a WDT reset, which means a certain value except 01010B and 10101B written into the WE4~WE0 bits, the second is using the Watchdog Timer software clear instruction, the third is via a HALT instruction.

There is only one method of using software instruction to clear the Watchdog Timer. That is to use the single "CLR WDT" instruction to clear the WDT.

The maximum time-out period is when the 2^{18} division ratio is selected. As an example, with a 32kHz LIRC oscillator as its source clock, this will give a maximum watchdog period of around 8 second for the 2^{18} division ratio, and a minimum timeout of 7.8ms for the 2^8 division ration.



Watchdog Timer

Reset and Initialisation

A reset function is a fundamental part of any microcontroller ensuring that these devices can be set to some predetermined condition irrespective of outside parameters. The most important reset condition is after power is first applied to the microcontroller. In this case, internal circuitry will ensure that the microcontroller, after a short delay, will be in a well-defined state and ready to execute the first program instruction. After this power-on reset, certain important internal registers will be set to defined states before the program commences. One of these registers is the Program Counter, which will be reset to zero forcing the microcontroller to begin program execution from the lowest Program Memory address.

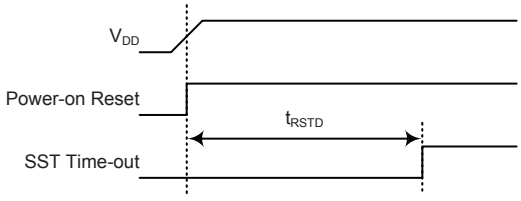
In addition to the power-on reset, another reset exists in the form of a Low Voltage Reset, LVR, where a full reset is implemented in situations where the power supply voltage falls below a certain threshold. Another type of reset is when the Watchdog Timer overflows and resets the microcontroller. All types of reset operations result in different register conditions being setup.

Reset Functions

There are several ways in which a microcontroller reset can occur, through events occurring both internally.

Power-on Reset

The most fundamental and unavoidable reset is the one that occurs after power is first applied to the microcontroller. As well as ensuring that the Program Memory begins execution from the first memory address, a power-on reset also ensures that certain other registers are preset to known conditions. All the I/O port and port control registers will power up in a high condition ensuring that all pins will be first set to inputs.



Power-on Reset Timing Chart

Internal Reset Control

There is an internal reset control register, RSTC, which is used to provide a reset when these devices operate abnormally due to the environmental noise interference. If the content of the RSTC register is set to any value other than 01010101B or 10101010B, it will reset these devices after a delay time, t_{SRESET}. After power on the register will have a value of 01010101B.

RSTC7~RSTC0 Bits	Reset Function
01010101B	No operation
10101010B	No operation
Any other value	Reset MCU

Internal Reset Function Control

- **RSTC Register**

Bit	7	6	5	4	3	2	1	0
Name	RSTC7	RSTC6	RSTC5	RSTC4	RSTC3	RSTC2	RSTC1	RSTC0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	1	0	1	0	1	0	1

Bit 7~0 **RSTC7~RSTC0**: Reset function control
01010101: No operation
10101010: No operation
Other values: Reset MCU
If these bits are changed due to adverse environmental conditions, the microcontroller will be reset. The reset operation will be activated after a delay time, t_{SRESET}, and the RSTF bit in the RSTFC register will be set to 1.

- **RSTFC Register**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	RSTF	LVRF	LRF	WRF
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	x	0	0

"x": unknown

Bit 7~4 Unimplemented, read as "0"

Bit 3 **RSTF**: Reset control register software reset flag
0: Not occurred
1: Occurred
This bit is set to 1 by the RSTC control register software reset and cleared by the application program. Note that this bit can only be cleared to 0 by the application program.

Bit 2 **LVRF**: LVR function reset flag
Described elsewhere.

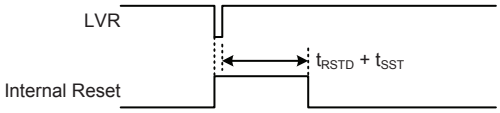
Bit 1 **LRF**: LVR control register software reset flag
Described elsewhere.

Bit 0 **WRF**: WDT control register software reset flag
Described elsewhere.

Low Voltage Reset – LVR

The microcontroller contains a low voltage reset circuit in order to monitor the supply voltage of these devices and provides an MCU reset should the value fall below a certain predefined level.

The LVR function is always enabled with a specific LVR voltage V_{LVR}. If the supply voltage of these devices drops to within a range of 0.9V~V_{LVR} such as might occur when changing the battery in battery powered applications, the LVR will automatically reset these devices internally and the LVRF bit in the RSTFC register will also be set to 1. For a valid LVR signal, a low supply voltage, i.e., a voltage in the range between 0.9V~V_{LVR} must exist for a time greater than that specified by t_{LVR} in the LVD & LVR Electrical Characteristics. If the low supply voltage state does not exceed this value, the LVR will ignore the low supply voltage and will not perform a reset function. The actual V_{LVR} value can be selected by the LVS bits in the LVRC register. If the LVS7~LVS0 bits are changed to some different values by environmental noise, the LVR will reset these devices after a delay time, t_{SRESET}. When this happens, the LRF bit in the RSTFC register will be set to 1. After power on the register will have the value of 01010101B. Note that the LVR function will be automatically disabled when these devices enter the power down mode.



Low Voltage Reset Timing Chart

- **LVRC Register**

Bit	7	6	5	4	3	2	1	0
Name	LVS7	LVS6	LVS5	LVS4	LVS3	LVS2	LVS1	LVS0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	1	0	1	0	1	0	1

Bit 7~0 **LVS7~LVS0**: LVR Voltage Select control
01010101: 2.10V
00110011: 2.55V
10011001: 3.15V
10101010: 3.80V
Any other value: Generates MCU reset – register is reset to POR value

When an actual low voltage condition occurs, as specified by one of the four defined LVR voltage values above, an MCU reset will be generated. The reset operation will be activated after the low voltage condition keeps more than a t_{LVR} time. In this situation the register contents will remain the same after such a reset occurs.

Any register value, other than the four defined LVR values above, will also result in the generation of an MCU reset. The reset operation will be activated after a delay time, t_{SRESET}. However in this situation the register contents will be reset to the POR value.

- **RSTFC Register**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	RSTF	LVRF	LRF	WRF
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	x	0	0

"x": unknown

Bit 7~4 Unimplemented, read as "0"

Bit 3 **RSTF**: Reset control register software reset flag
Describe elsewhere.

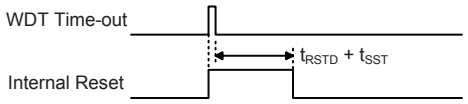
Bit 2 **LVRF**: LVR function reset flag
0: Not occur
1: Occurred
This bit is set to 1 when a specific Low Voltage Reset situation condition occurs. This bit can only be cleared to 0 by the application program.

Bit 1 **LRF**: LVR control register software reset flag
0: Not occur
1: Occurred
This bit is set to 1 if the LVRC register contains any non-defined LVR voltage register values. This in effect acts like a software-reset function. This bit can only be cleared to 0 by the application program.

Bit 0 **WRF**: WDT control register software reset flag
Describe elsewhere.

Watchdog Time-out Reset during Normal Operation

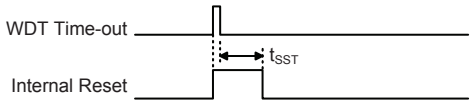
The Watchdog time-out Reset during normal operations in the FAST or SLOW mode is the same as a LVR reset except that the Watchdog time-out flag TO will be set to "1".



WDT Time-out Reset during Normal Operation Timing Chart

Watchdog Time-out Reset during SLEEP or IDLE Mode

The Watchdog time-out Reset during SLEEP or IDLE Mode is a little different from other kinds of reset. Most of the conditions remain unchanged except that the Program Counter and the Stack Pointer will be cleared to "0" and the TO flag will be set to "1". Refer to the System Start Up Time Characteristics for tSST details.



WDT Time-out Reset during SLEEP or IDLE Timing Chart

Reset Initial Conditions

The different types of reset described affect the reset flags in different ways. These flags, known as PDF and TO are located in the status register and are controlled by various microcontroller operations, such as the SLEEP or IDLE Mode function or Watchdog Timer. The reset flags are shown in the table:

TO	PDF	RESET Conditions
0	0	Power-on reset
u	u	LVR reset during FAST or SLOW Mode operation
1	u	WDT time-out reset during FAST or SLOW Mode operation
1	1	WDT time-out reset during IDLE or SLEEP Mode operation

"u" stands for unchanged

The following table indicates the way in which the various components of the microcontroller are affected after a power-on reset occurs.

Item	Condition After RESET
Program Counter	Reset to zero
Interrupts	All interrupts will be disabled
WDT, Time Base	Clear after reset, WDT begins counting
Timer Modules	Timer Modules will be turned off
Input/Output Ports	I/O ports will be setup as inputs
Stack Pointer	Stack Pointer will point to the top of the stack

The different kinds of resets all affect the internal registers of the microcontroller in different ways. To ensure reliable continuation of normal program execution after a reset occurs, it is important to know what condition the microcontroller is in after a particular reset occurs. The following table describes how each type of reset affects each of the microcontroller internal registers. Note that where more than one package type exists the table will reflect the situation for the larger package type.

Register	BH67F2260	BH67F2270	Power On Reset	LVR Reset (FAST)	LVR Reset (IDLE/SLEEP)	WDT Time-out (FAST)	WDT Time-out (IDLE/SLEEP)
IAR0	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
MP0	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
IAR1	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
MP1L	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
MP1H	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
ACC	●	●	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
PCL	●	●	0000 0000	0000 0000	0000 0000	0000 0000	0000 0000
TBLP	●	●	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
TBLH	●	●	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
TBHP	●	—	--xx xxxx	--uu uuuu	--uu uuuu	--uu uuuu	--uu uuuu
	—	●	-xxx xxxx	-uuu uuuu	-uuu uuuu	-uuu uuuu	-uuu uuuu
STATUS	●	●	xx00 xxxx	uuuu uuuu	uu01 uuuu	xx1u uuuu	uu11 uuuu
PBP	●	—	---- ---0	---- ---0	---- ---0	---- ---0	---- ---u
	—	●	---- --00	---- --00	---- --00	---- --00	---- --uu
IAR2	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
MP2L	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu

Register	BH67F2260	BH67F2270	Power On Reset	LVR Reset (FAST)	LVR Reset (IDLE/SLEEP)	WDT Time-out (FAST)	WDT Time-out (IDLE/SLEEP)
MP2H	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
RSTFC	•	•	---- 0x00	---- uuuu	---- uuuu	---- uuuu	---- uuuu
SCC	•	•	000- 0000	000- 0000	000- 0000	000- 0000	uuu- uuuu
HIRCC	•	•	---- 0001	---- 0001	---- 0001	---- 0001	---- uuuu
HXTC	•	•	---- -000	---- -000	---- -000	---- -000	---- -uuu
LXTC	•	•	---- --00	---- --00	---- --00	---- --00	---- --uu
PA	•	•	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PAC	•	•	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PAPU	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PAWU	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
RSTC	•	•	0101 0101	0101 0101	0101 0101	0101 0101	uuuu uuuu
LVRC	•	•	0101 0101	0101 0101	0101 0101	0101 0101	uuuu uuuu
LVDC	•	•	--00 0000	--00 0000	--00 0000	--00 0000	--uu uuuu
MFI0	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
MFI1	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
MFI2	•	•	--00 --00	--00 --00	--00 --00	--00 --00	--uu --uu
WDTC	•	•	0101 0011	0101 0011	0101 0011	0101 0011	uuuu uuuu
INTEG	•	•	---- 0000	---- 0000	---- 0000	---- 0000	---- uuuu
INTC0	•	•	-000 0000	-000 0000	-000 0000	-000 0000	-uuu uuuu
INTC1	•	•	1000 0000	1000 0000	1000 0000	1000 0000	uuuu uuuu
INTC2	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
INTC3	•	—	---0 ---0	---0 ---0	---0 ---0	---0 ---0	---u ---u
	—	•	--00 --00	--00 --00	--00 --00	--00 --00	--uu --uu
PB	•	•	---- 1111	---- 1111	---- 1111	---- 1111	---- uuuu
PBC	•	•	---- 1111	---- 1111	---- 1111	---- 1111	---- uuuu
PBPU	•	•	---- 0000	---- 0000	---- 0000	---- 0000	---- uuuu
PC	•	•	--11 1111	--11 1111	--11 1111	--11 1111	--uu uuuu
PCC	•	•	--11 1111	--11 1111	--11 1111	--11 1111	--uu uuuu
PCPU	•	•	--00 0000	--00 0000	--00 0000	--00 0000	--uu uuuu
PSCR	•	•	---- --00	---- --00	---- --00	---- --00	---- --uu
TB0C	•	•	0--- -000	0--- -000	0--- -000	0--- -000	u--- -uuu
TB1C	•	•	0--- -000	0--- -000	0--- -000	0--- -000	u--- -uuu
U0SR	•	•	0000 1011	0000 1011	0000 1011	0000 1011	uuuu uuuu
U0CR1	•	•	0000 00x0	0000 00x0	0000 00x0	0000 00x0	uuuu uuuu
U0CR2	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
TXR_RXR0	•	•	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
BRG0	•	•	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
SIMC0	•	•	111- 0000	111- 0000	111- 0000	111- 0000	uuu- uuuu
SIMC1	•	•	1000 0001	1000 0001	1000 0001	1000 0001	uuuu uuuu
SIMD	•	•	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
SIMA/SIMC2	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
SIMTOC	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
SPIAC0	•	•	111- --00	111- --00	111- --00	111- --00	uuu- --uu
SPIAC1	•	•	--00 0000	--00 0000	--00 0000	--00 0000	--uu uuuu
SPIAD	•	•	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu

Register	BH67F2260	BH67F2270	Power On Reset	LVR Reset (FAST)	LVR Reset (IDLE/SLEEP)	WDT Time-out (FAST)	WDT Time-out (IDLE/SLEEP)
EEA	•	•	--00 0000	--00 0000	--00 0000	--00 0000	--uu uuuu
EED	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
U1SR	—	•	0000 1011	0000 1011	0000 1011	0000 1011	uuuu uuuu
U1CR1	—	•	0000 00x0	0000 00x0	0000 00x0	0000 00x0	uuuu uuuu
U1CR2	—	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
TXR_RXR1	—	•	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
BRG1	—	•	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
STMC0	•	•	0000 0---	0000 0---	0000 0---	0000 0---	uuuu u---
STMC1	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
STMDL	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
STMDH	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
STMAL	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
STMAH	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
STMRP	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTM0C0	•	•	0000 0---	0000 0---	0000 0---	0000 0---	uuuu u---
PTM0C1	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTM0DL	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTM0DH	•	•	---- --00	---- --00	---- --00	---- --00	---- --uu
PTM0AL	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTM0AH	•	•	---- --00	---- --00	---- --00	---- --00	---- --uu
PTM0RPL	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTM0RPH	•	•	---- --00	---- --00	---- --00	---- --00	---- --uu
MDUWR0	•	•	xxxx xxxx	0000 0000	0000 0000	0000 0000	uuuu uuuu
MDUWR1	•	•	xxxx xxxx	0000 0000	0000 0000	0000 0000	uuuu uuuu
MDUWR2	•	•	xxxx xxxx	0000 0000	0000 0000	0000 0000	uuuu uuuu
MDUWR3	•	•	xxxx xxxx	0000 0000	0000 0000	0000 0000	uuuu uuuu
MDUWR4	•	•	xxxx xxxx	0000 0000	0000 0000	0000 0000	uuuu uuuu
MDUWR5	•	•	xxxx xxxx	0000 0000	0000 0000	0000 0000	uuuu uuuu
MDUWCTRL	•	•	00-- ----	00-- ----	00-- ----	00-- ----	uu-- ----
REGC	•	•	---- --00	---- --00	---- --00	---- --00	---- --uu
PGAC0	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PGAC1	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PGAC2	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PGAC3	•	•	00-0 0000	00-0 0000	00-0 0000	00-0 0000	uu-u uuuu
SCFC0	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
SCFC1	•	•	-000 00--	-000 00--	-000 00--	-000 00--	-uuu uu--
SCFCKD	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
CCVREFC	•	•	000- 0000	000- 0000	000- 0000	000- 0000	uuu- uuuu
SADOL	•	•	xxxx ----	xxxx ----	xxxx ----	xxxx ----	uuuu ---- (ADRFS=0& ADACCM=0) uuuu uuuu (ADRFS=1& ADACCM=0) or (ADACCM=1)

Register	BH67F2260	BH67F2270	Power On Reset	LVR Reset (FAST)	LVR Reset (IDLE/SLEEP)	WDT Time-out (FAST)	WDT Time-out (IDLE/SLEEP)
SADOH	•	•	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu (ADRFS=0& ADACCM=0) or (ADACCM=1) ---- uuuu (ADRFS=1& ADACCM=0)
SADC0	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
SADC1	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
LCDC0	•	•	0000 -000	0000 -000	0000 -000	0000 -000	uuuu -uuu
LCDCP	•	•	---- 0-00	---- 0-00	---- 0-00	---- 0-00	---- u-uu
LCDC2	•	•	000- -000	000- -000	000- -000	000- -000	uuu- -uuu
PD	•	•	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PDC	•	•	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PDPU	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PE	•	—	111- -111	111- -111	111- -111	111- -111	uuu- -uuu
	—	•	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PEC	•	—	111- -111	111- -111	111- -111	111- -111	uuu- -uuu
	—	•	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PEPU	•	—	000- -000	000- -000	000- -000	000- -000	uuu- -uuu
	—	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PF	—	•	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PFC	—	•	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PFPU	—	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PG	—	•	---- -111	---- -111	---- -111	---- -111	---- -uuu
PGC	—	•	---- -111	---- -111	---- -111	---- -111	---- -uuu
PGPU	—	•	---- -000	---- -000	---- -000	---- -000	---- -uuu
PTM1C0	•	•	0000 0---	0000 0---	0000 0---	0000 0---	uuuu u---
PTM1C1	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTM1DL	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTM1DH	•	•	---- --00	---- --00	---- --00	---- --00	---- --uu
PTM1AL	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTM1AH	•	•	---- --00	---- --00	---- --00	---- --00	---- --uu
PTM1RPL	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTM1RPH	•	•	---- --00	---- --00	---- --00	---- --00	---- --uu
PTM2C0	•	•	0000 0---	0000 0---	0000 0---	0000 0---	uuuu u---
PTM2C1	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTM2DL	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTM2DH	•	•	---- --00	---- --00	---- --00	---- --00	---- --uu
PTM2AL	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTM2AH	•	•	---- --00	---- --00	---- --00	---- --00	---- --uu
PTM2RPL	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PTM2RPH	•	•	---- --00	---- --00	---- --00	---- --00	---- --uu
EEC	•	•	---- 0000	---- 0000	---- 0000	---- 0000	---- uuuu
FC0	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
FC1	•	•	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu

Register	BH67F2260	BH67F2270	Power On Reset	LVR Reset (FAST)	LVR Reset (IDLE/SLEEP)	WDT Time-out (FAST)	WDT Time-out (IDLE/SLEEP)
FC2	●	●	---- ---0	---- ---0	---- ---0	---- ---0	---- ---u
FARL	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
FARH	●	—	--00 0000	--00 0000	--00 0000	--00 0000	--uu uuuu
	—	●	-000 0000	-000 0000	-000 0000	-000 0000	-uuu uuuu
FD0L	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
FD0H	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
FD1L	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
FD1H	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
FD2L	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
FD2H	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
FD3L	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
FD3H	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
IFS0	●	●	00-- 0--0	00-- 0--0	00-- 0--0	00-- 0--0	uu-- u--u
IFS1	●	—	-000 -0--	-000 -0--	-000 -0--	-000 -0--	-uuu -u--
	—	●	-000 ----	-000 ----	-000 ----	-000 ----	-uuu ----
PAS0	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PAS1	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PBS0	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PCS0	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PCS1	●	●	---- 0000	---- 0000	---- 0000	---- 0000	---- uuuu
PDS0	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PDS1	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PES0	●	—	--00 0000	--00 0000	--00 0000	--00 0000	--uu uuuu
	—	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PES1	●	—	0000 00--	0000 00--	0000 00--	0000 00--	uuuu uu--
	—	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PFS0	—	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PFS1	—	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PGS0	—	●	--00 0000	--00 0000	--00 0000	--00 0000	--uu uuuu
SLEDC0	●	●	--00 0000	--00 0000	--00 0000	--00 0000	--uu uuuu
SLEDC1	●	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
SLEDC2	●	—	---- 0000	---- 0000	---- 0000	---- 0000	---- uuuu
	—	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
SLEDC3	—	●	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu

Note: “u” stands for unchanged
“x” stands for unknown
“-” stands for unimplemented

Input/Output Ports

Holtek microcontrollers offer considerable flexibility on their I/O ports. With the input or output designation of every pin fully under user program control, pull-high selections for all ports and wake-up selections on certain pins, the user is provided with an I/O structure to meet the needs of a wide range of application possibilities.

These devices provide bidirectional input/output lines labeled with port names PA~PG. These I/O ports are mapped to the RAM Data Memory with specific addresses as shown in the Special Purpose Data Memory table. All of these I/O ports can be used for input and output operations. For input operation, these ports are non-latching, which means the inputs must be ready at the T2 rising edge of instruction "MOV A, [m]", where m denotes the port address. For output operation, all the data is latched and remains unchanged until the output latch is rewritten.

Register Name	Bit							
	7	6	5	4	3	2	1	0
PA	PA7	PA6	PA5	PA4	PA3	PA2	PA1	PA0
PAC	PAC7	PAC6	PAC5	PAC4	PAC3	PAC2	PAC1	PAC0
PAPU	PAPU7	PAPU6	PAPU5	PAPU4	PAPU3	PAPU2	PAPU1	PAPU0
PAWU	PAWU7	PAWU6	PAWU5	PAWU4	PAWU3	PAWU2	PAWU1	PAWU0
PB	—	—	—	—	PB3	PB2	PB1	PB0
PBC	—	—	—	—	PBC3	PBC2	PBC1	PBC0
PBPU	—	—	—	—	PBPU3	PBPU2	PBPU1	PBPU0
PC	—	—	PC5	PC4	PC3	PC2	PC1	PC0
PCC	—	—	PCC5	PCC4	PCC3	PCC2	PCC1	PCC0
PCPU	—	—	PCPU5	PCPU4	PCPU3	PCPU2	PCPU1	PCPU0
PD	PD7	PD6	PD5	PD4	PD3	PD2	PD1	PD0
PDC	PDC7	PDC6	PDC5	PDC4	PDC3	PDC2	PDC1	PDC0
PDPU	PDPU7	PDPU6	PDPU5	PDPU4	PDPU3	PDPU2	PDPU1	PDPU0
PE	PE7	PE6	PE5	—	—	PE2	PE1	PE0
PEC	PEC7	PEC6	PEC5	—	—	PEC2	PEC1	PEC0
PEPU	PEPU7	PEPU6	PEPU5	—	—	PEPU2	PEPU1	PEPU0

"—": Unimplemented, read as "0"

I/O Logic Function Registers List – BH67F2260

Register Name	Bit							
	7	6	5	4	3	2	1	0
PA	PA7	PA6	PA5	PA4	PA3	PA2	PA1	PA0
PAC	PAC7	PAC6	PAC5	PAC4	PAC3	PAC2	PAC1	PAC0
PAPU	PAPU7	PAPU6	PAPU5	PAPU4	PAPU3	PAPU2	PAPU1	PAPU0
PAWU	PAWU7	PAWU6	PAWU5	PAWU4	PAWU3	PAWU2	PAWU1	PAWU0
PB	—	—	—	—	PB3	PB2	PB1	PB0
PBC	—	—	—	—	PBC3	PBC2	PBC1	PBC0
PBPU	—	—	—	—	PBPU3	PBPU2	PBPU1	PBPU0
PC	—	—	PC5	PC4	PC3	PC2	PC1	PC0
PCC	—	—	PCC5	PCC4	PCC3	PCC2	PCC1	PCC0
PCPU	—	—	PCPU5	PCPU4	PCPU3	PCPU2	PCPU1	PCPU0
PD	PD	PD7	PD6	PD5	PD4	PD3	PD2	PD1
PDC	PDC	PDC7	PDC6	PDC5	PDC4	PDC3	PDC2	PDC1
PDPU	PDPU	PDPU7	PDPU6	PDPU5	PDPU4	PDPU3	PDPU2	PDPU1
PE	PE7	PE6	PE5	PE4	PE3	PE2	PE1	PE0
PEC	PEC7	PEC6	PEC5	PEC4	PEC3	PEC2	PEC1	PEC0
PEPU	PEPU7	PEPU6	PEPU5	PEPU4	PEPU3	PEPU2	PEPU1	PEPU0
PF	PF7	PF6	PF5	PF4	PF3	PF2	PF1	PF0
PFC	PFC7	PFC6	PFC5	PFC4	PFC3	PFC2	PFC1	PFC0
PFPU	PFPU7	PFPU6	PFPU5	PFPU4	PFPU3	PFPU2	PFPU1	PFPU0
PG	—	—	—	—	—	PG2	PG1	PG0
PGC	—	—	—	—	—	PGC2	PGC1	PGC0
PGPU	—	—	—	—	—	PGPU2	PGPU1	PGPU0

"—": Unimplemented, read as "0"

I/O Logic Function Registers List – BH67F2270

Pull-high Resistors

Many product applications require pull-high resistors for their switch inputs usually requiring the use of an external resistor. To eliminate the need for these external resistors, all I/O pins, when configured as an input have the capability of being connected to an internal pull-high resistor. These pull-high resistors are selected using registers, namely PAPU~PGPU, and are implemented using weak PMOS transistors.

Note that the pull-high resistor can be controlled by the relevant pull-high control register only when the pin-shared functional pin is selected as an input or NMOS output. Otherwise, the pull-high resistors cannot be enabled.

PxPU Register

Bit	7	6	5	4	3	2	1	0
Name	PAWU7	PAWU6	PAWU5	PAWU4	PAWU3	PAWU2	PAWU1	PAWU0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

PxPUn: I/O Port x Pin pull-high function control

0: Disable

1: Enable

The PxPUn bit is used to control the pin pull-high function. Here the "x"can be A, B, C, D, E, F and G. However, the actual available bits for each I/O Port may be different.

Port A Wake-up

The HALT instruction forces the microcontroller into the SLEEP or IDLE Mode which preserves power, a feature that is important for battery and other low-power applications. Various methods exist to wake-up the microcontroller, one of which is to change the logic condition on one of the Port A pins from high to low. This function is especially suitable for applications that can be woken up via external switches. Each pin on Port A can be selected individually to have this wake-up feature using the PAWU register.

Note that the wake-up function can be controlled by the wake-up control registers only when the pin-shared functional pin is selected as general purpose input/output and the MCU enters the Power down mode.

PAWU Register

Bit	7	6	5	4	3	2	1	0
Name	PAWU7	PAWU6	PAWU5	PAWU4	PAWU3	PAWU2	PAWU1	PAWU0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **PAWU7~PAWU0**: PA7~PA0 wake-up function control
0: Disable
1: Enable

I/O Port Control Registers

Each I/O port has its own control register known as PAC~PGC, to control the input/output configuration. With this control register, each CMOS output or input can be reconfigured dynamically under software control. Each pin of the I/O ports is directly mapped to a bit in its associated port control register. For the I/O pin to function as an input, the corresponding bit of the control register must be written as a "1". This will then allow the logic state of the input pin to be directly read by instructions. When the corresponding bit of the control register is written as a "0", the I/O pin will be setup as a CMOS output. If the pin is currently setup as an output, instructions can still be used to read the output register. However, it should be noted that the program will in fact only read the status of the output data latch and not the actual logic status of the output pin.

PxC Register

Bit	7	6	5	4	3	2	1	0
Name	PxC7	PxC6	PxC5	PxC4	PxC3	PxC2	PxC1	PxC0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	1	1	1	1	1	1	1	1

PxCn: I/O Port x Pin type selection
0: Output
1: Input
The PxCn bit is used to control the pin type selection. Here the "x" can be A, B, C, D, E, F and G. However, the actual available bits for each I/O Port may be different.

Source Current Selection

The source current of each pin in these devices can be configured with different source current which is selected by the corresponding pin source current select bits. These source current bits are available when the corresponding pin is configured as a CMOS output. Otherwise, these select bits have no effect. Users should refer to the Input/Output Characteristics section to obtain the exact value for different applications.

Register Name	Bit							
	7	6	5	4	3	2	1	0
SLEDC0	—	—	SLEDC05	SLEDC04	SLEDC03	SLEDC02	SLEDC01	SLEDC00
SLEDC1	SLEDC17	SLEDC16	SLEDC15	SLEDC14	SLEDC13	SLEDC12	SLEDC11	SLEDC10
SLEDC2	—	—	—	—	SLEDC23	SLEDC22	SLEDC21	SLEDC20

I/O Port Source Current Selection Registers List – BH67F2260

Register name	Bit							
	7	6	5	4	3	2	1	0
SLEDC0	—	—	SLEDC05	SLEDC04	SLEDC03	SLEDC02	SLEDC01	SLEDC00
SLEDC1	SLEDC17	SLEDC16	SLEDC15	SLEDC14	SLEDC13	SLEDC12	SLEDC11	SLEDC10
SLEDC2	SLEDC27	SLEDC26	SLEDC25	SLEDC24	SLEDC23	SLEDC22	SLEDC21	SLEDC20
SLEDC3	—	—	—	—	—	—	SLEDC31	SLEDC30

I/O Port Source Current Selection Registers List– BH67F2270

SLEDC0 Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	SLEDC05	SLEDC04	SLEDC03	SLEDC02	SLEDC01	SLEDC00
R/W	—	—	R/W	R/W	R/W	R/W	R/W	R/W
POR	—	—	0	0	0	0	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5~4 **SLEDC05~SLEDC04**: PB3~PB0 source current selection
00: Source current=Level 0 (Min.)
01: Source current=Level 1
10: Source current=Level 2
11: Source current=Level 3 (Max.)

Bit 3~2 **SLEDC03~SLEDC02**: PA7~PA4 source current selection
00: Source current=Level 0 (Min.)
01: Source current=Level 1
10: Source current=Level 2
11: Source current=Level 3 (Max.)

Bit 1~0 **SLEDC01~SLEDC00**: PA3~PA0 source current selection
00: Source current=Level 0 (Min.)
01: Source current=Level 1
10: Source current=Level 2
11: Source current=Level 3 (Max.)

SLEDC1 Register

Bit	7	6	5	4	3	2	1	0
Name	SLEDC17	SLEDC16	SLEDC15	SLEDC14	SLEDC13	SLEDC12	SLEDC11	SLEDC10
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **SLEDC17~SLEDC16**: PD7~PD5 source current selection
00: Source current=Level 0 (Min.)
01: Source current=Level 1
10: Source current=Level 2
11: Source current=Level 3 (Max.)

Bit 5~4 **SLEDC15~SLEDC14**: PD3~PD0 source current selection
00: Source current=Level 0 (Min.)
01: Source current=Level 1

10: Source current=Level 2
11: Source current=Level 3 (Max.)

Bit 3~2 **SLEDC13~SLEDC12**: PC5 and PC4 source current selection
00: Source current=Level 0 (Min.)
01: Source current=Level 1
10: Source current=Level 2
11: Source current=Level 3 (Max.)

Bit 1~0 **SLEDC11~SLEDC10**: PC3~PC0 source current selection
00: Source current=Level 0 (Min.)
01: Source current=Level 1
10: Source current=Level 2
11: Source current=Level 3 (Max.)

SLEDC2 Register – BH67F2260

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	SLEDC23	SLEDC22	SLEDC21	SLEDC20
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	0	0	0

Bit 7~4 Unimplemented, read as "0"

Bit 3~2 **SLEDC23~SLEDC22**: PE7~PE5 source current selection
00: Source current=Level 0 (Min.)
01: Source current=Level 1
10: Source current=Level 2
11: Source current=Level 3 (Max.)

Bit 1~0 **SLEDC21~SLEDC20**: PE2~PE0 source current selection
00: Source current=Level 0 (Min.)
01: Source current=Level 1
10: Source current=Level 2
11: Source current=Level 3 (Max.)

SLEDC2 Register – BH67F2270

Bit	7	6	5	4	3	2	1	0
Name	SLEDC27	SLEDC26	SLEDC25	SLEDC24	SLEDC23	SLEDC22	SLEDC21	SLEDC20
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **SLEDC27~ SLEDC26**: PF7~PF4 source current selection
00: Source current = Level 0 (Min.)
01: Source current = Level 1
10: Source current = Level 2
11: Source current = Level 3 (Max.)

Bit 5~4 **SLEDC25~ SLEDC24**: PF3~PF0 source current selection
00: Source current = Level 0 (Min.)
01: Source current = Level 1
10: Source current = Level 2
11: Source current = Level 3 (Max.)

Bit 3~2 **SLEDC23~ SLEDC22**: PE7~PE4 source current selectio
00: Source current = Level 0 (Min.)
01: Source current = Level 1
10: Source current = Level 2
11: Source current = Level 3 (Max.)

Bit 1~0 **SLEDC21~ SLEDC20**: PE~PE0 source current selection
00: Source current = Level 0 (Min.)
01: Source current = Level 1
10: Source current = Level 2
11: Source current = Level 3 (Max.)

SLEDC3 Register – BH67F2270

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	SLEDC31	SLEDC30
R/W	—	—	—	—	—	—	R/W	R/W
POR	—	—	—	—	—	—	0	0

Bit 7~2 Unimplemented, read as "0"

Bit 1~0 **SLEDC31~ SLEDC30**: PG2~PG0 source current selection
00: Source current = Level 0 (Min.)
01: Source current = Level 1
10: Source current = Level 2
11: Source current = Level 3 (Max.)

Pin-shared Functions

The flexibility of the microcontroller range is greatly enhanced by the use of pins that have more than one function. Limited numbers of pins can force serious design constraints on designers but by supplying pins with multi-functions, many of these difficulties can be overcome. For these pins, the desired function of the multi-function I/O pins is selected by a series of registers via the application program control.

Pin-shared Function Selection Registers

The limited number of supplied pins in a package can impose restrictions on the amount of functions a certain device can contain. However by allowing the same pins to share several different functions and providing a means of function selection, a wide range of different functions can be incorporated into even relatively small package sizes. these devices include Port "x" Output Function Selection register "n", labeled as PxSn, and Input Function Selection register "i", labeled as IFSi, which can select the desired functions of the multi-function pin-shared pins.

The most important point to note is to make sure that the desired pin-shared function is properly selected and also deselected. For most pin-shared functions, to select the desired pin-shared function, the pin-shared function should first be correctly selected using the corresponding pin-shared control register. After that the corresponding peripheral functional setting should be configured and then the peripheral function can be enabled. However, a special point must be noted for some digital input pins, such as INTn, xTCKn, xTPnI, etc, which share the same pin-shared control configuration with their corresponding general purpose I/O functions when setting the relevant pin-shared control bit fields. To select these pin functions, in addition to the necessary pin-shared control and peripheral functional setup aforementioned, they must also be setup as an input by setting the corresponding bit in the I/O port control register. To correctly deselect the pin-shared function, the peripheral function should first be disabled and then the corresponding pin-shared function control register can be modified to select other pin-shared functions.

Register Name	Bit							
	7	6	5	4	3	2	1	0
PAS0	PAS07	PAS06	PAS05	PAS04	PAS03	PAS02	PAS01	PAS00
PAS1	PAS17	PAS16	PAS15	PAS14	PAS13	PAS12	PAS11	PAS10
PBS0	PBS07	PBS06	PBS05	PBS04	PBS03	PBS02	PBS01	PBS00
PCS0	PCS07	PCS06	PCS05	PCS04	PCS03	PCS02	PCS01	PCS00
PCS1	—	—	—	—	PCS13	PCS12	PCS11	PCS10
PDS0	PDS07	PDS06	PDS05	PDS04	PDS03	PDS02	PDS01	PDS00
PDS1	PDS17	PDS16	PDS15	PDS14	PDS13	PDS12	PDS11	PDS10
PES0	—	—	PES05	PES04	PES03	PES02	PES01	PES00
PES1	PES17	PES16	PES15	PES14	PES13	PES12	—	—
IFS0	PTP2IPS	PTP1IPS	—	—	PTCK2PS	—	—	STCKPS
IFS1	—	SCSABPS	SDIAPS	SCKAPS	—	RXPS	—	—

Pin-shared Function Selection Registers List – BH67F2260

Register Name	Bit							
	7	6	5	4	3	2	1	0
PAS0	PAS07	PAS06	PAS05	PAS04	PAS03	PAS02	PAS01	PAS00
PAS1	PAS17	PAS16	PAS15	PAS14	PAS13	PAS12	PAS11	PAS10
PBS0	PBS07	PBS06	PBS05	PBS04	PBS03	PBS02	PBS01	PBS00
PCS0	PCS07	PCS06	PCS05	PCS04	PCS03	PCS02	PCS01	PCS00
PCS1	—	—	—	—	PCS13	PCS12	PCS11	PCS10
PDS0	PDS07	PDS06	PDS05	PDS04	PDS03	PDS02	PDS01	PDS00
PDS1	PDS17	PDS16	PDS15	PDS14	PDS13	PDS12	PDS11	PDS10
PES0	PES07	PES06	PES05	PES04	PES03	PES02	PES01	PES00
PES1	PES17	PES16	PES15	PES14	PES13	PES12	PES11	PES10
PFS0	PFS07	PFS06	PFS05	PFS04	PFS03	PFS02	PFS01	PFS00
PFS1	PFS17	PFS16	PFS15	PFS14	PFS13	PFS12	PFS11	PFS10
PGS0	—	—	PGS05	PGS04	PGS03	PGS02	PGS01	PGS00
IFS0	PTP2IPS	PTP1IPS	—	—	PTCK2PS	—	—	STCKPS
IFS1	—	SCSABPS	SDIAPS	SCKAPS	—	—	—	—

Pin-shared Function Selection Registers List – BH67F2270

- **PAS0 Register – BH67F2260**

Bit	7	6	5	4	3	2	1	0
Name	PAS07	PAS06	PAS05	PAS04	PAS03	PAS02	PAS01	PAS00
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PAS07~PAS06**: PA3 Pin-Shared function selection
00: PA3/PTP1I
01: PTP1
10: SDOA
11: OSC2

Bit 5~4 **PAS05~PAS04**: PA2 Pin-Shared function selection
00/01/10: PA2/PTCK0
11: XT2

Bit 3~2 **PAS03~PAS02**: PA1 Pin-Shared function selection
00: PA1/INT0/STCK
01: SEG28
10: LVDIN
11: PTP0B

Bit 1~0 **PAS01~PAS00**: PA0 Pin-Shared function selection
00/01: PA0/PTP0I
10: PTP0
11: XT1

- **PAS0 Register – BH67F2270**

Bit	7	6	5	4	3	2	1	0
Name	PAS07	PAS06	PAS05	PAS04	PAS03	PAS02	PAS01	PAS00
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PAS07~PAS06**: PA3 Pin-Shared function selection
00: PA3/PTP1I
01: PTP1
10: SDOA
11: OSC2

Bit 5~4 **PAS05~PAS04**: PA2 Pin-Shared function selection
00/01/10: PA2/PTCK0
11: XT2

Bit 3~2 **PAS03~PAS02**: PA1 Pin-Shared function selection
00: PA1/INT0/STCK
01: SEG42
10: LVDIN
11: PTP0B

Bit 1~0 **PAS01~PAS00**: PA0 Pin-Shared function selection
00/01: PA0/PTP0I
10: PTP0
11: XT1

- **PAS1 Register – BH67F2260**

Bit	7	6	5	4	3	2	1	0
Name	PAS17	PAS16	PAS15	PAS14	PAS13	PAS12	PAS11	PAS10
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PAS17~PAS16**: PA7 Pin-Shared function selection
00/01: PA7/PTCK2
10: SEG27
11: SDI/SDA

Bit 5~4 **PAS15~PAS14**: PA6 Pin-Shared function selection
00: PA6/STCK
01: SDIA
10: STP
11: RX0

Bit 3~2 **PAS13~PAS12**: PA5 Pin-Shared function selection
00: PA5/STPI
01: STP
10: SCKA
11: TX0

Bit 1~0 **PAS11~PAS10**: PA4 Pin-Shared function selection
00: PA4/PTP2I
01: PTP2
10: $\overline{\text{SCSA}}$
11: OSC1

- **PAS1 Register – BH67F2270**

Bit	7	6	5	4	3	2	1	0
Name	PAS17	PAS16	PAS15	PAS14	PAS13	PAS12	PAS11	PAS10
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PAS17~PAS16**: PA7 Pin-Shared function selection
00/01: PA7/PTCK2
10: SEG41
11: SDI/SDA

Bit 5~4 **PAS15~PAS14**: PA6 Pin-Shared function selection
00: PA6/STCK
01: SDIA
10: STP
11: RX0

Bit 3~2 **PAS13~PAS12**: PA5 Pin-Shared function selection
00: PA5/STPI
01: STP
10: SCKA
11: TX0

Bit 1~0 **PAS11~PAS10**: PA4 Pin-Shared function selection
00: PA4/PTP2I
01: PTP2
10: $\overline{\text{SCSA}}$
11: OSC1

- **PBS0 Register – BH67F2260**

Bit	7	6	5	4	3	2	1	0
Name	PBS07	PBS06	PBS05	PBS04	PBS03	PBS02	PBS01	PBS00
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PBS07~PBS06**: PB3 Pin-Shared function selection
00: PB3
01: SEG23
10: SDIA
11: SDO

Bit 5~4 **PBS05~PBS04**: PB2 Pin-Shared function selection
00: PB2
01: SEG24
10: $\overline{\text{SCS}}$
11: SCKA

Bit 3~2 **PBS03~PBS02**: PB1 Pin-Shared function selection
00/01: PB1/INT1
10: STPB
11: SEG25

Bit 1~0 **PBS01~PBS00**: PB0 Pin-Shared function selection
00/01: PB0
10: SCK/SCL
11: SEG26

- **PBS0 Register – BH67F2270**

Bit	7	6	5	4	3	2	1	0
Name	PBS07	PBS06	PBS05	PBS04	PBS03	PBS02	PBS01	PBS00
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PBS07~PBS06**: PB3 Pin-Shared Function selection
00: PB3
01: SEG37
10: SDIA
11: SDO

Bit 5~4 **PBS05~PBS04**: PB2 Pin-Shared Function selection
00: PB2
01: SEG38
10: $\overline{SCS}$
11: SCKA

Bit 3~2 **PBS03~PBS02**: PB1 Pin-Shared Function selection
00/01: PB1/INT1
10: STPB
11: SEG39

Bit 1~0 **PBS01~PBS00**: PB0 Pin-Shared Function selection
00/01: PB0
10: SCK/SCL
11: SEG40

- **PCS0 Register**

Bit	7	6	5	4	3	2	1	0
Name	PCS07	PCS06	PCS05	PCS04	PCS03	PCS02	PCS01	PCS00
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PCS07~PCS06**: PC3 Pin-Shared function selection
00/01/10: PC3/PTCK2
11:AN1

Bit 5~4 **PCS05~PCS04**: PC2 Pin-Shared function selection
00: PC2/PTP2I
01: PTP2
10: VREF
11: AN0

Bit 3~2 **PCS03~PCS02**: PC1 Pin-Shared function selection
00/01/10: PC1/PTCK1
11: AN3

Bit 1~0 **PCS01~PCS00**: PC0 Pin-Shared function selection
00/01: PC0/PTP1I
10: PTP1
11: AN2

- **PCS1 Register – BH67F2260**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	PCS13	PCS12	PCS11	PCS10
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	0	0	0

Bit 7~4 Unimplemented, read as "0"

Bit 3~2 **PCS13~PCS12**: PC5 Pin-Shared function selection
00/01: PC5
10: TX0
11: SDOA

Bit 1~0 **PCS11~PCS10**: PC4 Pin-Shared function selection
00/01: PC4
10: $\overline{\text{RX0}}$
11: $\overline{\text{SCSA}}$

- **PCS1 Register – BH67F2270**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	PCS13	PCS12	PCS11	PCS10
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	0	0	0

Bit 7~4 Unimplemented, read as "0"

Bit 3~2 **PCS13~PCS12**: PC5 Pin-Shared Function selection
00/01: PC5
10: TX1
11: SDOA

Bit 1~0 **PCS11~PCS10**: PC4 Pin-Shared Function selection
00/01: PC4
10: RX1
11: $\overline{\text{SCSA}}$

- **PDS0 Register**

Bit	7	6	5	4	3	2	1	0
Name	PDS07	PDS05	PDS04	PDS03	PDS02	PDS02	PDS01	PDS00
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PDS07~PDS06**: PD3 Pin-Shared function selection
00/01: PD3
10: SEG3
11: COM7

Bit 5~4 **PDS05~PDS04**: PD2 Pin-Shared function selection
00/01: PD2
10: SEG2
11: COM6

Bit 3~2 **PDS03~PDS02**: PD1 Pin-Shared function selection
00/01: PD1
10: SEG1
11: COM5

Bit 1~0 **PDS01~PDS00**: PD0 Pin-Shared function selection
00/01: PD0
10: SEG0
11: COM4

- **PDS1 Register – BH67F2260**

Bit	7	6	5	4	3	2	1	0
Name	PDS17	PDS16	PDS15	PDS14	PDS13	PDS12	PDS11	PDS10
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PDS17~PDS16**: PD7 Pin-Shared function selection
00/01/10: PD7
11: SEG19

Bit 5~4 **PDS15~PDS14**: PD6 Pin-Shared function selection
00/01/10: PD6
11: SEG18

Bit 3~2 **PDS13~PDS12**: PD5 Pin-Shared function selection
00/01/10: PD5
11: SEG17

Bit 1~0 **PDS11~PDS10**: PD4 Pin-Shared function selection
00/01/10: PD4
11: SEG16

- **PDS1 Register – BH67F2270**

Bit	7	6	5	4	3	2	1	0
Name	PDS17	PDS16	PDS15	PDS14	PDS13	PDS12	PDS11	PDS10
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PDS17~PDS16**: PD7 Pin-Shared Function selection
00/01/10: PD7
11: SEG36

Bit 5~4 **PDS15~PDS14**: PD6 Pin-Shared Function selection
00/01/10: PD6
11: SEG35

Bit 3~2 **PDS13~PDS12**: PD5 Pin-Shared Function selection
00/01/10: PD5
11: SEG34

Bit 1~0 **PDS11~PDS10**: PD4 Pin-Shared Function selection
00/01/10: PD4
11: SEG33

- **PES0 Register – BH67F2260**

Bit	7	6	5	4	3	2	1	0
Name	—	—	PES05	PES04	PES03	PES02	PES01	PES00
R/W	—	—	R/W	R/W	R/W	R/W	R/W	R/W
POR	—	—	0	0	0	0	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5~4 **PES05~PES04**: PE2 Pin-Shared function selection
00/01/10: PE2
11: SEG22

Bit 3~2 **PES03~PES02**: PE1 Pin-Shared function selection
00/01/10: PE1
11: SEG21

Bit 1~0 **PES01~PES00**: PE0 Pin-Shared function selection
00/01/10: PE0
11: SEG20

- **PES0 Register – BH67F2270**

Bit	7	6	5	4	3	2	1	0
Name	PES07	PES06	PES05	PES04	PES03	PES02	PES01	PES00
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PES07~PES06**: PE3 Pin-Shared Function selection
00/01/10: PE3
11: SEG28

Bit 5~4 **PCS05~PCS04**: PE2 Pin-Shared Function selection
00/01/10: PE2
11: SEG27

Bit 3~2 **PCS03~PCS02**: PE1 Pin-Shared Function selection
00/01/10: PE1
11: SEG26

Bit 1~0 **PCS01~PCS00**: PE0 Pin-Shared Function selection
00/01/10: PE0
11: SEG25

- **PES1 Register – BH67F2260**

Bit	7	6	5	4	3	2	1	0
Name	PES17	PES16	PES15	PES14	PES13	PES12	—	—
R/W	R/W	R/W	R/W	R/W	R/W	R/W	—	—
POR	0	0	0	0	0	0	—	—

Bit 7~6 **PES17~PES16**: PE7 Pin-Shared function selection
00/01: PE7
10: V2
11: SEG31

Bit 5~4 **PES15~PES14**: PE6 Pin-Shared function selection
00/01: PE6
10: C2
11: SEG30

Bit 3~2 **PES13~PES12**: PE5 Pin-Shared function selection
00/01: PE5
10: C1
11: SEG29

Bit 1~0 Unimplemented, read as "0"

- **PES1 Register – BH67F2270**

Bit	7	6	5	4	3	2	1	0
Name	PES17	PES16	PES15	PES14	PES13	PES12	PES11	PES10
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PES17~PES16**: PE7 Pin-Shared Function selection
00/01/10: PE7
11: SEG32

Bit 5~4 **PES15~PES14**: PE6 Pin-Shared Function selection
00/01/10: PE6
11: SEG31

Bit 3~2 **PES13~PES12**: PE5 Pin-Shared Function selection
00/01/10: PE5
11: SEG30

Bit 1~0 **PES11~PES10**: PE4 Pin-Shared Function selection
00/01/10: PE4
11: SEG29

- **PFS0 Register – BH67F2270**

Bit	7	6	5	4	3	2	1	0
Name	PFS07	PFS06	PFS05	PFS04	PFS03	PFS02	PFS01	PFS00
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PFS07~PFS06**: PF3 Pin-Shared Function selection
00/01/10: PF3
11: SEG20

Bit 5~4 **PFS05~PFS04**: PF2 Pin-Shared Function selection
00/01/10: PF2
11: SEG19

Bit 3~2 **PFS03~PFS02**: PF1 Pin-Shared Function selection
00/01/10: PF1
11: SEG18

Bit 1~0 **PFS01~PFS00**: PF0 Pin-Shared Function selection
00/01/10: PF0
11: SEG17

- **PFS1 Register – BH67F2270**

Bit	7	6	5	4	3	2	1	0
Name	PFS17	PFS16	PFS15	PFS14	PFS13	PFS12	PFS11	PFS10
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PFS17~PFS16**: PF7 Pin-Shared Function selection
00/01/10: PF7
11: SEG24

Bit 5~4 **PFS15~PFS14**: PF6 Pin-Shared Function selection
00/01/10: PF6
11: SEG23

Bit 3~2 **PFS13~PFS12**: PF5 Pin-Shared Function selection
00/01/10: PF5
11: SEG22

Bit 1~0 **PFS11~PFS10**: PF4 Pin-Shared Function selection
00/01/10: PF4
11: SEG21

- **PGS0 Register – BH67F2270**

Bit	7	6	5	4	3	2	1	0
Name	—	—	PGS05	PGS04	PGS03	PGS02	PGS01	PGS00
R/W	—	—	R/W	R/W	R/W	R/W	R/W	R/W
POR	—	—	0	0	0	0	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5~4 **PGS05~PGS04**: PG2 Pin-Shared Function selection
00/01: PG2
10: V2
11: SEG45

Bit 3~2 **PGS03~PGS02**: PG1 Pin-Shared Function selection
00/01: PG1
10: C2
11: SEG44

Bit 1~0 **PGS01~PGS00**: PG0 Pin-Shared Function selection
00/01: PG0
10: C1
11: SEG43

- **IFS0 Register**

Bit	7	6	5	4	3	2	1	0
Name	PTP2IPS	PTP1IPS	—	—	PTCK2PS	—	—	STCKPS
R/W	R/W	R/W	—	—	R/W	—	—	R/W
POR	0	0	—	—	0	—	—	0

Bit 7 **PTP2IPS**: PTP2I input source pin selection
0: PA4
1: PC2

Bit 6 **PTP1IPS**: PTP1I input source pin selection
0: PA3
1: PC0

Bit 5~4 Unimplemented, read as "0"

Bit 3 **PTCK2PS**: PTCK2 input source pin selection
0: PC3
1: PA7

Bit 2~1 Unimplemented, read as "0"

Bit 0 **STCKPS**: STCK input source pin selection
0: PA1
1: PA6

- **IFS1 Register – BH67F2260**

Bit	7	6	5	4	3	2	1	0
Name	—	SCSABPS	SDIAPS	SCKAPS	—	RXPS	—	—
R/W	—	R/W	R/W	R/W	—	R/W	—	—
POR	—	0	0	0	—	0	—	—

Bit 7 Unimplemented, read as "0"

Bit 6 **SCSABPS**: $\overline{\text{SCSA}}$ input source pin selection
0: PA4
1: PC4

Bit 5 **SDIAPS**: SDIA input source pin selection
0: PA6
1: PB3

Bit 4 **SCKAPS**: SCKA input source pin selection
0: PA5
1: PB2

Bit 3 Unimplemented, read as "0"

Bit 2 **RXPS**: UART0 RX input source pin selection
0: PA6
1: PC4

Bit 1~0 Unimplemented, read as "0"

- **IFS1 Register – BH67F2270**

Bit	7	6	5	4	3	2	1	0
Name	—	SCSABPS	SDIAPS	SCKAPS	—	—	—	—
R/W	—	R/W	R/W	R/W	—	—	—	—
POR	—	0	0	0	—	—	—	—

Bit 7 Unimplemented, read as "0"

Bit 6 **SCSABPS**: $\overline{\text{SCSA}}$ input source pin selection
0: PA4
1: PC4

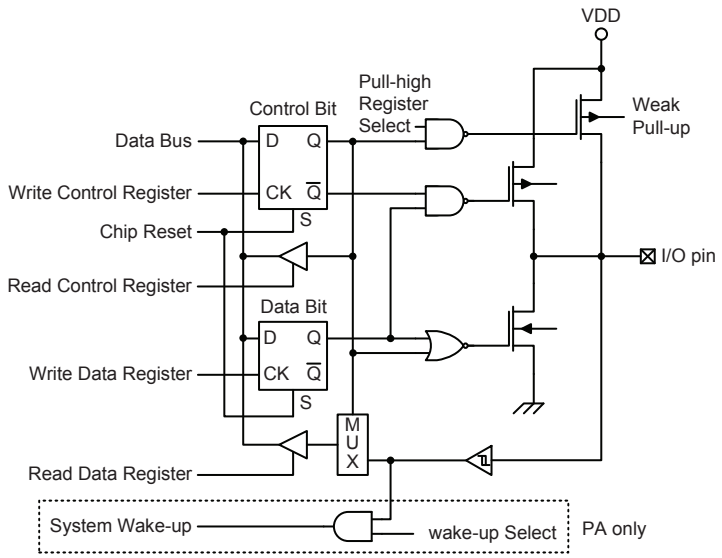
Bit 5 **SDIAPS**: SDIA input source pin selection
0: PA6
1: PB3

Bit 4 **SCKAPS**: SCKA input source pin selection
0: PA5
1: PC4

Bit 3~0 Unimplemented, read as "0"

I/O Pin Structures

The accompanying diagram illustrates the internal structure of the I/O logic function. As the exact logical construction of the I/O pin will differ from this drawing, it is supplied as a guide only to assist with the functional understanding of the I/O logic function. The wide range of pin-shared structures does not permit all types to be shown.



Logic Function Input/Output Structure

Programming Considerations

Within the user program, one of the first things to consider is port initialisation. After a reset, all of the I/O data and port control registers will be set high. This means that all I/O pins will default to an input state, the level of which depends on the other connected circuitry and whether pull-high selections have been chosen. If the port control registers are then programmed to setup some pins as outputs, these output pins will have an initial high output value unless the associated port data registers are first programmed. Selecting which pins are inputs and which are outputs can be achieved byte-wide by loading the correct values into the appropriate port control register or by programming individual bits in the port control register using the "SET [m].i" and "CLR [m].i" instructions. Note that when using these bit control instructions, a read-modify-write operation takes place. The microcontroller must first read in the data on the entire port, modify it to the required new bit values and then rewrite this data back to the output ports.

Port A has the additional capability of providing wake-up function. When these devices are in the SLEEP or IDLE Mode, various methods are available to wake these devices up. One of these is a high to low transition of any of the Port A pins. Single or multiple pins on Port A can be setup to have this function.

Timer Modules – TM

One of the most fundamental functions in any microcontroller these devices is the ability to control and measure time. To implement time related functions each device includes several Timer Modules, abbreviated to the name TM. The TMs are multi-purpose timing units and serve to provide operations such as Timer/Counter, Input Capture, Compare Match Output and Single Pulse Output as well as being the functional unit for the generation of PWM signals. Each of the TMs has two individual interrupts. The addition of input and output pins for each TM ensures that users are provided with timing units with a wide and flexible range of features.

The common features of the different TM types are described here with more detailed information provided in the individual Standard and Periodic TM sections.

Introduction

These devices contain up to four TMs and each individual TM can be categorised as a certain type, namely Standard Type TM or Periodic Type TM. Although similar in nature, the different TM types vary in their feature complexity. The common features to all of the Standard and Periodic TMs will be described in this section. The detailed operation regarding each of the TM types will be described in separate sections. The main features and differences between the two types of TMs are summarised in the accompanying table.

Function	STM	PTM
Timer/Counter	√	√
Input Capture	√	√
Compare Match Output	√	√
PWM Channels	1	1
Single Pulse Output	1	1
PWM Alignment	Edge	Edge
PWM Adjustment Period & Duty	Duty or Period	Duty or Period

TM Function Summary

STM	PTM0	PTM1	PTM2
16-bit STM	10-bit PTM	10-bit PTM	10-bit PTM

TM Name/Type Reference

TM Operation

The different types of TM offer a diverse range of functions, from simple timing operations to PWM signal generation. The key to understanding how the TM operates is to see it in terms of a free running counter whose value is then compared with the value of pre-programmed internal comparators. When the free running counter has the same value as the pre-programmed comparator, known as a compare match situation, a TM interrupt signal will be generated which can clear the counter and perhaps also change the condition of the TM output pin. The internal TM counter is driven by a user selectable clock source, which can be an internal clock or an external pin.

TM Clock Source

The clock source which drives the main counter in each TM can originate from various sources. The selection of the required clock source is implemented using the xTnCK2~xTnCK0 bits in the xTM control registers, where "x" stands for S or P type TM and "n" stands for the specific TM serial number. For the STM there is no serial number "n" in the relevant pins, registers and control bits since there is only one STM in these devices. The clock source can be a ratio of the system clock f_{SYS} or the internal high clock f_H, the f_{SUB} clock source or the external xTCKn pin. The xTCKn pin clock source is used to allow an external signal to drive the TM as an external clock source or for event counting.

TM Interrupts

The Standard and Periodic type TMs each have two internal interrupts, one for each of the internal comparator A or comparator P, which generate a TM interrupt when a compare match condition occurs. When a TM interrupt is generated it can be used to clear the counter and also to change the state of the TM output pin.

TM External Pins

Each of the TMs, irrespective of what type, has two TM input pins, with the label xTCKn and xTPnI respectively. The xTMn input pin, xTCKn, is essentially a clock source for the xTMn and is selected using the xTnCK2~xTnCK0 bits in the xTMnC0 register. This external TM input pin allows an external clock source to drive the internal TM. The xTCKn input pin can be chosen to have either a rising or falling active edge. The xTCKn pin is also used as the external trigger input pin in single pulse output mode.

The other xTMn input pin, xTPnI, is the capture input whose active edge can be a rising edge, a falling edge or both rising and falling edges and the active edge transition type is selected using the xTnIO1~xTnIO0 bits in the xTMnC1 register. There is another capture input, PTCKn, for PTMn capture input mode, which can be used as the external trigger input source except the PTPnI pin.

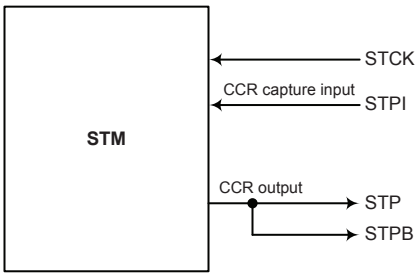
The TMs each have one output pin with the label xTPn while some TMs have an additionl output pin with the lebel xTPnB. When the TM is in the Compare Match Output Mode, these pins can be controlled by the TM to switch to a high or low level or to toggle when a compare match situation occurs. The external xTPn and xTPnB output pins are also the pins where the TM generates the PWM output waveform. As the TM input and output pins are pin-shared with other functions, the TM input and output functions must first be setup using the relevant pin-shared function selection bits described in the Pin-shared Function section.

STM		PTM0		PTM1		PTM2	
Input	Output	Input	Output	Input	Output	Input	Output
STCK, STPI	STP, STPB	PTCK0, PTP0I	PTP0, PTP0B	PTCK1, PTP1I	PTP1	PTCK2, PTP2I	PTP2

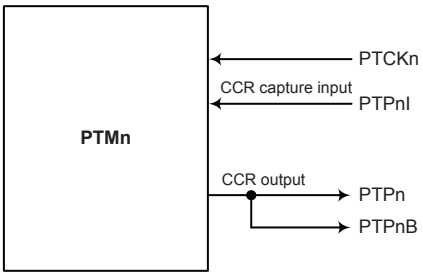
TM External Pins

TM Input/Output Pin Selection

Selecting to have a TM input/output or whether to retain its other shared function is implemented using the relevant pin-shared function selection registers, with the corresponding selection bits in each pin-shared function register corresponding to a TM input/output pin. Configuring the selection bits correctly will setup the corresponding pin as a TM input/output. The details of the pin-shared function selection are described in the pin-shared function section.



STM Function Pin Control Block Diagram



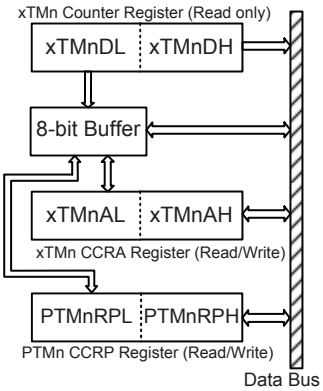
Note: Only the PTM0 has the inverted output pin PTP0B.

PTM Function Pin Control Block Diagram (n=0~2)

Programming Considerations

The TM Counter Registers and the Capture/Compare CCRA and CCRP registers, all have a low and high byte structure. The high bytes can be directly accessed, but as the low bytes can only be accessed via an internal 8-bit buffer, reading or writing to these register pairs must be carried out in a specific way. The important point to note is that data transfer to and from the 8-bit buffer and its related low byte only takes place when a write or read operation to its corresponding high byte is executed.

As the CCRA and CCRP registers are implemented in the way shown in the following diagram and accessing these register pairs is carried out in a specific way as described above, it is recommended to use the "MOV" instruction to access the CCRA and CCRP low byte registers, named xTMnAL and PTMnRPL, using the following access procedures. Accessing the CCRA or CCRP low byte registers without following these access procedures will result in unpredictable values.

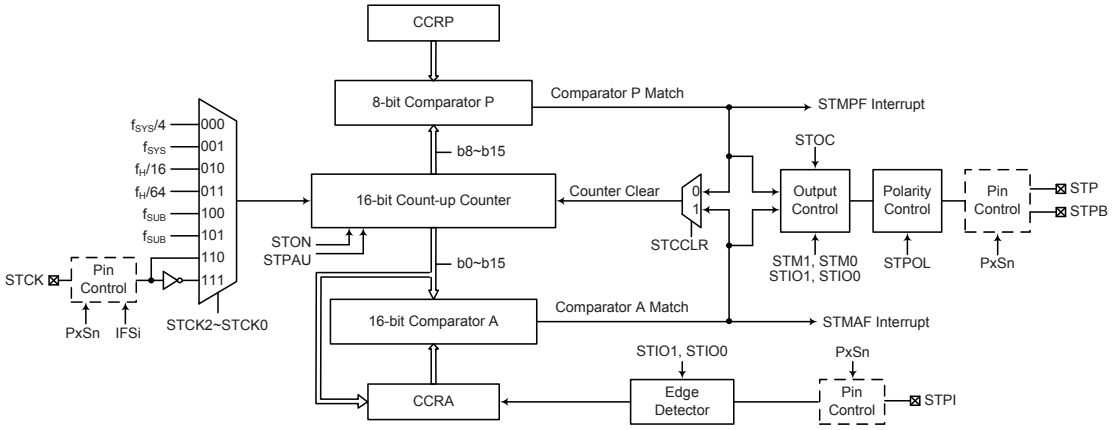


The following steps show the read and write procedures:

- Writing Data to CCRA or CCRP
  - Step 1. Write data to Low Byte xTMnAL or PTMnRPL
    - Note that here data is only written to the 8-bit buffer.
  - Step 2. Write data to High Byte xTMnAH or PTMnRPH
    - Here data is written directly to the high byte registers and simultaneously data is latched from the 8-bit buffer to the Low Byte registers.
- Reading Data from the Counter Registers, CCRA or CCRP
  - Step 1. Read data from the High Byte xTMnDH, xTMnAH or PTMnRPH
    - Here data is read directly from the High Byte registers and simultaneously data is latched from the Low Byte register into the 8-bit buffer.
  - Step 2. Read data from the Low Byte xTMnDL, xTMnAL or PTMnRPL
    - This step reads data from the 8-bit buffer.

Standard Type TM – STM

The Standard Type TM contains five operating modes, which are Compare Match Output, Timer/ Event Counter, Capture Input, Single Pulse Output and PWM Output modes. The Standard TM can also be controlled with two external input pins and can drive two external output pins.



Note: The STPB is the inverted output of the STP.

Standard Type TM Block Diagram

Standard TM Operation

The size of Standard TM is 16-bit wide and its core is a 16-bit count-up counter which is driven by a user selectable internal or external clock source. There are also two internal comparators with the names, Comparator A and Comparator P. These comparators will compare the value in the counter with CCRP and CCRA registers. The CCRP comparator is 8-bit wide whose value is compared the with highest 8 bits in the counter while the CCRA is the sixteen bits and therefore compares all counter bits.

The only way of changing the value of the 16-bit counter using the application program, is to clear the counter by changing the STON bit from low to high. The counter will also be cleared automatically by a counter overflow or a compare match with one of its associated comparators. When these conditions occur, a STM interrupt signal will also usually be generated. The Standard Type TM can operate in a number of different operational modes, can be driven by different clock sources including an input pin and can also control an output pin. All operating setup conditions are selected using relevant internal registers.

Standard Type TM Register Description

Overall operation of the Standard TM is controlled using a series of registers. A read only register pair exists to store the internal counter 16-bit value, while a read/write register pair exists to store the internal 16-bit CCRA value. The STMRP register is used to store the 8-bit CCRP value. The remaining two registers are control registers which setup the different operating and control modes.

Register Name	Bit							
	7	6	5	4	3	2	1	0
STMC0	STPAU	STCK2	STCK1	STCK0	STON	—	—	—
STMC1	STM1	STM0	STIO1	STIO0	STOC	STPOL	STDPX	STCCLR
STMDL	D7	D6	D5	D4	D3	D2	D1	D0
STMDH	D15	D14	D13	D12	D11	D10	D9	D8
STMAL	D7	D6	D5	D4	D3	D2	D1	D0
STMAH	D15	D14	D13	D12	D11	D10	D9	D8
STMRP	D7	D6	D5	D4	D3	D2	D1	D0

16-bit Standard TM Registers List

STMC0 Register

Bit	7	6	5	4	3	2	1	0
Name	STPAU	STCK2	STCK1	STCK0	STON	—	—	—
R/W	R/W	R/W	R/W	R/W	R/W	—	—	—
POR	0	0	0	0	0	—	—	—

Bit 7 **STPAU**: STM Counter Pause control
0: Run
1: Pause

The counter can be paused by setting this bit high. Clearing the bit to zero restores normal counter operation. When in a Pause condition the STM will remain powered up and continue to consume power. The counter will retain its residual value when this bit changes from low to high and resume counting from this value when the bit changes to a low value again.

Bit 6~4 **STCK2~STCK0**: Select STM Counter clock
000: $f_{SYS}/4$
001: f_{SYS}
010: $f_H/16$
011: $f_H/64$
100: f_{SUB}
101: f_{SUB}
110: STCK rising edge clock
111: STCK falling edge clock

These three bits are used to select the clock source for the STM. The external pin clock source can be chosen to be active on the rising or falling edge. The clock source f_{SYS} is the system clock, while f_H and f_{SUB} are other internal clocks, the details of which can be found in the oscillator section.

Bit 3 **STON**: STM Counter On/Off control
0: Off
1: On

This bit controls the overall on/off function of the STM. Setting the bit high enables the counter to run while clearing the bit disables the STM. Clearing this bit to zero will stop the counter from counting and turn off the STM which will reduce its power consumption. When the bit changes state from low to high the internal counter value will be reset to zero, however when the bit changes from high to low, the internal counter will retain its residual value until the bit returns high again. If the STM is in the Compare Match Output Mode, PWM Output Mode or Single Pulse Output Mode then the STM output pin will be reset to its initial condition, as specified by the STOC bit, when the STON bit changes from low to high.

Bit 2~0 Unimplemented, read as “0”

STMC1 Register

Bit	7	6	5	4	3	2	1	0
Name	STM1	STM0	STIO1	STIO0	STOC	STPOL	STDPX	STCCLR
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **STM1~STM0**: Select STM Operating Mode
00: Compare Match Output Mode
01: Capture Input Mode
10: PWM Output Mode or Single Pulse Output Mode
11: Timer/Counter Mode

These bits setup the required operating mode for the STM. To ensure reliable operation the STM should be switched off before any changes are made to the STM1 and STM0 bits. In the Timer/Counter Mode, the STM output pin control will be disabled.

Bit 5~4 **STIO1~STIO0**: Select STM external pin (STP or STPI) function

Compare Match Output Mode
00: No change
01: Output low
10: Output high
11: Toggle output

PWM Output Mode/Single Pulse Output Mode
00: PWM output inactive state
01: PWM output active state
10: PWM output
11: Single Pulse Output

Capture Input Mode
00: Input capture at rising edge of STPI
01: Input capture at falling edge of STPI
10: Input capture at rising/falling edge of STPI
11: Input capture disabled

Timer/Counter Mode
Unused

These two bits are used to determine how the STM external pin changes state when a certain condition is reached. The function that these bits select depends upon in which mode the STM is running.

In the Compare Match Output Mode, the STIO1 and STIO0 bits determine how the STM output pin changes state when a compare match occurs from the Comparator A. The STM output pin can be setup to switch high, switch low or to toggle its present state when a compare match occurs from the Comparator A. When the bits are both zero, then no change will take place on the output. The initial value of the STM output pin should be setup using the STOC bit in the STMC1 register. Note that the output level requested by the STIO1 and STIO0 bits must be different from the initial value setup using the STOC bit otherwise no change will occur on the STM output pin when a compare match occurs. After the STM output pin changes state, it can be reset to its initial level by changing the level of the STON bit from low to high.

In the PWM Output Mode, the STIO1 and STIO0 bits determine how the STM output pin changes state when a certain compare match condition occurs. The PWM output function is modified by changing these two bits. It is necessary to only change the values of the STIO1 and STIO0 bits only after the STM has been switched off. Unpredictable PWM outputs will occur if the STIO1 and STIO0 bits are changed when the STM is running.

Bit 3 **STOC**: STM STP Output control

Compare Match Output Mode
0: Initial low
1: Initial high

PWM Output Mode/Single Pulse Output Mode
0: Active low
1: Active high

This is the output control bit for the STM output pin. Its operation depends upon whether STM is being used in the Compare Match Output Mode or in the PWM Output Mode/Single Pulse Output Mode. It has no effect if the STM is in the Timer/Counter Mode. In the Compare Match Output Mode it determines the logic level of the STM output pin before a compare match occurs. In the PWM Output Mode it determines if the PWM signal is active high or active low. In the Single Pulse Output Mode it determines the logic level of the STM output pin when the STON bit changes from low to high.

Bit 2 **STPOL**: STM STP Output polarity control
0: Non-inverted
1: Inverted

This bit controls the polarity of the STP output pin. When the bit is set high the STM output pin will be inverted and not inverted when the bit is zero. It has no effect if the STM is in the Timer/Counter Mode.

Bit 1 **STDPX**: STM PWM duty/period control
0: CCRP – period; CCRA – duty
1: CCRP – duty; CCRA – period

This bit determines which of the CCRA and CCRP registers are used for period and duty control of the PWM waveform.

Bit 0 **STCCLR**: STM Counter Clear condition selection
0: Comparator P match
1: Comparator A match

This bit is used to select the method which clears the counter. Remember that the Standard TM contains two comparators, Comparator A and Comparator P, either of which can be selected to clear the internal counter. With the STCCLR bit set high, the counter will be cleared when a compare match occurs from the Comparator A. When the bit is low, the counter will be cleared when a compare match occurs from the Comparator P or with a counter overflow. A counter overflow clearing method can only be implemented if the CCRP bits are all cleared to zero. The STCCLR bit is not used in the PWM Output Mode, Single Pulse Output Mode or Capture Input Mode.

STMDL Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R	R	R	R	R	R	R	R
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: STM Counter Low Byte Register bit 7~bit 0
STM 16-bit Counter bit 7~bit 0

STMDH Register

Bit	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R	R	R	R	R	R	R	R
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D15~D8**: STM Counter High Byte Register bit 7~bit 0
STM 16-bit Counter bit 15~bit 8

STMAL Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: STM CCRA Low Byte Register bit 7~bit 0
STM 16-bit CCRA bit 7~bit 0

STMAH Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D15~D8**: STM CCRA High Byte Register bit 7~bit 0
STM 16-bit CCRA bit 15~bit 8

STMRP Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: STM CCRP 8-bit register, compared with the STM counter bit 15~bit 8

Comparator P Match Period =
0: 65536 STM clocks
1~255: (1~255) × 256 STM clocks

These eight bits are used to setup the value on the internal CCRP 8-bit register, which are then compared with the internal counter's highest eight bits. The result of this comparison can be selected to clear the internal counter if the STCCLR bit is set to zero. Setting the STCCLR bit to zero ensures that a compare match with the CCRP values will reset the internal counter. As the CCRP bits are only compared with the highest eight counter bits, the compare values exist in 256 clock cycle multiples. Clearing all eight bits to zero is in effect allowing the counter to overflow at its maximum value.

Standard Type TM Operation Modes

The Standard Type TM can operate in one of five operating modes, Compare Match Output Mode, PWM Output Mode, Single Pulse Output Mode, Capture Input Mode or Timer/Counter Mode. The operating mode is selected using the STM1 and STM0 bits in the STMC1 register.

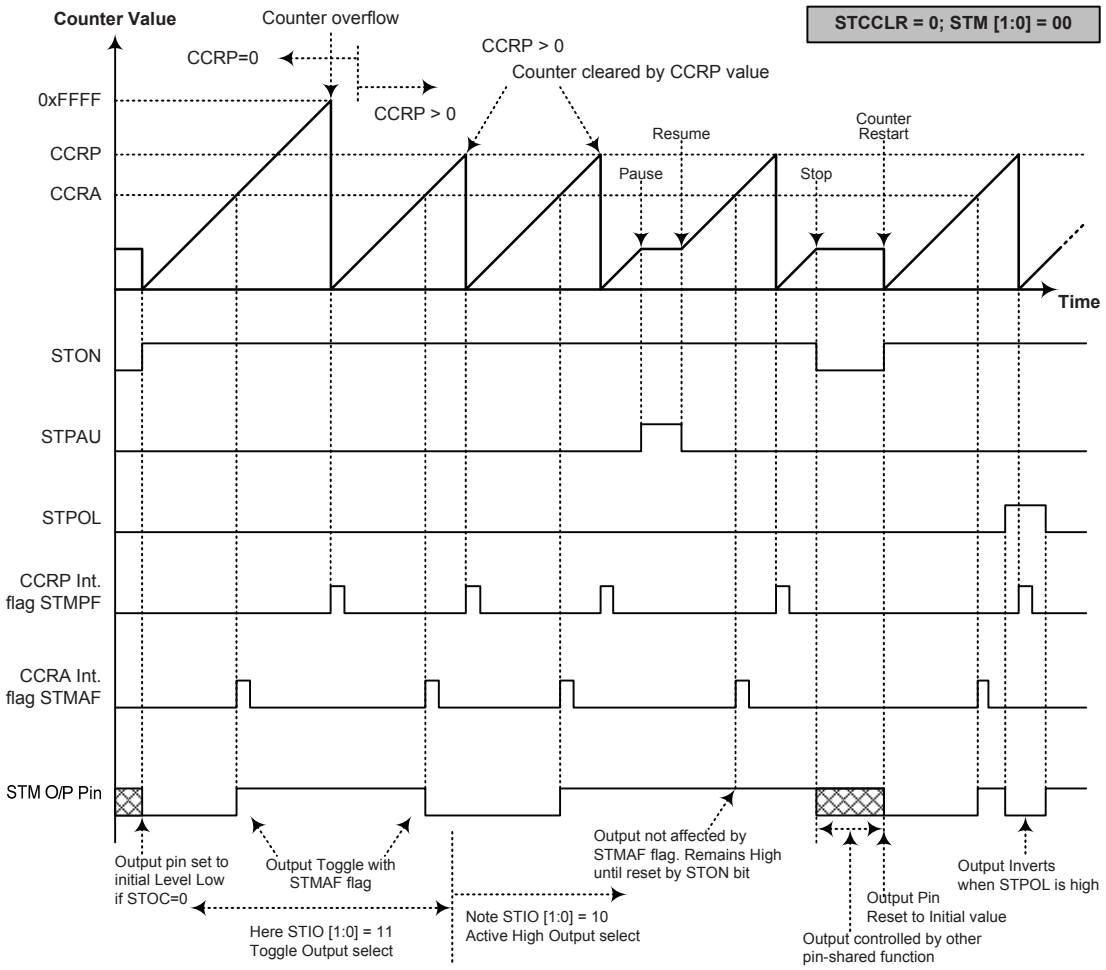
Compare Match Output Mode

To select this mode, bits STM1 and STM0 in the STMC1 register, should be set to 00 respectively. In this mode once the counter is enabled and running it can be cleared by three methods. These are a counter overflow, a compare match from Comparator A and a compare match from Comparator P. When the STCCLR bit is low, there are two ways in which the counter can be cleared. One is when a compare match from Comparator P, the other is when the CCRP bits are all zero which allows the counter to overflow. Here both STMAF and STMPF interrupt request flags for Comparator A and Comparator P respectively, will both be generated.

If the STCCLR bit in the STMC1 register is high then the counter will be cleared when a compare match occurs from Comparator A. However, here only the STMAF interrupt request flag will be generated even if the value of the CCRP bits is less than that of the CCRA registers. Therefore when STCCLR is high no STMPF interrupt request flag will be generated. In the Compare Match Output Mode, the CCRA can not be set to “0”.

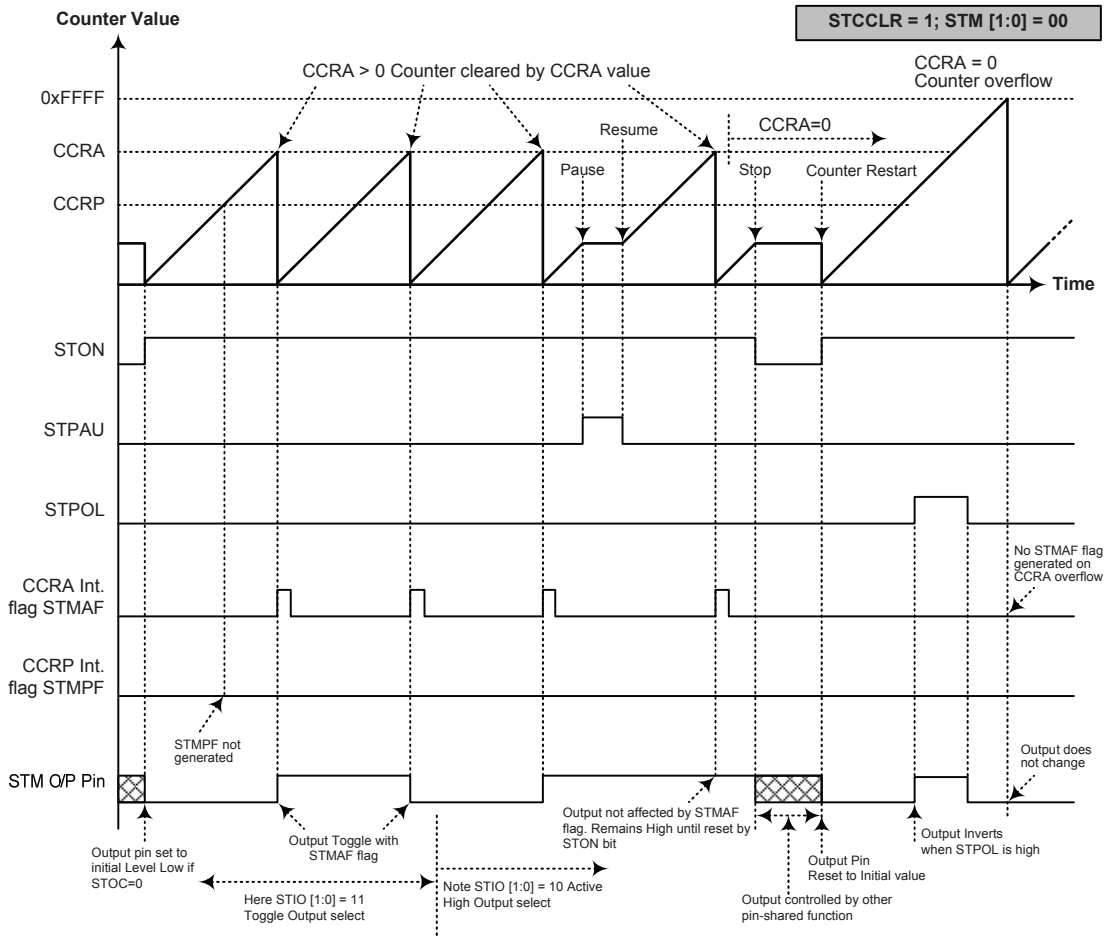
If the CCRA bits are all zero, the counter will overflow when its reaches its maximum 16-bit, FFFF Hex, value, however here the STMAF interrupt request flag will not be generated.

As the name of the mode suggests, after a comparison is made, the STM output pin, will change state. The STM output pin condition however only changes state when a STMAF interrupt request flag is generated after a compare match occurs from Comparator A. The STMPF interrupt request flag, generated from a compare match occurs from Comparator P, will have no effect on the STM output pin. The way in which the STM output pin changes state are determined by the condition of the STIO1 and STIO0 bits in the STMC1 register. The STM output pin can be selected using the STIO1 and STIO0 bits to go high, to go low or to toggle from its present condition when a compare match occurs from Comparator A. The initial condition of the STM output pin, which is setup after the STON bit changes from low to high, is setup using the STOC bit. Note that if the STIO1 and STIO0 bits are zero then no pin change will take place.



Compare Match Output Mode – STCCLR=0

Note: 1. With STCCLR=0 a Comparator P match will clear the counter
2. The STM output pin is controlled only by the STMAF flag
3. The output pin is reset to itsinitial state by a STON bit rising edge



Compare Match Output Mode – STCCLR=1

Note: 1. With STCCLR=1 a Comparator A match will clear the counter
2. The STM output pin is controlled only by the STMAF flag
3. The output pin is reset to its initial state by a STON bit rising edge
4. A STMPF flag is not generated when STCCLR=1

Timer/Counter Mode

To select this mode, bits STM1 and STM0 in the STMC1 register should be set to 11 respectively. The Timer/Counter Mode operates in an identical way to the Compare Match Output Mode generating the same interrupt flags. The exception is that in the Timer/Counter Mode the STM output pin is not used. Therefore the above description and Timing Diagrams for the Compare Match Output Mode can be used to understand its function. As the STM output pin is not used in this mode, the pin can be used as a normal I/O pin or other pin-shared function.

PWM Output Mode

To select this mode, bits STM1 and STM0 in the STMC1 register should be set to 10 respectively and also the STIO1 and STIO0 bits should be set to 10 respectively. The PWM function within the STM is useful for applications which require functions such as motor control, heating control, illumination control etc. By providing a signal of fixed frequency but of varying duty cycle on the STM output pin, a square wave AC waveform can be generated with varying equivalent DC RMS values.

As both the period and duty cycle of the PWM waveform can be controlled, the choice of generated waveform is extremely flexible. In the PWM output mode, the STCCLR bit has no effect as the PWM period. Both of the CCRA and CCRP registers are used to generate the PWM waveform, one register is used to clear the internal counter and thus control the PWM waveform frequency, while the other one is used to control the duty cycle. Which register is used to control either frequency or duty cycle is determined using the STDPX bit in the STMC1 register. The PWM waveform frequency and duty cycle can therefore be controlled by the values in the CCRA and CCRP registers.

An interrupt flag, one for each of the CCRA and CCRP, will be generated when a compare match occurs from either Comparator A or Comparator P. The STOC bit in the STMC1 register is used to select the required polarity of the PWM waveform while the two STIO1 and STIO0 bits are used to enable the PWM output or to force the STM output pin to a fixed high or low level. The STPOL bit is used to reverse the polarity of the PWM output waveform.

- **16-bit STM, PWM Output Mode, Edge-aligned Mode, STDPX=0**

CCRP	1~255	0
Period	CCRP×256	65536
Duty	CCRA	

If f_{SYS}=16MHz, STM clock source is $f_{SYS}/4$, CCRP=2 and CCRA=128,

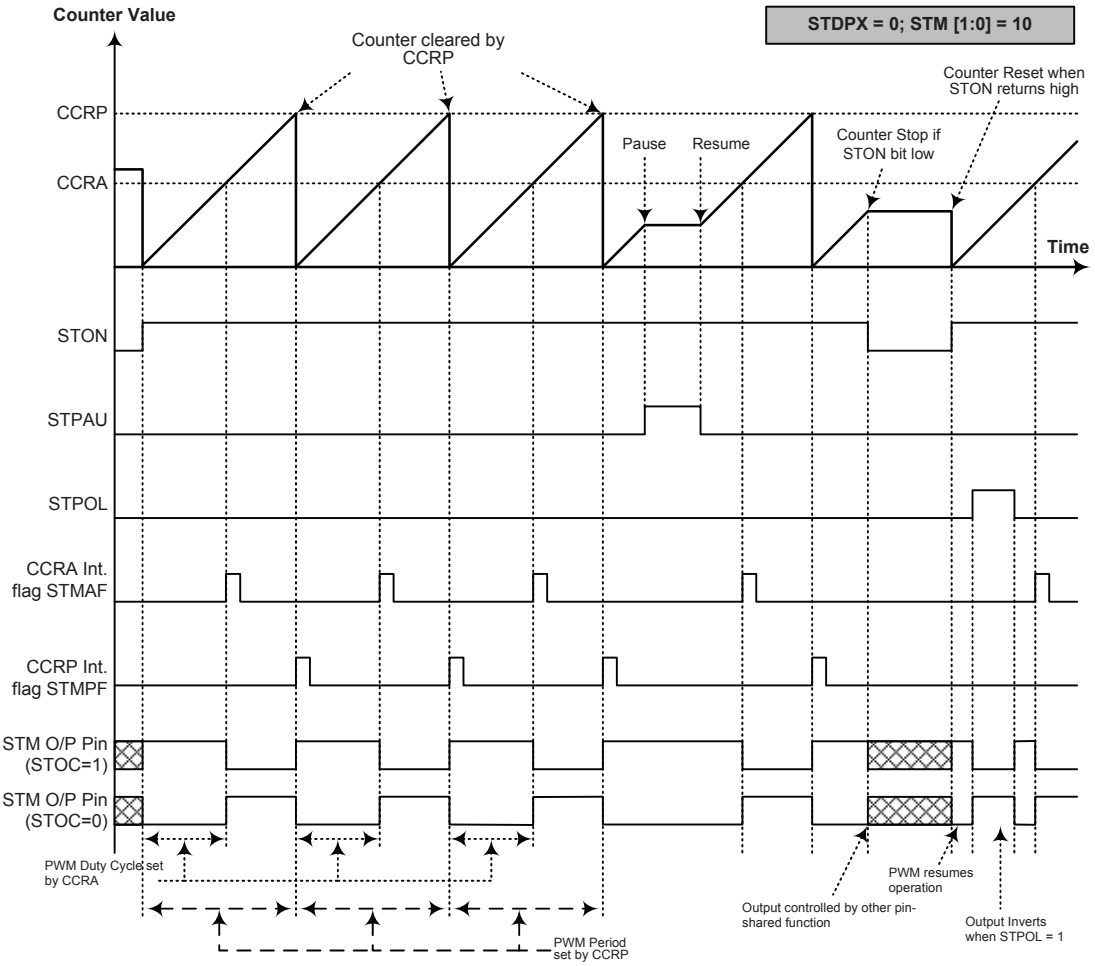
The STM PWM output frequency=$(f_{SYS}/4)/(2\times256)=f_{SYS}/2048$=7.8125kHz, duty=128/(2×256)=25%.

If the Duty value defined by the CCRA register is equal to or greater than the Period value, then the PWM output duty is 100%.

- **16-bit STM, PWM Output Mode, Edge-aligned Mode, STDPX=1**

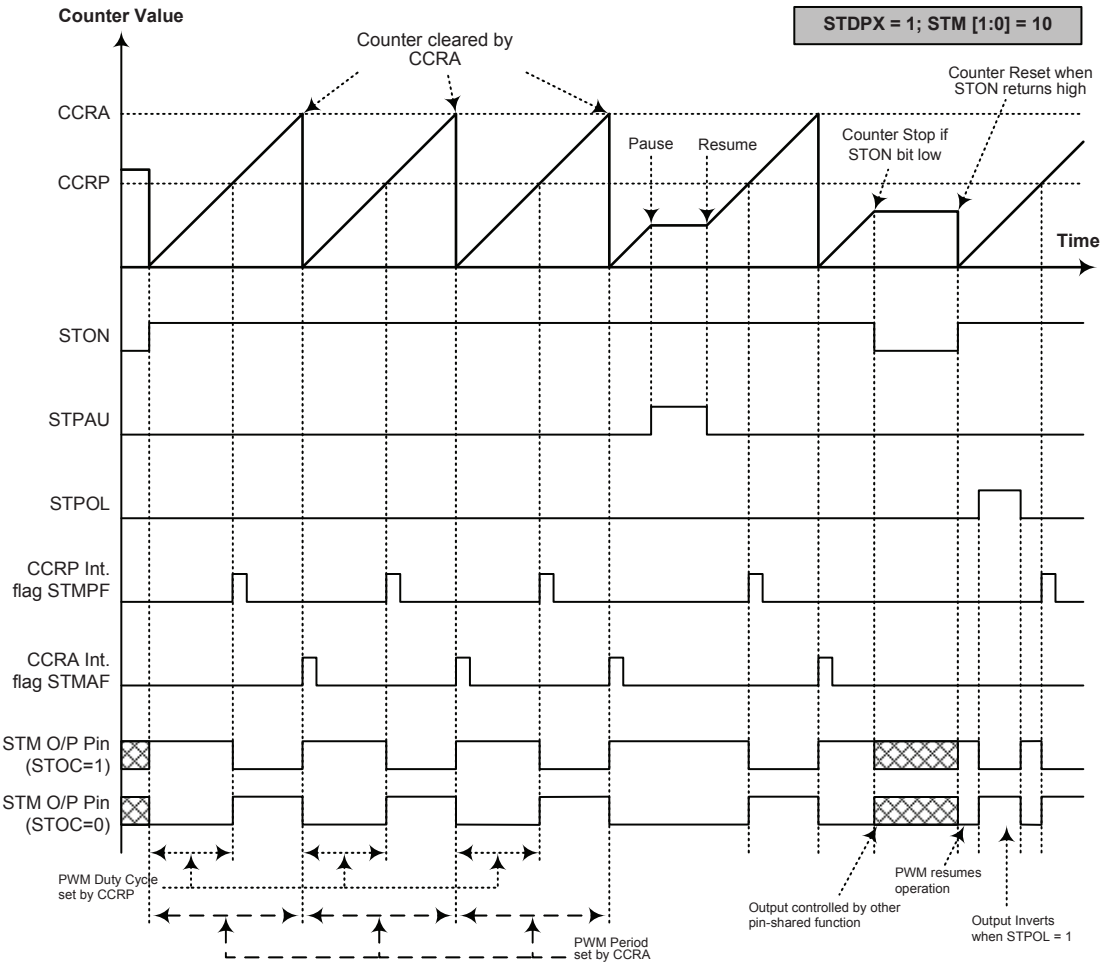
CCRP	1~255	0
Period	CCRA	
Duty	CCRP×256	65536

The PWM output period is determined by the CCRA register value together with the STM clock while the PWM duty cycle is defined by the CCRP register value except when the CCRP value is equal to “0”.



PWM Output Mode – STDPX=0

Note: 1. Here STDPX=0 – Counter cleared by CCRP
2. A counter clear sets the PWM Period
3. The internal PWM function continues running even when STIO [1:0]=00 or 01
4. The STCCLR bit has no influence on PWM operation



PWM Output Mode – STDPX=1

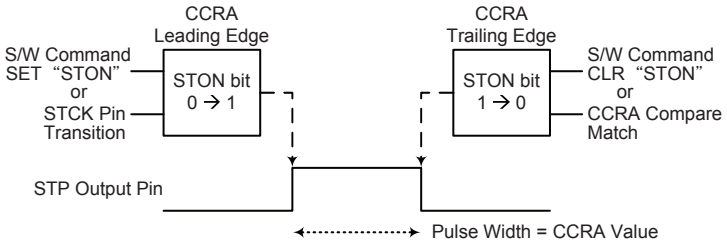
Note: 1. Here STDPX=1 – Counter cleared by CCRA
2. A counter clear sets the PWM Period
3. The internal PWM function continues even when STIO [1:0]=00 or 01
4. The STCCLR bit has no influence on PWM operation

Single Pulse Output Mode

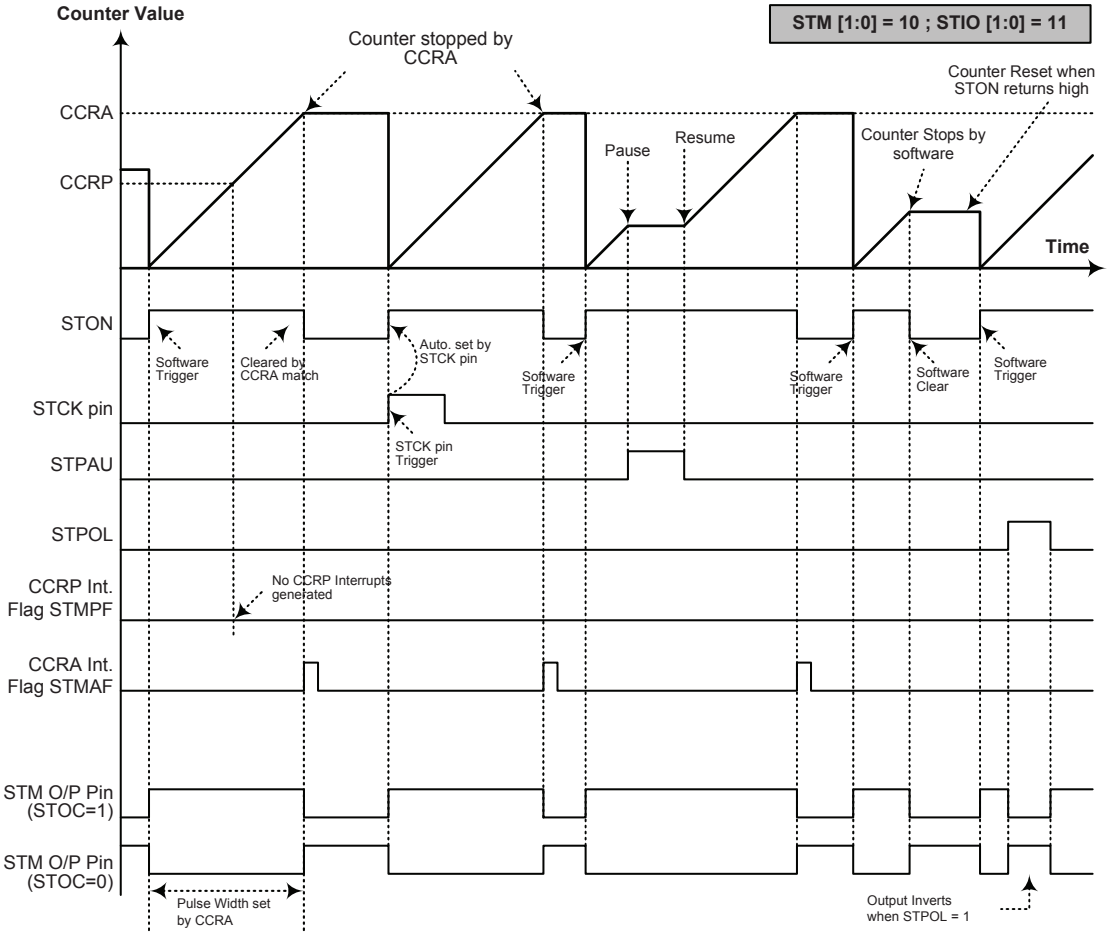
To select this mode, bits STM1 and STM0 in the STMC1 register should be set to 10 respectively and also the STIO1 and STIO0 bits should be set to 11 respectively. The Single Pulse Output Mode, as the name suggests, will generate a single shot pulse on the STM output pin.

The trigger for the pulse output leading edge is a low to high transition of the STON bit, which can be implemented using the application program. However in the Single Pulse Output Mode, the STON bit can also be made to automatically change from low to high using the external STCK pin, which will in turn initiate the Single Pulse output. When the STON bit transitions to a high level, the counter will start running and the pulse leading edge will be generated. The STON bit should remain high when the pulse is in its active state. The generated pulse trailing edge will be generated when the STON bit is cleared to zero, which can be implemented using the application program or when a compare match occurs from Comparator A.

However a compare match from Comparator A will also automatically clear the STON bit and thus generate the Single Pulse output trailing edge. In this way the CCRA value can be used to control the pulse width. A compare match from Comparator A will also generate a STM interrupt. The counter can only be reset back to zero when the STON bit changes from low to high when the counter restarts. In the Single Pulse Output Mode CCRP is not used. The STCCLR and STDPX bits are not used in this Mode.



Single Pulse Generation



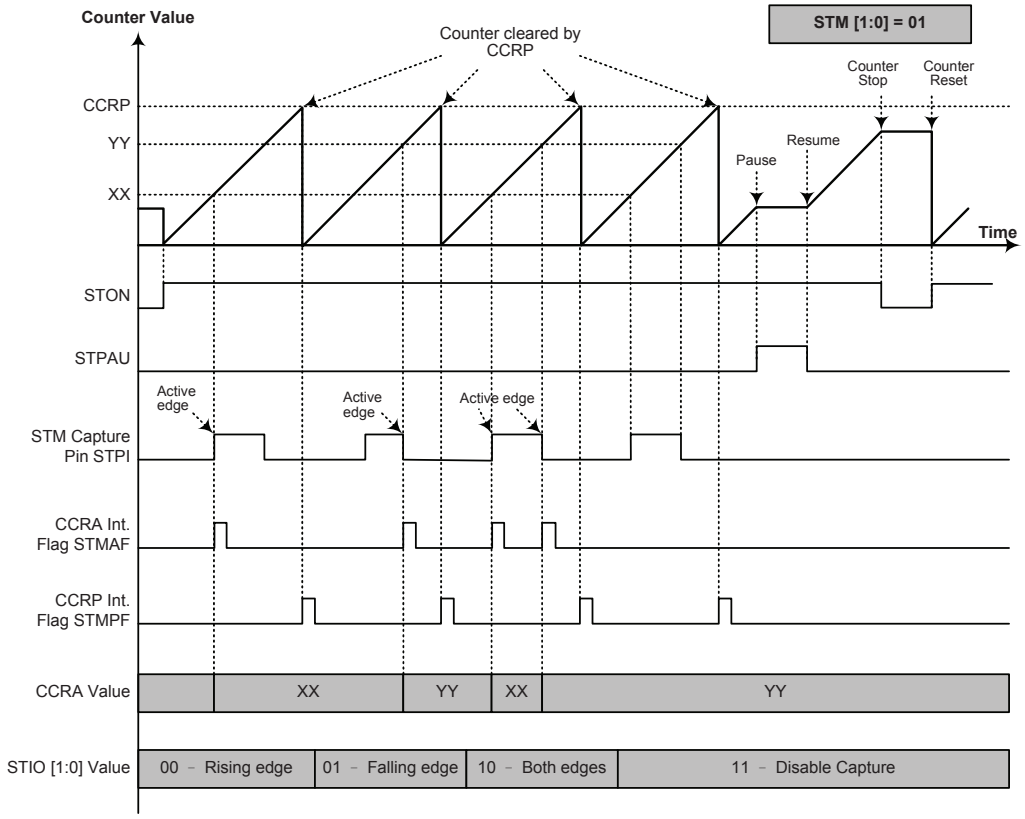
Single Pulse Output Mode

Note: 1. Counter stopped by CCRA
2. CCRP is not used
3. The pulse triggered by the STCK pin or by setting the STON bit high
4. A STCK pin active edge will automatically set the STON bit high.
5. In the Single Pulse Output Mode, STIO [1:0] must be set to “11” and can not be changed.

Capture Input Mode

To select this mode bits STM1 and STM0 in the STMC1 register should be set to 01 respectively. This mode enables external signals to capture and store the present value of the internal counter and can therefore be used for applications such as pulse width measurements. The external signal is supplied on the STPI pin, whose active edge can be a rising edge, a falling edge or both rising and falling edges; the active edge transition type is selected using the STIO1 and STIO0 bits in the STMC1 register. The counter is started when the STON bit changes from low to high which is initiated using the application program.

When the required edge transition appears on the STPI pin the present value in the counter will be latched into the CCRA registers and a STM interrupt generated. Irrespective of what events occur on the STPI pin the counter will continue to free run until the STON bit changes from high to low. When a CCRP compare match occurs the counter will reset back to zero; in this way the CCRP value can be used to control the maximum counter value. When a CCRP compare match occurs from Comparator P, a STM interrupt will also be generated. Counting the number of overflow interrupt signals from the CCRP can be a useful method in measuring long pulse widths. The STIO1 and STIO0 bits can select the active trigger edge on the STPI pin to be a rising edge, falling edge or both edge types. If the STIO1 and STIO0 bits are both set high, then no capture operation will take place irrespective of what happens on the STPI pin, however it must be noted that the counter will continue to run. The STCCLR and STDPX bits are not used in this Mode.

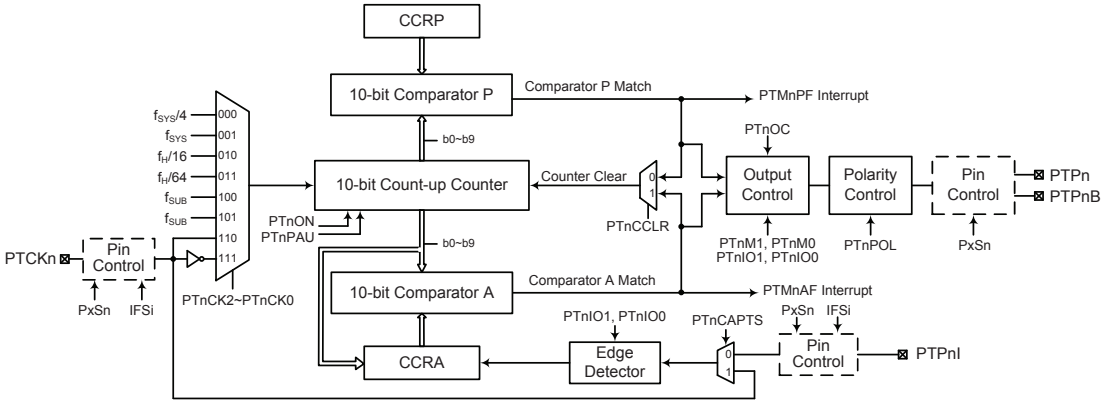


Capture Input Mode

Note: 1. STM [1:0]=01 and active edge set by the STIO [1:0] bits
2. A STM Capture input pin active edge transfers the counter value to CCRA
3. STCCLR bit not used
4. No output function -- STOC and STPOL bits are not used
5. CCRP determines the counter value and the counter has a maximum count value when CCRP is equal to zero.

Periodic Type TM – PTM

The Periodic Type TM contains five operating modes, which are Compare Match Output, Timer/ Event Counter, Capture Input, Single Pulse Output and PWM Output modes. The Periodic TM can be controlled with two external input pins and can drive one or two external output pins.



Note: The inverted output pin PTPnB and the external clock input source being selected using the IFSi register are only for the PTM0.

Periodic Type TM Block Diagram (n=0~2)

Periodic TM Operation

The Periodic Type TM core is a 10-bit count-up counter which is driven by a user selectable internal or external clock source. There are also two internal comparators with the names, Comparator A and Comparator P. These comparators will compare the value in the counter with CCRP and CCRA registers. The CCRP comparator is 10-bit wide.

The only way of changing the value of the 10-bit counter using the application program, is to clear the counter by changing the PTnON bit from low to high. The counter will also be cleared automatically by a counter overflow or a compare match with one of its associated comparators. When these conditions occur, a PTMn interrupt signal will also usually be generated. The Periodic Type TM can operate in a number of different operational modes, can be driven by different clock sources including an input pin and can also control more than one output pin. All operating setup conditions are selected using relevant internal registers.

Periodic Type TM Register Description

Overall operation of the Periodic Type TM is controlled using a series of registers. A read only register pair exists to store the internal counter 10-bit value, while two read/write register pairs exist to store the internal 10-bit CCRA value and CCRP value. The remaining two registers are control registers which setup the different operating and control modes.

Register Name	Bit							
	7	6	5	4	3	2	1	0
PTMnC0	PTnPAU	PTnCK2	PTnCK1	PTnCK0	PTnON	—	—	—
PTMnC1	PTnM1	PTnM0	PTnIO1	PTnIO0	PTnOC	PTnPOL	PTnCAPTS	PTnCCLR
PTMnDL	D7	D6	D5	D4	D3	D2	D1	D0
PTMnDH	—	—	—	—	—	—	D9	D8
PTMnAL	D7	D6	D5	D4	D3	D2	D1	D0
PTMnAH	—	—	—	—	—	—	D9	D8
PTMnRPL	D7	D6	D5	D4	D3	D2	D1	D0
PTMnRPH	—	—	—	—	—	—	D9	D8

10-bit Periodic TM Registers List (n=0~2)

PTMnC0 Register

Bit	7	6	5	4	3	2	1	0
Name	PTnPAU	PTnCK2	PTnCK1	PTnCK0	PTnON	—	—	—
R/W	R/W	R/W	R/W	R/W	R/W	—	—	—
POR	0	0	0	0	0	—	—	—

Bit 7 **PTnPAU**: PTMn Counter Pause Control
0: Run
1: Pause

The counter can be paused by setting this bit high. Clearing the bit to zero restores normal counter operation. When in a Pause condition the PTMn will remain powered up and continue to consume power. The counter will retain its residual value when this bit changes from low to high and resume counting from this value when the bit changes to a low value again.

Bit 6~4 **PTnCK2~PTnCK0**: Select PTMn Counter clock
000: $f_{SYS}/4$
001: f_{SYS}
010: $f_H/16$
011: $f_H/64$
100: f_{SUB}
101: f_{SUB}
110: PTCKn rising edge clock
111: PTCKn falling edge clock

These three bits are used to select the clock source for the PTMn. The external pin clock source can be chosen to be active on the rising or falling edge. The clock source f_{SYS} is the system clock, while f_H and f_{SUB} are other internal clocks, the details of which can be found in the oscillator section.

Bit 3 **PTnON**: PTMn Counter On/Off Control
0: Off
1: On

This bit controls the overall on/off function of the PTMn. Setting the bit high enables the counter to run, clearing the bit disables the PTMn. Clearing this bit to zero will stop the counter from counting and turn off the PTMn which will reduce its power consumption. When the bit changes state from low to high the internal counter value will be reset to zero, however when the bit changes from high to low, the internal counter will retain its residual value until the bit returns high again.

If the PTMn is in the Compare Match Output Mode, PWM output Mode or Single Pulse Output Mode then the PTMn output pin will be reset to its initial condition, as specified by the PTnOC bit, when the PTnON bit changes from low to high.

Bit 2~0 Unimplemented, read as "0"

PTMnC1 Register

Bit	7	6	5	4	3	2	1	0
Name	PTnM1	PTnM0	PTnIO1	PTnIO0	PTnOC	PTnPOL	PTnCAPTS	PTnCCLR
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **PTnM1~PTnM0**: Select PTMn Operating Mode
00: Compare Match Output Mode
01: Capture Input Mode
10: PWM Output Mode or Single Pulse Output Mode
11: Timer/Counter Mode

These bits setup the required operating mode for the PTMn. To ensure reliable operation the PTMn should be switched off before any changes are made to the PTnM1 and PTnM0 bits. In the Timer/Counter Mode, the PTMn output pin control must be disabled.

Bit 5~4 **PTnIO1~PTnIO0**: Select PTMn external pin (PTPn, PTPnI or PTCKn) function

Compare Match Output Mode
00: No change
01: Output low
10: Output high
11: Toggle output

PWM Output Mode/Single Pulse Output Mode
00: PWM Output inactive state
01: PWM Output active state
10: PWM output
11: Single pulse output

Capture Input Mode
00: Input capture at rising edge of PTPnI or PTCKn
01: Input capture at falling edge of PTPnI or PTCKn
10: Input capture at falling/rising edge of PTPnI or PTCKn
11: Input capture disabled

Timer/Counter Mode
Unused

These two bits are used to determine how the PTMn output pin changes state when a certain condition is reached. The function that these bits select depends upon in which mode the PTMn is running.

In the Compare Match Output Mode, the PTnIO1 and PTnIO0 bits determine how the PTMn output pin changes state when a compare match occurs from the Comparator A. The PTMn output pin can be setup to switch high, switch low or to toggle its present state when a compare match occurs from the Comparator A. When the bits are both zero, then no change will take place on the output. The initial value of the PTMn output pin should be setup using the PTnOC bit in the PTMnC1 register. Note that the output level requested by the PTnIO1 and PTnIO0 bits must be different from the initial value setup using the PTnOC bit otherwise no change will occur on the PTMn output pin when a compare match occurs. After the PTMn output pin changes state, it can be reset to its initial level by changing the level of the PTnON bit from low to high.

In the PWM Output Mode, the PTnIO1 and PTnIO0 bits determine how the PTMn output pin changes state when a certain compare match condition occurs. The PWM output function is modified by changing these two bits. It is necessary to only change the values of the PTnIO1 and PTnIO0 bits only after the TM has been switched off. Unpredictable PWM outputs will occur if the PTnIO1 and PTnIO0 bits are changed when the PTMn is running.

Bit 3 **PTnOC**: PTMn PTPn Output control bit

Compare Match Output Mode
0: Initial low
1: Initial high

PWM Output Mode/Single Pulse Output Mode
0: Active low
1: Active high

This is the output control bit for the PTMn output pin. Its operation depends upon whether PTMn is being used in the Compare Match Output Mode or in the PWM Output Mode/Single Pulse Output Mode. It has no effect if the PTMn is in the Timer/Counter Mode. In the Compare Match Output Mode it determines the logic level of the PTMn output pin before a compare match occurs. In the PWM Output Mode it determines if the PWM signal is active high or active low. In the Single Pulse Output Mode it determines the logic level of the PTMn output pin when the PTnON bit changes from low to high.

Bit 2 **PTnPOL**: PTMn PTPn Output polarity Control
0: Non-invert
1: Invert

This bit controls the polarity of the PTPn output pin. When the bit is set high the PTMn output pin will be inverted and not inverted when the bit is zero. It has no effect if the PTMn is in the Timer/Counter Mode.

Bit 1 **PTnCAPTS**: PTMn Capture Trigger Source Selection
0: From PTPnI pin
1: From PTCKn pin

Bit 0 **PTnCCLR**: Select PTMn Counter clear condition
0: PTMn Comparator P match
1: PTMn Comparator A match

This bit is used to select the method which clears the counter. Remember that the Periodic TM contains two comparators, Comparator A and Comparator P, either of which can be selected to clear the internal counter. With the PTnCCLR bit set high, the counter will be cleared when a compare match occurs from the Comparator A. When the bit is low, the counter will be cleared when a compare match occurs from the Comparator P or with a counter overflow. A counter overflow clearing method can only be implemented if the CCRP bits are all cleared to zero. The PTnCCLR bit is not used in the PWM Output Mode, Single Pulse Output Mode or Capture Input Mode.

PTMnDL Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R	R	R	R	R	R	R	R
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: PTMn Counter Low Byte Register bit 7~bit 0
PTMn 10-bit Counter bit 7~bit 0

PTMnDH Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	D9	D8
R/W	—	—	—	—	—	—	R	R
POR	—	—	—	—	—	—	0	0

Bit 7~2 Unimplemented, read as "0"

Bit 1~0 **D9~D8**: PTMn Counter High Byte Register bit 1~bit 0
PTMn 10-bit Counter bit 9~bit 8

PTMnAL Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: PTMn CCRA Low Byte Register bit 7~bit 0
PTMn 10-bit CCRA bit 7~bit 0

PTMnAH Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	D9	D8
R/W	—	—	—	—	—	—	R/W	R/W
POR	—	—	—	—	—	—	0	0

Bit 7~2 Unimplemented, read as "0"

Bit 1~0 **D9~D8**: PTMn CCRA High Byte Register bit 1~bit 0
PTMn 10-bit CCRA bit 9~bit 8

PTMnRPL Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: PTMn CCRP Low Byte Register bit 7~bit 0
PTMn 10-bit CCRP bit 7~bit 0

PTMnRPH Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	D9	D8
R/W	—	—	—	—	—	—	R/W	R/W
POR	—	—	—	—	—	—	0	0

Bit 7~2 Unimplemented, read as "0"

Bit 1~0 **D9~D8**: PTMn CCRP High Byte Register bit 1~bit 0
PTMn 10-bit CCRP bit 9~bit 8

Periodic Type TM Operating Modes

The Periodic Type TM can operate in one of five operating modes, Compare Match Output Mode, PWM Output Mode, Single Pulse Output Mode, Capture Input Mode or Timer/Counter Mode. The operating mode is selected using the PTnM1 and PTnM0 bits in the PTMnC1 register.

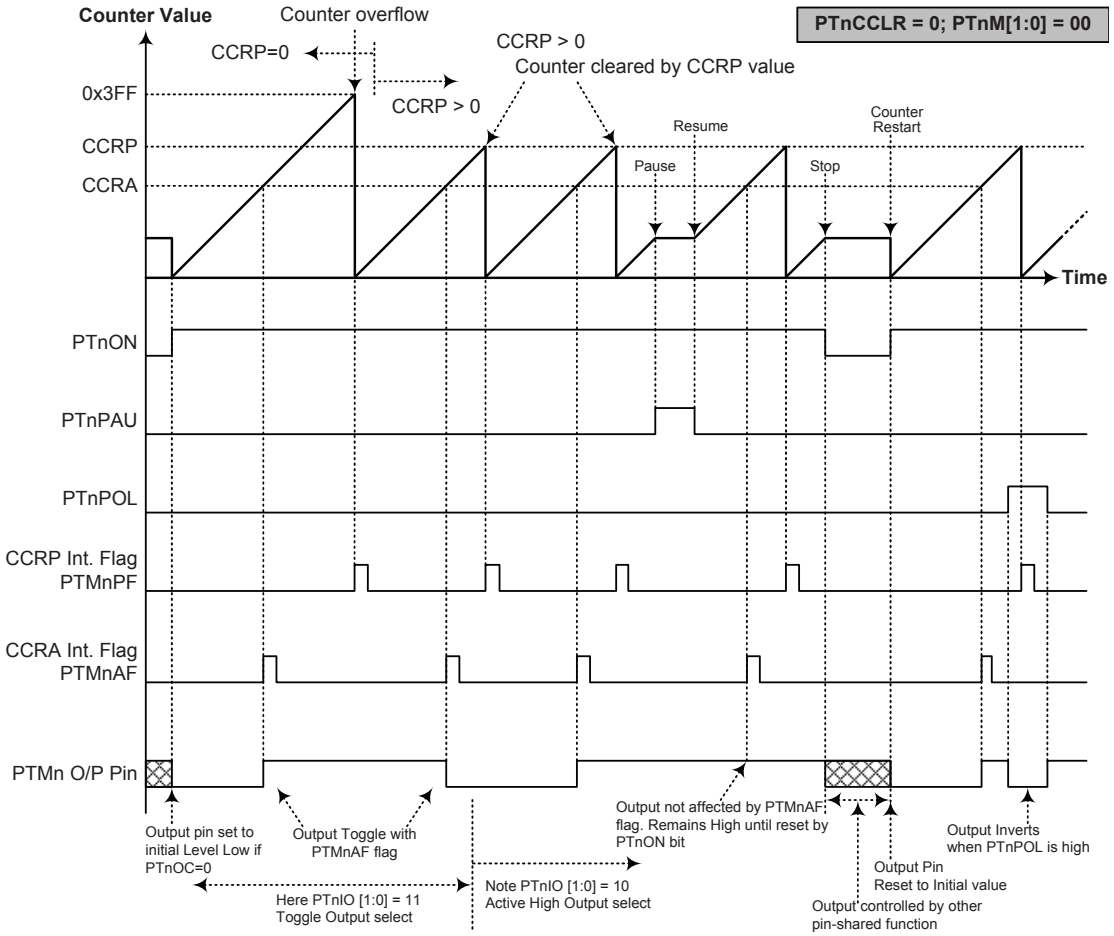
Compare Match Output Mode

To select this mode, bits PTnM1 and PTnM0 in the PTMnC1 register, should be set to 00 respectively. In this mode once the counter is enabled and running it can be cleared by three methods. These are a counter overflow, a compare match from Comparator A and a compare match from Comparator P. When the PTnCCLR bit is low, there are two ways in which the counter can be cleared. One is when a compare match from Comparator P, the other is when the CCRP bits are all zero which allows the counter to overflow. Here both PTMnAF and PTMnPF interrupt request flags for Comparator A and Comparator P respectively, will both be generated.

If the PTnCCLR bit in the PTMnC1 register is high then the counter will be cleared when a compare match occurs from Comparator A. However, here only the PTMnAF interrupt request flag will be generated even if the value of the CCRP bits is less than that of the CCRA registers. Therefore when PTnCCLR is high no PTMnPF interrupt request flag will be generated. In the Compare Match Output Mode, the CCRA can not be cleared to zero.

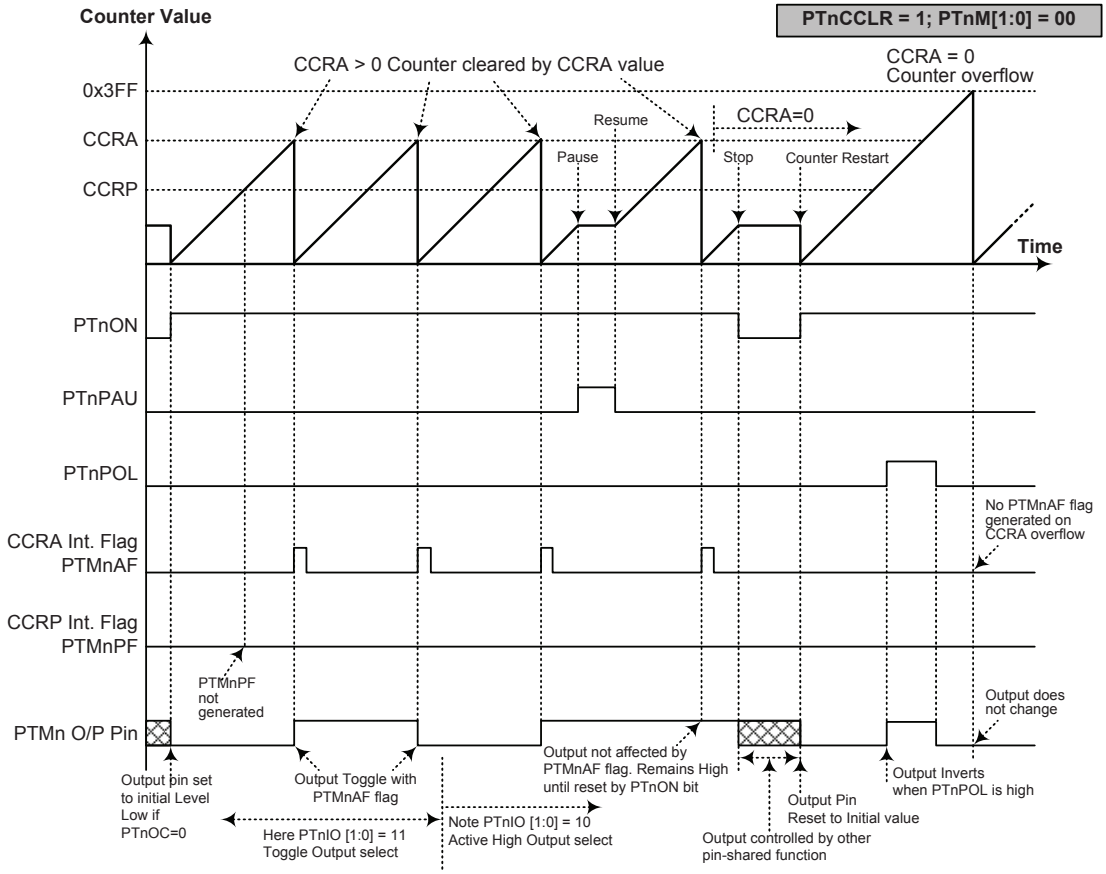
If the CCRA bits are all zero, the counter will overflow when its reaches its maximum 10-bit, 3FF Hex, value, however here the PTMnAF interrupt request flag will not be generated.

As the name of the mode suggests, after a comparison is made, the PTMn output pin, will change state. The PTMn output pin condition however only changes state when a PTMnAF interrupt request flag is generated after a compare match occurs from Comparator A. The PTMnPF interrupt request flag, generated from a compare match occurs from Comparator P, will have no effect on the PTMn output pin. The way in which the PTMn output pin changes state are determined by the condition of the PTnIO1 and PTnIO0 bits in the PTMnC1 register. The PTMn output pin can be selected using the PTnIO1 and PTnIO0 bits to go high, to go low or to toggle from its present condition when a compare match occurs from Comparator A. The initial condition of the PTMn output pin, which is setup after the PTnON bit changes from low to high, is setup using the PTnOC bit. Note that if the PTnIO1 and PTnIO0 bits are zero then no pin change will take place.



Compare Match Output Mode – PTnCCLR=0 (n=0~2)

Note: 1. With PTnCCLR=0 a Comparator P match will clear the counter
2. The PTMn output pin is controlled only by the PTMnAF flag
3. The output pin is reset to its initial state by a PTnON bit rising edge



Compare Match Output Mode – PTnCCLR=1 (n=0~2)

Note: 1. With PTnCCLR=1 a Comparator A match will clear the counter
2. The PTMn output pin is controlled only by the PTMnAF flag
3. The output pin is reset to its initial state by a PTnON bit rising edge
4. A PTMnPF flag is not generated when PTnCCLR=1

Timer/Counter Mode

To select this mode, bits PTnM1 and PTnM0 in the PTMnC1 register should be set to 11 respectively. The Timer/Counter Mode operates in an identical way to the Compare Match Output Mode generating the same interrupt flags. The exception is that in the Timer/Counter Mode the TM output pin is not used. Therefore the above description and Timing Diagrams for the Compare Match Output Mode can be used to understand its function. As the TM output pin is not used in this mode, the pin can be used as a normal I/O pin or other pin-shared function.

PWM Output Mode

To select this mode, bits PTnM1 and PTnM0 in the PTMnC1 register should be set to 10 respectively. The PWM function within the PTMn is useful for applications which require functions such as motor control, heating control, illumination control etc. By providing a signal of fixed frequency but of varying duty cycle on the PTMn output pin, a square wave AC waveform can be generated with varying equivalent DC RMS values.

As both the period and duty cycle of the PWM waveform can be controlled, the choice of generated waveform is extremely flexible. In the PWM Output Mode, the PTnCCLR bit has no effect on the PWM operation. Both of the CCRA and CCRP registers are used to generate the PWM waveform, one register is used to clear the internal counter and thus control the PWM waveform frequency, while the other one is used to control the duty cycle. The PWM waveform frequency and duty cycle can therefore be controlled by the values in the CCRA and CCRP registers.

An interrupt flag, one for each of the CCRA and CCRP, will be generated when a compare match occurs from either Comparator A or Comparator P. The PTnOC bit in the PTMnC1 register is used to select the required polarity of the PWM waveform while the two PTnIO1 and PTnIO0 bits are used to enable the PWM output or to force the PTMn output pin to a fixed high or low level. The PTnPOL bit is used to reverse the polarity of the PWM output waveform.

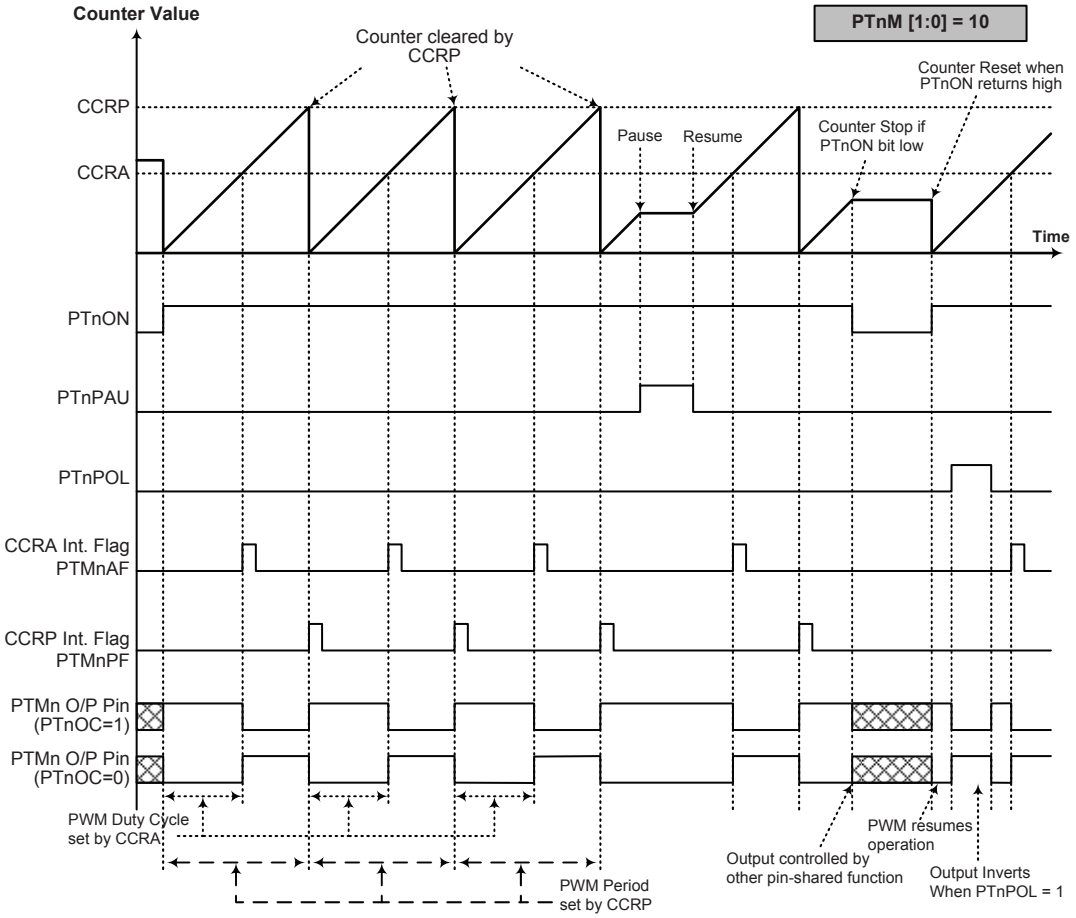
- **10-bit PTMn, PWM Output Mode, Edge-aligned Mode**

CCRP	1~1023	0
Period	1~1023	1024
Duty	CCRA	

If f_{SYS}=12MHz, PTMn clock source select f_{SYS}/4, CCRP=512 and CCRA=128,

The PTMn PWM output frequency=(f_{SYS}/4)/512=f_{SYS}/2048=5.8594kHz, duty=128/512=25%.

If the Duty value defined by the CCRA register is equal to or greater than the Period value, then the PWM output duty is 100%.



PWM Output Mode (n=0~2)

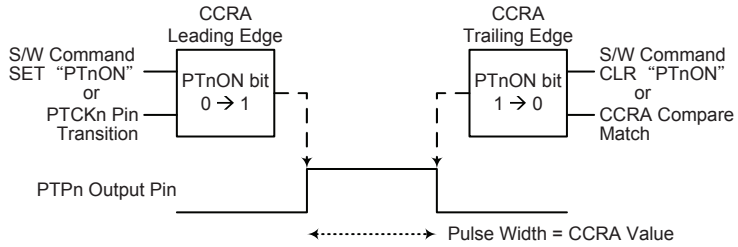
Note: 1. Counter cleared by CCRP
2. A counter clear sets the PWM Period
3. The internal PWM function continues running even when PTnIO[1:0]=00 or 01
4. The PTnCCLR bit has no influence on PWM operation

Single Pulse Output Mode

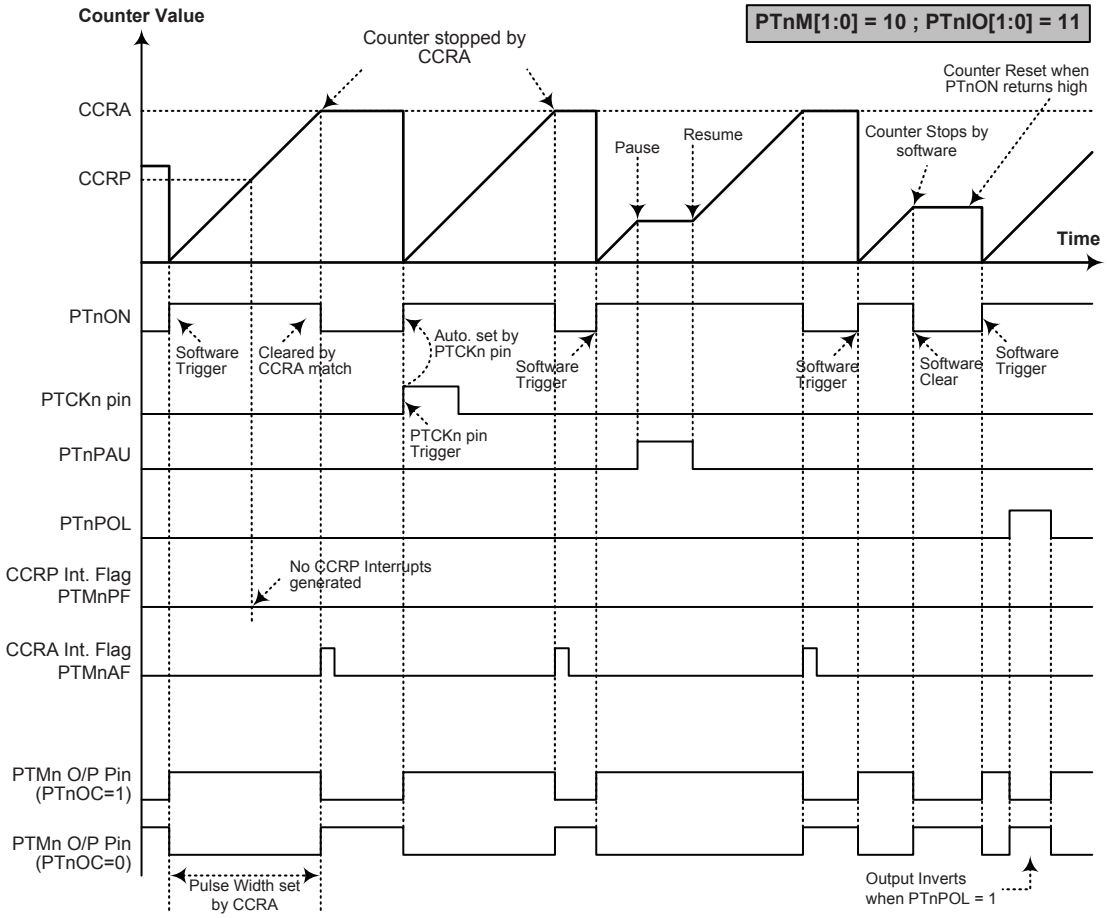
To select this mode, bits PTnM1 and PTnM0 in the PTMnC1 register should be set to 10 respectively and also the PTnIO1 and PTnIO0 bits should be set to 11 respectively. The Single Pulse Output Mode, as the name suggests, will generate a single shot pulse on the PTMn output pin.

The trigger for the pulse output leading edge is a low to high transition of the PTnON bit, which can be implemented using the application program. However in the Single Pulse Output Mode, the PTnON bit can also be made to automatically change from low to high using the external PTCKn pin, which will in turn initiate the Single Pulse output. When the PTnON bit transitions to a high level, the counter will start running and the pulse leading edge will be generated. The PTnON bit should remain high when the pulse is in its active state. The generated pulse trailing edge will be generated when the PTnON bit is cleared to zero, which can be implemented using the application program or when a compare match occurs from Comparator A.

However a compare match from Comparator A will also automatically clear the PTnON bit and thus generate the Single Pulse output trailing edge. In this way the CCRA value can be used to control the pulse width. A compare match from Comparator A will also generate a PTMn interrupt. The counter can only be reset back to zero when the PTnON bit changes from low to high when the counter restarts. In the Single Pulse Output Mode CCRP is not used. The PTnCCLR bit is not used in this Mode.



Single Pulse Generation (n=0~2)



Single Pulse Output Mode (n=0~2)

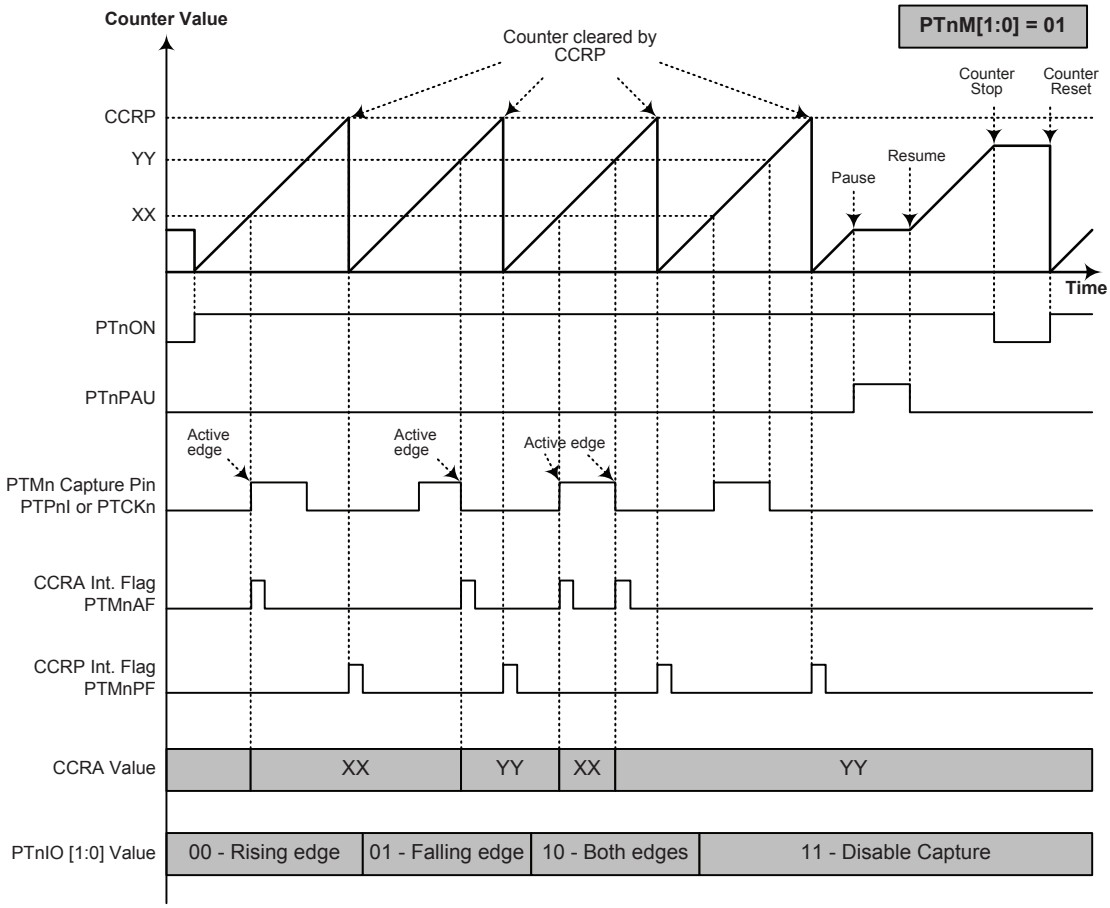
Note: 1. Counter stopped by CCRA
2. CCRP is not used
3. The pulse is triggered by the PTCKn pin or by setting the PTnON bit high
4. A PTCKn pin active edge will automatically set the PTnON bit high
5. In the Single Pulse Output Mode, PTnIO[1:0] must be set to "11" and cannot be changed.

Capture Input Mode

To select this mode bits PTnM1 and PTnM0 in the PTMnC1 register should be set to 01 respectively. This mode enables external signals to capture and store the present value of the internal counter and can therefore be used for applications such as pulse width measurements. The external signal is supplied on the PTPnI or PTCKn pin which is selected using the PTnCAPTS bit in the PTMnC1 register. The input pin active edge can be either a rising edge, a falling edge or both rising and falling edges; the active edge transition type is selected using the PTnIO1 and PTnIO0 bits in the PTMnC1 register. The counter is started when the PTnON bit changes from low to high which is initiated using the application program.

When the required edge transition appears on the PTPnI or PTCKn pin the present value in the counter will be latched into the CCRA registers and a PTMn interrupt generated. Irrespective of what events occur on the PTPnI or PTCKn pin, the counter will continue to free run until the PTnON bit changes from high to low. When a CCRP compare match occurs the counter will reset back to zero; in this way the CCRP value can be used to control the maximum counter value. When a CCRP compare match occurs from Comparator P, a PTMn interrupt will also be generated. Counting the number of overflow interrupt signals from the CCRP can be a useful method in measuring long pulse widths. The PTnIO1 and PTnIO0 bits can select the active trigger edge on the PTPnI or PTCKn pin to be a rising edge, falling edge or both edge types. If the PTnIO1 and PTnIO0 bits are both set high, then no capture operation will take place irrespective of what happens on the PTPnI or PTCKn pin, however it must be noted that the counter will continue to run.

As the PTPnI or PTCKn pin is pin shared with other functions, care must be taken if the PTMn is in the Capture Input Mode. This is because if the pin is setup as an output, then any transitions on this pin may cause an input capture operation to be executed. The PTnCCLR, PTnOC and PTnPOL bits are not used in this Mode.



Capture Input Mode (n=0~2)

Note: 1. PTnM[1:0]=01 and active edge set by the PTnIO[1:0] bits
2. A PTMn Capture input pin active edge transfers the counter value to CCRA
3. PTnCCLR bit not used
4. No output function – PTnOC and PTnPOL bits are not used
5. CCRP determines the counter value and the counter has a maximum count value when CCRP is equal to zero.

Voltage Regulator – LDO

These devices include a voltage regulator, LDO. The REGC register controls the regulator module to work in three modes. In Hi-impedance mode, the LDO will enter power down mode and the VOREG pin will be floating. In the V_{DD} mode, the V_{DD} will bypass the LDO circuit and be connected to the VOREG pin directly. In the third mode the regulator is turned on, when the input voltage is over 3.7V, the LDO will output a fixed voltage of 3.3V through the VOREG pin.

REGC Register

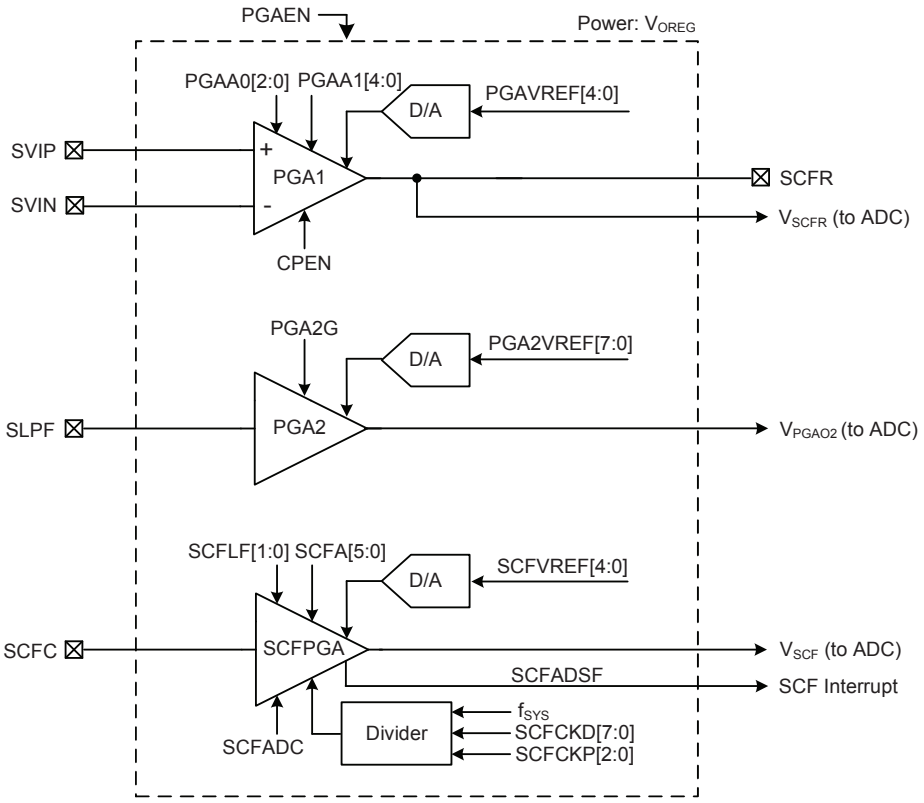
Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	REGEN1	REGEN0
R/W	—	—	—	—	—	—	R/W	R/W
POR	—	—	—	—	—	—	0	0

Bit 7~2 Unimplemented, read as "0"

Bit 1~0 **REGEN1~REGEN0**: Regulator on/off control
00: Regulator off, the VOREG pin is in Hi-impedance mode
01: Regulator off, V_{DD} will bypass the regulator and be sent to the VOREG pin directly
10: Regulator on, V_{OREG} output is 3.3V
11: Regulator on, V_{OREG} output is 3.3V

Programmable Gain Amplifier and Switched Capacitor Filter

These devices include several Programmable Gain Amplifiers, PGAs, as well as a Switched Capacitor Filter, SCF, which is a bandpass filter for sensor signal processing.



PGA Block Diagram

PGA Operation

The overall enable/disable function of the PGA circuits is controlled by the PGAEN bit in the PGAC3 register. When this bit is low the PGA circuits will be powered down, which will be an important consideration in battery powered equipment. The PGA functions include two PGAs, PGA1 and PGA2 as well as a combined PGA and switched capacitor filter. Note that when using the PGA function, the user must wait for about 15ms after enabling the Regulator. Then setup the PGA options and wait for about 400ms, before starting the A/D conversion. In this way the correct A/D conversion value can be obtained.

PGA1

The PGA1 input voltage range is from -20mV to 100mV. The gain of PGA1 is subdivided into two stages. The first stage, known as G11, has a value of 8, 16, 32, 64 or 128 and is selected by the PGAA02~PGAA00 bits in the PGAC0 register. The second stage, known as G12, and has a value of (32~95)/32 and is controlled by the PGAA14~PGAA10 bits in the PGAC1 register. The PGA1 Offset Voltage, V_{OF1}, can be (PGAVREF[4:0]/32)×V_{OREG}, giving a range of 32 discrete values, and is controlled by the PGAVREF4~PGAVREF0 bits in the PGAC0 register. The PGA1 output voltage, V_{PGAO1}, is given by the following formula:

$$V_{PGAO1}=(V_{+} - V_{-}) \times G11 \times G12 + V_{OF1}$$

PGA2

The gain of PGA2, known as G2, has a value of 1 or 2 and is selected by the PGA2G bit in the PGAC3 register. The PGA2 offset voltage, V_{OF2}, is given by the following formula:

$$V_{OF2}=V_{OREG}\ (3.3V) \times (0\sim255)/256$$

The PGA2 output voltage, V_{PGAO2}, is given by the following formula:

$$V_{PGAO2}=(V_{PGAO1} \times G2) - V_{OF2}$$

It is the V_{PGAO2} signal that is provided to the A/D converter for blood pressure measuring.

Switched Capacitor Filter

These devices include a band pass switch capacitor filter. The SCF PGA input voltage, V_{IN}, has a range of 30μV~150μV. In the SCF the Low Pass Filter cut-off frequency can be selected to be 9Hz, 10Hz, 11Hz and 12Hz, selected using the SCFLF1~SCFLF0 bits in the SCFC0 register. The high pass filter cut-off frequency is fixed at 0.7Hz. The SCF also includes a PGA function whose gain can be setup to have a value between 56 and 308, selected in 64 discrete stages, using the SCFA5~SCFA0 bits in the SCFC0 register. The SCF gain is given by the following formula:

$$\text{SCF Gain}=56 + 4 \times \text{SCFA[5:0]}$$

The SCF requires a clock with a frequency of about 488Hz. The SCF clock is sourced from the system clock and is subdivided using bits in the SCFC1 and SFCKD registers. The SCF clock is given by the following formula:

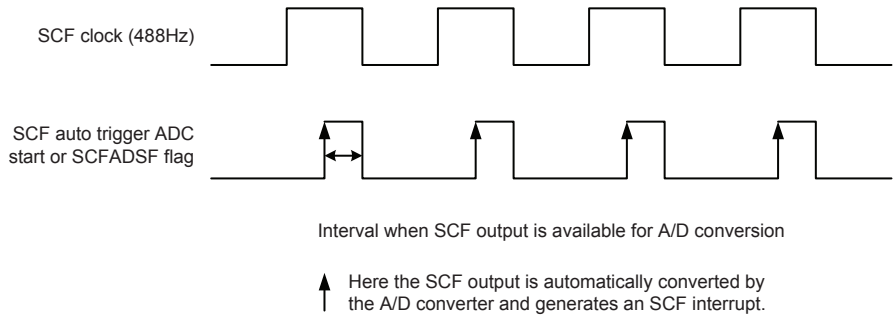
$$\text{SCF clock}=f_{SCF} / (\text{SCFCKD} + 1)$$

where SCFCKD represent the decimal value of the 8 bits in the SCFCDK register, and where $f_{SCF}=f_{SYS}/8$, $f_{SYS}/16$, $f_{SYS}/32$, $f_{SYS}/64$, $f_{SYS}/128$, $f_{SYS}/256$, $f_{SYS}/512$, $f_{SYS}/1024$ selected using the SCFCKP2~SCFCKP0 bits in the SCFC1 register.

SCF Signal Automatic A/D Conversion

The SCF is connected to the A/D converter and can be setup to execute automatic A/D conversion for the SCF output signal. When the A/D converter auto conversion mode triggered by the SCF PGA control bit, SCFADC, is high, then the A/D converter will automatically select the SCF output as its input channel and will override any application program A/D channel selection configuration. Here, an A/D conversion process, initiated by the application program will still be effective. If an A/D conversion process, initiated by either the SCF or application program, is still in progress, and another A/D initiation request (i.e. START) occurs, then this last A/D request will always have a higher priority.

The accompanying diagram shows the relationship between the automatic A/D conversion process and the SCF clock.



SCF Signal Automatic A/D Conversion Timing

PGA Control Register

PGAC0 Register

Bit	7	6	5	4	3	2	1	0
Name	PGAA02	PGAA01	PGAA00	PGAVREF4	PGAVREF3	PGAVREF2	PGAVREF1	PGAVREF0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~5 **PGAA02~PGAA00**: PGA1 first stage gain selection
000: ×8
001: ×16
010: ×32
011: ×64
100: ×128
101: ×128
110: ×128
111: ×128

Bit 4~0 **PGAVREF4~PGAVREF0**: PGA1 offset voltage selection
PGA1 Offset Voltage = (PGAVREF[4:0] / 32) × V_{OREG}

PGAC1 Register

Bit	7	6	5	4	3	2	1	0
Name	CPEN	D6	D5	PGAA14	PGAA13	PGAA12	PGAA11	PGAA10
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7 **CPEN**: PGA1 chopper enabled/disabled control
0: Disabled
1: Enabled
When the PGA1 chopper is enabled, the system will supply a 12kHz to PAG1 for chopper operation.

Bit 6~5 Reserved bits, can not be used and must be fixed at 0

Bit 4~0 **PGAA14~PGAA10**: PGA1 second stage gain selection
Gain = (1 + 3×PGAA1[4:0] / 32)

PGAC2 Register

Bit	7	6	5	4	3	2	1	0
Name	PGA2VREF7	PGA2VREF6	PGA2VREF 5	PGA2VREF4	PGA2VREF3	PGA2VREF2	PGA2VREF1	PGA2VREF0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **PGA2VREF7~PGA2VREF0**: PAG2 Offset Voltage selection
PGA2 Offset Voltage = (V_{OREG} × PGA2VREF[7:0] / 256)

PGAC3 Register

Bit	7	6	5	4	3	2	1	0
Name	PGAEN	PGA2G	—	SCFVREF4	SCFVREF3	SCFVREF2	SCFVREF1	SCFVREF0
R/W	R/W	R/W	—	R/W	R/W	R/W	R/W	R/W
POR	0	0	—	0	0	0	0	0

Bit 7 **PGAEN**: PGA circuits enabled/disabled control
0: Disabled
1: Enabled
When this bit is equal to 0, the PGA circuits including the PGA1, PGA2 and SCF PGA will enter the power down mode.

Bit 6 **PGA2G**: PGA2 gain selection
0: ×2
1: ×1

Bit 5 Unimplemented, read as "0"

Bit 4~0 **SCFVREF4~SCFVREF0**: SCF PGA offset voltage selection
SCF PGA Offset Voltage = (SCFVREF[4:0] / 32) × V_{OREG}

SCFC0 Register

Bit	7	6	5	4	3	2	1	0
Name	SCFLF1	SCFLF0	SCFA5	SCFA4	SCFA3	SCFA2	SCFA1	SCFA0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **SCFLF1~SCFLF0**: SCF PGA Low Pass Filter cut-off frequency selection
Band-pass filter – 3dB selection:
00: 9Hz
01: 10Hz
10: 11Hz
11: 12Hz

Bit 5~0 **SCFA5~SCFA0**: SCF PGA gain selection
Gain = 56 + 4 × SCFA[5:0]

SCFC1 Register

Bit	7	6	5	4	3	2	1	0
Name	—	SCFADSF	SCFADC	SCFCKP2	SCFCKP1	SCFCKP0	—	—
R/W	—	R	R/W	R/W	R/W	R/W	—	—
POR	—	0	0	0	0	0	—	—

Bit 7 Unimplemented, read as "0"

Bit 6 **SCFADSF**: SCF PGA output status flag
0: Not ready
1: Ready
This flag indicates the SCF PGA output status. When this bit is equal to 0, the SCF PGA is under transformation state, there is no available output signal for A/D conversion. When this bit changes from 0 to 1, the SCF PGA output is ready, the SCFF interrupt flag will be set high to generate an SCF interrupt request. In this case, the A/D converter will also be automatically triggered to start an SCF PGA signal conversion if the SCFADC bit has been set high.

Bit 5 **SCFADC**: A/D converter auto conversion mode triggered by the SCF PGA
0: Disable
1: Enable
When this bit is equal to 1, the A/D converter will be automatically triggered by the SCFADSF signal to start a conversion when the SCF PGA output is ready. When this bit is equal to 0, the auto conversion mode will be disabled

Bit 4~2 **SCFCKP2~SCFCKP0**: SCF PGA clock prescaler
f_{SCF}=
000: $f_{SYS}/8$
001: $f_{SYS}/16$
010: $f_{SYS}/32$
011: $f_{SYS}/64$
100: $f_{SYS}/128$
101: $f_{SYS}/256$
110: $f_{SYS}/512$
111: $f_{SYS}/1024$

Bit 1~0 Unimplemented, read as "0"

SCFCKD Register

Bit	7	6	5	4	3	2	1	0
Name	SCFCKD7	SCFCKD6	SCFCKD5	SCFCKD4	SCFCKD3	SCFCKD2	SCFCKD1	SCFCKD0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

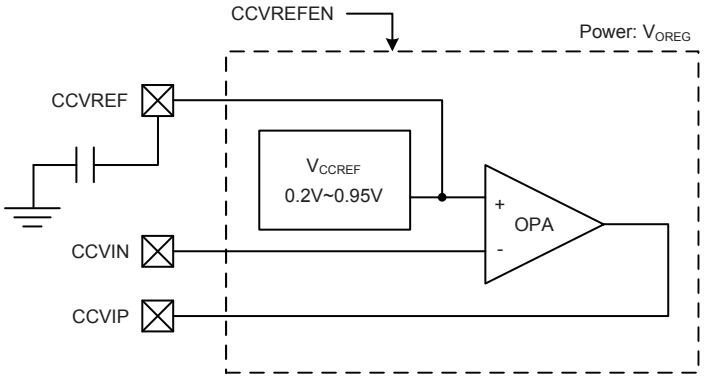
Bit 7~0 **SCFCKD7~SCFCKD0**: The SCF PGA circuit clock divider.
The SCF PGA clock should be around 488Hz.
The f_{SCF} clock can be divided by 1~256 using these 8 bits.
Following the below equation: SCF PGA clock = f_{SCF} / (SCFCKD+1)

Sensor Constant Current Generator Circuit

These devices include a constant current generator for driving the pressure bridge sensor. This is formed using a programmable voltage reference and an operational amplifier.

Constant Current Generator Operation

The constant current generator must be first enabled by setting the CCVREFEN bit in the CCVREFC register high. If cleared to zero then the circuits will be powered down, which will be an important consideration in battery powered equipment. The constant current reference voltage circuit output can be selected to be between 0.2V~0.95V, in intervals of 0.05V, providing 16 selections using the CCVREF3~CCVREF0 bits in the CCVREFC register. This voltage is available on pin CCVREF to which a capacitor should be connected for stabilisation purposes. This voltage is provided to the positive input of an internal operational amplifier. By connecting an external resistor to the negative operational amplifier input, a constant current can be setup.



Constant Current Generator Block Diagram

Pressure Sensor Constant Current Control Register

CCVREFC Register

Bit	7	6	5	4	3	2	1	0
Name	CCVREFEN	BATDEN	ADACCM	—	CCVREF3	CCVREF2	CCVREF1	CCVREF0
R/W	R/W	R/W	R/W	—	R/W	R/W	R/W	R/W
POR	0	0	0	—	0	0	0	0

Bit 7 **CCVREFEN**: Sensor constant current circuit enable/disable control
0: Disable
1: Enable
When this bit is equal to "0", the constant current circuit, including constant current

generation OPA and reference voltage generation circuit, will enter the power down mode. When this bit is equal to "1", the related circuit is enabled.

Bit 6 **BATDEN**: Battery voltage detection circuit enable/disable control
0: Disable
1: Enable
This bit is used to enable or disable the V_{DD} bias resister strings. When this bit is equal to "0", the bias resister strings are disabled. When this bit is equal to "1", the bias resister strings are enabled.

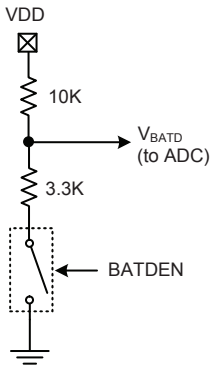
Bit 5 **ADACCM**: A/D conversion accumulation mode enable/disable control
0: Disable
1: Enable
When the A/D conversion accumulation function is enabled the A/D converter will convert 16 times continuously and the accumulated value will be stored in the full 16 bits of registers SADOL and SADOH. After the 16 conversions have been completed, the ADBZ bit will be automatically cleared to zero and an A/D converter interrupt is generated if it is enabled.
When this function is disabled, the A/D converter is in the 12-bit mode and is used to perform normal A/D conversions.

Bit 4 Unimplemented, read as "0"

Bit 3~0 **CCVREF3~CCVREF0**: Sensor constant current generator voltage reference selection
0000: 0.2V
0001: 0.25V
0010: 0.3V
0011: 0.35V
0100: 0.4V
0101: 0.45V
0110: 0.5V
0111: 0.55V
1000: 0.6V
1001: 0.65V
1010: 0.7V
1011: 0.75V
1100: 0.8V
1101: 0.85V
1110: 0.9V
1111: 0.95V

Battery Voltage Detection

These devices include a battery voltage detection function which is controlled by the BATDEN bit in the CCVREFC register. The battery detection voltage can be converted by the A/D converter if is selected as the A/D converter internal input signal.



Analog to Digital Converter

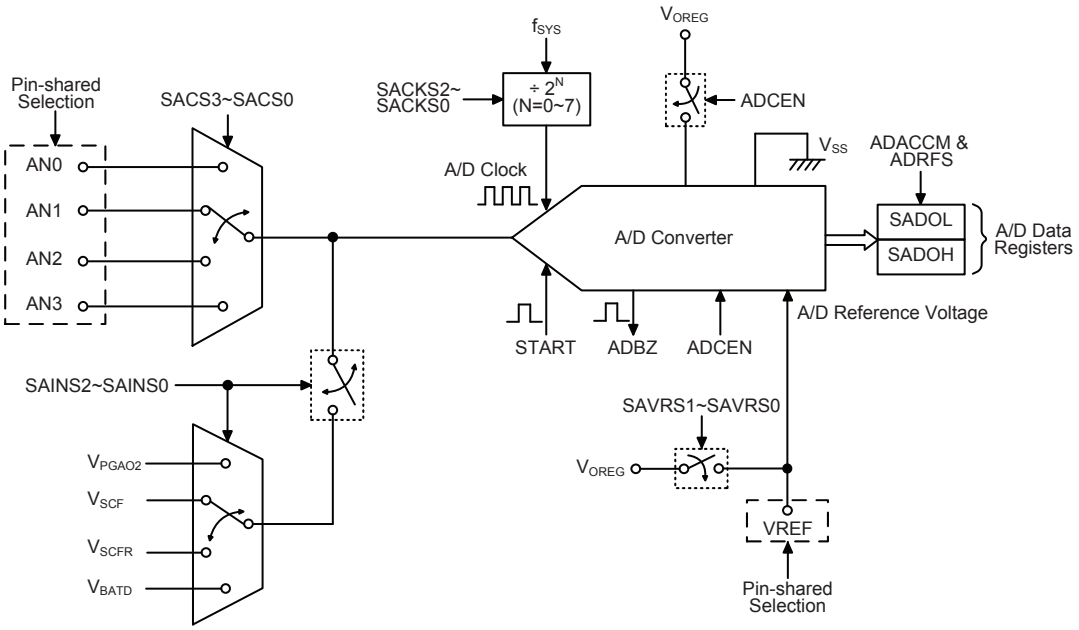
The need to interface to real world analog signals is a common requirement for many electronic systems. However, to properly process these signals by a microcontroller, they must first be converted into digital signals by A/D converters. By integrating the A/D conversion electronic circuitry into the microcontroller, the need for external components is reduced significantly with the corresponding follow-on benefits of lower costs and reduced component space requirements.

A/D Converter Overview

These devices contain a multi-channel analog to digital converter which can directly interface to external analog signals, such as that from sensors or other control signals and convert these signals directly into a 12-bit digital value. The external or internal analog signal to be converted is determined by the SAINS2~SAINS0 bits together with the SACS3~SACS0 bits. When the external analog signal is to be converted, the corresponding pin-shared control bits should first be properly configured and then desired external channel input should be selected using the SAINS2~SAINS0 and SACS3~SACS0 bits. Note that when the internal analog signal is to be converted, the pin-shared control bits should also be properly configured except the SAINS and SACS bit fields. More detailed information about the A/D input signal is described in the “A/D Converter Control Registers” and “A/D Converter Input Signals” sections respectively.

External Input Channels	Internal Signal	A/D Channel Select Bits
4: AN0~AN3	4: V_{PGAO2}, V_{SCF}, V_{SCFR}, V_{BATD}	SAINS2~SAINS0, SACS3~SACS0

The accompanying block diagram shows the overall internal structure of the A/D converter, together with its associated registers.



A/D Converter Structure

A/D Converter Register Description

Overall operation of the A/D converter is controlled using four registers. A read only register pair exists to store the A/D converter data 12-bit single value or 16-bit assumulated value. The remaining two registers are control registers which setup the operating and control function of the A/D converter.

Register Name	Bit							
	7	6	5	4	3	2	1	0
SADOL (ADACCM=0 & ADRFS=0)	D3	D2	D1	D0	—	—	—	—
SADOL (ADACCM=0 & ADRFS=1)	D7	D6	D5	D4	D3	D2	D1	D0
SADOL (ADACCM=1)	D7	D6	D5	D4	D3	D2	D1	D0
SADOH (ADACCM=0 & ADRFS=0)	D11	D10	D9	D8	D7	D6	D5	D4
SADOH (ADACCM=0 & ADRFS=1)	—	—	—	—	D11	D10	D9	D8
SADOH (ADACCM=1)	D15	D14	D13	D12	D11	D10	D9	D8
SADC0	START	ADBZ	ADCEN	ADRFS	SACS3	SACS2	SACS1	SACS0
SADC1	SAINS2	SAINS1	SAINS0	SAVRS1	SAVRS0	SACKS2	SACKS1	SACKS0

A/D Converter Registers List

A/D Converter Data Registers – SADOL, SADOH

As the internal A/D converter provides a 12-bit digital conversion value, it requires two data registers to store the converted value. These are a high byte register, known as SADOH, and a low byte register, known as SADOL. After the conversion process takes place, these registers can be directly read by the microcontroller to obtain the digitised conversion value. Whether all the 16 data register bits are used is determined by the ADACCM bit in the CCVREFC register. For the conversion accumulation mode, that is when the ADACCM bit is set high, the full 16 bits are used. For the single conversion mode, that is when the ADACCM bit is set low, only 12 bits of the 16-bit register space is utilised, the format in which the data is stored is furtherly controlled by the ADRFS bit in the SADC0 register, as shown in the accompanying table. Any unused bits will be read as zero. Note that A/D data registers contents will be unchanged if the A/D converter is disabled.

ADACCM	ADRFS	SADOH								SADOL							
		7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
0	0	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	0	0	0	0
	1	0	0	0	0	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
1	x	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

"x": Don't care

A/D Converter Data Registers

A/D Converter Control Registers – SADC0, SADC1

To control the function and operation of the A/D converter, two control registers known as SADC0 and SADC1 are provided. These 8-bit registers define functions such as the selection of which analog channel is connected to the internal A/D converter, the digitised data format, the A/D clock source as well as controlling the start function and monitoring the A/D converter busy status. As these devices contain only one actual analog to digital converter hardware circuit, each of the external or internal analog signal inputs must be routed to the converter. The SACS3~SACS0 bits in the SADC0 register are used to determine which external channel input is selected to be converted. The SAINS2~SAINS0 bits in the SADC1 register are used to determine that the analog signal to be converted comes from the internal analog signal or external analog channel input.

The relevant pin-shared function selection bits determine which pins on I/O Ports are used as analog inputs for the A/D converter input and which pins are not to be used as the A/D converter input. When the pin is selected to be an A/D input, its original function whether it is an I/O or other pin-shared function will be removed. In addition, any internal pull-high resistor connected to the pin will be automatically removed if the pin is selected to be an A/D converter input.

- **SADC0 Register**

Bit	7	6	5	4	3	2	1	0
Name	START	ADBZ	ADCEN	ADRFS	SACS3	SACS2	SACS1	SACS0
R/W	R/W	R	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7 **START**: Start the A/D conversion
0→1→0: Start
This bit is used to initiate an A/D conversion process. The bit is normally low but if set high and then cleared low again, the A/D converter will initiate a conversion process. When the bit is set high the A/D converter will be reset.

Bit 6 **ADBZ**: A/D converter busy flag
0: No A/D conversion is in progress
1: A/D conversion is in progress

This read only flag is used to indicate whether the A/D conversion is in progress or not. When the START bit is set from low to high and then to low again, the ADBZ flag will be set to 1 to indicate that the A/D conversion is initiated. The ADBZ flag will be cleared to 0 after the A/D conversion is complete.

Bit 5 **ADCEN**: A/D converter function enable control
0: Disable
1: Enable

This bit controls the A/D internal function. This bit should be set to one to enable the A/D converter. If the bit is set low, then the A/D converter will be switched off reducing these devices power consumption. When the A/D converter function is disabled, the contents of the A/D data register pair known as SADOH and SADOL will be unchanged.

Bit 4 **ADRFS**: A/D converter data format select (ADACCM=0)
0: A/D converter data format → SADOH=D[11:4]; SADOL=D[3:0]
1: A/D converter data format → SADOH=D[11:8]; SADOL=D[7:0]

This bit controls the format of the 12-bit converted A/D value in the two A/D data registers. Details are provided in the A/D data register section.

Bit 3~0 **SACS3~SACS0**: A/D converter external analog channel input select
0000: AN0
0001: AN1
0010: AN2
0011: AN3
0100~1111: Floating

- **SADC1 Register**

Bit	7	6	5	4	3	2	1	0
Name	SAINS2	SAINS1	SAINS0	SAVRS1	SAVRS0	SACKS2	SACKS1	SACKS0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~5 **SAINS2~SAINS0**: A/D converter input signal select
000: External input – External analog channel input
001: Internal input – Internal PGA2 output, V_{PGAO2}
010: Internal input – Internal SCFPGA output, V_{SCF}
011: Internal input – Internal PGA1 output, V_{SCFR}
100: Internal input – Internal battery detection voltage, V_{BATD}
101~111: External input – External analog channel input

Care must be taken if the SAINS2~SAINS0 bits are set from "001" to 100" to select the internal analog signal to be coverted. When the internal analog signal is selected to be converted, the external input pin must never be selected as the A/D input signal by properly setting the SACS3~SACS0 bits with a value from 0100 to 1111. Otherwise, the external channel input will be connected together with the internal analog signal. This will result in unpredictable situations such as an irreversible damage.

Bit 4~3 **SAVRS1~SAVRS0**: A/D converter reference voltage select
00: External VREF pin
01: Internal regulator output, V_{OREG}
1x: External VREF pin

These bits are used to select the A/D converter reference voltage. Care must be taken if the SAVRS1~SAVRS0 bits are set to "01" to select the internal regulator output as the reference voltage source. When the internal regulator output is selected as the reference voltage, the VREF pin can not be configured as the reference voltage input by properly configuring the corresponding pin-shared function control bits. Otherwise, the external input voltage on the VREF pin will be connected to the internal regulator output.

Bit 2~0 **SACKS2~SACKS0**: A/D conversion clock source select
000: f_{SYS}
001: $f_{SYS}/2$
010: $f_{SYS}/4$
011: $f_{SYS}/8$
100: $f_{SYS}/16$
101: $f_{SYS}/32$
110: $f_{SYS}/64$
111: $f_{SYS}/128$
These three bits are used to select the clock source for the A/D converter.

A/D Converter Operation

The START bit in the SADC0 register is used to start the AD conversion. When the microcontroller sets this bit from low to high and then low again, an analog to digital conversion cycle will be initiated.

The ADBZ bit in the SADC0 register is used to indicate whether the analog to digital conversion process is in progress or not. This bit will be automatically set to "1" by the microcontroller after an A/D conversion is successfully initiated. When the A/D conversion is complete, the ADBZ will be cleared to "0". In addition, the corresponding A/D interrupt request flag will be set in the interrupt control register, and if the interrupts are enabled, an appropriate internal interrupt signal will be generated. This A/D internal interrupt signal will direct the program flow to the associated A/D internal interrupt address for processing. If the A/D internal interrupt is disabled, the microcontroller can poll the ADBZ bit in the SADC0 register to check whether it has been cleared as an alternative method of detecting the end of an A/D conversion cycle.

The clock source for the A/D converter, which originates from the system clock f_{SYS}, can be chosen to be either f_{SYS} or a subdivided version of f_{SYS}. The division ratio value is determined by the SACKS2~SACKS0 bits in the SADC1 register. Although the A/D clock source is determined by the system clock f_{SYS} and by bits SACKS2~SACKS0, there are some limitations on the maximum A/D clock source speed that can be selected. As the recommended range of permissible A/D clock period, t_{ADCK}, is from 0.5μs to 10μs, care must be taken for system clock frequencies. For example, as the system clock operates at a frequency of 8MHz, the SACKS2~SACKS0 bits should not be set to 000, 001 or 111. Doing so will give A/D clock periods that are less or larger than the minimum or maximum A/D clock period which may result in inaccurate A/D conversion values. Refer to the following table for examples, where values marked with an asterisk * show where, depending upon these devices, special care must be taken, as the values may be less than or larger than the specified A/D clock period range.

f_{SYS}	A/D Clock Period (t_{ADCK})							
	SACKS[2:0] =000 (f_{SYS})	SACKS[2:0] =001 ($f_{SYS}/2$)	SACKS[2:0] =010 ($f_{SYS}/4$)	SACKS[2:0] =011 ($f_{SYS}/8$)	SACKS[2:0] =100 ($f_{SYS}/16$)	SACKS[2:0] =101 ($f_{SYS}/62$)	SACKS[2:0] =110 ($f_{SYS}/64$)	SACKS[2:0] =111 ($f_{SYS}/128$)
1MHz	1μs	2μs	4μs	8μs	16μs *	32μs *	64μs *	128μs *
2MHz	500ns	1μs	2μs	4μs	8μs	16μs *	32μs *	64μs *
4MHz	250ns *	500ns	1μs	2μs	4μs	8μs	16μs *	32μs *
8MHz	125ns *	250ns *	500ns	1μs	2μs	4μs	8μs	16μs *
12MHz	83ns *	167ns *	333ns *	667ns	1.33μs	2.67μs	5.33μs	10.67μs *
16MHz	62.5ns *	125ns *	250ns *	500ns	1μs	2μs	4μs	8μs

A/D Clock Period Examples

Controlling the power on/off function of the A/D converter circuitry is implemented using the ADCEN bit in the SADC0 register. This bit must be set high to power on the A/D converter. When the ADCEN bit is set high to power on the A/D converter internal circuitry a certain delay, as

indicated in the timing diagram, must be allowed before an A/D conversion is initiated. Even if no pins are selected for use as A/D inputs, if the ADCEN bit is high, then some power will still be consumed. In power conscious applications it is therefore recommended that the ADCEN is set low to reduce power consumption when the A/D converter function is not being used.

A/D Converter Reference Voltage

The reference voltage supply to the A/D converter can be supplied from the regulator output, V_{OREG}, or from an external reference source supplied on pin VREF. The desired selection is made using the SAVRS1 and SAVRS0 bits. When the SAVRS bit field is set to "01", the A/D converter reference voltage will come from the regulator output. Otherwise, if the SAVRS bit field is set to other value except "01", the A/D converter reference voltage will come from the VREF pin. As the VREF pin is pin-shared with other functions, when the VREF pin is selected as the reference voltage supply pin, the VREF pin-shared function control bits should be properly configured to disable other pin functions. However, if the regulator output voltage is selected as the reference voltage, the VREF pin must not be configured as the reference voltage input function to avoid the internal connection between the VREF pin and the regulator output voltage. The analog input values must not be allowed to exceed the selected reference voltage.

SAVRS[1:0]	Reference	Description
00, 10, 11	VREF pin	External A/D converter reference pin VREF
01	V_{OREG}	Internal regulator output voltage

A/D Converter Reference Voltage Selection

A/D Converter Input Signals

All the external A/D analog channel input pins are pin-shared with the I/O pins as well as other functions. The corresponding control bits for each A/D external input pin in the PCS0 register determine whether the input pins are setup as A/D converter analog inputs or whether they have other functions. If the pin is setup to be as an A/D analog channel input, the original pin functions will be disabled. In this way, pins can be changed under program control to change their function between A/D inputs and other functions. All pull high resistors, which are setup through register programming, will be automatically disconnected if the pins are setup as A/D inputs. Note that it is not necessary to first setup the A/D pin as an input in the port control register to enable the A/D input as when the pin-shared function control bits enable an A/D input, the status of the port control register will be overridden.

If the SAINS2~SAINS0 bits are set to "000" or "100~111", the external analog channel input is selected to be converted and the SACS3~SACS0 bits can determine which actual external channel is selected to be converted. If the SAINS2~SAINS0 bits are set to "001~011", the V_{PGAO2}, V_{SCF}, V_{SCFR} or V_{BATD} voltage is selected to be converted. Note that if the internal analog signal is selected to be converted, the external input channel determined by the SACS3~SACS0 bits must be switched to a non-existed A/D input channel by properly setting the SACS bit field with a value from 0100 to 1111.

SAINS[2:0]	SACS[3:0]	Input Signals	Description
000, 101~111	0000~0011	AN0~AN3	External pin analog input
	0100~1111	—	Non-existed channel, input is floating
001	0100~1111	V_{PGAO2}	Internal PGA2 output
010	0100~1111	V_{SCF}	Internal SCFPGA output
011	0100~1111	V_{SCFR}	Internal PGA1 output
100	0100~1111	V_{BATD}	Internal battery detection voltage

A/D Converter Input Signal Selection

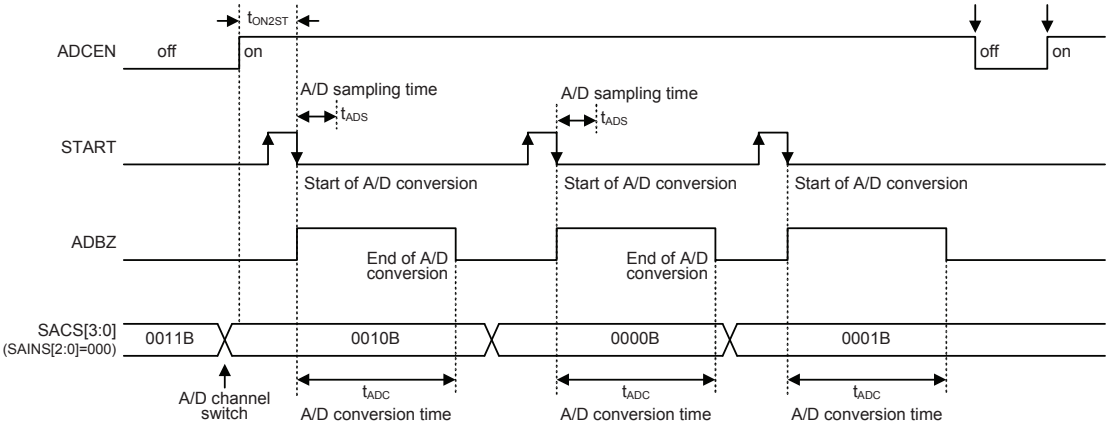
Conversion Rate and Timing Diagram

A complete A/D single conversion contains two parts, data sampling and data conversion. The data sampling which is defined as t_{ADS} takes 4 A/D clock cycles and the data conversion takes 12 A/D clock cycles. Therefore a total of 16 A/D clock cycles for an external input A/D conversion which is defined as t_{ADC} are necessary.

Maximum single A/D conversion rate = A/D clock period / 16

The accompanying diagram shows graphically the various stages involved in an analog to digital conversion process and its associated timing. After an A/D conversion process has been initiated by the application program, the microcontroller internal hardware will begin to carry out the conversion, during which time the program can continue with other functions. The time taken for the A/D conversion is 16 t_{ADCK} clock cycles where t_{ADCK} is equal to the A/D clock period.

If the ADACCM bit is zero then only a single A/D conversion process will take place. However if the ADACCM bit is set high then the A/D converter will be in the conversion accumulation mode. In this mode, 16 repetitive A/D conversion operations are made with each new converted value being added to the previous accumulated value. After 16 conversions, all the 12-bit values have been completed and added together, a 16-bit wide digital result value is obtained and stored in the two A/D data registers.



Single A/D Conversion Timing – External Channel Input

Summary of A/D Conversion Steps

The following summarises the individual steps that should be executed in order to implement an A/D conversion process.

- Step 1
  Select the required A/D conversion clock by correctly programming bits SACKS2~SACKS0 in the SADC1 register.
- Step 2
  Enable the A/D by setting the ADCEN bit in the SADC0 register to one.
- Step 3
  Select which signal is to be connected to the internal A/D converter by correctly configuring the SAINS2~SAINS0 bits
  Select the external channel input to be converted, go to Step 4.
  Select the internal analog signal to be converted, go to Step 5.
- Step 4
  If the A/D input signal comes from the external channel input selected by configuring the SAINS bit field, the corresponding pins should be configured as A/D input function by configuring the relevant pin-shared function control bits. The desired analog channel then should be selected by configuring the SACS bit field. After this step, go to Step 6.
- Step 5
  Befor the A/D input signal is selected to come from the internal analog signal by configuring the SAINS bit field, the corresponding external input pin must be switched to a non-existed channel input by setting the SACS3~SACS0 bits with a value from 0100 to 1111. The desired internal analog signal then can be selected by configuring the SAINS bit field. After this step, go to Step 6.
- Step 6
  Select the reference voltage source by configuring the SAVRS1~SAVRS0 bits in the SADC1 register.
- Step 7
  Select A/D converter output data format by setting the ADACCM bit in the CCVREFC register together with the ADRFS bit in the SADC0 register.
- Step 8
  If A/D conversion interrupt is used, the interrupt control registers must be correctly configured to ensure the A/D interrupt function is active. The master interrupt control bit, EMI, and the A/D conversion interrupt control bit, ADE, must both be set high in advance.
- Step 9
  The A/D conversion procedure can now be initialized by setting the START bit from low to high and then low again.
- Step 10
  If A/D conversion is in progress, the ADBZ flag will be set high. After the A/D conversion process is complete, the ADBZ flag will go low and then the output data can be read from SADOH and SADOL registers.

Note: When checking for the end of the conversion process, if the method of polling the ADBZ bit in the SADC0 register is used, the interrupt enable step above can be omitted.

Programming Considerations

During microcontroller operations where the A/D converter is not being used, the A/D internal circuitry can be switched off to reduce power consumption, by clearing bit ADCEN to 0 in the SADC0 register. When this happens, the internal A/D converter circuits will not consume power irrespective of what analog voltage is applied to their input lines. If the A/D converter input lines are used as normal I/Os, then care must be taken as if the input voltage is not at a valid logic level, then this may lead to some increase in power consumption.

A/D Conversion Function

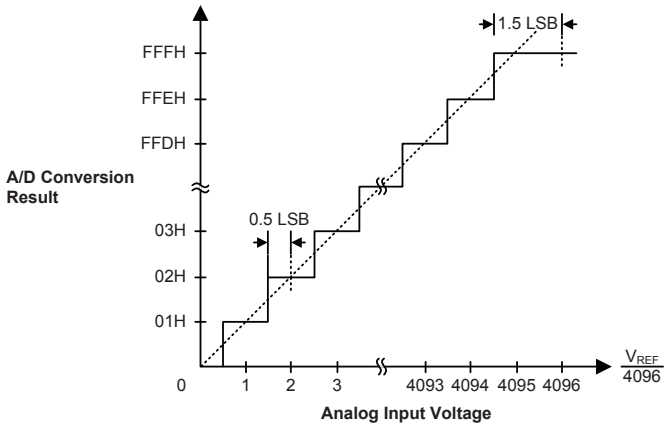
As these devices contain a 12-bit A/D converter, its full-scale converted digitised value is equal to FFFH. Since the full-scale analog input value is equal to the actual A/D converter reference voltage, V_{REF}, this gives a single bit analog input value of V_{REF} divided by 4096.

$$1\ LSB=V_{REF} \div 4096$$

The A/D Converter input voltage value can be calculated using the following equation:

$$A/D\ input\ voltage=A/D\ output\ digital\ value \times (V_{REF} \div 4096)$$

The diagram shows the ideal transfer function between the analog input value and the digitised output value for the A/D converter. Except for the digitised zero value, the subsequent digitised values will change at a point 0.5 LSB below where they would change without the offset, and the last full scale digitised value will change at a point 1.5 LSB below the V_{REF} level. Note that here the V_{REF} voltage is the actual A/D converter reference voltage determined by the SAVRS field.



Ideal A/D Transfer Function

A/D Conversion Programming Examples

The following two programming examples illustrate how to setup and implement an A/D conversion. In the first example, the method of polling the ADBZ bit in the SADC0 register is used to detect when the conversion cycle is complete, whereas in the second example, the A/D interrupt is used to determine when the conversion is complete.

Example: using an ADBZ polling method to detect the end of conversion

```
clr  ADE              ; disable ADC interrupt
clr  ADACCM           ; disable the A/D conversion accumulation mode
mov  a,03H
mov  SADC1,a          ; select fSYS/8 as A/D clock
set  ADCEN
mov  a,30h            ; setup PCS0 to configure pin AN0
mov  PCS0,a
```

```
mov  a,20h
mov  SADC0,a          ; enable and connect AN0 channel to A/D converter
:
:
start_conversion:
clr  START            ; high pulse on start bit to initiate conversion
set  START            ; reset A/D
clr  START            ; start A/D
polling_EOC:
sz   ADBZ             ; poll the SADC0 register ADBZ bit to detect end of A/D conversion
jmp  polling_EOC      ; continue polling
mov  a,SADOL          ; read low byte conversion result value
mov  SADOL_buffer,a   ; save result to user defined register
mov  a,SADOH          ; read high byte conversion result value
mov  SADOH_buffer,a   ; save result to user defined register
:
:
jmp  start_conversion ; start next A/D conversion
```

Example: using the interrupt method to detect the end of conversion

```
clr  ADE              ; disable ADC interrupt
clr  ADACCM           ; disable the A/D conversion accumulation mode
mov  a,03H
mov  SADC1,a          ; select fSYS/8 as A/D clock
set  ADCEN
mov  a,30h            ; setup PCS0 to configure pin AN0
mov  PCS0,a
mov  a,20h
mov  SADC0,a          ; enable and connect AN0 channel to A/D converter
:
:
start_conversion:
clr  START            ; high pulse on START bit to initiate conversion
set  START            ; reset A/D
clr  START            ; start A/D
clr  ADF              ; clear ADC interrupt request flag
set  ADE              ; enable ADC interrupt
set  EMI              ; enable global interrupt
:
:
; ADC interrupt service routine
ADC_ISR:
mov  acc_stack,a      ; save ACC to user defined memory
mov  a,STATUS
mov  status_stack,a   ; save STATUS to user defined memory
:
:
mov  a,SADOL          ; read low byte conversion result value
mov  SADOL_buffer,a   ; save result to user defined register
mov  a,SADOH          ; read high byte conversion result value
mov  SADOH_buffer,a   ; save result to user defined register
:
:
EXIT_INT_ISR:
mov  a,status_stack
mov  STATUS,a         ; restore STATUS from user defined memory
mov  a,acc_stack      ; restore ACC from user defined memory
reti
```

Serial Interface Module – SIM

These devices contain a Serial Interface Module, which includes both the four line SPI interface and the two line I^2C interface types, to allow an easy method of communication with external peripheral hardware. Having relatively simple communication protocols, these serial interface types allow the microcontroller to interface to external SPI or I^2C based hardware such as sensors, Flash or EEPROM memory, etc. The SIM interface pins are pin-shared with other I/O pins therefore the SIM interface functional pins must first be selected using the corresponding pin-shared function selection bits. As both interface types share the same pins and registers, the choice of whether the SPI or I^2C type is used is made using the SIM operating mode control bits, named SIM2~SIM0, in the SIMC0 register. These pull-high resistors of the SIM pin-shared I/O are selected using pull-high control registers when the SIM function is enabled and the corresponding pins are used as SIM input pins.

SPI Interface

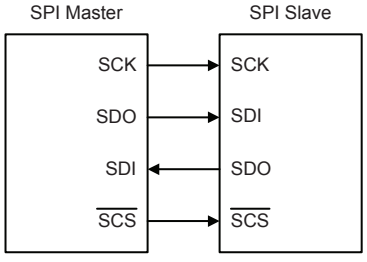
This SPI interface function, which is part of the Serial Interface Module, should not be confused with the other independent SPI function, which is described in another section of this datasheet.

The SPI interface is often used to communicate with external peripheral devices such as sensors, Flash or EEPROM memory devices etc. Originally developed by Motorola, the four line SPI interface is a synchronous serial data interface that has a relatively simple communication protocol simplifying the programming requirements when communicating with external hardware devices.

The communication is full duplex and operates as a slave/master type, where these devices can be either master or slave. Although the SPI interface specification can control multiple slave devices from a single master, but these devices provides only one $\overline{SCS}$ pin. If the master needs to control multiple slave devices from a single master, the master can use I/O pin to select the slave devices.

SPI Interface Operation

The SPI interface is a full duplex synchronous serial data link. It is a four line interface with pin names SDI, SDO, SCK and $\overline{SCS}$. Pins SDI and SDO are the Serial Data Input and Serial Data Output lines, the SCK pin is the Serial Clock line and $\overline{SCS}$ is the Slave Select line. As the SPI interface pins are pin-shared with normal I/O pins and with the I^2C function pins, the SPI interface pins must first be selected by configuring the pin-shared function selection bits and setting the correct bits in the SIMC0 and SIMC2 registers. Communication between devices connected to the SPI interface is carried out in a slave/master mode with all data transfer initiations being implemented by the master. The Master also controls the clock signal. As these devices only contain a single $\overline{SCS}$ pin only one slave device can be utilized. The $\overline{SCS}$ pin is controlled by software, set CSEN bit to 1 to enable $\overline{SCS}$ pin function, set CSEN bit to 0 the $\overline{SCS}$ pin will be floating state.

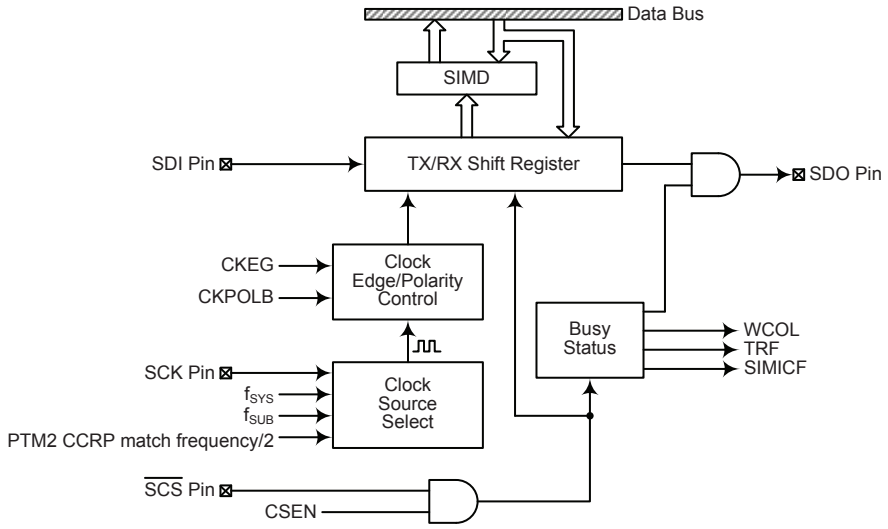


SPI Master/Slave Connection

The SPI function in these devices offer the following features:

- Full duplex synchronous data transfer
- Both Master and Slave modes
- LSB first or MSB first data transmission modes
- Transmission complete flag
- Rising or falling active clock edge

The status of the SPI interface pins is determined by a number of factors such as whether these devices are in the master or slave mode and upon the condition of certain control bits such as CSEN and SIMEN.



SPI Block Diagram

SPI Registers

There are three internal registers which control the overall operation of the SPI interface. These are the SIMD data register and two control registers, SIMC0 and SIMC2.

Register Name	Bit							
	7	6	5	4	3	2	1	0
SIMC0	SIM2	SIM1	SIM0	—	SIMDEB1	SIMDEB0	SIMEN	SIMICF
SIMC2	D7	D6	CKPOLB	CKEG	MLS	CSEN	WCOL	TRF
SIMD	D7	D6	D5	D4	D3	D2	D1	D0

SPI Registers List

- **SPI Data Register – SIMD Register**

The SIMD register is used to store the data being transmitted and received. The same register is used by both the SPI and I^2C functions. Before these devices write data to the SPI bus, the actual data to be transmitted must be placed in the SIMD register. After the data is received from the SPI bus, these devices can read it from the SIMD register. Any transmission or reception of data from the SPI bus must be made via the SIMD register.

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	x	x	x	x	x	x	x	x

"x": unknown

Bit 7~0 **D7~D0**: SIM data register bit 7~bit 0

- **SPI Control Registers – SIMC0 Register**

There are also two control registers for the SPI interface, SIMC0 and SIMC2. Note that the SIMC2 register also has the name SIMA which is used by the I²C function. The SIMC0 register is used to control the enable/disable function and to set the data transmission clock frequency. The SIMC2 register is used for other control functions such as LSB/MSB selection, write collision flag etc.

Bit	7	6	5	4	3	2	1	0
Name	SIM2	SIM1	SIM0	—	SIMDEB1	SIMDEB0	SIMEN	SIMICF
R/W	R/W	R/W	R/W	—	R/W	R/W	R/W	R/W
POR	1	1	1	—	0	0	0	0

Bit 7~5 **SIM2~SIM0**: SIM Operating Mode Control
000: SPI master mode; SPI clock is $f_{SYS}/4$
001: SPI master mode; SPI clock is $f_{SYS}/16$
010: SPI master mode; SPI clock is $f_{SYS}/64$
011: SPI master mode; SPI clock is f_{SUB}
100: SPI master mode; SPI clock is PTM2 CCRP match frequency/2
101: SPI slave mode
110: I²C slave mode
111: Unused mode
These bits setup the overall operating mode of the SIM function. As well as selecting if the I²C or SPI function, they are used to control the SPI Master/Slave selection and the SPI Master clock frequency. The SPI clock is a function of the system clock but can also be chosen to be sourced from PTM2 and f_{SUB}. If the SPI Slave Mode is selected then the clock will be supplied by an external Master device.

Bit 4 Unimplemented, read as "0"

Bit 3~2 **SIMDEB1~SIMDEB0**: I²C Debounce Time Selection
These bits are only available when the SIM is configured to operate in the I²C mode. Refer to the I²C register section.

Bit 1 **SIMEN**: SIM Enable Control
0: Disable
1: Enable
The bit is the overall on/off control for the SIM interface. When the SIMEN bit is cleared to zero to disable the SIM interface, the SDI, SDO, SCK and $\overline{SCS}$, or SDA and SCL lines will lose their SPI or I²C function and the SIM operating current will be reduced to a minimum value. When the bit is high the SIM interface is enabled. If the SIM is configured to operate as an SPI interface via the SIM2~SIM0 bits, the contents of the SPI control registers will remain at the previous settings when the SIMEN bit changes from low to high and should therefore be first initialised by the application program. If the SIM is configured to operate as an I²C interface via the SIM2~SIM0 bits and the SIMEN bit changes from low to high, the contents of the I²C control bits such as HTX and TXAK will remain at the previous settings and should therefore be first initialised by the application program while the relevant I²C flags such as HCF, HAAS, HBB, SRW and RXAK will be set to their default states.

Bit 0 **SIMICF**: SIM SPI Incomplete Flag
0: SIM SPI incomplete condition is not occurred
1: SIM SPI incomplete condition is occurred

This bit is only available when the SIM is configured to operate in an SPI slave mode. If the SPI operates in the slave mode with the SIMEN and CSEN bits both being set to 1 but the $\overline{SCS}$ line is pulled high by the external master device before the SPI data transfer is completely finished, the SIMICF bit will be set to 1 together with the TRF bit. When this condition occurs, the corresponding interrupt will occur if the interrupt function is enabled. However, the TRF bit will not be set to 1 if the SIMICF bit is set to 1 by software application program.

- **SPI Control Registers – SIMC2 Register**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	CKPOLB	CKEG	MLS	CSEN	WCOL	TRF
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~6 **D7~D6**: Undefined bits
These bits can be read or written by the application program.

Bit 5 **CKPOLB**: SPI clock line base condition selection
0: The SCK line will be high when the clock is inactive
1: The SCK line will be low when the clock is inactive
The CKPOLB bit determines the base condition of the clock line, if the bit is high, then the SCK line will be low when the clock is inactive. When the CKPOLB bit is low, then the SCK line will be high when the clock is inactive.

Bit 4 **CKEG**: SPI SCK clock active edge type selection
CKPOLB=0
0: SCK is high base level and data capture at SCK rising edge
1: SCK is high base level and data capture at SCK falling edge
CKPOLB=1
0: SCK is low base level and data capture at SCK falling edge
1: SCK is low base level and data capture at SCK rising edge
The CKEG and CKPOLB bits are used to setup the way that the clock signal outputs and inputs data on the SPI bus. These two bits must be configured before data transfer is executed otherwise an erroneous clock edge may be generated. The CKPOLB bit determines the base condition of the clock line, if the bit is high, then the SCK line will be low when the clock is inactive. When the CKPOLB bit is low, then the SCK line will be high when the clock is inactive. The CKEG bit determines active clock edge type which depends upon the condition of CKPOLB bit.

Bit 3 **MLS**: SPI data shift order
0: LSB first
1: MSB first
This is the data shift select bit and is used to select how the data is transferred, either MSB or LSB first. Setting the bit high will select MSB first and low for LSB first.

Bit 2 **CSEN**: SPI $\overline{SCS}$ pin control
0: Disable
1: Enable
The CSEN bit is used as an enable/disable for the $\overline{SCS}$ pin. If this bit is low, then the $\overline{SCS}$ pin will be disabled and placed into a floating condition. If the bit is high the $\overline{SCS}$ pin will be enabled and used as a select pin.

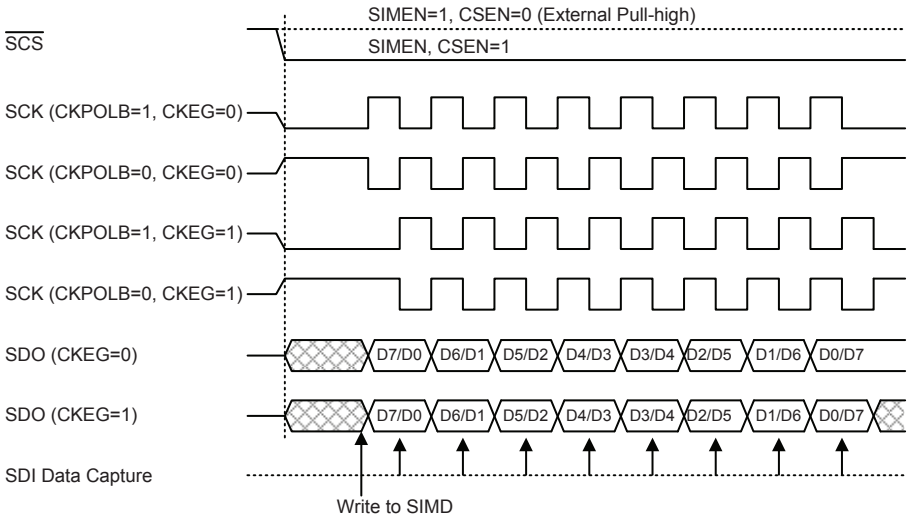
Bit 1 **WCOL**: SPI write collision flag
0: No collision
1: Collision
The WCOL flag is used to detect if a data collision has occurred. If this bit is high it means that data has been attempted to be written to the SIMD register during a data transfer operation. This writing operation will be ignored if data is being transferred. The bit can be cleared by the application program.

Bit 0 **TRF**: SPI Transmit/Receive complete flag
0: SPI data is being transferred
1: SPI data transmission is completed
The TRF bit is the Transmit/Receive Complete flag and is set "1" automatically when an SPI data transmission is completed, but must set to "0" by the application program. It can be used to generate an interrupt.

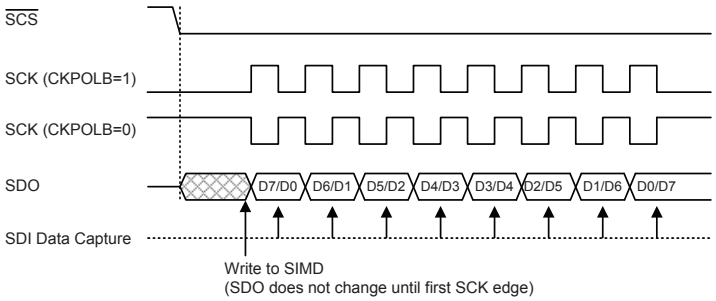
SPI Communication

After the SPI interface is enabled by setting the SIMEN bit high, then in the Master Mode, when data is written to the SIMD register, transmission/reception will begin simultaneously. When the data transfer is completed, the TRF flag will be set automatically, but must be cleared using the application program. In the Slave Mode, when the clock signal from the master has been received, any data in the SIMD register will be transmitted and any data on the SDI pin will be shifted into the SIMD register. The master should output an $\overline{SCS}$ signal to enable the slave devices before a clock signal is provided. The slave data to be transferred should be well prepared at the appropriate moment relative to the $\overline{SCS}$ signal depending upon the configurations of the CKPOLB bit and CKEG bit. The accompanying timing diagram shows the relationship between the slave data and $\overline{SCS}$ signal for various configurations of the CKPOLB and CKEG bits.

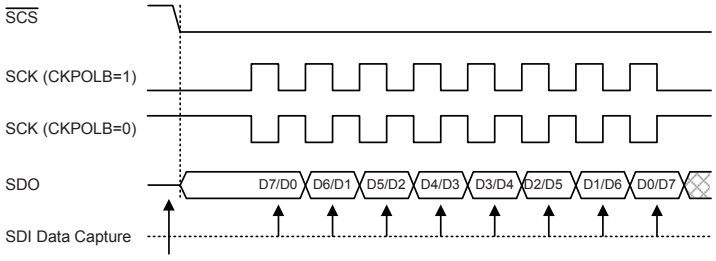
The SPI will continue to function in certain IDLE Modes if the clock source used by the SPI interface is still active.



SPI Master Mode Timing

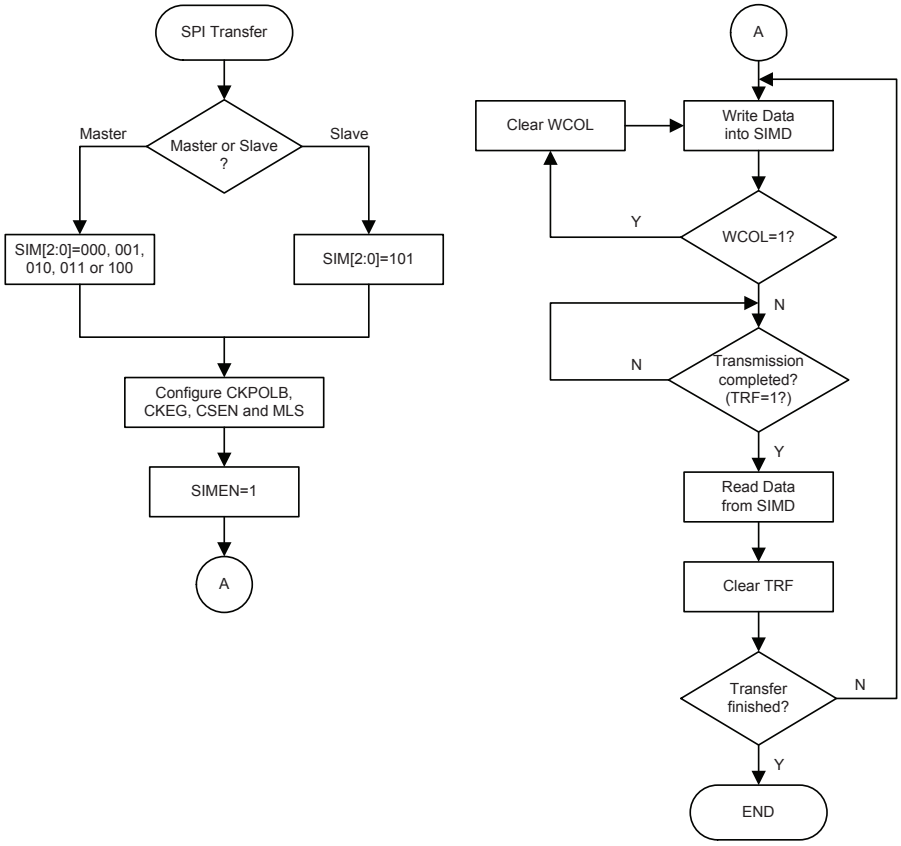


SPI Slave Mode Timing – CKEG=0



Note: For SPI slave mode, if SIMEN=1 and CSEN=0, SPI is always enabled and ignores the SCS level.

SPI Slave Mode Timing – CKEG=1



SPI Transfer Control Flowchart

SPI Bus Enable/Disable

To enable the SPI bus, set CSEN=1 and $\overline{SCS}$=0, then wait for data to be written into the SIMD (TXRX buffer) register. For the Master Mode, after data has been written to the SIMD (TXRX buffer) register, then transmission or reception will start automatically. When all the data has been transferred, the TRF bit should be set. For the Slave Mode, when clock pulses are received on SCK, data in the TXRX buffer will be shifted out or data on SDI will be shifted in.

When the SPI bus is disabled, SCK, SDI, SDO and $\overline{SCS}$ can become I/O pins or other pin-shared functions using the corresponding pin-shared control bits.

SPI Operation Steps

All communication is carried out using the 4-line interface for either Master or Slave Mode.

The CSEN bit in the SIMC2 register controls the overall function of the SPI interface. Setting this bit high will enable the SPI interface by allowing the $\overline{SCS}$ line to be active, which can then be used to control the SPI interface. If the CSEN bit is low, the SPI interface will be disabled and the $\overline{SCS}$ line will be in a floating condition and can therefore not be used for control of the SPI interface. If the CSEN bit and the SIMEN bit in the SIMC0 are set high, this will place the SDI line in a floating condition and the SDO line high. If in Master Mode the SCK line will be either high or low depending upon the clock polarity selection bit CKPOLB in the SIMC2 register. If in Slave Mode the SCK line will be in a floating condition. If the SIMEN bit is low, then the bus will be disabled and $\overline{SCS}$, SDI, SDO and SCK will all become I/O pins or the other functions using the corresponding pin-shared control bits. In the Master Mode the Master will always generate the clock signal. The clock and data transmission will be initiated after data has been written into the SIMD register. In the Slave Mode, the clock signal will be received from an external master device for both data transmission and reception. The following sequences show the order to be followed for data transfer in both Master and Slave Mode.

Master Mode

- Step 1
  Select the SPI Master mode and clock source using the SIM2~SIM0 bits in the SIMC0 control register.
- Step 2
  Setup the CSEN bit and setup the MLS bit to choose if the data is MSB or LSB first, this setting must be the same with the Slave devices.
- Step 3
  Setup the SIMEN bit in the SIMC0 control register to enable the SPI interface.
- Step 4
  For write operations: write the data to the SIMD register, which will actually place the data into the TXRX buffer. Then use the SCK and $\overline{SCS}$ lines to output the data. After this, go to step 5.
  For read operations: the data transferred in on the SDI line will be stored in the TXRX buffer until all the data has been received at which point it will be latched into the SIMD register.
- Step 5
  Check the WCOL bit if set high then a collision error has occurred so return to step 4. If equal to zero then go to the following step.
- Step 6
  Check the TRF bit or wait for a SPI serial bus interrupt.
- Step 7
  Read data from the SIMD register.

- Step 8
  Clear TRF.
- Step 9
  Go to step 4.

Slave Mode

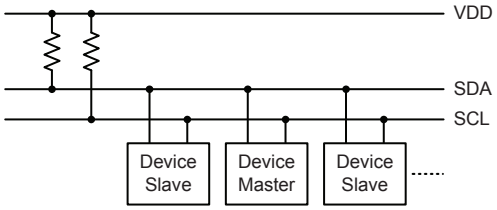
- Step 1
  Select the SPI Slave mode using the SIM2~SIM0 bits in the SIMC0 control register
- Step 2
  Setup the CSEN bit and setup the MLS bit to choose if the data is MSB or LSB first, this setting must be the same with the Master devices.
- Step 3
  Setup the SIMEN bit in the SIMC0 control register to enable the SPI interface.
- Step 4
  For write operations: write the data to the SIMD register, which will actually place the data into the TXRX buffer. Then wait for the master clock SCK and $\overline{SCS}$ signal. After this, go to step 5.
  For read operations: the data transferred in on the SDI line will be stored in the TXRX buffer until all the data has been received at which point it will be latched into the SIMD register.
- Step 5
  Check the WCOL bit if set high then a collision error has occurred so return to step 4. If equal to zero then go to the following step.
- Step 6
  Check the TRF bit or wait for a SPI serial bus interrupt.
- Step 7
  Read data from the SIMD register.
- Step 8
  Clear TRF.
- Step 9
  Go to step 4.

Error Detection

The WCOL bit in the SIMC2 register is provided to indicate errors during data transfer. The bit is set by the SPI serial Interface but must be cleared by the application program. This bit indicates that a data collision has occurred which happens if a write to the SIMD register takes place during a data transfer operation and will prevent the write operation from continuing.

I²C Interface

The I²C interface is used to communicate with external peripheral devices such as sensors, EEPROM memory etc. Originally developed by Philips, it is a two line low speed serial interface for synchronous serial data transfer. The advantage of only two lines for communication, relatively simple communication protocol and the ability to accommodate multiple devices on the same bus has made it an extremely popular interface type for many applications.

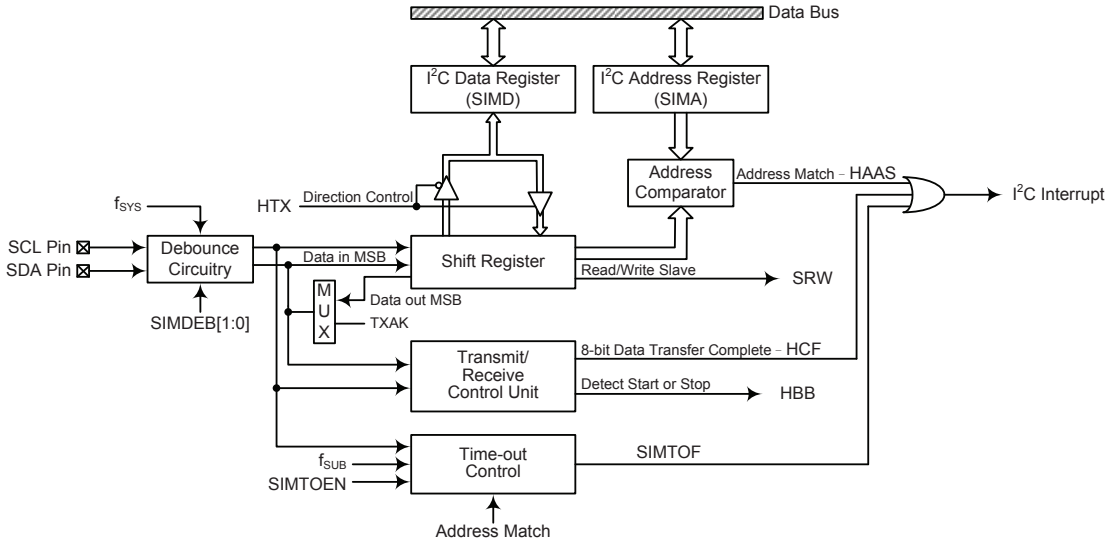


I²C Master Slave Bus Connection

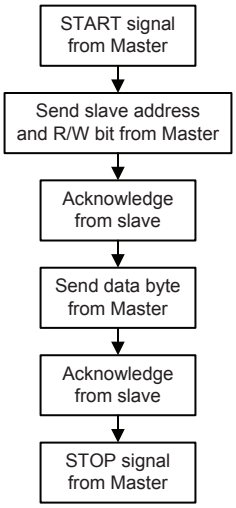
I²C Interface Operation

The I²C serial interface is a two line interface, a serial data line, SDA, and serial clock line, SCL. As many devices may be connected together on the same bus, their outputs are both open drain types. For this reason it is necessary that external pull-high resistors are connected to these outputs. Note that no chip select line exists, as each device on the I²C bus is identified by a unique address which will be transmitted and received on the I²C bus.

When two devices communicate with each other on the bidirectional I²C bus, one is known as the master device and one as the slave device. Both master and slave can transmit and receive data, however, it is the master device that has overall control of the bus. For these devices, which only operates in slave mode, there are two methods of transferring data on the I²C bus, the slave transmit mode and the slave receive mode. The pull-high control function pin-shared with SCL/SDA pin is still applicable even if I²C device is activated and the related internal pull-high register could be controlled by its corresponding pull-high control register.



I²C Block Diagram



The SIMDEB1 and SIMDEB0 bits determine the debounce time of the I²C interface. This uses the internal clock to in effect add a debounce time to the external clock to reduce the possibility of glitches on the clock line causing erroneous operation. The debounce time, if selected, can be chosen to be either 2 or 4 system clocks. To achieve the required I²C data transfer speed, there exists a relationship between the system clock, f_{SYS}, and the I²C debounce time. For either the I²C Standard or Fast mode operation, users must take care of the selected system clock frequency and the configured debounce time to match the criterion shown in the following table.

I²C Debounce Time Selection	I²C Standard Mode (100kHz)	I²C Fast Mode (400kHz)
No Debounce	f_{SYS} > 2MHz	f_{SYS} > 5MHz
2 system clock debounce	f_{SYS} > 4MHz	f_{SYS} > 10MHz
4 system clock debounce	f_{SYS} > 8MHz	f_{SYS} > 20MHz

I²C Minimum f_{SYS} Frequency

I²C Registers

There are three control registers associated with the I²C bus, SIMC0, SIMC1 and SIMTOC, one address register SIMA and one data register, SIMD.

Register Name	Bit							
	7	6	5	4	3	2	1	0
SIMC0	SIM2	SIM1	SIM0	—	SIMDEB1	SIMDEB0	SIMEN	SIMICF
SIMC1	HCF	HAAS	HBB	HTX	TXAK	SRW	IAMWU	RXAK
SIMD	D7	D6	D5	D4	D3	D2	D1	D0
SIMA	A6	A5	A4	A3	A2	A1	A0	D0
SIMTOC	SIMTOEN	SIMTOF	SIMTOS5	SIMTOS4	SIMTOS3	SIMTOS2	SIMTOS1	SIMTOS0

I²C Registers List

- **I²C Data Register – SIMD Register**

The SIMD register is used to store the data being transmitted and received. The same register is used by both the SPI and I²C functions. Before these devices write data to the I²C bus, the actual data to be transmitted must be placed in the SIMD register. After the data is received from the I²C bus, these devices can read it from the SIMD register. Any transmission or reception of data from the I²C bus must be made via the SIMD register.

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	x	x	x	x	x	x	x	x

"x": unknown

Bit 7~0 **D7~D0**: SIM data register bit 7~bit 0

- **I²C Address Register – SIMA Register**

The SIMA register is also used by the SPI interface but has the name SIMC2. The SIMA register is the location where the 7-bit slave address of the slave device is stored. Bits 7~1 of the SIMA register define these devices slave address. Bit 0 is not defined. When a master device, which is connected to the I²C bus, sends out an address, which matches the slave address in the SIMA register, the slave device will be selected. Note that the SIMA register is the same register address as SIMC2 which is used by the SPI interface.

Bit	7	6	5	4	3	2	1	0
Name	A6	A5	A4	A3	A2	A1	A0	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~1 **A6~A0**: I²C slave address
A6~A0 is the I²C slave address bit 6~bit 0.

Bit 0 **D0**: Reserved bit, can be read or written

- **I²C Control Registers – SIMC0 Register**

There are three control registers for the I²C interface, SIMC0, SIMC1 and SIMTOC. The SIMC0 register is used to control the enable/disable function and to set the data transmission clock frequency. The SIMC1 register contains the relevant flags which are used to indicate the I²C communication status. Another register, SIMTOC, is used to control the I²C time-out function and is described in the corresponding section.

Bit	7	6	5	4	3	2	1	0
Name	SIM2	SIM1	SIM0	—	SIMDEB1	SIMDEB0	SIMEN	SIMICF
R/W	R/W	R/W	R/W	—	R/W	R/W	R/W	R/W
POR	1	1	1	—	0	0	0	0

Bit 7~5 **SIM2~SIM0**: SIM Operating Mode Control
000: SPI master mode; SPI clock is $f_{SYS}/4$
001: SPI master mode; SPI clock is $f_{SYS}/16$
010: SPI master mode; SPI clock is $f_{SYS}/64$
011: SPI master mode; SPI clock is f_{SUB}
100: SPI master mode; SPI clock is PTM2 CCRP match frequency/2
101: SPI slave mode
110: I²C slave mode
111: Unused mode
These bits setup the overall operating mode of the SIM function. As well as selecting if the I²C or SPI function, they are used to control the SPI Master/Slave selection and the SPI Master clock frequency. The SPI clock is a function of the system clock but can also be chosen to be sourced from PTM2 and f_{SUB}. If the SPI Slave Mode is selected then the clock will be supplied by an external Master device.

Bit 4 Unimplemented, read as "0"

Bit 3~2 **SIMDEB1~SIMDEB0**: I²C Debounce Time Selection
00: No debounce
01: 2 system clock debounce
1x: 4 system clock debounce
These bits are used to select the I²C debounce time when the SIM is configured as the I²C interface function by setting the SIM2~SIM0 bits to "110".

Bit 1 **SIMEN**: SIM Enable Control
0: Disable
1: Enable
The bit is the overall on/off control for the SIM interface. When the SIMEN bit is cleared to zero to disable the SIM interface, the SDI, SDO, SCK and $\overline{SCS}$, or SDA and SCL lines will lose their SPI or I²C function and the SIM operating current will be reduced to a minimum value. When the bit is high the SIM interface is enabled. If the SIM is configured to operate as an SPI interface via the SIM2~SIM0 bits, the contents of the SPI control registers will remain at the previous settings when the SIMEN bit changes from low to high and should therefore be first initialised by the application program. If the SIM is configured to operate as an I²C interface via the SIM2~SIM0 bits and the SIMEN bit changes from low to high, the contents of the I²C control bits such as HTX and TXAK will remain at the previous settings and should therefore be first initialised by the application program while the relevant I²C flags such as HCF, HAAS, HBB, SRW and RXAK will be set to their default states.

Bit 0 **SIMICF**: SIM SPI Incomplete Flag
This bit is only available when the SIM is configured to operate in an SPI slave mode. Refer to the SPI register section.

- **I²C Control Registers – SIMC1 Register**

Bit	7	6	5	4	3	2	1	0
Name	HCF	HAAS	HBB	HTX	TXAK	SRW	IAMWU	RXAK
R/W	R	R	R	R/W	R/W	R	R/W	R
POR	1	0	0	0	0	0	0	1

Bit 7 **HCF**: I²C Bus data transfer completion flag
0: Data is being transferred
1: Completion of an 8-bit data transfer
The HCF flag is the data transfer flag. This flag will be zero when data is being transferred. Upon completion of an 8-bit data transfer the flag will go high and an interrupt will be generated.

Bit 6 **HAAS**: I²C Bus address match flag
0: Not address match
1: Address match
The HAAS flag is the address match flag. This flag is used to determine if the slave device address is the same as the master transmit address. If the addresses match then this bit will be high, if there is no match then the flag will be low.

Bit 5 **HBB**: I²C Bus busy flag
0: I²C Bus is not busy
1: I²C Bus is busy
The HBB flag is the I²C busy flag. This flag will be "1" when the I²C bus is busy which will occur when a START signal is detected. The flag will be set to "0" when the bus is free which will occur when a STOP signal is detected.

Bit 4 **HTX**: I²C slave device is transmitter or receiver selection
0: Slave device is the receiver
1: Slave device is the transmitter

Bit 3 **TXAK**: I²C Bus transmit acknowledge flag
0: Slave send acknowledge flag
1: Slave do not send acknowledge flag
The TXAK bit is the transmit acknowledge flag. After the slave device receipt of 8 bits of data, this bit will be transmitted to the bus on the 9th clock from the slave device. The slave device must always set TXAK bit to "0" before further data is received.

Bit 2 **SRW**: I²C Slave Read/Write flag
0: Slave device should be in receive mode
1: Slave device should be in transmit mode
The SRW flag is the I²C Slave Read/Write flag. This flag determines whether the master device wishes to transmit or receive data from the I²C bus. When the transmitted address and slave address is match, that is when the HAAS flag is set high, the slave device will check the SRW flag to determine whether it should be in transmit mode or receive mode. If the SRW flag is high, the master is requesting to read data from the bus, so the slave device should be in transmit mode. When the SRW flag is zero, the master will write data to the bus, therefore the slave device should be in receive mode to read this data.

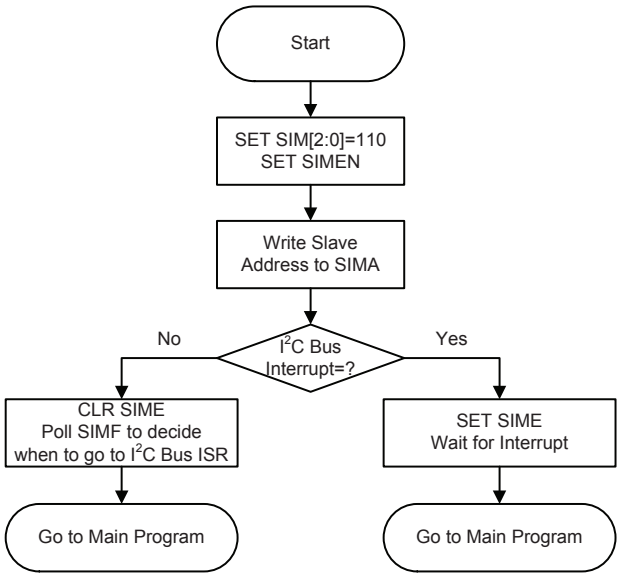
Bit 1 **IAMWU**: I²C Address Match Wake-up control
0: Disable
1: Enable
This bit should be set to 1 to enable the I²C address match wake up from the SLEEP or IDLE Mode. If the IAMWU bit has been set before entering either the SLEEP or IDLE mode to enable the I²C address match wake up, then this bit must be cleared by the application program after wake-up to ensure correction device operation.

Bit 0 **RXAK**: I²C Bus Receive acknowledge flag
0: Slave receive acknowledge flag
1: Slave does not receive acknowledge flag
The RXAK flag is the receiver acknowledge flag. When the RXAK flag is "0", it means that a acknowledge signal has been received at the 9th clock, after 8 bits of data have been transmitted. When the slave device in the transmit mode, the slave device checks the RXAK flag to determine if the master receiver wishes to receive the next byte. The slave transmitter will therefore continue sending out data until the RXAK flag is "1". When this occurs, the slave transmitter will release the SDA line to allow the master to send a STOP signal to release the I²C Bus.

I²C Bus Communication

Communication on the I²C bus requires four separate steps, a START signal, a slave device address transmission, a data transmission and finally a STOP signal. When a START signal is placed on the I²C bus, all devices on the bus will receive this signal and be notified of the imminent arrival of data on the bus. The first seven bits of the data will be the slave address with the first bit being the MSB. If the address of the slave device matches that of the transmitted address, the HAAS bit in the SIMC1 register will be set and an I²C interrupt will be generated. After entering the interrupt service routine, the slave device must first check the condition of the HAAS and SIMTOF bits to determine whether the interrupt source originates from an address match or from the completion of an 8-bit data transfer completion or from the I²C bus time-out occurrence. During a data transfer, note that after the 7-bit slave address has been transmitted, the following bit, which is the 8th bit, is the read/write bit whose value will be placed in the SRW bit. This bit will be checked by the slave device to determine whether to go into transmit or receive mode. Before any transfer of data to or from the I²C bus, the microcontroller must initialise the bus, the following are steps to achieve this:

- Step 1
  Set the SIM2~SIM0 and SIMEN bits in the SIMC0 register to "110" and "1" respectively to enable the I²C bus.
- Step 2
  Write the slave address of these devices to the I²C bus address register SIMA.
- Step 3
  Set the SIME interrupt enable bit of the interrupt control register to enable the SIM interrupt.



I²C Bus Initialisation Flow Chart

I²C Bus Start Signal

The START signal can only be generated by the master device connected to the I²C bus and not by the slave device. This START signal will be detected by all devices connected to the I²C bus. When detected, this indicates that the I²C bus is busy and therefore the HBB bit will be set. A START condition occurs when a high to low transition on the SDA line takes place when the SCL line remains high.

I²C Slave Address

The transmission of a START signal by the master will be detected by all devices on the I²C bus. To determine which slave device the master wishes to communicate with, the address of the slave device will be sent out immediately following the START signal. All slave devices, after receiving this 7-bit address data, will compare it with their own 7-bit slave address. If the address sent out by the master matches the internal address of the microcontroller slave device, then an internal I²C bus interrupt signal will be generated. The next bit following the address, which is the 8th bit, defines the read/write status and will be saved to the SRW bit of the SIMC1 register. The slave device will then transmit an acknowledge bit, which is a low level, as the 9th bit. The slave device will also set the status flag HAAS when the addresses match.

As an I²C bus interrupt can come from three sources, when the program enters the interrupt subroutine, the HAAS and SIMTOF bits should be examined to see whether the interrupt source has come from a matching slave address or from the completion of a data byte transfer or from the I²C bus time-out occurrence. When a slave address is matched, these devices must be placed in either the transmit mode and then write data to the SIMD register, or in the receive mode where it must implement a dummy read from the SIMD register to release the SCL line.

I²C Bus Read/Write Signal

The SRW bit in the SIMC1 register defines whether the master device wishes to read data from the I²C bus or write data to the I²C bus. The slave device should examine this bit to determine if it is to be a transmitter or a receiver. If the SRW flag is "1" then this indicates that the master device wishes to read data from the I²C bus, therefore the slave device must be setup to send data to the I²C bus as a transmitter. If the SRW flag is "0" then this indicates that the master wishes to send data to the I²C bus, therefore the slave device must be setup to read data from the I²C bus as a receiver.

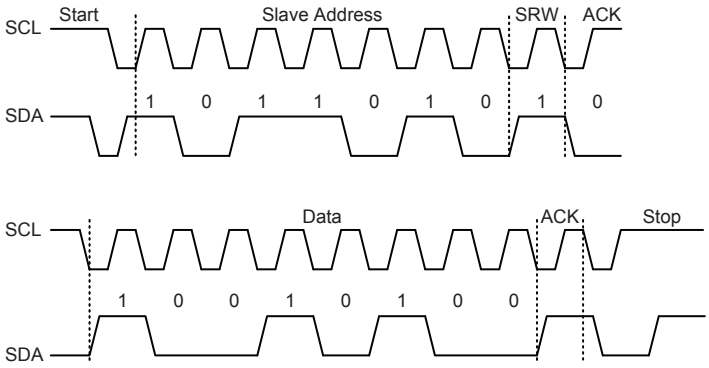
I²C Bus Slave Address Acknowledge Signal

After the master has transmitted a calling address, any slave device on the I²C bus, whose own internal address matches the calling address, must generate an acknowledge signal. The acknowledge signal will inform the master that a slave device has accepted its calling address. If no acknowledge signal is received by the master then a STOP signal must be transmitted by the master to end the communication. When the HAAS flag is high, the addresses have matched and the slave device must check the SRW flag to determine if it is to be a transmitter or a receiver. If the SRW flag is high, the slave device should be setup to be a transmitter so the HTX bit in the SIMC1 register should be set to "1". If the SRW flag is low, then the microcontroller slave device should be setup as a receiver and the HTX bit in the SIMC1 register should be set to "0".

I²C Bus Data and Acknowledge Signal

The transmitted data is 8-bit wide and is transmitted after the slave device has acknowledged receipt of its slave address. The order of serial bit transmission is the MSB first and the LSB last. After receipt of 8 bits of data, the receiver must transmit an acknowledge signal, level "0", before it can receive the next data byte. If the slave transmitter does not receive an acknowledge bit signal from the master receiver, then the slave transmitter will release the SDA line to allow the master to send a STOP signal to release the I²C Bus. The corresponding data will be stored in the SIMD register. If setup as a transmitter, the slave device must first write the data to be transmitted into the SIMD register. If setup as a receiver, the slave device must read the transmitted data from the SIMD register.

When the slave receiver receives the data byte, it must generate an acknowledge bit, known as TXAK, on the 9th clock. The slave device, which is setup as a transmitter will check the RXAK bit in the SIMC1 register to determine if it is to send another data byte, if not then it will release the SDA line and await the receipt of a STOP signal from the master.

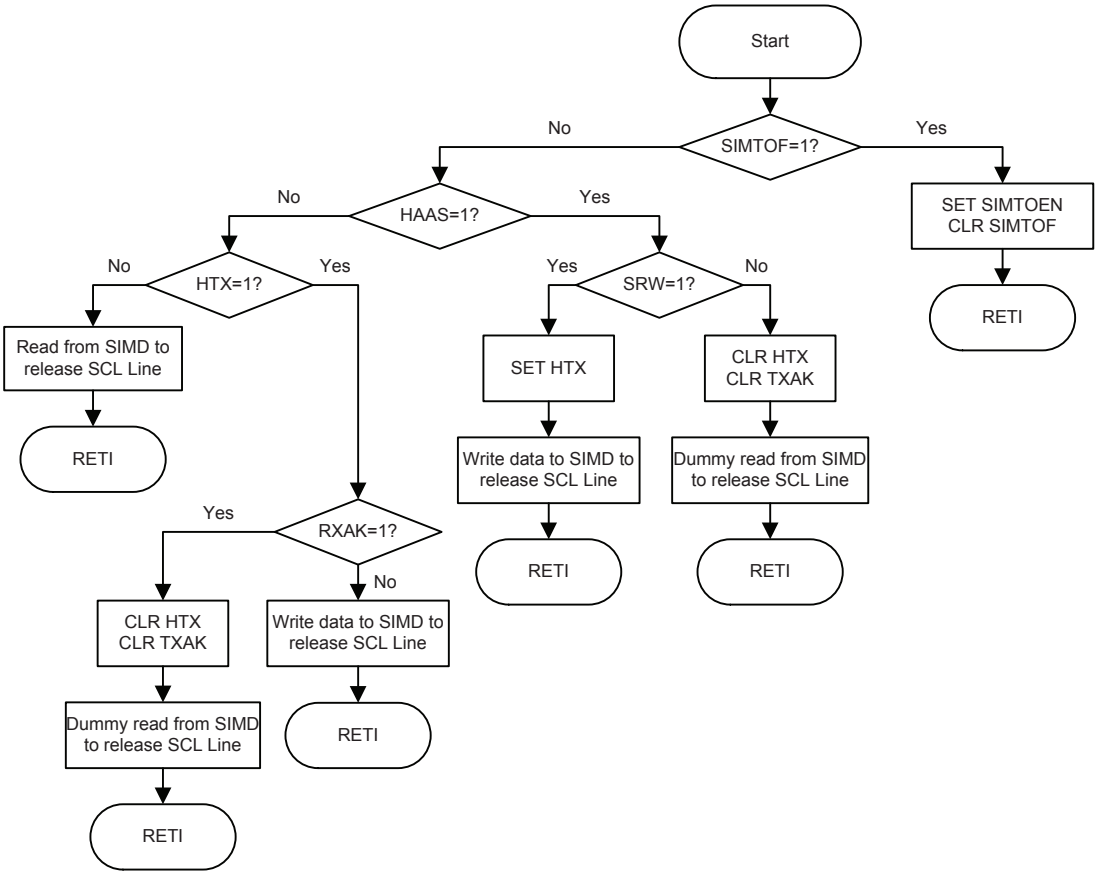


S=Start (1 bit)
SA=Slave Address (7 bits)
SR=SRW bit (1 bit)
M=Slave device send acknowledge bit (1 bit)
D=Data (8 bits)
A=ACK (RXAK bit for transmitter, TXAK bit for receiver, 1 bit)
P=Stop (1 bit)

S	SA	SR	M	D	A	D	A	·····	S	SA	SR	M	D	A	D	A	·····	P

I²C Communication Timing Diagram

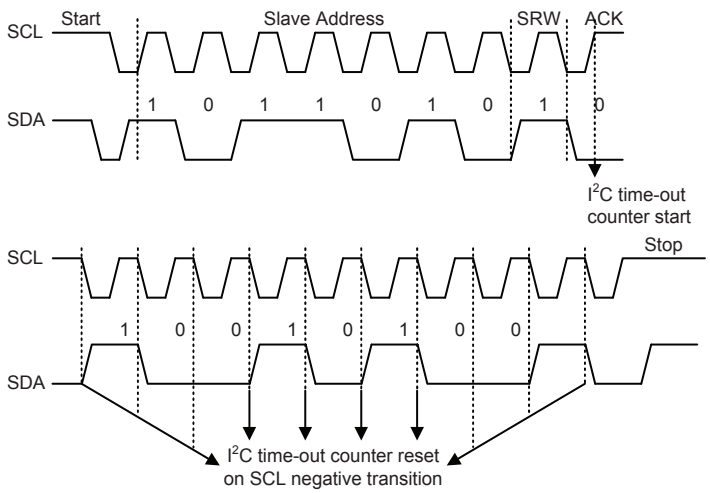
Note: When a slave address is matched, these devices must be placed in either the transmit mode and then write data to the SIMD register, or in the receive mode where it must implement a dummy read from the SIMD register to release the SCL line.



I²C Bus ISR Flow Chart

I²C Time-out Control

In order to reduce the problem of I²C lockup due to reception of erroneous clock sources, a time-out function is provided. If the clock source to the I²C is not received for a while, then the I²C circuitry and registers will be reset after a certain time-out period. The time-out counter starts counting on an I²C bus "START" & "address match" condition, and is cleared by an SCL falling edge. Before the next SCL falling edge arrives, if the time elapsed is greater than the time-out setup by the SIMTOC register, then a time-out condition will occur. The time-out function will stop when an I²C "STOP" condition occurs.



I²C Time-out

When an I²C time-out counter overflow occurs, the counter will stop and the SIMTOEN bit will be cleared to zero and the SIMTOF bit will be set high to indicate that a time-out condition has occurred. The time-out condition will also generate an interrupt which uses the I²C interrupt vector. When an I²C time-out occurs, the I²C internal circuitry will be reset and the registers will be reset into the following condition:

Registers	After I²C Time-out
SIMD, SIMA, SIMC0	No change
SIMC1	Reset to POR condition

I²C Registers after Time-out

The SIMTOF flag can be cleared by the application program. There are 64 time-out periods which can be selected using SIMTOS bit field in the SIMTOC register. The time-out time is given by the formula: ((1~64) × 32) / f_{SUB}. This gives a time-out period which ranges from about 1ms to 64ms.

- **SIMTOC Register**

Bit	7	6	5	4	3	2	1	0
Name	SIMTOEN	SIMTOF	SIMTOS5	SIMTOS4	SIMTOS3	SIMTOS2	SIMTOS1	SIMTOS0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7 **SIMTOEN**: SIM I²C Time-out control
0: Disable
1: Enable

Bit 6 **SIMTOF**: SIM I²C Time-out flag
0: No time-out occurred
1: Time-out occurred

Bit 5~0 **SIMTOS5~SIMTOS0**: SIM I²C Time-out period selection
I²C time-out clock source is f_{SUB}/32.
I²C time-out time is equal to (SIMTOS[5:0]+1) × (32/f_{SUB}).

Serial Peripheral Interface – SPIA

These devices contain an independent SPI function. It is important not to confuse this independent SPI function with the additional one contained within the combined SIM function, which is described in another section of this datasheet. This independent SPI function will carry the name SPIA to distinguish it from the other one in the SIM.

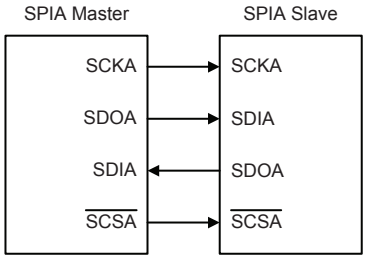
The SPIA interface is often used to communicate with external peripheral devices such as sensors, Flash or EEPROM memory devices etc. Originally developed by Motorola, the four line SPIA interface is a synchronous serial data interface that has a relatively simple communication protocol simplifying the programming requirements when communicating with external hardware devices.

The communication is full duplex and operates as a slave/master type, where these devices can be either master or slave. Although the SPIA interface specification can control multiple slave devices from a single master, however these devices are provided with only one $\overline{\text{SCSA}}$ pin. If the master needs to control multiple slave devices from a single master, the master can use I/O pins to select the slave devices.

SPIA Interface Operation

The SPIA interface is a full duplex synchronous serial data link. It is a four line interface with pin names SDIA, SDOA, SCKA and $\overline{\text{SCSA}}$. Pins SDIA and SDOA are the Serial Data Input and Serial Data Output lines, the SCKA pin is the Serial Clock line and $\overline{\text{SCSA}}$ is the Slave Select line. As the SPIA interface pins are pin-shared with normal I/O pins, the SPIA interface must first be enabled by configuring the corresponding selection bits in the pin-shared function selection registers. The SPIA can be disabled or enabled using the SPIAEN bit in the SPIAC0 register. Communication between devices connected to the SPIA interface is carried out in a slave/master mode with all data transfer initiations being implemented by the master. The Master also controls the clock signal. As these devices only contain a single $\overline{\text{SCSA}}$ pin only one slave device can be utilized.

The $\overline{\text{SCSA}}$ pin is controlled by the application program, set the SACSEN bit to "1" to enable the $\overline{\text{SCSA}}$ pin function and clear the SACSEN bit to "0" to place the $\overline{\text{SCSA}}$ pin into a floating state.

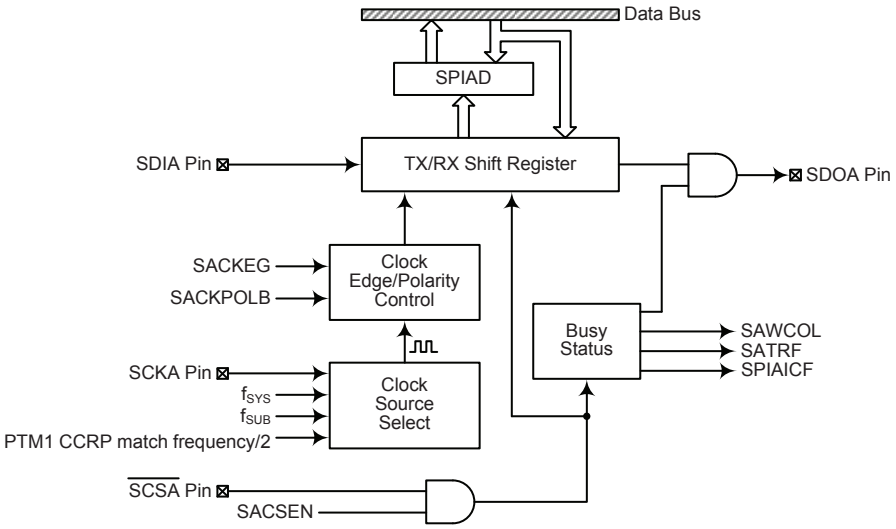


SPIA Master/Slave Connection

The SPIA function in these devices offer the following features:

- Full duplex synchronous data transfer
- Both Master and Slave modes
- LSB first or MSB first data transmission modes
- Transmission complete flag
- Rising or falling active clock edge

The status of the SPIA interface pins is determined by a number of factors such as whether these devices are in the master or slave mode and upon the condition of certain control bits such as SACSEN and SPIAEN.



SPIA Block Diagram

SPIA Registers

There are three internal registers which control the overall operation of the SPIA interface. These are the SPIAD data register and two registers, SPIAC0 and SPIAC1.

Register Name	Bit							
	7	6	5	4	3	2	1	0
SPIAC0	SASPI2	SASPI1	SASPI0	—	—	—	SPIAEN	SPIAICF
SPIAC1	—	—	SACKPOLB	SACKEG	SAMLS	SACSEN	SAWCOL	SATRF
SPIAD	D7	D6	D5	D4	D3	D2	D1	D0

SPIA Registers List

SPIA Data Register

The SPIAD register is used to store the data being transmitted and received. Before these devices write data to the SPIA bus, the actual data to be transmitted must be placed in the SPIAD register. After the data is received from the SPIA bus, these devices can read it from the SPIAD register. Any transmission or reception of data from the SPIA bus must be made via the SPIAD register.

- **SPIAD Register**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	x	x	x	x	x	x	x	x

"x": unknown

Bit 7~0 **D7~D0**: SPIA data register bit 7~bit 0

SPIA Control Registers

There are also two control registers for the SPIA interface, SPIAC0 and SPIAC1. The SPIAC0 register is used to control the enable/disable function and to set the data transmission clock frequency. The SPIAC1 register is used for other control functions such as LSB/MSB selection, write collision flag etc.

- **SPIAC0 Register**

Bit	7	6	5	4	3	2	1	0
Name	SASPI2	SASPI1	SASPI0	—	—	—	SPIAEN	SPIAICF
R/W	R/W	R/W	R/W	—	—	—	R/W	R/W
POR	1	1	1	—	—	—	0	0

Bit 7~5 **SASPI2~SASPI0**: SPIA Operating Mode Control
000: SPIA master mode; SPIA clock is $f_{SYS}/4$
001: SPIA master mode; SPIA clock is $f_{SYS}/16$
010: SPIA master mode; SPIA clock is $f_{SYS}/64$
011: SPIA master mode; SPIA clock is f_{SUB}
100: SPIA master mode; SPIA clock is PTM1 CCRP match frequency/2
101: SPIA slave mode
110: Unimplemented
111: Unimplemented
These bits are used to control the SPIA Master/Slave selection and the SPIA Master clock frequency. The SPIA clock is a function of the system clock but can also be chosen to be sourced from PTM1 and f_{SUB}. If the SPIA Slave Mode is selected then the clock will be supplied by an external Master device.

Bit 4~2 Unimplemented, read as "0"

Bit 1 **SPIAEN**: SPIA Enable Control
0: Disable
1: Enable
The bit is the overall on/off control for the SPIA interface. When the SPIAEN bit is cleared to zero to disable the SPIA interface, the SDIA, SDOA, SCKA and $\overline{SCSA}$ lines will lose their SPIA function and the SPIA operating current will be reduced to a minimum value. When the bit is high the SPIA interface is enabled.

Bit 0 **SPIAICF**: SPIA Incomplete Flag
0: SPIA incomplete condition is not occurred
1: SPIA incomplete condition is occured
This bit is only available when the SPIA is configured to operate in an SPIA slave mode. If the SPIA operates in the slave mode with the SPIAEN and SACSEN bits both being set to 1 but the $\overline{SCSA}$ line is pulled high by the external master device before the SPIA data transfer is completely finished, the SPIAICF bit will be set to 1 together with the SATRF bit. When this condition occurs, the corresponding interrupt will occur if the interrupt function is enabled. However, the SATRF bit will not be set to 1 if the SPIAICF bit is set to 1 by software application program.

- **SPIAC1 Register**

Bit	7	6	5	4	3	2	1	0
Name	—	—	SACKPOLB	SACKEG	SAMLS	SACSEN	SAWCOL	SATRF
R/W	—	—	R/W	R/W	R/W	R/W	R/W	R/W
POR	—	—	0	0	0	0	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5 **SACKPOLB**: SPIA clock line base condition selection
0: The SCKA line will be high when the clock is inactive
1: The SCKA line will be low when the clock is inactive
The SACKPOLB bit determines the base condition of the clock line, if the bit is high, then the SCKA line will be low when the clock is inactive. When the SACKPOLB bit is low, then the SCKA line will be high when the clock is inactive.

Bit 4 **SACKEG**: SPIA SCKA clock active edge type selection
SACKPOLB=0
0: SCKA has high base level with data capture on SCKA rising edge
1: SCKA has high base level with data capture on SCKA falling edge
SACKPOLB=1
0: SCKA has low base level with data capture on SCKA falling edge
1: SCKA has low base level with data capture on SCKA rising edge
The SACKEG and SACKPOLB bits are used to setup the way that the clock signal outputs and inputs data on the SPIA bus. These two bits must be configured before a data transfer is executed otherwise an erroneous clock edge may be generated. The SACKPOLB bit determines the base condition of the clock line, if the bit is high, then the SCKA line will be low when the clock is inactive. When the SACKPOLB bit is low, then the SCKA line will be high when the clock is inactive. The SACKEG bit determines active clock edge type which depends upon the condition of the SACKPOLB bit.

Bit 3 **SAMLS**: SPIA data shift order
0: LSB first
1: MSB first
This is the data shift select bit and is used to select how the data is transferred, either MSB or LSB first. Setting the bit high will select MSB first and low for LSB first.

Bit 2 **SACSEN**: SPIA $\overline{\text{SCSA}}$ pin control
0: Disable
1: Enable
The SACSEN bit is used as an enable/disable for the $\overline{\text{SCSA}}$ pin. If this bit is low, then the $\overline{\text{SCSA}}$ pin will be disabled and placed into a floating condition. If the bit is high the $\overline{\text{SCSA}}$ pin will be enabled and used as a select pin.

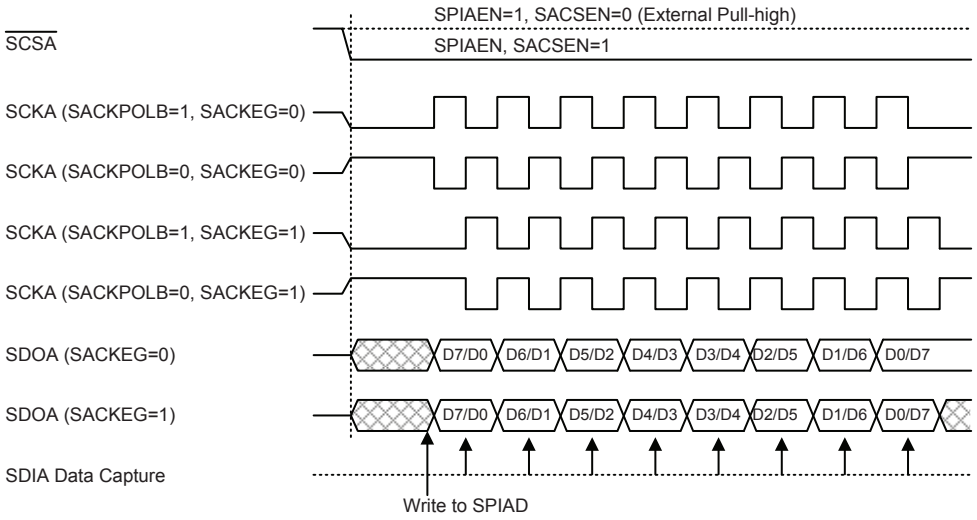
Bit 1 **SAWCOL**: SPIA write collision flag
0: No collision
1: Collision
The SAWCOL flag is used to detect if a data collision has occurred. If this bit is high it means that data has been attempted to be written to the SPIAD register during a data transfer operation. This writing operation will be ignored if data is being transferred. The bit can be cleared by the application program.

Bit 0 **SATRF**: SPIA Transmit/Receive complete flag
0: SPIA data is being transferred
1: SPIA data transmission is completed
The SATRF bit is the Transmit/Receive Complete flag and is set "1" automatically when an SPIA data transmission is completed, but must set to zero by the application program. It can be used to generate an interrupt.

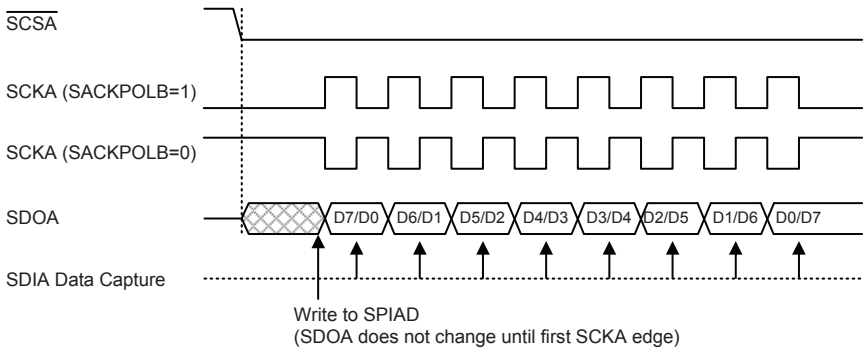
SPIA Communication

After the SPIA interface is enabled by setting the SPIAEN bit high, then in the Master Mode, when data is written to the SPIAD register, transmission/reception will begin simultaneously. When the data transfer is complete, the SATRF flag will be set automatically, but must be cleared using the application program. In the Slave Mode, when the clock signal from the master has been received, any data in the SPIAD register will be transmitted and any data on the SDIA pin will be shifted into the SPIAD register. The master should output an $\overline{SCSA}$ signal to enable the slave device before a clock signal is provided. The slave data to be transferred should be well prepared at the appropriate moment relative to the $\overline{SCSA}$ signal depending upon the configurations of the SACKPOLB bit and SACKEG bit. The accompanying timing diagram shows the relationship between the slave data and $\overline{SCSA}$ signal for various configurations of the SACKPOLB and SACKEG bits.

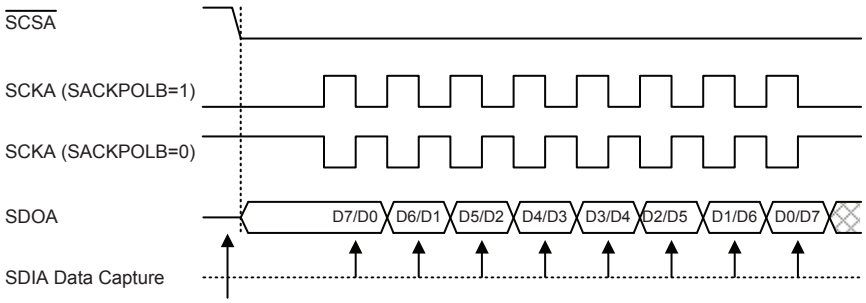
The SPIA will continue to function in certain IDLE Modes if the clock source used by the SPIA interface is still active.



SPIA Master Mode Timing

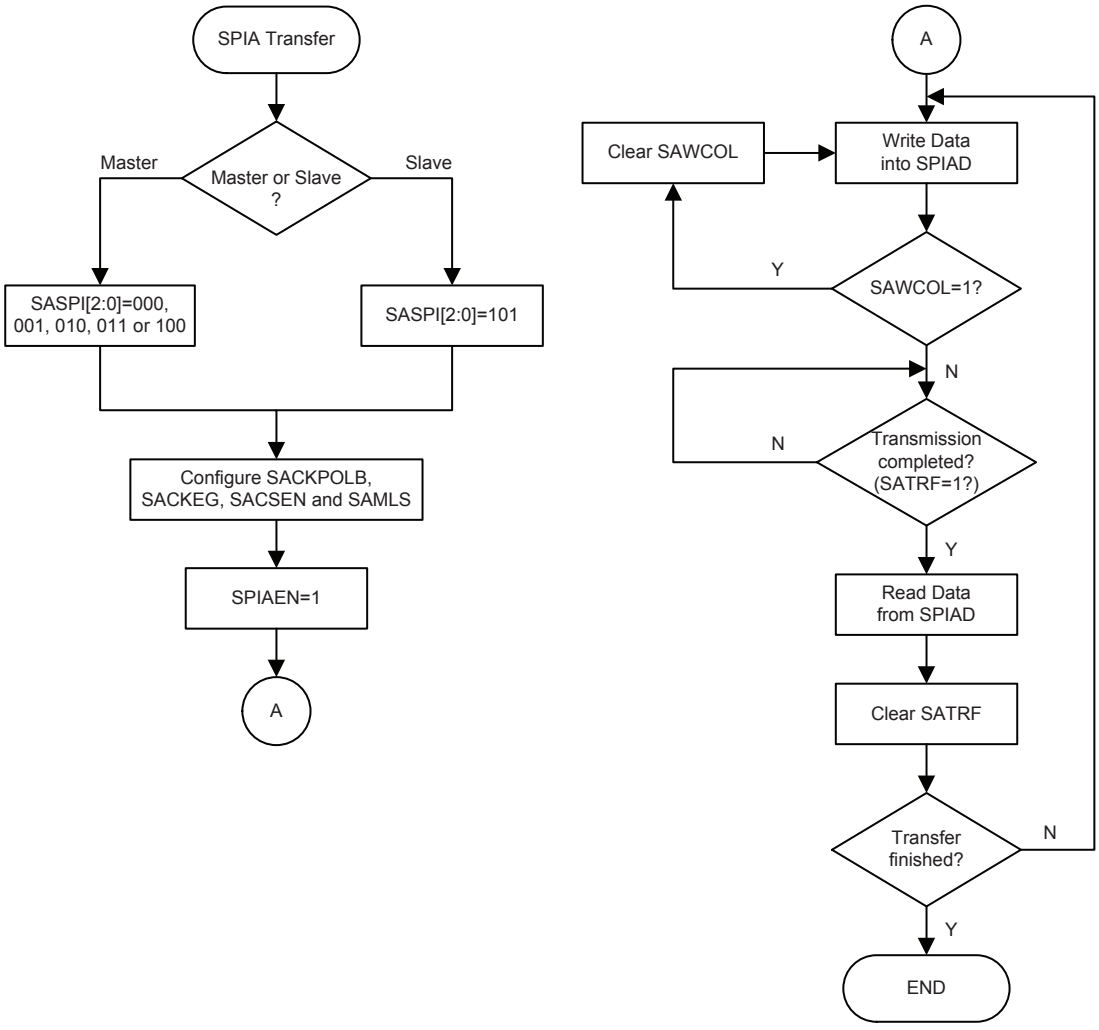


SPIA Slave Mode Timing – SACKEG=0



Note: For SPIA slave mode, if SPIAEN=1 and SACSEN=0, SPIA is always enabled and ignores the SCSA level.

SPIA Slave Mode Timing – SACKEG=1



SPIA Transfer Control Flowchart

SPIA Bus Enable/Disable

To enable the SPIA bus, set SACSEN=1 and $\overline{\text{SCSA}}$=0, then wait for data to be written into the SPIAD (TXRX buffer) register. For the Master Mode, after data has been written to the SPIAD (TXRX buffer) register, then transmission or reception will start automatically. When all the data has been transferred the SATRF bit should be set. For the Slave Mode, when clock pulses are received on SCKA, data in the TXRX buffer will be shifted out or data on SDIA will be shifted in.

When the SPIA bus is disabled, SCKA, SDIA, SDOA, $\overline{\text{SCSA}}$ can become I/O pins or other pin-shared functions using the corresponding pin-shared control bits.

SPIA Operation Steps

All communication is carried out using the 4-line interface for either Master or Slave Mode.

The SACSEN bit in the SPIAC1 register controls the overall function of the SPIA interface. Setting this bit high will enable the SPIA interface by allowing the $\overline{\text{SCSA}}$ line to be active, which can then be used to control the SPIA interface. If the SACSEN bit is low, the SPIA interface will be disabled and the $\overline{\text{SCSA}}$ line will be in a floating condition and can therefore not be used for control of the SPIA interface. If the SACSEN bit and the SPIAEN bit in the SPIAC0 register are set high, this will place the SDIA line in a floating condition and the SDOA line high. If in Master Mode the SCKA line will be either high or low depending upon the clock polarity selection bit SACKPOLB in the SPIAC1 register. If in Slave Mode the SCKA line will be in a floating condition. If SPIAEN is low then the bus will be disabled and $\overline{\text{SCSA}}$, SDIA, SDOA and SCKA will all become I/O pins or the other functions using the corresponding pin-shared control bits. In the Master Mode the Master will always generate the clock signal. The clock and data transmission will be initiated after data has been written into the SPIAD register. In the Slave Mode, the clock signal will be received from an external master device for both data transmission and reception. The following sequences show the order to be followed for data transfer in both Master and Slave Mode.

Master Mode

- Step 1
  Select the clock source and Master mode using the SASPI2~SASPI0 bits in the SPIAC0 control register.
- Step 2
  Setup the SACSEN bit and setup the SAMLS bit to choose if the data is MSB or LSB first, this must be same as the Slave device.
- Step 3
  Setup the SPIAEN bit in the SPIAC0 control register to enable the SPIA interface.
- Step 4
  For write operations: write the data to the SPIAD register, which will actually place the data into the TXRX buffer. Then use the SCKA and $\overline{\text{SCSA}}$ lines to output the data. After this go to step 5.
  For read operations: the data transferred in on the SDIA line will be stored in the TXRX buffer until all the data has been received at which point it will be latched into the SPIAD register.
- Step 5
  Check the SAWCOL bit if set high then a collision error has occurred so return to step 4. If equal to zero then go to the following step.

- Step 6
  Check the SATRF bit or wait for a SPIA serial bus interrupt.
- Step 7
  Read data from the SPIAD register.
- Step 8
  Clear SATRF.
- Step 9
  Go to step 4.

Slave Mode

- Step 1
  Select the SPIA Slave mode using the SASPI2~SASPI0 bits in the SPIAC0 control register.
- Step 2
  Setup the SACSEN bit and setup the SAMLS bit to choose if the data is MSB or LSB first, this setting must be the same with the Master device.
- Step 3
  Setup the SPIAEN bit in the SPIAC0 control register to enable the SPIA interface.
- Step 4
  For write operations: write the data to the SPIAD register, which will actually place the data into the TXRX buffer. Then wait for the master clock SCKA and $\overline{\text{SCSA}}$ signal. After this, go to step 5.
  For read operations: the data transferred in on the SDIA line will be stored in the TXRX buffer until all the data has been received at which point it will be latched into the SPIAD register.
- Step 5
  Check the SAWCOL bit if set high then a collision error has occurred so return to step 4. If equal to zero then go to the following step.
- Step 6
  Check the SATRF bit or wait for a SPIA serial bus interrupt.
- Step 7
  Read data from the SPIAD register.
- Step 8
  Clear SATRF.
- Step 9
  Go to step 4.

Error Detection

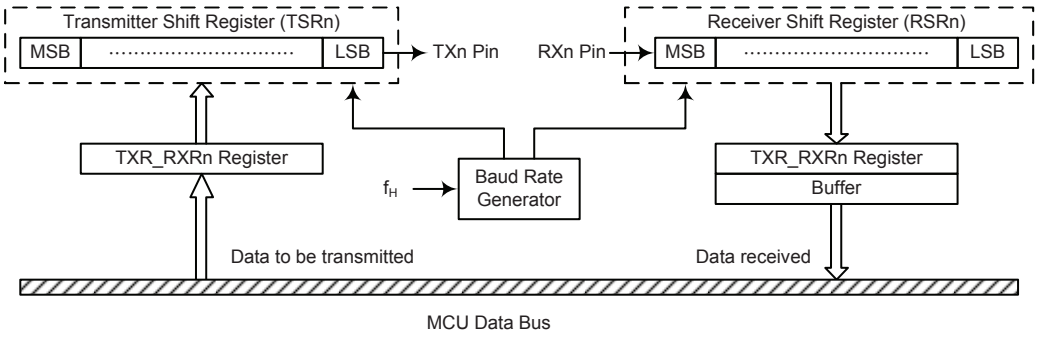
The SAWCOL bit in the SPIAC1 register is provided to indicate errors during data transfer. The bit is set by the SPIA serial Interface but must be cleared by the application program. This bit indicates a data collision has occurred which happens if a write to the SPIAD register takes place during a data transfer operation and will prevent the write operation from continuing.

UART Interfaces – UART0 & UART1

These devices contain up to two integrated full-duplex asynchronous serial communications UART interfaces that enable communication with external devices that contain a serial interface. Each UART function has many features and can transmit and receive data serially by transferring a frame of data with eight or nine data bits per transmission as well as being able to detect errors when the data is overwritten or incorrectly framed. Each UART function possesses its own internal interrupt which can be used to indicate when a reception occurs or when a transmission terminates.

The integrated UART functions contain the following features:

- Full-duplex, asynchronous communication
- 8 or 9 bits character length
- Even, odd or no parity options
- One or two stop bits
- Baud rate generator with 8-bit prescaler
- Parity, framing, noise and overrun error detection
- Support for interrupt on address detect (last character bit=1)
- Separately enabled transmitter and receiver
- 2-byte Deep FIFO Receive Data Buffer
- RXn pin wake-up function
- Transmit and receive interrupts
- Interrupts can be initialized by the following conditions:
  - Transmitter Empty
  - Transmitter Idle
  - Receiver Full
  - Receiver Overrun
  - Address Mode Detect



Note: n=0 for BH67F2260 while n=0~1 for BH67F2270.

UARTn Data Transfer Block Diagram (n=0 ~ 1)

UARTn External Pins

To communicate with an external serial interface, the internal UARTn has two external pins known as TXn and RXn. The TXn and RXn pins are the UART transmitter and receiver pins respectively. The TXn and RXn pin function should first be selected by the corresponding pin-shared function selection register before the UARTn function is used. Along with the UARTENn bit, the TXENn and RXENn bits, if set, will setup these pins to their respective TXn output and RXn input conditions and disable any pull-high resistor option which may exist on the TXn and RXn pins. When the TXn or RXn pin function is disabled by clearing the UARTENn, TXENn or RXENn bit, the TXn or RXn pin will be placed into a floating state. At this time whether the internal pull-high resistor is connected to the TXn or RXn pin or not is determined by the corresponding I/O pull-high function control bit.

UARTn Data Transfer Scheme

The above block diagram shows the overall data transfer structure arrangement for the UARTn. The actual data to be transmitted from the MCU is first transferred to the TXR_RXRn register by the application program. The data will then be transferred to the Transmit Shift Register from where it will be shifted out, LSB first, onto the TXn pin at a rate controlled by the Baud Rate Generator. Only the TXR_RXRn register is mapped onto the MCU Data Memory, the Transmit Shift Register is not mapped and is therefore inaccessible to the application program.

Data to be received by the UARTn is accepted on the external RXn pin, from where it is shifted in, LSB first, to the Receiver Shift Register at a rate controlled by the Baud Rate Generator. When the shift register is full, the data will then be transferred from the shift register to the internal TXR_RXRn register, where it is buffered and can be manipulated by the application program. Only the TXR_RXRn register is mapped onto the MCU Data Memory, the Receiver Shift Register is not mapped and is therefore inaccessible to the application program.

It should be noted that the actual register for data transmission and reception only exists as a single shared register in the Data Memory. This shared register known as the TXR_RXRn register is used for both data transmission and data reception.

UARTn Status and Control Registers

There are five control registers associated with the UARTn function. The UnSR, UnCR1 and UnCR2 registers control the overall function of the UARTn, while the BRGn register controls the Baud rate. The actual data to be transmitted and received on the serial interface is managed through the TXR_RXRn data register.

Register Name	Bit							
	7	6	5	4	3	2	1	0
UnSR	PERRn	NFn	FERRn	OERRn	RIDLEn	RXIFn	TIDLEn	TXIFn
UnCR1	UARTENn	BNOn	PRENn	PRTn	STOPSn	TXBRKn	RX8n	TX8n
UnCR2	TXENn	RXENn	BRGHn	ADDENn	WAKEn	RIEn	TIIEn	TEIEn
TXR_RXRn	TXRXn7	TXRXn6	TXRXn5	TXRXn4	TXRXn3	TXRXn2	TXRXn1	TXRXn0
BRGn	BRGn7	BRGn6	BRGn5	BRGn4	BRGn3	BRGn2	BRGn1	BRGn0

Note: n=0 for BH67F2260 while n=0~1 for BH67F2270.

UARTn Registers List (n=0 ~ 1)

UnSR register

The UnSR register is the status register for the UARTn, which can be read by the program to determine the present status of the UARTn. All flags within the UnSR register are read only. Further explanation on each of the flags is given below:

Bit	7	6	5	4	3	2	1	0
Name	PERRn	NFn	FERRn	OERRn	RIDLEn	RXIFn	TIDLEn	TXIFn
R/W	R	R	R	R	R	R	R	R
POR	0	0	0	0	1	0	1	1

Bit 7 **PERRn**: Parity error flag
0: No parity error is detected
1: Parity error is detected
The PERRn flag is the parity error flag. When this read only flag is "0", it indicates a parity error has not been detected. When the flag is "1", it indicates that the parity of the received word is incorrect. This error flag is applicable only if Parity mode (odd or even) is selected. The flag can also be cleared by a software sequence which involves a read to the status register UnSR followed by an access to the TXR_RXRn data register.

Bit 6 **NFn**: Noise flag
0: No noise is detected
1: Noise is detected
The NFn flag is the noise flag. When this read only flag is "0", it indicates no noise condition. When the flag is "1", it indicates that the UARTn has detected noise on the receiver input. The NFn flag is set during the same cycle as the RXIFn flag but will not be set in the case of as overrun. The NFn flag can be cleared by a software sequence which will involve a read to the status register UnSR followed by an access to the TXR_RXRn data register.

Bit 5 **FERRn**: Framing error flag
0: No framing error is detected
1: Framing error is detected
The FERRn flag is the framing error flag. When this read only flag is "0", it indicates that there is no framing error. When the flag is "1", it indicates that a framing error has been detected for the current character. The flag can also be cleared by a software sequence which will involve a read to the status register UnSR followed by an access to the TXR_RXRn data register.

Bit 4 **OERRn**: Overrun error flag
0: No overrun error is detected
1: Overrun error is detected
The OERRn flag is the overrun error flag which indicates when the receiver buffer has overflowed. When this read only flag is "0", it indicates that there is no overrun error. When the flag is "1", it indicates that an overrun error occurs which will inhibit further transfers to the TXR_RXRn receive data register. The flag is cleared by a software sequence, which is a read to the status register UnSR followed by an access to the TXR_RXRn data register.

Bit 3 **RIDLEn**: Receiver status
0: Data reception is in progress (Data being received)
1: No data reception is in progress (Receiver is idle)
The RIDLEn flag is the receiver status flag. When this read only flag is "0", it indicates that the receiver is between the initial detection of the start bit and the completion of the stop bit. When the flag is "1", it indicates that the receiver is idle. Between the completion of the stop bit and the detection of the next start bit, the RIDLEn bit is "1" indicating that the UARTn receiver is idle and the RXn pin stays in logic high condition.

Bit 2 **RXIFn**: Receive TXR_RXRn data register status
0: TXR_RXRn data register is empty
1: TXR_RXRn data register has available data
The RXIFn flag is the receive data register status flag. When this read only flag is "0", it indicates that the TXR_RXRn read data register is empty. When the flag is "1", it indicates that the TXR_RXRn read data register contains new data. When the contents of the shift register are transferred to the TXR_RXRn register, an interrupt is generated if RIEn=1 in the UnCR2 register. If one or more errors are detected in the received word, the appropriate receive-related flags NFn, FERRn, and/or PERRn are set within the same clock cycle. The RXIFn flag is cleared when the UnSR register is read with RXIFn set, followed by a read from the TXR_RXRn register, and if the TXR_RXRn register has no data available.

Bit 1 **TIDLEn**: Transmission idle
0: Data transmission is in progress (Data being transmitted)
1: No data transmission is in progress (Transmitter is idle)
The TIDLEn flag is known as the transmission complete flag. When this read only flag is "0", it indicates that a transmission is in progress. This flag will be set high when the TXIFn flag is "1" and when there is no transmit data or break character being transmitted. When TIDLEn is equal to "1", the TXn pin becomes idle with the pin state in logic high condition. The TIDLEn flag is cleared by reading the UnSR register with TIDLEn set and then writing to the TXR_RXRn register. The flag is not generated when a data character or a break is queued and ready to be sent.

Bit 0 **TXIFn**: Transmit TXR_RXRn data register status
0: Character is not transferred to the transmit shift register
1: Character has transferred to the transmit shift register (TXR_RXRn data register is empty)
The TXIFn flag is the transmit data register empty flag. When this read only flag is "0", it indicates that the character is not transferred to the transmitter shift register. When the flag is "1", it indicates that the transmitter shift register has received a character from the TXR_RXRn data register. The TXIFn flag is cleared by reading the UARTn status register (UnSR) with TXIFn set and then writing to the TXR_RXRn data register. Note that when the TXENn bit is set, the TXIFn flag bit will also be set since the transmit data register is not yet full.

UnCR1 register

The UnCR1 register together with the UnCR2 register are the two UARTn control registers that are used to set the various options for the UARTn function, such as overall on/off control, parity control, data transfer bit length etc. Further explanation on each of the bits is given below:

Bit	7	6	5	4	3	2	1	0
Name	UARTENn	BNOn	PRENn	PRTn	STOPSn	TXBRKn	RX8n	TX8n
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R	W
POR	0	0	0	0	0	0	x	0

"x": unknown

Bit 7 **UARTENn**: UARTn function enable control
0: Disable UARTn. TXn and RXn pins are in a floating state
1: Enable UARTn. TXn and RXn pins function as UARTn pins
The UARTENn bit is the UARTn enable bit. When this bit is equal to "0", the UARTn will be disabled and the RXn pin as well as the TXn pin will be in a floating state. When the bit is equal to "1", the UARTn will be enabled and the TXn and RXn pins will function as defined by the TXENn and RXENn enable control bits.
When the UARTn is disabled, it will empty the buffer so any character remaining in the buffer will be discarded. In addition, the value of the baud rate counter will be reset. If the UARTn is disabled, all error and status flags will be reset. Also the TXENn, RXENn, TXBRKn, RXIFn, OERRn, FERRn, PERRn and NFn bits will be

cleared, while the TIDLEn, TXIFn and RIDLEn bits will be set. Other control bits in UnCR1, UnCR2 and BRGn registers will remain unaffected. If the UARTn is active and the UARTENn bit is cleared, all pending transmissions and receptions will be terminated and the module will be reset as defined above. When the UARTn is re-enabled, it will restart in the same configuration.

Bit 6 **BNOn**: Number of data transfer bits selection
0: 8-bit data transfer
1: 9-bit data transfer

This bit is used to select the data length format, which can have a choice of either 8-bit or 9-bit format. When this bit is equal to "1", a 9-bit data length format will be selected. If the bit is equal to "0", then an 8-bit data length format will be selected. If 9-bit data length format is selected, then bits RX8n and TX8n will be used to store the 9th bit of the received and transmitted data respectively.

Bit 5 **PRENn**: Parity function enable control
0: Parity function is disabled
1: Parity function is enabled

This is the parity enable bit. When this bit is equal to "1", the parity function will be enabled. If the bit is equal to "0", then the parity function will be disabled.

Bit 4 **PRTn**: Parity type selection bit
0: Even parity for parity generator
1: Odd parity for parity generator

This bit is the parity type selection bit. When this bit is equal to "1", odd parity type will be selected. If the bit is equal to "0", then even parity type will be selected.

Bit 3 **STOPSn**: Number of Stop bits selection
0: One stop bit format is used
1: Two stop bits format is used

This bit determines if one or two stop bits are to be used. When this bit is equal to "1", two stop bits are used. If this bit is equal to "0", then only one stop bit is used.

Bit 2 **TXBRKn**: Transmit break character
0: No break character is transmitted
1: Break characters transmit

The TXBRKn bit is the Transmit Break Character bit. When this bit is "0", there are no break characters and the TXn pin operates normally. When the bit is "1", there are transmit break characters and the transmitter will send logic zeros. When this bit is equal to "1", after the buffered data has been transmitted, the transmitter output is held low for a minimum of a 13-bit length and until the TXBRKn bit is reset.

Bit 1 **RX8n**: Receive data bit 8 for 9-bit data transfer format (read only)

This bit is only used if 9-bit data transfers are used, in which case this bit location will store the 9th bit of the received data known as RX8n. The BNOn bit is used to determine whether data transfers are in 8-bit or 9-bit format.

Bit 0 **TX8n**: Transmit data bit 8 for 9-bit data transfer format (write only)

This bit is only used if 9-bit data transfers are used, in which case this bit location will store the 9th bit of the transmitted data known as TX8n. The BNOn bit is used to determine whether data transfers are in 8-bit or 9-bit format.

UnCR2 register

The UnCR2 register is the second of the two UARTn control registers and serves several purposes. One of its main functions is to control the basic enable/disable operation of the UARTn Transmitter and Receiver as well as enabling the various UARTn interrupt sources. The register also serves to control the baud rate speed, receiver wake-up enable and the address detect enable. Further explanation on each of the bits is given below:

Bit	7	6	5	4	3	2	1	0
Name	TXENn	RXENn	BRGHn	ADDENn	WAKEn	RIEn	TIIEn	TEIEn
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7 **TXENn**: UARTn Transmitter enabled control
0: UARTn transmitter is disabled
1: UARTn transmitter is enabled
The bit named TXENn is the Transmitter Enable Bit. When this bit is equal to "0", the transmitter will be disabled with any pending data transmissions being aborted. In addition the buffers will be reset. In this situation the TXn pin will be in a floating state.
If the TXENn bit is equal to "1" and the UARTENn bit is also equal to "1", the transmitter will be enabled and the TXn pin will be controlled by the UARTn. Clearing the TXENn bit during a transmission will cause the data transmission to be aborted and will reset the transmitter. If this situation occurs, the TXn pin will be in a floating state.

Bit 6 **RXENn**: UARTn Receiver enabled control
0: UARTn receiver is disabled
1: UARTn receiver is enabled
The bit named RXENn is the Receiver Enable Bit. When this bit is equal to "0", the receiver will be disabled with any pending data receptions being aborted. In addition the receive buffers will be reset. In this situation the RXn pin will be in a floating state. If the RXENn bit is equal to "1" and the UARTENn bit is also equal to "1", the receiver will be enabled and the RXn pin will be controlled by the UARTn. Clearing the RXENn bit during a reception will cause the data reception to be aborted and will reset the receiver. If this situation occurs, the RXn pin will be in a floating state.

Bit 5 **BRGHn**: Baud Rate speed selection
0: Low speed baud rate
1: High speed baud rate
The bit named BRGHn selects the high or low speed mode of the Baud Rate Generator. This bit, together with the value placed in the baud rate register BRGn, controls the Baud Rate of the UARTn. If this bit is equal to "1", the high speed mode is selected. If the bit is equal to "0", the low speed mode is selected.

Bit 4 **ADDENn**: Address detect function enable control
0: Address detect function is disabled
1: Address detect function is enabled
The bit named ADDENn is the address detect function enable control bit. When this bit is equal to "1", the address detect function is enabled. When it occurs, if the 8th bit, which corresponds to RX7n if BNOn=0 or the 9th bit, which corresponds to RX8n if BNOn=1, has a value of "1", then the received word will be identified as an address, rather than data. If the corresponding interrupt is enabled, an interrupt request will be generated each time the received word has the address bit set, which is the 8th or 9th bit depending on the value of BNOn. If the address bit known as the 8th or 9th bit of the received word is "0" with the address detect function being enabled, an interrupt will not be generated and the received data will be discarded.

Bit 3 **WAKEn**: RXn pin wake-up UARTn function enable control
0: RXn pin wake-up UARTn function is disabled
1: RXn pin wake-up UARTn function is enabled
This bit is used to control the wake-up UARTn function when a falling edge on the RXn pin occurs. Note that this bit is only available when the UARTn clock (f_H) is switched off. There will be no RXn pin wake-up UARTn function if the UARTn clock (f_H) exists. If the WAKEn bit is set to 1 as the UARTn clock (f_H) is switched off, a UARTn wake-up request will be initiated when a falling edge on the RXn pin occurs. When this request happens and the corresponding interrupt is enabled, an RXn pin wake-up UARTn interrupt will be generated to inform the MCU to wake up the UARTn function by switching on the UARTn clock (f_H) via the application program. Otherwise, the UARTn function can not resume even if there is a falling edge on the RXn pin when the WAKEn bit is cleared to 0.

Bit 2 **RIEn**: Receiver interrupt enable control
0: Receiver related interrupt is disabled
1: Receiver related interrupt is enabled
This bit enables or disables the receiver interrupt. If this bit is equal to "1" and when the receiver overrun flag OERRn or receive data available flag RXIFn is set, the UARTn interrupt request flag will be set. If this bit is equal to "0", the UARTn interrupt request flag will not be influenced by the condition of the OERRn or RXIFn flags.

Bit 1 **TIIEn**: Transmitter Idle interrupt enable control
0: Transmitter idle interrupt is disabled
1: Transmitter idle interrupt is enabled
This bit enables or disables the transmitter idle interrupt. If this bit is equal to "1" and when the transmitter idle flag TIDLEn is set, due to a transmitter idle condition, the UARTn interrupt request flag will be set. If this bit is equal to "0", the UARTn interrupt request flag will not be influenced by the condition of the TIDLEn flag.

Bit 0 **TEIEn**: Transmitter Empty interrupt enable control
0: Transmitter empty interrupt is disabled
1: Transmitter empty interrupt is enabled
This bit enables or disables the transmitter empty interrupt. If this bit is equal to "1" and when the transmitter empty flag TXIFn is set, due to a transmitter empty condition, the UARTn interrupt request flag will be set. If this bit is equal to "0", the UARTn interrupt request flag will not be influenced by the condition of the TXIFn flag.

TXR_RXRn register

Bit	7	6	5	4	3	2	1	0
Name	TXRXn7	TXRXn6	TXRXn5	TXRXn4	TXRXn3	TXRXn2	TXRXn1	TXRXn0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	x	x	x	x	x	x	x	x

"x": unknown

Bit 7~0 **TXRXn7~TXRXn0**: UARTn Transmit/Receive Data bit 7 ~ bit 0

BRGn Register

Bit	7	6	5	4	3	2	1	0
Name	BRGn7	BRGn6	BRGn5	BRGn4	BRGn3	BRGn2	BRGn1	BRGn0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	x	x	x	x	x	x	x	x

"x": unknown

Bit 7~0 **BRGn7~ BRGn0**: Baud Rate values

By programming the BRGHn bit in UnCR2 Register which allows selection of the related formula described above and programming the required value in the BRGn register, the required baud rate can be setup.

Note: Baud rate=f_H / [64 × (N+1)] if BRGHn=0.

Baud rate=f_H / [16 × (N+1)] if BRGHn=1.

Baud Rate Generator

To setup the speed of the serial data communication, the UARTn function contains its own dedicated baud rate generator. The baud rate is controlled by its own internal free running 8-bit timer, the period of which is determined by two factors. The first of these is the value placed in the baud rate register BRGn and the second is the value of the BRGHn bit with the control register UnCR2. The BRGHn bit decides if the baud rate generator is to be used in a high speed mode or low speed mode, which in turn determines the formula that is used to calculate the baud rate. The value N in the BRGn register which is used in the following baud rate calculation formula determines the division factor. Note that N is the decimal value placed in the BRGn register and has a range of between 0 and 255.

UnCR2 BRGHn Bit	0	1
Baud Rate (BR)	f_H / [64 (N+1)]	f_H / [16 (N+1)]

By programming the BRGHn bit which allows selection of the related formula and programming the required value in the BRGn register, the required baud rate can be setup. Note that because the actual baud rate is determined using a discrete value, N, placed in the BRGn register, there will be an error associated between the actual and requested value. The following example shows how the BRGn register value N and the error value can be calculated.

Calculating the Baud Rate and Error Values

For a clock frequency of 4MHz, and with BRGHn cleared to zero determine the BRGn register value N, the actual baud rate and the error value for a desired baud rate of 4800.

From the above table the desired baud rate BR = f_H / [64 (N+1)]

Re-arranging this equation gives N = [f_H / (BR×64)] - 1

Giving a value for N = [4000000 / (4800×64)] - 1 = 12.0208

To obtain the closest value, a decimal value of 12 should be placed into the BRGn register. This gives an actual or calculated baud rate value of BR = 4000000 / [64 × (12+1)] = 4808

Therefore the error is equal to (4808 - 4800) / 4800 = 0.16%

UARTn Setup and Control

For data transfer, the UARTn function utilizes a non-return-to-zero, more commonly known as NRZ, format. This is composed of one start bit, eight or nine data bits, and one or two stop bits. Parity is supported by the UARTn hardware, and can be setup to be even, odd or no parity. For the most common data format, 8 data bits along with no parity and one stop bit, denoted as 8, N, 1, is used as the default setting, which is the setting at power-on. The number of data bits and stop bits, along with the parity, are setup by programming the corresponding BNOn, PRTn, PRENn, and STOPSn bits in the UnCR1 register. The baud rate used to transmit and receive data is setup using the internal 8-bit baud rate generator, while the data is transmitted and received LSB first. Although the UARTn transmitter and receiver are functionally independent, they both use the same data format and baud rate. In all cases stop bits will be used for data transmission.

Enabling/Disabling the UARTn Interface

The basic on/off function of the internal UARTn function is controlled using the UARTENn bit in the UnCR1 register. If the UARTENn, TXENn and RXENn bits are set, then these two UARTn pins will act as normal TXn output pin and RXn input pin respectively. If no data is being transmitted on the TXn pin, then it will default to a logic high value.

Clearing the UARTENn bit will disable the TXn and RXn pins and allow these two pins to be used as normal I/O or other pin-shared functional pins by configuring the corresponding pin-shared control bits. When the UARTn function is disabled the buffer will be reset to an empty condition, at the same time discarding any remaining residual data. Disabling the UARTn will also reset the error and status flags with bits TXENn, RXENn, TXBRKn, RXIFn, OERRn, FERRn, PERRn and NFn being cleared while bits TIDLEn, TXIFn and RIDLEn will be set. The remaining control bits in the UnCR1, UnCR2 and BRGn registers will remain unaffected. If the UARTENn bit in the UnCR1 register is cleared while the UARTn is active, then all pending transmissions and receptions will be immediately suspended and the UARTn will be reset to a condition as defined above. If the UARTn is then subsequently re-enabled, it will restart again in the same configuration.

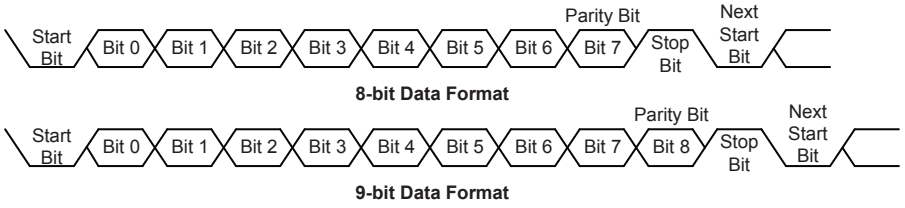
Data, Parity and Stop Bit Selection

The format of the data to be transferred is composed of various factors such as data bit length, parity on/off, parity type, address bits and the number of stop bits. These factors are determined by the setup of various bits within the UnCR1 register. The BNOn bit controls the number of data bits which can be set to either 8 or 9, the PRTn bit controls the choice of odd or even parity, the PRENn bit controls the parity on/off function and the STOPSn bit decides whether one or two stop bits are to be used. The following table shows various formats for data transmission. The address bit, which is the MSB of the data byte, identifies the frame as an address character or data if the address detect function is enabled. The number of stop bits, which can be either one or two, is independent of the data length and is only used for the transmitter. There is only one stop bit for the receiver.

Start Bit	Data Bits	Address Bit	Parity Bit	Stop Bit
Example of 8-bit Data Formats				
1	8	0	0	1
1	7	0	1	1
1	7	1	0	1
Example of 9-bit Data Formats				
1	9	0	0	1
1	8	0	1	1
1	8	1	0	1

Transmitter Receiver Data Format

The following diagram shows the transmit and receive waveforms for both 8-bit and 9-bit data formats.



UARTn Transmitter

Data word lengths of either 8 or 9 bits can be selected by programming the BNOn bit in the UnCR1 register. When BNOn bit is set, the word length will be set to 9 bits. In this case the 9th bit, which is the MSB, needs to be stored in the TX8n bit in the UnCR1 register. At the transmitter core lies the Transmitter Shift Register, more commonly known as the TSRn, whose data is obtained from the transmit data register, which is known as the TXR_RXRn register. The data to be transmitted is loaded into this TXR_RXRn register by the application program. The TSRn register is not written to with new data until the stop bit from the previous transmission has been sent out. As soon as this stop bit has been transmitted, the TSRn can then be loaded with new data from the TXR_RXRn register, if it is available. It should be noted that the TSRn register, unlike many other registers, is not directly mapped into the Data Memory area and as such is not available to the application program for direct read/write operations. An actual transmission of data will normally be enabled when the TXENn bit is set, but the data will not be transmitted until the TXR_RXRn register has been loaded with data and the baud rate generator has defined a shift clock source. However, the transmission can also be initiated by first loading data into the TXR_RXRn register, after which the TXENn bit can be set. When a transmission of data begins, the TSRn is normally empty, in which case a transfer to the TXR_RXRn register will result in an immediate transfer to the TSRn. If during a transmission the TXENn bit is cleared, the transmission will immediately cease and the transmitter will be reset. The TXn output pin can then be configured as the I/O or other pin-shared function by configuring the corresponding pin-shared control bits.

Transmitting Data

When the UARTn is transmitting data, the data is shifted on the TXn pin from the shift register, with the least significant bit first. In the transmit mode, the TXR_RXRn register forms a buffer between the internal bus and the transmitter shift register. It should be noted that if 9-bit data format has been selected, then the MSB will be taken from the TX8n bit in the UnCR1 register. The steps to initiate a data transfer can be summarized as follows:

- Make the correct selection of the BNOn, PRTn, PRENn and STOPSn bits to define the required word length, parity type and number of stop bits.
- Setup the BRGn register to select the desired baud rate.
- Set the TXENn bit to ensure that the TXn pin is used as a UARTn transmitter pin.
- Access the UnSR register and write the data that is to be transmitted into the TXR_RXRn register.

Note that this step will clear the TXIFn bit.

This sequence of events can now be repeated to send additional data.

It should be noted that when TXIFn=0, data will be inhibited from being written to the TXR_RXRn register. Clearing the TXIFn flag is always achieved using the following software sequence:

1. A UnSR register access

2. A TXR_RXRn register write execution

The read-only TXIFn flag is set by the UARTn hardware and if set indicates that the TXR_RXRn register is empty and that other data can now be written into the TXR_RXRn register without overwriting the previous data. If the TEIEn bit is set then the TXIFn flag will generate an interrupt.

During a data transmission, a write instruction to the TXR_RXRn register will place the data into the TXR_RXRn register, which will be copied to the shift register at the end of the present transmission. When there is no data transmission in progress, a write instruction to the TXR_RXRn register will place the data directly into the shift register, resulting in the commencement of data transmission, and the TXIFn bit being immediately set. When a frame transmission is complete, which happens after stop bits are sent or after the break frame, the TIDLEn bit will be set. To clear the TIDLEn bit the following software sequence is used:

1. A UnSR register access

2. A TXR_RXRn register write execution

Note that both the TXIFn and TIDLEn bits are cleared by the same software sequence.

Transmit Break

If the TXBRKn bit is set then break characters will be sent on the next transmission. Break character transmission consists of a start bit, followed by 13×N '0' bits and stop bits, where N=1, 2, etc. If a break character is to be transmitted then the TXBRKn bit must be first set by the application program, and then cleared to generate the stop bits. Transmitting a break character will not generate a transmit interrupt. Note that a break condition length is at least 13 bits long. If the TXBRKn bit is continually kept at a logic high level then the transmitter circuitry will transmit continuous break characters. After the application program has cleared the TXBRKn bit, the transmitter will finish transmitting the last break character and subsequently send out one or two stop bits. The automatic logic highs at the end of the last break character will ensure that the start bit of the next frame is recognized.

UARTn Receiver

The UARTn is capable of receiving word lengths of either 8 or 9 bits. If the BNOn bit is set, the word length will be set to 9 bits with the MSB being stored in the RX8n bit of the UnCR1 register. At the receiver core lies the Receive Serial Shift Register, commonly known as the RSRn. The data which is received on the RXn external input pin is sent to the data recovery block. The data recovery block operating speed is 16 times that of the baud rate, while the main receive serial shifter operates at the baud rate. After the RXn pin is sampled for the stop bit, the received data in RSRn is transferred to the receive data register, if the register is empty. The data which is received on the external RXn input pin is sampled three times by a majority detect circuit to determine the logic level that has been placed onto the RXn pin. It should be noted that the RSRn register, unlike many other registers, is not directly mapped into the Data Memory area and as such is not available to the application program for direct read/write operations.

Receiving Data

When the UARTn receiver is receiving data, the data is serially shifted in on the external RXn input pin, LSB first. In the read mode, the TXR_RXRn register forms a buffer between the internal bus and the receiver shift register. The TXR_RXRn register is a two byte deep FIFO data buffer, where two bytes can be held in the FIFO while a third byte can continue to be received. Note that the application program must ensure that the data is read from TXR_RXRn before the third byte has been completely shifted in, otherwise this third byte will be discarded and an overrun error OERRn

will be subsequently indicated. The steps to initiate a data transfer can be summarized as follows:

- Make the correct selection of BNOn, PRTn and PRENn bits to define the word length, parity type.
- Setup the BRGn register to select the desired baud rate.
- Set the RXENn bit to ensure that the RXn pin is used as a UARTn receiver pin.

At this point the receiver will be enabled which will begin to look for a start bit.

When a character is received the following sequence of events will occur:

- The RXIFn bit in the UnSR register will be set when the TXR_RXRn register has data available. There will be at most one more character available before an overrun error occurs.
- When the contents of the shift register have been transferred to the TXR_RXRn register, then if the RIEn bit is set, an interrupt will be generated.
- If during reception, a frame error, noise error, parity error, or an overrun error has been detected, then the error flags can be set.

The RXIFn bit can be cleared using the following software sequence:

1. A UnSR register access
2. A TXR_RXRn register read execution

Receive Break

Any break character received by the UARTn will be managed as a framing error. The receiver will count and expect a certain number of bit times as specified by the values programmed into the BNOn bit plus one stop bit. If the break is much longer than 13 bit times, the reception will be considered as complete after the number of bit times specified by BNOn plus one stop bit. The RXIFn bit is set, FERRn is set, zeros are loaded into the receive data register, interrupts are generated if appropriate and the RIDLEn bit is set. A break is regarded as a character that contains only zeros with the FERRn flag set. If a long break signal has been detected, the receiver will regard it as a data frame including a start bit, data bits and the invalid stop bit and the FERRn flag will be set. The receiver must wait for a valid stop bit before looking for the next start bit. The receiver will not make the assumption that the break condition on the line is the next start bit. The break character will be loaded into the buffer and no further data will be received until stop bits are received. It should be noted that the RIDLEn read only flag will go high when the stop bits have not yet been received. The reception of a break character on the UARTn registers will result in the following:

- The framing error flag, FERRn, will be set.
- The receive data register, TXR_RXRn, will be cleared.
- The OERRn, NFn, PERRn, RIDLEn or RXIFn flags will possibly be set.

Idle Status

When the receiver is reading data, which means it will be in between the detection of a start bit and the reading of a stop bit, the receiver status flag in the UnSR register, otherwise known as the RIDLEn flag, will have a zero value. In between the reception of a stop bit and the detection of the next start bit, the RIDLEn flag will have a high value, which indicates the receiver is in an idle condition.

Receiver Interrupt

The read only receive interrupt flag RXIFn in the UnSR register is set by an edge generated by the receiver. An interrupt is generated if RIEn=1, when a word is transferred from the Receive Shift Register, RSRn, to the Receive Data Register, TXR_RXRn. An overrun error can also generate an interrupt if RIEn=1.

Managing Receiver Errors

Several types of reception errors can occur within the UARTn module, the following section describes the various types and how they are managed by the UARTn.

Overrun Error – OERRn

The TXR_RXRn register is composed of a two byte deep FIFO data buffer, where two bytes can be held in the FIFO register, while a third byte can continue to be received. Before this third byte has been entirely shifted in, the data should be read from the TXR_RXRn register. If this is not done, the overrun error flag OERRn will be consequently indicated.

In the event of an overrun error occurring, the following will happen:

- The OERRn flag in the UnSR register will be set.
- The TXR_RXRn contents will not be lost.
- The shift register will be overwritten.
- An interrupt will be generated if the RIEn bit is set.

The OERRn flag can be cleared by an access to the UnSR register followed by a read to the TXR_RXRn register.

Noise Error – NFn

Over-sampling is used for data recovery to identify valid incoming data and noise. If noise is detected within a frame the following will occur:

- The read only noise flag, NFn, in the UnSR register will be set on the rising edge of the RXIFn bit.
- Data will be transferred from the Shift register to the TXR_RXRn register.
- No interrupt will be generated. However this bit rises at the same time as the RXIFn bit which itself generates an interrupt.

Note that the NFn flag is reset by an UnSR register read operation followed by a TXR_RXRn register read operation.

Framing Error – FERRn

The read only framing error flag, FERRn, in the UnSR register, is set if a zero is detected instead of stop bits. If two stop bits are selected, both stop bits must be high; otherwise the FERRn flag will be set. The FERRn flag and the received data will be recorded in the UnSR and TXR_RXRn registers respectively, and the flag is cleared in any reset.

Parity Error – PERRn

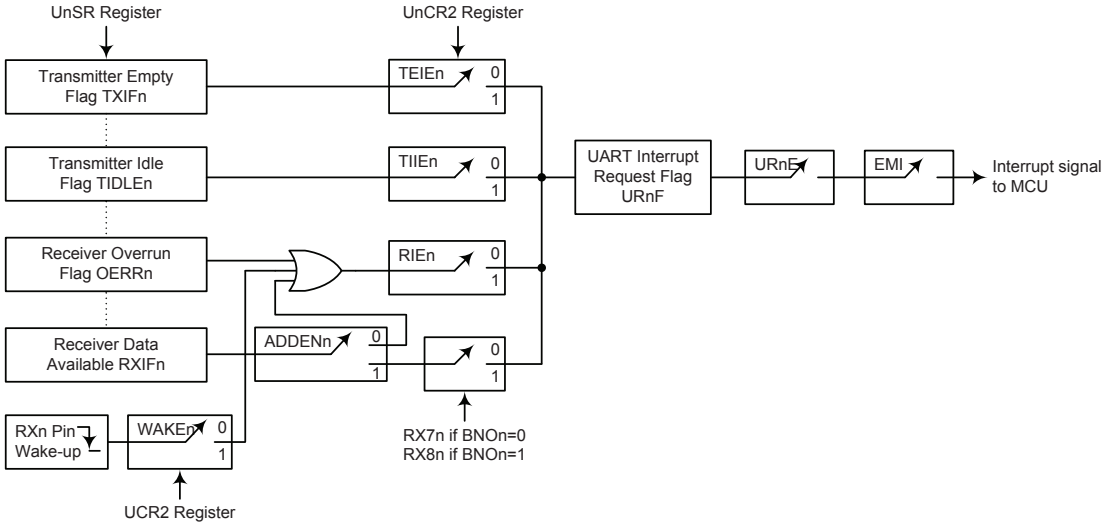
The read only parity error flag, PERRn, in the UnSR register, is set if the parity of the received word is incorrect. This error flag is only applicable if the parity is enabled, PRENn = 1, and if the parity type, odd or even is selected. The read only PERRn flag and the received data will be recorded in the UnSR and TXR_RXRn registers respectively. It is cleared on any reset, it should be noted that the flags, FERRn and PERRn, in the UnSR register should first be read by the application program before reading the data word.

UARTn Interrupt Structure

Several individual UARTn conditions can generate a UARTn interrupt. When these conditions exist, a low pulse will be generated to get the attention of the microcontroller. These conditions are a transmitter data register empty, transmitter idle, receiver data available, receiver overrun, address detect and an RXn pin wake-up. When any of these conditions are created, if the global interrupt enable bit, multi-function interrupt enable bit and its corresponding interrupt control bit are enabled and the stack is not full, the program will jump to its corresponding interrupt vector where it can be serviced before returning to the main program. Four of these conditions have the corresponding UnSR register flags which will generate a UARTn interrupt if its associated interrupt enable control bit in the UnCR2 register is set. The two transmitter interrupt conditions have their own corresponding enable control bits, while the two receiver interrupt conditions have a shared enable control bit. These enable bits can be used to mask out individual UARTn interrupt sources.

The address detect condition, which is also a UARTn interrupt source, does not have an associated flag, but will generate a UARTn interrupt when an address detect condition occurs if its function is enabled by setting the ADDENn bit in the UnCR2 register. An RXn pin wake-up, which is also a UARTn interrupt source, does not have an associated flag, but will generate a UARTn interrupt if the UARTn clock (f_H) source is switched off and the WAKEn and RIEn bits in the UnCR2 register are set when a falling edge on the RXn pin occurs.

Note that the UnSR register flags are read only and cannot be cleared or set by the application program, neither will they be cleared when the program jumps to the corresponding interrupt servicing routine, as is the case for some of the other interrupts. The flags will be cleared automatically when certain actions are taken by the UARTn, the details of which are given in the UARTn register section. The overall UARTn interrupt can be disabled or enabled by the related interrupt enable control bits in the interrupt control registers of the microcontroller to decide whether the interrupt requested by the UARTn module is masked out or allowed.



UARTn Interrupt Structure

Address Detect Mode

Setting the Address Detect Mode bit, ADDENn, in the UnCR2 register, enables this special mode. If this bit is enabled then an additional qualifier will be placed on the generation of a Receiver Data Available interrupt, which is requested by the RXIFn flag. If the ADDENn bit is enabled, then when data is available, an interrupt will only be generated, if the highest received bit has a high value. Note that the URnE and EMI interrupt enable bits must also be enabled for correct interrupt generation. This highest address bit is the 9th bit if BNOn=1 or the 8th bit if BNOn=0. If this bit is high, then the received word will be defined as an address rather than data. A Data Available interrupt will be generated every time the last bit of the received word is set. If the ADDENn bit is not enabled, then a Receiver Data Available interrupt will be generated each time the RXIFn flag is set, irrespective of the data last bit status. The address detect mode and parity enable are mutually exclusive functions. Therefore if the address detect mode is enabled, then to ensure correct operation, the parity function should be disabled by resetting the parity enable bit PRENn to zero.

ADDENn	Bit 9 if BNOn=1, Bit 8 if BNOn=0	UARTn Interrupt Generated
0	0	√
	1	√
1	0	×
	1	√

ADDENn Bit Function

UARTn Power Down and Wake-up

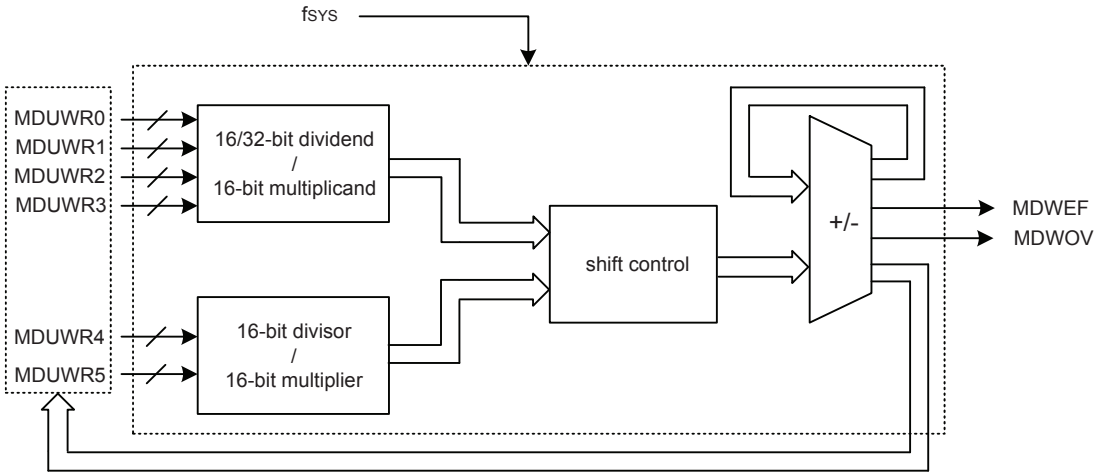
When the UARTn clock (f_H) is off, the UARTn will cease to function, all clock sources to the module are shutdown. If the UARTn clock (f_H) is off while a transmission is still in progress, then the transmission will be paused until the UARTn clock source derived from the microcontroller is activated. In a similar way, if the MCU enters the Power Down Mode while receiving data, then the reception of data will likewise be paused. When the MCU enters the Power Down Mode, note that the UnSR, UnCR1, UnCR2, transmit and receive registers, as well as the BRGn register will not be affected. It is recommended to make sure first that the UARTn data transmission or reception has been finished before the microcontroller enters the Power Down mode.

The UARTn function contains a receiver RXn pin wake-up function, which is enabled or disabled by the WAKEn bit in the UnCR2 register. If this bit, along with the UARTn enable bit, UARTENn, the receiver enable bit, RXENn and the receiver interrupt bit, RIEn, are all set when the UARTn clock (f_H) is off, then a falling edge on the RXn pin will trigger an RXn pin wake-up UARTn interrupt. Note that as it takes certain system clock cycles after a wake-up, before normal microcontroller operation resumes, any data received during this time on the RXn pin will be ignored.

For a UARTn wake-up interrupt to occur, in addition to the bits for the wake-up being set, the global interrupt enable bit, EMI, and the UARTn interrupt enable bit, URnE, must be set. If the EMI and URnE bits are not set then only a wake up event will occur and no interrupt will be generated. Note also that as it takes certain system clock cycles after a wake-up before normal microcontroller resumes, the UARTn interrupt will not be generated until after this time has elapsed.

16-bit Multiplication Division Unit – MDU

The 16-bit MDU (Multiplication Division Unit) is a 16-bit unsigned multiplier and a 32-bit/16-bit unsigned divider. Executing a 16-bit multiplication operation only requires 11 f_{SYS} clock cycles while executing a 16-bit division only requires 9 f_{SYS} clock cycles. Executing a 32-bit/16-bit division only requires 17 f_{SYS} clock cycles. The MDU, in replacing software multiplication and division operations, can therefore save large amounts of computing time as well as Program Memory and Data Memory space. This reduces the overall load on the microcontroller with resulting improvements to the overall system performance.



16-Bit MDU Block Diagram

Multiplication Division Unit Operation

Whether the MDU is used for multiplication or division operation is determined by the writing order to the registers MDUWR0~MDUWR5. The relationship between the writing order and the multiplication or division operation is as the follows:

- When the writing order is from MDUWR0 to MDUWR5: 32-bit/16-bit division operation.
- When the writing order is MDUWR0, MDUWR1, MDUWR4, MDUWR5, do not write to MDUWR2 and MDUWR3: 16-bit/16-bit division operation.
- When the writing order is MDUWR0, MDUWR4, MDUWR1, MDUWR5, do not write to MDUWR2 and MDUWR3: 16-bit×16-bit multiplication operation.

Operation	32-bit / 16-bit	16-bit / 16-bit	16-bit × 16-bit
First write (Low byte) ↓ ↓ Last write (High byte)	Write the dividend byte0 to MDUWR0 Write the dividend byte1 to MDUWR1 Write the dividend byte2 to MDUWR2 Write the dividend byte3 to MDUWR3 Write the divisor byte0 to MDUWR4 Write the divisor byte1 to MDUWR5	Write the dividend byte0 to MDUWR0 Write the dividend byte1 to MDUWR1 Write the divisor byte0 to MDUWR4 Write the divisor byte1 to MDUWR5	Write the multiplicand byte0 to MDUWR0 Write the multiplier byte0 to MDUWR4 Write the multiplicand byte1 to MDUWR1 Write the multiplier byte1 to MDUWR5

Note: 1. The operation to be executed is determined by the writing order to the registers MDUWR0~MDUWR5, before the register MDUWR5 is written, the other registers must be written in a correct order.
2. The MDUWRn (n=0~5) registers do not need to be written continuously, a non-write MDUWRn instruction or an interrupt, etc., can be inserted.
3. All operations are started after the register MDUWR5 is written.

Users need to calculate the required time for each operation, during which period the MDUWRn (n=0~5) register is forbidden to be written or read. After the completion of each operation, it is necessary to read the MDUWCTRL register firstly to confirm whether the operation state is correct, if correct, then read the result of the operation.

Operation	32-bit / 16-bit	16-bit / 16-bit	16-bit × 16-bit
Required Time	$17\times t_{SYS}$	$9\times t_{SYS}$	$11\times t_{SYS}$

The relationship between the operation results and the storage registers are as follows:

- 32-bit / 16-bit (division) → division quotient: MDUWR0~MDUWR3, remainder: MDUWR4, MDUWR5
- 16-bit / 16-bit (division) → division quotient: MDUWR0~MDUWR1, remainder: MDUWR4, MDUWR5
- 16-bit × 16-bit (multiplication) → multiplication result: MDUWR0~MDUWR3

Operation	32-bit / 16-bit	16-bit / 16-bit	16-bit × 16-bit
First read (Low byte) ↓ ↓ Last read (High byte)	MDUWR0 quotient byte0 MDUWR1 quotient byte1 MDUWR2 quotient byte2 MDUWR3 quotient byte3 MDUWR4 remainder byte0 MDUWR5 remainder byte1	MDUWR0 quotient byte0 MDUWR1 quotient byte1 MDUWR4 remainder byte0 MDUWR5 remainder byte1	MDUWR0 product byte0 MDUWR1 product byte1 MDUWR2 product byte2 MDUWR3 product byte3

Note: 1. When an operation is completed, the MDUWRn (n=0~5) register must be read in the sequence described above.
2. The MDUWRn (n=0~5) registers do not need to be read continuously, a non-read MDUWRn instruction or an interrupt, etc., can be inserted.

MDU Registers

The multiplication and division operations are implemented by using a series of registers. The status register MDUWCTRL provides the user with the operation status. The six data registers each play a role depending on the required operation.

Register Name	Bit							
	7	6	5	4	3	2	1	0
MDUWR0	D7	D6	D5	D4	D3	D2	D1	D0
MDUWR1	D7	D6	D5	D4	D3	D2	D1	D0
MDUWR2	D7	D6	D5	D4	D3	D2	D1	D0
MDUWR3	D7	D6	D5	D4	D3	D2	D1	D0
MDUWR4	D7	D6	D5	D4	D3	D2	D1	D0
MDUWR5	D7	D6	D5	D4	D3	D2	D1	D0
MDUWCTRL	MDWEF	MDWOV	—	—	—	—	—	—

16-bit MDU Registers List

MDUWCTRL Register

Bit	7	6	5	4	3	2	1	0
Name	MDWEF	MDWOV	—	—	—	—	—	—
R/W	R	R	—	—	—	—	—	—
POR	0	0	—	—	—	—	—	—

Bit 7 **MDWEF**: 16-bit MDU error flag
0: Normal
1: Abnormal
When the register MDUWRn (n=0~5) is changed or read during the operation, the MDWEF bit is set to "1" by hardware. When the operation is finished and the MDWEF bit is set to "1", it can be cleared by reading the MDUWCTRL register.

Bit 6 **MDWOV**: 16-bit MDU overflow flag
0: No overflow occurs
1: Multiplication result > FFFFH or divisor=0
Each time an operation is completed, this bit will be updated by hardware to a new value corresponding to the current operation situation.

Bit 5~0 Unimplemented, read as "0"

MDUWR0 Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	x	x	x	x	x	x	x	x

"x": unknown

Bit 7~0 **D7~D0**: 16-bit MDU data register 0

MDUWR1 Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	x	x	x	x	x	x	x	x

"x": unknown

Bit 7~0 **D7~D0**: 16-bit MDU data register 1

MDUWR2 Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	x	x	x	x	x	x	x	x

"x": unknown

Bit 7~0 **D7~D0**: 16-bit MDU data register 2

MDUWR3 Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	x	x	x	x	x	x	x	x

"x": unknown

Bit 7~0 **D7~D0**: 16-bit MDU data register 3

MDUWR4 Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	x	x	x	x	x	x	x	x

"x": unknown

Bit 7~0 **D7~D0**: 16-bit MDU data register 4

MDUWR5 Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	x	x	x	x	x	x	x	x

"x": unknown

Bit 7~0 **D7~D0**: 16-bit MDU data register 5

Interrupts

Interrupts are an important part of any microcontroller system. When an external event or an internal function such as a Timer Module or an A/D converter requires microcontroller attention, their corresponding interrupt will enforce a temporary suspension of the main program allowing the microcontroller to direct attention to their respective needs. These devices contain several external interrupt and internal interrupt functions. The external interrupts are generated by the action of the external INT0~INT1 pins, while the internal interrupts are generated by various internal functions such as the TMs, LVD and the A/D converter, etc.

Interrupt Registers

Overall interrupt control, which basically means the setting of request flags when certain microcontroller conditions occur and the setting of interrupt enable bits by the application program, is controlled by a series of registers, located in the Special Purpose Data Memory, as shown in the accompanying table. The number of registers falls into three categories. The first is the INTC0~INTC3 registers which setup the primary interrupts, the second is the MFI0~MFI2 registers which setup the Multi-function interrupts. Finally there is an INTEG register to setup the external interrupt trigger edge type.

Each register contains a number of enable bits to enable or disable individual registers as well as interrupt flags to indicate the presence of an interrupt request. The naming convention of these follows a specific pattern. First is listed an abbreviated interrupt type, then the (optional) number of that interrupt followed by either an "E" for enable/disable bit or "F" for request flag.

Function	Enable Bit	Request Flag	Notes
Global	EMI	—	—
INTn Pin	INTnE	INTnF	n=0~1
SCF PGA	SCFF	SCFE	—
SIM	SIME	SIMF	—
SPIA	SPIAE	SPIAF	—
Time Base	TBnE	TBnF	n=0~1
A/D Converter	ADE	ADF	—
UARTn	URnE	URnF	n=0~1
Multi-function	MFnE	MFnF	n=0~2
EEPROM	DEE	DEF	—
LVD	LVE	LVF	—
STM	STMPE	STMPF	—
	STMAE	STMAF	—
PTM	PTMnPE	PTMnPF	n=0~2
	PTMnAE	PTMnAF	

Interrupt Register Bit Naming Conventions

Register Name	Bit							
	7	6	5	4	3	2	1	0
INTEG	—	—	—	—	INT1S1	INT1S0	INT0S1	INT0S0
INTC0	—	ADF	INT1F	INT0F	ADE	INT1E	INT0E	EMI
INTC1	SCFF	MF2F	MF1F	MF0F	SCFE	MF2F	MF1E	MF0E
INTC2	SIMF	URF	TB1F	TB0F	SIME	URE	TB1E	TB0E
INTC3	—	—	—	SPIAF	—	—	—	SPIAE
MFI0	PTM0AF	PTM0PF	STMAF	STMPF	PTM0AE	PTM0PE	STMAE	STMPE
MFI1	PTM2AF	PTM2PF	PTM1AF	PTM1PF	PTM2AE	PTM2PE	PTM1AE	PTM1PE
MFI3	—	—	DEF	LVF	—	—	DEE	LVE

Interrupt Registers List – BH67F2260

Register Name	Bit							
	7	6	5	4	3	2	1	0
INTEG	—	—	—	—	INT1S1	INT1S0	INT0S1	INT0S0
INTC0	—	ADF	INT1F	INT0F	ADE	INT1E	INT0E	EMI
INTC1	SCFF	MF2F	MF1F	MF0F	SCFE	MF2E	MF1E	MF0E
INTC2	SIMF	UR0F	TB1F	TB0F	SIME	UR0E	TB1E	TB0E
INTC3	—	—	UR1F	SPIAF	—	—	UR1E	SPIAE
MFI0	PTM0AF	PTM0PF	STMAF	STMPF	PTM0AE	PTM0PE	STMAE	STMPE
MFI1	PTM2AF	PTM2PF	PTM1AF	PTM1PF	PTM2AE	PTM2PE	PTM1AE	PTM1PE
MFI2	—	—	DEF	LVF	—	—	DEE	LVE

Interrupt Registers List – BH67F2270

INTEG Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	INT1S1	INT1S0	INT0S1	INT0S0
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	0	0	0

Bit 7~4 Unimplemented, read as "0"

Bit 3~2 **INT1S1~INT1S0**: Interrupt edge control for INT1 pin
00: Disable
01: Rising edge
10: Falling edge
11: Rising and falling edges

Bit 1~0 **INT0S1~INT0S0**: Interrupt edge control for INT0 pin
00: Disable
01: Rising edge
10: Falling edge
11: Rising and falling edges

INTC0 Register

Bit	7	6	5	4	3	2	1	0
Name	—	ADF	INT1F	INT0F	ADE	INT1E	INT0E	EMI
R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	—	0	0	0	0	0	0	0

Bit 7 Unimplemented, read as "0"

Bit 6 **ADF**: A/D Converter interrupt request flag
0: No request
1: Interrupt request

Bit 5 **INT1F**: INT1 interrupt request flag
0: No request
1: Interrupt request

Bit 4 **INT0F**: INT0 interrupt request flag
0: No request
1: Interrupt request

Bit 3 **ADE**: A/D Converter interrupt control
0: Disable
1: Enable

Bit 2 **INT1E**: INT1 interrupt control
0: Disable
1: Enable

Bit 1 **INT0E**: INT0 interrupt control
0: Disable
1: Enable

Bit 0 **EMI**: Global interrupt control
0: Disable
1: Enable

INTC1 Register

Bit	7	6	5	4	3	2	1	0
Name	SCFF	MF2F	MF1F	MF0F	SCFE	MF2E	MF1E	MF0E
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	1	0	0	0	0	0	0	0

Bit 7 **SCFF**: SCF interrupt request flag
0: No request
1: Interrupt request

Bit 6 **MF2F**: Multi-function interrupt 2 request flag
0: No request
1: Interrupt request

Bit 5 **MF1F**: Multi-function interrupt 1 request flag
0: No request
1: Interrupt request

Bit 4 **MF0F**: Multi-function interrupt 0 request flag
0: No request
1: Interrupt request

Bit 3 **SCFE**: SCF interrupt interrupt control
0: Disable
1: Enable

Bit 2 **MF2E**: Multi-function interrupt 2 interrupt control
0: Disable
1: Enable

Bit 1 **MF1E**: Multi-function interrupt 1 control
0: Disable
1: Enable

Bit 0 **MF0E**: Multi-function interrupt 0 control
0: Disable
1: Enable

INTC2 Register

Bit	7	6	5	4	3	2	1	0
Name	SIMF	UR0F	TB1F	TB0F	SIME	UR0E	TB1E	TB0E
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7 **SIMF**: SIM interrupt request flag
0: No request
1: Interrupt request

Bit 6 **UR0F**: UART0 request flag
0: No request
1: Interrupt request

Bit 5 **TB1F**: Time Base 1 request flag
0: No request
1: Interrupt request

Bit 4 **TB0F**: Time Base 0 request flag
0: No request
1: Interrupt request

Bit 3 **SIME**: SIM interrupt control
0: Disable
1: Enable

Bit 2 **UR0E**: UART0 interrupt control
0: Disable
1: Enable

Bit 1 **TB1E**: Time Base 1 interrupt control
0: Disable
1: Enable

Bit 0 **TB0E**: Time Base 0 interrupt control
0: Disable
1: Enable

INTC3 Register – BH67F2260

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	SPIAF	—	—	—	SPIAE
R/W	—	—	—	R/W	—	—	—	R/W
POR	—	—	—	0	—	—	—	0

Bit 7~5 Unimplemented, read as "0"

Bit 4 **SPIAF**: SPIA interrupt request flag
0: No request
1: Interrupt request

Bit 3~1 Unimplemented, read as "0"

Bit 0 **SPIAE**: SPIA interrupt control
0: Disable
1: Enable

INTC3 Register – BH67F2270

Bit	7	6	5	4	3	2	1	0
Name	—	—	UR1F	SPIAF	—	—	UR1E	SPIAE
R/W	—	—	R/W	R/W	—	—	R/W	R/W
POR	—	—	0	0	—	—	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5 **UR1F**: UART1 interrupt request flag
0: No request
1: Interrupt request

Bit 4 **SPIAF**: SPIA interrupt request flag
0: No request
1: Interrupt request

Bit 3~2 Unimplemented, read as "0"

Bit 1 **UR1E**: UART1 interrupt control
0: Disable
1: Enable

Bit 0 **SPIAE**: SPIA interrupt control
0: Disable
1: Enable

MFI0 Register

Bit	7	6	5	4	3	2	1	0
Name	PTM0AF	PTM0PF	STMAF	STMPF	PTM0AE	PTM0PE	STMAE	STMPE
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7 **PTM0AF**: PTM0 Comparator A match interrupt request flag
0: No request
1: Interrupt request

Bit 6 **PTM0PF**: PTM0 Comparator P match interrupt request flag
0: No request
1: Interrupt request

Bit 5 **STMAF**: STM Comparator A match interrupt request flag
0: No request
1: Interrupt request

Bit 4 **STMPF**: STM Comparator P match interrupt request flag
0: No request
1: Interrupt request

Bit 3 **PTM0AE**: PTM0 Comparator A match interrupt control
0: Disable
1: Enable

Bit 2 **PTM0PE**: PTM0 Comparator P match interrupt control
0: Disable
1: Enable

Bit 1 **STMAE**: STM Comparator A match interrupt control
0: Disable
1: Enable

Bit 0 **STMPE**: STM Comparator P match interrupt control
0: Disable
1: Enable

MFI1 Register

Bit	7	6	5	4	3	2	1	0
Name	PTM2AF	PTM2PF	PTM1AF	PTM1PF	PTM2AE	PTM2PE	PTM1AE	PTM1PE
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7 **PTM2AF**: PTM2 Comparator A match interrupt request flag
0: No request
1: Interrupt request

Bit 6 **PTM2PF**: PTM2 Comparator P match interrupt request flag
0: No request
1: Interrupt request

Bit 5 **PTM1AF**: PTM1 Comparator A match interrupt request flag
0: No request
1: Interrupt request

Bit 4 **PTM1PF**: PTM1 Comparator P match interrupt request flag
0: No request
1: Interrupt request

Bit 3 **PTM2AE**: PTM2 Comparator A match interrupt control
0: Disable
1: Enable

Bit 2 **PTM2PE**: PTM2 Comparator P match interrupt control
0: Disable
1: Enable

Bit 1 **PTM1AE**: PTM1 Comparator A match interrupt control
0: Disable
1: Enable

Bit 0 **PTM1PE**: PTM1 Comparator P match interrupt control
0: Disable
1: Enable

MFI2 Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	DEF	LVF	—	—	DEE	LVE
R/W	—	—	R/W	R/W	—	—	R/W	R/W
POR	—	—	0	0	—	—	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5 **DEF**: Data EEPROM interrupt request flag
0: No request
1: Interrupt request

Bit 4 **LVF**: LVD interrupt request flag
0: No request
1: Interrupt request

Bit 3~2 Unimplemented, read as "0"

Bit 1 **DEE**: Data EEPROM interrupt control
0: Disable
1: Enable

Bit 0 **LVE**: LVD interrupt control
0: Disable
1: Enable

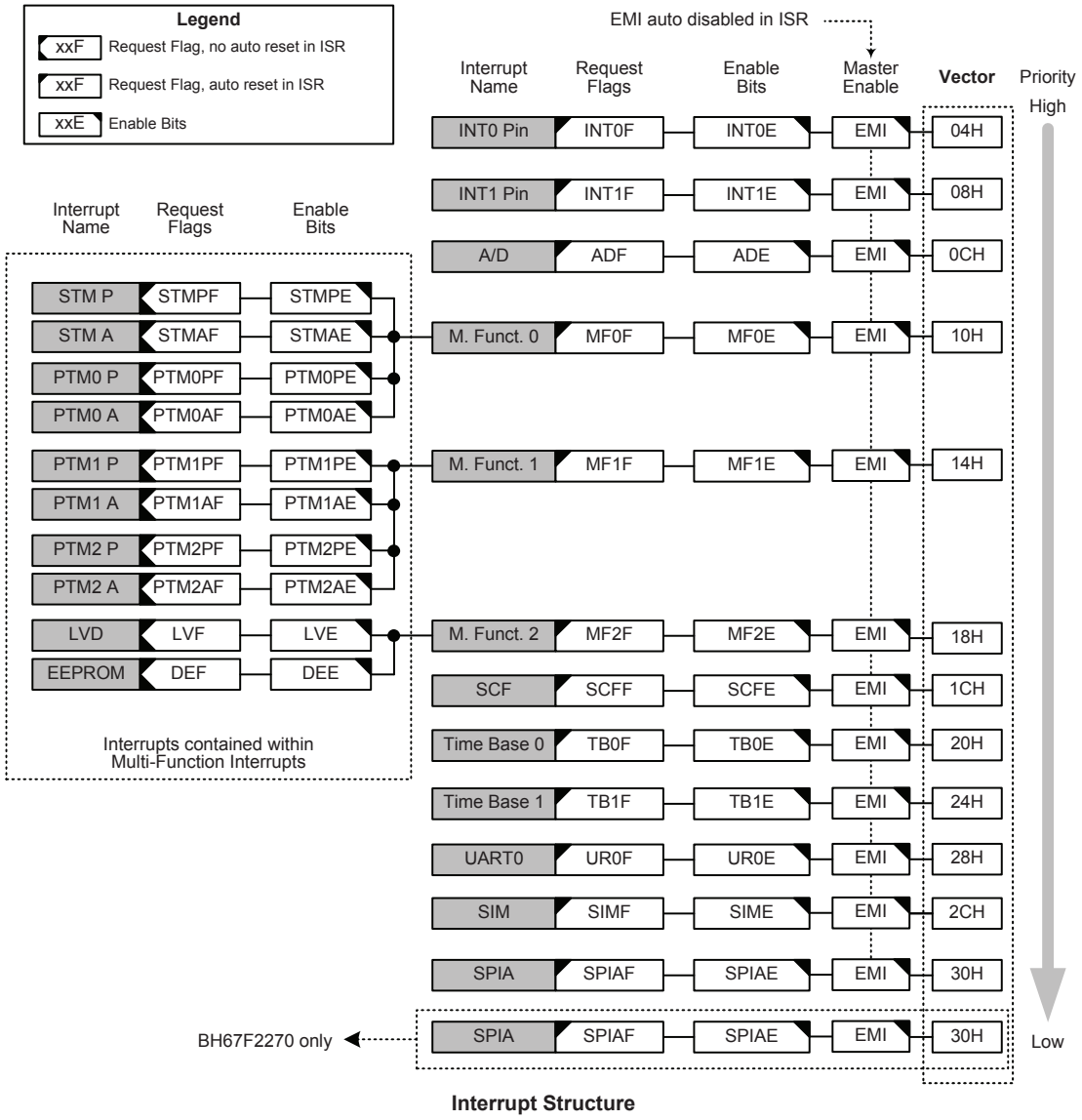
Interrupt Operation

When the conditions for an interrupt event occur, such as a TM Comparator P or Comparator A match or A/D conversion completion etc., the relevant interrupt request flag will be set. Whether the request flag actually generates a program jump to the relevant interrupt vector is determined by the condition of the interrupt enable bit. If the enable bit is set high then the program will jump to its relevant vector; if the enable bit is zero then although the interrupt request flag is set an actual interrupt will not be generated and the program will not jump to the relevant interrupt vector. The global interrupt enable bit, if cleared to zero, will disable all interrupts.

When an interrupt is generated, the Program Counter, which stores the address of the next instruction to be executed, will be transferred onto the stack. The Program Counter will then be loaded with a new address which will be the value of the corresponding interrupt vector. The microcontroller will then fetch its next instruction from this interrupt vector. The instruction at this vector will usually be a "JMP" which will jump to another section of program which is known as the interrupt service routine. Here is located the code to control the appropriate interrupt. The interrupt service routine must be terminated with a "RETI", which retrieves the original Program Counter address from the stack and allows the microcontroller to continue with normal execution at the point where the interrupt occurred.

The various interrupt enable bits, together with their associated request flags, are shown in the accompanying diagrams with their order of priority. Some interrupt sources have their own individual vector while others share the same multi-function interrupt vector. Once an interrupt subroutine is serviced, all the other interrupts will be blocked, as the global interrupt enable bit, EMI bit will be cleared automatically. This will prevent any further interrupt nesting from occurring. However, if other interrupt requests occur during this interval, although the interrupt will not be immediately serviced, the request flag will still be recorded.

If an interrupt requires immediate servicing while the program is already in another interrupt service routine, the EMI bit should be set after entering the routine, to allow interrupt nesting. If the stack is full, the interrupt request will not be acknowledged, even if the related interrupt is enabled, until the Stack Pointer is decremented. If immediate service is desired, the stack must be prevented from becoming full. In case of simultaneous requests, the accompanying diagram shows the priority that is applied. All of the interrupt request flags when set will wake-up these devices if it is in SLEEP or IDLE Mode, however to prevent a wake-up from occurring the corresponding flag should be set before these devices are in SLEEP or IDLE Mode.



Interrupt Structure

External Interrupts

The external interrupts are controlled by signal transitions on the pins INT0 and INT1. An external interrupt request will take place when the external interrupt request flags, INT0F~INT1F, are set, which will occur when a transition, whose type is chosen by the edge select bits, appears on the external interrupt pins. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and respective external interrupt enable bit, INT0E~INT1E, must first be set. Additionally the correct interrupt edge type must be selected using the INTEG register to enable the external interrupt function and to choose the trigger edge type. As the external interrupt pins are pin-shared with I/O pins, they can only be configured as external interrupt pins if their external interrupt enable bit in the corresponding interrupt register has been set and the external interrupt pin is selected by the corresponding pin-shared function selection bits. The pin must also be setup as an input by setting the corresponding bit in the port control register. When the interrupt is enabled, the stack is not full and the correct transition type appears on the external interrupt pin, a subroutine call to the external interrupt vector, will take place. When the interrupt is serviced, the external interrupt request flags, INT0F~INT1F, will be automatically reset and the EMI bit will be automatically cleared to disable other interrupts. Note that any pull-high resistor selections on the external interrupt pins will remain valid even if the pin is used as an external interrupt input.

The INTEG register is used to select the type of active edge that will trigger the external interrupt. A choice of either rising or falling or both edge types can be chosen to trigger an external interrupt. Note that the INTEG register can also be used to disable the external interrupt function.

SCF Interrupt

When the SCFADSF bit changes from 0 to 1, which means the SCF PGA output is ready, its interrupt request flag, SCFF will be set. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and SCF interrupt enable bit, SCFE, must first be set. When the interrupt is enabled, the stack is not full and the SCF PGA outputs a rising edge, a subroutine call to the SCF interrupt vector, will take place. When the interrupt is serviced, the SCF interrupt request flag, SCFF, will be automatically reset and the EMI bit will be automatically cleared to disable other interrupts.

SIM Interrupt

The Serial Interface Module Interrupt, also known as the SIM interrupt, will take place when the SIM Interrupt request flag, SIMF, is set, which occurs when a byte of data has been received or transmitted by the SIM interface, or an I^2C slave address match occurs, or an I^2C bus time-out occurs. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and the Serial Interface Interrupt enable bit, SIME, must first be set. When the interrupt is enabled, the stack is not full and any of the above described situations occurs, a subroutine call to the respective Interrupt vector, will take place. When the interrupt is serviced, the Serial Interface Interrupt flag, SIMF, will be automatically cleared. The EMI bit will also be automatically cleared to disable other interrupts.

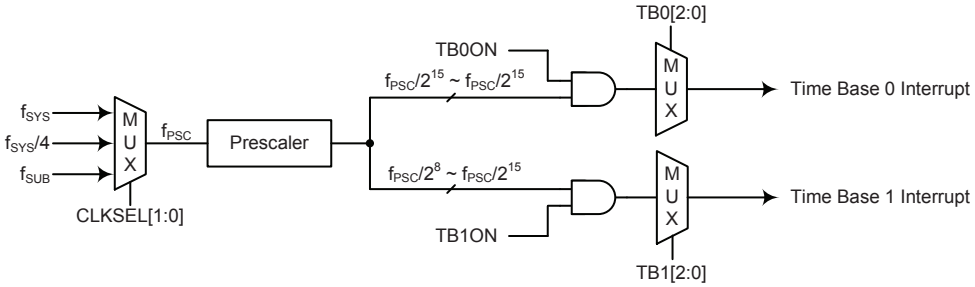
SPIA Interrupt

The Serial Peripheral Interface Interrupt, also known as the SPIA interrupt, will take place when the SPIA Interrupt request flag, SPIAF, is set, which occurs when a byte of data has been received or transmitted by the SPIA interface or an SPIA incomplete transfer occurs. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and the Serial Interface Interrupt enable bit, SPIAE, must first be set. When the interrupt is enabled, the stack is not full and any of the above described situations occurs, a subroutine call to the respective Interrupt vector, will take place. When the interrupt is serviced, the Serial Interface Interrupt flag, SPIAF, will be automatically cleared. The EMI bit will also be automatically cleared to disable other interrupts.

Time Base Interrupts

The function of the Time Base Interrupts is to provide regular time signal in the form of an internal interrupt. They are controlled by the overflow signals from their respective timer functions. When these happens their respective interrupt request flags, TB0F or TB1F will be set. To allow the program to branch to their respective interrupt vector addresses, the global interrupt enable bit, EMI and Time Base enable bits, TB0E or TB1E, must first be set. When the interrupt is enabled, the stack is not full and the Time Base overflows, a subroutine call to their respective vector locations will take place. When the interrupt is serviced, the respective interrupt request flag, TB0F or TB1F, will be automatically reset and the EMI bit will be cleared to disable other interrupts.

The purpose of the Time Base Interrupt is to provide an interrupt signal at fixed time periods. Its clock source, f_{PSC}, originates from the internal clock source f_{SYS}, $f_{SYS}/4$ or f_{SUB} and then passes through a divider, the division ratio of which is selected by programming the appropriate bits in the TB0C and TB1C registers to obtain longer interrupt periods whose value ranges. The clock source which in turn controls the Time Base interrupt period is selected using the CLKSEL1~CLKSEL0 bits in the PSCR register.



Time Base Interrupts

PSCR Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	CLKSEL1	CLKSEL0
R/W	—	—	—	—	—	—	R/W	R/W
POR	—	—	—	—	—	—	0	0

Bit 7~2 Unimplemented, read as "0"

Bit 1~0 **CLKSEL1~CLKSEL0**: Prescaler clock source selection
00: f_{SYS}
01: $f_{SYS}/4$
1x: f_{SUB}

TB0C Register

Bit	7	6	5	4	3	2	1	0
Name	TB0ON	—	—	—	—	TB02	TB01	TB00
R/W	R/W	—	—	—	—	R/W	R/W	R/W
POR	0	—	—	—	—	0	0	0

Bit 7 **TB0ON**: Time Base 0 Control
0: Disable
1: Enable

Bit 6~3 Unimplemented, read as "0"

Bit 2~0 **TB02~TB00**: Select Time Base 0 Time-out Period
000: $2^8/f_{PSC}$
001: $2^9/f_{PSC}$
010: $2^{10}/f_{PSC}$
011: $2^{11}/f_{PSC}$
100: $2^{12}/f_{PSC}$
101: $2^{13}/f_{PSC}$
110: $2^{14}/f_{PSC}$
111: $2^{15}/f_{PSC}$

TB1C Register

Bit	7	6	5	4	3	2	1	0
Name	TB1ON	—	—	—	—	TB12	TB11	TB10
R/W	R/W	—	—	—	—	R/W	R/W	R/W
POR	0	—	—	—	—	0	0	0

Bit 7 **TB1ON**: Time Base 1 Control
0: Disable
1: Enable

Bit 6~3 Unimplemented, read as "0"

Bit 2~0 **TB12~TB10**: Select Time Base 1 Time-out Period
000: $2^8/f_{PSC}$
001: $2^9/f_{PSC}$
010: $2^{10}/f_{PSC}$
011: $2^{11}/f_{PSC}$
100: $2^{12}/f_{PSC}$
101: $2^{13}/f_{PSC}$
110: $2^{14}/f_{PSC}$
111: $2^{15}/f_{PSC}$

A/D Converter Interrupt

An A/D Converter Interrupt request will take place when the A/D Converter Interrupt request flag, ADF, is set, which occurs when the A/D conversion process finishes. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and A/D Interrupt enable bit, ADE, must first be set. When the interrupt is enabled, the stack is not full and the A/D conversion process has ended, a subroutine call to the A/D Interrupt vector, will take place. When the A/D Converter Interrupt is serviced, the A/D Interrupt flag, ADF, will be automatically cleared. The EMI bit will also be automatically cleared to disable other interrupts.

UART Interrupt

Several individual UARTn conditions can generate a UARTn interrupt. When one of these conditions occurs, an interrupt pulse will be generated to get the attention of the microcontroller. These conditions are a transmitter data register empty, transmitter idle, receiver data available, receiver overrun, address detect and an RXn pin wake-up. To allow the program to branch to the respective interrupt vector addresses, the global interrupt enable bit, EMI, and the UARTn interrupt enable bit, URnE, must first be set. When the interrupt is enabled, the stack is not full and any of these conditions are created, a subroutine call to the UARTn Interrupt vector, will take place. When the UARTn Interrupt is serviced, the UARTn Interrupt flag, URnF, will be automatically cleared. The EMI bit will also be automatically cleared to disable other interrupts. However, the UnSR register flags will only be cleared when certain actions are taken by the UARTn, the details of which are given in the UART Interfaces chapter.

Multi-function Interrupts

Within these devices there are up to three Multi-function interrupts. Unlike the other independent interrupts, these interrupts have no independent source, but rather are formed from other existing interrupt sources, namely the TM Interrupts, EEPROM Interrupt and LVD Interrupt.

A Multi-function interrupt request will take place when any of the Multi-function interrupt request flags, MFnF are set. The Multi-function interrupt flags will be set when any of their included functions generate an interrupt request flag. To allow the program to branch to its respective interrupt vector address, when the Multi-function interrupt is enabled and the stack is not full, and either one of the interrupts contained within each of Multi-function interrupt occurs, a subroutine call to one of the Multi-function interrupt vectors will take place. When the interrupt is serviced, the related Multi-Function request flag will be automatically reset and the EMI bit will be automatically cleared to disable other interrupts.

However, it must be noted that, although the Multi-function Interrupt flags will be automatically reset when the interrupt is serviced, the request flags from the original source of the Multi-function interrupts will not be automatically reset and must be manually reset by the application program.

EEPROM Interrupt

The EEPROM interrupt is contained within the Multi-function Interrupt. An EEPROM Interrupt request will take place when the EEPROM Interrupt request flag, DEF, is set, which occurs when an EEPROM Write cycle ends. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and EEPROM Interrupt enable bit, DEE, and associated Multi-function interrupt enable bit, must first be set. When the interrupt is enabled, the stack is not full and an EEPROM Write cycle ends, a subroutine call to the respective EEPROM Interrupt vector will take place. When the EEPROM Interrupt is serviced, the EMI bit will be automatically cleared to disable other interrupts, however only the Multi-function interrupt request flag will be also automatically cleared. As the DEF flag will not be automatically cleared, it has to be cleared by the application program.

LVD Interrupt

The Low Voltage Detector Interrupt is contained within the Multi-function Interrupt. An LVD Interrupt request will take place when the LVD Interrupt request flag, LVF, is set, which occurs when the Low Voltage Detector function detects a low power supply voltage or a low LVDIN input voltage. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, Low Voltage Interrupt enable bit, LVE, and associated Multi-function interrupt enable bit, must first be set. When the interrupt is enabled, the stack is not full and a low voltage condition occurs, a subroutine call to the Multi-function Interrupt vector, will take place. When the Low Voltage Interrupt is serviced, the EMI bit will be automatically cleared to disable other interrupts, however only the Multi-function interrupt request flag will be also automatically cleared. As the LVF flag will not be automatically cleared, it has to be cleared by the application program.

TM Interrupts

The Standard and Periodic Type TMs each have two interrupts, one comes from the comparator A match situation and the other comes from the comparator P match situation. All of the TM interrupts are contained within the Multi-function Interrupts. For all of the TM types there are two interrupt request flags and two enable control bits. A TM interrupt request will take place when any of the TM request flags are set, a situation which occurs when a TM comparator P or A match situation happens.

To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, respective TM Interrupt enable bit, and relevant Multi-function Interrupt enable bit, MFnE, must first be set. When the interrupt is enabled, the stack is not full and a TM comparator match situation occurs, a subroutine call to the relevant Multi-function Interrupt vector locations, will take place. When the TM interrupt is serviced, the EMI bit will be automatically cleared to disable other interrupts, however only the related MFnF flag will be automatically cleared. As the TM interrupt request flags will not be automatically cleared, they have to be cleared by the application program.

Interrupt Wake-up Function

Each of the interrupt functions has the capability of waking up the microcontroller when in the SLEEP or IDLE Mode. A wake-up is generated when an interrupt request flag changes from low to high and is independent of whether the interrupt is enabled or not. Therefore, even though these devices are in the SLEEP or IDLE Mode and its system oscillator stopped, situations such as external edge transitions on the external interrupt pins, a low power supply voltage or comparator output bit change may cause their respective interrupt flag to be set high and consequently generate an interrupt. Care must therefore be taken if spurious wake-up situations are to be avoided. If an interrupt wake-up function is to be disabled then the corresponding interrupt request flag should be set high before these devices enter the SLEEP or IDLE Mode. The interrupt enable bits have no effect on the interrupt wake-up function.

Programming Considerations

By disabling the relevant interrupt enable bits, a requested interrupt can be prevented from being serviced, however, once an interrupt request flag is set, it will remain in this condition in the interrupt register until the corresponding interrupt is serviced or until the request flag is cleared by the application program.

Where a certain interrupt is contained within a Multi-function interrupt, then when the interrupt service routine is executed, as only the Multi-function interrupt request flags, MFnF, will be automatically cleared, the individual request flag for the function needs to be cleared by the application program.

It is recommended that programs do not use the "CALL" instruction within the interrupt service subroutine. Interrupts often occur in an unpredictable manner or need to be serviced immediately. If only one stack is left and the interrupt is not well controlled, the original control sequence will be damaged once a CALL subroutine is executed in the interrupt subroutine.

Every interrupt has the capability of waking up the microcontroller when it is in the SLEEP or IDLE Mode, the wake up being generated when the interrupt request flag changes from low to high. If it is required to prevent a certain interrupt from waking up the microcontroller then its respective request flag should be first set high before enter SLEEP or IDLE Mode.

As only the Program Counter is pushed onto the stack, then when the interrupt is serviced, if the contents of the accumulator, status register or other registers are altered by the interrupt service program, their contents should be saved to the memory at the beginning of the interrupt service routine.

To return from an interrupt subroutine, either a RET or RETI instruction may be executed. The RETI instruction in addition to executing a return to the main program also automatically sets the EMI bit high to allow further interrupts. The RET instruction however only executes a return to the main program leaving the EMI bit in its present zero state and therefore disabling the execution of further interrupts.

LCD Driver

For large volume applications, which incorporate an LCD in their design, the use of a custom display rather than a more expensive character based display reduces costs significantly. However, the corresponding COM and SEG signals required, which vary in both amplitude and time, to drive such a custom display require many special considerations for proper LCD operation to occur. These devices contain an LCD Driver function, which with their internal LCD signal generating circuitry and various options will automatically generate these time and amplitude varying signals to provide a means of direct driving and easy interfacing to a range of custom LCDs.

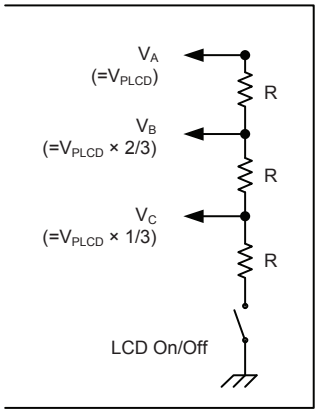
These devices include a wide range of options to enable LCD displays of various types to be driven. The table shows the range of options available across these devices range.

Driver No.	Duty	Bias	Bias Type	Wave Type
32×4	1/4	1/3	R or C	A or B
30×6	1/6	1/3	R or C	A or B
28×8	1/8	1/3	R	A or B
28×8	1/8	1/4	R	A or B

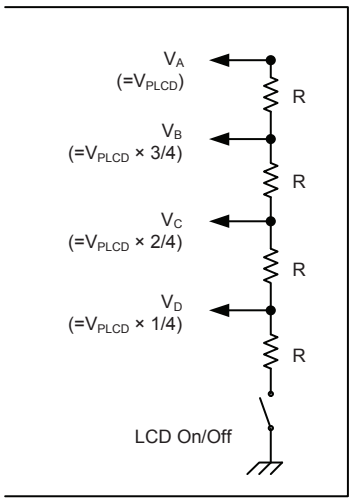
LCD Selection – BH67F2260

Driver No.	Duty	Bias	Bias Type	Wave Type
46×4	1/4	1/3	R or C	A or B
44×6	1/6	1/3	R or C	A or B
42×8	1/8	1/3	R	A or B
42×8	1/8	1/4	R	A or B

LCD Selection – BH67F2270



R Type 1/3 Bias



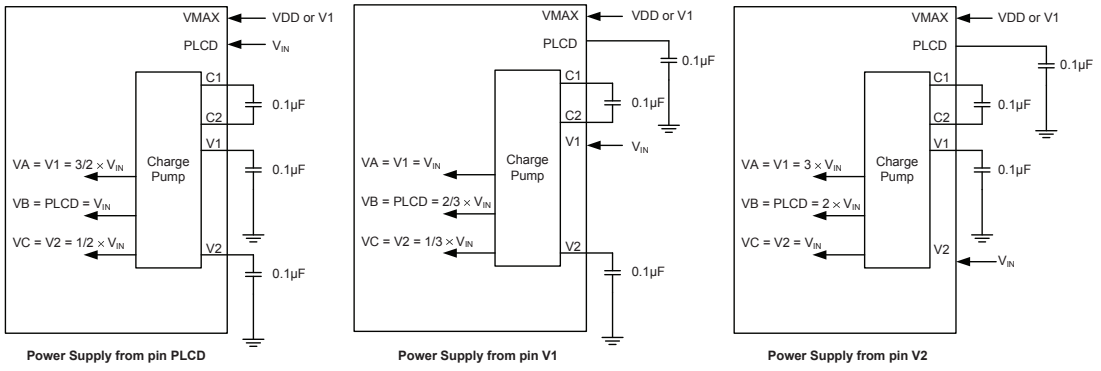
R Type 1/4 Bias

Note: 1. For R-type LCD, when LCDPR=1, PLCD pin must be connected to 4.7μF capacitor, when LCDPR=0, PLCD pin not be connected to 4.7μF capacitor.

2. Use restrictions: When C-type, LCDPR fixed to 0.

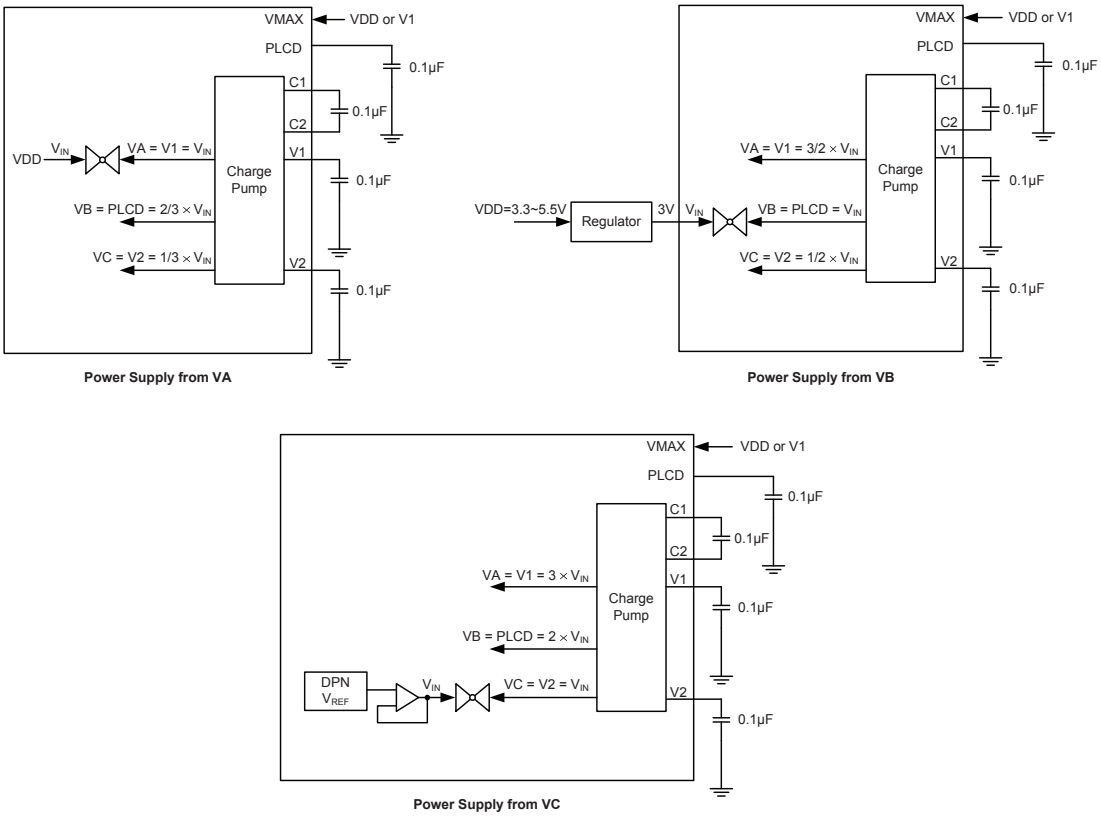
3. When the R-type LCD is in disable state, the DC path doesn't exist.

R Type Bias Voltage Generation



Note: The pin VMAX must be connected to the maximum voltage to prevent from the pad leakage.

C Type Bias External Power Supply Configuration – 1/3 Bias



Note: The pin VMAX must be connected to the maximum voltage to prevent from the pad leakage.

C Type Bias Internal Power Supply Configuration – 1/3 Bias

LCD Display Memory

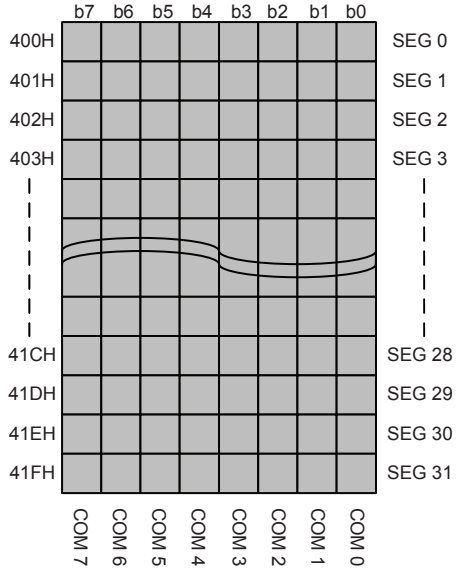
An area of Data Memory is especially reserved for use for the LCD display data. This data area is known as the LCD Memory. Any data written here will be automatically read by the internal display driver circuits, which will in turn automatically generate the necessary LCD driving signals. Therefore any data written into this Memory will be immediately reflected into the actual display connected to the microcontroller.

These devices provide an area of embedded data memory for the LCD display. This area is located at 00H to 1FH in Sector 4 of the Data Memory for BH67F2260. This area is located from 00H to

2DH of the RAM at Sector 4 of the Data Memory for BH67F2270. If using the indirect addressing to access the Display Memory therefore requires first that Sector 4 is selected by writing a value of 04H to MP1H or MP2H. After this, the memory can then be accessed by using indirect addressing through the use of MP1L or MP2L. With Sector 4 selected, then using MP1L/MP2L to read or write to the memory area, from 00H to 2DH, will result in operations to the LCD memory. Directly addressing the Display Memory is not applicable and will result in a data access to the Sector 0 General Purpose Data Memory.

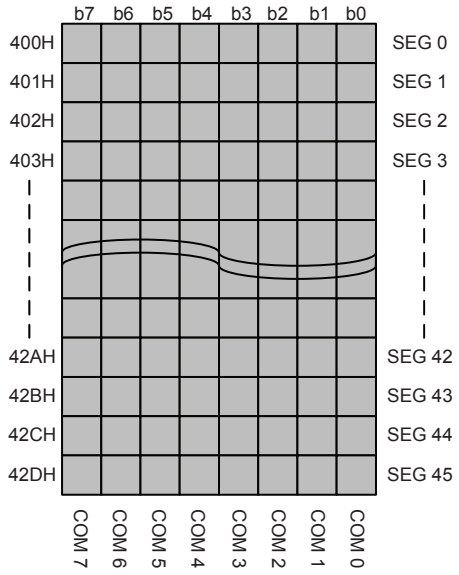
The LCD display memory can be read and written to only by indirect addressing mode using MP1L/MP1H and MP2L/MP2H. When data is written into the display data area, it is automatically read by the LCD driver which then generates the corresponding LCD driving signals. To turn the display on or off, a "1" or a "0" is written to the corresponding bit of the display memory, respectively. The figure illustrates the mapping between the display memory and LCD pattern for these devices.

The unimplemented LCD RAM bits cannot be used as general purpose RAM for application. For example, if the LCD duty is selected as 1/4 duty (4COM), the COM bit 4~7 will be read as 0 only.



32 SEG x 8 COM

LCD Memory Map – BH67F2260



32 SEG x 8 COM

LCD Memory Map – BH67F2270

LCD Clock Source

The LCD clock source is the internal clock signal, f_{SUB}, divided by 8, using an internal divider circuit. The f_{SUB} internal clock is supplied by either the LIRC or LXT oscillator, the choice of which is determined by the FSS bit in the SCC register. For proper LCD operation, this arrangement is provided to generate an ideal LCD clock source frequency of 4kHz.

The c-type LCD pump clock source is from the internal clock signal, f_{SUB}, which divided by an internal divider circuit. The divider value is decided by LCDPCK[2:0] in the LCDC2 register.

f_{SUB} Clock Source	LCD Clock Frequency
LIRC	4kHz
LXT	4kHz

LCD Clock Source

LCD Registers

Control Registers in the Data Memory, are used to control the various setup features of the LCD Driver. There are several control registers for the LCD function, LCDCP, LCDC0 and LCDC2.

The LCDPR bit in the LCDCP register is used to select the PLCD pin or the internal charge pump regulator to supply the power for the R type LCD COMs and SEGs pins. Bits CPVS1 and CPVS0 in the same register are used to select an appropriate charge pump output voltage level for the R type LCD.

The TYPE bit in the LCDC0 register is used to select whether Type A or Type B LCD control signals are used. The RCT bit in the LCDC0 register is used to select whether R type or C type LCD drive bias. Bits LCDP1 and LCDP0 in the LCDC0 register are used to select the power source to supply the C type LCD panel with the correct bias voltages. Bits LCDIS0 and LCDIS1 in the LCDC0 register are used to select the internal bias current to supply the R type LCD panel with the correct bias voltages. A choice to best match the LCD panel used in the application can be selected also to minimise bias current. The LCDEN bit in the LCDC0 register, which provides the overall LCD enable/disable function, will only be effective when these devices are in the Fast, Slow or Idle

Mode. If these devices are in the Sleep Mode then the display will always be disabled.

The LCDC2 register is used for LCD duty, C-type LCD Pump Clock divider and bias selection.

Register Name	Bit							
	7	6	5	4	3	2	1	0
LCDC0	TYPE	RCT	LCDP1	LCDP0	—	LCDIS1	LCDIS0	LCDEN
LCDCP	—	—	—	—	LCDPR	—	CPVS1	CPVS0
LCDC2	LCDPCK2	LCDPCK1	LCDPCK0	—	—	DTYC1	DTYC0	BIAS

LCD Registers List

LCDC0 Register

Bit	7	6	5	4	3	2	1	0
Name	TYPE	RCT	LCDP1	LCDP0	—	LCDIS1	LCDIS0	LCDEN
R/W	R/W	R/W	R/W	R/W	—	R/W	R/W	R/W
POR	0	0	0	0	—	0	0	0

Bit 7 **TYPE**: LCD Waveform Type Selection
0: Type A
1: Type B

Bit 6 **RCT**: R/C LCD Type Control
0: R type
1: C type

Bit 5~4 **LCDP1~LCDP0**: LCD power source selection for C type
00: The power source is from PLCD/V1/V2
01: The power source is from V_C=DPN V_{REF} (~1.08V)
10: The power source is from V_B=3V
11: The power source is from V_A=V_{DD}

Bit 3 Unimplemented, read as "0"

Bit 2~1 **LCDIS1~LCDIS0**: LCD Bias Current Selection for R type LCD (VA=PLCD=VDD, 1/3 bias)
00: 25μA
01: 50μA
10: 100μA
11: 200μA
When using the C type LCD, these bits are fixed at 00.

Bit 0 **LCDEN**: LCD Enable Control
0: Disable
1: Enable
In the Fast, Slow or Idle mode, the LCD on/off function can be controlled by this bit. In the Sleep mode, the LCD is always off.

LCDCP Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	LCDPR	—	CPVS1	CPVS0
R/W	—	—	—	—	R/W	—	R/W	R/W
POR	—	—	—	—	0	—	0	0

Bit 7~4 Unimplemented, read as "0"

Bit 3 **LCDPR**: LCD Power selection for R type
0: PLCD pin
1: R type Internal charge pump
This bit is only available for R type LCD applications. When the LCDPR bit is set to 0, the R type LCD power will be derived from the PLCD pin and its internal charge pump circuit will be disabled. This internal charge pump will also be disabled when the C type LCD driver is selected by setting the RCT bit to 1 or the LCD driver is disabled by setting the LCDEN bit to 0.

Bit 2 Unimplemented, read as "0"

Bit 1~0 **CPVS1~CPVS0**: Charge pump output voltage selection for R type
00: 3.3V
01: 3.0V
10: 2.7V
11: 4.5V

LCDC2 Register

Bit	7	6	5	4	3	2	1	0
Name	LCDPCK2	LCDPCK2	LCDPCK2	—	—	DTYC1	DTYC0	BIAS
R/W	R/W	R/W	R/W	—	—	R/W	R/W	R/W
POR	0	0	0	—	—	0	0	0

Bit 7 ~ 5 **LCDPCK2 ~LCDPCK0**: C-type LCD Pump Clock divider selection
000: 32kHz/128
001: 32kHz/64
010: 32kHz/32
011: 32kHz/16
100: 32kHz/8
101: 32kHz/4
110: 32kHz/ 2
111: 32kHz/2
Note: C-type LCD Pump Clock divider base on the 32K LCD clock.

Bit 4~3 Unimplemented, read as "0"

Bit 2~1 **DTYC1~DTYC0**: LCD duty selection
00: 1/4 Duty (COM0~COM3)
01: 1/6 Duty (COM0~COM5)
10: 1/8 Duty (COM0~COM7), for R type only
11: Unimplemented
The unused COM pins are allowed to be configured as normal I/O or other pin-shared functions.

Bit 0 **BIAS**: LCD bias selection
0: 1/3 bias
1: 1/4 bias, for R type only

LCD Voltage Source and Biasing

The time and amplitude varying signals generated by the LCD Driver function require the generation of several voltage levels for their operation. These devices can have either R type or C type biasing selected via a software control bit named RCT. Selecting the C type biasing will enable C type internal charge pump circuitry.

R Type Biasing

For R type biasing the LCD voltage source, the PLCD voltage can be supplied by the PLCD pin or internal charge pump regulator, selected by the LCDPR bit in the LCDCP register, to generate the internal biasing voltages. The source on the PLCD pin could be the microcontroller power supply or some other voltage source. Note that the PLCD voltage should be equal or less than V_{DD}. There are four kinds of the internal charge pump voltage output, managed by the CPVS[1:0] bits in the LCDCP register.

For the R type 1/3 bias scheme, four voltage levels V_{SS}, V_A, V_B and V_C are utilised. The voltage V_A is equal to PLCD. The voltage V_B is equal to PLCD×2/3 while the voltage V_C is equal to PLCD×1/3.

For the R type 1/4 bias scheme, five voltage levels V_{SS}, V_A, V_B, V_C and V_D are utilised. The voltage V_A is equal to PLCD. The voltage V_B is equal to V_A×3/4, the voltage V_C is equal to V_A×2/4 and the voltage V_D is equal to V_A×1/4.

Different values of internal bias current can be selected using the LCDIS1~LCDIS0 bits in the LCDC0 register. The connection to the VMAX pin depends upon the voltage that is applied to the PLCD pin. If the V_{DD} voltage is greater than or equal to the voltage applied to the PLCD pin then the VMAX pin should be connected to V_{DD}. Note that for R type biasing the voltage on the PLCD pin should not be greater than the VDD pin voltage. Note that no external capacitors or resistors are required to be connected if R type biasing is used.

Condition	VMAX Connection
$V_{DD} \geq$ PLCD	Connect VMAX to V_{DD}
V_{DD} < PLCD	Forbidden condition

R Type Bias VMAX Pin Connection

C Type Biasing

For C type biasing the LCD voltage source can be supplied on the external pin PLCD, V1 or V2 or derived from the internal voltage source to generate the required biasing voltages. The C type bias voltage source is selected using the LCDP1 and LCDP0 bits in the LCDC0 register. The C type biasing scheme uses an internal charge pump circuit can generate voltages higher than what is supplied on PLCD or V2. This feature is useful in applications where the microcontroller supply voltage is less than the supply voltage required by the LCD. Additional charge pump capacitors must also be connected between pins C1 and C2 to generate the necessary voltage levels.

For C type 1/3 bias external power supply scheme, the LCD power can be supplied on PLCD, V1 or V2 pin. However, the LCD power is internally supplied on V_A, V_B or V_C for C type 1/3 bias internal power supply scheme. Four internally generated voltage levels V_{SS}, V_A, V_B and V_C are utilised. These bias voltages have different levels depending upon different LCD power supply schemes.

LCD Power Supply		V_A Voltage	V_B Voltage	V_C Voltage
External Power Supply	V_{IN} on V1	V_{IN}	2/3 × V_{IN}	1/3 × V_{IN}
	V_{IN} on PLCD	3/2 × V_{IN}	V_{IN}	1/2 × V_{IN}
	V_{IN} on V2	3 × V_{IN}	2 × V_{IN}	V_{IN}
Internal Power Supply	V_{DD} on VA	V_{DD}	2/3 × V_{DD}	1/3 × V_{DD}
	V_{DD} on VB	3/2 × V_{DD}	V_{DD}	1/2 × V_{DD}
	V_{REFIN} on VC	3 × V_{REFIN}	2 × V_{REFIN}	V_{REFIN}

C Type Bias Power Supply Scheme

The connection to the VMAX pin depends upon the bias and the voltage that is applied to the PLCD pin, the details are shown in the table. It is extremely important to ensure that these charge pump generated internal voltages do not exceed the maximum V_{DD} voltage of 5.5V.

Condition	VMAX Connection
V_{DD} > PLCD × 1.5	Connect VMAX to VDD
Otherwise	Connect VMAX to V1

C Type Bias VMAX Pin Connection

LCD Reset Function

The LCD has an internal reset function that is an OR function of the inverted LCDEN bit in the LCDC0 register and the SLEEP function. When the LCDEN bit is set to 1 to enable the LCD driver function before these devices enter the SLEEP mode, the LCD function will be reset after these devices enter the SLEEP mode. Clearing the LCDEN bit to zero will also reset the LCD function.

SLEEP Mode	LCDEN	LCD Reset	COM & SEG Voltage Level
Off	1	No	Normal Operation
Off	0	Yes	Low
On	x	Yes	Low

"x": Don't care

LCD Reset Function

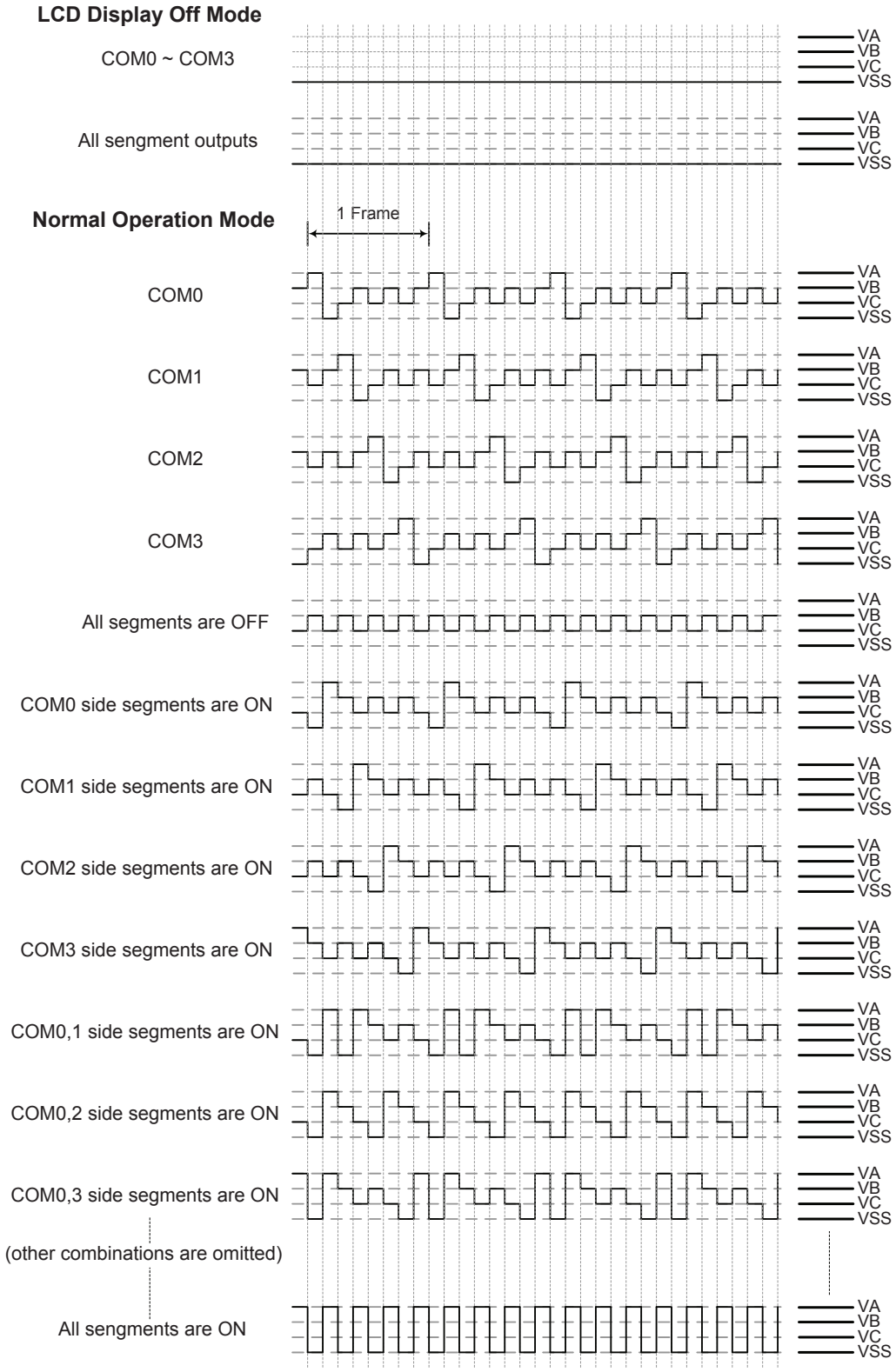
LCD Driver Output

The number of COM and SEG outputs supplied by the LCD driver, as well as its biasing and wave type selections, are dependent upon how the LCD control bits are programmed. The Bias Type, whether C or R type is also selected by a software control bit.

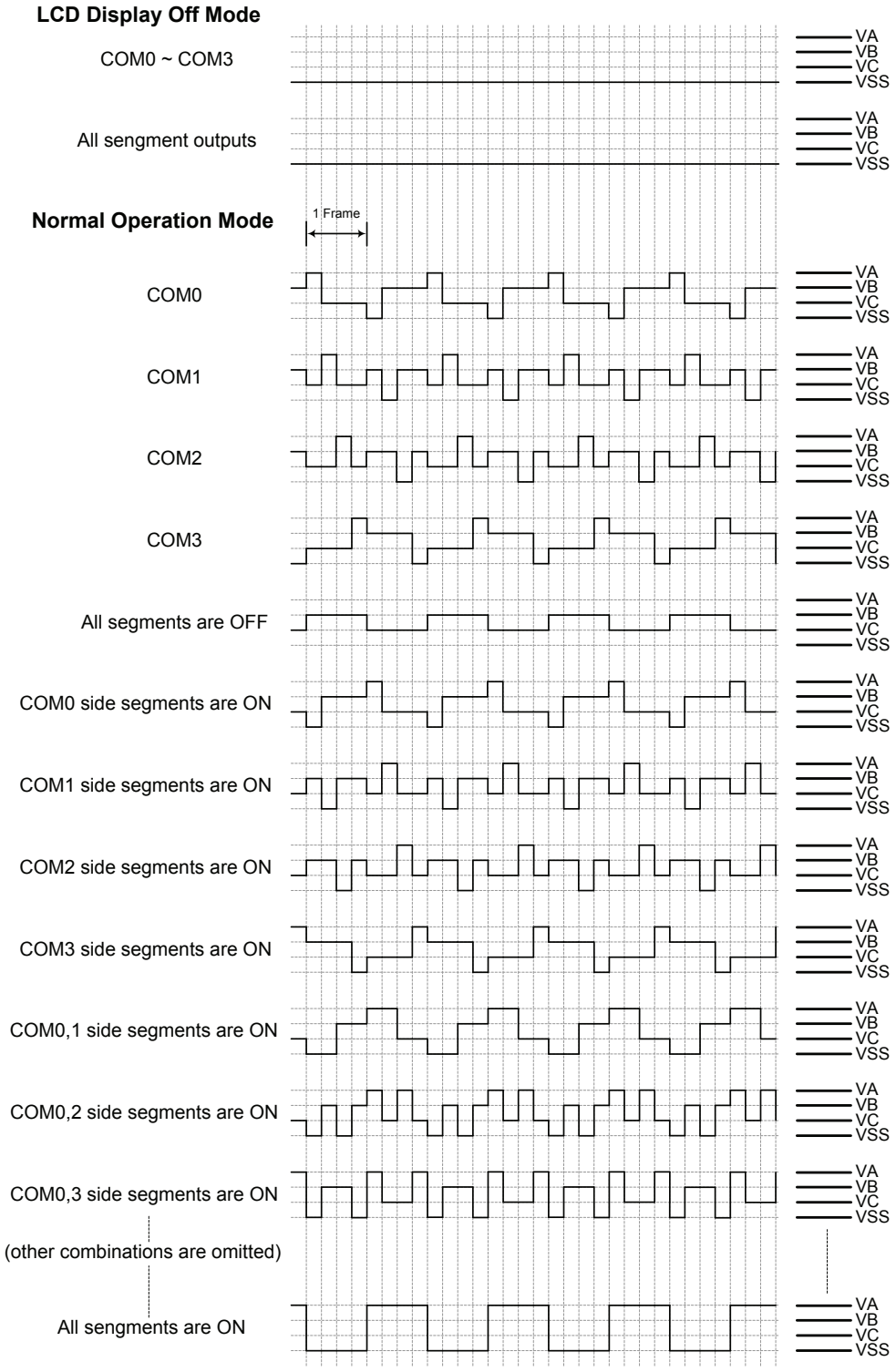
The nature of Liquid Crystal Displays require that only AC voltages can be applied to their pixels as the application of DC voltages to LCD pixels may cause permanent damage. For this reason the relative contrast of an LCD display is controlled by the actual RMS voltage applied to each pixel, which is equal to the RMS value of the voltage on the COM pin minus the voltage applied to the SEG pin. This differential RMS voltage must be greater than the LCD saturation voltage for the pixel to be on and less than the threshold voltage for the pixel to be off.

The requirement to limit the DC voltage to zero and to control as many pixels as possible with a minimum number of connections requires that both a time and amplitude signal is generated and applied to the application LCD. These time and amplitude varying signals are automatically generated by the LCD driver circuits in the microcontroller. What is known as the duty determines the number of common lines used, which are also known as backplanes or COMs. For example, the duty is 1/4 and equates to a COM number of 4, therefore defines the number of time divisions within each LCD signal frame. Two types of signal generation are also provided, known as Type A and Type B, the required type is selected via the TYPE bit in the LCDC register. Type B offers lower frequency signals, however lower frequencies may introduce flickering and influence display clarity.

R & C Type, 4-COM, 1/3 Bias

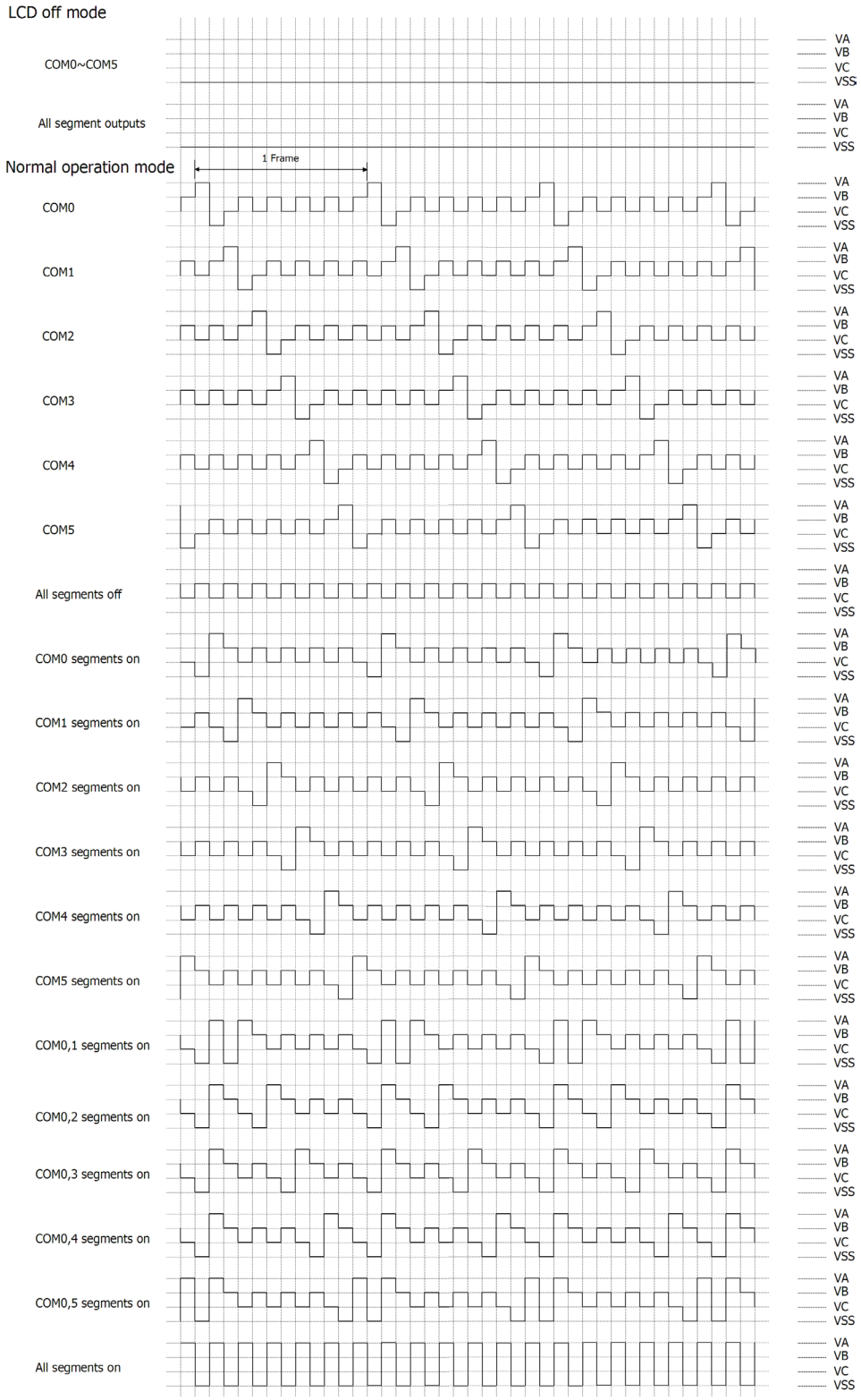


LCD Driver Output – Type A, 1/4 Duty, 1/3 Bias

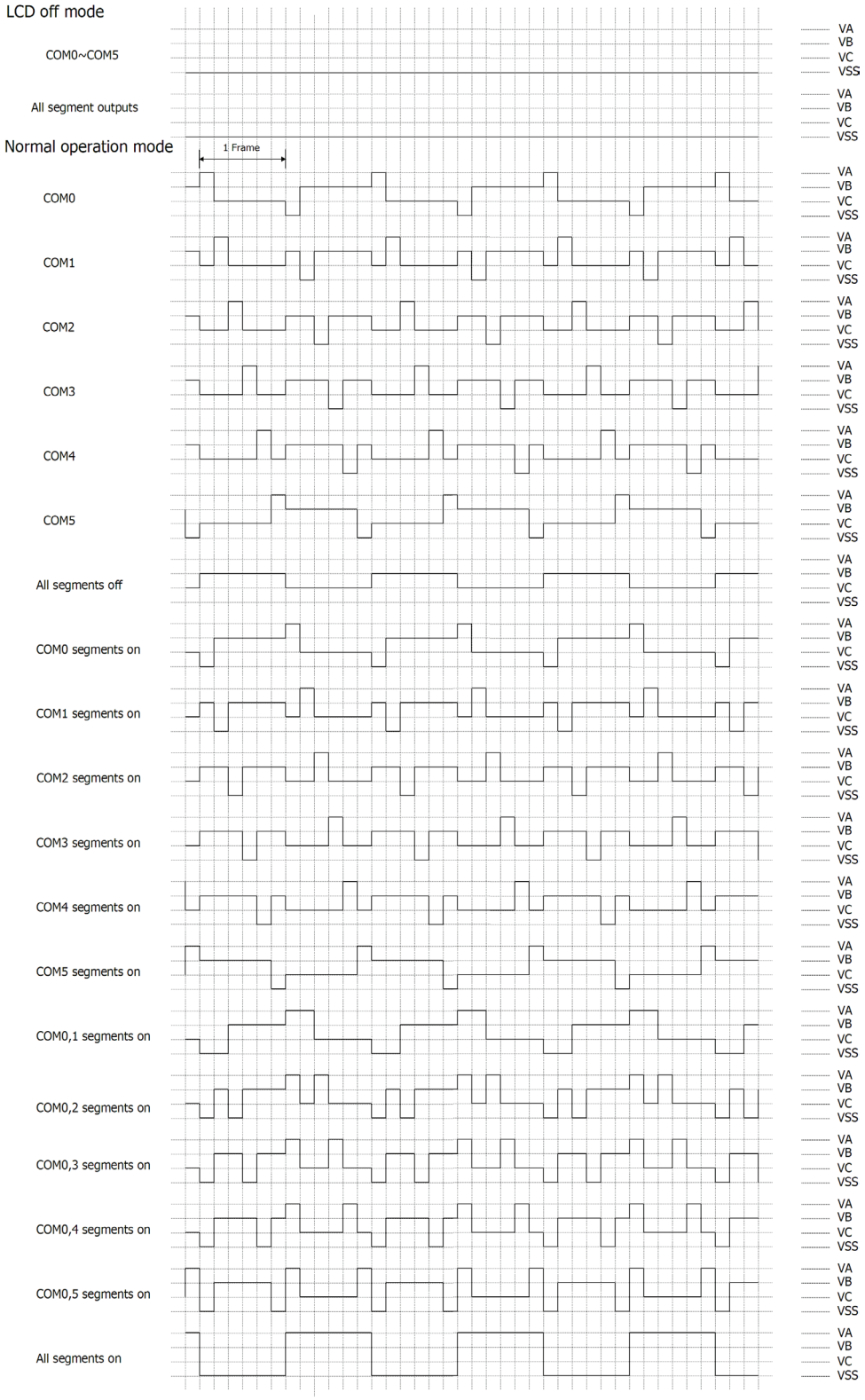


LCD Driver Output – Type B, 1/4 Duty, 1/3 Bias

R & C Type, 6-COM, 1/3 Bias

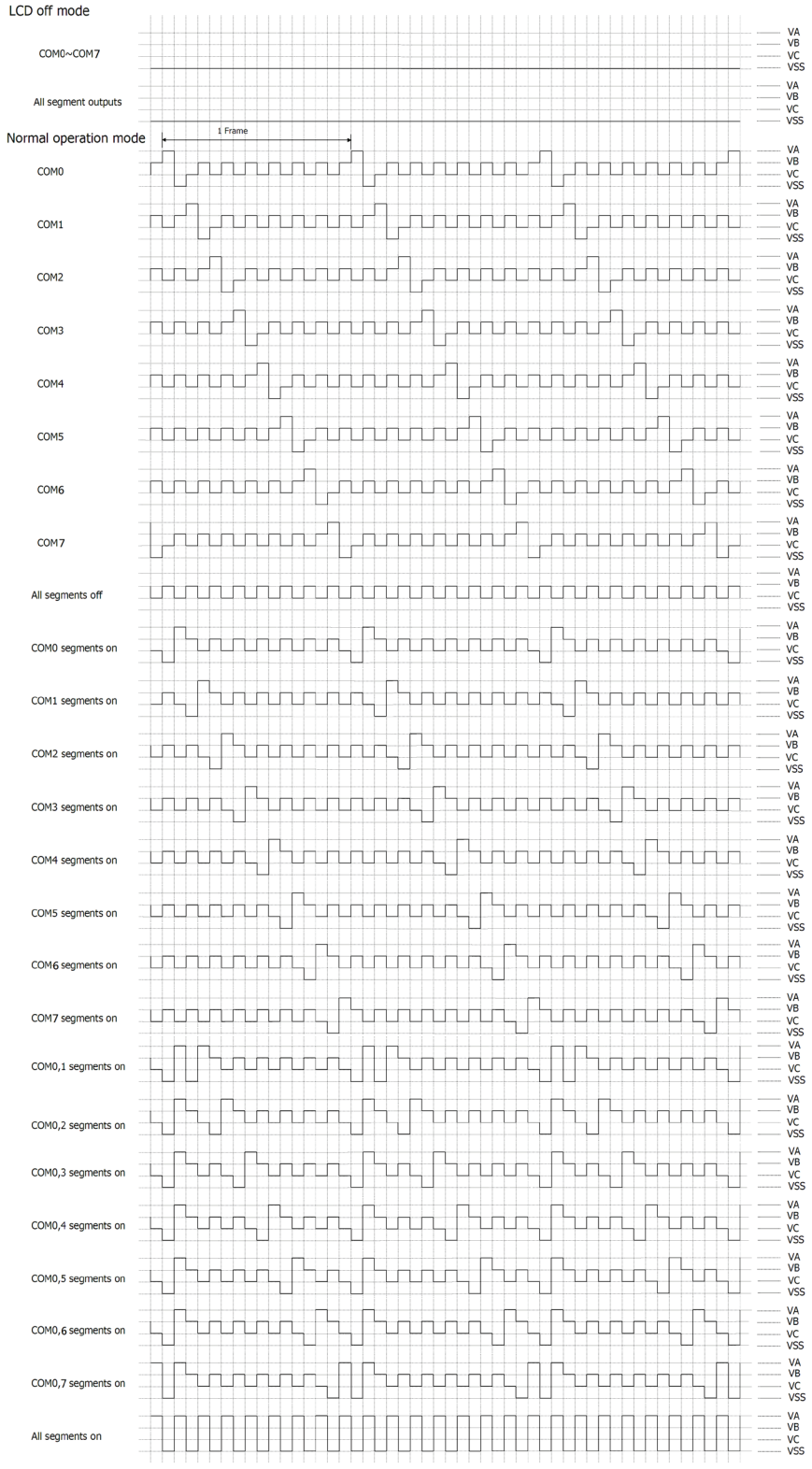


LCD Driver Output – Type A, 1/6 Duty, 1/3 Bias

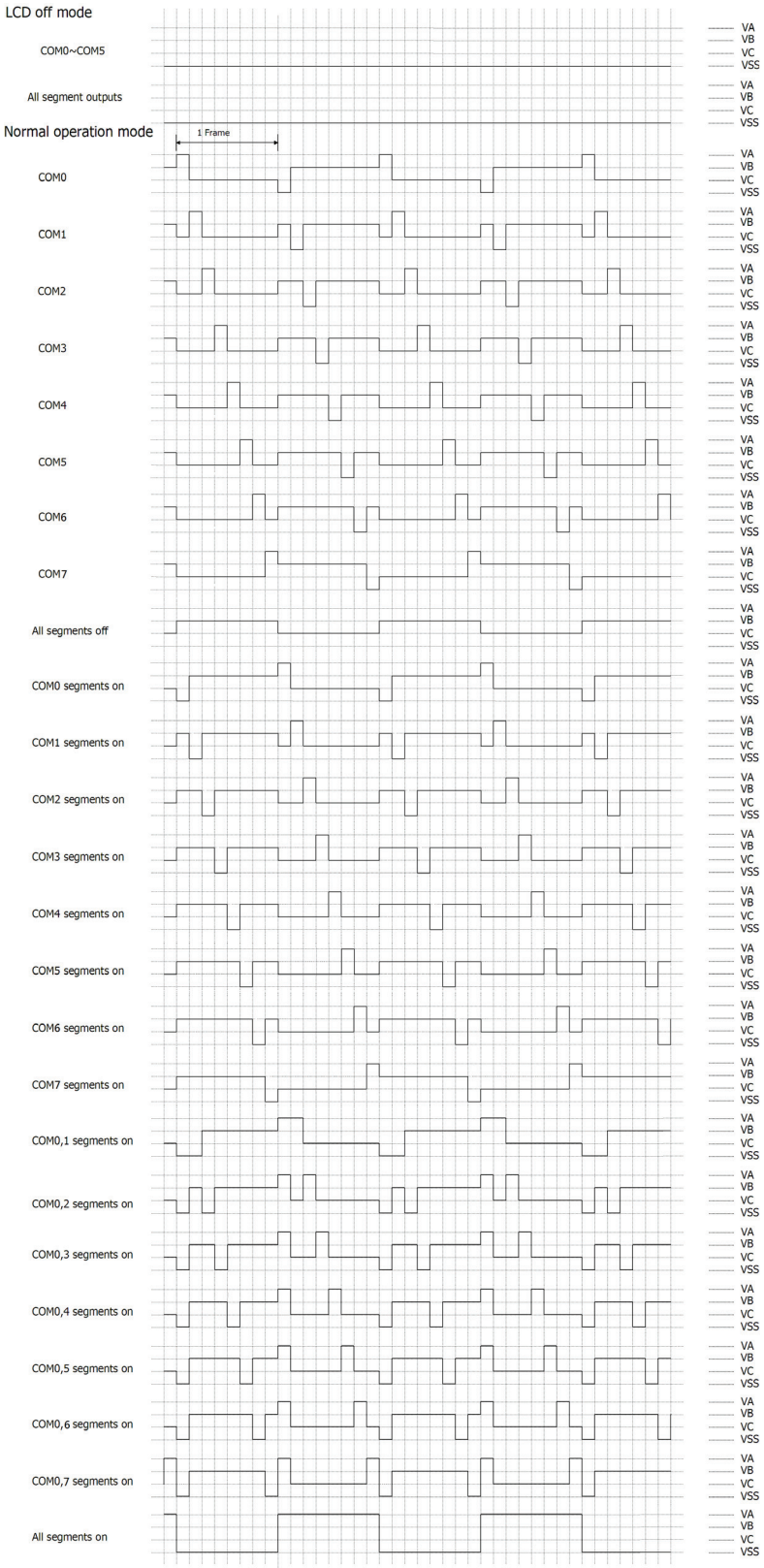


LCD Driver Output – Type B, 1/6 Duty, 1/3 Bias

R Type, 8-COM, 1/3 Bias

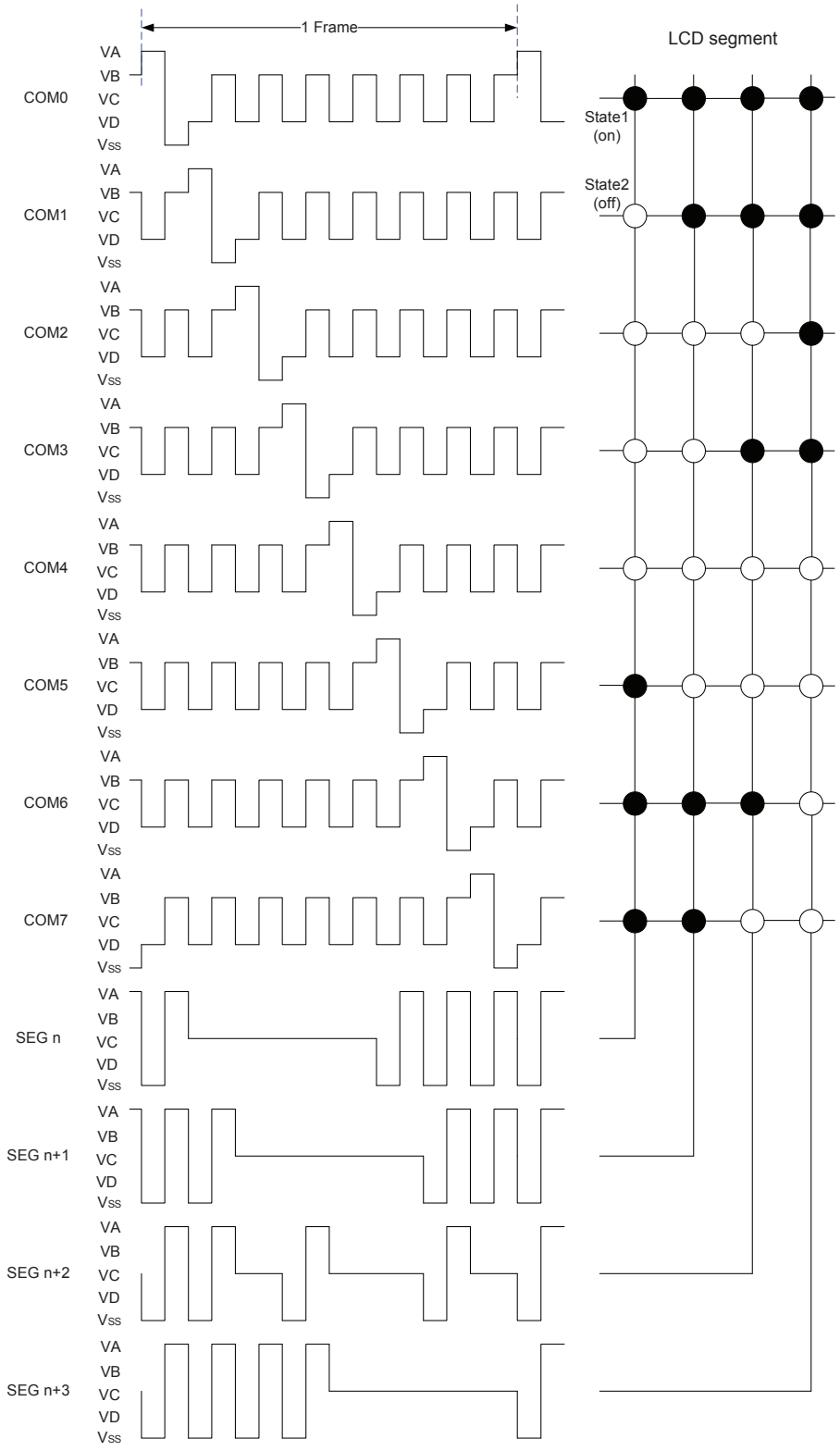


LCD Driver Output – Type A, 1/8 Duty, 1/3 Bias

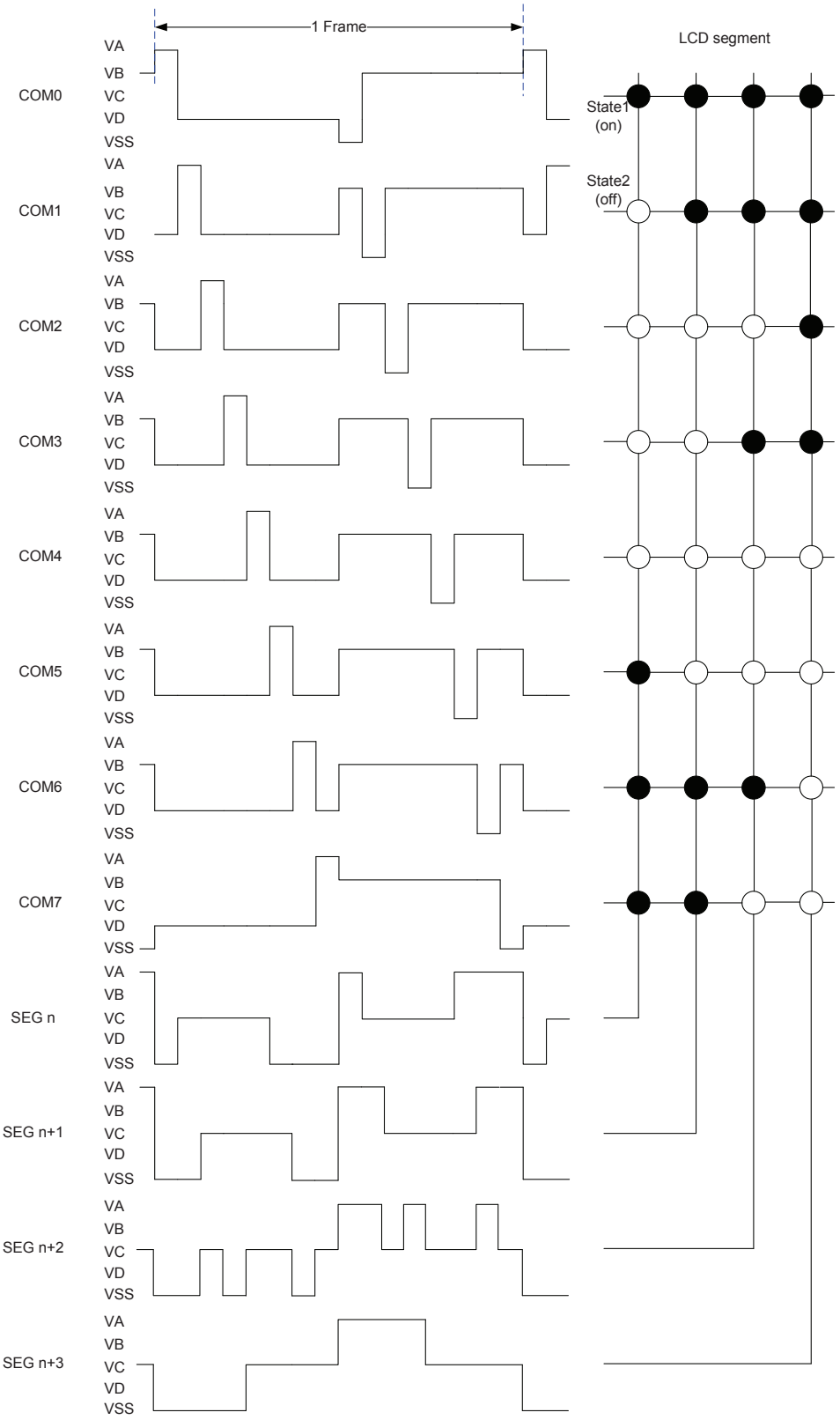


LCD Driver Output – Type B, 1/8 Duty, 1/3 Bias

R Type, 8-COM, 1/4 Bias



LCD Driver Output – Type A, 1/8 Duty, 1/4 Bias



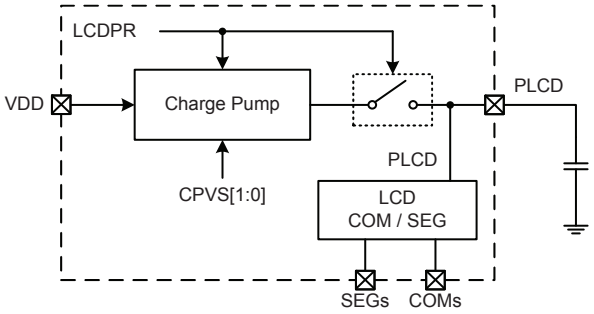
LCD Driver Output – Type B, 1/8 Duty, 1/4 Bias

LCD Charge Pump

For the R type LCD, the COMs and SEGs pins can be powered up by the external PLCD pin or internal charge pump circuit which is determined by the LCDPR bit in the LCDCP register. When the LCDPR bit is set low, the LCD driver power is supplied by the external PLCD pin. The PLCD pin voltage should be equal to or less than V_{DD} if the PLCD pin is selected to be used. If the LCDPR bit is set high, the LCD driver power is supplied by the internal charge pump circuit. There are four charge pump output voltage levels which are selected by the CPVS1~CPVS0 bits in the LCDCP register. If the internal charge pump circuit is used, an external 4.7μF capacitor should be connected to the external PLCD pin for output voltage stability. Note that there is also a relationship between the selected charge pump output voltage and V_{DD} when the internal charge pump circuit is used. In addition, when using the C type LCD, the LCDPR bit should be fixed at 0.

LCDPR	LCD Driver Power Supply	Relationship
0	PLCD pin	PLCD ≤ V_{DD}
1	Charge Pump Circuit	PLCD ≤ V_{DD} + 0.7V

LCD Driver Power Supply Relationship



R Type LCD Driver Charge Pump Circuit

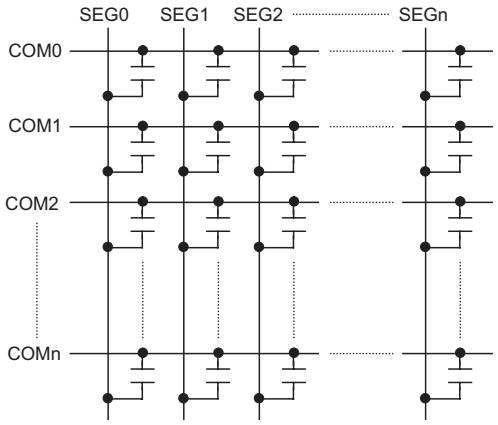
Programming Considerations

Certain precautions must be taken when programming the LCD. One of these is to ensure that the LCD Memory is properly initialised after the microcontroller is powered on. Like the General Purpose Data Memory, the contents of the LCD Memory are in an unknown condition after power-on. As the contents of the LCD Memory will be mapped into the actual display, it is important to initialise this memory area into a known condition soon after applying power to obtain a proper display pattern.

Consideration must also be given to the capacitive load of the actual LCD used in the application. As the load presented to the microcontroller by LCD pixels can be generally modeled as mainly capacitive in nature, it is important that this is not excessive, a point that is particularly true in the case of the COM lines which may be connected to many LCD pixels. The accompanying diagram depicts the equivalent circuit of the LCD.

One additional consideration that must be taken into account is what happens when the microcontroller enters the Idle or Slow Mode. The LCDEN control bit in the LCDC register permits the display to be powered off to reduce power consumption. If this bit is zero, the driving signals to the display will cease, producing a blank display pattern but reducing any power consumption associated with the LCD.

After Power-on, note that as the LCDEN bit will be cleared to zero, the display function will be disabled.



LCD Panel Equivalent Circuit

Low Voltage Detector – LVD

These devices have a Low Voltage Detector function, also known as LVD. This enabled these devices to monitor the power supply voltage, V_{DD}, or the LVDIN input voltage, and provide a warning signal should it fall below a certain level. This function may be especially useful in battery applications where the supply voltage will gradually reduce as the battery ages, as it allows an early warning battery low signal to be generated. The Low Voltage Detector also has the capability of generating an interrupt signal.

LVD Register

The Low Voltage Detector function is controlled using a single register with the name LVDC. Three bits in this register, VLVD2~VLVD0, are used to select one of eight fixed voltages below which a low voltage condition will be determined. A low voltage condition is indicated when the LVDO bit is set. If the LVDO bit is low, this indicates that the V_{DD} voltage or the LVDIN input voltage is above the preset low voltage value. The LVDEN bit is used to control the overall on/off function of the low voltage detector. Setting the bit high will enable the low voltage detector. Clearing the bit to zero will switch off the internal low voltage detector circuits. As the low voltage detector will consume a certain amount of power, it may be desirable to switch off the circuit when not in use, an important consideration in power sensitive battery powered applications.

LVDC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	LVDO	LVDEN	VBGEN	VLVD2	VLVD1	VLVD0
R/W	—	—	R	R/W	R/W	R/W	R/W	R/W
POR	—	—	0	0	0	0	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5 **LVDO**: LVD Output flag
0: No Low Voltage Detected
1: Low Voltage Detected

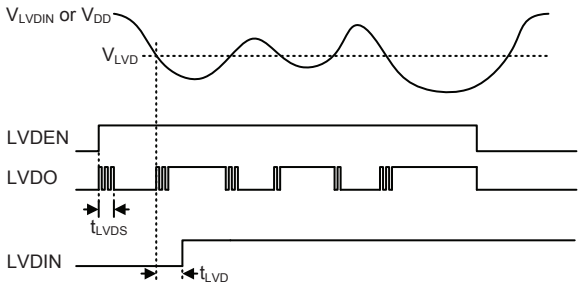
Bit 4 **LVDEN**: Low Voltage Detector Enable control
0: Disable
1: Enable

Bit 3 **VBGEN**: Bandgap Voltage Output Enable control
0: Disable
1: Enable
Note that the Bandgap circuit is enabled when the LVD or LVR function is enabled or when the VBGEN bit is set to 1.

Bit 2~0 **VLVD2~VLVD0**: LVD Voltage selection
000: $V_{LVDIN} \leq 1.04V$
001: 2.2V
010: 2.4V
011: 2.7V
100: 3.0V
101: 3.3V
110: 3.6V
111: 4.0V
When the VLVD bit field is set to 000B, the LVD function operates by comparing the LVD reference voltage with the LVDIN pin input voltage. Otherwise, the LVD function operates by comparing the LVD reference voltage with the power supply voltage when the VLVD bit field is set to any other value except 000B.

LVD Operation

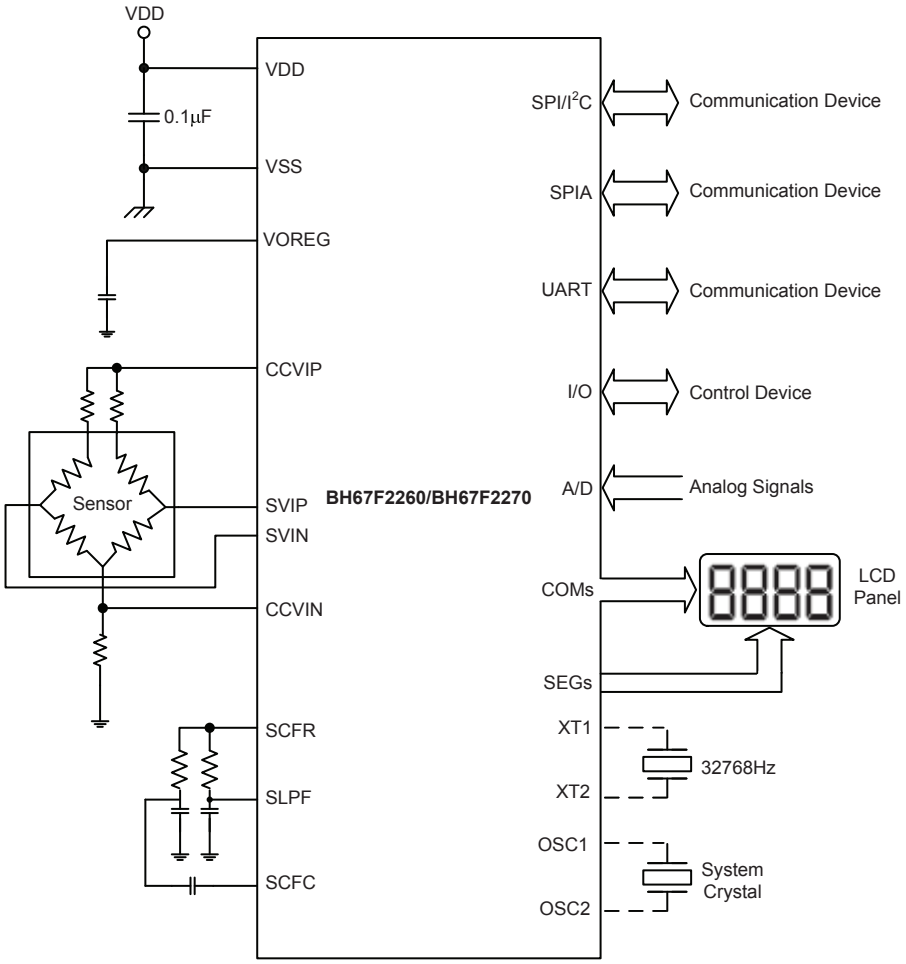
The Low Voltage Detector function operates by comparing the power supply voltage, V_{DD}, or the LVDIN input voltage, with a pre-specified voltage level stored in the LVDC register. This has a range of between 1.04V and 4.0V. When the power supply voltage, V_{DD}, falls below this pre-determined value, the LVDO bit will be set high indicating a low power supply voltage condition. The Low Voltage Detector function is supplied by a reference voltage which will be automatically enabled. When these devices are in the SLEEP mode, the low voltage detector will be disabled even if the LVDEN bit is high. After enabling the Low Voltage Detector, a time delay t_{LVDS} should be allowed for the circuitry to stabilise before reading the LVDO bit. Note also that as the V_{DD} or VLVDIN voltage may rise and fall rather slowly, at the voltage nears that of V_{LVD}, there may be multiple bit LVDO transitions.



LVD Operation

The Low Voltage Detector also has its own interrupt which is contained within one of the Multi-function interrupts, providing an alternative means of low voltage detection, in addition to polling the LVDO bit. The interrupt will only be generated after a delay of t_{LVD} after the LVDO bit has been set high by a low voltage condition. In this case, the LVF interrupt request flag will be set, causing an interrupt to be generated if V_{DD} or VLVDIN falls below the preset LVD voltage. This will cause these devices to wake-up from the IDLE Mode, however if the Low Voltage Detector wake up function is not required then the LVF flag should be first set high before these devices enter the IDLE Mode.

Application Circuits



Instruction Set

Introduction

Central to the successful operation of any microcontroller is its instruction set, which is a set of program instruction codes that directs the microcontroller to perform certain operations. In the case of Holtek microcontroller, a comprehensive and flexible set of over 60 instructions is provided to enable programmers to implement their application with the minimum of programming overheads.

For easier understanding of the various instruction codes, they have been subdivided into several functional groupings.

Instruction Timing

Most instructions are implemented within one instruction cycle. The exceptions to this are branch, call, or table read instructions where two instruction cycles are required. One instruction cycle is equal to 4 system clock cycles, therefore in the case of an 8MHz system oscillator, most instructions would be implemented within 0.5μs and branch or call instructions would be implemented within 1μs. Although instructions which require one more cycle to implement are generally limited to the JMP, CALL, RET, RETI and table read instructions, it is important to realize that any other instructions which involve manipulation of the Program Counter Low register or PCL will also take one more cycle to implement. As instructions which change the contents of the PCL will imply a direct jump to that new address, one more cycle will be required. Examples of such instructions would be "CLR PCL" or "MOV PCL, A". For the case of skip instructions, it must be noted that if the result of the comparison involves a skip operation then this will also take one more cycle, if no skip is involved then only one cycle is required.

Moving and Transferring Data

The transfer of data within the microcontroller program is one of the most frequently used operations. Making use of several kinds of MOV instructions, data can be transferred from registers to the Accumulator and vice-versa as well as being able to move specific immediate data directly into the Accumulator. One of the most important data transfer applications is to receive data from the input ports and transfer data to the output ports.

Arithmetic Operations

The ability to perform certain arithmetic operations and data manipulation is a necessary feature of most microcontroller applications. Within the Holtek microcontroller instruction set are a range of add and subtract instruction mnemonics to enable the necessary arithmetic to be carried out. Care must be taken to ensure correct handling of carry and borrow data when results exceed 255 for addition and less than 0 for subtraction. The increment and decrement instructions such as INC, INCA, DEC and DECA provide a simple means of increasing or decreasing by a value of one of the values in the destination specified.

Logical and Rotate Operation

The standard logical operations such as AND, OR, XOR and CPL all have their own instruction within the Holtek microcontroller instruction set. As with the case of most instructions involving data manipulation, data must pass through the Accumulator which may involve additional programming steps. In all logical data operations, the zero flag may be set if the result of the operation is zero. Another form of logical data manipulation comes from the rotate instructions such as RR, RL, RRC and RLC which provide a simple means of rotating one bit right or left. Different rotate instructions exist depending on program requirements. Rotate instructions are useful for serial port programming applications where data can be rotated from an internal register into the Carry bit from where it can be examined and the necessary serial bit set high or low. Another application which rotate data operations are used is to implement multiplication and division calculations.

Branches and Control Transfer

Program branching takes the form of either jumps to specified locations using the JMP instruction or to a subroutine using the CALL instruction. They differ in the sense that in the case of a subroutine call, the program must return to the instruction immediately when the subroutine has been carried out. This is done by placing a return instruction "RET" in the subroutine which will cause the program to jump back to the address right after the CALL instruction. In the case of a JMP instruction, the program simply jumps to the desired location. There is no requirement to jump back to the original jumping off point as in the case of the CALL instruction. One special and extremely useful set of branch instructions are the conditional branches. Here a decision is first made regarding the condition of a certain data memory or individual bits. Depending upon the conditions, the program will continue with the next instruction or skip over it and jump to the following instruction. These instructions are the key to decision making and branching within the program perhaps determined by the condition of certain input switches or by the condition of internal data bits.

Bit Operations

The ability to provide single bit operations on Data Memory is an extremely flexible feature of all Holtek microcontrollers. This feature is especially useful for output port bit programming where individual bits or port pins can be directly set high or low using either the "SET [m].i" or "CLR [m].i" instructions respectively. The feature removes the need for programmers to first read the 8-bit output port, manipulate the input data to ensure that other bits are not changed and then output the port with the correct new data. This read-modify-write process is taken care of automatically when these bit operation instructions are used.

Table Read Operations

Data storage is normally implemented by using registers. However, when working with large amounts of fixed data, the volume involved often makes it inconvenient to store the fixed data in the Data Memory. To overcome this problem, Holtek microcontrollers allow an area of Program Memory to be setup as a table where data can be directly stored. A set of easy to use instructions provides the means by which this fixed data can be referenced and retrieved from the Program Memory.

Other Operations

In addition to the above functional instructions, a range of other instructions also exist such as the "HALT" instruction for Power-down operations and instructions to control the operation of the Watchdog Timer for reliable program operations under extreme electric or electromagnetic environments. For their relevant operations, refer to the functional related sections.

Instruction Set Summary

The instructions related to the data memory access in the following table can be used when the desired data memory is located in Data Memory sector 0.

Table Conventions

x: Bits immediate data
m: Data Memory address
A: Accumulator
i: 0~7 number of bits
addr: Program memory address

Mnemonic	Description	Cycles	Flag Affected
Arithmetic			
ADD A,[m]	Add Data Memory to ACC	1	Z, C, AC, OV, SC
ADDM A,[m]	Add ACC to Data Memory	1Note	Z, C, AC, OV, SC
ADD A,x	Add immediate data to ACC	1	Z, C, AC, OV, SC
ADC A,[m]	Add Data Memory to ACC with Carry	1	Z, C, AC, OV, SC
ADCM A,[m]	Add ACC to Data memory with Carry	1Note	Z, C, AC, OV, SC
SUB A,x	Subtract immediate data from the ACC	1	Z, C, AC, OV, SC, CZ
SUB A,[m]	Subtract Data Memory from ACC	1	Z, C, AC, OV, SC, CZ
SUBM A,[m]	Subtract Data Memory from ACC with result in Data Memory	1Note	Z, C, AC, OV, SC, CZ
SBC A,x	Subtract immediate data from ACC with Carry	1	Z, C, AC, OV, SC, CZ
SBC A,[m]	Subtract Data Memory from ACC with Carry	1	Z, C, AC, OV, SC, CZ
SBCM A,[m]	Subtract Data Memory from ACC with Carry, result in Data Memory	1Note	Z, C, AC, OV, SC, CZ
DAA [m]	Decimal adjust ACC for Addition with result in Data Memory	1Note	C
Logic Operation			
AND A,[m]	Logical AND Data Memory to ACC	1	Z
OR A,[m]	Logical OR Data Memory to ACC	1	Z
XOR A,[m]	Logical XOR Data Memory to ACC	1	Z
ANDM A,[m]	Logical AND ACC to Data Memory	1Note	Z
ORM A,[m]	Logical OR ACC to Data Memory	1Note	Z
XORM A,[m]	Logical XOR ACC to Data Memory	1Note	Z
AND A,x	Logical AND immediate Data to ACC	1	Z
OR A,x	Logical OR immediate Data to ACC	1	Z
XOR A,x	Logical XOR immediate Data to ACC	1	Z
CPL [m]	Complement Data Memory	1Note	Z
CPLA [m]	Complement Data Memory with result in ACC	1	Z
Increment & Decrement			
INCA [m]	Increment Data Memory with result in ACC	1	Z
INC [m]	Increment Data Memory	1Note	Z
DECA [m]	Decrement Data Memory with result in ACC	1	Z
DEC [m]	Decrement Data Memory	1Note	Z
Rotate			
RRA [m]	Rotate Data Memory right with result in ACC	1	None
RR [m]	Rotate Data Memory right	1Note	None
RRCA [m]	Rotate Data Memory right through Carry with result in ACC	1	C
RRC [m]	Rotate Data Memory right through Carry	1Note	C
RLA [m]	Rotate Data Memory left with result in ACC	1	None
RL [m]	Rotate Data Memory left	1Note	None
RLCA [m]	Rotate Data Memory left through Carry with result in ACC	1	C
RLC [m]	Rotate Data Memory left through Carry	1Note	C

Mnemonic	Description	Cycles	Flag Affected
Data Move			
MOV A,[m]	Move Data Memory to ACC	1	None
MOV [m],A	Move ACC to Data Memory	1Note	None
MOV A,x	Move immediate data to ACC	1	None
Bit Operation			
CLR [m].i	Clear bit of Data Memory	1Note	None
SET [m].i	Set bit of Data Memory	1Note	None
Branch Operation			
JMP addr	Jump unconditionally	2	None
SZ [m]	Skip if Data Memory is zero	1Note	None
SZA [m]	Skip if Data Memory is zero with data movement to ACC	1Note	None
SZ [m].i	Skip if bit i of Data Memory is zero	1Note	None
SNZ [m]	Skip if Data Memory is not zero	1Note	None
SNZ [m].i	Skip if bit i of Data Memory is not zero	1Note	None
SIZ [m]	Skip if increment Data Memory is zero	1Note	None
SDZ [m]	Skip if decrement Data Memory is zero	1Note	None
SIZA [m]	Skip if increment Data Memory is zero with result in ACC	1Note	None
SDZA [m]	Skip if decrement Data Memory is zero with result in ACC	1Note	None
CALL addr	Subroutine call	2	None
RET	Return from subroutine	2	None
RET A,x	Return from subroutine and load immediate data to ACC	2	None
RETI	Return from interrupt	2	None
Table Read Operation			
TABRD [m]	Read table (specific page) to TBLH and Data Memory	2Note	None
TABRDL [m]	Read table (last page) to TBLH and Data Memory	2Note	None
ITABRD [m]	Increment table pointer TBLP first and Read table to TBLH and Data Memory	2Note	None
ITABRDL [m]	Increment table pointer TBLP first and Read table (last page) to TBLH and Data Memory	2Note	None
Miscellaneous			
NOP	No operation	1	None
CLR [m]	Clear Data Memory	1Note	None
SET [m]	Set Data Memory	1Note	None
CLR WDT	Clear Watchdog Timer	1	TO, PDF
SWAP [m]	Swap nibbles of Data Memory	1Note	None
SWAPA [m]	Swap nibbles of Data Memory with result in ACC	1	None
HALT	Enter power down mode	1	TO, PDF

Note: 1. For skip instructions, if the result of the comparison involves a skip then up to three cycles are required, if no skip takes place only one cycle is required.
2. Any instruction which changes the contents of the PCL will also require 2 cycles for execution.
3. For the "CLR WDT" instruction the TO and PDF flags may be affected by the execution status. The TO and PDF flags are cleared after the "CLR WDT" instructions is executed. Otherwise the TO and PDF flags remain unchanged.

Extended Instruction Set

The extended instructions are used to support the full range address access for the data memory. When the accessed data memory is located in any data memory sections except sector 0, the extended instruction can be used to access the data memory instead of using the indirect addressing access to improve the CPU firmware performance.

Mnemonic	Description	Cycles	Flag Affected
Arithmetic			
LADD A,[m]	Add Data Memory to ACC	2	Z, C, AC, OV, SC
LADDM A,[m]	Add ACC to Data Memory	2Note	Z, C, AC, OV, SC
LADC A,[m]	Add Data Memory to ACC with Carry	2	Z, C, AC, OV, SC
LADCM A,[m]	Add ACC to Data memory with Carry	2Note	Z, C, AC, OV, SC
LSUB A,[m]	Subtract Data Memory from ACC	2	Z, C, AC, OV, SC, CZ
LSUBM A,[m]	Subtract Data Memory from ACC with result in Data Memory	2Note	Z, C, AC, OV, SC, CZ
LSBC A,[m]	Subtract Data Memory from ACC with Carry	2	Z, C, AC, OV, SC, CZ
LSBCM A,[m]	Subtract Data Memory from ACC with Carry, result in Data Memory	2Note	Z, C, AC, OV, SC, CZ
LDAA [m]	Decimal adjust ACC for Addition with result in Data Memory	2Note	C
Logic Operation			
LAND A,[m]	Logical AND Data Memory to ACC	2	Z
LOR A,[m]	Logical OR Data Memory to ACC	2	Z
LXOR A,[m]	Logical XOR Data Memory to ACC	2	Z
LANDM A,[m]	Logical AND ACC to Data Memory	2Note	Z
LORM A,[m]	Logical OR ACC to Data Memory	2Note	Z
LXORM A,[m]	Logical XOR ACC to Data Memory	2Note	Z
LCPL [m]	Complement Data Memory	2Note	Z
LCPLA [m]	Complement Data Memory with result in ACC	2	Z
Increment & Decrement			
LINCA [m]	Increment Data Memory with result in ACC	2	Z
LINC [m]	Increment Data Memory	2Note	Z
LDECA [m]	Decrement Data Memory with result in ACC	2	Z
LDEC [m]	Decrement Data Memory	2Note	Z
Rotate			
LRRA [m]	Rotate Data Memory right with result in ACC	2	None
LRR [m]	Rotate Data Memory right	2Note	None
LRRCA [m]	Rotate Data Memory right through Carry with result in ACC	2	C
LRRC [m]	Rotate Data Memory right through Carry	2Note	C
LRLA [m]	Rotate Data Memory left with result in ACC	2	None
LRL [m]	Rotate Data Memory left	2Note	None
LRLCA [m]	Rotate Data Memory left through Carry with result in ACC	2	C
LRLC [m]	Rotate Data Memory left through Carry	2Note	C
Data Move			
LMOV A,[m]	Move Data Memory to ACC	2	None
LMOV [m],A	Move ACC to Data Memory	2Note	None
Bit Operation			
LCLR [m].i	Clear bit of Data Memory	2Note	None
LSET [m].i	Set bit of Data Memory	2Note	None

Mnemonic	Description	Cycles	Flag Affected
Branch			
LSZ [m]	Skip if Data Memory is zero	2Note	None
LSZA [m]	Skip if Data Memory is zero with data movement to ACC	2Note	None
LSNZ [m]	Skip if Data Memory is not zero	2Note	None
LSZ [m].i	Skip if bit i of Data Memory is zero	2Note	None
LSNZ [m].i	Skip if bit i of Data Memory is not zero	2Note	None
LSIZ [m]	Skip if increment Data Memory is zero	2Note	None
LSDZ [m]	Skip if decrement Data Memory is zero	2Note	None
LSIZA [m]	Skip if increment Data Memory is zero with result in ACC	2Note	None
LSDZA [m]	Skip if decrement Data Memory is zero with result in ACC	2Note	None
Table Read			
LTABRD [m]	Read table to TBLH and Data Memory	3Note	None
LTABRDL [m]	Read table (last page) to TBLH and Data Memory	3Note	None
LITABRD [m]	Increment table pointer TBLP first and Read table to TBLH and Data Memory	3Note	None
LITABRDL [m]	Increment table pointer TBLP first and Read table (last page) to TBLH and Data Memory	3Note	None
Miscellaneous			
LCLR [m]	Clear Data Memory	2Note	None
LSET [m]	Set Data Memory	2Note	None
LSWAP [m]	Swap nibbles of Data Memory	2Note	None
LSWAPA [m]	Swap nibbles of Data Memory with result in ACC	2	None

Note: 1. For these extended skip instructions, if the result of the comparison involves a skip then up to four cycles are required, if no skip takes place two cycles is required.

2. Any extended instruction which changes the contents of the PCL register will also require three cycles for execution.

Instruction Definition

ADC A,[m] Add Data Memory to ACC with Carry

Description The contents of the specified Data Memory, Accumulator and the carry flag are added. The result is stored in the Accumulator.

Operation ACC ← ACC + [m] + C

Affected flag(s) OV, Z, AC, C, SC

ADCM A,[m] Add ACC to Data Memory with Carry

Description The contents of the specified Data Memory, Accumulator and the carry flag are added. The result is stored in the specified Data Memory.

Operation [m] ← ACC + [m] + C

Affected flag(s) OV, Z, AC, C, SC

ADD A,[m] Add Data Memory to ACC

Description The contents of the specified Data Memory and the Accumulator are added. The result is stored in the Accumulator.

Operation ACC ← ACC + [m]

Affected flag(s) OV, Z, AC, C, SC

ADD A,x Add immediate data to ACC

Description The contents of the Accumulator and the specified immediate data are added. The result is stored in the Accumulator.

Operation ACC ← ACC + x

Affected flag(s) OV, Z, AC, C, SC

ADDM A,[m] Add ACC to Data Memory

Description The contents of the specified Data Memory and the Accumulator are added. The result is stored in the specified Data Memory.

Operation [m] ← ACC + [m]

Affected flag(s) OV, Z, AC, C, SC

AND A,[m] Logical AND Data Memory to ACC

Description Data in the Accumulator and the specified Data Memory perform a bitwise logical AND operation. The result is stored in the Accumulator.

Operation ACC ← ACC "AND" [m]

Affected flag(s) Z

AND A,x Logical AND immediate data to ACC

Description Data in the Accumulator and the specified immediate data perform a bit wise logical AND operation. The result is stored in the Accumulator.

Operation ACC ← ACC "AND" x

Affected flag(s) Z

ANDM A,[m] Logical AND ACC to Data Memory

Description Data in the specified Data Memory and the Accumulator perform a bitwise logical AND operation. The result is stored in the Data Memory.

Operation [m] ← ACC "AND" [m]

Affected flag(s) Z

CALL addr Subroutine call

Description: Unconditionally calls a subroutine at the specified address. The Program Counter then increments by 1 to obtain the address of the next instruction which is then pushed onto the stack. The specified address is then loaded and the program continues execution from this new address. As this instruction requires an additional operation, it is a two cycle instruction.

Operation: Stack ← Program Counter + 1
Program Counter ← addr

Affected flag(s): None

CLR [m] Clear Data Memory

Description: Each bit of the specified Data Memory is cleared to 0.

Operation: [m] ← 00H

Affected flag(s): None

CLR [m].i Clear bit of Data Memory

Description: Bit i of the specified Data Memory is cleared to 0.

Operation: [m].i ← 0

Affected flag(s): None

CLR WDT Clear Watchdog Timer

Description: The TO, PDF flags and the WDT are all cleared.

Operation: WDT cleared
TO ← 0
PDF ← 0

Affected flag(s): TO, PDF

CPL [m] Complement Data Memory

Description: Each bit of the specified Data Memory is logically complemented (1′s complement). Bits which previously contained a 1 are changed to 0 and vice versa.

Operation: [m] ← $\overline{[m]}$

Affected flag(s): Z

CPLA [m] Complement Data Memory with result in ACC

Description: Each bit of the specified Data Memory is logically complemented (1′s complement). Bits which previously contained a 1 are changed to 0 and vice versa. The complemented result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation: ACC ← $\overline{[m]}$

Affected flag(s): Z

DAA [m] Decimal-Adjust ACC for addition with result in Data Memory

Description: Convert the contents of the Accumulator value to a BCD (Binary Coded Decimal) value resulting from the previous addition of two BCD variables. If the low nibble is greater than 9 or if AC flag is set, then a value of 6 will be added to the low nibble. Otherwise the low nibble remains unchanged. If the high nibble is greater than 9 or if the C flag is set, then a value of 6 will be added to the high nibble. Essentially, the decimal conversion is performed by adding 00H, 06H, 60H or 66H depending on the Accumulator and flag conditions. Only the C flag may be affected by this instruction which indicates that if the original BCD sum is greater than 100, it allows multiple precision decimal addition.

Operation: [m] ← ACC + 00H or
[m] ← ACC + 06H or
[m] ← ACC + 60H or
[m] ← ACC + 66H

Affected flag(s): C

DEC [m] Decrement Data Memory

Description Data in the specified Data Memory is decremented by 1.

Operation [m] ← [m] − 1

Affected flag(s) Z

DECA [m] Decrement Data Memory with result in ACC

Description Data in the specified Data Memory is decremented by 1. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.

Operation ACC ← [m] − 1

Affected flag(s) Z

HALT Enter power down mode

Description This instruction stops the program execution and turns off the system clock. The contents of the Data Memory and registers are retained. The WDT and prescaler are cleared. The power down flag PDF is set and the WDT time-out flag TO is cleared.

Operation TO ← 0
PDF ← 1

Affected flag(s) TO, PDF

INC [m] Increment Data Memory

Description Data in the specified Data Memory is incremented by 1.

Operation [m] ← [m] + 1

Affected flag(s) Z

INCA [m] Increment Data Memory with result in ACC

Description Data in the specified Data Memory is incremented by 1. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.

Operation ACC ← [m] + 1

Affected flag(s) Z

JMP addr Jump unconditionally

Description The contents of the Program Counter are replaced with the specified address. Program execution then continues from this new address. As this requires the insertion of a dummy instruction while the new address is loaded, it is a two cycle instruction.

Operation Program Counter ← addr

Affected flag(s) None

MOV A,[m] Move Data Memory to ACC

Description The contents of the specified Data Memory are copied to the Accumulator.

Operation ACC ← [m]

Affected flag(s) None

MOV A,x Move immediate data to ACC

Description The immediate data specified is loaded into the Accumulator.

Operation ACC ← x

Affected flag(s) None

MOV [m],A Move ACC to Data Memory

Description The contents of the Accumulator are copied to the specified Data Memory.

Operation [m] ← ACC

Affected flag(s) None

NOP No operation

Description No operation is performed. Execution continues with the next instruction.

Operation No operation

Affected flag(s) None

OR A,[m] Logical OR Data Memory to ACC

Description Data in the Accumulator and the specified Data Memory perform a bitwise logical OR operation. The result is stored in the Accumulator.

Operation ACC ← ACC ″OR″ [m]

Affected flag(s) Z

OR A,x Logical OR immediate data to ACC

Description Data in the Accumulator and the specified immediate data perform a bitwise logical OR operation. The result is stored in the Accumulator.

Operation ACC ← ACC ″OR″ x

Affected flag(s) Z

ORM A,[m] Logical OR ACC to Data Memory

Description Data in the specified Data Memory and the Accumulator perform a bitwise logical OR operation. The result is stored in the Data Memory.

Operation [m] ← ACC ″OR″ [m]

Affected flag(s) Z

RET Return from subroutine

Description The Program Counter is restored from the stack. Program execution continues at the restored address.

Operation Program Counter ← Stack

Affected flag(s) None

RET A,x Return from subroutine and load immediate data to ACC

Description The Program Counter is restored from the stack and the Accumulator loaded with the specified immediate data. Program execution continues at the restored address.

Operation Program Counter ← Stack
ACC ← x

Affected flag(s) None

RETI Return from interrupt

Description The Program Counter is restored from the stack and the interrupts are re-enabled by setting the EMI bit. EMI is the master interrupt global enable bit. If an interrupt was pending when the RETI instruction is executed, the pending Interrupt routine will be processed before returning to the main program.

Operation Program Counter ← Stack
EMI ← 1

Affected flag(s) None

RL [m] Rotate Data Memory left

Description The contents of the specified Data Memory are rotated left by 1 bit with bit 7 rotated into bit 0.

Operation [m].(i+1) ← [m].i; (i=0~6)
[m].0 ← [m].7

Affected flag(s) None

RLA [m] Rotate Data Memory left with result in ACC

Description The contents of the specified Data Memory are rotated left by 1 bit with bit 7 rotated into bit 0. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC.(i+1) ← [m].i; (i=0~6)
ACC.0 ← [m].7

Affected flag(s) None

RLC [m] Rotate Data Memory left through Carry

Description The contents of the specified Data Memory and the carry flag are rotated left by 1 bit. Bit 7 replaces the Carry bit and the original carry flag is rotated into bit 0.

Operation [m].(i+1) ← [m].i; (i=0~6)
[m].0 ← C
C ← [m].7

Affected flag(s) C

RLCA [m] Rotate Data Memory left through Carry with result in ACC

Description Data in the specified Data Memory and the carry flag are rotated left by 1 bit. Bit 7 replaces the Carry bit and the original carry flag is rotated into the bit 0. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC.(i+1) ← [m].i; (i=0~6)
ACC.0 ← C
C ← [m].7

Affected flag(s) C

RR [m] Rotate Data Memory right

Description The contents of the specified Data Memory are rotated right by 1 bit with bit 0 rotated into bit 7.

Operation [m].i ← [m].(i+1); (i=0~6)
[m].7 ← [m].0

Affected flag(s) None

RRA [m] Rotate Data Memory right with result in ACC

Description Data in the specified Data Memory is rotated right by 1 bit with bit 0
rotated into bit 7. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC.i ← [m].(i+1); (i=0~6)
ACC.7 ← [m].0

Affected flag(s) None

RRC [m] Rotate Data Memory right through Carry

Description The contents of the specified Data Memory and the carry flag are rotated right by 1 bit. Bit 0 replaces the Carry bit and the original carry flag is rotated into bit 7.

Operation [m].i ← [m].(i+1); (i=0~6)
[m].7 ← C
C ← [m].0

Affected flag(s) C

RRCA [m] Rotate Data Memory right through Carry with result in ACC

Description: Data in the specified Data Memory and the carry flag are rotated right by 1 bit. Bit 0 replaces the Carry bit and the original carry flag is rotated into bit 7. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation:
ACC.i ← [m].(i+1); (i=0~6)
ACC.7 ← C
C ← [m].0

Affected flag(s): C

SBC A,[m] Subtract Data Memory from ACC with Carry

Description: The contents of the specified Data Memory and the complement of the carry flag are subtracted from the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation: ACC ← ACC − [m] − C

Affected flag(s): OV, Z, AC, C, SC, CZ

SBC A, x Subtract immediate data from ACC with Carry

Description: The immediate data and the complement of the carry flag are subtracted from the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation: ACC ← ACC - [m] - $\overline{C}$

Affected flag(s): OV, Z, AC, C, SC, CZ

SBCM A,[m] Subtract Data Memory from ACC with Carry and result in Data Memory

Description: The contents of the specified Data Memory and the complement of the carry flag are subtracted from the Accumulator. The result is stored in the Data Memory. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation: [m] ← ACC − [m] − C

Affected flag(s): OV, Z, AC, C, SC, CZ

SDZ [m] Skip if decrement Data Memory is 0

Description: The contents of the specified Data Memory are first decremented by 1. If the result is 0 the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation:
[m] ← [m] − 1
Skip if [m]=0

Affected flag(s): None

SDZA [m] Skip if decrement Data Memory is zero with result in ACC

Description: The contents of the specified Data Memory are first decremented by 1. If the result is 0, the following instruction is skipped. The result is stored in the Accumulator but the specified Data Memory contents remain unchanged. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0, the program proceeds with the following instruction.

Operation:
ACC ← [m] − 1
Skip if ACC=0

Affected flag(s): None

SET [m]	Set Data Memory
Description	Each bit of the specified Data Memory is set to 1.
Operation	[m] ← FFH
Affected flag(s)	None

SET [m].i	Set bit of Data Memory
Description	Bit i of the specified Data Memory is set to 1.
Operation	[m].i ← 1
Affected flag(s)	None

SIZ [m]	Skip if increment Data Memory is 0
Description	The contents of the specified Data Memory are first incremented by 1. If the result is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.
Operation	[m] ← [m] + 1 Skip if [m]=0
Affected flag(s)	None

SIZA [m]	Skip if increment Data Memory is zero with result in ACC
Description	The contents of the specified Data Memory are first incremented by 1. If the result is 0, the following instruction is skipped. The result is stored in the Accumulator but the specified Data Memory contents remain unchanged. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.
Operation	ACC ← [m] + 1 Skip if ACC=0
Affected flag(s)	None

SNZ [m].i	Skip if Data Memory is not 0
Description	If the specified Data Memory is not 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is 0 the program proceeds with the following instruction.
Operation	Skip if [m].i ≠ 0
Affected flag(s)	None

SNZ [m]	Skip if Data Memory is not 0
Description	If the specified Data Memory is not 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is 0 the program proceeds with the following instruction.
Operation	Skip if [m]≠ 0
Affected flag(s)	None

SUB A,[m]	Subtract Data Memory from ACC
Description	The specified Data Memory is subtracted from the contents of the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.
Operation	ACC ← ACC − [m]
Affected flag(s)	OV, Z, AC, C, SC, CZ

SUBM A,[m] Subtract Data Memory from ACC with result in Data Memory

Description The specified Data Memory is subtracted from the contents of the Accumulator. The result is stored in the Data Memory. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation [m] ← ACC − [m]

Affected flag(s) OV, Z, AC, C, SC, CZ

SUB A,x Subtract immediate data from ACC

Description The immediate data specified by the code is subtracted from the contents of the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation ACC ← ACC − x

Affected flag(s) OV, Z, AC, C, SC, CZ

SWAP [m] Swap nibbles of Data Memory

Description The low-order and high-order nibbles of the specified Data Memory are interchanged.

Operation [m].3~[m].0 ↔ [m].7~[m].4

Affected flag(s) None

SWAPA [m] Swap nibbles of Data Memory with result in ACC

Description The low-order and high-order nibbles of the specified Data Memory are interchanged. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.

Operation ACC.3~ACC.0 ← [m].7~[m].4
ACC.7~ACC.4 ← [m].3~[m].0

Affected flag(s) None

SZ [m] Skip if Data Memory is 0

Description If the contents of the specified Data Memory is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation Skip if [m]=0

Affected flag(s) None

SZA [m] Skip if Data Memory is 0 with data movement to ACC

Description The contents of the specified Data Memory are copied to the Accumulator. If the value is zero, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation ACC ← [m]
Skip if [m]=0

Affected flag(s) None

SZ [m].i Skip if bit i of Data Memory is 0

Description If bit i of the specified Data Memory is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0, the program proceeds with the following instruction.

Operation Skip if [m].i=0

Affected flag(s) None

TABRD [m] Read table (specific page) to TBLH and Data Memory

Description The low byte of the program code (specific page) addressed by the table pointer pair (TBLP and TBHP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

TABRDL [m] Read table (last page) to TBLH and Data Memory

Description The low byte of the program code (last page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

ITABRD [m] Increment table pointer low byte first and read table to TBLH and Data Memory

Description Increment table pointer low byte, TBLP, first and then the program code addressed by the table pointer (TBHP and TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

ITABRDL [m] Increment table pointer low byte first and read table (last page) to TBLH and Data Memory

Description Increment table pointer low byte, TBLP, first and then the low byte of the program code (last page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

XOR A,[m] Logical XOR Data Memory to ACC

Description Data in the Accumulator and the specified Data Memory perform a bitwise logical XOR operation. The result is stored in the Accumulator.

Operation ACC ← ACC ″XOR″ [m]

Affected flag(s) Z

XORM A,[m] Logical XOR ACC to Data Memory

Description Data in the specified Data Memory and the Accumulator perform a bitwise logical XOR operation. The result is stored in the Data Memory.

Operation [m] ← ACC ″XOR″ [m]

Affected flag(s) Z

XOR A,x Logical XOR immediate data to ACC

Description Data in the Accumulator and the specified immediate data perform a bitwise logical XOR operation. The result is stored in the Accumulator.

Operation ACC ← ACC ″XOR″ x

Affected flag(s) Z

Extended Instruction Definition

The extended instructions are used to directly access the data stored in any data memory sections.

LADC A,[m] Add Data Memory to ACC with Carry

Description The contents of the specified Data Memory, Accumulator and the carry flag are added. The result is stored in the Accumulator.

Operation ACC ← ACC + [m] + C

Affected flag(s) OV, Z, AC, C, SC

LADCM A,[m] Add ACC to Data Memory with Carry

Description The contents of the specified Data Memory, Accumulator and the carry flag are added. The result is stored in the specified Data Memory.

Operation [m] ← ACC + [m] + C

Affected flag(s) OV, Z, AC, C, SC

LADD A,[m] Add Data Memory to ACC

Description The contents of the specified Data Memory and the Accumulator are added. The result is stored in the Accumulator.

Operation ACC ← ACC + [m]

Affected flag(s) OV, Z, AC, C, SC

LADDM A,[m] Add ACC to Data Memory

Description The contents of the specified Data Memory and the Accumulator are added. The result is stored in the specified Data Memory.

Operation [m] ← ACC + [m]

Affected flag(s) OV, Z, AC, C, SC

LAND A,[m] Logical AND Data Memory to ACC

Description Data in the Accumulator and the specified Data Memory perform a bitwise logical AND operation. The result is stored in the Accumulator.

Operation ACC ← ACC ″AND″ [m]

Affected flag(s) Z

LANDM A,[m] Logical AND ACC to Data Memory

Description Data in the specified Data Memory and the Accumulator perform a bitwise logical AND operation. The result is stored in the Data Memory.

Operation [m] ← ACC ″AND″ [m]

Affected flag(s) Z

LCLR [m] Clear Data Memory

Description Each bit of the specified Data Memory is cleared to 0.

Operation [m] ← 00H

Affected flag(s) None

LCLR [m].i Clear bit of Data Memory

Description Bit i of the specified Data Memory is cleared to 0.

Operation [m].i ← 0

Affected flag(s) None

LCPL [m] Complement Data Memory

Description Each bit of the specified Data Memory is logically complemented (1′s complement). Bits which previously contained a 1 are changed to 0 and vice versa.

Operation $[m] \leftarrow \overline{[m]}$

Affected flag(s) Z

LCPLA [m] Complement Data Memory with result in ACC

Description Each bit of the specified Data Memory is logically complemented (1′s complement). Bits which previously contained a 1 are changed to 0 and vice versa. The complemented result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation $ACC \leftarrow \overline{[m]}$

Affected flag(s) Z

LDAA [m] Decimal-Adjust ACC for addition with result in Data Memory

Description Convert the contents of the Accumulator value to a BCD (Binary Coded Decimal) value resulting from the previous addition of two BCD variables. If the low nibble is greater than 9 or if AC flag is set, then a value of 6 will be added to the low nibble. Otherwise the low nibble remains unchanged. If the high nibble is greater than 9 or if the C flag is set, then a value of 6 will be added to the high nibble. Essentially, the decimal conversion is performed by adding 00H, 06H, 60H or 66H depending on the Accumulator and flag conditions. Only the C flag may be affected by this instruction which indicates that if the original BCD sum is greater than 100, it allows multiple precision decimal addition.

Operation $[m] \leftarrow ACC + 00H$ or
$[m] \leftarrow ACC + 06H$ or
$[m] \leftarrow ACC + 60H$ or
$[m] \leftarrow ACC + 66H$

Affected flag(s) C

LDEC [m] Decrement Data Memory

Description Data in the specified Data Memory is decremented by 1.

Operation $[m] \leftarrow [m] - 1$

Affected flag(s) Z

LDECA [m] Decrement Data Memory with result in ACC

Description Data in the specified Data Memory is decremented by 1. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.

Operation $ACC \leftarrow [m] - 1$

Affected flag(s) Z

LINC [m] Increment Data Memory

Description Data in the specified Data Memory is incremented by 1.

Operation $[m] \leftarrow [m] + 1$

Affected flag(s) Z

LINCA [m] Increment Data Memory with result in ACC

Description Data in the specified Data Memory is incremented by 1. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.

Operation $ACC \leftarrow [m] + 1$

Affected flag(s) Z

LMOV A,[m] Move Data Memory to ACC

Description The contents of the specified Data Memory are copied to the Accumulator.

Operation ACC ← [m]

Affected flag(s) None

LMOV [m],A Move ACC to Data Memory

Description The contents of the Accumulator are copied to the specified Data Memory.

Operation [m] ← ACC

Affected flag(s) None

LOR A,[m] Logical OR Data Memory to ACC

Description Data in the Accumulator and the specified Data Memory perform a bitwise logical OR operation. The result is stored in the Accumulator.

Operation ACC ← ACC ″OR″ [m]

Affected flag(s) Z

LORM A,[m] Logical OR ACC to Data Memory

Description Data in the specified Data Memory and the Accumulator perform a bitwise logical OR operation. The result is stored in the Data Memory.

Operation [m] ← ACC ″OR″ [m]

Affected flag(s) Z

LRL [m] Rotate Data Memory left

Description The contents of the specified Data Memory are rotated left by 1 bit with bit 7 rotated into bit 0.

Operation [m].(i+1) ← [m].i; (i=0~6)
[m].0 ← [m].7

Affected flag(s) None

LRLA [m] Rotate Data Memory left with result in ACC

Description The contents of the specified Data Memory are rotated left by 1 bit with bit 7 rotated into bit 0. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC.(i+1) ← [m].i; (i=0~6)
ACC.0 ← [m].7

Affected flag(s) None

LRLC [m] Rotate Data Memory left through Carry

Description The contents of the specified Data Memory and the carry flag are rotated left by 1 bit. Bit 7 replaces the Carry bit and the original carry flag is rotated into bit 0.

Operation [m].(i+1) ← [m].i; (i=0~6)
[m].0 ← C
C ← [m].7

Affected flag(s) C

LRLCA [m] Rotate Data Memory left through Carry with result in ACC

Description Data in the specified Data Memory and the carry flag are rotated left by 1 bit. Bit 7 replaces the Carry bit and the original carry flag is rotated into the bit 0. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC.(i+1) ← [m].i; (i=0~6)
ACC.0 ← C
C ← [m].7

Affected flag(s) C

LRR [m] Rotate Data Memory right

Description The contents of the specified Data Memory are rotated right by 1 bit with bit 0 rotated into bit 7.

Operation [m].i ← [m].(i+1); (i=0~6)
[m].7 ← [m].0

Affected flag(s) None

LRRA [m] Rotate Data Memory right with result in ACC

Description Data in the specified Data Memory is rotated right by 1 bit with bit 0 rotated into bit 7. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC.i ← [m].(i+1); (i=0~6)
ACC.7 ← [m].0

Affected flag(s) None

LRRC [m] Rotate Data Memory right through Carry

Description The contents of the specified Data Memory and the carry flag are rotated right by 1 bit. Bit 0 replaces the Carry bit and the original carry flag is rotated into bit 7.

Operation [m].i ← [m].(i+1); (i=0~6)
[m].7 ← C
C ← [m].0

Affected flag(s) C

LRRCA [m] Rotate Data Memory right through Carry with result in ACC

Description Data in the specified Data Memory and the carry flag are rotated right by 1 bit. Bit 0 replaces the Carry bit and the original carry flag is rotated into bit 7. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation ACC.i ← [m].(i+1); (i=0~6)
ACC.7 ← C
C ← [m].0

Affected flag(s) C

LSBC A,[m] Subtract Data Memory from ACC with Carry

Description The contents of the specified Data Memory and the complement of the carry flag are subtracted from the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation ACC ← ACC − [m] − C

Affected flag(s) OV, Z, AC, C, SC, CZ

LSBCM A,[m] Subtract Data Memory from ACC with Carry and result in Data Memory

Description The contents of the specified Data Memory and the complement of the carry flag are subtracted from the Accumulator. The result is stored in the Data Memory. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation [m] ← ACC − [m] − C

Affected flag(s) OV, Z, AC, C, SC, CZ

LSDZ [m] Skip if decrement Data Memory is 0

Description The contents of the specified Data Memory are first decremented by 1. If the result is 0 the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation [m] ← [m] − 1
Skip if [m]=0

Affected flag(s) None

LSDZA [m] Skip if decrement Data Memory is zero with result in ACC

Description The contents of the specified Data Memory are first decremented by 1. If the result is 0, the following instruction is skipped. The result is stored in the Accumulator but the specified Data Memory contents remain unchanged. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0, the program proceeds with the following instruction.

Operation ACC ← [m] − 1
Skip if ACC=0

Affected flag(s) None

LSET [m] Set Data Memory

Description Each bit of the specified Data Memory is set to 1.

Operation [m] ← FFH

Affected flag(s) None

LSET [m].i Set bit of Data Memory

Description Bit i of the specified Data Memory is set to 1.

Operation [m].i ← 1

Affected flag(s) None

LSIZ [m] Skip if increment Data Memory is 0

Description The contents of the specified Data Memory are first incremented by 1. If the result is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation [m] ← [m] + 1
Skip if [m]=0

Affected flag(s) None

LSIZA [m] Skip if increment Data Memory is zero with result in ACC

Description The contents of the specified Data Memory are first incremented by 1. If the result is 0, the following instruction is skipped. The result is stored in the Accumulator but the specified Data Memory contents remain unchanged. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation ACC ← [m] + 1
Skip if ACC=0

Affected flag(s) None

LSNZ [m].i Skip if Data Memory is not 0

Description If the specified Data Memory is not 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is 0 the program proceeds with the following instruction.

Operation Skip if [m].i ≠ 0

Affected flag(s) None

LSNZ [m] Skip if Data Memory is not 0

Description If the content of the specified Data Memory is not 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is 0 the program proceeds with the following instruction.

Operation Skip if [m] ≠ 0

Affected flag(s) None

LSUB A,[m] Subtract Data Memory from ACC

Description The specified Data Memory is subtracted from the contents of the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation ACC ← ACC − [m]

Affected flag(s) OV, Z, AC, C, SC, CZ

LSUBM A,[m] Subtract Data Memory from ACC with result in Data Memory

Description The specified Data Memory is subtracted from the contents of the Accumulator. The result is stored in the Data Memory. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation [m] ← ACC − [m]

Affected flag(s) OV, Z, AC, C, SC, CZ

LSWAP [m] Swap nibbles of Data Memory

Description The low-order and high-order nibbles of the specified Data Memory are interchanged.

Operation [m].3~[m].0 ↔ [m].7~[m].4

Affected flag(s) None

LSWAPA [m] Swap nibbles of Data Memory with result in ACC

Description The low-order and high-order nibbles of the specified Data Memory are interchanged. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.

Operation ACC.3~ACC.0 ← [m].7~[m].4
ACC.7~ACC.4 ← [m].3~[m].0

Affected flag(s) None

LSZ [m] Skip if Data Memory is 0

Description If the contents of the specified Data Memory is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation Skip if [m]=0

Affected flag(s) None

LSZA [m] Skip if Data Memory is 0 with data movement to ACC

Description The contents of the specified Data Memory are copied to the Accumulator. If the value is zero, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation ACC ← [m]
Skip if [m]=0

Affected flag(s) None

LSZ [m].i Skip if bit i of Data Memory is 0

Description If bit i of the specified Data Memory is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0, the program proceeds with the following instruction.

Operation Skip if [m].i=0

Affected flag(s) None

LTABRD [m] Read table (current page) to TBLH and Data Memory

Description The low byte of the program code (current page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

LTABRDL [m] Read table (last page) to TBLH and Data Memory

Description The low byte of the program code (last page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

LITABRD [m] Increment table pointer low byte first and read table to TBLH and Data Memory

Description Increment table pointer low byte, TBLP, first and then the program code addressed by the table pointer (TBHP and TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

LITABRDL [m] Increment table pointer low byte first and read table (last page) to TBLH and Data Memory

Description Increment table pointer low byte, TBLP, first and then the low byte of the program code (last page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

LXOR A,[m] Logical XOR Data Memory to ACC

Description Data in the Accumulator and the specified Data Memory perform a bitwise logical XOR operation. The result is stored in the Accumulator.

Operation ACC ← ACC ″XOR″ [m]

Affected flag(s) Z

LXORM A,[m] Logical XOR ACC to Data Memory

Description Data in the specified Data Memory and the Accumulator perform a bitwise logical XOR operation. The result is stored in the Data Memory.

Operation [m] ← ACC ″XOR″ [m]

Affected flag(s) Z

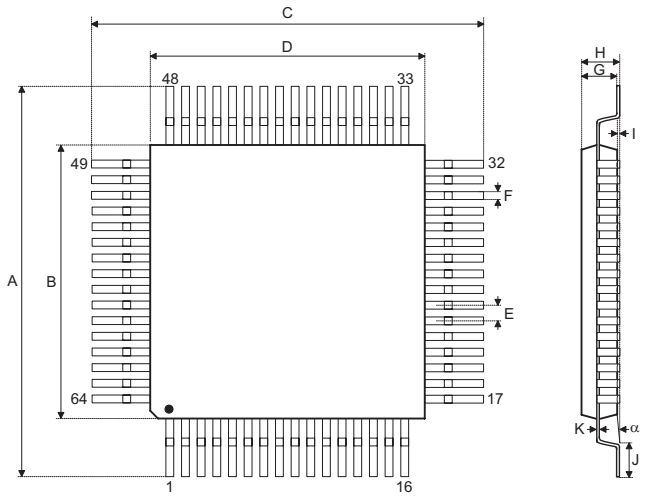
Package Information

Note that the package information provided here is for consultation purposes only. As this information may be updated at regular intervals users are reminded to consult the Holtek website for the latest version of the Package/Carton Information.

Additional supplementary information with regard to packaging is listed below. Click on the relevant section to be transferred to the relevant website page.

- Package Information (include Outline Dimensions, Product Tape and Reel Specifications)
- The Operation Instruction of Packing Materials
- Carton information

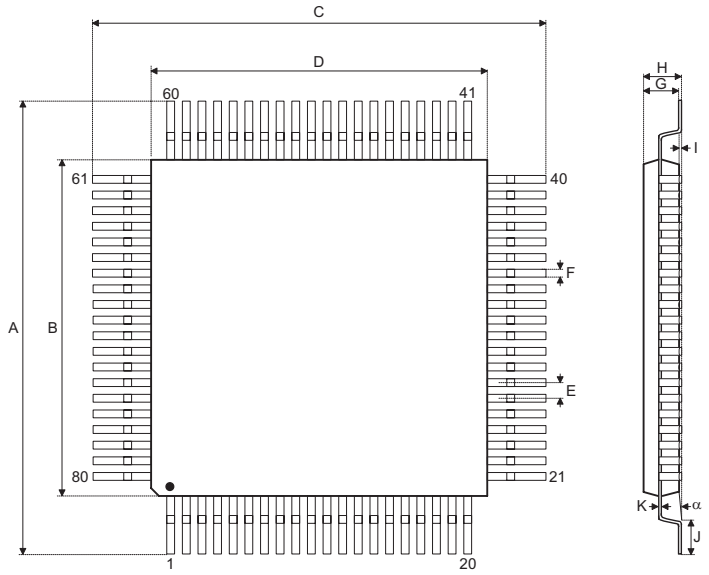
64-pin LQFP (7mm × 7mm) Outline Dimensions



Symbol	Dimensions in inch		
	Min.	Nom.	Max.
A	—	0.354 BSC	—
B	—	0.276 BSC	—
C	—	0.354 BSC	—
D	—	0.276 BSC	—
E	—	0.016 BSC	—
F	0.005	0.007	0.009
G	0.053	0.055	0.057
H	—	—	0.063
I	0.002	—	0.006
J	0.018	0.024	0.030
K	0.004	—	0.008
α	0°	—	7°

Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	—	9.0 BSC	—
B	—	7.0 BSC	—
C	—	9.0 BSC	—
D	—	7.0 BSC	—
E	—	0.4 BSC	—
F	0.13	0.18	0.23
G	1.35	1.40	1.45
H	—	—	1.60
I	0.05	—	0.15
J	0.45	0.60	0.75
K	0.09	—	0.20
α	0°	—	7°

80-pin LQFP (10mm × 10mm) Outline Dimensions



Symbol	Dimensions in inch		
	Min.	Nom.	Max.
A	—	0.472 BSC	—
B	—	0.394 BSC	—
C	—	0.472 BSC	—
D	—	0.394 BSC	—
E	—	0.015 BSC	—
F	0.007	0.009	0.011
G	0.053	0.055	0.057
H	—	—	0.063
I	0.002	—	0.006
J	0.018	0.024	0.030
K	0.004	—	0.008
α	0°	—	7°

Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	—	12.00 BSC	—
B	—	10.00 BSC	—
C	—	12.00 BSC	—
D	—	10.00 BSC	—
E	—	0.40 BSC	—
F	0.13	0.18	0.23
G	1.35	1.40	1.45
H	—	—	1.60
I	0.05	—	0.15
J	0.45	0.60	0.75
K	0.09	—	0.20
α	0°	—	7°